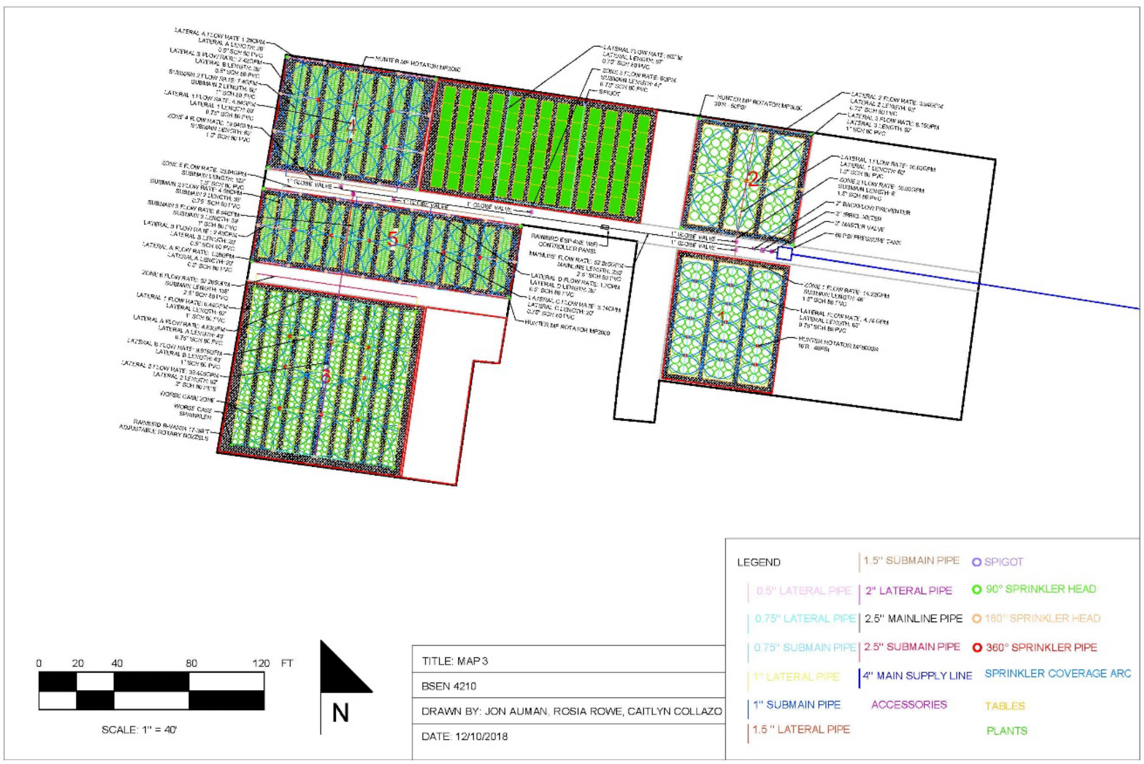
Collier's Greenhouse Design Project



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Final Design Project Report

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Executive Summary

The objective of this project was to design an irrigation system with the capacity to sufficiently serve the Collier Greenhouse and Garden Center in Jackson, Georgia. The greenhouse was designed using three different Hunter sprinkler heads and one Rainbird head. The system, overall, is comprised of various Schedule 80 pipes, many 1-inch PVC Globe Control Valves, a 2-inch 200B Threaded Brass Electric Globe, an irrigation controller, a backflow preventer, and a pump. This allows the entire system to irrigate to meet the water requirements of each of the plant types in each zone. All the piping materials selected in the retrofitted design of the greenhouse are made of Polymerized Vinyl Chloride (PVC) plastic.

The cost analysis and estimate for the greenhouse is based on the price for individual components of the greenhouse, but also for cost of operating the irrigation system. The total estimated cost of materials for this design is about $8,733.87. This figure includes each of the components necessary to retrofit the design system to the greenhouse. Overall, it was estimated that the greenhouse needs about 2,995.362 gallons of water per day to sufficiently water each zone. Reasonably, the irrigation system would be running about 242 days out of the entire calendar year. This equates to a total run time of 3.42 hours per day, and an overall water use of 724,877.604 gallons per year. In order to meet this need, a 5HP motor should be purchased, and this is priced at approximately $750. The Collier Greenhouse does not have a point of connection in order to transport municipal water into the system for irrigation. Pumping water from the privately-owned body of water located to the east of the greenhouse is projected to save $4,831.80 per year on water costs. This greenhouse pumping system could be run on either diesel or electric power. A traditional diesel pump operation at the design specifications of this plan would cost approximately $3.478 per day. An electric pump fitted to the same design specifications would cost $2.175 per day to operate. Installing an electric system over a traditional diesel system would save upwards of 37% of irrigation costs. A detailed analysis of the cost of the retrofit design can be found in the *Capital and Operating Costs*.

Introduction

The objective of the final design project is to retrofit a new greenhouse irrigation system to Collier's Greenhouse. Located in Jackson, Georgia (Butts County), this ornamental greenhouse serves as a retailer for vegetable plants, annuals, perennials, and herbs.

There are six different zones that are to be irrigated within the Collier Greenhouse. Within each zone, there is one type of plant. This ensures that all the plants within a certain zone meet the same water requirements in order for each plant to be properly irrigated. **Table 1** below illustrates the zones, area of the zones, the types of plants housed within that zone, and their water requirements. Items found within the greenhouse would not only include the potted plants, but the tables upon which the plants are being irrigated.

The greenhouse is irrigated using water sourced from a pond located to the east of the greenhouse. Because of the pond being on private property, the ownership of the water source would belong to the Collier Greenhouse. There is no point of connection to facilitate the transportation of city water to the greenhouse; meaning there is no backup water source.

The Collier Greenhouse is made up of 30,726.84 ft^2 within the six zones. This equates to roughly 0.705 acres of utilized space within the greenhouse. The various types of plant material present in the Collier Greenhouse are separated by how much water each plant type requires during irrigation. In Zones 1 and 2, the plant material is comprised of assorted shrubs. In Zone 3, geraniums make up the plant material in that portion of the greenhouse. Zones 4 and 5 are comprised of trays of flats and plugs, while Zone 6 has azaleas. This information is demonstrated in **Table 1**.

When designing a greenhouse, controlling the climatic conditions within is one of the most important design decisions to make. The climate of any greenhouse should be one that combats limitations of weather conditions in that region. If regional temperatures are freezing, a greenhouse within that area should be designed to ensure that the plants do not freeze and die in artic temperatures. If weather patterns in any particular region are hot enough to kill plants, the greenhouse should be designed to bring moisture and coolness to the plants that need it. The ability for the plant life within the greenhouse to be able to overcome factors that would limit them in outside, harsh climates is what determines the climate of any particular greenhouse.

The soil textural classes that were irrigated are dependent on the plant material being planted in the different pots and irrigation zones. Some variables that effect the soil textural class that was irrigated include: necessary pH requirements of some of the plants, temperature requirements, irrigation requirements, and nutrient requirements that the plants would require from the potted soils.

Below is map of the location of the Collier Greenhouse. To the left is the greenhouse itself. To the east of the greenhouse is the body of water that the water for irrigation within the greenhouse is sourced from.

Figure 1: Aerial View of the Collier Greenhouse & Private Water Source from Google Earth

Design Recommendation

To begin the design process, an area of irrigation is determined by using the area of the six zones provided in AutoCAD Civil 3D. This was done by creating tables and arrays of plants within each zone, which is illustrated in Appendix C on **Map 1**. **Table 1** provides the number of plants in each zone, along with the assumptions made for each plant type. For Zone 1 and Zone 2, the assumption of a five-foot canopy is made to ensure that the larger of the assorted shrubs will obtain the sufficient water requirement that is needed. Canopies that are smaller than five feet will be provided enough water, because the runtime will be based on the water requirement for the larger shrubs. For Zone 3, the assumption of a 0.5-ft diameter for a one-gallon pot is made to allow for a large quantity of plants located within this zone. Zones 4 and 5 consist of trays, and tables were drawn in these zones to fill as much of the area as possible while maintaining adequate walkways. 2-ft by 1-ft trays are drawn to fit within each of these 6-foot-wide tables, providing relatively large quantities of plants. Lastly, there is an assumption made for Zone 6, entailing a canopy of 3 feet for each plant, allowing for 8 plants to fit on a 6-ft by 12-ft table.

Table 1: The number of plants in each zone, and the assumptions made about these plants or their containers.

Zone	Type of Plant	Number of Plants	Assumptions
1	Assorted Shrubs	108	5 ft canopy
2	Assorted Shrubs	90	5 ft canopy
3	1 gallon Geraniums	14586	0.5 ft diameter pots
4	Flats/Plugs (Trays)	1296	2ft x 1ft trays
5	Flats/Plugs (Trays)	1485	2ft x 1ft trays
6	1 gallon Azaleas	560	3ft canopy

Sprinkler coverage arcs are then drawn to ensure that there was head to head coverage for all the plants in each zone. This is demonstrated on **Map 2** in Appendix C. Because the area of each zone varies, the radius of the sprinkler coverage differs based on the number of plants, number of tables, and the layout of the plants within the zone. The area of irrigation may include the entire zone, which contains the walls and walkways. Irrigating the walkways and the hitting the walls decrease the efficiency, however not irrigating the walkways and walls would increase the number of sprinklers necessary to properly irrigate all of the plants. For example, in Zone 6, if each table had head-to-head coverage with multiple 6-ft radius sprinklers, then there would be approximately 420 sprinklers in one zone. 420 sprinklers for about 7,308 square feet is excessive. This is why the walkways and most of the zones' walls are included in the area of irrigation. Next, sprinkler heads are placed on the CAD map to describe where a quarter, half, and full sprinklers are located.

Once the area of irrigation is determined based on where the sprinklers and arcs are placed, the runtimes are calculated. In order to calculate runtime, the plant water requirement (PWR) is required for each plant type, and can be found in **Table 2**.

Table 2: The plant water requirement (PWR) for each type of plant in each zone.

Zone	Type of Plant	Plant Water Requirement
1	Assorted Shrubs	1.4 Gal/day
2	Assorted Shrubs	1.4 Gal/day
4	Flats/Plugs (Trays)	0.15 in/day
5	Flats/Plugs (Trays)	0.15 in/day
6	1-gallon Azaleas	0.35 Gal/day

After plant water requirement is determined, the gross water requirement (GWR) for each plant type can be calculated. The gross water requirement is defined as the plant water requirement divided by the application efficiency. GWR should also have the units of inches per day, and when the PWR is given in gallons per day, conversions are necessary to yield an accurate result. In addition to the GWR, precipitation rate (PR) is needed to calculate runtimes. Precipitation rate can be determined using **Equation 1** and is given in inches/hour. For this design project, the application efficiency is estimated at 75%.

$$PR = \frac{96.3 \times Q\ (sf)}{Area\ of\ Irrigation\ (sf)} = \frac{inches}{hour}$$

(Eq. 1)

The runtime for each zone is the gross water requirement for a specific type of plant, divided by the precipitation rate for that plant. This results in an irrigation runtime in hours per day or minutes per day. **Table 3** displays the runtime for each zone, which specifies the amount of time that the irrigation system is operated per day. The calculations for the runtimes for each zone can be found in Appendix A (Zone 1, Zone 2, Zone 3, Zone 4, Zone 5, Zone 6). The total runtime for all zones for one day is 205.2 minutes, or approximately 3.5 hours. Annually, the design would have a water year of 242 days, from February to October, and the total runtime for the year would be 827.64 hours.

Table 3: Irrigation Schedule, the number of hours operated per day, the Runtimes.

Zone	Area of Irrigation (sf)	Plant Gross Water Requirement (in/day)	Precipitation Rate (in/hr.)	Runtime (min/day)
1	3587.88	0.153	0.382	24
2	3615.85	0.153	0.427	22
3	5957.712	0.15	0.97	90
4	4782.5	0.2	0.395	30
5	5474.899	0.2	0.405	30
6	7308	0.106	0.69	9.2

In addition to requiring irrigation runtimes for each zone, the model, type, and quantity of sprinklers are needed to design a functioning, retrofitted irrigation system for the greenhouse. Each type of sprinkler-the quarters, halves, and the fulls-have different flows depending on the pressure and radius for each model. Each sprinkler is mapped in the rendering of the Collier Greenhouse, and is illustrated on **Map 2** in Appendix C. **Table 4** summarizes the models of sprinkler in each zone, including the radii and pressures for the specific models, and the necessary quantities of each sprinkler model.

In Zone 1, the sprinkler coverage arcs have a radius of 10 feet, making the Hunter MP Rotator MP800SR the optimal choice for that zone. According to the specifications provided the Hunter MP Rotator MP800SR requires 40psi of pressure. The specifications for the MP800SR model used are located Appendix B. In Zone 2, the sprinkler coverage arc radius is 30 feet, requiring the Hunter MP Rotator MP3000, which needs a pressure of 50 psi to operate. The specifications used for the MP3000 can also be found in Appendix B. Zone 3, does not require sprinklers because that zone is hand-watered. Zone 3 is designed to have four spigots, and is illustrated in Appendix C on **Map 2**. Zone 4 and Zone 5 both have sprinkler coverage arcs with radiuses of 20 feet, and require the Hunter MP Rotator model, MP2000. The MP2000 requires a pressure of 45 psi to operate properly, and the specifications can be found on the rotary specifications chart in Appendix B. Zone 6 contains sprinkler coverage arcs with a radius of 22.5 feet, but because this is not a standard radius, an adjustable rotary nozzle is necessary. The model used in Zone 6 is the Rainbird R-Van24-17-24ft. The pressure required for the R-Van24 nozzle, with a radius of 22.5 feet, is 43psi.The specifications for this model include the radii of 22-ft and 23-ft, therefore, interpolation is used to find the pressure for a mean radius of 22.5ft. The specifications used for the Rainbird nozzle can be found in Appendix B.

Table 4: The different models of sprinklers used, including the radius, pressure, and how many are needed for each type.

Zone	Model of Sprinkler	Radius (ft)	Pressure (psi)	Number of 90˚ Sprinklers	Number of 180˚Sprinklers	Number of 360˚ Sprinklers
1	Hunter MP Rotator MP800SR	10	40	-	6	15
2	Hunter MP Rotator MP3000	30	50	4	4	1
3	Spigots	-	-	-	-	-
4	Hunter MP Rotator MP2000	20	45	4	10	6
5	Hunter MP Rotator MP2000	20	45	4	14	6
6	Rainbird R-Van24-17-24ft Adj. Rotary Nozzles	22.5	43	4	12	9

Each model and sprinkler type has a different flow rate which is used to calculate the overall flow rate for each zone. **Table 5** summarizes the flow rates for each type of sprinkler and sprinkler model. The full sprinklers have a larger flow rate than the quarter sprinklers. Because the full sprinklers have more area to cover, more water is required to irrigate the larger area.

