EVALUATION, DESIGN AND COST ANALYSIS OF A 256 ACRE ALMOND ORCHARD

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ABSTRACT

This project discusses the evaluation, design, and cost analysis of a 256 acre almond orchard. This is a high flow low head system, and the application method is referred to as dual line drip. The system will be designed to be able to meet weekly water requirements within a tight time constraint, and it is important that it can do so efficiently while providing good uniformity.

A dual line drip system was designed for this almond orchard using the correct engineering standards and integrated field and farmer constraints. The system design was based on a peak evapotranspiration rate of 7.69 inches per month. The weekly operating hours for the entire parcel would be 96 hours, 4 days a week for 24 hours. The design DU was 0.93, and the final DU of the manifold came out to be 0.96. The system operates with an application rate of 0.087 inches/hour. The total fixed cost to install the entire system will be $363,024 or $1418 per acre, not including pump and labor.

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INTRODUCTION

Background

California has currently been experiencing one of the worst droughts in history to hit the Central Valley, with empty storage facilities and a vanishing Sierra snowpack the water supply for the future is seemingly disappearing. Although the Central Valley is known for its rich soil and ideal growing conditions, it hasn't always been a land that flourished with crops. Through State and Federal Water Projects California was able to construct a water conveyance system which would supply water to the dessert area of the San Joaquin Valley so that crop and life could flourish. Without the constant water supply from the water storage along the Sierra Nevada's arms the California Central Valley would not be as prosperous as it is today.

The California Central Valley being one of the largest producers for both domestic and global produce has become crippled with the fact that water is becoming scarcer than ever. With dwindling water allocations and water table levels dropping, efficient use of water is becoming more apparent than ever. Conventional ways of irrigation, for example flood irrigation, is becoming less popular and more farmers are beginning to make the switch to drip and micro irrigation. Drip and micro irrigation has steadily increased in popularity since the first large commercial installations of the early 1970's (Burt and Styles, 2011). Drip and micro irrigation delivers water directly to relatively small areas adjacent to individual plants through emitters placed along a water delivery line (Burt and Styles, 2011). With farmers seeking an answer to improving yields as well as on farm water use efficiency, they turn to drip and micro irrigation.

Justification

At Jerry Goubert Farms (JGF) the practice of drip and micro is widespread, almost all of their fields are either already equipment with an irrigation system, or will be equipped with one in the near future. In order for JGF to generate large yields during times of deficit water allocations, water must be tightly managed and water use efficiency must be increased. The alternate methods of irrigation like drip and micro help Jerry Goubert Farms operate sufficiently and meet their demands. However, in order to meet evapotranspiration requirements the Gouberts are forced to pump their wells in order to make up for the deficit amount of water allocated by their water district.

Often times the Gouberts will blend both well water and district water in efforts to minimize the water salinity coming from the well sources. Other times the pH levels of the water is monitored and stabilized at the filter station where they inject acid in efforts to get the pH to come down. Almost all of the Gouberts fields are equipped with filter stations so they can easily manage water use and salinity issues. Irrigation systems have become necessary for Jerry Goubert Farms, not only to manage the salinity issue but also to provide high yield during times of low water allocations.

This project is an evaluation, design, and cost analysis of a 256 acre almond orchard.

Objectives

Parameters that were established by Justin Goubert includes a dual line drip irrigation system, tree spacing of 20 feet between rows by 14 feet between trees down the rows, planted offset, tree rows facing North to South, and a sand media tank filter station.

For this project I will evaluate the field so that a proper design can be developed. Research will be conducted on all aspects of the projects to gain a better understanding for the project at hand. This project will clearly layout the design portion of the project, the procedure will outline and address the core value of the design and explain why certain decisions were made. A cost estimate will also be put together regarding all of the prices associated with all of the necessary equipment.

LITERATURE REVIEW

The research conducted for this senior project was done to develop an accurate evaluation and design to improve on farm irrigation for growing almonds. Almonds being a stress sensitive crop must meet the evapotranspiration requirements so that they can supply their full potential. Water requirements and how evenly water is applied throughout the field directly attributes to crop quality and yield. Having a wide variety of irrigation methods and soil preparation philosophies, research must be conducted to develop this Almond Orchard.

Almonds

The first almond trees were brought from Spain to California by Franciscan Padres in the 1700's, these trees would later be introduced to the ideal growing conditions of the Central Valley in the following century (Almond Board of California, 2015). California's Central Valley is home to some of the most ideal conditions for growing almonds with its mild climate, rich soil and abundant sunshine (Almond Board of California, 2013). California almonds make up about 80% of the global and virtually 100% of the domestic supply, making California the largest supplier of almonds globally (Almond Board of California, 2013).

With health trends on the rise and the growing demand for a global and domestic supply the need for a larger production of almond supply is more apparent than ever. Almonds trees produce one crop per year and it is not until year three or four where we begin to see relevant crop yields.

The tree is dormant from October to late February, February they begin to bloom and pollination begins taking place. Once pollinated the nuts begin to form during the months from March to October, water requirements and irrigation must be tightly monitored throughout these following months as it pertains directly to growth and yields.

Irrigation Scheduling

Irrigation scheduling involves managing the soil reservoir so that water is available when and in the amounts the plants need it (Burt 2013). Important concepts in irrigation scheduling include when one should irrigate and how much water should be applied during an irrigation (Burt 2013). In order for one to know how much and how often to irrigate one must fully understand the characteristics of both the water use rate and soil texture which indicates Available Water Holding Capacity (AWHC).

Each soil has different moisture holding characteristics that are affected by AWHC per foot of soil, soil depth, and the relationship between soil water depletion and matrix potential (Burt 2013). It must be emphasized that while it is reasonably simple to estimate soil moisture depletions and ET rates, it is considerably more difficult to make the proper decision of when and how much to irrigate (Burt 2013).

There are various techniques for predicting when and how much to irrigate, for example we can graph soil moisture depletion vs. time, utilization of crop stress indicators, soil moisture stress indicators, or we can achieve even more precision using evapotranspiration values (Burt 2013). The CIMIS program provides a valuable service by collecting weather data and calculating hourly reference ET (ETo) values, making it possible to determined how much and how often to irrigate (Burt 2013).

Evapotranspiration and Crop Coefficients

Evapotranspiration (ET) is the sum of transpiration (T) and evaporation (E) (Burt 2013). Evaporation can be defined as the water that evaporates on the wet soil or wet plant into the atmosphere, and transpiration is the movement of water through the plant, water transpires from the roots to the leaves.

As a designer it is important to understand the evapotranspiration rates so that you can properly design the irrigation system for the peak crop evapotranspiration (ETc), usually July. ETc can be calculated using this equation: ETc = (Kc x ETo), Kc is defined as the crop coefficient and ETo is defined as the evapotranspiration rate of the reference crop (Burt and Styles 2011). Kc is calculated for several reasons, including irrigation planning and design, irrigation management, basic irrigation schedules, and real time irrigation scheduling for non-frequent water applications (FAO).

Crop coefficients help determine the ETc and all the crop coefficients are based on a reference crop ETo (Burt and Styles 2011). The Kc for the same crop is different depending on location due to the differences in weather, size of the tree, ground cover, evaporation and many other factors. Factors that affect evapotranspiration rate include, climate (solar radiation, temperature, humidity, wind), plant (crop type, stage of growth, health), and soil moisture content (Hanson). There are two different reference crops that help determine this ET value, those include grass and alfalfa (Hanson).

Here in California our reference crop for ETo is grass (Burt 2013). ETo can be found online from the California Irrigation Management Information System (CIMIS) (Burt, 2013). CIMIS stations take direct readings and log weather data that can be accessed for any individuals use, the CIMIS station develop an idea for the water use of the reference crop in that specific area would be (Burt 2013).

However direct evapotranspiration rates of crops in certain zones in California can specifically be found online. The Irrigation Training and Research Center offers accessible online databases of decades of research that give designers accurate values and numbers to help develop design constraints (ITRC).

In Table 1 below, each crop has its own evapotranspiration value (ETc), measured in inches per month. Referring to Table 1, are ETc values provided by the Department of Water Resources, this Table is for irrigation scheduling and designing for drip and micro irrigation during a dry year in Zone 14. These values represent monthly evapotranspiration, we will specifically be using the ETc value for Almonds.

Table 1. ETc Table for Irrigation Design – Zone 14 (monthly ETc) (ITRC 1999)

			1999	**(Dry Year)**			
	January	**February**	**March**	**April**	**May**	**June**	**July**
	inches	inches	inches	inches	inches	inches	inches
Precipitation	2.56	4.69	1.34	1.01	0.1	0.26	0.13
Grass Reference ETo	0.83	1.35	2.97	5.67	7.31	7.59	8.18
Almonds	0.76	1.58	2.39	4.11	6.63	7.18	7.69
Almonds w/ covercrop	0.94	1.59	3.46	5.97	7.82	8.22	8.84

Figure 1 lays out the state of California and the different zones that the state is split up into with regards to similar and consistent evapotranspiration rates.

Figure 1. California DWR CIMIS ETo Zone Map (ITRC 1999)

Soil

When designing an irrigation system it is very important to take into consideration the soil type so that we can choose the correct type of application method. We have several different application methods to choose from, for example, micro sprayers, micro sprinklers, single line drip, or double line drip. Relative to the soil type is the soil wetted volume and AWHC per foot, this will help us choose the irrigation method of choice. In Table 2 below we can determine the inches of available water holding capacity per foot of soil based on the type of soil texture we are dealing with (Burt and Styles 2011).

Table 2. AWHC per foot of soil (Burt and Styles, 2015)

Soil Texture	Inches Available Water/Ft of soil
Course sand	0.50
Fine sand	0.75
Loamy sand	1.00
Sandy loam	1.25
Loam	1.50-2.0
Clay loam, silt loam	1.75-2.50
Clay	2.0-2.4

Wetted Area

For an irrigation design it is important to take into consideration the desirable wetted area, and with this chart below you can determine the amount of additional lateral movement of water based on the soil type. A designer should have a target percentage wetted area, what one wants is a certain percentage of the soil volume wetted, but it is often easiest to just refer to it as a percentage of the "area" assuming that all root zone soil volume within this area is wet (Burt and Styles 2011). The lateral movement depends upon soil structure, organic matter, and emitter flow rate and duration, and water quality (Burt and Styles 2011). In Table 3 below this table represents the additional lateral movement of water through the various different types of soil when using drip irrigation.

Table 3. Additional Lateral movement for drip (Burt and Styles, 2015)

"Typical" values for drip are:

Soil Type	Additional Lateral Movement for **Drip** (ft)	(m)
Coarse Sand	0.5 - 1.5	0.15 - 0.5
Fine Sand	1.0 - 3.0	0.3 - 0.9
Loam	3.0 - 4.5	0.9 - 1.4
Heavy Clay	4.0 - 6.0	1.2 - 1.8

Roads

Orchard operations must provide accessibility for maintenance crews, cultivating, and harvesting equipment to avoid heavy equipment soil compaction. We need to limit how often equipment will travel up and down rows because it can limit the soils ability to store water. From the standpoint of crop production, the adverse effect of soil compaction on water flow and storage may be more serious than the direct effect of soil compaction on root growth (DeJong-Hughes 2001). In order to avoid heavy soil compaction and its affects, the amount of traffic throughout the orchard needs to be condensed to one area to minimize the effects to the entire field. A road width of 20 feet offers enough clearance for all necessary equipment.

Tree Spacing and Soil Preparation

In the past many different tree spacings are commonly used for almonds, including 10 feet by 22 feet, 14 feet by 22 feet, 18 feet by 22 feet, and 22 feet by 22 feet (Duncan 2010). There have been studies if yields are better based off of tree spacing, but the studies showed there is not a significant difference in yields based on tree spacing (Duncan 2010). There are many philosophies with regards tree spacing and how soil should be prepared prior to planting. Third generation tree farmer Justin Goubert, states, the ground should first be ripped multi directional at three and a half feet deep and then disked to break up large clods. Then the ground should be land planed and leveled. Once the ground is ready and level the tree rows and tree locations will be marked with a global positioning system (GPS). Once planting locations for the trees are identified each hole must be excavated with a back hoe, and then gypsum and fertilizer are spread throughout the entire field. The holes are then back filled and the field must again be leveled using a tri plane. The field will then be sprinkler irrigated to settle the soil, and once the field dries out it will again be marked out using GPS. Borders will then put up and each hole for each tree will be hand dug (Goubert 2015). Justin Goubert prefers to prepare his soil in this manner, it is a technique that his family has had great success with and continue to practice currently. As far as tree spacing goes Goubert prefers 22 foot rows with 16 feet between trees, all offset.

Water Quality and Salinity Issues

When designing for an irrigation system it is important to understand the salt levels in both the water and the soil. Water quality and salinity issue can have significant effect on crop yields if held constant at toxic levels. The water source for this irrigation system comes from both wells and district surface water, and it has been determined that there are high levels of salt in the water source coming from the aquifers in this location.

The district water is of much better quality, obtaining smaller levels of salt, and at certain points during the year it is important to leach the salts out of the soil using clean district water. However, all irrigation water has some amount of salt. For this reason, the water and soil chemistry should always be examined before starting a reclamation or irrigation management plan (Burt and Styles 2011). There are three potential problems associated with salt:

1. Salt can accumulate in the soil, causing osmotic stress which has the same effect on plants as a very negative matrix potential when the soil is dry. High salt levels also inhibit plant germination and emergence (Burt and Styles 2011).
2. If there is a disproportionate amount of magnesium, sodium, bicarbonate and/or carbonate in the water the soil surface will seal up, causing infiltration problems (Burt and Styles 2011) .
3. Some specific types of salt, including boron and lithium, are highly toxic to plants in relatively low concentrations (Burt and Styles 2011).

Salinity of the soil is measured as a weight measurement in parts per million (PPM), PPM is measured as milligrams of salt divided by liters of solution (Burt and Styles 2011). A good soil from a salinity standpoint is one with fairly neutral pH (6.5-7.5), low ECe (less than 1 dS/m), and a low ESP (less than 15%) (Burt and Styles 2011). 1 dS/m is equivalent to 700 PPM.

Since we are planning on planting an almond crop we will have to turn to a study made by Maas and Hoffman in 1977 that determined tolerances of various crops to soil salinity. For almonds the threshold ECe (ECe at initial yield decline) dS/m is 1.5 dS/m (Maas and Hoffman 1977). This means that once we reach 1.5 dS/m of salinity in the soil the yields will begin to decrease at 19 percent for every unit increase in salinity (Maas and Hoffman 1977).

Distribution Uniformity

Distribution Uniformity (DU) is a term that relates to the evenness of water application to plants throughout a field (Burt and Styles 2011). As a designer it is important to take into consideration distribution uniformity, so it is important to choose an irrigation method that will help you achieve your desirable distribution uniformity ratio. DU low quarter can be computed as the average low quarter depth of water, divided by the average depth of water accumulated in all elements. Where the average of the lowest quarter of the values. Rather than the absolute minimum value is used as a minimum value (Burt and Styles 2011).

In the preliminary design phase it is important to take into account distribution uniformity and to create a target DU based on the constraints of the design requirements. An irrigation design is designed based on either distribution uniformity or economics (Howes 2014). If we are designing upstream of the pressure regulator and the change in pressure doesn't matter then we are designing for economic (Howes 2014). If we are designing downstream of the pressure regulator and pressure changes matter then we are designing for distribution uniformity (Howes 2014).

When designing for either economics or distribution uniformity it is important to set a design constraint and set a desired DU as well as an estimate future DU. It is important to note that over time the irrigation system if not perfectly maintained the distribution uniformity will get worse, so it is important to plan ahead and design the system for how it will be operating in the future years to come. The primary causes of the drop in the DU are a result of clogging or plugged emitters, wear of emitters, deterioration of the physical components of emitters, and maladjustment of pressures (Burt and Styles 2011).

Jain Hose Information vs. ITRC Single Hose Program

In order to achieve good distribution uniformity we need to design the irrigation system downstream of the pressure regulator. We have one of two ways that we can determine the max length we can run our drip tape before seeing significant pressure differentials. We can either use a hose information provided by the manufacturer, or we can use the single hose program provided by the Irrigation Training and Research Center. However it is important to note that the hose information provided by the manufacture only works if you field is a zero percent slope. It is important to know the max length that this drip tape can be ran so that we can get an idea of how we can break this field into separate zones. Table 4 shows a results provided by a manufacturer. The chart compares the head loss vs. the dripline length.

