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A Study and the Calibration Of a Submerged Weir

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A STUDY AND THE CALIBRATION OF A SUBMERGED WEIR

By

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J. N. R.

Dedication

This thesis is dedicated to my mother and father, Mr. and Mrs. Nelson Robinson, to my younger sister, Naomi Robinson, my major professor, Mr. W. O. Mack, who greatly influenced my decisions and the development of my education thus far.

J. N. R.

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CHAPTER I

INTRODUCTION

Water means life to all living things. Without it they perish.

The National Association of Manufacturer's (14) reports that perhaps the largest single user of water is irrigators. It is estimated that anywhere from seventy-five to one-hundred billion gallons of water a day go for irrigation purposes.

There being an ever increasing need of efficiency in water use for irrigation purposes, the accurate measurement of water to each irrigator is a prime necessity of every irrigation system. In many areas, the water supply is limited and thereby limits the area of irrigation. The problem in this case is that of getting maximum economic production from limited water supplies. This requires great care, both in preparation of the land and in application of the water, since most irrigators are charged for water service by the quantity used. Therefore, systematic measurement of the water to each irrigator is desired.

Stanberry (18) indicates that emphasis should be given to increasing the efficiency of water utilization to permit the farmer to grow the crop he chooses.

The standard unit for the measurement of flowing water in English-speaking countries is the cubic foot per second. This may be defined as a stream of such velocity and volume that one cubic foot of water passes a given point in a second of time.

Open channels are mostly used for the flow of water for irrigation. Therefore, some type of device such as the weir must be used to determine the discharge. Of course, weirs are not used only for measuring water for irrigation; they are used to determine the run-off, the velocity of flow, the depth of flow and many other uses.

The weir is a device designed to measure the flow of any fluid that is not under pressure. It is sometimes referred to as a wall over which a stream of water flows.

There are two general types of weirs, namely, free weirs and submerged weirs.

A free weir is one wherewith the downstream water elevation is lower than the crest or vertex of the weir.

A submerged weir is one wherewith the downstream water elevation is higher than the crest or vertex of the weir but lower than the upstream water. A free weir is sometimes converted into a submerged weir by increasing the discharge sufficiently to cause the downstream water elevation to rise above the level of the weir crest.

An orifice, similiar to the weir, is a relative small opening for passage through or between an object. An orifice may become a weir by decreasing the water upstream until the head of the water is less than the vertical dimension of the orifice.

Weirs may be nearly any shape; the most common are the rectangular, triangular or v-notch, and trapezoidal. The rectangular shaped weir is of primary importance in this study.

Israelsen (12) suggest the following as some of the advantages of weirs and orifices.

Some of the advantages of weirs for water measurements are:

1. Accuracy.
2. Simplicity.
3. Non-obstruction by moss or floating materials.
4. Durability.

Some of the disadvantages of weirs for water measurement are:

1. The requirement of considerable fall of the water surface, or

loss in head, which makes their use in sections having level land impracticable.

2. The collection of gravel, sand, and silt above the weir, which prevents accuracy of measurement. This is due largely to the construction of the weir across a stream at a point which tends to decrease the flow of water considerably allowing sand and silt to settle out.

The principal advantage of the orifice for the measurement of water is the relatively small loss of head. Orifices have in addition most of the advantages enumerated for weirs.

Some of the more serious disadvantages of orifices for water measurements are:

1. Collecting of floating debris.

2. Collecting of sand and silt above the orifice, thus preventing accurate measurement.

The weir in this study is to be considered as a device for measuring the flow of water in an open channel.

Purpose of the Study

The author believes that all our actions are motivated by some need, and for every underlying cause there is a reason. Keeping this statement in mind, the purpose of this study is long range in nature. It is to establish a drainage coefficient for a watershed area in the southeast section of Prairie View A & M College campus. At the same time it is to determine if the amount of rainfall that escapes from the watershed as run-off is sufficient to be diverted to irrigation purposes.

The practice of drainage consists mainly in preventing surplus water from getting on or into the soil wherever possible and in removing from the surface and from the interior of the soil that surplus water which cannot be held off or intercepted.

The object of drainage is to control the surplus water in such a way as to render the soil more suitable for cultivation and growth of crops; to provide more healthy surrounding; and to prevent erosion.

There are two kinds of drainage___surface drainage and subsurface. Surface drainage consists of preventing surplus water from getting onto the surface of the soil as well as the removal of all surplus water directly applied. Subsurface drainage consists of the removal of the surplus water from the interior of the soil.

The drainage coefficient is considered as the amount of water that runs off from a given area in twenty-four hours. The unit of measure most commonly used for the drainage coefficient is depth in inches per twenty-four hours. Another unit sometimes used is the cubic foot per square mile per twenty-four hours. The determination of a drainage coefficient where the run off for a given area is known as well as the number of acres in the watershed, is easy to solve. The run-off of the area is found by gaging or measuring the stream which carries the water, the discharge being given in cubic feet per second. The total discharge of this stream is determined for twenty-four hours by multiplying the discharge per second by the number of seconds in the twenty-four hours. This amount of water divided by the number of square feet in the area discharging the water will give the drainage coefficient in feet per twenty-four hours, and by changing feet to inches, it is obtained in inches per twenty-four hours.

It is not often possible to determine with any degree of accuracy the drainage coefficient. Run-off for the area cannot be easily determined, because during the storm periods, the present drainage channels are not sufficient, and the run-off spreads over considerable land, making measurement impossible.

Frevert, Schwab, Edminster, and Barnes (10) recommend that the drainage coefficient should be such as to remove excess water from the soil at a rate which will not cause serious damage to the soil or vegetation. Coefficients less than one-fourth inch are seldom recommended.

Until recently, attention to water problems on the farm has been largely concerned with insuring adequate water for livestock. Most farms have enough water for this purpose, although many additional watering facilities need to be developed. The big task ahead is to increase the amount of water available for the production of crops. Of the measures available for doing so irrigation offers great possibilities.

Irrigation is the artificial application of water for the purpose of supplying sufficient moisture for plant growth.

Irrigation is practiced to some extent in nearly all countries. Frevert, Schwab, Edminster, and Barnes (11) reports that while China and India have by far the greatest acreage, the United States has over twenty-five million acres (1949) or about ten per cent of the total irrigated land in the world.

Irrigation is an extremely old practice and was known to be of considerable importance during early Biblical history. In the United States, modern irrigation practice dates back to eighteen hundred and forty-seven where the Mormons in Utah first used water for growing crops.

For successful irrigation there must be an adequate supply of water of suitable quality; the right amount of water must be applied at the proper time; a suitable method of applying the water must be provided; there must be facilities for removing the excess water, salt, and alkali from the soil; erosion must be controlled; and the project must be economically feasible.

Frevert, Schwab, Edminster, and Barnes (11) also indicates that from the standpoint of the agricultural engineer the major problems are:

1. Water supply and storage of water, including efficiency of the

application.

2. Water required and consumptive use by plants,

3. the relationship between soil, water, and plant,

4. the hydraulics of moving water, including pumping, seepage, drainage, and erosion.

The source of all irrigation water is precipitation. This precipitation may occur near the area to be irrigated or at considerable distance, as in mountainous areas. In some areas most precipitation falls during the period of the year when it is not needed. Therefore, irrigation water must be stored either in surface reservoirs or as ground water.

The expansion of irrigation is limited largely by the available water supply. This situation exists in the arid west as well as the East.

