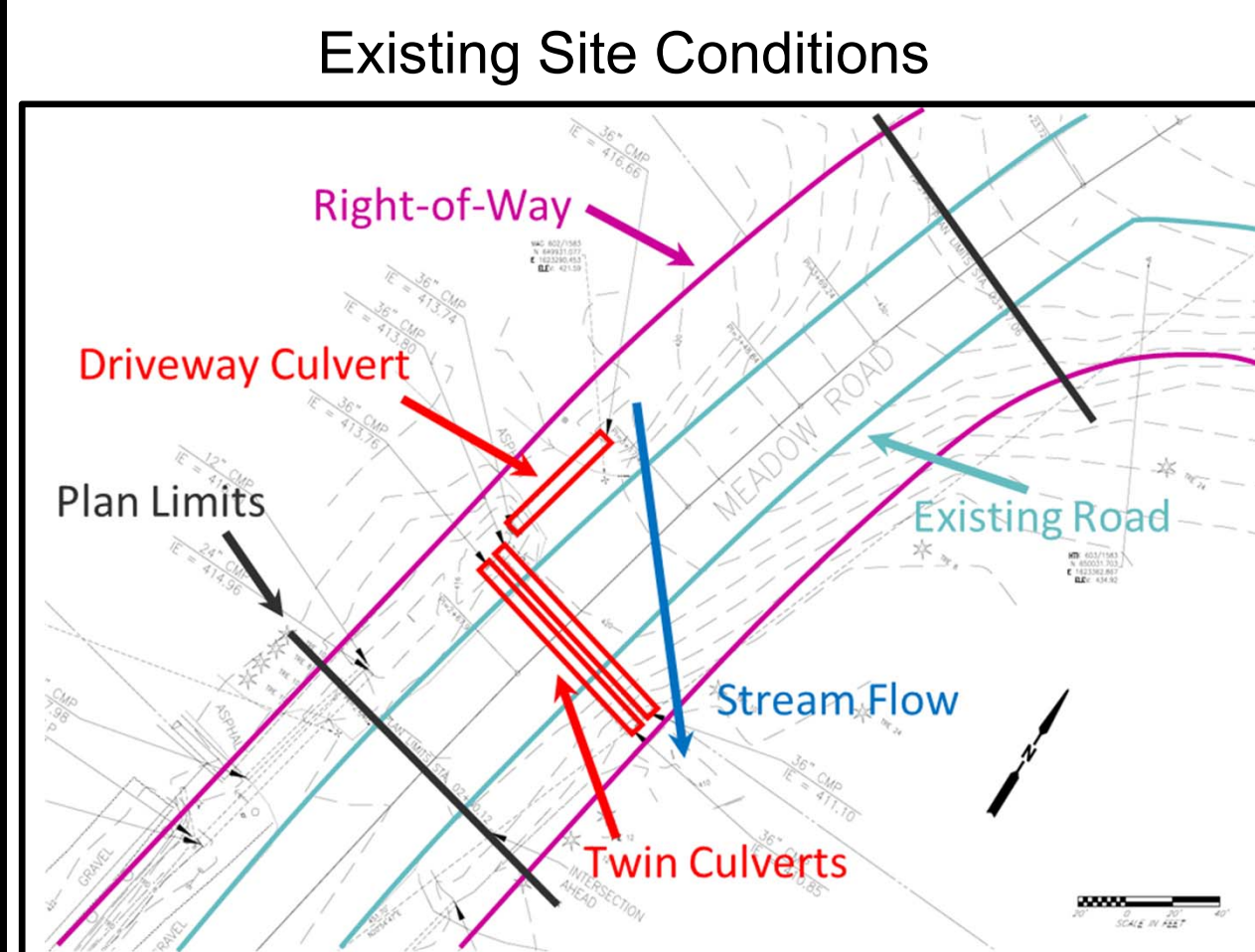


Infrastructure Improvement of a County Road

Project Background, Client Need and Deliverables



Local county partnered with our department to improve a portion of a roadway as part of its Six-year Transportation Improvement Plan (TIP). Five civil engineering students worked on this as their year-long, capstone project under the supervision of a faculty advisor (PE, PLS) and two county engineers (both PE).

Client Needs

- Widen existing roadway to meet growth in the region, improve pedestrian safety
- Replace three existing culverts to make it fish passable

Major Deliverables

- Prepare 30% engineering design drawings
- Provide preliminary cost estimates, list of applicable permits, and construction plans

Roadway looking South



Driveway culvert Team member at work

Collaboration with Faculty and Licensed Engineers

- Five civil engineering students worked with **faculty advisor (PE, PLS)** and **two engineers from county** (both PEs)
- Students presented their work to the civil engineering department advisory board twice during school year (**eight PEs and an Environmental Scientist**)
- Team participated in annual local section ASCE presentation contest which was judged by a **panel of PEs**

Multidiscipline and Allied Professional Participation

- Project spanned multiple disciplines
 - **transportation, water resources, geotechnical, and environmental engineering,**
 - **fish biology, stream morphology, fisheries regulations.**
 - **construction planning, cost estimating, permitting.**
 - **Socio-economic impacts** of project on the public
- Student interacted with **multiple stakeholders** to complete the project
 - **Native American Tribe fisheries division representative** advised team on fish migration issues
 - **State Fish and Wildlife and US Army Corps of Engineers** educated team on fish passage design and governing regulations
 - **Aquatic Biologist from county** served as additional resource
 - **Managers and construction personnel from county** provided feedback on presentations

Project Approach - Design Development

1. Performed Field work, Collected Data



2. Compiled Design Parameters and Designed Roadway and Culvert

Surveyed stream profile and compiled topographic map from LiDAR, new and existing grounds surveys.

Sized roadway widths per TIP requirements and County development guidelines.

