Preliminary Evaluation of the Aquaculture Potential in Palestine

Masters Thesis
International Agricultural Development
Leonardo M. Hosh
June 1995

Abstract

The success of aquaculture systems is dependent upon the physical and chemical properties of the water resources and the site. Thus, prior to the introduction of aquaculture in Palestine, the natural resources of the areas must be determined as adequate. In this study, sites with viable water flow rate and climate were located. The physical and chemical properties of the water resources were tested to determine water dissolved oxygen, carbon dioxide, pH, total ammonia, nitrite-nitrogen, chloride, total dissolved solids, total alkalinity, total hardness, turbidity and temperature. The topography, climate, and existing agricultural activities in each of the viable sites were also examined. This information will provide the basis necessary to assess the potential of introducing aquaculture in Palestine.

Two of the West Bank regions were found suitable for warm freshwater aquaculture: the Jordan Rift and the northern parts of the Eastern Slopes. The richness in water resources, the moderate climate, and suitable landscape of these two regions set them apart from the other regions. The Mediterranean Sea on the Gaza Strip coast constitutes the sole resource for marine aquaculture. However, pollution of the marine environment in this region is severe and may threaten the survival of fish and thus the success of aquaculture projects.

Due to time and financial restrictions, on-site research produced limited data, primarily confined to water quality testing and field observation. Other data, such as climate and water discharge, were gathered from primary sources published by institutions in both Israel and Palestine. Further site-specific examination of other water quality elements, such as heavy metals, agrochemicals, and pathogens, is essential before determining the adequacy of a site for aquaculture.

Acronyms and Abbreviations

ARIJ	The Applied Research Institute of Jerusalem
'Ein	Spring
ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agriculture Organization
IFAD	International Fund for Agricultural Development
JMCC	Jerusalem Media and Communication Center
Km	Kilometer (s)
m	Meter (s)
m^3	Cubic meter (s)
MCM	Million cubic meters
mg	Milligram
mg/l	Milligram per liter
mm	Millimeters
ND	Not detected (i.e., concentration of thesubstance is less than the sensitivity of the testing kit)
PASSIA	Palestinian Academic Society for the Study of International Affairs
PNA	Palestinian National Authority
ppm	Parts per million (mg/l)
UNEP	United Nations Environment Program
UNRWA	United Nations Relief and Work Agency
USAID	United States Agency for International Development
Wadi	Valley

INTRODUCTION

Palestine is a small country divided into two geographic areas:

The West Bank, including East Jerusalem, and the Gaza Strip.

The total land area of Palestine is approximately 6,000 square kilometers (3,750 square miles) (World Bank, 1993). The West Bank is located West of Jordan on the western bank of the Jordan River. The Gaza Strip is located on the eastern extremity of the Mediterranean Sea. It is bordered by the Mediterranean Sea in the west and the Negev Desert and Egyptian Sinai Peninsula in the south. Israel borders the Gaza Strip in the north and west, separating it from the West Bank (Figure 1).

Figure 1: Geographic location of Palestine (From JMCC, 1994 with permission)

The Mediterranean Sea is the primary local source of fishery products for Palestine and it has accommodated a thriving fishing industry over the years. However, Palestinian fishers have faced many obstacles, especially during the past fifteen years, resulting in a steady decline in fishery catch (pages 15-17). Due to low catches and the need to import, fish prices are extremely high. Few Palestinians can afford to purchase seafood in spite of the increasing need for this vital source of healthy animal protein.

Aquaculture may be a viable alternative to overcome the shortage of fish in Palestine. Although Palestinians realize the exigency of introducing such an industry, the lack of knowledge, scientific research and expertise, and the absence of governmental support and infrastructure, have hindered any serious achievements in this field.

Different types of aquaculture need to be explored and evaluated. The success of aquaculture, however, depends upon the quantity and physical and chemical properties of the water resources, and of the site. Thus, prior to the introduction of aquaculture in Palestine, the natural resources of the areas must be evaluated. As Palestine is characterized by a high variation in climate and topography, these variables are also critical when examining the area's adequacy for aquaculture.

This study is anticipated to explore the adequacy of Palestine's natural resources to support aquaculture ventures, mainly by identifying viable sites, assessing water resources, and examining the geography and climate in each of the viable sites. For this purpose, field examination of the several viable sites and on-site water testing were conducted in Palestine. Data and information, although scarce, were obtained from local Palestinian research institutions, agricultural directorates, the Israeli meteorological and hydrological services, private voluntary organizations (PVO's), and non-governmental organizations (NGO's) operating in Palestine.

Economic feasibility and marketing aspects of aquaculture are not included in this research. These aspects require specialized study of the socioeconomic and market status in Palestine, which exceeds the limits and purpose of this study.

CHAPTER ONE

Criteria For The Evaluation Of Aquaculture Potentials

Types Of Aquaculture Systems

There are two major types of aquaculture production systems which greatly vary in their design, requirement of water resources, and sensitivity to the surrounding environment. First, in *open aquaculture systems* water enters the system from one place, exits from another place, and then is discarded (Lee & Newman, 1992). Open systems such as earthen ponds, tanks, and raceways, require a large and continuous supply of water. In the case of a series of containers, water from one container is carried to the next and reused without filtration or treatment, then discarded. Production in open systems is highly dependent on the physical and chemical properties of the available water resources and on climatic conditions.

The second type of aquaculture production system is the *closed system* where little or no new water is added to the system (Lee & Newman, 1992). These systems recirculate water by passing it through filters and aerators before pumping it back to the fish holding containers. In recirculating, water is reconditioned and its quality is restored. Closed systems may require less than 10% of the water required by open systems and are nearly independent of the quality of the water source and the surrounding environment (Losodo, et al., 1992). The main consideration for the success of these systems is their economic feasibility (cost of production and market prices). However, as economic aspects of aquaculture are excluded from the core of this study, little emphasize is paid to closed systems.

Open aquaculture systems may vary between intensive, semi-intensive or extensive utilization of the water body. The selection of the intensity of the aquaculture systems depends on numerous variables, including availability of water resources, fish culture technique, water quality and management, cost of fish feed, the selected fish species, and weather conditions.

Site Location

Careful selection and examination of sites for aquaculture projects are crucial, and in fact determine the success or failure of the intended projects. Sites may vary in their suitability for various types of aquaculture. However, consideration of the following elements is essential in all cases (Blakely & Hrusa, 1989; Helfrich & Pardue, 1994):

- Availability of good-quality water with adequate quantities for aquaculture needs.

- Land topography which enables simple and inexpensive design of the aquaculture system. Preference of land topography varies with the type of the desired aquaculture system. For example, raceway systems require land with slight sloping so that raceways can be filled and drained by gravity. Earthen ponds, on the other hand, generally require large area of relatively flat land. Sloping ponds have different water depths at various sides, and thus different environment, which makes ponds difficult to manage for aquaculture. Areas exposed to flooding should be avoided as well to prevent flushing of the fish from the containers.
- Microclimate and weather conditions. This includes weather factors such as rainfall, solar radiation, air temperature, humidity, and wind. Such factors are vital in aquacrop species selection as well as cost analysis and construction design of the aquaculture unit. Aquaculture unit design should be adapted to minimize risks of overflooding and excessive rainfall, water loss due to evaporation, erosion and wave action relative to wind direction and speed.
- Solar radiation data are also important to estimate photosynthesis activity and oxygen production by plankton in the water. Moderate exposure to sunlight is desirable for certain aquaculture systems, especially ponds, as it encourages algal growth and rate of photosynthesis, a natural source of food and dissolved oxygen for fish. Lengthy exposure to sunlight, especially in shallow aquaculture systems, may induce fish skin irritation and corrosion due to exposure to ultraviolet radiation.
- Soil type and rock formation in the area, especially if earthen ponds are under consideration. Constructing ponds in land with ample rocks or sandy or broken soil may be problematic. Such soil is usually porous, permitting water to seep through the pond walls unless lined with plastic lining which increases costs of pond construction.
- Identification of existing and planned uses of the area surrounding the site, mainly agricultural activities, industries and waste disposal, and the degree to which they would interfere with fish farming.
- Site location relative to accessible roads, fish markets, and infrastructure facilities, e.g., ports, refrigerating rooms, processing and canning factories. Such elements are of little importance in Palestine due to the country's small size which allows transportation between various sites to be achieved in less than 4 hours.
- Altitude of the site. This factor, although minor, affects the growth and reproduction abilities of a few fish species, specifically tilapia. Scientists observed that several tilapia species fail to reproduce at elevations higher than 1,220 m above sea level (Balarin & Hatton, 1979). This phenomenon may be related to water temperature or low atmospheric pressure at high altitudes. Balarin and Hatton in 1979 reported that tilapia prefer to live in coastal zones or areas near sea level.
- Collecting information regarding these elements usually requires extensive observation and on-site testing. Some information may be available at the country's meteorological and hydrological services; otherwise, cases such

as measuring fluctuation in water flow may require years of observation. In countries where such technology is available, satellite imagery, remote sensing, and aerial photography are very useful in providing information concerning dry or irrigated farming, soil type, climatic factors, wave action, and algal bloom (especially in marine areas) (UNEP, 1990).

Water Supply

The water source for aquaculture should provide both high quality water and continuous flow throughout the year. Regardless of the type of aquaculture system used, water is continuously needed to replenish losses due to evaporation or seepage, and for fish management purposes (Helfrich et at, 1994).

Water sources should be monitored carefully for several years to determine fluctuation and identify upper and lower flow limits. Based on water flow data, aquaculturalists may calculate the suitable size of the aquaculture system. While shortfalls in water flow may cause deterioration of water quality, flood and excessive water flow may flush nutrients as well as fish out of the aquaculture system.

Underground water, mainly springs, are the major source of water for aquaculture in Palestine. Although water from this source is usually of high quality and free of fish diseases, parasites, predators, and pollutants, it is generally characterized by high fluctuation in discharge. Further examination of the underground water resources in Palestine is provided in Chapter Five.

Water Quality

Water quality for aquaculture is defined as the combination of chemical, physical, and biological characteristics of water which have direct or indirect influence on fish growth and survival (Lee & Newman, 1992). Water properties may change rapidly with environmental and climatic changes. A change in one factor of water quality may also affect one or more of the other water quality factors. The following sub-sections discuss the major water quality factors affecting fish survival and growth and their interaction. These water quality factors were primarily considered in evaluating the adequacy of water resources for aquaculture.

Water Temperature

Fish are ectothermic animal; their body temperature is determined by the temperature of the surrounding water. Different fish species require different water temperatures for their survival and growth. Unsuitable water temperature may slow down feeding, metabolism, reproduction, and growth rate and may even kill the fish. As controlling water temperature in open aquaculture systems is impractical, the given water temperature of the available resource determines the suitable fish species for aquaculture. Stocking a fish farm with inappropriate species may either kill the fish or slow down their growth. Table 1 lists common aquaculture species with temperature ranges required for survival, optimum growth, and breeding.

Table 1:Temperature Requirements for Various Fish species in °C

Species	Optimal Range	Breeding Range	Upper Range	Lower Range
Brook trout, *Salvelinus*fontinalis	NA	11.7	23-25.3	NA
Rainbow trout, *Oncorhynchus mykiss*	13-21	5.5-17	24-28	NA
Yellow perch, *Perca flavescens*	19-21	6.7-12.2	21.3-29.7	0-3.7
Largemouth bass,*Micropterus salmoides*	22.8-30	11.5-29	28.9-38.9	0-11.8
Channel catfish, *Ictalurus punctatus*	21-27	15.5-29.5	30.3-35	0-6
Common carp, *Cyprinus carpio*	26.7-29.4	17-28	31-35.7	0-0.7
Java tilapia, *Tilapia mossambica*	22-30	>21.1	NA	9-12
Blue tilapia, *Tilapia aurea*	29.4	23.3	42	8.9-12.8
Source: McLarney, 1987				

Dissolved Oxygen

The dissolved oxygen concentration in water is critical for fish survival. In natural waters, dissolved oxygen concentration, expressed in mg/l, constantly changes with variation in water biological activities and chemical and physical properties. The saturation level of dissolved oxygen in water ranges from 6.5 to 10.2 depending on water temperature, salinity, and on atmospheric pressure. Dissolved oxygen level decreases with increased water temperature or salinity and increases with increased atmospheric pressure (Delince, 1992).

In ponds, most of the dissolved oxygen is produced by phytoplankton photosynthesis and depleted by plant respiration and biochemical reactions (Lee

& Newman, 1992). The rate of oxygen production by photosynthesis is controlled by sunlight (Delince, 1992).

On average, most fish species require dissolved oxygen concentration of at least 4-5 mg/l (parts per million) to sustain normal growth and survival. Some fish, such as tilapia, catfish and carp, can tolerate short exposures to dissolved oxygen levels as low as 1 mg/l (Blakely & Hrusa, 1989). However, most fish stop growing and fail to reproduce or feed at such low oxygen levels.

Water from underground sources tends to have a low dissolved oxygen concentration and elevated concentration of carbon dioxide and nitrogen gases. Aeration of underground water is sometimes essential to overcome the negative effects of this property.

pH

pH, which expresses the concentration of hydrogen ions in water, is a dimensionless figure ranging from 0 to 14. pH values below 4 and above 11 are lethal to most fish (Delince, 1992). The optimum pH is between 6.5 and 9 for most species (Helfrich et al., 1994). Continuous exposure to pH higher or lower than the optimum levels suppress fish growth and reproduction. Inappropriate pH levels stress fish, reducing their ability to balance blood ions and the efficiency of their immune system.

Water pH is inversely related to carbon dioxide (CO2) concentration in water. In daytime, during photosynthesis, phytoplankton removes CO2 from water thus causing an increase in the pH and the reverse during the night, where plants produce CO2 by respiration.

Carbon Dioxide

Carbon dioxide in water is a product of fish and plankton respiration and also a byproduct of organic matter decomposition. Adequate levels of carbon dioxide are necessary for phytoplankton photosynthesis especially where phytoplankton provide the main source of food and oxygen to the system. Safe levels of CO2 in the water range from 5 to 10 mg/l (Lee & Newman, 1992). High levels of carbon dioxide of about 60 mg/l are toxic to fish, especially when combined with a low dissolved oxygen concentration (Blakely & Hrusa, 1989).

Water from underground resources is usually characterized by elevated CO2 levels and thus requires special treatment before being rendered suitable for aquaculture.

Ammonia and Nitrite

Low levels of ammonia and nitrite in water are sufficient to inhibit growth and threaten the survival of the fish. Ammonia is a byproduct of fish metabolism and the decomposition of organic matter. It exists in water in two forms, ionized and un-ionized. The ionized ammonia (NH_4^+) is highly tolerated by fish (Lee & Newman, 1992). Minute amounts of un-ionized ammonia (NH_3), on the other hand, is extremely toxic to most fish species (Boyd, 1990). The commonly acceptable ammonia concentration in culture water is 0.1 mg/l of ammonia nitrogen (NH_3-N) (Delince, 1992).

Un-ionized ammonia concentration is directly related to pH levels in water. Higher pH levels raise NH_3-N concentration in water, increasing its level of toxicity to fish. Furthermore, NH_3-N concentration, to a less extent, increases with increased water temperature (Boyd, 1990). Un-ionized ammonia toxicity causes osmoregulation imbalance, kidney failure, and gill damage. It also causes reduction in fish growth due to loss of appetite (Moyle & Cech, 1988).

Nitrite (NO_2^-) is produced by bacterial oxidation of ionized ammonia (nitrification) or by reduction of nitrate (denitrification). Nitrification occurs in two steps. In the first step, ionized ammonia is converted to nitrite by the action of the Nitrosomonas bacteria. In the second step, Nitrobacter bacteria convert nitrite into nitrate (Boyd, 1990). Both nitrification processes are oxygen demanding where it requires 4.6 mg of oxygen to convert 1 mg of ionized ammonia into nitrate (Delince, 1992). In the case of inadequate oxygen supply, microorganisms in water use nitrate as an electron receptor instead of oxygen, thus converting it to nitrite (denitrification) (Boyd, 1990). Therefore, nitrite presence in water is usually accompanied by low levels of dissolved oxygen.

Alkalinity and Hardness

Alkalinity, expressed in mg/l as $CaCO_3$, is a measure of the capability of water to neutralize acids (Tucker, 1991). Both bicarbonate and carbonate compounds are main contributors to water alkalinity. These compounds combine with the H^+ ion in water and thus neutralize its effect on water pH. Therefore, low alkalinity water is, by definition, poorly buffered and pH may easily fluctuate with small additions of acid or base. Dissolved metals of high toxicity such as copper and zinc tend to leach out from metal pipes in the system under conditions of low alkalinity (Alabaster & Lloyd, 1982). A minimum value of 40 mg/l as $CaCO_3$ is preferred in water for aquaculture (Delince, 1992).

The carbon dioxide (CO_2) concentration in water, which is an essential element for photosynthesis, is a function of water alkalinity, as well as temperature and pH. Thus, in unfertilized water bodies, low alkalinity levels in water limit the photosynthesis reaction of phytoplankton and aquatic plants, depriving fish from a main source of food and oxygen (Boyd, 1990).

Hardness, expressed as mg/l as $CaCO_3$, is a measure of the amount of calcium and magnesium in the water. Optimal levels of water hardness are between 50 and 300 mg/l (Lee & Newman, 1992). Total hardness is generally higher in groundwater (approximately 300 mg/l) relative to surface water, while averages 6,600 mg/l in seawater (Boyd, 1990).

Water with low hardness may have a reduced buffering capacity despite the presence of high total alkalinity. Adequate water hardness is essential for hatchery production as it is required for hardening of eggs and the development of the fry's bone and tissue (Tucker, 1991).

Salinity

Salinity is a measure of dissolved salt in water and is expressed in mg/l or in parts per thousand (ppt). Salinity, though differs with location, is generally low in surface water, approximately 30 mg/l, and higher in groundwater, averaging 300 mg/l. In seawater, salinity maintains a nearly constant level of approximately 34 ppt (34,000 mg/l) (Boyd, 1990).

Generally, fish are divided into four major groups in regard to water salinity: marine, freshwater, stenohaline (tolerate a narrow range of salinities), and euryhyaline (tolerate a wide range of salinities). These four groups are defined by the ability of the fish to regulate salt content in their bodies (Moyle & Cech, 1988). Thus fish species for marine aquaculture differ from those of fresh or brackish waters.

Turbidity and Water Organisms

Turbidity is a measure of the dissolved solids, water color and suspended particulate matter in water such as clay particles, organic matter, and plankton (Boyd, 1990). The secchi disk, a 20 cm in diameter disk painted with alternating black and white quadrants, is commonly utilized to measure water turbidity by recording the maximum depth that the disk maintains visibility in water (Stirling, 1985).

Turbidity caused by plankton is generally desirable in water if maintained at a secchi depth of 30-45 cm (Boyd, 1990). It provides certain cultured species with a food source and encourages the growth of other food organisms in the water. Plankton also helps eliminate unwanted underwater weeds by obstructing sunlight (Boyd, 1990). High plankton density, on the other hand, may restrict light penetration to shallow water depths which hinders plant photosynthesis and oxygen production in the lower water layers. Plankton may also clog fish gills.

Turbidity caused by organic and clay particles is generally undesirable as it may increase water acidity and limits light penetration for photosynthesis. The aerobic decomposition of organic particulates by microorganisms in water requires oxygen. Therefore, water with high organic content is characterized by high biochemical oxygen demand (BOD). Moreover, in the absence of oxygen, anaerobic breakdown of organic particulate releases acids into the water.

Examination of water resources for water-carried pathogens and parasites is essential especially when the water source is threatened by sewage pollution. Numerous organisms such as protozoa, flukes, mollusks, fungi, viruses and coliform bacteria may affect fish. The presence of other disease-carrying water animals, such as snails and water snakes, should also be considered (Helfrich et al., 1994).

Dissolved Metals

Several metals are extremely toxic to fish. Metals such as zinc, copper, mercury, nickel, and cadmium in water may kill the fish, especially in the ion form, even in trace concentrations. The solubility of such metals is controlled mainly by water hardness, dissolved oxygen, pH, temperature and salinity (Alabaster & Lloyd, 1982). Water with elevated levels of total hardness and pH leads to the precipitation of metal ions, greatly reducing their toxicity.

Chapter Two
Research Objective And Methods

The main objective of this study is to explore the potential of Palestine's natural resources and environment to support aquaculture. The success of aquaculture depends upon the quantity and physical and chemical properties of the water resources, and of the site. Thus, prior to the introduction of aquaculture in Palestine, the natural resources of the areas must be evaluated. As Palestine is characterized by a high variation in climate and topography, these variables are also critical when examining the area's adequacy for aquaculture.

To achieve the objective of this research, information on natural resource, climate and environment was compiled and on-site testing of water quality was carried out in each of the potential sites. The results of this research provide the base needed to assess the viability of Palestine's natural resources for aquaculture.

Information And Data Collection

Information related to water resources, climate, and geography in Palestine is scarce. With the absence of a proper infrastructure, data recording is mostly done independently by individual researchers or non-profit non-governmental organizations (NGO's). Such a system of data recording makes it difficult to compile and verify. Therefore, field examination and on-site water testing were vital for the validity of this study.

Field examination and on-site visits were carried out during July and August of 1994. It included on-site observation of topography and agricultural practices in each potential location, and water testing. The limited duration of the field work did not permit recording data on climate and water resource discharge which requires longer term observation. Three sources of information, however, were particularly helpful in providing such data: the Israeli Hydrological Services, the Agricultural Directorate offices, and the Database Unit of the Applied Research Institute of Jerusalem (ARIJ).

Field Examination And On-Site Water Testing

Potential sites for aquaculture were identified according to the availability of water resources. Water samples from each site were tested for temperature, dissolved oxygen, pH, carbon dioxide, total ammonia, nitrite-nitrogen, total alkalinity, total hardness, chloride, turbidity, and total dissolved solids. A portable unit of water testing kits (LaMotte water aquaculture test kit model AQ-2), pH meter (pH Pen Plus model PHP-3), TDS meter (Oakton TDSTester Model 2), Secchi disk (Aquatic Eco-System, Inc., Apopka, Florida), and a water sampler (Forestry Suppliers, Inc., Jackson, Missouri) were used for water testing (Photo 1). Table 2 shows test type and reading scale for each test.

Photo 1: Water testing kit and instruments used for on-site water testing

Table 2: Test Type and Reading Scale of the Water Testing Kits

Test (abbreviation)	Test Type	Reading Scale	Units
Temperature (Temp.)	Simple thermometer	-10-100°C	°C
Dissolved oxygen (D.O.)	Titrimetric	0 and up	ppm
pH	Electronic reading	0-14	Dimensionless
Carbon dioxide (CO_2)	Titrimetric	0 and up	ppm
Total ammonia nitrogen (TAN)	Colorimetric	0.2-3.0	ppm
Nitrite nitrogen (NO_2^- N)	Colorimetric	0.05-0.8	ppm
Total Alkalinity (T.Alk.)	Titrimetric	0 and up	ppm as $CaCO_3$
Total Hardness (T. Hard.)	Titrimetric	0 and up	ppm as $CaCO_3$
Chloride (Cl^-)	Titrimetric	0 and up	ppm

Turbidity (Turb.)	Secchi disk	0 and up	meters
Total dissolved solids (TDS)	Conductivity meter	0-10	ppt

Conversions:

Total ammonia nitrogen:	Includes toxic (NH_3) and non-toxic (NH_4^+) ammonia. Check Appendix A for percentage of (NH_3) at various pH's, salinities, and water temperatures
Nitrite-nitrogen:	Nitrite-nitrogen x 3.3 = ppm nitrite (NO_2^-)
Chloride:	ppt salinity = ((1.805 x ppm chloride) /1000) + 0.03
Alkalinity and hardness:	1 meq/l = 50 ppm as $CaCO_3$
Source: LaMotte, 1993	

Due to time and financial restrictions, the analytical capabilities used in this research were limited to the above mentioned water quality elements. Further site-specific examination of other water quality elements, such as heavy metals, agrochemicals, and pathogens, is certainly essential before determining the adequacy of a site for aquaculture.

Chapter Three
Aquaculture Versus Fishery

An Overview Of The Palestinian Fishery Sector

Prior to 1948, Palestinians enjoyed relatively free access to the Mediterranean Sea along the length of Palestine's western border. Coastal cities such as Gaza, Haifa, Acre, and Jaffa were the main centers of fishing activities in Palestine with an annual catch that satisfied the local demand. However, in 1948, the geopolitical map of the area drastically changed and access to the sea for Palestinians became limited to the coastline of the Gaza Strip, a stretch of only 40 km in length.

The Israeli occupation of the West Bank and Gaza Strip in 1967 brought with it further limitations on the Palestinian fishing areas and practices. Palestinian fishers were not allowed to sail into areas further than 20 km away from shore. Fishing hours were restricted to less than ten hours a day. The size of Palestinian fishing boats and their motors were strictly limited (Awad, 1987). In addition, Palestinian fishers were denied access to the fishing areas adjacent to the Israeli settlements on the Gaza Strip coast.

In 1979, and after the signing of the Camp David Peace Treaty between Egypt and Israel, Egypt regained the Sinai Peninsula from Israel. Palestinian fishers, previously allowed to enter the Sinai zone, lost access to fishing areas along the Sinai coast after Camp David. The fishing areas specified for the Palestinian fishers were reduced again to a length less than 30 km along the Gaza Strip coast (Palestine Environment Protection National Authority, 1994).

These political factors, combined with environmental, economic and infrastructure barriers (Page 17) resulted in a sharp decline in the fishery catch and a deficit in fish supply. The fishery catch dropped dramatically from over 3,700 metric tons in 1970 to less than 510 metric tons in 1991 (Table 3).

Table 3: The Fishery Annual Catch in the Gaza Strip in Tons For the Years 1970 - 1991

	Fish Species								
Year	**Flounder, halibut, soles**	**Red-fish, basses, congers**	**Mullets, jacks, sauries**	**Herring, sardine, anchovy**	**Mackerel, snoek, cutlass**	**Sharks, rays, chimaera**	**Shrimp, prawns**	**Misc. marine fishes**	**Total**
1970	0	500	1500	1500	100	100	0	0	3700
1971	0	400	900	1900	100	100	0	0	3400

1972	0	1000	1000	2100	200	100	0	0	4400
1973	0	1400	900	1600	200	100	0	0	4200
1974	67	1344	720	1213	57	91	33	40	3565
1975	59	1835	631	1725	59	130	19	128	4586
1976	56	1613	640	1433	91	89	21	126	4069
1977	63	1797	711	1593	99	99	23	140	4525
1978	93	1966	500	1630	42	40	0	429	4700
1979	23	675	176	794	75	54	26	90	1913
1980	0	137	30	665	7	30	25	78	972
1981	0	125	25	814	35	47	24	69	1139
1982	0	93	47	758	143	63	11	64	1179
1983	0	69	10	576	20	58	7	58	798
1984	0	211	32	1120	120	9	2	59	1553
1985	0	56	6	205	50	25	0	74	416
1986	0	61	7	222	54	27	0	79	450
1987	0	61	7	222	54	27	0	79	450
1988	0	68	8	247	60	30	0	87	500
1989	0	68	8	247	60	30	0	87	500
1990	0	70	10	250	60	30	0	90	510
1991	0	70	10	250	60	30	0	90	510
Source: FAO AGROSTAT Database, Agrostat P.C. 2, 1992									

The Current Status Of The Fishery Sector Under The Palestinian Self-Rule

After the May 1994 Gaza-Jericho agreement between Israel and the Palestinians, Palestinians were granted semi-autonomous territory in parts of the Gaza Strip and Jericho area. Consequently, the fishing zone was expanded and several political restrictions imposed earlier on the fishery sector were lifted. The fishing zone currently extends to 20 miles in the sea covering an area of approximately 500 square miles (Palestine Environment Protection Authority, 1994) (Figure 2). However, a ban on coastal areas near the Israeli settlements as well as restrictions on fishing vessel movements and motor size are still in effect (Government of Israel, 1994).

