ENVIRONMENTAL ENGINEERING BODY OF KNOWLEDGE

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The Environmental Engineering Body of Knowledge Task Force

January 2009

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Executive Summary: A diverse group of environmental engineers has developed a Body of Knowledge which defines the knowledge, skills and abilities needed to practice environmental engineering at the professional level. The BOK includes 18 outcomes grouped as Fundamental, Enabling Knowledge and Skills, and Professional Outcomes. Bloom's Taxonomy enhanced by the Daggett Rigor/Relevance Framework ™ was used to estimate the appropriate cognitive rigor and applicative relevance level expected for each outcome at the baccalaureate, masters (or equivalent) and after the masters plus 4 years of professional experience.

The development of the EnvE BOK is a continuous process of testing and improvement. As it is implemented, practitioners and educators must evaluate the EnvE BOK and determine whether all issues necessary to the practice of environmental 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 environmental engineers, such as the AAEE sponsoring organizations. Practitioner task forces should examine the EnvE 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 EnvE undergraduate and graduate programs should be identified and asked to evaluate whether curricula can be reasonably designed to adopt the EnvE BOK. Educators should also determine whether the levels of achievement are correctly defined. Finally, it is recommended that an implementation task force be created to make recommendations regarding how the EnvE BOK should be used for accreditation, licensing, and promotion of the profession.

I. INTRODUCTION

In 2005 the American Academy of Environmental Engineers (AAEE) celebrated its 50th anniversary. The practice of Environmental engineering certainly predates AAEE; however, it had traditionally been viewed as "sanitary engineering," a subset of civil engineering. In the latter half of the twentieth century, particularly in the1980's and 1990's, environmental engineering evolved into a stand-alone engineering discipline. During that time a number of universities awarded undergraduate and graduate degrees in environmental engineering. Also during that time, public and private sector employers of engineers came to view this discipline as separate from, albeit related to, allied engineering disciplines such as civil and chemical engineering.

At the American Academy of Environmental Engineers Board of Trustees annual meeting in November 2005, a Body of Knowledge Development Task Force (BOKTF) was created with the following charge:

> "The Body of Knowledge Development Task Force is charged with defining the BOK needed to enter the practice of environmental engineering at the professional level (licensure) in the 21st century taking into account other issues, including, but not limited to, the impact on AAEE, on the profession, on environmental engineering academic programs (undergraduate and graduate), and on accreditation of environmental engineering programs at the basic and

advanced levels."

The Environmental Engineering BOK (EnvE BOK) describes the knowledge and core competencies important for the understanding and practice of environmental engineering. It builds on ABET outcomes applicable to all engineering specialties by adding outcomes specific and unique to environmental engineering. For each outcome, the EnvE BOK estimates the cognitive rigor and applicative relevance level appropriate for the baccalaureate, masters, and practitioner levels. However, it may not be reasonable to expect all individuals to attain all outcomes at the estimated levels. Accordingly, the estimated rigor and relevance levels should be viewed as targets or guides to an appropriate level of outcome attainment. Likewise, statements made relating to "meeting" or "attaining" the EnvE BOK outcomes should be interpreted as targets or guides to an appropriate level of attainment. As the profession gains more experience and familiarity with the EnvE BOK, some outcomes and performance levels may be judged to be of universal importance and could become part of accreditation and licensure criteria.

The EnvE BOK recognizes that environmental engineering is rapidly evolving. Therefore, the EnvE BOK is intended to be an aspirational guide for environmental engineering educational programs and for individual professional development. It is intended to facilitate adaptation to future challenges and needs. It is not expected that every graduating or practicing environmental engineer will achieve all outcomes at the same level. Rather, educational programs will develop unique educational objectives based on the needs of their constituencies and will emphasize the outcomes that support those objectives. Likewise, environmental engineers will pursue life-long learning activities to emphasize the outcomes that support their professional career objectives. Accordingly, the EnvE BOK is not intended to be prescriptive, but instead to be directional, forward looking; and more of a compass than a detailed roadmap.

II. BACKGROUND

A. Need for the Environmental Engineering BOK

Environmental engineering is a relatively new and rapidly evolving discipline. Moreover, the environment is large, and so is the environmental engineering knowledge base. Because of this, the competencies expected of environmental engineers are not well understood by students, the public, and even other engineers. It follows that some consensus on the knowledge, skills and abilities most important for the environmental engineer will be useful for defining and improving the environmental engineering profession. Moreover, this consensus will be useful for communicating the scope of environmental engineering to other engineers and to the general public.

The need for a Body of Knowledge is not unique to environmental engineering. In 2008, the American Society of Civil Engineers (ASCE) published the second edition of the Civil Engineering Body of Knowledge for the 21st Century (ASCE, 2008). The Environmental Engineering Body of Knowledge has many things in common with the Civil Engineering BOK, and the AAEE EnvE BOKTF acknowledges the help received from ASCE.

B. Definition of Environmental Engineering

Various definitions of environmental engineering have appeared in the literature, and these have been summarized by Baillod et al (1991). The following definition adapted from Gilbertson (1973) is used herein:

Environmental engineering is defined as that branch of engineering concerned with the application of scientific and engineering principles for:

- Protection of human populations from the effects of adverse environmental factors;
- Protection of environments, both local and global, from the potentially deleterious effects of natural and human activities; and
- Improvement of environmental quality.

Environmental engineers practice in both the public and private sectors. Typical duties of environmental engineers may include:

- Evaluation of environmental quality, especially when it involves a risk to public health, and/or when degradation has or may occur as a result of anthropogenic activities – e.g., quality of water, air, soils;
- Development of strategies and methods to prevent environmental degradation or public health risk;
- Development of regulations and requirements for performance of pollution prevention or environmental quality improvement, protection, or remediation projects;
- Design of facilities or programs for pollution prevention or environmental quality improvement, protection, or remediation;
- Evaluation of the results of pollution prevention or environmental quality improvement, protection, or remediation;
- Assessment of the economics and efficiency of processes and procedures used in pollution prevention or environmental quality improvement, protection, or remediation and
- Management, operation, and maintenance of systems for pollution prevention or environmental quality improvement, protection, or remediation.

C. Education for Environmental Engineering

Most practicing environmental engineers have post-baccalaureate education, frequently earning masters degrees. Civil engineering programs have traditionally emphasized specialization at the graduate level, and many programs still use the “civil” descriptor for programs that emphasize environmental engineering. However, an increasing number of institutions now offer baccalaureate and masters degrees designated as Environmental Engineering. Even though the number of baccalaureate degrees designated as environmental engineering is increasing (899 in 2006-2007), the number is small compared to civil engineering (9,402 in 2006-2007, ASEE, 2008). Accordingly, a common entry route to environmental engineering is via a baccalaureate degree in civil or other related engineering or science discipline followed by a masters degree in environmental engineering. While an appreciable number of baccalaureate graduates in environmental and related engineering disciplines begin employment in environmental engineering directly following the baccalaureate degree, an increasing number (estimated by the BOKTF to be roughly one third) 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 environmental 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 is necessary for the engineer to understand processes and relationships essential to environmental engineering.
- Many professionals and other engineers practicing or employing environmental 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 environmental and other engineering specialties. The complexity of modern environmental problems has increased the emphasis on advanced education in consulting practice.
- Within industry it is widely recognized that an advanced degree in environmental engineering is an asset to interface responsibly with regulators and with vendors who are interested in providing environmental equipment and services.

Even though education beyond the baccalaureate degree is important for career advancement and is helpful for licensure, most environmental 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 2020. Licensing boards of some states are considering adoption of the post-baccalaureate education provisions of the model law.

D. Professional Licensure and Specialty Certification

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 and environmental engineering. Environmental engineering practice at the supervisory or responsible charge level generally requires that the engineer be licensed. This is particularly true for projects that involve public safety, health, and welfare such as municipal water and wastewater projects. To a certain extent, most of the 55 licensing jurisdictions (50 states, the District of Columbia, and the four U.S. territories of Guam, Northern Mariana Islands, Puerto Rico, and the Virgin Islands) grant engineers working for industry an "industrial exemption" from licensure. However, for project manager level environmental engineers employed by industry, licensure is advised because most environmental projects will be reviewed, approved, and permitted by local and/or state agencies that will then require the project be performed under the supervision of a licensed engineer.

