INTEGRATED INFRASTRUCTURE IMPROVEMENTS FOR A YOUTH SCOUT RANCH

Abstract

Our Civil Engineering Department was approached by a youth scouting ranch for infrastructure design assistance in early 2010. A variety of improvements were required for future growth and camper safety. Four areas of need were identified:

- Water: new fire protection, drinking water storage, distribution, and treatment systems.
- Drainage: hydrologic study, drainage structures, erosion control, and emergency access.
- Wastewater: new collection and treatment systems.
- Structural: new pedestrian bridge and trading post structures.

Twenty-two senior undergraduate Civil Engineering and Construction Management students were organized into four professional engineer (PE) mentor-led teams to address each of these project areas as part of our Fall 2010 Capstone Design Course. Each team created a fictitious firm with well-defined roles. Tasks included site assessment (including field measurements and gathering existing data), engineering modeling and calculations, design and comparison of preliminary alternatives using decision analysis tools, preparation of full-size construction drawings and specifications, cost estimation, scheduling, and construction phasing. The teams had to consider site constraints such as rugged terrain, remote location, a need to maximize use of volunteer labor, and limited budgets. Deliverables included statements of qualifications, weekly meeting notes, mid-semester reports and presentations, and final reports and presentations with construction drawings and specifications, cost estimates, and schedules.

The project was highly successful, providing exceptionally **strong collaboration between faculty, students, and practicing professional engineers.** The student teams worked closely with PE mentors, meeting at least weekly and performing much work in their offices. The scopes of work were developed collaboratively by faculty, mentors, and the client. Formal and informal feedback mechanisms were provided for intermediate deliverables and presentations. The projects yielded tangible **benefits to public welfare, health, and safety** by providing realistic designs for safe drinking water, fire and flood protection, wastewater treatment, emergency road access, and a pedestrian bridge to bypass a steep ravine.

The incorporation of four discrete but related sub-projects at a single site provided a unique opportunity for students to explore specific disciplines within Civil Engineering deeply, while requiring inter-group coordination. Integration of Civil Engineering and Construction Management students on the same teams successfully provided **multidiscipline and allied profession participation,** with students gaining excellent opportunities to work with the "other sides" of their professions. **A variety of knowledge and skills were developed,** including extensive presentation and writing skills (with outside professional guidance), gathering of existing data, field investigations, application of modeling skills to real-world problems, permitting applications and communication with government officials, use of decision analysis tools to compare design alternatives and to communicate with clients, incorporation of engineering design with construction management tasks, and development of a full set of design plans and specifications for use on a real project.

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1. BACKGROUND

In the Spring of 2010 our Civil Engineering Department was approached by a large youth scouting ranch (the Client) for infrastructure design assistance. A variety of improvements were needed for future growth, safety, and to comply with county permitting requirements. Through several meetings with representatives of the scouting organization, four areas of specific need were identified:

- Water: new fire protection, drinking water storage, distribution, and treatment systems.
- Drainage: hydrologic study, drainage structures, erosion control, and emergency access.
- Wastewater: new collection and treatment systems, including likely conversion from septic to a lagoon or package system.
- Structural: new pedestrian bridge and trading post structures.

These projects were recognized as excellent opportunities for our senior undergraduate capstone design course to produce a class project focused on a single site, with four sub-projects. Particular strengths of using these projects included the potential to produce an integrated design, in which students could go deeply into their areas of interest, while also coordinating with their colleagues in different groups. Furthermore, the students addressed the real-world needs of a highly motivated client, with the expectation that their final designs would be used directly or as the basis for actual infrastructure improvements. Four teams were created with students from both our Civil Engineering (CE) and Construction Management (CM) Programs, each of which worked closely with a licensed Professional Engineer mentor with appropriate expertise. The remainder of this document describes the project descriptions, benefits to the public, multidisciplinary aspects, and knowledge and skills gained.

2. PROJECT DESCRIPTION

The Client

The scout ranch occupies 2,650 acres located in the foothills of a mountain range in the U.S. Southwest. The Ranch was operated primarily in the summer, and served thousands of youth campers each year. Existing facilities include 12 developed campsites, dining hall and kitchen (capacity of 300), swimming pool, rifle and archery ranges, climbing area and tower, nature and crafts pavilions, hiking trails, and campfire arena. Critical improvements with respect to water, drainage, wastewater, and structures (described below) were needed to accommodate increasing numbers of youth campers, and the Ranch had reached a critical size that the County permitting agency would require significant improvements (for example, with respect to wastewater treatment) before future growth could occur. Critical considerations for this project included its remote location, cost constraints, desire to maximize use of volunteer labor, use of appropriate technologies, and safety for the youth campers.

