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Desert Irrigation Efficiency

Final Report

To

International Development Research Center Of Canada

(IDRC)

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Executive Summary

This report presents the activities of the project (May, 1995-April, 1997) parts:

Part I: Presents the historical and measured data on changes in quality of groundwater in the study area. It also gives a briefing on groundwater development studies. Data obtained demonstrate that agriculture horizontal expansion in Sadat City and Wadi El-Natrun has gone beyond the groundwater potential in these areas and discussed identified policy options for groundwater development in the area.

One study showed that uncontrolled development will lead to a lowering of the groundwater head of maximum 80 meters after 50 years. This will result in depletion of the aquifer in the area south of the Dina Farm and will cause many existing wells to fall dry, particularly in the area east of the Cairo-Alexandria desert road.

Controlled development by limiting the cultivable area to 130000 fed. will limit the lowering to a maximum of 25 meters and assure that most of the existing wells remain in operation.

Controlled groundwater development in conduction with additional surface water is the only option to reclaim all the cultivable area in the groundwater development areas (400,000 feddans). Implementation of surface water projects will also prevent (uncontrolled) drilling of wells in these areas and will eventually provide additional recharge to the groundwater system.

Combined surface water/groundwater systems may also be designed such that excess (surface) water during the winter months is infiltrated and stored in the aquifer and

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subsequently pumped during the summer. It is recommended to investigate the feasibility of this artificial recharge option as one of the means to utilize the excess Nile water during the winter.

Monitoring changes in the groundwater regime and groundwater quality during the coming years is essential in order to provide the necessary data to verify and update the present plan and to forecast the water quality changes in time.

Control of groundwater development plans should be implemented by a licensing. Licenses for the installation of new wells should include guidelines for the minimum drilling depth and screed depth and for minimum distance between wells.

The salinity of groundwater was measured in a number selected wells in the study area and compared with available historic data. Groundwater salinity in 12 wells representing the area of Sadat City was measured in DDC laboratory in Sadat City in 1987, 1988, and 1995 through 1997. In general Sadat City has good groundwater quality. With the exception of wells 90, 92 (1), 92(2). The groundwater salinity for the rest of the wells ranges between 0.38 and 0.86 dS/m (243-550 pmm) over the period 1987-1997. 92(1), 92(2) ranged between 1.22 and 2.41 dS/m (780-1542 pmm) and was attributed to the presence of clay lenses and the intercalation of clay and sand

Over the past ten years (1987-1997), however, salinity rose by 64-103% in four out of the twelve wells under investigation but it remained below 0.86 dS/m (550 ppm) in wells of AUC, W_4 and W_9 and groundwater in these wells remained of good quality. The remaining 8 wells showed very slight and insignificant changes in groundwater salinity over the same period. $NaHCO_3$ and NaC1 are the major salinity constituents of Sadat City groundwater at low levels of salinity. However at higher level of salinity NaC1 became the major salinity constituents. The SAR values were low-moderate in most wells (1.9-6.5) with higher values associated with higher

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salinity. Due to the moderate salinity and the coarse texture of soil in the area these SAR values are not expected to present any sizable restriction on water use for irrigation. Again boron concentrations are low-medium and do not exceed 1.0 ppm in most of the well. Values higher than 1.0 ppm occurred only in wells with moderate salinity. concentrations of NO3-N and NH_4-N are within acceptable limits and showed no environmental pollution that restrict water use for irrigation or drinking.

The heavy metal concentrations (Fe, Zn, Mn, Cu, Pb, and Cd) in these wells were very low and far below the acceptable limits in irrigation water for long term use. The concentrations did not exceed 0.09 ppm Fe, 0.01 ppm Zn, 0.04 ppm Mn, 0.03 ppm Cu, 0.08 ppm Pb and 0.03 ppm Cd.

The seasonal variations in groundwater table in Sadat City in 1989 showed a slight difference between spring and summer seasons, which indicate slight fluctuations in this area. At that time the effect of discharge was not detected and the aquifer was characterized to be of good potentiality. However these investigations need to be updated in view of the increasing agriculture expansion in the area in recent years.

In Wadi-El-Natrun, groundwater salinity varied widely with location and showed much higher values than Sadat City especially in the North sector of Wadi-El-Natrun where it reaches 4000 ppm. Data on groundwater salinity were collected for 31 well for the period 1966-1985 and salinity of these wells was determined in 1995-1997. Most wells in the southern sector are at much lower salinity with total salinity ranging between 346-909 ppm.

In 1966 groundwater salinity in the monitored wells were mostly between 300 and 700 ppm with the exception of 3 wells where it was slightly higher than 1000 ppm. In 1995-1997 salinity rose appreciably in 15 out of the 31 wells under study where it rose to 2-8 times its salinity in 1966 reaching values ranging between 2000 and 4000 ppm in most of these wells especially those located in the northern sector of Wadi El Natrun. However changes in groundwater salinity in most of the well in the southern sector were slight and water quality in terms of total salinity remained of fairly good quality ranging between 346 and 870 ppm in 1997.

Most of the wells in Wadi El-Natrun have groundwater of medium SAR values (3-9). Few have high SAR values of >9 and reaches 16.5. High SAR values are directly related to high ground water salinity (1850-3354 ppm). However, the high SAR values of groundwater under high salinity and course textured soil may not have such a deleterious effect on soil permeability. Heavy metal concentrations in Wadi El-Natrun groundwater are mostly low and within the permissible levels of these metals in irrigation water, i.e., 5.0 ppm pb, 2.0: ppm Zn, 0.01 ppm Cd, 5.0 ppm Fe, ppm Mn and 0.2 ppm Cu with some exception of Cd concentration reaching 0.04 ppm. These concentration do not posses a potential pollution hazards to the soil or toxicity to plant. Elemental N (expressed as N03 - and NH_4-N) has medium values falling in the range 5-30 ppm according to guidelines for irrigation water quality and present slight to moderate restriction in water use for irrigation. The high NO_3-N in groundwater is probably due to excessive use and leaching of N-fertilizer in addition to waste water pollution especially in shallow wells. Measures against the use of high NO_3-N water for drinking and monitoring these values in groundwater should be taken into consideration.

The salinity of groundwater was measured in 1995-1997 in 31 wells in Fath sector, South Tahrir, where it is used as a supplementary source of irrigation during the canal shutdown and when the level of the Nile-water in the irrigation canal is low. Historic data on salinity of these wells are limited but for South Tahrir area, in general, it was 200-1000 ppm in 1973 and rose in 1993 to 312-1700 ppm. Out of the 31 wells tested only two have groundwater of very good quality with salinity <0.7 dS/m (450 ppm).

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Only one well had high salinity of >3.0 dS/m (2000 ppm). The rest of the wells have groundwater of medium salinity ranging from 0.7-3.0 dS/m (450-2000 ppm). More than 50% of the tested wells have salinity below 1000 ppm.

The SAR values of groundwater in South Tahrir are low (<3) to medium (3-9) and expected to exert no deleterious effect on soil permeability in view of the coarse texture of the soil. Similar to the ground water of Wadi El Natrun all heavy metal concentrations are below the permissible levels in irrigation water with some exceptions of Cd concentration reaching 0.05 ppm. Inorganic nitrogen, however, presented by NO3-N and NH_4-N is mostly, of moderate values (5-30 ppm) and presents slight to medium restriction for the use of water in irrigation.

Part II: Describes existing irrigation systems in the study area. Bustan, Sadat City, and Wadi El-Natrun. Bustan and South Tahrir areas use surface water as the main source of irrigation, while Sadat City and Wadi El-Natrun use only groundwater for irrigation. In South Tahrir and Bustan, the most widely used pressurized irrigation system is the reinstalled hand-move sprinkler system. Other systems such as fixed sprinkler, draghose, and drip irrigation cover only a small percentage. While in Sadat City and Wadi El-Natrun, the most widely used pressurized irrigation system is the drip irrigation system. Other systems such as fixed sprinkler covers only a small percentage. However, some irrigators are illegally practicing flood irrigation in the four areas under study. Land holders in Bustan area are small holders, graduates, and private investors, while in South Tahrir are settlers, private investors, and large agricultural companies. In Sadat City and Wadi El-Natrun, however, they are mainly investors.

This chapter describes in details the open channel water distribution system is surface irrigated areas, the irrigation system components such as deep well pumps, irrigation pump stations, pressure distribution system of collective pump stations and design and performance of sprinkler and drip irrigation systems.

Party III: Discusses and analyzes survey data collected from 109 farms in the study areas on technical and socio-economic aspects of desert irrigation efficiency.

Technical Aspects of Desert Irrigation:

Data obtained included the present status of water source, pump stations, and problems related to irrigation systems in the four areas of study. Thirty three percent of the responding farmers agree that the insufficient water is the most predominant problem, while this percent reaches 43.6% in South Tahrir and Bustan. Costly spare parts, fuel and electricity, and maintenance and repair are the common problems with pump stations for more than 85% of the responding farmers, while unavailability of skilled technicians was a problem for 71.4 percent. Most of the farmers (90%) felt electricity was very costly and beyond the purchasing capability of the common farmer.

The sprinkler irrigation systems were less than 10 years old in Bustan area while 90% of the sprinkler systems exceeded the expected life (15 years of age) in South Tahrir. About 56.1% of the responding farmers stated having problems with hand-move systems, all of them located in South Tahrir. Operating at too low a pressure is common problem on 72% of the hand-move sprinkler systems. The more logical explanation for operating at low pressure lies in the exceptionally high level of water losses from the irrigation hydrants (common problem on 42% of the systems). In addition, 36% of the responding farmers attributed the low pressure to the illegally surface irrigation practice. Low pressure also increase droplet size which cause physical damage to plants common problem for 64% of the responding farmers). The hand-move sprinkler has high labor requirements (common problem for 53% of the responding farmers).

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Of the 52 farms with drip irrigation systems, 36 farms only had filtration systems. Sand filters were not used in 50% of the cases in Bustan and South Tahrir although the water source contained silt and algae (Nile water). However, screen filters were used in most of the cases (94%). Chemical fertilizers were not applied through the drip systems in 29.2% of the total farms and it reaches 44.5% of the farms in Sadat and Bustan, while in Wadi-El Natron, the fertilizer injection devices are common. Among the injection devices fertilizer tank was the widely used (82.7%). Out of 35 farms using chemical injection devices 27 farms use acid treatments, mainly in the form of phosphoric acid, which is also used as a fertilizer. Out of 52 farms with drip irrigation, only 28.8% use air release valve, 40.4% use check valve, 26.9% use flow meter, 67.9% use flushing valve, 13.5% use pressure regulator, 15.4% use pressure relief valve, and 59.6% use pressure gauges. Therefore, large percentage of drip irrigation systems are loosing the essential parts of a well designed irrigation systems.

Social Aspects of Desert Irrigation:

A social survey of the irrigation efficiency in desert lands aimed to explore the socio-economic characteristics of the holders of desert lands, the systems of irrigation in use, the knowledge level about sprinkler and drip irrigation as the most prevailing modern techniques, and the attitudes towards water and irrigation practices applied in the areas of study.

The survey was planned to be applied on a representative sample of the holders of desert lands. Hence, secondary data about holders of desert lands in four areas selected for this study; South Tahrir, Al-Sadat agricultural zone, Wadi Al-Natron, and Al-Bostan were collected to portray the population of this study. A quota stratified random sample of holders was drawn accordingly.

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A questionnaire was designed to collect the field data along with personal interview from the drawn sample. A final version of a pretested and preceded questionnaire was applied to the sample by enumerators trained for this purpose in summer 1995. Analysis of data took place after the data verification.

- ***Farmers Attitude Towards The Use Of Irrigation Water:***

  Distribution of the sample by the regions of residency, the farm holding size, and the type of irrigation system(s) used in the farm was discussed. Some of the main social demographic characteristics of the representative sample was discussed too.

  An attitude scale related to the various aspects of rational use of water in irrigation and the applied irrigation practices was designed and pretested. The scale is constructed from 29 items that cover all the above mentioned three components and seven dimensions; cultural value of water, economic value of water, information aspects of available water resources, on-farm water management, applied irrigation practices, willingness to share in responsibility of rational use of water and experiences needed in the irrigation process. About 38% of the items were formulated in passive form to reflect the action tendency component of the scale.

  Significant differences of the holders' attitudes were found among the four regions of residency towards the rational use of water and the modern irrigation techniques. These differences could be partially attributed to the distinctive characteristics of settlers more dominant in each area as mentioned before. Analysis showed no significant difference among the various categories of holding size concerning their attitudes towards water. However, a very high significant difference of the holders' attitudes was found among the five categories of users of the various irrigation systems. Those who use modern irrigation systems and techniques tend more to have higher positive attitudes towards the rational use of water and the modern irrigation techniques.

The relationships between some attitude components and some study variables (area of study, education levels, and type of irrigation system used) were analyzed and statistically tested. More than 86% of the sample interviewed have high to very high estimation for the economic value of water specially those of Bustan and Tahrir area with agriculture education and those having medium education (91.4%) and university education (80%). As to the willingness of landholders to share cost of irrigation public works, 83.4% of the sample interviewed showed high to very high attitude. Landholder of Wadi-El Naturn who relay totally on groundwater showed less willingness to share such cost. The percentage of those having high to very high willingness was 95.2% for those having medium education, 78% for university graduate and only 60% for holder who just read and write. The preference of landholders to use modern irrigation systems was related to direct experience of landholder to use those systems and level of education. In Tahrir and Sadat where some landholders practice flood irrigation show lower preference to use modern techniques. Those who have high to very high preference to using modern irrigation techniques represent about 87% of sprinkler and drip irrigation users, 63.6% of those using mixed systems and only 6.7% of those using flood irrigation. The percentage of those having high to very high preference was about 82% for those having medium and university education and only 25% for illiterates.

- ***Knowledge level of land holders:***

Knowledge level of land holders of desert lands with the various technical aspects of sprinkler irrigation is low in average. This means that there are real training needs that should be satisfied through tailored training and extension programs. However, full detailed training needs assessment should be undertaken prior to any

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design or planning of such programs . Training needs are not related to technical knowledge only. They are also related to the attitudes and skills related to the recommended irrigation system.

It could be concluded, in general, that the level of technical knowledge with the various aspects of drip irrigation is rather higher than other modern irrigation systems due to the characteristics of users and the importance of using this system efficiently where water resources are more scarce. When the holders are mostly investors they seek more efficient systems regardless of their initial costs.

The characteristics of the holders and their period of practice with farming seem influential in determining their need of knowledge about irrigation systems and practices. Those who had long period of practicing farming and those with agricultural background whether by practice or education helped them to feel more satisfied with their knowledge in irrigation. The investors seem more active in getting the knowledge they need regardless of the existence of extension service in the area.

- ***Training and organizational aspects of desert irrigation***

Efficiency of irrigation is determined in great part by the farmers' irrigation practices aside from the conditions of irrigation system used. Many social aspects such as the type of social network of relationships between farmers and officials and the farmers' involvement in the decision making process related to selection of and operating the irrigation system are among the important variables affecting these practices.

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In old lands, accumulated experiences related to irrigation practices are transmitted from one farmers' generation to another through the socialization process. There are also well established institutions, norms and organizations that facilitate the transmission of adopted practices to the successive new generations. Informal organization among farmers play major role in the scheduling of irrigation rotation and distribution of water in any specific area in the old lands. Yet, such situation does not exist, though it is more needed, in the case of settlements in the new lands.

Studying the social aspects of current irrigation practices associated with the various irrigation systems in new desert lands might help planners and practitioners who are interested in the efficiency of irrigation in these lands to outline the needed reorganization of the whole irrigation process to enhance its efficiency. Importance of such aspects is becoming more serious because of the increasing proportion and role of desert lands in Egypt agriculture in the present and future.

Data showed that the majority of the whole sample 82.6 % had no previous formal training experience in farming prior to their settlement in the new reclaimed desert lands.

It was found that the type of irrigation system was determined for the majority of the whole sample (57.8%) by the authorities. The farm holder made his own decision in 30.3% of the cases. Technical consultation was used only in 4.6% of the cases.

Of the users of sprinkler irrigation 48.9% were found suffering frequent problems with neighbors against 23.1%, 10.5% and 9.5% of the users of surface method, mixed and drip systems respectively. The users of mixed and drip systems seem to have the least frequency of exposure to such problems.

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Of the whole sample 57.3% reported that officials never or rarely response to the complaints of irrigation problems of farm holders. The highest absence of such response were found in the case of users of mixed and drip systems 73.7% and 61.9% respectively.

For 34.7 percent of the whole sample the agricultural cooperative in the farm holders' area took the responsibility of solving irrigation problems. At the category level of the users of irrigation systems coops play higher role for 63.6% of the users of surface method, private irrigation staff plays the highest role for 75% of the users of drip system. This trend of relationship seem to be logical since the problems related to drip systems might need more experienced and professional staff to deal with.

It was shown that leadership is missing in organizing irrigation process. the role of some sort of social organizations exist in the areas where farm holders use conventional methods of irrigation techniques while such social arrangements for organization of irrigation are missing or at least have less role in the areas using modern technologies.

Data show that only 28.9% of all the sample had high willingness to collaborate with others whether officials or non officials in solving encountered irrigation problems. This clarify the absence of enough common social interests among the farm holders to collaborate in solving encountered irrigation problems. Social network of relationships and other ties among farm holders in such new communities seem in need of some new institutional arrangements to be more effective.

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The users of surface method seem to be slightly more organized socially than the users of sprinkler irrigation. Yet, both were more organized than the users of drip and mixed systems. It seems that the last two sub groups had a more individualistic approach. They seem to have more educational qualifications than the others which might explain their tendency to be more self reliant than the others.

Nevertheless, the need of a more social approach to the organization of irrigation process for all farm holders seem more urgent. This will help improvement of the efficiency of irrigation in desert land and enhancement and stability of social life in such new rural communities.

Economic Aspects:

The economic evaluation of crop production functions under different irrigation systems sheds light on the problem of water productivity and water use efficiency in the new lands on the micro level. More important, a quantification of the impact of irrigation water on the level and/or value of output is assessed under the three dominant irrigation methods: sprinkler, flooding, and drip. A random sample of 109 farmers was interviewed during the summer and fall of 1995 for the purposes of this study. This sample covers four areas in the new lands (South Tahrir, El-Bostan, Wadi-El-Natroun, and El-Sadat). Eight Cobb-Douglas production functions were estimated for peanuts (sprinkler and flooding), wheat (sprinkler and flooding), summer crops (sprinkler), winter crops (sprinkler and flooding), and vegetables (drip).

Despite a variety of issues related to the measurement of the water input, the positive statistical significance of its estimated coefficient in all of the estimated functions is a telling sign. Equally telling, is its ranking as the most important input in the study area. This implies that water is the limiting factor for desert development.

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The study showed that: (1) On the grounds of production (technical) efficiency, the cubic meter of irrigation water for the sprinkler system possesses on the average higher efficiency than the flooding system for the same crop. Although, this comparison could not be made for the drip system, the highest average value product was obtained in the case of the drip system. This implies the highest production efficiency in the estimated functions. (2) On the grounds of price (allocative) efficiency, which is the other component of economic efficiency of water use, farmers are found to be price efficient in one function only under the first scenario of calculating the imputed cost of water (design expectation of the pump). Under this scenario, the cubic meter of irrigation water is priced at 0.070, 0.124, and 0.143 Egyptian pounds for the flooding, sprinkler, and drip systems, respectively. Under the second scenario, three function are found to achieve price efficiency. Under this scenario (actual operation hours of the pump), the cubic meter of irrigation water is priced at: 0.140, 0.248, and 0.286 pounds for the three irrigation systems, respectively.

It is concluded that, given these figures for the imputed cost of water and that irrigation water is not priced in Egypt, the majority of the estimated functions (seven under the first scenario and four under the second one) displayed that the farmers are under-utilizing irrigation water. This rather striking result could be due to the fact that farmers face problems of water shortages which affect their level of water use. that is to say, the quantities of water they apply per feddan depend upon availability more than choice. In addition, altering the assumption through which the imputed cost of water is calculated from may alter the final results. More investigations are needed on this ground. The least of which is to determine the shadow (economic) price of irrigation water in the study area through mathematical programming techniques. In addition, thorough examination of some sample farms is needed to examine their irrigation systems, modify them, and economically evaluate their status before and after modification.

Part IV: is devoted to the technical evaluation of the existing irrigation system performance and efficiency in the study areas. A total of 101 sprinkler and drip irrigation systems were evaluated in a number of selected farms in South Tahrir, Bustan, Sadat City and Wadi El Natrun.
Sprinkler systems were evaluated in the field by determining the uniformity coefficient (UC), distribution uniformity (DU), and potential application efficiency (PELQ). Drip irrigation systems are evaluated in the field by determining the emission uniformity (Eu) and the application efficiency (Ea).

The results show that sprinkler and drip irrigation systems throughout the project area are performing poorly. About 85% of the fixed and hand-move systems and 78% of the side-roll systems had uniformity coefficient <80% and about 33% of the fixed systems, 36% of the hand-move systems, and 11% of side-roll systems had uniformity coefficient <60%. It was found that the poor water distribution pattern can be improved by using the proper sprinkler nozzle pressure and the proper lateral spacing (50% of the wetted diameter). A total of 50 drip systems have been evaluated throughout the project area. About 80% of the drip systems had emission uniformity (EU) <80% and 70% of the systems had EU's <70%. The low emission uniformity (below 80%) can be raised through preventive maintenance that includes water filtration, field inspection, pipeline flushing, and chemical water treatment.

Part V: Presents and discusses the development of specifications for improved irrigation systems and modifications for the existing systems to improve their performance and control water losses. They also help reduce time and effort needed to operate the system, reduce the cost of installation and operation, and improve fertilizer efficiency. These modification included :

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- **Introducing a screen filter for the hand-move sprinkler irrigation system:**
  Most farms surveyed in this project do not used any screen filters for their hand-move sprinkler systems or used local low quality screens causing blockage of the sprinkler nozzles and contributing to the low irrigation efficiency. After surveying the most common hole diameter, sprinkler nozzle diameters, type of impurities and length of perforated pipe. Screen filters were designed tested, modified and specifications for the most efficient screen filter were selected and filters manufactured and used in the DDC farm and 10 other private farms.

- **Developing a fertigation unit for the hand-move sprinkler system:**
  Fertigation is particularly important for irrigated agriculture in Egypt new lands particularly because of the sandy nature of the soil (field capacity is 6-8%, very poor in nutrients with practically no exchange capacity) where large quantities of fertilizers are applied to meet crop requirement and leaching loss need to be minimized. Although fertigation is practiced with drip irrigation systems, practically no fertigation is being practiced with the most common irrigation systems; namely, the hand-move sprinkler system. A fertigation unit was modified to cope with hand-move system. The advantage of such unit is its simplicity in construction and operation, no need for external power supply, the pressure loss and the pressure required to operate the system is low. The unit serves 20 feddans and the cost per feddan is only L.E. 12.8 which represent 5% of initial cost of the hand-move irrigation system. This fertigation unit was tested, proved to be highly efficient and was installed in all handmove laterals in DDC farms and some private farms.

- **The use of alternate offsets:**
  Use of offsets refers to the practice of not placing the lateral in exactly the same position in the field each time a particular section of the field is irrigated. This is applicable only with hand-move and side-roll systems the principle of using

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offsets to change position of the lateral so that high and low water application points tend to balance out over a growing season. This requires the use of pipe connection whose length is half the distant between lateral positions. Using offset operation increased the low uniformity coefficient from 65 to 80% and the high coefficient from 80 to 90%.

- **Sprinkler spacing:**

  Tests were conducted on sprinklers available in the market mounted on 3/4 inch galvanized steel riser 70cm tall. These sprinklers are: Naan 5033, Dan, 30H, 30TNT, Lego, RB70, and Hadie Model S. Tests were made on actual sprinkler patterns at different pressures using catch data from a single radial row of containers placed on the ground 1 m a part for 30 min. Each type of sprinkler has certain precipitation profile characteristics that changes as nozzle size and operation pressure change. Each profile has its spacing recommendations based on the diameter of effective coverage under the particular field conditions of operation. The computer sprinkler overlap program, CATCH3D, was used to evaluate the radial catch data. The program generates a grid pattern from a single radial line of catch data and superimposes the grid pattern to simulate various sprinkler spacings. The coefficient of uniformity, CU, application efficiency of low quarter, AELQ, and distribution uniformity, DU, were then determined for each simulated spacing. The results of the program were compared with field data and used to improve the operation of existing installation by modifying the lateral move spacing of the hand-move system.

Optimum recommended spacing for sprinklers with nozzle diameter < 5 mm (Nann 5033, Dan, 30H and 30 TNT) at 3 bar was 12x12m for CU> 90% and DU >85% under no wind conditions. The maximum spacing for sprinklers with nozzle diameter <5 mm (RB 70 and Hardie Model S) was 18x18 m which would produce CU>80%. However, the Hardie Model S perform best a

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12x15m while RB 70 perform best at 15x18 m. Lego sprinkler, however, have single small nozzle and is mainly used for irrigating landscape and greenhouses, they perform best at 9x9 m producing CU of 87.7%.

The use of alternate offsets increased the uniformity of application from 65% to 80%, from 80 to 89% and from 85 to 92%.

- **Drag hose sprinkler system**

The hand-move sprinkler is a labor intensive system. The introduction of drag hose sprinklers would reduce the labor demand to about half of that required for a comparable hand-move lateral system. It is also more convenient, easier to operate and decreases deterioration of lateral pipes and fittings. The Model Farm demonstrates to the farmers how to convert their hand-move sprinkler to drag hose. The drag hose system extends the life of the aluminum laterals and couplers which is an improvement consideration in the project area in view of the present intensive use of equipment. It is more flexible and ensures a better distribution of water, particularly on windy days. It also has a greater social acceptability in terms of reduced need for manual pipe transport.

The drag hose sprinkler is considered as a modification of the hand move sprinkler system. In drag hose system individual sprinklers are supplied by hoses and periodically moved to cover several positions. In this case sprinklers are attached to flexible hoses (48 m length and 25 mm diameter) and the lateral line remains stationary. Sprinklers are mounted on skids and towed periodically to give grid patterns of 12 x12m. Risers are one meter tall to keep the sprinklers above the mature crop. The cost per feddan was estimated to be L.E. 389.

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Part VI: Represents the design and implementation of model farms of irrigation systems.

The model farm was designed to demonstrate that the existing irrigation systems can be made to operate correctly and within the design criteria originally established. The farm serves as a training and demonstration site for the farmers and graduates when they receive the standard 5-feddan farm. The design itself varies from the standard or dominant hand-move systems to the other systems such as drag hose, fixed, and drip systems. These systems were laid down on a net area of 20 feddans, then divided into 4 model farms, thus 4 separate farms representing different plans of irrigating and farming the land. The model farm was desinged to include different modifications such as introducing screen filter to hand-move system, using offsets technique, using fertigation with hand-move system, using optimum sprinkler spacing, and introducing drag hose system as a modification of hand-move system. Demonstration of side-roll and gun systems are not considered necessary as there are plenty of good examples in the DDC experimental farm in South Tahrir.

These model farms suggest and emphasize the advantage of various possibilities within the reach of the farmer.

Working together, four neighbor farmers with an independent pump unit, could have the same possible irrigation layout as in the model farms. Also economically designed, these model farms shed light on the profit of investing in such systems. The blending of "cash crops" with a larger investment of orchards can be an appealing choice, or the more simple but durable systems to irrigate field crops with quick profits in return could be more favorable to other. Varying the type of field crops or orchards can support a farmer more firmly in the rise and fall of market prices, therefore decreasing his risk of misfortune.

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The layouts presented convey the contrast between the different available systems. Model farm #1 represents the most commonly used hand-move sprinkler system. Other systems are more simply maintained, and also differ in cost. Model farm # 2 consisting of a fixed and trickle systems (2.5 feddans each) could grow a mixture of field crops, orchards, and vegetables. Despite being the most expensive (2780 LE / fed.), the fixed system is the most preferable and easiest to apply. Respectively, a drip irrigation system (995 LE / fed. for orchard and 2608 LE/fed. for vegetables) has the advantage of limiting the water loss, which is the main concern in desert farming. Model # 3, providing a clear picture of in between, affordable (389 LE/ fed. for drag hose), more than adequate efficiency system, producing also a mixture of crops. Model # 4, consisting of primarily drip and producing large investment orchards, varying in water requirements and salt tolerant. This models act as demonstration farm that will encourage and teach young farmers the correct ways of irrigating and farming.

All recommended modifications specified in part V were implemented to control water losses, maximize irrigation efficiency and minimize cost.

In model # 4 the entire standard area of five feddans were dedicated to emphasizing possible mixed orchards of deciduous trees like grapes, apples and pears with olives and citrus fruits as examples of the evergreen family. In Model # 3, half the standard area; which is 2.5 feddans was divided into two separately irrigated plots. One for irrigating vegetables and the other for an evergreen orchard which is planted mangoes. similarly model # 2 irrigates both vegetables and an orchard of peaches and almonds.

The installed drip irrigation systems were evaluated to check the design and confirm the design efficiency as presented in the evaluation sheets for different emitters.

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Field evaluation of the installed irrigation systems of the model farms were analyzed and performance parameter were calculated. The application efficiency of the low quarter (AELQ), the distribution uniformity (DU), and the coefficient of uniformity (CU), for the hand-move system were 78.3, 84.8 and 90.2% respectively. Using alternate offset operation increased CU to 95%. The fixed system had CU of 85% and application efficiency of 76%. The drag hose sprinkler system had a CU of 83% and DU of 74%. The model farm demonstrates to farmers how to convert hand-move system to drag hose. The cost per feddan was shown to be L.E. 389.

The GR drip line showed a high performance of 92% emission uniformity and 83% application efficiency. The Tubo-SC emitters gave an emission uniformity as high as 94% and a high application efficiency of 85% . Similarly, the regular Turbo-key emitter showed an emission uniformity of 93% and application efficiency of 84%.

Part 7: Presents the on-farm modifications of irrigation systems and their technical and economic evaluation. Ten farms in Bustan and South Tahrir areas were selected to implement the proper modifications and evaluate technically and economically the impact of such modifications on irrigation efficiency and the value of water under different irrigation and cropping systems.

Five farms were selected in each area and included the most common irrigation systems in the area; namely, hand-move sprinkler, fixed sprinkler, and drip systems. Detailed technical observations were carried out on each farm to record what is actually practiced rather than what farmers say. The ten farms were subjected to intensive observation and monitoring to collect information related to crop grown yield, area, fertilizer application, labor, energy consumption, and other agriculture practices, soil type, soil and water salinity ... etc. The irrigation systems were fully reviewed and modifications to improve their performance and control water losses

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were specified and implemented. For drip systems, these included installing creen filter, correct size PVC submains, lateral lines, grommets, emitters, seals, figure 8 ending, flush system, a number of modified fertilizer tank and flow meters were also distributed among the farms.

For sprinkler systems, modifications included the optimum sprinkler spacing for different sprinkler types to obtain maximum water uniformity. A screen filter has been introduced in hand-move systems at the head of the lateral line between the valve elbow and the first section of pipe to avoid nozzle blocking. The project has also introduced a modified fertilizer tank to hand-move systems. The performance of the irrigation systems was evaluated before and after modifications. The irrigation water used through the growing season was measured using flow meters installed in the system. All inputs and outputs over the growing season were recorded. Using the change in application efficiency the percent of water saved was calculated. An inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring and accurate determination was prepared for each farm and used in the economic analysis. The delivery cost of water was calculated using the total annual cost (fixed + operational) and the total amount of water pumped annually. The opportunity cost of water was also calculated as the net benefit in L.E. per fed/water pumped per fed. in m3.

Following these modifications Application Efficiency increased from 59% to 83% and 59%-83%. Accordingly, 33%-45% of water was saved.

The average delivery cost of water which includes the cost of pumping ranged between 0.04% L.E./m3 and 0.1 LE/m3. One approximation of this opportunity cost of water would be to consider the profit available were another feddan of land brought under irrigation using the water saved the opportunity cost ranged between LE 0.1 and 1.27.

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It should be mentioned however, that the calculation of the opportunity cost was affected by the yield which in turn is affected by management. The limited data (10 farms) did not permit more analysis relating the percent water saved, the delivery and the opportunity cost of water to the type of irrigation system and crop although they indicate the delivery cost of water in drip system is higher than in the sprinkler systems.

The data, however, emphasize that the opportunity cost of water is much higher than the its delivery cost and this should be considered when the real value of water is evaluated (water pricing). The data emphasize also that existing irrigation systems could be modified to save water and the percent water saved in the ten farms studied varied between 13-56% with an average of 35%.

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Introduction

The general objective of this project in the original document was to conserve irrigation water by optimizing on-farm water use efficiency through the evaluation of the present situation and practices and the improvement of the irrigation systems at the farm level. Also to furnish background information of the feasibility to introduce water pricing (cost recovery) in the new land based on the farmers perception. Ultimately the finding of the project will be demonstrated, recommended and disseminated to desert farmers, extension specialists and to government officials and policy makers

The specific objectives were stated as follows:

1. Analyze and monitor changes in quantity and quality of groundwater in the project area

2. Survey and quantify on-farm water losses related to irrigation

3. Evaluate existing irrigation systems under specific cropping patterns in desert farming

4. Survey and analyze technical and socio-economic aspects of irrigation practices in representative farms.

5. Evaluate crop production function under different irrigation systems and water salinity levels and to furnish background information for water pricing polices.

6. To modify and develop specifications for irrigation systems that would reduce water losses, improve irrigation efficiency, protect the environment and maximize yield under prevailing conditions.

7. To disseminate results to desert farmers and government agencies.

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Objective 1 was covered in chapter 1. Changes in groundwater quality are presented and discussed through historic data collected and groundwater salinity determined in 31 wells in South Tahrir, 12 wells in Sadat City and 31 wells in Wadi El-Natrun in DDC laboratory. Data presented cover the period 1973-1997 in South Tahrir, 1987-1997 in Sadat City and 1966-1997 in Wadi El Natrun area. Monitoring these changes in groundwater quality will continue throughout the project period and on to establish data base of groundwater changes in the area. Data obtained demonstrates that agricultural expansion in Sadat City and Wadi El-Natrun areas has gone beyond the ground potential in these areas and discussed identified policy options for groundwater development in the area.

Objectives 2, and 3 were covered by evaluating the existing irrigation system in 101 selected desert farms representing South Tahrir, Bustan, Sadat City, and Wadi El Natrun areas under different cropping system.

Objective 4, was covered by carrying out the technical and socio-economic survey on 109 desert farms representing the four study areas. Data were collected by visiting all respondents at their farms after preparing and pretesting the questionnaire. The technical aspects of desert irrigation in the questionnaire included source and quality of irrigation water, problems associated with pump stations: problem associated with sprinkler and drip irrigation systems, fertilizer and chemical injection devices, water filtration, and control units in modern irrigation systems. Data were analyzed discussed and presented in this report. The social aspects of desert irrigation concentrated on attitudes and knowledge of farmers towards water use and irrigation practices. The scale of attitudes cover 7 dimensions; cultural values of water, economic values of water, cognitive aspects of available water resources, on farm management, irrigation practices, and sharing responsibility of rational use of water and experiences needed in irrigation.

Analysis of data took into consideration testing the relationship between the attitudes of the farmers toward water use and irrigation practices and three main variables; the region where the farm is located, farm size, type of irrigation system used in the farm.

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A similar scale of knowledge towards water use and irrigation practices was designed, pretested, used in the questionnaire, and data were similarly analyzed. Training and organizational aspects of desert irrigation were also analyzed and discussed.

Objective 5 is achieved by collecting the required economic data using the questionnaire on 109 forms using different irrigation systems under different cropping systems. Economic analysis was carried out and crop production functions were evaluated under different irrigation systems.

Objective 6 focusing on the development of specification for improved irrigation systems and modifications for the exisisting systems to improve their performance and control on farm water losses were carried out in part 5, 6, 7 of this report. Modifications to improve irrigation and fertilizer efficiency, reduce time and effort needed to operate the irrigation systems, and to reduce the cost of installation and operation were designed implemented in the model farm and on ten private farm. The impact of such modifications on irrigation efficiency and percent of water saved was evaluated and reported. Economic aspect regarding the delivery and opportunity value of water was discussed.

Objective 7: Dissemination of results, was achieved through the following:

a) The establishment of pilot rehabilitation field (Model Farm for irrigation System) at the DDC farm in South Tahrir to demonstrate that the existing irrigation systems can be made to operate correctly and within the design criteria originally established. The pilot project was established on 20 feddan area and demonstrates the cost of any further improvement and modifications and serve as a training and demonstration site for the most common sprinkler and drip irrigation systems.

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b) Four scientific papers presenting some of the achievements in project were presented in national and international conferences or submitted to scientific journals. They are as follows:

1. The first paper entitled "Attitudes of Desert Farmers Towards Water Use and Irrigation Practices in New Land" was orally presented in the Annual AUC conference on April, 22, 1996 and was published in the proceeding.

2. The Second paper entitled "Irrigation Systems Evaluation in Desert Farming" by S. Ismail, A. Metwally and M. Sabbah" was orally presented at the 5th Internal conference on Desert Development. Texas Tech. Univ. Lubbock Texas, Aug., 12-17, 1996. It was also presented in the above conference.

3. The third paper entitled "Economic Evaluation of Crop Production Functions under different Irrigation Systems in the Egyptian New Lands" by Sherin A. Sherif. The accepted for publication by the Alexandria Journal of Agricultural Research.

4. The fourth paper entitled "Some Social Aspects of Farmers' Irrigation Practices in Reclaimed Desert Lands in Egypt" by Mohamed H. A. Nawar, Mohamed A. Sabbah and Abdel - Alim Metwally. Local response to global integration towards a new Era of Rural reconstructing, Chania, Crete, Greece, August 25-29, 1997.

c) Brochures containing guidelines for improved irrigation systems efficiencies and reducing on-farm water losses have been made available to farmers using various sprinkler and drip irrigation systems along with tips for better performance and higher yields.

d) Video film illustrating the various aspects of desert irrigation in Egypt New Land with special emphasis on the activity of the project was produced. A copy of the film is submitted with the final report.

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e) Results of the research project have been shared with national and international research institutes having common interest in technical and socio-economic aspects of desert irrigation. Progress reports were exchanged with these institutes and the final report and recommendations well be shared as well.

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I. Groundwater in the study area

1.1 General Outlines:

Reclamation of desert land has been undertaken during the last four decades to overcome the problem of over population. In this respect, priorities are given to the area west of the Nile Delta due to its accessibility, availability of surface water and groundwater supplies as well as the presence of wide plains with deep sandy soil. Extensive large reclamation projects using Nile water and groundwater in irrigation are now under execution at several parts of west Nile Delta region. Of these projects, are west Nubariya canal area, El-Bustan area, Sadat city, South Tahrir province and the stretch along the Cairo-Alexandria Desert Road from El-Nasr canal in the north till Cairo in the south (about 153 km long). Focus will be on groundwater development and changes in quantity and quality of groundwater in the study areas (South Tahrir, Bustan, Sadat City and Wadi El-Natrun (Fig. 1.1) over the last few decades.

1.2. General Features:

The area of west Nile Delta constitutes a portion of the great arid belt dominating north Egypt. Aridity in this area is manifested by the degradation of the surface, the presence of old and short drainage lines, the lack of rainfall, the development of surface salinity and the accumulation of sand sheets. The alluvial plains which extend to the east of Cairo-Alexandria desert road, comprise most of the areas under reclamation. Its surface is generally flat and sloping in the northward direction (gradient 0.1 m/km). Most of this surface is also covered with gravels in the southern portions while sand sheets dominate the surface at north and northwest near El-Nasr and El-Nobariya canals.

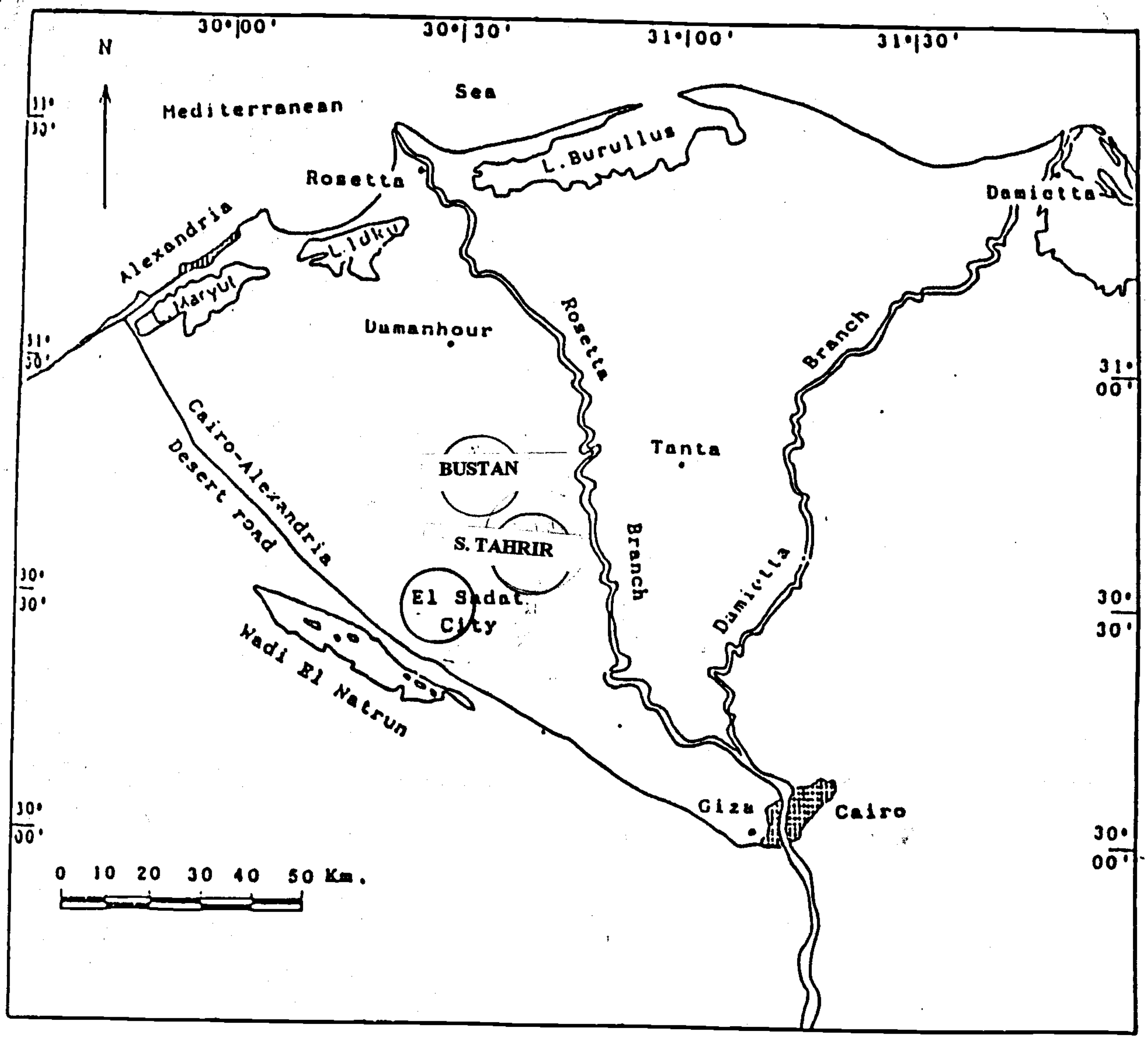

Fig.(1.1): Location map of Study Areas

1.3 Geology:

The area west of Nile Delta is dominated by a sedimentary succession ranging from late Cretaceous to quaternary, the oldest sedimentary rocks are represented by the late Cretaceous which cover a small locality to the west of Giza. Eocene and Oligocene sediments are of limited distribution in the environs of Cairo. Miocene and quaternary (Pleistocene & Holocine) deposits are the most outcropping sediments.

Mid-Tertiary basalt is the only exposed volcanic rocks in the area which is mainly localized in its southeastern corner. In the subsurface, the sedimentary section resting on the basement rocks has a thickness of about 4000m as indicated from a deep petroleum well (Sahara well).

1.4. Groundwater in Early Pleistocene Nile Sediments:

These sediments cover the area between the Rosetta Branch in the east and El-Nobariya and El-Nasr canals to the north and northwest and extend to the eastern fringes of Wadi El-Natrun (Alluvial Plains). Such sediments constitute the main aquifer in the area. Hundreds of water wells are now producing from this aquifer at several locations for melioration activities. These locations are scattering along both sides of Cairo-Alex-Desert Road, South El-Tahrir Province, Sadat City, El-Bustan new area and the western fringes of Rosetta Branch.

The Early Pleistocene aquifer is made up of Nile sands and gravels with thin streaks of clay. Near Wadi El-Natrun and the Cairo-Alex-Desert Road, the aquifer has a thickness varying between 60 and 80 m, which increases successively in the eastward direction till it reaches about 300m at South El-Tahrir province and about 500 m in the central part of the Delta. The groundwater exists mainly under free water table condition (unconfined) at depths varying from few meters close to the Delta to about 50-65 m near Wadi

El-Natrun. Near El-Nasr canal and El-Nobaryia canal, where a proper clay facies are developed, the groundwater exists under semi-confined condition and therefore it exists near the ground surface, where the depth of water ranges between 2m and 18m. In El-Bustan area (about 35 km South El-Nasr canal) the depth of water varies between 12m and 27.5m from the ground surface.

It was found that the groundwater movement is from east to west and from north to south. So, the aquifer receives its recharge from the Delta reservoir and from the northern, and northwestern lands behind El-Nobariya and El-Nasr canals.

A trial has been made recently to calculate the quantity of water that flows in the reservoir as groundwater inflow from the above mentioned directions. The total quantity estimated was found to be about 41 million m3/year. The greater part of this quantity is fairly saline water and is particularly noticeable at the northwest along El Nasr canal, while about 35% of the total amount of inflow is fresh and recharged from the northern and eastern portions along El-Nobariya canal and the fringes of the Nile Delta. Furthermore, the infiltrated water from irrigation constitutes another important source for groundwater recharge. It was roughly estimated as 58 million m3/year. This constitutes 10% of the total amount used for irrigation, which amounts to about 580 million m3 annually (average 7000 m3/year/feddan).

A general view of the groundwater conditions in the areas adjacent to the study area has been outlined in previous progressive reports. These included west Nobaria canal area, Southwest Nile Delta (Wadi El-Farigh and its western extension to qattara depression and west of Giza areas.

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1.5. Groundwater Development in the Western Nile Delta[1]

This area is characterized by a rapid development in land reclamation both with surface and groundwater. Extensive large reclamation projects using surface water from Nubariya canal system started in the fifties and now covers about feddans. New extensions of about feddans will be completed in the coming years.

The projects are located north and north east of Wadi El-Natrun depression use surface water and are implemented by the Government. Reclamation projects with groundwater which is only source in the South and East of Wadi El Natrun are more recent but showed a rapid increase in the last five years. These projects are generally carried out by the private sector and are mostly found along main roads (Cairo-Alexandria desert road, El Khatatba road and El Birigat road). The present cultivated area with groundwater is about 70,000 feddans. Extension in reclamation with groundwater is continuously going on.

Groundwater use for domestic and industrial purposes is a minimum. The only water supply source is Sadat City authority, with present pumping capacity of about 15 million m3/year.

The increasing groundwater extraction is accompanied by a continuous lowering of the water table resulting in depletion of the aquifer and increasing pumping costs. Therefore, groundwater development planing is needed to prevent existing wells from falling dry and to control the feasibility of future reclamation projects.

The groundwater development scenarios may range from zero development (no more wells to be drilled) to maximum development (all areas under groundwater irrigation). Between zero and maximum development there are

[1]Farid and Tuinof (1991). Groundwater Development. Water Sci. Rol. Special Issue, 43-52.

numerous options. The selection of a scenario depends on the criteria that is formulated with respect to its effects. The starting step in the definition of scenarios is the existing projects both with surface water and groundwater. The step is the expected trends in land reclamation policies.

Four groundwater development scenarios (table 1.1) were selected covering the expected groundwater plans for a period of 10 years (1990-2000). The scenarios propose the groundwater extraction in 9 sub areas (table 1.2) and (Figure 1.2).

The scenarios are evaluated with a numerical model which is calibrated simulating the piezometric levels in 1960 (pre-development steady state), and the subsequent changes in development during the period 1960-1990. Development in the absence of drainage system was during the period 1960-1974. After 1974 a drainage system was installed.

The effects of the scenarios are simulated for a period of 50 years (1990-2040) as changes are non-steady process. Changes cannot be observed in early stage of the projects and become critical after 10-20 years.

1.5.1. Identified Policy Options:

Results obtained from the above mentioned methodology show that:

- Without further groundwater development (scenario 1) there is still a lowering of the groundwater head of 10-15 meters in the coming 50 years.

- Uncontrolled development (scenario 2: full development in area 4-8) will lead to a lowering of the groundwater head of maximum 80 meters after 50 years. This will result in depletion of the aquifer in the area south of the Dina Farm and will cause many existing wells to fall dry, particularly in the area east of the Cairo-Alexandria desert road.

Table (1.1) Groundwater Development scenarios

no	Description(location see No. in figure)	Groundwater extraction (10^6m)	Representative cultivated area*2) (feddan)	Remaining area available for cultivation*1(feddan)
i	No development after 1990	460	70,000	330,000
ii	Full development in areas 4-8, partial development in areas 9	1140	190,000	210,000
iii	Controlled development in areas 4-11	770	130,000	270,000
iv	Controlled development with additional surface water suplly	770	>130,000*3	< 270,000*3

* 1) Total area available for cultivation: 400,000 feddan.
* 2) Indicate figures, exact figures will depend on irrigation method, crop types and farm management.
* 3) Depends on the area to be irrigated with surface water.
after Farid and Tuinof (1991).

Table (1.2) Proposed groundwater development 1990-2000

			1990		2000	
Area	Description	Total area available for cultivation	Groundwater extraction $10^6m^3/y$	Cultivated area feddan 2)	Groundwater extraction $10^6m^3/y$	Cultivatable area feddan* 3)
4	Birigat	40,000	80	12,000	141	25,000
5	Kafr El-Dawed	30,000	165	26,000	165	26,000
6	Desert Road					
	- north Dina Farm	40,000	60	9,000	144	25,000
	- south Dina Farm	30,000	55	9,000	63	11,000
7	Khatatba road	25,000	23	3,500	29	5,000
8	Dina Farm	10,000	18	4,000	37	8,000
9	South Khatatba	40,000	31	4,000	48	8,000
10	Sadat City *1)	60,000	20*1)	2,000	75	10,000
11	Wadi El-Farigh					
	-west Wadi El-Farigh	50,000	1	250	52	10,000
	-east Wadi El-Farigh	75,000	1	250	10	2,000
12	Wadi El Narun		6		6	
	Total	400,000	460	70,000	770	130,000

Note:
*1) Includes drinking water supply and industrial water supply
*2) Indicate figures
after Farid and Tuinof (1991)

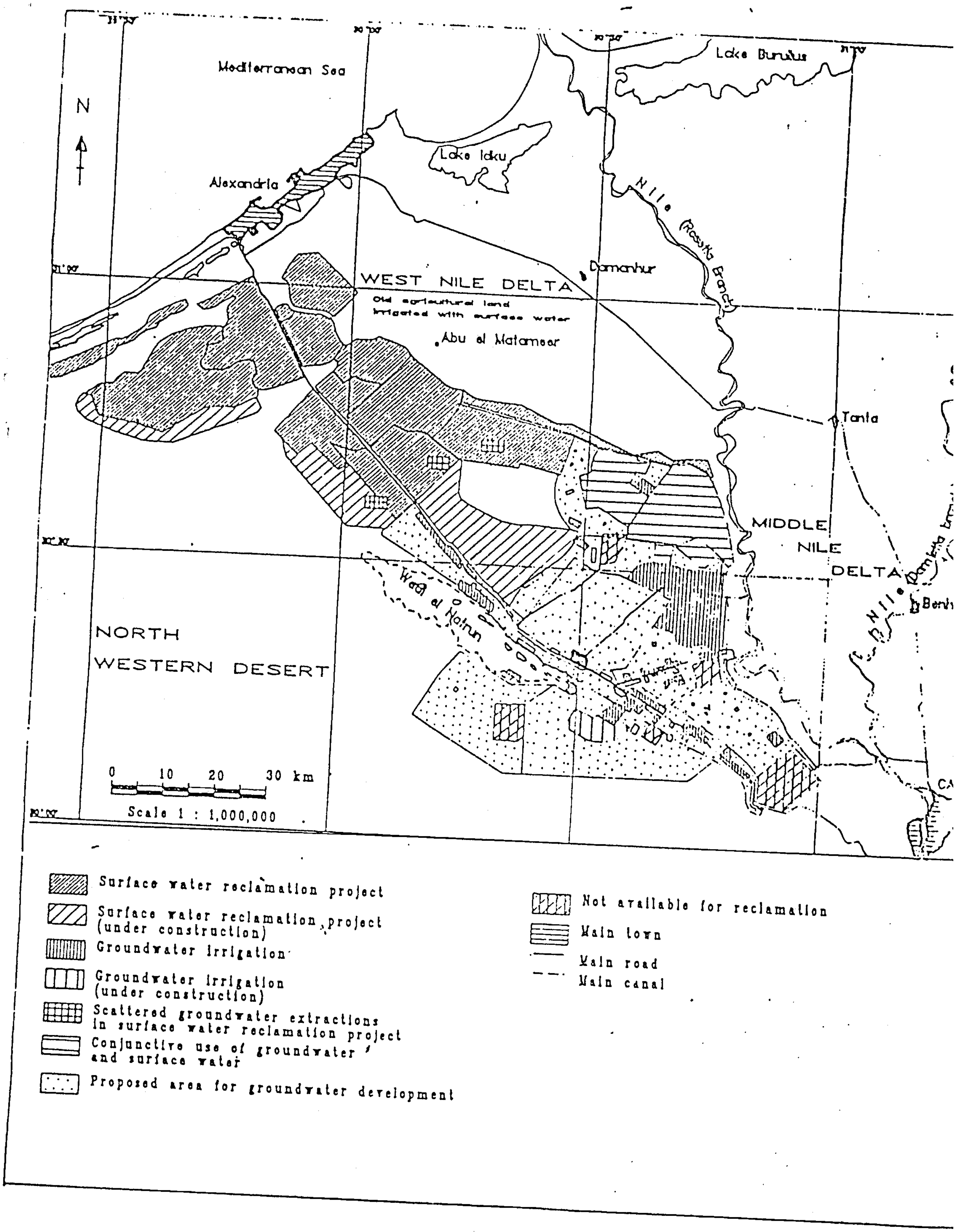

Figure 1.2 Landuse and groundwater development areas

After Farid and Tuinof (1991)

- Controlled development (scenario 3) will limit the lowing of maximum 25 meters and assure that most of the existing wells remain in operation.

- Controlled groundwater development in conduction with additional surface water (scenario 4) is the only option to reclaim all the cultivable area in the groundwater development areas (400,000 feddans). Implementation of surface water projects will also prevent (uncontrolled) drilling of wells in these areas and will eventually provide additional recharge to the groundwater system.

The proposed groundwater development plan is based on scenarios (3) and (4).

The plan foresees an increase of the groundwater extraction from 460 (1990) to 770 million m3/year is the year 200. The representative cultivated area is indicative and may be larger if irrigation efficiency increases (table 2).

- It is recommended to go ahead with the planning and implementation of surface water projects in Sadat City area, Khataba area and in Wadi El Farigh, in order to cultivate part of the remaining area (270,000 feddans).

- Surface water projects should be planned and designed in conjunction with groundwater projects. The conjunctive use of groundwater and surface water will prevent possible negative side effects of surface water reclamation (rising water tables).

- Combined surface water/groundwater systems may also be designed such that excess (surface) water during the winter months is infiltrated and stored in the aquifer and subsequently pumped during the summer. It is recommended to investigate the feasibility of this artificial recharge option as one of the means to utilize the excess Nile water during the winter.

Monitoring of changes in the groundwater regime and groundwater quality during the coming 10 years is essential in order to provide the necessary data to verify and update the present plan after 5-10 years. This information is also required to forecast the water quality changes in time.

Control of these development plans should be implemented by a licensing system. Licenses for the installation of new wells should include guidelines for the minimum drilling depth and screed depth and for minimum distance between wells.

The above mentioned controlled groundwater development plan 1990-2000 suggests that the cultivable area in Sadat city can be increased from 2000 feddan to 10,000 feddan to limit the lowering of the groundwater level to maximum of 25m and assure that most of existing wells remain in operation. However, the present cultivable area in Sadat city is 10,000 feddan in addition to 18000 to 20000 feddan divided into 100 feddan farms and leased to large investors. This means that cultivable area is being developed to about 30,000 feddan while groundwater potential can support only 10,000 feddan. Groundwater extraction is expected to be 3 times as much as the safe discharge of 75 million m3/year with the subsequent lowering of the groundwater level and the possibility of some wells to fall dry.

The situation in Wadi El-Natrun is even more drastic. The controlled development plan suggest that groundwater extraction should not exceed 6 million m3 which irrigates a cultivable area of 1000 feddan. The potential cultivable area in Wadi El-Natrun is however, about 30,000 feddan, of which 4000 feddan have been cultivated since the 1960's, 14000 feddan have been allocated to agricultural cooperatives, and 12000 feddan are available fore investor.

When a situation of groundwater exhaustion is created in an existing agriculture in the absence of proper planning as was the case in El-Safe area (Giza governorate) the groundwater wells fall dry and saline. Salinity rose from 450 ppm in 1981 to 4200 ppm in 1986 in this area. The government was compelled to supply surface water through an open canal mixed with sewage and industrial waste water. *The environmental impact of a sing this waste warer is yet to be evaluated.*

Control of the groundwater development should be implemented by licening system. Licenses for the installation of new wells should include guidelines for the drilling depth; the screen depth and minimum distance between wells. Only recently the Groundwater Research Institute has assumed responsibility to such licening system.

1.6. Changes in Quality Groundwater in the Study areas:

Historic data of the groundwater salinity of some selected wells in different areas of the western desert are presented in table (1.3). They show that South Tahrir, Bustan and Sadat city has good quality water. However salinity slightly increased in these areas from the 1970's to the 1990's. Over three years groundwater salinity in Sadat city slightly rose from 266-812 in 1990 to 312-915 ppm in 1993 .

1.6.1. Groundwater Quality in Sadat City

Groundwater Salinity in 12 wells representing the area of Sadat City was measured in DDC laboratory in Sadat City in 1987, 1988, and 1995 through 1997. The salinity values are presented in table 1.4. In general Sadat City has good groundwater quality. With the exception of wells 90, 92 (1), 92(2) located close and along the Cairo-Alexandria road. The groundwater salinity for the rest of the wells ranges between 0.38 and 0.86 dS/m (243-550 pmm) over the period 1987-1997. The higher salinity of groundwater in well 90, 92(1), 92(2) ranged between 1.22 and 2.41 dS/m (780-1542 pmm) and was attributed to the presence of clay lenses and the intercalation of clay and sand

Table (1.3). Salinity and chemical characteristics of the Early pleistocence groundwater

Locality	Water Salinity (ppm)	Dominant chemical type
northern portions and the cultivated area near El-Nasr canal	500 - 4500(1973-1977) 700 - 4660(1993-1994)	HCO3 - Na & Na-Cl
* Southern portions	300 - 500 (1975-1977) 370 - 750 (1994)	HCO3 - Na
* Cultivated Area of South El-Tahrir	200 - 500 (1973) 620- above 1000 (1973) 312- 1700 (1993)	HCO3 - Na Cl- Na
* Bustan Area	660 - 1700 (1993)	HCO3 - Na
* Sadat City	266 - 812 (1990) 312 - 915 (1993)	HCO3 - Na
* Cairo- Alexandria Desert Road:		
Km 85	746 (1990)	HCO3 - Na
Km 73	232 (1990)	HCO3 - Na
Km 60	774 (1990)	HCO3 - Na
Km 44	2944 (1990)	Cl- Na
Km 42.5	2680 (1990)	Cl- Na
Km 35	14,000 (1993)	Cl - Na
Km 28	7250 (1993)	Cl -Na

in the vicinity of these wells in addition to possible seepage of wastes from the Egyptian Poultry Company located near well 92..

Slight salinity changes with time could be noticed over short periods between 1987 and 1988 (table 1.4). Over the past ten years (1987-1997), however, salinity rose by 64-103% in four out of the twelve wells under investigation (Figs. 1.3). These wells are AUC, W4, W9 and 90. Although salinity rose by such a high percentage it remained below 0.86 dS/m (550 ppm) in wells of AUC, W_4 and W_9 and groundwater in these wells remained of good quality. The remaining 8 wells showed very slight and insignificant changes in groundwater salinity over the same period. Monitoring salinity and chemical composition of groundwater will continue in DDC Laboratory in Sadat City to asses changes in groundwater quality as affected by the agriculture expansion in the area.

Table (1.4) : Changes in Groundwater salinity in Sadat City wells (1987-1997)

Well	***Electrical conductivity (ds/m)***				
#	***1987***	***1988***	***1995***	***1996***	***1997***
A	0.423	0.410	0.399	0.40	0.42
AUC	0.450	0.490	0.745	0.65	0.77
W1	0.404	0.400	0.397	0.37	0.40
W3	0.400	0.400	0.391	0.38	0.45
W4	0.427	0.450	0.713	0.59	0.70
W5	0.420	0.430	0.399	0.39	0.44
W6	0.410	0.400	0.411	0.38	0.41
W7	0.423	0.420	--	0.39	0.46
W9	0.423	0.430	0.750	0.79	0.86
W11	0.410	0.420	0.421	0.39	0.42
W12	0.398	0.410	0.453	0.45	0.48
Km 90	0.496	0.650	1.527	1.47	1.62
Km 92.1	2.210	2.41	2.240	2.10	2.20
Km92.2	1.54	1.37	1.390	1.41	1.40

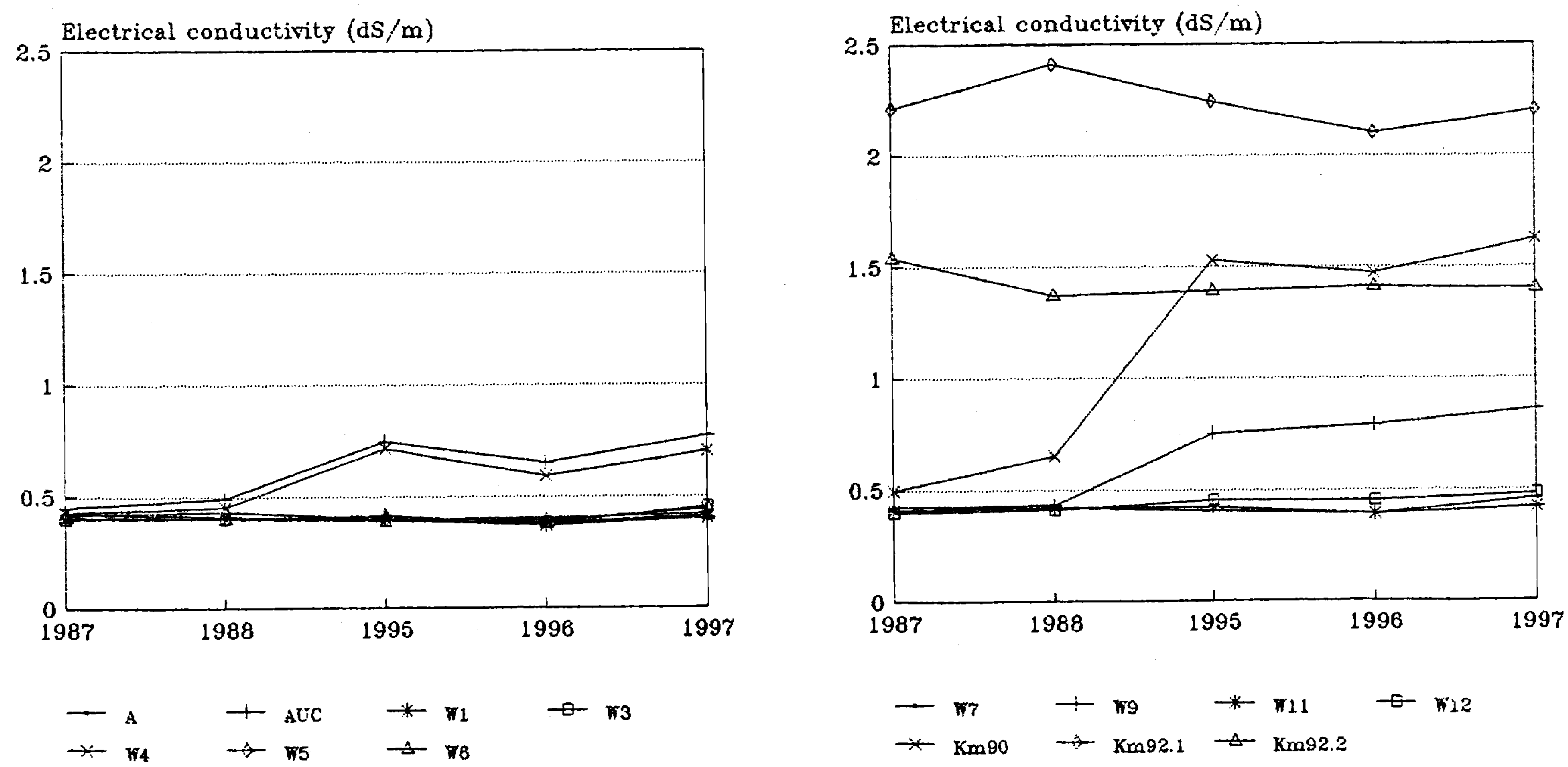

Fig. 1.3 : Changes in groundwater salinity in Sadat City wells (1987-1997)

The water table contour maps of Sadat City in April and July 1989 [1] the 2nd progress indicated that the general flow pattern of the groundwater in the Pleistocene gravely aquifer in Sadat City coincides with the general flow pattern of groundwater in west of the Nile Delta. Generally the water flows from northeast to southwest in the direction of Wadi El Natrun depression. This provides an additional evidence for the hydraulic connection between Pleistocene aquifer beneath the Delta and the whole region to the west of the aquifer. It also suggests the presence of an important recharge source located in the northeast direction and is presented by Rosette branch. The seasonal variations in groundwater table showed a slight difference between the spring and summer season, which indicate slight fluctuations in this area. At that time the effect of discharge in the area was not detected and therefore, the aquifer was characterized to be of good quality.

These investigations need to be updated in view of the agriculture expansion in the area in recent years to evaluate its effect on the potentiality of the aquifer.

Data presented in the 2nd progress report showed that $NaHCO_3$ and NaC1 are the major salinity constituents of Sadat City groundwater at low levels of salinity. However at higher level of salinity (wells #92 (1) and #92 (2) $NaSO_4$ and NaC1 became the major salinity constituents. The SAR values were low-moderate in most wells (1.9-6.5) with higher values associated with higher salinity (table 1.5). Due to the moderate salinity and the coarse texture of soil in the area these SAR values are not expected to present any sizable restriction on water use for irrigation. Again boron concentrations are low-medium and do not exceed 1.0 ppm in most of the well. Values higher than 1.0 ppm occurred only in wells 90 and 92 with moderate salinity. concentrations of NO3-N and NH_4-N are within acceptable limits and showed no environmental polution that restrict water use for irrigation or drinking.

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[1] El- Maghraby, M.M. (1990). Geograhpical and hydorological studies of Sadat City, Egypt. M.Sc. Thesis, Fac. Sci., Alexandria University.

Table (1.5): Some Chemical Constituents (ppm) in Groundwater in Sadat City

Well #	*ppm*									*pH*	*SAR*
	B	***NO3-N***	NH_4-*N*	***Fe***	***Zn***	***Mn***	***Cu***	***Pb***	***Cd***		
1	0.62	6.4	6.4	0.02	T.	0.04	0.01	0.04	0.01	7.5	3.9
2	0.98	6.4	6.4	0.01	T.	0.02	0.01	0.04	0.01	7.4	1.8
	0.09	3.1	3.1	0.01	0.01	0.02	0.01	0.03	0.03	7.5	2.2
1	0.35	6.4	6.4	0.03	0.01	0.01	0.01	0.07	0.02	7.3	1.9
3	0.59	6.4	6.4	0.04	T.	0.01	0.02	0.07	0.01	7.4	2.2
4	1.09	9.5	6.4	0.01	0.01	0.02	0.01	0.06	0.02	7.5	4.2
5	0.3	3.1	6.4	0.03	0.01	0.02	0.03	0.05	0.02	6.9	1.9
6	0.49	6.4	6.4	0.07	0.01	0.01	0.02	0.08	0.02	7.4	2.5
7	0.72	3.1	6.4	0.09	T.	0.02	0.01	0.01	0.01	7.6	4.0
9	0.45	3.1	6.4	0.08	0.01	0.01	0.01	0.02	0.02	7.6	3.6
11	0.49	3.1	6.4	0.08	T.	0.01	0.01	0.0	0.01	7.4	2.3
12	0.98	3.1	6.4	0.01	0.01	0.01	0.01	0.08	0.01	7.4	2.2
90	1.47	6.4	3.1	0.01	T.	0.03	0.01	0.01	0.02	7.5	4.9
92	1.51	6.4	6.4	0.04	0.01	0.03	0.01	0.03	0.01	7.7	6.5

The heavy metal concentrations (Fe, Zn, Mn, Cu, Pb, and Cd) in these wells were very low and far below the acceptable limits in irrigation water for long term use. The concentrations did not exceed 0.09 ppm Fe, 0.01 ppm Zn, 0.04 ppm Mn, 0.03 ppm Cu, 0.08 ppm Pb and 0.03 ppm Cd.

1.6.2. Changes in Groundwater Quality in Wadi El Natrun Area:

Table (1.6) and Fig (1.4) show changes in groundwater salinity in 31 wells in Wadi El Natrun between 1966 and 1997. Data for the period 1966-1985 were collected from Wadi El Natrun authority. Samples from most of these wells where collected and analyzed in 1995-1997 in DDC laboratory in Sadat City.. Data show that groundwater salinity in Wadi El Natrun area varies widely between different locations and shows much higher values compared to Sadat area especially in the Northern sector of Wadi El Natrun where it reached about 4000 ppm (6.2 dS/m). Most wells in the southern sector are at much lower salinity (see map for the locations of the wells in Fig. 1.5) with total salinity ranging between 346-909 ppm.

Data presented show changes in well water salinity between 1966 and 1997. In 1966 groundwater salinity in the monitored wells were mostly between 300 and 700 ppm with the exception of 3 wells where it was slightly higher than 1000 ppm. In 1995-1997 salinity rose appreciably in 15 out of the 31 wells under study to 2-8 times its salinity in 1966 reaching values ranging between 2000 and 4000 ppm in most of these wells especially those located in the northern sector of Wadi El Natrun. However changes in groundwater salinity in most of the well in the southern sector were slight and water quality in terms of total salinity remained of fairly good quality ranging between 346 and 870 ppm in 1997.

