Description: Town Water Supply Engineering Design

Submission category: Community enhancement projects

Project description

A rural community in Eastern Tennessee is seeking assistance to prepare preliminary engineering designs for a water storage solution. The town has 350 customers. Their current system uses water pumped up to a steel storage tank residing on a hillside on the southeastern border of the town.

The storage tank on the hillside is approaching a point of critical failure; the hillside is increasingly losing stability. Emergency repairs were conducted a few years ago during a period where the tank was in an active failure, and these repairs were intended to be temporary while an alternative storage solution was designed. The existing water tank is shown in figure 1. The photograph was taken during a three-day trip by the first of two student teams and two faculty advisors.

Figure 1: Existing Water Tank

During the site visit the condition of the existing tank became clearer. The hillside showed evidence of multiple landslides over time, including trees that were bent 30 degrees between growth before and after landslides. The hillside near the tank has deep fissures in the soil. The tank has no foundation and is simply sitting on soil. In addition, it was learned that the tank provides water to the system only during periods of high demand. At other times, the tank is by-passed, since adequate pressure and flow is provided by the nearby town that provides the water. As a result, the water in the tank occasionally exceeds the recommended water age, resulting in an inadequate chlorine residual.

The site visit was very useful for clarifying the issues and refining the list of available alternatives. Based on preliminary analysis and meetings with the town's stakeholders, three alternatives were developed and analyzed:

Alternative 1 – Rehabilitation

Keeping the current site and rehabilitating the current tank would require improving the site to a condition that does not require constant emergency maintenance. To stabilize the land, sheet piling could be installed to help prevent the hillside from deteriorating further. A few other options that could be used in conjunction with the sheet piling would include dropping riprap or crushed stone and building terraces to slow water runoff. Planting some natural vegetation around the area would help restore the area as well as provide stabilization through their roots. This is not a do-nothing alternative because there would be ongoing maintenance costs. Furthermore, the existing pipes connecting the town to the water tank are vulnerable to local landslides. This alternative would not address the water quality concerns.

Alternative 2 – Standpipe

The second alternative is a standpipe water tank system which would be installed next to the town's baseball field. A standpipe would be easily accessible due to the new utility office being close to the baseball field as well. The standpipe would include placing a new foundation and the erection of the standpipe. Since proposed location has the same elevation as the whole town, the standpipe alone would not have enough head to provide the required 20 PSI to the final connection in the event that the town supplying the waster experiences a pressure drop. If the standpipe option is selected, an additional pump will be required to supply this pressure. A pump will require increased maintenance and may be less reliable.

Alternative 3 – Elevated Storage Tank

The final alternative would be the construction of a new elevated water storage tank with a capacity of 100,000 gallons. An elevated tank would also require site preparation and foundation work. Both the standpipe and elevated tank would be located south of the baseball field. Due to location, this alternative would also have much easier site access than the current tank. In addition, a new tank can be equipped with the appropriate circulation valves to ensure the water in the tank is circulated periodically, preventing the loss of chlorine residual.

Recommendation

After taking into consideration the multiple design alternatives, the client's opinion, and the sustainability analysis, the recommended solution was the elevated storage tank. The elevated storage tank will provide the required pressure at the final connection. No additional pump will be needed to fill the tank, as the incoming pressure is adequate. And the tank alone can provide the elevation head needed as back-up for the supplying town's pump. This solution will provide better water quality and is not at risk from the unstable slope that the existing tank uses.

Collaboration of faculty, students, and licensed professional engineers

The project extended across an entire academic year, with two student teams, each of four students, under the supervision of two faculty co-teaching the course (both PEs). The University requested the project from a national list maintained by Engineering Society A. Because the project was located in a separate state from the University, it was necessary to find one or more PEs licensed in that jurisdiction. Firm B, which provides support to the University through the departmental Advisory Board, agreed to collaborate and provided its engineers licensed in the project's location. Therefore, between the University and Firm B, there were 5 PEs involved in the project. One of the PEs from Firm B accompanied the team on the site visit.

A separate consulting firm, Firm C, conducts a workshop to introduce the Institute for Sustainable Infrastructure Envision® sustainability analysis framework each semester. During the two-hour workshop, the firm introduces general principles of sustainability and how they can be applied through the Envision® model, and then coaches each team about how to apply the model to their specific project.

