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GROUNDWATER QUALITY MODELLING IN NARGUND - NAVALGUND

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ABSTRACT

Groundwater quality scenarios of worst affected region of Nargund-Navalgund area of Malaprabha command, are simulated through a Three Dimensional Finite Difference code SWIFT III. Simulations were carried out for the steady state condition, which can be extended to other areas and also for transient condition subjected to generation of more and more informations; which was the most severe limitation felt during carrying out this study. It has been overcomc to possible extent through various field tests carried out at various locations. Encouraging increase in Groundwater abstraction in planned manner in the study domain shows overall improvement in the Quality of Groundwater. The study can be useful as a pilot study for delineating rural water supply resources and conjunctive-use strategies for Nargund-Navalgund area in Dharwar district under Malaprabha Command .

1.0 INTRODUCTION

1.1 Salinity of Irrigation and Drainage Water:

The salinity in irrigation water expressed in total dissolved solids ranges from a few tens of ppm in the case of runoff from mountain snows to several thousand ppm in some highly salinized rivers, groundwaters, and waste waters. The main factors that control the salt concentrations in water that drains from irrigated lands are (1) the salt concentration of the irrigation water, (2) the leaching fraction (LF, defined as the fraction of the irrigation water entering the soil that appears as drainage water), and (3) the loss of salts from the water to the soil or the gain from the soil. Small LF values can be obtained by careful irrigation to apply water uniformly and efficiently. Most successful irrigation projects have Lfs of 0.25 to 0.50 or higher because there are practical limitations to reducing Lfs , such as variations in plant response caused by soil heterogeneity, and the high costs of applying water uniformly.

In general, the salt concentration of the water leaching below the root zone is approximately two or four times greater than that of irrigation water. If the LF is greater than 0.5, the salt concentration in the drainage water will be less than twice that of the irrigation water. In less arid regions and in humid regions where supplemental irrigation is practiced, rainfall can produce high LFs, and the salt concentration in the drainage water can be much less than twice that of the irrigation water used. Data published by Carter et al. (1971) and Carter (1972) illustrate the practical situation in an area of 203, 000 acres of irrigated land in southern Idaho. Fifty percent of the water applied in irrigation and precipitation appeared as subsurface flow (groundwater), 14 % appeared as surface flow, and the remaining 36 % presumably was lost by evaporation from the soil and the plants. In this instance, the average ratio of salt concentration in the effluent water to that in the added water was 2.26.

In an experiment in a citrus orchard in southwestern Arizona(Hoffman et all 1984), a drip irrigation system gave an LF value of 0.2, and a flooding system gave an LF of 0.47. The drip-irrigation system used less water than the flood-irrigation system , and it added less total salt to the drainage water, but it added this salt in a relatively concentrated solution.

The dilemma of keeping excess salts out of waters that move downward beyond the root zone of crop plants or continuing to flush them out of the root zone to maintain a reasonably salt free growth medium cannot be resolved by any known technology (Haise and Viets, 1972). The severity of effects of irrigation on the salinity of groundwater ranges from no deleterious effects to severe degradation, depending upon many local conditions, such as the initial salinity of the groundwater, the salinity of the irrigation water, the LF, the amount of water used, and the rainfall.

The addition of salt to groundwater from irrigated lands can be reduced by careful water management to reduce the LF and precipitate more of the salts in the soil and /or reduce the dissolution of salts from the soil. The principal practical limitation of this approach is the cost of installing, maintaining, and operating the irrigation system required (Jensen, 1977).

Salinity of groundwater has no direct effect on the crops grown on the land above it as long as the groundwater remains in place, but it can have an important effect if it is pumped for use in irrigation. And the portion of the groundwater that reappears in streams as surface water may have an effect on crop production downstream if it is used again for irrigation.

1.2 Health Effects in Drinking Water:

Excessive salinity in drinking water is undesirable because of objectionable tastes and the laxative effect associated with sulfate. The U S Environmental Protection Agency(1976) recommended that concentration of chloride or sulfate should not exceed 250 ppm in domestic water supplies.

