February 20, 2017

Jared Penrod, EIT
City of Orem
56 North State Street
Orem, Utah 84057
(801) 229-7331

Dear Jared Penrod:

We are very grateful for the recent meeting in regards to the Soil Data Percolation App Development. We have readjusted the project scope based on our discussion. We hope to exceed your expectations and we are devoted to your satisfaction.

Please look over the 50% report enclosed and feel free to contact us regarding anything that you see fit to mention. We appreciate this opportunity and look forward completing the project soon.

With warm regards,

SWL Engineers
Alex Arndt
Cameron Lusvardi
William Shelton
Jacob Wadman

clusvardi@gmail.com
(801) 745-7357

Enclosed

# SOIL DATA PERCOLATION APP DEVELOPMENT
# CEEn-2016CPST-002

**By**

**SWL Engineers**
**Alex Arndt / Project Manager**
**Cameron Lusvardi / Team Lead**
**William Shelton / Task Lead**
**Jacob Wadman / Task Lead**

**A 50% Report for the Capstone Project submitted to**

**Jared Penrod**
**City of Orem**

**Department of Civil and Environmental Engineering**
**Brigham Young University**

**Feb 20, 2016**

# Executive Summary

**PROJECT TITLE:** Soil Data Percolation App Development
**PROJECT ID:** CEEn-2016CPST-004
**PROJECT SPONSOR:** Jared Penrod, City of Orem
**TEAM NAME:** SWL Engineers

The following report contains the current progress and updates towards the requested soil data percolation application. The desired outcome of the spreadsheet application has been dissolved into individual tasks which will contribute to a user friendly interface. Each task has been organized in the spreadsheet and further development is underway. The primary inputs of the application are storm type, areas with corresponding C values, available detention design area, soil type and ground water table. Additional inputs are system design specific and will be defined under each system's sheet. The systems available to choose from will be Storm Chambers, Swales, Sumps, R-Tanks, Groundwater Trenches and Vertical/Horizontal Perforated Pipes. A few of the expected outputs from the application will be the maximum detention available, detention volume over time, suggested detention design and determined percolation rates.

In regards to our recent discussion about percolation rates for Orem, UT, soil data was extracted from the United State Geological Survey (USGS) to examine the correlations between infiltration rates and soil types that were presented in the provided soil reports. Currently, further research is underway to determine reliable infiltration rates for varying soil types but conservative rates used in prior investigations are is cited herein. These correlations between the provided soil reports, USGS soil data, and conservative percolation rates look great.

The soil data percolation application project has progressed on schedule and completion is expected by April 10, 2017. The team has overcome many obstacles such as determining the best approach to the lack of percolation data for Orem, UT, bringing the team together by clarifying the scope of the project, lack of education and code for storm system design, and learning how to predict the design life for the indicated stormwater systems. The schedule has undergone minimal changes and no further adjustments are expected for the duration of the project.

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# Introduction

Currently, Orem City has a few applications that are mildly used in the design process of sumps. However, these applications are limited in their application and do not take into consideration percolation, various stomwater systems or multiple storm events when detention systems contain leftover runoff. Another problem of the current applications is that they do not account for the buildup of sediment inside the detention system yielding a diminishing return.

The Project that the SWL Engineers will complete for the City of Orem is the development of a spreadsheet application capable of comparing different stormwater detention devices primarily R-Tanks, Sumps, Swales, Horizontal and Vertical Redistribution Pipes and Doghouses. The team consists of Alex Arndt as the project manager, Cameron Lusvardi as the application specialist, William Shelton as the ArcGIS specialist, and Jacob Wadman as the data analysis and technical writing specialist.

The project began in January of 2017. The City of Orem has provided the city IDF curve, current available percolation data, and soil reports to the SWL Engineers for use in the project. The soil data has been analyzed and compared with USGS soil data. The research on the various stormwater detention devices and equations has been completed. Application development began on February 6 and will continue through March 24, 2017. The SWL Engineers will deliver the final product as an Excel spreadsheet application. A final report, presentation, and poster will be included with the application and all items are to be delivered by April 10, 2017 to the sponsor and Capstone Committee. Between January and April 2017, monthly progress reports have been and will continue to be shared with the sponsor to aid in accounting for the progress of the project and to identify any issues that the team may have encountered.

