# Golf Course Water Conservation

In partial fulfillment of the requirements for the degree of Master's of Landscape Architecture in the College of Art and Architecture, University of Idaho

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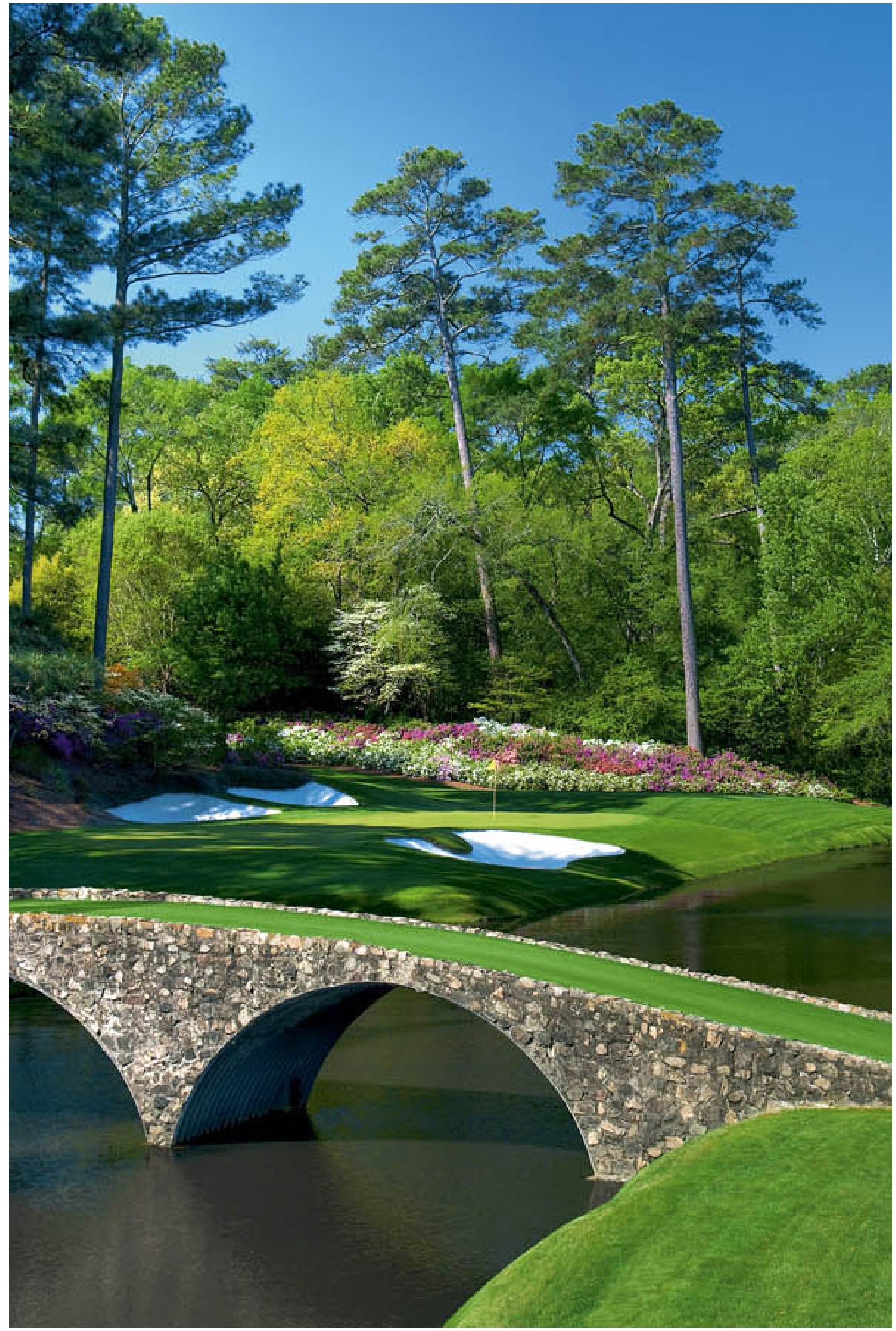

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# Introduction

## Research Question

The primary research question for this project is, how can golf course design and stormwater management practices help with the collection and re-use of stormwater for irrigation on the Charbonneau Golf Course?

## Problem Statement

The main source of water for golf course irrigation is groundwater. There are many important roles that groundwater plays in our everyday lives. Groundwater also supplies drinking water for 51% of the U.S. population and 99% of the rural population. Groundwater helps grow our food; 64% of groundwater is used for crop irrigation. It is also an important component in many industrial processes. Therefore, golf courses have to compete with other demand for groundwater, and the priority is likely to go to drinking water and crops, instead of using billions of gallons for irrigation on golf courses. Using alternative water sources like stormwater, can cut the usage of groundwater by 50%.(Groundwater Foundation, 2018)

Stormwater runoff from golf courses and urban areas is often presumed to be a significant contributor to non-point source (NPS) water pollution originating from the urban environment. Surface water contamination with excess nutrients (nitrogen and phosphorus) or pesticides from the course can pose a risk to both public and environmental health, while excessive nitrogen and phosphorus can lead to degradation of drinking water. Excessive nitrogen and phosphorus can also cause algal blooms and eutrophication of surface lakes and coastal waters. Stormwater runoff containing pesticides can potentially affect aquatic species and the drinking water quality of terrestrial species including humans. Nutrient and pesticide management is largely handled by soils on golf courses but the use of constructed wetlands can contain these materials when they migrate into the drainage or stormwater, mitigating their harmful effects.

## Background Information

In semi-arid and arid climates, land developers can not build golf courses because of their intensive water demand. This is having a negative impact on golf course designers and developers because there is not as much work for them as in previous decades. However, golf course restoration and conservation is a growing movement.(Garrity, 2017)

Water use on golf courses is a growing issue because 408 billion gallons of water are used for golf course irrigation every year. With approximately 16,ooo golf courses in the United State and 25,000 in the world, the magnitude of this problem is obvious(Garrity, 2017). The main source of water for golf courses is groundwater. The volume of groundwater in storage is decreasing in many areas of the United States in response to pumping of aquifers. Some of the negative effects of groundwater depletion are water table levels decreasing and reduction of water in streams and lakes. Subsidence is also an issue, leading to structural problems in buildings, roads, and other infrastructure.

One way to minimize groundwater use is to collect and reuse stormwater within large stormwater ponds or constructed wetlands for irrigation. One challenge in stormwater collection is how to store the stormwater for later use, especially over the summer. Some stormwater may require treatment before storage. For example, habitat for amphibians may be compromised within stormwater ponds or constructed wetlands from urban runoff con-

# Introduction

## Contribution to Landscape Architecture

The American Society of Landscape Architects (ASLA) states that the landscape architect's: role is to "analyze, plan, design, manage, and nurture the built and natural environments". Landscape architects have a significant impact on communities and quality of life.  This graduate research and design project will contribute to the body of knowledge in landscape architecture because it can help landscape architects adopt feasible and effective sustainable golf course planning and implementation techniques and support golf as a recreational and economic asset.

This project demonstrates a specific design implementation of stormwater management best practices and the introduction of constructed wetlands on the Charbonneau Golf Course in Wilsonville, OR.

This graduate project demonstrates stormwater practices on golf courses in urban and ex-urban areas.  The project also investigates maximizing storage capacity of stormwater for long periods of time, reduced usage of groundwater, and the reuse of stormwater for irrigation on site.

## Methodology

Methods used for this project include literature review, case studies, GIS data analysis for the site, surface hydrologic modeling to calculate stormwater flow and accumulation, and a design process that synthesizes the research undertaken for this project.

In order to fully understand the scope of research in the topic of golf course sustainability a literature review collected and summarized previous research. Key references were used to assemble design criteria for the design application portion of the project.  Similarly, several different case studies were analyzed to reveal best planning, design and maintenance practices that lead to better sustainability. The literature review and case studies were used to identify gaps of knowledge that are still present.  Learning from projects that failed is just as important as learning from the successful ones.

GIS data was used to make topographic maps and to inventory and analyze other site conditions.  Specifically, GIS evaluated slope, inlet and outlet locations, and flow direction across the site. Additionally, the amount of stormwater that can be collected on site was evaluated by using the TR-55 software developed by the US Natural Resource Conservation Service.

This project depends on case studies and literature reviews to establish techniques and criteria that are likely to result in sustainable designs for golf courses. In addition, investigation of irrigation design techniques and innovative equipment extended the capacity of stormwater to substitute for potable water and to minimize the use of potable water if stormwater is insufficient. The project starts by making topographic maps in GIS in order to tell the direction of stormwater runoff.  In addition, topographic maps identify low spots for the possible constructed wetlands and stormwater ponds.  It's important for the project to locate the stormwater inlets and outlets are on and around the site, in order to know where the stormwater is entering and exiting.  Understanding where the floodplains are on site is important because it tells us if the course is susceptible to flooding.  The amount of stormwater that can be collected on site-will be estimated using the National Stormwater Calculator and TR-55.   Understanding the distribution of rainfall reveals irrigation demand for the golf course.

# Introduction

Historic vegetation data tells what kind of vegetation is there now and what kind of vegetation used to be there. Soil data was collected from the USDA Natural Resources Conservation Service Web Soil Survey  to understand the hydrologic soil groups and which plants can grow in those conditions and which parts of the site are best suited for constructed wetlands.  Another determination on where a constructed wetland will go is evaluating existing water conditions, where ponds are already present.

# Literature Review
Introduction to Stormwater Management Best Practices

## Introduction

The topics in this section covers different types of BMP's that can be applied on golf courses and how phytoremediation works and be applied. It provides several different graphics to show how each BMP looks and operates. There are a couple detailed sections to illustrate how some of these BMP's work with the landscape and their components.

Definitions:

•Constructed Wetland: is an artificial wetland to treat municipal or industrial wastewater, grey water or stormwater runoff

•Sustainability: the quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance

•Phytoremediation: is the direct use of living green plants for in situ, or in place, removal, degradation, or containment of contaminants in soils, sludge's, sediments, surface water and groundwater

•BMP: Best Management Practices (BMPs) EPA defines stormwater BMPs as "methods that have been determined to be the most effective, practical means of preventing or reducing pollution from nonpoint sources."

•Stormwater: surface water in abnormal quantity resulting from heavy falls of rain or snow

## Introduction to BMP's

Best management practices or BMP's are used for methods of controlling and mitigating adverse impacts of development and redevelopment. In the state's stormwater manual, BMP's are defined as schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices. When BMP's are used singly or together, they will prevent or reduce the release of pollutants into the water. The primary purpose of using BMPs is to protect beneficial uses of water resources through the reduction of pollutant loads and concentrations, and through reduction of discharges (volumetric flow rates) causing stream channel erosion (MRSC, 2018).

The EPA uses sustainable stormwater management practices which are also called low impact development (LID). The focus of LID's is to reduce runoff and improve water quality. These practices help maintain natural hydrological cycles through site grading, vegetation, soils and natural processes that absorb and filter stormwater. Some of these LID's include, green roofs, rain barrels and cisterns, permeable pavements, bio retention areas, vegetated swales or dry swales, curb and gutter eliminations, vegetated filter strips, sand and organic filters, constructed wetlands, and riparian buffers.

# Types of BMP's
Used on golf courses

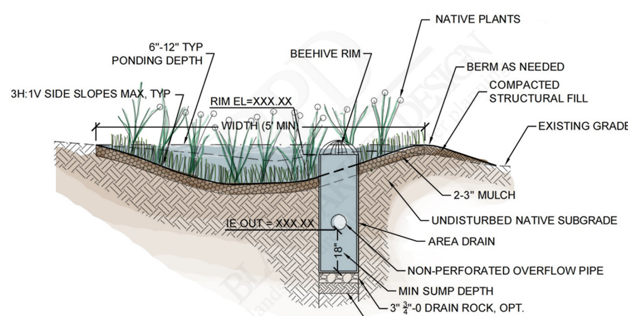
## Rain Barrels and Cisterns

Rain barrels are used to collect water off of rooftops. They are located at the bottom of downspouts in order to collect and store the rain water.

Cisterns store rain water in large volumes in tanks for non potable uses. Golf courses in urban areas with a lot of development built around or on the golf course can use rain barrels or cisterns to collect and store stormwater from their roofs. Most golf courses have residential homes built around their golf course which increases the ability to collect more rain water.

## Vegetated Swales

Swales are used as channels to transfer stormwater to larger holding areas. Vegetated swales help with infiltration and filtering out pollutants as it runs through the system. A vegetated swale system can be implemented on golf courses and allowing runoff to be directed towards larger holding areas such as ponds and wetlands. By doing so, this increases the amount of rainfall that can be collected on site and be re-used for irrigation needs.