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Table (1.6) : Changes of groundwater salinity in Wadi El Natrun wells (1966-1997)

Well #	Location	Total Soluble Salts (ppm)							
		1966	1970	1975	1980	1985	1995	1996	1997
1	N	700	850	984	1345	1350	2406	2822	2701
2	N	630	455	445	700	600	877	1094	1203
5	N	378	322	500	500	500	390	525	461
6	N	400	322	365	530	550	698	755	--
12	N	700	1470	1900	2200	2650	2797	3021	3040
13	N	980	1260	1910	1900	2100	2118	1882	1843
14	N	490	490	600	670	680			700
22	N	1100	770	504	1100	1500			--
23	N	515	910	1442	2500	3500	3994	3648	3860
25	N	595	406	406	540	690	819	781	818
40	S	380	450	513	620				512
42	S	385	392	420	476	500	531	627	582
44	S	320	345	335	350	400	390		352
46	S	330	322	347	340	350	358	314	350
47	S	317	315	350	390	420			450
50	S	490	525	600	530	600	416	390	365
51	S	490	392	500	500	500	384	339	346
52	S	360	507	336	510	350	346	288	350
54	S	630	539	490	1100	1000	819	700	698
57	N	1200	1820	2350	3000	3150	3200	2739	3100
58	N	700	1960	2800	2950	3300			--
60	N	490	1330	1455	1500	1550			--
61	N	1050	1600	1748	1850	1800	1965	1478	1850
62	N	700	1680	1540	1800	1900	1978	1702	1741
63	N	595	880	915	920	1400	1824	1664	1850
64	N	770	490	455				442	510
67	N	735	1400	1300	1390	1550	1683		1705
70	N	595	1890	2030	2150	2500	3654	2925	2854
73	N	490	1845	2300	2750	3100	3994		3354
74	N	525	420	454	849	1150	1811	1630	1750
76	S	434	620	800	900	900	909		870

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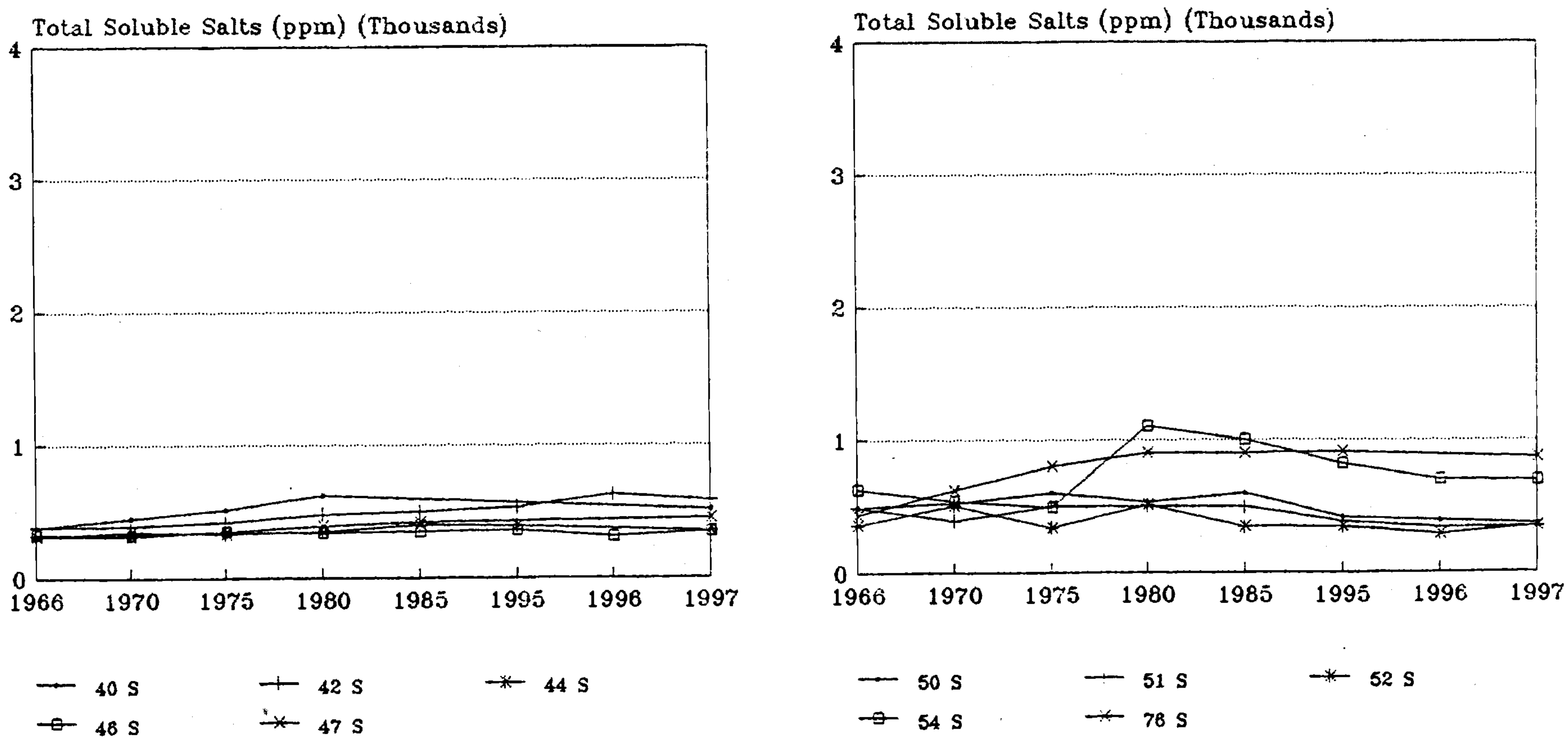


Fig. 1.4 : Changes of groundwater salinity in south sector of Wadi El Natrun wells (1966–1997)

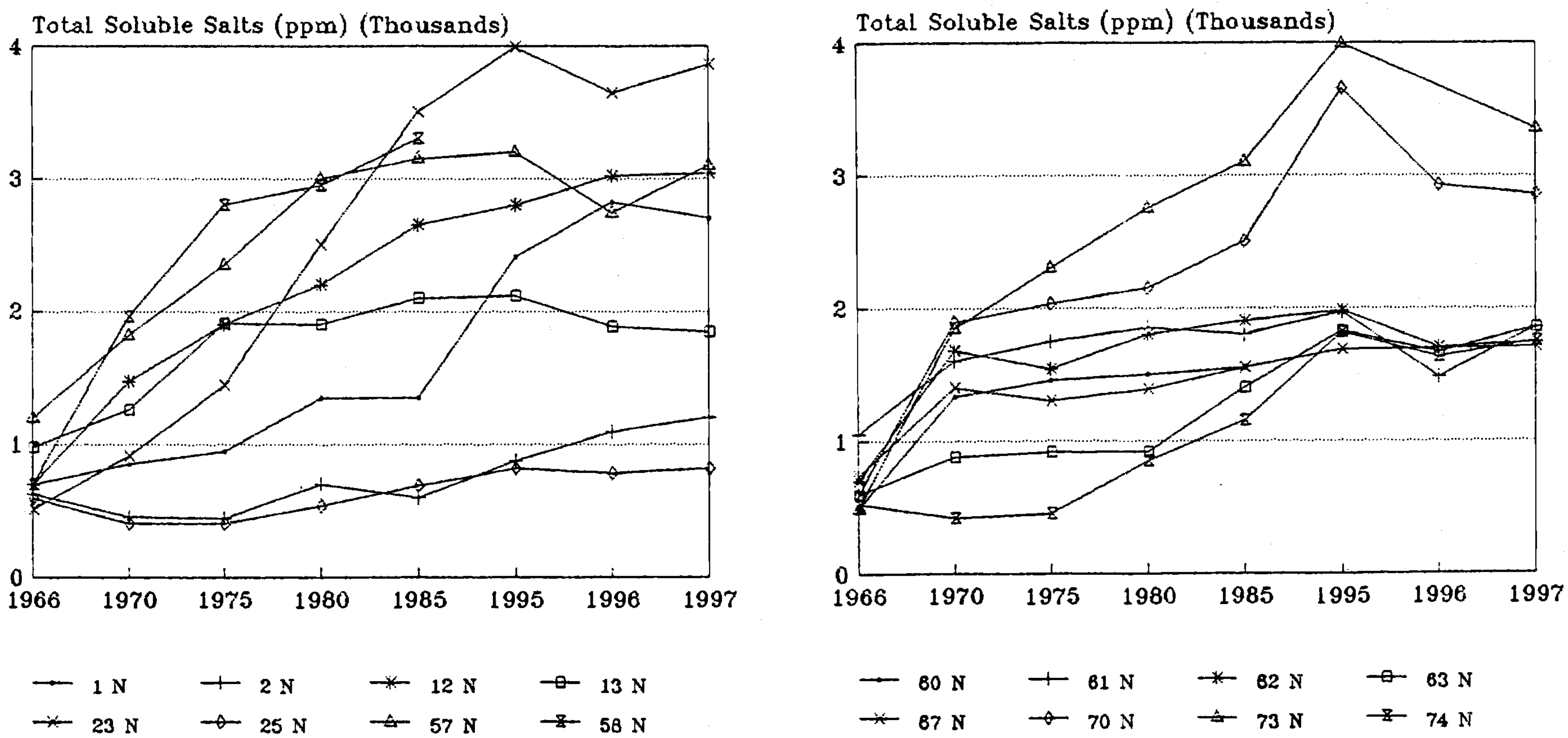
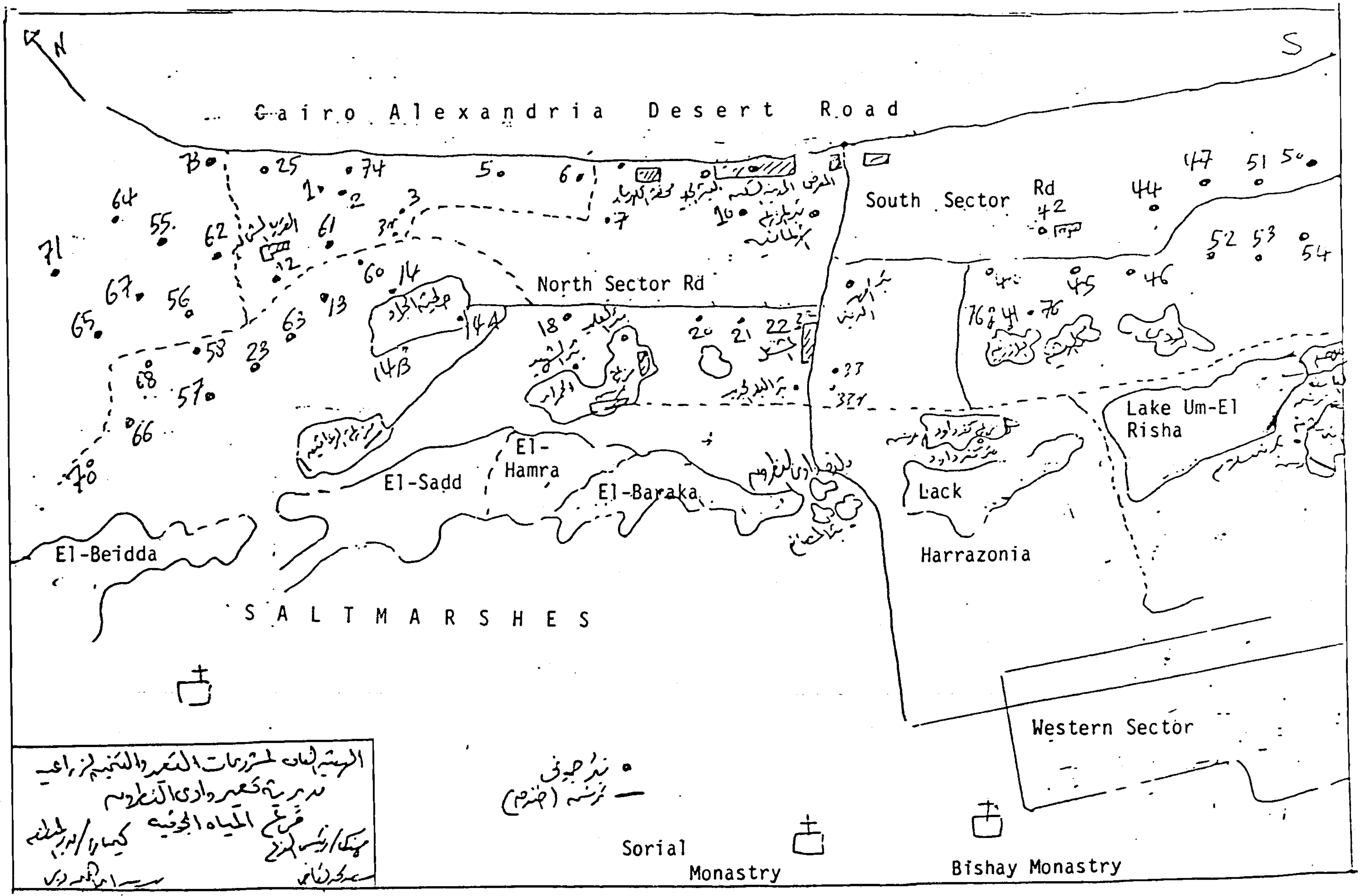


Fig. 1.4 : Changes of groundwater salinity in north sector of Wadi El Natrun wells (1966-1997)

Fig. 1.5 : Location of Wells in Wadi El-Natroun



Most of the wells in Wadi El-Natrun (table 1.7) have groundwater of medium SAR values (3-9). Few have high SAR values of >9 and reaches 16.5. High SAR values are directly related to high ground water salinity (1850-3354 ppm). However, the high SAR values of groundwater under high salinity and course textured soil may not have such a deleterious effect on soil permeability. Heavy metal concentrations in Wadi El-Natrun groundwater (table 1.7) are mostly low and within the permissible levels of these metals in irrigation water, i.e., 5.0 ppm pb, 2.0: ppm Zn, 0.01 ppm Cd, 5.0 ppm Fe, ppm Mn and 0.2 ppm Cu with some exception of Cd concentration reaching 0.04 ppm. These concentration do not posses a potential pollution hazards to the soil or toxicity to plant. Elemental N (expressed as N03 - and NH_4-N) has medium values falling in the range 5-30 ppm according to Ayers and Westcot guidelines for irrigation water quality and present slight to moderate restriction in water use for irrigation. The high NO_3-N in groundwater is probably due to excessive use and leaching of N-fertilizer in addition to waste water pollution especially in shallow wells. Measures against the use of high NO_3-N water for drinking and monitoring these values in groundwater should be taken into consideration.

1.6.3. ***<u>Groundwater Salinity in South Tahrir Area:</u>***

The salinity of groundwater was measured in 31 wells in Fath sector, South Tahrir area. Groundwater is used for supplementary irrigation during the period of canal shutdown and when the level of Nile water in the irrigation canals are low. Groundwater wells in Tahrir area are usually dug 1.2 km apart along the feeding canals and adjacent to the collective pump station (serving 400-600 feddans). Groundwater is usually pumped, using desil or electric power to the feeding canals and then pumped to the field irrigation network by the booster pump in the collective pump station.

Table (1.7) : Heavy Metals and NO_3 and NH_4 farms in Groundwater in Wadi El-Natrun

Well #	PPM						NH_4-N	NO_2 + NO_3 - N	SAR
	Pb	Cd	Fe	Zn	Mn	Cu			
1	0.20	0.03	0.25	0.03	0.11	0.09	4.8+	17.5	12.1
2	0.25	0.02	0.21	0.01	0.09	0.05	4.8	6.4	7.9
3	0.17	0.02	0.09	0.01	0.10	0.06	3.2	4.8	7.6
5	0.24	0.01	0.08	tr	0.10	0.08	4.8	1.6	7.2
6	0.23	0.01	0.07	0.01	0.11	0.08	6.4		7.3
7	0.29	0.02	0.13	0.01	0.11	0.07	3.2	1.6	5.8
12	0.39	0.04	0.16	0.02	0.09	0.05	1.6	11.1	13.3
13	0.30	0.02	0.08	0.01	0.10	0.09	1.6	14.3	11.9
61	0.28	0.04	0.21	0.01	0.08	0.08	1.6	1.6	7.4
62	0.32	0.01	0.23	0.01	0.10	0.08	1.6	6.4	10.7
64	0.30	0.03	0.18	0.01	0.09	0.08	3.2	1.6	6.4
67	0.16	0.01	0.12	0.01	0.11	0.07	1.6	1.6	7.3
71	0.08	0.04	0.08	0.01	0.10	0.04	1.6	12.7	7.9
73	0.21	0.04	0.21	0.02	0.11	0.08	3.2	11.1	15.9
74	0.20	0.02	0.22	0.03	0.10	0.04	1.6	1.6	7.8
14	0.19	0.01	0.21	0.01	0.13	0.02	1.6	3.2	6.3
25	0.21	0.01	0.23	0.01	0.10	0.02	4.8	1.6	7.4
40	0.27	0.03	0.18	0.01	0.08	0.06	tr	1.6	7.4
42	0.05	0.02	0.19	0.01	0.08	0.05	1.6	4.8	6.0
44	0.20	0.03	0.22	0.01	0.06	0.05	1.6	tr	6.7
45	0.18	0.03	0.22	0.01	0.10	0.04	**		6.4
50	0.25	0.01	0.23	tr	0.08	0.04	1.6	1.6	6.5
51	0.16	0.01	0.18	0.01	0.09	0.05	tr	3.2	6.1
53	0.15	0.02	0.29	0.01	0.08	0.05			5.4
54	0.20	0.02	0.21	0.01	0.07	0.07	1.6	3.2	6.4
63	0.23	0.02	0.23	0.01	0.09	0.04	1.6	4.8	10.3
68	0.20	0.02	0.25	0.01	0.11	0.08			14.2
70	0.18	0.03	0.35	0.01	0.08	0.11	1.6	15.2	16.5
76	0.17	0.03	0.23	0.01	0.09	0.12	3.2	17.7	8.3

The salinity of groundwater in these wells were determination in May, . and Jan., 1995-1997 and presented in table (1.8). Historical data on water quality of these wells were unavailable. Out of the 31 wells tested only two have groundwater of very good quality with salinity <0.7 dS/m (450 ppm). Only one well had high salinity of >3.0 dS/m (2000 ppm). The rest of the wells have groundwater of medium salinity ranging from 0.7-3.0 dS/m (450-2000 ppm). More than 50% of the tested wells have salinity below 1000 ppm.

However historical data available for the area and presented in the first progress report show that groundwater salinity in cultivated area of South Tahrir were in the range 200-500 ppm in 1973 when HCO3 and Na were dominant and 620-1000 ppm when Cl and Na were dominant. In 1993, however groundwater salinity rose to 312-1700 ppm. Comparing these ranges of salinity with that measured in Fath sector, South Tahrir in 1995-1997 (429-2336 ppm) we could detect a sligh salinity rise of groundwater in the cultivated area, probably due to the leaching of salts and fertilizers to the groundwater since the static level of groundwater ranges between 5 and 12 m below surface.

The SAR values of groundwater in South Tahrir (table 1.9) are low (<3) to medium (3-9) and expected to exert no deleterious effect on soil permeability in view of the coarse texture of the soil. Similar to the ground water of Wadi El Natrun all heavy metal concentrations are below the permissible levels in irrigation water with some exceptions of Cd concentration reaching 0.05 ppm. The high levels of Cd, however are believed to be partly due to low accuracy of determining the element under such low concentration using atomic absorption spectroscopy. Inorganic nitrogen, however, presented by NO3-N and NH_4-N is mostly of moderate values (5-30 ppm) and presents slight to medium restriction for the use of water in irrigation. Well 1/2, however has higher value reaching 43 ppm.

Data presented in (table 1.4) show that groundwater in Sadat city is of much better quality than in South Tahrir area. Eleven out of the 14 wells tested in

Table (1.8) : Groundwater Salinity (ppm) in South Tahrir Area (Fath Sector) (1995-1997)

Well #	*Depth m*	*Static level m*	*May 1995*	*Jan. 1996*	*May 1996*	*Jan. 1997*	*May 1997*
1/2	100	10.5	640	653	646	--	652
2/2	100	9.5	797	832	813	--	768
3/2	100	11.5	1177	1114	1120	1049	1088
4/2	100	12.0	1280	1114	1337	1331	1004
6/2	100	11.0	1305	1370	909	934	1325
1/3	100	10.0	-	-	--	--	--
2/3	100	9.5	435	435	435	--	448
3/3	100	9.5	1369	1267	1248	--	1280
4/3	70	9.5	768	730	749	684	698
5/3	50	9.5	1088	-	800	--	787
6/3	40	9.5	908	-	774	819	--
8/3	100	7.0	780	806	768	800	825
9/3	100	6.0	714	794	697	755	800
1/4	100	10.5	-	-	--	--	563
2/4	100	10.5	-	986	966	1050	934
3/4	100	10.5	-	-	--	--	--
4/4	70	10.5	550	461	627	531	--
5/4	100	10.5	691	-	633	672	691
6/4	100	10.5	448	-	429	435	473
7/4	70	9.0	-	-	448	499	--
8/4	70	9.5	755	768	749	780	780
A	100	6.0	1049	1050	960	1062	--
B	100	7.5	844	858	915	1081	1088
C	100	9.5	2201	2266	--	2342	2336
D	100	10.5	921	986	--	--	--
E	100	11.0	998	1050	1075	--	--
F	100	10.5	537	563	845	1056	1171
G	100	12.0	1280	1114	1024	1081	--
H	100	5.0	345	-	301	326	--

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Table (1.9) : Heavy Metals and NO3 and NH_4 farms in Groundwater in South Tahrir

Well #	*PPM*						NH_4-*N*	*NO2+ NO3-N*	*SAR*
	Pb	Cd	Fe	Zn	Mn	Cu			
1/2	0.26	0.02	0.16	0.01	0.07	0.11	14.3	28.6	2.8
2/2	0.26	0.05	0.15	0.01	0.09	0.10	9.5	11.6	4.3
4/2	0.18	0.01	0.20	0.01	0.09	0.10	1.5	14.3	5.6
6/2	0.14	0.02	0.19	0.01	0.08	0.11	3.2	15.9	6.0
2/3	0.13	0.01	0.23	0.01	0.07	0.09	3.2		2.6
3/3	0.19	0.04	0.18	0.01	0.18	0.08	3.2	11.6	5.5
4/3	0.12	0.04	0.22	0.01	0.09	0.09	trace	12.7	4.5
5/3	0.10	0.03	0.21	0.01	0.10	0.10	6.4	14.3	6.8
8/3	0.17	0.01	0.23	0.01	0.10	0.10	trace	11.1	5.9
9/3	0.10	0.04	0.22	0.03	0.09	0.10	4.8	9.5	5.3
1/4	0.11	0.05	0.24	0.01	0.10	0.09	trace	9.5	4.3
2/4	0.13	0.01	0.20	0.02	0.07	0.08	trace	9.5	5.3
5/4	0.12	0.01	0.24	0.01	0.07	0.09	trace	12.7	5.9
8/4	0.16	0.02	0.34	trace	0.08	0.08	trace	12.7	7.4
B	0.15	0.04	0.36	0.01	0.06	0.07	trace	1.6	1.5
C	0.22	0.02	0.27	0.01	0.09	0.03	trace	23.8	4.3
D	0.14	0.02	0.21	0.01	0.06	0.07	1.6	17.5	2.3
F	0.15	0.03	0.23	0.03	0.07	0.07	trace	14.3	7.1
G	0.15	0.01	0.25	0.01	0.05	0.08	trace	22.4	6.7
3/2	0.24	0.04	0.09	0.01	0.09	0.02	trace	trace	4.3
4/2	0.07	0.04	0.13	0.01	0.04	0.05	trace	1.6	1.2
6/2	0.05	0.03	0.17	0.01	0.05	0.03	1.6	4.8	6.9
E	0.31	0.01	0.07	trace	0.07	0.04	1.6	22.4	5.9

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Sadat city had groundwater salinity < 500 ppm, two had salinity 500-1000 ppm and only one had salinity of about 1600 ppm in 1995. On the other hand, groundwater salinity in South Tahrir is considerably lower than in Wadi El Natrun (table 1.6). Thirteen out of the 31 wells tested had salinity <1000 ppm while the remaining wells had high salinity in the range 1800-4000 ppm. It should be emphasized that groundwater in both Sadat and Wadi El-Natrun areas is the only source of irrigation water while it only represent a supplementary source of irrigation in South Tahrir area.

Inorganic N in South Tahrir, groundwater is considerably higher than that in Sadat and Wadi El-Natrun areas probably due to excessive use and leaching of N-fertilizers to the relatively shallow groundwater (static level 5-12 m). High values of NO3-N in these shallow well could present a potential hazard if water is use for drinking if measures are not taken to rationalize N-fertilizers and prevent groundwater pollution. the levels of heavy metals however are generally within the permissible levels for irrigation.

Monitoring groundwater quality and quantity in these areas of study will continue to assess the potentiality of this water resource.

2. Irrigation System Review in South-Tahrir and Bustan Areas

The main source of irrigation water in South Tahrir and Bustan areas is Nile water which is carried to the areas through the open channel distribution system. Groundwater represents a standby and a supplementary source through deep wells. Water is distributed to the farms using a pressure distribution system using booster pump stations and networks of burried pipes. The field irrigation system used is mostly preinstalled handmove sprinkler system.

The sprinkler system of the settlements in South-Tahrir Sector are part of a very complex distribution system. Water is carried to the area by Al-Riah El-Nasery Canal which is a distributor of the Nile. The area of South Tahrir is served by a number of branch canals that flow under gravity, whilst some of them run against the slope and water is raised in a number of lift pump stations as shown in figure (2.1).

Operation of the open channel distribution system is controlled by the Ministry of Publich Works and Water Resources. They establish the month's irrigation requirements, and therefore the flow in the main and branch canals. The Electrical and Mechanical Division of the Ministry control the lift pump stations, and their staff at the control structures determine when to close or partially close their gates, when to open them again to operate the storage function of the canals.

The South Tahrir and Bustan sectors, are mostly irrigated by sprinkler systems, served by several pumpstations taking water from the branch canals. The settlements area is provided with the same field irrigation systems throughout. The land is allocated in 20 feddan plots to settlers.

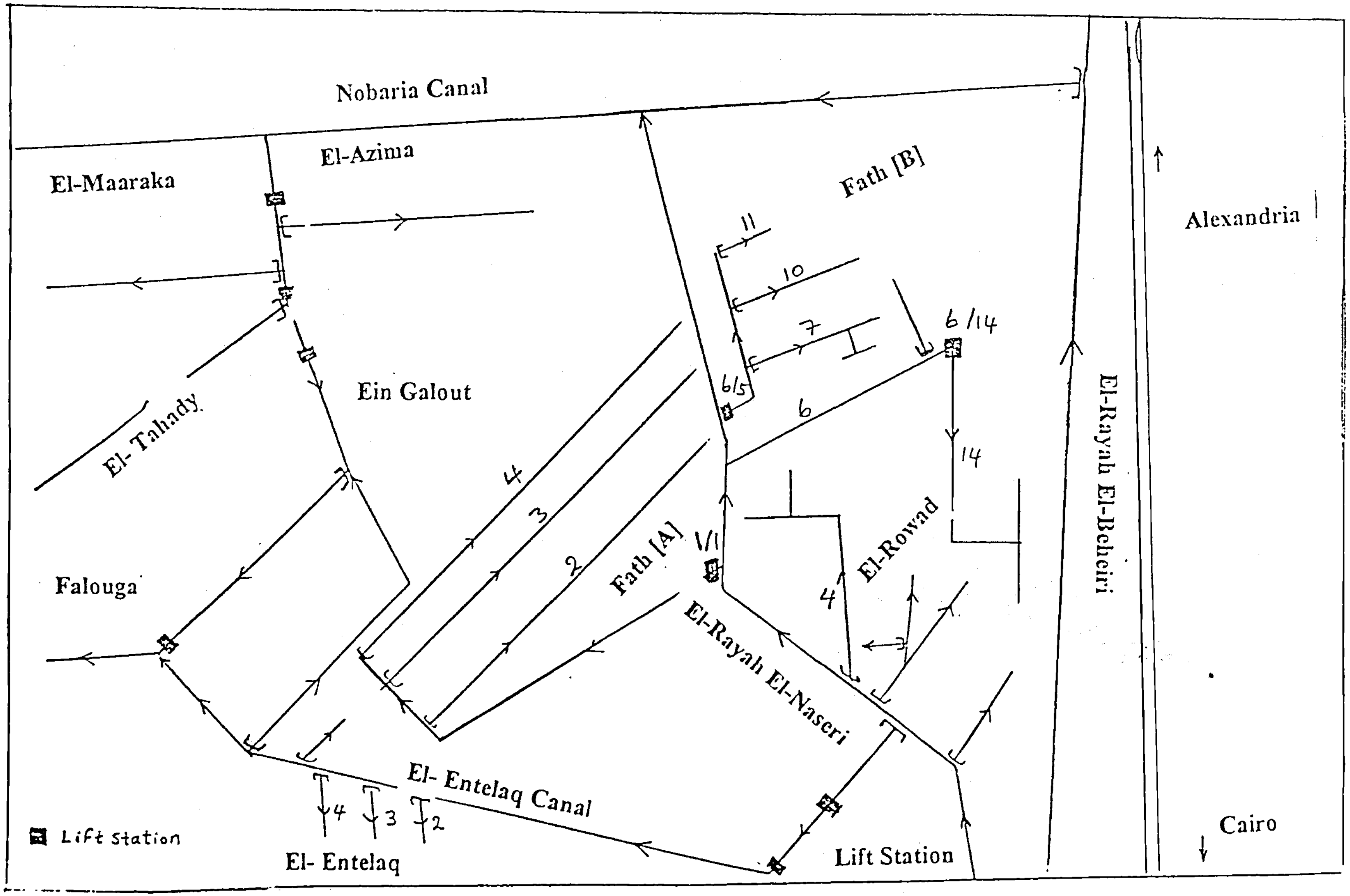

Fig.2-1. The open channel water distribution system in South Tahrir sector

The South Tahrir sector and Bustan are subdivided into sections. Each section has a pump station and a deep-well pump which feeds an area of 200-600 feddans. In Bustan area, however, there are also individual pumps serving 20 feddan each. Each section is subdivided into 20 feddans plots and allocated to settlers. Each section in South Tahrir was numbered according to its branch canal number and its location on the branch canal. For example, the section number 6/2 means branch canal number 2 and the pump station number 6 on the branch canal.

2.1. Irrigation System Components:

2.1.1. Deep-Well Pump

An electrically powered deep-well turbine pump of about 100 horse power is used to lift water from underground to discharge into the branch canal. The static underground water level in the area ranges between 20-40 meter.

The deep-well pump works as an alternate source of water and certainly during the period of shut-down of the canals in January/February.

2.1.2. Irrigation Pump Station

The old installation of pump station includes an electrically pwoered vertical centrifugal pump house and the pipe inlet with trash gate. The branch canal feeds a number of pump stations.

The pumpstation are designed for a water duty of about 2 m3/hr per feddan. This flow is not enough if the operating hours per day is less than 15 hours due to power outage. The pumpstations contain electrically powered centrifugal pumps. No standby units are provided. The settlers operate the irrigation pump stations under the supervision of the staff of the Electrical and Mechanical Division of the Ministry of Public Works and water Resources. There are automatic cut-outs to prevent abstreaction when the canal level is too low.

The design sprinkler operating pressure is 3.5 atmospheres, which with allowance for losses in the laterals and buried pipelines plus the suction head, gives a dynamic pumping head of about 5.5 atmospheres depending on ground level variations. Sprinkler pressures as low as 0.5 atmosphere were observed due to different leakage from the irrigation system and wear in the pump impellers. The designers intend the pump station to operate 15 hours per day, but it seems that due to a shortage of water or electrical failure, and possibly other reasons, they operate on average less than 10 hours per day.

2.1.3. Sprinkler system

The sprinkler system consists of the buried pipe system, terminating in the hydrants that supply the portable farm laterals. The pipe work system Asbestos - Cement, with pipes ranging in diameter from 16 inches to 4 inches.

The field irrigation equipment provided in the 20 feddan plot of South Tahrir and Bustan comprises one portable aluminum lateral line of 270 meter length with two pipe sizes. The lateral line starts with a diameter of 4 inches for 90 meter length and 3 inches diameter for 180 meter length. On each lateral in South Tahrir there is thirty twin nozzle Rain Bird 30 TNT sprinklers that have the following characteristics:

- Nozzle diameters: 4.8 x 2.4 - 27°
- Design operating pressure: 3.5 atmospheres;
- Effective diameter of wetting: 30 m
- Sprinkler discharge: 34 L/Min

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Which at the design spacing of 9 x 18m gives:

$$Application\ rate = \frac{Sprinkler\ Discharge}{Sprinkler\ Spapcings} = \frac{34 \times 60}{9 \times 18} = 12.6\ mm/hr$$

The sprinklers are locally manufactured by Helwan Co. for Non-Ferrous Industries.

The field irrigation equipment in the small holder areas of Bustan comprises two portable aluminum 3.0 inches diameter lateral lines per 20 feddans unit (i.e. lateral line would be shared by two 5.0 feddan settlers). The sprinklers have the following characteristics:

- Nozzle diameters: 5.5 and 4.4 mm
- Design operating pressure: 3.5 atmospheres (50 psi)
- Effective diameter of spray: 36m
- Sprinkler discharge: 61 l/min
- Design spacing of 15 x 18 m which gives 13.5 mm/hr.

Each 20 feddan plot has 5 hydrants rising from the buried branch pipeline, refer to figure 2.2 and 2.3, giving a total of fifteen lateral positions. Irrigation of a 20 feddan plot is to be accomplished in 5 days, with 3 lateral positions per day.

It can be assumed that the available water is 60 mm/m, with irrigation being necessary when 50% of this is depleted. Thus 30 mm/m is considered readily available water. For a 0.7 m rooting depth (common for most field crops), the net application depth is 21 mm. This confirms the necessity for a 3 days irrigation interval in the peak period (July/August) for most crops, hence the peak consumption use of most crops lies between 7 and 8 mm per day. If the 20 feddans plot must be irrigated within 3 days, then 5 lateral movement must be done every day. According to the above computations, the operating time must

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be 12 hours at peak period. The irrigation time would be 2.25 hours per lateral position, equivalent to 12.6 mm/hr x 2.25 hr = 28.35 mm. If the irrigation efficiency is 75% then the net application depth is 21mm. As the irrigation interval in the peak period is 3 days this is equivalent to a peak crop consumptive use of 7 mm/day. It was observed that the Rain Bird 30 TNT sprinkler is not suitable for all uses. It cannot be used for under tree irrigation of citrus.

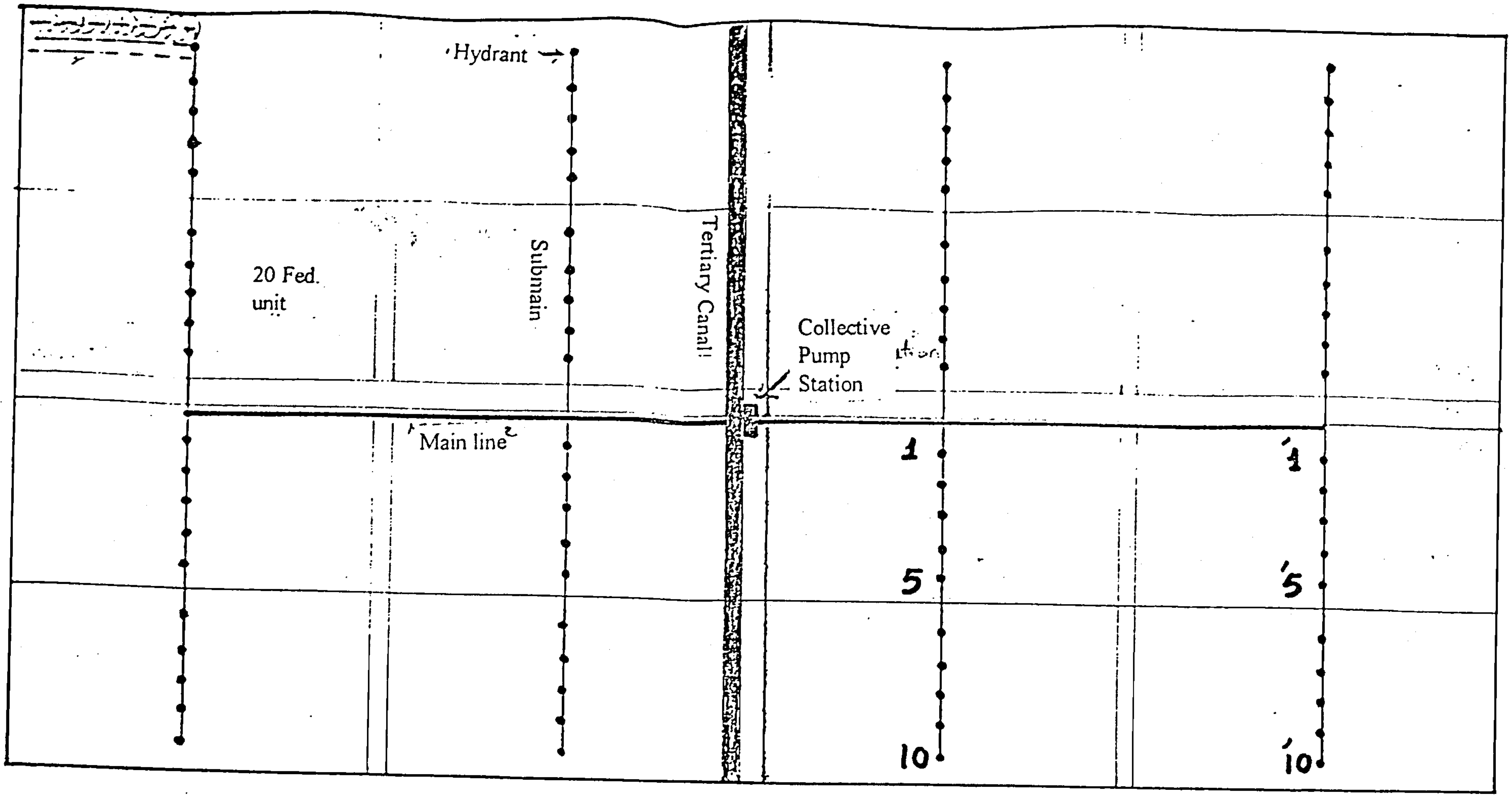

Fig. (2.2) Pressure Distribution System of a Collective Pump Station Serving 640 Feddan in South Tahrir

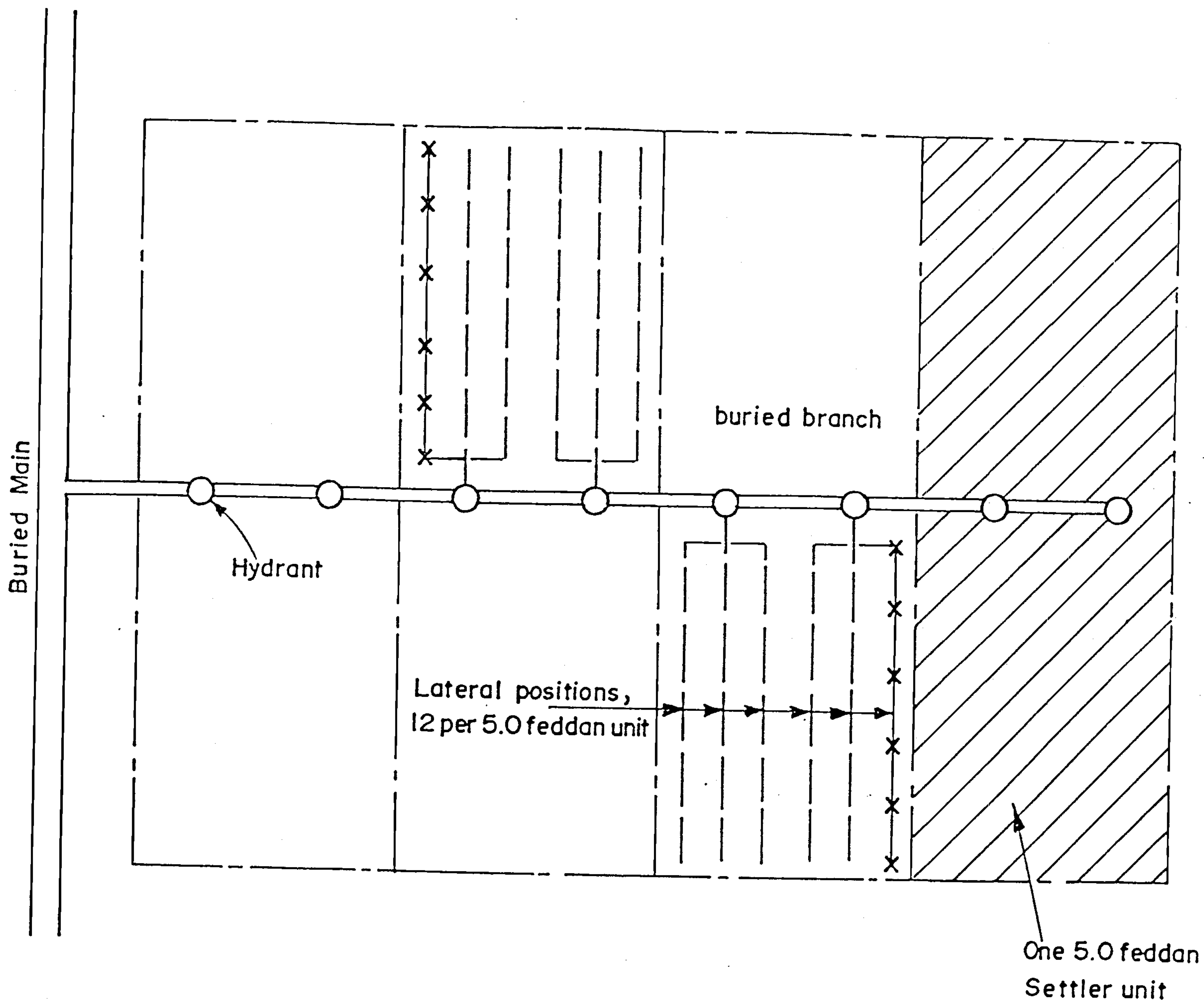

Fig 2.3 Layout of a 20 feddan unit supplied by a branch pipeline.

The field irrigation equipment, and its operation, is the same for all the land allocated within the settlement project, both in 5.0 feddan plots to "settlers" and in 20 feddan units to old graduates and investors. However, the large investors with hundreds of feddans, receive only the land, with no irrigation equipment; and they generally purchase mechanized and automated equipment, center-pivot for example.

In addition to the preinstalled handmove sprinkler system, the following systems area are also used in Bustan though in limited scale.

2.1.4 Solid Sprinkler System

Two types of sprinklers are used. The RB 70, with the sprinklers spaced 15 x 18 m and the RB 30 with sprinklers spaced at 12 x 12 m. The discharge of the RB 30 sprinkler is 1.4 m3/hr at a working pressure of 2.8 atm.

2.1.5 Drip System for Citrus:

Citrus trees are planted at 6 x 6 m spacing and no provision is made for growing other crops. Each tree is provided with 4 drippers each giving 4 l/hour at a working pressure of 1 atm. Polyethylene 13 mm OD. lateral of a length, of about 80-90 m serving 14 trees is used (Fig. 2.4). This is equivalent of 4.3 mm/day.

The drip system is under designed and no provision was made for more drippers once the trees have grown. Although the working hours of pumping stations are higher than in West Nubaria, the design criteria of 15 hours are not met. In practice, the uniformity of water application is only marginally more effective with the individual pumps (Fig. 2.5) than with the collective pumping stations.

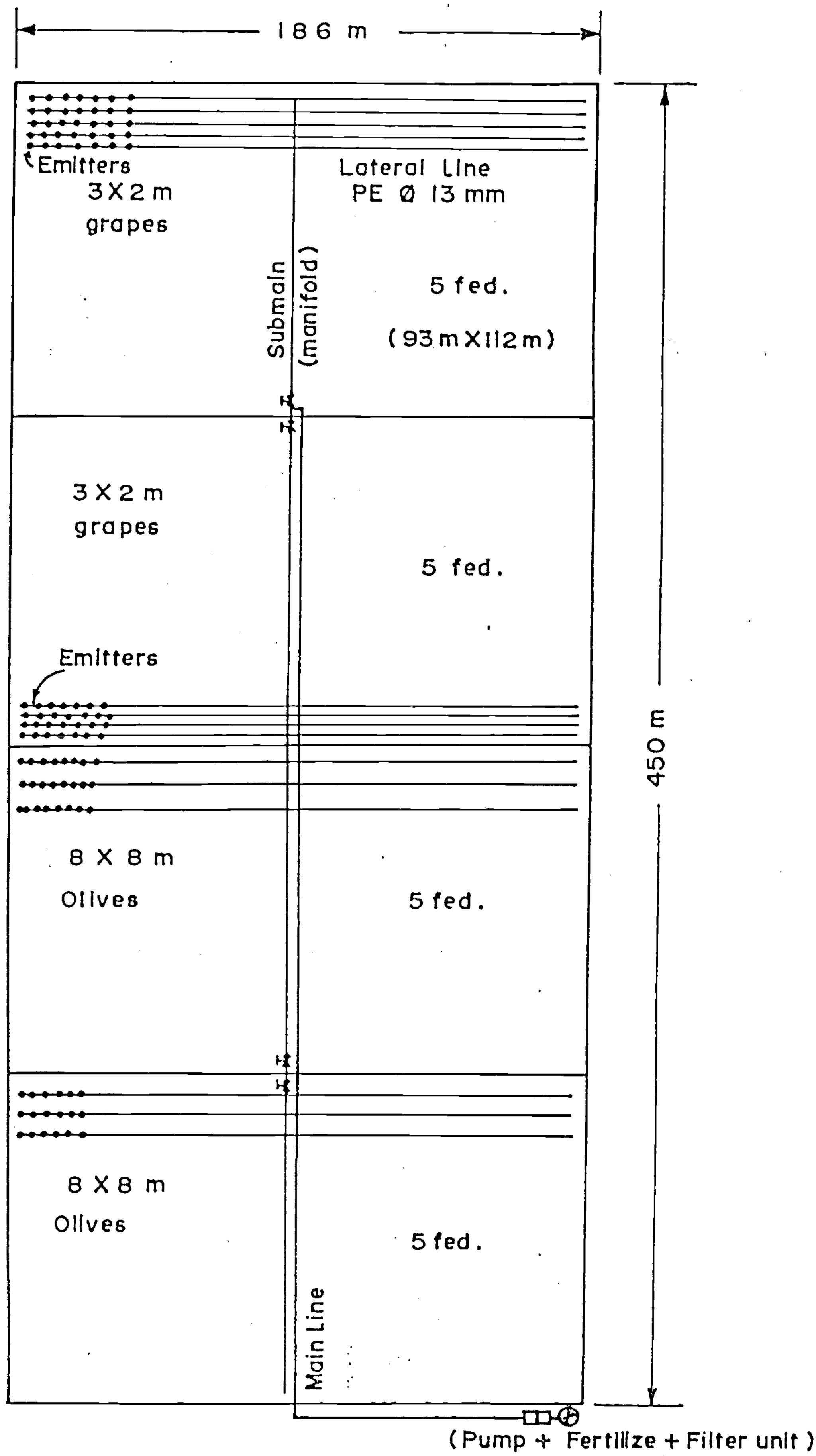

fig 2.4 Typical drip irrigation system , seving 20 fed in Sugar Beat area.

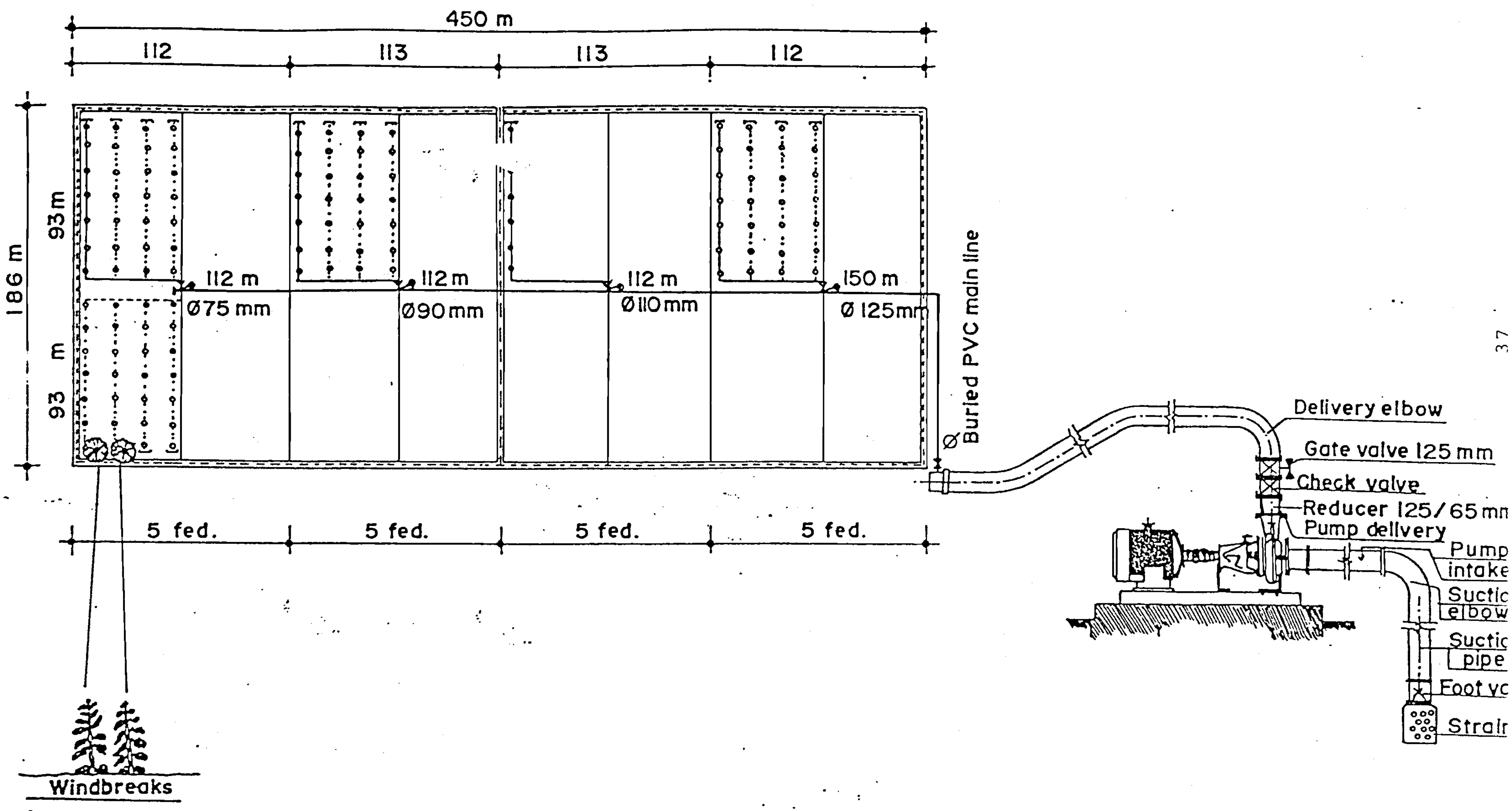

Fig. (2.5) Pressure Distribution System of an Individual Pump

2.2. *Drainage Facilities:*

At South Tahrir no drainage facilities are provided. At present, El-Bustan areas are provided with open drains ending with the main drains, No. 3 and No. 5 which, according to designs, will discharge their water in Nubaria canal. No collectors or field drains have been installed.

When reclamation started, the water table was at a depth of 20 m or more below the surface. Considering that the canals are lined and pressurized irrigation system are used, it is expected that drainage problems will be reduced, and delayed, but not necessarily eliminated. Unless a clay or impermeable layer exists at a shallow depth, permitting a perched water table to develop, drainage problems are unlikely to become significant for several years.

A drainage network could be added as the need arises. To ensure early awareness of the situation a hydropedological study with several deep wells and piezometers would be needed in these areas.

The quality of the irrigation water of the main and branched canals is excellent and its salinity is between 0.60-0.9 ds/m. Salinity of drainage water is rather small, ranging from 1.4 - 3.6 ds/m.

3. Survey of Technical and Socio Economic Aspects of Irrigation in the Desert Lands

3.1. __Background:__

Agriculture in new desert lands is considered a new experience for the majority of holders of these lands. Hence it is expected that their experience with irrigation technologies relevant to the reclaimed lands in most cases is new too. Thus the irrigation practices of those holders related to handling of the costly transported water are considered crucial to the success or failure of investments and efficiency of cultivating these new lands.

The frequent complaints of holders of new desert lands from irrigation problems is well known. So several questions may rise here; what are the main characteristics and categories of the holders in each area of the reclaimed desert lands? What are the main irrigation systems that prevail in each area? What are the main irrigation practices of the different categories of holders that prevail in each area of the desert lands? What are their sources of knowledge and skills related to these practices? Are the irrigation practices of holders relevant to the physical and chemical characteristics of the soil there? How efficient is handling of the available water resources for the different categories of holders, irrigation systems, and cropping patterns in each area? What are the most frequent irrigation problems for each category of holders in these areas?.

In the old lands, experiences related to irrigation practices are transmitted from one farmers' generation to another through the socialization process. Such process does not exist in the case of the settlements in these new lands. In old lands, there are well established institutions, norms and organizations that facilitate the transmission of adopted practices and experiences to the successive new generations. Informal organizations among farmers play major role with the scheduling of irrigation in any specific area in the old lands. Yet such situation does not exist though it is needed in the new lands.

3.2. *The Objectives:*

According to the main objective of the project, it is needed to fulfill the following detailed objectives;

1. To establish a baseline data about the socio-economic and technical aspects of the irrigation systems that exist in the areas of study for the purpose of planning monitoring and evaluation of the subsequent stages of the project,

2. To identify the categories of settlers and their attitudes towards the different systems of irrigation in the areas of study,

3. To identify and priorities major problems of irrigation according to its frequency of occurrence and significance for each category of holders in the study area,

4. To identify the knowledge level of holders related to irrigation practices in the new lands, their sources of experience, and their current sources information and knowledge with irrigation technologies,

5. To assess the training needs, target groups and training sessions needed for each category of holders for different irrigation systems according to the recommended technical packages,

6. To identify the power and communication structures and other social organizations; whether formal or informal, related to irrigation in desert lands.

3.3. *The Methodology:*

It is suggested that the most relevant analytical framework for the study of irrigation efficiency in desert lands could be the systems approach. In a situation of studying factors affecting efficiency we should take into consideration all technical, human, economic, organizational and administrative aspects of operation of the specified system. However such type of analysis should take into consideration the need to employ other analytical frameworks such as structural and functional approaches to secure more comprehension of the phenomena under study. Irrigation systems in desert lands were introduced to comparatively new communities. Thus time constraints has not yet given communities the opportunity to institutionalize stable patterns of behavior and practices related to irrigation in the desert lands such as these existing in old lands. Thus exogenous variables to the system should be considered too. This would provide more accurate information about the different factors and conditions that might affect the efficiency of various irrigation systems whether internally or externally.

Exploring present situation of irrigation in desert lands might require application of more than one method for studying all aspects. Two methods are recommended to be applied in such studies; sample survey and case studies. This would secure the type and amount of information needed to fulfill the above mentioned objectives. However, to collect needed data two types of data collection techniques are suggested to be used in this study. These are the questionnaire and interview. In the survey, a pre-tested questionnaire was applied to the sample along with personal interview to assure getting accurate data and high rate of questionnaire return.

A representative stratified random sample was drawn from the population of study which will include all holders of the farms in the specified four areas of study; South Tahrir, Al Bustan, Wadi Al-Natrun, and Sadat City. However, this population will be classified first according to many variables. From among these variables we could distinguish a wide variety of irrigation systems used, existing tenure systems, and different levels of development of the established communities of new settlers. Categories of holders vary widely. Moreover, the water resources used and other environmental considerations related to the cropping pattern and agricultural practices applied vary as well.

3.3.1. The Survey:

According to the proposal, one sample survey was applied in each of the four areas specified for this study. Thus, the population of each area and categories of holders was portrayed first. This was a necessary step to draw representative stratified random sample at the areas level to assure generalization of the findings to the respective populations. This needed a priori collection of secondary data about the holders of new lands in these areas. However, the unit of study was the farm. Based upon the early review of the available data about the population of study the sample size was estimated to be about 110 farm.

The survey was undertaken using a pre-tested questionnaire along with interviews. Due to previous experience of low response to questionnaires in rural areas, they were filled in the presence of trained enumerators to secure high rate of questionnaire return, unified understanding of what is meant by each question, and control over the environment of response to the questions.

The questionnaire is designed to include three main components to constitute all measures and scales related to the social, economic, and technical information needed for analysis of the present situation of operating irrigation systems in desert lands under study. It included valid and reliable measures and scales related to the holders' irrigation practices, their knowledge level, the past and present sources of their knowledge and experiences, and other aspects related to the efficiency of irrigation systems that prevail in the area. Some attitude scales were included in the questionnaire. This was to try uncover all the three dimensions of the respondents' attitudes; i.e. the knowledge, the sentimental, and directional towards subjects such as the issues related to water pricing, willingness to establish new organizational irrigation schemes, to cooperate with other neighbors, officials and private sector in process of enhancement of their irrigation systems and related knowledge and skills. It also included scales concerning the changing conditions that might have occurred in relation with the studied attitudes. This should help formulating recommendations related to the enhancement of irrigation efficiency in the area of study. A copy of the draft of the questionnaire form was presented in the first progress report.

Screening of all the categories to be survey is shown in the following table

Category	*Survey & Interview*	*Case Studies*
Small holders	20	5
Old graduates	15	5
New graduates	25	5
Investors	20	5
Co-Operative	20	5
Major Companies	10	5
Total	110	25

3.3.2. The Case Studies:

Case study is an approach which is more useful where there is a need to have a guide for research or action. It stimulates insights and in-depth understanding and explanation of the phenomena under study. Hence in a situation like that of seeking enhancement of the irrigation activities, systems and practices in a very dynamic changing conditions sought changes should be based on accurate information about the present attitudes and behavior of past and present experience.

The advantage of the case study approach is its ability to reveal historical follow up of the development of the given phenomena whether it is attitude, behavior or something else. However, following up the development of current attitudes would help understanding of the knowledge bases and past experiences that helped forming the specified attitudes. Such type of information can not be gathered easily without the application of the in-depth discussion with the respondent. The discussions should therefore be tailored to each case. It should follow a chronological order of reviewing, which starts from the past to the present or backward; i.e. flash back method to relate events with each other.

Application of the case study method in our study took into consideration specific aspects. In order to select representative cases according to a carefully pre-specified set of characteristics for each category, a specific check list of questions that better reflect the information needed from each case and category and to recruit trained experienced personnel; was adopted. The check list started with relatively general questions leading to more specific ones. Building confidence between the researchers and respondents is of great importance in the design and the sequence of the questions of the check list.

3.4. *Technical Aspects of the Irrigation Survey*

A total of 109 farmers were selected for this survey. All respondents were visited and interviewed at their farms. The irrigation technical questionnaire is a survey of the following information : water source, pump stations, and irrigation systems.

3.4.1. Water Source

The main source of irrigation water in south Tahrir and Bostan is Nile water. However, Wadi-Natron and Sadat depend only on groundwater as presented in Table (3.1). Most of the responding farmers (85%) in Wadi-Natron use their own private wells, while 15% use collective wells. In South Tahrir, small percent of the responding farmers (5.1%) use private wells since the main source of irrigation water is Nile water.

3.1.) : Distribution of the sample in areas of study according to the main source of irrigation water.

Main source of irrigation	Tahrir		Sadat		W.N		Bostan		Total	
	#	%	#	%	#	%	#	%	#	%
Nile water	37	94.9	-	-	-	-	30	100	67	61.5
Private well	2	5.1	9	45	17	85	-	-	28	25.7
Collective well	-	-	11	55	3	15	-	-	14	12.8
Total	39	100	20	100	20	100	30	100	109	100

Most of the responding farmers (63.3%) face problems in obtaining the irrigation water through the source, the major percentage of them are located in South Tahrir (47.8%), Bustan (27.5%), and Sadat (17.4%). Thirty three percent of the responding farmers agree that the insufficient water is the most predominant problem through the water source in South Tahrir (43.6%) and Bostan (43.6%). However, thirty five percent of the responding farmers in Sadat area, attributed the problem of the water source to the illegal practice of flood irrigation that some farmers usually do. Twenty four of the responding farmers have a well as a secondary water source, most of them located in south Tahrir (65.4%).

3.4.2. Pump Stations

Most pumps (55%) were new (Table 3.2). About 84.6% of the pumps were under 5 years old in South Tahrir, 75% in Sadat, 75% in Wadi-Natron, and 100% in Bostan. This suggests that an extensive program of

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maintenance and repair will be needed in the near future. In addition, skilled technicians and spare parts should be available.

Table (3.2) Distribution of the sample in areas of study according to pump age

Pump age years	Tahrir		Sadat		W.N.		Bostan		Total	
	#	%	#	%	#	%	#	%	#	%
0	20	51.3	11	55	1	5	28	93.3	60	55
<5	13	33.3	4	20	14	70	2	6.7	33	30.3
5 - 10	5	12.8	4	20	5	25	-	-	14	12.8
> 10	1	2.6	1	5	-	-	-	-	2	1.8
Total	39	100	20	100	20	100	30	100	109	100

Over half (55%) of the responding farmers (Table 3.3) had no private pumps or additional pumps in case of using collective pump stations. About 39.4% of the responding farmers were using Diesel engines to operate their private pumps. However, 5.5% of the responding farmers were using Electric motors to operate their private pumps. The reason for wide use of Diesel engine could be attributed to either the unavailability of electricity in the farm or the feeling that electricity is costly. About 15.6% of the responding farmers stated having had frequent problems in operating their private pumps.

Table (3.3): Private pumps and type of engine distribution in areas of study

Private pump and type of engine	Tahrir		Sadat		W.N		Bostan		Total	
	#	%	#	%	#	%	#	%	#	%
No private pump	20	51.3	11	55	1	5	28	93.3	60	55
Diesel engine	18	46.2	9	45	14	70	2	6.7	43	39.4
Electric motor	1	2.6	-	-	5	25	-	-	6	5.5
Total	39	100	20	100	20	100	30	100	109	100

The various problems responding farmers faced with pump stations are categorized and given in Table 3.4. Costly spare parts, fuel and electricity, and maintenance and repair are the common problems with pump stations for more than 85 % of the responding farmers, while unavailability of skilled technicians was a problem for 71.4 percent. Most of the farmers (90%) felt electricity was very costly and beyond the purchasing capacity of the common farmer without capital subsidy.

Table (3.4) : . Frequency of problems with pump stations

Problems	Tahrir		Sadat		Natron		Total	
	#(per 0)	%	# (per 6)	%	# (per 5)	%	# (per2)	%
Frequent cut-off of electricity	1	10	0	0	1	20	2	9.5
Low water pressure	4	40	2	33.3	2	40	8	38.1
Low water level	1	10	0	0	0	0	1	4.8
unavailable spare parts	3	30	0	0	2	40	5	23.8
Costly spare parts	9	90	5	83.3	4	80	18	85.7
Costly fuel & electricity	9	90	6	100	4	80	19	90.5
Costly maintenance & repair	9	90	5	83.3	5	100	19	90.5
Unavailable skilled technicians	8	80	3	50	4	80	15	71.4
Inappropriate design of pumps	4	40	1	16.7	0	0	5	23.8
Wearing of pump impeller	3	30	6	100	2	40	11	52.4

3.4.3. <u>Sprinkler Irrigation Systems</u>

About 26.6% of the responding farmers changed their preinstalled irrigation system, while 56.7% of the responding farmers in El-Bostan area changed their preinstalled irrigation system. The reason for the wide change of irrigation system in El-Bostan area could be attributed to the unsuitability of the preinstalled hand-move sprinkler irrigation system. The hand-move sprinkler system supplied to the settler is cheap and very inflexible, and it is not entirely suitable. It cannot be used for orchards, and the farmers with supplementary employment off-farm are unable to fully utilize their irrigation system.

The sprinkler irrigation systems were less than 10 years old in Bostan area. However, 90% of the sprinkler systems exceeded the expected life (15 years of age) in South Tahrir. Sprinkler nominal discharge rates were less than 1.8 m^3/hr for 76 percent of the systems. Seventeen percent of the responding farmers installed the sprinkler heads directly on the lateral line without using risers. The risers raise the sprinkler above the ground so that the jet will not be interfered with the growing crop.

About 56.1% of the responding farmers stated having had problems with hand-move systems, all of them located in south Tahrir.

The various problems farmers faced when using hand-move sprinkler system are categorized and given in Table (3.5). Thirty six evaluations were conducted on hand-move sprinkler systems. The most common problems were with low pressure in the lateral lines and unsuitability of hand-move for either orchard irrigation or supplementary off-farm employment. The hand-move system that has been designed and provided for the settlers is cheap and very inflexible, and it is not entirely suitable. In particular it does not allow the farmer to take up supplementary employment. At the root of the problem is the high application rate and the small soil moisture reservoir which requires the laterals to be moved every 2.25 hours. With movement of this frequency night-time irrigation, which could facilitate off-farm employment, is not socially acceptable, nor even practical. Night-time irrigation is usually based upon a ten to twelve hours irrigation shift, which eliminates the need to move laterals at night. It cannot be used for undertree

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irrigation of citrus, because the branches interfere with the water jet. Branches blocking spray occurred where low tree branches deflected the spray pattern; while not affecting the flow rate, the intended wetted diameter was not uniformly irrigated. Operating at too low a pressure is common problem on 72 % of the hand-move sprinkler systems. The direct impact of low pressure is a reduction in wetted diameter and sprinkler nozzle discharge and hence a distortion of the optimum water distribution pattern. Low pressure also increase droplet size which damage delicate crops and some soils by breaking down the surface structure and reducing the infiltration rate. Low pressures also cause the rubber ring in the pipe couplers to leak, since it seals only under the correct pressure.

The more logical explanation for operating at low pressure lies in the exceptionally high level of water losses from the irrigation hydrants (common problem on 42 % of the systems), valve elbows (common problem on 33% of the systems), lateral pipe seals (common problem on 22 % of the systems), sprinkler bearings (common problem on 25 % of the systems), and buried main pipelines(common problem on 14 % of the systems). In addition, 36 % of the responding farmers attributed the low pressure to the illegally surface irrigation practice. All these reasons cause the pumps to deliver much higher discharges than designed with a consequent drop in pressure. Low pressures also increase droplet size which cause physical damage to plants (common problem for 64 % of the responding farmers).

The hand-move sprinkler has high labor requirements (common problem for 53 % of the responding farmers) and subjects equipment to an exceptionally high rate of wear due to the high number of lateral movements required by the large number of irrigations necessary. The policy of sharing one lateral sprinkler line between two earlier settlers is clearly unsatisfactory for 39% of the responding farmers in relation to the highly intensive use of equipment. The recently designed and constructed sprinkler projects in Bostan area provides one sprinkler lateral for 5 feddans unit, and thus this problem is limited to the earlier settlers.

Table (3.5): Frequency of problems with Hand-move sprinkler system.

Problems	Tahrir		Bostan		Total	
	# (per20)	%	# (per 15)	%	# (per 36)	%
Sprinkler operating at low pressure	17	85	8	53	26	72
Leakage from irrigation hydrants	10	50	5	33	15	42
Leakage from valve elbows	10	50	2	13	12	33
Leakage from lateral pipe seals	6	30	2	13	8	22
Leakage from sprinkler bearings	8	40	1	7	9	25
Leakage from buried main pipe line	3	15	2	13	5	14
Some farmers practice surface irrigation illegally	11	55	2	13	13	36
Physical damage to plants from large water droplets	17	85	6	40	23	64
Not possible to share one lateral line between settlers	9	45	5	33	14	39
Most of the lateral pipes are damaged	12	60	3	20	15	42
Lateral pipes and seals are not available	14	70	10	67	24	67
Hand move is unsuitable for supplementary off-farm employment	17	85	12	80	29	81
Hand-move is unsuitable for irrigating orchards	19	95	12	80	31	86
It is difficult to move lateral pipes six or even four times everyday	15	75	2	13	17	47
The system is high labor requirement	7	35	12	80	19	53

3.4.4. Drip Irrigation Systems

a) *Filtration System.*

Of the 52 farms with drip irrigation systems, 36 farms only had filtration systems. In all of the 36 farms, the filters are cleaned manually. Although all filters are cleaned manually, 59.6% only had pressure gauges attached to the filters to indicate when cleaning is required. Out of the 36 farms, 29 farms use only screen filters, 2 farms use only gravel (sand media) filters, while 5 farms use gravel and screen filters. Out of 19 farms in Sadat area, only 8 farms use filters, while the percentage are 94% in Wadi-Natron and 64% in Bostan. It can be said that sand filters were not used though the water source contained silt and algae (Nile water) in 50% of the cases in Bostan and South Tahrir. However, screen filters were used in most of the cases (94%). In Wadi-Natron and Sadat the source of water is wells. Therefore, screen or disc filter is satisfactory for the filtration system.

b) *Fertigation*

Fertigation is necessary for more efficient use of fertilizers, especially nitrogen, for fields irrigated with drip systems. This is because dry fertilizer broadcasted over the soil surface will not move into the plant root zone by the irrigation water. The same type of equipment can be used to inject either fertilizer solutions or chemicals that help prevent emitters from clogging.

Out of 48 farms with drip irrigation systems, 14 farms had no fertilizer injection device (Table 3.6). Chemical fertilizers were not applied through the drip systems in 29.2% of the total farms and it reaches 44.5% of the farms in Sadat and Bostan, while in Wadi-

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Natron, the fertilizer injection devices are common. In drip irrigation, the fertilizer spread on the soil surface does not leach into the root zone, therefore it has to be injected into the drip system.

Table (3.6): The distribution of using fertilizer injection device in the survey sample

Study area	Tahrir		Sadat		W.N		Bostan		Total	
Distribution	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**
Yes	4	80	10	55.5	15	93.7	5	55.5	34	70.8
No	1	20	8	44.5	1	6.3	4	44.5	14	29.2
Total	5	100	18	100	16	100	9	100	48	100

The distribution of drip sets according to type of injection device is presented in Table (3.7). Fertilizer-injection equipment employed (Table 8) are: tanks (85.7%), venturi type (2.9 %), and hydraulic pump (11.4%). The maximum number of drip sets (85.7%) used fertilizer tank as injection device. The fertilizer tank is simple and does not require additional motorized pump for injection. The concentration of chemicals injected into the irrigation system from the fertilizer tank changes continuously with time; consequently uniformity of distribution may be a problem, if the fertilizer is to be applied to several blocks through a cycles system.

Table (3.7): Distribution of drip sets according to type of injection device.

Type of injection device	Tahrir		Sadat		W.N		Bostan		Total	
	#	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**
Fertilizer tank	4	80	10	100	11	73.3	5	100	30	85.7
Venturi	-	-	-	-	1	6.7	-	-	1	2.9
Injection pump	1	20	-	-	3	20	-	-	4	11.4
Total	5	100	10	100	15	100	5	100	35	100

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c) Acid Treatment.

The injection of acid is generally done to lower the pH as a control mechanism for various water quality problems. Out of 35 farms with chemical injection device, 27 farms use acid treatments, mainly in the form of phosphoric acid, which is also used as a fertilizer (adds phosphate to the root zone). Phosphoric acid has been applied successfully through trickle irrigation systems and causes no precipitation or clogging of emitters even when the irrigation water is relatively high in bicarbonate plus calcium and magnesium. Because phosphoric acid will not form insoluble precipitates and keep the pH low enough.

d) Emitters

The most widely used emitter types are: GR driplines (40%), Katif point source emitter (25%), and E2 point source emitter (20%). Most of the GR and E2 in the market are locally made, while Katif is totally imported.

e) Valves

Valves form an integral part of drip irrigation systems. The nature of the valving for a given installation will depend on the level of automation, degree of pressure regulation, and number of set required. Several types of automatic, manual, check and air release valves are used in drip systems. Check valves are normally used only at the pump station and particularly when pumping out of a sump or deep well. Air release and vacuum relief valves are located at high points or mains, submains, and laterals. Air release valves are generally placed at high points in mainlines, submains, and pump stations. They release entrapped air on system start up, and allow air to enter the pipeline under conditions of negative pressure. Check valves are used to prevent unwanted flow reversal. They are used to prevent possibly damaging backflow through a pump, to prevent pump suction lines from draining (cause loss of "prime"), or to protect water supplies against contamination. Pressure relief valves are used to relieve excessive pressure surges. They are usually spring loaded and set to open above the operating pressure. Flushing valves are usually hand-operated and on the end of a line for flushing out dirt and debris. Pressure regulators are installed to keep a constant pressure regardless of whether the pipelines go up or downhill. Pressure gauges are used to indicate the pressure at the pump or at the beginning and the end of filters and lateral lines to check the pressure loss. Flow meter offers the farmer an unprecedented degree of control over his water and power costs, and over the growing conditions of his crop. To take full advantage of this ability to control the irrigation system, it is necessary to have useful feedback information on flow rates and total water applied during a given time period. Accurate flow rate information is also indispensable for the analysis of crop response to water and nutrients, and for monitoring the continuing performance of the irrigation system. A good quality system flow meter is therefore an essential part of a well designed irrigation system.