Sized culvert using bankfull width of stream field measurements, hydraulic/hydrologic analyses results

Designed stream bed inside culvert from pebble count field measurement and DOT guidelines for fish passage to replicate natural streambed for fish habitat

3. Investigated Culvert Options

Team evaluated pros and cons of four culvert types

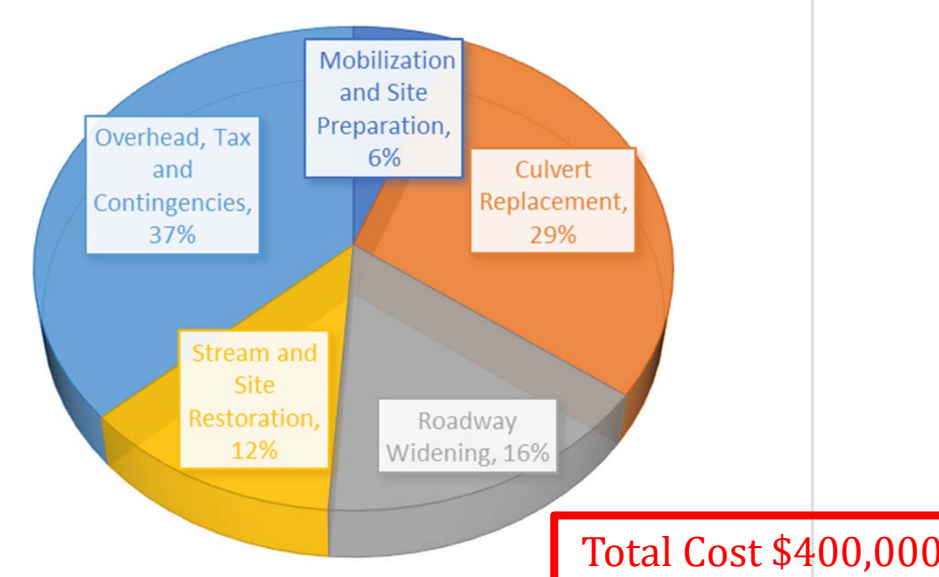


6. Assisted with Project Implementation

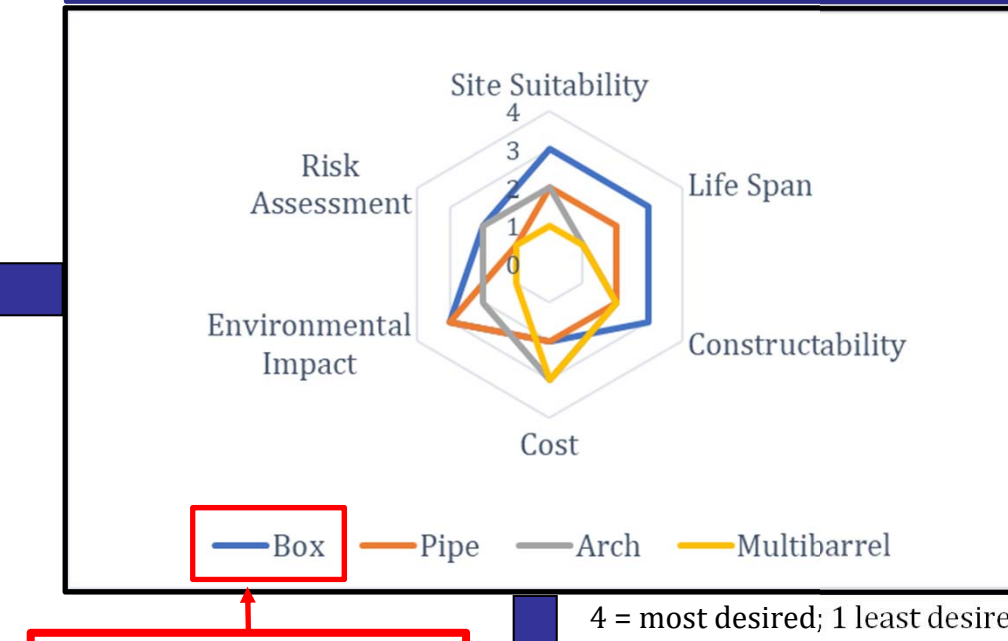
- Team provided following information to county:
- **construction sequencing plan**
 - **erosion control and traffic detour plans**
 - list of applicable **permits**
 - information on **utility relocation**

5a. Estimated Cost

Team prepared a detailed itemized cost estimate. A cost summary is presented.



