PLANNING AND DESIGNING OF A MINOR IRRIGATION **SCHEME** WITH REFERENCES TO PLANNING AND DESIGNING OF **'GAFARA** IRRIGATION SCHEME' IN YAURI DIVISION OF N.W. STATE

BY

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PREFACE

This thesis attempts to put forward precisely, the essential elements to be dealt with when planning and designing a new irrigation scheme. Although the title is for the planning and design ning a minor irrigation scheme it is kept in mind that owing to the substantial amount of money spent in establishing even a small irrigation scheme, planning and designing a minor and a major scheme are carried out more or less on the flame principles, The difference being only in magnitude but not in performance.

The scope of irrigation is world wide, and extends from the sources of water supplied to the drainage outlets. In between these limits are such items as how to use land and water efficient tly, when to irrigate and how to irrigate, the relationship of soil, water, climate and irrigation practices which are all embodied under various headings in this thesis.

The first part of the thesis deals comprehensively with most of the major features in irrigation planning and designing,Typical nomographs and designs of certain irrigation elements, backed with thepratical considerations have been included for illustrations.

The second part deals specifically with Gafara irrigation Scheme in Yauri division of the North Wsstern State, In this part althoug a review of the available informations regarding planning and designing of the Scheme was made by the Author no attempts have been made to alter any designed elements which are included in the thesis. Some of these elements are the designs of the distributery canal design and the irrigation design data.

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SECTION 1.

INTRODUCTION

Irrigation is essentially a method of providing water for plant growth when the natural rainfall is inadequate. To a minor extent irrigation can be employed to aid in the control of soil and air temperatures and of insect pests and to lead out excess soluble salts.

Irrigation projects are agricultural establishments where controlled water supplies are applied to lands in order to grow crops. They include engineering works required to obtain, to convey and deliver water as well as areas on which crops are grown. They must include drainage works as well as supply works.

Many irrigation projects contain some lands that cannot be formed and some other lands which are used for ancillary works. They include areas used for farm buildings, farm schools, canals, roads, highways, small bodies of water, low areas that become water logged, areas of unsuitable soils, areas too rough for cultivation or other lands that cannot be made productive at reasonable costs.

Irrigation projects vary in size from small single - farm units to extensive areas of several hundred thousand acres. On a small farm project, works needed to convey water may be simply a diversion weir or an inexpensive pumping plant, together with shallow ditches and a few minor controlled structures. It is on the planning and designing of this type of scheme that this thesis refers to. However, it is good to remember that on a large project that includes many farms all

features of irrigation are magnified, more complicated and more costly. In some regions supply works of small or medium size irrigation schemes may consist of several pumping plants and continuous pipe conveyance and distribution systems.

In this country irrigation is becoming increasingly important especially in the Northern parts of the country like parts of North Western, Kano, North Central and North Eastern States where the devastaking effect of drought has been experienced. It is therefore necessary in such places to resort to irrigated agriculture since the natural rainfall is uncertain and unevenly distributed both in tune and space.

Table 1 below illustrates projected development of irrigation by some states in this country.

PROJECTED IRRIGATION AND DRAINAGE DEVELOPMENT IN SOME STATES

STATES EXISTING DEVELOPMENT ACRES		Planned Development 1970 - 1974			Project Development 1974 - 1980	
		New Acres	Total Area in'74 Acres	Estimated Expenditure ₦	New Areas Acres	Total Area Acres
1. Kano	1400	50000	50000	12300000	125,000	175000
2. N.West	5300	22600	28000	2140000	56,000	84000
3. N.East	6500	5500	12000	2684000	75,000	87000
4. N.Central	700	12300	13000		22,000	35000

However in planning irrigation projects to a gainful benefits certain conditions must prevail in order to achieve success. Among these conditions are the suitability of the irrigable area for continued Agricultural operations, cheap and dependable water supply to farmers and prevailing climatic conditions adequate for proper growth and maturity of crops.

PLANNING IRRIGATION PROJECTS.

INTRODUCTION.

In all irrigation projects adequate planning is essential and it is one of the first procedures undertaken in the development of an irrigation scheme. Preliminary plan must be prepared and often modified as development continues.

Planning work should be carried on in as complete a manner as possible. Preliminary plan which often are based on existing informations are necessarily approximate. Subsequent plan on field measurements should be more accurate. However, some changes may be found advisable as work progresses and new data become available. Alteration may be necessary even after construction begins.

The work required in planning a new project increases with the size of the project. Small projects that include only adjacent areas ordinarily can be planned without lengthy procedures. However, no matter the size of the scheme the objectives of its planning should be realised.

THE PLANNING OBJECTIVES.

The objectives that should be attained during planning include determinations and evaluations of all general factors involved in the development of a project. Planning studies should consider also general types, locations and costs of irrigation works, methods of operation and all conditions of land and water use. The irrigation systems must ensure in due time the required amount of the water delivery to the irrigated areas for maintaining the most economical, optimal, water-air, salt and nutrient regime of the soil with a view of continuous increase of fertility of lands under irrigation.

Keeping the above objectives in mind, there are certain principal factors which constitute the preliminary planning and the feasibility of the project which the designer should determine.

THE PRELIMINARY PLANNING.

The preliminary planning of the project should work out the major features in enough details to determine the feasibility of the proposed project. The first stage in the preliminary planning is the assembling and digesting of all available data. These available data may include early reports on land, soil, geological surveys, weather and stream flow records. Others may be general informations on agricultural experience on adjoining lands, marketing centres and other local developments.

Some sources from which data may be collected include:- Country Surveyors, State Engineers and departments of public works, Agricultural experimental stations and extension services, Federal power authorities and ministries responsible for agriculture, plant industry, soils, geological surveys and weather conditions.

When existing data have been collected, analysed and adapted to current studies, additional data needed in preparing preliminary plans for major project features can be secured by special surveys and other limited field investigations.

Preliminary designs for conduits and structures and estimated costs of construction usually can be based on the data for completed projects. Where storage reservoirs are required approximate capacities can be calculated from measurements of typical Cross Sections.

DETERMINATION OF FEASIBILITY.

In making the preliminary planning it is necessary to determine the feasibility of the project in order to judge whether the project will be both technically and economically sound. Some of the aspects that should constitute the determination of the project such as its location, magnitude and its major features; the economic aspects and technical soundness; the financial aspect and the national economic benefits.

PLANNING FOR LAND USE.

BACK GROUND INFORMATIONS.

The importance of proper planning of land to be used under irrigation can be realised when considering certain physical characteristics of the land. Some lands which may be easily and economically watered may not merit inclusion in the irrigable acreage because of unproductive soil composition, undesirable soil texture, difficult drainage possibilities, presence of undesirable soluble salts or danger of developing alkali surfaces under continued irrigation. Other lands which may cost more to irrigate may deserve inclusion because of ideal soil characteristics, easy drainage, and high prospects of developing into permanent and prosperous productive areas.

LAND CLASSIFICATION.

For the purpose of identifying the soil types and their characteristics the land to be irrigated should then be classified into categories. Usually Land Classification Field Sheets are prepared and detail land classification reports should be made. The detail required for planning the irrigation system of the scheme should be done based on the informations contained in the Field Sheets and the classification reports.

SOIL SURVEYS - MEEHODS.

Another important back ground information required for planning of the irrigation system of a project is the soil survey of the project site.

Soil surveys are made by examining and recording all pertinent soil conditions in the field, taking representative samples in the laboratory. Test pits are dug at appropriate locations and borings are made to determine the characteristics of the principal soil horizons. All soil conditions are carefully observed and recorded including surface drainage, subsoil drainage, presence of of alkali salts, types of existing natural vegetation, stoniness, gravel constituents, organic matter, texture structure etc.

From the soil survey investigations of the field the following important relationship can be determined:

(a) Water relation of soils - water retaining and water transmitting capacities.

(b) Water - obsorbing - and - transmitting ability.

PLANNING FOR WATER USE.

The success of every irrigation project depends largely on the adequacy and the dependability of its water supply. In planning and designing for an irrigation project therefore a detail study of the dependable source of water as well as its quality must be made.

WATER SUPPLY STUDIES.

The planning of irrigation water must be preceded by and based on the accumulation of dependable information concerning water supply.

QUALITY OF THE IRRIGATION WATER.

The quality of Irrigation Water is determined by the composition of disolved substances in it. The principal solutes in water are the cations e.g. sodium, calcium, magnesium, onion e.g. bicarbonate, sulphates, chloride. Boron, floride and nitrate are usually present in low but significant concentration.

CHARACTERISTICS THAT DETERMINE THE QUALITY OF IRRIGATION WATER.

When investigating for the quality of irrigation water it is useful to know that the characteristics of irrigation water that are most important in determining its quality:-

(1) Total concentration of soluble salts.

(2) Relative proportion of sodium to other cations.

(3) Concentration of boron or other elements that may be toxic.

(4) Under same condition the bicarbonate concentration as related to the concentration of calcium or magnesium.

The total concentration of soluble salts is related to and can be expressed in terms of electrical conductivity of the irrigation water.

Relative proportion of sodium to other cations can be expressed in terms of sodium Absorption Ratio (SAR). As this is the absorption ratio of sodium in a soil solution it is an indication of sodium or alkaline bazard of the irrigation water. The ratio is defined by the equation:-

$$SAR = \frac{Na^{+}}{\sqrt{(ca^{++} + mg^{++})}/2}$$

where Na^{+} Ca^{++}, and Mg^{++} represent the concentration in milli-equivelents per litre of thesame ions. A nomogram for estimating the S.A.R. value of an irrigation water is usually prepared and a typical one is shown in Figure 1. An E S P scale is included in the nomogram opposite the SAR scale.

The Exchangeable Sodium Percentage (ESP) is expressed as:

$$ESP = \frac{100(-0.0126 + 0.01475\ SAR)}{1+(-0.126 + 0.01475\ SAR)}$$

The ESP is also a valuable index of quality of irrigation water. It is the percentage of the cations that may cause undesirable reactions of base exchange when the irrigation water infiltrates into the root zone.

CLASSIFICATION OF THE IRRIGATION WATER.

It is worthwhile during the feasibility study of the project to classify the water that is to be used for irrigation. However, it is to be understood that there are many ways of classifying irrigation waters. But whatever general method is used it is assumed that the water will be used under average conditions with respect to soil texture, infiltration rate, drainage, quantity of water used, climate and salt tolerance of crop.

Irrigation waters may be classified into four classes with respect to conductivity, (See Fig. 2) the dividing points between classes being at 250, 750, 2250 micromhos/cm. These class limits were selected in accordance with the relationship between the electrical conductivity of irrigation waters and the electrical conductivity of saturation extracts of soil.

PLANNING AND DESIGNING FOR PLANT-WATER RELATIONSHIP.

INTRODUCTION.

The importance of this aspect of planning lies in the necessity of having a continuous supply of available moisture in the root zone of crops.

During planning and designing of this important aspect therefore it is necessary to determine not only how much water the soil will hold but also how fast this selected crops use moisture and from what depth they withdraw it. It is necessary also to find out the distribution of plant's roots as this determines its moisture extraction pattern on which depends the size of the soil reservoir holding water available to the plant.

ROOTING CHARACTERISTICS OF PLANTS AND THE CONSUMPTIVE USE.

The determinations of the rooting characteristics of the plants to be grown and their consumptive use are compulsory in this aspect of the design. Usually two types of consumptive use of the plants should be determined and these are:

1. Seasonal Consumptive Use ---- total amount of water used in evaporation by a crop during its growing season. This consumptive use is useful in evaluating and determining seasonal irrigation water supplies.

2. Peak — Period Consumptive Use — This is the average daily water-use rate during the 6 to 10 days of the highest consumptive use of the season. This is the design rate to be used in planning an irrigation system.

METHODS OF DETERMINING CONSUMPTIVE USE.

There are five principal methods by which consumptive use can be measured:- tank and lysimeter experiments, field experimental plots, soil moisture studies, integration and inflow - outflow for large areas.

Climatic observations as an index to consumptive use have been used by researchers to calculate consumptive use of crops. In this regard low temperature, humidity, wind velocity, vapour pressure and solar ratiation influence on consumptive use has been studied. Penman in England, has made the most complete analysis using several climatic variables, whereas temperature has been used as the principal variable to obtain index to consumptive use by Thornthwaite in the humid eastern United States, by Lowry and Johnson, and by Blaney and Criddle in the arid western United States.

In the Lowry - Johnson method a linear relationship is assumed between "effective heat" and consumptive use. The effective heat is taken as the accumulation, in degrees, of maximum daily growing season temperatures above 32 ^{o}F.

