2010

River Engineering: Past, Present And Future – A Comprehensive Systems Approach

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RIVER ENGINEERING: PAST, PRESENT AND FUTURE – A COMPREHENSIVE SYSTEMS APPROACH

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Abstract River engineering is one of the core competencies of the Army Corps of Engineers. In fact, the Corps has traditionally been the leader among federal agencies in this area, having both developed the specialty area and literally having "written the book" in delivering guidance and tools used by others. However, the Corps' superior performance is based in large part on the institutional knowledge of experienced river engineers, many of whom are near retirement age. This underlines the need to act quickly to implement an innovative technical transfer process to develop this core competency in younger USACE staff. In particular, the comprehensive systems approach used in river engineering must be thoroughly documented and disseminated throughout our organization. Several factors make this of paramount importance. First, as previously stated, many experienced engineers are nearing retirement. Second, this rapidly approaching exit of expertise does not allow for a slow and gradual knowledge transfer, but requires quick and innovative action. Third, the comprehensive systems approach used by river engineers is critical to ensuring the success of multi-disciplinary projects such as ecosystem restoration and watershed management projects. An accurate understanding of water and sediment process, and river channel changes, is fundamental to the success of most Corps civil works projects. There is a need for innovative technology transfer of river engineering expertise to support the comprehensive systems approach endorsed by Corps leadership. To respond to the above concerns, a work effort has been initiated under the Corps Actions for Change, Theme 1 (Knowledge Transfer) to perform an initial evaluation of river engineering discipline within the Corps. The observations and recommendations in this paper derive from a workshop held in 2009 to discuss the status of river engineering capability within the Army Corps of Engineers.

INTRODUCTION

River engineering can be broadly defined as the practical application of science to further the understanding a river's behavior. This combines skills in sediment transport analysis, hydrology and hydraulics, fluvial geomorphology, and a strong practical background in the selection, design and impacts of river and watershed training structures and modifications.

River engineering is a signature Corps of Engineers discipline, with much of the expertise in the Corps growing out of the inland navigation program. However, river engineering skills are now needed for a much wider range of projects, and on all sizes and types of streams and watersheds. Expertise in evaluating sediment processes in alluvial channels (whether on a single reach or an entire watershed) is necessary to solve many problems of current interest, including topics such as watershed sediment management, design of stream restoration projects, and evaluation of complex changes in watersheds (affected by dam construction, dam removal, sediment loads from volcanic debris, wildfires, or urbanization). Channel morphology may be altered by ice effects, gravel mining, or water withdrawals. From the Santa Ana River in California to the Susquehanna River and Chesapeake Bay, an understanding of sediment processes in watersheds and the design of remedial measures are of immense practical importance.

WHAT IS RIVER ENGINEERING?

River engineering requires the skill set of a Corps hydraulic engineer, with additional expertise in areas related to alluvial channel mechanics. In particular, a river engineer must have practical experience with design, construction, and observation of channel and watershed modifications. River engineering also demands a strong field component, including the observation and evaluation of river and watershed behavior and response.

The engineering design and river management aspect of river engineering distinguishes it from related scientific fields such as geology, hydrology and geomorphology. River engineering demands a technical understanding of hydrology, hydraulics, sediment transport, along with knowledge of model inputs, capabilities and limitations. Because a river engineering project, by definition, often results in physical changes to a river system, a river engineer's responsibility is to achieve the intended results while avoiding unintended consequences. Specifically, the practice of river engineering is to determine how a river system is functioning, how it has functioned in the past, and how the system is likely to respond to changes (natural or anthropogenic) in the basin. The fact that a river engineer designs projects that physically affect a river system distinguishes him or her from the pure scientist.

A river engineer is uniquely skilled at conceptualizing how river and watershed systems work: how they respond to modifications, stress, and other factors. Skills include the following critical components and capabilities:

1. The ability to visualize response and identify potential problems
2. Prediction of river and watershed behavior and response
3. Understanding the underlying physical processes involved, especially those of sediment sources, transport, sinks, and how those interact with the mechanics of alluvial channels.
4. Selection, siting and design of river training structures. Structures must match sediment transport and geomorphology. Understanding of design conditions, construction materials, construction techniques, etc. Ongoing involvement in monitoring constructed projects.
5. A scientific and engineering approach to prototype experimentation.
6. A knowledge of field methods and office analyses to support the items above.

River engineering is not a cookbook exercise. River basin characteristics and problems vary widely from one region to another, and from one site to another. For this reason, expertise may have local or regional components. The wide variation in situations requires a willingness to learn, the understanding that one's knowledge is incomplete, and a burning desire to understand processes.

