Under-Tree Sprinkler Design in a Walnut/Cherry Orchard

By

Edward Caminata

BioResource and Agricultural Engineering

BioResource and Agricultural Engineering Department

California Polytechnic State University

San Luis Obispo

2014

TITLE: Under-Tree Sprinkler Design in a Walnut/Cherry Orchard

AUTHOR: Edward Caminata

DATE SUBMITTED: March 21, 2014

Daniel J. Howes
Senior Project Advisor

Signature

Date

Art MacCarley
Department Head

Signature

Date

ACKNOWLEDGMENTS

First, I would like to thank my family and friends who have always supported me in my goal of becoming an engineer. I especially want to thank my parents who taught me the value of hard work and encouraged me to always to my best. Next I would like to thank the faculty and staff in the BioResource and Agricultural Engineering Department. There has never been a doubt in my mind that this department was the right place for me. Lastly, I would like to thank Dr. Howes for all his support and guidance throughout this project.

ABSTRACT

The goal of this project is to design a permanent under-tree sprinkler system for a 50 acre walnut and cherry orchard in Linden, CA. This will allow irrigation water to be delivered to the trees more uniformly and decrease the labor requirements needed to irrigate. This design will target a value of 0.92 for the Distribution Uniformity of each set throughout the system.

DISCLAIMER STATEMENT

The university makes it clear that the information forwarded herewith is a project resulting from a class assignment and has been graded and accepted only as a fulfillment of a course requirement. Acceptance by the university does not imply technical accuracy or reliability. Any use of the information in this report is made by the user(s) at his/her own risk, which may include catastrophic failure of the device or infringement of patent or copyright laws.

Therefore, the recipient and/or user of the information contained in this report agrees to indemnify, defend and save harmless the State its officers, agents and employees from any and all claims and losses accruing or resulting to any person, firm, or corporation who may be injured or damaged as a result of the use of this report.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Background

Due to the increasing population in California, it is becoming increasingly difficult to maintain an adequate water supply for both agricultural uses and those of the general population. California, being a semi-arid environment, relies heavily on irrigation for agriculture. Because of the declining water supply, it is more important than ever that water used for irrigation be used efficiently. An irrigation system with a high distribution uniformity (DU) can meet crop water requirements while using less water than can a system with a low DU. In some cases, converting the field to a new irrigation system with a higher DU will result in an increase in water use because much of the field was being under-irrigated with the old system.

J. Caminata Ent. Inc. has been farming in Linden, CA for over 80 years. This operation has grown a vast variety of crops, including walnuts, cherries, peaches, sugar beets, and various other crops. Currently J. Caminata Ent. Inc. farms only walnuts and cherries and all but one field has been converted from flood irrigation to sprinkler irrigation. Looking at figure 1 below, this field seems to have a poor distribution uniformity with the flood irrigation system currently in use. Due to the high labor requirement associated with flood irrigation and the apparent uniformity issue in the field, J. Caminata Ent. Inc has

Figure 1. Caminata Ent. Inc. 50 acre walnut and cherry orchard on Duncan Rd. Linden, CA

asked me to design a sprinkler system for the field in figure 1. This field includes several walnut blocks and several cherry blocks that will be irrigated using the same pump.

Objectives

The design objectives for this field are as follows:

1) Design a sprinkler system with a distribution uniformity of at least 0.92 that is capable of supplying the water needed to satisfy peak crop Evapotranspiration.
2) Minimize friction loss throughout the system to minimize pump horsepower requirement
3) Maintain a maximum water velocity of 5 feet per second in pipeline.
4) Use economic pipe sizing techniques to minimize system cost.
5) Design a filtration system to minimize system plugging.

LITERATURE REVIEW

Crop Evapotranspiration

Evapotranspiration is the made up of two parts: the water that the plant takes up and uses for transpiration, and the water that evaporates off the plant and surrounding soils surface. (Burt, 2012b). This system will be designed to meet ET requirements when they are at their peak. ET is typically at its peak sometime during the summer when temperatures are hot and longer periods of daylight cause higher activity in plants. (Allen et al, 1998). According to the Irrigation Training and Research Center's published ET rates, sprinkler irrigation results in a peak monthly total of 9.22 inches for cherries and 8.72 inches for walnuts in a typical year, both occurring in July. Because the data for walnuts is only applicable for bare ground, the data for almonds in the same region with bare ground and a cover crop was used to find the percent increase in ET due to the presence of a cover crop. That percent increase was then applied to the walnut data resulting in a peak monthly ET of 10.06 inches. The total ET occurring in a typical year for cherries and walnuts are 57.08 and 56.6 inches, respectively. (ITRC 1997)

Soils

When designing a sprinkler irrigation system, one important factor to take into account is the soil type of the field. The soil type affects the available water holding capacity and the maximum application rate permissible. At J. Caminata Ent. Inc. each sprinkler block is typically irrigated 42-54 hours every 2 weeks during the summer months. It is necessary to ensure the soil has an available water holding capacity to supply the trees with water during that 2 week span. For a sprinkler design, the application rate should never exceed the infiltration rate of the soil throughout the irrigation event. If the application rate exceeds the infiltration rate ponding and potentially runoff will occur. (Burt, 2012b) According to the Natural Resources Conservation Service, the soil in this area is 85% Cogna loam. This soil is classified as prime farmland if irrigated. Two reasons for this classification are the depth to restrictive features and an available water holding capacity of 9.3 inches. This soil has at least 80 inches before encountering any restrictive features and the drainage capacity of the most restrictive layer is high at 0.57 inches per hour when saturated. (Web Soil Survey 2008) When using sprinkler irrigation, the soil will not become saturated, except on the surface in some areas, therefore the infiltration rate will be lower than the 0.57 inches per hour stated in the web soil survey. This is still acceptable since the approximate application rate will only be 0.08 inches per hour.

Sprinklers versus Flood Irrigation

It is important to compare the benefits and drawbacks of different irrigation systems before a system is chosen. One of the main benefits of flood irrigation is the low initial cost of the system. In the case of J. Caminata Ent. Inc. the system was already in place when the field was purchased. The main drawback to using flood irrigation is the high labor cost. During a flood irrigation event, it is necessary to have an irrigator working at

all times, day and night, since once the event starts it continue until the entire field has been irrigated. Flood irrigation is also more susceptible to changes in soil type throughout the field, potentially decreasing the distribution uniformity. Sprinkler systems are less susceptible soil changes throughout the field, and allow for leaching of salts while using less water than with a flood system (Burt et al, 2000). The biggest drawback to a sprinkler system, when compared to flood is the high initial installation cost. Sprinkler systems; however, require much less labor during irrigation, resulting in significantly lower labor costs. Sprinkler systems also allow for chemical injection into the system easily, while flood does not.

Sprinklers versus Microsprayers

Both sprinkler and microsprayer systems have high initial installation costs. Sprinklers will generally have higher power requirements, and therefore costs, due to higher pressures throughout the system than does a microsprayer system (Burt, 2012b). However, microsprayers will have a higher cost for the filtration system, which will be discussed more in depth later in the filtration section. Sprinkler systems will wet the entire soil surface area while microsprayers will typically be designed to wet about 60 percent of the soil surface (Burt and Styles, 2012). Due to the larger spacing of walnut trees, sprinklers have traditionally been used in order to cover the entire soil surface. J. Caminata Ent. Inc. has much experience with sprinkler systems and none with microsprayers. Because of this, they desire a sprinkler system to make management and maintenance easier for them.

Sprinkler Nozzle

There are many different options to choose from when choosing which sprinklers to use. Two main types of sprinklers are impact type and rotator type. Some of the factors that must be considered when deciding what sprinklers to use are: cost, droplet size, throw radius, durability, flow rate capabilities, and uniformity. Because this is a permanent sprinkler system, the hours of operation will be significantly lower than that of a hand-move system. This allows for sprinklers heads and nozzles to be made of plastic rather than a more durable material, such as brass, resulting in a lower materials cost. J. Caminata Ent. Inc. has specified that they want to use Nelson R2000 rotators in this field. One reason for this choice is the need for low-angle nozzles in the cherry blocks. The R2000 rotators offer low angle nozzle options that require little to no work on the part of the farmer or irrigator. Low angle streams can be achieved with impact sprinklers through the design of the sprinkler head itself or the use of off-axis nozzles (Burt, 2013). J. Caminata. Ent. Inc. has used off-axis nozzles to achieve low angle streams with reasonable success. However, if these nozzles need replacing, due to their off-axis nature, care must be taken to ensure the nozzle is aligned properly. If the nozzle is aligned improperly, these nozzles could actually put out their stream at a higher angle than a standard angle sprinkler of the same type.

Figure 2. Nelson R2000 Rotator
sprinkler head (citation)

Distribution Uniformity and Design

Irrigation Efficiency is defined as irrigation water beneficially used divided by irrigation water applied. (Burt, 2012b). Irrigation beneficially used is generally defined as water used to support the production of crops or to achieve an agronomic objective. (Burt et al, 2000). Irrigation efficiency contains several components, however, only distribution uniformity can be affected by good design practices. Other components, such as excessive irrigation or spray losses due to high winds, have to do with irrigation management.

Distribution Uniformity is the uniformity with which irrigation water is distributed throughout the field. (Burt et al, 2000). For under-tree sprinkler systems flow rate differences are the most important factor in uniformity (Burt, 2013). For under-tree sprinkler systems the catch can DU (CCDU) is not important. Since this is the case, and because the field is essentially flat, the GPMDU is the only concern for this design. Because flow rate and pressure are related, high GPMDUs can be obtained by minimizing pressure differences through the DU zone of the system. Flow rate and pressure are related through the equation:

$$Q = K * P^X$$

Where,

Q= flow rate in gpm
K=a constant, unique to the nozzle used,
P=pressure in psi
X=an exponent equal to 0.5 for sprinklers

With sprinkler systems using PVC pipe, pipe sizes can be easily varied to reduce friction losses throughout the system. In order to minimize pressure differences throughout the system, the pressure must be known and each point in the system. The pressures throughout the system can be found using two equations, Bernoulli's equation and one of

many friction equations. For PVC pipe, Hazen-Williams friction equation is commonly used as it provides a good approximation of friction and is more simply used than other friction equations, such as Darcy-Weisbach.

Bernoulli's equation is as follows:

$$\left[\frac{V^2}{64.4} + Elev + P\right]_{u/s} = \left[\frac{V^2}{64.4} + Elev + P\right]_{d/s} + Hf - Hp$$

Where,

V=velocity of the water
Elev=the elevation at the point in question
P=the pressure at the point in question
Hf= the pressure loss due to friction between the two points
Hp=energy added by a pump

Hazen-Williams equation is as follows:

$$Hf = K * \left(\frac{GPM}{C}\right)^{1.852} * L * ID^{-4.87}$$

Where,

K=a constant equal to 10.5 for English units
GPM=the flow through the pipe in gallons per minute
ID=the actual inside diameter of the pipe
C=a friction factor dependent on pipe size and material

Sizing Strategies. High Distribution Uniformities can be obtained by using flow controls nozzles or pressure regulators. Because of the high cost of pressure regulators, and the ease with which PVC pipe size can be varied throughout the system, it is not cost effective to use them at each sprinkler or at the heads of each lateral. For under-tree sprinkler systems, it is most cost effective to use pressure regulators at the heads of each block or set. Downstream of the pressure regulators, inside the DU zone, pipes will be sized to minimize pressure loss, thus giving high DUs. Upstream of the pressure regulators pipes will be sized to keep the velocity of the water inside the pipe below five feet per second. By keeping velocities below five fps, the risk of damage from water hammer is greatly reduced.

Filtration

Filtration for any system is a big consideration. Since this design will utilize sprinklers, which will have much larger flow rates and nozzles than drip or microsprayer systems, filtration is not as critical as with drip/micro designs, but still needs to be accounted for. The water source for this field is a well, thus the biggest concern for filtration will be sand.

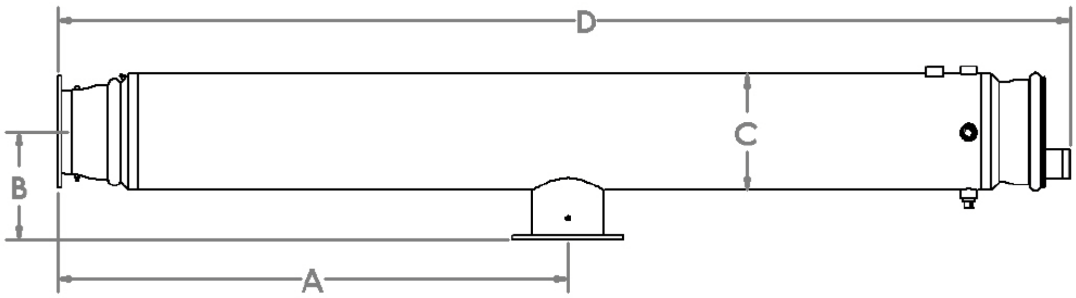


Figure 3. Tubular Screen Filter (Morrill, 2010)

This field has traditionally used flood irrigation and therefore, did not use a filtration system. The main filtration concern for this system is sand because sprinklers do not have plugging problems from silt and clay and organic matter is not an issue because the field water supply comes from a well. Because sand will be the main concern, a centrifugal action sand separator may be necessary. A tubular screen will likely be used downstream of the sand separator to filter any other particles that may be in the water.

