Engineering Design Standards and Liability for Stream Channel Restoration

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At the annual meeting of the Environmental and Water Resources Institute (EWRI) River Restoration Committee at the World Water and Environmental Resources Congress in May of 2005, a lively discussion was held on engineering liability issues associated with river restoration projects. Why *engineering* liability issues? Because by sealing river restoration designs, engineers assume professional liability for those designs. The course of the liability discussion led the authors to conclude that there is a need for objective, performance-based guidelines or a manual of practice for river and stream restoration design as well as improved channel design standards.

This article reviews the state of practice of restoration design and suggests a basis for design standards to improve project results and manage risk. The River Restoration Committee hopes to see a broader professional acceptance of multiple scientific design approaches for river restoration projects, a distinction between engineering and nonengineering practices, *and* quantifiable project goals to more easily evaluate success or failure. For example, the Committee would like to see regulatory agencies adopt performance-based criteria for river restoration designs to meet specific objectives rather than guidelines or rules that constrain engineers to use a prescribed design approach. By gearing designs to satisfy specified, measurable criteria, engineers will be able to select the most appropriate design methods for a given project across a wide variety of boundary conditions and system processes. Tailoring a solution to satisfy quantifiable goals for given stream and watershed conditions over the lifespan of the design makes more sense than trying to fit a prescribed design approach to all types of projects over a wide range of project and watershed scales.

Although this article focuses on the practice of engineering for river restoration projects, the committee strongly agrees that (1) the river restoration design process requires a community of professionals with a variety of skills; and (2) incorporation of ecological criteria in the design process is important. The authors ask this community of professionals to indulge us by looking at river restoration from the engineer's point of view in the interest of mutual understanding and healthier rivers and streams.

Introduction

Stream restoration is big business, with annual expenditures in the billions of dollars (Bernhardt et al. 2005). ASCE journals and conference proceedings devote considerable space to stream restoration and associated topics. Although stream and river restoration refer to a broad spectrum of activities, this paper focuses on channel design. Many stream restoration projects involve channel design, either for modification or reconstruction of unstable or otherwise degraded streams. Standard civil engineering practice for open channel design uses methodologies based on hydraulic and geotechnical principles (FISRWG 1998; Copeland et al. 2001; Soar and Thorne 2001; Shields et al. 2002; USDA-NRCS 2005) that are supported by over 50 years of research and are documented in peer-reviewed literature (ASCE 1975; Julien 1998; Sturm 2001).

In contrast to these methods, over the last 15 years an analog-empirical channel design approach has developed and gained great popularity. This analog-empirical methodology is often referred to as the Rosgen or reference reach method (Rosgen 1996; Hey 2006). In general, this approach is based on concepts from fluvial geomorphology that emphasize form over process (Doyle et al. 1999; Kondolf et al. 2001; Simon et al. 2005; Smith and Prestegaard 2005). Importantly, this essay is not a criticism of the reference reach approach per se, nor is it a debate of form versus process geomorphology. Our interest is in defining what constitutes "engineering" practices within the wide range of skills needed for river and stream restoration. This is especially important in urban or urbanizing areas where stable channel design becomes more complex due to changing flow regimes and sediment loads, infrastructure that must be protected, water quality issues, fish passage through hydraulic structures, and other constraints. The crucial concern to the civil engineering community involved with river restoration is increasing recognition of the reference reach approach as the standard of practice by state and other regulators. Professional engineers designing channels are often required by clients to use the Rosgen approach by name even when its applicability to a specific project and the associated risk level are in question. Moreover, current state guidelines for stream channel mitigation projects in North Carolina and Kentucky are based on Rosgen's design approach coupled with USEPA Rapid Bioassessment Protocols (USACE et al. 2003;

Kentucky Division of Water 2002). If there are no references to engineering hydrology, hydraulics, sediment transport, open channel flow, *or* explicit requirements to perform engineering analyses, then why is an engineer's seal required on the drawings? What parts of these drawings are considered engineered and for what will the engineer be held liable? The issue is critical to the engineering community because project failures have occurred nationally, and the public, rightly or wrongly, often identifies liability with the engineer.

