City of Flagstaff
Drywell Feasibility Study

Aggasiz
Municipal Consulting
Flagstaff, AZ

Prepared by: Matthew Scragg, Tanner Fuhrmann, & Abdulaziz Alkanderi
CENE476 Capstone Group, Spring 2020

Tuesday, May 5th , 2020

Table of Contents

Table of Figures/Tables

Figures

Tables

1.0 Project Understanding

1.1 Project Purpose

Currently, the City of Flagstaff sets design requirements on all new construction projects to address stormwater runoff quantity and quality. The city requires the use of detention and retention basins which utilize low impact development (LID) techniques in order to control peak discharge rates and runoff water quality within the city. Low impact development techniques aim to preserve pre-development watershed characteristics after the construction of new infrastructure.

The objective of this study is to address the feasibility of drywells for LID stormwater management within the City of Flagstaff. Key considerations for the feasibility of drywells include soil characteristics, peak runoff volumes, storage capacity, water quality, constructability, and cost-effectiveness. Primary constraints for dry well implementation include City of Flagstaff stormwater management codes as well as Environmental Protection Agency (EPA) and Arizona Department of Environmental Quality (ADEQ) water quality standards.

A drywell is a vertical retention system which allows excess storm runoff to infiltrate into the ground. Drywells allow runoff to collect in an underground chamber filled and lined with highly-permeable materials. Drywells commonly implement pretreatment systems to improve water quality such as preliminary settling ponds. Figure 1.1 shows a typical drywell design.

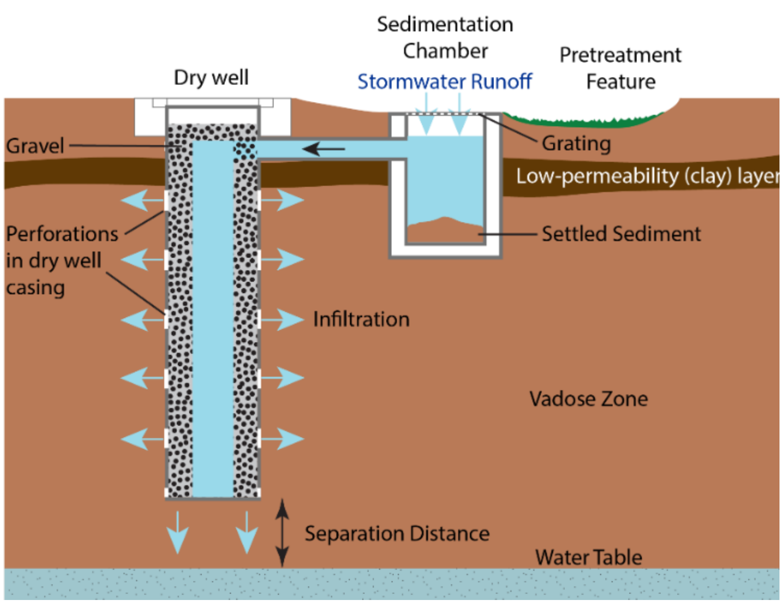


Figure 1.1: Typical Drywell Design [1]

1.2 Project Background/Location

Flagstaff is the largest municipality located within Northern Arizona's Coconino County. The city is located 144 miles North of Phoenix at an elevation of 6909' above sea level. Flagstaff has a population of 72,000 people and is home to the state's third largest school, Northern Arizona University. The city sits just Southeast of the San Francisco peaks and is surrounded by the Coconino National Forest which is encompassed by the nation's largest contiguous ponderosa pine forest.

