Worcester Polytechnic Institute

ABET Outcomes Assessment

Civil and Environmental Engineering Department

A report submitted by the Working Committee:

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1. Objectives and Scope

The Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET) evaluated the CEE program during the 1996-97 academic year. The evaluation was conducted as a pilot application of the ABET Engineering Criteria 2000 (EC2000). The CEE program received accreditation through September 2003. Review of the ABET report indicates that the CEE program earned compliments for "its efforts to achieve accreditation under EC2000; however, "the lack of a formal process for continuous improvement" was cited as a primary weakness. There are two full academic years remaining until the next accreditation visit, and the Civil Engineering and Environmental Department Working Committee on ABET Outcomes Assessment (hereinafter referred to as the Committee) has focused on developing a process to assess student performance. The following objectives for the Committee were established in May 2000:

- Compile baseline data to demonstrate the relationship between Program Outcomes and the current curriculum (including consideration of both courses and MQPs)
- Identify Program Outcomes that are not well supported by the current CEE curriculum
- Present specific recommendations to the Department for developing clearly defined and measurable Program Outcomes to assess the current CE curriculum
- Establish a process to demonstrate, to evaluate, and to provide feedback regarding how graduates satisfy the Program Outcomes and how continuous improvement of the curriculum is addressed.
- Summarize the outcomes from the Exit B Interviews (EBI) student satisfaction surveys for presentation to the CEE Department

The scope of the Committee's work is limited to defining a formal process that will be embraced and implemented by all members of the CEE faculty. The committee was not involved in the gathering and evaluating assessment data to satisfy EC2000, Criterion 3. It is expected that the needed data will be identified, gathered, and evaluated by the Department during the 2000-01 and 2001-02 academic years as part of preparation for the 2002-03 accreditation process.

The work done by the Committee has been documented on this report. Its final recommendations have been summarized in terms of six motions for CEE Department action and five items for CEE department discussion. These recommendations are included in this report in Section 4.0 and Appendices I and II. During Term A, 2000 the CEE faculty discussed, made minor modifications and approved the first five of these motions. During Term B, 2000 the CEE faculty discussed and approved the sixth motion, approved a seventh motion added by the Committee and started implementation of the Department s process model for outcomes assessment.

2. Methodology

The Committee was established in May 2000 to develop a process to assess student performance in the Civil and Environmental Engineering (CEE) Department. This section includes a description of the overall approach taken by the Committee, followed by a summary of the presentations and meetings related to the Committee s work.

2.1 Approach

The Committee s approach included the following tasks:

- Compile baseline data to demonstrate the relationship between Program Outcomes and the current curriculum (including consideration of both courses and MQPs)
- Identify Program Outcomes that are not well supported by the current CEE curriculum
- Present specific recommendations to the Department for developing clearly defined and measurable Program Outcomes to assess the current CE curriculum
- Establish a process to demonstrate, to evaluate, and to provide feedback regarding how graduates satisfy the Program Outcomes and how continuous improvement of the curriculum is addressed.
- Summarize the outcomes from the Exit B Interviews (EBI) student satisfaction surveys for presentation to the CEE Department

The following information was available to initiate this effort:

- Completed MQP reports and course submittals
- Faculty worksheets to demonstrate how each course and MQP related to Program Outcomes
- Engineering Criteria 2000 (requirements and program self-study instructions)
- ASCE Commentary on Engineering Criteria 2000
- A number of articles pertaining to accreditation (available through ABET web site)
- Examples of efforts from other institutions (available through the WWW)
- Program objectives (outcomes) for the CEE Department

At the outset, the Committee recognized that any assessment of our curriculum had to be conducted in the context of the Department s Program Outcomes. The Committee began its deliberations at its first meeting by reviewing a list of 11 program objectives (these are also listed as Program Outcomes in other parts of this report), which had been developed during academic year 1999-2000. A copy of this list is shown in Table 1. The Committee found this list to be sufficiently complete and proceeded to decide the role that courses, MQPs, and other WPI degree requirements and activities would play in fulfilling these objectives. The committee also began to consider the means by which the department could assess (and modify as needed) their suggestions and how ABET visitors would assess our approach. It immediately became clear that both courses and MQPs would play a major role in meeting

these objectives. The role of the Fundamentals of Engineering Exam (FEE) as an assessment tool was thoroughly discussed in this context. Consequently, the Committee reviewed work that had been done along these lines and determined what additional work needed to be done. The results are presented in the following report sections.

Table 1. Program Outcomes

1. Components of Civil Engineering Practice
    a. Technical
    b. Professional
    c. Ethical
2. Preparation for the future changes in Civil Engineering
3. Understanding of Basic Principles of Civil Engineering
4. Understanding and application of:
    a. Biology
    b. Chemistry
    c. Geology
    d. Physics e. Differential and Integral Calculus
    f. Differential Equations
    g. Probability and Statistics
    h. Linear Algebra
    i. Higher Mathematics
5. Understanding of Design Process, including the following:
    a. Ability to Perform Design
    b. Multidisciplinary Aspects
    c. Collaboration Skills
    d. Communication Skills
    e. Consideration of Cost
    f. Consideration of Time Management
6. Demonstration of an ability to:
    a. Set up experiments
    b. Gather and analyze data
    c. Apply the data to practical engineering problems
7. Demonstration of an in-depth understanding of at least 1 specialty within CEE
8. Understanding of options for careers and further education
9. An ability to learn independently
10. Broad education envisioned by the WPI Plan & described by the Goal & Mission of WPI
11. Understanding of the Civil Engineering profession in a societal and global context

2.2 Summary of meetings and presentations

The process began on May 17, 2000 with a meeting of all committees that had been designated by their respective departments to prepare strategies for successfully obtaining ABET accreditation in 2002. Representatives from each of the departments reported on the status of their respective departments strategies at this meeting. Professor Mathisen spoke for the Civil & Environmental Engineering Department.

The Civil & Environmental Engineering Department committee then formally met at least twice a week up to and including the last week of July. The meetings consisted of extensive deliberations by the committee to define what it was that needed to be assessed and to identify a process to assess it in such a way that it would be practical and supported by all faculty members of the Civil and Environmental Engineering Department. An interim meeting of all departmental committees was held on June 29, 2000. At this meeting, each Department provided an update regarding the status of its ABET strategy. The presentations and comments in this interim meeting were considered to the fullest extent possible when developing the results and recommendations presented in this report

During one of the final July meetings, an outline of a preliminary draft of the report of the committee s findings was prepared. This outline listed various sections of the report and responsibility for writing working draft versions of these sections was assigned to the individual committee members. A complete version of the report was prepared in late August. The final version is now being presented. A copy of this report is being forwarded to Professor Schachterle.

3. Results

This section describes the process that the Committee developed for continuous improvement of the curriculum of the Department of Civil & Environmental Engineering. This process provides a methodology for defining and measuring program educational outcomes (Program Outcomes). Note that outcomes refer to abilities that each student possesses at the time of his or her graduation. These Program Outcomes have to reflect the Department s program educational objectives.

Section 3.1 identifies components of the CEE curriculum that provide appropriate opportunities for assessment. The results pertaining to the civil engineering principles and MQP review and assessment are presented in Sections 3.2 and 3.3 respectively. Finally, Section 3.4 proposes a process for continuous improvement of the Civil and Environmental Engineering Program

3.1 Defining Components of the CEE Curriculum for Assessment

3.1.1 Importance of the MQP and courses as assessment tools

Courses and MQPs represent the primary components of the CEE curriculum that can be effectively assessed. Since courses and MQPs are the only available assessment tools, they also need to provide students with exposure to all Program Outcomes. For every Program Outcome it is necessary to identify specific outcomes in the Department s courses and MQPs that can be assessed to evaluate student learning. Accordingly, for each of the Program Outcomes, the Committee identified the components of the CEE curriculum that would be appropriate for assessment.

The Committee recognized that the MQP is ideal for assessment because it has practical significance and all students are required to complete it. Furthermore, formal MQP assessment has been ongoing for six years. However, since each MQP typically addresses a specific sub-area within civil engineering, the MQP may not be an adequate tool to assess the principles of civil engineering and ethics. Consequently, courses are considered to be a more appropriate vehicle for assessing the students understanding of CEE principles and ethics, while the MQP is currently considered to be appropriate for assessing most other Program Outcomes. In particular, courses that all (or almost all) students take, such as CE 1030 and the other fundamental courses, provide ideal opportunities for assessment. Accordingly, the Committee agreed that the assessment plan should emphasize the fundamental courses, and the plan should also include assessment of breadth courses and depth courses to demonstrate how students apply and extend the principles that they ve learned from the fundamental courses.

3.1.2 Assessment Matrix

The final assessment recommendations are presented as a matrix in Table 2. The means of assessment for various outcomes are also discussed in more detail below:

1. Components of Civil Engineering Practice
    a. Technical
    b. Professional
    c. Ethical

The technical and professional components of civil engineering practice are considered to be validated by successful completion of the MQP. Ethical components are provided in courses such as CE 1030, CE 3022 and CE 501.

2. Preparation for the future changes in Civil Engineering - The MQP usually requires students to research state-of-the-art technology in some area(s) of CEE and to experiment with new methods and techniques. Completion of the MQP prepares the student to deal with future changes in the profession.

3. Understanding of Basic Principles of Civil Engineering - This may be demonstrated by successful completion of courses which sufficiently cover the principles of Civil Engineering as defined and discussed in a Section 3.2.

4. Understanding and application of:

a. Biology- Those CEE students concentrating on environmental engineering commonly take courses in biology. This outcome may be demonstrated by successful completion of courses offered by the Biology Department.

b. Chemistry - This may be demonstrated by successful completion of courses offered by the Chemistry Department as part of distribution requirements.

c. Geology - This may be demonstrated by successful completion of course GE 2341.

d. Physics - This may be demonstrated by successful completion of by courses offered by the Physics Department as part of distribution requirements.

e. Differential and Integral Calculus - This may be demonstrated by successful completion by courses offered by the Mathematics Department as part of distribution requirements.

f. Differential Equations -This may be demonstrated by successful completion by courses offered by the Mathematics Department as part of distribution requirements.

g. Probability and Statistics - This may be demonstrated by successful completion by courses offered by the Mathematics Department or by CEE courses requiring statistical manipulation of data such as CE 3026.

h. Linear Algebra - This may be demonstrated by successful completion by courses offered by the Mathematics Department or by CEE courses requiring the use of matrix algebra such as CE 4007.

i. Higher Mathematics - This may be demonstrated by successful completion of courses offered by the Mathematics Department whether the student takes them as part of distribution requirements or by completion of a CEE course requiring sophisticated mathematical modeling (such as the finite element method as presented in CE 4048).

5. Understanding of Design Process, including the following:

a. Ability to Perform Design

b. Multidisciplinary Aspects

c. Collaboration Skills

d. Communication Skills

e. Consideration of Cost

f. Consideration of Time Management

All of these 6 components of design may be validated by successful completion of an MQP as defined and discussed in Section 3.3. Furthermore, since WPI features project oriented education, the requirements of many individual CEE courses include completion and presentation of a number of small design projects. Completion of such courses may also be used to a lesser extent to assess this outcome.

6. Demonstration of an ability to:

a. Set up experiments

b. Gather and analyze data

c. Apply the data to practical engineering problems

The first two components may be satisfied by successful completion of at least two lab courses such as CE2020, CE3026, CE 4046 and CE 4060 as specified by distribution requirements. The third component may be satisfied through elements of the MQP where students integrate data (although others often supply the data) into their final designs.

7. Demonstration of an in-depth understanding of at least 1 specialty within CEE - This could be demonstrated by completion of the MQP.

