FKA. SAC

Small Scale Irrigation Systems Designs for Four Mauritanian Oases

by

Ross E. Hagan
Agricultural Engineer

11 January to 7 February 1982
(field work)

Oasis Development Project
PIO/T No. 682-0207-3

Frederiksen, Kamine and Associates, Inc.
1900 Point West Way, Suite 270
Sacramento, California 95815
(916) 922-5481

Table of Contents

Acknowledgement
I. Sani Research Station, Domestic Water Supply
II. Sani Research Station, Tent Camp Site
III. Sani Research Station, Irrigation System
IV. Samoga, El Grahan, N'Tarhad El Ouassa
Annex

ACKNOWLEDGEMENT

The Hydra-drill 201-P well drilling rig and ten pounds of hole stabilizing jell were furnished by the Vegetable Production Project.

I. Sani Research Station, Domestic Water Supply

A borehole was constructed near the road and in close proximity to one of the cooking areas. The borehole had the following profile characteristics:

0- 10.4 m	fine sand
10.4m- 14.9 m	compacted clay (rock like)
14.9m-	sandstone (drilling stopped at 16.8 m)

On Jan. 21, 1982 the static water level in the borehole was at 3.1 meters. The top 10.4 meters of the well was lined with a 4 inch diameter PVC pipe, the bottom 2.4 meters of which were slotted to allow an inflow of about 6 gallons per minute at an entrance velocity of 0.1 ft/sec. The casing was seated in about 6 inches of the compacted clay and gravel packed. A two meter diameter, three inch thick reinforced concrete pad has been placed around the well head to divert runoff water away from the well.

The well was developed and a hand pump installed. The water from the well contains some fine sand and clay. Over time the clay particles will be flushed from the aquifer, they are in the aquifer as a result of the drilling operation. To eliminate them during development would require continuous pumping of the well for longer than 24 hours, this is not practical. The fine sand may or may not diminish with time. In the event it does not diminish, or for the interim period, a simple filter can be used to remove the sand from the water.

The well was pumped for four hours with a mptor pump, the water level dropped from 3.1 to 4.8 meters; at the termination of pumping the water level returned to the 3.1 meter level in a very short time. This would indicate that the aquifer is large and transmissivity is high.

The well is located about 35 meters from the seepage pit for the bathroom/shower. Given the type of soil, a sandy loam, this distance exceeds the minimum recommended by the Iowa Department of Health.

II. Sani Researhh Station, Tent Camp Site

- Water Distribution System

The distribution system design is based on the assumptions:

(1) No flush toilets will be used

(2) Each person uses no more than the equivalent of 100 liters of water per day

(3) The peak water use is concentrated in two two hour periods of the day (morning and evening)

(4) There will be 10 living units (tents), one central kitchen/dining unit, and one community/recreation unit

(5) Water will be pumped to a cistern located at elevation 179 m (approx) and will backflow by gravity to the units, a drop of 15m (approx).

	Water Demand				
Persons	Liters per day	Four hour rate (l/h)	Nominal pipe size	Water pressure	Lateral line pipe size
10	1000	250	1 in.	20 psi	$\frac{3}{4}$ in.
20	2000	500	1	20	$\frac{3}{4}$
25	2500	625	1	19	$\frac{3}{4}$
30	3000	750	$1\frac{1}{4}$	20	$\frac{3}{4}$
35	3500	875	$1\frac{1}{4}$	20	1
40	4000	1000	$1\frac{1}{2}$	20	1

From the table it is apparent that the main line need be no larger than 1 inch diameter for up to 25 persons and $1\frac{1}{4}$ inch diameter for up to 40 persons (4 persons per tent) which is assumed the maximum allowable. The use of larger pipe will not be cost effective, for zero head loss (100% efficiency) the water pressure is only 21.3 psi. The head loss is calculated for 305 m (1000 ft) of run, this allows about 25 meters for all secondary head losses (pipe fittings, valves) which is somewhat liberal.

The lateral lines should be $\frac{3}{4}$ and 1 inch diameters as shown in the table. This is assuming that each lateral serves 5 tent units and the service units are on a separate lateral.

It is <u>impractical</u> to use a hand pump to fill the cistern. Consider, the cistern is located at a distance of about 250 meters from the well. Considering only the mass of water in a 1 inch diameter plastic pipe:

$$A = \frac{\pi d^2}{4} = \frac{3.14(.083)^2}{4} = 0.0055 \text{ ft}^2$$

$$V = A \times L = 0.0055 \times 250 \times 3.281 = 4.51 \text{ ft}^3$$

Water weighs about 62.4 pounds per cubic foot, therfore, the water in the pipe will weigh 281.4 pounds. To this must be added the weight of the water in the pipe from pump head to the water level in the well and the friction forces between the water and walls of the pipe.

For each stroke of the pump this mass of water must be moved. With a pump lever arm ratio of about six to one, a force of about 50 pounds will be needed to raise the piston for each stroke.

Since an electric pump may be used, the cistern could be eliminated and pressure tanks used instead. The pump would only need to run for about four hours per day, two hours each morning and evening. Throughout the rest of the day water demand should be low and could be supplied by the residual water in the tanks.

- Well

A borehole lined with a 4 inch PVC slotted pipe has been installed in the approximate location of the camp. The well is about 18½ meters deep through fine sand and seated in heavy compacted clay (similar to the well on the research station proper). The water level is at the 9 meter level (approx). Mr. George Collins has the details for this well.

III. Sani Research Station, Irrigation System

- Delivery System

A main delivery canal would run along the upper (next to the road) edge of the station. This canal should be lined as it will pass through sandy soil. Along the canal five large diameter lined wells would be constructed. These wells are to be used for the various water lifting options and will supply water to the canal. The canal would more or less follow contour line 158 (see maps); it is normal practice to cut through high sections and fill low ones to keep the canal from having sharp bends. The central well (number 3) will be located at the high point in the canal. From this point water will flow both directions, i.e., the canal slopes downhill both directions from this point. The slope of the canal would be about 0.001 m/m.

From trial calculations it was found that it is impractical to construct the optimum canal size for the given irrigable area. The optimum canal has a four inch bottom width and a three and one half to four inch water flow depth. This is to small to be constructed with ease considering the tools on hand. Therefore, the canal constructed will be significantly oversized. Small channels are more easily formed if a semicircle is used for the bottom (the shape of a commom shovel). The sides are then flattened to the correct side slope.

Given the difficulty in shaping a trapezoidal canal it is unlikely that precast concrete channel liners can be used. In most cases where concrete is used for lining it is more economical, in terms of time and labor as well as material, to cast the lining in place. See annex for more details on channel linings.

The simplest channel offtake to construct is a pipe through the channel bank. A steel pipe is to be preferred over one of plastic, concrete and most other materials do not adhere to plastic. If the seal between the channel lining and pipe is not water tight seeping water will over time cause that section of the channel to fail. Often a concrete cut off wall is placed around the offtake. This is a thin section slab through which the pipe passes and about which the earth of the channel bank is compacted, see figure. As an alternative, siphon tubes may be used. Siphon tubes can be made locally from nonrigid plastic

pipe. See annex for figure and rating curves for small siphons.

Check structures are used to control the water height in the channel. Checks are nothing more than a wall in the channel that have an adjustable height. They can be made of steel, concrete block, or reinforced concrete. Wood would probably not last in Mauritania. See annex for a figure.

- Distribution System

The tree nursery area can best be irrigated by a buried pipe system. This would put the system underground and out of the way when seedlings are moved about and other necessary work is accomplished. The system would use a $\frac{3}{4}$ inch diameter pipe for the main line with tees at each bed for an outlet. See figure in the annex. The elbow at the end of the pipe (for each bed) should be fitted with a male hose thread. An alternative would be the use of a hose bib in place of the gate or globe valve. This will allow the use of a garden hose or drip irrigation on each bed.

- Care must be taken in choosing fittings such as hose connections. The French fittings available locally do not fit American hoses.

The drip irrigation system for the beds can be variable, i.e., the number of lateral lines may vary, depending on the number of rows in each bed. Normally for potted seedlings each bed contains 15 to 16 rows of pots (pots are 8 cm diameter by 30 cm deep). For open-rooted beds there are normally 6 rows of trees, planted at 5 cm intervals in each 1.2 m bed. In one sense the number of laterals is determined by the number of trees, there is only so much lateral surface area in which to place microtubing.

- For short laterals all microtubing in each bed should be the same length to ensure that each plant receives the same amount of water.
- If one hose is used per bed and it is serpentined around the bed, significant flow differences can be expected between the first and last emmitter. This is due to a combination of friction losses and pressure loss as water is removed from the lateral.

For the areas where trees are growing, the best irrigation system would probably be serpentined open channel. This will allow the channel to move down the area from tree to tree at a relatively flat slope. Given the sandy soil of Sani these channels may have to be lined to hold water losses to a reasonable level. In some cases drop structures may have to be used where the channel doubles back. This will to a large extent depend upon the relationship between tree rows and the land contour.