Table 5: Flow Rate, Q, for each model and type of sprinkler.

Type of Sprinkler	Radius (ft)	Pressure (psi)	Q for 90° Sprinklers (gpm)	Q for 180° Sprinklers (gpm)	Q for 360° Sprinklers (gpm)
Hunter MP Rotator MP800SR	10	40	-	0.42	0.78
Hunter MP Rotator MP3000	30	50	0.95	2.04	4.07
Hunter MP Rotator MP2000	20	45	0.43	0.85	1.57
Rainbird R-Van24-17-24ft Adj. Rotary Nozzles	22.5	43	0.805	1.61	3.305

The total flow rate for each zone is determined by the total flow rate of each type of sprinkler located in each zone. **Table 6** provides the total flow rates for each zone in the greenhouse. It is important to note that only one zone will be irrigated at a time. Therefore, the largest flowrate at any given time will be 52.285 gpm. This flow rate, the largest flow rate for any of the zones, will determine the pipe size of the mainline.

Table 6: The total flow rate for each zone.

Zone	Total Flow Rate
1	14.22 gpm
2	16.03 gpm
3	6 gpm
4	19.64 gpm
5	23.04 gpm
6	52.285 gpm

The layout of the sprinklers within each zone determines the manner that the pipe will be laid. Each zone consists of submain pipes and lateral pipes all connected to the mainline. The six tables below (Table 7, Table 8, Table 9, Table 10, Table 11, and Table 12) summarize the main, submain, and lateral pipe size specifications for each zone, as illustrated in Appendix C on **Map**

3. These specifications include the pipe size, the flow rate for each pipe, the length of the pipe, and how many sprinklers are attached to each pipe. However, when sizing these pipes for each zone, knowing the flow of each pipeline is crucial.

Table 7: Zone 1 pipe design specifications

Type of Pipe	Flow Rate (gpm)	Pipe Size (inch)	Length (feet)	Number of Sprinklers
Submain	14.22	1.5	46	-
Lateral (x3)	4.74	0.75	63	7

Table 8: Zone 2 pipe design specifications

Type of Pipe	Flow Rate (gpm)	Pipe Size (inches)	Length (feet)	Number of Sprinklers
Submain	16.03	1.5	6	-
Lateral 1	16.03	1.5	60	3
Lateral 2 (x2)	3.94	0.75	62	3
Lateral 3	8.15	1	62	3

Table 9: Zone 3 pipe design specifications

Type of Pipe	Flow Rate (gpm)	Pipe Size (inches)	Length (feet)	Number of Spigots
Submain	6	0.75	47	-
Lateral (x2)	6	0.75	57	2

Table 10: Zone 4 pipe design specifications

Type of Pipe	Flow Rate (gpm)	Pipe Size (inches)	Length (feet)	Number of Sprinklers
Submain	19.64	1.5	63	-
Submain 2 (x2)	7.4	1	60	-
Lateral 1	4.84	0.75	60	4
Lateral A (x4)	1.28	0.5	20	2
Lateral B (x4)	2.42	0.5	20	2

Table 11: Zone 5 pipe design specifications

Type of Pipe	Flow Rate (gpm)	Pipe Size (inches)	Length (feet)	Number of Sprinklers
Submain	23.04	1.5	122	-
Submain 2 (x2)	4.98	0.75	39	-

Submain 3 (x2)	6.54	1	39	-
Lateral A (x4)	1.28	0.5	20	2
Lateral B (x4)	2.42	0.5	20	2
Lateral C (x2)	3.14	0.75	20	2
Lateral D (x2)	1.7	0.5	20	2

Table 12: Zone 6 pipe design specifications

Type of Pipe	Flow Rate (gpm)	Pipe Size (inches)	Length (feet)	Number of Sprinklers
Submain	52.285	2.5	138	-
Lateral 1 (x2)	6.44	1	92	5
Lateral 2	39.405	2	92	5
Lateral A (x2)	4.83	0.75	43	2
Lateral B (x3)	9.915	1	43	2

For this design, all pipe used is schedule 80 PVC. To size the pipes, the Hayward Table (Flow of Water Through Schedule 80 Plastic Pipe) was used. The velocity of water flowing through the pipe at any given time should be less than 5-ft per second. All the laterals in each of the zones contain sprinklers, while the submain pipes connecting to lateral pipes to provide water to the sprinklers in order for irrigation to occur. The mainline will be the largest pipe size due to its capacity to handle the largest flow rate. The submain pipe for Zone 6 will be the largest due to the zone having the largest flow rate. Because the irrigation system will only operate one zone at a time, the mainline and submain for Zone 6 will be based off the entire flow for the zone due to its magnitude. The mainline pipe must hold a flow of 52.285 gpm. This is the system's design capacity, so the mainline requires a 2.5-inch pipe size. The size of laterals will vary based on the number of sprinklers attached to each lateral.

Valves are components that have the ability to turn on and off the irrigation system for an entire area. Each zone requires a valve on the submain line leading into each of the zones. Zones 1 through 5 all contain a 1-inch valve on their submain pipes. The entire system needs a master valve as well, which is located on the mainline. Because the mainline is based on the zone with the largest flow, which is in Zone 6, the master valve requires the flowrate in Zone 6 for sizing. However, the pressure for the mainline is 60 psi, which is a higher specification than the zone's pipelines. This means that the valves for Zone 6 and the master valve are sized to handle the largest flow, and in this situation a 2-inch valve will suffice. Ten percent of the zonal pressure must be known in order to properly size valves. The ten percent of the known pressure is compared to a standard pressure loss value based on flows in each zone. Each of the zones are sized using the Pressure Loss through Typical Electric Globe Valves Table located in Appendix B. An irrigation meter is also required, which will measure the amount of water used for irrigation. For this design, a 2-inch irrigation meter is needed. The meter is also sized based on the pressure loss and the flow rate of the entire system. The Water Meter Pressure Loss Chart was used in order to size the meter. In addition to the master valve and the meter, a 2-inch backflow preventer was included. This apparatus ensures that contamination or pollution does not occur do to backflow back into the active irrigation system. To choose a size for a backflow preventer, a chart of the Typical Pressure Loss in Backflow Preventer Devices was used, specifically the double-check assembly. A drawing of the valve, meter, and backflow preventer sizes can be found on page 27 in Appendix A.

Results of System Friction Analysis

The system design and the pump selection are dependent on the friction loss in the pipes that lead to the worst-case sprinkler in the worst-case zone. A total dynamic head calculation is done to determine the fiction head losses, the elevation head losses, and the operating head losses in the system design. Using the Hazen-Williams Equation, the frictional loss calculations can be found in Appendix A (page 26, page 27, page 28), expressed in feet. **Table 13** provides the velocities in the pipe segments leading to the worse case sprinkler, which are needed to calculate the friction head. For the operating head, it was assumed that, in each zone, the over-head sprinklers were situated 8-ft above the plants. Additionally, the operating head is determined by converting the operating pressure at 60psi into feet. With the overall friction head calculated at 13.1087 feet, the elevation head is 8 feet, and the operating head is 138.6 feet. To conclude the system friction analysis, the total dynamic head is 52.285 gpm at 160 feet. When searching for a pump using Berkley, the pump size provided is B1-1/2TRLS. The pump specs and pump curve charts can be found on page 36 in Appendix B.

Table 13: The length and velocities of the pipes leading to the worst-case sprinkler.

Section	Length (ft)	Flow (gpm)	Size (in)	Velocity (ft/s)
Supply line	585	52.285	4	1.495
Mainline	228.0116	52.285	2.5	4.021
Submain 1	50.9390	52.285	2.5	4.02
Submain 2	44.8304	17.428	2.5	1.34
Lateral	91.8077	6.44	1	2.99

Capital & Operating Costs

Estimations operating costs were calculated using the summation of the total water requirements for Zones 1 through Zone 6 in gallons per day. Because the retrofitted design was rendered for a greenhouse the irrigation period was assumed to be 242 days per year between February 1st and October 1st. By multiplying he irrigation period and the water requirement (calculated by the amount of water required per day), the yearly water requirement was calculated at 724,877.604 gallons per year. The operating cost calculations performed to find this figure, including individual water requirements for Zones 1 through 6, can be found in Appendix A.

After determining the quantity of sprinklers, valves, pumps, and controllers were necessary for the retrofit design, the price of the individual parts were considered to find the gross capital cost required for the irrigation system. **Table 14** below demonstrates the individual costs for the parts necessary for the rendered greenhouse irrigation design.

The cost for using resources from the local municipal water supply was valued at $\frac{\$181}{ac-in}$. This value was used to determine the total cost of solely using a municipal water supply for irrigation needs. Using the local water supply on site, to the east of the Collier Greenhouse facility, would save upwards of $4,832 each year in irrigation costs. These values were found via the yearly savings calculations found in Appendix A.

It was determined that a $750 motor with a rated capacity of 5-HP is required due to a calculated braking horse power of 4.07 HP. Using a 5-HP rating, diesel and electric pumping cost per day were determined to be $3.478 and $2.174, respectively. Therefore, using comparative calculations located found in Appendix A, it was concluded that using an electric pump rather than a diesel pump would save approximately 37% of operating costs.

Table 14: Capital Costs of Greenhouse Supplies

Item	Quantity	Price ($)	Total Price ($)
PGV 1-inch Globe Flow Control Valve	5	33.5	167.5
200B 2-inch Threaded Brass Electric Globe	2	148	296
Hunter MP800SR (180 deg.)	6	5.59	33.54
Hunter MP800SR (360 deg.)	15	5.59	83.85
Hunter MP3000 (90 deg.)	4	5.59	22.36
Hunter MP3000 (180 deg.)	4	5.59	22.36
Hunter MP3000 (360 deg.)	1	5.59	5.59
Hunter MP2000 (90 deg.)	8	5.59	44.72
Hunter MP2000 (180 deg.)	24	5.59	134.16
Hunter MP2000 (360 deg.)	12	5.59	67.08
Rainbird R-Van24-17-24ft (90 deg.)	4	4.93	19.72
Rainbird R-Van24-17-24ft (180 deg.)	12	4.93	59.16
Rainbird R-Van24-17-24ft (360 deg.)	8	4.93	39.44
0.5" pipe	360	0.379	136.44
0.75" pipe	740	0.4479	331.45
1" pipe	580	0.6425	372.65
1.5" pipe	300	1.199	359.7
2" pipe	100	1.5064	150.64
2.5" pipe	380	2.699	1025.62
4" pipe	600	3.5985	2159.1
Irrigation Controller	1	87.79	87.79
Pump	1	3115	3115
		Total	**$8,733.87**

Appendix A: Calculations

Runtime Calcs

Zone 1

Hunter Rotator MP800SR

$(6) - 180° @ 10'R, 40psi : Q = 0.42 gpm$

$6(0.42 gpm) = \underline{2.52 gpm}$

$(15) - 360° @ 10'R, 40psi : Q = 0.78 gpm$

$15(0.78 gpm) = \underline{11.7 gpm}$

$\underline{Q_{total} = 14.22 gpm}$

$$PR = \frac{96.3(14.22 gpm)}{3587.88 sf} = \underline{0.382\ in/hr}$$

$$GWR = \frac{RWR}{Ea} = 1.4\ \cancel{gal}/day \times \frac{231\ in^3}{\cancel{gal}} \times \frac{1}{\underbrace{\frac{\pi}{4}(5)^2 (ft^2)}_{19.63 ft^2}} \times \frac{ft^2}{144 in^2} \times \frac{1}{0.75}$$

$\underline{GWR = 0.153\ in/day}$

$$Runtime = \frac{GWR}{PR} = \frac{0.153\ in/day}{0.382\ in/hr} = 0.4\ hr/day \times \frac{60 min}{1 hr}$$

$$\boxed{= 24\ min/day}$$

Zone 1 runtime calculations

Runtime Calcs

$\boxed{\text{Zone 2}}$

[Hunter MP Rotator
MP 3000]

(4) - 90° @ 30'R, 50psi : $Q = 0.95$ gpm

$4(0.95\text{ gpm}) = \underline{3.8\text{ gpm}}$

(4) - 180° @ 30'R, 50psi : $Q = 2.04$ gpm

$4(2.04\text{ gpm}) = \underline{8.16\text{ gpm}}$

(1) - 360° @ 30'R, 50psi : $\underline{Q = 4.07}$

$\underline{\underline{Q_{total} = 16.03\text{ gpm}}}$

$$PR = \frac{96.3\,(16.03)\text{ gpm}}{3615.85\text{ sf}} = \underline{0.427\text{ in/hr}}$$

$$GWR = \frac{PWR}{E_a} = 1.4\text{ gal/day} \times \frac{231\text{ in}^3}{\text{gal}} \times \frac{1}{\frac{\pi}{4}(5)^2(\cancel{ft^2})} \times \frac{\cancel{ft^2}}{144\text{ in}^2}$$

$$\times\ 1/0.75$$

$$GWR = 0.153\text{ in/day}$$

$$\text{Runtime} = \frac{GWR}{PR} = \frac{0.153\text{ in/day}}{0.427\text{ in/hr}} = 0.36\text{ hr/day} \times \frac{60\text{ min}}{1\text{ hr}}$$

$$\boxed{= 21.5\text{ min/day}}$$

$$\approx 22\text{ min/day}$$

Zone 2 runtime calculations

Runtime Calcs

Zone 3

$A = 5957.712\ sf$

$Q = 6\ gpm$

$$PR = \frac{96.3(6\,gpm)}{5957.712\,sf} = 0.097\ \frac{in}{hr}$$

$$GWR = 0.35\ \frac{gal}{day} \times 231\ \frac{in^3}{gal} \div \frac{\pi}{4}(.5^2) \times \frac{ft^2}{144\,in^2} \div 0.75$$

$$GWR = 0.15\ in/day$$

$$RT = \frac{GWR}{PR} = \frac{0.15\ in/day}{0.097\ in/hr} = 1.5\ \frac{hr}{day} = \boxed{90\ \frac{min}{day}}$$

Zone 3 runtime calculations

Runtime calcs

$\boxed{\text{Zone 4}}$

[Hunter MP Rotator
MP2000]

(4) - 90° @ 20'R, 40psi: Q = 0.43gpm

4(0.43gpm) = 1.72gpm

(10) - 180° @ 20'R, 45psi: Q = 0.85gpm

10(0.85gpm) = 8.5gpm

(6) - 360° @ 20'R, 45psi: Q = 1.57gpm

6(1.57gpm) = 9.42gpm

$Q_{total} = 19.64\text{gpm}$

$$PR = \frac{96.3(19.64\text{gpm})}{4782.5\text{sf}} = 0.395 \text{ in/hr}$$

PWR = 0.15 in/day

$$GWR = \frac{PWR}{\text{Application efficiency}} = \frac{0.15 \text{ in/day}}{0.75} = 0.2 \text{ in/day}$$