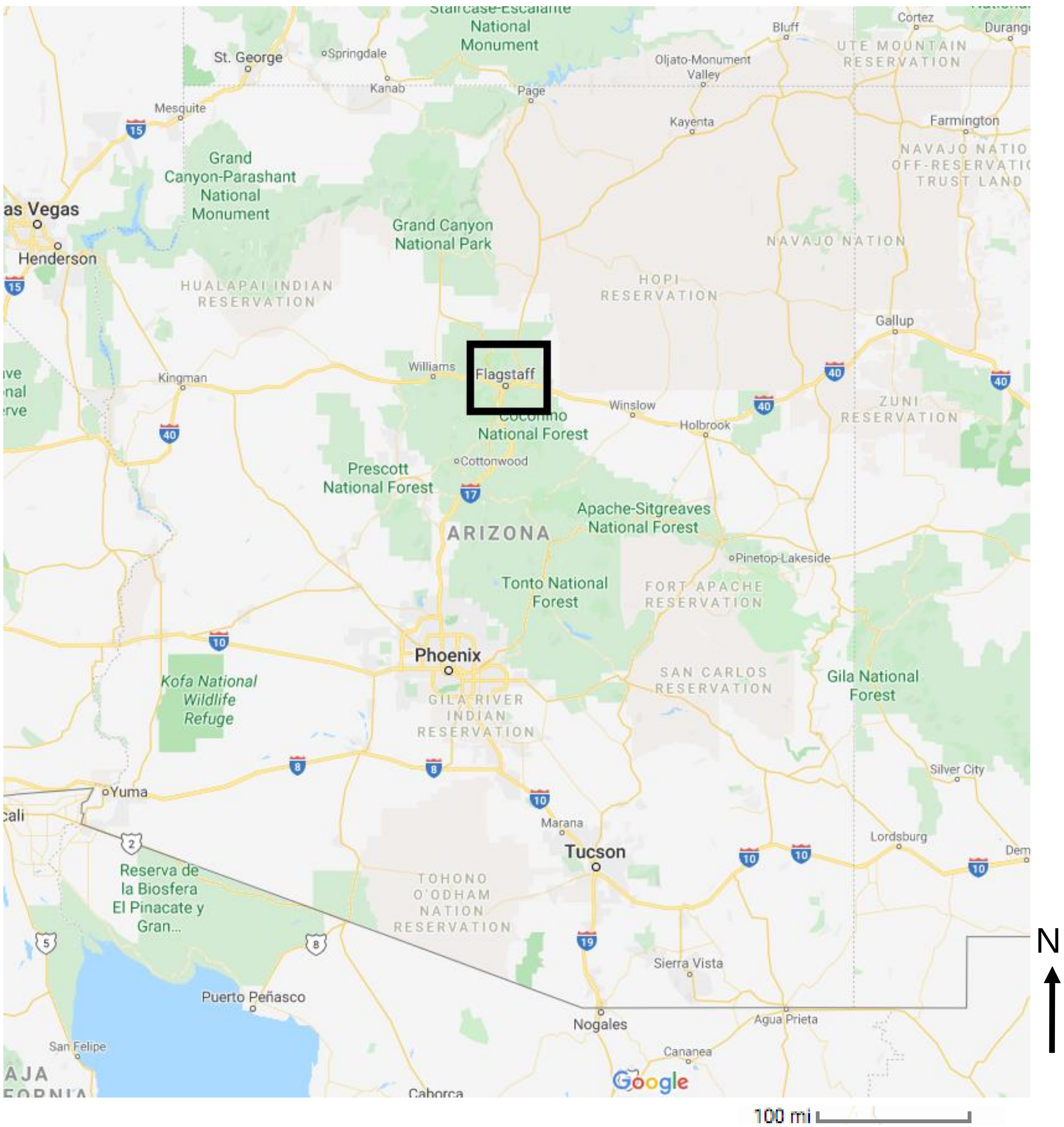


Figure 1.2: Map of Arizona [2]

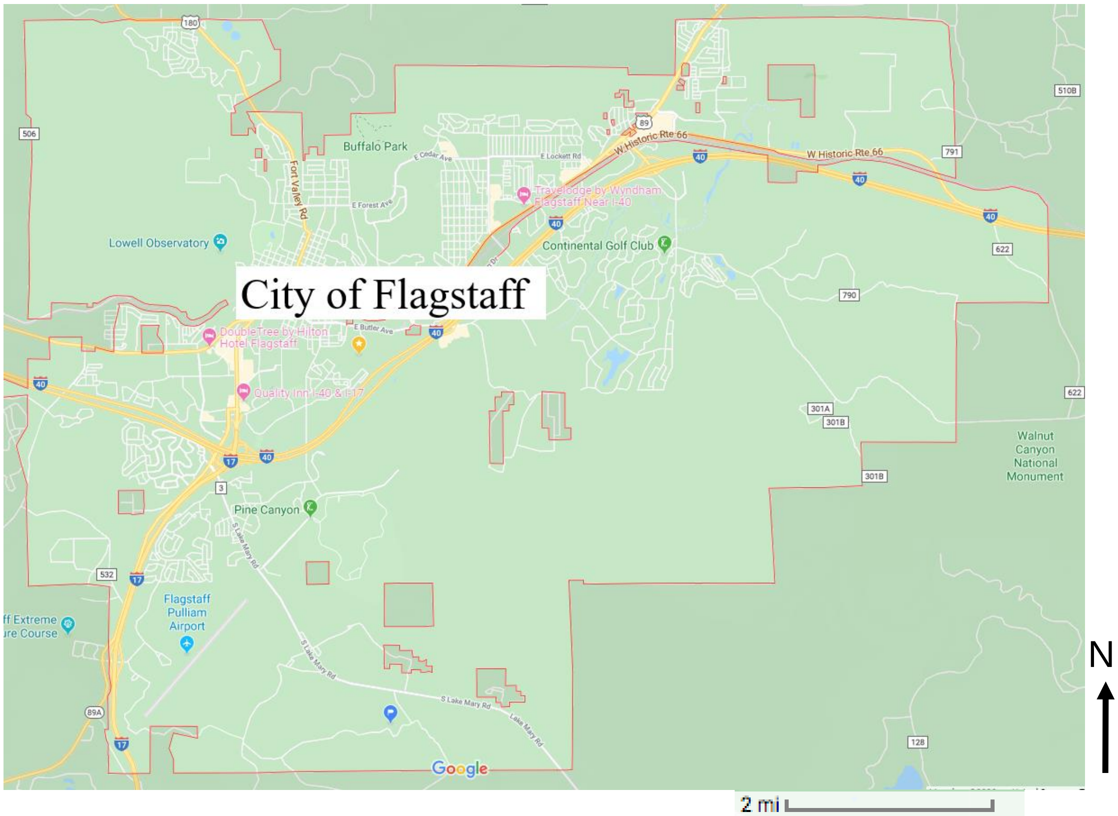


Figure 1.3: Map of City of Flagstaff [2]

1.3 Technical Consideration

1.3.1 Geotechnical Characteristics

The majority of Flagstaff contains soils that are generally shallow and alkaline with a pH of at least 7. Downtown Flagstaff and its surrounding neighborhoods consist of soils heavy in clay, which are highly impermeable. Because of this, infiltration rates in certain areas of the city are low, resulting in the majority of excess stormwater exiting these areas as surface runoff.

The City of Flagstaff has never utilized drywells for stormwater management, likely due to the impermeability of soil and cost considerations, although drywells are relatively common in other areas of Arizona. Appendix A shows a map of soil groups and lists the types of soils around the downtown Flagstaff/ NAU area, acquired from the U.S. Department of Agriculture (USDA) Web Soil Survey (WSS). The majority of soils within the downtown/NAU area consist of loamy soils, with varying proportions of sand, silt, and clay. On average, bedrock is approximately 12-24 inches below the ground surface.

(specific layers and depths can be found for each soil group on the USDA WSS). Eastern Flagstaff consists of cinder soils which are much more conducive to infiltration. Appendix B shows a map of soil groups and lists the types of soils around the Eastern Flagstaff area.

