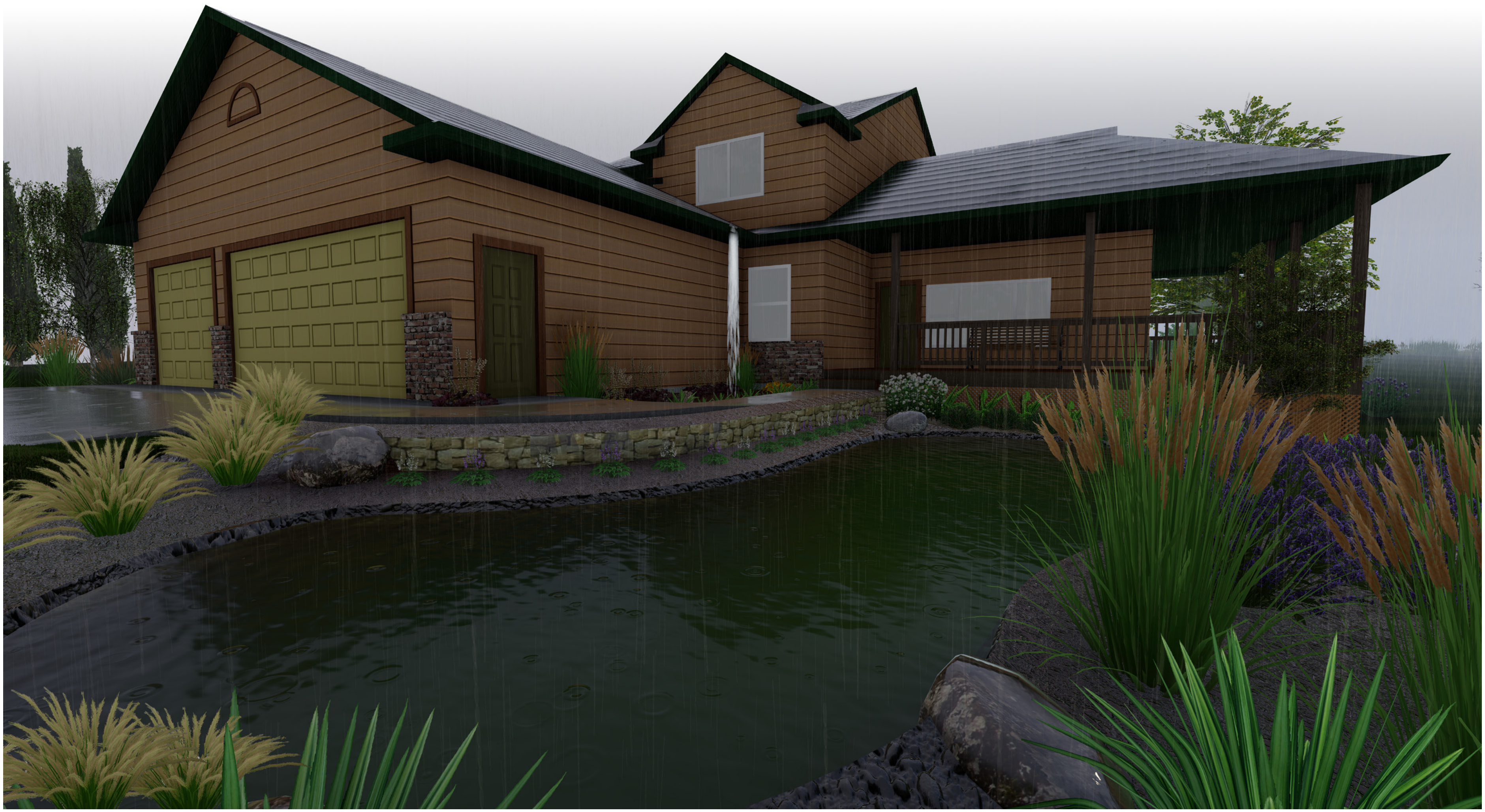
FAIR CATCH



FAIR CATCH

Implementing effective stormwater management within the constraints of a hypothetical client's design and site-use preferences.

A Design Thesis Submitted to the Department of Landscape Architecture of North Dakota State University

By

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In Partial Fulfillment of the Requirements for the Degree of Master of Landscape Architecture

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Thesis Abstract

What seems to be the problem?

The problem is nationwide- Minnesota is just late to the party. Our privilege of 10,000(+) lakes has led us to turn somewhat of a blind eye to stormwater management. This is especially true on a residential scale. Yes, certain jurisdictions & municipalities are rolling out increased restrictions and standards. However, the qualifications are still limited in quantity and often they focus solely on hard cover restrictions.

Through my professional work and my research on this topic I have uncovered an unpleasant trend: Residential stormwater management landscape design is boring. Whether that is due to its relative infancy [of intensive focus] in the profession or some other circumstances, solutions are often redundant from one site to another. Landowners are left with few options.

By working on two sides of the same coin' Stormwater v. Client, I have compiled the following thesis proposal. It serves as a comprehensive landscape design and a highly functional stormwater management solution.

Thesis Narrative

For decades the people of Minnesota have looked for ways to optimize their time outdoors in the warmer months. A relatively short warm season means people are looking to get the most out of their time outdoors, including at their home. As landscape architecture and design has grown in popularity over the years, so has the complexity of the designs. Pools, patios, fire & water features, expansive plantings, and more all become part of an experience to enjoy while in the comfort and privacy of your own home; or rather just outside.

As great as these landscapes are they often overlook the environmental impacts they induce. In some cases, this is unintentional but for others it is simply because there is no legal ramifications or guidelines to uphold. Cities, townships, counties, and other governing bodies have implemented requirements regarding stormwater and runoff management. Hardscape cover limitations are most commonly an initial step in mandating landscape designs to meet a level of performance for stormwater. These hardscape materials are constantly being developed in new colors, sizes, patterns, and even various levels of permeability. Choices in landscape materials that are permeable or semi-permeable are becoming more widely available and with that availability comes more popularity.Permeable materials allow for higher retention rates of stormwater on a site and less pollution in our stormwater treatment facilities, and even out drinking water sources. Permeable hardscapes are not a singular option for reducing runoff or increasing retention and filtration. Careful selectin of plants and ground covers in conjunction with thoughtful planting design can also help to retain, filter, and slow stormwater runoff. Rain gardens and dry creek beds are examples of how organic materials can help aid in increasing a site's stormwater management performance.

Project Typology

+ Residential Landscape Design
+ Stormwater Management
+ Hydrology

This project will strive to display exemplary examples of the three typologies listed at the left of this page. Residential Landscape Design encompasses the entire project as the site dictates this. Stormwater Management is where the bulk of the research was conducted, and play a role throughout the entire design. And lastly, Hydrology, as the design works on managing stormwater across the site. Whether that be collecting, dispersing, routing, or holding there will be several operations functioning under Hydrology.

Typological Precedents & Research (A)

Research Topic: Hardscape Materials

- Permeable Pavers
- Commercially available options
- Specifications
- Applications

Context

Hardscapes are a popular addition to many residential landscapes. This can include walkways, driveways, patios, fire pits, pool decks, and many other spaces. These spaces operate under many functions. Sometimes as specific utilitarian modes, like how a driveway primarily exists to move vehicles between the house and the street. Others, like patios, exist more for the purpose of entertainment or relaxation. The flexibility of hardscapes is a major reason why they are widely popular in landscape design, especially in residential design.

Belgard | Aqualine Permeable Paver (Figure 1)

Because of their popularity, hardscapes play an important role in the workings of a site's stormwater impact on a larger scale. A singular addition of more hard cover increases the burden off site as it introduces more runoff. Comparatively, electing to replace existing hardscapes (or constructing new ones) with permeable materials helps to diminish or reduce the burden of off-site stormwater management. This improvement is extremely important to consider as our industry's awareness of stormwater runoff continues to expand. Promoting better infiltration and reducing the load on stormwater treatment infrastructure through thoughtful residential landscape design is arguably the single greatest impact future designers can have.

Belgard | Dimensions Paver (Figure 2)

Contribution to Thesis

The research into permeable pavers contributed to my thesis by cultivating a greater understanding of how they work, their performance metrics, and how they can be implemented into a design. The research came from seeking out manufacturers that offered permeable pavers. From there began a process of recording options including style and pattern scale, as well as looking for data on how much volume of water the selected permeable pavers could absorb as opposed to direct as runoff.

Not all manufacturers listed this data as far as stormwater values are concerned. It is worth noting that among the ones that did, all their products perform similarly.

Belgard | TurfStone Permeable Paver (Figure 3)

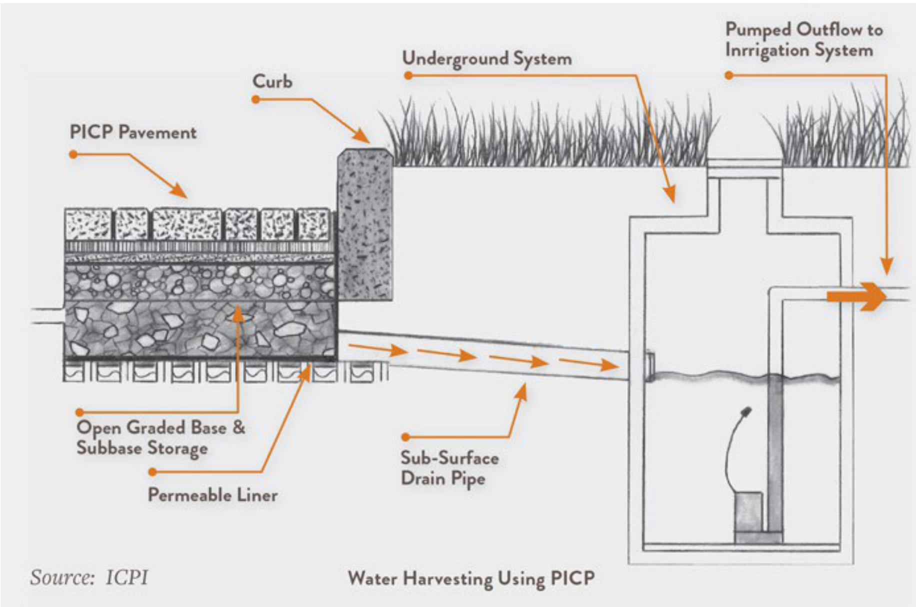
Project Elements

+ Site Preparation

+ Base Materials & Layers

+ Pavers

+ Joint Material



Belgard Permeable Paver Construction Detail (Figure 4)

Permeable Pavers do require different methods when constructing and installing a hardscape. Firstly, excavation depth will be deeper than a traditional, non-permeable paver. Industry standard is typically twenty-four" for a patio. This is because permeable pavers require three or four base layers that increase in course size as they are deeper in the ground. The accompanying Figure 3 from Belgard shows the complexity of some permeable paver installations. Pictured are how permeable pavers can allow for stormwater collection, storage, and re-use. Alternately, without the collection methods, a permeable patio would simply allow the stormwater to run across the surface and begin percolating through the various courses of material.

The materials gradually increase in size and depth with each layer, working further below grade. This allows the stormwater to be filtered amongst the course layers before reaching the soil surrounding the excavated area. In soils with poor drainage, such as clay, soil amendments may be necessary for a permeable hardscape installation to be successful. In the event this is needed the existing soil is excavated and removed or reused elsewhere on site if possible. Amended soil, with better drainage properties, is brought in and dispersed before beginning the course lifts of the varying gravel and stone.

Permeable pavers often look very close to their traditional counterparts. The biggest differences become apparent with the tabs on the side of each paver. These are manufactured into the paver to allow for proper and consistent spacing when installing. For permeable pavers these tabs are simply thicker which allows for greater spacing between each paver; thus, allowing for easier infiltration of stormwater. Another difference is permeable pavers will typically have a larger chamfer on their edges, again promoting stormwater infiltration.

An important part of all hardscape installations is the choice of joint material. This is the material that fills in the joints, the spaces between pavers, and is typically the last step of installation. In a non-permeable application, a polymeric sand is typically used. This water-activated product installs as a fine sand that fills each joint and is then sprayed with water, activating the polymers. These polymers react with water to adhere to one another and once dry create a semi-rigid bond between the pavers. This prevents infiltration of water to the base course but does allow for some movement and flexibility amongst the pavers (typically accounting for seasonal freeze-thaw cycles). Permeable applications however must allow water to pass between the pavers. For this to happen a different material is selected, which is usually a small "chipped" stone. It can fill the joints to prevent shifting of pavers but still allow for water to penetrate below to the base course materials.

Conclusion

Hardscapes undoubtedly play an important role in residential landscape design. They are one of the most popular requests in the industry. By choosing to entertain the possibility of permeable paver construction a client and designer can significantly reduce their stormwater runoff volumes. This will be addressed later in the Thesis Design Proposal section.