The approximate relationship

$$U = 0.8 + 1.156\ F$$

is used in estimating the valley consumptive use by the Lowry - Johnson method.

Where U = Consumptive use in acre feet per acre

F = effective heat in thousands of day degrees.

PLANNING AND DESIGNING FOR FREQUENCY AND AMOUNT OF IRRIGATION.

IRRIGATION WATER REQUIREMENT - Having determined the consumptive use of Crop the designer should now proceed with the design of the irrigation requirement which is the net requirement plus the loss incurred in distribution and in the application of water; the net requirement is the amount exclusive of precipitation required by the Crop to the amount of water that must be stored in the root zone to meet the consumptive use required by the crop.

TYPICAL DESIGN.

Suppose the following are typical data collected for a new irrigation project:-

1. Field Capacity (FC) is 33%
2. Wilting Point (WP) is 26%
3. Available moisture content is 7%
4. Bulk density (BD) of soil is 1.25
5. Max. design infiltration rate is 12mm/hour
6. Suppose the crop is alfalfa and its peak consumptive is 5mm/day
7. Effective design root zone (R_Z) is 1.2m.

8. Critical moisture content for the effective root zone is 40% above wilting point (i.e. next irrigation is carried out when 60% of the available moisture in the effective root zone has been used up).

9. Design system efficiency is 75%

Net Water Requirement: = (N.W.R.) is given as

$$= (FC - WP)\ (\%\ of\ C.P.)\ (R.Z.) \times 10$$

$$= (33 - 26)\% \times 60\% \times 1.25 \times 1.2 \times 10$$

$$= \underline{63\ m^3/\ 1000\ m^2}$$

Gross Water Requirement: = (G.W.R.) is given as

$$\frac{\text{Net Water application For Design}}{\text{Efficiency of System}}$$

$$= \frac{63}{75} \times 100$$

$$\therefore\ G.W.R. = \underline{84\ m^3/\ 1000\ m^2}$$

Theoretical Irrigation Internal or Frequency:

$$= \frac{\text{Net amount of moisture between field capacity and moisture starting level}}{\text{Peak period moisture use rate of Crops.}}$$

OR

$$= \frac{\text{Net depth of application}}{\text{Peak - period use rate}}$$

$$= \frac{63}{5\text{mm/day}}$$

$$= 12.6 \text{ days}$$

$$= \underline{12 \text{ days}}.$$

Irrigation Period - This refers to the number od days that can be allowed for applying one irrigation to a given design area during the peak consumptive. It gives the bases for capacity and equipment design. This can be determined as:

Net amount of moisture in soil between start of irrigation and lower limit of moisture depletion.

Peak - period moisture use rate of crops.

Other methods of determining frequency of irrigation include:

1. The 'feel and appearance method'
2. Irrigation by determining soil moisture.

Time Required For Water Application.

The time required for water application is designed as:

$$\text{Time in Hours} = \frac{\text{depth in inches} \times \text{Acres}}{\text{g. p. m.}}$$

PLANNING AND DESIGNING FOR METHODS OF IRRIGATION

There are various means by which irrigation water can be applied to farms. The three general methods by which this can be carried out are:-

1. By surface irrigation in which furrows, borders, basins and wild flooding may be used.
2. By sprinkling.
3. By sub surface.

EVALUATION OF IRRIGATION SYSTEMS.

Before any one method is adapted it should be evaluated with respect to soil and topography. Some of the governing factors of what method to use include: the type of soil, the topography of the land, the intake rate of soil, water holding capacities and the type of crops to be grown.

Three types of methods and their requirements are discussed in A, B and C.

A. Method of Furrow Irrigation.

Furrows are small channels laying along the length of an area at definite intervals, with predetermined slopes. The water enters the furrow through its upper inlet and thus convey the water over the soil surface in small indivisual parallel streams.

PROPERTIES AND REQUIREMENTS.

1. Diamensions - The length depends on the soil type, crop, water flow rate, soil slope and cultivation practices. The reasonable allowable lengths are 30 - 400 metres. The furrow interval is fixed generally by the type of crop irrigated.

2. Maximum allowable length of furrow - This can be decided after knowing the rate at which the differennt size of streams advance and determining time that can be allowed for it to get down the furrow.

3. Sizes of streams - This is generally a matter of judgement through irrigation trials, but the decision can be affected by the slope of the field, type of soil and the length of run. Generally the discharge depending on the above factors can be between 0.5 to 2m^3/hr.

4. Time required to refil the soil reservoir - If the necessary depth of water put into the soil has been determined the time required to put this depth into soil should be calculated.

This could be calculated by the formula:-

$$T = \left(\frac{60\ D\ (n+1)}{K}\right)^{\frac{1}{n+1}}$$ where

T = Time required to refil the soil reservoir.

K = intake rate intercept at unit time.

h = slope of the furrow line.

5. Maximum Allowable time to get water through the furrow- In order to meet the criterion for good irrigation the stream fronts should reach the lower ends of the furrows within one-forth of the total time needed to refil the soil in the zone.

6. Slope Requirement - The furrow is limited by two requirements:

(a) the minimum slope that will allow a reasonable flow without overtopping.

(b) the maximum slope that will not cause erosion due to high velocity. The reasonable allowable furrow slopes are between 0.1% to 0.5%.

7. Adaption - Furrow can be suitably adapted to all row crops and where hand is sloping or the soil has a tendency to bake or crust.

METHODS AND MEANS OF DISTRIBUTION OF WATER TO FURROWS.

Uniform distribution of water to furrows is the most important practice in the furrow method of irrigation.

Some of the methods by which water can be distributed to furrows are:-

1. By means of temporary irrigation networks. Depending on the slope and the land levelling a temporary irrigation network may be made running either longitudinally (Fig.3) or crosswise (Fig.4). In the former case the field ditches are constructed parallel to the irrigation furrow and perpendicular in the latter case.

2. By means of temporary irrigation networks using small irrigation accessories (siphons, irrigation tubes, etc.) See Fig. 5 A and B.

3. By means of flexible or rigid irrigation pipe lines to replace distributing furrows and sometimes, field ditches. See Fig. 7.

B. Method of Border Irrigation System.

The border method of irrigation consists of dividing the field into a series of borders by low flat dykes, or ridges constructed in the direction of greatest slope. Water turned into the upper end of each border moves down the slope in a thin sheet guided by ridges.

The following are the properties and the requirements of border irrigation system:-

1. Dimension - Although this depends on the soil type, crop discharge, slope and method of cultivation (width of tractor or plough), planting distances, field dimensions etc. There are some standards as stated below:

Width of strip: 5 - 20 metres.

Length of strip: 75 -400 metres.

Height of ridge: 0.5 metres.

2. A level surface with a mild slope - This method is commonly used when slope in the direction of irrigation ranges from 0.1% for most crops to as much as 6% for pasture land.

3. A smooth homogenous surface.

4. Limits of Discharge - The reasonable limits of the discharge for these strips are between 50 - 500 m^3/hour.

C. The Sprinkling Method.

Sprinkling method is adopted in the conditions where surface irrigation methods are in-efficient. For example sprinkling can be adopted to lands that cannot be economically prepared for surface methods, to lands with excessive slopes, irregular topography, erosive soil, excessively perimeable or impermeable soil etc.

THE SPRINKLER SYSTEM.

The sprinkler system includes the sprinkler, the riser pipe, the laberal distribution pipe, the main pipe line and the pumping plant. Sprinkling systems may be classified as semi-permanent, permanent or portable according to the make up of its components.

Three general types of sprinklers are use:- fixed nozzles attached to the pipe, perforated pipe, and rotating sprinklers.

THE SPRINKLER SYSTEM DESIGN REQUIREMENT.

The important factors in the success of sprinkler systems are first, the correct design and second the efficient operation of the designed system. The basic informations necessary for the design of a farm irrigation system is obtained from four sources, namely; the soil, the water supply, the crop to be irrigated and the climate.

Other requirements are that the sprinkling should be designed to correct performance, sufficient capacity and pressure.

THE PLANNING AND DESIGNING OF A SPRINKLER SYSTEM.

Adequate planning for sprinkler irrigation includes an inventory of the resources of the farm and integration of the operation of a system with other required farm operations. Planning should be done to accomodate different cropping pattern which may arise as the result of the development of a balanced crop rotation and also to provide for future expansion needs.

To design a sprinkler irrigation system the following items are determined:-

1. Collection of data.
2a. Cross water requirement after consideration of effective rainfall.
 b. Consumptive use of water for all irrigated crops.
 c. Effective irrigation interval for all crops.
3. Selection of sprinkler.
4. The system layout.
5. The number of laberal positions needed per shift and also determination of lateral discharge.
6a. Sprinkler operating time.
 b. Number of irrigation shift per day.
 c. Number of lateral per irrigation shift.
 d. Total number of laterals per field.
7. Lateral diameter.
8. Submain diameter.
9. Main line diameter.
10. Preparation of instruction plan for the farmer.

Typical designs of sprinkler lateral and submain are shown in the appendix.

PLANNING AND DESIGNING FOR CONVEYANCE CHANNELS.

BACKGROUND INFORMATION.

The conveyance of irrigation water may be in closed conduit such as pipes or in open earth canals. The following paragraphs are on the process of establishing an earth canal. The canal and the channel will be inter-changeably used since their function is to convey water and their difference is in size.

Before starting off to design a canal or a channel certain basic data must be known. Among these are hydrologic history of location, soil condition such as horizon and permeability, source to supply delivery system, area to be supplied by the canal or channel and the irrigation farm requirement.

THE DESIGN OF A CANAL.

To design a canal use must be made of weather charts of the area. Graphs and monographs or algebraic calculations are also used to get a solution. For example, in locating the canal on the ground the cut and fill at any particular section may be accomplished by using the algebraic expression as given below:-

$$bx + \Sigma S_1 = \frac{\left\{ (t_1 + t_2)(h - x) + (S_1 + S_2)(h-x)^2 \right\}}{(1 + K)}$$

(See the sketch of a typical canal section for the notation (Fig.6).

THE DISCHARGE Q OF THE CANAL.

Having known the specific quantity of water that the farm requires in say, X - acre metre of water, this amount is then converted to rate in metre cube per second usually designated as Q. This can be done by using the emperical formula for the water applied to the farm:-

$Qt = da$

Where

Q = the discharge rate.

t = time required to irrigate the area.

a = area to be irrigated.

d = depth that the volume of water used would cover the land irrigated if quickly spread uniformly over its surface.

Substitution of the variables a, d and t will yield Q in desired units.

USING CONTINUITY EQUATION.

With the knowledge of Q, the continuity equation can be employed in solving the problems of the canal design. The continuity equation is given below:-

$Q = A, V, = A_2 \quad V_2 = \ldots\ldots\ldots \quad A_n \quad V_n$

Where

A = Cross sectional area.

V = the average velocity.

The direct measurements of the canal or channel section give the area A. Although the cross section may change e.g. when A increases, V decreases and vise vasa nevertheless Q remains constant.

THE VELOCITY.

The velocity of water in channel is affected by the friction, obstruction and slope. The velocity used in the mannings formula is determined by three dependent variables, namely, S the slope; R the hydraulic radius and n, called mannings n after the man who developed the equation.

Mannings equation states:

$$V = \frac{I}{n} \quad R^{\frac{2}{3}} \quad S^{\frac{1}{2}}$$

where

R = the hydraulic radius $= \frac{A}{P}$ and

P = wetted perimeter.

For uniform flow the depth and the velocity terms are thesame at all points, from this $Z_1 - Z_2 = h$. This the energy loss from point to point. If the energy loss per foot of length is called S, then for any open channel $S = \frac{h}{T} = \text{Sin } \theta$

where

θ = the angle between the energy gradient and a horizontal plane.

Rearranging $h = SI$

The relation between the bottom slope S_o, the angle of the bottom with the horizontal, θ, I, and $2 - 2_2$ is expressed by the equation:-

$$S_o = \frac{2_1 - 2_2}{1 \cos \theta}$$

$$So = \frac{2_1 - 2_2}{I} \quad \left(\frac{1}{\cos \theta} \right).$$

$$S_o = \frac{\sin \theta}{\cos \theta} = \tan \theta$$

and $Z_1 - Z_2 = SoI \cos \theta$

since the bed slope θ is small (5° θ) we find $\cos \theta I$, or $\sin \theta = \tan \theta$ and $S = SO$.

The above relation applies only to uniform flow. S is the energy loss per foot length. With the knowledge of what variables are in mannings equation, velocity can be solved and used to compute rate of discharge per given time.

NON-SILTING VELOCITIES.

When determining the canal gradient, the velocity of flowing water should be fixed up in such a way as to secure the transport of sediment on the one hand, and to avoid the washing out of the material of canal section, on the other hand.

