P62 LID Basin Design

Earthwise Civil Solutions

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Site: Northern Arizona University Parking Lot P62 (South Commuter Lot)

Date: December 10, 2024

CENE 476

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List of Abbreviations

CAD .... Computer Aided Drafting
CFM .... Certified Floodplain Manager
COF .... City of Flagstaff
EIT .... Engineer-in-training
ENG .... Design Engineer
EOPC .... Engineer's Opinion of Probable Costs
EPA .... Environmental Protection Agency
ERU .... Equivalent Unit Rate
FUTS .... Flagstaff Urban Trail System
HEC-HMS .... Hydrological Engineering Center Hydrological Modeling Software
HEC-RAS .... Hydrological Engineering Center River Analysis Software
LAB TECH .... Laboratory Technician
LID .... Low Impact Development
NAU .... Northern Arizona University
PE .... Professional Engineer
SENG .... Senior Engineer
SF .... Square Feet
TKN .... Total Kjeldahl Nitrogen
TSS .... Total Suspended Solids

1.0 Project Understanding

1.1. Project Purpose

As the population of the City of Flagstaff (COF) and Northern Arizona University (NAU) grow due to regional and state migration, development increasingly puts a strain on existing stormwater infrastructure. Starting in 2024, COF has offered private landowners an incentive to detain impervious runoff by offering tax reduction credits for specific detention infrastructure. The eligible credits are provided in response to an increase in stormwater capture rates. The increase in rates is enacted to support increased COF stormwater infrastructure costs due to use and wear. Recent wildfires have required city wide improvements to channels and detention basins. COF stormwater capture rates will nearly double the equivalent unit-rate (ERU) cost over the next four years (2024 to 2028). The equivalent unit-rate, used to determine a property owner's impervious runoff contribution cost, is defined as the square footage of the impervious area over 1500 square feet (sf). The current ERU rate is $4.19 and will increase to $7.38 by 2028.

> For example, a property owner with 3000 sf of impervious area that runs off into COF stormwater infrastructure pays $8.38 annually (3000 sf / 1500 sf = 2 ERU, 2 ERU x $4.19) considering 2024 rates.

A range of reduction credits are available on this impervious runoff tax through the implementation Low Impact Development (LID) basins. Additional stormwater credit information and eligibility is available on the COF stormwater credit website [1]. A LID basin utilizes infiltration technologies to detain peak runoff and promote infiltration of captured runoff into groundwater. The COF identifies LID as an active rainwater harvesting method able to detain one inch of rainfall over the entire watershed area regardless of storm duration [2]. For example, a 3-hour and 6-hour duration storm that both produce one inch of total precipitation are treated equally.

The NAU South Commuter parking lot, P62, has been identified as a major contributor to impervious runoff into Sinclair Wash by Dr. Adam Bringhurst of NAU and the NAU Facility Services. The existing stormwater infrastructure feeding P62 runoff into Sinclair Wash is a potential site for the implementation of LID basins to reduce the downstream flood impact by increasing the peak flow lag time and promoting groundwater recharge through detention. Additionally, NAU will receive the runoff credits available from LID basin use. This project demonstrates the design of a LID basin on the NAU campus. NAU requests that landscape design remains in accordance with the Landscape Master Plan [3].

1.2. Project Background

The project is located at the P62 commuter parking lot and adjacent areas on the NAU Mountain Campus, Flagstaff, AZ. This site is near the junction of Interstate 17 and Interstate 40. This lot is in the southwestern most portion of the campus. P62 is approximately 6.1 acres and 178 ERUs according to COF definition [1]. There is a segment of COF Flagstaff Urban Trail System (FUTS) that provides pedestrian and bicycle access to the Sinclair Wash corridor within the project area. Dr. Adam Bringhurst has identified an area of the FUTS that experiences inundation by high-flow events near the P62 outlet into Sinclair Wash.

Figure 1-1 depicts NAU's Mountain Campus and project area within the Greater COF and relative location within the State of Arizona.