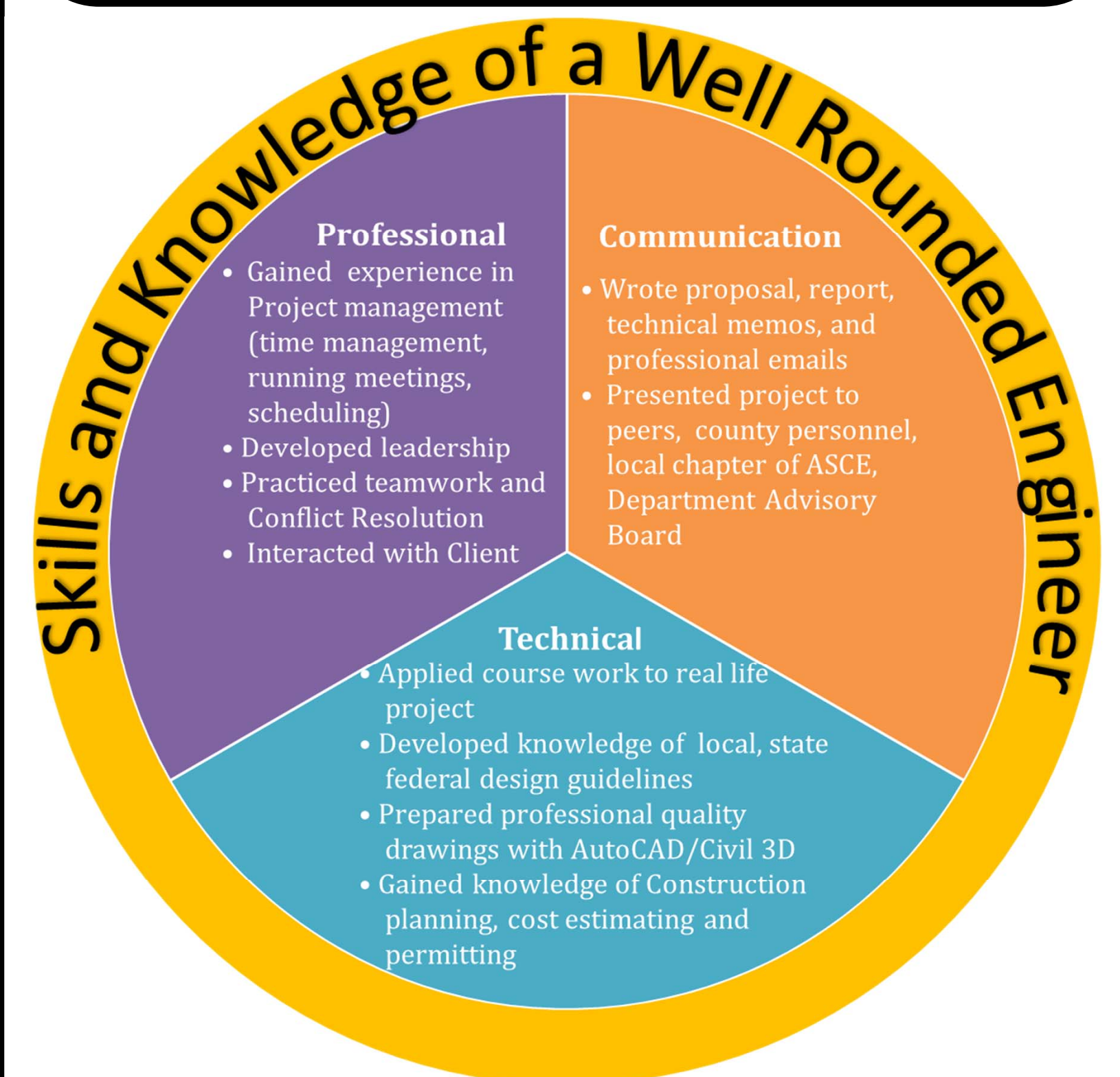
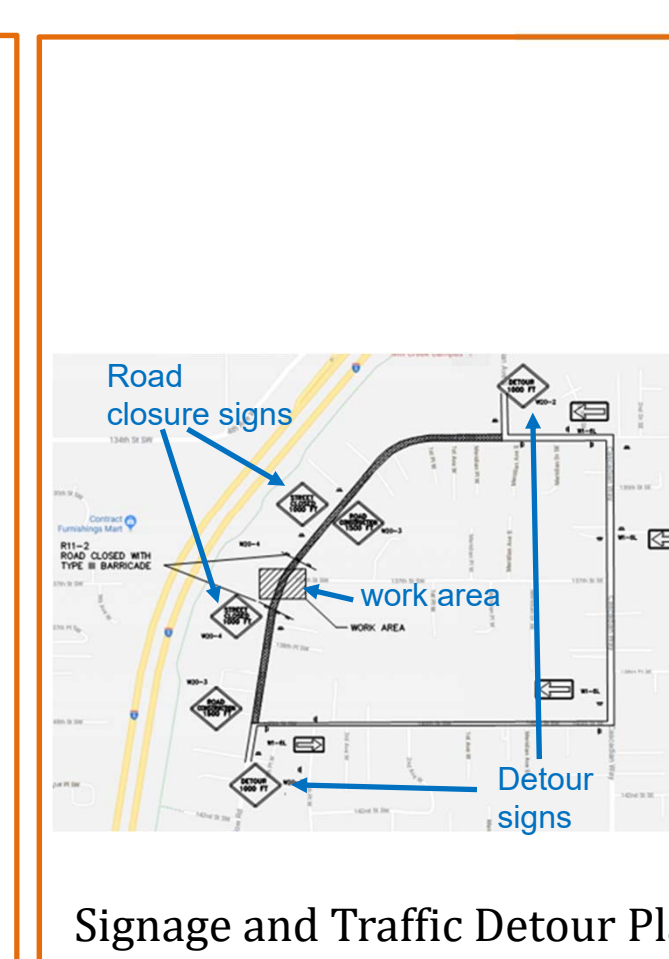
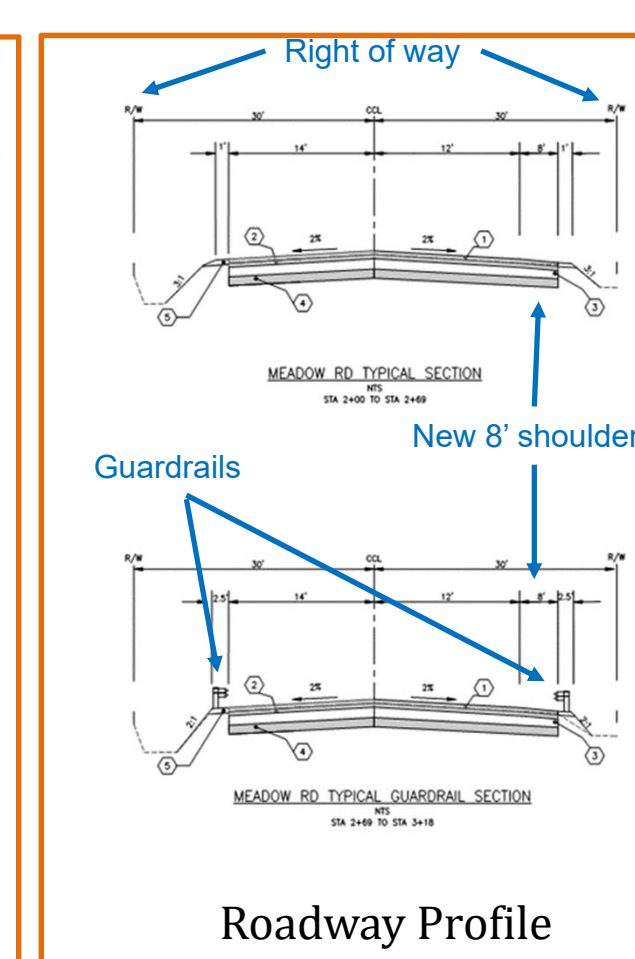
