DESIGN OF SPRINKLER IRRIGATION IN NALANI TEA ESTATE

A dissertation submitted in partial fulfilment of the requirements for the award for the degree of

MASTERS OF TECHNOLOGY IN WATER RESOURCES ENGINEERING

under

ASSAM SCIENCE AND TECHNOLOGY UNIVERSITY

for the session 2021-23

<u>SUBMITTED BY –</u>

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Guwahati- 781013

CERTIFICATE FROM THE HEAD OF THE DEPARTMENT

This is to certify that the following 4th Semester student of M.Tech. in Water Resources Engineering has successfully carried out and completed the project on '**Design of sprinkler irrigation in Nalani Tea Estate'** in partial fulfilment of the award of Masters of Technology (M.Tech.) in Water Recourses Engineering under Assam Science and Technology University. Her work is a bonified project under my supervision and guidance.

I wish her success and accolades in all walks of her life.

Name of the student –

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Dr. Jayanta Pathak

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CERTIFICATE FROM THE GUIDE

This is to certify that the following 4th Semester student of M.Tech. in Water Resources Engineering has successfully carried out and completed the project on '**Design of sprinkler irrigation in Nalani Tea Estate'** in partial fulfilment of the award of Masters of Technology (M.Tech.) in Water Recourses Engineering under Assam Science and Technology University. Her work is a bonified project under my supervision and guidance.

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DECLARATION

This is to certify that the work presented in this project entitled ‘**Design of sprinkler irrigation in Nalani Tea Estate’** in fulfilment of the award of Masters of Technology (M.Tech.) in Water Resources Engineering under Assam Science and Technology University is submitted to the Department of Civil Engineering, Assam Engineering College, Jalukbari-13, Guwahati. The project has been performed under the esteemed guidance and supervision of Dr. Bibhash Sarma, Professor, Civil Engineering Department of Assam Engineering College.

The matter embodied in this project has not been submitted for the sword of any other degree by us.

Date:

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ABSRACT

Agriculture is one of the prime means of livelihood for a developing country like India. Almost two third of the entire population at the present depends on agriculture as their prime source of income. The growing population and the increasing demand of food grains makes agriculture a lucrative source of income. However, when it comes to agriculture, resource allocation becomes an important factor. With the climate changes, the water availability has also become a question, that needs to be addressed as soon as possible.

Cultivation of tea is important for the economic development of North-East India. The tea industry in assam is about 172 years old. Discovered by Rubert Bruce, in 1823, growing wild in upper Brahmaputra Valley, tea cultivation has an indispensable part to play to improve the Indian economy. Assam on an average alone produces about 630 to 700 million kgs of tea annually which accounts to be more than 50% of the total annual tea production in India. Tea cultivation also provides livelihood and creates huge amount of employment in Assam.

However, it has to be noted that, tea growth is very sensitive towards climate changes. The increase or decrease in temperature, availability or scarcity of water for its growth have an impact on the quality and production rate of tea.

Irrigation is the process of artificially applying water to the crops when there is scarcity of rainfall. When the natural water availability is not sufficient for the growth of the plants, artificial supply of water becomes of utmost importance. In Assam during the months of November to March due to insufficient rainfall, the tea plants undergo moisture stress problem. To meet their water demand, it becomes necessary to make artificial supply of water available. In most of the tea estates in Assam, it has been seen that, the topography is not even. Thus, to satisfy the topography mainly sprinkler irrigation is used in such tea estates.

Generally, the laying out and the design of sprinkler irrigation is based on general thumb rule and not based on the soil characteristics, climatological conditions or topography of the soil. Here a case study has been done at Nalani Tea Estate at Guijan where sprinkler irrigation design and layout will be suggested for the tea plants based on climatology, water demand and topography of the tea estate.

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Agriculture is one of the most important sources of living of the people in Assam. Tea forms an indispensable part in the growth and development of the Indian economy. With that much importance in the real world, its growth and development need to be taken care of. In Assam the moisture stress problem mainly takes place in the dry winter season, namely from the month of November to March. During this dry season, irrigation facility needs to be utilized to meet the demands of the crops. Considering the fact that topography of the tea estates is mostly uneven, sprinkler irrigation is mainly used. The design and layout of the irrigation system has to be analyzed based on the type of soil, its infiltration rate etc. In this project sprinkler irrigation system has been designed not based on the general thumb rules but based on real time factors analyzed for the tea estate which has been selected for the case study.

Water is essentially the most vital element of plant growth. Mostly water is provided to the plants through rainfall, but due to climate changes, there is a difference in rainfall pattern in and around the world. If cultivation is solely dependent on rainfall, then due to insufficient or ill-timed rainfall the cultivation of crops may get affected. Hence in order to make sure that the water requirement of the crops are satisfied no matter what, and a systematic irrigation system should be introduced.

Tea in Assam is mostly entirely a rain-fed crop and irrigation is yet to make an impact on its production. In the months from November to March usually in Assam, the tea plants usually undergo a moisture stress problem So, it is necessary to arrange for irrigation. However, due to the uneven topography of the land here in Assam, sprinkler irrigation is suited best for the purpose.

1.2 INTRODUCTION TO SPRINKLER IRRIGATION SYSTEM

Sprinkler irrigation is the concept of spraying water over the crops under a required water pressure. Considering the fact that the topography of the soil here in Assam is mostly uneven, sprinkler irrigation type of irrigation system hence becomes of utmost help. The greatest advantage of sprinkler irrigation is its adaptability to use under conditions where surface irrigation is not efficient.

1.3 OBJECTIVES OF THE STUDY

1. To find if the area requires irrigation for cultivation of tea and to find the water deficit.
2. To conduct laboratory tests required for the designing of sprinkler irrigation.
3. To design sprinkler irrigation system which suits the need for the tea estate.

1.4 STUDY AREA

The tea estate that has been selected for the study is at Guijan in Tinsukia district. The name of the tea estate is Nalani Tea Estate, which spreads in around 472 hectares of land area and has a work force of 965 people. The tea estate is located in latitude 27.570710 and longitude 95.328280. The name Nalani comes from the Assamese word ‘Nalani’ meaning ‘reeds growing from water’. The garden came into being in 1904, following the purchase of the Kamptigoalli Tea Estate and merger with Woodbine tea estate, belonging to Jokai Group.

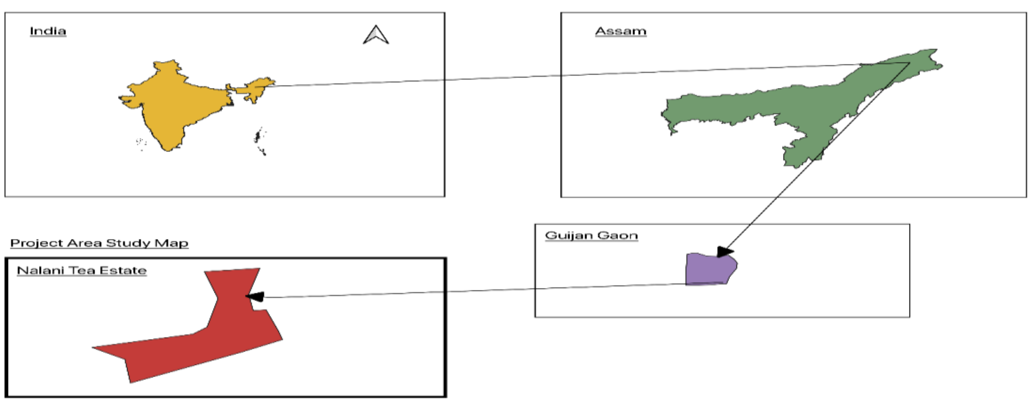

Fig 1.1: *Location of the study area.*

The current population of the locality is per the 2021 census report is 658.

The land area under study is being used for the cultivation of tea for commercial purposes.

1.5 CHAPTER WISE SCHEME OF THE DISSERTATION

Chapter 1**:** This chapter deals with a brief introduction of the area under our study, need of irrigation, the type of irrigation to be used and tea cultivation.

Chapter 2: This chapter talks about the review of literature.

Chapter 3: Introduction to Sprinkler Irrigation.

Chapter 4: The methodology being used.

Chapter 5: The case study

Chapter 6: This chapter covers results and discussions.

References and Bibliography: This chapter covers references and bibliography.

CHAPTER: 2

REVIEW OF LITERATURE

2.1GENERAL

The cultivated area needs to be irrigated properly and scientifically for the production to be as per our requirement. For this an efficient and convenient system have to be designed to make it work. For tea cultivation in practice mainly drip irrigation and sprinkler irrigation is used. Drip irrigation tends to be more costly than sprinkler irrigation and hence sprinkler irrigation is getting widely adopted in the tea estates of Assam as a preferred mode of irrigation.

2.2 HISTORY OF RESEARCH ON SPRINKLER IRRIGATION

The Division of Irrigation, at the University of California, USA, was the first ever pitstop where the initial studies on sprinkler irrigation took place in the year 1932.

Christian Sen and Jerald Emmet (1942), at Devis, USA, performed the most intensive series of experiments on sprinkler irrigation and recorded all his observation in his book “Irrigation by Sprinkling”.

Dutta (1942), did a comparative study on sprinkler irrigation and furrow irrigation for potato cultivation and found out that both the application and water use efficiencies are higher in case of sprinkler irrigation. About 35% of water saving was reported for sprinkler irrigation over furrow irrigation. (*in Shankar et.al (2018)***).***

Agarwal and Agarwal (1977) compared sprinkler irrigation with surface irrigation and published their results as an increase in the land area under irrigation from 8% to 140% and a decrease of 30% to 50% time that is required for irrigation over surface irrigation. (*in Shankar et.al (2018)***).***

Malhotra (1984) went for a comparative study between sprinkler irrigation and surface irrigation for a variety of crops and found out that sprinkler irrigation is preferrable for water saving purpose over surface irrigation. (*in Shankar et.al (2018)***).***

Suryavanshi and Pampattiwar (1985) compared sprinkler irrigation with surface irrigation and found out that water application, distribution, storage and water storage capacity were higher for sprinkler irrigation with an increase of yield of 13.9% for the use of sprinkler irrigation. (*in Shankar et.al (2018)***).**

Latif and Keller (1990) brought into light a good example of sprinkler irrigation in Saudi Arabia, where a desert is blossoming. About 25,000 of center irrigating pivot systems has been used to irrigate 1.2 million hectares of desert land and interestingly the crop yields have been almost equivalent to that of the developed countries. (*in Shankar et.al (2018)***).**

Arup Kumar Sarma and Dr. Nayan Sharma (1997) published a paper on, "A case study of sprinkler irrigation application for tea plantation in Assam." Where they designed sprinkler irrigation system for a tea estate in Assam through a software and compared its efficiency to the present system installed there on the field.

Perry et al. (2009) suggested that compared to flood and furrow irrigation the use of sprinkler irrigation can reduce the loss of water by almost 30%. (*in Shankar et.al (2018)***).**

Aqeel AL-Adili (2016) published an article "Sprinkler Irrigation Systems and Water Saving, A Case Study from South of Iraq" where he discussed how sprinkler irrigation can be applied in the fields and un-necessary wastage of water thus can be stopped.

***M. Shiva Shankar, A.V. Ramanjaneyulu, T.L. Neelima and Anup Das (2018*)** published a paper on 'Sprinkler irrigation- an asset in water scarce undulating areas.' Where they have studied the various types of sprinkler irrigation systems and gave a brief history of the study of sprinkler irrigation system.

Y. Kamala Raju and Muhammed Hussain (2019) published a paper based on their study titled, 'Field evaluation of sprinkler irrigation to improve crop productivity - a case study' where they studied the efficiency of an existing sprinkler irrigation system and suggested timely corrective measures to improve the water efficiency.

Shibani Chourushi and N P. Singh (2020) published a paper on 'Sprinkler irrigation in the Indian context: a literature review' where they studied the pros and cons of using sprinkler irrigation and how the benefit of using sprinkler irrigation depends on various factors

2.3 HISTORY OF TEA CULTIVATION IN ASSAM

The tea was first discovered by Robert Bruce in Assam in the year 1823. Later in the year 1833, erstwhile Lakhimpur, a tea company was started by the government in Assam. With the commercial export of tea in London, the business-men in London started taking interest in the cultivation of Tea here in Assam. To fulfil the growing demand of tea in the foreign land and to increase its production the commercial circle of the London city started the Assam Company here in India in the year 1839. This was the first company built in Assam which undertook the production of tea in the history of mankind.

Keeping in view the growing business and demand for the tea cultivated in Assam, a second company was established in the year 1859 which was the Jorhat Tea Company. This company also saw its fair share of rises and failures during the years. However, over the years of development, various preventive measures have been taken to safeguard this industry as it contributes to the Indian economy.

In the present day, tea is a booming industry and to improve its quality and productivity various tea research centers have been established to carry out research and to be prepared for any tough scenario that might affect the industry. One such research centers that is actively working presently in Assam is the Tokai Tea Research Center, in 1911, near Jorhat.

The marketing of tea has always been a problem in Assam, to solve this issue, The Tea Auction center was established in Guwahati in 25th September 1970. This establishment augured a new era for the tea industry in Assam.

In today's time Assam tea holds a significant share in the international market. The total area under tea cultivation in Assam is more than half of the total land area under tea cultivation in India. Assam alone produces more than half of the total amount of tea produced in India. Assam alone produces on an average of about 630 to 700 million kgs annually.

2.4 STUDY AT NALANI TEA ESTATE

In the present case study as well, in the Nalani Tea Estate which have a CCA of about 472 hectares, making it a prominent area of study. It's located at a latitude of 27.570710 and longitude of 95.328280. It contributes to cater the demand of people keeping the quality of the tea intact. Sprinkler irrigation is the mode of irrigation that is being currently used in the estate which has been designed based on the general thumb rule. However, we are going to design a sprinkler irrigation keeping in mind both the topography of the land, the cost effectiveness and the other criteria of design and would also conclude if the present sprinkler irrigation design is effective enough or not as per out findings.

Previously, in the early years of tea cultivation the irrigation facility was not provided. The needs of the pants were satisfied though rains itself and thus it could be said that the entire cultivation of tea was rain-fed. But with the increasing population and the international demands, the production of tea, its yield needs to be increased. The quality if the tea directly depends on the quality of its cultivation and hence the quality of its cultivation can't be compromised. With that being said, it has been noticed that the climate change has caused a significant reduction in rainfall which directly has started affecting the production and yield of the tea industries.

To mitigate the deficit of water during those months of low rainfall, hence irrigation facilities are being put to practice. Usually, two types of irrigation facilities are mainly recommended for tea cultivation, one is drip and the other is sprinkler irrigation. Based on cost effectiveness and topography of land, sprinkler irrigation is being mostly used.

The design of the sprinkler irrigation and its layout however should be site specific based on the topography, soil type and keeping in mind the other climatic conditions which tend to affect the water requirement of the tea plants.

CHAPTER 3

SPRINKLER IRRIGATION

3.1 INTRODUCTION

In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. With careful selection of nozzle sizes, operating pressure and sprinkler spacing the amount of irrigation water required to refill the crop root zone can be applied nearly uniform at the rate to suit the infiltration rate of soil.

3.2 ADVANTAGES OF SPRINKLER IRRIGATION:

(a) Elimination of the channels for conveyance, therefore no conveyance loss.
(b) Suitable to all types of soil except heavy clay.
(c) Suitable for irrigating crops where the plant population per unit area is very high.
(d) Water saving.
(e) Closer control of water application convenient for giving light and frequent irrigation.
(f) Higher water application efficiency.
(g) Increase in yield.
(h) Mobility of system.
(i) May also be used for undulating area.
(j) Saves land as no bunds etc. are required.
(k) Influences greater conducive micro-climate.
(l) Areas located at a higher elevation than the source can be irrigated.
(m) Possibility of using soluble fertilizers and chemicals.
(n) Less problem of clogging of sprinkler nozzles due to sediment laden water.