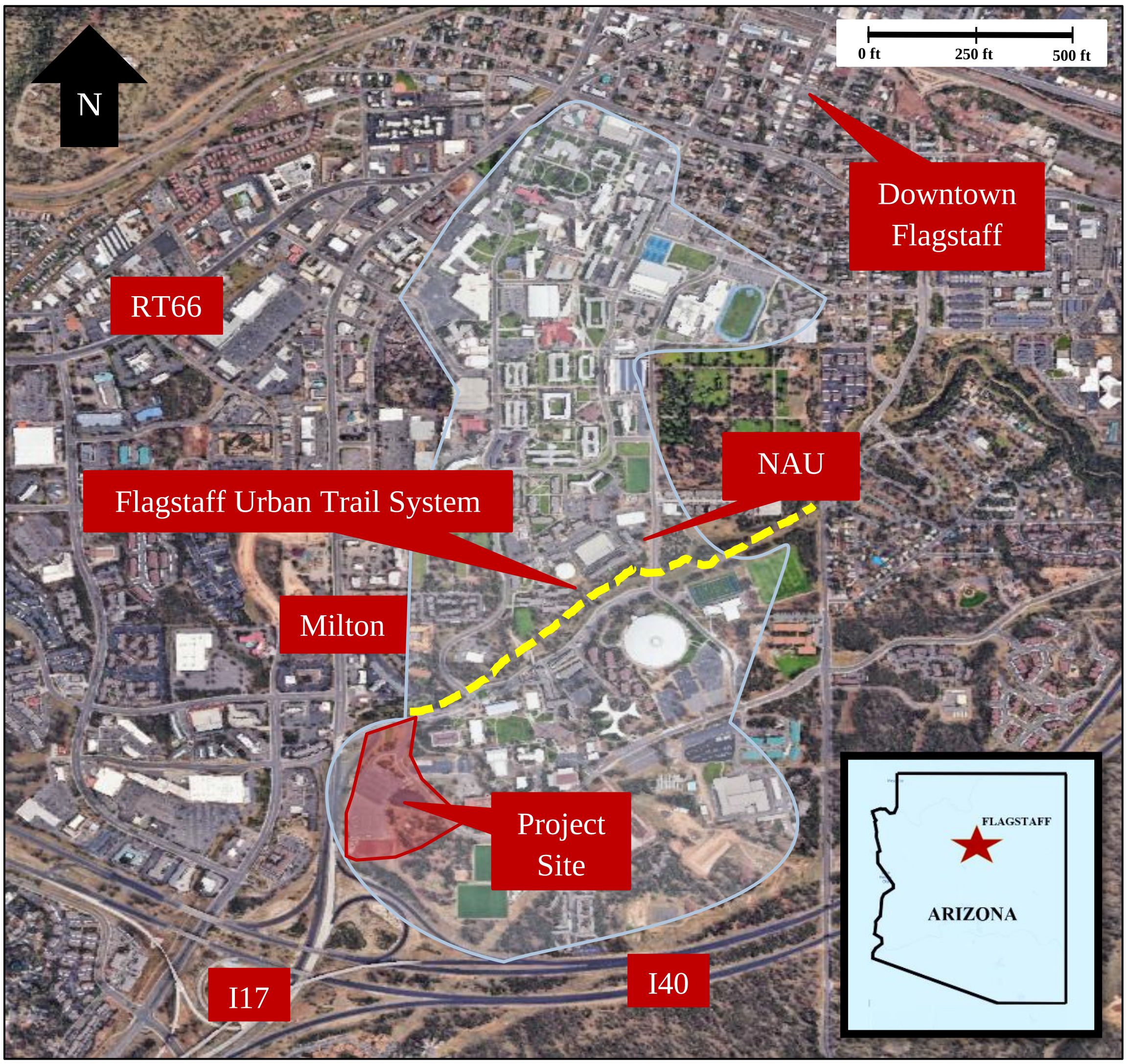

Figure 1-1: Project Site Location Map within the Greater Flagstaff Area

Figure 1-2 depicts the project area and Sinclair Wash within NAU's Mountain Campus. Callouts are included on this map to identify site investigation images in Figure 1-3, Figure 1-4, and Figure 1-5.