Conventional drop structures of reinforced concrete can be prohibitively expensive. A cheaper drop structure can be constructed using a pipe with a stilling basin at the lower end. The pipe at the upper end can be bent upright, or a larger pipe installed around it, to control the water elevation in the upper channel. Another option would be a check structure just before the drop.

In the garden areas basins can be used to hold water which will be distributed by watering can. The basins can be constructed from concrete block and plastered with a waterproofing mixture on the inside. The basin size is up to the builder, a common size would be 1.5 m wide by 2 m long by 1 m deep.

Two methods can be used to fill the basins. Open channels would seem to be the simplest, however, there are problems involved. The use of open channels would require the presense of someone each time water is turned into the basin. This person must monitor the inflow and close the channel outlet when the basin is full. The basins are at a lower elevation than the canal and could overflow. The channels will also remove land from production and may complicate traffic patterns in the garden.

Pipes can be used to fill the basins. The pipe inlets can be fitted with a float valve which would automatically close off the water inflow when the basin is full. As long as the canal has water over the pipe offtake, the basins will continue to fill as water is removed from them for watering. The pipe can be buried thereby limiting the land removed from production to that required by the basins.

The pipes should enter the basins at least 15 cm above the floor of the basin and not have any sharp bends, such as elbows. In the event a branch line is necessary, to fill another basin perhaps, a Y fitting should be used. These construction practices will allow for unplugging the pipe if it becomes necessary. Where the pipe exits the canal it should be protected from plugging material by screening.

The steep slope of Sani Station away from the canal makes the use of furrow irrigation somewhat difficult. The furrow across the slope is no problem because it follows the contour. The difficulty comes in getting water from the canal to the furrows. It can be done if several drop structures are used. Between the drop structures the channel will be relatively flat and the water level can be controlled high enough to allow the use of siphons to supply the furrows. In planche number II for example three one meter drops would get the water down to a level where it can be used. Several checks in the channel could keep the water elevation high enough to allow the use of siphons for diverting water into the furrows.

In summary, the designs for Sani Research Station would be as follows:

Planche	C & D	Serpentine
	I	Basin
	II	Furrow or basin
	III	Serpentine
	IV	Serpentine
	V	Drip (nursery)
	VI	Serpentine
	VII	Channels with siphons

IV. Samoga, El Grahan, N'Tarhad El Ouassa

- Overview

- - First priority in all the oasis project sites should be the installation of a fence to protect later plantings. Fencing in advance of planting will in some senses decrease the incentive for livestock to try to break through the fence, there will be no lush greenery to attract. Once livestock are used to the fence there is a lower likelyhood of later breakage.

- - Second priority is the installation of a good water source. N'Tarhad El Ouassa already has a well in the approximate center of the project site. El Grahan and Samoga do not have wells on the project sites. In El Grahan there are wells on each side of the site so getting a good well should be no problem.

For Samoga the project site is at the end of the oasis, however there is a well about 100 m south of the project site. An unsuccessful attempt was made to install a borehole at the lower end of the site. The borehole passed through four meters of sand before hitting campacted clay. Continued drilling through the clay generated a clay-water slurry which sealed the sides of the well. Since there was a shortage of water on site and a lack of carrying containers the well was not developed. It is possible that there is water in the sand layer but it cannot enter the well because of the clay seal.

In Samoga another well should be drilled at a higher elevation, Drilling should be terminated upon encountering the clay layer. Several barrels or other large containers should be on hand to provide water for developing the well. It has been observed in some oases that there is a concentration of clay in the center low point of the oasis. Wells dug in this part of the oasis are generally dry whereas wells dug to either side (5 - 20 m) often have water. The same sort of trata may exist at the lower edge of the project site, hence, another well should be attempted.

- - Starting trials and nurseries at the three sites will be difficult until a trained person is on hand to oversee the work. The logistics of trying to operate trials in four widely separated sites with limited trained personnel are complicated. It is doubtful that any meaningful data could be collected. However, if someone reliable can be hired to water plants, the third

priority can be beginning the establishment of wind [illegible] and living fences. See annex for wind barrier details. At tr present there are enough neem seedlings in Sani to start a wind barrier at N'Tarhad El Ouassa which already has a water supply.

Neem (Azadirachta indica) yields azadirachtin, a compound that is a systemic pesticide. It has been proven effective against the Japanese beetle and desert locust. There are indications that azadirachtin is a nematode repellent. Neem is to be preferred over Prosopis which some believe harbors nematodes. Nematodes are a major pest in Mauritania.

Several precautions can be taken to increase the percentage of seedlings surviving transplant.

- Before transporting seedlings to the planting site, gradually put the seedlings into the full sunlight. This will help prepare them to survive full exposure to the sun.
- In preparation for the trip to the planting site most leaves should be carefully stripped from the tree (neem). Care should be taken that the tree is not injured. The terminal bud and the three of four leaves just below it should be left. Removal of the leaves reduces plant water loss during transport.
- Plant the tree so that its collar is even with the ground. The collar is the point where the tree's stem came through the surface of the soil in the pot. The first small roots often start under the collar and these roots must be covered if the tree is to grow well.
- Seedlings must be abundantly watered after transplanting. Watering serves several purposes; water forces air from the soil near roots, compacts the soil around roots, and supplies the plants needs.

• • <u>Fourth</u> priority would be the construction of a materials storage and work area. A "hanger" or some similar structure could serve as a multipurpose unit; protection of materials, meeting area and living area for overnighting visitors.

• • <u>Fifth</u> priority would be the construction of a water distribution system. This construction could serve as a training exercise if the Oasis Development Workers are on site and can involve some of the oasis residents in the work. This system does not have to be finished in its entirity before beds can

be put into production. Allowance must however be made for the placement of the remainder of the water distribution system.

- - Sixth priority would be the beginning of trials and tree nursery stock. As stated previously this can almost be done at the same time as water distribution system construction.

- Irrigation Systems
- - The elevations on the project site contour maps bear no relation to the elevations on the oases contour maps. The lowest point in the site was determined, set equal to zero and all other points adjusted accordingly.

Given the small sizes of the project sites in the three oases it will be difficult to construct and use a large number of wells in each site and still have enough land for trials. This limitation means that most of the water lifting trials will have to be on the plots of cooperating farmers. This is more realistic in terms of the water lifting options gaining farmer acceptance and adoption.

El Grahan, see figure, has the smallest project site at 0.09 hectare with an average downslope of 0.14 m/m. This slope is to steep for unlined channels and lined channels would require drop structures. To maximize usable area, the irrigation plan is for a small lined channel along the west side of the site containing four one meter drop structures. A large diameter irrigation well at the upper edge of the site would supply water to the channel. The trial beds (1m x 5m) would be irrigated by watering can dipped into the channel upstream of the drop. The cross slope is sufficiently flat that channels could be run west to east to irrigate beds. This option would be more costly, channel lining, and remove area from crops.

Seven beds (1m x 5.5m) in the NE corner of the site are reserved for a tree nursery. For potted trees this area can produce about 5,500 seedlings per cycle, this should be sufficient for the oasis. This number of trees will plant 13.2 km on a 2.4 m spacing. Irrigation for this section of the site can be by drip

irrigation or by watering can. A second well dug at the upper end of the seven beds would provide water for irrigation and other uses. See annex and Sani nursery description for drip irrigation details.

The south and east edges of the site would be protested by a wind barrier. The north edge of the site is protected by the oasis proper and should at most require a low hedge. The lower part of the east barrier could be made up of date palms up to where the water table exceeds 3.5 meters during dry season. See annex for wind barrier details.

A building for storage and general use should be constructed in the NW corner of the site. The structure shown has a 4m x 2.5m storage area (enclosed) and a 4m x 4.5m general purpose area. The general purpose area could be left open on three sides with provision for temporary sides (tenting material) if the need arrises. This area would be used for training, meetings, over-nighting visitors, and such other uses that may come up. The entry gate is located in the NW corner because there is a path through the oasis at this point. The width of the gate will depend upon the type of traffic passing through.

The Samoga project site is 0.25 ha in size and also has a steep slope of 0.12 m/m. The following irrigation design is based on the assumption that sufficient water can be found on site. The site lends itsself to being split into sections based on topography, The NE half has a steeper slope than the SW half.

Since the site is relatively unprotected from the winds a wind barrier should be planted on all four sides of the site. Hedge or other intermediate height vegetation should be planted across the center of the site to divide it into quadrants and increase the effectiveness of the outer wind barrier in the early period. When the outer barrier has reached about three meters in height the inside rows can be removed.

The two upper quadrants can be irrigated by basins fed by large diameter wells. The Southern quadrant can be irrigated by short furrows filled with water from a well located on the high side of the quadrant. These furrows would have to be lined if the water is being further diverted into beds. If planting is on the furrow ridge or in the furrow valley lining would not be

necessary. The western quadrant could use any of several irrigation options. It is the site of the storage and general purpose structure. The structure could be of the same design as the one in El Grahan.