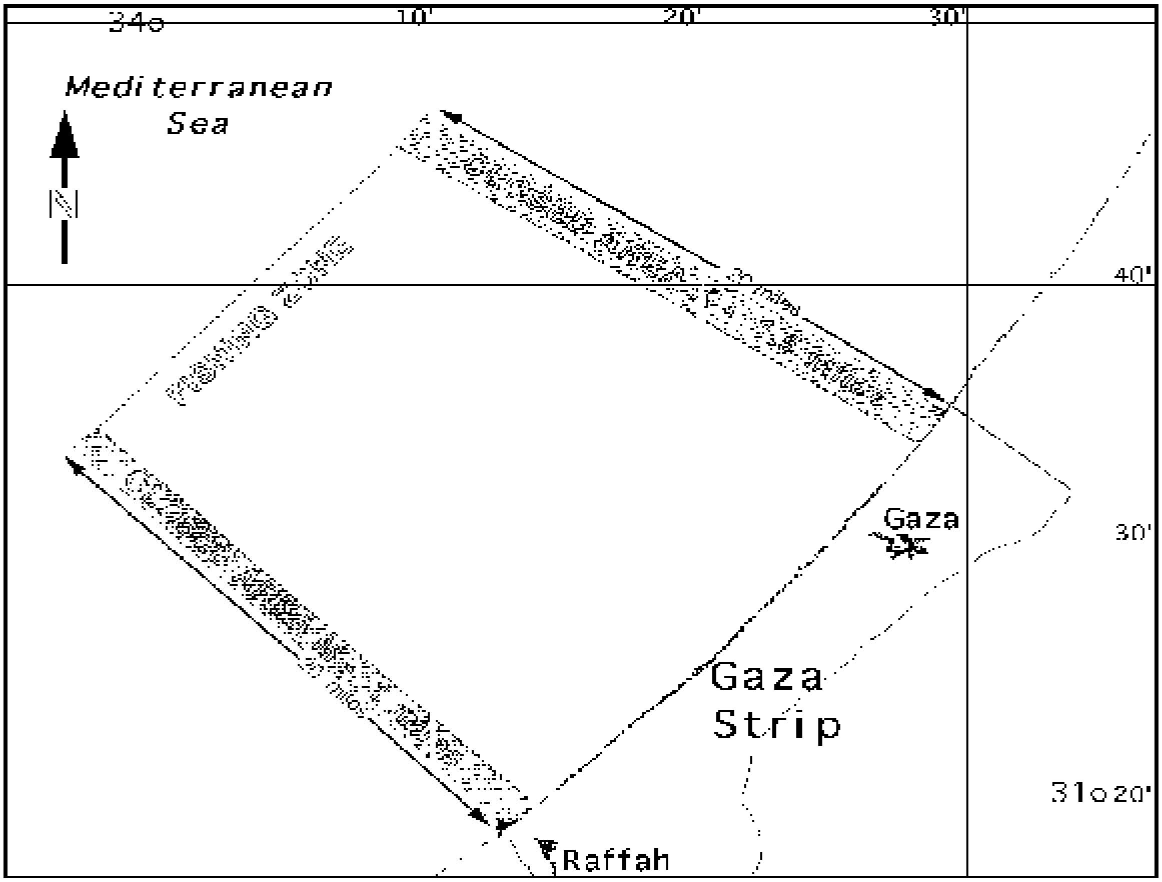


Figure 2: The Palestinian fishing zone in the Gaza Strip as specified in the Gaza-Jericho agreement of May 1994 (Adapted from Government of Israel, 1994).

The change in the political environment brought with it an increased interest in the fishery sector. Several projects to enhance the fishery sector are currently ongoing in the Gaza Strip. These projects, initiated by the newly established Palestinian National Authority (PNA) and funded by foreign organizations -- mainly IFAD, USAID, CARE-Canada, and World Bank -- include construction of new port facilities, a provision of credit and loan programs to fishermen, fishermen training programs, and the building of infrastructure for post-harvest facilities.

In spite of the above mentioned projects, the extent to which Palestinians can exploit the marine resources in the Mediterranean Sea is limited by several environmental factors, mainly:

Completion of the Aswan dam on the Nile River. The dam trapped the plankton and suspended biomass that once flowed into the Mediterranean Sea. This biomass, which was carried from Egypt to the Gaza Strip coast by the counter-clockwise current, constituted a main source of food for the marine population. Its loss has greatly reduced fish density in the area (Palestine Environment Protection Authority, 1994).

Deterioration of the coastal marine environment due to continuous discharge

of large volumes of untreated or insufficiently treated sewage and wastes into the Mediterranean Sea along the Gaza Strip coast. Figure 3 shows various locations of these sewage discharges (Commission of European Communities, 1993). Pollution, combined with over-exploitation has reduced fish stock in the area (World Bank, 1993). Pollution of the marine environment also threatens the survival of the Posidonia plant beds.

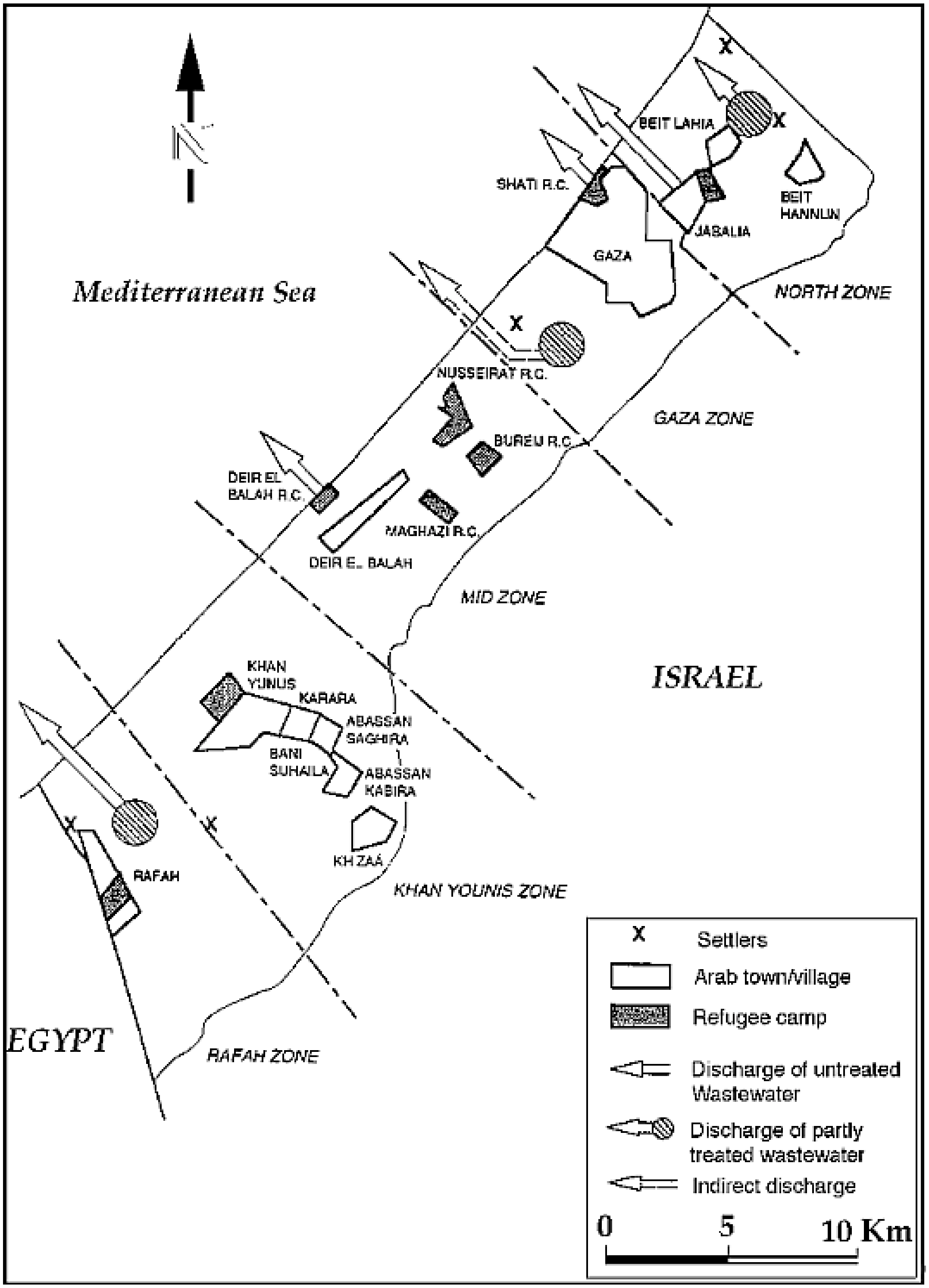


Figure 3: Sewage discharge into the Mediterranean along the Gaza Strip coastline (Adapted from Commission of European Communities, 1993)

Posidonia, a marine plant specific to the Mediterranean sea, grows in near-shore water of 35-40 m in depth. The Posidonia beds provide an oasis for marine life.

They support more than 600 diverse animal species which use the beds as refuge, habitat and breeding grounds (UNEP, no date).

- Physical structure of the Gaza Strip coastal sea floor. The Gaza coastal basin which is bounded to the south by the Nile Delta and to the north by and the Haifa coast, is an extension of the Nile River system. Its geographic location in the course of the counter-clockwise current, which characterizes the eastern parts of the Mediterranean Sea (World Bank 1993), causes siltation of enormous amounts of sand particles and suspended solids at the Gaza coast. The amount of silt deposition is estimated at 650,000 tons per year (Palestine Environment Protection Authority, 1994). The dominantly sandy and rockless sea floor of the Gaza coast does not encourage fish to inhabit it (Awad, 1987).
- After the peace agreement, substantial development in the industrial and physical infrastructure of the Gaza Strip is expected to take place. Special note should be made of the newly proposed Gaza commercial seaport project to be constructed south of the city of Gaza in the near future. The construction of the port facilities, as well as other planned industrial facilities and power plants, will introduce the transport of oil and chemicals to the area. Chances of marine pollution from oil spills and industrial wastes will indeed heighten.

These major environmental factors may soon diminish the short term increase in fishery catch brought by the recent expansion of the fishing zone and restrict further growth of the fishing industry. The existing Palestinian fishing fleet, which comprises vessels and gear types capable of exploiting all commercial fish species, already imposes a threat of over-exploitation of pelagic and demersal species (Pearson & Davis, 1994). Thus further expansion of the fishing fleet may damage the marine environment. Furthermore, to date, there has been no significant acoustical, biological or statistical surveys of the Gaza Strip marine resources (Pearson & Davis, 1994). The lack of such surveys makes it difficult to regulate or assess the environmental impact of the expansion of the fishing fleet on the marine resources.

Need For Aquaculture

In view of the current trend of industrialization in the area, the increased pollution of the Gaza Strip coastal area and degradation of the marine environment will certainly, if they have not already, deteriorate marine fish quality and threaten the safety of the consumer. In addition, the fishery catch, as of today, is not enough to satisfy the local demand for fish or much less to provide surplus for export; fish export would constitute a major source of foreign currency to such an area of extremely limited resources.

Introducing aquaculture to Palestine seems vital to sustainably overcome the shortage of fish supply. Several other reasons justify the preference of aquaculture over fishery in Palestine, mainly that aquaculture provides:

- Increased production beyond the natural sustainable fishery yield for a given water volume.
- Less fluctuation and shortfalls in catch due to seasonality.
- Better production efficiency of fish protein and enhancement of fish quality.
- Improved water quality for irrigation purposes when integrated with the existing irrigation systems and utilizes water bodies unsuitable for domestic or agricultural purposes.

Furthermore, aquaculture facilities may soon be needed to support the fishery sector in the Gaza Strip. Establishment of fish hatcheries to release fish stock into the sea is essential to compensate for fish stock losses due to over-exploitation and marine pollution of the Gaza Strip coast.

Chapter Four

An Overview Of The Water Resources In Palestine

Palestine's natural water resources are relatively limited and scarce. The existing regulations imposed by the Israeli government on water utilization and the denied access to the Jordan River, the only surface water system in Palestine, have further reduced water quantities at hand. Lack of permits to construct water reservoirs and structures to capture runoff water has also decreased the efficiency of utilizing rain water.

Water Resources In Palestine

The major portion of fresh water supply in Palestine originates from four main water aquifers: three in the West Bank and one in the Gaza Strip. Water from these aquifers reaches the surface through either wells or as natural springs. The total annual replenishable water in these aquifers is estimated at 600 million cubic meters (MCM) in the West Bank (Isaac & Zarour, 1992) and 60-80 MCM in the Gaza Strip (Al-Afifi, 1992).

Palestine's aquifers depend solely on rainfall for the replenishment of their water. However, in Palestine, a semi-arid region, annual rainfall ranges from 150 mm in the east and south to 600 mm in the north (ESCWA, 1993) with drastic fluctuations from year to year (Figures 4,5). Therefore, rain water infiltration to the groundwater aquifers in Palestine barely makes up for the current water consumption levels from these aquifers. Consequently, quantities and methods of water utilization for aquaculture from these aquifers are limited and must not affect water availability for either domestic or agricultural uses.

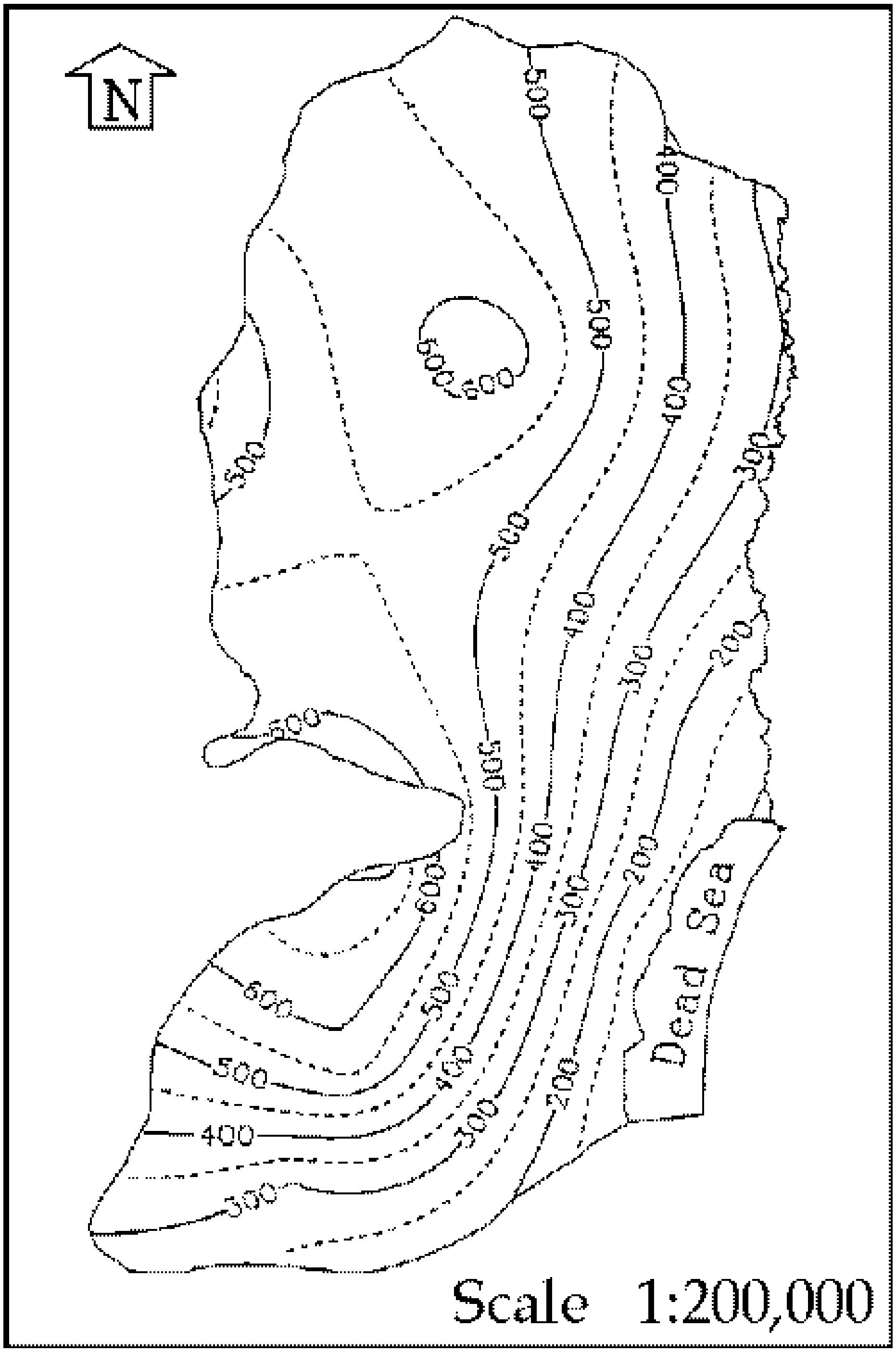


__Figure 4:__ Average Rainfall in the West Bank in mm (Adapted from ARIJ1994)

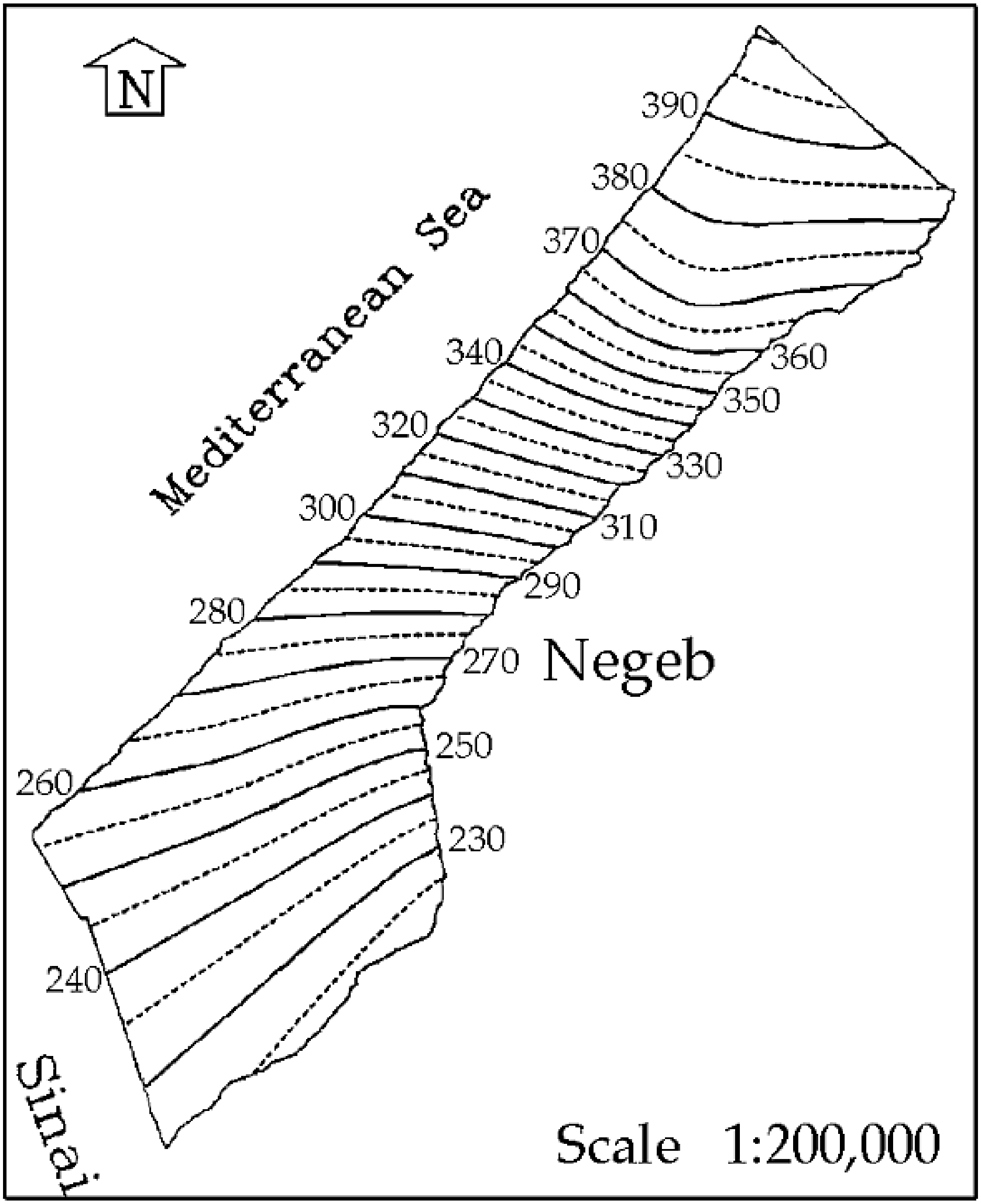


Figure 5: Average Rainfall in the Gaza Strip in mm (Adapted from ARIJ, 1994)

Palestinian use of groundwater is regulated by Israel. Palestinians in the West Bank and Gaza Strip are strictly confined to a total quota of approximately 200

MCM out of the available 660-680 MCM while the remaining water is used by Israel (Lowi, 1992). In spite of the current peace negotiations between the Israelis and the Palestinians, limitation on groundwater use is likely to remain in effect (Government of Israel, 1994).

West Bank Water Resources

Approximately 364 Palestinian-owned and 32 Israeli-controlled water wells are currently tapping water from the West Bank aquifers (JMCC, 1994). The total pumping from the Palestinian wells reaches approximately 58 MCM every year for both domestic and agricultural uses (JMCC, 1994). Few permits are given to Palestinians to drill new water wells and water pumpage from the aquifers is strictly limited. Most Palestinian wells operate at low efficiency and are low in depth in the groundwater table (ESCWA,1993). Thus water availability for aquaculture from underground sources is limited. Fewer restrictions are imposed on use of springs in Palestine. Thus, under the context of the existing political environment, springs have better potential for aquaculture uses.

There are several advantages to utilizing West Bank groundwater for aquaculture. As water is stored deep underground, it maintains a constant temperature ranging from 18-22°C throughout the year. Water in these aquifers is also unpolluted and of high quality for aquaculture. On the other hand, aquaculture projects may enable better utilization of water wells suffering from increased concentration of salts and chlorides, mainly in the Jordan Valley, which otherwise have little use.

West Bank Springs

Springs are a major source of groundwater in Palestine. Spring water originates from underground aquifers, and discharges to the surface from naturally existing water holes or wet spots on the hillsides of the West Bank middle mountain range and along the banks of the wadis (Valleys). While none exist in the Gaza Strip, West Bank springs constitute an important component of the total water resources available for aquaculture.

There are approximately 527 known springs in the West Bank and many other smaller springs and seeps (JMCC, 1994). Figures 6 and 7 show the location of several major springs in the West Bank. The total annual flow of the West Bank springs has been estimated at over 57 MCM a year, approximately 50% of the annual West Bank water consumption (ESCWA, 1993). Nearly 42% of these springs are used for irrigation at some level and about 25% are used for drinking and domestic purposes. The remaining 33% of West Bank springs remain unused (ESCWA, 1993).

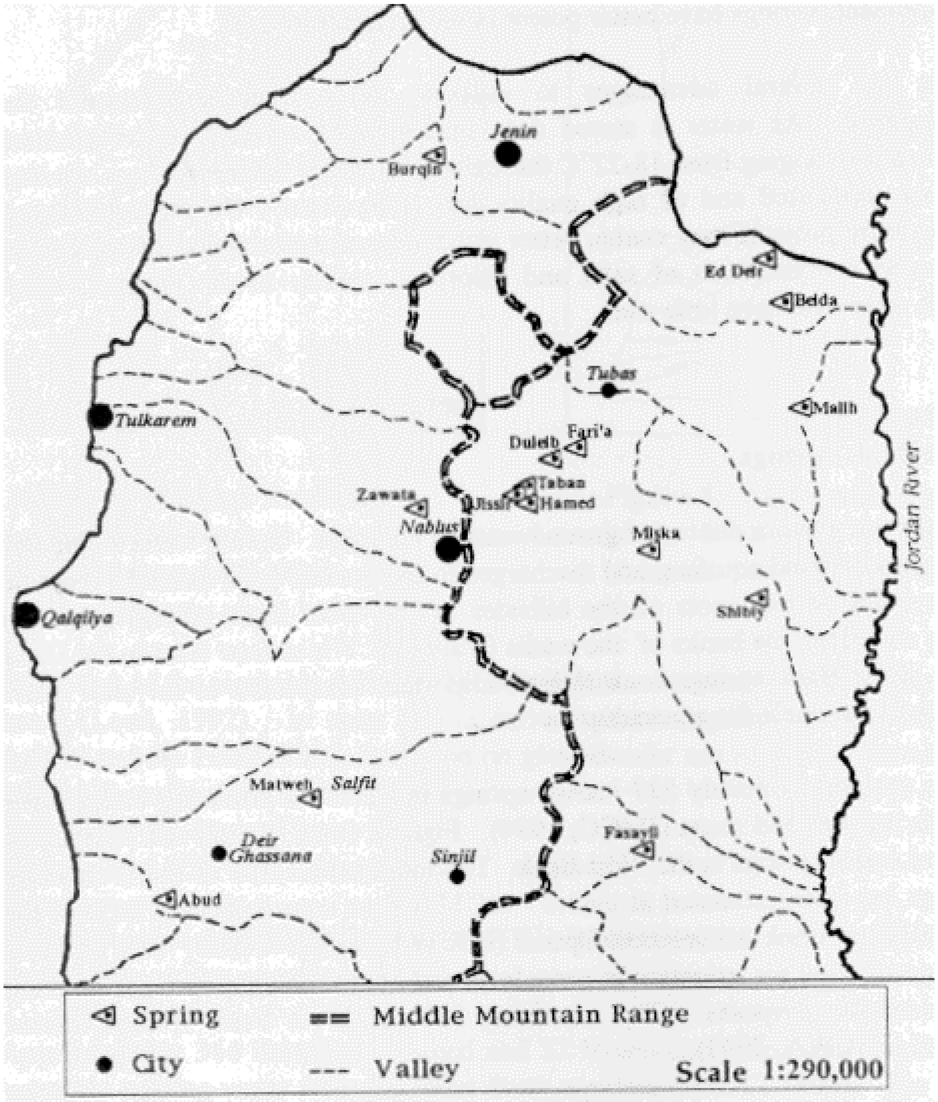


Figure 6: Major springs in the northern parts of the West Bank ([Adapted from Rofe & Raffety, 1965])

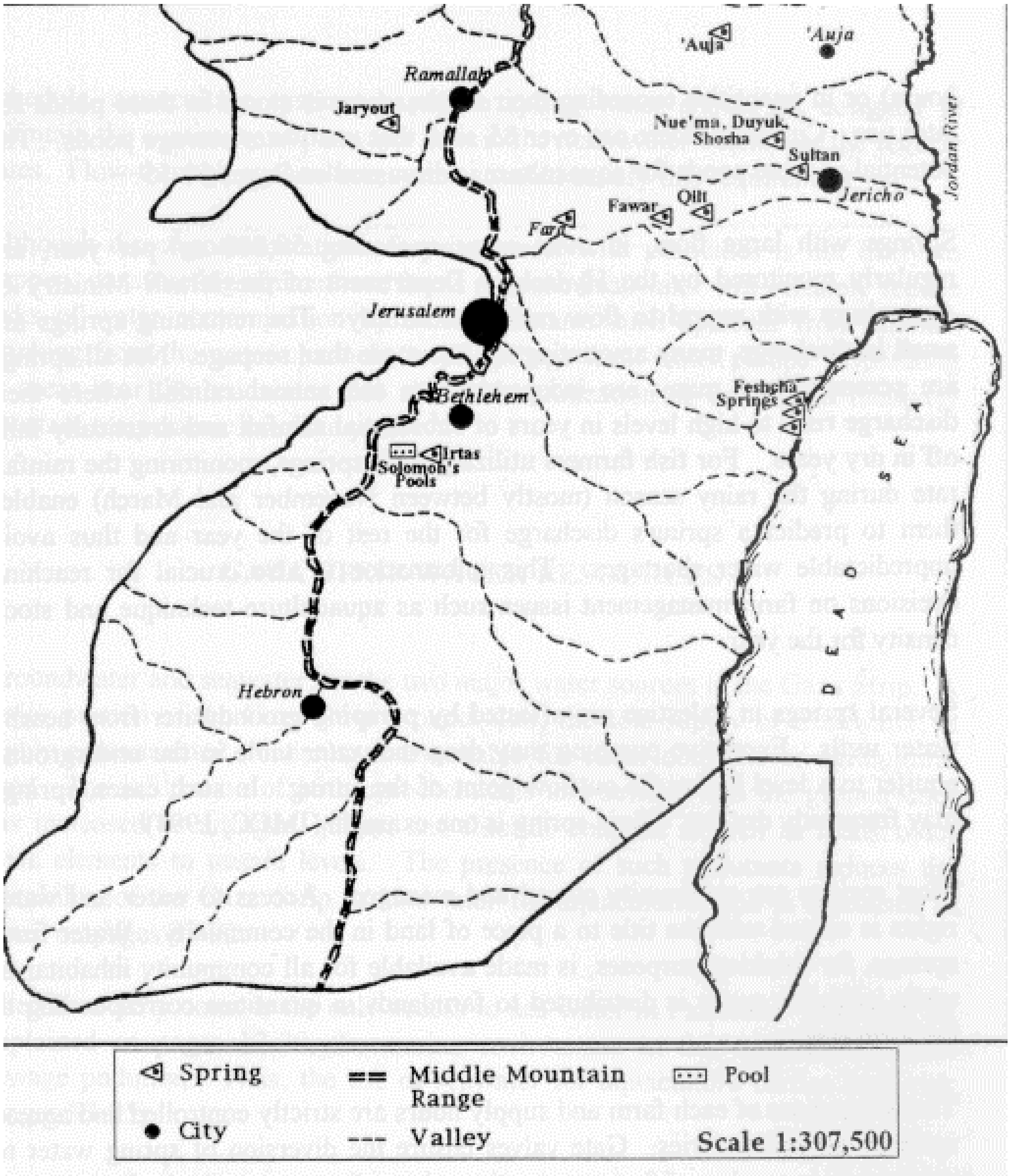


Figure 7: Major springs in the central and southern parts of the West Bank (Adapted from Rofe & Raffety, 1965)

The way springs are utilized in Palestine varies with location and discharge. In most locations, water flows by gravity in open dirt or cement channels or in pipes to irrigate the fields. This simple method is used in more than forty locations -- mainly in Valleys of Bidan and Fari'a, in the northern parts of the Eastern Slopes region. To increase the efficiency of utilization, many farmers

have built various sized water storage ponds. When farmers receive their share of water at times inconvenient for irrigation (e.g., after dark or during sleeping hours) or in quantities exceeding their needs, water is stored in these ponds for later use. Currently, there are over 85 sites that use water storage ponds. The potential of these ponds for aquaculture is discussed on Pages 50-55.