3.3 GENERAL CLASSIFICATION OF DIFFERENT TYPES OF SPRINKLER SYSTEMS

Sprinkler systems are classified into the following two major types on the basis of the arrangement for spraying irrigation water.

(a) Rotating head or revolving sprinkler system: Small size nozzles are placed on riser pipes fixed at uniform intervals along the length of the lateral pipe and the lateral pipes are usually laid on the ground surface. They may also be mounted on posts above the crop height and rotated through 90 0, to irrigate a rectangular strip. In rotating type sprinklers, the most common device to rotate the sprinkler heads is with a small hammer activated by the thrust of water striking against a vane connected to it.

Fig .3.1: *Example of a few rotating type sprinkler irrigation systems*

Source – Google images

(b) Perforated pipe system: This method consists of drilled holes or nozzles along their length through which water is sprayed under pressure. This system is usually designed for relatively low pressure (1 kg/cm2). The application rate ranges from 1.25 to 5 cm per hour for various pressure and spacing. This method consists of drilled holes or nozzles along their length through which water is sprayed under pressure. This system is usually designed for relatively low pressure (1 kg/cm2). The application rate ranges from 1.25 to 5 cm per hour for various pressure and spacing.

Based on the portability, sprinkler systems are classified into the following types:

(a) Portable system: A portable system has portable main lines, laterals and pumping plant.

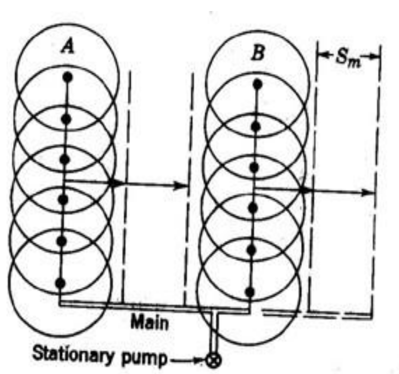

Fig .3.2: *Fully portable sprinkler irrigation system*

Source – Google images

(a) Semi portable system: A semi portable system is similar to a portable system except that the location of water source and pumping plant is fixed.

(b) Semi-permanent system: A semi-permanent system has portable lateral lines, permanent main lines and sub mains and a stationery water source and pumping plant.

(c) Solid set system: A solid set system has enough laterals to eliminate their movement. The laterals are positions in the field early in the crop season and remain for the season.

(d) Permanent system: A fully permanent system consists of permanently laid mains, sub mains and laterals and a stationery water source and pumping plant.

3.4 COMPONENTS OF SPRINKLER IRRIGATION SYSTEM

The components of portable sprinkler system are shown through fig .4. A sprinkler system usually consists of the following components:

(a) A pump unit

(b) Tubings- main/submains and laterals

(c) Couplers

(d) Sprinker head

(e) Other accessories such as valves, bends, plugs and risers.

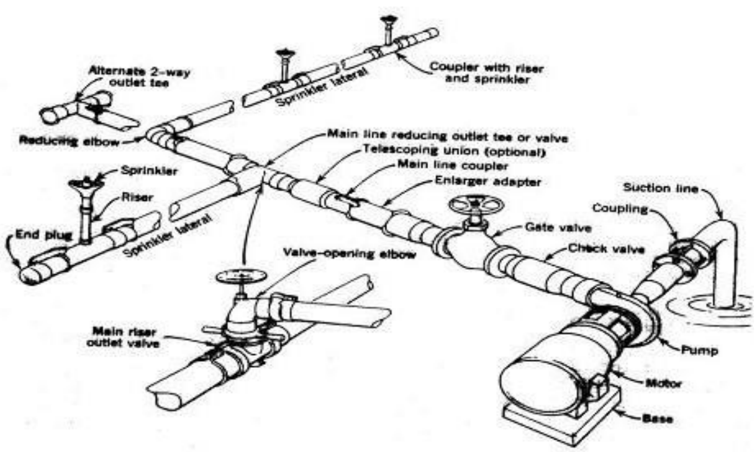

Fig. 3.3: *Component of a portable sprinkler irrigation system.*

Source – Google images

(a) Pumping Unit: Sprinkler irrigation systems distribute water by spraying it over the fields. The water is pumped under pressure to the fields. The pressure forces the water through sprinklers or through perforations or nozzles in pipelines and then forms a spray. A high speed centrifugal or turbine pump can be used for operating sprinkler irrigation for individual fields. Centrifugal pump is used when the distance from the pump inlet to the water surface is less than eight meters. For pumping water from deep wells or more than eight meters, a turbine pump is suggested. The driving unit may be either an electric motor or an internal combustion engine.

(b) Tubings: Mains/submains and laterals: The tubings consist of mainline, submains and laterals. Main line conveys water from the source and distributes it to the submains. The submains convey water to the laterals which in turn supply water to the sprinklers. Aluminum or PVC pipes are generally used for portable systems, while steel pipes are usually used for center-pivot laterals. Asbestos, cement, PVC and wrapped steel are usually used for buried laterals and main lines.

(c) Couplers: Couplers are used for connecting two pipes and uncoupling quickly and easily. Essentially a coupler should provide

(i) a reuse and flexible connection

(ii) not leak at the joint

(iii) be simple and easy to couple and uncouple

(iv) be light, non-corrosive, durable.

(d) Sprinkler head: The sprinkler head is responsible to distribute the water uniformly throughout the field without any loss of water through run off or deep percolation. There are mainly two types of sprinkler heads, one is fixed and another is rotating in nature. The rotating type can be adapted for a wide range of application rates and spacing. They are effective with pressure of about 10 to 70 m head at the sprinkler. Pressure between about 16-40 m are considered the most practical for farmers.

Fig 3.4: *Sprinkler head*

Source – Google images

(e) Fittings and accessories: The following are some of the important fittings and accessories used in sprinkler system.

(i) Water meters: It is used to measure the volume of water delivered. This is necessary to operate the system to give the required quantity of water.

(ii) Flange, couplings and nipple used for proper connection to the pump, suction and delivery.

(iii) Pressure gauge: It is necessary to know whether the sprinkler system is working with desired pressure to ensure application uniformity.

(iv) Bend, tees, reducers, elbows, hydrants, butterfly valve and plugs.

(v) Fertilizer applicator: Soluble chemical fertilizers can be injected into the sprinkler system and applied to the crop. The equipment for fertilizer application is relatively cheap and simple and can be fabricated locally. The fertilizer applicator consists of a seal.

3.5 GENERAL RULES FOR SPRINKLER SYSTEM DESIGN

(a) Main should be laid up and down hill.

(b) Lateral should be laid across the slope or nearly on the contour.

(c) For multiple lateral operation, lateral pipe sizes should not be more than two diameters.

(d) Water supply source should be nearest to the center of the area.

(e) Layout should facilitate and minimize lateral movement during the season.

(f) Booster pump should be considered where small portion of field would require high pressure at the pump.

(g) Layout should be modified to apply different rates and amounts of water where soils are greatly different in the design area.

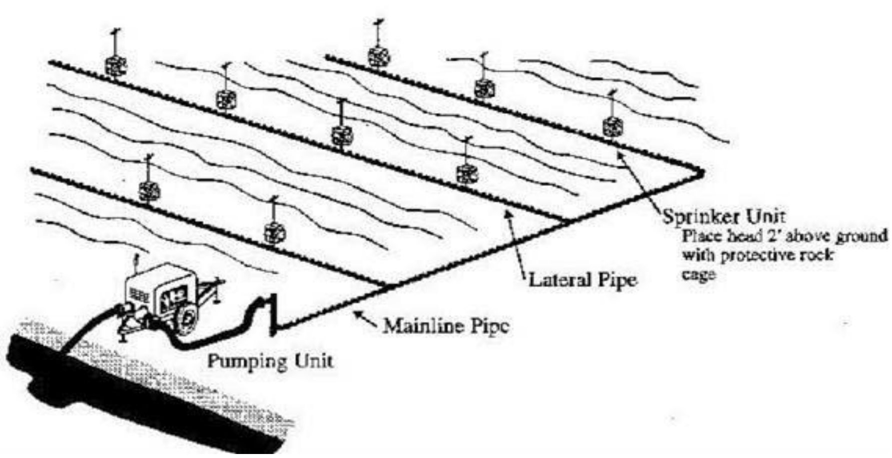

***Fig.3.5**: Layout of sprinkler irrigation system*

Source – Google images

3.6 SELECTING THE MOST APPROPRIATE SPRINKLER SYSTEMS

While selecting a sprinkler system, the most important physical parameters to considered are:

(a) The crop or crops to be cultivated.

(b) The shape and size (acres) of the field.

(c) The topography of the field.

(d) The amount of time and labor required to operate the system.

3.7 SELECTING SPRINKLER SYSTEM CAPACITY

A sprinkler system must be designed to apply water uniformly without runoff or erosion. The application rate of the sprinkler system must be matched to the infiltration rate of the most restrictive soil in the field. If the application rate exceeds the soil intake rate, the water will run-off the field or relocate within the field resulting in over and under watered areas. The sprinkler system capacity is the flow rate needed to adequately irrigate an area and is expressed in liters per minute per acre. The system capacity depends upon on the: Peak crop water requirements during the growing season; effective crop rooting depth; texture and infiltration rate of the soil; the available water holding capacity of the soil; pumping capacity of the well or wells (if wells are the water source).

3.8 CONSTRAINTS IN APPLICATION OF SPRINKLER IRRIGATION

(a) Uneven water distribution due to high winds

(b) Evaporation loss when operating under high temperatures

(c) Highly impermeable soils are not suitable

(d) Initial cost is high

(e) Proper design

(f) Lack of Package of practices

(g) Lack of awareness

(h) Lack of social concern to save natural resources

(i) High water pressure required in sprinkler (>2.5kg/cm^2)

(j) Difficulty in irrigation during wind in sprinkler

3.9 OPERATION OF SPRINKLER SYSTEMS

Proper design of a sprinkler system does not in itself ensure success. It should be ensured that the prime mover and the pump are in alignment, particularly in the case of tractor-driven pumps. For these the drive shaft as well as the pump shaft should lie at nearly the same height to prevent too great an angle on the universal shaft. While laying the main and lateral pipes, always begin laying at the pump. This necessarily gives the correct connection of all quick coupling pipes. While joining couplings, it is ensured that both the couplings and the rubber seal rings are clean.

In starting the sprinkler system, the motor or engine is started with the valves closed. The pump must attain the pressure stated on type-plate or otherwise there is a fault in the suction line. After the pump reaches the regulation pressure, the delivery valve is opened slowly. Similarly, the delivery valve is closed after stopping the power unit.

The pipes and sprinkler-lines are shifted as required after stopping. Dismantling of the installation takes place in the reverse order to the assembly described above.

3.10 MAINTENANCE OF SPRINKLER SYSTEMS

General principles regarding the maintenance of the pipes and fittings and sprinkler heads are given below:

(a) Pipes and fittings

The pipes and fittings require virtually no maintenance but attention must be given to the following procedures:

(i) Do not lay pipes on new damp concrete or on piles of fertilizer. Do not lay fertilizer sacks on the pipe.

(ii) Keep all nuts and bolts tight.

(b) Sprinkler heads

The sprinkler heads should be given the following attention:

(i) Do not apply oil, grease or any lubricant to the sprinklers. They are water lubricated using oil grease or any other lubricant may stop them from working.

(ii) Sprinklers usually have a sealed bearing and at the bottom of the bearing there are washers. Usually, it is the washers that wear and not the more expensive metal parts.

(iii) Check the washers for wear once a season or every six months which is especially important where water is sandy. Replace the washers if worn.

(iv) After several season's operation the swing arm spring may need tightening. This is done by pulling out the spring end at the top and rebending it. This will increase the spring tension.

In general, check all equipment at the end of the season and make any repairs and adjustments and order the spare parts immediately so that the equipment is in perfect condition to start in the next season.

3.11 STORAGE

The following points are to be observed while storing the sprinkler equipment during the off season:

(a) Remove the sprinklers and store in a cool, dry place.

(b) The pipes can be stored outdoors in which case they should be placed in racks with one end higher than the other. Do not store pipes along with fertilizer.

(c) Disconnect the suction and delivery pipe-work from the pump and pour in a small quantity of medium grade oil. Rotate the pump for a few minutes. Blank the suction and delivery branches. This will prevent the pump from rusting. Grease the shaft.

(d) Protect the electric motor from the ingress of dust, dampness and rodents. Check the washers for wear once a season or every six months which is especially important where water is sandy. Replace the washers if worn.

CHAPTER 4

THEORITICAL BACKGROUND ON SPRINKLER IRRIGATION SYSTEM

4.1 INTRODUCTION

In sprinkler irrigation system, the water is sprayed on to the field to provide irrigation system. The water that is sprayed is drawn out of the ground with the help of a pump, and then sprayed with the help of a sprinkler. The water is sprayed into the atmosphere with the help of a pressure and at an application rate which is lesser than or equal to the infiltration rate of the soil.

The water in order to be sprayed at the required rate needs to be drawn out of the source at a desired. To achieve this a suitable pump and sprinkler heads are selected. However, we need to design the system in such a way that the irrigation requirement is fulfilled.

4.2 DEFINATION OF IMPORTANT TERMS

Terms related to sprinkler irrigation system have been explained as follows:

4.2.1 Field Capacity

Field capacity refers to the maximum amount of water that soil can retain against the force of gravity after excess water has drained away. It is the point at which the soil is saturated, and any additional water infiltrating the soil will result in gravitational drainage. Field capacity is an important characteristic of soil that influences plant growth and irrigation practices.

When it rains or irrigation water is applied to soil, the water initially infiltrates the soil pores. As the infiltration continues, air is gradually displaced from the soil pores, and the soil becomes saturated. The rate at which water infiltrates the soil slows down until it reaches a point where the downward gravitational force equals the upward capillary force, causing the excess water to drain away. This is known as the field capacity of the soil.

Field capacity is typically expressed as a percentage of the soil's volume or weight. For example, a soil with a field capacity of 30% means that it can retain 30% of its volume or weight in water after excess water has drained away. The field capacity of soil depends on various factors, including soil texture, structure, organic matter content, compaction, and hydraulic conductivity.

Understanding the field capacity of soil is crucial for agricultural practices, as it helps determine the irrigation requirements of crops. By providing water to the soil up to its field capacity, farmers can ensure that plants have access to sufficient moisture for their growth and development without causing waterlogging or excessive drainage.

4.2.2 Water Holding Capacity

Water holding capacity refers to the ability of soil to retain water for plant use after excess water has drained away. It represents the maximum amount of water that soil can hold and make available to plants. The water holding capacity of soil is influenced by various factors, including soil texture, organic matter content, compaction, and structure.

Soil texture plays a significant role in determining water holding capacity. Fine-textured soils, such as clay soils, have smaller particles and more surface area, which enables them to hold more water compared to coarse-textured soils, such as sandy soils. Clay soils have high water holding capacity because the fine particles can hold water tightly between them. Sandy soils, on the other hand, have larger particles with larger gaps between them, resulting in lower water holding capacity.

Organic matter content is another crucial factor affecting water holding capacity. Soils rich in organic matter have higher water holding capacity due to the presence of humus, which acts like a sponge, holding onto water and releasing it slowly to plant roots.

Soil compaction can reduce water holding capacity by reducing pore spaces and restricting water movement. Compacted soils have decreased water-holding capacity as the tightly packed soil particles leave fewer spaces for water to be retained.

Soil structure also influences water holding capacity. Well-structured soils with good aggregation have more stable pore spaces, allowing for better water infiltration and retention. Poorly structured soils with compacted layers or weak aggregation may have reduced water holding capacity.

