American Academy of Water Resources Engineers

Water Resources Engineering (WRE)

Body of Knowledge (BOK)

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Introduction

A water resources engineer must have a broad array of technical and non-technical knowledge, abilities, skills, and attitudes. This document articulates the Body of Knowledge for the practice of water resources engineering. The Water Resources Engineering Body of Knowledge (WRE-BOK) describes the knowledge and skills required to practice water resources engineering, and follows the lead established by the American Society of Civil Engineers (ASCE) to define a Body of Knowledge for the practice of Civil Engineering, of which water resources engineering is a part. Leading engineering educators and practitioners have come to believe that, at this time, there is a need to identify this knowledge and these skills and to articulate how they might be best acquired via a defined Water Resources Engineering Body of Knowledge (WRE-BOK). Given the expanding nature of the water resources engineering discipline and the many changes occurring today and in the future defining a WRE-BOK is particularly important. In addition, the American Academy of Water Resources Engineers (AAWRE) Board of Trustees desires to incorporate the WRE-BOK into the process of evaluating prospective Diplomates.

At the AAWRE Board of Trustees annual meeting in September 2007, a committee of trustees was created with the following charge:

> "The committee is charged with defining the WRE BOK needed to enter the practice of water resources engineering at the professional level (licensure) in the 21st century taking into account other issues, including, but not limited to, the impact on the American Academy of Water Resources Engineers, on the profession, on water resources engineering academic programs (undergraduate and graduate), and on accreditation of water resources engineering aspects of degree programs at the basic and advanced levels."

It should be noted that the WRE-BOK has not been defined for a specific career path; rather it captures the knowledge and skills for the archetypical water resources engineer that were deemed important by consensus of the AAWRE Board of Trustees. It is not expected that every practicing water resources engineer will achieve all outcomes at the same level, but rather each educational program and each individual will follow an educational and experiential path suitable to their respective professional objectives. Further, achieving the WRE-BOK relies on a combination of formal education, extracurricular activities, professional experience, practitioner mentoring, and peer interactions.

The Water Resources Engineering Body of Knowledge describes the knowledge and core competencies integral to understanding the practice of water resources engineering. Acquiring the WRE-BOK should lead to licensure and later could lead to specialty certification through AAWRE. The WRE-BOK builds on the body of knowledge appropriate for all civil engineers, then expands into areas specific and unique to water resources engineering. The WRE-BOK is not overly prescriptive and is outcomes-based. As does the BOK adopted for civil engineers, the outcomes will help educators design curricula that provide the basis to gain the competencies needed for professional practice and licensing boards to determine the expertise required for licensure. The WRE-BOK also will provide a basis for the AAWRE to evaluate the education and experience of water resources engineers applying for advance certification.

Background

How We Got Here

The practice of water resources engineering predates AAWRE; however, it had traditionally been viewed as a subset of civil engineering. In the latter half of the twentieth century, water resources engineering, like many disciplines within civil and environmental engineering, evolved and became an area of engineering practice that required specific and unique engineering education, knowledge and expertise. During that same time a number of universities awarded undergraduate and graduate program options in water resources engineering. Also during that time, public and private sector employers of engineers came to view this discipline as separate from, albeit related to, allied civil and environmental engineering disciplines.

As water resources engineering was establishing its standing as a unique area of practice, the scope and depth of the discipline was expanding rapidly. Statutory and regulatory actions drove the need to create engineered solutions for a plethora of water resources problems, e.g. water quality, water supply reliability, competing needs for limited water supplies, mathematical and physical modeling, pollution control, and sustainable design to name just a few of the emerging challenges. At the same time, technology was expanding at an ever-accelerating pace, with improvements in information technology and more detailed and innovative computational applications applied to the tasks of analysis and design.

Lastly, water resources development and conservation received an increasing level of interest and scrutiny from the public and political leaders at all levels of government. This and other issues that, while not unique to water resources engineering, have impacted the practice of water resource engineering and demanded the water resource engineer have not only a sound technical foundation, but also must be a manager, a diplomat, a negotiator, and an orator. Water resources engineers often are challenged with leading very controversial projects where partnership with the public and collaboration with stakeholders is important. Thus, excellent communication skills are essential to a successful practice. Water resources engineers need to evaluate solutions in the context of the overall impact on the environment. What are the effects of an engineered solution on the environment and how far geographically and temporally do these effects extend? The issue of sustainability must be considered. Finally, the water resources engineer must have a good grounding in engineering ethics and environmental ethics; particularly considering the dependence of the health, welfare and safety of the public on this area of practice.

Definition of Water Resources Engineering

AAWRE defines water resources engineering as the professional discipline for the stewardship and sustainable use of the world's water and related resources that develops and applies scientific and engineering principles to plan, design, construct, manage, operate, and maintain infrastructure and programs. Water resources engineers are employed in both public and private sectors, as well as by colleges and universities.

Education for Water Resources Engineers

Civil and environmental engineering programs traditionally have emphasized specialization at the graduate level, and many programs still use the "civil" or "environmental" descriptor for programs that emphasize water resources engineering. However, it is hoped that an increasing number of institutions will offer baccalaureate and masters programs designated as water resources engineering. Moreover, it is hoped that the number of baccalaureate degrees designated as water resources engineering will increase. Accordingly, a common entry route to water resources engineering is via a baccalaureate degree in civil, environmental, or other related engineering or science discipline followed by a masters or a Doctor of Philosophy degree with emphasis in water resources engineering. While many baccalaureate graduates in water resources and related engineering disciplines begin employment directly following the baccalaureate degree, an increasing number of them earn graduate degrees either directly following the baccalaureate degree or during their first few years of employment. The need for post-baccalaureate education is driven by the following factors:

- A significant increase in knowledge applicable to water resources engineering has taken place over the past 50 years, while the number of credits required for the typical baccalaureate engineering degree has decreased. Accordingly, education beyond the baccalaureate degree may be necessary for the engineer to understand processes and relationships essential to water resources engineering.
- Many professionals and other engineers practicing or employing water resources engineers consider a masters degree to be the minimal qualification for practice at the professional level.
- An increasing number of regulatory agencies recognize that an advanced degree is necessary to provide adequate understanding of environmental issues and potential remediation actions to be effective.
- Consulting engineering firms have a long-standing practice of valuing advanced degrees in engineering specialties. The complexity of modern water resources engineering problems has increased the emphasis on advanced education in consulting practice.
- It is widely recognized that an advanced degree in water resources engineering is an asset to interface responsibly with regulators and with vendors who are interested in providing related equipment and services.

Even though education beyond the baccalaureate degree is important for career advancement and is helpful for licensure, many water resources engineers begin professional employment holding a baccalaureate degree. However, recent changes in the National Council of Examiners for Engineering and Surveying (NCEES) model licensure law require post-baccalaureate education prior to licensure by 2015. Licensing boards of some states are considering adoption of the post-baccalaureate education provisions of the model law.

Employment Sectors

For the most part, water resources engineers are employed in government service, consulting service, industry, and education. Although the skills and duties required of water resources engineers in each sector are similar, there are some differences. Licensure, like accreditation, is a credential of minimal acceptable engineering competence for protection of the public. The importance of licensure varies among engineering disciplines and is generally most important in civil, environmental, and water resources engineering. Within water resources engineering, the importance of licensure varies among employment sectors.

A regular tenure-track appointment at a college or university will normally require a doctoral degree with expectation of on-going scholarly productivity. There also are many practicing water resources engineers who serve as adjunct faculty members teaching applied and design courses. In some states licensure as a professional engineer is required for teaching engineering design. Water resources engineering program criteria for ABET accreditation require that programs demonstrate that a majority of those faculty teaching courses that primarily are design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and equivalent design experience. Licensure of water resources engineering educators is important as a visible professional credential to emphasize the engineer's responsibility for protecting the public health, safety and welfare. An increasing number of water resources engineering faculty members are licensed professional engineers and have specialty certification as Diplomates by the AAWRE.

Water resources engineering positions in public service, at the federal, state, and local levels, and in the private sector, cover a broad range of duties. Functions range from operational management of water utilities at the city or regional level to administration of programs at the state and federal level, to research on a broad range of water resources engineering topics. Generally licensure is encouraged, and sometimes required for engineers responsible for review and approval of plans for projects that affect the health, safety and welfare of the public. Licensure is not required for water resources engineers in federal service, although many practicing in this area do become licensed. Municipally employed water resources engineers and private utility engineers normally become licensed as a requirement for advancement and career development. They frequently are responsible for projects where the public health, safety and welfare are clear concerns.