Typological Precedents & Research (B)

Research Topic: Rain Gardens & Dry Creek Beds

+ Rain Garden Design & Functionality
+ Grading & Drainage
+ Garden vs. Dry Creek
+ Plant Selection

Rain Garden Example (Figure 5)

Project Elements

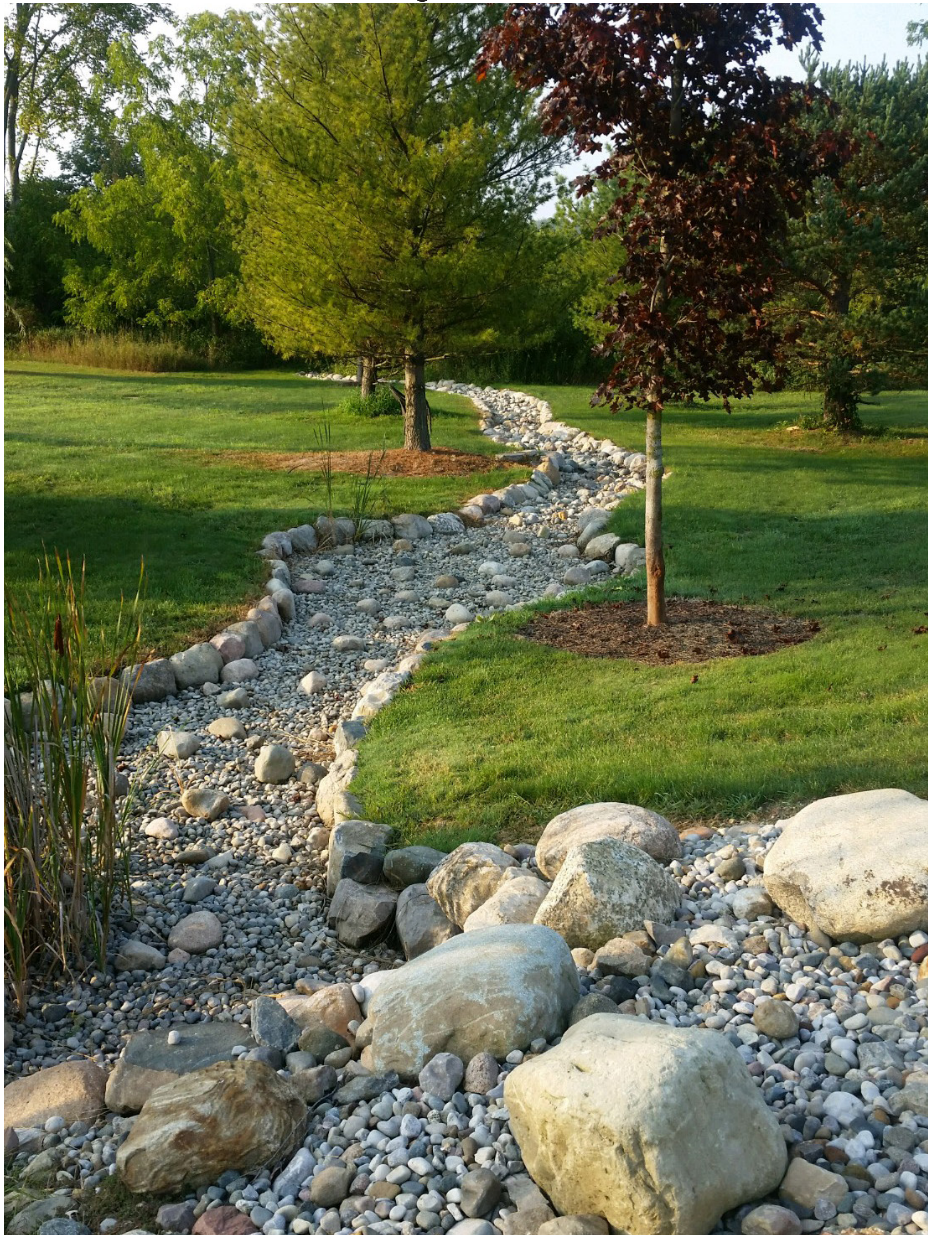
Another option for capturing and managing stormwater are rain gardens and dry creek beds. These two elements are similar in their functionality but have fundamental differences in their design and their uses. Beginning with rain gardens it is important to establish their purpose. Rain gardens exist to capture stormwater during a storm event, occasionally hold a volume of water, filter it, and allow it to percolate below eventually recharging groundwater resources. This means their design, and especially their location, on a site is critical.

Typically found in depressions, naturally or constructed, rain gardens passively collect stormwater runoff. Runoff can be deliberately directed, such as a curb cut from a hardscape surface with the rain garden adjacent to the hardscape. Or it can be passively directed through purposeful grading. Obviously, water flows downhill. By placing rain gardens in depressions or below slopes they are poised to have their greatest impact on managing stormwater runoff.

Dry creek beds operate similarly to rain gardens but are more often found along slopes rather than in depressions. Another distinction is dry creek beds are mulched with rock as opposed to (typically) wood mulch in rain gardens. This is due to the creek beds being on slopes and having a more linear footprint. During storm events this means water will be flowing through the creek bed and if wood mulch was used it would likely be washed away. Creek beds can be built with a liner or without. This option affects how quickly water will move as well as how much. If no liner is used water will be able to percolate into the ground along the creek bed; if a liner is present, it will not be allowed to do so.

Grading and drainage also change how rain gardens and dry creek bed's function. Their cross sections typically look similar, with rain gardens being wider. The center is the lowest point with gentle slopes on either side. A dry creek bed may utilize a liner to help move water to a specific point in the site. Sometimes this is a rain garden, with the two elements working together. As previously mentioned, rain gardens are found in depressions. If none currently exist, one must be constructed. Without a depression stormwater will not concentrate and allow a rain garden to properly function.

Plant selection is also extremely important. Plants selected for rain gardens must be able to handle a wide array of conditions. During and after storm events the plants will be responsible for uptake of pollutants as stormwater moves across the site. Rain gardens can sometimes be subjected to standing water during and after storms. Plants must be tolerant of these conditions as well. In between wet periods the rain garden is typically exposed to a lot of sun. Plants must be able to survive in full sun exposure; if they cannot, they will become stressed and not perform optimally when needed for stormwater management.



Example of a dry creek bed (Figure 6)

Typological Precedents & Research (C)

Research Topic: Plant Selection

Continuing the importance of plant selection, this section will discuss different plants that fit the needs of stormwater management landscape design. There is nothing substantially new about this premise. The University of Minnesota Extension has done an incredible job compiling information about rain gardens, and more specifically the plants that are optimal for these conditions. For the sake of this project that list was studied and cross referenced with suppliers local to the Twin Cities Metro Area. These suppliers are Garten’s Greenhouses & Garden Center and Bachman’s Nursery.

Botanical Name	Common Name	Color	Native Habitat
Perennials			
Allium stellatum	Prairie Wild Onion	Pink	Prairie, savanna
Asclepias tuberosa	Butterfly Flower	Orange	Prairie, savanna
Aster novae-angliae	New England Aster	Blue	Prairie, marsh, swamp
Echinacea angustifolia	Purple Coneflower	Purple	Prairie, savanna
Geum triflorum	Prairie Smoke	Purple	Dry prairie, woodland
Lobelia cardinalis	Cardinal Flower	Red	Prairie, marsh, lake edge
Rudbeckia laciniata	Wild Goldenglow	Yellow	Prairie, swamp, lake edge
Grasses			
Andropogon geradii	Big Bluestem	Burgandy	Prairie, savanna, woodland
Koeleria macrantha	June Grass	Green	Prairie, savanna, woodland
Schizachyrium scoparium	Little Bluestem	Amber	Prairie, savanna, woodland
Miscanthus sinensis 'Purpurascnes'	Miscanthus Flame Grass		
Miscanthus sinensis 'Silberfeder'	Silver Feather Maiden Grass		
Shrubs			
Aronia melanocarpa	Black Chokeberry	White	Lake edge, forest, swamp
Cornus stolonifera 'Farrow'	Arctic Fire Red Twig Dogwood	White & Red	Forest, wetland, lake edge
Hydrangea arborescens 'Annabelle'	Annabelle Smooth Hydrangea	White	
Syringa x 'SMNJRPU'	Bloomerang Dwarf Purple Lilac		
Trees			
Thuja occidentalis	American Pillar Arborvitae	Green	East screen
Betula platyphylla 'Fargo'	Dakota Pinnacle Birch	Yellow	Rain garden
Betula 'Royal Frost'	Royal Frost Birch	Burgundy	Patio corners
Acer tataricum 'GarAnn'	Hot Wings Tatarian Maple	Red	Dry Creek confluence
Syringa pubescens subsp. patula 'Miss Kim'	Miss Kim Korean Lilac	Purple	Front pond accent

Plant List for Thesis Design (Figure 7)

Typological Precedents & Research (D)

Research Topic: Stormwater Collection

+ Cisterns

+ Retention & Detention Basins

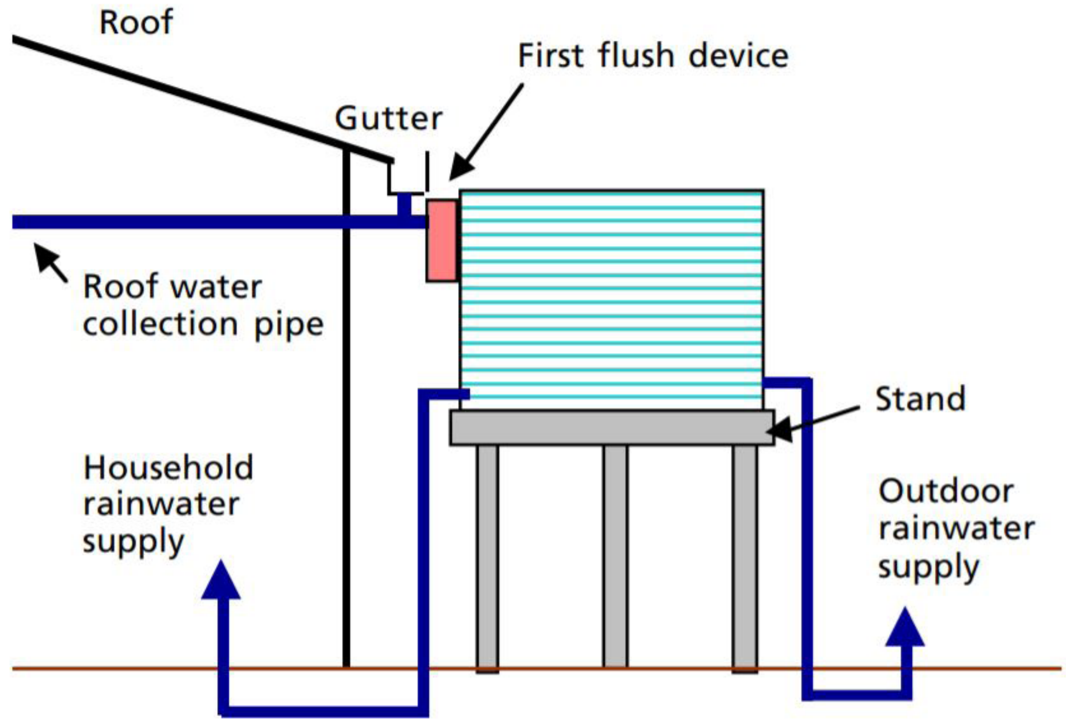
Cisterns

For the purposes of this research and thesis design proposal, a cistern is a container that collects and stores stormwater runoff for later use. Furthermore, this runoff is collected from the roof of a house and directed to the cistern via gutters.

There are three common rainwater collection systems for domestic use. They include gravity systems, pressure systems, and dual supply systems (Rainwater Tanks). All these systems are meant to capture rainwater from the roof of a structure and store the rainwater for later use. The ideal use for any of these systems is to lower the rate of use of treated water. Activities such as irrigation, toilet flushing, laundry, which all can be done using collected rainwater.

Gravity Systems

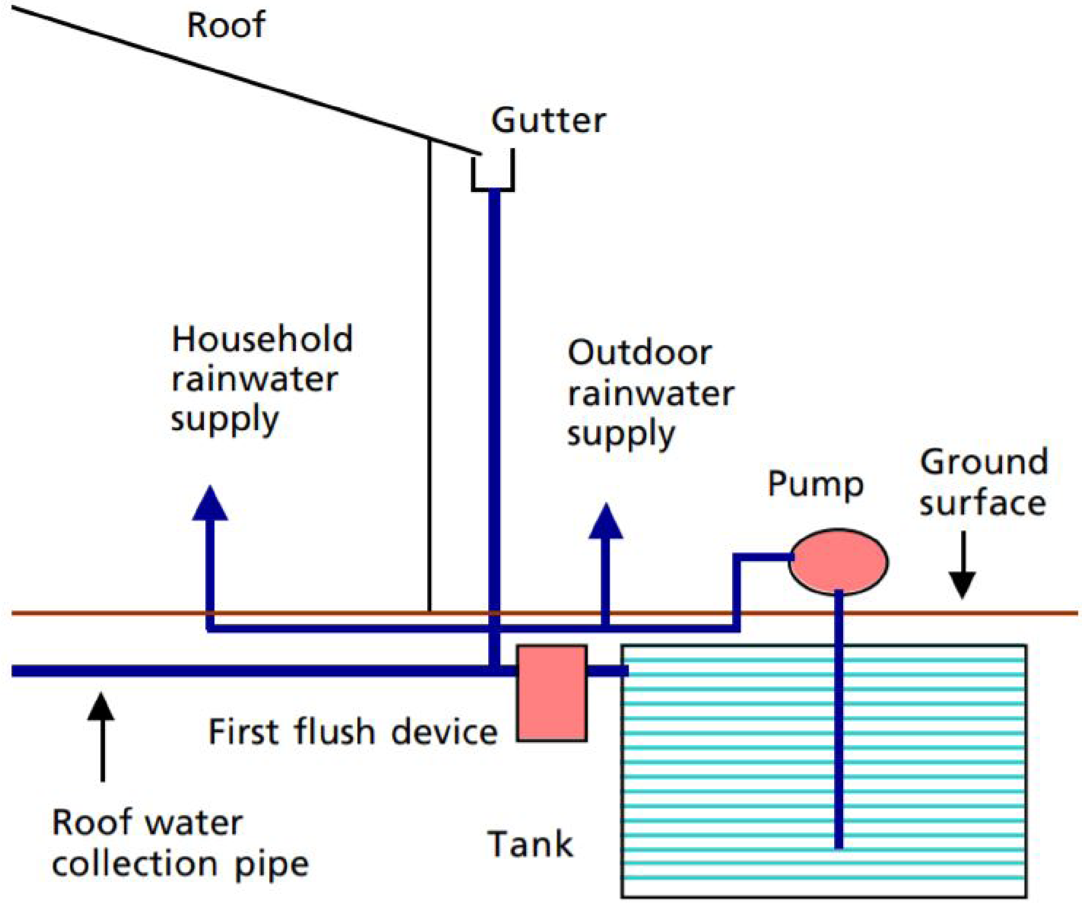
Gravity systems collect rainwater from the roof, typically with gutters, and then direct the water towards a tank. The tank is elevated off the ground on a stand. Before the water reaches the tank, it passes through a first flush device that acts as a primary filter. Once in the tank, gravity creates the pressure to feed the system(s) in the house. Toilets, laundry tubs, and garden hoses typically do not require high pressure to operate and are strong candidates for a gravity fed collection system. All of these uses normally utilize the same highly filtered water that we use to drink. By using this secondary system, it drives down costs associated with the filtered water (typically purchased from a municipal source).



