

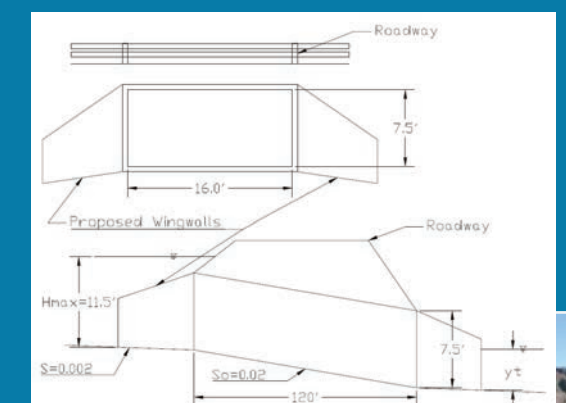
Capstone Design Project - X Connector

Project Description

For the Capstone Design Course, the student teams acted as consulting firms hired by the Metropolitan Planning Organization to prepare design documents for the proposed improvements on a portion of the X Connector; a much needed roadway that connects the southern part of City A to the eastern part of City B in the metropolitan area. The work is concentrated on the pivotal intersection of X Connector and P Drive and the restoration of S Creek while protecting the nearby areas from flooding.

TRAFFIC VOLUMES				DESIGN LANE VOLUMES			
Link	Left	Thru	Right	Left	Thru	Right	Right
Link and Shading (ID)	1	2	3	4	5	6	7
Link Volume (VD)	25	25	25	25	25	25	25
Link Type	Put	Put	Put	Put	Put	Put	Put
Proposed Phases	7	8	9	0	1	2	3
Vehicle Type	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Vehicle Delay (s)	8.0	20.0	8.0	20.0	8.0	20.0	8.0
Vehicle Delay (h)	0.8	2.0	0.8	2.0	0.8	2.0	0.8
Vehicle Delay (d)	25	25	25	25	25	25	25
Link Delay (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Link Delay (h)	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Link Delay (d)	25	25	25	25	25	25	25

Traffic Analysis: Provide geometric design recommendations, including lane configurations and turn pockets storage length, based on the traffic demands and the local Level of Service requirements.

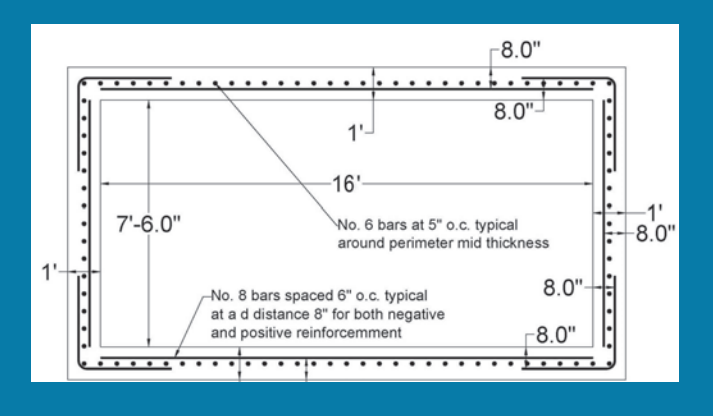


Hydrology/Hydraulics: Determine the design flows based on data from hydrological analyses and design a concrete culvert to convey the flow.

Geotechnical Investigation: Estimate forces on culvert and assess the geotechnical stability under loading based on site information provided by consultant, culvert dimensions, and roadway location and cut/fill information.



Culvert Structural Design: Design a reinforced concrete cast-in-place box culvert under the roadway based on the culvert dimensions, culvert forces, and geotechnical stability information gathered.

