Coleman Sewer Collection System Optimization
Project ID: CEEn-2019CPST-006

by

UCR
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A Capstone Project Final Report

Submitted to

Chad Coleman
Coleman Engineering

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Ira A Fulton College of Engineering
Brigham Young University
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April 13, 2020

Executive Summary

PROJECT TITLE: Coleman sewer collection system optimization
PROJECT ID: CEEn-2019CPST-006
PROJECT SPONSOR: Coleman Engineering
TEAM NAME: UCR

Coleman Engineering is an engineering firm based in Roseville, California which deals primarily with water and wastewater systems. The Sewer Collection System Optimization project will serve as a marketing outreach to the Ironhouse Sanitary District. Coleman has historically worked with the district by working with developers and is seeking to improve the relationship between the firm and the district proper. Coleman, through this Capstone project, plans to be able to present a digitized AutoCAD file of the collection system as well as recommendations for ways to optimize the system by replacing existing lift stations with gravity options.

A PDF file exists that maps the collection system, but the electronic file used to create that map has been lost. By creating an electronic file of the system map, new developments to the region can be able to be added to the map, creating a more comprehensive file that can be updated as development occurs. A digitized map created in AutoCAD is being presented to the client with this report.

The analysis of the lift stations and presentation of recommendations for removal in favor of gravity systems is the second part of the marketing project by Coleman Engineering. The goal is to build a stronger relationship with the District and to produce a project opportunity through the requisite design work that would accompany the replacement of the lift stations. Many of the lift stations are old and were built when they were needed on the edge of development. Now that the development has surrounded the existing lift stations, the thought is that opportunities can be found to construct new gravity pipes, turning the existing wet wells into gravity sewers and allowing lift stations to be abandoned. Analysis of the sewer system in its current state suggests that several pump stations have potential for retirement, but that no replacement would be economical under current circumstances. The existing layout of the system would require extensive reorganization of sewer pipes to accommodate the removal of any pump stations, and waiting until new developments begin construction may be a better time to revisit the idea of retiring some of the pump stations.

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Introduction

The client, Coleman Engineering, has requested two deliverables which can in turn be shared with the Ironhouse Sanitary District to improve business relations. The first is a CAD file that can be used by the District to keep an easily updated file that documents the entire sewer system. The second is a list of pump stations that can be retired and replaced with gravity systems.

The recommendation report concerning which pump stations can potentially be removed will be the main deliverable, as this report has the ability to create work for Coleman Engineering. These recommendations have been determined by using engineering judgement as directed by Coleman Engineering. The recommendations are based primarily on an analysis of surface elevation data from Google Earth and pump station elevation from the provided pdf of the collection system. As these recommendations will only concern whether any of the lifts in the system can be replaced with gravity lines, an advanced analysis of fluid mechanics in the sewer system was not performed in this project. More detailed analysis based on fluid mechanics, cost effectiveness, and other factors may be performed by Coleman Engineering to evaluate the existing recommendations. These recommendations are listed in the "Design, Analysis, and Results" section of the report.

Creating a CAD model of the sewer system in Civil 3D constitutes the second deliverable to Coleman Engineering. Because no local governmental organizations were able to provide a base map CAD file for use within the model, in order to create a usable map the pdf pages themselves were uploaded, arranged, and cleaned up in Civil 3D according to direction from Coleman Engineering. The CAD file is being submitted to Coleman Engineering with this report.

Schedule

To ensure steady progress and reinforce accountability, team meetings were held weekly, and meetings with Coleman Engineering were held about twice each month. The frequency of these meetings allowed for more frequent adjustments in the approach to the project instead of large, periodic changes. Additional status reports were submitted weekly, with this final report being submitted in April 2020. Meetings with faculty advisors were held as needed for support in certain technical aspects of the project.

Key project activities and milestones and the corresponding dates were as follows:

-Met with representatives of Coleman Engineering and faculty mentor to discuss the overview of the project on September 30, 2019.

-Met with Steven Sowby, a local professional engineer that has worked extensively in water resources, to discuss general details and factors to consider when optimizing a collection system on October 28, 2019.

-Met with the CAD/Revit professor at Brigham Young University, Jeremy Dye, to discuss options for digitizing the collection system map on November 18, 2019.

-Confirmed that Contra Costa County and other local government agencies were unable to provide a usable CAD base map for use in the digitization of the collection system by December 10, 2020.