Application efficiency = 75%

$$\text{Runtime} = \frac{GWR}{PR} = \frac{0.2 \text{ in/day}}{0.395 \text{ in/hr}} = 0.506 \text{ hrs/day} \times \frac{60\text{min}}{1\text{hr}}$$

$$\boxed{= 30 \text{ min/day}}$$

Zone 4 runtime calculations

Runtime Calcs

$\boxed{\text{Zone 5}}$

[Hunter MP Rotator MP 2000]

(4)-90° @ 20'R, 40 psi : Q = 0.43gpm

$4(0.43\text{ gpm}) = \underline{1.72\text{ gpm}}$

(14)-180° @ 20'R, 45psi : Q = 0.85gpm

$14(0.85\text{ gpm}) = \underline{11.9\text{ gpm}}$

(6)-360° @ 20'R, 45psi : Q = 1.57gpm

$6(1.57\text{ gpm}) = \underline{9.42\text{ gpm}}$

$\underline{Q_{total} = 23.04\text{ gpm}}$

$$PR = \frac{96.3(23.04\text{ gpm})}{5474.899\text{ sf}} = \underline{0.405\text{ in/hr}}$$

PWR = 0.15 in/day

$$GWR = \frac{PWR}{\text{Application Efficiency}} = \frac{0.15\text{ in/day}}{0.75} = \underline{0.2\text{ in/day}}$$

Application Efficiency = 75%

$$\text{Runtime} = \frac{GWR}{PR} = \frac{0.2\text{ in/day}}{0.405\text{ in/hr}} = 0.5\text{ hrs/day} \times \frac{60\text{ min}}{1\text{ hr}}$$

$$\boxed{= 30\text{ min/day}}$$

Zone 5 runtime calculations

Runtime Calcs

$\boxed{\text{Zone 6}}$

[Rainbird
R-VAN24-17-24ft Adjustable Rotary Nozzels]

Interpolate to accomodate for 22.5'R

(4)-90° @ 22.5'R, 43psi : Q=0.805gpm

$4(0.805gpm) = \underline{3.22gpm}$

(12)-180° @ 22.5'R, 43psi : Q=1.61gpm

$12(1.61gpm) = \underline{19.32gpm}$

(9)-360° @ 22.5'R, 43psi : Q=3.305gpm

$9(3.305gpm) = \underline{29.745gpm}$

$Q_{total} = 52.285gpm$

$$PR = \frac{96.3(52.285gpm)}{7308sf} = 0.69\ in/hr$$

$$GWR = \frac{PWR}{E_a} = 0.35\ Gal/day \times 231\ in^3/gal \div \frac{\pi}{4}(3^2)(ft)^2 \times ft^2/144in^2 \div 0.75$$

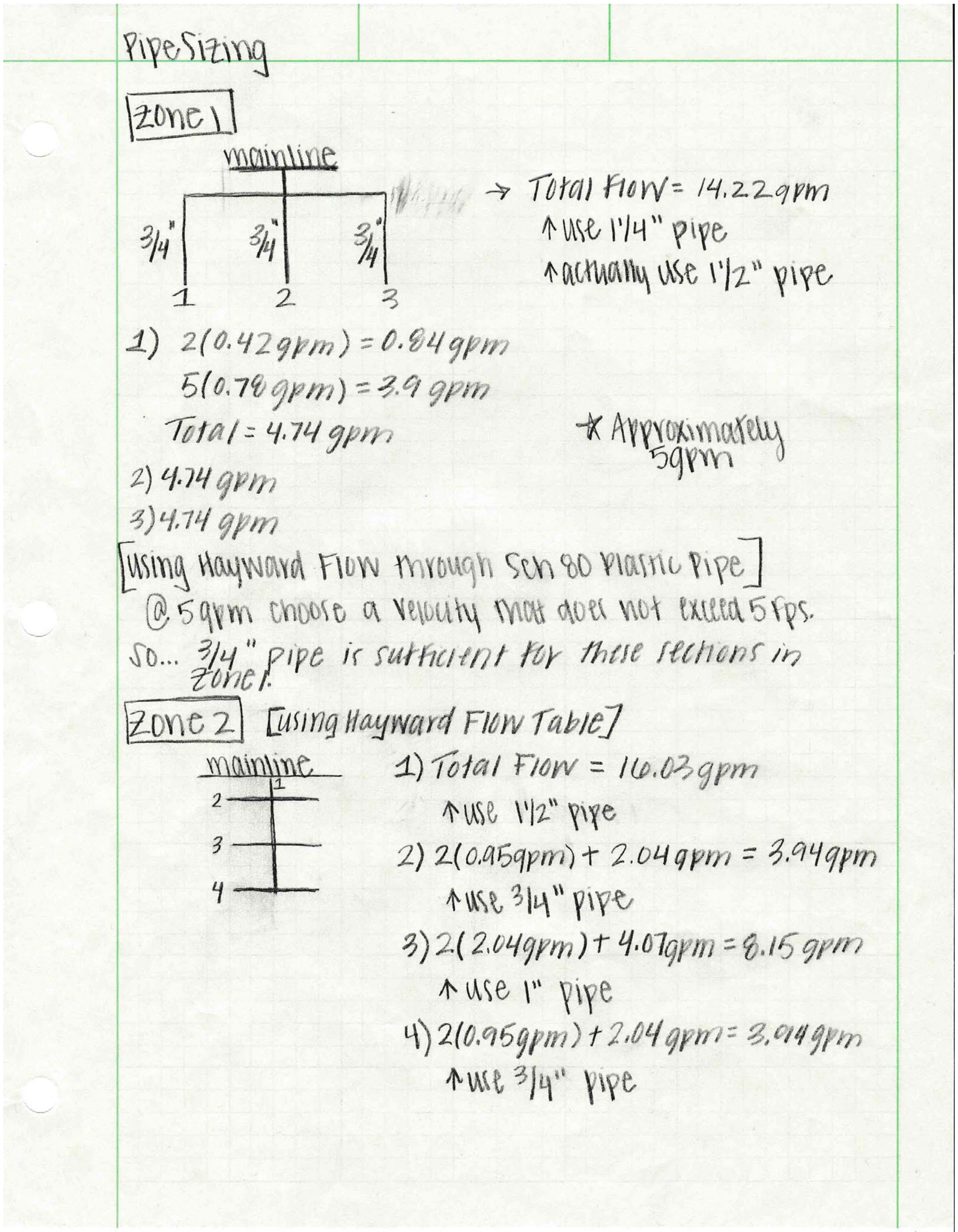
7.07ft²

$$GWR = 0.106\ in/day$$

$$Runtime = \frac{GWR}{PR} = \frac{0.106\ in/day}{0.69\ in/hr} = 0.15\ hr/day \times \frac{60min}{1hr}$$

$$\boxed{= 9.2\ min/day}$$

Zone 6 runtime calculations



Pipe Sizing

Zone 1

mainline

3/4" 3/4" 3/4"

1 2 3

→ Total Flow = 14.22 gpm
↑ use 1 1/4" pipe
↑ actually use 1 1/2" pipe

1) 2(0.42 gpm) = 0.84 gpm
5(0.78 gpm) = 3.9 gpm
Total = 4.74 gpm

★ Approximately 5 gpm

2) 4.74 gpm
3) 4.74 gpm

[using Hayward Flow through Sch 80 Plastic Pipe]
@ 5 gpm choose a velocity that does not exceed 5 fps.
So... 3/4" pipe is sufficient for these sections in Zone 1.

Zone 2 [using Hayward Flow Table]

mainline

1 2 3 4

1) Total Flow = 16.03 gpm
↑ use 1 1/2" pipe
2) 2(0.95 gpm) + 2.04 gpm = 3.94 gpm
↑ use 3/4" pipe
3) 2(2.04 gpm) + 4.07 gpm = 8.15 gpm
↑ use 1" pipe
4) 2(0.95 gpm) + 2.04 gpm = 3.94 gpm
↑ use 3/4" pipe

Pipe sizing for Zone 1 & Zone 2

Pipe Sizing

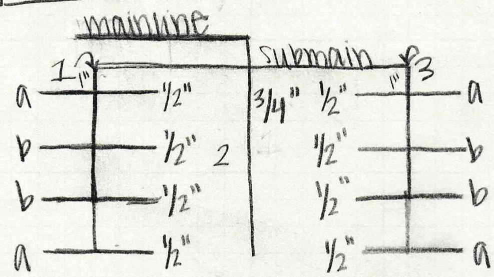
$\boxed{\text{Zone 3}}$

Assume 10 gpm flowing through zone 3, so 3/4" pipe is needed.

Pipe sizing in Zone 3

Pipe Sizing

Zone 4



submain: total flow = 19.64 gpm

↑use 1½" pipe

1) 2(0.43 gpm) + 4(0.85 gpm) + 2(1.57 gpm) = 7.4 gpm

↑use 1" pipe

2) 2(0.85 gpm) + 2(1.57 gpm) = 4.84 gpm

↑use 3/4" pipe

3) flow = 7.4 gpm

↑use 1" pipe

a) 0.43 gpm + 0.85 gpm = 1.28 gpm

↑use 1/2" pipe (not 3/8" even though sufficient)

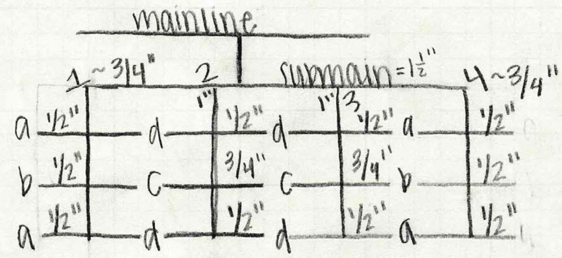
b) 0.85 gpm + 1.57 gpm = 2.42 gpm

↑use 1/2" pipe

Zone 4 pipe sizing

Pipe Sizing

$\boxed{\text{Zone 5}}$



Submain: total flow = 23.04gpm → use 1½" pipe

1) 2(0.43gpm) + 3(0.85gpm) + 1.57gpm = 4.98gpm

↑use 3/4" pipe

2) 4(0.85gpm) + 2(1.57gpm) = 6.54gpm

↑use 1" pipe

3) flow = 6.54 gpm → use 1" pipe

4) flow = 4.98gpm → use 3/4" pipe

a) 0.43 gpm + 0.85gpm = 1.28gpm

↑use 1/2" pipe (not using 3/8" pipe)

b) 0.85gpm + 1.57gpm = 2.42gpm

↑use 1/2" pipe

c) 2(1.57gpm) = 3.14gpm

↑use 3/4" pipe

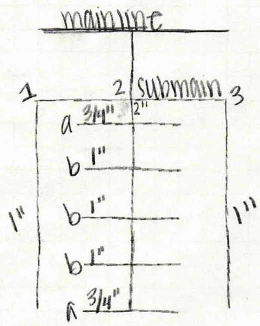
d) 2(0.85gpm) = 1.7gpm

↑use 1/2" pipe (not using 3/8" pipe)

Zone 5 pipe sizing

Pipe Sizing

Zone 6



Submain: total flow = 52.285 gpm

↑use 2 1/2" pipe

1) 2(0.805 gpm) + 3(1.61 gpm) = 6.44 gpm

↑use 1" pipe

2) 6(1.61 gpm) + 9(3.305 gpm) = 39.405 gpm

↑ use 2" pipe

3) flow = 6.44 gpm

↑use 1" pipe

a) 3(1.61 gpm) = 4.83 gpm

↑use 3/4" pipe

b) 3(3.305 gpm) = 9.915 gpm

↑use 1" pipe

Zone 6 pipe sizing

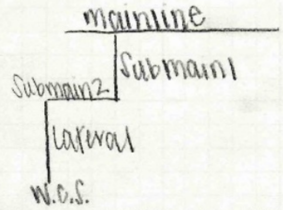
Total Dynamic Head Calculations

mainline = 228.0116 ft

Submain1 = 50.9390 ft

Submain 2 = 44.8304 ft

Lateral to W.C.S. = 91.8077



Friction Head for Submain1:

$$Vel = \frac{Q}{A} = \frac{0.1165\,cfs}{0.029sf} = 4.02\,ft/s$$

52.285 gpm = 0.1165 cfs

$A = 0.029sf = \pi r^2$

$I.D. = 2.29\,in\left(\frac{1ft}{12in}\right) = 0.19083ft\ \phi$ $\quad R_H = 0.0484ft$

$$\boxed{h_L = L\left(\frac{V}{1.318(150)R_H^{0.63}}\right)^{1/0.54}}$$

$$h_L = 50.9390\left(\frac{4.02\,ft/s}{1.318(150)(0.0484)^{0.63}}\right)^{1/0.54}$$

$= 50.9390(0.025)$

$h_L = 1.284ft$

Friction Head for Submain 2:

$Vel = \frac{Q}{A} = \frac{0.0388\,cfs}{0.029sf} = 1.34\,ft/s$ $\quad Q = 17.428\,gpm = 0.0388\,cfs$

$h_L = 44.8304ft\left(\frac{1.34\,ft/s}{1.318(150)(0.0484)^{0.63}}\right)^{1/0.54}$ $\quad A = 0.029sf$, $R_H = 0.0484ft$

$h_L = 44.8304ft(0.003295)$

$h_L = 0.1477ft$

Total Dynamic Head Calculations Page 1

Total Dynamic Head Calculations

Friction loss for Mainline:

$V = Q/A = \frac{0.1166\ cfs}{0.029\ sf}$

$L = 228.0116\ ft$

$Q = 52.285\ gpm \times \frac{1\ cfs}{448.48\ gpm} = 0.1166\ cfs$

$ID = 2.29" \times \frac{1\ ft}{12\ in} = 0.191\ ft$

$h_L = 228.0116\ ft \left[\frac{4.021\ \frac{ft}{s}}{1.318(150)(.0484\ ft)^{.63}}\right]^{1/.54}$

$A = \pi \frac{(.191)^2}{4} = 0.029\ ft^2$

$\underline{h_L = 5.749\ ft}$

$R_H = \frac{A}{P_w} = \frac{.029\ sf}{\pi(2.29\ in \times \frac{1\ ft}{12\ in})} = 0.0484\ ft$

Friction loss for lateral:

$V = Q/A = \frac{.01436\ cfs}{.0048\ sf} = 2.99\ \frac{ft}{s}$

$Q = 6.44\ gpm \rightarrow 0.01436\ cfs$

$A = \pi \frac{(.078\ ft)^2}{4} = 0.0048\ sf$

$h_L = 91.8077\ ft \left[\frac{2.99\ ft/s}{1.318(150)(.0196)^{.63}}\right]^{1/.54}$

$L = 91.8077\ ft \qquad ID = .078\ ft$

$R_H = A/P_w = \frac{.0098}{\pi(.078)} = 0.0196\ ft$

$\underline{h_L = 3.842\ ft}$

TDH, ft.