The National Academy of Sciences (1974) suggested that water having a total salinity of 3000 ppm or less should be satisfactory for livestock. Waters having total salinity of 3000 to 5000 ppm were aid to be satisfactory for livestock but not for poultry, especially turkeys. Dyer et al. (1974) noted that for livestock it is important to distinguish between the value of 3000 ppm set on a physiological basis by the National Academy of Sciences and a higher value that corresponds to a practical or economic limit. They stated that livestock tolerate drinking water with total salinity at least as great as 10000ppm, generally with no more apparent effects than mild diarrhoea. They pointed out that if the maximum permissible limit were to be set below 10000 ppm, some areas where livestock are now raised would be closed to this enterprise.

1.3 Effect of Water Movement:

Since transport by moving water is the principal mechanism by which dissolved chemicals are moved through the distances enquired to reach the groundwater, the amount of water movement through the unsaturated zone to the groundwater is an important determinant of the extent of groundwater contamination by the agricultural chemicals applied. Under, other wise equal conditions, the amount of downward movement increases with the amount of water applied by precipitation or irrigation.

The distance, dissolved chemicals can be transported by a given amount of water moving downward depends in part upon the capacity of the soil to hold water. For example, application of 1 inch of water at the surface may result in 5 to 10 inches of downward transport in a sand with a low capacity to retain water, but by only 2 to 3 inches in a clay with a much higher capacity to retain water.

Preferential flow paths, such as cracks, old root channels, animal burrows, and, on a grand scale, the large channels in limestone in karst areas, may promote rapid downward transport (Thomas and Philips, 1979; Beven and Germann, 1982; Hallberg and Hoyer, 1982; Hallberg et al., 1983). Preferential flow paths permit rapid and deep movement of a small part of the total amount of dissolved chemicals (Kissel et al., 1973).

1.4 Transport Through the Unsaturated Zone:

The unsaturated zone includes the soil at the surface and the underlying materials down to the water table. The soil is characterized by the presence of organic matter, the content of which typically decreases with depth. The proportion of the volume occupied by solids commonly is about 50 % and tends to increase some what with depth in soils with medium and vertically uniform texture.

Conversely, the proportion of the soil volume occupied by pore space commonly is greatest near the surface and decreases somewhat with increasing depth. Except for tillage effects at the surface, the total volume of pore space remains about the same with time. The proportion of water tends to increase and the proportion of air to decrease as the water table is approached, but the proportions vary greatly with time in the upper few feet of soil, depending upon additions and losses of water. Sometimes the pores at the surface are essentially filled with water while those beneath contain considerable air. This variability is the reason for using a broken line to portray the boundary between air and water.

Agricultural chemicals applied to soil may potentially occur in the soil air or the soil water, on the surface of the soil solids, or as discrete undissolved particles. Under normal circumstances, chemicals are transported to groundwater in solution and not as gases or as components of solid particles.

1.5 Transport Processes:

Dissolved chemicals move through soil by two mechanisms: (1) movement of water in which they are dissolved (known also as mass flow), and (2)diffusion, resulting from the random motion of the molecules and ions of the dissolved chemicals(Gardner, 1965). In practice, both mechanisms occur simultaneously, and movement of the water occurs at different rates through pores and channels of different sizes, so that the incoming water mixes to some extent with the existing water while displacement of the latter is occurring. The overall process is known as hydrodynamic dispersion (Bear, 1971; Biggar and Nielsen, 1976).

1.6 Effect of Adsorption on Transport

Certain chemicals in the soil water are attracted to the surfaces of clay minerals, organic matter, or both. These attractive interactions, which remove chemicals from solution and attach them to solid surfaces, are called adsorption. Adsorption decreases the rate of transport of chemicals because it reduces the amount in solution (van Genuchten and Wierenga, 1976).

Positively charged ions(cations), such as calcium, magnesium, potassium, ammonium and sodium are adsorbed by both clay minerals and organic matter. Clay and organic matter have the capacity to hold positively charged ions in forms that will exchange with other positively charged ions. Because of the chemical equivalence of the exchange, the positively charged ions added to soil may be adsorbed by the soil in exchangeable form, but other positively charged ions will emerge in the drainage water in chemically equivalent amounts.

Among the negatively charged ions(anions), nitrate and chloride are not adsorbed appreciably, The sulfate anion is adsorbed readily by clay particles in acid soils. The phospate anion is either adsorbed or precipitated from solution under nearly all conditions, and thus does not move freely(Ryden and Pratt, 1980).