The quality of irrigation water depends on the amount of suspended sediment and chemical constitutents in the water. The effect of sediment is influenced by the nature of the material and soil condition of the irrigated area. The chemical suitability of water is influence by the following factors: total quantity of dissolved salts, contituents in the water and their relative concentrations, soil, crops, irrigation practice, and climates.

Rain and snow provide the principal source of water for irrigation. Water for irrigation is stored on the surface either in natural lakes or constructed reservoirs. Small lakes and farm ponds are normally suitable only for small irrigation projects. Such reservoirs may be used to advantage for irrigation in the East. Natural streams may provide a source of irrigation water for at least a portion of the irrigated season. In general, stream flow seldom coincides with irrigation demands.

Measurement of irrigation water is essential for efficient use as well as for promoting harmony among users. Limited water supplies necessitate greater accuracy of distribution to prevent waterlogging and to reduce erosion.

Water must be conveyed to the farm from its source or place of storage by means of such facilities as earth canals, lined canals, flumes, chutes, and pipes. With increasing demands for irrigation water and with limited supplies available, more effective use of water is becomming essential. It has been estimated in some areas that less than one-fourth of the water diverted from the original source is actually made available to plants. Application losses include evaporation, deep percolation, and surface runoff.

There are many methods of applying irrigation water. For efficient and economical distribution the water must be under control at all times as it flows from the source to the plant roots. The most suitable method depends on the soil condition, topography, water supply, crops, initial cost, labor requirements, and local customs.

There are three general methods of applying irrigation water, namely:

1. On the surface by surface flooding and by furrows which wet only a portion of the surface.

2. Above the surface by overhead sprinkling and by seepage from porous tubing.

3. Subsurface irrigation in which little, if any, of the soil surface is wetted.

Water requirements and time of maximum demand vary with different crops. Some crops are able to withstand drouth or high moisture content much better than others.

From soil moisture measurements the irrigator is able to determine when water should be applied.

To make maximum use of available water, the irrigator should have a knowledge of the water requirements of crops at all times during the growing season. With a knowledge of this information it may be possible to select the crop to fit the water supply.

Statement of Problem

In this study the author seeks to collect and analize the data secured through the calibration of a rectangular weir in a dam across the spillway of a fish pond East of Prairie View campus garden.

The problem is to estimate the per cent of rainfall that is retained in the soil, that is, rainfall less run-off. This is to be accomplished by using the weir to measure the amount of run-off and observing the amount of rainfall taken from the weather station of sub station No. 18, Prairie View A & M College. The amount of rainfall minus the run-off tends to represent the per cent of rainfall that is retained in the soil.

Ayres and Scoates (1) found out the following:

1. Intense storms usually cover only small areas and are of short duration.

2. Storms lasting several days cover large areas and fall at low intensity.

3. The magnitude and intensity of any storm bears a direct relation to its average frequency of recurrence.

4. There does not appear to be any close relationship between the total annual rainfall at a given locality and the number or magnitude of intense storms likely to occur in a given time period.

5. The total or mean annual rainfall does give a good indication of the total volume of run-off.

The amount of evaporation that takes place is very hard to determine accurately. It varies with meteorological and physical conditions.

Meteorological conditions that influence the rate of evaporation are vapor temperature, wind, and rainfall, while the physical conditions are topography, vegetation, and surface condition of the soil.

Run-off is usually considered as the difference between rainfall, evaporation, and the per cent of rainfall retained in the soil. The exact measurement of the amount of water that runs off, as in the case of evaporation, cannot be obtained. Most of the run-off will go into open channels where it is easily measurable; this is the run-off that is of particular interest.

Factors affecting run-off may be grouped into rainfall characteristics, and watershed characteristics.

The rainfall characteristic producing the largest percentage and rate of run-off will invariably be storms of high intensity and short duration, because of the rolling or hilly nature and small size of the areas involved.

Watershed characteristics governing the amount and rate of run-off are: type, erosive condition, and physical nature of the soil; degree and length of slope; distribution and kind of vegetel cover; size and shape of drainage area; and upon whether or not channels exist to hasten the time required for water to concentrate at the point of exit.

The "time of concentration" is important because it determines the minimum duration of the rain that will produce maximum run-off. It is the time it takes a given particle of water to travel from the most remote part of the watershed to the point of exit on into a common channel.

The more intense the rate of rainfall the shorter the time it lasts, so that, for a watershed of a given size and shape, the more the time of concentration can be prolonged, the lower the rate of rainfall which must be dealt with.

Run-off varies with rainfall, soil, topography, temperature, vegetation, shape and size of watershed, and natural storage basins.

The run-off will increase, all other things being equal, with the increase in intensity of rainfall and will increase with the amount of area affected by the storm. There is less run-off when the rainfall occur in light showers and the area affected by the storm is small.

The kind of soil and the condition that it is in having a very direct bearing on the amount of run-off. A sandy soil will sbsorb more water before there is any run-off than will clay soil; in the case of rocky soil the ground will be more impervious and the run-off will be great. There is not as much run-off on a rough soil as on a smooth soil. Fertile soils containing considerable humus have great absorbing capacity and they do not allow the water to run off so rapidly or to the same extent as soils with small amounts of humus. The run-off will be much greater if the ground is saturated from previous rains at the time a given storm begins than it would have been on a dry soil.

The topography of the land has to do with the amount of run-off, because it determines to a large extent the length of time required for water to concentrate or pile up at a given point. The run-off is greater on very hilly land than on flat land.

The amount and kind of existing vegetation over an area have a direct bearing upon the run-off. Land having vegetation takes up and holds more water than land having little or none.

Large areas will have a smaller rate of run-off than small areas, because it takes the water longer to get to the ditch, and more of it soaks into the land.

The shape of the tract will influence the run-off. A long, narrow tract with a ditch on the narrow side will have a smaller run-off than would the same tract with the ditch on the long side. In the former case, the water takes longer to get into the ditch and more of it soaks into the soil.

The type of outlet in which run-off goes from the various areas influences the amount of run-off. The water gets away more quickly if the outlets are good; the water moves slowly if the outlets are poor. Storage basins when so located that they absorb a considerable amount of water which would otherwise be discharged into open channels have a direct bearing on the amount of run-off that must be taken care of by drainage channels.

The encyclopaedia britannica (6) indicated that the method to be adopted in gauging a stream depends on the size of the stream, its state, and on the degree of accuracy required. Where the installation of a weir capable of taking the whole flow is feasible, this installation forms the most accurate method. For a stream of medium size the rectangular weir is the most suitable. For small flows the triangular notch weir has advantages.

Basic Concepts

The following are some of the basic concepts pertaining to terms and phrases used in this study:

Flow in open channels - An open channel is a conduit that is open to the atmosphere and therefore, subject to atmospheric pressure. As a result, flow takes place because of a difference in elevation between two points.

Steady Flow - is said to exist if the flow of a fluid in a pipe, channel, or other conduit remains constant over a period of time, that is, exactly as much going out as the amount comming in.

Uniform Flow - is said to exist in a conduit when the velocity at each cross section along the conduit is the same.