The measurement of water holding capacity is typically expressed as the amount of water held per unit volume of soil (e.g., millimeters of water per centimeter of soil depth or inches of water per foot of soil depth).

Understanding the water holding capacity of soil is essential for effective irrigation and water management in agriculture. It helps determine irrigation schedules, prevent overwatering or underwatering, and optimize water use for plant growth and productivity.

The difference of the moisture content between the field capacity and the permanent wilting point is known as the water holding capacity of the soil.

4.2.3 Depth of Irrigation

The depth of irrigation refers to the vertical extent to which water is applied to the soil during the process of irrigation. It represents the depth at which water penetrates into the soil profile to reach the plant's root zone. The appropriate depth of irrigation is crucial for ensuring that plants receive an adequate water supply for their growth and development.

The depth of irrigation can vary depending on several factors, including the crop type, stage of growth, soil characteristics, and climate conditions. Different crops have varying root depths, and the irrigation depth should be adjusted accordingly to ensure that water reaches the active root zone where plants can access it.

Ideally, irrigation should aim to wet the soil to a depth that matches the root zone of the crop being cultivated. This allows plant roots to efficiently extract water and nutrients from the soil. It is important to avoid shallow irrigation depths that only wet the surface soil layers, as this can lead to limited root development and increased susceptibility to drought stress. On the other hand, excessive irrigation depths that go beyond the root zone can result in water wastage, leaching of nutrients, and potentially waterlogging issues.

Determining the appropriate depth of irrigation requires understanding the soil's water holding capacity, the crop's water requirements, and the desired balance between deep watering and minimizing runoff. Factors such as soil texture, structure, and permeability influence how water moves vertically in the soil profile.

Techniques such as soil moisture monitoring, evapotranspiration-based scheduling, and understanding the specific needs of the crop being grown can help determine the optimal depth and frequency of irrigation. Efficient irrigation practices aim to minimize water loss through evaporation, runoff, and deep percolation while ensuring that the water applied reaches the plant's root zone effectively.

4.2.4 Wilting Point

The wilting point is a critical moisture threshold in soil where the available water content becomes so low that plants are unable to extract sufficient water to meet their transpiration demands. At the wilting point, plants wilt and show visible signs of water stress, such as drooping leaves and reduced growth.

When soil moisture drops below the wilting point, the remaining water becomes strongly bound to the soil particles, making it difficult for plant roots to extract. At this point, the soil water potential is usually very low, and the plant's ability to take up water is hindered.

The wilting point is influenced by several factors, including soil texture, organic matter content, and root characteristics. Soils with high clay content tend to have a higher wilting point because clay particles hold water more tightly and have a higher water-holding capacity. Sandy soils, on the other hand, typically have a lower wilting point due to their coarse texture and lower water-holding capacity.

The wilting point is an essential parameter in irrigation management and plant water requirements. It helps determine the timing and frequency of irrigation to ensure that plants do not experience prolonged water stress. Irrigation should be scheduled to replenish the soil moisture above the wilting point, allowing plants to maintain healthy growth and prevent yield losses.

It's worth noting that the wilting point is different for various plant species, and some plants are more tolerant of drought conditions than others. Additionally, the wilting point can vary depending on environmental factors such as temperature, humidity, and solar radiation, which influence plant transpiration rates.

Overall, understanding the wilting point is crucial for effective water management in agriculture, as it helps determine irrigation strategies, conserve water resources, and optimize plant productivity.

4.2.5 Consumptive Use of Water

Consumptive use of water refers to the total amount of water consumed or used by plants through evapotranspiration, which is the combined process of water loss through evaporation from the soil surface and transpiration from plant leaves. It represents the portion of water taken up by plants that is not available for other uses or does not return to the water source.

When plants undergo photosynthesis, they open tiny pores called stomata on their leaves, allowing water to evaporate from the plant surface and escape into the atmosphere. This process, known as transpiration, is essential for plant growth and the movement of water and nutrients from the roots to the leaves. Additionally, water evaporates directly from the soil surface into the air through the process of evaporation.

The consumptive use of water is influenced by various factors, including plant type, growth stage, climate, soil moisture availability, and environmental conditions. Different plant species have varying rates of transpiration and water requirements, leading to differences in their consumptive water use. Additionally, climatic factors such as temperature, humidity, wind speed, and solar radiation affect the rate of evapotranspiration.

The measurement and estimation of consumptive water use are important for water management, especially in agriculture. By quantifying the amount of water consumed by plants, farmers can optimize irrigation practices, schedule water deliveries, and ensure that plants receive adequate water for their growth while avoiding overwatering or water stress.

Techniques for estimating consumptive use of water include weather-based methods that utilize meteorological data, such as the Penman-Monteith equation, and crop-specific methods that consider factors like crop coefficient and reference evapotranspiration. These methods provide insights into the water requirements of crops and assist in making informed decisions regarding irrigation scheduling and a

the formula to determine evapotranspiration is as follows

$ET_c = ET_o \times K_c$

Where,

ET_c = Evapotranspiration.

ET_o= Evapotranspiration for reference crops.

K_c = Crop Co-efficient.

4.2.6. Methods of Computing ET_o

There are several methods for calculating reference evapotranspiration (ETo) along with their respective mathematical equations:

4.2.6.1 Penman-Monteith method:

$ET_o = (0.408 \times \Delta \times (R_n - G) + \gamma \times (900 / (T + 273)) \times u_2 \times (e_s – e_a)) / (\Delta + \gamma \times (1 + 0.34 \times u_2))$

This method considers various meteorological parameters, including temperature (T), relative humidity, wind speed (u_2), solar radiation (R_n), and atmospheric pressure. It also requires the calculation of the saturation vapor pressure (e_s), actual vapor pressure (e_a), slope of the saturation vapor pressure curve (Δ), and the psychrometric constant (γ).

4.2.6.2 Hargreaves-Samani method:

$ET_o = 0.0023 \times R_a \times (T_{max} - T_{min}) \times (0.5 \times (T_{mean} + 17.8))$ ^ 0.6

This method estimates ETo using temperature data only. It requires the average daily temperature (Tmean), maximum temperature (Tmax), and minimum temperature (Tmin). Ra represents the extraterrestrial radiation, which can be calculated based on latitude and day of the year.

4.2.6.3 Blaney-Criddle method:

ETo = (0.0123 × N × (Tmean + 17.8)) + b

This method estimates ETo using temperature and a potential evapotranspiration coefficient (b). The coefficient b is derived from historical data and represents the relationship between temperature and ETo. N is the number of days in the month.

4.2.6.4 Priestley-Taylor method:

ETo = $\alpha \times \Delta / \lambda \times$ (Rn - G)

In this method, ETo is estimated using the net radiation (Rn) and an empirical coefficient (α). The coefficient α is usually taken as 1.26 and Δ represents the slope of the vapor pressure curve. G is the soil heat flux density.

4.2.6.5 Pan evaporation method:

ETo = k × Ep

This method uses pan evaporation (Ep), which is the measured rate of water evaporation from a pan, and applies a conversion factor (k) to estimate ETo. The conversion factor k is specific to the pan type and location.

These are just a few examples of the methods available for estimating ETo. The choice of method depends on the available data, level of accuracy required, and the specific context or application.

4.2.7 Maximum Application Rate

Sprinkler irrigation involves the use of overhead sprinklers that spray water over the crop or soil surface, simulating natural rainfall. The maximum application rate is crucial to ensure that the water applied by the sprinkler system can be effectively absorbed by the soil, preventing water loss and promoting efficient water distribution to the crop root zone.

Several factors influence the determination of the maximum application rate for sprinkler irrigation, including soil characteristics, infiltration rate, sprinkler design, nozzle size, and operating pressure. Here are some key considerations:

Soil infiltration rate: The soil's ability to absorb water plays a crucial role in determining the maximum application rate. Soils with high infiltration rates can accept water at a faster rate, allowing for higher application rates. However, soils with low infiltration rates require slower application rates to prevent runoff.

Sprinkler design and nozzle size: The design of the sprinkler system, including the nozzle size and spray pattern, affects the application rate. Different sprinklers have varying flow rates, and the nozzle size determines the rate at which water is distributed. It is important to select sprinklers and nozzles that match the desired application rate.

Operating pressure: The operating pressure of the sprinkler system affects the distribution pattern and intensity of water application. Higher pressures may result in finer droplets and faster application rates, while lower pressures may lead to larger droplets and slower application rates.

To determine the maximum application rate for sprinkler irrigation, it is recommended to consider the soil's infiltration characteristics, the sprinkler system's design and operating conditions, and the crop's water requirements. Field trials, soil moisture monitoring, and irrigation scheduling techniques can help determine the optimal application rate to ensure effective water penetration, minimize runoff, and avoid water wastage.

Adhering to the maximum application rate for sprinkler irrigation promotes efficient water use, reduces the risk of soil erosion and runoff, and helps maintain uniform moisture distribution across the irrigated area, supporting optimal crop growth and productivity.

4.2.8 Potential Evapotranspiration

The maximum application rate for sprinkler irrigation refers to the highest rate at which water can be applied to a specific area using sprinkler irrigation systems without causing detrimental effects such as surface runoff, soil erosion, or inefficient water distribution.

Potential evapotranspiration (PET) refers to the theoretical or estimated amount of water that could potentially be evaporated and transpired by a well-watered and actively growing reference crop under specific climatic conditions. It represents the evaporative demand of the atmosphere and is primarily influenced by meteorological factors such as temperature, solar radiation, humidity, wind speed, and atmospheric pressure.

Potential evapotranspiration is a crucial parameter in agricultural and water management practices as it helps estimate the water requirements of crops and provides a baseline for irrigation scheduling. By understanding the potential evapotranspiration, farmers and irrigation planners can determine the amount of water that needs to be supplied to the crops to meet their water demands and avoid water stress.

There are various methods to estimate potential evapotranspiration, with the Penman-Monteith equation being one of the most widely used and recommended. This equation takes into account multiple meteorological parameters and crop-specific factors to calculate potential evapotranspiration accurately.

It's important to note that potential evapotranspiration is a theoretical concept and represents the maximum possible water loss from a well-watered reference crop. Actual evapotranspiration (ETa) for specific crops can be different and is influenced by factors such as crop type, growth stage, soil moisture, and management practices. The crop coefficient (Kc) approach is often used to adjust the potential evapotranspiration values to estimate actual evapotranspiration for specific crops under different growth stages.

4.2.9 Distribution Pattern of Sprinkler Irrigation System

The distribution pattern is influenced by various factors, including the design of the sprinkler system, nozzle type, operating pressure, spacing between sprinklers, and the characteristics of the water being applied. The objective is to achieve a uniform and even distribution of water across the entire irrigated area to ensure consistent moisture levels for optimal crop growth.

A well-designed sprinkler system should strive for a uniform distribution pattern to avoid over-watering or under-watering certain areas within the irrigation zone. A uniformly distributed water pattern helps maintain a balanced soil moisture profile, prevents localized water stress or waterlogging, and promotes even crop growth and yield.

4.2.9.1 Common distribution patterns of sprinklers include:

Full circle or 360-degree pattern: In this pattern, water is sprayed in a complete circular shape, covering the area around the sprinkler head in all directions. It is often used for small to medium-sized areas or in cases where complete coverage is desired.

4.2.9.1.1 Part circle or sector pattern:

Water is sprayed in a specific sector or arc angle, covering a portion of the area. Part circle patterns are commonly used for larger areas where multiple sprinklers are spaced apart, allowing for overlapping coverage.

4.2.9.1.2. Rectangular pattern:

Sprinklers are positioned in a rectangular layout, providing water distribution in a rectangular shape. This pattern is suitable for long and narrow fields or areas with a specific shape.

Irregular or custom-shaped pattern: In some cases, sprinklers are designed or positioned to provide a custom-shaped water distribution pattern tailored to the specific field shape or crop requirements.

It's important to consider the characteristics of the distribution pattern when designing a sprinkler irrigation system. Uniformity of water distribution can be influenced by factors such as nozzle selection, spacing between sprinklers, operating pressure, and proper maintenance of the system to prevent clogging or malfunctioning. Regular monitoring and adjustment of the sprinkler system can help ensure that the desired distribution pattern is achieved and maintained for efficient water use and optimal crop performance.

The irrigation efficiency of the sprinklers depends on the uniformity of the water application. The water spray characteristics and the spacing between the sprinklers regulate the uniformity of the water application in sprinkler irrigation system. The spray distribution characteristics of the sprinklers depend on the pressure with which the sprinklers work and also the size of the nozzles. When sprinkler head pushes water out with very high operating pressure, the water droplets break out into smaller crystals and falls down very near to the sprinkler. On the other hand, when the water is pushed out of the nozzle at a comparatively lower pressure, the water falls in a ring away from the sprinklers

***4**.2.10 Selection of Sprinkler Head*

The selection of sprinkler heads refers to the process of choosing the appropriate type and characteristics of sprinkler heads for a specific irrigation system based on factors such as water requirements, area size, soil type, and desired distribution pattern. Selecting the right sprinkler heads is crucial for achieving efficient and effective irrigation, ensuring uniform water distribution, and optimizing water use.

4.2.11. Factors to be considered in selecting sprinkler heads:

- Water requirements: Different crops have varying water requirements, and sprinkler heads should be selected based on the specific crop's needs. Consider factors such as the crop's growth stage, root depth, and evapotranspiration rates to determine the appropriate precipitation rate and application uniformity required.
- Area size and shape: The size and shape of the area to be irrigated influence the selection of sprinkler heads. Larger areas may require sprinklers with longer throw distances or higher flow rates, while smaller areas may need sprinklers with shorter throw distances.
- Soil type and infiltration rate: The soil's infiltration characteristics affect how quickly it can absorb water. Sandy soils, for example, may require sprinklers with lower precipitation rates to prevent runoff, while clay soils may benefit from sprinklers with higher precipitation rates to ensure adequate water penetration.
- Distribution pattern: Consider the desired distribution pattern for the area to be irrigated. Some sprinkler heads provide full-circle coverage, while others offer part-circle or adjustable patterns to match the shape of the field or specific irrigation requirements.
- Operating pressure: Sprinkler heads have different pressure requirements for optimal performance. Ensure that the selected sprinkler heads match the available operating pressure of the irrigation system to achieve the desired distribution pattern and water distribution uniformity.
- Efficiency and conservation: Select sprinkler heads that are designed for efficient water use, such as those with pressure regulation, low precipitation rates, or built-in mechanisms to minimize wind drift. These features help reduce water waste and improve irrigation efficiency.

4.2.12 Sprinkler Spacing

Sprinkler spacing refers to the distance between individual sprinkler heads within an irrigation system. It is an important design parameter that determines the arrangement and layout of sprinklers across an irrigated area. The spacing between sprinklers influences the uniformity of water distribution, coverage efficiency, and overall effectiveness of the irrigation system.