Neutral non ionic organic compounds, such as many pesticides, are adsorbed primarily by soil organic matter(Green, 1974; weed and Weber, 1974). As a consequence, the transport of many pesticides to groundwater is restricted in soils having a high content of organic matter.

1.7 Degradation of Chemicals in Soil:

Dissolved organic chemicals, including pesticides, are broken down at different rates, and the breakdown reduces the downward transport of the original substances through the unsaturated zone to the groundwater. An index sometimes used to represent the rate at which this breakdown takes place is the time for 50 % within a few weeks or less usually disappear before reaching groundwater.

1.8 Measuring the Downward Movement Chemicals :

The downward movement of a chemical in the field generally is measured by applying a known amount of the chemical at the surface and then measuring at one or more later times the increase in the amount of the chemical found at different depths in all or part of the unsaturated zone. Alternatively, the downward movement may be represented more simply by the increase in the amount of the chemical below some arbitrary depth, such as the root zone. Because of the variability from one site to another, measurements at many locations are needed to obtain a good estimate of the downward movement in an area such as a field (Biggar and Nielsen, 1976; Van de Pol et al., 1977; Jury et al., 1982).

In humid climates, water tables generally are close to the land surface, and freely moving dissolved chemicals, such as nitrate salts, may move from the point of application to groundwater in a year or less (Saffigna and Keeney, 1977). Conversely, in arid climates groundwater tables are frequently tens or even hundreds of feet below the surface, and the residence time of agricultural chemicals in the unsaturated zone can be very long. Pratt et al. (1972) took deep soil cores below a number of commercial citrus groves and concluded that from 19 to 49 years were required for nitrate to move from surface to the 100-foot depth. These extremely long travel times are probably typical for irrigated fields in low rainfall areas when irrigation management provides water applications that are sufficient for plant and evaporation demands, but when little water passes through the root zone.

1.9 Movement of Fertilizer Constituents to Groundwater :

Historically, agricultural productivity depended almost entirely upon nutrients from soils and from wastes and crop residues. This system resulted in impoverished soils of low productivity and in human migrations to more fertile areas. As a result of the development of modern scientific concepts of plant nutrition and soil science, starting in the nineteenth century modern agriculture depends upon chemical fertilizers to supplement the natural supplies of nutrients.

The relatively high yields of today's crops remove more phosphorous, potassium, and particularly nitrogen than can be supplied by many soils without fertilizers. Some soils require additions of sulfur and other nutrients needed by plants in smaller quantities to maintain the crop yields. Fertilizers supplement the natural supplies of the inorganic salt constituents in soils that are required for plant growth. In most instances, the chemical forms added in fertilizers are the same as those naturally present in soils and absorbed by plants, but in some instances the forms added are transformed after addition to the forms naturally present in soils.

Plant absorb only part of each of the nutrients present in soluble forms in soils. As the concentration of the nutrients in the soil water increases, generally leading to greater total nutrients in the soil water increases, generally leading to greater total nutrient absorption and greater crop yields, the percentage of the total amount absorbed by the plants decreases. Thus, when fertilizers are added to supplement the supplies of particular nutrients that are deficient in soils, one result is greater residues of the nutrients in the soils. Part of the excess may be lost to the groundwater if it remains in solution.

Most of the chemical ions added in fertilizers are retained to some degree by soils as a result of chemical interactions, and this reduces their potential for loss to groundwater. Phosphorus is an extreme example. Two ions, however, nitrate and chloride, undergo virtually no chemical attachments to soils and are highly mobile in water. Fertilizers are not regarded as making an important contribution to the salinity of groundwater. For example, 200 to 1000 pounds of fertilizer might be added per acre in a year, but 2 feet of irrigation water containing salts at a concentration of 1000 ppm (a typical addition) would add 5400 pounds of salts per acre.

1.10 Objectives behind the present study

Groundwater pollution of command areas due to excessive use of fertilizers and pesticides is a major point of concern for Environmental Engineers and Scientists. Agricultural pollution through non-point source in Nargund-Navalgund area in Malaprabha command is being felt by the local habitant and raised by the concerned authority since long. Present study is to formulate a finite difference model in the region to simulate groundwater flow and contaminant transport which would analyse possible scenarios. Accordingly remedial measures would also be tested and suggested.