Design of water resources infrastructure traditionally has been a major responsibility for water resources engineers in consulting service. Virtually all water resources engineers employed by consulting companies are licensed. The laws of all states clearly require licensure for individuals in responsible charge of such projects. Many water resources engineers in responsible charge have masters degrees and an increasing number of water resources engineers in the consulting field have doctoral degrees. A growing number, of consulting water resources engineers in responsible positions are seeking specialty certification by the AAWRE. Frequently water resources engineers are in responsible overall charge of large and complex projects and supervise or coordinate with engineers from other disciplines. A broad technical background provided by advanced education and experience is important for this responsibility.

Technical Specialties

Given the breadth of the water resources engineering field, most professionals specialize in a subset of the field, with a basic understanding of the other areas of water resources engineering particularly as it influences their specialty. Within the area of specialization, it is expected that the engineer's formal education and early years of professional practice enable them to conceptualize and solve real world, complex problems that are often different from prior experiences. These efforts require high level critical thinking skills (evaluation, synthesis, analysis) and modern engineering tools for information management, computation and design.

Many professionals in consulting firms and government agencies work within groups that have similar traditional boundaries with titles often associated with a single medium or application within a medium. Some examples of traditional areas of competence are:

- Environmental impact analysis and remediation design
- Hydrologic engineering analysis
- Hydraulic engineering modeling, analysis, and design
- Hydroelectric power generation project design and operations
- Irrigation systems analysis and design
- Project operations and management
- Basic and applied research
- Stormwater collection and control systems
- Flood control and drainage systems
- Water supply collection, transport, and distribution systems
- Wastewater collection and transport systems
- Water storage infrastructure planning, management, and operations
- Water supply planning and management
- Water quality
- Environmental restoration and management

As a result of an emerging understanding of complexity, traditional specializations are being stretched and integrated to include knowledge from across specializations and in many cases across traditional disciplines. Thus, the areas of specialization within the water resources engineering discipline are changing in response to the demands from society for professionals to address complex water resources, natural, and environmental processes with a more comprehensive scope.

Possible alternative ways to describe areas of technical competence are summarized below:

- **By the nature of the natural processes:** The next generation of water resources engineer will need to be able to understand and interact with diverse disciplines.

- **By the broad system of interest**: This has been defined as the natural versus engineered systems or the non-built and built environments. However, these distinctions are becoming blurred as green infrastructure and hybrid eco-design processes become more common. Many future water resources engineers will be characterized by the systems (both ecological and technological) being utilized in the design process rather than the traditional applications being designed.

- **By the nature of the processes being designed:** These could include biological, fluid flow and transport. Fundamental transformation and transport processes are common across natural and engineered systems. A technical specialization in biological processes, for example, would require depth in microbial processes ranging from the molecular to the reactor scale. This specialization could lead towards the application of these processes to constructed wetlands, municipal stormwater treatment processes, solid waste landfills, or in-situ groundwater remediation design. The fundamental science and engineering would be common across all of these application areas.

- **By the nature of the intervention** – such as minimization (including management practices or engineered solutions), treatment, or assimilation. Engineered solutions can take many forms. Many water resources engineers now consider themselves specialists in the area of minimizing releases or waste generation, others focus primarily on environmental assimilation of pollutants, while others focus on treatment of pollution.

In addition to the changes in the way the current practice of water resources engineering is separated into specializations; new specializations also are emerging based on recent innovations in research and the expansion of the discipline. Emerging areas of specialization utilize approaches such as:

- **Green Infrastructure Design** includes designing the infrastructure for built environments (streets, sidewalks, drainage systems, etc) to include living and dynamic elements, and to incorporate low impact and environmentally benign design criteria. Examples include designing streets to infiltrate water using low impact development technologies rather than collect and discharge it into a gutter, or the integration of a living stream into a wastewater treatment plant site layout.

- **Sustainability Design** includes quantifying and designing the long-term viability of each element of a project and its associated systems in terms of energy, materials, labor, and other resource costs and availability. Examples include quantifying the solar heat budget associated with new structures and the impact those costs will have on the local and larger communities, or the viability of a highway system for a region in the context of the water resources available to the potential urban growth the system is designed to support.

- **Ecosystem Services Design** includes explicitly incorporating the goods and services we get from ecosystems that are necessary for life into the design process. Examples include designing sediment retention and nutrient cycling into an urban stream restoration project, or designing a refuge for endangered birds into a park, neighborhood, or other built or non-built environment.

- **Ecological Risk Assessment** includes calculating the exposure and hazard of human-made chemicals (toxicants) to living things other than humans (Environmental Risk Assessment is traditionally focused on human endpoints). Examples include assessing the impact of pharmaceutical residuals on indigenous amphibian species based on estimated doses from hospitals, regional health facilities, and other sources; or determining the impact of hydrologic modification from urban development on critical fish species in a stream.

Society's Future Needs & the Role of the Water Resources Engineer

In developing a body of competencies and knowledge for the water resources engineer of the future, it is appropriate to consider the problems that these engineers will face. The future of humankind on the earth will, based on currently available historical information, be profoundly influenced by two phenomena, continued human population growth and need for water resources to support new residences and at the same time to raise the standard of living for a large percentage of the world's citizens who currently exist on limited or degraded water supplies. These two phenomena may, in turn, influence climate and lead to water and food scarcity. Water resources engineers must be prepared not only to react to changes in climate and resource availability but also to help manage that change through sustainable engineering.

Population Growth and Declining Resources: A plot of human population from prehistoric times to the present shows that we are in a period of unprecedented growth in the numbers of humans inhabiting earth. The current population is six billion and is increasing by 80 million per year. This growth has resulted in increased use of water, fossil fuels, and mineral resources for agriculture, transportation, materials, heat, and other human needs. Water resources engineers will need to assist society in the management, design, and development of the built environment for more humans while making more efficient use of water, land, materials, and energy. At the same time, they will have to manage the by-products of society while helping to provide for more renewable energy sources.

Climatic Impact: The earth's climate has changed throughout history and currently is in a warming period (IPCC, 2007). As it has in the past, society will have to adapt to an altered climate. Violent weather events may become more frequent. The boundary between cold and warm regions and between wet and dry regions may shift. Through this, humankind may be stressed, but will adapt. Increased water scarcity will probably be one of the most serious impacts of population growth and climate change, and will likely be felt most acutely by agriculture and by cities located in arid regions. Indirect water reuse will become the norm, and direct, large-scale potable water reuse will begin. The potential of the seas will be brought into play as a major water supply source. Water resources engineers will need to enhance their competence related to water reuse, disinfection, and distribution. They will also need new skills for coping with adverse climatic and weather conditions. Promoting and then designing, constructing and operating water resources project will become more controversial and at the same time more important.

Water, the Developing World, and Human Health: Clean water and environmental sanitation intrinsically are related. Much of the world's population does not have access to either clean water or adequate sanitation facilities. Consider the following:

The United Nations (UNEP 2007; UN Water 2007) and World Health Organization (WHO and UNICEF 2004) report that:

- Approximately 2.5 billion people do not have access to improved sanitation facilities, and 1.1 billion people lack access to clean water.
- By 2025, nearly 2 billion people will be living in regions of absolute water scarcity, and two-thirds of the world population could be under conditions of water stress.

Epidemiological studies reported by Clasen and Cairncross (2004) estimate that waterborne diarrheal diseases:

- Kill 2.5 million people per year, mostly children under five years old (Kosek et al. 2003);
- Account for about 5.7% of the global disease burden with 4 billion cases per year (Pruess et al 2002);
- Account for 21% of deaths of children under five years old in developing countries (Parashar et al. 2003).

Clearly, the water scarcity, sanitation and health problems are most acute in the developing world, and these problems can lead to conflict. Water resources engineers already are working on these problems and this activity will increase as more attention and resources are directed at these problems.

Sustainability: Sustainability is the ability to meet human needs by making use of natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and enhancing environmental quality and the natural resource base essential for the future. Sustainable engineering meets these human needs. Humankind is becoming aware that sustainability is important, but so far has taken only limited action toward achieving sustainability. More serious actions will be taken in the future as resources become more depleted. The water resources engineer will need to be a leader in implementing actions that enhance sustainability. The role of the water resources engineer in this effort will most likely focus on water and on sustainable material and energy use in the built environment.