4"

Friction Head = $1.284\ ft + 0.1477\ ft + 5.749\ ft + 3.842\ ft + 2.086\ ft = \underline{13.1087\ ft}$

Elevation Head = $\underline{8\ ft}$ *Assumed

Operating Head = $60\ psi \times \frac{2.31\ ft}{1\ psi} = \underline{138.6\ ft}$

$\boxed{\text{Pump Spec.}\quad 52.285\ gpm\ @\ 160\ ft}$

From Berkeley Pumps → Size: B1-1/2 TRLS

Total Dynamic Head Page 2

Total Dynamic Head Calculations

Friction loss for supply pipe: 4"- SCH 80

$$V = \frac{Q}{A} = \frac{0.1166\,cfs}{0.0785\,ft} = 1.495\,ft/s$$

$L = 350 + 235 = 585\,ft$

$Q = 0.1166\,cfs$

$ID = 3.786'' \times \frac{1\,ft}{12\,in} = 0.3155\,ft$

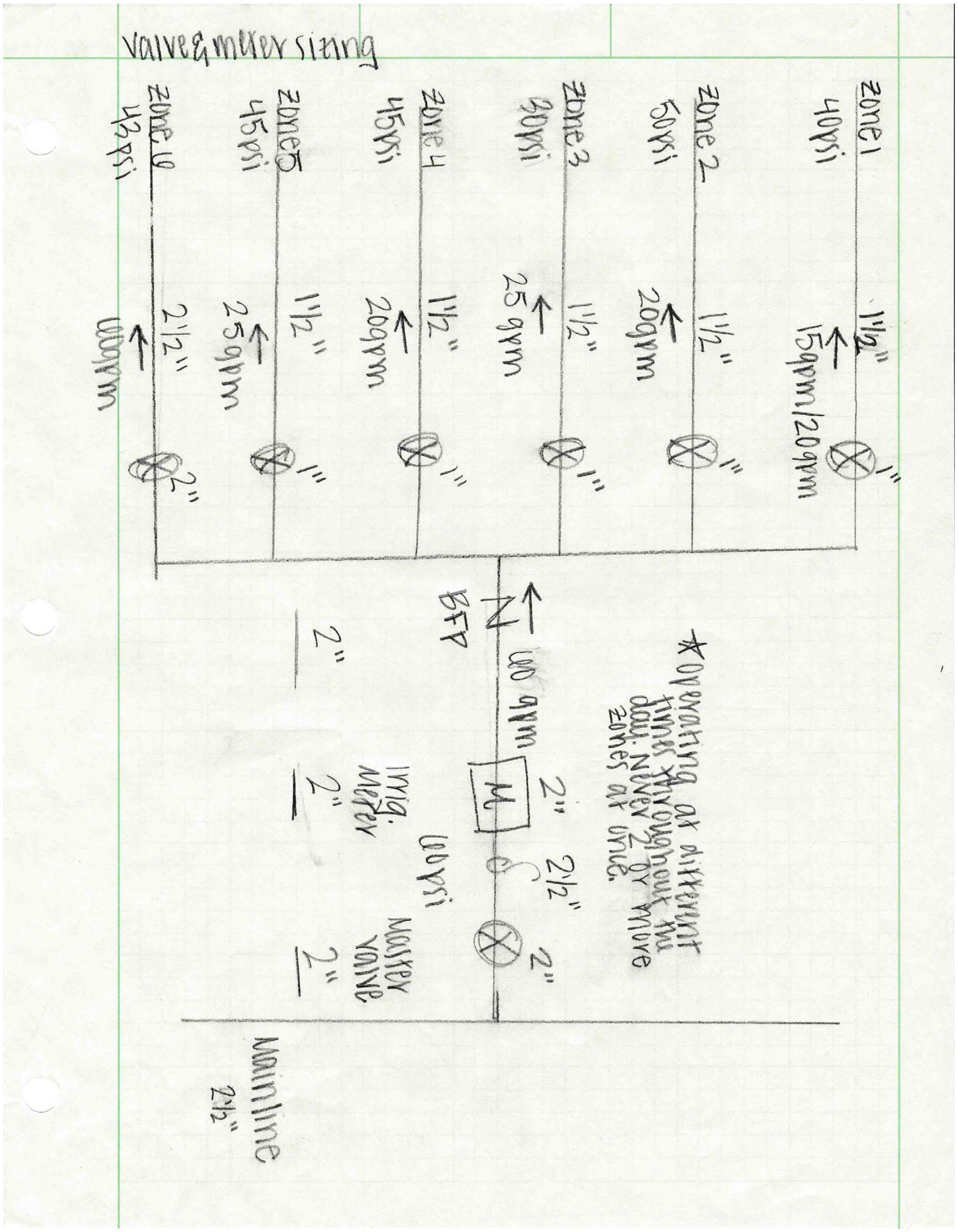
$$h_L = 585\,ft\left[\frac{1.495}{1.318(150)(0.0787)^{0.63}}\right]^{1/0.54}$$

$$A = \frac{\pi(0.3155)^2}{4} = 0.0785\,ft$$

$$h_L = 2.086\,ft$$

$$R_H = \frac{A}{P_W} = \frac{0.078}{\pi(0.3155)} = 0.0787\,ft$$

Total Dynamic Head Page 3



Sizing for Valve & Meter

Cost estimates

Municipal Water Supply

Zone 1: GWR = 0.153 in/day

Zone 4: GWR = 0.2 in/day

Zone 2: GWR = 0.153 in/day

Zone 5: GWR = 0.15 in/day

Zone 3: GWR = 0.15 in/day

Zone 6: GWR = 0.106 in/day

Total Gross Water Requirement Per Day:

$$= 0.153 + 0.153 + 0.15 + 0.15 + 0.2 + 0.15 + 0.106$$

$$= 0.912 \text{ in/day}$$

* 242 assumed days of irrigation *
(Feb. 1st – Oct. 1st)

$$0.912 \text{ in/day} \times \frac{365 \text{ days}}{1 \text{ year}} = 303.6 \text{ in/year}$$

Zone 1: $14.22 \text{ gpm} \times 24 \frac{\text{min}}{\text{day}} = 341.28 \text{ gpd}$

Zone 2: $16.03 \text{ gpm} \times 22 \frac{\text{min}}{\text{day}} = 352.66 \text{ gpd}$

Zone 3: $6 \text{ gpm} \times \frac{90 \text{ min}}{\text{day}} = 540 \text{ gpd}$

Zone 4: $19.64 \text{ gpm} \times 30 \frac{\text{min}}{\text{day}} = 589.2 \text{ gpd}$

Zone 5: $23.08 \text{ gpm} \times 30 \frac{\text{min}}{\text{day}} = 691.2 \text{ gpd}$

Zone 6: $52.285 \text{ gpm} \times 9.2 \frac{\text{min}}{\text{day}} = 481.022 \text{ gpd}$

Σ Zone (1-6) = 2,995.362 GPD

* mutiplied by 242 operating days *

$$2,995.362 \times 242 = 724,877.604 \frac{\text{gallons}}{\text{year}}$$

Total Run Time $= 205.2 \frac{\text{mins}}{\text{day}} \times \frac{1 \text{ hr}}{\text{min}} = 3.42 \frac{\text{hrs}}{\text{day}}$

Water Use Cost Estimates (Zones 1 – 6)

Cost Estimates

Irrigation Pumping Costs

$$BHP = \frac{Q \times H}{3960 \times \eta} = \frac{52.285\,gpm \times 160\,ft}{3960 \times .5193} = 4.07 \text{ HP} \qquad \eta = 51.93\%$$

*Should get a 5 HP motor

Cost of Motor

$$5HP \times \frac{\$150}{HP} = \boxed{\$750}$$

Diesel Pump Operating Cost

$$5\,HP \times 3.42 \frac{hr}{day} \times \frac{\$3.00}{gal} \times \frac{0.0678\,gal}{HP \cdot hr} = \$3.478/day$$

Electric Pump Operating Cost

$$5HP \times 3.42 \frac{hr}{day} \times \frac{\$0.15}{KWH} \times \frac{KWH}{1.18\,HP \cdot hr} = \$2.174/day$$

Savings from Diesel to Electric Pump

$$\$3.478/day - \$2.174/day = \$1.304/day$$

$$\$1.304/day \div \$3.478/day = \boxed{37\%}$$

Irrigation Cost Estimate Comparisons

Cost estimates

$$\frac{\$181}{\text{ac-in}} \times \frac{1 \text{ ac-in}}{27{,}154 \text{ gal}} \times \frac{724877.604 \text{ gallons}}{\text{year}}$$

$$= \$4831.8/\text{year}$$

* savings from using local pond H_2O rather than municipal water *

Cost Per Year (Cost Estimate)

Appendix B: Tables, Maps & Figures

Pressure Loss through Typical Electric Globe Valves
(Loss in pounds per square inch)

Flow (gpm)	1 in.	1½ in.	2 in.
0-4	1.2		
6	1.4		
8	1.6		
10	1.7		
15	2.0		
20	2.3	1.3	
25	3.0	1.6	
30	4.3	1.9	
35	6.0	2.4	
40	7.7	3.0	2.3
45	9.5	3.8	2.4
50	11.5	4.6	2.6
55		5.6	2.7
60		6.7	2.9
70		9.5	3.3
80		10.0	3.4
90			4.2
100			5.2
110			6.7
120			7.7
130			8.8

5 1/2"
10 3/4"
15 1"
25 1 1/4"
35 1 1/2"
55 2"

35 gpm @ 60 psi
50 gpm @ 60 psi

446 Appendix C: Tables

Pressure Loss Through Typical Electric Globe Valves Table

DRIP IRRIGATION DESIGN DATA:

Approximate daily water requirement for individual plants and beds.

Plant (Mature Canopy Diameter)	Water Required Per Day (Avg.)		
	Cool Climate	Warm/Humid Climate	Hot/Arid Climate
Small Shrub (3 ft)	0.3 G	0.5 G	0.8 G
Large Shrub (5 ft)	0.7 G	1.4 G	2.1 G
Small Tree (10 ft)	2.7 G	5.4 G	8.1 G
Large Tree (20 ft)	10.9 G	21.7 G	32.6 G
Ground Cover	0.1 in/day	0.15 in/day	0.2 in/day
Bedding Plants	0.1 in/day	0.15 in/day	0.2 in/day
Container (small)	0.2 G	0.3 G	0.4 G
Container (large)	0.3 G	0.4 G	0.6 G

Approximate size and number of emitters for shrubs and trees.

Emitter	Size of Plant	Emitters Per Plant
0.5 GPH	Young Shrub	2
1 GPH	Small Shrub (3 ft dia.)	2
	Large Shrub (5 ft dia.)	4
2 GPH	Young Tree (4 ft dia.)	2
	Small Tree (10 ft dia.)	4
	Large Tree (20 ft dia.)	10

Above numbers are used as guidelines. Run time flexibility provides a wide range of irrigation depths and frequencies.

Drip Irrigation Design Data Table

Table 2 AVERAGE DAILY WATER NEED OF STANDARD GRASS DURING IRRIGATION SEASON

Source: FAO – Food Agricultural Organization
http://www.fao.org/docrep/S2022E/s2022e02.htm

Climatic zone	Mean daily temperature		
	low	medium	high
	(less than 15°C) (less than 59°F)	(15-25°C) (59-77°F)	(more than 25°C) (more than 77°F)
Desert/arid	4-6 (0.2")	7-8 (0.3")	9-10 (0.4")
Semi arid	4-5 (0.2")	6-7 (0.3")	8-9 (0.3")
Sub-humid	3-4 (0.1")	5-6 (0.2")	7-8 (0.3")
Humid	1-2 (0.1")	3-4 (0.1")	5-6 (0.2")

Example: The standard grass crop grown in a semi-arid climate with a mean temperature of 20°C (68°F) needs approximately 6.5 mm (0.26 in) of water per day. The same grass crop grown in a sub-humid climate with a mean temperature of 30°C (86°F) needs some 7.5 mm (0.30 in) of water per day.

Above daily water need for standard grass crop is also called "reference crop evapotranspiration", ET_{ref}.

Table of Average Daily Water Need of Standard Grass (Irrigation Season)

Caitlyn

Water Meter Pressure Loss Chart

Typical Pressure Losses (psi)

5"

Flow (gpm)	5/8"	3/4"	1"	Nominal size 1-1/2"	2"	3"	4"
1	0.2	0.1					
2	0.3	0.2					
3	0.4	0.3					
4	0.6	0.5	0.1				
5	0.9	0.6	0.2				
6	1.3	0.7	0.3				
7	1.8	0.8	0.4				
8	2.3	1.0	0.5				
9	3.0	1.3	0.6				
10	3.7	1.6	0.7				
11	4.4	1.9	0.8				
12	5.1	2.2	0.9				
13	6.1	2.6	1.0				
14	7.2	3.1	1.1				
15	8.3	3.6	1.2				
16	9.4	4.1	1.4	0.4			
17	10.7	4.6	1.6	0.5			
18	12.0	5.2	1.8	0.6			
19	13.4	5.8	2.0	0.7			
20	15.0	6.5	2.2	0.8			
22		7.9	2.8	1.0			
24		9.5	3.4	1.2			
26		11.2	4.0	1.4			
28		13.0	4.6	1.6			
30		15.0	5.3	1.8	0.7		
32			6.0	2.1	0.8		
34			6.9	2.4	0.9		
36			7.8	2.7	1.0		
38			8.7	3.0	1.2		
40			9.6	3.3	1.3		
42			10.6	3.6	1.4		
44			11.7	3.9	1.5		
46			12.8	4.2	1.6		
48			13.9	4.5	1.7		
50			15.0	4.9	1.9		
52				5.3	2.1		
54				5.7	2.2		
56				6.2	2.3		
58				6.7	2.5		
60				7.2	2.7	1.0	
65				8.3	3.2	1.1	
70				9.8	3.7	1.3	
75				11.3	4.3	1.5	
80				12.8	4.9	1.6	0.7
90				16.1	6.2	2.0	0.8
100				20.0	7.8	2.5	0.9
110					9.5	2.9	1.0
120					11.3	3.4	1.2
130					13.0	3.9	1.4
140					15.1	4.5	1.6
150					17.3	5.1	1.8
160					20.0	5.8	2.1
170						6.5	2.4
180						7.2	2.7
190						8.0	3.0
200						9.0	3.2
220						11.0	3.9
240						13.0	4.7
260						15.0	5.5
280						17.3	6.3
300						20.0	7.2
350							10.0
400							13.0
450							16.2
500							20.0
75% of max meter capacity	15 gpm	22.5 gpm	37.5 gpm	75 gpm	120 gpm	225 gpm	375 gpm