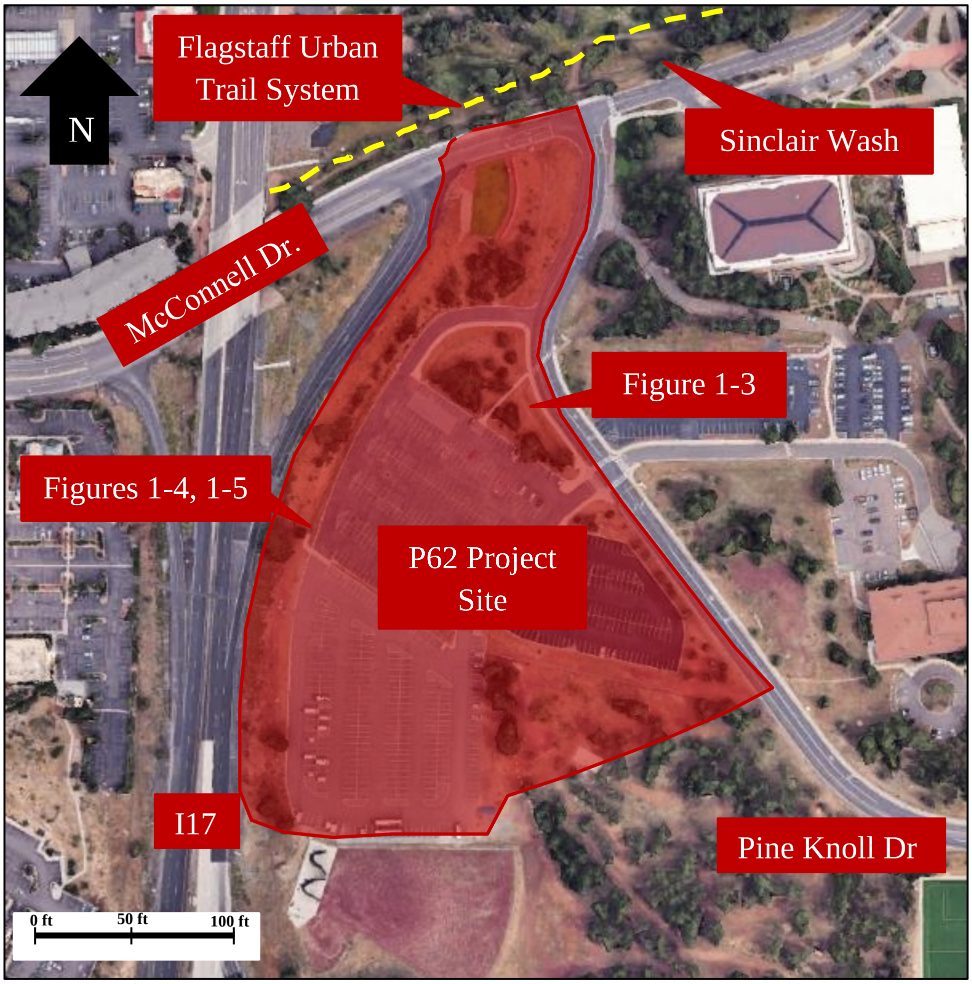

Figure 1-2: Project Site Map on NAU Mountain Campus

The project site is located within a subbasin of Sinclair Wash, a west–east intermittent stream that transverses the southern portion of the Mountain Campus along McConnell Dr. Sinclair Wash anecdotally experiences overtopping of the channel banks during high discharge events, such as prolonged monsoons or snowmelt. Overtopping of the channel inundates McConnell Dr. around The Suites apartment complex causing unsafe travel conditions for motorists and pedestrians, infrastructure damage, and sedimentation. The project site has been identified as a large impervious runoff contributor to Sinclair wash. Currently, all impervious runoff on the site travels through existing stormwater infrastructure and is un-detained. This existing infrastructure does not significantly increase the lag time from precipitation events to discharge to lessen occurrences of overtopping of the channel further downstream.

Figure 1-3 displays an existing channel along Pine Knoll Dr. This image is facing the downstream direction (north) towards McConnell Dr. and Sinclair Wash.

Figure 1-3: Existing Channel near Pine Knoll Dr.

Figure 1-4 depicts an existing channel on the western side of P62 facing the downstream direction. This channel is constrained by the I17 off ramp onto McConnell Dr. to the west.

Figure 1-4: Downstream view of Existing Channel near I-17 offramp to McConnell Dr.

Figure 1-5 depicts the upstream view of the same channel feature above. The I17 off ramp is visible on the right side of the image.

Figure 1-5: Upstream view of Existing Channel near I-17 offramp to McConnel Dr.

1.3. Technical Considerations

Earthwise Solutions will implement industry typical stormwater detention basin design requirements including the following analysis:

- Hydrological analysis determines the peak runoff from the specified design storm.
- Hydrological and hydraulic modeling of existing conditions in *HEC-HMS* and *HEC-RAS* to identify areas for proposed improvements
- Hydraulic analysis to design stormwater infrastructure using governing body specified parameters [1].
- The development of a construction plan set in *AutoCAD*.
- Additional mapping exhibits in *ARCPRO*.