-Completed tabulation of pump station and force main elevation data as provided in the provided pdf of the collection system by January 14, 2020.

-Completed tabulation of surface elevation near each pump station as displayed on Google Earth by January 28, 2020.

-Determined the best approach for creating the CAD map after concluding that no usable geographic data was available by February 3, 2020. The chosen approach was to upload each page of the pdf into an AutoCAD file and arrange them accordingly.

-Uploaded all pages of the pdf into AutoCAD by February 21, 2020.

-Identified the pump stations that could be replaced by gravity stations by March 23, 2020. This task was completed independently of the progress on the AutoCAD file. Existing information regarding the location and elevation data throughout the sewer system as well as engineering judgement were used to make the appropriate recommendations.

-Cleaned up and finalized the AutoCAD map for submission by April 13, 2020.

-Prepared the final report on the overall project by April 13, 2020. The final report includes an oral presentation summarizing the work conducted during the project and a poster detailing the results obtained.

Assumptions & Limitations

The digitization of the Ironhouse Sanitary District sewer collection system is based upon the schematic provided by Coleman Engineering, which is also available on the District website. Elevation data in the proposed AutoCAD digital map was derived from the information provided in that document.

The recommended optimization of pump stations is dependent on ground surface elevation, downstream elevation, and belowground pump station elevation. It is suggested that a Professional Engineer review other aspects of this optimization further. Factors such as energy, cost, maintenance, profitability, and environmental impact are worth considering, but they are outside the scope of the project and were not considered in this evaluation of the sewer collection system.

The final AutoCAD file submitted to the team is not a completely accurate rendering of the geography and land usage in Oakley, the region covered by the Ironhouse Sanitary District. The information included in the file is limited to the information provided in the District's pdf of the system, including pipe material, diameter, and length, elevations, pump station locations, land parcels, and pipe locations. No data is stored in the lines representing the pipes or in any other features of the AutoCAD file, but are instead represented by labels adjacent to the corresponding features. Some data was not included in the pdf file, and that data was therefore not included in the AutoCAD file.

Design, Analysis & Results

In order to provide recommendations for which pump stations could potentially be removed and replaced with gravity systems, the provided collection system pdf was analyzed. Elevation data of the pumps and surrounding gravity lines and force mains, provided within the pdf, was recorded, as well as surface elevation data taken from Google Earth. Using this data as a starting point, engineering judgement was used to study each pump station individually to determine if the station could be removed now or in the future, as per the direction of the client. The results of that study can be seen below, being organized by alphabetical order according to pump. Pumps with potential for replacement or improvement in the future have their names highlighted in yellow.

Pump Name: BIP

This station needs more information. It seems a little unnecessary to have an extra pump station in place that is fed by a different pump station and eventually meets up with the other force main created by the pump that feeds it, as shown in Figure 1. However, this may be in place because past expansions required adding capacity but upsizing the existing force main was not a viable option. BIP feeds into the long force main that goes most of the way across the system to feed the water treatment plant. However, this area is pretty lightly developed and it may be easier to do work on.