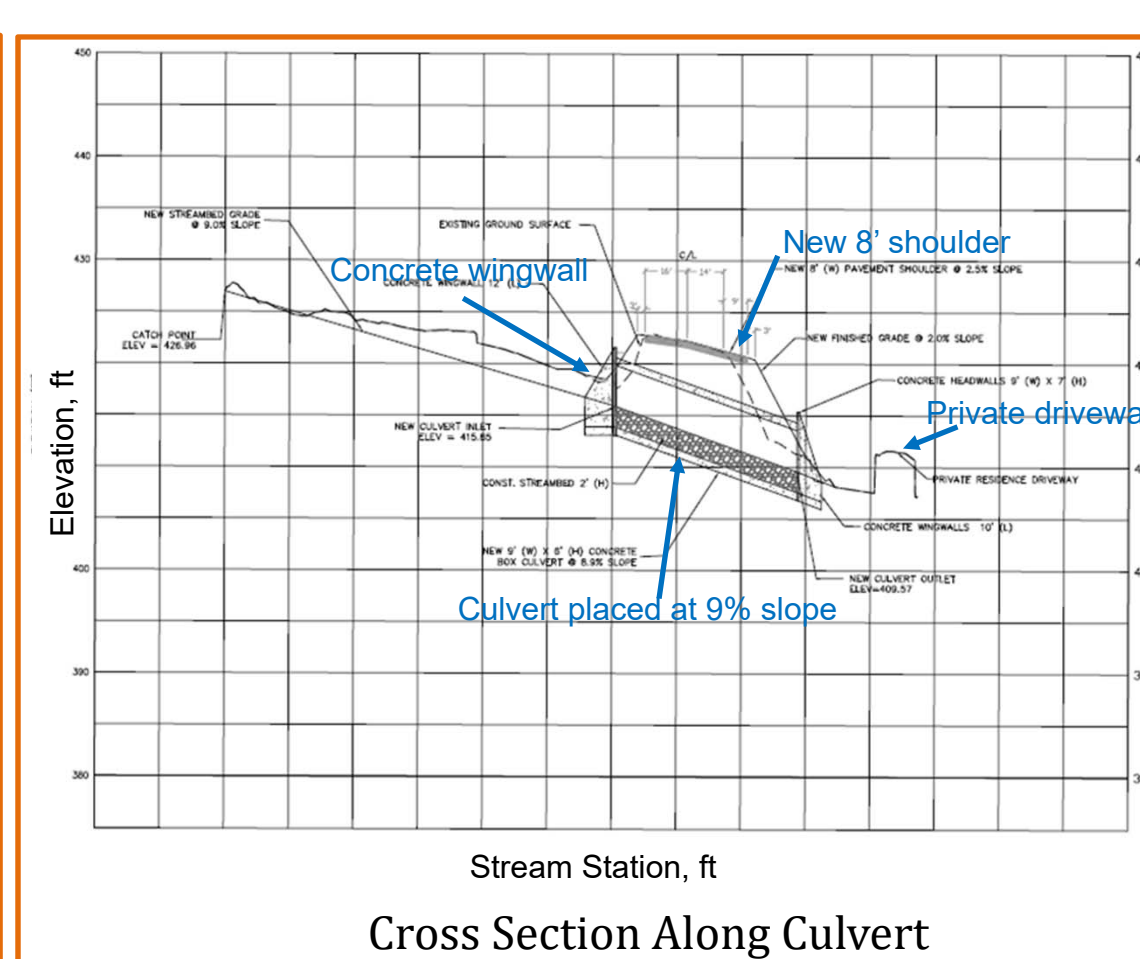
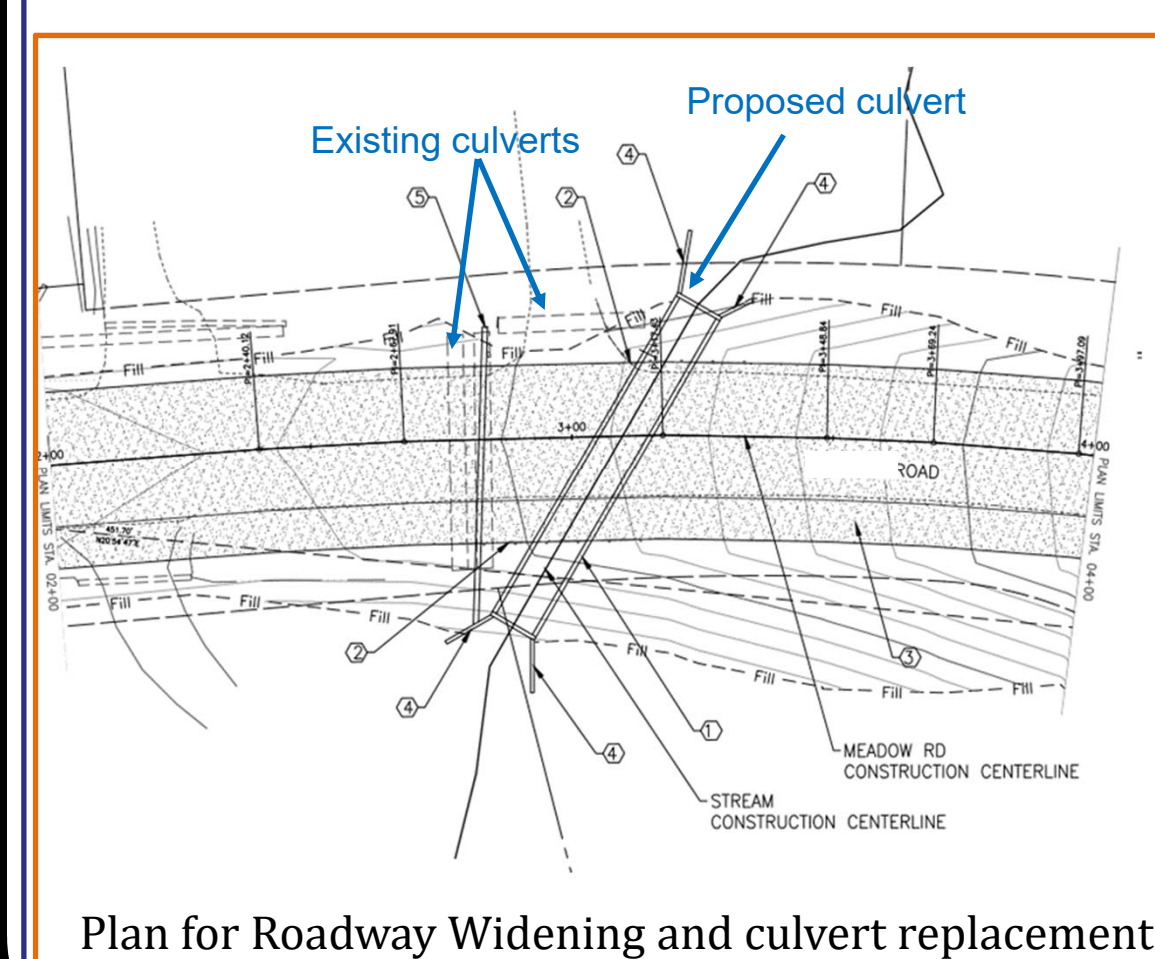
4. Developed Decision Matrix