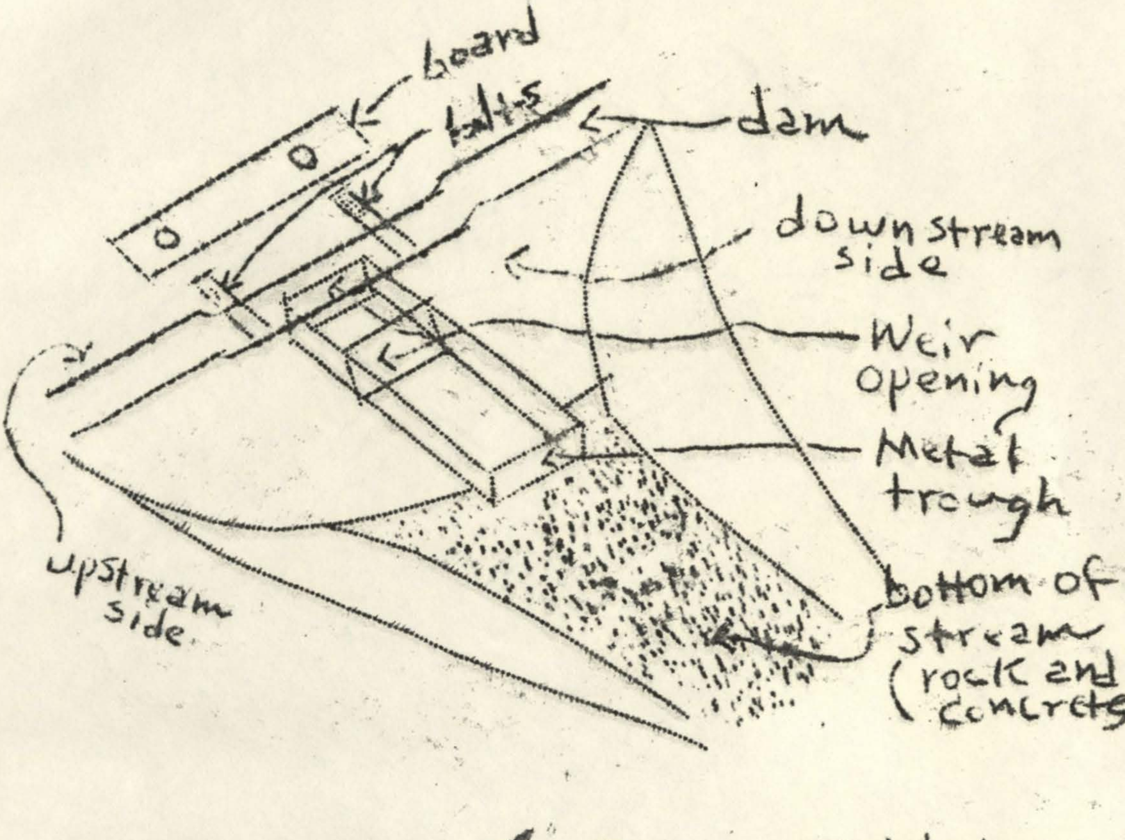

Fig. — 1 Dam and Weir

Forces causing water Flow - in rivers, canals, and soils as a result of being acted on by forces, the most important being:

1. The attraction of the earth.

2. The action of pressures of different intensities which give rise to resultant forces.

3. Shearing force due to head differential.

Head - is the elevation of the fluid above a given point or plane.

Discharge - is the rate at which a fluid passes a given point at a given time. It is measured in cubic feet per second, gallons per minute, and acre inches per hour.

Run-off - is the difference between rainfall, evaporation, and the percent of water in the soil. Ayres and Scoates (2) suggests Mead's defnition of run-off as that portion of the rainfall that is not absorbed by deep strata, utilized by vegetation or lost by evaporation and which finds its way into the streams as surface flow.

Watershed - is an area drained by a stream, river, or lake.

Drainage coefficient - is the amount of rainfall that runs off from a given area in twenty-four hours.

Acre inch - is an area of one acre with a depth of one inch.

Rainfall intensity - is the rate of rainfall in inches per hour.

Run-off coefficient - is the percent of rainfall that runs off a given area in twenty-four hours.

Frequency of storm - is the period of years during which one storm of a given duration and intensity can be expected to occur.

Objectives

The overall objective is to establish a run-off coefficient of a watershed in the Southeast section of Prairie View A & M College campus. The run-off coefficient represents the ratio of the rate of run-off to the rate of rainfall.

In order to establish a drainage coefficient the problem is divided into several parts, and some of these parts are subdivided again. This study is concerned with measuring the run-off of the watershed of the fish pond. To do that, this study was subdivided, and the objective has been broken down into more specific objectives.

The specific objectives are three-fold:

1. Designing of the weir.
2. Construction of the weir.
3. Calibration of the weir.

Source of data

The source of data for obtaining the intended information was to be through direct experimentation.

From the intended information on the data sheets, the author wish to accomplish the following:

1. Secure data to determine the flow of water through the indicated weir.

2. To obtain the necessary data to plot a correlation curve.

3. To determine the correlation between the calculated values and the test values.

The correlation curve can provide a check on the accuracy of the measurements.

The intended data is to be presented and interpreted in Chapter V.

CHAPTER II

THEORY AND HISTORICAL BACKGROUND OF THE NEED FOR A WEIR

The quantity of water discharged over a weir bears a definite relation to the depth of flow over the crest of the weir.

The depth is called the head on the weir and it should be kept constant, or the variations carefully noted to accurately determine the quantity of water passing over the crest of the weir in a given time.

The discharge is evaluated by measuring the depth of back water, that is, the water above the weir crest, produced above the bottom of the notch.

In order to understand and appreciate the need for a weir, mention may be made of the many countries where irrigation has been developed. As irrigators are the largest single users of the weir as a water measuring device, it is necessary to give a more detailed statement regarding only one of the countries to realize its important effects. Egypt has been chosen because its very life depended on its irrigation, whereas in most other cases irrigation is only a subsidiary aid to rainfall.

The encyclopaedia britannica (8) reports that the Egyptians were probably the first to develop a weir known as a barrage usually consisted of a wide masonry platform carrying a bridge of one hundred and eleven arches each of five-metre span, with piers two metres thick. In each opening between the piers are fitted two gates. This barrage was designed to hold the water necessary to irrigate the vast area of the nile valley when needed.

It is also reported in the encyclopaedia britannica (7) that the measurement of the volume of water flowing in a canal or river, of course, was formerly obtained by noting the speed of objects floating with the stream. In the first half of the twentieth century current meters replaced floats and gave more regular results, but it was not definitely known for a time, just as in the case of floats, whether or not these results indicated actual volumes when measuring large rivers. This doubt was set to rest by the calibration of water passing through the sluices of the Aswan dam in Egypt soon after its construction.

The English (9) used weirs formed of stakes and brushwood across a stream to catch fish.

This should give one an idea why weirs are needed and what they are used for.

Of course, the development of weirs has been designed, primarily, to determine the measurement of water. Therefore, the weir can be used to great advantage in determining the amount of water delivered to the irrigator.

In European countries, a weir is considered as any type barrier placed across a stream. While in America, a weir is consisered as a device used primarily for the measurement of water.

The weir is needed in this study to measure the discharge to determine the run-off. With the knowledge of this information, an estimate of the percent of rainfall retained in the soil can be calculated.

CHAPTER III

REVIEW OF RELATED STUDIES

Davis and Wilson (4) indicates that for accurate measurements of water, weirs should be constructed with the following characteristics:

1. The crest and sides of the weir should be sharp and smooth, and should be distant from the bottom and sides, respectively, both above and below the weir, not less than three times the depth of water on the weir.

2. The crest should be level from end to end.

3. The upstream face of the weir should be vertical.

4. Air should circulate freely under the flowing sheet.

5. The cross-sectional area of the stream above the weir should be not less than seven times than that of the overflowing sheet of water.