The wells to serve basins should be located next to the basin in the approximate center of the area irrigated. This would keep the maximum distance walked to a reasonable amount. If a canal is used in the lower quadrant it should be located along the outer wind barrier. This is the high side of the quadrant and acanal along the edge of a field removes the least amount of land from production.

- Beds should run east - west to minimize sunlight differences and to decrease wind effects.

Any more detailed design must wait the successful completion of irrigation wells. Designs will be variations on the Sani and El Grahan designs.

The N'Tarhad El Ouassa project site is the largest of the three at 0.47 hectares. The terrain is almost flat which gives the greatest flexibility in irrigation system options. This site has a well which is rock lined in the approximate center of the site. There are numerous date palms planted in the east half of the site.

This site is at the edge of the oasis proper and exposed to the winds. A wind barrier should be planted around the site with smaller cross barriers in the interior. These will effectively divide the site into six sections.

Irrigation system design in the sections where date palms are growing may be constrained. A serpentine system could be used to water the trees with small offtakes to water interplanted beds. Basin irrigation could also be used in any of the sections. Wells should be installed in the sections where the present well is not located. These wells can be used for the different water lifting options.

Admittedly most of these designs are general in nature, it it is difficult to be specific when the crops are unknown

for each given area. The irrigation systems break out as follows. For tree crops such as dates or citrus the serpentine system is generally best if the terrain allows its use. For cereal or other row planted large crops, furrow irrigation is generally best. In sandy soil the furrow length must be kept short but most oasis parcels are small so this is self limiting. For bed crops such as vegetables the use of basins and watering cans or drip irrigation is generally best. Drip can also be used for tree and other crops but the long application times would not be feasible for hand drawn watering, i.e., the barrel will have to be filled many times each day. For forage crops such as alfalfa flooding of the planche is generally used. For large planches a large stream of water is required if the whole area is to be wetted uniformly. This may require the filling of a reservoir which can be opened to give a high volume flow.

ANNEX

Text

Activities Schedule

Citrus Nursery

Canal Linings

Wind Barriers

Drip Irrigation

Miscellaneous Information

Figures

Pipe Offtakes

Siphons

Siphon Flow

Check

Drops

Large Diameter Well Discharge Structure

Maps

Sani Oasis Project Site

Samoga Oasis Project Site

El Grahan Oasis Project Site

N'Tarhad El Ouassa Oasis Project Site

Activities Schedule, Oasis Project

January 82

11 Depart NKTT 10:30 arrive Guerou 18:00, vehicle trouble

12 Depart Guerou after radio contact with NKTT, arrive Sani Oasis at 12:30. Afternoon spent staking main canal for Sani

13 Survey main canal line, calculate slope, restake line for correct slope, test drilling at site of large diameter well for irrigation, water table at two meters

14 Removal of drilling rig, well digging, collection of well lining materials

15 Well digging, rough digging of 60 meters of main canal

16 Canal shaping (½ day)

17 Travel to Samoga, selection of Oasis Project Trial site, travel to El Grahan for same purpose

18 Depart El Grahan in morning proceed to Kiffa then on to N'Tarhad El Ouassa for selection of trial site, return to Kiffa in afternoon

19 Load materials in Kiffa and proceed to Sani, begin slotting PVC pipe for well casing, preparation of site for drilling of domestic water supply well

20 Drilling domestic water well for Sani Research Station

21 Continued drilling of well, reamed first 34.5 feet of well to 6 inch diameter, installed 4 inch PVC well casing, gravel packed well

22 Continued drilling through compacted clay and sandstone, stopped at 55 feet

23 Travel to Samoga, drilled well 0 - 13ft sand, 13 - 28 ft compacted clay

24 Reamed well to 5 inches diameter, installed 3 inch diameter slotted PVC pipe casing, gravel packed well, set fence posts and started running woven wire

25 Finished stringing woven wire, started running barbed wire, surveyed plot, proceeded to El Grahan and surveyed plot, continued to Kiffa where materials were loaded for Sani, returned to Sani

26 Pumped Sani domestic well, cleaned equipment and prepared to start drilling well at camp site on hill

27 Started well on hill, well collapse at 7.5 meters after using 6 pounds of stabilizing jell, attempted to pull drill stem with hydraulic jacks, no luck

28 Dug out drill stem, dismantled drill rig and moved all material back to the station

29 Paper work, survey notes workup, preliminary calculations of water delivery system for camp site

30 Travel to Samoga to finish fence and check water level in well, well dry with mud in bottom, proceed to Kiffa, buy gasoline and travel to Guerou (¾ day)

31 Travel to N'Tarhad El Ouassa, <u>No work</u>

February 82

1 Survey and measure trial plot at N'Tarhad El Ouassa, return to Kiffa where materials for Sani and watering cans for Samoga are loaded, return to Sani

2 Enlarged irrigation well and true up sides, install steel well lining forms (borrowed from Service Hydraulique), place concrete for first ring

3 Remove steel forms, true up next section of well sides, place form and place concrete for next well section, level area for pad (domestic water well) and place bottom row of blocks for retaining wall, begin placing concrete for pad

4 Finished placing concrete for well pad, removed forms from the other well

5 Survey of gardening and tree crop area of Sani Research Station, begin preparing drilling equipment for another attempt on the hill (camp site)

6 Preliminary work on the irrigation system design for Sani, depart for Kiffa in the afternoon, search for gasoline

7 Depart Kiffa at 8:00 arrive NKTT at 18:00 numerous stops, reasons unknown

10 Begin drawing up contour maps of Samoga, El Grahan, and N'Tarhad El Ouassa, meeting with John Grazel

11 Continue work on maps and writeup of reports

16 Working on reports

In addition to the above listed days 9 hours were spent on Oasis project work in the month of December 81, meetings with Oasis Project Staff (Wedberg, Collins, Paulas and Grazel).
In the month of March the equivalent of four days time has been spent completeing the reports.

Because of the long time from planting until production the top priority for citrus crops is to get root and grafting material started. This requires the consultation of a citrus expert to determine the best root stock for the oasis environment and the appropriate fruiting varieties.

In Sani Oasis, where citrus is presently being produced, there have been cases where it appears the grafted material has died off. In some cases the trees have been several years old. After a period without vegetation, growth begins again. Of the trees inspected all appeared to put out new growth <u>below</u> the graft line. This would mean the growth is of the root stock material and not suitable for fruit production.

- This phenomena should be investigated by an expert in citrus diseases to determine the impact if any on future citrus production in Sani.
- It is important that this question be resolved before citrus stock from Sani is planted in other oases, there is a risk that the disease (if one exists) could contaminate other sites.

Many citrus experts are on the staffs of the University of California at Davis and the University of Florida.

Because of the long resident times in the nursery, citrus seedlings should be grown in open rooted beds with wider spacings. If it is determined that there are no problems with the production of citrus seedlings at Sani, Sani can easily produce seedlings for all the other oases.

Canal Lining

In the sandy soils typical of oases and most of Mauritania any water delivery system using channels must be lined. If the channel is not lined water losses can be substantial. There are numerous methods of lining channels in use throughout the world. However many are not practical, for various reasons, for use in Mauritania. The options listed below are those which seem to offer the most likelyhood of success in Mauritania. Most require the channel be protected from livestock traffic, and human for that matter, to ensure the integrity of the lining remains intact. As with most options there is a range in cost, maintenance requirements, and durability of the linings.

- Before placing any lining it is essential that all filled sections (banks included) are compacted or fully settled. If settling takes place after the lining has been placed, the lining can crack and move out of line. In some cases this movement can ppen an area to erosion which ultimately causes a break in the channel bank.

- Concrete lined channels must be used as the ideal against which the other linings are measured. Concrete is expensive and may not be practical for widespread use. The installation of concrete panel-formed lining requires only semiskilled labor and a minimum of equipment. After excavating the ditch to grade, guide forms are set about three meters apart. Concrete is then placed in alternate three meter sections. When the concrete is set, the forms are removed and the skipped panals are completed. The bottom in each section is filled first, and then the fresh concrete is screeded up the slope. Concrete used in ditch lining should be plastic enough for thorough consolidation but stiff enough to stay in place on the side slopes. The side slopes should be no steeper than one vertical to one horizontal (1:1).

- Soil cement can be used to form a durable channel lining. Soil cement is particularly useful in sandy loam soils. One part cement is used to 4 - 12 parts soil, thoroughly mixed dry then moistened to the optimum moisture content and compacted. Mixing is done in place, i.e., the cement is stirred into the top layer of the soil with a rake or similar implement. The

layer is kept moist until it is thoroughly cured. Normally a two inch layer is used on the parts of the channel exposed to water. This lining can be durable and long lasting. It is subject to cracking if it is walked upon by livestock. In some instances aggressive vegetation can grow through the layer if there are weak spots in the mix. Trials must be carried out for each soil type to determine the best soil-cement mix ratio.