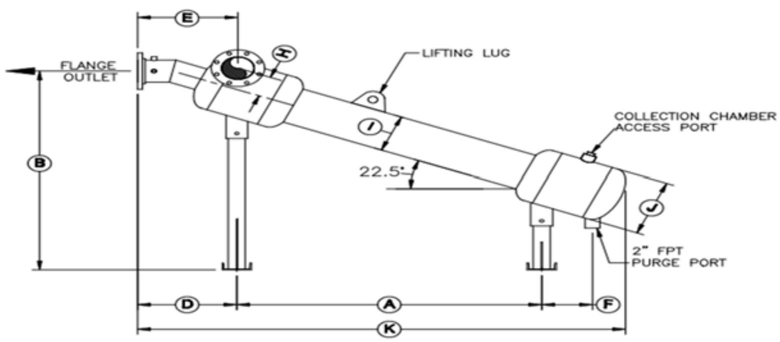


Figure 4. Centrifugal Action Sand Separator (Yardney, 2013)

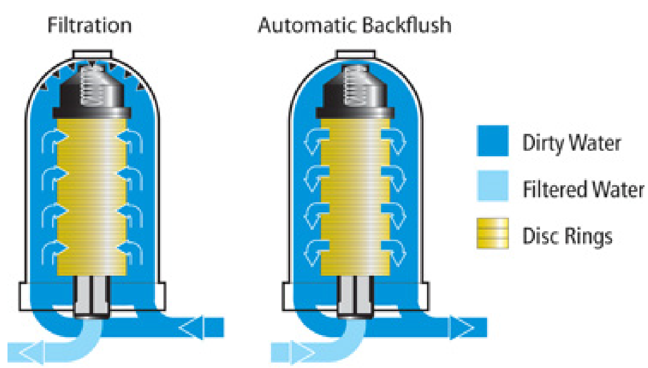


Figure 5. Disc Filter Water Flow (Netafim)

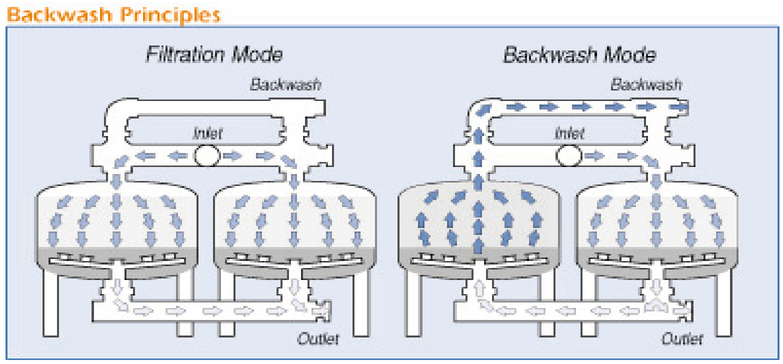
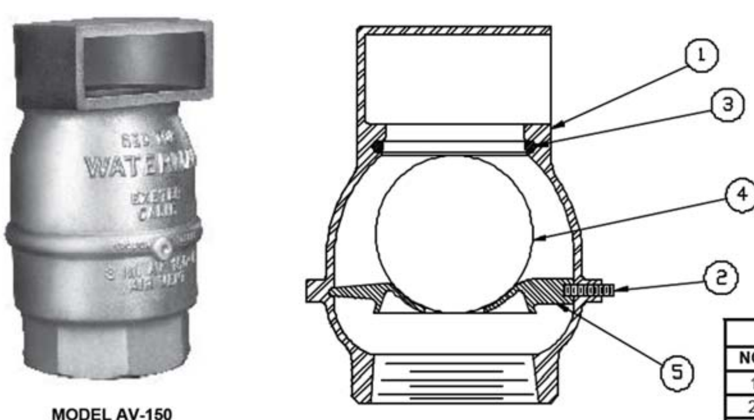


Figure 6. Sand Media Tanks Water Flow (Western Irrigation)

Media filters are unnecessary for sprinkler systems because sprinklers do not require as fine of filtration as microsprayer or drip systems. Sand media filters have a high cost and require a considerable amount of maintenance, making them especially undesirable for sprinkler systems. Disc filters would be much less expensive and lower maintenance than media filters, however, they have problems with sand getting caught between discs during backflush, "propping" open the discs, causing poor filtration. (Burt and Styles, 2012)

<u>Air Vents</u>

Due to the nature of closed system irrigation, it is possible for air to enter the pipes during operation. If enough air enters the system, air bubbles can form in the pipes causing water flow problems and potentially water hammer. The two types of air vents used are continuous acting and large acting air vents. The different types of air vents are placed at specific locations to ensure the release of any air that may enter the system. Continuous acting air vents should be placed at high points in the design, downstream of any air entrainment points (pumps, fertilizer injectors, etc.), and every quarter mile (preferably every 660 feet) on pipelines. Large acting air vents should be placed immediately



PARTS LIST	
NO.	NAME
1	Body
2	Set Screw
3	O-Ring
4	Float Ball
5	Baffle

Figure 7. Large Acting Air Vent (Waterman Industries)

downstream of any valve, at the entrance to any downhill sloping pipeline, at all high points, near the end of a pipe, upstream of pump check valve, and every quarter mile along pipe. (Burt, 1995)

PARTS LIST	
No.	Name
1	Poppet Assy.
2	Body
3	Float
4	Base

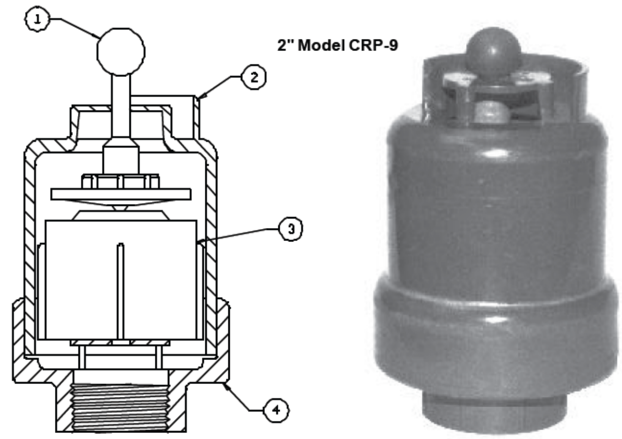


Figure 8. Continuous Acting Air Vent (Waterman Industries)

PROCEDURES AND METHODS

Irrigation Design Procedures

This section will cover the design and calculations of the irrigation system.

Field Information Supplied by Grower

Because every field is unique, it is necessary to gather information about a field before an irrigation system can be designed. In most cases, much of this information will be supplied by the grower. Any information not supplied by the grower must be collected by the designer. Key considerations necessary for design include: field location, size and shape, crop, row orientation, field slope, ET values, water source, soil type, crop spacing, and hours of operation. If any of the information listed above is not supplied by the grower, it must be gathered by the designer before design procedures begin.

The information provided by J. Caminata Ent. Inc. for this field includes:
Location: Linden, CA
Water Source: Well
Crop: Cherries and Walnuts
Field Size: 49.24 acres
Row Orientation: varies, N-S, E-W, SE-NW
Tree Spacing: varies, Walnuts 22' x 22', Cherries 22' x 22' and 24.75' x 24.75'
Slope:
West to East: 0.1%
South to North: 0.05%
SW to NE: 0.11% (calculated)
NW to SE: 0.035 % (calculated)

Information gathered for design:
Walnut Peak ET_c: 10.06 inches/month with cover crop
Cherry Peak ET_c: 9.22 inches /month with cover crop
Peak ET_c month: July for both crops
(ITRC, 1997)
Note: The information provided for walnut ET_c is only valid for fields with bare soils. Because of this, the ET_c values for almonds in the same region with and without a cover crop were compared to determine the percent increase in ET_c due to the presence of a cover crop. This percent increase was then applied to the ET_c data for walnuts to determine the peak ET_c value listed above.
Soil Type: Cogna Loam
Soil Available Water Holding Capacity: 7.0 inches (with 5 foot root depth)
(Web Soil Survey, 2008)

Before the design can begin, information pertaining to any constraints or restrictions must be gathered for the field. These constraints may include, but are not limited to the

following: salinity problems in the field, water supply reliability, hours of operation allowed, and specific equipment desired.

Some constraints for this design are:

- Pump already chosen by grower, pump horse power limited by electrical service already in place
- Pump available flow rate: 600 gpm approx.
- Pump TDH (at 600 gpm): 310 feet
- Time-of-Use service: 18 hours Monday through Friday, 24 hours Saturday and Sunday
- Irrigations scheduled on two-week cycle during summer
- Desired Sprinklers: Nelson R2000
- Pipe layout determined by growers intended orientation of drive rows

Field Layout

The next step in the design process is to look at the size and shape of the field. Since this field is already established with mature walnut and cherry trees in different blocks, it will be important to take the size and orientation of each specific block into account. As can be seen in Figure 9 below, there are currently six different blocks, all of which are different sizes.

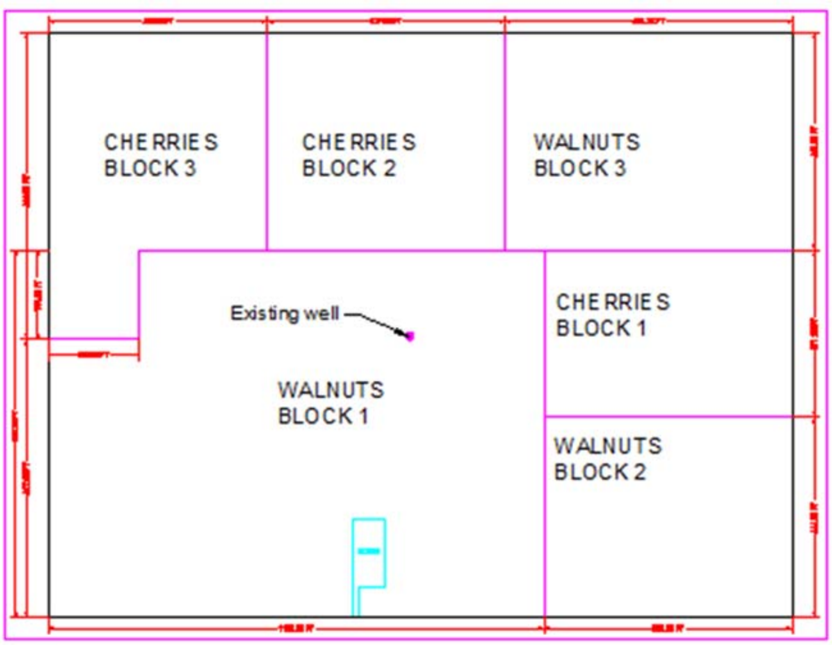


Figure 9. Initial field layout with existing well location

Due to the relative size of the cherry and walnut blocks, it was determined that the field would be irrigated as three sets, two walnut and one cherry. All three cherry sets combined equal approximately one third of the total area of the field, however walnut block number one was larger than blocks two and three combined. Because of this the decision was made to irrigate a portion of block one, a strip along the right side with

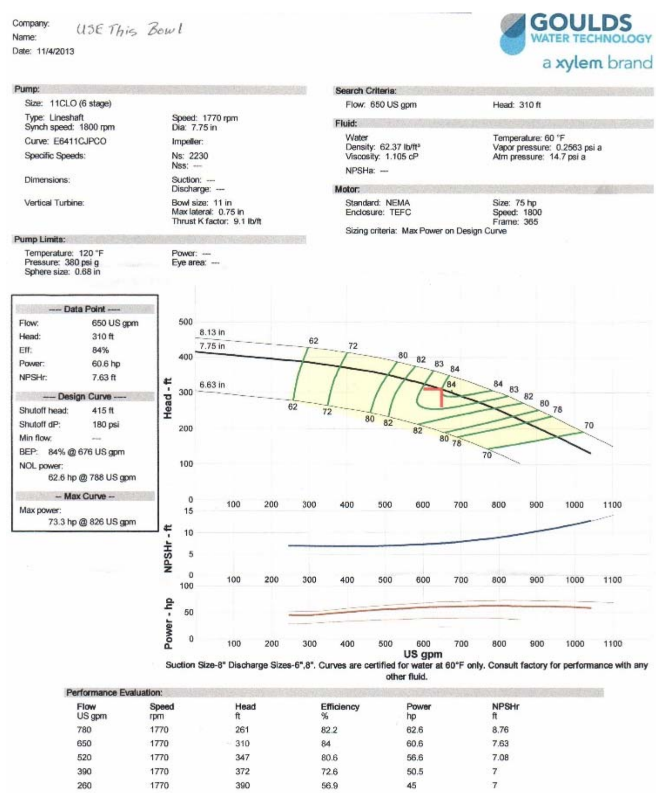
respect to Figure 9, with the two smaller walnut blocks. This divided the field into three roughly equal sets.