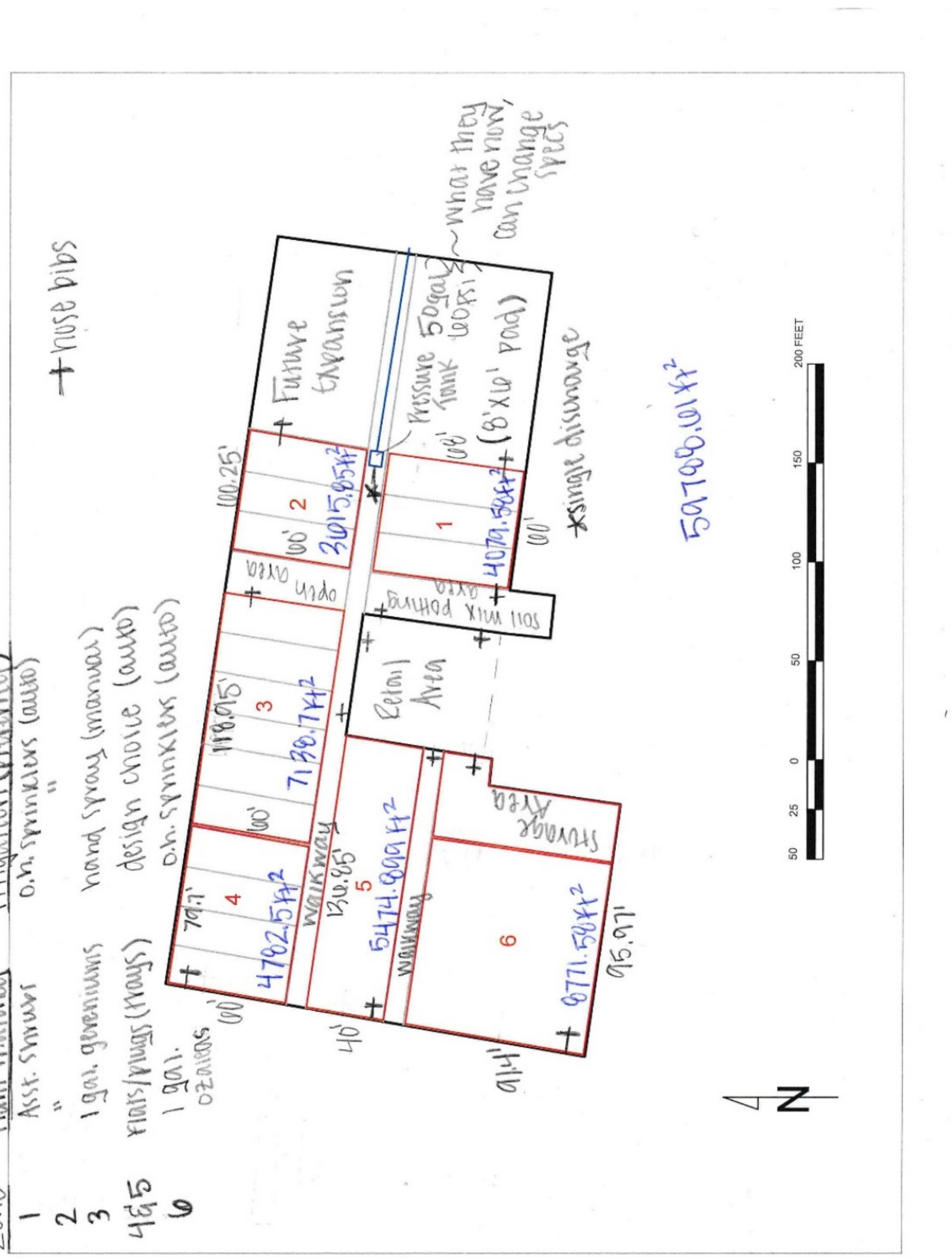
Shaded areas exceed 75% of maximum safe meter capacity.

Water Meter Pressure Loss Chart

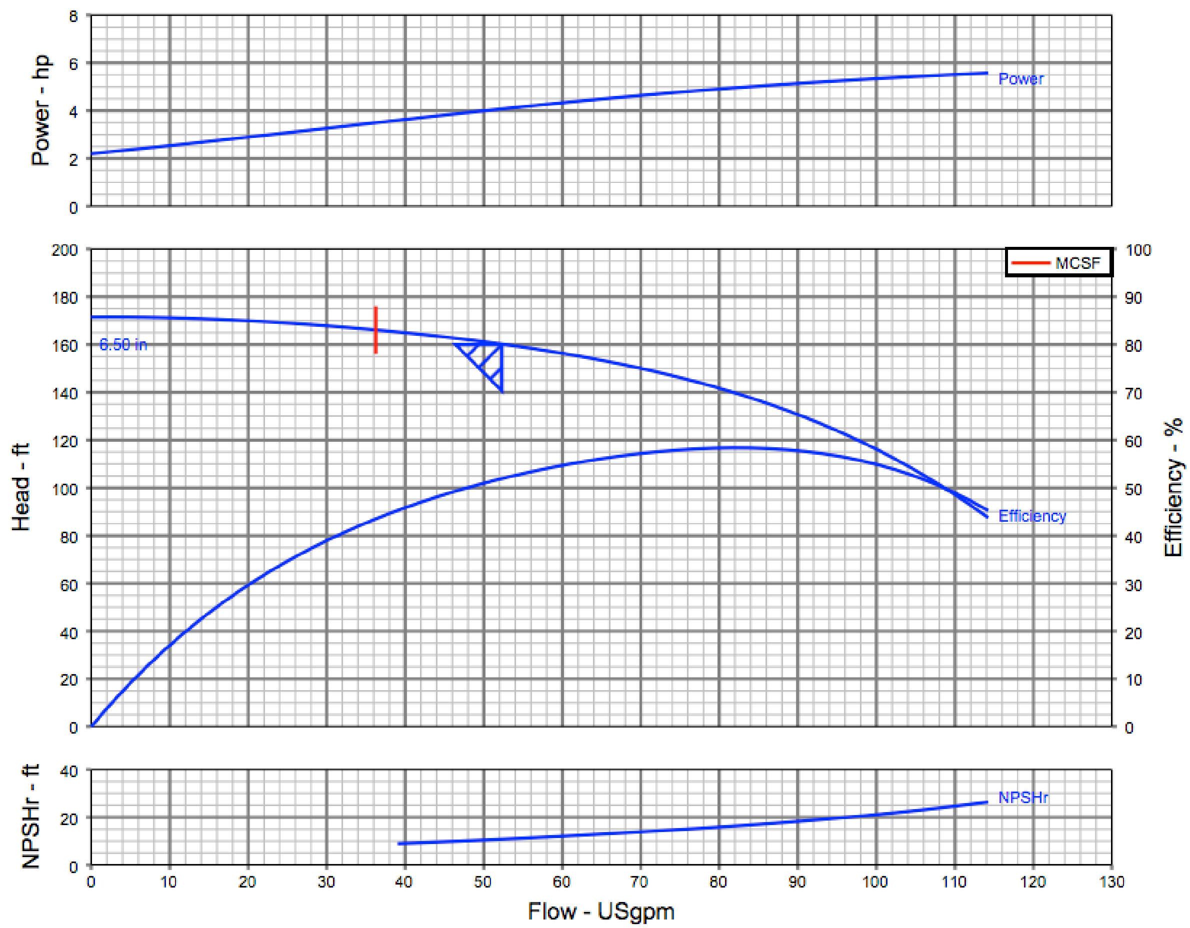
Typical Pressure Loss in Backflow Prevention Devices
{psi}

	Pressure vacuum breaker					Double check assembly					Reduced pressure principle assembly				
gpm	3/4"	1"	1-1/4"	1-1/2"	2"	3/4"	1"	1-1/4"	1-1/2"	2"	3/4"	1"	1-1/4"	1-1/2"	2"
5	3.5					5.5					10.5				
10	4.0					6.0					11.2				
15	4.6	2.9				6.9					11.9				
20	5.5	4.2				8.0	5.5				12.7	12.0			
25	6.5	4.5				8.9	5.7				13.3	12.1			
30	7.5	5.0	4.5			9.5	6.0				14.0	12.2	13.8		
35		5.5	4.8			10.5	6.5				15.1	12.4	13.9		
40		6.0	5.1	3.6		11.5	7.1	6.7			16.9	12.8	14.1		
45		6.6	5.4	3.7			8.0	7.0				13.1	14.3		
50		7.5	5.6	3.8			8.9	7.5				13.7	14.5		
55		8.0	5.9	3.9			9.5	7.7				14.3	14.8		
60		8.5	6.2	4.0	4.5		10.0	8.0	6.8			15.0	15.0	13.7	
70			6.8	4.2	5.0		12.3	8.5	7.0			16.5	15.5	14.0	
80			7.5	4.6	5.1			9.1	7.2				16.0	14.2	13.1
90				4.8	5.3			10.0	7.5				16.8	14.8	13.3
100				5.0	5.6			10.9	7.9	6.5			17.5	15.0	13.5
110				5.5	5.8				8.1	6.8				15.2	13.7
120				5.9	5.9				8.5	7.0				15.8	13.9
130				6.9	6.0				9.0	7.2				16.1	14.1
140					6.1				9.5	7.8				16.9	14.4
150					6.2				10.5	8.1					14.9
160					6.5					8.5					15.1
170					6.8					9.0					15.8
180					7.0					9.4					16.5
190					7.2					9.9					17.1
200					7.5					10.2					18.0

Typical Pressure Loss In Backflow Prevention Devices Chart



Rendering of Collier Greenhouse (By Zone)



B1-1/2TRLS Berkeley Pump Curve

Liquid	
Liquid type	: --Water
Additional liquid description	
Solids diameter, max	0.00 in
Solids concentration, by volume	0.00 %
Temperature, max	68.00 deg F
Fluid density, rated / max	1.000 / 1.000 SG
Viscosity, rated	1.00 cP
Vapor pressure, rated	0.00 psi.a
Cq/Ch/Ce/Cn ANSI/HI 9.6.7-2010	: 1.00 / 1.00 / 1.00 / 1.00
Material	
Material requested	Auto
Material selected	: Not specified
Pressure Data	
Maximum working pressure	: 74.27 psi.g
Maximum allowable working pressure	: 85.00 psi.g
Maximum allowable suction pressure	: N/A
Hydrostatic test pressure	: N/A
Driver & Power Data	
Driver sizing specification	Rated power
Margin over specification	0.00 %
Service factor ✓Use service factor	1.15
Power, hydraulic	: 2.12 hp
Power, rated	: 4.07 hp
Power, maximum, rated diameter	: 5.58 hp
Power reserve (rated / max / sizing spec)	: 41.17 / 3.04 / 41.17 %
Minimum recommended motor rating	: 5.00 hp / 3.73 kW (Fixed)
Size	: B1-1/2TRLS
Stages	: 1
Operating Conditions	
Flow, rated	52.28 USgpm
Differential head / pressure, rated (requested)	160.0 ft
Differential head / pressure, rated (actual)	: 160.2 ft
Suction pressure, rated / max	0.00 / 0.00 psi.g
NPSH available, rated	Ample ft
Frequency	60 Hz
Performance	
Speed criteria	○ Synchronous ● Variable
Speed, rated ☐ set @	3492 rpm
Impeller diameter, rated ☑ set @	6.50 in ☐ Catalog only
Impeller diameter, maximum	: 6.50 in
Impeller diameter, minimum	: 6.50 in
Efficiency	: 51.93 %
NPSH required / margin required	: 10.78 / 0.00 ft
Ns (imp. eye flow) / Nss (imp. eye flow)	: 780 / 3,890 US Units
MCSF	: 36.26 USgpm
Head, maximum, rated diameter	: 171.6 ft
Head rise to shutoff	: 7.06 %
Flow, best eff. point	: 82.16 USgpm
Flow ratio, rated / BEP	: 63.64 %
Diameter ratio (rated / max)	: 100.00 %
Cutwater ratio (rated / cutwater)	: N/A
Head ratio (rated dia / max dia)	: 100.00 %
Selection status	: Acceptable