Springs with large flow, in most cases exceeding 50,000 m3 per year, are regularly monitored by the Hydrology Department of the Israeli Ministry of Agriculture with regard to flow rates and salinity. The remaining springs are small in discharge, many amounting to little more than seepage. Not all springs are perennial and many are independent on the annual rainfall where their discharge rises to high levels in years of substantial rainfall and drastically falls off in dry years. For fish farmers utilizing such springs, monitoring the rainfall rate during the rainy season (mostly between November and March) enables them to predict a spring's discharge for the rest of the year and thus avoid unpredictable water shortages. This information is also crucial for reaching decisions on farm management issues such as aquaculture technique and stock density for the year.

Several springs in Palestine are affected by pumping groundwater from nearby water wells. Excessive pumping may drop the water table in the underground aquifer to a level below the outflow point of the spring. In such cases, springs may frequently dry out. 'Auja spring is one example (JMCC, 1994).

Most springs are community owned and managed. Access to water and water rights is earned with the title to a piece of land in the community. Water from springs, for drinking purposes, is made available for all community inhabitants, while irrigation water is distributed to farmlands in quantities corresponding to the farm size.

The water share of each farm and supply hours are strictly controlled and agreed upon by all beneficiaries. Gate valves ensure the diversion of spring water to only a certain number of farmers at a time, depending on a spring's discharge, to allow enough water flow.

The prevalent water distribution system limits the type and scale of aquaculture projects which may depend on these springs for water supply. A more steady water supply can be obtained at sites near major water channels or adjacent to a spring's headwater. To respect the existing water shares and distribution schedule, aquaculture systems based on spring water should be designed to maintain the continuity of the water flow in the main water channel at the regular rates. Flow-through aquaculture systems would satisfy this requirement.

Although direct contamination of spring water with pesticides is not likely to happen, constructing aquaculture farms near the headwater will certainly reduce risks of water contamination by other pollutants such as feces from animals drinking from the water channels, or oil spillage from water pumps. Operating at areas near the headwater also allows the utilization of water with relatively constant temperature over the year.

Gaza Strip Water Resources

Groundwater and seawater are the two major water sources in the Gaza Strip. A major portion of the Gaza Strip groundwater, the sole supply of freshwater, is highly contaminated, rendering it unsuitable for either domestic or agricultural uses. The infiltration of both agrochemicals and sewage into the groundwater has increased its nitrogen, sulfur, and fluoride contents as well as many other toxic elements to unsafe levels. The presence of such pollutants reduces the suitability of the Gaza Strip groundwater for aquaculture, and is discussed in detail in chapter five.

The Gaza Strip coast is the only access to sea water in Palestine. However, as explained on pages 17-20, the marine environment in this area suffers from sewage pollution. Thus, the use of seawater for aquaculture carries high risk (see chapter five).

Chapter Five
Potential Of Aquaculture
In The Five Climatic Regions Of Palestine

Palestine is highly influenced by the Mediterranean climate, which is characterized by long, hot, dry summers and short, cool, rainy winters (ARIJ, 1994). Rainfall is limited to the winter and spring months, mostly between November and March; summer is completely dry. Snow and hail, although uncommon, may occur anywhere in the area especially to the west of and over the highlands (Rofe & Raffety, 1965).

Climate within the relatively small area of Palestine is modified by the diverse topography and altitude. Accordingly, Palestine is divided into five main distinct climatic regions: the Jordan Valley, the Eastern Slopes region, the Central Highlands region, the Semi-Coastal region, and the Coastal region of the Gaza Strip (ARIJ, 1994) (Figure 8). For the purpose of this study, climatic factors such as rainfall, temperature, and evaporation rates, were primarily considered in assessing the potential of each of the five regions for aquauclture. Water resources of each of these regions were examined and their adequacies for aquaculture were evaluated.

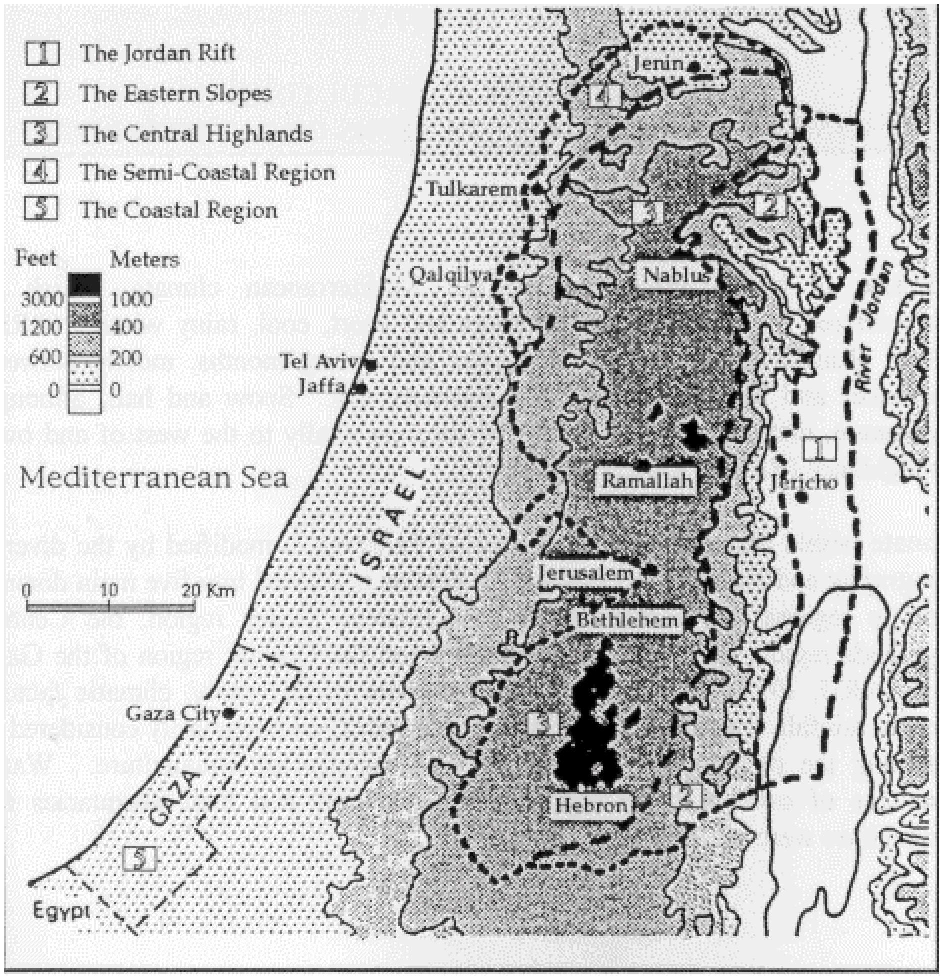


Figure 8: The five climatic regions in Palestine (Adapted from Rowley, 1990)

The Jordan Rift

The Jordan Rift extends along the western bank of the Jordan River from the Israeli border in the north to the northern borders of the Dead Sea in the South. It is approximately 70 km long with a total area of about 400 km2 (ARIJ, 1994). Elevation ranges from sea level to 390 m below sea level. The climate in the Jordan Rift is semi-tropical, characterized by hot summers and warm winters.

This strip of land, though small in area, considerably varies in its climatic characteristics. This is due to the gradual decline in altitude towards the south to reach its deepest point of 390 m below sea level near the Dead Sea area (Khamar, 1988). Accordingly, the southern parts of the Jordan Rift are characterized by warmer temperature, higher evaporation rates and lower rainfall.

Climate and weather data for this region are available through two weather stations, one located in Jericho and the other in the Kalia area (Figure 9). The Jericho station readings are more representative of the central and northern parts of the Jordan Rift, collectively called the Jordan Valley. The Kalia station readings, on the other hand, are representative of the southern parts of the Jordan Rift, called the Dead Sea area, as the station is affected by its closeness to the Dead Sea.

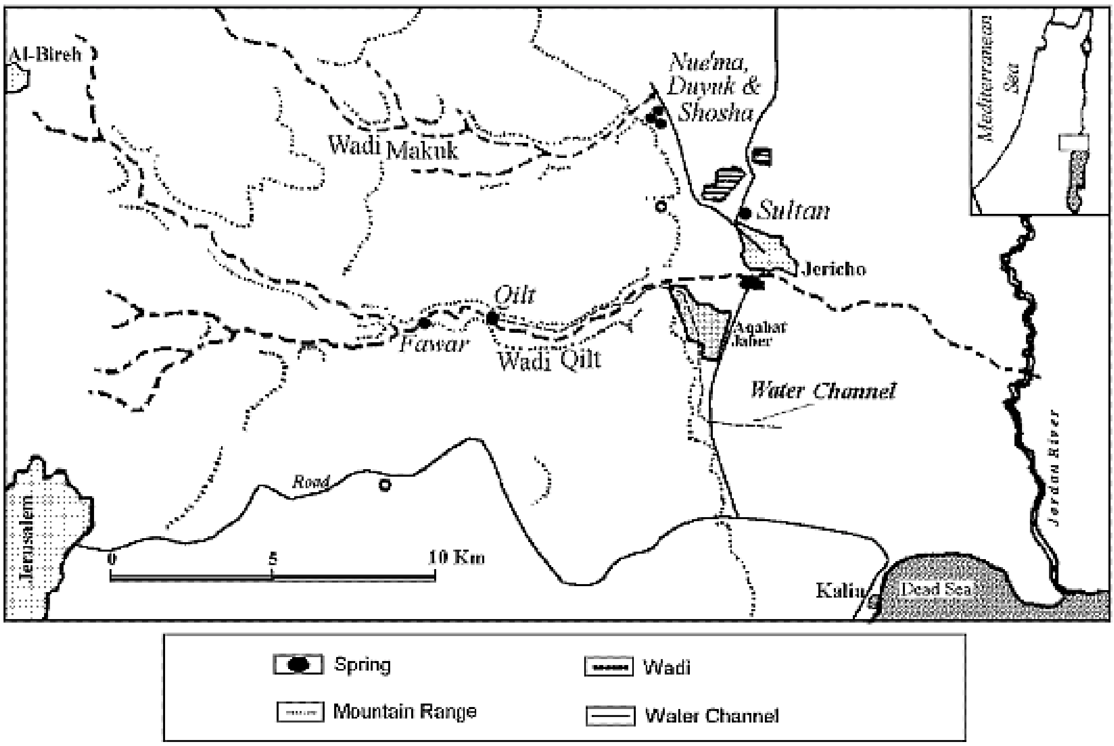


Figure 9: Map showing the location of the major springs in the Jordan Valley (Adapted from Palestine Encyclopedia, 1984)

The Jordan Rift is rich in natural water resources, without which it would have become a desert. Its warm climate, richness in water resources, and fertile soil make the Jordan Valley the main agricultural producer in Palestine. The Jordan Valley also contains approximately 5,720 hectares of irrigated land which constitutes around 53% of the total West Bank's irrigated land (ARIJ, 1994). The widespread use of irrigation in this area will facilitate the introduction of aquaculture systems which can be integrated with the existing irrigation system.

The Dead Sea Area

Climate

The Dead Sea area is unique in its climate. It is situated in the lowest altitude area in the world and surrounded by a series of high mountains from both the east and west which creates a natural greenhouse climate.

The average monthly air temperature in this depression ranges from 30-32°C in the Summer and 15-20°C in the Winter. The lowest daily temperature is approximately 7°C in January, while the highest daily temperature is approximately 46°C in June (Records of the Israeli Meteorological Services). The annual rainfall in this area averages 170 mm (Mazor & Molcho, 1972). Evaporation rates are extremely high, averaging 2,600 mm annually (Al-Afifi, 1992).

Water Resources

The Dead Sea area contains a series of more than 17 closely located springs, collectively called the Feshcha Springs. The majority of these springs outflow in two main groups stretching along an approximately 4 km long and 600 m wide strip of land at the northwestern Dead Sea shore (Figure 10) (Mazor & Molcho, 1972). The Feshcha Springs are characterized by a large and nearly steady outflow of over one thousand cubic meters per hour year round. Recent studies estimated the total annual outflow of these springs at 11,983,000 m3 (Abu Sa'da et al., 1992).

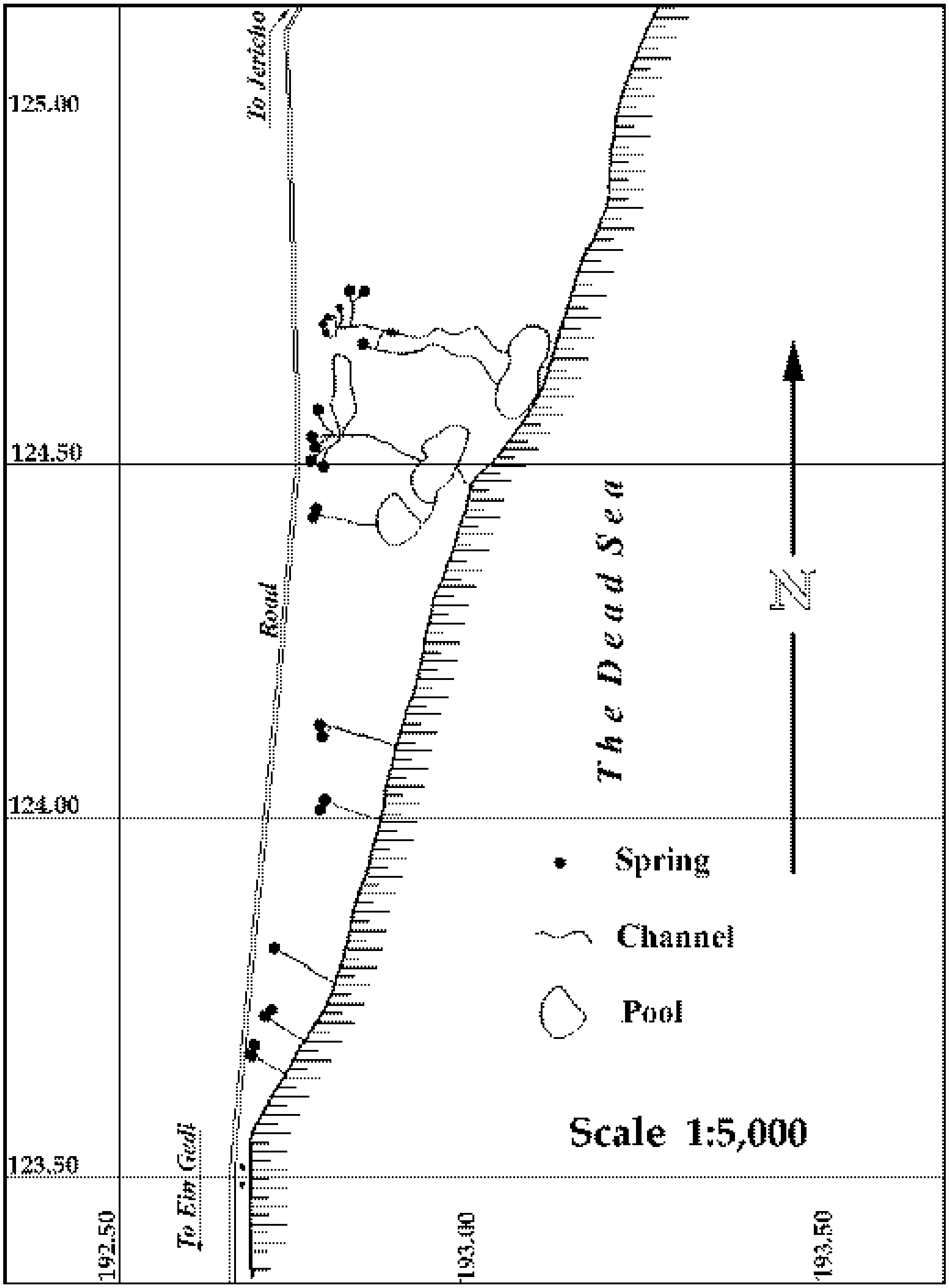


Figure 10: The Feshcha springs along the northwestern shore of the Dead Sea (Adapted from the Israeli Hydrogeographical Department, 1973)

Although classified as fresh water springs, the Feshcha Springs have relatively high salinity levels. Table 4 shows the water chemical composition of 14 of the Feshcha Springs.

Table 4: Chemical Composition of the Feshcha Springs (in mg/l)

Spring Number	K^+	Na^+	Mg^{++}	Ca^{++}	Cu^{++}	Br^-	Cl^-	HCO_3^-	Temp.°C
1	7	42	38	64	62	<0.001	118	233	NA
2	8	43	44	56	53	<0.001	132	274	NA
3	19	43	44	64	63	<0.001	1515	277	26
4*	14	77	70	88	86	1.4	285	319	27
5	31	107	82	80	80	3.2	385	290	30
6	76	350	290	176	175	25.9	1390	294	NA
7	79	368	276	176	180	25.7	1405	329	28
8	68	370	302	192	190	30.0	1540	293	28
9	87	460	375	257	260	42.0	2218	322	28
10*	107	625	412	273	270	44.0	2299	322	28
11	79	437	450	281	280	46.3	2470	335	28.5
12*	120	781	562	297	300	63.3	2971	276	29
13	92	687	550	297	300	60.3	3099	340	30.5
14	137	750	625	353	340	71.2	3484	353	31

Source: Mazor & Nadler, 1973
* indicates that these springs are inhabited by wild fish.

The high level of copper in the Feshcha Springs, as shown in Table 4, is a major concern when assessing the adequacy of these springs for aquaculture. High levels of copper ions are known to damage the gills, cause liver failure and kidney disorders in fish. Elevated copper concentrations may leave copper residues in the fish tissues, which, if consumed, may threaten human health. The maximum acceptable level of dissolved copper in water for the culture for most fish species is 0.5 mg/l (Alabaster & Lloyd, 1982).

However, the toxicity of copper to aquatic animals, particularly fish, is determined by its solubility, i.e. Cu++ concentration. Therefore, toxicity is greatly modified by the physical and chemical qualities of the water. Toxicity is reduced by increased water hardness, water pH, salinity, and organic substances in the water (Alabaster & Lloyd, 1982). Despite the elevated copper concentration, many of the Feshcha Springs are inhabited by fish (Mazor & Molcho, 1972) which is a primary indication of their suitability for fish growing. This may be attributed to high hardness and alkalinity levels in the water. Further testing of the Feshcha Springs is certainly needed to determine the actual concentration of dissolved copper and other toxic metals that may exist in the water. Furthermore, fish inhabiting these springs may have developed tolerance to elevated concentrations of toxic metals in water. Thus, testing fish tissues for traces of toxic metals is essential in evaluating the adequacy of these springs for aquaculture.

The wide range of temperatures in the Dead Sea area, combined with high salt concentrations in the Feshcha Springs, limit the species of fish suitable for aquaculture in this area. Table 5 lists several fish species which are adapted to conditions similar to those of the Feshcha Springs.

Table 5: Freshwater Fish Species Which Maintain Survival and Normal Growth Under High Water Salinities and a Wide Range of Water Temperatures.

Fish Species	**Salinity[1], mg/l**	**Lower temp.[2], °C**	**Upper temp.[2], °C**	**Optimum temp.[2], °C**
Common carp, *Cyprinuscarpio*	0-32,000	0-0.7	31-35.7	26.7-29.4
Channel catfish, Ictalurus punctatus	0-11,000	0-6	30.3-35	21-27
Blue tilapia, *Tilapiaaureua*	0-18,900	8.9-12.8	42	29.4
Java tilapia, *Tilapia mossambica*	0-30,000	9-12	38.2	22-30
Goldfish, *Carassius auratus*	0-15,000	0-9	29-41	7.2-26.7(3)

1 = Source, Boyd, 1990
2 = Source, McLarney, 1987
3 = Source, Conte, 1992; converted from Fahrenheit

Investment in aquaculture in the Feshcha Springs is not recommended unless preceded by further investigation of the potential risk factors related to the combined effects of water properties and chemical composition on fish survival. Culturing fish on an experimental basis may seem essential in the evaluation process of these springs.

Special consideration should be given to the Red-Dead Sea project which has been discussed during the Jordanian-Israeli bilateral talks which began in 1992. The project is designed to connect the Red Sea with the Dead Sea by a water canal. According to the preliminary details released by the Israeli government, the canal will raise the water level in the Dead Sea, possibly submerging land areas around it (Israeli Ministry of Tourism, 1993).

In early 1994, the Israeli News released information regarding the discovery of a new water aquifer in the portion of the Dead Sea area which lies in the West Bank. Little information about the size or water quality of this new aquifer was given. However it was stated that the high water salinity of this aquifer makes it unsuitable for agricultural or domestic uses. Further investigation of the potential use of the water from the new aquifer for aquaculture is needed in the future.

The Jordan Valley Area

The Jordan Valley is the major supplier of agricultural products in Palestine, contributing approximately 35% of the total production (Abed El-Razeq, 1991). Such large production from a relatively small area is attributed to the warm climate, fertile soil, and the abundance of springs which provide the major source of irrigation water.

Climate

The average monthly air temperature in the Jordan Valley ranges from 38°C in the Summer and 7°C in the Winter. The lowest daily temperature recorded between 1970 and 1981 was -1°C, in December/January, while the highest daily temperature reached was 49°C, in June (Records of the Israeli Meteorological Services). Despite the infrequent drop in air temperature to below 0°C, warm-water fish species such as tilapia, carp, and catfish are certainly suitable for aquaculture in this area. The decline in water temperature is slow relative to air temperature over short periods of time.

The average annual rainfall in the Jordan Valley area is 158 mm. However, rainfall varies from year to year, with the lower and upper limits of 63 mm and 259 mm respectively (Records of the Israeli Meteorological Services). The number of rainy days in each season ranges from 35 to 60 days. The Jordan Valley area is also characterized by high evaporation rates, averaging from 200 to 260 mm per month. Table 6 shows the evaporation rates in the Jericho area for 1993.

Table 6: Evaporation Rates in the Jericho Area for 1993

Months	mm/day	mm/month	Minimum Temp.°C	Maximum Temp.°C
January	1.6	49.6	0.5	22.0
February	1.85	55.5	0.6	26.8

March	.93	21.8	4.2	33.8
April	6.2	186.0	8.6	38.8
May	6.9	213.9	11.4	38.6
June	8.0	240.0	18.2	45.0
July	9.1	282.1	19.8	41.2
August	8.8	272.8	21.8	45.6
September	6.7	201.0	18.0	40.8
October	5.1	158.1	16.4	38.0
November	3.0	90.0	6.4	32.8
December	2.1	65.1	5.8	26.8
Total	**1785.9**			
Source: Records of the Jericho Agricultural Directorate				

The high evaporation rates in the Jordan Valley, though they moderate water temperature in the Summer, induce a substantial loss in water resources. Due to the demand on water and the need for water conservation, the use of large shallow open-pond systems for aquaculture, similar to those used in the US, is therefore not recommended. Such ponds are characterized by a large surface area exposed to the atmosphere and thus by large water loss due to evaporation. In a one-acre pond, for example, water loss is estimated at 7,143 m^3/year according to the evaporation rate of the year 1993.

During the hot seasons in the Jordan Valley, water temperature in ponds less than one meter in depth can reach as high as 40°C or more under direct sunlight (Delince, 1992). Such elevated temperature reduces dissolved oxygen concentration in the water and stresses the fish. In deeper ponds, water stratifies thermally with heating restricted to the upper water layers (Delince, 1992). Thus, during periods of high temperatures, fish can seek refuge in the deeper and cooler water layers.

Water Resources - Springs

The Jordan Valley is fed by eight major springs: Sultan, Duyuk, Fawar, Qilt, Nue'ma, Shosha, 'Auja, and Fasayel. These springs provide the majority of irrigation water to the area. During field examination, all these springs, except Fasayel, were tested for water quality (Table 7).

As expected for underground water, the chemical and physical properties of the Jordan Valley springs are of high quality for aquaculture. Although water gases in groundwater are usually not of optimum levels, dissolved oxygen concentration in these springs was satisfactory for aquaculture uses. Carbon dioxide, however, was not of optimum levels at sites close to the headwaters. Carbon dioxide concentration may be corrected by simple water aeration methods during which excessive amounts of carbon dioxide dissipate into the air (McLarney, 1987). Furthermore, the year round water temperature of these springs is relatively constant, a main characteristic of water from deep underground sources (McLarney, 1987). Such water characteristic greatly reduces risks of temperature seasonality and variability in weather conditions.

Table 7: Water Properties[1] of the Jordan Valley Springs August, 1994

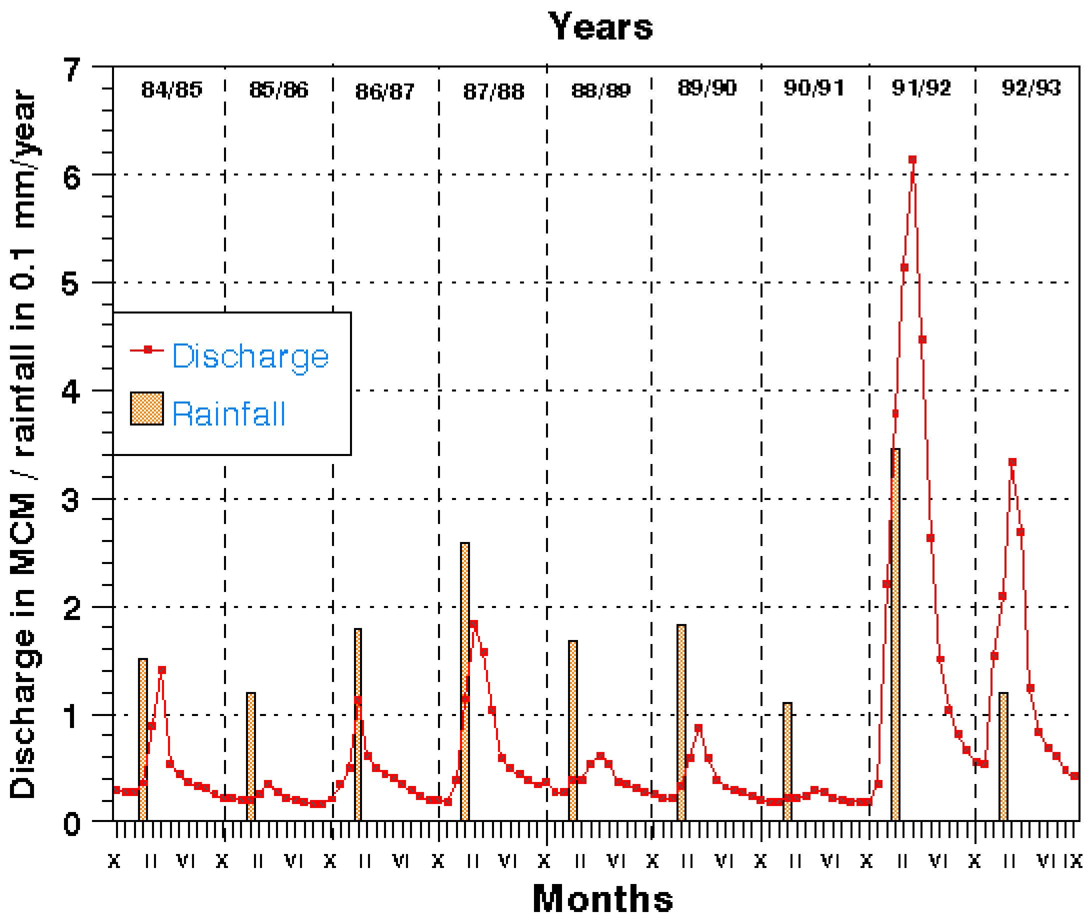
Water Properties	Sultan[2]	Duyuk[2]	Fawar & Qilt[3]	Neu'ma[2]	Shosha[2]	'Auja[4]
Temp. (°C)	20	20	21	21	20	22
D.O. (ppm)	7.8	7.3	7.4	7.5	7.5	8.1
pH	7.5	7.6	8.7	7.5	7.6	8.7
CO_2 (ppm)	10	16	ND	16	16	ND
TAN (ppm)	0.3	ND	ND	ND	ND	ND
NO_2^-N (ppm)	ND	ND	ND	ND	ND	ND
T. alk. (ppm as $CaCO_3$)	280	310	256	300	305	254
T. hard. (ppm as $CaCO_3$)	288	292	232	306	298	258
Cl^-	36	39	44	37	37	36
Turb. (m)	>1.5	>1.5	>1.5	>1.5	>1.5	>1.5
TDS (ppt)	0.4	0.4	0.4	0.4	0.4	0.3

1 =Three samples were tested at each site. Tests were performed during daytime (10:00 - 16:00).
2 = Samples taken at spring's headwater, thus CO2 is relatively high.
3 = Both springs pour into a common water canal. Samples taken approx-imately 13 km to the east of the headwater site.
4 = Samples taken approximately 1.5 km to the east of the headwater site.

Qilt and Fawar Springs

The Qilt and Fawar springs are located in the upper parts of the Wadi Qilt which extends from the eastern parts of Jerusalem to Jericho (Figure 9). Fawar spring flows from a site approximately 1.5 km above Qilt spring in the Wadi Qilt. The spring water flows down the bottom of the valley to meet with the Qilt and continue together towards Jericho city in a 15 km open cement channel (Quara'en, 1992). The total discharge of both springs is estimated at 5.5 MCM annually. The previous records of these springs show substantial fluctuation in discharge from year to year and a dependence on the rainfall rates and seasonalities in the area (Chart 1). However, a flow of more than 2.64 MCM per year was maintained between 1984 and 1993 (Israeli Hydrological Services, 1988-1994).