This 50% report includes a brief project description, current project limitations, obstacles encountered, proposed solutions and updates to the project schedule.

## Project Description

The Project that the SWL Engineers will complete for the City of Orem is the development of a spreadsheet application capable of comparing different stormwater detention devices primarily R-Tanks, Sumps, Swales, Horizontal and Vertical Redistribution Pipes and Doghouses. This will be accomplished by using correlations between percolation rates and soil types, interpolating the city's Intensity Duration Frequency (IDF) curve, and collating the calculations into a spreadsheet capable of designing the various indicated stormwater systems. The City of Orem has provided the city IDF curve, current available percolation data, and soil reports to the SWL Engineers for use in the project. The soil data has been analyzed and compared with USGS soil data. The excel spreadsheet application will be built to analyze the efficiencies and capacities of stormwater retention devices by referring to the user inputs and will be capable of calculating detention volume over time, percolation rates over time, and determining max storage for 1+ storms.

The desired outcome of the spreadsheet application has been dissolved into individual tasks which will contribute to a user friendly interface. Each task has been organized in the spreadsheet and further development is underway. The primary inputs of the application are storm type, areas with corresponding C values, available detention design area, soil type and ground water table. Additional inputs are system design specific and will be defined under each system's sheet. The sheets available to choose from will be named as Storm Chamber, Swale, Sums, R-Tank, Groundwater Trench, Vertical/Horizontal Perforated Pipe and Multi System. A few of the expected outputs of the application will be the maximum detention available, detention volume over time, suggested detention design and determined percolation rates. These outputs will be displayed on the Home sheet along with each system's sheet.

The USGS data has been beneficial due to the correlations between the soil reports and soil data. A map will be put together to aid the user in selecting the soil type which will determine the correct percolation rate based on researched relationships. The input of soil type will be used in the user-friendly application to help calculate the capacities and efficiencies for the various storm water detention devices in any location of the city.

The deliverables to be produced by SWL Engineers are the soil data percolation spreadsheet application, soil percolation database, a final report, detailed instructions on how to use the application, and a final presentation of the project on or before April 10, 2017.

## Project Limitations

The results of this project are limited to areas along the gravel belt on the eastern side of the city and outside of well protection zones. Other locations around the city which have soils with a high proportion of silt and clay decrease the infiltration rate. This will limit the effectiveness of the percolation outflows in the detention design. Although the application will consider the soil type, this does not tackle the main purpose for the proposed project.

Other limitations of the project include the assumptions in code or criteria for the systems. Information such as thickness of concrete or length of pipe will need to be correctly accounted for by the construction engineer. All coding for the application will be done "in-cell" and not performed by macros or visual basic such that if alterations need be performed, anyone with moderate excel experience will be able to make the adjustments.

Limited education as to the correct time of concentration, design life, detention holding time and infiltration may give bias to the results of the application. Only those equations researched and provided by professors will be supported in the initial draft.

# Current Obstacles and Project Progress

The project is currently on schedule and most of the major obstacles have been overcome. The first few weeks of the project consisted of research into the various storm water detention systems. Cameron performed research on R-Tank design, William Shelton researched Storm Chamber design, and Jacob Wadman researched Sump design. Each team member examined and analyzed the current spreadsheets used by the city in order to understand the design methodology implemented. Ideas were shared amongst the team on how to incorporate the infiltration and percolation rate data into the design equations.

After sufficient research was performed, analyses of the geotechnical reports began and a draft of the spreadsheet was created. The NRC soil data was collected from USGS and collated into Geographic Information Systems (GIS) software.

A meeting was scheduled with the project sponsors to discuss the progress on the project and to seek answers to additional questions that arose during the research and organizational phase of the project. The meeting also ensured that main assumptions made were deemed acceptable. The scope was redefined and the application development phase of the project could then move forward.