1.3.2 Precipitation Characteristics

The climate of Flagstaff is generally arid, with a rainy monsoon season occurring in late summer. On average, the city receives 23.14 inches of rainfall and 77 inches of snowfall annually. Figure 1.2 shows the city's annual distribution precipitation (with snowfall shown as a snow-water-equivalent), high temperatures, and low temperatures.

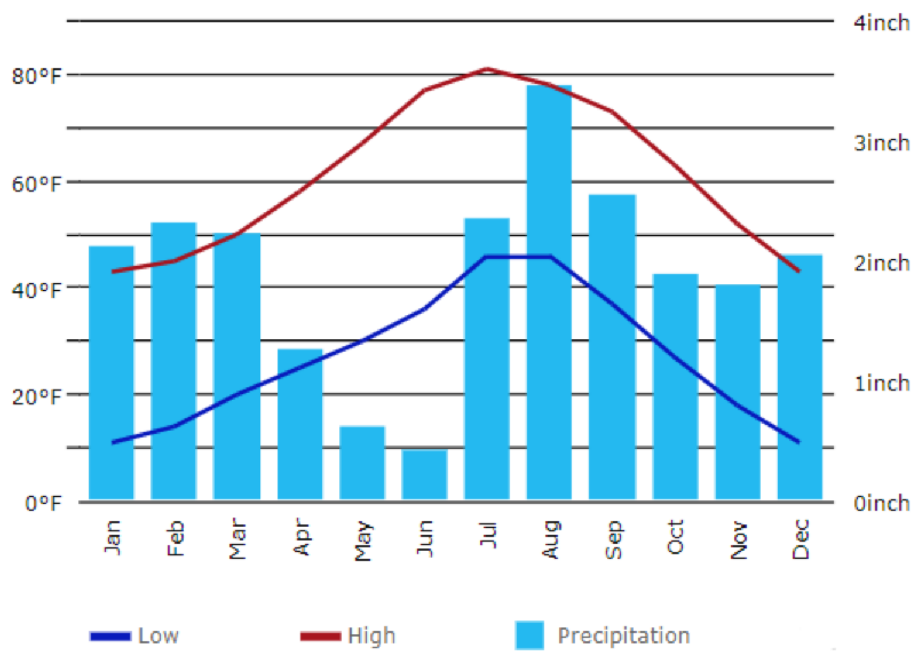


Figure 1.4: Flagstaff Climate [3]

Design rainfalls shall be determined from the *National Oceanic and Atmospheric Administration* (NOAA) *Atlas-14 Point Precipitation Frequency Estimates*. Design durations are to be determined independently based on the time of concentration for any given location and recurrence intervals are to be chosen based on *City of Flagstaff Stormwater Design Manual.*

1.4 Constraints/Challenges

In order for the City of Flagstaff to consider implementing drywells in their stormwater plans and standards, they must meet the constraints and criteria. In this section the requirements of the constraints and criteria are displayed as well as some of the expected challenges in meeting these constraints.

1.4.1 Cost Consideration

In order for drywells to be feasible, they must be cost effective. A specific cost maximum has not been provided but certain considerations concerning cost must be evaluated and compared to average costs of drywells. There are certain factors of drywells that affect the cost such as the necessary depth of the drywell, the diameter of the well, and the pretreatment necessities. There is a $100 fee for registering each drywell with ADEQ and average drywell installations cost between $1,500 to $4,000 but could be more depending on the volume of water it can hold and the depth that must be drilled. The main concern for this project associated with price is the depth at which the drywell must be in order to maintain LID and city code. An aquifer protection permit (APP) will be required for certain drywells if the drywell "discharges either directly into an aquifer or to the land surface or the vadose zone in such a manner that there is a reasonable probability that the pollutant will reach an aquifer" [4]. This permit can cost up to $3,000. An APP might also be required if precautions are taken in the drywell to remove pollutants. A type 2.01 and 2.04 General Permits may also be required for drywells that drain specific hazardous material like motor fuels. The costs of these permits will also have to be considered in the cost feasibility of the drywell.

A monetary advantage of a drywell is its conservation of surface area available for development compared to other stormwater management methods. This developable space has monetary value to the developer and will be included in the cost analysis. A drywell typically has a greater implementation cost than a standard detention basin, but its indirect monetary advantage of addition to developable space may be greater than the implementation cost. The monetary value of the developable space per unit surface area will have to be determined through research. The cost feasibility will consist of a comparison between the cost of implementing the drywell including the costs listed above and the monetary advantages of a drywell.

1.4.2 Regulations/Codes

Along with the cost consideration it is important to abide by the codes, regulations and standards regulated by the City of Flagstaff, the State of Arizona, and the Federal Government. According to the City of Flagstaff, the goals of LID include the following:

- Micromanaging stormwater at its source
- Preserving open space and minimizing land disturbance
- Incorporating natural site elements as design elements
- Protecting natural systems and processes
- Re-examining the use and sizing of traditional site infrastructure and customizing site design to each site [5]

The LID requirement from the city is to retain / infiltrate the first one inch of runoff from all impervious areas on sites that are also required to provide stormwater detention (typically sites that are greater than a fourth of an acre) [5]. The goal of this project is to assess the feasibility of this LID requirement through the use of drywells for all new developments. Along with infiltrating the first one inch it is important to mitigate the peak flow from a property within 0.5 cfs in comparison to pre development. This means that the flow leaving a property after development must be ± 0.5 cfs from the pre development after a 100 year storm.

Drywells are addressed specifically in the Arizona revised statutes: Title 49 Article 8. Here, the process for registration, regulation, enforcement, and rules are explained according to the State of Arizona. Other sections of Title 49 may need to be addressed in order to be in compliance with the State.

The main focus of this project is on space conservation with stormwater management and is not as much interested in the recharging of the Coconino Aquifer, but one benefit of the drywell is that it infiltrates water back into the soil which makes its way to the aquifer. With this an aquifer protection permit may be necessary to obtain from the ADEQ. According to the ADEQ the quality of the water must meet the standards shown in the Arizona Administrative Code [6].