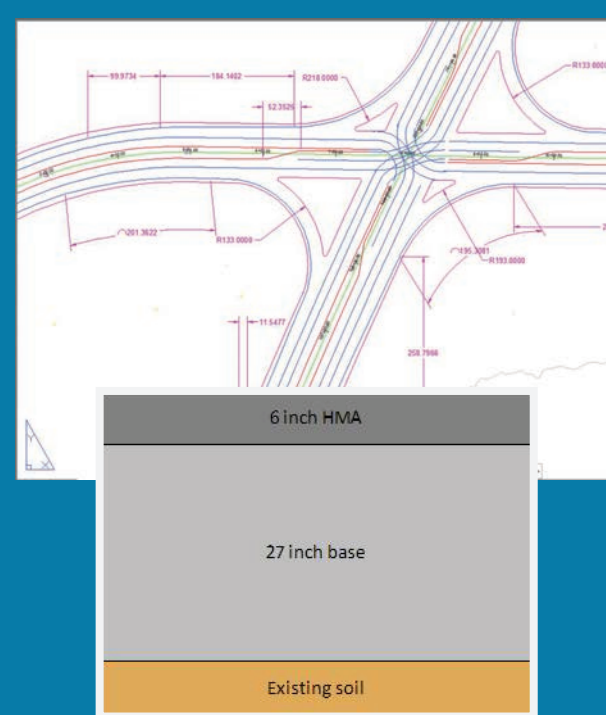


Estimating: Perform in-depth cost estimate for the proposed improvements.

Presentation: Compile the individual design memorandum into a comprehensive project report and perform an oral presentation.

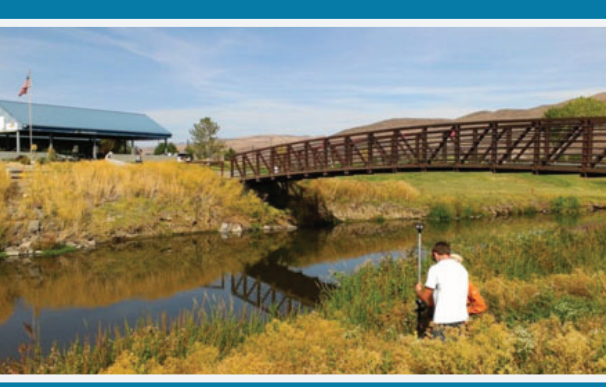


Roadway Design & Earthwork: Based on the traffic, surveying, and hydrology and hydraulics information, design the intersection and the horizontal and vertical alignments, and estimate cut/fill quantities.



Pavement Design: Design a flexible pavement section to service the anticipated traffic and truck loads with information from traffic analysis, geotechnical investigation, and consider economics of using site materials.

Surveying: Verify existing survey data and collect additional data as required to produce a Survey Report.



Environmental Assessment: Study the potential environmental impacts and identify possible mitigations.

Channel & Floodplain:

Perform hydrologic & hydraulic analyses for the S Creek realignment. Design of a flood channel to carry the low flows and a terraced floodplain to convey the 117-year flows while considering different stabilizing materials and existing vegetations.

Existing S Creek with straight runs and vertical banks

Terracing and flow easement

Design channel and terraced floodplain conforming to the River Living Plan

Public Health, Safety & Welfare

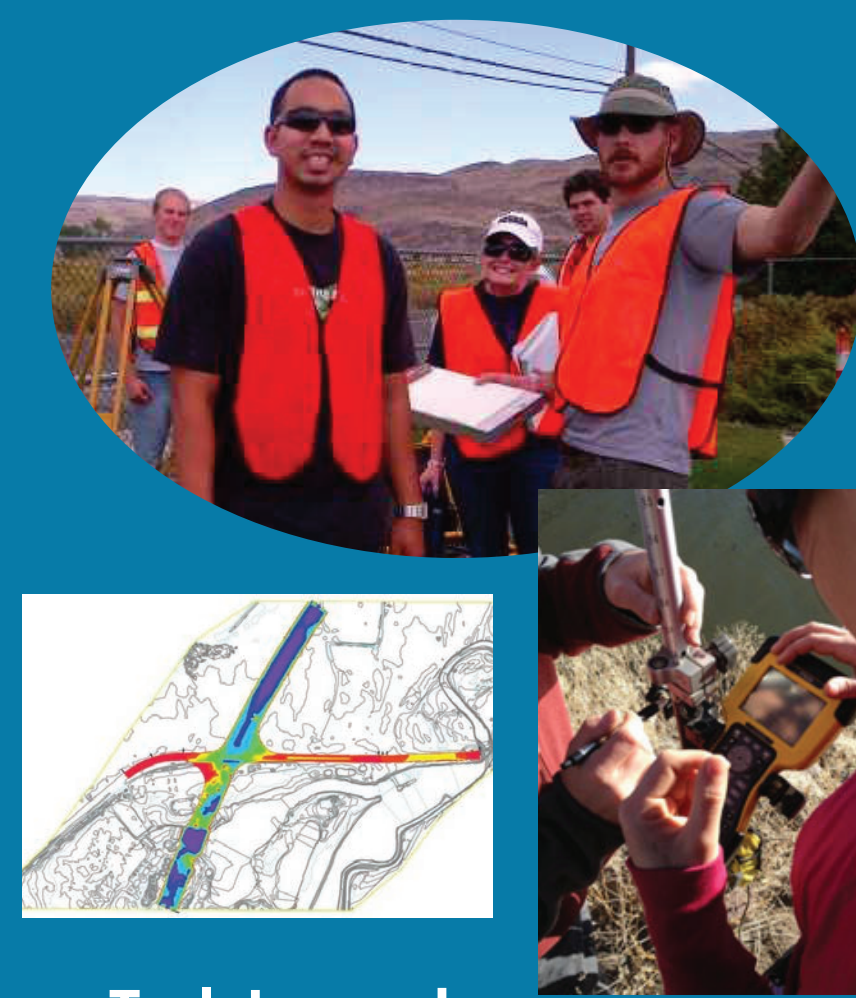
The X Connector provides other benefits in addition to its primary goals of providing a much needed connection between two cities and relieving the traffic on the freeway:



