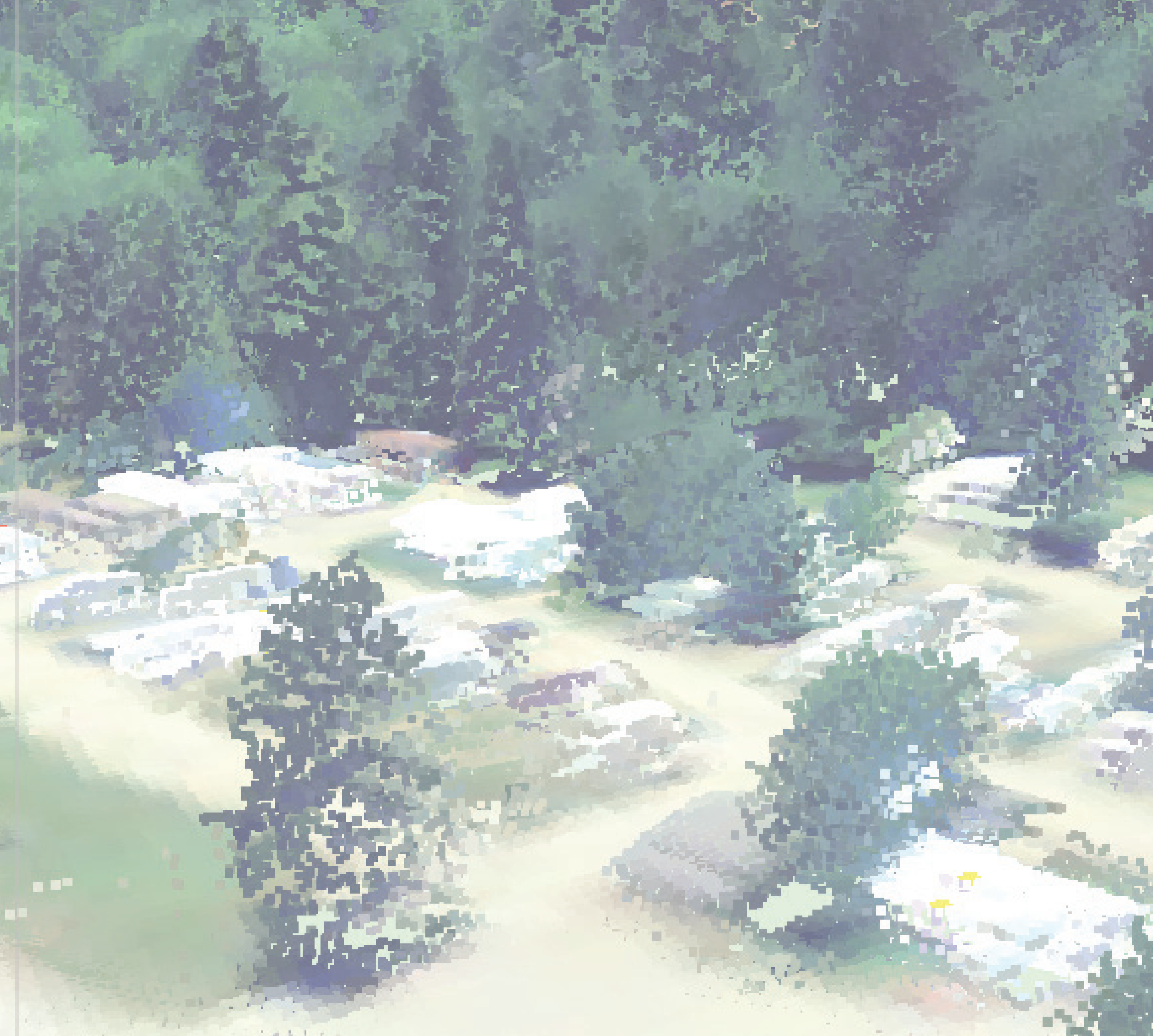

BIM-SCAPES

FRAMEWORK FOR MODELING SITE SCALE PERFORMANCE THROUGH DESIGN

ALDEN CARR: 2018

AKNOWLEDGEMENTS

KORY RUSSEL

Many thanks for helping me to critically evalute design and sustainability through a unique lens. This has been a fun and compelling process.

MASTERS PROJECT COMMITTEE

Patience, active listening and guiding me towards self discovery.

ROSA

Your support throught the the many late nights that went into this project was greatly appreciated. Thanks for the many conversations and feedback which has lead to break throughs and growth during this project.v

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ABSTRACT

Extending the workflow of Building Information Modeling (BIM) to the field of landscape architecture has significantly improved the workflow across design disciplines. This project explores how BIM can assist landscape architects in innovative planning for site scale storm and wastewater systems.

As a proof of concept, this project produced three redevelopment plans for the Saginaw Mobile Home Park in Saginaw, Oregon. The design goals created strategies for providing equitable living spaces for maintaining manufactured home parks as a type of affordable housing.

BIM was pivotal in the design process as early schematic designs were able to tabulate and inform sizing and locations of stormwater treatment facilities based on the site-specific geospatial information. As the design process refined the level of detail, results were continuously re-evaluated to inform the design process and adhere to the site needs.

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CHAPTER ONE

1. INTRODUCTION

1.1 INTRODUCTION

Since the field of landscape architecture's analog foundation, design tools have evolved in sophistication. In today's modern world, digital tools dominate in their power and uniqueness, allowing for projects to develop at unprecedented rates. As contemporary projects in landscape architecture begin to address more complex challenges and collaborate with multiple agencies, there is an urgent need to effectively communicate, organize, and document large sets of information. The aspect of file sharing has been problematic as the abundance of available digital tools for designers of the built environment do not always produce interchangeable information. Building Information modeling (BIM) has emerged as an industry standard and platform for designers to collaborate and share site design information. Designers have embraced BIM as it involves establishing workflows for seamless information sharing. The core of the information sharing is a responsive three-dimensional model which enables all designers to continually refine their work as other components of the design evolve. This workflow has been instrumental in reducing design omissions and project errors.

Although Building Information Modeling (BIM) has become standardized in the process of designing and developing the architecture of buildings, it is less prevalent within the field of landscape architecture. BIM is an established workflow, which allows for the integration of efficiencies for using the information to guide the creation of built projects. Working with standards for sustainable certifications such as LEED, BIM has grown significantly in the field of Architecture since its origins in the 1970's and resurgence in the 1990's (Ahmad & Aliyu 2012). These workflows are based on the ability of designers to create 2D/3D models which have embedded databases of information into the designed geometry which quickly generate reports (Figure 1.1). The automation of such processes has allowed for projects to produce fewer errors and omissions throughout the lifecycle of a project from design development and construction to the operation and management of the site over time.

The key to fully engaging in the BIM workflow pertains to interoperability of software in which the design is created, and to transfer the information between users. The field of landscape architecture has been slow to adopt BIM as a workflow, as they typically draft in 2D-programs. Although some designers and firms are beginning to explore the software, there is a limited number of resources, standards, and documentation to guide landscape architects into fully participating in the BIM workflow. (The Landscape Institute 2014).

Currently, in the field of landscape architecture, BIM is underutilized as an established workflow. Geographic Information Systems (GIS) are frequently used instead to contextualize sites to existing natural and social conditions. The product is a synthesis of information embedded in geospatial data models. These models can analyze existing site conditions and project future scenarios. However, they become disconnected from the context of the design process as they cannot continue to inform the design process as the site develops.

Incorporating BIM with GIS can integrate a site analysis into the design process, enhancing a project's contextualization to the existing site. This method allows landscape architects to convey the large-scale site analysis of ecological and human uses within sites. Essential features are location planning, site suitability, viewshed analysis, solar radiance, and transportation (The Landscape Institute 2016). This systems-based approach allows for site design to efficiently

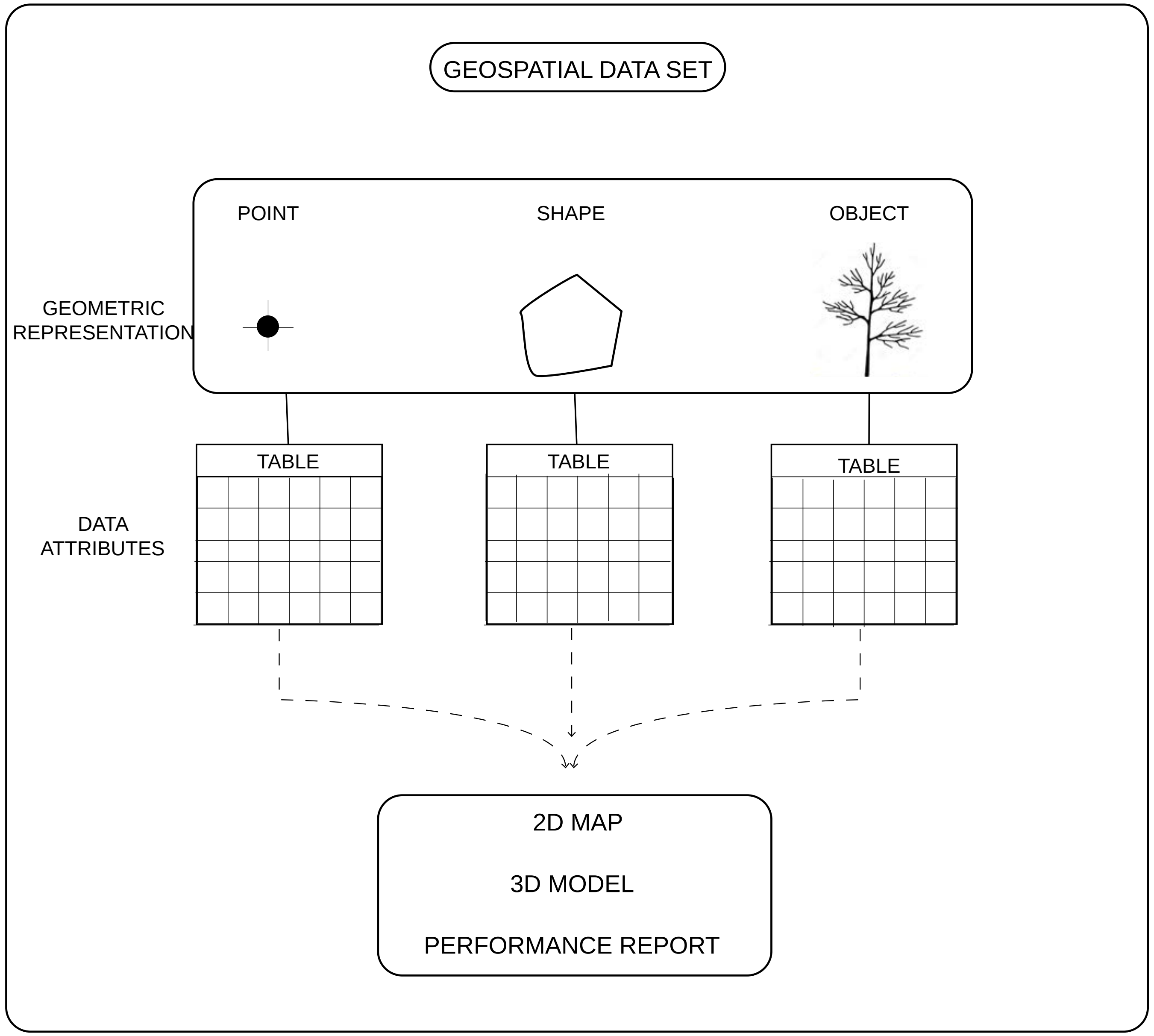


Figure 1.1 Process of Information Management for BIM

identify the components which are essential to a site so that designers can thoughtfully weave dynamic systems into the built environment which improve both social and ecological conditions.

Within the site design, BIM can be used to calculate relevant space data, such as net area and efficiency ratio. The creation and visualization through 3D models make it possible to calculate volumes. For example, the potential carbon sequestration of plants can be attributed to specific species. A finalized planting report can quickly determine the carbon offset of a site design. The ability to produce evidence supported design is one of the strengths BIM has to offer the field of landscape architecture.

Countries other than the United States have developed policy standards for the built environment that utilize BIM to document the materiality of the sites and their effects on the criteria they wish to hold. Large-scale international projects that take place in the U.K. or Singapore are required to be generated within a BIM workflow as demonstrated in the book, BIM for Landscape Architecture (Landscape Institute 2016). BIM is a promising tool for landscape architecture to create sites that are responsive to the needs which a growing population places on built environments. Unfortunately, the lack of policies regarding sustainability constrains the use of BIM by designers in the United States. Designers in the United States will be able to adhere to ecological voluntary performance-based assessments guided by standards such as SITES AP, and Stormwater Management requirements.