Preferred Alternative 4 = most desired; 1 least desired

5b. Prepared 30% Design Engineering Drawings

Team prepared a set of 11 professional quality preliminary engineering design drawings – excerpts of these drawings are shown below. Design package also included survey control sheet, temporary erosion and sediment control plan, demolition plan, and construction sequence.



Protection of Health, Safety and Welfare of Public

- Project was part of a 6-year development plan for the region
- **Widening of roadway** to accommodate increased traffic, **adding sidewalk**, and providing **signage and detours** during construction to improve **public safety**.
 - Making **culverts fish passable**, developing **erosion and sediment control plan** during construction to alleviate environmental impacts.

Infrastructure Improvement of a County Road

Abstract

Project Description: A local county requested our engineering program to assist with a roadway enhancement project which was part of their six-year transportation improvement plan (TIP). Specifically, the project involved, a) widening a stretch of road to accommodate the rapid growth in the region and to improve pedestrian access and safety and, b) replacing three culverts in the project area making them fish passable. This was a capstone project to a student team.

The team performed a site reconnaissance to understand the client needs and project constraints. Following that they surveyed the land to develop a topographic map of the project site, took relevant measurements of the stream and studied the stream bed characteristics. The team researched the relevant design codes, compiled the necessary design parameters, developed a hydraulic/hydrologic model for the site and based on the findings designed the roadway alignment and replaced the three-culvert system with the single culvert underneath the roadway.

Furthermore, the team took the project to a 30% design; prepared a 11-page professional quality engineering drawing set using AutoCAD-Civil 3D; carried out a cost estimate; and identified eight county/state/federal permits applicable for the project.

Collaboration of Faculty, Students, Licensed Professional Engineers and other Allied Professionals: A diverse group of five students worked on this project for a whole academic year under the supervision of two faculty members (one a PE and the other a PE/PLS) and three staff members from the county, two of them professional engineers (PEs) and one a fish biologist. The students also presented their project twice to the civil engineering department advisory board and once to the local section of the American Society of Civil Engineers (ASCE). Several PEs attended these two events and provided feedback to the team. Because the project had multiple stakeholders, the students interacted with a representative from a native American tribe fisheries division, staff from state Fish and Wildlife and US Army Corps of Engineers. The team also presented their work to county engineers, managers and construction personnel.

Multidisciplinary Nature: The project encompassed a wide range of disciplines: transportation geotechnical and environmental subdisciplines within civil engineering, fish biology, environmental science, permitting, and cost estimating.

Knowledge and Skills Gained: The students developed several skills useful to entry level engineers. They learned how to apply the technical knowledge gained in the classroom to a real-life project. They practiced the basics of project management, leadership, team management, and client interaction. They honed their communication skills through presentations to a range of audience and preparation of memos, proposal and report to the county.

Benefits to Public Health, Safety and Welfare: The primary goal of the six-year TIP is to improve traffic flow and pedestrian safety in the region. In addition to striving for this in their design, the team planned signage and detours to be used during construction phase of the project to improve public safety. Making the culverts fish passable and developing an erosion and sediment control plan during construction improve public welfare.

Infrastructure Improvement of a County Road

I. Project Description

Introduction

A local county approached our engineering program requesting assistance on a roadway enhancement project which was part of their six-year transportation improvement program (TIP). The project involved two parts: a) widening one of the roadways (hereafter called Road X) to accommodate the rapid growth in the region and improve pedestrian access and safety; and b) replacing three culverts making them fish passable. This project was the capstone experience for a team of civil engineering undergraduates.