B1-1/2TRLS Berkeley Pump Specifications

HAYWARD®

Flow of Water Through Schedule 80 Plastic Pipe

DISCHARGE		VELOCITY IN SCHEDULE 80 PLASTIC PIPE FOR WATER @ 60°F VELOCITY							
Gallons / Minute	Cubic Feet / Second	Feet / Second	Feet / Second	Feet / Second	Feet / Second	Feet / Second	Feet / Second	Feet / Second	Feet / Second
			1/4"	3/8"	1/2"	3/4"	1"	1-1/4"	1-1/2"
0.2	0.000446	—	0.824	—	—	—	—	—	—
0.3	0.000668	—	1.237	0.651	0.392	—	—	—	—
0.4	0.000891	—	1.646	0.867	0.529	—	—	—	—
0.5	0.00111	—	2.061	1.083	0.653	0.359	—	—	—
0.6	0.00134	—	2.476	1.303	0.782	0.431	—	—	—
0.8	0.00178	—	3.295	1.728	1.043	0.574	—	—	—
1	0.00223	—	4.122	2.167	1.311	0.718	0.435	—	—
2	0.00446	—	8.245	4.335	2.609	1.432	0.871	0.525	—
3	0.00668	—	12.381	6.502	3.919	2.161	1.306	0.788	0.538
4	0.00891	2"	16.502	8.671	5.218	2.876	1.747	1.051	0.717
5	0.01114	—	—	10.837	6.528	3.592	2.181	1.313	0.896
6	0.01337	0.65	2-1/2"	13.005	7.827	4.308	2.614	1.579	1.076
8	0.01782	0.86	—	—	10.448	5.741	3.482	2.105	1.434
10	0.02228	1.08	0.752	3"	13.057	7.185	4.351	2.632	1.798
15	0.03342	1.61	1.134	—	—	10.778	6.531	3.941	2.697
20	0.04456	2.15	1.505	0.986	—	—	8.712	5.252	3.596
25	0.0557	2.69	1.886	1.238	—	4"	10.881	6.574	4.484
30	0.06684	3.23	2.256	1.476	—	—	13.062	7.884	5.383
35	0.07798	3.78	2.638	1.726	—	0.973	15.232	9.193	6.282
40	0.08912	4.32	3.009	1.976	—	1.114	17.413	10.515	7.171
45	0.1003	4.84	3.391	2.215	—	1.247	—	11.838	8.069
50	0.1114	5.39	3.761	2.465	—	1.391	—	13.147	8.969
60	0.1337	6.47	4.513	2.953	—	1.665	—	15.779	10.778
70	0.156	7.55	5.266	3.453	—	1.942	—	—	12.577
80	0.1782	8.62	6.018	3.942	—	2.228	—	6"	14.36
90	0.2005	9.69	6.771	4.442	—	2.504	—	—	16.162
100	0.2228	10.77	7.523	4.931	—	2.781	—	1.225	17.96
125	0.2785	13.48	9.409	6.168	—	3.475	—	1.534	22.445
150	0.3342	16.18	11.284	7.395	—	4.171	—	1.893	—
175	0.3899	18.87	13.171	8.633	—	4.865	—	2.141	8"
200	0.4456	21.56	15.068	9.861	—	5.561	—	2.451	—
225	0.5013	—	16.943	11.098	—	6.255	—	2.759	1.577
250	0.557	—	—	12.325	—	6.951	—	3.069	1.752
275	0.6127	—	—	13.563	—	7.645	—	3.367	1.927
300	0.6684	—	—	14.768	—	8.341	—	3.675	2.102
325	0.7241	—	—	16.041	—	9.035	—	3.985	2.277
350	0.7798	—	—	—	—	9.731	—	4.294	2.453
375	0.8355	—	—	—	—	10.425	—	4.592	2.628
400	0.8912	—	—	—	—	11.121	—	4.901	2.803
425	0.9469	10"	—	—	—	11.815	—	5.211	2.989
450	1.003	—	—	—	—	12.511	—	5.519	3.164
475	1.059	2.199	—	—	—	13.205	—	5.817	3.329
500	1.114	2.229	—	—	—	13.901	—	6.126	3.515
550	1.225	2.459	—	—	—	15.279	—	6.744	3.865
600	1.337	2.679	12"	—	—	16.681	—	7.352	4.215
650	1.225	2.899	—	—	—	—	—	7.971	4.566
700	1.56	3.129	2.205	—	—	—	—	8.588	4.916
750	1.671	3.349	2.359	—	—	—	—	9.195	5.267
800	1.56	3.569	2.513	—	—	—	—	9.802	5.617
850	1.782	3.799	2.677	—	—	—	—	10.421	5.968
900	2.005	4.019	2.831	—	—	—	—	11.028	6.318
950	2.117	4.239	2.984	—	—	—	—	11.646	6.668
1000	2.228	4.469	3.149	—	—	—	—	12.253	7.019
1100	2.451	4.919	3.458	—	—	—	—	13.489	7.719
1200	2.674	5.359	3.775	—	—	—	—	14.715	8.431
1300	2.896	5.809	4.093	—	—	—	—	15.929	9.121
1400	3.119	6.259	4.401	—	—	—	—	17.165	9.833
1500	3.342	6.698	4.718	—	—	—	—	18.391	10.534
1600	3.565	7.148	5.037	—	—	—	—	19.611	11.235
1800	4.01	8.038	5.662	—	—	—	—	22.067	12.636
2000	4.456	8.938	6.228	—	—	—	—	24.517	14.038
2500	5.57	11.168	7.868	—	—	—	—	—	17.552
3000	6.684	13.396	9.437	—	—	—	—	—	21.068
3500	7.798	15.637	11.006	—	—	—	—	—	24.572
4000	8.912	17.866	12.587	—	—	—	—	—	28.08
4500	10.13	20.106	14.156	—	—	—	—	—	31.613
5000	11.14								
6000	13.37								
7000	15.6								
8000	17.82								
9000	20.05								
10000	22.28								
12000	26.74								

The following wave surge constants may be used to quickly calculate pressure rise due to water hammer where: "C"= the wave surge constant from the table below multiplied by "V" the line velocity in feet per second. The resultant number is then added to the line pressure to determine the resulting wave surge (Water Hammer Effect).

Pipe Size	1/4"	1/2"	3/4"	1"	1-1/2"	2"	3"	4"	6"	8"	10"	12"
Constant	40	35	32	31	27	25	23	23	21	20	19	19

Maximum recommended fluid velocity is 8 feet per second (solenoid valves 5 feet per second)

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FILTER BAGS

Flow of Water Through Schedule 80 Plastic Pipe Table

MP ROTATOR DESIGN GUIDE

MP800 Series

MP ROTATOR PERFORMANCE DATA

MP800SR
Radius: 6' to 12'
Adjustable Arc and Full-Circle
● Orange and Gray: 90° to 210°
● Lime Green and Gray: 360°

Arc	Pressure PSI	MAX RADIUS Radius ft.	Flow GPM	Flow GPH	Precip in/hr ■	Precip in/hr ▲	MIN RADIUS Radius ft.	Flow GPM
90°	30	8	0.17	9.6	0.90	1.04	6	0.13
	35	9	0.21	11.4	0.89	1.03	7	0.15
	40	**10**	**0.23**	**13.8**	**0.83**	**0.96**	**8**	**0.16**
	45	11	0.25	15.0	0.80	0.92	8	0.18
	50	11	0.27	16.2	0.79	0.92	9	0.19
	55	12	0.28	16.8	0.80	0.93	10	0.20
180°	30	8	0.33	19.2	0.88	1.02	6	0.26
	35	9	0.38	22.2	0.85	0.99	7	0.29
	40	**10**	**0.42**	**25.2**	**0.81**	**0.93**	**8**	**0.32**
	45	11	0.46	27.6	0.77	0.88	8	0.36
	50	11	0.48	28.8	0.76	0.88	9	0.38
	55	12	0.50	30.0	0.73	0.84	10	0.40
210°	30	8	0.35	22.2	0.80	0.93	6	0.30
	35	9	0.38	26.4	0.77	0.89	7	0.34
	40	**10**	**0.43**	**29.4**	**0.81**	**0.91**	**8**	**0.37**
	45	10	0.45	31.8	0.82	0.95	8	0.42
	50	11	0.49	33.6	0.73	0.85	9	0.44
	55	12	0.56	34.8	0.70	0.81	10	0.47
360°	30	8	0.66	37.8	0.89	1.03	6	0.47
	35	9	0.71	42.0	0.80	0.92	7	0.52
	40	**10**	**0.78**	**46.8**	**0.79**	**0.91**	**8**	**0.56**
	45	10	0.85	51.0	0.78	0.90	8	0.59
	50	11	0.88	52.8	0.73	0.85	9	0.63
	55	12	0.98	58.8	0.70	0.81	10	0.70

Due to its precipitation rate of approximately 0.8 in/hr, we strongly recommend zoning the MP800 Series separately from the Standard MP Rotator Series.

MP ROTATOR PERFORMANCE DATA

MP815
Radius: 8' to 16'
Adjustable Arc and Full-Circle
● Maroon and Gray: 90° to 210°
● Lt. Blue and Gray: 210° to 270°
● Olive and Gray: 360°

Arc	Pressure PSI	Radius ft.	Flow GPM	Flow GPH	Precip in/hr ■	Precip in/hr ▲
90°	30	14	0.42	25.2	0.83	0.95
	35	15	0.46	27.6	0.79	0.91
	40	**15**	**0.49**	**29.4**	**0.84**	**0.97**
	45	16	0.52	31.2	0.78	0.90
	50	16	0.55	33.0	0.83	0.96
	55	16	0.58	34.8	0.87	1.01
180°	30	13	0.75	45.0	0.85	0.99
	35	14	0.86	51.6	0.84	0.98
	40	**15**	**0.93**	**55.8**	**0.80**	**0.92**
	45	15	0.96	57.6	0.82	0.95
	50	16	1.06	63.6	0.80	0.92
	55	16	1.11	66.6	0.83	0.96
210°	30	13	0.88	52.8	0.86	0.99
	35	14	0.96	57.6	0.81	0.93
	40	**15**	**1.10**	**66.0**	**0.81**	**0.93**
	45	15	1.16	69.6	0.85	0.98
	50	16	1.24	74.4	0.80	0.92
	55	16	1.30	78.0	0.84	0.97
270°	30	13	1.14	68.4	0.87	1.00
	35	14	1.24	74.4	0.81	0.94
	40	**15**	**1.40**	**84.0**	**0.80**	**0.92**
	45	15	1.47	88.2	0.84	0.97
	50	16	1.54	92.4	0.77	0.89
	55	16	1.61	96.6	0.81	0.93
360°	30	13	1.52	91.2	0.87	1.00
	35	14	1.70	102.0	0.83	0.96
	40	**15**	**1.87**	**112.2**	**0.80**	**0.92**
	45	15	2.00	120.0	0.86	0.99
	50	16	2.13	127.8	0.80	0.92
	55	16	2.26	135.6	0.85	0.98

PERFORMANCE DATA NOTE FOR ALL CHARTS:

Bold = Recommended Pressure.

The MP Rotator is designed to maintain matched precipitation after radius adjustment. Optimal pressure for the MP Rotator is 40 PSI. This can be achieved easily by using the MP Rotator with the Pro-Spray PRS40 Spray Body, pressure regulated at 40 PSI.

MP800 Rotator Design Guide Chart

MP ROTATOR DESIGN GUIDE

MP1000, MP2000, MP3000, MP3500

MP ROTATOR PERFORMANCE DATA

MP1000 — Radius: 8' to 15'; Adjustable Arc and Full-Circle; ● Maroon: 90° to 210°; ● Lt. Blue: 210° to 270°; ● Olive: 360°

MP2000 — Radius: 13' to 21'; Adjustable Arc and Full-Circle; ● Black: 90° to 210°; ● Green: 210° to 270°; ● Red: 360°

MP3000 — Radius: 22' to 30'; Adjustable Arc and Full-Circle; ● Blue: 90° to 210°; ● Yellow: 210° to 270°; ● Gray: 360°

Arc	Pressure PSI	MP1000 Radius ft.	Flow GPM	Flow GPH	Precip in/hr ■	Precip in/hr ▲	MP2000 Radius ft.	Flow GPM	Flow GPH	Precip in/hr ■	Precip in/hr ▲	MP3000 Radius ft.	Flow GPM	Flow GPH	Precip in/hr ■	Precip in/hr ▲
90°	25	--	--	--	--	--	17	0.34	20.4	0.45	0.52	25	0.71	42.6	0.44	0.51
	30	12	0.17	10.2	0.45	0.52	18	0.38	22.8	0.45	0.52	27	0.76	45.6	0.40	0.46
	35	13	0.19	11.4	0.43	0.50	19	0.40	24.0	0.43	0.49	28	0.82	49.2	0.40	0.46
	40	**14**	**0.21**	**12.6**	**0.41**	**0.48**	**20**	**0.43**	**25.8**	**0.41**	**0.48**	**30**	**0.86**	**51.6**	**0.37**	**0.42**
	45	14	0.23	13.8	0.45	0.52	21	0.46	27.6	0.40	0.46	30	0.90	54.0	0.39	0.44
	50	15	0.25	15.0	0.43	0.49	21	0.47	28.2	0.41	0.47	30	0.95	57.0	0.41	0.47
	55	15	0.27	16.2	0.46	0.53	21	0.48	28.8	0.42	0.48	30	1.01	60.6	0.43	0.50
180°	25	--	--	--	--	--	16	0.6	36.0	0.45	0.52	25	1.44	86.4	0.44	0.51
	30	12	0.34	20.4	0.45	0.52	17	0.64	38.4	0.43	0.49	27	1.58	94.8	0.42	0.48
	35	13	0.38	22.8	0.43	0.50	18	0.71	42.6	0.42	0.49	28	1.70	102.0	0.42	0.48
	40	**14**	**0.42**	**25.2**	**0.41**	**0.48**	**19**	**0.77**	**46.2**	**0.41**	**0.47**	**30**	**1.82**	**109.2**	**0.39**	**0.45**
	45	14	0.44	26.4	0.43	0.50	20	0.85	51.0	0.41	0.47	30	1.93	115.8	0.41	0.48
	50	15	0.50	30.0	0.43	0.49	21	0.91	54.6	0.40	0.46	30	2.04	122.4	0.44	0.50
	55	15	0.51	30.6	0.44	0.50	21	0.95	57.0	0.41	0.48	30	2.13	127.8	0.46	0.53
210°	25	--	--	--	--	--	16	0.72	43.2	0.46	0.54	25	1.68	100.8	0.44	0.51
	30	12	0.40	24.0	0.46	0.53	17	0.75	45.0	0.43	0.49	27	1.84	110.4	0.42	0.48
	35	13	0.45	27.0	0.44	0.51	18	0.81	48.6	0.41	0.48	28	1.99	119.4	0.42	0.48
	40	**14**	**0.49**	**29.4**	**0.41**	**0.48**	**19**	**0.86**	**51.6**	**0.39**	**0.45**	**30**	**2.12**	**127.2**	**0.39**	**0.45**
	45	14	0.51	30.6	0.43	0.50	20	0.91	54.6	0.38	0.43	30	2.25	135.0	0.41	0.48
	50	15	0.57	34.2	0.42	0.48	21	0.98	58.8	0.37	0.42	30	2.37	142.2	0.43	0.50
	55	15	0.59	35.4	0.43	0.50	21	1.01	60.6	0.38	0.44	30	2.49	149.4	0.46	0.53
270°	25	--	--	--	--	--	16	0.87	52.2	0.44	0.50	25	2.19	131.4	0.45	0.52
	30	12	0.48	28.8	0.43	0.49	17	0.95	57.0	0.42	0.49	27	2.37	142.2	0.42	0.48
	35	13	0.53	31.8	0.40	0.46	18	1.03	61.8	0.41	0.47	28	2.55	153.0	0.42	0.48
	40	**14**	**0.63**	**37.8**	**0.41**	**0.48**	**19**	**1.10**	**66.0**	**0.39**	**0.45**	**30**	**2.73**	**163.8**	**0.39**	**0.45**
	45	14	0.67	40.2	0.44	0.51	20	1.17	70.2	0.38	0.43	30	2.89	173.4	0.41	0.48
	50	15	0.72	43.2	0.41	0.47	21	1.23	73.8	0.36	0.41	30	3.06	183.6	0.44	0.50
	55	15	0.75	45.0	0.43	0.49	21	1.30	78.0	0.38	0.44	30	3.22	193.2	0.46	0.53
360°	25	--	--	--	--	--	16	1.20	72.0	0.45	0.52	25	2.88	172.8	0.44	0.51
	30	12	0.69	41.4	0.46	0.53	17	1.28	76.8	0.43	0.49	27	3.15	189.0	0.42	0.48
	35	13	0.77	46.2	0.44	0.51	18	1.37	82.2	0.41	0.47	28	3.40	204.0	0.42	0.48
	40	**14**	**0.84**	**50.4**	**0.41**	**0.48**	**19**	**1.48**	**88.8**	**0.39**	**0.46**	**30**	**3.64**	**218.4**	**0.39**	**0.45**
	45	14	0.88	52.8	0.43	0.50	20	1.57	94.2	0.38	0.44	30	3.86	231.6	0.41	0.48
	50	15	0.98	58.8	0.42	0.48	21	1.68	100.8	0.37	0.42	30	4.07	244.2	0.44	0.50
	55	15	1.01	60.6	0.43	0.50	21	1.74	104.4	0.38	0.44	30	4.27	256.2	0.46	0.53