6. The depth of water on the weir should be not more than one-third its length.

Israelsen (12) states that for the construction of weirs, the general requirements for proper setting and operating should be used:

1. The weir should be set at the lower end of a long pool sufficiently wide and steep to give an even, smooth current with a velocity of approach of not over 0.5 feet per second, which means practically still water.

2. The centerline of the weir box should be parallel with the direction of the flow.

3. The face of the weir should be perpendicular, i.e., leaning neither upstream nor downstream.

4. The crest of the weir should be level, so that the water passing over it will be of the same depth at all points along the crest, and sharp so that the overflowing water touches the crest of the weir at only

one point.

5. The distance of the crest above the bottom of the pool should be about three times the depth of flowing water over the weir crest; the sides of the pool should be at a distance from the sides of the crest not less than twice the depth of the water passing over the crest.

6. The gage or weir scale may be placed on the upstream face of the weir structure and far enough to one side so that it will be in comparatively stillwater, or it may be placed at any point in the weir pond or box, so long as it is a sufficient distance from the weir notch as to be beyond the downward curve of the water as it flows over the weir crest. The zero of the weir scale or gage should be placed level with the weir crest.

7. The crest should be placed high enough so that the water will fall freely below the weir, leaving an air space under the over-falling sheet of water.

8. For accurate measurements the depth over the weir crest should be no more than one-third the length of the crest.

9. To prevent washing by the falling water, the ditch downstream from the weir should be protected by loose rock or by other material.

Roe and Ayres(18) emphasized that the following rules to be observed is very essential for good results:

1. Set weir at lower end of long pool, of width and depth to assure velocity of approach not over 0.5 feet per second____practically stillwater.

2. Set centerline of weir box parallel with line of flow.

3. Set face of weir vertical, perpendicular transversely to flow line.

4. Be sure of straight, sharp crest, set absolutely level.

5. Place gage or weir scale in weir pond or box far enough upstream (4' or 5') to be free of the drawdown curve over the crest, absolutely

level with the weir crest.

6. For measurements of head use carpenter's rule or equivalent scale, fastened vertically to gage post___zero of scale exactly level with weir crest.

7. Set weir crest high enough to leave air space under free falling water.

8. The head of water should not exceed one-third the length of the crest.

9. Riprap or otherwise protect the ditch bed just below the weir against scouring by the falling water.

The encyclopaedia britannica (5) reports that for accurate measurement the following are necessary essentials:

1. Sharp edged weir sill, fixed so as to be incapable of vibration, having its face vertical and perpendicular to the direction of the stream, and, if rectangular, having its seal horizontal.

2. Clear discharge into air, with no adherence of the vein to the weir face.

3. Weir long in proportion to its depth, that is, "b" not less than 3H; "b" is the length of the weir in feet; "H" is the head over the weir crest, measureed to the level of still water above the weir.

4. Head small in comparison with depth of the approach channel, and sectional area of vein (bH) not greater than one-sixth that of this channel.

5. Suitable channel of approach. This should be as long and of as uniform section as possible so as to allow of the motion becomming steady before reaching the weir. The length should, if possible, exceed 30H, this ratio being increased where the length of the weir is largely in excess of 3H.

6. Accurate determination of the head. For accurate work the surface-level should not be taken in the stream itself, but in a stilling-box or pit from eighteen inches to two feet square communicating with the stream through a pipe of about one-inch in diameter.

CHAPTER IV

DESIGN AND CONSTRUCTION OF THE WEIR

Design

In this study, the weir was designed at an angle of ninety degrees. It is a rectangle nine inches long and three and one-half inches wide.

Construction

The weir, probably should be called an orifice, was constructed in a concrete dam, eight inches thick, erected across the spillway of a fish pond East of Prairie View campus garden. A rectangular hole is provided in the center of the dam about ten inches from the top.

A thin piece of sheet metal (fig. 1 and 4) designed similiar to a trough, was constructed with two inch flanges on each side and the bottom; the top was left open. This piece of metal, approximately, twenty inches long was placed in the rectangular notch of the dam; the flanges were cemented to the dam to hold the metal trough in place. This metal trough is used to allow the water to spill further from the dam. A top nine inches long is attached to the metal trough six inches from the wall of the dam. The end is closed to allow the water to flow straight downward into a container provided for it. This container (fig. 2 and 4) is a wooden box thirty-seven inches long and thirty-one inches wide. It has a depth of ten inches; it also has a metal bottom with a one and one-half inch overlap on each side to allow it to be folded and attached to the sides.

The box is constructed from four pieces of two by ten yellow pine lumber. The bottom, corners, and sides are covered with tar to prevent leakage of the water. Metal cross sections are placed in the box equidistant lengthwise and crosswise slightly above the bottom. These cross sections

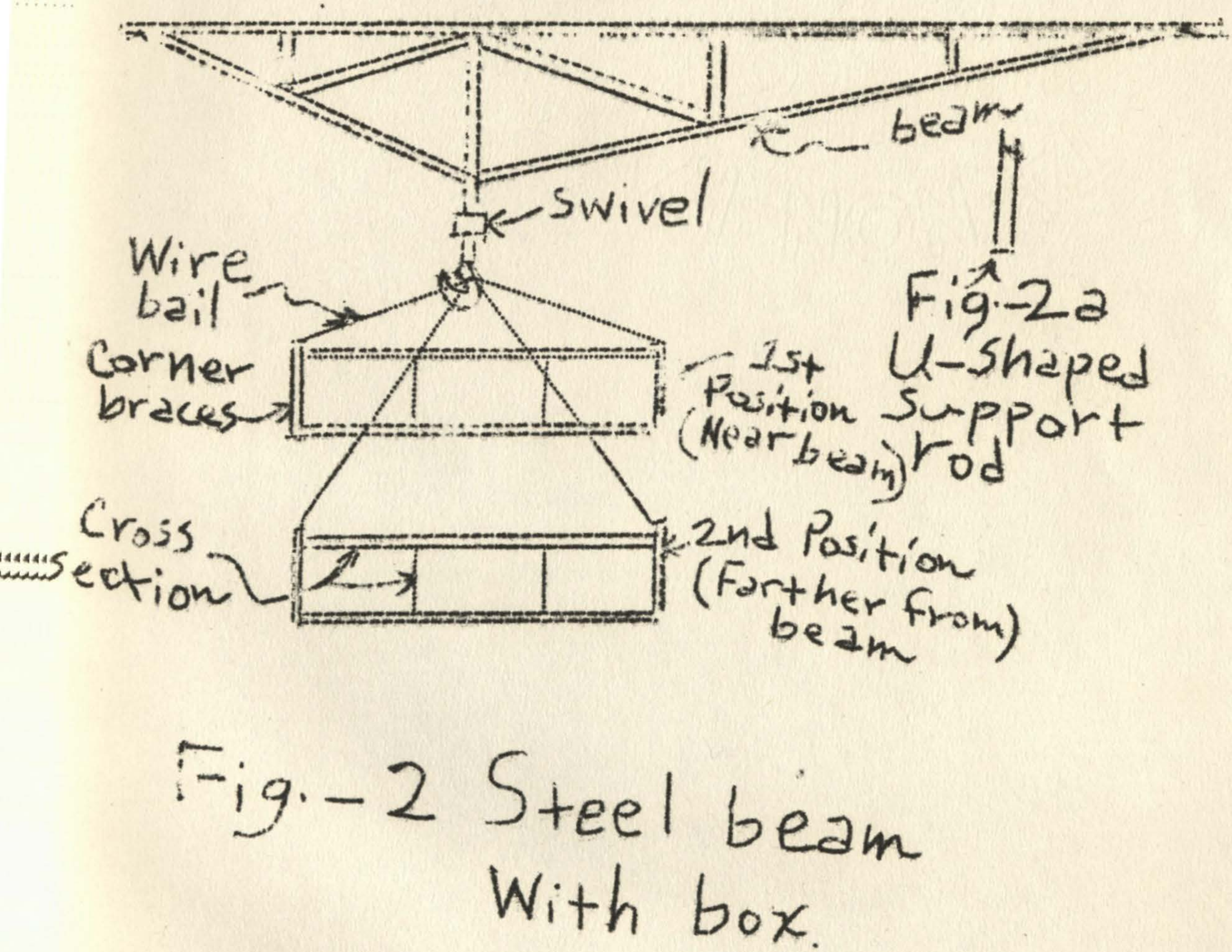

Fig.-2 Steel beam With box.