2.0 STUDY AREA

2.1 Location:

Nargund and Navalgund taluks in Malaprabha subbasin are located in Dharwad district in Karnataka. The area of the study is about 743 SQ. Km, surrounded by Malaprabha river in the north, Tupari nalla in the south, and Bennihalla on the East. Length of the Malaprabha river comes out to be about 30 kms. Western boundary of the study area is considered as outcrop boundary. The study zone lies between latitude 15^0 30` and 16 N and longitude 75^0 30' and 75 45'E. Location map is appended as Fig 1. Ground level contours are plotted in fig 2. Average surface gradient is 0.80 m/Km and in general West to East.

2.2 Soils:

Deep black to medium black soils constitute the important group of soils in the study area. These soils are derived mainly from the parent materials like gneiss, schists and traps. The texture of the soil is usually clayey and highly throughout the profile. At places, on surface, clay loam to silty clay texture is also common. Soils are highly retentive and fertile and are moderately well drained to imperfectly drained with very low permeability.

As per the work carried out by University of Agricultural Sciences, Dharwar during 1989-90, the moisture retained at 1/3 bar tension ranged from 41.74 to 50.50% and 22.38 to 28.24% at 15 bar tension, in these type of soils. Infiltration rate found out to be as low as 0.6 cm/hr. Some physical and chemical properties of this soil are enumerated in Annexure 1 & 2 of this report, which ensures that this soil series falls under clay. Coarse and fine sand content decreases with increase in depth whereas clay content, content of $CaCo_3$ and electrical conductivity showed increasing trend with depth. Accumulation of water soluble sodium in lower horizones(18.47 me/l) was observed(APR,1090).

Number of infiltration and permeability tests were conducted during 1995-96 in the study area using Double Ring Infiltrometer, Guelph permeameter and Disc Permeameter. Location wise results are depicted below in Table 1. Very high spatial variation is observed in the same series. Tensiometers were also installed to acknowledge the soil-water relation of this soil type but results were not found suitable even after monitoring for a full season 1995-96.

Table 1. **Results of Infiltration and Permeability tests carried out in the study area.**

S. No.	Location	Infiltration cm / hour	Permeability
1	Hulikatti	5.4	Very low
2	Belvatgi	3.0	2.9 mm/hr.
3	Alagwadi	3.3	3.5 mm/hr.
4	Konnur	4.8	very low
5	Nargund	6.0	6.5 mm/hr.
6	Kalvad	1.2	very low
7	Manoli	4.8	very low

2.3 Geology:

Geologically, the area comprises of schistose rock formations (Dharwar Super Group),which includes granites , gneisses and crystalline rocks. The lithological sequence of the study area shows that top 3m is composed of purely black soil, below that upto 30 m weathered granite and medium hard granites with fractures. There is no major fault or dykes controlling the ground water flow.

2.4 Hydrogeology:

Hydrogeological studies conducted by various state and Central departments reported that groundwater occur in all formations of the study area, however, the movement of the groundwater in these rocks is controlled by degree of weathering and presence of joints. There are very few Open wells existing in Nargund and Navalgund Taluks. They are in Jawor, Alagwadi, Shirkol, Shirur, Gobargumpi, Navalgund, Shalavadi, Kumargoppa, Morab, Talemorab in Navalgund and Surkod, Shirol, Chicknargund, Chikkoppa, Hirekoppa, Nargund, Madagunki, Konnur, Hadli, Lakmapur, Kopli, Kallapur, Wasan, Bellery in Nargund taluk. Most of these wells are on river/nalla banks and the depth ranges between 10mt to 20mt . Bore well extension data of the region reveals that at present only 242 nos.(Deptt.of M&G) of borewells are in use mainly for domestic water supply. Depth of these bore wells lies within 40mts and mostly are fully penetrating wells. Some of the Well Characteristics of the region is depicted below in Table 2.

Table 2. Well Characteristics of the region.