Chart 1: Monthly Discharge of the Qilt and Fawar Springs For the Years 1984 - 1993*



* See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

After 1967, the Israeli authorities named the Wadi Qilt area as a natural reserve and applied restrictions on the use of the Wadi's water resources. Regardless of these restrictions, the topography of Wadi Qilt and the location of the water channel do not encourage the establishment of commercial fish farms. Wadi Qilt is characterized by sharp slopes on both its sides. Furthermore, the Qilt water channel lies midway up the slopes whereas the bottom of the valley constitutes a runway for the seasonal runoff water. Thus suitable locations for aquaculture are limited. Accessible roads are also not available to most parts of the valley.

It is important to note that the United Nations Relief and Work Agency (UNRWA) built a small scale water treatment unit on the Qilt water channel at the eastern gate of the Wadi Qilt near Jericho city. This unit provides drinking water for approximately 3,300 Palestinian refugees (PASSIA 1994) living in the nearby Aqabat Jaber refugee camp. Therefore, if aquaculture projects are to be constructed in the Wadi Qilt at locations above the water treatment plant, the elimination of pollutants from the aquaculture water discharge should be considered by fish farmers.

The sharp slopes of Wadi Qilt end at approximately 2 km west of Jericho city where land topography becomes relatively flat. The Qilt water channel continues after this location through the plain fields south of Jericho city to irrigate an area of approximately 150 hectares (Abed El-Razeq et al., 1991). This flat area is certainly suitable for aquaculture ventures, especially for those projects that can be integrated with the existing irrigation systems. Accordingly, sampling of the Qilt and Fawar water was done in this area.

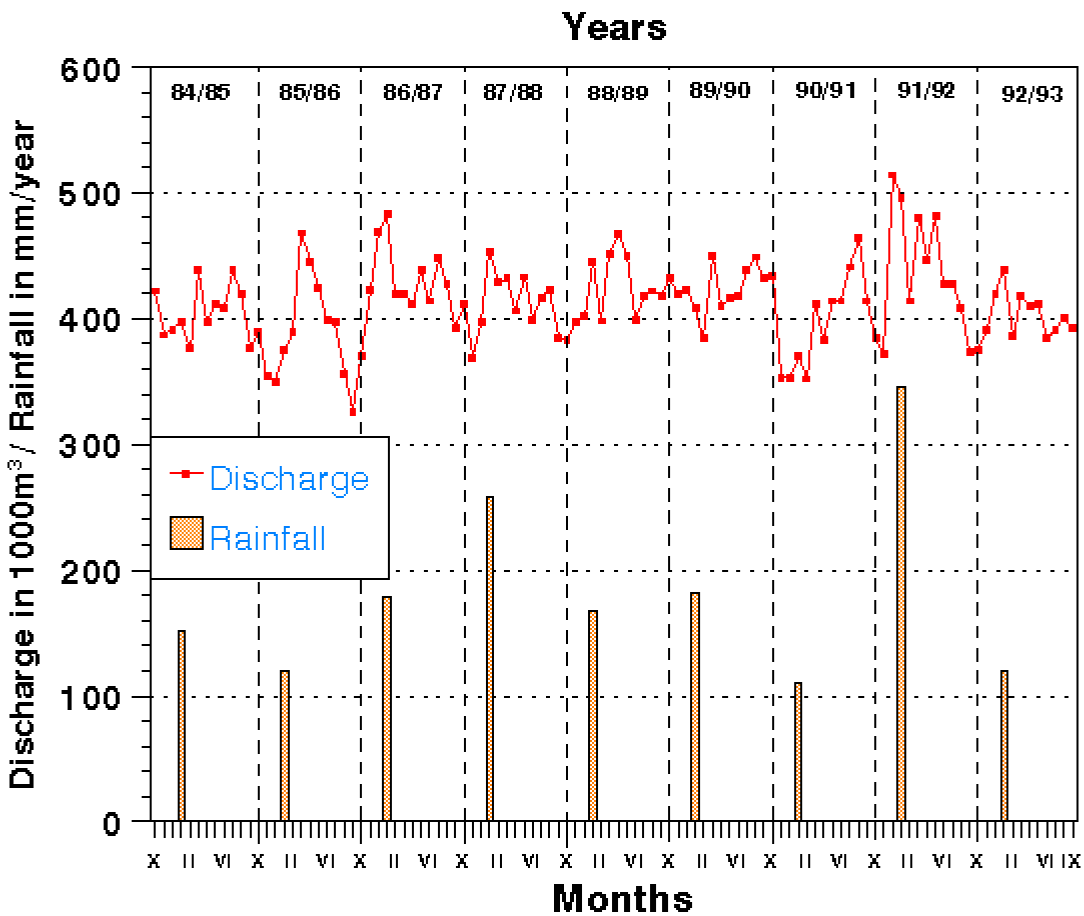
Duyuk, Nue'ma, and Shosha

The Duyuk, Nue'ma and Shosha springs are located at the foot of the West Bank's eastern slopes and the western edge of Jericho city (Figure 9). The three springs originate from a common underground aquifer and discharge at locations a few meters apart from each other. Each individual spring flows into a separate open-cement channel (Photo 2) and irrigates vast areas of relatively flat agricultural lands in the Jericho area which are primarily cultivated with bananas and vegetables.

Photo 2: The water channels of the Duyuk, Neu'ma and Shosha springs (August 1994)

Duyuk, the largest of the three springs, has an average annual discharge of approximately 5 MCM (Israeli Hydrological Services, 1988, 1994). It is a major source of irrigation water for nearly 350 hectares of land (Abed El-Razeq, 1991). The spring's discharge is relatively stable from year to year and little affected by rainfall and seasonalities (Chart 2), making it a preferable water source for aquaculture.

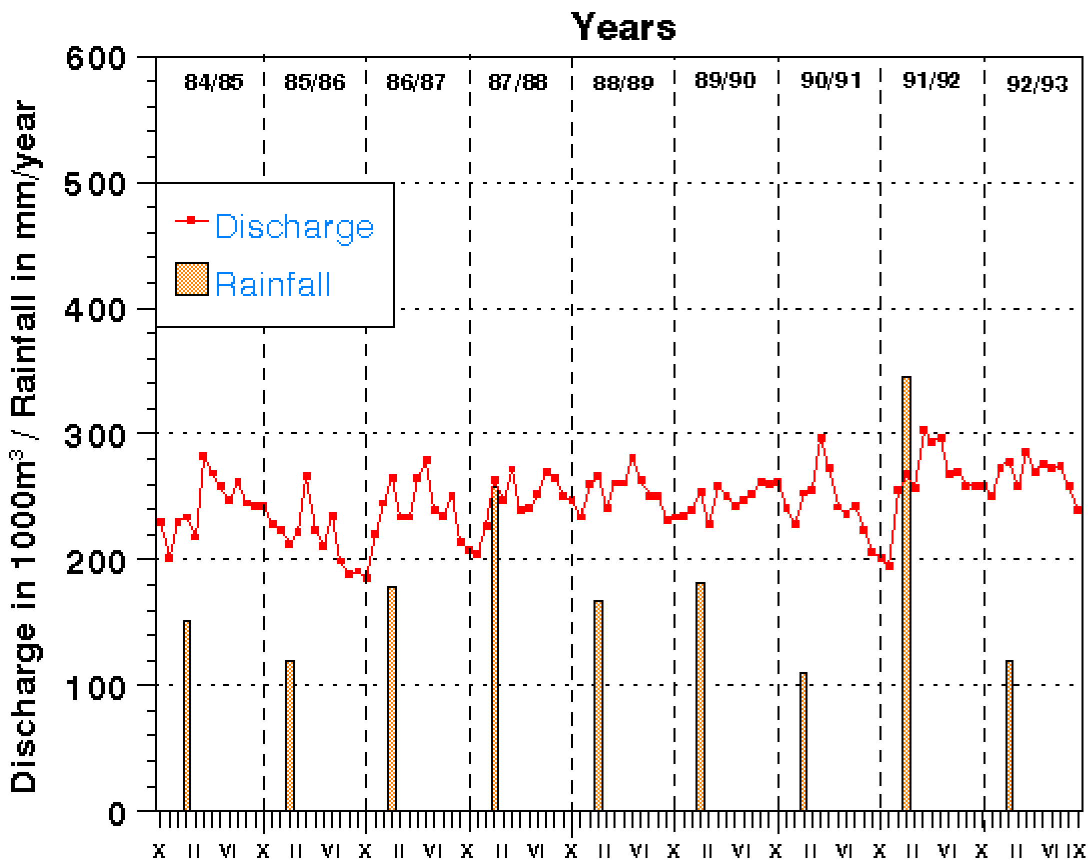
Chart 2: Monthly Discharge of Duyuk Spring For the Years 1984 - 1993*



*** See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)**

Nue'ma spring, the second in size of discharge, has an average annual discharge of approximately 2.4 MCM and irrigates an area of approximately 275 hectares (Abed El-Razeq). Its discharge is characterized by steady flow throughout the year (Chart 3).

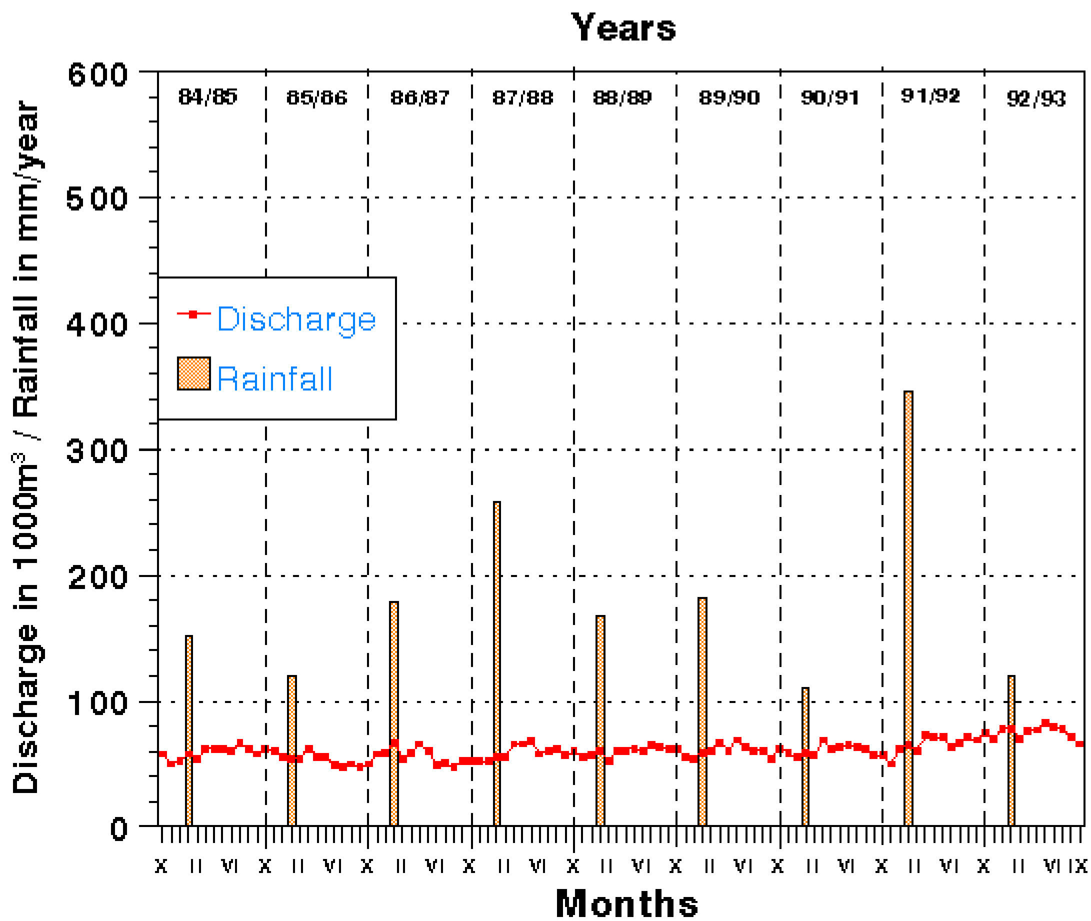
Chart 3: Monthly Discharge of Nue'ma Spring For the Years 1984 - 1993*



* See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

Shosha spring is the smaller of the three with an average annual discharge of 0.5 MCM (Israeli Hydrological Services, 1988-1994). It irrigates an area of approximately 60 hectares cultivated with bananas and vegetables (Abed El-Razeq, 1991). The spring discharge is characterized by little or no variation between seasons or years (Chart 4).

Chart 4: Monthly Discharge of Shosha Spring For the Years 1984 - 1993*



* See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

The steady and large flow of the Duyuk, Nue'ma and Shosha springs, combined with their high water quality, render them suitable for relatively large scale aquaculture ventures.

Their independence from seasonality and variation in rainfall reduces risk and allows better estimation of farm size, simpler management, and consistent operational strategies.

The area west of the three springs is much higher in altitude and characterized by sharp topographical variation which renders them unsuitable for aquaculture ventures (Figure 9). The remaining land surrounding the springs is relatively flat and lower in altitude which allows the utilization of gravity water flow systems, eliminating the costs and risks of operating water pumps.

In sum, the good quality water, large annual flow, steady discharge, and relatively flat topography render the Duyuk, Neu'ma and Shosha springs and the surrounding areas ideal for aquaculture projects.

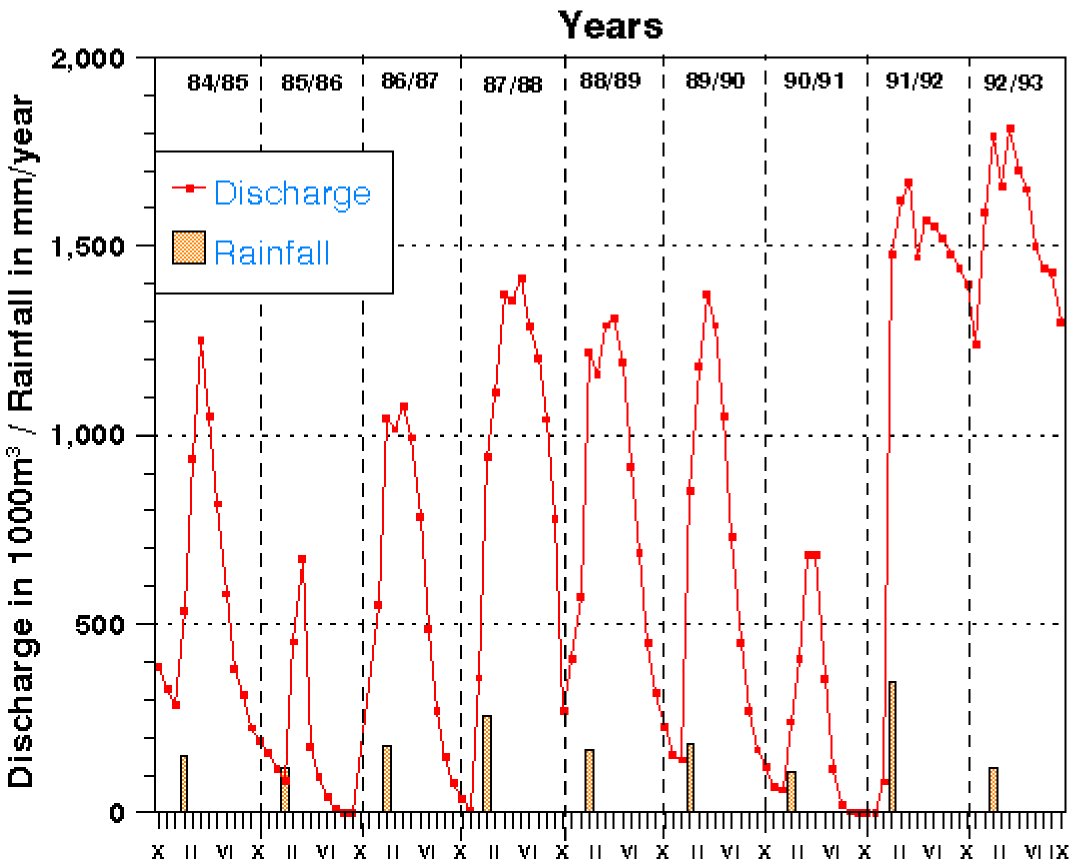
'Auja Spring

'Auja spring is located approximately 7 km north of Jericho city in the Wadi 'Auja (Figure 7). It is the largest spring in the West Bank with an average annual discharge of approximately 10 MCM (Israeli Hydrological Services, 1988-1994). The spring flows into an open-cement channel of approximately 6 km in length, which carries water to the neighboring agricultural land, mainly to the nearby 'Auja village (Photo 3). The land area surrounding the water channel is flat and un-utilized which would make it a suitable location for aquaculture projects if 'Auja spring had a dependable water supply.

Photo 3: 'Auja spring channel in the Jordan Valley, August 1994

Although 'Auja spring alone constitutes 23% of the total discharge of all West Bank springs (Abed El-Razeq, 1991), it is characterized by irregular and highly fluctuating flow which varies from month to month and year to year. Chart 5 illustrates the fluctuation in discharge and specifically the dryness of the 'Auja spring in the late summers of 1986 and 1991.

Chart 5: Monthly Discharge of 'Auja Spring in the years 1984 - 1993*



* See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

The fluctuation in 'Auja's discharge is highly related to the precipitation rates in the area and the geophysical structure of the spring (JMCC, 1994). 'Auja spring emerges from a point high in altitude relative to the water table in the tributary aquifer. Thus water leaves the aquifer in large quantities during the rainy winter

season. Discharge declines rapidly after the rainy season is over as the water table in the tributary aquifer drops to levels close or less than the level of the spring outlet. Therefore, the annual discharge of 'Auja spring represents only a portion of the carrying capacity (storage potential) of the tributary aquifer.

Fluctuation in outflow constitutes a risk factor for aquaculture and threatens the survival of the fish stock in dry years. Fish with a relatively short growing period, such as tilapia, may still be cultured in this location if the growing cycles are adjusted to spring seasonality or if the aquaculture system is designed to easily switch between flow-through and static systems. This imposes low fish stock density in the system all year around.

Irrigation Ponds

To increase efficiency in water consumption and land production, farmers in the Jordan Valley built various sized water storage ponds. When farmers receive their share of water in times inconvenient for irrigation (e.g., after dark or during sleeping hours) or in quantities exceeding their needs, water is stored in these ponds. These ponds are also used to store springs' night-time flow, especially in areas where spring discharge is low and not sufficient to meet water needs. Saving night flow water from waste certainly increases quantities of water available for irrigation.

The extensive adoption of drip irrigation techniques in the Jordan valley in the late 1980's also added to the value of these ponds and encouraged the construction of many others. Drip irrigation requires steady water supply with ample water pressure which could not be provided by the traditional spring water supply systems or channels.

The number of irrigation ponds in the Jordan Valley by the end of 1990 exceeded 177 with a total carrying capacity of approximately 0.5 MCM of water. Table 8 shows the distribution and average capacity of these ponds.

Table 8: Irrigation Ponds in the Jordan Valley

Area	**Number of ponds**	**Carrying capacity in m^3**	**Average carrying capacity in m^3/pond**
Jericho	44	118,959	2,703
Duyuk	10	16,972	1,697
'Auja	38	199,400	5,247
Fasayel	10	13,000	13,000
Jiftlik	61	151,011	2,475
Frush Beit Dajan	8	18,104	2,263
Nue'ma	10	11,800	1,180
Zbeidat & Marj Na'ja	4	6,000	1,500
Bardala	1	1,300	1,300
Total		**536,546**	

Source: records of the Jericho Agricultural Directorate

Though the size of the water storage ponds, commonly known as irrigation ponds, may vary, their design is fairly similar. The majority of these ponds are either circular or elongated with conical walls sloping inwards towards the center and a depth averaging 3-3.5 meters. About two thirds of the pond is under ground level with levees supporting the one third above ground (Figure 11). Pond walls are usually lined with thick plastic and covered with a layer of dirt (approximately 20 cm in thickness).

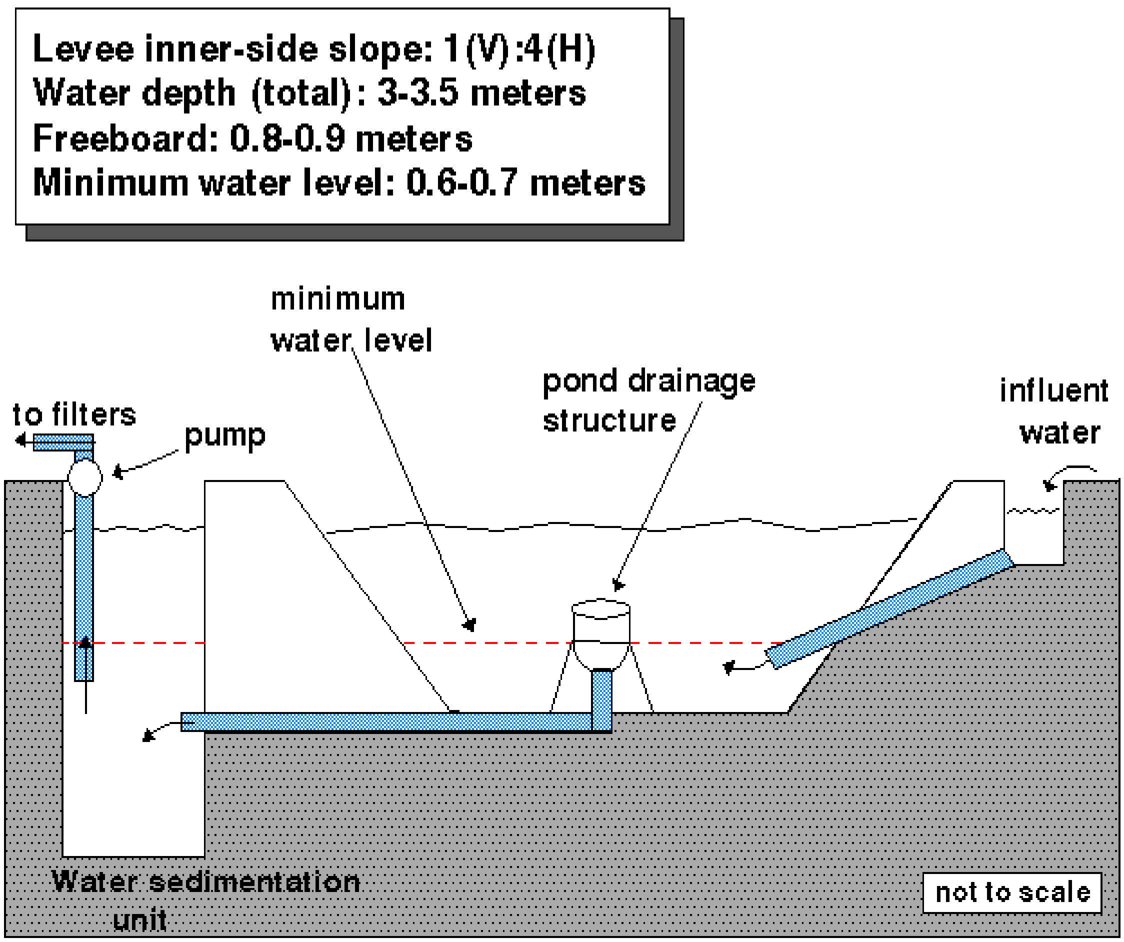


Figure 11:Schematic diagram of the irrigation ponds in the Jordan Valley

The drainage structure, which lies at the bottom center of the pond, is made of a cement box with the effluent opening approximately 60-70 cm above the floor of the pond (Photo 4). This design allows settlement of suspended solids in water and reduces the flow of dirt into the effluent pipes. To prevent clogging, the drainage hole is covered with a relatively wide-mesh screen. As drip irrigation pipes tend to clog easily, effluent water from the irrigation ponds is passed through a settlement unit before being pumped into the irrigation pipe network.

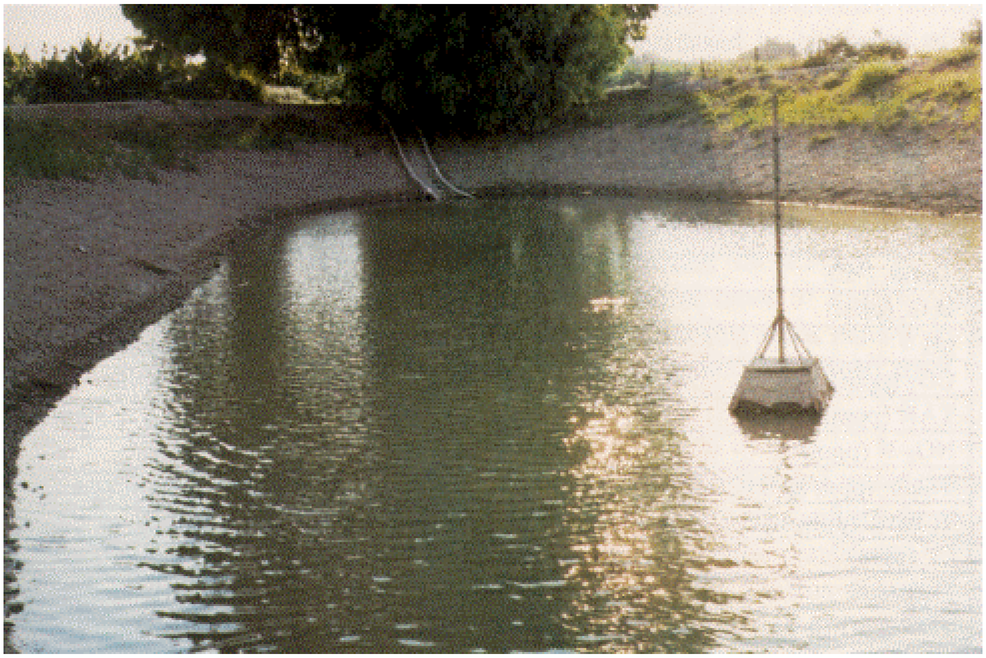


Photo 4: Irrigation pond in the Jordan Valley, August 1994

Water quality in irrigation ponds varies from site to site depending on the water source, irrigation schedule, and quantity of water in the pond. Table 9 lists water properties in three irrigation ponds that were examined during the summer of 1994.

Water quality in irrigation ponds deteriorates rapidly especially after partial drainage of the pond for irrigation purposes. This is attributed to the engineering of the pond which was designed to ensure minimum water circulation, especially at the lower water layers. The drainage hole is positioned 0.6-0.7 m above the pond floor which permits the accumulation of organic precipitants in the dead water zone below the drainage level. Such accumulation, combined with the increase in water temperature when the pond is partially drained, depletes the dissolved oxygen in water and creates a suitable environment for anaerobic decomposition.

Table 9:Water Properties* of the Jordan Valley Irrigation Ponds August 1994

Water Properties	Irrigation Pond#1	Irrigation Pond#2	Irrigation Pond#3
Temp. (°C)	30	26	26
D.O. (ppm)	6.6	7.8	8
pH	8.8	7.6	8.4

CO_2 (ppm)	ND	17	3
TAN (ppm)	0.9	2.5	0.5
NO_2^-N (ppm)	0.075	ND	ND
T. alk. (ppm as $CaCO_3$)	187	550	302
T. hard. (ppm as $CaCO_3$)	200	1200	306
Cl^- (ppm)	46	378	76
Turb. (m)	1	0.8	0.9
TDS (ppt)	0.3	1.7	0.5

* = Three water samples were tested from each pond. Samples were gathered around noon time.
Irrigation pond #1: located at the Jericho Agricultural Directorate; filled with spring water only.
Irrigation Pond #2: Located in 'Auja village; half-filled; mixed spring and groundwater. Irrigation Pond #3 Located in 'Auja village; half filled; spring water only.

Although water in the irrigation ponds is partially renewed once or twice a week, little improvement of their water quality is noticed. Therefore, major structural adjustments of water influent/effluent systems are essential before rendering irrigation ponds adequate for aquaculture. Adjustments should correspond to the minimum water level desired to be maintained in the pond and the technical requirements of the drip irrigation systems, and should allow efficient water circulation in the pond. Additional water sedimentation and filtration units may be needed to prevent clogging of the drip irrigation network.

As Table 9 shows, irrigation ponds which receive supplementary water supply from underground water wells have elevated chloride and ammonia nitrogen concentration in their water. This is due to the increased brackishness of the aquifer underneath the Jordan Valley, a condition caused by overpumping and contamination with agricultural inputs, mainly fertilizers.

Each pond represents an extensive semi-static aquaculture/irrigation system with water being partially renewed once or twice a week. The rapid fluctuation of the micro-environment in each pond necessitates constant monitoring of water quality and percentage of water renewed in the pond at times of supply. Such monitoring is crucial in calculating the maximum allowable stock density in the pond, water supply from underground sources, and water withdrawal from the pond.

The warm climate in the Jordan Valley combined with the declined water quality in the irrigation ponds limits the fish species suitable for aquaculture to warm water varieties of high tolerance to unsuitable environmental conditions. Fish species such as tilapia, carp and catfish may be suitable for this area. These ponds may also be simpler to manage if they are limited to fish grow-out where fish seeds and fingerlings can be purchased from off-farm sources.

Using irrigation ponds for aquaculture purposes generates multiple benefits for farmers. Although it may increase water filtration costs, it enhances water quality for irrigation purposes by providing a source of nitrogen and phosphorus and generates additional income for farmers by increasing farm outputs. Farm byproducts may also be incorporated into the fish feed. This integrated system is a proper model for integrated farm management and permaculture in the area.