1.2 PROJECT SIGNIFICANCE

Given the various fields of science that guide landscape architecture and the vast databases of information and knowledge they already utilize, it is perhaps surprising that landscape architecture has not adopted BIM workflows. It is not uncommon for landscape architects to expand the notion of what a landscape is to large scales when engaging with fields such as Geographic Information Systems, Green Infrastructure, Geodesgin, Ecological Design, and Alternative Futures. However, the resolution in which these previously mentioned fields evaluate landscapes tends to be at a coarser resolution. It is essential to understand how these disciplines manage datasets as they can inform the adoption of BIM for landscape architecture (Ervin 2016).

Green Infrastructure is becoming a new standard in landscape design with functions like stormwater filtration designs expanding to new territories such as rooftop gardens and urban plazas. Integration of these cross-disciplinary teams requires the sharing of a single site model to reduce the risk of design-based errors. Additionally, there is a need for landscape architects to more efficiently tabulate site scale water budgets about the materials. As projects evolve and change throughout the design and development process, BIM automatically conducts new tabulations. The framework of BIM allows designers to refine features that improve site performance in context to the sites climatic data, saving time while improving accuracy.

To further explore how BIM can benefit the field of landscape architecture, this project will create and utilize a BIM workflow to create a master plan for the Saginaw Mobile Home park in Saginaw, Oregon. As human populations continue to grow, design will need more integrative approaches to evaluate design sites. With design becoming more integrated, tools to meet future challenges related to human population growth, and competition for resources, our research and education systems need to encourage the level of interdisciplinarity that will produce experts trained in both ecology and design (Lovel 2008). This project is using the framework developed within the field of landscape ecology, that human-designed environments can maximize efficiencies of ecological functions through thoughtful design. Specifically, this project looks at the built environment through a multifunctional perspective which serves economic, social, and environmental needs of our cities by the production of performative landscapes (Lovell and Johnston 2009).

The goal of this project is to explore the generation of a BIM workflow for landscape architecture and thus enable the creation of more sustainable masterplans. Without a foundation of methods for using BIM in landscape architecture, the new knowledge will be produced by research through designing as a methodology. The project is working with an applied affordable housing project based in Saginaw Oregon. The development and documentation of BIM as a design tool will assist faculty at the University of Oregon in re-evaluating ways in which they teach students to identify landscape performance into the curriculum. New tools for modeling environmental performance as required for future accreditation standards implemented by the Landscape Architecture Foundation (LAF). Currently, the LAF-Performance series does not have any information, or case studies regarding BIM as a design tool.

1.3 The Process of Inquiry

The design portion of this project aims to develop guidelines for designing sites with net-zero water waste. The knowledge generated will allow landscape architects to coordinate and contribute site-specific information to interdisciplinary design teams using the BIM workflow. Although the information generated from this project is site-specific, research through designing will allow for an in depth understanding of the capabilities of BIM for landscape architecture. Throughout the design process, a reflexive approach will allow design decisions to be made by using both inductive and deductive reasoning guided by the project goals. This workflow allows for the design to respond to changes of the existing site as the plan develops by integrating site information into the geometry of the site design. This approach to developing new knowledge was validated by Lenzholzer et al. 2013 where they clarify how (post) positivist knowledge claims allow landscape architects to translate specialized knowledge, such as ecological design, into applicable design methods through the process of designing (Deming and Swaffield 2011).

My background in environmental science and restoration ecology trained me to approach design through the lens of systems thinking. Linking the way in which we build upon a site and how it interacts with natural systems fascinates me. I approached my graduate project through the lens of performance-oriented site design.

It was my goal to improve the process of integrating site information with digital design tools. Through exploring various parametric tools and workflows, I decided that Building Information Modeling (BIM) would be an intriguing topic of inquiry.

The ability to use BIM for landscape architecture is growing amongst professionals. However, there are minimal examples and guidelines of the process of BIM being used for site design. The most comprehensive study I found during my literature review called for innovative explorations to integrate the process of BIM to the field of landscape architecture (Sipes 2017). Through the lens of stormwater management, this project will present how and why BIM can be a useful tool for site design and development. With a vision of how to include BIM as a tool, this project uses a reflexive framework to inquire how BIM can be integrated into the field of landscape architecture.

Deming and Swaffield recognize that there are non-traditional approaches to develop inquires that are relevant to the field of landscape architecture. They define the reflexive approach as “researchers [that] move back and forth between deductive and inductive perspectives, modifying their theoretical concepts and exploring new possibilities of understanding significance in the light of theoretical concepts and exploring new possibilities of understanding and new ways of knowing.” By translating the empirically produced site information into guidelines, research through design allows bridging the “Utility gap” between academic knowledge and applicability (Lenzholzer et al. 2013).

The specific scope of this project is exploring the ability of BIM to inform site designs to manage waste and stormwater better. The nonprofit, Saint Vincent de Paul provided an opportunity for a site-specific project at the Saginaw Mobile Home Park, which they own. The end product of this project will be a master plan. The master plan will guide the current park to transform into a community-oriented village with sustainable wastewater management.

1.4 GOALS AND OBJECTIVES

Motivation: Creating a water budget for the Saginaw mobile home park can allow the site to develop in such a way that it accommodates the social and recreational needs of the residents. In order to blend the storm and waste water into the designed elements of the park I will need to know the following.

- What is the process of implementing BIM into the workflow for landscape architecture?
- Can BIM improve the process of designing for stormwater management during a master planning project?

CHAPTER TWO:

2. METHODS

The first chapter introduced the current state of digital tools in landscape architecture. With the development of high powered tools, communication is considered a problematic element of design utilizing the full capabilities which BIM software can support. Without using BIM, it is challenging to organize the information needed to evaluate site performance through matrices such as SITES AP and LEAD. The building design field has significantly benefited from the assistance of BIM. This Chapter explores the question of how BIM can be integrated into landscape architecture to improve waste and stormwater management. This project is using the specific location of the Saginaw mobile home park, to apply Research through design. The design goal is to present Saint Vincent de Paul with three design option with a balance of sustainability, social responsibility, and economic feasibility. The three preliminary site designs can begin a dialogue within the non-profit to generate a long-term vision for the mobile home park. This chapter contains the methods and processes the project used in exploring the capabilities of BIM to inform design regarding conditions of storm and wastewater needs of the site. The goal is to reach a net zero water project through the integration of stormwater design as well as black and greywater treatment.

2.1 REGIONAL SITE INFORMATION

This Project takes place within the Willamette River Basin, a tributary of the Columbia River (Figure 2.1 Context map). The Willamette River Basin as a hydrologic Unit is 180 miles long and consists of 12 sub-basins. The watershed hosts 70-percent of Oregon's populations 1,080,932 and six of Oregon's largest cities: Portland, Eugene, Salem, Gresham, Hillsboro, and Beaverton (DEQ). Through strategic planning, the state of Oregon regulates an urban growth boundary (UGB). The UGB contains urban growth to delineated areas while allowing rural communities to support rural Industry such as Timber and Agriculture. The rural communities that are outside of the UGB have developed within the floodplain area, which is a considered critical habitat and host natural ecosystem processes.

The Oregon Department of Environmental Quality has listed: Temperature, Bacteria, & Mercury as primary agents of concern for deteriorating natural conditions in the Willamette River Basin (DEQ 2018). Large-scale community design work has approached improving the future ecological functions and processes for this region through the development of the WIllamete River Basin Planning Atlas. Such alternative futures work by Dave Hulse has collaboratively connected stakeholders in considering various visions for the future of the Willamette River Basin. The future trajectories and restoration plans that the Atlas project identified can significantly improve most of the environmental conditions that threaten the watershed by recovering habitat and increasing cooling potential of the river (Hulse et al. 2001). However, The Department of Environmental Quality has deemed the issue of bacterial contamination to still be of concern. One of the non-point source contaminations of bacteria for the river comes from residential homes located in rural sub-basins of the Willamette River. This issue will continue to develop as the population is anticipated to keep growing within the Willamette Valley, and rural areas (DEQ 2012).

The research site, Saginaw Mobile Home Park exists within the Coast Fork River of the Willamette River Basin. The basin is an 8-Hydrologic Unit Code river that spans 426,000 acres and hosts a population of 35,600 people as of 2006 (DEQ 2018). Most of this watershed is within Lane County, with a portion occupied by Douglas County (Figure 2.3 site Map). The NRCS has identified poor water quality as a growing concern as development continues to occur within the floodplain. Failing septic systems in conjunction with significant storm events have released untreated raw sewage into the adjacent rivers. The increasing rate of chemical and biological contaminations to the Willamette River poses a serious risk to human and ecological health (DEQ 2018).

Figure 2.1 Regional Context Map

2.2 REGIONAL CLIMATE

The climate within the Willamette River Basin (WRB) is a moderate Mediterranean climate. The WRB has both a warm and cold months with minimal extremes. There is a distinct wet and dry season associated with the seasonal climate. Precipitation predominantly occurs during the colder seasons, from October through April. Between May and November, the region receives less than 5% of its annual rainfall. The wet season can produce heavy precipitation loads, in short, concentrated periods of time. Extreme storm events with occurrences of 10 and 25-year frequencies can convey a large flux of contaminants to the river. Urban areas such as Portland and Eugene, have established frameworks for reducing overflows from sanitary sewage networks which combine stormwater and wastewater. Combined Sewage Overflow has historically been an issue during heavy rains causing systems to overflow and emit raw sewage into the Willamette River. Currently there is a limited amount of resources and strategies for rural communities which depend on decentralized waste treatment options.

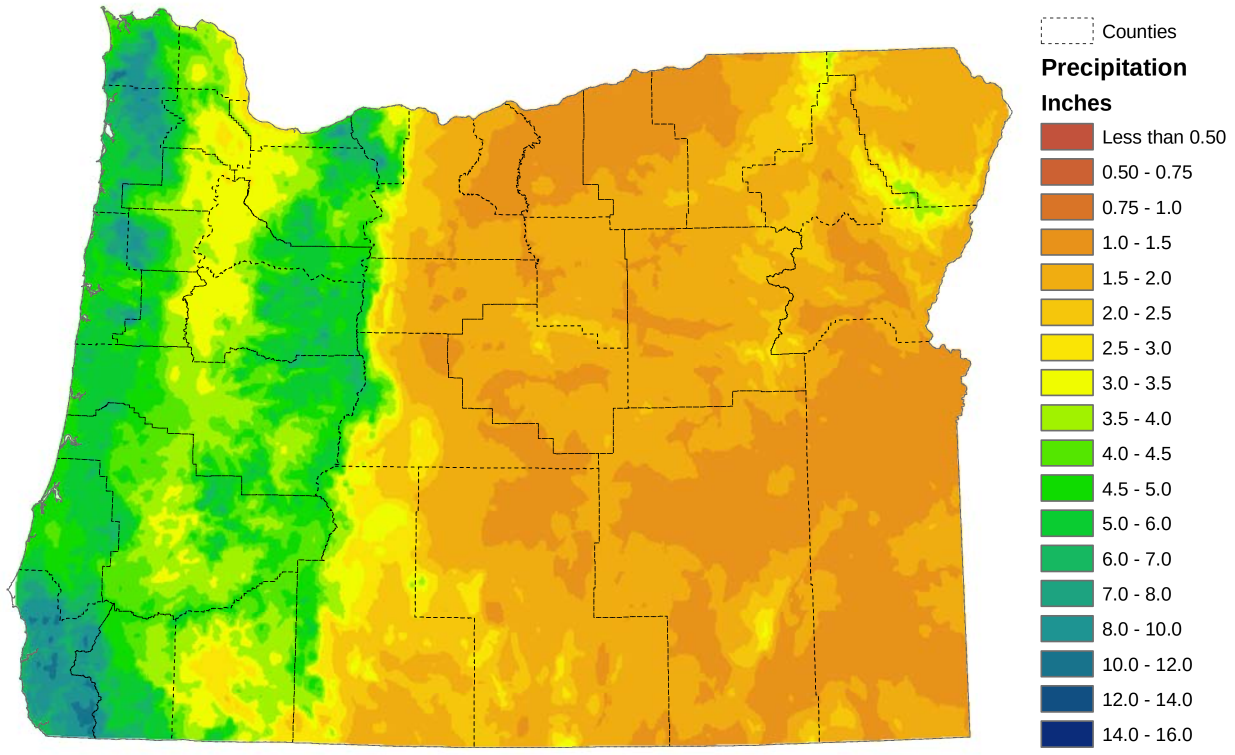


Figure 2.2: Oregon 24-hour 10-year Precipitation

2.3 SITE HISTORY

The mobile home park has existed as a business for more than 30 years. Although the sign upon entering says, overnighters welcome, most of the homes on the site support longtime residents. As people continued to permanently place their homes on the property they developed a spatial arrangement through piecemealing the placemente of dwelling units rather than trategically planning the arrangement. As the number of full-time residents increased, the infrastructure was unable to support the basic needs of the residents. Raw sewage regularly emerged to the surface and entered the groundwater posing a human and ecological health risk. In the same course of time, community spaces which once hosted showers and amenities deteriorated to an unusable condition.