To know the critical non-silting flow velocity, it is necessary to have information about the composition and the amount of sediments in the irrigation source. It happens very often that mud content in the river water is so great that the transportation of the whole volume of sediments to the field through canal is rather difficult through technical and economical stant points. In this case it is expedient to envisage Silt - excluders at the headworks of the irrigation system which will serve for trapping the coarse sediments. Due to this canals should be designed for transporting only the remaining sediments which are mainly of fine clay.

Table 2 shows limiting velocities for essentially straight canals after Aging. (computed from Fortier and scobey).

TABLE 2.

LIMITING VELOCITIES FOR ESSENTIALY STRAIGHT CANALS.

M A T E R I A L	Value of Mannings	Velocities in m/sec. Clear Water	water transporting colloidal Silts.
Fine Sand colloidal	0. 020	0.4	0.8
Sandy loam, non-colloidal	0. 020	0.5	0.8
Sukt kiam bib-colloidal	0. 020	0.6	0.9
Alluvial Silts, non-colloidal	0. 020	0.6	1.1
Ordinary firm loam	0. 020	0.8	1.1
Volcanic Ash	0. 020	0.8	1.1
Stiff clay, very colloidal	0. 025	1.1	1.5
Alluvial silts, colloidal	0. 025	1.1	1.5
Shales and hardpans	0. 025	1.8	1.8
Fine gravel	0. 020	0.8	1.5
Graded loam to cobbles when non colloidal	0. 030	1.1	1.5
Graded silts to cobbles when colloidal	0. 030	1.2	1.7
Coarse gravel, non-colloidal	0. 025	1.2	1.8
Cobbles and shingles	0. 035	1.5	1.7

CANAL SHAPES.

The shapes in which the canals can be made are:-

(a) trapezoidal (b) Rectangular (c) Triangular
(d) Circular (e) Parabolic.

The trapezoidal shape is the easiest and most suitable to earth ditches because it lets the soils assume their natural slopes when wet.

The most economic section for a trapezoidal channel is when the discharge is a maximum for a given excavation. One of the conditions for this maximum discharge is when the hydraulic radius, m is equal to half the depth d i.e. $m = \frac{d}{2}$

Another condition is when the proportions of the channel is as stated below:-

$$\tfrac{1}{2}(B + 2nD) = \sqrt{n^2 + 1}$$

where

A = width of channel bed.

D = depth of channel.

n = side slope of channel.

THE CANAL LINING.

Irrigation canals are lined because of the following reasons:-

(1) To decrease conveyance seepage loss, erosion from high velocities, drainage problems, local growths and maintenance costs.

(2) To provide safety against seepage and higher velocities.

(3) To increase the capacity to convey water.

The most used materials for canal lining includes:- Concrete, rock masonry, brick bentonite rubber, plastic and asphalt compounds. Clay and grass are sometimes used to cut down erosion.

DRAINAGE REQUIREMENT IN IRRIGATION SYSTEM.

As a consequence of irrigation drainage problems usually arise. This is because water losses in excess to the actual requirements are either unavoidable or may even be necessary. Drainage of the irrigated field is therefore necessary not only because of the harmful effect of too much water to the crop but also because of reducing or preventing the accumulation of salts in the soil.

DRAINAGE INVESTIGATION.

Before designing the drainage system field investigations must be made for drainage apkraisal. The five elements of primary concern in making a field investigation for drainage are topography, soils, water lable, water source and crops.

DRAINAGE METHODS.

The layout of irrigation and drainage systems are closely related to the topography of the area and to the required or existing percolation, field and farm size. The systems are complementary, not only as far as flow is concerned, but also because the aligments of the irrigation and drainage conducts have to be located in such a way that a logical and economical layout is obtained with a minimum of crossings.

The most common of the drainage devices are the open and the subsurface drains.

THE DESIGN CRITERIA.

The required depth of the ground water, table drainage rate, the depth and spacing of the drains all have to be designed based on the informations collected from the drainage investigations.

The depth - Some factors enfluencing the depth are water table, quantity of excess mineral salts, etc. In most cases water table must be lowered to between 1 - 1.6 meters.

The spacing - The spacing of the drains is influenced by the topography of the area, types of soil etc. parallel open drains or tile drains should be spaced so that the minimum drawdown of the groundwater at the midpoint between drains is about 1 to 1.6 metres from the ground surface. A number of formulae have been developed for the calculation of drain spacing. However, it must be understood that the spacing will depend on:-

(1) the permissible water table depth between drains.

(2) the hydraulic conductivity of the soil to be drained and the quantity of water to be drained.

A more commonly used formula for drain spacing is the one developed by Hooghoudt. His equation states:-

$$L^2 = \frac{8k_2dh}{q} + \frac{4K_1h^2}{q}$$

where

L = drain spacing in m

q = drain discharge in m/day

K_2 = hydraulic conductivity of the layer below the drains in m/day.

h = the height of the water table above the drain lever midway between the drains in m.

d = tickness of the "equivalent layer" viz. a value depending on the drain spacing L, the drain radius r and the depth D of the impermeable layer below the bottom of the drain in m.

Hoodhaudt's equation is based on a number of assumptions among these are:-

(1) that drains are equally spaced.

(2) that Darcy's law is valid.

(3) that there is constant application rate of water.

(4) that an impermeable layer underlies the drain at depth d etc.

FIELD HYDRAULIC STRUCTURES.

The plan and the design of a new irrigation scheme will be incomplete if field hydraulic structures are not included. It is well known that a crop goes to its optimum yield if irrigated with a certain amount of water according to a certain programme which is deduced from pre-experiments on the same crop. The excess of irrigation water is wate, and besides it destroys the irrigable land and gives poor crops.

Thus the hydraulic structure used must be of the kind which can be easily operated to control the flow.

Field hydraulic structures can be grouped under three categories, namely:-

1) THE CONVEYANCE STRUCTURES - Such as those required where canal flows must be carried under or across drainage courses or other pronounced depressions; or where the flows must be carried under highways, railways or other permanent obstructions or where sizes and shapes of cross sections must be materially modified etc. Siphons, flumes, culverts, drops or chutes are examples in this category. See a sketch of siphon in Fig. 7.

2) THE CONTRAL STRUCTURES - These are required where main supplies must be divided between branch canals, or where water surface must be raised to facilitate deliveries or where canal flows must be discharged to natural channels or other suitable outlets.

Intake structures, division works, tail escapes and checks etc. fall in this category. A typical design of intake of lateral or main ditch taking water from canal is shown in Fig. 8 while Fig. 9 shows intake of small ditch from a main ditch.

3) THE PROTECTIVE AND MISCELLANEOUS CANAL STRUCTURES - These include structures installed to ensure the safety of the irrigation system and provide the facilities required in maintaining operation. Culverts to carry drainage water under canals, and measuring structures such as

ring flume and weirs are examples in this group. Fig. 10 shows typical design of metal and wood portable weirs.

DESIGN OF STRUCTURES.

The designs of field hydraulic structures at particular site very widely with local conditions and operational requirements. Features planned for different purposes often are incorporated in thesame structure. In some instances, features needed for certain protective purposes, may be built as elements of conveyance or contral structures.

The dimensions of the field structures refered to above depends on field conditions and the purpose for which they are designed to serve.

SECTION II

GAFARA IRRIGATION SCHEME - PLANNING AND DESIGN

INTRODUCTION.

One of the benefits to be derived from the gigantic Kainji Dam is the expansion of agriculture along the lake shores. The Kainji Lake is located between 9° 51'N to 10° 57'N and 4° 20'E to 4° 50'E. The western shore-line is situated in Kwara State while its Eastern shore-line is in North - West State. The length of the lake is about 130 Km and its maximum width is 24 Km. The highest water mark of the lake is fixed at 465ft (141.73 metres) contour level and this height is usually reached in around January/February. The lowest level of the lake is normally set at 430ft (131.06 metres) contour mark which is reached in August/September. These two levels are fixed by the NEPA.

As a result of this fluaction of the lake level two areas are available along the shore-line for irrigation practices. These areas are:-

1) The Draw Down.

This is the part of the shore-line available for cropping as the lake level recedes to the river channel from its maximum level of 465ft (141.73 metres) to 435ft (132.58 metres) contour mark.

2) The Upland Areas.

This is the area adjacent to the maximum lake that is not submerged by the flooding of the lake. This area is contained between contour 465 to 480 (141.73 to 146.31 metres) and above. Irrigation of this area is made possible during the period of the maximum lake level i.e. between November to May. Gafara Irrigation Scheme comes between these contour levels. (See the contour map).

SCOPE AND MAGNITUDE OF THE PROJECT.

The size of the scheme for this is 100 acres and this is the first phase of 4600 acres to be developed in the area by the government. The first phase is still in the construction stage. On the same site with the 100 acre-scheme is a research farm of 40 acres being constructed by the Kainji Lake Research Authority.

The following are the informations on the physical features, engineering aspects, technical soundness relating to the design of the 100 acre-scheme.

THE FEASIBILITY SURVEY.

LOCATION OF GAFARA.

Gafara is situated between 10° 21' and 4° 31'E in the Ngaski area of Yauri Division of the North Western State. (K.Klinkenberg IAR).

ACCESS ROUTE TO THE SCHEME.

The accessibility to the site is from three directions:

(1) Through Kainji - Auna - Wara - Gafara.

(2) Through Kontagora - Auna - Wara - Gafara.

(3) Yauri - Malando - Gafara.

SPECIAL CONSTRUCTION PROBLEM.

The greatest single construction problem of the scheme is the accessibility to the site. From my investigations the road from Ibeto - Auna - Wara - Gafara is a distance of 100 Km. This road is of earth surface with ten bridges built of timber beams spanning between abutments built with pieces of wood and stones stacked together. The road from Kainji through Auna and Wara to Gafara is a dry season road only while that from Yauri through Malando to Gafara is of similar nature to those described above (See Map No. 1).

It can be judged from the above report that to make the project a success the necessity of improving the access routes cannot be overemphasised.

MAJOR FEATURES OF THE SCHEME.

Physical features that may privide obstacles to construction of the scheme are absent on this site. The site is a plane of aluvial dotted here and there with some tree stumps which can be removed by mannual labour.

TOPOGRAPHY OF THE SCHEME.

The contour map of the area, has been produced(See Map No. 2) showing the tentative aligments of pipe line, main canal, the distributories and the drains.

CLIMATOLOGICAL DATA.

The representative meteorological stations for this area are at Yelwa about 60 Km away and Mokwa about 170 Km. No installation of any Agro-meteorological station has yet been carried out for the scheme but arrangements are underway to effect this.

The summerised data for Yelwa (FAO 1965) are these:-

1. Average daily minimum of the coldest month - 14.1°C.
2. Average daily maximum of the warmest - 39.1°C.
3. Men annual rainfall - 1010 mm.
4. Potential evaporation - 2310 mm.
5. Humid season June/July - End September.
6. Dry season November - end April.
7. Rainfall surplus (P-Ept) during humid season is 385 mm.
8. Drought stress Ept - P during hot humid s eason is 2185 mm.

The humidity is related to the movement of the ITD. Highest values are recorded during the rainy season (about 80%). Lowest values occur in January (Approx. 30%).

The mean annual solar radiation is 500 cal/cm^2/day.

During the rainy season squalls are common and blow from the east. They may reach peak velocities of about 45.72 km/hr. and occasionally up to 110 km/hour.

HYDROLOGICAL INFORMATIONS.

The source of water for the irrigation is from the flood water of the Kainji lake. During the period between November to May the level of the lake is allowed to rise to its maximum. This brings flood water to contour level mark of 465ft (141.73 metres) and thereby filling all the creeks along the Kainji lake shore line. Water can then be pumped from intake constructed from the creek to water the adjacent land of higher level.

THE QUALITY OF THE IRRIGATION WATER.

In general there seems to be little variation in chemical composition of lake water during the irrigation season, indicating that the lake is vertically fairly well mixed, although the degree of mixing of inflow and lake water decreases with increasing inflow rate (Zimmermann etal 1973). The general composition of the lake water is given below in Table 3.

CHEMICAL COMPOSITION OF THE LAKE WATER.

TABLE 3.

Dissolved Oxygen		Sulphide	Cations (Me/L)				Anions (Me/L)				
Oxygen	Conc.	Conc.	Ca	Mg	Na	K	Ko3	So4	No3	CL	EC
70%	1.4Mg/L	0.6Mg/L	0.2	0.2	0.01	0.04	0.55	0.05	0.05	0.05	45-60

Since the impoundment Na and K concentrations have decreased but the mg concentration has increased (Henderson, 1973). The PH value ranges from 6.2 to 8.5. Nitrates and phosphate are low but variable while silica conc. is very high.

