Effect of Pesticides and Fertilizers on Shallow Groundwater Quality

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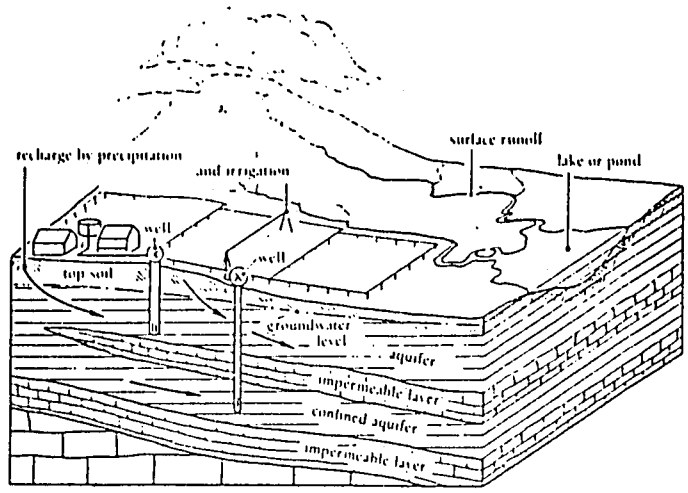
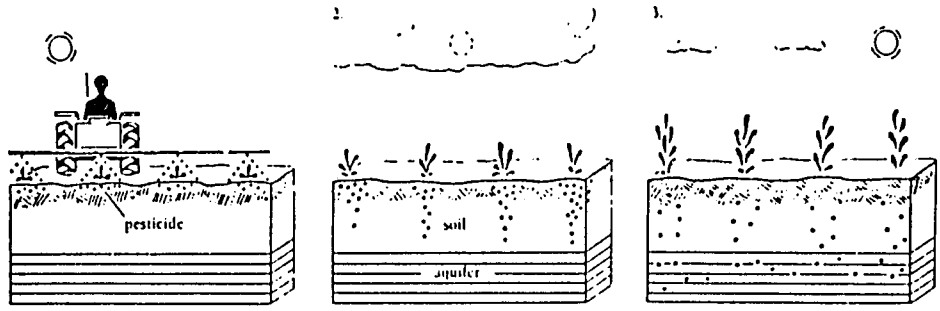
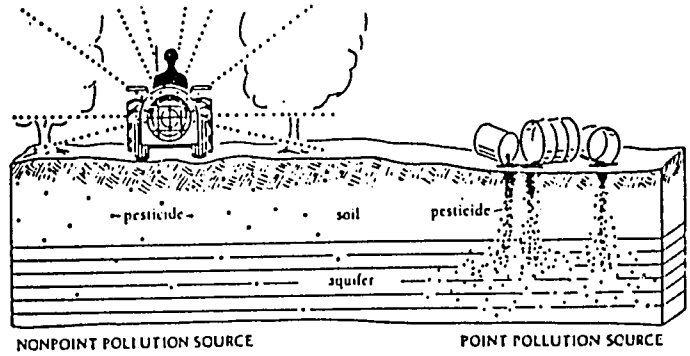


Water is present in underground reservoirs called aquifers, diagrammed here. This water is contained in sand and gravel formations. Impermeable layers of clay and silt or solid rock prevent water from leaving the aquifer.



Water enters aquifers by percolation through the soil. As water passes down through the soil it may dissolve some pesticides and carry them into the aquifer. This process is called leaching.



Point pollution sources are areas where large quantities of pesticide or other pollutants are discharged into the environment, such as from spills, waste discharge pipes, or dump sites. Nonpoint pollution sources are those arising from normal application where the pesticide or other material is applied over a large area.

C

TABLE OF CONTENTS

CHAPTER I

	Page
Summary	1
Introduction	4
Groundwater	4
Salinity	5
Fertilizers	6
Inorganic soil amendments	7
Organic residues	7
Pesticides	8
Groundwater quality	9

CHAPTER II

Pesticide usage in Pakistan	11
Pesticide manufacture in Pakistan	13
Fertilizer usage in Pakistan	15
Formulation of project	17

CHAPTER III

Project area	23
Climate of study area	23

CHAPTER IV

Geohydrology	28
Punjab plain	28
Geology	28
Hydrological character	30
Geohydrology of the study area	30
Quality of native groundwater	33

CHAPTER V

Croping pattern and agrochemical usage	38
Pesticide usage in the study area	42
Fertilizer usage in the study area	45
Groundwater contamination by pesticides	46
Soil contamination by pesticides	48
Groundwater contamination by fertilizers	51
Soil contamination by fertilizers	58
Cations and anions in soil	67
Heavy metals in soil	74

CHAPTER VI

Discussion	83

CHAPTER VII

Conclusions and Recommendations	92
Literature cited	95
Annexure I Depth profile of elements in soil	99
Annexure II Contour maps of elements in soil	109

D

LIST OF TABLES

		Page
1.	Summary of the prominent facts about the constituents of principal concern in groundwater underlying cropland	10
2.	Pesticide consumption in Pakistan	12
3.	Production/formulation of pesticides in Pakistan	14
4.	World fertilizer consumption	16
5.	Fertilizer consumption in Pakistan	16
6.	Consumption of fertilizer per ha of agricultural area in Pakistan	16
7.	Faisalabad climate data	27
8.	Cumulative (%) data of land use in Samundri, Faisalabad	41
9.	Cumulative (%) data on pesticide usage	41
10.	Cumulative (%) data on fertilizer usage	41
11.	Farm holding size and plant protection practices in Samundri, Faisalabad	43
12.	Monitoring of pesticide residues in water	47
13.	Pesticide contamination of shallow groundwater	47
14.	Pesticide residues in soil	49
15.	Pesticide contamination of farming land	50
16.	Chemical analysis of groundwater of samundri, Faisalabad	52
17.	Groundwater quality analysis in Samundri, Faisalabad	53
18.	Physico-chemical properties of drain water and mud	54
19.	Chemical analysis of shallow groundwater in Faisalabad	55
20.	Common ranges (%) of the principal cations in the groundwater	56
21.	Ranges (%) of the principal cations in the groundwater in Samundri, Faisalabad	56
22.	Drinking water quality standards	57
23.	Physico-chemical characteristics of soil of Samundri, Faisalabad	66
24.	Pathological effects of heavy metal ingestion in humans	82
Annex. 1.	Depth profile of elements in soil and sub-soil of Samundri, Faisalabad	98

LIST OF FIGURES

		Page
1.	Land use in Pakistan	18
2.	Irrigation map of Pakistan	19
3.	Indus basin irrigation system	20
4.	Irrigation system of Faisalabad	21
5.	Map of Faisalabad showing selected area	24
6.	Map of the project area	25
7.	Water-table depth from surface	26
8.	Resistivity configuration	32
9.	Interprated subsurface lithologies	32
10.	Map of wheat and rice growing area in Pakistan	39
11.	Map of cotton and sugarcane growing area in Pakistan	40
12.	Electrical conductivity of groundwater	59
13.	Sodium distribution in groundwater	60
14.	Potassium distribution in groundwater	61
15.	Calcium distribution in groundwater	62
16.	Magnesium distrbution in groundwater	63
17.	Chloride distribution in groundwater	64
18.	Nitrate distribution in groundwater	65
19.	Depth profile of sodium in soil of Samundri, Faisalabad	68
20.	Depth profile of potassium in soil of Samundri, Faisalabad	69
21.	Depth profile of magnesium in soil of Samundri, Faisalabad	70
22.	Depth profile of calcium in soil of Samundri, Faisalabad	71
23.	Depth profile of chloride in soil of Samundri, Faisalabad	72
24.	Depth profile of nitrate in soil of Samundri, Faisalabad	73
25.	Depth profile of iron in soil of Samundri, Faisalabad	75
26.	Depth profile of copper in soil of Samundri, Faisalabad	76
27.	Depth profile of zinc in soil of Samundri, Faisalabad	77
28.	Depth profile of manganese in soil of Samundri, Faisalabad	78
29.	Depth profile of cobalt in soil of Samundri, Faisalabad	79
Annex. 2.	Contour maps of elements in upper soil of Samundri, Faisalabad	109

EFFECT OF PESTICIDES AND FERTILIZERS ON SHALLOW GROUNDWATER QUALITY

SUMMARY

The concern on quality of our water resources is becoming increasingly important in the face of ever growing population, accelerated agricultural activity, and expanding industry. A pilot project was conducted in the Samundri, district Faisalabad, to look into the extent of groundwater contamination by agrochemicals.

The water-table depth varies from 10 feet in the north to more than 40 feet in the south. The electrical conductivity of groundwater is found to be minimum, 1000 micro mhos/cm, along the canal and is increased to 2500 micro mhos/cm away from canal towards river Ravi in the south, and north of Samundri main drain. The top soil is clay or clay loam. The sand starts from 12 feet deep in the north to around 40 feet in the south of study area. Canal and groundwater mixing is the most favoured mode of irrigation. The annual precipitation averages 12 inches and total evaporation is about 80 inches in a year.

The quality of water in Samundri, is much deteriorated. Total dissolved solids (TDS) in shallow groundwater used for drinking as well as irrigation is >500 ppm along the Munianwala canal and about 2000 ppm away from the canal. Drinking water regulation prescribed by US Environmental Protection Agency recommend that the TDS content for human consumption should not exceed 500 ppm, whereas US Geological Survey states that waters with TDS about 2000 ppm are generally unfit for long term irrigation.

The agricultural activity based heavily on the usage of pesticides and fertilizers to increase crop yields has proved to be a potential source of groundwater contamination. The shallow groundwater in Samundri area drawn from a depth of 30-40 feet is contaminated with pesticide residues. Monocrotophos is detected in the range of 0.04 to 0.06 ppm, cyhalothrin in the range of traces to 0.0002 ppm, and endrin is present in the range of 0.0001 to 0.0002 ppm.

The soil of Samundri in cotton growing area is contaminated with pesticide residues. Monocrotophos is detected in the top 1 foot soil in the range of 0.3331 to 0.6429 ppm. Cyhalothrin is present in top 1 foot in the range of traces to 0.1932 whereas dimethoate is detected at one site at a concentration of 0.3858 ppm. The pyrethroids fenvalerate, cypermethrin and organophosphate profenofos are present in traces in the top 1 foot layer. The organochlorine insecticide residues of aldrin, dieldrin, endrin, p,p'-DDT and its metabolites p,p'-DDD and p,p'-DDE are detected in the lower 2 to 3 feet layers of the soil. Their concentrations varied from traces to 0.0096 ppm. The presence of pesticides in the soil is of concern as these enter our food chain through the crop produce. The earlier studies have shown that endrin even after the ban on its use is finding its way into vegetables grown on the contaminated soils.

EPA has estimated that as many as 50 out of 1000 registered pesticides qualify for detection in groundwater under conditions conducive to downward movement. Fertilizers, inorganic soil amendments, and organic residues also have the ability to move downwards from soil to groundwater and cause pollution.

Among the elements of fertilizer supplementation nitrates are of most concern as human health hazard because of their leachability character. Our survey in Samundri area has indicated that nitrates applied as fertilizers have moved down to lower horizons as a consequence of flushing process. The top 0-6 inches of soil under cotton crop have an average of 27 ppm nitrate nitrogen which declines to around 5 ppm by 4-6 feet depth. Similarly depth profile studies have shown that nitrate levels in subsoil samples are varied and occasionally values of 35 ppm at the top surface and around 10 ppm at lower depths have been detected. At present the shallow groundwater nitrate levels are below 1 ppm. However, the groundwater is under a constant threat of contamination from the subsurface soils with higher nitrate contents. Perhapse the nitrates in water have been diluted through the recharge process by canal or other water sources.

The salinity in the area has increased since the start of irrigation system in 1886. The common ranges of cations (Sodium+Potassium) have increased in the shallow groundwater

(45-96%) as compared to those of native (pre-1886) groundwater values (40-70%). Chloride values have also increased over the period. Calcium has shown a corresponding decrease in its range.

The five metals (Zinc, Manganese, Copper, Iron and Cobalt) analyzed in the present investigations revealed higher concentrations rather accumulation in the top 1-3 feet of soils. These values are about 3-4 folds higher than the normal concentrations found in the lower subsoil horizons. The accumulation of these metals may be from the organic recycling processes or from the fertilizers for which these metals are minor constituents. If taken by the crops and consumed by humans over the period in large quantities these could have severe pathological consequences to our health.

Generally the metal concentrations of the groundwater are within safer limits described by the WHO or USEPA. However, Zinc concentration is far higher in the water drawn from hand-pumps as compared to bore-hole drawn groundwater. The zinc may have been originating from the hand pump pipes. Further investigations in this respect are suggested.

To conclude, the extensive use of agrochemicals in Pakistan for the last three decades has become a danger to our shallow groundwater. Pesticide residues have already reached the aquifer and fertilizers (nitrates) though yet in safer limits in groundwater are present in considerable concentrations in the lower subsoil layers, a possible threat to the groundwater in future.

EFFECT OF PESTICIDES AND FERTILIZERS ON SHALLOW GROUNDWATER QUALITY

CHAPTER I

INTRODUCTION

Much of the drinking water used by humans and domestic animals is derived from groundwater, and this is the primary reason for the concern about the influence of agriculture on its quality. This report describes the results of the study on quality of groundwater as related to agriculture.

GROUNDWATER

Groundwater is the water that occurs in the earth below the depth to which water will rise in a well. Below this depth, the pore spaces between the solid particles are all filled or saturated with water. The soil and other unconsolidated materials above this depth contain water, but the larger pore spaces are not filled with water. These materials collectively make up the unsaturated zone. Water must move down through the unsaturated zone before it reaches the saturated zone, where it becomes groundwater.

In some places, particularly in areas in humid regions where the land is relatively level, the saturated zone may be only a few feet below the surface of the soil. In others, particularly in arid regions, the saturated zone may lie several hundred feet below the surface of the soil. Water carrying dissolved materials moves downward from the surface of the soil through the unsaturated zone to the saturated zone. The time in transit may be only a few days in humid regions where the saturated zone is close to the surface, the soil is

readily permeable to water, and the precipitation is excessive, but it may be measured in centuries in arid regions, irrigation may greatly hasten the downward movement.

SALINITY

Water often is termed the "universal solvent". The water in streams, lakes, oceans, and soils naturally contains a variety of dissolved substances. In humid regions, the precipitation continually flushes the soluble substances from soils and moves them to the groundwater. Neither the soils nor the groundwater are saline because of the small amounts of salts relative to the amounts of almost pure water received in the precipitation.

For crop production in dry regions, the precipitation is supplemented by additions of irrigation water from streams, lakes, and groundwater, and the dissolved substances from these sources thus are added to the soils. When the water evaporates from plant surfaces or directly from soils, it leaves the soluble salts behind, and this increases their concentration in the remaining water. If so little water is added that all of it evaporates without drainage all the salts remain in the soil. If the content of dissolved salts in the irrigation water is great enough, repetition of this process over a period of only a few years may make the soil too salty or saline to support plants. On the other hand, if enough irrigation water is added to flush the excess salts out of the soil, the salinity of the groundwater is increased. The addition of salts to ground water from irrigated lands can be reduced by careful water management, but the principal practical limitation of this kind of management is the cost of installing, maintaining, and operating the irrigation system required.

Excessive salinity of ground water is undesirable in agriculture because some of the ground water may be pumped for irrigation, and some of it reappears as surface water in streams and may be used again downstream for irrigation. Excessive salinity in groundwater used for drinking is undesirable because of objectionable taste and the laxative effect associated with sulfate. The Environmental Protection Agency has recommended that concentrations of chloride or sulphate should not exceed 250 parts per million in domestic

water supplies. The National Academy of Sciences suggested that water having a total salt content or salinity of 3,000 parts per million or less should be satisfactory for livestock. Water having total salinity of 3,000 to 5,000 parts per million were reported to be satisfactory from most farm animals, but not for poultry.

FERTILIZERS

Among the dissolved inorganic substances occurring naturally in surface water and groundwater are the nutrients plants require for growth. Originally, agriculture depended almost entirely upon nutrients from the soil and from organic residues derived from agriculture. This system resulted in impoverished soils of low productivity. Eventually agriculture was improved by introducing legumes as an integral part of cropping systems. The legumes added available nitrogen as a result of fixation of atmospheric nitrogen and other inorganic nutrients in soils that are required for plant growth, and agricultural productivity is consequently much increased.

Plants absorb only part of each of the nutrient present in soluble forms in the soil. As the concentration in the soil water increases (generally leading to greater uptake by plants and greater yields), the percentage of the total amount absorbed decreases, and greater residues are left in the soil. Most of the chemical ions added in fertilizers are retained by soils as a result of chemical interactions, but a few are not. Of those not retained, only nitrate is of concern in ground water used for drinking. Although loss of nitrate from soils to groundwater is a natural process, the potential for loss to groundwater is increased in local areas by high concentrations of livestock and in much of the cropland by nitrogen fertilizers.

To date, the adoption or non-adoption of alternative agricultural practices that would reduce, nitrate loss from soil to groundwater has been based upon economics and convenience. In USA there has been no special incentive to override these practical

considerations with health concerns for private wells because the use of bottled water for drinking by infants has made it possible to adjust to the hazard of nitrate occurrence in groundwater at little cost and inconvenience. Some municipalities, however, have incurred considerable expense in efforts to develop alternative source of water so the water supply will conform to the public health standard for nitrate.

INORGANIC SOIL AMENDMENTS

Another group of chemicals added to soils in modern agriculture is classed as inorganic amendments. These include limestone and other materials that neutralize soil acidity, sulfur and other materials that acidify soils, and gypsum, which is used to increase the rate of entry of surface water into certain soils. Both the neutralizing materials and the acidifying materials may influence to some degree the reactions pesticides undergo in soils and the potential for transfer of these substances to groundwater. The acidifying materials and gypsum have the potential for increasing the soluble salt content of groundwater. The magnitudes of the possible effects on groundwater are considered to be of great concern.

ORGANIC RESIDUES

Organic materials added to soils include crop residues, food processing waste, animal manures, and sewage sludges. These materials, which are valuable in agriculture for their properties as soil conditioners and fertilizers, have the potential for contaminating groundwater with nitrate and bacteria. Nitrate contributes to the hazard of methemoglobinemia and bacteria to the hazard of diarrhea and other diseases.

The principal concern is for nitrate associated with animal feeding operations in out-of-door feedlots. The reason is the deposition of great quantities of nitrogen in the excreta on small areas of land. In the presence of free oxygen, the nitrogen is transformed gradually to nitrate. Nitrate from animal manures and other organic sources behaves like that from fertilizers.

Bacterial contamination is also of great concern. Some shallow farm wells located near livestock quarters are contaminated with fecal coliform bacteria. There is evidence that infant diarrhea associated with consumption of bacterially contaminated water from such wells greatly enhances the risk of methemoglobinemia from the nitrate also present in the water.

PESTICIDES

The pesticides used at present are mostly synthetic organic compounds. The principal processes that influence their potential for loss from soil to groundwater are volatilization (and subsequent diffusion), decomposition, retention by the soil, and transport by water.

Synthetic organic pesticides may be decomposed in different ways. Those applied to plant foliage or the soil surface may be broken down rapidly by sunlight. Decomposition by sunlight may be one reason for the fact that most of the pesticides that have been detected in groundwater are applied to soil.

Some organic pesticides, such as chlordane, DDT and dieldrin, decompose very slowly and may persist for years. These pesticides, however, are of little concern as groundwater contaminants from agricultural use because they are relatively insoluble in water and are retained strongly by the soils.

The soil constituent of greatest importance in retaining pesticides is the organic matter. Binding to the organic matter decreases the potential for downward movements of many pesticides in soils. The capacity of the soil to hold positively charged ions in exchangeable form is important in retaining paraquat and other pesticides that are positively charged.

The principal mechanism by which pesticides are transported from soil to groundwater is downward percolation of water containing dissolved pesticides. The relative potentials for movement of different pesticides to groundwater in different soils may be

estimated by applying known quantities of the pesticides to the soils, adding equal quantities of water, and measuring the contents of the various pesticides in the drainage water or the distance to which the pesticides move in the soil. The potentials found in this way depend mostly upon the retention of the pesticides by the soil. They exceed the "worst case" situations for comparable thicknesses of soil in the field because they do not allow for the full effects of loss by volatilization and decomposition by microorganisms.

An Environmental Protection Agency (EPA) official has estimated that as many as 50 of the more than 1,000 registered pesticides possess the potential for detection in groundwater under conditions conducive to downward movement (Table 1).

GROUNDWATER QUALITY

Groundwater is an important source of water for irrigation and domestic use. Its purity and drinkability matters in all water supply schemes. Three fourth of earth's crust is covered with water, however, out of this vast source very little of the world's water is drinkable. 97.2% of the world's water is saline ocean water, 2.14% is in ice caps and glaciers, 0.61% is groundwater, 0.009% is surface water, and 0.005% is soil moisture. Only a small percentage of the world's total water supply is available to humans as a supply of fresh water. Of the total amount of fresh water that is available, over 98% is groundwater (Fetter, 1988). In any assessment of groundwater sources the quality is of prime importance for the safety of public health. But unfortunately, this water on which the structure of life is based, is becoming polluted by our own artificial means. The extent of the groundwater contamination potential is just beginning to be realized. Originally it was believed that pesticides were not a threat to the groundwater. Most recently the modern detection methods have shown that small amounts of chemicals, including pesticides, can be found in some groundwater locations.

Table 1. Summary of Prominant Facts about the Constituents of Principal Concern in Groundwater Underlying Cropland

Constituent	Sources	Soil Processes Affecting the Amount Lost to Groundwater	Tendency to Move Downward Through Soils in Percolating Water	Comments
Soluble salts	Irrigation water Organic materials Fertilizers Weathering of soil minerals Rainfall	Precipitation and dissolution of carbonates and sulfates Weathering if soil minerals	High	Must be leached from irrigated soils to maintain crop production
Nitrate	Nitrogen fertilizers Organic materials Atmospheric nitrogen fixed by legumes Rainfall	Production and removal by microorganisms Removal by plants	High	Loss to groundwater is identical to water movement and is loss to crop potential
Pesticides	Commercial products	Retention by soil Decomposition Volatilization Removal by plants	Varies widely among Pesticides and soils	Principal occurence in groundwater result from pesticides that remain in solution in the soil are not decomposed rapidly, and are applied to sandy soils with ground water near the surface and with much water movement through the soil to groundwater

CHAPTER II

PESTICIDE USAGE IN PAKISTAN

In Pakistan pesticide usage started in 1954. Insecticides make up 85% of the total pesticides and herbicides as 6%. In all 91% goes directly to soil or plantations. Upto 75% of insecticides are used on cotton crop alone and the rest is used on crops like rice, sugarcane, maize, vegetables etc. The research findings on the agrochemicals are alarming that long term exposures to pesticides (particularly persistent classes) is resulting in carcinogenic, mutagenic, and teratogenic consequences. Also death due to pesticides can result from cardiac failure, failure of respiratory centres, paralysis of the respiratory musculature and broncho constriction, etc., (Muhammed and Borstel, 1985).

Before 1980 the pesticide import and distribution was the responsibility of Plant Protection Department, Government of Pakistan. Afterwards the pesticide business was transferred to private sector. Since then the pesticide consumption has increased from 906 m ton a. i. in 1981 to 5296 m ton a.i. (with a market price of Rs. 4581 million) in 1990 at a rate of 40% per annum. The sprayed area has increased from 1.8 million hectare to about 5.5 million hectare. Due to the complexities in cropping system and small holdings, ground spray has always been preferred. Aerial spraying has been restricted to epidemic outbreaks of pests like locusts, sugarcane pyrilla, white-backed planthoppers, crickets, etc. The result of the transfer of pesticide business to private sector was a steady increase in the pesticide sale (Table 2) because: (i) pesticides are offered in small unit packs, (ii) these are available in time before the start of the crop season, (iii) these are provided to the farmers on credit and deferred payment basis and (iv) the farmers are properly advised about the time and mode of application. As mentioned before the insecticides comprise of 85% of the total pesticides consumed and of this almost 75% is used for cotton pest control. Herbicide use though proportionally small is increasing. There is more or less a steady import of fungicides, however , the proportional share is decreasing. Use of rodenticide and fumigants,

Table 2. Pesticide consumption in pakistan (000 Kg/Lit a.i.)

	1982	1984	1986	1988	1990
Insecticide	952 (74)	2162 (88)	3480 (87)	4173 (85)	4265 (85)
Fungicide	171 (13)	204 (8)	283 (7)	277 (6)	365 (7)
Herbicide	94 (7)	102 (4)	162 (4)	277 (6)	365 (7)
Acaricide	3 (-)	51 (2)	81 (2)	82 (2)	- -
Rodenticide	69 (6)	25 (1)	41 (1)	44 (1)	27 (1)
Total	1289	2544	4047	4853	5296
Value (m Rs)	200	1120	2933	4021	4581

Data source : Kafi and Baig, (1987)
Jabbar et al., (1988)
Pakistan Agricultural Pesticide Association, 1991)

* values in parenthsis represent percent of the total.

though considered a small components, is also increasing. It is evident from Table 2 that the pesticide use has increased by 5 folds whereas it has gone up by about 19 times. this represents both inflation over the years and also the shift from cheaper organochlorines to costly organophosphates, carbamates and pyrethroids.

MANUFACTURE/FORMULATION OF PESTICIDES IN PAKISTAN

Many futile attempts were made in the past to manufacture pesticides in Pakistan. The matter has been discussed in detail by Kafi and Baig (1987) in their report on Needs and Prospects of manufacturing pesticides in Pakistan, published by Government of Pakistan. Recently the share by the local formulation plants is increasing. For example, from only 14% in 1984 within two years it captured the 38% of the total pesticide consumed in Pakistan. At present 14 manufacturing/formulation plants are in the country, 9 in Karachi, 2 at Lahore, 1 each at Jamshoro, Sargodha, and Nooriabad with an annual production capacity of 58428 m tonnes formulated product. This target is hardly achieved, for example the total production during 1988 was 12908 m tones. Since 1990 B.S. insecticides have gone into production of nicotine sulfate. Two more companies have been granted licence in 1991. A survey was conducted during 1988 which showed that only 2 multinational companies (Hoechst Pak Ltd and Sandoz Pak Ltd) were manufacturing granular pesticides to their full capacity at their plants at Korangi, Karachi and Jamshoro, Sind respectively (Table 3). Whereas most of the other companies were operating at 5-20% of their manufacturing capacity. Ittehad Pesticides have stopped production of DDT and BHC. Dow Pecific ltd. never went into production. No data was available from other companies, therefore, the situation can not be commented upon. BS pesticides have started producing Nicocide-40 since 1990. Till 1988 non of the companies were producing dimethoate, however, there is a strong move that this insecticide should be manufactured locally.

The Government regulatory policies favour the import of the active ingredient of pesticide alongwith emulsifier, carrier and stabilizer for local formulation rather than manufacture. Furadan, Sevin, DDT, BHC, Sevidol, Thiodan, Diazinon, Malathion, Zolon-

Table 3. PRODUCTION/FORMULATION OF PESTICIDES IN PAKISTAN (1988)

Manufacturer	Location	Pesticides Active ingredient	Capacity Tons	Production Tons	%
Granulars (pvt)ltd	Site Karachi	Padan Cartap	6,250	720	11.5
Burmah shell ltd	Keamari Karachi	Dieldrin Birlane Bidrin	2,250	100	4.5
Pakistan Agro chemicals (pvt)ltd	Site Karachi	Monocrotophes Dimetoxal Cypermethrin	1,500	300	20
Agricide (pvt) ltd	Site Karachi	Dimethoate Monocrotophos Endosulfan Methamidophos Disulfoton Corbofuran Paraquat	3,000 1,800	- 300	- 16.7
Hoechst Pak. ltd	Korangy Karachi	Deltamethrin Triazophos Endosulfan	1,200	1,352	Full Capacity
Sandoz Pak . ltd	Jamshoro,Sind	Disulfoton Quinalphos Formathion Fenvalerate	250 1000	40 1000	16.0 Full Capacity

DT, Methyl-parathion, etc., are among the locally formulated pesticides. The main constraint faced by the local industry is the availability of suitable containers. Most of the companies have so far concentrated on the imports of pesticides in finished form because such products are allowed free of duty, sales tax and local levies. This in turn accelerates the pace of development of pesticide use allowing significant gains for the companies.

FERTILIZER USAGE IN PAKISTAN

The fertilizer consumption in Pakistan rather worldwide has been steadily increasing over the years (Table 4). The total consumption in the world which was 115.16 m ton in 1981 has increased to 145.64 m ton nutrients by 1988. Likewise in Pakistanthe fertilizer consumption which was 1.08 m ton in 1981 has increased to 1.74 m ton by 1988. Nitrogen fertilizers are the main component. The Pakistani soils are deficient in nitrogen hence the emphasis had been on supplementing nitrogen fertilizers. The values in Table 5 show that nitrogen in the form of urea or ammonium mixtures is the main supply. Phosphorus and potash supplementation is on limited scale. Nitrogen fertilizers are consumed to the tone of 1.33 m ton annually whereas the corresponding figures for phosphates and potash are 0.39 and 0.025 m ton respectively. World wide consumption during 1989 of nitrogen was 79.58 m ton, phosphates 38.07 m ton and potash 27.99 m ton. The fertilizer consumption per hectare of agricultural area of Pakistan is given in Table 6. Nitrogen fertilizers are added @ 51.2 kg/ha whereas phosphates are used @ 15.1 kg/ha and potash @ 0.9 kg/ha. The fertilizer usage in irrigated area is higher and on the average in Punjab 104 nutrient kg/ha are applied as against 76, 57 and 12 nutrient kg/ha in Sind, NWFP and Baluchistan, respectively. The average fertilizer consumption on Pakistan basis in 1989 is @ 86 kg/ha.

Since the green revolution in the 60's extensive use of fertilizers has boosted the agricultural productivity, however, this way a lot of chemicals are going into the soil and drinking water. Annually around 2 million nutrient tons of fertilizers are used in Pakistan. In Punjab during October 1988 to March 1989 alone about 0.75 million nutrient tons were applied (PAD&SC, 1989).

Table 4. World fertilizer consumption (000 mt)

Area/Country	1978	1980	1982	1984	1986	1988
World	108757	116798	115018	130546	132361	145642
Africa	2653	3294	3448	3441	3556	3725
North America	24291	25636	21196	24794	22475	22909
South America	4235	5291	3669	4567	5494	5829
Asia	25655	30974	33730	40832	40337	51851
Europe	31822	31196	31205	32070	32352	32272
Oceania	1690	1651	1626	1771	1641	1869
USSR	18412	18756	20144	23071	26506	27187
Pakistan	880	1080	1244	1253	1785	1740

Table 5. Fertilizers consumption in Pakistan (000 mt)

Fertilizer	1985/86	1986/87	1987/88	1988/89
Nitrogen Fertilizers				
Total	1128	1333	1282	1325
Ammonium sulphate	19	22	20	-
Ammonium nitrate	132	110	87	-
Urea	795	1000	968	-
Ammonium phosphate	89	116	99	-
Other	93	85	108	-
Phosphatic fertilizers				
Total P_2O_5	21	20	19	-
Concen Superphos	7	8	14	-
Ammonium phosphate	228	295	253	-
Other	9	9	11	-
Potash fertilizers				
Total	33	43	45	25
Potassium Sulphate	24	29	32	-
Other	10	14	13	-

Table 6. Consumption of fertilizer/hactare of agricultural area in Pakistan

Fertilizer	1973	Consumption in kgs 1978	1983	1988	%age
Nitrogen	14.0	27.4	36.1	51.2	76.19
Phosphate	2.4	7.5	10.3	15.1	22.47
Potash	0.1	0.3	1.1	0.9	1.34
Total	16.5	35.2	47.2	67.2	

Ref: FAO, (1990).

FORMULATION OF PROJECT

Pakistan spreads over an area of 198.7 million acres, and cultivated areas lie in the Indus basin particularly below the Salt Range and comprises nearly 34% of the total (Fig 1). Wheat, sugarcane, fodder, maize, cotton, and rice are the major crops. Since this is mainly the agricultural area, the agricultural productivity, like other parts of the world, is being enhanced through the use of fertilizers and pesticides. The extensive use of fertilizers and pesticide in the last three decades has caused expectedly an effective leaching of agrochemicals due to rainfall and soil irrigation processes, and consequently the pollution. The pollution is carried into the ground by the movement of surface water through infiltration and percolation processes. If the subsurface strata is permeable, then the polluted water percolates downward under the influence of gravity to join the zone of saturation. Thus, groundwater is polluted, and generates health hazards when used for drinking purposes. Groundwater is an important source of water for irrigation and domestic use, therefore, its purity and drinkability matter in all water supply schemes all over the world.

The study area (Samundri, district Faisalabad) lies in Rachna Doab (Punjab plain) which consists of all the lands between the Ravi and Chenab rivers and comprises about 28500 square kilometers, out of which 70% is under cultivation. The lower chenab is the major source of water to Jhang and Rakh Branch Canals which serve the Paharang and Samandar I unit. Chenab canal began irrigation deliveries in 1887 and later was converted to water control in 1890. Samundri drain flowing south west passes through the area, and carries the industrial effluents of Faisalabad.

The canal irrigation system in northern and central Punjab was introduced in 1886 (Fig 2-4). The groundwater level for example in Faisalabad (Lyallpur) which was 25 meters before the start of canal irrigation system rose to as high as 3 meters in most areas and in some low lying areas it was even higher where water logging ensued. Upon the suggestion that canal irrigation was the recharge source and responsible for resultant water logging (Tipton and Kalambach, 1967), tube-well installation was recommended for lowering water

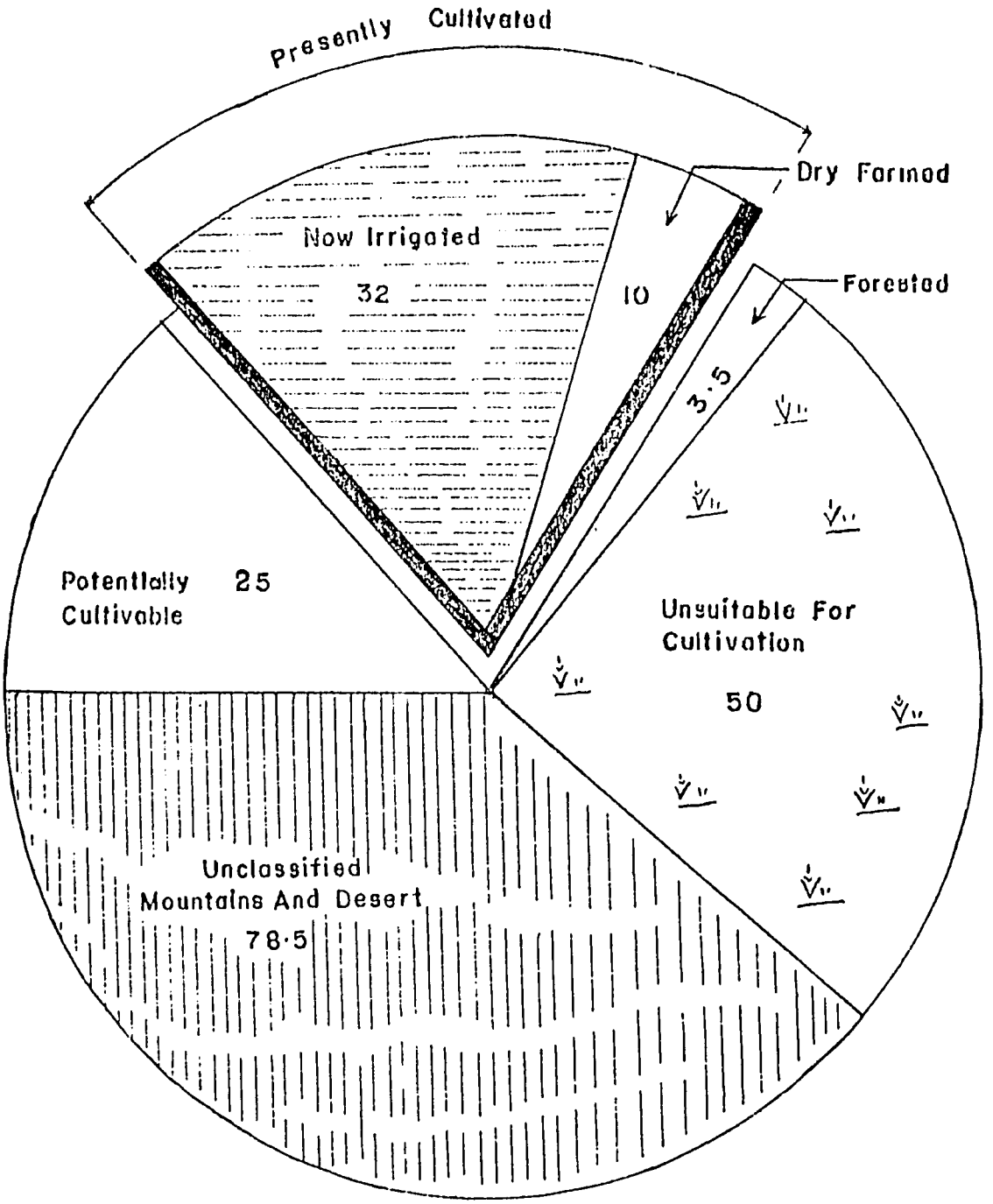


Fig. 1. LAND USE IN PAKISTAN (million of acres)

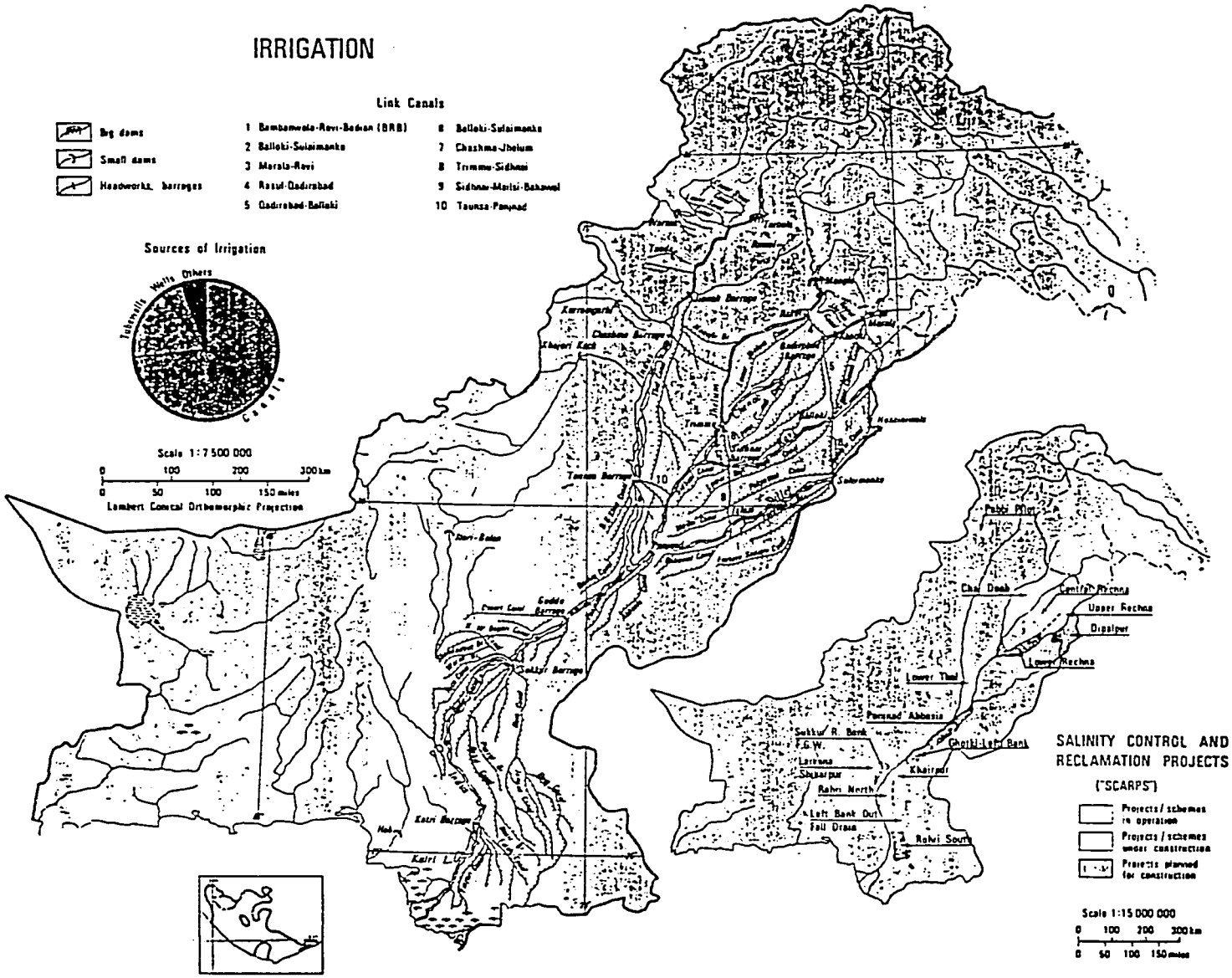

IRRIGATION
Big dams
Small dams
Headworks, barrages
Link Canals
1 Bambanwala-Ravi-Bedian (BRB)
2 Balloki-Suleimanka
3 Marala-Ravi
4 Rasul-Qadirabad
5 Qadirabad-Balloki
6 Balloki-Suleimanka
7 Chashma-Jhelum
8 Trimmu-Sidhnai
9 Sidhnai-Mailsi-Bahawal
10 Taunsa-Panjnad
Sources of Irrigation
Others
Wells
Tubewells
Canals
Scale 1:7 500 000
0 100 200 300 km
0 50 100 150 miles
Lambert Conical Orthomorphic Projection
Kalabagh
Khairi Murat
Chashma Barrage
Taunsa Barrage
Sukkur Barrage
Kotri Barrage
Kotri L.C.
Sukkur
Hyderabad
Karachi
Sahiwal
Multan
Lahore
Rawalpindi
Peshawar
Quetta
Pabbi Pilot
Chak Doab
Central Rechna
Upper Rechna
Dipalpur
Lower Rechna
Lower Thal
Panjnad Abbasia
Sukkur R. Bank
F.G.W.
Larkana
Shikarpur
Rahri North
Left Bank Out Fall Drain
Rahri South
Khairpur
Cholistan Left Bank
SALINITY CONTROL AND RECLAMATION PROJECTS
("SCARPS")
Projects / schemes in operation
Projects / schemes under construction
Projects planned for construction
Scale 1:15 000 000
0 100 200 300 km
0 50 100 150 miles