Water Wells

A major portion of the West Bank water wells is located in the Jordan Valley. There are 88 Palestinian wells in the Jordan Valley which comprise approximately 40% of the total wells in the West Bank. Most of these wells are privately owned (some are owned by groups of farmers) and are primarily used for agricultural purposes, providing a backup source of water in times of spring water shortfalls (ESCWA, 1993).

Due to the restrictions on the use of underground water, the existing Palestinian wells in the Jordan Valley are entitled to a water quota of only 9.9 MCM per year (Naff & Matson, 1984). Furthermore, the total salt concentration in most of the Jordan Valley wells rose by 130% from 1967 to 1991 (JMCC, 1994). The overpumping by Israeli and Palestinian wells from the Jordan Valley underground water is a major cause of this increased water salinity. The water table dropped 16 m from 1969 to 1991 which also caused a tangible decline or even the complete drying up of several Palestinian wells, rendering many of them unsuitable for agriculture (Awartani, 1992).

The relatively high salinity levels in well water might be preferred for growing salt-tolerant fish species such as tilapia, carp and catfish. However, the limited availability of water, the difficulty in disposing of the saline effluent, and the increased contamination of the aquifer, reduce the potential of these wells for aquaculture uses.

Jordan Rift Potential for Aquaculture

The Jordan Rift region is the richest of all Palestine's regions in terms of freshwater resources. It is also considered Palestine's food basket where intensive irrigated agriculture is widely practiced. The relatively flat topography, warm climate and fertile soil greatly contribute to its high productivity.

Similarly, the Jordan Valley's plentiful water resources, smooth topography, and warm climate would encourage warm-water aquaculture. The good quality water and steady flow of most springs would facilitate the introduction of aquaculture industry in this region. However, as water is mainly utilized for irrigation, integrated irrigation/aquaculture flow-through systems are more suitable in this area. Irrigation ponds, after several modifications, can serve as a model for such systems.

The low and fluctuating rainfall in the Jordan Rift region reduces the aquaculture viability of water resources which are highly dependent on rainfall. The 'Auja spring is a major example. Steady flowing springs of good quality water, such as Duyuk, Shosha, and Neu'ma, are, in contrast, ideal sites for aquaculture projects. The elevated evaporation rates in this region discourage the use of broad shallow open-pond systems as water losses become huge.

The Feshcha Springs and ground water in the Jordan Rift, although of considerable volume, carry a high risk for aquaculture due to their contamination with toxic metals or agricultural inputs. Further study is recommended to determine the viability of these resources.

THE EASTERN SLOPES REGION

The Eastern Slopes region extends along the length of the eastern side of the West Bank covering an area of approximately 1,500 km2 (Figure 8) (ARIJ, 1994). It ranges from 800 m above to approximately 200 m below sea level. As this region lies in the rain-shadow area of Central Highlands, it is characterized by semi-arid climate with low annual rainfall ranging from 200 to 400 mm. The southern parts of the Eastern Slopes region are dry except for underground water to which Palestinians have restricted access. The northern parts, however, are rich in water resources. Therefore, the emphasis in this study is on the water-rich northern parts.

There are five main spring groups in the northern parts of the Eastern Slopes region: Badan, Fari'a, Miska, Bardala, and Malih. Together these include approximately 32 springs. Due to time restrictions, on-site examination and water testing included only springs from the Fari'a, Miska, and Badan groups which are located in two main geographically integrated areas: Fari'a and Badan valleys.

The Fari'a and Badan Valleys

Site Topography

The catchment area of the Fari'a and Badan valleys is nearly 30 km in length, extending from the eastern parts of Nablus city to the Jordan River, covering an area of approximately 400 km2 (Palestine Encyclopedia, 1984). The Fari'a, Badan and Miska spring groups, which feed the Fari'a and Badan valleys, have a flow estimated at 7.1, 4.7 and 1.4 MCM respectively and ensure a continuous water flow in the area. The Fari'a Valley begins at a location near the headwater of the

Fari'a spring group (Figure 12). Deep, narrow and sheer, the valley extends southeast for 3 km with a slope of 1:11-20 before it meets with Wadi Badan (Palestine Encyclopedia, 1984). Wadi Badan originates at a location east of Nablus city and captures the water of the Badan spring group.

The Fari'a and Badan Valleys meet at a point near the Nablus-Tubas road junction (Figure 12) and form one valley, collectively called the Wadi Fari'a, which continues towards the Jordan River. Water from the Fari'a and Badan spring groups also meet at this location and constitute a stream which flows eastward for nearly 2 km of sharp slopes of approximately 1:16.

As it reaches the upper parts of the Jordan Valley, the Wadi Fari'a levels off to a slope of approximately 1:100. The Wadi also widens to reach 1 to 1.5 km in width. Water from the Miska spring group flows out at this location (Figure 13). The Wadi later levels more to a slope of about 1:200 and widens to over 2 km as it nears the Jordan River area (Palestine Encyclopedia, 1984).

The Wadi Fari'a floor is generally characterized by alluvial soils and is regularly cultivated year round. Although rainfall is relatively low in this area, the large watershed catchment area from the surrounding subsidiary valleys insures rich water flow in the Wadi Fari'a year round.

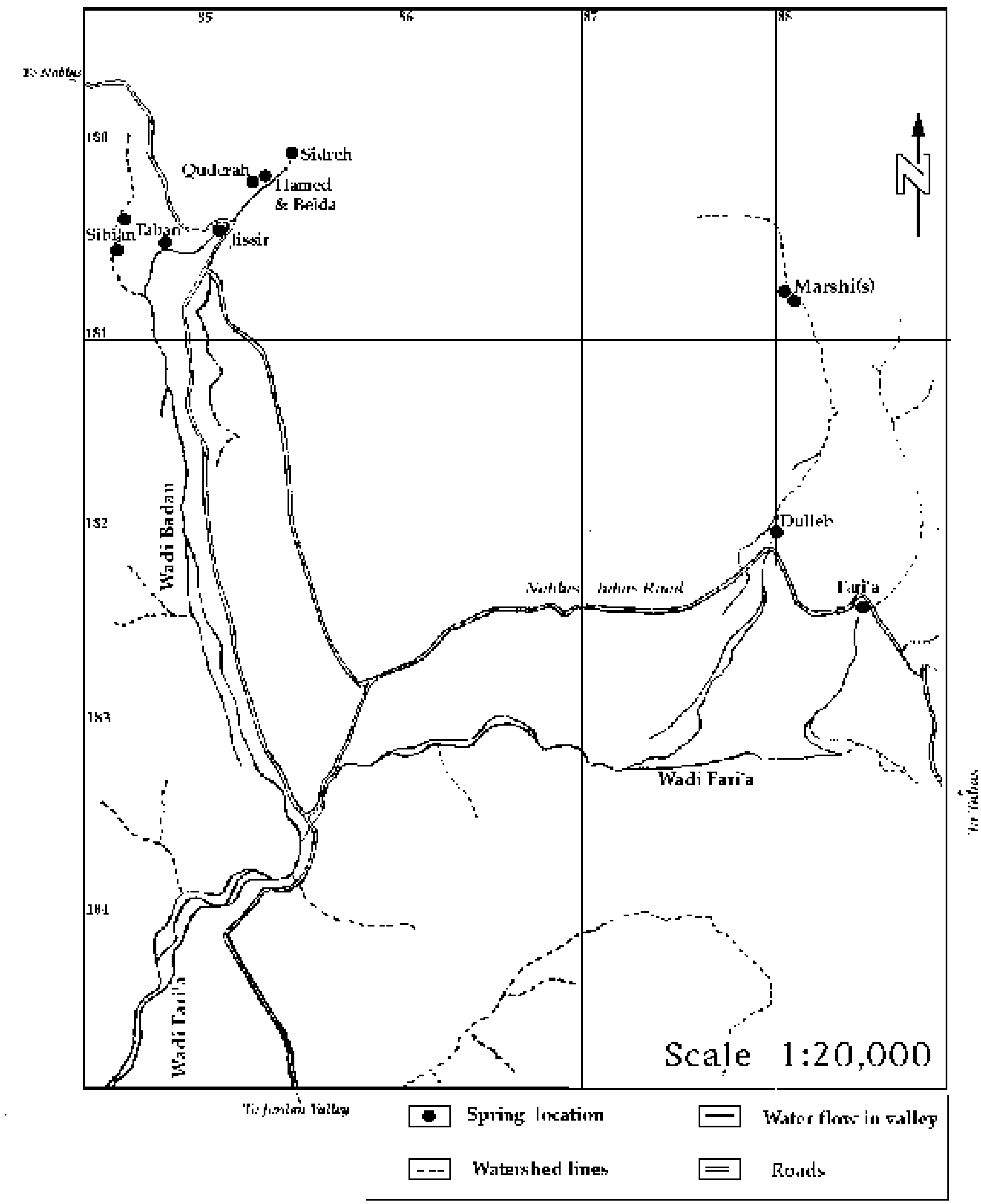


Figure 12: The upper parts of the Fari'a and Badan Valleys (Adapted from the Israeli Hydrographical Department, 1973)

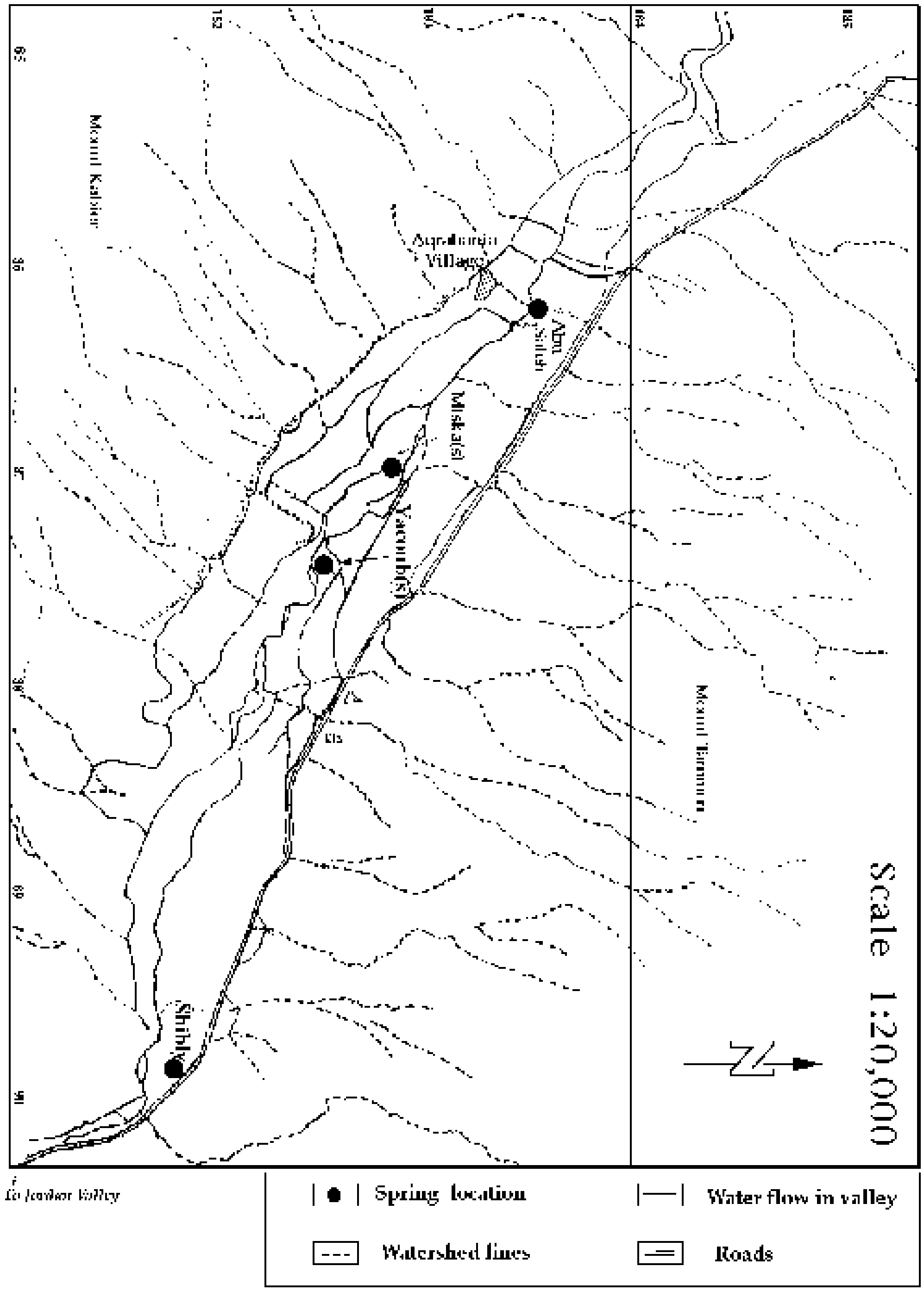


Figure 13: The central and lower parts of Wadi Fari'a (Adapted from The Israeli Hydrographical Department, 1973)

Climate

An agricultural weather station, which exists in the upper parts of the Wadi Fari'a provided information, though very limited, on the micro-climate of the area. As the Wadi Fari'a slope from an elevation of approximately 800 m above to less than 200 m below sea level, climatic elements, mainly temperature, evaporation rate, and rainfall, vary from the western to the eastern parts of the Wadi.

The average monthly air temperature in this area ranges from 15°C in the Winter to 31°C in the Summer. The upper temperature limits may reach an average of 39°C while lower limits reach an average of 9°C. The maximum temperature recorded between 1967 and 1981 was 48°C in the Summer and the minimum temperature was 3°C in the Winter (Records of the Israeli Meteorological Services).

Evaporation rates are relatively high in this area averaging 300 mm per month in the Summer, 120 mm in the Winter, and 180-240 mm in the intermediate seasons (Records of the Israeli Meteorological Services). Evaporation rates also vary with elevation, being higher in the lower parts of the valley. For example, the evaporation rate for the year 1962-1963 was 1,400 mm at an elevation of 250 m above sea level and 1,950 mm at the lowest level (358 m below sea level) of the Wadi Fari'a near the Jordan River (Rofe & Raffety, 1965).

Recent rainfall data for this area were not available. Old records, however, show that the average annual rainfall between 1969 and 1981 was 225 mm. The maximum amount recorded in this period was 424 mm and the minimum was 151 mm (Records of the Israeli Meteorological Services) (Table 10). Note that rainfall is limited to the Winter, mainly between the months of December and March.

Table 10: Monthly Rainfall in the Fari'a Valley in mm For the Years 1969-1981

	Y E A R											
Month	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81
Oct	7.6	0.0	0.0	0.7	0.0	0.0	0.0	6.7	23.7	12.4	27.9	0.0
Nov	10.3	9.1	51.02	23.8	41.8	25.9	1.7	49.7	0.0	18.7	37.8	0.0
Dec	12.6	41.1	68.0	27.7	11.0	35.0	26.4	7.8	91.7	50.0	106.2	65.3
Jan	64.6	53.9	49.3	60.1	204.1	13.5	25.1	35.1	18.5	26.9	52.3	68.5
Feb	4.0	35.7	51.9	2.0	60.4	79.0	15.2	3.7	12.0	16.3	43.2	25.6
Mar	47.8	20.3	67.5	52.8	84.4	22.3	49.5	26.9	23.0	54.6	70.0	29.0
Apr	17.7	78.4	14.1	0.5	22.6	7.5	41.5	21.5	0.0	0.0	7.5	19.0
May	0.0	0.0	0.2	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0
Jun	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Aug	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sept	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0
Total	164.6	238.5	302.1	167.6	424.3	183.2	174.0	151.4	168.9	178.9	344.9	207.4
Source: Records of the Israeli Meteorological Services												

Water Quality

During the site examination, water from five springs was tested as representatives of the more than 14 springs that are located in the area. Fari'a and Dulieb springs were tested as representatives of the Fari'a spring group, Quderah and Taban as representatives of the Badan spring group, and Shibly as representative of the Miska spring group. The selected springs are the largest in discharge and share the same tributary aquifers with other springs in their groups. Water quality of these springs, as seen in Table 11, was generally found suitable for aquaculture. As it emerges from underground sources, water is characterized by low levels of dissolved oxygen and high concentrations of carbon dioxide at locations near the headwater. Therefore, mechanical aeration of water may be required for aquaculture uses at sites close to the headwater.

Table 11: Water Properties1 of Selected Springs from the Fari'a, Badan, and Miska Groups August 1994

Water Properties	Fari'a[2]	Dulieb	Quderah[2]	Taban[2]	Shibly
Temp. (°C)	21	23	20	19	22.5
D.O. (ppm)	6.3	6.4	6.0	6.2	6.6
pH	7.3	7.6	7.4	7.3	7.3
CO_2 (ppm)	23	12	23	23	12
TAN (ppm)	ND	0.3	0.4	0.4	ND
NO_2^-N (ppm)	ND	ND	ND	ND	ND
T. alk. (ppm as $CaCO_3$)	310	264	240	244	284
T. hard. (ppm as $CaCO_3$)	328	315	276	264	320
Cl^- (ppm)	52	55	42	40	62
Turb. (m)	>1.5	>1.5	>1.5	>1.5	>1.5
TDS (ppt)	0.5	0.5	0.4	0.4	0.5

1 = Three samples were tested at each site. Tests were performed during daytime (10:00 - 16:00).
2 = Samples taken at spring's headwater, thus dissolved oxygen is low and CO2 is relatively high.

It was noticed that the Badan and Dulieb springs have higher concentrations of ammonia than other springs, which is of concern for aquaculturalists. Although the moderate value of the water pH decreases the percentage of the un-ionized toxic ammonia (See Appendix A), the presence of ammonia in the water may indicate possible pollution of the water source.

Fari'a Springs Group

The Fari'a spring group, which is the major contributor of the water in the area, consists of two springs, Fari'a and Dulieb. Both springs, which are located less than 1 km apart in the upper parts of the Fari'a valley, flow into Wadi Fari'a and continue with its course.

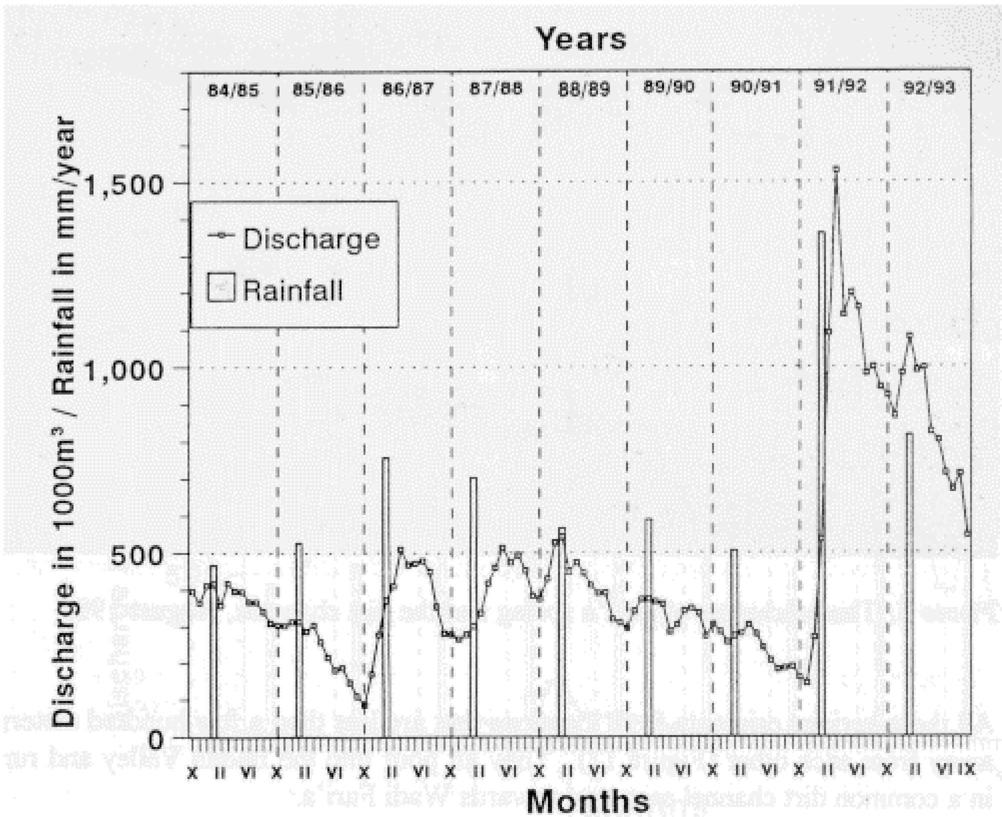
Fari'a spring is the second largest spring after 'Auja in regard to annual discharge. The spring discharge, averaging 6 MCM annually (Israeli Hydrological Services, 1988-1994) and is characterized by moderate seasonal fluctuation (Chart 6). It constitutes the main source of irrigation water for around 1,500 hectares of agricultural land cultivated with vegetables and orchard trees. It also provides drinking water for the Fari'a refugee camp and the neighboring communities.

A portion of the spring water is pumped through pipes to irrigate 600 hectares of the 1,500 hectares benefiting from the spring water. The remaining 900 hectares of land are irrigated by open-dirt channels, a system that causes the loss of large quantities of water due to seepage and evaporation (Photo 5).

The availability of water and the spread of agricultural land around the Fari'a spring encourage the introduction of aquaculture into this area where aquaculture systems may utilize irrigation or the spring's excess water.

In contrast, Dulieb spring is small in discharge, averaging 1 MCM annually. Its discharge is also affected by seasonality and variability in rainfall and has previously suffered from extended periods of dryness (Chart 7).

Chart 6: Monthly Discharge of Fari'a Spring for the Years 1984-1993*



*

See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

Badan Springs Group

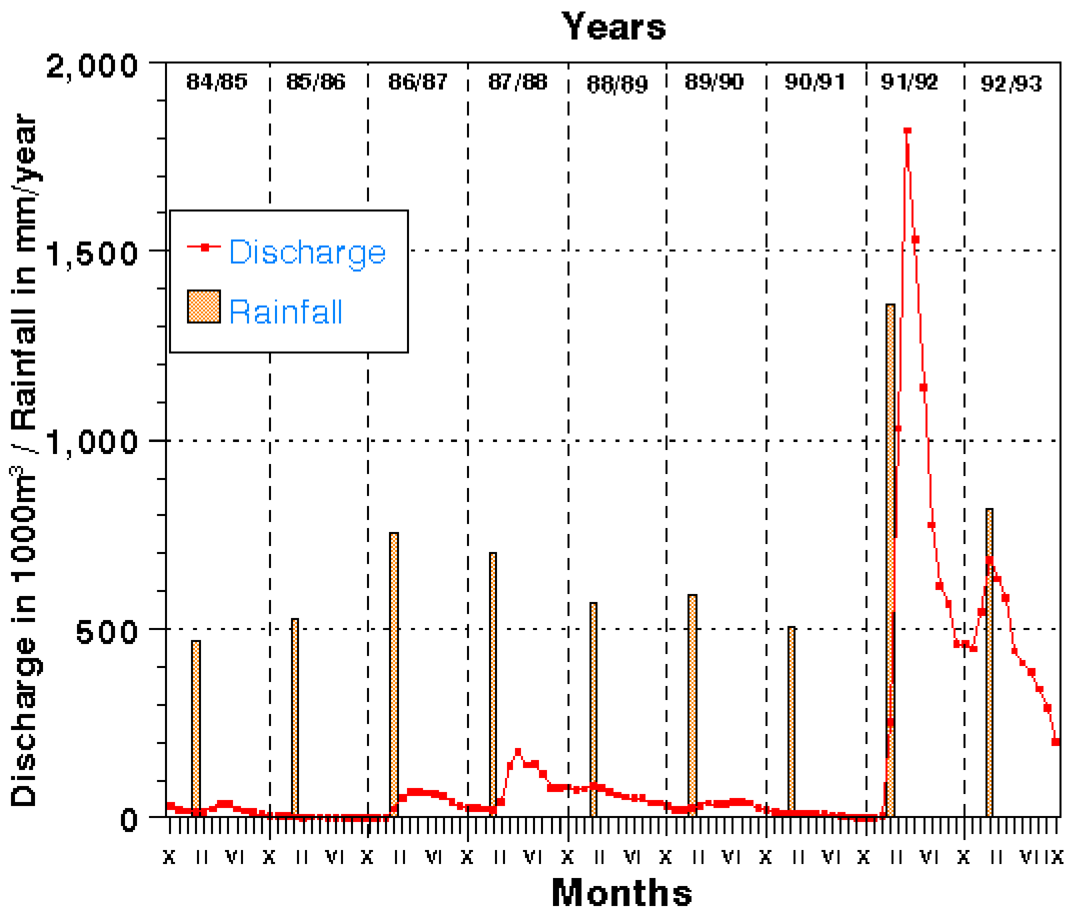
This group contains the seven springs of Sidri, Taban, Quderah, Jissir, As-Subian, Hamed, and Beida as well as the minor spring of Abu Zein.

Photo 5: The headwater of Fari'a spring and the dirt channels, August 1994

All these springs originate from locations that are less than a few hundred meters away from each other (Figure 12). They all pour into the Badan Valley and run in a common dirt channel eastward towards Wadi Fari'a.

The total average discharge of the Badan springs is estimated at 4.7 MCM annually (Table 12). Not all springs have equal flow and some of them dry completely in dry years. However, as these springs pour into a common water channel, continuous flow is maintained in the valley (Chart 8). Appendix B shows the discharge of each individual spring of the Badan group.

Chart 7: Monthly Discharge of Dulieb Spring for the Years 1984-1993*



* See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

The fluctuating discharge of the individual springs of the Badan spring group (Appendix B) discourages the dependency on a sole spring for the supply of water, especially Sidri, Quderah, and As-Subian.

Table 12: Total Monthly Discharge of Badan Springs Group in 1000 m^3
For the Years 1984-1993

	YEARS								
Months	**84/85**	**85/86**	**86/87**	**87/88**	**88/89**	**89/90**	**90/91**	**91/92**	**92/93**
October	293.7	183.3	155	408.3	406	335.5	289.3	180.9	738
November	244.2	178	156.6	376.7	369.4	292.6	233.2	178.1	618

December	208.1	115.6	185.2	359	370.8	242.7	194.9	296.4	991
January	216.8	154.8	384.1	352.4	342.1	217.8	192.8	942	1262
February	252.1	141.6	525.8	442	343.7	274.6	189.1	1496	1159
March	332.6	179.3	842.3	1065	447	350	258.2	2114	1251
April	339.8	177.1	814.9	933	528	359	301.6	1931	1100
May	344.4	170.7	696	893	476	367	311	1771	876
June	284.8	158.3	598.5	753	421	351	275.5	1458	777
July	229	147.4	550.4	694	418	346	256.1	1368	680
August	194.6	142.3	497.9	555	380	320	226.8	1203	580
September	172.7	137.1	441.6	435	340	300	189.9	1190	419
Total	3113	1886	5848	7266	4842	3756	2918	14128	10451
rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	4713	4552	4635	4776	4786	4752	4704	5078	5298

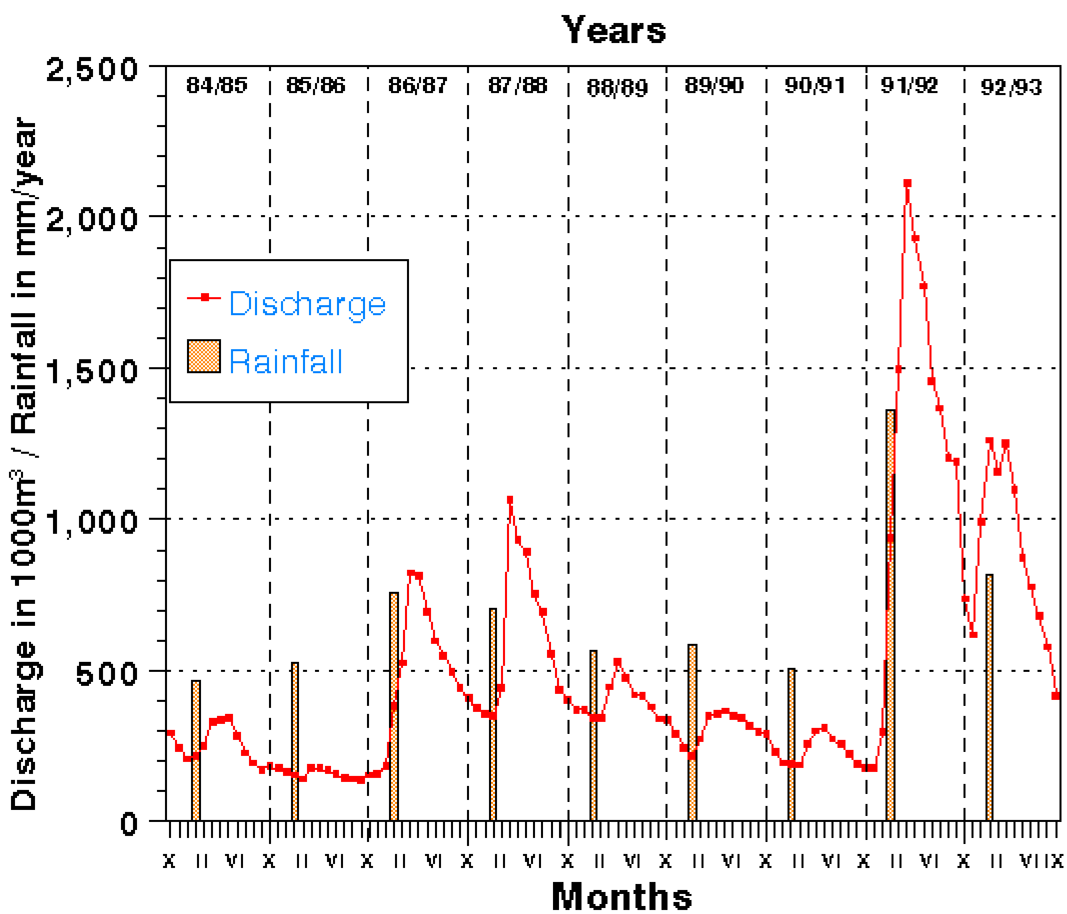
Source: Israeli Hydrological Services, 1988-1994.
* = Rainfall in mm/year. Data recorded in this table are for the Nablus area as no recent data for the Fari'a were found. Nablus is the closest area and also rainfall on its area constitutes the majority of the replenishment water for the springs' aquifers.
Source: Records of Nablus Agricultural Directorate.