Pump Curve and Information

The next step in the design was to perform a preliminary check of the selected pumps capabilities. It was determined the pump would output approximately 600 gallons per minute during operation. Based on the pump curve seen below in Figure 10, the pump will output 600 gpm with a total dynamic head (tdh) of about 310 feet.

Check of total dynamic head needed:
Pressure at pump outlet= 50 psi (assumed)
Pressure at pump outlet= 115.5 feet of water
Depth to standing water level= 150 feet
Drawdown = 6 feet
Additional losses= 20 feet (assumed)
Total dynamic head needed= 291.5 feet

The preliminary check of total dynamic head needed versus available suggests this pump will be adequate for this design.


Company:
Name: USE This Bowl
Date: 11/4/2013

GOULDS WATER TECHNOLOGY
a xylem brand

Pump:
Size: 11CLO (6 stage)
Type: Lineshaft
Synch speed: 1800 rpm
Speed: 1770 rpm
Dia: 7.75 in
Curve: E6411CJPCO
Impeller:
Specific Speeds: Ns: 2230 Nss: ---
Dimensions: Suction: --- Discharge: ---
Vertical Turbine: Bowl size: 11 in Max lateral: 0.75 in Thrust K factor: 9.1 lb/ft

Search Criteria:
Flow: 650 US gpm
Head: 310 ft

Fluid:
Water
Density: 62.37 lb/ft³
Viscosity: 1.105 cP
NPSHa: ---
Temperature: 60 °F
Vapor pressure: 0.2563 psi a
Atm pressure: 14.7 psi a

Motor:
Standard: NEMA
Enclosure: TEFC
Size: 75 hp
Speed: 1800
Frame: 365
Sizing criteria: Max Power on Design Curve

Pump Limits:
Temperature: 120 °F
Pressure: 380 psi g
Sphere size: 0.68 in
Power: ---
Eye area: ---

--- Data Point ---
Flow: 650 US gpm
Head: 310 ft
Eff: 84%
Power: 60.6 hp
NPSHr: 7.63 ft

--- Design Curve ---
Shutoff head: 415 ft
Shutoff dP: 180 psi
Min flow: ---
BEP: 84% @ 676 US gpm
NOL power: 62.6 hp @ 788 US gpm

-- Max Curve --
Max power: 73.3 hp @ 826 US gpm

Suction Size-8" Discharge Sizes-6",8". Curves are certified for water at 60°F only. Consult factory for performance with any other fluid.

Performance Evaluation:

Flow US gpm	Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft
780	1770	261	82.2	62.6	8.76
650	1770	310	84	60.6	7.63
520	1770	347	80.6	56.6	7.08
390	1770	372	72.6	50.5	7
260	1770	390	56.9	45	7

Figure 10. Pump Curve for Selected Pump

Peak ETc

The purpose of any irrigation system is to supply the crop or crops with water. In order to do this properly, the peak ETc rates for the crop or crops in the field were determined. ETc values for crops in California are listed on the ITRC's website (itrc.org) in tables listing ETc values for various crops in different areas of California. Linden is in zone 12. The ETc values listed above were taken from the zone 12 table for sprinkler irrigation. The ETc values were then used to determine the application rate necessary to supply the crop with adequate water.

Pipe Layout

Now that the sets sizes and boundaries were determined, the pipe layout throughout the field could be decided. With the exception of cherry block number 2, all blocks had drive rows running East and West. This in combination with tree spacing dictated the orientation of the laterals and submains throughout the field. The pipe layout can be seen in Figure 11 below.

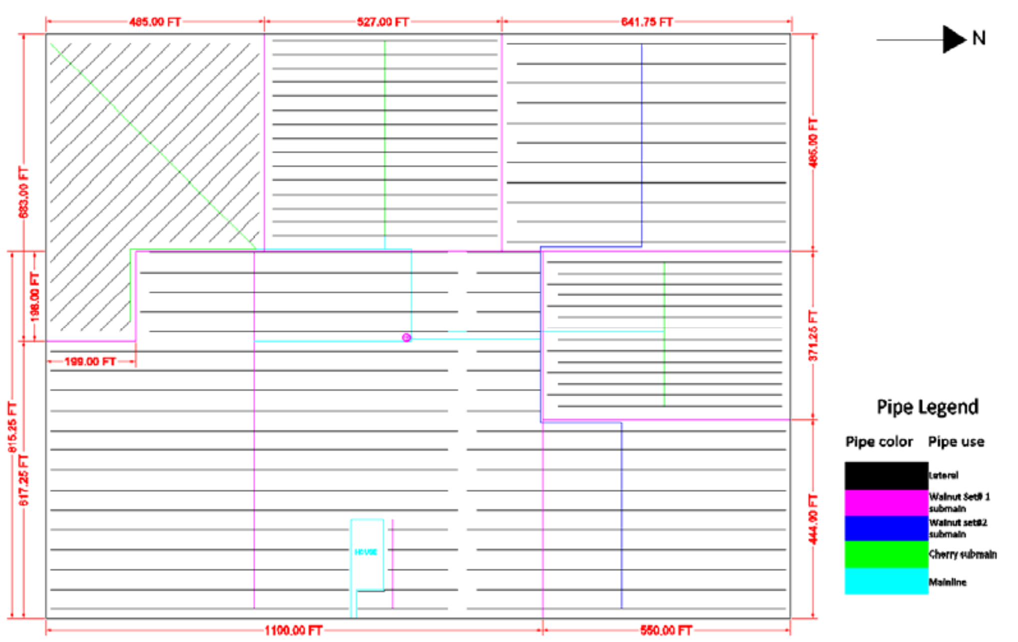


Figure 11. Pipe layout

Sprinkler Selection

Due to constraints by the electrical service, J. Caminata Ent. Inc. had already chosen and purchased a pump for the field. Knowing the approximate flow rate available from the pump and the sprinkler layout throughout the field, the flow rate per sprinkler was calculated for each set, as shown in Table 1

Table 1. Flow rate per sprinkler

	Set 1	Set 2	Set 3	
			C1	C2&3
GPM from pump=	600	581.7	166.9	433.1
sprinklers/block	378	366	161	526
GPM/sprinkler(gross)=	1.59	1.59	1.04	0.82
appl. Rate (in/hr)	0.079	0.079	0.082	0.082

Hours of Operation. Knowing the flow rate per sprinkler and the ETc, the number of hours each set needs to operate every two weeks during July, the month of peak ETc for both cherries and walnuts, was calculated. This was done using the inches per hour equation.

$$\frac{inches}{hour} = \frac{flow\ rate * 96.3}{area}$$

Where,

Flow rate is in gallons per minute

Area is in square feet

This equation was rearranged and altered to include a future system DU of 0.85 to account for system deterioration over time. The equation was then as follows:

$$\frac{Hours}{2\ weeks} = \frac{inches/2\ weeks * area}{gpm * 96.3 * 0.85}$$

For Set number 1 (walnuts) the values were:
Inches/ 2 weeks= 4.54 inches/2 weeks
Area of the entire set= 688,251 square feet
Flow rate from the pump= 600 gpm

This yielded that set number 1 needs to run for 64 hours every two weeks during July to satisfy the ETc. The hours of operation for each set and total per two weeks are shown in Table 2 below.

Table 2. Hours of operation for sprinkler system

Set 1 Walnuts	Set 2 Walnuts	Set 3 Cherries	Total for 3 sets	Total hours available for 2 weeks
64	68	62	194	276

<u>Nozzle Selection</u>. The next task in the design was to determine what sprinkler nozzle would supply to required sprinkler flow rate at a reasonable operating pressure. Since J. Caminata Ent. Inc. specified the use of Nelson R2000 nozzles, the choices were already narrowed down quite a bit. To determine which nozzles were eligible, the Nelson R2000 brochure was obtained. The brochure lists all of the nozzle and plate combinations and their respective flow rates for given pressures, as shown in Figure 12 below.

Plate Series	Plate Options	Recommended Nozzles	PSI 30	35	40	45	50	55	60	BAR 2.0	2.5	3.0	3.5	4.0
K2	K2 9° Green Radius: 23-27' (7.0-8.2 m) Stream Ht.: 17-28" (43-71 cm)	Gray #8.3	.67	.72	.77	.82	.86	.90	.94	150	166	183	197	210
		White #9	.77	.83	.89	.94	1.00	1.05	1.10	172	192	210	229	245
	K2 15° Yellow Radius: 27-30' (8.2-9.1 m) Stream Ht.: 37-48" (94-122 cm)	Dark Blue #10	.97	1.05	1.12	1.19	1.25	1.31	1.37	217	242	266	286	306
		.85 2000FC	.85 2000FC flow control nozzles are flow regulating within a flow range of no more than 3.5% greater and 8% less than the nominal flow — .85 GPM (193 LPH).											
		1.0 2000FC	1.0 2000FC flow control nozzles are flow regulating within a flow range of no more than 3.5% greater and 8% less than the nominal flow — 1.0 GPM (227 LPH).											
K3	K3 9° Brown Radius: 25-28' (7.6-8.5 m) Stream Ht.: 17-25" (43-64 cm)	Orange #11	1.17	1.27	1.36	1.45	1.53	1.61	1.68	261	294	323	350	375
	K3 15° Red Radius: 27-31' (8.2-9.4 m) Stream Ht.: 37-45" (104-130 cm)	Purple #12	1.39	1.50	1.61	1.70	1.80	1.89	1.98	311	347	380	412	442
	K3 24° Gray Radius: 29-35' (8.8-10.7 m) Stream Ht.: 73-89" (185-226 cm)	1.25 2000FC	1.25 2000FC flow control nozzles are flow regulating within a flow range of no more than 3.5% greater and 8% less than the nominal flow — 1.25 GPM (284 LPH).											
		1.5 2000FC	1.5 2000FC flow control nozzles are flow regulating within a flow range of no more than 3.5% greater and 8% less than the nominal flow — 1.5 GPM (341 LPH).											

Figure 12. R2000 Nozzle and Plate Combinations

The next step in the design process was to take to information about flow rate and pressure listed in the R2000 brochure and use that to find the operating pressure for the sprinkler flow rates calculated earlier. Since pressure and flow rate are related by the following equation:

$$Q = K * P^X$$

K can be determined from the flows and pressure given. Once K was determined, the required pressure for each nozzle was determined as shown in Table 1 and Table 4 below.

Table 3. Sprinkler nozzle operating pressure and flow rate, walnuts

	Set #1		Set #2	
	Q (GPM)	P (psi)	Q (GPM)	P (psi)
orange #11	1.59	54.3	1.59	54.3
Purple #12	**1.59**	**39.1**	**1.59**	**39.1**

Table 4. Sprinkler nozzle operating pressure and flow rate, cherries

	Block 1			Blocks 2&3		
	Q(GPM)	P(psi)	k	Q(GPM)	P(psi)	k
Gray #8.3	1.04	72.5	0.121764	0.82	45.7	0.121764
White #9	1.04	54.1	0.140963	**0.82**	**34.1**	**0.140963**
Dk Blue#10	**1.04**	**34.3**	**0.177049**	0.82	21.6	0.177049

Pipe Sizing Strategy

Once the layout of pipe throughout the field was determined, and the sprinkler sizes, including operating flow rates and pressures, were calculated, the next step was to size the pipe in the field. Two different pipe sizing strategies were used depending where the pipe was in the field. The two different strategies were: 1) maximizing DU, and 2) economic pipe sizing. Maximizing DU was used downstream of the pressure regulators. By using this strategy, this sprinkler design will deliver water to the trees in a very uniform manner, saving money in water and electrical costs throughout the life of the system. The laterals and the submains are downstream of the pressure regulators and will be sized based on maximizing DU. Upstream of the pressure regulators, economic pipe sizing was used because the amount of friction loss in those pipe would not affect the DU of the system. For economic pipe sizing, this design assumes the break-even point to be at five feet per second for the velocity of the water in the pipe.