The State of Oregon notified the original park owner unless they repaired the sanitation system the business would face closure. This would be problematic as most of the residents were unable to move their homes due to financial constraints or physical condition of their homes, leaving the residents at risk of becoming homeless. The non-profit St. Vincent De Paul of Eugene, Oregon chose to service the needs of the residents as part of their mission statement. Through purchasing the park, they invested in bringing the site up to the codes of Lane County and The state of Oregon. Additionally, they have set the goal of improving the park for the social well-being of the residents through grants and donations. This project plans to further refine the vision through exploring the variations between three site design with different spatial arrangements and types of housing units.

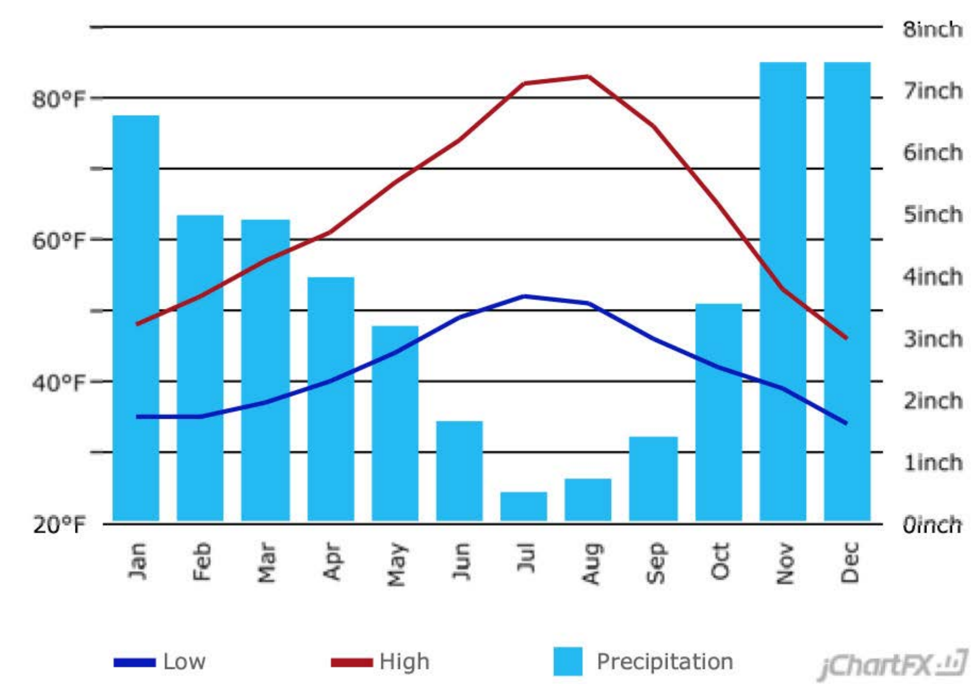


Figure 2.3: Monthly Precipitation Graph

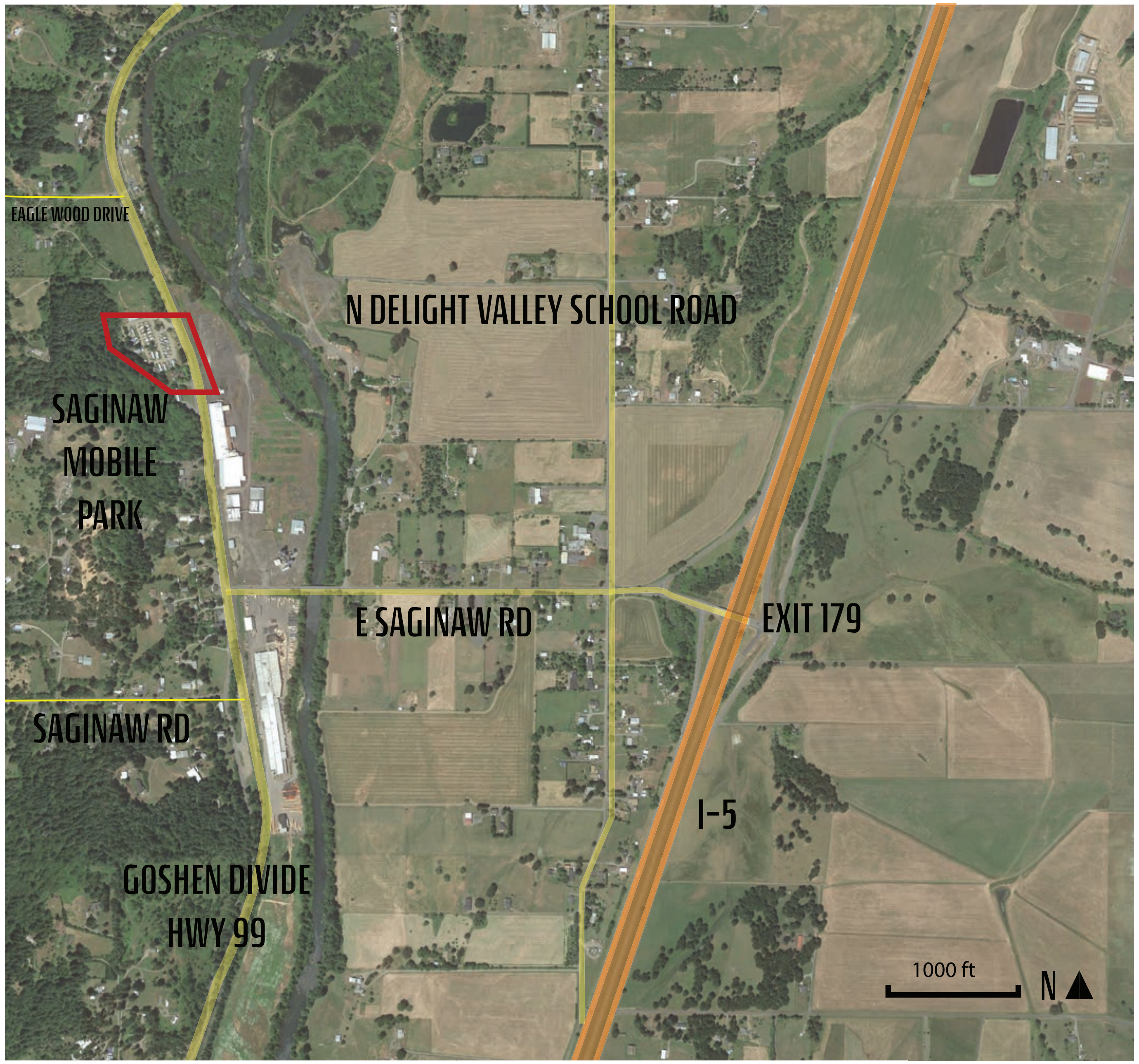
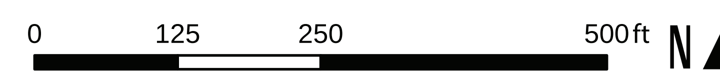


Figure 2.4 Saginaw Context Map

Figure 2.5: Existing Site Map



2.4 THE RESEARCH

Given that BIM is a dynamic process of designing and synthesizing information based on the parameters of the project, there is not a linear path for researching through design. This project required an assortment of dynamic methods to understand how to acquire, process, and align the site information to achieve the goals of the project. Additionally, there are specific zoning restrictions and constraints by environmental systems which inhibit the innovative pursuits of this project (State of Oregon 2018). The project can be broken down into the following phases and methods (Figure 2.4).

2.5 LITERATURE REVIEW

Literature of academic journals, as well as industry related reports, were reviewed to inform design-based criteria that would link Building Information Modeling and sustainable site design. From this literature, the project adopted the site design parameters for which scale and scope of this project could relate the built site to the existing natural systems and processes. I extracted this framework from work in the field of Geodesign (Ervin, Stephan 2013).

Additional articles were read to instruct on technical aspects of building information modeling. I researched different types of software to evaluate which would be most useful for the field of landscape architecture. For this project I chose Vectorworks, as it has seamless interoperability with GIS shapefiles. Additionally, the software represents curved geometry through Non-Uniform Rational Basis Splines (NURBS), which describe 3-D geometry accurately when drawn in 2-D. The accuracy which NURBS provide is more conducive to depicting the irregular landscape features. The Vectorworks company provided me with the Designer suite of software as well as supplemental online training courses and seminars.

Additional research was conducted to establish best practices for waste and stormwater design. For this project, all stormwater designs will be constructed to handle the 10-year storm event and comply with the standards defined in the 2014 Eugene Stormwater Manual.

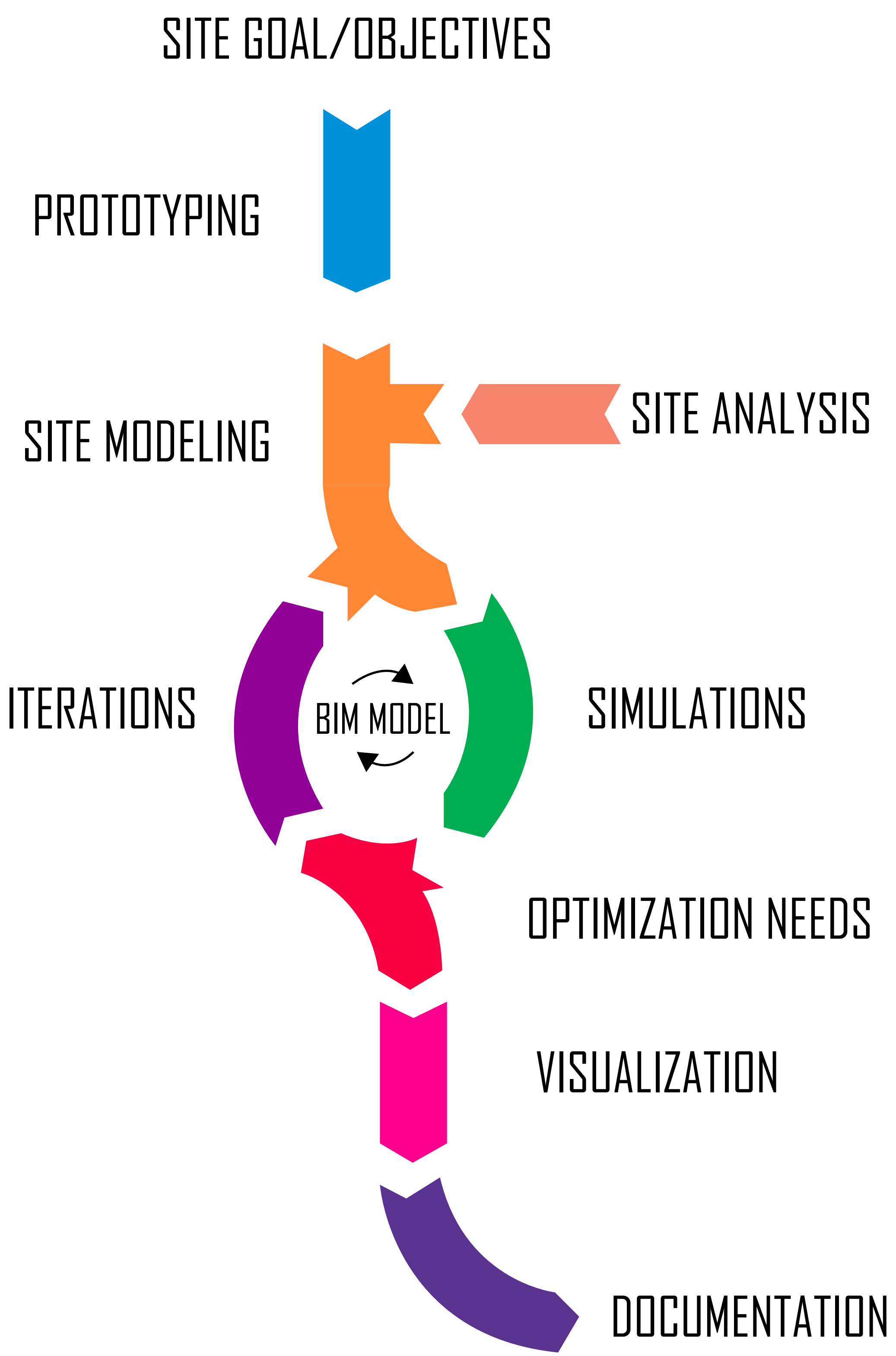


Figure 2.6: Research Process Diagram

2.6 PERSONAL COMMUNICATION WITH AGENCIES FOR REGULATION AND COMPLIANCE

Upon deciding to use the Saginaw Mobile Home Park as a research site, two preliminary site visits occurred at the beginning of the project. From these visits, I developed personal relationships with the property manager as well as on-site staff. Information was shared regarding a successful mobile home park transformation which St. Vincent de Paul had previously completed, located in Oakridge, Oregon. From these visits, conversations between myself and the park manager identified the initial site design needs and programming. At this point I was also orientated with the site and existing structures, both functioning and not. Two of the significant changes facing this park were replacing existing dwelling units with double wide homes, 29'x48', that will be owned by Saint Vincent de Paul and leased to occupants. Additionally, the owners would like to provide paved circulation paths and retrofit an alternative wastewater treatment onsite.