8. Understanding of options for careers and further education — This may be demonstrated by successful completion of courses such as CE 1030 and to a lesser extent in the breadth courses. Active participation in the student related to professional societies such as the ASCE and DBIA student chapters, including attending lectures by guest speakers, provides the student with their first networking experience. Completion of the Fundamentals of Engineering Exam may also be used to demonstrate that the student is willing to take an action that is not required for graduation but which will have an effect on his/her future career. Formal application and acceptance to graduate programs may also be used to demonstrate this Program Outcome.

9. An ability to learn independently - This may be demonstrated by successful completion of the MQP.

10. Broad education envisioned by the WPI Plan & described by the Goal & Mission of WPI - Successful completion of all degree requirements should be sufficient to insure that this outcome has been met.

11. Understanding of the Civil Engineering profession in a societal and global context
This is also part of the WPI Plan to educate the technological humanist. Successful completion of the IQP (particularly if at a foreign site) as well as other features of WPI s academic program could be used to demonstrate this outcome.

3.1.3 Conclusions and Recommendations

The Committee concluded that there are means for satisfying and assessing each outcome within the present academic program, provided the Department carefully defines a process to objectively and efficiently identify how and where the students can demonstrate the Program Outcomes.

This procedure may require verification that students have taken certain courses since, according to the WPI Plan policy, no particular course may be designated as required . Therefore, it may be possible that a student graduates without taking a specific course. And consequently, it is also possible that a student could graduate without demonstrating satisfaction of every single outcome. The Civil & Environmental Engineering Department faculty has already developed advising tools and procedures to minimize the probability that such a situation could occur.. Nevertheless, the Department should develop a plan to assess the effectiveness of this effort.

In particular, the Committee recommends the following:

- The Department should adopt the matrix shown in Table 2 linking Program Outcomes to elements of the undergraduate curriculum. This is necessary to establish a clear relationship between the various elements of the CEE curriculum and stated CEE program objectives. (See Motion 1 in Appendix I)
- The Department should continue its current efforts to improve student course selection and advising
- The Department should request student manuscript data from the Registrar s office from graduating seniors. These data can be used to track courses completed by students in each graduating class. This effort will help to assess the impact of changes in distribution requirements and academic advising practices. It will also verify that students are taking the courses identified by the Department to assess Program Outcomes such that, if necessary, any corrective actions can be taken in the future. (See Motion 2 in Appendix I)

The Committee agreed that the present curriculum should provide a means for satisfying all Program Outcomes. However, the role that the MQP, courses and, to some extent, the Fundamentals of Engineering Exam could play in addressing outcomes pertaining to ethics, multi-disciplinary aspects of design, and fundamental principles of civil engineering prompted considerable discussion. The committee recommends that data in the area of ethics should be gathered from courses. Since only CE 1030, CE 3022, and CE 501 currently deal explicitly with ethics; the Department may consider incorporating ethics as a component of Department s breadth courses. The Committee recommends that the appropriate treatment of ethics in the CEE curriculum be considered as an item for CEE Department discussion (See Item 5 of the Items for CEE Department discussion in Appendix II). In addition, the Committee felt that the multi-disciplinary aspects of design could be provided by the MQP. This requires that the department establish a clear definition for what is meant by the multidisciplinary aspects of design. This recommendation is included as Item 2 in the items for CEE Department discussion in Appendix II. Finally, the Committee recognized the important role of courses in addressing the principles of civil engineering. This topic prompted considerable discussion and the results are therefore presented in the next section.

Table 2 Matrix Linking Program Outrcomes to Elements of the Curricula

CEE PROGRAM EDUCATIONAL OUTCOMES	PRIMARY AREAS FOR ASSESSING OUTCOMES		
	MQPs	Courses	Other
1. Components of civil engineering practice:			
a. Technical	x		
b. Professional	x		
c. Ethical		x	
2. Preparation for the future changes in civil engineering.	?*		
3. Understanding of basic principles of civil engineering			
a. Computers and information technology		x	
b. Geographic positioning (or spatial representation) and measurements		x	
c. Solid (structural) Mechanics		x	
d. Soil Mechanics		x	
e. Fluid Mechanics		x	
f. Design, problem - solving and decision - making techniques		x	
g. Construction material		x	
h. System analysis and modeling		x	
I. Engineering economics and risk management		x	
4. Understanding and application of math and science		x	
5. Understanding of engineering design process, including the following:			
a. Ability to perform design	x		
b. Multidisciplinary aspects	?*		
c. Collaboration skills	x		
d. Communication skills	x		
e. Consideration of cost	x		
f. Consideration of time management	x		
6. Demonstration of and ability to setup experiments, gather and analyze date,		LABS	
and apply the data to practical engineering problems.			
7. Demonstration of an in-depth understanding of at least one specialty within civil engineering	x		
8. Understanding of options for careers and further education		CE 1030	CO-Curricular activities
9. An ability to learn independently	x		
10. Broad education envisioned by the WPI Plan, and described by the Goal and Mission of WPI			WPI Degree requirements
11 Understanding of the civil engineering profession in a societal and global context	?*		

3.2 Principles of Civil Engineering

As noted in the previous section, the Committee established a matrix linking the CEE Program Outcomes to elements of the undergraduate curriculum. For each of the eleven CEE Program Outcomes, this matrix shows the primary area of the curriculum (courses, projects and other WPI degree requirements) that is recommended for assessing outcomes. Assessing outcomes requires clear definitions so that measurable student performance criteria can be defined and measurement methods can be designed. The Committee felt that, in most cases, the Program Outcomes definitions were clear and faculty could consistently address them in MQP and course assessment forms; however, the definition of the Principles of Civil Engineering (which is central to Program Outcome 3 in Table 1: graduates have a solid understanding of the basic principles of civil engineering) resulted in a wide range of interpretations by the CEE faculty when asked to identify the extent and ability to which their courses meet this outcome. Therefore, the Committee defined a set of basic principles to encompass all of the principles that the CEE Faculty considered essential for their courses. The Committee also concluded that the fundamental courses of the CEE curriculum offered the best area to demonstrate and assess Program Outcome 3.

3.2.1 Background

Previous actions have been taken by the Civil & Environmental Engineering Department faculty in order to quantify the correlation between courses and Program Outcomes. These efforts included a written review of each course currently offered by the CEE Department. The reviews were part of the CEE Course Assessment Workbook that the CEE faculty completed during February 2000 for each of the courses they teach. A copy of the Workbook is contained in Appendix V.

3.2.2 Approach

To establish a set of Principles of Civil Engineering (PCEs), the Committee completed the following three tasks:

Task 1	Compiled baseline data.
Task 2	Compiled a comprehensive listing of PCEs.
Task 3	Condensed the comprehensive list into a smaller working set of PCEs.

Task 1

The CEE Course Assessment Workbooks that were completed by the CEE faculty members (see Appendix V) provided baseline data concerning the relationship between each of the eleven CEE Program Outcomes and each undergraduate course offerings. An Excel© spreadsheet was used to compile and organize this data.

Task 2
As part of the CEE Course Assessment Workbook, CEE faculty were asked to identify explicitly the basic principles of civil engineering associated with their courses. The CEE faculty identified 56 different principles in their courses, reflecting the diverse areas of the civil engineering profession.

Task 3
The Committee used its collective background, abstraction, and other resources to propose replacing the list of 56 principles with a more manageable set of 9 basic PCEs.

3.2.3 Results

Table 3 is an Excel© spreadsheet that presents the baseline data obtained from the completed CEE Course Assessment Workbooks. The rows of the spreadsheet refer to the principles of civil engineering as identified by the CEE faculty members for CEE Program Outcome 3, and the columns refer to specific undergraduate courses. The numerical data entries *Aij* for each row *i* and column *j* indicate the extent to which a particular principle was an aspect of a given course. The numerical entries reflect the following Likert scale: 0 = Not at all, 3 = Moderate, 4 = Significant, and 5 = Highly significant.

In total, 56 principles were identified, and they are listed in Table 3. This large list illustrates the wide array of topics that are important to the civil engineering curriculum. If these 56 principles were incorporated into the definition of Program Outcome 3, then it would be a significant challenge for the Department to assess whether all graduates have achieved this outcome. Therefore the Committee decided to develop and propose a consolidated list of principles for the Department s consideration.

The Committee proposed consolidating the 56 principles into the following 9 categories or basic PCEs:

1. Computers and Information Technology
2. Geographic Positioning [or spatial representation] and Measurements
3. Solid [Structural] Mechanics
4. Soil Mechanics
5. Fluid Mechanics
6. Design
7. Construction Materials
8. Systems Analysis and Modeling
9. Engineering Economics and Risk Management

The Committee developed this list after several iterations that involved discussions on separate proposals made by each member of the Committee and the review of material published by, among others, ASCE, ABET and NCEES. For completeness, Table 4 illustrates how each of 56 principles identified by the faculty can be mapped to one of the above 9 PCEs. If the Department accepts this reduced list of PCEs, then a systematic process will be needed to

demonstrate that all graduates have demonstrated satisfactory performance with respect to each PCE.

As a check of the Committee s work, it referred to a curriculum chart that the Department developed during Spring 2000 to aid students in planning their academic program. This chart is presented in Table 5, and it is intended to be included in future versions of the undergraduate catalog. The chart clearly identifies a set of introductory courses that the faculty has designated to contain fundamental CEE knowledge, and the faculty advises CEE undergraduates to complete these six courses. These courses are CE1030, CE2000, CE2001, CE2020, ES3004 and CE3041. Table 6 shows the PCEs that can be demonstrated by each of these six introductory courses. The data in Table 6 is based on the compiled baseline data and the past experience of the Committee members. Note that the six introductory courses provide opportunities for students to demonstrate understanding of the following PCEs: Computers and Information Technology, Geographic Positioning [or spatial representation] and Measurements, Solid [Structural] Mechanics, Soil Mechanics, Fluid Mechanics, and Design. The introductory courses do not seem to provide opportunities to demonstrate the students understanding of Construction Materials, Systems Analysis and Modeling, and Engineering Economics and Risk Management.

3.2.4 Recommendations

The Committee submits the following list of 9 basic Principles of Civil Engineering for faculty discussion and resolution.

1. Computers and Information Technology
2. Geographic Positioning [or spatial representation] and Measurements
3. Solid [Structural] Mechanics
4. Soil Mechanics
5. Fluid Mechanics
6. Design
7. Construction Materials
8. Systems Analysis and Modeling
9. Engineering Economics and Risk Management

Any solution that is reached for defining basic principles of civil engineering will impact the Department s practices for academic advising. (See Item 3 in Appendix II for CEE Departmental discussion). For example, the six introductory courses (CE1030, CE2000, CE2001, CE2020, ES3004 and CE3041) provide opportunities for students to demonstrate their understanding of the following PCEs: Computers and Information Technology, Geographic Positioning [or spatial representation] and Measurements, Solid [Structural] Mechanics, Soil Mechanics, Fluid Mechanics, and Design. The six introductory courses do not seem to provide opportunities for students to demonstrate their understanding of Construction Materials, Systems Analysis and Modeling, and Engineering Economics and Risk Management. The Committee recommends that the Department complete reach an agreement on the basic principles that it expects all graduates to demonstrate and implements an appropriate strategy for academic advising.