The upper part of Badan valley, near the spring headwaters, is very narrow, highly cultivated and with relatively sharp slopes (Photo 6) which hinder the construction of large scale aquaculture projects. The use of the Badan springs water by several restaurants and a public swimming pool at this location further discourages aquaculture projects.

Photo 6: The narrow Badan valley and the water course of the Badan spring group, August 1994

As the valley heads eastward towards Wadi Fari'a, it slightly levels off and becomes less cultivated. Thus, though construction of commercial aquaculture projects is difficult in the upper part of the valley, it becomes more feasible at the lower parts. However, water quality and availability at the lower part of the

Chart 8: Monthly Discharge of Badan Springs Group for the Years 1984-1993*



* See appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

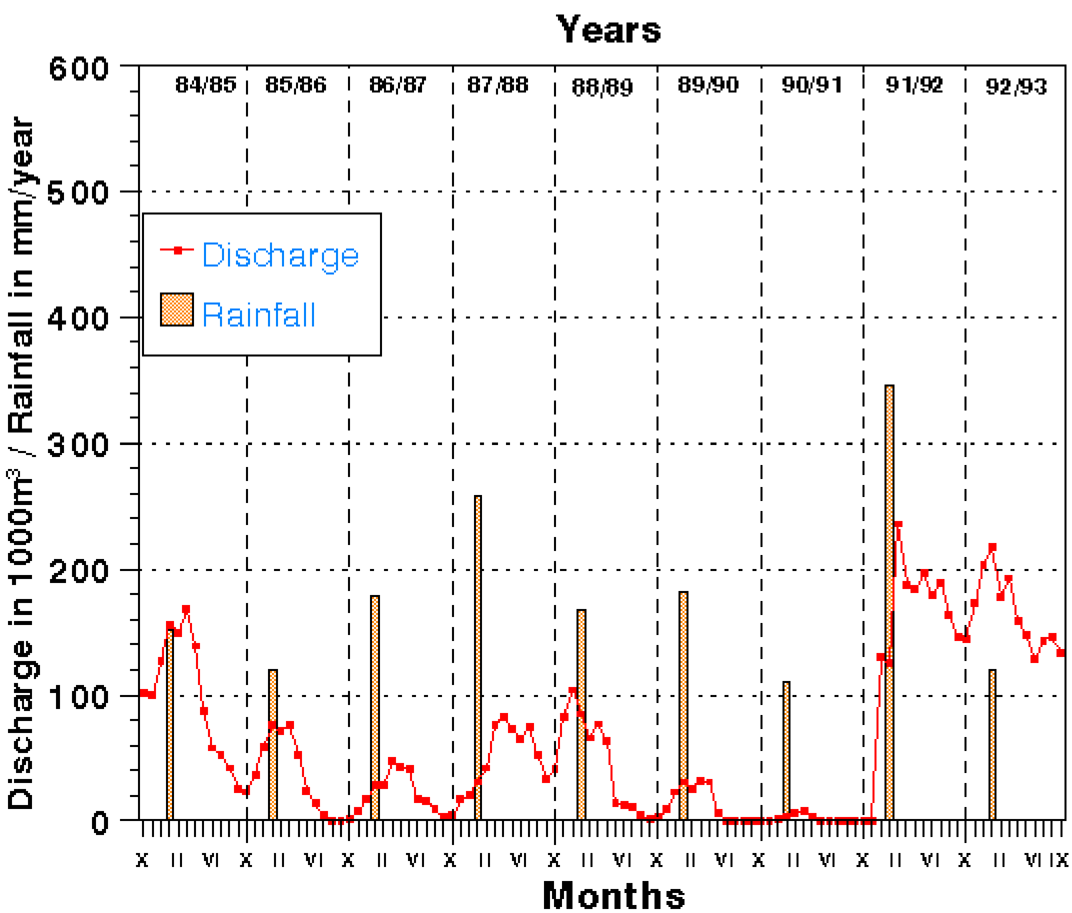
Badan valley are greatly affected by the upstream activities and consumption. Further monitoring and testing of the water flow in the valley are therefore essential to assess its viability for aquaculture.

Miska Springs Group

This group includes four major springs: Miska, Shibly, Abu Saleh, and Yacoub, which are located in the central and lower parts of the Wadi Fari'a (Figure 13). Miska and Shibly springs are by far the largest in discharge among the four springs and are monitored by the Israeli Hydrological Services. No data were available for the remaining two springs.

The Miska spring in itself is a name given to seven adjacent spring eyes located along the Wadi Fari'a in close locations which pour into a common water channel. The average discharge of the Miska spring eyes collectively is estimated at 1.4 MCM annually. However, the spring is characterized by high fluctuation in discharge and has been completely dry in various years (Chart 9).

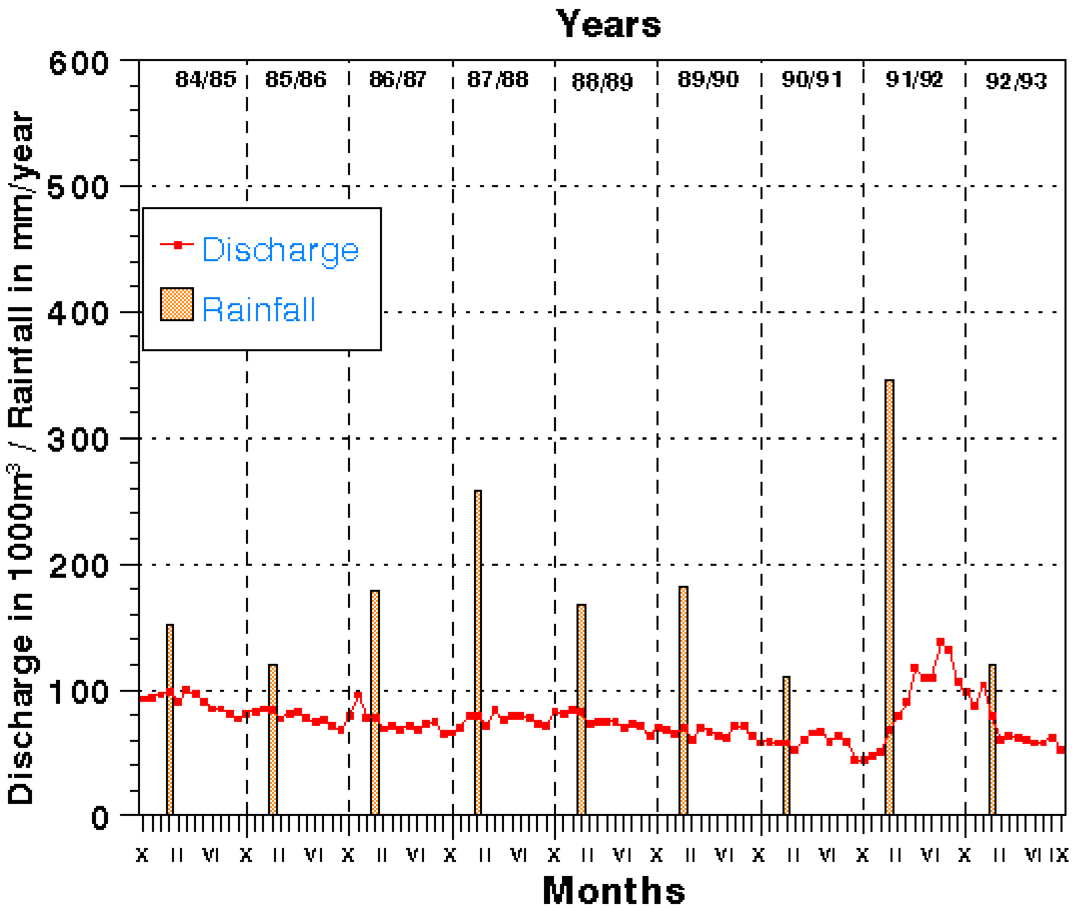
Chart 9: Monthly Discharge of Miska Spring for the Years 1984-1993*



* See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

In comparison, Shibly spring, though lower in discharge, maintained a relatively constant flow throughout the years (Chart 10). Its average annual discharge was estimated at 0.95 MCM (Israeli Hydrological Services, 1988-1994).

Chart 10: Monthly Discharge of Shibly Spring for the Years 1984-1993*



* See Appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

The Miska and Shibly springs irrigate vast areas of agricultural land, estimated at 200 hectares. Their water flows down the Wadi Fari'a in open-dirt and cement channels for a distance of around 10 km. Several irrigation ponds exist in this area to store water and accommodate the widely used drip irrigation systems. These two springs are also the sole source of drinking water for many villages and small communities around the valley where water is transferred to houses via trucks supplied with water tanks.

The richness of Wadi Fari'a in good water quality and the suitable warm climate encourage investment in aquaculture projects in the area. Although many of the springs in the area suffer from low discharge and seasonal flow, the multiple suppliers of each water channel in both valleys reduce risk of water shortfalls and seasonalities. Accordingly, for site selection, sites with multiple water sources and suitable topography such as the Fari'a, Miska, and Shibly are preferred over those of the Badan spring group.

As Wadi Fari'a is continuously under irrigated cultivation, there is a high potential for aquaculture systems which integrate with the existing irrigation systems.

Other Spring Groups in the Region

Two other major spring groups exist in the northern parts of the Eastern Slopes region, the Malih and Bardala. Appendix B lists the monthly discharge of several springs of these two groups.

The Malih group, which includes two springs, is classified as hot springs with water temperature as high as 38°C. The spring group is also characterized by relatively high salinity and TDS levels. The chloride level of these springs ranges from 147 to 1,387 ppm while the TDS ranges from 1 to 3 ppt (Rofe & Raffety, 1965). The salinity of these springs makes them unsuitable for irrigation.

The Bardala group includes more than 13 springs of considerable size which are scattered over a large area of the Wadi Bardala in the northeastern parts of the West Bank. The collective annual discharge of these springs is estimated at 2.7 MCM (Rofe and Raffety, 1965). On-site examination and water testing are required to determine the potential of the Malih and Bardala spring groups for aquaculture.

THE CENTRAL HIGHLANDS REGION

Topography

The Central Highlands region includes a range of mountains and their western slope areas (Figure 8). This range extends over the length of the central parts of the West Bank, from Jenin in the north to Hebron in the south (Figures 6, 7). The Central Highlands region constitutes a major part of the West Bank, covering an area of approximately 3,500 km2 of the West Bank total 5,600 km2. This predominantly mountainous region ranges in elevation from 400 m to more than 1,000 m above sea level (ARIJ, 1994). Most major wadis in the West Bank run either eastward or westward from this range (Figures 6, 7). The Central Highland region is the main catchment area of rain water which replenishes the entire West Bank underground water aquifers.

Climate

As the majority of the main cities in Palestine lie in this region, several weather stations exist in the Central Highlands. The Nablus weather station monitors the climate of the northern parts of the region; the Jerusalem and Bethlehem stations cover the central parts; and the El-Aroub and Hebron stations cover the southern parts.

The average temperatures vary slightly from one part of the region to another depending on the altitude. The Hebron and Ramallah areas, which include mountainous areas with elevations exceeding 1,000 meters above sea level (Figure 8), are characterized by lower temperatures than the remaining parts of the Central Highlands. The average monthly air temperature in these two areas was 8°C in the Winters and 26°C in the Summers between 1967 and 1981, with a maximum temperature of 38°C and a minimum temperature of -3°C (Records of the Israeli Meteorological Services).

In areas where altitude is below 1,000 m above sea level, the average monthly air temperature ranges from 10-12°C in the Winter to 22-23°C in the Summer (Records of the Israeli Meteorological Services). The maximum temperature recorded in these areas, between 1967 and 1981 was 40°C while the lowest temperature was -1°C.

The large difference between the upper and lower temperatures in this region limits the number of fish species suitable for culture. Warm water fish such as tilapia would hardly survive the harsh winters where the temperature continuously drops below 8°C, the minimum temperature tolerated by this species. In addition, frost and water freezing, though sporadic, occur on the Central Highlands thus reducing its suitability to warm water fish species. The high summer temperatures, on the other hand, do not permit the growing of cold water fish species such as salmon and trout.

Rainfall in the Central Highlands region varies from 400 to more than 700 mm a year (Figure 4). Rainy seasons are limited to the winter months when rainy days rarely exceed 80 days. Evaporation rates are lower here than in other regions. In the summer months, the evaporation rate averages around 200 mm per month while it reaches only 60-80 mm in the Winter and intermediate months. Evaporation rates also are lower in the northern parts of the region and increase towards the south.

Water Resources

The Central Highlands region is relatively poor in water resources. Although there is a large number of springs in this area, many are little more than seepage and not all are perennial. The approximately 315 known springs in this region have a total average annual discharge of less than 10 MCM (Al-Rabi & Tamimi, 1989), which is about the same as the average discharge of the 'Auja spring alone, located in the Jordan Rift region. Irrigation is not a common agricultural practice and the several existing underground water wells in this region are primarily utilized to satisfy domestic consumption.

There are approximately seven spring groups in the Central Highlands and they are mostly concentrated in the northern and central parts of the region. The largest of these groups is the Nablus group which consists of nine small springs: El-'Askar, El-'Assal, Beit El-Ma'a, Difna, Qaryon, Ras El-Ein, El-Fawwar, Sur, and Tell. These springs, which have a total average annual discharge of 1.2 MCM (Rofe & Raffety, 1965), are used for domestic water supply to the city of Nablus. It has also been reported that a number of springs in the Nablus group are polluted with coliform bacteria (Rofe & Raffety, 1965). However, no recent data were available for these springs.

The second largest spring group in the Central Highlands region is Sabastiya which includes 14 small springs with a total annual discharge of approximately 0.5 MCM. The largest of these springs is Zawata which is located around 6 km east of Nablus city.

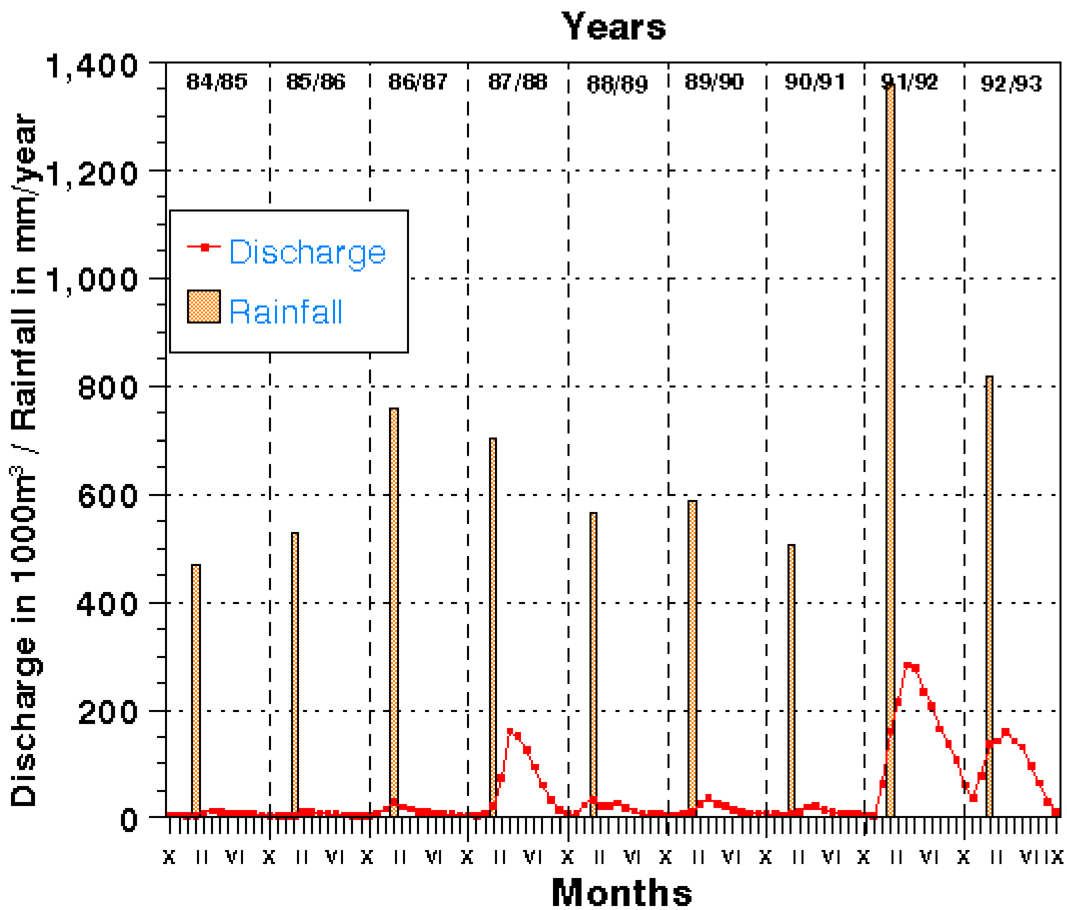
Zawata Spring

Zawata spring has an average flow of 390,000 m3 a year and is slightly affected by seasonality. The spring supplies Zawata village and the neighboring areas with both drinking and irrigation water. A portion of the spring water is utilized to irrigate a small area of land (about 1.5 hectares) via open-cement channels while the rest of the water is left unused (Al-Rabi & Tamimi, 1989) (Photo 7).

Photo 7: Zawata spring in Nablus area, August 1994

The good quality water of the Zawata spring (Table 13) makes it suitable for aquaculture. The dominance of agricultural land in the area and the presence of several water irrigation ponds may encourage integrated aquaculture/irrigation schemes. However, like many springs in Palestine, Zawata spring's discharge drops down during the summer and increases in the winter months. Between 1984 and 1993, the spring reached a low of 70,000 m3 per year (Chart 11). Thus the monthly supply of the spring does not support large scale aquaculture projects, however, backyard fish farming would be suitable in this area.

Chart 11: Monthly Discharge of Zawata Spring for the Years 1984-1993*



* See appendix B for discharge and rainfall data; (X = October, II = February, VI = June, IX = September)

Table 13: Water Properties of Zawata and Jaryout springs, and Solomon's Pools August 1994

Water Properties	Zawata[1]	Jaryout[1]	Solomon's Pools[2] sample1	Solomon's pools[3] sample[2]
Temp. (°C)	18	20	26 °C	25.7
D.O. (ppm)	7.2	8.2	7.2	7.1
pH	7.7	8	8	8
CO_2 (ppm)	8	5	ND	ND
TAN (ppm)	0.1	ND	0.6	0.6

NO_2^-N (ppm)	ND	ND	ND	ND
T. alk. (ppm as $CaCO_3$)	180	276	162	0.72
T. hard. (ppm as $CaCO_3$)	184	276	243	240
Cl^- (ppm)	22	21	86	86
Turb. (m)	>1.5	>1.5	1.1	1.5
TDS (ppt)	0.2	0.4	0.5	0.5

1 = Samples taken at spring's headwater, thus CO2 is relatively high.
2 = Sample 1 is taken from the side of the third pool at a depth of 0.7 m below water level.
3 = Sample 2 is taken from the middle of the third pool at a depth of 1.50 m below water level.

Jaryout Spring

Jaryout spring is located at the bottom of a valley east of Beitunyia village in the Ramallah area. The spring has an annual discharge of approximately 200,000 m3 (Al-Rabi & Tamimi, 1989) and is easily accessible by a newly constructed dirt road.
A stone structure and a small water storage pond are built around the spring site (Photo 8). A small portion of the spring's water is currently utilized for irrigation, while the remaining portion is wasted. The good water quality of Jaryout spring (Table 13) makes it suitable for aquaculture. Unfortunately, no

Photo 8: Jaryout spring in the Ramallah area, August 1994

data on the discharge history of the spring were available. The monitoring of the Jaryout spring or questioning of the local people may provide information on fluctuation or previous shortfalls in discharge.

Solomon's Pools

Solomon's Pools are three large water catchment pools located around three kilometers southeast of Bethlehem city in the central parts of the West Bank (Figure 7). The Pools were constructed in two stages between the years 2000 BCE and 30 EC. Each Pool, built of stone and masonry, is located at a considerably lower level than the one above it. Since their construction and until 1967, they were used to provide drinking water for the Jerusalem area.

An extensive system of ancient aqueducts which extends towards the Hebron area is the major supplier of water for these pools. The Wadi Arrub and Biyar aqueducts (Figure 14) gather the abundant waters of the springs of these wadis, as well as surface runoff water, and carry it to Solomon's Pools (Amiran, 1976). Two springs, Ein Saleh and Ein Burak, also supply these pools with water.

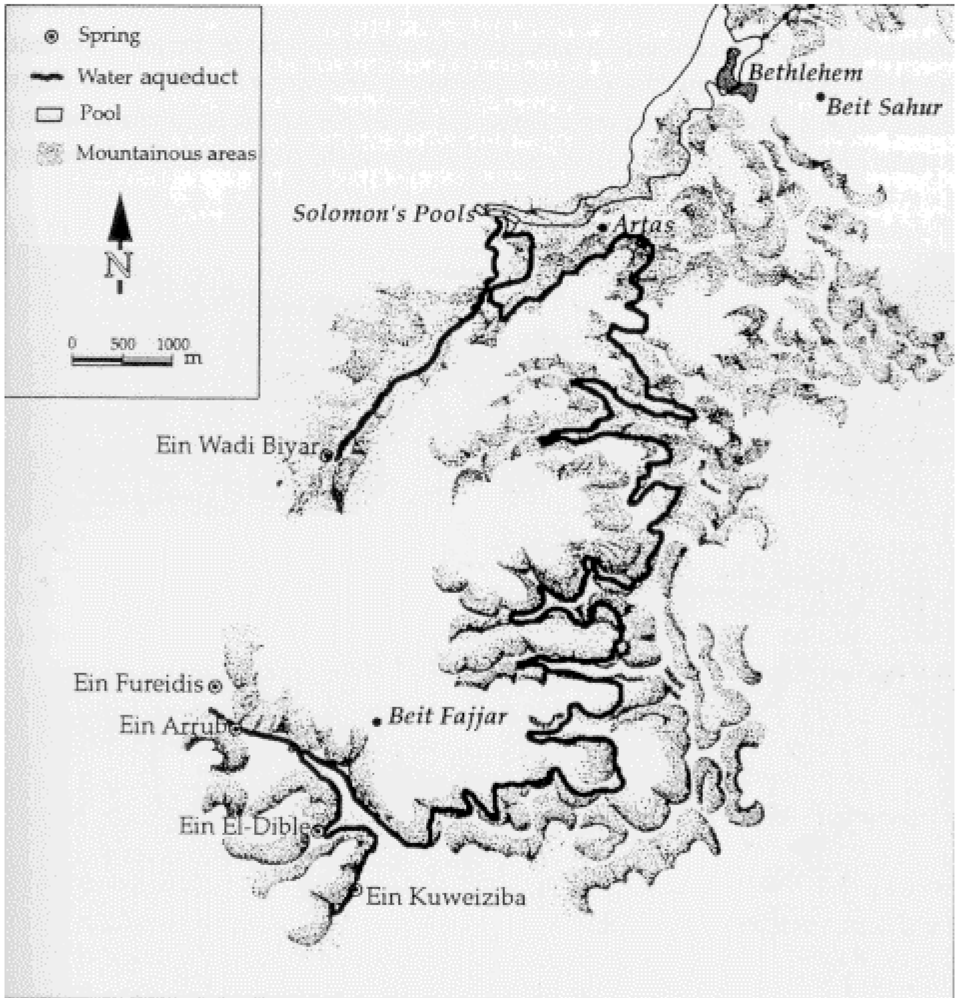


Figure 14: The aqueduct water feeding system of Solomon's Pools (adapted from Amiran, 1976)

The capacity of each of Solomon's Pools is estimated at 160,000 m3 of water (Muhaisen, 1993). Each pool is approximately 160 m in length, 50 m in width and 20 m deep. Data regarding the fluctuation of the water level in these pools are not available.

Solomon's Pools are currently neglected, and are in miserable shape. The fence around the pools is torn; the pools are leaking; the water is filthy and full of leaches, snakes, and diseased organisms; car skeletons and trash are abundant in the water (Photo 9). Nevertheless, testing water of the Solomon's Pools quality under the parameters defined earlier (chapter one) showed chemical and physical properties suitable for aquaculture (Table 13). This may be attributed to the enormous biological activity in the water due to its richness in protozoa, zooplankton, and high oxygen-producing algae. However, further water testing for heavy metals, pesticides, and other toxic chemicals is essential as car parts, possibly lead batteries, and other garbage are dumped in the Pools without regulation. Under the current conditions, Solomon's Pools are not recommended for aquaculture as the filthiness of the water may affect fish health and induce diseases.

Photo 9: The Solomon's Pools, August 1994

All three Solomon's Pools are currently inhabited by wild species of fish. The depth of these pools makes it difficult to utilize them as fish containers for an aquaculture system, unless for cage aquaculture. However, these pools can certainly provide enough water for an aquaculture project in the area. Water may have to be treated for diseases before utilization for aquaculture. Aquaculture projects built in the Artas valley east of the Pools may secure a gravity-driven water supply. The effluent water from the aquaculture system may be used to irrigate the intensively utilized agricultural areas in the valley.

The Pools, an Islamic Waqf property (the government-recognized national Islamic institution), were rented to the Arab Jerusalem municipality in 1929 for the purpose of maintaining water supply to Jerusalem (Muhaisen, 1993). After the Israeli military occupation of the West Bank in 1967, the new Israeli Jerusalem Municipality cited this renting contract and claimed their rights to the Pools (Muhaisen, 1993). Palestinian utilization of Solomon's Pools or their water is currently prohibited. The pools are deserted and their water is left unused. Access to this water resource may be available after the implementation of the Israeli-Palestinian Peace agreement.

Other Water Resources

Several other water resources, minor to those mentioned in this study, may constitute viable sites for aquaculture endeavors. However, visiting all of the potential water resources and examining their feasibility were not possible within the time limit of this study. The monthly discharge of a number of these water resources can be found in Appendix B.

Potentials for Aquaculture

The absence of irrigated farming and the relative scarcity of water in the Central Highlands will hinder the development of commercial aquaculture projects in this region. Water wells and many of the large-flowing springs in the region are predominantly used for domestic consumption. Other springs amount to little more than seepage.

The wide differences in the upper and lower air temperature limits in the Central Highlands are another obstacle to open-system aquaculture. Selecting a fresh water fish species that may tolerate temperatures below freezing as well as adjust to temperatures above 30°C adds to the complexity of the situation.

THE SEMI-COASTAL REGION

The Semi-Coastal region is the smallest of all West Bank regions with an area of approximately 400 km2 (ARIJ, 1994). It comprises the northwestern parts of the West Bank including parts of the Jenin and Tulkarem districts (Figure 8). Climate-wise, this region is considered an extension of the Mediterranean coastal region with elevation varying between 100 to 400 m above sea level.

The Semi-Coastal region is characterized by extensive plains which are highly cultivated with vegetables and field crops. Unfortunately, little information was found about this region which made it difficult to investigate its potential for aquaculture. The 15 springs existing in this region have a total average discharge of 0.35 MCM per year. Almost all of them are used for domestic consumption (Al-Rabi & Tamimi, 1989).

Many groundwater wells exist in this region. In Tulkarem and Qalqilya, there are approximately 70 water wells with an allowable water pumping quota of 20 MCM per year. However, "Out of the 70 small wells, at least 60 are in a desperate state" (Awartani, 1992). Thus, most of these wells are in bad condition and run with minimum efficiencies.

Three weather stations, Meithalun, Beit Qad, and Tulkarem, are located in the semi-coastal region. Although these are located at different elevations, 400, 200, and 65 m above sea level respectively, they provide similar climatic data.

The average air temperature in this region between 1967 and 1981 was 10-12°C in Winter and 25-27°C in Summer. The maximum temperature was 46°C, in May, and the minimum was -2°C, in January. The minimum monthly average temperature reached 7°C in the Winter and the maximum was 34°C in the Summer (Israel Meteorological Services, 1993).

The average annual rainfall recorded from 1967 to 1981 was 414 mm in the northern parts of the Semi-Coastal region and 621 mm in the Tulkarem area. Evaporation is high in this region reaching an average of 200 mm per month in the Summer, 80 mm in the Winter and 110-150 mm in the intermediate months of the year (Israel Meteorological Services, 1993).

Regardless of water quality and availability in the region, the vast difference of approximately 46°C between the maximum and minimum temperatures is a major concern. Only fish species which can tolerate wide range of temperature are suitable for aquaculture in this area. The lack of more detailed information regarding water resources and topography prevents the making of any recommendations regarding the potentials of this region for aquaculture.