## Obstacles Encountered

Upon the receipt of the soil data from Orem City, the geotechnical reports were divided into three groups. Each team member received a group of reports to read and analyze in order to extract data pertinent to the project. In all of the reports received, only three percolation rates were given. Thus, the data necessary to compile a proposed database was absent.

Additionally another obstacle to overcome was the lack of expertise in the subject matter and a seemingly unclear project scope due to the lack of data, equations and correlations.

During the research phase of the project, an absence of policy and design standards for the design of storm water detention systems created another obstacle. Only one official stormwater system design for a city was found.

The inputs and outputs of the application also served as an obstacle. The goal of the spreadsheet was to assist in the design of storm water detention systems in a user-friendly manner. This requires a limited amount of inputs. Too many inputs may overwhelm the user. Additional equations were needed to connect each aspect of the design.

Lastly, another issue about the project is determining the design life of the various systems. Over time, the course soil fill surrounding the systems is clogged by fines which lowers the percolation rate. There is currently no method in place to model the decrease in infiltration over time experienced by such systems.

## Solutions to Obstacles

The absence of data made the creation of a percolation database unfeasible for a capstone project. A new method or source of data was required. First, an attempt was made to find other parameters in the geotechnical reports that could be correlated to the infiltration rate. The parameters that were explored were soil type, hydraulic conductivity, moisture content, void ratio, and particle size. All of these parameters indeed can be correlated to infiltration rate generally but not in a way that can be calculated easily. Out of all of the soil parameters explored, soil type was found to be the best fit for the purposes of the project. A table of minimum infiltration rates related to soils was found (Wanielista). This stimulated an interest into additional tables which are currently being received from a hydrology professor at Brigham Young University. To understand the layout of different types of soils for Orem City, a GIS map of soil types was developed and is shown in Figure 1. This map can be related to the minimum infiltration rate table shown in Table 1.