Lateral Pipe Sizing. The lateral pipes were designed in order to maximize Distribution Uniformity. When maximizing DU it is necessary to ensure the pressure along the lateral does not change beyond what is allowable for a target DU value. For this design, the target DU was 0.92 throughout the field. To determine the pressure in the lateral at each sprinkler, two equations were used. These equations were Bernoulli's equation and Hazen-Williams equation. Both of these equations are shown in the Sizing Strategies section of the Literature Review on page 6. The DU of the system is found by multiplying the DU of the lateral and the DU of the submain. A spreadsheet was used for these calculations as the process is iterative and would be very time consuming and tedious if done by hand. In this design, because not all laterals are the same length, the longest laterals in each set were chosen for the calculations. This is because they will have the highest friction loss due to their length and larger flow at the inlet to the lateral. In choosing the longest laterals, the pressure loss is found for the worst case.

An example of the spreadsheet calculations performed for sizing the laterals can be seen in Table 5 below. The laterals were sized so that the operating pressure for the sprinklers determined earlier occurred as that average pressure along the lateral. The inlet pressure for the lateral was noted for use later when sizing the submains.

Table 5. Lateral Sizing Table

Set #1			Set #1 Walnuts			k=	0.2543			
			laterals	**downhill**						
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
11	37.04	1.55	1.55	1	1.189	141	44	0.0202	-0.0095	0.0107
10	37.05	1.55	3.10	1	1.189	141	44	0.0730	-0.0095	0.0635
9	37.12	1.55	4.65	1	1.189	141	44	0.1548	-0.0095	0.1453
8	37.26	1.55	6.20	1	1.189	141	44	0.2641	-0.0095	0.2546
7	37.52	1.56	7.76	1	1.189	141	44	0.4000	-0.0095	0.3905
6	37.91	1.57	9.32	1	1.189	141	44	0.5624	-0.0095	0.5528
5	38.46	1.58	10.90	1	1.189	141	44	0.7512	-0.0095	0.7417
4	39.20	1.59	12.49	1	1.189	141	44	0.9671	-0.0095	0.9575
3	40.16	1.61	14.10	1	1.189	141	44	1.210	-0.0095	1.201
2	41.36	1.64	15.74	1	1.189	141	44	1.483	-0.0095	1.474
1	42.84	1.66	17.40	1	1.189	141	11	0.4468	-0.0024	0.4444
0	43.28	inlet								
Avg. P=	39.1	psi		DUlateral =	37.04/ 39.1	0.95				
min P=	37.04									
max P=	43.27									

Submain Pipe Sizing. The submains throughout the field were sized using the same strategy as the laterals. When sizing the laterals, we made note of the inlet pressure to the laterals. This pressure was then used as the desired average pressure along the submain when sizing the pipe. Table 6 shows the spreadsheet calculations used for sizing the submain directly upstream of the laterals in Table 5.

Table 6. Submain Sizing Table

				Set #1 Walnuts						
				submain	**uphill**					
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
15	42.66	25.4	25.4	4	4.28	149	44	0.0063	0.0952	0.0158
14	42.67	25.4	50.9	4	4.28	149	44	0.0229	0.0095	0.0325
13	42.70	25.4	76.3	4	4.28	149	44	0.0486	0.0095	0.0582
12	42.76	25.4	101.7	4	4.28	149	44	0.0829	0.0095	0.0924
11	42.85	25.4	127.2	4	4.28	149	24	0.0684	0.0051	0.0736
(T) 10	42.93	38.1	165.3	5	5.291	150	20	0.0325	0.0043	0.0369
9	42.96	33.4	198.7	5	5.291	150	44	0.1007	0.0095	0.1103
8	43.07	34.2	232.8	5	5.291	150	44	0.1352	0.0095	0.1447
7	43.22	33.4	266.2	5	5.291	150	44	0.1733	0.0095	0.1828
6	43.40	34.2	300.4	6	6.301	150	44	0.0925	0.0095	0.1020
5	43.50	33.4	333.8	6	6.301	150	44	0.1125	0.0095	0.1220
4	43.63	34.2	367.9	6	6.301	150	44	0.1347	0.0095	0.1443
3	43.77	33.4	401.3	6	6.301	150	44	0.1582	0.0095	0.1678
2	43.94	34.2	435.5	6	6.301	150	44	0.1841	0.0095	0.1936
1	44.13	33.4	468.9	6	6.301	150	22	0.1055	0.0047	0.1103
0	44.24	inlet								
average P=	43.28							Set #1		
min P=	42.66			DUsub=	42.66/ 43.28	=0.99	DU=	DUlat* DUsub	0.93	
max P=	44.24									

Table 7. DU for each set

Distribution Uniformity by Set	
Set #1	0.93
Set #2	0.92
Set #3	
Block #1	0.96
Block #2	0.92
Block #3	0.92

Mainline Sizing. The last section of pipe to size was the mainline. Because the mainline is upstream of all sprinklers, the change in pressure along the mainline does not affect the DU. Knowing this, the mainline was sized to ensure the water velocity inside the pipe did not exceed five feet per second. This was done by creating Table 8 below and comparing the sizes and flows to the flow in each section of the mainline. Also, this design utilized pressure regulators at the head of each block. Because pressure regulators are used, the design must ensure the pressure in the mainline is higher than the pressure regulators' setting for each block.

Table 8. GPM at 5 fps for various pipe sizes

nom. Pipe	pipe ID	gpm @ 5 fps
3	3.284	132
4	4.28	224
5	5.291	343
6	6.301	486
8	8.205	824
10	10.226	1280

Additional Losses Throughout the System

After the different sections of pipe are sized and the energy lost due to friction in the pipe has been calculated, the additional energy losses throughout the system were determined. If these additional losses were not accounted for, the pressure regulators would be set too low and the calculated pump discharge pressure required would be too low as well.

Additional Pressure Requirements Downstream of Pressure Regulators. Once the mainline was sized, any additional pressure requirements within the DU zone needed to be computed. These additional requirements are important because they affect the pressure regulator setting and the pump requirement. These additional requirements include: the elevation change from lateral to sprinkler, the losses through elbows and tees, and the elevation change from submain to lateral.

The losses through elbows and tees were computed using the minor loss equation. The equation is as follows:

$$H_{f,minor} = K * \frac{v^2}{2 * g}$$

Where,

K is a coefficient dependant on the type of fitting
v is the velocity in the pipe
g is the acceleration due to gravity, in English units = 32.2 ft/sec^2

Table 9. Table of K values used

Minor Loss K Values	
Valve/Fitting	K
Check valve	2.0
Butterfly valve	0.6
Tee, branch flow 1/2"	2.2
Tee, line flow 1"	2.0
Tee, branch flow 4" and up	0.7
Elbow	0.6

At this point in the design, enough information was known to determine the pressure setting for the pressure regulators at the head of each block. Each pressure regulator will be set so that the pressures listed below in Table 10 will occur at the first sprinkler downstream on the pressure regulators.

Table 10. Pressure Regulator Settings by Block

Pressure Regulator Settings		
Set #1	47	psi
Set #2	43	psi
Set #3		
Block #1	38	psi
Block #2	40	psi
Block #3	37	psi

<u>Energy Losses Upstream of Pressure Regulators</u>. Once the pressure required at the pressure regulators in known, the next step in the design was to calculate the energy losses upstream of the pressure regulators. These losses were calculated using the same methods as were listed in the section downstream of the pressure regulators. Once these losses were calculated, it was determined that set #1 required the highest pump discharge pressure; therefore, that pressure requirement would be used in checking the pumps adequacy.

<u>Losses at Pumping Station</u>. The last step in determining the required pump discharge pressure was finding the energy losses at the pumping station. For this system, the losses at the pumping station consisted of the losses through the tubular screen filter and the loss through the check valve. According to Morrill Industries website, the losses through the filter are less than 1 pound per square inch when the filter is 25% plugged. For this design, a pressure loss of 2 pounds per square inch was used as a factor of safety. The loss through the check valve was computed using the minor loss equation listed earlier. Once these losses were calculated, it was determined that the minimum discharge pressure required at the pump was 51.2 psi.

The last step in designing this system was to re-check the adequacy of the pump chosen using the actual numbers calculated in the design. The total dynamic head available at 600 gpm is 310 feet. The total dynamic head required at 600 gpm is calculated below:

$$TDH\ required = standing\ water\ level + drawdown + column\ friction + pump\ discharge\ pressure$$

$$TDH\ required = 150\ ft + 6\ ft + 0.7\ ft + 118.3\ ft = 275\ ft$$

From the calculation above, it can be seen that the pump chosen is adequate for the system designed. At this TDH the pump will supply over 700 gpm, more than adequate. If the water level decreases over time, the pump will still be able to supply the amount of water necessary for the system. The extra pressure created by the pump will be burned up through the pressure regulators, and in the future a Variable Frequency Drive could be considered.

Air Vents

With any closed system irrigation design, air vents are a critical component. According to Burt and Styles (2012) air vents are required in irrigation systems to release large volumes of air on startup, prevent air blockages, release air that enters the system after system startup, prevent vacuums in the lines, and to prevent water hammer.

For this design it was determined that air vents with a diameter of two inches would be adequate. This system will have large acting air vents placed upstream of the pump check valve, downstream of the filter, and at the end of all submains throughout the system. Dual acting air vents, air vents that provide large volume air release, vacuum relief, and continuous air release, will be used upstream and downstream of all pressure regulators.

Flushouts

For any irrigation system, it is important that there be a way to flush the lines of any build up. In this system, valves were placed at the end of every submain. These valves are sized according to the size pipe at that location.

Filter Sizing

Every irrigation system requires some kind of filtration to prevent plugging of the lines and nozzles. Because the existing well in this field pumps very clean water, a simple tubular screen filter will be used. This screen can be removed and cleaned manually when necessary, though this will be infrequent. A filter manufactured by Morrill Industries was chosen because J. Caminata Ent. Inc. uses these filters at other locations and is happy with their performance. The screen chosen has a filter size of 0.050 inches and is capable of handling 750 gpm with up to 25% plugging according to the

manufacturers brochure. This screen was chosen because it will filter particles smaller than the smallest nozzle in the field.

RESULTS

The design of the sprinkler irrigation system for J. Caminata Ent. Inc. was completed. The field will be irrigated using three different set: two walnut sets and one cherry set. All sets for the system met the design goal of a distribution uniformity equal to 0.92. This design uses Nelson R2000 Rotator sprinkler heads with #9 and #10 nozzles with a 9 degree plate for the cherries and #12 nozzles with a 15 degree plate for the walnuts. The system flow rate is approximately 600 gpm for all sets. The filtration for the system is a Morrill Industries tubular screen filter with 0.050 inch diameter holes. The pipe layout and sizes can be seen below in Figure 13. For this design, all lateral pipe is one inch diameter Class 200 IPS.

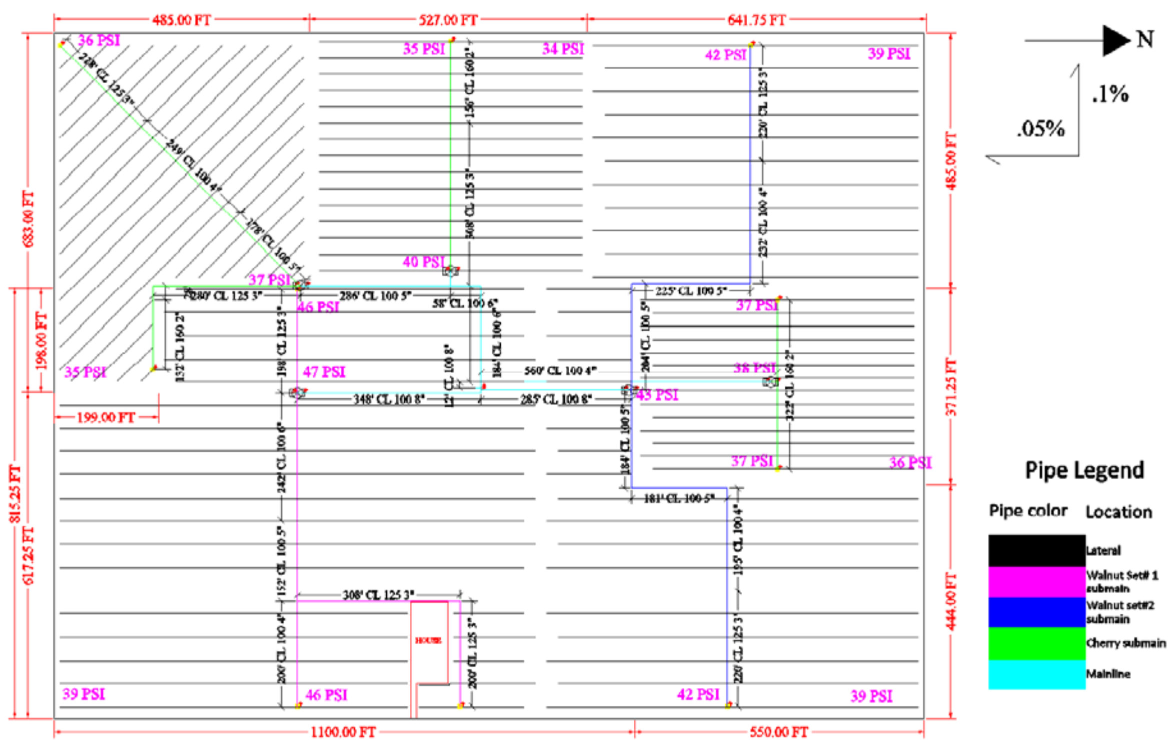


Figure 13. Pipe Sizes and Layout

DISCUSSION

The most difficult part of this design was accounting for the different block sizes, tree spacing, and the fact that one irrigation system would be used to irrigate two different crops. This was made slightly easier by the fact that the walnut blocks were able to be split up to make two sets close in size to one another. The design was also made easier by the use of pressure regulators which were used to burn up the extra pressure created by the pump. This allowed the system to be designed to meet the desired DU.