Completion of this analysis is essential to deliver industry-standard solutions.

1.4. Potential Challenges

Identified challenges include area constraints and topographical survey timeline from subcontractor. The available design space to implement efficient design geometries is constrained by existing infrastructure both at the western edge of P62 and along Pine Knoll Dr. Addressing this challenge will require iterative analysis using the Engineering Design Method to optimize available area. As mentioned in Section 0 Exclusions, Earthwise Solutions will not be conducting the topographical survey and will instead subcontract the service out. The subcontractor has identified that collecting existing conditions data through a topographic survey may prove challenging since the parking lot is in use during the university semester. The schedule will identify sufficient lead time so that surveying will occur when the lot is less used.

1.5. Stakeholders

Identified stakeholders for stormwater improvements at P62 are NAU Facilities Services, client Dr. Adam Bringhurst, on-campus floodplains residents (The Suites), motorists, bicyclists, and pedestrians utilizing McConnell or the FUTS on south campus, and downstream users of Sinclair Wash. NAU will benefit financially from stormwater capture credit from LID implementation. Floodplain residents will benefit from reduced occurrences of inundation causing property damage. Motorists and pedestrians will benefit from reduced occurrences of travel path inundation. The addition of upstream stormwater infrastructure will benefit users of the Sinclair Wash corridor on the Mountain Campus.

2.0 Scope of Services

2.1. Task 1.0: Data Collection

Earthwise Solutions will subcontract out the following services to assist engineering design.

- Topographical Features Survey
- Water Sampling Survey
- Soil Matrix Analysis

A topographical survey will be subcontracted to provide information on existing site conditions. The subcontractor will follow industry standard topographic survey procedures and deliver the data as a CAD enabled file. The survey data will then be uploaded to AutoCAD to create an existing topographical surface for engineering design.

The client, Dr. Adam Bringhurst, has requested a water sampling survey of existing LID basins located at NAU to collect data on pollutant removal percentages of basins. A subcontractor will collect inflows and outflows and conduct lab analyses to determine pollutant levels. This will be done following Environmental Protection Agency (EPA) runoff testing procedures for Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) and Total Kjeldahl Nitrogen (TKN) [5]. The subcontractor will provide all lab and analysis data in a laboratory notebook and prepared datasheets.

The same water sampling contractor will conduct a geotechnical analysis to provide Earthwise Solutions with information on the local soil matrix as well as alternative soil matrices to obtain data on infiltration ability because infiltration rates control hydraulic design. The subcontractor will provide a recommended soil matrix with depths and materials determined. The subcontractor will provide the recommended design in an inter-office memorandum with hydraulic conductivity results.

2.2. Task 2.0: Site Investigation

Earthwise Solutions will investigate the existing conditions at the project site to inform the design of a proposed solution. This includes stormwater channel and culvert conditions, and a general information survey. This does not include a topographic features survey as detailed in Section 2.1 above. Investigation of site conditions is essential to confirm the comprehensiveness of site details. Earthwise Solutions will collect images, hydraulic feature dimensions, and take notes as appropriate to inform the engineering design.

2.3. Task 3.0: Hydrologic Analysis

Earthwise Solutions will conduct a hydrological analysis of current site conditions based on required storm parameters to determine flow volumes at the site. The modelling will be performed in HEC-HMS, an industry standard rainfall modeling software. The resulting model will inform the hydraulic design of the proposed basins with a derived runoff volume. The following model steps are shown as individual tasks.

2.3.1 Task 3.1: Watershed Delineation

The hydrologic watershed will be defined as the contributing area to the existing low point and outflow into Sinclair Wash. The topographic surface from the survey will be used in the hydrologic model to consider site topography. When delineating watersheds for LID design, it is not required to consider permeable, non-developed areas. COF identifies the contributing watershed as the total impervious area owned by a private entity that directly contributes to city stormwater infrastructure [4]. Thus, paved areas upstream of P62 must be considered, but landscaped areas between major impervious surfaces will not be considered.

2.3.2 Task 3.2: Determination of Site Runoff Coefficients

Earthwise Solutions will refer to industry standard runoff coefficients for all onsite conditions. Task 2.0: Site Investigation will inform the determination of appropriate runoff coefficients to accurately model the hydrologic behavior of the site. The runoff coefficient is a measure of the roughness, or resistance of water traveling over a surface.