- Heavy clay can be transported to the channel and a compacted layer applied to the channel sides. The layer is generally about two inches thick. If it is compacted at optimum moisture content an impervious layer can be formed. The lining has a high maintenance requirement if the channel is not protected from traffic. Each time the channel is allowed to dry completely there is a tendency for the clay lining to crack. Upon rewetting the clay will swell and reseal but water losses can be great in the interim. Breaking up the surface clods and repacking can diminish water losses, labor required for this is traded off against the labor required to lift the water lost due to seepage.

- Manure is sometimes mixed with clay and used as a channel lining. This mix is similar to that used for traditional housing but with a lower sand content. The fiber in the manure tends to decrease the cracking problem when the channel drys out. The mix is applied the same as heavy clay. This type of lining will normally last for only one season because soil microbes break down the organic matter in the manure.

- Stone linings can be used in areas with an abundance of stones. The stones are mortared in place as brick. This method is more labor intensive than the use of concrete but less cement is required and the durability is almost the same.

- Where the lined channel is below the normal soil surface and may be subject to hydrostatic pressure, weep holes must be provided to relieve the pressure. This is of particular importance where the channel runs across the slope of a hill. In this case the ditch can also be used as a drain during rainy season. The weep holes reduce the hydrostatic pressure by allowing the groundwater to flow into

the ditch. If weep holes are not provided the lining may fail due to the pressure. Failure can take the form of severe cracks or rupture of the lining. Where concrete or stone are used it is not unusual for a whole section of the lining to be pushed out of place.

Weep holes are normally placed just above the normal water level in the channel. Under Mauritanian conditions a hole 6 - 10 mm in diameter spaced every meter should be sufficient. The hole must be completely through the lining material.

Wind Barriers

In desert sandstorms several things happen. The particles of sand, at temperatures much above that of the air, give up heat to it, and in addition absorb incoming radiation, thus acquiring more heat. The main injurious effect is on the water economy of the plant, the transpiration demand is higher than the plant can satisfy resulting in plant desiccation. The mass of moving sand decreases with height but the wind speed increases, the maximum energy level was found to be at about 15 cm above the soil surface. This then is the height at which most damage is done to growing plants. The moving sand uncovers and exposes seeds, smothers young plants, and can cause mechanical damage to the plant (shredding leaves for example).

Shelter from wind is generally provided by long narrow strips of barrier material set up perpendicular to the direction of the prevailing winds. Figure 1 shows the effect of wind barriers on several micrometeorological factors. A medium-dense barrier was used to measure the effects on air and soil temperature, relative humidity, evaporation, and soil moisture. From Figure 1 one can see that the denser the obstruction, the greater is the amount of shelter immediately behind it, but the effect in depth is less (less protection is offered at distances from the barrier). The most favorable results are obtained with a penetrability of 60 to 80 percent (medium-dense). When penetrability is variable, it is better if it increases from below upward (more dense at the bottom).

Studies have shown that a change in wind direction of $\pm 45^{\circ}$ from the perpendicular did not produce any significant change in the shelter effect. This gives one sufficient latitude to make the best use of topography and present fence and plot layout without sacrificing any barrier effectiveness.

An incidental result of employing a single wind barrier is the undesirable increase in wind speed which always occurs around the ends of the barrier. Winds around the ends of barriers

have been measured at velocities over 20 percent stronger than the open area wind speed. The same applies to gaps or breaks in the barrier. Rather than a single barrier, a much more favorable arrangement is that of a network of shelterbelts perpendicular to each other. In this case the shelter effect is more uniform and the corners provide positions where it is particularly suitable to make the openings necessary for access.

Wind barriers of living vegetation are the most effective because their flexing stalks/branches and fluttering leaves better break up the wind eddies causing increased energy dissipation. To be most useful the barriers should be made up of plants that have other uses and a variety of growth characteristics. For example, a wind barrier could be made up of neem (Azadirachta indica) planted on 2.4 meter spacing with rows of henna (Lawsonia alba) a more bushy plant on each side. See Figure 2 for a possible garden wind barrier configuration.

In each gardening area one must look for plants that are of economic importance that lend themselves to use as wind barriers. For plants that periodically drop their leaves, they must be in leaf at the time of high winds in order to be effective.

In the near term, before a planted wind barrier is effective, one can use rough woven mats of coarse grass, sacking, or any type of material that can make a porous vertical barrier. Where metal fences are used the material can be woven through the mesh. This is an area for individual ingenuity.

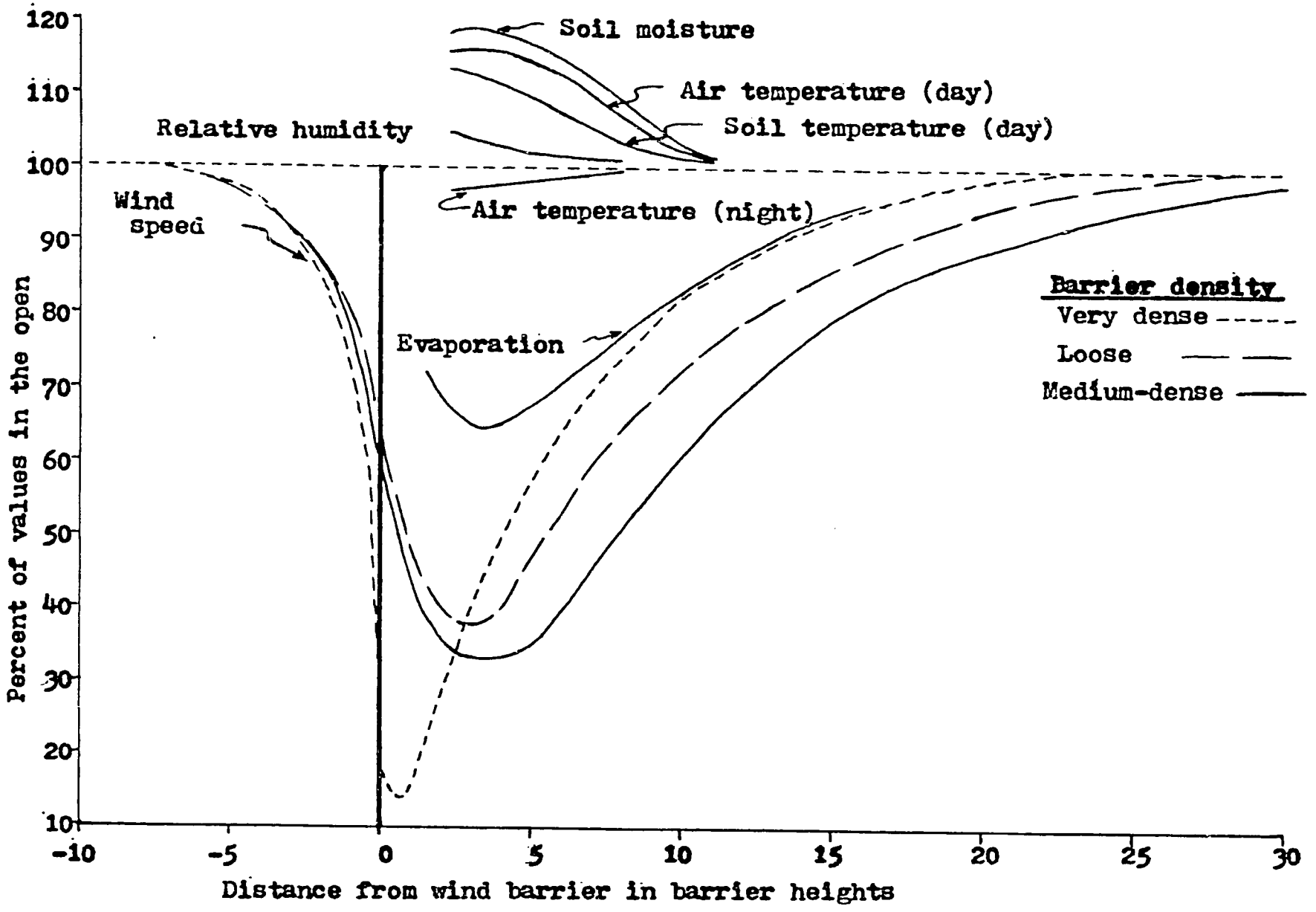


Figure 1. The effect of wind barriers on micrometeorological factors.