There is no national professional engineering license. Each jurisdiction has its own particular set of criteria for granting licensure which is similar to the situation in medicine and law. All jurisdictions require that the engineer demonstrate a minimum level of education and experience and then pass an examination or series of examinations. Typically a bachelor's degree in engineering is required (some jurisdictions will accept a science or technology degree) followed by passing the Fundamentals in Engineering Examination. After achieving several years of responsible documented experience (usually 4 or 5 years) the engineer is eligible to sit for the Professional Engineering examination and upon passing becomes a licensed Professional Engineer.

An engineer must be licensed in the jurisdiction in which he or she practices. In many cases, licensure in one jurisdiction will enable the engineer to obtain licensure in another jurisdiction through a comity agreement between the jurisdictions. This is specific to the jurisdiction in question and a summary of comity relationships can be obtained from the National Society of Professional Engineers.

Specialty certification, which is voluntary, i.e. not mandated by statute, establishes a high level of professional competency in a particular area of specialization as determined by peer review. Certification typically involves the three elements of education, experience and examination. AAEE, for example, conveys the Board Certified Environmental Engineer (BCEE) certification. Other examples of technical specialty areas where specialty certification is available are water resources engineering, structural engineering, industrial hygiene, and hazardous materials management. Specialty certification does not carry any right or privilege and is not a substitute for licensure. It does, however, provide the public with an indication of special knowledge and expertise in environmental engineering.

E. Employment Sectors

Environmental engineers are employed in government service, consulting service, industry, and education. Although the skills and duties required of environmental engineers in each sector are similar, there are some differences. Within environmental engineering, the importance of licensure varies among employment sectors.

> **Education –** The education sector is broad, ranging from continuing citizen and professional education provided by community colleges to graduate instruction provided by research universities. A regular tenure-track appointment at a college or university will normally require a doctoral degree with expectation of on-going scholarly productivity. There are also many practicing environmental 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. Environmental Engineering Program Criteria for ABET, Inc (Formerly Accreditation Board for Engineering and Technology) accreditation require that programs demonstrate that a majority of those faculty teaching courses who are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and equivalent design experience. Licensure of environmental engineering educators is important as a visible professional credential to emphasize the engineer's responsibility for protecting public health, safety and welfare. A number of environmental engineering faculty members are

licensed professional engineers and BCEE by the AAEE.

Public Service – Environmental engineering positions in public service, both governmental and private company owned, cover a broad range of duties. Functions range from operational management of water, wastewater or solid waste utilities at the city or regional level to administration of environmental regulations at the state and federal level, to environmental research. Most environmental engineers in responsible public service positions have at least masters level education. Generally licensure is encouraged, and sometimes required for engineers responsible for review and approval of plans for environmental projects that affect the health, safety and welfare of the public. Municipally employed environmental engineers and private utility engineers normally become licensed as a requirement for advancement and career development. They are frequently responsible for projects where the public health, safety and welfare are clear concerns.

Industry – Many environmental engineers are employed in the industrial and construction sectors. Generally these engineers have BS or MS degrees but are not licensed. As an example many of these industrial engineers deal with compliance of environmental regulations as a major responsibility. Many of these positions also have some responsibility for treatment facility operation and design. Most states exempt engineers working for industry from licensing requirements. This licensure exemption should be discouraged as industrial engineers may be involved in projects where public health, safety and welfare are issues. In many cases the lead construction engineer at a major construction site is licensed.

Consulting Engineering Service – Facility design has traditionally been a major responsibility for environmental engineers in consulting service. However, environmental engineering consulting has expanded to include more emphasis on Brownfield investigations, pollutant transport, regulatory guidance, sustainability and facility operation. Virtually all consulting environmental engineers responsible for project design and construction are licensed. The laws of all jurisdictions clearly require licensure for individuals in responsible charge of such projects. Most environmental engineers in responsible charge have masters degrees and an increasing number of environmental engineers in the consulting field have doctoral degrees. A growing number of consulting environmental engineers in responsible positions are becoming board certified by the AAEE. Frequently environmental 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.

Non-Governmental Organizations - Many Non-Governmental Organizations (NGOs) are involved in environmental issues and include environmental engineers on staff as well as in executive leadership positions. Examples of NGOs are technical/professional societies, trade associations, citizens’ advocacy groups, and accreditation/certification boards. Many environmental engineering students are members of student chapters of professional societies such as the AAEE, the American Society of Civil Engineers, the Water Environment Federation, and the American Water Works Association.

Environmental engineers can be employed by these organizations to work with members in writing standards, design guidelines, books, and other educational materials. They can work as environmental engineering experts in the governmental affairs and advocacy areas of an NGO. Environmental engineers can manage and oversee the dissemination and publication of research. NGOs with an environmental mission will generally have technical departments that are led by environmental engineers or scientists. Masters level education is generally desired for management positions and, while licensure is usually not required for the work done by an NGO, it is often sought for engineering positions due to the engineering experience it typically represents and the professional credibility it conveys.

F. Technical Specialties of Environmental Engineering

Given the breadth of the environmental engineering field, most professionals specialize in a subset of the field, with a basic understanding of the other areas of environmental 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.

Currently, most environmental engineering specialties have traditional roots that correlate to the historical development of the field from sanitary engineering and/or the promulgation of federal and state laws and regulations that divide the environment into silos (e.g., air, waste, drinking water, etc.). The result is that 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. These boundaries are also reflected in the titles of various professional trade associations such as the Water Environment Federation, the American Water Works Association, and the Solid Waste Association of North America. Some examples of traditional areas of competence are:

- Air quality
- Water quality
- Water/wastewater transport systems
- Water supply and treatment
- Wastewater treatment
- Storm water management
- Air pollution control
- Solid waste management
- Hazardous waste management
- Contaminated site remediation

- Environmental health

Berthouex et al, (1986) recognized the limitation of the traditional single media approaches and recommended integrated, air-water-land approaches to environmental engineering problems. Since then, environmental engineers have learned more about how ecosystems function, and how connected every component of the ecosystem is to the other. As a result of this emerging understanding of complexity, traditional specializations are being stretched and integrated to include knowledge from across specializations and in many cases across traditional disciplines. For example, assessing the fate and hazards associated with contaminants and their releases might have traditionally been the purview of an environmental engineer working with geochemists; today, this team may well include toxicologists, risk analysts, ecologists, and even social and political scientists. Thus, the areas of specialization within the environmental engineering discipline are changing in response to the demands from society for professionals to address complex environmental processes with a more comprehensive scope.

There is a trend away from specialization by media to provide a broader, systems-based perspective on the nature of the problems and solutions relevant to environmental engineering. Although traditional media-based areas of competence will continue to be used, many schools and consulting firms are describing their areas of competence in much more innovative and diverse ways.

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

- **By the nature of the contaminants** (toxic/carcinogenic, animal (including human) excreta, household wastes, etc.) - the nature of contaminant sources, releases, fate in the environment, treatment and risk all vary substantially based on the fundamental source of the contaminants. The biochemical oxygen demand, pathogen and nutrient loading problems associated with early sanitary engineering could identify a continuing area of specialization. However, toxic contaminants behave quite differently, are generally detected at much lower concentrations but still pose significant human and ecosystem risks, and require very different treatment or remediation technologies. The science and engineering skills needed to address the significantly diverse problems of environmental contaminants may require technology teams composed of eco-toxicologists, bio-geochemists, epidemiologists, wildlife ecologists, etc. The next generation environmental engineer will need to understand and interact with these 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 environmental 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, physical-chemical, 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 wastewater 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 environmental engineers now consider themselves specialists in the area of minimizing releases or waste generation, while others focus primarily on environmental assimilation of pollutants.

In addition to the changes in the way we segregate the current practice of environmental engineering into specializations; new specializations are also emerging based on recent innovations in research and the expansion of the discipline. Areas of emerging research, innovation and practice in environmental engineering include ecological engineering, restoration engineering, sustainability engineering, and risk assessment engineering. These emerging areas of specialization utilize approaches including:

- **Green Infrastructure Design** involves designing the living and dynamic infrastructure elements for built environments (streets, sidewalks, drainage systems, etc) and to incorporate low energy 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 refuge for endangered birds into a park, neighborhood, or other built/non-built system.
- **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.
- **Design for Energy** includes recognition of the nexus among resource consumption, energy utilization and greenhouse gas emissions. Recycling and reuse are essential to reduce energy consumption and the concomitant carbon impact and must be considered while designing to protect human health and the environment. Further, all environmental designs should consider energy conservation, efficiency, generation and capture.