Figure 1 shows the project site and the surrounding area. Road X is east of a major interstate highway in a residential neighborhood with a thick canopy. Three culverts in the project site, two underneath Road X (hereafter referred to as twin culvert) and one underneath a private driveway, act as the surface water conveyance system for a stream within the project site, as shown in Figure 2. The driveway culvert is a 30 in. diameter, 30 ft long Corrugated Plastic Pipe (CPP). From field measurements taken by the team, the twin culverts were determined to be 42 in. x 29 in. arch corrugated metal pipe (CMP) approximately 45 ft long, that have been damaged and deformed over time. The stream flows through the driveway culvert and then is diverted under Road X through the twin culverts. Due to stream erosion, the culverts are perched above the stream and are a barrier to fish passage. The county requested that the new culvert under Road X be designed to provide fish passage as well as meet the TIP needs.



Figure 1 Project Vicinity

Project Challenges

Currently the three culverts do not conform to the natural stream's alignment, which generally follows the flow direction arrow shown in Figure 2. The driveway culvert is almost perpendicular to the natural stream flow direction. Once the stream exits the driveway culvert, it is then forced to take a 90° bend to flow under Road X. The twin culverts serve as the conveyance system for the stream as well as any storm water

flowing from the residential neighborhood towards the culvert inlet. The twin culverts are found to be undersized and have a nick point (ie. a sudden change in slope) at the outlet making the culverts a fish barrier. The county desired a culvert that was aligned with the natural flow of the stream, and be designed to meet fisheries requirements. The design problem included replicating the original streambed materials and flow characteristics of the natural stream while providing suitable flow depths and velocities for fish passage, as well as meeting the county road standards for road widening according to the TIP.

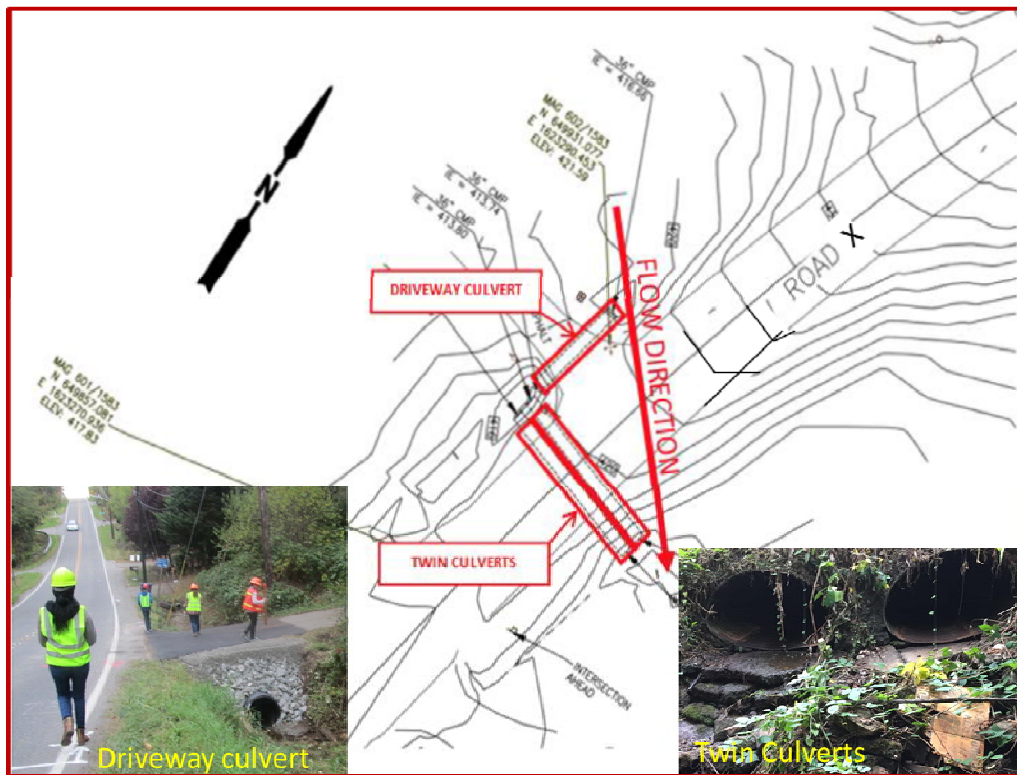


Figure 2. Plan View of Existing Roadway Alignment and Culvert Locations and Pictures of Culverts

Holistic Nature of Project

This project gave the students an opportunity to apply their technical knowledge gained from various courses (land surveying, hydraulics and hydrology, transportation, geotechnical and environmental engineering) and to acquire new knowledge in the areas of fish biology, stream morphology, fisheries regulations, permitting, construction planning, cost estimation and drafting using AutoCAD Civil 3D. These skills are useful to students when they enter the workforce and highly valuable to employers.

Project Approach and Design Development

a) Field Work

The team performed a field reconnaissance to observe site conditions and constraints, and to have a better understanding of the problem posed. The engineers from the county and the faculty advisor accompanied the team providing guidance on what site features to look for. Thereafter the students surveyed the project area under the supervision of the

faculty advisor who is a PE-PLS and developed a topographic map of the site. The students surveyed a profile of the stream and took measurements to determine the natural stream's bank-full discharge. The students also studied the natural stream bed characteristics by performing pebble counts at five different locations upstream and downstream of the twin culverts under the tutelage of a fish biologist from the county.

b) Design Work

Compiling of Design Parameters

Student measurements showed that the average bank-full width of the stream was 5.8 ft and the gradient of the stream was 9% in the project area. Using the field measurements and the state Fish and Wildlife design criteria for culverts, the team came up with a minimum culvert opening of 9 ft.