Saint Vincent De Paul was initially interested in a nutrient recovery system to treat the waste generated onsite that could generate revenue through bi-product production/extraction. With the assistance of professor Kory Russel, I evaluated a series of alternative wastewater treatment options to replace the existing system. Sizing requirements, input requirements, and net return on investment were critical factors considered in choosing the most compatible option for the population of the park. To determine if it is possible to reuse grey and wastewater on site, the department of environmental quality was consulted to verify the limitations and constraints. Each state can monitor and regulate wastewater regulations within the standards of the federal requirements. In seeking to reuse greywater, projects must comply with Oregon State Law OAR 340-045-0033. Additionally, two permit options classify the Water Pollution Control Facility, 2401, and 2501. For the reuse of treated wastewater, Oregon's Recycled Water Use Rules allow the use of recycled water for beneficial purposes so long as the system provides a resource value, protects public health, and protects the environment [OAR 340-055-0007].

Water reuse use in Oregon requires at a minimum:

1. Recycled Water Use Plan (RWUP)
2. (i) National Polution Discharge Ellimination System (NPDES)
   OR
   (ii) Water Pollution Control Facility (WPCF)

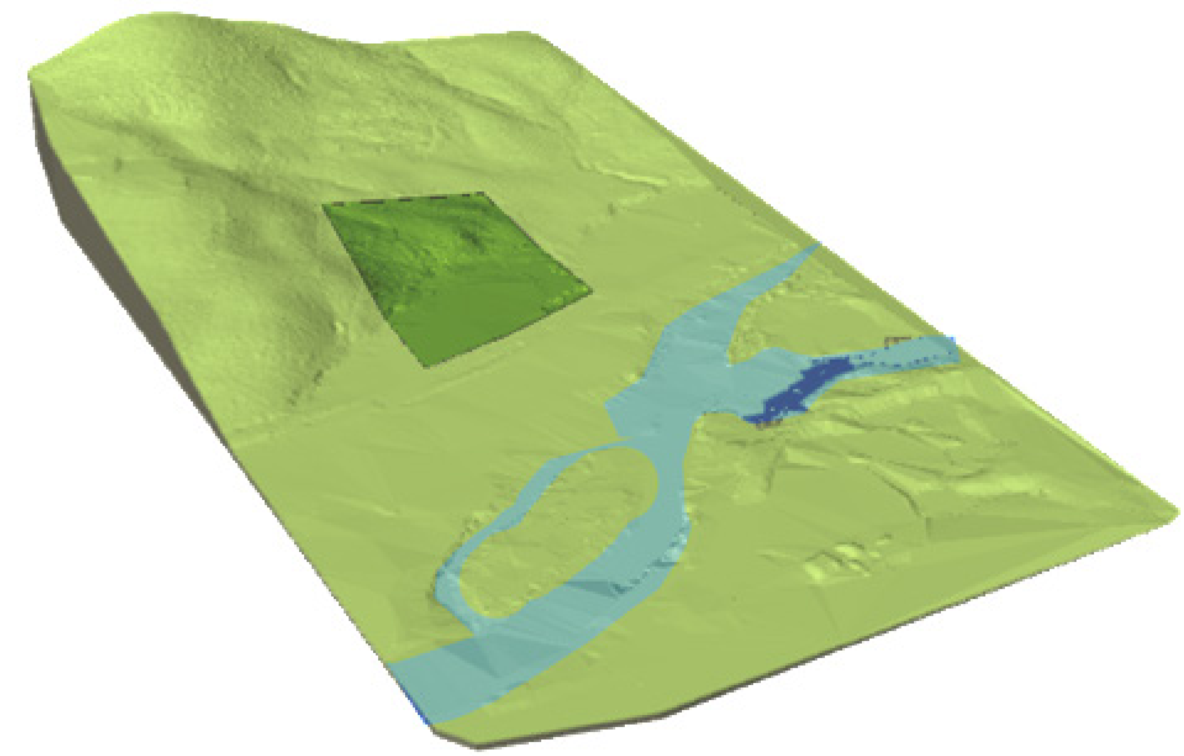


Figure 2.7: Digital Surface Model

2.7 SITE ANALYSIS & INVENTORY

Site analysis gave design insight to understand how stormwater interacts with the existing site by evaluating the current topography and hydrology. Design strategies for stormwater management that optimize connected open and social spaces can be developed by contextualizing the built components of the park with its natural ecological systems. All site information came from publicly available geospatial information sources. Lane County Geographical Information System & Maps and Services provided tax lot information, as well as hydrologic, vegetation, soils, and natural resource inventories. The information was sorted and processed so that useful site information could be formatted and projected to be compatible with the Vectorworks software.

The Oregon State Lidar Consortium provided Lidar datasets for the region. These point cloud objects were processed and evaluated in ArcMap 10.4. The Lidar dataset produced both Digital Terrain Models, as well as Digital Elevation models (figure 2.5). Slope and aspect were used to determine both optimal building orientation using a plugin for Grasshopper called Ladybug (Sadeghipour Mostapha 2013.) Additional preliminary analysis identified optimal building locations by locating land with slopes less than 5% to minimize the need for excavation. The preferred area for the building was modeled and georefferenced in ArcGIS then integrated intothe BIM model.

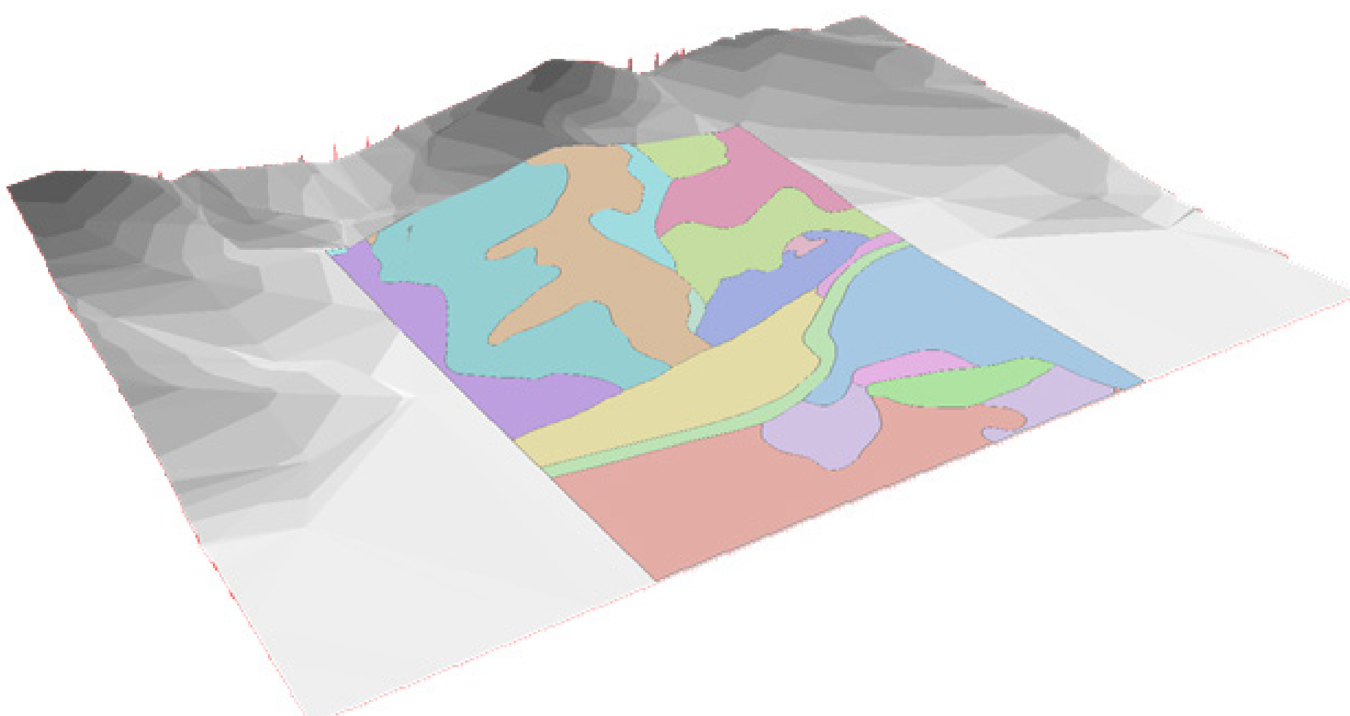


Figure 2.8: Site Soil and Topography Model

2.8 INFORMATION BASED DESIGN DEVELOPMENT

Upon gathering the necessary parameters of the site, I produced a physical model to explore various spatial arrangements for the park. Units based on the new mobile home dimensions were constructed to represent a potential parcel size. The placement of homes was created to accommodate a community center, open space, circulation, and existing established vegetation. To optimize passive heating and cooling, buildings with the most extended sides facing south/southeast. I photographed the arrangements to document the process (See figure 2.9 and 2.10).

2.9 BIM PERFORMANCE MODELING

The three park typologies were constructed in Vectorworks to produce conceptual digital models. The units were double wide mobile homes that have a footprint of 29 feet by 48 feet. The design incorporated setbacks and regulations according to the 2010 Oregon state regulations for mobile home parks (state of Oregon 2002). The Schematic plan included vehicle circulation with a standard two-lane road with six-inch curbs on both sides. The model was developed to differentiate and account for the various nonpermeable surface materials. The square footage of roof surface areas, asphalt/concrete, and gravel is determined so that the stormwater simulations can be applied.