III. SOCIETY'S FUTURE NEEDS & THE ROLE OF THE ENVIRONMENTAL ENGINEER

Overview

In developing a body of competencies and knowledge for the environmental 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 depletion of natural resources, particularly fossil fuels. These two phenomena may, in turn, influence climate and lead to water and food scarcity. Environmental 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.

1. 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 fossil fuels, water, and mineral resources for agriculture, transportation, materials, heat and other human needs. Environmental 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. This demand to serve growing populations coincides with the need to replace aging infrastructure now serving the world's population centers. They will also have to manage the by-products of society while helping to provide for more renewable energy sources.

2. Climatic Impact

The earth's climate has changed throughout history and currently is in a warming period (IPCC, 2007). 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. Environmental 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.

3. Water, the Developing World and Human Health

Clean water and environmental sanitation are intrinsically 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. Environmental engineers are already working on these problems and this activity will increase as more attention and resources are directed at these issues.

4. Sustainability

Sustainability is a condition in which the use of natural resources and cycles in human and industrial systems does not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment. This definition recognizes that considering social conditions, economic opportunity and environmental quality are essential if we are to reconcile society's development goals with international environmental limitations (Mihelcic et al 2003). 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 environmental engineer will need to be a leader in implementing actions that enhance sustainability. The role of the environmental engineer in this effort will most likely focus on water and on sustainable material and energy use in the built environment.

5. Multi- and Interdisciplinary Interactions

The foregoing discussion suggests 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 environmental engineer will be best equipped to lead and coordinate the multidisciplinary engineering team in addressing environmental impacts. Therefore the environmental 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.

IV. DEVELOPMENT OF THE ENVIRONMENTAL ENGINEERING BODY OF KNOWLEDGE

A. Education for the BOK

The competencies described in the EnvE BOK can be acquired through a combination of baccalaureate-level education, masters-level education and professional experience. Attainment of these competencies does not require a BS EnvE degree; those with BS degrees in science or other engineering fields could attain these competencies through additional undergraduate course work coupled with a masters program. Attaining the EnvE BOK will prepare one not only for professional licensure, but also for alternate careers that do not require licensure. Licensure is not a goal of all environmental engineers; therefore, the BOK was designed to broadly prepare professionals for practice of EnvE that includes, but is not limited to, planning, design, teaching, applied or fundamental research, public administration, or operations. Individuals receiving a degree in EnvE may not elect to continue their education at the masters level, and in fact may never practice EnvE, but rather may seek other professional degrees, such as law or medicine, and follow an entirely different career path. Therefore some paths beginning with a baccalaureate degree in EnvE may not lead to complete BOK attainment. With this in mind the baccalaureate-level outcomes incorporated into the BOK were designed to prepare students for a broad range of careers.

Figure 1 is a conceptual illustration of the role of the EnvE BOK in the education and development of an environmental engineer. Although a growing number of environmental engineers enters the profession via a baccalaureate degree in environmental engineering, many if not most still enter via baccalaureate degrees in civil engineering or other engineering or science specialties. The diversity of engineering and science backgrounds is a hallmark and strength of environmental engineering. These diverse routes for entry into the environmental engineering profession must be recognized and facilitated.

There are several possible paths for individuals holding baccalaureate degrees in other engineering or science specialties to enter the environmental engineering profession. One common route is via prerequisite course work coupled with an environmental engineering graduate program . Another route would be via professional experience combined with part-time undergraduate and graduate education. Because holders of accredited engineering degrees in other specialties will already meet the eleven ABET Criterion 3 outcomes (ABET, Inc. 2007), they are well on their way toward meeting the estimated baccalaureate levels of the 18 environmental engineering BOK outcomes. Specific outcomes that might need to be addressed could include aspects of Outcome 1, BEMS; Outcome 4, In-Depth Competence and Outcome 9, Multi-Media Breadth. Graduate and/or part-time educational programs are available to address these outcomes.

The entry route for holders of non-engineering science degrees will depend on the educational preparation of the particular person. Some science degrees incorporate more than enough mathematics to satisfy engineering outcomes, while others do not. Science degrees do not always incorporate engineering topics and design. A common entry route for holders of non-engineering science degrees would be via a second baccalaureate degree in environmental engineering or via prerequisite course work coupled with a masters degree program designed to meet both the baccalaureate and masters level outcomes at an appropriate level.

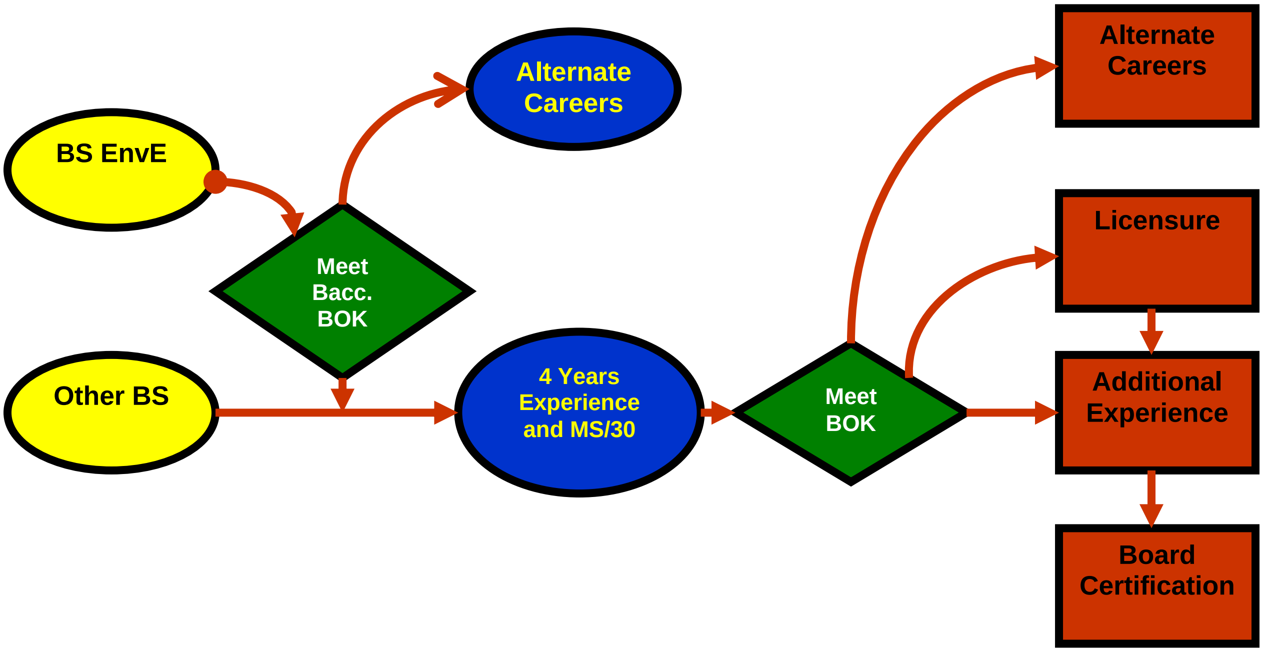

Figure 1. BOK and the Education and Professional Development of an Environmental Engineer.

B. Outcomes-Based Structure of the BOK

The EnvE BOK is defined by outcomes consistent with ABET 2000 Criteria, but placed in the context of environmental 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 (see Section IV B 3).
- 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 for each outcome. The EnvE BOK identifies specific desirable attributes of environmental engineers, provides a guide for curriculum development and reform and provides a means for employers to better understand the knowledge base of environmental engineers. The competence and skill requirements are in agreement with those identified at the 1991 and 1996 Environmental Engineering Education Conferences (Baillod et al, 1991; Marini, 1996).

1. Outcomes

The Environmental Engineering Outcomes have been arranged in three groups (see Table 1). The **first group** includes an outcome that provides foundational basis for environmental engineering education. This fundamental outcome related to abilities in science, mathematics and areas of discovery and design that will enable environmental engineers to function effectively 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 implementation and after the solution is implemented. 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. Environmental engineering problem formulation and solution 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 can only 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 environmental engineers must have to successfully implement solutions. Fulfilling these outcomes will enable them to communicate well, to effectively manage projects and to successfully engage other engineers and the public. Throughout their career, environmental engineers must remain cognizant of changing technology, issues, environmental policy and legislation. The public must appreciate the role environmental engineers may play as leaders as well as society - particularly when the recommended solutions to environmental engineering issues require policy changes. Public confidence in these solutions requires that environmental engineers conduct themselves ethically.