An important benefit of working with this client was their high level of motivation and the availability of PE mentors with personal involvement with the site. Other Client professionals,

such as administrators and caretakers/advisors, provided students with the opportunity for real Client interactions, particularly with respect to site assessment and historical observations, determination of Client needs, and determination of available materials.

Course organization

Our Department has both Civil Engineering (CE) and Construction Management (CM) degree programs, both of which are accredited. Our senior design capstone course has successfully capitalized on the proximity of these programs by incorporating both sets of students into project teams. This enabled production of projects that integrated sets of skills particular to each program (e.g., engineering calculations for modeling and design, integrated with construction management scheduling, costing, and phasing) in a realistic format, such as students might encounter in real-world consulting firms.

The learning objectives for the course were to:

- Develop abilities to function on multidisciplinary teams.
- Develop designs and plans that work within project constraints, such as economic, environmental, social, political, ethical, safety, manufacturability, and sustainability.
- Develop effective communication skills.
- Identify, formulate, and solve engineering problems (CE students).
- Apply techniques, skills, and modern engineering tools necessary for engineering practice (CE students).
- Apply technical skills to solve construction management problems (CM students).
- Use technology to solve construction problems (CM students).

For the Scout Ranch project, which was undertaken in the Fall of 2010, a detailed scope of work for each project was developed collaboratively by the faculty, mentors and client. Twenty-two (11 CE and 11 CM) senior undergraduate students were split into four teams of 5 to 6 students each. Each team included both Civil Engineering and Construction Management students, with a mix of abilities such as academic performance and AutoCAD skills. Each team created a fictitious student firm and an organizational chart delineating tasks and responsibilities of each team member. These were presented as part of a Statement of Qualifications.

A professional engineer mentor with relevant expertise was assigned to each project and met at least weekly with the students. These meetings typically took place at the mentor's office, which gave students the opportunity to experience a realistic work environment. Some mentors provided dedicated space for the student teams, which allowed them to work in the consultant offices as well. Teams also met with client representatives as needed to obtain site information and to assess needs.

Deliverables and presentations provided by each team included:

- *Statement of Qualifications* for the students and their fictitious firms, including a written document and a formal presentation/interview with the client to get the design contract.
- Formal *weekly meeting notes* written as memoranda to the course instructor, including accomplishments, questions, and action items.
- *Mid-semester report and presentation* detailing preliminary design alternatives.

- *Final report and presentation* documenting modeling studies, calculations, alternatives development, design drawings, specifications, schedule, and cost estimates.

Each final report had a professional appearance and included at least the following elements:

- Executive summary.
- Description of student firm and qualifications, with organizational chart.
- Scope of work.
- Existing site conditions, including student-performed surveying and summary of existing reports and data.
- Project approach, including quality assurance, safety, phasing, on-site storage, and cost control plans.
- Studies, such as hydraulic, hydrologic, and structural modeling.
- Alternatives descriptions and comparisons using weighted (by factors such as cost, safety, constructability, and effectiveness) Decision Analysis tools.
- Project design, including narrative, full-size drawings, and specifications.
- Construction schedule and cost estimate with guaranteed maximum price.
- Appendices with calculations.

Project 1: Drinking water and fire protection improvements

Student firm: *Prestige International*

Water system deficiencies were determined to include: (1) low water pressure in parts of the system, (2) a lack of overall fire protection, (3) lack of plans for expanding the system to accommodate the expansion of the campgrounds, and (4) non-compliance with State Drinking Water Standards.

The project work began with collecting existing conditions data, including a site survey, and developing a site base-map in AutoCAD Civil 3D showing the topography, existing utilities, and existing structures. Historical daily water demand was determined based on-site records and engineering calculations. The condition of the existing facilities was also determined, and hydraulic models were developed using EPANET and WaterCAD.