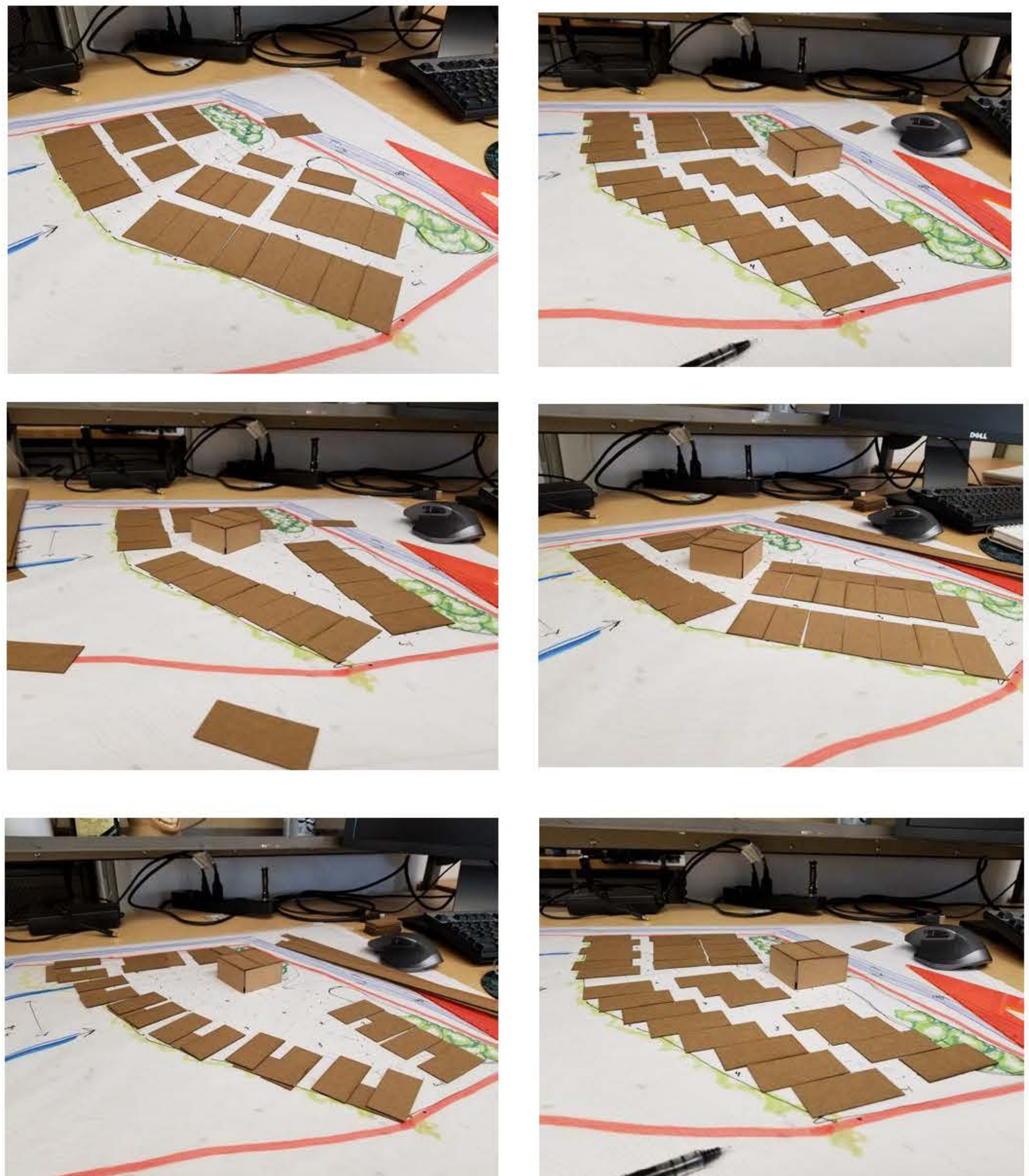


Figure 2.9: Prototyping Physical Model

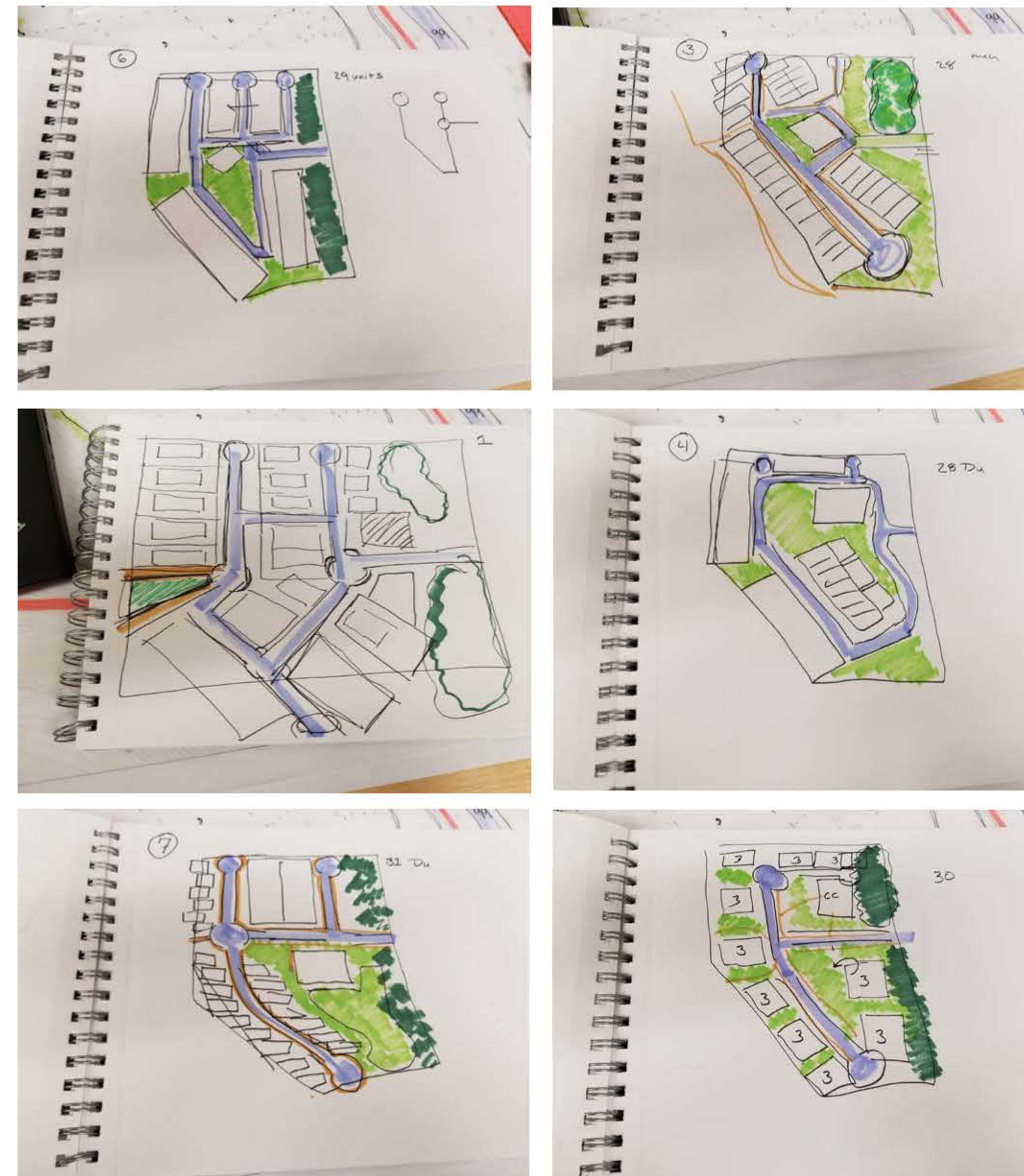


Figure 2.10: Schematic Site Designs

2.10 MODELING VOLUMES OF STORMWATER RUNOFF

This project aims to treat, and fully infiltrate all stormwater produced onsite for the duration of a 10-year storm event. The ten-year storm event is the peak volume of rain, which has the probability of re-occurring once every ten years. To adequately size Stormwater facilities for the 10-year storm, information of rainfall intensity, and existing soils are required.

Weather data supplied from Eugene, Malheur Weather Station was used to generate the peak rainfall intensity. The rainfall intensity is graphed and normalized for the 10, 25, and 100-year storms (figure 2.11). Rainfall intensity is considered to be the volume of precipitation that occurs over a 24 hour period. Rainfall intensities, or storms, were ranked and evaluated by their reoccurrence interval.

The ten-year storm event is a standard metric for designing stormwater runoff for both the city of both Eugene and Portland, Oregon. Upon knowing the peak intensity, The Rational Stormwater Runoff equation (figure 2.12) was used within the BIM worksheets to determine the volume of runoff generated by each non-permeable surface by specific location. Being able to define spatial organization for the calculation improved the ability of design stormwater treatment facilities as a system, with independent units throughout the park (Apendix A).

Upon knowing the quantity of stormwater produced on site by single, and group sources, the design for the site can better incorporate the treatment of stormwater. Using the presumptive approach for designing was necessary as the project aims to treat more than 10,000 square feet of surface for the project. The runoff generated by each zone determined the stormwater facility sizing, which included assumed rates of infiltration, and type of soil, to determine the specific size required. These designs were prepared and documented with the intention of being delivered to assist with generating a master plan vision for the Saint Vincent de Paul.

Rational Stormwater Equation: $Q = CiA$

Q = peak runoff rate, in cubic feet per second

C = dimensionless coeffcient between I and Q
(See tables below)

i = rainfall intensity, inches per hour for the design storm frequency and for the time of concentration of the drainage area

A = area of drainage area (acres)

C Runoff Coeficient Values

BUILT SURFACES	
ASPHALT	0.80-0.95
GRAVEL	0.75-0.95
ROOFS	AS0.35-0.70

NATURAL	SANDY LOAM	CLAY, SILT, LOAM	CLAY
WOODLAND			
0-5%	0.10	0.30	0.40
5-10%	0.25	0.35	0.50
10-30%	0.35	0.50	0.60
PASTURE/LAWN			
0-5%	0.10	0.30	0.40
5-10%	0.16	0.36	0.55
10-30%	0.22	0.42	0.60

Figure 2.12: Rational Equation and Values

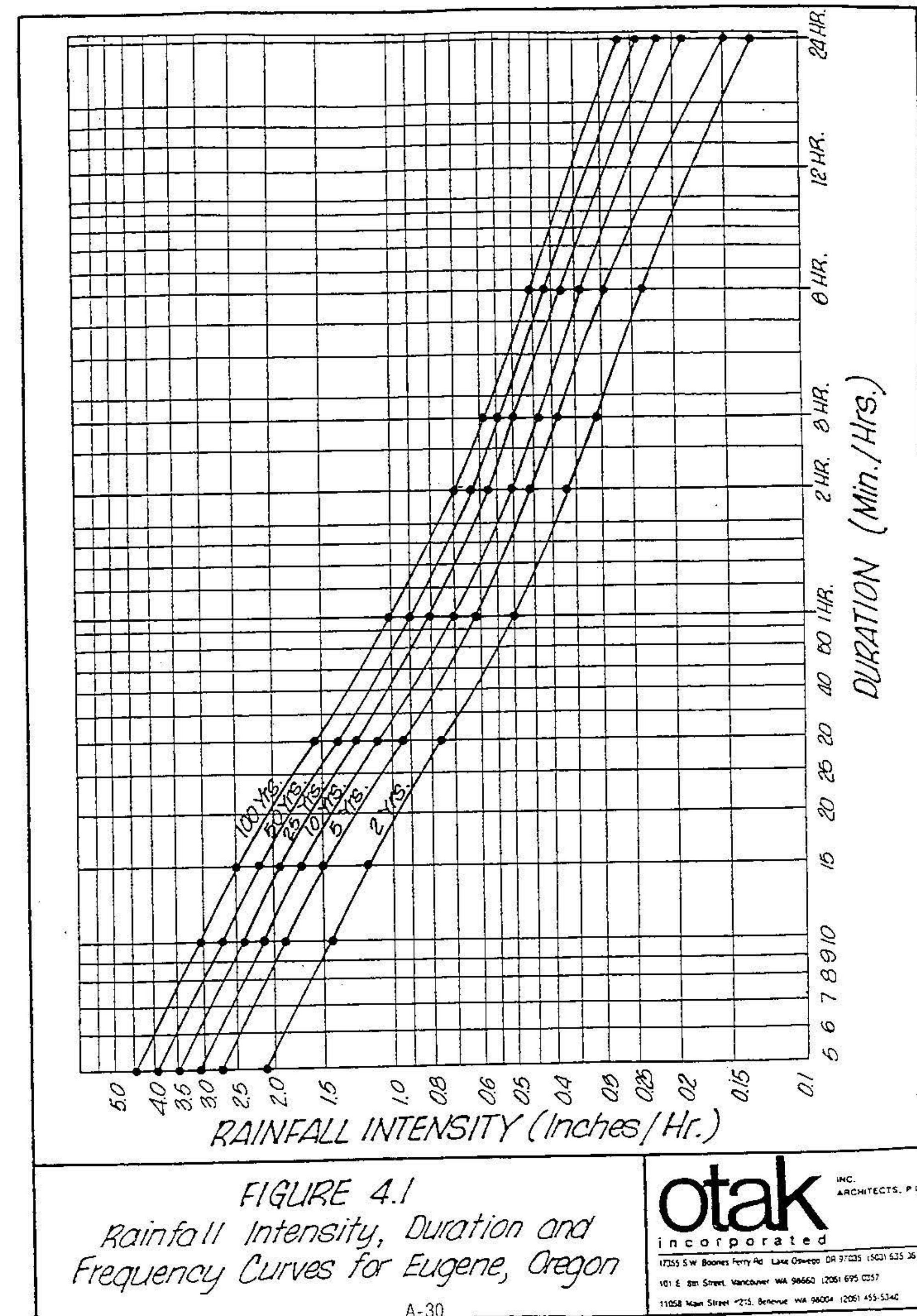


Figure 2.11: Rainfall Intensity Graph

CHAPTER THREE

3. PROJECT FINDINGS

Through the process of using BIM as a workflow, this project was able to obtain tangible results for creating site-specific master planning. Included in this section of the project findings is a recommendation for an innovative wastewater sanitation system called the Living Machine. Additional results include three variations of site plans that have responsive strategies for stormwater management and community development.

The production of three design alternatives to begin a conversation with aint Vincent De Paul, to envision the future use of the site. Each of the three designs include a total of 42 dwelling units comprised of double wide pre-manufactured homes and clusters of tiny homes.

At this stage of the design development for Saginaw Mobile Home Park, site programming has been left to a minimum. Future conversation with members of Saint Vincent de Paul will provide opportunities to shape their vision of what the park will become, and how they wish to program the site to achieve that.

3.1 WASTE SANITATION

The client, St. Vincent De Paul, was initially interested in a waste sanitation system that could offer nutrient recovery. They hoped to produce revenue which could offset the overhead cost of owning and operating the mobile home park.

Nutrient recovery and extraction from bio-solid waste is a viable opportunity within the rules and regulations of Oregon State. We chose to look at various sanitation systems that can provide such services. For the Saginaw Mobile Home Park, we found that there is not enough waste generated to make nutrient extraction a cost-effective option. A higher density site that produces at minimum 1 million gallons per day would be necessary for making the system payback.

To meet the clients desire to use a system that is unique, user-friendly, and protects the water quality of the region, we suggested that they use a system called the Living Machine.

THE LIVING MACHINE

The living machine is a proprietary sanitation system which offers innovative wastewater management. The manufacturer develops a site-specific design that can treat grey and black water to a standard of reuse. The system uses living organisms to provide a complete cyclical process of collecting and treating, as well as an opportunity for reuse, before returning wastewater towards the aquifer. The system shares similar traits to conventional septic systems. However, the additional stages provided by the plants remove nutrients which the EPA and Oregon DEQ have deemed dangerous for this region. A recent study by the EPA has shown that Living Machines can create monetary savings in comparison to conventional septic and leach field systems (EPA 2011).