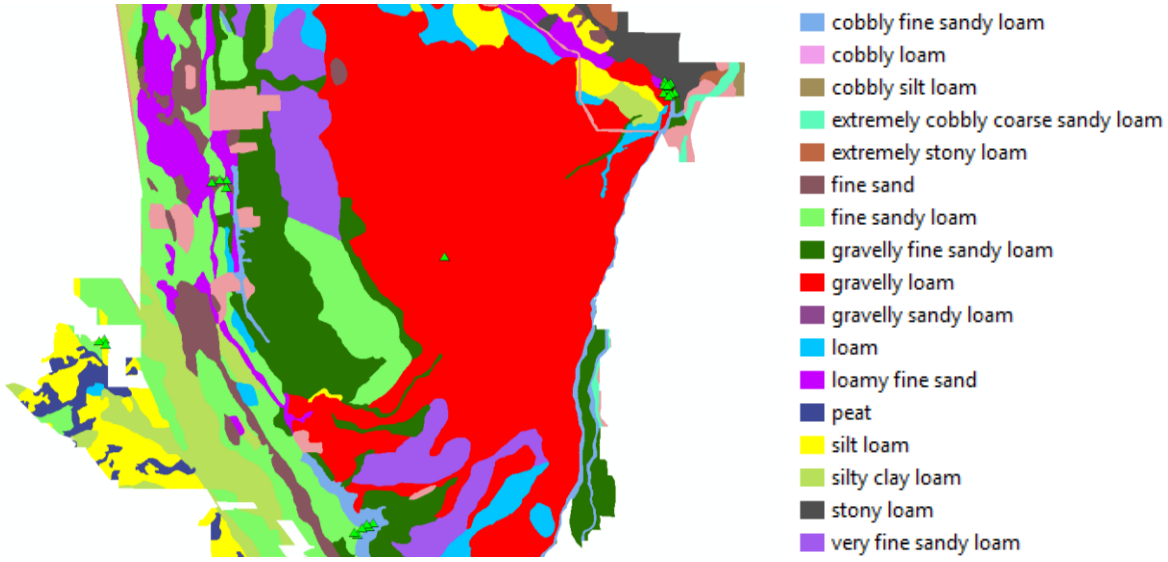


***Figure 1: Map of Soils by Type within Orem City Limits***

***Table 1: Minimum Infiltration Rates by Soil Type***

| Texture class | Effective Water Capacity (in./in) | Minimum Infiltration rate ($f_c$) (in./hr) | SCS Hydrologic Soil Grouping |
|---|---|---|---|
| Sand | 0.35 | 8.27 | A |
| Loamy sand | 0.31 | 2041 | A |
| Sandy loam | 0.25 | 1.02 | B |
| Loam | 0.19 | 0.52 | B |
| Silt loam | 0.17 | 0.27 | C |
| Sandy clay loam | 0.14 | 0.17 | C |
| Clay loam | 0.14 | 0.09 | D |
| Silty clay loam | 0.11 | 0.06 | D |
| Sandy clay | 0.09 | 0.05 | D |
| Silty clay | 0.09 | 0.04 | D |
| Clay | 0.08 | 0.02 | D |

* *Source:* Rawls et al., 1982

The previously mentioned gravel bar can be clearly seen in Fig. 1 shaded in red. As the map moves westward toward Utah Lake the gravel and sand becomes clay and silt. As stated in the project limitation section of this report, the results of this project are limited to areas along the gravel bar where the infiltration rates are conducive to the use of Sump, R-Tank, Storm Chamber, and other designs. The values that are described in Table 1 are the minimum infiltration rates by soil type in inches/hour. The values that will be encountered in the field are likely to be higher than these values making them highly conservative. A method to find a multiplier for these values in order to have a more average value is currently being investigated along with additional tables.

The lack of policy regarding the design of the detention systems lead the team to, instead, investigate the preexisting design criteria and methodology already in place. This was done using the existing excel applications as a guide. The examination of the preexisting applications also rendered numerous ideas into the organization of the finished application. Addition criteria about the designs were clarified in the recent meeting with Orem City.

The issue in determining the design life of the systems has not yet been solved. Over time, the ability of a detention system implementing soil percolation to introduce stormwater directly into the soil diminishes at a currently unspecified rate. A method or reasonable assumption for defining the diminishing return is being investigated in order to overcome this obstacle. Based on a comment from the recent meeting with Orem City, typical sumps gain about 2 feet of fine sediment over a few years. Working with an environmental professor at Brigham Young University could aid in finding the solution to this problem.

## Schedule

The project schedule has undergone minimal changes. The original project schedule which is still being used is shown below in Figure 2. The team will continue to spend 8 hours a week per student with at least 3 hours a week working together. Weekly meetings are being held to account for the work individually performed, to converse about problems encountered, and to create action plans to keep the project on schedule.