- It will be an alternative route for emergency responders.
- It will be an emergency access to the communities and public facilities during large flood events.
- This project improves utilities for pedestrian, cyclists, and public transit.
- This project will enhance safety by separating motorized and non-motorized travel.
- This project will protect wildlife, improve water and air quality, restore vegetation, and replace wetlands at a 2:1 ratio.

Most importantly, the project opens the understanding of any design impact to the society and allow the students to hold paramount the considerations of public health, safety, and welfare in their future role as engineers.

Knowledge/Skills Gained



Skills Gained:

- Teamwork
- Communication
- Project Management
- Professional Responsibility
- Gathering & analyzing data
- Design & analysis of improvements
- Professional writing
- Public Speaking

Design Standards Learned:

- Local LOS Requirements
- Local Survey Controls
- Local Benchmarks Locations
- AASHTO Green Book
- AASHTO LRFD Bridge Design Specs
- ASSHTO Pavement Design Guide

Tools Learned:

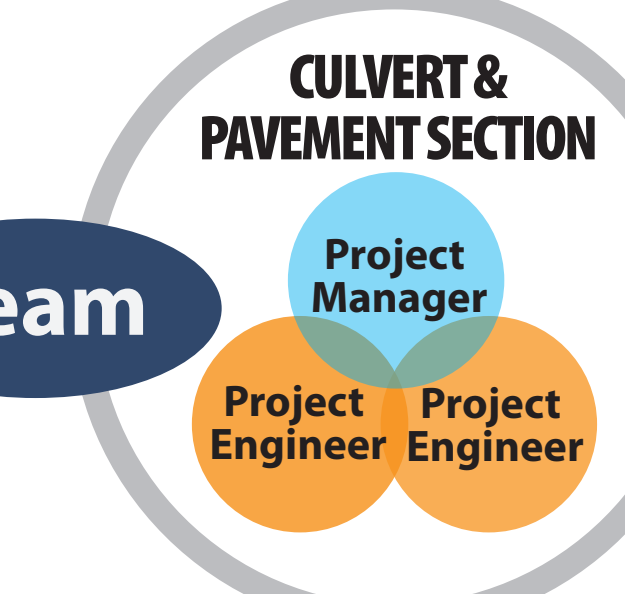
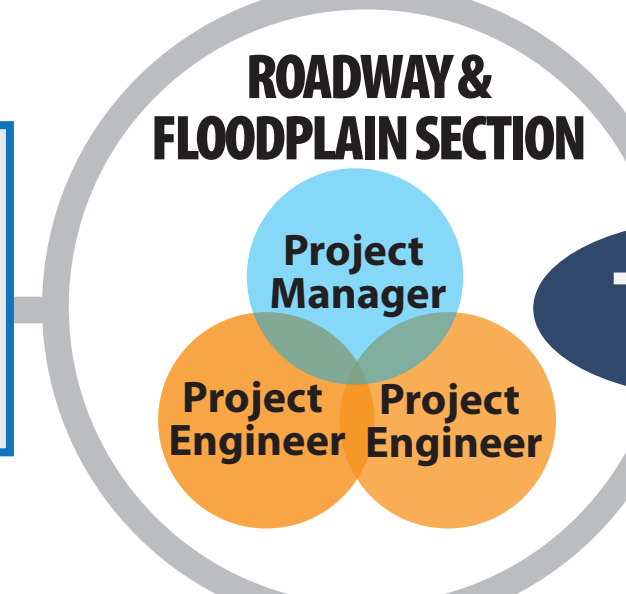
- Synchro & SimTraffic
- GPS Surveying Equipment
- AutoCAD & Civil 3D
- HY-8 & HEC-RAS