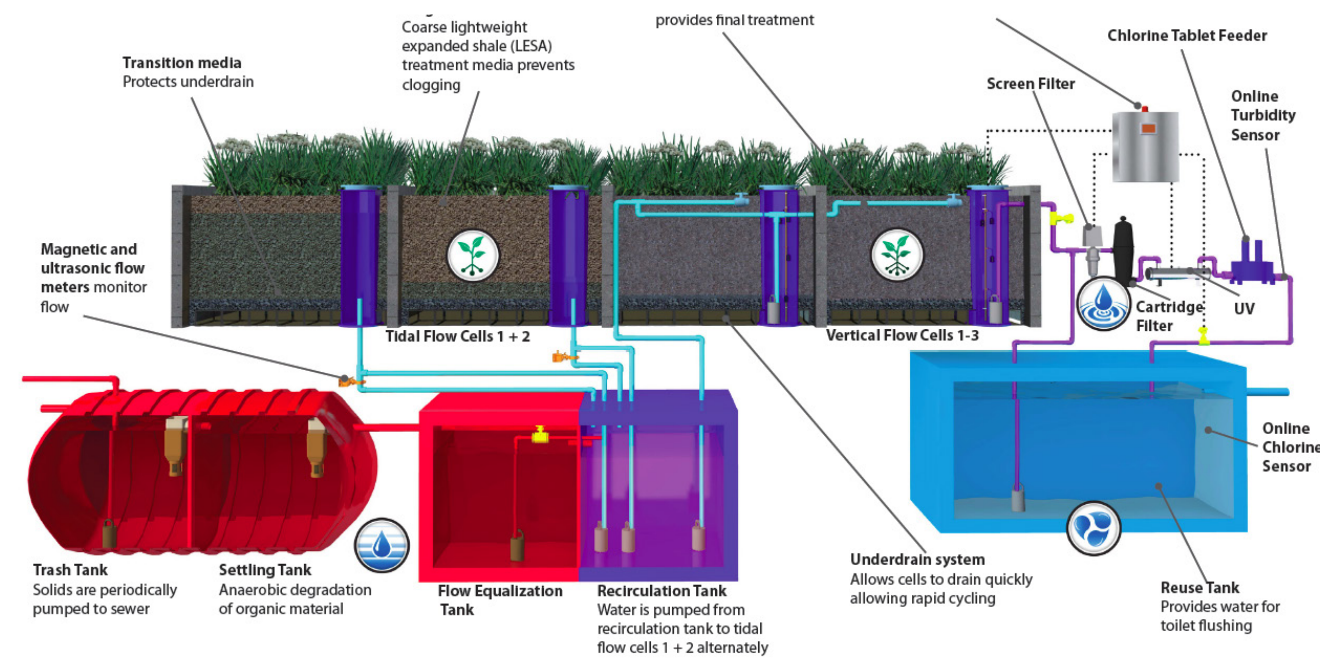


Figure 3.1: Living Machine Schematic Design

Living Machine Treatment Stages

1. Solid Settlement Tanks
   - All solids settle out in the tanks, as sludge and are injected with microorganisms to accelerate the decomposition.
2. Equalization Tanks
   - Tanks equalize the daily accumulation of waste in the system, keeping the downstream components on a regular interval/load.
3. Anoxic/Anaerobic Tanks
   - Microorganisms assist in the decomposition of waste transferring it into small organic compounds.
4. Tidal Tanks
   - The fluxuation of water through the rootzone allows micro-organisms to increase water clarity through the process of denitrification.
5. Aerated Lagoons
   - Water is aerated to increase the final nutrient breakdowns.
6. Recirculation/Sand Filter
   - Course sand filters polish and remove any last bacterial/pathogens and brings the water to the Advanced Waste Water Standards

3.2 LIVING MACHINE

Figure 3.2: Living Machine

PROPOSED LIVING MACHINE

To implement the Living Machine at this site, the various components that create the system need to be sized appropriately. Depending on the future population, and water use behaviors of the park I estimated that water use would range between 10,000 – 12,600 gallons per day. In addition to standard system elements, Allison Kwok's, Green Studio Handbook was consulted to estimate the number and size of components (Kwok & Grondzik 2012).

SYSTEM SIZING:

- 6 Aerobic tanks, 8 feet in diameter and 4ft tall.
- 1 Clarifier will be 8 feet diameter 4 ft tall, and a depth of 8 feet.
- 1 Constructed wetland will need 20x20 feet.

Additionally, the local climate requires that the vegetative components of the system need to be within a greenhouse structure (Figure 3.2). Given that the water passing through this component of the system is free of pathogens, the greenhouse becomes a biophilic site attraction. Placing the greenhouse in a prominent location will encourage people to interact and relate to their resource consumption.

PLANT POWERED SYSTEM

The choice of plants to be used in this system needs to be aquatic perennials requiring low maintainence. These plants have been sucessful species for living systems and offer a diversity of canopy height and textures:

- Rumohra adiantiformis, Leather Leaf Fern
- Agapanthus Praecox, Lily of the Nile
- Zantedeschia aethiopica, Giant Calla Lily
- Cyperus alternifolius gracilis, Umbrella Plant

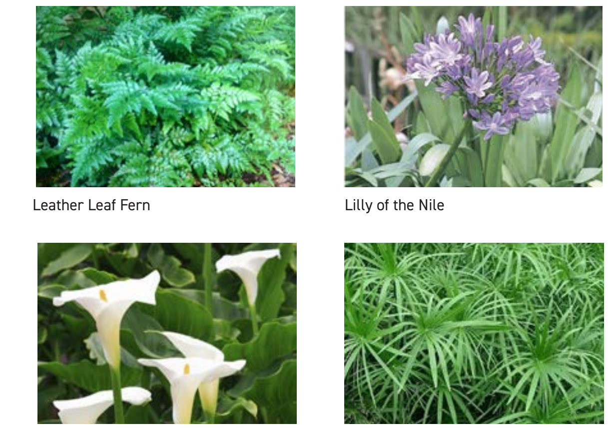


Figure 3.3: Plants Pallete for Living Machines

NUTRIENT EXTRACTION

The core concept of the living machine has to do with the plant based extraction of excess nutrients. Water is pulsed through the system which raises and lowers through the hydric rooting zone of the plants. This process allows for plants to break down nutrients such as nitrates and phosphorus.

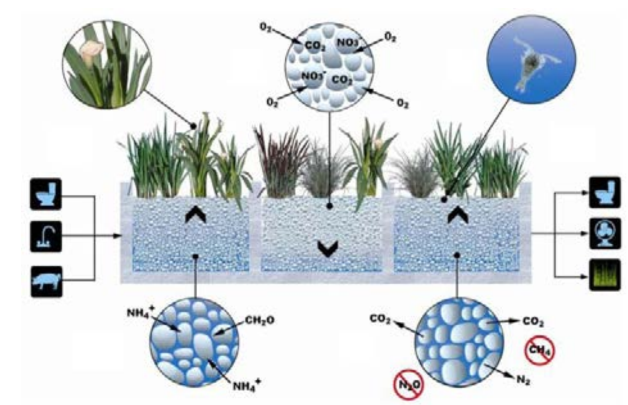


Figure 3.4: Living Machine Schematic Design

POTENTIAL FOR WATER REUSE

Approved systems in compliance with OAR 340-045-0033 can reuse gray and black water for nonpotable and sanitary purposes. Typical opportunities for reuse include subsurface irrigation, flushing toilets, and laundry machines. The approved reuses of gray and black water typically represent 60 percent per person average daily water use.

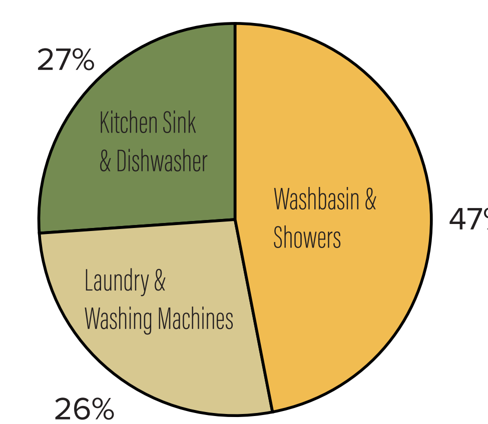


Figure 3.5: Source of Graywater by Use

3.3 Housing Typologies

Figure 3.6 Double Wide Units With Typical Setbacks

For this project the standard dimension for double wide homes was 48'x29'. All of the units were placed predominantly on an east west axis to provide optimal solar orientation. Additionally the private yards were placed on the southern side of the home where the entrance to the home typically is. In addition to the modular homes, it was my recommendation to include a porch for each unit. The porch creates a shared sense of access within the site and extends the access towards the community. the porch creates a intermediate spaces that are semi public, and encourage interaction and visibility between residents.

3.4 Tiny Homes

Figure 3.7: Tiny House Axon

Tiny Homes

Preliminary site designs were only able to accommodate 30-32 dwelling units with only double-wide pre-manufactured homes. To maintain the same number of dwelling units as the park currently has, tiny homes became integrated as a design strategy. Further research into the opportunities which tiny houses could provide identified a need for small units, as there is an increasing decline in a compact, affordable housing options for one or two people. Square One Village is a nonprofit in Eugene, Oregon that has implemented three successful projects, Opportunity, Cottage, and Emerald Village. These small house communities partner with local architects and designers to create elegant and straightforward designs, which are efficient to build. Through the donation of construction labor, the Square One Village has been able to

Figure 3.8: Top View of Tiny House

construct permanent units with electricity and plumbing within the range of $20,000.00. For this project, I used a tiny house concept plan, inspired by Architect and Professor Michael Fifield's Emerald Village Design.

3.5 STORMWATER MANAGEMENT

FIGURE 3.9: Flow Through Stormwater Planters

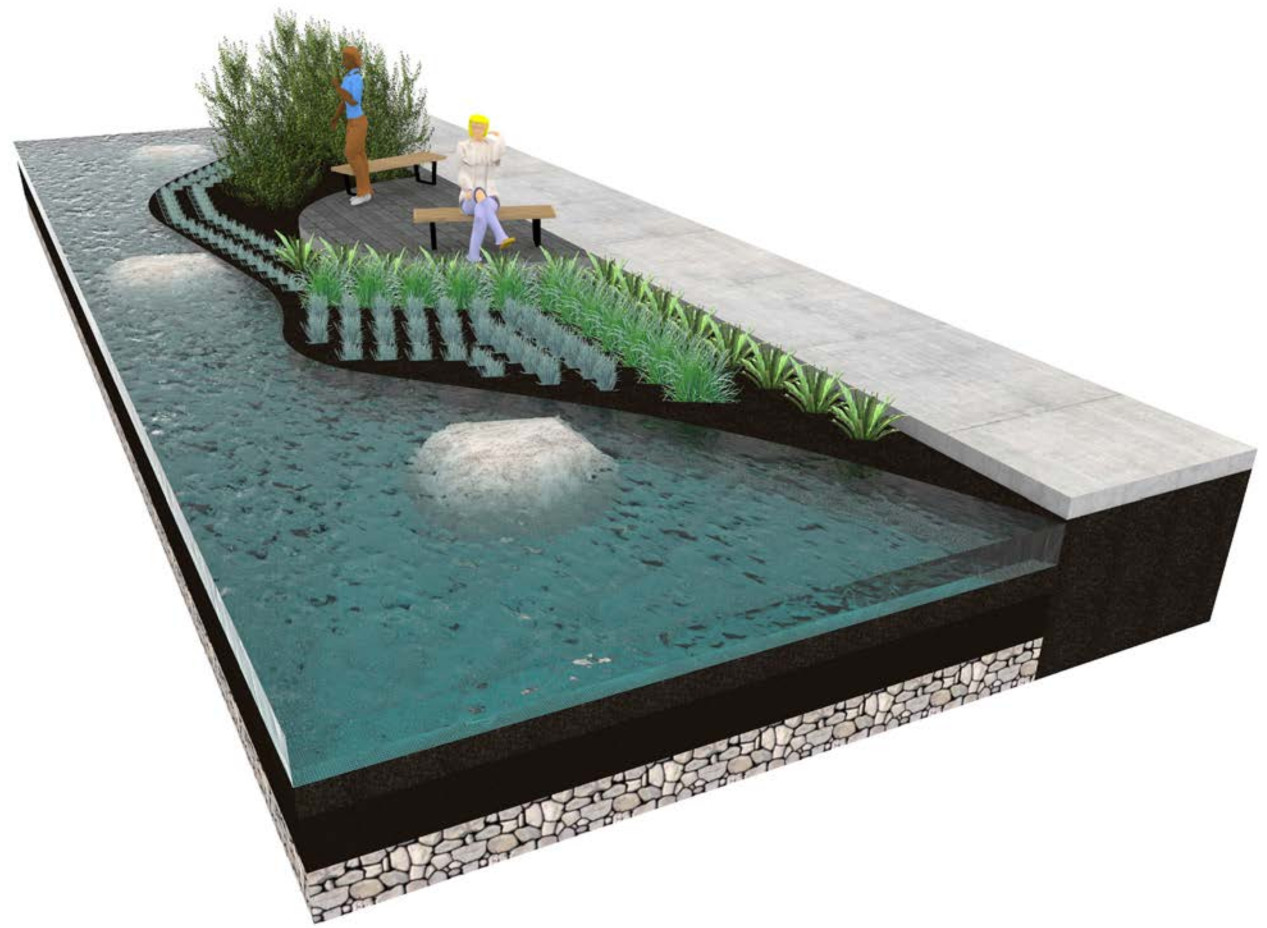


FIGURE 3.10: Bioswales With Overlook Seating

Using the BIM worksheets for calculating stormwater runoff paired with the City of Eugene's Stormwater Facility Sizing Formula allowed for the general sizing requirements to be tabulated (Figure 3.15). Flow-Through Planters, and Bio-swales are proposed to capture, treat, and infiltrate stormwater produced on site. Flow-through planters collect stormwater runoff from roads. These planters use concrete forms to provide larger storage volumes with smaller footprints. The placement of the planters at set intervals along the downslope side of the road create a circuit system. When a single facility reaches its capacity, it has an outlet which conveys water to the next planter in the circuit.

