IRRIGATION OF COMMUNITY GARDENS IN PANAMA

by

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RECOMMENDATIONS

1. Since successful irrigation of the community gardens will depend on many factors including a suitable water supply and properly planned system, it is recommended that only a few pilot projects be undertaken at this time. Every effort should be made to make these projects successful and if so they could then be used as demonstration projects to encourage the irrigation of vegetables throughout the country either as community or private enterprises.

2. If and when a decision is made to promote irrigation of the community gardens throughout Panama, the services of an experienced irrigation engineer should be obtained for at least a two year period. This engineer should be able to speak Spanish and should be furnished adequate transportation, preferably a 4-wheel drive vehicle. He should also have available a complete set of surveying instruments including level, transit, tapes, level rods, etc., and in the office, a drafting table and necessary drawing instruments. He should also have a full time Panamanian engineer counterpart. This team should be able to make the necessary field studies, prepare the maps and make the necessary designs and select the pumping equipment for each project undertaken. They would investigate the water supply situation, help select locations for gardens that could be served from perennial streams, or from wells or storage ponds. When the plans are approved, they would supervise the installation of the irrigation systems.

3. Since the success of vegetable growing will depend also to a large extent on the selection of varieties, control of diseases and insects, and a knowledge of soils, extension specialists in these fields should be available to give the necessary help to the communities when projects are undertaken.

INTRODUCTION

Purpose

The primary purpose of this assignment in Panama was to assist USAID and the Ministerio de Salud in improving the irrigation of community gardens. In an effort to improve the nutrition of the people living in small communities throughout the country, there are plans to organize more than 200 small community gardens to produce fresh vegetables for local consumption. The climate of Panama is such that in most places there is a dry period of about four months when irrigation of the vegetables would be beneficial.

The plan was to have the writer visit a number of areas throughout the country to see first hand the problems involved in the irrigation of these gardens and to make recommendations and prepare plans for the irrigation systems. He has attempted to obtain information with respect to the climate and other factors that have a bearing on the problems of irrigation such as topography, soils and availability and cost of irrigation equipment.

IRRIGATION IN PANAMA

General

Because of the relatively high rainfall in the Republic of Panama, irrigation has been practiced to only a limited extent. Therefore, the need for and the benefits to be derived from irrigation are not well known.

Resource Data

A three-year resource study entitled "Final Report on the Catastro Rural de Tierras y Aguas de Panama, July, 1970" by CATAPAN* provides a considerable amount of data on the climate, soil and water resources of Panama. The final report was presented in three volumes. Volume I comprised the text, Volume II included various appendices, figures and plates and Volume III contained the larger size foldout figures and plates. This study included a survey of irrigation projects. (See Appendix Table 9).

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* CATAPAN, a Joint Venture of International Resources and Geotechnics, Inc. and International Engineering Company, Inc. - The Jacobs Company - supported in part by the USAID.

There are also available data on climate, especially precipitation, published by Estadistica Panameña and on stream flow on all of the major rivers in Panama, published by Instituto de Recursos Hidraúlicos y Electrificación (IRHE).

Need for Irrigation

The need for irrigation in Panama appears to be associated with specific crops such as fresh vegetables, where year around production is desired, and for perennial crops, such as bananas, where both production and quality are important. Some sugar cane and rice are also irrigated. The need is greatest where the dry season is the longest and where the precipitation during this period is lowest.

For fresh vegetables to be grown in the community gardens, it would appear that irrigation would be beneficial during the dry period at almost any place in Panama, even in the mountains near the Costa Rican border where the annual precipitation is from 4 to 5 meters per year.

CLIMATE OF PANAMA

Precipitation

The climate of Panama can be briefly characterized as consisting of two periods, a rainy period from May thru December and a dry period from January thru April. Precipitation records for 1970* listed 88 precipitation stations. The records are being collected mostly by two agencies; the Instituto de Recursos Hidraulicos y Electrificacion (IRHE) and the Panama Canal Company which operates 14 stations in and near the Canal Zone.

Long records of more than 70 years (one for 100 years) are available for 3 stations. Two stations have records for 30 years or more and the remainder are mostly for 12 years or less with many for less than 5 years.

CATAPAN has plotted the mean annual isolines and the isolines for the four driest months on maps with a scale of 1:500,000. These maps show that the driest part of Panama is along the coast in the Golfo de Parita where the mean

* Meteorolgia, Año 1970, Estadistica Panameña, Ano XXX, Serie "L".

precipitation for the four driest months was less than 20 mm. along the coast and less than 100 mm. for a distance inland of about 50 km. in the vicinity of Santiago.

The mean annual precipitation for the country is probably above 3000 mm. ranging from less than 1000 mm. near the Golfo de Parita to more than 5000 mm. in the highest mountains in the Western part of Panama. In the province of Chiriqui, the coastal area has a mean annual rainfall of 2000 mm. or more but less than 200 mm. for January - April. In the central provinces of Cocle, Herrera, Los Santos and the Eastern part of Veraguas, the mean annual precipitation is under 2000 mm. in most places. (See Appendix Table 10).

Temperature

Temperature data are available at 16 stations. Mean temperatures generally vary from about 25 to 29 degrees C but are as low as 16.5° C at one of the high elevation stations. The usual daily range from minimum to maximum temperature varies from less than 3 to more than 8° C in different parts of Panama.

Humidity

Relative humidity data are reported for 11 stations. The range is generally from a minimum of about 75% for the drier areas for March and April to more than 95% for some stations during the rainy season. There is a note to the effect that relative humidity readings are taken at 7 a.m. by IRHE and at 8 a.m. by the Panama Canal Company. The values given apparently represent the relative humidity of those hours and not the mean daily values. At Tocumen Airport maximum, minimum and mean values are given. For 1970 these were 95.1, 66.2 and 80.7 percent.

Evaporation

Mean daily values of evaporation in millimeters are given for 8 stations (1970). No mention is made of the method by which the evaporation was measured (Piche, Fuess or Class A pan) but are believed to be Piche evaporation values. Mean annual daily values range from 3.2 to 4.3 with both minimum and maximum values being for the two stations in the same province, Panama. For the province of Los Santos, one of the drier areas, the mean monthly values for two stations ranged from a minimum of 2.8 mm. for July to a maximum of 6.4 mm. for April, with an annual mean of 4.2 mm. per day.

Wind Velocities

Another factor that has a significant effect on evaporation and evapotranspiration, but for which there is little available data in Panama, is the mean wind velocity. This was indirectly taken into account by its effect on evaporation in the procedure used by CATAPAN in estimating potential evapotranspiration.

In "Meteorologia Año 1970," wind data are given for 3 stations in the Canal Zone and at Tocumen Airport. The mean monthly values, in km. per hour, are given in Table 1 for 1970:

TABLE 1. Wind Velocities as Reported for Panama

Month	Altos de Balboa	Madden Dam	Cristobal	Tocumen Airport*
		Km per Hour		
January	10.3	9.8	17.9	28.2
February	13.5	11.7	24.0	33.8
March	10.6	8.7	17.7	26.1
April	10.9	8.5	18.2	26.2
May	9.3	6.9	13.8	25.7
June	7.7	4.7	10.4	21.1
July	7.1	4.2	9.2	20.9
August	6.9	3.7	6.4	20.9
September	4.5	4.0	6.9	20.6
October	5.6	4.2	8.8	24.0
November	10.8	.60	14.0	24.8
December	7.6	6.0	12.9	20.0
Annual	8.7	6.5	13.4	24.4

This tabulation shows that the wind velocities are highest during the four driest months of the year at all four stations. This is typical of other stations with similar climates in Central and South America.

Potential Evapotranspiration

Potential evapotranspiration was computed by CATAPAN for the Madden Dam area, for which the most complete climatic data were available. CATAPAN used and compared eight formulas. The mean annual values computed by the Hargreaves' (1,336 mm.) and Blaney-Criddle (1,417 mm.) formulas were judged to be the closest to the "yearly evapotranspiration." The mean of these values (1,376 mm.) was assumed to be the annual potential evapotranspiration at Madden Dam. This compares with a lake evaporation figure of 1,365 mm. derived from the pan evaporation data by the method of Kohler, Nordenson and Fox, which is assumed by some authorities to be approximately potential evapotranspiration.

Estimates of potential evapotranspiration for other areas of Panama were then made by correlating the available data from 5 evaporation stations with temperature and elevation. These estimated values were then plotted as isolines on a topographic map with a scale of 1:250,000. The evapotranspiration map was then reduced to a scale of 1:500,000. The mean monthly percentages of the annual values were computed for elevations of 100, 500, 1000 and 1500 meters. These values were given in a table on the map, Plate 9-5. The monthly percentages for 100 m. elevation range from a minimum of 5.6% for November to a maximum of 13.2% for March. The maximum annual values of potential evapotranspiration exceed 1,380 mm. for an area near the coast of the Golfo de Parita. Using this value of 1,380 and the monthly percentages given, the estimated potential evapotranspiration (Etp) together with the mean monthly precipitation at Divisa is given in Table 2.

Table 2. Estimated Evapotranspiration (Etp) for Central Provinces and Precipitation at Divisa

Month	Etp mm	Precip. mm	DP mm	Month	Etp mm	Precip. mm	DP mm
Dec.	95	77.5	43	March	182	3.9	0
Jan	151	9.5	0	April	154	35.3	11
Feb	165	3.4	0	May	110	217.7	147

The dependable precipitation, DP, is that for which there is a probability of occurance 75 percent of the time, or 3 out of 4 years. The DP has been estimated from the emperical equation: DP = -15 + 0.75 PM. This dependable precipitation is obviously so little for January through April that it could be neglected in estimating irrigation water requirements.

DESIGN OF AN IRRIGATION SYSTEM

Irrigation Requirement

The mean monthly irrigation requirement depends upon the potential evapotranspiration, the reliable effective precipitation, the crop cover factor, the soil moisture retention of the soil and rooting depth of the crops grown. Since data are not available for all of these factors, and also because the maximum requirement will occur in March when carryover soil moisture from the rains will not be a factor, only the potential evapotranspiration and crop cover factor need be considered to obtain an estimate of the maximum monthly requirement. This estimated maximum requirement determines the required capacity of an irrigation system to meet the full irrigation requirement of the crops. For this report mixed vegetables will be considered and it is assumed that in order to provide fresh produce throughout the year, these vegetables will be in all stages of growth with actual consumptive use varying from possibly 20 percent of Etp for periods of soil preparation to more than 100 percent for some crops during their stage of maximum demand. It would seem that a fair mean value might be from 60 to 70 percent and since this is about the same as the irrigation efficiency, it is believed that the estimated monthly Etp values might well be considered as the field irrigation requirement. The maximum value for March, 182 mm. or about 6 mm. per day, will be considered as a design value.