Out of 52 farms with drip irrigation, 28.8% use air release valve, 40.4% use check valve, 26.9% use flow meter, 67.9% use flushing valve, 13.5% use pressure regulator, 15.4% use pressure relief valve, and 59.6% use pressure gauges.

3.5 Summary

Irrigation technical survey was conducted to study the present status of water source, pump stations, and irrigation systems in the four areas of study. Thirty three percent of the responding farmers agree that the insufficient water is the most predominant problem through the water source, while this percent reaches 43.6% in South Tahrir and Bostan.. Costly spare parts, fuel and electricity, and maintenance and repair are the common problems with pump stations for more than 85 % of the responding farmers, while unavailability of skilled technicians was a problem for 71.4 percent. Most of the farmers (90%) felt electricity was very costly and beyond the purchasing capacity of the common farmer without capital subsidy. The sprinkler irrigation systems were less than 10 years old in Bostan area. However, 90% of the sprinkler systems exceeded the expected life (15 years of age) in South Tahrir. About 56.1% of the responding farmers stated having problems with hand-move systems, all of them located in south Tahrir.Operating at too low a pressure is common problem on 72 % of the hand-move sprinkler systems.

The more logical explanation for operating at low pressure lies in the exceptionally high level of water losses from the irrigation hydrants (common problem on 42 % of the systems). In addition, 36 % of the responding farmers attributed the low pressure to the illegally surface irrigation practice. Low pressures also increase droplet size which cause physical damage to plants (common problem for 64 % of the responding farmers). The hand-move sprinkler has high labor requirements (common problem for 53 % of the responding farmers).

Of the 52 farms with drip irrigation systems, 36 farms only had filtration systems. Sand filters were not used in 50% of the cases in Bostan and South Tahrir though the water source contained silt and algae (Nile water). However, screen filters were used in most of the cases (94%). Chemical fertilizers were not applied through the drip systems in 29.2% of the total farms and it reaches 44.5% of the farms in Sadat and Bustan, while in Wadi-Natron, the fertilizer injection devices are common. Among the injection devices used fertilizer tankwas the most (85.7%) common. Out of 35 farms using chemical injection devices, 27 farms use acid treatments, mainly in the form of phosphoric acid, which is also used as a fertilizer. Out of 52 farms with drip irrigation, 28.8% use air release valve, 40.4% use check valve, 26.9% use flow meter, 67.9% use flushing valve, 13.5% use pressure regulator, 15.4% use pressure relief valve, and 59.6% use pressure gauges. Therefore, large percentage of drip irrigation systems are loosing the essential parts of a well designed irrigation systems.

3.5 *The Social Aspects of Desert Irrigation in the New Lands*

3.5.1 Introduction:

One of the specific objectives of this research project is to study the social aspects of irrigation through the application of a sample survey on the holders of desert lands. This is to explore the possible relations between these aspects and the efficiency of using water and irrigation systems there. Man and his behavior are considered among the important determinant factors for such efficiency. Experience of holders with technical aspects of irrigation, their approach to acquire needed knowledge and their attitudes towards using water and related irrigation systems are some of the social aspects to be clarified in such situations. Facts about these aspects could be very informative in the interpretation of the relationships between these social factors and present situation of efficiency of irrigation of desert lands. Meanwhile such findings could be used in projection of the potential changes in irrigation efficiency and assessing the applicability of certain irrigation practices and related trainning, extension and maintenance programs in future, given the continuity of present conditions.

3.5.2. Distribution of the Sample Study

Sample was selected from among all the farm holders in the four regions of the newly reclaimed lands; South Tahrir, Al-Sadat City agricultural zone, Albostan and Wadi Alnatron. Based on the secondary data collected about the number of land holders and their holding size in each of the above mentioned regions a quota stratified random sample was selected. About 120 holders were interviewed during the period of field data collection. Due to the uncooperative attitudes of some interviewees and the false or ambigious responses of some others only 112 interviews were completed. Yet, after the verification of data only 109 questionnaires were accepted and processed for statistical analysis.

Depending on the descriptive statistics of the data some of the main findings are presented. However, distribution of the sample by the region of residency, the farm holding size, the type of irrigation system(s) used in the farm, and some other social demographic characteristics were shown in the second annual report.

3.5.3 Attitudes of Holders of Desert Land Towards Water Use and Irrigation Practices

Attitudes are considered important aspects of personality that reflect the action tendency of a person towards all various objects in his life in future situations. These objects could be persons, social or economic situations, specific agricultural practices or other things. Attitudes are related to all aspects of life. They show the preference patterns of behavior of specific individual or group in a very wide area of human activities. Attitudes are composed of the person's cognition, his feelings and action tendencies developed through his past experience whether acquired by practice or transmitted by some other means. They could be seen as relatively stable interrelated systems of the above mentioned three components.

Hence, an attitude scale related to the various aspects of rational use of water in irrigation and the applied irrigation practices was designed and pretested. The scale is constructed from 29 items that cover all the above mentioned three components and seven dimensions; cultural value of water, economic value of water, information aspects of available water resources, on-farm water management, applied irrigation practices, willingness to share in responsibility of rational use of water and experiences needed in the irrigation process. About 38% of the items were formulated in passive form to reflect the action tendency component of the scale. Table (3.8) below presents the component structure of the applied attitudes scale.

Table (3.8): Component Structure of the Attitudes Scale

Type of item	Dimension														Total
	Cultural		Economic		Informa-tion		On Farm Water Manage.		Irrigation Practices		Parti-cipation		Experience in Irrigation		
	Item	No.	Item	No	Item	No.	Item	No.	Item	No.	Item	No.	Item	No.	No.
Positive	12	1	7& 17	2	6	1	13, 15, 16 & 25	4	9, 10, 11& 29	4	2, 20 21	4	24 & 27	2	18
Negative	1	1	19	1	3	1	14& 26	2	8& 18	2	4	1	22, 23& 28	3	11
Total		2		3		2		6		6		5		5	29

The scale was designed using the Likert pattern of attitude scales. This is to locate the response to each item on a five point continuum starts with "strongly agree" to "strongly disagree" on the statement. Responses to each item ranked between 5 to 1 for the positive statements and vise versa for the negative statements respectively. Thus each respondent total score ranged between 29 and 145 . Accordingly five categories of attitude were identified; highly positive (123-145), positive (100-122), neutral (77-99), negative (53-76) and highly negative (less than 53).

Analysis of data took into consideration testing the relationship between the attitudes of holders towards water use and irrigation practices and three main variables; the region of residency where the farm is located, the farm holding size, and the kind of irrigation system(s) in use in the farm . Following are the results of this analysis .

3.5.4 Attitudes Of Farmers In The Various Regions Of Study :

Results show that the attitudes for the whole sample is positive the attitudes of all subsamples are also positive and followed the order, Bostan> Wadi El Natrun > Sadat area.

Table (3.10): Average Values Of Farmers' Attitudes Towards Water And Irrigation Practices By Region Of Residency

Region	Mean	Std. Dev.	Cases
S.Tahrir	112.05	11.90	39
Sadat	106.95	8.49	20
W. Natron	111.55	13.39	20
Bostan	116.77	8.74	30
Total	*112.32*	*11.21*	*109*

Analysis of variance revealed a significant difference among the average attitudes towards water for the four regional subsamples at a 0.0219 level of significance. This could be partially attributed to the distinctive characteristics of settlers more dominant in each area. Bostan are new graduates with higher positive attitudes than small investors with variable background in Sadat and Wadi Al-Natron. South Tahrir is characterized by a wide variety of settlers; small holders, old graduates, and recently small investors. Attitudes towards water use and irrigation practices for all categories of farm holding size were positive and ranged between 106.5 and 115.6 on the scale. Distribution of all categories spread over a range of 9 degrees difference . The least average was that of the less than 5 feddans category who are mostly old settlers having low

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educational background. Yet, the highest average is that of the category of five to less than ten feddans which mostly represent the new university graduates.

Analysis of variance, however showed no significant difference among the various categories of holding size.

Average values of farmers' attitudes were calculated for all categories of farmers classified according to the irrigation systems they use . Means of the attitudes of the farmers classified into five categories ; sprinkler only , drip only , surface only , sprinkler and drip together and surface and drip together are shown in table.

It was found that all categories have positive attitudes towards water. The data showed that those who use both drip and sprinkler irrigation systems together have the highest positive attitudes among all users of all different irrigation systems . The users of sprinkler irrigation system alone come next then the users of both drip and surface systems together. The users of drip irrigation system alone come fourth while the users of surface irrigation have the lowest attitudes towards water.

Analysis of variance of the data showed a very high significant difference among the attitudes of the five categories of users of the various irrigation systems .

These results seem very logical . Those who invest high capital in establishment of two modern systems of irrigation together have high attitude towards costs of using water. Thus they estimate the value of water accordingly . Yet, on the contrary, the users of surface irrigation who do not pay the cost the water they use , estimate the water value accordingly .

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Though all farmers categories have positive attitudes towards water the significant differences of their attitudes towards water and the irrigation practices could be attributed to the costs they pay and the knowledge background for using specific irrigation techique. Hence it seems logical to conclude that there is a positive relationship between the farmers' attitudes towards irrigation water and the investments they allocate to cover the costs of water they use. Meanwhile the users of modern irrigation techniques have more knowledge about the pros and cons of the irrigation technique and related infromation to estimate the value of water accordingly more than the useres of surface irrigation.

3.5.5. *Analysis of the Relationship Between Some Attidute Components Used*

The following is the analysis of the relationship between each of the three components of the attitude namely; the estimation of the economic value of water, the willingness to share costs of irrigation public works, and the preference of landholders to using modern irrigation systems in relation to area, the level of education and the type of irrigation system used.

a) *Landholders Estimation of the Economic Value of Water*

Measurement of the estimation of the economic value of water was undertaking using a three items scale. The range of scale was between 3 and 15. Table (3.11) presents the distribution of the sample by the area of study and the economic value of water.

Table (3.11) : Distribution of the Sample by Estimation ofEconomic Value of Water and Area of Study

Category	*Area*									
	South Tahrir		*Al-Sadat*		*Wadi Alnatron*		*Albostan*		*Total*	
	No	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
5 -	0	0	0	0	2	10	0	0	2	1.8
8 -	2	5.1	5	25	4	20	2	6.7	13	11.9
11-	18	46.2	10	50	9	45	14	46.7	51	46.8
14- 15	19	48.7	5	25	5	25	14	46.7	43	39.5
Total	39	35.8	20	18.3	20	18.3	30	27.5	109	100.

Ch2= 18.49 D.F.= 9 Prob. = 0.0299

The range of scale was classified into four categories; low (<8) medium (8 to 10), high (11 to 13) and very high(14 to 15). The distribution shows that more than 70% of the landholders of each area have high to very high estimation of the economic value of water. More the 86% of the sample interviewed fall in this catagory. The above catagories showed some differences which were found significant at 0.03 using Chi2. Those who have high to very high economic value of water represent 94.9% in South Tahrir and 93.4% in Bustan areas. Landholders of these two areas include mostly young and old graduates and who have agricultural background through education or practice. Landholder of Sadat City and Wadi El-Natrun area have 75% and 78% of those with high to very high economic value of water. Settler of these two areas are mainly small investors with variable background and less agricultural education.

These results suggest that the estimation of the economic value of water is high among desert landholders and is higher at those having agriculture education. Yet this does not reflect the approval of direct water pricing which was refused by all catagories during the pretest of the questionnaire.

Table (3.12) represents the distribution of sample by the education status and estimation of the economic value of water. The percentage of those who have high to very high estimation for the economic value of water was 91.4% of the holder of medium education, about 80% for the university graduate but only 70% for those who read and write. Testing the difference of distribution, however, show that the relationship is insignificant using Chi2. It was noticed, however, that those who have less education tend generally to have low estimation of the economic value of water.

Table (3.12) : Distribution of the Sample by estimation of Economic Value of Water and Educational Status

	Educational Status											
Category	*Illiterate*		*Read& Write*		*Basic Ed.*		*Medium Ed.*		*Univer. Ed.*		*Total*	
	No	%	No	%	No	%	No	%	No	%	No	%
5 -	0	0	0	0	0	0	0	0	2	0	2	1.8
8 -	2	16.7	3	30	1	14.3	3	8.6	4	8.9	13	11.9
11-	5	41.7	4	40	5	71.4	16	45.7	21	46.7	51	46.8
14- 15	5	41.7	3	30	1	14.3	16	40.0	18	40.0	43	39.5
Total	12	100	10	100	7	100	35	100	45	100	109	100

Ch2== 9.320 D.F.= 12 Prob. = 0.6754

b) Landholders' willingness to share cost of irrigation public works.

Table (3.13) shows the sample distribution by the area of study and willingness to share cost of irrigation public works. This willingness was measured on a continuum ranging between 5 and 25 degree. The catagories of willingness were; low (5-10), medium (11-15), high (16-20) and very high (21-25). On the basis of the whole survey sample, 83.4% of the interviewed landholder have high to very high willingness to share cost of the irrigation works. Testing the difference of distribution of the subsamples using Chi2, it was found to be significant at the level of 0.05.

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Table (3.13)Distribution of the Sample by Willingness to share in the Costs of Irrigation public Works and area of study

Category	Area									
	South Tahrir		*Al-Sadat*		*Wadi Alnatron*		*Albostan*		*Total*	
	NO.	*%*	*NO.*	*%*	*NO.*	*%*	*NO.*	*%*	*NO.*	*%*
5 -	1	2.6	0	0	3	15	0	0	4	3.7
11 -	6	15.4	2	10	5	25	1	3.3	14	12.8
16-	22	56.4	13	65	8	40	17	56.7	60	55.0
21- 25	10	25.6	5	25	4	20	12	40	31	28.4
Total	39	35.8	20	18.3	20	18.3	30	27.5	109	100.

Ch2== 17.008 D.F.= 9 Prob. = 0.0486

Those who have high to very high willingness represent 96.7% in Bustan area, 90% in Sadat area, 82% in Tahrir and only 60% in Wadi El Natrun area. Land holders of Wadi El Natrun are investors relying totally on groundwater and therefore they have the lowest willingness to share cost of irrigation works, since they do not benefit from public irrigation works. The situation in Bustan is different since they all use Nile water and benefit directly from irrigation works. The relatively lower percentage of willingness in Tahrir is probably due to high percentage of smallholders with low education background and using flood irrigation which affect their awareness of the benefit of such irrigation public works. This is beside the long history of reliance on state and public authorities in providing these farmers with all their needs free of charge. The high percentage of willingness in Sadat City is probably due to their hope of having Nile water reaching their lands since they have been trying to convince the authorities to dig a canal through the area to prevent the groundwater wells from falling dry.

The relationship between the willingness to share such costs and the level of eduction of the landholders is presented in table (3.14). The precentage of those having high to very high willingness of sharing such costs ranges between 60% of the holder who just read and write to 95.2%

Table (3.14) : Distribution of the Sample by Willingness to share in the Costs of Irrigation Public Works and Educational Status

Category	*Educational Status*										*Total*	
	Illiterate		*Read & Write*		*Basic Ed.*		*Medium Ed.*		*Univer. Ed.*			
	No	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
5 -	0	0	1	10	0	0	0	0	3	6.7	4	3.9
11 -	2	16.7	3	30	1	14.3	1	2.9	7	15.6	14	12.8
16-	7	58.3	5	50	5	71.4	24	68.6	19	22	60	55.1
21- 25	3	25	1	10	1	14.3	10	26.6	16	56	31	28.4
Total	12	100	10	100	7	100	35	100	45	100	109	100

Ch2== 15.048 D.F.= 12 Prob. = 0.2388

for those having medium education. The university graduates show less willingness to share costs compared to those having medium education. Only about 78% of those have high to very high willingness. The difference of this distribution was, however, statistically insignificant using Chi2.

Table (3.15) shows that those who have high to very high willingness to share costs represent 90.9% of the users of sprinkler irrigation systems, 86.7% of those using surface irrigation, 81.8% of the users of mixed irrigation systems, 75% of the users of drip and sprinkler irrigation systems and 74% of the users of drip irrigation systems. The difference between these categories was, however, insignificant using Chi square. The results, however, show that more than 83% of the land holders interviewed have high to very high willingness to share costs and at least 74% of the users of any irrigation system fall in this category.

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Table (3.15) : Distribution of the Sample by Willingness to share Costs of Irrigation Public Works and Irrigation System(s) used

Category	*Irrigation System*										*Total*	
	Sprinkler		*Drip*		*Surface*		*Sprink.&Drip*		*Mixed*			
	No	%	No	%	No	%	No	%	No	%	No	%
5 -	0	0	3	13.0	0	0	1	6.2	0	0	4	3.7
11 -	4	9.1	3	13.0	2	13.3	3	18.8	2	18.2	14	12.8
16-	30	68.2	12	52.3	9	60.0	4	25.	5	45.4	60	55.1
21- 25	10	22.7	5	21.7	4	26.7	8	50	4	36.4	31	28.4
Total	44	40.4	23	21.1	15	13.8	16	14.7	11	10.1	109	100

Ch2== 17.562 D.F.= 12 Prob. = 0.1297

c) <u>*Preference of Desert Land Holders to Using Modern Irrigation Systems:*</u>

The preference to use modern irrigation systems and techniques was measured on a scale of six items ranged between 6 and 30. It was classified into five categories; very low (6-10), low (11-15), medium (16-20), high (21-25) and very high (26-30). Table (3.16) presents the distribution of sample by preference in the four areas of study.

Table (3.16) : Distribution of the Sample by Preference of Modern Irrigation Systems and Areas of Study

	Area									
Category	**South Tahrir**		**Al-Sadat**		**Wadi Alnatron**		**Albostan**		**Total**	
	NO.	**%**	**NO.**	**%**	**NO.**	**%**	**NO.**	**%**	**NO.**	**%**
6 -	5	12.8	0	0	2	10	0	0	7	6.4
11 -	3	7.7	2	10	1	5	1	3.3	7	6.4
16-	10	25.6	6	30	0	0	1	3.3	17	15.6
21-	15	38.5	10	50	14	70	21	70	60	55.1
26 -30	6	15.4	2	10	3	15	7	23.3	18	16.5
Total	39	35.8	20	18.3	20	18.3	30	27.5	109	100.

Chi2== 23.786 D.F.= 12 Prob. = 0.0218

On the basis of the whole sample interviewed 71.6% have high to very high preference to using modern irrigation systems and techniques. Difference between areas was found significant at 0.02 level using Chi square. Those who have high to very high preference represent 93.3% of the land holders in Bustan area, 85% in Wadi Al-natron, 60% in Sadat and only 53.9% in Tahrir. This trend seems to be in accordance with the diversity of irrigation systems in use in these areas. In Bostan only sprinkler and drip irrigation systems are used. In Wadi AL-Natron drip irrigation is the dominant system used. In Tahrir and Sadat flood irrigation is practiced along with other systems of irrigation. This means that the direct experience with modern irrigation system beside the availability of alternatives strongly affect the preference of land holders to use these modern systems and techniques.

The relation between the level of education and the preference to modern irrigation systems and techniques is illustrated in table (3.17)

Table (3.17) : Distribution of the Sample by Preference of Modern Irrigation ystems and Educational Status

Category	*Educational Status*										*Total*	
	Illiterate		*Read & Write*		*Basic Ed.*		*Medium Ed.*		*Univer. Ed.*			
	No	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
6 -	3	2.5	1	10	2	28.6	1	2.9	0	0	7	6.4
11 -	2	16.7	1	10	1	14.3	1	2.9	1	2.2	6	5.5
16-	4	33.3	1	10	2	28.6	4	11.4	7	15.6	18	16.5
21-	3	25	5	50	2	28.6	23	65.7	27	60.0	60	55.1
26- 30	0	0	2	20	0	0	6	17.1	10	22.2	18	16.5
Total	12	100	10	100	7	100	35	100	45	100	109	100

Ch2== 32.408 D.F.= 16 Prob. = 8.844E-03

The percentage of those having high to very high preference to using modern irrigation systems and techniques represent 82.8% of landholders having medium education, 82.2% of the university graduates and only 25% of the illiterates. The difference of distribution was found significant at 0.0088 level using Chi2. It could be concluded that there is a positive trend of relationship

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between the educational status and the preference of using modern irrigation systems and technique.

3.5.6. *The Sample Knowledge Levels of Modern Irrigation Techniques*

In this section interest will be directed towards the assessment of the technical knowledge level related to the different aspects of sprinkler and drip irrigation techniques separately. Related data were collected from those who were using these techniques either solely or in parallel with other techniques at the time of data collection.

a) *Technical Knowledge of Sprinkler Irrigation*

The data used in this part were that collected from 60 farmers who were using this technique either alone or along with some other systems. Table (3.18) below presents the distribution of this sub-sample by item grouping of knowledge scale and the areas of study.

Table (3.18): Sample Distribution by Arae of Study and Technical Knowledge of Sprinkler Irrigation

ITEM	*S. Tahrir N = 21*		*Sadat N = 4*		*W. Al-Natro N = 11*		*Bostan N = 24*		*TOTAL N == 60*	
	No	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Manage. (8)	110	65.5	19	59.4	44	50	102	53.1	275	57.3
Op. Cond.(3)	13	20.6	9	75.0	22	25	43	59.7	87	48.3
Fertigation (1)	12	57.1	2	50	10	90.9	7	29.2	31	51.7
Efficiency (1)	20	95.2	4	100	11	100	23	95.8	58	96.7
Labor Req.(1)	11	52.4	2	50	00	00	3	12.5	16	26.7
Crop Serv.(1)	1	4.8	1	25	3	27.3	8	33.3	13	21.7
Total (15)	167	53.0	37	55	90	54.5	186	51.7	480	53.3

It is shown from the above table that the whole sample has relatively low level of knowledge with the measured items. The average level was 53.3% for the whole sample and it ranged between 51.7% and 55% for the four areas of

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study. However when this level was measured for each group of items it was found very high with the knowledge related to the measure of efficiency of sprinkler irrigation system (96.7%). However, the level of knowledge was found very low for the items related to labor requirements and the crop service and advantage of this system. They were found 26.7% and 21.7% respectively. Average knowledge level with operating conditions, fertigation and on farm water management groups of items ranged between 48.3% and 57.3%.

It seems that knowledge level of holders of desert lands with the various technical aspects of sprinkler irrigation is low in average. This means that there are real training needs that should be satisfied through tailored training and extension programs. However, full detailed training needs assessment should be udertaken prior to any design or planning of such programs . Training needs are not related to technical knowledge only. They are also related to the attitudes and skills related to the recommended irrigation system.

b) *Technical Knowledge of Drip Irrigation*

Data were collected from the users of drip irrigation. Table (3.19) presents the distribution of the sample by areas of study and the groups of items of technical knowlegde with drip irrigation.

The over all average of knowledge level of the sample with the technical aspects of drip irrigation was found 67.3%. It is relatively higher than that of the users of sprinkler irrigation. It ranged between 65.2% in Tahrir and 68.8% in Sadat.

When these averages were estimated for the groups of items they were found very high for crop service, the costs of the system and efficiency measures of the system. They were 93.9%, 87.8% and 81.6% respectively. Knowledge level was found moderate with the groups of items of advantages of the system, maintenance and the operating conditions where they were 76.9%, 72.2% and 71.0% respectively. The groups of other items ranged between 45.6% for

TABLE (3.19) : Sample Distribution by Region and Technical Knowledge of Drip Irrigation

ITEM	*Tahrir N = 5*		*Sadat N = 19*		*W. Alnatron N = 19*		*Bostan N = 6*		*TOTAL N = 49*	
	No	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Mainten. (5)	18	72	71	74.7	65	68.4	23	67.7	177	72.2
Oper.Cond. (5)	20	80	69	72.6	63	66.3	22	73.3	174	71.0
Fertigation (4)	10	50	56	73.7	54	71.1	16	66.7	136	69.4
Manage. (3)	7	46.7	28	49.1	24	42.1	8	44.4	67	45.6
Adventage (3)	10	66.7	44	77.2	46	80.7	13	72.2	113	76.9
Weeding (2)	5	50	25	65.8	20	52.6	7	58.3	57	58.2
Costs	4	80	14	73.7	19	100	6	100	43	87.8
Labor	2	40	3	15.8	3	15.8	0	0	8	16.3
Efficiency	5	100	13	68.4	17	89.5	5	83.3	40	81.6
Pesticide	3	60	12	63.2	11	57.2	4	66.7	30	61.2
Crop Service	4	80	18	94.7	18	94.7	6	100	46	93.9
Total (27)	88	65.2	353	68.8	340	66.3	110	67.9	891	67.3

on farm water management and 69.4% for fertigation. The lowest level of knowledge was that related to the labor requirements of the system (16.3).

It could be concluded, in general, that the level of technical knowledge with the various aspects of drip irrigation is rather higher than other modern irrigation systems due to the characteristics of users and the importance of using this system efficiently where water resources are more scarce. This system is mostly used in Sadat and Wadi Al-natron areas (see table (8) above) where holders are mostly investors and seek more efficient systems regardless of their initial costs.

c) *Irrigation Knowledge Needs:*

Table (3.19) presents the distribution of the sample by the areas of study and their need to knowledge related to irrigation systems and practices.

Table (3.19) : Sample Distribution by Area of Study and Irrigation Knowledge Needs

Response	Tahrir		Sadat		W. Alnatron		Bostan		TOTAL	
	No	%	No	%	No	%	No	%	No	%
Yes	11	28.2	9	45	14	70	20	66.7	54	49.5
No	28	71.8	11	55	6	30	10	33.3	55	50.5
TOTAL	39	100	20	100	20	100	30	100	109	100

In general it was found that about 49.5% of the whole sample feel they are need of knowledge related to irrigation. This percentage was found highest in Wadi Al-natron (70%), then in Bostan (66.7%), and moderate in Sadat area (45%), while it was the least in Tahrir (28.2%). These figures show again that the type of the holders and their period of practice with farming seem influential in determining their feeling of need to knowledge about irrigation systems and practices. The lower percentage of holders in Tahrir who feel in need of knowledge confirm that the long period of practicing farming beside their agricultural background whether by practice or education helped them to feel more satisfied with their knowledge in irrigation. However this does not mean they have the right knowledge they need for their farming conditions. On the other hands, investors of Wadi El Natrun who rely on groundwater and pay high cost for extracting ground water and installing drip irrigation system are more welling to improve their agriculture performance through gaining more knowledge about irrigation. In South Tahrir, however, where smallholders with poor education backaground and use surface irrigation and who pay no cost for water or irrigation systems do not feel the need to irrigation knowledge or training.

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3.5.6. Training and Organizational Aspects of Desert Irrigation

Efficiency of irrigation is determined in great part by the farmers' irrigation practices aside from the conditions of irrigation system used. Many social aspects such as the type of social network of relationships between farmers and officials and the farmers' involvement in the decision making process related to selection of and operating the irrigation system are among the important variables affecting these practices.

In old lands, accumulated experiences related to irrigation practices are transmitted from one farmers' generation to another through the socialization process. There are also well established institutions, norms and organizations that facilitate the transmission of adopted practices to the successive new generations. Informal organization among farmers play major role in the scheduling of irrigation rotation and distribution of water in any specific area in the old lands. Yet, such situation does not exist, though it is more needed, in the case of settlements in the new lands.

Studying the social aspects of current irrigation practices associated with the various irrigation systems in new desert lands might help planners and practitioners who are interested in the efficiency of irrigation in these lands to outline the needed reorganization of the whole irrigation process to enhance its efficiency. Importance of such aspects is becoming more serious because of the increasing proportion and role of desert lands in Egypt agriculture in the present and future.

The social aspects investigated are; the previous farm manager training and experience in agriculture, the farmers' involvement in decision making process related to the selection of irrigation system used, the criteria of this selection, frequency of occurrence of irrigation problems among farm holders, willingness of farm holders to collaborate in organizing the irrigation process in their area, their willingness to collaborate with the officials and non officials in solving encountered irrigation problems, the officials and other agencies role in solving irrigation problems, and leadership in organizing irrigation process.

The results of analysis of data related to the above mentioned social aspects are presented in the following summarizing table. Chi square was used to test the significance of differences of distribution of the four groups of users of the various irrigation systems according to the categories of response to these variables. The detailed tables are presented in the annex.

Ser	*Variable*	*Chi Square*	*d.f.*	*Prob.*
1	Education & Practical Experience of Farm Manager	15.912	6	0.0142
2	Criteria used for Selection of Irrigation System	23.958	12	0.0206
3	Decision Maker in the Selection of Irrigation System	51.583	9	3.944E-07
4	Occurrence of Irrigation Related Problems between Neighbors	21.207	6	1.684E-03
5	Frequency of Officials' Response to Irrigation Problems	19.010	9	0.0251
6	Officials Take Part in Solving Irrigation Problems	24.975	9	2.998E-03
7	Leadership in Organizing irrigation Process	59.604	12	2.665E-08
8	Farm Holders Willingness to Collaborate with Others to solve Irrigation Problems	33.337	9	1.162E-04

a) Education and Practical Experience of Farm Manager:

Data in table (3.20) in the annex showed that the majority of the whole sample 82.6 % had no previous formal training experience in farming prior to their settlement in the new reclaimed desert lands. However, there was about 6.4% got some educational degree of technical high school and above in agriculture while the rest of the sample 11% have got some practical experience beside their educational background. When testing the difference among the four groups of users concerning their source of experience it was found that about one third of the users of drip irrigation have some sort of educational background beside 21.7% have practical experience. Only 6.8% of the users of sprinkler irrigation have got some sort of educational background beside practical experience but the majority 93.3% have got no experience prior to their settlement in these new communities. All users of surface irrigation have got neither formal education nor previous practical experience prior to their move to the new communities. Graduates of high technical schools and above level were found only in the categories using drip or mixed systems. These differences could be understood in the light of higher technicalities of drip system in comparison with the other irrigation techniques.

Table (3.20) : Distribution of Sample by Irrigation System and Education & Practical Experience of Manager

Irrigation System	*Manager Education & Previous Practical Experience*						*TOTAL*	
	Nothing		*Graduate*		*Tech. Ed. & Practice*			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
SPRINKLER	41	93.2	0	0	3	6.8	44	100
DRIP	12	65.2	3	13.0	5	21.7	23	100
SURFACE	15	100	0	0	0	0	15	100
MIXED	19	70.4	4	14.8	4	14.8	27	100
TOTAL	90	82.6	7	6.4	12	11	109	100

CHI SQUARE = 15.912 D.F. = 6 PROB. = 0.0142

b) ***Decision Maker in the Selection of Irrigation System:***

Table (3.21) in the annex shows distribution of the four categories of users of various irrigation systems according to the decision maker in the selection of irrigation system. It was found that the type of irrigation system was determined for the majority of the whole sample (57.8%) by the authorities. It should be mentioned that in most of the cases specially the areas use sprinkler irrigation these systems were provided by the reclamation authorities during the preparation of infrastructure in the reclaimed land. The farm holder made his own decision in 30.3% of the cases. Technical consultation was used only in 4.6% of the cases.

Table (3.21) : Distribution of Sample by Irrigation System and

Irrigation System	*Decision Maker*								*TOTAL*	
	Authority		*Holder*		*Authority & Holder*		*Irrigation Engineer*			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
R	40	90.9	3	6.8	0	0	1	2.3	٤٤	100
DRIP	10	43.5	10	43.5	1	4.3	2	8.7	٢٣	100
SURFACE	9	60	6	40	0	0	0	0	١٥	100
MIXED	4	14.8	14	51.8	7	25.9	2	7.4	٢٧	100
TOTAL	63	57.8	33	30.3	8	7.3	5	4.6	١٠٩	100

CHI SQUARE = 51.583 D.F. = 9 PROB. =3.944E-07

Technical consultation was used in 8.75% of the cases of users of drip systems and 7.4% of the users of mixed irrigation systems which are more than the average. Farm holder is the one who made decision in 51.8% of the case of users of mixed systems against 43.5% of the users of drip system, 40% of the users of surface method, and only 6.8% of the users of sprinkler system. The higher technicalities included in the modern irrigation techniques seem to push farm holders to take the responsibility himself and with the help of technical assistance of professionals in making his decision concerning the system to use in his farm. This situation is clear in the case of users of drip and mixed systems.

c) ***<u>Occurrence of Irrigation Related Problems between Neighbors:</u>***

Table (3.22) in the annex presents the distribution of the sample by irrigation system and according to the frequency of occurrence of irrigation related problems among neighbors. It was found that the majority of the whole sample 57.3% had no problems, 29.2% had frequent problems but only 13.5% had such kind of problems infrequently. However, for the four groups of users of irrigation systems about 48.9% of the users of sprinkler irrigation were found

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suffering frequent problems against 23.1%, 10.5% and 9.5% of the users of surface method, mixed and drip systems respectively. The users of mixed and drip systems seem to have the least frequency of exposure to such problems since 84.2% and 76.2% of these two categories reported they had no such problems respectively. It seems that using modern irrigation techniques or a mix of them minimizes the possible situations that create conflict among farm holders on the scarce resource of water.

Table (3.22) : Distribution of Sample by Irrigation System and ccurrence of Irrigation Related Problems between Neighbors

Irrigation System	*Irrigation Problems*						*TOTAL*	
	Frequently		*Infrequently*		*Never*			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
SPRINKLER	21	48.9	5	11.6	17	39.5	٤3	100
DRIP	2	9.5	3	14.3	16	76.2	٢1	100
SURFACE	3	23.1	4	30.8	6	46.1	١3	100
MIXED	2	10.5	1	5.3	16	84.2	19	100
TOTAL	28	29.2	13	13.5	55	57.3	96	100

Missing Cases 12
CHI SQUARE = 21.207 D.F. = 6 PROB. = 1.684E-03

d) ***Frequency of Officials' Response to Irrigation Problems:***

Table (3.23) in the annex shows distribution of the sample of users of various irrigation systems according to the frequency of officials' response to irrigation problems. It was found that about 57.3% of the whole sample reported that official officials never or rarely response to the complaints of irrigation problems of farm holders. They responded always in 24.2% only of the cases. When these high responses matched with the irrigation systems the highest percentage of 46.2% was found in the case of surface irrigation. The highest absence of such response were found in the case of users of mixed and drip systems where they were 73.7% and 61.9% respectively. The high frequency of officials' response to the irrigation problems of users of surface method and the absence of such response to the users of modern irrigation systems might be attributed to the relatively old and well established organization of irrigation system in the areas using surface method as it was mentioned before.

Table (3.23) : Distribution of Sample by Irrigation System and Frequency of Officials' Response to Irrigation Problems

Irrigation System	*Frequency of Officials Response to Irrigation Problems*								*TOTAL*	
	Always		*Sometimes*		*Rarely*		*Never*			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
R	9	23.7	12	31.6	5	13.2	12	31.6	38	100
DRIP	5	23.8	1	4.7	2	9.5	13	61.9	21	100
SURFACE	6	46.2	1	7.7	2	15.4	4	30.8	13	100
MIXED	2	10.5	2	10.5	1	5.3	14	73.7	19	100
TOTAL	22	24.2	16	17.6	10	11	43	47.3	91	100

CHI SQUARE =19.010 D.F. = 9 PROB. =.0251

e) ***Officials and Other Agencies Involved in Solving Irrigation Problems:***

Table (3.24) in the annex presents the distribution of the four categories of users of various irrigation systems according to the officials and other agencies involved in solving irrigation problems. For 34.7 percent of the whole sample the agricultural cooperative in the farm holders' area took the responsibility of solving irrigation problems. Irrigation staff in the area took this responsibility in other 26.7 % of the cases. Other agencies are involved in 9.3% of the cases. At the category level of the users of irrigation systems coops play higher role for 63.6% of the users of surface method, while the irrigation staff plays the highest role for 75% of the users of drip system. This trend of relationship seem to be logical since the problems related to drip systems might need more experienced and professional staff to deal with. This trend goes in consistence

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with the previously proved results about the tendency of users of drip systems to depend on technical assistance more than the others.

Table (3.24) : Distribution of Sample by Irrigation System and the Officials Took Part in Solving Irrigation Problems

Irrigation System	*Officials Took Part in Solving Irrigation Problems*								*Total*	
	Cooperative Manager		*Irrigation Staff*		*None*		*Others*			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
SPRINKLER	17	40.5	7	16.7	4	.3	4	9.5	2	100
DRIP	0	0	9	75	3	25	0	0	2	100
SURFACE	7	63.6	2	18.2	1	1	1	9.1	1	100
MIXED	2	20	2	20	4	40	2	20	0	100
TOTAL	26	34.7	20	26.7	2	.3	7	9.3	5	100

Missing Cases 34
CHI SQUARE = 24.975 D.F. = 9 PROB. = 2.998E-03

f) ***Leadership in Organizing irrigation Process:***

Table (3.25) in the annex shows the distribution of the sample by the used irrigation system and leadership in organizing irrigation process at the local level. It was found that 43.1% of the whole sample have some of their neighbors took a leading role in the organization of irrigation process in their areas. Yet, about 25.7% of the surveyed sample took this leading role themselves. Agricultural cooperatives played this leading role in 14.7% of the cases. Distribution of the subsamples of the four categories of users of irrigation systems showed that farm holders play leading role in organization of irrigation process in 51.8% and 43.5% of the cases of mixed and drip groups of users respectively. Cooperatives play their role in 46.7% of the areas of users of surface irrigation method but only in 20.5% in the areas of the users of sprinkler systems. These figures show

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again that the role of some sort of social organizations exist in the areas where farm holders use conventional methods of irrigation techniques while such social arrangements for organization of irrigation are missing or at least have less role in the areas using modern technologies.

Table (6) : Distribution of Sample by Irrigation System and Leadership in Organizing irrigation Process

Irrigation System	*Leadership in Organizing irrigation Process*										*Total*	
	Holder		*Neighbors*		*Irrigation Engineer*		*Cooperative Staff*		*Others*			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
SPRINKLER	0	0	31	70.5	0	0	9	20.5	4	9.1	4	0
DRIP	10	43.5	7	30.4	0	0	0	0	6	26.1	3	0
SURFACE	4	26.7	2	13.3	0	0	7	46.7	2	13.3	5	0
MIXED	14	51.8	7	25.9	1	3.7	0	0	5	18.5	7	0
TOTAL	28	25.7	47	43.1	1	0.9	16	14.7	7	15.6	9	0

CHI SQUARE =59.604 D.F. =12 PROB. =2.665E-08

g) <u>*Farm holders' willingness to collaborate with others to solve encountered irrigation problems:*</u>

Table (3.26) in the annex presents the sample distribution by irrigation system and degree of farm holders' willingness to collaborate with others to solve encountered irrigation problems. Data in the tables show that only 28.9% of all the sample had high willingness to collaborate with others whether officials or non officials in solving encountered irrigation problems, 25.7% had moderate willingness to collaborate, but the highest percentage 37.% was that of the group of negative attitude towards collaboration in solving encountered irrigation problems. This result clarify the absence of enough common social interests among the farm holders so far to collaborate in solving encountered irrigation problems. Social network of relationships and other ties among farm

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holders in such new communities seem in need of some new institutional arrangements to be more effective. However, the distribution of subsamples by the different responses showed that the users of drip and mixed systems tend to be more negative in their attitudes where 61.9% and 65% expressed their complete unwillingness to collaborate respectively. The users of sprinkler irrigation system showed a rather more positive attitude than the users of surface method where the percentage of high and moderate willingness respondents together were 83.8% and 38.5% respectively. This situation is not unexpected in new communities but needs rapid reconciliation within an overall social reform of the social infrastructure of new desert rural communities.

Table (3.26) : Distribution of Sample by Irrigation System and their Willingness to Collaborate with Others to solve Irrigation Problems

Irrigation System	*Willingness to Collaborate with Others*								*TOTAL*	
	Always		*Sometimes*		*Rarely*		*Never*			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
SPRINKLER	18	41.9	18	41.9	3	6.9	4	9.3	43	100
DRIP	5	23.8	1	4.8	2	9.5	13	61.9	21	100
SURFACE	1	7.7	4	30.8	2	15.4	6	46.2	13	100
MIXED	4	20	2	10	1	5	13	65	20	100
TOTAL	28	28.9	25	25.7	8	8.2	36	37.1	97	100

Missing cases 12
CHI SQUARE = 33.337 D.F. = 9 PROB. = 1.162E-04

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Conclusion:

Analysis of the data displayed showed a general and significant trend of differences among the four categories of users of irrigation systems. However the users of surface method seem to be slightly more organized socially than the users of sprinkler irrigation. Yet, both were more organized than the users of drip and mixed systems. It seems that the last two sub groups had a more individualistic approach. They seem to have more educational qualifications than the others which might explain their tendency to be more self reliant than the others.

Nevertheless, the need of a more social approach to the organization of irrigation process for all farm holders seem more urgent. This will help improvement of the efficiency of irrigation in desert land and enhancement and stability of social life in such new rural communities.

3.6. *Economic Evaluation of Crop Production Functions Under Different Irrigation Systems*

3.6.1 Background:

In Egypt, water is considered to be the most important constraint which hinders agricultural expansion. Decision makers can no longer plan any agricultural expansion without seriously considering the limited supply of water provided by the Nile River. Moreover, the demand for water, for almost all uses, has risen and is continually rising. Pressure of rising population, by itself, underscores the need to revitalize the agricultural sector. This will definitely possess important implications for water use and constitutes a pressing need for the country to maximize the returns to this valuable resource in an environmentally sound manner.

One of the major steps the Egyptian government has taken in recent years to increase agricultural production is to reclaim new lands. Land reclamation is another major water consumer and promises to become an increasingly important component of demand in the near future. Originally, this practice has started in the early fifties. The government has restarted its land reclamation program in the mid seventies with ambitious objectives based on its experience with old new lands (the Tahrir area). This interest in reclamation stems mainly from the government's need for an outlet to deal with the demands of a growing population. [1] The political and social importance of this activity explains the government insistence on expanding its reclaiming efforts despite of a widespread criticism of the economic costs and high water consumption.

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1 Waterbury, J., and Rignall, K. Agriculture and Water Use in Egypt: Policy Task Force 402(e), Managing a Vital Resource: Conflict and Cooperation in the Nile Basin. USAID/Cairo, Development Information Center. April 29, 1991.

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Since 1952, the government has reclaimed 1.6 million feddans and has lost approximately one million feddans of the old Delta lands to urban encroachment during this period. Accordingly, net gains have been significantly reduced. Moreover, the productivity on the new lands did not meet expectations due to a number of administrative, technical, and natural constraints. Of the 900,000 reclaimed feddans between 1967 and 1975, only 500,000 feddans were farmed, with only 200,000 feddans of that reaching submarginal productivity. [2]

the reasons for this disappointing performance are believed to be economic inefficiency combined with some technical bottlenecks. High investment cost is the character of land reclamation. In other words, it takes an average of ten years before reclaimed lands reach submarginal productivity. Not enough attention was paid to irrigation and drainage infrastructure. Moreover, 500,000 feddans had to be completely excluded from crop rotations because of salination problems in some areas; in other areas the water table rose an average of three meters a year. [3] Water shortages were common, and the cost of lifting water became an issue, as did the problem of an unreliable electricity supply. Egypt's Water Master

Plan predicted future reclamation to require 5,400 cubic meters per feddan, while IBRD considered 9,200 cubic meters per feddan more realistic given current methods of reclamation.[4]

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[2] Barth, H.K., and Shata, A.A., Natural Resources and Problems of Land reclamation in Egypt. Wiesbaden: Dr. Ludwig Reichert Verlag, 1987.

[3] El-Batran, M.M. "The Impact of Alternative Policies on the Food Gap for Strategic Crops in Egypt." Diss. Colorado State University, 1989.

[4] Waterbury, J. Riverains and Lacustrines: Toward International Cooperation in the Nile Basin. Research program in Development Studies 107. Princeton: Princeton U, Undated.

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The fiscal constraints of the mid seventies as well as the recognized inefficiencies in reclamation efforts spurred a reassessment of the government's program in the early eighties. With a revised plan based on improved planning and more appropriate technology, the government hopes to achieve greater economic and water use efficiency in future reclamation.

This report sheds the light on the problem of economic and water-use efficiency in the new lands on the micro level. Marginal analysis is used through the estimation of crop production functions under different irrigation systems. The objective is to assess the role of irrigation water for some chosen crops under each system, in addition to testing the economic efficiency of the farmers residing in the new lands. More specifically, a quantification of the impact of irrigation water on the level of agricultural output is made. A random sample of 109 farmers (this represents the number of farmers who responded) was interviewed during the summer and fall of 1995. This sample covers four areas in the new lands: South Tahrir, El-Bostan, Wadi-El-Natroun, and El-Sadat. All of which are located in El-Beheira governorate.

3.6.2. <u>The Production Function Approach:</u> [5]5/ and [6]6/

Knowledge of water response functions constitutes an important set of information needed in either private or public decisions on optimal water use. Unfortunately, however, yield response functions for water have seldom been known before large or small irrigation practices have been initiated from either surface or groundwater. Decision rules for optimal water use depend

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[5] Hexem, R.W. and E.O. Heady. Water Production Functions for Irrigated Agriculture. Center for Agricultural and Rural Development CARD, The Iowa State University Press, Ames, Iowa, USA, 1978.

[6] Doll, J.P. and F. Orazem. Production Economics: Theory with Applications. Grid Inc., Columbus, Ohio, USA. 1978.

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upon: (a) the knowledge of the water production function relative to various soils, environmental variables, and management variables with which it can be used, and (b) the stochastic, i.e., probabilistic or uncertain, nature of the water supply. In this report, soil types and environmental variables are found to be of no importance due to their relative homogeneity in the study area; while the stochastic nature of water supply is not considered.

A production function represents a schedule or mathematical formulation expressing the relationships between inputs and outputs. It also indicates the maximum amount of product obtainable from a specified quantity of inputs given the existing technology governing the input-output relationships. By definition, a production function embodies technical efficiency. This requires that a specified set of inputs cannot be recombined to produce a larger output or that a specific level of output cannot be produced with fewer inputs. The input-output relationships are assumed to be known with certainty, i.e., the farmer knows the eventual outcome of the production process at the beginning of the production period. Since these relationships are neither fully known nor controllable, a distribution a distribution of yields would be associated with each input-use level. This range of expected yields depends on the estimated variability of the predicted yield corresponding to the specified input use-level. Finally, inputs included in a production function are assumed to be homogeneous and prices of inputs and outputs are known with certainty.

A production function can be expressed in different ways: in written form; enumerating and describing the inputs that have a bearing on output; by listing inputs and the resulting outputs numerically in a table; in the form of a graph or a diagram; and as an algebraic equation.

A single-variable production function is of little practical significance. Few, if any, actual production relationships involve a single input. A more meaningful relationship is expressed symbolically as follows:

$Y = f(X1, X2, X3.............Xn)$ ....(1)

Where Y denote output (or Total Physical Product TPP), X1 denote the variable input (water in our case), X2 to Xn stand for the levels of other variable inputs, and f is the mathematical form of the input-output relationship that transforms inputs into output.

Some important derivatives which could be obtained once a production function is estimated include: Average physical Product (APP), Marginal Physical Product (MPP), and elasticity of production Ep. The first, APP, is obtained by dividing total output Y by the total amount of the variable input X. Geometrically, it is defined in terms of the slope of a particular straight line. This slope represents the average rate at which the input X is transformed into product Y. The straight line (ray) must always pass through the origin and intersects the estimated production function. The second, MPP, is the change in output Y resulting from a unit increment or unit change in the variable input. It measures the amount that total output increases or decreases as input increases. Geometrically, MPP represents the slope of the estimated production function. The third, the elasticity of production Ep, is a concept that measures the degree of responsiveness between output Y and input X. Like any other elasticity, Ep is independent of units of measure.

Furthermore, there is a duality between production and cost functions, i.e., cost functions and production functions are by nature inversely related to each other. Knowledge of one implies knowledge of the other (when input prices are known).

3.6.3 Economic Efficiency:

This concept refers to the combinations of inputs that maximize individual or social objectives. It is defined in terms of two conditions: necessary and sufficient. The first is met in the production process when: (a) there is no possibility of producing the same amount of product Y with fewer inputs and

(b) there is no possibility of producing more product Y with the same amount of inputs. This necessary condition for economic efficiency is met when estimating a production function (given that the previously-mentioned assumptions are satisfied) in the second stage of production, i.e., when Ep is equal to or greater than zero and equal to or less than one.

The second, i.e., the sufficient condition of economic efficiency, varies with the objectives of the individual farmer. It is called the choice indicator. An individual farmer whose objective is to increase yield per feddan will be different from that of an individual whose objective is maximization of profits per feddan. It is assumed in this report, like most of the economic literature under perfect knowledge, that the individual's farmer main objective is to maximize profits. This implies that the sufficient condition for economic efficiency will turn out to be what is known as the price or allocative efficiency. This efficiency is defined as profit maximization through equating the value of marginal product of the input VMP(X) (water in this case) to its unit price. Where VMP(X) is the outcome of multiplying the MPP of water which is derived from the estimated production function by the unit price of output (the farmgate price). Because irrigation water is not priced in Egypt, a method had to be deduced in this report to calculate the imputed cost of water, which is a measure of the opportunity cost of water. In other words, the cost the farmer would bear should water was not delivered to him free of charge. In this report, the imputed cost of water is the cost of constructing a well taking into consideration the type of irrigation system utilized.

3.6.4. <u>Input And Output Measurements:</u>

Eight per-feddan production functions of the Cobb-Douglas (double-logarithmic type) are estimated separated by the type of crop grown and method of irrigation. They are: peanuts (sprinkler) PNT1, peanuts (flooding) PNT2, wheat (sprinkler) WHT1, wheat (flooding) WHT2, winter crops (sprinkler) WC1, winter crops (flooding), summer crops (sprinkler) SC1, and vegetables (drip) VEG3. Two equally-good functions are found to represent

VEG3. The numbers 1, 2, and 3 stand for the three irrigation systems: sprinkler, flooding, and drip, respectively. Winter crops include: wheat, onions, peas, and clover. Summer crops include: peanuts, maize (corn), darawa, kidney-beans for forage, sorghum, and sesame. Vegetables include: watermelons, watermelons for seeds, green beans, potatoes, egg plant, squash, strawberries, tomatoes, cucumbers, bell peppers, green beans, and melons (cantaloup). This almost includes all of the major crops grown in the study area but citrus. Although data for citrus was collected and analyzed, no functions could be estimated due to the problem of having different maturity dates for citrus. In other words, farmers who have mature and productive citrus trees were characterized by having great output with very few inputs; while some other farmers who have young nonproductive citrus trees were characterized by employing lots of inputs and having a slim or no output. When a trial was made to group the trees of the same age together in one function the problem of having few degrees of freedom was raised. This eventually prevented a correct statistical estimation of production functions for citrus utilizing the sprinkler or the drip systems.

Functions such as winter crops (drip), summer crops (flooding or drip), vegetables (sprinkler or flooding), peanuts (drip), and wheat (drip) could not be estimated due either to the nonexistence of enough degrees of freedom or the fact that no farmer utilized a certain irrigation system for a particular crop.

The dependent variables in the estimated functions are either the quantity of output in physical units, i.e., kilograms/feddan, or monetary unit, i.e., value of output in L.E./feddan. The first was employed for the functions which portrayed one output, i.e., wheat (sprinkler and flooding) and peanuts (sprinkler and flooding). For the functions where the dependent variable was a collection of products, i.e., winter crops (sprinkler and flooding), summer crops (sprinkler), and vegetables (drip), the dependent variable was the value of output per feddan.

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The explanatory (independent) variables are: education measured as a dummy variable 1, 2, and 3 which stand for elementary, intermediate, and high education, respectively; seeds in kilograms; organic fertilizers in cubic meters, nitrate fertilizer, phosphate fertilizer, and potassium fertilizer, all measured by the quantity of active ingredient; machinery in monetary units, labor in man/days, and water in cubic meters.

3.6.5. Production Function Estimates:

Table (3.27) presents a summary of the production function estimates. The F-ratios of all of the estimated functions (regressions) are found to be statistically significant. All of the estimated coefficients are statistically significant (at different significance levels as shown by the P-values in parentheses). The adjusted R2 and the number of observations N are shown at the extreme right of the table. The first indicates the contribution of the explanatory variables in the estimated function in explaining the variation in the level of the dependent variable (physical output for the first four functions and the value of output for the next four functions). For instance, an adjusted R-square of 0.55 for the function PNT1 implies that the explanatory variables: water, nitrogen fertilizer, and labor account for 55% of the variation in output. The second, N, shows the number of observations. The table also shows that VEG3 has two equally-good functions which represent it.

Because all of the estimated functions are of the Cobb-Douglas type, the estimated regression coefficients shown in table (1) are the elasticity of production for the corresponding inputs. For instance, for peanuts (sprinkler) PNT1, a water coefficient of 0.231 means that an increase in the level of water by 100% results in increasing the level of output by 23.1%, and so forth for the rest of the estimated coefficients. On the other hand, the table shows that most of the signs of the estimated coefficients are positive and match with economic logic (except for four variables scattered in PNT2, WHT2, and WC1).

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Table (3.27) : Summary of Production Function Estimates

Function	Explanatory Variables (P-Values)											
	Edu.	*Water*	*Seeds*	*Orgf.*	*N.*	*P.*	*K.*	*Mach.*	*Labor*	*F-ratio*	*Adj.R2*	*N*
PNT1		0.231			0.244				0.383	19.75	0.55	47
		(0.01)			(0.004)				(0.001)	(0.000)		
PNT2		1.227				-0.296	-0.09		1.421	18.02	0.84	14
		(0.002)				(0.09)	(0.02)		(0.001)	(0.000)		
WHT1		0.901	0.304		0.145	0.054				14.51	0.65	30
		(0.000)	(0.06)		(0.07)	(0.07)				(0.000)		
WHT2	-0.347	0.491				0.097			0.269	8.41	0.68	15
	(0.02)	(0.02)				(0.01)			(0.002)	(0.003)		
SC1		0.447			0.232	0.103			0.366	7.69	0.42	47
		(0.03)			(0.04)	(0.06)			(0.004)	(0.000)		
WC1		1.330			0.164	0.088		-0.144	0.195	15.46	0.60	50
		(0.000)			(0.003)	(0.08)		(0.03)	(0.002)	(0.000)		
WC2		0.923			0.508				0.271	10.07	0.63	17
		(0.03)			(0.08)				(0.03)	(0.001)		
VEG3												
(1)		1.400	1.111	1.400						8.85	0.54	21
		(0.04)	(0.01)	(0.001)						(0.000)		
(2)		1.340		0.774					0.333	7.68	0.50	21
		(0.06)		(0.04)					(0.03)	(0.001)		

Legend: PNT, WHT, SC, WC, and VEG stand for peanuts, wheat, summer crops, winter crops, and vegetables, respectively. The numbers 1, 2, and 3 which are attached to those symbols represent the three irrigation systems under study: sprinkler, flooding, and drip, respectively. The explanatory variables: Edu., Orgf., N., P., K., and Mach. stand for education, organic fertilizer, Nitrogen, phosphate, potassium, and machinery, respectively.
Source: Calculated through multiple regression analysis.

3.6.6. Ranking of Inputs:

The inputs of the eight estimated production functions are ranked according to their relative importance in affecting the level (or value) of output. This is done by estimating the standardized regression coefficients (Beta). This could be obtained utilizing the previously estimated regression coefficients and the standard deviation of both the input and the output. Table (3.28) shows the standardized regression coefficients for the eight estimated functions.

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Comparisons should be made within the estimated function only (not across functions) according to the size of the Beta coefficient (including the sign). The bigger the Beta coefficient the more important the variable becomes.

Table (3.28) : The Estimated Standardized Regression Coefficients for the Estimated Production Functions

Function					*Explanatory Variables*				
	Edu.	*Water*	*Seeds*	*Orgf.*	*N.*	*P.*	*K.*	*Mach.*	*Labor*
PNT1		2.29			0.03				0.01
PNT2		2.17				-0.008	-0.002		0.01
WHT1		1.00	0.01		0.02	0.002			
WHT2	-0.0006	0.76				0.004			0.005
SC1		0.57			0.02	0.003			0.009
WC1		0.81			0.01	0.002		-0.02	0.007
WC2		1.32			0.04				0.006
VEG3 (1)		0.09		0.002			0.002		
(2)		0.09	0.003	0.003					

Source: Calculated form the estimated functions and standard deviations of inputs and output.

The table shows that within the eight estimated functions, water is by far the number one input for the above indicated crops. For peanuts (sprinkler) PNT1, nitrogen and labor followed; for peanuts (flooding) PNT2, labor, phosphate, and potassium followed; for wheat (sprinkler) WHT1, seeds, nitrogen, and phosphate followed; for wheat (flooding) WHT2, labor, phosphate, and education followed; for summer crops (sprinkler) SC1, nitrogen, phosphate, and labor followed; for winter crops (sprinkler) WC1, nitrogen, phosphate, and labor followed; for winter crops (flooding) WC2, nitrogen and labor followed; and finally for vegetables (drip), organic fertilizer and potassium fertilizer were of the same relative importance (for the first function), while seeds and organic fertilizer were of the same relative importance (for the second estimated function).

3.6.7. Economic Efficiency of Water Use:

Technical (or production) efficiency, as defined earlier, could be explicitly deduced from the estimated production functions through the calculation of the Average Physical Product APP of water. That is to say, a measure of the number of units of output produced by one unit of water. Table (3.29) shows a summary of the calculated APP for the water input for the eight estimated functions. The APP for water could be calculated in either one of two ways: by solving the estimated function to obtain Y/X, where Y is the level of output per feddan (in physical or monetary units) and X represents the amount of water in cubic meters applied per feddan; or directly by dividing the average amount of Y by the average amount of X. Both ways are found to yield the same results (which is a proof that the estimated functions are statistically correct). For the first four estimated functions, Y was measured in physical units (kilograms), while for the last four functions Y was measured in Egyptian pounds. In the latter case, it is not proper to call it APP but rather Average Value Product (AVP). For instance, for PNT1, an APP of water of 0.476 implies that a cubic meter of water increases on the average the level of output by 0.476 kilogram. On the other hand, for a value function like SC1, a cubic meter of water results in increasing the value of output by 0.482 pound. Comparisons of the calculated APP or AVP of water are of value only when we consider the comparisons between the production efficiency of the sprinkler and the flooding irrigation systems for the same crop, i.e., when we compare between PNT1 and PNT2 or WHT1 and WHT2 or WC1 and WC2. These comparisons reveal one simple fact: the cubic meter of irrigation water for the sprinkler system possesses on the average high production efficiency than the flooding system. Note also the high AVP of water in case of vegetables. This may indicate the high production efficiency of drip irrigation against either the flooding or the sprinkler systems, in addition to the fact that vegetables are considered cash crops and it pays to water them (a cubic meter of water on the average increases the value of output by almost three pounds). Unfortunately, statistical analysis could not be performed for other crops utilizing the drip system either because of the nonexistence of enough degrees of freedom to allow a justifiable statistical estimation of the production function, or that the drip system already is not installed yet for some crops.

Table (3.29) : Production (Technical) Efficiency of Water for the Estimated Production Functions

Production Function	*Average Physical Product of Water (APP)*
Peanuts (sprinkler) PNT1	0.476
Peanuts (flooding) PNT2	0.327
Wheat (sprinkler) WHT1	0.687
Wheat (flooding) WHT2	0.634
	Average Value Product of Water (AVP)
Summer Crops (sprinkler) SC1	0.482
Winter Crops (sprinkler) WC1	0.422
Winter Crops (flooding) WC2	0.331
Vegetables (drip) VEG3	2.969

Source: Calculated from the estimated production functions.

On the other hand, the farmer is considered price efficient in the use of irrigation water if he gets a high value for the unit of output compared with the unit cost of water. In other words, if the Value of Marginal Product VMP of water is equal to the unit cost of water. Stated differently, if the ratio of the VMP of water to its own price equals one. If this ratio is greater than one then the farmer is under utilizing water. While if the ratio is less than one then the farmer is over utilizing water.

In Egypt, irrigation water is not priced. Consequently, some assumptions have to be made to calculate the imputed cost of water which in this case represents the opportunity cost of water. That is to say, the cost the farmer would have paid should water was not delivered to him free of charge.

The assumptions used in this report to deduce the cost of one cubic meter of irrigation water in the study area are as follows: The area the well serves is 50 feddans; the discharge of the pump is 150 cubic meter/hour; the cost of digging the well, the pump, and the diesel engine is estimated at L.E. 73,000; the well is of an average depth of 100 meters; the average life of the well that is adequately maintained is 15 years; the costs of the flooding, sprinkler, and drip systems are: zero, 1500, and 3000 Egyptian pounds per feddan, respectively; average annual fixed costs are 4867, 12367, and 19867 Egyptian pounds for the flooding, sprinkler, and drip systems, respectively; cost of fuel (diesel) is estimated at 9600, 17600, and 15360 pounds per year for the flooding, sprinkler, and drip systems, respectively; oil and lubricant costs per year are estimated at 200, 366, and 320 pounds for flooding, sprinkler, and drip systems, respectively; annual cost of repairs and maintenance for the engine and pump for the three systems is estimated at 2920 pounds; annual maintenance and repair costs of the whole irrigation system are estimated at zero, 375, and 750 pounds, for flooding, sprinkler, and drip systems, respectively; total annual fixed and variable costs for the three systems are 17587, 33628, and 30217 pounds, respectively; the pump discharges 300,000 cubic meter per year on the basis that the number of operating hours for the system is estimated at 2000 hours (design expectation) and 1000 hours (actual operation in the study area).

Accordingly, two scenarios are made for the cost of one cubic meter of irrigation water in the study area. The first is based on an annual operating hours of 2000/year; the second on 1000 hours/year. Under the first scenario, the cost of the cubic meter of water for the flooding, sprinkler, and drip systems is estimated at: 0.07, 0.124, and 0.143 pounds, respectively. Under the second scenario, these same figures are multiplied by two yielding an imputed cost of the cubic meter of water in the study area of: 0.14, 0.248, and 0.286 pounds for the flooding, sprinkler, and drip irrigation systems, respectively.

Table (3.30) shows the ratio of the VMP of water and its imputed cost along with the corresponding t-statistic when rendered necessary (that is to say, only when the tested ratio is close to one). The null hypothesis (Ho) is that the ratio is equal to one. These VMP's for water are deduced form the estimated functions by multiplying the estimated water coefficient by the average value of output over the average value of the water input. Furthermore, output prices were based on the average of the years 1991 through 1993 (the last available published data).

Table (3.30) : Results of the Price (Allocative) Efficiency of Water Under the Two Scenarios of the Imputed Cost of Water for the three irrigation systems

Function	*VMP(W) L.E.*	*C(W) L.E./m3 (1) Design*	*(2) Actual*	*VMP(W)/C(W) (1)*	*(2)*	*Estimated t-test (When Necessary)* (1)*	*(2)*	*Ho: The Ratio Equals One (1)*	*(2)*
PNT1	0.118	0.124	0.248	0.952	0.476	-0.235	-7.232	do not reject	reject
PNT2	0.429	0.070	0.140	6.129	3.064			reject	reject
WHT1	0.318	0.124	0.248	2.565	1.282		1.352	reject	do not reject
WHT2	0.160	0.070	0.140	2.286	1.143		1.006	reject	do not reject
SC1	0.215	0.124	0.248	1.734	0.867	2.099	-0.659	reject	do not reject
WC1	0.561	0.124	0.248	4.524	2.262			reject	reject
WC2	0.305	0.070	0.140	4.357	2.179			reject	reject
VEG3									
(1)	3.978	0.143	0.286	27.818	13.909			reject	reject
(2)	4.156	0.143	0.286	29.063	14.531			reject	reject

Source: Calculated through the estimated production functions, the imputed cost of water in the study area, and the cross section data.

* The level of significance is the 1% level.

The table shows that allocative (price) efficiency was achieved in four cases (that is to say, the ratio was equal to one in only four case). Under the first scenario of the imputed cost of water (where the design expectations of operating hours is embodied), only one function displayed allocative efficiency, peanuts (sprinkler) PNT1. Under the second scenario of the imputed cost of water (where actual operating hours are considered), three functions portrayed allocative efficiency, Wheat (sprinkler) and (flooding) WHT1 and WHT2, and summer crops (sprinkler) SC1. Of course, any alteration in the assumptions through which the imputed cost of water is calculated from will result in changing these results.

3.6.8. Conclusions

The results of the study could be summarized as follows: (1) The sprinkler system is more production efficient than the flooding irrigation system in terms of the amount or value of output obtained from the unit of irrigation water. (2) The drip system possesses the highest production efficiency in terms of water use. (3) Water is by far the most important input in desert agriculture in the new lands in the study area. The water coefficient was always positive and statistically significant across all estimated production functions. (4) Because irrigation water is not priced in Egypt, a method has to be developed to calculate the imputed cost of water. Two scenarios for the price of the cubic meter of irrigation water are presented in the study area. Under the first scenario (design expectation of pump-operating hours of 2000 hours/year), the imputed cost of the cubic meter of irrigation water was estimated at: 0.070, 0.124, and 0.143 pounds for the flooding, sprinkler, and drip systems, respectively. Under the second scenario (actual operating hours of the pump of 1000 hours/year), which portrays the problem of water shortage in the area, the cubic meter of irrigation water was priced at 0.140. 0.248, and 0.286 pounds for flooding, sprinkler, and drip irrigation systems, respectively. (5) As far as allocative (price) efficiency is concerned, one function (peanuts sprinkler) out of possible eight is found to achieve it under the first scenario (design expectation); while three functions (wheat sprinkler, wheat flooding, and summer crops sprinkler) are found to achieve it under the second scenario (actual operation).

3.6.9. Implications for further research:

The marginal analysis employed in this study, though considered sound in the economic literature, has some deficiencies. These shortcomings are embodied in its main assumptions of: perfect knowledge of the prices of inputs and outputs, perfect competition in input and output markets, the knowledge of the technical relationships between inputs and outputs on behalf of individual farmers, and the unconsideration of the stochastic nature of any variable and specially irrigation water. this type of analysis is in need to be complemented with other analyses to strengthen it. For instance, one of the items in this study which affected the results obtained concerning economic efficiency is the imputed cost of irrigation water. It is clear that altering any of the assumptions through which this cost is calculated from will alter the results.

Accordingly, another economic analysis is needed to complement the results of the production function estimation. This could be in the form of a mathematical programming technique through which the shadow (economic) price of irrigation water is determined. The mathematical programming technique will also help in determining the optimal cropping pattern in the study area, in addition to the area that should be grown of each crop given the existing resources if the farmer is to maximize profits or any other function.

Furthermore, a closer examination of a sample farmers (who were originally included in the analysis) should help in determining the status of their irrigation systems, allow modification to their systems, and eventually evaluating their economic status before and after modifications. This is rendered necessary since the results of this study showed that most farmers are under-utilizing irrigation water. The only reasonable explanation of this, other than the method and/or assumptions of calculating the imputed cost of water, is that individual farmers face problems of water shortages which alter their problem from a choice problem to an availability one. This is a rather important aspect in economic analysis, since that the economic problem under the theory of production is the problem of choice. That is, the choice among available production alternatives to achieve some goals taking into consideration scarcity of resources.

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4. Irrigation Systems Evaluation

4.1. Background

Evaluation of the existing irrigation systems was carried out in 101 desert farms representing four areas namely; South Tahrir, El-Bustan, Sadat and Wadi El-Natron. These areas vary in the main source of irrigation water (Surface and groundwater), dominant modern irrigation systems (sprinkler and drip), and the type of settlers (small holders old graduates, new graduates, and investors). The evaluation of sprinkler irrigation systems included 21 fixed systems, 22 hand-move systems and 9 side-roll systems addition to 49 drip irrigation systems.

Irrigation uniformity for sprinkler irrigation systems are evaluated by measuring the application depths with catch cans. Trickle systems measure the emitter discharge for evaluating irrigation uniformity. Field evaluation tests were conducted in accord with: ASAE Standard S 330.1 (ASAE, 1990), Merriam et al. (1983), and Merriam and Keller (1978).

A common way to evaluate sprinkler uniformity is the Christiansen's Uniformity Coefficient (CU), a statistical representation of the catch pattern, when expressed as a percentage, it is calculated by:

$$CU = \frac{\text{Average deviation from mean depth caught}}{\text{Mean depth caught}} = 100$$

1- ASAE Standards, 37th Ed. 1990. S330.1. Procedure for sprinkler distribution testing for research purposes, 568-570. St. Joseph, MI: ASAE.

2. Merriam, J.L., M. N. Shearer, and C.M. Burt. 1983. Evaluating Irrigation Systems and Practices. In Design and Operation of Farm Irrigation Systems, ed. M.E. Jensen. Monograph No. 3, St. Joseph, MI: ASAE

3. Merriam, J.L., and J. Keller. 1978. Farm Irrigation System Evaluation, 3rd. ed., Logan, Utah: Agricultural and Irrigation Engineering Department, Utah State University.

To achieve high values of uniformity, close sprinkler spacing are usually required. In general, the closer the sprinkler spacing, the more expensive the system costs. Griffin (1978) reported that most agricultural sprinkler applications require a uniformity coefficient of at least 80 percent for market acceptance. Low uniformity coefficient values often indicate an incorrect combination of sprinkler size, operating pressure, and spacing.

The pattern of drops falling from sprinklers was determined by measuring the depths of water caught in small containers. The above definition requires that each catch can represent the depth applied to equal areas. The sprinkler flow rate was obtained by filling a known volume container in a measured time. A loose fitting section of hose was slipped over the nozzle to deflect the stream into the container. The sprinkler pressure was measured using a pressure gauge with a pitot tip, which was placed directly in line with the center of the jet flow.

Distribution uniformity (DU) indicates the uniformity of infiltration throughout the field and expressed as follows:

$$DU = \frac{\text{Average low quarter depth caught}}{\text{Mean depth caught}} = 100$$

The distribution uniformity is often applied to sprinkler and trickle irrigation systems. The average low quarter depth of water infiltrated is the lowest one-quarter of the measured values where each value represents an equal area. For sprinkler and trickle irrigation, the depth infiltrated is presumed equal to the depth applied or caught on the surface if there is no runoff. The DU is useful indicator of the magnitude of distribution problems. A low DU value indicates that losses due to deep percolation are excessive if adequate irrigation is applied to all areas. Although the concept of a low DU is relative, value less than 67 percent are generally considered as unacceptable.

Potential application efficiency of low-quarter (PELQ) is the efficiency that is obtainable when the average low-quarter (LQ) depth of irrigation water infiltrated just equals the desired management allowed deficiency (MAD) and is expressed as:

$$PELQ = \frac{\text{Average low - quarter of water caught}}{\text{Average depth of water applied}} = MAD \times 100$$

The average depth applied was obtained by dividing the sprinkler flow rate over the area served by single sprinkler (sprinkler spacing). Low PELQ values indicate design problems. The water that goes to excessive deep percolation, surface runoff, wind drift, and spray evaporation would tend to decrease the irrigation application efficiency.

The PELQ is always a little lower than the DU of a sprinkler irrigation system because the average water applied (which is the denominator for PELQ) is larger than the average water caught (which is the denominator for DU). The numerator for both PELQ and DU is the average low quarter depth of catch. The difference between the average water applied and the water caught or received is an approximation of losses due to evaporation and wind drift plus loss of water due to some of the area's being ungauged and some evaporation from the gauge cans.

The emission uniformity of drip systems can be determined in the field by the following equation:

$$EU = \frac{\text{Minimum rate of discharge per plant}}{\text{average rate of discharge plant}}$$

Drip irrigation has significant advantages over other techniques in minimizing or preventing water loss because leakage from the delivery system is negligible. Evaporation is minor as water is not discharged in the air, as with sprinkler irrigation, or left on the soil surface as with surface irrigation methods. Only a small fraction of the soil surface is wet. Therefore, the only considerable water loss in drip irrigation is deep percolation. With drip irrigation it is always very difficult to determine the soil moisture deficit in the field because of the small soil moisture variations which occur in the wetted soil before and after irrigation. Therefore reasonable deep percolation will be taken as 10 percent of the amount of water applied. The application efficiency (AE) is therefore: AE = 0.9 EU.