Table 4. Head loss vs. dripline length (Jain Irrigation 2015)

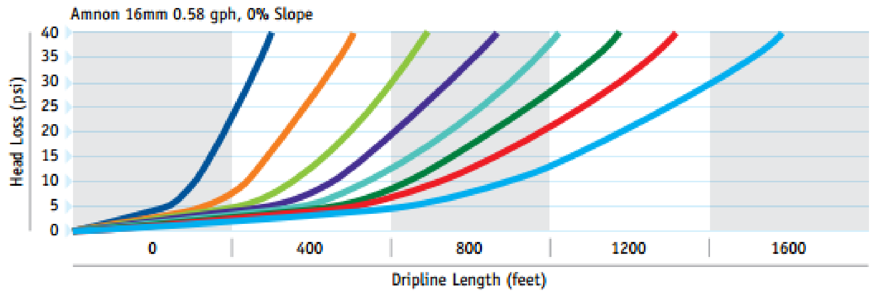

Table 5 allows you to determine the max lateral length you can run your drip tape based on emitter spacing, flow rate (gph), and inlet pressure if you have a slope of zero percent. Since our field has a slight slope the Jain hose information will not be feasible for this design.

Table 5. Maximum lateral lengths (Jain Irrigation, 2015)

Amnon Maximum Lateral Lengths (0% Slope)
16 mm (0.630 x 0.540)

gph	psi Inlet	Emitter Spacing (inches)							
		12"	18"	24"	30"	36"	42"	48"	60"
0.29	25	432	607	767	914	1052	1182	1306	1537
	35	520	731	923	1101	1267	1423	1572	1851
	45	587	826	1043	1244	1432	1609	1777	2092
	55	643	905	1143	1363	1569	1763	1947	2292
0.42	25	341	480	606	722	831	934	1032	1215
	35	410	578	729	870	1001	1124	1242	1463
	45	464	653	824	983	1131	1271	1404	1653
	55	508	715	903	1077	1239	1392	1538	1811
0.58	25	278	391	493	588	677	760	840	989
	35	334	470	594	708	815	916	1011	1191
	45	378	532	671	800	921	1035	1143	1346
	55	414	582	735	877	1009	1134	1252	1475
1.0	25	196	276	349	416	479	538	594	700
	35	236	333	420	501	576	648	715	842
	45	267	376	475	566	651	732	808	952
	55	293	412	520	620	714	802	886	1043

The hose program offered by the Irrigation Training and Research Center is a much more accurate hose program that allows you to set a number of constraints, for example hose specs, temperature, field slope and distribution uniformity. Based on the parameters of the hose or drip hose design it will calculate a max length that you can run the hose where you are meeting your max pressure differential before affecting distribution uniformity.

<u>In-line Emitters vs. On-Line Emitters</u>

When it comes down to choosing the emitter type for this drip irrigation application we must decide on either in-line emitters or on-line emitter. In the California Central Valley it is typical to find on-line emitters in vineyards and in-line emitters in orchards. The emitters used in orchards and vineyards are often manufactured separately from the hose, and those on-line emitters may be installed on the hose either at the factory or in the field, depending on the motor configuration and design (Burt and Styles 2011). The general trend, however, is to purchase in-line emitters that come pre-installed in the hose because this reduces the labor required for field installations and reduces costs. Almond growers prefer the in-line emitters opposed to the on-line emitters because it is cheaper way to get a close emitter spacing. Being that this design is a double line application it is just not economically feasible to punch and install this many emitters. The main disadvantage associated with in-line emitters as oppose to on-line emitters is that it is not possible to replace clogged emitters. Most emitters now are either one of two designs, tortuous path or smooth path. Tortuous path designs provide a reasonable degree of pressure compensation, this means that the flow rate changes are approximately proportional to the square root of pressure changes (Burt and Styles 2011). Since they have no moving parts, emitters with a tortuous design tend to be relatively inexpensive, well-made, and durable (Burt and Styles 2011). It is much more expensive to use on-line emitters rather than in line emitters, being that emitters and hose must be purchased separately. As far as double line drip applications go, it is much more inexpensive and just as effective to use in-line emitters rather than on-line emitters.

As a designer when determining the most suitable emitter for the application it is important to consider two factors, the coefficient of variation of the emitter and the emitter exponent. The coefficient of variation is a value this is given to all emitters of various manufacturers and it helps designers estimate how much the flow rates from the identical emitters will vary. Being that emitters are manufactured in the tens of thousands in a factory it is very difficult to get all of the emitters to provide the exact same flow rate, so it is important to consider the coefficient of variation in a design so that you can meet your target distribution uniformity. The emitter exponent is also another important factor to consider when trying to achieve a specific distribution uniformity. Flow (Q) for an emitter can be calculated using the discharge equation $Q=KP^x$, K being an emitter constant, P being a pressure, and x being the emitter exponent. The larger the x value the more the emitter flow will fluctuate at varying pressures, however the smaller the x value the less the emitter flow will fluctuate at varying pressures. As a designer it is important to understand that a smaller emitter exponent will deliver a pressure compensating flow, therefore the smaller the x value the easier it will be to achieve the target distribution uniformity.

Basic Pipeline Hydraulics

The Hazen-Williams Equation will be used to help calculate friction loss and will be demonstrated further in the design procedures. The equation will be used for a pipeline with no outlets in which there is only one diameter, and all of the flow that enters the pipeline flows the entire pipe length (Burt and Styles, 2011). Microsoft excel is the tool that will be used to calculate friction loss at every pipe length for different flows.

Pressure Regulation Valves

Pressure reducing valves, also referred to as pressure regulating valves are commonly used on many drip systems as a strategy to improve distribution uniformity. They typically placed at the head of a manifold, which is the pipe that supplies the water to the above ground hoses. Pressure regulating valves (PRV) help regulate the pressure within that manifold so that pressure is maintained at its design specification. When developing and installing a design it is important to supply that manifold with the pressure that you designed it for. If a manifold is designed to operate at a certain pressure and that pressure is not sustained, then the distribution uniformity will not be what you designed the system for. Utilizing pressure regulating valves is a strategy for achieving a good distribution uniformity (Burt and Styles, 2011). In order to achieve pressures at operating design parameters we use pressure regulating valves to ensure we are getting the correct pressures at the manifold inlet. In Figure 2 below is a Netafim pressure reducing valve, very commonly used in the Central Valley. The need for a pressure regulating valve in a field is apparent when we need to supply a sub-main with a lower pressure than that provided by the mainline. Pressure regulating valves do have a fairly large range of control, they are best for adjustable pressure above 15 psi, but are fairly worthless at low pressures (Burt and Styles, 2011).

Figure 2. Netafim Pressure Reducing PVC Threaded Valve

As a designer it is important to consider the accuracy and precision of pressure regulation valves, being that these valves have an optimal operating pressure range. The Irrigation Training and Research Center at California Polytechnic State University San Luis Obispo tested performance characteristics of pressure regulating valves from a variety of manufacturers. Testing and evaluations were conducted to gain a better understanding of the ability of different models of valves to regulate pressure in a low-pressure system (Burt and Feist 2013). Pressure regulating valves with 2-way pilots are not suited for truly low pressure systems due to an inherently higher pressure differential (Burt and Feist 2013). In other words, if the valves with 2-way pilots are adjusted to regulate an outlet pressure of 13 psi, the majority of the valves tested required an inlet pressure of 20 psi to function (Burt and Feist 2013). All of the comparable valves with 3-way pilots were affected by regulated outlet pressure consistency and hysteresis. A majority of the valves with the three way pilots have the ability to maintain an outlet pressure of +/- 1.5 psi and they all also exhibited measurable differences in regulated outlet pressures as much as 2 psi between on and off cycles (Burt and Feist 2013).

Filtration

When designing a drip irrigation system it is very important to choose the correct and most effective means of filtration for the situation. Traditionally media tanks have been the most popular filter for dirty water situations, they are excellent for removing organic material, and are the most frequent choice where there is a high dirt load of organic and/or inorganic material (Burt and Styles, 2011). Media tanks are pressure tanks filled with some type of sand-sized particles. They are also referred to as sand tanks (Burt and Styles, 2011). Any debris that enter the media tanks must be small enough to pass through diffuser plates, valves, and backflush mechanism so that the system can flush the tank of the foreign material. Some debris for example, like clays and fine silts are too small to be captured in the filter, so therefore sometimes means for prefiltration is necessary. What is unique about the sand media tanks is that they have an effective backflush system, it is sufficient in terms of how much surface area it has for filtration. These tanks can filter large amounts of water and require large backflush flows in order to restore a clean filter. Proper backflushing requires the proper underdrain design, correct installation and adjustment of the filters, and correct backflushing management (frequency, rate, and duration) (Burt and Styles, 2011). Frequency refers to how often the filters backflush, every couple hours or so a timer will forward the filters into a backflush sequence. Rate refers to the backflush flow rate, which can be set on the valve on the outlet side of the backflush manifold. Duration refers to how long a backflush cycle will last, and depending on how dirty the filters get the duration lengths can vary significantly. There is also dwell time, which refers to the period of time between individual tank backflushes, using lasting about 30 seconds. Frequency, dwell time and duration are backflush adjustments that can be made on the control panel at the filter station.

Figure 3 illustrates the two important processes performed by the media tanks: filtration and backwash. Compared to other methods of filtration this method is the best and will be utilized for its ability to filter the cleanest water under the worst conditions as well as provide sufficient ability for automation and adjustability.

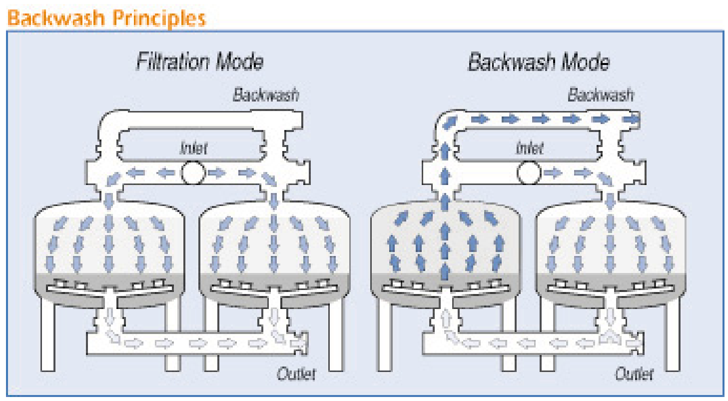

Figure 3. Sand Media Tank Backwash Principles (Fresno Valves, 2015)

As far as design constraints go and the amount of filters that your design requires is dependent of the system flow rate as well as the dirt load in the water itself. The dirty the water and the more extreme the condition you will need more filters.

Table 6 is provided to us by the Irrigation Training and Research Center, it will give us a number of filters necessary and there size relevant to the water quality and system flow rate.

Table 6. Vertical media tank sizes for emitter drip (Burt and Styles, 2015)

Irrigation System Flow Rate, GPM		**Number and Size (Dia) of Tanks**
Moderate Dirt Load	Moderately Heavy Dirt Load	
50	35	2 - 18"
100	70	3 - 18"
150	105	3 - 24"
175-275	122-192	3 - 30"
276-425	193-299	4 - 30"
426-575	300-399	4 - 36"
576-775	400-539	3 - 48"
776-1025	540-719	4 - 48"
1026-1275	720-899	5 - 48"
1275-1525	900-1069	6 - 48"
1526-1675	1070-1170	7 - 48"

Air Vents

Large acting air vents are used to prevent vacuuming and they release large amounts of air during startup and prevent air blockages as well as water hammer. There are either fully closed or fully open, and once the system becomes pressurized they become fully closed. However, continuous acting air vents are used to provide a constant release of air even after the system is pressurized, this is necessary to prevent water hammer and air blockages (Burt, 1995).

Pump Information Curves and HP

For drip irrigation applications it is necessary to choose the right pump for your application. Based on the results from the design we will have a flow rate and pressure that we need to supply. For this given pressure we can convert it into total dynamic head (TDH) versus flow rate. Once these two values are obtained they can be passed on to the grower so that they will know there pumping requirements.

PROCEDURES

Field Constraints

For every agricultural irrigation design there will be constraints and given information that will help with getting started on the design. All constraints help with the development of the project throughout the project procedures. Field constraints include field shape and size, slope and elevation changes, planting direction, irrigation scheduling, soil type, water quality, water source, crop type, peak ET, and irrigation method of choice. With all of this information a design procedure can begin being developed; most of the given information can give a designer a really good idea of what the project will look like. The main constraint for this irrigation design would be the crop type and the irrigation scheduling. For this project the first constraint is a 256 acre piece of land with mild slopes that is to be developed into an almond orchard. The project is to be developed over the course of two years, half of the field will be developed this year, and the following year the second half of the field will be tied in as well. This means that this winter half of the irrigation system will need to be installed in order to support the life of 125.5 acres. The hours of operation that we will be designing for will be based on the 125.5 acres, 2 days a week, 24 hours a day. It is important to mention that once the second half of the field is tied in the system operating hours will be double that what they are right now. When the piece of ground is fully developed it will operate 4 days a week, 24 hours a day. This is the most important constraint to think about. This piece of ground has sufficient amounts of water, it receives water from the irrigation district and water can be diverted to it from surrounding wells.

Topography

As a designer it is necessary to understand the topography of the field even if it appears to be level. The field for this design is located near the San Joaquin River and there is a small slope aspect associated with the long runs. Topographical maps provided by the grower come from United States Geographical Survey (USGS) outlining the growers plot (plot 31), as seen in Figure 4 below.

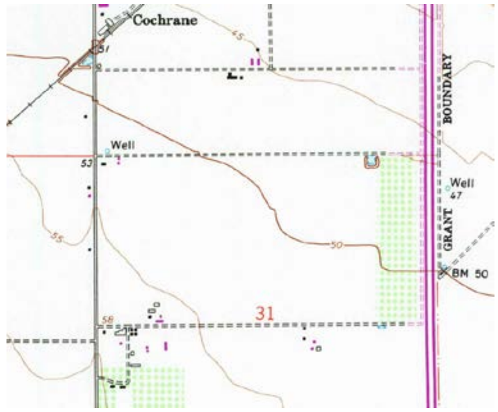

Figure 4. USGS Topographical map of Plot 31

The contour lines indicate that the field elevations vary from approximately 48-55 feet in the west/east direction. Using Google Earth Pro a secondary topographical survey is conducted to determine the exact slope in each direction. In figure 5 below is the survey conducted to help determine the average slope across the field from the west to the east, and north to south. Figure 5 below illustrates the survey conducted and its outputs listed.

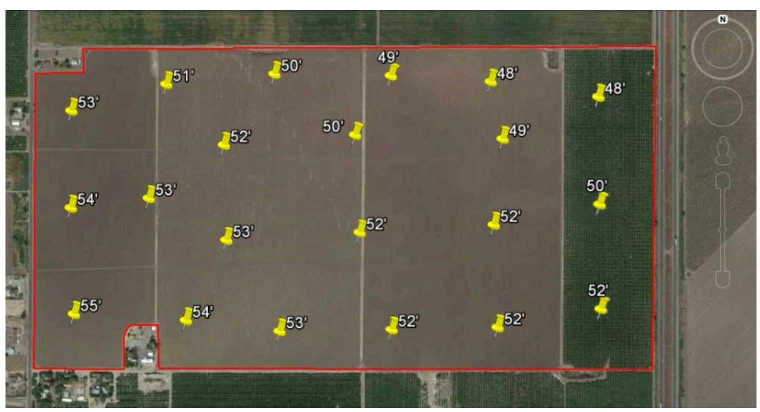

Figure 5. Google Earth Pro Slope Survey (West to East)

First the slope must be estimated in both directions. As seen in Figure 5 there is an obvious slope from the west to the east and from the south to the north. Equation 1 shows how to calculate the slope from the West to the East:

(1)

$$Slope = \frac{\Delta Elev}{Distance}$$

The average of the elevations on the west side is 54 feet, and the average elevation from the east side is 50 feet. The overall distance across the field is 4341 feet, therefore the slope from west to east is 0.09%. The slope from south to north is computed the same way, the slope from south to north is 0.12%.

Peak ET.

As a designer it is very important to make sure that the design meets the requirements for the worst case scenario. Being that weather is variable the evapotranspiration requirements will have to meet the peak evapotranspiration rates. Peak evapotranspiration rates occur during the hottest point in the summer where water requirements are at its highest. Using the ITRC ET Database it is determined that in July Zone 14 of the San Joaquin County had a peak ET value for almonds with no cover crop of 7.69 inches per month. 7.69 inches/month is our peak ET and it is important to convert the peak ET from inches per month to inches per day. The peak ET is 0.25 inches/day.

Estimate GPH/Tree.