Expert river engineers typically have 15-20 years of experience. Journeyman level is defined as "highly effective, but not expert," and would typically be an engineer with 5-10 years of river engineering experience. Apprentice level employees still require supervision. In this specialty area, the "bench" is hydraulic engineers with at least five years of experience, rather than entry-level engineers.

The scope of river engineering is not confined to the channel and the adjacent flood plain, but rather is concerned with the dynamic nature of the entire basin. This requires river engineers to have an understanding of geology and geologic processes, knowledge of hydrology, and an understanding of the physical processes (hydraulics) at work in the basin. River engineering combines knowledge from multiple disciplines:

- hydraulic engineering
- hydrology
- hydraulics
- geology
- fluvial geomorphology
- sediment transport and sedimentation engineering
- mechanics of alluvial channels, and
- design of river training structures.

Although river engineering has primarily been practiced by individuals with a hydraulic engineering background, the field has been developed in conjunction with scientists in other disciplines, in particular geologists and geomorphologists.

HISTORIC PERSPECTIVE: HOW WAS CORPS RIVER ENGINEERING EXPERTISE DEVELOPED?

The Corps expertise in river engineering was developed slowly over decades, through a combination of mentoring, on-the-job training, and formal training. This expertise represents a substantial investment.

Many river engineers received at least some formal training in the use of numerical hydrodynamic and sediment transport models, field data collection techniques, sedimentation, hydraulic engineering, etc.

Large projects and stable funding fostered the development of technical expertise. In many cases, operations and maintenance (O&M) funding provided the basis for engineers to review project performance over a period of years, and to share empirical knowledge on lessons learned.

River engineers developed their skills through their work on challenging projects. On-the-job training is a critical element in developing expertise.

River engineers at USACE Divisions and Headquarters played a critical role in providing mentoring, advice on scopes and studies, networking, and professional development opportunities. They also maintained a critical focus of both research and training related to river engineering.

River engineering expertise is now almost absent in Division offices. Corps Headquarters has one hydraulic engineer with river engineering expertise. This is a direct result of the removal of the technical engineering review function from division and Headquarters. Although the technical review function was removed in the mid-1990s, the full impacts are still being felt. This re-organization precipitated the retirement of a significant number of river engineering experts, essentially severing the mentoring chain. Division experts whose job descriptions were modified (to remove technical components) have often continued to provide expert technical assistance informally until they retire, at which point their technical expertise is not replaced. The full impacts of the Corps reorganization will not be felt until the last division "expert" retires.

CURRENT STATUS OF RIVER ENGINEERING IN THE CORPS

Aging Work Force An informal survey suggests that most experienced river engineers are within five years of retirement age. Many experienced river engineers have already retired.

Lack of Time for Gradual Knowledge Transfer Because most experienced river engineers are near retirement age, there is not sufficient time to train the next generation of river engineers gradually over 10-15 years. Innovative methods for knowledge transfer are outlined in this document, and are required to retain this critical area of expertise.

Fewer Projects Historically, river engineers developed their skills working on large projects that had multiple phases and lasted several years. Projects such as the Mississippi River and Tributaries Project, Missouri River Bank Stabilization and Navigation Project, Mississippi Delta Headwaters Project, and others provided long-term opportunities to design-construct-monitor-learn at the system scale. Smaller site specific projects do not offer the proper resources and time frames to allow for this type of learning. There are fewer large projects, and therefore fewer opportunities to develop river engineering skills

More Complex Issues and Continuing Need for River Engineering Expertise Although there are fewer large projects, the issues are more complex, and require a greater understanding of the interaction between the basin and the stream. There are an increasing number of multi-objective projects. There are also more small projects, which if incorrectly designed, may have unintended adverse consequences. These include removal of small dams and stream re-meandering projects.

As previously stated, river engineering in the Corps grew out of the inland navigation program. However, this expertise has been extended successfully to smaller projects and watersheds, such as the Missouri River Recovery Program and the Mississippi Delta Headwaters Project. River engineering expertise was used to develop guidelines for equilibrium channel design for restoration projects, and to provide input into the federal interagency document, "Stream Corridor Restoration: Principles, Processes, and Practices" (FISRWG, 1998).

In the **Missouri River Recovery Program**, river engineers are being asked to restore the geomorphological function of the river while maintaining all of the authorized project benefits (flood control, navigation, hydropower, etc.). This project requires a complete understanding of the sources of sediment, the physical and chemical characteristics of the sediments, the hydrologic cycles, and management objectives, as well as a basic understanding of the needs of the ecosystem. The construction phase of this project will span 30 years (requiring multiple generations of river engineers) and the operational phase will continue into the foreseeable future.

In the **Mississippi Delta Headwaters Project**, river engineering principles were used to reduce excessive erosion and sedimentation in 17 watersheds covering over 2500 square miles.