For convenience in converting irrigation requirement to flow rates some equivalent values are given below:

1 mm/day on 1 hectare (ha) = 0.116 liters per sec. (l/s)

1 liter per second per ha (l/s/ha) = 8.65 mm. depth of water per day

1 liter per sec. (l/s) = 15.9 gallons per minute (gpm US)

Required Capacity of Irrigation System

These relationships will enable one to quickly estimate the required capacity of an irrigation system. For example, for a community garden with a maximum daily demand of 6 mm., the required system capacity would be:

$$q = 6 \times 0.116 = 0.7 \text{ (approx.) liters per second per hectare}$$
$$= 11.1 \text{ gallons per minute per hectare}$$

This assumes continuous flow 24 hours per day, 7 days per week. For convenience, it might be decided that the system should be operated only 12 or possibly 8 hours per day. This would double or triple the required capacity. If it is assumed that the system would be used only 6 days, or possibly only 5 days per week, the requirements would be increased accordingly. Thus, if it was decided that the system would be operated only 8 hours per day for 6 days per week, this would then require a capacity of 0.7 x 7/6 x 24/8 = 2.45 liters per second per hectare of net area or 39 gallons per minute per hectare. The most economical system would obviously be one that would be operated 24 hours per day during periods of maximum demand.

Frequency of Irrigation

The required frequency of irrigation will depend upon the water retention properties of the soil and the rooting depth of the crop grown. The latter depends not only on the crop but on the stratification of the soil. For example, a crop with a normal rooting depth of 1 meter when grown on a soil with a dense hardpan at 50 centimeters may not be able to utilize the water below that depth. Vegetable crops are ordinarily considered shallow rooted compared with many field and perennial crops. For the purpose of estimating required frequency of irrigation, a depth of 50 cm. will be assumed. A lesser depth might be considered during the early stages of growth.

The water retention properties (field capacity or upper level of moisture retention when drained and the wilting percentage or lower available level) depend primarily on the soil texture. The difference between field capacity and wilting percentage may vary from less than 5 to more than 15 percent by dry weight of soil or 7 to 20 percent by volume. For a soil with medium texture, such as a sandy loam, a value of 13 percent by volume would be reasonable. Such a soil, 50 cm. deep, would retain about 6.5 cm. of water that could be used by the crop. For best results not more than about 60 percent of this amount should be used between irrigations. One should irrigate when about 40 percent of the available moisture is still in reserve.

Thus, if the actual maximum consumptive use was 6 mm. per day and the usable moisture in the root zone was only 60 percent of 65 mm., or 39 mm., this could be exhausted in 6.5 days. An extra day could be added to this because the soil moisture would still be above field capacity for about 1 day, sometimes longer, after an irrigation. Thus one could say that when a crop is at the stage when it is using water at the maximum rate, under the soil condition assumed, it should be irrigated about once each week. Considering an irrigation efficiency of 70 percent, which should be obtainable with a sprinkle system, one should apply 7 x 6.0/.70 = 60 mm. of water at each irrigation every seven days. A lesser amount could be applied more frequently but larger amounts less frequently would not be desirable.

During earlier stages of growth, and for the months of less than maximum Etp, a lesser application or less frequent applications would be satisfactory.

A vegetable grower at Boquete stated that because of the drying winds and low water holding capacity of the soil, it was necessary to sprinkle his vegetables every three days during the dry period. He also stated that for potatoes planted in November, only three irrigations in January were required. He harvested them in February.

Water Supply

The water supply to be used for the irrigation of community gardens is a most important factor to be considered. During the dry season, water is not readily available in many places. These are four possible sources of supply that might be considered: streams, wells, ponds or the community water system.

In some places the flow may be insufficient for all of the garden and a decision may have to be made as to what area and location within the garden should be irrigated. A small stream may require that a small dam be constructed so that the flow can be accumulated over a period of several hours for use during a few hours of the day. Since there are no flow records available for these small streams, an inspection of the site, possibly including an actual measurement of the flow, and discussions with local people who are familiar with the stream, will be necessary to insure that there will be water when needed.

There is also a possibility that, although a small stream is present, this water is required downstream for livestock and would not be available for the community garden. This should be ascertained before an irrigation system is installed.

In some locations, water may be available in larger streams at some distance from the garden from which it could be diverted by gravity, or more probably by pumping and conducted to the garden in a small canal. This is done at Dos Rios in Chiriqui Province.

Wells. There is always a possibility that a water supply may be obtained from a well for the garden. The geology of Panama is such, however, that only very small capacity wells, less than 10 gallons per minute, (0.6 l/s) can be developed in most places.*

Where satisfactory wells can be obtained, they can provide a desirable water supply for sprinkler systems since the water is always clean and needs no screening to prevent clogging of sprinkler nozzles. The principal problem to overcome would be the relatively high cost of a satisfactory well and pump. Ordinarily where pumps and wells are used for irrigation, the cost of the well and pump would not exceed $300 to $500 per hectare of the area irrigated. For small community gardens, the cost of developing the well and providing the pump and motor (or gasoline or diesel engine) would probably greatly exceed this amount. The cost of power (or fuel) for pumping from a well would usually be

* From map showing Ground Water Resources of Panama, scale 1:1,000,000 AID Resources Inventory Center, Corps of Engineers, Wash., D.C. Based on Geologic Map of Panama, Administracion de Recursos Minerales.

higher than for pumping from a stream because of the likelihood of the higher pumping head.

Data from which to determine the capacity of wells for any area are somewhat limited. The ground water resource map referred to previously does not indicate the depth or thickness or aquifer materials, nor the relationship between the discharge from a well and the drawdown, i.e. the lowering of the water level in the well during pumping. Many small wells have been drilled for domestic purposes but adequate tests on these wells have not been made, or if made, they have not been reported. Possibly tests could be made on some of these small wells so that estimates of the most economical pumping head could be arrived at.

In areas where there are no wells that might be tested and especially in areas indicated on the map as low producing areas, the chances of developing a well suitable for the irrigation of gardens of 2 ha or more are not good. The drilling of wells in such areas involves considerable risk since well drilling is relatively expensive.

There are many small wells in Panama that have been drilled to supply domestic water to small groups of houses. Most of these wells are equipped with hand pumps. In some communities more modern water systems have been provided by the Ministerio de Salud in recent years. These hand pumped wells are no longer needed and conceivably could be used for irrigating small gardens if they were found to have sufficient capacity and were located reasonably close to the gardens. They could readily be equipped with a portable gasoline engine and jack for use with the hand pump so that the well could be tested and if found suitable they could be equipped with a suitable pump and motor. The cost of testing and equipping these wells with pumps and motors would be small compared with the cost of drilling new wells.

<u>Ponds</u>. In some places it might be possible to construct storage ponds on small streams of sufficient capacity to provide the water supply needed during the dry period. This would depend primarily on the topography which would need to be such that a pond with sufficient capacity could be provided with a low

dam that could be constructed at a reasonable cost. Such a dam would have to be limited in height to of not more than 4 or 5 meters and the pond should have a capacity of not less than about 20,000 m^3 per hectare of irrigated area. This capacity should be sufficient to allow for evaporation and seepage during the dry period.

A spillway around the dam would have to be constructed to prevent overflow and failure of the dam. The capacity of such a spillway would depend mostly upon the drainage area above the dam. This would limit the location to places where the drainage area was sufficient to provide the water needed but small enough so that the cost of the spillway would not be excessive.

Ponds of this kind would have other beneficial uses such as for the propagation of fish and as a water supply for livestock during the dry period. There are many places in the United States where ponds of this kind are used for a combination of these purposes.

Before the construction of a pond is undertaken, the services of an experienced civil or agricultural engineer should be obtained to make the necessary investigations and to design and supervise the construction of the dam in order to insure its safety. An evaluation of the likely effect of the pond on the health of people and domectic animals by a public health official would be desirable.

The investigations must determine from surveys, the drainage area above the dam site and the relationships between the height of the dam, the capacity of the pond and the volume of fill in the dam. A pipe outlet through the dam, or preferably through the natural abutment at one end of the dam with a control gate on the upper end must also be provided. The dam must have sufficient freeboard or height above the maximum water level in the pond to insure its safety. This freeboard above the maximum water level over the spillway for the estimated maximum flow should be approximately 1 meter. The top width should be about 1 vertical to 2.0 or 2.5 horizontal. The top soil must be removed from the area of the fill and a cutoff trench excavated along the center line of the dam. This trench should be then backfilled with least permeable soil available and thoroughly compacted.

The dam should be constructed by placing the fill in thin layers of not more than 15 cm. and thoroughly compacting each layer. Special care should be exercised in backfilling around the outlet pipe to prevent any possibility of water following along the outside of the pipe which might result in a failure. The upstream of the dam should be protected against erosion by wave action by first covering it with some of the surface soil and then planting a suitable grass that makes a good sod. The downstream slope should also be protected to prevent erosion by precipitation.

The soil for the fill could be taken from within the pond area but should not be taken closer than about 50 meters of the dam. The surface soil containing organic matter, roots, etc. should first be removed from the borrow area. This surface soil could later be used to cover the slopes in order to establish a grass cover. These brief and incomplete details are included to indicate some of the factors that must be considered by the designer and builder.

The minimum drainage area required to produce the desired volume of water cannot be accurately estimated from presently available records. The Boletin Hidrologico, Ano Hidrologico, 1969-70, gives runoff data for 37 measuring stations in Panama. Most of these stations are on larger rivers with drainage areas in excess of 100 km^2. The data for 8 stations with drainage areas of less than 50 km^2 were analyzed to determine the total runoff during the period May-December. Unfortunately, most of these stations were in the upper reaches of the rivers at elevations above 600 meters and they probably do not represent the flow that might be available from much smaller drainage areas of less than 1 km^2 at low elevations. Excluding one station for which the reported drainage area was probably in error, the total runoff in depth over the area for the eight months ranged from 1.1 to 4.95 meters. From this preliminary analysis it would appear that a runoff of 1.0 meter or more in depth over the drainage area might be expected in most places. Assuming that the storage capacity should be 20,000 m^3 per hectare of irrigated area, it would appear that a drainage area of three times the area to be irrigated might suffice. To be sure of having a dependable supply, however, it would be safer to have the dam located where the drainage area above it was at least 5 times the area to be irrigated. The principal disadvantage in locating the dam on a larger watershed would be the added cost of the larger spillway required to pass the flood flows.