THE CLASSIFICATION OF THE IRRIGATION WATER.

Considering the preding information the lake water seems to be very suitable for irrigation. The quantity of the water is in the class of C1 - S1, low conductivity and SAR (USDA 1969).

INFORMATION ON THE LAND USE.

The Soil Survey Report - The soil survey was carried by two members of the Institute for Agricultural Research A.B.U. from 13th to 28th March 1973 under the supervision of Mr. Khinkenberg. According to this report and other previous work on Gafara the area can be said to have two main units:

(1) a plain with loam or loamy sand over clay and

(2) a levee complex where the soils tend to be more sandy.

The levee complex occupies the northern part of the area. The general soil profile in this area is:-

0 - 12in light grey sandy loam or loamy sand over 30 - 60 in or more very pale brown to pale yellow sand over light grey mottled sandy clay loam.

The sand varies from fine to coarse grained and depth to mottling is also variable. The profile described above is the most extensive in this part of the area although some slight varieties of this general type are found within various levels of the profile.

In the clay plain the normal profile is 0 - 24 in. sandy loam, often containing gravel, over strongly structural clay. Most of the areas are inperfectly to poorly drained. This is why adequate drainage should be provided for the scheme.

This soil survey of the area is carried out only on the 40 acres scheme but this is considered adequately representative for the main development area of about 2000 to 4000 acres of alluvial complex near Ngoski.

CONSTRUCTION, LABOUR, MATERIALS AND EQUIPMENT.

The required personnel for the construction of 100 acre - scheme are:- One Irrigation Engineer, one Irrigation Superintendent and two Irrigation Assistants. The skilled labourers required are: two Masons, one Carpenter and two Artisans.

MATERIALS.

All cements and reinforcements needed for the construction are to be transported to site from the urban centres. Stones and agreggates can be obtained on the site.

EQUIPMENT/PLANT/VEHICLE.

1 earth - carrying scraper.

1 tractor and trailor.

1 fuel tank.

1 land-rover.

2 sets of radio tranceivers.

2 sets of workshop tools and equipment.

THE MANAGEMENT OF THE COMPLETED PROJECT.

After the project has been completed it will be managed by the staff of the State's Ministry of Agriculture deployed to the division concerned. All matters relating to agronomy will be referred to the Agricultural Officer while the engineering aspects will be dealt by the Divisional Irrigation Engineer.

THE FINANCIAL ASPECT.

Dependable figures for the estimated capital cost, maintenance and operating cost, overall annual cost and estimated revenues have not yet been worked out for the project. However, according to the Engineer in-charge of the project no less than ₦200 - ₦250 will be spent per acre of the scheme. As the size of the scheme increases the cost per acre is expected to reduce.

ECONOMIC ASPECT AND BENEFITS.

The following informations have been collected to determine the economic as well as beneficial aspects of the project:

A. Present Agricultural Production.

1. The main crops grown in the area are rice, millet and guinea-corn. Acreages belonging to individual ranges from 0.5 to 5 for rice.
2. The yields per acre of rice ranges from 6 to 10 bags. The farmers make very little or no use of fertilizers.
3. The prices receive at farm depends upon the time of the year. During the harvesting season a bag of rice usually costs ₦8.00 to ₦10.00. Thus a farm of 3 acres of rice would worth between 24 to 30 Naira.
4. The above figure for farm product can be regarded as the net Agric. production since apart from the manual labour no other input costs are usually incurred by the farmers.

By introducing irrigation project in the area increased Agric. production is expected. This factor brings the question of finding markets for additional crops.

MARKETS FOR ADDITIONAL CROPS.

Only village markets are available in the vicinity of the scheme and these are the Ngoski and the Wara markets. With the expected increase in Agricultural production these small markets cannot content with the volume of the new farm products. These have to be disposed through transporting them to other urban centres. The nearest of these centres are Yauri, Kontagora and New Bussa. However, for easy transportation there must be good roads. This is why access routes to the scheme need to be improved.

AGRICULTURAL PRODUCTION AFTER COMPLETION OF THE PROJECT.

No figures for the expected agricultural production after the completion of the project has been worked yet. This is because the 40 acres research farm adjaint to this scheme which will be put to irrigation trials to determine the optimum yield of crops is still in the construction stage. However, it is envisaged that the alluvial soils which dominate the area will give excellent result for rice cultivation. In expectation of this the director of the Kainji Lake Research Authority has recommended the establishment of modern rice mill in the area.

THE ECONOMIC BENEFIT TO BE DERIVED FROM THE SCHEME.

Although no actual figures have been worked out yet to substantiate the benefit the State Government will derive from the establishment of the scheme, I hold the opinion that substantial benefit will be derived. For instance, it is undoubtful that there will be increase in business and industry caused by the additional crop production.There will be also increase in general tax receipts. To the Federal Government gains and savings in foreign exchange will be recorded where farm products are exported. To the community living in the area their stanadard of living will be raised. Direct benefit will come to them through the local expenditure of the project funds for labour,materials food, rent etc.

THE DESIGNED IRRIGATION DATA.

METHODS OF DELIVERING WATER TO THE SCHEME.

An intake has been dug from the end of a creek projection (See part of Kainji Lake plan Map No. 3). At the end of the intake a pump house will be built to pump water into two pipe lines laid in parallel. These pipe lines will be discharge into concrete lined main canal.Water will be applied to the fields from distributory canals taking off from the main canal (See the tentative assignment of canals distributeries drains etc. on the contour map).

To ensure high irrigation efficiencies the "system of rotation" will be used in the delivery of water while the "graduated or excess rate charge" will be the method used for the water rate charge.

THE PUMP DATA.

Twin lister/Horland Units operating in parallel are to be installed. They are single stage S N R 5 centrifugal pumps direct coupled to lister H R 3 engines.

Designed total out-put will be 76 litres/sec. Total manometric head is 25 metres. Designed pump operating speed = 1400 r p m.

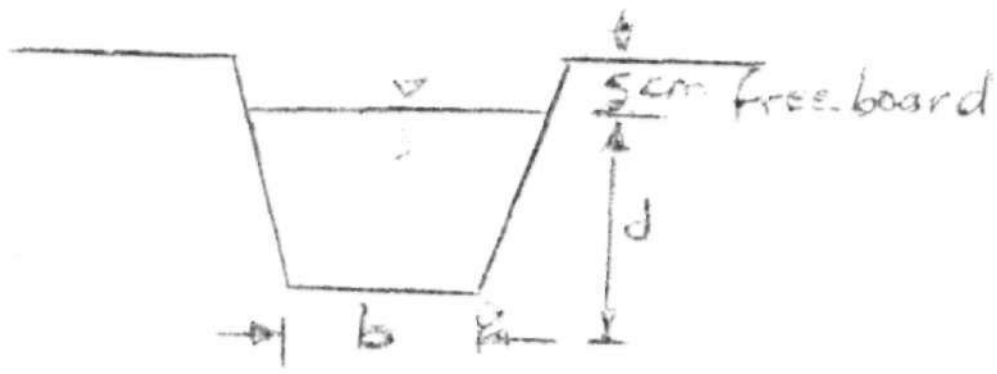
HEAD WORKS.

Measurement and control of water will be by Parshall Flume fitted with lenpold and stevens Type F automatic stage recorder.

THE DESIGN OF CANAL/DISTRIBUTERY CANAL.

The maximum capacity of the two pumps is 160 litres/sec approx. and this will be discharged into the main canal. Thus the main canal is designed to a maximum capacity of 160 litres/sec. Water will be diverted from the canal into two distributeries at a time. Therefore, each distributery canal will have a maximum capacity of 80 litres/sec.

Calculation for the design of one of the distributeries is as follows:-



From mannings,

$$Q = \frac{1}{h} AR^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where:-

Q = discharge in $cm^3/sec.$

A = cross sectional area.

R = hydraulic radius.

S = longitudinal slope.

For concrete lined canal with gravel bottom mannings n is taken as 0.0166. The designed slope, S of all the distributeries is 0.001.

For optimum discharge for the most economic section for a trapezoidal section:-

$R = \frac{d}{2}$ and the proportion will be that $\frac{1}{2}(b + 2md) =$

$$\frac{d\sqrt{m^2 + 1}}{}$$

where

m = slope of the side.

Using side slope of 45°

$$\frac{b + 2d}{2} = \frac{d\sqrt{1 + 1}}{}$$

$$b + 2d = 2.828d$$

$$b = 0.828d$$

Area of section.

$$A = (b + d)\,d$$

$$= (0.828d + d)\,d$$

$$= 1.828d^2$$

Capacity of distributory = 80 litres/sec.

$$80 \times 10^{3} = \frac{1}{0.0166} \times 1.828d^2 \times \left(\frac{d}{2}\right)^{\frac{2}{3}} (0.001)^{\frac{1}{2}}$$

d is worked out to be 51.5cm.

Now 6 = 0.828d

b = 0.828 x 51.5

= 43.0 cm

Allowing for 5cm for free board, total depth of the channel =57cm.

METHODS OF IRRIGATION.

The field is to be prepared mainly for surface irrigation. Below is the designed data for the irrigation:-

Designed monthly max. (G.I.R.) = 213mm in March.

Furrow length = 120m.

Furrow slope = 0.005 (average).

Application 46mm. gross on 6 day cycle.

Optimum furrow spacing = 0.75m)
Cycle 7 days = 1.5 litres/Sec) Set. = 1½ hours.

Printing flow
Cut back flow = 0.75

Border Strip:

Length = 120m.

Width = 10m.

Height of dykes = 0.5m.

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A P P E N D I X A

DESIGN OF SPRINKLER SYSTEM.

Suppose the following is a typical data collected for design of a sprinkler lateral.

The nozzle diameter of the sprinkler is 4.0mm (two nozzles). The selected discharge of each sprinkler is 2.61 m^3/hour obtained at a pressure head of 30m. Spacing of the sprinklers along the lateral is 12m except first which is 6m. The length of the field is 120m. The lateral operates along contour line and pipe should be aluminium.

Solution:

$$\text{No. of sprinkling positions} = \frac{\text{Length of field}}{\text{Spacing of sprinklers}}$$

$$= \frac{120}{12}$$

$$= 10 \text{ positions.}$$

Discharge at head of lateral:

disch. of one sprinkler x No. of sprinkling positions.

$$= 2.61 \times 10$$

$$= 26.1 \ m^3/\text{hour.}$$

Computation of head loss at the head of lateral:

Hazen-Williams formular gives the relation between the head loss and discharge for any pipe or system of pipes.

The formula is;

$$V = 1.10 \times 10^{-4} \; C.H.W. \; J. \; D^{0.63}$$

Simplifying give

$$J = \frac{2.16 \times 10^{7} \; V^{1.852}}{CHW \; 1.852 \; D^{1.167}}$$

where J = hydraulic gradient and units are m/km.

V = mean velocity in m/sec.

D = pipe dia in mm.

CHW = Hazen Williams coefficient.

The Hazen-Williams is also multiplied by a factor K which is a constant for the pipe or system of pipes. In this case K = 0.536.

According to Jensen and Frutini the first sprinkler position is assumed to be at a distance equal to half the sprinkler spacing. Christiansen, however, considered the first sprinkler as equally spaced as the rest.

The table below (Table 4) gives the different coefficients. These coefficients are multiplied by J. computed from Hazen - Williams equation in order to arrive at the head loss at the head of the sprinkler lateral.

The Table showing Christiansen and Jensen and Frutini coefficients.

TABLE 4.

No. of Sprinkler along Lateral	Coeff F. Christiansen	Coeff F. Jensen and Fruitiri
1	1. 00	1. 00
2	0. 639	0. 519
5	0. 457	0. 396
10	0. 402	0. 371
12	0. 394	0. 366
15	0. 384	0. 363
20	0.37376	0. 360
30	0. 368	0. 357
50	0. 361	0. 354
00	0. 351	0. 351

Continuing with the design, the head is computed for pipes sizes of 2", 3", and 4" diameter using Hazen-Williams equation and Jensen and Frutinis coefficient. (See Table 5).

TABLE 5. COMPUTATION OF HEAD LOSS FOR LATERAL.

Diameter of	J for C = 100	J for C = 140	Head loss = J for C = 140 x Lateral Length.
2	502 ‰	502 x 0.536 = 270‰	270 x 0.114 x 0.371 = 11.5m.
3"	98 ‰	98 x 0.536 = 525‰	52.5 x 0.114 x 0.371 = 2.2m.
4"	17 ‰	17 x 356 = 9.2‰	9.2 x 0.114 x 0.371 = 0.4m.

DETERMINATION OF SIZE OF PIPE.