Village	Type of Well	Depth in metres	Size in metres	Average Water Level	Formation
Nargund	Dug	28.10	4.8 X 4	2.55	Granite Gneiss
Konnur	Dug	8.55	2.0X2.1	1.12	Quartzite
Hadli	Dug	11.00	2.4 Dia	0.81	Granite Gneiss
Mudagunki	Dug	19.00	2.55Dia	0.89	Granite Gneiss
Shirol	Dug	10.10	4.75Dia	0.57	Granite Gneiss
Lakhmapur	Dug		2.5 Dia	0.13	Granite Gneiss
Kopli	Dug	7.45	2.5 Dia	1.15	Granite Gneiss
Kallapur	Dug	8.55	2.55Dia	0.38	Granite Gneiss
Wasan	Dug	8.10	2.5 Dia	1.18	Granite Gneiss
Belleri	Dug	13.00	2.55Dia	0.45	Granite Gneiss
Navalgund	Dug	18.05	2.5 Dia	0.54	Granite Gneiss
Shelvadi	Dug	11.98	2.55Dia	0.53	Granite Gneiss
Kumargoppa	Dug	17.75	2.50Dia	2.19	Granite Gneiss
Sirkol	Dug	9.5	3.35Dia	1.15	Granite Gneiss
Alagwadi	Dug	13.4	4.40Dia	1.03	Granite Gneiss
Gobargumpi	Dug	11.40	3.05Dia	0.23	Granite Gneiss
Shirur	Dug	16.05	2.45Dia	0.78	Granite Gneiss

2.5 Agriculture practices :

The cropping pattern proposed in the project report is 40 % of the irrigated area for kharif, 20 % for biseason and 40 % for rabi crops. During Kharif, Maize, Bajra, Pulses, Sunflower, Jowar and Groundnut are grown. During, Rabi season Wheat, Jowar, Maize, Bengal gram, Sunflower and Safflower are commonly grown. Perennial crop like sugarcane is widely cultivated in the command area. Biseason crop like Cotton is also grown in the command area. Irrigation water requirement has shown increasing trend against a decreasing trend of water availability over last 10 to 15 years. On introduction of irrigation in command area the fertiliser consumption has also been increased. During 1990-91 the total fertiliser consumption was of the order of 7962, 6567 and 4348 tons of nitrogenous, phosphatic and potassic respectively.

2.6 Climate and Meteorology:

Rainfall is the one of the source of recharge to groundwater storage. Rainfall occurs due to SW monsoon from June to October. Average annual rainfall over the region has been estimated through Thiessen Polygon method considering the rainfall figures of 8 rainguage stations in and around the region. They are Ramdurg, Mudakavi, Bellary, Hulikatti, Morab, Nargund, Navalgund and Holeallur. Thiessen weightages are shown in Table 4 and annual average rainfall comes out to be 487 mm on the basis of 1978 to 1995 data . Annual average isohyetal map of the region is appended in Fig 3 .

Table 3. Mean monthly weather data as recorded at Water Management Research Centre, Belvatgi for the year 1989-90.

Month	Pan evaporation Total mm	Pan evaporation Per day mm	Temperature Maximum C	Temperature Minimum C	RH % Morning	RH % Evening
July	34.85	4.98	32.40	23.475	89	65.75
August	42.10	6.01	31.725	23.15	91	68
September	26.28	3.75	32.24	23.16	87	68.80
October	38.93	5.56	34.275	22.825	85	57.50
November	39.55	5.65	33.65	22.65	74	51.50
December	34.80	4.85	31.82	20.38	75.20	41.40
January	38.15	5.45	33.35	20.475	67.75	50.25
February	50.80	7.25	35.95	21.3	66.25	60.25
March	67.25	9.63	38.30	23.725	57.50	46.50
April	82.32	11.78	40.40	24.50	71.00	31.20
May	42.50	6.08	37.525	26.10	79.25	46.75
June	46.50	6.64	33.82	25.82	91.20	68.80