Successful Collaboration



Guest Speakers consist of Professional Engineers and Industry Representatives: Project Management, Graduate School, Interchange Operations, Geotechnical, Environmental Assessment, Constructor's Perspective, Aesthetics, Investment, Public Hearing, Licensing, Ethics

Core Mentors consist of Professors & Professionals:
Traffic Analysis
Channel & Floodplain
Roadway Design
Earthwork



Core Mentors consist of Professors & Professionals:
Hydrology/Hydraulics
Geotechnical
Culvert Structural Design
Pavement Design



Core Mentors:

- 6 Professors
- 2 Professional Engineers (1 Public Sector, 1 Private Sector)
- 1 Professional Land Surveyor
- 1 Certified Professional Estimator/LEED AP Building Design + Construction

The students prepare their designs and reports under guidance from the mentors through an iterative process. The final deliverables included a comprehensive written report and an oral project presentation. The scoring panel for the presentations include the core team of mentors and a representative from the industry who was not previously associated the course.

Students:

- 31 students worked in teams of 6 or 7 as consulting firms
- 2 sections in each team handling special design modules
- 1 project manager in each section (2 in each team)
- The project managers also handle the cross-team modules

Core Mentors consist of Professors & Professionals:
Surveying, Environmental, Estimating, Reporting

Guest Speakers:

- Professional Engineers
- Geotechnical Engineers
- Construction Managers
- Water Resources Firm
- Public Hearings Officer
- Public Information Officer
- State Board of PE & PLS

CAPSTONE DESIGN PROJECT – X CONNECTOR

Abstract

The Department of Civil and Environmental Engineering requires all undergraduates to complete two capstone courses in their senior year. One is a Capstone Design Course which is structured to provide significant design experience to the students in their education by utilizing a real-world project that is local to the area.

The X Connector Project was chosen for the course in the Fall 2012 semester. The project involves designing five and a half miles of new roadways that connects the southern part of City A to the eastern part of City B in the metropolitan area. To keep the scope within a one-semester period and still satisfy the multi-discipline aspect, the course project is concentrated on the pivotal intersection of X Connector and P Drive and the restoration of S Creek.

The students work in teams of six, as consulting firms, participating in the roles of specialty design engineers and project managers. The roadway has to serve the 20-year traffic demand with a culvert that can safely pass the 117-year storm runoff. The teams also design the S Creek channel and floodplain to convey the discharge to the T River while protecting the nearby areas from flooding. The work each team performs includes traffic analysis, hydrology/hydraulic analysis, intersection layout, roadway profile, earthwork computation, geotechnical analysis, pavement design, and culvert structure design. The firms also survey the site to validate the topographic information provided to them and prepare a construction cost estimate for the improvements they designed. While environmental assessment is not part of the design services required, the firms have to review issues identified by others to gain an appreciation of any design impact to the environment and the society.

The core team of mentors includes six professors and four professionals. Each mentor first meets with the teams three times a week for one to two weeks to provide guidance related to his/her respective discipline. Upon the interim submittals, the mentor reviews the reports. Based on the feedback from the mentors, the teams then complete their final deliverables of a comprehensive written report and an oral project presentation. The scoring panel includes the core team of mentors and a representative from the industry who was not previously associated with the course.

Outside the area of the design services, guest speakers with different backgrounds also come to share their practical experiences. The topics are both technical and non-technical and include project management, intersection operations, design aesthetics, construction elements, public hearing, professional licensing, and ethics. The guest speaker sessions also provide ideal on-campus networking opportunities.