are provided to prevent the water from flowing to one side of the box too rapidly causing the box to tilt. A four inch close nipple six inches long is placed in one corner of the box near the bottom. It is an outlet for the water after the box is filled. A flat-banded cap the same size as the close nipple is used to open and close when necessary. Steel corner braces are placed in the corners. They were originally placed there to attach strands of wire to suspend the box from a steel beam (fig. 2).

The idea of suspending the box from the steel beem was soon abandoned. This was because of the difficulty in getting the container to hang steady, that is, to prevent it from swinging from side to side or tilting.

The larger the horizontal angle (fig. 2) that the bail makes with the top of the box, the less the box will swing or tilt. Smaller the horizontal angle, the more easily the box will swing or tilt.

The steel beam (fig. 2) is constructed from three-fourth inch steel pipe. The pipe is eighteen feet and four inches in length. Notches are filed on the side that is to be turned downward two inches from each end. These notches are designed to keep the beam in the U-shaped slot (fig. 2a) in the end of another pipe providing support for the beam. This pipe is flattened on the U-shaped end, and the U-slot is sharpened to fit the notches on the beam.

The vertical pipe of the beam that is provided with a swivel for suspending the container is braced to prevent the beam from bending. Three-fourth inch solid steel rods are welded on each side and top of the beam to prevent warping.

After abandoning the steel beam, the original box container and ordinary platform scales were to be used to weigh the water.

The bottom of the ditch on the downstream side was removed to a depth and width sufficient enough to place the scales under the trough provided to spill the water several inches from the dam. The bottom of the ditch was covered with a layer of rock and concrete. This was to establish substantial foundation for the scales and also prevent washing or scouring.

The bottom of the stream is about four inches from the weir crest on the upstream side of the dam and approximately sixteen inches from the weir crest on the downstream side.

One-half inch machine bolts, six inches long were cemented into the dam nine inches from each side of the weir on the upstream side. The bolts (fig. 1) are to be used to secure a thirty-four inch board two inches thick and six inches wide over the upstream face of the weir. The board is covered with plastic tar to prevent seepage of the water after the board is secured, in the proper place.

A measuring device (fig. 3 and 4) was constructed from a small steel rod about one-fourth of an inch in diameter. One end of the rod was filed to a very sharp point; this end is to be placed slightly on the surface of the water. The other end is left blunt to be placed into the provided slots in a two by four piece of lumber.

A rough two by four inch piece of lumber, thirty-five inches long, was attached to a plained piece of two by four thirty-one inches from the top. The rough two by four piece was provided with two slots to allow the blunt end of the steel rod to slide upward and downward freely.

The steel rod was suppressed into a U-shape with braces placed in each corner. A cylinder (fig. 3 and 4) three inches in diameter and twenty inches long was attached to the side of the rough two by four at the same heighth of the piece. Three-eighth inch holes are alternated around the side to allow water to enter. A piece of screen mesh was placed around the cylinder to prevent the entering of large particles of foreign material.

The blunt end of the steel rod is placed into the provided slots

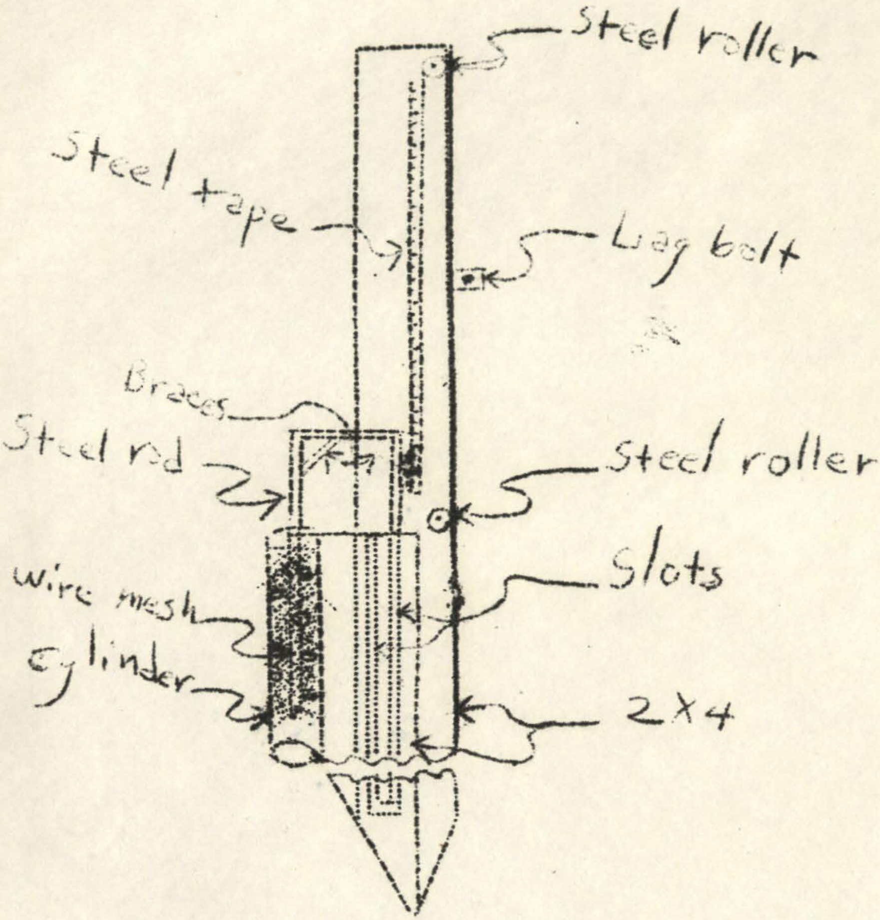

Fig. — 3 Measuring Device

while the sharp end of the rod is placed into the cylinder.

A steel tape is attached to the upper part of the planed two by four to measure the head. Steel rollers are placed near the right edge about twenty-six inches apart, beginning two inches from the top of the piece. A string is attached to the upper right corner of the steel rod and around the two rollers to a lag bolt. The lag bolt is used to adjust the steel rod upward or downward.

The complete measuring device (fig. 3 and 4) is placed about twenty-four inches to the East of the weir, two inches from the dam on the upstream side.