MP3500 90° — Radius: 31' to 35'; Adjustable Arc; ● Light Brown: 90°

MP3500 180° — Radius: 31' to 35'; Adjustable Arc; ● Light Brown: 180°

MP3500 210° — Radius: 31' to 35'; Adjustable Arc; ● Light Brown: 210°

Pressure PSI	90° Radius ft.	Flow GPM	Flow GPH	Precip in/hr ■	Precip in/hr ▲	180° Radius ft.	Flow GPM	Flow GPH	Precip in/hr ■	Precip in/hr ▲	210° Radius ft.	Flow GPM	Flow GPH	Precip in/hr ■	Precip in/hr ▲
25	33	1.04	62.4	0.37	0.42	33	2.21	132.6	0.39	0.45	33	2.59	155.4	0.39	0.45
30	34	1.13	67.8	0.38	0.43	34	2.24	134.4	0.37	0.43	34	2.84	170.4	0.41	0.47
35	34	1.21	72.6	0.40	0.47	34	2.65	159.0	0.44	0.51	34	3.08	184.8	0.44	0.51
40	**35**	**1.28**	**76.8**	**0.40**	**0.46**	**35**	**2.86**	**171.6**	**0.45**	**0.52**	**35**	**3.29**	**197.4**	**0.44**	**0.51**
45	35	1.38	82.8	0.43	0.50	35	3.10	186.0	0.49	0.56	35	3.54	212.4	0.48	0.55
50	35	1.43	85.8	0.45	0.52	35	3.21	192.6	0.50	0.58	35	3.76	225.6	0.51	0.59
55	35	1.50	90.0	0.47	0.54	35	3.28	196.8	0.52	0.60	35	3.94	236.4	0.53	0.61

MP Rotator Design Guide Chart (MP1000, MP2000, MP3000, MP3500)

R-VAN Adjustable Rotary Nozzles

Tech Spec

Adjustable Arc Nozzles (45° to 270°)

R-VAN14 8' - 14' (2.4 to 4.6m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	Precip. (in/h) ▲
270°	30	13	0.84	0.64	0.76
	35	13	0.87	0.66	0.74
	40	14	0.92	0.60	0.71
	45	**14**	**0.94**	**0.62**	**0.70**
	50	15	1.11	0.63	0.73
	55	15	1.17	0.67	0.77
210°	30	13	0.65	0.64	0.76
	35	13	0.68	0.66	0.74
	40	14	0.72	0.60	0.71
	45	**14**	**0.73**	**0.62**	**0.70**
	50	15	0.86	0.63	0.73
	55	15	0.91	0.67	0.77
180°	30	13	0.56	0.64	0.76
	35	13	0.58	0.66	0.74
	40	14	0.61	0.60	0.71
	45	**14**	**0.63**	**0.62**	**0.70**
	50	15	0.74	0.63	0.73
	55	15	0.78	0.67	0.77
90°	30	13	0.28	0.64	0.76
	35	13	0.29	0.66	0.74
	40	14	0.31	0.62	0.71
	45	**14**	**0.32**	**0.61**	**0.70**
	50	15	0.37	0.63	0.73
	55	15	0.39	0.67	0.77

R-VAN18 13' - 18' (4.0 to 5.5m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	Precip. (in/h) ▲
270°	30	16	1.26	0.65	0.75
	35	16	1.35	0.64	0.74
	40	17	1.42	0.63	0.73
	45	**17**	**1.51**	**0.64**	**0.73**
	50	18	1.57	0.60	0.69
	55	18	1.62	0.60	0.69
210°	30	16	0.98	0.63	0.73
	35	16	1.05	0.68	0.78
	40	17	1.10	0.63	0.73
	45	**17**	**1.17**	**0.64**	**0.77**
	50	18	1.22	0.62	0.72
	55	18	1.26	0.64	0.74
180°	30	16	0.85	0.65	0.75
	35	16	0.91	0.64	0.74
	40	17	0.98	0.63	0.73
	45	**17**	**1.01**	**0.64**	**0.73**
	50	18	1.07	0.60	0.69
	55	18	1.09	0.60	0.69
90°	30	16	0.42	0.65	0.75
	35	16	0.47	0.64	0.74
	40	17	0.50	0.63	0.73
	45	**17**	**0.50**	**0.64**	**0.73**
	50	18	0.54	0.60	0.69
	55	18	0.58	0.60	0.69

R-VAN24 17' - 24' (5.2 to 7.3m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	Precip. (in/h) ▲
270°	30	19	1.80	0.64	0.74
	35	20	1.95	0.63	0.72
	40	22	2.31	0.61	0.71
	45	**23**	**2.52**	**0.61**	**0.71**
	50	24	2.82	0.63	0.73
	55	24	2.88	0.64	0.74
210°	30	19	1.40	0.64	0.74
	35	20	1.52	0.63	0.72
	40	22	1.80	0.61	0.71
	45	**23**	**1.96**	**0.61**	**0.71**
	50	24	2.19	0.63	0.73
	55	24	2.24	0.64	0.74
180°	30	19	1.20	0.64	0.74
	35	20	1.30	0.63	0.72
	40	22	1.54	0.61	0.71
	45	**23**	**1.68**	**0.61**	**0.71**
	50	24	1.88	0.63	0.73
	55	24	1.92	0.64	0.74
90°	30	19	0.60	0.64	0.74
	35	20	0.65	0.63	0.72
	40	22	0.77	0.61	0.71
	45	**23**	**0.84**	**0.61**	**0.71**
	50	24	0.94	0.63	0.73
	55	24	0.96	0.64	0.74

Full Circle Nozzles (360°)

R-VAN14-360 8' - 14' (2.4 to 4.6m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	Precip. (in/h) ▲
360°	30	13	1.10	0.63	0.72
	35	13	1.12	0.64	0.74
	40	14	1.22	0.60	0.69
	45	**14**	**1.27**	**0.62**	**0.72**
	50	15	1.41	0.60	0.70
	55	15	1.45	0.62	0.72

R-VAN18-360 13' - 18' (4.0 to 5.5m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	Precip. (in/h) ▲
360°	30	16	1.65	0.62	0.72
	35	16	1.67	0.63	0.73
	40	17	1.80	0.60	0.69
	45	**17**	**1.85**	**0.62**	**0.71**
	50	18	2.05	0.61	0.70
	55	18	2.11	0.63	0.72

R-VAN24-360 17' - 24' (5.2 to 7.3m)

Arc	Pressure psi	Radius ft.	Flow gpm	Precip. (in/h) ■	Precip. (in/h) ▲
360°	30	19	2.35	0.63	0.72
	35	20	2.52	0.61	0.70
	40	22	3.13	0.62	0.72
	45	**23**	**3.48**	**0.63**	**0.73**
	50	24	3.61	0.60	0.70
	55	24	3.74	0.62	0.72

Strip Nozzles (Left Corner, Side, Right Corner)

R-VAN-LCS 5' x 15' (1.5 x 4.6m)

Arc	Pressure psi	Size ft.	Flow gpm	Precip. (in/h) –	Precip. (in/h) ▲
Left Corner Strip	30	4'x14'	0.18	0.62	0.62
	35	5'x15'	0.22	0.56	0.56
	40	5'x15'	0.23	0.59	0.59
	45	**5'x15'**	**0.24**	**0.62**	**0.62**
	50	5'x15'	0.25	0.64	0.64
	55	6'x16'	0.28	0.56	0.56

R-VAN-SST 5' x 30' (1.5 x 9.1m)

Arc	Pressure psi	Size ft.	Flow gpm	Precip. (in/h) –	Precip. (in/h) ▲
Side Strip	30	4'x28'	0.36	0.62	0.62
	35	5'x30'	0.44	0.56	0.56
	40	5'x30'	0.46	0.59	0.59
	45	**5'x30'**	**0.48**	**0.62**	**0.62**
	50	5'x30'	0.50	0.64	0.64
	55	6'x32'	0.56	0.56	0.56

R-VAN-RCS 5' x 15' (1.5 x 4.6m)

Arc	Pressure psi	Size ft.	Flow gpm	Precip. (in/h) –	Precip. (in/h) ▲
Right Corner Strip	30	4'x14'	0.18	0.62	0.62
	35	5'x15'	0.22	0.56	0.56
	40	5'x15'	0.23	0.59	0.59
	45	**5'x15'**	**0.24**	**0.62**	**0.62**
	50	5'x15'	0.25	0.64	0.64
	55	6'x16'	0.28	0.56	0.56

Note: *All R-VAN nozzles tested on 4" (10.2 cm) pop-ups*
Performance data taken in zero wind conditions
Note: *Radius reduction over 25% of the normal throw of the nozzle is not recommended*

■ *Square spacing based on 50% diameter of throw for 14', 18', and 24'*
▲ *Triangular spacing based on 50% diameter of throw for 14', 18' and 24'*
– *Straight-line spacing based on 50% overlap of throw for LCS, SST, and RCS*
▲ *Triangular spacing based on 50% overlap of throw for LCS, SST, and RCS*

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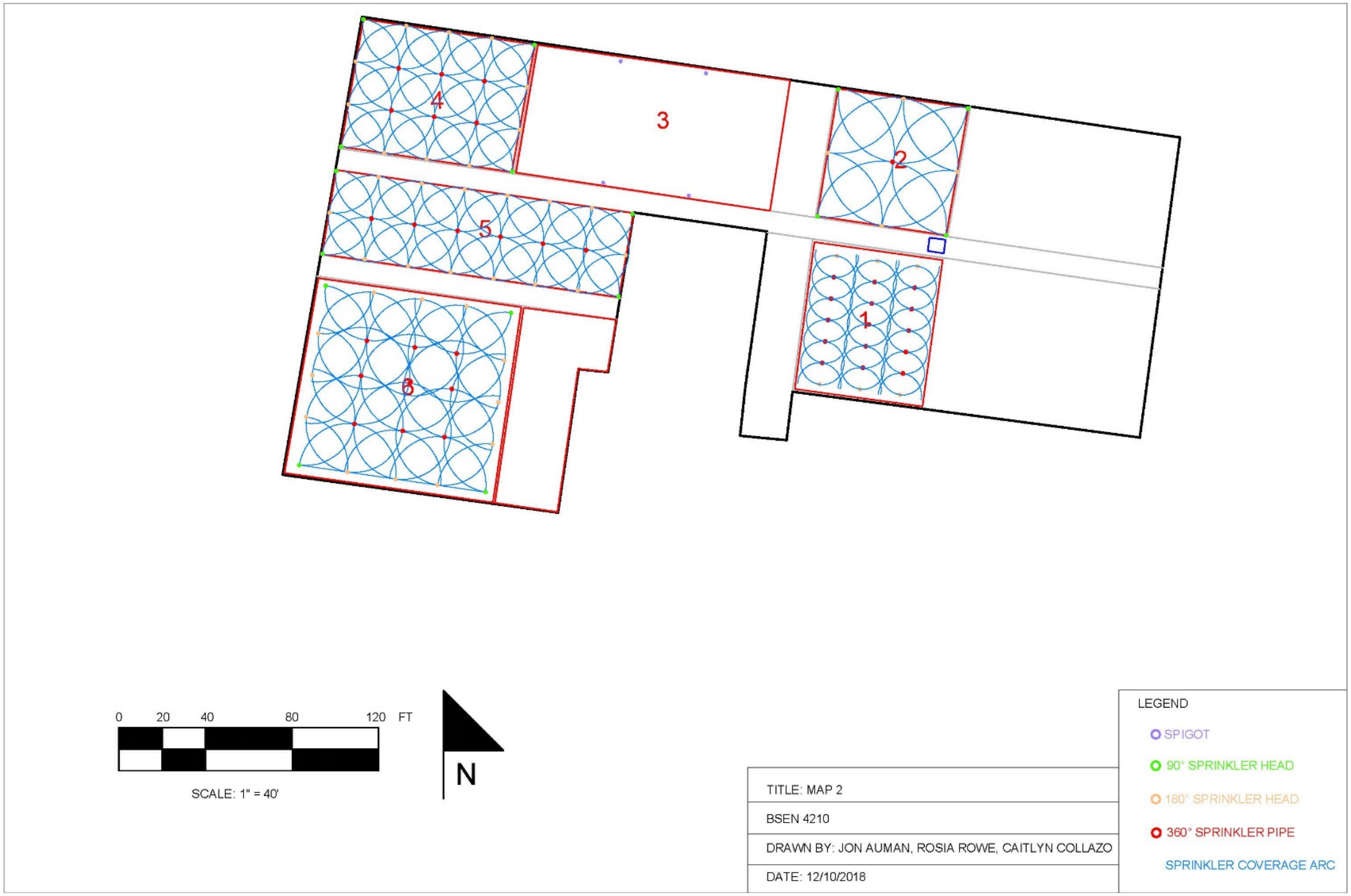
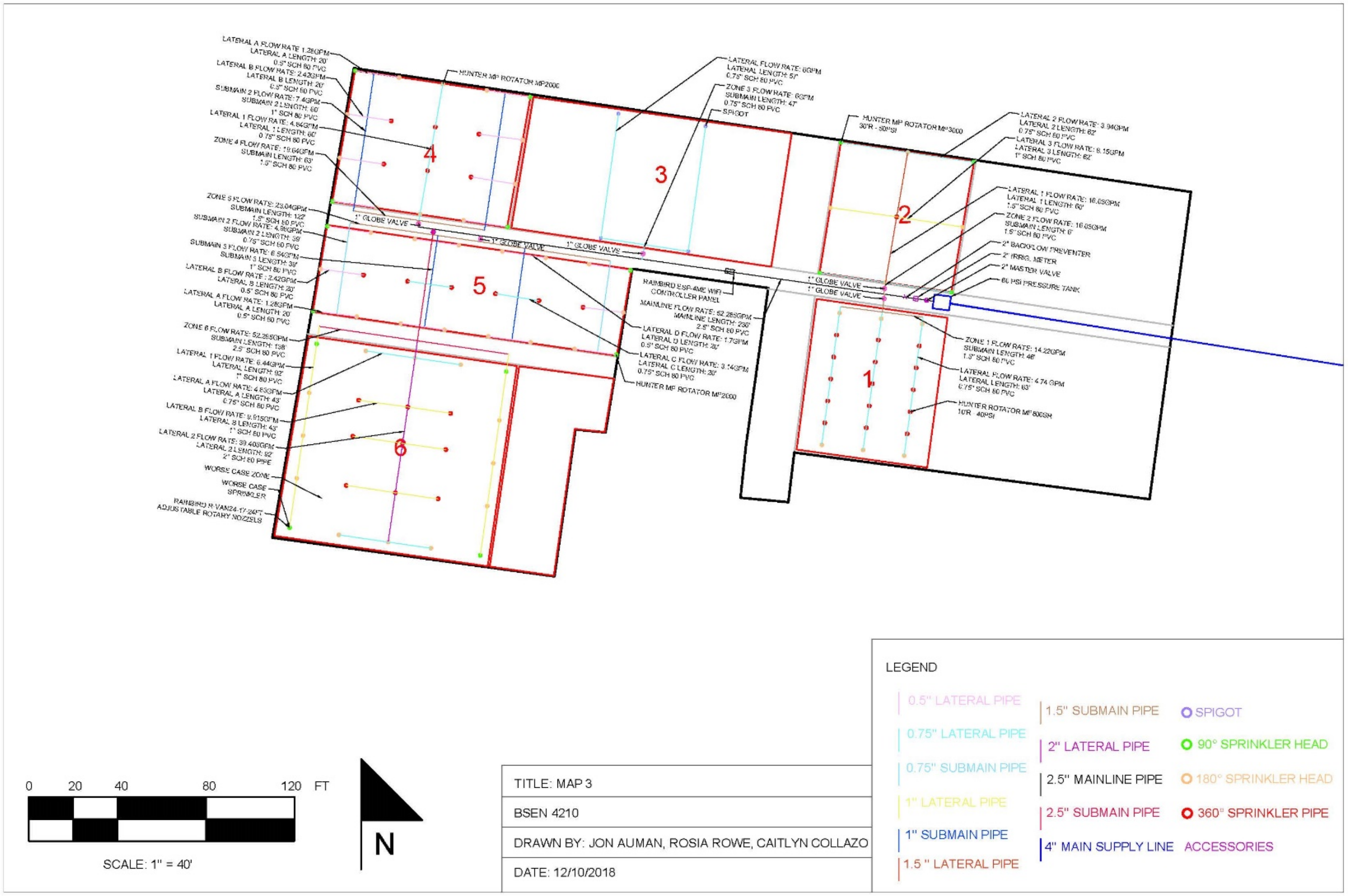
Specifications for R-Van Adjustable Rotary Nozzles