1.4.3 Challenges

The main challenge of staying within these constraints will be in relation to the depth of the wells and its relation to cost effectiveness..The wells may need additional surface area to infiltrate due to the soil characteristics of most of Flagstaff. Most of Flagstaff has soil profiles full of clay and bedrock which have low permeability making it necessary to dig deeper holes. With shallow bedrock being common throughout Flagstaff, drywells must be located around areas with cracks or fissures in the bedrock, to allow for deeper infiltration. ADEQ specifies that drywells must be located at least 10 feet above the groundwater table. Flagstaff's groundwater table is located relatively deep, except in areas that are above or near perched aquifers, so the location of these potential perched aquifers and their depth must be determined so that it can be determined whether the aquifer poses as a problem area for the implementation of drywells.

1.5 Stakeholders

The primary stakeholder for the study is the City of Flagstaff Stormwater Management department, as they set standards for stormwater infrastructure and management, as well as review stormwater systems for both public and private developers. Secondary stakeholders include developers and landowners, as the introduction of drywells as a LID stormwater management practice within the city will alter existing and future systems and developments.

2.0 Scope of Services/ Research Plan

2.1 Task 1: Hydrologic Analysis

2.1.1 Task 1.1: Sample Site Identifications

Identify list of five sample sites, of different sizes around the City of Flagstaff based on neighborhood (e.g. downtown, NAU, southside, 4th Street, eastside, etc.) and size of site (between 1-10 acres). This will allow analysis of drywells in Flagstaff under different surface and subsurface conditions which will provide a general idea of where drywells may or may not be feasible.

2.1.2 Task 1.2: Sample Site Characteristics

Determine general characteristics for each sample site including site type (commercial/residential), area, ground cover, soil conditions, runoff coefficients, rainfall data for 1-hour 100 year storm, and retention volumes for 1-inch of impervious surface per LID requirements. This will assist in stormwater runoff analysis using the rational method.

2.1.3 Task 1.3: Code Research

2.1.3.1 Task 1.3.1: Research Existing Code from Outside Municipalities

Because there are little to no standards regarding drywells for the City of Flagstaff, outside municipalities will be a primary source of guidance on the standards and codes associated with drywell implementation. The three agencies that will be researched will be as follows:

- Maricopa County
- City of Surprise
- City of El Mirage

These municipalities implement a large amount of drywells throughout their respective cities and counties. It will be helpful to derive a method, based on the standards of these municipalities, to determine factors that are necessary in determining the retention volumes and the drywell dimensions.

2.1.3.2 Task 1.3.2: Research Zoning Code to Verify Lot Coverage

Using zoning standards from the City of Flagstaff or Maricopa County, impervious surface coverage will be determined for different sized commercial developments. This will help to determine a composite runoff coefficient for each sample site that will be used in the Rational Equation

2.1.4 Task 1.4: Post-Development Characteristics of Sample Sites

Determine general characteristics for each post-development sample site including area, ground cover, soil conditions, runoff coefficients, and rainfall intensity data for 1-hour 100 year storm event.

2.1.5 Task 1.5: Determination of Necessary Storage based upon Rational Method

Following the *Drainage Policies and Standards for Maricopa County*, determine necessary storage volumes based upon the post-development runoff volumes for the 100 year 1-hour storm using the rational method.

2.1.6 Task 1.6: Determination of Necessary Storage based LID Requirements

Following the *Drainage Policies and Standards for Maricopa County*, determine necessary storage volumes based upon the low impact development requirements.

(Retain/detain the first 1” of rainfall over the entire new development/impervious area).

2.1.7 Task 1.7: Determine Required Retention Volume for each Sample Site

The necessary retention volume will be determined based on the results of tasks 1.5 and 1.6. The greater volume of the two for each respective site will be the required retention volume for that site. This is necessary because both conditions must be met and the greater volume will meet both conditions.

2.2 Task 2: Geotechnical Analysis

2.2.1 Task 2.1: Consult Geotech and Drywell Specialists, and request Existing Soil Data from Flagstaff

Research consulting firms specializing in geotechnical analysis in Northern Arizona and drywell design in the state of Arizona. Set up consultation meetings with applicable firms to inquire upon key processes, methods, and costs involved with site analysis & development for the implementation of drywells in Arizona, request existing soil data for Flagstaff from firms. Since this is a feasibility study, and not a design for a specific site, the collection of soil samples is requested by the client to be kept to a minimum. This task will assist with the replacement of data that could be acquired by soil samples.

2.2.2 Task 2.2: Acquire Existing Geotechnical Reports from Flagstaff

Acquire existing geotechnical information available to the public from the USGS, ADWR Well Registry, and other public agencies. These are reliable sources that can provide valuable data with respect to soil testing and classification. Siol reports can be acquired through these sources without having to go to the field and collect samples, test them, and classify them.

2.2.3 Task 2.3: Compile Known Soil Conditions in Flagstaff

Compile the data obtained in Task 2.1 and Task 2.2. Use compilation of data to determine any known hydraulic conductivity, particle size distribution, and existing soil characteristics.

2.3 Task 3: Drywell Design

2.3.1 Task 3.1: Determine Drywell Dimensions for each Sample Site

Determine design dimensions of drywells for each sample site based off of storage & infiltration volumes and hydraulic conductivities determined in Task 1.7 and 2.3 respectively.

2.3.2 Task 3.2: Determine Pretreatment Features Necessary for Certain Sites

Based upon Maricopa County and ADEQ stormwater runoff quality standards, determine pretreatment features necessary for certain sites based upon contaminants that may be present at each site.

2.4 Task 4: Cost Analysis

2.4.1 Task 4.1: Determine Costs of Other Stormwater Management Systems For Certain Development Sizes

Determine costs of the alternative stormwater management systems (e.g detention basin) for specified development site sizes. This will be used in the determination of the overall feasibility of drywells (see Task 5).