Bioswale Detail

## Constructed Wetlands

Constructed wetlands mimic natural wetlands by capturing and filtering stormwater while creating diverse habitats for wildlife. They are created to contain standing water on the surface or to keep the soil saturated at the bottom. Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality. Constructed wetlands are a viable option to collect and treat the stormwater on urban golf courses. They help with the removal of nutrients, metals, and pesticides

# Types of BMP's
Used on golf courses

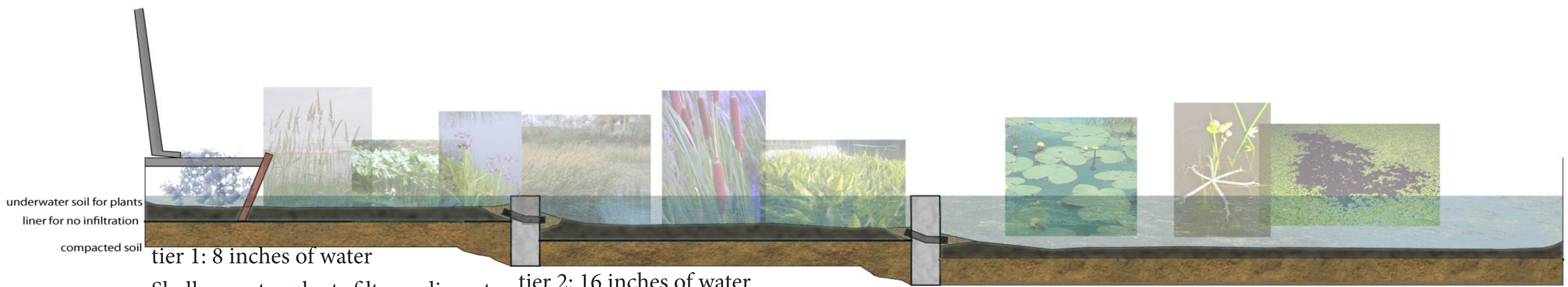
## Constructed Wetlands Continued

water enters
from overpass

water flows
through plant roots
where it is cleaned

water slowly passes
through gravel bed
and pipe to next tier

cleaned water is allowed
to slowly inflitrate
through compacted soil



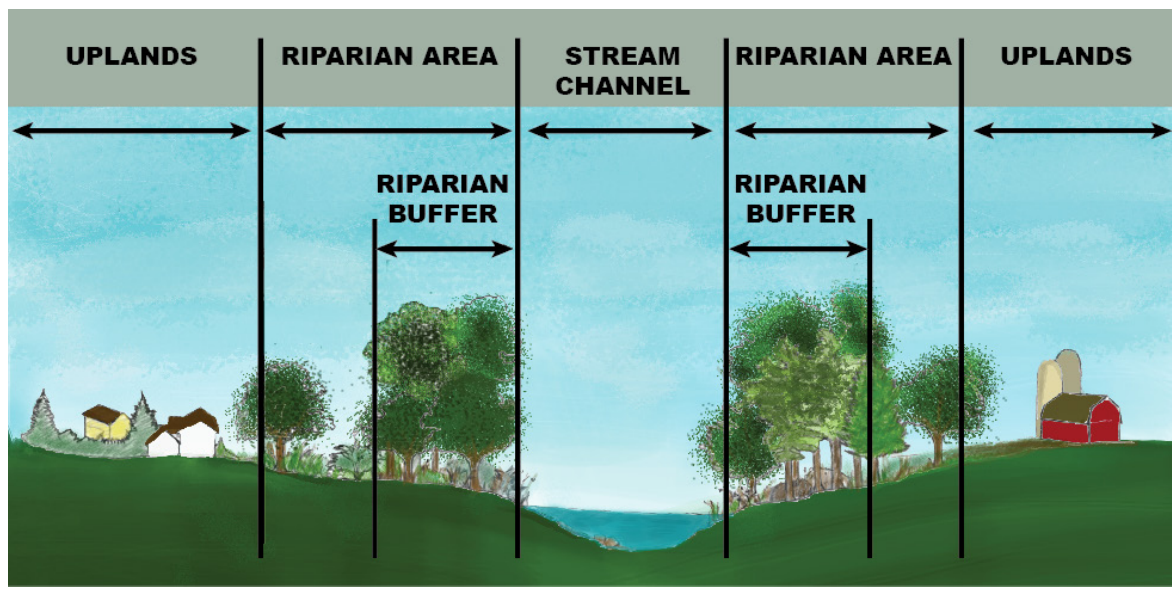

tier 1: 8 inches of water
Shallow water plants filter sediments

tier 2: 16 inches of water
deeper water plants filter polutants and heavy metals

tier 3: 24 inches of water
floating plants continue to filter and water slowly infil-trates soil

## Riparian Buffer

Riparian buffers are along shorelines to prevent development from happening. It is designed to protect natural areas from being disturbed from any future development. A properly designed buffer can help with flood control, which helps sustain the aquatic ecosystem and its habitats. Buffer zones should be implemented on golf courses in order to preserve things such as wetlands or other natural streams going through it. This will help with pre-serving water quality and protecting wildlife habitats.



# Phytoremediation

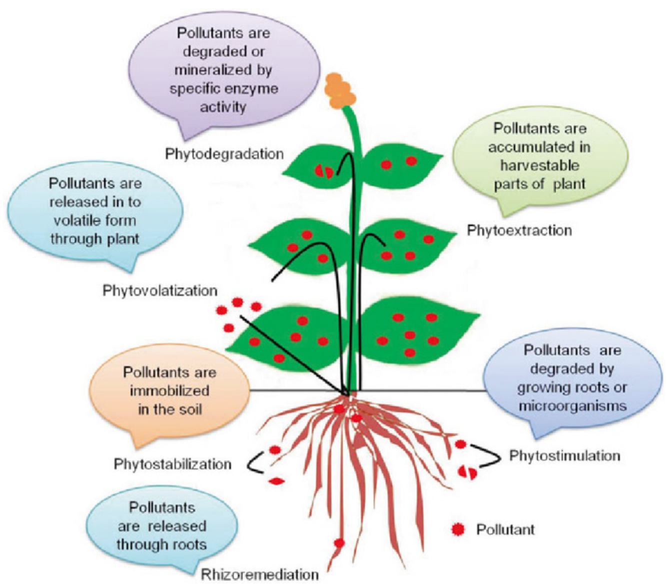
## Introduction

Phytoremediation is the direct use of green plants to remove contaminates from surface water, soils, sludge, sediments, and groundwater. Phytoremediation can be defined as "the efficient use of plants to remove, detoxify or immobilize environmental contaminants in a growth matrix (soil, water or sediments) through the natural biological, chemical or physical activities and processes of the plants" (UNEP, 2018). Plants have great abilities to absorb metal and can take up nutrients and contaminants through their growth matrix, soil or water.

Phytoremediation involves growing plants into a contaminated matrix for a required growth period to remove contaminants from that matrix or facilitate degradation or immobilization in pollutants. Then the plants can be harvested, processed and disposed. Plants have evolved into being able to handle a great amount of pollutants that occur in our environment. Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons, and landfill leachates. (UNEP, 2018)

## How does it work?

Most of the contaminants get absorbed in the plants roots system. The root system absorbs a great surface area which uptakes essential nutrients and water for growth purposes but it will also absorb unwanted contaminants. Researchers have found that tree roots can do better with absorbing contaminants because their root systems penetrate the ground deeper. In addition, contaminated groundwater can be pumped out and put through plants in order to clean out the pollutants.




## Phytoremediation's Role in a Constructed Wetland

Constructed wetland phytoremediation is an aesthetically pleasing, solar-driven, passive technique useful for cleaning up wastes including metals, pesticides, crude oil, polyaromatic hydrocarbons, and landfill leachates and has become an increasingly recognized pathway to advance the treatment capacity of wetland systems. Wetland plants also help prevent wind, rain, and groundwater from carrying pollution away from sites to other areas. Plants in a natural wetland provide a substrate (roots, stems, and leaves) upon which microorganisms can grow as they break down organic materials and uptake heavy metals. A constructed wetland (CW) is an artificial marsh or swamp, which have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in waste treatment. It usually consists of a number of individual rectangular and/or irregularly-shaped basins (cells) connected in series and surrounded by clay, rock, concrete or other materials. Three types of cells may be used in a constructed wetland system (CWS): free water surface (FWS) cells, sub-surface flow (SSF) cells, and hybrid cells that incorporate surface and subsurface flows. (UNEP, 2018)

# Phytoremedation Continued

## Constructed Wetland Plant Types

| Plant type | Species name | Common name | Range of depths (m) |
| --- | --- | --- | --- |
| Emergent | *Typha* spp. | Cattail | > 0.1 to < 1 |
| | *Scirpus* spp. | Bulrush | > 0.1 to < 1 |
| | *Juncus* spp. | Rushes | > 0.1 to < 0.3 |
| | *Carex* spp. | Sedges | > 0.1 to < 0.3 |
| | *Phragmites* spp. | Reeds | > 0.1 to < 1 |
| Submerged | *Potamogeton* spp. | Pond weeds | > 0.5 |
| | *Vallisneria* spp. | Tapegrass, wild celery | > 0.5 |
| | *Ruppia* spp. | Widgeongrass | > 0.5 |
| | *Nuphar* spp. | Spatterdock | > 0.5 |
| | *Elodea* spp. | Waterweed | > 0.5 |
| Floating | *Lemna* spp. | Duckweed | Flooded |
| | *Eichhornia crassipes* | Water hyacinth | Flooded |
| | *Hydrocotlye umbellata* | Water pennywort | Flooded |
| | *Azolla* spp. | Water fern | Flooded |
| | *Wolffia* spp. | Watermeal | Flooded |

## Disadvantages

Performance of CWS may be less consistent than in conventional treatments due to the environmental changes at different seasons; the biological components are sensitive to toxic chemicals (e.g., ammonia and pesticides); and flushes of pollutants or surges in water flow may temporarily reduce treatment effectiveness. (UNEP, 2018)

## Eagle Valley and Prestwick Golf Course Case Study

### Baseline Information

•Project Name: Harvesting Stormwa ter for Reuse on Woodbury Drive

•Location: Woodbury, MN

•Date Designed/Planned: 2013

•Construction Completed: 2014

•Cost: $700,000

•Size: 430 acres (Eagle Valley) 130 acres (Prestwick)

•Client: Eagle Valley Golf Course/ Prestwick Golf Course

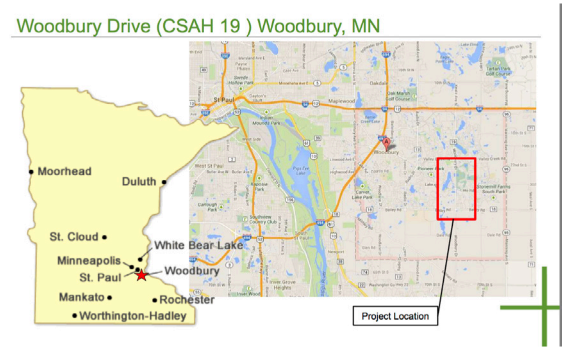
•Designers: Water in Motion, Hr Green

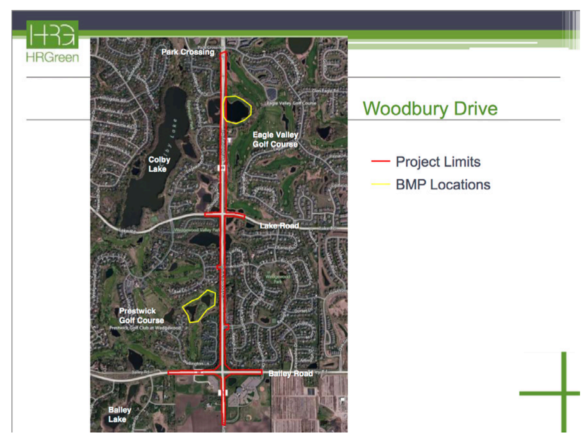
•Consultants: HR Green

•Managed by: City of Woodbury/ Eagle Valley Golf Course/ Prestwick Golf Course

### Context

In 2013, Washington County widened Woodbury Drive, also known as County Road 19, from Valley Creek Road to Bailey Road. When planners decided how to manage over 77 acres of rain and snow runoff, they came up with a fiscally and environmentally smart approach – stormwater reuse. Water in Motion worked with the city of Woodbury and the South Washington Watershed District to implement a landmark stormwater collection and reuse system as part of the roadway improvement. Eagle Valley and Prestwick golf courses adjoin Woodbury Drive in the area of work. Together, the two courses irrigate over 100 acres annually over a seven-month season. Water in Motion redesigned existing stormwater ponds at Eagle Valley and Prestwick golf courses so that irrigation systems could reuse runoff from the road. Instead of pumping water from wells as their primary sources of irrigation water, the two courses receive nutrient-rich stormwater for irrigation, eliminating millions of gallons of excess water and unwanted nutrients from flowing into Colby and Bailey Lakes. The project also included installation of a babbling brook amenity at Eagle Valley that circulates, aerates and preconditions stormwater - and challenges golfers.



# Case Studies

## Project Background

In order to complete roadway construction, the County needed to obtain a stormwater permit from the South Washington Watershed District (SWWD). The SWWD permit application stated rate control, volume reduction, and water quality improvements were required to achieve the SWWD's goals. Rate control requirements included matching or decreasing existing 2-, 10-, and 100-year runoff rates. Washington County needed to in infiltrate the first 1/2 inch of runoff over the entire site to complete the volume reduction requirements. Since approximately half of the roadway drains to Colby Lake, an impaired water downstream, water quality improvements included meeting a target standard maximum allowable unit load of 0.34 lbs. /ac/yr. of total phosphorous (TP).