2.3.3 Task 3.3: Calculation of Peak Design Flow

Using the results of the previous subtasks, modeling of the watershed, watershed conditions, and rainfall intensities will produce design peak flows at the identified boundary conditions. The boundary conditions are the locations where runoff leaves the South Commuter lot into existing stormwater infrastructure via curb cuts. Peak flows at the boundary conditions will be used for the hydraulic analysis in Task 4.0. Per COF LID design, a 500-year occurrence interval storm will be used to size LID basins. Detention of the 500-year storm will be eligible for the maximum tax reduction per COF stormwater credit manual. Additionally, a 100-year occurrence design storm will be modeled to represent lower tax reductions eligibility. Using HEC-HMS, these design storms will be modeled using the Rational Method for peak runoff determination [6]. In HEC-HMS this will be done by applying the site conditions rainfall intensities over the delineated watershed to determine the maximum expected flow to points of rainfall concentration.

2.4. Task 4.0: Existing Conditions Hydraulic Analysis

Following the completed hydrological analysis, Earthwise Solutions will use the calculated peak flows and runoff volumes to assess required hydraulic capacity. Modeling of the hydraulic conditions will be done in HEC-RAS [7]. Inputs into a HEC-RAS model plan include the flow and geometry data. The geometry data from the subcontractor survey will be used for existing conditions. Model outputs include water surface elevations and depths in plan and profile views.

2.5. Task 5.0: Ecological and Environmental Considerations

This task will inform basin design development to optimize ecological and environmental efficiency. Results of the water sampling and the soil matrix recommendation will be used for this task.

2.5.1 Task 5.1: Selection of Appropriate Vegetation

Vegetation that will increase biodiversity, include native species, improve water quality, have an acceptable infiltration rate, decrease water velocity, optimize hydrological function, and meet relevant regulations will be selected for basin use. The vegetation will also increase aesthetic value, create habitat for wildlife, and increase sustainability in the area. Final selection of basin vegetation will be done in accordance with the NAU Landscaping Master Plan [3]. Earthwise Solutions will develop vegetation plan alternatives meeting the above criteria and will use a decision matrix to determine a recommended selection.

2.5.2 Task 5.2: Selection of Soils

An appropriate soil media used to line the basins will be determined. This medium will be designed to optimize infiltration as well as attenuate pollutants within the soil matrix. Examples of pollutants that will be considered include total suspended soils, total dissolved solids, chemical oxygen demand, and turbidity. Soil properties such as depth, particle, and aggregate sizes to optimize hydraulic conductivity will be considered to determine effective soil layering. The determination will also consider code requirements (COF and NAU infiltration rates), the ability to support selected vegetation, and pollutant removal effectiveness.

2.6. Task 6.0: LID Basin Design

2.6.1 Task 6.1: Development of Alternative Solutions

Earthwise Solutions will use the existing topographic surface to generate alternative basin designs. This work will be completed using CAD software. The alternatives must make use of existing curb cuts. Hydraulic analysis of each alternative will be performed as part of the preliminary design process. Earthwise Solutions will generate three alternative designs to meet the detainment constraints of a 500-year occurrence storm. Alterative solutions will be designed to 30% completion. A 30% completion includes preliminary hydrologic and hydraulic analysis and not for construction design CAD sketches.

2.6.2 Task 6.2: Selection of Preferred Alternative

A decision matrix will be used to evaluate the alternatives to determine the recommended solution. Evaluation criteria may include hydrologic capacity, hydraulic efficiency, COF LID basin requirements, and estimated cost of implementation.

2.6.3 Task 6.3: Design of Preferred Alternative

The selected alternative will be design to 100% completion for presentation to the client. The 100% design includes complete existing and proposed hydrologic and hydraulic analysis, and completed Section 2.7, 2.8, 2.9, and 2.10. Additionally, the soil matrix report from the subcontractor will be included as an appendix.

2.7. Task 7.0: Development of a Maintenance and Monitoring Plan

Earthwise Solutions will develop a maintenance and monitoring plan for the proposed basins. Contents will include a monitoring schedule and checklist, and maintenance plan based on the estimated life cycle of proposed basins.

2.8. Task 8.0: Development of Construction Plan Set

Earthwise Solutions will create a plan set to ensure the construction of the detention basin will follow specifications and regulations. The plan set will contain: A Cover Page, General Notes, Details, Plan and Profile, Drainage and Grading, Erosion and Sediment Control Plan, and Landscape and Vegetation Sheet for a total of seven (7) construction plan sheets.