Figure 2

INDUS BASIN IRRIGATION SYSTEM

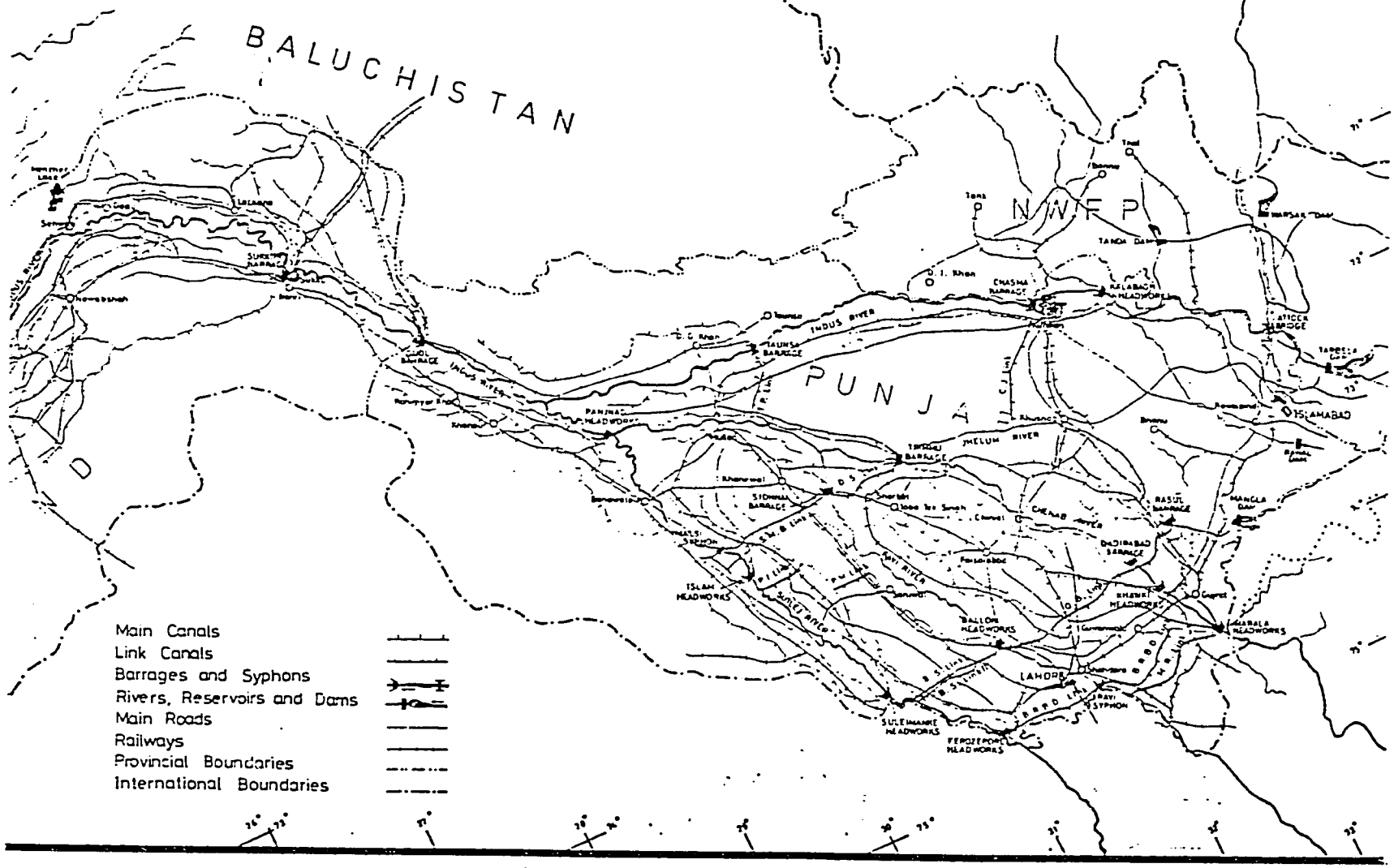


Figure 3

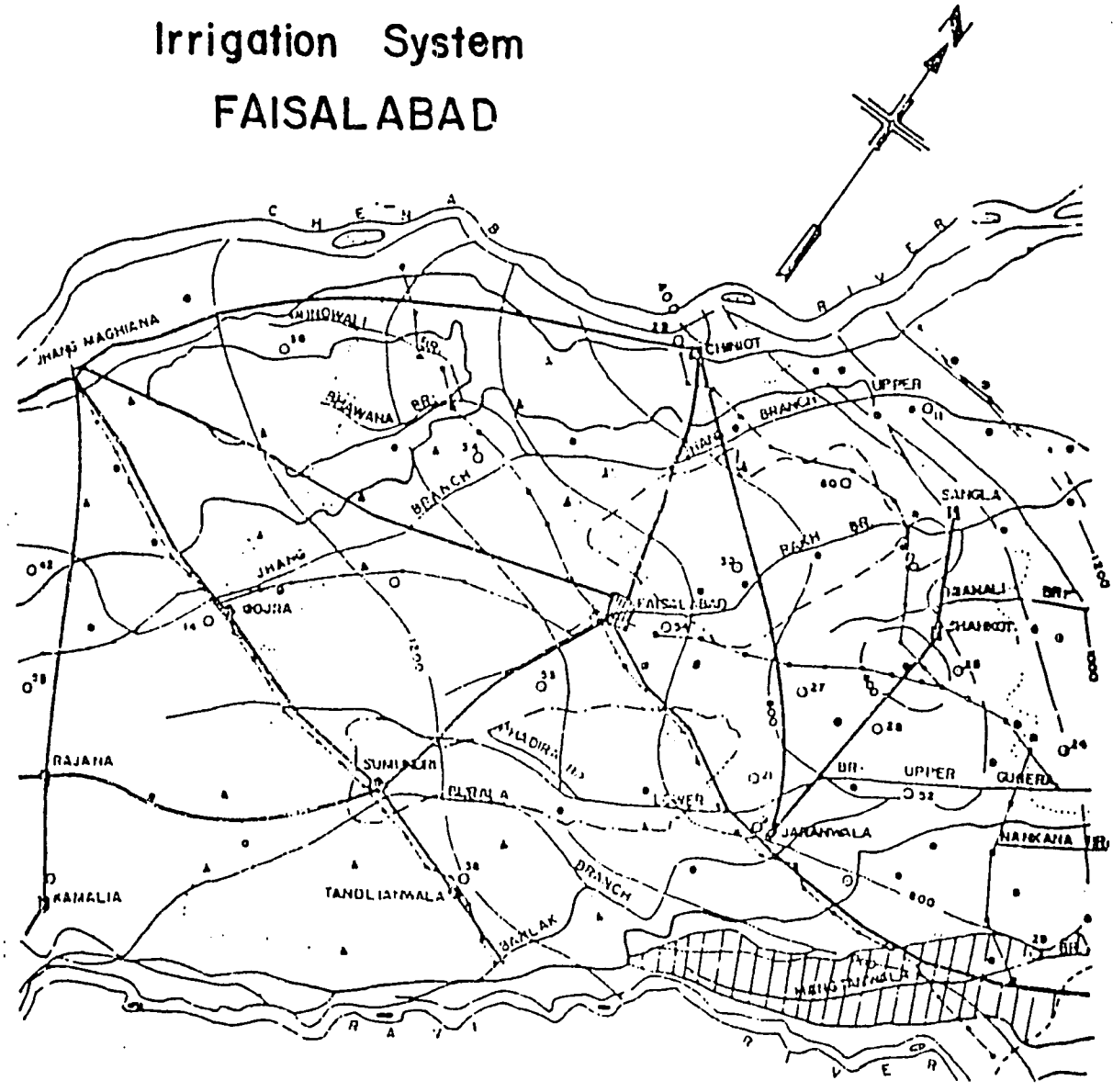

Irrigation System
FAISALABAD
CHENAB
RIVER
JHANG MAGHIANA
CHINIOT
UPPER
BRANCH
SANGLA
JHANG
GOJRA
FAISALABAD
RAJANA
SUMUNDRI
PATMALA
UPPER
GUNERA
JARANWALA
NANKANA
KAMALIA
TANDLIANWALA
BRANCH
RAVI
RIVER

Figure 4

table. Although this method could not solve the problem, however, tube-wells coupled with drains dug through the area lowered the water table to 20 meters in certain areas. Generally the water table is between 4-25 meters. Faisalabad is an agriculture intensive area mainly irrigated by canal waters. Wheat, sugarcane, cotton and maize are the major cash crops in addition to fodder crops, vegetables and fruit trees. Fertilizers are employed extensively since 1950's and insecticide usage started with the application of organochlorine insecticides for the control of sugarcane pests. Because of the long history of the agrochemical usage and higher water table there is a great possibility of shallow groundwater contamination by these pollutants.

The agricultural practices and sufficient permeability of alluvial complex generated the fears of pollution of groundwater in the area, and consequently, a project was designed to look into the quality of groundwater in the area.

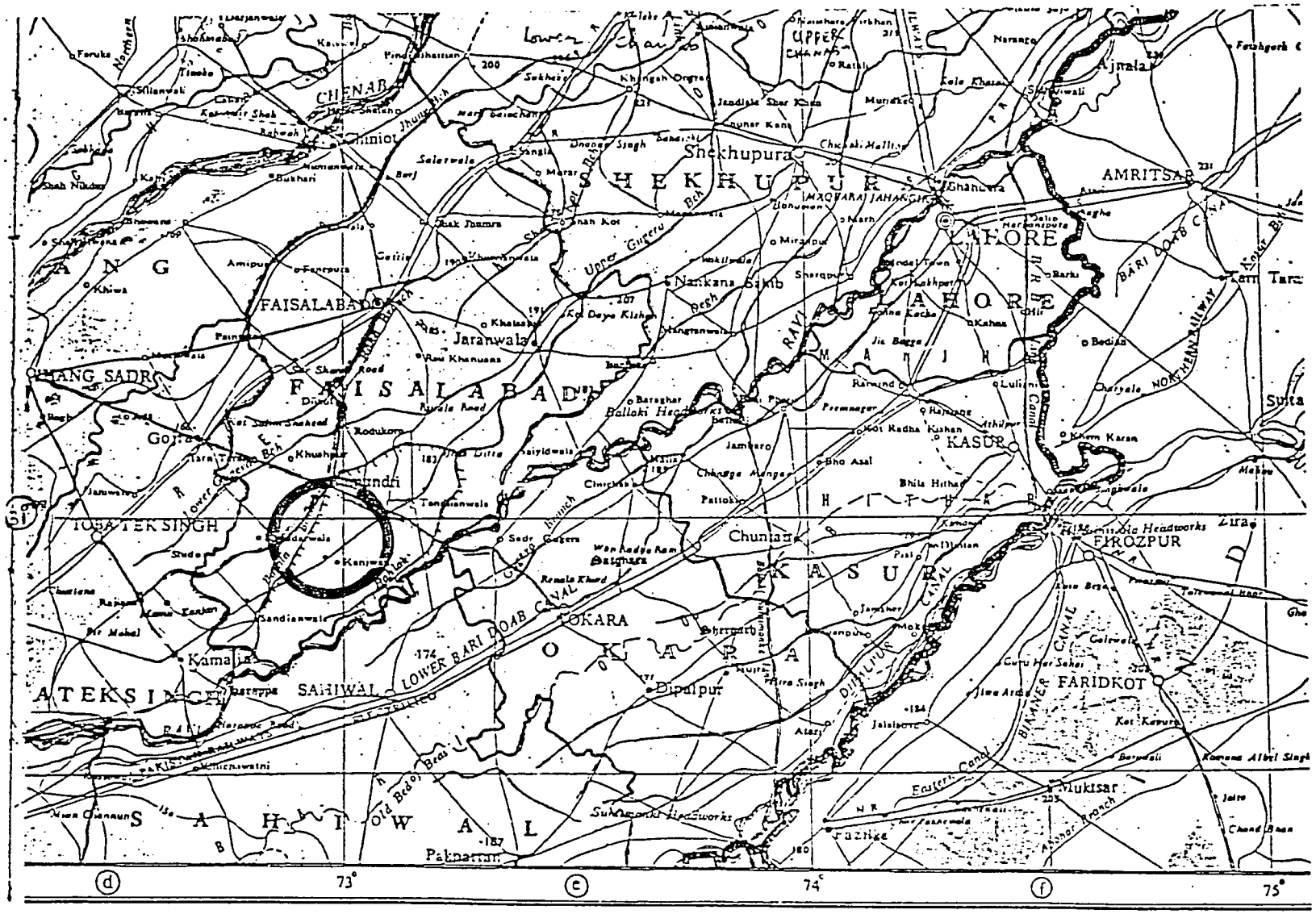
CHAPTER III

PROJECT AREA

For groundwater pollution study Samundri area, District Faisalabad (Fig 5), has been picked because of higher water table condition and long history of agrochemical usage. The project area (Fig 6) is 30 km south of Faisalabad and is bounded by latitude 30°45' to 31°05'N and longitude 72°45' to 73°00'E, giving total coverage of 700 sq kms. Topographically the area is almost flat with elevation change from 540' in south to 567'(above sea level) in the north. The water table depth varies from 10 feet to more than 40 feet (Fig. 7).

CLIMATE

The climatic conditions have marked variations in temperature and precipitation (Table 7). Summers are long and hot, lasting April through September, with temperature range of 70°F to 120°F. Winter lasts from December to February with minimum temperature range of 32°F to 45°F. The spring (March) and Autumn (October) are moderate. Annual precipitation averages about 12 inches. The monsoon occurs from June to September and accounts for 75% of the total precipitation. Total evaporation is about 80 inches a year.



Selected area encircled

Projection International Polyconic

Canal

River

Roads, Main, Other, Tracks.

Railways

H Q Prov, Div, Dist., Tahsil,

Figure 5

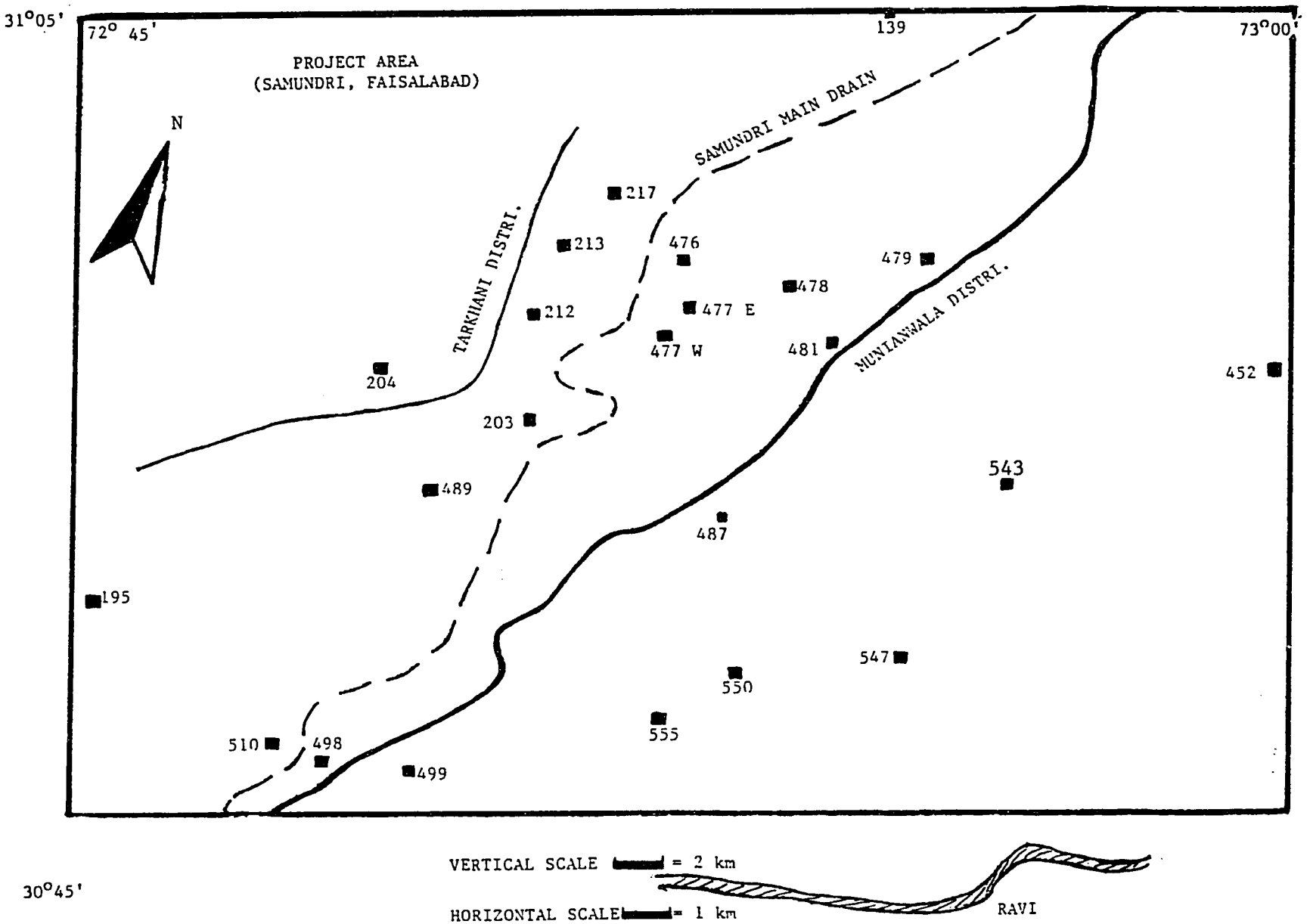

31°05'
72° 45'
139
73°00'
PROJECT AREA
(SAMUNDRI, FAISALABAD)
N
SAMUNDRI MAIN DRAIN
TARKHANI DISTRI.
MUNTANWALA DISTRI.
217
213
476
479
478
212
477 E
477 W
481
204
452
203
543
489
487
195
547
550
555
510
498
499
VERTICAL SCALE = 2 km
HORIZONTAL SCALE = 1 km
RAVI
30°45'

FIGURE 6

WATER TABLE DEPTH FROM SURFACE
(Feet)

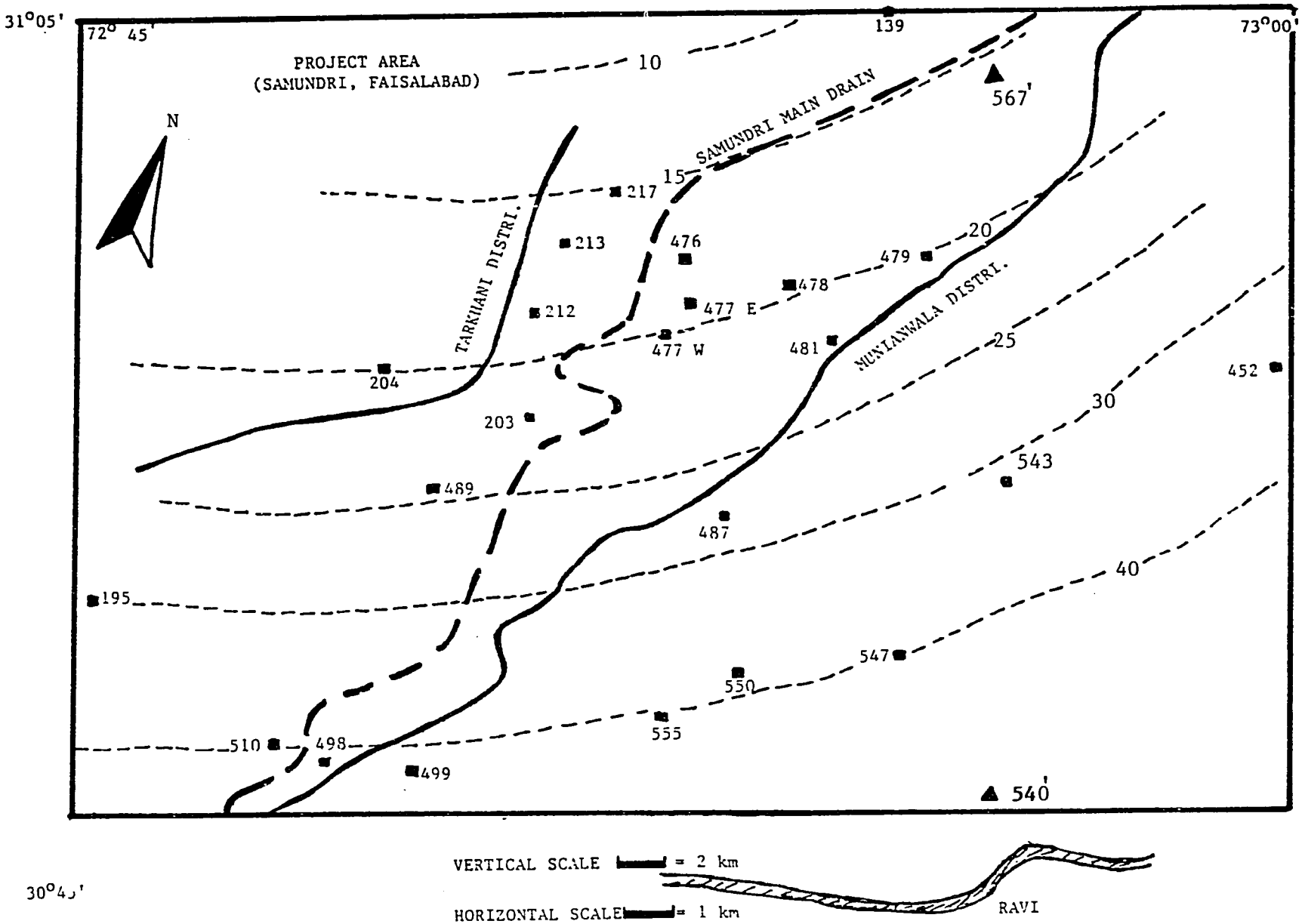


Figure 7

Table 7. Faisalabad climate data

Month	Temperature Min.	Temperature Max.	Precipatation Mean	Precipatation Max.	Pan evaporation Average	Pan evaporation Max.
	Degrees Celcius(°C)		24-hour (Millimeters)		(Inches)	
January	4.8	19.4	16.3	36.8	2.7	4.0
February	7.6	22.4	18.0	43.7	3.0	4.1
March	12.6	27.4	23.1	41.1	5.4	7.5
April	18.3	34.2	13.7	30.7	7.8	9.3
May	24.1	39.7	8.6	44.7	12.3	20.8
June	27.6	41.0	28.7	87.6	14.5	21.9
July	27.9	37.7	96.5	100.1	11.7	19.5
August	27.2	36.5	97.5	155.7	9.8	13.0
September	24.5	36.6	28.5	149.4	5.8	10.8
October	17.7	33.9	5.1	39.1	6.5	9.0
November	10.4	28.2	2.3	22.6	4.0	5.5
December	6.1	22.1	7.8	38.1	2.8	4.4

Ref: Ahmad (1974)

CHAPTER IV
GEOHYDROLOGY

PUNJAB PLAIN

Punjab plain is a part of the Indus Plain, and five major rivers flow through it. From West to East, these are the Indus, Jhelum, Chenab, Ravi and Sutlej. Of these, the Indus is by far the longest river arising in Himalayas, it flows for a thousand miles in a deep gorge through the mountains and then enters the plains. The other four rivers are tributaries of the Indus, and arise in the hills of Kashmir and Jammu, and are fed by the western slopes of the Himalayas. The Jhelum and Chenab converge at Trimmu, and in turn, they are joined by the Ravi some 40 miles further down-stream. The Sutlej joins the others at Panjnad, and combined stream flows on to meat The Indus near northern edge of Sind. There are four doabs (Thal, Chaj, Rachna, and Bari) that make up the southern part of Punjab.

GEOLOGY

The Indus Plain is rimmed abruptly on west by the Kirthar and Suleman mountains, on north-west by the Salt Range, and the north by the foothills of Himalayas. To the north-east and east, the plain extends into Kashmir and India, whereas on the south-east, the sand dunes of the desert press against the plain and restrict its width. Its southern most boundary is the delta of the Indus which fades into a giant saltpan of Rann of Kutch and gradually becomes submerged beneath the Arabian Sea.

The Indus Plain geologically is a part of the broad downwarp that extends westward from the Bay of Bengal under the flood plain of the Ganges and thence across the subcontinent to the Arabian sea. The downwarp or Indo-gangetic synclinorium which was formed in the basement of metamorphic and igneous rocks of Pre-cambrian age as a fore-deep valley, is synchronous with the Himalayan orogenesis that started in early tertiary (40

million years ago) as a consequence of collision between the Indian and Euresian Plates (Molnar and Tapponier, 1975, 1984). This downwarp, in its western half, has been leveled and filled to depths of several thousand feet with sands and silts deposited by the Indus and its tributaries.

Alluvial complex of the plain derived from the mountain ranges to the north, has been deposited by the present and ancestral tributaries of the Indus river The alluvium is of Pleistocene to recent age, and represents the latest phase of sedimentation in tectonic environments that started in mid-Tertiary age, the deposition of predominantly fluviatile sediments in a subsiding trough or fore-deep adjacent to the rising Himalayan mountain ranges. The alluvial complex consists principally of fine to medium sand, silt and clay. Beds of very course sand or gravel are also found. Associated with fine-grained strata are concretionary nodules (Kankar) of secondary origin, sometimes pebble of siltstone or mudstone may be found. The alluvium upto a depth of 600 ft is generally of heterogeneous character in downstream and transverse directions.

In Punjab plain, the quaternary alluvium has been deposited on semi-consolidated tertiary rocks or on the pre-Cambrian basement. As regards the Tertiary rocks (Siwalik system), except for Pabbi Hills area (northern Chaj Doab) their distribution is unknown. In the areas of Chaj, Rachna, and Bari Doabs, exploratory drilling has revealed the fact that quaternary alluvium directly overlies the Pre-Cambrian basement. Basement rocks are exposed in Chiniot, Sangla, Shahkot, and in Kirana. These exposures represent the peaks of Shahpur-Delhi buried ridge which probably is northwesterly extension of the ancient Aravali mountain system in India.

Test drilling close to the outcrops and few miles away in northeast indicated shallow and thick (more than 1500 ft) alluvium cover over the basement, giving a clue of steep dip. The alluvial thickness on the ridge crest along the strike (NW-SE) is about 400-500 ft, and is off-set by the presence of channel/gorge.

HYDROLOGICAL CHARACTER

The alluvial deposits of the Punjab, inspite of heterogeneous composition, form a unified, highly transmissive aquifer, in which groundwater occurs essentially under water table conditions. As mentioned by Ahmad (1974), the uppermost 300 ft of aquifer is the most productive zone. The blocking effects of the bedrock outcrops on regional movement of groundwater are probably negligible, as only a very small proportion of the total area of Rachna and Chaj is occupied by the bedrock hills. The large gaps between outcrops and occurrence of interrelated sandy zones in alluvium are expectedly the factors to deblock the movement of groundwater on regional scale. The lateral permeability of the alluvium ranges from $5x10^{-4}$ to $5x10^{-3}$ cusec/ft^2 (Ahmad, 1974), and is roughly of an order of magnitude higher than the vertical permeability (10^{-3} to 10^{-5} cusec/ft^2).

The hydraulic balance of the Punjab Plain has been altered significantly during the past century through a continuous and expanding diversion of river flows for irrigation purposes. In the natural environments of pre-perennial canal irrigation, the groundwater hydraulic system was in a state of dynamic equilibrium, i.e.,recharge to the ground balanced discharge and the water table remained generally static. The configuration was controlled by the pattern of evapotranspiration loss, the geometry of doab, and by the flow system. The water table was generally more than 70 feet deep in the central part of a doab.

The hydraulic situation in Punjab changed after the introduction of irrigation system in 1886. the canal system generated additional factors of recharge and water table started rising first slowly and then rapidly. By 1982, watertable reached near the surface within 5 feet depth, causing waterlogging problems. This alarming situation received attention, and watertable was lowered to some extent by the installations of tube-wells and development of drains in the area.

GEOHYDROLOGY OF THE STUDY AREA

Groundwater is stored in both permeable and less permeable lithologies, but those layers which store and transmit water are significant. To determine thickness and areal

distribution of those layers with the help of resistivity survey it is usually possible to estimate the thickness of layers containing coarse material. However, due to heterogeniety of alluvial fill it is sometimes difficult to correlate electrical resistivity values as determined from resistivity soundings with hydraulic characteristics. The expected correlation between high electrical resistivities and the presence of coarse sediments with a high permeability can be distributed by several factors such as cementation or occurence of accumulated boulders. Nevertheless, on the basis of resistivity soundings and bore hole description four classes have been established according to their general hydraulic properties:

1 - Clay, silt
2 - Clay silt with some amounts of kankars or/and sand patches
3 - Sand with minor clay
4 - Sand or gravel

As to hydraulic properties the classes 1 and 2 hardly transmit water and are considered aquiclude. The formations of classes 3 and 4 may contain some intercalated clay but their mean transmissivity is much higher and are considered aquifers.

The electrical resistivity survey (Fig. 8) generally provides information on subsurface lithology extracted from transformation of apparent resistivities measured in the field to true resistivity values through computer methodology or curve matching schemes. Resistivity data acquisited from each chak of the area, using Schlumberger configuration of varied spreads, suggest multilayered system of the alluvium complex. Upper layer or the surficial soil is mainly composed of clay or silt, the second layer is also of similar composition but with added kankars on places, the third layer which is quite thick shows sand as the major constituent with varied grain size vertically as well as laterally. The fourth layer at majority of places is the response of a decreased resistivity which most probably is the result of clay mixed sand. Below that an increase in resistivity corresponds to the revival of medium to coarse grained sand.

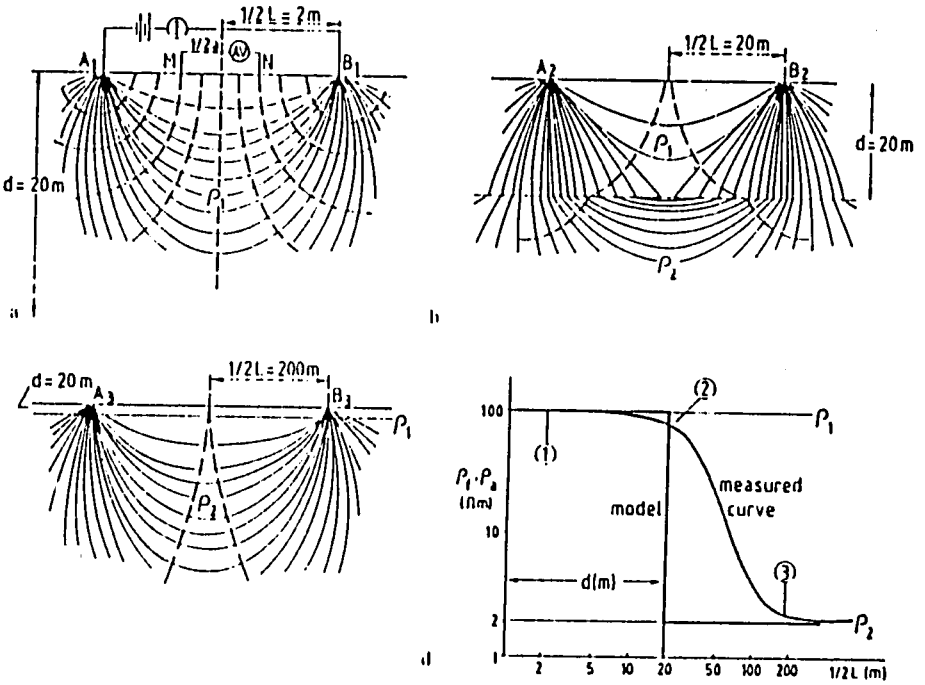


Fig. 8. Principle of the vertical electrical sounding (a-c). The sounding graph (measured curve) and the interpretation are shown in (d).

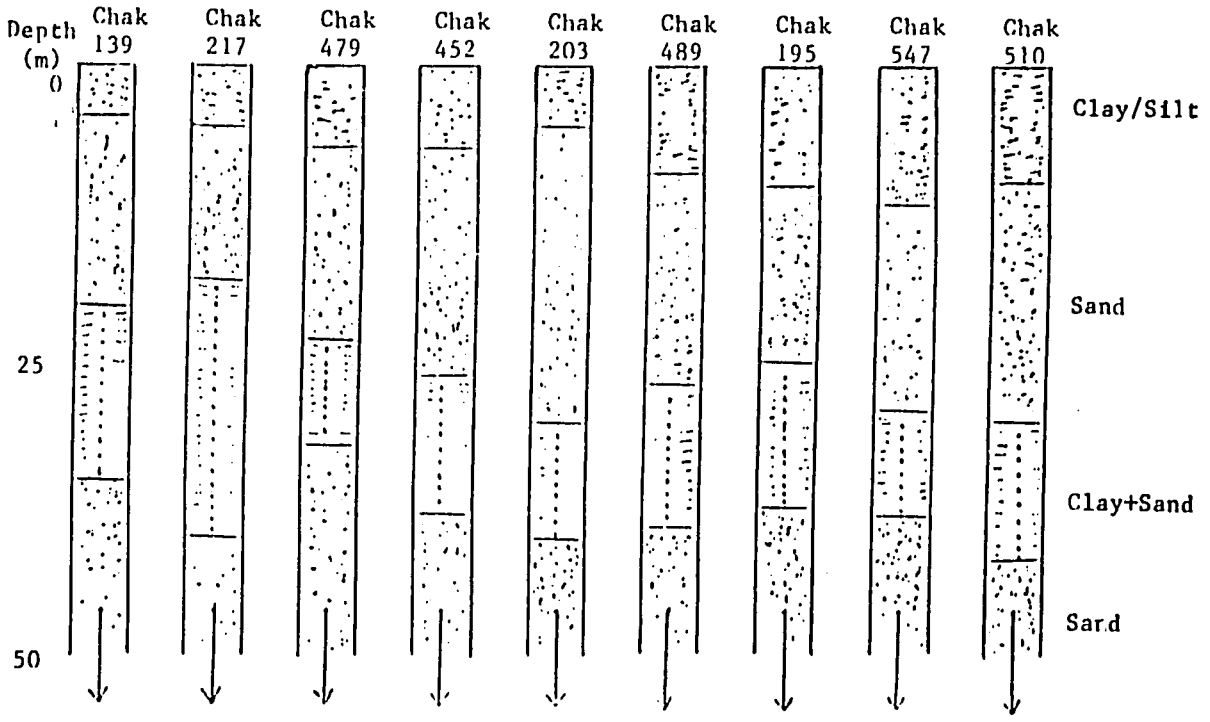


Fig. 9. Interpreted subsurface lithologies

As regards thickness of respective layers, it varies reasonably on places. However, there exists a generalized trend. The thickness of upper impermeable layer (layer 1 and 2) varies from 4 meters in the north to about 12 meters in the south. The permeable sandy layer with varied hydraulic properties is about 16±5 meters thick. Next layer which appears to be composed of clay mixed sand, thus of low transmissivity, is again 15 to 20 meters thick. Below that, permeable sandy layer extends down sufficiently (Fig. 9). When these results are compared with the water-table distribution, the first permeable layer directly corresponds to that. As regards the deeper permeable layer, although it is separated by clay mixed zone, but seems to be connected at places with the shallow aquifer through breaks/leakage in the aquiclude. This view gets support from the observed similarity in the quality of groundwater (electrical conductivity and water chemistry, Fig 12, and Tables 20,21) obtained from shallow (drilled holes and hand pumps) and deeper (tube-well) aquifer(s).

The measured electrical conductivity and laboratory analysis (cations and anions) of water of different sources (drilled holes, hand pumps, and tube-wells) are presented in the form of contours maps in Figs. 12-18. These illustrations expose one prominant feature or trend, i.e., the reduction in EC, anions and cations, is in a narrow belt along the canal (Munianwala distributary) following the hydraulic gradient. This is an indication of dilution process of the groundwater. This means that the groundwater is getting recharge from the canal directly (in the north where permeable bed is quite shallow) or through seepage, or in other words, the canal (Munianwala distributary) most probably is behaving as influent stream. The behaviour of Tarkhani distributary is not discussed because of lack of data. As regards, Samundri Main Drain, the contribution to groundwater in this area is probably negligible at present.

QUALITY OF THE NATIVE GROUNDWATER

Native groundwater is that existed in the aquifer pre-irrigation period and whose quality is least disturbed by admixture of seepage water from canal system. This has been assumed (Shamsi and Hamid, 1960 cf Ahmad, 1974) that water at depth more than 100 ft is representative of native groundwater. With that assumption more than 2500 water samples

were collected from 800 test holes of about 450 ft depth drilled the Punjab during 1955-60, and were analyzed for chemical quality (Shamsi and Hamid, 1961 cf Ahmad, 1974).

Originally the variation in groundwater chemistry is largely the result of pattern of circulation in pre-irrigation environments, stagnation and evaporation from the watertable, presence of abandoned river/channel courses, and of local factors.

The distribution of fresh and saline groundwater zones is locally controlled by the presence of extensive clay deposits within the alluvium. If these are present in proximity to the rivers, they may effectively reduce or prevent recharge, and restrict the circulation of fresh water to give concentrations of dissolved salts.

Variations in the composition of the native groundwater, are largely due to chemical changes in the course of progressive mineralization of groundwater. These changes are universal under similar conditions of climate and localized recharge. They reflect the geochemical evolution of the groundwater in the hydrological environment. In areas of recharge along the rivers and in the upper reaches of the doabs, where precipitation is relatively high, groundwater generally contains between 200 to 500 ppm of Total Dissolved Solids (TDS). Water from the five major rivers of the area, providing the bulk of groundwater recharge, has an average mineral content of about 150-170 ppm. River water is in all cases of the calcium- bicarbonate type, having relative Ca and HCO_3 concentration in excess of 65 percent each of the total cations and anions. The infiltrating river waters, upon entering groundwater circulation, gradually becomes more mineralized and may be modified to the sodium bicarbonate type within a few miles from the rivers. An increase in sodium content is also common in progressively deeper water samples. The relative increase in sodium at the expense of calcium appears to be the result of base exchange in clays of the alluvial deposits.

The moderate transition in chemical quality downgradient to a concentration of about 2,000 ppm TDS is largely the result of chemical reaction between groundwater and the sediments. The increased concentration chiefly involved the accretion of the more soluble

constituents of the rocks-- sodium of the cations and chloride and sulphate of the anions. Thus groundwater in the range of concentration of TDS between about 500 and 2,000 ppm is commonly a sodium-bicarbonate water, or it may be of the mix type; sodium generally is the dominant cation, but the anion may be relatively evenly distributed among bicarbonate, chloride, and sulphate.

Evaporation appears to be an important factor in the more abrupt increase in mineral content above a concentration of about 2,000 ppm TDS. Sodium and chloride account for much of the increase, and in the range of concentration between about 2,000 and 4,000 ppm TDS, the character of the groundwater evolves from a mixed type to a sodium-chloride type, in which these ions comprise about 50 percent or more of their respective groups. Increasing concentration of TDS above, 4,000 ppm is marked by an increase in the relative concentrations of sodium and chloride, and in many of the highly mineralized water reflects the differential solubilities of the various ions. With increasing concentration of TDS, the least soluble constituents, the alkaline earths, as sulfates. Therefore, the relative concentration of these ions in groundwater diminished with increasing total mineral content. Geological studies have shown that the precipitation of carbonate, as kankar, is most common in the zones of highly mineralized groundwater.

There are some slight differences in the chemical character of the groundwater in different doabs. For example, the relative concentration of sulphate is characteristically high in Bari Doab, and Bahawalpur and low in Chaj Doab, as compared to Rachna and Thal Doabs. These differences cannot be correlated with any obvious feature, but they are probably related to the local geological environment.

Thus the mineralization of the groundwater in the Punjab generally supports the thesis that the doabs function as more-or-less discrete hydrological units. In that connection, the salient features are first, the progressive deterioration of the quality of water with distance from the rivers and secondly, the differences in the composition of the groundwater between the doabs. If underflow were a major factor in the water balance it would be expressed by continuation of highly mineralized zones beneath the river accompanied by

gradual changes in the chemical character. These factors are not evident within depths of several hundred feet below land surface and at greater depths groundwater movement probably is insignificant.

Changes in the quality of groundwater: The quality of the shallow groundwater - that is, the water derived principally from leakage from the irrigation system - in Rachna and Chaj Doabs has been described, respectively, by Shamsi & Hamid (1960) and Gilani & Hamid (1960). Data on the quality of water from shallow sources in other parts of the Punjab are available in the files of WASID. In the course of the investigation, about 120,000 shallow dug or driven wells were inventoried and the conductivity and pH of water samples were determined. In addition, complete chemical analysis of a large number of samples were made in the Water Quality Laboratory of WASID. The following summary is based largely on these data.

The shallow groundwater occupies the interval between the native, pre-irrigation water table, and the existing water table. In this zone canal leakage has resulted in two related major changes: the saturation of formerly dry sediments with water of generally good quality and the dilution of the native groundwater adjacent to the canals. The thickness of the shallow water zone commonly ranges from less than 20 feet along the margins of the doabs to 100 feet or more in the lower and central parts of the doabs. Locally, however, seepage from the major canals has improved the quality of the native groundwater.

Studies by Shamsi & Hamid (1960) and Gilani & Hamid (1960) as cited by Ahmad (1974), show that the general pattern of the quality of groundwater at shallow depths resembles the regional pattern of the underlying native water. In areas of pre-dominantly saline groundwater, supplies from shallow sources generally are also saline, but mineral concentration in the shallow water are less because of dilution by canal seepage. In general, water from shallow wells located near sources of recharge is of good quality. Along the rivers and in the upper reaches of the doabs, where precipitation is a factor of recharge and maximum canal supplies are available, groundwater contains commonly less than 1,000 ppm of TDS.

The quality of individual supplies is determined largely by the local environment, although the average conditions in the area dominated by the efforts of climate and the availability of recharge from the irrigation system. Shallow groundwater, derived from canal leakage, is of acceptable quality in most of the area.