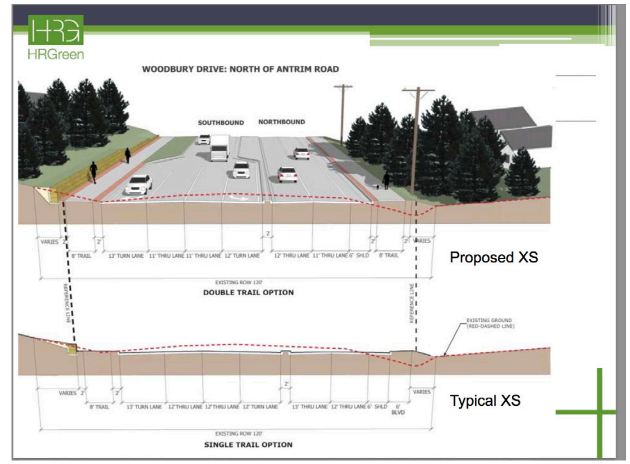
## Scope and Goals

Project Scope:
•Increase road capacity & safety
•Minimize impacts to private property
•Minimize impact to wetlands
•Meet watershed's stormwater goals
•Meet City's Stormwater goals

Goals:
Regulatory goal 1: Water quality
•Reduce post-development load by 60%
•Achieve Colby Lake target standard maximum allowable unit load of 0.34 pounds per acre a year

Regulatory goal 2: Volume reduction
•Infiltrate either the first ½- inch of runoff over the entire site or the first inch of runoff over the site's new impervious surface
•½-inch of runoff over the entire site (1.84 ac-ft)

Regulatory goal 3: Peak elevations
•Manage I and Manage II wetlands maintain 2 and 100-yr peak inflow rates
•Manage I wetlands maintain 10-yr flood levels or raise a maximum of one foot
•FEMA Zone A areas maintain 100-yr flood levels or raise a maximum of ½ foot




## Design/Decision Process

The original idea for this project was to increase road capacity and safety on Woodbury Drive. With this road expansion, it leaves more stormwater running off the road and ending up in Colby Lake which is directly west of the road. Colby Lake has a watershed area of 2,839 acres. It allows 1,461 pounds of phosphorus per year and they need it to be at 979 pounds a year. There are two golf courses along Woodbury road and the designers thought it would be a good idea to use both of them for collecting stormwater. Eagle Valley Golf Course collects stormwater draining off the right side of the road into a large stormwater pond. They pump the stormwater from the large pond to an irrigation pond. From there, it can be pumped straight into the irrigation system. For left over water that doesn't need to be used for irrigation gets transferred to the babbling brook water feature. The babbling brook is designed as a river rock swale that directs the stormwater back to the original collecting pond. This makes it possible for the stormwater to be recycled throughout their course until they need it for irrigation. Eagle Valley Golf Course pumps 30 million gal/yr from an aquifer. With the new stormwater system they are proposing to pump only 7.5 million gal/yr from the aquifer and also pump 22.5 million gal/yr from the stormwater pond. The designers also wanted to achieve their water quality goal of having only 0.12 pounds/ac/yr of total phosphorus. Prestwick Golf Course had a similar design but without a babbling brook water feature. The Prestwick golf course pumps 35 million gal/yr from an aquifer and the goal is to cut that in half. Then, 17.5 million gal/yr would come directly from the stormwater pond, rather than from the aquifer.

## Eagle Valley Reuse System


Figure by Water in Motion

## Prestwick Reuse System


Figure by Water in Motion

## Significance

The significance of this project was to increase road capacity and safety while collecting and treating stormwater before it gets into Colby Lake. Collecting and treating stormwater is very important because polluted stormwater will get into our streams, rivers, and lakes. The pollution can cause algae blooms which lead to eutrophication. Eutrophication depletes the oxygen in water which kills off any aquatic life in the area. The unique part of this project was the re-use of stormwater for irrigation. When starting this project, it seemed that the irrigation part was a last minute idea. The main goal was to clean up the water before reaching Colby Lake. It was also realized that this water can irrigate the neighborhing courses, which helps minimize the impact of pumping groundwater.

## Limitations

HR Green listed potential set backs for this project that include salinity, recharge volumes, and infiltration rates. They were worried that the salinity of the stormwater could affect the aquatic life living in Colby lake. Being able to recharge the volume of water in the stormwater ponds was another limitation. If Woodbury ever suffered a long drought, the stormwater ponds could be left dry. That would cause problems making it difficult to meet their goals of pumping from the stormwater pond instead of the aquifer. One of their goals was to infiltrate the first half inch of rainfall. They were worried the stormwater wouldn't be able to infiltrate fast enough to collect the first half inch before it goes into the stormwater ponds.

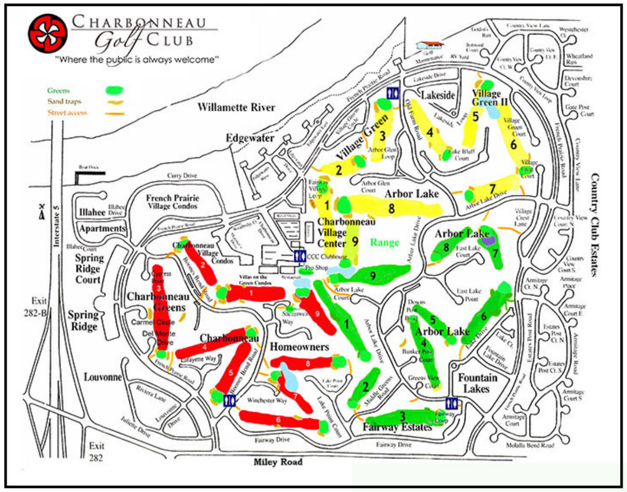
## Conclusion

This project is directly related to the proposed redesign for stormwater management at Charbonneau Golf Course. Eagle Valley Golf Course limited pumping from an aquifer by 75%, meaning they only pump 25% of their water from an aquifer while the rest is coming from a stormwater pond. Prestwick Golf Course pumps 50% of their water supply from a stormwater pond and 50% from an aquifer. The goal for Charbonneau Golf Course is to cut groundwater pumping by 50%. After looking at these two courses, this seems to be a realistic goal. One question not answered by this case study is how to store the stormwater for later use. Eagle Valley Golf Course installed a babbling brook water system that circulates the water around the course. First the water gets collected into a stormwater pond, then gets transferred to an irrigation pond. The stormwater that doesn't need to be pumped for irrigation gets transferred through their babbling brook system that transfers the water back to the original stormwater pond. So the all the stormwater collected stays on site for later use.

# Design

## Introduction

The design application for the Charbonneau Golf Course has several parts. First, groundwater levels are being depleted, so we need an alternative water source for irrigation needs. This project involves collecting and re-using stormwater for irrigation purposes. This is explained through design concepts and a final stormwater management master plan. Finally, the stormwater management master plan shows how the stormwater is treated and transferred from wetland to wetland.




# Goals and Objectives Recap

1. Stormwater Collection and Reuse

- Collection through constructed wetlands/irrigation ponds
- Treatment through constructed wetland plants
- Minimizing polluted stormwater runoff going into streams/rivers
- Cut groundwater usage by 50% or more

2. Constructed Wetlands

- Suitability criteria analysis to determine best location
  Hydrological soils
  Runoff direction
  Depth to water table/bedrock
  Impervious surfaces
  Buffers around streams
  Slope
- Minimize pesticide and fertilizer inputs with no spray zones around wetlands/ponds
- Enhancing the golfing experience through beautification and providing more challenges

3. Storing Stormwater on Site

- Detention vaults
- Aquifer injections
- Babbling brook water feature

# Watershed Analysis

To figure out how much rainfall that can be collect, TR-55 was ran for a 2-year storm. The 2-year storm was chosen because it's the smallest of the storms and to be able to know how much can be collected and irrigated for each year. To be able to run the 2-year storm, the area of the watershed needed to be calculated. All the high points surrounding the course were found and then followed the ridges down to see where the water would travel.

The total acreage of the watershed is 616.62 acres. After running the 2-year storm with TR-55, .872" of rainfall occurred over the watershed. In order to figure out how much rainfall can be collected, the watershed acres need to be converted into square feet and the inches of rainfall into feet. Then the square feet was multiplied by the rainfall in feet to get 1,960,777.61 cubic feet per acre of water. That's how much water will fall within the watershed but then water loss through evaporation, infiltration, and vegetation needed to be factored in which was ran through TR-55. 30% of the 1,960,777.61 cubic feet per acre was lost which came out to be 588,233.282 cubic feet per acre, which equals 4,400,290.53 gallons of water.

Now the amount of rainfall that can be potentially collected is known but how much water that is needed to irrigate successfully over each summer months is still unknown. Each rainfall to evaporation ratio for each month came from a Rainbird irrigation chart in inches. The inches was then converted feet and multiplied by 1 acre in square feet to get cubic feet per acre. Then multiplied that by how many acres the golf course is (311 acres). The golf course is not all grass because it is dominated by housing developments, so the percentage of the course that would need to be irrigated came out to be only 4.5% of the site.

Example:

•May: 0.61"/12= 0.05ft

•0.05ft x 43560sqft= 2,214.3 cubic feet per acre

•311 acres x 2,214.3= 688,647.3 cubic feet per acre

•4,436,726 x 0.045= 30,989 cubic feet per acre

•231,813 gallons

Number of gallons per month for irrigation

•May = 231,813 gallons
•June = 767,643 gallons
•July = 1,797,508 gallons
•August = 1,493,500 gallons
•Total gallons for the summer = 4,290,464 gallons

The nature of how often this 2-year storm would occur needs to be figured out in order to be able to collect that much water during the summer months. Rainfall data was collected for each summer month (May-August) over an 8-year span from 2010-2017. The 2-year storm only occurred once in May. Then took a look at each day in each month to look at if the rainfall was occurring all in one day or spread out to determine if you would even be able to collect enough.

Since the 2-year storm only occurred once in May and the Charbonneau Golf Course doesn't need 4 million gallons of water to irrigate for one month, TR-55 was ran again for half of what the 2-year storm brings which is about .40" of rainfall. A storm that would bring .40" of rainfall occurred twice in May and twice in June which would give us enough stormwater to irrigate for the months of May, June, and July but not August. This would cut groundwater usage by 65% which is 15% more than the previous goal. If the 2-year storm occurred more than once in one month then the stormwater that has already been cleaned by the wetlands, can be released back into the Willamette River to make room for more stormwater.

# Design Program

## Objectives

Collect and re-use stormwater for irrigation on site

Storing stormwater on site

## Solutions

Constructed Wetlands for collection and treatment (0.12 pounds/ac/yr of total phosphorus)

Ability to hold storm-water for later use (1.5 million gallons)

## Elements

Vegetated swales

Wetland plants (Cattails,bulrushes, rushes, sedges, reeds)