The maximum flow that might be expected, which would determine the capacity of the spillway, would be ev ore difficult to estimate with any degree of accuracy because this maximum flow is much higher for very small watersheds than for the larger ones for which data are available. This could best be estimated from data on maximum precipitation rates for fairly short periods of time, say 15 minutes, 30 minutes and 1 hour. The only published data on maximum values are for 24 hours*. In 1970, 200 mm. or more precipitation in a 24-hour period was recorded 15 times. Amounts of 300 mm. or more were recorded 4 times in Chiriqui Province with a maximum of 497 at Hornito. All four of these highest occurances were in April. There were no occurances of 200 mm. or more during the months of July through October, when apparently the storms are more general and of less intensity.

Since many of the precipitation stations are equipped with an intensity measuring instrument (pluviografo) data can undoubtedly be obtained on short duration intensities from which maximum flood flows could be estimated for small drainage areas from a rational formula which can be written

$$q = 2.78 \, C \, A \, I$$

where q = the maximum flood flow rate in l/s

C = a coefficient of runoff, which for extreme conditions would approach 1.0

A = drainage area in hectares

I = maximum expected rainfall intensity in mm/hr for the estimated time of concentration

Assuming a drainage area, A, of 10 hectares and a maximum intensity rate, I, of 100 mm/hr for a 30-minute time of concentration and C = 1.0, the maximum flood flow that might occur would be

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* Meteorologia, Ano 1970.

$$q = 2.78 \times 10 \times 10 = 2780 \text{ l/s}$$
$$= 2.78 \text{ m}^3/\text{s}$$

For large drainage areas above the dam, the cost of providing a safe spillway might be a major part of the cost of the dam.

Another possibility that might be considered is the construction of an off-stream pond that could be filled during the rainy period from a nearby stream. Providing a location with suitable topography could be found for such a storage pond, it would have the advantage of not requiring an expensive spillway. Many small ponds of this kind have been constructed in Venezuela to provide water for livestock. In general, these ponds were smaller than would be required for irrigation.

Use of Community Water System for Irrigating Gardens

There also appears to be a possibility that in some localities the community water system might be used to a limited extent for sprinkling the gardens without interfering with the primary purpose for which the system was installed, that of providing a safe dependable water supply for domestic needs. Where the system has a sufficient capacity to provide water for the garden, this would be a very desirable way to irrigate a part of the garden during the dry period. A small pipe (probably 1 inch PVC pipe) leading from the well to the garden and some hydrants with hose and sprinklers are the only requirements. One of the community gardens in Herrera Province that was visited was being irrigated to a limited extent in just this manner.

It would seem that, where the community water system could provide irrigation water, there would need to be adequate control over the amount of water that was used for the garden. This might be accomplished by limiting the area to be irrigated, the size of pipe supplying the garden, or possibly the time during the day (or night) when garden sprinkling would be permitted. Another solution might be to provide a water meter and limit the quantity used, or make a charge for water used.

Summary - Water Supply. In summary, it would appear that the problem of supplying the community gardens with an economical and dependable water supply may be difficult in many places. Each garden must be considered separately and the best solution selected, preferably before the location of the garden is fixed. It is also entirely possible that there are many places where irrigation for the community gardens is just not feasible.

Method of Irrigation for Community Gardens

The method of irrigation for the community gardens should be given careful consideration. This will depend largely on the topography, i.e. the slopes and general smoothness of the terrain and on the soil characteristics, principally the infiltration rate and water retaining properties of the soil. Surface methods of irrigation are not very satisfactory where slopes exceed 2 or 3 percent or where the surface is very uneven and would require considerable grading or leveling. Neither is it satisfactory where small amounts of water must be applied at frequent intervals, where infiltration rates are excessive, or where it is difficult to cover the area without considerable waste of water by deep percolation below the rooting depth of the crop grown.

A first step to be taken in the selection of method of irrigation and the planning of the system would be to make a satisfactory topographic map of the community garden. Such a map should be drawn to a scale of 1:500 or 1:1000, with a contour interval of 10 or 20 cm. for the flatter areas and 50 cm. or 1.0 m. on sloping areas. The map should show all pertinent features such as fences, location of water supply and roadways or permanent pathways within or near the garden should be shown as they might serve as a location for a storage tank.

With such a map the actual area to be irrigated could be determined. The size and shape of the area would be a major factor in determining the required capacity of the system and the layout for the distribution system regardless of whether surface irrigation or a sprinkler system was to be used. For vegetables grown in rows, the choice of irrigation method would obviously be between furrow irrigation and sprinkling.

Furrow Irrigation

Furrow irrigation is used extensively for row crops including all vegetable crops. To obtain a fairly uniform application of water without surface runoff at the end of the furrows or deep percolation losses (that penetrating below the root zone) and hence a satisfactory irrigation efficiency, requires the correct relationship between the flow of water in the furrow, the length of furrow and the infiltration rate. The gradient of the furrow is also important. It should be fairly uniform, but it can be shown that maximum uniformity and highest efficiency can be obtained when the profile is concave, i.e. the furrow is steeper at the upper end and flattens to nearly zero at the lower end. The maximum slope should not be errosive, which limits the gradient to about 1 percent for most soils, less for non-cohesive sandy soils. For steeper slopes, the furrows should be placed on contour grades of 0.5 to 1.0 percent.

Since the rate of infiltration varies considerably with soils, and always decreases with time, the relationship between the factors involved are not simple. Experience in a given area is the best guide to an efficient design. Some soils have very low infiltration rates and long furrows, sometimes several hundred meters, are used for field crops. For flat gradients, less than 0.1 percent, short furrows can be used and the water can be retained in the furrow a sufficient length of time to obtain the desired infiltration. Each furrow is then a small basin.

Irrigation efficiencies vary greatly under furrow irrigation. Losses by runoff at the end of the furrow are visible and an effort is usually made to minimize this loss by cutting back the flow in the furrow when the water approaches the lower end of the furrow. Losses by deep percolation below the root zone go undetected in most instances, and where there is good natural subsoil drainage this deep percolation loss may be appreciable.

Under some conditions of low infiltration rates, the main problem with furrow irrigation is to obtain the desired penetration. The water reaches the end of the furrow and the irrigation appears to have been completed, but upon probing with a soil tube or auger it will be found that the soil has been wetted to only a fraction of the desired depth. Since there may have been no loss by runoff or deep percolation, the efficiency will be high but the irrigation would be unsatisfactory, and would require frequent irrigations.

For the community gardens that the writer has seen, it would appear that furrow irrigation, in the ordinary sense of the term, would not be satisfactory in many places for several reasons. It requires considerable skill, based on experience, to satisfactorily irrigate under the topographic conditions generally prevailing.

There is one type of furrow irrigation that might be satisfactory and that would be to distribute the water throughout the garden in a pipe system and to use several garden hoses to distribute the water to the furrows. This would give adequate control of the water if the furrows were nearly level (along the contour) and were quite short so they would serve as small basins. This would require constant attention on the part of the irrigator to prevent overflow of the furrows and to move each hose at frequent intervals. One could do a good job of irrigating in this manner if water was available in the distribution system under moderate pressure.

<u>Sprinkler Irrigation</u>

The alternative to furrow irrigation for the community gardens would be to use small rotating sprinklers that would apply water at such a rate that it would be absorbed by the soil without puddling the soil or causing runoff. The most feasible scheme would be to distribute the water over the total area of the garden in either an underground or surface pipe system to hydrants to which moveable hoses with sprinklers would be attached. The entire pipe system would be stationary. The sprinkler attached to the hose would be moved from place to place around each hydrant and left in each position a sufficient length of time to apply the desired amount of water. For example, the entire system might consist of a main pipeline from the pump running through the center of the area with two or more cross laterals and hydrants spaced at appropriate intervals. Each hydrant would consist of a short riser of 3/4 inch pipe with a hose bib to which would be attached a length of 3/4 inch garden hose of 15 to 25 meters in length with a small sprinkler on a moveable stand. Each hydrant could serve from 4 to 16 sprinkler settings depending on a diameter of coverage of the sprinkler and the spacing of the laterals and hydrants.

Design of a Sprinkler System for a Community Garden

Assuming that the conditions are such that a sprinkler system would be selected as the irrigation method to use, the following steps might be followed in designing the system. The arrangement of the piping system would be decided. As mentioned previously, an ideal arrangement would be to have a main pipeline go through the approximate center of the area with as many cross laterals as would be required to distribute water to the small hydrants. The spacing of these laterals and the spacing of the hydrants on the laterals would depend on the diameter of coverage of the sprinklers selected which, in turn, would depend primarily on the water pressure.

In some places, such as at Cerro Cama, there is already present a main pipeline crossing the area from the pump location on the adjacent stream. This pipe extends almost to the top of the hill on the upper side of the garden at an elevation of approximately 20 meters above the stream level. There is also a pump that can be powered with the garden tractor. The characteristics of this pump should be determined, but is would appear that it would have a capacity of at least 100 gallons per minute under a head of 25 meters. To distribute this flow of water on the fairly steep side hill and irrigate with furrows would be very difficult. With a low pressure sprinkler system, the water could be distributed through 2 cross laterals spaced about 30 meters apart with 2 or 3 hydrants on each lateral. A storage tank could be constructed at the top of the hill so as to give maximum flexibility in use. The excess water from the pump would go into the tank. From 4 to 6 sprinklers could be used at one time. When the tank was nearly full the pump could be shut off while the water from the tank was being drawn upon.

A more satisfactory arrangement in most places would be to use a lower capacity pump with higher pressure and operate the pump only when the sprinklers are in use. No tank would be required. Pressures of 35 pounds per square inch (25 meters head) or more at the sprinklers produces a better break up of the jet and a more uniform distribution of the water over a larger area.

The diameter of coverage of the sprinklers is primarily a matter of the pressure on the system. Under low pressures, less than 15 pounds per square inch, (10 meters head) a sprinkler such as the Rainbird 20L would be most desirable. This sprinkler has a single nozzle with a fixed pin that intersects the jet causing it to break up into small drops that are distributed over the area covered. Such a sprinkler has a limited diameter of coverage of from about 10 to 15 meters, depending on both the nozzle diameter and pressure. For satisfactory uniformity of coverage these sprinklers should be spaced not more than 60 percent of the diameter covered in a square pattern or 70 percent in a triangular pattern. The spacing would then be 6 to 10 meters.

For higher pressures of 35 pounds per square inch or more, a #20 sprinkler would be most satisfactory. Such a sprinkler would cover a much greater diameter, from about 25 to 30 meters, depending on nozzle size and pressure. Their use would permit a greater spacing of the pipelines and hydrants, or fewer settings around each hydrant. They would also permit lower rates of application and there would be less tendency to puddle the soil. Such sprinklers would be moved at less frequent intervals to apply the same depth of water.