Multi- and Interdisciplinary Interactions: It is apparent from the foregoing discussion that addressing the environmental impacts of population growth, resource depletion, climatic change, water scarcity, and sanitation will require a team approach. Many engineering specialties will be involved as well as scientists, politicians, government personnel, and a variety of stakeholders. The water resources engineer will be best equipped to lead and coordinate the multidisciplinary engineering team in addressing environmental impacts. It follows that the water resources engineer practicing at full professional capacity should have the technical breadth to relate to engineers and specialists from other disciplines as well as the non-technical breadth to positively influence society and stakeholders.

Development of the WRE-BOK

Scope

The WRE-BOK is fulfilled through a combination of baccalaureate-level work, masters-level work, and professional experience. Fulfillment of the WRE-BOK requires a BS degree plus 30 hours of postgraduate studies in business, public administration, science, or other engineering fields relevant to the practice of water resources engineering. It is recognized that licensure is not a goal of all water resources engineers; therefore, the WRE-BOK is designed to broadly prepare professionals for practice of water resource engineering that includes, but is not limited to, planning, design, teaching, applied or fundamental research, public administration, or operations. The baccalaureate-level work comprising the WRE-BOK was designed to provide comprehensive undergraduate preparation for a broad range of water resources engineering careers.

WRE-BOK Structure

The WRE-BOK is defined by outcomes consistent with ABET 2000 Criteria, but placed in the context of water resources engineering. For each outcome, performance levels are specified, and relevant knowledge domains are identified. As used herein:

- An **Outcome** states or describes an ability to perform a task,
- A **Performance Level** defines the intellectual depth of the task and relates to Bloom's cognitive levels.
- A **Knowledge Domain** is an organized field of human cognition such as history or mathematics.

Core competencies are defined in outcomes; knowledge areas required for each outcome are identified. The WRE-BOK identifies specific desirable attributes of water resources engineers, provides a guide for curriculum development and reform, and provides a means for employers to better understand the knowledge base of water resources engineers.

Outcomes

The Water Resources Engineering Outcomes have been arranged in three groups (see Table 1). The **first group** includes an outcome that provides foundational basis for water resources engineering education. This fundamental outcome ensures abilities in science, mathematics, and areas of discovery and design that will enable water resources engineers to succeed in a future of technological change innovation.

The **second group** identifies outcomes essential to the problem-solving process. Problem solving involves problem definition, identifying constraints and alternatives, analyzing alternatives, selecting and optimizing the appropriate solution, and implementation. The process is iterative, requiring problem redefinition and refining as information is acquired, followed by verification of results during and after implementation of the solution. Problem solving involves both analytical and creative skills. Analytical skills include the ability to comprehend, define and analyze the problem; while creativity is necessary in identifying alternative solutions and envisioning possible unanticipated consequences of the solution. Water resources engineering problem and solution formulation must be accomplished in the context of sustainability, must meet societal needs, and must be sensitive to global implications. The ability to envision the individual steps in a solution and their results only can be gained through practice, acquisition of subject specific knowledge and understanding, and experience using state-of-the art tools.

The **third set of outcomes** defines professional skills, knowledge and attributes that water resource engineers must have to implement solutions successfully. Fulfilling these outcomes will enable them to communicate well, to effectively manage projects, and to successfully engage other engineers, stakeholders, and the public. Throughout their careers, water resources engineers must remain cognizant of changing technology and issues. The public must appreciate the role water resources engineers may play as leaders - particularly when the solutions to water resources engineering issues require policy changes. Public confidence in these solutions requires that water resources engineers conduct themselves ethically.

Table 1. Water Resources Engineering BOK Outcomes

Outcome Number and Title	**Outcome**
Fundamental Outcome	
1. Basic Math & Science Knowledge	*Mathematics; physics; chemistry; biological science; earth science, mass, energy and mass conservation and transport principles needed to understand and solve water resources engineering problems.*
Enabling Knowledge and Skills Outcomes	
2. Design and Conduct Experiments	*Design and conduct experiments necessary to gather data and create information for use in analysis and design*
3. Modern Engineering Tools	*The techniques, skills, and modern engineering tools necessary for engineering practice*
4. In-Depth Competence	*Advanced knowledge and skills essential for professional practice of water resources engineering*

5. Risk, Reliability and Uncertainty	*The risks associated with human or environmental exposure to contaminants in our environment and uncertainty and reliability principles as they affect the engineered systems designed, built or operated to protect the environment and the public health, welfare and safety*
6. Problem Formulation and Conceptual Analysis	*Problem formulation and analysis based on proper water resources engineering problem identification, obtaining background knowledge, development and analysis of alternatives, understanding existing requirements and/or constraints and recommendation of effective solutions*
7. Creative Design	*Design of a system, component or process to meet desired needs related to a problem appropriate to water resources engineering.*
8. Sustainability	*Integration of sustainability into the analysis and design of engineered systems*
9. Multimedia Breadth and Interactions	*Application of basic math and science to predict and determine fate and transport of substances in and among air, water and soil as well as in engineered systems*
10. Societal Impact	*Societal impact of public policy affecting water resources engineering issues and solutions.*
11. Contemporary and Global Issues	*Globalization and other contemporary issues vital to water resources engineering*
Professional Outcomes	
12. Multi-disciplinary Teamwork	*Skills and expertise of multiple disciplines used to address complex engineering problems as a team*
13. Professional and Ethical Responsibilities	*Professional and ethical issues in water resources engineering*
14. Effective Communication	*Effective communications when interacting with the public and the technical community*
15. Lifelong Learning	*Life-long learning leading to enhanced skills, awareness of technology, regulatory, industrial, and public concerns*
16. Project Management	*Principles of project management relevant to water resources engineering*
17. Business and Public Administration	*Business knowledge and communication skills necessary to the administration of*

	both private and public organizations
18. Leadership	*Engagement, motivation and leadership of others to achieve common vision, mission and goals*

Knowledge Domains

Knowledge domains identify specific areas of learning that are essential to accomplishing the outcome. They are not necessarily curricular courses. They may, for example, represent a single lecture within a course, or they may be topics within multiple courses taught at different levels. Figure 2 provides a rubric with knowledge domains identified and mapped to the eighteen outcomes that is used in the ASCE BOK (2008).

Performance Levels

Fulfillment of outcomes occurs at three points in the professional development of a water resources engineer, at the completion of a baccalaureate program in water resources engineering, completion of 30 hours post-baccalaureate or a masters degree and after ten years of professional practice. A level of achievement for WRE-BOK fulfillment at each of these points is described using a two-dimensional scale that characterizes the performance of the outcome in terms of its cognitive rigor and its practical relevance. The rigor and relevance framework (Figure 3) was first presented in 2005 by Willard R. Daggett, Ed.D. of the International Center for Leadership in Education. The application of this scale is more clearly seen in Appendix A where Outcomes are mapped to cognitive levels and practical relevance.

Knowledge Domain Required	**Outcome**																	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Mathematics, Computer Languages	■	■	■	■	■	■	■	■	■	■	■				■			
Physics, Mechanics	■	■		■	■			■	■	■	■				■			
Chemistry	■	■		■	■	■	■	■	■	■	■				■			
Biology and Ecology	■	■		■	■		■	■	■	■	■				■			
Conservation of Mass	■			■	■	■	■	■	■		■				■			
Conservation of Energy	■			■	■		■		■		■				■			
Mass Transport	■			■	■		■		■		■				■			
Heat Transport	■			■	■						■				■			
Fluid Mechanics	■			■	■		■	■	■		■				■			
Earth Science	■			■	■	■		■	■		■				■			
Systems Analysis	■	■	■	■	■	■	■	■	■	■	■				■			
Probability and Statistics		■	■		■			■	■		■				■			
Humanities, Social Studies						■	■			■	■		■	■	■	■	■	■
Economics							■	■	■	■	■				■		■	■
Business Management						■		■	■		■	■	■		■		■	■

Figure 2. Matrix of Outcomes and Knowledge Domain

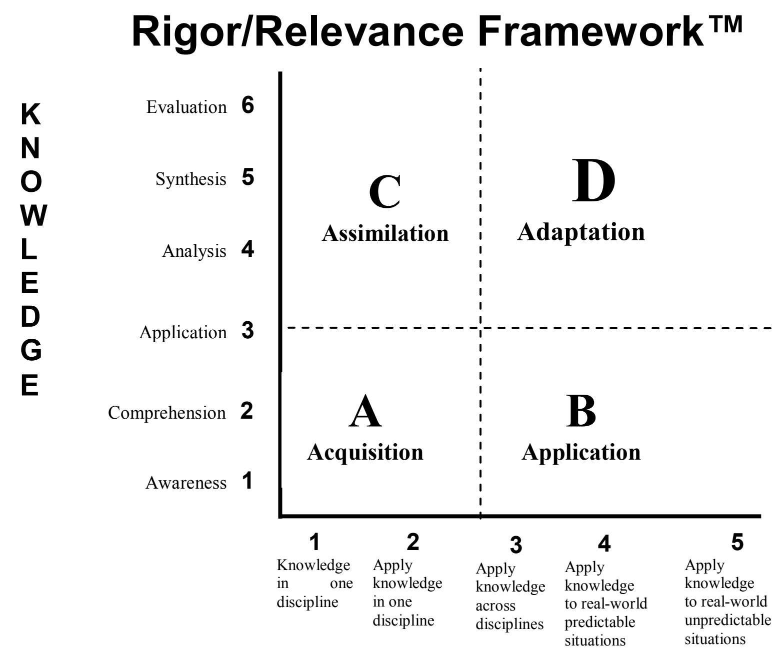

Figure 3. Rigor/Relevance Framework Used in Formulating the Performance Levels.