Because this system uses PVC pipe throughout, it is fairly easy to change size, giving the designer more freedom. However, by changing pipe sizes throughout the field, many iterations were necessary in order to find the best design. All laterals in this design are one inch PVC pipe. By keeping all the laterals the same size and adjusting the size of the submain pipe, less iterations were needed. This only worked; however, because the target DU was able to be obtained without adjusting the lateral pipe sizes.

Like any irrigation system, this design is specific to the field J. Caminata Ent. Inc. owns in Linden, CA. This design cannot be taken and used in a different field, as that field will have different requirements due to soil variation, size, orientation, layout, etc.

Historically this field has been flood irrigated. By switching to sprinklers, the amount of labor required to irrigate will be dramatically reduced. This system will have a high initial cost when compared the fact that a flood irrigation system is already in place; however, this system will save J. Caminata Ent. Inc. money over time due to the savings from decreased water and energy usage, and the decrease in labor required.

RECOMMENDATIONS

One possible change to this design would be to use a Variable Frequency Drive. This would allow the pump to be dialed back when operating in sets that require less pressure. In the current design, the pump will create approximately the same pressure, regardless of which set is running. Because the sets do not all require the same pressure to operate, this excess pressure is burned up in the pressure regulators. By using a VFD, less pressure would be created by the pump for the sets that require less. By creating less pressure, the pump will use less energy. In the long run a VFD would likely pay for itself and more in the energy savings it would create. The main reason this design does not incorporate the use of a Variable Frequency Drive is the designers lack of knowledge and experience with VFDs. In the future, J. Caminata Ent. Inc. could choose to add a VFD to the system.

Another issue that could arise is the filtration system not being adequate. Currently, the existing well in the field pumps very clean water, and only a screen filter is necessary. However, if the standing water level were to drop, the well may begin to pump more sand. If this happens a centrifugal action sand separator would be required. Fortunately, the pump chosen is capable of creating enough pressure at the required flow rate that a sand separator could be added to the system without causing problems with pressure or flow.

REFERENCES

Allen et al. 1998. Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements- FAO 56. Natural Resources Management and Environmental Department. United Nations

Burt, C. 1995. *The Surface Irrigation Manual.* Waterman Industries

Burt C.M., A.J. Clemmens, R Bliesner, J.L. Merriam, L. Hardy. 2000. Selection of Irrigation Methods for Agriculture. American Society of Civil Engineers, USA

Burt, C.M. 2012. Basic Hydraulics. Cal Poly Irrigation Training and Research Center, San Luis Obispo, CA.

Burt, C.M. 2012. Ag-Irrigation Management. Cal Poly Irrigation Training and Research Center, San Luis Obispo, CA.

Burt, C. and Styles, S. 2012. Drip and Micro Irrigation Design and Management for Trees, Vines, and Field Crops: Practice Plus Theory. Cal Poly Irrigation Training and Research Center.

Burt, C.M. 2013. Irrigation Design Manual. Cal Poly Irrigation Training and Research Center, San Luis Obispo.

ITRC. 1997. ETc Table for Irrigation Scheduling and Design. Zone 12 Monthly Evapotranspiration, Sprinkler Irrigation, Typical Year. Cal Poly Irrigation Training and Research Center.

ITRC. 2008. Principles of Irrigation. Cal Poly Irrigation Training and Research Center, San Luis Obispo, CA.

Morrill Industries Inc. 2010. 1000 Series Horizontal Filter. http://www.morrillinc.com /specs/Horizontal_Filter.pdf, referenced November 8, 2013.

Netafim USA. Automatic Disc-Kleen Filters. http://www.netafimusa.com/greenhouse /products/filters-op, referenced February 18, 2014.

Waterman Industries. AV-150 Air Vent and Vacuum Relief Valve. http://watermanusa.com/wpcontent/themes/watermantheme/Product%20Information/Irrigation/AirVents/av-150.pdf, referenced November 8, 2013.

Waterman Industries. CRP-9 Continuous Acting Air Vent and Vacuum Relief Valve. http://watermanusa.com/wpcontent/themes/watermantheme/Product%20Information/Irrigation/AirVents/crp-9.pdf, referenced November 8, 2013.

Web Soil Survey. 2008. United States Department of Agriculture, Natural Resource Conservation Center. http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx, referenced November 8, 2013.

Western Irrigation. Backwash Principles. http://www.westernirrigation.com/Fresno%20sand%20media.htm, referenced February 18, 2014.

Yardney Water Management Systems, Inc. 2013. Centrifugal Sand Separators. http://www.yardneyfilters.com/files/literature/Irrigation/Centrifugal%20Sand%20Separators.pdf, referenced February 18, 2014.

APPENDIX A
HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR

Major Design Experience

The first phase of this project will involve be determining the Evapotranspiration requirements for mature walnut and Cherry trees. The second phase of this project will be to design a sprinkler system to meet the ET requirements, while maintaining a high Distribution Uniformity and Irrigation Efficiency.

Establishment of Objectives and Criteria

Project objectives and criteria are established to meet the needs and expectations of J. Caminata Ent. Inc. See "Design Parameters and Constraints" section below for specific objectives and criteria for the project.

Synthesis and Analysis

This project will include Energy and friction calculations in Pipelines

Construction, Testing and Evaluation

N/A

Incorporation of Applicable Engineering Standards

High Distribution Uniformity

Capstone Project Experience

This project incorporates the knowledge and skills gained in the following classes: 151 AutoCAD, 236 Principles of Irrigation, 312 Hydraulics, 331 Irrigation Theory, 414 Irrigation Engineering, Technical Writing

Design Parameters and Constraints

This project will address a significant number of the categories of constraints listed below

Physical

All PVC pipelines will be buried, so different size pipes must be buried to certain depths to reduce risk of damage from farm equipment driving over them.

Economic

The system will operate only during "off-peak" energy times to decrease energy costs.

Environmental

By designing this system to have a high Distribution Uniformity, the system may use less water and energy each year.

Ergonomics

N/A

Manufacturability

N/A, Irrigation designs are unique to the field for which they are designed.

Health and Safety

N/A

Ethical

N/A

Political

N/A

Productivity

The system must be designed so that during the summer (peak Evapotranspiration) there will be time the system is not operating to allow work to be done in the field.

APPENDIX B
Irrigation Design Calculations

J. CAMINATA ENT. INC.

Buried PVC Sprinkler System										
Field Constraints:										
crops:	walnuts	cherries								
Location:	Linden, CA									
Tree Spacing:		Block:								
W1	22	x	22	ft		C1	24.75	x	24.75	ft
W2	22	x	22	ft		C2	22	x	22	ft
W3	22	x	22	ft		C3	22	x	22	ft
Trees in Blocks:										
W1	1771	trees				C1	333	trees		
W2	505	trees				C2	512	trees		
W3	639	trees				C3	566	trees		
Area of each Block										
W1	857373	sq. ft.	19.68	ac		C1	204187.5	sq. ft.	4.69	ac
W2	244200	sq. ft.	5.61	ac		C2	255595	sq. ft.	5.87	ac
W3	309430	sq. ft.	7.10	ac		C3	274142	sq. ft.	6.29	ac
Field Area:	49.24	ac								
Set 1:	W1	688251	sq. ft.	15.80	ac					
Set 2:	W2&3	711047	sq. ft.	16.32	ac					
Set 3:	C1,2&3	733925	sq. ft.	16.85	ac					
Area/sprinkler:										
W1	1936	sq. ft.	2298.59			C1	1225	sq. ft.	1268.25	BLK AREA/#SPRINKLERS
W2	1936	sq. ft.	1141.12			C2	967.8321	sq. ft.	1002.33	
W3	1936	sq. ft.	1875.33			C3	967.8321	sq. ft.	1011.59	
# of Sprinklers/Block										
W1	373	sprinklers				C1	161	sprinklers		
W2	214	sprinklers				C2	255	sprinklers		
W3	165	sprinklers				C3	271	sprinklers		
Pump max capacity:										
650	gpm									
310	ft	134.2	psi	tdh						
		69.3	psi	available						

Solution:

1. Determine Peak ET Rate

No data available for Walnuts with a cover crop. Use almond data from the same region to determine percent additional water necessary for walnuts with a cover crop.

Peak ETc for almonds=	7.21		
Peak ETc for almonds with cover crop=	8.32		
Percent water needed with cover crop=	115%		52.2

Walnuts:	Peak ET Rate=	10.06	in/31 days	0.32	in/day	4.54	in/14 days
Cherries:	Peak ET Rate=	9.22	in/31 days	0.30	in/day	4.16	in/14 days

Peak ET occurs in July

2. Estimated GPM/sprinkler needed

Flow rate available from pump=	600	gpm

	Set 1	Set 2	Set 3					
			C1	C2&3		405.02		
GPM from pump=	600	581.7	166.9	433.1				
sprinklers/block	378	366	161	526		23.8923	22.42181	43.25271
GPM/sprinkler(gross)=	1.59	1.59	1.04	0.82				
appl. Rate (in/hr)	0.079	0.079	0.082	0.082				

AWHC (approx. 80 soil depth)=	9.3	inches
AWHC with 60 inch root depth=	7.0	inches

Assume DU of 0.85 to ensure the system provides adequate water when the system deteriorates.

in/hr(gross)=gpm*96.3/area

hr=in(gross)*area/(gpm*96.3)

	Set 1 Walnuts	Set 2 Walnuts	Set 3 Cherries	Total for 3 sets	Total hoursavailable for 2 weeks	
Set hrs/2-weeks needed to satisfy ET=	64	68	62	194	276	hours

3. Select the proper sprinkler

Nelson Rotator R2000 sprinklers will be used in this design.

WALNUTS

For walnut blocks, use K3 15 degree Red. Gives radius of 27-31 ft

k=Q/(P^0.5)

Nozzle #	Q(GPM)	P(psi)	K
	1.17	30	0.213612

orange #11	1.27	35	0.214669		
	1.36	40	0.215035		
	1.45	45	0.216153		
	1.53	50	0.216375		
	1.61	55	0.217092		
	1.68	60	0.216887		
		K avg=	0.215689		
Purple #12	1.39	30	0.253778		
	1.5	35	0.253546		
	1.61	40	0.254563		600.53
	1.7	45	0.253421		
	1.8	50	0.254558		
	1.89	55	0.254848		
	1.98	60	0.255617		
		K avg=	0.254333		

Sprinkler operating pressure for walnuts:

	Set #1		Set #2	
	Q (GPM)	P (psi)	Q (GPM)	P (psi)
orange #11	1.59	54.3	1.59	54.3
Purple #12	**1.59**	**39.1**	**1.59**	**39.1**

Use Purple #12 nozzle with K3 15 degree Red Plate for Walnut sets.

CHERRIES

For Cherry blocks, use K2 9 degree Green Plate, gives radius 23-27'

Nozzle #	Q(GPM)	P(psi)	K
Gray #8.3	0.67	30	0.122325
	0.72	35	0.121702
	0.77	40	0.121748
	0.82	45	0.122238
	0.86	50	0.121622
	0.9	55	0.121356
	0.94	60	0.121353
		K avg=	0.121764

Nozzle #	Q(GPM)	P(psi)	K
White #9	0.77	30	0.140582
	0.83	35	0.140296
	0.89	40	0.140721
	0.94	45	0.140127
	1	50	0.141421
	1.05	55	0.141582
	1.1	60	0.142009
		K avg=	0.140963

Nozzle #	Q(GPM)	P(psi)	K
	0.97	30	0.177097
	1.05	35	0.177482
	1.12	40	0.177088
Dk Blue#10	1.19	45	0.177395
	1.25	50	0.176777
	1.31	55	0.17664
	1.37	60	0.176866
		K avg=	0.177049

Sprinkler operating pressure for Cherries:

	Block 1			Blocks 2&3		
	Q(GPM)	P(psi)	k	Q(GPM)	P(psi)	k
Gray #8.3	1.04	72.5	0.121764	0.82	45.7	0.121764
White #9	1.04	54.1	0.140963	0.82	34.1	0.140963
Dk Blue#10	1.04	34.3	0.177049	0.82	21.6	0.177049

For Cherry Block 1, use K2 9 degree Green Plate with Dk Blue #10 nozzle.
For Cherry Blocks 2&3 use K2 9 degree Green Plate with White # 9nozzle.