Table 4. Average Annual Rainfall

Year	Ramdurg	Mudakavi	Bellary	Hullikatti	Morab	Nargund	Navalgund	Holehalur	Average	Desrain
1978	572.5	450	550	350	521.8	629.3	559	556	577.995	680.81
1979	572.5	450	550	350	1869	732.7	889	451	680.813	624.56
1980	221.3	461.8	106.8	340	951	439.8	554	324	349.624	593.54
1981	572.5	356.4	662	350	672	528.7	694	479	573.887	581.11
1982	560	334	556.9	663.5	805	535.9	731	530	570.147	578
1983	615	326	453.7	409.3	611	491.1	548	440	491.933	573.89
1984	508	372	550	240.3	472.2	288	476.9	421	400.667	573.04
1985	338	341	550	201.2	587.3	353	359	238	396.952	570.15
1986	395	461.8	514	350	314.3	600	679.8	571.5	549.098	551.05
1987	572.5	356.4	508.1	375	738.9	579.2	560.5	593	551.053	549.1
1988	507.1	435.4	542	552.4	744.4	577.5	774.4	551.1	581.106	502.25
1989	401.5	528	570.1	423	860.1	480.2	450.1	311	493.462	493.46
1990	572.5	276	273.3	281	713.6	307.2	385.2	227	331.797	491.93
1991	797.5	514.2	613.1	350	854.2	545.1	737.3	385	593.537	429.13
1992	415.6	488.9	496	394	644.1	512.3	620.4	368.2	502.251	400.67
1993	632.9	422.2	597.3	545.4	771.6	550.3	553.5	568	573.045	396.95
1994	538	450	314.9	280.2	601	483.8	478.1	274	429.131	349.62
1995	738	450	661.1	274.9	580.8	651.3	553.9	481	624.556	331.8
THWEIT	0.08223	0.01419	0.2575	0.04099	0.02176	0.44456	0.09679	0.04198	1	487.95

2.7 Water Resources:

Habitants of the study area consume much of the surface water resources like canal water and small storages in village tanks in black cotton soils. These tanks are planned as per the population of the local village and mostly it serves the purpose of that village only for domestic purpose. Irrigation water requirement is mainly met by the Nargund branch canal which irrigates round about 26270 hectares of command area. Wells are existing only in patches where there is no surface water supply available or near the Malaprabha river and Benninalla banks.

2.8 Water Level Fluctuation

Monsoon prevails from June to October due to SW monsoon. Water Table contours for the premonsoon and postmonsoon for 1978-79 and 1980-81 are depicted in Fig 4(a) to 4(d). Monthly water level fluctuation at selected locations are depicted vide figure 5(a) and 5(b). Average seasonal water table fluctuation comes out to be 1.0887 m. on the basis of four years data from year 1978 to 1981. Results of the analysis of Pumping test data, carried out in two dug wells of the study area are given in Table 5, using Kumarswamy's method of analysis.

Table 5. Results of the pumping tests carried out in the study area.

Village	CS Area sq. mt.	Duration hrs.	Permeability m/hr.	Qmax cum/hr
Alagwadi	33.67	7	0.0366	0.163
Virakthmath	1.0	8	0.061	0.976

2.9 Groundwater Process:

Groundwater table contours for the year 1978-79 and 1980-81 shows that groundwater flows from west to east of the study area at an average gradient of 0.2153 m per km which is very low. There is scope of groundwater interaction between the study area and Bennihalla river which has shown maximum flow in the period between August to October and substantial discharge has been noticed after the month of October also. That is mainly because of the regenerated flow from command area.

2.10 Water Quality:

Overall groundwater quality of the region is poor. Almost all the chemical constituents either have crossed or on the verge of crossing its permissible limits in most of the locations. As per the data provided by Dept. of Mines & Geology in some places TDS value is as high as 9000 mg/l. Chloride, Sulphate, Bicarbonate and Sodium content in groundwater is alarming in almost all the places. Highest values noticed for various chemical constituents in various locations are enumerated in the table 6.

Table 6. Maximum Water Quality parameters :

(a). Cations

Location	Ca	Mg	Na	K	Fe	Al
Nargund	464	133.0	455	22	0.28	0.35
Hadli	225	43.0	N.A.	N.A.	1.15	0.80
Surkol	610	97.5	N.A.	N.A.	3.00	0.80
Konnur	450	220.0	786	52	0.05	0.03
Belleri	20	75.7	109	7	0.005	N.A.
Alagwadi	83	24.0	296	N.A.	0.14	0.00
Navalgund	88	71.0	859	N.A.	N.A.	N.A.
Nagnur	80	14.1	200	9	0.40	0.80
Belvatgi	35	57.5	250	15	1.00	N.A.
Jagapura	360	310.0	1600	70	0.00	0.04
Kanakikop	295	49.0	N.A.	N.A.	0.00	0.5

