Challenges in Managing and Rehabilitation of Functional Riverine Systems

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Background

People have been and will be dependant upon river systems through the ages. Many of our services are derived from river systems including the provision of food, fresh water, transportation, and a conveyance for waste products. Rivers are a reflection of their watershed, but the focus of this paper is the channel and riparian floodplain system (termed herein as the riverine system). River systems are inherently complex and man has sought ways to understand, predict, and control their behavior to maximize their utility to society and reduce the risk for harm. This has given rise to the application of the engineering method of problem-solving. This perspective generally includes the quantification of isolated driving forces, material properties, and relations to offer predictions of behavior to quantify risk and facilitate the design of interventionist measures. Simplifying assumptions need to be made for complex systems to facilitate the analytical process. The goal of interventionist measures is to modify the system behavior to improve its predictability and optimize service to society.

As our understanding of riverine systems has grown, we have learned of the dynamic and ‘chaotic’ nature of these systems (Gleick 1987, Mandelbradt 1977). This has exposed some of the limitations of applying a purely ‘engineering perspective’ and the implications of managing to optimize services to human society. Experience has shown that a functional river system is not static and must be able to adapt to natural changes in sediment load, hydrology, and hydraulics due to disturbances, natural fluctuations, and progressions. We understand that ecosystems are dynamic in nature and a “stable” ecosystem can be considered a ‘dead’ ecosystem. We recognize that ecosystems are continually in the process of deconstruction and reconstruction in response to external and internal influences.

A riverine system must be able to function at numerous temporal and spatial scales. Consider stream velocity as an example of the spatial scale issue. The computation of a hydraulic profile using the conventional one-dimensional backwater analysis assumes average conditions over a cross-section and reach. However, we know that there are 4 dimensions to velocity (including time) in a river system. The microhydraulics of the cross-section and reach are critical to ecological complexity and function. Hence, the problem becomes how to incorporate microhydraulic variance and be able to adequately understand and communicate the level of risk to the public.

Temporal scale is also a major issue in the management and restoration of riverine systems. The communication of risk to the public is based upon a set of assumptions on the land use, vegetative characteristics and succession, social demands, climate, and infrastructure. These assumptions set the river system in a single form that is tied to a specific snapshot in time. Yet as described above, we know that systems can and must vary over time.

It becomes obvious that the objective of developing a stable system to maximize the accuracy of our predictions (or reduce uncertainty) and optimize the service to society runs counter to these natural processes and negatively impacts the functions of the ecosystem. In fact, a ‘deep ecologists’ perspective is that the natural functions of a riverine system (such as the production of a fish population and nutrient cycling) are inherently valuable unto themselves and independent of the services to human society.

The characteristics and differences between the ecological and engineering perspectives have been described in detail by others (Mitsch 2004, Simpson 1997, and van Eeten 2002). The study and development of the engineering and ecological perspectives have been advanced by different professions and include different backgrounds, persona, and skills. Both the engineers and scientists have worked hard to become experts in their respective fields. However, this focus has generally not allowed them to be well-versed in the ‘other’ perspective. Hence, each has developed what has been termed their own ‘well-earned blind spots’ or ‘well-earned areas of ingorance' (Simpson 2002). These differences in goals, perspectives, expertise, approaches, and management objectives has been has been an impediment to successful management of riverine systems.

There are many 'users' of the riverine system that derive a service (such as obtaining drinking water or fishing) or can be potentially harmed (such as those who live in a floodplain or transient users of a transportation corridor). Much of our riverine (floodplain) management focus has been on attempting to maintain the existing condition and not allow an increase in the regulatory flood profile through filling, inadequate crossings, etc. The maintenance of an assumed static condition will help maintain an assumed level of risk to the users. However, this has the unintended effect of maintaining historic interventionist impacts to the system that have negative ecological consequences and are not naturally sustainable.

The natural scientific and engineering professions have not successfully developed the fully integrated cooperation needed to effectively communicate the complexity of management issues to the policy-makers and these users. Developing a comprehensive understanding of the natural complexities and the social demands is critical to developing a comprehensive management framework. Ultimately all ecosystem management is people management and strategies must be adopted to modify human behavior to retain or restore a functional river system.

Issues Specific to Rehabilitation Design

Management of the regulatory flood profile is one of the areas of focus to minimize the risk to users. Society has spent a lot of time and resources managing our riverine systems to maximize flood conveyance capacity which minimizes this risk. Optimizing the flood conveyance capacity has meant modifying the slope, roughness, and flow area of a river and its floodplain. Riverine management and rehabilitation to improve ecological function often involves the active restoration of one or all of these stream elements. It should be noted that as described above, true rehabilitation and management needs to recognize and accommodate for variability of all of these parameters in systems.