The allowable pressure head difference should not be greater than 20% i.e. not greater than 20% of 30m = 6m.

From the above table it can be seen that 2" dia pipe would be too small because the pressure head of 11.5m is greater than allowable of 6m. Therefore the right size is 3" diameter pipe. The 4" dia. pipe will be uneconomical.

As the lateral is being operated along the contour line there will be no addition of elevation difference. It should be noted that the difference in pressure head along the sprinkler laterals is equal to the sum of the longitudinal head loss and the elevation differences along the pipe.

DESIGN OF SUBMAIN.

Two possible positions could be used for submain. The submain could either run at the centre of the field or at the edge of it. The bases of the design of the submain is to try as much as possible to reduce the losses at the barest minimum by positioning the laterals.

Suppose the following is a typical data collected for the design of a sprinkler submain:
Size of field - 360m x 240m; Submain runs at centre line at uniform slope of 2.2%; sprinkler opening is 5.5 x 4.0 mm diameter; selected pressure head and discharge os sprinklers are 30m and 2.61 respectively; lateral spacing is 18m and sprinkler spacing is 12m; height of

sprinkler rise is 0.8m; laterals operate along contour lines; number of sprinklers along lateral is 10; size of each lateral is 3" dia and discharge at its head is 26.1m^3/hour; pressure head at upstream of lateral is 33m. All riser value turn out are 3" and local head loss is 0.6m; the value of C is 100 and Hazen - Williams coefficient is 140, K = 0.536; submain is burried 0.6m below ground surface; energy loss at main and submain junction is 37.5m; the design irrigation interval is 10 days and one shift per day.

The design:

The number of sprinkling lateral positions along the submain is:

$$\frac{\text{length of field}}{\text{spacing of lateral}}$$

$$= \frac{360 \times 2}{18}$$ (this is multiplied by two because submain runs at centre of field).

For one daily irrigation shift the required number of laterals is given by:

$$\frac{\text{number of lateral positions}}{\text{Irrigation interval}}$$

$$= \frac{40}{10} = 4.$$

At Submain Riser Out,

The minimum required pressure head is calculated as: Press head at U/S at lateral + Elevation difference + local head loss.

$$= 33 + 0.6 + 0.6$$

$$= 34.2\text{m}.$$

This pressure head is assumed to be available at the end of the submain.

SELECTION OF SUBMAIN DIAMETERS AT VARIOUS SECTIONS:

The submain diameters are computed starting from point (4) upstream. Each submain riser outlet is checked against the required pressure of 34.2m. and 37.5m pressure available at the submain.

Using Hazen - Williams equation head losses are computed as shown in Table 6 for various selected pipe diameter and the respective partial discharges along the submain.

TABLE 6.

COMPUTATION OF HEAD LOSS FOR SUBMAIN.

For disch. = 26.1m^3/hour, L = 90m = 0.090 km.

DIAMETER	J	Head loss, YL	
3"	98 ‰	98 x 0.090 x 0.536	4.7m
4"	17 ‰	17 x 0.090 x 0.536	0.8
For disch. = 52.2m^3/hr.			
4"	62 ‰	62 x 0.090 x 0.536	3.0m.
6	9 ‰	9 x 0.090 x 0.536	0.4m.
For disch. = 78.3m^3/hr.			
4"	131 ‰	131 x 0.090 x 0.536	6.3m.
6	18 ‰	18 x 0.090 x 0.536	1.0m.
8	5 ‰	5 x 0.090 x 0.536	0.3m.
For disch. = 104.4m^3/hr. L = 100m = 0.10Km.			
6"	31 ‰	31 x 0.10 x 0.536	1.7m.
8"	8 ‰	8 x 0.10 x 0.536	0.4m.

Section (4) to (3)

The required pres. head at point (4) is 34.2m. Observing the table above 3" dia. pipe would be too small therefore 4" pipe is selected.

The computed pres. head at point (3) is therefore 34.2 + 0.8 - 2.0 (Elevation difference is 92 - 94 = $^{-2}$) = 33m. As this falls below the required min. of 34.2m. the hydraulic grade line is raised by 1.2m making the pressure head of point (4) equal to 35.4m.

Section (3) To (2)

From the above table it can be observed that the 4" diameter pipe is suitable.

As before the elevation difference between (3) and (2) is 94-96 = $^{-2}$. The longitudinal head loss of 4" pipe is 3.0. Therefore the computed pressure head at point (2) is 34.2 + 3.0 $^{-2}$ = 35.2m.

Section (2) To (1)

A 4" pipe seems too small, a 6" pipe is selected.

The elevation difference between points (2) and (1) is 96-98 = $^{-2}$. The longitudinal head loss due to 4" dia. pipe is 1.0. The computed pressure head at point (1) is therefore 35.2 + 1.0 $^{-2}$ = 34.2m.

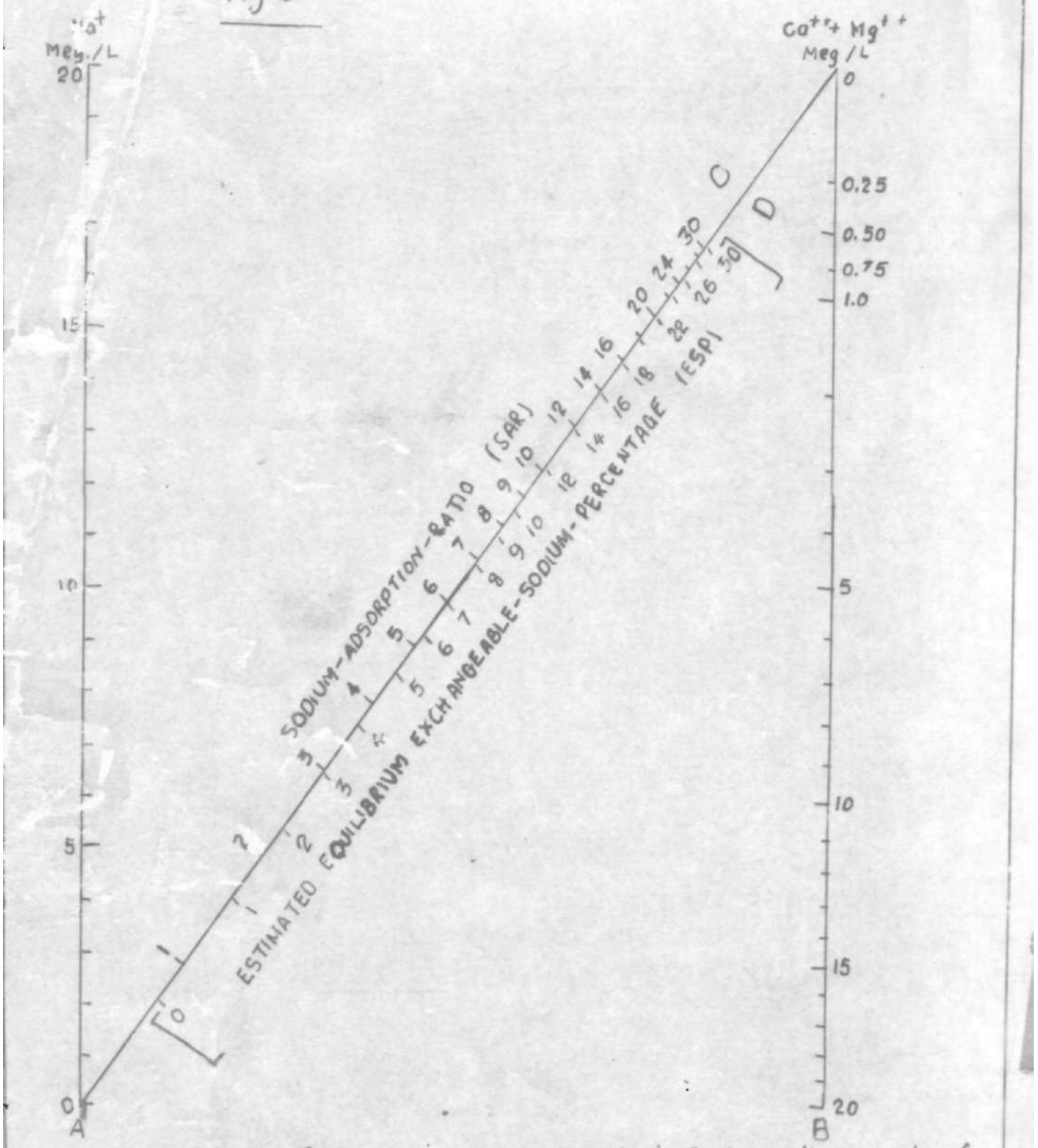
Section (1) To (A)

From observation a 6" dia. pipe seems more suitable.

The elevation difference between points (A) and (1) is 98 - 100 = $^{-2}$. The local head loss is 1.0m. The longitudinal head loss due to the 6" pipe is 1.7. The computed pressure head at point A is therefore 34.2 + 1.7 + 1.0 -2 = 34.9m. It can be noted that this pressure head is less than the available pressure head of 37.5m. The difference of 2.6m may be regarded as factor of safety.

****

Fig 1.



Nomogram for determing the SAR value of irrigation water and for Estimating the Corresponding ESP value of a Soil that is at equilibrium with the water.