The flow rate per tree must now be estimated. The given information that will be needed to calculate this estimation includes the plant spacing and the hours or operation. For this project the farmer has recommended a 20 foot by 14 foot spacing, and he wants to limit his irrigations for the 125.5 acres to 24 hours a day, 2 days a week. Using the above values, the GPM/tree (gross) can be computed. But first the gross peak ET's needs to be calculated in inches per day. Equation 2 shows how to calculate gross peak ET, using a future distribution uniformity of 0.85 and the net ET rate of 0.25 in/day:

$$(Gross)ET\ Rate\ after\ deterioration = \frac{Net\ ET}{Future\ DU} \tag{2}$$

After inputting the given constraints into the equation, the gross ET rate for future DU is 0.292 inches/day. The reason why a lower DU is used than that of the target DU is because irrigation system distribution uniformity decreases over time, so it is very important to plan ahead and achieve a gross flow rate that meets crop requirements even after deterioration has taken place. Now gross flow rate per tree must be estimated based on the calculated gross inches per day, plant spacing and hours of operation. Equation 3 below shows how to do just that:

$$(Gross)\frac{GPH}{Tree} = (gross\ inches\ per\ day * plant\ spacing\ area)/(96.3 * hrs\ of\ operation) \tag{3}$$

The Gross flow rate per tree GPH/Tree came out to be 7.42 GPH/Tree.

Estimate the Number of Emitters/Tree

For this part of the design it is very important to choose the correct number of emitters per tree, in doing so understanding the soil characteristics in important so that the design can achieve the desired amount of wetted area. To get additional information on the soil properties from this field a soil survey will be conducted using the Web soil survey provided by the NRCS. Figure 3 below illustrates how a web soil survey is conducted through the NRCS, but first a field outline must be set. The soil type for this piece of ground was determined to be Capay Clay. The complete soil survey can be found as Figure 10 in Appendix B.

Figure 6. (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx,2015)

Once the soil type is determined by NRCS, Table 3 helps determine the lateral movement of water in soil. Since the properties of this soil hint towards a light clay it will define the lateral movement of the soil, in this case it is 4 feet (R=4). In order to choose the correct emitter one must first understand how many emitters needed to achieve the desired wetted area. A normally assumed wetted area for drip to be around 60%, However the Goubert's insist that this drip irrigation design be a dual line drip system so that they have a variable wetted area. First the wetted area provided by one emitter miust be calculated. When calculating the wetted area for one emitter the equation for calculating the area of a circle is used, being that the radius is 4 feet. The wetted area of a single emitter is 50.24 square feet.

Next, tree area must be calculated. The area per tree can be calculated by multiplying the tree spacing by the row spacing, the area per tree comes out to be 280 square feet.

Although this is a design for dual line drip it must first be understood how much wetted area can be achieved with a single line. Knowing that the lateral water movement in the soil for a radius of 4 feet one can determine a wetted area if the wetted area is viewed in the form of a rectangle. The rectangle would be 14 feet long and 8 feet wide. The wetted area for single line drip is computed as 112 square feet, which is a wetted area of 40 %.

Based on the lateral movement of water in this soil type the wetted area of a single line hose limits the wetted area to only 40%. Therefore it is evident to have more than one line. However for dual line drip it is possible to achieve a much higher wetted area. With dual line drip the wetted area is 224 square feet. With the lines pulled as part apart as possible we are able to achieve 80% wetted area with no overlap. However if someone were to put the two lines closer together it could make the wetter area smaller but then there will be overlap. Now the number of emitters per tree will be determined. Equation 4 shows us how to determine number of emitters per tree:

$$\#\ emitters\ per\ tree = \frac{Tree\ area * fraction\ of\ wetted\ area}{Wetted\ area\ per\ emitter} \tag{4}$$

In order to achieve an 80% wetted area 5 emitters per tree will be necessary. The 5 emitters per tree is the estimated number of emitters per tree, 2.5 emitters per line per tree. However, there is no manufacturer that makes an in-line emitter that exceeds a flow rate above 2.0 GPH. In this case using 5 emitters per tree cannot be used because the flow would be greater than any in-line emitter provided by the manufacturer. Adding addition emitters will not negatively affect the wetted area, however adding additional emitters will reduce the flow rate per emitter to a reasonable constraint so that we can utilize the desired resources provided by Netafim for the project. At this point an assumption should be made, instead of using 5 emitters per tree, 7 emitters per tree will be used. With the addition of 2 emitters per tree, this will be necessary to achieve the desired pressures for the nominal sized emitters provided by the manufacturer.

Emitters are chosen by closely examining our calculated emitter pressures. The most sufficient emitter operating pressure for this scenario is about 11-13 psi. With different combinations of emitters/tree and hours of operation the designer can achieve these goals. For each calculated pressure there is a set emitter size and number of irrigation blocks. Based on farmer preference and well as an ergonomic feasibility, this will be a four block system. This allows the farmer to pulse irrigate as well as have the ability to do ground work while part of the field is irrigating.

Determining Emitter Spacing

Next, the designer must determine the emitter spacing. This is necessary so that the designer can decide which emitter manufacturer to be used for the design. All manufactures offer a wide variety of emitter lines that have differently sized emitters and emitter spacing. Emitter spacing is calculated in Equation 5:

(5)

$$Emitter\ Spacing\ (in) = \frac{Feet\ between\ trees}{\#\ emitters/tree \big/ \#\ lines/tree} * (12''/\text{foot})$$

The emitter spacing was determined to be 48 inches with a tree spacing of 14 feet, 7 emitters per tree, and two lines per tree.

Emitter Selection and Number of Blocks

First the proper emitter must be selected. The emitter sizes vary in flow rate and operating pressures. To determine an emitters flow rate a simple equation is used, in equation 6 you can see how pressure are calculated:

(6)

$$GPH = K * P^x$$

Where,

GPH = Gallon per hour

K = Constant

P = Pressure (psi)

x = emitter exponent

However, equation 6 must be manipulated so that operating pressures can be calculated. The manufacturer of the emitter that will be using is called Netafim, and the emitter hose that will be used is called Triton x. Netafim provides the given technical information in Table 7 below.

Table 7. Netafim Triton Dripper Data/Heavywall 45 Mil or greater

Dripper (GPH)	Exponent (x)	Constant (k)	Required Filtration
0.26	0.46	0.0817	120 Mesh
0.4	0.46	0.125	121 Mesh
0.5	0.46	0.164	122 Mesh
1.0	0.46	0.327	123 Mesh
2.0	0.46	0.655	124 Mesh

Equation 6 must be rearranged to solve for (P), Pressure. Equation 7 below will be used to help choose the best emitter based on average pressure:

$$P = \left(\frac{GPH}{K}\right)^{1/x} \tag{7}$$

Where,

GPH = Gallon per hour

K = Constant

P = pressure (psi)

x = exponent

The average pressures help determine the number of blocks as well the emitter flow rate. Having more than one block allows the field to be irrigated at different times however it will increase the emitter flow rates. The more blocks the larger the emitter must be. Table 8 below shows the calculated pressure for the four emitter sizes provided by Netafim.

Table 8. Average Emitter Pressures

		Pressures, psi			
# of Blocks	GPH/emitter	Emitter 1	Emitter 2	Emitter 3	Emitter 4
1	1.06	104.44	57.87	12.91	2.85
2	2.12	471.28	261.16	58.26	12.87
3	4.24	2126.62	1178.45	262.89	58.07
4	8.49	9596.29	5317.72	1186.30	262.02

As a designer when analyzing the average pressures one must target for a desirable pressure between 11-13 psi. As a designer you also have to make sure that the GPH/emitter you choose is a nominally sized emitter provided by the manufacturer. In this case Emitter 3 and Emitter 4 have the most desirable average pressures. One must now decide either between one block or two blocks for the 125.5 acres. The farmer did mention he would prefer to have multiple blocks, so for this design emitter 4 will be used. Emitter 4 has an average operating pressure of 12.87 psi at 2.12 GPH. Netafim Triton X drip hose will be used for the design, 2 GPH emitters on a 48 inch spacing.

Evaluate and Position Manifolds

At this point it is important to note that there will be 4 blocks for the entire 256 acres, being that in Table 8 each block is 125.5 acres. So for right now from a design perspective the focus is on the two blocks for the first set since both sets will be identical.

What it is that needs to determine is how many manifolds are needed per block. The manifold placement and number of manifolds will be determined on how far above ground hose can efficiently be ran. In order to determine this one must use the manifold placement program to help resolve the issue.

The ITRC provides a very helpful drip hydraulics program which calculates important factors such as uphill length of hose, downhill length of hose, hose inlet pressure, and DU low quarter for various hose inside diameters. In order to use the Manifold placement program the designer will need the input values from Table 9 below.

Table 9. Manifold Placement Input Values

Hose Length	656	ft
Emitter flow	2.12	GPH
Avg Pressure	12.87	psi
7 emitter per tree, 3.5 emitters/line		
For DU computation	7	number of emitters servicing a tree
slope along hose	0.12	%
Distance between emitters	48	inches
Manufacturer CV	0.035	
Emitter Exponent	0.46	
Extra length for temp. expansion	1.5	%
Nominal Emitter flow	2.0	GPH
Nominal Emitter operating P	12.0	psi

Table 10 then shows the outputs from the program for the different inside diameter hoses. A hose inside diameter of 0.82 inches was selected because it had the most appealing DU and allowed the most pressure differential. You can see it is the cell that is highlighted yellow in Table 10.

Table 10. Manifold Placement Program Outputs (ITRC)

Hose Dia	Inlet P psi	# manifolds	Length ft	Uphill ft	Downhill ft	$DU_{lq\ hose}$	$DU_{manifold}$
0.54	20.3	4	656	321.44	334.56	0.91	1.02
0.62	17.1	4	656	321.44	334.56	0.94	0.989
0.69	15.7	4	656	321.44	334.56	0.96	0.96
0.82	**14.6**	**4**	**656**	**314.88**	**341.12**	**0.97**	**0.95**
0.54	15.9	5	437	214.13	222.87	0.95	0.97
0.62	14.8	5	437	214.13	222.87	0.97	0.95
0.69	14.3	5	437	209.76	227.24	0.97	0.95
0.82	13.9	5	437	201.02	235.98	0.98	0.94

The designer must double check the flow rate and the velocity coming through each riser in the manifold before making a decision on the number of manifolds. Each riser will be suppling a total of 46 trees. Being that the flow rate per tree is 7.42 GPH, we can determine that the flow rate through each riser is about 11.6 GPM. It is vital to not exceed the velocity of 5.0 FT/Second.

The velocity through the riser checks out below 5.0 FT/Second, so the designer will be able to continue with four manifolds per block. Based on Table 10, the number of trees per manifold can be calculated. Table 11 shows how many trees there are in the uphill and downhill directions off the manifold.

Table 11. Number of Trees per manifold (Uphill/Downhill)

PER Manifold:				
	Uphill:	315'/14'	**22**	**trees**
	Downhill:	341'/14'	**24**	**trees**

Allowable Change in Pressure

Every properly designed irrigation system should have a calculated allowable change in pressure for the critical manifold. This is one of the most important aspects of trying to maintain good distribution uniformity. The importance of calculating the allowable change in pressure will help achieve the distribution uniformity that is planned for. In this design we plan for a distribution uniformity of 0.93 in order to determine the allowable pressure differential for this manifold. This is shown in Equation 8 below:

$$\text{Allowable } \Delta P = 2 * (\text{Pavg} - (\text{Pavg} * (\text{DUsystem} / \text{DUhose})^{1/x})) \tag{8}$$

The distribution uniformity of the hose was determined to be 0.97 by the ITRC Manifold Placement Program, and the allowable change in pressure was calculated to be 2.08 psi.

Manifold Sizing

It has been determined how many manifolds there will be per block, and how far they will be spaced out. However, the way that the blocks are broken up for irrigation will be vital for how accessible the field will be during irrigations. As a designer it is decided that three quarters the field is to be accessible for equipment use while the other quarter is being irrigated; Figure 7 illustrates how the blocks will be broken down into operating sets. Purple lines represent main supply lines, and red lines represent the manifolds.

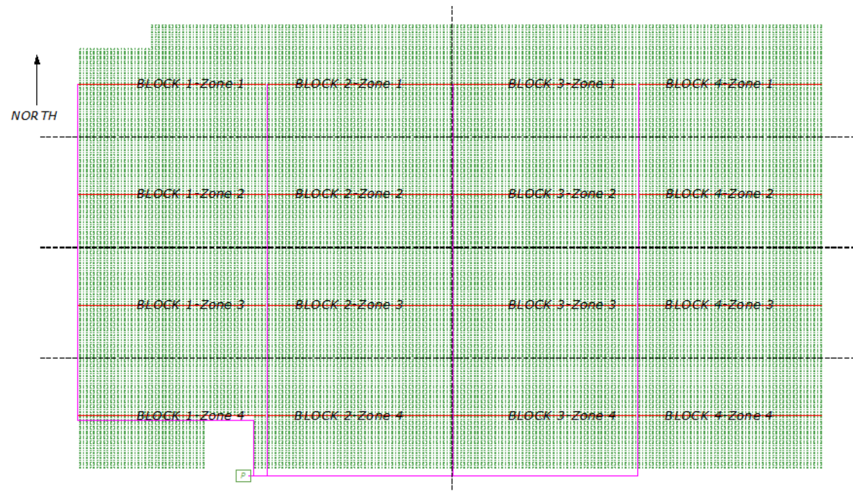

Figure 7. Block/Zone Map

There will be four manifolds per block and all manifolds will be end feed by the submain in the downhill sloping direction, from west to east.

When sizing a manifold what has to be taken into consideration next is how to size the pipe appropriately to achieve the allowable pressure change with reasonable velocity. It is standard to keep flow velocities below 5.0 FT/Second, so for this manifold design one will stay below 5.0 FT/second at about 2.0 psi of pressure change. It is important to note that for this design there will be two different sized manifolds, one with 54 points and the other with 55 points. Being that the field is not completely symmetrical the four zones on Block 1 will have 55 points along the manifold. It is also important to note that all manifolds flow in the downhill direction so there will be some pressure acquired.

As far as sizing for the manifolds go there is a slope from the West to East at about 0.12%. Table 15 in Appendix C shows the manifold design table used for the 54 outlets and Table 16 also in Appendix C is the manifold design for 55 outlets. This table shows how pipe sizes are managed according to relative velocity and pressure. The ΔP along the manifold needs to be less than 2.08 psi, if the ΔP is above that number then the manifold pipe size needs to be adjusted. In order to do this one needs to replace a couple segments of smaller pipe with larger pipe, doing so will decrease velocities as well as friction loss. After Tables 15 and 16 from Appendix C were adjusted, the ΔP for the 54 outlet manifold was 1.91 psi and the 55 outlet manifold was 1.94 psi. The ΔP for the table is less than the allowable ΔP so this will be acceptable for the design. The reason why the actual pressure differential is less than the pressure differential allowed is because we want to add some type of safety factor. In this case our safety factor was 0.2 psi, or ten percent.

Main Line Sizing

The critical paths have been identified based on our decision to end feed the manifolds from the west to east. The critical path is effected upon where the pump site is located, Figure 8 illustrates where the pump site is located. There will be two critical paths that will have to be examined in order to determine which path will require the most pressure, one heading in the uphill direction close to the pump site and the other facing the downhill direction furthest from the pump site. Critical path number one is illustrated in Figure 8.

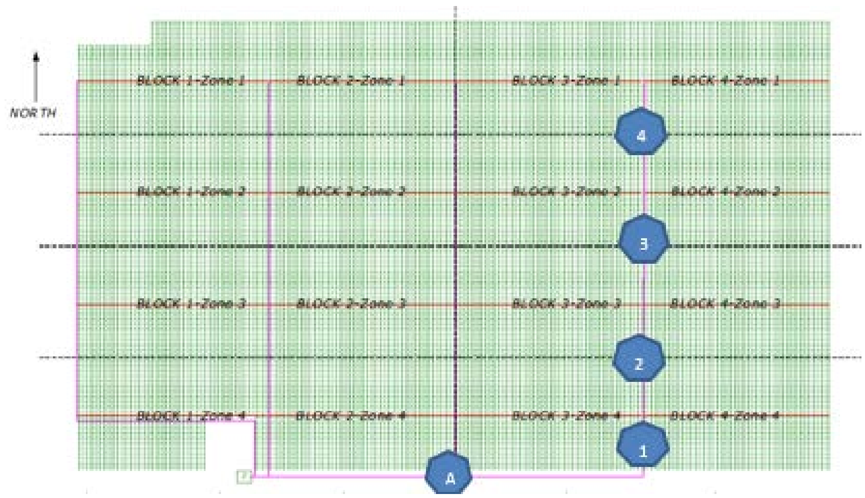

Figure 8. Critical Path #1

Figure 9 below illustrates critical path number 2 in the uphill direction from the pump.