Since the advent of the steam and later the diesel engine, man has been aggressively modifying stream slopes across America. Optimizing for floodwater conveyance led many entities to straighten streams in order to maximize the downstream gradient. However, this increased flood conveyance efficiency comes with a cost. A straightened reach is not in equilibrium with the sediment supply, valley slope, and hydrology. Hence, there is significant labor and capital expense over time associated with maintaining an artificially steep profile. In addition, straightened reaches are generally more uniform and have less ecological diversity than natural reaches. Rehabilitation of a stream system that has been straightened generally includes the re-establishment of a meander form. This meander form helps re-introduce the in-channel complexity by re-establishing pools, riffles, and other hydraulic variability. Increasing the channel length decreases the slope and channel conveyance capacity. This can increase the regulatory flood profile within a project reach and for upstream property owners. In addition, the slope (and planform) of a alluvial stream will change over time as the result of disturbances and natural variations. Infrastructure must be designed to anticipate these changes and not think of a ‘restored’ reach as the eternal condition.

The resistance to flow in the channel and floodplain are important components of stream rehabilitation design. Resistance due to form and vegetation are both critical to managing upstream flooding risk and supporting the ecological diversity needed to sustain a functional system. Historically, reducing the floodplain or channel roughness has been seen as an easy solution to upstream flooding problems or mitigation for infringement on the floodplain. However, this approach typically carries significant long-term management expenses and ecological impacts for the subject reach and the stream system. Impacts on temperature, nutrient cycling, woody debris recruitment potential, and floodplain diversity are often associated with the conversion of a floodplain to a less resistant herbaceous cover. Loss of microhabitats and food source is an important impact associated with the removal of woody debris commonly associated with reducing resistance within a channel. The rehabilitative management strategy of a stream corridor by allowing a floodplain to reforest (conversion from row crops to a floodplain forest) or the introduction of additional channel and floodplain roughness elements associated with a stream reconstruction often increases the roughness. This roughness increase can increase the upstream flood profile.

As with slope, the advent of mechanical dredging equipment has allowed significant increases in available cross-sectional flow area. Oversizing channels to optimize for flood conveyance is not sustainable because of poor sediment transport characteristics. Rehabilitation of streams with dredged (or greatly incised) cross-section generally includes the reduction of channel cross-sectional area. The result of this activity can be the increase in the regulatory flood profile for the project reach and upstream.

These potential increases in the regulatory profile associated with stream rehabilitation can be in direct conflict with existing management (permitting) and legal (easement) requirements. Hence, measures must often be taken to purchase the ‘rights’ of upstream property owners based upon their assumed risk, include mitigative design features to increase the conveyance capacity (such as modifying the roughness or flow area) or purchase of rights through easements. While not insurmountable, many times these measures can be expensive in political, ecological, and monetary terms.

While managing for the reconstructed form is important, it is vital to understand the dynamic nature of a functioning river system. A riverine management framework that is based upon a static condition (even though closer to a ‘natural form’) will not realize the benefits of a functioning system and will be subject to the destiny of eternal maintenance activities.

Conclusions and Recommendations

An effective management strategy needs to be based upon the understanding of the dynamic nature of riverine systems. This reality must be balanced with the need to protect the users of the riverine system from undue harm and manage risk. A social contract between the users of the riverine system and the management professionals seems to have been developed. The users have developed an understanding of risk assumption communicated to them based upon deterministic analytical tools and a management framework that is focused on maintaining the existing condition. However, the accuracy of this risk assumption and the ecological (and social) costs of maintaining this condition has not been adequately explained or understood by the managers, engineers, policy-makers, and the users themselves. We need to re-visit the social contract with the public for the management of assumed risk. The implicit goal of risk minimization needs to be placed within the context of other social and ecological costs. An open dialogue needs to be developed between the managers, engineers, policy-makers, and users of the riverine environment to allow fully informed decisions based upon commonly shared values. This dialogue must respect our individual ‘well-earned blind spots’ associated with different disciplines and perspectives.

Present discussions regarding the modification of behavior or land use rights based upon changing conditions and attitudes has been considered a ‘takings’ in the legal realm. It is this author’s opinion that the concept of a ‘keepings’ should be introduced into the philosophical, legal, and management discussions regarding the riverine environment. In addition, the definitions of risk and rights need to be fully explored. In other words, we should consider the social and ecological cost of keeping an impact for the benefit of selected users. These costs must be considered over the long-term to fully understand the trade-offs being contemplated. Maximizing short-term use optimization and risk reduction at the expense of long-term function does not seem to meet our stewardship obligations to future generations.

Management strategies must be developed that recognize the need for riverine systems to be functional at multiple temporal and spatial scales. These strategies need to recognize chaotic nature of natural systems and limitations of deterministic tools. Continued focus on the elimination and removal of structures within the riverine environment can reduce the impact to stream systems. However, additional efforts are needed in the management of the installation and design of transportation, sewer and other infrastructure within the riverine corridor. Specifically, the design of our transportation network as related to the frequency of crossings, alignment, conveyance capacity, ability to pass woody debris, fish passage, and floodplain drainage need to be addressed.

Liability exposure and expectations for managers and design professionals needs to be modified to allow a more comprehensive definition of design performance.

It is important to implement these changes as soon as possible. Early implementation means they will likely need to be developed at the local level (as some presently do). National policies and managers need to ensure these local initiatives can be integrated into national initiatives and programs.

In summary, our present floodplain management system is relatively young, but the implications of present philosophies will have long-lasting effects. We must consider broad changes in the management of riverine systems to recognize the complexities associated with a functioning natural system. Implementing these strategies will help ensure systems are naturally sustainable and fulfill our stewardship responsibility to future generations.

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