Gravity System Cistern Diagram (Figure 8)

Pressure Systems

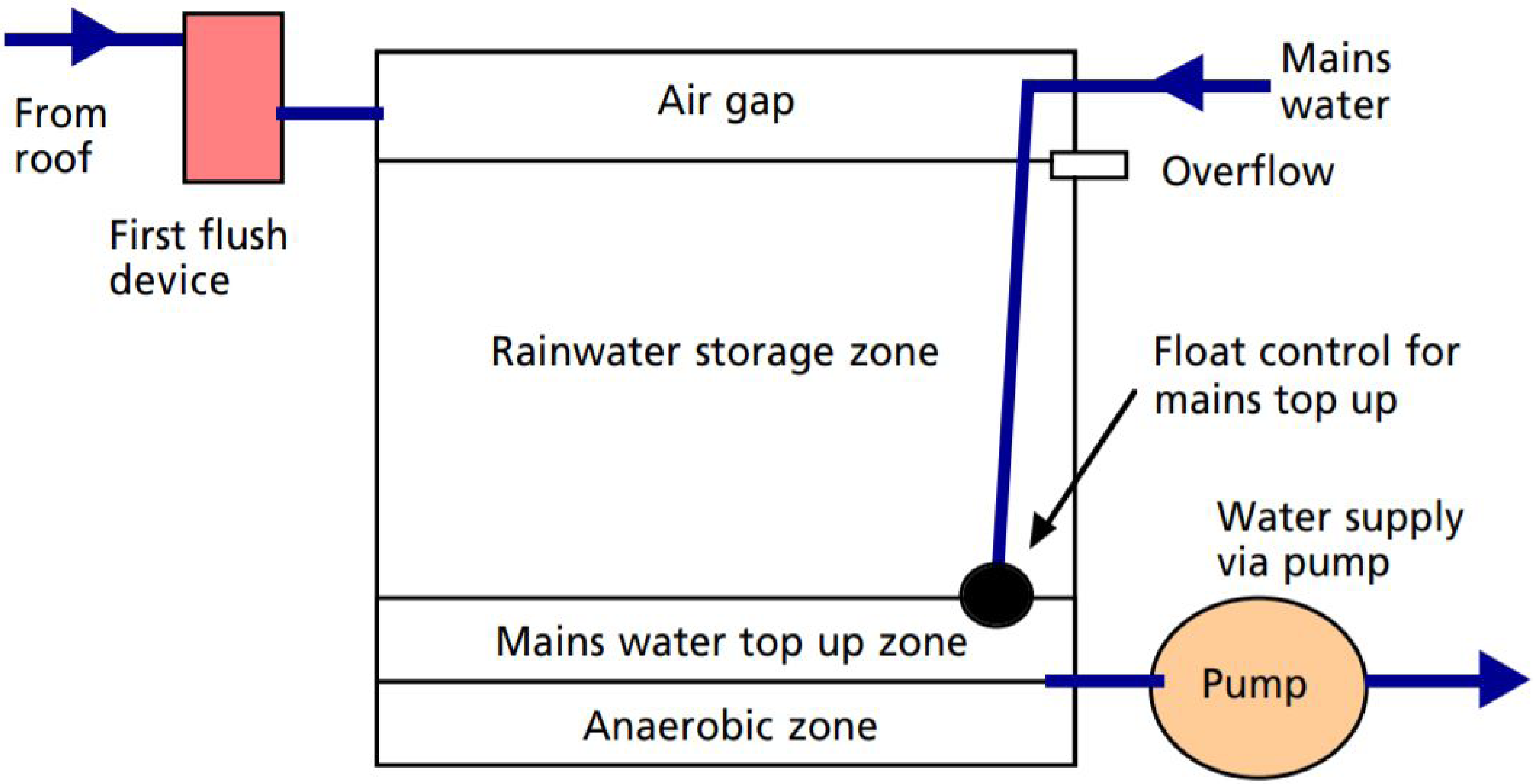
The second and slightly more sophisticated system is a pressure system. These are installed when it is not feasible to have the storage tank elevated as is necessary with a gravity system. This can also be a choice for aesthetic reasons since the tank can be buried underground. Because the tank is below ground the system utilizes a pump to supply the water to fixtures in the house or on the exterior. Besides the pump and physical location of the tank, the system operates and supplies water much like a gravity system does.



Pressure System Cistern Diagram (Figure 9)

Dual Supply Systems

The third and most sophisticated system is called a dual supply system. In this configuration the rainwater storage is linked with the main water system. In the case of low water supply via rainwater the main water supply can top off the storage tank. Conversely, when rain events are frequent the system may not need to rely on the mains. In this situation all the house's water supply comes from one source, or tank. Because of this the tank needs to be significantly larger than what is used in a gravity or pressure system. This is dependent on size and number of people living in a house, water usage, rainfall, and roof area. A larger roof area will collect more water, but usually means a larger house and more demanding water needs.



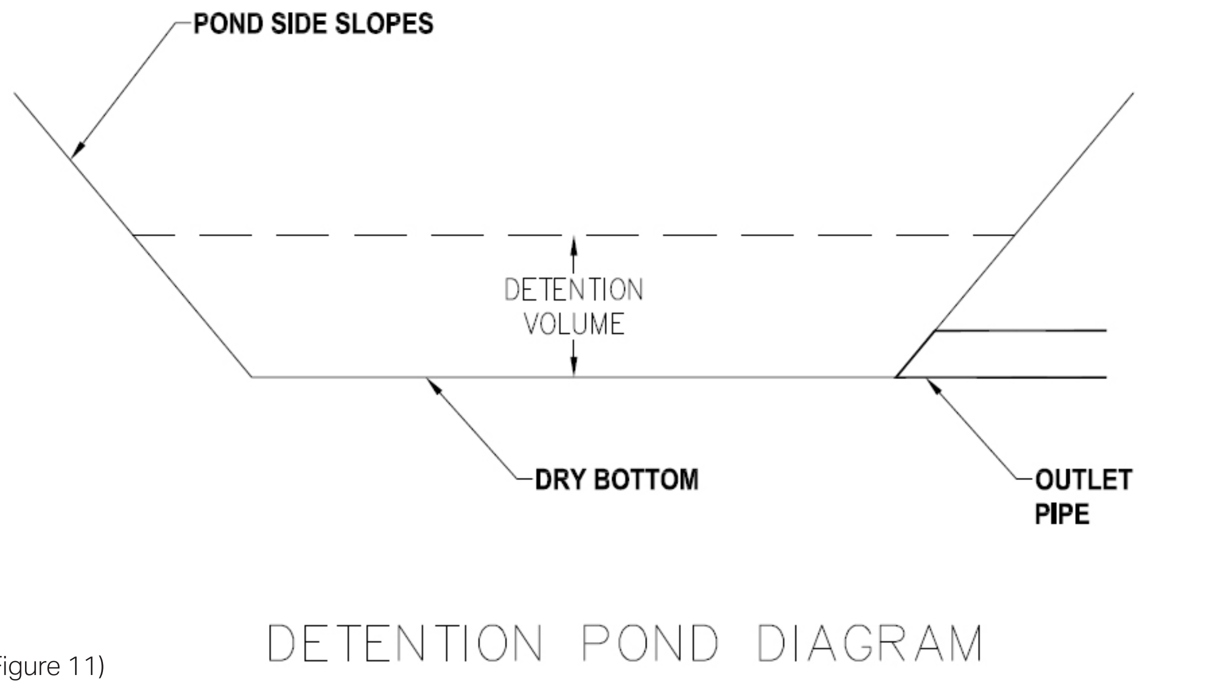
Dual Supply System Cistern Diagram (Figure 10)

All three of these systems share the same benefits to different degrees of results. They all can help to lower the cost of water use. Rainwater collection systems also can reduce erosion, ponding, or flooding in yards during heavy rain events. Where a gutter system downspout may wash out the earth below it; or a house without gutters, the rainwater collection system harnesses that water and stores it for later use.

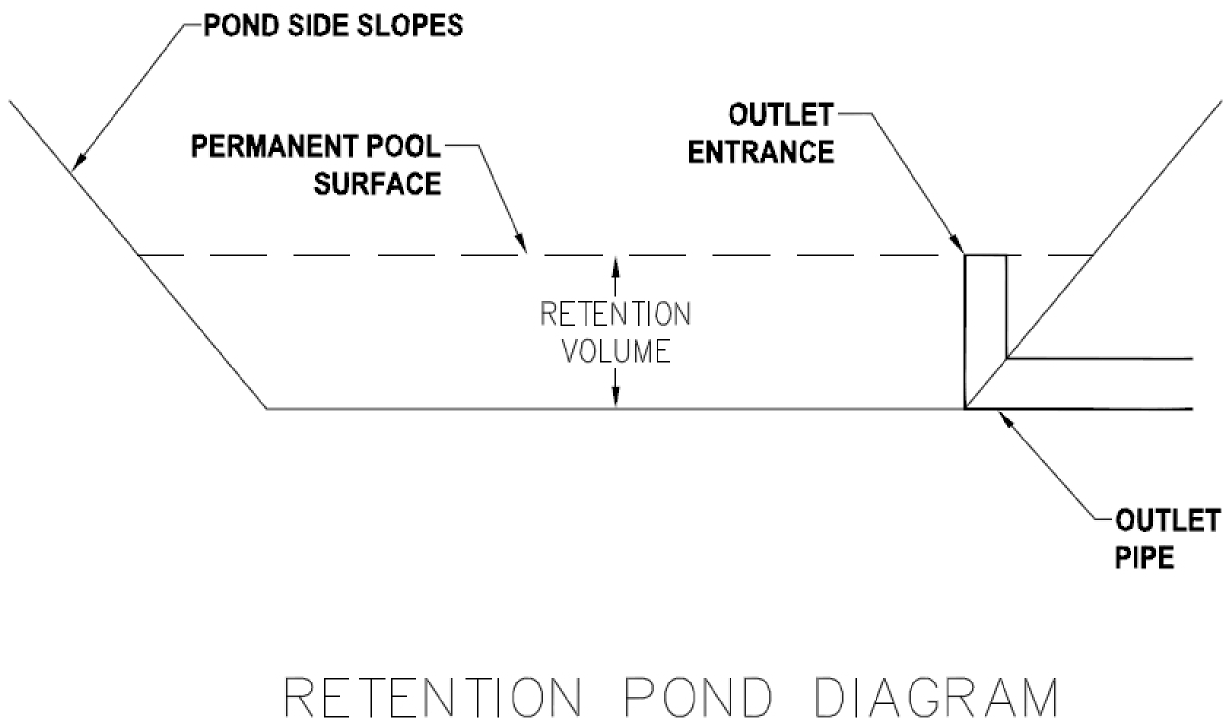
Retention and Detention Basins

Retention basins & ponds are a unique addition to any landscape. They have many uses beyond just helping account for stormwater management. Housing small fish, providing auditory and visual interest in the landscape, and opportunity for aquatic plantings are just some of their potentials as landscape features. More importantly for the sake of this thesis, they can be utilized to hold stormwater- temporarily or permanently.

Although visually they appear very similar, there are small but significant differences between detention and retention ponds (or basins). Firstly, detention ponds only detain water; meaning they hold water for a finite period but eventually that water is dispersed. That can be through an outlet pipe and via percolation into the ground. This can occur because detention ponds do not use impervious liners. They serve to collect excess surface runoff and slowly release it over extended periods of time.



Detention Pond (Figure 11)



Retention Pond (Figure 12)

Retention and Detention Basins

Retention ponds however are typically built with an impervious liner that allows them to maintain a volume of water. An outlet pipe (or other provision) is installed with an elevated point of egress that accounts for any overflow. Should a large storm event, or several in close succession, occur the retention pond may reach or surpass maximum capacity. Therefore, it is imperative that an outlet provision be included, otherwise flooding of the site may occur. Retention ponds often look “low” because they are meant to accommodate excess water; with the excess evaporating over time or exiting via the outlet provision if volumes dictate.

Typological Precedents & Research (E)

Research Topic: Storm Events

Farmington, MN

The site for this thesis is in Farmington, Dakota County, MN. The basic storm measurables were researched. The average annual rainfall is 32.4”. A 10-year frequency, 60-minute duration storm was chosen for the purpose of establishing baseline quantities. That yielded a 2.28 inch-per-hour intensity and a time of concentration of 34 minutes and 45 seconds.

The site was divided into two parts, the yard and the roof/house. The inflow rate for the yard was 0.638 cubic feet per second. The inflow volume for the yard was 2296.8 cubic feet. The inflow rate for the roof was 0.142 cubic feet per second. The inflow volume for the roof was 515.6 cubic feet.