CHAPTER V

CROPPING PATTERN AND AGROCHEMICAL USAGE

Wheat, cotton, and sugarcane are the major crops in the area (Fig 10,11). The average holding size in the study area is, less than 5 hectares (42%), between 5 to 10 hectares (47%), and more than 10 hectares (11%). Minimum size of holding is 2 hectares and maximum is 55 hectares. 32% farmers use canal water for irrigation, only 5% use tube-well water alone, and about 63% farmers combine canal and tube-well water, hence, canal and groundwater mixing is the most favoured mode of irrigation. Main rabi crop is wheat and is sown by more than 84% farmers, sugarcane by 11%, and mustard by 5%. Almost all the farmers in selected area grow cotton to some extent as the main kharif crop. In fact the study area was selected such that it received maximum inputs both in the form of fertilizers and pesticides (Table 8).

The demand for enhancing crop productivity has shifted the reliance upon improving the soil fertility by supplementing farm yard manure with synthetic chemical fertilizers. Better crop protection measures have also been instrumental in improving yields. Agrochemicals (fertilizers, pesticides, growth regulators) are chemicals that, when properly used, have a positive effect on food production and other agricultural activities. The application of pesticides can replace many pest control practices which make heavy demands on labour. For example in Europe between 1939 and 1966 the cost of labour on the land increased at least eight-fold, the price of land five fold, but the farmers return only three-fold. The farmers responded to this by increasing their yield by 50% through the use of machinery, fertilizers and pesticides. Since 1940s the use of pesticides has greatly improved pest management as well as public health. In many ways the discovery of DDT was the most important medical discovery of the century. In the warmer parts of the world DDT and its other organochlorine analogues have probably saved more lives, by the destruction of disease-transmitting insects, than penicillin. It almost certainly spared war-torn

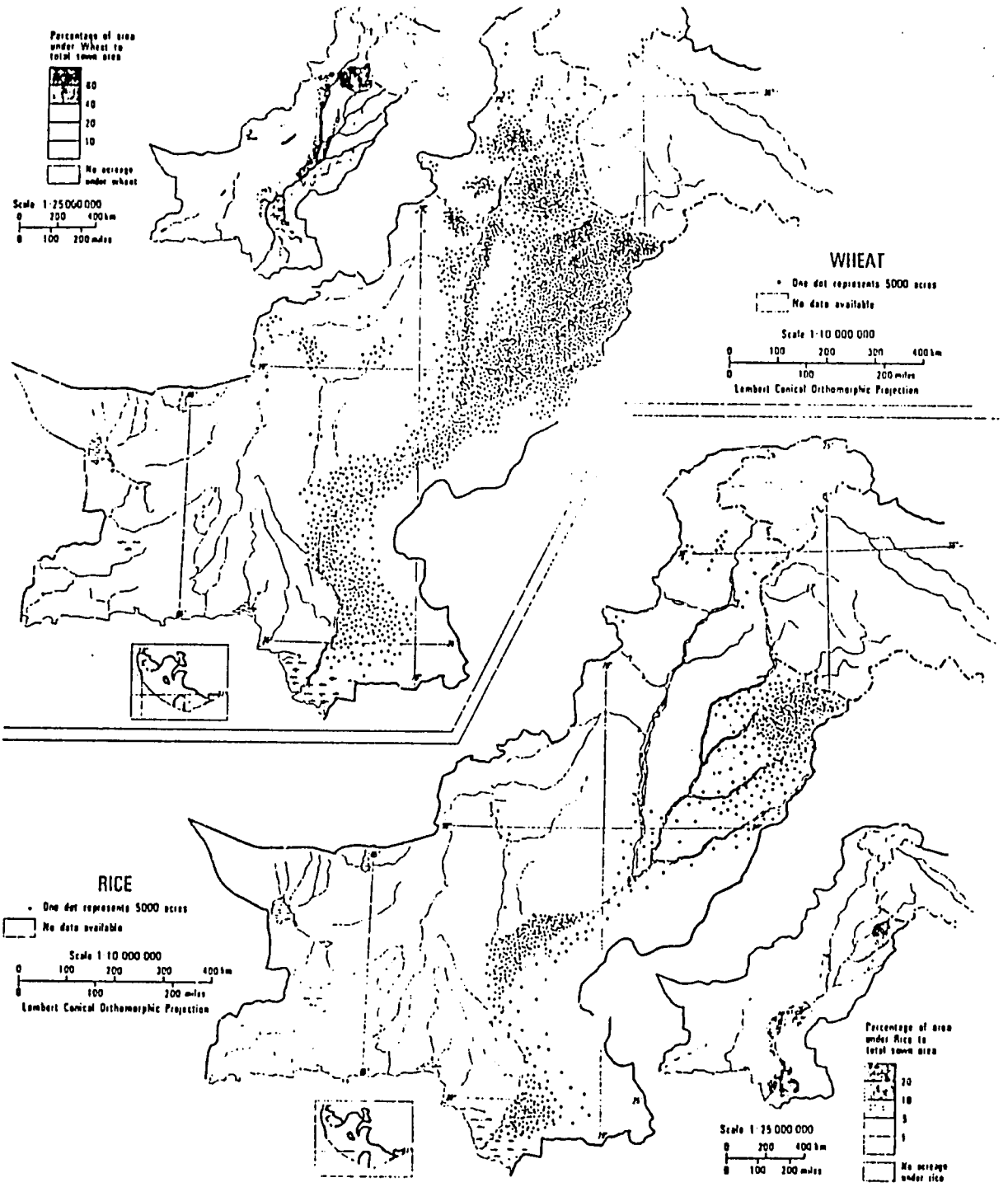

Percentage of area under Wheat to total sown area
60
40
20
10
No acreage under wheat
Scale 1:25000000
0 200 400 km
0 100 200 miles
WHEAT
One dot represents 5000 acres
No data available
Scale 1:10 000 000
0 100 200 300 400 km
0 100 200 miles
Lambert Conical Orthomorphic Projection
RICE
One dot represents 5000 acres
No data available
Scale 1:10 000 000
0 100 200 300 400 km
0 100 200 miles
Lambert Conical Orthomorphic Projection
Percentage of area under Rice to total sown area
20
10
5
1
No acreage under rice
Scale 1:25 000 000
0 200 400 km
0 100 200 miles

Figure 10

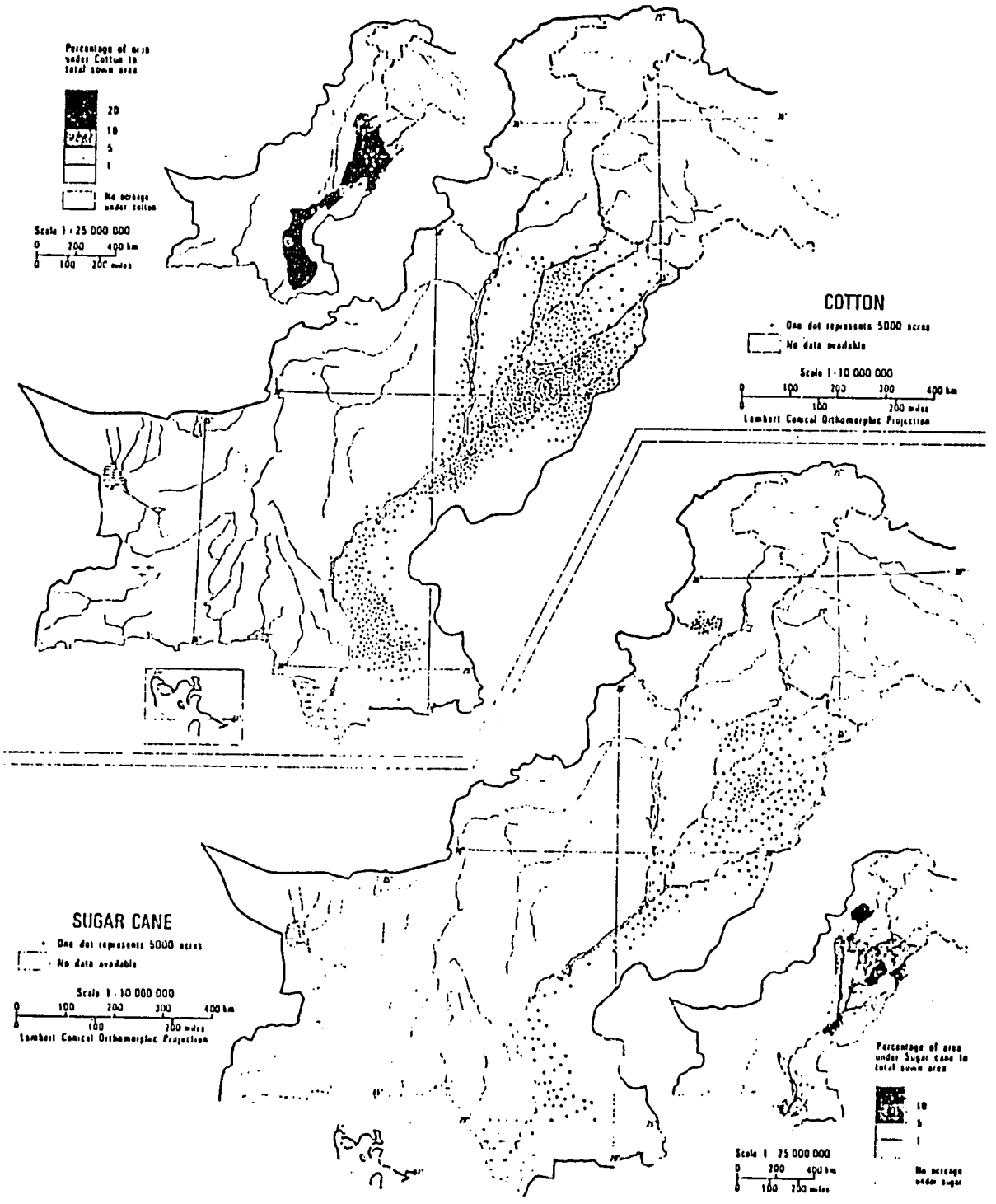


Figure 11

Table 8. Cumulative (%) data of land use in Samundri, Faisalabad

Land holding	% age	Major crops	% age
5 > hac	47	Wheat	84
5-10 hac	47	Sugarcane	11
> 10 hac	11	Mustard	5
Mode of irrigation	**%age**	Cotton	100
Canal	32	**Cultivated area**	
Tubewell	5		
Canal+Tubewell	63	Under crop	100

Table 9. Cumulative (%) data on pesticide usage

Plant protection measures adopted	%	Advisory service	%
Yes	88	Yes	40
No	12	No	60
Mechanical weeding in Wheat	100	Use fresh pesticides	100
Herbicides in wheat	47		
Insecticides in cotton	89	No of insecticide sprays on cotton	
Insecticides in sugarcane	47	4	13
Pesticide application		4-5	7
- according to schedule	100	5	40
- recommended dose	100	5-6	33
		6	7
Spray as mode of application	100		

Table 10. Cumulative (%) data on fertilizer usage

Fertilizer	No of bags	%	Fertilizer	No of bags	%
DAP	1	61	NP	1	44
	2	6		2	6
AN	1	11	K	1	11
	2	17		2	6
Urea	1	44	SSP	1	6
	2	33		4	11
	3	22		8	6
Goara	1	11			

Europe from the ravages of typhus when the outbreak was checked in Naples. Insecticides, fungicides and weed killers have played an essential role in the provision of food and fibre for a starving world.

Increasing quantities of agrochemicals are being used in developing countries. Not only are progressively larger amounts being imported from Europe, USA and Japan but the production capacity of the developing countries themselves is also increasing rapidly. According to world Health Organization report (1985), in developing countries, in Central and South America, Asia, the Mediterranean region, Africa, and the Western Pacific, at least 90% of pesticides are used on agricultural crops, particularly cotton and rice. The remaining 10% are used for the control of vectors of human diseases. The market for agricultural chemicals in the developing countries has reached a considerable size and will continue to grow in the coming years. The possible hazards to human health and the environment associated with increased use of such chemicals have been controlled fairly effectively in developed countries but the situation could be worse if the use of chemicals in agriculture and disease prevention and control is allowed to develop haphazardly. In Pakistan better crop protection measures (with heavy emphasis on insecticide usage) coupled with the introduction of high-yielding varieties the cotton production has increased from 4.2 to 9.2 billion bales from 1981 to 1990. The heavy reliance on chemicals may have adverse effects on our environment through polluting our ecosystem. These risks can be eliminated or minimized by careful handling and use of pesticides. A strategy for increasing agricultural yield should not emphasize economic returns to the exclusion of any consideration of the negative effects on health and the environment.

PESTICIDE USAGE IN THE STUDY AREA

In the study area three major crops receive pesticide cover (Table 9,11). Sugarcane used to be treated by endrin during 60's and 70's. Since the ban on endrin the pesticide application has been minimized to Nuvacron, Azodrin and Karosine oil (for termites only). 47% of the surveyed farmers are applying insecticides. Mechanical weeding in wheat is still the most favoured practice, however, since last 4-5 years Arelon and Dicuron is being

Table 11. Farm holding size and plant protection practices in Samundri, Faisalabad

Farmer No	Holding Size (Acre)	Pl.Prot. measure adopted	What	Advisory Service	Application Dose	No. of Appl.	Pesticide	crop	Since Years
1	12.5	Yes	Pesticide	No	Recommended	1 (Sugarcane)	Nuvacron	Sugarcane	2
						5-6 (cotton)	Azodrin	"	3
							Endrin	"	15*
							Nuvacron	Cotton	5-6
							Polytrin C	"	"
							Ripcard	"	"
							Knokout	"	"
3	25	Yes	Pesticide	No	Schedule Recommended	1 (Sugarcane)	Dicuran MA	Wheat	4
						5 (Cotton)	Arelon	"	"
							Nuvacron	Sugarcane	5
							Azodrin	"	5
							Nuvacron	Cotton	7
							Perfekthian	"	"
							Danital	"	"
							Ripcard	"	"
							Cymbush	"	"
							Arrivo	"	"
4	15	Yes	Pesticides	No	Schedule Recommended	1 (wheat)	BHC	Maize	1
						1 (Sugarcane)	"	Tobacco	"
						5,6 (Cotton)	Nuvacron	Sugarcane	4
							Gesapex	Sugarcane	5
							Polytrin C	Cotton	7,8
							Ripcard	"	"
							Cymbush	"	"
							Nuvacron	"	"
							Danital	"	"
5	25	Not Regularly	- -	No	Recommended	1 (wheat)	Arelon	Wheat	4
						1 (Sugarcane)	Endrin	Sugarcane	20*
6	12.5	Yes	Pestisides	No	Schedule Recommended	4 (Cotton)	Dicuran MA	Wheat	3
							Nuvacron	Cotton	2
							Polytrin C	"	"
7	25	No	-	No	-	-	-	-	-
8	20	Yes	Pesticides	Yes	Schedule Recommended	5 (Cotton)	Endrin	Sugarcane	20*
9	20	Yes	Pesticides	Yes	Schedule	4-5 (cotton)	Nuvacron	Cotton	4
							Polytrin C	"	"
							Karate	"	"
							Sumicidin	"	"

Cont. next page

10	5	Yes	Pesticides	No	Recommended 4 (Cotton)	Nuvacron	Cotton	2
						Rogor	"	"
						Polytrin C	"	"
						Sumicidin	"	"
11	6	Yes	Mechanical weeding	Yes	Recommended 1(Sugarcane) 5-6 (cotton)	Nuvacron	Sugarcane	2
						Nuvacron	Cotton	5
						Decis-D	"	"
						Polytrin-C	"	"
						Baythroid TM	"	"
12	25	Yes	Mechanical weeding Pesticides		Recommended 5 (cotton) Scheduled	Dicuran MA	Wheat	1
						Tribunal	"	"
						Endrin	Sugarcane	15*
						Padan	"	2
						Karosin oil	"	"
						Tameron	Cotton	4
						Talstar	"	"
						Baythroid TM	"	"
14	10	Yes	Pesticides		Recommended 1 (Sugarcane) Schedule 5-6 (Cotton)	Dicuran	Wheat	4-5
						Arelon	"	"
						Polytrin C	Cotton	6
						Nuvacron	"	"
						Endrin	Sugarcane	20*
						Karosine oil	"	3
15	11.5	Yes	Mechanical Pesticides	No	Recommended 1 (Wheat) Schedule 5-6 (Cotton)	Decadron	Wheat	1
						Arelon	"	"
						Polytrin C	Cotton	4
						Ripcord	"	"
						Nuvacron	"	"
						Danital	"	"
						Azodrin	"	"
16	30	Yes	Mechanical Pesticides	No	Recommended 5 (Cotton) Schedule	Nuvacron	Cotton	4
						Polytrin C	"	"
17	8	Yes	Mechanical Pesticides	No	Recommended 6 (Cotton) Schedule	Polytrin C	Cotton	4
						Karate	"	"
18	25	Yes	Mechanical Pesticides	No	Recommended 5 (Cotton) Schedule	Nuvacron	Cotton	7
						Polytrin C	"	"
						Sumicidin	"	"
						Azodrin	"	"
						Danital	"	"
20	137	Yes	Mechanical Pesticide	Yes	Recommended 5 (Cotton) Schedule	Dicuran MA	Wheat	3
						Nuvacron	Cotton	3
						Polytrin C	"	"

* = Use of Endrin has been stopped after Government ban.

applied by about 47% of the surveyed farmers to control weeds in wheat. A single application in the form of spray is applied. Cotton is the crop which receives the bulk of insecticides. Nearly 90% farmers in the area use insecticide spray to control insect pests. The extensive insecticide application on cotton had started around 1982, soon after the transfer of pesticide business to private sector. The farmers are using fresh insecticides, and recommended doses are applied per schedule rather disregarding infestation level. Only 40% farmers surveyed responded affirmative that advisory service was available and that again from the pesticide company representatives. Almost all farmers were unanimous that Government agencies were not providing full advice to the farming community. The number of applications of pesticides on cotton were 4 by 13%, 4-5 by 7%, 5 by 40%, 5-6 by 33 and 6 by 7%. In other words 80% farmers are applying insecticides as 5-6 spray per season. The main insecticides in use are:

Brand Name	Technical name	Company
Nuvacron	Monocrotophos	CIBA GEIGY (Pak) Ltd.
Polytrin-C	Cypermethrin + Profenofos	CIBA GEIGY (Pak) Ltd.
Ripcord	Cypermethrin	PAK BURMAH SHELL Ltd.
Knokout		FARM SERVICES
Perfekthion	Dimethoate	BASF (Pak) Ltd.
Danital	Fenpropathrin	AGRICHEM & DYESTUFF Ltd.
Cymbush	Cypermethrin	ICI (Pak) Ltd.
Arivo	Cypermethrin	FMC CORPORATION
Karate	Cyhalothrin	ICI (Pak) Ltd.
Sumicidin	Fenvalerate	AGRICHEM & DYESTUFF Ltd.
Rogor	Dimethoate	ALINTCO Ltd.
Azodrin	Monocrotophos	PAK. BURMAH SHELL

FERTILIZER USAGE IN THE STUDY AREA

The three major forms of fertilizers i.e., nitrogenous, phosphatic, and potash are being used for improving soil fertility. Diammonium phosphate (DAP), Ammonium nitrate (AN), Urea, Nitrophos (NP), Single Super Phosphate (SSP), Potash (K) and Goara fertilizers are applied in various combinations as shown in Table (10). Generally for each

crop the ratio was K 1 bag, Urea 1-3 bags, and SSP 4 bags. Earlier the practice was to apply the recommended fertilizers on crop basis, for the past 2-3 years the trend has changed particularly with regards to phosphatic fertilizers. Now a days the recommended dose is applied on yearly basis not on seasonal crop basis. Urea and SSP are applied on split basis. Nearly 48% farmers apply fertilizers in 2-3 splits. Only 11% as single dose, 5% as 4 splits. A sizable 36% apply fertilizers as they wish without any regard to single application or split. 61% farmers put 1 bag of DAP and 6% 2 bags. 11% farmers add 1 bag of AN and 17% add 2 bags. 44% farmers use 1 bag of Urea, 33% use 2 bags and 22% use 3 bags. 44% farmers put 1 bag of NP and 6% put 2 bags. Only 11% farmers add Goara fertilizer and that again only 1 bag. 11% farmers use 1 bag of K and 6% use 2 bags. 6% farmers use 1 bag of SSP, 11% 4 bags and 6% as many as 8 bags of SSP fertilizer.

GROUNDWATER CONTAMINATION BY PESTICIDES

The pesticide application can pose a non-point pollution source, as some insecticides and herbicides degrade slowly and can persist in soils for years or even centuries. As pointed out earlier that usage of both insecticides and herbicides has increased in the last decade, the downward leaching and surface flushing of soil-applied persistent pesticides can be a major threat to aquifer. For the study of shallow groundwater contamination by pesticides drinking water samples were taken from the hand pumps drawing water from the depth of 30-45 feet. Seven samples were taken from the cotton growing area and 3 samples were also collected from the chemical (pesticide) industrial area of Kala Shah Kaku (Lahore) for comparison. The pesticide residue analysis were carried out using Gas Liquid Chromatography. Seven out of 10 water samples were contaminated with one or more pesticides (Tables 12,13). Three samples contained monocrotophos in the range of 0.04 to 0.06 ppm. Four samples had cyhalothrin ranging from traces to 0.0002 ppm. Endrin was present in 3 samples at a concentration of 0.0001 to 0.0002 ppm. The contamination of groundwater samples is a great concern and demands that such monitoring studies be extended to other areas of the country as well. Unfortunately there has been no such study in the country in the past.

Table 12. Monitoring of pesticide residues in groundwater

S.No.	Location	Depth (feet)	Pesticide detected		Quantity (ppm)
Faisalabad area					
1	Chak 452 G.B.	40	Monocrotophs	(Nuvacron) (Azodrin)	0.04
			Endrin		0.0002
2	Chak 455 G.B.	45	Monocrotophos	(Novacron) (Azodrin)	0.06
			Cyhalothrin	(Karate)	Traces
3	Chak 542 G.B.	45	Monocrotophos	(Novacron) (Azodrin)	0.05
			Endrin		0.0001
4	Chak 543 G.B.	45	Nil	Nil	Nil
5	Chak 204 G.B.	45	Cyhalothrin	(Karate)	Traces
6	Chak 477 G.B.	35	Endrin		0.0002
7	Chak 478 G.B.	30	Nil	Nil	Nil
Kala Shah Kaku area					
8	Rice Research Institute	-	Cyhalothrin	(Karate)	Traces
9	Near Ittehad Chemicals	-	Cyhalothrin	(Karate)	0.0002
10	Near Ravi Engineering	-	Nil	Nil	Nil

Table 13. Pesticide contamination of shallow groundwater

Insecticides	No. of samples*	Range (ppm)	Average (ppm)
Monocrotophos	3	0.04-0.06	0.05
Cyhalothrin	4	Traces-0.0002	0.00005
Endrin	3	0.0001-0.0002	0.00017
Non	3	-	-

* - Water was drawn from hand-pumps at 10 different sites.

SOIL CONTAMINATION BY PESTICIDES

Leaching of agro-chemicals is controlled by the amount of excess water required for evapotranspiration and nature of compound. Soil contamination by pesticides and possible downward leaching was assessed in the study area by drawing soil samples at 1, 2, and 3 feet depths. Results of the samples taken from 5 different sites in the cotton/wheat growing area revealed that the organophosphate/ pyrethroid insecticides residues were restricted to top 1 foot of soil (Tables 14,15). Whereby at Chak 550 G.B and Chak 452 G.B. monocrotophos was detected as 0.3331 and 0.6429 ppm respectively. Cyhalothrin was present at Chak 452 G.B. and Chak 499 G.B. from traces to 0.1932. Dimethoate was detected at Chak 547 G.B. only at a concentration of 0.3858 ppm. Fenvalerate, cypermethrin and profenofos were present as traces at Chak 547 G.B., Chak 550 G.B., and Chak 499 G.B. respectively. However, the organochlorine insecticides extensively used during 1960's and 1970's had moved to lower layers of soil. Aldrin was detected at Chak 452 G.B., Chak 547 G.B., Chak 550 G.B., and Chak 498 G.B. as 0.0013 to 0.0018 ppm at 2 feet and 0.0004 ppm at 3 feet depth. Dieldrin was also detected at Chak 452 G.B., Chak 547 G.B., Chak 550 G.B., and Chak 498 G.B. where its concentration was 0.0031 to 0.0096 ppm at 2 feet and traces to 0.0103 ppm at 3 feet depth. Endrin was present at Chak 550 G.B., Chak 499 G.B., and Chak 498 G.B. as 0.0002 to 0.0006 ppm at 2 feet and traces to 0.0004 ppm at 3 feet depth. p,p'-DDT was only detected at Chak 547 G.B. and Chak 550 G.B. where its concentration was in traces at 2 feet and traces to 0.0002 ppm at 3 feet. The metabolites of DDT were also studied. p,p'-DDD was detected at Chak 547 G.B., Chak 550 G.B., and Chak 499 G.B. as traces to 0.0002 ppm at 2 feet and in traces at 3 feet depth. Similarly p,p'-DDE was present at Chak 547 G.B., Chak 452 G.B., Chak 550 G.B., and Chak 499 G.B. from traces to 0.0021 ppm at 2 feet and from traces to 0.0002 ppm at 3 feet depth. In fact all the soils have been contaminated by varying amounts of different pesticides residues. As the most recently used insecticides were not found in the lower depths of the soil the analysis was not further carried out. The presence of persistent organochlorine insecticides in deeper soil (crop root zone) may explain why even after the restriction on the use of this class of insecticides their residues are still being detected in the vegetables and other edible crops as reported by Ilahi (1984) and NIH (1984).

Table 14. Pesticides residues (ppm) in Soil

S.No.	Location	Psticides		Quantity(ppm) at		
		Technical name	Common name	1 ft.	2 ft.	3ft.
1	Chak 452 G.B. Faisalabad	Monorotophos	Nuvacron Azodrin	0.3331	-	-
		Cyhalothrin	Karate	Traces	-	-
		p,p'-DDE		-	Traces	-
		Aldrin		-	0.0018	0.0004
		Dieldrin		-	0.0096	0.0011
2	Chak 547 G.B. Faisalabad	Dimethoate	Rogar Perfekthion	0.3858	-	-
		Fenvalerate	Sumicidin	Traces	-	-
		Profenophos	Curacron	-	0.0007	-
		Aldrin		-	-	0.0004
		Dieldrin		-	-	0.0011
		p,p'-DDD		-	0.0020	-
		p,p'-DDE		-	0.0014	-
		p,p'-DDT		-	Traces	0.0002
3	Chak 550 G.B. Faisalabad	Monocrotophos	Nuvacron Azodrin	0.6429	-	-
		Cypermethrin	Ripcord Arrivo Cymbush Polytrin-C	Traces	-	-
		Aldrin		-	0.0013	-
		Dieldrin		-	0.0031	-
		Endrin		-	0.0002	Traces
		p,p'-DDD		-	-	Traces
		p,p'-DDE		-	-	0.0037
		p,p'-DDT		-	-	Traces
4	Chak 499 G.B. Faisalabad	Cyhalothrin	Karate	0.1932	-	-
		Profenophos	Curacron Polytrin-C	Traces	-	-
		Endrin		-	0.0006	0.0002
		p,p'-DDD		-	Traces	-
		p,p'-DDE		-	0.0021	0.0001
5	Chak 498 G.B. Faisalabad	Profenophos	Curacron Polytrin-C	Traces	-	-
		Cypermethrin	Ripcord Arrivo Cymbush Polytrin-C	Traces	-	-
		Aldrin		-	-	0.0004
		Dieldrin		-	-	0.0103
		Endrin		-	0.0003	0.0040

Table 15. Pesticide contamination of farming land*

Insecticides	No. of sites	Depths (feet)		
		1	2	3
Monocrotophos	2	0.3331-0.6429	-	-
Cyhalothrin	2	Traces-0.1932	-	Traces
Dimethoate	1	0.3858	-	-
Fenvalerate	1	Traces	-	-
Profenofos	3	Traces	0.0007	-
Cypermethrin	2	Traces	-	-
Aldrin	4	-	0.0013-0.0018	0.0004
Dieldrin	4	-	0.0031-0.0096	Traces-0.0103
Endrin	3	-	0.0002-0.0006	Traces-0.0004
p,p'-DDD	3	-	Traces-0.002	Traces
p,p'-DDE	4	-	Traces-0.002	0.001-0.0037
p,p'-DDT	2	-	Traces	Traces-0.0002

* Soil samples were collected from 5 different sites.

WATER CONTAMINATION BY FERTILIZERS

Continuous use of fertilizers can pollute our water supplies either through the major constituents like nitrates, nitrites and phosphates or by their minor constituent like trace metals.

For this study water samples were collected from randomly selected hand pumps from each village of the project area. Depth of these hand pumps ranged from 25 to 40 feet (Table 16). Nitrates were analyzed colourimetrically and sodium and potassium on fluorometer. The nitrate values ranged from 0.02 to 0.30 ppm with an average values of 0.15 ppm. Results show that in all water samples nitrates were below toxic levels to human being and as well as for animals, but in samples from Chak 477 E & W, Chak 476 G.B., and Chak 478 G.B. nitrate concentration was three to ten times higher than other samples. Sodium is the dominant cation in all water samples. High sodium concentration of water can be toxic for sensitive plants and soil health when calcium concentration is low or is applied without mixing with good quality water. The results also show that this water is not good for drinking due to high sodium concentration which deteriorates its taste.

Second round of study in the area during 1991 showed that the groundwater obtained either from hand pumps (at a depth of 25-40 feet), or from directly drilled holes upto water table (25-30 feet), is almost similar as for as its ionic contents were concerned (Tables 17-22). The nitrate contents are found to be less than 0.5 ppm, and are below the acceptable limit of 5 ppm. The copper content varied from 0.03 ppm in directly drilled to a maximum of 0.28 ppm in hand pump water. On the average the iron content of water obtained from directly drilled holes, hand pumps, drains and tube-well, was in the range of 0.10-0.36ppm except in Chak 100 J.B. where a value of 0.62 was recorded. Zinc is found to be at much higher concentration in hand pumps drawn water than directly drilled holes. The corresponding concentrations were 0.24-0.75ppm and 0.01-0.03ppm respectively. Drain and tube-well waters ranged from 0.02-0.05 ppm. Chromium could not be detected in the hand pump water whereas the rest of the samples had a chromium content of 0.01-0.03 ppm.

Table 16. Chemical analysis of Groundwater of Samundri, Faisalabad.

Site	Depth (Feet)	E.C. m mole	Ca ppm	Mg ppm	NO3-N ppm	Na ppm	K ppm
Chak No 477 (W) G.B.	25	2.02	8.38	29.12	0.05	327	18.7
Chak No 481 G.B.	45	1.24	16.34	18.52	0.07	161	12.1
Chak No 477 (W) G.B.	28	1.27	11.12	22.30	0.18	179	17.2
Chak No 477 (W) G.B.	40	1.97	4.22	22.84	0.30	340	6.2
Chak No 212 G.B.	35	2.04	8.56	20.42	0.02	359	11.7
Chak No 212 G.B.	35	2.05	6.28	15.56	0.10	382	7.8
Chak No 213 G.B.	40	2.05	6.72	20.68	0.13	363	14.8
Chak No 477 (E) G.B.	30	1.08	17.04	48.18	0.36	69	10.9
Chak No 478 G.B.	30	1.20	6.06	16.62	0.25	198	9.4
Chak No 476 G.B.	30	1.51	4.18	9.82	0.28	290	9.4
Average SD		1.63 ± 0.40	8.79 ± 4.38	22.41 ± 9.85	0.17 ± 0.11	266.8 ± 101.6	11.82 ± 3.82

Table 17. Groundwater quality analysis in Samundri, Faisalabad

S.No.	Sample Site	Depth (Ft)	pH	EC (mmole)
Groundwater (Bore hole)				
1	Chak 139 G.B.	16	7.62	2.50
		26	7.65	-
2	Chak 479 G.B.	20	7.26	1.00
		25	7.25	-
3	Chak 452 G.B.	33	7.40	1.75
4	Chak 79	12	7.35	-
5	Chak 217 R.B.	12	7.43	2.25
6	Chak 100 J.B.	12	7.20	-
Hand pump-water				
1	Chak 217 G.B.		7.71	-
2	Chak 479 G.B.		7.20	1.60
3	Chak 452 G.B.		7.54	2.00
4	Chak 487 G.B.		8.15	0.85
5	Chak 203 G.B.		7.50	2.30
6	Chak 510 G.B.		-	2.90
7	Chak 477 (W) G.B.	25	-	2.02
8	Chak 481 G.B.	45	-	1.24
9	Chak 212 G.B.	35	-	2.05
10	Chak 213 G.B.	40	-	2.05
11	Chak 477 (E) G.B.	30	-	1.08
12	Chak 478 G.B.	30	-	1.20
13	Chak 476 G.B.	30	-	1.51
Tube-well water				
1	Chak 195 G.B.		7.50	2.00
2	Chak 477 (W) G.B.	100	-	1.52

Table 18. Physico-chemical properties of drain water and mud

S.No.	Site	Water pH	Water Ec	Mud pH
1	Chak 139 G.B.	8.16	-	
2	Chak 217 G.B.	8.09	3.5	6.94
3	Chak 203 G.B.	8.03	3.5	7.20
4	Chak 510 G.B.	8.06	3.75	7.72
5	Chak 236 R.B.	7.67	-	7.80
6	Chak 79 G.M.	7.6	-	-
7	Chak 217 R.B.	8.5	-	-
8	Chak 100 J.B.	8.18	-	-

Table 19. Chemical analysis of shallow groundwater in Faisalabad

Site	Depth (Ft)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cr (ppm)	Co (ppm)	Ca (ppm)	K (ppm)	Na (ppm)	Mg (ppm)	NO_3 (ppm)	Cl (ppm)
Bore hole water													
Chak 139 G.B.	16	0.03	0.10	0.04	0.01	0.01	0.01	9.8	8.58	566	30.0	0.00	22.57
Chak 139 G.B.	26	0.03	0.20	0.02	0.01	0.02	0.01	14.7	8.58	695	22.0	0.00	21.15
Chak 139 G.B.	30	0.04	0.03	0.08	0.01	0.00	0.00	13.8	7.80	506	12.5	0.40	18.88
Chak 217 G.B.	19	0.03	0.19	0.07	0.01	0.01	0.00	13.1	10.92	515	10.0	0.00	10.93
Chak 217 G.B.	20	0.03	0.16	0.08	0.01	0.02	0.00	9.3	10.14	626	9.0	0.00	19.31
Chak 479 G.B.	25	0.03	0.20	0.03	0.02	0.01	0.01	37.1	7.80	51	35.0	0.14	2.55
Chak 452 G.B.	32	0.03	0.30	0.05	0.02	0.01	0.02	49.0	24.96	216	67.5	0.72	8.09
Chak 487 G.B.	25	0.03	0.24	0.36	0.03	0.02	0.00	26.2	10.14	129	40.0	0.27	6.95
Chak 203 G.B.	24	0.03	0.20	0.06	0.02	0.00	0.02	39.4	14.04	189	32.5	0.64	8.94
Chak 79 G.M.	12	0.03	0.28	0.04	0.03	0.01	0.04	41.5	40.56	681	50.0	1.74	211.43
Chak 217 R.B.	12	0.04	0.26	0.05	0.02	0.00	0.05	39.2	9.36	391	21.0	0.00	19.73
Chak 100 J.B.	12	0.03	0.62	0.05	0.03	0.00	0.03	69.4	9.36	276	29.0	0.40	15.62
Hand pump water													
Chak 479 G.B.		0.28	0.30	0.06	0.36	0.00	0.03	66.0	26.52	175	58.0	0.00	4.40
Chak 452 G.B.		0.11	0.28	0.17	0.30	0.00	0.04	52.0	34.32	184	74.0	0.00	12.63
Chak 203 G.B.		0.05	0.32	0.05	0.75	0.00	0.05	30.6	22.62	373	56.0	0.00	14.05
Chak 510 G.B.		0.23	0.36	0.12	0.37	0.00	0.05	20.9	28.05	580	44.0	0.00	39.33
Chak 236 R.B.		0.03	0.20	0.07	0.24	0.00	0.05	9.0	12.48	515	24.0	0.00	39.47
Tube well water													
Chak 195 G.B.	100	0.03	0.26	0.14	0.03	0.00	0.01	31.0	12.48	239	26.0	0.00	9.23
Drain water													
Chak 139 G.B.		0.04	0.26	0.04	0.04	0.00	0.02	34.8	19.50	755	54.0	0.00	89.17
Chak 217 G.B.		0.04	0.26	0.06	0.04	0.00	0.02	33.6	19.50	759	66.0	15.40	141.14
Chak 203 G.B.		0.04	0.26	0.05	0.04	0.00	0.03	33.6	17.94	800	54.0	4.43	152.50
Chak 510 G.B.		0.02	0.25	0.05	0.03	0.00	0.02	32.2	17.94	842	54.0	0.97	165.28
Chak 236 R.B.		0.05	0.40	0.17	0.04	0.03	0.02	40.2	37.44	869	100.0	0.00	85.05
Chak 79 G.M.		0.05	0.37	0.20	0.04	0.01	0.03	39.6	56.94	414	68.0	0.00	83.21
Chak 217 R.B.		0.04	0.40	0.04	0.02	0.04	0.04	29.7	14.82	432	33.0	0.00	26.83
Chak 100 J.B.		0.06	0.40	0.16	0.05	0.03	0.05	36.1	85.02	570	82.0	0.00	124.81
Jaranwala		0.03	0.30	0.17	0.03	[illegible]	0.04	35.4	27.30	690	64.0	0.00	54.52

Table 20. Common ranges (%) of the principal cations in the groundwater

Area	Total Dissolved Solids (ppm)	Calcium	Magnesium	Sodium & Potassium
Rachna*	500-1000	20-50	20-40	40-70
	1000-3000	4-20	6-25	60-85
Samundri**	500-1000	1-28	3-33	45-96
	1000-2000	1-15	2-21	64-95

* = Native groundwater (pre-1886) from a depth below 100 feet

** = Shallow groundwater from a depth of 25-40 feet

Table 21. Ranges (%) of the principal cations in the groundwater in Samundri area

Water source	Calcium	Magnesium	Sodium & Potassium
Bore hole	13-28	12-27	45-76
Hand pump	1-20	3-33	55-96
Tube well	10	8	82

Table 22. Drinking water quality standards

Constituent	USEPA Standard mg/L	Chinese standard mg/L
pH	6.5-8.5	
$CaCO^3$	-	450
Total dissolved solids	500	1000
Chloride	250	250
Sulfate	250	250
Nitrate (as N)	10	20
Iron	0.3	0.3
Manganese	0.05	0.1
Copper	1.0	-
Zinc	5.0	1.0
Boron	1.0	-
Arsenic	0.05	0.05
Cadmium	0.01	0.01
Chromium	0.05	0.05
Lead	0.05	0.05
Mercury	0.002	0.001
Selenium	0.01	0.01
Silver	0.05	0.05
Fluoride	1.4-2.4	1.0
Cyanide	0.05	0.05
Endrin	0.0002	-
Lindane	0.004	-
Methoxychlor	0.1	-
Toxaphene	0.005	-
DDT	-	1.0
HCH	-	5.0
2,4-D	0.1	-
2,4,5-TD Silvex	0.01	-
Phenol	0.001	0.002
Synthetic detergent	0.5	0.3
Total Coliform activity	10.0	3.0

As for as the cations are concerned, potassium and sodium are found to be on the higher side in drain water with respective maximum values of 85.2 and 869.4 ppm. The concentrations of potassium and sodium in water from hand pumps, directly drilled holes, and tube-well, ranged from 7.8-40.6and 50.6-694.6ppm. Magnesium was detected in the range of 9-74 ppm in directly drilled, hand pump and tube-well waters whereas its concentration in the drain water was higher with upper limit around 100 ppm. Water contours of the above mentioned elements are presented in Figs. 12-18.

SOIL CONTAMINATION BY FERTILIZERS

It has been hypothesized that extensive use of phosphatic fertilizers alongwith unplanned industrial activities have contributed to the accumulation of heavy metals in soils. Presence of heavy metals in soils, even in traces, may pose hazards to human life due to possibility of their translocation into edible plant parts and accumulation in human and animal bodies. Specific information on pollutant sources, quantity, chemistry and movement in soil is sporadic. Generally, sources of soil contamination are landfills, industrial effluents, phosphatic fertilizers and the gaseous exhausts of automobiles.

During an experiment in the study area in June, 1990 fifty soil samples were drawn from 0-6, 6-12, 12-24, 24-48 and 48-72 inches deep after wheat crop. Fields selected were having cotton-wheat or sugarcane-wheat rotation from the last 6-10 years. Every sample was analyzed for its physico-chemical properties and nitrate contents (Table 23). Soil in the test area had wide range of texture from clay loam to sandy clay loam. Sand and silt contents increased with the depth. Soil pH and EC (1:1 soil water ratio) values increased downwards. Upper 0-6 inch layer had the lowest pH value of 8.35 while pH value for 48-72 inch deep soil was 8.80. Similarly EC value for the top 0-6 inch soil was 0.85 which increased to 2.00 in the bottom of 48-72 inch deep soil. This indicates flushing of salts from surface to lower depths with irrigation water. It also suggests the accumulation of salts in lower soil horizons. Water soluble nitrate contents were directly related to crop rotation, higher nitrate contents were found where cotton-wheat rotation was followed. Top 0-6 inch soil had nitrates as 27.4 ppm which gradually decreased to 4.4 ppm in the 48-72 inch deep soil. This reflects downward leaching of nitrates with irrigation.