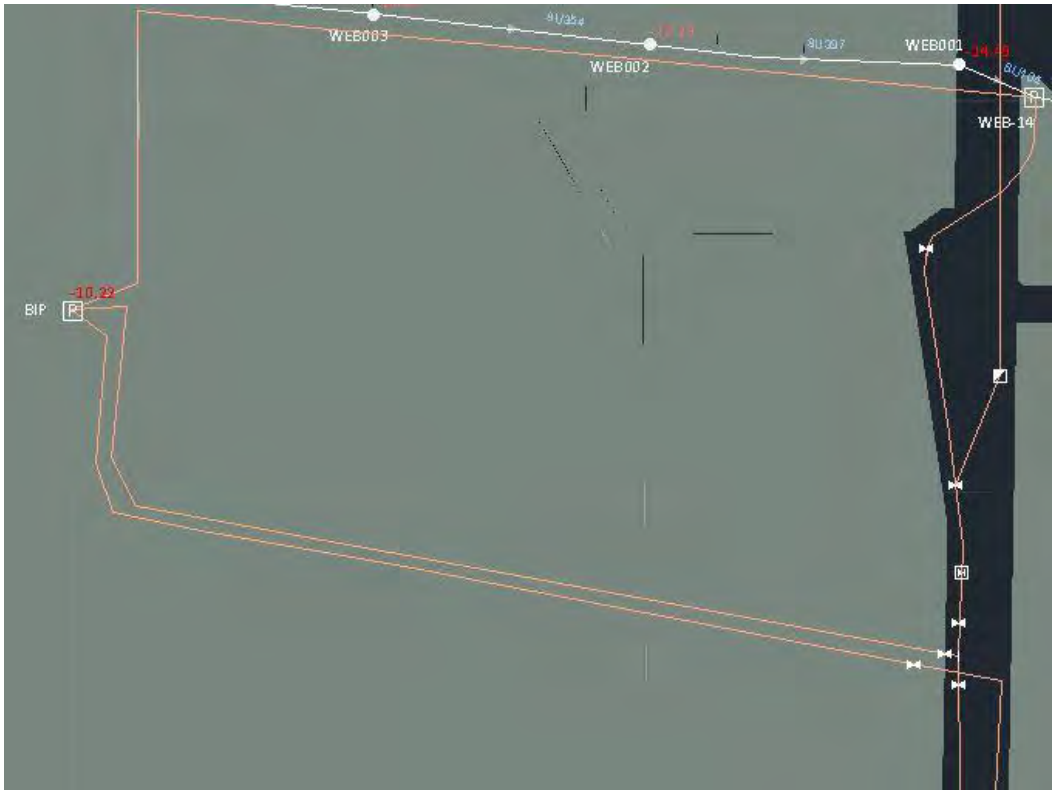

Figure 1: BIP and WEB-14 Pump Stations

Pump Name: Bridgehead

This pump could potentially be removed if the Lauritzen Pump Station force main was extended to cover the force main line of the existing Bridgehead Pump Station. However, as both

the Bridgehead and Lauritzen Pump Stations sit at the end of development, both stations could be kept as a way to prepare for future development in the area.

Pump Name: Cypress Grove

The Cypress Grove pump station services all developed areas surrounding it. There are no nearby gravity lines that do not flow into the pump station, and at this point there is not enough development to look at alternative solutions. This pump station cannot be removed.

Pump Name: D-13

This station cannot be replaced without leaving the sewer over 20 feet underground, which would be much more impractical than leaving the pump station in place. It provides about 9 feet of head that probably can't be provided by a gravity line.

Pump Name: G-1

The way the gravity pipes feed into the pump station is a little odd, but it doesn't seem like the pump station can be removed right now.

Pump Name: G-2

This pump station probably cannot be removed, but the difference here is only about 1 foot, and there may be sufficient head to continue flow because it is being pumped such a short distance.

Pump Name: GW-3

This station cannot be removed.

Pump Name: Hoffman

The Hoffman Pump Station services a highly developed area and is fed by three different gravity lines. The elevation at the beginning and the end of the force main is not such that the pump station can be removed.

Pump Name: HW-12

It seems like this station can't be replaced. It is fed by three different gravity lines, and only one might have rerouting as an option, while the other two lines seem like they are dependent on the presence of a lift station.

Pump Name: Ironwood

The force main connected to the Ironwood Pump Station services the southern half of the development, where Hoffman services the northern half. The force main for Ironwood could potentially be dramatically shortened by redirecting the flow to the gravity lines that eventually flow into the Hoffman Pump Station. However, this would not completely remove the need for the Ironwood pump, and it would put greater pressure on the other lines, whose capacity might not be great enough to support the increased flow. Thus, it would be better to leave the Ironwood Pump Station as is for now.

Pump Name: Laurel Heights

This is in a fairly undeveloped area, so at this point the system cannot support the pump station being removed to be replaced with a gravity line.

Pump Name: Lauritzen

The Lauritzen Pump is located at the end of the current development, and cannot be removed at this time as the system stands.

Pump Name: Marsh Creek

The Marsh Creek Pump is on the edge of development, with a subdivision to the north and south, but it sits in the middle of nowhere. As the current system stands, it cannot be taken out. The force main line could be shortened by connecting Marsh Creek Pump Station up to the gravity line at Sierra Trail Rd, however that course of action might be more expensive than it is worth, since the pump cannot be removed.

Pump Name: MPS

This station meets up with the BIP and WEB-14 pump stations. It seems like it might be replaceable if 1) it can feed into WEB-14 as a gravity line and 2) WEB-14 has the capacity for increased flow taken from the lines that used to feed the MPS station.

Figure 2: MPS and WEB-14 Pump Stations

Pump Name: P-10

This station cannot be removed.