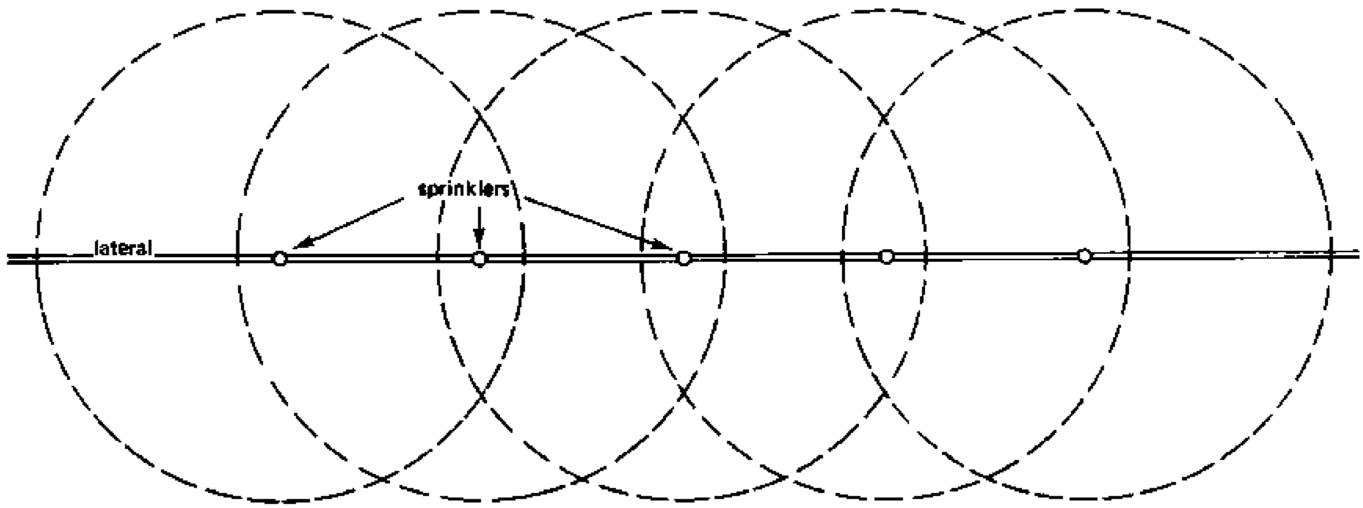

Fig 4.1: *Overlapping wetting patterns of Sprinklers*

Source – Google images

4.3 Design Steps

The design of sprinkler irrigation system is unique for each site. The design specification is unique to its own location and thus has to be done very specifically based on the demand at site. A step-by-step procedure throughout the designing process is as follows.

Step 1:

A thorough study of the location is necessary. This topographic study will include the topographical features, the drainage system, water supply, the power source, the climatic information on climate, temperature, rainfall etc. will be gathered

a) Topographic Features: The size, shape, and other topographical features should be known so as to properly design the irrigation system

b) Climatic Data: the temperature, sunshine hours, humidity, wind velocity, data, radiation etc. should be calculated because these data will be required by the software to determine the water required for evapotranspiration. Using these data, the consumptive use of water will be determined.

c) Water Supply: The source of water has to be decided upon before selecting the layout of the sprinkler irrigation system. The source should be sufficient to meet the demand of the water and ideally is placed at the highest elevation.

d) Properties of the Soil: The properties of the soil as in the infiltration rate of the soil, the field capacity, the moisture content of the soil, the soil type etc. should be knows. These data are required by the software to compute the water requirement of the soil.

e) Source of Power: The sprinkler irrigation system requires a high-capacity source of power to usually operate. The use of electric pump or diesel pump both is possible depending upon the cost, availability and suitability. For stationery pump, the use of electric pump is mostly suitable is the cost and source of power is readily available.

Step 2

Determination of depth of irrigation:

The depth of irrigation in this case have been determine with the help of CROPWAT 8.0 software. The details have been discussed later.

Step 3

Studying the contour map and deciding on the layout design of the sprinkler irrigation system. The layout needs to be designed keeping in mind the guidelines that has already been discussed earlier.

Step 4

Selecting the sprinkler head. A proper sprinkler head needs to be selected. Sprinkler heads come along with specifications which mention the pressure at which it is going to sprinkle the water out of the nozzle, the wetting diameter, and the flow of water that the head is capable of providing. This thus becomes an important step because based on this the layout of the sprinklers will be decided.

Step 5

Calculation of the number of sprinklers that will be required to irrigate the entire filed. This calculation needs to be done by making sure that the overlapping of the wetting area of the sprinklers is considered. Each sprinkler head comes with a specification of its wetting diameter. Now for a proper irrigation design it is necessary to consider overlapping of the diameters so make sure no area remains un-irrigated.

By deciding on the required type of sprinkler head, we can calculate the number of laterals that needs to be laid.

Step 6

The number of laterals that need to be placed is then calculated based on sprinkler spacing.

Step 7

The total capacity of the system is then calculated in terms of Discharge or Flow.

Discharge = (flow through each sprinkler) × Number of sprinklers

Step 8

Hydraulic Design of Mains and Laterals is done. The water or the flow that is required to be provided through the pipes is calculated. Since the entire flow through the system is known, the total amount of flow can be easily divided equally to the number of mains and then the number of laterals.

$$\boldsymbol{Flow\ through\ one\ main\ or\ lateral\ line = \frac{Discharge\ through\ the\ entire\ system}{Total\ number\ of\ mains\ or\ laterals}}$$

Once we know the flow through one main / lateral line we can easily find out the diameters. During the design of sprinkler irrigation system, it has to be kept in mind that as per Bureau of India Standards (BIS) IS12232:1987 "Code of practice for design and installation of overhead irrigation systems using sprayers and nozzles" the maximum velocity in pipe for sprinkler irrigation design should not exceed 3.0 m/s. This limit is based on the consideration of avoiding water hammering effect and ensuring the stable operation of the system.

The diameter of the pipe that will be required for the flow of the required given water with a maximum average velocity of 3 m/s can thus be calculated with the help of Continuity Equation:

Discharge = Velocity × Area

Step 9

Designing the capacity of the Pumps. Calculating the capacity of the pump that will be required for irrigation. That ca be done with the help of the following formula

$$\mathbf{Power} = \boldsymbol{\frac{Flow \times Total\ Dynamic\ Head}{3960 \times Efficiency}}$$

Where,

Power is in Horse power

Flow in GPM (Gallons per Minute)

Total dynamic head in Foot

Total Dynamic Head can be calculated with the following mathematical formula,

Total Dynamic Head, $H_{t} = H_{n} + H_{m} + H_{j} + H_{s}$

Where,

H_{t} = Total design head against the pump in working.

H_{n} = Maximum head required at the main to operate the sprinklers on the lateral at the required average pressure including riser height.

H_{m}= Maximum friction loss in the main and in the suction line.

H_{j} = Elevation difference between the pump and junction of the lateral and the main

H_{s}= Suction head which is the elevation difference between the pump and the source of the water after drawdown

CHAPTER 5

CASE STUDY AT NALANI TEA ESTATE

5.1 INTRODUCTION

The study is done at a tea estate in Tinsukia known as Nalani Tea Estate which is owned by Jokai Group. The location of the tea estate is at Guijan. The tea estate is mainly supported by the rains all around the year for production. During the months of November to February which is the dormant state of the year the production of the tea estate is low. The lesser production can be because of various reasons which includes lesser rain, low temperatures and the naturally dormant stage the tea plants tend to enter. However, the production no matter what can be increased with the increase in water supply if the production is somewhat being affected due to lack of rainfall.

To check if the tea production of the estate is being affected by the lack of rain a thorough study is to be carried out to find the moisture requirements. To find out if the tea estate requires moisture additionally supplied to it, we need to gather some on filed data from the estate and use it in CROPWAT 8.0 software.

5.2. INTRODUCTION TO CROPWAT 8.0

CROPWAT 8.0 is a computer-based software program developed by the Food and Agriculture Organization of the United Nations (FAO). It is a widely used tool for assessing crop water requirements and irrigation scheduling. CROPWAT stands for "CROP WATer use and production model."

CROPWAT 8.0 assists agricultural professionals, researchers, and irrigation planners in estimating the water requirements of different crops, determining irrigation schedules, and optimizing water management practices. It helps in making informed decisions related to irrigation planning, water allocation, and resource management.

5.3 WORKING OF CROPWAT 8.0

The software utilizes various climatic, soil, and crop data to calculate key parameters such as reference evapotranspiration (ETo) and crop water requirements (ETc). ETo represents the amount of water lost from a reference crop through evaporation and transpiration under standard climatic conditions. ETc, on the other hand, represents the crop's actual water requirements, which are influenced by factors such as crop type, growth stage, climate, and soil conditions.

CROPWAT 8.0 incorporates multiple methods to estimate ETo, including the Penman-Monteith method, which is widely recognized as one of the most accurate methods for calculating evapotranspiration. The software also considers factors such as crop coefficients (Kc), which represent the crop's water consumption at different growth stages.

By inputting relevant data such as weather data, crop information, soil characteristics, and irrigation system parameters, CROPWAT 8.0 provides detailed outputs and recommendations for irrigation scheduling, including the amount and timing of water application.

The software offers a user-friendly interface and provides graphical representations, reports, and tables to facilitate data interpretation and decision-making. It can be used for a wide range of crops and irrigation systems in different regions worldwide.

CROPWAT 8.0 is a valuable tool in agricultural water management, helping users optimize irrigation practices, improve water use efficiency, and enhance crop production while minimizing water stress and environmental impacts. It is widely used by irrigation professionals, agricultural researchers, water resource managers, and policymakers to promote sustainable water management in agriculture.

5.4. DATA RECEIVED FROM THE TEA ESTATE

A variety of data has been received from the field to make the CROPWAT 8.0 work. The software requires a variety of data for it to give an accurate result. Some data have been received from the Tea Estate and some data required field tests to be done. The following are the list of data that have been received from the Tea Estate:

a) Rainfall data

b) Temperature (Minimum and Maximum)

c) Yield Data

5.4.1 Rainfall Data:

Rainfall data plays a crucial role in agricultural planning and management, and tools like CROPWAT 8.0

rely on accurate and reliable rainfall data for their analysis. CROPWAT 8.0 is a widely used software developed by the Food and Agriculture Organization (FAO) that helps assess crop water requirements and irrigation scheduling. This software utilizes rainfall data to estimate the amount of water needed by crops, taking into account various factors such as crop type, growth stage, soil properties, and climate conditions. By inputting reliable rainfall data into CROPWAT 8.0, farmers, agronomists, and water managers can obtain valuable insights into the irrigation needs of specific crops, helping optimize water use, irrigation scheduling, and crop yield. Moreover, CROPWAT 8.0 can also analyze long-term rainfall patterns to assess the impact of climate change on crop water requirements, allowing for better adaptation and resilience in agricultural practices. Accurate rainfall data is therefore essential for the effective utilization of CROPWAT 8.0 and other similar tools in supporting sustainable and efficient water management in agriculture.

Table No. 5.1: *Average Rainfall data obtained from the field*

Sl. No.	Months	Rainfall data (mm)
1	January	0.9
2	February	1.9
3	March	2.9
4	April	6.2
5	May	10.1
6	June	15.7
7	July	16.8
8	August	12.7
9	September	8.1
10	October	4.5
11	November	1.2
12	December	0.4

5.4.2 Data of Temperature, Humidity, Wind and Sun:

Temperature, rainfall, wind speed, and humidity are essential meteorological parameters that significantly influence crop growth and water requirements. CROPWAT 8.0, a widely used software developed by the

Food and Agriculture Organization (FAO), takes into account these factors to estimate crop water requirements and aid in irrigation scheduling.

Temperature affects crop development, evapotranspiration rates, and water demand. CROPWAT 8.0 incorporates temperature data to calculate reference evapotranspiration (ET0), which represents the evaporative demand of the atmosphere. ET0 serves as a basis for determining crop water requirements.

Rainfall data is critical for assessing the water supply component of crop water requirements. CROPWAT 8.0 incorporates historical or observed rainfall data to calculate effective rainfall, which is the portion of rainfall that contributes to soil moisture and reduces the need for irrigation.

Wind speed affects crop water requirements by increasing evapotranspiration through enhanced evaporation rates. CROPWAT 8.0 utilizes wind speed data to estimate crop water needs accurately, considering the evaporative losses due to wind.

Humidity influences evapotranspiration rates, as high humidity reduces the evaporative demand of the atmosphere. CROPWAT 8.0 incorporates humidity data to adjust ET0 calculations, ensuring more accurate estimations of crop water requirements.

By integrating temperature, rainfall, wind speed, and humidity data, CROPWAT 8.0 provides valuable insights into crop water needs, helping farmers, agronomists, and water managers optimize irrigation scheduling and water use efficiency. These parameters are crucial inputs for the software, enabling informed decision-making and supporting sustainable agricultural practices.

Table No. 5.2: *Data of temperature, humidity, wind speed and Sunshine hours*

Sl. No.	Months	Temperature (Min) (‘C)	Temperature (Max) (‘C)	Humidity (%)	Wind (Km/day)	Sunshine (hours)
1	January	11	24	61	211.20	10.86
2	February	14	27	56	225.60	11.47
3	March	17	31	52	247.20	12.24
4	April	20	33	57	259.20	13.05
5	May	23	35	63	240.00	13.74
6	June	25	35	72	235.20	14.11
7	July	25	35	76	240.00	13.78
8	August	26	36	74	232.80	13.32

9	September	24	35	74	218.40	12.57
10	October	21	33	69	211.20	11.87
11	November	16	30	64	206.40	11.02
12	December	13	25	64	208.80	10.96

5.4.3 Yield Data

Yield data refers to the quantitative measurements or records that reflect the productivity of agricultural crops within a specific area. It provides information about the amount of crop harvested per unit of land, usually expressed as a yield per hectare or per acre. Yield data takes into account various factors such as climatic conditions, soil characteristics, crop varieties, and management practices. It serves as a crucial indicator of crop performance and productivity, allowing farmers, researchers, and policymakers to assess the effectiveness of different agricultural techniques, monitor trends over time, and make informed decisions regarding crop planning, resource allocation, and agricultural sustainability.

Table No. 5.3: *Yield Data*

Sl. No.	Months	Yield (Kg)
1	January	1
2	February	1
3	March	142
4	April	145
5	May	190
6	June	73
7	July	189
8	August	334
9	September	211
10	October	206
11	November	180
12	December	86

5.5. LABORATORY TESTS DONE FOR THE CASE STUDY

5.5.1 Field Capacity Test

The field capacity of soil is the amount of water held by the soil after excess water has drained away and the soil has reached an equilibrium state under the influence of gravity. It can also be defined as the maximum amount of water that soil can retain after excess water has drained away under the influence of gravity. It represents the moisture content at which soil pores are filled with water, and gravity has removed the excess water. At field capacity, the soil is considered to be adequately wet for plant growth, and it provides plants with the necessary water for root uptake.

The importance of field capacity lies in its role in determining irrigation practices and plant water availability. To find the field capacity of soil, you can follow these steps:

I. Wetting the soil: Water the soil thoroughly to ensure that it is uniformly wetted to a depth of at least 30 cm (12 inches).

II. Allowing drainage: Allow the soil to drain for a period of 24-48 hours, or until no more water drains from the soil.

III. Sampling soil: Take soil samples using a soil auger or a soil corer, from different parts of the field to ensure representative sampling.

IV. Weighing soil: Weigh the soil samples and record the weight.

V. Oven drying the soil: Dry the soil samples in an oven at a temperature of 105-110 °C (221-230 °F) until they reach a constant weight. This usually takes 24-48 hours.

VI. Weighing dry soil: Weigh the dry soil samples and record the weight.

VII. Calculating water content: Subtract the dry weight of the soil from the wet weight of the soil to determine the amount of water in the soil.

VIII. Calculating field capacity: The field capacity is the amount of water held in the soil after excess water has drained away. It is typically around 50% of the soil's water holding capacity.