Typological Precedents & Research (F)

Case Study: International Student Center Rain Garden

+ Kansas State University, Manhattan, Kansas

+ **Designed by:** Department of Landscape Architecture and Regional & Community Planning, Kansas State University

+ **Client:** Kansas State University

+ **Utility Goals:** Reduce pollutant loads in rainwater; reduce downstream damage from runoff; safely move, control, contain rainwater; capture rain for reuse, restore or create habitat

+ **Amenity Goals:** Education, recreation, safety, public relations, aesthetic richness

Contribution to Thesis

This project incorporated addressing the roof as a source of runoff, which was an inspiration for the thesis design proposal. The basis of a rain garden also played an important role in the thesis, as rain gardens were an integral part of the research material. The use of native plants, wood mulch, and natural stone appeared to fit initial design direction.

Project Elements

+ Rooftop scuppers

+ Reclaimed limestone splash pads

+ Two-celled rain garden

+ Checkdam & weirs systems

+ Permeable limestone pavers

+ Overflow lawn

Kansas State University Rain Garden (Figure 13)

Typological Precedents & Research (G)

Case Study: The Rain Garden at the Oregon Convention Center

+ Portland, Oregon

+ **Designed by:** Mayer/Reed, Inc. | Landscape Architecture & Visual Communications

+ **Client:** Metropolitan Exposition Recreation District

+ **Utility Goals:** Reduce pollutant loads in rainwater; reduce downstream damage from runoff; safely move, control, contain rainwater; capture rain for reuse, restore or create habitat

+ **Amenity Goals:** Education, recreation, safety, public relations, aesthetic richness

Oregon Convention Center Rain Garden (Figure 14)

Contribution to Thesis

This project again utilized scuppers to focus attention on stormwater management taking place within the landscape. Natural stone was used as accents across the rain garden, and native plants filled in most of the space. The convention center's roof encompasses 5.5 acres that feeds five distinct scuppers. This visually dramatic approach was a source of inspiration for the thesis design. Liberal use of natural stone also played an important role in shaping the design process.

Project Elements

+ Roof scuppers
+ Series of biofiltration basins
+ Checkdams

Oregon Convention Center Rain Garden [2] (Figure 15)

Typological Precedents & Research (H)

Queens Botanical Garden (Figure 16)

Case Study: Queens Botanical Garden

Flushing, New York

+ **Designed by:** Atelier Dreiseitl with Conservation Design Forum; BKSK Architects

+ **Client:** Queens Botanical Garden

+ **Utility Goals:** Reduce pollutant loads in rainwater; reduce downstream damage from runoff; safely move, control, contain rainwater; capture rain for reuse, restore or create habitat

+ **Amenity Goals:** Education, recreation, safety, public relations, aesthetic richness

Contribution to Thesis

This stormwater design took a unique approach of using water to visually separate constructed areas from planted areas. Of the case studies, the Queens Botanical Garden has the most attention drawn to water and stormwater alike. Dense plantings and strong geometry in hardscapes really guide visitor's views as well as their travels through the site. This site also has the most diverse solution as it incorporates landscape and mechanical stormwater management features. A cistern collects surface runoff, filters it, and supplies irrigation and cleaning machinery. The use of the cistern is a goal in the thesis design with the versatility of applications, such as this one, being a main reason for its inclusion.

Project Elements

+ Permeable paving

+ Mechanical filtration

+ Cisterns

+ Green roof

+ Roof runoff harvesting

+ Scuppers

User Description

This thesis operates under the guise of a Client & Landscape Designer relationship.

Client Narrative

The clients are a middle-aged couple that are now empty nesters. Two adult children are beginning families of their own and the clients are looking to expand their outdoor spaces in terms of use and beauty. Thus, making room for visiting friends and family to enjoy time together privately, while being outdoors.

The husband is retired and enjoys working outdoors and maintaining the yard and plant life. Landscape maintenance is expected but should be designed with longevity and some level of autonomy in mind. The wife has requested that the proposed deck should include a connection to the existing wrap around porch. Collectively, a fire pit patio should have a “cozy and private feel, but still be able to comfortably host 8-10 people.”

Stormwater management solutions are eagerly welcomed. While no major concerns need to be addressed, the clients have requested that any stormwater management solutions not become the focus of the design. Working in the background and seamlessly coinciding with the existing and proposed elements is a must. This is not only a personal request but also abiding by homeowner’s association (HOA) covenants.

Client Requests

+ Fire pit & patio for backyard

+ Deck and connecting walkway to existing porch

+ Adhere to HOA covenants

    - "All structures and site modifications must uphold a naturalistic style and palette of materials."

    - "Outdoor storage and utility items, excluding auxiliary buildings, must not be visibly from the road."

Major Project Elements

+ Fire Pit Patio (client)

+ Deck (client)

+ Cistern (stormwater)

+ Rain Garden (stormwater)

+ Retention Ponds (stormwater)

+ Dry Creek Bed (stormwater)

+ Detention Basin (stormwater)

Project Emphasis

Material Choices

Comprehensive market research of commercially available products that are designed and selected with stormwater management as an emphasis. This includes construction materials and plant materials.

Planting Design

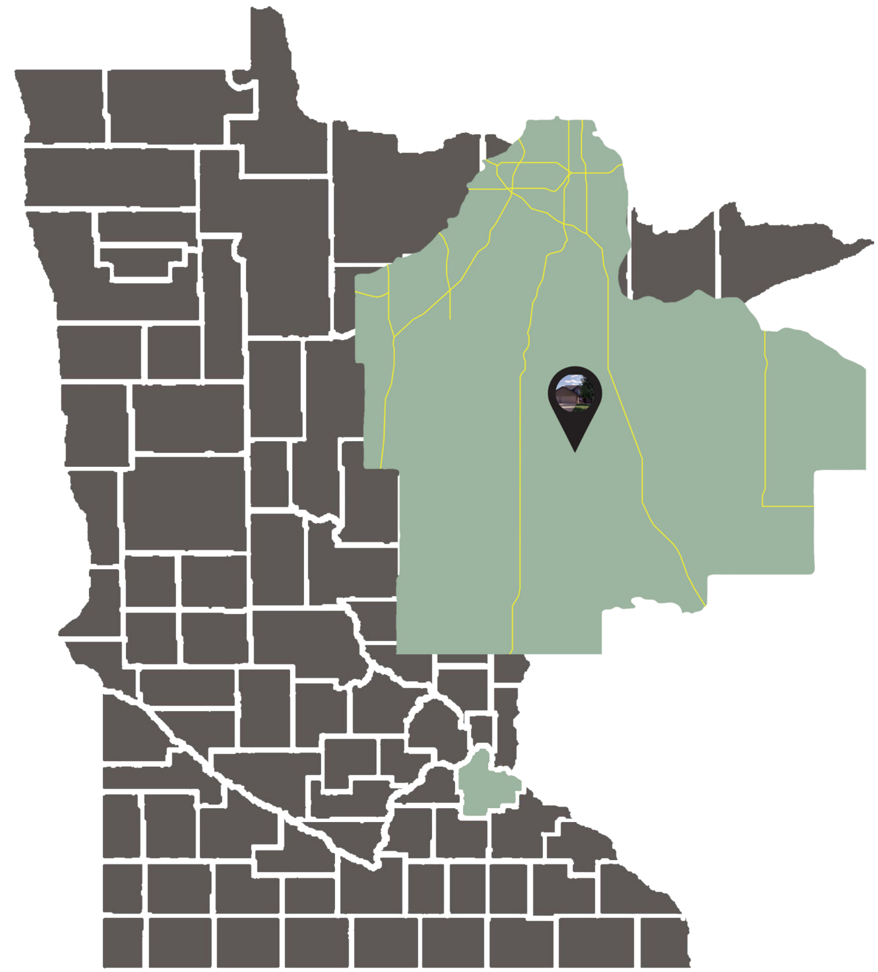
Compiling a plant list that can be referenced for design purposes with stormwater benefits, while still meeting the client's preferences.

Clever Balance

Setting goals for stormwater management while upholding the standards set forth by the client for the design of the site. The client's design preferences will drive the layout and portion of the material choices, but it is up to the designer (thesis student) to incorporate diverse stormwater solutions across the site.

Site Inventory & Context

+ Location: Farmington, Dakota County, MN
+ Size: 1.62 Acres
+ Site Typology: Single family residential, semi-rural
+ Population: 22,869 (Farmington – 2019)
+ MSP International Airport: 32-minute drive
+ Farmington High School: 17-minute drive



Key Map (Figure 17)

Site Context

The site lies outside of Farmington, MN. A private road is maintained by 12 residences that make up an HOA. At 1.62 acres the site is the smallest of the 12 lots in the development. Sitting atop a hill, the house boasts expansive views; the pinnacle of which come from a West facing wrap around porch. Just far enough away from town to enjoy quiet and privacy, but still close enough to all major conveniences of modern-day living.

Site Photo | Front of House, Facing South (Figure 18)

Site Photo | West Yard, Facing East (Figure 19)

Site Photo | Backyard, Facing West (Figure 20)

Site Photo | East Yard, Facing Southwest (Figure 21)

Site Analysis

The initial site visit did not yield any major concerns regarding stormwater (flooding, washout, etc.). With over 20 feet of elevation change across the site there is ample opportunity for utilizing existing grading to direct stormwater runoff. There are three existing retaining walls which will serve as inspiration for the wall necessary for the backyard patio. Existing driveway and front sidewalk are poured concrete which present a possibility for intervention. Permeable pavers could be used to replace the poured concrete.

Plant materials have reached maturity across the board. For the sake of a comprehensive design plan, all plant materials around the yard will be replaced. Refer to research portion on the plant list material. The East property line is significantly more exposed and vacant compared to the rest of the site. A privacy screen would help close in the site and increase the private feel of the yard.

Adjacent to the garage wall and front sidewalk are two, small, existing ponds. This feature could be expanded to accommodate for a larger stormwater management purpose. The clients enjoy the noise of the water being recirculated between the two ponds.

Applications of Results from Theoretical Premise/Unifying Idea Research

Referencing **Major Project Elements** each element will be briefly discussed as to why they are included based on my research.

The backyard elements- the deck and patio- have arguably the least importance in the scope of stormwater management. They exist primarily to meet the client's requests. The patio, however, will be specified to be built as a permeable surface. This will allow for stormwater to permeate the surface rather than generating more runoff across the site.

Cistern:

Concluding my research into cisterns and roof runoff collection there will be a cistern in the design proposal. The proposed cistern is 1500 gallons in capacity and will be above ground.

Rain Garden:

A rain garden will be included somewhere in the design, likely to address a portion of the runoff coming from the roof of the house.

Retention Ponds:

As mentioned in the site analysis, there will be an expansion of the existing ponds on the site. This will be to accommodate more of the roof runoff and to add a higher degree of visual interest to the front façade of the house.

Dry Creek Bed:

Dry creek bed(s) will be added to the master plan in a concerted effort to get stormwater moved across the site to a dedicated location. This more assertive approach will help to prevent stormwater from pooling at other areas of the site.

Detention Basin:

The dedicated location, or terminal point, of the dry creek beds will be a detention basin. This area may hold stormwater during and after storm events; but not permanently holding water. Aside from their functionality the dry creek bed and detention basin will be planted thematically like the rain garden and other foundation plantings found around the site.

Performance Criteria for the Thesis Project

Initial Design Storm:

10-year frequency, 60-minute duration

Initial design storm intensity:

2.28 inches per hour (iph)

Time of Concentration:

34:45 (34 minutes, 45 seconds)

(Existing site TOC)

Volumes of the Design Storm:

Yard inflow rate:

0.638 cubic feet per second

Yard inflow volume:

2296.8 cubic feet (17,181 gallons)

House inflow rate:

0.142 cubic feet per second

House inflow volume:

515.6 cubic feet (3,857 gallons)

The roof of the house is divided into three sections...

Section A: 176.58 cubic feet, 1,320 gallons; Cistern

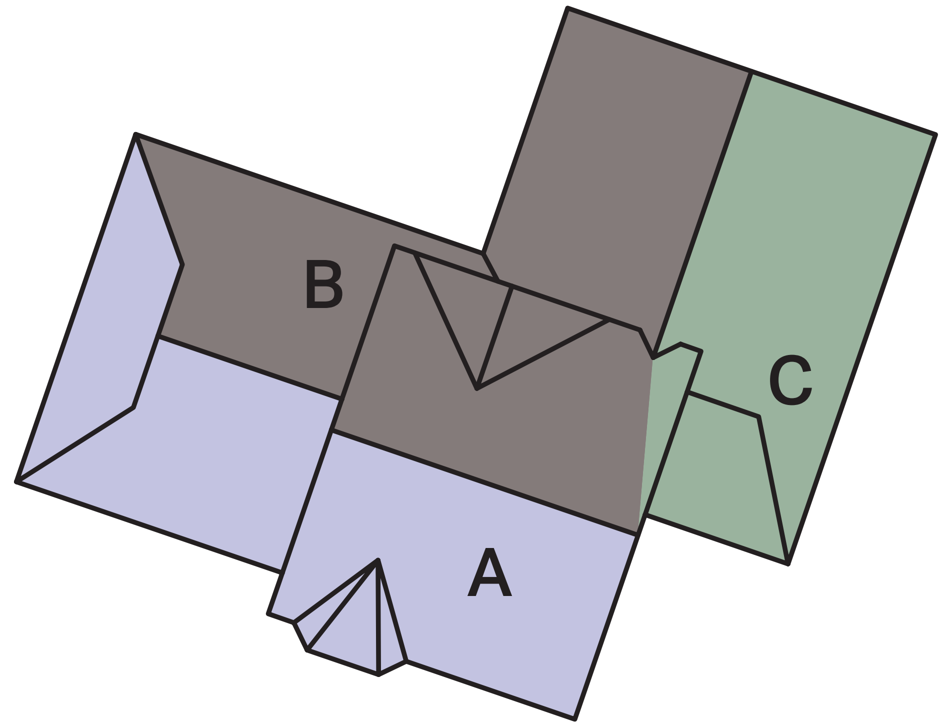
Section B: 218.95 cubic feet, 1,637 gallons; Retention Ponds