Protection of health, safety, and/or welfare of the public

Water supply to the town is vital for health, sanitation, and fire protection. The current tank location represents a risk to the public in the town. The 65,000-gallon tank is nearly 60 years old, and the hill is unstable and prone to landslides, so the tank could fall onto the houses below. Also, due to the unstable hillside, the pipe connecting the tank to the town is vulnerable. The site is difficult to reach and has erosion issues due to silty soil, and is seismically vulnerable. Conditions at the site continue to worsen with each rainfall and seismic episode. Emergency repairs have been conducted by the town to stabilize the tank. However, these repairs were intended to be temporary, and the tank needs to be replaced before its expected failure. As a result, this team project was intended to provide sufficient information for the City to apply for funding to replace the water tank.

To further illustrate the risk, on December 5th, 2021, the town was struck by a tornado. Although the existing tank was not damaged, there was extensive damage to the southwestern part of the town. The incident illustrates the vulnerability of the current system. Furthermore, a reliable water supply will be important as the town rebuilds. The new system will also eliminate the risk of water quality violations caused by excess water age in the current tank.

Multidiscipline and/or allied profession participation

In addition to the Engineering Society A that provided the initial project information, a local community organization (Organization C) provided meeting coordination with the own water board as well as the adjacent town that provided the water to the town.

From the beginning, the intent was to provide Organization C and the town with a complete grant proposal application for emergency funds. Due to the prior landslide and the ongoing risk to the existing tank, the State has emergency funding for this type of project.

Knowledge or skills gained

The project was carried out under the department's final capstone senior design course. It's a single semester intensive course, with project teams of approximately four students. The course description is "Major comprehensive design experience using the team approach. Industry practitioners provide design projects and analyze and critique results. Extends the undergraduate experience and provides the student with opportunities to analyze and design complex structures. Capstone course." Some of the elements were common to all fifteen projects carried out this academic year, and some were particular to this project.

Student projects need to meet the Engineering Accreditation Commission (EAC) of ABET requirements Criterion 5 including "Engineering design involves identifying opportunities, developing requirements, performing analysis and synthesis, generating multiple solutions, evaluating solutions against requirements, considering risks, and making trade-offs, for the purpose of obtaining a high-quality solution under the given circumstances." In addition, the projects must address the civil engineering program specific ABET EAC requirements, including "design a system, component, or process in at least two civil engineering contexts; [and] include principles of sustainability in design." (ABET EAC Criteria).

The two student teams had the opportunity to learn several important engineering tasks:

- Understanding requirements for a grant application and preparing the application
- Developing project constraints and evaluation criteria based on conversations with clients and stakeholders
- Determining which codes and standards apply, and using those in design
- Site evaluation and assessment
- Development and analysis of alternatives. The decision matrix used to compare the alternatives is shown in figure 2.

Decision Matrix				
	Weight	Alt 1-Rehabilitation	Alt 2-Stand Pipe	Alt 3-Elevated Tank
Construction Cost	35%	3	4	2
Maintenance Cost	20%	1	2	4
Sustainability	20%	1	3	5
Public/Client Opinion	10%	1	2	5
Risk/Safety	15%	1	5	5
Sum	100%	1.7	3.35	3.75
Rank		3	2	1
1 = Bad 5 = Good				

Figure 2: Project Decision Matrix

- Management and coordination of a complex project across multiple states
- Data gathering and analysis – topography, water usage data, flood plain maps, StreamStats, soil maps (USDA Soil Survey)
- Modeling water flow and pressure using EPANET software. The incoming water supply is at 140 psi. The fire hydrants on the network and the flows are shown in figures 3 and 4. The first student team developed the EPANET model, and the second team refined it further. The model was used to ensure that each fire hydrant would meet minimum flow requirements under all conditions of operation. The pins in figure 3 represent either fire hydrants or other key points for monitoring water pressure.