Principles Identified by CEE Faculty	CEE UNDERGRADUATE COURSES																												
	CE 1030	CE 2000	CE 2001	CE 2002	CE 2020	CE 3006	CE 3008	CE 3010	CE 3020	CE 3021	CE 3022	CE 3023	CE 3026	CE 3030	CE 3041	CE 3044	CE 3050	CE 3051	CE 3054	CE 3059	CE 3060	CE 3061	CE 3062	CE 3070	CE 3074	CE 4007	CE 4017	CE 4024
3. Understanding of basic principles of civil engineering (please list and assess each principle).																													
Static equilibrium		5	5			5																							
Funicular shape		3																											
Friction Laws		3																											
Muller-Breslau Principle		3																											
Stress and strain			5																										
Constitutive Laws			4																										
Force-Deformation Relationships			4																										
Compatibility of Deformations			4																										
Stability						5																							
Limit States Design						5																							
Constructibility						3																							
Building Codes and Specifications						4																							
Analytical Mechanics							5		1	2																	5		
Mechanics of Materials							5																				5		
Structural Analysis							5																				5		
Structural Design							5																				5		
Fluid Mechanics							4		1	1										4							4		
Dynamics							3																				3		
Soil Mechanics							3																				3		
Matrix Structural Analysis							4																				4		
Systems Analysis							3													3							3		
Probabilistic Methods							3													3							3		
Engineering Economics									5	4																			
Computers & Information Technology									4	4																			
Management Science & Organization Science									4	3																			
Ethics & Business Practice									4	4																			
Materials Science									2	2																			
Surveying									2	2																			
Electrical Circuits & Thermodynamics									1	1																			
Nature of civil engineering services											5																		
Principles of professional standards and ethics											5																		
Visualization of loading within a structure												5																	
Development of design documents												5																	
Traffic Engineering																	5												
Highway Capacity																	5												
Highway Safety																	5												
Geometric Design																	5												
Physical properties of materials																		5	5										
Principles of design																		5		3									
Concepts of stability																			5										
Concepts of durability																			5										
Principles of production																			4										
Quality control																			4										
Ideal reactors																				3	5								
Tracer analysis																				4	4								
Reactor efficiency evaluations																				4	3								
Fundamental hydraulics																				4	3		5						
Open channel flow																				3			4						
Dimensional analysis & hydraulic modeling																							3						

Table 4 Consolidated Principles of Civil Engineering

Principles Identifed by CEE Faculty	Computers & Information Technology	Geographic Positioning or Spatial Representation	Solid (Structural) Mechanics	Soil Mechanics	Fluid Mechanics	Design	Construction Materials	Systems Analysis & Modeling	Engineering Economics & Risk Management
Static equilibrium			X						
Funicular shape			X						
Friction Laws			X						
Mohr-Streckeisen Principle			X						
Stress and strain			X						
Constitutive Laws			X						
Force-Deformation Relationships			X						
Compatibility of Deformations			X						
Stability			X						
Limit States Design						X			
Constructibility						X			
Building Codes and Specifications						X			
Analytical Mechanics			X						
Mechanics of Materials			X						
Structural Analysis			X						
Structural Design						X			
Fluid Mechanics					X				
Dynamics			X						
Soil Mechanics				X					
Matrix Structural Analysis			X						
Systems Analysis								X	
Probabilistic Methods								X	
Engineering Economics									X
Computers & Information Technology	X								
Management Science & Organization Science								X	
Ethics & Business Practice						X			
Materials Science							X		
Surveying		X							
Electrical Circuits & Thermodynamics								X	
Nature of civil engineering services						X			
Principles of professional standards and ethics						X			
Visualization of loading within structures			X			X			
Development of design documents		X				X			
Traffic Engineering								X	
Highway Capacity								X	
Highway Safety								X	
Geometric Design						X			
Physical properties of materials							X		
Principles of design						X			
Concepts of stability			X						
Concepts of durability			X				X		
Principles of production								X	
Quality control								X	X
Ideal reactors								X	
Tracer analysis					X				
Reactor efficiency evaluations								X	
Fundamental hydraulics					X				
Open channel flow					X				
Dimensional analysis & hydraulic modeling					X				
Pumps and pump systems					X				
Hydrologic cycle & its components								X	
Probability and statistics								X	
Hydrograph analysis					X				
Groundwater flow				X	X				
Hydrologic modeling & Rainfall/runoff relationships								X	
Reservoir routing & reservoir yield								X	

Table 5 CEE Department Curriculum Chart

CIVIL AND ENVIRONMENTAL ENGINEERING PROGRAM CHART

STUDENTS EARNING AN ABET ACCREDITED DEGREE IN CIVIL ENGINEERING MUST COMPLETE A MINIMUM OF 15 UNITS OF STUDY ARRANGED IN ACCORDANCE WITH THE DISTRIBUTION REQUIREMENTS. THIS CHART SUMMARIZES COURSE RECOMMENDATIONS - SEE YOUR ADVISOR TO DEVELOP YOUR PROGRAM SCHEDULE.

MATHEMATICS	SCIENCE
4 Units Required	
MA 1020/1021 *	CH 1010
MA 1022 *	CH 1020
MA 1023 *	CH 1030
MA 1024	PH 1110
MA 2051 *	PH 1120
MA 2071	PH 1130
MA 2210	BB 1001
MA 2611	GE 2341

NOTES
Basic math and science courses should be completed early in the curriculum, prior to taking many CE courses. Students may select from other math and science courses in addition to those listed here.
* Mathematics requirements include differential and integral calculus, and differential equations.
Science: Must include both chemistry and physics with a minimum of two courses in either.

ENGINEERING SCIENCE AND DESIGN 6 Units Minimum Required (Minimum 4 Units in the Civil Engineering area as noted in Distribution Requirements)						
Fundamental Courses	CE 1030 (1), CE 2000 (1), CE 2001 (1), CE 2020 (3), ES 3004 (1), CE 3041					
Background Courses	CE 3030, ES 2503 (1), ES 3001 (1, 2), EE 3601 (1, 2)					
Area (4, 5)	Structural	Geotechnical	Environmental and Hydraulics	Urban and Environmental Planning	Transportation	Construction and Management
Breadth	CE 3010	CE 3041	CE 3059	CE 3070	CE 3050	CE 3020 (1)
Depth	CE 2002 CE 3006 CE 3008 CE 3026 (3) CE 4007 CE 4017	CE 3044 CE 4046 (3) CE 4048	CE 3060 CE 3061 CE 3062 CE 4060 (3) CE 4061	CE 3074 CE 4071	CE 3051 CE 3054 (3) CE 305X	CE 3021 CE 3022 (1) CE 3023 CE 3024 (3) CE 4024
MQP	1 Unit Emphasizing Design (in area of choice) Should be completed in senior year and meet capstone design requirement.					

NOTES
1. Includes material covered on Fundamentals of Engineering General Exam.
2. Meets the requirement for at least one engineering science course outside of Civil Engineering.
3. Meets the requirement for appropriate laboratory experience (two laboratory courses required).
4. To demonstrate breadth, students must select courses from a minimum of four areas. Courses should also be selected to demonstrate depth in at least one area.
5. Many areas are interrelated. See your advisor for information on depth courses that are related to your area of interest.

ADDITIONAL DEGREE REQUIREMENTS

4 Units Required

Social Science	2/3 Units
Humanities and Arts	2 Units (includes Sufficiency)
IQP	1 Unit
Physical Education	1/3 Unit

Fundamental Courses	Computers & Information Technology	Geographic Positioning or Spatial Represe	Solid (Structural) Mechanics	Soil Mechanics	Fluid Mechanics	Design
CE 1030	■					■
CE 2000			■			■
CE 2001						■
CE 2020		■				
CE 3041				■	■	
ES 3004					■	

Table 6 Proposed Principles of Civil Engineering Addressed in the Six Fundamental Courses

3.3 MQP Review and Assessment

As discussed in Section 3.1, MQPs are considered to be the primary tool for assessing the following CEE Program Outcomes:

- Components of civil engineering practice (technical and professional parts) (Program Outcomes 1a & 1b)
- Understanding the engineering design process (Program Outcome 5)
- Demonstration of an in-depth understanding of at least one specialty within civil engineering (Program Outcome 7)
- Ability to learn independently (Program Outcome 9)
- Understanding of the civil engineering profession in a societal and global context (Program Outcome 11)

Due to the importance of the MQP in meeting these outcomes, the Committee evaluated the current procedures for MQP review and assessment to verify that the MQP can be used to demonstrate the student achievement of the outcomes noted above. After a brief review of the Department's previous MQP review procedures, this section summarizes the Committee's approach and results for addressing the role of the MQP in the CEE Department's assessment program.

3.3.1 Background

Since 1993, the CEE department has been conducting biannual summer reviews of the MQPs as part of a campus-wide reviews sponsored by the office of the Provost. This summer, the

departmental MQP review, for the academic year 1999-2000 was conducted as an integral part of the Department s ABET assessment activities.

Over the last four years the CEE Department has been collecting data about its MQPs using a form that is filled out by the MQP Faculty advisors at the time of completion of the MQP. A copy of this form is included in Appendix IV. In this form, the advisor assesses the level of attainment of the MQP objectives beyond the academic grade. The form also provides administrative information such as the number of terms the students registered, the number of students involved, the number of academic credits received by the students, etc.

Several types of indicators have resulted from these reviews including the Department's use of resources, technical areas covered by the MQP, overall quality of the MQP, and the use of the MQP as the tool by which students meet the new ABET 2000 requirements.

Since its initial development in 1996, the MQP evaluation form has been redesigned three times based on a continuous assessment of the results from the Department's viewpoint and the WPI campus wide review process. This has allowed the CEE Department to generate better data and to more effectively address the issues related to the MQPs such as the fulfillment of the capstone design requirement. The most recent version of this form is now a more comprehensive one. It contains provisions to generate data of interest to WPI at large and to the CEE department. A special section has been added to capture information related to its Program Outcomes. A sample of the most recent version of the MQP Review form can be found in Appendix IV.

3.3.2 Approach

As part of its summer activities, the Committee reviewed a selected number of MQPs for the 1999-2000 Academic Year and examined in detail the extent in which MQPs can be used to in assessing outcomes related to these Program Outcomes. As part of this examination, the Committee performed the following tasks:

- Task 1 - Compiled baseline data for MQPs
- Task 2 - Analyzed extent to which specific program outcomes were reflected in MQPs
- Task 3 - Analyzed extent to which MQPs provided experience with the engineering design process
- Task 4 - Evaluated current MQP review procedure

These tasks are described in more detail in the following paragraphs.

Task 1 — Compiled baseline data for MQPs

CEE Faculty who advise projects currently complete MQP Review Forms for use in assessing the student outcomes associated with the MQP. The Committee compiled data from these forms for the 16 MQPs completed in the 1999/2000 academic year. The MQP review form used to evaluate the design aspects of projects the 1999/2000 year included a modification that provides

more detailed information in regard to the capstone design. This information was very helpful in the review.

Task 2 — Analyzed extent to which specific program outcomes were reflected in MQPs
On MQP evaluation forms, the faculty advisors provided a measure of the extent to which selected program outcomes were reflected in MQPs. This measure was defined in terms of a Likert scale from 1 to 5 (with 1 indicating very low extent, 3 indicating a medium extent, and 5 indicating a very high extent) level of achievement. The Committee summarized these data and used it to verify that assessment of MQPs could demonstrate achievement of POs 1(a and b), 5,7, 9, and 11.

Task 3 - Analyzed engineering design experience provided by MQP
As noted previously, the Committee identified the MQP as an ideal curricular component for demonstrating that CEE students understand the engineering design process (as indicated by Program Outcomes 5a through 5f). Using a Likert scale similar to that described for Task 2, the MQP Review forms that project advisors complete include indications of the extent to which the MQP addresses POs 5a through 5f. These data were reviewed and evaluated to define the design experience provided by the MQP, as indicated by the project advisors. (See Table 9).

Task 4 - Evaluated current MQP review procedure
To evaluate the current procedure for reviewing MQP s, the Committee completed an independent review and evaluation of four MQPs that were completed during the past academic year. This review focused on the need for design, design problem definition, design criteria, consideration of alternatives, development of design, final design review, and economic analysis. The reviewed MQPs were selected to represent each of the four major CEE areas Each Committee member independently read each MQP and completed an MQP Review Form (2000) for each project. The Committee members assessments were compared to each other and also to the original project advisor s assessment.