This course leads students to learn new tools such as SimTraffic, GPS, HEC-RAS, AutoCAD Civil 3D and to synthesize the material they have learned in the prerequisite courses. It provides an opportunity to apply the tools and skills they have learned in a real-world project. Through the strong collaboration among faculty, students, and practicing professionals, experiences is gained not only on the technical aspects of engineering, but also on many other aspects including teamwork, communication, project management, funding constraints, ethics, and the engineer's role in regard to public welfare, health, and safety.

CAPSTONE DESIGN PROJECT – X CONNECTOR

1. PROJECT DESCRIPTION

The Department of Civil and Environmental Engineering requires all undergraduates to complete two capstone courses in their senior year. One is a Capstone Design Course that parallels the ideals of the NCEES Engineering Award. The course allows the students to direct the knowledge they acquired in previous courses into a real-world project. By collaborating with the industry and faculty, the students perform work involving many disciplines on a project that provides multiple public benefits. Through this process, the students gain hands-on skills and practical knowledge.

The university has collaborated with the Metropolitan Planning Organization in the project selection since the inception of the Capstone Design Course in 2006. The project selected is always local, multi-discipline in nature, and currently in design or construction. The X Connector Project was chosen for the course in the Fall 2012 semester in particular given its emphasis in environmental aspects.

The metropolitan area consists of two cities and several unincorporated county areas. Two intersecting freeways and an arterial ring road serve the major commutes among these areas. The traffic demand is estimated to exceed the capacity of these facilities in twenty years. The X Connector is a new roadway that provides a connection between the southern part of City A to the eastern part of City B. The entire roadway is five and a half miles long and exists in a flood zone. It is to be constructed in two phases. In Fall 2012, construction of Phase 1 was in solicitation using the Construction Management at Risk (CMAR) delivery method, and Phase 2 was in preliminary design. To keep the scope within a one-semester period and still satisfy the multi-discipline aspect, the course project concentrates on roadway and drainage improvements for the intersection of X Connector and P Drive. Included in the scope also is to restore S Creek with provision of a terraced floodplain from P Drive to the confluence of the T River in order to protect the neighboring areas from flooding. These improvements are in Phase 2 of the X Connector Project. The P Drive intersection is a pivotal one as P Drive is one of only two accesses to a neighborhood that has been flooded during several recent wet seasons.

The students generally work in teams of six, as consulting firms, participating in the roles of specialty design engineers and project managers. Through collaboration with the mentors, made up of faculty and professionals, the teams produce interim reports of their design and analysis of the improvements needed for the project throughout the semester. The final deliverables include a comprehensive written report and an oral project presentation.

2. COLLABORATION OF FACULTY, STUDENTS, & PROFESSIONAL ENGINEERS

With thirty-one students in the class, there were four teams of six and one team of seven. The teams worked as consulting firms providing services in various disciplines as required by the project. Even though the project is the same, the work performed by each team is independent from other teams.

To mimic the business environment, the teams were divided into two sections. Each section consisted of a Project Manager (PM) and two Project Engineers. The Roadway and Floodplain Section (R Section) handled Traffic Analysis, Roadway Design, Earthwork Calculations, and Channel and Floodplain Analysis. The Culvert and Pavement Section (C Section) was responsible for Culvert Sizing, Geotechnical Investigations, Culvert Structural Design, and Pavement Design. The Project Engineers were the lead for the modules of the Section's responsibilities and the PMs played a supporting role. For the four general and encompassing modules of Surveying, Environmental Assessment, Estimating, and Reporting, the PMs led and the Project Engineers provided support. The PMs were also in charge of the overall project management and compilation of the final deliverables.

This structure was established so that the work of one section directly affects the work of the other section as in real-world design. For example, a wider roadway designed by the R Section will require the C Section to lengthen the culvert; a thicker pavement section designed by the C Section will lead the R Section to re-evaluate cut-and-fill quantities. The grading is set up such that all team members share one team grade for each module with weight given to the members who led particular modules. In this manner, each team member had specific responsibilities and each team member contributed to others' work for the overall success of the team. Homework and examinations were given throughout the semester to assess individual student understanding of specific subjects.