The Y-axis of Figure 3 utilizes Bloom's Taxonomy to describe cognitive levels of learning and application. This taxonomy was first developed in 1956 by Benjamin Bloom, who headed a group that developed a classification of levels of intellectual behavior important in learning.

Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order, which is classified as evaluation. Unfortunately, Bloom found that over 95 percent of typical test questions students encounter require them to think only at the lowest possible level – knowledge and the recall of information. In the WRE-BOK, it is clear that the capacity to use this knowledge for engineering applications, synthesis and evaluation of alternatives must be defined. Each of the cognitive levels is defined below.

> **Knowledge** is defined as the remembering of previously learned material. This may involve the recall of a wide range of material, from specific facts to complete theories. However all that is required is the bringing to mind of the appropriate information – nothing further. Knowledge represents the lowest level of learning outcomes in the cognitive domain.

Comprehension is defined as the ability to grasp the meaning of material. Comprehension may be demonstrated by translating material from one form to another (words to numbers), by interpreting material (explaining or summarizing), and by estimating future trends (predicting consequences or effects). These learning outcomes go one step beyond the simple remembering of material, and represent the lowest level of understanding.

Application refers to the ability to use learned material in new and concrete situations. This may include the application of such things as rules, methods, concepts, principles, laws, and theories. Learning outcomes in this area require a higher level of understanding than those under comprehension.

Analysis refers to the ability to break down material into its component parts so that its organizational structure may be understood. This may include the identification of parts, analysis of the relationship between parts, and recognition of the organizational principles involved. Learning outcomes here represent a higher intellectual level than comprehension and application because they require an understanding of both the content and the structural form of the material.

Synthesis refers to the ability to put parts together to form a new whole. This may involve the production of a unique communication (theme or speech), a plan of operations (research proposal), or a set of abstract relations (scheme for classifying information). Learning outcomes in this area stress creative behaviors, with major emphasis on the formulation of new patterns or structure.

Evaluation is concerned with the ability to judge the value of material (statement, theory, equation, research report) for a given purpose. The judgments are based on definite criteria. These may be internal criteria (organization) or external criteria (relevance to the purpose) that may need to be determined or already defined. Learning outcomes in this area are highest in the cognitive hierarchy because they contain elements of all the other categories, plus conscious value judgments based on clearly defined criteria.

Studies have shown that students understand and retain knowledge best when they have applied it in a practical, relevant setting. A teacher who relies on lecturing does not provide students with optimal learning opportunities. Instead, students go to school to watch the teacher work. Daggett extended the commonly used Bloom's taxonomy scale to include a second dimension related to the relevance of the material. The relevance scale spans from knowledge in one discipline to application of knowledge in real world unpredictable situations. Students need to begin with knowledge in single disciplines (quadrant A) and move upwards and to the right towards quadrant D (see Figure 3). These quadrants include:

Quadrant A – Acquisition: Students gather and store bits of knowledge and information. Students are primarily expected to remember or understand this knowledge.

Quadrant B – Application: Students use acquired knowledge to solve problems, design solutions, and complete work. The highest level of application is to apply knowledge to new and unpredictable situations.

Quadrant C – Assimilation: Students extend and refine their acquired knowledge to be able to use that knowledge automatically and routinely to analyze and solve problems and create solutions.

Quadrant D – Adaptation: Students have the competence to think in complex ways and to apply their knowledge and skills. Even when confronted with perplexing unknowns, students are able to use extensive knowledge and skill to create solutions and take action that further develops their skills and knowledge.

As with many professions, the combination of education, training and experience needs to help guide an engineer through these quadrants in order to operate at the highest levels of both cognitive function and relevant applications in order to meet the expectations of a professional engineer. Thus, many of the performance levels presented in the next section include specification of the level of cognitive ability and relevance/complexity of the problems addressed at each level of accomplishment.

WRE-BOK Outcomes

Foundational Outcome

Outcome 1 – Basic Engineering Math and Science Knowledge for Water Resources Engineering

Mathematics; physics; chemistry; biological science; earth science, mass, energy and mass conservation and transport principles needed to understand and solve water resources engineering problems.

Outcome Explanation: Underlying the professional role of the water resources engineer as the master integrator and technical leader is a firm foundation in mathematics, physics, chemistry, biology, ecology, and earth science. The water resources engineer draws on these knowledge domains along with principles of conservation and transport of mass, momentum, and energy to analyze natural systems and to design, construct, and manage engineered systems.

Level of Achievement:

At completion of baccalaureate degree:

- **Define** key factual information related to the knowledge domains of mathematics, physics, chemistry, biology, ecology, conservation and transport principles, and earth science.
- **Explain** key concepts and problem-solving processes involved in each knowledge domain.
- **Apply** each knowledge domain to well-defined problems appropriate to Water Resources Engineering

At completion of masters degree or 30 hours post-baccalaureate:

- **Analyze** a complex problem to determine relevant knowledge domains.
- **Apply** knowledge domains, as necessary, to analyze and solve a predictable problem appropriate to water resources engineering.

After ten years of professional experience:

- **Evaluate** innovative engineering approaches to solve real-world problems appropriate to water resources engineering **using knowledge domains of the first outcome**.

Knowledge Domains: Physics, chemistry, biology/ecology, earth science, energy and mass conservation and transport principles

Enabling Knowledge and Skills Outcomes

Outcome 2 - Design and Conduct Experiments

Design and conduct experiments necessary to gather data and create information for use in analysis and design.

Outcome Explanation: An experiment is a procedure carried out in order to discover information, to test or establish a hypothesis, or to determine characteristics of environmental media or processes. Water resources engineers frequently conduct experiments to gather data and create information for use in analysis and design. Such experiments may be conducted in the field or the laboratory or may involve numerical simulation. These experiments would involve some direct measurements or simulations of physical, chemical and biological characteristics of water, air and soil or processes used in their treatment, remediation or restoration. To efficiently design and conduct experiments, the water resources engineer must be familiar with the appropriate tools and should have the ability to interpret the results.

Level of Achievement:

At completion of baccalaureate degree:

- **Identify** the procedures and equipment required to conduct common experiments.
- **Explain** the purpose, procedures, equipment and practical application of experiments.
- **Conduct** appropriate experiments.
- Use statistics to **analyze** experimental uncertainties and error and interpret results.
- **Design** an experiment based on accepted procedures and measurements to develop specific information or to test a specific hypothesis.

At completion of masters degree or 30 hours post-baccalaureate:

- **Design and conduct** experiments using appropriate state-of-the-art tools to develop specific information or to test a specific hypothesis related to a predictable appropriate problem.
- **Analyze** and **interpret** the results and **explain** the resulting information using appropriate communication tools.
- **Design** an experiment to develop specific information or to test a specific hypothesis related to a complex problem.

After ten years of professional experience:

- **Evaluate** the effectiveness of an experiment designed to obtain information related to a complex problem and communicate the evaluation to stakeholders.

Knowledge Domains: Math and computational science, physics, biology/ecology, chemistry, ecology, systems analysis, probability

Outcome 3. Use of Modern Engineering Tools

The techniques, skills, and modern engineering tools necessary for engineering practice.

Outcome Explanation: A practicing water resources engineer must be able to apply state-of-the-art tools in analyzing problems and creating solutions and designs. Such tools include, as examples, measurement tools and techniques, programming languages, and software for graphics, GIS, modeling, statistical analysis, and risk analysis.

Level of Achievement:

At completion of baccalaureate degree:

- **Identify** and **describe** the engineering tools available to solve problems.
- **Select** the most appropriate tool for application to various types of problems and projects.
- **Apply** modern tools to the various elements of engineering problem solving and project analysis for well-defined problems.