2.4.2 Task 4.2: Determine Value of Land Saved Through Implementation of Drywells

Based on local property values, determine the monetary value of undeveloped and developed land saved through the development of a drywell versus alternative stormwater management systems (e.g. detention basin). This will be used in the determination of the overall feasibility of drywells (see Task 5).

2.4.3 Task 4.3: Cost of Drywell Per Site Given Certain Site Characteristics

Compile table of associated costs for materials, construction labor, permits, etc. Catalog site attributes to formulate drywell expenditure based upon given dimensions, location, and characteristics. This will be used in the determination of the overall feasibility of drywells (see Task 5).

2.4.5 Task 4.4: Determine Monetary Cost Increase or Decrease of Using Drywells as Compared to Using Other Stormwater Management Systems

Index predicted drywell expenditures in comparison to alternative stormwater management systems.

2.5 Task 5: Feasibility Determination

2.5.1 Task 5.1: Determining Overall Feasibility of Drywell Use to Manage Stormwater in Flagstaff

Based on the results from tasks 4, 5.1, and 5.2, the overall feasibility of drywell implementation based upon location for the City of Flagstaff will be determined. Generate a matrix of feasibility outcomes for each location based upon varying site conditions and areas.

2.5.1.1 Task 5.1.1: Feasibility of Necessary Dimensions

Determine cost feasibility of drywells based upon site location and drywell dimensions.

2.5.1.2 Task 5.1.2: Feasibility of Using Drywells in Tandem with Retention/Detention

Determination of the practicality and feasibility of systems integrating retention/detention basins and drywells.

2.5.2 Task 5.2: Recommendations

Based on the findings from task 1.3.1 and the results from task 5.1 recommendations will be made for the implementation of drywells in Flagstaff based on location and general characteristics

2.6 Task 6: Impact Assessment

2.6.1 Task 6.1 Economic Impact Assessment

Based upon the results of task 5, determine economic impact drywells may have in the City of Flagstaff.

2.6.2 Task 6.2 Social Impact Assessment

Determine the potential local social impacts as a result of the implementation of drywells in the city of Flagstaff

2.6.3: Task 6.3 Environmental Impact Assessment

Determine the potential local environmental impacts as a result of the implementation of drywells in the city of Flagstaff

2.7 Task 7: Project Deliverables

2.7.1 Task 7.1: 30% Deliverable

30% Deliverable will include Task 1 and part of Tasks 2, 3 and 4.

2.7.2 Task 7.2: 60% Deliverable

60% Deliverable will include Tasks 1-4.

2.7.3 Task 7.3: 90% Deliverable

90% Deliverable will include Tasks 1-6, a preliminary final report, and a preliminary website.

2.7.4 Task 7.4: Final Deliverable

Final deliverable will include a finalized report and complete project website.

2.8 Task 8: Project Management

2.8.1 Task 8.1: Meetings

Schedule necessary meetings within the team, with the client, with the technical advisor, and with the grading instructor for project development based upon deadlines.

2.8.2 Task 8.2: Coordination

Coordinate essential functions for project development (e.g. field work, lab work, computational work, etc.

2.8.3 Task 8.3: Schedule Management

Determine/adjust schedule based upon deliverable deadlines. Make any necessary adjustments to schedule and notify team members of such adjustments.

2.8.4 Task 8.4: Resource & Financial Management

Manage resources based upon scheduling and availability. Keep track of all expenditures.

2.8.5 Task 8.5: Record All Hours Worked

2.9 Exclusions

2.9.1 Geotechnical Sampling and Testing

Geotechnical sampling and testing will not be included

2.9.2 Specific Site Design

Specific designs of drywells for particular sites will not be included in this feasibility study

3.0 Project Schedule

3.1 Discussion of Schedule

The project Gantt chart can be found in *Appendix C: Schedule*. The project start date is August 24th, 2020 and the anticipated project end date is December 7th, 2020. The duration of the project is 72 days. The 30% deliverable will be submitted the week of 9/21/20 to 9/25/20. The 60% deliverable will be submitted the week of 10/19/20 to 10/23/20. The 90% deliverable will be submitted the week of 11/16/20 to 11/20/20/ The final deliverable will be submitted the week of 12/7/20 to 12/11/20. See section 2.7 above to see a description of which tasks will be included in each deliverable. Labor Day, Veteran's Day, Thanksgiving Break, and weekends are non-working days. *Table 3.1* outlines start dates, end dates, and durations for all major tasks.

Table 3.1: Schedule of Tasks

Task	Duration	Start Date	End Date
			Project Start Date: 08/24/20
1: Hydrologic Analysis	15 days	08/24/20	09/11/20
2: Geotechnical Analysis	24 days	08/31/20	10/01/20
3: Drywell Design	27 days	09/04/20	10/12/20
4: Cost Analysis	35 days	09/04/20	10/22/20
5: Feasibility Determination	10 days	10/20/20	11/02/20
6: Impact Assessment	1 day	11/04/20	11/04/20
7: Project Deliverables	42 days	10/12/20	12/09/20
			Project End Date: 12/09/20

3.2 Critical Path

The critical path for this project includes major tasks 1-6, as all are necessary for the completion of the drywell feasibility study. The critical path can be found in *Appendix C: Schedule*. Timing and duration of all tasks within the schedule and critical path shall be maintained and updated through weekly team meetings, as established in Task 8.3: Schedule Management.

4.0 Staffing and Cost of Engineering Services

4.1 Staff Positions & Person Hours

The Senior Engineer (SEGR) is an experienced professional engineer in charge of overseeing and reviewing project design and deliverables. The SEGR will review the work accomplished in tasks 1-4, will assist with tasks 5 & 6, and will complete tasks 7 & 8. The Project Engineer (EGR) is an experienced professional engineer in charge of completing design analysis tasks 1-4. The EGR will assist with tasks 5-8. The Project Manager (PM) will assist with tasks 1-5. The PM will also largely contribute towards tasks 7 & 8. *Table 4.1* below shows the total person-hours for each staff classification. See *Section 2.0 - Scope* for a description of tasks.