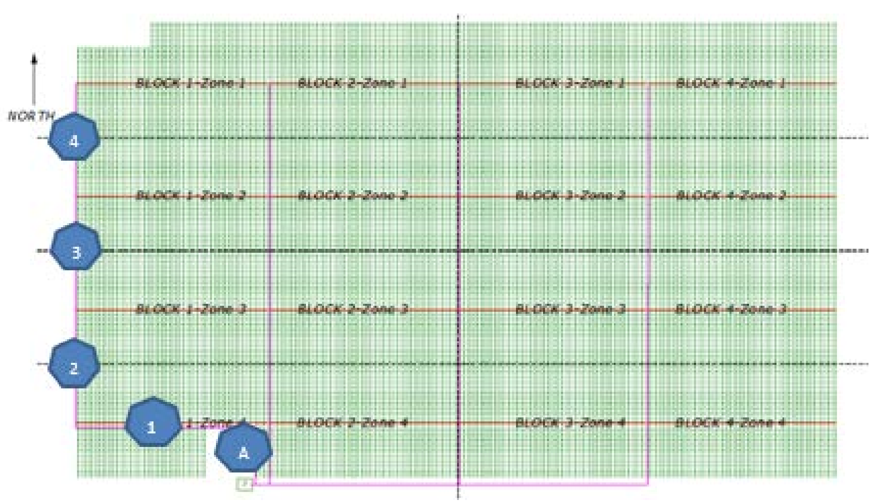

Figure 9. Critical Path #2

The constraints involved for sizing the mainline include end inlet pressure, segment lengths, flow rates, and elevation change. At each point along the critical path the mainline will have accommodate for the accumulative flows for the supply to each manifold. For sizing this path one always works from the furthest point to the source of the water supply. Table 17 and 18 in Appendix C show the accumulative flows from each point in each critical path. As you can see there are two critical paths, and both will have to have the pipe sized based on the velocity rule, of not exceeding more than 5.0 FT/Second. Table 19 and 20 in Appendix C shows the sizing of the mainline for both possible critical paths. Pipe is sized according at critical points based on velocity and fiction loss. If velocity at a point ever exceeds the 5.0 FT/Second rule, then the pipe size for this point will be bumped up to the next pipe size.

Critical path number two requires 19.14 psi at the pump, and critical path number one requires 21.69 psi. In Table 19 in Appendix C you can see the pressure requirement for the pump. Therefore the most critical path is the path that requires the most pressure. By meeting the pressure requirements for critical path number one the requirements are also met for critical path number two. The critical path must be supplied with at least 21.69 psi from the pump in order to achieve the desired 15.60 psi at the end of the critical path.

Pressure Regulating Valves

For proper manifold operation and achieving DU the minimum inlet pressure is 15.6 psi, shown Table 15 and Table 16 from Appendix C. However there will be manifolds along the critical path with inlet pressures greater than 15.6 psi. Since non-pressure compensating emitters are being used the need for some type of pressure regulation is necessary to ensure that we keep a good distribution uniformity. The inlet pressure at each point will be regulated using a pressure regulating valve, the pressure regulators will all be set at 15.6 psi. It is important to note that there is a pressure loss that occurs through these pressure regulation valves, it is normally about 3-4 psi. So, in order to achieve the needed 15.6 psi for the inlet on the last manifold on the critical path the designer will have to add 4 psi to the pump requirement. From the calculations in Table 19 from Appendix C the critical path requires 21.69 psi, but with the additional 4 psi required to operate the valve the pressure requirement for the critical path is now 25.69. We will be using a six inch pressure regulation valve with a three way pilot to control the pressure into each manifold. We will have a total of sixteen pressure regulating valves for this field.

Filtration

The next step for the design procedure requires determining which method of filtration to use. For filtration requirements one always wants to design based on the worst case scenario. The worst case scenario for this situation the grower will be getting water from both the irrigation district as well as well water. The district turnout comes from a portion of canal that is not line with cement. The water here contains moderate amounts of dirt load in the water. The design will require sand media tanks to sufficiently filter the moderate dirty water. For drip irrigation a common rule of thumb is to remove all particles greater than 1/10th the diameter of the emission holes. This will help eliminate emitter plugging. Therefore the sand media in the filter will have to remove particles down to the 0.001"-0.007". The orifice diameter for Netafim Triton is 0.049 inches. The calculated minimum particle diameter is 0.0049 inches, which would require a mesh size of 120. Table 12 below shows how the type of media for this design was chose.

Table 12. Typical media sizes and types for media tanks (Burt and Styles, 2007)

Media #	Media Type	Mean Effective Media Size (mm)	Mean Filtration Capacity (mm) (@ 15-25 GPM/sq.-ft)	
12	Round Monterey Sand	1.30	0.16 - 0.15 mm	90-70 mesh
16	Round Monterey Sand	0.65	0.12 - 0.15	125-100
8	**Crushed Granite**	**1.50**	**0.11 - 0.15**	**140-100**
12	Crushed Silica	1.20	0.11	140-130
20	Round Monterey Sand	0.50	0.11	140-130
11	Crushed Granite	0.78	0.08 - 0.11	200-140
16	Crushed Silica	0.70	0.08 - 0.10	200-150
20	Crushed Silica	0.47	0.06 - 0.08	250-200

Media # 8 will be used for this design, the media type will be crushed granite because it meets the mean filtration capacity. Next the designer needs to determine how many filters will be necessary and what size. The number of tanks necessary and their size is relative to the system flow rate and the water quality coming into the system in a worst case scenario. In this case the nominal flow rate for the system is 2504 GPM with a moderate dirt load. In order to determine how many filters are necessary one needs to estimate the square footage of filtration surface necessary to filter our moderately dirty water. For average water design for 20-25 GPM per square foot, and for extra dirty water design for 10-15 GPM per square foot. For this design the farmer has average water. It must now be determine how much square footage of filtration surface is needed. This is determined by dividing the system flow rate by the design GPM square footage. Since the system flow rate is 2504 GPM and the design GPM per square foot is 20 GPM. The necessary square footage of filtration necessary is 125 square feet. The area of filtration that one 48 inch tank is calculated using the area of a circle based on the dimension of the tank. The area of filtration that one tank provides is about 12.56 square feet. Therefore the system flow rate requires the need for ten tanks, however consideration must be taken for the extra flow necessary for proper back flushing. Based on Table 13 below we can determine the additional flow rate for our 48 inch media tank.

Table 13. Backflush flow requirement for media tanks (Burt and Styles, 2007)

Tank Dia.	BF GPM
18"	25
24"	50
30"	80
36"	110
48"	190

48 inch tanks have the addition back flush flow rate of 190 GPM, so it is necessary to determine if we need an extra filter with the addition flow that we need for backflush. Flow rate per square foot needs to be calculated to see if the flow is staying within our design constraint of 20-25 GPM per square foot. The accumulative flow rate of both the back flush and the system we can divide this total flow rate of 2694 GPM by the filtration area for 10 tanks. The backflush flow rate per square foot is 21.4 GPM. If an addition tank were to be used the backflush flow rate per square foot would be 19.5 GPM

When designing tanks for average water quality the target flow rate per square foot is 20-25 GPM. It is designed for 20 GPM per square foot, however when the system is operating in a backflush with only 10 tanks the system is still operating within the constraint. Eleven tanks is simply not necessary, because when system is running either on a back flush or not the system flow rate per square foot is always below 20 GPM. One can use 11 tanks, but it is not necessary. In this design there will be ten 48 inch tanks. The backflush cycle will be triggered when the system reads a pressure differential of 7 psi, so in order to ensure adequate pressure for back flushing an addition 7 psi will be tacked on the pumping requirements.

Air Vents

There are two types of air vents that will be used in this design, the first is a large acting air vent (LAV) and the other is a continuous acting air vent (CAV). Continuous release of air is to be provided to the following: every 1320 feet of continuous pipe, at all the highest points, on filter inflow manifolds (at the downstream end), at all points where a mainline begins to slope downhill, and upstream of an on/off control valve. Vacuum relief of air is to be provided to every 1320 feet of continuous pipe, at all of the highest points, upstream of the pump check valve, on the filter backflush(at the downturn), at the end of all mainlines, and downstream of an on/off control valve (Jain, 2015).

Chemigation Check Valve

A designer it is important to consider adding a chemigation check valve to the system, this will help protect the clean sources of water everyone shares. These valves keep the water that is pulled into the system in our controlled environment. The pipelines for this system in the future may contain water that may have levels of fertilizer and acid in them, so it is important that the water that enters this system does not return back to the source.

Pre-Filter

Since the water for this system is to be pulled from an open canal pre-filtering of larger materials will be necessary. In order to prevent large pieces of debris, moss, fish, boards, and any other obstructing materials from entering our pump and media tanks, a pre-filter will be added to the system.

Pressure Relief Valve

In order to protect the system from water hammer and its devastating effects on pvc pipe the use of a pressure relief valve at the pump site is necessary. A pressure relief valve is located upstream of the filters and one will be necessary for the safety of the system.

TDH Required

Once all of the above procedures and items are completed and taken into consideration the Total Dynamic Head (TDH) can be calculated. Once the designer knows the TDH the System GPM one can size the pump based on these requirements. The upstream pressure of point A is 21.69 psi, 0.5 psi is required for the pre filter, 7.0 psi is required for proper filtration for sand media, 4.0 psi is required for the pressure regulation valve, and 3.0 psi will be added for any minor losses. The total dynamic head for this system is 36.2 psi.

RESULTS

A proper drip irrigation system has been designed, and priced out for Jerry Goubert Farms. This 256 acre parcel has been evaluated to sustain 256 acres of California grown almonds in Zone 14 of the Central Valley. The emitter that was chosen for this dual line system was the Netafim Triton X, 2.0 gallons per hour on a 48” spacing. This design is a four set system that is operated with butterfly block valve assemblies as well as pressure regulating valve assemblies. There are four butterfly block valves that allow the user to change between sets. The butterfly valves must be manually opened and closed by irrigators every 24 hours. Each set has four manifolds that are regulated by pressure regulating valves, each of these must be set at specifically 15.6 psi in order to provide the design distribution uniformity. The target DU of 0.93 for this design is maintained with the allowable change of pressure in the manifold. Not only does this system provide a good DU but it is also provides efficiency, we are able to supply a large flow with low head. Being that this system provides 2504 GPM at a total dynamic head of 83.6 feet or 36.2 psi. As far as filtration goes the system will be fitted with ten 48 inch sand media filters with # 8 sand media, as well as a pre-filter. Below in Table 14 is a simple cost summary of the system, a detailed cost analysis can be found in Appendix E. For parts alone not including the pump or labor the project works out to be $1418 per acre.

Table 14. Simple Cost Summary

Description :	**COST**
Above Ground and Fittings	$ 109,722
Riser Assemblies	$ 9,544
Manifolds and Fittings	$ 64,174
Mainline/Submain Pipe and Fittings	$ 93,378
4" Flushout Assemblies	$ 3,871
Butterfly Block Valve Assemblies	$ 13,400
PRV Block Valve Assemblies	$ 25,837
Miscellaneous	$ 3,284
Filter Station	$ 32,120
10" Pre Screen	$ 4,252
12" Flow Meter	$ 1,426
12" Chemigation Check Valve	$ 2,016
Total =	$ 363,024

DISCUSSION

One of the most challenging aspects of this project that I struggled with was creating a balance between designing for DU as well as designing for economics. As important as it is to achieve a high distribution uniformity it is also equally important to make decisions that will cut down on costs. The procedure that I focused on mainly to save cost was the step where the emitter and the number of blocks were selected. When I first started the design I was trying to irrigate the entire 256 acres in two days on two blocks, which resulted in large flow rates that could not be supplied. The high flow rates also result in large pipe sizes that would be very costly. After discussions with the grower it was decided to increase the days of operation per week to 4 resulting in lower flow rates that were practical for economic purposes. With a smaller flow rate the pipes do not need to be as big and a practical emitter sizes become viable for the project. Selecting the number of blocks and the emitter was a decision based on economics, however the sizing of manifolds was strictly designed based on DU. The manifold pipe sizes are adjusted to provide the allowable change of pressure which sustains the DU, so it is important to not design the manifold conservatively.

This design is very unique in its own because it is designed to be able to be developed and installed in segments. The Groubert's plan on doing just that by installing 125.5 acres this year and following the next year with 125.5 acres more. The system is designed with four sets that are operated independently, each set operating at 2504 GPM for 24 hours a week. The first year the system will operate 24 hours a day, 2 days a week. When the system is installed in entirety it will operate for 24 hours a day, 4 days a week. This almond orchard is a large investment and will require large funds, and being that the grower will have the option of expanding at his own rate is pretty unique in itself.

RECOMMENDATIONS

As far as recommendations using a different method of pressure regulation would be viable and less expensive. As of right now the cost for pressure regulation for this system is $25,837, this cost includes sixteen pressure regulating valves and all of the fittings and air vents that come with them. In order to save money on pressure regulation and ensure good uniformity pressure compensating hose can be used. The savings would be significant if pressure regulation valves were not necessary. It doesn’t make sense to purchase non-pressure compensating hose when you can get pressure compensating hose at almost the same price.

As far as recommendations go for installation the installer should work smarter, not harder. The first install recommendation would be for the installer to put the mainline and manifold on the south eastern side of the field in the same trench. Instead of trenching out two trenches right next to one another the manifold pipe should be laid on top of the mainline. Also it is important for the installer to install the manifolds at the correct depth so that the riser assembly is at a reasonable height, having berms will affect trenching depth. It is also very important for the installer to take into consideration thrust blocks for places where 4 inch or above pipe intersect or turn. It is important to do the job right the first time so that pipes don’t start blowing apart due to water hammer and high velocities.

Installing the system in segments is a really good idea, but it will require doing some extra trenching and using 15 inch caps. One needs to keep in mind that if the project is to be put in the ground at separate times the underground work must be able to be retrofitted later down the road. This means that fittings must be able to accommodate for what is to be put in the place for the future.

The final recommendation would be to keep up on the system maintenance. Being that the system has the capability of injecting chemicals it is necessary to take the precautions of flushing the system so that the effective life of the system is not diminished. The first maintenance recommendation is frequent flushing as well as flushing’s that take place after chemical ejections. Main lines and manifolds also require regular flushing for maintenance purposes. At the end of each pipeline segment there is a flush out with a four inch ball valve, these segments of pipe require high velocities to flush sediment. A close eye should be kept on the backflush controller, it needs to be set up so that the filters never clog up. Based on the water quality and system operation the duration, frequency, and dwell time should be set accordingly. If all maintenance precautions are taken the system should have a long productive life.

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APPENDIX A

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

ASM Project Requirements

The ASM project must include a problem solving experience that incorporates the application of technology and the organizational skills of business and management, and quantitative, analytical problem solving. This project addresses these issues as follows.

Application of Agricultural Technology. The evaluation portion of this design lead me to use several resourceful agricultural technology's. The first and most important of which was technology from the ITRC Department. From the ITRC the excel design spreadsheet was used as well as the Manifold placement program and the CIMIS data logs found online. I also used technology provided by the NRCS, I used their online soil survey to determine the soil type for this parcel. I also used USGS online to find topographical maps to better understand the contours throughout the parcel. I also used Google Earth Pro to do measurements and double check elevations and certain aspects of the field that would only be noticeable through satellite imagery.

Application of Business and/or Management Skills. The project involves business/management skills in the area of cost analysis and labor considerations for installation purposes. In this design there are two segments of manifold and mainline that run next to one another. In my recommendations I mention that the installer should put these pipes in the same trench. By putting the two pipes in the same trench it saves time and money, therefore being a good management skill.

Quantitative, Analytical Problem Solving. An analysis of design was conducted to help with the selection of emitters and number of blocks. Analytical problem solving helped determine which material and which manufactures to use for parts.

Capstone Project Experience

The ASM project must incorporate knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge/skills from these key courses.

- BRAE 438 Drip and Micro Irrigation
- BRAE 532 Pumps and Wells
- BRAE 343 Mechanical System Analysis
- BRAE 340 Irrigation Scheduling
- BRAE 418/419 Ag Systems Management
- BRAE 151 AutoCAD
- BRAE 133 Engineering Drafting
- BRAE 152 Solid Works

- ENGL 145
- AGB 401Managing Cultural Diversity
- AGB 214 Financial Accounting
- AGB 212 Agricultural Economic

ASM Approach

Agricultural Systems Management involves the development of solution to technological, business or management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving. While technical in nature, this approach must also have a clear and present emphasis on planning and management of time, people, and other resources. This project addresses these issues as follows.