(b). Anions

Location	HCO3	CO3	NO3	SIO2	SO4	Cl
Nargund	412	190	43.37	72	496	1420
Hadli	510	90	2.65	20	205	1990
Surkol	200	50	0.70	10	120	3890
Konnur	552	48	33.00	95	790	1732
Belleri	N.A.	N.A.	44.00	N.A.	220	65
Alagwadi	182	40	28.00	30	50	515
Navalgund	542	58	25.00	N.A.	256	1250
Nagnur	140	N.A.	N.A.	N.A.	240	686
Belvatgi	N.A.	N.A.	45.00	N.A.	85	47.98
Jagapura	2900	140	0.70	100	875	2900
Kanakikop	275	N.A.	3.5	10	440	4000

3.0 PROBLEM DEFINITION

Pollution due to agricultural activities is probably the most difficult pollution to model because it is usually diffuse and governed by chemical and microbiological phenomena not well known or represented(Bogardi et.al.,1988). The problem becomes more complicated when dealing with swelling type of soil like black cotton soil, as classical concepts of groundwater hydrology, based as they are on the behaviour of nonswelling soils, fail in many important ways for swelling ones due to difference in equilibrium moisture profiles, distribution of hydraulic conductivity relative to the water table, effect of topography on moisture distribution, variation of specific yield with water-table elevation and stratum thickness, and the character of steady and unsteady vertical flows. It has also been found that for swelling soils, many aspects of the microhydrological processes of the irrigation cycle differ significantly from those of nonswelling soils: those affected include the dynamics of infiltration, the physics of water retention against drainage, and the general character of evaporation from bare soil(Philip,1972).

Generalisation of any mathematical model, therefore would be difficult preposition in such type of circumstances. Here our problem definition would strictly be confined to the periphery of simulating the model through a three-dimensional source code named, "SWIFT" and predicting some of the possible future scenarios based on that. Black cotton Soil strata will completely be eliminated, by appropriate adjustment to the top boundary condition of the subsequent layer, as subsurface hydraulics in those type of soils are governed by more of a drainage phenomena than ground water flow.

4.0 SWIFT Description: A Review

This Flow and Transport Model is a fully transient, three-dimensional model which solves the coupled equations for transport in geologic media. The processes included are : Fluid Flow, Heat transport, Dominant-species miscible displacement, Trace-species miscible displacement. The first three processes are coupled via fluid density and viscosity. Together they provide the velocity field on which the fourth process depends. The computer model described herein extends the capabilities of SWIFT(Reeves and Cranwell, 1981) to include fractured media.

Applications of Swift:

Because the SWIFT model is general, it has many possible applications. They include, but are not limited to, the following:

1. Nuclear waste isolation in both fractured and unfractured formations
2. Injection of industrial wastes into saline aquifers
3. Heat storage in aquifers
4. In-situ solution mining
5. Migration of contaminants from landfills
6. Disposal of municipal wastes
7. Salt-water intrusion in coastal regions
8. Brine disposal from petroleum-storage facilities
9. Brine disposal as a byproduct of methane production from geo-pressured aquifers
10. Determination of aquifer transport parameters from well-test data

Mathematical Implementation :

The SWIFT II model is designed to simulate flow and transport processes in both singly and doubly porous media. The analyst designates the fractured regions of the system to which dual porosity is to be applied. In those particular regions, two sets of equations are solved, one for the fracture processes and the other for the matrix processes. The fracture-porosity equations describing flow and transport for the fractured regions are identical to the singly-porosity equations for the nonfractured zone, except for sink terms giving the losses to the matrix. Consequently, one general set of equations which applies to both zones is presented, which will be called the global set of equations. The matrix-porosity equations for the fractured zone differ somewhat from their global counterparts. Therefore, a separate set of equations is presented which will be called the local set of equations. As was mentioned in the introduction, a variable-density formulation is used throughout. Density (and viscosity, porosity and enthalpy) is taken to depend relatively heavily on pressure, temperature and brine concentration, but not on radionuclide concentrations. For this reason, the flow, heat, and brine equations are termed the primary equations.

A steady-state solution option is provided for the global primary equations with two qualifications. First, it is assumed that heat-transport is basically a transient process. Certainly, this is true for high-level nuclear waste repositories, a dominant application for the code. Thus, heat transport, like radionuclide transport, is not included in the steady-state option. Secondly, it is assumed that matrix processes are negligible at steady-state. Consequently, the state equations for the matrix porosity are not solved for the steady-state option. Of course, the code will permit transient solution of radionuclide transport (with or without dual porosity) in conjunction with steady-state solution of the primary equations since this is perceived as a very desirable simulation procedure.