Characteristics of Sprinklers

Some characteristics of small rotating sprinklers are given in Table 3. This selection of Rainbird sprinklers is intended to be illustrative only, as there are many other makes of sprinklers with similar characteristics. Specifications for the Rainbird 20 and 20L sprinklers are reproduced here as Appendix Table II.*

Other nozzle sizes are available for both the 20 and 20L sprinklers including 9/64, 13/64 and 9/32 inch. The pressures given in Table 3 for the

*Page, II, Rain Bird Agricultural Catalog 69A, 1969).

TABLE 3. CHARACTERISTICS OF TWO TYPES OF SMALL ROTATING SPRINKLERS

Sprinkler Model	RAINBIRD 20 (High Pressure)				RAINBIRD 20L (Low Pressure)			
Nozzle size inches	1/8	5/32	11/64	3/16	3/16	13/64	7/32	1/4
Pressure, PSI	35	40	40	45	10	12	15	15
Head, ft.	81	92	92	104	23	28	35	35
Head, m	25	28	28	32	7.0	8.4	10.6	10.6
Discharge, gpm	2.66	4.40	5.32	6.66	3.15	3.97	5.08	6.36
Discharge, l/s	0.168	0.276	0.335	0.418	0.198	0.250	0.318	0.400
Diam of coverage, ft.	77	80	81	82	36	40	44	45
Diam. of coverage, m.	23.5	24.4	24.7	25.3	11.0	12.2	13.2	13.7
Suggested spacing								
Square pattern (*) ft.	46	48	49	50	21.5	24.0	26.5	27.0
m.	14.0	14.6	14.9	15.1	6.5	7.3	7.8	8.2
Net area covered, $ft.^2$	2120	2300	2400	2500	460	516	580	580
Net area covered, $m.^2$	196	214	224	233	42.8	48.0	53.0	54.0
Applic. rate in/hr.	0.122	0.185	0.214	0.257	0.660	0.743	0.860	1.050
Applic. rate mm/hr.	3.08	4.70	5.42	6.50	16.8	18.9	21.8	26.6
Suggested spacing								
Triangular pattern (+) Ft.	54	56	57	58	25	28	31	32
Triangular pattern m.	16.5	17.1	17.4	17.7	7.6	8.5	9.4	9.8
Net area covered, $ft.^2$	2530	2700	2800	2900	540	670	830	880
Net area covered, m^2	235	250	260	270	50.0	62.0	77.0	81.6
Applic. rate, in/hr	0.105	0.160	0.184	0.222	0.570	0.640	0.740	0.905
Applic. rate, mm/hr.	2.66	4.06	4.66	5.63	14.4	16.2	18.8	23.0

(*) Based on 60% of diameter covered, Satisfactory for low and moderate wind conditions, under 10 km/hr. For higher wind velocities, decrease spacing to 50% of diameter covered which will increase mean application rate 40%.

(+) Based on 70% of diameter covered forequilateral triangle. For wind velocities above 10 km/hr decrease spacing to 60% of diameter of covered which will increase application rate 37%.

TABLE 3. CHARACTERISTICS OF TWO TYPES OF SMALL ROTATING SPRINKLERS

Sprinkler Model	RAINBIRD 20 (High Pressure)				RAINBIRD 20L (Low Pressure)			
Nozzle size inches	1/8	5/32	11/64	3/16	3/16	13/64	7/32	1/4
Pressure, PSI	35	40	40	45	10	12	15	15
Head, ft.	81	92	92	104	23	28	35	35
Head, m	25	28	28	32	7.0	8.4	10.6	10.6
Discharge, gpm	2.66	4.40	5.32	6.66	3.15	3.97	5.08	6.36
Discharge, l/s	0.168	0.276	0.335	0.418	0.198	0.250	0.318	0.400
Diam of coverage, ft.	77	80	81	82	36	40	44	45
Diam. of coverage, m.	23.5	24.4	24.7	25.3	11.0	12.2	13.2	13.7
Suggested spacing								
Square pattern (*) ft.	46	48	49	50	21.5	24.0	26.5	27.0
m.	14.0	14.6	14.9	15.1	6.5	7.3	7.8	8.2
Net area covered, $ft.^2$	2120	2300	2400	2500	460	516	580	580
Net area covered, $m.^2$	196	214	224	233	42.8	48.0	53.0	54.0
Applic. rate in/hr.	0.122	0.185	0.214	0.257	0.660	0.743	0.860	1.050
Applic. rate mm/hr.	3.08	4.70	5.42	6.50	16.8	18.9	21.8	26.6
Suggested spacing								
Triangular pattern (+) Ft.	54	56	57	58	25	28	31	32
Triangular pattern m.	16.5	17.1	17.4	17.7	7.6	8.5	9.4	9.8
Net area covered, $ft.^2$	2530	2700	2800	2900	540	670	830	880
Net area covered, m^2	235	250	260	270	50.0	62.0	77.0	81.6
Applic. rate, in/hr	0.105	0.160	0.184	0.222	0.570	0.640	0.740	0.905
Applic. rate, mm/hr.	2.66	4.06	4.66	5.63	14.4	16.2	18.8	23.0

(*) Based on 60% of diameter covered, Satisfactory for low and moderate wind conditions, under 10 km/hr. For higher wind velocities, decrease spacing to 50% of diameter covered which will increase mean application rate 40%.

(+) Based on 70% of diameter covered for equilateral triangle. For wind velocities above 10 km/hr decrease spacing to 60% of diameter of covered which will increase application rate 37%.

TABLE 4. Friction Loss in Standard Pipe in Feet per 100 Feet per 100 Feet (m./100 m.) "C" equals 100

Flow		Pipe Size - Inches									
gpm	l/s	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6
4	0.25	7.0	2.1	0.6	0.3						
6	0.38	14.7	4.6	1.2	0.6	0.2					
10	0.63	38.0	11.7	3.0	1.4	0.5	0.2				
15	0.94	80.0	25.0	6.5	3.0	1.1	0.4	0.2			
20	1.26		42.0	11.1	5.2	1.8	0.6	0.3			
25	1.57		64.0	16.6	7.3	2.7	0.9	0.4	0.1		
30	1.89		89.0	23.0	11.0	3.8	1.3	0.5	0.1	0.04	
35	2.20			31.0	14.7	5.1	1.7	0.7	0.2	0.06	
40	2.52			40.0	18.8	6.6	2.2	0.9	0.2	0.08	
50	3.14			60.0	28.4	9.9	3.3	1.4	0.3	0.11	0.04
60	3.77			85.0	39.6	13.9	4.6	1.9	0.5	0.16	0.06
70	4.40				53.0	18.4	6.2	2.6	0.6	0.21	0.08
80	5.04				68.0	23.7	7.9	3.3	0.8	0.27	0.11
90	5.66				84.0	29.4	9.8	4.1	1.0	0.34	0.14
100	6.28					35.8	12.0	5.0	1.2	0.41	0.17
120	7.53						16.8	7.0	1.6	0.58	0.24
140	8.80						22.3	9.2	2.3	0.76	0.32
160	10.00						29.0	11.8	2.9	0.98	0.40
180	11.40						35.7	14.0	3.6	1.22	0.50
200	14.60						43.1	17.8	4.4	1.48	0.62

Coefficients "C" and Friction Factor "K" for Different Kinds of Pipe* - Sizes 1/8 to 3 inches

Condition of Pipe	"C"	"K"
Very smooth and straight	140	.54
Ordinary straight, Brass etc.	130	.62
Smooth, new steel pipe	120	.71
Ordinary steel pipe	100	1.00
Old steel pipe	80	1.52
Very rough corroded pipe	60	2.58

* Multiply values in Table 4 by the "K" factor.

Table 5. Friction Loss in Feet per 100 Feet (m/100 m.) for Smooth Bore Hose.

Flow		HOSE SIZE - INCHES					
gpm	l/s	5/8	3/4	1"	1 1/4	1 1/2	2"
1.5	0.10	2.3	1.0				
2.5	0.16	6.0	2.5				
5	0.31	21.4	8.9	2.2	0.7	0.3	
10	0.63	76.8	31.8	7.8	2.6	1.0	
15	0.94		68.5	16.8	5.7	2.3	
20	1.26			28.7	9.6	3.9	
25	1.57			43.2	14.7	6.0	1.4
30	1.89			61.2	20.7	8.5	2.0
35	2.20			80.5	27.6	11.2	2.7
40	2.52				35.0	14.3	3.5
50	3.14				52.7	21.8	5.2
60	3.77				73.5	30.2	7.3
70	4.40					40.4	9.8
80	5.04					52.0	12.6
90	5.66					64.2	15.7

From PACO Pumping Manual, page 10.

Table 6. Friction Loss Through Pipe Fittings in Terms of Equivalent Lengths of Standard Pipe, Meters.*

Nominal Pipe Size Inches	Actual Inside Diam. mm.	Gate Valve	Standard Elbow	Angle Valve	Tee Through Side Outlet	Globe Valve
1/2	16.2	0.10	0.27	0.37	0.55	0.82
3/4	20.9	0.15	0.39	0.52	0.77	1.16
1	26.6	0.20	0.52	0.70	1.04	1.56
1 1/4	35.0	0.28	0.74	0.99	1.46	2.20
1 1/2	41.0	0.33	0.89	1.20	1.76	2.66
2	52.3	0.48	1.22	1.64	2.42	3.64
2 1/2	62.5	0.57	1.52	2.05	3.03	4.55
3	77.7	0.75	2.03	2.70	4.00	6.00
4	102.2	1.05	2.81	3.77	5.80	8.40
5	128.0	1.40	3.72	5.00	7.40	11.15

* Add amount given here to length of pipe in meters. From PABCO Pumping Manual, page 9.

Table 7. Friction Loss in Feet per 100 Feet (m/100 m.) in Aluminum Pipe, O.D. Sizes, Inches

Flow gpm	Flow l/s	Pipe Size, O.D. - Inches: 2	3	4	5	6
		Wall Thickness - Inches: 0.5	.05	.063	.063	.063
5	0.31	0.07				
10	0.63	0.32	0.04			
20	1.26	1.20	0.15	0.04		
30	1.89	2.58	0.32	0.08		
40	2.52	4.49	0.56	0.13	0.04	
50	3.14	6.85	0.85	0.20	0.07	0.03
60	3.77	9.67	1.21	0.28	0.09	0.04
70	4.40	12.95	1.61	0.38	0.12	0.05
80	5.04	16.70	2.06	0.49	0.16	0.06
90	5.66	20.80	2.58	0.60	0.20	0.08
100	6.28	25.40	3.18	0.74	0.24	0.10
120	7.53		4.51	1.06	0.34	0.14
140	8.80		6.00	1.41	0.46	0.19
160	10.00		7.76	1.82	0.59	0.24
180	11.40		9.67	2.27	0.73	0.30
200	12.60		11.83	2.78	0.89	0.36
220	13.80		14.12	3.31	1.07	0.44
240	15.10		16.72	3.91	1.27	0.52
260	16.40		19.42	4.56	1.47	0.60
300	18.80		25.45	5.98	1.93	0.79

Based on Scobey's Formula with KS for 2" pipe = 6.34, for 3" pipe, KS = 0.33 and for larger sizes, KS = 0.32. From Marlow Engineering Manual, p. 25.