THE COASTAL REGION OF THE GAZA STRIP

The Coastal region of the Gaza Strip is a narrow stretch of land which borders the eastern extremity of the Mediterranean Sea. It is small in size, with an area of approximately 365 km2; 45 km in length and 5-12 km in width (Bruins et al., 1991). The region is characterized by flat plains and sandy soil with few mounds of less than 80 m of elevation above sea level.

Climate

Being close to the Mediterranean Sea, the Coastal region of the Gaza Strip is affected by the moderate Mediterranean climate. The temperature difference between the winter and the summer months is thus minimal (Table 14).

Table 14: Average Monthly Temperature in the Coastal Region of the Gaza Strip in °C For the Years 1970-1985			
Month	**Lower limit**	**Upper limit**	**Average**
January	9.2	17.9	13.6
February	10.2	18.3	14.3
March	11.7	20.5	16.1
April	14.2	22.7	18.5
May	17.3	24.3	20.8
June	19.1	26.9	23.0
July	21.5	27.0	24.3
August	21.9	29.2	25.6
September	20.6	28.6	24.6
October	17.6	26.6	22.1
November	14.5	23.2	18.9
December	10.9	18.7	14.8
Mean summer Temperature	19.7	27.1	23.4
Mean winter Temperature	11.8	20.0	15.9
Source: Al-Afifi, 1992			

The average annual rainfall in Gaza is estimated at 300 mm. The northern parts of the region enjoy higher rainfall rates of approximately 350 mm per year while the southern parts, affected with the semi-arid climate of the nearby Negev desert, suffer from low rainfall of approximately 150 mm per year (Figure 5). The total amount of rainwater falling on the Gaza Strip is estimated at 125 MCM per year (ARIJ). Evaporation rates in the Coastal region are high, averaging 1300 mm/year (Bruins et al., 1991).

Topography and Soil

The landscape in the Coastal region of the Gaza Strip is primarily flat with elevations ranging from sea level to 80 meters above sea level in the northwestern and central southern parts (Palestine Environment Protection National Authority, 1994). This region has predominately sandy soil (Figure 15). Sandy beaches and sand dunes are concentrated in the coastal belt in the western parts of the Gaza Strip. A considerable portion of this sandy area has been cultivated with citrus and vegetables (ARIJ 1994). The eastern parts of the Gaza Strip are characterized by deep layers of loessial sandy to loess soil in the south and clayey in the north. Alluvial soils are abundant in the mostly-cultivated wadis in the northeastern parts of the region. These parts are also characterized by good quality water relative to the other parts of the Gaza Strip.

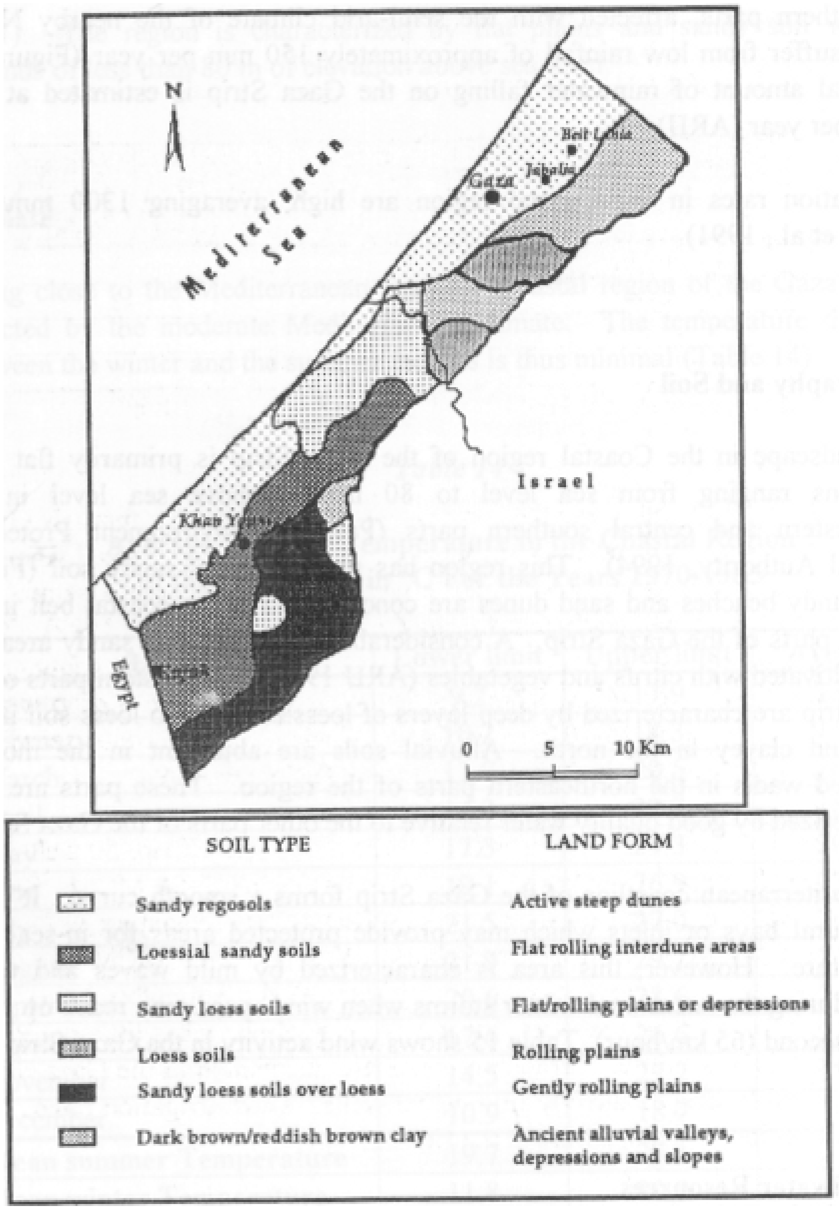


Figure 15: Soil type and land forms in the Coastal region of the Gaza Strip (Adapted from Palestine Environment Protection National Authority, 1994)

The Mediterranean coastline of the Gaza Strip forms a smooth curve. It lacks any natural bays or inlets which may provide protected areas for in-sea cage aquaculture. However, this area is characterized by mild waves and winds except during the occasional winter storms when wind speed may reach up to 18 meters/second (65 km/hour). Table 15 shows wind activity in the Gaza Strip.

Groundwater Resources

The Coastal region of the Gaza Strip lacks a permanent supply of surface water or springs. The only source of fresh water in the Gaza Strip is the Gaza aquifer.

Table 15: Wind Speed and Direction over the Gaza Strip Coastal Area

Month	Wind Direction	Average Wind Speed at noon (meters/second)	Maximum wind speed at noon (meters/second)
January	**Southwestern**	4.2	18
April	**Northwestern**	3.9	13
July	**Northwestern**	3.9	7
October	**Northern**	2.8	11

Source: Palestine Environment Protection National Authority, 1994

Although in years of heavy rain temporary runoff streams flow through Gaza Strip wadis, almost none of their water is captured (JMCC, 1994). Rainfall infiltration and underground flow from the Negev area in the southeast are the main sources of water replenishment for the Gaza aquifer (Al-Afifi, 1992). The annual potential of the Gaza aquifer is 60-80 MCM. At present, the continuous overpumping of 100-120 MCM from this aquifer has resulted in a drop in the water table at a rate of 15-20 cm per year. Such a drop permits seawater intrusion and increased brackishness of the aquifer (Schrader, 1994).

Out of the nearly 1,900 existing Palestinian wells in the Gaza Strip, 50 wells are used for domestic purposes with an annual consumption of 20-30 MCM. Small amounts of water are used of industrial purposes. The remaining wells are primarily used for irrigation which consumes a total of 50-66 MCM per year (JMCC, 1994). Thus, the annual share of each of the agricultural wells is approximately 0.03 MCM per year. Such a quantity of water has little potential for commercial aquaculture. Irrigation ponds are uncommon in the Gaza Strip as farmers tend to irrigate directly from water wells. Thus, irrigation ponds are not a viable option for aquaculture in the Coastal region.

A large portion of the underground water in the Gaza Strip is highly contaminated by irrigation run-off and sewage sources. The unregulated use of pesticides and fertilizers and the accumulation of sewage in cesspools has led to the infiltration of both organic and inorganic contaminants into the groundwater especially due to the shallowness and sandy top cover of the Gaza aquifer.

A study by Isaac and others in 1993 shows elevated levels of TDS, K^+, SO_4^{-2}, and HCO_3^- in the Gaza aquifer, especially the central and southeastern parts. Bruins and co-workers reported in 1991 that all Gaza Strip wells had nitrate (NO_3^-) levels ranging from 35 mg/l up to 150 mg/l (Figure 16). According to World Health Organization, a maximum level of nitrate in drinking water should not exceed 45 mg/l (Bruins et al., 1991). No data were available for ammonia levels in the Gaza aquifer, but with this level of contamination, they are expected to be high as well.

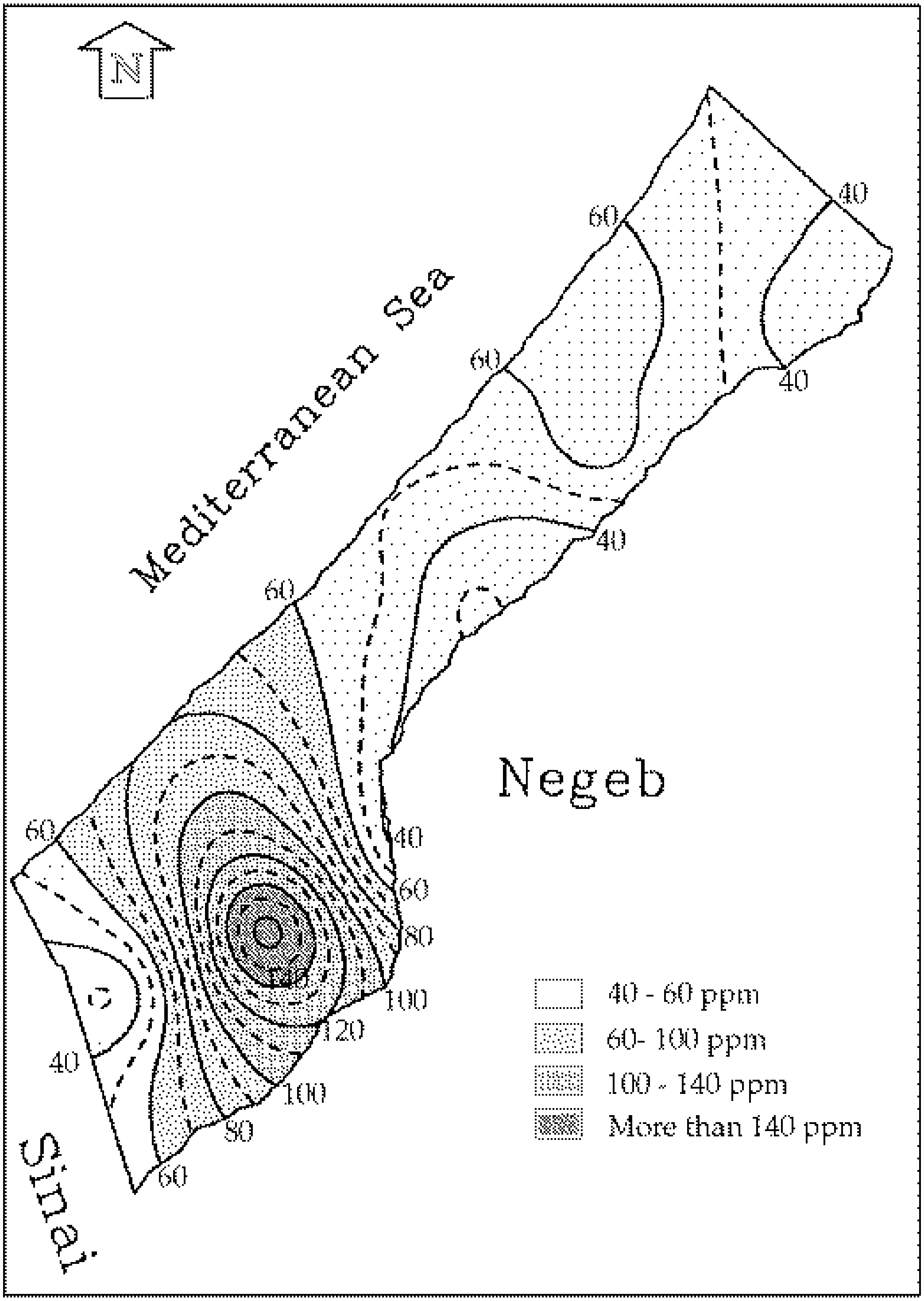


Figure 16: Nitrate levels in the Gaza aquifer in ppm (Adapted from Isaac et al., 1993)

Although tolerated by fish at elevated concentrations, continuous exposure to nitrate in levels as high as that of the Gaza aquifer may eventually affect fish health. The combination of nitrate and potassium in the water and the formation of potassium nitrate is also reported to have a toxic effect on fish (Alabaster & Lloyd, 1982).

The declining level of the underground water table in the Gaza aquifer has led to the intrusion of sea water into the aquifer and increased water salinity. Underground infiltration of saline water from the southeastern borders of the Gaza Strip also contributes to the aquifer's salinity (Figure 17). Currently over 60% of the water in the Gaza aquifer has a chloride level of above 330 ppm (Schrader, 1994) rendering them unsuitable for both agricultural and domestic uses.

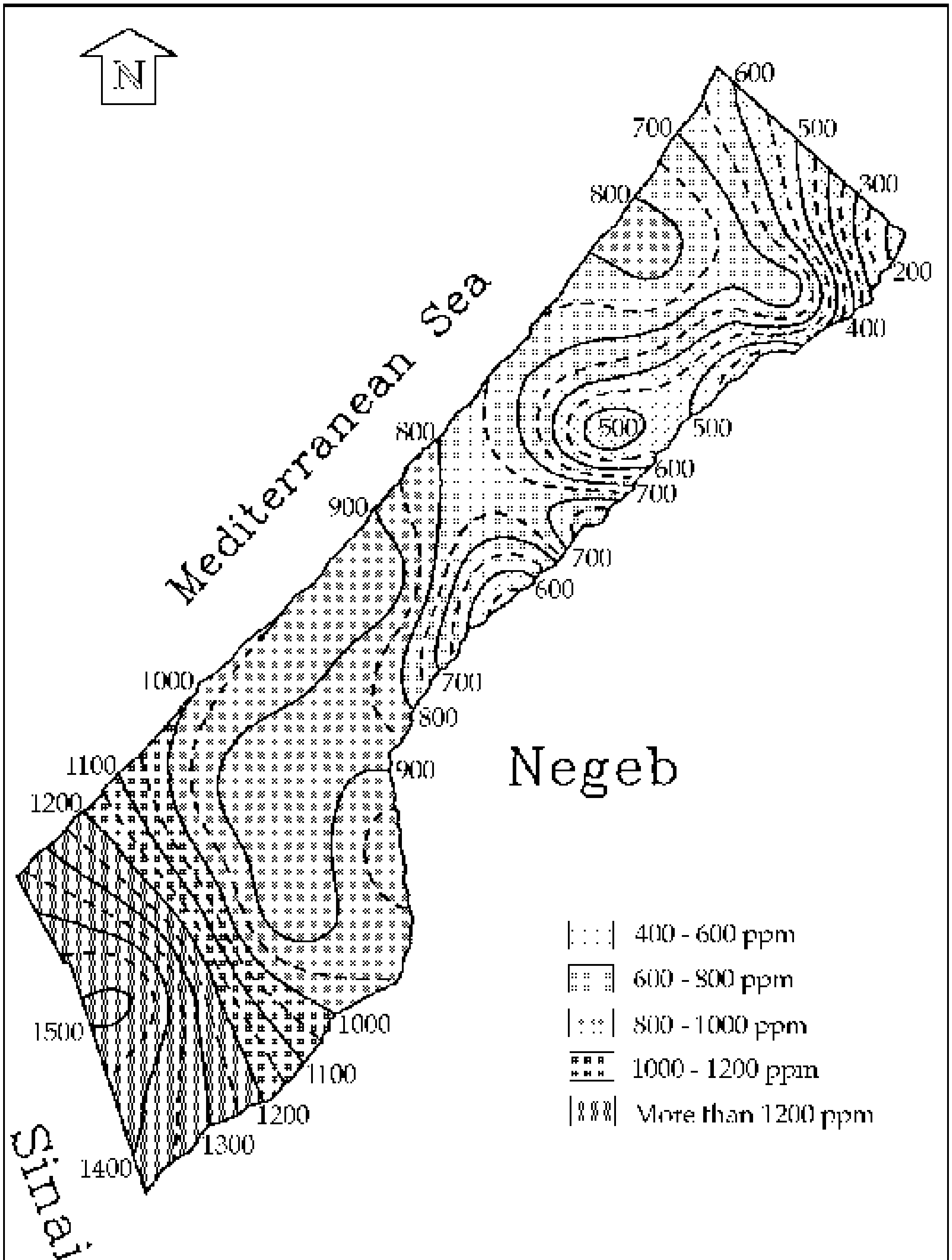


Figure 17: Chloride concentration in ppm in the Gaza aquifer (Adapted from Isaac et al., 1993)

The Gaza aquifer in the Coastal region is not an ideal water resource for aquaculture. Although various fish species can tolerate high salinities, contaminants in the water may prevent the utilization of this water for aquaculture purposes. Nevertheless, water quality differs considerably from one part of the

Coastal region to another. Water testing for ammonia, pollutants and pathogens is essential for each part of the Gaza Strip to determine its potential for aquaculture.

Marine Water

As the Coastal region of the Gaza Strip borders the Mediterranean Sea, seawater is a second resource for aquaculture. After the May 1993 treaty with Israel, Palestinians gained more control of and less restricted access to the Gaza coast (Figure 2) which may encourage investment in this area. However, various environmental factors, stated on pages 17-21, especially those related to sewage and oil pollution, remain an obstacle for marine aquaculture in the Gaza Strip. Although seawater properties, as tested in August 1994, do not reveal a strong impact by these pollutants (Table 16), rapid deterioration of the Gaza Strip coastal zone is expected. Large scale investment in marine aquaculture on the Gaza Strip coast is not recommended unless an efficient coastal environment conservation program is established.

Table 16: Water Properties in the Gaza Strip Coastal Area August 1994

Water Properties	at hour 12:00*	at hour 18:00*
Temp. (°C)	26	31
D.O. (ppm)	8.4	8.3
pH	8.3	8.3
CO_2 (ppm)	ND	ND
TAN (ppm)	1.0	1.0
NO_2^-N (ppm)	ND	ND
T. alk. (ppm as $CaCO_3$)	162	160
T. hard. (ppm as $CaCO_3$)	1230	1200
Cl^- (ppm)	>10ppt	>10ppt
Turb. (m)	>1.5	>1.5
TDS (ppt)	>10	>10

* = Both samples were taken from a location 200 m from shore and at a depth of 3.5 m.

Water testing revealed relatively high total ammonia nitrogen (TAN) levels in the seawater probably due to sewage discharge into the Mediterranean Sea. Such TAN levels require special attention when designing in-shore or in-sea marine aquaculture projects. Biological examination for pathogens in the water is also essential as the discharge of untreated sewage into the Mediterranean may increase the density of coliform bacteria and other microorganisms to critical disease-inducing densities.

Marine water may still constitute a viable source for cage aquaculture in contaminant-free areas that may exist deep in the sea. Sea bass, striped mullet, and sea bream are three potential fish species for aquaculture that are well adapted to the area and demanded by local consumers (Pearson & Davis, 1994).

Although TAN levels may be lower in areas far from the many sewage outlets along the coast (Figure 3), the planned projects for the Gaza Strip may not guarantee a continuous safe supply of good quality seawater.

Potentials for Aquaculture

The scarce and contaminated freshwater resources in the Coastal region undermine the Gaza Strip's viability for aquaculture. Lack of water reservoirs and irrigation ponds reduces the potential for integrated aquaculture/irrigation systems similar to those in the Jordan Rift area. The dominant sandy soils in most parts of the Gaza Strip will cause further difficulty in constructing pond systems for aquaculture. Use and maintenance of plastic liners to prevent water seepage in ponds add to production costs and may render aquaculture economically unfeasible.

The northeastern parts of the Gaza Strip, which are characterized by clayey soil and better water quality, may constitute a nucleus for aquaculture projects. However the good quality water in this area is scarce and highly demanded for human consumption, thus spending it on aquaculture may not be wise.

Utilization of seawater for marine aquaculture is more viable than for freshwater aquaculture in the Gaza Strip. Cage aquaculture in areas deep in the sea is more favorable than seawater-supplied in-land ponds or tanks. Although the Gaza Strip coast is contaminated by sewage, areas deep in the sea may be less affected.

The lack of marine environment monitoring and conservation programs, especially with the ongoing industrial and port development projects planned for the Gaza Strip, hinders large scale investment in marine aquaculture. Further examining seawater quality, testing for pathogens, and monitoring algal blooms are essential to assess the area's potential for aquaculture.

CONCLUSION

Developing the aquaculture industry in Palestine did not seem urgent until a few years after the Israeli occupation in 1967. Limitations on the fishing industry in the Gaza Strip as well as the lack of a supportive infrastructure have led to the drastic decline in fishery catch (pages 15-16). Today, although many obstacles were removed as the Palestinian National Authority took over the Gaza Strip, the increased contamination of the coastal zone comprises a major threat to the development of the fishing industry and survival of the marine fish stock (pages 17-21).

Recently, there has been increased interest in introducing aquaculture in Palestine. The need to enhance the nutritional status of and to create job opportunities for Palestinians have deepened such interest in aquaculture. Several local and international non-governmental organizations are currently trying to incorporate aquaculture into their programs in Palestine. Although, natural resources in Palestine appear to have a potential for aquaculture, no substantial scientific survey or preparation has yet been done to examine the viability of these resources.

Palestine is divided into five regions of distinctive climate, water availability and topography. During the field examination, selected sites of ample water resources in each region have been visited to determine their adequacy for future aquaculture projects. Two of these regions, the Jordan Rift and the northern parts of the Eastern Slopes, have been identified by this study as suitable for warm freshwater aquaculture (pages 31-74). Fish species such as tilapia, carp, and catfish are likely to be most suitable for culture in these two regions. The richness in good quality water, adequate climate, and appropriate landscape of these two regions permit the introduction of relatively large scale aquaculture projects. In the Jordan Rift and Eastern Slopes regions available water is intensively utilized for irrigation. Aquaculture projects which can be integrated with the existing irrigation systems may easily be adopted. Spring fed flow-through ponds or tanks with small water evaporation surface area are recommended.

Water sites in the Central Highlands and the Semi-Coastal regions of Palestine, although greater in number, contribute a small portion to the total water supply. The generally low annual spring discharge and the limited access to groundwater prevents the introduction of large scale aquaculture projects into these two regions. The absence of irrigated agriculture and water reservoirs adds further limitations to their viability for aquaculture. In addition, few fish species may survive under the wide temperature fluctuation between seasons in these two regions (pages74-84).

In the Coastal region of the Gaza Strip, the scarce freshwater resources are highly polluted with sewage and agricultural run offs, rendering them unsuitable for aquaculture (pages85-95). Marine aquaculture, however, may constitute an alternative. The Gaza Strip provides the only access to seawater in Palestine. Offshore cage culture may prove successful as the coastal areas are rarely exposed to strong winds. Sea bream, striped mullet, and sea bass are three endemic species that may be cultured off the Gaza Strip coast. Utilizing seawater to supply in-shore aquaculture systems in the Coastal region may be unfeasible. The Gaza Strip coastal area suffers from severe contamination from sewage discharge into the Mediterranean Sea. Further contamination from oil and industrial wastes is expected in the near future after the completion of a modern seaport and industrial parks in the Gaza Strip.

This study is only a first step in exploring the potential of aquaculture in Palestine. My limited water analysis capabilities and the diverse geographical and climatic zones did not allow a comprehensive examination of all potential sites in this study. Furthermore, site-specific examination of water quality, discharge, topography, and related factors is essential before determining the adequacy of the site for aquaculture. It is anticipated that this research will initiate further study of Palestine's resources and lay the basis for introducing aquaculture in Palestine.

References

1. Abed El-Razeq, U. & M. Abu Saleh, **Agricultural Ponds in the Jordan Valley (in Arabic)**, The Rural Research Center of An-Najah National University, Specialized Studies Series No. 25, West Bank, November 1991.
2. Abu Sa'da, Hawash & Qumsyieh, **Water in Palestine (in Arabic)**, Volume 5 of the series: Environmental Public Awareness, edited by Dr. Jad Isaac, The Franciscan Press, Jerusalem 1992.
3. Alabaster, J.S. & R. Lloyd, **Water Quality Criteria for Freshwater Fish**, Butterworth Scientific, second edition, Britain, 1982.
4. Al-Afifi, J., **Water in the Gaza Strip - sources, utilization and problems (in Arabic)**, The Arab Thought Forum, Jerusalem, November 1992.
5. Al-Rabi, A. & A. Tamimi, **A Guide to the West Bank Springs and their Hydrology (In Arabic)**, published by the Palestinian Agricultural Relief Committees (PARC), Jerusalem 1989.
6. Amiran, R., ***The Water Supply of Israelite Jerusalem***, in **Jerusalem Revealed - Archaeology in the Holy City 1968-1974**, edited by Yigael Yadin, The Israel Exploration Society, Jerusalem, 1975.
7. ARIJ, **Dry Land Farming in Palestine**, ARIJ, Jerusalem, 1994.
8. Awad, M., **Fish Resources in Gaza Strip (in Arabic)**, Rural Research Center, AnNajah National University, Technical Publication Series No. 14, June 1987.
9. Awartani, H., **Artesian Wells in Palestine; Present Status and Future Aspirations (in Arabic)**, Palestine Hydrology Group, Jerusalem, 1992.
10. Balarin, D. & J. Hatton, **A Guide to Their Biology and Culture in Africa**, University of Stirling, Stirling, 1979.
11. Blakely, D. & C. Hrusa, **Inland Aquaculture Development Handbook**, Fishing New Books, UK, 1989.
12. Boyd, C., **Water Quality in Ponds for Aquaculture**, Birmingham Publishing Co., Alabama, USA, 1990.
13. Bruins, H. J., A. Tuinhof & R. Keller, ***Water in the Gaza Strip***, a report published by the Ministry of Foreign affairs of the Government of the Netherlands, September, 1991.
14. Commission of the European Communities, ***Working Paper on the Specific Environmental Problems on the South East Mediterranean Coastal Region***, prepared by the Working Group for Environment of the Middle East Peace Process, October 1993.
15. Conte, F., **Evaluation of a Freshwater Site for Aquaculture Potential**, Western Regional Aquaculture Center (WRAC) , Publication No. 92-101, 1992.
16. Delince, G., **The Ecology of the Fish Pond Ecosystem**, Kluwer Academic Publishers, Netherland, 1992.
17. ESCWA, ***Rehabilitation of the Agricultural Sector in the Occupied Palestinian Territories***, a report published by United Nations Economic and Social Council, 1993.
18. FAO, FAO AGROSTAT Database, Agrostat P.C. 2, 1992.
19. Government of Israel, **Agreement on the Gaza Strip and the Jericho Area**, Ministry of Foreign Affairs, Jerusalem, 1994.

20. Helfrich, L., G. Pardue & P. Bromley, ***Solutions to Common Farm Pond Problems***, Virginia Cooperative Extension Service, Publication 420-019, 1994.
21. Hutton, L., **Field Testing of Water in Developing Countries**, Water research Center, University of Technology, England, 1983.
22. Isaac, J., V. Qumsieh & H. Zarour, ***Hydrochemical Indicators of the Severe Water Crisis in the Gaza Strip,*** a paper submitted by ARIJ to the "International Symposium on Water in the Middle East: Technical and Institutional Aspects" at the University of Illinois at Urbana-Champaign, October 25-28, 1993.
23. Israeli Hydrological Services, **Hydrological Year-Book of Israel 1984/1985 to 1992/1993 (in Hebrew)**, Israeli Ministry of Agriculture, Jerusalem 1988-1994.
24. Israeli Hydrographical Department, **Judean and Samarian Springs (in Hebrew)**, Water Commission of the Israeli Ministry of Agriculture, Jerusalem, January 1973
25. Israeli Ministry of Tourism, ***The Tourism Potential in The Negev During Peacetime***, prepared by the Authority for the Development of Tourism in the Negev, July 1993.
26. JMCC, **Water - The Red Line**, JMCC Publications, Jerusalem, May 1994.
27. Khamar, C., **Palestine Geographic Encyclopedia**, Dar Al-Awar, second edition, Israel, 1988.
28. LaMotte, **Fresh Water Aquaculture Test Kit Guidebook**, LaMotte, USA, 1993.
29. Lee, J. & M. Newman, **Aquaculture - An Introduction**, Interstate Publishers, Inc., Illinois, U.S.A., 1992.
30. Losodo, T., M. Masser & J. Rackoy, ***Recirculating Aquaculture Tank Production Systems, An Overview of Critical Considerations***, Southern Regional Aquaculture Center publication No. 451, January 1992.
31. Lowi, M., ***West Bank Water Resources and the Resolution of Conflicts in the Middle East***, published by Peace and Conflict Studies Program of the University of Toronto and the International Security Studies Program of the American Academy of Arts and Sciences, Paper series no. 1, September, 1992.
32. Mazor, E. & M. Molcho, ***Geochemical Studies of the Feshcha Springs, Dead Sea Basin***, **Journal of Hydrology**, Vol. 15, 1972.
33. Mazor, E. & A. Nadler, ***Notes on the Geochemical Tracing of the Kane-Samar Springs complex, Dead Sea Basin***, **Israel Journal of Earth-Sciences**, Vol. 22, 1973.
34. McLarney, W., **The Freshwater Aquaculture Book**, Hartley & Marks, Ltd., Canada, 1987.
35. Moyle, P. & J. Cech, **Fishes - An Introduction to Ichthyology**, Prentice-Hall, Inc., USA 1988.
36. Muhaisen, M., ***Solomon's Pools, A National Disgrace Waiting For A Savior***, **Al-Fajer Newspaper**, Jerusalem, July 26, 1993, pg. 6.
37. Naff, T. & R. Matson, **Water in the Middle East: Conflict or Cooperation?**, Westview Press Inc., Boulder, Colorado, 1984.
38. Newman, L., **Aquaculture - An Introduction**, Interstate Publishers, Inc., Danville, illionis, 1992.
39. **PASSIA Diary 1994**, PASSIA, Jerusalem, 1994.