This issue greatly underscores the engineering community's need for a performance-based manual of practice for river and stream restoration design and improved channel design standards. The goals of this paper are to bring to debate these issues to clarify (1) responsibility and liability of the engineer; (2) the role of the engineer in a complex design process where restoration objectives are typically multidisciplinary; and (3) how to move forward to ultimately develop peer-reviewed, objective-based design standards for engineering channel design.

Liability Lies with the Engineer

Outreach is needed to clarify the significance of an engineering seal in the eyes of the public. The purpose of licensure is to demonstrate competence in the field of engineering and to perform engineering services safeguarding the life, health, and welfare of the public and to comply with the principles of sustainable development (ASCE 2006; NSPE 2006). Professional engineers are bound to uphold the Code of Ethics for Engineers or risk losing their license and their right to practice. Licensure and the affixing of an engineering seal to a design do not guarantee "success" of a project. The seal indicates that the engineer has exercised his or her best professional judgment upholding the industry "standard of care" in the design process. Furthermore, engineering law states that to practice engineering a professional license is required; hence, the need for a document that clearly defines standard engineering practice in river restoration design.

In many states, stream restoration projects require the seal of a licensed professional engineer. Upon affixing his or her seal to design documents and drawings, the engineer assumes the responsibility for the accuracy of the design and affirms that the work was directly conducted or overseen by him or her. Professional ethics dictate that the work be within the engineer's area of expertise, that the engineer has kept abreast of the state of the practice through continuing education, and that a reasonable standard of care has been exercised in developing the design project (ASCE 2006). In many areas of civil engineering, the design standards are such that following those standards will guarantee success of the project, such as given a certain load and span length, specifying beams of a particular strength, and applying a factor of safety will ensure the bridge will not collapse when opened to traffic. However, in river restoration, the factors necessary to ensure successful projects are less clear. This could be due to the relative newness of the science, its multidisciplinary nature, a shift in societal values and expectations, lack of systematic monitoring and adaptive management, poor communication among stakeholders, or other influencing factors.

High levels of uncertainty accompany prediction of river response, and "success" tends to be poorly defined in restoration projects (Palmer et al. 2005). A good standard of practice (1) allows certification of appropriate professional behavior even in the event of project failure; (2) can help design teams educate stakeholders as to which design approach is most appropriate and why; and (3) opens conversations about various levels of risk and strategies to best manage risk. Clear expectations, mutual understanding of assumptions, uncertainties, and risk defined during the budget and scoping phase of a project benefit and protect both client and engineer.

Collaboration Is Essential

While the conversation up to now has focused on the role of the engineer, channel design for stream restoration involves many sciences, and successful collaboration is essential (Wear 1999; Slate et al. 2004; Gillilan et al. 2005). There is a need for members of the design team to appreciate and understand the roles and responsibilities of each discipline (Frissell and Nawa 1992; Kondolf 1998; Brown 2000). Development of a performance-based manual of practice must be supported by and incorporate input from experts in many disciplines (Table 1). Some disciplines squarely fall into the realm of traditional engineering practice, such as hydraulics and geotechnical engineering, while others are based in physical, biological, or social sciences. Still others could be considered an indistinguishable blend of engineering and science, such as river mechanics and bioengineering. Clearly, there is a need for a suite of design approaches that combine engineering, geomorphology, hydraulics, and biology. This committee strongly advocates the development of performance-based design guidance that refer to a broad base of disciplines (hydrology, hydraulics, geomorphology, river mechanics, sediment transport, biology and ecology), and thus open up more options for channel design.

If engineering is required to meet project objectives, ideally the designer or project engineer works with other professionals throughout the design process in crafting a solution. Engineers may receive input from fluvial geomorphologists, geologists, fisheries biologists, ecologists, or other professionals. The engineer then converts that input into a solution (reports, drawings, specifications) affixed with seal and signature, which is presented with supporting information that clearly defines design criteria, risks, and measurable performance standards.