Table 4.1: Staff Position Person-Hours

Task	**Senior Engineer (SEGR)**	**Project Manager (PM)**	**Project Engineer (EGR)**
	# person-hours	# person-hours	# person-hours
1: Hydrologic Analysis			
1.1: Sample Site Identifications		16	16
1.2: Sample Site Characteristics		8	24
1.3: Code Research		8	16
1.4: Post-Development Characteristics of Sample Sites	0.5	8	24
1.5: Determination of Necessary Storage based upon Rational Method	0.5		24
1.6: Determination of Necessary Storage based LID Requirements	0.5		24

1.7: Determine Required Retention Volume for each Sample Site	0.5		24
2: Geotechnical Analysis			
2.1: Consult Geotech and Drywell Specialists, and request Existing Soil Data from Flagstaff		8	24
2.2: Acquire Existing Geotechnical Reports from Flagstaff		8	24
2.3: Compile Known Soil Conditions in Flagstaff	1	8	24
3: Drywell Design			
3.1: Determine Drywell Dimensions for each Sample Site	1	16	48
3.2: Determine Pretreatment Features Necessary for Certain Sites	1		36
4: Cost Analysis			
4.1: Determine Costs of Other Stormwater Management Systems For Certain Development Sizes		8	24
4.2: Determine Value of Land Saved Through Implementation of Drywells		8	16
4.3: Cost of Drywell Per Site Given Certain Site Characteristics	1	8	24
4.4: Determine Monetary Cost Increase or Decrease of Using Drywells as Compared to Using Other Stormwater Management Systems	1	8	16
5: Feasibility Determination			
5.1: Determining Overall Feasibility of Drywell Use to Manage Stormwater in Flagstaff	20	20	48
5.2: Recommendations	20	20	48
6: Impact Assessment			
6.1 Economic Impact Assessment	8		8

Task 6.2 Social Impact Assessment	8		8
Task 2.3 Environmental Impact Assessment	8		8
7: Project Deliverables			
7.1: 30% Deliverable	8	16	16
7.2: 60% Deliverable	8	16	16
7.3: 90% Deliverable	8	16	16
Final Deliverable	8	16	16
8: Project Management			
Task 8.1: Meetings	16	16	16
Task 8.2: Coordination	16	24	16
Task 8.3: Schedule Management	24	24	
8.4: Resource & Financial Management	24	24	
8.5: Record All Hours Worked		16	
Subtotal (person-hours)	183	320	604
Total (person-hours)	**1107**	**(138 person-days @ 8 hrs/day)**	

4.2: Cost of Engineering Services

Table 4.2 below outlines the total number of person-hours for each personnel classification as determined from *Table 4.1* above. See *Appendix D* for determination of pay rate. The total cost of engineering services for the drywell feasibility study is estimated at $172,555.

Table 4.2: Cost of Engineering Services

1.0 Personnel	**Hours**	**Rate, $/hr**	**Cost**
SEGR	183	168	$30,824
PM	320	110	$35,235
EGR	604	77	$46,508
3.0 Total			**$112,567**

References

[1] Edwards, E., Mandler, B. *Dry Wells for Stormwater Management*. September 2017. [Accessed 29 January 2020]. americangeosciences.org.

[2] *Google Maps*. Copywrite Google 2020. [Accessed 29 January 2020]. google.com/maps.

[3] Data, US Climate. *Climate Flagstaff - Arizona and Weather Averages Flagstaff*. 2020. www.usclimatedata.com/climate/flagstaff/arizona/united-states/usaz0068.

[4] ADEQ, "Implementation Guidelines for Drywells That Use Flow Control and/or Pretreatment Technologies Under the Aquifer Protection Program General Permit Types 2.01 and 2.04," Arizona Department of Environmental Quality, Phoenix, 2012.

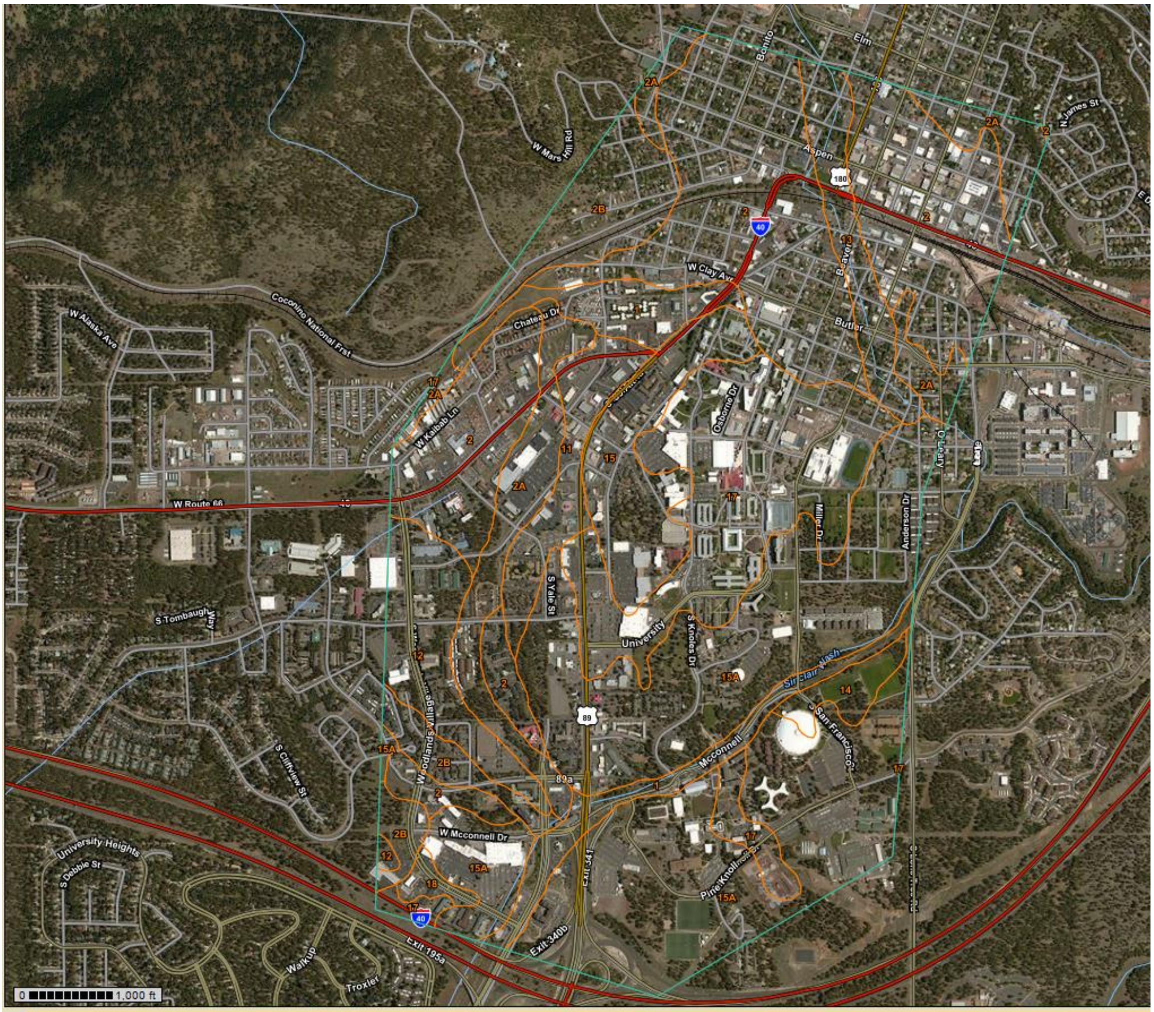
[5] C. Palmer, "City of Flagstaff LID Requirement," City of Flagstaff, [Online]. Available: https://www.flagstaff.az.gov/3736/City-of-Flagstaff-LID-Requirement. [Accessed 29 January 2020].