5.5.1.1 Laboratory Test Results for Field Capacity

The laboratory test of the following soil samples have been done. The results of which is shown as

Table No. 5.4: *Laboratory test results of field capacity for sample 1 and 2*

Sample Number	Trial Number	Weight of Container and Soil (grams)	Weight of Container and Dry Soil (grams)	Weight of Water (grams)	Weight of Dry soil (grams)	Moisture Content (%)
1	1	50	45.50	4.50	22.50	20.00
1	2	50	45.00	5.00	22.00	22.73
1	3	50	45.32	4.68	22.32	20.97
Sample Number	Trial Number	Weight of Container and Soil (grams)	Weight of Container and Dry Soil (grams)	Weight of Water (grams)	Weight of Dry Soil (grams)	Moisture Content (%)
2	1	50	45.23	4.77	22.23	21.50
2	2	50	45.27	4.73	22.27	21.20
2	3	50	45.32	4.68	22.32	20.96

Table No. 5.5: *Laboratory test results of field capacity for sample 3*

Sample Number	Trial Number	Weight of Container and Soil (grams)	Weight of Container and Dry Soil (grams)	Weight of Water (grams)	Weight of Dry Soil (grams)	Moisture Content (%)
3	1	50	45.35	4.65	22.35	20.80
3	2	50	45.22	4.78	22.22	21.52
3	3	50	45.24	4.76	22.24	21.43

The field capacity from the first sample is 21.23%

The field capacity from the second sample is 21.22%

The field capacity from the third sample is 21.25%

On an average the final field capacity can be written as 21.23%

5.5.2 Infiltration Rate Test

The double-ring infiltrometer test is a widely used method to measure the infiltration rate of water into the soil. It involves the use of two concentric rings, an outer ring and an inner ring, which are inserted into the soil surface. Here is the general process for conducting a double-ring infiltrometer test:

a) Site Selection: Choose a representative area that represents the soil conditions you wish to measure. Ensure that the soil is relatively homogenous and free from surface obstructions.

b) Equipment Setup: Place the larger outer ring (typically 60-90 cm in diameter) on the soil surface and gently press it into the ground until it is firmly embedded. The ring should have an open bottom to allow water to infiltrate. Next, insert the smaller inner ring (typically 30-45 cm in diameter) into the center of the outer ring, leaving a space between the two rings.

c) Water Application: Fill the space between the inner and outer rings with water, making sure to maintain a constant water level throughout the test. The water level should be kept above the soil surface but below the top of the rings.

d) Measurement of Water Level: Measure and record the starting water level in the inner ring. Use a ruler or measuring tape to measure the distance between the water level and the soil surface. This initial measurement is typically taken as soon as the water is poured into the rings.

e) Time and Measurement Intervals: Start a timer or stopwatch to record the time. Measure and record the water level in the inner ring at regular intervals, such as every minute or every five minutes, depending on the expected infiltration rate and the duration of the test.

f) Calculation: Calculate the infiltration rate by dividing the volume of water added to the inner ring by the time taken for the water level to drop a certain distance. The most common calculation is to determine the infiltration rate in terms of centimeters per hour (cm/hr).

g) Repeat and Average: To ensure accuracy, conduct multiple tests at different locations within the study area and average the results to obtain a representative infiltration rate.

Table No. 5.6: *Double Ring Infiltrometer Test Results*

Measurement	Time Interval (minutes)	Infiltration Rate (inches)	Infiltration Rate (mm/day)
1	15	0.032	80.000
2	30	0.098	120.00
3	45	0.194	160.00
4	60	0.210	140.00
5	75	0.147	80.000
6	90	0.177	80.000

The average infiltration rate from the soil from the double ring infiltrometer test is = 110 mm/day.

CHAPTER 6

SPRINKLER IRRIGATION SYSTEM AT NALANI TEA ESTATE

6.1 IRRIGATION REQUIREMENT AND SCHEDULING AS OBTAINED FROM CROPWAT 8.0

Keeping in mind all the data that has been achieved from the tea estate and the laboratory tests, the data then have been used in the CROPWAT 8.0 software to determine the irrigation requirement if any. And if there is an irrigation requirement then, it is by how much and what should be its scheduling.

CROP IRRIGATION SCHEDULE

ETo station: guijan   Crop: tea   Planting date: 09-03-1994
Rain station: guijan   Soil: silty caly loam soil   Harvest date: 05-03-1995

Yield red.: 0.0 %

Crop scheduling options
Timing: Irrigate at 30 % depletion
Application: Refill to 100 % of field capacity
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
9 Mar	1	Init	0.0	1.00	100	12	4.3	0.0	0.0	6.2	0.71
10 Mar	2	Init	0.0	1.00	100	11	4.3	0.0	0.0	6.2	0.71
13 Mar	5	Init	0.5	1.00	100	13	4.9	0.0	0.0	7.0	0.27
16 Mar	8	Init	0.0	1.00	100	13	5.3	0.0	0.0	7.6	0.29
19 Mar	11	Init	0.0	1.00	100	13	5.3	0.0	0.0	7.6	0.29
22 Mar	14	Init	0.0	1.00	100	13	5.5	0.0	0.0	7.9	0.30
25 Mar	17	Init	0.0	1.00	100	13	5.6	0.0	0.0	8.0	0.31
28 Mar	20	Init	0.0	1.00	100	11	5.0	0.0	0.0	7.1	0.27
31 Mar	23	Init	0.0	1.00	100	12	5.6	0.0	0.0	8.0	0.31
3 Apr	26	Init	0.9	1.00	100	11	5.1	0.0	0.0	7.3	0.28
6 Apr	29	Init	0.0	1.00	100	12	6.0	0.0	0.0	8.5	0.33
9 Apr	32	Dev	0.0	1.00	100	12	6.0	0.0	0.0	8.5	0.33
12 Apr	35	Dev	0.0	1.00	100	13	6.5	0.0	0.0	9.3	0.36
15 Apr	38	Dev	0.0	1.00	100	13	6.8	0.0	0.0	9.7	0.37
19 Apr	42	Dev	0.0	1.00	100	15	8.0	0.0	0.0	11.5	0.33
22 Apr	45	Dev	0.0	1.00	100	13	7.4	0.0	0.0	10.5	0.41
25 Apr	48	Dev	0.0	1.00	100	13	7.7	0.0	0.0	11.0	0.42
29 Apr	52	Dev	0.0	1.00	100	15	9.0	0.0	0.0	12.8	0.37
2 May	55	Dev	0.0	1.00	100	14	8.3	0.0	0.0	11.8	0.46
5 May	58	Dev	0.0	1.00	100	14	8.6	0.0	0.0	12.2	0.47
9 May	62	Dev	0.0	1.00	100	16	10.0	0.0	0.0	14.3	0.41
12 May	65	Dev	0.0	1.00	100	14	9.2	0.0	0.0	13.1	0.51
15 May	68	Dev	0.0	1.00	100	14	9.5	0.0	0.0	13.6	0.52
19 May	72	Dev	0.0	1.00	100	16	11.0	0.0	0.0	15.7	0.46
22 May	75	Dev	0.0	1.00	100	14	10.0	0.0	0.0	14.3	0.55
25 May	78	Dev	0.0	1.00	100	15	10.2	0.0	0.0	14.6	0.56
29 May	82	Dev	0.0	1.00	100	16	11.7	0.0	0.0	16.7	0.48
1 Jun	85	Dev	0.0	1.00	100	14	10.5	0.0	0.0	15.0	0.58
5 Jun	89	Dev	0.0	1.00	100	16	12.3	0.0	0.0	17.5	0.51
9 Jun	93	Dev	0.0	1.00	100	16	12.3	0.0	0.0	17.5	0.51
13 Jun	97	Dev	2.7	1.00	100	16	12.6	0.0	0.0	18.0	0.52
17 Jun	101	Dev	2.7	1.00	100	16	12.8	0.0	0.0	18.3	0.53
21 Jun	105	Dev	0.0	1.00	100	19	15.7	0.0	0.0	22.5	0.65
25 Jun	109	Dev	0.0	1.00	100	16	13.6	0.0	0.0	19.4	0.56
30 Jun	114	Dev	0.0	1.00	100	21	17.7	0.0	0.0	25.2	0.58
5 Jul	119	Dev	0.0	1.00	100	21	18.4	0.0	0.0	26.2	0.61
10 Jul	124	Mid	0.0	1.00	100	21	18.4	0.0	0.0	26.2	0.61
15 Jul	129	Mid	0.0	1.00	100	21	18.1	0.0	0.0	25.9	0.60
20 Jul	134	Mid	0.0	1.00	100	21	18.1	0.0	0.0	25.9	0.60
25 Jul	139	Mid	0.0	1.00	100	21	18.3	0.0	0.0	26.2	0.61
30 Jul	144	Mid	0.0	1.00	100	21	18.3	0.0	0.0	26.2	0.61
4 Aug	149	Mid	0.0	1.00	100	21	18.6	0.0	0.0	26.5	0.61
9 Aug	154	Mid	0.0	1.00	100	21	18.6	0.0	0.0	26.5	0.61

Fig 6.1: *Crop Irrigation Schedule*

13 Aug	158	Mid	2.1	1.00	100	17	14.6	0.0	0.0	20.8	0.60
17 Aug	162	Mid	2.1	1.00	100	17	14.6	0.0	0.0	20.8	0.60
21 Aug	166	Mid	0.0	1.00	100	19	16.5	0.0	0.0	23.6	0.68
26 Aug	171	Mid	0.0	1.00	100	21	18.2	0.0	0.0	25.9	0.60
30 Aug	175	Mid	0.0	1.00	100	18	16.0	0.0	0.0	22.9	0.66
4 Sep	180	Mid	0.0	1.00	100	20	17.7	0.0	0.0	25.3	0.59
9 Sep	185	Mid	0.0	1.00	100	20	17.6	0.0	0.0	25.1	0.58
14 Sep	190	Mid	0.0	1.00	100	19	17.2	0.0	0.0	24.5	0.57
19 Sep	195	Mid	0.0	1.00	100	19	17.0	0.0	0.0	24.3	0.56
24 Sep	200	Mid	0.0	1.00	100	19	16.4	0.0	0.0	23.4	0.54
29 Sep	205	Mid	0.0	1.00	100	18	16.2	0.0	0.0	23.1	0.54
4 Oct	210	Mid	0.0	1.00	100	18	15.6	0.0	0.0	22.3	0.52
9 Oct	215	Mid	0.0	1.00	100	18	15.4	0.0	0.0	22.0	0.51
14 Oct	220	Mid	0.0	1.00	100	17	14.8	0.0	0.0	21.2	0.49
19 Oct	225	Mid	0.0	1.00	100	17	14.6	0.0	0.0	20.9	0.48
25 Oct	231	Mid	0.0	1.00	100	19	16.8	0.0	0.0	24.0	0.46
31 Oct	237	Mid	0.0	1.00	100	19	16.6	0.0	0.0	23.7	0.46
5 Nov	242	End	0.0	1.00	100	19	16.9	0.0	0.0	24.1	0.56
10 Nov	247	End	0.0	1.00	100	19	16.9	0.0	0.0	24.1	0.56
15 Nov	252	End	0.0	1.00	100	18	16.1	0.0	0.0	23.1	0.53
20 Nov	257	End	0.0	1.00	100	18	16.1	0.0	0.0	23.1	0.53
26 Nov	263	End	0.0	1.00	100	21	18.0	0.0	0.0	25.8	0.50
2 Dec	269	End	0.0	1.00	100	20	17.6	0.0	0.0	25.1	0.48
8 Dec	275	End	0.0	1.00	100	19	16.3	0.0	0.0	23.3	0.45
15 Dec	282	End	0.0	1.00	100	20	17.8	0.0	0.0	25.5	0.42
22 Dec	289	End	0.0	1.00	100	20	17.4	0.0	0.0	24.8	0.41
29 Dec	296	End	0.0	1.00	100	20	17.6	0.0	0.0	25.1	0.41
5 Jan	303	End	0.0	1.00	100	20	17.6	0.0	0.0	25.1	0.42
12 Jan	310	End	0.0	1.00	100	20	17.6	0.0	0.0	25.1	0.42
19 Jan	317	End	0.0	1.00	100	20	17.5	0.0	0.0	25.0	0.41
25 Jan	323	End	0.0	1.00	100	19	16.5	0.0	0.0	23.5	0.45
31 Jan	329	End	0.0	1.00	100	19	16.8	0.0	0.0	24.0	0.46
6 Feb	335	End	0.0	1.00	100	21	18.8	0.0	0.0	26.8	0.52
12 Feb	341	End	0.0	1.00	100	22	19.6	0.0	0.0	28.0	0.54
17 Feb	346	End	0.3	1.00	100	19	17.0	0.0	0.0	24.3	0.56
22 Feb	351	End	0.0	1.00	100	21	18.2	0.0	0.0	25.9	0.60
27 Feb	356	End	0.4	1.00	100	22	19.1	0.0	0.0	27.2	0.63
4 Mar	361	End	0.0	1.00	100	24	20.7	0.0	0.0	29.6	0.69
5 Mar	End	End	0.0	1.00	0	0					

Totals:

Total gross irrigation	1566.8	mm	Total rainfall	81.5	mm
Total net irrigation	1096.8	mm	Effective rainfall	68.8	mm
Total irrigation losses	0.0	mm	Total rain loss	12.6	mm
Actual water use by crop	1165.6	mm	Moist deficit at harvest	0.0	mm
Potential water use by crop	1165.6	mm	Actual irrigation requirement	1096.	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	84.5	%
Deficiency irrigation schedule	0.0	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.10	0.65	0.85	0.55	0.44	
Yield reduction	0.0	0.0	0.0	0.0	0.0	%
Cumulative yield reduction	0.0	0.0	0.0	0.0		%

Fig 6.2: *Crop Irrigation Schedule*

6.2 SELECTION OF SPRINKLER HEADS

Sprinkler heads to be selected should be such that they are readily available in the market and have the capacity to meet the water requirements of the plants. They should also be durable and economical. We must also keep in mind the pressure at which they will operate, their effective radius of work etc. when selecting the sprinkler head. The following sprinkler heads have been selected keeping in mind the various criteria. While selecting the sprinkler head, the suggestion of the Tea Estate manager has also been considered. Rainbird sprinklers have been used and the following are the specification.

__Table 6.1:__ Specifications of Rainbird sprinkler nozzles

Pressure (Psi)	Nozzle	Radius (Foot)	Flow (GPM)
35	10	41.00	4.80
	07	37.00	2.70
	06	37.00	2.00

Note: *The data in the above table have been collected from (rainbird.com). The data have been retrieved from (https://www.rainbird.com/agriculture/products/impact-sprinklers)*

Based on the effective radius of influence of the sprinkler heads, the distance between each sprinkler head is decided. It has to be kept in mind that there should be an overlapping of the effective radius to make the irrigation procedure more effective.

6.2.1 Calculation of Total Numbers of Sprinkler Heads

To calculate the total number of sprinkler heads we need to decide the effective radius of influence of the sprinkler heads. Here when we select the 10 number nozzle as a sprinkler head we can see that the effective radius is given as 41 foot.

6.2.1.1 Calculation of Sprinkler Head along the Length of the field

Now we need to find out the number of sprinkler head that will be required to be distributed along the length of the field.

Considering the effective radius as 40 foot instead of 41 foot because we need to overlap the sprinkles, here is how we find the number of sprinkler heads required along the length of the field,

$$\textbf{Number of sprinkler head} = \frac{\textbf{Length of the field (in foot)}}{\textbf{Effective radius of each sprinkler head (in foot)}}$$

Therefore,

- $\text{Number of sprinkler head} = \frac{734.90'}{40'} = 18.37 \simeq 19$

So, the recommended spacing between the sprinkler heads along the length of the field will be given as,

- $\text{Spacing between sprinkler heads} = \frac{734.90'}{19} = 38.68'$

Thus, total number of sprinkler heads that we need to use along the length of the field is 20.

6.2.1.2. Calculation Of Sprinkler Head along the Breadth of the field

By following the step-by-step procedure as shown above, we can calculate the total number of sprinkler heads required to irrigate the field along it's breadth,

- Number of Sprinkler head $= \frac{571.19'}{40} = 14.29 \simeq 15$

So, the recommended spacing between the sprinkler heads along the length of the field is given as,

- Spacing between sprinkler heads $= \frac{571.19'}{15} = 38.08'$

Thus, the total number of sprinkler heads along the breadth of the field is 16.