TABLE 8. Friction Loss in PVC Plastic Pipe, in Feet per 100 Feet (m./100 m.)

Flow		Pipe Size in Inches						
gpm	l/s	3/4	1	1 1/4	1 1/2	2	3	4
5	0.31	5.0	1.5	0.5	---			
10	0.63	19.0	5.0	1.5	1.0			
15	0.94	30.0	10.0	3.5	1.5	---		
20	1.26		17.0	5.5	2.5	1.0		
25	1.57		26.0	8.0	4.0	1.5		
30	1.89			11.0	5.5	2.0		
35	2.20			14.0	7.0	2.5		
40	2.52			18.0	8.5	3.0	---	
50	3.14			25.0	13.0	4.0	1.0	
75	4.71				27.0	8.0	1.5	
100	6.28					15.0	2.0	
125	7.85					22.0	3.5	
150	9.40					30.0	5.0	---
200	12.60						8.0	2.0
300	18.80						16.0	4.0

From Marlow Engineering Manual, page 25.

Tables 7 and 8 were reproduced from page 25 of the Engineering Manual published by Marlow Pumps, I. T. T. The friction loss in PVC pipe is less than for iron pipe or smooth bore hose.

In the design of the sprinkler system, the pipe layout must first be made, then the pipe sizes are selected so that the friction losses are reasonable. Where a gravity source of pressure is available, the friction loss limits the amount of water that will flow through the pipeline, but where pumps are used, a smaller pipe may mean an increased pumping head.

Suggested Layout of Low Pressure Sprinkler System

A suggested layout of a low pressure sprinkler system for an area of 2 hectares (100 m x 200 m) is shown in Figure 1. This layout assumes that a source of water supply is available near the long side of the rectangle. For the design of this system it will be assumed that the system will be operated only during the daytime (12 hours), 6 days per week during periods of maximum demand and that 60 mm. of water is to be applied to the entire area every 7 days. This would require 52 gallons per minute (3.1 l/s) and a total of 10 sprinklers with a capacity of 5.2 gallons per minute (0.31 l/s) #20L sprinkler with 7/32" nozzle operating at a pressure of about 16 pounds per square inch (11 meters head) at the sprinkler. Since all of the area would not require the maximum assumed irrigation requirement at the same time and also because the actual net area irrigated will be less than 2 ha., it will be assumed that 9 sprinklers with a discharge of 5 gpm (0.32 l/s) would suffice and that a total of 45 gallons per minute (2.8 l/s) would be a satisfactory design value.

For the arrangement shown in Figure 1, with 18 hydrants, each sprinkler could serve 2 hydrants and that there would be 3 sprinklers operating on each lateral simultaneously. The flow to the first hydrant on each lateral would be 10 gpm and to the last hydrant, 5 gpm. The friction loss calculations are given below:

For lateral and hose	Friction loss ft.	Friction loss m.
75' 3/4" hose, 5 gpm (0.32 l/s)	6.7	2.0
208' 1" PVC pipe, 5 gpm (0.32 l/s)	3.1	1.0
60' 1" PVC pipe, 10 gpm (0.64 l/s)	3.0	1.0
	12.8	4.0

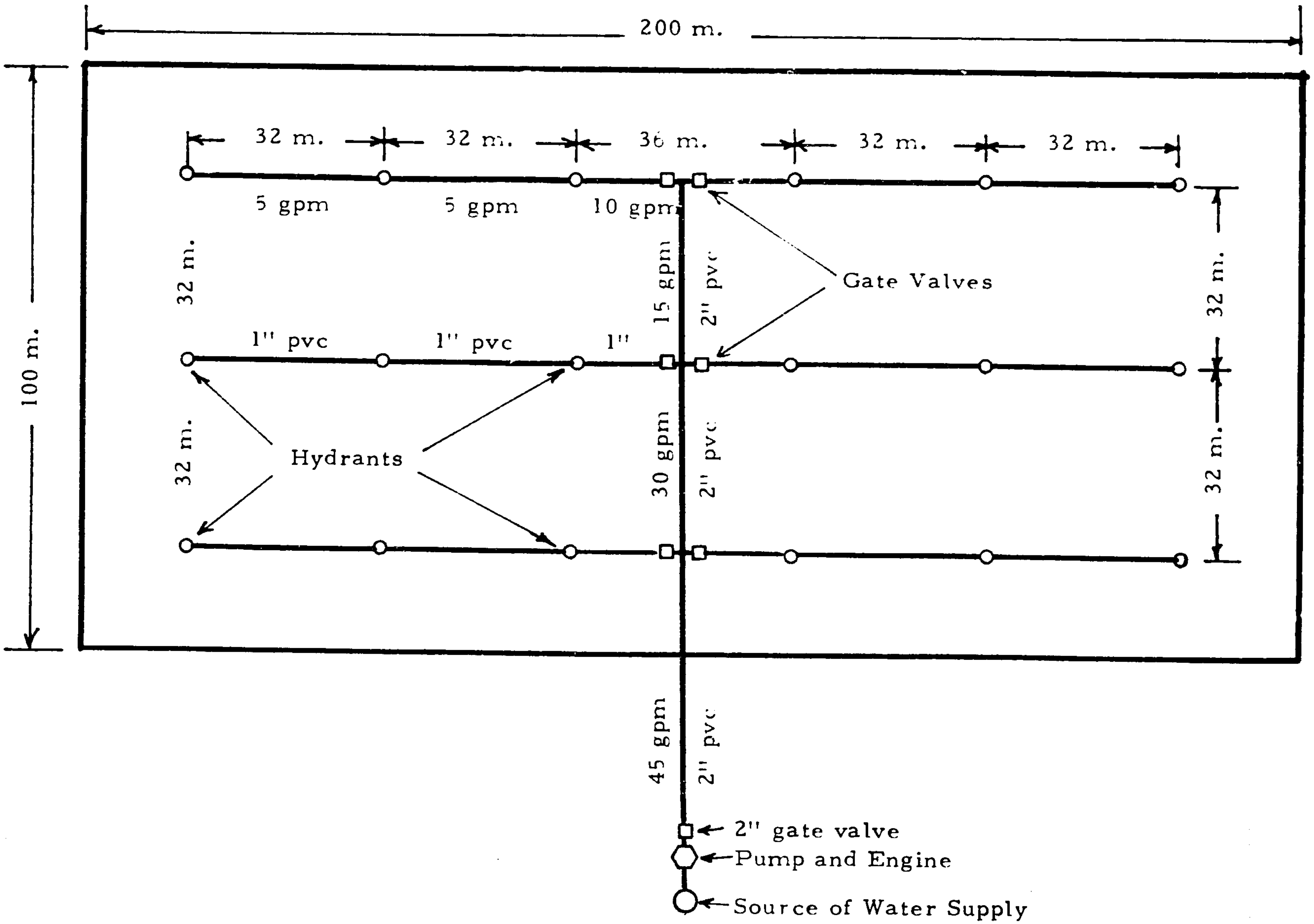


Figure 1. Suggested Layout of Irrigation System for Two Hectare Garden Scale 1 cm. = 10 m.

	Friction loss ft.	m.
For main line from pump		
106' 2" PVC pipe, 15 gpm (1 l/s)	0.5	0.15
106' 2" PVC pipe, 30 gpm (2 l/s)	2.1	0.65
150' (assumed) 2" PVC pipe, 45 gpm (3 l/s)	5.3	1.60
10' 2" discharge hose, 45 gpm (3 l/s)	0.5	0.15
	8.4	2.55
Friction losses at pump		
20' 2 1/2" suction hose	0.5	0.15
2 1/2" foot valve	1.5	0.45
2" tee, side outlet	0.7	0.23
2" gate valve	0.1	0.03
Suction lift (assumed)	10.0	3.04
	12.8	3.90
For sprinkler pressure		
Elevation of highest sprinkler above pump (assumed)	10.0	3.04
Pressure at sprinkler 15 psi	36.0	11.00
	46.0	14.04
Total dynamic head at pump	80.0	24.40

With the low pressure sprinkler covering a circular area of 14 meters diameter, the sprinklers should be spaced about 8 meters apart. This would mean that there will be 16 settings of the sprinkler around each hydrant. For this spacing the sprinkler would have a net application rate of about 21.8 mm. per hour, which is somewhat higher than would be desirable. The actual application rate will be less than this amount over most of the circular area covered, averaging only about 9 mm. per hour. The sprinklers would be moved about every 3 hours and thus 4 settings could be made in a 12-hour day.

High pressure sprinklers could be spaced about twice as far apart and thus only four settings around each hydrant would be required to cover the same area. The sprinklers would need to be moved only once in 12 hours for the same application of water.

A pump would next be selected that would have a discharge of 45 gpm (2.8 l/s) at 80 feet (24.4 m.) total head. Since the discharge of pumps decreases with wear, one should add about 20% to the required discharge and select a pump for about 54 gpm (3.4 l/s) at 80 feet (24.4 m) head.

The power required for such a pump would be given by the formula

HP = q H/ (3960 x E)

Where HP is the required horse power

q is the pump discharge in gpm

H is the total dynamic head in feet.

For the example above, assuming a pump efficiency of 50 percent

HP = 54 x 80/ (3960 x .50) = 2.2 HP

In metric units, the required horsepower would be

HP = 3.4 x 24.4/ (76 x .50) - 2.2 HP

One would select a 2.5 or 3.0 HP electir motor or 3 or 3.5 HP gasoline engine.

A 1 1/2" or 2" centrifugal pump with proper impeller diameter and driven at the correct speed should meet this requirement.

The same pump with a larger diameter impeller or driven at a higher speed, could be used for a high pressure sprinkler system.

Assuming the same sprinkler discharge, 5 gpm (0.31 l/s), but at a pressure of 45 psi (32 m. head), the friction losses through the entire system would be the same. The only difference would be the static head of 32 m. instead of 11 m., an increase of 21 m., making a total dynamic head of 24.4 + 20.6 or 45 m. The power requirement would then be

HP = 3.4 x 45/ (76 x .50) = 4 HP

For continuous duty, one would probably select a 4 HP electric motor or a 5 HP gasoline or diesel engine for this installation.

Cost Estimate

Data are not available from which an accurate cost estimate can be made. The unit prices given here are only approximations. They are intended to give only a rough idea as to what the cost might be for the suggested layout shown in Figure 1. They do not include transportation of pipe and other equipment to the site nor installation costs. If the pump and engine and other equipment must be purchased from U.S. manufacturers, the cost may be higher than if Japanese or possibly European equipment is used.