ELECTRICAL CONDUCTIVITY OF GROUNDWATER
(micro mhos per cm)

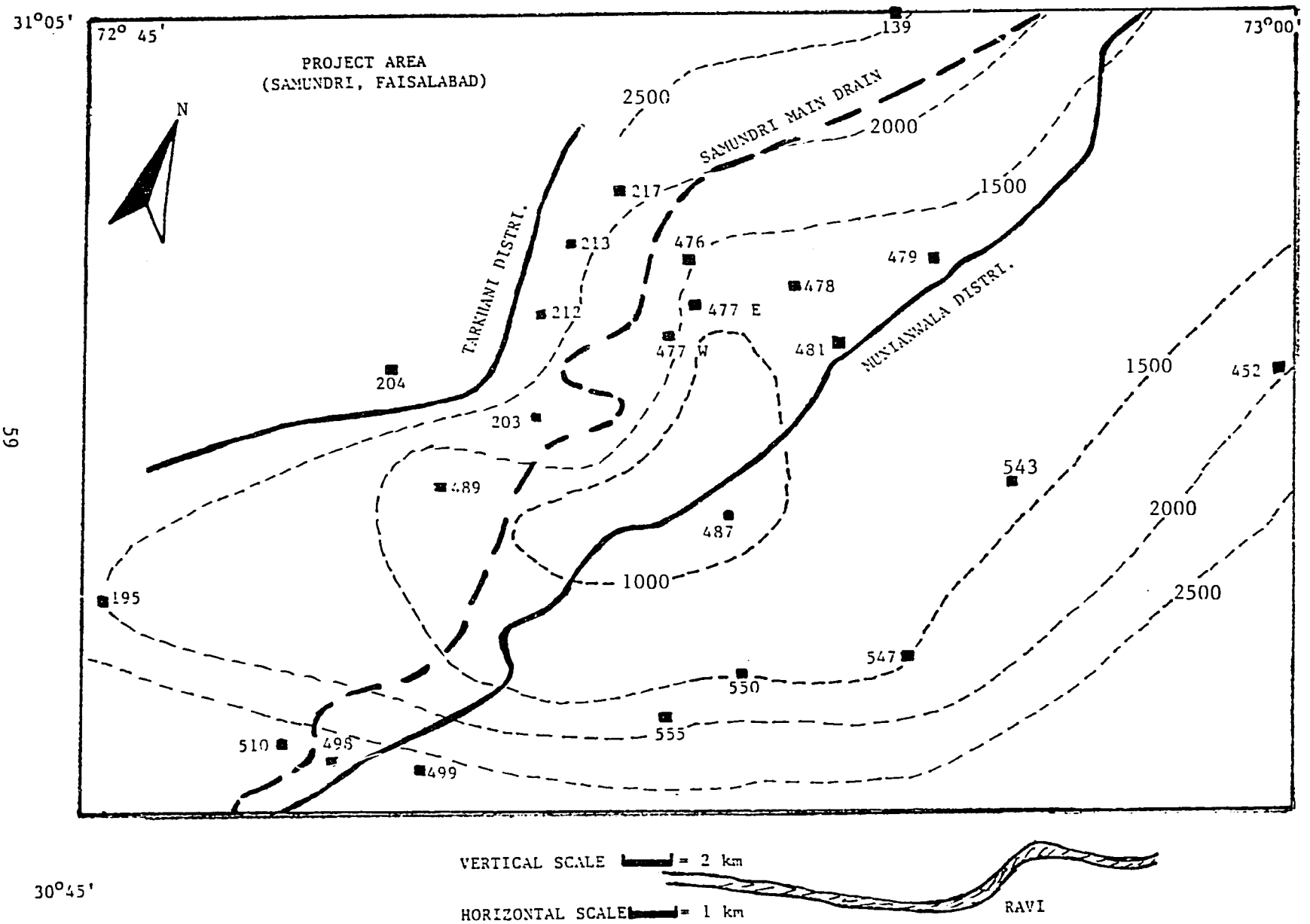


Figure 12

SODIUM DISTRIBUTION IN GROUNDWATER
(ppm)

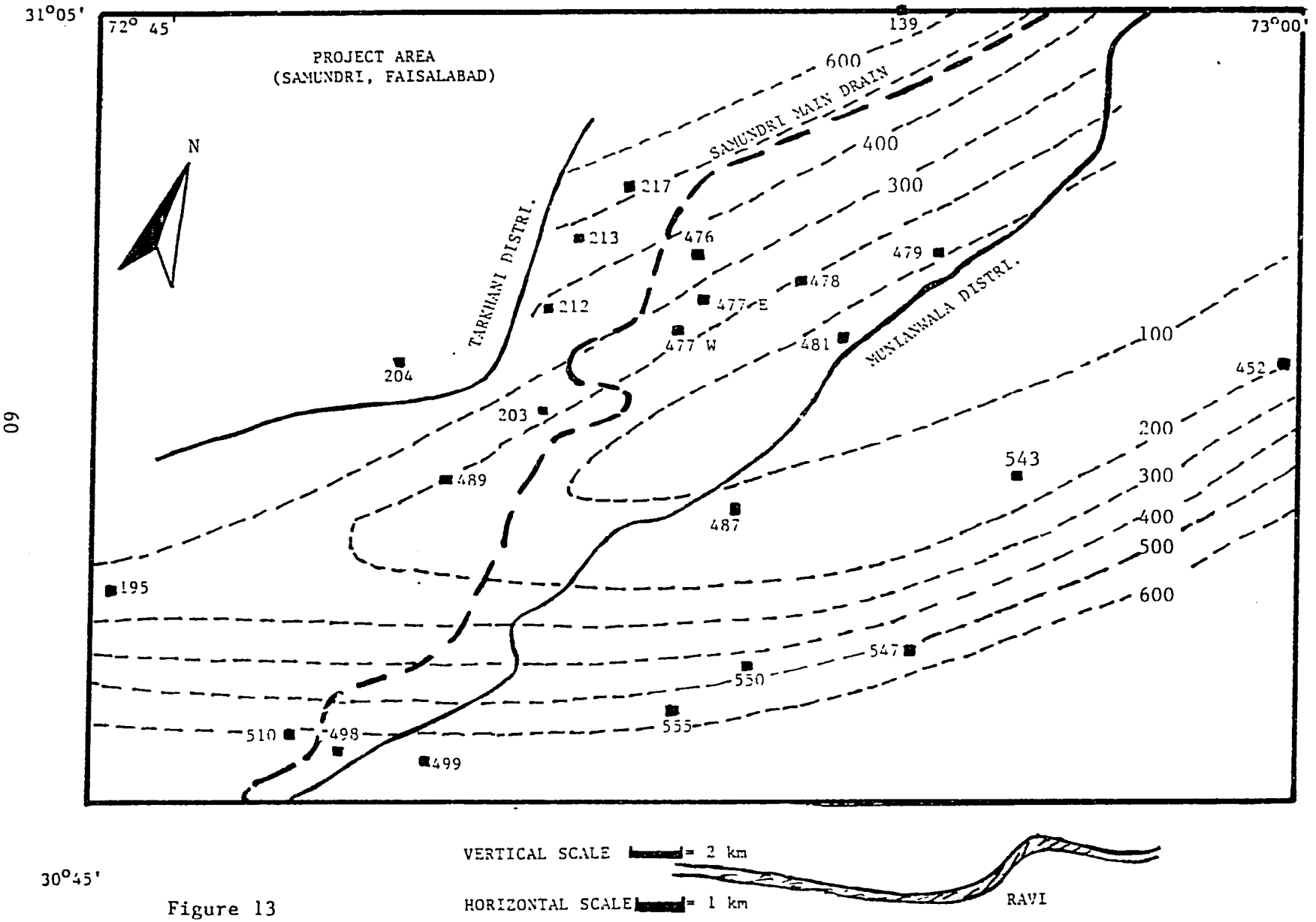


Figure 13

POTASSIUM DISTRIBUTION IN GROUNDWATER
(ppm)

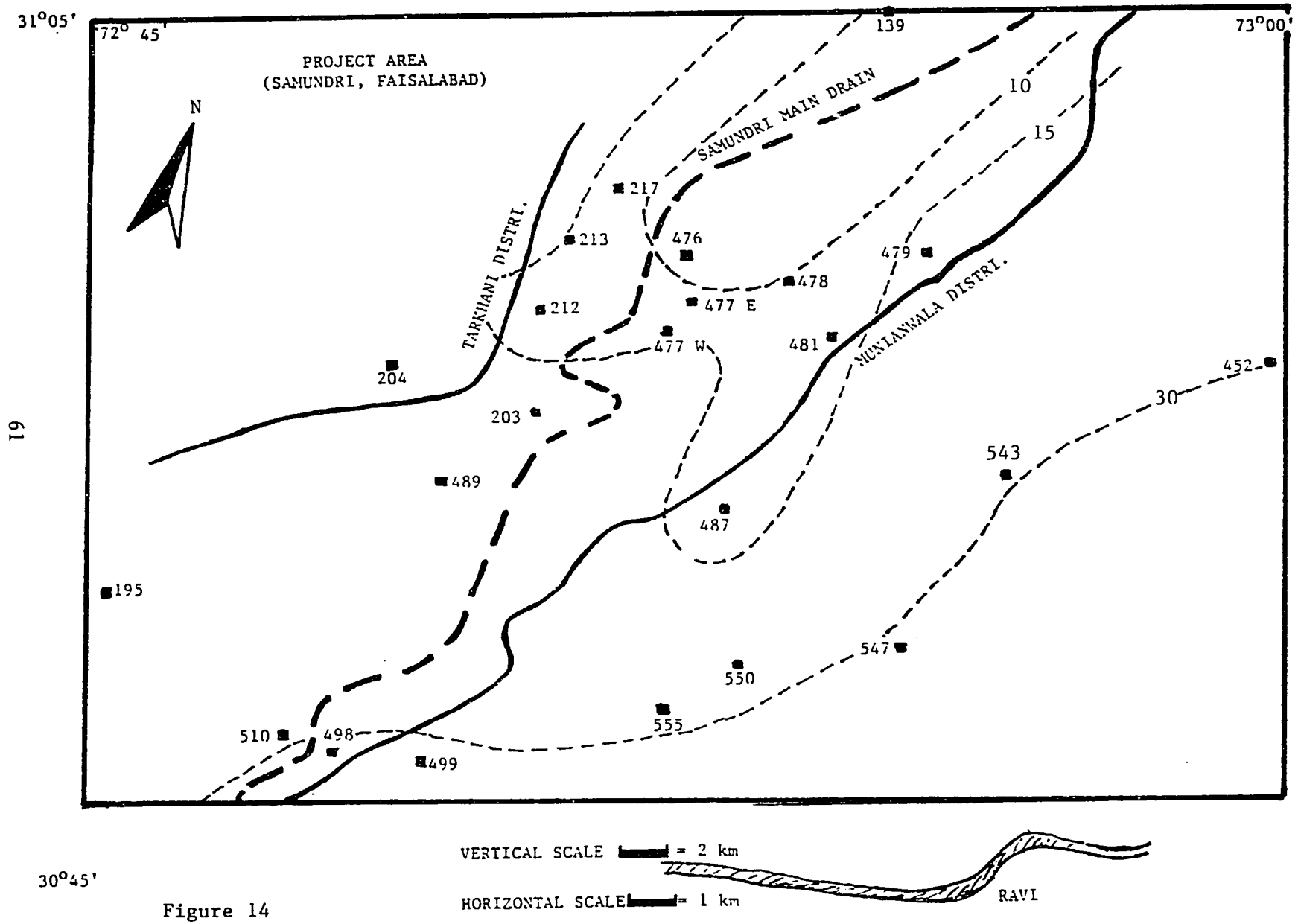


Figure 14

CALCIUM DISTRIBUTION IN GROUNDWATER
(ppm)

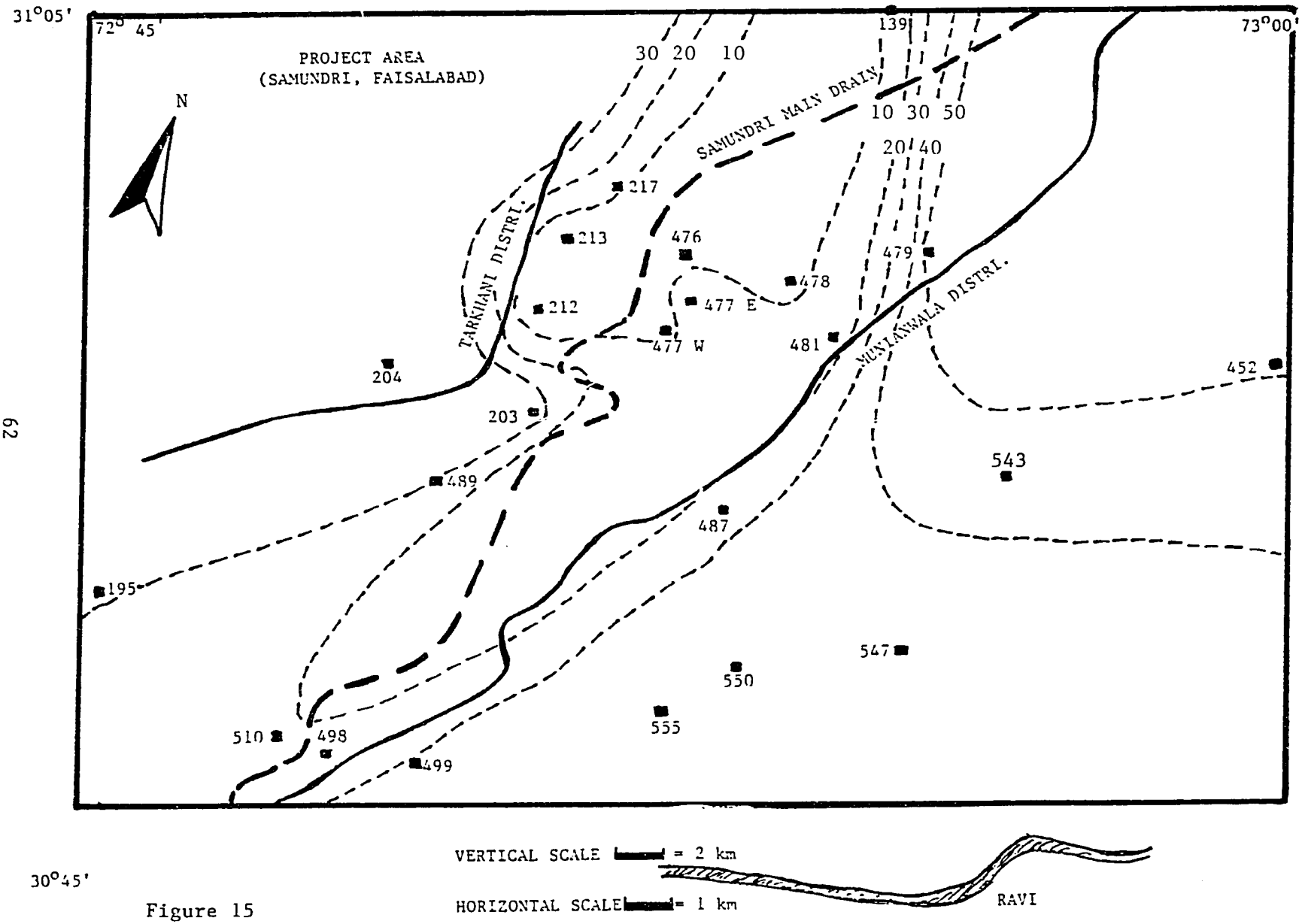


Figure 15

MAGNESIUM DISTRIBUTION IN GROUNDWATER
(ppm)

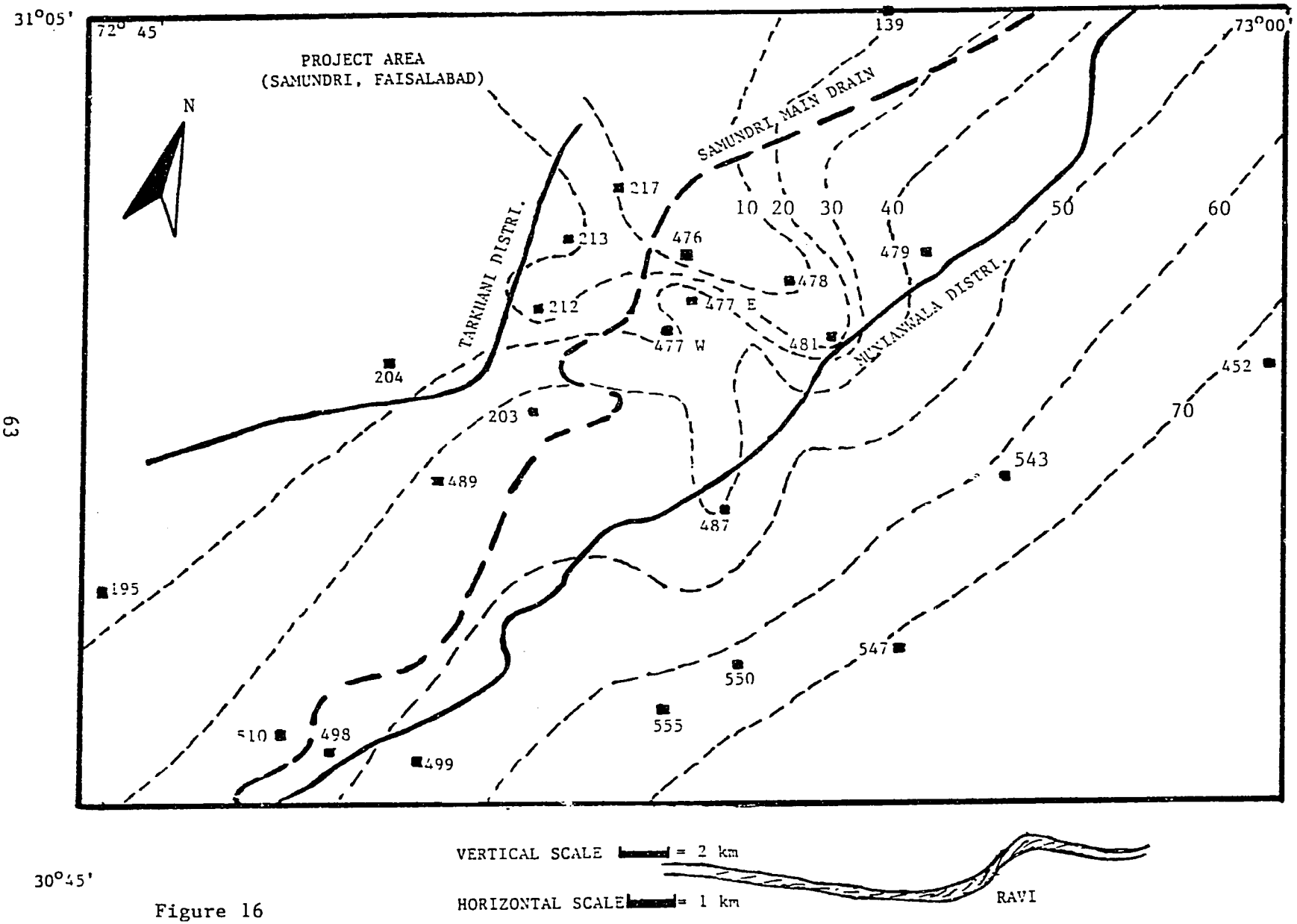


Figure 16

CHLORIDE DISTRIBUTION IN GROUNDWATER
(ppm)

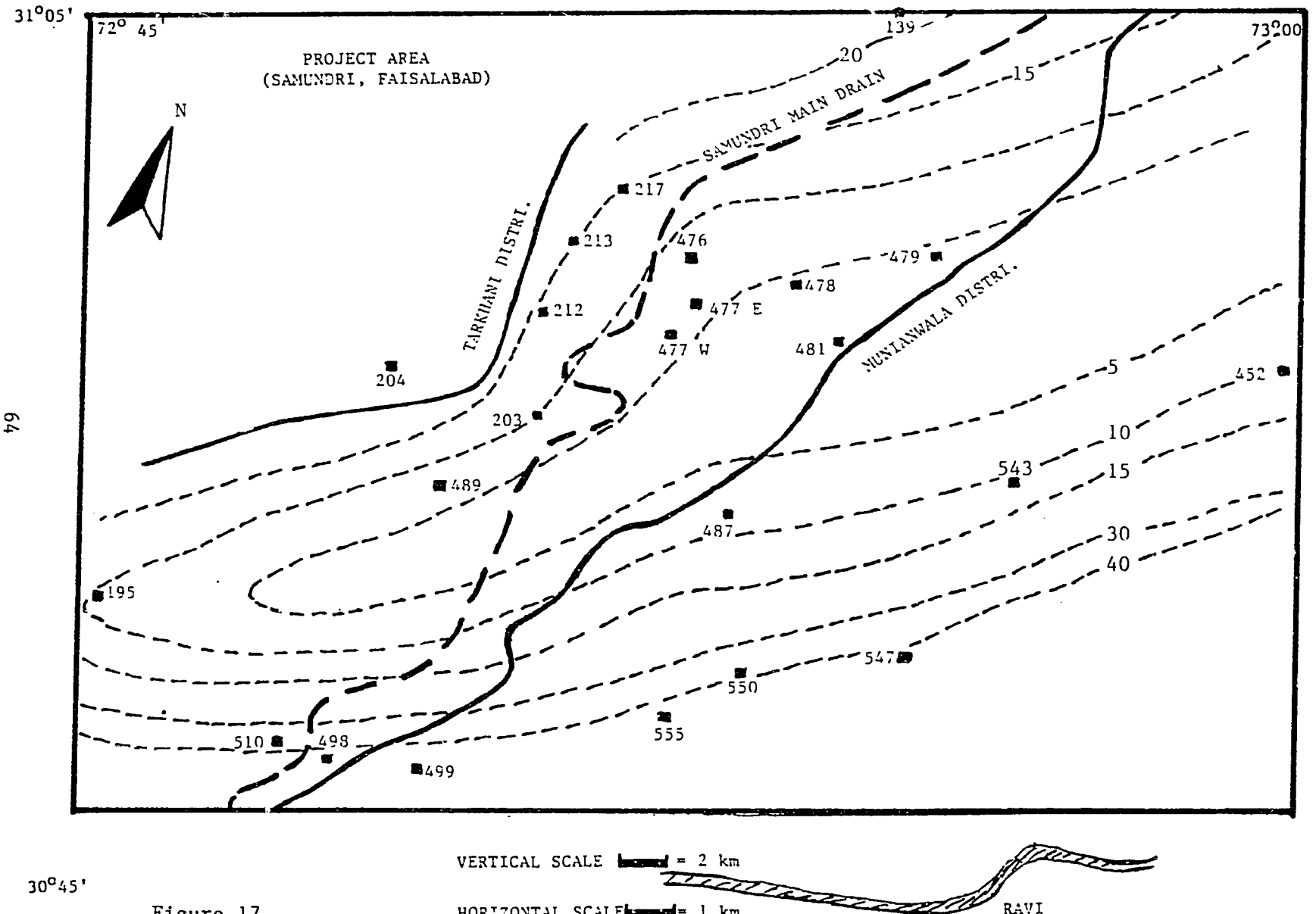


Figure 17

NITRATE DISTRIBUTION IN GROUNDWATER
(ppm)

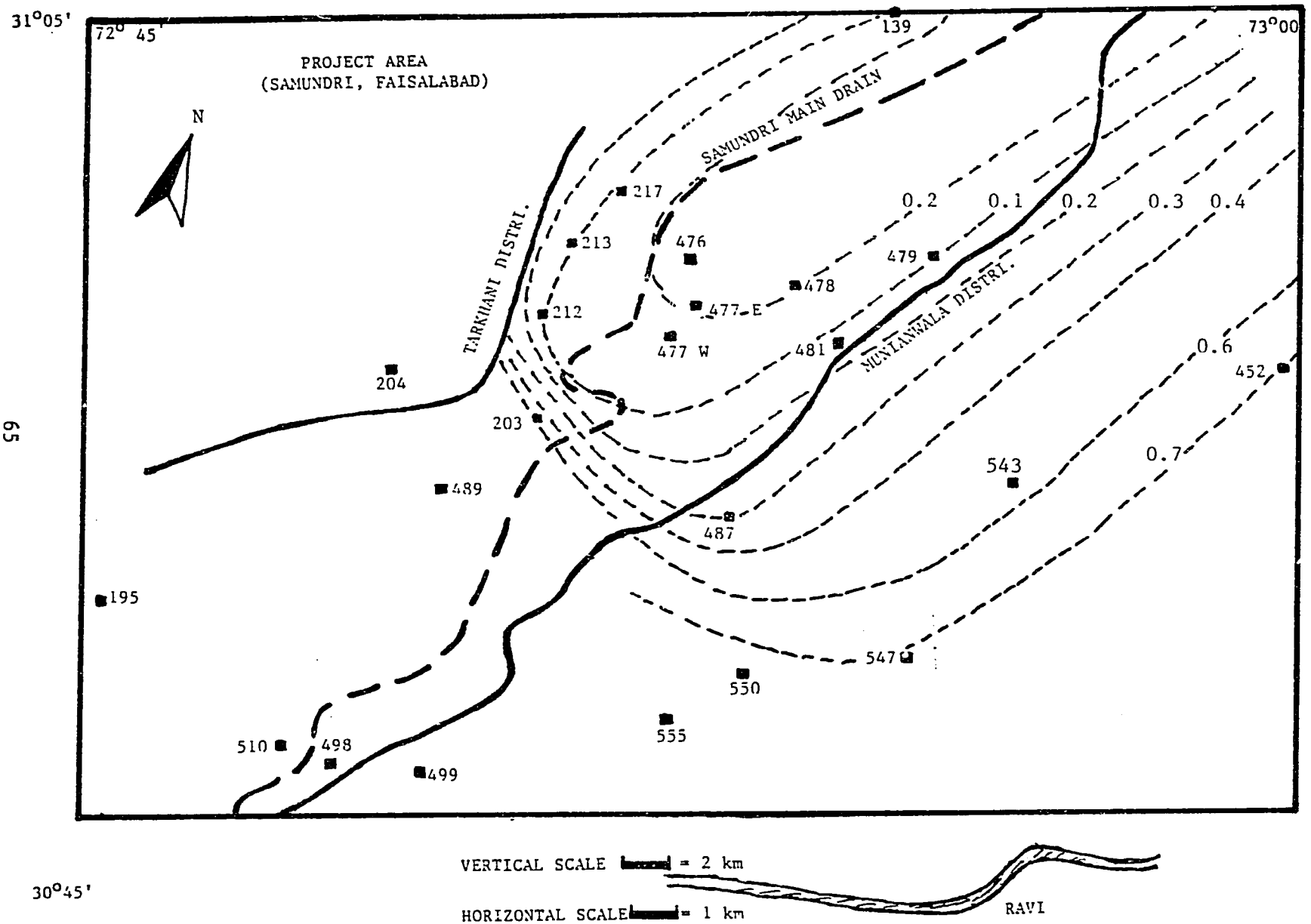


Figure 18

Table 23. Physico-chemical characteristics of soil of Samundri, Faisalabad.

Depth (inches)	NO3-N ppm	pH	E.C. m mole	Texture %Clay	%Silt	%Sand	Class	Na ppm	K ppm
0-06	27.44 ±13.00	8.35 ±0.30	0.85 ±0.50	25.33 ± 7.04	27.68 ± 8.56	48.68 ±12.45	Clay loam	207.9	276.8
6-12	15.30 ± 8.80	8.47 ±0.32	0.92 ±0.58	24.30 ± 6.31	26.85 ± 4.88	48.95 ± 6.09	Clay loam	257.9	238.2
12-24	8.40 ± 5.20	8.51 ±0.33	1.88 ±1.99	26.68 ±10.46	26.20 ± 4.68	47.13 ±10.30	Clay loam	363.7	209.1
24-48	6.10 ± 3.50	8.68 ±0.46	2.44 ±2.34	26.56 ± 9.90	27.45 ± 9.97	46.13 ±14.02	Clay loam	1398.9	150.3
48-72	4.40 ± 1.60	8.80 ±0.41	2.00 ±2.43	26.08 ±13.10	25.30 ± 5.89	48.85 ±16.51	Clay loam	1446.3	153.1

Chemical analysis of soil samples also showed that most dominant cation (1:1 soil water ratio extract) was sodium, and was found in all depths. Its concentration was increased with soil depth. Sodium concentration in 24-48 inches depth was 3-5 times higher than at 12-24 inches soil depth in all the samples. It showed flushing of sodium from surface layers to lower layers during the desalinization process in the area. Potassium concentration is highest in the surface 0-6 inch soil layer, and decreased with increasing soil depth. It is possible due to higher clay contents of surface layer. As silicate clays are the major reservoir of potassium and they release it when mica is converted to illitic forms.

CATIONS AND ANIONS IN SOIL

The detailed depth profile analysis of soil was carried out during January, 1991. Soil samples were collected at each foot upto the water table. Generally in some places water wet soil started appearing around 15.20 feet. At other places samples upto 26-30 feet were taken. The soil was shade dried, and thoroughly mixed, representative portions were subjected to chemical analysis. The results are presented in annexture I. Soil samples taken from the villages alongside the Samundri main drain were grouped together as group 1. Those alongside canal were placed in group 2. Samples taken from villages away from canal about 12-15 km north of river Ravi were placed in group 3 to be considered as normal soils or control without the localized influence of canal or drain water. The detailed analysis and contour maps of elements in top soils are given as annexure II. The results of various cations and anions are represented in Figs. 19-24). It is observed that almost all the ions analyzed are concentrated in the top 5-10 feet of soil. Sodium, potassium and magnesium were all found in higher concentrations in the group represented by samples nearer to drain, followed by the samples away from recharge/discharge sources. The concentrations of these elements nearer to canal was the lowest and at about 10 feet depth (equal to canal bed) their concentration was minimum which leveled off. This is indication of leaching and dilution of these cations with the fresh canal water. Samples alongside the drain were showing accumulation of the cations with the upward movement of groundwater towards drain. Evidently the calcium concentrations were inverse to sodium and potassium. However, the trend of calcium with in the groups was similar to sodium, except in samples