Source - Agriculture Handbook 00 U.H Dept of Agriculture

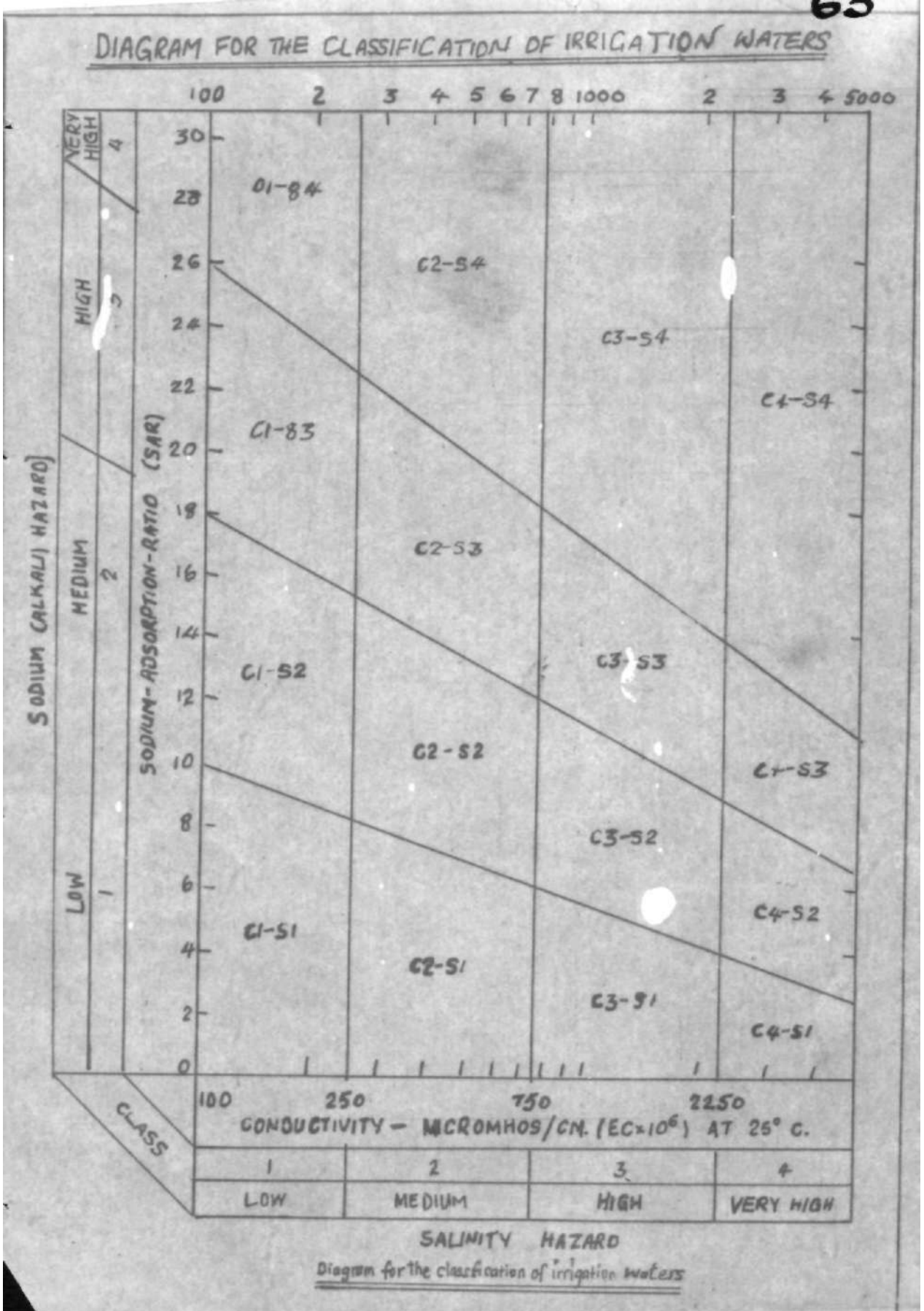
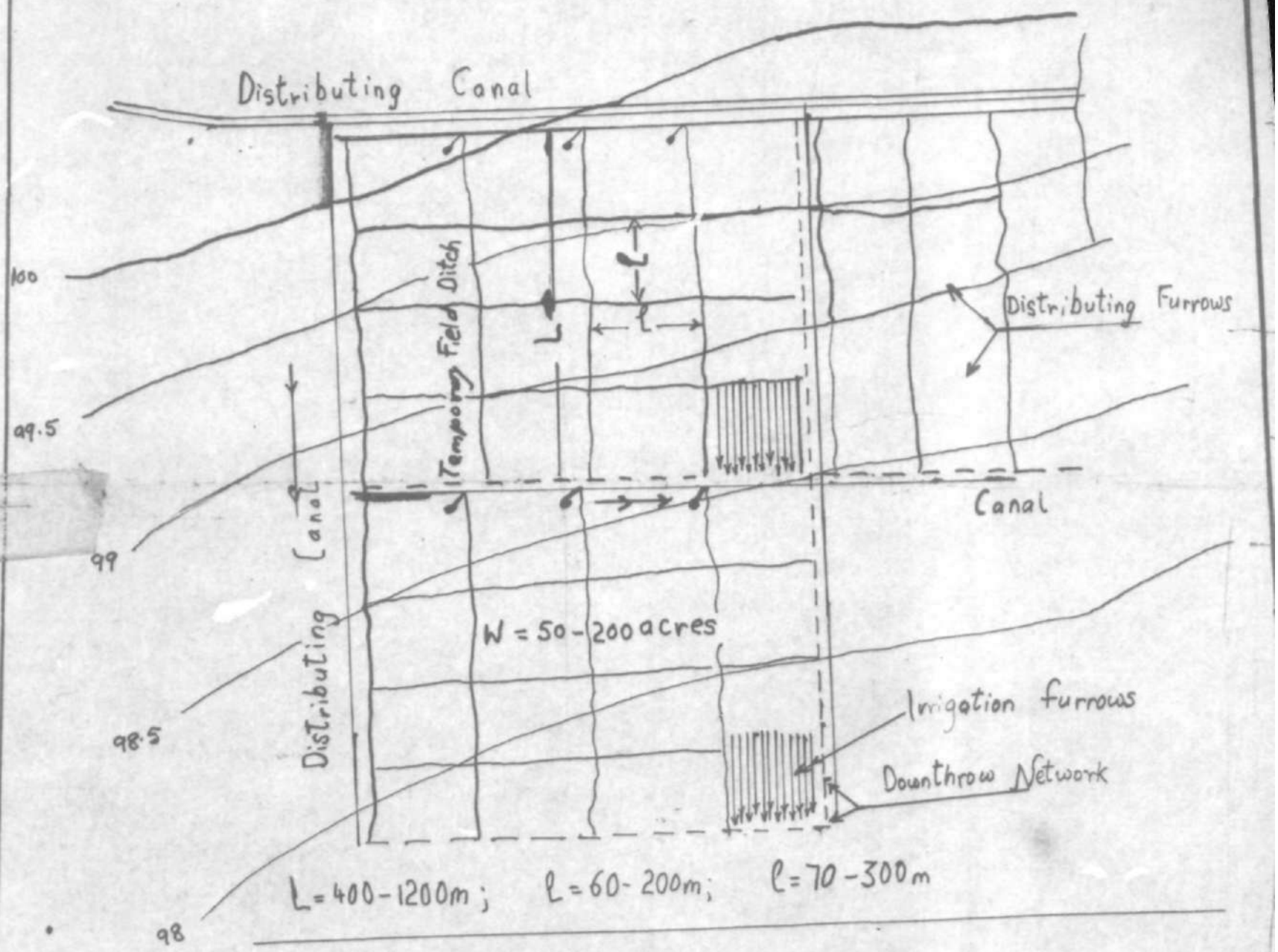


Diagram for the classification of irrigation waters

Sourse _ Agriculture Handbook of U.H. Dept of Agriculture

Fig 2

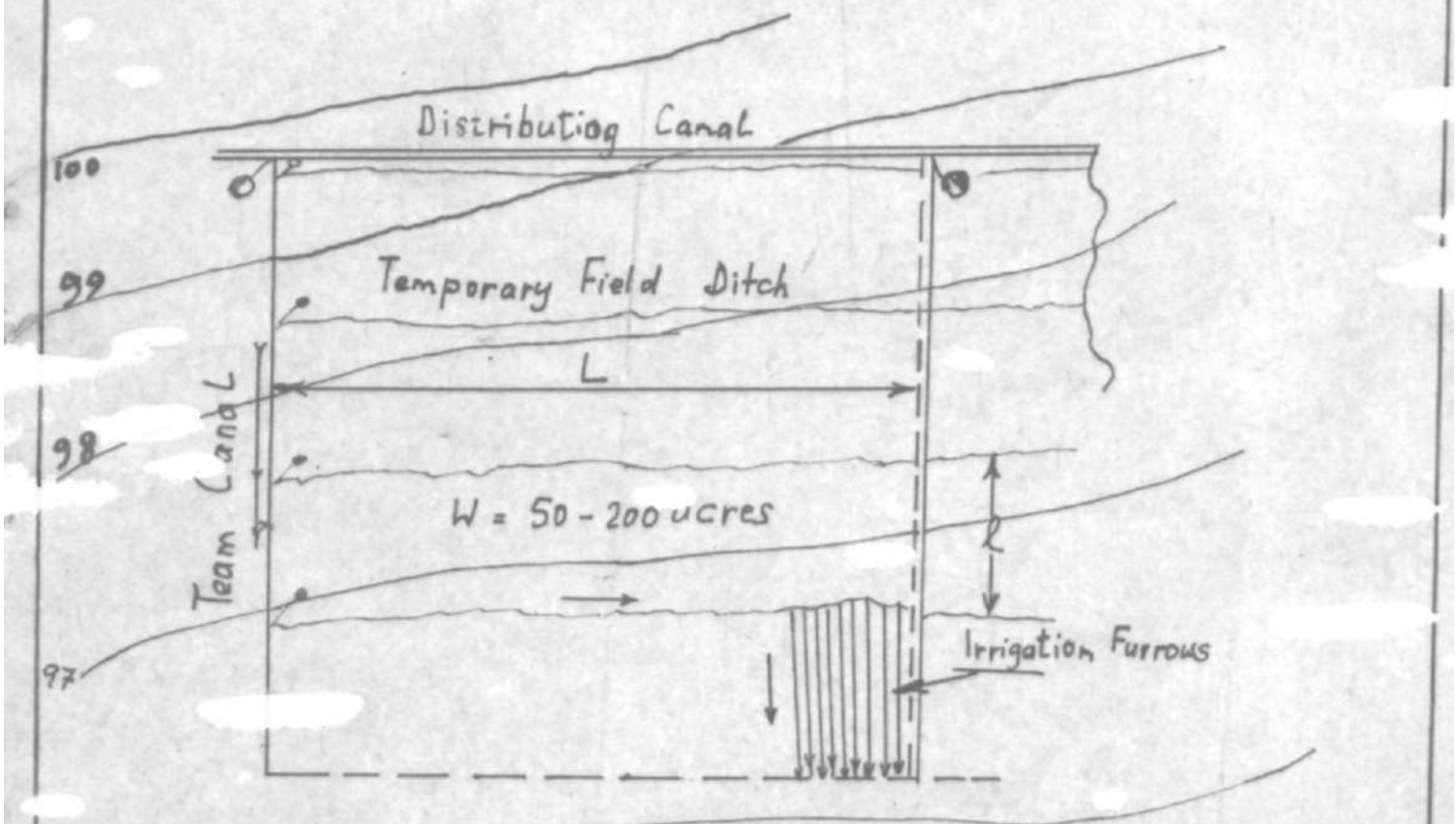
Scheme. - Showing Longitudinal System of Arrangement of Temporary Irrigation Network



Longitudinal System of Arrangement is recommended on slopes of up to 0.004

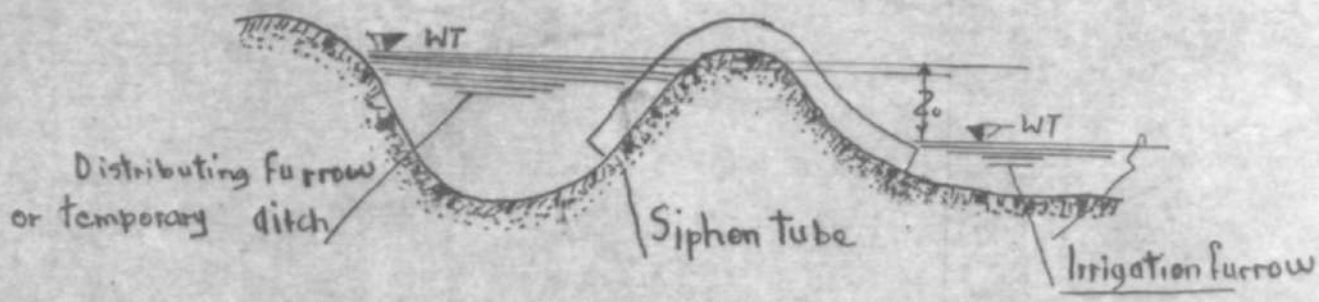
Fig 3

Scheme - Showing Cross System of Arrangement of Temporary Irrigation Network*



* Cross system of arrangement is favoured on slopes of more than 0.004

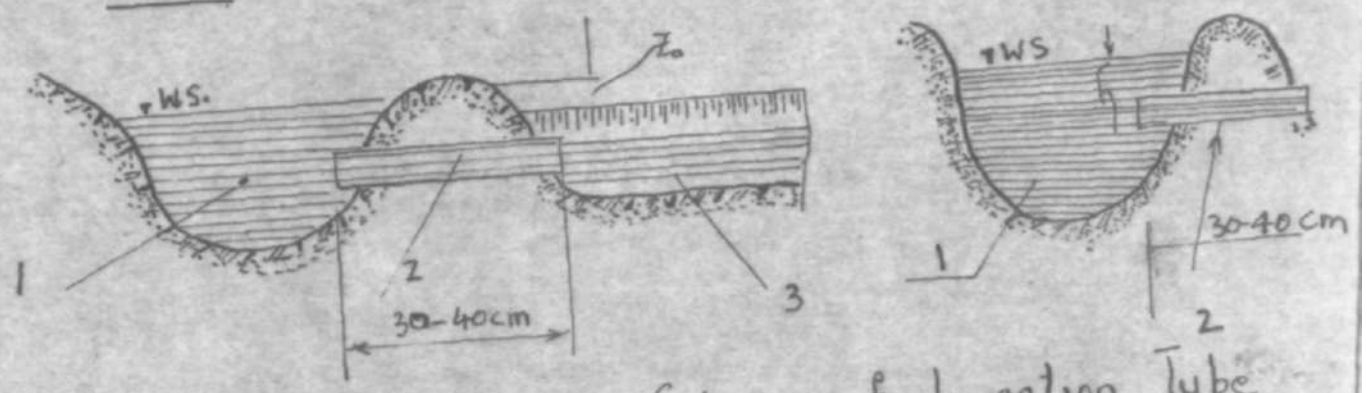
Fig 6.