Other examples of complex system-wide river engineering challenges include Coastal Louisiana, the Everglades, and the Illinois River Basin.

Although smaller projects do not have the name recognition of the larger projects listed above, they number in the thousands. Studies, plans and projects relating to stream restoration, watershed sediment management, dam removal/decommissioning, and reservoir sedimentation have been initiated everywhere in the nation.

FUTURE

The majority of the following recommendations were developed in a workshop held in May 2009 to discuss river engineering capability in the Army Corps of Engineers. The first proposal, the development of a "River Engineering Associates" Program, was viewed as the most important recommendation.

1. Develop a "River Engineering Associates" Program, similar in concept to the Planning Associates program. This would be a developmental program aimed at a more rigorous training element for river engineers. A description of the proposed program is as follows:

a. This program would provide the opportunity to develop the knowledge and skills necessary to advance apprentice-level engineers to the journeyman level in the river engineering capability.
b. Applicants would have 5-10 years experience in river engineering, and would be in a position to develop additional skills
c. A group of river engineering experts would establish the curriculum and determine course content
d. The overall coordination group would also include a Headquarters advocate and a logistical support manager.
e. Training modules would be developed for this course. These modules would then be available for Corps-wide use.
f. The HOBB (home office back briefs) from the program would provide technical transfer to the districts.
g. The program would provide mentoring and exposure to existing expertise
h. The associates group might also be used to review R&D needs
i. The workshop group recommended using the funding plan used by the PA program, where the student's organization pays for labor, and all non-labor expenses are

centrally funded (travel, training, tuition, program management and logistical support, etc.)

j. Benefits would be the knowledge transfer of river engineering capability, development of a cohesive sub-CoP (under the HH&C CoP), development of increased coordination among current river engineering experts, and improved feedback and direction for R&D.

2. Create a Sub-CoP for River Engineering (under the existing HH&C CoP)

3. Develop a national /regional plan for capability, and identify resources and responsibility

4. Hiring. The Corps cannot buy river engineering capability on the open market. To retain river engineering capability, we must hire at the apprentice or entry level, and grow this capability in-house. It's helpful to recruit engineers who already have demonstrated an interest in this specialty area.

5. Retention.

a. Providing employees quality work is a very high factor in both retention and professional development. Challenging projects are essential to the professional development of river engineers. Good supervisors will feed their engineers a diet of challenging projects, and will often look for suitable work in other divisions and districts if it is not available in-house. River engineering work should be viewed regionally and nationally as a resource for maintaining capability.

b. Other ideas that were considered included work for other districts, details at ERDC and HEC, and professional activities.

c. Other motivating techniques include recognition, bonuses, improved job tools, involvement in a river engineering team, external awards and exposure, regional and national projects, etc.

d. The River Engineering Associates program would provide mentoring and a career path.

e. The effort to share river engineering projects could be brokered through the sub-CoP.

6. Resources. Compile available resources. River engineering (by its nature) is such that you cannot capture it in a single document. However, it would be helpful to have a central reference site for documents, studies, pertinent guidance, reports, and other items.

7. Guidance Evaluate the need for corporate guidance. This might include improving or updating existing guidance.

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8. Research and Development (R&D)

a. There is a need for continued R&D in the river engineering field - that is, not all the work has been done.

b. The river engineering specialty group needs to identify and articulate R&D needs. The sub-CoP could screen R&D needs. The workshop group suggested taking the river engineering topics from the existing list of research statements of need (SONs), and using that as a start.

9. Committee on Channel Stabilization as a resource. The Corps expert Committee on Channel Stabilization, which focuses on river engineering topics, can be used as an advisory group in the development or implementation of these proposals.

10. Preserve Institutional Knowledge A great deal of institutional knowledge is poorly documented, and will not be retained without action. For instance, lessons learned are frequently passed on as anecdotes, and will disappear from the corporate knowledge base after retirement of key personnel.

a. Develop one-page fact sheets on important projects, studies, and lessons learned.
b. Archive significant documents.

SUMMARY AND CONCLUSIONS

River engineering is one of the essential technical competencies of the Corps of Engineers. This paper discusses how this competency was developed in the Corps, what its current status is, and recommends measures which could be implemented to retain and develop this capability.

ACKNOWLEDGEMENTS

The ideas and proposals in this paper came out of a two-day workshop held in 2009. The attendees included the authors and David Biedenharn (ERDC-CHL, retired), Craig Fischenich (ERDC-EL), Lisa Hubbard (ERDC-CHL), Charlie Little (ERDC-CHL), and Andy Tuthill (CRREL). This work unit was supported by Dr. Kate White under the Corps Actions for Change, Theme One, Knowledge Transfer. The authors would also like to express their appreciation to the past and present members of the Corps expert committee on Channel Stabilization, and to the river engineering community within the Corps.

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