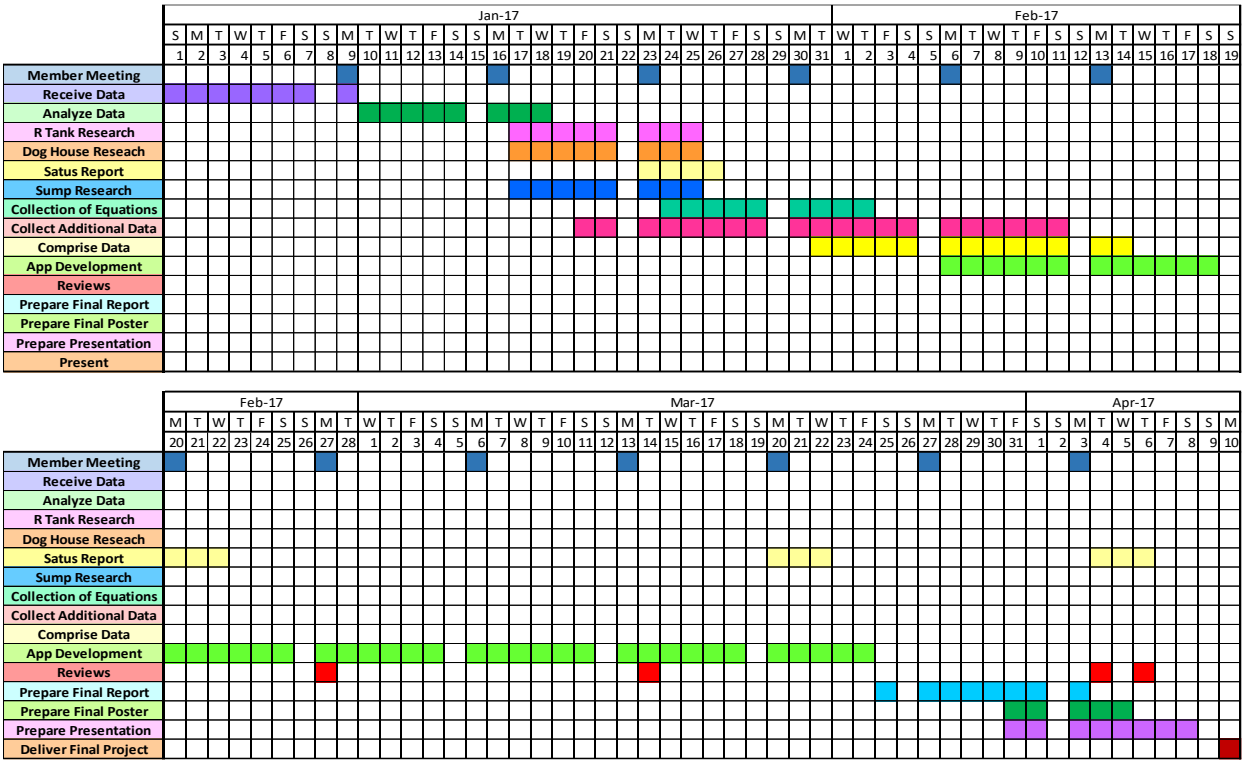


***Figure 2. Original Project Schedule***

The only change to the schedule was the elimination of the collection of additional data. Due to the lack of recent percolation data and difficulty to obtain percolation data for the whole city, the solution has changed to using a table for the percolation rates based on soil type. Since there was only one elimination from the main schedule Figure 2 doesn't represent that change. The second half of the project plan includes the Application Development phase, Final Report, Presentation and Poster Phase and finally delivering the Project.

# Summary

The report contained the current progress and updates towards the requested soil data percolation application. The desired outcome of the spreadsheet application has been dissolved into individual tasks which will contribute to a user friendly interface. Each task has been organized in the spreadsheet and further development is underway. The primary inputs of the application are storm type, areas with corresponding C values, available detention design area, soil type and ground water table. Additional inputs are system design specific and will be defined under each system's sheet. The systems available to choose from will be Storm Chambers, Swales, Sumps, R-Tanks, Groundwater Trenches and Vertical/Horizontal Perforated Pipes. A few of the expected outputs from the application will be the maximum detention available, detention volume over time, suggested detention design and determined percolation rates.

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# Appendix A

## Team Credentials

**Alex Arndt**

Project Manager
BS in Civil Engineering, BYU
Geotechnical Engineering experience with Gerhart Cole INC.

**Cameron Lusvardi**

**Excel Specialist**
Team Lead
Liaison between the Team and the Sponsor
Task Lead
App Development, R-tank Research
Relevant Coursework
CEEn 270 Computational methods
Relevant Work Experience
Teaching Assistant for CEEn 270 Computational methods
Managerial experience with TRACO Manufacturing
Research Assistant for Dr. Kyle Rollins

**William Shelton**

**ArcGIS Specialist**
Task Lead
GIS mapping, Dog-house Research
Relevant Coursework
CEEn 414 Engineering Applications of GIS
CEEn 270 Computational methods
Relevant Work Experience
Experience with water facilities
Engineer in Training with Redwood Engineering
Research Assistant

**Jacob Wadman**

**Data Analyst and Technical Writer**
Task Lead
Data Analysis, Report Building, Sump Research
Relevant Coursework
ENGL 316 Technical Writing
CEEn 270 Computational methods

**Norman Jones, Ph.D.**
Project Faculty Advisor
Professor for Seepage and Groundwater Modeling

## References

Rawls et al., (1982). "Estimation of Soil Water Properties." ASAE Transactions, 25(5), 1316-1320.

Wanielista, M. P. et al., (1997). *Hydrology: water quantity and quality control*. John Wiley & Sons, New York.