At completion of masters degree or 30 hours post-baccalaureate:

- **Recognize** the limitations of the various tools with respect to appropriateness, accuracy, consistency, sensitivity.
- **Apply** engineering tools to multidisciplinary water resources engineering problem solving.

After ten years of professional experience:

- **Evaluate** the benefits, risk, and uncertainty associated with the use of specific tools in analysis of projects.

Knowledge Domains: Math and computational science, systems analysis, and probability

Outcome 4: In-Depth Competence

Advanced knowledge and skills essential for professional practice of water resources engineering.

Outcome Explanation: In-depth competence based on advanced knowledge and skill is essential for professional practice of water resources engineering. This competence may be attained in a traditional specialty such as water transport design, it could span a range of traditional specialties, or it could focus on an emerging or non-traditional area such as ecological engineering or aspects of sustainability.

Level of Achievement:

At completion of baccalaureate degree:

- **Recognize** and **describe** the need for in-depth competence for solution of complex problems.
- **Describe** the traditional specialties as well as some of the emerging specialties.

At completion of masters degree or 30 hours post-baccalaureate:

- **Apply** specialized tools, methodology or technology to solve well-defined problems.
- **Analyze** a predictable environmental process or system in a traditional or emerging area
- **Design** a predictable environmental process or system in a traditional or emerging area.

After professional practice with ten years experience:

- **Design** and **implement** a complex system or process in a traditional or emerging area.

Knowledge Domains: Math and computational science, physics, chemistry, biology/ecology, mass and energy conservation and transport, fluids, earth science, and systems analysis

Outcome 5: Risk, Reliability, and Uncertainty

GENERAL COMMENT: ENGINEERS GO BEYOND RISK ASSESSMENT AND EVALUATE HOW RISKS SHOULD BE MANAGED.

The risks associated with human or environmental exposure to contaminants in our environment and uncertainty and reliability principles as they affect the engineered systems designed, built or operated to protect the environment and the public health, welfare and safety.

Outcome Explanation: From a water resources engineering context, risks to humans or environmental systems can occur from exposure to physical, chemical, and biological hazards or from a failure of engineered systems designed to protect the environment and the public health, welfare, and safety. Risk often is defined as a measure of the probability and severity of adverse effects. Its assessment includes definition of context and system, exposure assessment, hazard identification, and risk quantification and assessment relative to specified criteria. Water resources engineers must use these assessments to determine what can be done, the available options, and the associated trade-offs in terms of cost, benefit, and risk, and the impacts of decisions on future options in order to develop a risk management strategy.

Level of Achievement:

At completion of the baccalaureate degree:

- **Identify** potential hazards, exposure pathways, and risks to the environment and the public health, welfare, and safety associated with exposure to physical, chemical and biological hazards.
- **Identify** the modes for failure of a system engineered to protect the environment and the public health, welfare and safety and the resulting consequences of such a failure.
- **Explain** the significance of uncertainties in data and knowledge on the performance and safety of engineering projects or systems.
- **Apply** the principles of probability and statistics to the design of a simple engineered component using data or knowledge-based uncertainties.
- **Determine** the potential exposure and risk to the environment and the public health, welfare and safety for a well-defined exposure or hazard.

At completion of masters degree or 30 hours post-baccalaureate:

- **Analyze** the potential exposure and risk to the environment and exposed populations for multiple chemical and biological exposure routes and hazards.
- **Analyze** the modes for failure of a system engineered to protect the environment and the public health, welfare and safety and **quantify** the resulting consequences of such a failure.
- **Design** an engineered system applying the principles of probability and statistics to uncertainties in data or knowledge to devise a risk management strategy.

After ten years of professional experience:

- **Assess** the risks of various engineering alternatives and integrate this assessment into the recommendation of a risk management strategy.
- **Employ** quantitative tools to analyze risk and reliability.

Knowledge Domains: Math and computational science, physics, chemistry, biology/ecology, mass and energy conservation and transport, fluids, earth science, systems analysis, and probability

Outcome 6: Problem Formulation and Conceptual Analysis

Problem formulation and analysis based on proper water resources engineering problem identification, obtaining background knowledge, development and analysis of alternatives, understanding existing requirements and constraints, and recommendation of effective solutions.

Outcome Explanation: Conceptual design includes assessing the engineering situation, articulating the problem through technical communication (written and oral), formulating alternative approaches, evaluation of the alternatives, and recommending feasible solutions. Approaches should include systems analysis, development of solutions, both routine and creative; evaluation of alternative solutions and their environmental and economic consequences; use of iterative process analysis and selection of the most appropriate solution(s), employing critical thinking and synthesis of fundamental knowledge appropriate to water resources engineering.

Level of Achievement:

At completion of baccalaureate degree:

- **Explain** key concepts related to problem recognition, articulation and solution.
- **Recognize** difficulties requiring innovative problem definition and solutions.
- **Analyze** a well-defined problem to identify the root cause.

At completion of masters degree or 30 hours post-baccalaureate:

- **Apply** advanced level technical knowledge and problem analysis/solving skills to complex multidisciplinary problems.
- **Analyze** problems having unpredictable or incomplete parameters to determine their root causes.
- **Analyze** feasibility and appropriateness of predictable solutions as alternatives to conventional solutions to problems.

After ten years of professional experience:

- **Synthesize** experience-acquired knowledge and skills to anticipate and identify unpredictable problems.
- **Develop** means for supplementing inadequate data or definition.
- **Evaluate** innovative solutions to complex real world problems and compare with conventional solutions based on environmental and economic consequences of implementation.

Knowledge Domains: Math and computational science, chemistry, conservation of mass, earth science, systems analysis, humanities and social sciences, business management.

Outcome 7: Creative Design

Design of a system, component or process to meet desired needs related to a water resources problem.

Outcome Explanation: Design is a creative and discovering process using iterative steps. Activities such as problem definition, stipulating problem specifications, analysis, performance prediction, implementation, and assessment are parts of this process. The design process is open-ended, frequently with a number of feasible solutions. Successful design requires creative and critical thinking, appreciation of uncertainties involved and use of engineering judgment.

Level of Achievement:

At completion of baccalaureate degree:

- **Define** problem objectives and specify design criteria.
- **Recognize** realistic constraints such as economics, environmental, social, political, ethical, health and safety, constructability and sustainability factors.
- **Apply** creativity and knowledge domains to design a system or process to meet desired needs.
- **Analyze** predictable situations to determine design needs and requirements.

At completion of masters degree or 30 hours post-baccalaureate:

- **Apply** creativity and knowledge domains to design a real world system or process to meet desired needs.
- **Analyze** real world situations to determine design needs and requirements.
- **Assess** compliance with customary standards of practice, client's needs, and relevant constraints to develop solutions to real world problems.

After ten years of professional experience:

- **Assess** the needs of the public and other stakeholders in formulating design constraints and objectives.
- **Understand** the design of a predictable system, component or process.
- **Understand** the interactions among planning, design, life-cycle assessment, construction and operational management.
- **Evaluate** design proposals as part of the peer review process

Knowledge Domains: Math and computational science, chemistry, biology, ecology, mass and energy conservation and transport, fluids, systems analysis, humanities and social sciences, and economics.

Outcome 8: Sustainability

Integration of the sustainability into the analysis and design of engineered systems.

Outcome Explanation: As defined by several engineering professional societies, the constraints imposed by the long-term sustainability of our natural and social systems must be a critical factor in the design and selection of engineered systems. For example, in June 2002, AAES, AIChE, ASME, NAE, and NSPE signed the declaration:

> *Creating a sustainable world that provides a safe, secure, healthy life for all peoples is a priority for the US engineering community. ... Engineers must deliver solutions that are technically viable, commercially feasible and, environmentally and socially sustainable.*

This has led to a statement adopted in 2006 by NSPE that was added to its Code of Ethics as a professional obligation of engineers:

> *Engineers shall strive to adhere to the principles of sustainable development in order to protect the environment for future generations.*

For the purposes of this document, the term sustainability is defined (ASCE, 2008) as:

> ***Sustainability** is the ability to meet human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and enhancing environmental quality and the natural resource base essential for the future. Sustainable engineering meets these human needs.*

The water resources engineer has a critical role in the emerging arena of sustainable engineering. It is expected that water resources engineers have sufficient understanding of natural system processes, that is - how our earth functions, to help define the extent of environmental alteration that may result from different engineered systems. At the same time, they must also integrate sustainability principles into the engineered systems they themselves design, build or operate to protect environmental and human health and well being.