Table 1. Environmental Engineering BOK Outcomes

Outcome Number and Title	**Outcome**
Fundamental Outcome	
1. Basic Environmental Math & Science (BEMS) Knowledge	*Mathematics; physics; chemistry; biological science; earth science, mass, energy and mass conservation and transport principles needed to understand and solve environmental 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 environmental 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 environmental 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 environmental engineering.*
8. Sustainability	*Integration of sustainability into the analysis and design of engineered systems*
9. Multi-Media Breadth and Interactions	*Application of BEMS to predict and determine fate and transport of substances in and among air, water and soil phases as well as in engineered systems*
10. Societal Impact	*Societal impact of public policy affecting environmental engineering issues and solutions.*
11. Contemporary and Global Issues	*Globalization and other contemporary issues vital to environmental 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 environmental 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 environmental 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*

2. 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 18 outcomes.

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 Sciences						■	■			■	■		■	■	■	■	■	■
Economics					■	■	■	■	■	■	■		■		■	■	■	■
Technical Communication										■	■	■	■	■		■		■
Business Management								■	■		■	■	■		■	■	■	■

Figure 2. Matrix of Outcomes and Primary Knowledge Domains.

3. Performance Levels

Fulfillment of outcomes occurs at three points in the professional development of an environmental engineer, at the completion of a baccalaureate degree in environmental engineering, at the completion of a masters degree or 30 semester credits or equivalent post baccalaureate and after four years of professional practice. A level of achievement for 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.

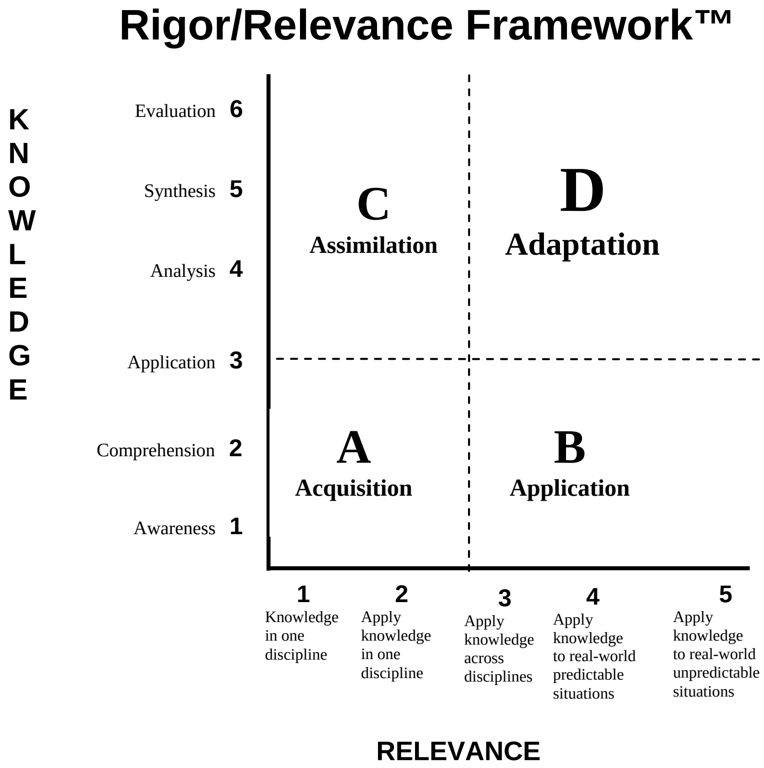

Figure 3. Daggett's Rigor and Relevance Framework (*Reproduced with permission from Daggett, W.R., Achieving Academic Excellence through Rigor and Relevance, Report prepared by the International Center for Leadership in Education - © 2005, Int'l Center for Leadership in Education*)

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. It is clear, that for engineers to function in a professional environment, they must think at higher cognitive levels than are often tested. Increasing capacity for analysis, synthesis and evaluation will be required. These cognitive levels are defined below.

a. Knowledge

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.

b. Comprehension

Comprehension is defined as the ability to grasp the meaning of material. This may be shown 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.

c. Application

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.

d. Analysis

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.

e. Synthesis

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.

f. Evaluation

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.

V. BODY OF KNOWLEDGES OUTCOMES

Foundational Outcome

Outcome 1: Basic Environmental Math and Science (BEMS) Knowledge for Environmental Engineering

Mathematics; physics; chemistry; biological science; earth science; and energy and mass conservation and transport principles needed to understand and solve environmental engineering problems

Outcome Explanation: Underlying the professional role of the environmental engineer as the master integrator and technical leader is a firm foundation in mathematics, physics, chemistry, biology, ecology and earth science. The environmental 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 in Environmental Engineering:

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

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

- **Analyze** a complex problem to determine relevant BEMS knowledge domains.
- **Apply** knowledge domains of the BEMS, as necessary, to analyze and solve a predictable problem appropriate to environmental engineering.

After four years of professional experience:

- **Evaluate** innovative engineering approaches to solve real-world problems appropriate to environmental engineering **using knowledge domains of the BEMS**.

Knowledge Domains: Mathematics,/computer languages, physics/mechanics, chemistry, biology/ecology, earth science, energy and mass conservation, mass and heat transport, fluid mechanics, systems analysis

Enabling Knowledge and Skill 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. Here "experiment" is broadly interpreted to include environmental monitoring programs. Environmental engineers frequently conduct experiments to gather data and create information for use in analysis and design; they are also often required to interpret data collected or reported by others. Such experiments may be conducted in the field or the laboratory, or may involve numerical simulation. These experiments would involve direct measurements or simulations of physical, chemical and biological characteristics of water, air and soil or processes used in their treatment, remediation or restoration. The environmental engineer must be familiar with the appropriate tools to effectively design and conduct experiments and interpret experimental data.

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

- **Identify** the procedures and equipment required to conduct common experiments appropriate to environmental engineering
- **Explain** the purpose, procedures, equipment and practical application of experiments appropriate to environmental engineering.
- **Conduct** experiments appropriate to environmental engineering
- 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 appropriate to environmental engineering.

At completion of masters degree or 30 semester credits or equivalent 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 problem appropriate to environmental engineering.
- **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 appropriate to environmental engineering.

After four years of professional experience:

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

Knowledge Domains: Mathematics/computer languages**,** physics/mechanics, chemistry, biology/ecology, systems analysis, probability/statistics

Outcome 3: Use of Modern Engineering Tools

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

Outcome Explanation: A practicing environmental 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 in Environmental Engineering:

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

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

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

After four years of professional experience:

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

Knowledge Domains: Mathematics/computer languages, systems analysis and probability/statistics

Outcome 4: In-Depth Competence

Advanced knowledge and skills essential for professional practice of environmental engineering

Outcome Explanation: In-depth competence based on advanced knowledge and skill is essential for professional practice of environmental engineering. This competence may be attained in a traditional specialty such as water/wastewater, 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 in Environmental Engineering:

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

At completion of masters or 30 semester credits or equivalent 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 four years experience:

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

Knowledge Domains: Mathematics/computer languages**,** physics/mechanics, chemistry, biology/ecology, earth science, energy and mass conservation, mass and heat transport, fluid mechanics, systems analysis

Outcome 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

Outcome Explanation: From an environmental engineering context, risks to humans or environmental systems can occur from exposure to physical, chemical and biological hazards or from the failure of engineered systems designed to protect the environment and the public health, welfare and safety. Risk is often defined as a measure of the probability and severity of adverse effects. Its assessment includes definition of context and system, exposure assessment, hazard identification, quantification of risk and assessment of risk relative to specified criteria. Environmental engineers must use these assessments to determine what can be done, what options are available and the associated trade-offs in terms of costs, benefits and risks and the impacts of current decisions on future options (UVCRMES, 2007).

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

- **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 an engineering system.
- **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, safety and welfare for a well-defined chemical and biological exposure and hazards (ASCE, 2008).

At completion of masters degree or 30 semester credits or equivalent 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, safety and welfare 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.

After four years of professional experience:

- **Assess** the risks of various engineering alternatives and integrate this assessment into the recommendation of an alternative.

- **Employ** quantitative tools to analyze risk and reliability.

Knowledge Domains: Mathematics/computer languages**,** physics/mechanics, chemistry, biology/ecology, earth science, energy and mass conservation, mass and heat transport, fluid mechanics, systems analysis, probability/statistics and economics.