The emission uniformity (distribution uniformity) of new drip irrigation installations may be close to 90 percent, but it usually decline appreciably with continued use. A more typical value of about 80 percent should be considered. Only the EU can be measured by evaluations so the AE (PELQ) must be estimated. Since the SMD cannot be measured, but is estimated.

4.2. Sprinkler System Evaluation

Unformity Coefficient (UC)

A common way to evaluate sprinkler uniformity is to determine the UC. For high valuecrops, especially those having shallow roots, the most economical systems usually operate at high uniformity, i.e., UC greater than 87%. For typical field crops, uniformities usually range between UC of 80 and 87%. For deep rooted and forage crops, economic uniformity is often relatively low in the range of 72-80%.

The data obtained from the field evaluations of hand-move, side-roll, and fixed sprinkler systems for the area under study tables (4.1) were analyzed and performance parameters were calculated. Figure (4.1), the frequency distribution of the uniformity coefficient for the sprinkler systems (hand-move, side-roll, and fixed), shows that 15.4 percent of the sprinkler systems were in the acceptable limits of CU (about 80 percent CU) and 30.7 percent of the systems showed very poor CU (below 60 percent CU). The system with the highest CU's was the side-roll, in which 22.2 percent of the systems had CU's greater than or equal to 80 percent. Lower uniformity coefficients were found for the hand-move system, in which 36.3 percent of the systems had CU's less than 60 percent. The maximum frequency of occurrence for the three systems was between 60 and 70 percent.

Table (4.1) : Frequency Of The Distribution Uniformity (DU) For Sprinkler Systems.

DU %	*Hand-move*		*Side-roll*		*Fixed*		*Total*	
	#	%	#	%	#	%	#	%
< 50	9	40.9	1	11.1	7	33.3	17	32.7
50 - 60	5	22.7	4	44.4	7	33.3	16	30.8
60 - 70	4	18.2	2	22.2	4	19.1	10	19.2
70 - 80	3	13.6	2	22.2	3	14.3	8	15.4
80 - 90	1	4.5	0	0	0	0	1	1.9
Total	22	100	9	100	21	100	52	100

Table (4.2) : Frequency Of Distribution Of The Potential Application Efficiency Of Low Quarter (PELQ) For Sprinkler Systems.

PELQ %	*Hand-move*		*Side-roll*		*Fixed*		*Total*	
	#	%	#	%	#	%	#	%
< 50	8	38.1	3	42.9	9	42.9	20	40.8
50 - 60	7	33.3	2	28.6	5	23.8	14	28.6
60 - 70	1	4.8	2	28.6	6	28.6	9	18.4
70 - 80	4	19	0	0	1	4.8	5	10.2
80 - 90	1	4.8	0	0	0	0	1	2
Total	21	100	7	100	21	100	49	100

As shown in Fig. (4.2), the hand-move systems in south Tahrir had the lowest uniformity coefficients, in which 22.2 percent of the systems had CU's less than 50 percent, comparing to zero percent of the systems in Bostan.

Hart and Reynolds, 1965 gave more useful meaning to the concept of CU. For example, if a sprinkler system has a CU of 85%, this implies that for each unit of the average application of water received by the crop, 80% of the area would receive 85% of the average application or more, and 20% of the area would receive less than 85%. To apply a net application depth of 1.0 unit of water to at least 80% of the area with a system having a CU of 85%, the average net application (after allowing for wind drift and evaporation losses) must be: 1.0/0.85 = 1.18 units of water. With a CU of only 70

Table 4.3 . Summary of the field evaluations for the Hand-move sprinkler in El-Bostan area

NO	Irrigation system characteristics						Wind	Irrigation system Performance				
	P, bar	q, m^3/hr	nozzle ϕ mm x mm	spacings m x m	wetted diameter m	Riser height m	speed Km/hr	$\frac{\Delta P}{P'}$	$\frac{\Delta q}{q'}$	DU	UC	PELQ
1	2.2	2.1	2.5 x 4.5	12 x 15	18	0.9	7.5	0.4	0.44	60.6	75.8	54.2
2	1.3	3.5	5 x with out nozzle mixed	9 x 15	21	None	3.6	0.37	0.24	76.7	86.4	71.7
3	1	3.8	5.5 x with out nozzle mixed	9 x 15	18	0.6	5.4	0	0.57	57.7	68	50.6
4	1	6.6	7.5 x with out nozzle mixed	15 x 15	17	0.6	9.6	0.57	0.66	36	56.4	17
5	1	3.9	5 x with out nozzle mixed	15 x 15	18	0.6	10	0.45	0.38	36.5	56.9	27.6
6	1.3	1.8	5.5x2.5 mixed	15 x15	18	0.6	10	0.45	0.38	36.5	56.9	27.6
7	2.5	3.6	mixed	12 x 18	19	0.2	10.8	0.04	0.77	43.9	65.7	28.5
8	1.8	1.7	4.5 x 3 mixed	15 x 15	-	1.2	18.0	0.73	0.31	50.5	68.6	48.1
9	1	3	5.5 x 0 mixed	9 x 15	15	None	9	0.1	0.17	25.5	56.1	18.6

%, an average net application of 1.43 would be required to apply a net depth of 1.0 or more units of water to 80% of the irrigated area. It can be seen that the lower the CU value, the greater the deep percolation losses.

Table (4.1), indicates that 36.5 percent of the sprinkler systems had DU's equal to or greater than 60%, while 32.7% of the systems had DU's less than 50%. This means non-uniform water application and excessive quantities of deep percolation. Table (4.2), the frequency distribution of the PELQ for sprinkler systems, shows that only 30.6 percent of the systems had PELQ's equal to or greater than 60 percent, while 40.8 percent of the systems had PELQ's less than 50 percent. As presented in Table 2, the actual average application efficiency of the sprinkler systems ranging between 50 and 60 percent. This low application efficiency causes excessive quantities of water losses. The PELQ is lower than the DU by the amount of the percent of evaporation and wind drift losses, which lies in the range of 10 percent. The application efficiency of low quarter has a direct effect on the amount of water losses. For example, if a PELQ has been improved from 50% to 70% there would be a water saving of 28.6% calculated as follows:

$$\text{Percentage of water saving} = \frac{PELQ1}{PELQ2} \times 100 = -\frac{50}{70} \times 100 = 28.6\%$$

Major factors responsible for low performance of sprinkler systems included: low operating pressure, leakage, wide sprinkler spacing in related to actual wetted diameter, short riser pipe, non-perpendicular riser orientation, riser vibration (not rigidly supported), mixed sprinklers, worn nozzles, and non-uniform rotation rate of sprinklers. The poor water distribution may be improved by using the correct sprinkler nozzle pressure as recommended by the manufacturer and limiting the sprinkler spacing to 50 percent of the sprinkler wetted diameter to match the prevailing 10 km/hour wind speed.

4.3 *Observation on Sprinkler Irrigation Systems:*

a) Hand-Move Sprinkler System

The hand-move sprinkler has high labor requirements and subjects equipment to an exceptionally high rate of wear due to the high number of lateral movements required by the large number of irrigations necessary. The policy of sharing one lateral sprinkler line between two earlier settlers is clearly unsatisfactory in relation to the highly intensive use of equipment. The recently designed and constructed sprinkler projects in Bustan area provides one sprinkler lateral for each 5 feddans unit, and thus this problem is limited to the earlier settlers.

Operating Pressure. Characteristics and performance of hand-move irrigation systems are shown in tables (4.3-4.5). Several observation and some recommendations can be based on these data.

From the field evaluation it was observed that on several occasions the sprinklers were operating at low pressure. The more logical explanation lies in the exceptionally high level of water losses from the irrigation hydrants, valve elbows, lateral pipe seals, and sprinkler bearings. In addition, some farmers practice surface irrigation illegally and there are possible leakage from buried main pipelines. All these reasons cause the pumps to deliver much higher discharges than designed with a consequent drop in pressure. As a result of having no desilting basins or sand separator at the pumping stations, there is wear in the impellers caused by sand blown into the irrigation canals.

The direct impact of low operating pressures is a reduction in sprinkler nozzle discharges and distortion of the optimum water distribution pattern thus reducing the application efficiency. Low pressures also increase droplet size which cause physical damage to plants.

Sprinkler Rotation. The rotation rate of sprinklers on the same lateral line are not uniform as presented in the evaluation sheets found in the Appendix. As a consequence, uniformity of water distribution is further reduced. Rotation rate is dependent on the mechanism; the bearing construction and the seals used; the nozzle diameter; the pressure; and the tension on the arm spring. Worn bearings or seals cause a variable rate of rotation and thus a poor distribution pattern. The wetted diameter becomes smaller with the faster rotation for the same sprinkler. If damage has occurred to the oscillating arm, the arm should be replaced. The angle of water-contact of the jet with the arm, if not correct, will change the turning characteristics of the sprinkler.

Wind Speed. Sprinkler systems were designed without adequate consideration of wind. However, it has been shown that the wind greatly affects sprinkler performanc. If the effect of speed and direction of the wind is not sufficiently considered in the design of a sprinkler irrigation system, the resulting system's performance may be suboptimal. Most researchers agree that uniformity coefficient decreases as wind speed increases. some combinations of nozzle size, pressure, and sprinkler spacing do show a slight increase in uniformity coefficient at low wind speeds. Redditt (1965) credited the reduced uniformities at higher wind speeds to a quicker breakup of the jet of water leaving the nozzle. The water begins traveling as individual drops sooner, and therefore travels a shorter distance from the nozzle.

Griffin (1978)1 reported that most agricultural sprinkler applications require a uniformity coefficient of at least 80 percent for market acceptance, but the appropriate design uniformity coefficient is a function of available water, crop water response, and crop price (Von Bernuth, 1983)2. Low uniformity coefficient values often indicate an incorrect combination of sprinkler size, operating pressure, and spacing.

Fig. 1. Frequency distribution of uniformity coefficient for hand-move, side-roll and fixed sprinkler systems.

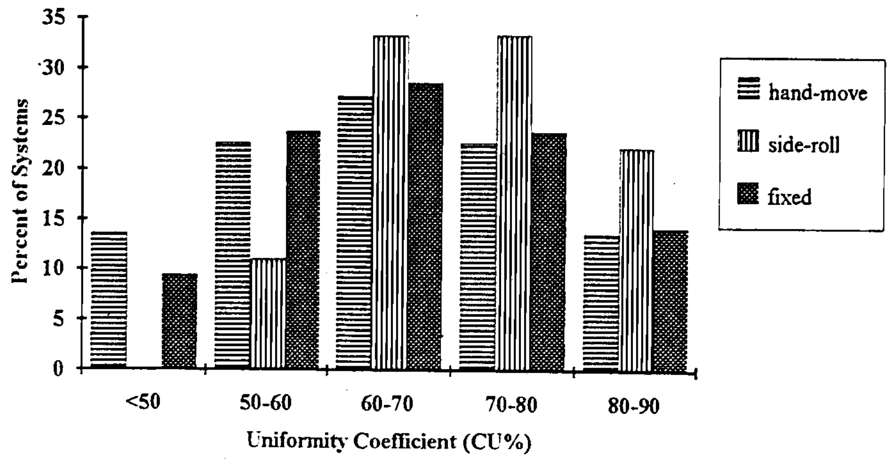

Fig. 2. Frequency distribution of uniformity coefficient (CU%) for hand-move system at Bostan and South-Tahrir areas.

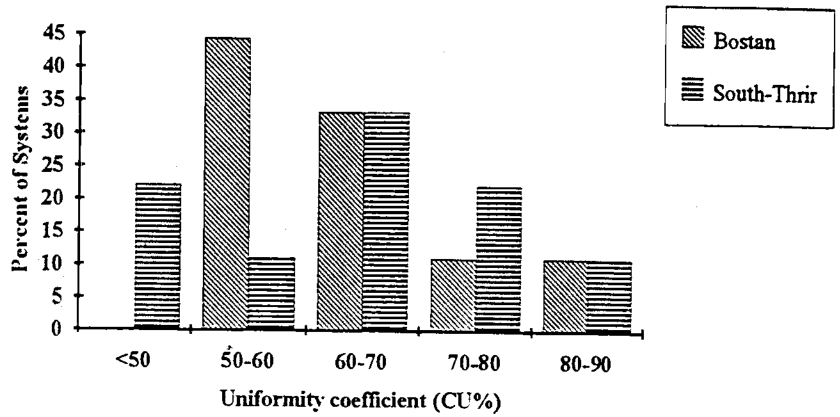

Fig. 3. Frequency distribution of emission uniformity for drip irrigation systems.

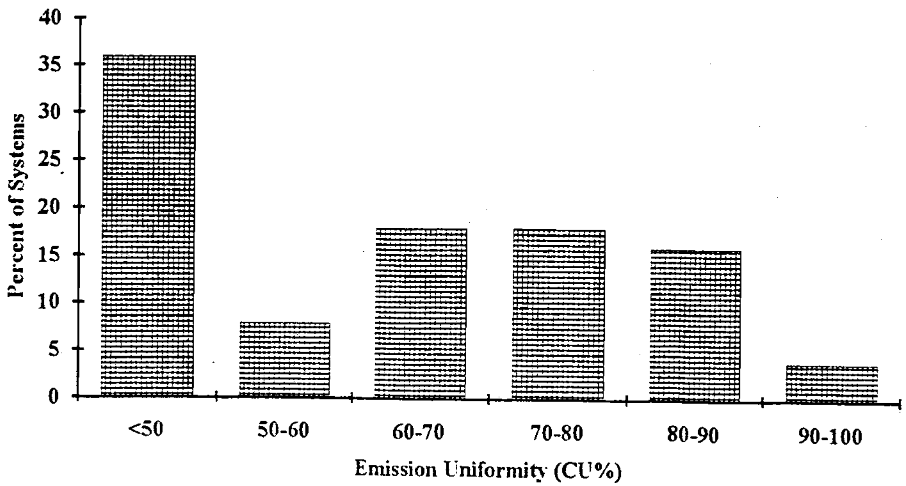

Fig. 4. Frequency distribution of emission uniformity for drip systems at different areas

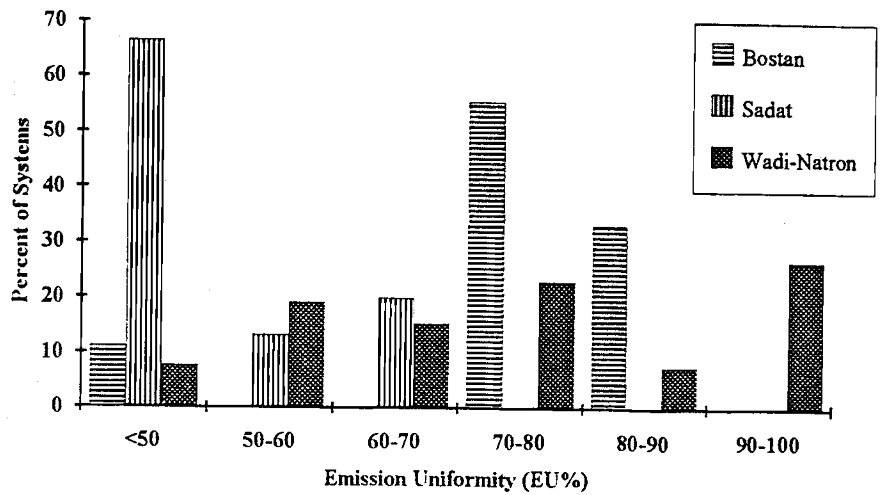

Table 4.5 Summary of the field evaluations made at the DDC Farm in South Tahrir farm

Field No.	Type of Irrigation System	Irrigation System Characteristics				Irrigation System Performance		
		P , bar	q, m3/h	Nozzle ∅ mm x mm	Spacings m x m	DU	UC	PELQ
3	Side-roll	3	2.1	5x3	12x18	59.8	73.5	70
	Side-roll	2	3	7x4	12x18	51.8	68.5	41
5	Side-roll	2.4	1.7	5.5x3.5	12x18	46.0	58	40.5
	Hand-move	2	1.8	5.5x2	9x18	81.4	86	73.6
7	Side-roll	3	2	5.5x2	12x18	53.7	66	62
	Hand-move	3.2	1.9	5x2	9x18	51.4	78.2	54
9	Side-roll	1.5	1.8	5.5x2.5	12x18	67.3	74	54
10	Side-roll	2.1	2.9	6.5x3.5	12x18	75.4	81.5	
12	Side-roll	2.5	2	5x2.5	12x18	54.7	64.8	
	Hand-move	3.3	2.5	5x2.5	9x18	40.0	47	
15	Hand-move	2	1.7	5x2.5	9x18	66.5	72	77
17	Side-roll	2.8	2.3	5.5x2.5	12x18	69.0	79.5	50
	Side-roll	2.6	2.7	6.5x2.5	9x18	78.6	86	40
8	Fixed system	2.1	3.05	7x2.5	18x18	60.8	76	43.6
	Fixed system	2.5	1.63	5x2.5	18x18	56.2	69	46.4
16	Fixed system	2.5	2.8	7x2.5	18x18	62.6	74.7	62.2
	Fixed system	3.4	1.55	5x2.5	18x18	64.0	73.5	69.6
11	Fixed system	3.5	1.7	5x2.5	18x18	65.6	75	51
8	Fixed system	2.4	1.66	5x2.5	18x18	50.0	62.7	58.5
	Fixed system	2.5	3.09	7x2.5	18x18	47.9	71.3	60.6
11	Fixed system	1.95	2.78	7x2.5	18x18	59.8	46.2	70

Table 4.6 Summary of the field evaluations for the fixed sprinkler in El-Bostan and Wadi El-Natron

O	Irrigation system characteristics						Wind	Irrigation system Performance				
	P. bar	q. m^3 hr	nozzle ϕ mm x mm	spacings m x m	wetted diameter m	Riser height m	speed Km/hr	$\frac{\Delta P}{P'}$	$\frac{\Delta q}{q'}$	DU	UC	PELQ
EL- Bostan												
10	1.4	6.17	-	18 x 18	23	0.6	9.3	0.214	0.17	42	59.4	40.7
11	1.9	1.7	5 x 3	18 x 18	23	0.5	4.8	.21	0.1	53	66.9	50.5
12	2	2.1	5 x 4	18 x 18	22	0.5	18.7	0.54	0.24	8.3	40.5	6.5
13	1.5	7.4	-	18 x 18	24.5	0.5	11.5	0.06	0.02	42.3	59.3	38.5
14	2.2	2.1	5 x 3	15 x 15	16	0.5	6.3	0.17	0.41	51.9	58.8	46.3
15	1.2	4.7	8 x 5	15 x 15	22	0.6	6	0.24	0.47	32.8	53.7	29.4
16	1.5	1.4	-	15 x 15	16	0.6	9.5	0.2	0.39	31.6	50.7	23.1
Wadi El-Natron												
1	0.8	075	3.9 x 3	12 x 12	16	0.75	9.7	0	0.318	45	62.4	33.1
1	1.1	0.7	4 x -	7 x 7	21	1	9	0.09	0.32	72.5	82.3	62.2
2	1.3	1.1	4 x 2.3	12 x 12	21	0.5	9	0.08	0.29	59.5	67	55.5
3	1	0.76	3.9 x 3	12 x 12	16.2	1	11.3	0	0.04	52.5	62.5	50.3
4	2.9	1.55	4.5 x 3	15 x 12	20.5	0.9	14.4	0.34	0.18	72.4	82.7	66.9
5	2	1.3	-	12 x 15	20	1	5.8	0	.14	74.62	82.76	68.15

Riser Height. Many farmers install the sprinkler heads directly on the lateral line without using risers (table 4.3). Risers are short pipes between the sprinkler and its supply pipe (lateral). Their purpose is twofold. They raise the sprinkler above the ground so that the jet will not be interfered with by the growing crop, and they provide a straight section of pipe leading to the sprinkler to help remove the turbulence set up when part of the flow in the lateral pipeline is diverted to an individual sprinkler. If not removed, this turbulence may carry through the nozzle and cause premature stream breakup and reduced diameter of coverage and hence produce a poor distribution pattern. The length of pipe needed to remove turbulence is about 30 cm. Some research studies indicate that 30 to 60 cm additional height improves the sprinkler distribution efficiency. However, there are obvious disadvantages to this, such as additional wind drift and problems with handling lateral pipes with long risers attached. The preferable riser height is 45- 60 cm except when irrigating higher growing crops or for fixed systems with buried lateral.

Mixed Sprinkler Head. Different type of sprinklers, nozzle sizes, nozzle configurations, and spacings were being used on the same lateral pipeline Table (4.3). As a consequence, levels of leakage increased and the efficiency of water application is further reduced.

Sprinkler nozzles are frequently plugged by dirt, grit, weeds, and trash that can be drawn into the system by the pump or enter the pipes when they are being moved from one setting to the next. To prevent blockage, filters should be placed at various places in the pipe system. The convenient location for the filter in the pipe is at the head of the lateral between the valve elbow and the first section of pipe. The filter can be made from thin sheet brass perforated with fine holes.

1- Griffin,S.B.1978.Computer programming solid set system,ASAE Paper No. 78-2o12, ASAE,St. Joseph, MI 49085.

2- Von Bernuth,R,D.1983. Uniformity design criteria under limited water. Transactions of the ASAE, 26(5):1418-1421.

While making the inspection tours, it was found that most sprinklers are not operating satisfactorily. This was clear from the diameter of pattern coverage and improper break up of nozzle stream.

Sprinkler application efficiency is reduced when worn nozzles unevenly or excessively apply water. The wear of sprinkler nozzles may be checked with a proper size drill bit.

If the proper size drill bit fits the nozzle tightly there is little if any wear but if the drill bit fits loosely the nozzle should be inspected for wear. Increasing discharge caused by worn nozzles may cause a pump to produce less pressure and/or maintain pressure and overload the motor.

Replacement equipment is frequently not compatible with existing equipment specifications. Since there is a range of sprinkler types installed, there is a risk of farmers purchasing the incorrect type of equipment and instances were observed during field evaluations where three types of sprinklers, discharge capacities and spacings were being used on the same lateral pipeline. As a consequence, the efficiency of water application is further reduced and levels of leakage increased.

Draghose Sprinkler System. The draghose sprinkler is considered as a modification of the hand move sprinkler system. In Draghose, individual sprinklers are supplied by hoses and periodically moved to cover several positions. In this case 7

sprinklers are attached to 7 flexible hoses (48 m length and 25 mm diameter) and the lateral line remains stationary. Sprinklers are mounted on skids and towed periodically to give grid patterns of 12x12 m. Risers should be high enough to keep the sprinklers above the mature crop.

The hand-move sprinkler is labor intensive system. The modification of existing hand-move by introducing draghose sprinklers would reduce labor demand to about half of that required for a comparable hand-move lateral system. It is also more convenient, easier to operate and saves deterioration of lateral pipes and fittings.

Improvements. Poor water distribution pattern may be improved by the following methods:

(1) use proper sprinkler nozzle pressure as recommended by the manufacturer.

(2) change lateral spacing. Lateral spacing should not exceed 65 percent of the diameter of the pattern under no-wind conditions. For the prevailing 10 km/hour wind speed, lateral spacing should be limited to 50 percent of the wetted diameter.

b) **Fixed (Solid) Sprinkler system**

Characteristics and performance of fixed sprinkler systems recommendation are shown in tables (4.5-4.6). Some observation and can be based on these data.

Two types of sprinklers are used. The RB70, with the sprinklers spaced 15x18 m, and the RB30 with sprinklers spaced at 12x12 m. The discharge of the RB30 sprinkler is 1.4 m3/hr at a working pressure of 2.8 bar.

Operating Pressure. Operating pressure as low as 0.8 bar was found as indicated in Table 4.6. The operating pressure for 69% of the systems evaluated are under the minimum manufacturer's recommended operating pressures of 2 bar for the sprinklers used. Operating at too low a pressure is a common problem on many sprinkler systems. It can be concluded that most sprinkler irrigation systems are operating below the correct pressure.

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The direct impact of low operating pressure is a reduction in wetted diameter and hence a distortion of the optimum water distribution pattern. As the pressure reduced, the water application pattern changes from the normal triangle shape to the doughnut shape. As a consequence, the uniformity of water application is further reduced.

Mixed Sprinkler Head. Different nozzle types and sizes were being used on the same lateral pipeline as indicated in Table 4 and in the evaluation sheets in the Appendix. Heavy wear of nozzles were found when checking with a proper size drill bit. Silt and sand particles in irrigation water can cause wear and increase the size of the bore. Sprinkler efficiency is reduced when worn nozzles unevenly or excessively apply water. Increasing discharge caused by worn nozzles may cause a pump to produce less pressure and/or maintain pressure and overload the motor. Heavy nozzle wear can mean up to 17 % more energy use by pumps to maintain correct operating pressures. This will result in extra cost and over irrigation.

Riser Height. The riser height ranges between 0.5 and 0.6 m in Bustan and reaches 1m in Wadi Natrun, as indicated in Table 4.6, which is suitable from the hydraulic point of view and also for low height crops. However, the problem lies in the erectness of the riser. Most risers are not in vertical positions. As a consequence, the uniformity of water application is reduced.

Sprinkler Spacings. The sprinkler spacings are either 15 x 15 m or 18 x 18 m in Bustan and mainly 12 x 12 m in Wadi Natrun, as indicated in Table 4.6. However, it has been shown that the wind greatly affects sprinkler performance as shown in the same Table. It can be seen that when the effect of speed and direction of the wind is not sufficiently considered in the design of the sprinkler irrigation system, the resulting system performance will be suboptimal.

As shown in Table 4.6, the sprinkler spacing exceeds 65 % of the actual measured wetted diameter of the sprinkler. However, the lateral spacing should not exceed 65 percent of the diameter of the pattern under no-wind conditions. For the prevailing 10 km/hr wind speed in the area, lateral spacing should be limited to 50 percent of the wetted diameter. Generally, highest uniformities are obtained at spacings of 40 percent or less of the diameter, but such close spacings raise both precipitation rates and costs.

Head Loss in Laterals. Sprinkler discharge is approximately equivalent to that of an orifice.

$$q_a = C\ H$$

Where H is the head at sprinkler, and C is a coefficient. In order to obtain the same discharge at every sprinkler along a lateral, H must be equal at each sprinkler. This does not usually occur in an installation and it is common practice to limit the difference in H along the lateral to 20 percent of the average H. Thus,

$$H_{max} = 0.2\ H$$

Where $\bar{H}$ is the average of the heads for all sprinklers along the lateral line, and is the maximum allowable difference in head between any two sprinklers on a lateral. This can result in a probable maximum discharge differential of

$$e = \frac{1.1\ H}{0.9\ H} = 1.11$$

or the maximum discharge rate is 11 percent greater than the minimum discharge rate. The value of H at any point (and hence of H for the line) is a function of the head loss in the laterals, the difference in elevation, and the pressure at the head of the line.

4.4. Drip System Evaluation

Figure (4.3), the frequency distribution of the emission uniformity for drip irrigation systems, shows that 20 percent of the systems had EU's equal to or greater than 80 percent. Forty-four percent had EU's equal to or less than 60%, while 36 percent of the systems were between 60 and 80 percent. Thirty-six of the drip systems, which was the maximum frequency of occurrence, had EU's less than 50 percent. It can be said that 20 percent of the drip systems were in the acceptable limits of EU (about 80 percent EU) and 44 percent of the systems showed very poor EU (below 60 percent EU).

As shown in Fig. 4.4 , drip irrigation systems in Wadi-Natron had the highest EU's (>90%), while in Sadat had the lowest EU's (<50%). Sixty-seven percent of the drip systems in Sadat area, which was the maximum frequency of occurrence, had EU's less than 50 percent. It was also observed that 33.3%, 26.9%, and none of the drip systems in Bostan, Wadi-Natron, and Sadat ,respectively, were in the acceptable limits of EU (about 80 percent EU).

Major factors responsible for low emission uniformity included: clogging of emitters, leakage, low operating pressure, mixed and broken emitters, inadequate filtration, insufficient control valves, and lengthy laterals. The study revealed that poor EU was not only due to improper design but also due to inadequate system maintenance with respect to leakage, clogging, insufficient filter capacity and system cleaning. Prevention rather than reclamation, has been the best solution to reducing or eliminating clogging. Preventive maintenance includes water filtration, field inspection, pipeline flushing, and chemical water treatment.

4.5. Observation on Drip Irrigation Systems

Drip irrigation has significant advantages over other techniques in minimizing or preventing water loss because leakage from the delivery system is negligible. Evaporation is minor as water is not discharged in the air, as with sprinkler irrigation, or left on the soil surface as with surface irrigation methods. Only a small fraction of the soil surface is wet. Therefore, the only considerable water loss in drip irrigation is deep percolation. With drip irrigation it is always very difficult to determine the soil moisture deficit in the field because of the small soil moisture variations which occur in

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the wetted soil before and after irrigation. Therefore reasonable deep percolation will be taken as 10 percent of the amount of water applied. The application efficiency is therefore: Ea = 0.9 . Eu.

In Bustan area, trickle irrigation is used mainly to irrigate citrus, apple, tomatoes, and vegetables as cucumber, pepper, squash, and eggplant. However, in wadi Natrun area, trickle irrigation is used mainly to irrigate citrus, mango, peaches, apple, tomatoes, and apricot.

Characteristics and performance of drip irrigation systems are shown in tables (4.7-4.8). Several observations and some recommendation can be based on these data.

The source of water in El-Bustan area is the Nile water, which contains organic matter, silt, and sand. Therefore, the filtration system should contain both media filter and screen filter, but as indicated in Table 4.7 about 33% of the drip systems have no filter at all. However, 66% of the drip systems have only screen filters. The screen filter does not remove organic materials, which is common in surface water.

The drip irrigation system in Sadat area is underdesigned and poorly constructed and used mainly for irrigating olives and fruit trees. As presented in Table 4.8, the groundwater salinity is variable and had values between 256-1523 ppm. Fifteen evaluations were conducted since September 1995 on drip systems in Sadat area. All of the 15 evaluations had EU's less than 70 %, as presented in Table 4.8. Of the 15 evaluations, only 3 systems had screen filter, and only 4 systems had fertilizer injection device. The most common problems were with low pressure in the lateral lines (less than 0.5 bar) and clogged emitters. The low pressure was related to low system pressure, due to the low pressure at the deep-well pump. There were instances that mixed emitters were used due to emitters from different manufacturers being used in the same zone and/or emitters in the same zone having different flow rates. Problems from leaks in laterals were due to leaks and/or cuts in the lateral along the length of the rows. In one instance, there were missing parts from the emitters, resulting in low emission uniformity.

Table 4.7 Summary of the field evaluation for the drip irrigation systems in El-Bostan

No	location	crop	EC ppm	Emitter type	P.bar	q_e L/H	spacing m x m	Lateral line			Filter		Fertilizer unit type	Performance		liter/day /plant
								Diameter mm	Lenght m	(Pmax-Pmin) bar	Type	P loss		E_u	Ea	
1	El-bostan	citrus +apple	-	spaghetti	0.5	90	4 x 2.5	16	20	0.2	Non	-	Non	78.4	70.5	90
2	El-bostan	citrus	-	spaghetti	0.5	50	4 x 4	11	20	0.2	Non	-	Non	41%	36.9	50
3	El-bostan	citrus	-	spaghetti	0.5	90	4 x 2.5	16	20	0.2	Non	-	Non	78.4	70.5	90
4	El-bostan	vegetable	-	GR	1.4	4	1.75 x 0.5	16	40	0.3	screen 60 . m3/h	-	-	87.4	78.6	2
5	El-bostan	vegetable	-	GR	1.5	4	1.85 x 0.5	16	45	0.3	screen	-	-	85.5	76.9	4
6	El-bostan	vegetable	-	GR	1	4	185 x 0.5	16	42	0.1	screen	-	-	89.8	80.8	8
7	El-bostan	squash + egg plant	-	GR	1.4	4	1.8 x 0.5	16	42	0.2	screen	-	-	72.7	65.4	4
8	El-bostan	Tomato	-	GR	0.7	4	1.7 x 0.5	16	45	0.1	screen	-	-	71.6	64.4	4
9	El-bostan	vegetable	-	GR	0.5	4	1.8 x 0.5	16	55	0.1	screen	-	-	71.2	64.1	4

Table 4 ; 8 . Summary of the field evaluation for the drip irrigation systems in Sadat

No	location	crop	EC ppm	Emitter type	P.bar	q_e, L/H	spacing s m x m	Lateral line			Filter		Fertilizer unit type	Performance	
								Diameter mm	Lenght m	(Pmax-Pmin) bar	Type	P loss		E_u	Ea
2	Sadat	olives	-	spagetti	0.25	30.9	6 x 5	16	55	0.2	Non	-	Non	24.8	22.3
3	Sadat	olives	294	spaghetti	0.15	17.9	5 x 7	16	40	0.1	Non	-	Non	5.02	4.52
4	Sadat	apple	256	E2	0.6	34.7	6 x 6	16	65	0	Non	-	Non	40.2	36.2
5	Sadat	Gawafa	-	spaghetti	1.0	60	5 x 2.5	16	30	0.6	gravel+ screen	-	-	69.5	62.5
6	Sadat	Lemon	-	spaghetti	0.25	26.73	5 x 5	16	60	0.2	Non	-	Non	11.22	10.09
7	Sadat	pepper	435	katif	0.2	4.05	0.5 x 1.9	16	30	0.1	Non	-	200 liter tank	58.8	53
8	Sadat	cucumber	435	katif	0.15	3.96	0.5 x 1.8	16	34	0.1	2 screen 3"	-	200 liter tank	57.8	52
9	Sadat	Mendalin	1203	microjet	0.7	35.96	4 x4	16	35	0.4	3 screen4"	0.2	venturi1"	49.4	44.46
10	Sadat	olives	-	spaghetti	0.3	36.23	4 x 4	16	35	0.3	Non	-	Non	45.37	40.84
11	Sadat	olives	294	E2	0.2	30.78	6 x 6	16	36	0.1	Nin	-	Non	38.3	34.47
12	Sadat	olives	1523	spaghetti	0.45	57.7	6 x 5	16	60	0.3	Non	-	Non	62.95	56.65
13	Sadat	Tomatoes	256	katif	0.3	8	0.5 x 1.5	16	30	0.2	2 screen3"	-	100 liter tank	46.8	42.12
14	Sadat	olives	-	spaghetti	0.55	91	6 x 6	16	78	0.2	Non	-	Non	69.3	62.37
15	Sadat	apple	-	saghetti	0.4	74.34	6 x 6	16	75	0.4	Non	-	Non	27.4	24.6
16	Sadat	olives	493	E2 without cap	0.4	54	6 x 5	16	75	0.5	Non	-	Non	40	36

In Wadi El-Natrun area the source of water is wells. Therefore, screen filter or disc filter is satisfactory for the filtration system. As indicated in Table 4.9, only 30% of the drip systems contain pressure gages before and after the filter to enable monitoring the pressure loss across the filter and hence know the time of cleaning and also figure out the filter efficiency. As also presented in Table 4.9, the pressure loss across the filter reached 3 bar in some drip systems which indicate a large pressure loss due to filter blockage and may need to change the media.

No fertilizer injection device was found in the drip systems evaluated in El-Bustan area. However, in Wadi Natrun area, the fertilizer injection devices are common. In drip irrigation, the fertilizer spread on the soil surface does not leach into the root zone, therefore it has to be injected into the drip system. The differential pressure tank of 150 liter capacity is the most widely used fertilizer injection device.

In Bustan area, the most widely used emitter types are GR dripper line, which deliver 4 liter/hour at 50 cm spacing and used for vegetables and tomatoes as well, and spaghetti tubes which used for irrigating citrus and deciduous trees as well. In Sadat City area, the most widely used emitter type is the spaghetti tubes for fruit trees. However, in Wadi Natrun area, the most widely used emitter types are GR for tomatoes, Turbo-key, Microjet, and Katif for fruit trees. Two emitters per tree is a common practice.

Table 4.9 presents a great difference in the irrigation water application in different areas for the same crop. For example a crop as tomatoes is given 8 liter per day per plant in Wadi Natrun, while is given 4 liter per day per plant in Bustan. Another example is citrus, the tree is given different amount of water at the same age which ranges between 12 to 32 liter/day per tree. However, the citrus tree in Bustan is given 50 to 90 liter/day per tree.

The spacing between driplines ranges between 1.6 - 1.85 m for vegetables. However, it ranges between 3.5 to 4 m for citrus and fruit trees, except for a small percentage which reaches 6 m.

Table 4.9 . Summary of the field evaluation for the drip irrigation systems in Wadi-El Natron

No	location	crop	EC ppm	Emitter type	P.bar	q_e L/H	spacings m x m	Lateral line			Filter		Fertilizer unit type	Performance		liter/day /plant
								Diameter mm	Lenght m	(Pmax-Pmin) bar	Type	P loss		Eu	Ea	
1	North section	orange	442	spaghetti	0.3	50	5 x 5	16	35	0.1	Non	-	Non	65	58.5	16.7
2	North section	olives	1107	spaghetti	0.6	81	5 x5	16	70	0.5	Non	-	150 liter tank	37.4	33.7	40.5
3	North section	appel	595	katif	0.68	7.5 x 2	3 x 4	16	45	0.1	4 screen	-	hydraulic	88.1	79.3	15
4	North section	olives	499	spaghetti	0.3	55,8	7 x 7	16	45	0.1	screen 2"	-	venturi 3/4"	60.7	54..7	37.2
5	North section	olives	704	Jet sprink	1.3	38.48	6 x 6	16	36	0.1	2 screen 3"	-	Non	91.6	82.44	64.1
6	North section	olives	1760	katif	0.77	8.8	5 x 5	16	100	0.2	4 screen	0.2	150 liter tank	67.3	68.7	92.4
7	North section	Grapes	-	microject	0.3	13.27	2.5 x 2.5	16	75	0.5	2 screen 3"	0.2	150 liter tank	34.36	30.93	2.6
8	North section	olives	448	spaghetti	0.15	38	7.5 x 7.5	16	55	0.1	disc 3"	0.2	150 liter tank	43.36	39.03	28.5
1	South section	citrus	505	microjet	0.4	27.4	3.5 x 3.5	16	30	0.1	3 screen filter 4"	0.2	hudraulic injection pump	45	40.5	27.4
2	South section	peaches	307	Rain bird	0.6	3.46	4 x 6	16	80	0.1	screen	3.0	150 liter tank	60.7	54.6	27.7
3	South section	citrus	480	microjet	0.475	24.3	3 x 4.5	16	50	0.3	3 screen 4"	-	150 liter tank	71.3	64.1	18.23
4	South section	appel	342	microjet	0.64	33.6	3 x 4	18	48	0.2	screen. 6"	0.20	Non	74.6	67.1	33.6
5	South section	tomatoes	237	Gr	0.4	2.0	0.5 x 1.6	16	45	0.1	screen 6"	0.1	250 liter tank	86.3	77.6	8
6	South section	citrus	256	turbo-key	1.3	7.8	3.5 x 4	18	50	0.3	screen 6"	0.1	250 liter tank	44.1	39.7	31.2
7	South section	Apricot	295	katif	0.7	4.47	4 x 6	16	50	0.1	screen + sand sep.	0.1	200 liter tank	78.9	70.97	17.9
8	South section	Tomatoes	384	GR	0.6	2.9	0.5 x 1.6	16	35	0.1	3 screens 3"	-	150 liter tank	95.8	86.2	5.8
9	South section	Apple	262	metalic plastic	0.33	5.53	3 x 4	16	45	0.3	3 disc 3" 120 mesh	-	200 liter tank	39	35.1	44.2
10	South section	olives	288	microjet	0.46	22.45	3 x 5	16	105	0.4	screen 6"	0.6	150 liter tank	39	35.1	44.2
11	South section	olives	-	spaghetti	0.54	95.4	6 x 6	16	90	0.5	3 screen	0.2	basin	53.8	48.5	95
12	South section	Apricot	250	turbo-key	1	3.93	3 x 6	16	85	0.2	screen 6"	0.25	venturi 1.3"	774	69.4	23.6
13	South section	Tomatoes	448	GR	0.9	3.2	0.5 x 2	16	45	0.2	screen 6"	0.2	venturi - 1"	83.2	74.9	12.6
14	South section	citrus	250	micro.spr	1.2	36.1	3.5 x 7	16	55	0.1	screen 6"	0.25	venturi 1.3"	84.4	76	54
15	South section	olives	288	Rainbird	1.0	4.57	6 x 6	16	100	0.1	4 screen 3"	0.2	200 liter tank	61.3	55.1	18.3
16	South section	Tomatoes	525	Gr	0.9	2.8	0.5 x 1.5	16	80	0.6	2 disc 3"	-	120 liter tank	60.8	54.7	1.4
17	South section	olives	396.8	microject	0.4	19.65	6 x 6	16	66	0.2	4 screen 6"	-	200 liter tank	53	47.7	14.7
18	South section	peaches	269	Rain Bird	0.6	4.5	5 x 5	16	50	0	2 screen 6"	0.1	venturi 1"	83.8	75.4	6.75

The calculated crop water requirement for the previous crops during the month of september is as follows:-

2. Tomatoes at emitters spacing of 0.5 x 1.75 m,

$$Crop\ water\ use\ (liter/day) = Et_o \times ke \times Sl \times Sm$$

$$Lpd = 6.2 \times 0.6 \times 0.5 \times 1.75 = 3.25\ lpd$$

where

Eto: potential evapotranspiration, mm/day

kc : crop coefficient

Sl : emitter spacing on lateral line, m

Sm: lateral spacing, m

2. Deciduous fruit trees at spacing 3.5 x 4 m

$$Crop\ water\ use\ (liter/day) = Et_o \times ke \times St \times Sr$$

$$Lpd = 6.2 \times 0.8 \times 3.5 \times 4 = 3.25\ lpd$$

where

St: tree spacing in row, m

Sr: row spacing, m

3. Citrus trees at spacing 3.5 x 4 m

$$Tree\ water\ use\ (liter / day) = Eto \times kc \times St \times Sr$$

$$Lpd = 6.2 \times 0.85 \times 3.5 \times 4 = 73.78\ Lpd$$

The typical irrigation frequency is either daily or every other day which is reasonable according to the following calculations:

$$dn = AW \times Dr \times depletion$$

$$= 60\ mm/m \times 0.7\ m \times 0.30 = 12.6\ mm$$

$$F = \frac{dn}{Eto \times Ke} = \frac{12.6}{6.2 \times 0.8} = 2.54 = 2\ days$$

where

dn: net application depth, mm

AW: soil available water, mm/m

Dr : Active root zone depth, m

F : irrigation frequency, days

The average emitter operating pressure for 67% of the drip systems evaluated is below one bar which is the correct design pressure.

The typical lateral line length is 50 meter and the typical lateral diameter is 16 mm. As a consequence, the pressure drop along the lateral line is limited to 0.3 bar, according to the line discharge. However, in Bustan area, the preinstalled drip system has lateral length of 90 m and lateral diameter of 13 mm, which is considered as a poor design. As a consequence, the graduates change the system to 50 m lateral length with a diameter of 16 mm.

The spaghetti tubing in El-Bustan gave an emission uniformity as high as 78% and application efficiency as high as 70%. The GR dripline used for vegetables in Wadi El-Natrun showed a high performance of 95% emission uniformity and 86% application efficiency, while in Bustan area the emission uniformity is as high as 87% and the associated application efficiency is 78%. The Katif emitter in Wadi El-Natrun showed emitter uniformity as high as 79% and application efficiency of 71%. However, the Microjet showed an emission uniformity of 74% and application efficiency of 67%.

The low emission uniformity (below 80%) can be attributed to:

1- low operating pressure

2- no water filtration or using unsuitable filter.

3- emitter clogging.

4- no line flushing.

5- no chemical water treatments.

6- leaks in laterals.

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Clogged emitters were determined when the flow rate from an emitter was not at the manufacturer's recommended rate at the operating pressure. The clogging was due to either a buildup of chemical precipitation or to mineral and organic particles. The problem with excessive and under watering was due to either operating schedule or unavailability of water. In most cases, the irrigator was unaware of how much water the system was delivering. Based on the calculations made by the research team, the irrigation duration was not correct on most cases. The problem with non-uniform pressure in the delivery system was due to design or installation errors. In many instances, the lateral pipe diameter was not the correct size for the length and total number of laterals in the zone. The problem with mixed emitters occurred where the irrigator replaced missing or clogged emitters with emitters that were from a different manufacturer or had a different flow rate.

Improvements. A major improvements would be to increase the percent of wetted area. This could be achieved by adding one or two emitters at each tree or increasing the duration of application, hence longer application wet more soil volume.

The number of emitters per plant is determined by two factors. First is the number of liters per day required and the number of hours of operation available to apply the quantity of water. For the required 80 liters per day per tree, 4 emitters of 4 liters per hour are required, or 2 emitters of 8 liters per hour. Both cases would then operate for 5 hours.

The second factor affecting the number of emitters per tree is the requirement to wet a given portion of the root zone. It is recommended that at least 50% of the root zone be wetted. In sandy soil, the average area wetted by one emitter is 1.8 m^2. The number of emitters required can be calculated as follows:

$$\textit{No. of emitters} = \frac{\textit{(Area per plant) } m^2 \textit{ x 0.5 (50\% of the soil)}}{R^2 \textit{ (Area wetted by each emitter)}}$$

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For the tree spacing of 3.5 x 4 m in sandy soil (1.8 m^2 - average area wetted by one emitter);

$$No.\ of\ emitters = \frac{3.5 \times 4 \times 0.4}{1.8\ m^2} = 4\ emitters$$

The preinstalled drip irrigation system in Bustan was designed for Citrus trees planted at 6x6 m spacing and no provision was made for growing other crops. Each tree is provided with 4 drippers each giving 4 *liter/hour* at a working pressure of 1 bar. Polyethylene 13 mm outside diameter lateral line of a length of about 80-90 m serving 14 trees is used.

The drip system introduced to El-Bustan is underdesigned and poorly constructed and no provision was made for more drippers once the trees have grown. The design working hours of pumping stations of 15 hours per day are not met. In addition, since the unit is designed for the production of fruit trees only, this would mean settlers have no income for the first 3-5 years. The modification of existing drip system by adding new drip laterals for vegetable cultivation (high value crops) would help the settlers to increase their income until their orchards came into production.

Most farmers are either adding fertilizer after filtration or adding fertilizer by spreading or broadcasting over the soil surface. Under trickle irrigation, the water does not leach the fertilizer spread or broadcast over the soil surface into the root zone; therefore, it is necessary to add much of the required fertilizer, especially nitrogen, directly to the irrigation water. Any fertilizer applied through the trickle irrigation system should be added before the screening or filtration.

Prevention, rather than reclamation, has been the best solution to reducing or eliminating emitter clogging. Preventive maintenance includes water filtration, field inspection, pipeline flushing, and chemical water treatment.

5. IRRIGATION SYSTEMS MODIFICATIONS

5.1. *Background*

One of the main objective of this project is to introduce some of the modifications to the typical irrigation systems within the project area to:

1- improve irrigation system efficiency and water distribution uniformity.
2- reduce the time and effort needed to operate the system.
3- reduce water losses.
4- reduce sprinkler blocking and damage.
5- reduce the cost of installation and operation of the system.
6- improve fertilizer efficiency.

The modifications included the optimum sprinkler spacing for different sprinkler types in the market to obtain maximum water uniformity and the use of offsets technique in hand-move systems. Every other irrigation the lateral line is laid down midway between where it was the previous irrigation. This practice of using alternate sets requires no more irrigations during the season, but it does provide water midway between the ordinary lateral location where overlap is often insufficient. Modifying hand-move system to drag hose sprinkler system would reduce the labor demand and save deterioration of lateral pipes and fittings and further reduce water leakage. A screen filter has been introduced in hand-move systems at the head of the lateral line between the valve elbow and the first section of pipe to avoid nozzle blocking. The project has also introduced a modified fertilizer tank to hand-move systems which will enable a substantial increase in yield and quality and furthermore, will potentially increase water and fertilizer efficiency and save labor and energy. In fact, no fertigation has been practiced with hand-move systems in Egypt.

5.2. *Hand-Move Screen Filter*

During the irrigation survey made by the project, farmers who used hand-move sprinkler systems indicated that they faced the problem of blocking the sprinkler nozzles and they had to clean the nozzles every time they moved the lateral sprinkler line from one setting to the next. Therefore, a study of samples of nine random farms that had hand-move systems was taken out in South Tahrir.

Three of the nine farms did not use any filter or screen and the remaining six farms used a local, low quality screen which became apparent by studying the hole diameters, sprinkler nozzle diameters, type of impurities, and length of perforated pipe. Measurements taken on the screens of the six farms in South Tahrir are as follows:

Hole diameter (mm) : 5 , 9.7 , 7 , 6 , 8, 14
Nozzle diameter (mm): 5 , 6 , 6 , 5 , 7, 6
Perforated pipe length (cm) : 70 , 50 , 70, 60, 50, 70

Samples of impurities were also collected from screens of the six farms in South Tahrir as shown in Figs. 5.1 and 5.2. The collected impurities indicated that the surface water supply is not clean and the sprinkler nozzles are prone to blockage. Therefore, sprinkler irrigation should be equipped with screens. A convenient location for a screen is at the head of the lateral line between the valve elbow and the first section of pipe.

Description of the typical screen: A section of pipe 1.0 m length and 3 inches in diameter was perforated by either a hand drill or nail. The screen lip was made by two different methods. The fist method is inserting a 2.5 inch metal pipe 10 cm long with a lip, inside the original pipe and fixing it with a bolt and screw (Fig.5.3). The second method is pounding on the pipes edges to bend it into the form of a lip and supporting it with a metal ring (Fig.5.4). The first technique was preferred.
The end of screen was made by:

(1) cutting lateral sections (strips) at the end of the pipe and bending them inside (Fig. 5.5).

(2) welding or compressing a plate of thin aluminum; which can also be perforated (Fig. 5.6).

It is apparent from the pictures that the end of the filter is damaged as a result of cleaning the screen by hitting the end against a hard surface. For this reason the end of the screen should not be perforated to withstand the external stresses when being cleaned. Another advantage of having the end not perforated is that it would act as a collector of impurities, and would reduce the disintegration of the impurities, clogging the perforations themselves, thus avoiding nozzle clogging.

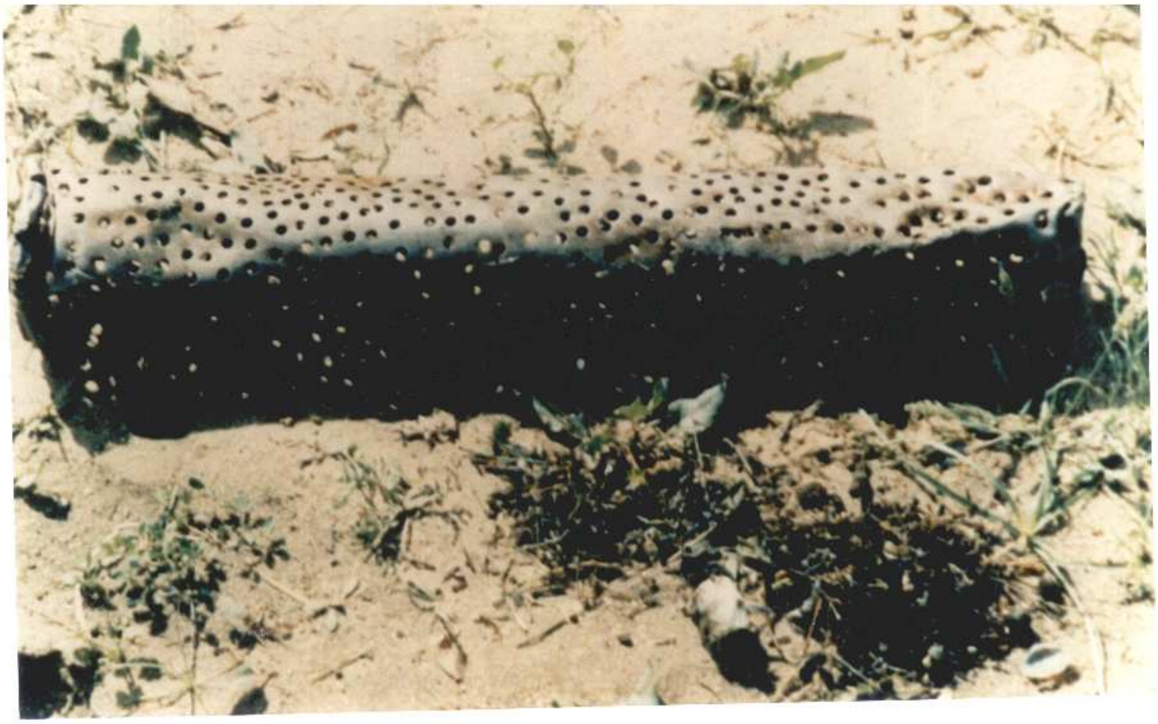

Fig. 5.1: Sample of Impuritie Collected by the creen at the End of the Irrigation Set

Fig. 5.2 : Sample of Imputritie After Drying

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It was necessary at the beginning before manufacturing the screen to calculate its' length first which would filter the water. From our experience, we suggest that the hole drilled into the pipe be of 4 mm in diameter (D = 4 mm) at equal distances, which would be smaller than the smallest nozzle diameter in the area.

1- In case of holes at equal distance of 2D;

$$P = \frac{\frac{\pi D^2}{4}}{(2D)^2} = 0.2$$

where P is the percentage of open area

2- In case of holes at equal distance of 3D;

$$P = \frac{\frac{\pi D^2}{4}}{(3D)^2} \cong 0.1$$

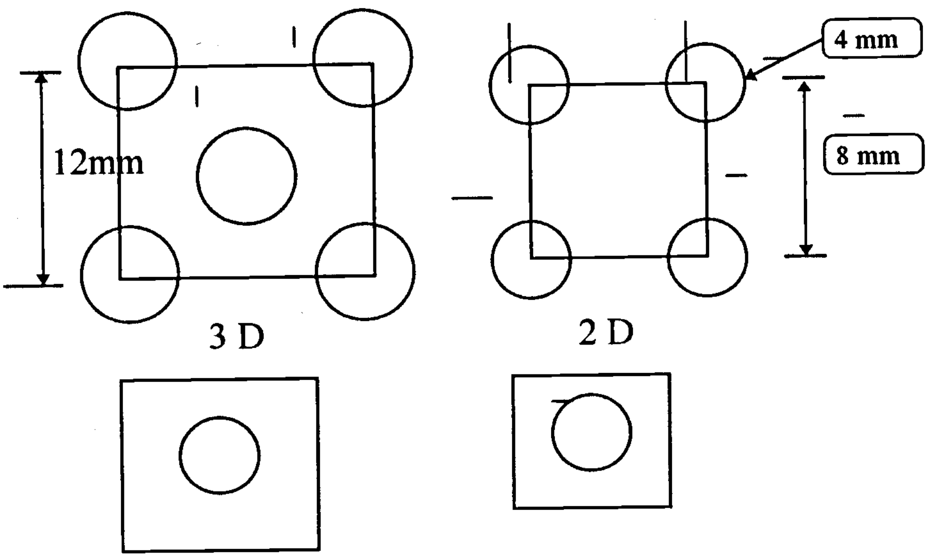

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Fig. 5.3: Making the screen lip by Inserting a 2.5 inch metal pipe with a lip inside the original pipe and Fixing it with a bolt and screw.

Fig. 5.4 : Making the Screen lip by Pounding on the Pipe edge to bend it into the form of a lip

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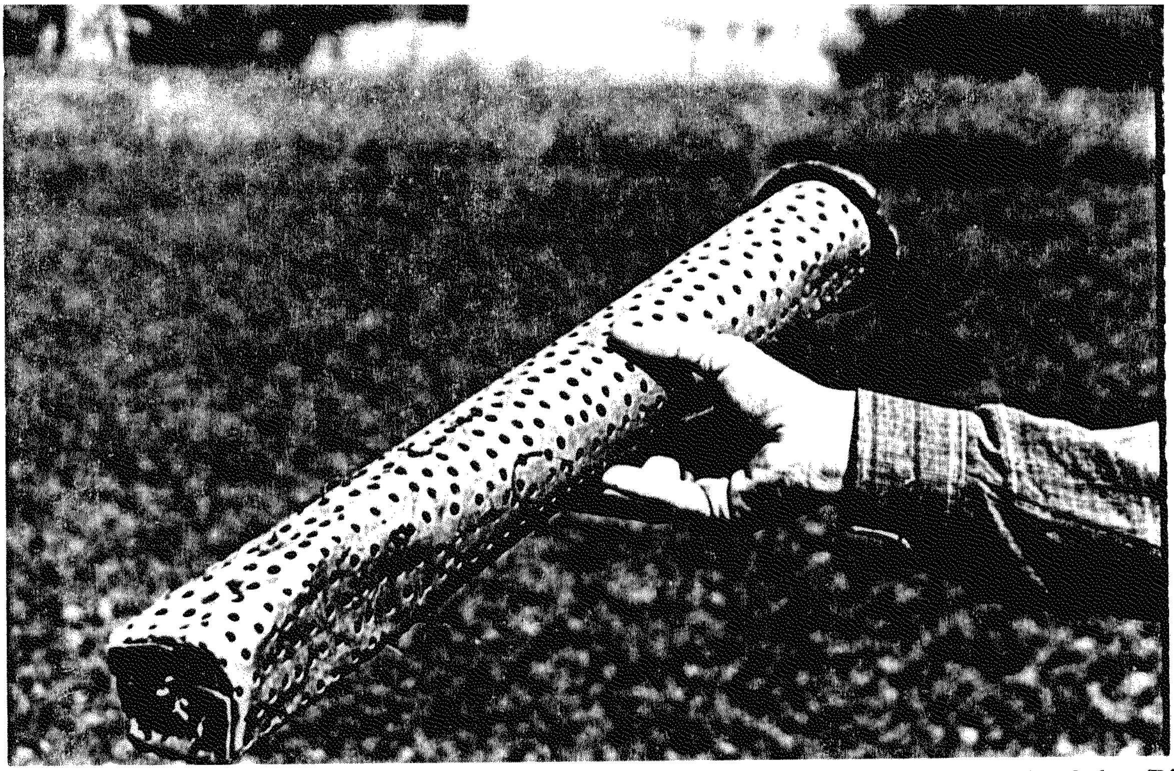

Fig. 5.5: Making the End of the Screen by cutting the End of the Pipe into Strips and bending them inside

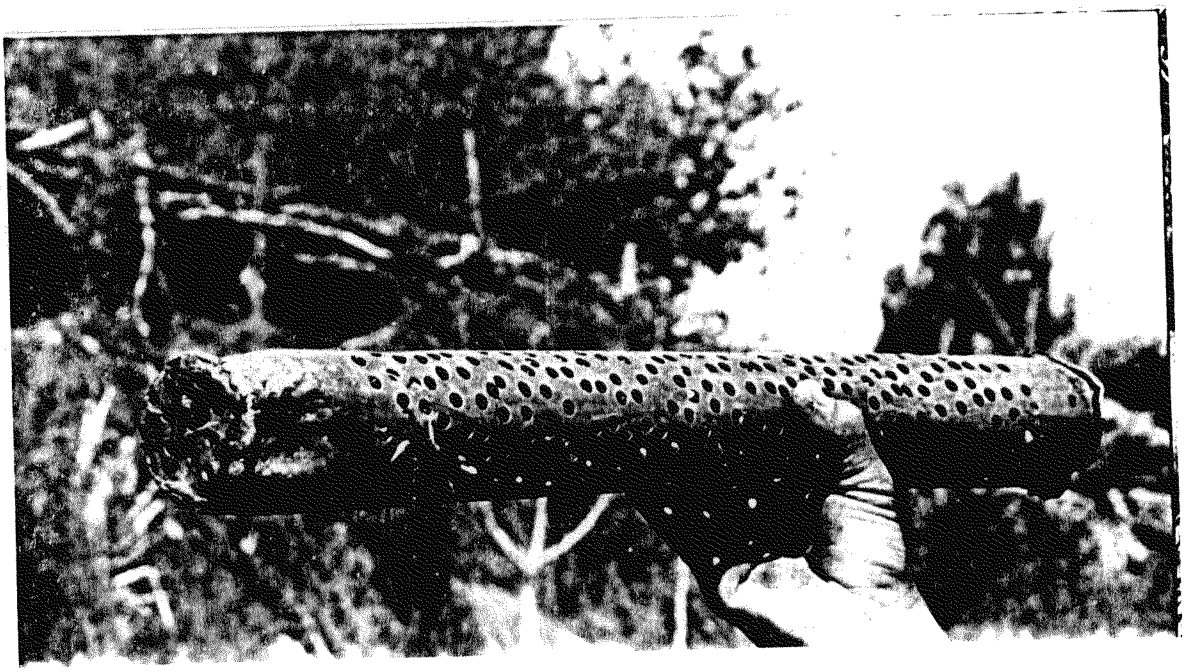

Fig. 5.6: Making the Screen by compressing a plate of thin aluminum; which can also be perforated

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The major factor in controlling head loss through the screen is the percentage of open area. For practical purposes a minimum open area of 15 percent is desirable; this value is readily obtained with many commercial screens. To minimize losses and screen clogging, entrance velocities should be kept within specified limits. To keep the flow velocity unchanged across the screen and prevent suppressing flow, the flow cross-sectional area of the lateral line should equal to the screen open area as follows;

Flow cross-sectional area of the lateral line = Screen open area

$$(\pi\, d^2)/4 = C\, \pi\, d_s\, L_s\, P$$

Where:

L_s = screen length

d_s = screen diameter

P = percentage of open area in the screen.

C = clogging coefficient (C = 0.5)

d = lateral pipe diameter

Substituting, <u>P= 0.1</u>, d = 4 in (4 x 2.54 cm), d_s = 3 in, and C = 0.5 into the previous equation, yields:

$(4 \times 2.54)^2 = 4 \times 3 \times 2.54 \times L_s \times 0.1 \times 0.5$

<u>L_s = 68 cm</u>

If **<u>P = 0.2</u>**, and C = 0.33, then;

<u>L_s = 51 cm</u>

When manufacturing the screen in a length equals 51 cm (C = 0.33), a factor of safety was provided so that the area of filtration would be 3 times that of the calculated, thus the perforations would not clog when impurities passed through the screen and would

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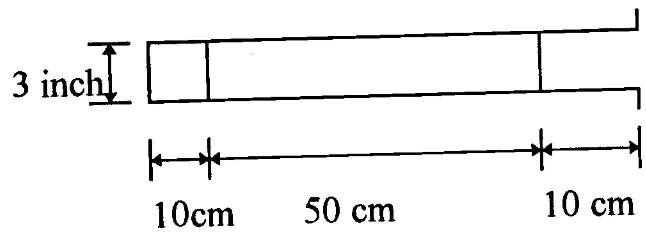
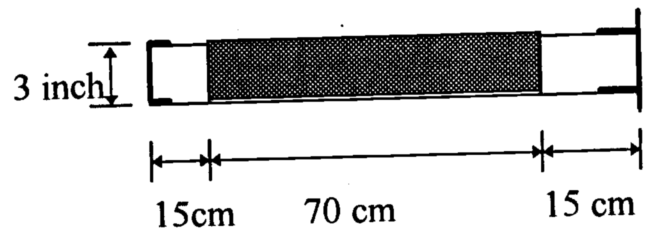
decrease the loss in head and discharge. Similarly, a factor of safety of 2 was provided in case of manufacturing the screen in a length equals 68 cm (C = 0.5).





Both types of filters were tested and the results were as follow:

(1) Both screens had a high cleaning efficiency before the first half hour was completed; no nozzle clogging, head loss did not exceed 1m.

(2) After the first half hour, Case Ls= 68 cm had a head loss of 3 m but no nozzle clogging occurred. Case Ls= 51 cm had a head loss of 5 m, that was the result of the heaviness of the perforations that became clogged, but no nozzle clogging was present.

As a result, the modified screen manufactured were of the following specifications:

(1) Perforations of 4 mm in diameter made with a hand drill at equal distances of 3D.

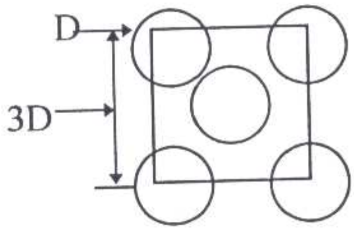
(2) Lip was made by using the first method.

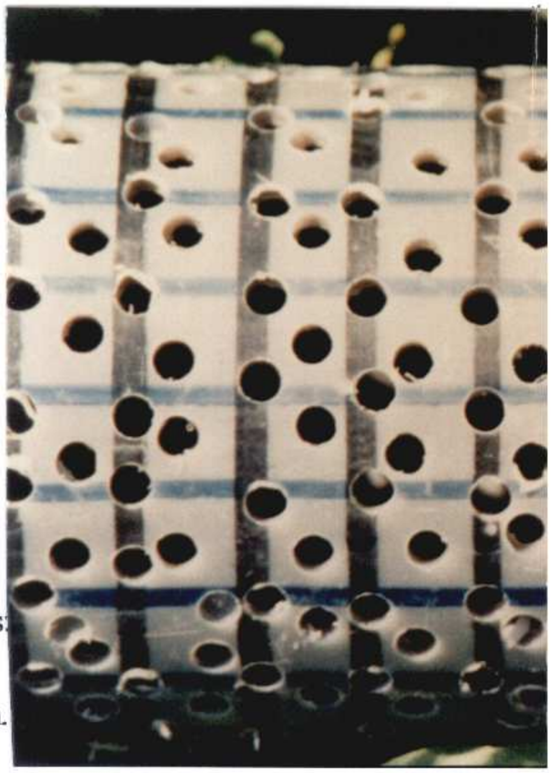
(3) End of screen by the second method.

(4) Both beginning and ending were left unperforated (10, 15 cm long).

A further modification was made by drilling a hole directly in the center of the surrounding 4 perforations as follows;

$$P = 2(\pi D^2/4)/(3D)^2$$
$$= 0.175$$





When evaluating the modified screen the results were as follows:

(1) No nozzle clogging.
(2) Reduction in head loss; lost head only reached 0.5 m.

These screens proved efficient after being distributed among the nine random farms in South Tahrir. The screen inside the quick coupling of the lateral line is shown in Fig. 5.7.

Other modifications in the screen were made using PVC pipes as an alternative to aluminum pipes reduced the cost from LE 15 to LE 7, reduced manufacturing time from 2.5 hrs. to 1 hr, produced a lighter more durable screen that would not corrode or wear (Fig.5.8).

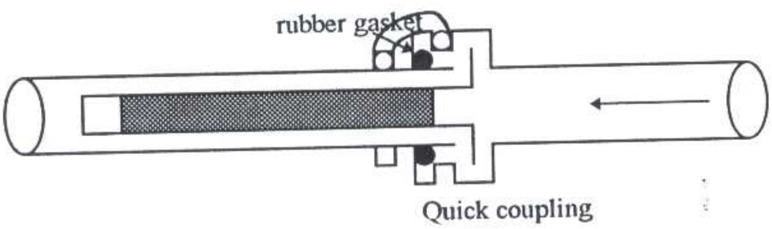


Fig. 5.7. Schematic drawing of the screen inside the lateral line.

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Final specifications of the modified screen.

- Perforations 4 mm in diameters using a spacing of 1.5 D.
- Lip was made by gluing a flanged short PVC pipe 75 mm / 3 inches to the 75 mm pipe.
- End of screen was a 75 mm cap of PVC.
- A distance of 15 cm was left at the beginning and end of the screen.

Fig. 5.8 The Modified PVC. Screen

5.3. *Fertigation*

One of the main strategies of agricultural development in Egypt is reclamation of the desert land. With such a development, it has become feasible the application of fertilizers (fertigation) and of other chemicals (chemigation) through the irrigation systems. In this way, water soluble fertilizers at certain concentration to meet nutrient requirements of the crop for maximum yield of a certain quality, are conveyed with every irrigation to that volume of the soil where most of the active root system is developed.

Fertigation is particularly important for the irrigated agriculture of Egypt in general and of desert land in particular because of the sandy nature of the soils (6-8% field capacity, very poor in nutrients, and particularly with no exchange capacity) where large quantities of fertilizers should be applied to meet crop requirement and yet no losses by leaching be occurred.

The project, therefore, had to introduce new technology which will enable substantial increase in yield and quality, and furthermore, will potentially increase water and fertilizer efficiency and yet saving labor and energy.

The government's policy encourages adoption of efficient methods of irrigation and fertigation. However, no fertigation is practiced at the desert land except at large companies and farmers are in general ignorant of this new technology. Because of this, water and fertilizer efficiency are hardly satisfactory .

One of the objectives of the project was, therefore, to study and evaluate the present situation and to introduce in the project area the new technology of fertigation, that will demonstrate to the farmers the benefits of this approach, for a wider use of the method in the future.

Some of the advantages of fertigation are: improved efficiency of fertilizer recovery, minimal fertilizer losses due to leaching control of nutrient concentration in soil solution, flexibility in timing of fertilizer application in relation to crop demand, and saving in energy and labor in application. In addition, fertigation reduces fluctuations of soil solutions, particularly for salt sensitive crops. Possible disadvantages include unequal fertilizer distribution when irrigation system design or operation is falulty, the possibility of over-irrigation or leaching if rainfall occurs at the time of fertilizer application, and chemical reactions in trickle system leading to corrosion, precipitation of chemical materials, and/or clogging of outlets. This is not the case in sprinkler irrigation where the water passage through the sprinkler nozzles is wide enough to prevent clogging.

Description of the fertigation system

The fertigation unit is composed of a fertigator (fertilizer injector, metering pump), a fertilizer tank for the concentrated stock solution, a non-return valve, a main filter and a water meter. Depending on the model of the fertigator additional equipment (valves, pressure and flow regulators) may be required. The incorporation system should be designed in such a way so as to accommodate all the fertilizers and/or other agri-chemicals that are used in the fertigation (chemigation) system. For this, the inserting equipment must overcome the water pressure in the system, and the fertilizer solution should be stored in a chemically intert container. The metal tanks may corrode and, therefore, plastic containers are preferred. To by-pass the filter when filtering not necessary two injection points are recommended, one before and one after the filter. Flushing after fertigation reduces both the corrosion hazard and microbial growth.

Do Fertilizers Ruin Sprinkler Systems

Care must be taken to see that the fertilizer and concentrations used are not corrosive to distribution system parts. Table 1 indicates the potential degree of corrosion problems on different types of metal from various sources of fertilizers.

The basic principle of operating fertilizer and chemical injection systems is that the material should not be allowed to sit in the lines when the system is not operating. This is done to avoid potential corrosion problems. Material should not be injected into the system until all lines are filled and sprinklers or emitters are discharging. Standard practice to accomplish the objectives is not to begin injection until half hour after flow has begun and to terminate injection until half hour before shutting down the system. This time period should insure adequate flushing of potentially problem chemicals from the line.

Table 5.1 Severity of Corrosion to Common Metals Caused by Fertilizers (Adapted from Martin, 1955)

Type of Metal	*Calcium Nitrate*	*Ammonium Nitrate*	*Ammonium Sulfate*	*Urea*	*Phosphoric Acid*
Galvanized Iron	M	SV	C	N	SV
Sheet Aluminum	N	SL	SL	N	M
Stainless Steel	N	N	N	N	SL
Yellow Brass	SL	C	M	N	M
pH of Fertilizer Solution	5.6	5.9	5.0	7.6	0.4

Note: N = None SL = Slight M = Moderate C = Considerable
SV = Server

5.3.1. Type of Equipment

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5.3.2. Venturi Injector

A constriction in the main water flow pipe causes a pressure differential (vacuum) which is sufficient to suck chemical solution from an open reservoir into the water flow. The installation of venturi injector is shown in Fig. 5.9. The rate of flow can regulated by means of valves. This is a simple and inexpensive method of chemical application, but it has some disadvantages: The pressure loss across a Venturi valve is high (about 1/3 of the operating pressure) and precise regulation of flow is difficult because the injection is very sensitive to the pressure and rate of flow in the system. In fixed systems, the venturi injector can be installed on a by-pass of the total irrigation flow. In this way, the head loss decreases considerably and the chemigation system can be disconneccted and moved easily. The apparatus is quite simple, relatively inexpensive and does not have moving parts. The suction is from an open plastic container; the dilution ratio does not fluctuate. Among the limitations are relatively large head loss, and sensitivity to changes in pressure and discharge rate. Therefore, for normal operation it requires high pressure in the irrigation system.