Detention vaults

Aquifer injections

Babbling brook water feature

## Criteria

Less than 15% slopes

Greater than 0% impervi-ous surfaces

100-foot buffer from

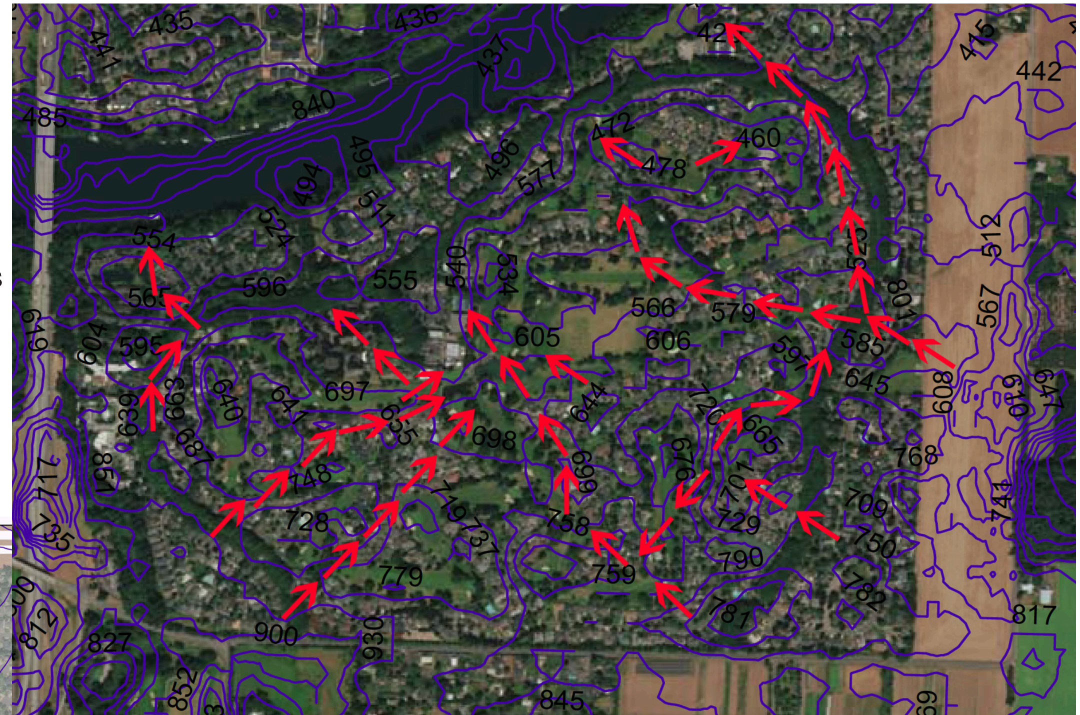
Drainage area greater than 25 acres

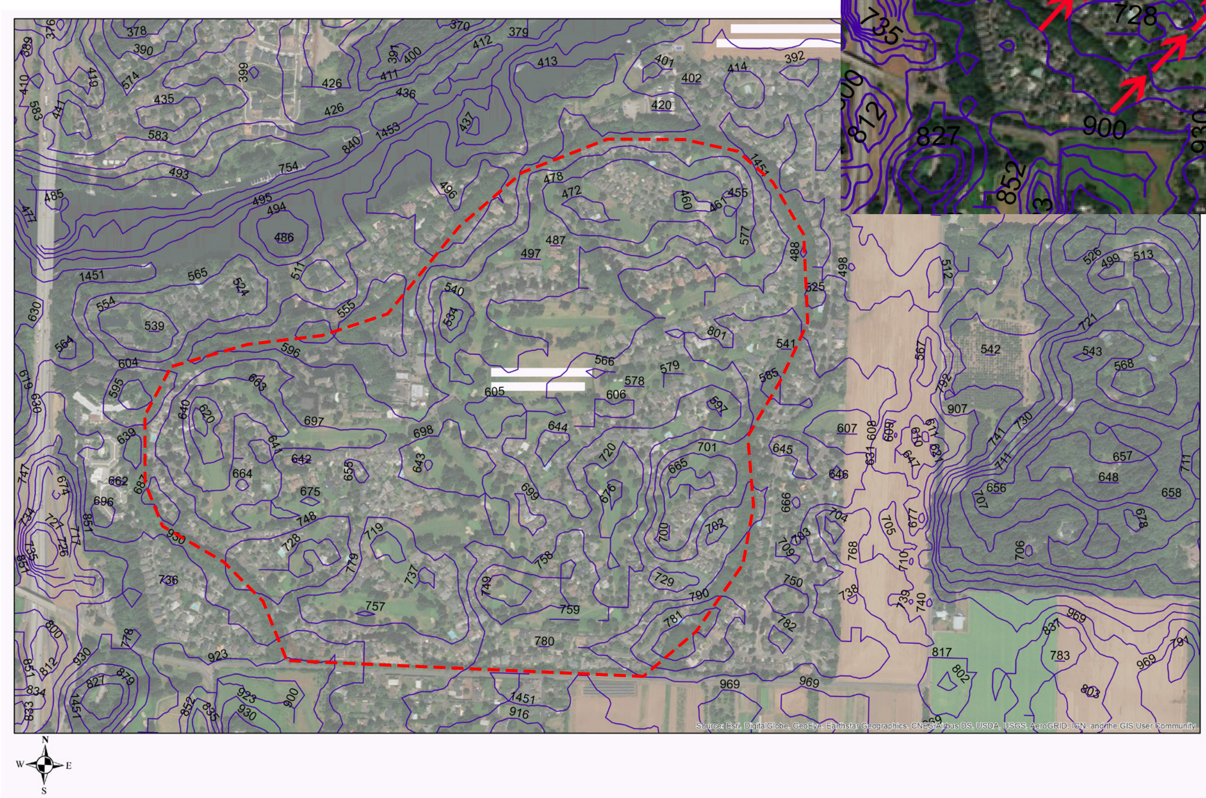
Hydrological soils A-D

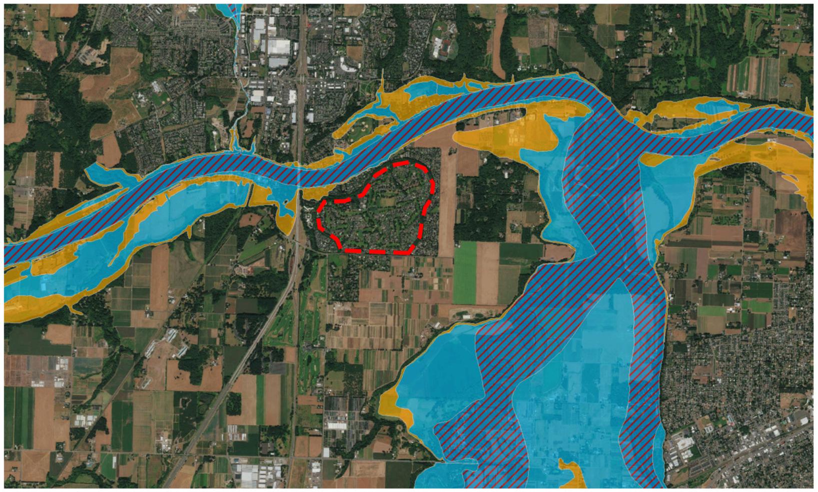
Depth to water table greater than 4 feet

## Topography Map

A contour map was made in order to determine how the site is sloped. I needed to figure out if stormwater would travel towards the site in order to be able to collect it. We can also determine where the best capture points would be. The map on the right shows the flow direction based of the topography map.







1% annual chance of flooding | Regular Flooding | 0.2% annual chance flood hazard

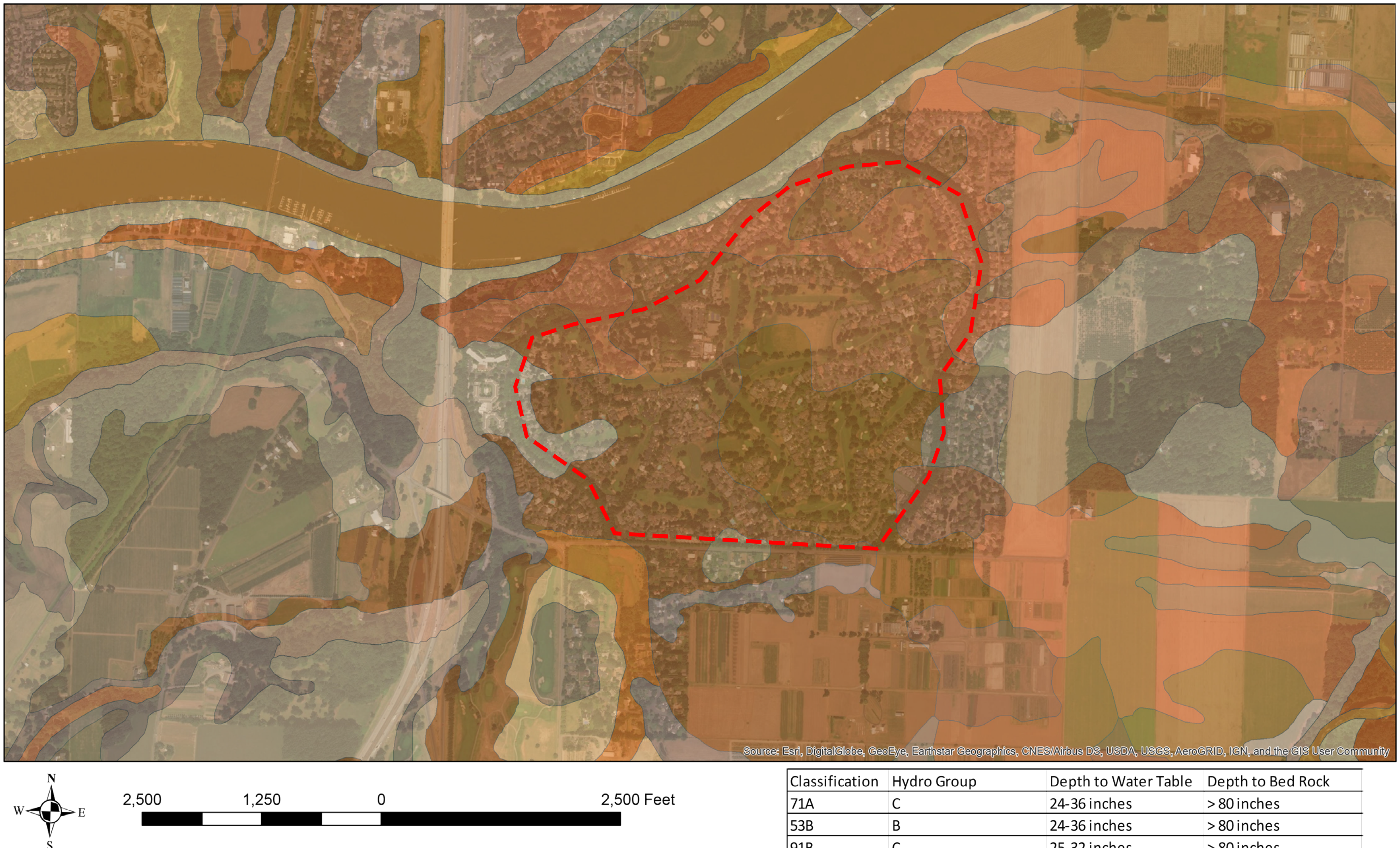
## Flood Plains

This map demonstrates the chance of flooding within the floodplain. You can see that the Charbonneau Golf Course is just outside the floodplain with no chance of flooding. One design criteria for constructed wetlands is to be built above the floodplain.

### Existing Water

This map shows the existing water on my site. It was important for this project to look up existing water like ponds and streams because we can utilize existing ponds for collection areas. There also has to be a 100-foot buffer between a stream and a wetland. Lucky for me there are no streams running through the golf course.

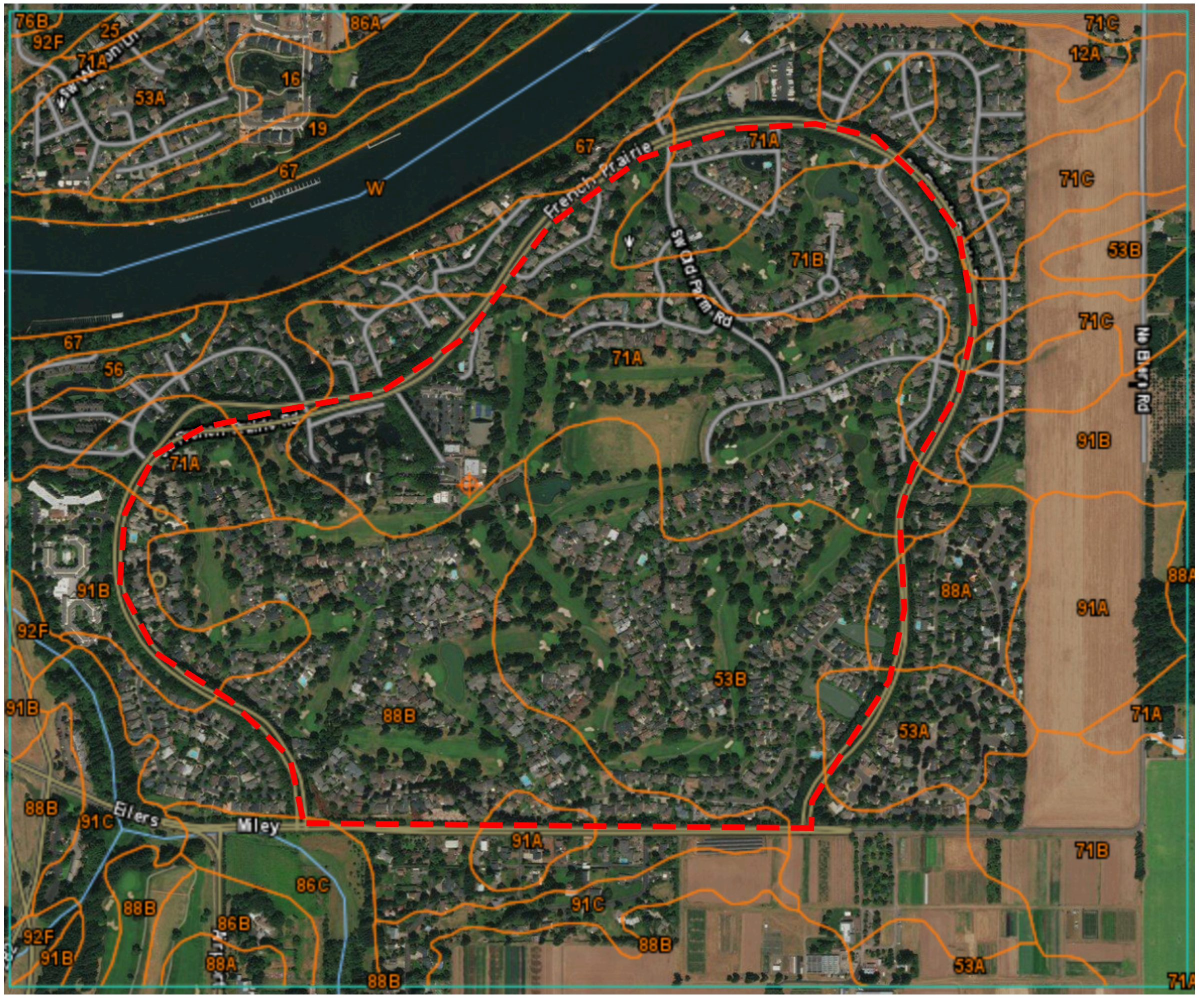
## Soils




The soil map indicates that all soils present on the golf course are in the hydrological group A-D. The table below the map provides information on the depth to water table and depth to bedrock. The shallowest depth to the water table is 24 inches and the deepest is greater than 80 inches. All soils indicated on the golf course have a depth to bedrock greater than 80 inches.

| Classification | Hydro Group | Depth to Water Table | Depth to Bed Rock |
|---|---|---|---|
| 71A | C | 24-36 inches | > 80 inches |
| 53B | B | 24-36 inches | > 80 inches |
| 91B | C | 25-32 inches | > 80 inches |
| 71A | C | 24-36 inches | > 80 inches |
| 67 | A | > 80 inches | > 80 inches |
| 56 | C | 24-36 inches | > 80 inches |
| 67 | A | > 80 inches | > 80 inches |
| 53A | B | > 80 inches | > 80 inches |
| 71B | C | 24-36 inches | > 80 inches |
| 88B | C | 30-42 inches | > 80 inches |
| 88A | C | 30-42 inches | > 80 inches |

## Soils continued




The soil map indicates that all soils present on the golf course are in the hydrological group A-D. The golf course has mostly B and A soils but has several C soils on the outside. C soils along the outside is good because C soils allow less infiltration and more runoff. B soils infiltrate moderatly and A soils infiltrate the best.