4. Application rate vs. Infiltration Rate Check

	Set 1	set 2	set 3		
	W1	W2&3	C1	C2&3	
GPM	1.59	1.59	1.04	0.82	gpm
Area/spr	1936	1936	1225	967.21	sq. ft.
App. Rate	0.079	0.079	0.082	0.082	in/hr

All application rates are lower than the 0.25 in/hr recommended for clay soils. OK

Pipe Selection Table

Nom. Dia	ID	PR	Type	H-W "C"
1/2	0.622	600 (sch 40)	IPS	140
3/4	0.93	200	IPS	140
1	1.189	200	IPS	141
1 1/2	1.72	200	IPS	145
2	2.193	160	IPS	146
2 1/2	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	10.226	100	IPS	150
12	12.128	100	IPS	150

		15	14.55	100	PIP	150				
		18	17.725	100	PIP	150				

4. Pipe Sizing

Set #1			**Set #1 Walnuts**			k=	0.254333			
			laterals	**downhill**						
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
11	37.04	1.55	1.55	1	1.189	141	44	0.020229	-0.009524	0.010705
10	37.05	1.55	3.10	1	1.189	141	44	0.073035	-0.009524	0.063511
9	37.12	1.55	4.65	1	1.189	141	44	0.154847	-0.009524	0.145323
8	37.26	1.55	6.20	1	1.189	141	44	0.264124	-0.009524	0.2546
7	37.52	1.56	7.76	1	1.189	141	44	0.400078	-0.009524	0.390554
6	37.91	1.57	9.32	1	1.189	141	44	0.562417	-0.009524	0.552894
5	38.46	1.58	10.90	1	1.189	141	44	0.751261	-0.009524	0.741737
4	39.20	1.59	12.49	1	1.189	141	44	0.967107	-0.009524	0.957583
3	40.16	1.61	14.10	1	1.189	141	44	1.21083	-0.009524	1.201306
2	41.36	1.64	15.74	1	1.189	141	44	1.483686	-0.009524	1.474162
1	42.84	1.66	17.40	1	1.189	141	11	0.44683	-0.002381	0.444449
0	43.27968	inlet								
Avg. P=	39.1	psi								
min P=	37.04									
max P=	43.27968									

			Set #1 Walnuts			k=	0.254333			
			laterals	**uphill**						
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
10	37.59	1.56	1.56	1	1.189	141	44	0.020504	0.009524	0.030027
9	37.62	1.56	3.12	1	1.189	141	44	0.074046	0.009524	0.083569
8	37.70	1.56	4.68	1	1.189	141	44	0.157026	0.009524	0.16655
7	37.87	1.57	6.25	1	1.189	141	44	0.267903	0.009524	0.277427
6	38.14	1.57	7.82	1	1.189	141	44	0.405896	0.009524	0.41542
5	38.56	1.58	9.40	1	1.189	141	44	0.570728	0.009524	0.580251
4	39.14	1.59	10.99	1	1.189	141	44	0.762533	0.009524	0.772057
3	39.91	1.61	12.59	1	1.189	141	44	0.981835	0.009524	0.991358
2	40.90	1.63	14.22	1	1.189	141	44	1.229534	0.009524	1.239058
1	42.14	1.65	15.87	1	1.189	141	33	1.130189	0.007143	1.137332
0	43.28	inlet								

Avg. P=	39.4	psi								
min P=	37.59			Lat. DU=	0.95					
max P=	43.28	inlet								
				Set #1 Walnuts						
				submain	**uphill**					
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
15	42.66	25.4	25.4	4	4.28	149	44	0.006366	0.009524	0.01589
14	42.67	25.4	50.9	4	4.28	149	44	0.022982	0.009524	0.032505
13	42.70	25.4	76.3	4	4.28	149	44	0.048697	0.009524	0.058221
12	42.76	25.4	101.7	4	4.28	149	44	0.082964	0.009524	0.092488
11	42.85	25.4	127.2	4	4.28	149	24	0.068411	0.005195	0.073606
(T) 10	42.93	38.1	165.3	5	5.291	150	20	0.03259	0.004329	0.036919
9	42.96	33.4	198.7	5	5.291	150	44	0.100796	0.009524	0.11032
8	43.07	34.2	232.8	5	5.291	150	44	0.135238	0.009524	0.144761
7	43.22	33.4	266.2	5	5.291	150	44	0.173317	0.009524	0.182841
6	43.40	34.2	300.4	6	6.301	150	44	0.092572	0.009524	0.102095
5	43.50	33.4	333.8	6	6.301	150	44	0.112518	0.009524	0.122042
4	43.63	34.2	367.9	6	6.301	150	44	0.134778	0.009524	0.144302
3	43.77	33.4	401.3	6	6.301	150	44	0.158292	0.009524	0.167816
2	43.94	34.2	435.5	6	6.301	150	44	0.184156	0.009524	0.193679
1	44.13	33.4	468.9	6	6.301	150	22	0.105573	0.004762	0.110334
0	44.24	inlet								
average P=	43.28									
min P=	42.66			main. DU=	0.99		Set #1	DU=	0.93	
max P=	44.24									
				Set #1 Walnuts						
				submain	**downhill**					
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
5	43.43	25.43	25.43	3	3.284	148	44	0.023417	-0.009524	0.013894
4	43.45	25.43	50.86	3	3.284	148	44	0.084537	-0.009524	0.075013
3	43.52	27.02	77.88	3	3.284	148	44	0.186102	-0.009524	0.176578
2	43.70	25.43	103.31	3	3.284	148	44	0.314068	-0.009524	0.304544
1	44.00	27.02	130.33	3	3.284	148	22	0.241469	-0.004762	0.236707
0	44.24	inlet								
average	43.72									
min P=	43.43326									
max P=	44.24									

				Set #1 Walnuts						
				submain	**Section by the house**					
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
5	42.33	8.74	8.74	3	3.284	148	44	0.003241	0.019048	0.022288
4	42.35	9.54	18.28	3	3.284	148	44	0.012703	0.019048	0.031751
3	42.38	6.36	24.64	3	3.284	148	44	0.02208	0.019048	0.041128
2	42.43	7.15	31.79	3	3.284	148	44	0.035401	0.019048	0.054449
1	42.48	6.36	38.15	3	3.284	148	332	0.374407	0.071861	0.446269
0	42.93	inlet								

<u>Additional pressure req'd:</u> note: this will not affect DU, only pump pressure requirement

elevation of riser above later=	30	inches= 1.082251	psi
friction in riser=		0.028716	psi

conversion for gpm to fps equation=	0.408526	
Hf minor, sprinkler=	0.041687	psi
Hf minor, lateral=	1.310962	psi
Hf minor, submain=	0.027209	psi
Elevation change mainline to submain=	0.649351	psi
total add. Pres. Req'd. due to Hfminor=	3.140175	psi

Set Pressure Regulator at head of block to 47.4 psi

mainline: Size based on a max velocity of 5 fps in pipe.

GPM	nom. Pipe	Pipe ID	velocity
599.2053	6	6.301	6.165616
599.2053	8	8.205	3.63612
599.2053	10	10.226	2.340905

use 8" IPS for mainline pipe.
350' of 8" pipe

hf in mainline= 0.73 psi

elev change= -0.075758 psi

Set #1 pump requirement (less losses from filter, check valves, etc.)

P=	48.0	psi

Set # 2 pipe sizing

avg. Sprinkler Q=		1.59
avg. Sprinkler P=		39.1

Set #2 Walnuts
downhill lateral

Outlet	Point P psi	Point Q gpm	u/s seg Q gpm	Nom. Dia in	Pipe ID in	H-W "C"	Segment length, ft	Segment Hf, psi	Δ Elev psi	Δ P psi
			0							
8	38.34	1.57	1.57	1	1.189	141	44	0.020882	-0.009524	0.011358
7	38.35	1.57	3.15	1	1.189	141	44	0.075396	-0.009524	0.065872
6	38.41	1.58	4.73	1	1.189	141	44	0.159851	-0.009524	0.150328
5	38.56	1.58	6.31	1	1.189	141	44	0.27266	-0.009524	0.263136
4	38.83	1.58	7.89	1	1.189	141	44	0.413007	-0.009524	0.403484
3	39.23	1.59	9.48	1	1.189	141	44	0.580592	-0.009524	0.571068
2	39.80	1.60	11.09	1	1.189	141	44	0.775532	-0.009524	0.766009
1	40.57	1.62	12.71	1	1.189	141	33	0.748757	-0.007143	0.741614
0	41.31	inlet								

avg. P=	39.27
Min P=	38.34
Max P=	41.31

Set #2 Walnuts
uphill lateral

Outlet	Point P psi	Point Q gpm	u/s seg Q gpm	Nom. Dia in	Pipe ID in	H-W "C"	Segment length, ft	Segment Hf, psi	Δ Elev psi	Δ P psi
			0							
9	37.68	1.56	1.56	1	1.189	141	44	0.020549	0.009524	0.030073
8	37.71	1.56	3.12	1	1.189	141	44	0.07421	0.009524	0.083734
7	37.79	1.56	4.69	1	1.189	141	44	0.157375	0.009524	0.166899
6	37.96	1.57	6.25	1	1.189	141	44	0.268498	0.009524	0.278022
5	38.24	1.57	7.83	1	1.189	141	44	0.406798	0.009524	0.416322
4	38.65	1.58	9.41	1	1.189	141	44	0.571996	0.009524	0.58152
3	39.23	1.59	11.00	1	1.189	141	44	0.764227	0.009524	0.77375
2	40.01	1.61	12.61	1	1.189	141	44	0.984014	0.009524	0.993538
1	41.00	1.63	14.24	1	1.189	141	11	0.308065	0.002381	0.310446
0	41.31	inlet								

avg. P=	39.10									
Min P=	37.71				lat. DU=	0.964385				
Max P=	41.31									

Set #2 Walnuts
submain uphill

Outlet	Point P psi	Point Q gpm	u/s seg Q gpm	Nom. Dia in	Pipe ID in	H-W "C"	Segment length, ft	Segment Hf, psi	Δ Elev psi	Δ P psi
			0							
14	39.46	27.02	27.02	3	3.284	148	44	0.0262	0.019048	0.045247
13	39.51	26.23	53.25	3	3.284	148	44	0.092022	0.019048	0.111069
12	39.62	27.02	80.26	3	3.284	148	44	0.19679	0.019048	0.215838
11	39.83	26.23	106.49	3	3.284	148	44	0.332199	0.019048	0.351247
10	40.18	27.02	133.51	3	3.284	148	44	0.504979	0.019048	0.524026
9	40.71	26.23	159.74	4	4.28	149	44	0.191362	0.019048	0.210409
8	40.92	27.02	186.75	4	4.28	149	44	0.255596	0.019048	0.274644
7	41.19	26.23	212.98	4	4.28	149	44	0.326018	0.019048	0.345066
6	41.54	27.02	240.00	4	4.28	149	44	0.406733	0.019048	0.42578
5	41.96	26.23	266.23	4	4.28	149	20	0.224025	0.008658	0.232683
	42.20	0.00	266.23	5	5.291	150	180	0.709025	0.038961	0.747986
	42.20	0.00	266.23	5	5.291	150	24	0.094537	0.01039	0.104926
4	42.20	6.36	272.58	5	5.291	150	44	0.18106	0.019048	0.200108
3	42.40	6.36	278.94	5	5.291	150	44	0.188959	0.019048	0.208006
2	42.60	6.36	285.30	5	5.291	150	44	0.197012	0.019048	0.21606
1	42.82	6.36	291.66	5	5.291	150	22	0.10261	0.009524	0.112134
0	42.93	inlet								
avg. P=	41.31									
Min P=	39.46									
Max P=	42.93									