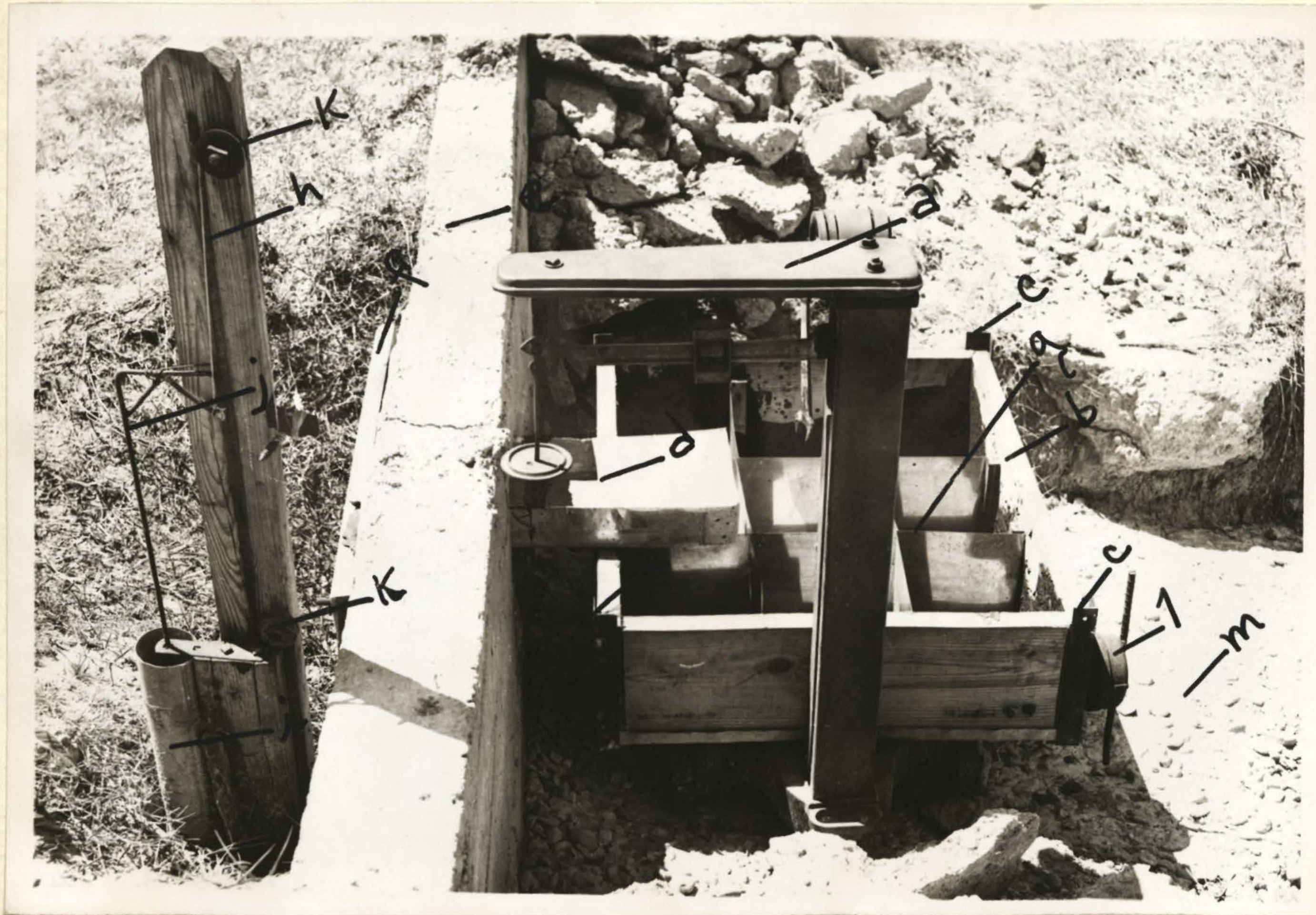

Fig. 4. Weir and Measuring Device

a. scales
b. box
c. corner braces
d. metal trough
e. dam
f. board
g. cross section
h. steel tape
i. cylinder
j. steel rod
k. rollers
l. close nipple with cap
m. bottom of stream

CHAPTER V

METHOD OF SECURING DATA

The intended method of securing the data is to be by timing the weight of a given number of pounds of water at a given head.

After the water has reached steady flow over the weir crest, that is, the flow remain constant over a period of time. The point of the steel rod on the gaging device is to be placed slightly on the surface of the water. This procedure is to be used for each head; the increments of the head are to be one-half of an inch.

After reaching steady flow, the water is allowed to flow into a rectangular box supported by ordinary platform scales to be weighed and timed by a stop watch at a given head.

The empty box weighed approximatedly eighty pounds. The scales were adjusted to balance at eighty pounds. The weight on the beam of the scales is to be set at one hundred pounds for each test. A device, similar to a trough, is constructed of metal to divert the water past the box.

Water is to be allowed to flow into the box until the weight of the water cause the beam of the scales to be raised. At this moment the stop watch is started; the weight on the beam of the scales is to be reset at three-hundred pounds. Three hundred pound weights are to be used until the flow of the water over the weir crest become low enough and to the extent that the time in seconds are excessively long. When this happens a lesser number of pounds are to be weighed.

The water is to be allowed to continue flowing into the box until the desired weight of water raises the beam of the scales a second time. The stop watch is to be stopped immediately, and the information of time and weight recorded. The water is then diverted past the box with the use of the metal trough. The water is allowed to flow out of the box through a hole provided in one of the corners. This procedure is to be repeated until all tests for each head is completed.

The reading taken from the stop watch is the time in seconds for the weight of the water at that particular head to pass over the weir.

Each test run is to consist of five trials that are to be conducted for each head with the weight remaining constant for that particular head. The averages of the time in seconds for these five trials are to be computed and this average time will be used to determine the unit flow. This is accomplished by dividing the weight of water in pounds by (62.4) sixty-two and four-tenths (approximate weight in pounds of one cubic foot of water) and multiplying the result by the average seconds of each test run.

CHAPTER VI

FINDINGS FROM THE STUDY

The findings from this study is based upon the following topic.

Precipitation

In all engineering problems dealing with the storage, utilization of, or removal of water, the amount of run-off from a watershed and the manner of its distribution are the chief factors upon which the engineering design is based.

If run-off data were available for all watersheds, there should be no particular need for precipitation records. Records of run-off are available for comparatively few watersheds. therefore, the engineer is compelled to estimate the run-off largely from his knowledge of precipitation. A knowledge of precipitation, its amount, occurrence, and distribution are of primary importance in determining the run-off or drainage coefficient.

The source of precipitation is water that has evaporated from oceans, lakes, rivers, and other water surfaces, also that which is given off through the leaves of plants in the process of transpiration.

Records of precipitation are used for many purposes. Pickels (16) states that prior to eighteen hundred and forty-nine, the only records available were those kept by private individuals. Some of the records date back as far as eighteen hundred and fourteen, but they were only local in value. The best criterion for judging future precipitation is the occurrence of precipitation in the past. Therefore, if reliable records were available for several hundred years, it would be possible to make satisfactory prediction in the future.

Appendix - I shows the amount of monthly rainfall for the first six month period of nineteen hundred and fifty-six; also the five-year average total of the first six month period of the years nineteen hundred and fifty-one through nineteen hundred and fifty-five. The total rainfall for the first six month period of nineteen hundred and fifty-six is 13.24 thirteen and twenty-four hundredth inches. The average total for the years nineteen hundred and fifty-one through nineteen hundred and fifty-five is 18.02 eighteen and two hundredth inches. There is nothing in this data to indicate how the five-year average total of the first six months are distributed. Such data are available in the meteorological records of substation number eighteen, Prairie View A & M College.