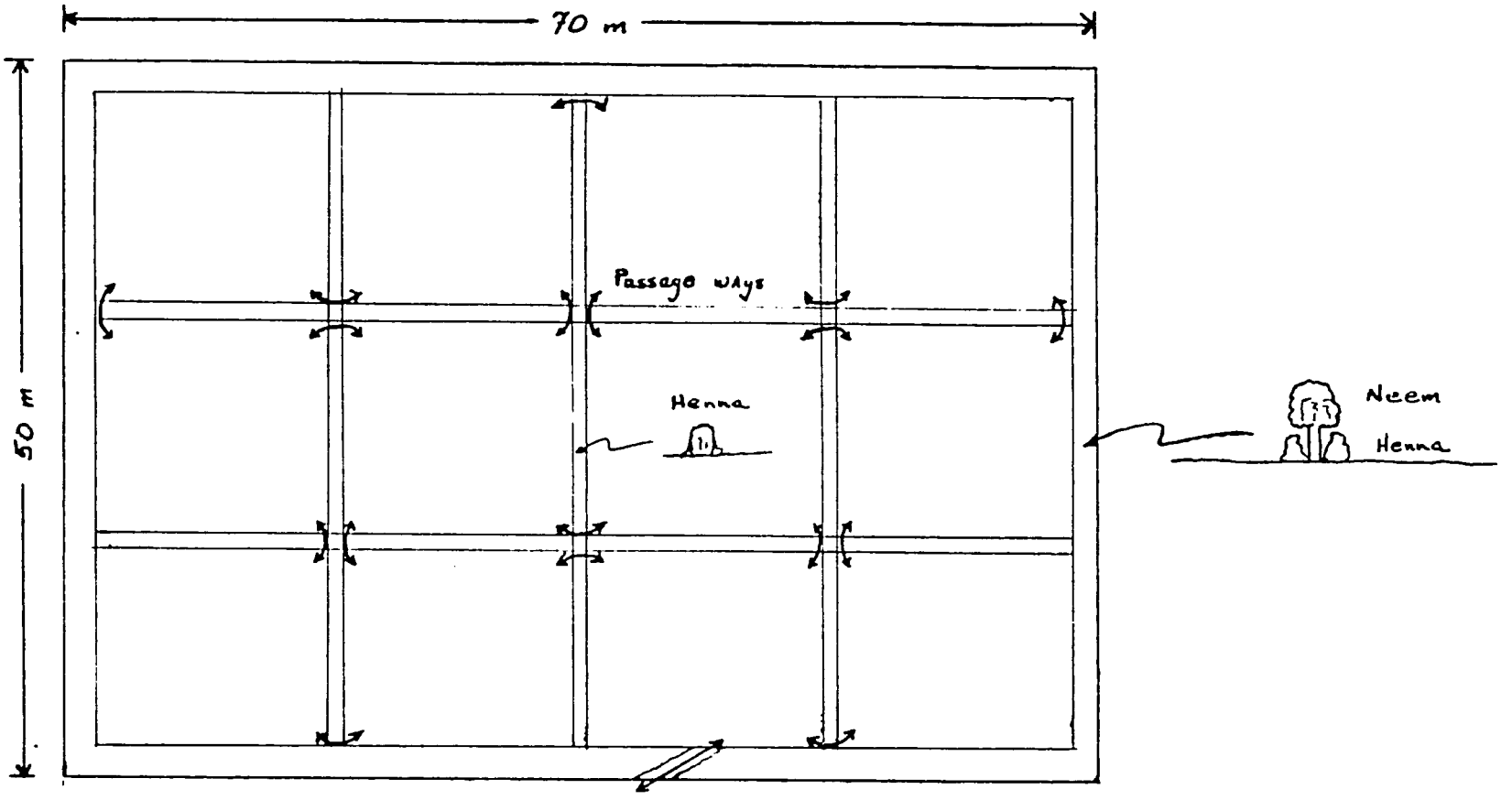


Figure 2. Grid pattern Wind Barrier.

Drip Irrigation

Drip irrigation has potential where good quality water is limited. With drip it is possible to water only that part of the bed where desirable plants are growing. This saves water and reduces the number of weeds that grow. Where high density planting is practiced drip irrigation has limited use because most of the bed must be wetted. In vegetable production drip is most useful for pepper, tomato, eggplant, okra, and other wide spaced crops. Systems can be installed using all imported materials or best use can be made of locally available supplies. Given the relatively high cost of the material to install a drip irrigation system it must be used for high value crops.

The imported drip irrigation system is easy to install and relatively trouble free throughout the life of the system. Figure 22 shows how the components would fit together in a typical installation. At the end of the main line a short section of hose is folded over and wired or clamped to close off the line. The same procedure is used to close off the ends of lateral lines. The total cost for the imported components used in the design of figure 22 is about $500 (1981) plus the cost of shipping. A steel barrel would have to be purchased locally for use as a reservoir.

The system assembled from locally available parts would use regular water hose or polyethylene pipe for the main line and water hose for the laterals. Steel pipe fittings are available and with nipples can be used in place of the imported plastic fittings. Emitter tubing is not available locally but can be imported at a cost of $95 (1981) per 1220 m (4000 ft) plus shipping. Without screens in the water lines, emitter lines tend to plug more quickly. Care has to be taken that water added to the barrel is clean and the barrel is protected from blowing material.

Tables 17 and 18 are used to select the proper main and lateral line sizes. First determine the area to be wetted by each emitter over a given time period. This value times the depth of water to be applied will give the emitter flow rate per unit time. Next determine the number of emitters on each lateral. From these two values, number of emitters and emitter flow rate, the size of the

lateral can be determined. From the lateral flowrate and the number of laterals the mainline size can be found.

Example: An area of 6 inch diameter is to be wetted 1 inch deep over a 1 hour period. There are 200 emitters per lateral and there are 20 laterals on the mainline. Determine the sizes of the mainline and the laterals.

$$\frac{0.5^2}{4} \times 0.08 = 0.02 \text{ ft}^3/\text{hr} \quad \text{or} \quad 0.12 \text{ gal/hr per emitter}$$

$$\frac{200 \times 0.12}{60} = 0.41 \text{ gal/min}$$

From table 18 the correct lateral size is 3/8 inch diameter.

$0.41 \times 20 = 8.2$ gal/min

From table 17 the mainline size would be 1 inch diameter.

- This design precedure is only appropriate for short run systems on relatively flat terrain. If the terrain has significant slope and/or the system is quite large the design procedure becomes quite sophisticated and technical assistance should be requested.

Table 16. Cost of imported components (1981)

½ inch mainline	100 ft	₱ 11.75
3/8 inch lateral	2500 ft	207.50
0.040 inch microtubing	4000 ft	95.00
Twist punch		2.50
Hose Y shut-off	17	51.00
Hose gaskets with screens	18	5.00
Flow controls	34	42.50
Female hose coupling	35	43.75
Male hose to poly tee	17	21.25
Hose bib brass	1	4.75
Hose strainer	1	7.75
TOTAL		₱ 492.75

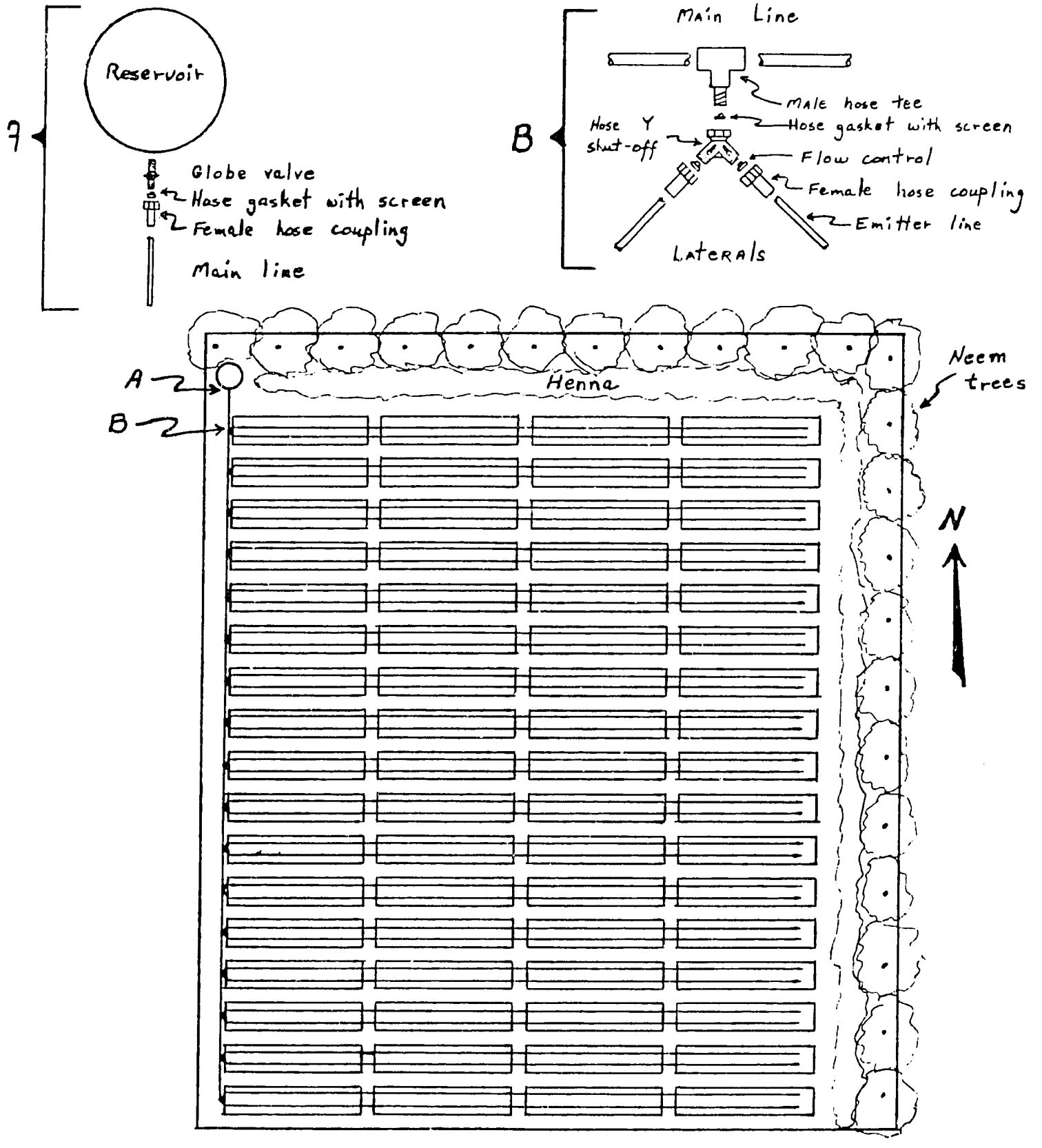
Table 17. Guide for selecting mainline and submain.