Pump Name: Quail Valley

Quail Valley Pump Station which works in a highly developed area and is fed by three gravity lines. The gravity lines in this area are isolated from all other parts of the collection system,

with the only connection being the force main of the Quail Valley Pump Station. All gravity lines of the connect system feed to a point lower than 8.67 feet according to the collection map, which means that the force main cannot be replaced by gravity line when looking at the other gravity lines.

Pump Name: S-8

It seems like this station is mostly necessitated by the line coming in from the east. Otherwise, this one could probably be replaced. However, the gravity line from the east does not appear to have viable options for rerouting.

Pump Name: S-9

This station cannot be removed.

Pump Name: SM-15

This station cannot be changed. There is a 10-foot elevation increase between the lines at the pump station and the final elevation of the force main.

Pump Name: SM-16

This station cannot be changed. However, with further development, this route could go southwest towards the treatment plant instead of looping north.

Pump Name: Summer Lakes 1

This station looks like it services about half of the subdivision, and therefore probably can't be removed.

Pump Name: Summer Lakes 2

This station cannot be removed.

Pump Name: Summer Lakes 3

This station might be redundant. It gets fed by the Summer Lakes 1 and Summer Lakes 2 pumps. It could become necessary if more development takes place, but it doesn't seem like it is necessary with regards to the elevations of the existing lines. Other factors like pressure may play a role, but this station might be replaceable.

Pump Name: T-5

This station is in a relatively undeveloped area (just one road with houses on one side). Both sides of the line running into the pump station are at noticeably lower elevations than the end of the force main. It is probably good for this station to stay, if anything it will need to be expanded in the future if the area develops.

Pump Name: T-6

The T-6 Pump is located at the end of the current development, and cannot be removed at this time as the system stands.

Pump Name: T-7

The T-7 pump is very short, and it appears that its main purpose is to prevent the gravity line from being below -20 feet. The pump brings up the gravity line a few feet so that it may continue to flow without going too far underground for reasonable maintenance.

Pump Name: W-4

This station cannot be removed.

Pump Name: W-11

This station seems like it cannot be removed. More information regarding the elevation of the pump would be necessary to make a more educated conclusion.

Pump Name: WEB 14

This is probably the main line feeding into the other side of the map. If it can handle an increase in size, that might allow for the removal of the BIP and MPS pump stations. However, it's difficult to tell what occurs between the three stations, and why they were all put in place to begin with. There are also lots of valves, which suggests that all three stations are in place to allow for adjustment between different flow rates over long distances. The BIP station might also be a backup pump, in which case replacing it would not be advisable. If the pdf provided by the district is accurate, the force mains also run underneath the road, so any major replacements would be difficult.

Pump Name: Willow Park Marina

The purpose of this pump station is somewhat ambiguous. Lines run down to the pump, which then pumps to a lower elevation. Based on the pdf, it looks like there may be a 1-foot elevation increase, but more detailed geography would be needed to make final conclusions.

Lessons Learned

Throughout the course of the project, the team members had the opportunity to work through challenges in order to digitize and optimize the sewer collection system. The first hurdle to overcome was the need for a basemap. In order to accurately map the sewer system, geographic references for the collection system that could provide latitude, longitude, and elevation data were preferred. The project sponsor suggested looking to the Contra Costa County GIS website for that information. Although the County Assessor's office had published parcel shapefiles, there were no files compatible with AutoCAD, Civil 3D, or ArcMap. Significant time was spent on the phone with various government departments in attempts to see if there were other file options that could serve as a basemap with minimal success. The team was eventually directed to the city of Oakley itself and emails were exchanged with various city employees, but no progress was made towards locating basemap files.

Next, Jeremy Dye, the BYU AutoCAD and Revit professor, was contacted. Options were discussed for how to create a basemap file using a combination of the PDF files of the system, Google Earth, and Google Maps. The team spent time working together in AutoCAD and Civil 3D to learn how to use the software and, more specifically, how to combine these files to create a surface for Civil 3D. It was confirmed again that none of the files on the Contra Costa County GIS website provided the necessary information. During this time the team also learned how to add a geographic data point with latitude and longitude, insert a map, and add PDF files into AutoCAD to create the needed basemap. This process of discovering how to obtain a basemap for the digitization portion of the project has allowed the team to learn about communicating with various agencies and disciplines as well as moving forward when original plans don't work out.