[6] Arizona Revised Statutes, "Title 49-The Environment," Arizona State Legislature, 2020 January 2020. [Online]. Available: https://www.azleg.gov/arsDetail/?title=49. [Accessed 29 January 2020].

[7] USDA NRCS. *Web Soil Survey*. [Accessed 29 January 2020]. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx.

Appendices

Appendix A: Downtown Flagstaff/NAU USDA Web Soil Survey



N

Figure A.1: Downtown Flagstaff/NAU Soil Map [7]

N

Table A.1: Downtown Flagstaff/NAU Soil Descriptions [7]

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Jacques clay loam, 0 to 2 percent slopes	67.4	4.70%
2	Brolliar stony clay loam, 0 to 2 percent slopes	357.5	24.80%
2A	Brolliar stony clay loam, 2 to 8 percent slopes	102.2	7.10%
2B	Brolliar stony clay loam, 8 to 30 percent slopes	79.5	5.50%
11	Collbran stony clay loam, 5 to 20 percent slopes	42.3	2.90%
12	Brolliar cobbly clay loam, deep variant, 0 to 5 percent slopes	58.7	4.10%
13	Lynx loam, 0 to 2 percent slopes	42.7	3.00%
14	Daze fine sandy loam, 0 to 8 percent slopes	15.8	1.10%
15	Tortugas cobbly loam, 2 to 15 percent slopes	70	4.90%
15A	Tortugas-Daze complex, 0 to 15 percent slopes	420.3	29.20%
17	Amos fine sandy loam, 0 to 3 percent slopes	178.4	12.40%
18	Boysag gravelly loam, 0 to 8 percent slopes	6.8	0.50%

Appendix B: Eastern Flagstaff USDA Web Soil Survey

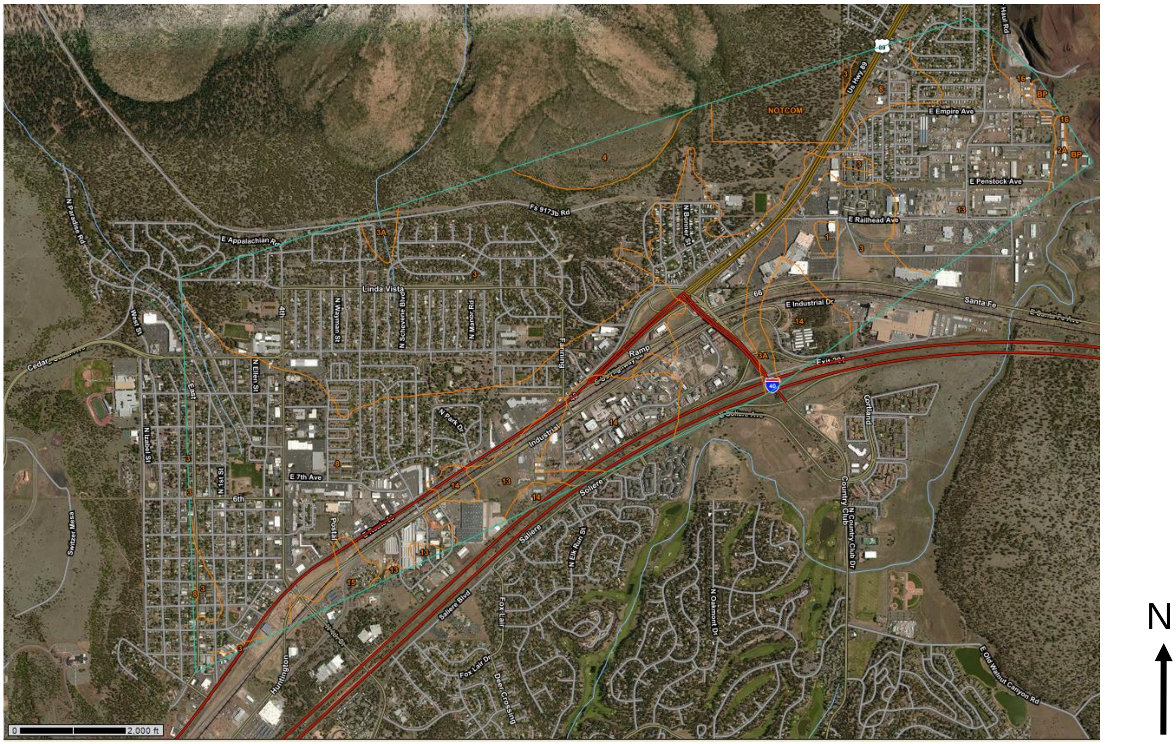


Figure B.1: Eastern Flagstaff Soil Map [7]