SODIUM IN SOIL

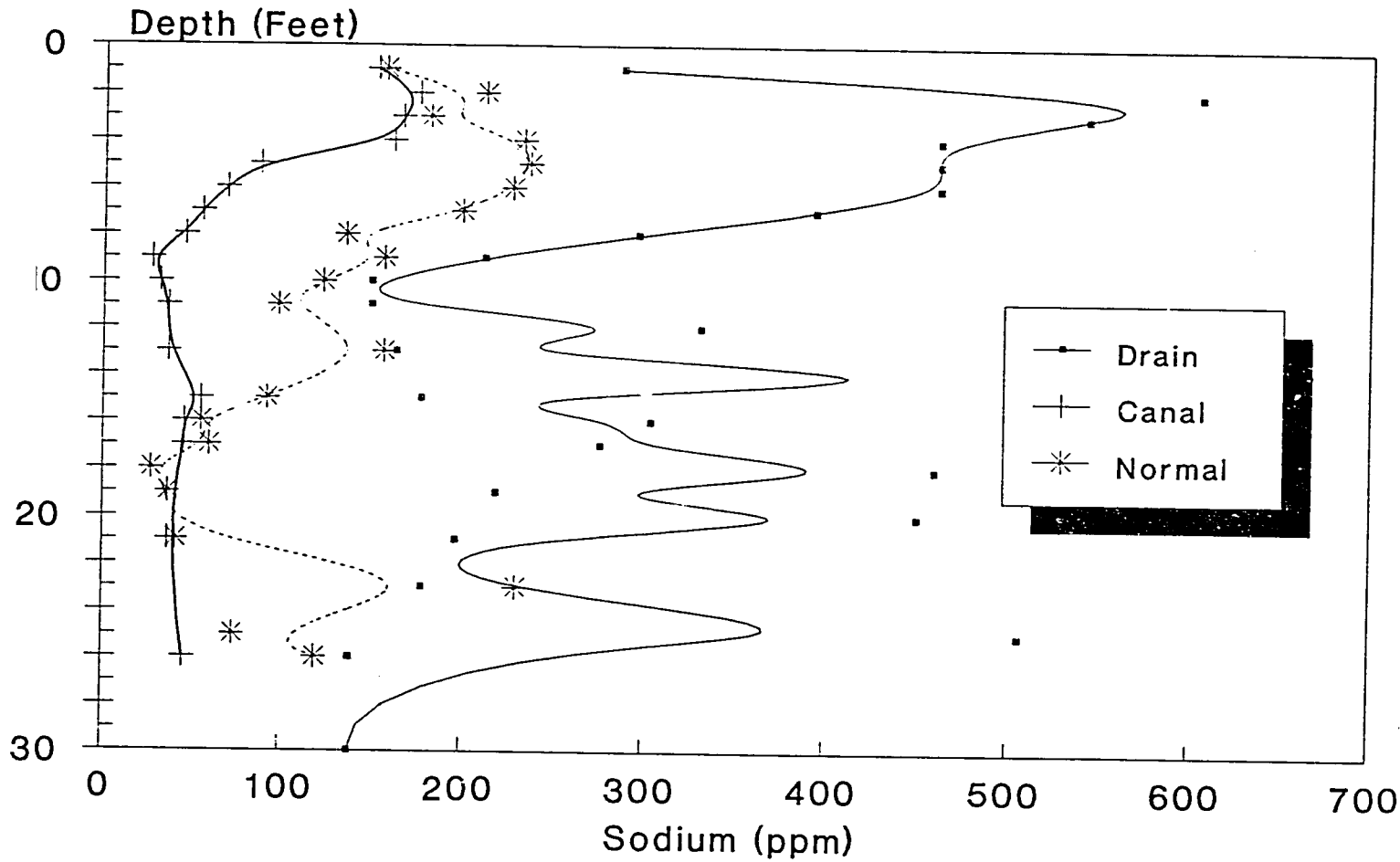


Fig.19 Depth profile of sodium in soil of Samundri, Faisalabad

POTASSIUM IN SOIL

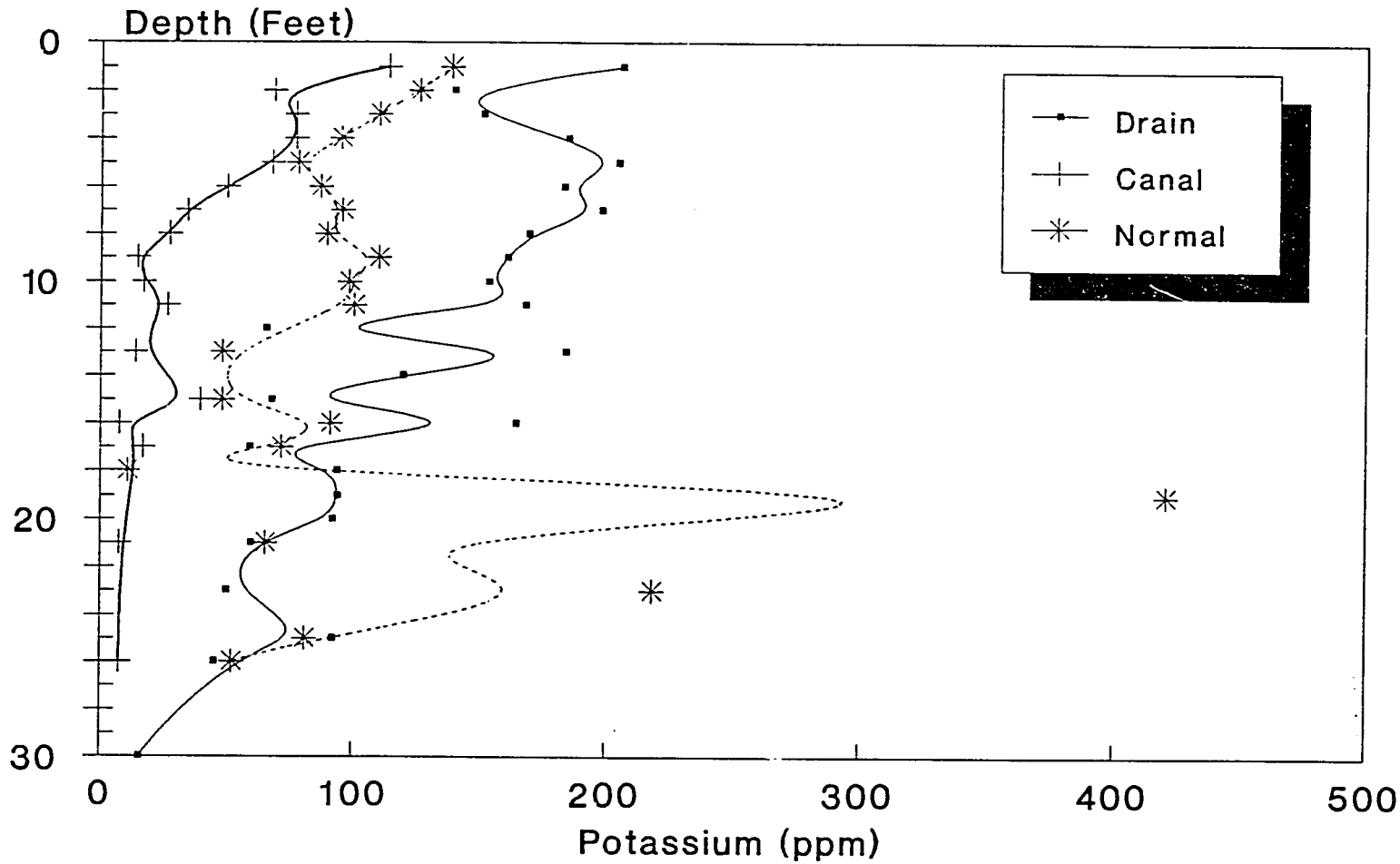


Fig.20 Depth profile of potassium in soil of Samundri, Faisalabad

MAGNESIUM IN SOIL

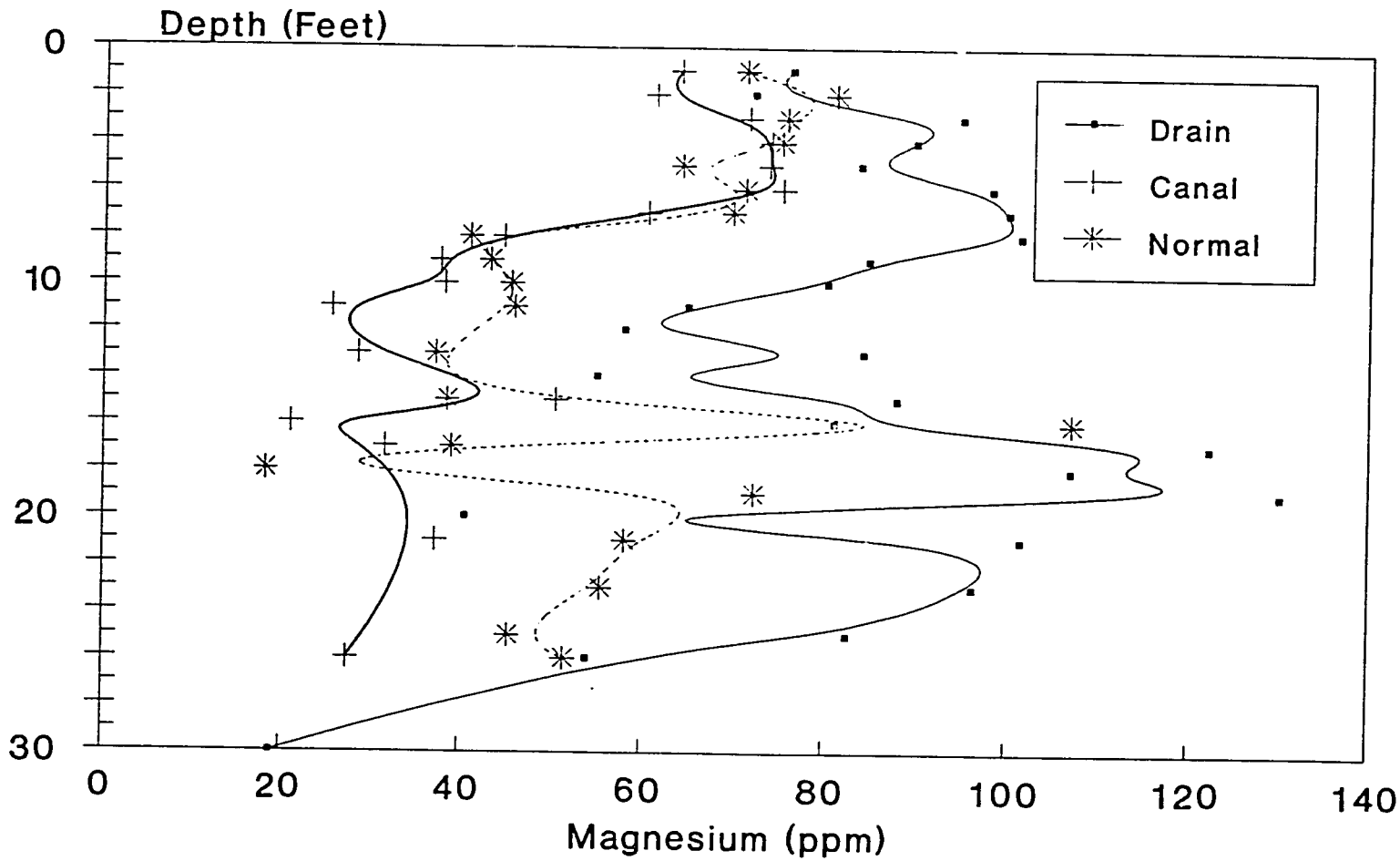


Fig.21 Depth profile of magnesium in soil of samundri, Faisalabad

CALCIUM IN SOIL

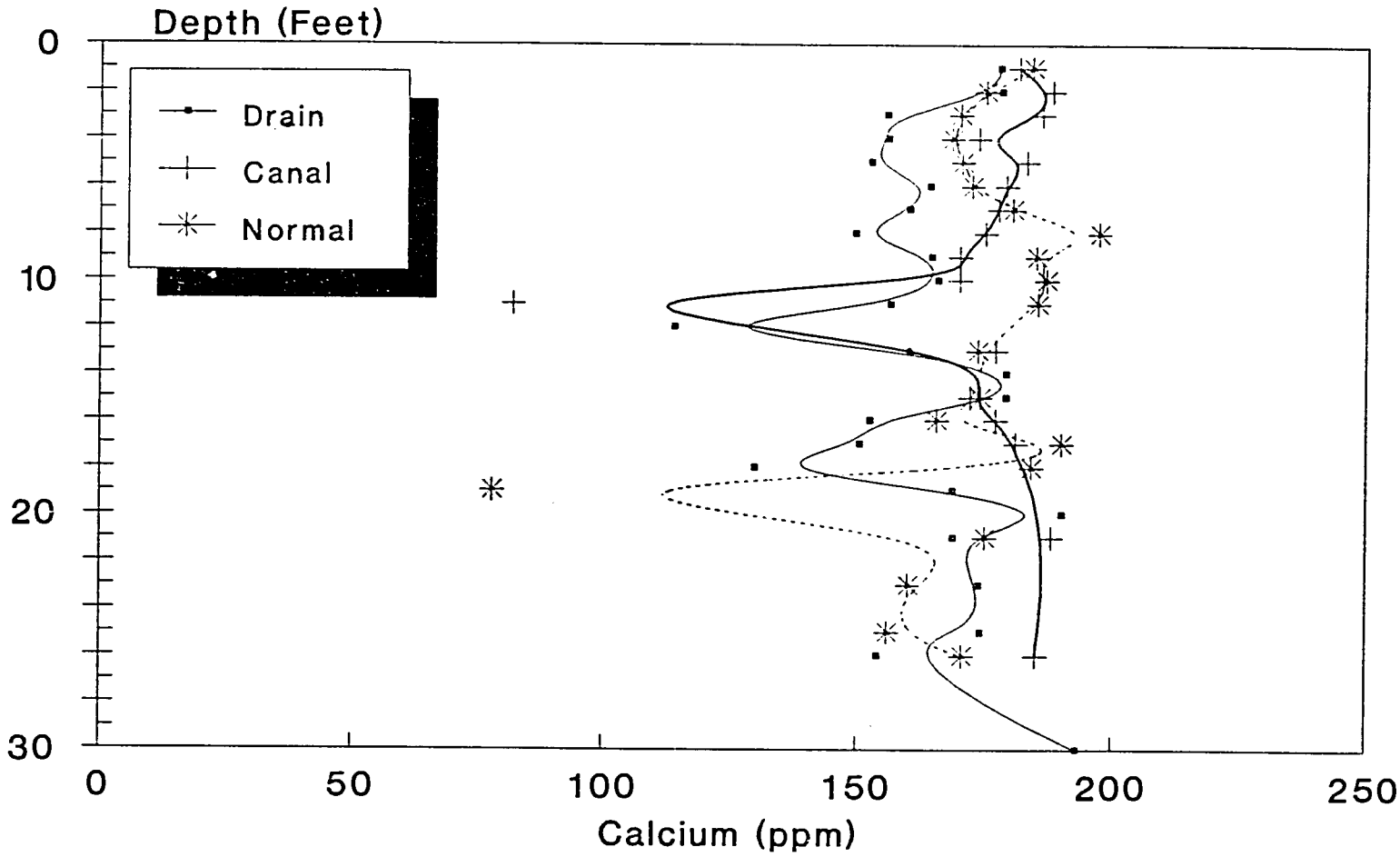


Fig.22 Depth profile of calcium in soil of Samundri, Faisalabad

CHLORIDE IN SOIL

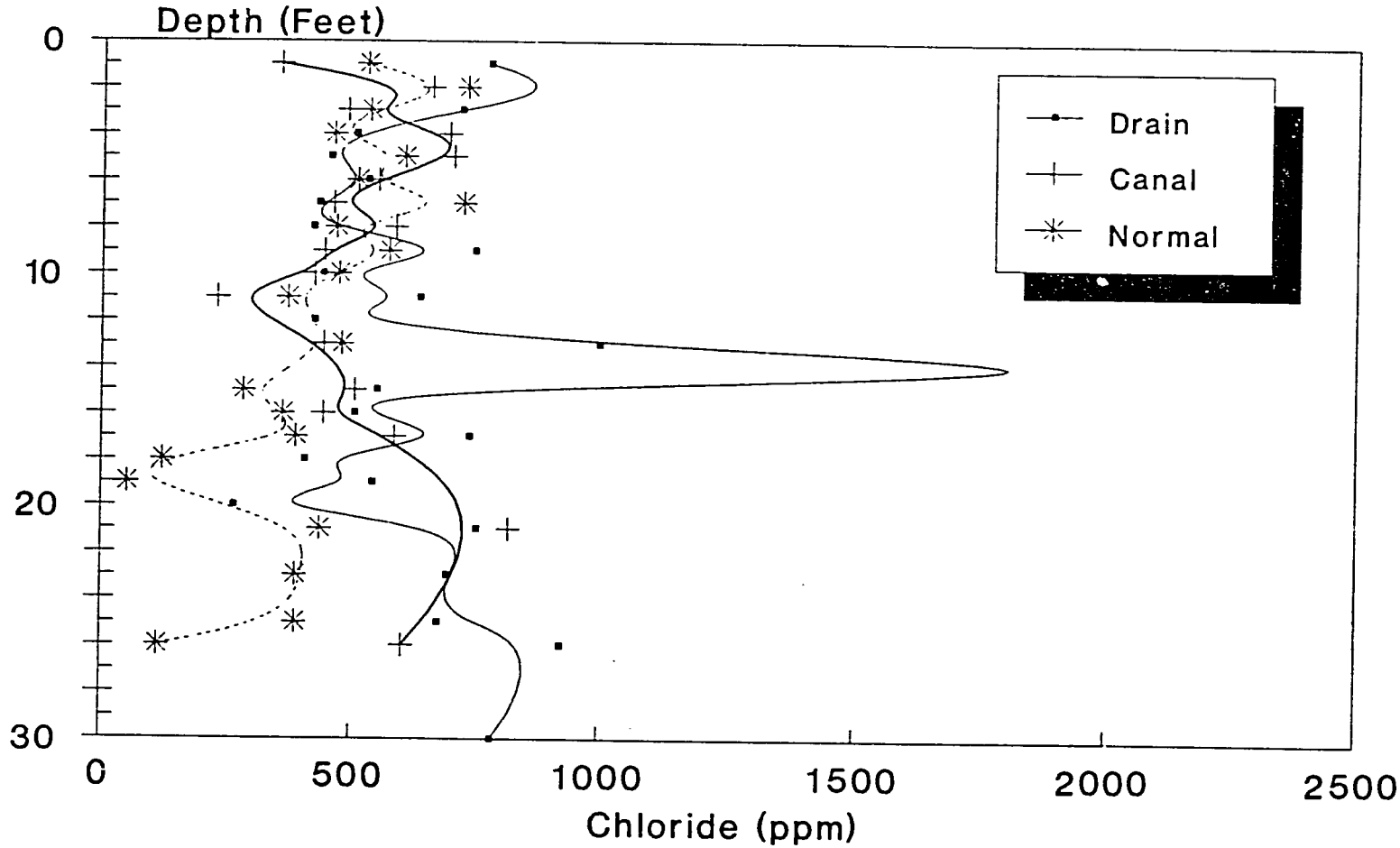


Fig.23 Depth profile of chloride in soil of Samundri, Faisalabad

NITRATE IN SOIL

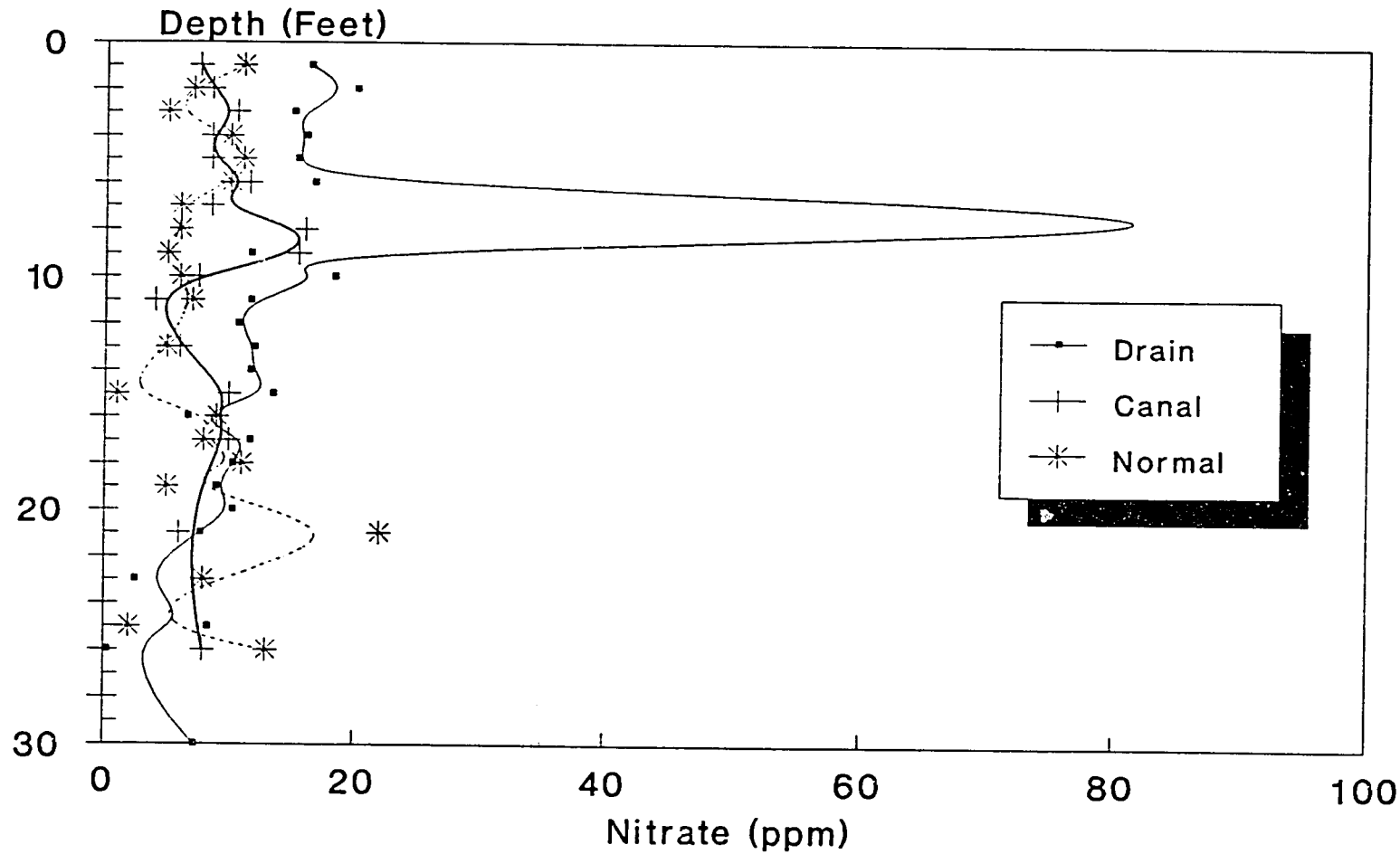


Fig.24 Depth profile of nitrate in soil of Samundri, Faisalabad

alongside drain where a spike of high concentration was recorded at the depth of 12-15 feet. This almost coincided with a decline in calcium concentration.

Nitrate concentration ranged from 7 to 35 ppm in samples alongside drain, except at the depth of 7-8 feet where a concentration of 51 ppm was recorded, from 4 to 16 ppm alongside the canal and from 2 to 11 ppm in soil samples from the group termed as normal soils. Evidently normal soil samples and those taken from near the canal had lower nitrate which were almost uniform with the depth in soil. An accumulation of nitrates was detected in soil samples taken near the drain. However, the flow of ground water at these points was anticipated to be upwards towards drain, therefore, downward leaching of nitrates to groundwater tables may not occur or be a source of contamination of groundwater. This was evident from the water samples drawn from the handpumps or bore holes (at a depth of 30-45 feet), where nitrate levels were below 1 ppm and within acceptable limits of 5 ppm.

HEAVY METALS IN SOIL

Five metals thought to be the minor component of the phosphatic fertilizers were also analyzed in the soil (Figs. 25-29). Iron, Copper, Zinc, Manganese, and Cobalt were all observed to be in higher concentrations in top 2-3 feet layer. Moreover, the samples taken either alongside drain or canal showed largest accumulation of these metals as compared to the soil samples from sites away from the immediate influence of canal or river. The iron concentration ranged between 1-5 ppm, both in drain and canal samples. In normal soils the concentration was more steady at lower depth were in the range of 1-2 ppm was recorded in samples taken alongside canal. The concentration in samples from canal and normal soils was nearly 1 ppm. In all the groups the copper concentration around 10 feet depth came to as low as 0.2-0.3ppm. Afterwards a steady decline to 0.1-0.2ppm was observed in all cases. The concentration of zinc in the samples from normal soils ranged between 0.10-0.18ppm. The highest concentration of 0.6ppm in samples alongside canal came down to 0.1 ppm by three feet depth and was more or less steady till the groundtable. The concentration of zinc alongside drain soils was more haphazard, however, it ranged between 0.1-0.26ppm. The manganese concentrations behaved in similar manner. The highest concentration of 0.8ppm

IRON IN SOIL

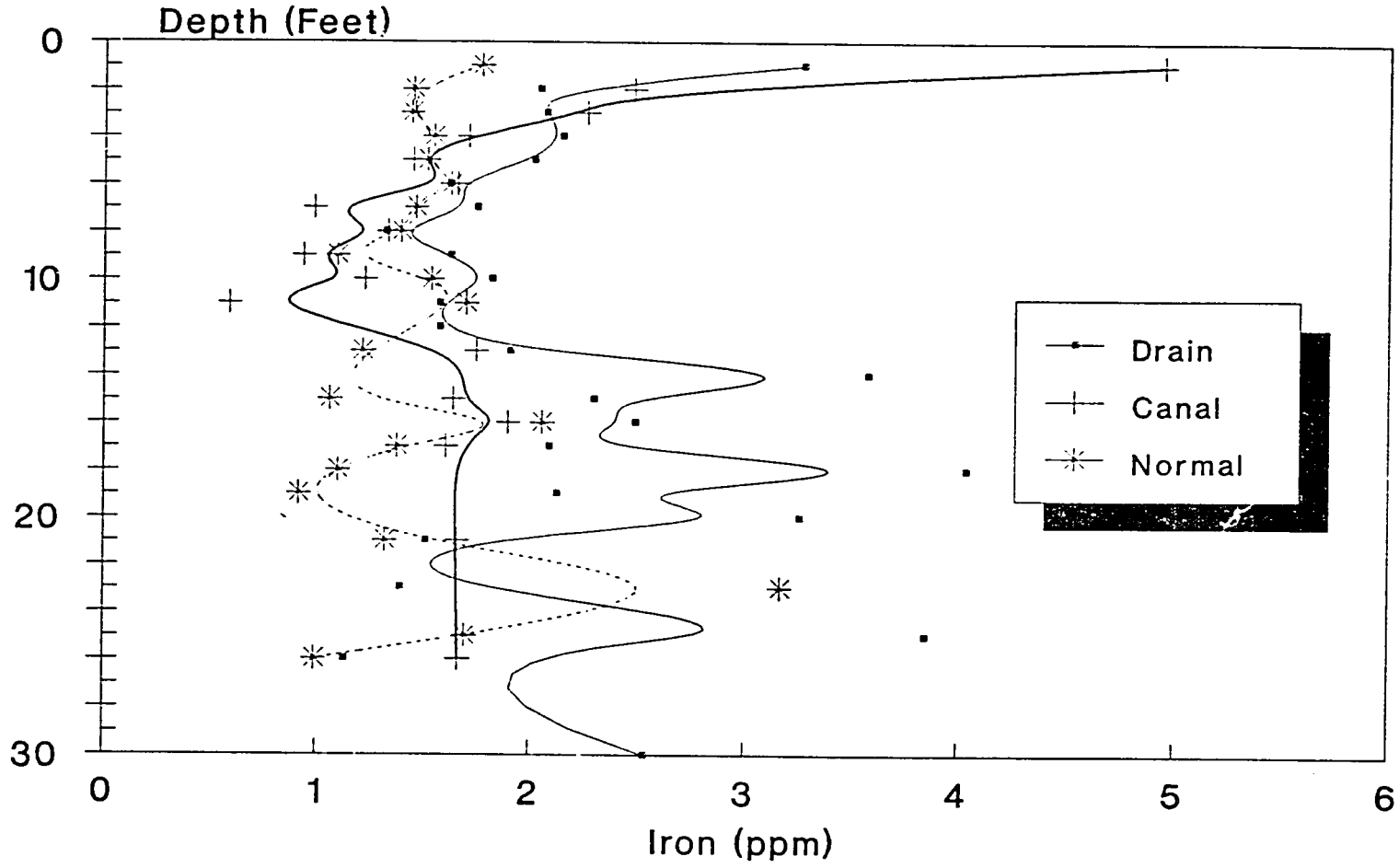


Fig.25 Depth profile of iron in soil of Samundri, Faisalabad

COPPER IN SOIL

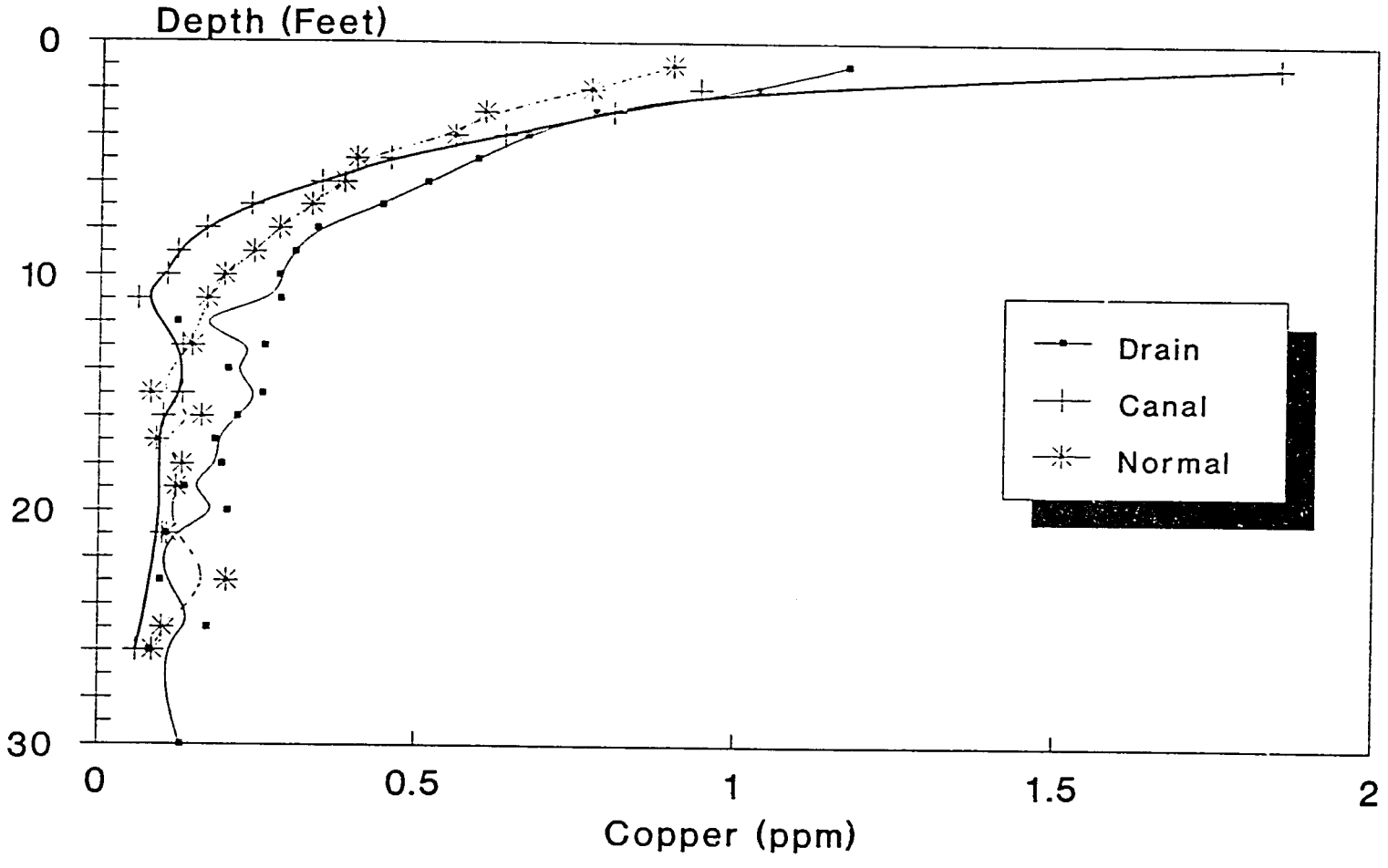


Fig.26 Depth profile of copper in soil of Samundri, Faisalabad

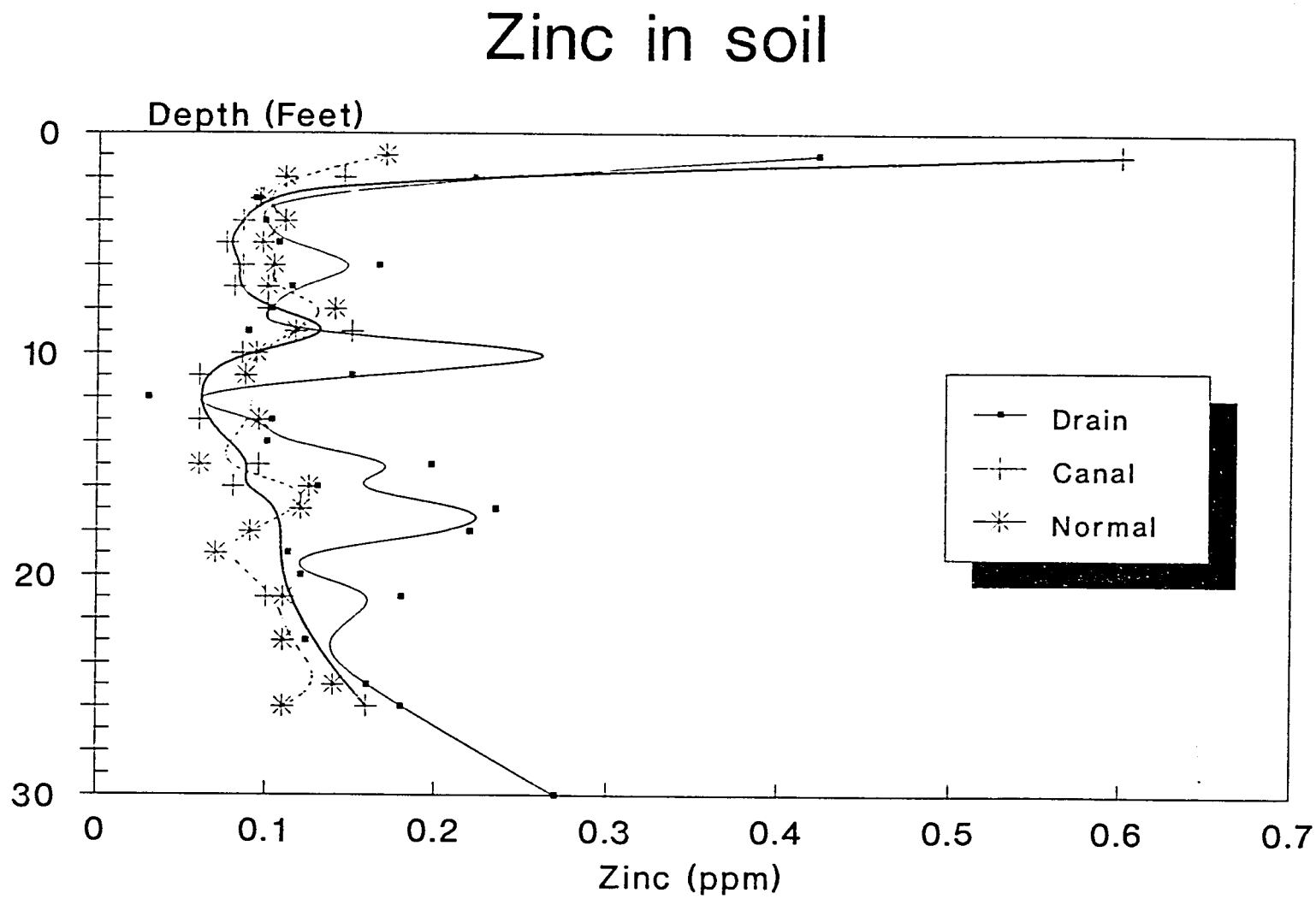


Fig.27 Depth profile of zinc in soil of Samundri, Faisalabad

MANGANESE IN SOIL

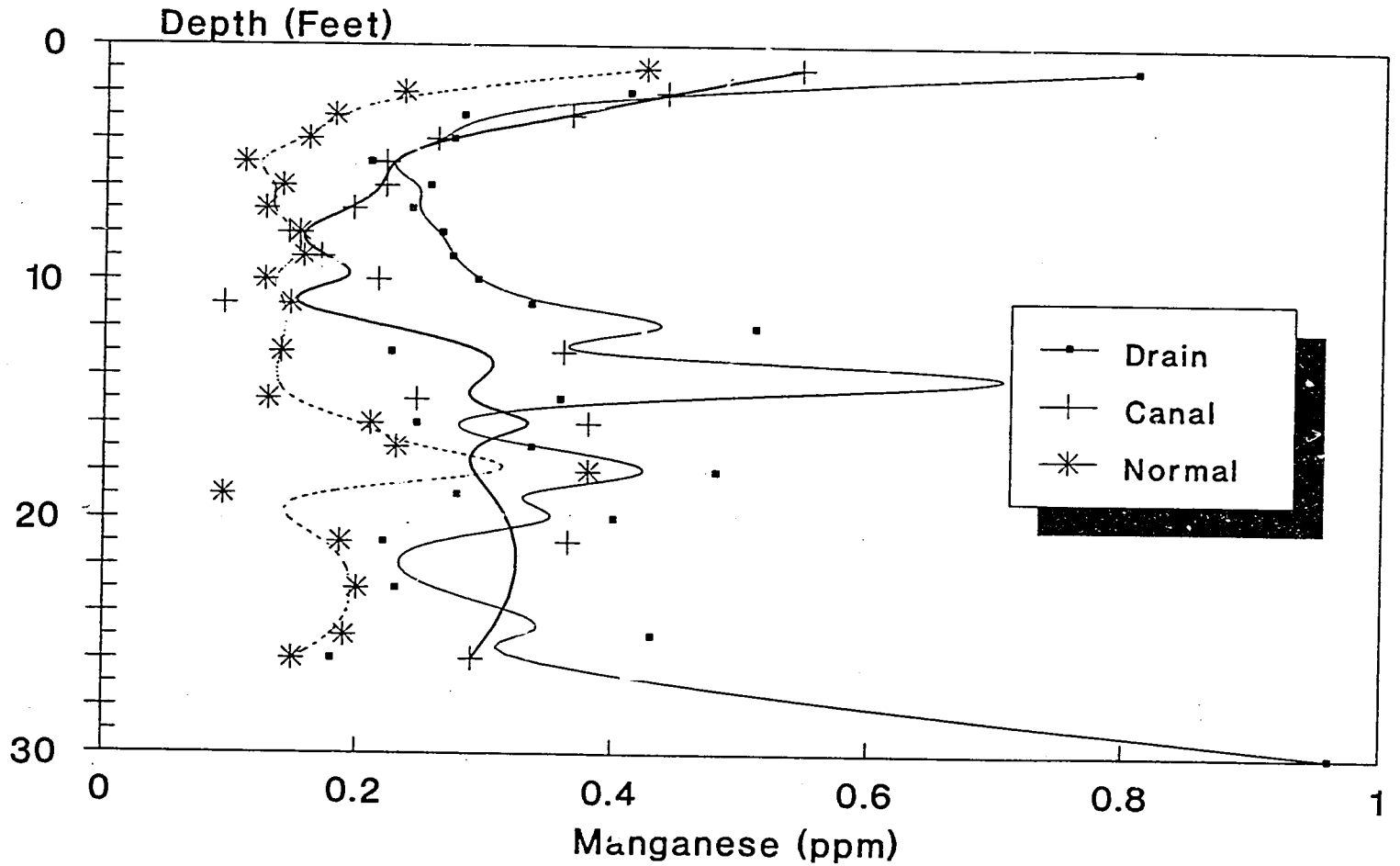


Fig.28 Depth profile of manganese in soil of Samundri, Faisalabad

COBALT IN SOIL

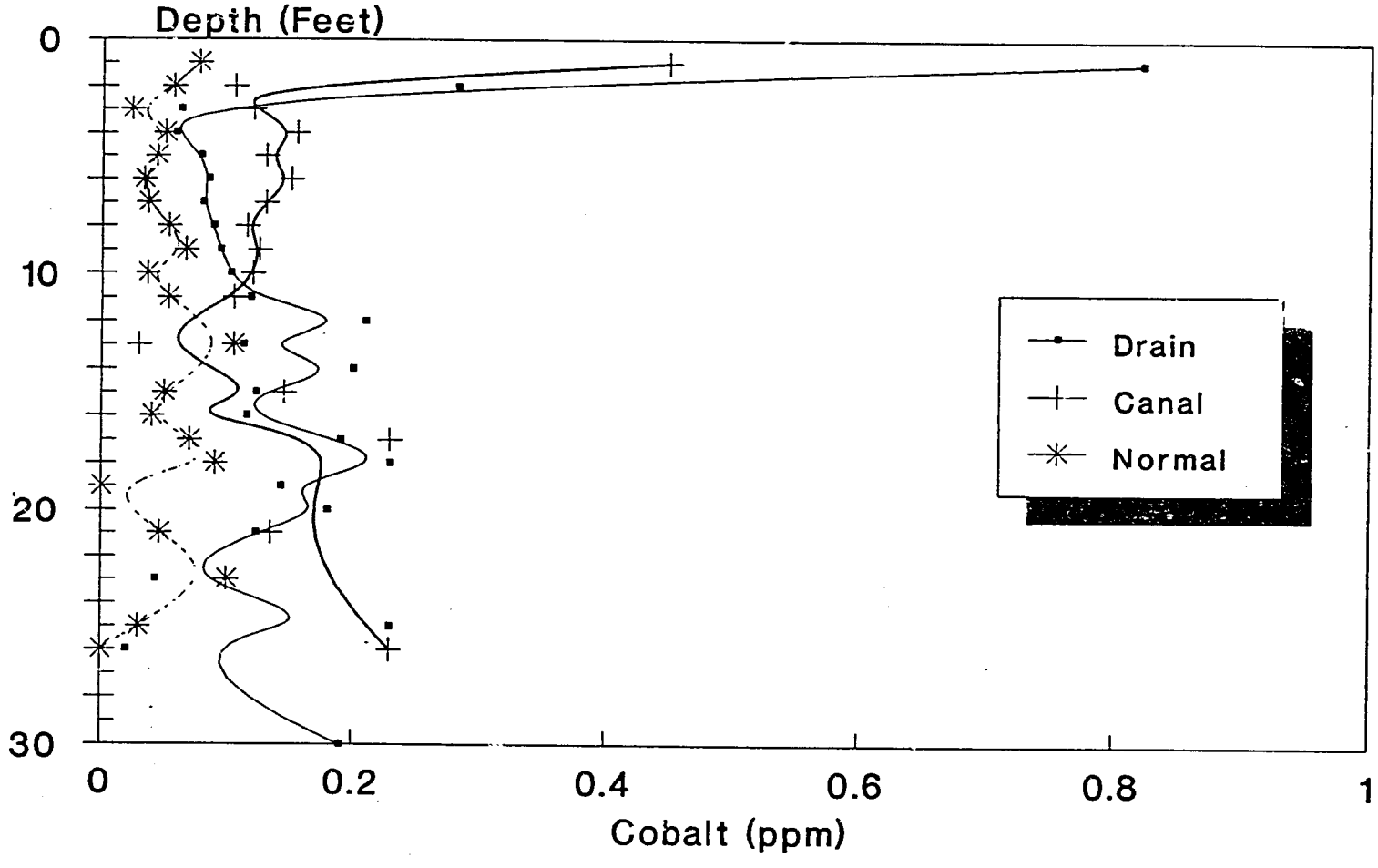


Fig.29 Depth profile of cobalt in soil of Samundri, Faisalabad

in samples alongside drain showed a wavy depth profile ranging from 0.2 to 0.95 ppm. the concentrations of manganese in samples alongside canal fell from 0.6 ppm to near 0.2 ppm which slightly increased to 0.3 ppm around 13 feet of depth and remained steady afterwards. After a steep decline from 0.4 to 0.10 ppm in samples from normal soils the concentration remained between 0.1-0.2 ppm till the groundwater table. Similarly the concentration of cobalt in the samples from the normal soil was around 0.1 ppm which remained almost the same till 26 feet depth; whereas in samples from alongside drain and canal higher concentrations of 0.8 to 0.4 ppm, respectively were recorded. These concentrations came to as low as 0.1-0.2ppm in both cases by three feet depth. Between 10 to 30 feet depth the concentration of cobalt slightly increased but was still around 0.2 ppm. Generally it was observed that heavy metals have accumulated in the top 0-3 feet of soils. Reports form National Agricultural Research Centre, Islamabad and Nuclear Institute for Agriculture and Biology, Faisalabad have also indicated the occurrence of these heavy metals in higher concentrations in the top horizons of the soils. This may have been due to built up from fertilizers but the major source could be through the recycling of organic mater including plant debris thereby releasing these metals in the top soil.

The heavy metals are essential for normal growth of animals and some plant species as well. The pathological effects of these compounds will depend upon the particular form of element or on the high dosage (Table 24). Copper is an essential element. It is closely associated with the absorption and metabolism of iron. It is necessary for the formation of haemoglobin, although it is not part of the molecule. Copper is also required for bone formation. The element is an integral part of cytochrome oxidase, tyrosinase, ascorbic acid oxidase, uricase, catalase and peroxidase. Many vegetables, cereals and meats contain between 1 to 10 ppm of copper, but liver contains about 24 ppm. The normal dietary intake of copper usually does not exceed 5 mg/day and 2 mg/day is adequate for metabolism.

Zinc like copper is an essential element. It forms a necessary part of carbonic anhydrase, carboxyl peptidase, alcohol dehydrogenase molecule. The deficiency of zinc leads to testicular atrophy and failure of body growth. Zinc is a normal constituent of food and only rarely is it possible to avoid an adequate intake. The range of concentration is 2 to 85

ppm in most fruits, vegetables and meats; 25 to 140 ppm in grain and 700 to 1600 ppm in seafood. Traces of zinc occur in water also. The average intake of the element is 10 to 15 mg/man/day.

Cadmium toxicity is pronounced in the deficiency of zinc, and within limits cadmium toxicity can be counteracted by supplementing the diet with zinc. Traces of cadmium are widely distributed in nature and may be found in human food. The city water supplies in USA ranges from 0.0004 to 0.600 ppm.

Traces of lead occur in many rocks. It finds its way into soil and water and hence into food and into human and animal tissues even in remote places where there is no use of the metal or its compounds. In spite of its widespread distribution in tissues, there is no indication that lead has any beneficial effects. The daily intake of general population is about 0.4 mg/man/day. Rocks have lead from 8 to 20 ppm, virgin soils 0.03 to 108 ppm, agricultural soils 0.5 to 1.0 ppm, urban soils 28 to 360 ppm, water 0.001 to 0.055 ppm, vegetables and meat 0.004 to 10.00 ppm.

Table 24. Pathological effect of heavy meatal ingestion in humans

Compound	LD_{50} (mg/kg) in rats	Poisoning dose mg/kg*	Reported pathological effects
Chromium	37-417	350	Bronchiogenic cancer, retarded growth, Injury to liver, blood and gastrointestinal system
Copper Sulphate	300	140	Nausea, diarrhea, renal failure, intra-vascular haemolysis, gastrointestinal irritation, and pneumoconiosis
Zinc Chloride	1914-2200	350	Dermititus, vlceration irritation in nasopharynx, trochea and bronchi
Cadmium chloride	88	6.7	Anemia, pulmonary irritation, hyperplasia of bone marrow and liver salivation, nausea, persistant vomiting mild diarrhea, abdominal pain and tenesmus.
Lead arsenate	100-849	0.21	Gastroenteritis, diarrhea, abdominal pain and constipation, headach, drowsiness confusion, incoordinaion, toxic psychosis, convulsions and neurological disorder leading to enceptolopathy

* Doses at which symptoms of poisoing occured either in human or animals.

CHAPTER VI

DISCUSSION

An assessment of the hydrologic factors, agricultural factors and chemical factors tha ...ay effect the leaching of agricultural chemicals to groundwater was conducted to evaluate the extent and severity of agricultural chemical contamination of groundwater resources.

The concern on quality of our water resources is becoming increasingly important ir the face of ever growing population, accelerated agricultural activity, and expanding industry Drinking water regulation prescribed by US Environmental Protection Agency recommend that the total dissolved solid (TDS) content for human consumption should not exceed 50(ppm, whereas US Geological Survey states that waters with TDS about 2000 ppm are generally unfit for long term irrigation. The quality of water in Samundri, district Faisalabad, is much deteriorated. TDS in shallow groundwater used for drinking as well as irrigation is >500 ppm along the Munianwala canal and about 2000 ppm away from the canal.

In dry regions the precipitation is supplemented with addition of irrigation water, and dissolved substances are added to the soils. If so little water is added that all of it evaporates without drainage, all the salts remain in the soil. If the contents of the dissolved salts in the irrigation water is great enough, repetition of this over a period of only a few years may make the soil too salty or saline to support plants. On the other hand, if enough irrigation water is added to flush the excess salts out of the soil, the salinity of the groundwater is increased. This dilemma can not be resolved by any known technology. The addition of salts to groundwater from irrigated lands can be reduced by careful water management.

Fertilizers are not regarded as making an important contribution to the salinity of groundwater. For example 100 to 500 kg of fertilizer might be added per acre in a year, but 2 feet of irrigation water containing salts at a concentration of 1,000 ppm would add over 2,000 kg of salts per acre.

Excessive salinity of groundwater is undesirable in agriculture because some of the groundwater may be pumped for irrigation and some of it reappears as surface water in streams and may be used again downstream for irrigation. Excessive salinity in groundwater used for drinking is undesirable because of the objectionable tastes and the laxative effect associated with sulfate. The recommended limits for chloride and sulfate in domestic water supply is not to exceed 250 ppm.

The salinity in the study area has increased since the start of irrigation system in 1886. The common ranges of cations (Sodium+Potassium) have increased in the shallow groundwater (45-96%) as compared to native (pre-1886) groundwater values (40-70%). Chloride values have also increased over the period. Calcium has shown the corresponding decrease.

The water-table depth varies from 10 feet in the north to more than 40 feet in the south. The electrical conductivity of groundwater is found to be minimum, 1000 micro mhos/cm, along the canal and is increased to 2500 micro mhos/cm away from the canal towards river Ravi in the south, and Samundri main drain in the north. The top soil is clay or clay loam. The sand starts from 12 feet deep in the north to around 40 feet in the south of study area. Canal and groundwater mixing is the most favoured mode of irrigation. The annual precipatation averages 12 inches and total evaporation is about 80 inches in a year.

The agricultural activity based heavily on the usage of pesticides and fertilizers to increase crop yields has proved to be a potential source of groundwater contamination. The shallow groundwater in Samundri area drawn from a depth of 30-40 feet is contaminated with pesticide residues. Monocrotophos is detected in the range of 0.04 to 0.06 ppm, cehalothrin in the range of traces to 0.0002 ppm, and endrin is present in the range of 0.0001 to 0.0002 ppm.

The only other report on drinking water contamination focuses on cattle drinking water in Karachi (Parveen and Masud, 1987). These authors analyzed 79 samples. The study revealed contamination of ten samples with chlorinated pesticides or their metabolites. Six samples were found to contain r-BHC in the range of 1.0 to 16.4 ppb, one contained p,p'-

DDT in traces. In two samples p,p'-DDE was found to be present in traces. Aldrin and dieldrin were present in one sample in quantities from 2.0 to 31.5 ppb, respectively.

The soil of Samundri in cotton growing area is contaminated with pesticide residues. Monocrotophos is detected in the top 1 foot soil in the range of 0.3331 to 0.6429 ppm. Cyhalothrin is present in top 1 foot in the range of traces to 0.1932 whereas dimethoate was detected at one site at a concentration of 0.3858 ppm. The pyrethroids fenvalerate, cypermethrin and organophosphate profenofos are present in traces in the top 1 foot layer. The organochlorine insecticide residues of aldrin, dieldrin, endrin, p,p'-DDT and its metabolites p,p'-DDD and p,p'-DDE are detected in the lower 2 to 3 feet layers of the soil. Their concentrations varies from traces to 0.0096 ppm. The presence of pesticides in the soil is of concern as these enter our food chain through the crop produce as shown by earlier studies that endrin even after ban on its use is finding its way into vegetables grown on the contaminated soils.

Studies on the pesticide residues in soil and environment have always lagged behind due to financial constraints and lack of proper laboratory facilities. However, the ones which have appeared are cited below. The Federal Pesticide Laboratory Karachi is continually monitoring pesticides in food commodities and environment, however, a detailed report appeared in 1985. The reported studies were carried out during 1978-1985. Under these studies the following aspects were covered: (i) Translocation of residues of DDT into seed oil (ii) DDT residue in agricultural soil environment of Punjab and NWFP (iii) Residue of DDT in tobacco in NWFP (iv) Contamination of paddy ecosystem with DDT spraying in Baluchistan.

In all these findings DDT was the only pesticide monitored. In the first instance, the p,p'-DDT under semifield conditions of 5-7 sprays was found to be 0.8 - 1.3 ppm in cotton seed oil. Moreover, the cotton seed oil from aerially sprayed cotton contained 0.18 - 0.92 ppm of DDE an isomer of DDT. These values were below the FAO/WHO limits of 0.5 - 5.00 for DDT and isomers, like DDE. One notable thing is that these experiments were carried out about 10 years ago when DDT was used abundantly, secondly after processing

of cotton seed oil a further .e was expected. The study was inconclusive as it did not look into situation in market products i.e. vegetable oil and "ghee" manufactured from cotton seed oil.

At Agricultural Research Institute, Tarnab, Peshawar, the tobacco nurseries were treated with DDT and analysis of crop leaves at 39 days after treatment revealed DDT at 2.5 ppm level. Though these were higher levels but the use of DDT on this crop was banned in 1976.