Bioswales are used to collect stormwater generated on building roofs. The design uses the swales to create vegetated buffers at the rear of the house for both aesthetic and privacy options. The swales have a gentle slope and can be planted with native plants which are tolerant

of the dry summer seasons. Stacking benefits occur when the linear swales can contain the pipes for waste and potable water to and from the dwelling units. The site will benefit financially from being able to use smaller diameter pipes. Typical domestic water services require larger pipes as they are placed underneath roads.

All of the designed stormwater facilities were engineered to handle the 48-hour period of time required for complete infiltration to occur, (draw down time). Although this strategy requires larger stormwater facilities it eliminated the infrastrctural needs of additional piping and detention basins.

3.6 PRELIMINARY SITE DESIGNS

The three site designs created, using BIM to manage stormwater, present unique opportunities to shape the future vision of the mobile home park. The following pages convey the specifics regarding site characteristics as well as potential demographics. All three designs include paved streets for both vehicle and pedestrian use. The central focus of each model is the community center which hosts shared open space with a play structure for children.

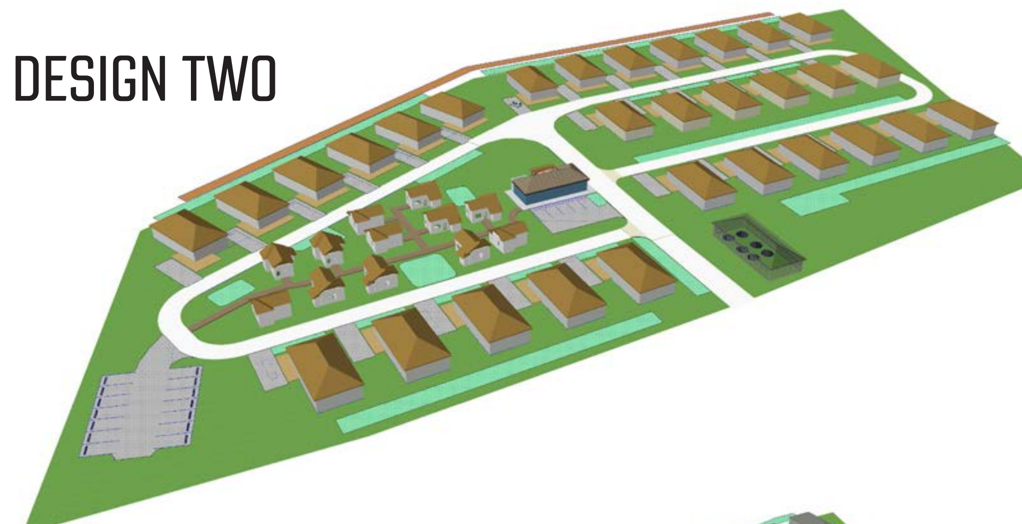
Not to scale N

Figure 3.11: Above Existing Site Saginaw Mobile Home Park

Figure 3.12: Right Preliminary Site Designs

3.7 DESIGN ONE

3.8 DESIGN TWO



3.9 DESIGN THREE

3.7 DESIGN ONE

- 41 Residential Units
- 29 double wides
- 12 Tiny Homes
- 78,484 square feet impervious surfaces
- 51,200 Square Feet from Roofs
- 7,711 Cubic Feet of Stormwater runoff during 25 year storm

Figure 3.13: Design One Axon Not to scale N

3.7 DESIGN ONE

Figure 3.14: Site Plan Design One

Figure 3.15: Stormwater Management Plan Design One

Design One was developed to mostly accommodate double wide mobile homes and a small number of Tiny Homes. All of the double-wide homes have private parking strips and private yards on the southern side of the home. For the cluster of Tiny Homes, there is a shared parking area with a walking path to access all of the homes. The center of the access path is an open green space that surrounds the bioswale for the rooftop stormwater. The community center is centrally located amongst the houses in the park, providing easy access from all major streets and homes. This site has the most flexibility for street width while still accommodating green infrastructure and building setbacks. This is the only design which includes a sidewalk as part of the street design.

3.7 DESIGN ONE

Figure 3.16: Community Center and Open Space

3.8 DESIGN TWO

- 42 Residential Units
- 30 double wides
- 12 Tiny Homes
- 81,176 square feet impervious surfaces
- 28,376 square feet Concrete
- 52,800 Square Feet Roofs
- 7,975 Cubic Feet of Stormwater Runoff
- during 25 year storm

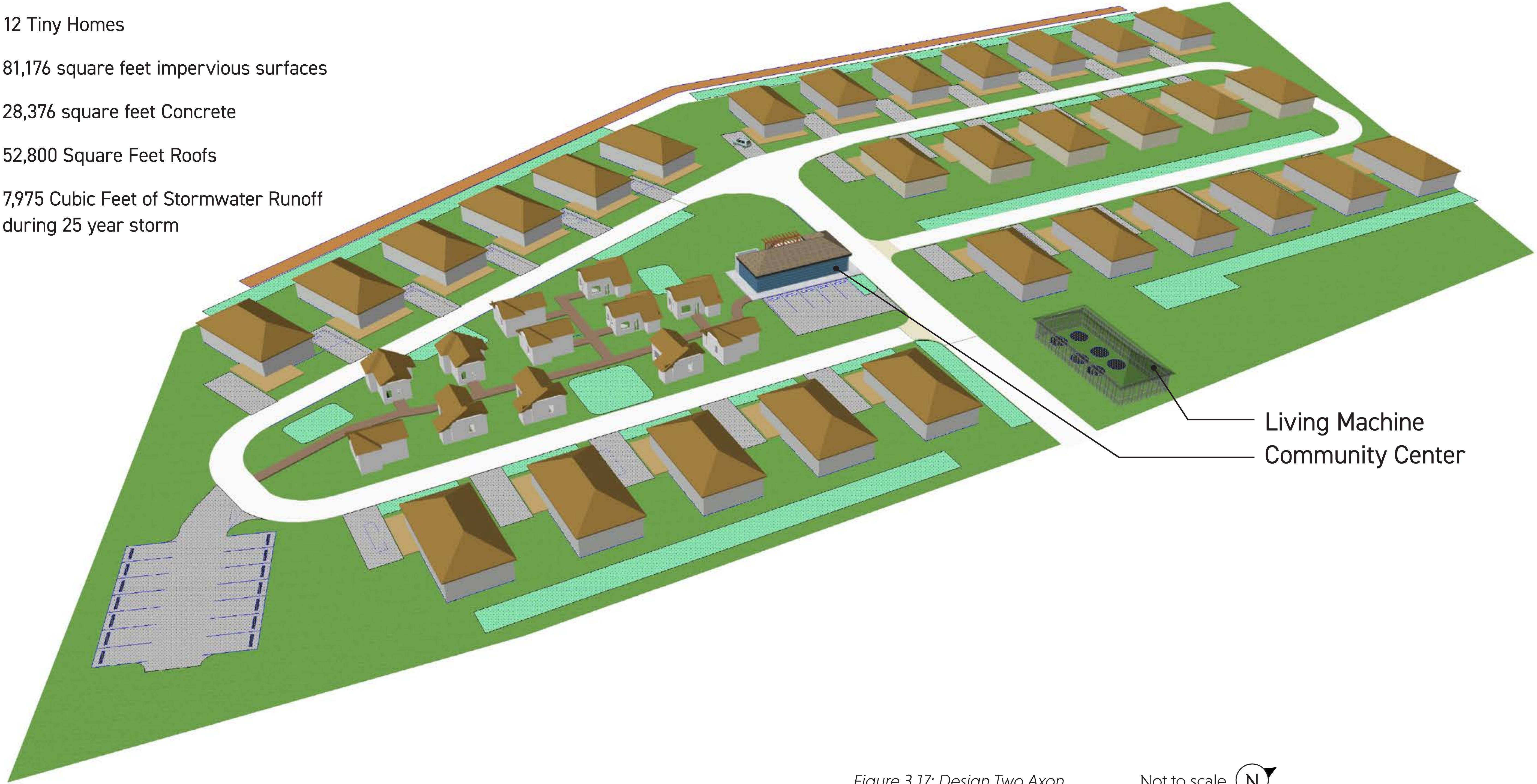


Figure 3.17: Design Two Axon

3.8 DESIGN TWO

Figure 3.18: Site Plan Design Two

Figure 3.19: Stormwater Management Plan Design Two

Design model two was established to provide continuous circulation through the park utilizing one-way streets. The double wide units are arranged along the perimeter of the site with three distinct clusters of tiny homes in the center. Although the total area of open community space is smaller than other the other models, there is a strong connection between the community building and open space. In order to generate the feeling of a neighborhood as well as reduce traffic speeds, the streets are also a circulation route for pedestrians.

3.8 DESIGN TWO

Figure 3.20: Community Center and Open Space

Figure 3.16: Perspective

3.9 DESIGN THREE

- 42 Residential Units
- 21 double wides
- 21 Tiny Homes
- 76,230 square feet impervious surfaces
- 33,830 Square Feet Concrete
- 42,400 Square Feet Roofs
- 7,490 Cubic Feet Stormwater
- Runoff during 25 year

Figure 3.21: Design Three Axon

3.9 DESIGN THREE

Figure 3.22: Site Plan Design Three

Figure 3.23: Stormwater Management Plan Design Three

The third site design model has an equal number of double-wide units as tiny homes. Although The square footage of livable space is smaller than other models, it offers the most substantial amount of open space. The more extensive public space creates a high number of nodes to connect to the community and improved the visibility between neighbors and the site management. In addition to potential recreational activities, the open space has good solar orientation and could offer an excellent location for food production. The large stormwater swale at the center includes a seating area to engage as a site amentity.

3.9 DESIGN THREE

Figure 3.24: Community Center & Open Space

3.10 Summary of Findings

Of the three designs generated, I used BIM to organize the information that would contribute towards volume of runoff, impermeable surfaces, and amount of livable and open spaces. Designs one and two had higher ratios of impermeable space in relation to the amount of livable space. Design Three had almost half the ratio of impermeable to livable space. Design three requires the largest quantity of paving.

Although these numbers can inform potential quantities of materials and associated costs as well as amount of stormwater generated, they alone should not determine which design would be more favorable.

General Findings

	1	2	3
Number of Units	41	42	43
Number of Double Wide	29	30	21
Number of Tiny Houses	12	11	22
Square Feet of Concrete	27284	28376	33830
Square Feet of Livable Space	45360	46500	36840
Total Square Feet Impervious	78484	74876	33830
Ratio of Impervious to Pervious	1.73	1.61	0.92
Open Community Space (SF)	9,900	7,000	12,000
Total Buildable Acres	5.79 acres	5.79 acres	5.79 acres
Toal site	14 acres	14 acres	14 acres

Design One

Source	Location	Dimension	Square Feet	Swale	Planter
road	NE	8x180	1440		x
road	NW	8x175	1400		X
road	CTR	8x225	1800		X
road	South	8x270	2160		X
6 Tiny Homes	w village	20x40	800	X	
3 Tiny Homes	se village	10x40	400	X	
3 Tiny Homes	ne village	10x40	400	X	
3 Double Wides	SE	12x125	1500	X	
2 Double Wides	s NE	14x65	910	X	
6 Double Wides	SW	12x270	3240	X	
7 Double Wides	NW	12x340	4080	X	
5 Double Wides	N Ctr	12x200	2400	X	
6 Double Wides	NE	12x270	3240	X	

FIGURE 3.25 Summary of Findings

Design Two

Source	Location	Dimension	Square Feet	Swale	Planter
road	NW	10x110			X
road	NE	10x145			X
road	CTR	15x180			X
road	SW	10x110			X
road	SE	10x115			X
7 Double Wides	NW	12x340	4080	X	
6 Double Wides	SW	12x270	3240	X	
6 Tiny Homes	CTR	20x40	800	X	
5 Double Wides	SE	12x200	2400	X	
6 Double Wides	NE	12x270	3240	X	
6 Double Wides	NCTR	12x270	3240	X	
5 s	CTR	20x30	600	X	

Design Three

Source	Location	Dimension	Square Feet	Swale	Planter
road	NW	12x125	1500		X
road	NE	12x85	1020		X
road	CTR	12x185	2220		X
road	SW	12x175	x		X
road	SOUTH	12x60	720		X
road	SE	12x110	1320		X
8 Double Wides	sw	12x325	46800	x	
5 Double Wides	nw	12x200	2400	x	
4 Double Wides	Nctr	12x145	1740	x	
4 Double Wides	NE	12x145	1740	x	
3 Tiny Homes	ctr	10x40	400	x	
3 Tiny Homes	ctr	10x40	400	x	
3 Tiny Homes	ctr	10x40	400	x	
3 Tiny Homes	ctr	10x40	400	x	
3 Tiny Homes	ctr	10x40	400	x	
3 Tiny Homes	ctr	10x40	400	x	

CHAPTER FOUR

4. CONCLUSION

This project demonstrated that BIM is a very fitting workflow for the field of landscape architecture. The ability to develop significant relationships between the site and the built environment early in the project allows for innovative cross-disciplinary responses and design strategies to occur during the preliminary design process. In using Vectorworks as the BIM software, I was able to organize the site design information efficiently. Additionally, I was able to efficiently generate area takeoffs for specific sources that would contribute to stormwater.