Table B.1: Eastern Flagstaff Soil Description [7]

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Jacques clay loam, 0 to 2 percent slopes	5.2	0.20%
2A	Brolliar stony clay loam, 2 to 8 percent slopes	9.3	0.40%
3	Baldy stony loam, 2 to 8 percent slopes	790.5	34.90%
3A	Baldy stony loam, 8 to 15 percent slopes	35.5	1.60%
4	Baldy-Rock outcrop association, 15 to 60 percent slopes	47.9	2.10%
8	Paymaster family fine sandy loam, 0 to 3 percent slopes	616.4	27.20%
13	Lynx loam, 0 to 2 percent slopes	494.9	21.80%
14	Daze fine sandy loam, 0 to 8 percent slopes	157.6	7.00%
15	Tortugas cobbly loam, 2 to 15 percent slopes	23	1.00%
16	Sizer-Bandera association, 15 to 60 percent slopes	12.1	0.50%
BP	Pits-Dumps complex	7.3	0.30%
NOTC	No Digital Data Available	66.2	2.90%

Appendix C: Schedule

Figure C.1: Critical Path

Task Name	Duration	Start
Project Start	1 day	Mon 8/24/20
Task 1: Hydrologic Analysis	**15 days**	**Mon 8/24/20**
Task 1.1 Sample Site Identification	5 days	Mon 8/24/20
Task 1.2: Sample Site Characteristics	3 days	Mon 8/31/20
Task 1.3: Code Research	**5 days**	**Mon 8/24/20**
Task 1.3.1: Research Existing Code from Outside Municipalities	5 days	Mon 8/24/20
Task 1.3.2: Research Zoning Code to Verify Lot Coverage	3 days	Mon 8/24/20
Task 1.4: Post-Development Characteristics of Sample Sites	3 days	Thu 9/3/20
Task 1.5: Determination of Necessary Storage based upon Rational	2 days	Tue 9/8/20
Task 1.6: Determination of Necessary Storage based LID Requirements	2 days	Tue 9/8/20
Task 1.7: Determine Required Retention Volume for each Sample Site	2 days	Thu 9/10/20
Task 2: Geotechnical Analy	**24 days**	**Mon 8/31/20**
Task 2.1: Consult Geotech and Drywell Specialists, and request Existing Soil Data	9 days	Mon 8/31/20
Task 2.2: Acquire Existing Geotechnical Reports from Flagstaff	9 days	Mon 9/14/20
Task 2.3: Compile Known Soil Conditions in	5 days	Fri 9/25/20
Task 3: Drywell Design	**27 days**	**Fri 9/4/20**
Task 3.1: Determine Drywell Dimensions for each Sample Site	7 days	Fri 10/2/20
Task 3.2: Determine Pretreatment Features Necessary for Certain	7 days	Fri 9/4/20
Task 4: Cost Analysis	**35 days**	**Fri 9/4/20**
Task 4.1: Determine Costs of Other Stormwater Management Systems	7 days	Tue 9/15/20
Task 4.2: Determine Value of Land Saved Through Implementation of	3 days	Fri 9/4/20
Task 4.3: Cost of Drywell Per Site Given Certain Site Characteristics	5 days	Tue 10/13/20
Task 4.4: Determine Monetary Cost Increase or Decrease of Using Drywells as Compared to Using Other Stormwater Management Systems	3 days	Tue 10/20/20
Task 5: Feasibility Determination	**10 days**	**Tue 10/20/20**
Task 5.1: Determine Overall Feasibility of Drywell Use to Manage Stormwater in Flagstaff	**8 days**	**Tue 10/20/20**
Task 5.1.1: Feasibility of Necessary	4 days	Tue 10/20/20
Task 5.1.2: Feasibility of Using Drywells in Tandem with Retention/Detention	6 days	Thu 10/22/20
Task 5.2: Recommendati	2 days	Fri 10/30/20
Task 6: Impact Assessment	**1 day**	**Wed 11/4/20**
Task 6.1 Economic Impact Assessment	1 day	Wed 11/4/20
Task 6.2 Social Impact Assessment	1 day	Wed 11/4/20
Task 2.3 Environmental Impact Assessment	1 day	Wed 11/4/20
Task 7: Project Deliverable	**44 days**	**Sun 10/11/20**
30% Deliverable	1 day	Mon 10/12/2
60% Deliverable	1 day	Fri 10/30/20
90% Deliverable	1 day	Thu 11/19/20
Final Deliverable	1 day	Wed 12/9/20
Task 8: Project Manageme	**77 days**	**Mon 8/24/20**
Task 8.1: Meetings	**76 days**	**Tue 8/25/20**
Team Meetings	**76 days**	**Tue 8/25/20**
Grading Instructor Meetings	**61 days**	**Fri 8/28/20**
Technical Advisor Meeting	**74 days**	**Tue 8/25/20**
Task 8.2: Coordination	1 day	Mon 8/24/20
Task 8.3: Schedule Management	1 day	Mon 8/24/20
Task 8.4: Resource & Financial Management	1 day	Mon 8/24/20
Task 8.5: Record All Hours Worked	1 day	Mon 8/24/20
Project End	1 day	Wed 12/9/20