Outcome 6: Problem Formulation and Conceptual Analysis

Problem formulation and analysis based on environmental engineering problem identification, obtaining background knowledge, development and analysis of alternatives, understanding existing requirements and/or constraints and recommendation of effective solutions

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

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

- **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 semester credits or equivalent post baccalaureate:

- **Apply** advanced level technical knowledge and problem analysis/solving skills to complex multidisciplinary problems.
- **Analyze** problems appropriate to environmental engineering 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 four 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: Mathematics/computer languages, chemistry, conservation of mass, earth science, systems analysis, humanities/social sciences and economics.

Outcome 7: Creative Design

Design of a system, component or process to meet desired needs related to a problem appropriate to environmental engineering.

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 in Environmental Engineering:

- **Define** problem objectives and specify design criteria.
- **Recognize** realistic constraints such as economics, environmental, social, political, ethical, health and safety, constructability and sustainability factors appropriate to environmental engineering.
- **Apply** creativity and knowledge domains of BEMS 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 semester credits or equivalent post baccalaureate:

- **Apply** creativity and knowledge domains of BEMS 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 appropriate to environmental engineering to develop solutions to real world problems.

After four 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 appropriate to environmental engineering.
- **Understand** the interactions among planning, design, life-cycle assessment, construction and operational management appropriate to environmental engineering.
- **Evaluate** design proposals appropriate to environmental engineering as part of the peer review process

Knowledge Domains: Mathematics/computer languages, chemistry, biology/ecology, mass and energy conservation, mass transport, fluid mechanics, systems analysis, humanities/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 following 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 (*Mihelcic et al 2003*) as:

> *Sustainability is a condition in which the use of natural resources and cycles in human and industrial systems does not lead to diminished quality of life due either to losses in future economic opportunities or to adverse impacts on social conditions, human health and the environment. This definition recognizes that it is essential to consider social conditions, economic opportunity and environmental quality if we are to reconcile society's development goals with international environmental.*

The environmental engineer has a critical role in the emerging subdiscipline of sustainable engineering. It is expected that environmental 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 in Environmental Engineering:

- **Recognize** life-cycle principles in the context of environmental engineering design.
- **Identify** components in 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 engineering disciplines and the role environmental engineers have in this.

- **Quantify** environmental releases or resources consumed for a given engineered process.

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

- **Analyze** the sustainability of an engineered system using traditional or emerging tools (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 four years of professional experience:

- **Design** a complex system, process, or project to perform sustainably (ASCE, 2008).
- **Evaluate** the sustainability of complex systems, whether proposed or existing (ASCE, 2008).

Knowledge Domains: Mathematics/computer languages, chemistry, physics/mechanics, biology/ecology, fluid mechanics, earth science, conservation of mass, systems analysis, probability/statistics, economics and business management

Outcome 9: Multi-Media Breadth and Interactions

Application of BEMS to predict and determine fate and transport of substances in and among air, water and soil phases as well as in engineered systems

Outcome Explanation: Environmental 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 environmental engineers must understand the principles that govern intermedia 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 in Environmental Engineering:

- **Explain** how intermedia transfer is relevant to environmental engineering 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 semester credits or equivalent post baccalaureate:

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

After professional practice with four years experience:

- **Design** a system that incorporates intermedia 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: Mathematics/computer languages, physics/mechanics, chemistry, biology/ecology, mass and energy conservation, mass transport, fluid mechanics, earth science, systems analysis, probability/statistics, economics and business management

Outcome 10: Societal Impact and Environmental Policy

Societal impact of environmental 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 of engineering and public policy must increase. Because environmental engineers are regularly 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 environmental policies. Further, environmental 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 in Environmental Engineering:

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

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

- **Integrate** potential societal impacts into solving environmental problems in a specialized area.

After four years of professional experience:

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

Knowledge Domains: Mathematics/computer languages**,** physics/mechanics, chemistry, biology/ecology, systems analysis, humanities/social sciences, economics and technical communication

Outcome 11: Globalization and other Contemporary Issues

Outcome Statement: Globalization and other contemporary issues vital to environmental engineering.

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 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 environmental 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 environmental engineer must be aware of emerging contemporary issues and of their impact on the profession.

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

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

At completion of masters or 30 semester credits or equivalent post baccalaureate:

- **Describe** how globalization of technology has influenced design and/or project delivery within a technical area of environmental engineering.
- **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 environmental engineering problems

After professional practice with fours years experience:

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

Knowledge Domains: Mathematics/computer languages**,** physics/mechanics, chemistry, biology/ecology, earth science, energy and mass conservation, mass and heat transport, fluid mechanics, systems analysis, humanities/social sciences, economics, probability/statistics, technical communication and business management

Professional Outcomes

Outcome 12: Multi-Disciplinary Teamwork to Solve Environmental 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 environmental engineer will use management and communication skills to create, manage and/or 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 an ability to foster and integrate diversity of perspectives, knowledge and experiences (ASCE, 2008).

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

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

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

- There are no achievement requirements at this level

After four years of professional experience:

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

Knowledge Domains: Technical communication and business management

Outcome 13: Professional and Ethical Responsibilities

Professional and ethical issues in environmental 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 environmental engineers.

The National Society of Professional Engineers has published a Code of Ethics for Engineers that applies to all engineering disciplines and has been adapted by many professional engineering societies. This Code promotes Rules of Practice and Professional Obligations that guide ethical decision-making, critical to the professional practice of engineering. It is a fundamental canon of this Code that engineers "Hold paramount the safety, health and welfare of the public." However, environmental engineering is unique in that it is the engineering discipline that as a whole serves the public welfare, health and safety directly.

In addition, although other engineering disciplines are becoming more aware of the need to understand the relationships between technology and environmental protection, environmental engineers are directly responsible for preserving our natural environment. Natural ecosystems support human existence and thus service to the public must include the preservation of species and habitats. In addition, environmental engineers recognize that all of nature has intrinsic value and that preventing the despoilment and destruction of the natural environment is part of their professional responsibility. Therefore, environmental ethics, defined by Brennan and Lo [11] as "the discipline that studies the moral relationship of human beings to, and also the value and moral status of, the environment and its nonhuman contents" is uniquely intrinsic to the field of environmental engineering.

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

- **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 environmental engineering situation.

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

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

After professional practice with four years experience:
- **Describe** a situation based on personal experience with environmental engineering situations and course of action that illustrates professional and ethical behavior.

- **Assess** personal professionalism and ethical development

Knowledge Domains: Humanities/social sciences, economics, technical communication and business management

Outcome 14: Effective Communication

Effective communications when interacting with the public and the technical community

Outcome Explanation: The environmental engineer is frequently the critical link to public understanding and interpretation of environmental policy, issues and implementation of plans for projects that affect public health and the environment. The environmental engineer must communicate using verbal, written, virtual and graphical means to describe a concept, an environmental degradation or enhancement issue and/or a project affecting the environment to technical and non-technical audiences and receive and interpret communications in return.

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

- **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 engineering 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 semester credits or equivalent 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 four 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/social sciences and technical communication

Outcome 15: Lifelong Learning

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

Outcome Explanation: Environmental 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 to environmental engineering.

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

- **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 semester credits or equivalent post baccalaureate:

- **Identify** additional knowledge, skills and attitudes appropriate for continued practice at the professional level.
- **Integrate** self-directed learning of issues that apply to environmental engineering.

After four 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: Mathematics/computer languages**,** physics/mechanics, chemistry, biology/ecology, earth science, energy and mass conservation, mass and heat transport, fluid mechanics, systems analysis, humanities/social sciences, economics, probability/statistics and business management

Outcome 16: Project Management

Principles of project management relevant to environmental 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 are the primary goals of project management.

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering:

- **List and explain** project management processes and principles.
- **Explain** how project management relates to the project delivery process.
- **Use** elementary project management techniques in the execution of an undergraduate level engineering design project.

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

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

After four 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: Humanities/social sciences, economics, technical communication and business management

Outcome 17: Business and Public Administration

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

Outcome Explanation: Environmental engineers dealing with private and public organizations must understand business fundamentals. Asset management is a business process and a decision making framework that covers an extended time and draws from both economics and engineering. Many environmental engineers use asset management principles in managing and maintaining environmental infrastructure.

Level of Achievement:

At completion of baccalaureate degree in Environmental Engineering**:**

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

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

- There are no achievement requirements at this level

After professional practice with four years experience:

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

Knowledge Domains: Humanities/social science, economics and business management

Outcome 18: Leadership

Outcome Statement: Engaging, motivating and leading 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 environmental engineering projects require that several individuals work collectively toward common goals, leadership abilities are critical for the environmental 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 in Environmental Engineering:

- **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.