Systems Approach. This project involves the integration of management skills where systems have to be put in place. The cost analysis of the project required a detailed parts list, so a system was put in place to clearly outline parts of the project in categories. Grouping certain parts together like "mainline and fittings" or "above ground and fittings" makes it easier to go back through your work to ensure that no parts are left out of the cost estimate.

Interdisciplinary Features. The project touches on aspects of agricultural safety, waste management, distribution uniformity, economics, and efficiency.

Specialized Agricultural Knowledge. The project applies specialized knowledge in the areas of water hydraulics and irrigation design.

Project Parameters and Constraints. This project addresses a significant number of the categories of constraints listed below.

Physical. The tree spacing is 20 feet by 14 feet. This means that there is 20 feet between the tree rows and there is 14 feet between the trees in the actual tree row. There is no set standard for the physical footprint of the trees, it's all based on grower preference.

Economic. The system was designed both on distribution uniformity and economics. Economic decisions were made when determining the hours of operation and the emitter selection process. I didn't want large flow rates in the mainlines because this meant that large pipe diameters would have to be used. I extended the hours of operation so that the flow rate would be smaller, and this meant that I could use smaller pipe. There is always a tradeoff between smaller and bigger pipe, and there is definitely a happy medium where you can save money on pipe and power costs.

Environmental. The design is an environment friendly design. It has a chemigation check valve that prevents chemical water from returning back to the water source. The system overall improves on farm efficiency being that no water is wasted.

Sustainability. The design was necessary for the farm because the farm is no longer sustainable on contemporary forms of irrigation. There is simply not enough water available to continue with wasteful forms of irrigation. This irrigation system provides sustainability for the Gouberts.

Manufacturability. It is important as designer to research components of the design that are readily available by manufactures. It only makes since to include parts in a design that are already used a lot and can be replaced easily.

Health and Safety. There was a multitude of health and safety factors applied into the design of this irrigation system. A chemigation check valve was used to keep the contaminated water in the system within its own pipeline to protect the safety of the wildlife. A pressure relief valve was used at the pump station to protect the system if there were to be some type of failure.

Ethical. Being that this system is designed for another person I wanted to include several safety features. One of which was the addition of a chemigation check valve. Chemigation check valves are used to stop the flow of water from the system back to the source. I want to isolate this system and block any harmful chemicals from getting into the clean water source. This also helps protect wildlife.

Social. The cost analysis of the project lead me to talk to some very interesting people. Along the way I had to talk to the growers, pump suppliers, hose suppliers, and many more people that helped the project come together. Talking to all these people in a profession business matter was a great social experience.

Political. People always say that farmers are wasteful people, so a system was designed that would make both the people happy and the farmer. The system was design as a high flow low head, making it very energy efficient. Not only do energy efficient systems save money with power costs, but being energy efficient is also looked upon as politically correct.

Aesthetic. Filter stations can be very expensive set ups, each sand media tank runs for about $2500 and each system needs multiple of these. For this design I determined that we only needed ten tanks, however I did look into using eleven tanks. It was a good thing that I didn’t need the extra tank because I didn’t want to have to use an odd number of tanks. The reason being why I didn’t want to use an odd number of tanks is that it makes the filter station look unsymmetrical. Now, odd number of tanks only looks good when you using three or five, however once you start getting up into the seven, nine or eleven tank systems its sometime better just to add on an extra tank so that the system looks complete. More filtration surface is better than less to a certain extent, so it doesn't hurt to add an extra tank every once in a while. Plus it looks really good.

APPENDIX B

NRCS Complete Soil Survey

Map Unit Description: Capay clay, wet, 0 to 2 percent slopes---San Joaquin County, California

San Joaquin County, California

121—Capay clay, wet, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: hhrn
Elevation: 30 to 140 feet
Mean annual precipitation: 10 inches
Mean annual air temperature: 61 degrees F
Frost-free period: 270 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Capay and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Capay

Setting

Landform: Basin floors
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from mixed rock sources

Typical profile

A - 0 to 20 inches: clay
Bk - 20 to 44 inches: clay
Bk - 44 to 60 inches: silty clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 48 to 72 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Salinity, maximum in profile: Nonsaline to slightly saline (0.0 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 10.0
Available water storage in profile: High (about 9.4 inches)

Interpretive groups

Land capability classification (irrigated): 2w
Land capability classification (nonirrigated): 4w

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Figure 10. NRCS Complete Soil Survey

Hydrologic Soil Group: C

Minor Components

El solyo
Percent of map unit: 4 percent

Stomar
Percent of map unit: 4 percent

Vernalis
Percent of map unit: 3 percent

Unnamed, saline-sodic
Percent of map unit: 2 percent

Unnamed, lack perched water table
Percent of map unit: 2 percent

Data Source Information

Soil Survey Area: San Joaquin County, California
Survey Area Data: Version 9, Sep 22, 2015

Figure 10. NRCS Complete Soil Survey

APPENDIX C

Manifold and Mainline Sheets

Table 15. Manifold Design with 54 Downhill Rows

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Point	Elevation	Point P	# of trees	Point Q	u/s Segment	Nominal	Pipe ID	C	Segment	Segment	Change in	Change in	V
	ft	psi	in row	GPM	Q (GPM)	inches	inches	value	Length (ft)	Hf (psi)	Elev (psi)	P (psi)	ft/s
					0.00								
1	48	13.71	37	11.60	11.60	4.0	4.28	149	20	0.001	-0.0104	-0.010	0.26
2	48.024	13.70	37	11.60	23.20	4.0	4.28	149	20	0.002	-0.0104	-0.008	0.52
3	48.048	13.69	37	11.60	34.80	4.0	4.28	149	20	0.005	-0.0104	-0.005	0.78
4	48.072	13.69	37	11.60	46.40	4.0	4.28	149	20	0.009	-0.0104	-0.002	1.03
5	48.096	13.69	37	11.60	58.00	4.0	4.28	149	20	0.013	-0.0104	0.003	1.29
6	48.12	13.69	37	11.60	69.60	4.0	4.28	149	20	0.019	-0.0104	0.008	1.55
7	48.144	13.70	37	11.60	81.20	4.0	4.28	149	20	0.025	-0.0104	0.014	1.81
8	48.168	13.71	37	11.60	92.80	4.0	4.28	149	20	0.032	-0.0104	0.021	2.07
9	48.192	13.73	37	11.60	104.40	4.0	4.28	149	20	0.040	-0.0104	0.029	2.33
10	48.216	13.76	37	11.60	116.00	4.0	4.28	149	20	0.048	-0.0104	0.038	2.59
11	48.24	13.80	37	11.60	127.60	4.0	4.28	149	20	0.057	-0.0104	0.047	2.85
12	48.264	13.85	37	11.60	139.20	4.0	4.28	149	20	0.067	-0.0104	0.057	3.10
13	48.288	13.90	37	11.60	150.80	4.0	4.28	149	20	0.078	-0.0104	0.068	3.36
14	48.312	13.97	37	11.60	162.40	4.0	4.28	149	20	0.090	-0.0104	0.079	3.62
15	48.336	14.05	37	11.60	174.00	4.0	4.28	149	20	0.102	-0.0104	0.092	3.88
16	48.36	14.14	37	11.60	185.60	4.0	4.28	149	20	0.115	-0.0104	0.104	4.14
17	48.384	14.25	37	11.60	197.20	4.0	4.28	149	20	0.128	-0.0104	0.118	4.40
18	48.408	14.36	37	11.60	208.80	6.0	6.301	150	20	0.021	-0.0104	0.011	2.15
19	48.432	14.38	37	11.60	220.40	6.0	6.301	150	20	0.024	-0.0104	0.013	2.27
20	48.456	14.39	37	11.60	232.00	6.0	6.301	150	20	0.026	-0.0104	0.016	2.39
21	48.48	14.40	37	11.60	243.60	6.0	6.301	150	20	0.029	-0.0104	0.018	2.51
22	48.504	14.42	37	11.60	255.20	6.0	6.301	150	20	0.031	-0.0104	0.021	2.63
23	48.528	14.44	37	11.60	266.80	6.0	6.301	150	20	0.034	-0.0104	0.023	2.75
24	48.552	14.47	37	11.60	278.40	6.0	6.301	150	20	0.037	-0.0104	0.026	2.86
25	48.576	14.49	37	11.60	290.00	6.0	6.301	150	20	0.039	-0.0104	0.029	2.98
26	48.6	14.52	37	11.60	301.60	6.0	6.301	150	20	0.042	-0.0104	0.032	3.10
27	48.624	14.55	37	11.60	313.20	6.0	6.301	150	20	0.045	-0.0104	0.035	3.22
28	48.648	14.59	37	11.60	324.80	6.0	6.301	150	20	0.049	-0.0104	0.038	3.34
29	48.672	14.63	37	11.60	336.40	6.0	6.301	150	20	0.052	-0.0104	0.042	3.46
30	48.696	14.67	37	11.60	348.00	6.0	6.301	150	20	0.055	-0.0104	0.045	3.58
31	48.72	14.71	37	11.60	359.60	6.0	6.301	150	20	0.059	-0.0104	0.048	3.70
32	48.744	14.76	37	11.60	371.20	6.0	6.301	150	20	0.062	-0.0104	0.052	3.82
33	48.768	14.81	37	11.60	382.80	6.0	6.301	150	20	0.066	-0.0104	0.056	3.94
34	48.792	14.87	37	11.60	394.40	6.0	6.301	150	20	0.070	-0.0104	0.059	4.06
35	48.816	14.93	37	11.60	406.00	6.0	6.301	150	20	0.074	-0.0104	0.063	4.18
36	48.84	14.99	37	11.60	417.60	6.0	6.301	150	20	0.077	-0.0104	0.067	4.30
37	48.864	15.06	37	11.60	429.20	6.0	6.301	150	20	0.081	-0.0104	0.071	4.42
38	48.888	15.13	37	11.60	440.80	6.0	6.301	150	20	0.086	-0.0104	0.075	4.54
39	48.912	15.21	37	11.60	452.40	8.0	8.205	150	20	0.025	-0.0104	0.014	2.75
40	48.936	15.22	37	11.60	464.00	8.0	8.205	150	20	0.026	-0.0104	0.016	2.82
41	48.96	15.24	37	11.60	475.60	8.0	8.205	150	20	0.027	-0.0104	0.017	2.89
42	48.984	15.25	37	11.60	487.20	8.0	8.205	150	20	0.028	-0.0104	0.018	2.96
43	49.008	15.27	37	11.60	498.80	8.0	8.205	150	20	0.030	-0.0104	0.019	3.03
44	49.032	15.29	37	11.60	510.40	8.0	8.205	150	20	0.031	-0.0104	0.021	3.10
45	49.056	15.31	37	11.60	522.00	8.0	8.205	150	20	0.032	-0.0104	0.022	3.17
46	49.08	15.33	37	11.60	533.60	8.0	8.205	150	20	0.034	-0.0104	0.023	3.24
47	49.104	15.36	37	11.60	545.20	8.0	8.205	150	20	0.035	-0.0104	0.025	3.31
48	49.128	15.38	37	11.60	556.80	8.0	8.205	150	20	0.036	-0.0104	0.026	3.38
49	49.152	15.41	37	11.60	568.40	8.0	8.205	150	20	0.038	-0.0104	0.028	3.45
50	49.176	15.43	37	11.60	580.00	8.0	8.205	150	20	0.039	-0.0104	0.029	3.52
51	49.2	15.46	37	11.60	591.60	8.0	8.205	150	20	0.041	-0.0104	0.030	3.59
52	49.224	15.49	37	11.60	603.20	8.0	8.205	150	20	0.042	-0.0104	0.032	3.66
53	49.248	15.53	37	11.60	614.80	8.0	8.205	150	20	0.044	-0.0104	0.033	3.73
54	49.272	15.56	37	11.60	626.40	8.0	8.205	150	20	0.045	-0.0104	0.035	3.80
Inlet	49.296	15.59											
	Paverage	14.60	psi	*Target Inlet P average*			*14.60*	*psi*					
	Pmax	15.59	psi										
	Pmin	13.69	psi										
	Pdiff	1.91	psi		*Pdiff allowed*		*2.08*	*psi*					

Table 16. Manifold Design with 55 Downhill Rows

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Point	Elevation ft	Point P psi	# of trees in row	Point Q GPM	u/s Segment Q (GPM)	Nominal inches	Pipe ID inches	C value	Segment Length (ft)	Segment Hf (psi)	Change in Elev (psi)	Change in P (psi)	V ft/s
					0.00								
1	48	**13.70**	37	11.60	11.60	4.0	4.28	149	20	0.001	0.000	0.001	0.26
2	48.024	13.70	37	11.60	23.20	4.0	4.28	149	20	0.002	-0.0104	-0.008	0.52
3	48.048	13.69	37	11.60	34.80	4.0	4.28	149	20	0.005	-0.0104	-0.005	0.78
4	48.072	13.69	37	11.60	46.40	4.0	4.28	149	20	0.009	-0.0104	-0.002	1.03
5	48.096	13.69	37	11.60	58.00	4.0	4.28	149	20	0.013	-0.0104	0.003	1.29
6	48.12	13.69	37	11.60	69.60	4.0	4.28	149	20	0.019	-0.0104	0.008	1.55
7	48.144	13.70	37	11.60	81.20	4.0	4.28	149	20	0.025	-0.0104	0.014	1.81
8	48.168	13.71	37	11.60	92.80	4.0	4.28	149	20	0.032	-0.0104	0.021	2.07
9	48.192	13.73	37	11.60	104.40	4.0	4.28	149	20	0.040	-0.0104	0.029	2.33
10	48.216	13.76	37	11.60	116.00	4.0	4.28	149	20	0.048	-0.0104	0.038	2.59
11	48.24	13.80	37	11.60	127.60	4.0	4.28	149	20	0.057	-0.0104	0.047	2.85
12	48.264	13.85	37	11.60	139.20	4.0	4.28	149	20	0.067	-0.0104	0.057	3.10
13	48.288	13.90	37	11.60	150.80	4.0	4.28	149	20	0.078	-0.0104	0.068	3.36
14	48.312	13.97	37	11.60	162.40	4.0	4.28	149	20	0.090	-0.0104	0.079	3.62
15	48.336	14.05	37	11.60	174.00	4.0	4.28	149	20	0.102	-0.0104	0.092	3.88
16	48.36	14.14	37	11.60	185.60	4.0	4.28	149	20	0.115	-0.0104	0.104	4.14
17	48.384	14.25	37	11.60	197.20	4.0	4.28	149	20	0.128	-0.0104	0.118	4.40
18	48.408	14.37	37	11.60	208.80	6.0	6.301	150	20	0.021	-0.0104	0.011	2.15
19	48.432	14.38	37	11.60	220.40	6.0	6.301	150	20	0.024	-0.0104	0.013	2.27
20	48.456	14.39	37	11.60	232.00	6.0	6.301	150	20	0.026	-0.0104	0.016	2.39
21	48.48	14.41	37	11.60	243.60	6.0	6.301	150	20	0.029	-0.0104	0.018	2.51
22	48.504	14.42	37	11.60	255.20	6.0	6.301	150	20	0.031	-0.0104	0.021	2.63
23	48.528	14.44	37	11.60	266.80	6.0	6.301	150	20	0.034	-0.0104	0.023	2.75
24	48.552	14.47	37	11.60	278.40	6.0	6.301	150	20	0.037	-0.0104	0.026	2.86
25	48.576	14.49	37	11.60	290.00	6.0	6.301	150	20	0.039	-0.0104	0.029	2.98
26	48.6	14.52	37	11.60	301.60	6.0	6.301	150	20	0.042	-0.0104	0.032	3.10
27	48.624	14.55	37	11.60	313.20	6.0	6.301	150	20	0.045	-0.0104	0.035	3.22
28	48.648	14.59	37	11.60	324.80	6.0	6.301	150	20	0.049	-0.0104	0.038	3.34
29	48.672	14.63	37	11.60	336.40	6.0	6.301	150	20	0.052	-0.0104	0.042	3.46
30	48.696	14.67	37	11.60	348.00	6.0	6.301	150	20	0.055	-0.0104	0.045	3.58
31	48.72	14.71	37	11.60	359.60	6.0	6.301	150	20	0.059	-0.0104	0.048	3.70
32	48.744	14.76	37	11.60	371.20	6.0	6.301	150	20	0.062	-0.0104	0.052	3.82
33	48.768	14.81	37	11.60	382.80	6.0	6.301	150	20	0.066	-0.0104	0.056	3.94
34	48.792	14.87	37	11.60	394.40	6.0	6.301	150	20	0.070	-0.0104	0.059	4.06
35	48.816	14.93	37	11.60	406.00	6.0	6.301	150	20	0.074	-0.0104	0.063	4.18
36	48.84	14.99	37	11.60	417.60	6.0	6.301	150	20	0.077	-0.0104	0.067	4.30
37	48.864	15.06	37	11.60	429.20	6.0	6.301	150	20	0.081	-0.0104	0.071	4.42
38	48.888	15.13	37	11.60	440.80	6.0	6.301	150	20	0.086	-0.0104	0.075	4.54
39	48.912	15.21	37	11.60	452.40	8.0	8.205	150	20	0.025	-0.0104	0.014	2.75
40	48.936	15.22	37	11.60	464.00	8.0	8.205	150	20	0.026	-0.0104	0.016	2.82
41	48.96	15.24	37	11.60	475.60	8.0	8.205	150	20	0.027	-0.0104	0.017	2.89
42	48.984	15.25	37	11.60	487.20	8.0	8.205	150	20	0.028	-0.0104	0.018	2.96
43	49.008	15.27	37	11.60	498.80	8.0	8.205	150	20	0.030	-0.0104	0.019	3.03
44	49.032	15.29	37	11.60	510.40	8.0	8.205	150	20	0.031	-0.0104	0.021	3.10
45	49.056	15.31	37	11.60	522.00	8.0	8.205	150	20	0.032	-0.0104	0.022	3.17
46	49.08	15.33	37	11.60	533.60	8.0	8.205	150	20	0.034	-0.0104	0.023	3.24
47	49.104	15.36	37	11.60	545.20	8.0	8.205	150	20	0.035	-0.0104	0.025	3.31
48	49.128	15.38	37	11.60	556.80	8.0	8.205	150	20	0.036	-0.0104	0.026	3.38
49	49.152	15.41	37	11.60	568.40	8.0	8.205	150	20	0.038	-0.0104	0.028	3.45
50	49.176	15.43	37	11.60	580.00	8.0	8.205	150	20	0.039	-0.0104	0.029	3.52
51	49.2	15.46	37	11.60	591.60	8.0	8.205	150	20	0.041	-0.0104	0.030	3.59
52	49.224	15.49	37	11.60	603.20	8.0	8.205	150	20	0.042	-0.0104	0.032	3.66
53	49.248	15.53	37	11.60	614.80	8.0	8.205	150	20	0.044	-0.0104	0.033	3.73
54	49.272	15.56	37	11.60	626.40	8.0	8.205	150	20	0.045	-0.0104	0.035	3.80
55	49.296	15.59	37	11.60	638.00	8.0	8.205	150	20	0.047	-0.0104	0.037	3.87
inlet	49.32	15.63											
	Paverage	14.60	psi		*Target Inlet P average*		*14.60*	*psi*					
	Pmax	15.63	psi										
	Pmin	13.69	psi										
	Pdiff	1.94	psi		*Pdiff allowed*		*2.08*	*psi*					