# Design Criteria

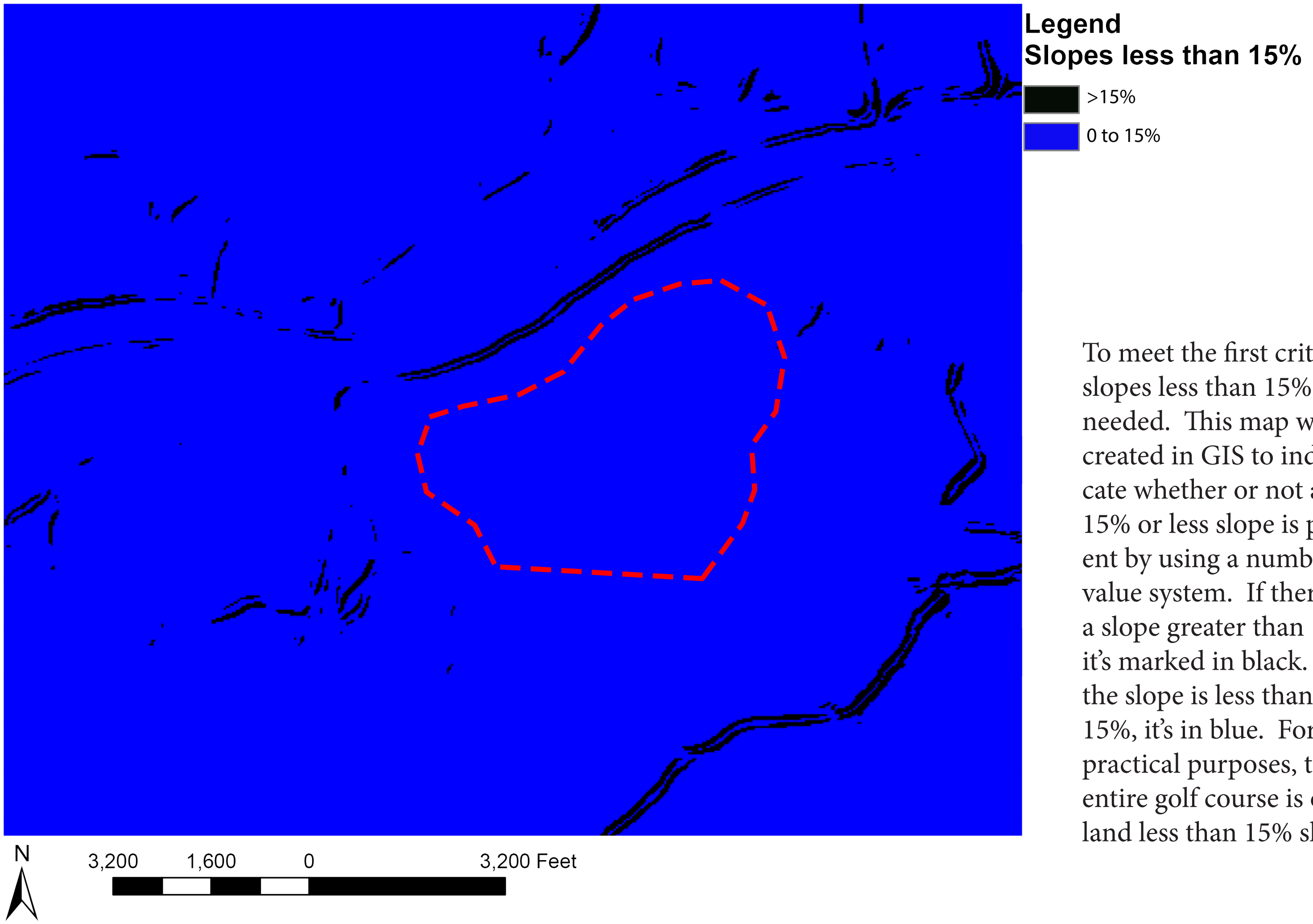
**Table 3-4. Default Criteria for BMP Suitable Locations Used in *SUSTAIN***

| BMP | Site Suitability Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Drainage Area (acre) | Drainage Slope (%) | Imperviousness (%) | Hydrological Soil Group | Water Table Depth (ft) | Road Buffer (ft) | Stream Buffer (ft) | Building Buffer (ft) |
| Bioretention | < 2 | < 5 | > 0 | A–D | > 2 | < 100 | > 100 | - |
| Cistern | -- | -- | -- | -- | -- | -- | -- | < 30 |
| Constructed Wetland | > 25 | < 15 | > 0 | A–D | > 4 | -- | > 100 | -- |
| Dry Pond | > 10 | < 15 | > 0 | A–D | > 4 | -- | > 100 | -- |
| Grassed Swale | < 5 | < 4 | > 0 | A–D | > 2 | < 100 | -- | -- |
| Green Roof | -- | -- | -- | -- | -- | -- | -- | -- |
| Infiltration Basin | < 10 | < 15 | > 0 | A–B | > 4 | -- | > 100 | -- |
| Infiltration Trench | < 5 | < 15 | > 0 | A–B | > 4 | -- | > 100 | -- |
| Porous Pavement | < 3 | < 1 | > 0 | A–B | > 2 | -- | -- | -- |
| Rain Barrel | -- | -- | -- | -- | -- | -- | -- | < 30 |
| Sand Filter (non-surface) | < 2 | < 10 | > 0 | A–D | > 2 | -- | > 100 | -- |
| Sand Filter (surface) | < 10 | < 10 | > 0 | A–D | > 2 | -- | > 100 | -- |
| Vegetated Filterstrip | -- | < 10 | > 0 | A–D | > 2 | < 100 | -- | -- |
| Wet Pond | > 25 | < 15 | > 0 | A–D | > 4 | -- | > 100 | -- |

To conceptualize the physical function of BMPs with regard to their associated landscape, four categories (or types) of BMPs are presented in the siting tool: (1) point LID, (2) point BMP, (3) linear BMP, and (4) area BMP. Point BMPs and LID include practices that capture upstream drainage at a specific location and can use a combination of detention, infiltration, evaporation, settling, and transformation to manage flow and remove pollutants. Linear BMPs are narrow linear shapes adjacent to stream channels that provide filtration of runoff; nutrient uptake; and ancillary benefits of stream shading, wildlife habitat, and aesthetic value. Area BMPs are land-based management practices that affect impervious area, land cover, and pollutant inputs (e.g., fertilizer, pet waste). Table 3-5 shows the structural BMP options included in BMP siting tool.

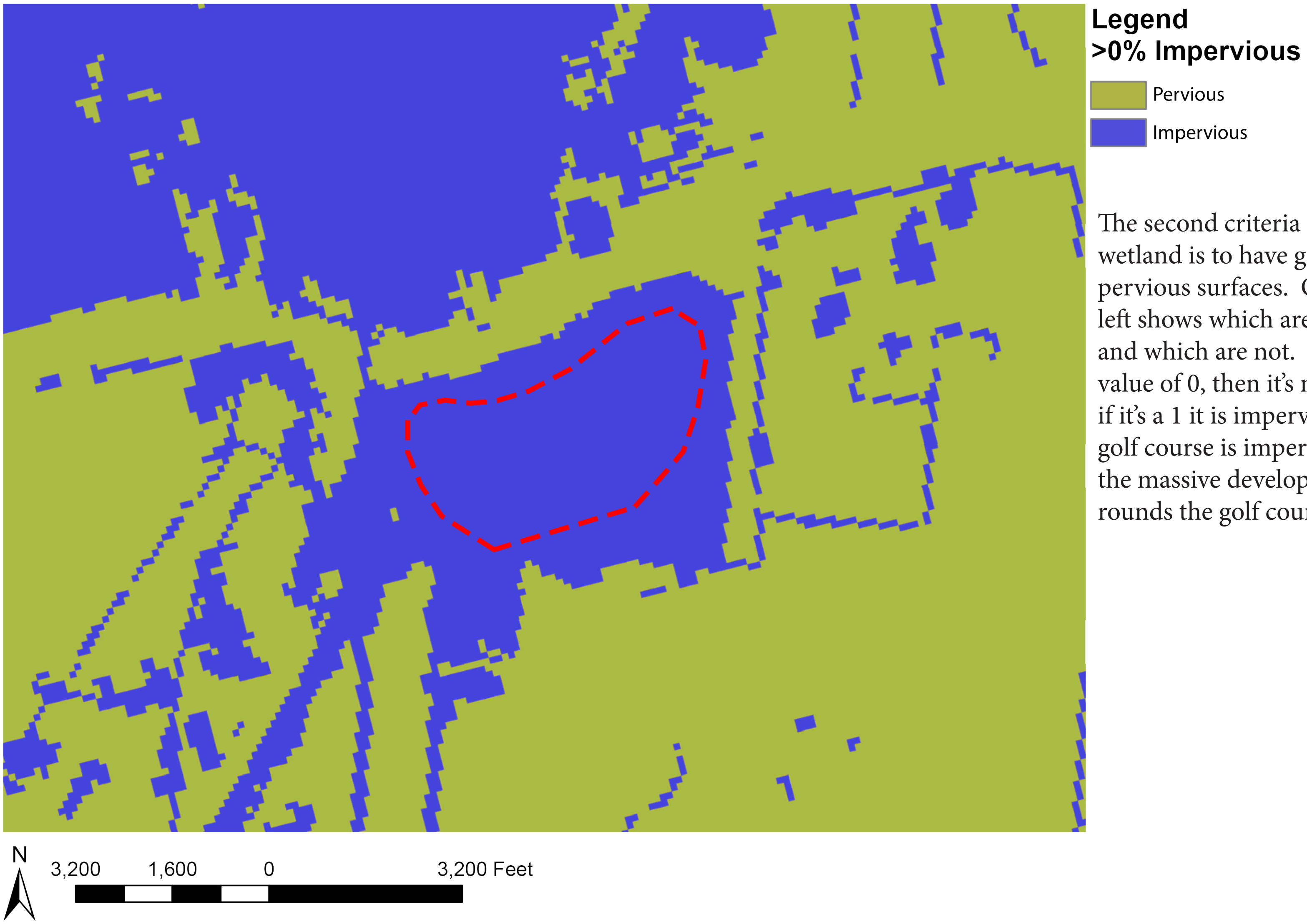
https://www.epa.gov/wetlands/constructed-wetlands

Slope Reclassified




To meet the first criteria, slopes less than 15% are needed. This map was created in GIS to indicate whether or not a 15% or less slope is present by using a number value system. If there is a slope greater than 15%, it's marked in black. If the slope is less than 15%, it's in blue. For all practical purposes, the entire golf course is on land less than 15% slope.