The shorter the period considered, the greater is the variation in rainfall; therefore, there is a much greater variation in the amount of monthly rainfall than there is in annual rainfall. The monthly distribution in individual years varies widely. There are records which show that for a particular month the rainfall during the wettest year of record was less than that during the driest year.

Intense precipitation considered in this study refers to heavy downpours in which several inches of water are precipitated within a period of one or two hours or less. Intense precipitations cover small areas and are of short duration.

Native Land (15) indicates that on the average more than thirty inches of rain fall over the United States each year. It adds up to one and one-half million billion gallons. It is enough to cover the entire land area of three million square miles with two and one-half feet of water. Of course, this is a tremendous amount of water, but one must realize that this wealth of water is not distributed equally throughout the nation. In some areas, annual precipitation averages less than five inches, while in others it reaches one hundred inches or more.

At present, only about three-fourths of an inch of our total thirty inch average rainfall is captured and used.

Very little rainfall occured during the first six month period of nineteen hundred and fifty-six. The amount of rainfall was only 13.24 thirteen and twenty-four hundredth inches, which is about two-third of the five-year average. The amount of rainfall that developed as run-off has not been sufficient to cause water flow over the dam since the first part of April, nineteen hundred and fifty-six.

Analysis of Findings

Calibration of the Weir

Test runs

To conduct the intended tests, a chart (Appendix II) is constructed to record the tests runs. The chart consists of seven columns with main headings, and twelve columns with subheads. The head in inches are in the first column, first trial in the second column, second trial in the third column, third trial in the fourth column, fourth trial in the fifth column, fifth trial in the sixth column, and the averages of all trials in the seventh column. The subheads under the test columns and average column consist of the weight of the water in pounds in the first column, and the time in seconds in the second column.

Calculations

As previously indicated, on the average, more than thirty inches of rain fall over the United States each year. Although this is a tremendous amount of water, one must realize that this wealth of water is not equally distributed throughout the nation, nor is it equally distributed throughout a given period, such as, a month, season, or year for any given area.

An analysis of the meteorological data of this area showed (Appendix I) that the total rainfall for the first six month period of nineteen hundred and fifty-six is considerably below the five-year average covering the years nineteen hundred and fifty-one through nineteen hundred and fifty-five of the same period.

Therefore, the rainfall covering this period was not sufficient to produce enough run-off to supply the fish pond with water enough to be measured at any given time during this period. The total rainfall for the period in nineteen hundred and fifty-six was thirteen and twenty-four hundredth inches which is about two-third of the five-year average total of nineteen hundred and fifty-five.

The intended calculations consist of a chart (Appendix III) with seven columns, lettered from "A" to "G" with the head in inches, head in feet, head in feet to the one-half power, weight of water in pounds, and acre inches per hour or cubic feet per second, respectively. Under the column heads stating pounds per second, and acre inches per hour or cubic feet per second are two sub-columns. The test values are to be in the first column, and the calculated values in the second column.

The test values in column (F_1) are to be calculated from the columns $(D \div E)$:

D = weight of water in pounds.

E = time in seconds.

The test values for (G_1) are to be calculated from column $(F_1 \div 62.4)$:

F_1 = pounds of water per second.

62.4 = number of pounds in a cubic foot of water.

The column $(F_1 \div 62.4)$ is expressed in cubic feet per second, which is approximately the same as acre inches per hour.

The formula below is to be used in determining the discharge of the weir in this study. It is expressed as:

$$Q = CA\sqrt{2\,g\,h}$$

Q = discharge in cubic feet per second or acre inches per hour.

A = cross sectional area of the weir in square feet. The weir is three and one-half by nine inches. $\frac{9 \times 3.5}{144} = 0.2187$ ft.^{2}

g = horizontal pull (32.2) in feet per second squared.

h = head in feet.

c = the coefficient of discharge.
$(0.6 \times 0.66 = 0.4)$

$$Q = CA\sqrt{2 \times 32.2h}$$

$$= CA\sqrt{64.4}\ \sqrt{h}$$

$$= 8.03\ CA\sqrt{h}$$

$$= 8.03 \times 0.4 \times 0.2187\ h^{\frac{1}{2}}$$

$$= 0.7025\ h^{\frac{1}{2}}$$

"C" is the coefficient of discharge which represents the coefficient of contraction times the coefficient of velocity. Binder (3) indicates that for sharp-edged circular orifices the coefficient of contraction range from about (0.61) sixty-one hundredth to (0.72) seventy-two hundredth. The coefficient of velocity is the ratio of the actual velocity to the ideal velocity. The coefficient of velocity is assumed to be about (0.66) sixty-six hundredth, because of the roughness of the edges of the weir. Therefore, the value of "C" is assumed (0.6 x 0.66) to be (0.4) four-tenth due to the friction loss.

CHAPTER VII

PROBLEMS ENCOUNTED IN THE STUDY

The following are some of the basic problems encounted in the study:

1. Rainfall did not occur in sufficient amounts to create sufficient run-off. It was observed that the total amount of rainfall for the first six months of nineteen hundred and fifty-six were about two-third of the five-year average total for nineteen hundred and fifty-one through nineteen hundred and fifty-five.

2. The beam being supported at a provided height made it difficult to adjust the bail of the container to allow the weight to be evenly distributed throughout the container. The higher the beam the farther the container can be suspended from the beam, thus, increasing the horizontal angle.

3. The retreating of water near the dam in the vicinity of the weir on the downstream side. The ditch should be at a slope and width enough to allow the water to run-off at such velocity as needed to prevent backwater.

4. Proper analizing of rainfall data. The rainfall data was not analyzed before the beginning of the study.

5. Time needed to collect and analyze the data. The data was collected and analyzed with hast, thereby, decreasing the thoroughness of the information obtained.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Water, life to all living things, supplies anywhere from seventy-five to one hundred gallons of water for irrigation purposes. Maximum economic production should be obtained from limited water supplies. The cubic foot per second is the standard unit for measuring flowing water.

Water for irrigation purposes is mostly conveyed in open channels, the weir being used to measure the discharge. The weir is used for other purposes other than measuring water for irrigation, such as, run-off, velocity of flow, and depth of flow.

Some of the advantages of weirs are:

1. Accuracy.
2. Simplicity of construction.
3. Non-obstruction by floating materials.
4. Durability.

Some of the disadvantages of weirs are:

1. Loss in head makes their use on level land impracticable.
2. Inaccurate measurements due to collection of sand and silt above the weir.

The orifice has similar advantages and disadvantages as the weir, but the principal advantage is the relatively small loss of head.

To determine the run-off or drainage coefficient for a given area, consideration should be given to all factors that come under rainfall, evaporation, and run-off. The drainage coefficient is the amount of water that runs off a given area in twenty-four hours. The unit measure is depth in inches per twenty-four hours.

Accurate measurement of the drainage coefficient is not often possible, because during the heavy storm periods the present channels are not sufficient to keep the run-off from spreading over large areas making measurement impossible. The drainage coefficient should be such that excess water can escape from the soil at a rate that will not cause serious damage to the soil or vegetation.

The problem of increasing the amount of water available for the production of crops is enlighten by great possibilities through irrigation.

Irrigation is the artificial application of water to supply sufficient moisture for plant growth.

Irrigation is an old practice known to be important in early Biblical history. It is practiced to some extent in all countries.

The source of irrigation water is precipitation. Precipitation may occur near the area to be irrigated or some distance away. It must be conveyed from its source or place of storage to the farm by earth canals, lined canals, flumes, chutes, and pipes.