Table 17. Critical Path #1 Accumulative Flow Rate

Possible Critical path #1

	Manifold Length	GPM/manifold				
Block #	feet	1st	2nd	3rd	4th	Set GPM
4	1080	626	626	626	626	2504

Table 18. Critical Path #2 Accumulative Flow Rate

Possible Critical path #2

	Manifold Length	GPM/manifold				
Block #	feet	1st	2nd	3rd	4th	Set GPM
1	1080	638	638	638	638	2552

Table 19. Mainline Design for Critical Path # 1

Point	Point P (psi)	Manifold inlet P (psi)	u/s Seg Q (gpm)	Pipe ID (in)	Seg length (ft)	Seg Hf (psi)	ΔElev (psi)	ΔP (psi)	Velocity (ft/s)
d/s pt 4	15.59	15.59	626	8.205	644	2.35	-0.33	2.01	3.80
d/s pt 3	17.61	17.61	1252	11.73	644	0.92	-0.33	0.59	3.72
d/s pt 2	18.20	18.20	1878	14.66	645	0.66	-0.34	0.33	3.57
d/s pt 1	18.52	18.52	2504	14.66	315	0.55	-0.16	0.39	4.76
d/s pt A	18.91	18.58	2504	14.66	2264	3.96	-1.18	2.78	4.76
u/s pt A	21.69	21.31							

Table 20. Mainline Design for Critical Path #2

Point	Point P (psi)	Manifold inlet P, psi	u/s Seg Q (gpm)	Pipe ID (in)	Seg length (ft)	Seg Hf (psi)	ΔElev (psi)	ΔP (psi)	Velocity (ft/s)
d/s pt 4	15.63	15.6306386	638	8.205	644	0.2	-0.33	-0.16	3.87
d/s pt 3	15.47	15.47	1264	11.73	644	0.94	-0.33	0.61	3.75
d/s pt 2	16.07	16.07	1890	14.66	645	0.67	-0.34	0.33	3.59
d/s pt 1	16.41	16.41	2516	14.66	1025	1.81	0.40	2.21	4.79
d/s pt A	18.61	18.61	2504	14.66	330	0.58	-0.17	0.41	4.76
u/s pt A	19.02	19.02	2504	14.66	100	0.17	-0.05	0.12	4.76
Pump	19.14	19.14							

APPENDIX D

Field Layout and Legend

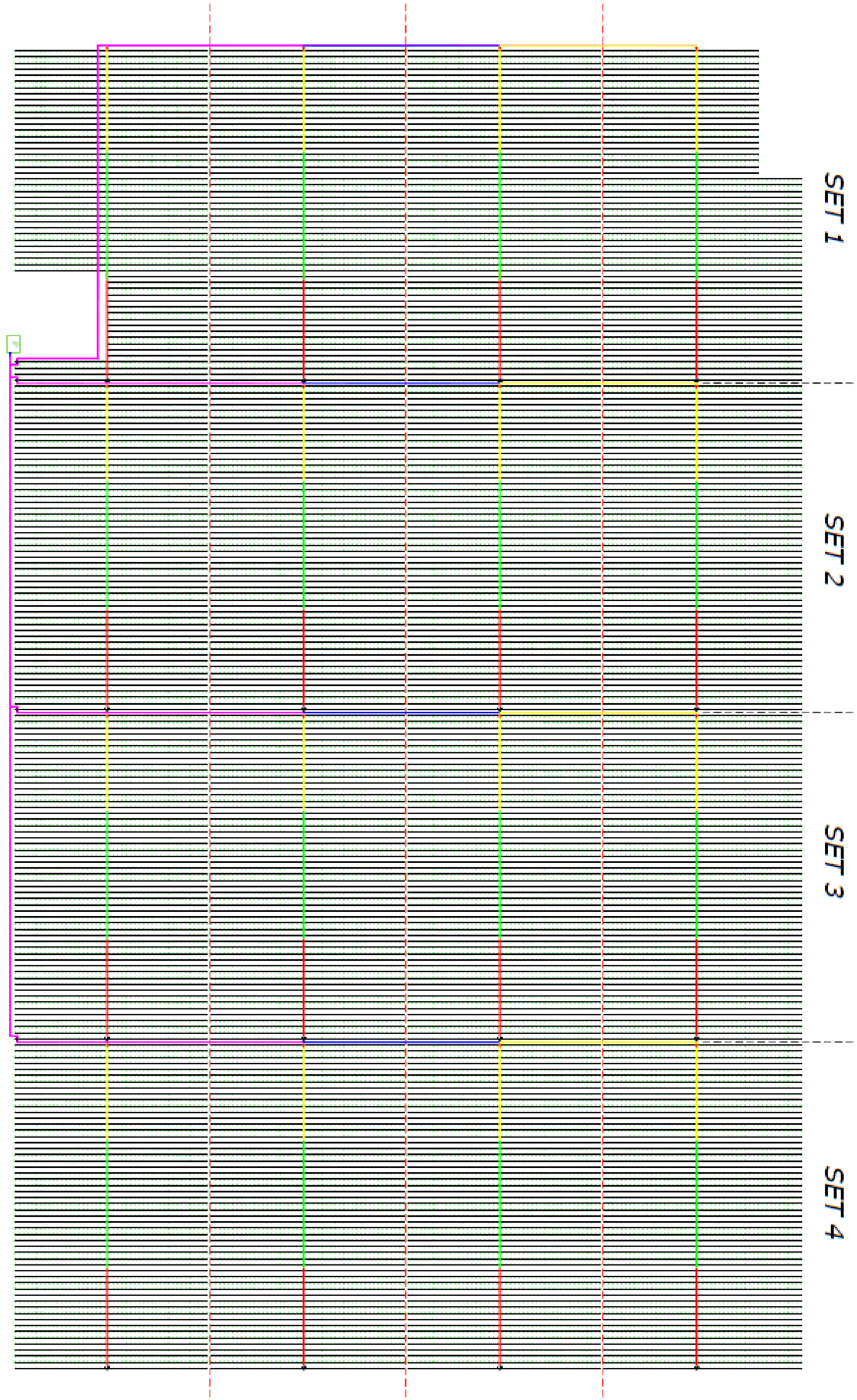


Figure 11. Field Layout

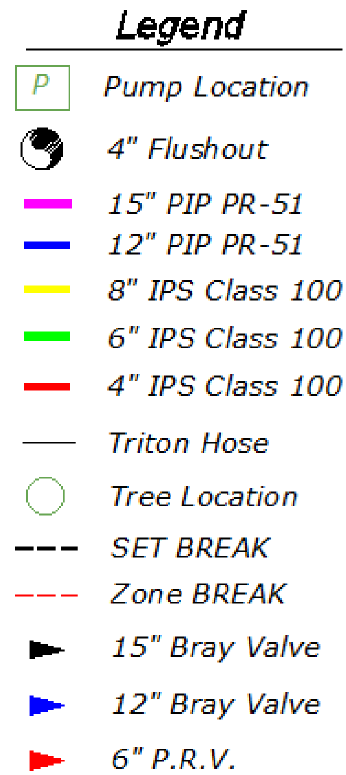


Figure 12. Field Layout Legend

APPENDIX E

Detailed System Cost Analysis

QTY.	PRODUCT DESCRIPTION	COST ($)
	Above Ground + FTS	
1142	Amnon AP22 1.06 GPH @ 24" Spacing	108490
3472	700-AP8	486
550	PI-80-PC	746
		$109,722
	Riser Assemblies	
868	1"x36" Flex Riser	2500
868	MST-WW	680
868	1" MHA	624
1736	PI-80-PST	5138
272	4"x1" Saddle	189
336	6"x1" Saddle	233
260	8"x1" Saddle	180
		$9,544
	Manifolds and Fittings	
5480	4" Class 100 IPS	6576
6760	6" Class 100 IPS	27040
5240	8" Class 100 IPS	29317
16	6"x4" RB IPS	229
16	8"x6" RB IPS	797
5	4" Coupler	21
5	6" Coupler	66
5	8" Coupler	128
		$64,174
	Mainline/Submain Pipe and Fittings	
2660	8" IPS 100 PSI	14882
2660	12" PIP 80 PSI	12635
5000	15" PIP 80 PSI	56250
4	15" x12" PIP Reducer	219
8	15"x8" PIPxIPS Reducer	3362
8	12"x8" PIPxIPS Reducer	1102
11	15" PIP Tee	2098
4	12" PIP Tee	500
11	15" PIP 90 Ell.	2072
4	8" IPS 90 Ell.	258
		$93,378
	4" Flushout Assemblies	
16	2" APVV A/V Relief Valve	640
16	4"x2" RB (SxT)	92

16	4" Tee (SxSxT)	757
16	4" Closed Nipple (TxT)	348
16	4" PVC Ball Valve	740
16	4" 90 Street Elbow	720
16	4" 90 Elbow (SxS)	152
160	4" Sch. 40 PVC Pipe	422
		$3,871
	Butterfly Block Valve Assemblies	
4	15" Bray LOV w/ 48" Extension	3476
8	15" PVC Flange	7185
32	7/8"x8" Bolts	280
32	7/8" Nuts	58
8	15"x15"x2" Tee IPS	1800
8	2" PVC FA SOCxFPT Sch.40	8
16	2" PVC 45 Elbow SOC Sch. 40	26
4	ARV-2	407
4	APVV-2	160
		$13,400
	PRV Block Valve Assemblies	
16	6" Cast Iron Pressure Regulating Valve	14807
32	6" PVC Flange	1180
128	3/4"x3" Bolts	272
128	3/4" Nuts	60
32	8"x8"x6" Tee IPS	2140
32	8"x2" RB IPS	1803
16	2" Closed nipple	28
16	ARV-2	1628
16	APVV-2	640
32	8" IPS 90 Ell.	2064
160	8" IPS 100 PSI	895
80	6" Pipe Sch. 40	320
		$25,837
	Miscellaneous	
10	Dauber for Quart Can	10
10	Cab Swab 3" to 8"	94
10	Large Mouth Can Swab	140
10	17-Grey (Gallon)	667
10	P-70-Purple (Gallon)	468
4	05-Clear (Gallon)	207
20	19-White (Quart)	478
10	95-Clear (Quart)	196

25	Polylube Pipe Pipe Joint Lubricant (Gallon)	270
1	Gloss Black Paint (Gallon)	52
2	Paint Brushes	19
2	Thread Sealant	56
2	Tephlon Tape	3
120	Quikrete 80 LB. Bags	624
		$3,284
	<u>FIlter Station</u>	
1	PROII-4812-10 Sand Media Filters	25000
1	PROII-4812-10 Install KIT	2500
130	#8 Sand Media	754
4	12" 60E Nipple	306
3	12" VIC. Couplings	223
3	12" x 90 Weld Elbows	567
20'	12" Steel Pipe	1008
1	10" Galv. Starter	165
16	3/4" x 2 1/2" Bolts	29
16	3/4" Nuts	7
2	2" THC	5
3	2" ARV	305
1	12" G.O. BFV	516
2	12" Steel Flanges	84
8	3/4" x 5" Bolts	28
8	3/4" Nuts	3
2	1" TOE	5
2	V100	55
2	PL-040 Site Glass	41
1	2" x 90 Galv. Street Elbow	14
1	2" Galv. Tee	13
1	2"x CL. Galv. TBE	4
1	2" PRV	107
6	4" x 90 SxS	57
40'	4" SCH. 40 Pipe	110
4	4" Tee	57
1	4"x2" SxT RB	6
1	3" Gate Valve	98
2	3"x4" MA	14
1	4" PVC Coupling	5
20'	1/2" SCH. 80 PVC Conduit Pipe	8

3	1/2" Conduit Tee	11
1	1/2" Conduit LB	3
20'	1/2" Flex Conduit	11
1	12" Saddle Type Flow Meter Mcrometer	1426
1	1/2" Conduit MA	1
		$33,546
	<u>10" Pre Screen</u>	
1	706-0750 HL Horizontal Pre Screen	1300
	10" Flanged IN and OUT	59
2	1020-061 10" Steel Flange	767
2	10" G.O. BFV	2126
		$4,252
	<u>Check Valve</u>	
1	12" Chemigation Check Valve	2016
		$2,016
	<u>Pump</u>	
1	75 HP Berkley Pump (14D-SS)	13,000
		$13,000
	TOTAL:	$376,024