5.3.3. Injection Pumps System:

With this method a pump is used to inject chemical solution from an open tank into the irrigation line. The solution is normally pumped from an unpressurized tank, and the choice of type of pump used is dependent on the power sources. The pump may be driven by water pressure (Fig 5.10), by an internal combustion engine, by an electric motor or by a tractor power take-off. The electric pump can be automatically controlled and is thus the most convnient to use. However, it use is limited by the availability of electyrical power, and is therefore, more suited to glasshouse than to filed cultivation. Changes in water flow, power failure of mechanical failure may caue serious deviations from the planned concentrations.

Another disadvantage of this system is the need for an external power source and the relatively high cost of the system. The use of a hydraulic motor, operated by the line pressure, avoids these difficulties. This device requires a minimal pressure of about 15m of water to operate. The general disadvantages of the injection pump system are outside power sources may needed and the installation is complex and costly compared to other applicances.

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Fig. 5.9 Venturi Fertilizer injector installation

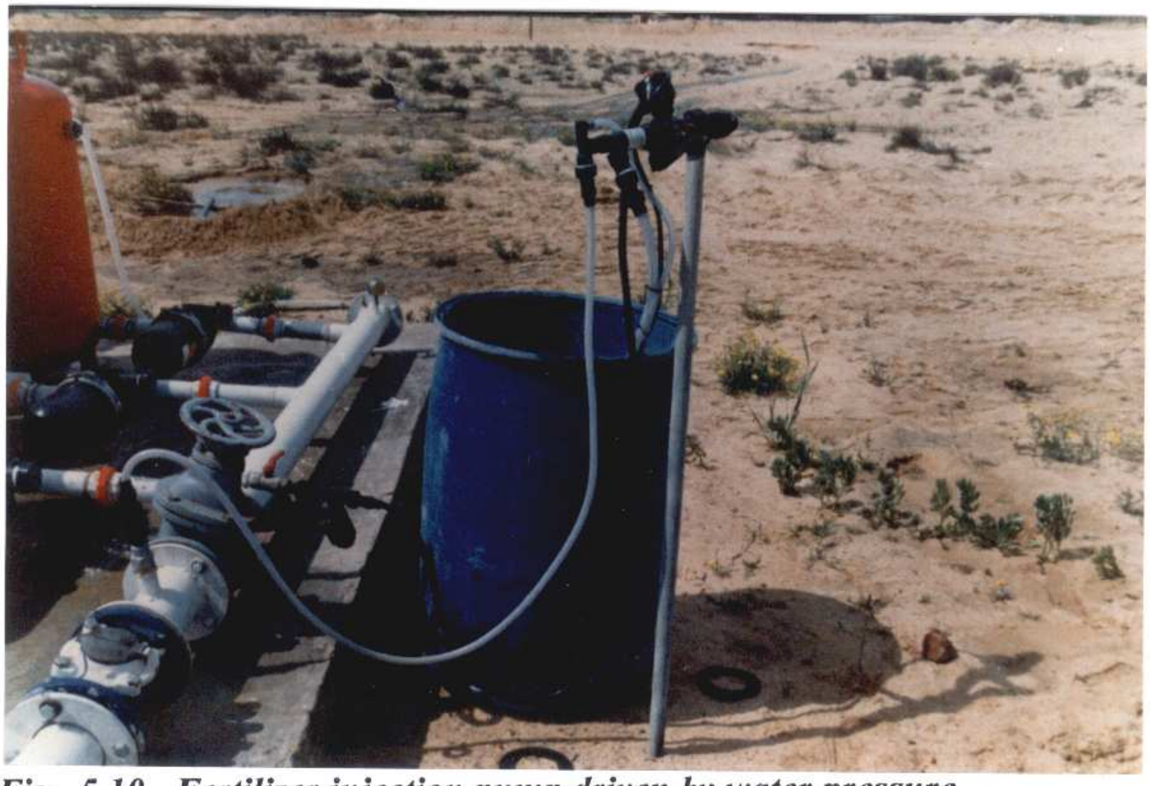

Fig. 5.10 Fertilizer injection pump driven by water pressure

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5.3.4. Fertilizer-Tank By-Pass System

This method employs a tank into which the dry or liquid chemical is placed. The tank is connected to the main irrigation line by means of a by-pass so that some of the irrigation water flows through the tank and dilutes the chemical solution. This by-pass flow is brough about by a pressure gradient between the entrance and exit of the tank caused by permanent constriction in the line or by a control valve (Fig. 5.11). The concentration of chemicals in the tank decreases gradually until it reaches the level of the irrigation water. Experience has shown that with liquid fertilizers it takes four tank-volume displacements to empty the tank of fertilizer. If solid fertilizer is used, at least ten volume displacements are needed to dissolve all the material.

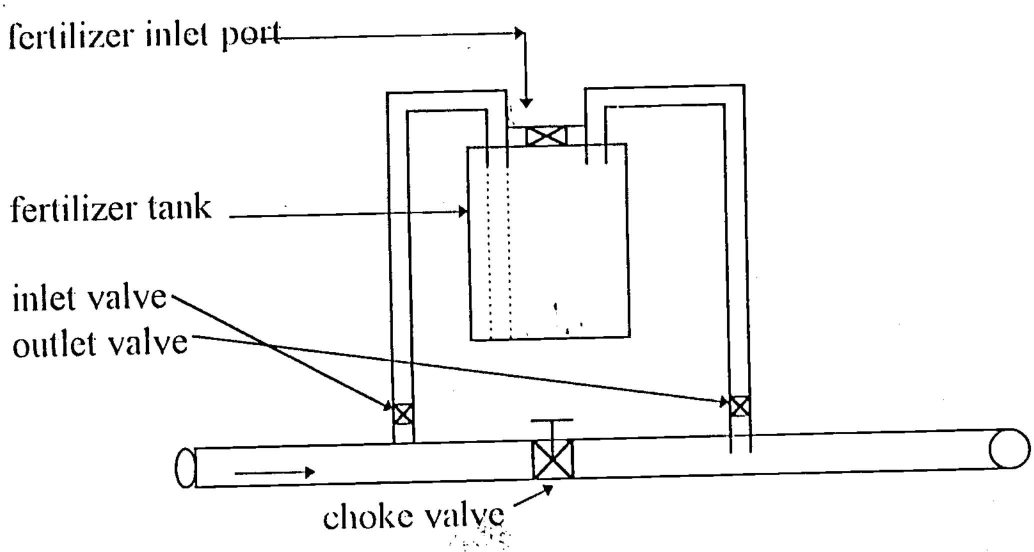

Fig. 5.11 Fertilizer Tank With Flow by-pass

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The rate of flow through the by-pass is determined by the pressure head difference between entrance and exit which is usually 0.1 to 0.6 bar. The choice of tank size is related to the area being irrigated. The pressure difference needed in order to empty the tank gradually during one irrigation has to be determined empirically.

The advantages of this system are its simplicity in construction and operation and its low cost. There is no need for an external power supply, and it is not very sensitive to changes in pressure or flow rate. However, the tank must be strong enough to withstand the pressure of the irrigation line. The disadvantages of the system are: The varying concentration of nutrients, the tank has to be refilled with solution for each irrigation cycle, so that the system is not suitable for automatic or serial irrigation.

5.3.5. A Modified Fertili8zer Tank

The fertilizer tank was modified to cope with the hand-mover system by reducing the pressure loss and the pressure required to operate the system and further reduce both weight and cost. A schematic of this modified system is shown in Fig. 5.12. The flow rate through the pressurized fertilizer holding tank is controlled by valves on either side of the tank as shown in Fig. 5.

The function for the concentration of material remaining in the tank as a ratio of original concentration is given as

$$\frac{C(1)}{C0} = e^{-\frac{q}{v}t}$$

Where:

C_1 = the fertilizer concentration in the tank at the time t(kg/m^3)

C_0 = the initial fertilizer concentration (kg/m^3)

q = the discharge through the tank m^3/hr

V = the volume of the tank (m^3)

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The equation can be used to calculate the time of application, for example if the flow through the fertilizer tank is controlled by the outlet valve to 240 l/hr and the tank volume was 60 liter, then it takes one hour to empty the tank of fertilizer or in other words $C_1/C_0 = 0.018$.

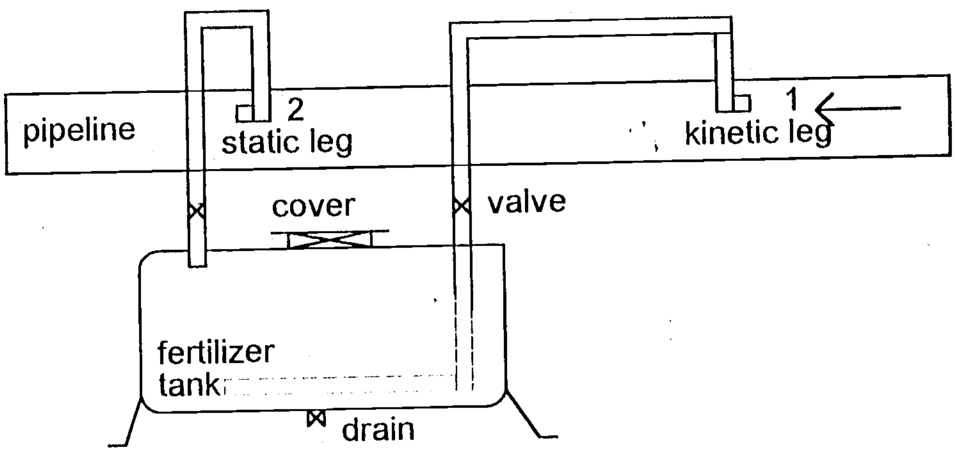

Fig. 5.12 Schematic Of The Modified Pressure Differential Fertilizer Tank

The tank is connedted to the main irrigation line by means of a by-pass so that some of the irrigation water flows through the tank and dilutes the chemical solution. This by-pass flow is broght about by a pressure difference between the kinetic and static legs. As a result of not using the valve, a save of 0.3 bar pressure loss was achieved, in addition to the price of the valve itself which is 200 L.E. The save of pressure loss by not constricting the flow is particularly important for most of the farmers as they always face the problem of low pressure.

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As shown in Fig. 3.13 the pressure difference is caused by a two simple L-shaped tubes one of them directed against the current (kinetic leg) and the other is pointed downstream facing the opposite direction (static leg). By Bernoulli's equation.

Total energy per unit weight @ 1 = Total energy per unit weight @ 2

$$\frac{V1^2}{2g} + \frac{P_1}{Y} = \frac{V2^3}{2g} + \frac{P_2}{Y}$$

Fig. 5.13 The Modified Fertilizer Tank Used with the Hand-Move Sprinkler System

If the velocity of the stream is v, a particle moving with the stream to the mouth of the tube 1 (kinetic leg) will be brought to rest so that v_1 at tube 1 is zero.

Since $v_1 = 0$. Thus, P_1 will be greater than P_2. Therefore,

$$\frac{P_1 - P_2}{Y} = \frac{V2}{2g}$$

$$\Delta h = \frac{V2}{2g}$$

Where Δh is the pressure head difference.

Cost estimate for the fertilzer tank

Item	*Unit*	*Quantity*	*Unit Cost*	*Total Cost L.E.*
Tank, 60 liter	item	1	165	165
Aluminum pipe 4 inches	m	1	13	13
Coupling 4"	item	1	20	20
Elbow 1"	item	2	3	6
Ball valve 1"	item	2	11	22
Elbow 1"/3/4"	item	2	3.5	7
Clamp 1"	item	4	0.5	2
Hose 3/4"	m	3	3.5	10.5
Elbow 3/4"	item	4	1	4
Ball valve 3/4"	item	1	6	6
Total = L.E. 255.5				

This fertilizer tank serves 20 feddans. The cost fertigation device per feddan is then qual to 12.8 L.E. which represents 5% of the initial cost of the hand-move irrigation system.

5.4. *Use of Alternate Offsets*

Use of offsets refers to the practice of not placing the lateral in exactly the same position in the field each time a particular section of the field is irrigated. This type of operation is applicable in systems in which the position of the lateral is determined by the operator and the laterals are moved over the total area to be irrigated to conserve equipment costs. Hand-move and side-roll systems fall into this category. If a lateral is always placed in the same position in a field, the parts of the field over-irrigated in previous irrigation's continue to be over-irrigated and those under-irrigated continue to have higher deficits. The principal of using offsets is to change the position of the lateral so the high and low water application points tend to balance out over a growing season.

Figure 5.14 is a schematic that indicates application of the offset principle. The hydrant spacing for lateral hookups along the mainline is given by 3sm. The laterals are shown in solid lines for irrigation number n. For the subsequent irrigation number n+1, the laterals are shown in dotted lines and placed at distance sm/2 from their position in the previous irrigation. The connection is made by a pipe section whose length is sm/2. Using offsets, the field sees a different water application pattern with each irrigation interval.

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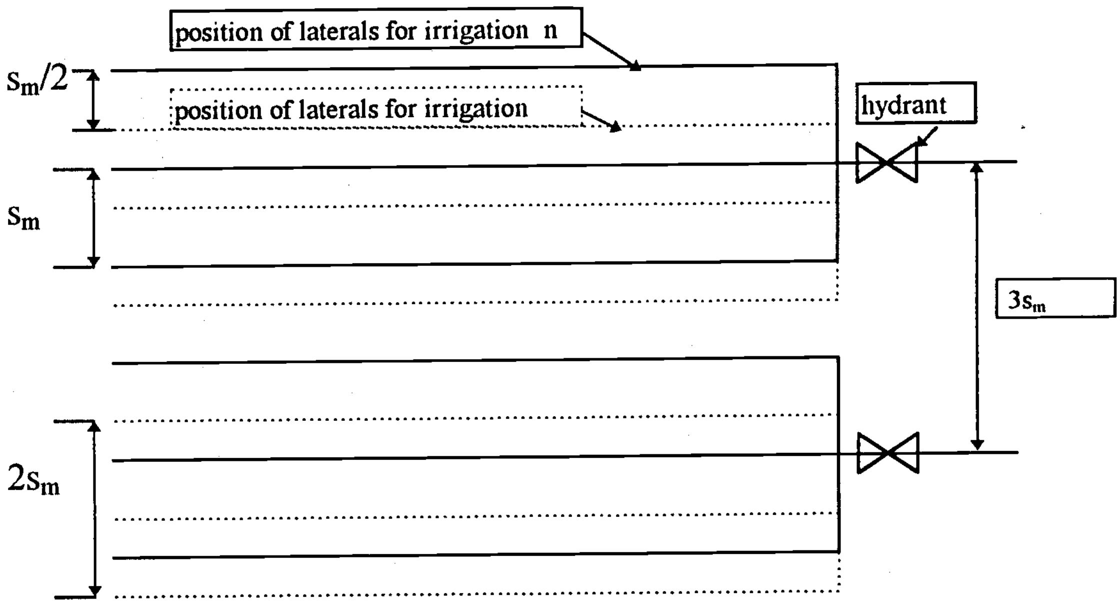

Figure 5.14 Schematic diagram indicating procedure for use of offsets in hand-move sprinkler system.

This variation in the application serves to balance out the maximum and minimum applied water locations and increase uniformity over the growing season. The increase in the seasonal uniformity coefficient is greater for those systems that have a somewhat low uniformity coefficient under standard design conditions. Standard design conditions refer to repeated placement of laterals opposite the mainline hydrant. Using offset operation, the uniformity coefficient increased from 65% to 80%. If the standard design uniformity coefficient is a relatively high 80%, the use of offsets has increased the uniformity of application to about 90% for a gain of 10%. The uniformity tests using offsets require that the lateral be operated in the standard position and in the offset position. The final catch for any can is the summation of the catches from the lateral in the two positions.

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5.5. ***Sprinkler Spacing***

A single leg test is characterized by a single radial line of catchments starting at the sprinkler and extending beyond the wetted radius of the sprinkler. Typically, the catchments are equally spaced. This type of test is done in a "no wind" environment (indoor). Eliminating the wind element allows direct comparisons of performance between many of sprinkler heads. For a given sprinkler / nozzle / pressure combinations, one can model different spacing to optimize that sprinkler performance.

Computer modeling does not provide all the answers. For instance, the single leg profile tests do not reflect the effect of wind on a pattern. However, indoor, single leg sprinkler testing is an efficient and economical way to gather a large data base for comparative purposes. Computer modeling is a new tool, which provides better information for a more informed selection of products and sprinkler spacing.

The procedure is basically as follows:

1) Begin with the sprinkler's radial water distribution curve measured indoors.
2) Overlap the water distribution pattern for a single sprinkler for any spacing and determine the parameters that characterize irrigation quality. Already existing programs for the overlapping of these distributions may be used, such as CATCH3D (Sprinkler Overlap Program, Allen 1992) in order to calculate the parameters that measure the quality of water distribution for any sprinkler spacings.

Tests were conducted on the available sprinklers in market with the sprinklers mounted on a 3/4-inch galvanized steel riser that was 70 cm tall. Operating characteristics for each of the seven types of sprinklers are presented in Table 5.2. The seven types include: Naan 5033, Dan, 30H, 30TNT, Lego, RB 70, and Hardie Model S. Sprinkler base pressures and nozzle discharges were carefully measured. Catch data from a single radial row of

Table 5.2 Sprinkler's radial water distribution measured indoors for seven sprinkler types.

		Naan 5033	Dan	30 H	30 TNT	Lego	RB 70	Model S Hardie
Nozzle dia. mm		5/4	4.7/3	4.3/2	5/2.4	4	8.4/ 4.6	7/2.5
rpm		1.8	1.24	1.73	1.86	6.66	0.65	3.09
Riser height m		0.5	0.5	0.5	0.5	0.5	0.5	0.5
m3/hr @3bar		2.7	1.85	1.8	2.3	1.1	4.5 @2bar	3.25
can #	dis. m	catch depth in mm per hour						
1	0.5	3.7	3.8	13.9	5.6	11.9	16.9	6.6
2	1.5	2.5	2.9	5.1	5.1	4.8	14.7	3.7
3	2.5	2.9	2.9	4	5.3	3.3	11.2	3.2
4	3.5	3.5	2.9	3.8	4.9	3.7	8.6	4
5	4.5	4.3	3.5	4	4.7	3.5	8.1	4.6
6	5.5	4.8	3.5	4	4.8	3.7	6.7	4.9
7	6.5	5.6	3.5	3.9	4.3	3.8	5.8	4.4
8	7.5	5.6	3.4	2.3	3	3.5	6.9	4.3
9	8.5	5.6	3.2	3	3	3	6.8	4
10	9.5	5.1	2.8	2.9	3.5	1.4	8.1	4.3
11	10.5	3.9	2.7	2.7	2.8	0.3	8.3	4.9
12	11.5	3.3	1.8	2.4	2.2	0	9.3	4.8
13	12.5	2.9	1.3	2.0	1.3	0	8.2	4.3
14	13.5	1.8	0.6	0.8	0.8	0	5.4	3.7
15	14.5	0.5	0.3	0	0	0	1.4	2.3
16	15.5	0	0	0	0	0	0	0.3

containers placed on the ground and spaced 1.0 m apart were taken after each sprinkler test had operated for a minimum of 30 minutes. The sprinklers were observed during operation and irregularities such as erratic turning and leakage of water at the bearings were noted.

Tests were conducted on actual sprinkler patterns at different pressures and shown in Figs. 5.15 - 5.21. It can be seen that each type of sprinkler has certain precipitation profile characteristics that change as nozzle size and operating pressure change. With lower sprinkler pressures the distribution is usually less uniform and the sprinklers must be spaced closer together. The relatively short wetted radius associated with low-pressure operation increase operating costs. Thus, the farmer is faced with either buying more sprinklers, pipes, and fittings per unit area, or moving the sprinklers more frequently. Both of these alternatives are expensive. Certain sprinklers under specific conditions produce atypical precipitation profile as shown in previous figures. Each profile type has its spacing recommendations based on the diameter of effective coverage under the particular field conditions of operation. Conditions that affect both the diameter and profile characteristics are direction and velocity of the wind measured from the ground level to the top of the jet trajectory, angle of stream trajectories, height and angle of risers, turbulence in the stream of water entering and leaving the nozzle, pressure at the nozzle, size of the nozzle, speed and uniformity of rotation and characteristics of the driving mechanism such as the shape, angle, and frequency of the spoon and lever action. With such a complex set of conditions the practical way of determining the profile type and diameter are by placing catchment gages in the precipitation area and evaluating the results.

The diameter of throw of a sprinkler as listed in the manufacturer's brochure is often for no wind and to the farthest droplet from the sprinkler. Under field operating conditions with 0 - 5 km/hr wind such diameters should be shortened by 10 percent from the listed figure to obtain the effective diameter. Effective diameters should be further reduced for winds exceeding 5 km/hr. A reduction of 1.5 percent for each km/hr over 5 km/hr is a fair estimate for the usual range of wind conditions under which sprinklers are operated. For

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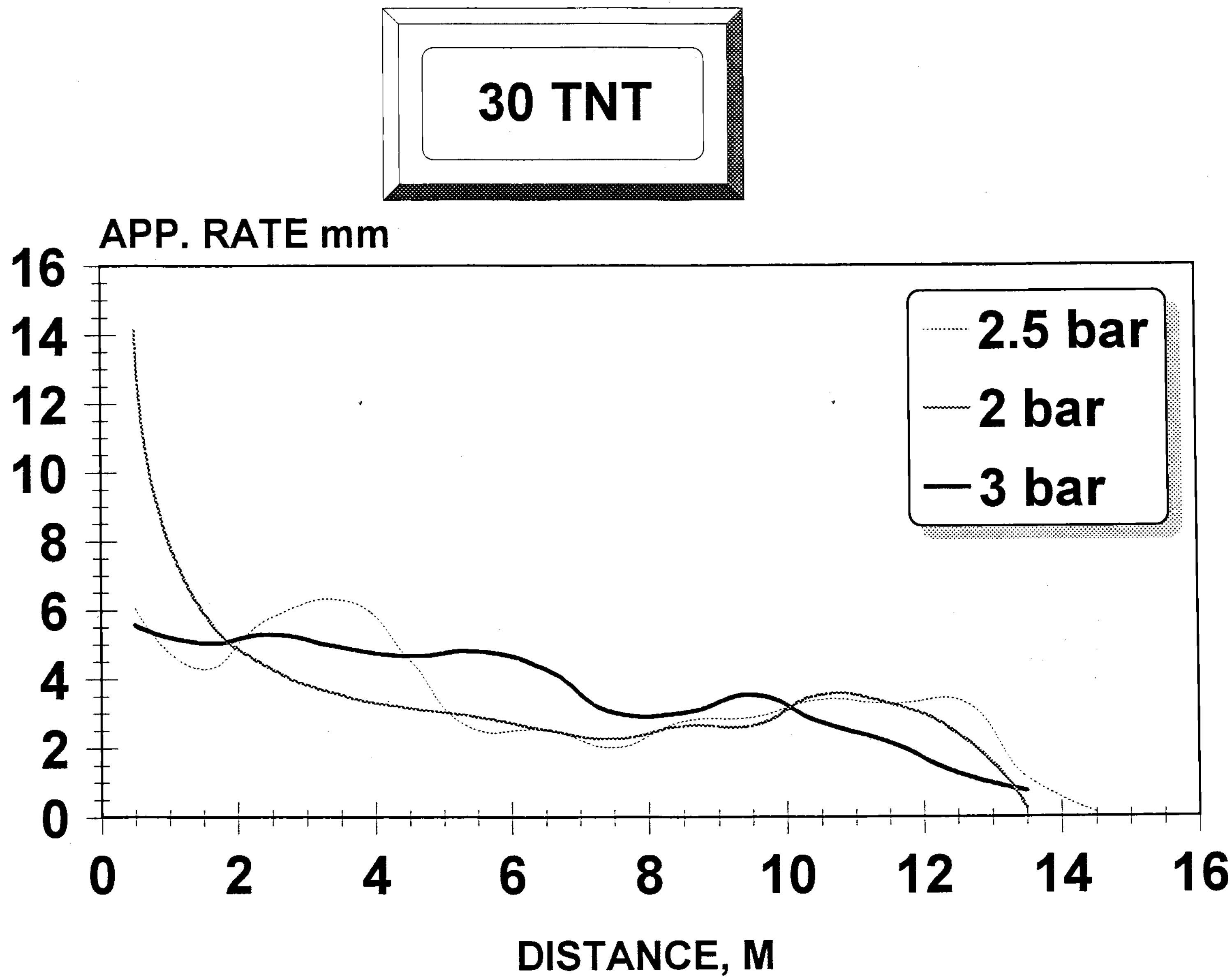


Fig. (5.15) Sprinkler Pattern at Different Pressures

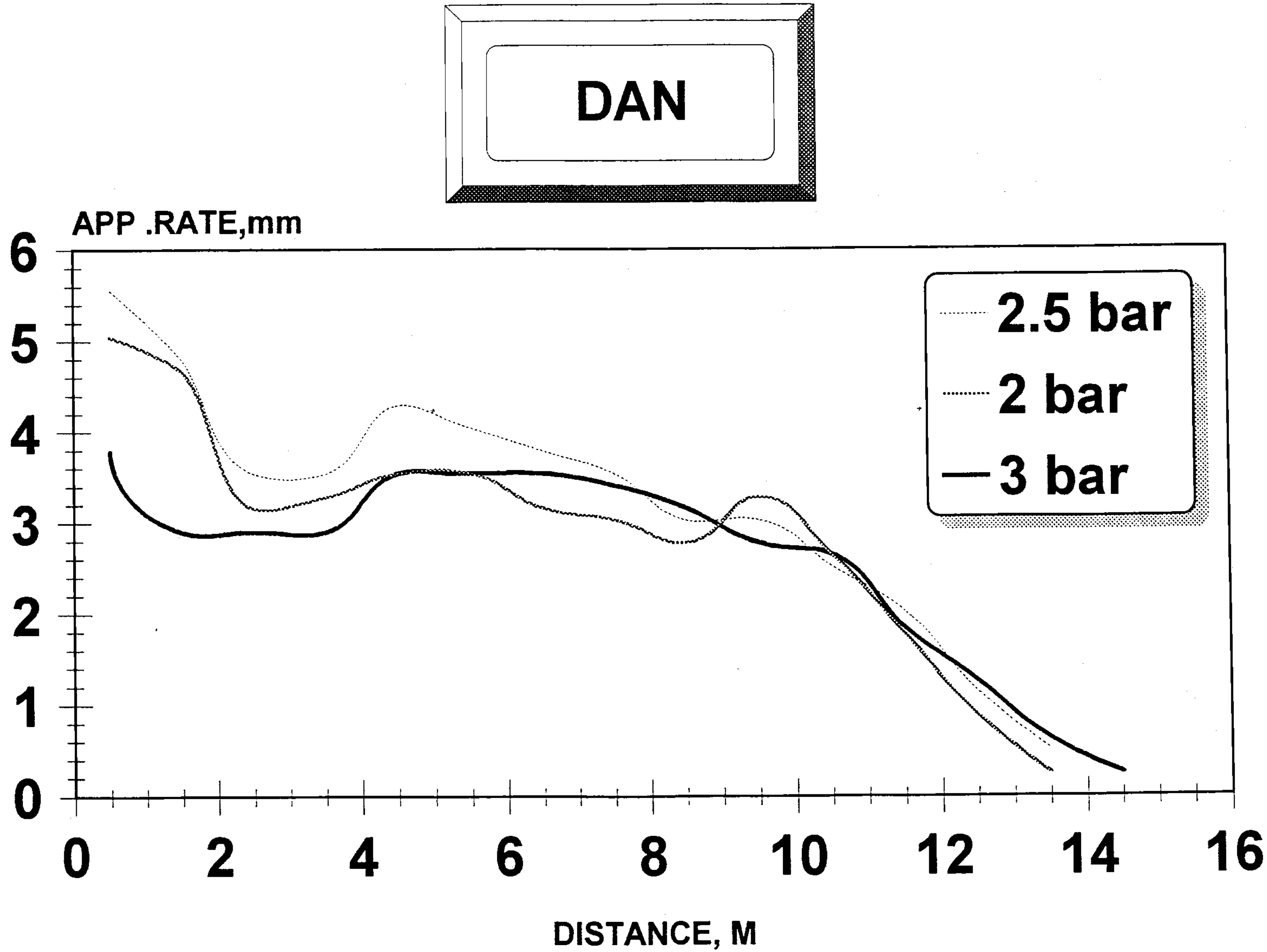


Fig. (5.16) Sprinkler Pattern at Different Pressures

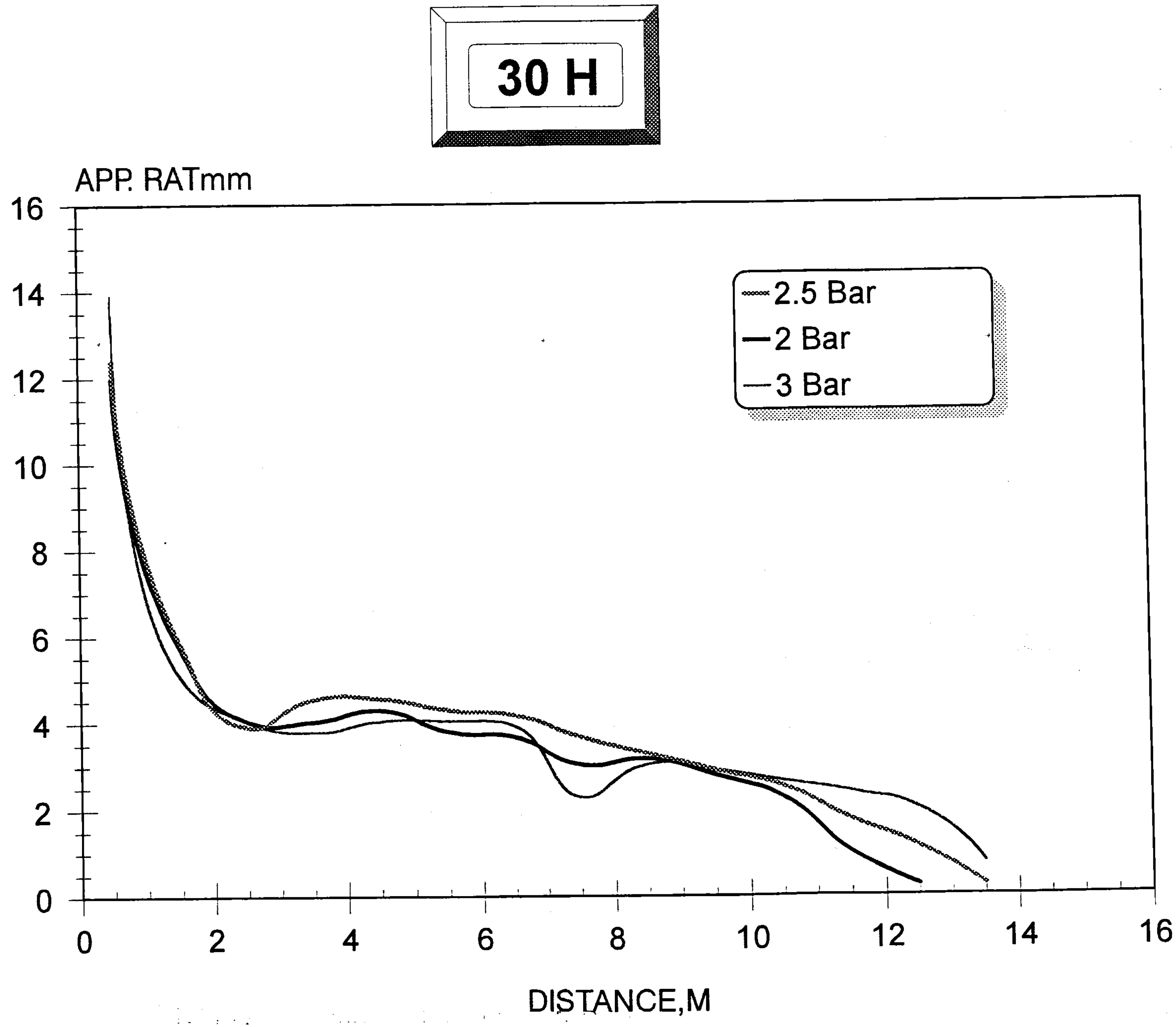


Fig. (5.17) Sprinkler Pattern at Different Pressures

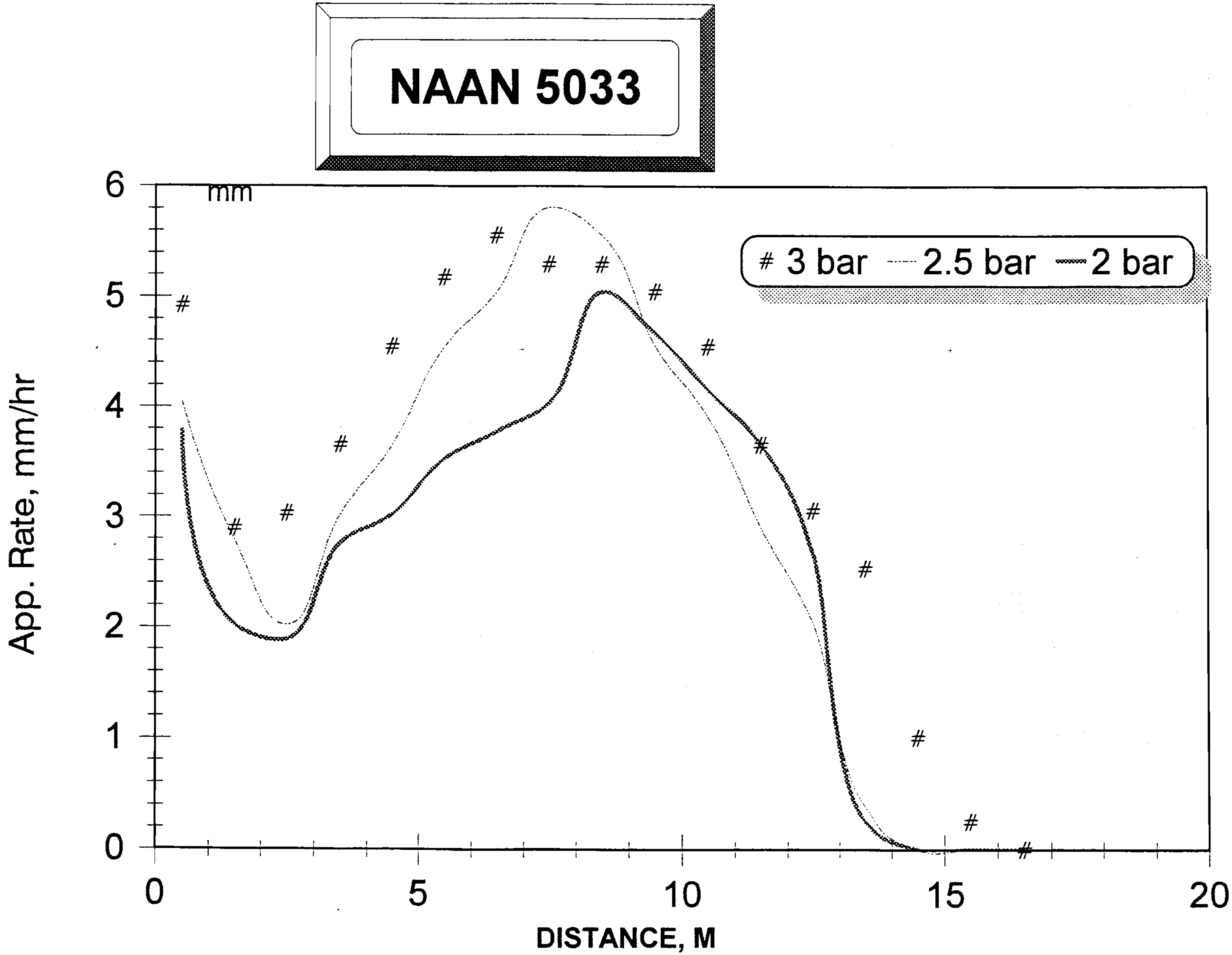


Fig. (5.18) Sprinkler Pattern at Different Pressures

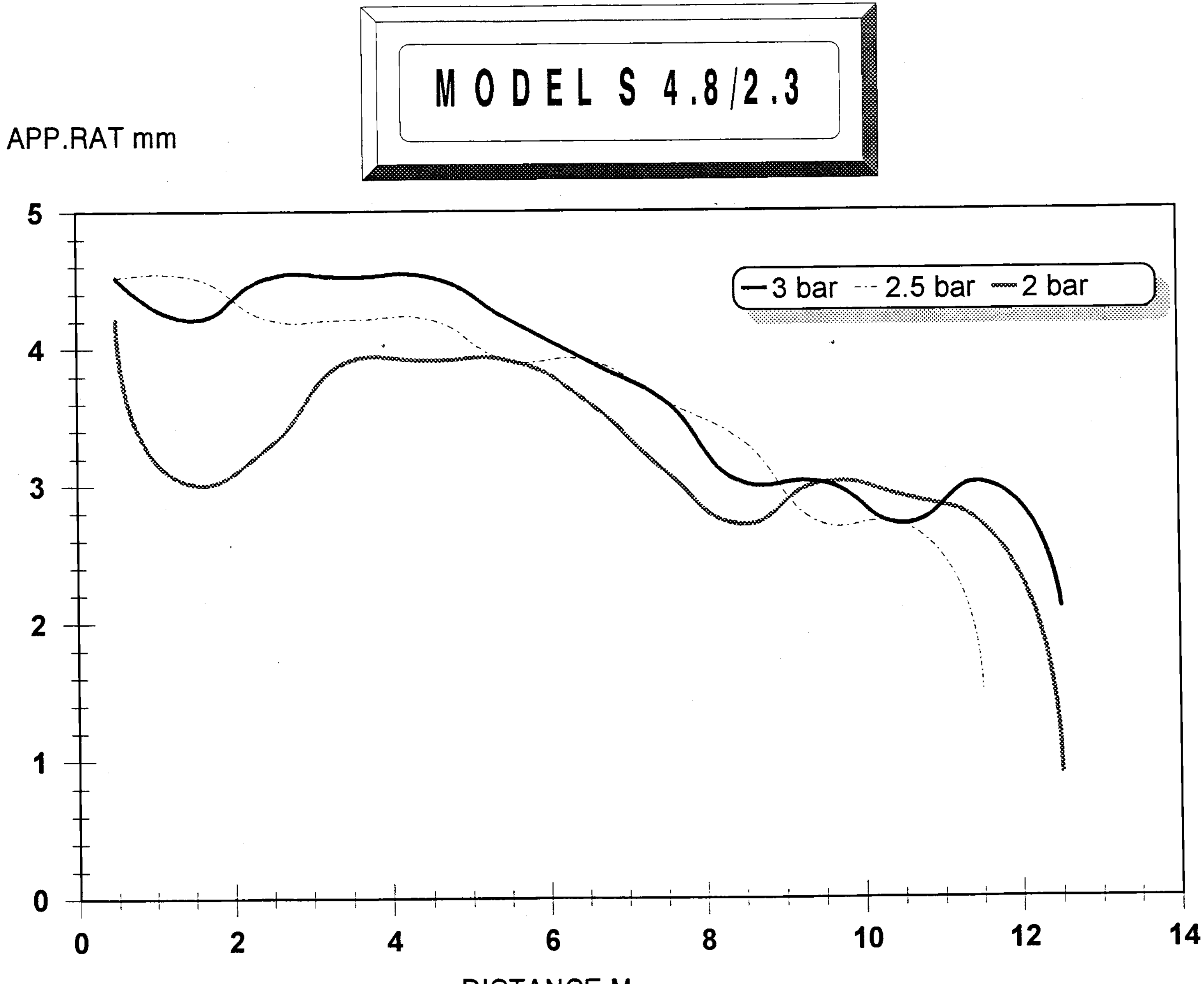


Fig.. (5.19) Sprinkler Pattern at Different Pressures

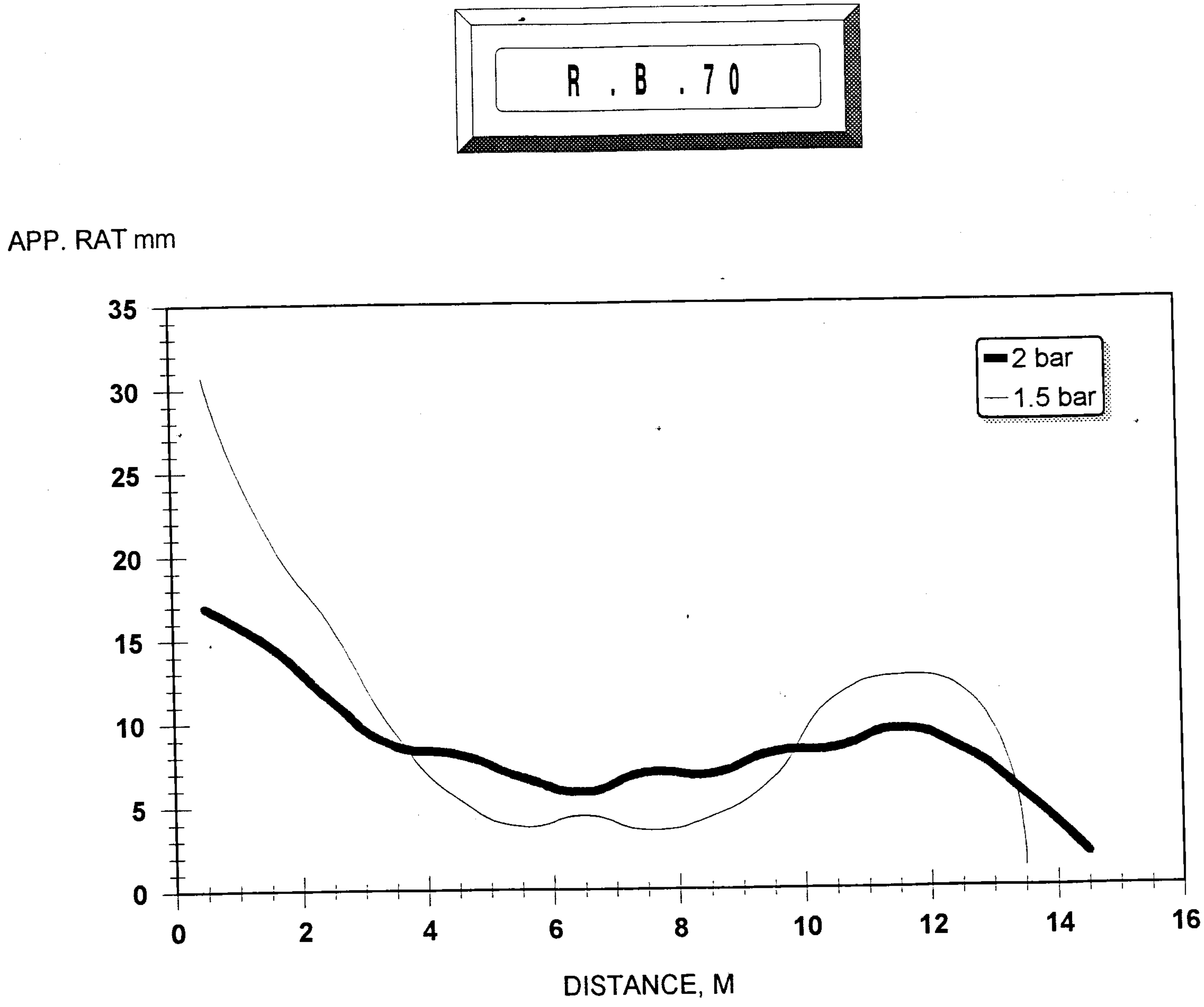


Fig. (5.20) Sprinkler Pattern at Different Pressures

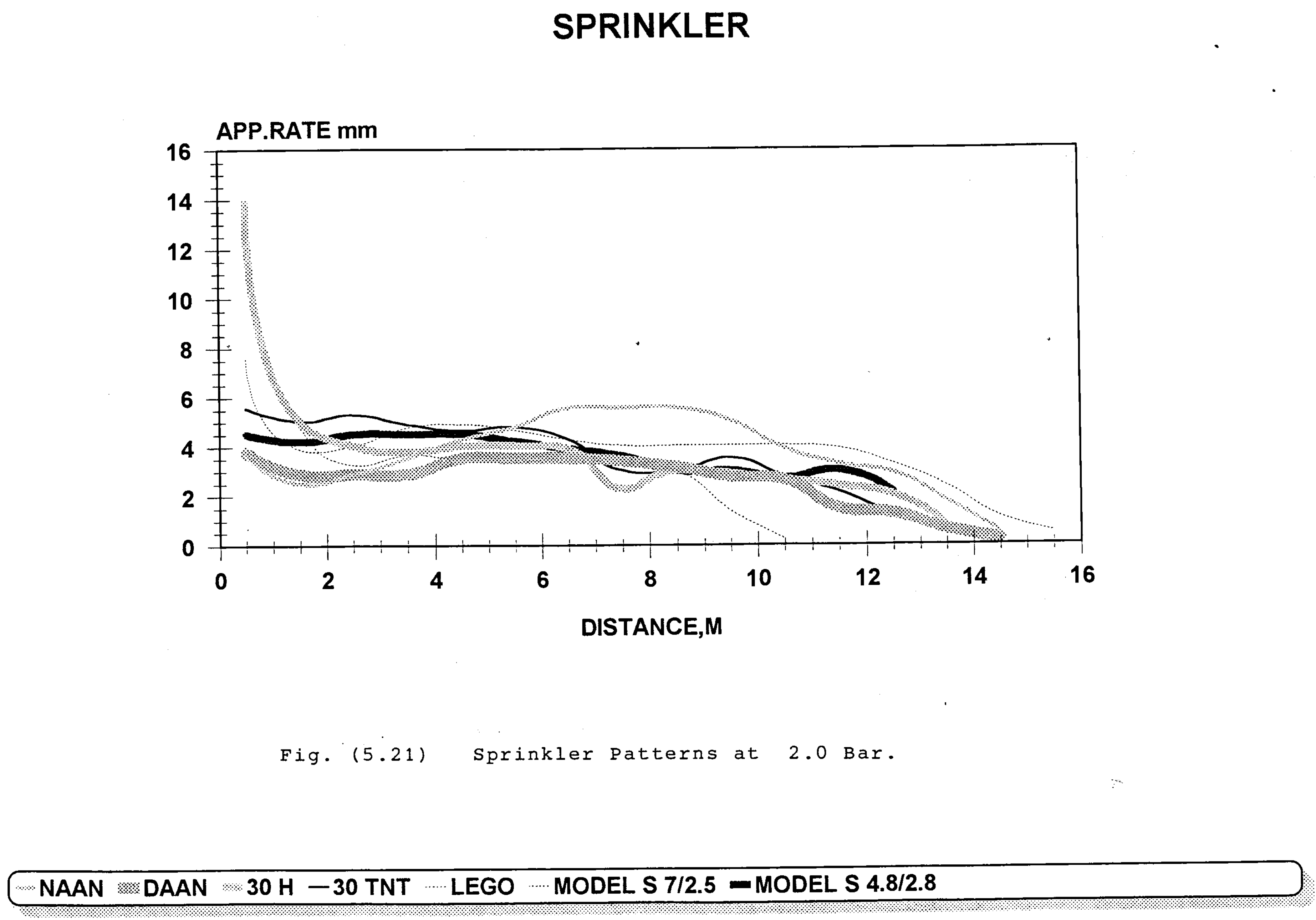
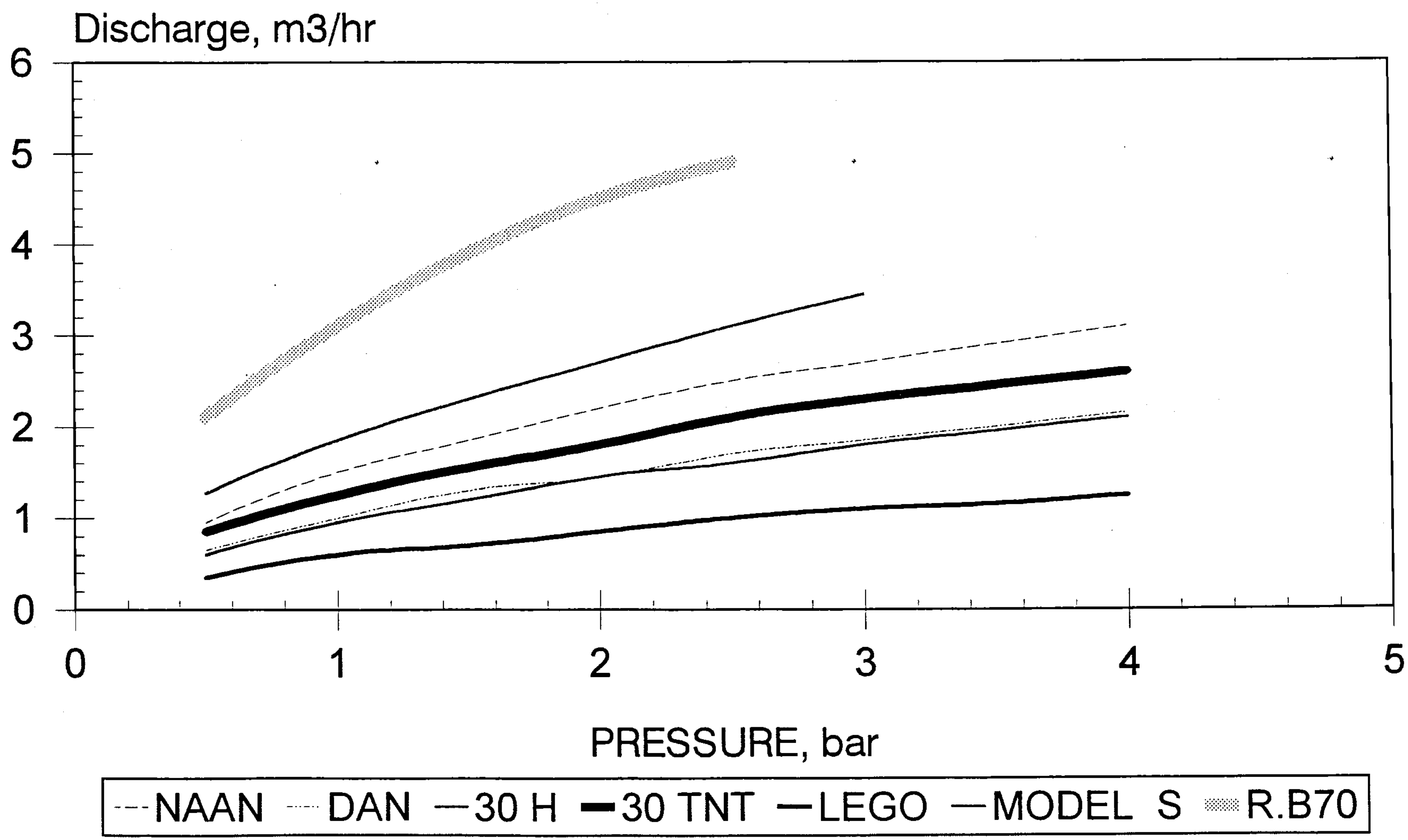


Fig. (5.21) Sprinkler Patterns at 2.0 Bar.

RELATION BETWEEN PRESSURE AND DISCHARGE FOR SPRINKLER



Sprinkler Discharge at Different Pressures

40 percent or less of the diameter, but such close spacings raise both application rates and costs. Application rates should not exceed the ability of the soil to absorb the water applied.

The computer sprinklers overlap program (CATCH3D, Allen 1992) was used to evaluate the radial catch data. The program generates a grid pattern from a single radial line of catch data and superimposes the grid patterns to simulate various sprinkler spacings. The coefficient of Uniformity, CU, (Christiansen, 1942), average gross application rate, Application Efficiency of Low Quarter (AELQ), and Distribution Uniformity (DU) are then determined for each simulated spacing and presented in tables 5.3 - 5.9.

The results of the program have been compared to field data and the applicability of the program has then been used to improve the operation of existing installations by modifying the lateral move spacing of the hand-move system.

Sprinklers that have been used in the desert land can be classified into two main groups according to their nozzle diameters. The first group includes nozzle diameters less than or equal to 5 mm such as Naan 5033 (5 x 4 mm), Dan (4.7, 3 mm), 30H (4.3, 2 mm), and 30TNT (5 x 2.4 mm). The second group includes nozzle diameters greater than 5 mm, such as the RB 70 (8.4, 4.6 mm) and the Hardie Model S (7, 2.5 mm). However, Lego sprinklers have a single small nozzle that are mainly used for irrigating landscape and greenhouse, and rarely used for irrigating field crops. Performance parameter values for different Lego-sprinkler spacings are presented in Table 3. It can be seen that Lego sprinklers perform best when placed in 9 x 9 m spacings which produce a CU of 87.7 %.

Optimum recommended spacing for the first group of sprinklers at 3 bar operating pressure is 12 x 12 m for coefficient of uniformity, CU, greater than 90 % and DU greater than 85% under a no wind conditions. However, in South Tahrir, the sprinkler spacing is 9 x 18 m which would produce a CU of 85 % under a no wind conditions. Under field operating conditions, a variety of wind speeds and directions usually exist during the

Table 5.3 Performance parameter values for different 30TNT-sprinkler spacings.

Spacing meters	*Av. gross App. rate mm/hr*	*Performance Parameters*			
		AELQ	***DU***	***CU***	***CU for Offsets***
9 x 9 m	28.4	69	90.2	94.5	97.2
9 x 12	21.3	70.5	92.2	94.6	97.2
9 x 15	17	67.2	88.0	91.9	95.9
9 x 18	14.2	68.6	89.7	94.1	97.0
12 x 12	16.0	69.6	91.3	95.0	97.5
12 x 15	12.8	65.5	85.6	90.6	95.2
12 x 18	10.6	67.7	88.6	92.2	96.0

* Catch efficiency = 76.5 %

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Table 5.4 Performance parameter values for different Lego-sprinkler spacings.

Spacing meters	*Av. gross App. rate mm/hr*	*Performance Parameters*			
		AELQ	***DU***	***CU***	***CU for Offsets***
6 x 6 m	30	88.4	93.2	92.6	96.2
6 x 9	20	86.7	91.4	92.4	96.1
6 x 12	15	76.0	80.1	84.5	91.9
9 x 9	13.3	79.2	83.5	87.7	93.6
9 x 12	10.0	73.3	77.3	81.6	90.3
12 x 12	7.5	65.9	69.5	82.5	90.9

* Catch efficiency = 94.9 %

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Table 5.5 Performance parameter values for different Dan-sprinkler spacings.

Spacing meters	***Av. gross App. rate mm/hr***	***Performance Parameters***			
		AELQ	***DU***	***CU***	***CU for Offsets***
9 x 9 m	22.7	76.1	93.7	96.1	98
9 x 12	17	72.9	89.9	92.9	96.4
9 x 15	13.6	64.7	79.8	85.8	92.6
9 x 18	11.3	71.4	88.0	91.5	95.6
12 x 12	12.8	70.7	87.1	90.1	94.9
12 x 15	10.2	64.5	79.5	85	92.2
12 x 18	8.5	70.0	86.3	90.7	95.2

* Catch efficiency = 81.1 %

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Table 5.6 Performance parameter values for different 30H-sprinkler spacings.

Spacing meters	*Av. gross App. rate mm/hr*	*Performance Parameters*			
		AELQ %	*DU %*	*CU %*	*CU for Offsets %*
9 x 9 m	22.2	82.4	89	93.3	96.6
9 x 12	16.7	81.7	88.2	91.7	95.8
9 x 15	13.3	75.7	81.8	87.6	93.6
9 x 18	11.1	79.6	86.0	89.8	94.8
12 x 12	12.5	82.2	88.8	91.7	95.8
12 x 15	10.0	71.9	77.7	86.2	92.9
12 x 18	8.3	75.8	81.9	85.9	92.7

* Catch efficiency = 92.6 %

Table 5.7 Performance parameter values for different Naan 5033-sprinkler spacings.

Spacing meters	***Av. gross App. rate mm/hr***	***Performance Parameters***			
		AELQ	***DU***	***CU***	***CU for Offsets***
9 x 9 m	33.3	88.1	96.5	97.2	98.6
9 x 12	25	81.4	89.2	92.0	95.9
9 x 15	20	66.2	72.6	82.0	90.6
9 x 18	16.7	72.5	79.5	84.1	91.7
12 x 12	18.7	78.0	85.5	90.4	95.1
12 x 15	15	66.1	72.5	80.2	89.6
12 x 18	12.5	70.0	76.7	83.8	91.5

Table 5.8 Performance parameter values for different Hardie Model S sprinkler's performance parameters.

Spacing meters	*Av. gross App. rate mm/hr*	*Performance Parameters*			
		AELQ	*DU*	*CU*	*CU for Offsets*
9 x 9 m	40.0	86.6	96.6	96.9	98.4
9 x 12	30.0	81.5	90.9	94.0	97.0
9 x 15	24.0	68.5	76.3	86.1	92.8
9 x 18	20.0	65.5	72.8	81.7	90.4
12 x 12	22.5	78.5	87.6	91.9	95.9
12 x 15	18.0	67.8	75.6	87.1	93.3
12 x 18	15.0	60.9	67.9	79.5	89.2
15 x 15	14.4	65.4	72.9	80.8	89.9
15 x 18	12	64.1	71.5	77.6	88.1
18 x 18	10	57.1	63.7	80.3	89.6

*Catch efficiency = 89.7%

Table 8. Performance parameter values for different RB70-sprinkler spacings.

Spacing meters	*Av. gross App. rate mm/hr*	*Performance Parameters*			
		AELQ	*DU*	*CU*	*CU for Offsets*
9 x 9 m	59.6	87.9	87	91.7	95.8
9 x 12	44.7	81.4	80.6	88.7	94.2
9 x 15	35.7	82.2	81.3	87.9	93.7
9 x 18	29.8	79.3	78.4	84.1	91.7
12 x 12	33.5	88	87.1	89.9	94.8
12 x 15	26.8	69.2	68.5	83	91.1
12 x 18	22.3	63.3	62.6	75.5	86.9
15 x 15	21.4	68.8	68.0	79.0	88.9
15 x 18	17.9	76.2	75.4	79.8	89.3
18 x 18	14.9	70.2	69.5	82.2	90.7

*Catch efficiency = 100 %

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irrigation set. In addition, with lower sprinkler pressures the distribution is usually less uniform and relatively short wetted radius associated. Therefore, a mixture of profiles is produced. Thus, the farmer is faced with either decreasing the sprinkler spacing to 9 m for hand-move, or buying more sprinklers, pipes, and fittings per unit area for fixed system. Both of these alternatives are either labor intensive or expensive.

The maximum spacing for the second group of sprinklers is 18 x 18 m at which would produce a CU greater than 80%. Maximum spacing for each sprinkler was assumed to be the widest spacing at which each sprinkler-nozzle-pressure would produce a CU greater than 80 percent. As shown in Table 7, when operating the Hardie Model S sprinklers at 3 bar on a 12 x 18 m spacing, the CU is less than for a 12 x 15 m spacing and equal to the CU for a 18 x 18 m spacing. Therefore, the Hardie Model S sprinklers perform best when placed in 12 x 15 m spacing. However, RB 70 sprinklers perform best when placed in 15 x 18 m spacing which produce a CU of 80 % and a DU of 75 % as shown in Table 8. The intake rate of the soils should not be exceeded by the application rate of the sprinklers. The previous Tables give application rates for various spacing combinations.

As presented in 5.3 - 5.9 the use of alternate offsets has increased the uniformity of application from 65 % to 80 % for a gain of 15 %, from 80 % to 89 % for a gain of 9 % and from 85 % to 92 % for a gain of 7 %.

5.6. ***Drag Hose Sprinkler System***

The hand-move sprinkler is a labor intensive system. The introduction of drag hose sprinklers would reduce the labor demand to about half of that required for a comparable hand-move lateral system. It is also more convenient, easier to operate and saves deterioration of lateral pipes and fittings. The Model Farm demonstrates to the farmers how to convert their hand-move sprinkler to drag hose. The drag hose system extends the life of the aluminum laterals and couplers that is an improvement consideration in the project area in view of the present intensive use of equipment. The drag hose is more flexible and ensures a better distribution of water, particularly on windy days. It also has a greater social acceptability in terms of reduced need for manual pipe transport.

The drag hose sprinkler is considered as a modification of the hand move sprinkler system. In drag hose system (Fig. 5.22), individual sprinklers are supplied by hoses and periodically moved to cover several positions. In this case 7 sprinklers are attached to 7 flexible hoses (48 m length and 25 mm diameter) and the lateral line remains stationary. Sprinklers are mounted on skids and towed periodically to give grid patterns of 12 x12 m. Risers are one meter tall to keep the sprinklers above the mature crop.

The seven sprinklers are Rain Bird 30TNT (locally manufactured by Helwan Company) and have the following characteristics:-

Fig. 5.22 Modification of Hand-Move to Drag Hose Sprinklers

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- Nozzle diameters: 5 x 2.4 mm
- Operating pressure : 3 bar
- Wetted diameter : 30 m
- Sprinkler discharge : 2.3 m3/hr

At the design spacing of 12 x 12 m, the application rate can be calculated as follows

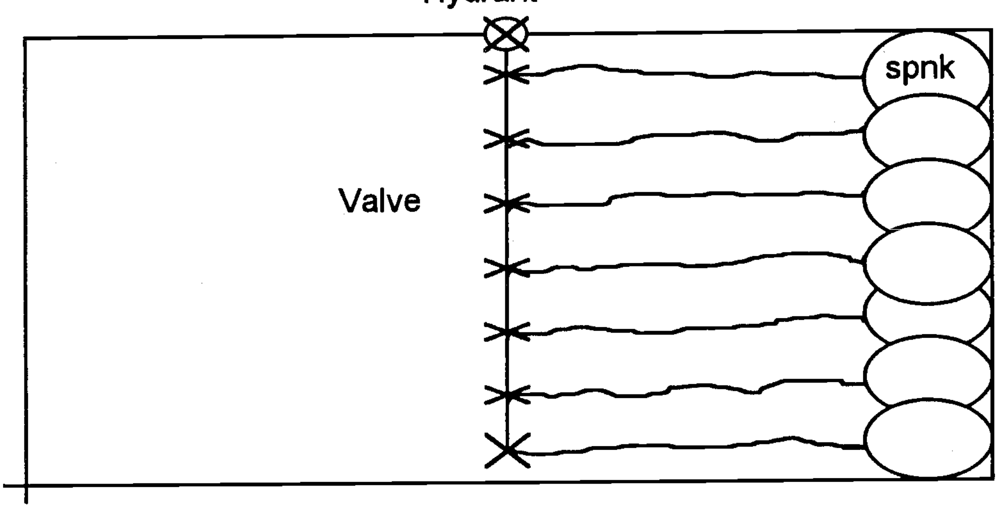
$$I = q / (sl \times sm)$$
$$= 2.3 \times 1000 / (12 \times 12) = 16 \text{ mm/hr}$$

Where q is the sprinkler discharge and sl, sm are sprinkler spacing. This application rate does not exceed the infiltration rate of the soil (20 mm/hr), therefore no runoff would occure. When sprinkler application rates exceed infiltration rates, water ponds and redistributes on the soil surface which results in reduced application uniformity, runoff losses, and soil erosion. Reducing application rates to avoid these problems usually increases sprinkler system costs because the supply rate required to meet crop water use must be applied across a larger wetted area.

If the irrigation efficiency is 75 % then the net application rate is 16 x 0.75 = 12 mm/hr. The available water for the sandy soil is 60 mm/hr, with irrigation being necessary when 50 % of this is depleted. Thus 30 mm/m is considered readily available water. For a 0.7m rooting depth (common for most field crops), the net application depth is 21 mm. This confirms the necessity for a 3 days irrigation interval in the peak period (July/August) for most crops, hence the peak consumptive use of most crops is 7 mm per day. The irrigation time at peak water use = 21mm / 12 (mm/hr) = 1.75 hr. Short irrigation intervals are required to provide crop water needs on limited storage-capacity soils. Since water holding capacity is small, the system must also be able to apply small irrigations efficiently.

Figure 5.23 shows the design and detail cost for changing only 50% of the area (2.5 feddans) from hand-move to drag hose. The cost per feddan is estimated to 389 LE.

Figure 5.23 Modification of Hand-move sprinkler to drag hose sprinkler (2.5 fd)



Cost Estimate

Item	Unit	Quantity	Unit cost	Total cost
PVC 110 mm	m	22	7.75	170.5
Clamp saddle 50mm/3/4"	item	7	1	7
riser & skid	item	7	20	140
Male adapter 25mm/1"	item	7	2.53	17.71
Elbow 1"	item	7	2	14
Ball valve	item	7	10	70
P.E. 25 mm	m	385	1	385
Sprinkler head 3/4" TNT	item	7	24	168

Total cost **LE. 972.21**

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6. Model Farm of Irrigation Systems

6.1. Background

The model farm was designed to demonstrate that the existing irrigation systems can be made to operate correctly and within the design criteria originally established. The farm will also serve as a training and demonstration site for the farmers and graduates when received the standard 5-feddan farm. The design itself varying from the standard or dominant hand-move systems to the other systems such as drag hose, fixed, and drip systems. These systems were laid down on a net area of 20 feddans, then divided into 4 model farms, thus 4 separate farms representing different plans of irrigating and farming the land. It was suggested that the role of the model farm should be expanded to include different modifications such as introducing screen filter to hand-move system, using of offsets technique, using fertigation with hand-move system, using optimum sprinkler spacing, and introducing drag hose system as a modification of hand-move system. Demonstration of side-roll and gun are not considered necessary as there are plenty of good examples in the DDC experimental farm in South Tahrir (Fig. 6.1).

Shortly after a graduate starts to irrigate his land using the standard hand-move aluminum pipes, a state of unsatisfaction start to fill the graduate. As a step to overcome these moods these model farms suggest and emphasize the advantage of other possibilities within his reach.

Working together, four neighbor farmers with an independent pump unit, could have the same possible irrigation layout as in the model farms (Fig. 6.2). Also economically designed, these model farms shed light on the profit of investing in such systems. The blending of "cash crops" with a larger investment of orchards can be an appealing choice, or the more simple but durable systems to irrigate field crops with quick profits in return could be more favorable to other. Varying the type of field crops or orchards can support a farmer more firmly in the rise and fall of market prices, therefore decreasing his risk of misfortune.

These layouts (Fig. 6.2) act as an approach to convey the contrast between the different available systems. The general problems of lateral pipe leakage, broken sprinklers and transferring the lateral line in the hand-move system (Model # 1) cease to exist with the other model designs. Opening a few simple ball valves to irrigate instead will gain not only efficiency but self satisfaction. These systems are more simply maintained, and also differ in cost. Model farm # 2 consisting of a fixed and trickle systems (2.5 feddans each) could grow a mixture of field crops, orchards, and vegetables. Despite being the most expensive (2780 LE / fed.), the fixed system is the most preferable and easiest to apply. Respectively, a drip irrigation system (995 LE / fed. for orchard and 2608 LE/fed. for vegetables) has the advantage of limiting the water loss, which is the main concern in desert farming. Model # 3, providing a clear picture of in between, affordable (389 LE/ fed. for drag hose), more than adequate efficiency system, producing also a mixture of crops. Model # 4, consisting of primarily drip and producing large investment orchards, varying in water requirements and salt tolerant. This model acts as demonstration farm that will encourage and teach young farmers the correct ways of irrigating and farming.

6.2. *Hand-move Sprinkler System*

The field irrigation equipment provided in the smallholder area of Bostan comprises one portable aluminum 3 inch diameter lateral line per 5 feddans unit as shown in Model #1 (Fig. 6.2). On each lateral seven twin nozzle Rain Bird 30 TNT sprinklers are mounted at 12 m intervals on 80 cm risers. The sprinklers have the following characteristics:

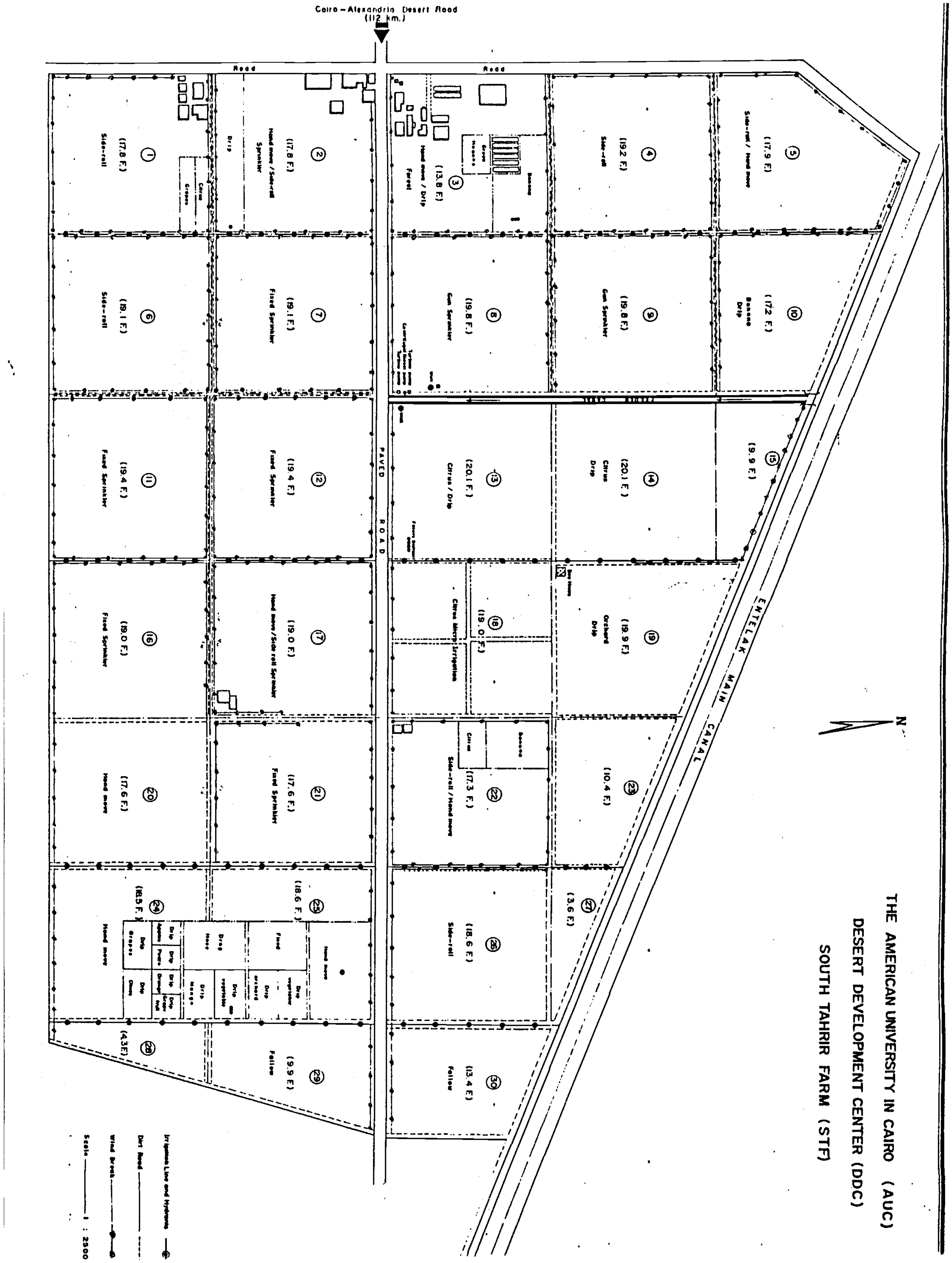

Fig. 6.1 Layout of South Tahrir Farm (DDC) and Location of Model Irrigation Site (Plot 24-25)

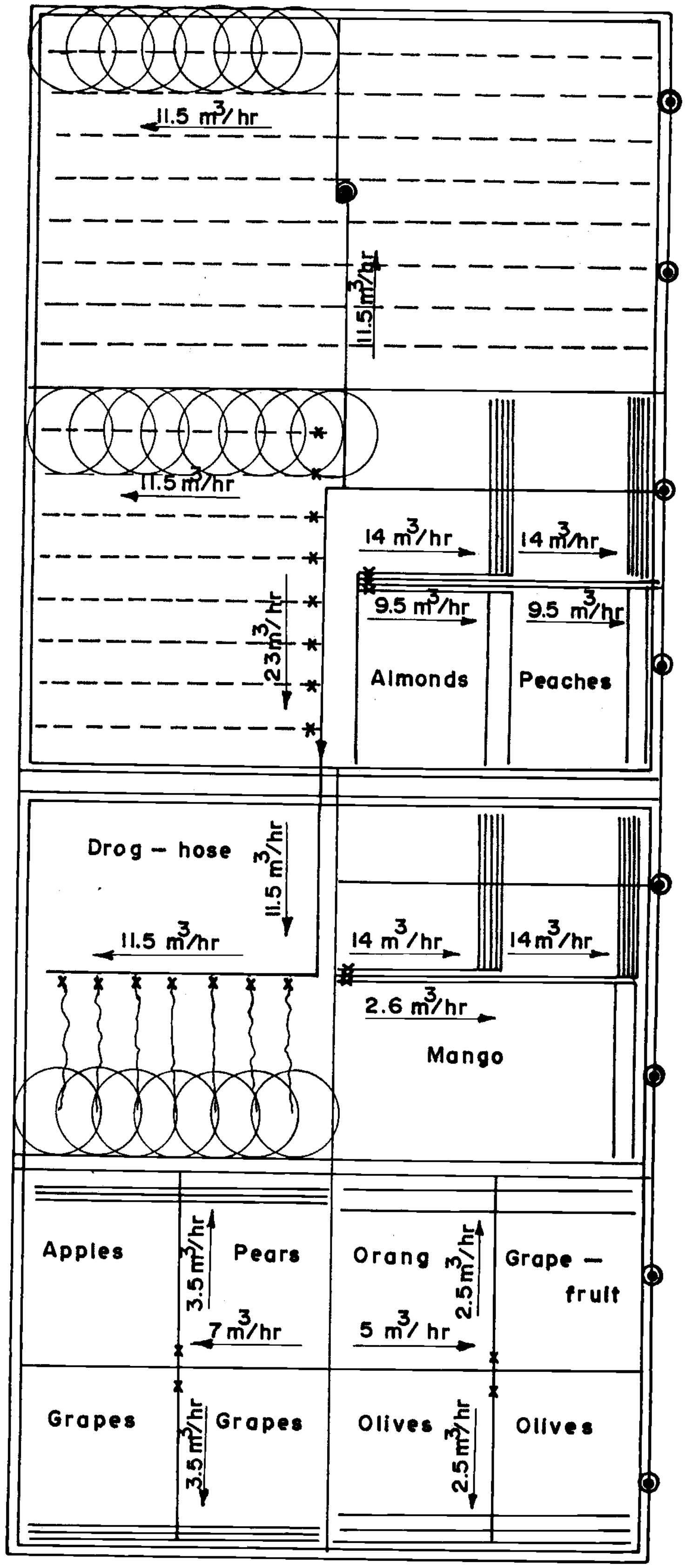

Fig. 6.2 Layout of the Model Farm of Irrigation System

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- nozzle diameters: 2.4 x 5 mm
- design operating pressure: 3 bar
- effective diameter of spray: 27 m
- sprinkler discharge: 1.8 m3/hr
- sprinkler spacing: 12x12 m
- Application rate = Q (m3/hr) x 1000 / (sm x sl)

  = 1.8 x 1000 / (12 x 12) = 12.5 mm/hr

The sprinklers are manufactured in Egypt by the Military Factory.