At completion of masters degree or 30 semester credits or equivalent post baccalaureate:

- There are no achievement requirements at this level

After professional practice with fours years experience:

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

Knowledge Domains: Humanities/social science, technical communication, economics and business management.

VI. IMPLEMENTATION OF THE EnvE BOK

Educators, students, young engineers and senior practitioners all share responsibility in implementing the EnvE BOK. Educators and students should be familiar with the EnvE BOK because it defines the outcomes of an environmental engineering education. From a faculty point of view, the EnvE BOK can guide curriculum and expectations of students; from a student point of view, the EnvE 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 EnvE BOK. The depth and breadth of the young environmental engineer's early professional experiences are critical to fulfilling the EnvE BOK. Senior practitioners should take an active role to help young environmental engineers continue the learning process toward fulfillment of the EnvE BOK and professional licensure.

A. Role of Educators

1. The Environmental Engineering Educational Team

Asked to state her profession, an environmental engineering professor replied "engineer" while a colleague in the same department replied "professor," and another colleague replied "scientist". All three answers were correct and illustrated the diversity of a typical environmental engineering teaching team. 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 environmental engineers. This section is intended to articulate the expectations that educational team members have expressed for the EnvE BOK as well as to provide guidance for preparing students to attain the outcomes of the EnvE BOK.

2. Educators' Expectations of the EnvE BOK

Many environmental engineering professors participated in the development of the EnvE BOK. Several professors were members of the Task Group and many more contributed to the EnvE BOK as corresponding members or through participation in workshops and input on EnvE BOK presentations. The expectations and concerns expressed by these educators are summarized below:

- **Adaptable**: The EnvE BOK should recognize that environmental engineering is rapidly evolving and that the EnvE BOK should facilitate adaptation to future needs. The EnvE BOK should not be prescriptive, following an established past practice. Rather, it should be directional, forward looking; more of a compass than a detailed roadmap or route from in the past.
- **Achievable**: The EnvE BOK outcomes should be achievable within the time constraints of the usual baccalaureate and masters degree programs while still leaving room for some outcomes and objectives unique to a given educational program.

- **Emphasis on Fundamentals**: The EnvE BOK should emphasize the application of fundamental math and science knowledge domains to solving environmental engineering problems. Reliance on unchanging fundamental principles will help the environmental engineer to adapt to a changing profession.
- **Flexible Specialty Competence**: In-depth or specialty competence should be flexible and conducive to innovation rather than tied only to traditional areas such as water, wastewater, or solid wastes.

3. Guidance for Educators

The EnvE BOK is intended to be a useful guidance document for all stakeholders. From the educators' perspective, if the EnvE BOK successfully meets all of the above qualities, it 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;
- Guidance for accreditation at the BS and MS level; and,
- Faculty members with a broader picture of the entire profession of environmental engineers that could be used in advising students about course selections and career opportunities.

It is essential that educators prepare environmental engineering students to attain the EnvE BOK outcomes through the development and delivery of effective curricula. The ASCE BOK 2nd Edition (ASCE, 2008) lists four characteristics of civil engineering faculty that are equally applicable, with some modifications, to environmental engineering educators. Members of the environmental engineering educational team should be:

- **Scholars.** Members of the educational team should have in-depth competence in the subjects that they teach. This competence should be shared with and validated by the profession through publication and participation in professional society activities. Boyer, in *Scholarship Reconsidered, Priorities of the Professorate* (1990) recognized the scholarships of Teaching, Discovery, Integration and Application. Because the academic reward system emphasizes the Teaching and Discovery (i.e. research) scholarships, faculty are well focused on these. However the scholarships of Integration (connecting between disciplines) and Application (applying new knowledge to problems) are particularly important for environmental engineers.
- **Effective Teachers.** Some members of the educational team will be superior teachers and some will be below average, but all must be effective and should strive for continuous improvement. Faculty can easily participate in university programs to improve teaching.
- **Experienced**. Faculty should have some practical experience relevant to the subjects that they teach. This experience may be gained through previous employment, through

applied research and interaction with practitioners, or through participation in advisory panels for environmental projects.

- **Role Models.** It follows that if a faculty member is a scholarly effective teacher with appropriate experience, he or she will be a positive professional role model for students. Taken as a whole, the environmental engineering educational team will offer a range of role models for students to emulate.

B. Role of Students

The EnvE 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 his/her education, prepare to move into an internship and, ultimately enter the practice of environmental engineering at the professional level (see Figure 1). The ASCE BOK, 2nd edition has an excellent treatment of this topic (http://www.asce.org/files/pdf/professional/BOK2E_(ASCE_2008)_ebook.pdf).

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 and computer use) 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 EnvE 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.

C. Role of New Engineers Prior to Licensure

Prior to licensure, engineers should become familiar with the EnvE BOK. Environmental 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 could be obtained through professional societies and civic activities.

Above all, engineers should take responsibility for professional development. This is especially important for new engineers at the beginning of their careers. These new engineers need not rely entirely on employer sponsored professional development programs. They should be proactive in developing their abilities in accord with the expected EnvE 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/or 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.

D. Role of Senior Environmental Engineer Practitioners

1. Mentoring

The most important role for senior environmental engineering practitioners in implementing the EnvE 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 environmental 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 environmental engineer with direct access to the mentor and senior professionals for further guidance. As the young environmental engineer progresses towards fulfilling the EnvE 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 environmental engineer.
Such practical learning offers valuable lessons to the young environmental 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 environmental engineer to the organization. The benefits of licensure to the individual, the organization and the public should be conveyed.

As a mentor, the environmental 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 environmental engineer practitioner encourages and supports professional licensing and where applicable, professional certification.

2. Competency and Knowledge Transfer

Environmental 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 EnvE BOK competency level expectations. The environmental 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.

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

3. Encourage Active Professional Society and Community Involvement

Active participation in professional and/or business societies is an important element of professional development and can play an important role in fulfilling the EnvE BOK. Senior environmental engineers should encourage young environmental 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 environmental 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 environmental engineer participates in public forums 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 (e.g. Water for the People). 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 EnvE 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.

4. Exemplify Professional and Ethical Behavior – Practice What You Preach

Most young environmental 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.

Environmental engineering practitioners should above all demonstrate a commitment to ethical standards of practice in their profession. The success of environmental engineering is largely dependent on self monitoring and open, honest communication with both internal and external clients regarding risks, problems and solutions. Such communication 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 environmental engineer practitioner mentor leads by example in exhibiting professional behavior in all interactions with peers, clients, government officials and the community at large. 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 environmental engineers to promote understanding and application of the engineering codes of ethics, particularly the ASCE and NSPE Codes.

VII. WHERE DO WE GO FROM HERE?

The development of the EnvE BOK is a continuous process of testing and improvement. As it is implemented, practitioners and educators must evaluate the EnvE BOK and determine whether all issues necessary to the practice of environmental 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 environmental engineers, such as the AAEE sponsoring organizations. Practitioner task forces should examine the EnvE 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 EnvE undergraduate and graduate programs should be identified and asked to evaluate whether curricula can be reasonably designed to adopt the EnvE BOK. Educators should also determine whether the levels of achievement are correctly defined. Finally, it is recommended that an implementation task force be created to make recommendations regarding how the EnvE BOK should be used for licensing, accreditation and promotion of the profession.

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APPENDIX A

MAPPING OFUTCOMES 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

FOUNDATIONAL OUTCOME						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A1 Within Discipline	A2 Within Discipline	A3 Across Disciplines	A4 Complicated Situations		A5 Complex Situations
Outcome 1						
Basic Environmental Math & Science (BEMS) Knowledge for Environmental Engineering	Define key factual information related to the knowledge domains of mathematics, physics, chemistry, biology, ecology, conservation and transport principles, and earth science (BEMS).	Explain key concepts and problem-solving processes involved in each knowledge domain of the BEMS.	Apply each knowledge domain of the BEMS to solve well-defined problems appropriate to environmental engineering. (B)		Create new ways to apply BEMS knowledge domains to environmental engineering.	Evaluate innovative engineering approaches to solve real-world problems appropriate to environmental engineering using knowledge domains of the BEMS.