Section C: 120.06 cubic feet, 900 gallons; East Rain Garden

Total volume: 2,812.4 cubic feet, 21,038 gallons

Initial thesis goal is to account for (retain, redirect, collect) **80%** of all stormwaters:

2,249.92 cubic feet, 16,830 gallons



Design Concept Statement

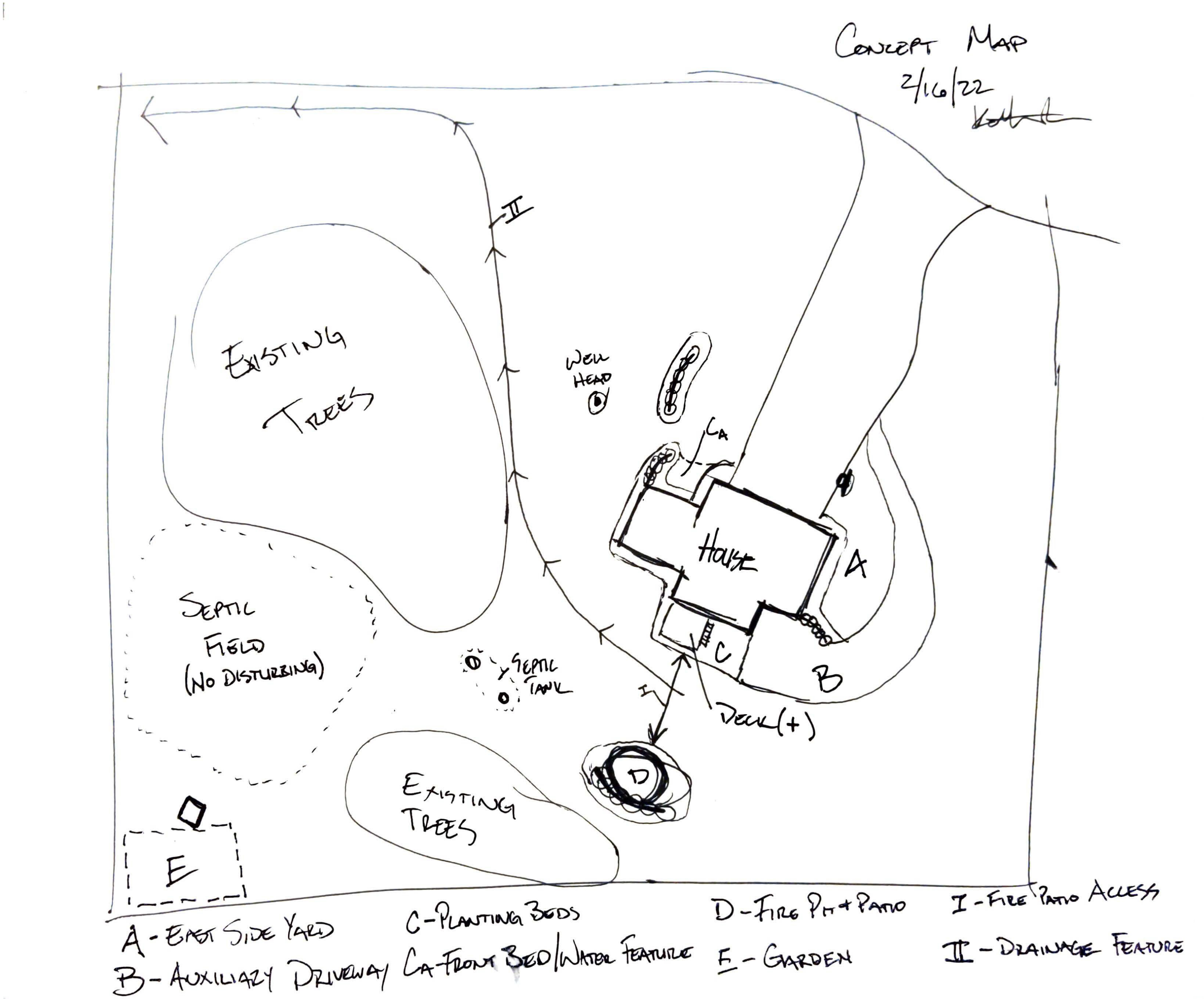
Implementing effective stormwater management within the constraints of a hypothetical client's design and site-use preferences.

"A fair catch is an unhindered catch of a scrimmage kick that has crossed the line of scrimmage and has not touched the ground, or of a free kick that has not touched the ground, by a player of the receiving team who has given a valid fair-catch signal." -NFL, Section 2-Fair Catch, Article 1-Defintion

If done correctly a Fair Catch is a passive response in an active environment. When done incorrectly the results often lead to chaos and unwanted outcomes.

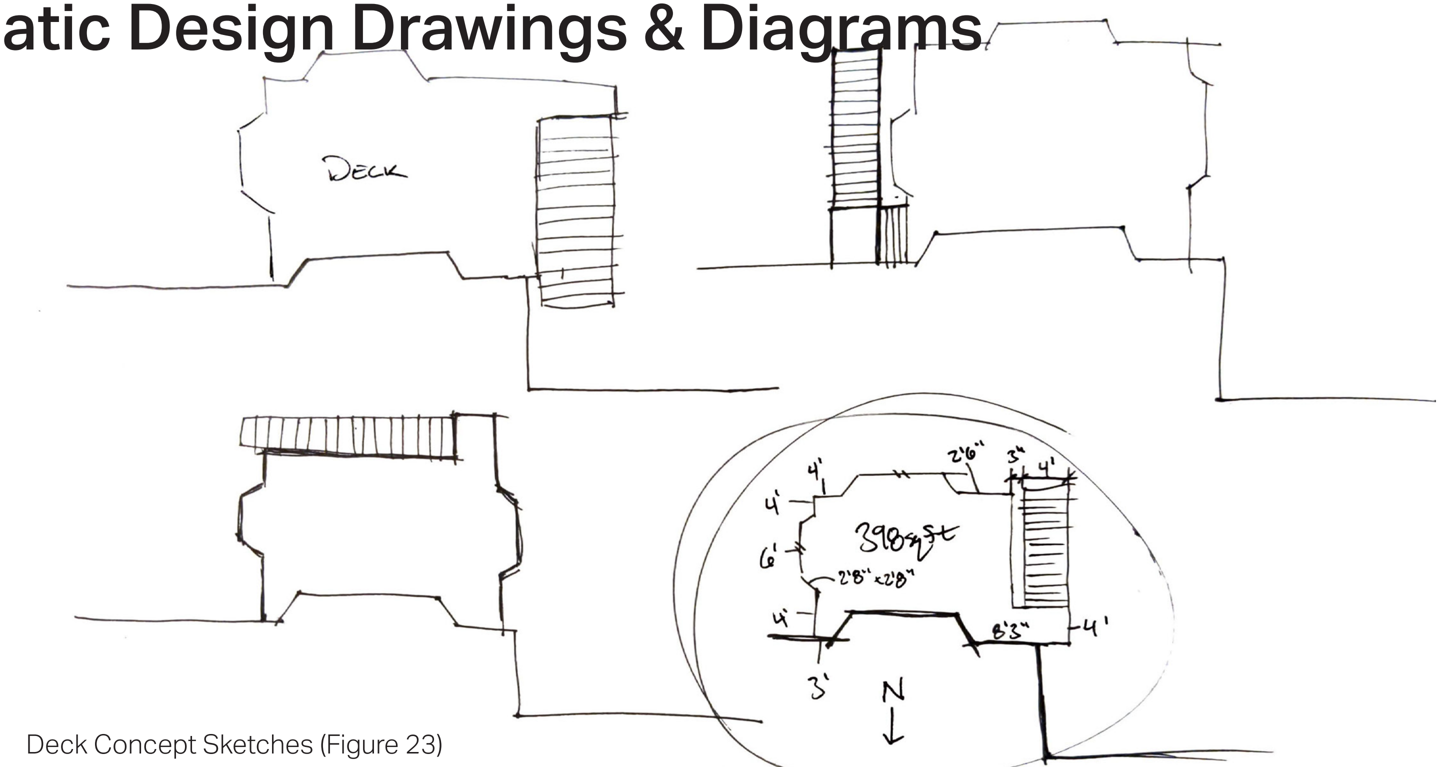
This is the encompassing approach of my thesis design: To address stormwater in a passive manner where the idea of stormwater management occurring is not immediately obvious to visitors to the site or passing by, while still being undoubtedly viable.

Schematic Design Drawings & Diagrams

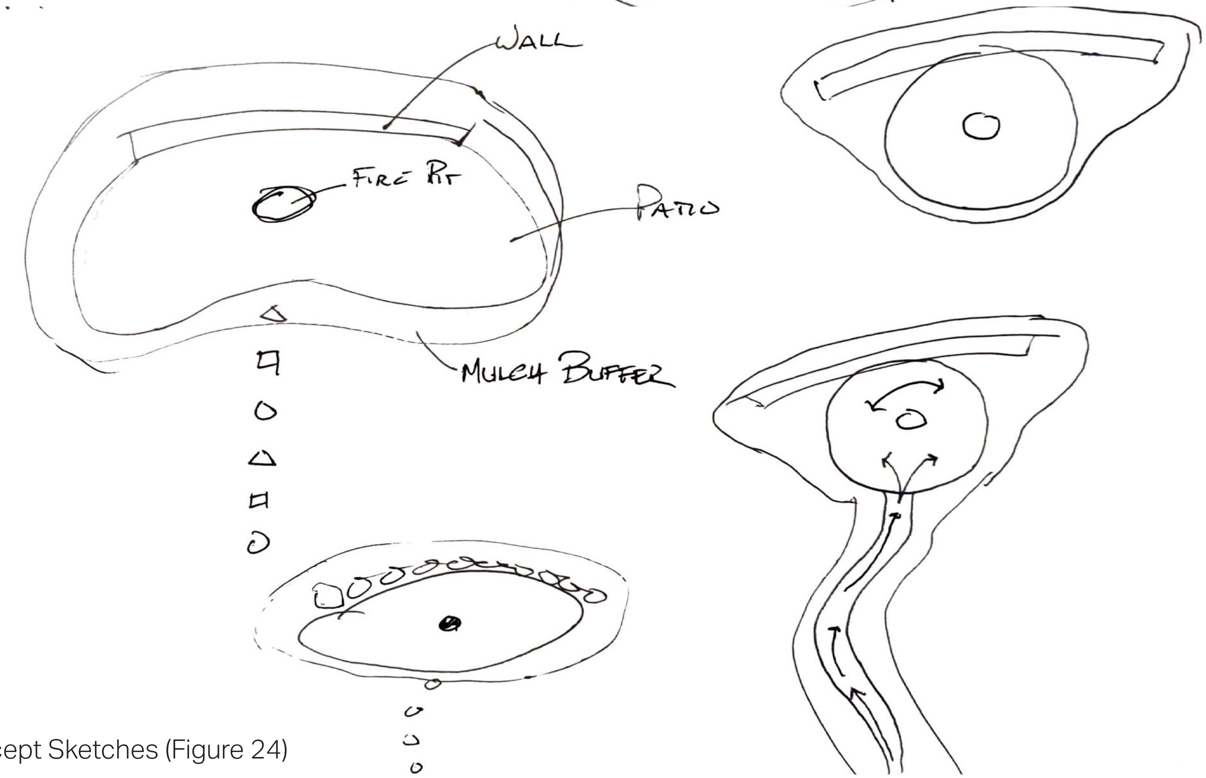


Site Plan Sketch (Figure 22)

Schematic Design Drawings & Diagrams

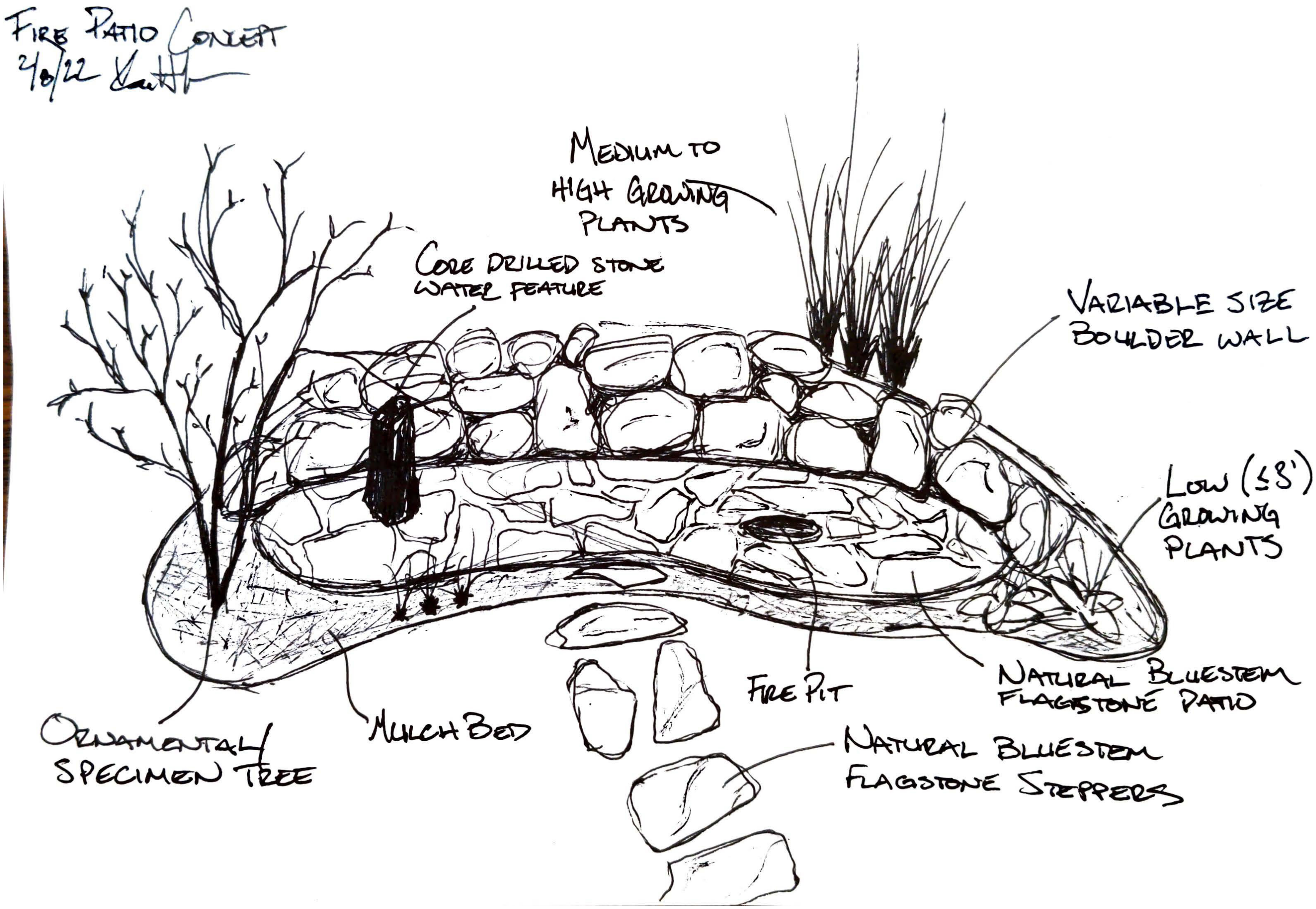


Deck Concept Sketches (Figure 23)