3.3.3 Results

Evaluation of the current MQP Review Forms and associated review procedures indicates that the MQP generally can be used to satisfy Program Outcomes 1a, 1b, 2, 5, 7, 9, and 11, and the MQP does provide students with a effective capstone design experience.

First, the extent to which each of the 16 MQPs satisfies Program Objectives 1a, 1b, 2, 5, 7, 9, and 11, as indicated by faculty advisor assessments, is shown in Table 7. The numbers in this table represent the faculty advisor s assessments on a Likert scale ranging from 1 to 5, with one representing very low content, and 5 representing very high content. In most cases, the MQPs are rated three or higher. Therefore, the Committee concluded that the MQP seems to be an adequate component of the curriculum for outcome assessment of CEE Program Outcomes 1a, 1b, 5, 7, and 9. It was not entirely clear whether or not the MQP accomplished this for CEE Program Outcomes 2 and 11, since some of the assessments in Table 7 are below three. As discussed in the following paragraphs, the Committee felt that the role of the MQP in addressing these outcomes could be clarified by improved definitions of expectations for the MQP. These

considerations are suggested for Departmental discussion.

Second, Table 8 shows the extent to which each MQP provides students with a capstone design experience, as indicated by faculty advisor assessments. The numbers in this table represent faculty advisors assessments following the same Likert scale used for Table 7. The table includes columns showing assessments of the need for design, design problem definition, design criteria, consideration of alternative designs, development of the design, final design review and/or test, and economic analysis. For most columns, assessments, the assessment indications are greater than or equal to three. For some of these items, however, the assessment indications are variable. In particular, wide variability was evident in economic analysis. The Committee attributed much of this variability to different interpretations of the requirements associated with the various levels of the Likert scale.

Table 7 Program Outcomes indicated by faculty in 1999/2000 MQP assessment

	MQP															
Outcome	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1a	**5**	**4**	**5**	**4**	**1**	**4**	**4**	**4**	**4**	**2**	**5**	**5**	**3**	**4**	**5**	**4**
1b	**5**	**2**	**5**	**4**	**1**	**4**	**3**	**3**	**3**	**4**	**4**	**5**	**3**	**4**	**5**	**4**
1c	**2**	**na**	**na**	**na**	**na**	**2**	**na**	**na**	**na**	**na**	**5**	**5**	**na**	**3**	**3**	**1**
2	**4**	**2**	**3**	**1**	**2**	**4**	**2**	**3**	**3**		**4**	**5**	**4**	**4**	**4**	**5**
4a	**3**	**4**	**3**	**4**		**4**	**4**	**5**	**5**	**2**	**5**	**5**	**3**	**4**	**3**	**2**
4b	**1**		**2**		**4**	**na**	**na**	**na**	**na**	**na**	**5**	**5**	**4**	**3**	**3**	**3**
9	**4**	**4**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**5**	**5**	**3**	**4**	**4**	**4**
11	**2**	**2**	**3**	**2**	**2**	**3**	**3**	**3**	**3**	**4**	**5**	**5**	**3**	**4**	**4**	**1**

Table 8 Capstone design experience indicated by faculty in 1999/2000 MQP review

MQP Number	Type of design	Open-ended need for design	Design problem definition	Statement of design criteria	Consideration of alternative designs	Development of design	Final design review or test	Economic analysis
1	System	2	3	4	4	3	3	2
2	System	2	4	5	5	5	3	4
3	System	2	4	5	3	4	2	2
4	--	-	-	-	-	-	-	na
5	System	3	4	4	3	4	3	1
6	System	2	4	4	2	3	4	2
7	System	2	4	4	4	4	2	3
8	System	4	5	4	5	4	3	4
9	Component	2	4	1	2	2	2	3
10	Experiment	5	4	4	3	5	5	na
11	Experiment	5	5	5	5	5	5	na
12	System	3	4	4	4	4	4	4
13	Process	4	4	4	3.5	2	na	1
14	Sys/proc	5	5	4	3	5	5	4
15	Sys/proc	5	3	5	5	4	3	4

Table 9 Capstone design experience indicated by faculty in 1999/2000 MQP review

	MQP 1					*MQP 2*					*MQP 3*					*MQP 4*				
	Rev 1	*Rev 2*	*Rev 3*	*Rev 4*	*Adv*	*Rev 1*	*Rev 2*	*Rev 3*	*Rev 4*	*Adv*	*Rev 1*	*Rev 2*	*Rev 3*	*Rev 4*	*Adv*	*Rev 1*	*Rev 2*	*Rev 3*	*Rev 4*	*Adv*
Open-ended need for Design	4	3	--	**5**	5	4	3	4	5	4	5	1	3	4	5	3	4	2	2	2
Design Problem Definition	4.5	4	--	5	4	4	5	4	5	4	4	5	4	4	3	3	4	4	4	4
Statement of Design Criteria	2.5	5	--	3	4	4	5	4	4	4	2.5	5	4	1	5	2	4	1	1	1
Consideration of Alternative Designs	2	3	--	0	3	4	2	4	4	3.5	3.5	2	3	0	5	3	0	2	2	2
Development of Design	5	5	--	2	5	2	5	0	2	2	2.5	5	3	4	4	4	4	2	2	2
Final Design Review and/or Test	5	5	--	5	5	1	5	0	2	0	2	5	0	2	3	2	4	2	2	2
Definition of Objectives & Scope	4	5	--	5	5	5	5	5	-	5	5	5	5	-	4	3	4	3	3	3
Conclusions	--	5	--	-		3.5	5	4	-	3.5	3	5	4	-	4	3	4	3	3	3
Procedures																				
Data Collection	5	5	--	5	5	5	5	5	5	5	5	5	3	5	5	3	4	4	4	4
Data Analysis	5	5	--	5	5	5	5	5	5	5	5	5	4	5	5	3	4	2	2	2
Economic Analysis	1	2	--	0	NA	2	5	2	1	1	1	2	2	2	4	4	2	3	3	3
Type of capstone design	Expt	Expt	--	Sys	Exp	Proc/ Sys	Proc		Sys	Proc/ sys		Proc		Proc Expt	Proc Sys	Sys	??	Com	Com	Com

Finally, to address these variations in more detail, the Committee completed a detailed review of selected MQPs. Results of this selective review of recently completed projects are summarized in Table 9. This table shows independent assessments by the four Committee members, along with the initial assessments completed by the project advisor. Again, the Committee found that MQP does provide students with a capstone design experience. Overall, the assessments in the

selective review are consistent with those of the project advisor, and the current assessment project is considered to be adequate. However, although the four Committee members ratings were consistent (with each other and with the advisors) for most aspects of the MQPs, the Committee noted that there were a number of instances where different Committee members rated the same aspect of the same MQP quite differently. Some differences are also apparent between assessments of individual reviewers and project advisors. Again, these differences were primarily attributed to different interpretations of the requirements associated with the various levels of the Likert scale. The nature of the MQP s documentation in regards to the execution of the design was also considered to be a factor.

The Committee agreed that these results, coupled with the need for the MQP to play an important role in meeting Program Outcome 5, showed that there is a need for the department to produce a more uniform method for interpreting the numbers in Parts III and IV of the current form in order to develop some rating consistency in such items as economic analysis, use of computers, etc. In particular, a more uniform method for interpreting the numbers of the Likert scale could help to reduce inconsistencies across the department in the documentation of the execution of the design, evaluation and selection of design alternatives, and performance of economic analysis

3.3.4 Recommendations

The Committee recommends that the Department continue using the MQP to demonstrate student performance in accordance with Program Outcomes 1(a and b), 5, 7, 9, and 11. .

With regards to these outcomes, the Committee recommends that the Department should take the following actions:

1. Establish clear goals and expectations with regard to each of the outcomes
2. Evaluate the MQP role in satisfying these outcomes as part of the Department s plan for continuous improvement.
3. Clearly define the expectations associated with each of the 5 elements of the Likert scale used to evaluate the relevant outcomes. This will yield more consistent evaluations of the MQP.

Due to the MQPs importance in providing the students with a design component (as defined by Program Outcome 5), these actions should include particular attention to this design experience. The Committee also recommends that the MQP be used to evaluate and demonstrate that our program provides students with an understanding of the multidisciplinary aspects of the engineering design process (CEE Program Outcome 5b). This requires the department to proceed with the following activities:

- Establish a clear definition for what is meant by the multi-disciplinary aspects of design
- Establish a consistent grading system for evaluating student performance

These recommendations are also presented as Items 1 and 2 of the Items for CEE Department discussion presented in Appendix II

3.4 CEE Continuous Improvement Program

As outlined in previous sections, the Committee recognized both courses and MQPs as the primary components for outcomes assessment. Collectively, CEE courses and MQPs must provide students with exposure to all of the CEE Program Outcomes. For each of the Program Outcomes, the Committee identified the components of the CEE curriculum that would be appropriate for assessment. The results are presented in Table 2. Courses are considered to be appropriate for assessing Program Outcomes #s 1c, 3 6 and 8 while the MQP is currently considered to be appropriate for Program Outcomes #s 1a, 1b, 2, 5, 7, 9 and 11.

This section summarizes the Committee s approach and results for integrating outcomes assessment activities in courses and MQPs into a system for continuous improvement. The system includes feedback loops for evaluation of and improvement to the Program Outcomes and the curriculum. It also indicates the roles of the CEE Faculty and the program constituents.

3.4.1 Background

Previous actions have been taken by the Civil & Environmental Engineering Department faculty in order to quantify the correlation between courses and Program Outcomes. These efforts included a written review of each course currently offered by the CEE Department. The reviews were part of the CEE Course Assessment Workbook that the CEE faculty completed during February 2000 for each of the courses they teach. A copy of the Workbook is contained in Appendix V.

In Spring 2000, the Department developed a curriculum chart to aid students in planning their academic program. This chart is presented in Table 5. Review of this chart indicates that the CEE Curriculum includes the following major components:

- Math and science courses
- CE 1030 and other fundamental courses
- Breadth courses
- Depth Courses
- Laboratory courses
- MQP

The breadth and depth courses are categorized according to six technical subgroups: Structural; Geotechnical; Environmental and Hydraulics; Urban and Environmental Planning; Transportation; and Construction and Management. In addition to the breadth and depth courses, MQP topics are often aligned with the interests of the six technical subgroups. Individual faculty members from the six technical subgroups also contribute to teaching the fundamental courses (i.e., CE 1030, CE 2000, CE 2001, CE 2020, ES 3004, and CE 3041) that are strongly recommended for all students.

CEE student programs also include the Sufficiency and the IQP. While these activities are considered to be valuable educational components for all students, their specific benefits vary from student to student. Because the outcomes of the Sufficiency and IQP cannot be uniformly assessed for all students, the Committee did not suggest use of these aspects of the curriculum for gathering and analyzing outcomes data, other than in the context of WPI degree requirements.

3.4.2 Approach

To establish a Continuous Improvement Program (CIP), the Committee completed the following three tasks:

Task 1	Identified the roles of the individual faculty and the technical subgroups with respect to assessment of the CEE Curriculum.
Task 2	Created a process flow chart with separate paths for outcomes assessment in courses and MQPs.
Task 3	Clarified the activities within the process flow chart.

Task 1
The Committee reviewed the curriculum chart developed by the Department in Spring 2000 (see Table 5). The Committee recognized the variety of disciplines within civil and environmental engineering. While individual faculty members were considered to be the most qualified to define specific measurables for their courses, faculty members and courses are aligned according to technical subgroups.