Figure 3: New Water Tower Site and Distribution Modeling

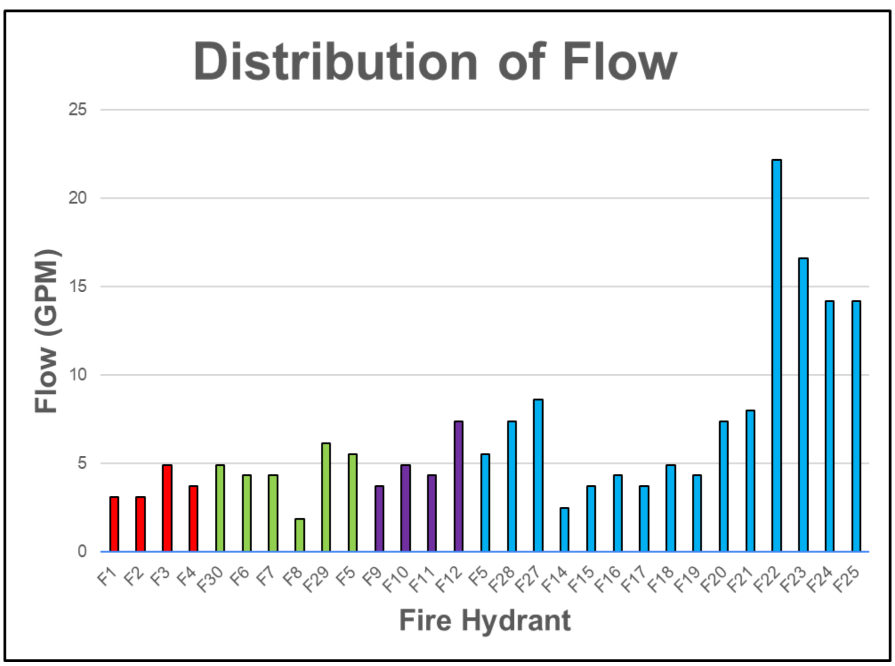

Figure 4: Results of Water Flow Modeling

- Determining head losses throughout the network. Calculated head losses are shown in figure 5. These were used to verify that the pressure and flow would be sufficient at the furthest hydrant in the system, F25.

Total Head Loss				
Fire Hydrant		Pipe Length	Flow	Head Loss
Start	End	L (FT)	Q (GPM)	h_L (FT)
F1	F2	578	15	0.07
F2	F3	527	12	0.04
F2	F4	365	7	0.01
F1	F30	1090	27	0.38
F30	F6	1091	23	0.28
F6	F7	400	18	0.07
F7	F8	378	17	0.05
F8	F9	314	13	0.03
F9	F10	493	20	0.10
F10	F11	695	11	0.04
F11	F12	913	9	0.04
F30	F5	450	7	0.01
F5	F28	926	132	6.07
F28	F27	834	124	4.82
F27	F14	2022	121	11.27
F14	F15	765	148	6.13
F15	F16	635	143	4.82
F16	F17	629	140	4.55
F17	F18	758	135	5.13
F18	F19	590	130	3.76
F19	F20	1332	123	7.62
F20	F21	841	115	4.24
F21	F22	1429	93	4.86
F22	F23	1804	76	4.25
F23	F24	1661	62	2.68
F24	F25	1828	48	1.82
		Total Head Loss		73.1

Figure 5 – Head Losses

- Application of the Institute for Sustainable Infrastructure Envision® sustainability model to a design project. It was estimated that the project would be able to attain a gold rating. Sustainability contributions were developed in the Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Resilience categories. The sustainability model is introduced during a two-hour live workshop conducted as part of the course by Firm C.
- Researching and specifying different new valves to add to the system to improve operations.
- Cost estimation. To refine the estimates, quotes were obtained from multiple standpipe and tank suppliers. This cost estimate includes all preliminary design work, the tank construction in a lump sum from the lowest vendor bid, ground site work for before and after project, and utilities to monitor and control the tank. These calculations were made using RS Means and are used in a classic risk method by using a 15% contingency on the project for any other unexpected costs in the project. The recommended water tower is shown in Figure 6.
- Communication of project results through interim and final reports. Interim reports include both written (partial final reports) and PowerPoint presentations. Final reports are presented through a two-hour poster session as well as the final 20-minute presentations and written reports. The poster session is college wide and open to the public.

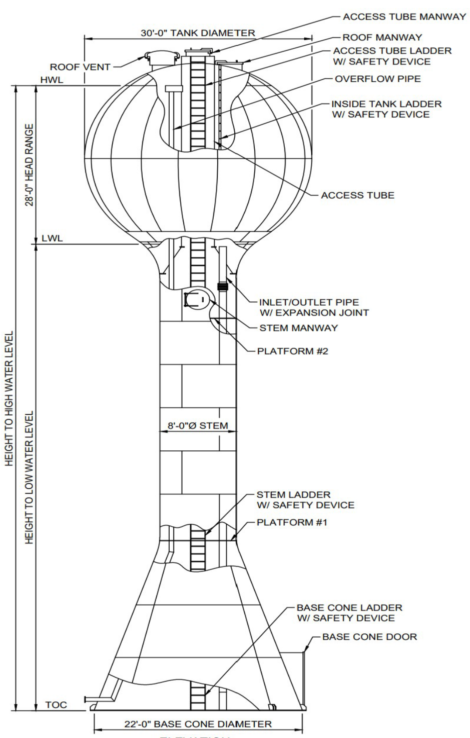

Figure 6: Recommended Water Tower