Level of Achievement:

At completion of baccalaureate degree:

- **Recognize** life-cycle principles in the context of design, operation, and maintenance.
- **Identify** components of an engineered system that are not sustainable.
- **Explain** the scientific basis of natural system processes and the impacts of engineered systems on these processes.
- **Explain** the need for and ethics of integrating sustainability throughout all disciplines and the role water resources engineers have in this.
- **Quantify** environmental releases or resources consumed for a given engineered process.

At completion of masters degree or 30 hours post-baccalaureate:

- **Analyze** the sustainability of an engineered system using traditional or engineered systems (e.g., industrial ecology, life cycle assessment, etc.)
- **Ascertain** where new knowledge or forms of analysis are necessary for sustainable design.
- **Design** traditional or emerging engineered systems using principles of sustainability.

After ten years of professional experience:

- **Design** a complex system, process, or project to perform sustainably.[5]
- **Evaluate** the sustainability of complex systems, whether proposed or existing.[5]

Knowledge Domains: math and computational science, chemistry, physics, biology, ecology, earth science, mass and energy conservation, systems analysis, probability, economics, business/management, humanities/social science.

Outcome 9: Multi-Media Breadth and Interactions

Application of basic engineering mathematics and science to predict and determine fate and transport of substances in and among air, water and soil as well as in engineered systems.

Outcome Explanation: Water resources engineers must have a holistic view of the environment so that pollutants removed from one medium do not cause problems by transfer to another. They must be able to apply fundamental principles to fate and transport of substances not only within a single medium but also to the transfer between media in natural or engineered systems. It follows that they must understand the principles that govern inter-media transfer and must be able to consider the impact of this transfer in problem formulation and design. The situation is complicated by laws and regulations that consider only single media.

Level of Achievement:

At completion of baccalaureate degree:

- **Explain** how inter-media transfer is relevant to real world problems.
- **Apply** conservation and transport principles to determine the fate of substances in air, water, and soil for well-defined situations.
- **Apply** the fundamental principles governing transfer of substances between phases to well-defined situations e.g. where equilibrium assumptions apply.

At completion of masters degree or 30 hours post-baccalaureate:

- **Apply** fundamental principles governing inter-media transport and fate of substances to a complex situation, e.g. where mass transfer is rate limited.
- **Analyze** a system that incorporates inter-media transport and fate of pollutants

After professional practice with ten years experience:

- **Design** a system that incorporates inter-media transport and fate of substances.
- **Appraise** the laws and regulations that pertain to the air, water and land environment applicable to a specific practice area.

Knowledge Domains: math and computational science, physics, chemistry, biology and ecology, mass and energy conservation and transport, fluids, earth sciences, systems analysis, probability, economics, and business management.

Outcome 10. Societal Impact and Environmental Policy

Societal impact of water resources engineering issues and solutions; engineering and communication skills that influence and implement public environmental policy.

Outcome Explanation: Public policy consists of political decisions for implementing programs to achieve societal goals (Cochran and Malone, 2005). As concluded in NAE's *The Engineer of 2020*, as technology becomes more ingrained in our lives, the convergence between engineering and public policy must increase. Because water resources engineers regularly are involved in the implementation of public environmental policy, they have a unique understanding of the elements of good environmental policy. It follows that they should be involved as stakeholders in the process of establishing public policies. Further, water resources engineers should recognize societal impacts of engineering activities, should communicate these impacts to stakeholders, and should consider stakeholder inputs in developing solutions.

Level of Achievement:

At completion of baccalaureate degree:

- **List** some important public policies as stated in international accords and federal laws.
- **Recognize** potential societal impacts of a solution to an environmental problem.
- **Discuss** and **explain** important processes involved in setting public environmental policy.

After ten years of professional experience:

- **Describe and explain** environmental policy in some detail in some area of practice.
- **Apply** knowledge of societal structure and dynamics when seeking solutions to problems.
- **Participate** as a citizen stakeholder in the development of public policy.

Knowledge Domains: basic engineering mathematics and sciences, humanities and social sciences and economics

Outcome 11: Globalization and Other Contemporary Issues

Outcome Statement: Globalization and other contemporary issues vital to water resources.

Outcome Explanation: Contemporary issues are problems and topics of emerging importance or recent discovery. Globalization refers to an integration of processes or delivery systems that transcends national, cultural and language differences. For example, awareness of the impact of inadequate sanitation and access to potable water on public health in many parts of the developing world and the impact of human activity on climate change are issues that are both global and contemporary. The water resources engineer must be able to function in a global system for delivery of engineering projects and services practice, taking into consideration the cultural appropriateness of technology. In addition, the water resources engineer must be aware of emerging contemporary issues and of their impact on the professional.

Level of Achievement:

At completion of baccalaureate degree:

- **Explain** some barriers to the delivery of services in a global context.
- **Utilize** modern tools to identify and understand contemporary issues
- **Define and analyze** and **propose** solutions to well-defined problems that are constrained by global and contemporary issues.

At completion of masters degree or 30 hours post-baccalaureate:

- **Describe** how globalization of technology has influenced design and/or project delivery.
- **Participate** in discussion and debate focused on globalization and contemporary issues and their relationship with and potential impact on public health and the environment.
- **Synthesize** information on contemporary issues to provide perspective on relevance to real world problems

After professional practice with ten years experience:

- **Evaluate** the impact of an important globalization and/ other contemporary issue on design and/or delivery of a project or case study.

Knowledge Domains: All

Professional Outcomes

Outcome 12 - Multi-Disciplinary Teamwork to Solve Water Resources Problems

Skills and expertise of multiple disciplines used to address complex engineering problems as a team.

Outcome Explanation: The solutions of most engineering problems require the expertise and participation of a variety of disciplines. The water resources engineer will use management and communication skills in engineering to create, manage, and participate in teams composed of professionals from a broad range of disciplines. This requires understanding team formation and evolution, individual characteristics, team dynamics, collaboration among diverse disciplines, problem solving, and time management and being able to foster and integrate diversity of perspectives, knowledge, and experiences (ASEC, 2008).

Level of Achievement:

At completion of baccalaureate degree:

- **Identify** disciplines necessary to solve a complex problem.
- **Describe** the characteristics of an effective team.
- **Function** in team activities to design and implement solutions.

After ten years of professional experience:

- **Function** effectively in multi-disciplinary team activities

Knowledge Domains: Business Management

Outcome 13. Professional and Ethical Responsibilities

Professional and ethical issues in water resources engineering.

Outcome Explanation: Whereas morals are values relating to how humans ought to treat each other, ethics are rules for how humans ought to treat each other in the absence of detailed moral values or when moral values conflict. Moral behavior, in both personal and professional matters, is expected of all water resources engineers. Professional ethics for engineers is spelled out in the various codes of ethics such as those adopted by professional societies. Often these codes provide guidance on how moral dilemmas can be honorably resolved, but sometimes the engineer is asked to make morally-significant decisions that do not have simple or straightforward resolutions. Ethical decision-making is thus a useful and required skill for all professional engineers.

Jon, Primary responsibility is to protect public health and safety.

Level of Achievement:

At completion of baccalaureate degree:

- **Recognize** moral and ethical problems that might arise in engineering practice.
- **Explain** tenets of professionalism and codes of engineering ethics.
- **Apply** standards of professionalism and codes of engineering ethics to determine an appropriate course of action for a given situation.

At completion of masters degree or 30 hours post-baccalaureate:

- **Analyze** a situation involving conflicting ethical and professional interests to determine an appropriate course of action.

After professional practice with ten years experience:

- **Describe** a situation based on personal experience with situations and courses of action that illustrates professional and ethical behavior.
- **Assess** personal professionalism and ethical development

Knowledge Domains: Humanities and social sciences

Outcome 14: Effective Communication

Effective communications when interacting with the public and the technical community.

Outcome Explanation: The water resources engineer frequently is the critical link to public understanding and interpretation of policy, issues, and implementation of plans for projects that affect public and the environment. The water resources engineer must communicate using verbal, written, virtual, and graphical means to describe concepts, environmental impact issues, and projects affecting the environment to technical and non-technical audiences, and receive and interpret communications in return.

Level of Achievement:

At completion of baccalaureate degree:

- **Describe** the characteristics of effective verbal, written, virtual and graphical communications.
- **Apply** the rules of grammar and composition in verbal and written communications, properly cite sources.
- **Use** appropriate graphical standards in preparing documents and presentations.
- **Summarize** the essential points and elements of verbal and written communications received from others.
- **Organize** and **deliver** effective verbal, written, virtual, and graphical communications.