	U.S. Dollars
Pump and engine (add about $200 for diesel engine)	$800.00
Suction hose and foot valve	55.00
Discharge hose	20.00
Gate valve, 2 inch (2")	25.00
Pumping plant complete	$900.00
<u>Pipe System</u>	
360 feet 2" PVC (200 psi) at .30/ft (110 m.)	108.00
2400 feet 1" PVC at .15/ft (7.30 m.)	360.00
6 - 1" gate valves at 5.00	30.00
18 hydrants complete at 5.00	90.00
9 Low pressure sprinklers at 7:00	63.00
9 - 75' lengths of 3/4" hose (plastic) at .25/ft (206 m.)	170.00
Miscellaneous pipe fittings allowance	29.00
Total for pipe system	$850.00
Total Cost	$1,750.00

APPENDIX

ITINERARY

May 7, 1972 (Sunday) - 2230 hrs. Arrived in Panama.

May 8, (Monday)

Picked up at Hotel by Mr. Nicanor Castillo, Jr. Spent day at USAID Office and visit to Ministerio de Salud to meet the Minister and Ing. Jose A. Sucre, Sanitary Engineer.

May 9, (Tuesday)

Made trip to Cerro Cama and El Zahino Projects. Rain prevented visit to another project.

May 10, (Wednesday)

Spent day at office and made visits to equipment companies in Panama. Made arrangements for visit to Colon area with Sr. Camarano of the Ministerio de Salud.

May 11, (Thursday)

Made trip to Colon area to visit community water systems being installed at Palmas Bellas and Pina.

May 12, (Friday)

Made trip to the office of Comision Nacional de Aguas to meet Ing. Terence Scharenguivel who came to Panama about 3 years ago and completed an irrigation project for UN Special Fund. This project is located near Chitre in the Peninsula de Azuero.

The afternoon was spent with Mr. Castillo contacting firms in Panama that supply various kinds of irrigation equipment.

May 15, (Monday)

Spent day at office

May 16, (Tuesday)

Left for a two-day trip to the provinces of Cocle and Veraguas with Sr. Castillo. Stayed overnight at Aguadulce. Visited Sr. Castillo's farm. Attempted to irrigate papayas but found that the soil had a very high infiltration rate. The flow (about 8 gallons per minute) failed to reach the end of the furrow, about 21 m.

May 17, (Wednesday)

Visited the Escuela Nacional deAgricultura at Divisa. Discussed both irrigation and drainage problems with 3 of the staff. Continued on to Potuga to see 2 community gardens. One is being cared for by the men of the community and the other by 29 women. The men's garden has been irrigated to a very limited extent by pumping from a stream in which a dam has been constructed to form a pool. A small part of the women's garden has also been irrigated from a half-inch PVC pipe connected to the community water system. These gardens differ from the ones previously seen in that the topography is much flatter and there is no convenient hill on which a storage tank could be built. Returned to Panama in the late afternoon.

May 18-19, (Thursday and Friday)

Spent 2 days at the office writing report.

May 22, (Monday)

Made trip to Las Mararitas near Chepo, east of Panama City with Sr. Castillo and Dr. Ervin Bullard. Saw the topographic conditions pertaining to this region and inspected 1 site that had been selected for the community garden. This site was adjacent to the Rio Mamoni. To irrigate this garden from the river would require that the pump be on one side of a public roadway and that the water be conducted across the roadway, probably through a cutout under the roadway.

May 23, (Tuesday)

Began 4-day trip to western part of Panama with Sr. Castillo. Followed the Interamerican Highway to David in the province of Chiriqui then on to Boquete in the mountains. Intended to visit a community garden at Dos Rios but rainstorm prevented it.

Discussed irrigation at Boquete with Sr. Lamastos who grows vegetables on the Mesa above Boquete. He irrigates from a 6-inch pipe line supplied by gravity from a perennial stream. Says water supply is not adequate. Must sprinkle vegetables every 3 days during the dry period. Irrigates potatoes 3 times only in January and harvests them in February.

May 24, (Wednesday)

Spent most of forenoon in Boquete discussing irrigation problems. Saw the flood damage and problems resulting from a flood that occurred in 1969 which drowned 10 persons and destroyed several bridges and buildings. Made suggestions for improving channel to help protect against reoccurance of similar floods.

Stopped at Dos Rios and inspected 2 community gardens. Each had an area slightly less than 2 ha. These gardens were on much flatter slopes, estimated to be about 1 percent slope, and probably could be irrigated by surface methods if the soil was not too permeable. They provide water to one garden from a canal that comes from a nearby perennial stream. The water is pumped into the canal. Water became available only a month or so ago and these has not been time to determine how satisfactory the surface irrigation will be.

May 25, (Thursday)

Spent some time at San Benito Vocational School in Volcan where they were having some drainage problems. This school is operated by 2 North Americans who began their carerrs in Panama as Peace Corps volunteers. This school trains young men in vocational skills including agriculture, farm mechanics, woodworking, furniture repair, etc. Advised with respect to the drainage problem. Rainfall here was reported to be about 130 inches per year. The major problem is surface drainage. Subsoil drainage is also needed. Some drains have been excavated, but were not deep enough. More and deeper drains are needed.

Returned to Concepcion, then West to the Costa Rican border. Saw some of the flatter areas in this region where some sugar cane is irrigated. Did not see the large irrigation project of the Chiriqui Land Company where more than 8000 ha. of bananas are irrigated because of road construction and lack of time. Returned to David for a late lunch, then back to Aguadulce for the night.

May 26, (Friday)

Returned to Divisa to discuss irrigation and drainage problems with Professors Rolando Lasso G. and Jose A. Dutary, at the Instituto Nacional Agricola. Was with a topographic map of one area where they need drainage during the wet season and would like a sprinkler system to use during the dry season. Promised to give them some assistance and recommendations.

After lunch at Anton returned to Panama City after 4 p.m.

May 29, (Monday - Memorial Day)

Office closed but spent most of the time at the apartment working on the INA sprinkler system and writing report.

May 30 - June 2

Spent time at office writing report.

June 3

Left Panama at 9:50 a.m.

Appendix Table 9. Mean Precipitation in mm, Republic of Panama

Province and Station	Elev. m	Lat °N	Long °W	Years of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Prec 1970
COCLE																		
Boca del Toabre	--	8 02	77 36	10+	301	147	154	378	478	362	351	391	290	356	491	594	4294	6238
Chiguiri Arriba	--	8 41	80 13	10+	97	69	46	156	335	426	444	425	391	449	431	306	3576	4314
El Cope	--	- --	-- --	1+	281	85	55	178	314	176	238	370	473	512	188	262	-	3133
El Cortezo	43	8 20	80 35	10+	17	9	6	35	213	351	186	229	315	522	348	87	2318	2024
El Harino	186	8 37	80 34	10+	58	21	17	69	180	286	128	197	214	291	154	62	1675	1960
El Valle	582	8 36	80 10	6+	35	41	26	101	347	449	406	460	484	519	341	165	3376	3571
La Pintada	--	- --	-- --	1+	212	153	101	252	300	401	254	532	901	707	544	754	-	5111
Rio Grande	18	8 25	80 29	10+	6	7	11	40	161	193	122	149	221	315	197	63	1485	1831
Santa Clara	--	8 24	80 07	10+	11	3	1	21	149	141	112	137	132	167	170	77	1122	968
Santa Rosa	24	8 12	80 40	9+	-	2	3	31	212	211	170	198	238	346	252	72	-	-
COLON																		
Agua Clara	457	9 22	79 43	4+	93	45	54	131	131	324	327	364	317	498	584	408	3544	4576
Cocle del Norte	2	9 04	80 34	1+	340	426	935	895	767	682	769	542	398	574	982	790	-	8836
Cristobal	12	9 21	79 55	10+	84	39	38	103	319	331	395	389	320	399	574	308	3300	4224
El Chorro	43	8 58	79 59	6+	70	32	34	86	272	261	202	276	310	330	329	203	2405	2869
Isla Grande	73	9 38	79 34	7+	67	38	71	75	372	274	300	-	-	-	-	-	-	-
Portobelo	5	9 32	79 40	10+	130	74	69	164	446	421	469	492	339	400	641	415	4061	4886
Salud	20	9 12	80 08	5+	149	73	96	204	509	381	524	487	329	500	714	513	4479	4956
Escandalosa	459	9 26	80 35	5+	-	-	71	150	372	331	368	322	278	315	481	326	-	-
CHIRIQUI																		
Alanje	--	8 18	82 32	10+	22	46	24	136	232	259	266	339	282	423	273	113	2415	2807
Angostura de Cochea	210	8 33	82 23	6+	35	44	71	184	437	582	434	606	665	790	582	154	4583	4521
Bajo Boquete	1100	8 47	82 28	4+	72	69	55	164	408	542	295	435	662	594	218	127	3641	4305
Bambito	--	8 50	82 37	5+	40	21	23	120	-	394	226	282	368	472	235	76	-	2016
Caldera	275	8 34	82 25	5+	21	55	53	199	466	612	385	437	652	747	384	89	4100	4862
Camaron	--	8 04	81 39	9+	25	32	42	137	350	488	378	456	531	784	524	136	4882	3669
Cermeno	300	- --	-- --	4+	62	37	44	145	365	443	299	439	385	505	320	128	3174	3899
Cuesta de Piedra	1000	8 41	82 37		196	51	-	461	706	772	546	994	1023	822	809	-	-	-
David	--	8 25	82 26	3+	50	65	59	183	203	323	309	402	356	473	312	115	2850	3118
Divala	100	8 25	82 43	2+	46	40	42	75	241	124	261	231	309	352	349	96	2169	2418

From Meteorologia, Ano 1970, Estadistica Panamina, Serie "L".