Scheme Showing Arrangement of Siphon Tube

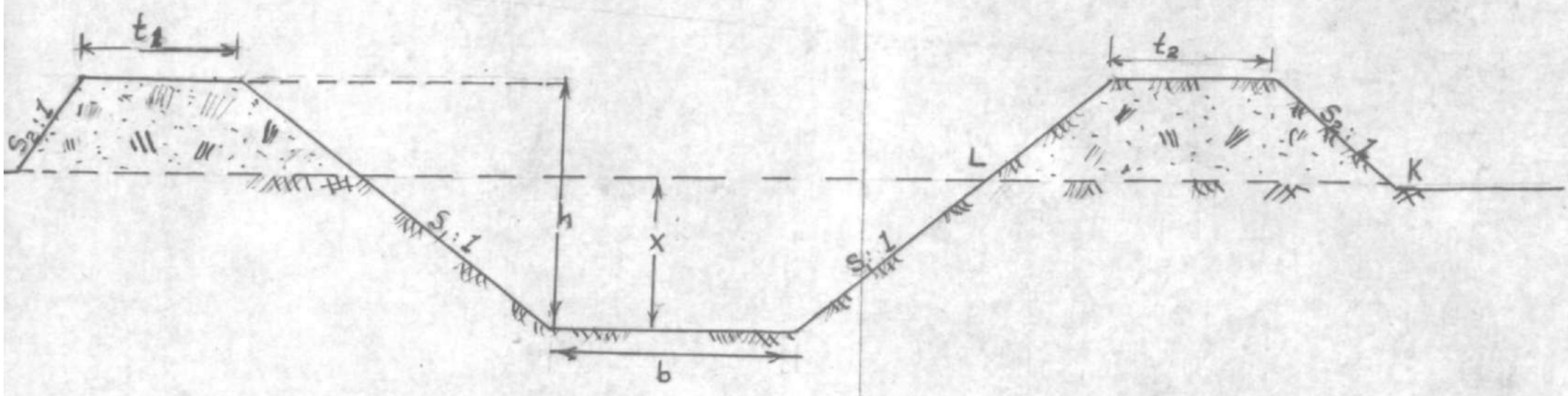
Fig 5A. 5(A)

Fig 58



Arrangement Scheme of Irrigation Tube

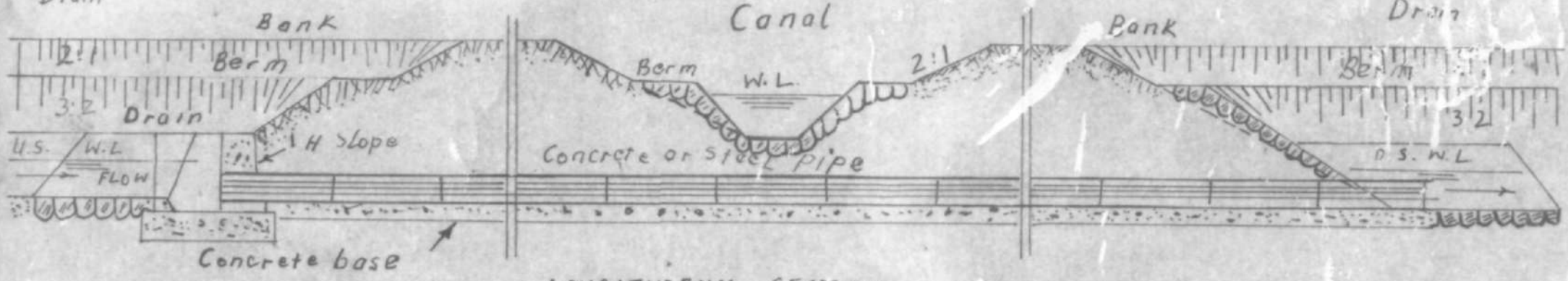
1. Distributing furrow or temporary field ditch
2 Irrigation tube
3 Irrigation furrow



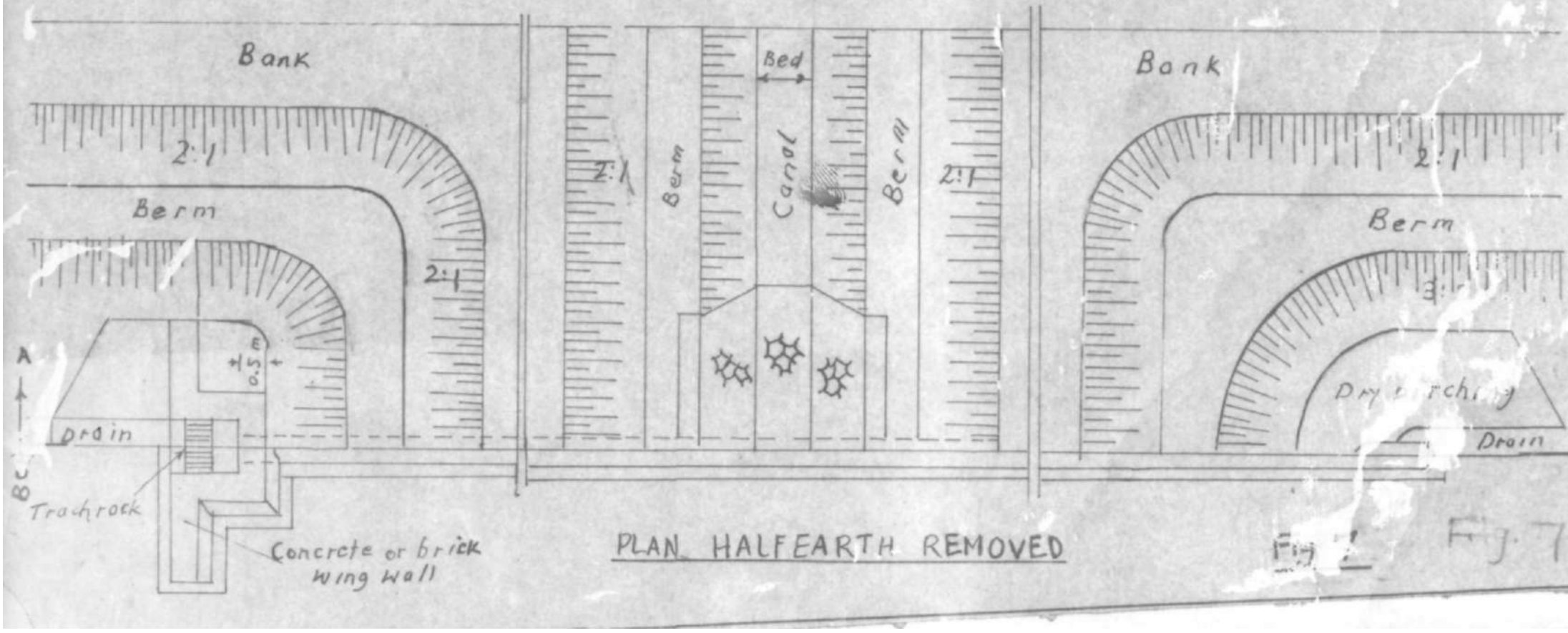
TYPICAL CANAL SECTION

Fig 6

SIPHON



LONGITUDENAL SECTION



PLAN HALFEARTH REMOVED

Fig 1 Fig 7

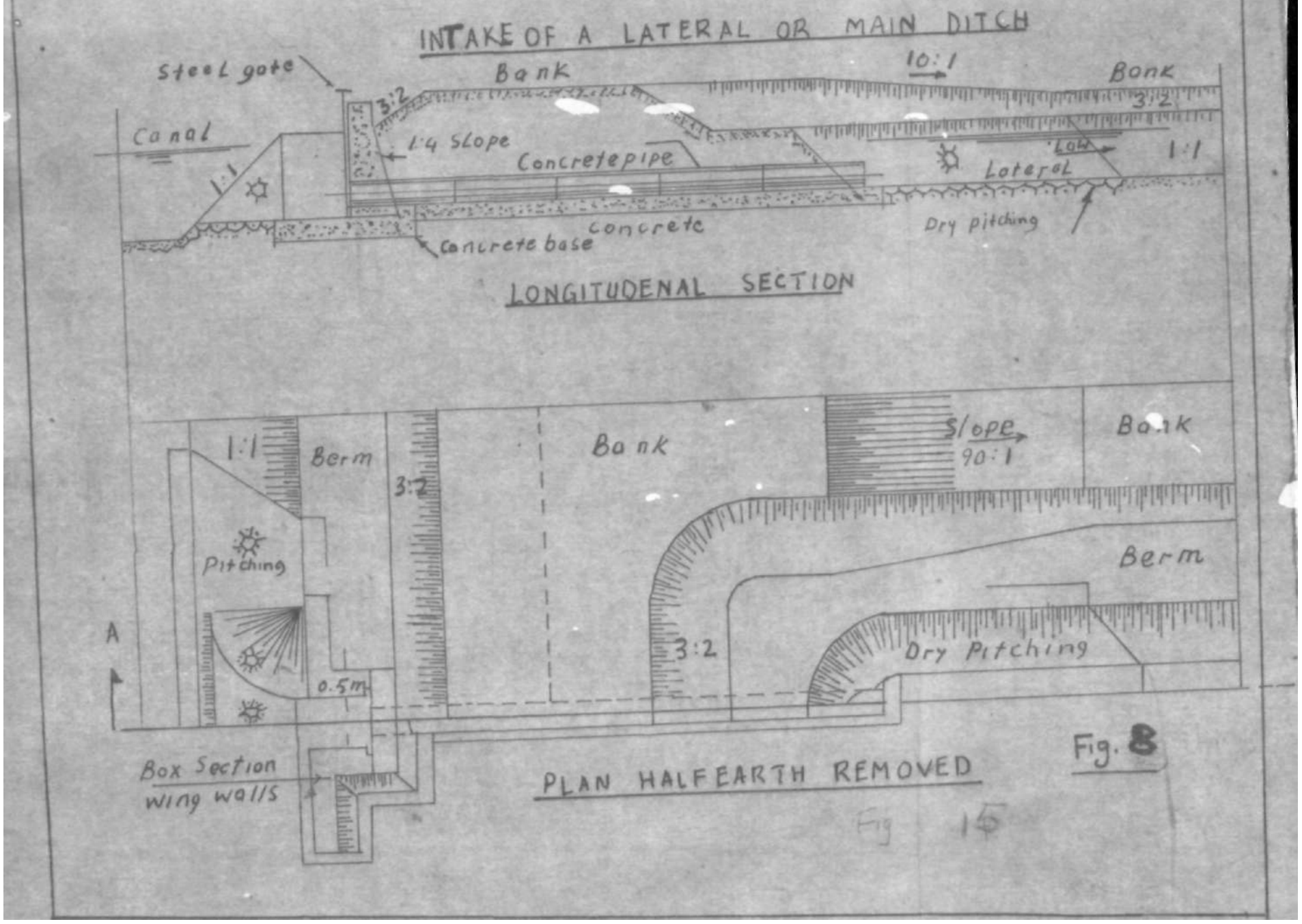
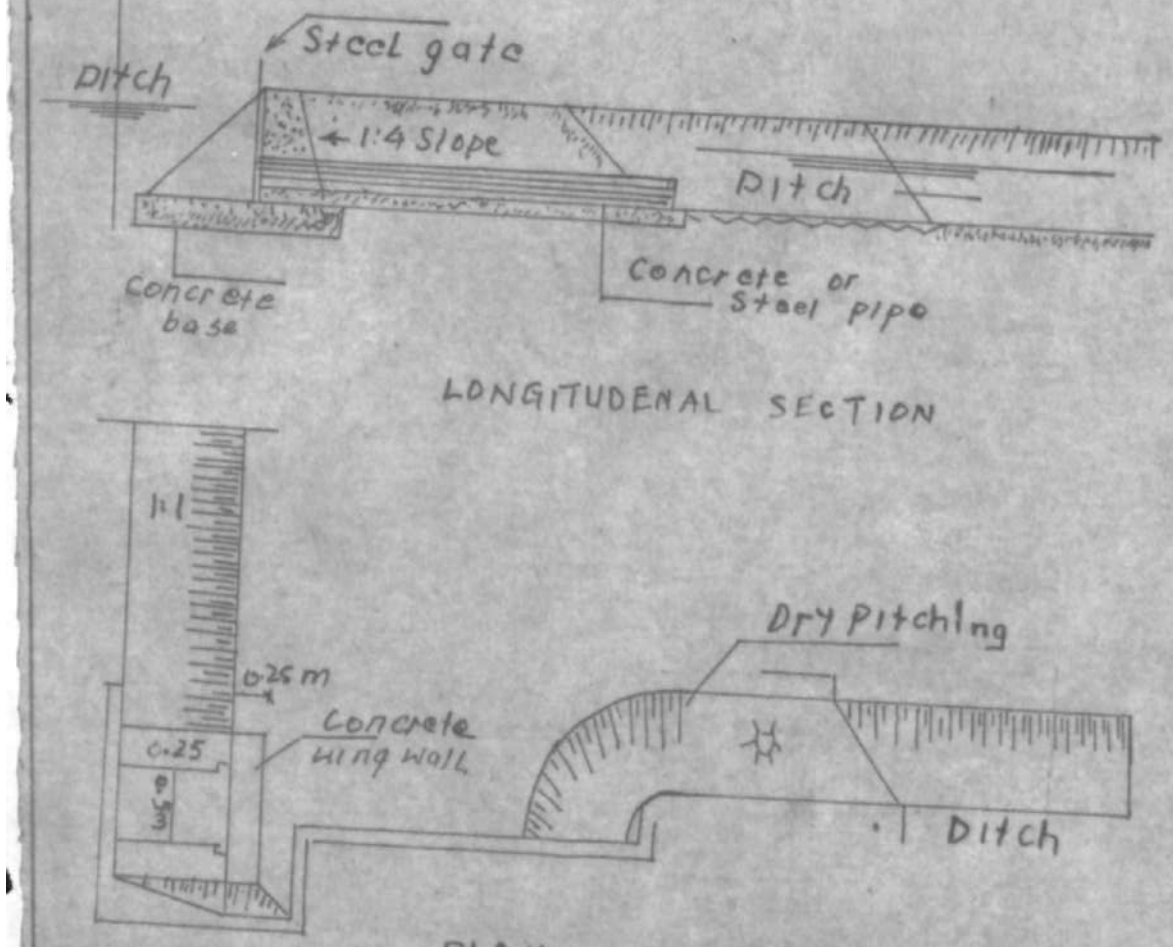