Similarly, it was found that after 10 days of aerial spray of paddy crop in Baluchistan DDT residues diminished by 85 and 39% in straw and pennicles, respectively, while 18% increase occurred in soil. There was decline in DDT in edible portion to much lower than tolerance limits for paddy, posing no direct hazard to human.

In second study random sampling of soil from agricultural areas of Punjab and NWFP, where DDT was in use for decades, was undertaken. Up to 0.6 ppm were detected in the rice fields around Kala Shah Kaku, and 0.2 - 0.59 ppm in sugarcane and tobacco fields of NWFP and in the orchards of Bhalwal. These levels of DDT were not considered to be a matter of great concern unless their seepage into water.

Carefully controlled studies by Hussain and his group (1988) at NIAB, Faisalabad using sandy loam soils have indicated that most of the applied DDT is retained by the top 5 cm layer. Movement down to 10 cm and 15 cm is very slow. This may be due to the fact that DDT is water insoluble. However, their important finding was that half life dissipation for DDT in laboratory was 890 days but under field conditions the half life was 110 days in irrigated and 112 days in rainfed soils. This trend is in conformity with other tropical and sub-tropical countries and has implication that DDT is degradable.

Herbicide usage has gained momentum very recently and will further increase with the adoption of zero-tillage technology in rice-wheat cropping system. The laboratory studies at weed sciences programme, NARC, during 1989-90 have shown that Diuron and

Metametron leached down to 20 and 27 cm, respectively, in 24 hours after application of water equivalent to 5" of rainfall. The herbicides are fairly water soluble. Extensive or long term use in fields may pose problems where groundwater tables are very high or flushing of soil does occur.

Breakdown of organic pesticides in soils beyond that involving reactions with water is attributed to micro-organisms and catalytic effects of soils. Pesticides such as dalopon, 2,4-D, malathion and parathion that breakdown rapidly (50% decomposition in 2 weeks or less under favourable conditions) are not likely to be detected in groundwater. Some organic pesticides such as DDT and dieldrin decompose very slowly and may persist for years. These pesticides, however, are not of concern as groundwater contaminants from agricultural use because they are relatively insoluble in water and are retained strongly by soils.

The decomposition (loss of 75 to 100% of the biological activity) of different classes of pesticides in soil varies. Studies under agricultural conditions with normal rates of application have shown various organophosphate and carbamate insecticides to persist for 1-12 weeks, herbicides from 1-18 months and chlorinated pesticides from 2-5 years. Tinsley (1979) noted that the 50% decomposition times for certain pesticides increased in the order malathion, 2,4-D, diazinon, atrazine, diuron, and DDT.

Depending upon the experimental conditions wide differences in the absolute values were found. For example, the 50% decomposition time for DDT was 240 days in a tropical environment, 3840 days in a temperate environment and 33 days in a laboratory test done in the absence of free oxygen. The 50% decomposition times were greater when measured in subsoil samples than in surface soil samples, presumably due to lesser microbial activity in the sub-soil samples.

Trace elements are also inorganic constituents of groundwater, but they have added significance in that most are toxic to humans and animals in large concentrations. Trace elements are present in the soil and geological formations, but due to their small solubility in water, only trace concentrations are found.

The five metals (Zinc, Manganese, Copper, Iron and Cobalt) analyzed in the present investigations revealed higher concentrations rather accumulation in the top 1-3 feet of soils. These values are about 3-4 folds higher than the normal concentrations found in the lower subsoil horizons. The accumulation of these metals may be from the organic recycling processes or from the fertilizer for which these metals are minor constituents. If taken by the crops and consumed by humans over the period in large quantities these could have severe pathological consequences to our health.

Generally the metal concentrations of the groundwater are within safer limits described by the WHO or USEPA. However, Zinc concentration is far higher in the water drawn from hand pumps as compared to bore hole drawn groundwater. The zinc may have been originating from the hand pump pipes. Further investigations in this respect are suggested.

When fertilizers are added to supplement the supplies of particular nutrients that are deficient in soils, the result is greater residues of nutrients in the soils. Part of the excess may be lost to the groundwater if it remains in the solution. Most of the chemical ions added in fertilizers are retained to some degree by soils as a result of the chemical interactions and this reduces their potential for loss to groundwater. Phosphorus is an examples. Two ions, nitrates and chloride, undergo virtually no attachments to soil and are highly mobile in water.

Among the elements of fertilizer supplementation nitrates are of most concern as human health hazard because of their leachability character. Our survey in Samundri area has indicated that nitrates applied as fertilizers have moved down to lower horizons as a consequence of flushing process. The top 0-6 inches of soil under cotton crop had an average of 27 ppm nitrate nitrogen which declined to around 5 ppm by 4-6 feet depth. Similarly depth profile studies have shown that nitrate in subsoil samples varied and occasionally values of 35 ppm at the top surface and around 10 ppm at lower depths have been detected. At present the shallow groundwater nitrate levels are below 1 ppm. However, the groundwater is under a constant threat of contamination from the subsurface soils with higher nitrate contents. Perhaps the nitrates in water have been diluted through the recharge

process by canal or other water sources.

Studies at the Faisalabad (Muhammed et al., 1989) and at Tandojam (Memon and Sial, 1990) have also observed the downward nitrate nitrogen movement in deeper soils after nitrogen fertilization of croplands. Similarly at the National Agricultural Research Centre, Islamabad during the period of 1987-1989, Salim and Rashid (1989) have shown the presence of residual nitrates in lower soil horizons. The 6-12 inch soil had an average concentration of 6-9 ppm of nitrate which declined to around 2 ppm in 48" deep soil. There was an enormous increase in nitrate levels at all studied depths upto 48 inches after nitrogenous fertilizer application. This clearly supports the hypothesis of leaching of nitrates (originating from fertilizers) to lower soil horizons with irrigation. However, these studies were conducted in rainfed area, and chances of runoff with heavy rains are more. The groundwater levels are deep hence the chances of groundwater contamination in this case are very low. Unfortunately at present no research report from Pakistan is available which can give indication of nitrate contents in soil upto the groundwater table.

In cropland of California the average concentration of nitrate nitrogen in the soil water at a depth of 10-20 feet was 290 ppm. At the top of the water table the concentration was 198 ppm (Branson, et al., 1975). Andriano, et al., (1972) found that nitrate nitrogen concentrations at 10-50 foot depth in cropped area of Los Angeles ranged from 36-122 ppm. They estimated that from 10-50 years would be required before current fertilization practices would affect the nitrate concentration of the groundwater because of the slow downward movement.

The California studies by Pratt (1978) indicated that the nitrate nitrogen concentration in groundwater under irrigated cropland were 25-30 ppm, and only when the quantities applied exceed those efficiently used by the crop does the loss of nitrate in drainage water become excessive.

Phosphate levels in excess of 5 ppm may indicate contamination of groundwater from human or animal wastes.

Bundschuh and Balke (1991) in their hydrochemical survey of groundwater in Peshawar Valley observed that in most of the samples (80%) the nitrate concentration was less than 20 ppm. The rest , except for three human-polluted wells where concentrations of more than 100 ppm were registered, had nitrate contents in the range of 20 to 50 ppm. Calcium concentrations in 85% of the samples ranged from 30-100 ppm without any regional trend. Only in some of the highly mineralized groundwater samples from the central part of the Peshawar Valley, contents ranging upto 260 ppm were found. The Magnesium concentrations in 94% samples ranged between 15-50 ppm except in the central part of the basin where values upto 240 ppm were observed. Sodium distribution was non-homogeneous with concentrations increasing from the boundaries of the basin towards the centre. Near the mountains the sodium concentrations were less than 50 ppm increasing to 200 ppm near the centre of the basin. The maximum values 850 ppm were also detected. The concentration of the potassium ranged between 1-6 ppm. Only in the highly mineralized (in the centre) the values upto 22 ppm were registered. The chloride concentration was less than 50 ppm, in most areas even less than 20 ppm. The highly mineralized groundwater in the centre registered fairly high chloride concentrations upto 1240 ppm.

A survey conducted by Ashraf (1986) on the quality of drinking water supplies (wells, tube-wells, springs and overhead tanks) in Islamabad revealed that nitrates were not found to be a problem in surface water supplies and in most areas are not in a problem creating range, however, some water supplies did contain significant nitrate plus nitrites. Well waters also contained nitrites to some extent but were within acceptable limits. The natural water contained sodium upto 25 ppm and potassium upto 10 ppm without being critical. The maximum concentration of Zinc was 3.6 ppm, within a safe range. All the water samples tested had copper content within safety limits. The highest concentration of copper recorded was 0.376 ppm. The maximum concentration of iron (0.39 ppm) is again below safer level, whereas the rest of the samples were below the limit of 0.10 ppm. Out of 125 different samples analyzed only one sample contained lead in excess of acceptable limits of 0.1 ppm. Whereas all the remaining water samples were found safe regarding their lead burden. Mercury and chromium were the two trace metals which in certain cases exceeded maximum acceptable limits of 0.001 and 0.05 ppm respectively.

Yaqub (1987) analyzed drinking water samples taken from different areas of Faisalabad city for nitrates and nitrites. Results indicated that nitrate and nitrite contents were higher in the area where industrial effluents and other waste water was available for seepage. Better drainage system areas contained lower nitrate and nitrite contents. Water and Sanitation Agency (WASA) tube-wells also showed low contents of nitrates and nitrites.

The primary drinking water standard for nitrate as nitrogen is 10 ppm. Excessive nitrate consumption by infants; less than 1 year in age may result in infant cyanosis, also called methemoglobinemia or "blue baby syndrome". A nitrate concentration of 10 ppm is considered safe for infants however, adults can tolerate larger concentrations without ill effects. In developed countries with long history of fertilizer applications the drinking water supplies have been reported to contain 30-180 ppm nitrate nitrogen.

This pilot project has indicated towards the dangers associated with the heavy and indiscriminate use of agrochemicals in the quest of boosting agricultural productivity. This kind of study should be extended to the other parts of the country particularly in the cotton intensive area where maximum input in the form of insecticides is being applied. It would be wise to scan the country and map out the potentially dangerous areas as for as groundwater contamination is concerned.

CHAPTER VII
CONCLUSIONS AND RECOMMENDATIONS

The occurrence of potentially toxic or hazardous chemicals in groundwater/drinking water, even in low concentrations, is of real concern because of the potential for long-term and widespread exposure to public. At the present time, only relatively shallow aquifers are affected. However, this may simply be a function of time when the deeper aquifers will also be contaminatted.

The present findings have revealed that the groundwater quality in Samundri, Faisalabad has been affected by the agrochemicals. Insecticides have reached the shallow aquifer. Nitrates are present in the subsurface soils in considerable quantities and it may be a matter of short time when these will reach the groundwater.

Comparison of the hand-pump drawn water and bore-hole water has revealed higher zinc contents in the hand-pump water. These higher levels of zinc may probably be originating from the hand-pump materials. The manufacturing industry should look into this matter in greater detail for replacing,if possible, zinc alloys with suitable safer material.

The following steps are suggested to be taken as remedial measures for protection of our groundwater from being polluted by the use of agrochemicals:

- Surveillance of extent of groundwater pollution throughout the country. Similar follow-up projects should be carried out in the areas of heavy agrochemical usage,

- Creation of public awareness through mass media and audio-visual communication,

- Education of farming community and personnel related to agrochemical industry. The pesticide and fertilizer manufacturers and distributors should be asked to take necessary measures in this aspect,

Implementation of the regulatory legislation related to agrochemical manufacturing, handling and usage.

Limiting or reducing groundwater contamination by pesticides

1 Discontinuation of a particular pesticide in the affected area.

2 Implementing Integrated Pest Management (IPM) practices to control the target pest using lower amounts of the chemical without loss in the efficiency of pest control.

3 Biotechnological manipulations of genetic engineering to breed crops with incorporated insect resistant genes.

4 Environmental warnings on pesticides labels to be heeded to.

5 Employment of techniques to reduce the concentrations of pesticides in potable water through:-

- Substituting alternative water sources
- Distillation of the water
- Use of ultraviolet light to decompose the pesticide residues
- Passing the water through an activated carbon filter to remove the residues.

Agricultural practices to reduce nitrate contamination of groundwater:

1 Reduction in the amount of nitrogen fertilizer applied in the current cropping system.

2 Adjustment of nitrogen fertilizer on the basis of soil or plant-tissue tests.

3 Application of nitrogen fertilizer in small amounts as needed during the growing season.

4 Use of slow release fertilizer formulations.

5 Use of chemical inhibitors to delay the formation of nitrate from the ammonium and other forms in which most of the fertilizers are applied.

6 Spraying plants with solutions of urea in place of soil application.

7 Changing the cropping systems that derive their supplemental nitrogen from legumes and can be used with little or no nitrogen fertilizers.

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ANNEXURE I

Tables giving depth profile data of elements in soils of Samundri

DEPTH PROFILE OF SODIUM (ppm) IN SOIL OF SAMUNDRI, FAISALABAD.

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	266.80	588.80	230.00	322.00	27.60	287.04	180.70	101.20	202.40	151.80	50.60	64.40	64.40	340.40	156.40	130.11
2	634.80	1554.80	478.40	331.20	27.60	605.36	515.25	138.00	211.60	174.80	36.80	119.60	73.60	441.60	211.60	163.72
3	809.60	1214.40	266.80	386.40	36.80	542.80	419.26	73.60	257.60	165.60	92.00	101.20	128.80	312.80	180.93	93.92
4	846.40	634.80	294.40	496.80	36.80	451.84	278.47	92.00	230.00	161.00	69.00	128.80	101.20	469.20	233.07	167.35
5	782.00	414.00	542.80	524.40	46.00	461.84	240.08	64.40	110.40	87.40	23.00	165.60	101.20	441.60	236.13	147.65
6	929.20	266.80	644.00	414.00	55.20	461.84	302.42	36.80	101.20	69.00	32.20	202.40	82.80	395.60	226.93	128.87
7	837.20	193.20	625.80	257.60	55.20	393.80	291.16	55.20	55.20	55.20	0.00	128.80	73.60	395.60	199.33	140.60
8	717.60	147.20	386.40	156.40	73.60	296.24	235.38	55.20	36.80	46.00	9.20	73.60	73.60	257.60	134.93	86.74
9	506.00	138.00	230.00	92.00	92.00	211.60	155.59	36.80	18.40	27.60	9.20	73.60	82.80	312.80	156.40	110.66
10	266.80	147.20	165.60	55.20	110.40	149.04	69.92	27.60	36.80	32.20	4.60	82.80	73.60	211.60	122.67	63.00
11	331.20	156.40	128.80	46.00	82.80	149.04	98.64		36.80	36.80	0.00	101.20	55.20	138.00	98.13	33.87
12	331.20					331.20	0.00									
13	432.40		55.20	46.00	119.60	163.30	157.93	36.80		36.80	0.00	193.20		119.60	156.40	36.80
14	533.60					533.60	0.00									
15	441.60	138.00	36.80	92.00		177.10	156.86	36.80	73.60	55.20	18.40			92.00	92.00	0.00
16	441.60				165.60	303.60	138.00	46.00		46.00	0.00	82.80	27.60		55.20	27.60
17	515.20		36.80			276.00	239.20		46.00	46.00	0.00			119.60	59.80	59.80
18	460.00					460.00	0.00					27.60			27.60	0.00
19	441.60		55.20	92.00	285.20	218.50	155.64						36.80		36.80	0.00
20	450.30					450.30	0.00									
21			147.20	73.60	368.00	196.27	125.10	36.80	36.80	36.80	0.00	18.40	64.40		41.40	23.00
23			101.20	36.80	395.60	177.87	156.19							230.00	230.00	0.00
25	506.00					506.00	0.00							73.60	73.60	0.00
26					138.00	138.00	0.00		46.00	46.00	0.00	73.60	165.60		119.60	46.00
30	138.00					138.00	0.00									

DEPTH PROFILE OF POTASSIUM IN SOIL OF SAMUNDRI, FAISALABAD
(ppm)

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	226.20	146.60	226.20	265.20	165.36	205.91	43.59	65.50	162.24	113.87	48.37	84.24	151.32	180.96	138.84	40.46
2	216.80	106.10	140.40	151.32	84.24	139.77	45.35	70.20	67.08	68.64	1.56	117.00	123.24	138.84	126.36	9.19
3	191.90	154.40	160.68	146.64	102.96	151.32	28.65	79.60	74.88	77.24	2.36	95.16	96.72	138.84	110.24	20.23
4	196.60	274.60	146.64	160.68	145.08	184.72	48.62	82.70	71.76	77.23	5.47	85.80	74.88	124.80	95.16	21.43
5	170.00	232.40	173.16	271.44	176.28	204.66	40.57	68.60	67.08	67.84	0.76	59.28	74.88	99.84	78.00	16.70
6	184.10	104.50	193.44	234.00	199.68	183.14	42.78	46.80	53.04	49.92	3.12	53.04	93.60	113.88	86.84	25.29
7	187.20	73.30	215.28	312.00	202.80	198.12	76.14	32.80	35.88	34.34	1.54	40.56	118.56	127.92	95.68	39.16
8	124.80	49.90	163.80	280.80	227.76	169.41	80.15	28.10	26.52	27.31	0.79	24.96	138.84	104.52	89.44	47.70
9	131.00	32.80	121.68	218.40	301.08	160.99	91.43	12.50	17.16	14.83	2.33	26.52	160.68	143.52	110.24	59.61
10	60.80	39.00	137.28	265.20	265.20	153.50	96.87	10.90	23.40	17.15	6.25	28.08	174.72	92.04	98.28	60.03
11	68.60	42.10	124.80	277.68	327.60	168.16	114.10		26.52	26.52	0.00	29.64	205.92	65.52	100.36	76.07
12	65.50					65.50	0.00									
13	110.80		82.68	215.28	327.60	184.09	96.47	14.00		14.00	0.00	37.44		59.28	48.36	10.92
14	120.10					120.10	0.00									
15	85.80	32.80	31.20	121.68		67.87	38.05	10.90	68.64	39.77	28.87			48.36	48.36	0.00
16	95.20				234.00	164.60	69.40	7.80		7.80	0.00	21.84	160.68		91.26	69.42
17	99.80		18.72			59.26	40.54		17.16	17.16	0.00			71.76	71.76	0.00
18	93.60					93.60	0.00					10.92			10.92	0.00
19	93.60		14.04	37.44	230.88	93.99	84.16						421.20		421.20	0.00
20	92.00					92.00	0.00									
21			17.16	31.20	131.04	59.80	50.70	9.40	6.24	7.82	1.58	12.48	118.56		65.52	53.04
23			17.16	3.12	129.48	49.92	56.55							218.40	218.40	0.00
25	92.00					92.00	0.00							81.12	81.12	0.00
26					45.24	45.24	0.00		7.80	7.80	0.00	18.72	85.80		52.26	33.54
30	15.60					15.60	0.00									

DEPTH PROFILE OF MAGNESIUMIN SOIL OF SAMUNDRI, FAISALABAD.
(ppm)

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	59.50	58.00	91.50	95.00	76.50	76.10	15.48	62.00	66.00	64.00	2.00	59.00	72.50	82.00	71.17	9.44
2	54.50	51.00	78.50	78.50	97.50	72.00	17.22	62.00	60.50	61.25	0.75	65.50	73.50	104.00	81.00	16.59
3	132.00	90.50	78.50	76.00	97.00	94.80	20.13	63.00	80.00	71.50	8.50	63.00	74.00	90.00	75.67	11.09
4	97.50	60.50	80.00	78.00	132.50	89.70	24.40	88.00	60.00	74.00	14.00	55.50	75.00	95.00	75.17	16.13
5	100.00	61.00	92.00	69.00	96.50	83.70	15.68	78.00	69.50	73.75	4.25	51.00	81.50	60.00	64.17	12.80
6	132.50	64.50	106.00	95.00	92.50	98.10	21.98	64.50	86.00	75.25	10.75	50.50	70.00	93.00	71.17	17.37
7	133.50	52.00	124.50	125.00	64.50	99.90	34.39	55.00	66.00	60.50	5.50	48.00	63.50	98.00	69.83	20.90
8	141.00	36.60	121.50	130.00	77.50	101.32	38.89	37.00	52.50	44.75	7.75	26.80	61.50	34.70	41.00	14.85
9	89.50	30.50	89.50	110.00	94.00	84.70	27.95	29.30	46.00	37.65	8.35	25.80	50.00	54.00	43.27	12.46
10	64.00	32.20	83.00	114.00	107.50	80.14	29.87	26.30	50.00	38.15	11.85	26.90	58.00	52.00	45.63	13.47
11	56.50	29.50	62.50	97.00	79.00	64.90	22.62		51.00	51.00	0.00	24.90	60.50	52.50	45.97	15.25
12	58.00					58.00	0.00									
13	44.00		43.50	87.00	161.00	84.13	48.30	28.50		28.50	0.00	41.90		32.50	37.20	4.70
14	55.00					55.00	0.00									
15	83.50	23.00	149.00	96.00		87.88	44.81	26.10	75.00	50.55	24.45			38.50	38.50	0.00
16	64.00				98.00	81.00	17.00	21.00		21.00	0.00	24.70	189.50		107.10	82.40
17	69.50		175.00			122.25	52.75		31.60	31.60	0.00			39.00	39.00	0.00
18	107.00					107.00	0.00					18.20			18.20	0.00
19	102.00		131.00	101.50	136.00	130.13	34.40						144.50		72.25	72.25
20	40.50					40.50	0.00									
21			145.50	57.00	102.00	101.50	36.13	20.00	51.50	37.25	14.25	18.90	101.50	54.00	58.13	33.85
23			127.50	29.80	101.50	96.27	47.03							55.50	55.50	0.00
25	32.50					32.50	0.00							45.50	45.50	0.00
26					54.00	54.00	0.00		27.40	27.40	0.00	27.20	76.00		51.60	24.40
30	18.80					18.80	0.00									

DEPTH PROFILE OF CALCIUM IN SOIL OF SAMUNDRI, FAISALABAD.
(ppm)

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	152.00	182.00	188.00	182.00	184.00	177.60	12.99	174.00	189.00	181.50	7.50	189.00	178.00	185.00	184.00	4.55
2	165.00	170.00	186.00	188.00	181.00	178.00	9.01	188.00	188.00	188.00	0.00	193.00	170.00	162.00	175.00	13.14
3	93.00	161.00	172.00	184.00	168.00	155.60	32.18	191.00	181.00	186.00	5.00	182.00	179.00	149.00	170.00	14.90
4	114.00	136.00	176.00	188.00	165.00	155.80	27.09	174.00	173.00	173.50	0.50	178.00	172.00	155.00	168.33	9.74
5	124.00	123.00	161.00	188.00	167.00	152.60	25.40	178.00	188.00	183.00	5.00	180.00	163.00	168.00	170.33	7.13
6	133.00	175.00	153.00	191.00	168.00	164.00	19.74	191.00	167.00	179.00	12.00	172.00	175.00	170.00	172.33	2.05
7	108.00	188.00	145.00	176.00	183.00	160.00	29.99	167.00	188.00	177.50	10.50	184.00	192.00	165.00	180.33	11.32
8	103.00	167.00	145.00	165.00	168.00	149.60	24.78	168.00	182.00	175.00	7.00	186.00	210.00	196.00	197.33	9.84
9	161.00	171.00	173.00	161.00	156.00	164.40	6.50	167.00	173.00	170.00	3.00	187.00	205.00	163.00	185.00	17.20
10	181.00	177.00	149.00	171.00	150.00	165.60	13.53	174.00	166.00	170.00	4.00	184.00	199.00	178.00	187.00	8.83
11	146.00	174.00	147.00	171.00	144.00	156.40	13.22		164.00	82.00	82.00	194.00	183.00	179.00	185.33	6.34
12	114.00					114.00	0.00									
13	188.00		158.00	161.00	134.00	160.25	19.14	177.00		177.00	0.00	172.00		175.00	173.50	1.50
14	179.00					179.00	0.00									
15	191.00	187.00	175.00	163.00		179.00	10.95	168.00	176.00	172.00	4.00			174.00	174.00	0.00
16	175.00				130.00	152.50	22.50	177.00		177.00	0.00	175.00	156.00		165.50	9.50
17	150.00		151.00			150.50	0.50		181.00	181.00	0.00			190.00	190.00	0.00
18	130.00					130.00	0.00					184.00			184.00	0.00
19	180.00		186.00	175.00	133.00	168.50	20.86						156.00		78.00	78.00
20	190.00					190.00	0.00									
21			186.00	174.00	146.00	168.67	16.76	191.00	185.00	188.00	3.00	190.00	175.00	160.00	175.00	12.25
23			183.00	181.00	157.00	173.67	11.61							160.00	160.00	0.00
25	174.00					174.00	0.00							156.00	156.00	0.00
26					154.00	154.00	0.00		185.00	185.00	0.00	183.00	158.00		170.50	12.50
30	193.00					193.00	0.00									

DEPTH PROFILE OF CHLORIDE IN SOIL OF SAMUNDRI, FAISALABAD.
(ppm)

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	1526.00	674.50	532.50	355.00	781.00	773.80	402.33	461.50	248.50	355.00	106.50	798.70	177.50	603.50	526.57	259.37
2	2201.00	355.00	816.50	568.00	798.70	947.84	648.94	1029.50	284.00	656.75	372.75	585.70	798.70	798.70	727.70	100.41
3	461.50	1278.00	923.00	461.50	461.50	717.10	332.57	532.50	443.70	488.10	44.40	532.50	585.70	479.20	532.47	43.48
4	674.50	177.50	674.50	585.70	408.20	504.08	190.05	994.00	390.50	692.25	301.75	745.50	248.50	390.50	461.50	209.02
5	177.50	355.00	923.00	514.70	301.70	454.38	258.11	781.00	621.20	701.10	79.90	639.00	532.50	639.00	603.50	50.20
6	230.70	284.00	1118.20	745.50	266.20	528.92	349.89	461.50	639.00	550.25	88.75	568.00	142.00	816.50	508.83	278.52
7	177.00	461.50	727.70	585.70	213.00	432.98	212.09	319.50	603.50	461.50	142.00	923.00	213.00	1029.50	721.83	362.42
8	142.00	159.70	781.00	639.00	390.50	422.44	254.62	532.50	639.00	585.75	53.25	621.20	284.00	497.00	467.40	139.24
9	1491.00	88.70	1065.00	727.70	355.00	745.48	498.41	461.50	426.00	443.75	17.75	976.20	426.00	319.50	573.90	287.77
10	106.50	266.20	656.70	745.50	426.00	440.18	237.45	284.00	568.00	426.00	142.00	816.50	355.00	248.50	473.33	246.52
11	1029.50	266.20	621.20	674.50	585.70	635.42	243.24		461.50	230.75	230.75	568.00	230.70	319.50	372.73	142.75
12	426.00					426.00	0.00									
13	2165.50		674.50	497.00	656.70	998.43	677.35	443.70		443.70	0.00	674.50		284.00	479.25	195.25
14	2307.50					2307.50	0.00									
15	390.50	532.50	674.50	603.50		550.25	105.01	568.00	443.70	505.85	62.15			284.00	284.00	0.00
16	248.50				763.20	505.85	257.35	443.70		443.70	0.00	248.50	479.20		363.85	115.35
17	550.20		923.00			736.60	186.40		585.70	585.70	0.00			390.50	390.50	0.00
18	408.20					408.20	0.00					124.20			124.20	0.00
19	195.20		479.20	763.20	727.70	541.33	227.83						106.50		53.25	53.25
20	266.20					266.20	0.00									
21			621.20	869.70	763.20	751.37	101.79	568.00	1065.00	816.50	248.50	656.70	230.70	426.00	437.80	174.11
23			639.00	639.00	798.70	692.23	75.28							390.50	390.50	0.00
25	674.50					674.50	0.00							390.50	390.50	0.00
26					923.00	923.00	0.00		603.50	603.50	0.00	53.20	177.50		115.35	88.15
30	1384.50					1384.50	0.00									

DEPTH PROFILE OF NITRATE IN SOIL OF SAMUNDRI, FAISALABAD
(ppm)

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	20.00	23.00	6.00			9.80	9.85	6.00	9.00	7.50	1.50	11.00	8.00	13.00	10.67	2.05
2	20.00	32.00	8.00			12.00	12.39	9.00	8.00	8.50	0.50	12.00	6.00	2.00	6.67	4.11
3	22.00	20.00	3.00			9.00	9.88	11.00	10.00	10.50	0.50	6.00	10.00		5.33	4.11
4	22.00	23.00	3.00			9.60	10.59	11.00	6.00	8.50	2.50	11.00	17.00	1.00	9.67	6.60
5	22.00	22.00	2.00			9.20	10.48	11.00	6.00	8.50	2.50	9.00	22.00	1.00	10.67	8.65
6	22.00	22.00	6.00			10.00	10.04	15.00	8.00	11.50	3.50	11.00	17.00	1.00	9.67	6.60
7	231.00	22.00	4.00			51.40	90.17	11.00	6.00	8.50	2.50	8.00	10.00	1.00	6.33	3.86
8	231.00	11.00	7.00			49.80	90.70	15.00	17.00	16.00	1.00	9.00	8.00	1.00	6.00	3.56
9	20.00	11.00	4.00			7.00	7.64	9.00	22.00	15.50	6.50	8.00	6.00	0.00	4.67	3.40
10	14.00	11.00	30.00			11.00	11.06	9.00	6.00	7.50	1.50	10.00	6.00	1.00	5.67	3.68
11	13.00	20.00	2.00			7.00	8.10		8.00	4.00	4.00	8.00	11.00	1.00	6.67	4.19
12	32.00					32.00	0.00									
13	33.00		3.00			9.00	13.91	6.00		6.00	0.00	9.00		1.00	5.00	4.00
14	35.00					35.00	0.00									
15	22.00	11.00	20.00			13.25	8.70	9.00	11.00	10.00	1.00			1.00	1.00	0.00
16	20.00				1.00	7.00	9.20	9.00		9.00	0.00	9.00	9.00		9.00	0.00
17	32.00		3.00			17.50	14.50		1.00	1.00	0.00			8.00	8.00	0.00
18	31.00					31.00	0.00					11.00			11.00	0.00
19	30.00		4.00		1.00	9.00	12.21						9.00		9.00	0.00
20	31.00					31.00	0.00									
21			28.00		1.00	10.33	12.55	11.00	1.00	6.00	5.00	6.00	13.00	47.00	22.00	17.91
23			8.00		2.00	3.33	3.40							8.00	8.00	0.00
25	25.00					25.00	0.00							2.00	2.00	0.00
26					1.00	1.00	0.00		8.00	8.00	0.00	17.00	8.00		12.50	4.50
30	22.00					22.00	0.00									

DEPTH PROFILE OF ZINC (ppm) IN SOIL OF SAMUNDRI, FAISALABAD.

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	0.06	0.40	0.15	0.60	0.90	0.42	0.31	0.30	0.90	0.60	0.30	0.11	0.14	0.26	0.17	0.06
2	0.16	0.08	0.13	0.14	0.60	0.22	0.19	0.14	0.15	0.15	0.00	0.07	0.11	0.15	0.11	0.03
3	0.12	0.00	0.10	0.12	0.12	0.09	0.05	0.08	0.11	0.10	0.01	0.06	0.08	0.15	0.10	0.04
4	0.07	0.06	0.12	0.12	0.12	0.10	0.03	0.07	0.10	0.09	0.01	0.07	0.12	0.14	0.11	0.03
5	0.08	0.09	0.13	0.12	0.11	0.11	0.02	0.05	0.10	0.08	0.02	0.07	0.09	0.13	0.10	0.02
6	0.40	0.06	0.13	0.13	0.11	0.17	0.12	0.06	0.11	0.09	0.02	0.07	0.13	0.11	0.10	0.02
7	0.06	0.09	0.19	0.10	0.13	0.11	0.04	0.05	0.11	0.08	0.03	0.06	0.12	0.12	0.10	0.03
8	0.14	0.04	0.14	0.08	0.11	0.10	0.04	0.07	0.13	0.10	0.03	0.12	0.11	0.19	0.14	0.04
9	0.06	0.07	0.12	0.09	0.10	0.09	0.02	0.16	0.14	0.15	0.01	0.04	0.14	0.17	0.12	0.06
10	1.15	0.06	0.12	0.10	0.23	0.33	0.41	0.04	0.13	0.09	0.05	0.06	0.11	0.11	0.09	0.02
11	0.16	0.21	0.13	0.11	0.14	0.15	0.03		0.12	0.12	0.00	0.06	0.13	0.07	0.09	0.03
12	0.03					0.03	0.00									
13	0.06		0.14	0.08	0.13	0.10	0.03	0.06		0.06	0.00	0.11		0.08	0.10	0.01
14	0.10					0.10	0.00									
15	0.40	0.15	0.15	0.09		0.20	0.12	0.04	0.15	0.10	0.06			0.06	0.06	0.00
16	0.15				0.11	0.13	0.02	0.08		0.08	0.00	0.09	0.16		0.13	0.04
17	0.37		0.10			0.24	0.13		0.12	0.12	0.00			0.12	0.12	0.00
18	0.22					0.22	0.00					0.09			0.09	0.00
19	0.13		0.10	0.10	0.12	0.11	0.01						0.14		0.07	0.07
20	0.12					0.12	0.00									
21			0.12	0.14	0.28	0.18	0.07	0.09	0.11	0.10	0.01	0.10	0.15	0.08	0.11	0.03
23			0.12	0.11	0.14	0.12	0.01							0.11	0.11	0.00
25	0.16					0.16	0.00							0.14	0.14	0.00
26					0.18	0.18	0.00		0.16	0.16	0.00	0.09	0.13		0.11	0.02
30	0.27					0.27	0.00									

DEPTH PROFILE OF IRON (ppm) IN SOIL OF SAMUNDRI, FAISALABAD.

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	2.98	6.00	1.58	3.20	2.60	3.27	1.47	5.50	4.40	4.95	0.55	1.10	1.63	2.58	1.77	0.61
2	3.49	2.14	1.44	2.12	1.00	2.04	0.84	2.55	2.40	2.48	0.07	1.22	1.39	1.74	1.45	0.22
3	2.78	2.54	1.11	2.16	1.75	2.07	0.59	2.28	2.24	2.26	0.02	1.09	1.48	1.76	1.44	0.27
4	3.10	2.93	0.99	2.17	1.53	2.14	0.81	1.58	1.84	1.71	0.13	1.29	1.57	1.79	1.55	0.20
5	2.44	2.54	1.42	2.23	1.44	2.01	0.49	1.21	1.69	1.45	0.24	1.22	1.27	2.07	1.52	0.39
6	1.98	1.38	1.44	1.97	1.36	1.63	0.29	1.51	1.81	1.66	0.15	1.22	1.52	2.15	1.63	0.39
7	2.67	1.41	1.88	1.95	0.84	1.75	0.61	0.99	0.98	0.99	0.00	1.31	1.04	2.05	1.47	0.43
8	1.04	1.07	1.45	1.80	1.25	1.32	0.28	1.57	1.10	1.34	0.23	1.71	0.97	1.51	1.40	0.31
9	1.95	1.51	1.39	1.99	1.31	1.63	0.29	1.01	0.86	0.94	0.07	0.81	1.02	1.45	1.09	0.27
10	2.99	1.34	0.94	1.99	1.84	1.82	0.69	1.18	1.27	1.23	0.04	0.90	0.97	2.75	1.54	0.86
11	2.93	0.64	1.07	1.51	1.75	1.58	0.77		1.17	1.17	0.00	0.96	2.70	1.45	1.70	0.73
12	1.58					1.58	0.00									
13	3.29		1.09	1.98	1.28	1.91	0.87	1.75		1.75	0.00	1.34		1.09	1.22	0.13
14	3.58					3.58	0.00									
15	2.98	1.84	2.12	2.24		2.30	0.42	1.27	2.02	1.65	0.37			1.06	1.06	0.00
16	3.59				1.38	2.49	1.11	1.90		1.90	0.00	0.81	3.30		2.06	1.24
17	3.20		0.98			2.09	1.11		1.61	1.61	0.00			1.38	1.38	0.00
18	4.04					4.04	0.00					1.10			1.10	0.00
19	3.64		1.26	1.80	1.80	2.13	0.90						1.83		0.92	0.92
20	3.26					3.26	0.00									
21			1.83	1.37	1.35	1.52	0.22	2.03	1.30	1.67	0.36	1.12	1.35	1.50	1.32	0.16
23			1.53	1.18	1.48	1.40	0.15							3.17	3.17	0.00
25	3.85					3.85	0.00							1.70	1.70	0.00
26					1.13	1.13	0.00		1.67	1.67	0.00	0.91	1.07		0.99	0.08
30	2.53					2.53	0.00									

DEPTH PROFILE OF COPPER IN SOIL OF SAMUNDRI, FAISALABAD.
(ppm)

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	0.10	2.20	0.86	1.00	1.70	1.17	0.72	2.10	1.60	1.85	0.25	0.73	0.92	1.04	0.90	0.13
2	0.85	1.05	0.75	0.91	1.60	1.03	0.30	0.95	0.93	0.94	0.01	0.71	0.70	0.90	0.77	0.09
3	0.72	0.67	0.60	0.90	0.99	0.78	0.15	0.80	0.81	0.81	0.01	0.61	0.51	0.69	0.60	0.07
4	0.65	0.47	0.43	0.88	0.92	0.67	0.20	0.59	0.68	0.64	0.04	0.60	0.38	0.69	0.56	0.13
5	0.53	0.38	0.36	0.88	0.81	0.59	0.22	0.35	0.50	0.46	0.11	0.51	0.34	0.35	0.40	0.08
6	0.54	0.31	0.30	0.82	0.60	0.51	0.19	0.27	0.42	0.35	0.07	0.44	0.32	0.38	0.38	0.05
7	0.55	0.24	0.28	0.65	0.49	0.44	0.16	0.19	0.28	0.24	0.05	0.27	0.31	0.41	0.33	0.06
8	0.44	0.15	0.21	0.49	0.40	0.34	0.13	0.18	0.15	0.17	0.01	0.18	0.32	0.34	0.28	0.07
9	0.39	0.14	0.21	0.43	0.35	0.30	0.11	0.14	0.10	0.12	0.02	0.18	0.23	0.31	0.24	0.05
10	0.24	0.17	0.14	0.38	0.47	0.28	0.13	0.10	0.11	0.11	0.00	0.17	0.24	0.17	0.19	0.03
11	0.36	0.15	0.15	0.31	0.44	0.28	0.12		0.12	0.12	0.00	0.13	0.24	0.13	0.17	0.05
12	0.12					0.12	0.00									
13	0.20		0.12	0.29	0.42	0.26	0.11	0.13		0.13	0.00	0.19		0.10	0.15	0.04
14	0.20					0.20	0.00									
15	0.41	0.12	0.23	0.26		0.26	0.10	0.12	0.14	0.13	0.01			0.08	0.08	0.00
16	0.18				0.25	0.22	0.04	0.10		0.10	0.00	0.14	0.18		0.16	0.02
17	0.30		0.06			0.18	0.12		0.09	0.09	0.00			0.09	0.09	0.00
18	0.19					0.19	0.00					0.13			0.13	0.00
19	0.15		0.08	0.13	0.17	0.13	0.03						0.24		0.12	0.12
20	0.20					0.20	0.00									
21			0.07	0.11	0.13	0.10	0.02	0.14	0.06	0.10	0.04	0.09	0.12	0.11	0.11	0.01
23			0.09	0.06	0.14	0.10	0.03							0.20	0.20	0.00
25	0.17					0.17	0.00							0.10	0.10	0.00
26					0.08	0.08	0.00		0.06	0.06	0.00	0.07	0.10		0.09	0.01
30	0.13					0.13	0.00									

DEPTH PROFILE OF MANGANESE IN SOIL OF SAMUNDRI, FAISALABAD.
(ppm)

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 195	Avg	SD
1	0.41	1.40	0.33	1.10	0.80	0.81	0.42	0.09	1.00	0.55	0.46	0.22	0.56	0.49	0.42	0.15
2	0.57	0.63	0.24	0.33	0.28	0.41	0.16	0.50	0.38	0.44	0.06	0.29	0.22	0.19	0.23	0.04
3	0.37	0.28	0.14	0.32	0.29	0.28	0.08	0.41	0.32	0.37	0.04	0.20	0.21	0.13	0.18	0.04
4	0.48	0.27	0.16	0.25	0.20	0.27	0.11	0.25	0.27	0.26	0.01	0.22	0.13	0.13	0.16	0.04
5	0.32	0.20	0.18	0.19	0.15	0.21	0.06	0.20	0.24	0.22	0.02	0.13	0.10	0.10	0.11	0.01
6	0.45	0.29	0.22	0.16	0.15	0.25	0.11	0.22	0.22	0.22	0.00	0.14	0.14	0.14	0.14	0.00
7	0.56	0.24	0.15	0.14	0.11	0.24	0.17	0.15	0.24	0.20	0.04	0.12	0.12	0.14	0.13	0.01
8	0.73	0.23	0.10	0.09	0.17	0.26	0.24	0.16	0.13	0.15	0.01	0.15	0.18	0.13	0.15	0.02
9	0.56	0.42	0.17	0.11	0.10	0.27	0.18	0.21	0.13	0.17	0.04	0.15	0.15	0.17	0.16	0.01
10	0.49	0.47	0.20	0.15	0.15	0.29	0.15	0.25	0.18	0.22	0.04	0.10	0.13	0.15	0.13	0.02
11	0.70	0.55	0.15	0.12	0.15	0.33	0.24		0.19	0.19	0.00	0.15	0.14	0.15	0.15	0.00
12	0.51					0.51	0.00									
13	0.52		0.15	0.10	0.13	0.23	0.17	0.36		0.36	0.00	0.13		0.15	0.14	0.01
14	0.91					0.91	0.00									
15	0.50	0.46	0.32	0.15		0.36	0.14	0.28	0.21	0.25	0.03			0.13	0.13	0.00
16	0.37				0.12	0.25	0.13	0.38		0.38	0.00	0.17	0.25		0.21	0.04
17	0.57		0.10			0.34	0.24		0.23	0.23	0.00			0.23	0.23	0.00
18	0.48					0.48	0.00					0.38			0.38	0.00
19	0.35		0.45	0.17	0.14	0.28	0.13						0.19		0.10	0.10
20	0.40					0.40	0.00									
21			0.35	0.12	0.19	0.22	0.10	0.34	0.39	0.37	0.02	0.27	0.15	0.14	0.19	0.06
23			0.32	0.20	0.17	0.23	0.06							0.20	0.20	0.00
25	0.43					0.43	0.00							0.19	0.19	0.00
26					0.18	0.18	0.00		0.29	0.29	0.00	0.20	0.10		0.15	0.05
30	0.96					0.96	0.00									