From here, it can also be concluded that the total number of laterals will thus be 16.

6.3 LAYOUT OF THE SPRINKLER IRRIGATION SYSTEM

Keeping in mind the contours of the land, the layout of the sprinkler irrigation has been designed. The main line is laid parallel to the contours and the laterals have been laid perpendicular to the contours.

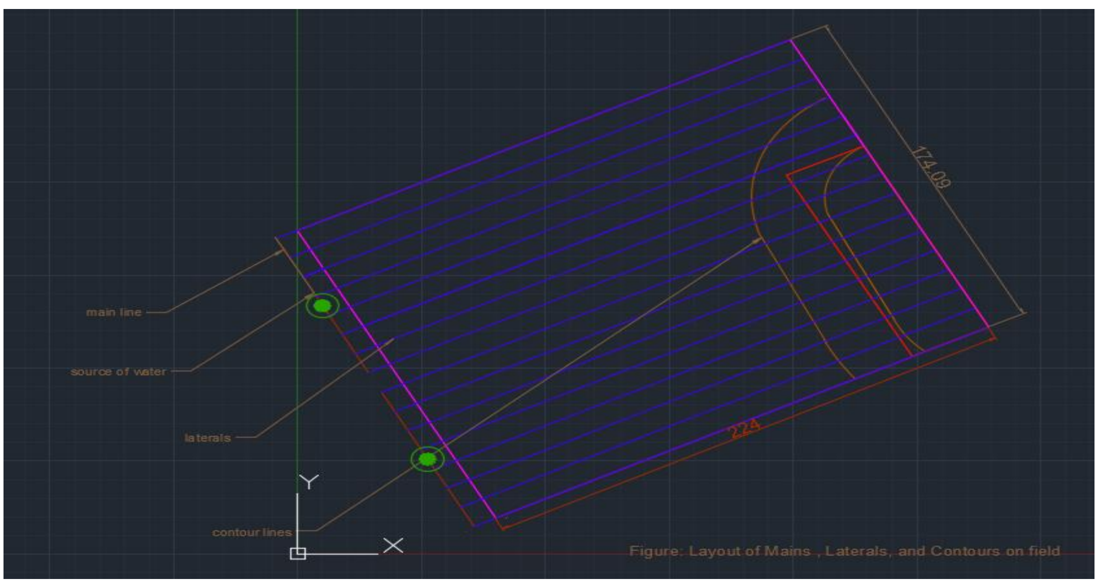

Fig 6.3: *Basic Layout of the Sprinkler Irrigation System*

The sizes of the pipes are different based on the hydraulic design of the pipes. As it can be seen in the figure above, two sources of water have been considered to irrigate the entire area of land. The land that has been selected by the estate to be irrigated first, has an area of about 3.90 Hectares. Length wise the field is extended to a length of about 734.90 foot and width wise it extends 571.19foot. This section of the tea estate is named as SEC.NO.KG&(P).

6.4 LAYOUT OF THE SPRINKLER HEADS ALONG WITH THEIR EFFECTIVE RADIUS OF CIRCLE

Based on the design calculations done above the layout of the sprinklers on the land area along with their effective radius can be shown as follows.

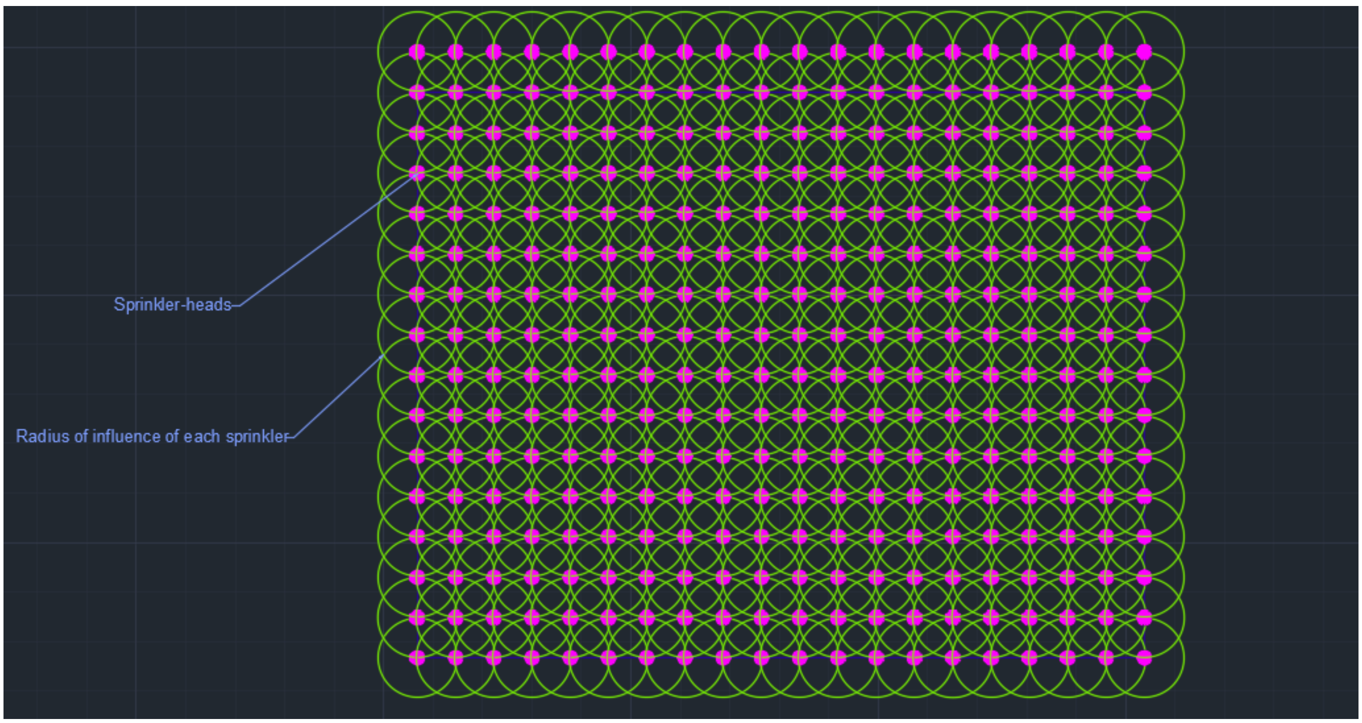

Fig 6.4: *Layout of Sprinkler Heads and their effective radius of influence*

Description:

- ✓ The rectangle is the entire field that needs to be irrigated
- ✓ The pink dots are the sprinkler heads
- ✓ The green circles are the effective radius of the sprinkler heads

Therefore, the final layout of the sprinkler heads, the laterals and the main can be shown as,

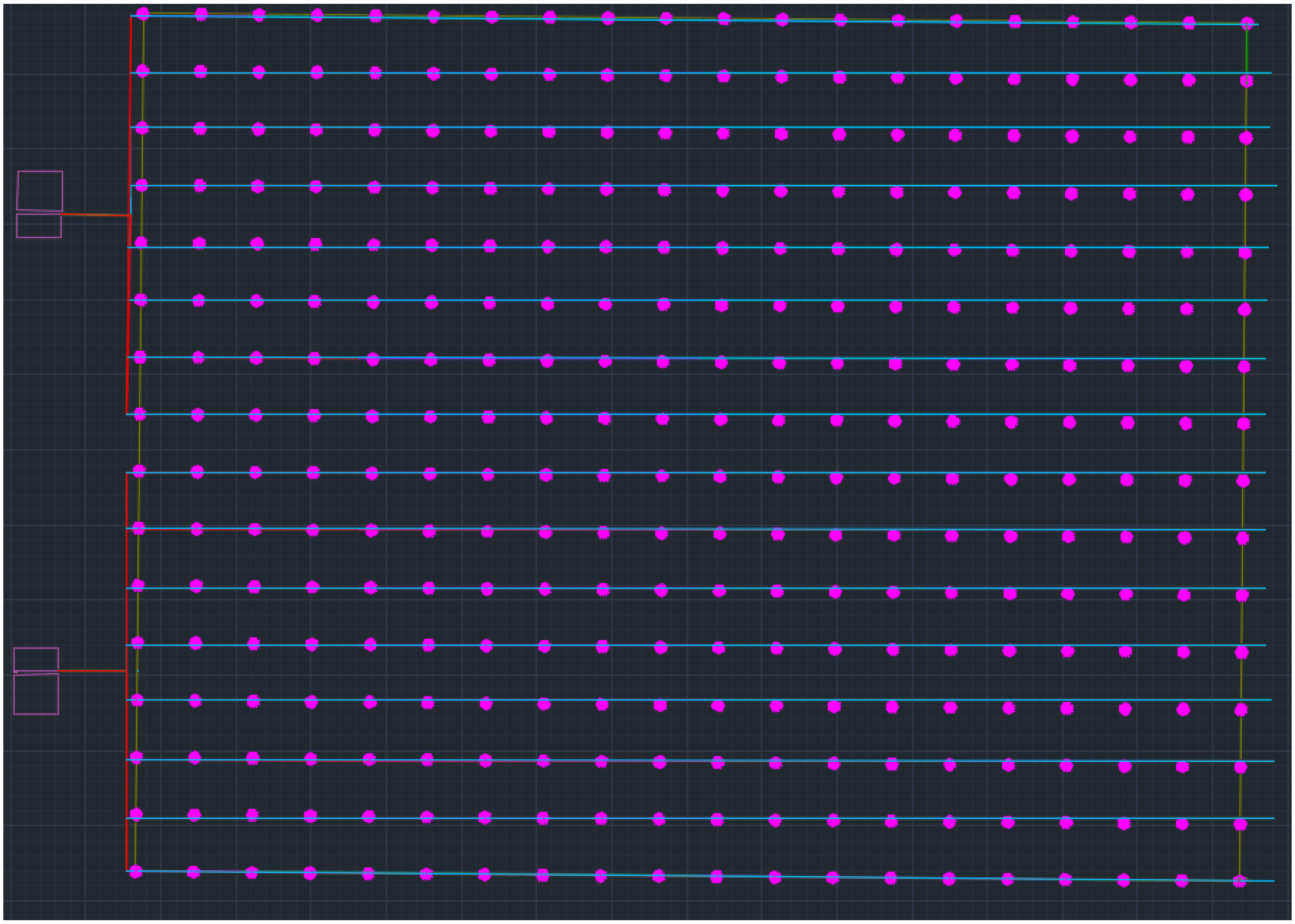

Fig 6.5: *Layout of Sprinkler heads, laterals, mains and water pumps*

Description:

- ✓ The Rectangular boxes are the source
- ✓ The red lines are the main lines
- ✓ The Blue lines are the laterals
- ✓ The Pink colored dots are the sprinkler heads

6.5 HYDRAULIC DESIGN OF THE SPRINKLER IRRIGATION SYSTEM

After the mains laterals and the sprinklers have been laid out on the diagram, now it's important to know how much flow of water can the sprinkler irrigation support. Then we need to design it in such a way that it is capable of satisfying the water demands of the agricultural field.

The entire area has been divided into two hydro-zones. Which means there are two sources of water, and they irrigate the field separately to fulfil the water demand. The hydraulic design of one hydro-zone will be same for the other. So, technically we will design the entire system for one hydro-zone and will apply it on the other zone later on.

6.5.1 Water calculation

Based on the number of sprinkler heads, we will now calculate the amount of water passing through each lateral.

6.5.1.1 Water Through First and the Last Lateral

From the table no. we can see the three types of sprinkler heads that we have used in the designing of the sprinklers. For the first and the last lateral line, the sprinkler nozzle number 07 and 06 will be used.

The reason of the selection is its effective radius of influence. For the two sprinklers placed at the corner, their effective radius of influence to irrigate the entire filed will be a quarter circle. So, for that reason, nozzle number 06 have been selected as the flow needed is comparatively less.

So, the corner two sprinklers for the first and the last lateral will cover only quarter circle of its area on the field. Thus, for them we will use 06 number nozzle which has a flow of 2.0 GPM.

The remaining 18 sprinklers of the first and the last lateral individually will cover half circle of its area on the field. Thus, for them we will use 07 number nozzle which has a flow of 2.7 GPM.

Therefore, the total flow through the first lateral = the total flow through the last lateral can be calculated as follows,

- $\text{Flow through the first lateral} = 2.0 \times 2 + 2.7 \times 18 = 52.6 \text{ GPM}$

Similarly, the flow through the last lateral on the field = 52.6 GPM

6.5.1.2 Water through the Remaining Laterals

For the remaining laterals, which are the laterals between the first and the last, two types of sprinkler head nozzles have been selected.

There are two numbers of corner sprinkler head nozzles, which will be the first and the last nozzle of the lateral the effective radius of the nozzle will be the area of a quarter circle. For these two sprinkler heads nozzle number 07 is being used, which has a flow of 2.7 GPM.

The remaining sprinkler head nozzles, which are between the first and the last nozzle will cover a complete circular field area, the diameter of which is 37 foot and the flow is 4.8 GPM. There are 18 numbers of full circular nozzles.

Therefore, the total flow through the remaining intermediate laterals can be calculated as follows,

- Flow through each intermediate lateral $= 2.7 \times 2 + 4.8 \times 18 = 91.8$ GPM

6.5.1.3 Water supply in one Hydro-zone

After the calculation of the total flow through each lateral, the total flow through a system can be calculated. Each hydro-zone will have a pump which will be responsible to pump out the total amount of water that will be irrigated. Thus, the total water that needs to be irrigated is the water requirement of the system. The total water that the pump will pump out can be calculated as follows,

- Flow $= 91.8 \times 7 + 52.6 = 695.2$ GPM

Therefore, the pump will need to provide a total amount of 695.2 GPM.

6.5.2 Hydraulic Design of the Laterals

The pipes that we will be using for laterals and mains will be uPVC pipes. To design the diameter of the pipe to be used for the irrigation system, we need to use the following equation,

Discharge = Velocity × Area.

As per the Bureau of Indian Standards IS12232:1987, "Code of Practice for design and installation of overhead irrigation systems using sprayers and nozzles", the maximum velocity in pipe for sprinkler irrigation design should not exceed 3 m/s which is 9 fps. This limit is based on the consideration of avoiding water hammering and ensuring stable operation of the system.

Keeping that in mind we will assume the velocity of flow in the system as 5 fps. Using a lower velocity such as 5 fps helps ensure a more controlled and steady flow of water through the pipes. It can also minimize pressure fluctuations and reduce the potential for damage or stress on the system components.

6.5.2.1 Hydraulic Design of the first and the last lateral

The Flow through the first lateral as per our calculation is 52.6 GPM

Therefore, by using the above-mentioned discharge formula and velocity of flow, the flow rate through the following diameter pipes has been calculated,

Table No. 6.2: *Details of different pipes diameters and their flow capacity*

Pipe Diameter (inches)	Flow provided (GPM)
2.50	76.25
2.00	49.15
1.50	27.54
1.00	12.21

Procedure:

- ✓ The maximum flow possible for 2.5 inch diameter pipe, 2 inch diameter pipe, 1.5 inch diameter pipe and 1inch diameter pipe have been separately calculated using the formula as follows

  - Discharge = Velocity ×Area of the pipe

  The velocity has already been considered to be taken as 5 foot per second (fps).

  The results obtained are as follows:

Table No. 6.3: *Results Obtained*

Pipe Diameter (inches)	Pipe Length (foot)	Flow Provided (GPM)
2.50	38.68	4.70
2.00	309.44	21.60
1.50	232.08	16.20
1.00	154.72	10.10

- ✓ Calculation for flow through 2.5 inch diameter Pipe.