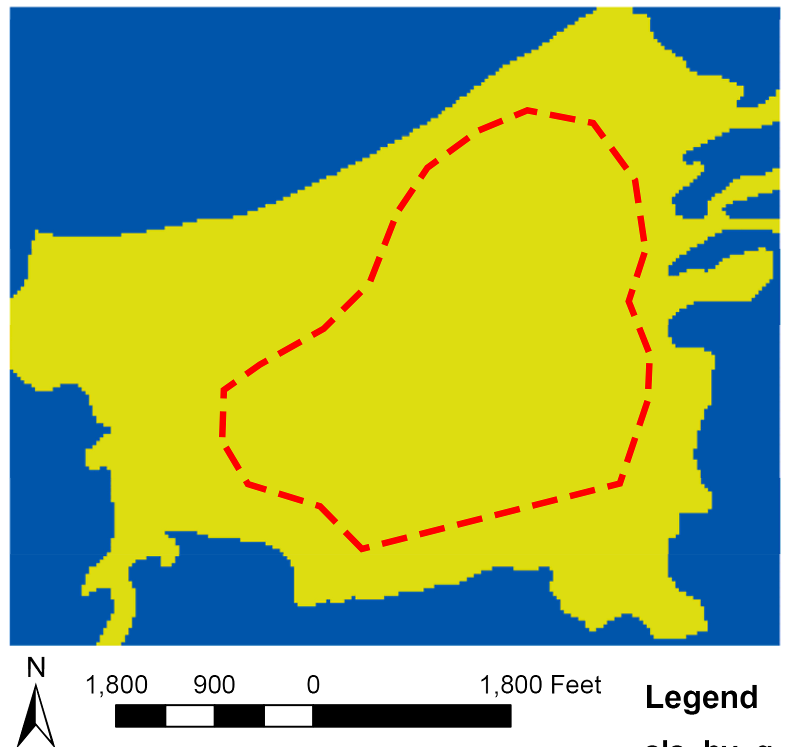
Impervious Surface Reclassified



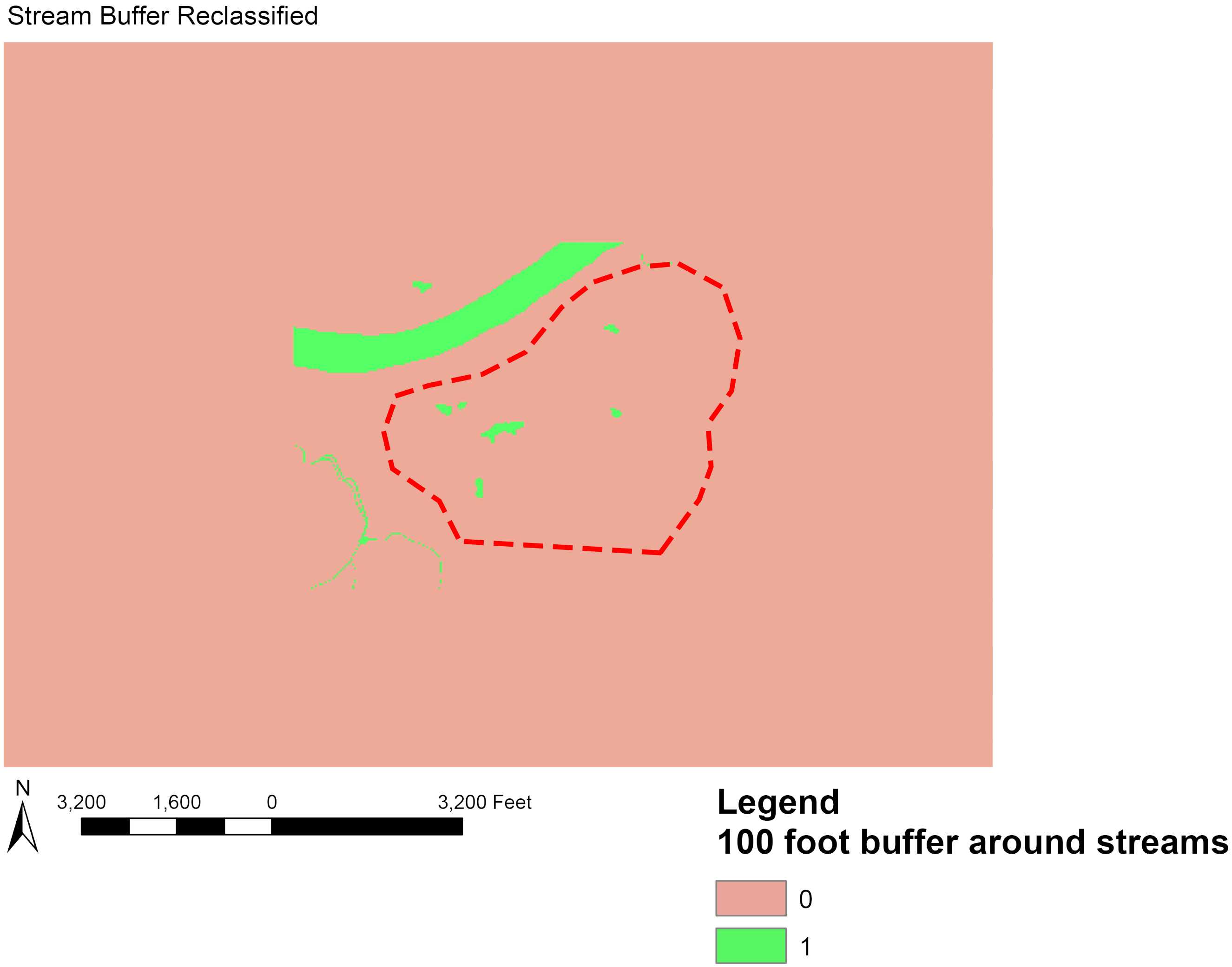

The second criteria for a constructed wetland is to have greater than 0% impervious surfaces. On the map the the left shows which areas are impervious and which are not. If it has a number value of 0, then it's not impervious but if it's a 1 it is impervious. The entire golf course is impervious because of the massive development that surrounds the golf course

# Design Criteria

## Soil Reclassified

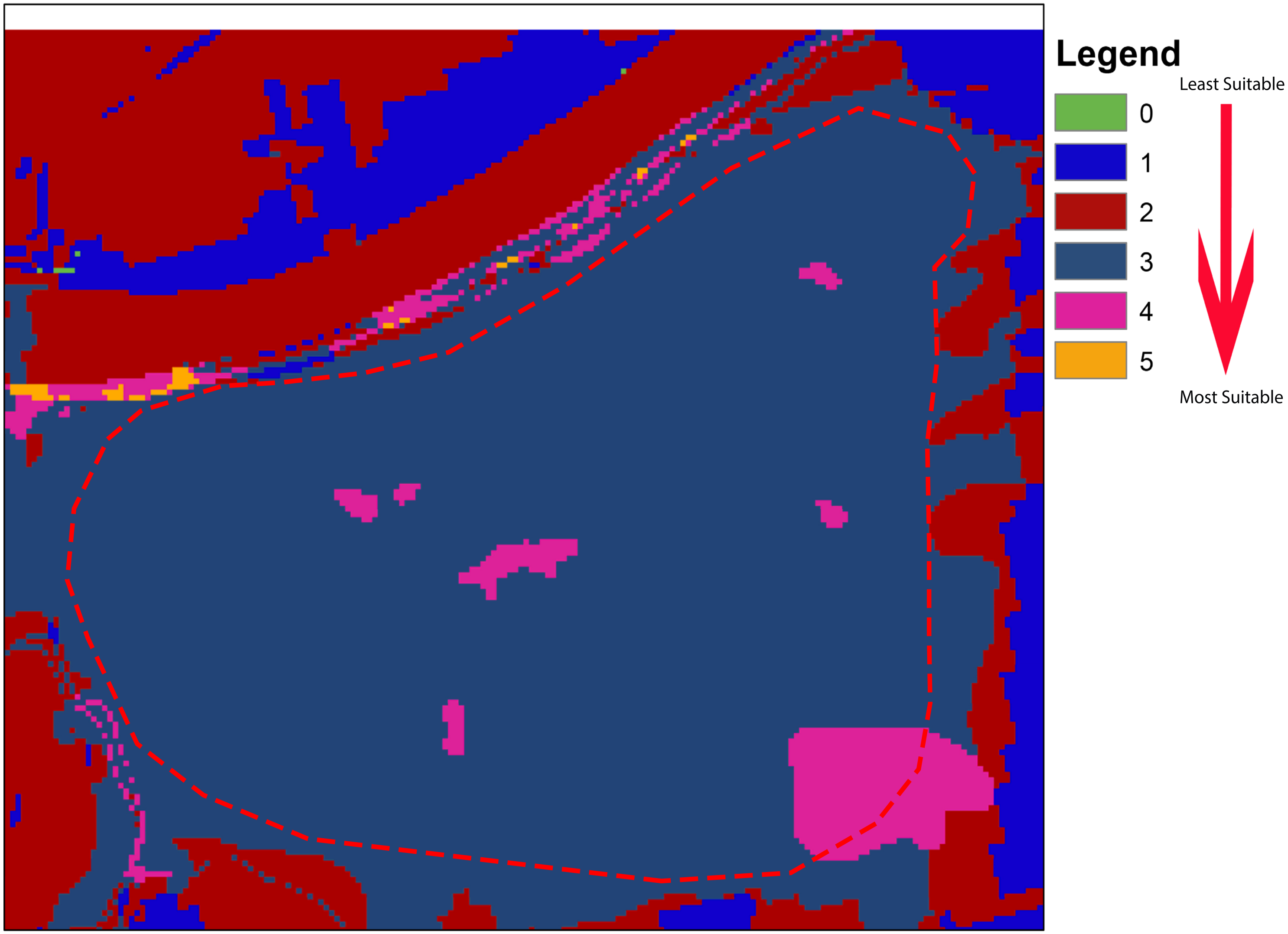




The third and fourth criteria have to do with soils. We need soils with a hydrological group of A-D and with a water table greater than 4 feet. This first map on the left shows the depth to water table being greater than 4 feet. Most of the water tables are at about 2 or 3 feet in depth which may cause problems.



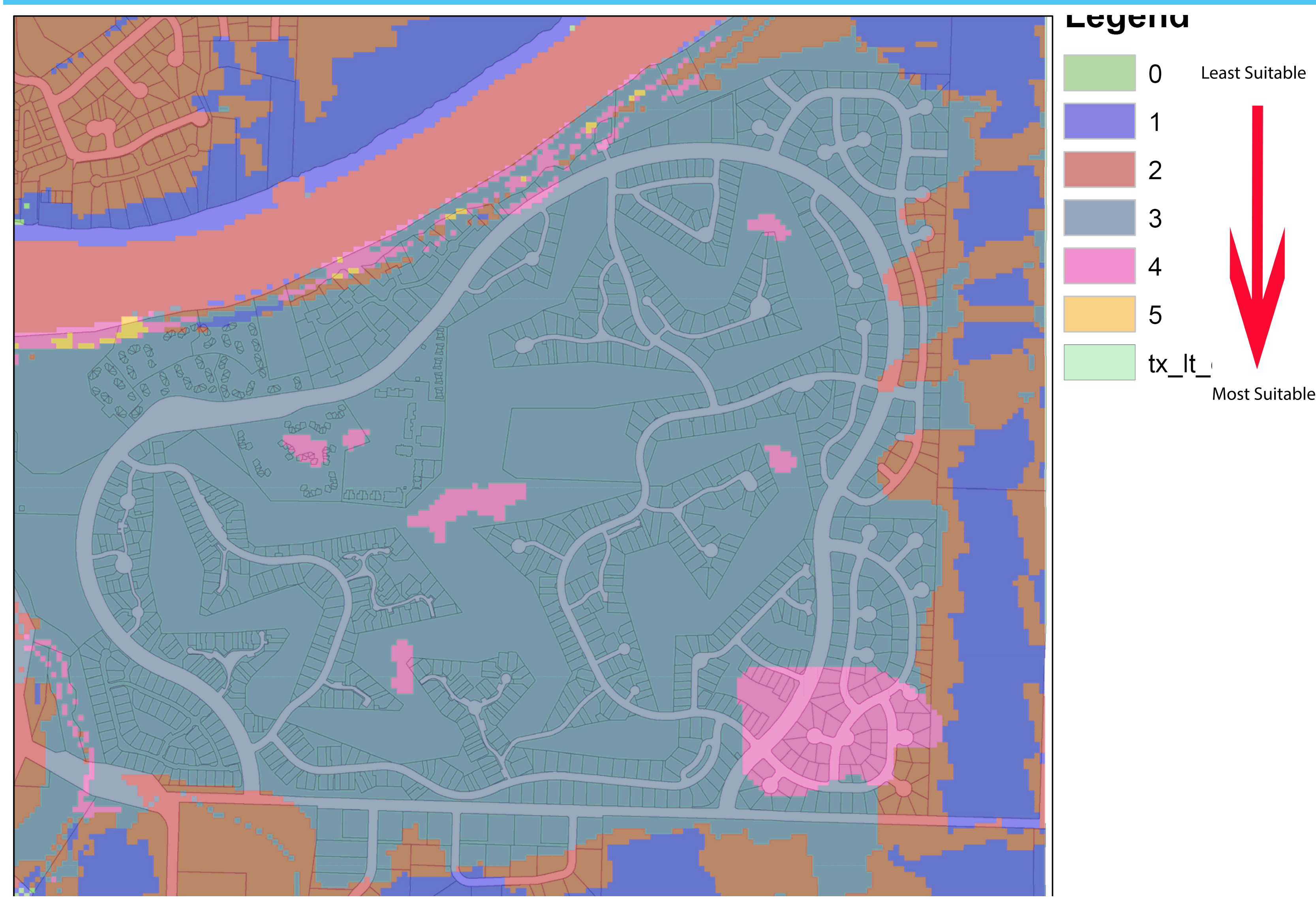

The last criteria that needed to be met was having a 100-foot buffer around streams. There were no streams going through the golf course. In GIS when doing this assessment highlighted all the bodies of water that were present, not just streams. So what you're seeing here should be a blank map with having a score of 1 because the buffer is irrelevant without any streams. The biggest green strip is the Willamette River but it's cut off and should not be highlighted since it is not a stream.