Patio Concept Sketches (Figure 24)

Schematic Design Drawings & Diagrams

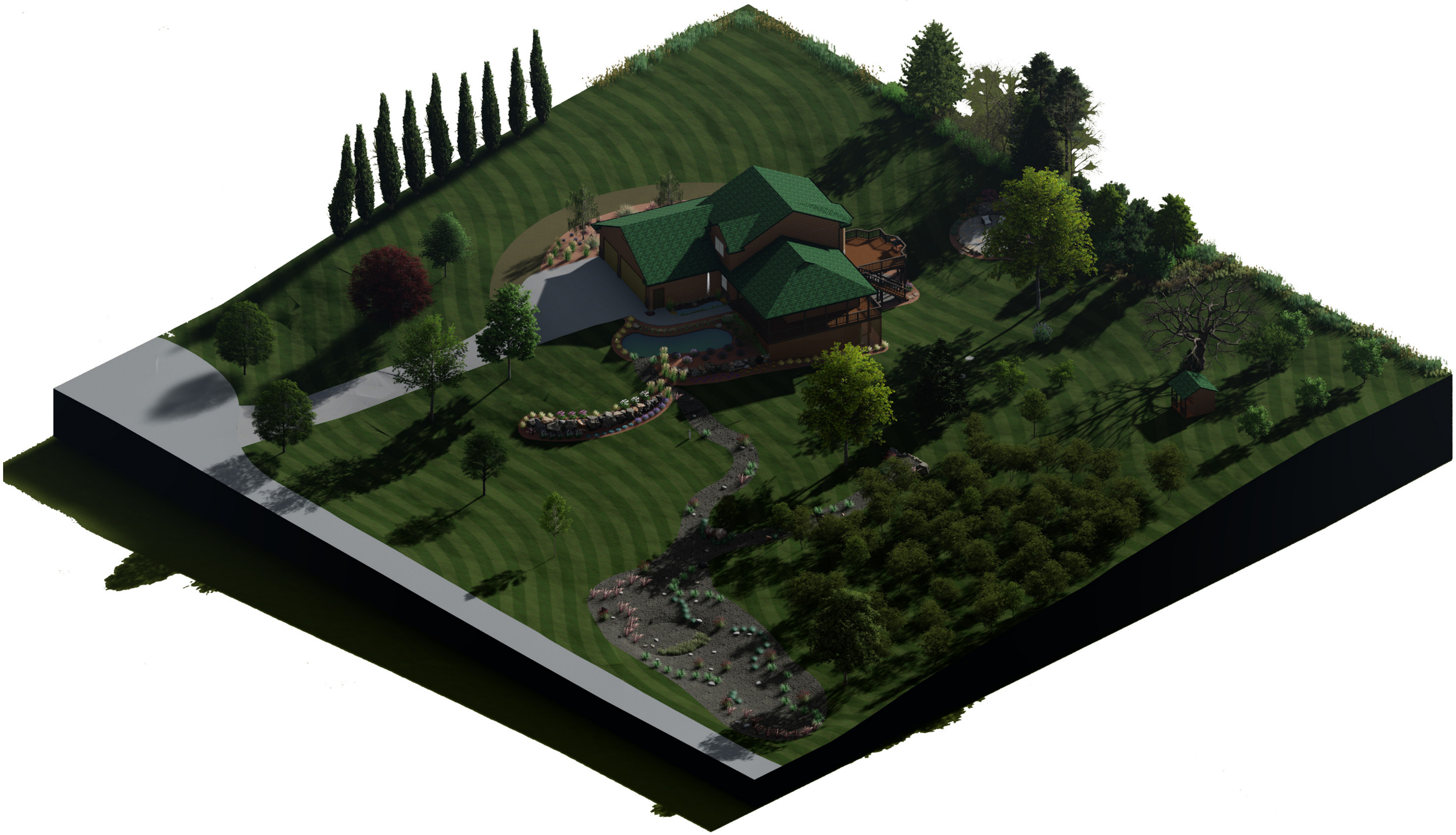


Patio Concept Sketch (Figure 25)

Schematic Design Drawings & Diagrams

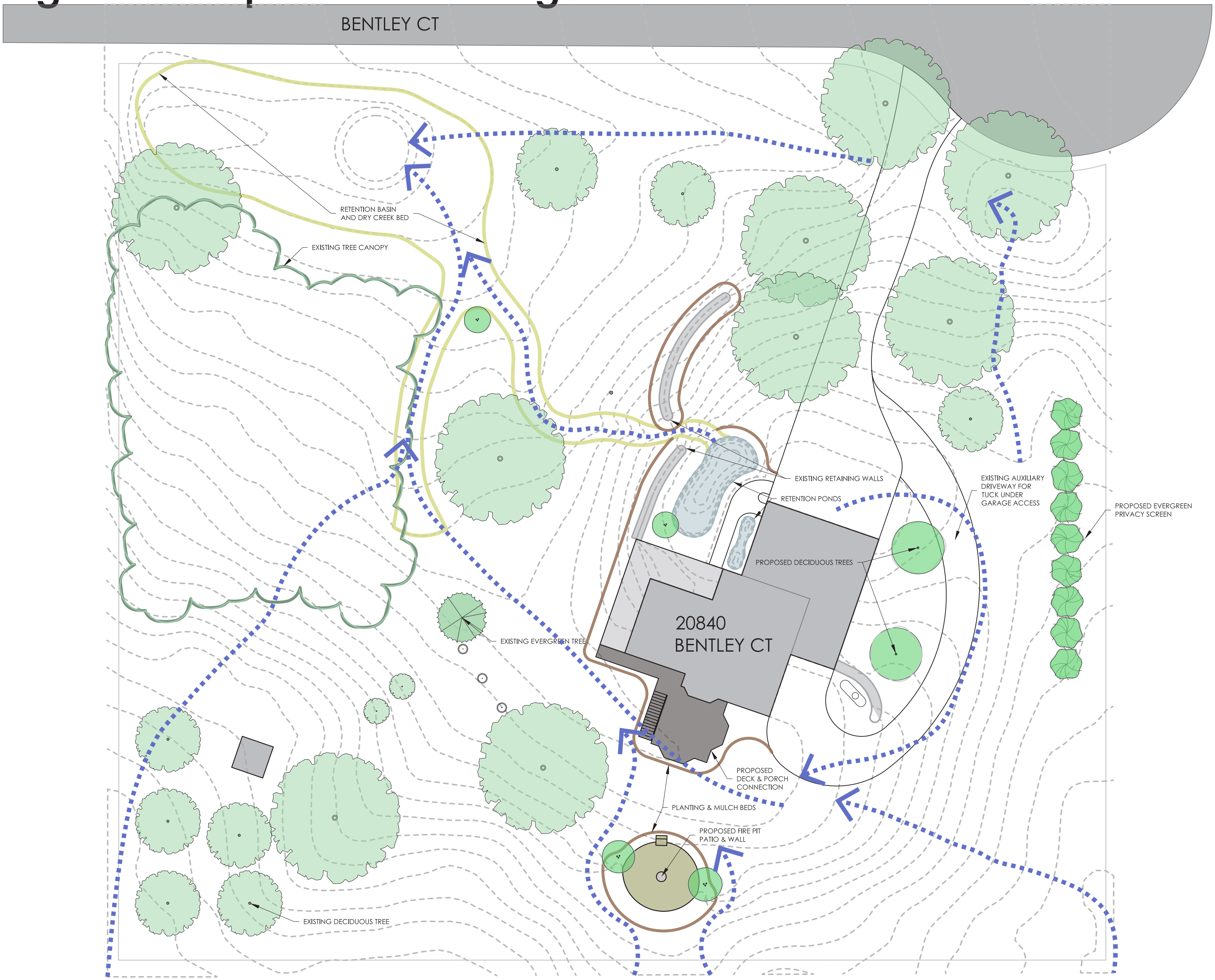
Front Yard Concept Sketch (Figure 26)

Design Development Drawings & Models



Site Aerial | Graphic Render (Figure 27)

Design Development Drawings & Models



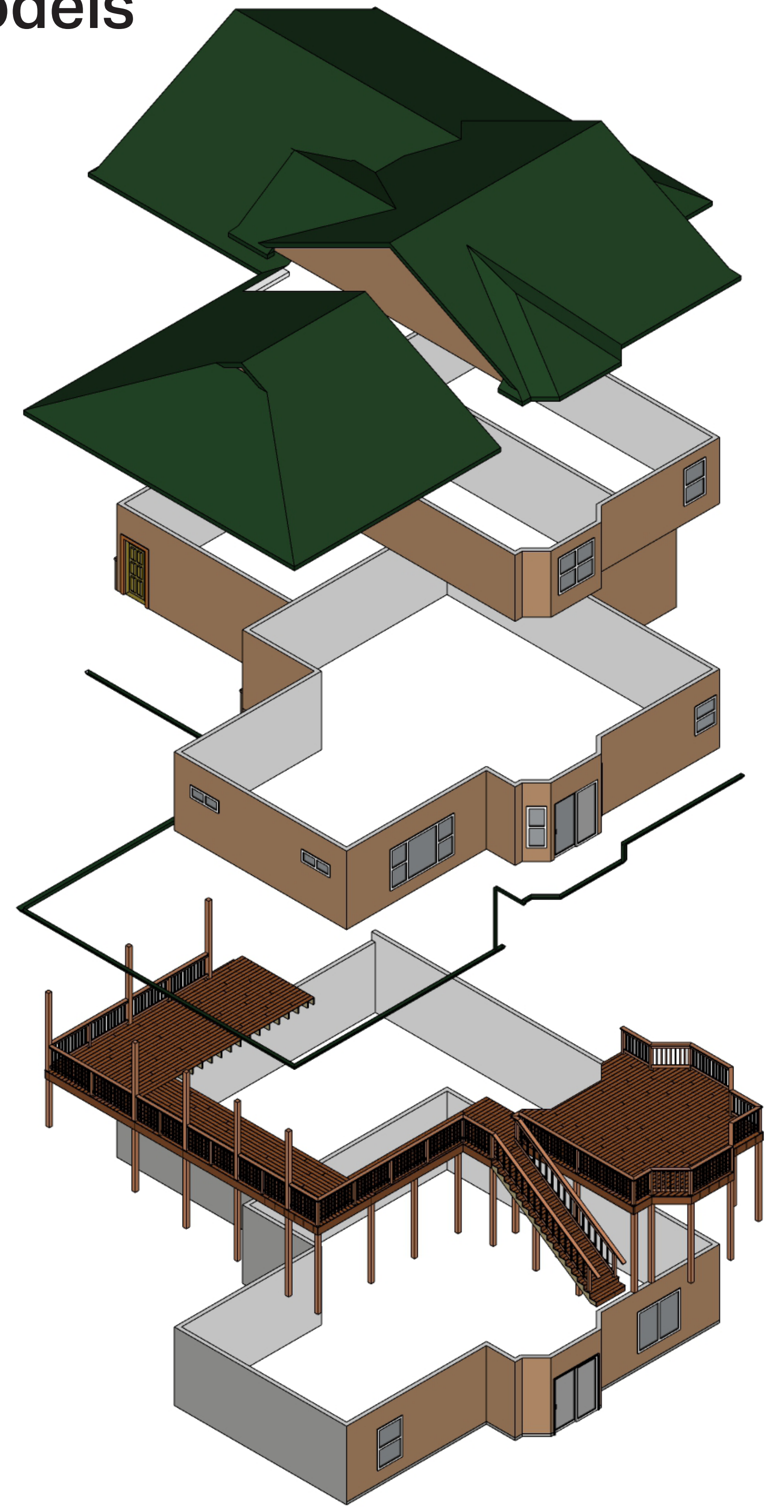
Master Plan | Showing Site Features & Water Flow (Figure 28)

Design Development Drawings & Models

This digital model represents the house and the proposed deck.

Design Development Drawings & Models

This exploded model shows the floors of the house and their relationship with the proposed deck. The deck is shown connected to the existing wrap around porch. Also pictured are the gutters that are used to direct stormwater runoff from the roof to the appropriate stormwater measures.