2.9. Task 9.0: Cost Estimation and Quantities

An Engineer's Opinion on Probable Costs (EOPC) provided by Earthwise Solutions will be developed and will include construction, materials, and maintenance costs with contingency. Additional quantity notes and specifics for contractor reference will be placed as appropriate within the plan set or on the Notes Sheet.

2.10. Task 10.0: Project Impacts

Environmental, economic, and social impacts will be discussed.

2.11. Task 11.0: Deliverables

2.11.1 Task 11.1: 30% Deliverables

This deliverable includes a report and presentation and is estimated to be due on February 13th, 2025. Tasks 1-4 will be complete by this time.

2.11.2 Task 11.2: 60% Deliverables

This deliverable includes a report and presentation and is estimated to be due on March 13th, 2025. Tasks 5 and 6 will be in process by this time.

2.11.3 Task 11.3: 90% Deliverable

This deliverable includes a report and 90% website and is estimated to be due on April 17th, 2025. All technical tasks will be complete at this deliverable.

2.11.4 Task 11.4: Final Deliverables

This deliverable includes a final report including the Plan Set, a final presentation, and the completed website. The estimated due date is May 6th, 2025

2.12. Task 12.0: Project Management

Earthwise Solutions will conduct meetings with project clients throughout the design process to ensure client product satisfaction. For all meetings, Earthwise Solutions will send an agenda 24 hours prior to all parties and will send meeting minutes within 24 hours to all invitees and attendees. Meeting agendas and minutes will be documented in a memo binder for all team, client, grading instructor and technical advisor meetings.

2.12.1 Task 12.1: Schedule Management

Earthwise Solutions will track the project schedule to ensure completion of all tasks on time. Any necessary changes to the schedule will be communicated to the client.

2.12.2 Task 12.2: Resource Management

Earthwise Solutions will track personnel time and expenses throughout the project to assure that the budget is met.

2.13. Exclusions

The following items are excluded from the scope of work of the project.

- Development of a Stormwater Management Plan to comply with the Arizona Department of Environmental Quality's general permit [5].
- An Environmental Impact Assessment in accordance with the Environmental Protection Agency [7].

3.0 Schedule

The project duration is 114 days and is scheduled to begin January 13, 2025, and end on May 6, 2025. This schedule is shown as a Gantt Chart (Appendix A). The schedule assumes an 8 hour workday for all tasks.

Estimated time for the major tasks are:

- Task 1.0: Data Collection and Subcontractors (5 Days)
- Task 2.0: Site Investigation (2 Days)
- Task 3.0: Hydrologic Analysis (1 Day)
- Task 4.0: Hydraulic Analysis (5 Days)
- Task 5.0: Ecological and Environmental Considerations (5 Days)
- Task 6.0: Basin Design (47 Days)
- Task 7.0: Development of Maintenance and Monitoring Plan (9 Days)
- Task 8.0: Development of Construction Plan Set (15 Days)
- Task 9.0: Cost Estimation and Quantities (42 Days)
- Task 10.0: Project Impacts (6 Days)
- Task 11.0: Deliverables (64 Days)
- Task 12.0: Project Management (114 Days)

The Gantt Chart shows the critical path of tasks to meet the required completion date. The critical path includes all tasks as this project follows a linear schedule that requires completion of prior tasks before advancing.

4.0 Staffing Plan

Earthwise Solutions staff includes a Senior Engineer (SENG), a Project Engineer (ENG) and an Engineering Technician (TECH). The staffing positions have the following qualifications:

- Senior Engineer: Professional Engineer (PE) and Certified Floodplain Manager (CFM) with 10 to 15 years of professional experience.
- Project Engineer: Professional Engineer (PE) with at least 5 years of professional experience.
- Technician: Engineer-in-training (EIT) with an ABET accredited degree and EIT Certificate, less than 5 years of experience.

Table 4-1 shows the proposed staffing table for completion of engineering services.