	(B)	(B)	Apply knowledge domains of the BEMS, as necessary, to analyze and solve a predictable problem appropriate to environmental engineering. (M/+30)		(E+*) *beyond four years of experience	(E)
ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A1 Within Discipline	A2 Within Discipline	(B): A2 (M/+30): A3/A4	(B): A2 (M/+30): A3/A4	(B): A2 (M/+30): A3/A4	A5 Complex Situations
Outcome 2						

Design and Conduct Experiments	Identify the procedures and equipment required to conduct common experiments appropriate to environmental engineering. (B)	Explain the purpose, procedures, equipment and practical application of experiments appropriate to environmental engineering. . (B)	Conduct experiments appropriate to environmental engineering. (B)	Use statistics to analyze experimental uncertainties and error and interpret results. (B)	Design an experiment based on accepted procedures and measurements to develop specific information or to test a specific hypothesis. (B)	Evaluate the effectiveness of an experiment designed to obtain information related to an unpredictable, problem appropriate to environmental engineering, communicate the results to stakeholders. (E)
			Conduct an experiment using appropriate state-of-the-art tools to develop information or to test a hypothesis related to a predictable problem appropriate to environmental engineering. (M/+30)	Analyze and interpret the results and explain the resulting information using appropriate communication tools. (M/+30)	Design an experiment to develop specific information or to test a specific hypothesis related to a predictable problem appropriate to environmental engineering (M/+30)	

ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A1 Within Discipline	A2 Within Discipline	A2 Within Discipline	A3 Across Disciplines	A5 Complex Situations	A5 Complex Situations
Outcome 3						
Modern Engineering Tools	Identify and describe engineering tools available to appropriate issues in environmental engineering problems.	Select the most appropriate tool for application to various types of engineering problems and projects. (B)	Apply modern engineering tools to the various elements of engineering problem solving and project analysis for well defined problems. (B)		Design new tools for application to environmental engineering.	Evaluate the benefits, risks and uncertainty associated with use of specific tools in analysis of environmental engineering projects.

	(B)	Recognize the limitations of the various tools with respect to appropriateness, accuracy, consistency and sensitivity. (M/30)	Apply modern engineering tools to multi-disciplinary environmental engineering problem solving. (M/+30)		(E+*) *beyond four years of experience	(E)

ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A2 Within Discipline	A2 Within Discipline	A4 Complicated Situations	A3 (M/+30) Across disciplines A4 (E)	A4 Complex Situations
Outcome 4						
In-depth Competence	Recognize and describe the need for in-depth competence for solution of complex environmental problems.	Describe the traditional specialties as well as some emerging specialties appropriate to environmental engineering.	Apply specialized tools, methodology, or technology to solve well-defined problems.	Analyze a predictable environmental process or system in a traditional or emerging area. (M/+30)	Design a predictable environmental process or system in a traditional or emerging area. . (M/30) Design and implement a complex system or process in a traditional or emerging area. (E)	Create and evaluate new knowledge or technologies in a traditional or emerging advanced specialized technical area appropriate to environmental engineering. (E+*)

	(B)	(B)	(B)			*beyond four years of experience

ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A1 One Discipline	A2 Within Discipline	A3 Across Disciplines	A4 Complicated Situations	A4 Complex Situations	A5 Complex Situations
Outcome 5						
Risk, Reliability, and Uncertainty	Identify potential hazards, exposure pathways, and risks to humans or the environment associated with exposure to chemical and biological hazards. Identify the modes for failure of a	Explain the significance of uncertainties in data and knowledge on the performance and safety of an engineering system.	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	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	Design an engineered system applying the principles of probability and statistics to uncertainties in data or knowledge.	Assess the risks of various engineering alternatives and integrate this assessment into the recommendation of an alternative. Employ quantitative tools to analyze risk and reliability. (E)

	system engineered to protect human or environmental health and the resulting consequences of such a failure. (B)	(B)	environment and the public for a well-defined chemical and biological exposure and hazards. (B)	protect human or environmental health and quantify the resulting consequences of such a failure. (M/30)	(M/30)	Evaluate design alternatives to select an engineered system that poses less inherent risk during normal operation or when it fails (e.g., less toxic chemicals, containment systems, etc.). (E+*) *beyond four years of experience

ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A2 Within Discipline	(M/+30): A3/A4	(B): A2 (M/+30): A3	A5 Complex Situations	A5 Complex Situations
Outcome 6						

Problem Formulation and Conceptual Analysis		Explain key concepts related to problem recognition, articulation and solution. Recognize difficulties requiring innovative problem definition and solutions. (B)	Apply advanced level technical knowledge and problem analysis/solving skills to complex, multidisciplinary problems. (M/30)	Analyze a predictable problem to identify the root cause (B) Analyze problems appropriate to environmental engineering having unpredictable or incomplete parameters to determine their root causes. Analyze feasibility and appropriateness of predictable solutions as alternatives to conventional solutions to problems.	Synthesize experience-acquired knowledge and skills to anticipate and identify unpredictable problems. Develop means for supplementing inadequate data or definition. . (E)	Evaluate novel solutions to complex real world problems and compare with conventional solutions based on environmental and economic consequences of implementation (E)

				(M/30)		

ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A3 Across Disciplines	(B): A3 (M/+30): A4/A5	(B): A3 (M/+30): A3/A4	A4 Complicated Situations	A4 Complicated Situations
Outcome 7						
Creative Design		Define problem objectives and specify design criteria. Recognize realistic constraints such as economics, environmental, social, political, ethical, health and safety, constructability and	Apply creativity and knowledge domains of BEMS to the design a system or process to meet desired needs. (B)	Analyze predictable situations to determine the design needs and requirements. (B)	Assess compliance with customary standards of practice, client's needs and relevant constraints appropriate to environmental engineering to develop solutions to real world problems. (M/+30)	Understand the interactions among planning, design, life-cycle assessment, construction and operational management appropriate to environmental engineering. Evaluate design

		sustainability factors appropriate to environmental engineering. (B)	Apply creativity and knowledge domains of BEMS to design a real world system or process to meet desired needs. (M/+30)	Analyze real world situations to determine design needs and requirements. (M/+30)	Understand the design of a predictable system, component or process appropriate to environmental engineering. (E)	proposals appropriate to environmental engineering as part of the peer review process. (E)
				Assess the needs of the public and other stakeholders in formulating design constraints and objectives of a complex problem. (E)		
ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A2/A3 Across Disciplines	A3 Across Disciplines	A3/A4 Complicated Situations	(M/+30): A4 (E): A5	A5 Complex Situations
Outcome 8						

Sustainability	Recognize life-cycle principles in the context of environmental engineering design. (B)	Identify components in 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 principles throughout all engineering disciplines and the role environmental engineers have in this.	Quantify environmental releases or resources consumed for a given engineered process. (B)	Analyze the sustainability of an engineered system using traditional or emerging tools (e.g., industrial ecology, life cycle assessment). Ascertain where new knowledge or forms of analysis are necessary for sustainable design. (M/+30)	Design traditional or emerging engineered systems using principles of sustainability. (M/+30) Design a complex system, process, or project to perform sustainably. (E)	Evaluate the sustainability of complex systems, whether proposed or existing. (E)

		(B)				

ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:		A2 Within Discipline	(B): A3 (M/+30): A4	A3/A4 Complicated Situations	A5 Complex Situations	A5 Complex Situations
Outcome 9						
Multimedia Breadth and Interactions		Explain how intermedia transfer is relevant to environmental engineering 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 distribution of substances between phases to well-defined situations when	Analyze a system that incorporates intermedia transport and fate of pollutants.	Design a system that incorporates intermedia transport and fate of pollutants.	Appraise the laws and regulations that pertain to the air, water and land environment applicable to a specific practice area

		(B)	equilibrium assumptions apply. (B)	(M/+30)	(E)	(E)
			Apply fundamental principles governing intermedia transport and fate of substances to a complex situation, e.g. where mass transfer is rate limited. (M/+30)			