Teams were formed using a qualification selection process. Each student presented his/her background, expertise, interest, and availability. Based on the information presented, the students chose their roles, sections, and their teams.

The core team of mentors include six professors, the majority of whom are licensed professional engineers (PEs), and four professionals, of whom two are PEs. One is a Professional Land Surveyor and one is a Certified Professional Estimator.

Each mentor first met with the teams three times a week for one to two weeks on their respective disciplines. Students in the R Section and the C Section met with the respective mentors of their modules, while all team members met with the mentors for the remaining modules. The purpose of these meetings was to refresh the knowledge the students acquired in the pre-requisite courses and to provide guidance on how to apply the knowledge to the Capstone Design Project.

The project design was reported through an iterative process. After the initial design/analysis of each module, each team submitted an interim report to the module mentor. Based on the feedback from the mentors, the teams revised their design or evaluated other alternatives if needed. One of the final deliverables was a comprehensive report for the project inclusive of all design and analysis performed. The other final deliverable was an oral presentation. Each team had 30 minutes to present their project. The scoring panel included the core team of mentors and a representative from the industry who was not previously associated with the course.

3. BENEFIT TO PUBLIC HEALTH, SAFETY, AND WELFARE

In addition to its primary goals of providing a much needed connection between two cities and relieving traffic on existing freeways and arterials, the X Connector also provides improved emergency response. Emergency responders must be able to access different parts of the metropolitan area using the shortest route available. In the existing condition, one way to go from the southern part of City A to the eastern part of City B requires use of a north-south freeway then to another east-west freeway through an interchange that is out-of-way for both termini. While this may be a fast route under optimum conditions, extra travel distance is involved, and extra risk is involved in traffic back-up. The other mean of commute is an arterial ring road, which again is not a direct route and is currently experiencing several bottlenecks. The X Connector being a direct connection between the south and the east will serve as a great emergency response route.

The majority of the X Connector is set in open land in a flood zone. The neighborhood to the east of the X Connector has been flooded several times in recent years. These floods had put the neighborhood's major access, P Drive, under water, and the residents would find themselves stranded. The X Connector and its intersection at P Drive will be designed to stay above the 117-year flood elevation per the requirements of the US Army Corps of Engineers. The project will therefore continue to provide access to the communities and public facilities east of it during large flood events.

Being a growing metropolitan area, many roadway expansions involve widening of existing roadways in urban settings. These projects are usually confined within existing right-of-ways as well as existing developments and therefore improvements such as bike lanes or wider sidewalks were not always possible. Since the X Connector is a brand new roadway on mostly vacant land, many "nice to have" improvements can be included, and will therefore greatly improve the utilities for pedestrian, cyclists, and public transit. It can also enhance safety by separating motorized and non-motorized travel.

This project includes many environmental aspects. There is wildlife in the vicinity that the project will take precaution to protect. The roadway alignment is chosen to minimize impact to wetlands. For locations that cannot be avoided, the project is planning on replacing the wetlands at a 2:1 ratio. The project will also improve water and air quality and restore any vegetation disturbed.

These are all direct benefits of the actual project to the community. An indirect benefit provided by this course was through the review of these benefits, the students were exposed to the long-term impact that an engineer can have on the society simply due to the nature of his/her work. The students learned to review and apply applicable engineering codes and standards in the design process. The project also includes an ethics discussion by an official from the State Board of Professional Engineers and Land Surveyors in a guest speaker session. The concepts of long-term impact, ethics, and codes/standards are critical for future engineers to carry throughout their career as they directly benefit public health, safety, and welfare.

4. MULTIDISCIPLINE AND/OR ALLIED PROFESSION PARTICIPATION

The Capstone Design Project includes two major scopes of work. One is designing a roadway intersection to serve the 20-year traffic demand with a culvert that can safely pass the 117-year storm runoff. The other is to design the S Creek channel with a terraced floodplain to convey the discharge to the T River to protect the nearby areas from flooding.

Each team performed design/analysis on eleven core modules encompassing multiple disciplines. Everything was carried out under the umbrella of environmental considerations and the final deliverable was a project presentation along with a comprehensive final project report. Some of the modules progressed in parallel because works were done by different sections of the team. In addition, because of the iterative process in the design/analysis of each module and that the modules were tightly integrated, the teams had to update their work continually until the design or analysis of each module were finalized.