Task 2
The Committee established a process flow chart that defines the roles of the individual faculty members and the technical subgroups in gathering and analyzing assessment data from courses and MQPs. A new CEE Department Committee, entitled the Curriculum & Assessment Committee (CAC), will coordinate the assessment and feedback activities conducted by individual faculty members and the technical subgroups.

Task 3
To prepare its recommendations for CEE Department acceptance and implementation, the Committee clarified the roles of the major participants in the process flow chart. Sample assessment strategies were prepared, and the composition of the CAC was proposed.

3.4.3 Results

3.4.3.1 Overall Assessment Approach

When reviewing the nature of the CEE curriculum and the associated curriculum chart, the Committee observed the diverse nature of the program and the role of the different CEE subgroups in teaching courses at all levels. In addition the Committee observed that all CEE

students take (or should take) CE 1030 and the fundamental courses, and all CEE students take most of the breadth courses. Therefore, the fundamental courses and breadth courses provide the best opportunities for assessing a high percentage of the student population.

For the most part, the responsibility for teaching each fundamental and breadth course falls within the domain of a specific subgroup. For example, the 2000 series is often taught by the structural group and fluid mechanics is typically taught by the environmental group. Since the subgroups typically assume responsibility for the content of the various fundamental and breadth courses, assessment of these courses is best reviewed by the appropriate subgroups (and faculty) as well. The subgroups would naturally review assessment data for the depth courses within their specific disciplines.

To maintain an integrated assessment approach that links individual courses and MQPs to the entire Departmental curriculum, the Committee recommends the assessment at three levels: individual courses by individual faculty members, CEE sub-disciplines by technical subgroups, and department-wide, by a new CEE Curriculum & Assessment Committee (CAC). These three assessment levels are clarified as follows:

a. Individual faculty members - For each course, the faculty member teaching the course is considered to be the most qualified to develop the appropriate assessment approaches and expectations. Therefore each faculty member should define the relevant Program Outcomes, course content, measurables and evaluation methods for his or her course offerings. To maintain consistency and ensure coverage of the appropriate Program Outcomes, however, individual faculty members need to work in conjunction with the other faculty members associated with their subgroup. In addition, individual faculty members should continue to complete the Department s established worksheets for Assessment of MQP Outcomes, as discussed in Section 3.3.
b. CEE subgroups - The Committee agreed that faculty members within each CEE technical subgroup could provide the best assessment of the curriculum within its associated sub-discipline. Each technical subgroup would develop a procedure for gathering and reporting assessment data pertaining to the courses within their sub-discipline.
c. CEE Curriculum & Assessment Committee - The creation of CAC is necessary to provide department-wide assessment and ensure consistent outcomes assessment approaches within courses for the various subgroups. CAC will assume responsibility for reviewing and evaluating outcomes associated with MQPs. This Committee would also document the development and implementation of the Department s system for outcome assessment and program improvement.

Assessment at these three levels accommodates the requirements associated with the wide variety of disciplines within civil and environmental engineering. With the technical subgroups gathering and reviewing assessment data from their respective courses, the curriculum associated with each of the disciplines can be more effectively assessed and improved. The addition of the CAC ensures that a uniform and objective approach is applied to assess and improve the overall program.

3.4.3.2 Process Flow Diagram

The Committee developed a process flow diagram to illustrate a system that will allow for outcome assessment and continuous program improvement. This flow chart is shown in Figure 1. In this chart, the three entities that perform assessment (CEE faculty, the technical subgroups, and CAC) are enclosed in rectangles.

For the first two years of implementation, the flow chart in Figure 1 represents a yearly cycle. However, after the process has been established, it is likely that the cycle can be lengthened such that the information is gathered every second or third year. For example, course data and MQP data will be gathered during the 2000-1 and 2001-2 academic years. Then, it is anticipated that these data can be obtained periodically thereafter.

Slightly different pathways are followed for improvement of courses, and improvement of MQPs, so these pathways are discussed separately below. For clarity, the numbers in listed brackets match specific pathways identified in Figure 1. Suggested guidelines for the role of individual faculty members, the technical subgroups, and the CAC are also provided.

Defining and assessing outcomes to demonstrate student performance in MQPs

On-going improvement of CEE MQPs will be demonstrated through the following process:

1. First, the CEE faculty identifies the subset of Program Educational Objectives that will be demonstrated by MQPs
2. The CEE faculty develops the associated Program Outcomes. These outcomes define the level of performance required for the Department to say it has achieved the subset of Program Educational Objectives.
3. MQPs are advised by individual faculty members (or by teams of faculty members). [1] With the completion of each MQP and the submittal of the associated Certificates of Degree Requirement (CDR s), the project advisors complete the Department s established worksheets for MQP outcomes. [3] The completed worksheets are filed in the department office, and this information is passed along directly to the CAC.[5]
4. At the end of each academic year, members of the CAC review and evaluate the completed MQPs with respect to the outcomes defined in the first step. The CAC members compare their findings with the assessment worksheets prepared by the project advisors.
5. The CAC summarizes and presents its findings and recommendations to the Department faculty at the start of the succeeding academic year. The CEE faculty can then discuss and plan programmatic changes in their MQPs. The CEE faculty may also decide to revise the outcomes identified in Step 1 as well as the related Program Educational Objectives.[6]
6. CEE Faculty reviews Program Outcomes that will be satisfied by the MQP. These recommendations are provided to CAC and CEE Technical Subgroups.[6 and 7] CAC documents the compiled assessment data and the resulting strategies for program improvement.[11]

Defining and assessing outcomes to demonstrate student performance in courses

Improvement of CEE courses will make use of the following seven-step process:

1 First, the CEE faculty identifies the subset of Program Educational Objectives that will be demonstrated by course assessment data. The relevant Program Educational Objectives are distributed to Technical subgroups [11]
2 Each of the four technical groups develops quantitative Program Outcomes. The outcomes define the level of performance for the department to say that it has achieved the subset of objectives identified in step 1.
3 Each of the four technical groups defines an implementation strategy for achieving the Program Outcomes defined in Step 2. The implementation strategy consists of departmental and classroom practices designed to provide opportunities for students to achieve the outcomes. The recommended implementation strategies are distributed to appropriate individual faculty members. [7]
4 Individual faculty members identify assessment methods for collecting student performance data in their courses. These methods must be consistent with the outcomes.
5 Individual members gather and process student performance data for their courses. The faculty members must present the student outcomes data in a format consistent with the outcomes [2]
6 Each of the four technical groups reviews the course-based assessment data and determines whether or not outcomes were met. The technical groups use the assessment data to provide feedback to the individual course instructors and identify strategies for program improvement.[7]
7 Technical groups share assessment data and program improvement strategies with the CAC. [12] The CAC also receives input from current and outgoing CEE students and alumni [16 and 17].
8 The CAC documents the compiled assessment data and resulting strategies for program improvement, and also shares assessment data across the Department [6 and 13]. In addition, this Committee shares data and strategies with CEE advisory Board [14] and receives feedback as appropriate [15]. The CAC also works with faculty members to coordinate catalog revisions.

Suggested Guidelines for the Role of Individual Faculty Members

To help start discussion on outcomes assessment in courses, the Committee developed sample criteria worksheets for some of the fundamental CEE courses to describe the assessment of the course with regard to the Program Outcome Solid understanding of the Basic Principles of Engineering . These criteria included the definition of performance, implementation strategy, assessment method, timeline and feedback. These sample criteria worksheets are included in Appendix III. Extension of course assessment activities beyond the fundamental CEE courses and into the breadth and depth courses is referred to the Department for discussion. In addition to gathering and reviewing course assessment data, individual faculty members should continue to complete the Department s established worksheets for Assessment of MQP Outcomes, as discussed in Section 3.3. Lastly, faculty members are expected to work within their technical

subgroups and across the Department to use the assessment data for continuous improvement of the curriculum.

Suggested Guidelines for the Role of the Technical Subgroups

Technical subgroups will provide recommendations to individual faculty members for assessing and reporting assessment results for their specific courses. They will also integrate assessment results from all faculty members within the subgroup and provide reports to the Curriculum and Assessment Committee (CAC). Any feedback from the CAC, CEE Faculty, or constituencies will be used to facilitate the assessment process. The technical subgroups will use the assessment data for continuous improvement of their course offerings.

Suggested Guidelines for the Role of the Curriculum and Assessment Committee (CAC)

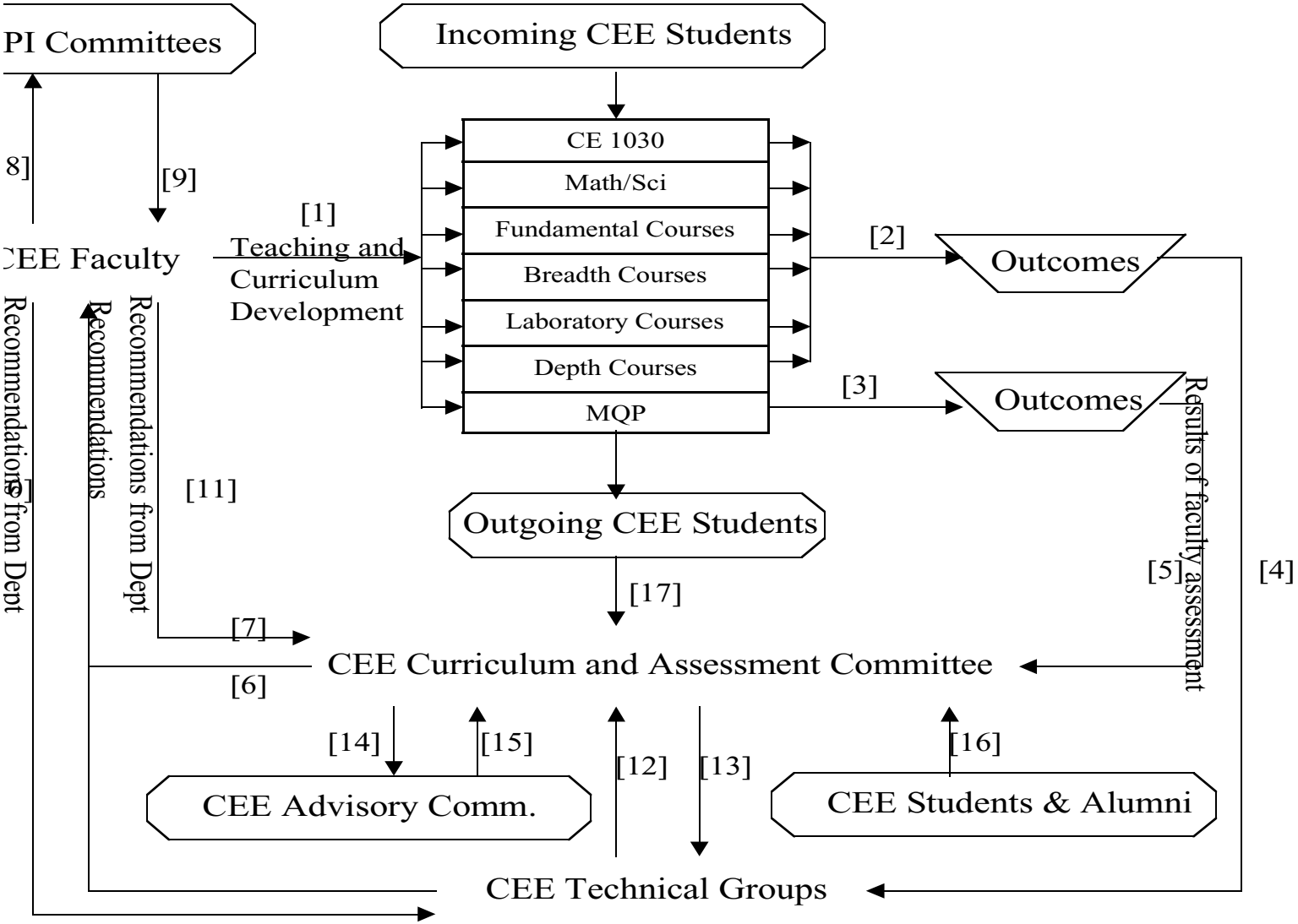
The CAC will share assessment data across the Department, interact with the Department s constituents for program improvement and to revise Program Educational Objectives, and share information and practices with WPI s campus-wide Student Outcomes and Assessment Committee (SOASC). The CAC will also coordinate the Department s plans to add or drop courses and to revise the undergraduate catalogs. One model for the composition of CAC would be to have one faculty member from each of the six recognized technical subgroups (i.e., Structural, Geotechnical, Environmental and Hydraulics, Urban and Environmental Planning, Transportation, and Construction and Management). The Committee thought that a six-member CAC would not be an effective operation, and faculty in the smaller technical subgroups would be unfairly burdened. Therefore, the Committee proposed clustering the six technical subgroups into the following four groups: Structural/Geotechnical, Environmental, Transportation/Planning, and Construction Management. One faculty member from each of these four new groups would comprise the membership of CAC. In order to ensure widespread participation, members may serve two-year terms.