Set #2 Walnuts
submain downhill

Outlet	Point P psi	Point Q gpm	u/s seg Q gpm	Nom. Dia in	Pipe ID in	H-W "C"	Segment length, ft	Segment Hf, psi	Δ Elev psi	Δ P psi
			0							
16	39.35	23.84	23.84	3	3.284	148	44	0.020779	-0.019048	0.001732
15	39.35	23.05	46.89	3	3.284	148	44	0.072714	-0.019048	0.053666
14	39.41	23.84	70.73	3	3.284	148	44	0.155694	-0.019048	0.136646
13	39.54	23.05	93.77	3	3.284	148	44	0.262498	-0.019048	0.24345
12	39.79	23.84	117.62	3	3.284	148	44	0.399324	-0.019048	0.380276
11	40.17	23.05	140.66	4	4.28	149	24	0.082479	-0.01039	0.072089
10	40.24	23.84	164.50	4	4.28	149	44	0.202075	-0.019048	0.183028
9	40.42	23.05	187.55	4	4.28	149	44	0.257614	-0.019048	0.238566
8	40.66	23.84	211.39	4	4.28	149	44	0.321527	-0.019048	0.302479
7	40.96	23.05	234.44	4	4.28	149	44	0.389445	-0.019048	0.370398

6	41.33	23.84	258.28	4	4.28	149	16	0.169438	-0.006926	0.162512
	41.50	0.00	258.28	5	5.291	150	225	0.837908	0.048701	0.886609
	42.38	0.00	258.28	5	5.291	150	16	0.059585	-0.006926	0.052658
5	42.38	6.36	264.64	5	5.291	150	44	0.171406	-0.019048	0.152358
4	42.38	6.36	270.99	5	5.291	150	44	0.17911	-0.019048	0.160062
3	42.54	6.36	277.35	5	5.291	150	44	0.18697	-0.019048	0.167922
2	42.71	6.36	283.71	5	5.291	150	44	0.194984	-0.019048	0.175937
1	42.89	6.36	290.07	5	5.291	150	22	0.101577	-0.009524	0.092053
0	42.98	inlet								
avg. P=	41.31			main. DU=	0.953903		set #2	DU=	0.920	
Min P=	39.41									
Max P=	42.98									
<u>Mainline:</u>		Use 8" IPS for mainline			note: approx. same flow as set #1, same size pipe.					
		285' of 8"pipe								
	additional pressure req'd:									
elevation of riser above later=			30	inches=	1.082251					
friction in riser=					0.028716					
conversion for gpm to fps equation=				0.408526						
Hf minor, sprinkler=				0.04435	psi					
Hf minor, lateral=				0.871935	psi					
Hf minor, submain=				0.0112	psi					
Elevation change mainline to submain=				0.649351	psi					
total add. Pres. Req'd. due to Hfminor=				2.687801	psi					
	Set PR at	43.0	psi							
						add'l pres due to elev change				
	hf in mainline=		0.563626	psi		0.061688	psi			
	pressure required at pump for set #2 (less loss in filter, check valve, etc.)									
	P=	43.6	psi							
<u>Set #3:</u>	**Cherries**		note: all blocks run at same time, PR at head of each block.							
			Block 1			Blocks 2&3				
			Q(GPM)	P(psi)	k	Q(GPM)	P(psi)	k		
		Gray #8.3	1.04	72.5	0.121764	0.82	45.7	0.121764		

		White #9	1.04	54.1	0.140963	0.82	34.1	0.140963		
		Dk Blue#10	1.04	34.3	0.177049	0.82	21.6	0.177049		
					Set #3 Cherries					
block #1:					uphill lateral					
							k=	0.177049		
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
6	33.95	1.03	1.03	1	1.189	141	24.75	0.005366	0.005357	0.010724
5	33.96	1.03	2.06	1	1.189	141	49.5	0.038752	0.010714	0.049466
4	34.01	1.03	3.10	1	1.189	141	49.5	0.082154	0.010714	0.092868
3	34.10	1.03	4.13	1	1.189	141	49.5	0.140087	0.010714	0.150802
2	34.25	1.04	5.17	1	1.189	141	49.5	0.212061	0.010714	0.222775
1	34.48	1.04	6.21	1	1.189	141	37.125	0.223353	0.008036	0.231389
0	34.71	inlet								
avg. P=	34.21	psi								
Min P=	33.95	psi								
Max P=	34.71	psi			Set #3 Cherries					
					downhill lateral					
							k=	0.177049		
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
6	34.30	0.52	0.52	1	1.189	141	49.5	0.003001	-0.010714	-0.00771
5	34.29	1.04	1.56	1	1.189	141	49.5	0.022957	-0.010714	0.012242
4	34.30	1.04	2.59	1	1.189	141	49.5	0.059131	-0.010714	0.048417
3	34.35	1.04	3.63	1	1.189	141	49.5	0.110313	-0.010714	0.099599
2	34.45	1.04	4.67	1	1.189	141	49.5	0.175842	-0.010714	0.165127
1	34.62	1.04	5.71	1	1.189	141	12.375	0.063833	-0.002679	0.061154
0	34.68	inlet								
avg. P=	34.43	psi			lat. DU=	0.986104				
Min P=	34.29	psi								
Max P=	34.68	psi								
					Set #3 Cherries					
					uphill submain					
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
7	33.84	11.44	11.44	2	2.193	146	24.75	0.021985	0.010714	0.032699

6	33.87	11.96	23.4	2	2.193	146	24.75	0.082737	0.010714	0.093451
5	33.96	11.44	34.84	2	2.193	146	24.75	0.172919	0.010714	0.183633
4	34.15	11.96	46.8	2	2.193	146	24.75	0.298681	0.010714	0.309396
3	34.46	11.44	58.24	2	2.193	146	24.75	0.447819	0.010714	0.458534
2	34.92	11.96	70.2	2	2.193	146	24.75	0.632891	0.010714	0.643606
1	35.56	11.44	81.64	2	2.193	146	12.375	0.418531	0.005357	0.423888
0	35.98	inlet								
avg. P=	34.70	psi								
Min P=	33.87	psi								
Max P=	35.98	psi		**Set #3 Cherries**						
				downhill submain						
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
7	33.91	11.96	11.96	2	2.193	146	24.75	0.023871	-0.010714	0.013157
6	33.93	11.44	23.40	2	2.193	146	24.75	0.082737	-0.010714	0.072023
5	34.00	11.96	35.36	2	2.193	146	24.75	0.177729	-0.010714	0.167014
4	34.17	11.44	46.80	2	2.193	146	24.75	0.298681	-0.010714	0.287967
3	34.45	11.96	58.76	2	2.193	146	24.75	0.455253	-0.010714	0.444538
2	34.90	11.44	70.20	2	2.193	146	24.75	0.632891	-0.010714	0.622177
1	35.52	11.96	82.16	2	2.193	146	12.375	0.423481	-0.005357	0.418124
0	35.94	inlet								
avg. P=	34.70	psi		main. DU=	0.976109		blk #1 DU=	0.96		
Min P=	33.93	psi								
Max P=	35.94	psi								
				Set #3 Cherries						
block #2:				**uphill lateral**						
							k=	0.140963		
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
8	33.80	0.82	0.82	1	1.189	141	31.11	0.004404	0.006734	0.011138
7	33.81	0.82	1.64	1	1.189	141	31.11	0.015902	0.006734	0.022636
6	33.83	0.82	2.46	1	1.189	141	31.11	0.033705	0.006734	0.040438
5	33.87	0.82	3.28	1	1.189	141	31.11	0.057445	0.006734	0.064179
4	33.94	0.82	4.10	1	1.189	141	31.11	0.086893	0.006734	0.093627
3	34.03	0.82	4.92	1	1.189	141	31.11	0.121895	0.006734	0.128629
2	34.16	0.82	5.75	1	1.189	141	31.11	0.162347	0.006734	0.169081
1	34.33	0.83	6.57	1	1.189	141	31.11	0.208185	0.006734	0.214919
0	34.54	inlet								
avg. P=	34.10	psi								

Min P=	33.83	psi								
Max P=	34.54	psi								
				Set #3 Cherries						
				downhill lateral						
							k=	0.140963		
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
8	33.87	0.82	0.82	1	1.189	141	31.11	0.004412	-0.006734	-0.00232
7	33.86	0.82	1.64	1	1.189	141	31.11	0.015928	-0.006734	0.009195
6	33.87	0.82	2.46	1	1.189	141	31.11	0.033754	-0.006734	0.02702
5	33.90	0.82	3.28	1	1.189	141	31.11	0.057519	-0.006734	0.050785
4	33.95	0.82	4.10	1	1.189	141	31.11	0.086989	-0.006734	0.080255
3	34.03	0.82	4.93	1	1.189	141	31.11	0.122007	-0.006734	0.115273
2	34.15	0.82	5.75	1	1.189	141	31.11	0.162466	-0.006734	0.155732
1	34.30	0.83	6.57	1	1.189	141	31.11	0.208299	-0.006734	0.201565
0	34.50	0.83	7.40	inlet						
avg. P=	34.10	psi		lat. DU=	0.992136					
Min P=	33.87	psi								
Max P=	34.50	psi								
				Set #3 Cherries						
				submain						
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
15	32.09	13.98	13.98	2	2.193	146	31.11	0.040036	-0.013468	0.026568
14	32.12	13.98	27.95	2	2.193	146	31.11	0.14453	-0.013468	0.131062
13	32.25	13.98	41.93	2	2.193	146	31.11	0.306251	-0.013468	0.292783
12	32.54	13.98	55.90	2	2.193	146	31.11	0.521752	-0.013468	0.508284
11	33.05	13.98	69.88	2	2.193	146	31.11	0.788754	-0.013468	0.775286
10	33.83	13.98	83.85	3	3.284	148	31.11	0.150875	-0.013468	0.137407
9	33.96	13.98	97.83	3	3.284	148	31.11	0.200725	-0.013468	0.187258
8	34.15	13.98	111.80	3	3.284	148	31.11	0.257041	-0.013468	0.243574
7	34.39	13.98	125.78	3	3.284	148	31.11	0.319696	-0.013468	0.306229
6	34.70	13.98	139.75	3	3.284	148	31.11	0.38858	-0.013468	0.375113
5	35.08	13.98	153.73	3	3.284	148	31.11	0.463596	-0.013468	0.450129
4	35.53	13.98	167.70	3	3.284	148	31.11	0.544658	-0.013468	0.531191
3	36.06	13.98	181.68	3	3.284	148	31.11	0.631689	-0.013468	0.618222
2	36.67	13.98	195.65	3	3.284	148	31.11	0.724619	-0.013468	0.711151
1	37.39	13.98	209.63	3	3.284	148	31.11	0.823382	-0.013468	0.809915
0	38.20	inlet								
avg. P=	34.50	psi		main. DU=	0.930196		blk #2 DU=	0.92		

Min P=	32.09	psi								
Max P=	38.20	psi								
				Set #3 Cherries						
Block #3				**uphill lateral**						
							k=	0.140963		
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
14	31.90	0.80	0.80	1	1.189	141	31.11	0.004175	0.004714	0.008888
13	31.91	0.80	1.59	1	1.189	141	31.11	0.015072	0.004714	0.019786
12	31.93	0.80	2.39	1	1.189	141	31.11	0.031945	0.004714	0.036658
11	31.96	0.80	3.19	1	1.189	141	31.11	0.054444	0.004714	0.059158
10	32.02	0.80	3.98	1	1.189	141	31.11	0.082352	0.004714	0.087066
9	32.11	0.80	4.78	1	1.189	141	31.11	0.115523	0.004714	0.120236
8	32.23	0.80	5.58	1	1.189	141	31.11	0.153857	0.004714	0.15857
7	32.39	0.80	6.38	1	1.189	141	31.11	0.197294	0.004714	0.202007
6	32.59	0.80	7.19	1	1.189	141	31.11	0.245804	0.004714	0.250518
5	32.84	0.81	8.00	1	1.189	141	31.11	0.299389	0.004714	0.304103
4	33.14	0.81	8.81	1	1.189	141	31.11	0.358076	0.004714	0.36279
3	33.51	0.82	9.62	1	1.189	141	31.11	0.421918	0.004714	0.426632
2	33.93	0.82	10.45	1	1.189	141	31.11	0.490997	0.004714	0.49571
1	34.43	0.83	11.27	1	1.189	141	31.11	0.565418	0.004714	0.570132
0	35.00	0.83	12.11	inlet						
avg. P=	33.64	psi								
Min P=	32.59	psi								
Max P=	35.00	psi								
				Set #3 Cherries						
				downhill lateral						
							k=	0.140963		
	Point P	Point Q	u/s seg Q	Nom. Dia	Pipe ID	H-W	Segment	Segment	Δ Elev	Δ P
Outlet	psi	gpm	gpm	in	in	"C"	length, ft	Hf, psi	psi	psi
			0							
7	34.54	0.83	0.83	1	1.189	141	31.11	0.004494	-0.004714	-0.00022
6	34.54	0.83	1.66	1	1.189	141	31.11	0.016223	-0.004714	0.011509
5	34.55	0.83	2.49	1	1.189	141	31.11	0.034379	-0.004714	0.029666
4	34.58	0.83	3.31	1	1.189	141	31.11	0.058586	-0.004714	0.053872
3	34.64	0.83	4.14	1	1.189	141	31.11	0.088605	-0.004714	0.083892
2	34.72	0.83	4.97	1	1.189	141	31.11	0.124278	-0.004714	0.119564
1	34.84	0.83	5.81	1	1.189	141	31.11	0.165494	-0.004714	0.160781
0	35.00	inlet								
avg. P=	34.70	psi		lat. DU=	0.939314					
Min P=	34.54	psi								
Max P=	35.00	psi								