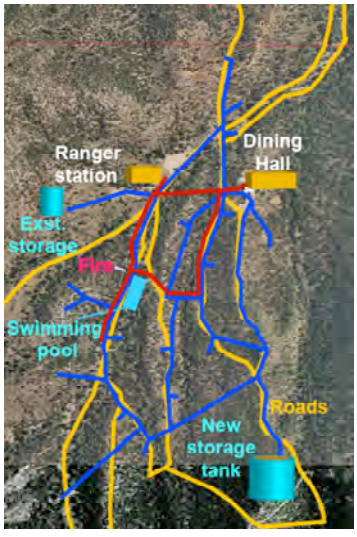

Figure 1: Water improvements, including potable (blue) and fire (red) distribution systems.

Design criteria were developed considering State Standards, forecasted growth, fire protection to meet Fire Marshall requirements, emergency storage, and EPA Primary Drinking Water Standards. Alternatives were developed addressing deficiencies as they applied to supply, treatment, storage and distribution. These design alternatives (such as tank sizes, and materials and pipe layouts) were compared using Decision Analysis matrices, and recommendations were provided. This work was described in the mid-semester report and presentation.

The final design was then developed for the selected alternatives, including construction drawings and specifications (including standard specifications as needed from State Standard

Specifications) for each component. Detailed cost estimates ($443,000 for construction of all components) and construction schedules (4 months estimated construction duration) were also developed. Key components of the final design included:

- Water storage tanks with 2 days of storage, at a new location to gain 120 feet of head.
- Mixing line for chlorination to meet drinking water standards.
- Properly looping pipe network, with expansion to accommodate predicted growth.
- A fire suppression system utilizing the existing swimming pool, with safety safeguards and pumps, and a new piping network.

Project 2: Drainage, erosion control, and emergency road access improvements

Student firm: *Drainage and Hydrology Specialists*

Several drainage deficiencies were identified, including a new swimming pool apparently constructed without considering drainage into it and channel erosion adjacent to the site. Most roads crossing the arroyos (drainage channels) had created head cuts (erosion of the bed and banks that progress upstream). Some existing structures used to stabilize arroyos were not properly constructed. Existing campsites and structures needed flood/drainage mitigation structures constructed to protect campers and infrastructure, with safety a primary concern.

The project began with site assessment, which included collecting existing drainage basin, rain, and soils data, and performing on-site measurements to determine arroyo profile dimensions. Thirty-four drainage basins covering 9.2 square miles were delineated, and an AHYMO_97 hydrologic model was developed for determination of design flows at 10-year and 100-year 24-hour storm events. Normal depths were calculated at critical points in the system. For example, it was determined that the swimming pool was not in the 100 year flood plain, although it was potentially vulnerable to erosion in the adjacent arroyo due to high velocities. Hydraulic modeling was also applied to size culverts and other features.

Design alternatives were developed, including options for an emergency road crossing, and these were compared using Decision Analysis Matrices. The modeling and alternative comparisons were presented to the Client, mentors, faculty, and students in a mid-semester report and presentation. The final design commenced with the recommended alternatives, and a complete set of construction drawings and specifications was prepared. The construction schedule indicated a total construction period of 5 weeks, with a total cost of $56,000 (the majority of this cost being the emergency road crossing, with culverts). Key design components included:

- Design for flow up to 240 CFS based on AHYMO_97 hydrologic model of basin and 100 year storm.
- Trail armor and water bars for trail protection.
- Check dams in channels to slow water flow.
- Grade control structures to protect channel crossings and embankment armoring at channel bends, and low-water crossings of roads through channels.

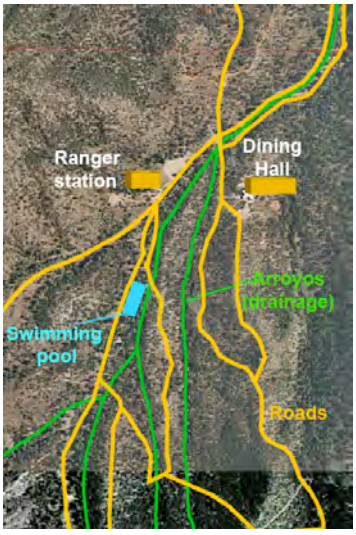

Figure 2: Drainage system.

- Emergency road channel crossing with three 48" x 50' culverts.