Need for Standards for Stream Restoration Channel Design

Development of engineering design standards for stream restoration projects has lagged for several reasons. There is a wide array of physical variables that control river channels that vary both temporally and spatially. The general lack of monitoring and applied research has hampered development of improved tools and design approaches. Specific projects differ widely in their levels of scale and risk (i.e., headwater streams versus 5th order rivers, presence of infrastructure needing protection, presence or absence of threatened or endangered species, etc.) It may at first appear that project uniqueness renders standards implausible or inappropriate (Miller and Skidmore 2003). However, this committee believes engineering standards of practice are necessary and feasible. Overall, the lack of rigorous engineering standards produces difficulty for designers in

- Identifying an appropriate design procedure and choosing which techniques are most suitable for given conditions;
- Effectively communicating with stakeholders on the suitability of a particular design procedure;
- Ascertaining the level of documentation necessary to convey

Table 1. Summary of Disciplinary Roles in Stream Restoration Projects

Discipline	Services/products
Hydrology	• Hydrograph generation illustrating hydromodification associated land use changes over time • Flood frequency analyses over a range of flows and watershed conditions • Hydrologic budget model development
Hydraulics	• Flood analysis • Water surface elevations/profiles • Shear stress computations and scour analysis • Hydraulic analysis for placement of in-stream structures
Fluvial geomorphology	• Characterization of channel form • Hydraulic geometry relationships • Analysis of lateral and longitudinal channel adjustment • Characterization of dominant geomorphic processes • Identification of processes responsible for forming and maintaining key habitats • Assessment of long-term project effects
River mechanics	• Determining sediment transport capacity,sediment supply,and particle sizedistributions • Analysis of lateral and longitudinal channel adjustment • Bank stability analysis • Model dynamic meander migration • Analysis of sediment transport capacity for self-maintenance of in-stream structures • Sediment transport model to analyze stability of bed forms
Sediment management	• Sediment budget model development for defining dynamic contributions of sediment sources and changes in sediment inputs characteristics associated with land use modifications • Identification of sediment sources for erosion control management
Geotechnical/bioengineering	• Bank stability analysis • Incorporation of geotextiles and planting requirements
Ecology/biology	• Habitat analysis: quantification of deficiencies • Analysis of biological integrity based on selected indicator groups (e.g, fish, benthic macroinvertebrates, periphyton) • Analysis of riparian ecological function • Habitat enhancement design for ecological recovery
Forest and wetlands management	• Analysis of riparian ecological function • Plant selection for stability and riparian enhancements
Landscape architecture	• Blending riparian corridor with built environment • Planting plans
General engineering	• Surveying, mapping, and project design drawings • Construction management and as-built drawings • Economic analysis • Risk assessments
Anthropology	• Cultural Resources/Historic preservation • Archeology • Facilitation
Law	• Regulatory compliance • Water rights • Flow diversions

design analysis into plans to ensure successful project implementation;

- Identifying measurable performance standards that can be monitored and assessed, thereby supporting an adaptive management approach to advance design methodologies; and
- Managing risk and liability.

Summary

This forum is offered as an aid in communicating with restoration project stakeholders as well as a call to develop standards of practice for the stream restoration discipline. We support the development of a performance-based manual of practice based on restoration objectives that link acceptable practices with measurable outcomes, validated by specified monitoring and assessment protocols. We ultimately support acceptance of engineering design standards based on practical application of hydraulic and geotechnical principles linked to specific morphological and hydrological conditions.

Standards of practice lead to more consistent results, promote public safety, and allow designers to manage risk (Miller and Skidmore 2003). This committee proposes that stream restoration channel design standards be based on measurable criteria supported by current peer-reviewed scientific publications. Design goals should be clearly defined and based on general physical principles, rather than referenced to an empirically defined equilibrium state. More specifically, the questions "What is the supply of water and sediment?" and "What do you want to do with them?" provide a sound framework for restoration design (Wilcock 1997), leading to consideration of physical, ecological and management objectives on a consistent and quantitative basis through space and time. In the absence of more refined materials, the authors support the work previously published by members of the River Restoration Committee (Shields et al. 2003) and suggest using this work as a starting point for channel design standards.

In conclusion, there is a need for river restoration design standards and improved guidelines for channel design. By gearing designs to satisfy specified criteria, engineers will be able to use all of the relevant methods that have withstood the scientific rigors of peer-review, better manage risk, and improve project success.

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