Appendix Table 9. (Continued)

Province and Station	Elev. m	Lat °N	Long °W	Years of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Prec 1970
CHIRIQUI (Cont)																		
Finca Gonzalez	1859	8 52	82 38	6	97	65	39	155	188	248	200	254	266	298	202	176	2190	3464
Finca Lerida	1580	8 48	82 29	6	98	86	55	182	245	318	193	268	387	426	255	181	2694	3828
Hato Viejo	--	8 24	82 31	5	26	32	32	150	299	385	399	420	453	586	321	148	3250	3404
Hornito	--	8 44	82 14	10+	376	295	247	338	285	392	358	399	342	410	375	458	4276	6609
La Cordillera	1300	8 44	82 16	7	146	81	74	267	371	454	312	406	496	599	338	188	3730	5240
La Esperanza	185	8 35	82 20	5	61	85	77	156	619	536	458	559	800	739	424	157	4671	4959
La Pita	--	8 24	82 14	2	29	0	52	238	268	430	247	505	471	468	336	91	-	-
Los Palomos	425	8 35	82 29	7	65	80	91	244	457	502	446	534	643	767	485	135	4449	5435
Nueva California	--	8 47	82 39	10+	19	33	26	134	293	370	289	330	441	500	268	52	2754	3677
Palo Grande	100	8 24	82 33	1+	54	8	48	44	218	135	285	283	273	-	289	114	-	-
Planta Caldera	--	8 39	82 23	10+	34	67	72	241	442	641	459	491	662	869	360	78	4416	5273
Potrerillos Arriba	1400	8 41	82 29	5	42	42	103	253	442	738	518	664	810	803	489	73	4976	5975
Pueblo Nuevo	270	8 34	82 25	8	37	67	36	214	396	518	376	425	542	700	390	100	3800	3369
Puerto Armuelles	15	8 17	82 52	8+	-	22	30	84	234	240	204	269	291	531	297	90	-	-
Remedios	20	8 14	81 49	1+	250	102	172	164	344	410		525	456	656	578	185	-	4203
San Lorenzo	30	8 19	82 06	3	30	57	33	124	373	438	416	500	461	566	391	103	3492	3860
Veladero (Guacaca)	--	8 25	82 18	7	32	36	32	143	312	412	412	509	510	659	373	140	3570	3838
Veladero (Tole)	350	8 13	81 40	6	29	39	43	124	337	464	331	404	451	579	349	111	3262	3704
DARIEN																		
Boca de Cupe	--	8 02	77 36	6	29	28	52	143	296	317	240	263	262	292	310	197	2429	4030
HERRERA																		
Divisa	180	8 08	80 42	5+	10	3	4	35	218	206	150	188	221	319	238	78	1670	1872
Las Minas	--	7 47	80 41	7+	27	20	16	73	300	276	199	285	334	379	280	157	2347	2830
Los Canelos	--	8 47	80 41	7	10	4	11	46	177	214	175	224	257	313	239	78	1746	1731
LOS SANTOS																		
Atalayita	50	7 52	80 32	5	7	18	6	19	187	178	122	186	237	313	178	40	1491	1766
Los Tablas	--	7 46	80 17	4	3	7	2	23	111	202	118	133	148	263	145	55	1209	1297
Los Santos	20	7 56	80 24	6	13	12	8	22	86	147	104	118	176	243	163	48	1140	1601
Macaracas	--	7 44	80 33	3+	-	13	4	48	210	218	-	-	238	316	265	65	-	-
Quebrada la Llana	--	- --	-- --	3	29	15	14	49	240	308	236	356	455	424	226	113	2542	2952
Tonosí	15	7 23	80 23	4+	29	13	22	69	316	191	257	294	320	325	305	119	2220	2609

Appendix Table 9. (Continued)

Province and Station	Elev. m	Lat °N	Long °W	Years of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Prec 1970
PANAMA																		
Altos de Balboa (2)	30	8 58	79 33	10+	30	17	16	71	205	204	188	199	199	271	262	128	1789	1799
Candelaria	101	9 23	79 32	4+	114	63	44	152	352	332	344	361	310	347	420	335	3173	4027
Canita	200	9 13	78 54	7	68	23	20	114	347	382	287	300	455	414	404	199	3013	4904
Capira	110	8 45	79 52	1+	54	25	51	84	335	-	207	443	152	310	226	147	-	2156
Chepo	80	9 10	79 05	10+	77	8	12	65	262	265	240	259	290	400	358	156	2394	3574
Chico	122	9 16	79 31	4+	46	18	12	76	299	303	338	344	334	388	369	203	2548	3439
Maje	130	9 10	78 49	8+	52	16	15	85	215	233	236	244	236	270	287	132	2022	3097
Piria	--	9 08	78 28	2+	-	27	37	96	240	350	210	239	247	261	238	170	-	-
Repressa Madden	76	9 12	79 37	10+	27	13	13	78	278	293	309	300	288	352	349	146	2445	2851
Tocumen	61	9 05	79 23	9+	15	10	6	57	211	258	171	218	231	310	270	104	1861	2154
Universidad	34	8 59	79 32	6+	49	22	17	44	246	223	208	237	227	326	350	148	2096	1864
Zanja Escondida	75	9 13	78 32	1+	63	49	20	98	120	97	96	148	246	199	273	273	-	1800
VERAGUS																		
Calobre	--	8 19	80 48	9+	19	28	33	124	322	342	305	326	383	508	371	110	2871	3397
Canto del Llano	250	8 08	80 58	4+	30	20	25	121	325	416	249	371	390	491	364	135	2936	3327
Casa de Maquinas	--	- --	-- --	2+	84	6	89	182	492	549	317	559	600	630	537	282	4328	4550
Cerro Redondo	--	- --	-- --	2+	32	51	180	212	279	314	379	550	498	557	550	139	3740	3799
El Cobrizo	470	8 28	81 23	8+	10	14	29	104	238	413	319	343	466	600	286	78	2900	4006
El Flor	550	8 25	80 51	9+	13	36	37	162	408	570	467	493	623	643	444	153	4050	4825
El Palmar	--	8 32	81 04	10+	92	60	52	249	204	324	201	273	306	336	276	169	2543	3681
Laguna la Yeguada	640	8 27	80 51	7+	12	46	14	113	316	555	356	421	571	585	361	120	3570	4185
Laguna San Juan	800	8 28	80 51	10+	21	15	22	129	293	530	353	406	552	570	419	95	3404	3868
Loma Llana	--	8 36	80 55	10+	81	64	28	172	250	490	503	598	714	709	594	258	4461	7279
Los Valles	--	8 27	81 13	4+	36	19	27	99	240	370	234	385	413	518	283	93	2717	3712
Rio Vigui	--	- --	-- --	2+	106	35	78	225	425	388	297	562	773	578	610	273	4352	4688
San Francisco	85	8 15	80 58	8+	16	31	22	112	276	364	287	336	363	474	295	99	2674	2788
San Juan	--	- --	-- --	2+	63	1	79	213	385	287	190	487	604	348	428	138	3223	3312
Santa Fe	463	8 31	81 05	7+	54	34	32	119	231	332	214	268	311	371	224	135	2325	3036
Sitio del Desvio	640	8 27	80 52	7+	12	48	15	140	357	572	387	441	575	639	366	129	3681	4218

APPENDIX 9B

TABLE 10. IRRIGATION PROJECTS IN PANAMA OF MORE THAN 100 HECTARES IRRIGATED FROM SURFACE WATER

No.	Name	Lat.	Long.	Area irrigated (hectares)	Source of water	Capacity of main canal (m^3/sec.)	Crops irrigated	Methods	Period of irrigation
	Azucarera "La Estrella"								
1a	(gravity)	8°17'	80°31'	925	Rio Chico	1.0	Sugar cane	C	January-April
1b	(bombas)	8°19'	80°29'	1550	Rio Chico	(4)	Sugar cane	B	January-April
	Azucarera Nacional								
2a	"Boquilla"	8°09'	80°35'	500	Rio Sta.Maria	1.03	Sugar cane	B	January-April
2b	"Panela"	8°08'	80°40'	120	Rio Sta.Maria	0.4	Sugar cane	B	January-April
2c	"Sta. Rosa"	8°12'	80°40'	100	Lagunas artificiales	0.2	Sugar cane	G	January-April
2d	"Sta. Teresa"	8°08'	80°39'	140	Rio Sta. Maria	0.57	Sugar cane	B	January-April
3	Bella Castillo	8°25'	80°33'	150	Rio El Cano	0.33	Pangola	B	January-April
4	Betty (Canal de)	8°35'	82°35'	400	Rio Chico	0.64	Rice, pasture	G	September-April
5	Bijagual (Canal de)	8°35'	82°24'	100	Rio Cochea	0.6	Tobacco, tomatoes	G	January-April
	Chiriqui Land Co.								
6a	"Almendro"	8°24'	82°51'		Rio Chiriqui Viejo	2.42	Bananas	G	December-April
6b	"Las Huacas"	8°22'	82°47'		Rio Colorado		Bananas	B	December-April
6c	"Sta. Librada"	8°24'	82°46'		Rio Gariche	2.18	Bananas	G	December-April
7	Churube Abajo	8°23'	80°32'	300	Rio Churube	Under const.	Pasture	B	
8	El Rosario	8°21'	80°20'	300	Rio Chorrerita	0.1	Pasture	G	January-April
	Escuela Nac. de Agric.								
9a	"Corita"	8°09'	80°42'		Rio Sta. Maria	0.35	Corn, sugar cane, rice	B	December-April

APPENDIX 9B

TABLE 10. IRRIGATION PROJECTS IN PANAMA OF MORE THAN 100 HECTARES IRRIGATED FROM SURFACE WATER (continued)

No.	Name	Lat.	Long.	Area irrigated (hectares)	Source of water	Capacity of main canal (m^3/sec.)	Crops irrigated	Methods	Period of irrigation
9a	"Nongo"	8°09'	80°42'		Rio Sta. Maria	0.1	Corn, sugar cane, rice, pasture	B	December-April
10	Estacion Exp.MACI (LaVilla)	7°57'	80°24'	50 (1)	Rio La Villa	0.12	Corn, beans, tomatoes, rice	B	January-April
11	Gualaca (Canal de)	8°32'	82°18'	40 (2)	Rio Chiriqui	0.53	Pasture	G	January-April
12	Hacienda Carta Vieja	8°27'	82°32'	160	Rio Chico	0.83	Sugar cane, rice	G	September-April
13	Hicaco (Finca)	8°23'	82°21'	100 (3)	Rio Chiriqui		Rice, pasture	G	September-April
14	Macho (Canal de)	8°23'	82°36'	300	Rio Chico	0.54	Tobacco, rice	G	September-April
15	Ramon Chen (Finca de)	8°23'	82°40'	600	Rio Escarrea	0.73	Rice	G	March-December
16	Rojos (Canal de)	8°26'	82°35'	750	Rio Chico	0.5	Tobacco, rice, pasture	G	September-April
17	Sanchez (Canal de)	8°23'	82°37'	120	Qda. Balsa	0.46	Rice, tobacco	G	September-April
	Santa Monica								
18a	Santa Monica	8°22'	80°13'	910	Rio Chico	2.0	Pasture	G	December-April
18b	Santa Monica	8°21'	80°11'	340	Rio Chico	0.5	Pasture	G	December-April
18c	Santa Monica	8°22'	80°14'	490	Rio Anton	0.46	Pasture	G	December-April
19	Vda. de Sanchez (Canal de)	8°23'	82°37'	100	Qdas. Bolsa y Chacona	0.4	Pasture	G	January-April

(1) This canal is designed to irrigate 150 hectares of land of which only 50 hectares are presently irrigated.
(2) This canal was originally constructed to irrigate 600 hectares but presently irrigates only 40 hectares.
(3) This canal is not in use at the present time.
(4) Water is supplied by 6 pumps with a total estimated capacity of 38,000 gallons per minute (2.4 m^3/sec.).