Project 3: Wastewater improvements – collection system and secondary treatment

Student firm: *Lobo Contractors*

The Ranch's existing wastewater system consisted of at-capacity septic systems and leach fields, with a flow rate near the existing Liquid Waste Permit limit of 2000 L/d. Expansion of the Ranch would likely require secondary wastewater treatment to meet new Ground Water Discharge and possibly NPDES permits. Construction of a new secondary treatment system would also require a new wastewater collection system.

The project began with survey of the existing site, including location and condition of existing utilities and structures and the development of a site base-map in AutoCAD Civil 3D. The team determined the current average yearly, monthly, and daily influent flow for the system based on site record and engineering calculations. Design criteria were developed for wastewater improvements considering state standards and planned growth of the facility, and based on this information capacity deficiencies were identified. The team developed alternatives for addressing each deficiency as they applied to collection, treatment, and disposal, and these were quantitatively compared using Decision Analysis. For example, new treatment alternatives included expanded septic systems, lagoon treatment, and package plant options (such as a membrane bioreactor system that was available for donation).

These alternatives were presented to the Client, mentors, faculty, and students in the mid-semester report and presentation, and alternatives were selected for the final design based on the team recommendations and discussion with the Client. As with the other projects, the final design included full size construction drawing and detailed specifications. The guaranteed maximum price was $570,000, largely for the lagoon and a lift station, with a 2-month construction schedule. The key design components included:

- Hydraulic models of the existing and designed systems.
- A PVC wastewater collection piping system with manholes and cleanouts, and plans and profiles with trench details.
- A 2 acre evaporative lagoon with a 3' liquid depth for natural aeration, including a liner and plan for 7 year cycle for sludge dredging.
- A lift station required to pump wastewater to the lagoon, sized for maximum flow rates to accommodate growth.

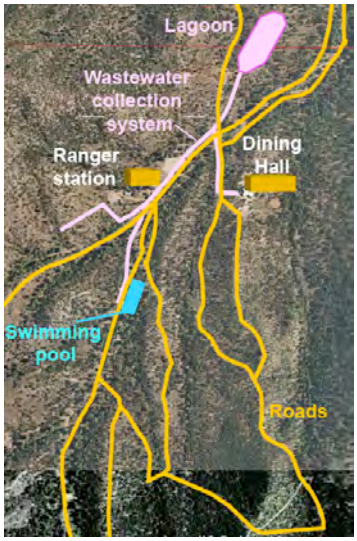

Figure 3: Wastewater collection system and lagoon.

Project 4: Structural improvements - pedestrian bridge and trading post structure

Student firm: *Character Design-Build Enterprises*

Structural deficiencies identified at the site included poor trail connection across a ravine near the existing swimming pool and planned new campsites, which could be remediated by a new pedestrian bridge. In addition a new camp trading post structure was needed, where campers could purchase convenience items.

Architectural drawings were available for this structure, but its location and engineering design had not been determined.

The project commenced with gathering of existing topological information and identification of potential sites for the bridge and trading post building. This included multiple site visits and survey measurements of ravine sections and other characteristics. Design alternatives were developed and modeled using SAP2000, including different bridge structure options (e.g., truss and girder designs). These required interactions with the drainage group to determine the 100-year flood elevation. Major cost savings were achieved by the identification by the project team of a new site for the pedestrian bridge that required only a 70' span, as opposed to the 110' span at a site originally suggested by the Client. As in the other projects, design alternatives were compared using Decision Analyses, and the work thus far presented in the mid-semester report and presentation.

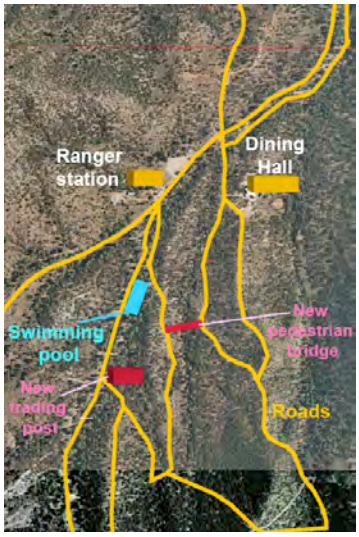

Figure 4: Pedestrian bridge and trading post structure.