Each 5.0 feddan plot has one hydrant rising from the buried branch pipeline, refer to Figure 11, giving a total of sixteen lateral positions. Irrigation of a 5.0 feddan plot is to be accomplished in four days, with four lateral positions (at 12 m spacing) per day. The design allows for 11 hours of irrigation per day. Deducting one hour for lateral movement (four positions per day) leaves 10 hours, which is 2.5 hours per lateral position, equivalent to 31.5 mm. The designs assumed 10% losses leaving 28 mm net delivered to the crop. As the irrigation interval in the peak period is 4 days this is equivalent to a peak crop consumptive use of 7 mm/day.

The design assumes that the available moisture (field capacity to wilting point) is 6% by volume, with irrigation being necessary when two thirds of this is depleted. Thus 4% is considered "readily available moisture". For a 70 cm rooting depth (common for most field crops) 4% amounts to 28 mm of readily available moisture. This corresponds to the design irrigation application (28 mm) and confirms the necessity for a 4 days irrigation interval in the peak period (July / August) for most crops.

The data obtained from the field evaluation of the installed hand-move sprinkler irrigation system were analyzed and performance parameters were calculated. The results of the evaluation is presented below. It can be seen that the aplication efficiency of low quarter (AELQ), the distribution uniformity (DU), and the coefficient of uniformity (CU) reached 78.3%, 84.8%, and 90.2% respectively. Using alternate offset operation, the uniformity coefficient (CU) increased from 90.2% to 95.0%.

An evaluation study, included 22 hand move system in the project area, was carried out by the project and reported in the second progress report indicated that one hand-move system had AELQ equal to 78%, and 38.1% of the systems had AELQ's less than 50%. However, 71.4% of the systems had AELQ's less than 60%. The application efficiency of low quarter has a direct effect on the amount of water losses. In this case, if an ALEQ has been improved from 60% to 78.3% there would be a water saving of 23.4% calculated as follows:

$$\text{Percent of water saving} = \left(1 - \frac{AELQ1}{AELQ2}\right) \times 100$$

$$= \left(1 - \frac{60}{78.3}\right) \times 100 = 23.37\%$$

The cost per feddan is estimated to 430 LE as presented in Table (9). Therefore, the hand-move sprinkler system has the lowest investment cost among all types of pressurized irrigation systems but the highest labor requirement.

With the increase of hand-move sprinkler system, there is a corresponding increase in the demand for soluble fertilizers that are applied through sprinkler systems. Application of fertilizers through the sprinkler system saves considerably in labor as both irrigation and fertilization are applied in one operation. The fertilizer, applied evenly throughout the area to be covered, can be placed to any desired depth without danger of leaching. With the fertilizer in solution, it is immediately for plant use. All of these factors combined produce a saving in both labor and fertilizer. Therefore, a modified portable fertilizer tank is being used with hand-move system for the first time in the Model farm.

An inlet screen filter was installed at the inlet of the hand-move lateral line to prevent debris from interring and clogging the sprinkle nozzles.

Table 6.1 Detailed cost of Hand-move for 5 feddans at 12 m by 12 m spacing.

Item	*Unit*	*Qty.*	*Unit price*	*Amount*
Aluminum pipe 3", 6 m with hook coupler	No.	15	104	1560
Aluminum pipe 3", 9 m with hook coupler	No.	1	132	132
Aluminum riser 1", 0.8 m	No.	7	11	77
Sprinkler 30 TNT, 3/4 inch	No.	7	24	168
Reducer 1/0.75 inch	No	7	2	14
End plug, 3 inch	No.	1	20	20
Hydrant aluminum value 3 inch	No.	1	65	65
Aluminum Elbow valve, 3 inch	No.	1	75	75
Aluminum Elbow 3 inch with hook coupler	No.	1	40	40
Total cost (L.E.)				*2151.00*

Cost per feddan $= \frac{2151}{5} = 430.2$ L.E.

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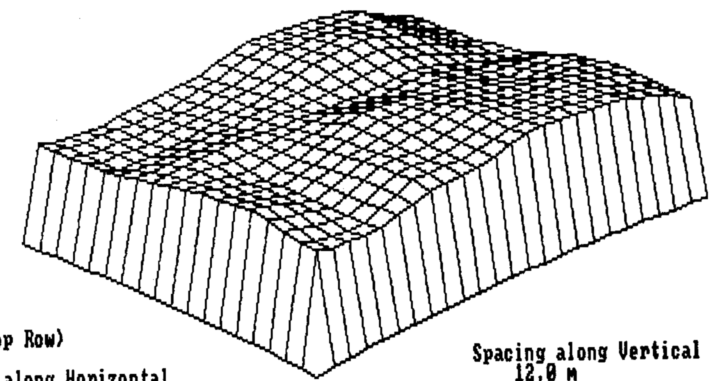
"Hand-move Model farm, 30TNT - 5 x 2.6 mm -1.83 m3/hr - 9 x12 m spacing"

Overlap Pattern for a 9 x 12 m Rectangular Spacing with sprinklers at each corner
Catch measurements are in milliliters
Catch Can Area: 3318 sq. mm
Test duration: 60 min. Discharge: 0.51 l/s (8.1 gpm)
Wind Speed: 1.00 m/s Direction: 0 deg from N
Grid Spacing: 1.50 m

Catch Efficiency = 92.3 percent

Application Depths from Overlapped Patterns (milliliters)

44.	50.	49.	48.	42.	44.
42.	44.	44.	50.	42.	44.
53.	52.	50.	49.	46.	45.
52.	55.	58.	50.	50.	51.
59.	61.	57.	50.	58.	60.
60.	57.	56.	55.	63.	61.
59.	58.	51.	50.	58.	63.
54.	56.	55.	45.	48.	51.



Rectangular Spacing with Sprinkler at Each Corner

STATISTICS for a 9 x 12 m Rectangular Spacing

Average Net Application 52.06 ml Test duration: 60 min.
Average Deviation from Mean 5.11 ml Discharge: 0.51 l/s
Standard Deviation 6.05 ml
Skew 0.01
Kurtosis 2.03
Average Net Application 15.7 mm/hr (0.62 in/hr)
Average Deviation from Mean 1.5 mm/hr (0.06 in/hr)
Average Gross Application 17.0 mm (0.67 in)
Average Net Application 15.7 mm (0.62 in)
Average Depth Highest 10% 18.6 mm (0.73 in)
Average Depth Lowest 10% 12.9 mm (0.51 in)
Average Depth Low Quarter 13.3 mm (0.52 in)
Average Depth Low Half 14.2 mm (0.56 in)
App. Eff. Low Quarter (AELQ) 78.3 %
App. Eff. Low Half (AELH) 83.3 %
Distribution Uniformity 84.8
Coefficient of Uniformity (CU):
CU from Christiansen 90.2 CU from Low Half 90.3
CU from Std. Dev. 90.7 CU from Distr. Unif. 90.4
CU for alternate offsets 95.0

6.3. *Fixed System*

Irrigation labor shortage has increased the number of fixed systems in use today. Figure 6.3 shows the fixed sprinkler system installed on 2.5 fedanns in the model farm. Fixed systems are found on high cash-return crops. High initial installation cost must be offset over the life of the system by labor savings and increased quality and quantity of crops produced. Fixed systems have brought the multiple-use concept to the irrigation field by permitting the irrigation equipment to be used in applying fertilizers, environmental control, weed and insect control, in addition to their original irrigation water application functions. All these additional uses reduce production costs and help amortize the original system investment. Individual laterals are controlled by valves and each lateral may be operated as desired.

All fixed systems are ideal for applying water-soluble fertilizers and other chemicals. The capacity of fixed systems can be 5 to 10 percent less than hand-move system in the same area because there is no down time during lateral moves. The capacity should be sufficient to apply the peak net crop water requirements for low frequency irrigations. These systems may be used to apply fertilizers and other chemicals and can be controlled by hand valves.

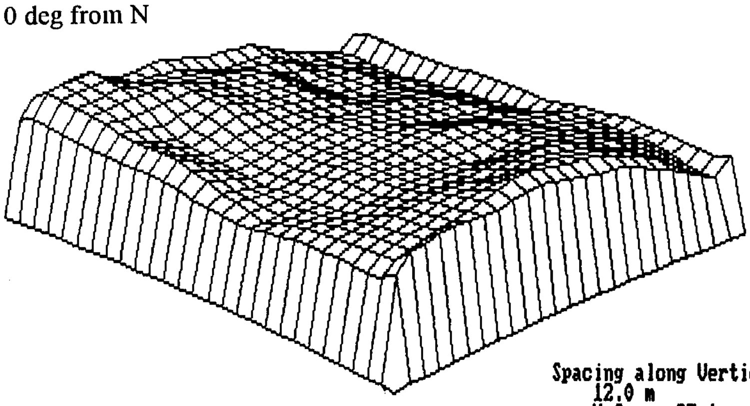
The detailed cost of fixed sprinkler system of 2780 L.E. / fd. is presented in Table 6.2. The installed fixed system was field evaluated to check the design and confirm the design efficiency as presented in the evaluation sheet. The system showed a performance of 85 % coefficient of uniformity and 76 % application efficiency.

Fixed System. 12x15m, 6x2.5 mm- 30TNT

Original data (Rectangular Catch Can Spacing) Units are milliliters.

Row/Col	1	2	3	4	5	6	7	8	9
1	70	67	65	56	64	77	78	87	95
2	77	73	62	60	57	61	67	90	99
3	84	77	68	68	65	67	82	89	79
4	93	75	68	68	68	71	74	78	78
5	87	82	64	73	67	63	71	75	68
6	81	77	72	69	57	62	53	56	70
7	67	67	64	59	57	56	51	55	52
8	44	53	55	55	45	43	43	41	48

Catch can volume = 2.761 cubic meters
Discharge volume = 3.430 cubic meters
Catch Efficiency = 80.5 percent
Catch measurements are in milliliters
Catch Can Area: 3959 sq. mm
Test duration: 60 min. Discharge: 0.95 l/s (15.1 gpm)
Wind Speed: 3.55 m/s Direction: 0 deg from N
Grid Spacing: 1.50 m



Spacing along Vertical
12.0 m
U.C. = 85.1

STATISTICS for ORIGINAL DATA

Average Net Application 67.49 ml Test duration: 60 min.
Average Deviation from Mean 10.04 ml Discharge: 0.95 l/s
Standard Deviation 12.93 ml
Skew 0.12
Kurtosis 2.81
Average Net Application 17.0 mm/hr (0.67 in/hr)
Average Deviation from Mean 2.5 mm/hr (0.10 in/hr)
Average Gross Application 21.2 mm (0.83 in)
Average Net Application 17.0 mm (0.67 in)
Average Depth Highest 10% 23.1 mm (0.91 in)
Average Depth Lowest 10% 11.4 mm (0.45 in)
Average Depth Low Quarter 12.9 mm (0.51 in)
Average Depth Low Half 14.5 mm (0.57 in)
App. Eff. Low Quarter (AELQ) 61.0 %
App. Eff. Low Half (AELH) 68.5 %
Distribution Uniformity 75.7
Coefficient of Uniformity (CU):
CU from Christiansen 85.1 CU from Low Half 85.1
CU from Std. Dev. 84.7 CU from Distr. Unif. 84.7
CU for alternate offsets 92.3
Ave. vol./sprinkler spacing 2.76 cu.m (97.5 cu.ft)

Table 6.2. Detailed cost of fixed sprinkler (2.5 feddans) 12 × 12 m spacing.

Item	*Unit*	*Quantity*	*Unit cost*	*Amount*
PVC 110 mm, 6 bar	m	45	7.75	348.75
PVC 90 mm, 6 bar	m	85	5.24	454.4
PVC 75 mm, 6 bar	m	207	3.65	755.55
PVC 63 mm, 6 bar	m	192	2.6	499.2
PVC 50 mm, 6 bar	m	288	1.95	561.6
Iron reducer 2/3 inch	No.	8	13.05	104.4
Nipple 2 inch	No.	32	3.75	120
Elbow 2 inch	No.	24	5.25	126
Union 2 inch	No.	8	9	72
Ball valve 2 inch	No.	8	30	240
Threaded 2 inch iron pipe 1 m long	No.	8	25.5	204
PVC male adapter 2 inch/75 mm	No.	8	2.25	18
PVC clamp saddle $\frac{3}{4}$ inch / 75 mm	No.	16	3.09	49.44
PVC clamp saddle $\frac{3}{4}$ inch / 63 mm	No.	16	2.15	34.4
PVC clamp saddle $\frac{3}{4}$ inch / 50 mm	No.	24	1	24
PVC threaded riser $\frac{3}{4}$ inch / 1.5 m long	No.	56	7.125	399
Iron socket $\frac{3}{4}$ inch	No.	56	1	56
Sprinkler 30 INT, 3/4 inch	No.	56	24	1344
PVC reducer 75/63 mm	No.	8	3.75	30
PVC reducer 63/50 mm	No.	8	2.6	20.8
Miscellaneous	L.S.	-	-	1488.70
Total cost	-	-	-	*6950.24*

$$\text{Cost per feddan} = \frac{6950.24}{2.5} = 2780.1 \quad \text{L.E.}$$

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Fig. 6.3 Fixed Sprinkler System in the Model Farm

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6.4. ***Drag Hose Sprinkler System***

The hand-move sprinkler is a labor intensive system. The introduction of drag hose sprinklers would reduce the labor demand to about half of that required for a comparable hand-move lateral system. It is also more convenient, easier to operate and saves deterioration of lateral pipes and fittings. The Model Farm demonstrates to the farmers how to convert their hand-move sprinkler to drag hose. The drag hose system extends the life of the aluminum laterals and couplers that is an improvement consideration in the project area in view of the present intensive use of equipment. The drag hose is more flexible and ensures a better distribution of water, particularly on windy days. It also has a greater social acceptability in terms of reduced need for manual pipe transport.

The drag hose sprinkler is considered as a modification of the hand move sprinkler system. In drag hose system (Fig 6.4), individual sprinklers are supplied by hoses and periodically moved to cover several positions. In this case 7 sprinklers are attached to 7 flexible hoses (48 m length and 25 mm diameter) and the lateral line remains stationary. Sprinklers are mounted on skids and towed periodically to give grid patterns of 12 x12 m. Risers are one meter tall to keep the sprinklers above the mature crop.

The detailed cost for changing only 50% of the area (2.5 feddans) from hand-move to drag hose is presented in the Table below. The cost per feddan is estimated to 389 LE.

The installed drag hose system was field evaluated to check the design and confirm the design efficiency as presented in the evaluation sheet. The drag hose showed a performance of 83 % coefficient of uniformity and 74 % distribution uniformity.

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Cost Estimate

Item	Unit	Quantity	Unit cost	Total cost
PVC 110 mm	m	22	7.75	170.5
Clamp saddle 50mm/3/4"	item	7	1	7
riser & skid	item	7	20	140
Male adapter 25mm/1"	item	7	2.53	17.71
Elbow 1"	item	7	2	14
Ball valve	item	7	10	70
P.E. 25 mm	m	385	1	385
Sprinkler head 3/4" TNT	item	7	24	168

Total cost	LE. 972.21

Fig. 6.4. Drag Hose Sprinkler System In The Model Farm.

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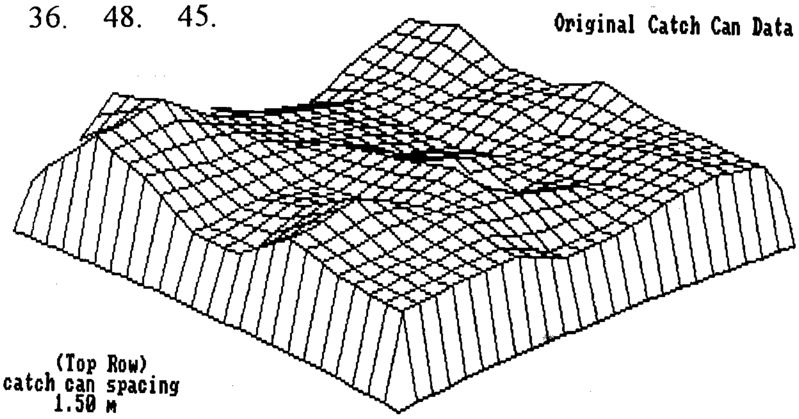
Drag hose 30TNT, 5 x 2.6mm, 1.73m3/hr @ 2.6 bar- 12x12 m spacing

Overlap Pattern for a 12 x 12 m Rectangular Spacing with sprinklers at each corner
Catch measurements are in milliliters
Catch Can Area: 3318 sq. mm
Test duration: 60 min. Discharge: 0.48 l/s (7.6 gpm)
Wind Speed: 3.85 m/s Direction: 0 deg from N
Grid Spacing: 1.50 m

Catch Efficiency = 80.6 percent

Application Depths from Overlapped Patterns (milliliters)

30.	31.	37.	23.	23.	37.	47.	27.
31.	33.	42.	32.	27.	34.	52.	48.
32.	37.	34.	28.	28.	36.	39.	30.
24.	36.	40.	36.	34.	29.	32.	29.
25.	33.	20.	30.	25.	28.	28.	21.
31.	29.	25.	25.	21.	23.	26.	18.
36.	35.	31.	28.	33.	29.	31.	33.
33.	35.	37.	43.	35.	36.	48.	45.



S T A T I S T I C S for a 12 x 12 m Rectangular Spacing

Average Net Application 32.09 ml Test duration: 60 min.
Average Deviation from Mean 5.42 ml Discharge: 0.48 l/s
Standard Deviation 7.09 ml
Skew 0.59
Kurtosis 3.47
Average Net Application 9.7 mm/hr (0.38 in/hr)
Average Deviation from Mean 1.6 mm/hr (0.06 in/hr)
Average Gross Application 12.0 mm (0.47 in)
Average Net Application 9.7 mm (0.38 in)
Average Depth Highest 10% 14.2 mm (0.56 in)
Average Depth Lowest 10% 6.3 mm (0.25 in)
Average Depth Low Quarter 7.2 mm (0.28 in)
Average Depth Low Half 8.0 mm (0.32 in)
App. Eff. Low Quarter (AELQ) 59.8 %
App. Eff. Low Half (AELH) 67.0 %
Distribution Uniformity 74.2
Coefficient of Uniformity (CU):
CU from Christiansen 83.1 CU from Low Half 83.2
CU from Std. Dev. 82.4 CU from Distr. Unif. 83.7
CU for alternate offsets 91.2

6.5. *Drip Irrigation System*

Evaluation of the existing drip irrigation systems was carried out in 49 desert farms representing four areas namely; South Tahrir, El-Bostan, Sadat and Wad: El-Natron, during the second year of the project and was reported in the second progress report. The data obtained from the field evaluations of drip systems for the area under study were analyzed and performance parameters were calculated. The frequency distribution of the emission uniformity for drip irrigation systems, showed that 20 percent of the systems had emission uniformity (EU) equal to or greater than 80 percent. Forty-four percent had EU's equal to or less than 60%, while 36 percent of the systems were between 60 and 80 percent. Thirty-six of the drip systems, which was the maximum frequency of occurrence, had EU's less than 50 percent. It can be said that 20 percent of the drip systems were in the acceptable limits of EU (about 80 percent EU) and 44 percent of the systems showed very poor EU (below 60 percent EU) .

Major factors responsible for low emission uniformity included : clogging of emitters, leakage, low operating pressure, mixed and broken emitters, in adequate filtration, insufficient control values, and lengthy laterals. The study revealed that poor EU was not only due to improper design but also due to inadequate system maintenance with respect to leakage, clogging, in sufficient filter capacity and system cleaning.

The drip system introduced to El-Bustan is designed for the production of fruit trees only, this would mean settlers have no income for the first 3-5 years. To help resolve this problem, it is proposed that the farmer install an additional drip system to irrigate part of his farm for vegetable production at a cost of 2600 LE/fd. The cost of additional drip system is presented in Tables 6.3 - 6.5.

Table 6.3 Detailed cost for installing Drip Irrigation Control Unit for 10 feddans.

Item	Unit	Quantity	Unit price	Amount
Media filter 20 inches with three way hydraulic flushing valve	item	3	2104.50	6313.50
Disc filter 2 inches	item	3	400	1200
Air valve 2 inches	item	1	150	150
Pressure relief valve 2 inches	item	1	425	425
flow meter 4 inches	item	1	1380	1380
Fittings & Miscellaneous	L.S.	-	-	1076.9
Total cost (L.S.)				10545.40

$$\text{Cost per feddan} = \frac{10545.4}{10} = 1054.54 \text{ LE}$$

Table 6.4 Detailed cost for installing 2.5 feddans drip vegetables (1.5m row Spacing)

Item	Unit	Quantity	Unit cost L.E	Amount L.E
PVC 110 mm	m	25	7.75	38.75
PVC 90 mm	m	100	5.24	524
PVC 75 mm	m	270	3.65	985.5
Gate value 3 inches	Item	1	177	177
Ball value 1.5 inches	Item	4	25	100
Ball value 2 inches	Item	4	30	120
Y filter $\frac{3}{4}$ inche	Item	1	35	35
venture injector 1 inch	Item	1	450	450
Grommet 14 mm	Item	260	0.100	26
PE dripper line (GR) 16 mm	Item	18	200	3600
Fittings	L.S.	-	-	247.1
Miscellaneous	L.S.	-	-	218
Total				6521.35

$$\text{Cost per feddan} = \frac{6521.35}{2.5} = 2608.54 \text{ L.E}$$

Table 6.5 Detailed cost for installing 2.5 feddans drip citrus and olives 5 × 5 m.

Item	Unit	Quantity	Unit cost(L.E)	Total cost(L.E)
PVC 90 mm	m	15	5.24	78.6
PVC 75 mm	m	40	3.65	146
PVC 50 mm	m	160	1.95	312
PVC 110 mm	m	25	11.75	193.75
Ball valve 2 inches	item	2	30	60
Ball valve 1 inch	item	2	10	20
Fertilizer Tank (120 liters)	item	1	300	300
PE 16 mm	item	5	200	1000
Katif emitter 4L/H	item	450	0.25	112.5
Fittings	L.S.	-	-	151.2
Miscellaneous	L.S.	-	-	114
Total				2488.05

$$\text{Cost per feddan} = \frac{2488.05}{2.5} = 995.22 \text{ LE}$$

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It was considered to the best advantage of the design to grow various crops such as different orchards and vegetables. By providing alternatives for the farmers desired contingencies appear; higher profit margin, different high valued crops (vegetables) or lowering their annual costs. In model # 4 the entire standard area of five feddans were dedicated to emphasizing possible mixed orchards of deciduous trees like grapes, apples and pears with olives and citrus fruits as examples of the evergreen family. In Model # 3, half the standard area; which is 2.5 feddans was divided into two separately irrigated plots. One for irrigating vegetables and the other for an evergreen orchard which is planted mangoes. similarly model # 2 irrigates both vegetables and an orchard of peaches and almonds.

The following factors were considered in the design of drip systems in the model farm:

6.5.1. Length of Lateral line:

The length of lateral line was limited to 50 m in order to limit the flow rate variation to 10% which corresponded to pressure variation of 18% calculated as follows:

GR Dripline ϕ 16 mm with drippers 4 liter/hr @ 1 bar pressure Dripper spacing 50 cm - pipe outside diameter = 16 mm
pipe inside diameter = 13.6 mm
Emitter flow equation $q\ (l/h) = 1.28\ H^{0.497}$
By differentiating the equation and dividing by the original equation, the following can be obtained

$$\frac{dq}{q} = 0.497 \frac{dH}{H}$$

$$\frac{dq}{q} = \textbf{Relative flow variation}$$

$$\frac{dq}{q} = \textbf{Relatine pressure variation}$$

if the lateral line length is 50 m then the head loss = 1.8 m which gives

$$\frac{dH}{H} = \frac{1.8}{10} = 0.18$$

then

$$\frac{dq}{q} = 0.497 \times 0.18 = 0.08$$

This means that 8.9 % of flow variation occurred in the lateral line of 50 m length which corresponded to a pressure variation of 18%.

If the lateral line length were 58m then the head loss would be 2.7 m which corresponded to an unacceptable variation of 13.5% and a pressure variation of 27%.

6.5.2. Control unit:

Media Filter: Three media fillers, 20 inches in size, provided with three way hydraulic flushing valve were used to remove suspended materials as finer sediments and suspended organics from surface water to prevent emitters clogging. Surface water is generally contains organic contaminants such as algae, weed seeds, snails, moss, certain forms of bacteria, and generally any thing that is or was alive. surface water contains inorganic contaminants as well such as sand, silt, and clay particles. Media filters are ideally suited for filtering water with either organic or inorganic contaminants. Sand media filters have the ability to entrap and hold large quantities of contaminants, due to the three-dimensional nature of the filter bed .

Screen filter: Three Disc filters 2 inches size were used as a backup for meddle filters.

Air Relief valves: Two inches air relief valve was installed for the following reasons:

1- To allow air to escape when filling pipelines with water.
2- To allow air to enter when draining pipelines.
3- To remove air pockets at system high points caused by entrained air.
4- To prevent negative (suction) pressure in laterals after system shutdown.

Pressure Relief Valve: two inches pressure relief valve was installed at the control unit to prevent the buildup of high pressures in the pipeline. The high pressure conditions may result from any of the following:

1- Sudden opening or closing of the valve.
2- Starting or stopping of the pump.
3- The slamming shut of the check valve.

Flow Meter: Four inches flow meter was installed at the control unit to record the flow rate and control the irrigation system. Flow meter is essential part of a well designed drip irrigation system. Accurate flow rate information is indispensable for monitoring the continuing performance of the irrigation system, and for analysis of crop response to water and nutrients.

6.5.3. Fertilizer unit:

Three different fertilizer units were installed to the systems in order to inject fertilizers into irrigation water, these being: 1- Venture 2- Closed tank with modified connections and 3- the hydraulic pump.

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6.5.4. Field evaluation

The installed drip irrigation systems were evaluated to check the design and confirm the design efficiency as presented in the evaluation sheets for different emitters.

The GR drip line showed a high performance of 92% emission uniformity and 83% application efficiency. The Tubo-SC emitters gave an emission uniformity as highs as 94% and a high application efficiency of 85% . Similarly, the regular Turbo-key emitter showed an emission uniformity of 93% and application efficiency of 84%.

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Trickle Irrigation Evaluation

Location:Model farms, Orchard Model
Observer: N. Dowidar date: \5\'97
Crop:Apple, Guava spacing: m
Soil: sandy available water: 60 mm/m
Irrigation: Duration: 1 hr. frequency: days
Filter Type and Preformance:3 Yamit filter (gravel filter) ,outlet 3 inches 35-30 m3/ hr,
3 Arkal disk filter 2 inch inlet, 120 micron, 130 mesh, 25 m3/hr
Pressure Inlet:2.1 Bar @ Pressure Outlet:2 Bar Loss:0.1 Bar
Fertilizer Unit Characteristics: Emitter: Make: Model: SC Turbo Key Point spacing: m
Rated discharge per emission point: 6.2775 l/hr @ Pressure:2.1 Bar
Emission points per plant: 1 giving l/day
Laterals: Diameter: 16 mm Material: P.V.C Length: 45 m
Spacing: m

outlet location on laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
INLET END	A	52	6.24	50	6	50	6	54	6.48
	B								
	TIME	30		30		30		30	
	AVERAGE		6.24		6		6		6.48
1/3 DOWN	A	48	5.76	55	6.6	56	6.72	50	6
	B								
	TIME	30		30		30		30	
	AVERAGE		5.76		6.6		6.72		6
2/3 DOWN	A	54	6.48	51	6.12	51	6.12	56	6.72
	B								
	TIME	30		30		30		30	
	AVERAGE		6.48		6.12		6.12		6.72
Far end	A	53	6.36	53	6.36	57	6.84	47	5.64
	B								
	TIME	30		30		30		30	
	AVERAGE		6.36		6.36		6.84		5.64
Pressure	INLET	2.1		2.1		2.1		2.1	
	OUTLET	2		2		2		2	
MINIMUM RATE OF DISHARGE	6.227 l/hr								
Average rate of discharge	5.85 l/hr	EU = 93.9%		E_a = 84.5%					

Trickle Irrigation Evaluation

Location:Model farms, oppositer drag lines
Observer: N. Dowidar date: \5\'97
Crop:mangp spacing: m
Soil: sandy available water: 60 mm/m
Irrigation: Duration: 1 hr. frequency: days
Filter Type and Preformance:3 Yamit filter (gravel filter) ,outlet 3 inches 35-30 m3/ hr,
3 Arkal disk filter 2 inch inlet, 120 micron, 130 mesh, 25 m3/hr
Pressure Inlet: 2.2 Bar @ Pressure Outlet: 2..1 Bar Loss: 0.1 Bar
Fertilizer Unit Characteristics: Emitter: Make: Model:Turbo Key Point spacing: 0.5 m
Rated discharge per emission point: 5.39 l/hr @ Pressure: 2.5 Bar
Emission points per plant: 1 giving l/day
Laterals: Diameter: 16 mm Material: P.V.C Length: 45 m
Spacing: 5 m

outlet location on laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A	38	4.56	43	5.16	47	5.64	46	5.52
INLET END	B								
	TIME	30		30		30		30	
	AVERAGE								
	A	51	6.12	41	4.92	45	5.4	46	5.52
1/3 DOWN	B								
	TIME	30		30		30		30	
	AVERAGE								
	A	42	5.04	49	5.88	42	5.04	53	6.36
2/3 down	B								
	TIME	30		30		30		30	
	AVERAGE								
far end	A	44	5.28	5.16	43	43	5.16	46	5.52
	B								
	TIME	30		30		30		30	
	AVERAGE								
Pressure	INLET	1.8		1.8		2.2		2.2	
	OUTLET	1.5		1.5		2.1		2.1	
MINIMUM RATE OF DISHARGE	5.01 l/hr								
Average rate of discharge	5.39 l/hr	Eu= 92.9%		Ea= 83.6%					

Trickle Irrigation Evaluation

Location:Model farms, opposite fixed system
Observer: N. Dowidar date: \5\'97
Crop:faba beans spacing: m
Soil: sandy available water: 60 mm/m
Irrigation: Duration: 1 hr. frequency: days
Filter Type and Preformance:3 Yamit filter (gravel filter) ,outlet 3 inches 35-30 m3/ hr, 3
Arkal disk filter 2 inch inlet, 120 micron, 130 mesh, 25 m3/hr
Pressure Inlet: 1.2 Bar @ Pressure Outlet: 1.2 Bar Loss: 0 Bar
Fertilizer Unit Characteristics: Emitter: Make: Model: GR Point spacing: 5 m
Rated discharge per emission point: 3.95 l/hr @ Pressure: 1.2 Bar
Emission points per plant: 1 giving l/day
Laterals: Diameter: 16 mm Material: P.V.C Length: 45 m
Spacing: m

outlet location on laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A	34	4.08	34	4.08	35	4.2	38	4.56
INLET END	B	30	3.6	36	4.32	37	4.4	41	4.9
	TIME	30		30		30		34.09	
	AVERAGE		3.84		4.2		4.3		4.73
	A	30	3.6	33	3.96	31	3.72	31	3.72
1/3 DOWN	B	27	3.24	34	4.08	34	4.08	35	4.2
	TIME	30		30		30		30	
	AVERAGE		3.42		4.02		3.9		3.96
	A	33	.96	31	3.72	31	3.72	32	3.84
2/3 DOWN	B	33	3.96	31	3.72	30	3.6	33	3.96
	TIME	30		30		30		30	
	AVERAGE						3.66		3.9
	A	29	3.48	32	3.84	34	4.08	36	4.32
Far end	B	33	3.96	30	3.6	31	3.72	35	4.2
	TIME	30		30		30		30	
	AVERAGE						3.9		4.26
Pressure	INLET	1.2		1.2		1.2		1.2	
	OUTLET	1.2		1.2		1.2		1.2	
MINIMUM RATE OF DISHARGE	3.63 l/hr								
Average rate of discharge	3.95 l/hr	Eu=92 %		Ea =82.7 %					

7. On-farm Modifications of irrigation systems and their technical and economic evaluation.

7.1 Background

The development of specifications for improved irrigation systems and modifications that improved their performance and controlled on farm water losses was discussed and presented in chapter 5 and implemented in the Model Farm of irrigation systems in chapter 6. Ten farms in Bustan and South Tahrir areas were selected to implement the proper modifications and evaluate technically and economically the impact of such modifications on irrigation efficiency and the value of water under different irrigation and cropping systems.

Five farms were selected in each area and included the most common irrigation systems in the area; namely, hand-move sprinkler, fixed sprinkler, and drip systems. Detailed technical observations were carried out on each farm to record what is actually practiced rather than what farmers say. The ten farms were subjected to intensive observation and monitoring to collect information related to crop grown yield, area, fertilizer application, labor, energy consumption, and other agriculture practices, soil type, soil and water salinity ... etc. The irrigation systems were fully reviewed and modifications to improve their performance and control water losses were specified and implemented. For drip systems, these included installing creen filter, correct size PVC submains, lateral lines, grommets, emitters, seals, figure 8 ending, flush system, a number of modified fertilizer tank and flow meters were also distributed among the farms.

For sprinkler systems, modifications included the optimum sprinkler spacing for different sprinkler types to obtain maximum water uniformity. A screen filter has been introduced in hand-move systems at the head of the lateral line between the valve elbow and the first section of pipe to avoid nozzle blocking. The project has also introduced a modified fertilizer tank to hand-move systems. The performance of the irrigation systems was evaluated before and after modifications. The irrigation water used through the growing season was measured using flow meters installed in the system. All inputs and outputs over the growing season were recorded. Using the change in application efficiency the percent of water saved was calculated. An inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring and accurate determination was prepared for each farm and used in the economic analysis. The delivery cost of water was calculated using the total annual cost (fixed + operational) and the total amount of water pumped annually. The opportunity cost of water was also calculated as the net benefit in L.E. per fed/water pumped per fed. in m3 as will be shown for each farm. The data are summarized and represented for each of the ten farms in table (7.1) and the detailed data and calculations are presented in the Appendix.

7.2 ***Results & Data Analysis:***

Ten representative farms were studied and irrigation systems were evaluated. Drip irrigation systems generally provided an average emission Uniformity of 39% - 65% with an application efficiency of 35% - 55%. This low efficiency was mainly due to both incompetent pumping units and poorly installed systems. The existing drip systems mostly consisted of the same common problems; i.e. damaged and loose grommets, laterals and emitters, along with the absence of flushing systems, lateral endings and negligent system maintenance.

Sprinkler irrigation however, ranged in Uniformity Coefficient 49% - 77% and application efficiency 32% - 39%. This low efficiency was a result strongly associated with the low available pressures, mixed nozzle diameters and makes, deteriorated sprinkler parts and fittings, inadequate spacing and absence of wind.

Operating pressures through the study area are significantly below the design values at the sprinkler nozzle. This applies to both collective and individual pumping stations. These must be restored if sprinkler irrigation is to achieve an acceptable level of water distribution efficiency through the distribution of water. This can only be achieved through better water management and the programmed maintenance of the equipment and elemination of causes of wear in pump impellers.

Table (7.1) : Effect of Irrigation Systems Modifications on Percent of Water Saved, and Delivery and Opportunity Cost of Water in Ten Farms

Farm	Type of Crop	Type of Irrigation System	Type of Pump	Cost of Electricity LE/fd or diesel LE/Day	Before Modifications		After Modifications		% Water Saved	Cost of Water LE/m3	
					Ea%	Cu/Eu %	Ea%	Cu/Eu %		Delivery	Opportnity
1	Banana	Drip	Turbine	100	53	58.8	77	85.76	31.16	0.1	1.0
2	Eggplant & Garlic	Drip	Centrifugal	12.8 (diesel LE/Day)	35.4	39.3	80	89	55.75	0.075	1.27
3	Tangerine	Hand-move	Centrifugal	121.5	43.6	68	65.5	78	33.43	0.067	0.42
4	Wheat	Hand-move	Turbine	89.1	39.5	77.7	58.8	85	32.82	0.04	0.36
5	Tomatoes	Drip	Turbine	114.46	55	65	83	92.4	33.75	0.12	--
6	Wheat	Hand-move	Turbine	85	51.2	60.97	59.07	81.55	13.32	0.054	0.54
7	Potatoes	Fixed	Centrifugal	135.26	50.2	74.3	77.52	88	35.24	0.05	0.1
8	Peanuts	Fixed	Centrifugal	135.26	44.84	66.5	45	82	0.35	0.058	0.11
9	Sorghum	Hand-move	Turbine	100	32.83	49.33	69.3	81.24	48.9	0.078	0.14
10	Strawberry	Drip	Turbine	114.46	52	57.8	77.2	86	32.64	0.12	0.5

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Many of the existing sprinklers do not meet performance specifications in terms of rotation speed, diameter of application and efficiency of uniformity. A nation wide testing laboratory should establish standards for pipes and fittings. What is needed currently is a sprinkler testing facility to ascertain distribution patterns and uniformity characteristics of sprinklers.

The basic supply of irrigation water to the collective and individual pumping stations does not fulfill ;the design expectations which, together with failure of the electricity supply and breakdown of pumps, means that the farmers are only able to get water for about 8-11 hours a day instead of the designed 15.

Consequently, this would reduce the area that can reliably be irrigated by about 53-73%. Possible solutions would be: decreasing the cultivated area, use of drought resistant crops, and thinking of maximum production per cubic meter of water used, instead of using maximum water requirements.

After evaluating the existing irrigation systems, solutions and modifications were suggested to improve the irrigation efficiency. These included: installing screen filters, correct size PVC submains, lateral lines, grommets, emitters, seals, figure 8 endings, flush systems, a number of modified fertilizer tanks and flow meters were also distributed among the farms.

Following these modifications evaluations were conducted. By comparing both efficiencies before and after modifications, it can clarify the increase in Application Efficiency to 59%-83%. Accordingly, 33%-45% of water was saved.

The average delivery cost of water which includes the cost of pumping ranged between 0.04% L.E./m3 and 0.1 LE/m3. Economic theory states that the opportunity cost is the best measure of value. In arid land this is much greater than in humid regions. One approximation of this opportunity cost of water would be to consider the profit available were another feddan of land brought under irrigation using the water saved from applying less. Using the values of net benefit and amount of water required to irrigate on feddan, the opportunity cost ranged between LE 0.1 and 1.27.

It should be mentioned however, that the calculation of the opportunity cost was affected by the yield which in turn is affected by management. The limited data (10 farms) did not permit more analysis relating the percent water saved, the delivery and the opportunity cost of water to the type of irrigation system and crop although they indicate the delivery cost of water in drip system is higher than in the sprinkler systems.

The data, however, emphasize that the opportunity cost of water is much higher than the its delivery cost and this should be considered when the real value of water is evaluated (water pricing). The data emphasize also that existing irrigation systems could be modified to save water and the percent water saved in the ten farms studied varied between 13-56% with an average of 35%.

APPENDIX

On-farm Modifications of irrigation systems and their technical and economic evaluation.

Individual Study Cases

FARM **# 1:**

Owner: Naser Manaa

Location: well # 5 on open canal # 3, Tahrir area

Type of irrigation system: Drip

(Farm description from questionnaire)

Existing Irrigation system Evaluation:

Trickle Irrigation Evaluation Sheet

Location: S. Tahrir Farm no. 4 Farmer's name: Naser Manaa

Observer: Yasser Zedan date:

Crop: Banannas spacing: 3.5x 3 m

Soil: Loamy-sandy available water: 60 mm/m slope: 0.5 %

Irrigation: Duration: 1 hr . frequency: daily

Filter Type and Performance: Six disc filters each 2 inch openings (120 micron, 130 mesh) 3 x 36 inch Yamit media filters

Pressure Inlet: 1.1 Bar @ Pressure Outlet: 0.3 Bar Loss: 0.8 Bar

Fertilizer Unit Characteristics: Emitter: Make: Israel Model: Kativ Point spacing: 0.5 m

Locally made 200 liter tank (closed)

Rated discharge per emission point: 4.05 l/hr @ Pressure: 0.7 Bar

Emission points per plant: 12 giving 48.6 l/day

Laterals: Diameter: 16 mm Material: P.E Length: 45 m Spacing: 3.5m

utlet cation laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A	37		37		34		47	
ET END	B	34		15		39		29	
	TIME	30		30		30		30	
	AVERAGE	35.5	4.26	26	3.12	36.5	4.38	38	4.56
	A	57		46		9		19	
DOWN	B	40		30		28		15	
	TIME	30		30		30		30	
	AVERAGE	48.5	5.82	38	4.56	18.05	2.22	17	2.04
	A	61		39		44		41	
DOWN	B	70		17		32		30	
	TIME	30		30		30		30	
	AVERAGE	65.5	7.86	28	3.36	38	4.56	35.5	4.26
	A	42		20		18		26	
R END	B	46		18		38		24	
	TIME	30		30		30		30	
	AVERAGE	44	5.28	19	2.28	28	3.36	25	3
essure	INLET	1.1		1		0.9		0.8	
	OUTLET	0.7		0.6		0.3		0.3	
NIMUM ATE OF HARGE	2.38l/hr								
verage ate of charge	4.05 l/hr	Eu=58.8 %		Ea = 53 %					

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1. Lack of maintenance. emitters continued to clog due to the lack of regular manual cleansing of lines. Furthermore the filteration efficiency of the fertilizer assisted in the clogging process.
2. Loose fittings between connecting gromets, seals and emitters. This was apparent wowing th the leakage in submain and laterals. Also, using insufficient tools and equipment during installation of the system caused a high percentage fo this leaking.
3. Insufficient submain diameter.

Suggested Solutions and Modifications:

1. Installing a new fertilizer filter to the control unit to avoid lateral and emitter clogging that prebiously complicated the constant discharges of the emitters.
2. Installing a new P.V.C submain (63 mm vs 50 mm) with the correct wqupment to avoid previous leakages and decrease in pressure.
3. Installing completely new laterals and emitters; to assure standards and end all leakages due to loose emitters and previously noted factors.
4. Organizing manual maintainment on a regular basis.

Materials Required and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

Farm: Naser Manaa System: Trickle

No.	Item	Unit	Amount	Price	Total Cost
1	seals		200	12	12
2	figure 8 endings		200	5	5
3	gromets		200	12	12
4	P.E coupling		200	12	12
5	Israelian Kativ emitters, 4 l/hr, package of 2000		4	450	1800
6	P.E Bakir laterals, 16 mm in coils of 400 m		4	204	816
7	P.V.C pipes, 63 mm, 6 atm.	meter	120	170.1	170.1
8	steel union, 2'		1	8	8
9	steel elbow, 2'		1	3.15	3.15
10	Arkal filter, 2', 120 micron, 130 mesh		1	470	470
11	male adaptor, 63 mm/2'		1	2	2
12	male adaptor, 63 mm/ 1'		1	3	3
13	ball valve, 1"		1	8.2	8.2
14	P.V.C glue	kg	1/2	25	25
15	pressure gauge, 6 atm.		1	35	35
16	flow meter, 4"		1	1312.5	1312.5
17	reducing bosch, 1/2"/ 1/4"		1	1	1
18	socket, 1"		6	1	6
19	socket, 1/2"		2	0.75	1.5
20	knife valve, 4"		1	225	225
21	bolts, 19 mm	kg	12	7.33	87.96
22	movable flange, 4"		3	5	15
23	stationary flange, 4"		3	6	18
24	steel pipe, 4"	meter	3.5	32	112
25	washer, 4"		3	3.5	10.5
26	end plug, 1"		4	1.64	6.56
27	P.V.C glue	kg	1/2	25	12.5

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluatiion was executed to confirm developement which appears in it's higher efficiency.

Trickle Irrigation Evaluation Sheet

Location: S. Tahrir Farm no. 4 Farmer's name: Naser Manaa
Observer: Yasser Zedan date:11/3/97
Crop: Bananas spacing: 3.5 x 3 m
Soil: Loamy-sandy available water: 60 mm/m slope: 0 %
Irrigation: Duration: 1 hr . frequency: daily
Filter Type and Preformance: six disc filters 2 inch openings (120 micron, 130 mesh), 3 x 36 inch Yamit media filters
Pressure Inlet: 1.5 Bar @ Pressure Outlet: 1.1 Bar Loss: 0.4 Bar
Fertilizer Unit Characteristics: Emitter: Make: Egyptian , Israel Model:GR & Kativ
Point spacing: 0.5 m Locally made 200 liter tank (closed)
Rated discharge per emission point: 4.26 l/hr @ Pressure: 1.3 Bar
Emission points per plant: 4 giving 32 l/day
Laterals: Diameter: 16 mm Material: P.E Lenght : 45 m Spacing: 3.5m

outlet location on laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A	35	4.2	39	4.68	36	4.32	30	3.6
INLET END	B	34	4.08	46	5.52	33	3.96	30	3.6
	TIME	30		30		30		30	
	AVERAGE		4.14		5.1		4.14		3.6
	A	36	4.32	38	4.56	35	4.2	34	4.08
1/3 DOWN	B	32	3.84	40	4.8	34	4.08	34	4.08
	TIME	30		30		30		30	
	AVERAGE		4.08		4.68		4.14		4.08
	A	33	3.96	40	4.8	33	3.96	31	3.72
2/3 DOWN	B	32	3.84	48	5.76	30	3.6	31	3.72
	TIME	30		30		30		30	
	AVERAGE		3.9		5.28		3.78		3.72
	A	27	3.24	49	5.88	39	4.68	38	4.56
FAR END	B	32	3.84	42	5.04	32	3.84	35	4.2
	TIME	30		30		30		30	
	AVERAGE		3.54		5.46		4.26		4.38
Pressure	INLET	1.1		1		0.9		0.8	
	OUTLET	0.7		0.6		0.3		0.3	
MINIMUM RATE OF DISHARGE	3.66l/hr	R.H= 40%		T = 25					
Average rate of discharge	4.26 l/hr	Eu=85.76 %		Ea = 77 %					

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Emission Uniformity (58.8% to 85.6%) and Application Efficiency (53% to 77%). Accordingly, as a result of the this difference 31.16% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = (1- AE_1/AE_2) x 100
= (1-53/77) x 100
= 31.16%

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labour and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

Farmer: Naser Manaa Location: Tahrir

COST AND RETURN FORM
PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	Bannanas, Wiliam
value of crop per unit (tons)	1500 LE/Ton
Seasonal consumptive use of crop	18985 m3
Number of hours operated each day	1.2
Minimum days required for each irrigation	1
Number of irrigation expected per season	365
Number of operated hours per year	443
Shape and dimensions of field	90 x 100 m
Type of irrigation system	drip
Number of feddands in field	12
Number of feddans irrrigated	2.14
Sprinkler or emitter discharge	4 lt/hr
Sprinkler or emitter spacings	1.75 x 0.5 m
Pumping rate needed (m3\hr)	42.8
Source of water	surface
Total height water is to be lifted	1.5 m
Total operationg head	5 Bar
Size fo power unit needed (hp)	500 Hp/ 640 feddans
Type of power unit	Electricity
Interest rate	9%
yield per unit area	13 ton
Hours labour feddan per irrigation	None

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initeal Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing				
Reservoir	30	180,000 LE/640 feddans	.097	17460 L.E/640 fd.
Pump Turbine Centrifugal				
Power Unit Electric Diesel				
Miscellaneous Electric switch Electric Transformer Fuel Tank Land Development	30	75,000 LE	0.097	7275
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC	30	1 million/ 640 fed.	0.097	97000
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable				
Surface systems: Land grading				
Drip systems:	10	5000 LE/ feddan	016	51200
Land Drainage				

COST AND RETURN FORM
PART C- ANNUAL OPERATING COST

ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel			16.7 LE/$area_{exam}$
Oil			
Repair & maintenance (power unit)			
Repair & maintenance (irrigation equipment)			214 LE/$area_{exam}$
Electricity			228.5 LE/$area_{exam}$
seed	5000		5992.5 LE/$area_{exam}$
fertilizer			9961.5 LE/$area_{exam}$
chemicals			
cosrs			
Labour			(8184 + 650) LE/$area_{exam}$

Total Income = yield x value of crop per unit
= 13 Tons/ feddan x 1500 LE/Ton
= 19500 LE/feddan
The Net Return = Total income/ feddan - Total annual cost/feddan
= 19500 - 11797.75 = 7702.24

Delivery Cost of Water

Total annual cost = Fixed cost for total area + Operating cost for total area
*Operating costs per total area only consists of irrigation costs and excludes other costs; i.e seeds, fertilizers and chemicals.
* Total area in Tahrir = 640 feddans
167935 LE/ 640 feddans + (303.7 +106.77 +100 +7.8) LE/feddan x 640 feddans
= 499630.19 LE/640 feddans

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 3000 hrs/yr x 1600 m^3/hr
= 4.8 x 10^6 m^3 /yr

Cost of pumping water = Total annual cost /Total amount of water pumped annually
= 499930.19 LE/yr / 48 x 10^5 m^3 /yr
= 0.10 LE

Therefore the amount of money saved in pumping water per feddan
$= 48 \times 10^3 m^3/yr \times 0.31 \times 0.1 / 640$ feddans = 232.5 LE/feddan
= water pumped annually x saved water x cost / Total area

Opportunity Cost of Water:

The net benefit function can be written as:

$$NB = P.Y - C.X - C_T$$

in which NB is the net benefit in LE/fd , P is the market price of the crop in LE/ton, Y is the crop yield in tons/fd, C is the delivery cost per unit of water in LE/m^3, X is the amount of water in m^3/fd, and C_t is all other costs in LE/fd.

The falacy of this analysis is equating the delibery costs. Economic theory states that theopportunity cost is the best measure of value. In an arid land, this is much greater than in humid regions.

One approximation of this opportunity cost of water would be to consider the profit available were another feddan of land brought under irrigation using the water saved from applying less.

Substituting values in the net benefit equation yields:

$$NB = 1500 \text{ LE/ton} \times 13 - 0.1 \times 7500 - 11279 = 7471 \text{ LE/m}^3$$

From the NB equation, water is worth 7471/ 7500 = 1 LE/m^3. This means that the delivery cost of water is much less than the opportunity cost.

One major point of this analysis is the dramatic difference between the delivery of water and its opportunity cost is almost 10 times more than the delivery cost. Only farmers with more land might possibly be influenced by this fact; however it is clear that such a cost ought to be considered as the value of water.

FARM #2:

Owner: Regab Bedawy Location: Arab land, Tahrir area

Type of irrigation system: Drip

(Farm description from questionaire)

Existing Irrigation system Evaluation:

Trickle Irrigation Evaluation Sheet

Location: S. Tahrir Farm no. 5 Farmer's name: Ahmed Bedawy

Observer: Yasser Zedan date:

Crop:Eggplant intercropped with garlic plant spacing: 40 x 25 cm

Soil: sandy available water: 60 mm/m

Irrigation: Duration: 1 hr. frequency: daily

Filter Type and Preformance: None

Pressure Inlet: 0.8 Bar Pressure Outler: 0.1 Bar Loss: 0.7 Bar

Fertilizer Unit Characteristics: Emitter: Make: Egyptian Model: Kativ Point spacing: 0.5 m

Tank 150 litre, locally made

Rated discharge per emission point: 5.34 l/hr @ Pressure: 0.7 kg/cm2

Emission points per plant: 1 giving 5.34 l/day

Laterals: Diameter: 16 mm Material: P.E Length: 30m Spacing: 1.65 m

outlet location on laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A		3.6		7.92		5.28		3.6
NLET END	B		9.36		9.00		3.48		4.2
	TIME		30		30		30		30
	AVERAGE		6.48		8.46		4.38		3.9
	A		6		4.32		2.28		2.04
1/3 DOWN	B		9.96		4.44		4.44		2.88
	TIME		30		30		30		30
	AVERAGE		7.98		3.38		3.36		2.46
	A		6.12		4.56		6.84		2.4
2/3 DOWN	B		7.32		7.56		6.36		2.04
	TIME		30		30		30		30
	AVERAGE		6.72		6.06		6.6		2.22
	A		6.12		4.08		4.68		2.04
FAR END	B		7.32		6.72		6.96		3.48
	TIME		30		30		30		30
	AVERAGE		6.72		5.40		5.82		2.76
Pressure	INLET	0.8		0.8		0.7		0.4	
	OUTLET	0.2		0.2		0.2		0.1	
MINIMUM RATE OF ISHARGE	2.1 l/hr								
Average rate of ischarge	5.34 l/hr	Eu=39.3 %		Ea = 35.4%					

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1.Absence of any filter either for filtering the water or fertilizer. This quickly resulted in clogged emitters, laterals and submain.

2. Damaged laterals and submain. This system's entire net work which consisted of P.E submain and laterals exceeded it's average life span and was ruined due to various cultivation operations and lack of proper maintenance.

3.Old, cracked gromets,seals and absence of lateral endings all decreased available pressure and kept emitters giving inconsistent discharges.

4. Absence of flush system.

Suggested Solutions and Modifications:

1.Installing an Arkal disc filter (120 micron, 130 mesh) to guarantee sufficient sub-farm water requirements,consistent emitter discharge and clean laterals and submain.

2. Installing an appropriately sized P.V.C submain (63 mm) and using the correct size of gromets, seals and figure 8 endings.

3. Replacing old damaged lateral lines with newer internal emitter lines to avoid loose emitters, loss of exessive water and pressure due to loose fittings between emitters and lateral.

4. Installing the correct flush system to maintain clean system.

Materials Required and Monitoring Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

Farm: Ahmed Bedawy System: Trickle

No.	Item	Unit	Amount	Price, L.E	Total Cost
1	pressure gauge	no.	1	35	35
2	package of Kativ emitters (1500)		1		
3	figure 8 endings ,16 mm		100	5 L.E	5
4	gromet seals		100	6 L.E	6
5	package of gromets		100	6 L.E	6
6	P.E coupling		100	6 L.E	6
7	P.E GR laterals 16 mm, 4 l\hr, coils of 400 m		4	172 L.E	688
8	submain P.V.C pipes, 63 mm	meters	60	170.1	170.1
9	P.V.C glue		1	25L.E	25
10	curved elbow, 63 mm		1	12	12
11	teflon spindle		10	0.5	5
12	P.V.C male adaptor 63/2"		1	2	2
13	male adaptor 63mm/1"		1	3	3
14	ball valve, 1 "		1	8.2	8.2
15	reduccing bosch, 1/2"/1/4"		1	1	1
16	socket, 1/2"		1	0.75	0.75
17	Arkal filter, 2'		1	470	470
18	steel elbow, 2"		1	3.15	3.15
19	steel union, 2"		1	8	8
20	steel socket, 2'		1	2.2	2.2
21	pressure gauage, 6 atm.		1	35	35
22	flow meter, 2"		1		

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluation was executed to confirm developement; which appears in it's higher efficiency.

Trickle Irrigation Evaluation Sheet

Location: S. Tahrir Farm no. 5 Farmer's name: Ahmed Bedawy
Observer: Naeem Dwidar Date: 7/1/97
Crop: Garlic plant spacing: 40x 25 cm
Soil: sandy available water: 60 mm/m
Irrigation: Duration: 1 hr. frequency: daily
Filter Vype and Preformance: Arkal filter, 2 inch opening 130 mesh, 120 micron
Pressure Inlet: 0.8 Bar Pressure Outler: 0.6 Bar Loss: 0.2
Fertilizer Unit Characteristics: Emitter: Make: Israel Type: Kativ Point spacing: 0.5 m
Rated discharge per emission point: 358 l/hr @ Pressure: 0.7 kg/cm2
Emission points per plant: 1 giving 8 l/day
Laterals: Diameter: 16 mm Material: PVC Length: 30m Spacing: 1.65 m

		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A	31	3.72	28	3.36	28	3.36	28	3.36
INLET END	B	29	3.48	28	3.36	28	3.36	28	3.36
	TIME	30		30		30		30	
	AVERAGE		3.6		3.36		3.36		3.36
	A	28	3.36	29	3.48	27	3.24	27	3.24
1/3 DOWN	B	30	3.6	30	3.36	26	3.12	26	3.12
	TIME	30		30		30		30	
	AVERAGE		3.48		3.42.		3.18		3.18
	A	29	3.48	28	3.36	28	3.36	28	3.36
2/3 DOWN	B	29	3.48	29	3.48	29	3.48	29	3.48
	TIME	30		30		30		30	
	AVERAGE		3.48		3.42		3.42		3.42
	A	30	3.6	28	3.36	27	3.24	27	3.24
FAR END	B	30	3.6	28	3.36	26	3.12	26	3.12
	TIME	30		30		30		3	
	AVERAGE		3.6		3.36		3.18		3.18
Pressure	INLET	0.8		0.6		0.6		0.6	
	OUTLET	0.8		0.6		0.6		0.6	
MINIMUM RATE OF ISHARGE	3.18 l/hr								
Average rate of ischarge	3.58 l/hr	Ea =80 %		Eu =89%					

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Emission uniformity (39.3% to 89%) and Applicaton

Efficiency (35.4% to 80%). Accordingly, as a result of the this difference 31.16% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = (1- AE_1/AE_2) x 100
= (1-35.4/80) x 100
= 55.75%

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labour and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

Farmer: Rageb Bedawy Location: Tahrir

COST AND RETURN FORM
PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	eggplant & onions
value of crop per unit (tons)	11531.71 LE/fd
crop yield per unit area	27.197 Tons + 0.32 Tons
Seasonal consumptive use of crop	
Number of hours operated each day	8
Minimum days required for each irrigation	1
Number of irrigation expected per season	300
Number of operated hours per year	2800 hrs/yr
Shape and dimensions of field	58 x 30
Type of irrigation system	drip
Number of feddands in field	25
Number of feddans irrigated	1
Sprinkler or emitter discharge	3.58 lt/hr
Sprinkler or emitter spacings	1.75 x 0.5 m
Pumping rate needed (m3\hr)	15 m3/hr
Source of water	well
Total height water is to be lifted	3.65
Total operationg head	2 Bar
Size fo power unit needed (hp)	16 Hp
Type of power unit	diesel
Interest rate	9%
Hours labour feddan per irrigation	None

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initeal Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing Reservoir Pump Turbine Centrifugal	13.5	3300	0.13	429
Power Unit Electric Diesel	10	8000	0.155	1240
Miscellaneous Electric switch Electric Transformer Fuel Tank Land Development				
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC				
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable				
Surface systems: Land grading				
Drip systems:	10	2000	0.155	311.64
Land Drainage				

COST AND RETURN FORM
PART C- ANNUAL OPERATING COST

.ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel	50 ltres/day	04 LE/litre	20 LE/day
Oil	16 litres/15 days	35 LE/16 litres	2.33 LE/day
Repair & maintenance (power unit)			2054 LE/yr
Repair & maintenance (irrigation equipment)			
Electricity			
seed	5000		937.5 LE/fd
fertilizer			827.43 LE/fd
chemicals			1000 LE/fd
cosrs			
Labour			415 LE/25 feddans

* Labour costs here do not include cultivation operation costs.

Total = 10605.45 LE/25 feddans

Total income = yield x value of crop per unit
= 11531.71 LE/fd
The net return = Total income/feddan - Total ann/ual cost/feddan
= 11531.71 - 3606.5 = 7925.21 LE/fd

Delivery Cost of Water

Total annual cost = Fixed cost for total area + Operating cost for total area
*Operating costs per total area only consists of irrigation costs and excludes other costs; i.e seeds, fertilizers and chemicals.
* Total area in Arab land = 25 feddans
Total annual cost = 10605.45 + 1980.64 = 12586.09 LE/25 feddan

Table of operating hrs per day during the year

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 2800 hrs/yr x 60 m^3/hr
= 168000 m^3/yr

Cost of pumping a m^3 of water = Total annual cost /Total amount of water pumped annually

= 12586.09 LE/yr / 16.8 x 10^4 m^3 /yr
= 0.0749 LE/ m^3

Therefore the amount of money saved in pumping water per feddan
= water pumped annually x saved water x cost / Total area

$= 16.8 \times 10^4\ m^3/yr \times 0.5575 \times 0.0749$ LE / 25 feddans = 280.66 LE/fedda

Opportunity Cost of Water:

The net benefit in LE/fd for eggplant inercropped with garlic under drip irrigation can calculated using the benefit function as follows:

$$NB = P.Y - CX - C_t$$

$$NB = 9234.85 - 0.0749 \times 5600 - (1348.72 + 300)$$

$$= 7166.69 LE/fd$$

Real value of water = 7166.69 / 5600 = 1.27 LE/ m^3

Notice that the opportunity cost is almost 1.27 / 0.1 = 17 times more than that of the delivery cost.

FARM # 3:

Owner: Mohammed Galal Location: Station no. 27, Nagah village, Tahady
Type of irrigation system: Drip
(Farm description from questionaire)

Existing Irrigation system Evaluation:

SPRINKLER - LATERAL IRRITGATION EVALUATION SHEET

location:S. Tahrir Farmer's name: Mohamed Galal
Observer: Y. Zedan
Crop: tangerines age: 3 yrs.
Soil: sandy available water:80 mm/m
Sprinkler: make: USA model: RB70
Sprinkler spacing : 15 by 15 m irrigation duration: 1hr.
Rated sprinkler discharge: 4.435 m3/hr, @ pressure 1.9 kg/cm2
Lateral: diameter: 3, 4 inch , slope: 0% riser height: 1 m

No. od sprinklers in the field	1	2	3	9 end
Pressure, Bar	1.9	1.9	1.9	1.9
Discharge, m3/hr	6.61	3.97	4.9	5.35
Nozzle dia., mm	6.8/5.2	7.4/7.1	8.2/7.5	9.1/5.7

Actual sprinkler pressure and discharge rates:

Wind: speed km/hr relative to lateral line:
initial 2.3, during 4.15, final 3.05

Duration of the exp.: 1 hr
Container rim diameter:71 mm
Container grid spacing: 1.5 by 1.5 m

28	27	46	64	75	80	81	60	44	31
31	34	50	72	84	87	81	67	44	31
37	36	68	89	141	104	111	80	59	45
72	60	95	123	127	127	128	72	81	78
67	71	86	118	143	154	134	102	93	77
71	56	81	95	119	137	136	3	86	92
71	20	74	67	71	90	100	88	76	113
50	44	50	54	60	67	70	70	52	123
43	22	43	43	119	54	59	66	72	157
11	23	44	50	45	46	52	64	65	220

Sprinkler radius of throw: 13.5m
Sprinkler's speed of rotation: 0.6 rpm
Sprinkler trajectory angle: 20
temp.= R.H= E.C = ppm

NOTES:

* Before modifications were applied.

Results: Cu = 68% Eu =44.8% Ea = 43.6 %

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1.Malfunctioning sprinklers, blocked nozzles, invariable sprinkler rpms and different wetted diameters which disrupted consistent application rates.

2. Damaged aluminum lateral line required mending in several places which led to the abrupt pressure drops and excessive leakages.

3. Loose fittings, bushings and seals between risers, respective sprinklers and lateral line pipes.

Suggested Solutions and Modifications:

1. Installing a hand-move screen and a modified technique of fertigation (solely designed for hand-move systems) at the head of the lateral line to avoid clogged nozzles and icrease fertilizer efficiency.

2. Replacing sprinkler components like sprinkler neks, springs, hammers and correct nozzle diameters.

3. Inserting new O-rubber gaskets and weld ruined areas along lateral line.

4.Providing advice as to how to operate and organize irrigation requirements.

Required Materials and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

Farm : Mohammed Galal System: Hand-move

No.	Item	Unit	Amount	Price	Total Cost
1	4" stationary flange	no.	3	6.00	18.00
2	4" movable flange	no.	2	6.50	13.00
3	1/2 "socket	no.	1	0.75	0.75
4	1" socket	no.	2	0.5	1
5	4" flange washer	no.	3		
6	RB70 sprinkler	no.	5		
7	4" O-gasket	no.	20		
8	set of hydrant gaskets		5		
9	جمة خط ريزر		2		
10	RB70 sprinkler springs		5		
11	RB70 sprinkler necks		5		
12	RB70 nozzles		20		
13	75mm/3" short flange pipe		1		
14	75 mm end plug		1		
15	4" Aluminum coupling		1	20	20
16	4" steel T		1	50	50
17	4" steel pipe	meter	2.5		
18	4" gate valve		1	225	225
19	1" steel socket		2		
20	4" steel socket		1		
21	fertilizer tank with hose, clamps, dellivery pipe + coupler & hitch				
22	1" steel plug		2		
23	4" flowmeter	no.	1	1250	1250
24	pressure gauge, 6 Atmosphere	no.	1	35	35
25	1/4"/1/2" reducer		1	1	1
26	19 mm bolts	kg	6		

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluation was executed to confirm developement; which appears in it's higher efficiency.

SPRINKLER - LATERAL IRRITGATION EVALUATION SHEET

location:S. Tahrir Farmer's name:Mohamed Galal
Observer: Y. Zedan
Crop: tangerines age: 3 yrs.
Soil: sandy available water:80 mm/m
Sprinkler: make: USA model: RB70
Sprinkler spacing : 15 by 15 m irrigation duration: 1hr.
Rated sprinkler discharge: 5.63 m3/hr, @ pressure 2 kg/cm2
Lateral: diameter: 3, 4 inch , slope: 0% riser height: 1 m

No. od sprinklers in the field	1	2	3	9 end
Pressure, Bar	2	2	2	1.9
Discharge, m3/hr	651	5.55	5.49	6.04
Nozzle dia., mm	7/6	7/6	7/6	7/6

Actual sprinkler pressure and discharge rates:

Wind: speed km/hr relative to lateral line:
initial 8.28, during 14.94, final 10.94

Duration of the exp.: 1 hr
Container rim diameter:71 mm
Container grid spacing: 1.5 by 1.5 m

114	87	44	57	94	32	55	91	90	116
93	92	75	71	69	90	119	91	98	115
96	123	93	88	106	114	110	119	115	104
94	149	109	120	114	125	125	105	82	94
150	85	114	125	116	115	125	165	84	82
69	79	115	123	135	110	120	102	112	113
65	77	93	96	91	125	110	90	95	162
53	71	82	76	79	89	98	82	79	80
56	66	78	68	64	58	53	61	70	89
88	123	88	65	52	45	64	75	82	109

Sprinkler radius of throw: 15 m
Sprinkler's speed of rotation: 0.25 rpm
Sprinkler trajectory angle: 20
temp.= R.H= E.C = pp

Results:

Cu = 78% Eu =67% Ea = 65.5 %

* An increase in: Cu by 10 % , Eu by 23 % and Ea by 21.9 %

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Uniformity efficiency (68% to 78%) and Applicaton Efficiency (43.5% to 66.5%). Accordingly, as a result of the this difference 31.16% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = (1- AE_1/AE_2) x 100
= (1-43.5/66.5) x 100
= 34.5%

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labour and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

Farmer: Mohammed Galal Location: Tahrir

COST AND RETURN FORM

PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	Tangerines, 5 yrs.
value of crop per unit (tons)	3 Tons/feddan 400 LE/ton
Seasonal consumptive use of crop	37698.48 m3 approximately
Number of hours operated each day	12
Minimum days required for each irrigation	1
Number of irrigation expected per season	62
Number of operated hours per year	744
Shape and dimensions of field	214.6 x180 m + 180 x 432 m
Type of irrigation system	hand-move
Number of feddans in field	27.7 feddans
Number of feddans irrigated	1.92
Sprinkler or emitter discharge	5.63 m3/hr
Sprinkler or emitter spacings	15 x 15 m
Pumping rate needed (m3\hr)	51 m3/hr
Source of water	surface
Total height water is to be lifted	
Total operating head	3 Bar
Size fo power unit needed (hp)	500 Hp
Type of power unit	electric
Interest rate	9%
Hours labor feddan per irrigation	0.7

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initeal Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
<u>Well</u> Casing Reservoir <u>Pump</u> Turbine Centrifugal <u>Power Unit</u> Electric Diesel	25	180000	0.101	18180 LE/ 500 fd.
<u>Miscellaneous</u> Electric switch Electric Transformer Fuel Tank Land Development	25	25000	0.101	2525 LE/500 fd
<u>*Water Pipe:*</u> <u>Underground pipe:</u> Concrete Steel Asbestos Cement PVC	25	1×10^6	0.101	101000 LE/500 fd
<u>Above Ground Pipe:</u> Aluminum Galvanized Steel				
<u>Sprinkler Systems</u>: Hand-move Fixed Gun- portable	15	1080	0.124	133.98 LE/ 27.77 feddans
<u>Surface systems:</u> Land grading				
Drip systems:				
Land Drainage				

Total annual fixed cost = 124116.23 LE/500 feddans

COST AND RETURN FORM
PART C- ANNUAL OPERATING COST

ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel			
Oil			300 LE/500 feddans
Repair & maintenance (power unit)			5000 LE/ 500 fedans
Repair & maintenance (irrigation equipment)			1555.63 LE/ 500 fedans
Electricity			60750 LE/ 500 fedans
seed			120
fertilizer			
chemicals			
costs			
Labor	0		3000 LE/ 500 fedans

total annual operating costs = 70605.63 LE/500 feddans
* Labor only includes engine operation attendance.