# Suitability Map



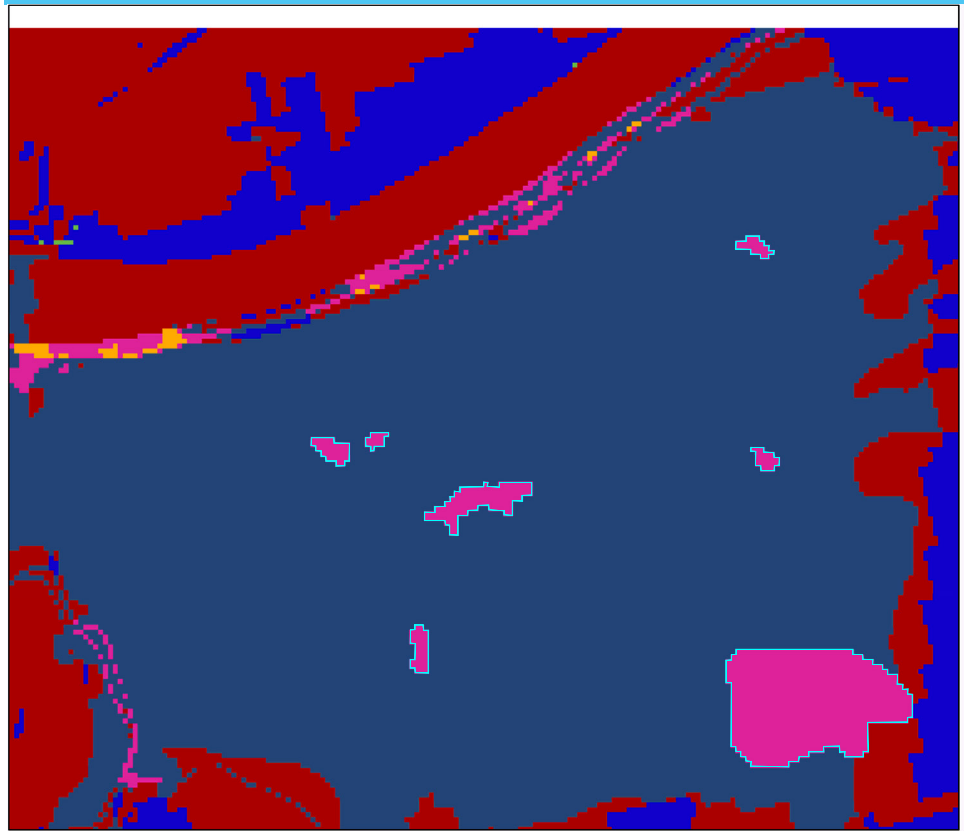

I ran a suitability analysis for where the best suitable location for a constructed wetland in the given area. The criteria for the wetlands is based of the federal EPA standards, which included 5 different criteria.That criteria included having slopes less than 15%, depth to water table greater than 4 feet, hydrological soils A-D, 100-foot buffer from streams, and greater than 0% of impervious surfaces. After creating a layer for each criterion, is assigned to indicate suitable or not suitable. So for example if in area had less than 15% slope than it would be a 1 but if it was greater than 15%, it's 0. The last step is to combine all the layers into one map which gives you values ranging from 0-5, 5 being the most suitable and 0 being the least

# Suitability Map with Tax Lot

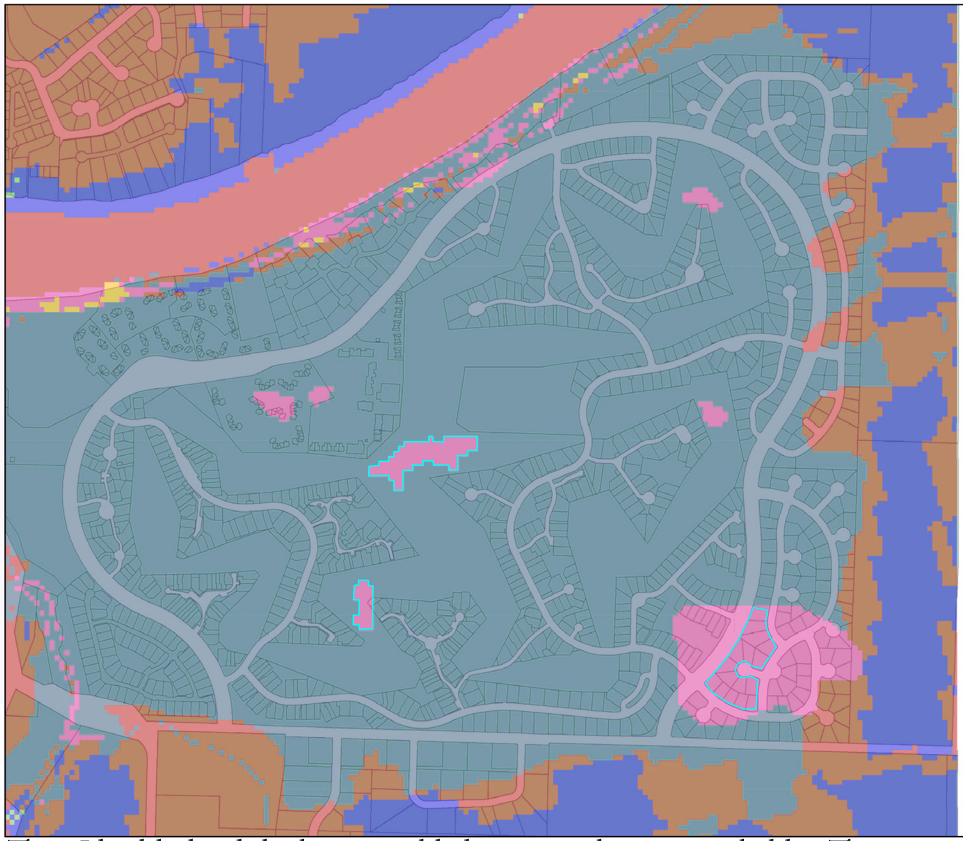



The above map shows tax lots overlain on the suitability map. The tax lot map shows where the buidlings are in relation to the suitable areas. If the suitable locations are underneath buildings and roads, it might be harder to make a wetland in that spot. The pink spot in the bottom right is the only suitable location that is located underneath buildings according to the map.

# Concept Diagrams

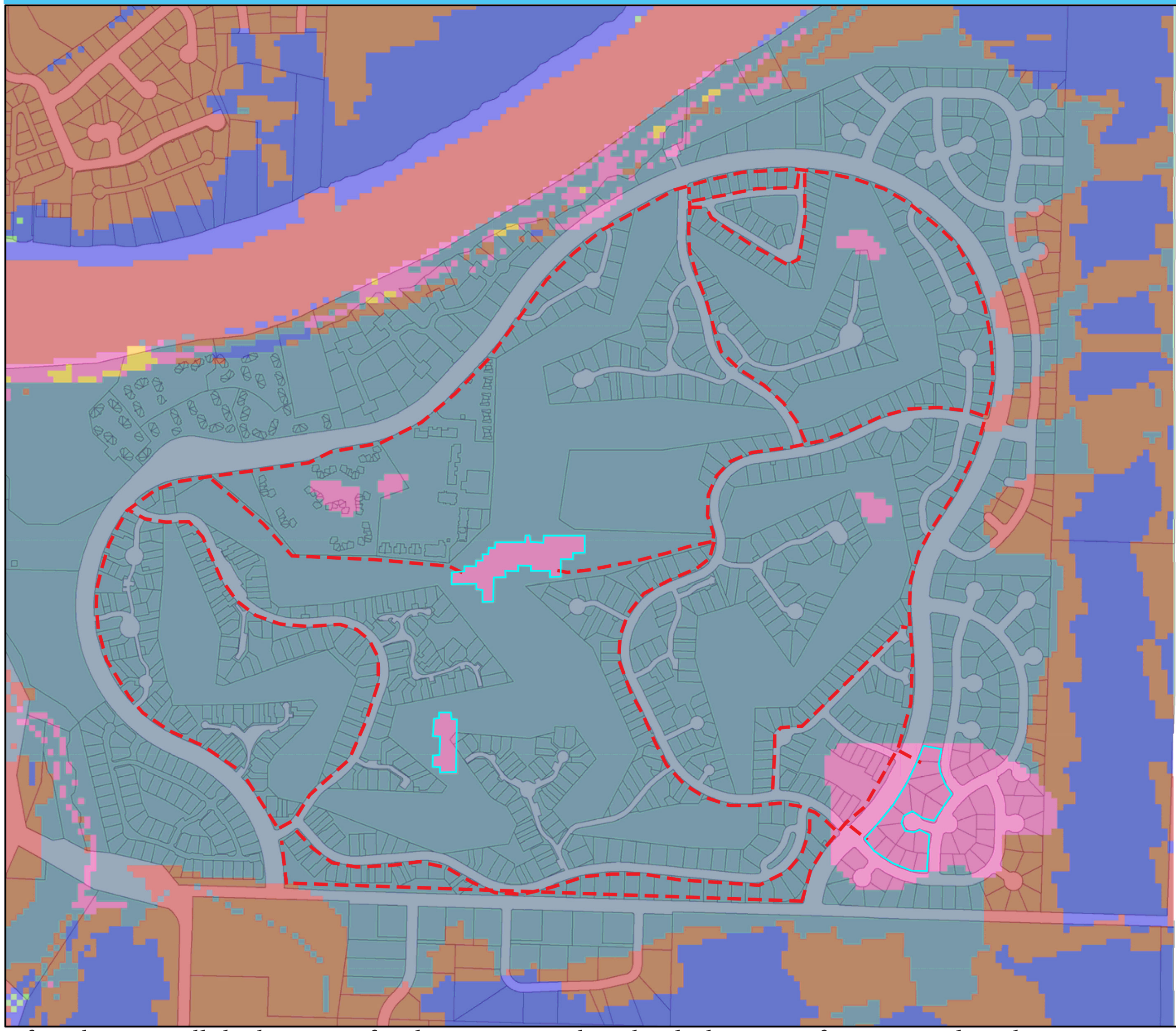


The first thing that I did was highlighting the best suitable locations.  There are seven locations that are best suited for constructed wetlands.



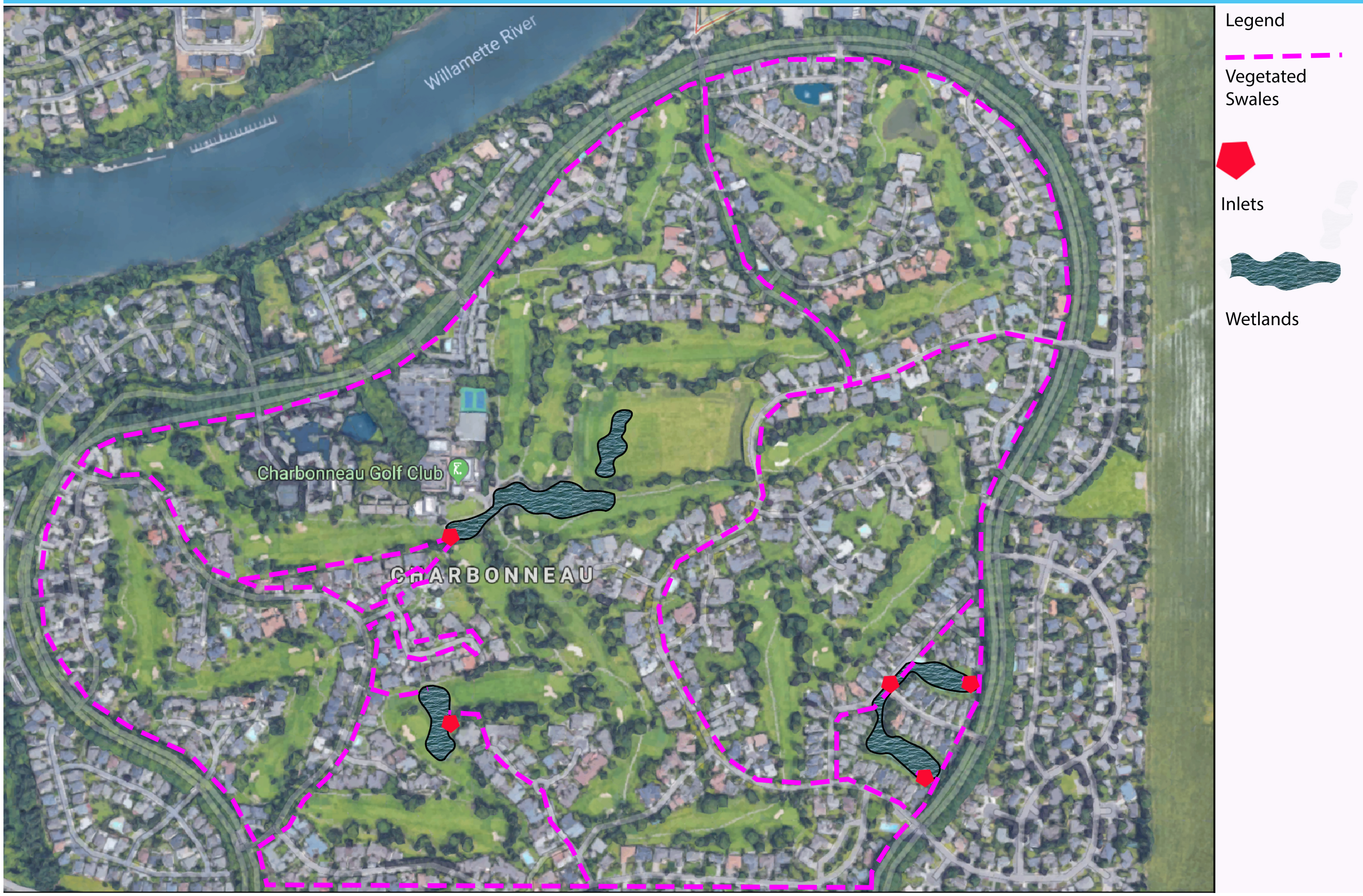
Then I highlighted the best suitable locations that are workable.  The two locations on the top right are too small for a wetland. The other suitable spot near the top left of the map wasn't chosen because it is on private land not owned by the golf course.  The three locations highlighted in blue on the above map were chosen for implementing stormwater management designs.  All three are existing ponds that can be transformed into constructed wetlands.