Recommended alternatives for the bridge (the 70' span with a truss design) and the trading post were then developed for the final design drawings and specifications. The estimated construction duration was 2 months, and the total estimated cost was $75,000 for all components, in part because the bridge design made use of some donated steel materials for the structure. Key structural design components included:

- 70' span pedestrian bridge conforming to AASHTO LRFD specifications for dead and live loads, wind, and snow, bridge abutments, and modeling (SAP2000 software).
- Trading post structure including foundation, walls, and roofing.
- Earthwork and retaining walls for trading post.

3. COLLABORATION OF FACULTY, STUDENTS, AND PROFESSION ENGINEERS.

This project provided an excellent example of collaboration between faculty, students, and practicing professional engineers. Our Department has a strong history in this regard, with all faculty licensed PE's. As described above, the Scout Ranch project included the primary involvement of 4 PE mentors leading the 4 project teams, beginning with the collaborative development of the Scopes of Work by the faculty, mentors, and the client. Additional PE's, typically colleagues of the mentors, served as informal advisors for specific project tasks. Close collaboration was insured in part through weekly meetings between students and mentors, typically in the mentor offices, and so students also gained a practical understanding of the routine work environment of professional engineers. Student teams also provided weekly update presentations and copies of all meeting notes to the faculty and mentors. A mid-semester progress report provided an opportunity for written feedback from mentors and faculty to the students. A separate mid-semester Client presentation was also included to the Scout Executive Council, which provided further feedback. This collaboration provided benefits to students by providing them with opportunities to gain practical experience in working with consultants, as well as learning the responsibilities of being an active member of the engineering community. In addition, the mentors gained a valuable opportunity to screen new graduates for potential hires; at least one of the students from this project was subsequently hired by their mentor's firm.

4. BENEFITS TO HEALTH, SAFETY, AND WELFARE OF THE PUBLIC

This project provided tangible aid to a non-profit youth scout ranch dedicated to developing character and skills. As noted, the Client initially contacted our Department requesting this help, and the student work verified that major deficiencies existed at the site with respect to drinking water, fire protection, drainage and protection of existing structures from erosion, emergency road access during storm events, wastewater upgrades needed for future expansion, a new pedestrian bridge required to improve safety and access to swimming facilities, and a new trading post structure. By providing engineering services free of charge, with the guidance of PE mentors, the students were able to provide real benefits to an organization in need. The projects helped to improve safety and protect of camper health, while improving opportunities for summer camp experiences for youth. Residing in a Hispanic-serving University, this project also helped prepare under-represented groups for careers in Civil Engineering.

5. MULTIDISCIPLINE AND/OR ALLIED PROFESSION PARTICIPATION

The integration of Civil Engineering and Construction Management students created an excellent opportunity for students with diverse skill sets to interface and create a final project design that included not only a range of engineering skills (e.g., hydraulic, hydrologic, structural, and geotechnical analyses), but also the construction skills required in a real construction project (e.g., cost estimating, scheduling, and construction phasing). In this manner, engineering students solve real-world design problems, while learning about practicalities of construction and management. Construction management students in turn learn about the challenges and practicalities of engineering design, and all students benefit from working in teams under strict time constraints for production of periodic deliverables, under the close mentorship of local engineering and construction professionals. That these programs reside in the same academic department provides a synergy between design and construction that is rare in higher education, although professionals in both fields must frequently work closely together.

6. KNOWLEDGE OR SKILLS GAINED

CE and CM students participating in this project gained knowledge of how to identify and gather needed information, to apply technical skills to solve real problems, and how to collaborate across technical and professional disciplines in a design/build project setting. The students gained skills in organizing and implementing fieldwork for site assessment. They also learned to apply modeling skills to real-world problems. They also learned how to develop a Decision Analysis as a tool to compare alternative designs and to communicate with a Client. The course also allowed students to meet and work in consulting office environments, which helped to develop their skills in professional interactions. Development of skills in working in teams was also emphasized, and students were mentored on how to productively manage internal conflicts. Communications were stressed throughout the course. Presentation and public speaking skills were developed through repetition to help students become comfortable in front of an audience. Weekly progress reports with visual aids were required, as well as longer presentations. Professional attitude and attire were required for all presentations. Outside professionals were invited as guest speakers to work with students on their presentations. Written skills were developed through production of major deliverable reports, and also more routine formats, such as production of professional memoranda and weekly meeting notes.