At completion of masters degree or 30 hours post-baccalaureate:

- **Make** effective presentations to technical audiences.
- **Interpret** the intent and content of communications from technical and non-technical stakeholders in a concept or project.
- **Plan, compose**, and **integrate** the verbal, written, virtual and graphical communication of a concept or project to technical and non-technical audiences.
- **Communicate** the concept of uncertainty and risk to technical and non-technical audiences.
- **Develop** conclusions that logically follow from data results and discussion.

After ten years of professional experience:

- **Make** effective presentations to technical and non-technical audiences.
- **Evaluate** the effectiveness of the integrated verbal, written virtual and graphical communication of a concept or a project to technical and non-technical audiences.
- **Evaluate** the accuracy of interpretations of communications from technical and non-technical stakeholders in a concept or project.

Knowledge Domains: Humanities and social sciences

Outcome 15: Lifelong Learning

Life-long learning leading to enhanced skills, awareness of technology, regulatory, industrial, and public concerns.

Outcome Explanation: Water Resources Engineering is an ever-developing profession, where environmental concerns multiply with additional complexity of society, and with the development and use of more complex materials that are frequently toxic or otherwise disruptive to the environment and to public health, welfare and safety. Demand for efficiency in processes, including processes for environmental risk management, requires awareness of impacts and developing technology; accordingly, life-long learning is essential.

Level of Achievement:

At completion of baccalaureate degree:

- **Define** life-long learning.
- **Explain** the need for life-long learning.
- **Describe** the skills required of a life-long learner.
- **Demonstrate** the ability for self-directed learning.

At completion of masters degree or 30 hours post-baccalaureate:

- **Identify** additional knowledge, skills and attitudes appropriate for continued practice at the professional level.
- **Integrate** self-directed learning of issues that apply one's career.

After ten years of professional experience:

- **Plan** a regimen of continued learning to maintain proficiency.
- Regularly **acquire** additional expertise and **maintain** skills and appropriate current knowledge.

Knowledge Domains: All

Outcome 16. Project Management

Principles of project management relevant to water resources engineering.

Outcome Explanation: Project Management is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. Project management is accomplished through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling, and closing (Project Management Institute, 2004). Meeting project budget, scope, and schedule and delivering a quality product are the primary goals of project management.

Level of Achievement:

At completion of baccalaureate degree:

- **List and explain** project management processes and principles.
- **Explain** how project management and construction relate to the project delivery process.
- **Solve** well defined project management problems.

At completion of masters degree or 30 hours post-baccalaureate:

- **Apply** project management to a project.

After ten years of professional experience:

- **Create** documents to be incorporated into a project management plan as a member of an engineering team.
- **Create** project management plans as a member of an engineering team.

Knowledge Domains: Systems analysis, humanities and social sciences, economics, and business management

Outcome 17. Business and Public Administration

Business knowledge and communication skills to the administration of both private and public organizations.

Outcome Explanation: Water resources engineers typically deal with both private and public organizations, and they must understand business fundamentals such as organizational structure, income statements and balance sheets as well as public administration fundamentals such as the political process, regulations, asset management and funding processes. Asset management is a business process and a decision-making framework that covers an extended time, and draws from both economics and engineering. Many water resources engineers use asset management principles in managing and maintaining environmental infrastructure.

Level of Achievement:

At completion of baccalaureate degree**:**

- **List and describe** important fundamentals of business and of public administration related to water resources engineering.

After professional practice with ten years experience:

- **Analyze** problems involving business and public administration as they relate to environmental problems.

Knowledge Domains: Economics and Ethics

Outcome 18. Leadership

Outcome Statement: Engaging, motivating and leadership of others to achieve common vision, mission and goals.

Outcome Explanation: Leadership is the art and science of influencing others toward achieving common goals (ASCE, 2008). Leadership abilities are important for success in all professional endeavors, and especially where teamwork is involved. Because many water resources engineering projects require that several individuals work collectively toward common goals, leadership abilities are critical for the water resources engineer. Leadership requires technical competence, continuous self-improvement, timely and responsible decision making, self-confidence effective communication, and moral behavior. Attributes of leaders include vision, enthusiasm, energy, commitment, selflessness, discipline, confidence, communication skills, and persistence. These abilities and attributes can be taught and developed in both formal education and engineering practice (ASCE, 2008). Examples of opportunities to develop leadership within the educational setting include leading design teams, team competitions, student organizations, and athletic teams. Leadership should be further developed during the professional career in real-world settings. Senior engineers should mentor junior engineers and provide opportunities for leadership.

Level of Achievement:

At completion of baccalaureate degree:

- **Define** leadership and the role of a leader.
- **List** leadership skills and attributes.
- **Explain** the role of a leader, leadership skills, and leadership attributes.
- **Apply** leadership skills to direct the efforts of a small group.

After professional practice with fours years experience:

- **Organize** and **direct** the efforts of a group to achieve a goal.

Knowledge Domains: communication skills, decision making, economics and business management.

Implementation of the WRE-BOK

Educators, students, young engineers and senior practitioners all share responsibility in implementing the WRE-BOK. Educators and students should be familiar with the WRE-BOK because it defines the outcomes of a water resources engineering education. From a faculty point of view, the WRE-BOK can guide curriculum and expectations of students. From a student point of view, the WRE-BOK can guide expectations of their technical and non-technical educational experience. As stakeholders in engineering education, practitioners, managers, and leaders of public and private engineering organizations should be familiar with the WRE-BOK. The depth and breadth of the young water resources engineer's early professional experiences are critical to fulfilling the WRE-BOK. Senior practitioners should take an active role to help young water resources engineers continue the learning process toward fulfillment of the WRE-BOK and professional licensure.

Role of Educators

Effective education of engineers requires the efforts of engineer practitioners, engineer teachers, and engineer scientists. In addition, the efforts of many non-engineer teachers are needed to prepare students to attain the daunting list of outcomes necessary for engineering practice. The breadth of team talent is particularly important for water resources engineers. The WRE-BOK is intended to be a useful guidance document for all stakeholders. From the educators' perspective, the WRE-BOK will provide:

- A benchmark for programs to determine if the curriculum, projects and degree requirements result in engineers who are ready to enter their chosen profession or continue their education in that direction;
- Details to help an instructor design the content of a particular class;
- Evidence of the depth of material required at the baccalaureate or masters level that can be used to support faculty members' efforts to garner resources to improve their courses or curriculum; and,
- Faculty members with a broader picture of the entire profession of water resources engineers that could be used in advising students about course selections and career opportunities.

It is essential that educators prepare students to attain the WRE-BOK outcomes through the development and delivery of effective curricula.

Role of Students

The WRE-BOK outcomes and levels of achievement should provide the student with a framework within which one can understand the purpose and measure the progress of one's education, prepare to move into an internship, and, ultimately enter the practice of Water Resources Engineering at the professional level (see Figure 1). During undergraduate engineering education, some important considerations for students are as follows:

- **Utilize Campus Resources.** The campus is likely to have programs, centers and offices that can assist with time management, writing, studying, tutoring, computing, financial aid, part-time work, summer and permanent employment.
- **Actively Participate in Campus Organizations.** Students can move toward fulfillment of Outcome 12, Teamwork; Outcome 14, Communication; and Outcome 18 Leadership, by active participation in one or more campus organizations (student chapters of professional societies, student government, sports teams, fraternities and sororities). Enhancement of knowledge, skills and attitudes, will result from this type of service.
- **Explore International Programs.** The explanation for Outcome 11, Globalization, offers this advice: "Globalization refers to an integration of processes and delivery systems that transcends national, cultural and language differences." Given the impact of globalization on engineering, students should at least explore participating in an international study program.
- **Seek Relevant Work Experiences.** Students can apply and augment classroom and laboratory learning during their formal education by finding relevant work experience. Work options may include part-time employment with engineering or industrial organizations and governmental agencies through summer employment, internships and cooperative education.
- **Protect Your Reputation.** Engineers are judged primarily by the credibility of their professional judgment and advice. Reputation, as a professional, begins during the education experience through the appropriate use of communication skills (speaking, writing, computer), and giving proper credit when using ideas, data and information developed by others. A concerted effort toward fulfilling Outcome 13, Professional and Ethical Responsibility is of utmost importance.
- **Following Your Formal Education.** As formal education draws to a close, whether it results in earning a baccalaureate, masters, or other degree, students naturally think about professional employment opportunities. A potential employer who is knowledgeable and supportive of the WRE-BOK will be of great benefit, as the young professional continues to work toward engineering licensure and specialty certification.