To predict the flow through the culvert during storm events, the team developed a hydrologic model using the US Army Corps of Engineers software, HEC-HMS. The team had to research the input parameters for the model from various sources. For example, it obtained the rainfall data from a USGS gage near the project site; predicted the surface runoff using Soil Conservation Service (SCS) curve number method. The HMS resulted in a peak 100-year storm flow of 18.1 cfs and a 2-year storm flow of 5.3 cfs through the twin culvert.

The flows from HEC-HMS results, land survey measurements, and stream roughness from field observations were used in the hydrology/hydraulic model, HEC-RAS, to obtain the water surface elevation and the velocities along the project alignment. This information was used to determine the cross-sectional area of the stream at the culvert that would provide uninterrupted fish migration while preventing backwater buildup upstream of the culvert inlet.

Road X is a two-lane roadway with a total width of 23-feet, average traffic volume of approximately 3200 vehicles/day and a posted speed limit of 35 mph. As can be seen in Figure 1 inset, the roadway is not pedestrian friendly. Therefore, the County TIP required an 8' shoulder on the east side of the roadway in the vicinity of the project site for pedestrian safety.

Culvert Design

Using the design parameters obtained from the above analyses, the team designed a single culvert to replace the three-culvert system as shown in Figure 3. The team researched four structural options for the culvert (4-sided concrete box, circular metal pipe, arch type, multiple barreled culvert) and developed a decision matrix. Details of the decision matrix are presented in the accompanying poster. The 4-sided box culvert was ranked the highest and was chosen as the preferred alternative.

Figure 3 shows an AutoCAD Civil 3D engineering drawing developed by the team. The proposed culvert alignment is shown in green in this figure. The team calculated the dimensions for the proposed culvert - an interior culvert width of 9 ft, interior height of 6 ft, a total length of 70 ft, installed at an 8.9% slope to mimic the natural slope of the

stream with a minimum soil cover of 2 ft; the invert elevations at the inlet and outlet of the culvert are to be 415.85 ft and 409.57 ft, respectively.

Roadway Design

The team designed the roadway to meet the County TIP requirements. This included an 8 ft shoulder on the east side of the roadway, embankments at the east and west sides of the roadway and guard rails at the culvert locations to comply with the state design standards. In Figure 3 the proposed roadway alignment is shown as a gray shaded area. The accompanying poster shows the engineering drawings the students prepared of the roadway cross section and the profile along the culvert.

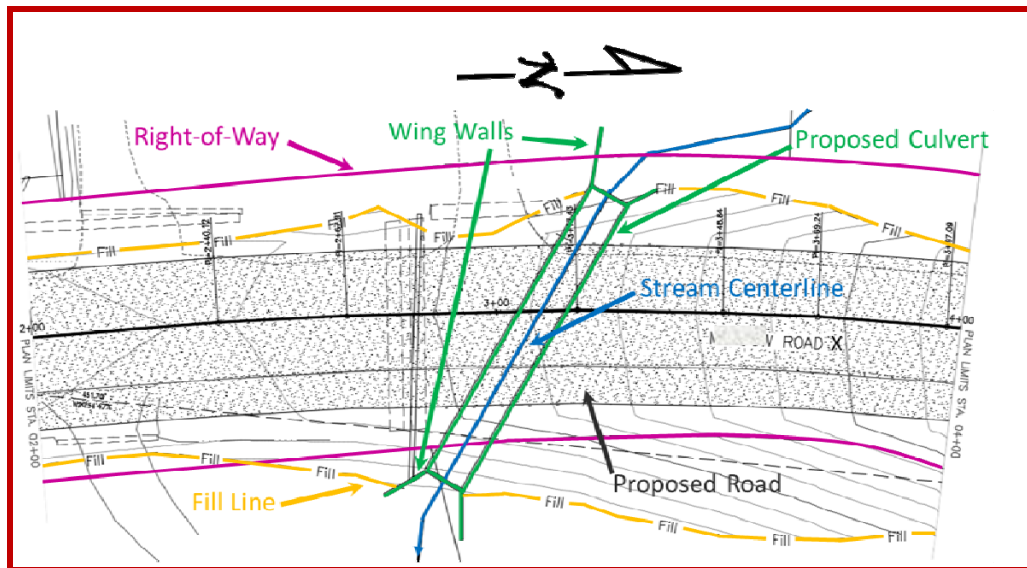


Figure 3. Planview of Proposed Roadway Alignment (shown in gray) and Culvert Placement (shown in green)

The 2:1 side slopes of the roadway embankments required designation of permanent easements and temporary construction easements outside the county's right of way on the east side of Road X as shown in Figure 3. The county decided to pay market rate for renting any temporary construction easements and for purchasing property for all permanent easements. The team included this information in the final report.

Removal of the existing driveway culvert, shown in Figure 1, would adversely impact the homeowners, cutting off their access to Road X. On Figure 3, the existing driveway culvert is just south of the proposed culvert inlet. To minimize adverse impact to homeowners, the team proposed temporarily filling in the existing drainage ditch and connecting the driveway to Road X further south, beyond the construction zone. The county will reconstruct this driveway to its original form after the new culvert is installed.

Culvert Bedding Design

To provide a culvert with the least impact on the natural processes of the stream according to the water crossing design guidelines, the students proposed that the culvert be partially backfilled with a sand/gravel/cobble mixture and anchor rocks to allow the

stream to form its own meandering streambed. The team used its pebble count readings and the design guidelines to develop the desired the soil composition for the culvert base.

c) Construction Planning

Upon completion of the design, the team developed a construction plan which entailed a temporary erosion and sediment control (TESC) plan during construction to maintain water quality and protect aquatic life, utility relocations which included an 8” ductile iron water main, water meter, power pole and guy wire anchor within the project area, and a traffic control plan including road closure, traffic detour and corresponding signage placement.

d) Preparation of Engineering Drawing

The team prepared 11 sheets of professional quality engineering drawings in AutoCAD - Civil 3D. The drawing set encompassed proposed alignment and design of Road X and replacement culvert and relevant cross sections, demolition plan for the existing culverts, construction sequence, utility relocation, detour plan, and temporary erosion control plan during construction. Examples of these engineering drawings are presented in the poster.

e) Cost Estimation and Applicable Permits

The team took this project to a 30% design. Then using RS Means 2018, state Department of Transportation unit bid tools and cost information from a concrete box-culvert manufacturer, estimated the cost for the preferred alternative to be approximately \$400,000. The project cost breakdown is illustrated in the poster.