# Concept Diagrams



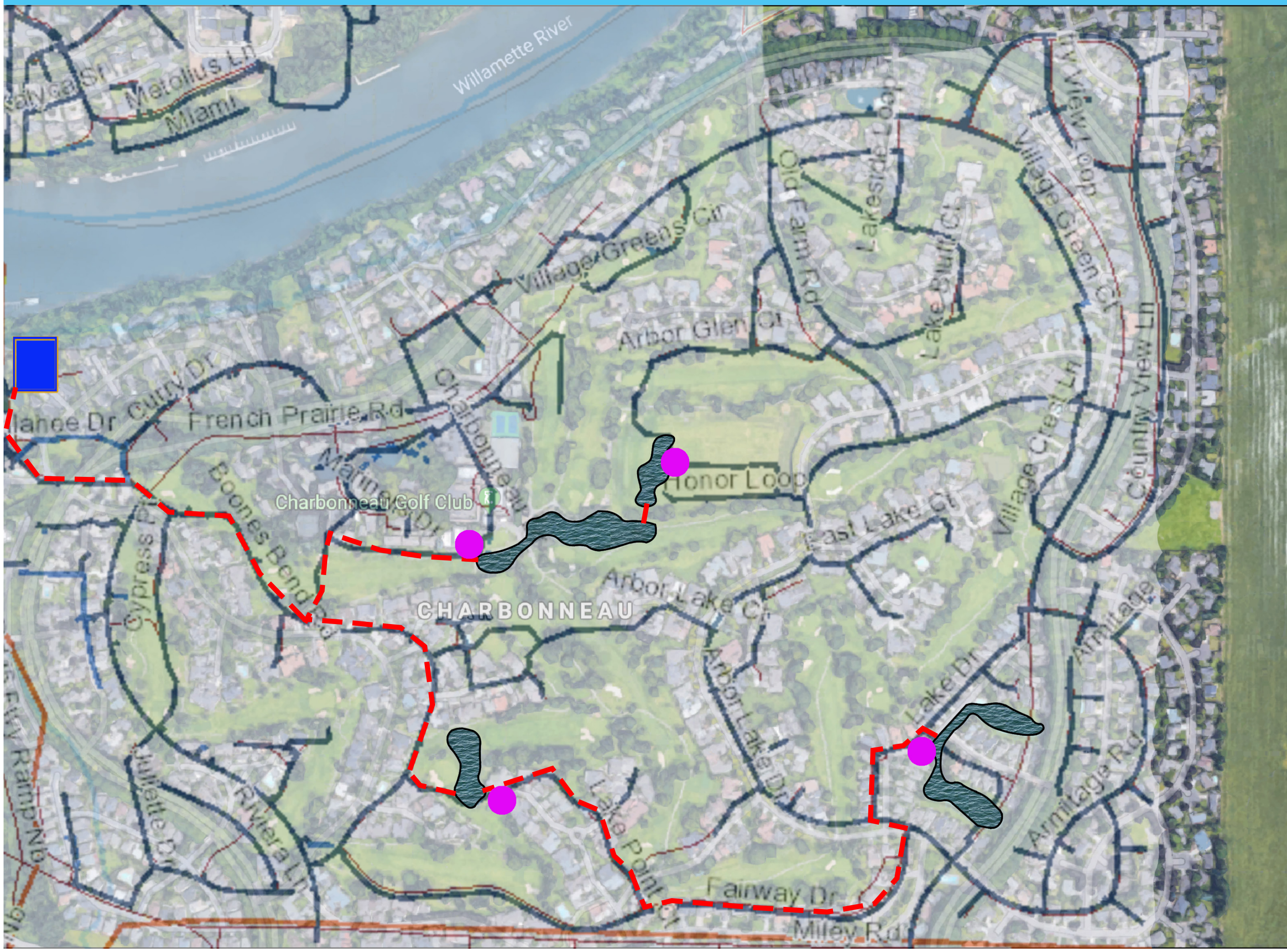
After choosing all the locaitons for the constructed wetlands, locations for vegetated swales were mapped out, shown by the dashed lines in the plan above. This process began with outlining all the existing roads with swales for collection and transfer of stormwater. There is a ring road around the whole course so all stormwater coming through the site will run onto the roads and into the swales.

# Master Plan




There are vegetated swales surrounding the ring road around the course. All water flowing into the course can be collected by the swales and transferred to one of the three constructed wetlands. The swales have been placed in areas were the water would flow naturally down hill towards each wetland. There might be area's where there would have to be some cut and fill for the swales. Each constructed wetland has one or two inlets to allow stormwater to flow in. Each inlet is marked as a red hexagon. The area of water located next the the central wetland is actually an irrigation pond and not anther wetland.

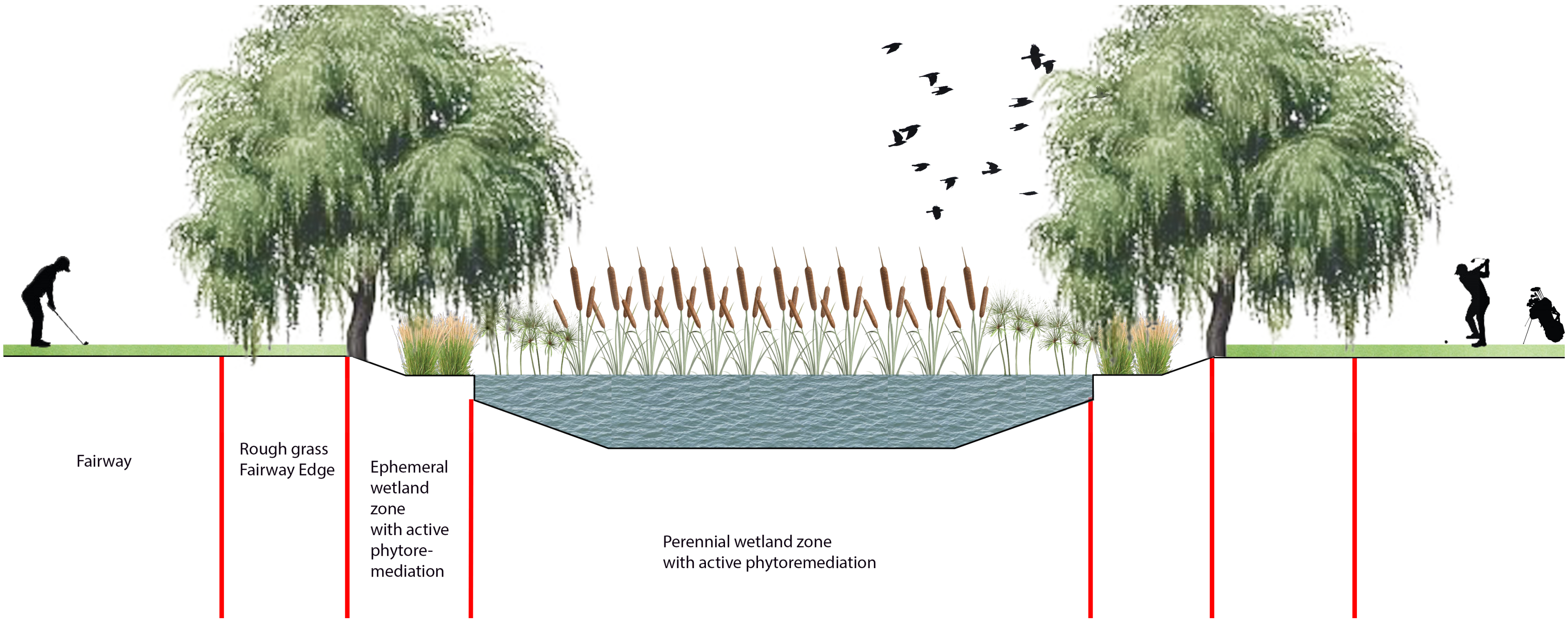
# Master Plan




There has to be a way to transfer stormwater from one wetland to another, so it can be transferred over to the irrigation pond. The blue lines are existing stormwater lines underneath the course. All the stormwater lines go through my wetlands and can be pumped from one wetland from another by installing pumps at each wetland and irrigation pond. On this map each inlet is marked with purple circles and how the water would be transferred is marked as a red dashed line. The blue rectangle on the top left is an outlet where excess clean water could be released back into the Willamette River.

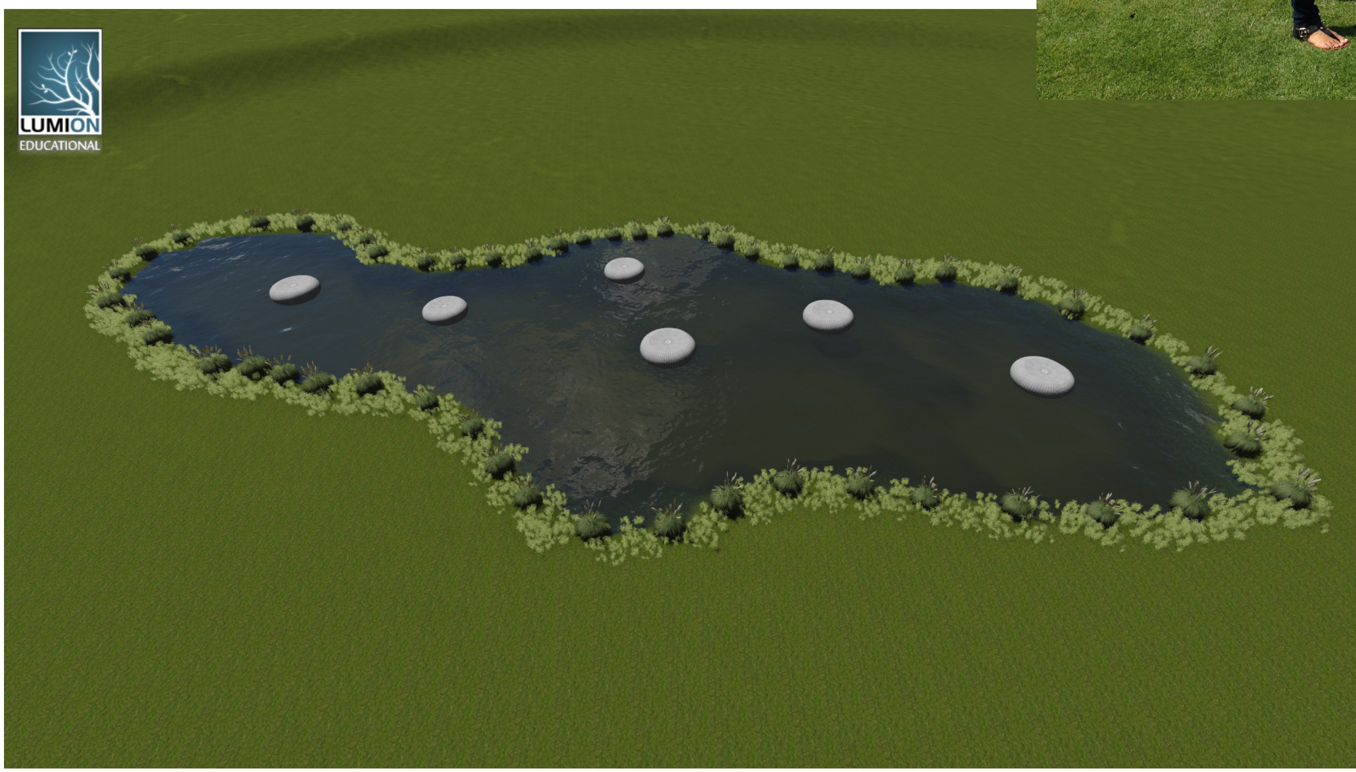
# Wetland Perspectives


On the left is a perspective of what any of the wetlands can look like. The wetlands should be full of vegetation to distance golfers from the water. The bottom section shows how the wetland will interact with the golf course. The wetlands are incorporated into the golf course as water hazards which makes the course more challenging and aesthetically pleasing.



# Irrigation Pond Perspectives

The irrigation pond is located within the driving range.  The irrigation pond includes floating targets for golfers to chip to on the range.  The irrigation pond's main purpose is pumping clean stormwater into the irrigation.system to irrigate the golf course when needed.



# Conclusion

## Challenges

There were many things that worked and didn't work while doing this project. One thing that worked well was utilizing Arc GIS. All the site inventory and suitability maps were made through the use of GIS. One thing that didn't work was having good communication with the Charbonneau Golf Course. If there was more cooperation with them, then base maps and irrigation layouts could have been available. When making the suitability map, it was soon realized there weren't very many suitable locations, as well as truly understanding the water demand for the course. This highlights the importance of planning the stormwater management elements in prior to development. If there were more suitable locations, more stormwater could be collected and easily be irrigated for the entire summer. Also, using a 2-year storm to model collection/transfer/storage capacity means that when heavier rainfall occurs, which could be fairly often in this area, the facilities wouldn't be able to manage the additional water. This suggests that storage would be useful at multiple points in the collection network. If this were possible, it would give the constructed wetlands the best chance of successfully being able to mitigate the pollutants captured in the runoff.

One thing that could have been done differently while designing this project was expanding the search for suitable locations outside of the golf course. It would allow the golf course to collect more stormwater but would pose the problem of getting the stormwater from off site to on site.

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