House | Exploded Digital Model (Figure 30)

Design Development Drawings & Models

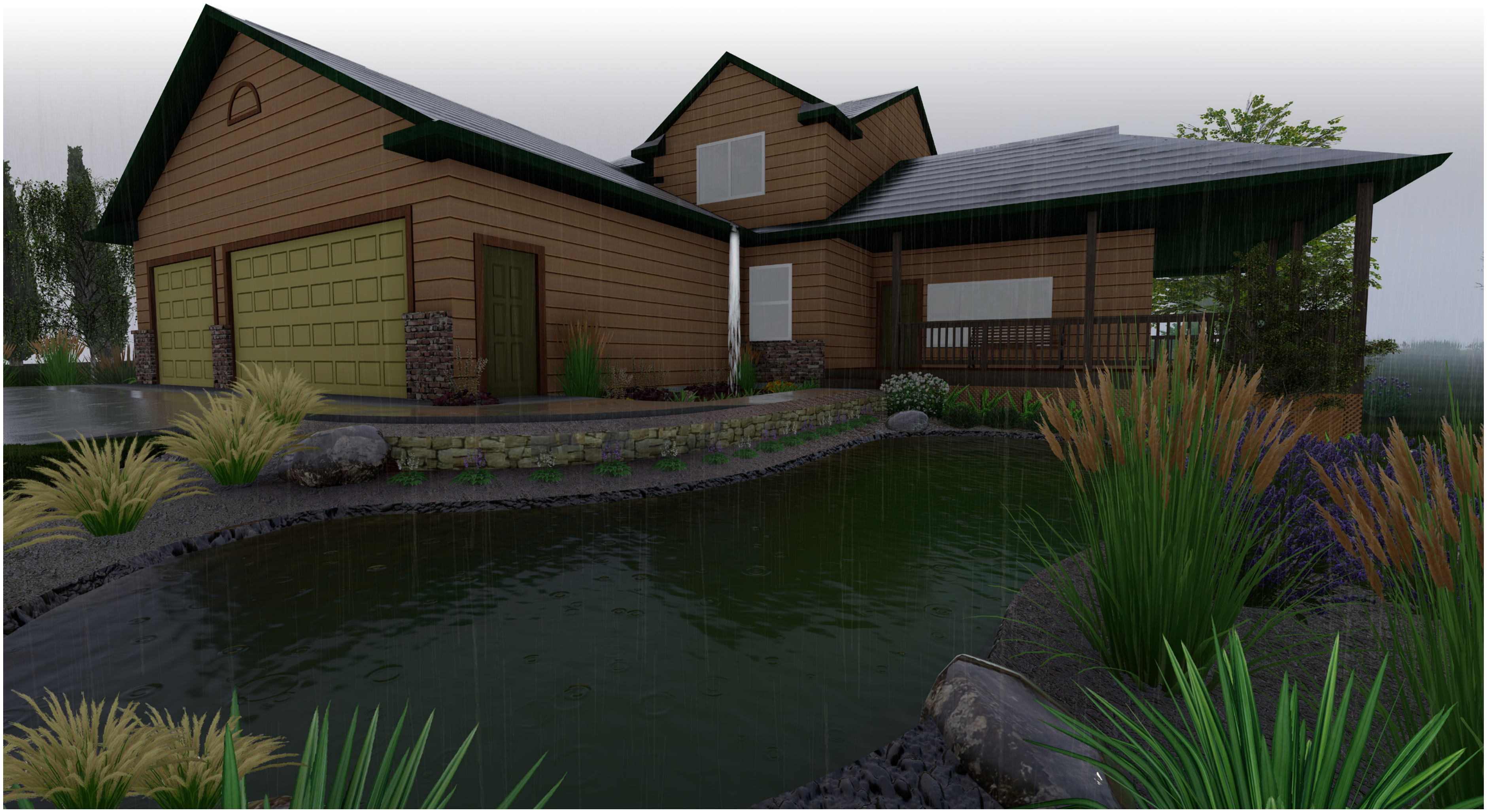
The detention basin is shown here. The dry creek beds can be seen traversing the yard on their way to the detention basin.

Design Development Drawings & Models

Pictured above, a section-elevation of the front yard. This shows how water can fall from the roof, work through the retention ponds, down through the creek bed, and land at the detention basin at the bottom of the hill.

Digital Render | Front Yard Section-Elevation (Figure 32)

Design Development Drawings & Models



Shown above are the retention ponds during a storm event. As water falls from the scupper on the roof, it collects in the upper pond. An underground pipe circulates water to the larger, lower pond. Should levels rise beyond capacity a provision in the grade allows for excess water to reach the detention basin via the dry creek bed.

Digital Render | Retention Ponds (Figure 33)

Design Development Drawings & Models

Pictured above: Cistern placed beneath the porch, proposed deck, proposed fire pit & patio.

Digital Render | Backyard, Facing East (Figure 34)

Design Development Drawings & Models

Digital Render | Backyard at night (Figure 35)

Design Development Drawings & Models

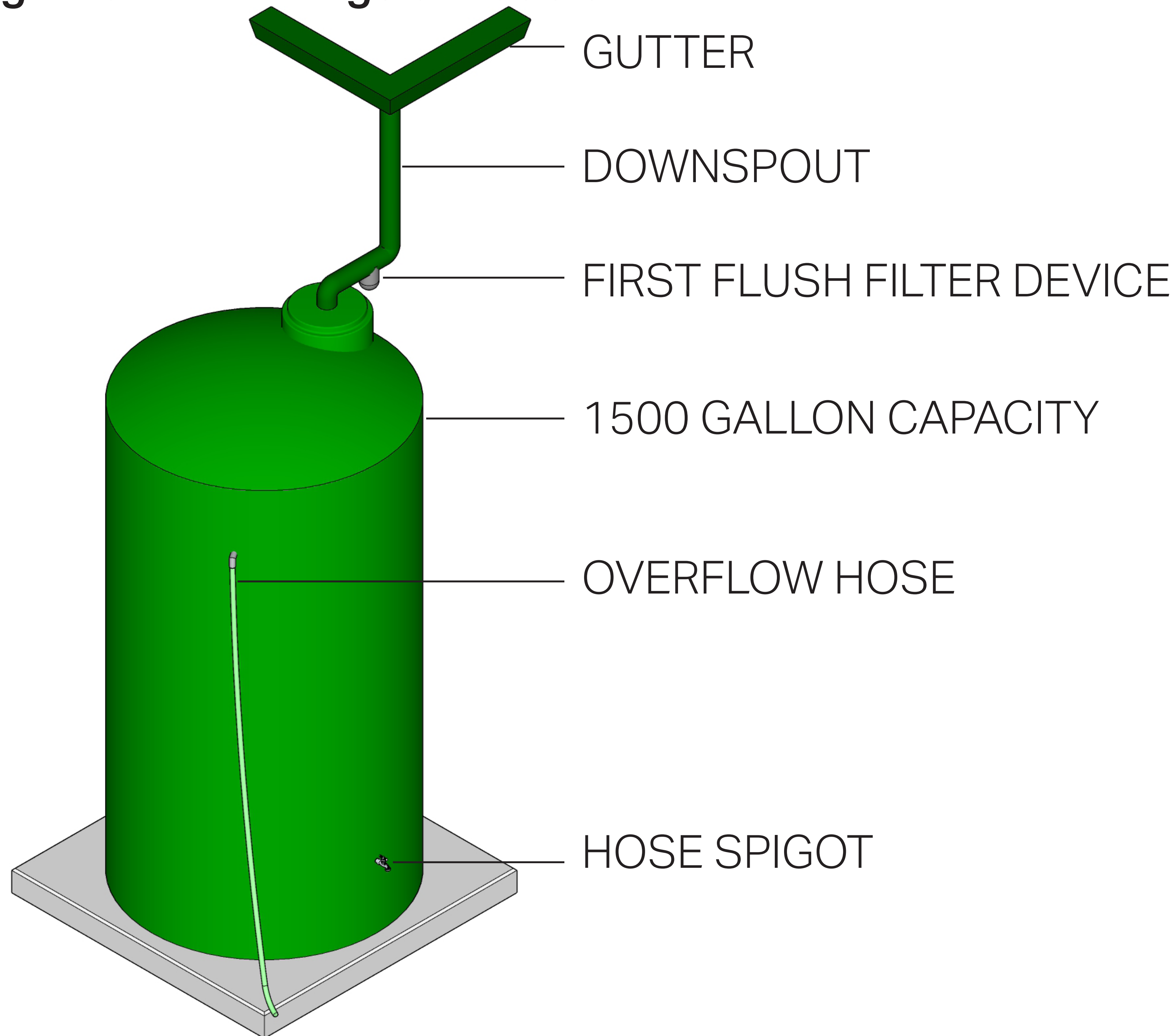
The East rain garden is fed by a scupper from the roof and accommodates all stormwater from that section of the roof. This prevents sending more runoff to the backyard and overloading the dry creek beds and detention basin.

Digital Render | East Yard Rain Garden (Figure 36)

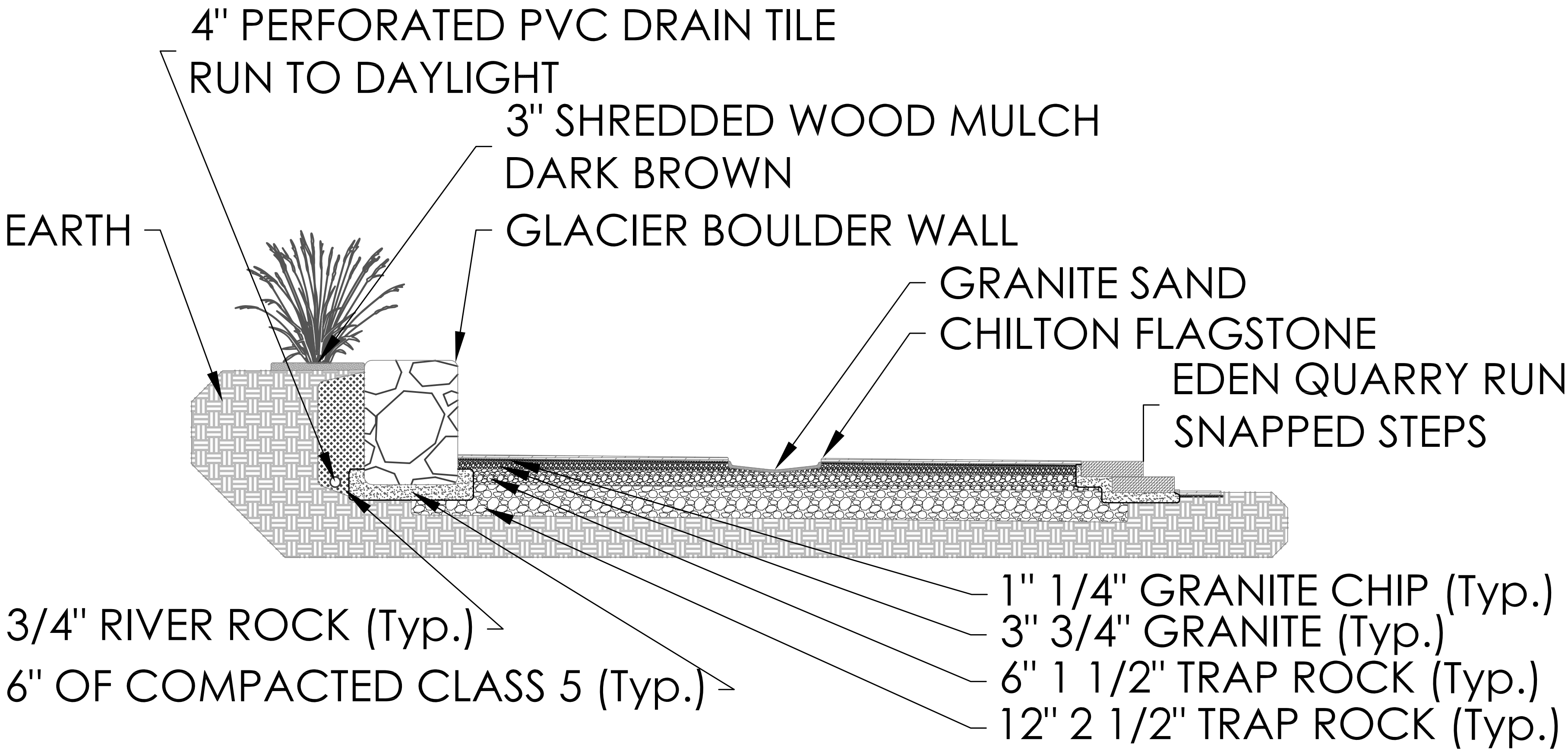
This step-section shows the relationship of the backyard and the East rain garden.