APPENDIX F

Isometric Sketches

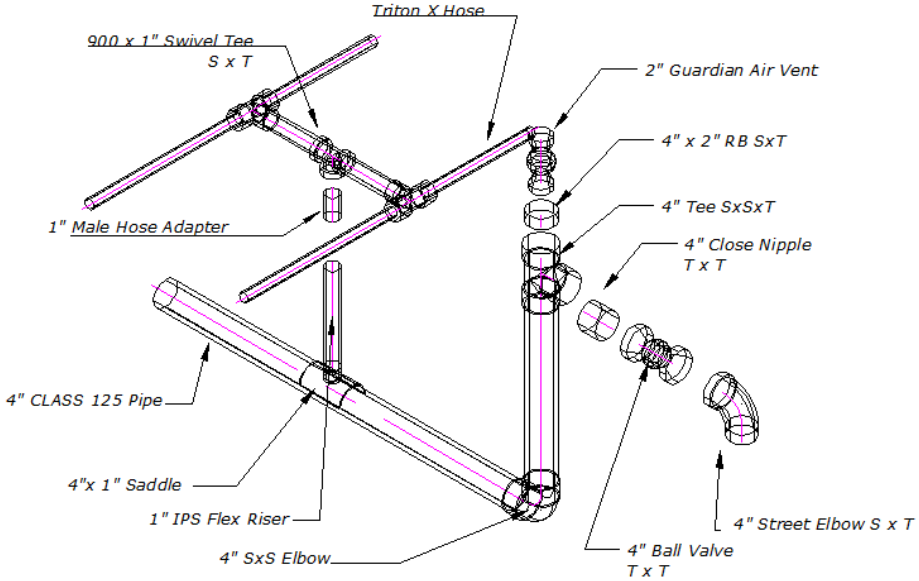


Figure 13. Riser and Flushout Detail

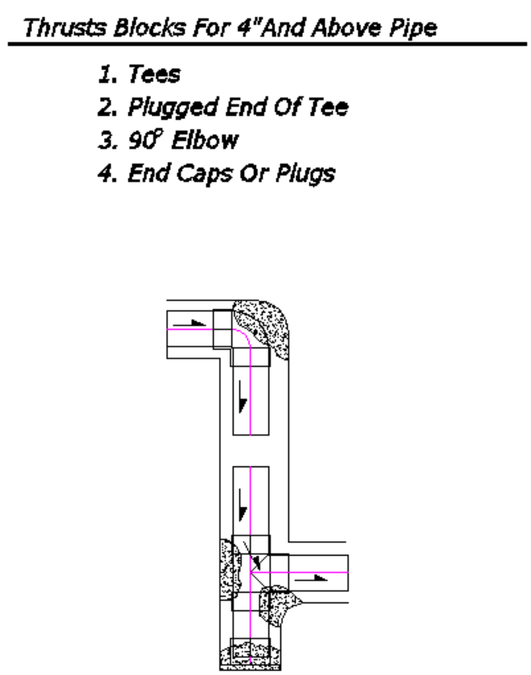


Figure 14. Thrust Block Detail

APPENDIX G

Excel Spreadsheet

Given

Field Size			126	Acres
Tree Spacing	20	x	14	feet
Peak ET Rate			7.69	inches per month
Days per Month			31	
Assumed increase in ETc with drip			0	%
System DUlq specified			0.93	
Planting Direction:			North/South	
Total Length Down Rows			2624	feet
Slope down the row			0.12	%
Hours per day			24	hours
Days per week operation			**2**	

Computed Values

Peak ET rate	0.25	inches/day
Field Area	5488560	sqft
Area per tree	280	ft2
Number of Trees	19602	trees/field

(net) ET rate 0.25 inches/day

1) Find Required GPH/Tree

Find: # emitters per tree

Formula

Gross = Net ET/DU

GPM=Inches*tree spacing/(96.3*hours)

Solution

Assume DU 0.85 future DU after deterioration

Gross 0.292 inches/day

Gross

GPM 0.1237 per tree

GPH 7.42 per tree

2) Find the estimated number of emitters per tree

"Typical Values for drip are:

Soil Type	Additional Lateral Movement for Drip	
	(ft)	(m)
Coarse Sand	0.5-1.5	0.15-0.5
Fine Sand	1.0-3.0	0.3-0.9
Loam	3.0-4.5	0.9-1.4
Heavy Clay	4.0-6.0	1.2-1.8

The design is based off of a Capay Clay.

Since this is a clay soil, the lateral movement of the water will be about 4 feet (R=4 feet)

R= 4 feet

Wetted Area of single emitter:

Area = 3.14R^2

Area = 50.24 ft2

Area per Tree:

Area = tree spacing*row spacing

Area = 280 ft2

Wetted Area per Tree, single line:

Area = (Wetted Area Length*Wetted Area Width)

Area = 112 ft2

Actual % Wetted Area 40%

Wetted Area per Tree, w/dual line:

Area = (Wetted Area Length*Wetted Area Width)*2

Area = 224 ft2

Actual % Wetted Area 80%

# of emitters needed per tree:

emitters/tree = (Tree Area*Fraction of Wetted Area)/Wetted area per emitter

Target wetted Area: 80%

emitters/tree = 4.46 emitters/tree

5 emitters/tree

**However, there is no manufacturer that make an in-line emitters that exceeds a flow rate above 2.0 GPH.
Adding addition emitters will not increase the wetted area. Additional emitters are necessary so that we can reduce the flow rate per emitters to a reasonable constraint so that we can utilize the desired reasources for the project. Therefore, we will be using 28 ft of emitter line per tree rather ath 14 ft of emitter line per tree.
Thus, contibuting to the need foe addition emitters.

emitters tree, per line= 5 emitters per tree, 2.5 from each line

An Addition 2 emitters per tree will be necessary to achieve the desried pressures for the nominal emitters provided by the manufacturer. We choose emitters by closing examining our calculated emitter pressures, The most sufficient emitter operating pressure for this scenario is about 11-13 psi. With different combos emitters/tree and hours of operation we can achieve these goals. For each calculated pressure there is a set emitter size and number of irrigation blocks. Based on preference you can set a # block constraint.
For this design the farmer is requesting a two set system for easibility and installation purposes.

7 emitters per tree, 3.5 from each line

3) Determine the emitter Spacing: 5.6 11.2

Emitter Manufacturer: Netafim
Emisson Device: Triton Heavy wall emitter line
Common emitter spacings: 18", 24",30",36",42",48"
**However Netafim allows you to custom order any emitter spacing to accommodate any design constraints.

Constraint 1: 7 emitters/tree
Constraint 2: 2 lines per tree (so 3.5 emitters per line per tree)
Constraint 3: 14 feet between trees
Emitter Spacing (inches)= (Feet between trees/((# emitters/tree) / (#lines/tree)))*12 inches/foot
48 inch emitter spacing

4) Examine the number of irrigation blocks needed:

First, the proper emitter must be selected.

- Emitter #1: GPH = 0.125P0.46
- Emitter #2: GPH = $0.164P^{0.46}$

	GPH/Emitter		
Emitter 1	0.4	K =	0.125
		x =	0.46
Emitter 2	0.5	K =	0.164
		x =	0.46
Emitter 3	1.0	K =	0.327
		x =	0.46
Emitter 4	2.0	K =	0.655
		x =	0.46
	Manufacturer CV		0.035

DRIPPER DATA / HEAVYWALL 45 MIL OR GREATER

DRIPPER (GPH)	EXPONENT (x)	CONSTANT (k)	REQUIRED FILTRATION
0.26	.46	.0817	120 MESH
0.4	.46	.125	120 MESH
0.5	.46	.164	120 MESH
1.0	.46	.327	120 MESH
2.0	.46	.655	120 MESH

		Pressures, psi			
# of Blocks	GPH/emitter	Emitter 1	Emitter 2	Emitter 3	Emitter 4
1	1.06	104.44	57.87	12.91	2.85
2	2.12	471.28	261.16	58.26	12.87
3	4.24	2126.62	1178.45	262.89	58.07
4	8.49	9596.29	5317.72	1186.30	262.02

P = (GPH/K)^(1/x)

Summary	# Blocks	2
	GPH/Emitter	2.12
	Avg emitter P	12.87

Field Constraints:

In order to have two symetrically sized blocks we will assume a set break at the midpoint of the field.
The two blocks are almost identical, but one block 1 will have one extra row.
We will assume 109 driving rows on the East set, and we will assume 108 rows in the Western set.
The mainline will be placed directly down the middle of each set so that the flows in all manifolds are somewhat consistent with each other.
On the western block there will be 54 inlets per zone.
On the eastern side half of the zones will have 54 inlets, and the other 5 zones will have 55 inlets.

5) Determine optimum location for the manifold

The field is almost symetrical and a large majority of the hoses will be the same overall length.
Some hose lengths will shorter du tonthe interferring property lines.

- Info for Manifold Placement Program

Hose Length	656	ft
Emitter flow	2.12	GPH
Avg Pressure	12.87	psi
7 emitter per tree, 3.5 emitters/line		
For DU computation	7	number of emitters servicing a tree
slope along hose	0.12	%
Distance between emitters	48	inches
Manufacturer CV	0.035	
Emitter Exponent	0.46	
Extra length for temp. expansion	1.5	%
Nominal Emitter flow	2.0	GPH
Nominal Emitter operating P	12.0	psi

Select the smallest Hose ID that gives allowable hose DUlq

PACKAGING INFORMATION

I.D.	WALL THICKNESS	COIL LENGTH	WEIGHT	Kd
.540"	35 MIL	1,000'	27 LBS.	0.45
.540"	45 MIL	1,000'	35 LBS.	0.45
.620"	35 MIL	1,000'	30 LBS.	0.25
.620"	45 MIL	1,000'	39 LBS.	0.25
.690"	45 MIL	1,000'	44 LBS.	0.10
.690"	48 MIL	1,000'	47 LBS.	0.10
.820"	45 MIL	1,000'	51 LBS.	0.10
.820"	60 MIL	1,000'	69 LBS.	0.10

Formula

DUlq target = DUhose * DUmanifold

DUlq target = 0.93

Hose Dia	Inlet P psi	# manifolds	Length ft	Uphill ft	Downhill ft	DUlq hose	DUmanifold
0.54	20.3	4	656	321.44	334.56	0.91	1.02197802
0.62	17.1	4	656	321.44	334.56	0.94	0.9893617
0.69	15.7	4	656	321.44	334.56	0.96	0.96875
0.82	14.6	4	656	314.88	341.12	0.97	0.95876289
0.54	15.9	5	437	214.13	222.87	0.95	0.97894737
0.62	14.8	5	437	214.13	222.87	0.97	0.95876289
0.69	14.3	5	437	209.76	227.24	0.97	0.95876289
0.82	13.9	5	437	201.02	235.98	0.98	0.94897959

The Inside diameter of the hose that is to be used is 0.82 inches.

PER Manifold:			
Uphill:	315'/14'	**22**	**trees**
Downhill:	341'/14'	**24**	**trees**

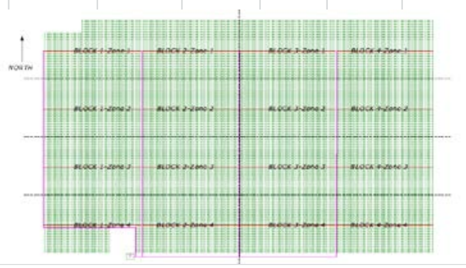
6) **Selection from Table**

Hose inlet Pressure = 14.6

DU Manifold = 0.958763

Allowable change in pressure along manifold = 2.08 psi

9) Sizing the **Critical** Manifolds (in RED)



PIPE SELECTION TABLE

Nom. Dia	ID	PR	Type	H-W "C"
1.5	1.72	200	IPS	144
2	2.193	160	IPS	145
2.5	2.655	160	IPS	147
3	3.284	125	IPS	148
4	4.28	100	IPS	149
5	5.291	100	IPS	150
6	6.301	100	IPS	150
8	8.205	100	IPS	150
10	9.78	80	PIP	150
12	11.73	80	PIP	150
15	14.66	80	PIP	150
18	17.92	80	PIP	150

In this case almost all manifolds are nearly identical,

.

Velocity thru 1" riser at 11.6 GPM

V (ft/s) = (GPM/449)/(3.14*(I.D. Pipe/12)^2/4)

V (ft/s) = 4.31 FT/S

Elevation Change per Point:

ECHANGE (FT) = (Slope/100)*Segment Length

ECHANGE (FT) = (0.12/100)*20

ECHANGE = 0.024 FT

Downhill 54 rows

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Point	Elevation ft	Point P psi	# of trees in row	Point Q GPM	u/s Segment Q (GPM)	Nominal inches	Pipe ID inches	C value	Segment Length (ft)	Segment Hf (psi)	Change in Elev (psi)	Change in P (psi)	V ft/s
					0.00								
1	48	13.71	37	11.60	11.60	4.0	4.28	149	20	0.001	-0.0104	-0.010	0.26
2	48.024	13.70	37	11.60	23.20	4.0	4.28	149	20	0.002	-0.0104	-0.008	0.52
3	48.048	13.69	37	11.60	34.80	4.0	4.28	149	20	0.005	-0.0104	-0.005	0.78
4	48.072	13.69	37	11.60	46.40	4.0	4.28	149	20	0.009	-0.0104	-0.002	1.03
5	48.096	13.69	37	11.60	58.00	4.0	4.28	149	20	0.013	-0.0104	0.003	1.29
6	48.12	13.69	37	11.60	69.60	4.0	4.28	149	20	0.019	-0.0104	0.008	1.55
7	48.144	13.70	37	11.60	81.20	4.0	4.28	149	20	0.025	-0.0104	0.014	1.81
8	48.168	13.71	37	11.60	92.80	4.0	4.28	149	20	0.032	-0.0104	0.021	2.07
9	48.192	13.73	37	11.60	104.40	4.0	4.28	149	20	0.040	-0.0104	0.029	2.33
10	48.216	13.76	37	11.60	116.00	4.0	4.28	149	20	0.048	-0.0104	0.038	2.59
11	48.24	13.80	37	11.60	127.60	4.0	4.28	149	20	0.057	-0.0104	0.047	2.85
12	48.264	13.85	37	11.60	139.20	4.0	4.28	149	20	0.067	-0.0104	0.057	3.10
13	48.288	13.90	37	11.60	150.80	4.0	4.28	149	20	0.078	-0.0104	0.068	3.36
14	48.312	13.97	37	11.60	162.40	4.0	4.28	149	20	0.090	-0.0104	0.079	3.62
15	48.336	14.05	37	11.60	174.00	4.0	4.28	149	20	0.102	-0.0104	0.092	3.88
16	48.36	14.14	37	11.60	185.60	4.0	4.28	149	20	0.115	-0.0104	0.104	4.14
17	48.384	14.25	37	11.60	197.20	4.0	4.28	149	20	0.128	-0.0104	0.118	4.40
18	48.408	14.36	37	11.60	208.80	6.0	6.301	150	20	0.021	-0.0104	0.011	2.15
19	48.432	14.38	37	11.60	220.40	6.0	6.301	150	20	0.024	-0.0104	0.013	2.27
20	48.456	14.39	37	11.60	232.00	6.0	6.301	150	20	0.026	-0.0104	0.016	2.39
21	48.48	14.40	37	11.60	243.60	6.0	6.301	150	20	0.029	-0.0104	0.018	2.51
22	48.504	14.42	37	11.60	255.20	6.0	6.301	150	20	0.031	-0.0104	0.021	2.63
23	48.528	14.44	37	11.60	266.80	6.0	6.301	150	20	0.034	-0.0104	0.023	2.75
24	48.552	14.47	37	11.60	278.40	6.0	6.301	150	20	0.037	-0.0104	0.026	2.86
25	48.576	14.49	37	11.60	290.00	6.0	6.301	150	20	0.039	-0.0104	0.029	2.98
26	48.6	14.52	37	11.60	301.60	6.0	6.301	150	20	0.042	-0.0104	0.032	3.10
27	48.624	14.55	37	11.60	313.20	6.0	6.301	150	20	0.045	-0.0104	0.035	3.22
28	48.648	14.59	37	11.60	324.80	6.0	6.301	150	20	0.049	-0.0104	0.038	3.34
29	48.672	14.63	37	11.60	336.40	6.0	6.301	150	20	0.052	-0.0104	0.042	3.46
30	48.696	14.67	37	11.60	348.00	6.0	6.301	150	20	0.055	-0.0104	0.045	3.58
31	48.72	14.71	37	11.60	359.60	6.0	6.301	150	20	0.059	-0.0104	0.048	3.70
32	48.744	14.76	37	11.60	371.20	6.0	6.301	150	20	0.062	-0.0104	0.052	3.82
33	48.768	14.81	37	11.60	382.80	6.0	6.301	150	20	0.066	-0.0104	0.056	3.94
34	48.792	14.87	37	11.60	394.40	6.0	6.301	150	20	0.070	-0.0104	0.059	4.06
35	48.816	14.93	37	11.60	406.00	6.0	6.301	150	20	0.074	-0.0104	0.063	4.18
36	48.84	14.99	37	11.60	417.60	6.0	6.301	150	20	0.077	-0.0104	0.067	4.30
37	48.864	15.06	37	11.60	429.20	6.0	6.301	150	20	0.081	-0.0104	0.071	4.42
38	48.888	15.13	37	11.60	440.80	6.0	6.301	150	20	0.086	-0.0104	0.075	4.54
39	48.912	15.21	37	11.60	452.40	8.0	8.205	150	20	0.025	-0.0104	0.014	2.75
40	48.936	15.22	37	11.60	464.00	8.0	8.205	150	20	0.026	-0.0104	0.016	2.82
41	48.96	15.24	37	11.60	475.60	8.0	8.205	150	20	0.027	-0.0104	0.017	2.89
42	48.984	15.25	37	11.60	487.20	8.0	8.205	150	20	0.028	-0.0104	0.018	2.96
43	49.008	15.27	37	11.60	498.80	8.0	8.205	150	20	0.030	-0.0104	0.019	3.03
44	49.032	15.29	37	11.60	510.40	8.0	8.205	150	20	0.031	-0.0104	0.021	3.10
45	49.056	15.31	37	11.60	522.00	8.0	8.205	150	20	0.032	-0.0104	0.022	3.17
46	49.08	15.33	37	11.60	533.60	8.0	8.205	150	20	0.034	-0.0104	0.023	3.24
47	49.104	15.36	37	11.60	545.20	8.0	8.205	150	20	0.035	-0.0104	0.025	3.31
48	49.128	15.38	37	11.60	556.80	8.0	8.205	150	20	0.036	-0.0104	0.026	3.38
49	49.152	15.41	37	11.60	568.40	8.0	8.205	150	20	0.038	-0.0104	0.028	3.45
50	49.176	15.43	37	11.60	580.00	8.0	8.205	150	20	0.039	-0.0104	0.029	3.52
51	49.2	15.46	37	11.60	591.60	8.0	8.205	150	20	0.041	-0.0104	0.030	3.59
52	49.224	15.49	37	11.60	603.20	8.0	8.205	150	20	0.042	-0.0104	0.032	3.66
53	49.248	15.53	37	11.60	614.80	8.0	8.205	150	20	0.044	-0.0104	0.033	3.73
54	49.272	15.56	37	11.60	626.40	8.0	8.205	150	20	0.045	-0.0104	0.035	3.80
Inlet	49.296	15.59											

Paverage	14.60	psi	*Target Inlet P average*	*14.60*	*psi*
Pmax	15.59	psi			
Pmin	13.69	psi			
Pdiff	1.91	psi	*Pdiff allowed*	*2.08*	*psi*

The ΔP for the table is less than the allowable ΔP so this will be acceptable.