Set #3 Cherries
Submain Downhill

Outlet	Point P psi	Point Q gpm	u/s seg Q gpm	Nom. Dia in	Pipe ID in	H-W "C"	Segment length, ft	Segment Hf, psi	Δ Elev psi	Δ P psi
			0							
21	34.41	0.82	0.82	3	3.284	148	31.11	2.88E-05	-0.014814	-0.01479
20	34.40	2.47	3.29	3	3.284	148	31.11	0.000376	-0.014814	-0.01444
19	34.39	4.12	7.41	3	3.284	148	31.11	0.001687	-0.014814	-0.01313
18	34.37	5.76	13.17	3	3.284	148	31.11	0.004897	-0.014814	-0.00992
17	34.36	7.41	20.58	3	3.284	148	31.11	0.011192	-0.014814	-0.00362
16	34.36	9.06	29.64	3	3.284	148	31.11	0.021988	-0.014814	0.007174
15	34.37	10.70	40.34	3	3.284	148	31.11	0.038919	-0.014814	0.024104
14	34.39	12.35	52.69	4	4.28	149	31.11	0.01735	-0.014814	0.002536
13	34.39	14.00	66.69	4	4.28	149	31.11	0.026839	-0.014814	0.012025
12	34.40	15.64	82.33	4	4.28	149	31.11	0.039651	-0.014814	0.024836
11	34.43	17.29	99.62	4	4.28	149	31.11	0.056437	-0.014814	0.041623
10	34.47	18.11	117.74	4	4.28	149	31.11	0.076901	-0.014814	0.062087
9	34.53	18.11	135.85	4	4.28	149	31.11	0.100237	-0.014814	0.085423
8	34.62	18.11	153.96	4	4.28	149	31.11	0.126386	-0.014814	0.111572
7	34.73	18.11	172.08	4	4.28	149	31.11	0.155296	-0.014814	0.140482
6	34.87	9.88	181.96	5	5.291	150	31.11	0.06056	-0.014814	0.045746
5	34.92	8.23	190.19	5	5.291	150	31.11	0.065733	-0.014814	0.050918
4	34.97	6.59	196.78	5	5.291	150	31.11	0.070011	-0.014814	0.055196
3	35.02	4.94	201.72	5	5.291	150	31.11	0.0733	-0.014814	0.058486
2	35.08	3.29	205.01	5	5.291	150	31.11	0.075532	-0.014814	0.060718
1	35.14	1.65	206.66	5	5.291	150	31.11	0.07666	-0.014814	0.061845
0	35.20	16.47	223.12	inlet						

average	35.00						
min P=	34.36		main. DU=	0.981682		blk #3 DU=	0.92
max P=	35.20						

additional pressure req'd:

all blocks:

elevation of riser above later=	30	inches=	1.082251
friction in riser=			0.028716
Elevation change mainline to submain=			0.649351 psi

block specific:

block 1:

conversion for gpm to fps equation=	0.408526
Hf minor, sprinkler=	0.017835 psi

Hf minor, lateral=			0.160049	psi
Hf minor, submain=			0.015797	psi
block 2:				
conversion for gpm to fps equation=			0.408526	
Hf minor, sprinkler=			0.011087	psi
Hf minor, lateral=			0.06152	psi
Hf minor, submain=			0.102842	psi
Block 3:				
conversion for gpm to fps equation=			0.408526	
Hf minor, sprinkler=			0.011087	psi
Hf minor, lateral=			0.166849	psi
Hf minor, submain=			0.116504	psi
add'l pres for each cherry block:				
		block #1=	2.0	psi
		block #2=	1.9	psi
		block #3=	2.1	psi

Set PR at each block to:		block #1=	38	psi
		block #2=	40	psi
		block #3=	37	psi

Size Cherry set mainline based of a max velocity of 5 fps

nom. Pipe	pipe ID	gpm @ 5 fps
3	3.284	132
4	4.28	224
5	5.291	343
6	6.301	486
8	8.205	824
10	10.226	1280

	560.5	4"		243'	6" pipe
	28.3	4"		12'	8" pipe
	343.5	4"			
total=	932.3	4" pipe			

losses along mainline in set #3:

				additional Pres due to change in elev. along mainline			
Hf segment 1=	2.309799	psi		seg 1=	-0.0619	psi	.
Hf segment 2=	1.001069	psi		seg 2=	-0.01255	psi	
Hf segment 3=	0.025131	psi		seg 2=	-0.00519	psi	
Set#3 mainline Hf=	3.3	psi		total=	-0.07965	psi	

Set #3 pump requirement (less loss due to filter, fitting losses, etc,)

P= 43.4 psi

Set requiring highest pump pressure= 48.0 psi Set #1

Filtration:

Grower has specified use of tubular screen filter. Well pumps clean water, therefore, centrifugal action sand separator is not necessary.

Use Morrill Industries tubular screen filter.
Filtration= 0.05 inch diameter

Additional losses (due to filtration, check valves, etc.):

losses due to screen filter=	2	psi	0.408526
minor losses u/s of PRs=	1	psi	
loss through check valve=	0.18	psi	
loss through butterfly valve=	0.05	psi	

Pressure required at pump outlet=	51	psi	60	psi
	118	feet	138.6	feet

Adequate pressure available for 60 psi at pump

TDH available at 600 gpm=	310	ft
distance to water level=	150	ft
drawdown at 600 gpm=	6	ft
Hf in column (old steel)=	0.70	ft
pressure available at the pump=	153.30	ft

adequate pressure at the pump

Sizing air vents:

PVC dia inches	release CFM	vacuum CFM	Cont. rel. CFM
1	5	2	0.2
2	16	8	1
3	35	18	2
4	60	30	3

5	90	45	5
6	130	65	6
8	220	110	11

From Waterman Discharge Curves: at a pipeline pressure of 20 psi, a 1 1/2" air vent can handle over 400 CFM of discharge.

1 1/2" air vents are adequate for this design

Summary Tables:

Pressure Regulator Settings		
Set #1	47	psi
Set #2	43	psi
Set #3		
Block #1	38	psi
Block #2	40	psi
Block #3	37	psi

Distribution Uniformity by Set	
Set #1	0.93
Set #2	0.92
Set #3	
Block #1	0.96
Block #2	0.92
Block #3	0.92

Minor Loss K Values	
Valve/Fitting	K
Check valve	2.0
Butterfly valve	0.6
Tee, branch flow 1/2"	2.2
Tee, line flow 1"	2.0
Tee, branch flow 4" and up	0.7
Elbow	0.6

APPENDIX C
NRCS Soils Report

Map Unit Description

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

San Joaquin County, California

129—Cogna loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 70 to 150 feet
Mean annual precipitation: 15 to 17 inches
Mean annual air temperature: 61 to 63 degrees F
Frost-free period: 230 to 250 days

Map Unit Composition

Cogna, loam, and similar soils: 85 percent
Minor components: 15 percent

Description of Cogna, Loam

Setting

Landform: Alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Fine-loamy alluvium derived from igneous, metamorphic and sedimentary rock

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum content: 2 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water capacity: High (about 9.3 inches)

Interpretive groups

Farmland classification: Prime farmland if irrigated
Land capability classification (irrigated): 1
Land capability (nonirrigated): 4c
Hydrologic Soil Group: B

Typical profile

0 to 25 inches: Loam
25 to 38 inches: Clay loam
38 to 64 inches: Loam

Minor Components

Archerdale

Percent of map unit: 6 percent
Landform: Stream terraces
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear

Nord

Percent of map unit: 4 percent
Landform: Fan skirts

Veritas

Percent of map unit: 3 percent
Landform: Fan remnants

Columbia

Percent of map unit: 1 percent
Landform: Flood plains

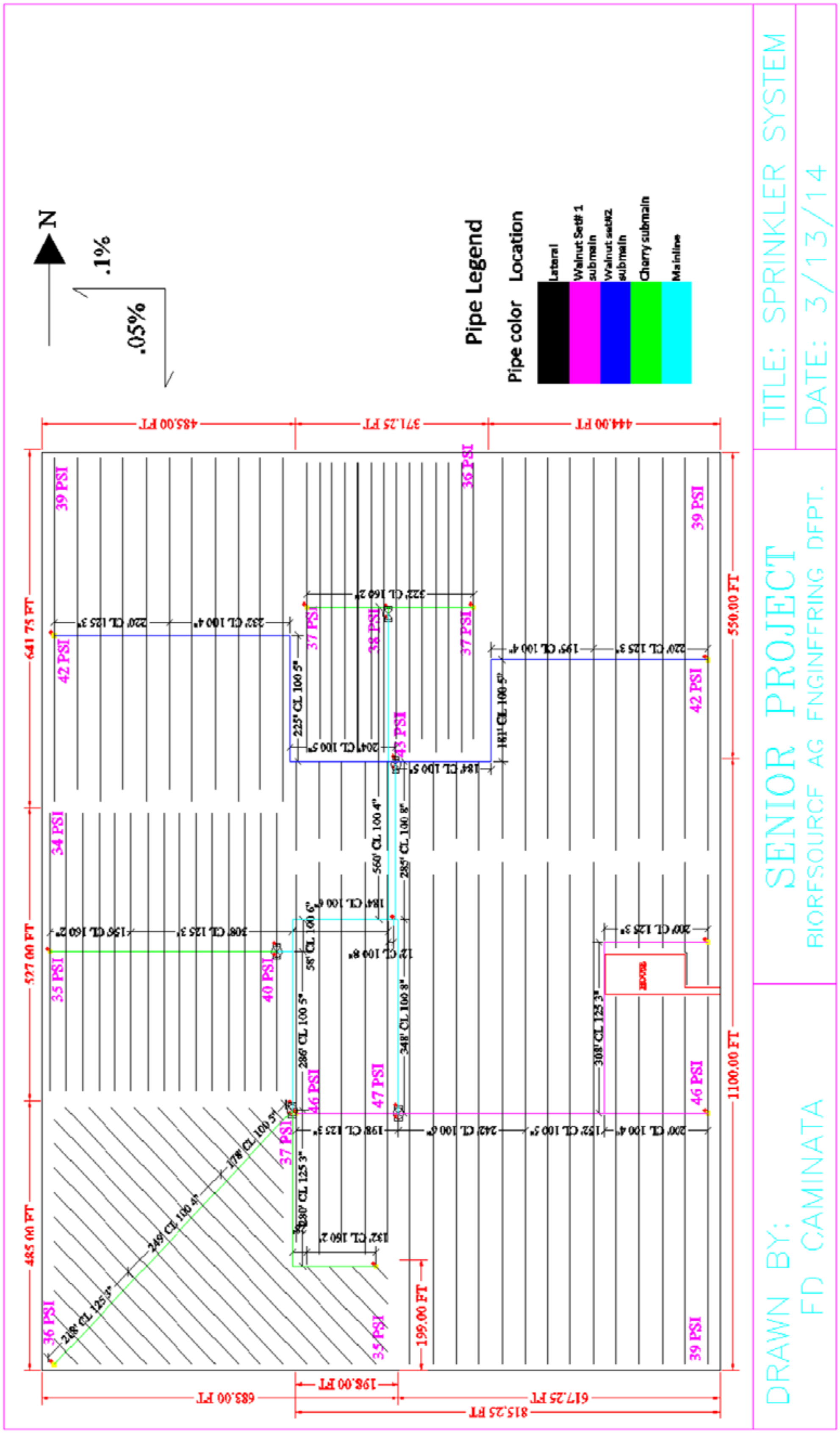
Honcut

Percent of map unit: 1 percent
Landform: Flood plains

Data Source Information

Soil Survey Area: San Joaquin County, California
Survey Area Data: Version 7, Nov 25, 2013

APPENDIX D
Drawing of Irrigation System


N
.1%
.05%
Pipe Legend
Pipe color
Location
Lateral
Walnut Set# 1 submain
Walnut set#2 submain
Cherry submain
Mainline
485.00 FT
371.25 FT
444.00 FT
641.75 FT
527.00 FT
485.00 FT
550.00 FT
1100.00 FT
199.00 FT
683.00 FT
198.00 FT
617.25 FT
815.25 FT
TITLE: SPRINKLER SYSTEM
DATE: 3/13/14
SENIOR PROJECT
BIORESOURCE AG ENGINEERING DEPT.
DRAWN BY:
ED CAMINATA