  The flow entering the pipe from the mains in the first lateral will be 52.6 GPM which flow can be handled by a uPVC pipe of diameter 2.5” as can be seen from the table above.

  Thereafter after the flow is provided through 2 sprinkler heads, one providing flow to the quarter area of a circle on the field and the other provides flow to the semi-circle area of a circle on the field. The total flow through the 2.5 inch diameter pipe = 2 + 2.7 = 4.7 GPM

  Now, the remaining flow in the lateral is calculated and can be given as:

  Balance = 52.6 – 4.7 = 47.9 GPM.

This flow can be handled by a pipe of diameter 2 inches, as shown in the table above.

Length of 2.5 inch diameter pipe = 1 × 38.68' = 38.68 foot

- ✓ Calculation for 2 inch diameter Pipe**.**

Calculation of the number of sprinkler heads which will be connected through a 2 inch diameter pipe. This can be done as follows by forming an equation:

Let's assume that x number of sprinkler heads each having a flow of 2.7 GPM (as all these sprinkler heads will provide flow in a semi-circular area on the field) is connected through a 2 inch diameter pipe. Now, the value of x can be calculated as follows:

$47.9 - 27.54 = x \times 2.7$ (here 27.54 GPM is the flow through a 1.5 inch diameter pipe)

After calculation $x = 7.5 \simeq 8$ number of sprinkler heads

Length of 2 inch diameter pipe = 8× 38.68' = 309.44 foot

Balance of water = 47.9 – (8 × 2.7) = 26.3 GPM

- ✓ Calculation for 1.5 inch diameter Pipe:

Balance of water = 26.3 GPM

Flow handled by a 1 inch diameter piper = 12.20 GPM (from the table above)

Let x be the number of sprinkler heads connected through a 1.5 inch diameter pipe. This can be solved with the help of following equation,

$26.3 - 12.20 = x \times 2.7$

Solving this the value of $x = 5.3 \simeq 6$

Which means 6 number of sprinkler heads will be attached through 1.5 inch diameter pipes

Length of the 1.5 inch diameter pipe = 6 × 38.68' = 232.08 foot.

- ✓ Calculation for 1 inch diameter Pipe:

Balance of water = 26.3 – (6 × 2.7) = 10.1 GPM

Out of these 4 sprinkler heads, one is the last sprinkler head placed just at the end of the lateral which will irrigate quarter circle of the area on the field. This is the "06" number sprinkler which has a flow of 2 GPM.

Let x be the number of sprinkler heads which provide the flow of 2.7 GPM.

$2 + x \times 2.7 = 10.1$

After calculation the value of x =3

Thus, total Sprinkler heads = 3+1 = 4

Length of 1 inch diameter pipe = 4 × 38.68’ = 154.72 foot.

6.5.2.2 Hydraulic Design of the intermediate laterals

The flow through the intermediate laterals as per our calculation is = 91.8 GPM

Therefore, by using the above-mentioned discharge formula the flow through the following diameter pipes has been calculated

Table No. 6.4: *Table showing different pipe diameters and their flow capacity*

Pipe Diameter (inches)	Flow provided (GPM)
3.50	148.00
3.00	109.96
2.50	76.25
2.00	49.15
1.50	27.54
1.00	12.21

To carry a flow of 91.8 GPM through the main line, a 3 inch diameter uPVC pipe needs to be used at first to carry the water from the main line.

Procedure to calculate the length of pipes being used:

- ✓ The maximum flow possible for 3-inch, 2.5-inch diameter pipe, 2-inch diameter pipe, 1.5-inch diameter pipe and 1inch diameter pipe have been separately calculated using the formula as follows

Discharge = Velocity ×Area of the pipe

The velocity has already been considered to be taken as 1.5 foot per second (fps).

The results obtained are as follows:

Table No. 6.5: *Results Obtained*

Pipe Diameter (inches)	Pipe Length (foot)	Flow Provided (GPM)
3.00	116.04	17.10
2.50	232.08	28.80
2.00	154.72	19.20
1.50	154.72	19.20
1.00	77.36	7.50

✓ Calculation for 3-inch diameter pipe

The flow entering the pipe from the mains in the intermediate will be 91.8 GPM which flow can be handled by a uPVC pipe of diameter 3” as can be seen from the table above.

Thereafter after the flow is provided through 4 sprinkler heads, one providing flow to the semi-circular on the field and the other provides flow to the fully-circular area on the field. The total flow through the 3-inch diameter pipe = 4.8 ×3 + 2.7 = 17.1 GPM

Now, the remaining flow in the lateral is calculated and can be given as:

Balance = 91.8 – 17.1 = 74.7 GPM.

Length of 3-inch diameter pipe = 3 × 38.68’ = 116.04 foot

✓ Calculation for 2.5-inch diameter pipe

As can be seen, the flow of water that a 2-inch diameter pipe can carry is 49.15 GPM.

Let us consider that x number of sprinkler heads be connected through 2-inch diameter uPVC pipe which provide flow to a circular area on the filed irrigates the land.

By solving the following equation, the value of x can be obtained

$74.7 - 49.15 = x \times 4.8$

Solving the above equation, we get the value of $x = 5.322 \simeq 6$

Balance = 74.7 – 28.8 = 45.9 GPM

Length of 2.5-inch diameter pipe = 6 × 38.68' = 232.08 foot

- ✓ Calculation for 2-inch diameter pipe

As can be seen, the flow of water that a 1.5-inch diameter pipe can carry is 27.54 GPM.

Let us consider that *x* number of sprinkler heads be connected through 2-inch diameter uPVC pipe which provide flow to a circular area on the filed irrigates the land.

By solving the following equation, the value of *x* can be obtained,

$45.9 - 27.54 = 4.8 \times x$

$x = 3.825 \simeq 4$

Balance = 45.9 – 19.2 = 26.7 GPM

Length of 2-inch pipe = 4 × 38.68' = 154.72 foot

- ✓ Calculation for 1.5-inch pipe

As can be seen, the flow of water that a 1.00-inch diameter pipe can carry is 12.21 GPM.

Let us consider that *x* number of sprinkler heads be connected through 1.5-inch diameter uPVC pipe which provide flow to a circular area on the filed irrigates the land.

By solving the following equation, the value of *x* can be obtained

$26.7 – 12.21 = x \times 4.8$

$x = 3.01 \simeq 4$

Length of 1.5-inch pipe = 4 × 38.68 = 154.72 foot

- ✓ Calculation for 1.00-inch pipe

Remaining discharge = 26.7 – (4 × 4.8) = 7.5 GPM

Length of 1.5-inch pipe = 2 × 38.68' = 77.36 foot.

6.5.3 Hydraulic Design of the main lines, sub-main lines and suction pipes

The entire area that is to be irrigated has been divided into two different hydro-zones. Each hydro-zone is given two different sources to provide the water supply. Whatever we design for one hydro-zone will be the exact mirror image for the other hydro-zone. So, let's just start decoding the main lines design for the lower hydro-zone.

For the lower hydro-zone, the pump is placed just at the middle from where the water will be distributed to the laterals through the main lines. The total amount of water that the pump needs to supply a single hydro-zone can be found out the dividing the total capacity of the sprinkler irrigation system into two equal parts.

The water in the entire system is = $91.8 \times 14 + 52.6 \times \mathbf{2} = 1390.4$ GPM

The water supply through one pump = $1390.4 \div 2 = 695.2$ GPM.

6.5.2.3.1 Water Supply design for one hydro-zone

Through one hydro-zine, one pump is working which is responsible for pumping a total amount of 695.2 GPM of water. The pump is connected through a main pipe which bifurcates into two parts. One section irrigates the upper half of the hydro-zone and another section of the main line irrigates the lower part of the hydro-zone as can be seen in the picture below,

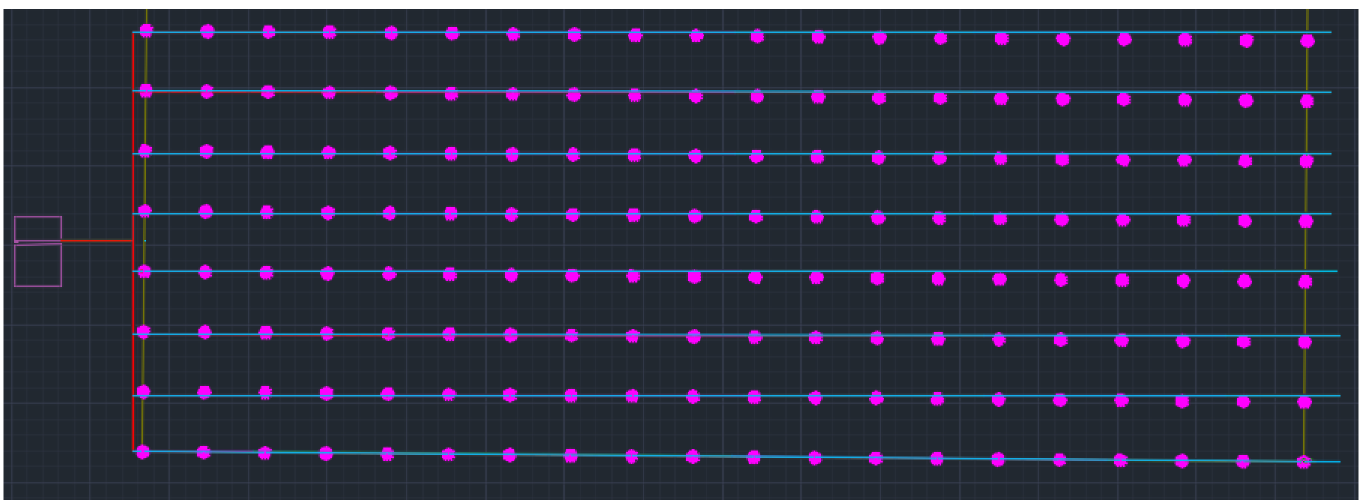

Fig 6.6: *Layout of sprinkler irrigation for a hydro-zone*

For a hydro-zone as can be seen above, there are in total 8 laterals. The main line bifurcates and each line then distributes water in 4 different laterals.

- ✓ Let's design the sub-main lines for the upper half of the hydro-zone

  Total number of laterals = 4

Flow through each lateral = 91.8 GPM

Total Flow being carried by the first main line = 91.8× 4 = 367.2 GPM

Discharge = Velocity × Area

Using the above formula, the following results have been obtained:

Q = 367.2 GPM = 0.818 cubic feet per second

Diameter of pipe required = $\sqrt{\frac{\mathbf{0.818 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.4564 foot = 5.17 inches ≃ 6 inches

Length of the pipe = 38.08÷ 2 = 19.04 foot

Second step,

Q = 367.2 – 91.8 = 275.4 GPM = 0.614 cubic feet per second

Diameter of the pipe required = $\sqrt{\frac{\mathbf{0.6136 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.395 foot = 4.74 inches ≃ 5 inches

Length of the pipe = 38.08 foot

Third step,

Q = 275.4 – 91.8 = 183 GPM = 0.40909 cubic feet per second

Diameter of pipe required = $\sqrt{\frac{\mathbf{0.40909 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.322759 feet = 3.87 inches ≃ 4 inches

Length of the pipe = 38.08 foot

Fourth step,

Q = 183- 91.8 = 91.2 GPM = 0.203 cubic feet per second

Diameter of pipe required = $\sqrt{\frac{\mathbf{0.203 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.227 feet = 2.72 inch ≃ 3 inches

Length of the pipe = 38.08 foot

✓ Let’s design the main lines for the upper half of the hydro-zone

Total number of laterals = 4

Flow through the first three laterals = 91.8 GPM

Flow through the last lateral = 52.6 GPM

Total Flow being carried by the first main line = 91.8× 3 + 52.6 = 328 GPM

Discharge = Velocity × Area

First step

Q = 328 GPM = 0.7308 cubic feet per second

Diameter of the pipe required = $\sqrt{\frac{\mathbf{0.7308 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.4314 foot = 5.17 inch ≃ 6 inch

Length of the pipe = 38.08÷ 2 = 19.04 foot

Second step

Q = 328 – 91.8 = 236.2 GPM = 0.526 cubic feet per second

Diameter of the pipe = $\sqrt{\frac{\mathbf{0.526 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.366 foot = 4.39 inch ≃ 5 inch

Length of the pipe = 38.08 foot

Third step

Q = 236.2 – 91.8 = 144.4 GPM = 0.32 cubic feet per second

Diameter of the pipe required = $\sqrt{\frac{\mathbf{0.32 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.285 foot = 3.42 inch ≃ 4 inch

Length of the pipe = 38.08 foot

Fourth step

Q = 52.6 GPM = 0.117 cubic feet per second

Diameter of the pipe = $\sqrt{\frac{\mathbf{0.117 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.173 foot = 2.07 inch ≃ 3 inch

Length of the pipe = 38.08 foot

Table No. 6.6: *Results Obtained*

Hydro-zone 1	Pipe Diameter (inches)	Length of the pipe (foot)	Flow provided (GPM)
Upper half	6	19.04	367.20
Upper half	5	38.08	275.40
Upper half	4	38.08	183.00
Upper half	3	38.08	91.80
Lower half	6	19.04	328.00
Lower half	5	38.08	236.20
Lower half	4	38.08	144.40
Lower half	3	38.08	52.60

- ✓ Let's design the main pipe which connects the pump

  Q = 695.2 GPM = 1.55 cubic feet per second

  Diameter of the pump required = $\sqrt{\frac{\mathbf{1.55 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.628 foot ≃ 8 inches

  Length of the pipe = 0.6 meters = 2 foot

- ✓ Let's design the suction pipe

  Q = 695.2 GPM = 1.55 cubic feet per second

  Diameter of the pump required = $\sqrt{\frac{\mathbf{1.55 \times 4}}{\mathbf{5 \times \Pi}}}$ = 0.628 foot ≃ 8 inches

  Length of the suction pipe = 15m = 50 foot

- ✓ The design thus can be shown as the picture below:

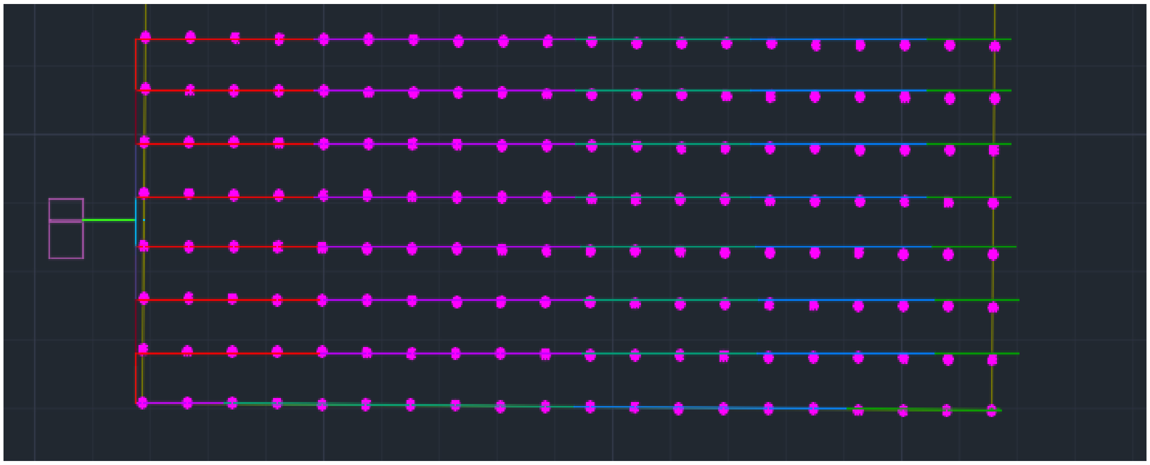

Fig 6.7: *Detailed layout of sprinkler irrigation system in a hydro-zone*

6.5.4 Hydraulic design of the Pump:

The hydraulic design of pumps for sprinkler irrigation involves the selection and sizing of pumps to meet the specific water requirements of a sprinkler irrigation system. It entails considering factors such as flow rate, pressure, TDH (total dynamic head), and other system parameters to ensure efficient and reliable operation. To determine the power of the pump required the following mathematical formula has been used:

✓ The formula to calculate horsepower (HP) in a pump using the discharge in gallons per minute (GPM) and the total dynamic head (TDH) in feet is as follows:

$HP = (Q \times H) / (3{,}960 \times \eta)$

Where:

HP is the horsepower of the pump

Q is the flow rate or discharge in GPM

H is th total dynamic head in feet

η is the pump efficiency (expressed as a decimal)

In this formula, the numerator ($Q \times H$) represents the hydraulic power required to overcome the TDH, and the denominator ($3{,}960 \times \eta$) is a constant to convert the units and account for the efficiency of the pump.