3.4.4 Recommendations

To implement a Continuous Improvement Process that satisfies the requirements of ABET 2000, the Committee recommends the following:

1. A Curriculum and Assessment Committee (CAC) should be established. This Committee will document the development and implementation of a systemic plan for outcome assessment and program improvement.
2. Assessment of courses by individual faculty members should be maintained. Assessment strategies should also be initiated by the Department s technical subgroups (i.e., Structural; Geotechnical; Environmental and Hydraulics; Urban and Environmental Planning; Transportation; and Construction and Management) and the CAC
3. The Continuous Improvement Process (CIP) outlined in Section 3.4.3 (and illustrated in Figure 1) should be adopted for both courses and MQPs.

Figure 1 Assessment Flow Chart



4.0 Committee Recommendations

The Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET) evaluated the CEE program during the 1996-97 academic year. The evaluation was conducted as a pilot application of the ABET Engineering Criteria 2000 (EC2000). The CEE program received accreditation through September 2003. Review of the ABET report indicates that the CEE program earned compliments for "its efforts to achieve accreditation under EC2000;" however, "the lack of a formal process for continuous improvement" was cited as a primary weakness. There are two full academic years remaining until the next accreditation visit, and the Committee has focused on developing a process to assess student performance.

The Committee s recommendations are presented in the form of six motions for CEE Department action and items for CEE Department discussion. The intent of these recommendations is for the Department to move as quickly as possible to implement the assessment process, gather and evaluate assessment data, and provide feedback and action items to the curriculum. The original versions of the six motions with rationale are provided below. The revised motions passed by the CEE Department during Fall 2000 are contained in Appendix I. The items for CEE Department discussion are provided in Appendix II.

The working committee on ABET Outcomes Assessment recommends the following six motions for CEE Department action.

Motion 1: Matrix Linking Program Objectives to Elements of the Undergraduate Curriculum for Outcomes Assessment.

Student achievement of the eleven CEE Program Outcomes will be demonstrated by gathering data from CEE courses, MQPs, and transcript analyses. Table 2 is a matrix that indicates what will be assessed to demonstrate each outcome.

Rationale: The goal of this motion is to establish a clear relationship between the various elements of the CEE curriculum and the stated CEE Program Outcomes. The matrix is a critical element of the proposed improvement process. It will also help the CEE Department prepare its Program Self-Study Report in preparation for the next ABET visit.

Motion 2: Student Data for Transcript Analysis

At the end of each academic year, the Department will request student transcript data for graduating seniors from the Registrar's Office. The data will be used to track the courses completed by the students in each graduating class and to help assess the impact of changes in distribution requirements and academic advising practices.

Rationale: In the absence of required courses, the CEE Department relies on academic advising to ensure that all students achieve the program outcomes. Transcript data will demonstrate that students are taking courses critical to satisfying the program outcomes.

Motion 3: Establishment of Curriculum and Assessment Committee.

A departmental Curriculum and Assessment Committee (CAC) will be established. The CAC will document the development and implementation of a systematic plan for outcomes assessment and program improvement. The CAC will share assessment data across the Department, interact with the Department's constituents for program improvement or to revise program objectives, and share information and practices with the WPI campus-wide Student Outcomes Assessment Committee (SOASC). The CAC will also coordinate the Department's plans to add/drop courses and to revise the undergraduate catalog.

The CAC will have four members, representing each of the four technical groups (i.e., Structural/Geotechnical, Environmental, Transportation, and Project Management). In order to ensure widespread participation, members will serve two-year terms.

Rationale: The creation of the Curriculum and Assessment Committee provides accountability for implementation of a formal process for continuous improvement. The broad, representative membership on the committee is an effort to balance the views of the respective technical groups and individual faculty members with the Department's goals and outcomes.

Motion 4: System Model for Continuous Improvement of CEE MQPs.

Systematic evaluation of CEE program outcomes and continuous improvement of CEE MQPs will be demonstrated through the following six step process (see the process flow diagram in Figure 1):

1. CEE faculty identify the subset of Program Objectives that will be demonstrated by MQPs.
2. The CEE faculty develop the associated Program Outcomes. These outcomes define the level of performance required for the Department to say it has achieved the subset of Program Objectives.
3. With the completion of each MQP and the submittal of the associated CDR(s), the project advisor(s) complete the Department's established worksheets for Assessment of MQP Outcomes. The completed worksheets are filed in the Department office.
4. At the end of each academic year, members of the Curriculum and Assessment Committee (CAC) review and evaluate the completed MQPs with respect to the outcomes defined in the first step. The CAC members compare their findings with the assessment worksheets prepared by the project advisor(s).
5. The CAC summarizes and presents its findings to the Department faculty at the start of the succeeding academic year. The CEE faculty can then discuss and plan programmatic changes in their MQPs. The faculty may also decide to revise the outcomes identified in the first step as well as the related Program Objectives.
6. The CAC documents the compiled assessment data and the resulting strategies for program improvement.

Rationale: The evaluation report from the 1996-97 accreditation process notes that the "program's process of ongoing evaluation that demonstrates achievement of its objectives is not well-defined and appears to rely heavily on anecdotal information." The proposed system model formalizes an evaluation and feedback loop for the MQP. The model complies with ABET EC2000 guidelines by identifying the significant participants and constituencies of the CEE program and how they are integrated into an overall process.

Motion 5: System Model for Continuous Improvement of CEE courses.

Systematic evaluation of CEE program outcomes and continuous improvement of CEE courses will be demonstrated through the following seven step process (see process flow diagram in Figure 1):

1. The CEE faculty identify the subset of Program Objectives that will be demonstrated by course assessment data.
2. Each of the four technical groups (i.e., Structural/Geotechnical; Environmental; Transportation; and Project Management) develop quantitative Program Outcomes. These outcomes define the level of performance required for the Department to say that it has achieved the subset of objectives identified in step 1.
3. Each of the four technical groups define an Implementation Strategy for achieving the Program Outcomes identified in the second step. The Implementation Strategy consists of Departmental and classroom practices designed to provide opportunities for students to achieve the outcomes.
4. Individual faculty members identify Assessment Methods for collecting student performance data in their courses. These methods must be consistent with the outcomes.
5. Individual faculty members gather and process student performance data for their courses. The faculty members present the student outcomes data in a format consistent with the outcomes.
6. Each of the four technical groups review the course-based assessment data and determine whether or not the outcomes were met. The technical groups use the assessment data to provide feedback to the individual course instructors and to identify strategies for program improvement. Course data will be gathered during the 2000-01 and 2001-02 academic years and every two or three years thereafter.
7. Technical groups share assessment data and program improvement strategies with the Curriculum and Assessment Committee (CAC). The CAC documents the compiled assessment data and the resulting strategies for program improvement. The CAC shares assessment data across the Department and interacts with the Department's constituents. The CAC also works with faculty members to coordinate adding/dropping courses and catalog revisions.

Rationale: The evaluation report from the 1996-97 accreditation process notes that the "program's process of ongoing evaluation that demonstrates achievement of its objectives is not well-defined and appears to rely heavily on anecdotal information." The proposed system model formalizes an evaluation and feedback loop for CEE courses. The model complies with ABET EC2000 guidelines by identifying the significant participants and constituencies of the CEE program and how they are integrated into an overall process.

Motion 6: Faculty compilation of learning objectives and assessment data for all CEE courses.

Faculty will continue to provide information on learning objectives and outcomes assessment for their courses. The individual faculty members will rate courses as to whether their contents meet any of the Program Outcomes defined by implementation of Motion 5, above.

Rationale: In addition to demonstrating the attributes listed under ABET EC2000, Criterion 3, this course data will facilitate the preparation of materials to satisfy EC2000, Criterion 4, the professional component and applicable program criteria.

Bibliography

Olds, B.M., and Miller, R.L., "An Assessment Matrix for Evaluating Engineering Programs" ASEE Journal of Engineering Education, pp. 173-178, April 1998.

Rogers, G.M., "EC 2000 and Measurement: How Much is Precision is Enough", ASEE Journal of Engineering Education, pp. 161-165, April 2000.

Appendixes

I. Motions Approved by the Department

The Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET) evaluated the CEE program during the 1996-97 academic year. The evaluation was conducted as a pilot application of the ABET Engineering Criteria 2000 (EC2000). The CEE program received accreditation through September 2003. Review of the ABET report indicates that the CEE program earned compliments for "its efforts to achieve accreditation under EC2000;" however, "the lack of a formal process for continuous improvement" was cited as a primary weakness. There are two full academic years remaining until the next accreditation visit, and the working committee on ABET Outcomes Assessment has focused on developing a process to assess student performance. The working committee's recommendations are presented in the form of motions for CEE Department action and items for CEE Department discussion. The intent of these recommendations is for the Department to move as quickly as possible to implement the assessment process, gather and evaluate assessment data, and provide feedback and action items to the curriculum.

Motions for CEE Department Action
The working committee on ABET Outcomes Assessment recommends the following six motions for CEE Department action.

Motion 1: Matrix Linking Program Outcomes to Elements of the Undergraduate Curriculum for Outcomes Assessment.

Student achievement of the eleven CEE Program Outcomes will be demonstrated by gathering data from CEE courses, MQPs, and transcript analyses. Table 2 is a matrix that indicates what will be assessed to demonstrate each objective.

Rationale: The goal of this motion is to establish a clear relationship between the various elements of the CEE curriculum and the stated CEE Program Outcomes. The matrix is a critical element of the proposed improvement process. It will also help the CEE Department prepare its Program Self-Study Report in preparation for the next ABET visit.

Motion 2: Student Data for Transcript Analysis

At the end of each academic year, the Department will request student transcript data for graduating seniors from the Registrar's Office. The data will be used to track the courses completed by the students in each graduating class and to help assess the impact of changes in distribution requirements and academic advising practices.

Rationale: In the absence of required courses, the CEE Department relies on academic advising to ensure that all students achieve the Program Outcomes. Transcript data will demonstrate that students are taking courses critical to satisfying the Program Outcomes.

Motion 3: Establishment of Curriculum and Assessment Committee.

A departmental Curriculum and Assessment Committee (CAC) will be established. The CAC will document the development and implementation of a systematic plan for outcomes assessment and program improvement. The CAC will share assessment data across the Department, interact with the Department's constituents for program improvement or to revise program objectives, and share information and practices with the WPI campus-wide Student Outcomes Assessment Committee (SOASC). The CAC will also coordinate the Department's plans to add/drop courses and to revise the undergraduate catalog.