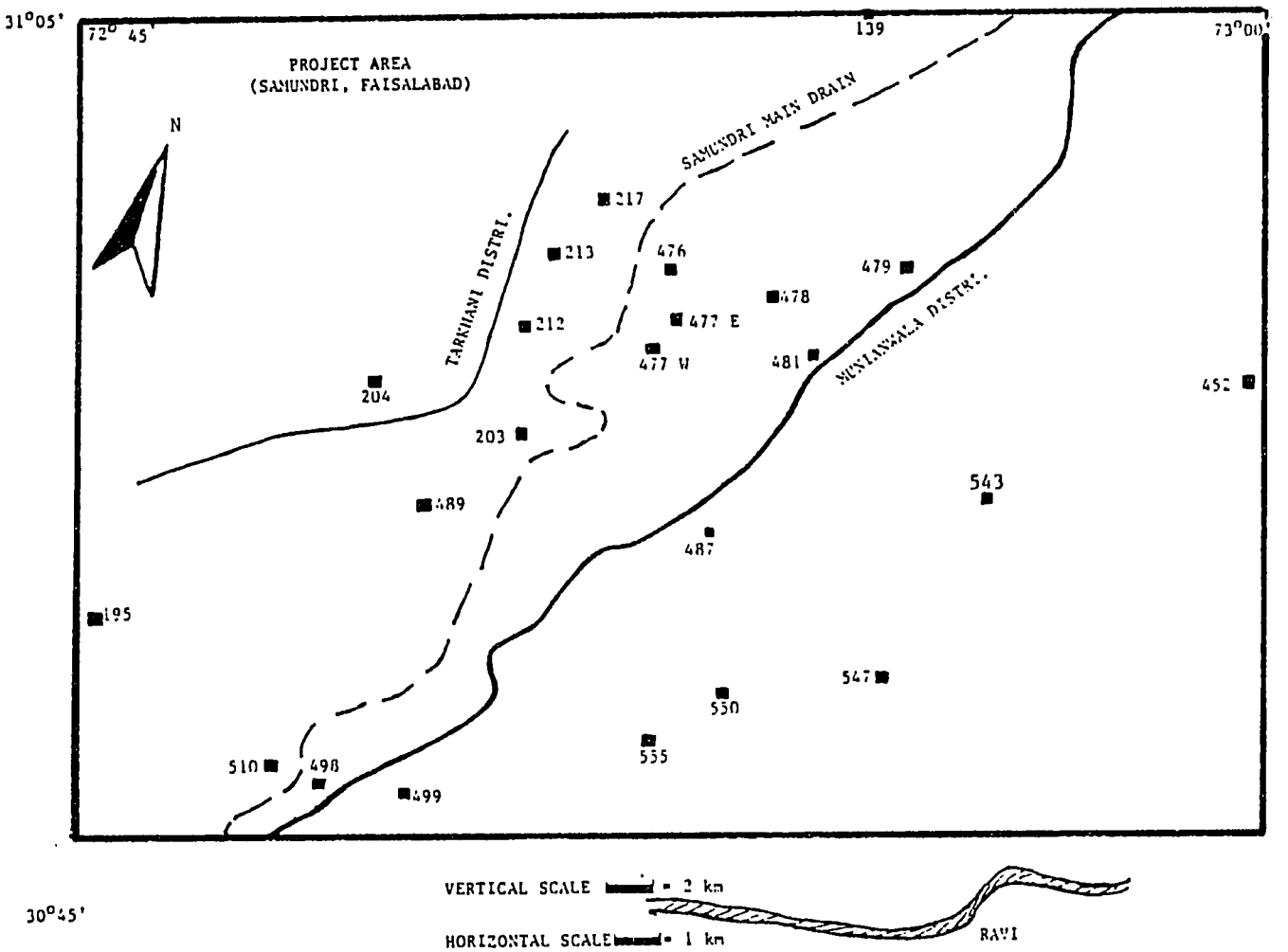
DEPTH PROFILE OF COBALT IN SOIL OF SAMUNDRI, FAISALABAD.
(ppm)

Depth (Ft)	Chak 139	Chak 217	Chak 203	Chak 510	Chak 489	Avg	SD	Chak 479	Chak 487	Avg	SD	Chak 452	Chak 547	Chak 185	Avg	SD
1	0.11	1.30	0.00	1.20	1.50	0.82	0.63	0.00	0.90	0.45	0.45	0.10	0.01	0.12	0.08	0.05
2	0.25	0.11	0.00	0.07	1.00	0.28	0.37	0.00	0.21	0.11	0.11	0.11	0.05	0.01	0.06	0.04
3	0.22	0.07	0.00	0.00	0.02	0.06	0.08	0.02	0.22	0.12	0.10	0.02	0.05	0.00	0.02	0.02
4	0.20	0.06	0.01	0.02	0.00	0.06	0.07	0.06	0.25	0.16	0.10	0.09	0.05	0.01	0.05	0.03
5	0.21	0.08	0.04	0.06	0.00	0.08	0.07	0.04	0.22	0.13	0.09	0.13	0.00	0.00	0.04	0.06
6	0.18	0.11	0.07	0.05	0.01	0.08	0.06	0.06	0.24	0.15	0.09	0.10	0.00	0.00	0.03	0.05
7	0.22	0.04	0.13	0.03	0.01	0.08	0.08	0.00	0.26	0.13	0.13	0.08	0.00	0.03	0.04	0.03
8	0.23	0.05	0.13	0.03	0.00	0.09	0.08	0.00	0.23	0.12	0.12	0.12	0.00	0.04	0.05	0.05
9	0.19	0.09	0.13	0.05	0.01	0.09	0.06	0.04	0.21	0.13	0.09	0.13	0.00	0.07	0.07	0.05
10	0.16	0.08	0.15	0.08	0.04	0.10	0.05	0.03	0.21	0.12	0.09	0.06	0.00	0.05	0.04	0.03
11	0.22	0.12	0.11	0.11	0.03	0.12	0.06		0.21	0.21	0.00	0.13	0.00	0.03	0.05	0.06
12	0.21					0.21	0.00									
13	0.22		0.14	0.09	0.00	0.11	0.08	0.03		0.03	0.00	0.12		0.09	0.11	0.02
14	0.20					0.20	0.00									
15	0.22	0.04	0.16	0.07		0.12	0.07	0.09	0.20	0.15	0.05			0.05	0.05	0.00
16	0.23				0.00	0.12	0.12	0.04		0.04	0.00	0.08	0.00		0.04	0.04
17	0.20		0.18			0.19	0.01		0.23	0.23	0.00			0.07	0.07	0.00
18	0.23					0.23	0.00					0.09			0.09	0.00
19	0.25		0.18	0.12	0.02	0.14	0.08						0.00		0.00	0.00
20	0.25					0.25	0.00									
21			0.22	0.16	0.05	0.14	0.07	0.02	0.25	0.14	0.12	0.00	0.00	0.14	0.05	0.07
23			0.00	0.11	0.02	0.04	0.05							0.10	0.10	0.00
25	0.25					0.25	0.00							0.03	0.03	0.00
26					0.02	0.02	0.00		0.23	0.23	0.00	0.00	0.00		0.00	0.00
30	0.19					0.19	0.00									

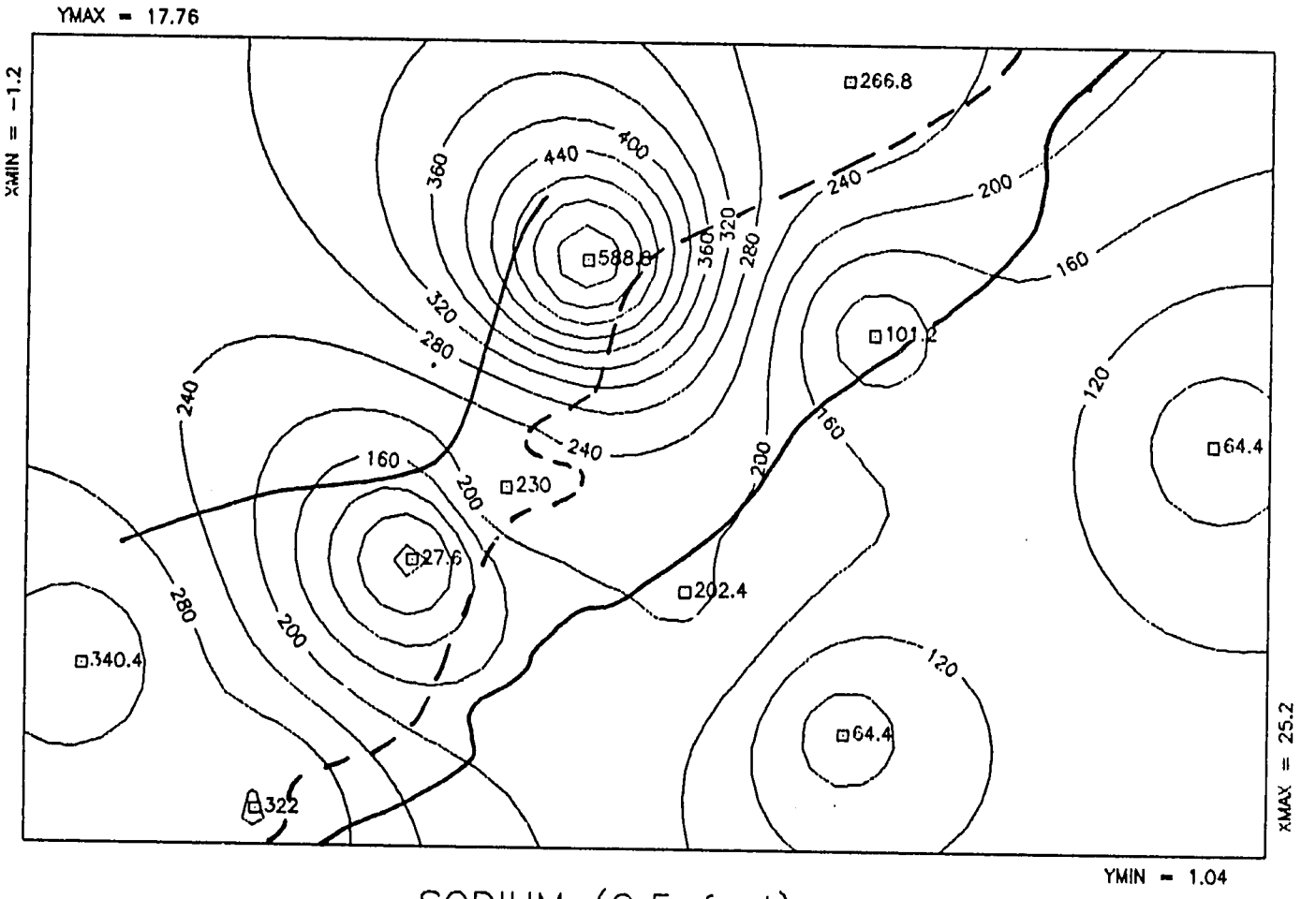
ANNEXURE II

MAP OF THE PROJECT AREA

CONTOUR MAPS OF ELEMENTS IN TOP SOIL OF SAMUNDRI, FAISALABAD

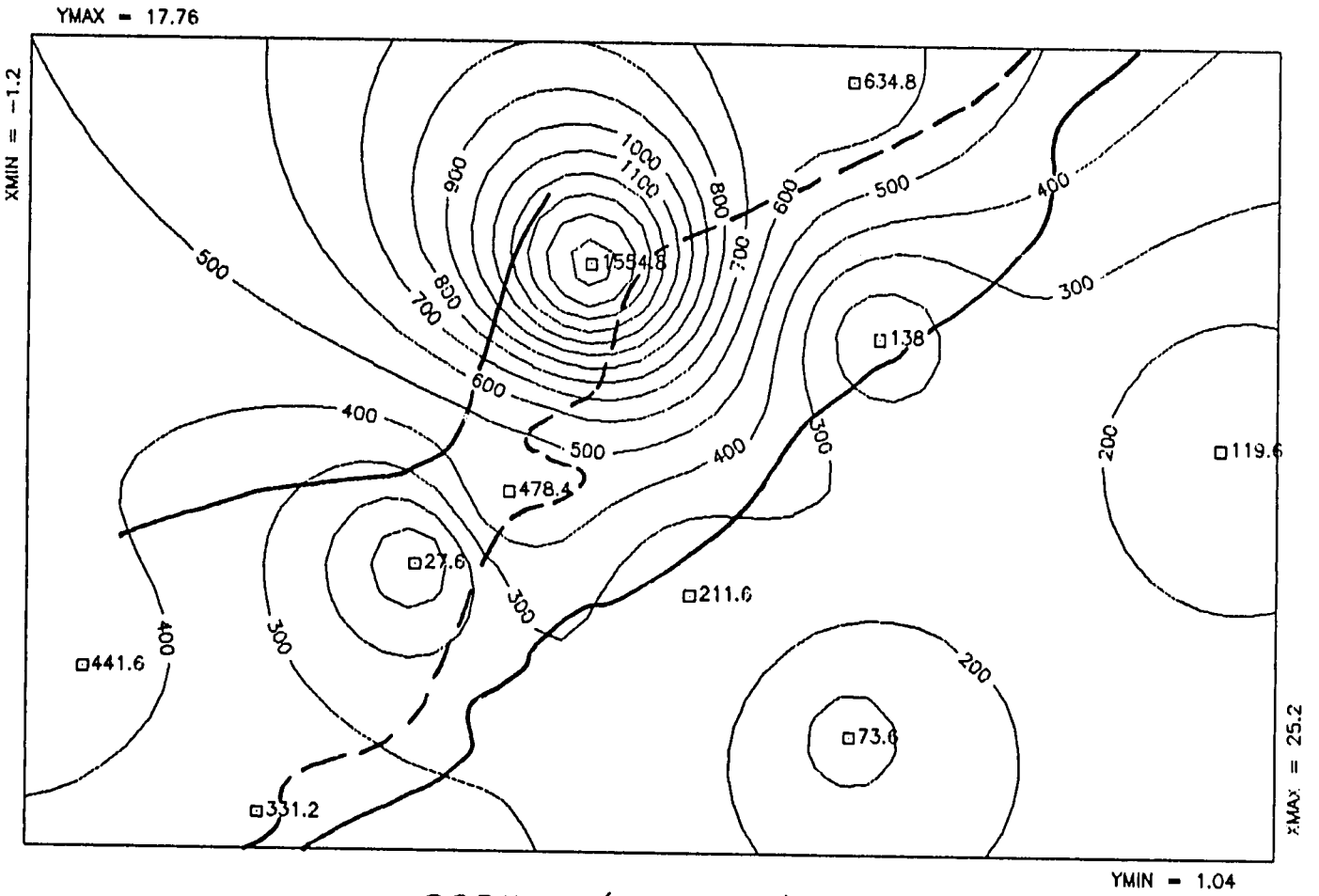

31°05'
72° 45'
139
73°00'
PROJECT AREA
(SAMUNDRI, FAISALABAD)
N
SAMUNDRI MAIN DRAIN
TARKHANI DISTRI.
MUNLANWALA DISTRI.
217
213
476
479
478
212
477 E
477 W
481
204
452
203
543
489
487
195
547
550
555
510
498
499
VERTICAL SCALE = 2 km
HORIZONTAL SCALE = 1 km
RAVI
30°45'

SODIUM DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



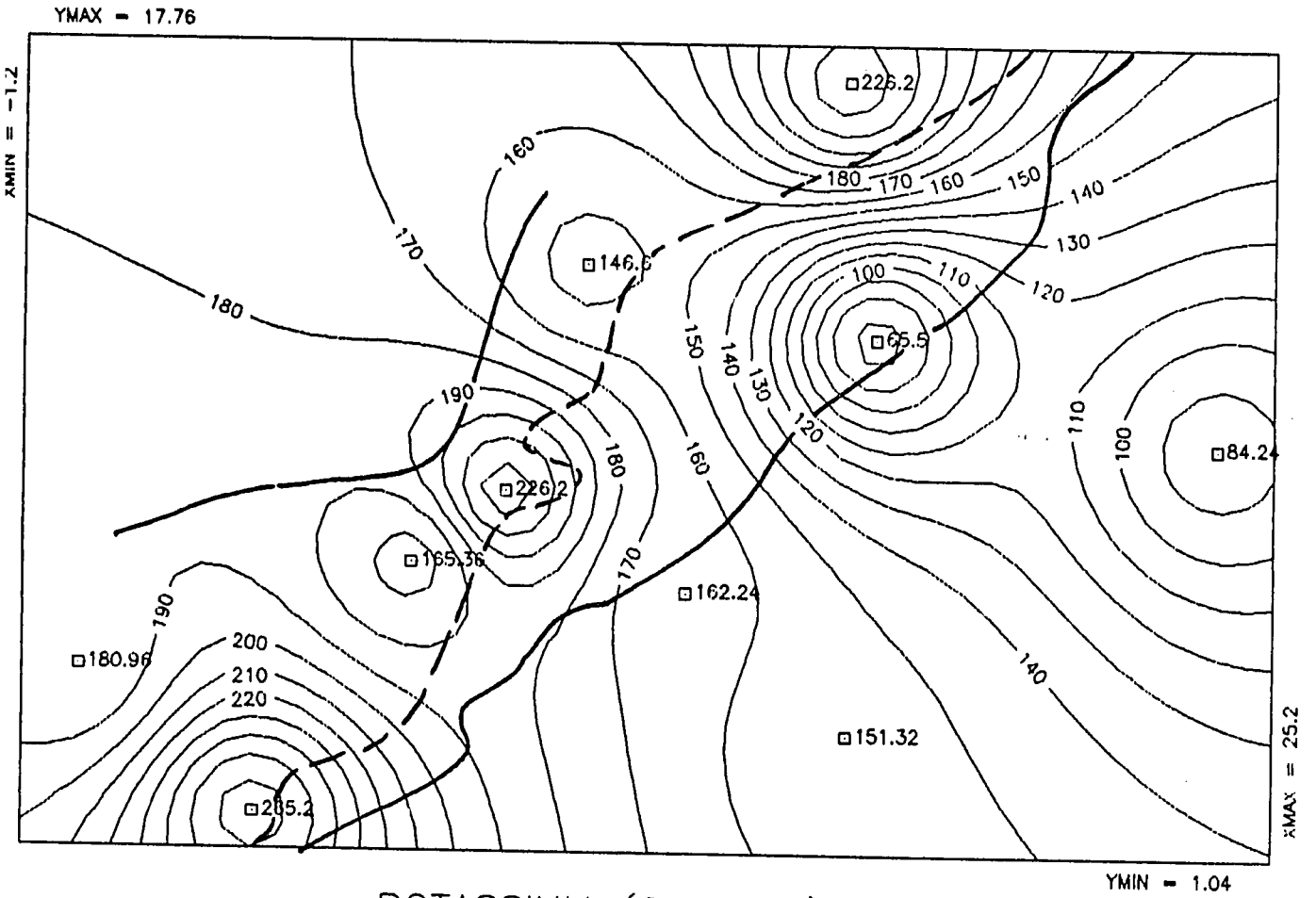
SODIUM (0.5 feet)
(ppm)

SODIUM DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



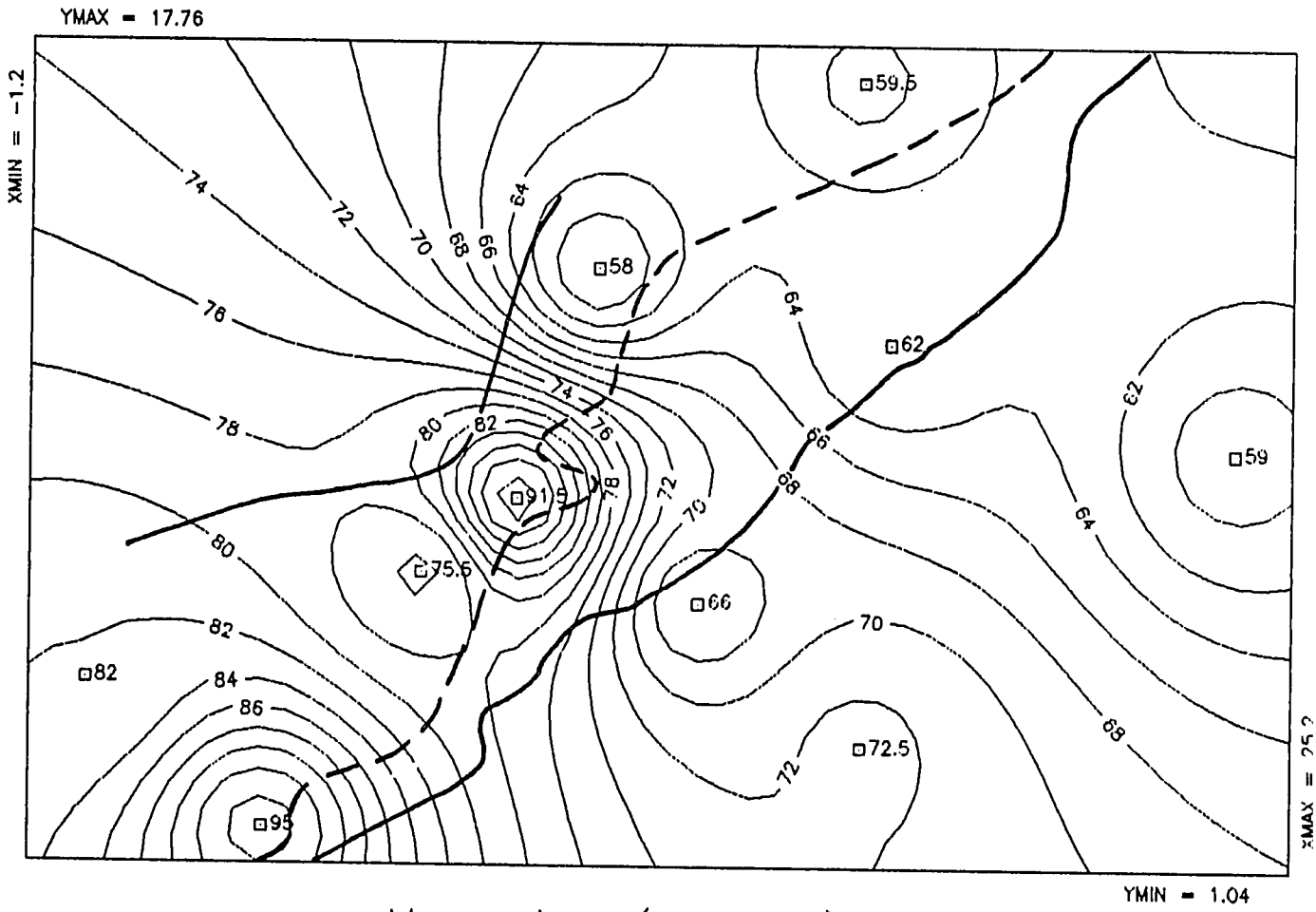
SODIUM (1.5 feet)
(ppm)

POTASSIUM DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



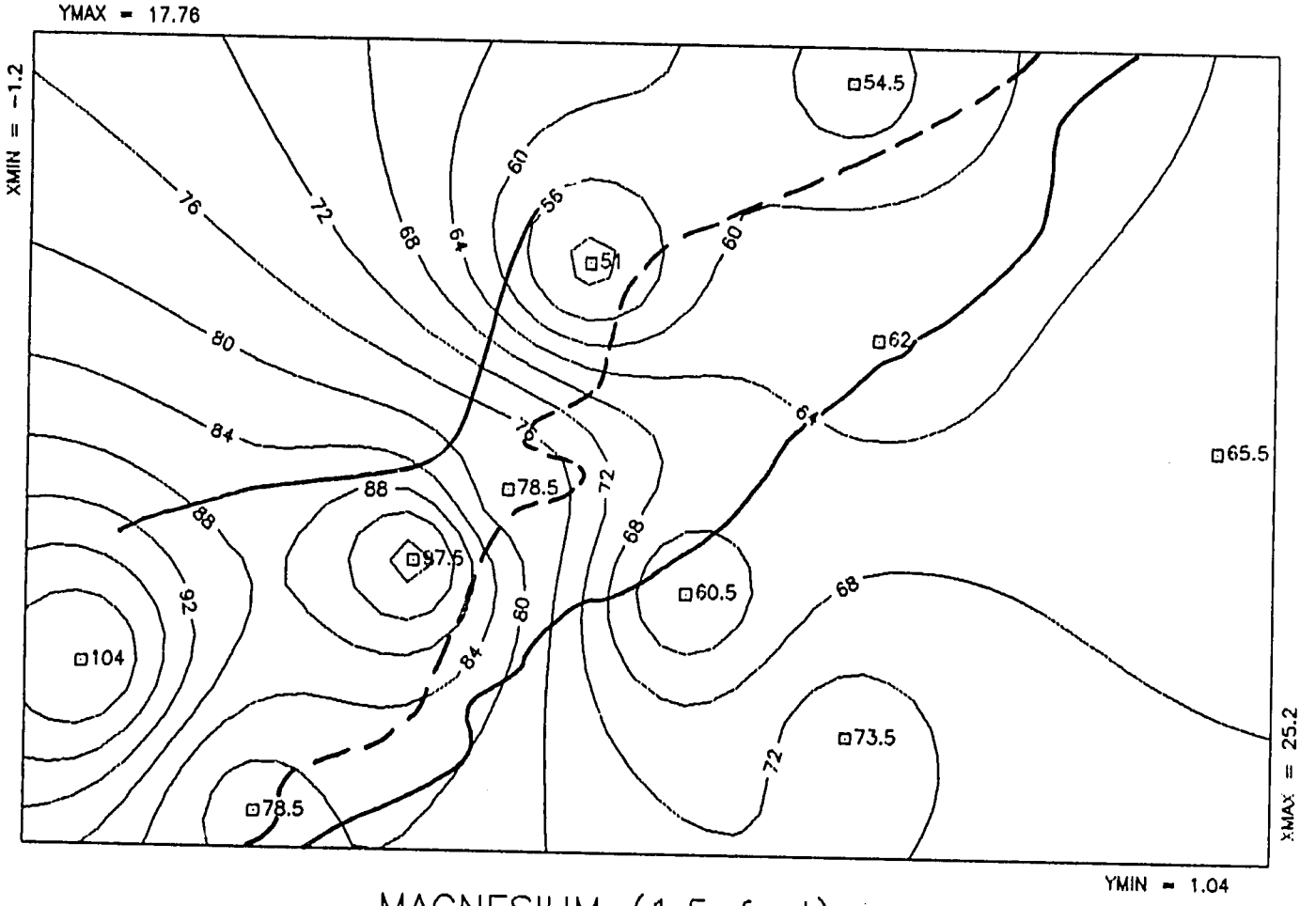
POTASSIUM (0.5 feet)
(ppm)

MAGNESSIUM DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



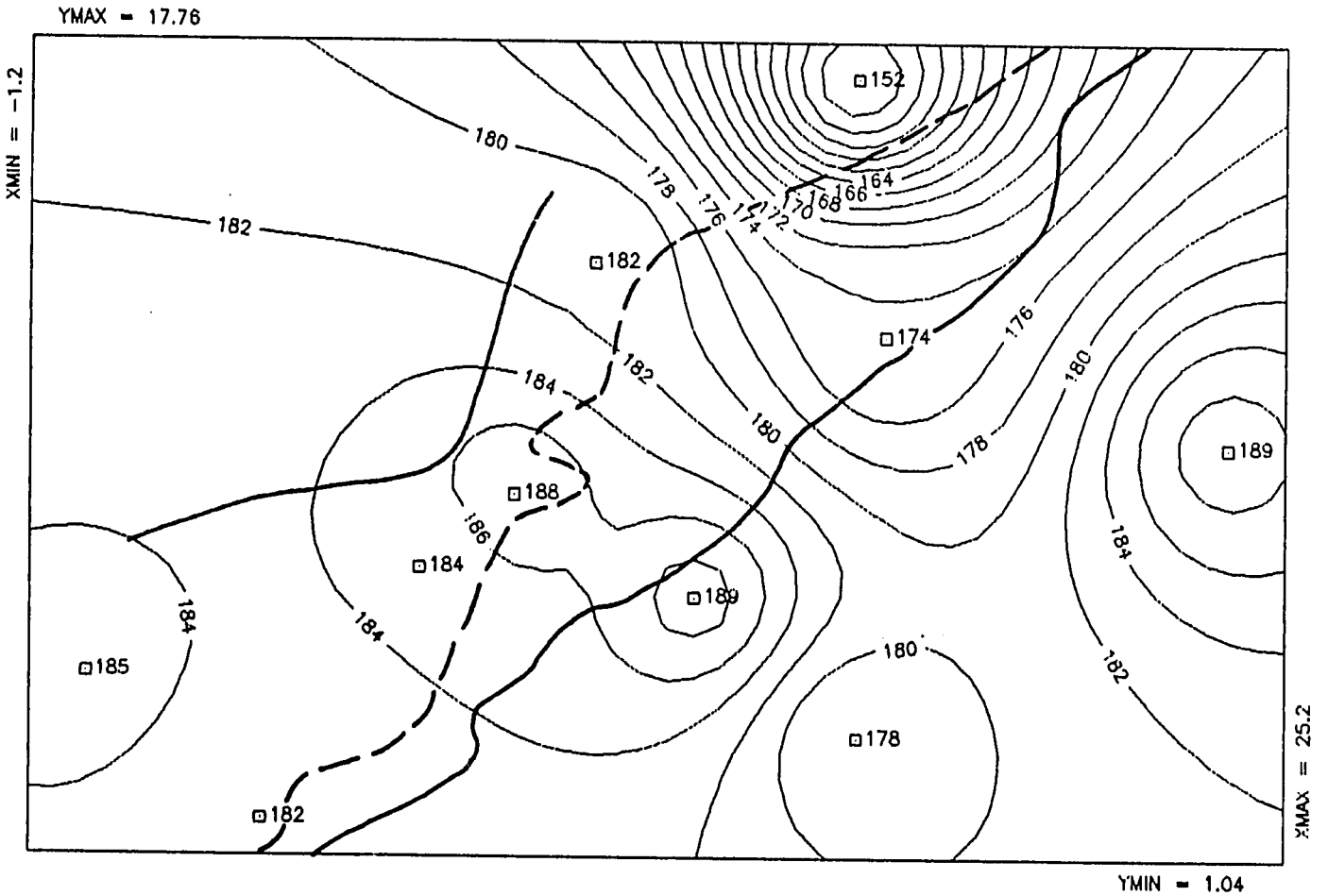
Magnesium (0.5 feet)
(ppm)

MAGNESIUM DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD

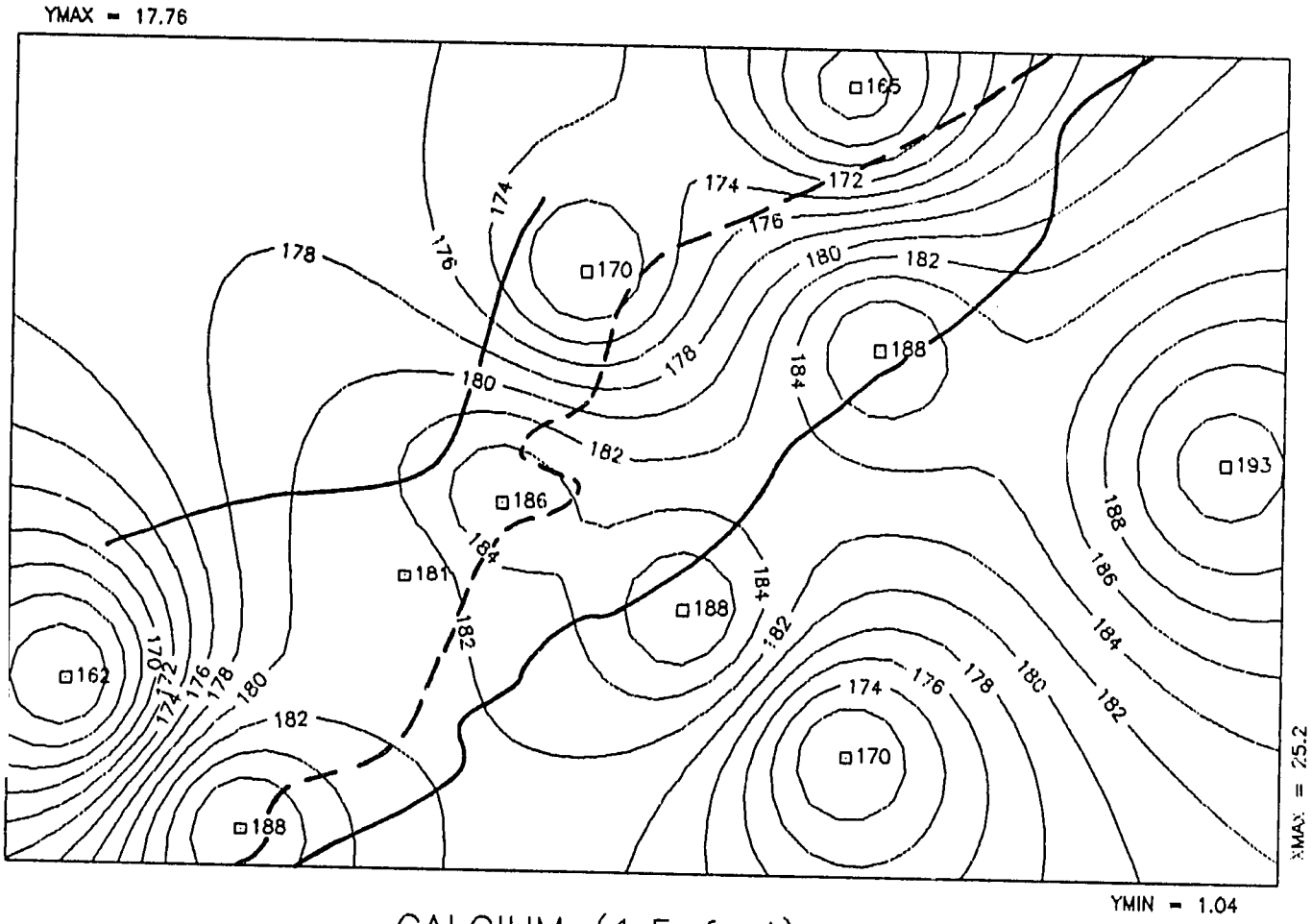


MAGNESIUM (1.5 feet)
(ppm)

CALCIUM DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



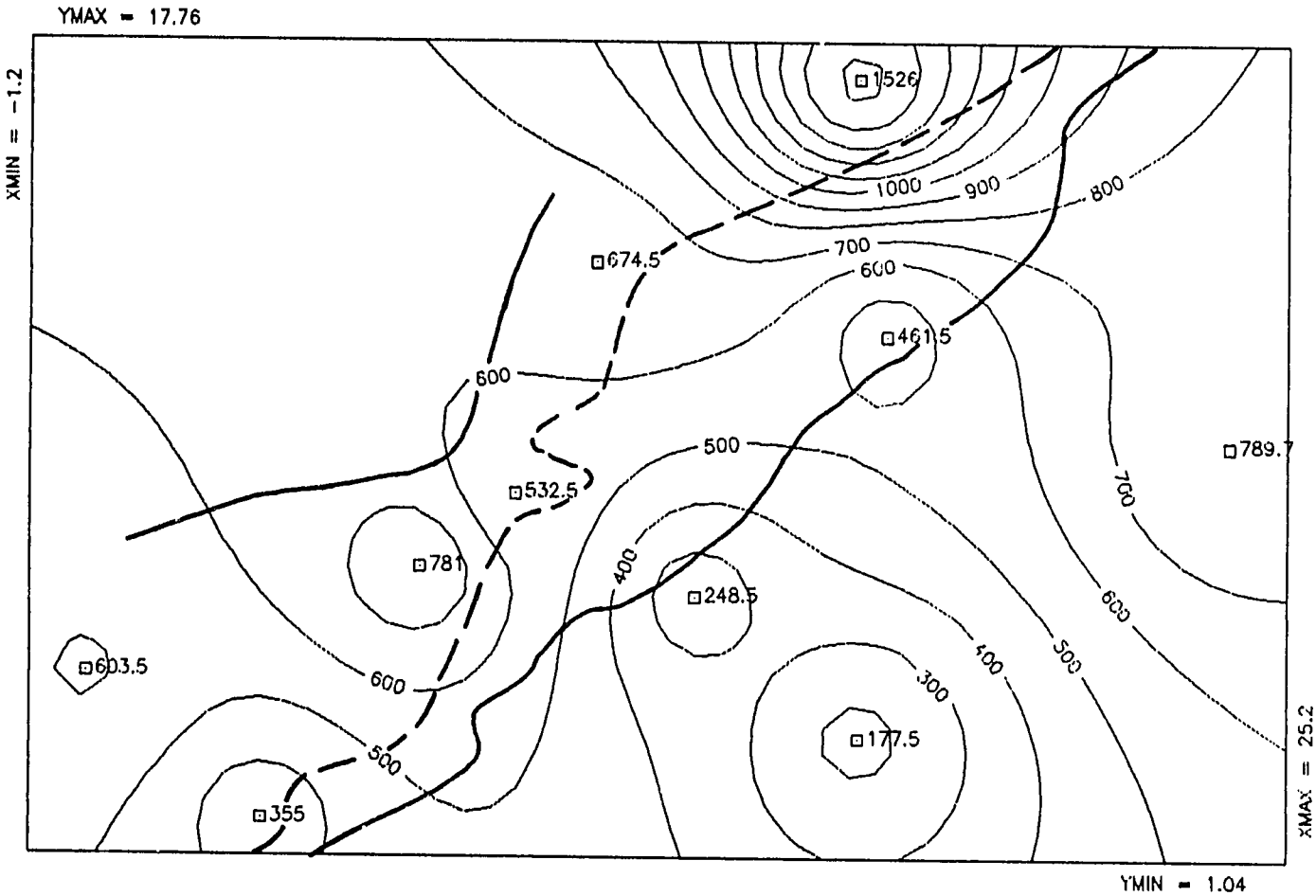
CALCIUM DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



CALCIUM (1.5 feet)

(ppm)

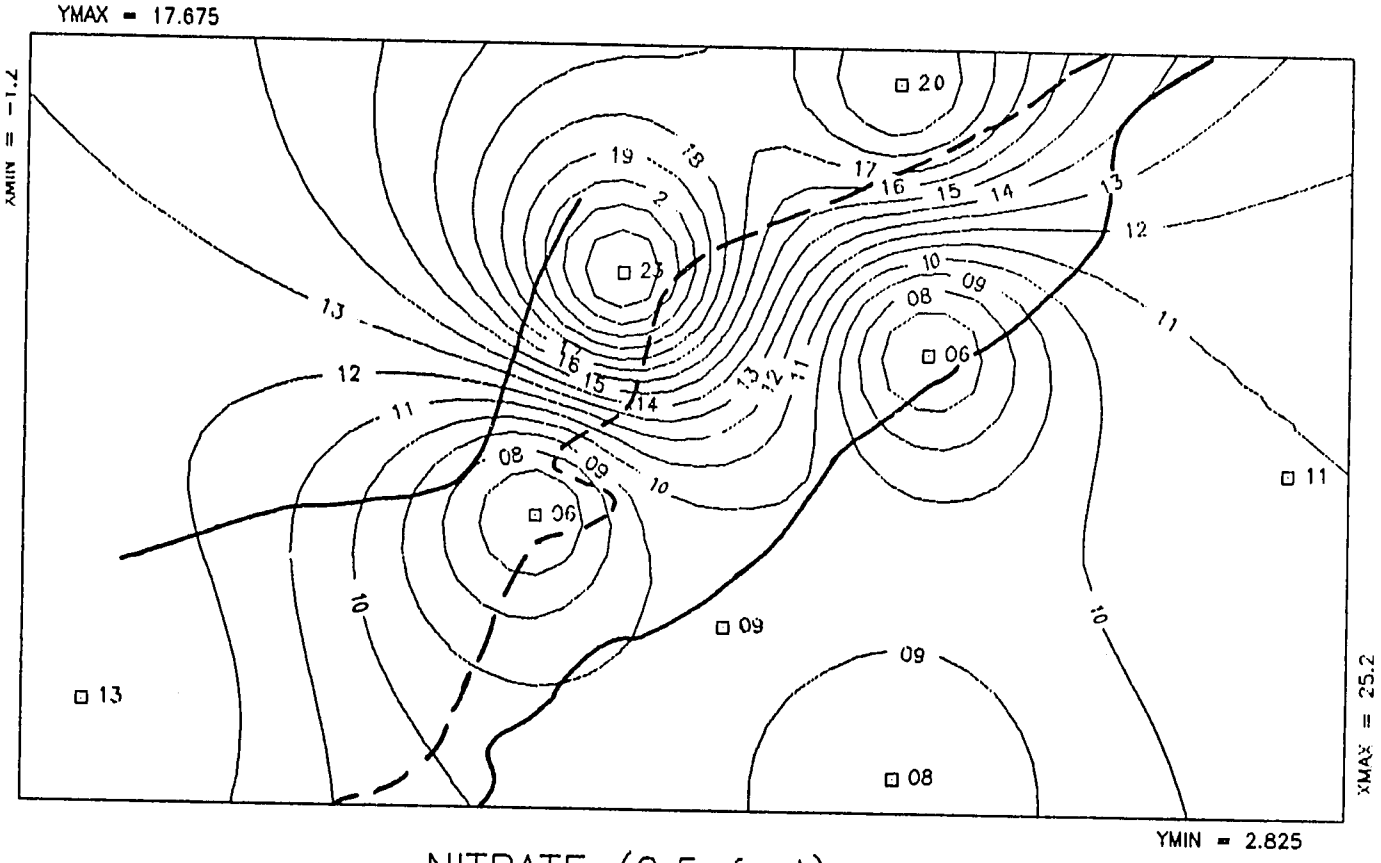
CHLORIDE DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