✓ Calculation of Total Dynamic Head (TDH)

In the context of a sprinkler irrigation system, the total dynamic head (TDH) refers to the total energy or pressure head required to effectively operate the system and deliver water through the sprinkler heads. It encompasses the various factors that influence the flow and distribution of water in the system.

Total Dynamic Head, $H_t = H_n + H_m + H_j + H_s$

Where,

$H_n =$ Maximum head required at the main to operate the sprinklers on the lateral at the required average pressure.

$H_m =$ Maximum frictional loss in the main and in the suction line.

H_j = Elevation difference between the pump and the junction of the lateral and the main

H_s = Suction head (elevation difference between the pump and the source of water after drawdown.

- Calculation H_n, H_m, H_i, H_s

  For calculation of friction losses, the following formulae have been used

  a) Re = (ρ × V × d) / μ

     Where:

     Re is the Reynolds number

     ρ is the density of the fluid (in kg/m^3)

     V is the velocity of the fluid relative to the object (in m/s)

     d is the diameter in m

     μ is the dynamic viscosity of the fluid (in kg/(m·s)

  b) Friction factor, $f = \frac{\mathbf{0.079}}{\sqrt[4]{\boldsymbol{Re}}}$

  c) Head loss due to friction, $h_f = \frac{\boldsymbol{f\,L\,V^2}}{\boldsymbol{2\,g\,d}}$

Pressure at which the sprinkler heads operate = 35 Psi = 24.6 m

Height of the sprinkler heads = 1.5 m

Total head loss due to friction using the above formulae including the laterals, sub-mains and main lines = 20.60 m

Therefore, $H_n = 24.6 + 1.5 + 20.60 = 46.70$ m

$H_s = 15$ m (Depth of boring is considered to be 15 m)

$H_j = 0.0018$ m (Considering 0.3 % Slope)

$H_m = 0.00076 + 0.45 = 0.45$m

Total dynamic head = 46.70 + 15 + 0.0018 + 0.45 = 62.15 m = 203.90 foot

Assuming the efficiency of pump = 90 % = 0.90

Power of the pump = $\frac{\mathbf{695.2 \times 203.90}}{\mathbf{3960 \times 0.90}} = 39.77$ hp

Thus, a 40 horsepower pump is to be used for irrigation purposes.

This entire design will be applied to both the hydro-zones to complete the irrigation design.

6.6 Results and Conclusion

The sprinkler irrigation design for the entire field has thus been done. When hydraulically designed, it can be seen that a variety diameter of pipes has been used to ensure that the irrigation requirement has been fulfilled. A 40-horsepower pump needs to be used to ensure the supply of required amount of water. In the market a 40-horsepower submersible pump that can be purchased is Kirloskar Submersible Water Pump having a model number KSG-4009- 8-inch pump.

6.6.1 Irrigation requirement

Irrigation requirement is a crucial factor in agricultural and landscaping practices. It is basically a method to determine the amount of water necessary to sustain healthy plant growth. It takes into account various factors such as plant species, growth stage, climate, soil type, and evapotranspiration rates. Understanding the specific water needs of plants is essential to provide adequate moisture for optimal development.

Monitoring soil moisture levels helps ensure efficient irrigation by preventing over- or under-watering. Different irrigation methods, such as sprinkler irrigation, drip irrigation, and surface irrigation, offer varying levels of efficiency and suitability depending on factors like water availability and crop type. By developing an irrigation schedule based on plant water requirements, soil moisture levels, weather conditions, and soil characteristics, water usage can be optimized, leading to sustainable and productive agricultural and landscaping practices.

The irrigation requirement of water can be derived from the CROPWAT 8.0 software itself. The software also gives us a detailed crop schedule as for when on which dates irrigation is required and the quantity of the irrigation requirement can also be seen on that chart. Based on that the hours for which the pump has to be run can be calculated.

Time requied to run the system to fulfil the demand			
Dates	Irrigation Requirement (mm)	Time(min)	Time (Hrs)
March			
4	20.7	308.9552	5.149254
9	4.3	64.1791	1.069652
10	4.3	64.1791	1.069652
13	4.9	73.13433	1.218905
16	5.3	79.10448	1.318408
19	5.3	79.10448	1.318408
22	5.5	82.08955	1.368159
25	5.6	83.58209	1.393035
28	5	74.62687	1.243781
31	5.6	83.58209	1.393035
April			
6	6	89.55224	1.492537
9	6	89.55224	1.492537
12	6.5	97.01493	1.616915
15	5.8	86.56716	1.442786
19	8	119.403	1.99005
22	7.4	110.4478	1.840796
25	7.7	114.9254	1.915423
29	9	134.3284	2.238806
May			
2	8.3	123.8806	2.064677
5	8.6	128.3582	2.139303
9	10	149.2537	2.487562

Fig 6.8: *Crop Schedule obtained from CROPWAT 8.0 and calculated pump running time*

	May		
2	8.3	123.8806	2.064677
5	8.6	128.3582	2.139303
9	10	149.2537	2.487562
12	9.2	137.3134	2.288557
15	9.5	141.791	2.363184
19	11	164.1791	2.736318
22	10	149.2537	2.487562
25	10.2	152.2388	2.537313
29	11.7	174.6269	2.910448
	June		
1	10.5	156.7164	2.61194
5	12.3	183.5821	3.059701
9	12.3	183.5821	3.059701
13	12.6	188.0597	3.134328
17	12.8	191.0448	3.18408
21	15.7	234.3284	3.905473
25	13.6	202.9851	3.383085
30	17.7	264.1791	4.402985
	July		
5	18.4	274.6269	4.577114
10	18.4	274.6269	4.577114
15	18.1	270.1493	4.502488
20	18.1	270.1493	4.502488
25	18.3	273.1343	4.552239
30	18.3	273.1343	4.552239

Fig 6.9: *Crop Schedule obtained from CROPWAT 8.0 and calculated pump running time*

Aug			
4	18.6	277.6119	4.626866
9	18.6	277.6119	4.626866
13	14.6	217.9104	3.631841
17	14.6	217.9104	3.631841
21	16.5	246.2687	4.104478
26	18.2	271.6418	4.527363
30	16	238.806	3.9801
Sept			
4	17.7	264.1791	4.402985
9	17.6	262.6866	4.378109
14	17.2	256.7164	4.278607
19	17	253.7313	4.228856
24	16.4	244.7761	4.079602
29	16.2	241.791	4.029851
Oct			
4	15.6	232.8358	3.880597
9	15.4	229.8507	3.830846
14	14.8	220.8955	3.681592
19	14.6	217.9104	3.631841
25	16.8	250.7463	4.179104
31	16.6	247.7612	4.129353
Nov			
5	16.9	252.2388	4.20398
10	16.9	252.2388	4.20398
15	16.1	240.2985	4.004975
20	16.1	240.2985	4.004975

Fig 6.10: *Crop Schedule obtained from CROPWAT 8.0 and calculated pump running time*

Nov			
5	16.9	252.2388	4.20398
10	16.9	252.2388	4.20398
15	16.1	240.2985	4.004975
20	16.1	240.2985	4.004975
26	18	268.6567	4.477612
Dec			
2	17.6	262.6866	4.378109
8	16.3	243.2836	4.054726
15	17.8	265.6716	4.427861
22	17.4	259.7015	4.328358
29	17.6	262.6866	4.378109
Jan			
5	17.6	262.6866	4.378109
12	17.6	262.6866	4.378109
19	17.5	261.194	4.353234
25	16.5	246.2687	4.104478
31	16.8	250.7463	4.179104
Feb			
6	18.8	280.597	4.676617
12	19.6	292.5373	4.875622
17	17	253.7313	4.228856
22	18.2	271.6418	4.527363
27	19.1	285.0746	4.751244

Fig 6.11: *Crop Schedule obtained from CROPWAT 8.0 and calculated pump running time*

The final layout of the sprinkler irrigation thus can be shown as follows:

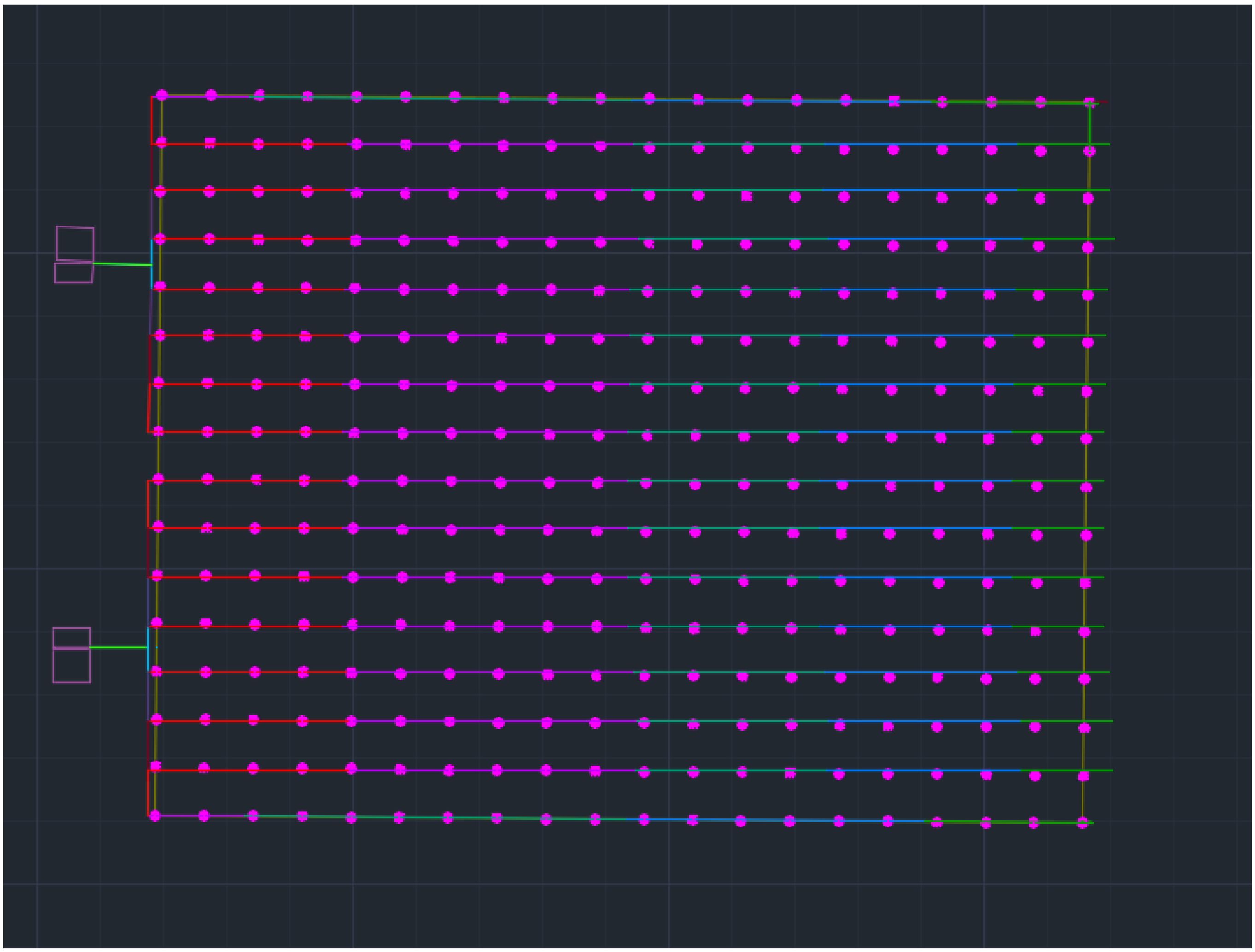

Fig 6.12: *The final design of Sprinkler Irrigation System on the entire field*

REFERENCES AND BIBLIOGRAPHY

1. Arup Kumar Sarma & Dr. Nayan Sharma. (1997). A case study of sprinkler irrigation application for tea plantation in Assam. Sodhbhagirathi: A digital repository of IIT Roorkee Research. http://shodhbhagirathi.iitr.ac.in:8081/jspui/handle/123456789/4771
2. Dr. K N Tiwari & Dr. N S Raghuwanshi. (2019). Irrigation Engineering, ICAR E-Course.
3. Hydro informatics Academy. (2021, May 4). How to calculate Crop and Irrigation Water requirement using CROPWAT 8.0 and CLIMWAT 2.0 [Part 1] [Video]. YouTube. https://www.youtube.com/watch?v=7gy9ZJCRdNU&list=PLSxG_R_25yhdqKWW5MLgPiD39GQonHf9t
4. IIT Kharagpur. (2018, August 23). Lecture 21: Sprinkler Irrigation Design [Video]. YouTube. https://www.youtube.com/watch?v=tZ1K3PFF0NU&t=14s
5. IIT Kharagpur. (2018, August 23). Lecture 22: Sprinkler Irrigation: Hydraulic Design [Video]. YouTube. https://www.youtube.com/watch?v=vd6yWcYxBrM&t=1245s.
6. M Shiva Shankar, A.V. Ramanjaneyulu, T.L. Neelima & Anup Das. (2018). Sprinkler Irrigation – An Asset in Water Scarce and Undulating Areas. In D.J. Rajkhowa (Ed.), Integrated Soil and Water Resource Management for Livelihood and Environmental Security (pp. 259-283). ICAR Research Complex for NEH Region, Umiam – 793 103, Meghalaya
7. Narender Kumar, Raj Kumar, Darshana Duhan, Amandeep Singh & Arvind. (2018). Uniformity of Sprinkler Irrigation System and Head Loss by Various Equations of Head Loss. Annals of Agri-Bio Research, 23(1), 65-68. DOI: 10.13140/RG.2.2.13475.09764.
8. Sen Christian & Emmet Jerald. (1942). Irrigation by Sprinkling. Berkeley, CA: Agricultural Experiment Station.
9. Shibani Chourushi & Dr. N. P. Singh. (2020). Sprinkler irrigation in the Indian context: A Literature Review. Paper presented at the Hydro-2017 International conference, L. D. College of Engineering, Ahmedabad, India.
10. Suray A. Rasheed & Dr. Aqeel Al-Adil. (2016). Sprinkler Irrigation Systems and Water Saving, A Case Study from South of Iraq. Eng. & Tech. Journal, 34(Part A, No. 4).
11. Y. Kamala Raju & Mohammed Hussain. (2019). Field Evaluation of Sprinkler Irrigation to Improve Crop Productivity - A Case Study. International Journal of Civil Engineering and Technology (IJCIET), 10(10), 107-114.

12. Zakari, M. D., Maina, M. M., Abubakar, M. S., Shanono, N. J., Lawan, I., Tadda, M. A., & Nasidi, N. M. (2012). Design, Construction and Installation of Sprinkler Irrigation System. Journal of Engineering and Technology (JET), 7(1&2), 109-117.