Flow range gpm	(lpm)	Mainline pipe size	Submain pipe size
0 - 3	(0 - 11)	½ inch	½ inch
3 - 6	(11 - 23)	¾ inch	½ inch
6 - 10	(23 - 38)	1 inch	¾ inch
10 - 20	(38 - 76)	1¼ inch	1 inch

Table 18. Emitter hose selection guide.

Size	Maximum flow in gpm	(lpm)	Maximum number of emitters ½ gph (2)*	1 gph (4)	2 gph (8)	4 gph (15)
3/8	1.5	(6)	200	100	50	25
½	3.0	(11)	400	200	100	50
¾	6.0	(23)	800	400	200	100

* Emitter flow in liters per hour



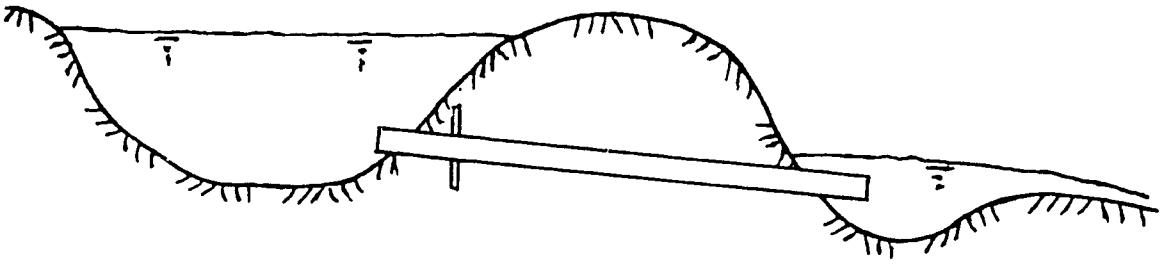
Typical drip irrigation installation

Miscellaneous Information

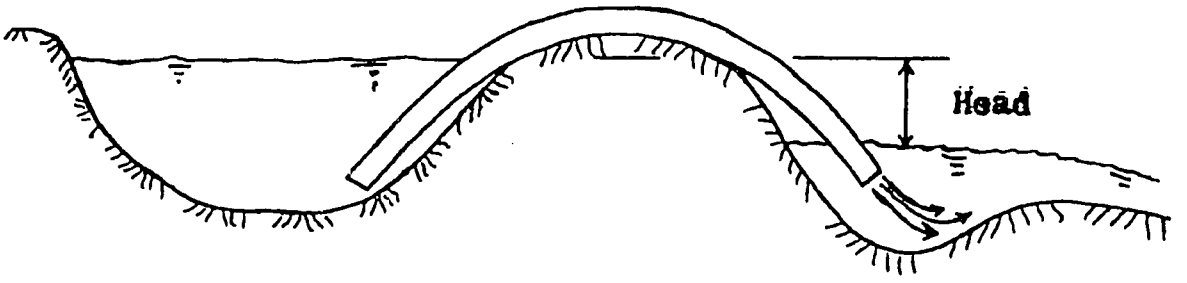
- Installation of a large diameter reinforced concrete lined well can be accomplished at the rate of about one meter per day if all materials are on hand and no hard strata is encountered. This requires a minimum of four good workers. When hand mixing concrete the quality of the mixture can be improved if a large mixing trough (36 in. x 75 in. for example) is used. The placement of concrete must be done as rapidly as possible to prevent cracks from forming between the different batches of concrete.

- When passing through sandy soil, the rough canal shape can be excavated at a fairly rapid rate. In Sani 10 workers excavated 60 meters of canal in about three hours. The final shaping of the sides and leveling the bottom to grade takes considerably longer.

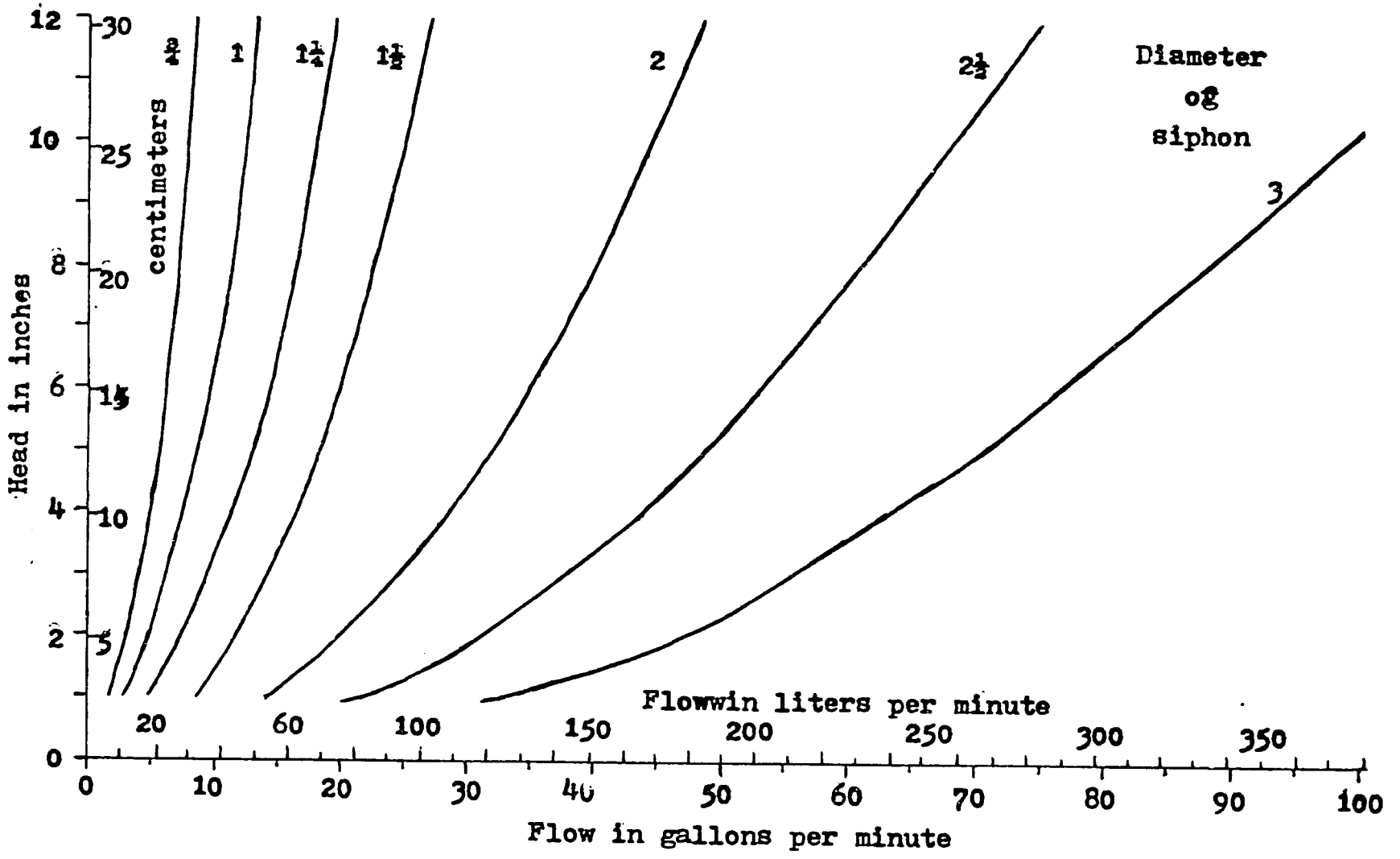
- When using the Hydra-drill 201-P to drill through sand, a well with a four inch casing can be installed in two days. Three workers are required to operate the system. When the strata changes to harder material such as compacted clay or sandstone the drilling becomes much slower. When drilling through sand, such as that at Sani a hole stabilizer is required.