Below is a listing of the modules and their scope of work.

Traffic Analysis: Provide geometric design recommendations, including lane configurations and turn pocket storage length, based on the future traffic demands and the local Level of Service requirements.

Culvert Sizing: Determine the design flows based on data from hydrological analyses and design a concrete culvert to convey the 117-year flow without overtopping the roadway.

Surveying: Verify existing survey data and collect additional data as needed in order to produce a Survey Report suitable for a professional design submittal.

Roadway Design: Based on the traffic, surveying, and hydrology and hydraulics information, design the intersection layout and determine the horizontal and vertical alignments for approximately 2,000 feet of the X Connector and 1,000 feet of P Drive.

Geotechnical Investigation: Estimate forces on culverts and assess the geotechnical stability under loading based on site information provided by other consultants, and culvert dimensions and roadway location derived in other modules. Because work is performed in parallel, the teams have to start with estimated cut/fill conditions and verify the analysis after the roadway design is performed.

Environmental Assessment: Review issues identified by other entities and gain an understanding of the potential environmental impacts of proposed projects; identify and evaluate possible strategies to mitigate environmental impacts.

Earthwork: Based on the roadway design and culvert information, estimate the cut/fill quantities using an assumed pavement thickness. The quantities will need to be updated when the pavement design is finalized and if the roadway and/or the culvert design are changed.

Culvert Structural Design: Design a reinforced concrete cast-in-place box culvert under the roadway based on the culvert dimensions, culvert forces, and geotechnical stability information gathered. The design may need to be updated if the culvert size is adjusted.

Pavement Design: Design a flexible pavement section to service the anticipated traffic and truck loads with information from the traffic analysis and geotechnical investigation, with considerations given to economics of onsite versus import material usage.

Channel & Floodplain: Perform hydrologic & hydraulic analyses for the S Creek realignment. The design includes a flood channel to carry the low flows and a terraced floodplain to convey the 117-year flows with considerations given to existing vegetations and the use of different stabilizing materials.

Estimating: Perform in-depth cost estimate for the proposed improvements.

Allied professions provided significant participation in the Capstone Design Course. There were four professionals in the core team of mentors. Their background and involvement are summarized below.

Professional Engineer 1: The course coordinator was a licensed professional engineer (PE) working for the Metropolitan Planning Organization as a Project Manager. In addition to administering the logistics of the course, she also assisted the students in managing the project, writing professional reports, and performing presentations.

Professional Engineer 2: The lecturer for Roadway Design and Earthwork was also a PE. Being a Project Manager/Designer for a private consulting firm in charge of different local projects, his experience contributed substantially to the students' understanding of how to practically apply national and local standards in their designs.

Professional Land Surveyor: The Surveying lecturer, Mr. A, was a Professional Land Surveyor and owner of a private surveying firm. His involvement did not stop at sharing his professional knowledge in mentoring the class. The class surveyed the project site and the cross section of the B Slough where a culvert will be placed. Mr. A provided the Global Positioning System (GPS) equipment for use by the students that would otherwise not be available to the students. Mr. A also allowed for two of his employees, also surveyors, to teach the teams how to use the equipment and to manage the logistics on surveying day.

Certified Professional Estimator: The lecturer for Estimating, Ms. K, was a Certified Professional Estimator for a local construction firm. She also holds the US Green Building Council's Leadership in Energy and Environmental Design (LEED) accreditation as LEED AP Building Design + Construction. Many students had the wrong impression that estimating involves the mechanic mathematics of measuring and adding quantities. Ms. K's insight from the construction industry helped the students to understand the art of estimating and the importance of performing reality checks on the costs, quantities, and even the designs.

The course allowed for many guest speaker sessions throughout the semester. The speakers were from different backgrounds. The topics may be technical, non-technical, and may or may not be related to a core module. The thing in common was that the guest speakers were all there to share their practical experiences.

The guest speaker topics and the information of the guest speakers are listed below.

The Real-World Project: PE, Project Manager of the Metropolitan Planning Organization who manages the real-world X Connector Project.

Project Management: PE, Project Manager of a worldwide private consulting firm.

Intersection & Interchange Operations: PE, Professional Traffic Operations Engineer (PTOE), Traffic Engineer of a local public entity.