CHLORIDE (0.5 feet)

(ppm)

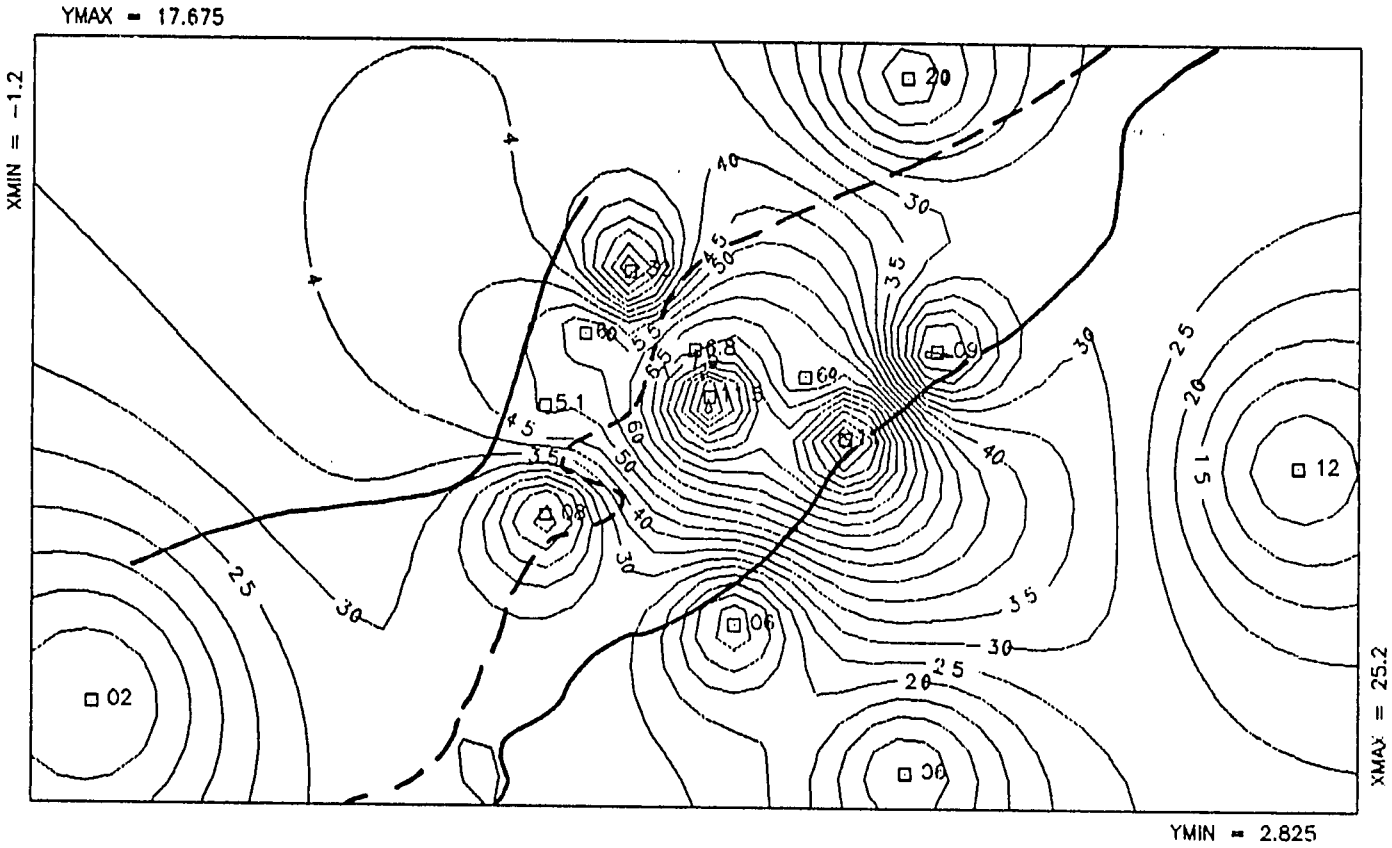
NITRATE DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



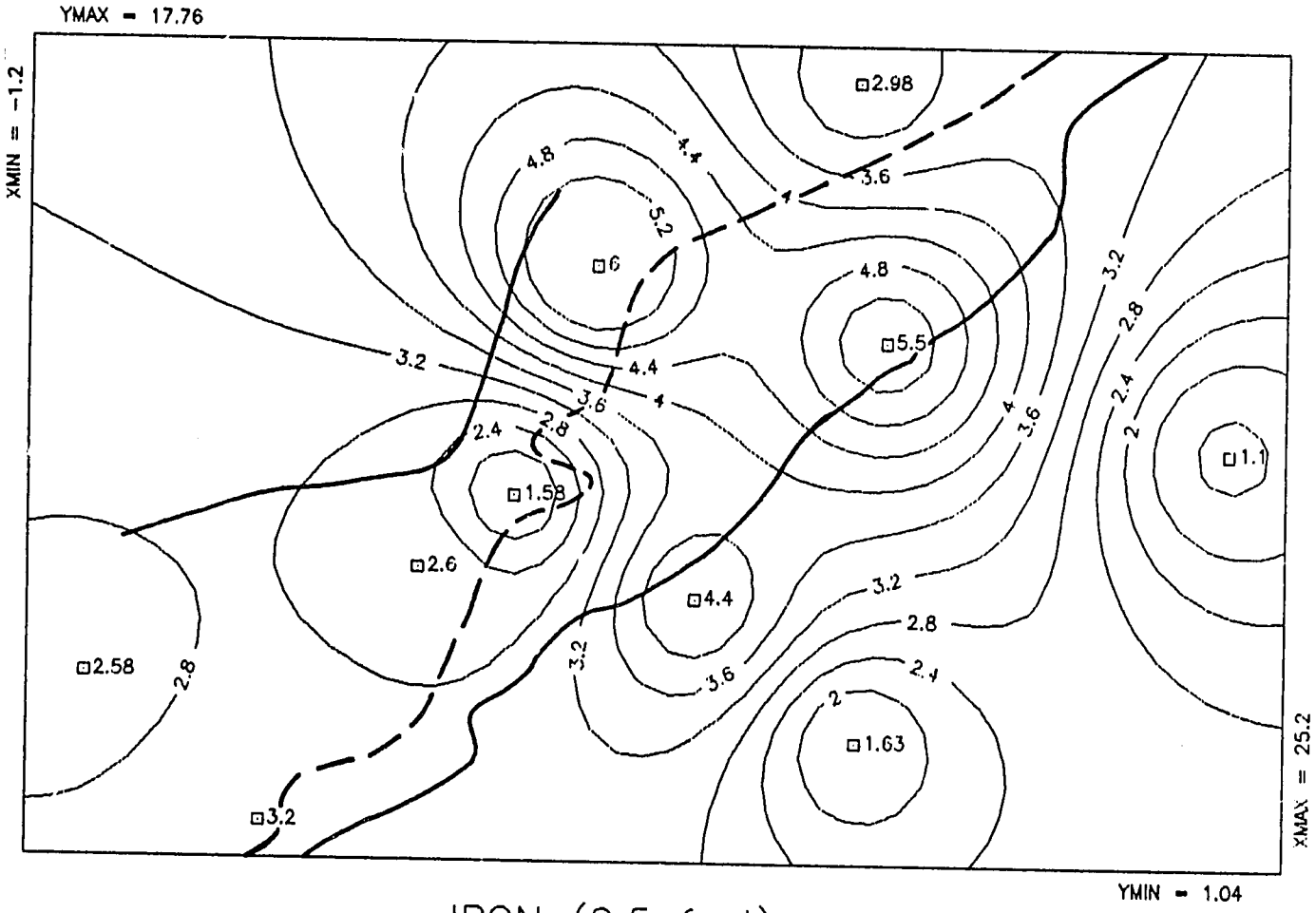
NITRATE (0.5 feet)

(ppm)

NITRATE DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD

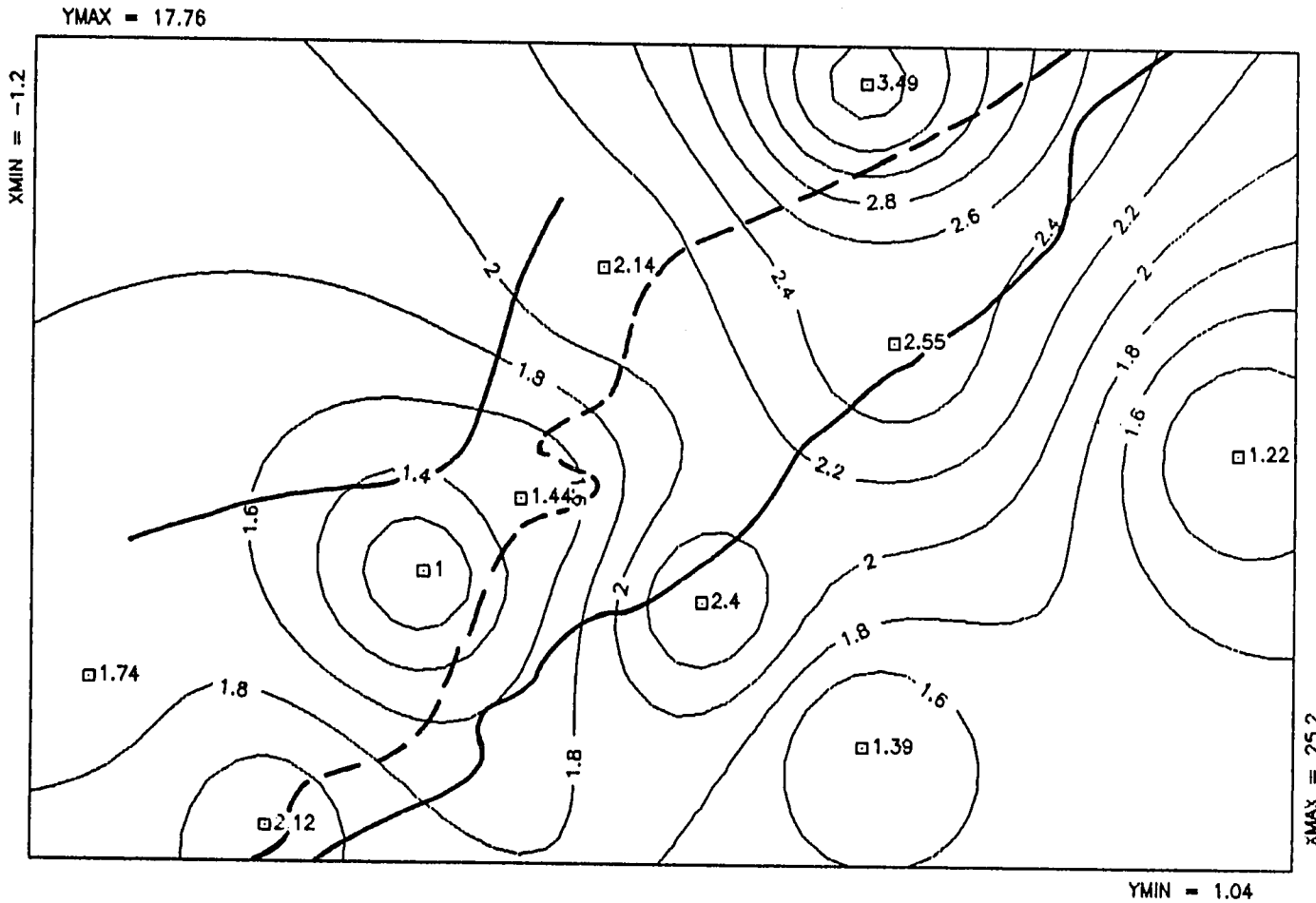


IRON DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



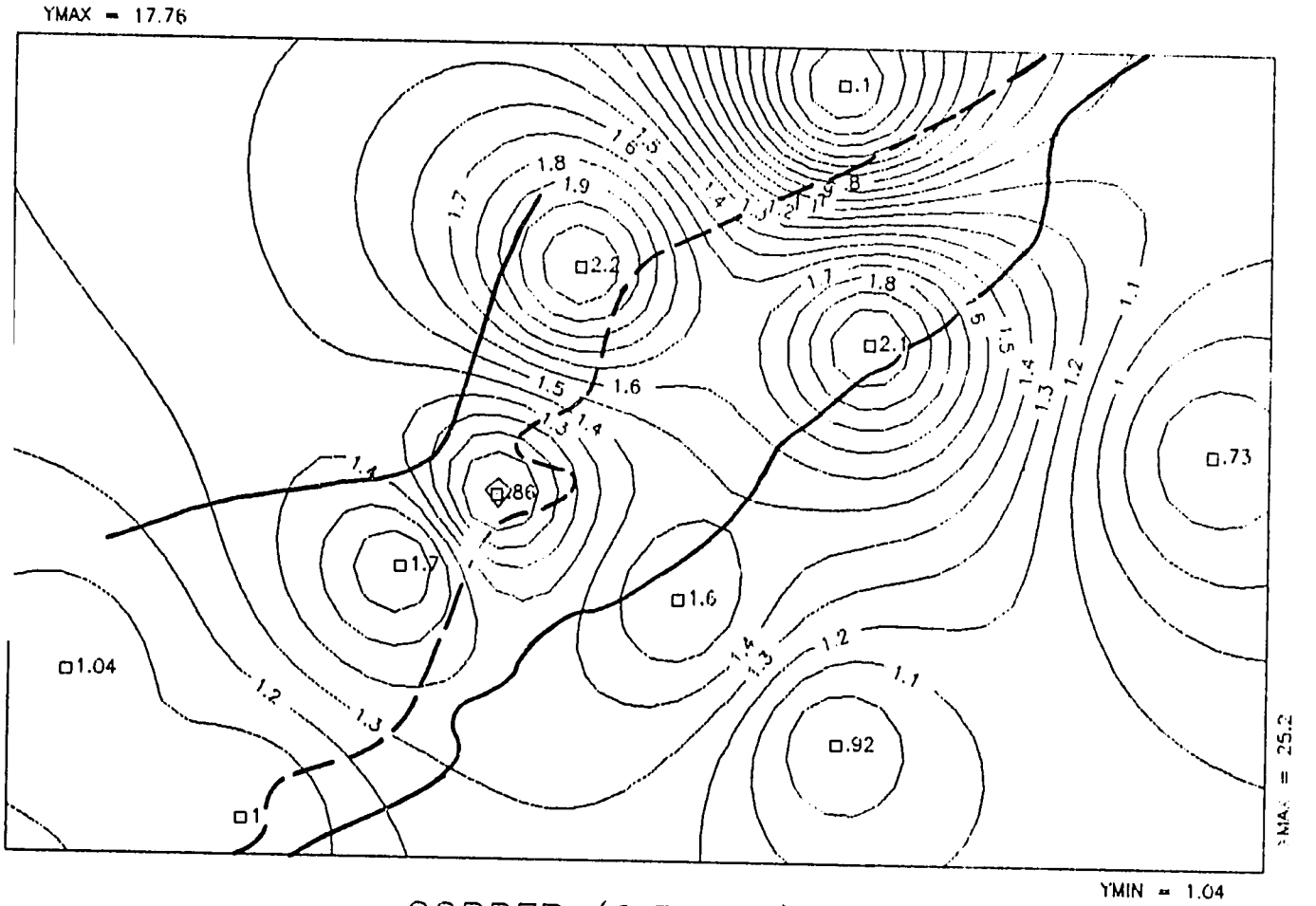
IRON (0.5 feet)
(ppm)

IRON DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



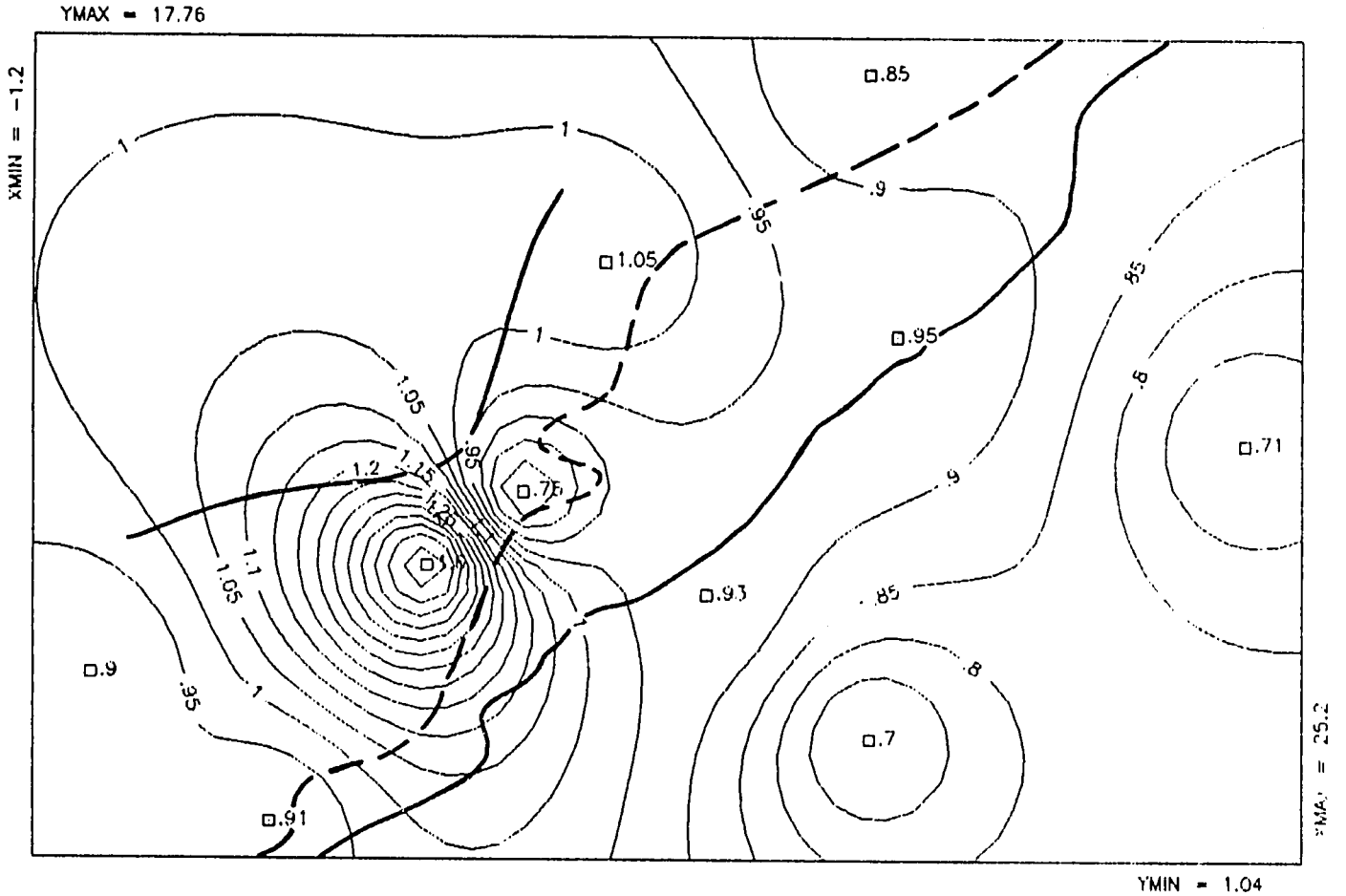
IRON (1.5 feet)
(ppm)

COPPER DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



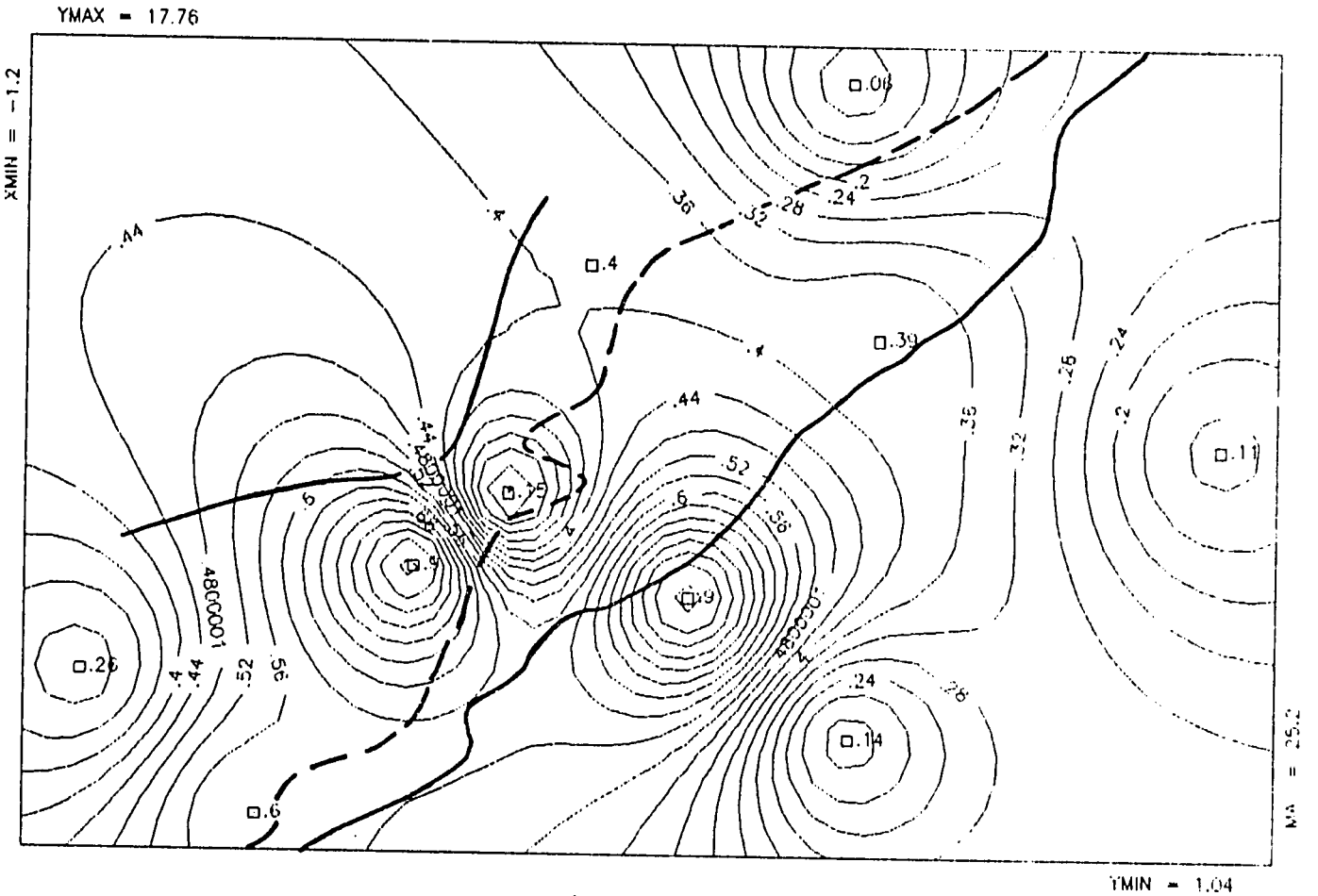
COPPER (0.5 feet)
(ppm)

COPPER DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



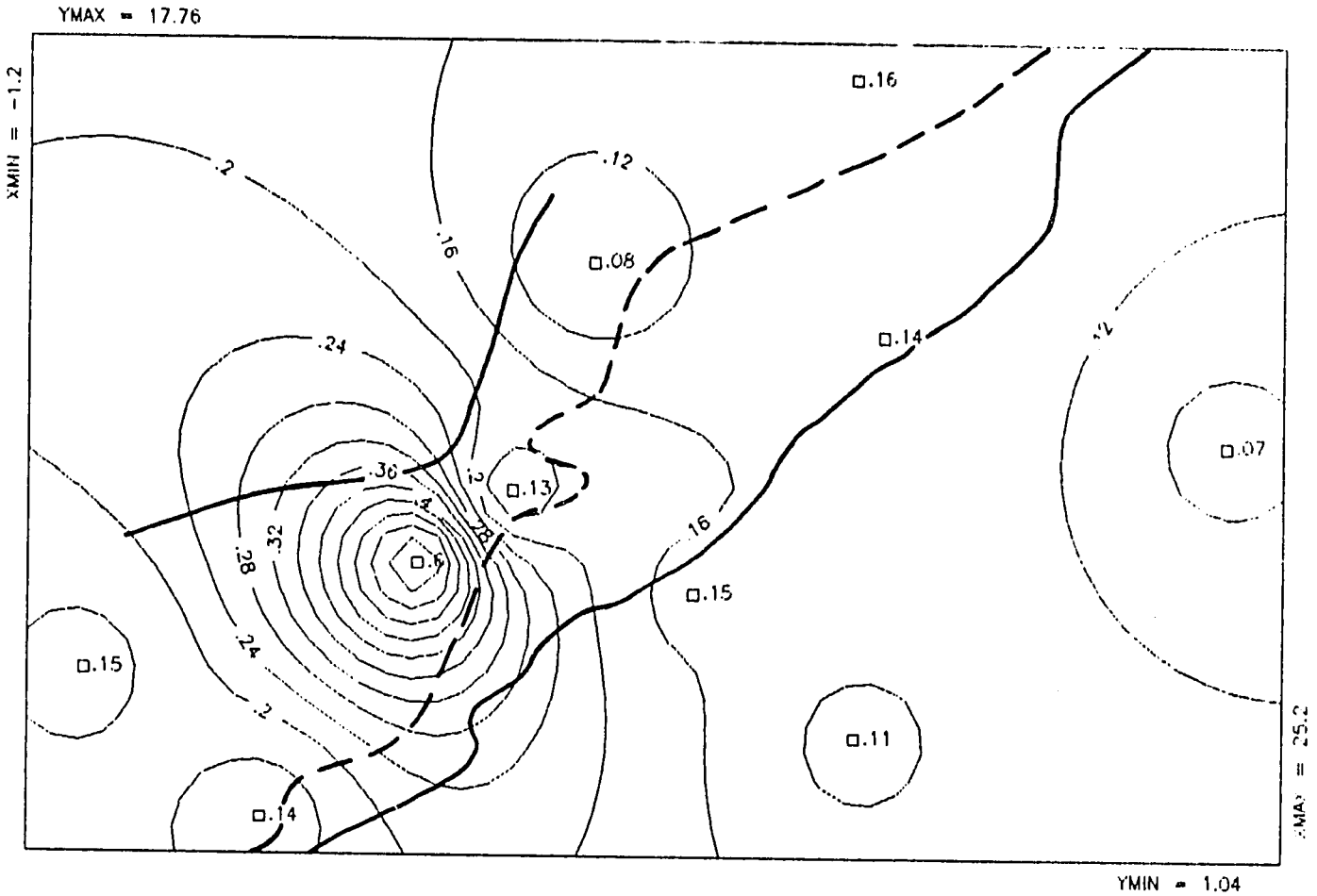
COPPER (1.5 feet)
(ppm)

ZINC DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



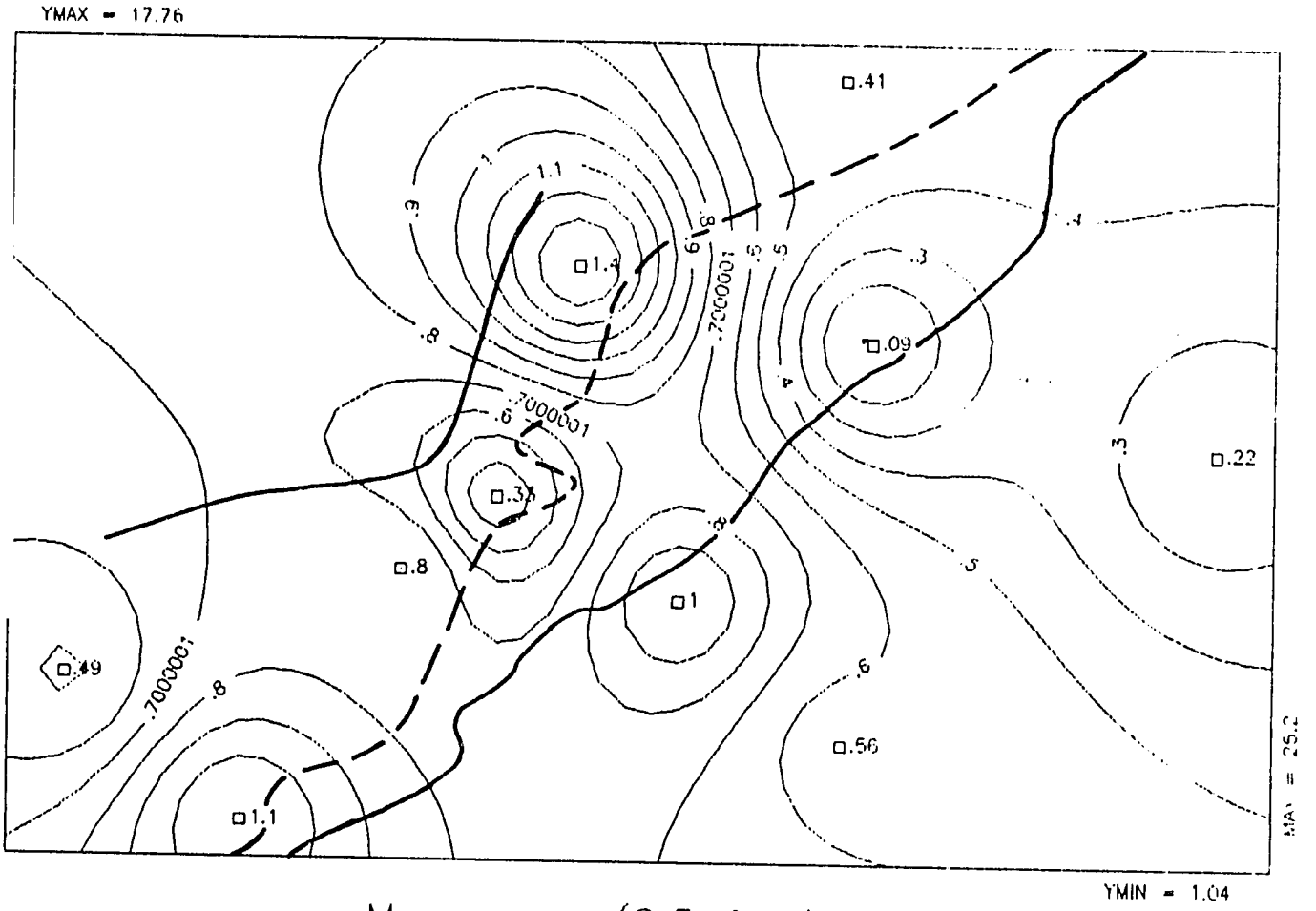
ZINC (0.5 feet)
(ppm)

ZINC DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



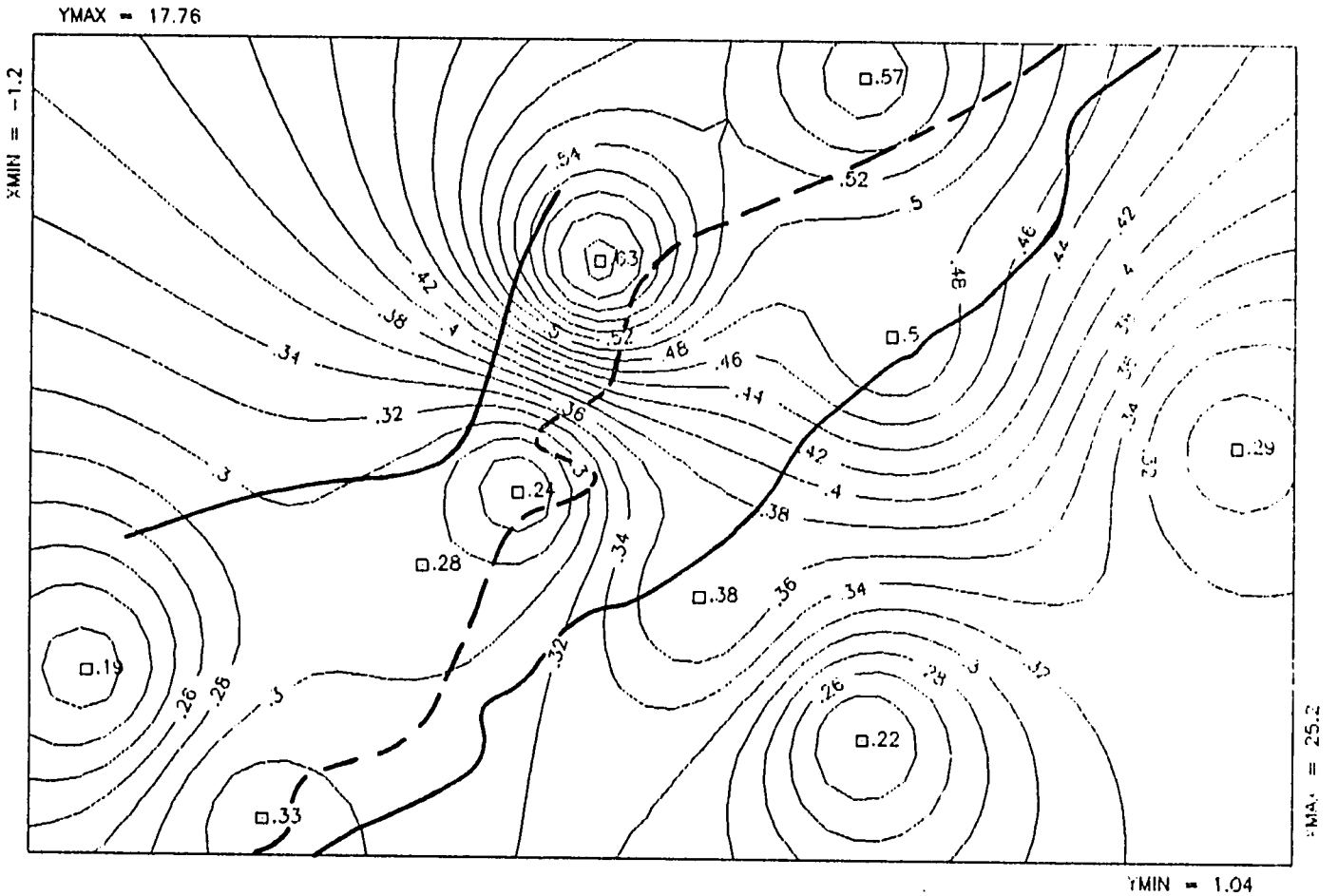
ZINC (1.5 FEET)
(ppm)

MANGANESE DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



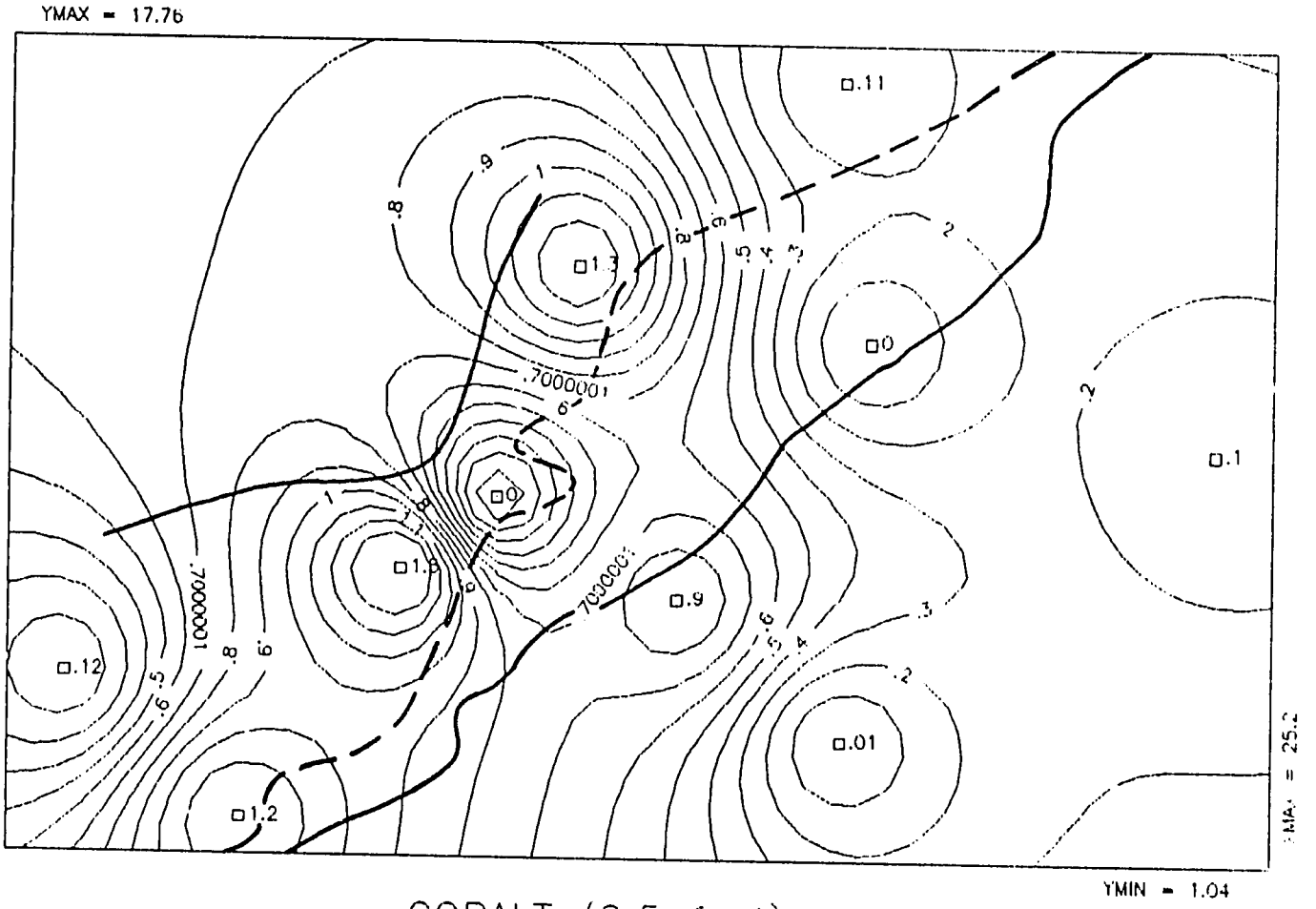
Manganese (0.5 feet)
(ppm)

MANGANESE DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



MANGANESE (1.5 feet)
(ppm)

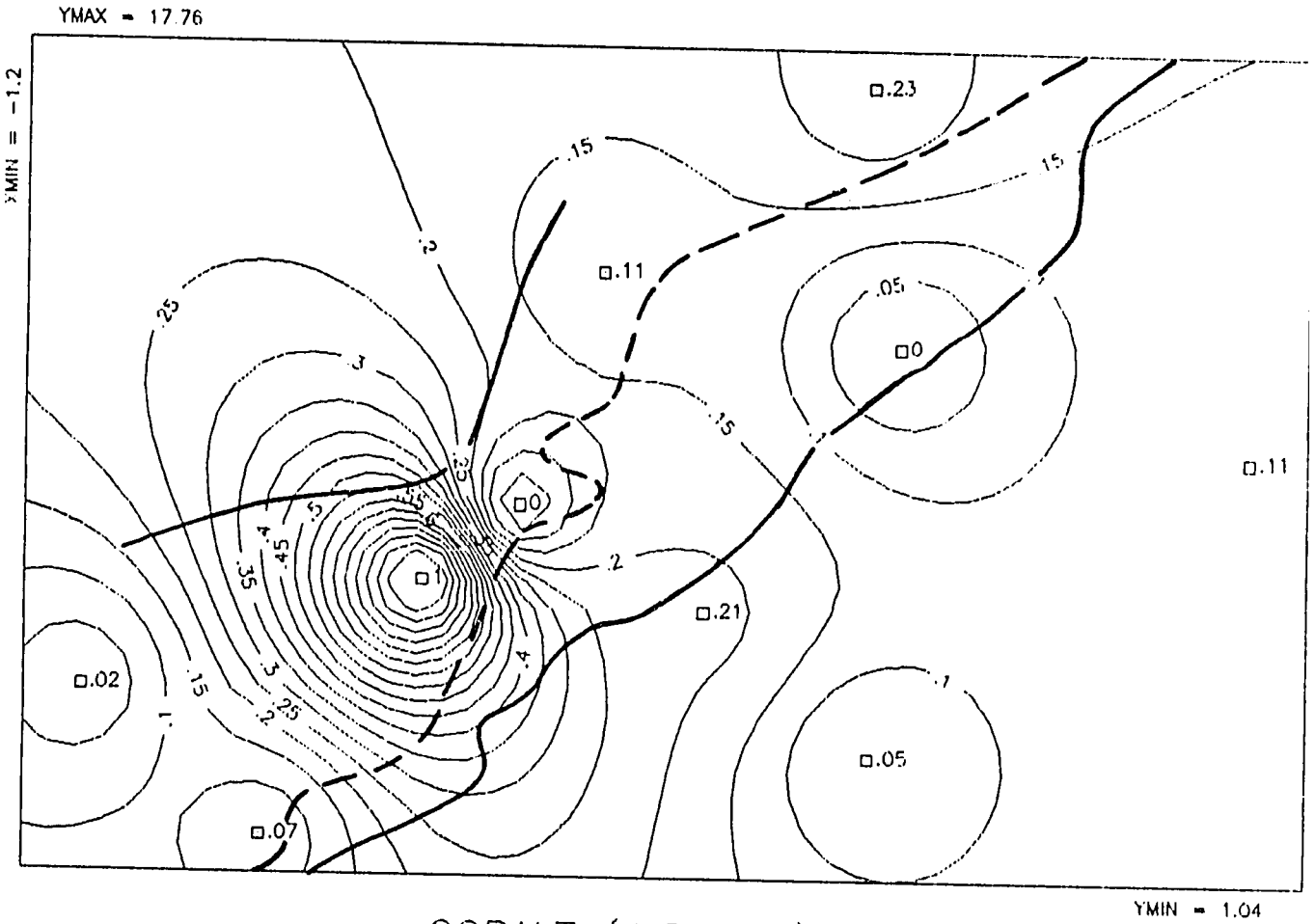
COBALT DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



COBALT (0.5 feet)

(ppm)

COBALT DISTRIBUTION IN THE TOP SOIL OF SAMUNDRI, FAISALABAD



COBALT (1.5 feet)
(ppm)