The CAC will consist of members that represent the various technical groups (i.e. Structural/Geotechnical, Environmental, Transportation, and Project Management) and ranks (i.e. full, associate, and assistant) held by faculty members. Membership will be designed to ensure widespread participation.

Rationale: The creation of the Curriculum and Assessment Committee provides accountability for implementation of a formal process for continuous improvement. The broad, representative membership on the committee is an effort to balance the views of the respective technical groups and individual faculty members with the Department's goals and outcomes.

Motion 4: System Model for Continuous Improvement of CEE MQPs

Systemic evaluation of CEE program outcomes and continuous improvement of CEE MQPs will be demonstrated through the following five step process:

1. CEE faculty develops subset of program outcomes that will be demonstrated by MQPs.
2. With the completion of each MQP and the submittal of the associated CDRs, the project advisor(s) complete the Department s established worksheets for assessment of MQP outcomes. The completed worksheets are filed in the Department office.
3. At the end of each academic year, members of the CAC review and evaluate the completed MQPs with respect to the outcomes defined in Step 1. The CAC members compare their findings with the assessment worksheets prepared by the project advisor(s)
4. The CAC presents its findings to the Department faculty at the start of the succeeding academic year. The CEE Faculty then can discuss and plan programmatic changes in their MQPs. The faculty may also decide to revise the outcomes identified in the first step.
5. The CAC documents the compiled assessment data and the resulting strategies for program improvement.

Motion 5: System Model for Continuous Improvement of CEE Courses

Systemic evaluation of CEE program outcomes and continuous improvement of CEE Courses will be demonstrated through the following seven step process:

1 CEE Faculty identifies subset of program outcomes that will be demonstrated by course assessment data.
2 Each of the four technical groups will develop quantitative program outcomes consistent with the list of program outcomes recommended by the CEE Department. These outcomes will define the level of performance required for the Department to say that it has satisfied the associated program educational objectives and ABET 2000 criteria.
3 Each of the four technical groups defines an implementation strategy for achieving the program outcomes defined in Step 2. The implementation strategy consists of Departmental and classroom practices designed to provide opportunities for students to achieve the outcomes.
4 Individual faculty members identify assessment methods for collecting student performance data in their courses. These methods must be consistent with the outcomes.
5 Individual faculty members gather and process student performance data for their courses. The faculty members present the student outcomes data in a format consistent with the outcomes.
6 Each of the four technical groups review the course-based assessment data an determine whether the outcomes were met. The technical groups use the assessment data to provide feedback to the individual course instructors and to identify strategies for program improvement. Course data will be gathered during the 2000-01 and 2001-02 academic years and in alternate years thereafter.
7 Technical groups share assessment data and program improvement strategies with the Curriculum and Assessment Committee (CAC). The CAC documents the compiled assessment data and resulting strategies for program improvement. The CAC shares assessment data across the Department and interacts with the Department s constituents. The CAC also works with faculty members to coordinate adding/dropping courses and catalog revisions.

Motion 6: Faculty compilation of learning outcomes and assessment data for all CEE courses

Faculty will continue to provide information on learning objectives and outcomes assessment for their courses. Courses will be rated by individual faculty members as to whether their contents meet any of the program outcomes defined by implementation of Motion 5.

Rationale: In addition to demonstrating the attributes listed under ABET EC2000, Criterion 3, this course data will facilitate the preparation of materials to satisfy EC2000, Criterion 4, the professional component and applicable program criteria.

Motion 7: System model for continuous improvement of CEE mission, objectives, and outcomes

Systemic evaluation of the CEE Department mission and CEE program objectives will be demonstrated through the following six-step process:

1. CEE Faculty develop, review and, if necessary, update mission. The mission is then provided to appropriate constituency groups for review.
2. CEE faculty develop, review and, if necessary, update program educational objectives (PEOs). The PEOs are provided to the CAC and technical subgroups. These PEOs are provided to appropriate constituency groups for review.
3. CEE faculty develop, review and, if necessary, update program outcomes and identify subsets of program outcomes that will be demonstrated by MQPs, courses, and other components of the WPI curriculum. These program outcomes reflect the program educational objectives and ABET 2000 criteria a — k. The program outcomes (and associated vehicles for assessment) are provided to the CAC, the CEE Technical Subgroups, and appropriate constituency groups for review.
4. CAC completes MQP assessment as described in Motion 4. CAC provides recommendations to CEE Faculty for improvement of objectives and outcomes.
5. Technical groups complete course assessment as described in Motion 5 and provide results to CAC. CAC provides recommendations to CEE Faculty for improvement of objectives and outcomes
6. CEE Faculty repeat steps 1, 2, and 3. It is anticipated that the process will be repeated annually during the 2000-01 and 2001-02 academic years, and periodically thereafter.

Rationale:

The CEE Faculty at large is responsible to define and, as necessary, update, the Department s educational mission, academic program objectives, and program educational outcomes. In accordance with ABET 2000 requirements, the review and evaluation process must include verification that

- objectives are published and consistent with the Department s mission and ABET 2000 criteria
- a process is in place to determine and periodically evaluate these objectives
- the objectives are based on needs of constituents
- the curriculum and processes are ensuring achievement
- evaluation is completed to ensure achievement, and
- the results of this evaluation are used to improve effectiveness of the program

This motion supplements Motions 4 and 5 and satisfies these requirements.

II. Items for CEE Department Discussion

The working committee on ABET Outcomes Assessment recommends the following five items for CEE Department discussion and resolution.

Item 1: Capstone Design.

The working committee on ABET Outcomes Assessment recommends continued use of the MQP to demonstrate student completion of a significant design exercise (CEE Program Objective #5 and ABET EC2000, Criterion 4). The committee reviewed completed worksheets for Assessment of MQP Outcomes and four sample MQP reports. The materials were reviewed to assess student performance with respect to the following established criteria for capstone design: Open-ended need for Design; Design Problem Definition; Statement of Design Criteria; Consideration of Alternative Designs; Development of Design; and Final Design Review and/or Test. The level of economic analysis performed by the students was also assessed. In general, it appears that MQPs provide the students with some amount of design experience. However, use of the current Likert scale is open to interpretation.

The working committee recommends that the Department proceeds with the following activities:

- Establish a consistent grading system for use with the Likert scale;
- Establish clear goals and expectations for the MQP design experience;
- Evaluate the MQP design experience as part of the Department's plan for continuous improvement.

Item 2: Multi-disciplinary Aspects of Design

CEE Program Objective #5 states that our students will have an understanding of the multidisciplinary aspects of the engineering design process. The working committee on ABET Outcomes Assessment recommends that the MQP be used to evaluate and demonstrate that our program achieves this objective. This requires the Department to proceed with the following activities:

- Establish a clear definition for what is meant by the multidisciplinary aspects of design.
- Establish a consistent grading system for evaluating student performance.

Item 3: Fundamental Principles of Civil Engineering.

The working committee on ABET Outcomes Assessment spent considerable time discussing and interpreting CEE Program Objective #3: Students will have a solid understanding of the basic principles of civil engineering. Given the diverse activities and skills associated with the civil engineering profession, it was difficult to establish a working set of principles to serve as the basis for assessing student outcomes. Based on review of the basic principles identified by all

CEE faculty members as part of their course inventory worksheets, the committee reached an agreement that the following nine areas reflect the basic principles of civil engineering:

1. Computers and information technology.
2. Geographical positioning and graphical representation.
3. Solid (structural) mechanics.
4. Fluid mechanics.
5. Soil mechanics.
6. Construction materials.
7. Design process and decision-making.
8. Systems analysis and modeling.
9. Engineering economics and risk management.

The working committee submits the above areas for faculty discussion and resolution. Any solution that is reached for defining the basic principles of civil engineering will impact the Department's practices for academic advising and implementation of Motions 1 through 6, identified above. Note the following comment taken from the 1996-97 ABET accreditation evaluation of the CEE program:

> Some concern exists that students are not required to obtain a grounding in the fundamentals because of the lack of required courses and prerequisites. The program should continually assess this situation to insure that students do graduate with the grounding in fundamentals necessary to be successful in entry-level engineering practice. Distribution requirements were apparently instituted for this reason.

Item 4: Identification of CE 3020 Project Management as a Fundamental Course.

If the concepts of Systems Analysis and Modeling and Engineering Economics and Risk Management are accepted as basic principles of civil engineering (see item 1 above), then a fundamental course should be identified to facilitate implementation and assessment of student performance. CE 3020 appears to be the only CEE course that provides substantive coverage of Engineering Economics and Risk Management. It also exposes students to Systems Analysis and Modeling.

Item 5: Ethics.

The working committee concluded that student outcomes data in the area of ethics should be gathered from courses so that MQPs do not become overburdened with Departmental requirements. Currently CE 1030, CE 3022, and CE 501 deal with ethics to some extent. It may be necessary to include ethics in the Department's recognized breadth courses. Program Outcomes, an implementation strategy, and assessment methods must be established to demonstrate that students have an understanding of ethics.

III. Principles of Civil Engineering sample criteria worksheets

These criteria included the definition of performance, implementation strategy, assessment method, timeline and feedback for some CEE fundamental courses to describe the assessment of the course with regard to the Program Outcome Solid understanding of the Basic Principles of Engineering . These courses are:

- CE 2000
- CE 2001
- CE 3004
- CE 3041
- CE 3020

CE 2000 & CE 2001

Program Outcome

3. A solid understanding of the basic principles of civil engineering.

3.1 Relevant to the area of solid/structural mechanics

3.1.1 Performance criteria

1. 100% of CEE students will complete or receive transfer credit for CE 2000 and CE 2001.
2. **90%** of students can distinguish between statically determinate and statically indeterminate systems.
3. **90%** of students can explain the concepts of elastic modulus, yield strength and poisson's ratio, and their application to engineering materials.
4. **90%** of students can apply the concepts of equilibrium and stress to the design and evaluation of structural members and components of statically determinate truss, beam, and frame systems.
5. **90%** of students can determine the external support reactions for statically-indeterminate truss, beam, and frame systems.

3.1.2 Implementation Strategy:

1. Establish CE 2000 and CE 2001 as fundamental courses recommended for all students.
2. Recommend that students complete one or more other courses in area of structural engineering.
3. Initiate outcomes assessment in CE 2000, CE 2001 and all other structural engineering courses.

3.1.3 Assessment Methods

1. Analysis of student transcripts.
2. Course exams for CE 2000 and CE 2001.
3. Course projects for CE 2000 and CE 2001.
4. Outcomes assessment data from upper level structural engineering courses (including CE 2002, CE 3006, CE 3008, CE 3010, CE 3044, and CE 4017) as determined by faculty members in the structural/geotechnical engineering subgroup
5. Faculty observations and reflections from CE 2002, CE 3006, CE 3008, CE 3010, CE 3044, and CE 4017, and MQPs.

3.1.4 Timeline

At end of academic years 2000-2001 and 2001-2002, then biannually.

3.1.5 Feedback

Results will be used by faculty instructors in area of structural engineering to improve instruction in CE 2000 and CE 2001.

CE 3004

Program Outcome

3. A solid understanding of the basic principles of civil engineering

3.1 Relevant to the area of fluid mechanics

3.1.1 Performance criteria

1. 100% of CEE students complete or receive transfer credit for ES 3004
2. 100% of students understand the concepts of fluid pressure and use these concepts to determine pressure forces on submerged structures
3. 100% of students can apply conservation of mass principles
4. 90% of students can apply conservation of momentum principles
5. 90% of students understand conservation of energy principles and can apply these principles to piping systems and other fluid mechanics systems.