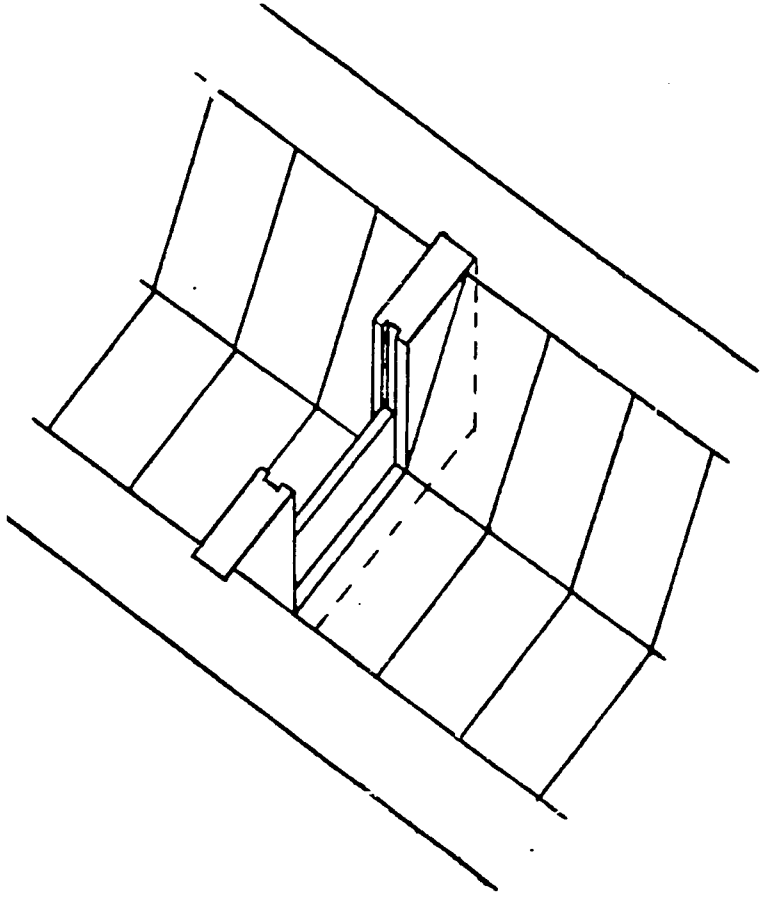
Pipe offtake from a channel



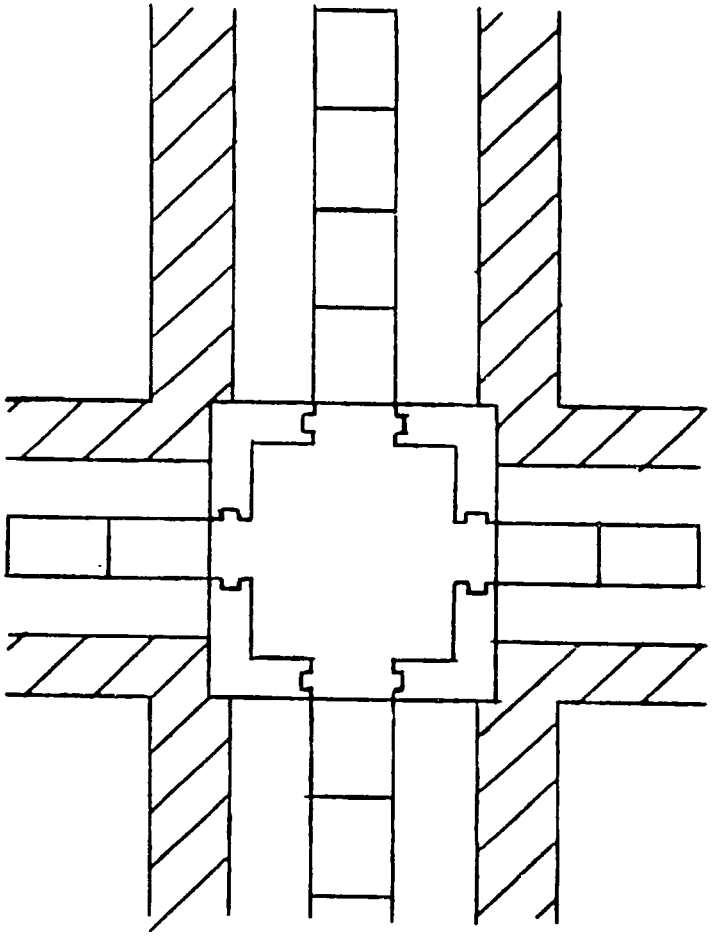
Siphon discharge into a furrow



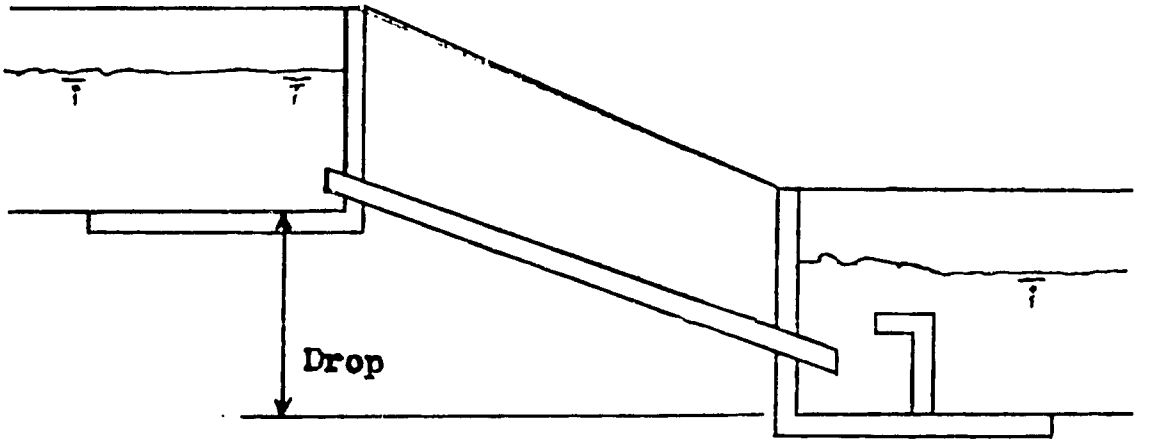
Flow through small siphons.