Table 4-1: Staffing Table

Task	SENG Hours	ENG Hours	TECH Hours
1.0: Data Collection from Subcontractors	5	5	5
2.0: Site Investigation	5	10	5
3.0: Hydrologic Analysis			
3.1: Watershed Delineation	1	1	2
3.2: Determination of Site Runoff Coefficients	1	1	1
3.3: Calculation of Peak Design Flow	1	1	1
4.0: Hydraulic Analysis	5	20	20
5.0: Ecological and Environmental Considerations			
5.1: Selection of Appropriate Vegetation	-	10	-
5.2: Selection of Soils	5	10	-
6.0: LID Basin Design			
6.1: Development of Alternative Solutions	5	35	40
6.2: Selection of Preferred Alternative	5	1	1
6.3: Design of Preferred Alternative	10	40	40
7.0: Development of Maintenance and Monitoring Plan	5	15	-
8.0: Development of Construction Plan Set	5	30	50
9.0: Cost Estimation and Quantities	10	15	-
10.0: Project Impacts	5	-	-
11.0: Deliverables			
11.1: 30% Deliverables	5	5	5
11.2: 60% Deliverables	5	5	5
11.3: 90% Deliverables	5	5	5
11.4: Final Deliverables	5	5	5
12.0: Project Management			
12.1: Schedule Management	10	5	5
12.2 Resource Management	10	5	5
Subtotal	**108**	**224**	**195**
Total (person-hours)			**527**

5.0 Cost of Engineering Services

Table 5-1 shows the cost estimate for engineering services.

Table 5-1:Cost Estimate for Engineering Services

Category		Hours	Rate, $ / Hour	Cost
1.0 Personnel	SENG	108	$ 138.32	$ 14,939
	ENG	224	$ 86.40	$ 19,354
	TECH	195	$ 60.00	$ 11,700
	Total Personnel			**$ 45,992**
2.0 Supplies	Software, Lab Use	60 Days	$100 / Day	**$ 6,000**
3.0 Travel	Travel Expenses	-	-	**$ -**
4.0 Subcontracting	Surveying	-	-	$ 6,000
	Runoff Water Sampling	-	-	$ 3,500
	Water Matrix Analysis	-	-	$ 3,500
	Total Subcontracting			**$ 13,000**
			Total Costs	**$ 64,992**

The personnel costs are broken down by staff members. The total personnel costs are estimated at $45,992 for the hours represented in Table. Supplies include software (AutoCAD, HEC-HMS, HEC-RAS) and associated computer lab use. Total supply costs are estimated to be $6,000. No travel is required for this project. Subcontracting includes surveying, water sampling and testing, and soil matrix analysis. Subcontractor expenses are $13,000. The subcontractor provided estimated staffing for the provided services to Earthwise Solutions to include in the total costs. The total costs for engineering services are an estimated $64,992.

6.0 References

[1] S. M. City of Flagstaff. [Online]. Available: https://www.flagstaff.az.gov/4781/Stormwater-Rate-Adjustment.

[2] C. o. F. S. Management, "Stormwater Credit Manual," October 2023. [Online]. Available: https://flagstaff.az.gov/DocumentCenter/View/75459/2023-03-21-Stormwater-Credit-Manual?bidId=. [Accessed September 2024].

[3] N. A. U. F. Services, "Comprehensive Sustainable Smart Campus Master Plan," October 2023. [Online]. Available: https://in.nau.edu/wp-content/uploads/sites/139/2023/11/NAU-Smart-Campus-Master-Plan_11202023_DLR-Group-Part-1.pdf. [Accessed September 2024].

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[6] O. D. o. Transportation, "Rational Method," [Online]. Available: https://www.oregon.gov/odot/hydraulics/Docs_Hydraulics_Manual/Hydraulics-07-F.pdf.

[7] A. C. o. Engineering, "HEC - RAS," [Online]. Available: https://www.hec.usace.army.mil/software/hec-ras/.