3.1.2 Implementation strategy

1. Establish ES 3004 as a fundamental course recommended for all students
2. Recommend that all students complete one or more other courses in the area of environmental engineering
3. Initiate course assessment for ES 3004 and all other environmental engineering courses

3.1.3 Assessment methods

1. Analysis of student transcripts
2. Course exams for ES 3004
3. Outcomes data from upper level environmental engineering courses (including CE 3060, CE 3061, CE 3062, CE 4060, and CE 4061) as determined by environmental subgroup and individual faculty members.
4. Faculty observations and reflections from CE 3060, CE 3061, CE 3062, CE 4060, and CE 4061

3.1.4 Timeline

At end of academic years 2000-2001 and 2001-20002 — then biannually

3.1.5 Feedback

Faculty instructors in area of environmental engineering will use the results to improve the CEE students understanding of fluid mechanics principles.

CE 3041

PROGRAM OUTCOME
3. A solid understanding of the basic principles of Civil Engineering.

3.1 Relevant to the area of Geotechnical Engineering,
3.1.1 Performance Criteria
1. 100% of students understand the nature of soil and rock, index properties of s -oil and soil classification.
2. 100% of students understand the effective stress principle.
3. 100% of students can apply Darcy's Law to analyze one-dimensional seepage through soils regardless of their homogeneity or isotropy.
4. ___ % of students can analyze 2 dimensional flow through homogeneous isotropic soil.
5. ___ % of students understand Terzaghi's one dimensional consolidation theory and can apply it to predict magnitude and rate of settlement of slowly draining soil.
6. ___ % of students can calculate changes in stress within a soil strata produced by surface loading.
7. ____% of students understand the nature of both short and long term shear resistance of rapid and slowly draining soil and can select the critical case in order to analyze bearing capacity of foundations and stability of slopes.
8. ___% of students are capable of determining earth pressures by Rankine and Coulomb methods.

3.1.2 Implementation Strategy
1. All students should complete CE 3041 as a fundamental background with GE 2341 suggested as an introductory science .
2. Students should complete additional courses in Geotechnical Engineering to employ these principles to design of Civil Engineering works relevant to their area(s) of interest in accordance with the following list:

Interest:	Course:
Buildings and Bridges	CE 3044
Retaining Structures	CE 3044
Excavations	CE 3044
Dams	CE 4048
Waste Containment Facilities	CE 4048
Highways	CE 4048

3.1.3 Assessment Methods
1. Examinations in 3000 level courses and examinations and projects in 4000 level courses.
2. MQP advisor observations
3. Student feedback with respect to their preparation and performance in the Geotechnical Engineering component oft he FE Exam.

3.1.4 Timeline
Annual review.

3.1.5 Feedback
Results will be used by faculty to modify instruction technique and edit published lecture notes as needed.

CE 3020

Program Outcome
3. A solid understanding of the principles of civil engineering

3.1 Relevant to the area of engineering economics and risk management

3.1.1 Performance Criteria

The student must demonstrate minimal competence at each and every one of the following goals related to this principle of engineering:

1. The students should develop a working knowledge of the concept of the Time Value of Money demonstrated by their ability to do the following:

- Build cash flow diagrams
- Determine interest, inflation and real rates applied to civil engineering projects
- Use of discounted cash flow methods

2. The students should be able to determine short-term and long-term cost and benefits of civil engineering projects
3. The students should be able to evaluate alternatives related to civil engineering projects in economic terms
4. The students should be able to quantify the effect of risk in the evaluation of economic alternatives

3.1.2 Implementation Strategy

1. Establish CE 3020 as a fundamental course recommended for all students
2. Recommend that students complete one or more courses in the area of engineering and construction management, particularly CE3021, CE4024 and of any other course that covers this topic
3. Initiate outcomes assessment in CE3020 and all other courses in the area of engineering and construction management.

3.1.3 Assessment Methods

Minimal competency is demonstrated by getting at least 70% of the possible points on exam questions and term project components related to the goal. The demonstration of minimal competency of this principle of engineering is a required, but not a sufficient condition to pass this course.

3.1.4 Timeline

At the end of academic years 2000-2001 and 2001-2002, then biannually

3.1.5 Feedback

Results will be used by faculty instructors in the area of engineering and construction management to improve instruction in CE3020

IV. CEE Department MQP Review Form

Civil and Environmental Engineering Department
Assessment of MQP Outcomes

I. GENERAL PROJECT INFORMATION

Project Title: _____

Student(s): _____

(List majors of non-CEE students)_____

Advisor(s): _____

(List departments of non-CEE faculty)
_____

Terms and credits: E _____ A _____ B _____ C _____ D _____

Total credit: _____ Page numbers: _____ Worth credit per student? Yes / No

Final Project Grade:

Was the project used for the capstone design requirement? ___ Yes ___ No

Where did the idea for the project originate? ___Students ___Advisor(s) ___External sponsor

The project was performed primarily: ___On campus ___Off campus. If off campus, where? _____

Primary financial sponsor:
___WPI ___Research grant ___Industry or government sponsor ___Other (please specify)

Approximate budget:

Did the students prepare the budget? ___ Yes ___ No

Did the students write a project proposal? ___ Yes ___ No

Did student(s) give an oral presentation: (check all that apply)
___Project Presentation Day ___On-campus research group ___Off-campus project sponsor
___Conference ___Other (please specify)

Has this project resulted in, or is it expected to result in a: ___conference presentation ___journal paper

___ Intellectual property (need to discuss how to protect)

Please specify any awards that have been applied for or received by the project students:

MQP Review Form (2000)
Department of Civil and Environmental Engineering

Part II

Civil Engineering Area (Appr. %)

Structures	%
Geotechnical	%
Environmental	%
Transportation	%
Urban Planning	%
Materials	%
Construction & Project Management	%
Architectural Engineering	%
Information Technology	%
Fire Protection	%

Percent Content: Research % Professional Practice %

Part III

Capstone Design: ***System*** ***Component*** ***Process*** ***Experiment***

Describe design briefly:

	Does Not Apply	None	V. Low	Low	Medium	High	V. High
Open-ended need for Design	NA	0	1	2	3	4	5
Design Problem Definition	NA	0	1	2	3	4	5
Statement of Design Criteria	NA	0	1	2	3	4	5
Consideration of Alternative Designs	NA	0	1	2	3	4	5
Development of Design	NA	0	1	2	3	4	5
Final Design Review and/or Test	NA	0	1	2	3	4	5

Part IV

Report Components	Does Not Apply	None	V. Low	Low	Medium	High	V. High
Definition of Objectives & Scope	NA	0	1	2	3	4	5
Conclusions	NA	0	1	2	3	4	5
Procedures							
Data Collection	NA	0	1	2	3	4	5
Data Analysis	NA	0	1	2	3	4	5
Economic Analysis	NA	0	1	2	3	4	5
References	NA	0	1	2	3	4	5
Use of Computers							
Analysis	NA	0	1	2	3	4	5
Design	NA	0	1	2	3	4	5
Report Generation	NA	0	1	2	3	4	5
Internet	NA	0	1	2	3	4	5
Professional Presentation	NA	0	1	2	3	4	5
Other Deliverables (List)							

Part V

Advisor's Comments

PART VI. Specific Program Outcomes

Please indicate the **extent** to which each CEE Department Program Outcome listed below was an aspect (or was intended to be an aspect) of the MQP. Use the following scale: **NA**, **1** = Very Low, **2** = Low, **3** = Medium, **4** = High, and **5** = Very High.
Then, for any outcome that was an aspect of the project, assess the level of ability that the student(s) demonstrated in this area. Use the following scale: **0** = None, **1** = Very Low, **2** = Low, **3** = Medium, **4** = High, and **5** = Very High.

OUTCOMES	**Extent**	**Ability**
1. Components of civil engineering practice:		
a. Technical		
b. Professional		
c. Ethical		
2. Preparation for the future changes in civil engineering.		
3. Understanding of basic principles of civil engineering (please list and assess each principle).		
a.		
b.		
c.		
d.		
e.		
f.		
4. Understanding and application of:		
a. Science (such as biology, chemistry, physics, geology)		
b. Mathematics (such as differential and integral calculus, differential equations, linear algebra, and probability and statistics).		
9. Independent learning.		
11. Understanding of civil engineering profession in a societal and global context.		

Comments:

_____
_____
_____
_____

PART VII. GROWTH IN STUDENT ABILITIES

It is possible that the final project results do not always indicate the growth of the students' skills and abilities during the course of the project. (For example, even if the writing in the final report is not excellent, perhaps at the start of the project it was horrendous.) Please indicate your assessment of the **students' growth** in the following areas using a scale of: **0 = not applicable (not a part of the project at all); 1 = no change; 2= marginal improvement; 3= expected improvement; 4 substantial improvement; 5= exceeded expectations.**

If the project was performed by a team of students and your answers to the following questions differ for different students, please fill out a separate form for each student.

1.	Analytical abilities	0	1	2	3	4	5
2.	Experimental skills	0	1	2	3	4	5
3.	Computational skills	0	1	2	3	4	5
4.	Design abilities	0	1	2	3	4	5
5.	Written communication skills 0	1	2	3	4	5	
6.	Oral communication skills	0	1	2	3	4	5
7.	Teamwork skills	0	1	2	3	4	5
8.	Professionalism	0	1	2	3	4	5
9.	Independence (ability to learn on their own)	0	1	2	3	4	5

Comments:

V. CEE Course Assessment Workbook

I. Course Learning Objectives

Course Number:	
Course Title:	
Term/Year:	
Instructor:	

LEARNING OBJECTIVES (please list)
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.

Add additional sheets as necessary.
Please provide a copy of the course syllabus.

CEE Course Assessment Workbook
II. Specific Learning Objectives

Course Number:	
Course Title:	
Term/Year:	
Instructor:	

Learning Objective:

1. Purpose:

2. Presentation:

3. Course Activities:

4. Outcomes (please provide examples of student work):

CEE Course Assessment Workbook
II. Specific Learning Objectives (cont)

Course Number:	
Course Title:	
Term/Year:	
Instructor:	

Learning Objective:

5. Assessment:

6. Comments/Future Action:

CEE Course Assessment Workbook
III. Specific Program Outcomes

Course Number:	
Course Title:	
Term/Year:	
Instructor:	

Please indicate the **extent** to which each CEE Department Program Outcome listed below was an aspect of the course due to the nature of the stated Learning Objectives. Use the following scale: 0 = Not at all, 3 = Moderate, 4 = Significant, and 5 = Highly significant.
Then, for any outcome that was an aspect of the course to a significant extent (4 or higher), identify the associated Learning Objectives.

OUTCOMES	**Extent**	**Learning Objectives**
1. Components of civil engineering practice:		
a. Technical		
b. Professional		
c. Ethical		
2. Preparation for the future changes in civil engineering.		
3. Understanding of basic principles of civil engineering (please list and assess each principle).		
a.		
b.		
c.		
d.		
e.		
f.		
g.		
h.		
i.		
j.		
4. Understanding and application of:		
a. Biology		
b. Chemistry		
c. Geology		
d. Physics		
e. Differential and Integral Calculus		
f. Differential Equations		
g. Probability and Statistics		
h. Linear Algebra		
i. Higher Mathematics		

CEE Course Assessment Workbook
III. Specific Program Outcomes (cont.)

OUTCOMES	Extent	Learning Objectives
5. Understanding of engineering design process, including the following:		
a. Ability to perform design.		
b. Multidisciplinary aspects.		
c. Collaboration skills.		
d. Communication skills.		
e. Consideration of cost.		
f. Consideration of time management.		
6. Demonstration of an ability to:		
a. Setup experiments.		
b. Gather and analyze data.		
c. Apply the data to practical engineering problems.		
7. Demonstration of an in-depth understanding of at least one specialty within civil engineering.		
8. Understanding of options for careers and further education.		
9. An ability to learn independently.		
10. Broad education envisioned by the WPI Plan, and described by the Goal and Mission of WPI.		
11. Understanding of the civil engineering profession in a societal and global context.		