Total income = yield x value of crop per unit
=
The net return = Total income/feddan - Total annual cost/feddan

Delivery Cost of Water

Total annual cost = Fixed cost for total area + Operating cost for total area
*Operating costs per total area only consists of irrigation costs and excludes other costs; i.e seeds, fertilizers and chemicals.
* Total area in Tahady (collective pumping unit) = 500 feddans
Total annual cost = 124116.23 + 70605.63 = 194721.86 LE/500 feddan

Table of operating hrs per day during the year

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 3000 hrs/yr x 972 m^3/hr
= 2916000 m^3/yr

Cost of pumping a m^3 of water = Total annual cost /Total amount of water pumped annually
= 194721.86 LE/yr / 291.6 x 10^4 m^3 /yr
= 0.0667 LE/ m^3

Therefore the amount of money saved in pumping water per feddan

= water pumped annually x saved water x cost / Total area
= 291.6 x 10^4 m^3/yr x 0.3458 x 0.0667 LE / 500 feddans = 134.53 LE/feddan

Opportunity Cost of Water:
The net benefit in LE/fd for eggplant inercropped with garlic under drip irrigation can calculated using the benefit function as follows:

$$NB = P.Y - CX - C_t$$

NB = 3 tons/fdd x 400 - 0.0667 x 5832 - 1050.26 = LE/fd

```
The yield is low because the trees are only 3 years old
Estimate yield at maturity = 7 ton
NB = 7 x 400 - 0.0667 x 5832 - 1050 - 1350
Opportunity cost of water = 1350/5832 = 0.42
```

FARM #4:

Owner:M. Abd El-Razeque Location: well 4 canal 2, Tahrir area
Type of irrigation system: Hand-move
(Farm description from questionaire)

Existing Irrigation system Evaluation:

SPRINKLER - LATERAL IRRITGATION EVALUATION
(Before Modifocations)

location:S. Tahrir Farm no.:1 Type of irrigation: Hand-move
Observer: Y. Zedan Date: 22/7/96
Crop: parsley Farmer's name: Mohammed Abd El-Razque
Soil: sandy available water:80 mm/m
Sprinkler: make:USA model: 30TNT
Sprinkler spacing : 9 by 9 m irrigation duration: 1hr.
Rated sprinkler discharge: 1.465 m3/hr, @ pressure 1.125 kg/cm2
Lateral: diameter: 4 &3 inch , slope: 0% riser height: 0.8 m

No. od sprinklers in the field	1	11	12	end (30)
Pressure, Bar	1.8	1	0.9	0.8
Discharge, m3/hr		1.82	1.11	
Nozzle dia., mm	5.5/2.5	5.5/2.5	5.5/2.5	5.5/2.5

Actual sprinkler pressure and discharge rates:
Wind: speed km/hr relative to lateral line: 5.4 initial, 7.2 during, 5.4 final

Duration of the exp.: 1 hr
Container rim diameter: 71 mm
Container grid spacing: 1.5 by 1.5 m

39	20	110	15	57	59
38	28	135	81	57	67
25	54	76	61	32	31
42	25	40	61	45	35
80	43	42	43	44	75
78	53	36	44	56	36

Sprinkler radius of throw: 8.25 m
Sprinkler's speed of rotation: 0.55 rpm
Sprinkler trajectory angle: 20
temp.=21 R.H=58% E.C = ppm

NOTES:
* *Nonconsistent brands of sprinklers distorted the distribution efficiencies and catch measurements.*

Results:
Cu = 77.7% Eu =64 % Ea = 39.5 %

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1.Damaged, old sprinklers differing in no. of nozzles and nozzle diameters, thus didrupting the application rates over the irrigated areas.

2.Numerous leakages from hydrant cap & thread, damaged couplings, hitches and fittings obliged longer irrigation periods, reduced applicable low pressure and efficiency of the system. Similarly, the poor state of the pumping unit was the main reason for low pressures that caused most of the problems.

3. Absence of wind breakers which gave a direct effect on the system's efficiency.

Suggested Solutions and Modifications:

1.Installing a hand-move screen and a modified technique of fertigation (solely designed for hand-move systems) at the head of the lateral line to avoid clogged nozzles and icrease fertilizer efficiency.

2. Unifying the nozzle diameters to a correct size in order to attain a closer constant application rate, wetted diameter and overlap. A numbero of newer , more appropriate sprinklers were donated to the system to provide a clearer picture to the tenant.

3. Supplying the correct fittings and gaskets greatly reduced the previous leakages and raised the pressure throughout the lateral line.

4. Through counceling and providing more up-to-date knowledge of maintaining and irrigating techniques, the farmer aquired a better understanding of irrigation and fertizing methods.

Required Materials and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

Farm: Mohammed Abd El-Razque **System: Hand-move**

No.	Item	Unit	Amount	Price	Total Cost
1	5.5 mm 30TNT nozzles	no.	30		
2	3" O-gasket		15		
3	75 mm/3" short flange pipe		2		
4	75 mm PVC end plug		2		
5	30TNT sprinkler	no.	5		
6	30TNT necks		5		
7	4" O-gasket		20		
8	3" O-gasket		20		
9	hydrant male thread and cap		1		
10	hydrant seal		1		
11	4" coupling		1		
12	4" steel pipe	meter	1.5		
13	4" stationary flange		1		
14	1/2" steel socket		1		
15	1/2"/1/4" reducer		1		
16	4" gasket		10		
17	4" flowmeter		1	1250	1250
18	fertilizer tank with hose, clamps, dellivery pipe + coupler & hitch		1		
19	4" gate valve		1		
20	1" steel plug		2		
21	4" steel T with welded falnges		1		
22	75 mm PVC end plug		1		

Modified Irrigation System Evaluation

SPRINKLER - LATERAL IRRITGATION EVALUATION

location:S. Tahrir, station 4/2 Farmer's name: Mohammed Abd El-Razque
Observer: N. Dowidar Date: 8/4/97
Crop: Wheat
Soil: loamy-sand available water:80 mm/m
Sprinkler: make: Egyptian Military Manufacture model: 30TNT
Sprinkler spacing : 9 by 9 m irrigation duration: 1hr.
Rated sprinkler discharge: 1.38 m3/hr, @ pressure 2.0 Bar
Lateral: diameter: 2 inch , slope: 0% riser height: 0.5 m

No. od sprinklers in the field	1	11	12	end (30)
Pressure, Bar	2	2	2	2
Discharge, m3/hr	1.4	1.3	1.3	1.1
Nozzle dia., mm	5.5/0	5.5/2.5	5.5/2.5	5.5/2.5

Actual sprinkler pressure and discharge rates:
Wind: speed km/hr relative to lateral line:
initial 9.36, during 14.22, final 18.18

Duration of the exp.: 1 hr
Container rim diameter: 65 mm
Container grid spacing: 1.5 by 1.5 m

38	49	41	49	50	63
40	48	45	50	51	37
39	43	38	39	39	51
47	44	46	42	58	39
31	51	53	51	62	59
21	32	48	65	51	63

Sprinkler radius of throw: m
Sprinkler's speed of rotation: rpm
Sprinkler trajectory angle: 20
temp.= 21 R.H= 58% E.C = ppm

NOTES:
* After modifications were applied.

Results:
Cu = 85% Eu =75.8% Ea = 58.8 %

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Uniformity efficiency (64% to 75.8%) and Applicaton Efficiency (39.5% to 58.8 %) Accordingly, as a result of the this difference 32.82% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = (1- AE_1/AE_2) x 100
= (1-39.5/58.8) x 100
= 32.82%

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labour and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

Farmer: M. Abd El- Razeque Location: Tahrir

COST AND RETURN FORM

PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	wheat, Giza 163
value of crop per unit (tons)	656.66 LE/Ton
Seasonal consumptive use of crop	1781 m3 (424 mm)
Number of hours operated each day	10 hrs/10 days
Minimum days required for each irrigation	2.5
Number of irrigation expected per season	17
Number of operated hours per year	170
Shape and dimensions of field	285 x 71 m
Type of irrigation system	hand-move
Number of feddands in field	4.81
Number of feddans irrrigated	4.81
Sprinkler or emitter discharge	2 m3/hr
Sprinkler or emitter spacings	9 x 9 m
Pumping rate needed (m3\hr)	60 m3/hr
Source of water	surface
Total height water is to be lifted	approximately 2 m
Total operationg head	3.6 Bar
Size fo power unit needed (hp)	350 Hp
Type of power unit	electric
Interest rate	9%
Hours labour feddan per irrigation	0.5 hr/fed/irrigation

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initeal Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing Reservoir Pump Turbine Centrifugal Power Unit Electric Diesel	18.5	180000	0.1129	20322
Miscellaneous Electric switch Electric Transformer Fuel Tank Land Development	21	35000	0.107	3745
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC	25	1,000,000	0.1018	101,800
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable	15	115,200	0.12	13624
Surface systems: Land grading				
Drip systems:				
Land Drainage				

COST AND RETURN FORM
PART C- ANNUAL OPERATING COST

ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel			
Oil			
Repair & maintenance (power unit)			5000 LE/640 feddans
Repair & maintenance (irrigation equipment)			9216 LE/640 feddans
Electricity			57024 LE/640 feddans
seed			550 LE/ 5 fd
fertilizer			159.21 LE/fd
chemicals			
cosrs			100 LE/fd
Engine Operation Attendance			2000 LE/640 feddans
Labour			

Total annual operating cost = 73240 LE/640 feddans

Total income = yield x value of crop per unit
= 11.26 x 150 / 1000 x 656.66 = 1109.1 LE
Total net return = total income/feddan - Total annual cost/feddan
= 1109.1 - 483.64 = 625.45 LE/fd

Delivery Cost of Water

Total annual cost = Fixed cost for total area + Operating cost for total area
*Operating costs per total area only consists of irrigation costs and excludes other costs; i.e seeds, fertilizers and chemicals.
* Total area in Tahrir (collective pumping unit) = 640 feddans
Total annual cost = 139491 + 73240 = 212731 LE/640 feddan

Table of operating hrs per day during the year

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 3000 hrs/yr x 1600 m^3/hr
= 4,800,000 m^3/yr

Cost of pumping a m^3 of water = Total annual cost /Total amount of water pumped annually

= 212731 LE/yr / 48 x 10^5 m^3 /yr
= 0.044 LE/ m^3

Therefore the amount of money saved in pumping water per feddan
= water pumped annually x saved water x cost / Total area
= 48 x 10^5 m^3 /yr x .3282 x 0.0443 LE / 640 feddans = 109.09 LE/feddan

Opportunity Cost of Water:
The net benefit in LE/fd for eggplant inercropped with garlic under drip irrigation can calculated using the benefit function as follows:

$$NB = P.Y - CX - C_t$$

$$NB = 1.68 \times 656.66 - 0.04 \times 1781 - 375 = 656.94 LE/fd$$

Real value of water = 656.94 / 1781 = 0.36 LE/ m^3

Notice that the opportunity cost is almost 0.36 / 0.04 = 9 times more than that of the delivery cost.

FARM #5

Owner:Fathy El- Hagazy Location: pumping unit canal 2, Boustan area
Type of irrigation system: Trickle
(Farm description from questionaire)

Existing Irrigation system Evaluation:

Trickle Irrigation Evaluation (Before Modifications)

Location: Boustan Farm no. 5 Farmer's name: Fathy Hagazy
Observer: Yasser Zedan date: 2 \12\97
Crop: Tomatos spacing: 0.5x 1.75 m
Soil: sandy available water: 60 mm/m slope: 0.5 %
Irrigation: Duration: 1 hr. frequency: every two days
Filter Type and Preformance: Local screen filter
Pressure Inlet: 1.2 Bar @ Pressure Outler: 0.8 Bar Loss: 0.4 Bar
Fertilizer Unit Characteristics: Emitter: Make: Egyptian Model:GR Point spacing: 0.5 m
Locally made 200 liter closed tank
Rated discharge per emission point: 3.93 l/hr @ Pressure: 1 Bar
Emission points per plant: 1 giving 8 l/day
Laterals: Diameter: 16 mm Material: P.E Lenght : 30 m Spacing: 1.75 m

outlet location on laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A	28	3.36	149	17.88	25	3	23	2.76
INLET END	B	28	3.36	21	2.52	25	3	20	2.4
	TIME	30		30		30		30	
	AVERAGE		3.36		10.2		3		2.58
	A	30	3.6	25	3	21	2.52	18	2.16
1/3 DOWN	B	30	3.6	25	3	22	2.64	18	2.16
	TIME	30		30		30		30	
	AVERAGE		3.6		3		2.58		2.16
	A	24	2.8	26	3.12	22	2.64	17	2.04
2/3 DOWN	B	24	2.8	25	3	16	1.92	17	2.04
	TIME	30		30		30		30	
	AVERAGE		2.8		3.06		2.28		2.04
	A	26	3.12	0		21	2.52	15	1.8
FAR END	B	21	2.52	0		21	2.52	4	0.48
	TIME	30		0		30		30	
	AVERAGE		2.82		0		2.52		1.14
Pressure	INLET	1.2		1.1		1		1	
	OUTLET	1.1		1		0.8		0.8	
MINIMUM RATE OF DISHARGE	3.9 l/hr								
Average rate of discharge	3.93 l/hr	Eu=65 %		Ea = 55 %					

Notes:
2/3 line: leakage between gromet & seal equal to 12.6 l/hr
Last line: leakage causing 112.6 l/hr due to fracture in submain.

Problem Identification:
After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.
1.Insufficient filter unit. Wihtout any support from an industrial brand filter the loaclly made filter could not fullfil efficient filteration of the incoming water.
2. Deteriorated laterals due to continuous manual cultivation processes over a long period of time.
3. Large number of leakages as a result of loose fittings between gromets, seels, submain and laterals. These factors reduced the pressure on the internal emitters which led to low Uniformity and Application efficiencies.
4. Bent P.E. submain ends which were tied or knotted instead of installing a flushsing system with the proper equiment.
5. Lack of valve opening schedules and periodical maintainment of system reduced standards.

Suggested Solutions and Modifications:
1. Installing a 2 inch Arkal disc filter(120 micron, 130 mesh) providing 25 m^3/hr.
2. Installing a new submain made of PVC with new laterals along with the correct sizes of gromets,seals and figure 8 endings.
3. Installing the proper flush system with ball valves, reducers and PVC necks.
4. Scheduling valve opening and maintaining a regular check up.

Required Materials and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

Farm: Fathy Hagazy system: Trickle

No.	Item	Unit	Amount	Price	Total Cos
	seals, 16 mm		100	6	
	gromets. 16 mm		100	6	
	couplings, 16 mm		100	6	
	figure 8 endings, 16mm		100	5	
	P.E G.R laterals, 16 mm, in groups of 400 m	meter	4	172	
	P.V.C pipe, 63 mm	meter	60	2.83	
	P.V.C glue	kg	1/2	25	
	P.V.C curved elbow, 63 mm		1	12	
	P.V.C male adaptor, 63 mm/ 1"		1	3	
	P.V.C male adaptor, 63 mm/2"		1	2	
	ball valve, 1"		1	8.2	
	reducing bosch, 1/2"/1/4"		1	1	
	socket, 1/2"		1	0.75	
	Arkal filter, 2", 120 micron, 130 mesh		1	470	
	steel elbow, 2"		1	3.15	
	steel union, 2"		1	8	
	nipple, 2"		1	2.15	
	socket, 2"		2	2.2	
	pressure gauge, 6 atm.		1	35	
	flow meter, 2"		1		
	teflon spindle		10	0.5	

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluation was executed to confirm developement; which appears in it's higher efficiency.

Trickle Irrigation Evaluation Sheet

Location: Boustan Farm no. 5 Farmer's name: Fathy Hagazy
Observer: Yasser Zedan date: 15\1\'97
Crop: Tomatos spacing: 0.5x 1.75 m
Soil: sandy available water: 60 mm/m
Irrigation: Duration: 1 hr. frequency: every two days
Filter Type and Preformance: Local screen filter ,outlet 3 inches 35-30 m hr, Arkal disk filter 2 inch inlet, 120 micron, 130 mesh, 25 m3/hr
Pressure Inlet: 1.4 Bar @ Pressure Outler: 1.3 Bar Loss: 0.1 Bar
Fertilizer Unit Characteristics: Emitter: Make: Egyptian Model:GR Point spacing: 0.5 m
Rated discharge per emission point: 4.22 l/hr @ Pressure: 1.35 Bar
Emission points per plant: 1 giving 4.22 l/day
Laterals: Diameter: 16 mm Material: P.V.C Length: 30 m Spacing: 1.75 m

outlet location on laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A	35	4.2	41	4.92	37	4.44	33	3.96
INLET END	B	32	3.84	40	4.8	37	4.44	35	4.2
	TIME	30		30		30		30	
	AVERAGE		4.02		4.86		44.44		4.08
	A	31	3.72	38	4.56	36	4.32	31	3.72
1/3 DOWN	B	33	3.96	40	4.8	36	4.32	32	3.84
	TIME	30		30		30		30	
	AVERAGE		3.84		4.68		4.32		3.78
	A	33	3.96	40	4.8	34	4.08	33	3.96
2/3 DOWN	B	33	3.96	40	4.8	33	3.96	35	4.2
	TIME	30		30		30		30	
	AVERAGE		3.96		4.8		4.02		4.08
	A	33	3.96	38	4.56	35	4.2	35	4.2
FAR END	B	34	4.08	36	4.32	36	4.32	32	3.84
	TIME	30		30		30		30	
	AVERAGE		4.02		4.44		4026		4.02
Pressure	INLET	1.4		1.4		1.4		1.4	
	OUTLET	1.3		1.3		1.3		1.3	
MINIMUM RATE OF DISHARGE	3.9 l/hr								
Average rate of discharge	4.22 l/hr	Eu=92.4 %		Ea = 83 %					

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Emission Uniformity (65% to92 %) and Applicaton Efficiency (55% to 83%). Accordingly, as a result of the this difference 31.16% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = $(1- AE_1/AE_2) \times 100$
= $(1-55/83) \times 100$
= 33.73%

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labour and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

Farmer: Fathy El-Hagazy Location: Boustan

COST AND RETURN FORM

PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	tomatoes, Super Marmond
value of crop per unit (tons)	798.85 L.E/Ton
Seasonal consumptive use of crop	2353.125
Number of hours operated each day	3 hrs. average
Minimum days required for each irrigation	1
Number of irrigation expected per season	69
Number of operated hours per year	
Shape and dimensions of field	186 x112 m
Type of irrigation system	Trickle
Number of feddans irrrigated	1.25 feddan
Sprinkler or emitter discharge	4.22 lt/hr
Sprinkler or emitter spacings	1.75 x 0.5 m
Pumping rate needed (m3\hr)	11.34 m3/hr
Source of water	surface
Total height water is to be lifted	
Total operationg head	4 Bar
Size fo power unit needed (hp)	3 x 148 Hp
Type of power unit	electric
Interest rate	9%
Hours labour feddan per irrigation	none

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initeal Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing Reservoir Pump Turbine Centrifugal Power Unit Electric Diesel	13.5	180,000	0.1129	20322
Miscellaneous Electric switch Electric Transformer Fuel Tank Land Development	21	35000	0.107	3745
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC	20	419731.2	0.109	45980.07
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable				
Surface systems: Land grading				
Drip systems:	10	2000	0.155	148800
Land Drainage				

Total annual costs = 218847.07

FARM #6:

Owner: Osama Belal Location: collective pumping unit # 6, Boustan area
Type of irrigation system: Hand-move
(Farm description from questionnaire)

Existing Irrigation system Evaluation:

SPRINKLER - LATERAL IRRITGATION EVALUATION SHEET

location: Boustan, El-Imam El-Ghazali Type of irrigation: Hand-move
Observer: Y. Zedan Date: 22/7/96
Crop: Peanuts Farmer's name: Osama Belal El-Misry
Soil: sandy available water:80 mm/m
Sprinkler: make: USA model: Naan, Dan, 30TNT
Sprinkler spacing : 9 by 15 m irrigation duration: 1hr.
Rated sprinkler discharge: 3.71 m3/hr, @ pressure 1.4 kg/cm2
Lateral: diameter: 3 inch , slope: 0% riser height: 0.8 m

No. od sprinklers in the field	1	2	3	end (7)
Pressure, Bar	1.4	1.4	1.4	1.4
Discharge, m3/hr	3.12	2.95	5.34	3.44
Nozzle dia., mm	7.1/6.8 Naan	6.2/5.6 Dan	8.5/3.2 30TNT	6.8/5.9 Nan

Actual sprinkler pressure and discharge rates:
Wind: speed km/hr relative to lateral line: 9 initial, 5.4 during, 12.6 final

Duration of the exp.: 1 hr
Container rim diameter: 71 mm
Container grid spacing: 1.5 by 1.5 m

100	80	87	66	63	42
55	71	74	63	63	45
71	72	74	75	46	52
58	87	104	61	42	37
76	76	71	52	36	35
80	76	64	47	48	50
94	94	82	79	79	79
66	106	93	91	106	99
87	121	129	105	88	78
73	113	113	898	56	66

Sprinkler radius of throw: 8.25 m
Sprinkler's speed of rotation: 0.55 rpm
Sprinkler trajectory angle: 20
temp.=21 R.H=58% E.C = ppm

NOTES:
** Non consistent brands of sprinklers ruined the distribution efficiencies and catch measurements.*

Results:
Cu = 60.97% Eu =52.96 % Ea = 51.2 %

No. od sprinklers in the field	1	2	3	end (7)
Pressure, Bar	1.4	1.4	1.4	1.4
Discharge, m3/hr	3.12	2.95	5.34	3.44
Nozzle dia., mm	7.1/6.8 Naan	6.2/5.6 Dan	8.5/3.2 30TNT	6.8/5.9 Nan

Actual sprinkler pressure and discharge rates:
Wind: speed km/hr relative to lateral line: 9 initial, 5.4 during, 12.6 final
Duration of the exp.: 1 hr
Container rim diameter: 71 mm
Container grid spacing: 1.5 by 1.5 m

100	80	87	66	63	42
55	71	74	63	63	45
71	72	74	75	46	52
58	87	104	61	42	37
76	76	71	52	36	35
80	76	64	47	48	50
94	94	82	79	79	79
66	106	93	91	106	99
87	121	129	105	88	78
73	113	113	898	56	66

Sprinkler radius of throw: 8.25 m
Sprinkler's speed of rotation: 0.55 rpm
Sprinkler trajectory angle: 20
temp.=21 R.H=58% E.C = ppm

NOTES:
** Non consistent brands of sprinklers ruined the distribution efficiencies and catch measurements.*

Results:

Cu = 60.97% Eu =52.96 % Ea = 51.2 %

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1.Various makes and models of utilized sprinklers on lateral line with different nozzle diameters. Additional problems accordingly occured due to the damaged sprinkler parts, thus reducing the consistency of rpms, sicharge, wetted diameter, overlap and distribution uniformity.

2.Non consistent riser height.

3. Incorrect application of O-gaskets along with damged fittings increased leakage which continued to reduce the low pressure available.

Suggested Solutions and Modifications:

1.Unifying the sprinkler brands and makes while supplying the correct riser geiht (0.8 m) in order to provide a more cocsistent distribution of water on the grown crop.

2. Install an appropriately designed hand-move screen filter at the begining of the head of the lateral line to prevent clogged nozzles.

3. Adjusting sprinkler spacing to 12 x 9 m.

9Required Materials and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

farm: Osam El-Misry   system: Hand-move

No.	Item	Unit	Amount	Price	Total Cost
1	3" O-gasket		40	0.7	10.5
2	Model S sprinkler		8	22	176
3	2"/50 mm van stone flange		3	4	12
4	50 mm lateral plug		3	1.73	5.2
5	3" pipe	meter	1.25	16.9	21.125
6	1" steel socket		2	1	2
7	1/2" steel socket		1	0.75	0.75
8	1/2"/1/4" reducing bosch		1	1	1
9	1" steel end plug		2	1.64	3.285
10	1"/3/4" reducer		1	1.5	1.5
11	1" steel pipe	meter	5.6	4.9	27.44
12	3" coupler		5	10	50
13	3" hitch		5	3	15
14	3" stationary flange		4	4.85	19.4
15	3" movable flange		2	5	10
16	3" flow meter		1	750	750
17	fertilizer tank with hose, clamps, dellivery pipe+ coupler & hitch				
18	pressure gauge. 6 atm.		1	35	35
19	3" knife valve		1	175	175
20	3" steel T, with flanges		1	51	51
21	3" coupler		1		
22	3" O-gasket		9		
23	19 mm bolts	kg	6		
24	3" gasket		7		

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluation was executed to confirm developement; which appears in it's higher efficiency.

SPRINKLER - LATERAL IRRITGATION EVALUATION SHEET

location: Boustan, El-Imam El-Ghazali   Type of irrigation: Hand-move
Observer: Y. Zedan   Date: 22/3/97
Crop: Wheat   Farmer's name: Osama Belal El-Misry
Soil: sandy   available water:80 mm/m
Sprinkler: make:Australian   model: Model S
Sprinkler spacing : 9 by 12 m   irrigation duration: 1hr.
Rated sprinkler discharge: 1.46 m3/hr, @ pressure 1.6 kg/cm2
Lateral: diameter: 3 inch , slope: 0%   riser height: 0.8 m

No. od sprinklers in the field	1	2	3	end (7)
Pressure, Bar	1.6	1.6	1.6	1.6
Discharge, m3/hr	1.39	1.48	1.45	1.56
Nozzle dia., mm	4.8/2.3	4.8/2.3	4.8/2.3	4.8/2.3

Actual sprinkler pressure and discharge rates:
Wind: speed km/hr relative to lateral line: 9.8

Duration of the exp.: 1 hr
Container rim diameter: 65 mm
Container grid spacing: 1.5 by 1.5 m

34	41	44	37	29	21
47	50	44	43	41	30
39	50	49	49	42	37
30	34	50	49	37	32
35	35	49	45	38	32
25	39	39	44	40	29
23	46	42	24	34	16
31	44	55	45	35	28

Sprinkler radius of throw: 8.5 m
Sprinkler's speed of rotation: rpm
Sprinkler trajectory angle: 20
temp.=21 R.H=58% E.C = ppm

NOTES:
* After modifications were applied.
* Low Pressure was the most prbable facror effecting the final calculations.

Results:

Cu = 81.55% Eu =69.43% Ea = 59.07 %

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Emission Uniformity (52.96% to 69.46%) and Applicaton Efficiency (51.2% to 59.07%). Accordingly, as a result of the this difference 13.32% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = $(1- AE_1/AE_2) \times 100$
$= (1-51.2/59.07) \times 100$
$= 33.73\%$

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labour and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

Farmer: Osama Belal Location: El-Imam El-Ghazali village

COST AND RETURN FORM
PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	Wheat, Sakha 69
value of crop per unit (tons)	820 LE/Ton
Seasonal consumptive use of crop	4594.59m3
Number of hours operated each day	13.5
Minimum days required for each irrigation	
Number of irrigation expected per season	34
Number of operated hours per year	459
Shape and dimensions of field	180 x 112 m
Type of irrigation system	Hand-move
Number of feddands in field	4.8
Number of feddans irrigated	2
Sprinkler or emitter discharge	1.43 m3/hr
Sprinkler or emitter spacing	1.75 x 0.5 m
Pumping rate needed (m3\hr)	10 m3/hr
Source of water	surface
Total height water is to be lifted	1.5 m
Total operating head	5 Bar
Size of power unit needed (hp)	444 Hp
Type of power unit	Electricity
Interest rate	9%
Hours labour feddan per irrigation	1.1 hr/labour/feddan

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initeal Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing				
Reservoir				
Pump Turbine Centrifugal	18.5	180000	01129	20322
Power Unit Electric Diesel				
Miscellaneous	21	35000	0.107	3745

Electric switch Electric Transformer Fuel Tank Land Development				
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC		419731.2	0.109	45980.07
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable	15	20160	0.124	2499.84
Surface systems: Land grading				
Drip systems:				
Land Drainage				

Total annual fixed cost = 72546.91

COST AND RETURN FORM
PART C- ANNUAL OPERATING COST

ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel			
Oil			0.41 LE/feddan
Repair & maintenance (power unit)			14.62 LE/feddan
Repair & maintenance (irrigation equipment)			20160 LE/408 feddans
Electricity			85 LE/feddan
seed	160 kg	0.7	228 LE
fertilizer			562.2LE
chemicals			
costs			140
Engine operation Attendance			1200 LE/480 feddans
Labour			25

Costs include: 40 LE chisel plow + 100 LE thresher

Total annual operating costs = 49214.4

Total income = yield x value of crop per unit
= x 820 = 6519
The net return = Total income/feddan - Total annual cost/feddan
= -

Delivery Cost of Water

Total annual cost = Fixed cost for total area + Operating cost for total area
*Operating costs per total area only consists of irrigation costs and excludes other costs; i.e seeds, fertilizers and chemicals.
* Total area in Imam El-Ghazali, Boustan (collective pumping unit) = 480 feddans
Total annual cost = 72546.91 + 49214.4 = 121761.31 LE/480 feddan

Table of operating hrs per day during the year

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 3000 hrs/yr x 753 m^3/hr
= 2,259,000 m^3/yr

Cost of pumping a m^3 of water = Total annual cost /Total amount of water pumped annually

= 121761.31 LE/yr / 225.9 x 10^4 m^3 /yr
= 0.0539 LE/ m^3

Therefore the amount of money saved in pumping water per feddan
= water pumped annually x saved water x cost / Total area
= 225.9 x 10^4 m^3 /yr x .3373 x 0.1249 LE / 480 feddans = 198.308 LE/feddan

Opportunity Cost of Water:
The net benefit in LE/fd for eggplant inercropped with garlic under drip irrigation can calculated using the benefit function as follows:

$NB = P.Y - CX - C_t$

NB = 1845 - 0.0539 x 2297.29 - 477.6 = 1243.5 LE/fd

Real value of water = 1243.5 / 2297.29 = 0.54 LE/ m^3
Notice that the opportunity cost is almost 0.54 / 0.05 = 10 times more than that of the delivery cost.

FARM # 7:

Owner:Ahmed El-Nagar Location: independent pumping, Boustan area
Type of irrigation system: Fixed
(Farm description from questionaire)

Existing Irrigation system Evaluation:

SPRINKLER-LATERAL IRRIGATION EVALUATION

location:Boustan Farm no.:2 Type of irrigation:Fixed system
Observer: Y. Zedan Date: / /96
Crop: peanuts Farmer's name: Ahmed El-Nagar
Soil: sandy available water:80 mm/m
Sprinkler: make:France model: Roland
Sprinkler spacing : 18 by 18 m irrigation duration: 1hr.
Rated sprinkler discharge: 2.14 m3/hr, @ pressure 2.35 kg/cm2
Lateral: diameter: 63 & 50 inch , slope: 0% riser height: 0.5 m

No. od sprinklers in the field	1	2	3	2	3	end (7)
Pressure, Bar	2.3	2.3	2.3	2.4	2.4	2.3
Discharge, m3/hr	1.8	2.08	2.06	2.35	2.29	2.3
Nozzle dia., mm		4.8/3	4.6/3.2	5.2/3.2	5.1/3.3	

Actual sprinkler pressure and discharge rates:

Wind: speed km/hr relative to lateral line: 5.4initial, 3.6 during, 5.4final

Duration of the exp.: 1 hr
Container rim diameter: 71 mm
Container grid spacing: 1.5 by 1.5 m

22	22	34	30	30	25	25	22	22	19	23	25
42	18	27	25	30	26	25	21	18	12	22	22
34	14	22	20	26	24	27	19	16	8	13	12
23	22	23	15	22	21	25	18	17	14	13	12
15	23	21	13	18	18	23	14	16	14	11	14
13	21	19	11	21	10	19	14	14	17	22	20
20	29	17	21	17	7	16	17	18	23	24	21
26	34	21	25	13	9	12	20	24	31	31	29
29	31	27	31	12	16	10	20	24	29	32	28
32	31	31	35	17	25	10	21	19	23	23	20
24	41	31	40	25	29	14	20	20	18	18	21
31	34	32	36	35	38	22	21	19	16	21	25

Sprinkler radius of throw: 10.5 m
Sprinkler's speed of rotation: 0.9rpm
Sprinkler trajectory angle: 20
temp.=33 R.H=48% E.C = ppm

Results:

Cu = 74.3 % Eu =59.2 % Ea = 50.2 %

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1.Mixed sprinklers, nozzle diameters and riser height. This radically hindered the consistency of sprinkler rpms, wetted diameters and application rates.

2. Absence of popper flushing system which resulted in the frequency of clogged nozzles.
3. Insufficient designed spacing resulted in low application rates and low overlap. This obliged the farmer to irrigate longer periods.

Suggested Solutions and Modifications:

1. Installing completely new lateral lines along with appropriate ball valves and flushing system in order to reduce sprinkler spacing and prevent recurring nozzle clogging.
2. Installing the correct riser heights with appropriate supports.
3. Unifying sprinkler make with a chosen brand (Model S 4.8/2.3 mm)
4. Advising and counseling proper methods of opening and closing valves, increasing applicable pressure and fertilizing techniques.
5. Readjusting sprinkler spacing to 12 x 12 m to attain higher standards.

Required Materials and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

farm: Ahmed El- Nagar **system: fixed**

No.	Item	Unit	Amount	Price	Total Cost
	63 mm P.V.C pipe, 6 atm.	meter	210	2.83	
	50 mm P.V.C pipe, 6 atm.	meter	150	2.1	315
	Model S sprinkler		12	22	
	3/4" ball valve		6	7.5	45
	2" ball valve		3	28	84
	2"/63 end plug		3	2.75	8.25
	63 mm/50 mm reducer		3	2.2	6.6
	3/4" spinkler riser, 0.75m		20	2.25	45
	P.V.C cement		2	25	50
	50 mm/3/4 " saddle		25	1.8	18
	63 mm/ 3/4" saddle		10	2	20
	teflon tape		10	0.5	
	1/2" //1/4" reducing bosch		1	1	
	63 mm/2" male adaptor		2	2	
	pressure gauge, 6 atm.		1	35	
	2" flow meter		1		
	2" steel pipe		6	9.1	54.6
	2" steel elbow		4	3.15	9.9225
	2" steel union		1	8	8
	2" steel socket		3	2.2	6.6
	1/2" socket		1	0.75	0.75
	P.V.C cement	kg	1/2	25	12.5

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluation was executed to confirm development; which appears in it's higher efficiency.

SPRINKLER - LATERAL IRRITGATION EVALUATION

location:Boustan Farm no.:2 Type of irrigation:Fixed system
Observer: Y. Zedan Date: 13/5/97
Crop: peanuts Farmer's name: Ahmed El-Nagar
Soil: sandy available water:80 mm/m
Sprinkler: make:Australian model: Model S
Sprinkler spacing : 12 by 12 m irrigation duration: 1hr.
Rated sprinkler discharge: 2.4 m3/hr, @ pressure 4.2 kg/cm2
Lateral: diameter: 63 & 50 inch , slope: 0% riser height: 0.5 m

No. od sprinklers in the field	1	2	3	end (7)
Pressure, Bar	4.2	4.2	4.2	4
Discharge, m3/hr	2.4	2.4	2.4	2.36
Nozzle dia., mm	4.8/2.3	4.8/2.3	4.8/2.3	4.8/2.3

Actual sprinkler pressure and discharge rates:

Wind: speed km/hr relative to lateral line: 4.8initial, 4.8 during, 1.8 final

Duration of the exp.: 1 hr
Container rim diameter: 65 mm
Container grid spacing: 1.5 by 1.5 m

69	61	59	55	54	46	59	52
59	57	63	55	53	52	54	60
45	65	51	49	47	49	56	56
46	59	47	51	44	49	51	48
47	55	42	54	43	52	53	47
45	45	40	44	46	49	52	58
37	38	39	46	42	45	56	59
38	38	41	41	41	50	46	42

Sprinkler radius of throw: 13.175 m
Sprinkler's speed of rotation: 0.573 rpm
Sprinkler trajectory angle: 20
temp.=33 R.H=48% E.C = ppm

Results:

Cu = 88 % Eu =82.8 % Ea = 77.52 %

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Emission Uniformity (59.2% to 82.8% %) and Application Efficiency (50.2% to 77.52%). Accordingly, as a result of the this difference 35.24% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = (1- AE_1/AE_2) x 100
= (1-50.2/77.52) x 100
= 35.24%

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labor and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

Farmer: Ahmed El- Nagar Location: Boustan

COST AND RETURN FORM

PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	Nickola Potatoes
value of crop per unit (tons)	600 LE/Ton (Yield 4 Tons)
yield per feddan	3.2 tons/feddan
Seasonal consumptive use of crop	1767.27 m3/fd (610 mm)
Number of hours operated each day	0.5
Minimum days required for each irrigation	1
Number of irrigation expected per season	54
Number of operated hours per year	27
Shape and dimensions of field	90 x 54 m
Type of irrigation system	fixed system
Number of feddans in field	4.71
Number of feddans irrigated	1.25
Sprinkler or emitter discharge	2.4 m3/hr
Sprinkler or emitter spacing	12 x 12 m
Pumping rate needed (m3\hr)	16.8 m3/hr
Source of water	surface
Total height water is to be lifted	approximately 2 m
Total operating head	4 Bar
Size of power unit needed (hp)	20 Hp
Type of power unit	electric
Interest rate	9%
Hours labor feddan per irrigation	None

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initial Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing				
Reservoir				
Pump Turbine Centrifugal	15	10,000	0.1308	1080
Power Unit Electric Diesel				
Miscellaneous Electric switch Electric Transformer Fuel Tank Land Development	20	8,000	0.105	840
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC	20	9728.5	0.109	1060.4
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable	20	10000	0.109	1090 LE/ 5 fd
Surface systems: Land grading				
Drip systems:				
Land Drainage				

Total annual costs = 7340.4 LE/ 20 feddans

COST AND RETURN FORM
PART C- ANNUAL OPERADING COST

ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel			
Oil			20 LE/ feddans
Repair & maintenance (power unit)			
Repair & maintenance (irrigation equipment)			5LE/ feddans
Electricity			135.26 LE/ feddan
seed	1.6 ton	650 LE/Ton	1040 LE/fd
fertilizer			305.2 LE/fd
chemicals			
costs			141.6 LE/fd
Labor			140LE/fd

100 kg. Sulfur Nitrate
10 m3 manure

250 kg. Super Phosphate
150 kg. Nitrate

Total income = yield x value of crop per unit
= 3.2 ton/fd x 600 LE/tons = 1920 LE/fd

The net return = Total income/feddan - Total annual cost/feddan
= 1920 - 1787.06 = 132.94 LE/feddan

Delivery Cost of Water

The total annual pumping cost can be calculated by substituting the values from tables as follows:
Total annual cost = Fixed cost for total area + Operating cost for total area
*Operating costs per total area only consists of irrigation charges and excludes the remaining costs; i.e seeds, fertilizers and chemicals.
* Total area in Imam El-Ghazali, Boustan (independent pump unit) = 20 feddans
Total annual cost = 7340.4 + 3205.2 = 10545.6 LE/20 feddan

Table of operating hrs per day during the year

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 3000 hrs/yr x 60 m^3/hr
= 180,000 m^3/yr

Cost of pumping water = Total annual cost /Total amount of water pumped annually

= 10545.6LE/yr / 180000 x 10^4 m^3 /yr

= 0.058 LE/ m^3

Therefore the amount of money saved in pumping water per feddan
= water pumped annually x saved water x cost / Total area
= 18 x 10^4 m^3 /yr x 0.3524 x 0.058 LE / 20 feddans = 185.8 LE/feddan

Opportunity Cost of Water:

The net benefit function in LE/fd for potatoes under this fixed irrigation system can be calculated using the net benefit function as follows:

NB = P.Y - C.X -C_T

NB = 600 LE/ton x 3.2 - 0.058 x 1767.27 - 1626.8 = 190.6 LE/fd

Real value of water = 190.6 / 1767.27 = 0.107

Notice that the opportunity cost is almost 0.1 / 0.05 = 2 times more that the delivery cost.

FARM # 8:

Owner: Abd El-Samed El-Sayed   Location: independent pumping unit canal , Boustan area

Type of irrigation system: Fixed

(Farm description from questionnaire)

Existing Irrigation system Evaluation:

Sprinkler- Lateral Irrigation Evaluation

Location: Imam El-Ghazali village, Boustan aree
Farmer's name: Abd El-Samed El-Sayed Abd El-Gowad
Observer: Naeem Dowidar/Yasser Zedan   Date: 15/10/96
Crop: Peanuts
Soil: Sandy   Available water: 60 mm/m
Sprinkler make :Russian   Model: 100
Sprinkler spacing: 18 x18 m   irrigation duration: 1 hr.
Rated sprinkler discharge: 7.37 m3/hr, @ 1.6 Bar
Lateral diameter: 3,4 inch   slope: 0%

NO. Of sprinklers in field	1	1	2	2
Pressure, Bar	1.6	1.6	1.6	1.6
Discharge, m3/hr	7.83	6.89	7.35	7.42
Nozzle diameter, mm	11/8.3	11/6.4	11.1/5.5	11.1/6

Actual sprinkler pressure and discharge rates:

Wind speed km/hr relative to lateral line:

initial , during, final

Duration of the exp.: 1 hr.
Container rim diameter : 71 mm
Container grid spacing: 3 x 3 m

60	31	62	97	129	40
49	48	45	82	140	37
96	71	41	76	149	124
78	103	23	120	75	102
103	135	70	112	65	91
82	52	79	105	113	60

sprinkler radius throw:13 m
Sprinkler's speed of rotation: 0.87 rpm
Sprinkler trajectory angle: 20
Temp: 30 c   R.H= 52 %   E.C= ppm

Results:

Cu=66.5%   Eu=49.6%   Ea=44.84%

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1. Low applicable pressures due to the simultaneous use of a large number of sprinklers with the intention of relieving the stresses on the connecting fittings, bearings and supports.
2. Fractures and cracks in the underground connecting fittings.
3. Absence of riser support and inappropriate height, distributing needle at nozzle opening and weight of sprinkler all contributed to dense sprinkler spry with large drops that harm the young crops, cause run off, decrease sprouting percentage, ruin weak risers and give low rpms.
4. Insufficient sprinkler spacing resulted in very low application rates (18 x 18 m).
5. Absence of sufficient flushing system to clean laterals and main lines of build up residue.

Suggested Solutions and Modifications:

1. Installing completely new PVC laterals with proper riser height and support, and ball valve flushing system.
2. Readjusting lateral spacing to 12 meters instead of 18 m.
3. Installing iron cross connections with new PVC short pipes.
4. Encourage recent methods of better advanced irrigation and water management.

Required Materials and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

Farm: Abd El-Samed Abd El-Gowad system: fixed system

No.	Item	Unit	Amount	Price	Total Cost
	3/4 " steel cross		7	71	497
	110 mm/ 4"van stone flange		14	7.5	105
	3"/75 mm van stone flange		14	4.25	59.5
	P.V.C cement	kg	1	25	25
	4" movable flange		14	6.5	
	3" movable flange		21	5	
	?				
	1"/63 mmsadle		8	4	
	1"/ 63 mm male adaptor		4	3	
	75mm/63 mm reducer		4	4.4	
	63 mm , P.V.C curved elbow		4	12	
	4" gasket		18	0.4	
	3" gasket		27	0.3	
	19 mm bolts	kg	10	4.75	
	1/2" socket		1	0.75	
	1/2"/1/4" reducing bosch		1	1	
	3" stationary flange		11	5	
	P.V.C cement	kg	1/2	25	
	3" knife valve		1	175	
	1" steel plug		2	1.64	

	pressure gauge, 6 atm.		1	35	
	3" flow meter		1	750	
	3" steel pipe	meter	4.5	16.9	
	3" steel elbow		4	12	

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluation was executed to confirm development; which appears in it's higher efficiency.

Sprinkler- Lateral Irrigation Evaluation

Location: Imam El-Ghazali village, Boustan area
Farmer's name: Abd El-Samed El-Sayed Abd El-Gowad
Observer: Naeem Dowidar/Yasser Zedan
Crop: Peanuts inter cropped with corn (maize)
Soil: Sandy Available water: 60 mm/m
Sprinkler make :Russian Model: 100
Sprinkler spacing: 12 x18 m irrigation duration: 1 hr.
Rated sprinkler discharge: 6.64 m3/hr, @ 1.9 Bar
Lateral diameter: 3,4 inch slope: 0%

NO. Of sprinklers in field	1	1	2	2
Pressure, Bar	1.9	1.9	1.9	1.9
Discharge, m3/hr	6.34	7.52	7.11	5.58
Nozzle diameter, mm	10..8/5	11.1/5.6	11.1/5.2	10.6/5.3

Actual sprinkler pressure and discharge rates:
Wind speed km/hr relative to lateral line:
initial 12.7 , during 11.16, final 15.66

Duration of the exp.: 30 min
Container rim diameter : 65 mm
Container frid spacing: 3 x 3 m

42	33	42 (86)	51 (105)	54	34
41	30	51	52 (177)	54	36
37 (86)	50	53	52 (77)	51	40
39	23	29	54	37	34

sprinkler radius throw:12 m
Sprinkler's speed of rotation: 1.65 rpm
Sprinkler trajectory angle: 20
Temp: 35 c R.H= 48 % E.C= ppm

Notes:
A low application efficiency was recorded due to the presence of the inter cropped maize, which was at an average height of 1 m, further more the high wind velocity along with the absence of wind breakers all contributed to the distribution of the efficiency.

Results:

Cu=82% Eu=72.6% Ea=45% .

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Emission Uniformity (49.6% to 72.6 %) and Application

Efficiency (44.84% to 45%). Accordingly, as a result of the this difference 35.24% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = (1- AE_1/AE_2) x 100
= (1-44.84/45) x 100
= 0.35 %

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labor and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

Farmer: Abd El-Samed Abd El-Goad Location: Boustan, Imam El-Ghazali

COST AND RETURN FORM
PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	Peanuts with inter cropped corn
value of crop per unit (tons)	1.71 LE/kg + 0.45 LE/kg
yield per feddan	12 x 75 + 200
Seasonal consumptive use of crop	2912.7 m3/fd
Number of hours operated each day	0.5
Minimum days required for each irrigation	1
Number of irrigation expected per season	30
Number of operated hours per year	240
Shape and dimensions of field	90x 233 m
Type of irrigation system	fixed
Number of feddands in field	5
Number of feddans irrigated	72 x 90 m
Sprinkler or emitter discharge	6.64 m3`/hr
Sprinkler or emitter spacing	12 x18 m
Pumping rate needed (m3\hr)	26.56 m3/hr
Source of water	surface
Total height water is to be lifted	1.5 m
Total operationg head	4 Bar
Size fo power unit needed (hp)	20 Hp
Type of power unit	Electricity
Interest rate	9%
Hours labour feddan per irrigation	None

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initial Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing Reservoir Pump Turbine Centrifugal Power Unit Electric Diesel	15	10,000	0.1308	1080
Miscellaneous Electric switch Electric Transformer Fuel Tank Land Development	20	8,000	0.105	840
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC	20	9728.5	0.109	1060.4
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable	20	10000	0.109	1090 LE/ 5 fd
Surface systems: Land grading				
Drip systems:				
Land Drainage				

Total annual costs = 7340.4 LE/ 5 feddans

COST AND RETURN FORM
Part C - Operating Costs:

ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel			
Oil			400 LE/ 20 feddans
Repair & maintenance (power unit)			
Repair & maintenance (irrigation equipment)			100 LE/ 20 feddans
Electricity			135.26 LE/ feddan
seed	30 kg		180 LE/fd
fertilizer			84 LE/fd
chemicals			
costs			128 LE/fd
Labor			160 LE/fd

Nitrate 550 kg   Sulfur nitrate 150 kg

Total income = yield x value of crop per unit
= 7.8 x 120 +130 = 1065 LE/fd

The net return = Total income/feddan - Total annual cost/feddan
= 1065 - 712.26 = 352.75 LE/feddan

Delivery Cost of Water

The total annual pumping cost can be calculated by substituting the values from tables as follows:

Total annual cost = Fixed cost for total area + Operating cost for total area

*Operating costs per total area only consists of irrigation charges and excludes the remaining costs; i.e seeds, fertilizers and chemicals.

* Total area in Imam El-Ghazali, Boustan (independent pump unit) = 20 feddans

Total annual cost = 7340.4 + 3205.2 = 10545.6 LE/20 feddan

Table of operating hrs per day during the year

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 3000 hrs/yr x 60 m^3/hr
= 180,000 m^3/yr

Cost of pumping water = Total annual cost /Total amount of water pumped annually
= 10545.6LE/yr / 180,000 x 10^4 m^3 /yr
= 0.058 LE/ m^3

Therefore the amount of money saved in pumping water per feddan
= water pumped annually x saved water x cost / Total area
= 18 x 10^4 m^3 /yr x 0.0033 x 0.058 LE / 20 feddans = 1.72 LE/feddan

<u>Opportunity Cost of Water:</u>

The net benefit function in LE/fd for peanuts inter cropped with corn (maize) under fixed irrigation can be calculated using the net benefit function as follows:

$$\mathbf{NB = P.Y - C.X - C_T}$$

$$NB = 1065 - 0.058 \times 2912.7 - 552 = 344 \text{ LE/fd}$$

Real value of water = 344 / 2912.7 = 0.11 LE/fd
This means that the opportunity cost is almost 0.11 / 0.05 = 2 times more than thatof the delivery cost.

FARM #9:

Owner: Naser Manaa Location: collective pumping unit canal 3 station 5, Boustan area

Type of irrigation system: Fixed

(Farm description from questionnaire)

Existing Irrigation system Evaluation:

SPRINKLER - LATERAL IRRITGATION EVALUATION

location:S. Tahrir Farmer's name: Naser Manaa

Observer: N. Dowidar

Crop: tangerines age: 3 yrs.

Soil: loamy-sandy available water:

Sprinkler: make: USA model: 30TNT

Sprinkler spacing : 9 by 9 m irrigation duration: 1hr.

Rated sprinkler discharge: 1.43 m3/hr, @ pressure1.5 kg/cm2

Lateral: diameter: 3, 4 inch , slope: 0% riser height: 0.75 m

No. of sprinklers in the field	1	11	11*	12	12*	end
Pressure, Bar	1.9	1.6	1.4	1.6	1.4	1.2
Discharge, m3/hr	1.85	1.21	1.14	1.61	1.34	
Nozzle dia. ., mm						

Actual sprinkler pressure and discharge rates:

Wind: speed km/hr relative to lateral line:

initial 8.28, during 16.2, final 10.8

Duration of the exp.: 1 hr

Container rim diameter:71 mm

Container grid spacing: 1.5 by 1.5 m

129	15	24	24	18	21
42	15	25	32	16	34
36	19	16	43	61	53
71	23	38	30	63	86
60	117	47	70	76	69
51	67	133	89	98	78

Sprinkler radius of throw: 9m

Sprinkler's speed of rotation: 0.8 rpm

Sprinkler trajectory angle: 20

temp.= R.H= E.C = pp

NOTES:

*After modifications: 1. replacement of sprinklers (5x 27 L.E)

2. specific parts of sprinklers such as: necks, nozzles, pipe gaskets

Results:

Cu = 49.33% Eu=38.46 % Ea = 32.83 %

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1. Malfunctioning sprinklers which was due to negligent maintenance of hammers, springs and necks.
2. Unequal nozzle diameters, which at low pressures also decreased overlap and uniformity.
3. Absence of lateral line filter to avoid nozzle blockage.
4. Absence of wind breakers that have a direct effect on the system's efficiency.
5. Numerous leakage along lateral line, which in turn reduces the pressure on the sprinklers
6. Damaged lateral line which appeared in the hydrant cap, fittings and riser connections. These accumulated problems all greatly reduced the available pressure on the sprinklers.

Suggested Solutions and Modifications:

1. Unifying all the nozzle diameters by replacing them with the correct size of nozzles.
2. Replacing old clamps, couplers, and O-gaskets with new ones.
3. Installing a hand-move screen designed to limit debris clogging the sprinkler nozzles.

Required Materials and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

farm: Naser Manaa **System: Hand-move**

No.	Item	unit	Amount	Price	Total
1	knife valve, 4"		1	225	
	steel elbow with flanges, 4"		4	35	
	socket, 1"		4	1	
	socket, 1/2"		1	0.75	
	fertilizer tank with hose,clamps, coupler and hitch		1		
	steel T, 4"		1	50	
	socket, 1/2"		1	0.75	
	flow meter, 4"		1	1312.5	
	pressure gauge, 6 atm.		1	35	
	steel pipe, 4"	meter	1.75	16.33	
	Aluminum coupler, 4"			20	
	van stone flange 110mm/4"		1	7.5	
	curved elbow, 63 mm		1	12	
	stationary flange, 4"		11	6	
	movable flange, 4"		5	5	
	reducing bosch, 1/2"/1/4"		1	1	
	washer, 4"		5	3.5	
	gasket, 4"		16	0.4	
	30 TNT nozzles		30	0.55	
	30TNT sprinkler, Military manufacture		5	27.5	
	30TNT sprinkler necks		5	5	
	O-gaskets, 4"		15	0.7	
	O-gaskets, 3"		15	0.7	
	female & male thread with cap		1	14	
	hydrant head		1	5	

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluation was executed to confirm development; which appears in it's higher efficiency.

SPRINKLER - LATERAL IRRITGATION EVALUATION
(After Modifications)

location:S. Tahrir Farmer's name: Naser Manaa
Observer: N. Dowidar
Crop: tangerines age: 3 yrs.
Soil: loamy-sandy available water:
Sprinkler: make: USA model:30TMT
Sprinkler spacing : 9 by 9 m irrigation duration: 1hr.
Rated sprinkler discharge: 1.735 m3/hr, @ pressure1.5 kg/cm2
Lateral: diameter: 3, 4 inch , slope: 0% riser height: 0.75 m

No. od sprinklers in the field	1	11	11*	12	12*	end
Pressure, Bar	2.1	1.6	1.6	1.6	1.6	1.4
Discharge, m3/hr	1.95	1.75	1.6	1.92	1.67	1.34
Nozzle dia., mm	5.7/2.6	5.7/2.6	5.7/2.6	5.7/2.6	5.7/2.6	5.7/2.6

Actual sprinkler pressure and discharge rates:
Wind: speed km/hr relative to lateral line:
initial 8.28, during 14.94, final 10.98

Duration of the exp.: 1 hr
Container rim diameter:71 mm
Container grid spacing: 1.5 by 1.5 m

72	88	95	109	102	114
94	105	88	90	93	75
89	94	78	89	88	81
81	63	61	77	74	62
49	52	67	59	68	58
58	51	67	81	70	80

Sprinkler radius of throw: 8068 m
Sprinkler's speed of rotation: 0.6 rpm
Sprinkler trajectory angle: 20
temp.= R.H= E.C = 0.48 ppm

NOTES:
*After modifications: 1. replacement of sprinklers
2. specific parts of sprinklers such as: springs, necks and nozzles
3. replacement of lateral line gaskets.

Results:
Cu = 81.24% Eu =72.6% Ea = 64.25 %

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Emission Uniformity (38.4% to 72.6 %) and Application

Efficiency (32.83% to 64.25%). Accordingly, as a result of the this difference 48.9% of wasted water was saved that can now be used in different areas.

Percent of Saved Water = (1- AE_1/AE_2) x 100
= (1-32.83/64.25) x 100
= 48.9%

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labor and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

COST AND RETURN FORM
PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	sorghum corn
yield per feddan	45.36 ton/feddan
value of crop per unit (tons)	30 LE/ton
Seasonal consumptive use of crop	7807 m3/2.5 fd
Number of hours operated each day	1 (150 days/ 150 hrs)
Minimum days required for each irrigation	1
Number of irrigation expected per season	20
Number of operated hours per year	150
Shape and dimensions of field	280 x 37.5 m
Type of irrigation system	hand-move
Number of feddans irrigated	2.5
Sprinkler or emitter discharge	1.735 m^3/hr
Sprinkler or emitter spacings	9 x 9 m
Pumping rate needed (m3\hr)	51.9 m^3/hr
Source of water	surface canal
Total height water is to be lifted	1.5 m approximately
Total operating head	5 Bar
Size of power unit needed (hp)	500 Hp
Type of power unit	electric
Interest rate	9%
Hours labour feddan per irrigation	0.86

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initeal Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing Reservoir Pump Turbine Centrifugal Power Unit Electric Diesel	30	180,000 LE/640 feddans	.097	17460 L.E/640 fd.
Miscellaneous Electric switch Electric Transformer Fuel Tank Land Development	30	75,000 LE	0.097	7275
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC	30	1 million/ 640 fed.	0.097	97000
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable				
Surface systems: Land grading				
Drip systems:	25	3600	0.1018	366.5 LE/6 feddan
Land Drainage				

Therefore the amount of money saved in pumping water per feddan
= water pumped annually x saved water x cost / Total area
= 48 x 10^5 m^3/yr x 0.489 x 0.078 LE / 640 feddans = 286.18 LE/feddan

<u>Opportunity Cost of Water:</u>

The net benefit in LE/fd for sorghum under the hand-move irrigation can be calculated using the net benefit function as follows:

$$\mathbf{NB = P.Y - C.X - C_T}$$

$$NB = 1360.8 - 0.078 \times 3122.8 - 652 = 465.22 \text{ LE/fd}$$

Real value of water = 465.22 / 3122.8 = 0.14 LE/m3
Notice that the opportunity cost is almost 0.14 /.0.7 = 2 times more than the delivery cost.

COST AND RETURN FORM
PART C- ANNUAL OPERATING COST

ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel			7.8 LE/fd
Oil			
Repair & maintenance (power unit)			
Repair & maintenance (irrigation equipment)			33.33 LE/fd
Electricity			106.77 LE/feddan
seed			106 LE/ fd
fertilizer			522 LE/ fd
chemicals			
costs			24 LE/fd
Irrigation Labor			186.06 LE/feddan

Total income = yield x value of crop per unit
= 45.36 x 30 LE/ton = 1360.8 LE/feddan

The net return = Total income/feddan - Total annual cost/feddan
= 1360.8 - 986 = 375 LE/feddan

Delivery Cost of Water

The total annual pumping cost can be calculated by substituting the values from tables as follows:
Total annual cost = Fixed cost for total area + Operating cost for total area
*Operating costs per total area only consists of irrigation charges and excludes the remaining costs; i.e seeds, fertilizers and chemicals.
* Total area in Tahrir (collective pumping unit) = 640 feddans
Total annual cost = 160828.6 + 213734.4 = 374563 LE/640 feddan

Table of operating hrs per day during the year

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 3000 hrs/yr x 1600 m^3/hr
= 4,800,000 m^3/yr

Cost of pumping water = Total annual cost /Total amount of water pumped annually
= 374563 LE/yr / 48x 10^5 m^3 /yr
= 0.078 LE/ m^3

Problem Identification:

After studying and evaluating the existing system it was possible to list the factors that led to the decrease in it's efficiency.

1.Insufficient filter unit. Without any support from an industrial brand filter the locally made filter could not fulfill efficient filtration of the incoming water.

2. Deteriorated laterals due to continuous manual cultivation processes over a long period of time.

3. Large number of leakage as a result of loose fittings between grommets, seals, submain and laterals. These factors reduced the pressure on the internal emitters which led to low Uniformity and Application efficiencies.

4. Bent P.E. submain ends which were tied or knotted instead of installing a flushing system with the proper equipment.

5. Lack of valve opening schedules and periodical maintenance of system reduced standards.

Suggested Solutions and Modifications:

1. Installing a 2 inch Arkal disc filter(120 micron, 130 mesh) providing 25 m^3/hr.

2. Installing a new submain made of PVC with new laterals along with the correct sizes of grommets, seals and figure 8 endings.

3. Installing the proper flush system with ball valves, reducers and PVC necks.

4. Scheduling valve opening and maintaining a regular check up.

Required Materials and Costs:

The following is an inventory sheet of the materials used to improve the system's efficiency and allow detailed monitoring, which also provided accurate calculations to analyze the project's future conclusions.

farm: Saad Khoudair system: Trickle

No.	Item	Unit	Amount	Price	Total Cost
	seal, 16mm		100	6	
	figure 8 endings		100	5	
	P.E coupling, 16 mm		100	6	
	grommets, 16 mm		100	6	
	hose, 50 mm	meter	100	150	
	male adapter, 63 mm/ 1"		1	3	
	male adapter, 63 mm/2"		1	2	
	ball valve, 1"		1	8.2	
	reducing bosch, 1/2"/1/4"		1	1	
	socket, 1/2"		1	0.75	
	teflon spindle		10	0.5	
	Arkal filter, 2", 120 micron, 130 mesh		1	470	
	steel elbow, 2"		1	3.15	
	steel union, 2"		1	8	
	nipple, 2"		1	2.15	
	socket, 2"		1	2.2	
	pressure gauge, 6 atm.		1	35	
	flow meter, 2"		1		
	P.E GR laterals 16 mm, 4 l\hr, coils of 400 m		4	172	
	P.V.C pipe, 63 nm, 6 atm.	meter	60	2.83	
	P.V.C glue	kg	1/2	25	
	P.V.C curved elbow, 63 mm		1	12	

Modified Irrigation System Evaluation

After applying the suggested proposals to improve this systems output an evaluation was executed to confirm development; which appears in it's higher efficiency.

Trickle Irrigation Evaluation Sheet

Location: Boustan Farm no. 5 Farmer's name: Saad El-Khoudair
Observer: Yasser Zedan date: 22\1\'97
Crop: Strawberry spacing: 0.5x 1.75 m
Soil: sandy available water: 60 mm/m
Irrigation: Duration: 1 hr. frequency: every two days
Filter Type and Performance: Local screen filter ,outlet 3 inches 35-30 m hr, Arkal disk filter 2 inch inlet, 120 micron, 130 mesh, 25 m3/hr
Pressure Inlet: 1 Bar @ Pressure Outlet: 0.9 Bar Loss: 0.1 Bar
Fertilizer Unit Characteristics: Emitter: Make: Egyptian Model:GR Point spacing: 0.5 m
Rated discharge per emission point: 3.04 l/hr @ Pressure: 1 Bar
Emission points per plant: 1 giving 6.08 l/day
Laterals: Diameter: 16 mm Material: P.V.C Length: 30 m
Spacing: 1.75 m

outlet location n laterlal		Lateral location on the Manifold							
		inlet end		1/3 down		2/3 down		far end	
		volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr	volume collected	discharge l/hr
	A	27	3.24	28	3.36	22	2.64	26	3.12
ILET END	B	27	3.24	30	3.6	23	2.76	26	3.12
	TIME	30		30		30		30	
	AVERAGE		3.24		3.48		2.7		3.12
	A	25	3	29	3.48	21	2.52	26	3.12
/3 DOWN	B	24	2.88	28	3.36	3.21	2.76	27	3.24
	TIME	30		30		30		30	
	AVERAGE		2.94		3.42		2.64		3.18
	A	24	2.88	31	3.72	20	2.4	24	2.88
/3 DOWN	B	24	2.88	30	3.6	22	2.64	25	3
	TIME	30		30		30		30	
	AVERAGE		2.88		3.66		2.52		2.94
	A	26	3.12	29	3.48	21	2.52	24	2.88
FAR END	B	25	3	29	3.48	22	2.64	23	2.76
	TIME	30		30		30		30	
	AVERAGE		3.06		3.48		2.82		2.82
Pressure	INLET	1		1		1		1	
	OUTLET	1		1		1		09	
INIMUM RATE OF ISHARGE	2.61 l/hr								
Average rate of lischarge	3.04 l/hr	Eu=86 %		Ea = 77.2 %					

By comparing both efficiencies before and after the improvements were installed it can clarify the increase in Emission Uniformity (57.8% to 86 %) and Application Efficiency (52% to 77.2%). Accordingly, as a result of the this difference 48.9% of wasted water was saved that can now be used in different areas.

$$\text{Percent of Saved Water} = (1 - AE_1/AE_2) \times 100$$
$$= (1 - 52/77.2) \times 100$$
$$= 32.64\%$$

Economic Analysis

The irrigation system must provide return to meet fixed and operation costs which include fuel, repairs, labor and additional expenses incurred by irrigation. Part A of the following tables gives the general information, while Part B gives the fixed cost and C the annual operation cost.

COST AND RETURN FORM
PART A- GENERAL INFORMATION

ITEM	INFORMATION NEEDED
Crop (s) to be irrigated	strawberries
yield per feddan	6 Tons/feddan
value of crop per unit (tons)	1000 LE/ ton
Seasonal consumptive use of crop	m3/fd/yr
Number of hours operated each day	4
Minimum days required for each irrigation	1
Number of irrigation expected per season	180
Number of operated hours per year	720
Shape and dimensions of field	112 x 186
Type of irrigation system	drip
Number of feddans irrigated	4.96
Sprinkler or emitter discharge	1
Sprinkler or emitter spacings	0.5 x1.75 m
Pumping rate needed (m3\hr)	22 m^3/hr
Source of water	surface canal
Total height water is to be lifted	1.5 m approximately
Total operating head	4 Bar
Size fo power unit needed (hp)	3 x 148 Hp
Type of power unit	electric
Interest rate	9%
Hours labour feddan per irrigation	

Cost and Return Form
Part B - Depreciation Costs

Item	years of life, N	Initeal Cost, LE	Capital Recovery Factor, (CFR)	Annual Cost LE= CRF x initial cost
Well Casing				
Reservoir				
Pump Turbine Centrifugal	13.5	180,000	0.1129	20322
Power Unit Electric Diesel				
Miscellaneous Electric switch Electric Transformer Fuel Tank Land Development	21	35000	0.107	3745
Water Pipe: Underground pipe: Concrete Steel Asbestos Cement PVC	20	419731.2	0.109	45980.07
Above Ground Pipe: Aluminum Galvanized Steel				
Sprinkler Systems: Hand-move Fixed Gun- portable				
Surface systems: Land grading				
Drip systems:	10	2000	0.155	148800
Land Drainage				

Total annual costs = 218847.07

COST AND RETURN FORM
PART C- ANNUAL OPERATING COST

ITEM	AMOUNT	COST PER UNIT	TOTAL
Fuel			
Oil			0.41
Repair & maintenance (power unit)			14.62
Repair & maintenance (irrigation equipment)			
Electricity			114.46
seed	1333	0.15 LE	2000
fertilizer			2154.37 LE/fd
chemicals			800 LE/fd
Engine operation Attendance			1200 LE/480 feddans

Total income = yield x value of crop per unit
= 6 ton/fd x 1000 LE/ton = 6000 LE/feddan

The net return = Total income/feddan - Total annual cost/feddan
= 6000 - 5086.36 = 913.64 LE/feddan

Delivery Cost of Water

The total annual pumping cost can be calculated by substituting the values from tables as follows:

Total annual cost = Fixed cost for total area + Operating cost for total area

*Operating costs per total area only consists of irrigation charges and excludes the remaining costs; i.e seeds, fertilizers and chemicals.

* Total area in Boustan (collective pumping unit) = 480 feddans

Total annual cost = 218847.07 +63355.2 = 282202.27 LE/480 feddan

Table of operating hrs per day during the year

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT		NOV	DEC
Hrs/day	8	8	9	9	9	11	11	11	11	9	8	8

Total amount of water pumped annually
= number of hours operation per year x pump discharge
= 3000 hrs/yr x 753 m^3/hr
= 2259000 m^3/yr

Cost of pumping water = Total annual cost /Total amount of water pumped annually
= 374563 LE/yr / 22.59 x 10^5 m^3 /yr
= 0.1249 LE/ m^3

Therefore the amount of money saved in pumping water per feddan
= water pumped annually x saved water x cost / Total area
= 22.59 x 10^5 m^3 /yr x 0.489 x 0.12 LE / 480 feddans = 276.16 LE/feddan

<u>Opportunity Cost of Water:</u>

The net benefit in LE/fd for strawberries under drip irrigation can be calculated using the net benefit function as follows:

$$NB = P.Y - C.X - C_T$$

NB = 8000 - 0.1249 x 4706.25 - 4954.3 = 2457.88 LE

Real Value = 2457 / 4706.25 = 0.5[illegible]

Project on: **Desert Irrigation Efficiency 1994-1997**

Report On: **Administrative Aspects**

Staff and Organizational Changes

- ☐ There has been practically no administrative changes in the staffing of the project or important changes during the last year. Dr. H. El Lakany, the DDC Director, was the project leader during the first year of the project. Dr. M. Sabbah assumed this responsibility since Sept., 1995. Dr. Cole (1994) and Dr. M. Nawar (1995-1997) assumed responsibility for the Social Aspects, Dr. R. El Amir and Dr. Sherin Sherif Covered the economical Aspect. The Technical aspects of desert irrigation were the responsibility of Drs. S. Ismail and A. Metwally. Dr. A. I. Metwally has been the Technical Coordinator of the Project 1994-1997.

Training

- ☐ A Summary of the training activities supported by the project is attached.

International travel to attend scientific Meetings:

- ☐ Dr. Metwally presented the paper "Integrated Soil-Water Management in the New Lands of Egypt" at the International Conference on Land and Water held in Valenzano, Bari, Italy, 4-8 Sept., 1994

- ☐ Dr. Metwally presented the paper "Irrigation Systems Evaluation in Desert Farming" at the Fifth International Conference on Desert Development" held in Lubbock Texas, U.S.A. July 12-17, 1996.

wy

- Dr. Nawar presented the paper "Some Social Aspects of Farmer Irrigation in Reclaimed Desert Lands in Egypt" at the 17th Congress of European Society for Rural Sociology, Chania, Crete, Greece, 25-27 Aug. 1997.

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TRAINING ACTIVITIES

SUPPORTED BY DESERT IRRIGATION EFFICIENCY PROJECT

The training activities which are totally or partially supported by the project include two categories of trainees:

A totally supported activity includes a number of research assistanntswho are involved in the project and participating in the fields of irrigation and socio - economics

The following is a list of the names of research assistans involved in period (1994 - 1996) :

1. Yasser Zidan
2. Ahmed Al Wakeel
3. Ahmed Maher
4. Mohsen Nawara
5. Mahmoud Saleh
6. Aabdel - Shafi Azzam
7. Ashraf Abdulla
8. Taha Mahmoud
9. Naeim Dowidar
10. Hassan Hossein
11. Moataz Mabrouk

A partially supported activity includes numbers of University graduates trained in the field of irrigation and water management in the new lands, as a partial fulfillment of a comprehensive Desert Agriculture Training Program . Number of trainees and number of training hours in irrigation and water management .

	Training Periods	No - of Trainees	Training Time (Hrs)	Person - Hr
1.	25/11/94 - 07/02/95	20	48	960
2.	25/03/95 - 01/07/95	55	48	2640
3.	25/06/95 - 04/09/95	55	48	2640
4.	29/09/95 - 19/11/95	75	32	2400
5.	18/11/95 - 01/02/96	75	32	2560
6.	02/03/96 - 23/05/96	80	32	2560
7.	11/05/96 - 13/06/96	100	16	1600
8.	15/06/96 - 14/07/96	100	16	1600
9.	10/08/96 - 15/09/96	59	16	944
10.	21/09/96 - 24/10/96	91	16	1456
11.	26/10/96 - 01/12/96	110	16	1760
12.	23/11/96 - 29/12/96	106	16	1696
13.	21/12/96 - 09/03/97	120	16	1920
14.	01/03/97 - 03/04/97	125	16	2000
15.	29/03/97 - 18/05/97	114	16	1824
16.	24/05/97 - 26/06/97	20	16	320
	TOTAL	**1305**	**400**	**28880**

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Some Social Aspects of Farmers' Irrigation Practices in Reclaimed Desert Lands in Egypt*

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ABSTRACT

Reclamation of desert lands is considered a new avenue of agricultural development in Egypt to overcome the problem of imbalance between the high population growth rate and limited land resources. Yet , the scarcity of water resources available for such purpose necessitate more emphasis on irrigation efficiency. Hence, irrigation efficiency in reclaimed desert lands is considered a vital factor in the success or failure of farming and agriculture enterprises in such arid areas.