4.1 The significance of Mobile Home Parks For Affordable Housing

This project has opened my eyes to the importance that mobile homes, and the parks where they are often concentrated, play in the affordable housing market. The parks are home to a significant proportion of at-risk populations and yet are rarely acknowledged as one of the few ownership opportunities for affordable housing. Nationwide, the people that live in mobile home parks are vulnerable to displacement due to closure. Closures occur either from cities creating zoning policies which prohibit mobile home parks, the sale of land for more profitable development, or owners unable to make critical infrastructure repairs. The overall risk of mobile home park closure is growing, which marginalizes a significant population of people. Nationwide, there have been considerable efforts to preserve mobile home parks as an accessible form of affordable housing.

Between 2003 and 2008 the State of Oregon saw the closure of 50 mobile home parks affecting thousands of individuals and families. Specific to Lane County where this project occurred, the city of Springfield is home to a community grappling with an estimated 1,400 households facing a substantial risk of displacement due to the closure of mobile home parks. As a response to the high rate of park closures, the state of Oregon has implemented multiregional and agency-based planning for identifying mobile home parks that are at risk for closure and directing the appropriate pathway for maintaining them as operating entities through state and non-profit sponsored programs (article 2015). Although there is an abundance of strategies for preserving mobile home parks across the state and country, there is a lack of strategies for creating equitable spaces that improve livability within parks.

The need to provide the maximum number of housing units has increased pressure to maximize density at minimal cost which leads to overcrowding and unsafe areas. Without long-term visions of how to develop into healthy communities quick and easy fixes run the risk of creating the same problems which have prevented mobile home parks from becoming a sought-after place to live. While working through the various design iterations, I implemented strategies to create a series of connected spaces that have distinct boundaries of both private and public elements. The motivation to create differentiation of space came from the urban design theory of defensible spaces. In addition to the spatial arrangement of the units in the park, it will be important to engage the designers of premanufactured homes to consider flexibility and modularity within the structural design.

The design of current manufactured homes is intended for detached single dwelling units. When mobile homes become consolidated into high-density areas, the potential for open space becomes greatly diminished when incorporating the minimum setback distances. The state of Oregon allows manufactured homes to be joined to create modular dwellings and multifamily units i.e. duplex/triplex. However, there are not off the shelf units available to generate this typology. Building new typologies and units that can be flexible can help generate higher density housing while providing more amenities and open space.

4.2 PROJECT CONCLUSION

The culmination of this research project gave me a keen insight into BIM as a tool for landscape architecture. As a proof of concept, BIM provided an efficient workflow for organizing site information into a tangible format for the process of designing. One of the strengths was the ability to produce worksheets which could account for materials generated and total surface areas by type. The software provided rapid recalculation of the site's information which continued to inform me as I adjusted the design and developed more refined levels of detail.

The ability to organize attributed information to site geometry allowed me to automate the calculation of stormwater runoff using the rational equation. By arranging materials into classes, it was convenient to determine runoff by region. For example, I chose to divide the portions of roads into segments which would be logical for site grading. Knowing the runoff for that specific region allowed the sizing of facilities which would directly process the runoff. The process of sizing stormwater treatment facilities presented a conflict within my approach to using BIM for site analysis. The city of Eugene's Stormwater Sizing Tool utilizes formulas that are in a multipage Microsoft Excel database. Although Vectorworks can import and use Excel in the software's database, Vectorworks uses a different data logic, which does not support databases that span multiple pages. This conflict required me to work between two databases instead of one. I was able to generate the surface area of materials, and the volume of stormwater produced during a 10-year storm event within Vectorworks. I would manually transfer the site information to Microsoft Excel to generate the individual facility sizes. As site performance and BIM becomes a standard protocol for site-based designs, it would be advantageous for cities such as Eugene and Portland that have stormwater sizing tools to work towards further developing the tools so that they can become integrated within standard

Overall This project was successful in creating a water budget for the Saginaw mobile home park. Through an iterative process, the three designs produced different options to accommodate the necessary housing needs of residents as well as shaping opportunities for social and recreational activities. All three plans were able to incorporate the maximum allowable residential units as well as treat, process, and infiltrate all stormwater runoff produced onsite for the duration of a 10-year peak storm event. Each of the three site designs will create a unique demographic and future for the mobile home park. It is the intention of this project to assist Saint Vincent De Paul in generating a comprehensive and long-term development plan for residents while accommodating infrastructure needs.

In concluding this project, I realize that each design project will present a unique opportunity to engage with BIM workflows. Using BIM will be unique for each project, and there is not one clear way to approach it. However, developing matrices, goals, and standards that reflect built materials interacting with the site will assist designers to utilize BIM. This project was able to demonstrate a component of landscape design that is suitable for BIM. The explicit use of BIM for stormwater highlighted one of the strengths of landscape architecture adopting BIM into the process of master planning and site design.

4.3 SUGGESTIONS FOR FURTHER STUDIES

The emerging site standards and ranking by SITES AP are potential matrices which could inform BIM standards in similar ways to the UK implementation that required landscape architects to produce BIM for all public projects. In spending the last year immersed in reading, researching, and interacting with BIM, I think that it is a useful workflow and tool for landscape architecture. A key component of BIM that this project was unable to engage with was the ability to work collaboratively with other designers and across disciplines. Although the analytical aspects of the software still need to be further developed to provide site analysis, the ability to work seamlessly with other disciplines is a promising future for BIM in landscape architecture.

It would be my recommendation that the Landscape Architecture program at The University of Oregon takes advantage of its recent integration to The School of Architecture and the Environment. There is potential to develop collaborative and cross-disciplinary design studios and courses to teach students, how to work and communicate with different disciplines, and reach shared goals. Cross-disciplinary and inter-institutional efforts by Professor Nancy Cheng (Architecture, University of Oregon) and Mariapaola Riggio (Engineering, Oregon State University) are embracing efforts towards BIM. Their shared course, Timber Tectonics, engage students from various disciplines to explore the ability to develop workflows for designing and analyzing structures using the parametric software Grasshopper. The specificity of technology, materials, and design tools provides a useful framework to develop courses which can implement BIM workflows amongst future generations of designers.

Stormwater Surface Filtration/Infiltration Facility Sizing Spreadsheet
24 Hour Storm, NRCS Type 1A Rainfall Distribution
City of Eugene

Version 2.1

Project Information

Project Name:	[Sample Project]	Date:	[Date]
Project Address:	[#### Street or Intersection]	Permit Number:	[Permit #]
	Eugene, OR [Zip Code]	Catchment ID:	[Catchment ID]
Designer:	[Designer Name]		
Company:	[Company Name]		

Instructions:
1. Complete this form for each drainage catchment in the project site that is to be sized per the Presumptive Approach.
2. Provide a distinctive Catchment ID for each facility coordinated with the site basin map to correlate the appropriate calculations with the facility.
3. The maximum drainage catchment to be modeled per the Presumptive Approach is 1 acre (43,560 SF)
4.For infiltration facilities in Class A or B soils where no infiltration testing has been perfromed use an infiltration rate of 0.5 in/hr. For all facilities use a maximum soil infiltration rate of 2.5 in/hr for topsoil/growing medium.

Design Requirements:

Choose "Yes" from the dropdown boxes below next to the design standards requirements for this facility.

Pollution Reduction (PR)	Yes
Flow Control (FC)	Yes
Destination (DT)	Yes

*An infiltration facility must be chosen as the facility type to meet destination requirements

Site Data-Post Development

Total Square Footage Impervious Area=	78484	sqft	Total Square Footage Pervious Area=	0	sqft
Impervious Area CN=	98		Pervious Area CN=	85	
Total Square Footage of Drainage Area=	78484	sft	Time of Concentration Post Development=	5	min
Weighted Average CN=	98				

Site Data-Pre Development (Data in this section is only used if Flow Control is required)

Pre-Development CN=	80		Time of Concentration Pre-Development=	10	min

Soil Data

Tested Soil Infiltration Rate=	0.57	in/hr (See Note 4)	Destination Design= Soil Infiltration Rate	0.285	in/hr
Design Soil Infiltration Rate=	0.57	in/hr			

Design Storms Used For Calculations

Requirement	Rainfall Depth		Design Storm
Pollution Reduction	1.4	inches	Water Quality
Flow Control	3.6	inches	Flood Control
Destination	3.6	inches	Flood Control

Facility Data

Facility Type=	Infiltration Stormwater Planter		Facility Surface Area=	2250	sqft
Surface Width=	15	ft	Facility Surface Perimeter=	330	ft
Surface Length=	150	ft	Facility Bottom Area=	2250	sqft
Facility Side Slopes=	0	to 1	Facility Bottom Perimeter=	330	ft
Max. Ponding Depth in Stormwater Facility=	6	in	Basin Volume=	1125.0	cf
Depth of Growing Medium (Soil)=	24	in	Ratio of Facility Area to Impervious Area=	0.029	

APENDIX A-1: EUGENE STORMWATER FACILITY SIZING SHEET

Pollution Reduction-Calculation Results

Peak Flow Rate to Stormwater Facility =	0.612	cfs	Peak Facility Overflow Rate=	0.582	cfs
Total Runoff Volume to Stormwater Facility =	7711	cf	Total Overflow Volume=	4233	cf
Max. Depth of Stormwater in Facility=	6.0	in			
Drawdown Time=	10.5	hours			

NO **Facility Sizing Meets Pollution Reduction Standards?**

NO Meets Requirement of No Facility Flooding?
YES Meets Requirement for Maximum of 18 Hour Drawdown Time?

Flow Control-Calculation Results

Peak Flow Rate to Stormwater Facility =	1.695	cfs	Peak Facility Overflow Rate=	1.665	cfs
Total Runoff Volume to Stormwater Facility =	21969	cf	Total Overflow Volume=	18350	cf
Max. Depth of Stormwater in Facility=	6.0	in	Peak Off-Site Flow Rate Filtration Facility Underdrain=	N\A	cfs
Drawdown Time=	10.5	hours			

Pre-Development Runoff Data

Peak Flow Rate =	0.712	cfs
Total Runoff Volume =	11224	cf

NO **Facility Sizing Meets Flow Control Standards?**

NO Meets Requirement for Post Development offsite flow less or equal to Pre-Development Flow?
YES Meets Requirement for Maximum of 18 Hour Drawdown Time?

Destination-Calculation Results

Peak Flow Rate to Stormwater Facility =	1.695	cfs	Peak Facility Overflow Rate=	1.680	cfs
Total Runoff Volume to Stormwater Facility =	21969	cf	Total Overflow Volume=	19593	cf
Max. Depth of Stormwater in Facility=	6.0	in			
Drawdown Time=	20.8	hours			

NO **Facility Sizing Meets Destination Standards?**

NO Meets Requirement of No Facility Flooding?
YES Meets Requirement for Maximum of 30 hour Drawdown Time?

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Figure 2.2 Rain Infor Chart: City of Eugene, Oregon. Stormwater Management Manual, 2014. Page 241

Figure 3.2 WATER SYSTEM CASE STUDY – SAN FRANCISCO PUBLIC UTILITIES COMMISSION (SFPUC) Plants for treatment: 11/14/2015 https://urbanecologycmu.wordpress.com/2015/11/14/water-system-case-study-san-francisco-public-utilities-commission-sfpuc-2/ Accessed 4/28/2018

Figure 3.6 Aeriel Image: Source: “Saginaw.” 43° 50’09.25” N and 123° 02’43.98 W. Google Earth. 6/28/2017. 5/6/2018