INTAKE OF A LATERAL OR MAIN DITCH
Steel gate
Bank
10:1
Bank
3:2
Canal
1:4 slope
Concrete pipe
1:1
Lateral
1:1
Concrete base
concrete
Dry pitching
LONGITUDENAL SECTION
1:1
Berm
3:2
Bank
Slope
90:1
Bank
Pitching
Berm
A
3:2
Dry Pitching
0.5m
Box Section
wing walls
PLAN HALFEARTH REMOVED

Fig. 8

Fig 15

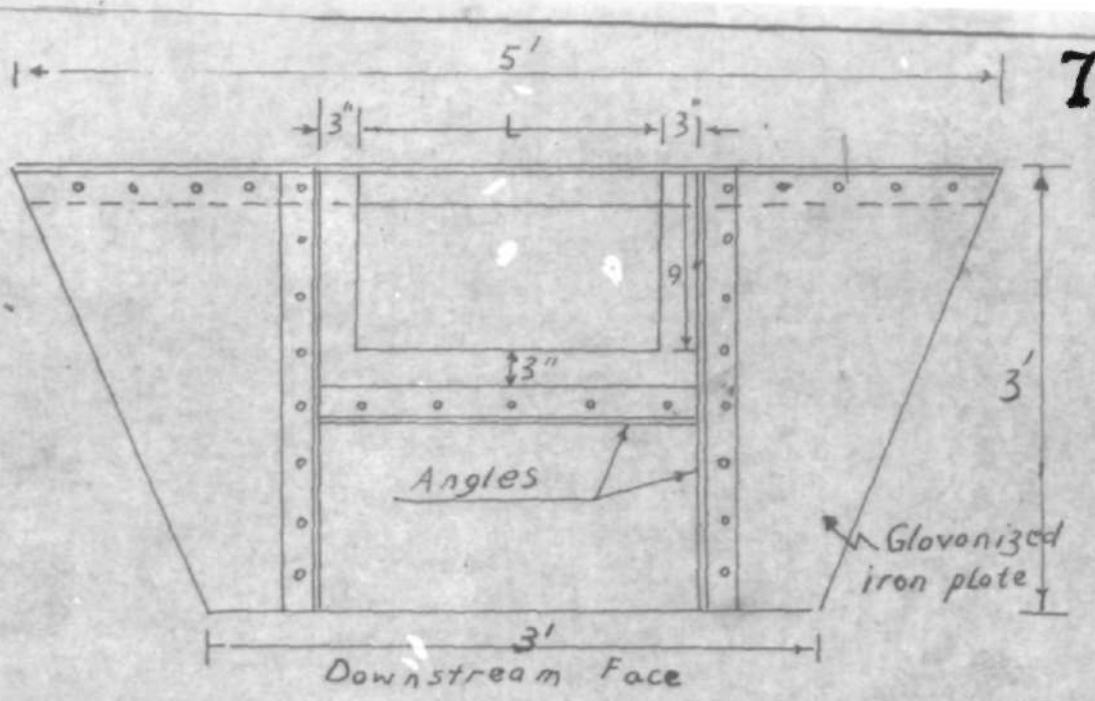
INTAKE OFASMALL DITCH



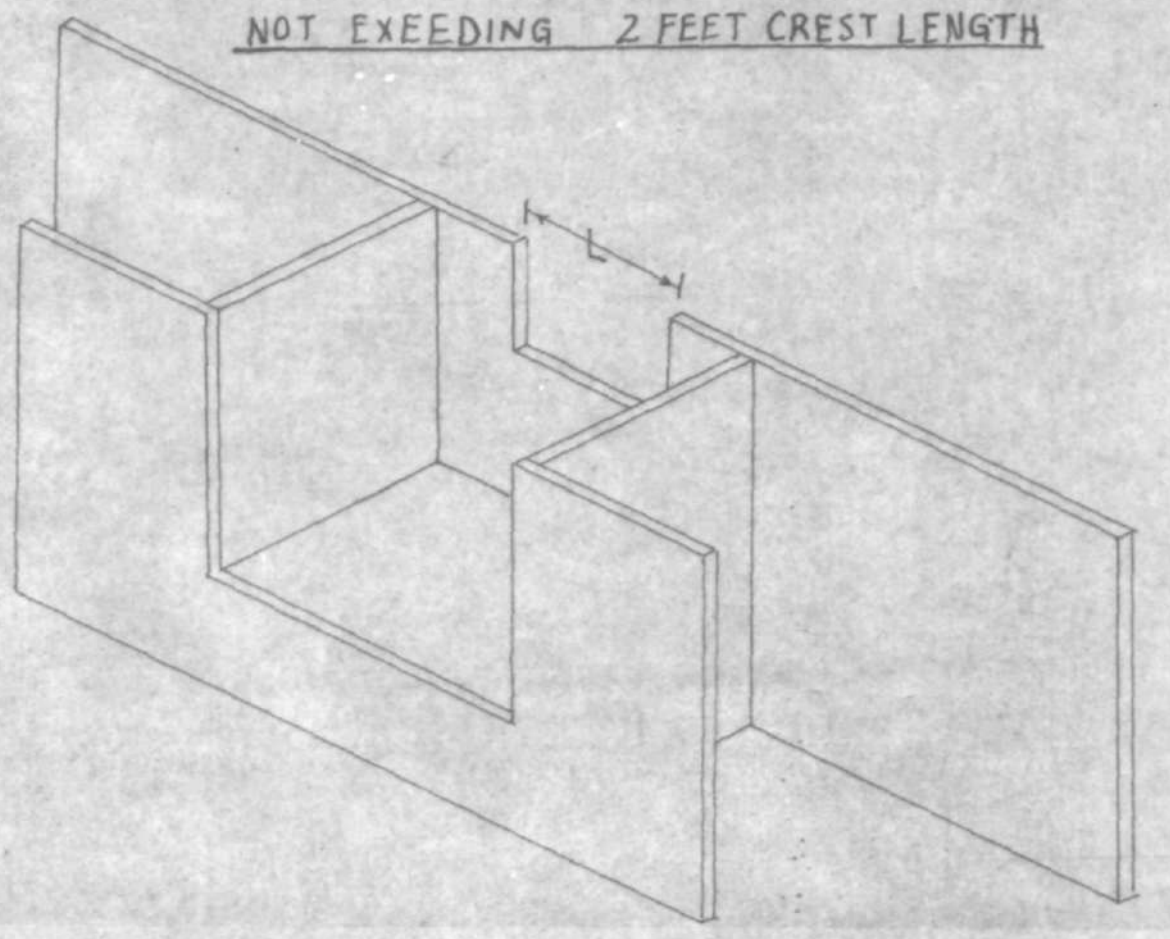
LONGITUDENAL SECTION

PLAN HALF EARTH REMOVED

Fig 9

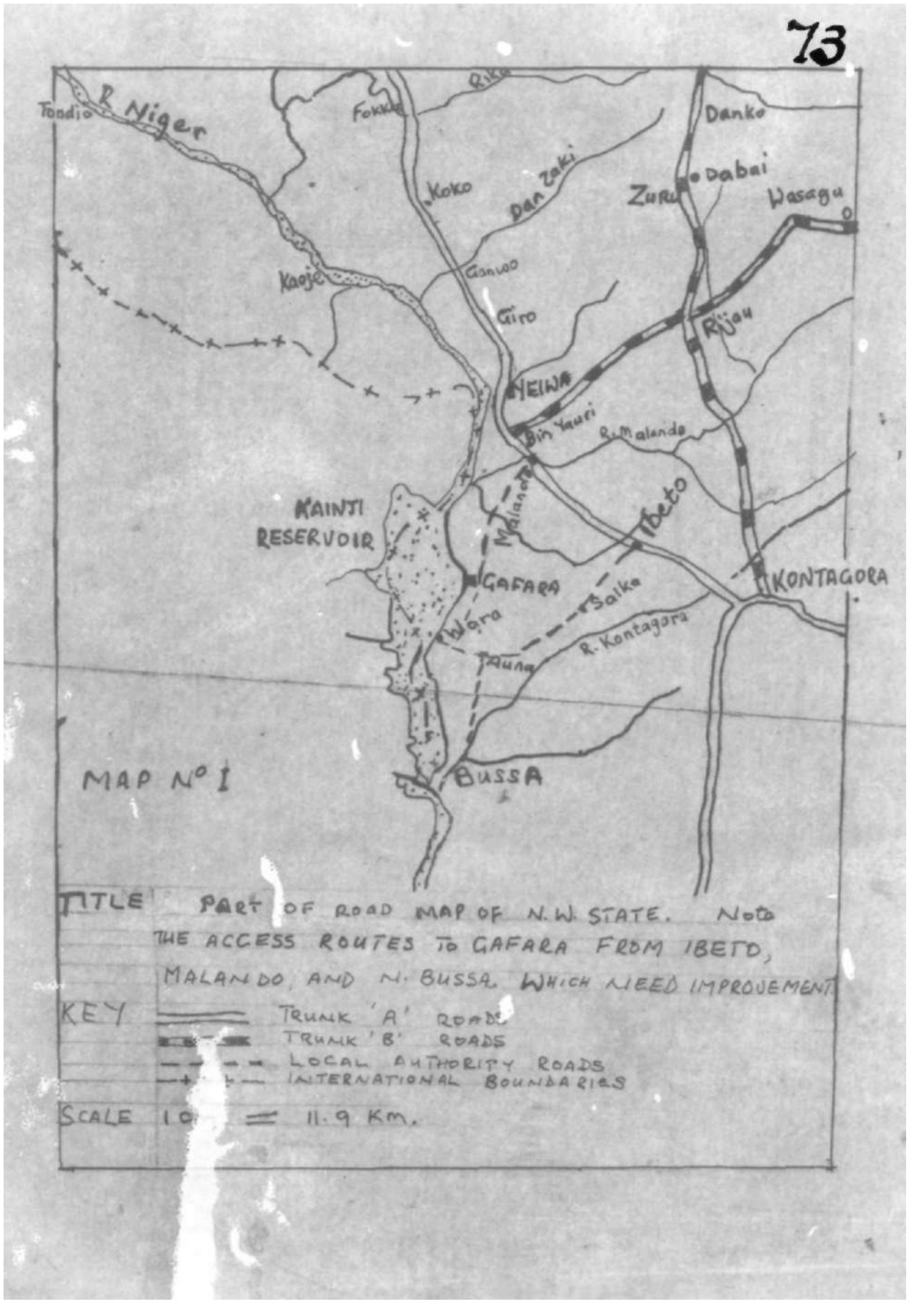


DOWNSTREAM FACE OF PORTABLE METAL WEIR NOTCHES NOT EXEEDING 2 FEET CREST LENGTH



DOWNSTREAM PERSPECTIVE OF WOODEN WEIR STRUCTURE

Fig. 10


Tondio
R. Niger
Fokku
Rika
Danko
Koko
Dan Zaki
Zuru
Dabai
Wasagu
Kaoje
Ginuoo
Giro
Rijau
YELWA
Bin Yauri
R. Malando
Malando
Ibeto
KAINJI
RESERVOIR
GAFARA
Wara
Salka
Fauna
R. Kontagora
KONTAGORA
BUSSA
MAP N° I
TITLE Part of road map of N.W. State. Note the access routes to Gafara from Ibeto, Malando, and N. Bussa. which need improvement.
KEY
Trunk 'A' roads
Trunk 'B' roads
Local Authority roads
International Boundaries
SCALE 10 = 11.9 Km.

MAP N° 2

PART PLAN OF KAINJI LAKE SHOWING POSITION OF GAFARA SCHEME.

Note The Basic Outline And Contour LINES TRACED FROM BEATTY AND Co. Ltd._ NEDEKO

Scale Miles ½ 0 1 2 3 4 5 6 7 8 9 10