Appendix C: Maps

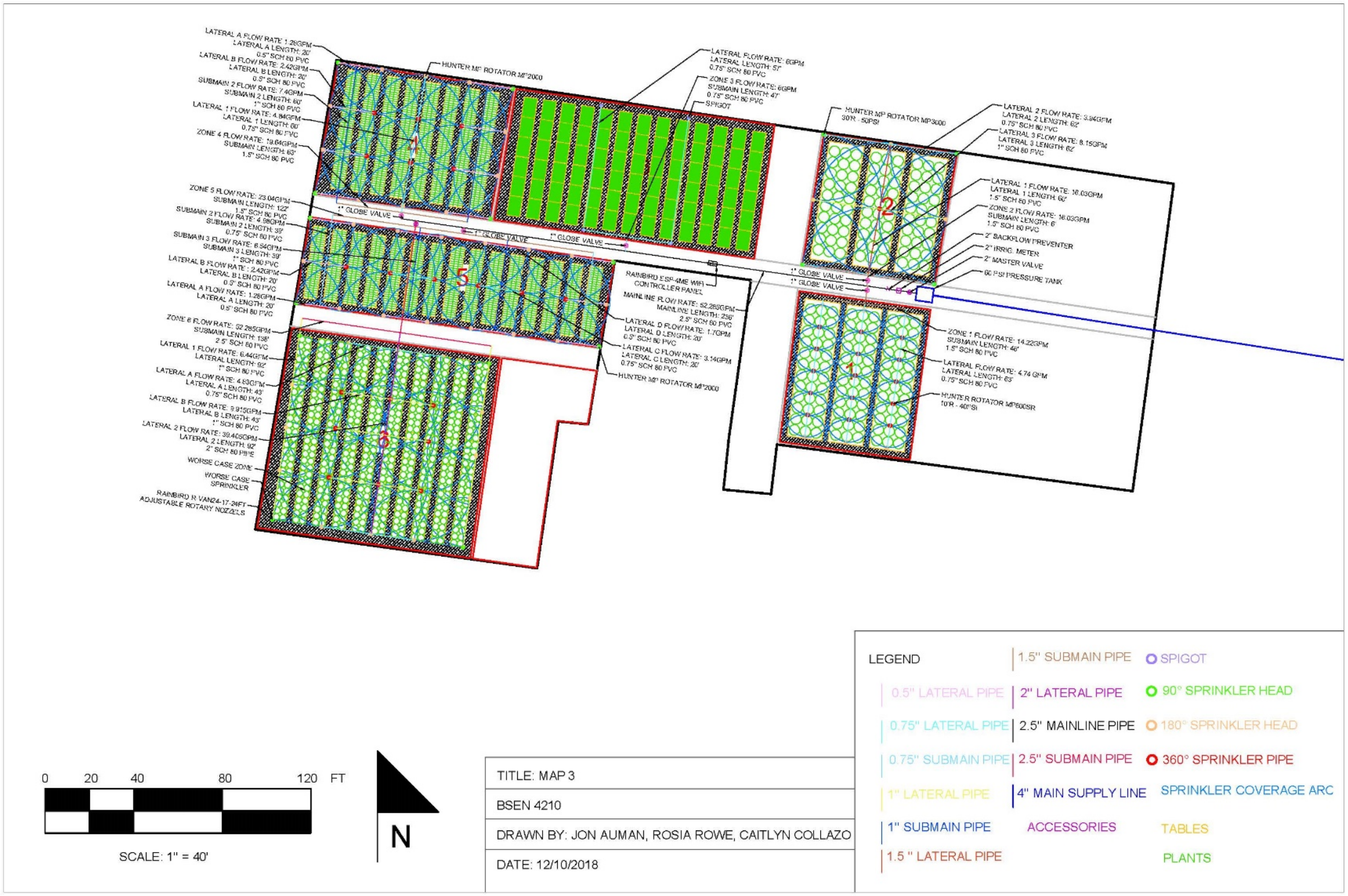
Map 1: Tables and Arrays of Plants in Each Zone



Map 2: Sprinkler Types & Locations



Map 3: Main, Submain, and Lateral pipe size specifications for each zone



Map 4: Final Collier Greenhouse Retrofit Design

Original Assignment

BSEN 4210 – Irrigation System Design

<u>Design Project Assignment – Final Report (150 points)</u>
Due date: Friday, Dec. 7, 2018, 4:45pm

Your design team has been retained to provide a preliminary engineering report for a greenhouse irrigation system retrofit at Collier's Greenhouse in Jackson, GA (Fig. 1). Partial cost estimate and scale ACAD design drawings will be required as part of your engineering report (one report per design team).

<u>Instructions</u>: Review existing aerial and CAD mapping provided (Fig. 1) for the proposed greenhouse irrigation and pumping project in Jackson, GA. Revise ACAD basemap as necessary to show your final design recommendations to scale. Report~~s~~ should include a partial cost estimate for immediate improvements, including pipe and irrigation components, but not including irrigation control wire, PVC fittings, backflow prevention, pressure regulation, filtration, and water meter. Use Ewing Irrigation's online Cost Estimator to determine irrigation system component capital costs. See complete instructions for Ewing's quotation website at bottom of this assignment.

A digital copy of your report in pdf format is required, including all Appendices hyperlinked and referenced within the body of the report. In addition to appendices in pdf form, a hard copy of all ACAD mapping to engineering scale must be assembled and turned in as a hard copy design packet bound with a title page and table of contents.

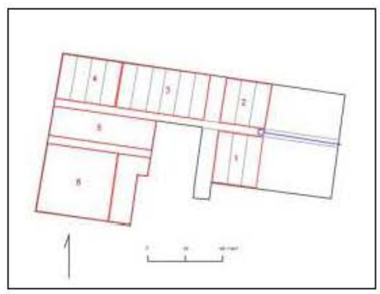


Figure 1. Left: Aerial image of Collier's Greenhouse, Jackson, Georgia (Source: Google Earth). Right: Planimetric base mapping derived from aerial photograph. (Source: Nursery owner).

<u>Deliverables</u>
(150 pts) Report should include the following titled sections:

- (5 pts.) Title page *with at least one image* (Preliminary Engineering Report for ...)
- (10 pts.) Table of contents - with complete page numbers, including labeled Appendices.
- (10 pts.) Executive summary – one or two paragraphs that summarize the main components and capabilities of your project design including selected materials and operating costs.
- (20 pts.) Introduction – written to introduce and describe the location of the project, areas being irrigated, ownership of water sources, plant material, acreage, climate, soil textural class, etc. Insert at least one general location map within the introduction.
- (70 pts.) Design recommendation – <u>written sections</u> describing recommended designs:

1

BSEN 4210 – Irrigation System Design

1. (25 pts) Engineer-scale AutoCAD layouts of the irrigation system (8-1/2x11" and/or 11x17" map folded to 8-1/2x11"). Include approximate project extents, location, size/layout of water sources, and all designed irrigation components. Use standard map format. Insert map as jpeg or pdf into body of report or appendix. <u>No hand sketches</u>.
2. (25 pts) Descriptive summary of major design specifications. Quantify main, submain, and lateral pipe sizes (w/ table of velocities in pipe segments to the worst-case sprinkler), SDC, peak crop ET, design depth of irrigation, number of hours operated per day (i.e., run times), assumed application efficiencies, number of sets or zones per irrigation, valve and meter sizes, and base and annual irrigation schedules. For sprinklers, specify sprinkler spacing and design precipitation rate. For trickle irrigation, if used, specify emitter and lateral spacing, flushing flow rates, and location of recommended filtration equipment. For all pressurized systems, specify recommended location of pressure regulation, air/vacuum relief, and/or backflow prevention.
3. (15 pts) <u>Results of system friction analysis in body of report. Identify worst case irrigation zone and sprinkler/emitter</u>. Include calculations and tables in appendix documenting adequate operating system pressure to provide pressure to WCS.
4. (5 pts) Provide at least one screen capture of the application system recommended, including a manufacturer name within the body of your report. You may use one or more of these images on the title page.

- (25 pts.) Capital and operating costs - estimate initial (capital) cost of irrigation equipment from manufacturers, including piping, sprinklers, and controllers, as needed, but not including pipe fittings, trenching, backflow prevention, filtration, meters, pressure tank, and equipment installation. Cost estimate will include a specified pump with associated annual operating costs, assuming either diesel or electric motor drive units. Pumped water from constructed earthen storage is not included in cost estimate. Specify a manufacturer's pump with pump curve that satisfies capacity and TDH requirements. Provide scale mapping and/or engineering sketches to document pump calculations. For comparison, estimate the cost of municipal water at $181/ac-in. Assume electricity costs are $0.15 per kWh (where one kW x 1 hour = 1 kWh) and diesel fuel consumption at $3.00/gal is 0.0678 gal/hp-hr (source: UF AE242).

- (10 pts.) Appendix – Provide a clear photocopy of all design procedures, highlighted tables, schedules, nomographs, figures, and hand calculations in *legible* format. Document all design steps in an organized way with supporting calculations (e.g., pump and/or pipe size, TDH, pipe friction loss, design depth of irrigation, irrigation run times, SDC, relevant manufacturer literature, handouts, etc.). <u>Reference all appendices in body of report with appropriate page numbers. Hyperlink all appendices from the text reference</u>. *If not referenced, appendices are ignored.*

Extra credit (15 pts): Provide an accurate GIS site map for the Jackson, Georgia greenhouse project including ACAD irrigation design overlaid onto a unique, high quality georeferenced aerial photo newly captured by your team. Provide the source of the aerial image as part of the GIS map. Project the map in State Plane Coordinates and provide SPCS coordinates (x,y) for two labeled, original ground control points of your choosing that would be suitable for land surveying at this site.

Deductions: (5 pt. deduction for each of the following missing):

- Typed report saved as a single pdf, pages numbered consecutively, including appendix.
- All tables numbered with labels *above* (eg., **Table 1. Typical irrigation schedule for...**).

- All figures numbered and labeled *below* (eg., **Figure 1. Location map of….**).
- All calculations should be shown legibly on engineering paper, referenced, *scanned*, and inserted into appendix. All appendices must be referenced in body of report. Cell phone camera photos of engineering calculations are not acceptable.
- Materials in landscape view should be inserted with top of page oriented towards binding edge. Maps and other graphics inserted into the pdf report document, including appendices, must be rotated for upright screen viewing.
- All appendices should be hyperlinked from the text reference location in the report body.
- Include copy of original assignment at end of report for grading.
- Hard copy of all ACAD mapping to engineering scale must be assembled and turned in as a hard copy design packet bound with title page and table of contents.

Instructions for Ewing quotation website:

1. Go to Ewing Irrigation at https://www.ewingirrigation.com/ and log in to class quotation account using bsen3560@gmail.com as the e-mail address and Auburn as the password. [Note: This is an administrative account set up for our class only.]
2. After log in (upper right of Ewing website), go to Quotes (top of page) / Unfinished Quotes (to start a new quote) / General Catalog (green menu bar at top to see categories of items for sale (e.g., PVC pipe, sprinklers/rotors, poly pipe, etc.)/
3. Click on each category. Select the item and quantity you want to quote. Add items to the quote by checking and adding a quantity (eg. 120 for 120 feet of PVC pipe).
4. Scroll to bottom of page and click Add to Quote/Order Pad to add to order pad (you will see check marks appear at right confirm item was added).
5. After selecting all items needed, go to Order Pad (green menu bar at top) and select Update Order Pad.
6. Go back to Quote Menu (green menu bar at top) and hit Unfinished Quotes
7. Select your quote, which now has a quote number. Give your quote a name, provide your name, review the quote, and save or change the quote.
8. Print the quote from the screen, continue working on the quote, or download as a CSV spreadsheet. After printing total cost of the quote, remember to add the cost for PVC fittings (elbows, tees, and bends) by estimating fitting cost as approximately 10% of total PVC pipe cost.

Shortcut instructions from Ewing Irrigation Quoting Center web site:
How to create a Quote

1. Search or browse for items.
2. Enter item quantity.
3. Click Add to Quote/Order Pad button.
4. Click View Quote link at the top of the page.
5. Click Job Info button.
6. Name your Quote and enter your name.
7. Click Final Review button to double check your quote details.
8. Click Finish Saving Quote button to Save the Quote to your Saved Quotes area.

When you need to modify, download or save your quote:

1. Click Saved Quotes
2. Click the Quote number you are looking for.
3. Choose an option from the "What would you like to do?" drop down list on the right side of the main area.

Extra Credit

Collier's Greenhouse: Jackson, Georgia

PROJECT ENGINEERS:
JON AUMAN
CAITLYN COLLAZO
ROSIA ROWE

SPCS COORDINATES:
x1 = 482.0789
y1 = -353.0992
x2 = 817.1375
y2 = -493.8532

***** Aerial Map Sourced from Google Earth**