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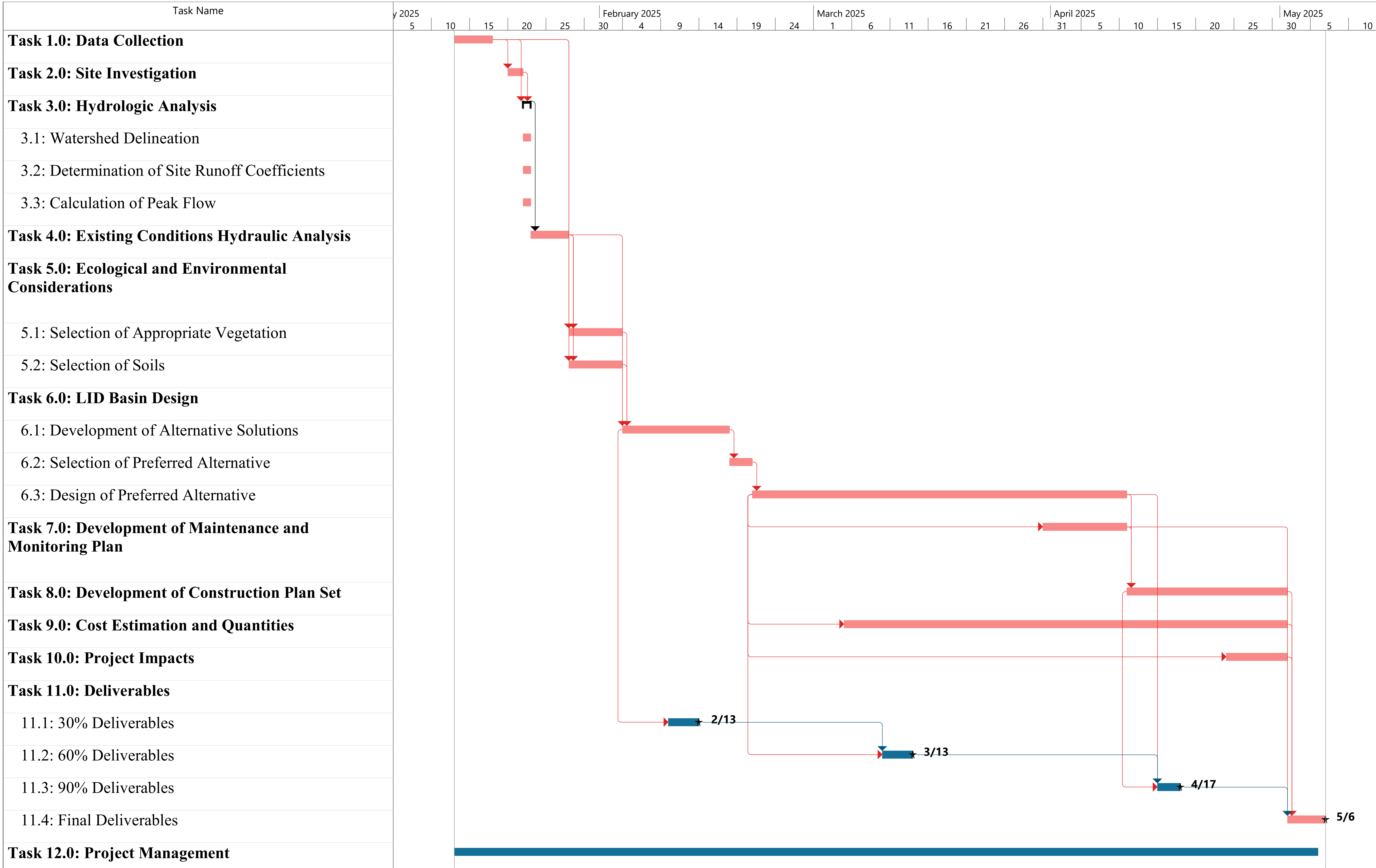
[9] Environmental Protection Agency, "National Environmental Policy Act Review Process," [Online]. Available: https://www.epa.gov/nepa/national-environmental-policy-act-review-process. [Accessed October 2024].

7.0 Appendix

Appendix A Gantt Chart


Task Name
y 2025
February 2025
March 2025
April 2025
May 2025
5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21 26 31 5 10 15 20 25 30 5 10
Task 1.0: Data Collection
Task 2.0: Site Investigation
Task 3.0: Hydrologic Analysis
3.1: Watershed Delineation
3.2: Determination of Site Runoff Coefficients
3.3: Calculation of Peak Flow
Task 4.0: Existing Conditions Hydraulic Analysis
Task 5.0: Ecological and Environmental Considerations
5.1: Selection of Appropriate Vegetation
5.2: Selection of Soils
Task 6.0: LID Basin Design
6.1: Development of Alternative Solutions
6.2: Selection of Preferred Alternative
6.3: Design of Preferred Alternative
Task 7.0: Development of Maintenance and Monitoring Plan
Task 8.0: Development of Construction Plan Set
Task 9.0: Cost Estimation and Quantities
Task 10.0: Project Impacts
Task 11.0: Deliverables
11.1: 30% Deliverables
11.2: 60% Deliverables
11.3: 90% Deliverables
11.4: Final Deliverables
Task 12.0: Project Management
2/13
3/13
4/17
5/6