40. Palestine Environment Protection National Authority, **Gaza Environmental Profile - Survey of Natural Resources**, Part 1, Gaza Strip, June 1994.
41. **Palestine Encyclopedia**, published by Palestine Encyclopedia Committee, volume 3, Damascus, 1984.
42. Pearson, J. & M. Davis, **Fisheries Sector Needs Analysis For Gaza Strip and the West Bank**, Marine Institute International, Canada, May 1994.
43. Quara'en, A., ***Water Qilt Canal:- a water vein, source of life and tourist attraction (in Arabic)***, Al-Quds newspaper, Jerusalem, January 1, 1992.
44. Rofe & Raffety Consulting Engineers, ***Nablus District Water Resources Survey - Geological and hydrological Report***, commissioned by the Hashemite Kingdom of Jordan, Central Water Authority, Feb., 1965.
45. Rowley, G., ***The Jewish Colonization of the Nablus Region - Perspectives and Continuing Developments***, **GeoJournal**, Vol. 21, No. 4, August 1990.
46. Schrader, M., ***Environment Degradation and Conflict in Palestine***, Najda Newsletter, Vol. 34, No. 4, California, Summer 1994.
47. Stirling, H., **Chemical and Biological Methods of Water Analysis for Aquaculturalists**, Institute of Aquaculture, University of Stirling, UK, 1985.
48. Tucker, C., ***Water Quantity and Quality requirements for Channel Catfish Hatcheries***, Southern regional Aquaculture Center, Publication No. 461, November 1991.
49. UNEP, **The Mediterranean Action Plan - Saving our Common Heritage**, UNEP, Greece, (year not indicated).
50. UNEP, **Environmental Guidelines for Fish Farming**, Environmental Management Guidelines Series no. 19, Nairobi, 1990.
51. World Bank & The European Investment Bank, **The Environmental Program for the Mediterranean - Preserving a Shared Heritage and Managing a Common Resource**, World Bank, second printing, 1993.
52. World Bank, **Agricultural**, Volume 4 of the series: Developing the Occupied Territories, An Investment in Peace, World Bank, Washington, D.C., Sept. 1993.

Appendixes

Appendix A

Percentage of Total Ammonia Nitrogen as Un-Ionized Ammonia (NH_3)

at Various Water pH's, Salinities and Temperatures

	10°C		**15°C**		20°C		25°C	
pH	**FW**	**SW**	**FW**	SW	FW	SW	FW	SW
7.0	0.19		0.27		0.40		0.55	
7.1	0.23		0.34		0.50		0.70	
7.2	0.29		0.43		0.63		0.88	
7.3	0.37		0.54		0.79		1.10	
7.4	0.47		0.68		0.99		1.38	
7.5	0.59	0.459	0.85	0.665	1.24	0.963	1.73	1.39
7.6	0.74	0.577	1.07	0.836	1.56	1.21	2.17	1.75
7.7	0.92	0.726	1.35	1.05	1.96	1.52	2.72	2.19
7.8	1.16	0.912	1.69	1.32	2.45	1.90	3.39	2.74
7.9	1.46	1.15	2.12	1.66	3.06	2.39	4.24	3.43
8.0	1.83	1.44	2.65	2.07	3.83	2.98	5.28	4.28
8.1	2.29	1.80	3.32	2.60	4.77	3.73	6.55	5.32
8.2	2.86	2.26	4.14	3.25	5.94	4.65	8.11	6.61
8.3	3.58	2.83	5.16	4.06	7.36	5.78	10.00	8.18
8.4	4.46	3.54	6.41	5.05	9.09	7.17	12.27	10.10
8.5	5.55	4.41	7.98	6.28	11.18	8.87	14.97	12.40

Source: Fresh Water Aquaculture Test Kit Guide Book, produced by LaMotte, 1993

FW = Fresh Water

SW = Sea Water

Appendix B

Monthly Discharge1 **of Main Springs in Palestine in 1000 m3**

for the Years 1984 - 1993

1- Jordan Valley Springs

Qilt & Fawar

				YEARS					
Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	**91/92**	92/93
October	292	224	212	198	377	262	211	179	555
November	279	228	346	188	271	227	190	352	538
December	275	206	494	388	277	217	190	2200	1540
January	361	198	1139	1140	381	329	213	3790	2100
February	894	265	604	1827	397	595	216	5140	3330
March	1400	359	508	1570	542	872	245	6130	2690
April	535	272	447	1029	613	591	287	4460	1240
May	436	222	413	592	539	397	278	2630	827
June	364	197	348	495	370	324	229	1510	692
July	337	192	292	436	352	304	201	1040	606
August	308	167	234	395	313	278	188	814	480

September	252	159	206	342	274	232	193	666	417
Total	5740	2670	5244	8598	4710	4630	2640	28900	15000
Rainfall2	151.2	119.6	178.6	257.7	167	182	110.6	345.1	119.5
10-yrs avg.	4610	4530	4559	----	4710	4710	4640	5450	5760

Duyuk

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	422	390	370	411	383	432	434	384	375
November	387	354	423	369	397	419	353	372	391
December	391	350	469	397	402	423	353	514	420
January	397	375	483	453	445	408	370	496	439
February	376	389	419	429	398	384	352	414	386
March	438	468	419	432	452	450	412	480	418
April	397	445	412	406	467	410	383	447	410
May	411	424	438	433	450	416	414	481	412
June	409	399	414	399	399	418	414	427	384
July	438	397	448	417	418	438	441	407	391
August	420	356	427	423	422	449	464	408	400

September	377	326	393	385	418	432	414	374	392
Total	4860	4670	5115	4953	5050	5080	4800	5200	4820
Rainfall	151.2	119.6	178.6	257.7	167	182	110.6	345.1	119.5
10-yrs avg.	5080	5060	5062	5058	5060	5060	5050	5060	5050

Neu'ma

					Y E A R S				
Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	230	243	185	208	247	234	262	202	259
November	202	228	221	205	234	235	241	195	251
December	230	224	245	227	260	240	228	255	273
January	234	213	265	263	266	254	253	268	278
February	218	222	234	247	241	228	256	257	258
March	282	266	234	272	261	258	297	303	286
April	269	223	265	239	261	251	273	294	270
May	258	211	279	241	281	243	242	297	276
June	247	235	239	252	263	247	237	268	273
July	262	199	235	270	251	252	243	270	274
August	245	188	251	265	250	262	224	259	258

September	243	191	214	250	232	260	206	259	239
Total	2920	2640	2866	2938	3050	2960	2960	3130	3200
Rainfall	151.2	119.6	178.6	257.7	167	182	110.6	345.1	119.5
10-yrs avg.	2320	2330	2350	2371	2390	2410	2430	2450	2480

Shosha

	YEARS								
Months	**84/85**	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	58	62	50	53	60	62	62	57	74
November	50	60	58	53	56	55	59	50	70
December	52	56	59	52	57	54	55	62	78
January	58	54	67	55	61	59	59	65	78
February	54	54	54	56	52	61	57	61	70
March	62	62	59	66	60	67	69	73	76
April	62	56	66	66	61	61	62	71	77
May	62	56	61	68	62	69	63	71	82
June	60	49	49	58	61	63	65	64	80
July	67	48	51	61	65	60	64	67	78

August	62	50	47	62	63	61	62	71	71
September	58	47	53	57	62	54	57	69	66
Total	705	654	676	707	720	726	733	780	900
Rainfall	151.2	119.6	178.6	257.7	167	182	110.6	345.1	119.5
10-yrs avg.	541	545	550	556	562	568	573	580	590

'Auja

Y E A R S

Months	**84/85**	**85/86**	**86/87**	**87/88**	88/89	89/90	90/91	91/92	92/93
October	386	189	---	35	269	226	123	0.0	1400
November	329	157	---	7.8	409	154	68	0.0	1240
December	285	118	551	357	574	140	61	82	1590
January	536	83	1045	942	1220	851	241	1480	1790
February	939	453	1014	1111	1160	1180	406	1620	1660
March	1250	672	1077	1372	1290	1370	683	1670	1810
April	1050	173	993	1357	1310	1290	684	1470	1700
May	818	95	782	1416	1190	1050	355	1570	1650
June	580	44	486	1289	917	730	116	1550	1500

July	379	10	269	1203	688	451	23	1520	1440
August	313	0.7	147	1041	450	269	2.1	1480	1430
September	225	0.0	78	780	316	167	0.0	1440	1300
Total	7090	1990	---	10910	10100	7880	2760	13900	18500
Rainfall	151.2	119.6	178.6	257.7	167	182	110.6	345.1	119.5
10-yrs avg.	10400	10500	---	10369	10400	10300	9970	10100	10400

2- Fari'a Spring Group

Fari'a

				YEARS					
Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	**91/92**	92/93
October	395	304	88	278	374	294	304	161	923
November	364	302	170	266	429	340	284	144	867
December	411	313	277	278	527	372	256	269	982
January	416	313	371	301	543	373	272	535	1080
February	357	287	410	336	449	366	279	1090	990
March	417	304	510	417	473	359	302	1530	998
April	396	258	468	459	444	284	278	1140	825

May	394	216	472	513	411	302	241	1200	803
June	366	181	479	473	389	340	206	1160	714
July	366	187	449	493	390	348	181	982	669
August	340	147	353	452	318	334	185	1000	712
September	309	110	281	383	308	271	189	945	545
Total	4530	2920	4329	4648	5060	3980	2980	10200	10100
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	5930	5810	5753	5712	5690	5630	5540	5690	5830

Dulieb

	YEARS								
Months	**84/85**	**85/86**	**86/87**	87/88	88/89	**89/90**	**90/91**	91/92	92/93
October	32	6.5	0	28	82	30	21	0	460
November	21	5	0	28	75	22	17	0	448
December	19	4.8	0.8	24	77	21	13	4.1	545
January	17	2.6	24	21	85	26	10	256	684
February	16	1.5	54	44	78	32	9.1	1030	633
March	24	2.5	68	138	69	39	9.1	1820	581

April	37	1.9	68	175	60	36	9.8	1530	442
May	37	0.9	66	140	55	35	9.7	1140	410
June	24	0	64	142	51	42	7.6	776	388
July	19	0	57	117	51	43	5.7	616	342
August	15	0	43	81	39	40	2.8	568	291
September	9.8	0	31	78	39	25	0.2	461	201
Total	270	26	475	1016	761	391	116	8200	5420
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	1100	1050	1027	1027	1020	995	964	1210	1340

3- Badan Spring Group

Sidri

	YEARS								
Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	0	0	0	0	22	0	0	0	371
November	0	0	0	0	0	0	0	0	272
December	0	0	0	0	0	0	0	6.6	598
January	0	0	14	0	0	0	0	395	846

February	0	0	57	26	0	0	0	844	748
March	0	0	244	559	24	0	0	1360	793
April	0	0	228	449	78	0	0	1260	682
May	0	0	93	402	39	0	0	1100	498
June	0	0	32	292	10	0	0	854	410
July	0	0	0	226	0	0	0	793	321
August	0	0	0	126	0	0	0	677	211
September	0	0	0	59	0	0	0	482	111
Total	0	0	668	2140	173	0	0	7770	5860
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	1110	1050	1032	1082	1040	999	999	1270	1450

Hamed & Beida

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	56	23	0.5	72	64	52	36	20	92
November	45	14	9.1	57	62	45	30	15	97
December	44	4.4	39	57	64	42	20	58	120
January	39	0.1	97	60	71	62	24	134	120

February	40	8.7	112	78	74	58	31	180	111
March	69	24	114	97	95	77	41	272	126
April	69	16	91	86	107	72	51	220	119
May	72	13	96	80	102	82	48	211	105
June	55	9.4	92	72	84	76	43	178	96
July	52	4	92	67	84	63	37	159	94
August	43	0.7	87	67	72	47	33	143	98
September	32	0	82	64	57	40	26	113	80
Total	616	117	913	856	936	716	419	1700	1260
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	843	808	813	815	820	816	800	835	850

Quderah

	Y E A R S								
Months	**84/85**	**85/86**	86/87	**87/88**	88/89	89/90	90/91	91/92	92/93
October	71	0	0	198	167	113	106	1.3	139
November	46	0	0	172	154	97	76	3.9	108
December	13	0	0	150	156	77	48	59	130

January	23	0	122	153	160	40	40	236	146
February	72	0	207	199	150	102	41	312	146
March	114	0	303	258	185	155	70	308	158
April	110	0	334	256	199	157	97	263	137
May	108	0	341	260	198	160	97	246	113
June	67	0	309	242	182	151	79	229	107
July	8.5	0	289	226	179	148	64	227	103
August	5.7	0	260	196	162	135	41	212	103
September	0.1	0	223	169	129	118	10	179	82
Total	639	0	2388	2479	2020	1450	769	2280	1470
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	1180	1100	1186	1267	1310	1320	1290	1340	1350

Jissir

	YEARS								
Months	**84/85**	**85/86**	86/87	**87/88**	88/89	89/90	90/91	91/92	92/93
October	5.7	3.3	0.5	5.3	11	7.5	9.3	5.6	18
November	5.2	3.0	1.5	4.7	9.4	6.6	8.2	5.2	17
December	5.1	2.2	3.2	5.0	8.8	6.7	7.9	7.8	18

January	4.8	1.7	7.1	5.4	9.1	7.8	7.8	16	19
February	5.1	1.9	7.8	10	8.7	8.6	7.1	22	17
March	7.6	3.3	9.3	16	10	12	8.2	29	19
April	7.8	3.1	9.9	16	12	14	7.6	29	20
May	8.4	3.7	10	15	14	15	8.0	32	19
June	6.8	2.9	9.5	14	13	13	7.5	28	16
July	5.5	2.4	8.4	13	12	13	7.1	25	15
August	4.9	1.6	6.9	13	10	12	6.8	22	14
September	3.6	1.1	5.6	11	9	11	5.9	18	12
Total	70	30	80	128	127	127	91	240	204
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	128	121	118	119	120	120	118	125	129

Taban

	YEARS								
Months	**84/85**	**85/86**	86/87	**87/88**	88/89	89/90	90/91	91/92	92/93
October	142	139	139	113	123	144	120	137	100
November	129	143	131	125	127	126	101	138	107
December	128	141	127	130	125	99	101	148	107

January	132	137	126	117	112	91	104	143	112
February	119	116	125	113	97	91	95	120	120
March	124	135	136	117	118	89	122	125	137
April	136	142	135	109	117	98	131	140	124
May	138	138	138	118	106	92	141	162	122
June	140	130	135	115	115	93	129	151	130
July	145	125	141	144	125	105	131	145	129
August	123	124	125	133	118	109	129	130	136
September	120	121	112	113	127	114	132	81	119
Total	1580	1590	1570	1448	1410	1250	1440	1620	1440
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	1270	1290	1302	1308	1310	1310	1310	1320	1330

As-Subian

Y E A R S

Months	**84/85**	**85/86**	86/87	**87/88**	88/89	89/90	90/91	91/92	92/93
October	19	18	15	20	19	19	18	17	18
November	19	18	15	18	17	18	18	16	17

December	18	18	16	17	17	18	18	17	18
January	18	16	18	17	17	17	17	18	19
February	16	15	17	16	14	15	15	18	17
March	18	17	18	18	15	17	17	20	18
April	17	16	17	17	15	18	15	19	18
May	18	16	18	18	17	18	17	20	19
June	18	16	21	18	17	18	17	18	18
July	18	16	20	18	18	17	17	19	18
August	18	16	19	20	18	17	17	19	18
September	17	15	19	19	18	17	16	17	15
Total	214	197	214	216	202	209	201	217	213
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	182	183	184	185	186	187	187	188	189

4- Miska Spring Group

Miska

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	**92/93**
October	102	23	1.5	4.1	41	2.5	0	0	145

November	100	37	8.2	17	83	9	0	0	173
December	127	59	17	20	104	23	1.2	130	204
January	156	76	29	31	85	31	3.8	125	217
February	150	71	28	42	66	26	5.6	236	178
March	168	76	47	76	77	32	7.4	188	193
April	139	53	43	83	63	31	3.7	184	159
May	88	24	41	73	14	6.2	0	197	148
June	58	14	18	65	13	0	0	180	128
July	53	4.5	16	75	11	0	0	189	143
August	42	0.3	9	53	4.2	0	0	164	146
September	26	0	3.3	34	2	0	0	146	134
Total	1210	437	261	572	563	161	22	1740	1970
Rainfall	151.2	119.6	178.6	257.7	167	182	110.6	345.1	119.5
10-yrs avg.	2213	2303	1553	1512	1470	1420	1370	1380	1410

Shibly

Y E A R S

Months	**84/85**	**85/86**	86/87	**87/88**	88/89	89/90	90/91	91/92	92/93
October	93	81	79	66	83	70	58	44	98

November	94	83	96	70	81	68	59	47	88
December	96	85	78	80	84	65	58	51	104
January	98	84	78	79	82	70	58	68	79
February	91	77	69	72	73	61	53	79	60
March	100	81	71	84	74	70	60	90	63
April	97	83	68	76	74	67	66	117	62
May	91	78	72	79	75	64	67	110	61
June	85	74	68	79	70	62	59	110	58
July	85	76	73	78	73	72	63	138	58
August	81	72	75	73	71	71	59	132	62
September	77	68	65	72	63	63	45	106	53
Total	1090	942	892	908	903	803	706	1090	846
Rainfall	151.2	119.6	178.6	257.7	167	182	110.6	345.1	119.5
10-yrs avg.	969	968	965	963	961	955	946	951	948

5- Malih Spring Group

Hammam El-Malih

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93

October	88	58	43	30	38	35	20	16	191
November	80	56	41	28	38	34	20	16	189
December	80	53	38	28	40	41	19	42	211
January	80	52	39	38	41	43	20	44	235
February	69	47	32	38	37	31	20	71	204
March	77	52	35	35	45	32	24	154	221
April	76	60	33	34	43	30	23	121	220
May	83	53	36	37	38	29	23	147	224
June	82	42	36	31	36	25	24	142	224
July	82	47	36	34	39	27	23	153	216
August	68	47	35	35	39	29	20	161	200
September	65	41	32	34	37	21	19	167	202
Total	930	609	436	401	471	377	256	1230	2540
10-yrs avg.	645	642	623	604	594	578	557	599	713

6- Nablus Spring Group

Ras El-Ein

	YEARS								
Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93

October	15	13	10	19	20	17	17	16	19
November	13	12	18	16	17	19	15	--	18
December	12	12	65	29	21	23	--	--	--
January	14	15	107	58	31	51	--	--	--
February	19	19	90	78	37	81	--	--	--
March	29	25	92	107	62	89	--	--	--
April	28	20	77	99	79	73	64	--	--
May	22	19	50	61	43	50	46	--	--
June	18	16	35	40	31	36	30	35	39
July	18	15	29	32	25	31	26	29	31
August	17	13	25	56	23	24	21	32	25
September	14	11	21	22	19	20	17	22	20
Total	219	189	618	587	408	514	--	--	--
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	445	440	442	449	447	450	450	450	450

Qaryon

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93

October	18	14	11	19	23	19	23	21	32
November	17	13	20	16	20	22	22	--	29
December	16	14	67	30	23	28	--	--	--
January	19	17	107	57	34	50	--	--	--
February	28	22	91	73	40	91	--	--	--
March	39	29	93	99	63	117	--	--	--
April	37	24	76	92	76	87	76	--	--
May	28	20	48	66	46	53	46	--	--
June	21	18	35	49	35	37	35	59	51
July	19	16	29	41	29	30	31	50	43
August	16	13	25	32	25	27	56	42	36
September	14	11	21	25	21	24	22	36	29
Total	273	211	624	600	435	585	--	--	--
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	552	533	542	541	535	538	538	538	538

Beit El-Ma'

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93

October	18	14	14	26	41	27	24	18	40
November	20	14	34	26	31	42	22	--	32
December	20	15	69	45	32	63	--	--	--
January	33	25	73	83	44	53	--	--	--
February	55	41	91	96	51	67	--	--	--
March	61	54	89	122	73	89	--	--	--
April	52	40	77	120	84	87	69	--	--
May	40	32	61	99	67	72	61	--	--
June	28	23	44	60	52	53	45	87	64
July	21	18	36	39	46	47	34	77	52
August	17	16	33	39	35	34	22	59	50
September	14	14	26	32	28	56	18	45	46
Total	379	305	648	787	584	660	--	--	--
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	568	556	560	570	571	574	574	574	574

7- Sabastiya Group

Kafr Farat

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	1.4	1.6	1.9	2.0	1.5	2.1	1.9	1.8	2.2
November	1.3	1.3	4.3	1.8	2.1	2.1	1.4	2.7	2.8
December	1.3	1.3	5.4	1.9	1.2	2.4	1.8	8.8	6.8
January	1.4	1.3	9.9	4.2	2.2	3.2	2.6	14	10
February	2.5	1.5	9.4	8.6	4.1	4.9	3.4	16	10
March	5.6	3.1	7.7	13	9.7	7.5	4.2	17	12
April	3.9	3.0	6.0	11	11	5.9	4.7	14	17
May	2.8	2.7	5.8	7.9	7.0	4.4	3.4	13	10
June	1.7	2.3	4.8	4.5	4.0	3.8	1.6	8.0	5.9
July	2.1	2.2	3.8	3.4	3.2	3.1	1.6	5.8	5.2
August	2.1	1.9	3.1	2.4	2.8	2.7	1.6	3.6	4.2
September	1.8	1.5	2.4	1.8	2.3	2.5	1.6	2.5	3.4
Total	28	24	65	62	50	45	30	108	90
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	48	47	48	49	49	49	48	50	52

Burqa

					YEARS				
Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	3.8	3.8	3.3	5.7	5.2	4.8	5.8	3.7	6.0
November	3.7	3.6	4.9	5.6	4.9	4.7	6.1	4.6	5.2
December	3.3	3.6	6.3	5.2	5.2	7.4	6.2	11	10
January	3.5	3.8	11	7.0	6.1	10	6.3	17	14
February	5.6	3.7	10	8.4	6.4	9.5	6.4	19	14
March	12	4.4	13	11	6.1	12	6.7	21	19
April	8.0	3.7	11	12	10	14	6.8	19	12
May	5.9	3.7	12	15	10	17	5.9	15	12
June	4.7	3.4	10	13	7.4	11	5.3	13	8.7
July	4.3	3.3	8.2	9.2	6.8	8.7	4.4	12	7.6
August	4.0	3.2	7.5	7.2	5.8	6.7	4.0	8.7	5.8
September	3.8	3.1	5.9	5.9	4.9	5.7	3.8	7.3	3.8
Total	62	43	103	105	79	112	68	151	118
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	81	79	80	81	81	82	82	84	85

Zawata

				YEARS					
Months	**84/85**	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	5.6	4.6	3.9	5.3	7.8	5.7	7.8	5.3	61
November	5.2	4	6	4.9	6.4	5.5	6.5	4.7	36
December	4.6	3.8	17	7.9	24	6.1	5.4	63	78
January	4.8	3.9	29	22	34	10	7.8	161	136
February	9.5	10	20	75	23	26	11	215	143
March	13	12	16	161	22	36	20	284	160
April	12	7.1	12	151	28	27	21	279	143
May	9.1	7.3	11	126	19	21	15	234	131
June	7.6	6.6	8.1	94	13	14	10	207	97
July	6.9	5.4	6.8	61	9.5	11	8.4	165	65
August	6	4.8	6.6	32	7.2	9.3	7.3	137	30
September	5.3	4.5	5.4	15	6.2	8.1	5.9	108	11
Total	90	74	142	755	200	180	126	1860	1090
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	414	399	388	403	395	387	377	430	453

8- Miscellaneous Central Highlands Springs

Burqin

Months	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93
	Y E A R S								
October	0.8	0	--	--	3.0	0.5	0.2	0	0.1
November	0	0	--	--	1.9	0.8	0.1	0	1.2
December	0	0	--	--	1.4	1.3	0	1.2	2.6
January	0	0	--	--	1.9	1.6	0	25	5.8
February	0	0	--	--	2.0	1.6	0	38	8.5
March	0	0	--	7.8	2.3	1.9	0.1	44	5.3
April	0	0	--	8.9	4.2	1.8	0.5	43	3.7
May	0	0	--	9.2	3.3	1.9	0.5	36	3.5
June	0	0	--	8.3	1.6	1.8	0.3	15	3.3
July	0	0	--	7.4	1.1	1.6	0	6.8	2.5
August	0	0	--	6.3	0.8	0.6	0	1.6	1.3
September	0	0	--	4.8	0.6	0.4	0	0.4	0.2
Total	0.8	0	--	--	24	16	1.7	211	38
10-yrs avg.	68	65	--	--	63	62	59	65	64

Mitwa

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	5.4	4.2	3.5	4.0	6.8	5.6	6.0	4.4	12
November	5.2	3.9	3.7	3.8	6.5	4.8	5.5	4.3	12
December	5.1	3.8	5.3	4.1	7.3	4.8	5.0	10	22
January	5.1	3.8	7.4	5.4	7.3	5.0	5.0	20	31
February	4.8	4.4	6.9	9.6	6.6	5.0	5.6	25	30
March	5.9	5.2	6.7	17	8.1	7.4	6.1	27	31
April	5.6	4.5	5.9	14	8.2	8.2	6.0	34	25
May	5.3	4.5	5.6	11	7.4	8.1	5.5	42	18
June	4.7	4.1	5.1	8.9	6.5	6.9	5.1	32	13
July	4.6	3.9	7.8	8.0	6.5	6.8	5.1	23	13
August	4.6	3.6	4.5	7.8	6.2	4.8	4.9	18	12
September	4.4	3.4	3.9	7.2	5.7	6.0	4.5	14	10
Total	61	49	63	101	83	73	64	254	229
Rainfall	467.3	526.7	757.1	703.9	567	589	505	1360	817.3
10-yrs avg.	89	87	86	87	87	86	85	92	96

Batir

Y E A R S

Months	**84/85**	**85/86**	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	3.9	3.8	3.5	5.8	7.0	6.4	8.1	4.6	7.6
November	3.6	3.4	5.7	4.6	6.2	5.2	7.0	4.5	7
December	3.7	3.7	8.8	6.6	6.2	5.4	6.0	21	10
January	3.7	3.8	21	12	6.6	6.9	5.3	47	61
February	4.7	5.9	19	50	9.2	11	4.5	64	40
March	8.0	4.9	19	70	12	17	5.2	76	46
April	7.4	4.0	14	41	12	18	7.7	49	25
May	6.5	4.2	11	24	13	20	7.6	26	15
June	5.7	3.9	8.9	14	11	14	6.0	18	14
July	5.2	3.8	9.3	11	9.0	11	5.6	14	11
August	4.8	3.6	7.3	9.1	7.2	10	5.0	11	8.6
September	4.3	3.3	6.2	7.4	6.5	8.7	4.6	8.7	6.9
Total	62	48	134	256	106	134	73	343	252
Rainfall	--	--	--	598.2	--	--	316.6	1180	643.5
10-yrs avg.	103	100	102	109	109	110	108	117	122

Sai'r

YEARS

Months	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93
October	2.4	1.8	0.8	1.4	1.4	1.0	0.5	1.9	5.5
November	1.8	1.6	1.0	1.5	1.5	0.8	0.5	1.9	4.9
December	1.6	1.8	1.1	3.0	1.4	0.8	0.4	9.4	5.3
January	1.4	2.2	2.3	15	2.3	0.7	0.7	36	31
February	1.9	3.0	13	21	6.4	1.1	1.3	46	20
March	7.1	2.7	20	24	6.6	3.4	1.9	57	27
April	5.9	1.9	13	17	5.2	3.3	3.5	44	25
May	3.6	1.6	9.2	14	4.2	2.5	4.9	29	22
June	5.6	1.3	4.8	8.0	2.7	1.2	4.0	26	16
July	4.0	1.3	2.9	4.0	1.8	0.8	3.4	21	7.8
August	2.7	1.2	2.2	3.3	1.4	0.6	2.2	12	5.7
September	1.9	1.0	1.7	2.1	1.1	0.1	1.8	7.0	4.1
Total	40	21	72	114	36	16	25	291	174
Rainfall	498.8	429.9	--	--	479	498	471.1	1028.5	--
10-yrs avg.	65	63	63	65	64	62	61	69	72