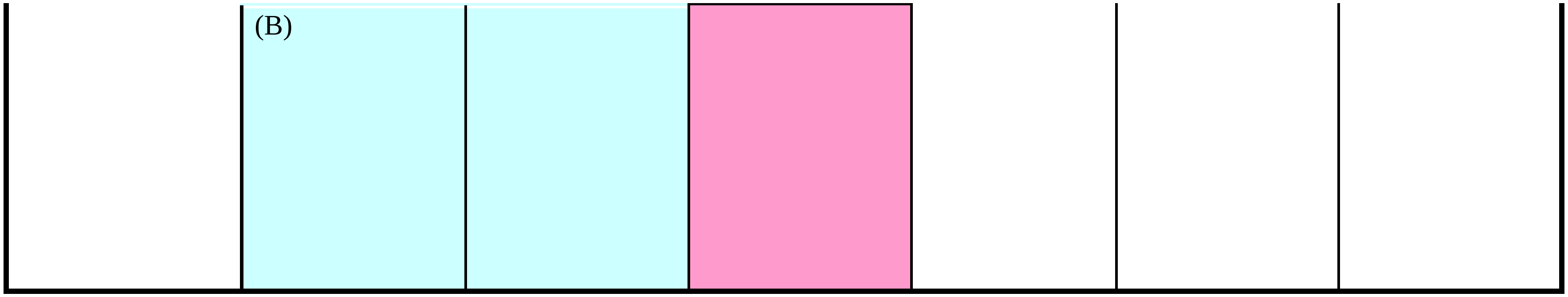
ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A3 Across Disciplines	A3 Across Disciplines	A5 Complex Situations	A5 Complex Situations	A5 Complex Situations
Outcome 10						
Societal Impact and Environmental Policy	List some important environmental policies as stated in international accords and federal, state and local laws.	Recognize potential societal impacts of a solution to an environmental problem. Discuss and explain important processes involved in setting public environmental policy (B)	Integrate potential societal impacts into solving environmental problems in a specialized area. (M)	Analyze environmental policy issues.	Develop environmental policy recommendations.	Evaluate the effectiveness of an environmental policy for a complex situation.
		Describe and explain environmental	Apply knowledge of societal structure			

	(B)	policy in some detail in some area of environmental practice. (E)	and dynamics when seeking solutions to environmental problems. Participate as a citizen stakeholder in the development of public environmental policy. (E)	(E+*) *beyond four years of experience	(E+)	(E+)

ENABLING KNOWLEDGE AND SKILL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A3 Across Disciplines	A3 Across Disciplines	A3 Across Disciplines	(B): A3 (M/+30): A4	A5 Complex Situations
Outcome 11						
Globalization and Other Contemporary Issues		Explain some barriers to the delivery of environmental engineering services in a global context. (B) Describe how globalization of technology and other contemporary issues has influenced design and/or	Utilize modern tools to identify and understand contemporary issues (B) Participate in discussion and debate focused on globalization and contemporary issues and their relationship with	Define and analyze a solution to well defined environmental engineering problems that are constrained by global and contemporary issues.	Propose solutions to well defined environmental engineering problems that are constrained by global and contemporary issues. (B) Synthesize information on contemporary issues to provide perspective on relevance to environmental engineering	Evaluate the impact of an important globalization and/ other contemporary issue on design and/or delivery of an environmental engineering project.

		project delivery within a technical area of environmental engineering (M/+30)	and potential impact on public health and the environment (M/+30)	(B)	problems. (M/+30)	(E)

PROFESSIONAL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A3 Across Disciplines	A3 Across Disciplines	(B): A3 (E): A4/A5	A5 Complex Situations	A5 Complex Situations	A5 Complex Situations
Outcome 12						
Multi-Disciplinary Teamwork to Solve Environmental Problems	Identify disciplines necessary to solve a complex environmental engineering problem.	Describe the characteristics of an effective team. (B)	Function in environmental engineering team activities to design and implement solutions (B)			
			Function effectively in multi-disciplinary team activities (E)			


(B)

PROFESSIONAL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A2 Within Discipline	A2 Within Discipline	A4 Complicated Situations	A5 Complex Situations	A5 Complex Situations
Outcome 13						
Professional and ethical responsibilities	Recognize moral and ethical problems that might arise in engineering practice (B)	Explain tenets of professionalism and codes of engineering ethics. (B)	Apply standards of professionalism and codes of engineering ethics to determine an appropriate course of action for a given environmental engineering situation (B)	Analyze an environmental engineering situation involving conflicting ethical and professional interests to determine an appropriate course of action (M/+30)	Describe a situation based on personal experience of an environmental engineering situations and course of action that illustrates professional and ethical behavior. (E)	Assess personal professionalism and ethical development. (E)

PROFESSIONAL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:		A3 Across Disciplines	A3 Across Disciplines	(B): A3 (M/+30): A4	(B): A3 (M/+30): A4	A5 Complex Situations
Outcome 14						
Effective Communication	.	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 engineering documents and presentations. (B)	Summarize the essential points and elements of verbal and written communications received from others. (B)	Organize and deliver effective verbal, written, virtual, and graphical communications. (B)	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

		(B)	Make effective presentations to technical audiences (M+ 30)	Interpret the intent and content of communications from technical and non-technical stakeholders in a concept or project. (M/+30)	Plan, compose, and integrate the verbal, written, virtual and graphical communication of a concept or project for 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. (M/+30)	from technical and non-technical stakeholders in a concept or project. (E)
			Make effective presentations to technical and nontechnical audiences (E)			

PROFESSIONAL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A3 Across Disciplines	A3 Across Disciplines	A2 Within Discipline	A3 Across Disciplines	(M/+30): A4 (E): A5	A5 Complex Situations
Outcome 15						
Lifelong Learning	Define life-long learning. (B)	Explain the need for life-long learning. Describe the skills required of a life-long learner. (B)	Demonstrate the ability for self-directed learning. (B)	Identify additional knowledge, skills and attitudes appropriate for continued practice at the professional level. (M/+30)	Integrate self-directed learning of issues that apply to environmental engineering. (M/+30) Plan a regimen of continued learning to maintain proficiency (E)	Regularly acquire additional expertise and maintain skills and appropriate current knowledge (E)

PROFESSIONAL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Disciplines	A2 Within Disciplines	(B): A2 (M/+30): A3	A3 Across Disciplines	A5 Complex Situations	A5 Complex Situations
Outcome 16						
Project Management	List project management processes and principles. (B)	Explain project management processes and principles. Explain how project management relates to the project delivery process. (B)	Use elementary project management techniques in the execution of an undergraduate level engineering design project. (B) Apply project management skills and approaches to a project. (M/+30) Apply principles of value engineering		Create documents to be incorporated into a project management plan as a member of an engineering team. Create project management plans plan as a member of an engineering team. (E)	Evaluate the effectiveness of a management plan for a particular project (E+*) *beyond four years of

			(E+)			experience

PROFESSIONAL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A2 Within Discipline	A2 Within Discipline	A4 Complicated Situations	A5 Complex Situations	A5 Complex Situations
Outcome 17						
Business and Public Administration	List important fundamentals of business and of public administration related to environmental engineering.	Describe important fundamentals of business and of public administration related to environmental engineering. .	.	Analyze problems involving business and public administration as they relate to environmental problems.		

	(B)	(B)		(E)		

PROFESSIONAL OUTCOMES						
Level of Achievement						
Cognitive Level:	C1 Knowledge	C2 Comprehension	C3 Application	C4 Analysis	C5 Synthesis	C6 Evaluation
Practical Relevance:	A2 Within Discipline	A2 Within Discipline	A2 Within Discipline	A4 Complicated Situations	A5 Complex Situations	A5 Complex Situations
Outcome 18						
Leadership	Define leadership and the role of a leader. List leadership skills and attributes. (B)	Explain the role of a leader, leadership skills, and leadership attributes. (B)	Apply leadership skills to direct the efforts of a small group. (B) Organize and direct the efforts of a group to achieve a goal. (E)		Plan, organize and direct the efforts of a group to achieve a goal. Create an organization to achieve a complex goal. Serve in a leadership role in action or in words. (E+*) *beyond four years of experience	Evaluate the leadership of an organization. (E+)

Appendix B

The Environmental Engineering Body of Knowledge Task Force

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Stuart G. Walesh PhD, PE, Hon.M.ASCE; Consultant

Appendix C

List of Acronyms

AAEE: American Academy of Environmental Engineers
AAES: American Association of Engineering Societies
AIChE: American Institute of Chemical Engineering
ASCE: American Society of Civil Engineers
ASME: American Society of Mechanical Engineers
BCEE: Board Certified Environmental Engineer
BEMS: Environmental Math and Science
BOK: Body of Knowledge
BOKTF: Body of Knowledge Task Force
BS: Bachelor of Science
EnvE BOK: Environmental Engineering Body of Knowledge
IPCC: International Panel for Climate Change
MS: Master of Science
NAE: National Academy of Engineering
NCEES: National Council of Examiners for Engineering and Surveying
NGO: Non-Governmental Organization
NSPE: National Society of Professional Engineers
UNEP: United Nations Environment Programme
UNICEF: United Nations Children’s Fund
UVCRMES: University of Virginia Center for Risk Management of Engineered Systems
WHO: World Health Organization