Digital Render | East Yard Section-Elevation (Figure 37)

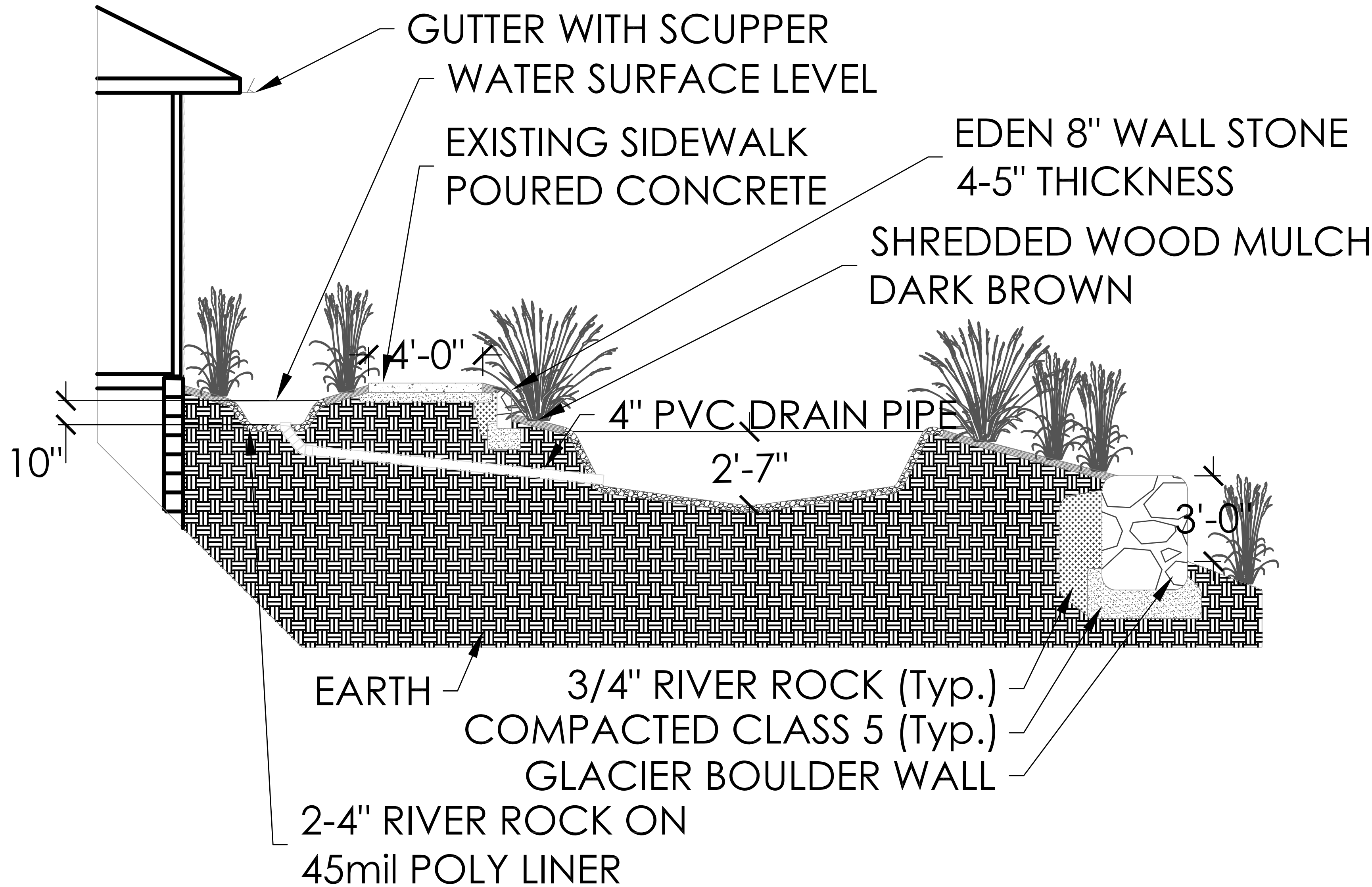
Design Detail Drawings & Models



Cistern Model (Figure 38)



Patio Section Detail | SCALE: 3/16" = 1'-0" (Figure 39)



Retention Ponds Section Detail | SCALE: 3/16” = 1’-0” (Figure 40)

Project Conclusion

In conclusion, my design was far beyond capable of managing stormwater given the chosen design storm. In the process of doing my research on storm events I had to decide of what storm I wanted to "design for" with my project. Hindsight is, of course, 20/20 but to do this again the designs storm could have been more aggressive. Meaning, it was an easy goal to meet. However, this goal was met unintentionally, blindly. At least at first. My design process began by simply getting ideas onto paper. It progressed from there with design as a higher priority than the stormwater attributes. I felt confident I would be safe in doing so given the scale of my site.

Conclusion of Design Capacity

Inflow Volumes (existing):

Yard: 17,205 gallons

House: 3,860 gallons

Total: 21,065 gallons

Design Management Capacity (proposed):

Ponds: 10,700 gallons

Detention Basin: 29,000 gallons

Dry Creek Beds: 21,700 gallons

Total: 61,400 gallons

Performance

+ This design accounts for nearly **3x** the design storm production (**291%** efficiency).

+ Time of concentration is now **28:10** (28 minutes, 10 seconds) This is getting water across the site and to the detention basin quicker, preventing any ponding or backups elsewhere on the site. Similarly, a **2-hour** event would yield **52,243** gallons of stormwater. Bringing the design's performance down to **117%** efficiency.

Future Applications

+ More urban/suburban lots, smaller, <1 acre

+ Less cost & complexity

+ A single solution may account for all needs as opposed to several working in conjunction with each other

+ When applied, even when scaled down, across an entire development these solutions may eliminate the need for out lots and stormwater storage ponds.

+ Leads to greater population density

+ Allows for developers to sell more lots

+ Less taxing on municipal stormwater & sewer infrastructure by sending less runoff to those facilities

With 3x efficiency for the 10-year, 60-minute design storm these solutions could easily be scaled down to fit smaller sites.

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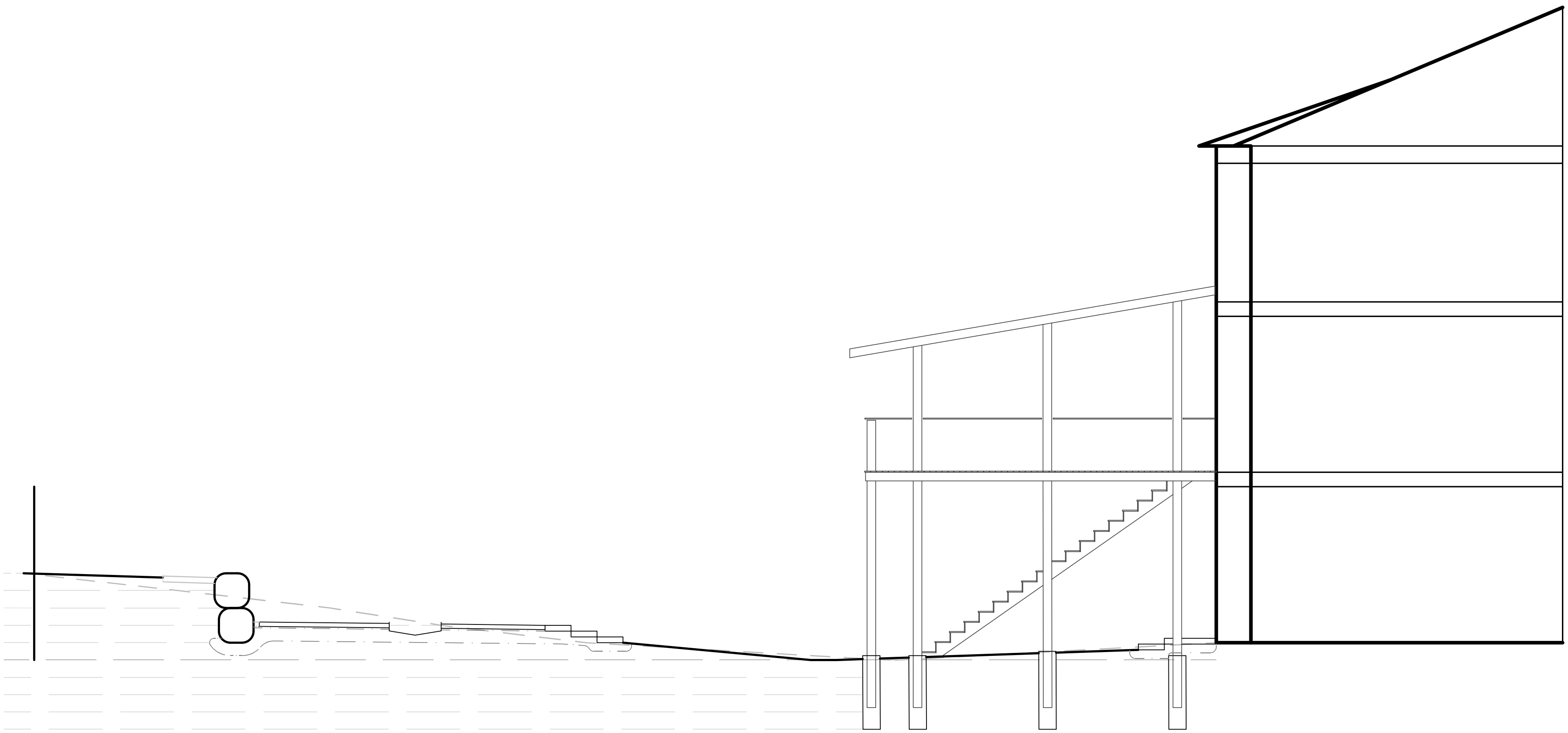
Appendix

Site Stormwater Values | Based on 10 year storm event

Type	Storm Frequency (year)	Duration (minutes)	Duration (seconds)	Intensity (iph)	C(a)	Acre	Maximum Inflow (cfs)	Inflow Volume (cubic ft)
C	10	15	900	1.15	1	1.5475	0.145	130.5
C	10	30	1800	1.64	1	1.5475	0.414	745.2
B	10	60	3600	2.18	1	1.5475	0.638	2296.8
B	10	120	7200	2.71	1	1.5475	0.793	5709.6
B	10	360	21600	3.55	1	1.5475	1.038	22420.8
B	10	720	43200	3.88	1	1.5475	1.135	49032

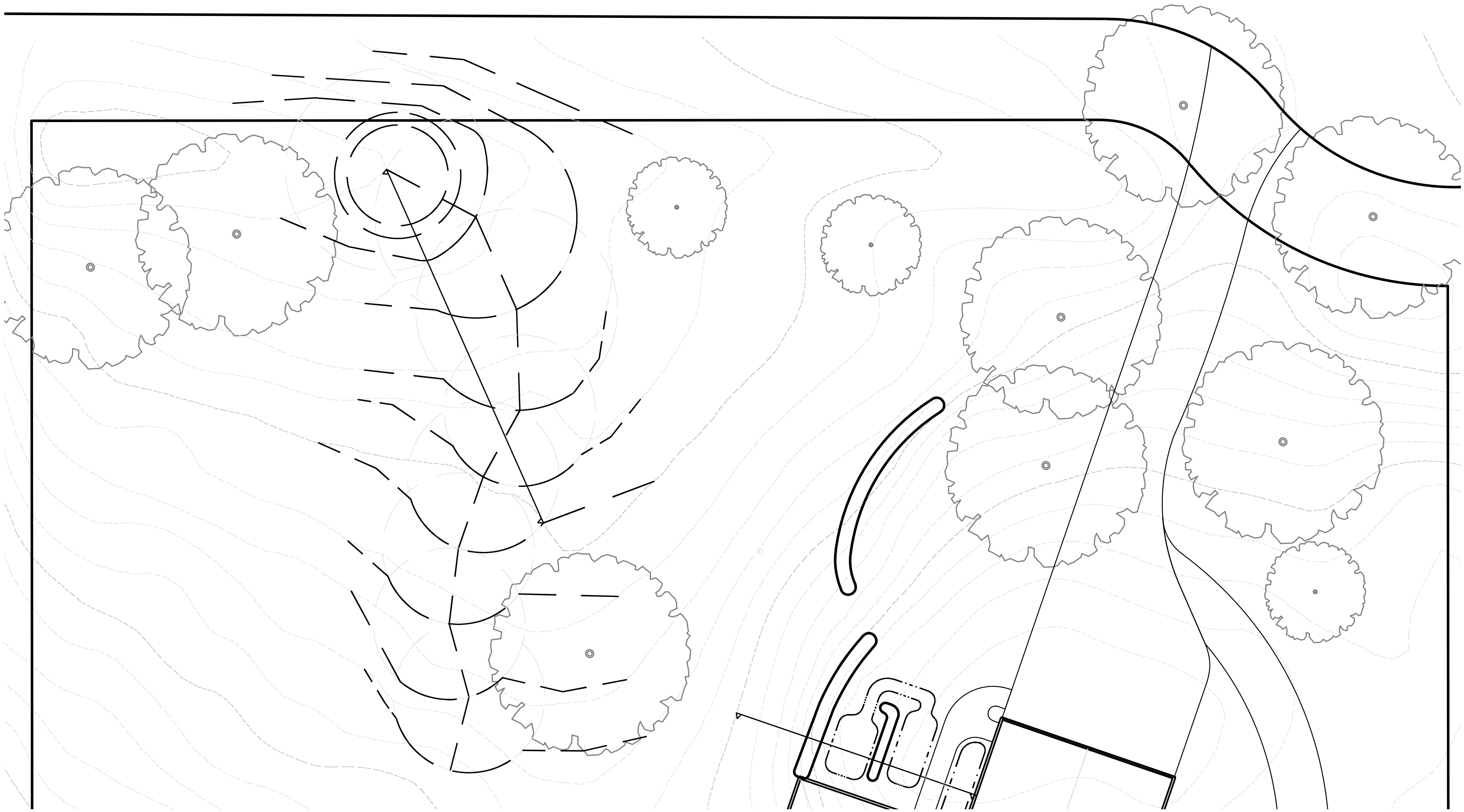
Roof Stormwater Values | Based on 10 year storm event

Type	Storm Frequency (year)	Duration (minutes)	Duration (seconds)	Intensity (iph)	C(a)	Acre	Maximum Inflow (cfs)	Inflow Volume (cubic ft)
C	10	15	900	1.15	1	0.0725	0.032	28.8
C	10	30	1800	1.64	1	0.0725	0.092	165.6
B	10	60	3600	2.18	1	0.0725	0.142	511.2
B	10	120	7200	2.71	1	0.0725	0.177	1274.4
B	10	360	21600	3.55	1	0.0725	0.232	5011.2
B	10	720	43200	3.88	1	0.0725	0.253	10929.6



Preliminary Backyard Design Section

Preliminary Front Yard & Retention Ponds Section



Preliminary Dry Creek Bed Grading Changes

“No book can ever be finished. While working on it we learn just enough to find it immature the moment we turn away from it.”

- Karl Popper, The Open Society and Its Enemies: The spell of Plato, 1945