Sheet 2 of 2

FULL CIRCLE SPRINKLERS — RAIN BIRD

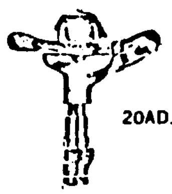
20 SERIES

20

½" male bearing. Standard or TNT.
Cast bronze body and arm
Brass straight bore lipped nozzle, bearing sleeve and nipple.
Stainless steel arm spring.

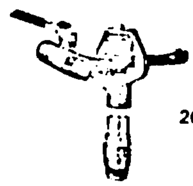
Highest point of stream is 7' above nozzle.*

P.S.I. Nozzle Pressure	Nozzle 7/64" Diameter Feet	Nozzle 7/64" Discharge G.P.M.	Nozzle 1/8" Diameter Feet	Nozzle 1/8" Discharge G.P.M.	Nozzle 9/64" Diameter Feet	Nozzle 9/64" Discharge G.P.M.	† Nozzle 5/32" Diameter Feet	† Nozzle 5/32" Discharge G.P.M.	Nozzle 11/64" Diameter Feet	Nozzle 11/64" Discharge G.P.M.	Nozzle 3/16" Diameter Feet	Nozzle 3/16" Discharge G.P.M.	Nozzle 13/64" Diameter Feet	Nozzle 13/64" Discharge G.P.M.	Nozzle 7/32" Diameter Feet	Nozzle 7/32" Discharge G.P.M.
[illegible]	[illegible]	[illegible]	72	[illegible]	73	[illegible]	73	[illegible]	[illegible]	[illegible]	74	[illegible]	75	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	75	2.21	76	2.83	76	[illegible]	77	4.17	77	4.85	78	5.75	79	6.54
30		[illegible]	76	2.44	77	3.10	78	[illegible]	79	4.57	79	5.3[illegible]	80	6.[illegible]	80	7.20
35	76	2.05	77	2.66	78	3.36	[illegible]	[illegible]	80	4.90	81	5.64	82	6.83	82	7.79
40	77	2.20	78	2.86	79	3.61	80	4.40	81	5.32	[illegible]	6.27	83	7.31	83	8.35
45	78	2.32	79	3.04	80	3.82	81	4.68	82	5.65	83	6.66	84	7.76	84	8.88
50	79	2.44	80	3.22	81	4.03	82	4.95	83	5.95	84	7.03	85	8.18	85	9.38



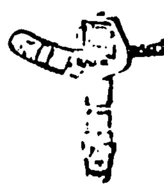
20ADJ

Same as 20 above except has adjustable pin type nozzle for better stream break up



20DC

Same as 20 above except has distance control nozzle to reduce diameter to 30 feet.

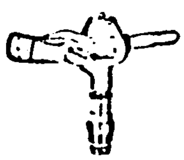


20L

Low pressure sprinkler.
½" male bearing. Standard or TNT.
Cast bronze body and arm
Low tension stainless steel arm spring and stainless steel bearing spring for low pressure operation
Special brass fixed pin nozzle for better stream break up at low pressure.

P.S.I.	Nozzle 11/64" Dia	Nozzle 11/64" G.P.M.	Nozzle 3/16" Dia	Nozzle 3/16" G.P.M.	Nozzle 13/64" Dia	Nozzle 13/64" G.P.M.	† Nozzle 7/32" Dia	† Nozzle 7/32" G.P.M.	Nozzle 1/4" Dia	Nozzle 1/4" G.P.M.	Nozzle 9/32" Dia	Nozzle 9/32" G.P.M.
3	18	1.45	19	1.71	19	1.94	20	2.30	21	2.95	21	3.52
4	23	1.68	24	1.99	24	2.04	25	2.67	26	3.42	27	4.07
5	27	1.89	28	2.24	28	2.39	29	2.98	30	3.82	31	4.55
6	30	2.09	31	2.46	31	2.59	32	3.29	33	4.20	34	4.98
8	33	2.40	34	2.83	34	3.05	35	3.74	36	4.74	37	5.67
10	35	2.67	36	3.15	37	3.63	38	4.11	39	5.19	40	6.20
12	38	2.94	39	3.47	40	3.97	41	4.52	42	5.62	43	6.71
15	41	3.30	42	3.91	43	4.46	44	5.08	45	6.36	46	7.59

20A-L-TNT 5°

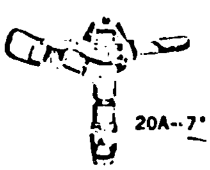


½" male TNT bearing only
Cast bronze body
Anodized aluminum arm with a brass bushing and a neoprene bumper
Stainless steel arm spring and bearing spring
Brass bearing sleeve, nipple and low angle 5° nozzle.

Highest point of stream is 1.5' above nozzle

P.S.I.	Nozzle 3/32" 5° Dia	Nozzle 3/32" 5° G.P.M.	Nozzle 7/64" 5° Dia	Nozzle 7/64" 5° G.P.M.	Nozzle †1/8" 5° Dia	Nozzle †1/8" 5° G.P.M.	Nozzle 9/64" 5° Dia	Nozzle 9/64" 5° G.P.M.	Nozzle 5/32" 5° Dia	Nozzle 5/32" 5° G.P.M.	Nozzle 11/64" 5° Dia	Nozzle 11/64" 5° G.P.M.
15	—	—	—	—	46	1.47	47	1.61	48	2.21	49	2.73
20	—	—	46	1.48	47	1.64	48	2.03	49	2.55	50	3.13
25	46	1.25	47	1.69	48	1.87	49	2.31	50	2.83	51	3.40
30	47	1.38	48	1.84	49	2.06	50	2.53	51	3.11	52	3.74
35	48	1.47	49	1.98	50	2.22	51	2.73	52	3.38	53	4.07
40	49	1.55	50	2.09	51	2.38	52	2.92	53	3.56	54	4.30
45	50	1.62	51	2.20	52	2.51	53	3.11	54	3.79	55	4.55
50	51	1.71	52	2.29	53	2.65	54	3.26	55	4.00	56	4.79

20A SERIES



20A-7°

½" male bearing. Standard or TNT
Cast bronze body
Anodized aluminum arm with brass bushing or cast bronze arm, both arms have neoprene arm bumper.
Brass bearing sleeve, nipple and low angle 7° nozzle.
Stainless steel arm spring and bearing spring.

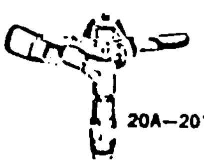
Highest point of stream is 3' above nozzle.*

ALUM ARM

P.S.I.	Nozzle 7/64" Dia	Nozzle 7/64" G.P.M.	† Nozzle 1/8" Dia	† Nozzle 1/8" G.P.M.	Nozzle 9/64" Dia	Nozzle 9/64" G.P.M.
15	—	—	43	1.75	45	2.20
20	43	1.55	45	1.97	47	2.53
25	45	1.73	47	2.21	49	2.83
30	47	1.89	49	2.44	51	3.10
35	48	2.05	51	2.66	53	3.36
40	50	2.20	52	2.86	54	3.61
45	51	2.32	54	3.04	56	3.82
50	52	2.44	55	3.22	57	4.03

BRONZE ARM

P.S.I.	† Nozzle 5/32" Dia	† Nozzle 5/32" G.P.M.	Nozzle 11/64" Dia	Nozzle 11/64" G.P.M.	Nozzle 3/16" Dia	Nozzle 3/16" G.P.M.	Nozzle 13/64" Dia	Nozzle 13/64" G.P.M.	Nozzle 7/32" Dia	Nozzle 7/32" G.P.M.
15	47	2.68	48	3.24	50	3.91	52	4.45	55	5.[illegible]
20	49	3.04	50	3.72	52	4.33	54	5.13	57	5.83
25	51	3.43	52	4.17	54	4.87	56	5.75	59	6.54
30	53	3.78	54	4.57	55	5.33	58	6.30	61	7.20
35	54	4.10	55	4.96	57	5.84	60	6.83	63	7.79
40	56	4.40	57	5.32	59	6.27	62	7.31	65	8.35
45	57	4.68	58	5.65	60	6.66	64	7.76	67	8.88
50	59	4.95	60	5.95	62	7.03	65	8.18	69	9.38



20A–20°*

Same as 20A–7° above except has a 20° nozzle.

Highest point of stream is 4' above nozzle.*

ALUM ARM

P.S.I.	† Nozzle 7/64" Dia	† Nozzle 7/64" G.P.M.	Nozzle 1/8" Dia	Nozzle 1/8" G.P.M.	Nozzle 9/64" Dia	Nozzle 9/64" G.P.M.
20	50	1.55	51	1.97	[illegible]	2.52
25	53	1.73	54	2.21	[illegible]	[illegible]
30	55	1.89	57	2.44	58	3.10
35	57	2.05	59	2.66	60	3.36
40	59	2.20	61	2.86	62	3.61
45	61	2.32	63	3.04	64	3.82
50	63	2.44	64	3.22	65	4.03

BRONZE ARM

P.S.I.	Nozzle 5/32" Dia	Nozzle 5/32" G.P.M.	Nozzle 11/64" Dia	Nozzle 11/64" G.P.M.	Nozzle 3/16" Dia	Nozzle 3/16" G.P.M.	Nozzle 13/64" Dia	Nozzle 13/64" G.P.M.	Nozzle 7/32" Dia	Nozzle 7/32" G.P.M.
20	53	3.04	54	3.72	55	4.33	57	5.13	53	5.40
25	55	3.43	57	4.17	58	4.87	63	5.75	66	6.54
30	59	3.78	61	4.57	63	5.34	65	6.30	70	7.20
35	61	4.10	63	4.96	65	5.84	67	6.83	72	7.79
40	63	4.40	65	5.32	67	6.27	69	7.31	74	8.35
45	65	4.68	67	5.65	68	6.66	71	7.76	75	8.88
50	66	4.95	68	5.95	70	7.03	73	8.18	76	9.38

*Shown for standard nozzle at 35 P.S.I.
The trajectory height may be slightly higher with larger nozzles and or higher pressures.

† Indicates standard nozzle size
Bold face [illegible] minimum recommended
[illegible]
SHADED [illegible] IN CHARTS INDICATE ONLY AVAILABLE WITH TNT BEARING

TABLE 11. Specifications of Rain Bird Full Circle Sprinklers.
See page 20, Rain Bird Agricultural Catalog 69A, 1969