Downhill 55 rows

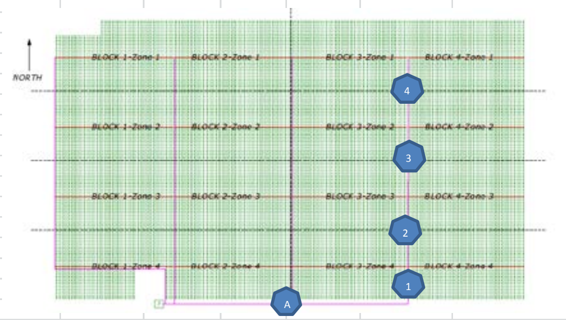
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Point	Elevation ft	Point P psi	# of trees in row	Point Q GPM	u/s Segment Q (GPM)	Nominal inches	Pipe ID inches	C value	Segment Length (ft)	Segment Hf (psi)	Change in Elev (psi)	Change in P (psi)	V ft/s
					0.00								
1	48	**13.70**	37	11.60	11.60	4.0	4.28	149	20	0.001	0.000	0.001	0.26
2	48.024	13.70	37	11.60	23.20	4.0	4.28	149	20	0.002	-0.0104	-0.008	0.52
3	48.048	13.69	37	11.60	34.80	4.0	4.28	149	20	0.005	-0.0104	-0.005	0.78
4	48.072	13.69	37	11.60	46.40	4.0	4.28	149	20	0.009	-0.0104	-0.002	1.03
5	48.096	13.69	37	11.60	58.00	4.0	4.28	149	20	0.013	-0.0104	0.003	1.29
6	48.12	13.69	37	11.60	69.60	4.0	4.28	149	20	0.019	-0.0104	0.008	1.55
7	48.144	13.70	37	11.60	81.20	4.0	4.28	149	20	0.025	-0.0104	0.014	1.81
8	48.168	13.71	37	11.60	92.80	4.0	4.28	149	20	0.032	-0.0104	0.021	2.07
9	48.192	13.73	37	11.60	104.40	4.0	4.28	149	20	0.040	-0.0104	0.029	2.33
10	48.216	13.76	37	11.60	116.00	4.0	4.28	149	20	0.048	-0.0104	0.038	2.59
11	48.24	13.80	37	11.60	127.60	4.0	4.28	149	20	0.057	-0.0104	0.047	2.85
12	48.264	13.85	37	11.60	139.20	4.0	4.28	149	20	0.067	-0.0104	0.057	3.10
13	48.288	13.90	37	11.60	150.80	4.0	4.28	149	20	0.078	-0.0104	0.068	3.36
14	48.312	13.97	37	11.60	162.40	4.0	4.28	149	20	0.090	-0.0104	0.079	3.62
15	48.336	14.05	37	11.60	174.00	4.0	4.28	149	20	0.102	-0.0104	0.092	3.88
16	48.36	14.14	37	11.60	185.60	4.0	4.28	149	20	0.115	-0.0104	0.104	4.14
17	48.384	14.25	37	11.60	197.20	4.0	4.28	149	20	0.128	-0.0104	0.118	4.40
18	48.408	14.37	37	11.60	208.80	6.0	6.301	150	20	0.021	-0.0104	0.011	2.15
19	48.432	14.38	37	11.60	220.40	6.0	6.301	150	20	0.024	-0.0104	0.013	2.27
20	48.456	14.39	37	11.60	232.00	6.0	6.301	150	20	0.026	-0.0104	0.016	2.39
21	48.48	14.41	37	11.60	243.60	6.0	6.301	150	20	0.029	-0.0104	0.018	2.51
22	48.504	14.42	37	11.60	255.20	6.0	6.301	150	20	0.031	-0.0104	0.021	2.63
23	48.528	14.44	37	11.60	266.80	6.0	6.301	150	20	0.034	-0.0104	0.023	2.75
24	48.552	14.47	37	11.60	278.40	6.0	6.301	150	20	0.037	-0.0104	0.026	2.86
25	48.576	14.49	37	11.60	290.00	6.0	6.301	150	20	0.039	-0.0104	0.029	2.98
26	48.6	14.52	37	11.60	301.60	6.0	6.301	150	20	0.042	-0.0104	0.032	3.10
27	48.624	14.55	37	11.60	313.20	6.0	6.301	150	20	0.045	-0.0104	0.035	3.22
28	48.648	14.59	37	11.60	324.80	6.0	6.301	150	20	0.049	-0.0104	0.038	3.34
29	48.672	14.63	37	11.60	336.40	6.0	6.301	150	20	0.052	-0.0104	0.042	3.46
30	48.696	14.67	37	11.60	348.00	6.0	6.301	150	20	0.055	-0.0104	0.045	3.58
31	48.72	14.71	37	11.60	359.60	6.0	6.301	150	20	0.059	-0.0104	0.048	3.70
32	48.744	14.76	37	11.60	371.20	6.0	6.301	150	20	0.062	-0.0104	0.052	3.82
33	48.768	14.81	37	11.60	382.80	6.0	6.301	150	20	0.066	-0.0104	0.056	3.94
34	48.792	14.87	37	11.60	394.40	6.0	6.301	150	20	0.070	-0.0104	0.059	4.06
35	48.816	14.93	37	11.60	406.00	6.0	6.301	150	20	0.074	-0.0104	0.063	4.18
36	48.84	14.99	37	11.60	417.60	6.0	6.301	150	20	0.077	-0.0104	0.067	4.30
37	48.864	15.06	37	11.60	429.20	6.0	6.301	150	20	0.081	-0.0104	0.071	4.42
38	48.888	15.13	37	11.60	440.80	6.0	6.301	150	20	0.086	-0.0104	0.075	4.54
39	48.912	15.21	37	11.60	452.40	8.0	8.205	150	20	0.025	-0.0104	0.014	2.75
40	48.936	15.22	37	11.60	464.00	8.0	8.205	150	20	0.026	-0.0104	0.016	2.82
41	48.96	15.24	37	11.60	475.60	8.0	8.205	150	20	0.027	-0.0104	0.017	2.89
42	48.984	15.25	37	11.60	487.20	8.0	8.205	150	20	0.028	-0.0104	0.018	2.96
43	49.008	15.27	37	11.60	498.80	8.0	8.205	150	20	0.030	-0.0104	0.019	3.03
44	49.032	15.29	37	11.60	510.40	8.0	8.205	150	20	0.031	-0.0104	0.021	3.10
45	49.056	15.31	37	11.60	522.00	8.0	8.205	150	20	0.032	-0.0104	0.022	3.17
46	49.08	15.33	37	11.60	533.60	8.0	8.205	150	20	0.034	-0.0104	0.023	3.24
47	49.104	15.36	37	11.60	545.20	8.0	8.205	150	20	0.035	-0.0104	0.025	3.31
48	49.128	15.38	37	11.60	556.80	8.0	8.205	150	20	0.036	-0.0104	0.026	3.38
49	49.152	15.41	37	11.60	568.40	8.0	8.205	150	20	0.038	-0.0104	0.028	3.45
50	49.176	15.43	37	11.60	580.00	8.0	8.205	150	20	0.039	-0.0104	0.029	3.52
51	49.2	15.46	37	11.60	591.60	8.0	8.205	150	20	0.041	-0.0104	0.030	3.59
52	49.224	15.49	37	11.60	603.20	8.0	8.205	150	20	0.042	-0.0104	0.032	3.66
53	49.248	15.53	37	11.60	614.80	8.0	8.205	150	20	0.044	-0.0104	0.033	3.73
54	49.272	15.56	37	11.60	626.40	8.0	8.205	150	20	0.045	-0.0104	0.035	3.80
55	49.296	15.59	37	11.60	638.00	8.0	8.205	150	20	0.047	-0.0104	0.037	3.87
inlet	49.32	15.63											
	Paverage	14.60	psi		*Target Inlet P average*		*14.60*	*psi*					
	Pmax	15.63	psi										
	Pmin	13.69	psi										
	Pdiff	1.94	psi		*Pdiff allowed*		*2.08*	*psi*					

In this case our saftey factor was 0.2 psi, or ten percent.

10) Sizing the critical path of the main line, determining losses starting at the manifold inlet.

Possible Critical path #1

Block #	Manifold Length feet	GPM/manifold 1st	2nd	3rd	4th	Set GPM
4	1080	626	626	626	626	2504



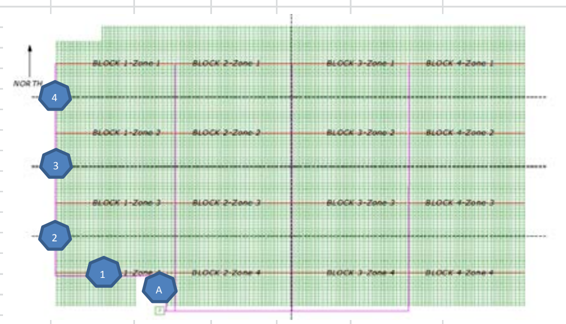
To size these sections of pipe the rule of "not exceeding 5.0 ft/s" is used.

CRITICAL PATH #1

	Point	Point P (psi)	Manifold inlet P, psi	u/s Seg Q (gpm)	Pipe ID (in)	Seg length (ft)	Seg Hf (psi)	ΔElev (psi)	ΔP (psi)	Velocity (ft/s)
	d/s pt 4	15.59	15.5937085	626	8.205	644	2.35	-0.33	2.01	3.80
	d/s pt 3	17.61	17.61	1252	11.73	644	0.92	-0.33	0.59	3.72
	d/s pt 2	18.20	18.20	1878	14.66	645	0.66	-0.34	0.33	3.57
	d/s pt 1	18.52	18.52	2504	14.66	315	0.55	-0.16	0.39	4.76
	d/s pt A	18.91	18.58	2504	14.66	2264	3.96	-1.18	2.78	4.76
Pump	u/s pt A	21.69	21.31							
									6.10	

Possible Critical path #2

Block #	Manifold Length feet	GPM/manifold 1st	2nd	3rd	4th	Set GPM
1	1080	638	638	638	638	2552



CRITICAL PATH #2

Point	Point P (psi)	Manifold inlet P, psi	u/s Seg Q (gpm)	Pipe ID (in)	Seg length (ft)	Seg Hf (psi)	ΔElev (psi)	ΔP (psi)	Velocity (ft/s)
d/s pt 4	15.63	15.6306386	638	8.205	644	0.2	-0.33	-0.16	3.87
d/s pt 3	15.47	15.47	1264	11.73	644	0.94	-0.33	0.61	3.75
d/s pt 2	16.07	16.07	1890	14.66	645	0.67	-0.34	0.33	3.59
d/s pt 1	16.41	16.41	2516	14.66	1025	1.81	0.40	2.21	4.79
d/s pt A	18.61	18.61	2504	14.66	330	0.58	-0.17	0.41	4.76
u/s pt A	19.02	19.02	2504	14.66	100	0.17	-0.05	0.12	4.76
Pump	19.14	19.14							

Critical Path number one will be the critical path because this is the path with the most pressure loss.

Critical Path Pressure Requirement = **21.69** PSI *At Pump*

11) Pressure Regulation Method and Requirements

For this design we must use pressure regulation valves to keep the inlet pressure for all manifolds at 15.63 psi.

Pressure loss across P.RV. = **4** PSI

12) Filtration Requirements

The next step for the design procedure requires determining which method of filtration to use.
For filtration requirements you always want to design based on the worst case scenario.
The design will require sand media tanks to sufficiently filter the moderately dirty water. For drip irrigation a common rule of thumb is to remove

Mesh Size	Opening Size (in)	(mm)
20	0.0280	0.71
80	0.0071	0.18
100	0.0060	0.15
120	**0.0049**	**0.12**
150	0.0041	0.1

Maximum flow rate= 2504 gpm
Orifice diameter= 0.049 in

Min. removed partical dia.= 0.0049 in
Mesh Size = 120

The Media Selection Table based on

Media #	Media Type	Mean Effective Media Size (mm)	Mean Filtration Capacity (mm) (@ 15-25 GPM/sq.-ft)	
12	Round Monterey Sand	1.30	0.16 - 0.15 mm	90-70 mesh
16	Round Monterey Sand	0.65	0.12 - 0.15	125-100
8	**Crushed Granite**	**1.50**	**0.11 - 0.15**	140-100
12	Crushed Silica	1.20	0.11	140-130
20	Round Monterey Sand	0.50	0.11	140-130
11	Crushed Granite	0.78	0.08 - 0.11	200-140
16	Crushed Silica	0.70	0.08 - 0.10	200-150
20	Crushed Silica	0.47	0.06 - 0.08	250-200

13) Sizing the media tanks required.

Water quality (flows/sq. ft):
For average water, design for 20-25 GPM/sq ft
For extra dirty water, design for 10-15 GPM/sq ft

Water quality: Average
Irrigation System GPM: 2504

Square footage needed = Irrigation System GPM / Design GPM/sq ft
= 125.2 sq. ft.

Area of 48" tank (sq. ft.) = 3.14*(Radius^2)
= 12.56 sq. ft.

Number of tanks needed = Square footage needed / Area per tank
= 10.0 tanks

Next we have to determine if an additional filter will be necessary for backflush requirements.
Since we are using 48" tanks we need to size the amount of filters based on the addition flow rate the BF would add to the overall system flowrate.
An additional 190 GPM is necessary for sizing the number of filters.

Tank Dia.	BF GPM
18"	25
24"	50
30"	80
36"	110
48"	190

Back Flush Flow Rate with 10-48" tanks:

BF Flow rate per sq ft = (System GPM/Area of Filtration)
= (2504 GPM+190 GPM/12.56 sq ft*10 tanks)
= 21.4 GPM

Back Flush Flow Rate with 11-48" tanks:

BF Flow rate per sq ft = (System GPM/Area of Filtration)
= (2504 GPM+190 GPM/12.56 sq ft*11 tanks)
= 19.5 GPM

When designing tanks for average water quality the target flow rate per square foot is 20-25 GPM.
We design for 20 GPM per square foot, however when the system is operating in a backflush
with only 10 tanks we are still within the constraint we want to see.

Filtration Summary:	
# of tanks:	**10**
Size:	**48"**
Media type:	**#8 Crushed Granite**
Pressure losses:	**7 psi when dirty**

14) Total Dynamic Head (TDH) Required from the Pump:

u/s Point A	21.7	PSI
Filter Pressure loss =	7.0	PSI
Pre-Filter loss	0.5	PSI
Valve Pressure loss	4.0	PSI
Minor losses	3.0	PSI
TDH =	36.2	PSI