Geotechnical Investigations: PE, Geotechnical Manager from the consulting firm who performed the geotechnical investigations for the roadway portion of the X Connector.

Geotechnical Investigations: PE, Geotechnical Engineer of the consulting firm who prepared the boring logs at the B Slough.

Investing Your Future: Retired PE, former Project Manager for a state entity.

Environmental Impact Statement: VP of a private-sector water resources company.

Design, Aesthetics, & the Human Experience: Retired CEO, University Advisory Board.

Contracting: PE, coordinator of the course.

Construction Elements: A Project Manager and a Project Engineer of a construction firm.

Public Hearing Elements: A Public Hearing Officer and a Public Information Officer from the State Department of Transportation.

Professional Engineering License: The Executive Director and an Exam Administrator from the State Board of Professional Engineers and Land Surveyors.

Engineering Ethics: PE, Chief Operating Officer of a local engineering firm, Chairman of the State Board of Professional Engineers and Land Surveyors.

The guest speaker sessions not only provided information on the subject matter, but also provided ideal on-campus networking opportunities that broadened the students' understanding of the local environment and job market. The guest speaker discussions were usually open-ended and enabled exchange of thoughts.

5. KNOWLEDGE OR SKILLS GAINED

Through the design process, the students learned many local and national design standards. On the local level, they were exposed to the roadway Level of Service adopted by the local entities, the survey control used in our area, and some benchmark locations. On the national level, they used several publications put forth by the American Association of State Highway and Transportation Officials (AASHTO), including A Policy on Geometric Design of Highways, AASHTO LRFD Bridge Design Specifications, and the AASHTO Guide for Design of Pavement Structures.

This course led the students to learn many new tools to perform their work. They used SimTraffic in the Traffic Analysis module to determine the lane configurations and turn pocket storage needs. In the Surveying module, the students gained hands-on experience on the GPS equipment currently used in the industry, including a Trimble R8 GPS Receiver and a Topcon GPT-8203A Robotic Total Station. To determine the dimension of the culvert needed at the B Slough crossing, the teams utilized the Federal Highway Administration (FHWA) Culvert Hydraulics Analysis Program, HY-8. For the S Creek realignment and restoration, the teams used a US Army Corps of Engineers' software, Hydrologic Engineering Centers River Analysis System (HEC-RAS), to determine the geometrics of the low flow channel and the terraced floodplain. The computer-aided design (CAD) software used is AutoCAD Civil 3D. The CAD course in the base curriculum of the Civil and Environmental Engineering program involves only the use of CAD as a drafting tool. This course exposed the students to Civil 3D, a special version for civil engineering design. The teams used it for laying out the intersection geometrics, set horizontal and vertical alignments, and estimating cut/fill quantities.

The Capstone Design Project requires the students to gather and analyze a large amount of data, and to prepare reports for their design and analysis. The students gained experience in gathering and analyzing data, design and analysis of various civil improvements, and in writing professional reports. With the structure of the teams, every member has a chance to participate as a project lead as well as a project support. This allows the students to grasp the true meaning of teamwork and increase their skills in managing a project that is constrained by scope, schedule, and budget. For successful project delivery, each student has to work with team members in their section and with team members outside their section. Through this working relationship, the students built necessary communication skills. Teams also made good use of the social media as a collaborating platform. The teams gave presentations of their project as one of the final deliverables. The pointers on various presentation skills provided in a class designated for that purpose, the information shared by the Public Hearing Elements guest speakers on handling of the public and the media, and the experience on actually presenting their project, synergistically contributed to the students learning the skills and developing the confidence needed for public speaking.

6. CONCLUSIONS

The Capstone Design Project provides the students a significant design experience to integrate the knowledge gained in the pre-requisite courses by utilizing a real-world project. The multidiscipline nature of the X Connector Project allows the students to grasp the complexity of a real-life project and understand that collaboration is a requirement for any successful project delivery. Through the process of providing the design services for the Capstone Design Project, the students gain new knowledge and skills that are not typically available in a classroom environment. Also, choosing the X Connector project that is local to the area allows the student to “feel” the project and fulfill the Capstone Design Course’s mission to introduce an appreciation and understanding of the natural and cultural environments in which we live and the role of engineers as responsible citizens of the community.