Another challenge the team experienced and overcame was the problem of optimizing the system. Before this project, the members of the team had very little experience with water resources. To help overcome this lack of experience, a meeting was held with a local water resources engineer, Steven Sowby, to discuss how to approach a sewage optimization project. The assumptions and limitations of the project were discussed, as well as general information on sewer systems. The understanding gained in this meeting enabled the comparison of elevations at the pump stations and the downstream ends of the force mains throughout the whole system. As optimization opportunities throughout the system have been analyzed, understanding of sewer system operations and constraints leading to inefficiency have been more fully understood by the team.

The largest lesson the team had the opportunity to learn was that of using engineering judgement. After reviewing the tabulated elevation data, it was determined with Coleman Engineering that it was not readily evident if any of the pump stations could be removed. The team was directed to go back through each pump station individually and analyze the potential for removal using the tabulated elevation data of the pump station in question, the elevation data of the existing surrounding gravity lines, the current development state as viewed via Google Earth, and personal judgement. The team viewed this opportunity as extremely valuable as it allowed them to work within the more subjective side of engineering. School work typically deals with the concrete aspects of the field, but this project did not necessarily have a right answer, instead the best solution had to be determined by looking at the data as a whole, discussing possibilities, and using

engineering judgement to make a decision. This practice with exercising professional judgment will be valuable as each team member will be entering the workforce soon.

Conclusions

Current analysis of the Ironhouse Sanitary District system suggests that most of the existing lift stations are necessary to maintain functionality. Based on the existing layout of the sewer system and the available elevation data, most of the stations are necessary to provide sufficient head to reach the water treatment plant. Though a detailed economic analysis was not conducted, it is expected that changes that would be necessary to phase out the pump stations in favor of gravity lines would cost more money and effort than they would save. Several pump stations have been identified that could be retired with less impact on the overall system, though a more detailed analysis would be necessary to determine the benefits of doing so. The pump stations identified, the BIP, MPS, Summer Lakes 3, and Willow Park Marina stations, either occur in areas where there is minimal elevation change in the system or are in parts of the system where multiple pumps are functioning in close proximity.

Recommendations

The main recommendation is to address the broader scope of optimizing the pump system, which would include having a Professional Engineer evaluate energy, cost, maintenance, profitability, and environmental impact. The locations that are most likely to require these analyses are the BIP, MPS, Summer Lakes 3, and Willow Park Marina stations. Obtaining additional data from the Ironhouse Sanitary District would be important to determine the usage of those stations and how their removal would impact the overall system. Based on the analyses already performed, at some point the four stations listed may have potential for retirement, but that cannot be conclusively determined until further data is gathered. As mentioned previously, these pump stations have been recommended based primarily on available elevation data.

Appendix A

MELISSA A. COWLEY

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EDUCATION

Brigham Young University *April 2020*
B.S. in Civil and Environmental Engineering
Recipient of Women in Engineering and Technology Mentorship Award August 2016

TECHNICAL STRENGTHS

Technical Knowledge CMS, liquefaction settlement, lateral spread, seismic slope stability
Software & Tools Settle3D, SeismoSignal, SeismoMatch, MS Office, ArcGIS, NGA West 2

EXPERIENCE

Geotechnical Engineering Intern April 2019 - Present
Kleinfelder, Inc.

- Performed geotechnical field work such as logging explorations, settlement instrumentation (vibrating wire systems) under embankments, and piezometer monitoring during excavation
- Designed soil profiles and settlement models based on design criteria determined by analyzing exploration and laboratory data
- Selected samples for laboratory testing based on exploration logs and desired outcomes of explorations
- Worked on multiple phases of design-build projects including explorations, assisting in writing design reports and proposals, addressing client comments, and field observation

Soil Mechanics Teaching Assistant January 2019 - Present
Brigham Young University

- Instructed nine students in structured laboratory exercises on a weekly basis
- Demonstrated and taught laboratory analyses including consolidation, mechanical sieve, hydrometer, Atterberg limits, compaction, sand cone, direct shear, unconfined compression
- Assisted students in writing, formatting and making plots for technical lab reports
- Lead weekly writing groups to help students improve writing

Concrete Canoe Head Captain/Project Manager June 2018 - Present
Brigham Young University ASCE Student Chapter

- Delegated a team of 20 plus students in hull and mix design, mix analysis, construction, paddling, aesthetics, fund raising and technical writing
- Performed laboratory analyses including compression, splitting tensile, flexural strength, unit weight, and slump tests
- Spearheaded writing technical design paper by logging progress and practiced time management to reach deadline