This project impacts the environment in a multitude of ways: the roadwork and culvert replacement require construction activity in the streambed, and the construction activities disturb the existing vegetation of the surroundings requiring removal of trees in some locations. Therefore, the project required several permits. The team provided a list of eight county/state/federal permits applicable for the project.

II. Collaboration of Faculty, Students and Licensed Professional Engineers

A diverse group of five students worked on this project throughout the academic year. They were mentored and supervised by two engineers and a fish biologist from the county and two faculty members from the university, all holding active PE licenses. In addition, one of the faculty members is also a professional land surveyor (PLS). Figure 4 shows the team during a site visit with the county engineers.

Our department has an Advisory Board consisting of a dozen practitioners from various subdisciplines related to civil engineering. All are PEs except for one who is an Environmental Scientist. The student team presented their project to the Advisory Board



Figure 4. Student Team with County Engineers

twice during the academic year – once in the early part of the year, of their project understanding and plan of implementation; the other at the end of the academic year when the project was completed.

The students also participated in the annual local section ASCE student presentation competition. Five PEs from various subdisciplines within civil engineering served as judges. Although the team did not win an award, the event gave them an additional opportunity to present their work to a group of licensed engineers and to answer questions.

III. Protection of Health, Safety and/or Welfare of the Public

The project is part of a six-year development plan for the region. It involves widening the roadway to alleviate traffic congestion and improving pedestrian safety. The team planned signage and detours during construction to improve public safety. Making the culverts fish passable and developing an erosion and sediment control plan to alleviate the environmental impacts improve public welfare.

IV. Multidiscipline and/or Allied Profession Participation

Multidisciplinary Nature: This project encompassed a range of sub-disciplines within civil engineering: transportation engineering for roadway alignment and design, water resources engineering for hydraulic and hydrologic analysis for the stream and storm flow, geotechnical engineering in the selection of base material inside the culvert, and environmental engineering in erosion and sediment control and permitting. Outside engineering, it incorporated fish biology and environmental science to understand fish behavior and migratory patterns. The students learned the socio-economic issues involved in a project of this nature when considering temporary and permanent easements, property acquisition outside county right of way and homeowner private driveway accessibility issues.

Allied Professionals: The project had several stakeholders: the county, a local native American tribe, state Fish and Wildlife and US Army Corps of Engineers. As a result, the team consulted with several individuals outside engineering to complete the project. The project site is close to a Native American tribe's historical region for harvesting finfish, shellfish and other natural resources. Thus, a native American tribe fisheries division representative advised the team on Native American issues and fish migration patterns. Staff from state Fish and Wildlife and US Army Corps of Engineers educated the team on fish passage design and governing regulations; an aquatic biologist from the county served as an additional resource to the team. In addition, when the team presented their work to the county, engineers, managers, and construction personnel attended the presentations, asked questions and provided valuable feedback to the team.

V. Knowledge and Skills Gained

The students developed a wide range of skills useful to them as entry level engineers. The knowledge and skills can be grouped into three main categories: technical skills, communication skills and professional skills.

Technical – The students applied what they have learned from their course work in environmental, water, transportation, and geotechnical engineering to a real-life situation. Through this project they also learned how to use the following tools effectively:

- Design Manuals, Specifications and Guidelines: Design guidelines by state Fish and Wildlife, USGS design guidelines, US Forest Service guidelines for water crossing, county Drainage Manual, state Hydraulic Manual, state and county Department of Transportation manuals and Standard Specifications, and state Administrative Codes.
- Computer Aided Drafting: AutoCAD Civil 3D
- Design Software: hydraulic/hydrologic modeling (HEC-RAS, HEC-HMS)
- Construction planning and socio-economic impacts of project on residents in the area
- Experience researching for applicable permits

Professional Skills – This college-industry partnership provided the students an opportunity to learn basics of project management, leadership, team work, and client interaction and apply them in a real-life setting. Each student served as the project manager for part of the year and was responsible for coordinating and running the meetings, keeping track of action items and tracking the project progress. Students met with the faculty advisor weekly and with the county personnel every month or more frequently as needed. Because the county office was further away from campus, students had weekly conference calls with their sponsors.

Communication – Students developed their writing and oral presentation skills through this experience. In the early stages of the project, the students prepared a written proposal to the county outlining their understanding of the problem and approach in completing the project. During the year they submitted several technical memos summarizing the various milestones of the project. At the end of the school year, they submitted a final report of all the work done, along with engineering drawings and calculations.

Students presented their project using audio-visuals to the class and departmental faculty several times during the year. In addition, at bi-weekly meetings the team gave a status report of the project progress to their peers. Students also presented their proposed work to the county in the early stages and then their final design recommendations at the completion of the project. The university held a special campus event at the end of school year, where the team presented its work to the entire university community, current and prospective project sponsors, and alumni. This event is also open to public.

VI. SUMMARY

A local county requested the help of one of our capstone design teams in improving a roadway as part of their six-year transportation improvement program. A team of five civil engineering seniors worked under the supervision of two county engineers and two faculty members from the university, all licensed professional engineers. One of the faculty members had a dual license, PE-PLS. The team redesigned the alignment and widened the roadway, replaced three culverts making them fish passable, developed a construction sequence for the project and estimated the construction cost. This project gave the students an opportunity to apply their technical skills to solve a real-life problem and hone their project management, leadership and communication skills.