The BOK, built on foundational, technical and professional outcomes, will help students adjust to inevitable career changes and prepare them for leadership opportunities.

Role of New Engineers Prior to Licensure

Prior to licensure, engineers should become familiar with the WRE-BOK. Water resources engineering students and graduates should know what the profession expects of them as they develop into experienced engineers. If not formally taught in coursework, this knowledge should be obtained through professional societies and civic activities.

Above all, engineers should take responsibility for their own professional development. This is especially important for new engineers at the beginning of their careers. These "young" should not rely entirely on employer sponsored professional development programs. They should be proactive in developing their abilities in accord with the expected WRE-BOK outcomes. Professional development opportunities include various combinations of the following:

- Internal employer sponsored and external seminars and courses;
- Local, national, and international conferences;
- Formal mentoring and coaching;
- Practical learning through a variety of office and field functions;
- Active participation in professional and business societies;
- Periodic (annual, at a minimum) reviews of individual goals and plans for achieving those goals.

Professional development programs should be monitored and improved for organizational and individual effectiveness. A professional development program will most likely be effective if it involves a partnership between individuals and the organization. For example, if the organization offers a two hour in-house seminar, it might be scheduled mid-day where one hour would be on "company time" and the other hour on personal (lunch) time. This partnership approach offers several benefits; it reduces the impact of lost productive time, it allows individuals to demonstrate commitment to professional development by investing their own time, and it creates a community within the organization that fosters employee connectedness.

Role of Senior Water Resources Engineer Practitioners

Mentoring

The most important role for senior water resources engineering practitioners in implementing the WRE-BOK is to mentor junior engineers. Effective mentoring is necessary for professional development, but also plays a broader role in attracting interest in the profession and in promoting retention within organizations. Indeed, they cite the availability of mentoring and training as a basis on which young professionals make career decisions, and propose that a successful mentoring relationship includes five elements:

- Initiation, whereby the young professional identifies an interest in an area of relevance to the organization,
- Integration, requiring the mentor to find professional development opportunities and financial support for the young professional,
- Training, involving the mentor allocating appropriate resources for professional development, licensure, and certification,
- Performance, as the young professional delivers quality work in a timely manner and develops professionally, and
- Maintenance, whereby the advancing professional's performance allows for transition to a mentor role.

Managers and mentors should assist young water resources engineers in identifying a variety of assignments and project functions. Examples include assisting with proposals, field work, statistical analyses, formulating and evaluating project alternatives, design, estimating costs, seeking permits, writing reports, and making presentations. Early project goals and methods should be detailed for the young water resources engineer with direct access to the mentor and senior professionals for further guidance. As the young water resources engineer progresses towards fulfilling the WRE-BOK and becoming licensed, broader or more in-depth tasks can be assigned. Direct mentor oversight is required for successful project completion, client satisfaction, and fostering the correct attitudes in the young water resources engineer.

Such practical learning offers valuable lessons to the young water resources engineer. "Lessons learned" are evident when a task or project is successful as well as when outcomes are undesirable. Active and progressive involvement in projects also helps to bond the young water resources engineer to the organization. The benefits of licensure to the individual, the organization, and the public should be conveyed.

As a mentor, the water resources engineer practitioner provides guidance to recent engineering graduates in defining a continuing professional development program including formal graduate course work and cross training work assignments or participation on a multi-disciplinary project team. Active participation in professional societies can also be encouraged as an element of professional development. Ultimately, the water resources engineer practitioner encourages and supports professional licensing and where applicable, professional certification.

Competency and Knowledge Transfer

Water resources engineering practitioners should demonstrate sound approaches to issue resolution and problem solving consistent with the competency levels outlined earlier. Practitioners know their own competency level and are familiar with the WRE-BOK competency level expectations. The water resources engineer practitioners seek guidance or expert help when confronting issues beyond their competency level. Internal and external communication, solving complex problems, and application of engineering judgment are areas where mentoring by experienced professionals is extremely valuable.

Water resources engineering practitioners should demonstrate a lifelong learning attitude and keep their knowledge current through self education, continuing education such as attendance at formal seminars and/or advanced course work. Water resources engineers are expected to share knowledge through participation in formal seminars and publishing of papers/articles as well as through informal meetings with educators, students and fellow practitioners.

The water resources engineer practitioner mentor should encourage and facilitate participation in continuous education programs by water resources engineers. Reference to the WRE-BOK serves as a starting point for the appropriate knowledge level. The water resources engineer practitioner mentor demonstrates knowledge through Professional Licensing and/or through Specialty Certification.

Professional Society and Community Involvement

Active participation in professional and business societies is an important element of professional development and can play an important role in fulfilling the WRE-BOK. Senior water resources engineers should encourage young water resources engineers to become actively involved in at least one professional society. Active participation extends beyond simple membership and may include serving on or leading a committee, organizing society activities such as seminars and workshops, and publishing in society newsletters, magazines and journals. Active professional society involvement supports professional development but also serves the organization and its clients by providing valuable perspective into issues, challenges, and opportunities in the field.

The water resources engineer practitioner possesses unique expertise, skills and ability that can assist neighborhood organizations and civic leaders in assessing alternatives and making decisions that can have a major impact on public health and the quality of life. The water resources engineer participates in public fora and volunteers for local community service through established organizations or ad hoc committees to support community development and civic progress. Volunteer efforts enable many neighborhood, religious, community-wide, national, and international organizations to provide valuable services or functions. Service organizations include those that were founded by, or are operated under the auspices of a professional society. Young professionals can participate in such organizations as engineers, for example by providing technical guidance to community committees or boards. They can also participate as citizens; examples include coaching younger athletes, judging science fair competitions, and running for elected office. Active participation in such organizations can help fulfill the WRE-BOK by providing valuable opportunities to interact with the public, develop effective communication skills, and provide exposure to contemporary issues. The mentor should encourage young engineers to become involved in civic and community projects and speak at community meetings when appropriate opportunities arise.

Professional and Ethical Behavior

Most young water resources engineers will listen respectfully to advice offered by experienced professionals; however, such advice will have the greatest impact when words are supported by actions. Coaching and mentoring effectiveness will be enhanced if the mentor serves as a positive role model and exemplifies the personal and professional behavior that is desired. The attitudes and actions of mentors and advanced professionals can provide a vivid illustration of the value of continued professional development, practical learning, client focus, licensure, and active involvement in professional societies and community groups.

Water resources engineering practitioners should above all demonstrate a commitment to ethical standards of practice. The success of water resources engineering is largely dependent on self-monitoring and open, honest communication with both internal and external clients regarding risks, problems, and solutions. Such open communications is driven by the practitioner from a full disclosure standpoint in concert with general business ethics policies, whenever and wherever issues or problems are encountered.

The water resources engineer practitioners mentor lead by example in exhibiting professional behavior in all interactions with peers, clients, government officials and the community at large. In short, they practice what they preach. It is especially important to be seen by young professionals as a role model to be truly effective as a mentor. Mentors should specifically work with young water resources engineers to promote understanding and application of the AAWRE code of ethics.

WHERE DO WE GO FROM HERE?

The development of the WRE-BOK is a continuous process of testing and improvement. As it is implemented, practitioners and educators must evaluate the WRE-BOK and determine whether all issues necessary to the practice of water resources engineering have been addressed and whether the outcomes can be achieved at the level recommended at the point in professional development indicated. It is recommended that such evaluation be accomplished utilizing task forces created by organizations serving significant numbers of water resources engineers, such as the AAWRE. Practitioner task forces should examine the WRE-BOK to ensure that engineers will be trained to meet the needs of the future, that the practitioner's role has been correctly identified, and that the levels of achievement are correct. Educators should conduct a curriculum reality check. A representative number of water resource engineering undergraduate and graduate programs should be identified and asked to evaluate whether curricula can be reasonably designed to adopt the WRE-BOK. Educators also should determine whether the levels of achievement are defined correctly. Finally, it is recommended that an implementation task force be created to make recommendations regarding how the WRE-BOK should be used for accreditation, licensing, and promotion of the profession.

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Appendix

Mapping of Outcomes to Levels of Achievement

Note: Practical Relevance of Knowledge Application references:

A1: Knowledge in one discipline
A2: Apply knowledge in one discipline
A3: Apply knowledge across disciplines
A4: Apply knowledge to real world predictable (complicated) situations
A5: Apply knowledge to real world unpredictable (complex) situations