Efficiency of irrigation is determined in great part by the farmers' irrigation practices aside from the conditions of irrigation system used. Many social aspects such as the type of social network of relationships between farmers and officials and the farmers' involvement in the decision making process related to selection of and operating the irrigation system are from among the important variables affecting these practices.

Accordingly, this study aims to clarify the pattern of relationships that might exist between some social variables under the different irrigation systems used in specific reclaimed desert lands. A sample of 109 farmers representing the users of surface, sprinkler and drip irrigation systems in four different areas in the Western Desert in Egypt were selected.

The social aspects investigated are; the previous farm manager training and experience in agriculture, the farmers' involvement in decision making process related to the selection of irrigation system used, the criteria of this selection, frequency of occurrence of irrigation problems among farm holders, willingness of farm holders to collaborate in organizing the irrigation process in their area, their willingness to collaborate with the officials and non officials in solving encountered irrigation problems, the officials and other agencies role in solving irrigation problems, and leadership in organizing irrigation process.

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INTRODUCTION

Egypt is the most populous Arab country. Its population was 9.7 million in 1897, 19 million in 1947 (CAPMAS, 1980) while it reached now 61.5 million according to the last census of November 1996 (CAPMAS,1997). This last population number exceeds all what was expected by the World bank where it had estimated the population in 1995 to be about 58 million (World Bank, 1997).

Hence, population in Egypt increased by more than six times since 1897 and by more than three times from 1947 to the present (CAPMAS, 1994). They grew slowly from 9.7 to 19 million at an average rate of about 1.3 percent per annum from 1897 to 1947. Yet, they grew rather faster from 19 to 61.5 million at an average rate of about 2.4 percent per annum from 1947 to 1996. At the beginning of the last period the rate increased greatly immediately after the revolution of 1952 to be around 2.7 percent in the Fifties and 2.9 percent in the early Sixties (Clark, 1968) and lasted at that high rate until late Seventies. But, it dropped to about 2.2 percent early Eighties and has begun to fall down to about 2.1 percent during the period 1986-1996 (CAPMAS, 1997).

This high growth rate of population in Egypt during the last half century has intensified demand on all natural resources specially water and land. The only source of fresh water in Egypt is the Nile river with fixed allocated quota of 55.5 billion cubic meter annually. Thus, with the high number of population and fixed quota of water Egypt has become under the **water poverty line** since mid Nineties. On the other hand the inhabited lands in Egypt represent only four percent of the one million square kilometer which is all Egypt area. Arable land resources is rather very scarce. They are limited to the old lands located in the Delta and aside the Nile River banks. They were the only land resources available for agriculture until recently. Coupled with the rapid growth of population this situation led to a sharp decline of the cultivated land per capita from about 0.6 acre/person in 1897 (CAPMAS, 1993) to about 0.11 acre/person in 1996 (NPI, 1995). Nevertheless, the limited arable land resources was exposed to a very hard period of high rate of corrosion for housing and other development purposes until recently when a very sharp decree was enacted in 1996 to crimanalize such behavior. This new situation has frozen this trend of arable land corrosion so far.

Hence, due to the above mentioned conditions a strong and a justifiable attitude to expand farming into desert lands has started in Egypt since the Fifties. Reclamation of desert lands has become the sole solution of population pressure on land resources. The actual start in this direction took place in the early Fifties after the 1952 revolution. The implementation of significant volume of reclamation of desert lands in Egypt took place during the period 1952-1967 and the period 1971-1991. Out of the total of 2.6835 million acres of the new lands cultivated so far there were about 48% and 42% reclaimed during these two periods respectively (CAPMAS, 1994).

Establishment of new settlements in desert has matched the desert reclamation process since then. Settlers in the new desert communities varied widely depending on the historical and socio-political background during which the settlement schemes were implemented. Their socio-economic characteristics differed accordingly. Their background according to their place of origin (rural/urban), educational status (literate/illiterate) and previous experience and occupation before their settlement in the new communities have affected their farming practices. This is more obvious in the issues related to the use of water, the most scarce resource in irrigation in such areas. Hence, efficiency of using water in desert irrigation has become now an urgent issue (Nygaard, 1991). It is by decree just recently, in the Eighties, that modern techniques of irrigation; such as the drip and sprinkler should be used in desert irrigation. Yet, due to several complicated historical, technical, socio-economic and other management conditions surface irrigation in many desert areas is still used too. Those who got their early experience in agriculture in old lands know nothing other than surface irrigation. Moreover, the first waves of settlers were mostly landless, peasants or small holders with low capital and scientific knowledge in agriculture, if any to invest in modern irrigation techniques in the new lands. It worth mentioning, however, that modern irrigation techniques have got its reputation in Egypt only since the Seventies. Hence, the first waves of settlers have accustomed to the use of surface irrigation in desert lands for long period even after their migration from their old lands.

Irrigation systems in the desert lands which are different from those prevailing in the old lands were introduced to comparatively new communities. Thus time constrain has not yet given these communities the opportunity to institutionalize stable patterns of behavior and practices related to irrigation in the desert lands such as these existing in old lands.

However, since the coverage of all Egypt by the perennial irrigation system in the sixties cropland became double that of the cultivated area. To cultivate the same area twice or somewhere three times a year it needed a more strict and rational management of water resources. This necessitated more emphasis on studying all aspects of efficiency of irrigation including the intangible social aspects. This study is one of the most recent comprehensive studies in this domain.

The Research Problem and Objective of Study:

Agriculture in new desert lands is considered relatively a new experience for the settlers of these new areas in Egypt. Most holders of these lands started farming in old lands. Hence their experience with modern irrigation technologies in the reclaimed lands is rather recent. The irrigation practices of those holders and the way they manage the costly transported and scarce water are considered crucial to the success or failure of their enterprises. These practices affect also their irrigation efficiency and hence their investments in cultivating these new lands.

Nevertheless, frequent complaints of holders of new desert lands from irrigation problems are frequently announced in the media. Their main complain is from the shortage of water. This could be easily explained by the expected contradiction between their past experience with surface irrigation using plenty of water in their old lands and their lack of experience with modern irrigation techniques using less quantities of water in the new lands. In old lands, accumulated experiences related to irrigation practices are transmitted from one farmers' generation to another through the socialization process. There are also well established institutions, norms and organizations that facilitate the transmission of adopted practices to the successive new generations. Informal organization among farmers play major role in the scheduling of irrigation rotation and distribution of water in any specific area in the old lands. Yet, such situation does not exist, though it is more needed, in the case of settlements in the new lands.

The main question that might rise here is concerned with the various social aspects of irrigation practices of farm holders who might have different irrigation systems in their desert lands. To what extent are these aspects of irrigation practices could be relevant or not to the irrigation systems applied?. Hence, to what extent are they relevant to the physical and chemical characteristics of the soils there?. Studying the social aspects of current irrigation practices associated with the various irrigation systems in new desert lands might help planners and practitioners who are interested in the efficiency of irrigation in these lands to outline the needed reorganization of the whole irrigation process to enhance its efficiency. Importance of such aspects is becoming more serious because of the increasing proportion and role of desert lands in Egypt agriculture in the present and future.

Thus the objective of this research could be elaborated in the identification of the pattern, significance and strength of relationships that might exist between some social aspects of irrigation practices and the irrigation systems applied in the selected desert areas.

Variables of Study:

Depending on the research problem the following variables were selected for study;

1. The irrigation system used by the farm holder. This could be either sprinkler, drip or surface irrigation or a mix of these three systems.
2. Education and previous practical experience of farm Manager.
3. Criteria of selection of irrigation system.
4. Decision maker in the selection of irrigation system.
5. Occurrence of irrigation related problems between neighbors.
6. Frequency of officials' response to irrigation problems.
7. The officials and other agencies took part in solving irrigation problems.
8. Leadership in organizing irrigation process.
9. Farm holder willingness to collaborate with others to solve irrigation problems.

METHODOLOGY:

Unit of Study and Sampling:

The unit of this study is the farm holder. A random quota stratified systematic sample was drawn from among all the population of farm holders of specific villages selected according to particular criteria. These criteria took into consideration; a) the different environmental conditions related to the type of soil, sources of water, and topographical characteristics, b) the different combinations of settlers categories; i.e. beneficiaries, graduates, small investors and large investors, and c) the different duration of settlements life span since the establishment of these settlements. Thus the population of farm holders in all the villages of the selected four areas was portrayed first. This was a necessary step to be able first to select the villages that satisfy the specified criteria and second to draw representative samples at the village level.

These procedures was adopted to secure generalization of the findings to the respective populations. A sample of 125 farm holders were selected and interviewed. After the data verification only 109 cases were accepted for analysis.

Geographical Area of Study:

Four desert land reclamation areas were selected as sites for this research. These are the South Tahrir, Al-Bostan, Wadi Al-Natroon and Sadat areas. These four areas are located in the West desert region of Egypt as shown in figure (1). Agriculture commenced in South Tahrir in the late fifties, while it started in the other three areas later. South Tahrir, Sadat and Al-Bostan have their main source of irrigation water from canals connected to the national irrigation system. Farms in the fourth area use deep ground water as the main source of their irrigation water. All these four areas are located south the coast of Mediterranean sea with about 60 to 100 Kilometers.

Data Collection Tools:

Exploring present situation of irrigation in desert lands required application of a sample survey. In the survey a pre-tested questionnaire along with personal interview was applied to the sample drawn. This double technique was adopted to assure getting accurate data and high rate of questionnaire return. In the light of previous experience with sample surveys in Egypt rural areas low response to questionnaires was reported. This is attributed to the low educational level prevailing in rural areas specially among small farm holders. Hence, the questionnaires were filled in the presence of trained enumerators, to secure high rate of questionnaire return, unified understanding of what is meant by each question, and control over the environment of response to the asked questions.

The questionnaire was designed to include three main components, the social, economic, and technical aspects for studying the efficiency of operating irrigation systems in desert lands selected for study. Data used in this paper were extracted from the social part of this questionnaire.

Method of Analysis:

All measures of the variables of this study were of nominal type. Hence, only frequencies and percentages were used for the display of data. Chi square was used to test significance of differences between the four groups of users of the applied irrigation techniques in connection with studied social aspects. Accepted level of significance is determined here by 0.05.

FINDINGS AND DISCUSSION

The results of analysis of data related to the above mentioned variables are presented in the following summarizing table. Chi square was used to test the significance of differences of distribution of the four groups of users of the various irrigation systems according to the categories of response to these variables. The detailed tables are presented in the annex.

Ser	Variable	Chi Square	d.f.	Prob.
1	Education & Practical Experience of Farm Manager	15.912	6	**0.0142**
2	Criteria used for Selection of Irrigation System	23.958	12	**0.0206**
3	Decision Maker in the Selection of Irrigation System	51.583	9	**3.944E-07**
4	Occurrence of Irrigation Related Problems between Neighbors	21.207	6	**1.684E-03**
5	Frequency of Officials' Response to Irrigation Problems	19.010	9	**0.0251**
6	Officials Take Part in Solving Irrigation Problems	24.975	9	**2.998E-03**
7	Leadership in Organizing irrigation Process	59.604	12	**2.665E-08**
8	Farm Holders Willingness to Collaborate with Others to solve Irrigation Problems	33.337	9	**1.162E-04**

1. Users of Irrigation Systems in Newly Reclaimed Desert Lands:

According to the field data gathered about 40.4% of the sample was found using sprinkler system in the irrigation of their desert lands. This is against 21.2% using drip system, 13.8% using surface irrigation and the rest 24.8% of the sample using a mix of these three irrigation methods though it is mostly a mix of drip and sprinkler systems. These percentages do not necessarily represent the distribution of irrigation systems used in all desert lands in the areas of study or other desert lands in all over Egypt.

2. Education and Practical Experience of Farm Manager:

Data in table (1) in the annex showed that the majority of the whole sample 82.6 % had no previous formal training experience in farming prior to their settlement in the new reclaimed desert lands. However, there was about 6.4% got some educational degree of technical high school and above in agriculture while the rest of the sample 11% have got some practical experience beside their educational background. When testing the difference among the four groups of users concerning their source of experience it was found that about third of the users of drip irrigation have some sort of educational background beside 21.7% have practical experience. Yet for the users of sprinkler irrigation only 6.8% have got some sort of educational background beside practical experience but the majority 93.3% have got no experience prior to their settlement in these new communities. All users of surface irrigation have got neither formal education nor previous practical experience prior to their move to the new communities. Graduates of high technical schools and above level were found only in the categories using drip or mixed systems. These differences could be understood in the light of higher technicalities of drip system in comparison with the other irrigation techniques.

Testing these differences using Chi square proved the existence of significant differences among the four groups at 0.014 level.

3. Criteria of Selection of the Irrigation System:

Table (2) in the annex present distribution of the sample by irrigation system and according to the criteria they consider in selecting irrigation system for their lands. For the whole sample and even for all the four categories the majority took more than one criterion in their consideration. However, there are fine differences between these categories regarding the weight of each criterion in separate. The percentage of users who took only availability of water as a criterion was found the highest 18.1% for the users of drip irrigation, 10% for the users of sprinkler irrigation but only 7.7% for the users of surface irrigation. The percentage of those who took the neighborhood experience and hence the social network of relationship into their consideration was found to be the highest 20% among the users of surface irrigation

Testing these differences using Chi square showed that differences among the four groups at are significant 0.021 level.

4. Decision Maker in the Selection of Irrigation System:

Table (3) in the annex shows distribution of the four categories of users of various irrigation systems according to the decision maker in the selection of irrigation system. It was found that the type of irrigation system was determined for the majority of the whole sample 57.8% by the authorities. It should be mentioned that in most of the cases specially the areas use sprinkler irrigation these systems were provided by the reclamation authorities during the preparation of infrastructure in the reclaimed land. The farm holder made his own decision in 30.3% of the cases. Technical consultation was used only in 4.6% of the cases.

In the case of the four categories technical consultation was used in 8.75% of the cases of users of drip systems and 7.4% of the users of mixed irrigation systems which are more than the average. Farm holder is the one who made decision in 51.8% of the case of users of mixed systems. This is against 43.5% of the users of drip system, 40% of the users of surface method, and only 6.8% of the users of sprinkler system. The higher technicalities included in the modern irrigation techniques seem to push farm holders to take the responsibility himself and with the help of technical assistance of professionals in making his decision concerning the system to use in his farm. This situation is clear in the case of users of drip and mixed systems.

Testing the above mentioned differences among the four groups using Chi square showed that differences are highly significant at 3.944E-07 level.

5. Occurrence of Irrigation Related Problems between Neighbors:

Table (4) in the annex presents the distribution of the sample by irrigation system and according to the frequency of occurrence of irrigation related problems among neighbors. It was found that the majority of the whole sample 57.3% had no problems, 29.2% had frequent problems but only 13.5% had such kind of problems infrequently. However, for the four groups of users of irrigation systems about 48.9% of the users of sprinkler irrigation were found suffering frequent problems which is more than the average. This is against 23.1%, 10.5% and 9.5% of the users of surface method, mixed and drip systems respectively. The users of mixed and drip systems seem to have the least frequency of exposure to such problems since 84.2% and 76.2% of these two categories reported they had no such problems respectively. It seems that using modern irrigation techniques or a mix of them minimizes the possible situations that create conflict among farm holders on the scarce resource of water.

Testing the significance of differences among the four categories of users of irrigation systems using Chi square showed that its value was 21.207 which is significant at 0.0017 level.

6. Frequency of Officials' Response to Irrigation Problems:

Table (5) in the annex shows distribution of the sample of users of various irrigation systems according to the frequency of officials' response to irrigation problems. It was found that for about 57.3% of the whole sample officials response never or rarely to the complaints of irrigation problems of farm holders. They responded always in 24.2% only of the cases. When these high responses matched with the irrigation systems the highest percentage of 46.2% was found in the case of surface irrigation. The highest absence of such response were found in the case of users of mixed and drip systems where they were 73.7% and 61.9% respectively. The high frequency of officials' response to the irrigation problems of users of surface method and the absence of such response to the users of modern irrigation systems might be attributed to the relatively old and well established organization of irrigation system in the areas using surface method as it was mentioned before.

Testing the significance of these differences using Chi square showed that they are significant at 0.025 level.

7. Officials and Other Agencies Involved in Solving Irrigation Problems:

Table (6) in the annex presents the distribution of the four categories of users of various irrigation systems according to the officials and other agencies involved in solving irrigation problems. For 34.7 percent of the whole sample the agricultural cooperative in the farm holders' area took the responsibility of solving irrigation problems. Irrigation staff in the area took this responsibility in other 26.7 % of the cases. Other agencies are involved in 9.3% of the cases. At the category level of the users of irrigation systems coops play higher role for 63.6% of the users of surface method, while the irrigation staff plays the highest role for 75% of the users of dripping system. This trend of relationship seem to be logical since the problems related to drip systems might need more experienced and professional staff to deal with. This trend goes in consistence with the previously proved results about the tendency of users of drip systems to depend on technical assistance more than the others.

Testing the significance of the above mentioned differences among the four users of irrigation systems using Chi square showed that they are significant at 0.003 level.

8. Leadership in Organizing irrigation Process:

Table (7) in the annex shows the distribution of the sample by the used irrigation system and leadership in organizing irrigation process at the local level. It was found that 43.1% of the whole sample have some of their neighbors took a leading role in the organization of irrigation process in their areas. Yet, about 25.7% of the surveyed sample took this leading role themselves. Agricultural cooperatives played this leading role in 14.7% of the cases. Distribution of the subsamples of the four categories of users of irrigation systems showed that farm holders play leading role in organization of irrigation process in 51.8% and 43.5% of the cases of mixed and drip groups of users respectively. Cooperatives play their role in 46.7% of the areas of users of surface irrigation method but only in 20.5% in the areas of the users of sprinkler systems. These figures show again that the role of some sort of social organizations exist in the areas where farm holders use conventional methods of irrigation techniques while such social arrangements for organization of irrigation are missing or at least have less role in the areas using modern technologies.

Testing the significance of the differences mentioned above among the four users of irrigation systems using Chi square showed that they are highly significant at the level of 2.665E-08.

9. Farm holders' willingness to collaborate with others to solve encountered irrigation problems:

Table (8) in the annex presents the sample distribution of by irrigation system and degree of farm holders' willingness to collaborate with others to solve encountered irrigation problems. Data in the tables show that only 28.9% of all the sample had high willingness to collaborate with others whether officials or non officials in solving encountered irrigation problems, 25.7% had moderate willingness to collaborate, but the highest percentage 37.% was that of the group of negative attitude towards collaboration in solving encountered irrigation problems. This result clarify the absence of enough common social interests among the farm holders so far to collaborate in solving encountered irrigation problems. Social network of relationships and other ties among farm holders in such new communities seem in need of some new institutional arrangements to be more effective. However, the distribution of subsamples by the different responses showed that the users of drip and mixed systems tend to be more negative in their attitudes where 61.9% and 65% expressed their complete unwillingness to collaborate respectively. The users of sprinkler irrigation system showed rather a more positive attitude than the users of surface method where the percentage of high and moderate willingness respondents together were 83.8% and 38.5% respectively. This situation is not unexpected in new communities but needs rapid reconciliation within an overall social reform of the social infrastructure of new desert rural communities.

Testing the significance of the above mentioned differences among the four groups of users of irrigation systems using Chi. square showed that they are highly significant at 0.00012 level.

Conclusion:

Analysis of the data displayed showed a general and significant trend of differences among the four categories of users of irrigation systems. However the users of surface method seem to be slightly more organized socially than the users of sprinkler irrigation. Yet, both showed more organized than the users of drip and mixed systems. It seems that the last two sub groups had a more individualistic approach. They seem to have more educational qualifications than the others which might explain their tendency to be more self reliant than the others.

Nevertheless, the need of a more social approach to the organization of irrigation process for all farm holders seem more urgent. This will help improvement of the efficiency of irrigation in desert land and enhancement and stability of social life in such new rural communities.

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ECONOMIC EVALUATION OF CROP PRODUCTION FUNCTIONS UNDER DIFFERENT IRRIGATION SYSTEMS IN THE EGYPTIAN NEW LANDS

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ABSTRACT

This paper sheds the light on the problem of water productivity and water use efficiency in the new lands on the micro level. A quantification of the impact of irrigation water on the level and/or value of output is assessed under the three dominant irrigation schemes: sprinkler, flooding, and drip. A stratified random sample of 109 farmers is interviewed during the summer and fall of 1996 for the purposes of this study. This sample covers four areas in the Egyptian new lands: South Tahrir, El-Bostan, Wadi-El-Natroun, and El-Sadat. Eight Cobb-Douglas production functions are estimated for: peanuts (sprinkler and flooding), wheat (sprinkler and flooding), summer crops (sprinkler), winter crops (sprinkler and flooding), and vegetables (drip).

The study showed that: (1) On the grounds of production (technical) efficiency, the cubic meter of irrigation water for the sprinkler system possesses, on the average, higher efficiency than the flooding system for the same crop. Although, this comparison could not be made for the drip system; the highest average value product was obtained in the case of the drip system, which implies the highest production efficiency across the estimated functions. (2) On the grounds of price (allocative) efficiency, which is the other component of economic efficiency of water use, farmers are found to be price efficient in only one function under the first scenario of calculating the imputed cost of water (design expectation of the pump). Under this scenario, the cubic meter of irrigation water is priced at 0.070, 0.124, and 0.143 Egyptian pounds for the flooding, sprinkler, and drip systems, respectively. Under the second scenario (actual operation hours of the pump), three functions are found to achieve price efficiency. Under this scenario, the cubic meter of irrigation water is priced at: 0.140, 0.248, and 0.286 pounds for the three irrigation systems, respectively.

It is concluded that, given these figures for the imputed cost of water and that irrigation water is not priced in Egypt, the majority of the estimated functions (seven under

the first scenario and four under the second one) display that farmers are "economically" under-utilizing irrigation water.

Key words: Production functions, Water economic efficiency, Water productivity.

INTRODUCTION

In Egypt, water is considered to be the most important constraint which hinders agricultural expansion. Decision makers can no longer plan any agricultural expansion without seriously considering the limited supply of water mainly provided by the Nile River. Moreover, the demand for water, for almost all uses, has risen and is continually rising, to the point that Egypt will be using more than its share of 55.5 billion cubic meters in the next decade. Pressure of rising population, by itself, underscores the need to revitalize the agricultural sector. This will definitely possess important implications for water use and constitutes a pressing need for the Government of Egypt to maximize the returns to this valuable resource in an environmentally sound manner (Abu-Zeid and Rady, 1991).

One of the major steps the Egyptian Government has taken in recent years to increase agricultural production is to reclaim new lands. Land reclamation is another major water consumer and promises to become an increasingly important component of water demand in the near future. Originally, this practice has started in the early fifties. The government has restarted its land reclamation program in the mid seventies with ambitious objectives based on its experience with the old new lands (the Tahrir area). This interest in reclamation stems mainly from the government's need for an outlet to deal with the demands of a growing population (Waterbury and Rignall, 1991). The political and social importance of this activity explains the government insistence on expanding its reclaiming efforts despite of a widespread criticism of the economic costs and high water consumption.

Since 1952, the government has reclaimed 1.6 million feddans and has lost approximately one million feddans of the old Delta lands to urban encroachment during this period. Accordingly, net gains have been significantly reduced. Moreover, the productivity on the new lands did not meet expectations due to a number of administrative, technical, and natural constraints (Sherbiny and Sherif, 1992). Of the 900,000 reclaimed feddans between 1967 and 1975, only 500,000 feddans were farmed, with only 200,000 feddans of that reaching submarginal productivity (Barth and Shata, 1987).

the reasons for this disappointing performance are believed to be economic inefficiency combined with some technical bottlenecks. High investment cost is the character of land reclamation. In other words, it takes an average of ten years before reclaimed lands reach submarginal productivity. Not enough attention is paid to irrigation and drainage infrastructure. Moreover, 500,000 feddans had to be completely excluded from crop rotations because of salination problems in some areas; in other areas the water table rose by an average of three meters a year (El-Batran, 1989). Water shortages are common, and the cost of lifting water is an issue, as does the problem of an unreliable electricity supply. Egypt's Water Master Plan predicts future reclamation to require 5,400 cubic meters per feddan, while IBRD considers 9,200 cubic meters per feddan more realistic given current methods of reclamation (Waterbury, undated).

The fiscal constraints of the mid seventies as well as the recognized inefficiencies in reclamation efforts spurred a reassessment of the government's program in the early eighties. With a revised strategy based on improved planning and more appropriate technology, the government hopes to achieve greater economic and water use efficiency in future reclamation.

MATERIALS AND METHODS

This paper sheds the light on the problem of economic and water-use efficiency in the new lands on the micro level. Marginal analysis is used through the estimation of crop production functions under different irrigation systems. The objective is to assess the role of irrigation water for some chosen crops under each system, in addition to testing the economic efficiency of the farmers residing in the new lands. More specifically, a quantification of the impact of irrigation water on the level of agricultural output for some crops grown in the study area is made.

Data:

A two-way stratified random sample of 109 farmers is interviewed during the summer and fall of 1996. The two stratas are the farmer's acquisition and the area in which the farmer is located. Four areas in the new lands are covered: South Tahrir, El-

Bostan, Wadi-El-Natroun, and El-Sadat. All of which are located in El-Beheira governorate. First, secondary data from the above four-areas' development directories and/or agricultural cooperatives are gathered; then a quota stratified random sample is withdrawn to represent farmers who reside in the above four areas. After the verification of these secondary data, 109 farmers are chosen randomly. 39, 20, 20, and 30 farmers represented the areas of: South Tahrir, El-Sadat, Wadi - El- Natroun, and El-Bostan, respectively.

The Production-Function Approach:

Knowledge of water response functions constitutes an important set of information needed in either private or public decisions on optimal water use. Unfortunately, however, yield response functions for water have seldom been known before large or small irrigation practices have been initiated from either surface or groundwater. Decision rules for optimal water use depend upon: (a) the knowledge of the water production function relative to various soils, environmental variables, and management variables with which it can be used, and (b) the stochastic, i.e., uncertain, nature of the water supply (Hexem and Heady, 1978). In this study, soil types and environmental variables are found to be of no significant importance due to their relative homogeneity in the study area; while the stochastic nature of water supply is not considered due to unavailable accurate data on Egyptian water resources, combined with the need to implement complicated mathematical tools to analyze and to interpret the results in this case.

The production function approach utilized in this paper represents a schedule or mathematical formulation expressing the relationships between inputs and outputs. It also indicates the maximum amount of product obtainable from a specified quantity of inputs given the existing technology governing the input-output relationships. By definition and according to economic theory, a production function embodies technical efficiency. This requires that a specified set of inputs cannot be recombined to produce a larger output or that a specific level of output cannot be produced with fewer inputs. The input-output relationships are assumed to be known with certainty, i.e., the farmer knows the eventual outcome of the production process at the beginning of the production period. Since these relationships are neither fully known nor controllable, a distribution of yields would be associated with each input-use level. This range of expected yields depends on the estimated variability of the predicted yield corresponding to the specified input use-level. Finally, inputs included in a production function are assumed to be homogeneous and prices of inputs and outputs are presumably known with certainty (Doll and Orazem, 1978; and Paul, 1982).

A single-variable production function is of little practical significance. Few, if any, actual production relationships involve a single input. A more meaningful relationship is expressed symbolically as follows:

$$Y = f(X1, X2, X3 \ldots\ldots Xn) \quad \ldots\ldots\ldots\ldots (1)$$

Where Y denotes output (or Total Physical Product TPP), X1 denotes the variable input (water in our case), X2 to Xn stand for the levels of other variable inputs, and f is the mathematical form of the input-output relationship that transforms inputs into output. Furthermore, there is a duality between production and cost functions, i.e., cost functions and production functions are by nature inversely related to each other. Knowledge of one implies knowledge of the other (when input prices are known).

The statistical estimation of the production functions in this paper utilized the technique of multiple regression analysis through the implementation of the ordinary least squares (OLS) procedure. In addition, other statistical tests such as: the F-ratio, P-values, and the student's t-test are all utilized to test for the significance of: the estimated functions, the estimated regression coefficients, and the null hypothesis regarding price efficiency, respectively.

Economic Efficiency:

This concept refers to the combinations of inputs that maximize individual or social objectives. It is defined in terms of two conditions: necessary and sufficient. The first is met in the production process when: (a) there is no possibility of producing the same amount of product Y with fewer inputs, and (b) there is no possibility of producing more product Y with the same amount of inputs. This necessary condition for economic efficiency is met when estimating a production function (given that the previously-mentioned assumptions are satisfied) in the second stage of production, i.e., when the elasticity of production (Ep) is equal to or greater than zero and equal to or less than one (Stigler, 1976).

The second, i.e., the sufficient condition of economic efficiency, varies with the objectives of the individual farmer. It is called the choice indicator. An individual farmer whose objective is to increase yield per feddan will be different from that of an individual whose objective is maximization of profits per feddan. It is assumed in this paper, like most of the economic literature under perfect knowledge, that the individual's farmer main objective is to maximize profits. This implies that the sufficient condition for economic efficiency will turn out to be what is known as the price or allocative efficiency. This efficiency is defined as profit maximization through equating the value of marginal product of the input VMP(X) (water in this case) to its unit price. Where VMP(X) is the outcome of multiplying the MPP of water which is derived from the estimated production function by the unit price of output (the farmgate price). Because irrigation water is not priced in Egypt, a method had to be deduced in this paper to calculate the imputed cost of water, which is a measure of its corresponding opportunity cost. In other words, the cost the farmer would bear should water was not delivered to him free of charge. In this paper, the imputed cost of water is the cost of constructing a well taking into consideration the type of irrigation system utilized.

Input and output measurements:

Eight per-feddan production functions of the Cobb-Douglas (double-logarithmic type) are estimated separated by the type of crop grown and method of irrigation utilized. They are: peanuts (sprinkler) PNT1, peanuts (flooding) PNT2, wheat (sprinkler) WHT1, wheat (flooding) WHT2, winter crops (sprinkler) WC1, winter crops (flooding) WC2, summer crops (sprinkler) SC1, and vegetables (drip) VEG3. Two equally-good functions are found to represent VEG3. The numbers 1, 2, and 3 attached to the above estimated functions stand for the three irrigation systems: sprinkler, flooding, and drip, respectively. Winter crops include: wheat, onions, peas, and clover. Summer crops include: peanuts, maize (corn), darawa, kidney-beans for forage, sorghum, and sesame. Vegetables include: watermelons, watermelons for seeds, green beans, potatoes, egg plant, squash, strawberries, tomatoes, cucumbers, bell peppers, green beans, and melons (cantaloupe). This almost includes all of the major crops grown in the study area but citrus. Although data for citrus is collected and analyzed, no functions could be estimated due to the problem of having different maturity dates for citrus trees. In other words, farmers who grow citrus trees for a long period of time are characterized by obtaining great output with very few inputs; while some other farmers who just started cultivating citrus trees are characterized by employing lots of inputs and having a slim or no output. When a trial was made to group the trees of the same age together in one function, the problem of having few degrees of freedom is raised. This eventually prevented a correct statistical estimation of production functions for citrus utilizing the sprinkler or the drip systems (no individual farmer in the study area utilizes flooding scheme for citrus trees).

Functions such as winter crops (drip), summer crops (flooding or drip), vegetables (sprinkler or flooding), peanuts (drip), and wheat (drip) could not be estimated due either to the nonexistence of enough degrees of freedom or the fact that no individual farmer utilizes a certain irrigation system for a particular crop.

The dependent variables in the estimated functions are either the quantity of output measured in physical units, i.e., kilograms/feddan, or monetary unit, i.e., value of output in L.E./feddan. The first is employed for the functions which portray one output, i.e., wheat (sprinkler and flooding) and peanuts (sprinkler and flooding). For the functions where the dependent variable is a collection of products, i.e., winter crops (sprinkler and flooding), summer crops (sprinkler), and vegetables (drip), the dependent variable is considered to be the value of output per feddan for a more meaningful interpretation of the results.

The explanatory (independent) variables are: education measured as a dummy variable 1, 2, and 3 which stand for elementary, intermediate, and high education, respectively; seeds in kilograms; organic fertilizers in cubic meters, nitrate fertilizer, phosphate fertilizer, and potassium fertilizer, all measured by the quantity of active ingredient; machinery in monetary units, labor in man/days, and water in cubic meters.

For surficial irrigation systems (flooding), the amount of water applied per feddan is measured through estimating the amount of water discharged from the pump. For the South Tahrir area (old new lands), the discharge from the gate of the canal which is used for flooding is measured at 80 m3/hr. For the new new lands (El-Bostan, El-Sadat, and Wadi-El-Natroun), the discharge from the gate of the canal is measured at 40 m3/hr. (note that the practice of flood irrigation in the new new lands is officially rendered an illegal activity). For pressurized irrigation systems, i.e., sprinkler and drip, the quantity of water per feddan is calculated through the estimation of the discharged water from the sprinkler and the emitter, respectively.

RESULTS AND DISCUSSION

Production Function Estimates:

Table (1) presents a summary of the production function estimates. The F-ratios of all of the estimated functions (regressions) are found to be statistically significant. All of the estimated coefficients are statistically significant (at different significance levels as shown by the P-values in parentheses). The adjusted R2 and the number of observations N are shown at the extreme right of the table. The first indicates the contribution of the explanatory variables in the estimated function in explaining the variation in the level of the dependent variable (physical output for the first four functions and the value of output for the next four functions) adjusted for the degrees of freedom. For instance, an adjusted R-square of 0.55 for the function PNT1 implies that the explanatory variables: water, nitrogen fertilizer, and labor account for 55% of the variation in output. The second, N, shows the number of observations used for the function in question. The table also shows that VEG3 has two equally-good functions which represent it.

Because all of the estimated functions are of the Cobb-Douglas type (the best fit obtained), the estimated regression coefficients shown in table (1) are the elasticity of production for the corresponding inputs. For instance, for peanuts (sprinkler) PNT1, a water coefficient of 0.231 means that an increase in the level of water by 100% results in increasing the level of output by 23.1%, and so forth for the rest of the estimated coefficients. On the other hand, the table shows that most of the signs of the estimated coefficients are positive and match with economic logic (except for four variables scattered in PNT2, WHT2, and WC1).

Table (1) Summary of Production Function Estimates

Function	Explanatory Variables (P-Values)											
	Edu.	Water	Seeds	Orgf.	N.	P.	K.	Mach.	Labor	F-ratio	Adj.R2	N
PNT1		0.231 (0.01)			0.244 (0.004)				0.383 (0.001)	19.75 (0.000)	0.55	47
PNT2		1.227 (0.002)				-0.296 (0.09)	-0.09 (0.02)		1.421 (0.001)	18.02 (0.000)	0.84	14
WHT1		0.901 (0.000)	0.304 (0.06)		0.145 (0.07)	0.054 (0.07)				14.51 (0.000)	0.65	30
WHT2	-0.347 (0.02)	0.491 (0.02)				0.097 (0.01)			0.269 (0.002)	8.41 (0.003)	0.68	15
SC1		0.447 (0.03)			0.232 (0.04)	0.103 (0.06)			0.366 (0.004)	7.69 (0.000)	0.42	47
WC1		1.330 (0.000)			0.164 (0.003)	0.088 (0.08)		-0.144 (0.03)	0.195 (0.002)	15.46 (0.000)	0.60	50
WC2		0.923 (0.03)			0.508 (0.08)				0.271 (0.03)	10.07 (0.001)	0.63	17
VEG3												
(1)		1.400 (0.04)	1.111 (0.01)	1.400 (0.001)						8.85 (0.000)	0.54	21
(2)		1.340 (0.06)		0.774 (0.04)			0.333 (0.03)			7.68 (0.001)	0.50	21

Legend: PNT, WHT, SC, WC, and VEG stand for peanuts, wheat, summer crops, winter crops, and vegetables, respectively. The numbers 1, 2, and 3 which are attached to those symbols represent the three irrigation systems under study: sprinkler, flooding, and drip, respectively. The explanatory variables: Edu., Orgf., N., P., K., and Mach. stand for education, organic fertilizer, Nitrogen, phosphate, potassium, and machinery, respectively.

Source: Calculated through multiple regression analysis.

Ranking of Inputs:

The inputs of the eight estimated production functions are ranked according to their relative importance in affecting the level (or value) of output. This is done by estimating the standardized regression coefficients (Beta). This could be obtained utilizing the previously estimated regression coefficients and the standard deviation of both the input and the output. Table (2) shows the standardized regression coefficients for the eight estimated functions. Comparisons should be made within the estimated function only (not across functions) according to the size of the Beta coefficient (including the sign). The bigger the Beta coefficient the more important the variable becomes.

Table (2) The Estimated Standardized Regression Coefficients for the Estimated Production Functions

Function	Explanatory Variables								
	Edu.	Water	Seeds	Orgf.	N.	P.	K.	Mach.	Labor
PNT1		2.29			0.03				0.01
PNT2		2.17				-0.008	-0.002		0.01
WHT1		1.00	0.01		0.02	0.002			
WHT2	-0.0006	0.76				0.004			0.005
SC1		0.57			0.02	0.003			0.009
WC1		0.81			0.01	0.002		-0.02	0.007
WC2		1.32			0.04				0.006
VEG3 (1)		0.09		0.002			0.002		
(2)		0.09	0.003	0.003					

Source: Calculated form the estimated functions and standard deviations of inputs and output.

The table shows that within the eight estimated functions, water is by far the number one input for the above indicated crops. For peanuts (sprinkler) PNT1, nitrogen and labor followed; for peanuts (flooding) PNT2, labor, phosphate, and potassium followed; for wheat (sprinkler) WHT1, seeds, nitrogen, and phosphate followed; for wheat (flooding) WHT2, labor, phosphate, and education followed; for summer crops (sprinkler) SC1, nitrogen, phosphate, and labor followed; for winter crops (sprinkler) WC1, nitrogen, phosphate, and labor followed; for winter crops (flooding) WC2, nitrogen and labor followed; and finally for vegetables (drip), organic fertilizer and potassium fertilizer were of the same relative importance (for the first function), while seeds and organic fertilizer were of the same relative importance (for the second estimated function).

Economic Efficiency of Water Use:

Technical (or production) efficiency, as defined earlier, could be explicitly deduced from the estimated production functions through the calculation of the Average Physical Product APP of water. That is to say, a measure of the number of units of output produced by one unit of water. Table (3) shows a summary of the calculated APP for the water input for the eight estimated functions. The APP for water could be calculated through either one of two ways: by solving the estimated function to obtain Y/X, where Y is the level of output per feddan (in physical or monetary units) and X represents the amount of water in cubic meters applied per feddan; or directly by dividing the average amount of Y by the average amount of X. Both ways are found to yield almost identical results (which is a proof that the estimated functions are statistically correct). For the first four estimated functions, Y was measured in physical units (kilograms), while for the last four functions Y was measured in Egyptian pounds. In the latter case, it is not proper to call it APP but rather Average Value Product (AVP). For instance, for PNT1, an APP of water of 0.476 implies that a cubic meter of water increases on the average the level of output by 0.476 kilogram. On the other hand, for a value function such as SC1, a cubic meter of water results in increasing the value of output by 0.482 pound. Comparisons of the calculated APP or AVP of water are of value only when we consider the comparisons between the production efficiency of the sprinkler and the flooding irrigation systems for the same crop, i.e., when we compare between PNT1 and PNT2 or WHT1 and WHT2 or WC1 and WC2. These comparisons reveal one simple fact: the cubic meter of irrigation water for the sprinkler system possesses on the average high production efficiency than the flooding system. Note also the high AVP of water in case of vegetables. This may indicate the high production efficiency of drip irrigation against either the flooding or the sprinkler systems, in addition to the fact that vegetables are considered cash crops and it pays to water them (a cubic meter of water on the average increases the value of output by almost three pounds). Unfortunately, statistical analysis could not be performed for other crops utilizing the drip system either because of the nonexistence of enough degrees of freedom to allow a justifiable statistical estimation of the production function, or that the drip system already is not yet installed for some crops.

Table (3) Production (Technical) Efficiency of Water for the Estimated Production Functions

Production Function	Average Physical Product of Water (APP)
Peanuts (sprinkler) PNT1	0.476
Peanuts (flooding) PNT2	0.327
Wheat (sprinkler) WHT1	0.687
Wheat (flooding) WHT2	0.634
	Average Value Product of Water (AVP)
Summer Crops (sprinkler) SC1	0.482
Winter Crops (sprinkler) WC1	0.422
Winter Crops (flooding) WC2	0.331
Vegetables (drip) VEG3	2.969

Source: Calculated from the estimated production functions.

On the other hand, the farmer is considered price efficient in the use of irrigation water if he gets a high value for the unit of output compared with the unit cost of water. In other words, if the Value of Marginal Product VMP of water is equal to the unit cost of water. Stated differently, if the ratio of the VMP of water to its own price equals one. If this ratio is greater than one then the farmer is "economically" under utilizing water. While if the ratio is less than one then the farmer is "economically" over utilizing water.

In Egypt, irrigation water is not priced. Consequently, some assumptions have to be made to calculate the imputed cost of water which in this case represents the opportunity cost of water. That is to say, the cost the farmer would have paid should water was not delivered to him free of charge.

The assumptions used in this paper to deduce the cost of one cubic meter of irrigation water in the study area are as follows: The area the well serves is 50 feddans; the discharge of the pump is 150 cubic meter/hour; the cost of digging the well, the pump, and the diesel engine is estimated at L.E. 73,000; the well is of an average depth of 100 meters; the average life of the well that is adequately maintained is 15 years; the costs of the flooding, sprinkler, and drip systems are: zero, 1500, and 3000 Egyptian pounds per feddan, respectively; average annual fixed costs are 4867, 12367, and 19867 Egyptian pounds for the flooding, sprinkler, and drip systems, respectively; cost of fuel (diesel) is estimated at 9600, 17600, and 15360 pounds per year for the flooding, sprinkler, and drip systems, respectively; oil and lubricant costs per year are estimated at 200, 366, and 320 pounds for flooding, sprinkler, and drip systems, respectively; annual cost of repairs and maintenance for the engine and pump for the three systems is estimated at 2920 pounds; annual maintenance and repair costs of the whole irrigation system are estimated at zero, 375, and 750 pounds, for flooding, sprinkler, and drip systems, respectively; total annual fixed and variable costs for the three systems are 17587, 33628, and 30217 pounds, respectively; and that the pump discharges 300,000 cubic meter per year on the basis that the number of operating hours for the system is estimated at 2000 hours (design expectation) and 1000 hours (actual operation time in the study area mainly due to water unavailability and the like).

Accordingly, two scenarios are made for the cost of one cubic meter of irrigation water in the study area. The first is based on an annual operating hours of 2000/year; the second on 1000 hours/year. Under the first scenario, the cost of the cubic meter of water for the flooding, sprinkler, and drip systems is estimated at: 0.07, 0.124, and 0.143 pounds, respectively. Under the second scenario, these same figures are multiplied by two yielding an imputed cost of the cubic meter of water in the study area of: 0.14, 0.248, and 0.286 pounds for the flooding, sprinkler, and drip irrigation systems, respectively.

Table (4) shows the ratio of the VMP of water and its imputed cost along with the corresponding t-statistic when rendered necessary (that is to say, only when the tested ratio is close to one). The null hypothesis (Ho) is that the ratio is equal to one. These VMP's for water are deduced form the estimated functions by multiplying the estimated water coefficient by the average value of output over the average value of the water input. Furthermore, output prices were based on the average of the years 1992 through 1994 (the last available published data).

operating hours are considered), three functions portrayed allocative efficiency, Wheat (sprinkler) and (flooding) WHT1 and WHT2, and summer crops (sprinkler) SC1. Of course, any alteration in the assumptions through which the imputed cost of water is calculated from will result in changing these results.

CONCLUSIONS

In sum, the above results show that: (1) The sprinkler system is more production efficient than the flooding irrigation system in terms of the amount (or value) of output obtained from the unit of irrigation water. (2) the drip system possesses the highest production efficiency in terms of water use. (3) Water is by far the most important input in desert agriculture in the new lands in the study area. The

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water coefficient is always positive and statistically significant across all estimated production functions. (4) Under the first scenario (design expectation of pump-operating hours of 2000 hours/year), the cubic meter of irrigation water in the study area is priced at 0.070, 0.124, and 0.143 pounds for the flooding, sprinkler, and drip schemes, respectively. Under the second scenario (actual operation of the pump of 1000 hours/year), which portrays the existing problem of water shortage in the study area, the three corresponding figures of the cost of the cubic meter of water for the above three irrigation schemes are 0.140, 0.248, and 0.286 pounds, respectively. (5) As far as the allocative efficiency of water is concerned, only one function (peanuts sprinkler) out of eight estimated functions is found to achieve it under the first scenario (design expectation); while three functions (wheat sprinkler, wheat flooding, and summer crops sprinkler) are found to achieve it under the second scenario (actual operation). (6) Finally, it is concluded that, given the above figures for the imputed cost of water and that irrigation water is not priced in Egypt, the majority of the estimated functions (seven under the first scenario and four under the second one) display that farmers in the study area are "economically" under-utilizing irrigation water (because the VMP of water is greater than its imputed cost). This seemingly striking result could be due to the fact that farmers in the new lands face problems of water shortages which eventually affect their level of water use. In other words, the quantities of water they apply per feddan depend upon "availability" more than "choice." It is recommended that more investigations are further needed in this regard since farmers face problems of water shortages which alter their problem from a choice problem to an availability one. This is a rather important aspect in economic analysis, since the economic problem is a problem of choice.

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IRRIGATION SYSTEMS EVALUATION IN DERSERT FARMING *

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Introduction

Water, more than land, is the major constraint to agricultural expansion in the deserts of Egypt. The River Nile is the most important source. It supplies Egypt with almost all of its water requirements. Egypt's current share of the Nile water is 55.5 billion cubic meter per year. The total net effective rainfall is insignificant; and in the context of the Nile basin, ground-water is not an additional resource since it is recharged from the Nile water. With limited quantities of water, the agriculture sector will have less water available to it than at present. Therefore, it is imperative to use and manage available water resources with maximum efficiency at present and in the future. This is particularly true in the new desert areas which are characterized by coarse textured soils and where water is often overused and miss-used.

Sustainable agriculture requires not only competitive yields but also competitive production costs and conservation of limited resources. Thus, constraints to production include not only conditions which decrease production, but also those which increase costs or deplete resources. Water is a limited resource in irrigated agriculture. The systems, energy, and labor required for irrigation are substantial production costs.

The possible continued degradation of the natural resource base, i.e., the land, water, and environment, under intensive crop production systems in which at least two irrigated crops are grown in a year is the main concern with regard to irrigation systems' sustainability. In many areas, large quantities of water is lost through the irrigated areas. Low irrigation efficiency or the non-uniform application of water in many irrigation systems often causes deep percolation in excessive quantities. Much of this water reaches and raises the water table. This process disturbs the natural hydrological balance in the area. When the water table reaches within about 2 m from the soil surface, the upward capillary movement of the groundwater, which often contains soluble salts, begins to add salts to the crop root zone, creating potential salinity problems. Continuous rise of the water table creates waterlogging and lowers the productivity of the land.

The objectives of evaluating the irrigation systems in desert farming are: (1) to determine the efficiencies of the systems as they are being used; (2) to determine how effectively the systems can be operated and whether they can be improved; (3) to obtain information that will assist in designing other systems and (4) to obtain information to enable comparing various methods, systems, and operating procedures.

Methodology

Evaluation of the existing irrigation systems was carried out in 101 desert farms representing four areas namely; South Tahrir, El-Bustan, Sadat and Wadi El-Natron. These areas vary in the main source of irrigation water (surface and groundwater), dominant modern irrigation systems (sprinkler and drip), and the type of settlers (small holders old graduates, new graduates, and investors). The evaluation of sprinkler irrigation systems included 21 fixed systems, 22 handmove systems and 9 side-roll systems in addition to 49 drip irrigation systems.

Irrigation uniformity for sprinkler irrigation systems are evaluated by measuring the application depths with catch cans. Trickle systems measure the emitter discharge for evaluating irrigation uniformity. Field evaluation tests were conducted in accord with: ASAE Standard S 330.1 (ASAE, 1990), Merriam et al. (1983), and Merriam and Keller (1978).

A common way to evaluate sprinkler uniformity is the Christiansen's Uniformity Coefficient (CU), a statistical representation of the catch pattern, when expressed as a percentage, it is calculated by:

$$CU = \left(1 - \frac{\text{Average deviation from mean depth}}{\text{Mean depth caught}}\right) \times 100$$

To achieve high values of uniformity, close sprinkler spacing are usually required. In general, the closer the sprinkler spacing, the more expensive the system costs. Griffin (1978) reported that most agricultural sprinkler applications require a uniformity coefficient of at least 80 percent for market acceptance. Low uniformity coefficient values often indicate an incorrect combination of sprinkler size, operating pressure, and spacing. The pattern of drops falling from sprinklers was determined by measuring the depths of water caught in small containers. The above definition requires that each catch can represent the depth applied to equal areas. The sprinkler flow rate was obtained by filling a known volume container in a measured time. A loose fitting section of hose was slipped over the nozzle to deflect the stream into the container. The sprinkler pressure was measured using a pressure gauge with a pitot tip, which was placed directly in line with the center of the jet flow.

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Table 1

Table 1. Frequency of the distribution uniformity (DU) for sprinkler systems.

DU %	Hand-move		Side-roll		Fixed		Total	
	#	%	#	%	#	%	#	%
< 50	9	40.9	1	11.1	7	33.3	17	32.7
50 - 60	5	22.7	4	44.4	7	33.3	16	30.8
60 - 70	4	18.2	2	22.2	4	19.1	10	19.2
70 - 80	3	13.6	2	22.2	3	14.3	8	15.4
80 - 90	1	4.5	0	0	0	0	1	1.9
Total	22	100	9	100	21	100	52	100

Distribution uniformity (DU) indicates the uniformity of infiltration throughout the field and expressed as follows:

$$DU = \left(\frac{\text{Average low quarter depth caught}}{\text{Mean depth caught}}\right) \times 100$$

The distribution uniformity is often applied to sprinkler and trickle irrigation systems. The average low quarter depth of water infiltrated is the lowest one-quarter of the measured values where each value represents an equal area. For sprinkler and trickle irrigation, the depth infiltrated is presumed equal to the depth applied or caught on the surface if there is no runoff. The DU is useful indicator of the magnitude of distribution problems. A low DU value indicates that losses due to deep percolation are excessive if adequate irrigation is applied to all areas. Although the concept of a low DU is relative, value less than 67 percent are generally considered as unacceptable.

Potential application efficiency of low-quarter (PELQ) is the efficiency that is obtainable when the average low-quarter (LQ) depth of irrigation water infiltrated just equals the desired management allowed deficiency (MAD) and is expressed as:

$$PELQ = \left(\frac{\text{Average low- quarter depth=MAD}}{\text{Average depth of water applied}}\right) \times 100$$

The average depth applied was obtained by dividing the sprinkler flow rate over the area served by single sprinkler (sprinkler spacing). Low PELQ values indicate design problems. The water that goes to excessive deep percolation, surface runoff, wind drift, and spray evaporation would tend to decrease the irrigation application efficiency.

The PELQ is always a little lower than the DU of a sprinkler irrigation system because the average water applied (which is the denominator for PELQ) is larger than the average water caught (which is the denominator for DU). The numerator for both PELQ and DU is the average low quarter depth of catch. The difference between the average water applied and the water caught or received is an approximation of losses due to evaporation and wind drift plus loss of water due to some of the area's being ungauged and some evaporation from the gauge cans.

The emission uniformity of drip systems can be determined in the field by the following equation:

$$EU = \frac{\text{Minimum rate of discharge per plant}}{\text{Average rate of discharge per palnt}}$$

Drip irrigation has significant advantages over other techniques in minimizing or preventing water loss because leakage from the delivery system is negligible. Evaporation is minor as water is not discharged in the air, as with sprinkler irrigation, or left on the soil surface as with surface irrigation methods. Only a small fraction of the soil surface is wet. Therefore, the only considerable water loss in drip irrigation is deep percolation. With drip irrigation it is always very difficult to determine the soil moisture deficit in the field because of the small soil moisture variations which occur in the wetted soil before and after irrigation. Therefore reasonable deep percolation will be taken as 10 percent of the amount of water applied. The application efficiency (AE) is therefore: AE = 0.9 EU.

The emission uniformity (distribution uniformity) of new drip irrigation installations may be close to 90 percent, but it usually decline appreciably with continued use. A more typical value of about 80 percent should be considered. Only the

Figure 1

Frequency distribution of uniformity coefficient for hand-move, side-roll and fixed sprinkler systems.

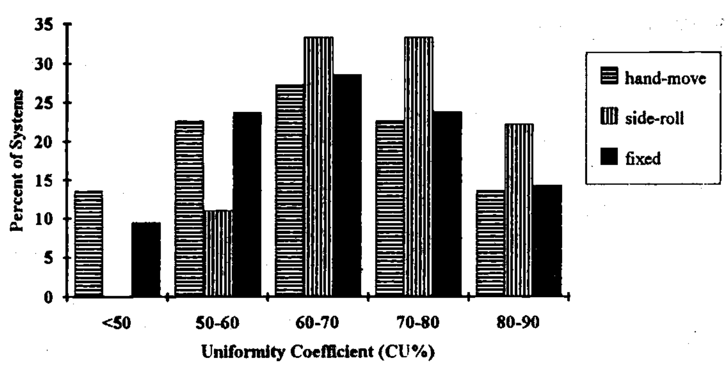


Table 2

Table 2. Frequency of distribution of the potential application efficiency of low quarter (PELQ) for sprinkler systems.

PELQ %	Hand-move		Side-roll		Fixed		Total	
	#	%	#	%	#	%	#	%
< 50	8	38.1	3	42.9	9	42.9	20	40.8
50 - 60	7	33.3	2	28.6	5	23.8	14	28.6
60 - 70	1	4.8	2	28.6	6	28.6	9	18.4
70 - 80	4	19	0	0	1	4.8	5	10.2
80 - 90	1	4.8	0	0	0	0	1	2
Total	21	100	7	100	21	100	49	100

EU can be measured by evaluations so the AE (PELQ) must be estimated. Since the SMD cannot be measured, but is estimated.

Results and Discussion

The data obtained from the field evaluations of hand-move, side-roll, and fixed sprinkler systems for the area under study were analyzed and performance parameters were calculated. Figure 1, the frequency distribution of the uniformity coefficient for the sprinkler systems (hand-move, side-roll, and fixed), shows that 15.4 percent of the sprinkler systems were in the acceptable limits of CU (about 80 percent CU) and 30.7 percent of the systems showed very poor CU (below 60 percent CU). The system with the highest CU's was the side-roll, in which 22.2 percent of the systems had CU's greater than or equal to 80 percent. Lower uniformity coefficients were found for the hand-move system, in which 36.3 percent of the systems had CU's less than 60 percent. The maximum frequency of occurrence for the three systems was between 60 and 70 percent.

As shown in Figure 2, the hand-move systems in south Tahrir had the lowest uniformity coefficients, in which 22.2 percent of the systems had CU's less than 50 percent, comparing to zero percent of the systems in Bostan.

Hart and Reynolds, 1965 gave more useful meaning to the concept of CU. For example, if a sprinkler system has a CU of 85%, this implies that for each unit of the average application of water received by the crop, 80% of the area would receive 85% of the average application or more, and 20% of the area would receive less than 85%. To apply a net application depth of 1.0 unit of water to at least 80% of the area with a system having a CU of 85%, the average net application (after allowing for wind drift and evaporation losses) must be: 1.0/0.85 = 1.18 units of water. With a CU of only 70 %, an average net application of 1.43 would be required to apply a net depth of 1.0 or more units of water to 80% of the irrigated area. It can be seen that the lower the CU value, the greater the deep percolation losses.

Table 1, indicates that 36.5 percent of the sprinkler systems had DU's equal to or greater than 60%, while 32.7% of the systems had DU's less than 50%. This means non-uniform water application and excessive quantities of deep percolation. Table 2, the frequency distribution of the PELQ for sprinkler systems, shows that only 30.6 percent of the systems had PELQ's equal to or greater than 60 percent, while 40.8 percent of the systems had PELQ's less than 50 percent. As presented in Table 2, the actual average application efficiency of the sprinkler systems ranging between 50 and 60 percent. This low application efficiency causes excessive quantities of water losses. The PELQ is lower than the DU by the amount of the percent of evaporation and wind drift losses, which lies in the range of 10 percent. The application efficiency of low quarter has a direct effect on the amount of water losses. For example, if a PELQ has been improved from 50% to 70% there would be a water saving of 28.6% calculated as follows:

$$\text{Percent of water saving} = \left(1 - \frac{PELQ1}{PELQ2}\right) \times 100 = \left(1 - \frac{50}{70}\right) \times 100 = 28.6\%$$

Major factors responsible for low performance of sprinkler systems included: low operating pressure, leakage, wide sprinkler spacing in related to actual wetted diameter, short riser pipe, non-perpendicular

Figure 2

Frequency distribution of uniformity coefficient (CU%) for hand-move system at Bostan and South-Tahrir areas.

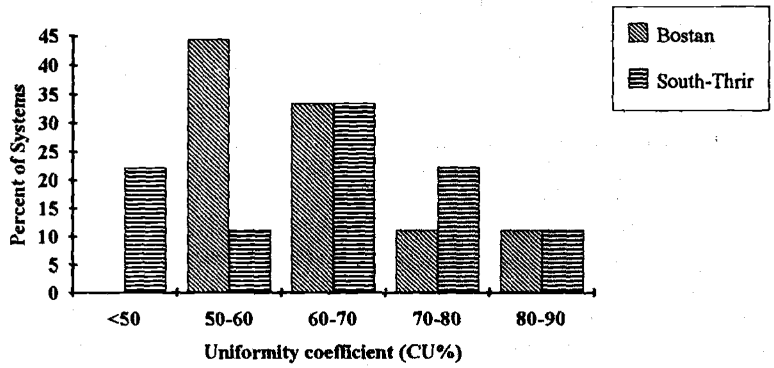


Figure 3

Frequency distribution of emission uniformity for drip irrigation systems.

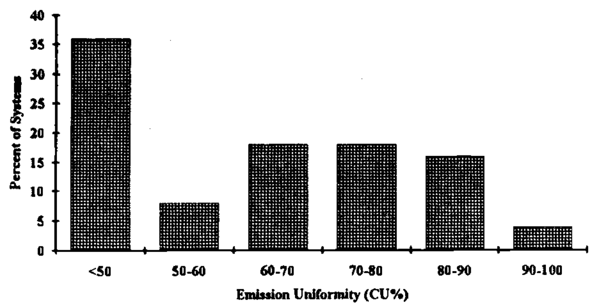
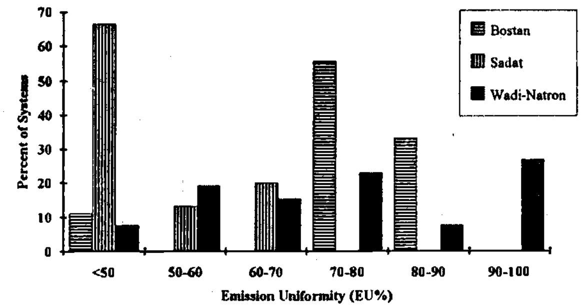


Figure 4

Frequency distribution of emission uniformity for drip systems at different areas



riser orientation, riser vibration (not rigidly supported), mixed sprinklers, worn nozzles, and non-uniform rotation rate of sprinklers. The poor water distribution may be improved by using the correct sprinkler nozzle pressure as recommended by the manufacturer and limiting the sprinkler spacing to 50 percent of the sprinkler wetted diameter to match the prevailing 10 km/hour wind speed.

Figure 3, the frequency distribution of the emission uniformity for drip irrigation systems, shows that 20 percent of the systems had EU's equal to or greater than 80 percent. Forty-four percent had EU's equal to or less than 60%, while 36 percent of the systems were between 60 and 80 percent. Thirty-six of the drip systems, which was the maximum frequency of occurrence, had EU's less than 50 percent. It can be said that 20 percent of the drip systems were in the acceptable limits of EU (about 80 percent EU) and 44 percent of the systems showed very poor EU (below 60 percent EU).

As shown in Fig. 4, drip irrigation systems in Wadi-Natron had the highest EU's (>90%), while in Sadat had the lowest EU's (<50%). Sixty-seven percent of the drip systems in Sadat area, which was the maximum frequency of occurrence, had EU's less than 50 percent. It was also observed that 33.3%, 26.9%, and none of the drip systems in Bostan, Wadi-Natron, and Sadat ,respectively, were in the acceptable limits of EU (about 80 percent EU).

Major factors responsible for low emission uniformity included: clogging of emitters, leakage, low operating pressure, mixed and broken emitters, inadequate filtration, insufficient control valves, and lengthy laterals. The study revealed that poor EU was not only due to improper design but also due to inadequate system maintenance with respect to leakage, clogging, insufficient filter capacity and system cleaning. Prevention rather than reclamation, has been the best solution to reducing or eliminating clogging. Preventive maintenance includes water filtration, field inspection, pipeline flushing, and chemical water treatment.

Summary and Conclusion

Results showed that most of the sprinkler and drip irrigation systems are performing poorly. However, the analysis also showed that uniformity coefficients greater than or equal to 80% occurred for 15.4% of the sprinkler systems. Emission uniformities equal to or greater than 80% occurred for 20% of the drip systems. This suggests that high uniformity coefficients and high emission uniformities are possible for properly designed and managed sprinkler and drip systems. Major factors responsible for low performance of sprinkler systems included: low operating pressure, leakage, wide sprinkler spacing in related to actual wetted diameter, non-perpendicular riser orientation, riser vibration, and mixed sprinklers. The poor water distribution may be improved by using the correct sprinkler nozzle pressure and limiting the sprinkler spacing to 50 percent of the sprinkler wetted diameter.

Major factors responsible for low emission uniformity of drip systems included: clogging of emitters, leakage, low operating pressure, mixed and broken emitters, and inadequate filtration. The study revealed that poor EU was not only due to improper design but also due to inadequate system maintenance. Prevention rather than reclamation, has been the best solution to reducing or eliminating clogging. Preventive maintenance includes water filtration, field inspection, pipeline flushing, and chemical water treatment.

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ATTITUDES OF DESERT LAND HOLDERS TOWARDS WATER USE AND IRRIGATION PRACTICES*

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In oduction

Investigation of the social aspects of irrigation became an important aspe to understand the human facto_ related to the efficiency of irrigation. This situation is rather more in ortant where farming is done by ne settlers in desert lands. Experience with farming in general and irrigation in particular of such settl s is generally recent. Their source o nowledge and experience is still not fully institutionalized. Experience of holders with technical asp ts of irrigation and their attitudes towards using water and related irrigation systems are some of the soc l aspects to be clarified in such s ations. Facts about these aspects could be very informative in the interpretation of the relationships bet een these social factors and p esent situation of efficiency of irrigation of desert lands. Meanwhile, ch findings could be used in the ojection of the potential changes in irrigation efficiency and assessing the applicability of certain irri- ition practices and related train- ig, extension and maintenance programs in future, given the continu- ty of present conditions.

One of these social aspects is the holders' attitudes towards water use and the irrigation systems and prac- ces. Differences in the background f settlers, their economic status as measured by their farm holding size and the irrigation system and prac- ices they adopt and use would be very helpful in the interpretation of holders attitudes.

Methodology

A sample survey was undertaken on a sample selected from among all the farm holders in the four regions of the newly reclaimed lands; South Tahrir, Al-Sadat City agricultural zone, Albostan and Wadi Alnatron. Based on the secondary data collected about the number of land holders and their holding size in each of the above mentioned regions, a quota stratified random sample was selected. About 120 holders were interviewed during the period of field data collection. Due to the uncooperative attitudes of some interviewees and the false or ambiguous responses of some others, only 112 interviews were completed. Yet, after the verification of data only 109 questionnaires were accepted and processed for statistical analysis.

Attitudes are considered important aspects of personality that reflect the action tendency of a person towards all various objects in his life in future situations. These objects could be persons, social or economic situations, specific agricultural practices or any other thing. Attitudes are related to all aspects of life. They show the preference patterns of behavior of specific individual or group in a very wide area of human activities. Attitudes are composed of the person's cognition, his feelings and action tendencies developed through his past experience, whether acquired by practice or transmission by some other means. They could be seen as relatively stable interrelated systems of the above mentioned three components.

Hence, an attitude scale related to the various aspects of rational use of water in irrigation and the applied irrigation practices was designed and pretested. The scale is constructed from 29 items that cover all the above mentioned three components and seven dimensions; cultural value of water, economic value of water, information aspects of available water resources, on-farm water management, applied irrigation practices, willingness to share in responsibility of rational use of water and experiences needed in the irrigation process. About 38% of the items were formulated in passive form to reflect the action tendency component of the scale. Table (1) presents the component structure of the applied attitudes scale.

The scale was designed using the Likert pattern of attitude scales. This is to locate the response to each item on a five point continuum starts with 'strongly agree' to 'strongly disagree' on the statement. Responses to each item ranked between 5 to 1 for the positive statements and vise versa for the negative statements respectively. Thus each respondent total score ranged between 29 and 145 . Accordingly five categories of attitude were identified; highly positive (123-145), positive (100-122), neutral (77-99), negative (53-76) and highly negative (less than 53).

Analysis of data took into consideration testing the relationship between the attitudes of holders towards water use and irrigation practices and three main variables; the region of residency where the farm is located, the farm holding size, and the kind of irrigation system(s) in use in the farm . Following are the results of this analysis .

Data Analysis and its Discussion

1. Attitudes of holders in the various areas of study :

* On going research project: "Desert Irrigation Efficiency (Egypt)", sponsored by the International Development Research Center (IDRC), Central File: 93-8606.

Table 1
Component Structure of the Attitudes Scale

Type of item	Dimension														Total
	Cultural		Ecouomic		-tion		On Farm . Water Manage.		Irrigation Practices		Parti-cipation		Experience in Irrigation		
	tem	No.	Item	o.	Item	No.	Item	No	Item	No.	Item	No.	Item	No.	No.
Positive	12	1	7& 17	2	6	1	13, 15, 16 & 25	4	9, 10, 11& 29	4	2,5, 20& 21	4	24 & 27	2	18
Negative	1	1	19	1	3	1	14& 26	2	8& 18	2	4	1	22, 23& 28	3	11
Total		2		3		2		6		6		5	.	5	29

The average value of attitudes and its standard deviation were calculated for each of the four subsamples of South Tahrir , Sadat , Wadi Al-Natron and Al- Bostan regions . Results are shown in table (2) below .

Figures in table 2 show that the average value of attitudes for the whole sample is 112.32 which is positive with standard deviation 11.21 . The averages of attitudes of all subsamples are positive and ranged between 106.95 in Sadat region and up to 116.77 in Bostan region . The averages in South Tahrir and Wadi Al- Natron are very near to each other with the values of 112.05 and 111.55 respectively. However, the average values of attitudes in the other two areas are highly different. They are 106.95 in Sadat and 116.77 in Bostan areas. Standard deviations for the extreme averages of Sadat (8.49) and Bostan (8.74) are so close and less than that of the other two areas of South Tahrir (11.9) and Wadi Alnatron (13.39). This shows rather stable attitudes among the farmers in both Sadat and Bostan which denotes to some real reasons for the differences between the farmers of these two areas.

Analysis of variance was applied on the above mentioned data . It revealed a significant difference among the average attitudes towards water for the four regional subsamples at 0.0219 level of significance as it is shown in the following ANOVA table (3) .

The above mentioned significant differences among the holders' attitudes towards water could be partially attributed to the distinctive characteristics of settlers more dominant in each area . All settlers in Bostan are new graduates while they are mostly small investors with variable background in Sadat and Wadi Al-Natron. Yet, South Tahrir is characterized by a wide variety of settlers; small holders, old graduates, and recently small investors. However, the situation in Bostan and South Tahrir areas, where attitudes are relatively high, is characterized by a wide application of the sprinkler irrigation. About 73.3% and 56.4% of the sub-samples in these two areas use sprinkler irrigation respectively.

2. Attitudes towards water among the various land holders' categories of farm size :

Average values of the holders' attitudes were calculated for all catego-

Table 2

Average values of farmers' attitudes towards water and irrigation practices by region of residency .

Region	Mean	Std. Dev.	Cases
S.Tahrir	112.05	11.90	39
Sadat	106.95	8.49	20
W. Natron	111.55	13.39	20
Bostan	116.77	8.74	30
Total	112.32	11.21	109

Table 3

ANOVA for the attitudes towards water in the four regions of study

Source	D.F	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Group	3	1184.60	394.87	3.35	0.0219
Within Group	105	12377.16	117.88		
Total	108	13561.76			

es of farm holding size. Means nd standard deviations of the attitudes for all categories are shown in table (4).

It is shown from the table above that all categories have positive attitudes towards water ranged between 106.5 and 115.6 on the scale. Distribution of all categories spread over a range of 9 degrees difference It is obvious that the least average s that of the less than 5 feddans category where they are mostly old settlers having low educational background. Yet, the highest average is hat of the category of five to less than ten feddans which mostly represent the new university graduates. Dispersion for all categories ranged between 4.9 and 14.6.

Analysis of variance was applied to the data related to the mean values of attitudes of the various categories of farm holding size . See ANOVA table (5).

Analysis showed that there is no significant difference among the various categories of holding size concerning their attitudes towards water.

3. Attitudes towards water among land holders according to their irrigation systems :

Average values of farmers' attitudes were calculated for all categories of farmers classified according to the irrigation systems they use . Means of the attitudes of the farmers classified into five categories ; sprinkler only, drip only, surface only, sprinkler and drip together and surface and drip together are shown in table (6).

It was found that all categories have positive attitudes towards water. Yet their means are dispersed on a relatively wide range extends from 103 to 118.1. The data showed that those who use both drip and sprinkler irrigation systems together have relatively the highest positive attitudes (118.1) among all users of all different irrigation systems. The users of sprinkler irrigation system alone come next (115.7) then the users of both drip and surface systems together (110.9). The users of drip irrigation system alone come fourth (108.3) while the users of surface irrigation have the lowest attitudes towards water (103). Application of ANOVA to the above mentioned data is presented in table (7).

Analysis of variance of the data showed a very high significant difference among the attitudes of the five categories of users of the various irrigation systems .

These results seem very logical. Those who invest high capital in establishment of two modern systems of irrigation together have high costs of using water. Thus they estimate the value of water accordingly . Yet, on the contrary, the users of surface irrigation who do not cost the water they use much, estimate the water itself accordingly

Though all categories of holders have relatively a high positive attitudes towards water the significant differences of their attitudes towards water and the irrigation practices could be attributed to the costs they pay and the knowledge background for using specific irrigation technique. Hence it seems logical to conclude that there is a positive relationship between the farmers' attitudes towards irrigation water and

Table 4

Average values of attitudes by farm holding size categories

Holding Size	Mean	Std. Dev.	No. of Cases
> 5	106.53	9.04	15
5 -	115.63	10.62	32
10 -	111.33	14.58	15
15 -	110.00	4.86	6
20 -	112.26	10.50	19
50 -	110.33	7.55	9
100 +	114.54	14.10	13
Total	112.32	11.21	109

the investments they allocate to cover the costs of water they use. Meanwhile the users of modern irrigation techniques should have more knowledge about the pros and cons of each irrigation technique and related information to decide to cost their irrigation more than the users of surface irrigation ■

Table 5

ANOVA of the average attitudes towards water for farm holding size categories

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Group	6	998.28	166.38	1.35	0.24
Within Group	102	12563.48	123.1714		
Total	108	13561.76			

Table 6

Average Values of Attitudes by Irrigation System

Irrigation system	Mean	St. Dev.	Cases
Sprink.	115.66	8.97	44
Drip	108.35	9.28	23
Surface	103.00	10.09	15
Sprink.&Drip	118.12	13.9	17
Drip & Surface	110.90	11.05	10
Total	112.32	11.21	109

Table 7

ANOVA of the attitudes towards water for users of different irrigation systems

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Group	4	2747.99	687.00	6.607	0.0001
Within Group	104	10813.77	103.90		
Total	108	13561.76			