ACTIVITIES

Women in Engineering and Technology Mentor August 2017 - Present

- Introduced 3 women new to the civil engineering program and helped them through freshman year

American Society of Civil Engineers (ASCE) Student Member November 2017 - Present

Katri R. Remson

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EDUCATION

Brigham Young University **Provo, UT**
Bachelor of Science in Civil Engineering and Minor in Mathematics Dec 2020

- **Cumulative GPA:** 3.96/4.00
- Four-year full academic scholarship
- Relevant Course Work: Drafting, Fluids and Hydraulics, GIS, Hydrology, Soils, Structural Analysis, Transportation Engineering
- American Society of Civil Engineers, BYU Chapter (Aug 2015-April 2016, Aug 2018-current)

EXPERIENCE

WSP **Salt Lake City, UT**
Structural Engineering Intern – Bridge Team May 2019 - Aug 2019

- Utilized Microstation to create and revise sheets within four different bridge plan sets, two different overhead sign structure plan sets, and a retaining walls plan set
- Performed review procedures applying UDOT standards and specifications
- Analyzed moments and deflections of a sign structure using SAP
- Created and managed Mathcad template to perform data analytics for multiple bridges
- Used VBA in Excel to optimize analysis of projects throughout the country to look at trends in profitability of various project types, contractors, delivery types, and owners
- Authored seven project summaries of Asset Management projects for company archive
- Wrote VBA code to analyze success of contractors, designers, and project type profitability for design build projects in Texas
- Investigated and analyzed sources of disparities between calculation sets and plan sets

Pavement Construction and Design Research Group (BYU affiliate) **Provo, UT**
Research Assistant Aug 2015 - Apr 2016, Jun 2018 - current

- Prepared aggregate base materials for laboratory aggregate frost-heave testing
- Investigated structural capacity of geogrid-reinforced aggregate base layers in flexible pavement
- Performed chloride concentration testing of concrete bridge deck samples
- Assisted with freeze-thaw testing and wet-dry testing of 24 samples of clay sample mixed with varying percentages of lime or concrete to determine added strength to the subgrade before road construction
- Created and managed data analytics procedures for various projects

TECHNICAL SKILLS

- *Drafting:* Proficient in Microstation, Familiar with AutoCAD and Revit
- *Calculation/Analysis:* Mathcad, SAP
- *Microsoft Office:* Excel, Visual Basic for Applications within Excel, Word, PowerPoint

James Umphress

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EDUCATION

Brigham Young University Apr 2021
B.S. Civil Engineering Provo, UT

- GPA: 3.89
- Mandarin Chinese Minor
- Member of ASCE for 3 years
- Member of BYU chapter of Tau Beta Pi
- University ¾ tuition scholarship recipient

SKILLS

- AutoCAD, including Civil 3D
- Microsoft Office (Word, Excel, Project)
- Technical writing

EMPLOYMENT EXPERIENCE

Weber Basin Water Conservancy District May 2019-Aug 2019
Engineering Intern Layton, UT

- Designed VBA-coded Excel spreadsheet to assist in managing district reservoirs
- Assisted in creating an inventory of district water meter vaults using AutoCAD
- Organized district documentation for completed projects

Oahu Psychological Services Sep 2013-Jul 2015, Jul 2017-Present
Editor Aiea, HI

- Review data and grammar in psychological evaluation reports written by five psychologists
- Promptly return 2-5 reviewed reports weekly, including reports issued on short notice
- Streamline company documentation system by organizing over 10 years of digital records

VOLUNTEER EXPERIENCE

BYU Concrete Canoe Team Jul 2019-Present
Project Manager Provo, UT

- Create project schedule and oversee completion of project milestones
- Manage team budget and organize fundraising efforts
- Spearhead team recruitment efforts and training of new team members

Compliance Officer Jul 2018-Jun 2019

- Coordinated with project managers to ensure that five team captains follow project schedule
- Ensured OSHA compliance by updating lab safety information
- Assisted in composition of 26-page comprehensive design paper
- Oversaw thorough documentation of team meetings and design decisions
- Presented on canoe design process to panel of engineering professionals

The Church of Jesus Christ of Latter-day Saints Aug 2015-Jul 2017
Full-time Representative, Illinois Chicago West Mission Illinois, USA

- Organized and coordinate community events with local businesses, churches, and colleges
- Volunteered weekly with local charitable organizations and churches of other faiths
- Increased missionary productivity in five areas through improved planning and hard work