There are many methods of applying irrigation water. Some of the methods are: (1) Surface flooding, (2) Overhead sprinkling, and (3) Subsurface. Soil moisture measurements helps the irrigator to determine when water should be applied to the soil.

Factors that affect run-off are rainfall characteristics and watershed characteristics. Storms of high intensity and short duration will produce the largest percentage and rate of run-off. Type, erosive condition, physical nature of the soil, degree and length of slope; distribution of vegetel cover; size and shape of drainage area governs the amount and rate of run-off of a watershed.

Run-off varies with rain-fall, soil, topography, temperature, vegetation, shape and size of watershed, and natural storage basins.

The conclusion proper is indefinite, but the following are some conclusions derived from the study:

1. The study should be planned far in advance, that is, it should be planned so that it can be conducted at a time of sufficient rainfall.

2. Rainfall is needed at the proper time and in sufficient amounts to create run-off. The rain should come when the soil is thoroughly saturated with water or it should fall with such intensity that very little enters the soil, thus creating sufficient run-off.

3. Proper slope is needed to allow the water to escape as run-off. The greater the slope the more run-off or lesser the slope the less run-off, therefore more of the rainfall enters the soil.

4. Annual rainfall data is needed to successfully perform the study. Rainfall data dating back several years or as far as possible should be analyzed. With the use of this information possible satisfactory predictions can be made as to the minimum and maximum amounts of precipitation which might occur in the future. Also, the frequency of occurrence, size and shape of the watershed, type of soil, condition of soil, vegetel cover, and whether most of the surplus water that falls on the watershed area make its way to the fish pond, or if it is diverted to another watershed or retained in other depressions in the soil.

Suggestive Further Study

The following are some suggestions for further study:

1. To determine if the study should be conducted in a period which provides enough rainfall to create sufficient run-off. Also, at what time of year this period usually occur, whether it is in the early spring and summer or in the late fall and winter.

2. To determine if rainfall data of the first six months of the year, monthly, seasonal, annual, or several years are a necessity, or if the use of rainfall data period is necessary to conduct this study.

3. If the beam is to be used, should it be raised to a height sufficient to lengthen the bail of the container, thus increasing the horizontal angle. Will the box hang steadier?

4. Should a survey be made of the ditch on the downstream side of the dam to determine if the bottom slope is sufficient to allow the water to run off at such velocity preventing backwater near the dam in the vicinity of the weir.

5. To determine if more time need to be expended in collecting and analyzing data, that is, should the study be conducted within six months, a year or several years.

Appendix I. Precipitation

January 1, 1956 - June 30, 1956

Days of Precipitation	Amount of Rainfall in inches	Five year total 1950 through 1955 Average
1-17-56	.24	
1-18-56	2.22	
1-22-56	.24	
1-23-56	.38	
1-27-56	.03	
1-30-56	.08	
1-31-56	.13	
2-1 -56	.12	
2-2 -56	.52	
2-3- 56	.38	
2-4-56	.11	
2-8-56	1.73	
2-15-56	.01	
2-18-56	.04	
3-3-56	.23	
3-12-56	.03	
3-15-56	.03	
3-21-56	.02	
4-3-56	.11	
4-4-56	.05	
4-5-56	.90	
4-9-56	1.86	
4-22-56	.04	
4-24-56	.22	
5-2-56	1.29	
5-15--56	.67	
6-10-56	.93	
6-12-56	.13	
6-13-56	.43	
6-18-56	.05	
6-21-56	.02	
Six month total.........	13.24	...............18.02

APPENDICES

APPENDIX II.

Head Inches	1st Run		2nd Run		3rd Run		4th Run		5th Run		Average	
	LBS.	SEC.	LBS.	SEC.	LBS.	SEC	LBS.	SEC.	LBS.	SEC.	LBS.	SEC.
10												
9½												
9												
8½												
8												
7½												
7												
6½												
6												
5½												
5												
4½												
4												
3½												
3												
2½												
2												
1½												
1												
½												

APPENDIX III

(A) Head in Inches	(B) Head in Feet	(C) Head in Feet ½ Power	(D) Wt. of Water Lbs.	(E) Time in Seconds	(F) Pounds per Second: (F_2) Test (D ÷ E)	(F) Pounds per Second: (F_2) Calculation (G_2X62.4)	(G) Acre in. per hr. or cu. ft. per sec.: (G_2) Test (F_2 ÷ 62.4)	(G) Acre in. per hr. or cu. ft. per sec.: (G_2) Calculations
10	.8333	.9128				40.91		.6412
9½	.7917	.8898				39.01		.6251
9	.7500	.8660				37.96		.6084
8½	.7084	.8417				36.90		.5913
8	.6667	.8165				35.79		.5736
7½	.6250	.7906				34.66		.5554
7	.5833	.7637				33.48		.5365
6½	.5417	.7360				32.26		.5170
6	.5000	.7071				30.99		.4967
5½	.4584	.6771				29.68		.4757
5	.4167	.6455				28.30		.4535
4½	.3750	.6124				26.83		.4302
4	.3333	.5773				25.30		.4055
3½	.2917	.5401				23.67		.3794
3	.2500	.5000				21.91		.3512
2½	.2083	.4564				20.01		.3206
2	.1667	.4082				17.90		.2868
1½	.1250	.3535				15.49		.2483
1	.0833	.3886				12.65		.2027
½	.0417	.2042				08.95		.1434

BIBLIOGRAPHY

BIBLIOGRAPHY

(1) Ayres, Quincy C., and Daniels Scoates. Land Drainage and Reclamation, 2nd Edition, New York: McGraw-Hill Book Company, Inc., 1939. 128.

(2) Ibid., 131.

(3) Binder, R. C. Fluid Mechanics, 2nd Edition, New York: Prentice-Hall, Inc., 1950. 129.

(4) Davis, Arthur P., and Herbert M. Wilson. Irrigation Engineering, 7th Edition, New York: John Wiley and Sons, Inc., 1919. 167.

(5) Encyclopaedia Britannica. "Hydraulics." Chicago: Encyclopaedia Britannica, Inc., Vol. XI (1954), 969.

(6) Ibid., 973.

(7) Encyclopaedia Britannica. "Irrigation," Chicago: Encyclopaedia Britannica, Inc., Vol. XII (1954), 687.

(8) Ibid., 688.

(9) Encyclopaedia Britannica. "Weirs." Chicago: Encyclopaedia Britannica, Inc., Vol. XXIII (1954), 488.

(10) Frevert, R. K., Schwab, G. O., Edminister, T. W., and K. K. Barnes. Engineering in Soil and Water Conservation. Ann Arbor, Michigan: Edward Brothers, Inc., 1953. 21.4.

(11) Ibid., 24.1

(12) Iraelsen, Orson W. Irrigation Principles and Practices. New York: John Wiley and Sons, Inc., 1950. 36.

(13) Ibid., 42

(14) Native Land. "Water." National Association of Manufacturers, New York: (November, 1955), 27.

(15) Ibid., 28.

(16) Pickels, George W. Drainage and Flood Control Engineering. 2nd Edition, New York: McGraw-Hill Book Company, Inc., 1941. 22.

(17) Roe, Harry B., and Quincy C. Ayres. Engineering of Agricultural Drainage. New York: McGraw-Hill Book Company, Inc., 1954), 442.

(18) Stanberry, C. O. "Irrigation Practices for the Production of Alfalfa." Water, Yearbook of Agriculture, U. S. D. A. (1955), 442.