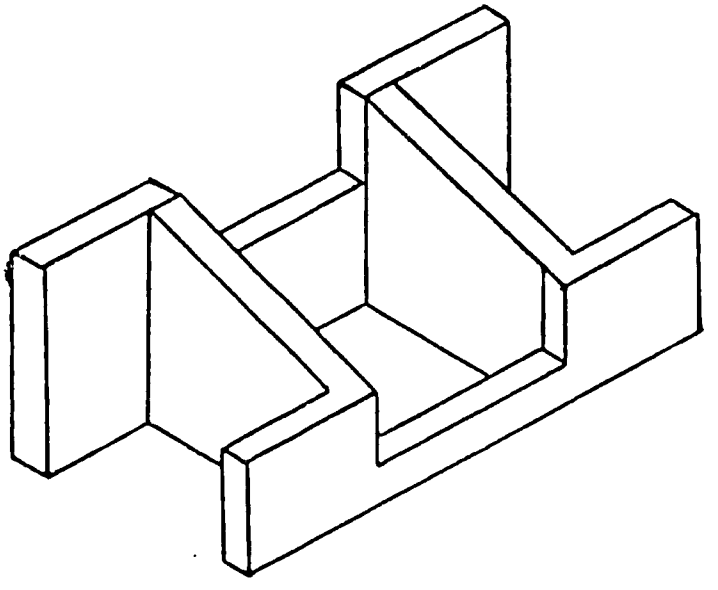
Check structure



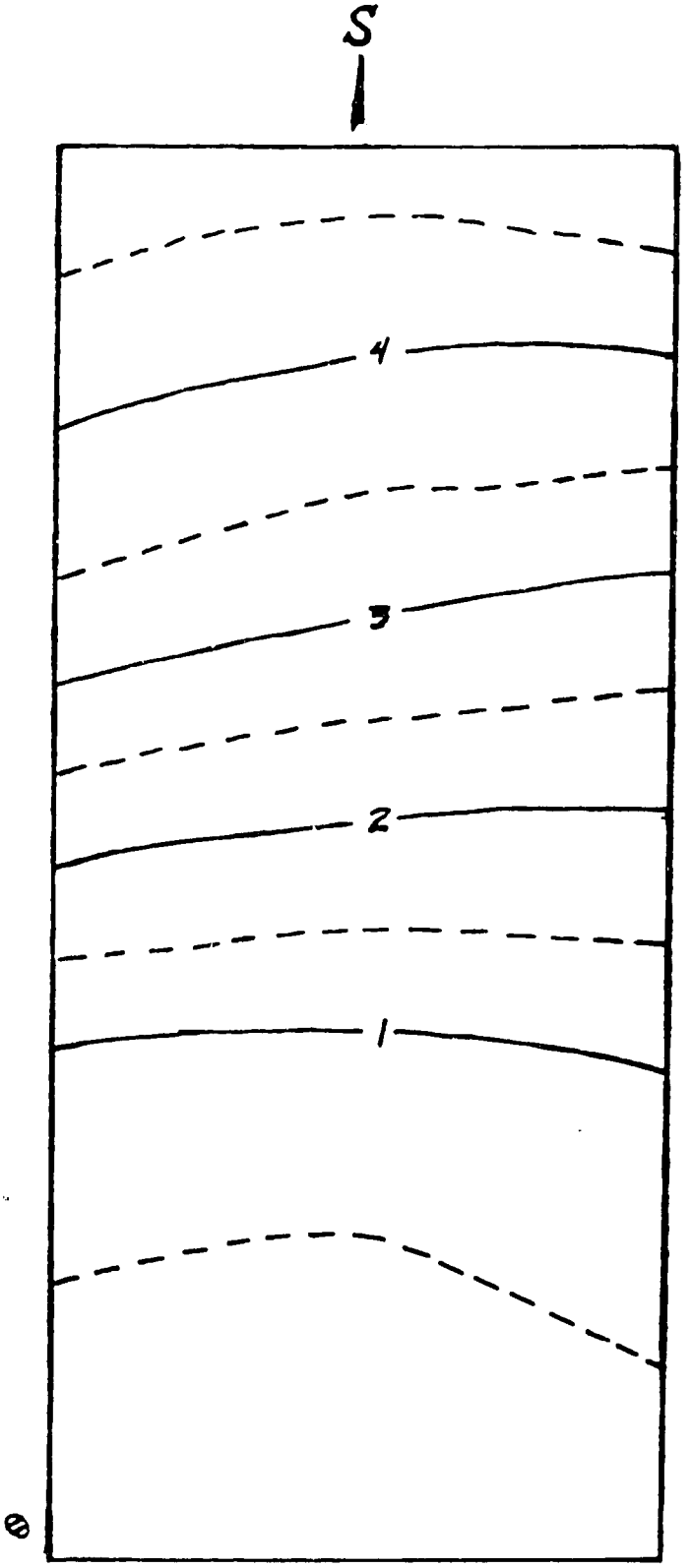
Check division box

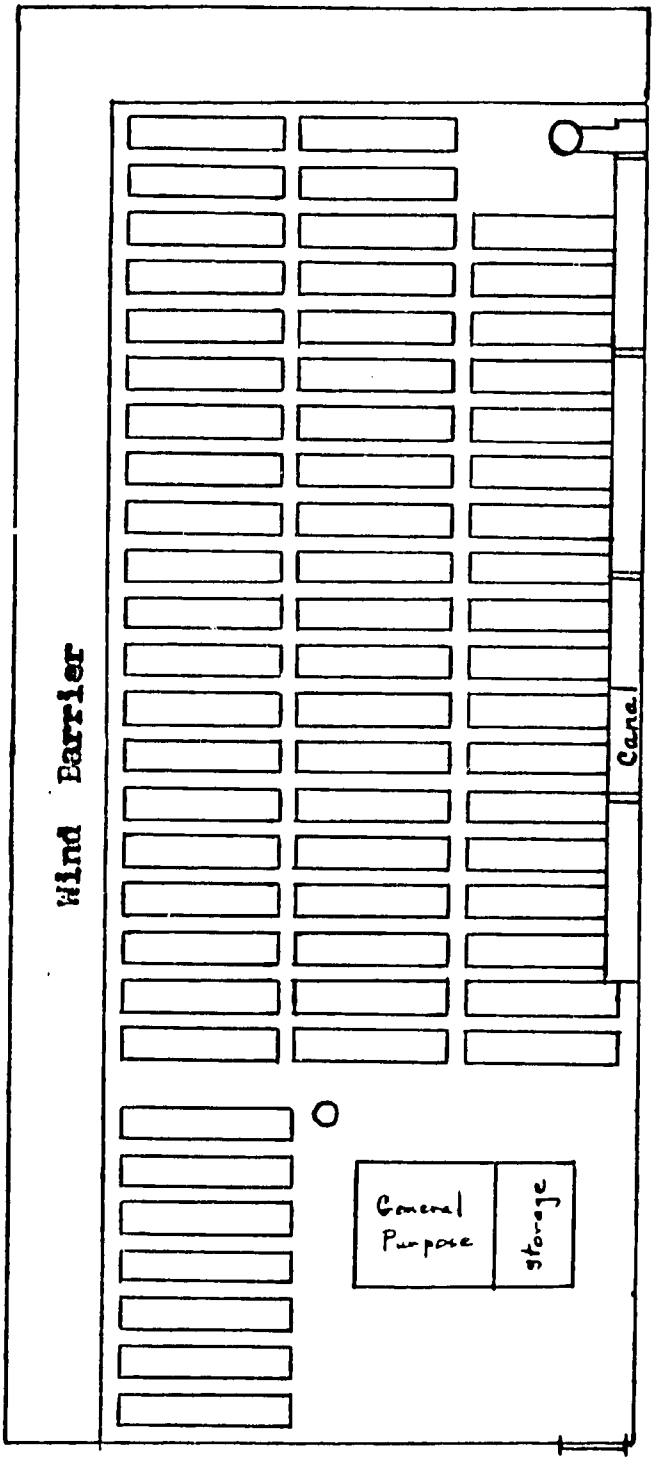


Pipe drop structure



Reinforced concrete drop structure





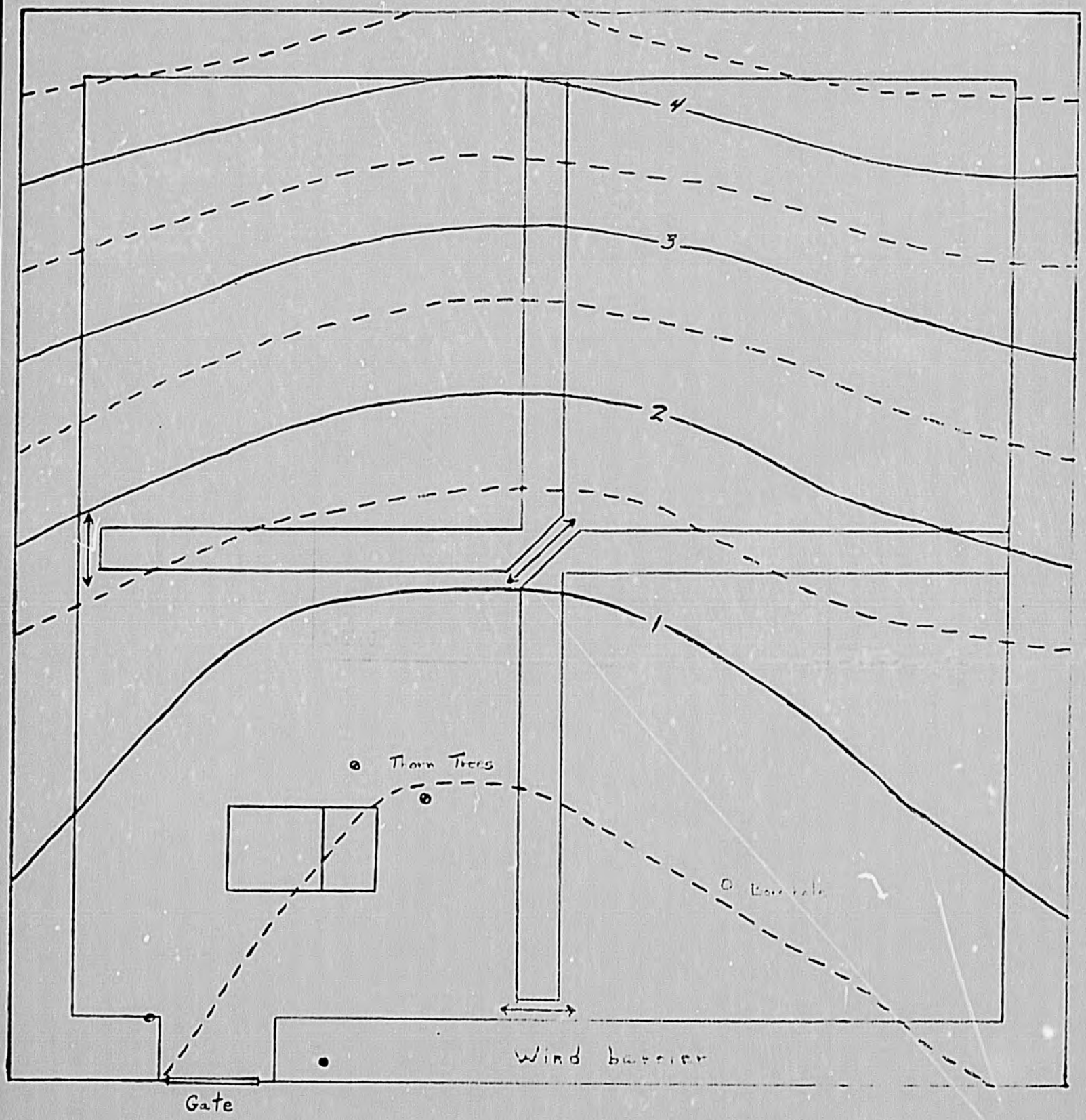
● Palm

Scale 1 : 250

Area 0.09 ha.

El Grahan Oasis

Samoga



Scale 1:250

Area 0.05 ha.

35