The Global Transient-state Equations for Flow:

The transport equations are obtained by combining the appropriate continuity and constitutive relations and have been presented by several authors, including Cooper(1966), Reddell and Sunada (1970), Bear(1979), and Aziz and Settari(2979). Sink terms are included for fractured zones in which losses to the rock matrix are significant. The resulting relation for flow may be stated as follows:

For Flow:

$$-\nabla.(\rho u) - q - q_W + R_C - \Gamma_W = \frac{\partial}{\partial t}(\varphi\rho)$$

convection | production | sink/source | salt dissolution | loss to matrix

For Transport:

$$-\nabla.(\rho C_r \underline{u}) + \nabla.(\rho E_C \nabla C) - Cq - C_q + R_C - (C\Gamma_W + C) = \frac{\partial}{\partial t}(\varphi\rho C)$$

convection | dispersion / diffusion | injected brine | produced brine | salt dissolution | loss to matrix

Several quantities in Equation require further definition in terms of the basic parameters. The tensors in above equation is defined as sums of dispersion and molecular terms:

$$\underline{\underline{E}}_C = \underline{D} + D_m I$$

where

$$D_{ij} = \alpha_T u \delta + (\alpha_L - \alpha_T) u_i u_j / u$$

in a Cartesian system.

Darcy flux:

$$u = -(k/\mu).(\nabla p - \frac{g}{g_c} \nabla z)$$

Porosity:

$$\varphi = \varphi_o [1+C_R (p-p_o)]$$

Fluid density:

$$\rho = \rho_o[1+C_W(p-p_o)- C_T(T-T_o)+ C_C C^\wedge]$$

Fluid viscosity:

$$\mu = \mu_R (C^\wedge)\exp[B(C^\wedge)(T^{-1}- T_R^{-1})]$$

Where parameter C_C is defined in terms of an input density range(ρ_I - ρ_N) and the reference density ρ_o:

$$C_C = (\rho_I - \rho_N)/ \rho_o$$

The Global Steady-state Equations for Flow:

In safety evaluations for nuclear-waste repositories, quite often the time frame of interest may extend over many thousands of years. Typically, the assumption of time-invariant flow and brine conditions is justified in such cases due to the lack of specific data for such a long period of time. For the fluid flow, the overall effect of transient rainfall boundary conditions may have a minor effect on radionuclide transport. Duguid and Reeves [1976] have shown this for a combined saturated-unsaturated simulation of tritium transport averaged over a period of only one month. Two steady-state options have been included. The first option permits solution of the time-independent flow equation:

Fluid (stead-state):

$$\underbrace{-\nabla .(\rho u)}_{\text{convection}} - \underbrace{q}_{\text{production}} - \underbrace{q_w}_{\text{sink/source}} + \underbrace{RC'}_{\text{salt dissolution}} = 0$$

In both options the accumulation and the matrix-loss term are set to zero. For the steady-state fluid-flow option, however, the salt dissolution term is also set to zero. The second option permits a coupled time-independent solution for fluid flow.

Transport (steady state):

$$-\nabla .(\rho C \underline{u}) + \nabla .(\rho E_C \nabla C) - C_I q - C_q + R_C = 0$$

convection; dispersion / diffusion; injected brine; produced brine; salt dissolution

In this case, in addition to a variable density and a variable viscosity , the salt dissolution term is generally non-zero.

Transport

$$-\nabla .(\rho C_r \underline{u}) + \nabla .(\rho' E_C \nabla C') - (C r + R) = \frac{\partial}{\partial t}(\varphi ' \rho ' C')$$

convection; dispersion/ diffusion; gain from fracture; accumulation

Both convection and dispersion terms are retained in the above Equations. These terms arise only through fluid-density changes and likely will be negligible except for highly presurized and /or highly heated regions. It is anticipated that either parallel fractures or intersecting sets of parallel fractures will be treated. A prismatic block is invoked in the numerical solution, and for the latter, either prismatic or spherical blocks may be used to approximate the actual matrix geometry. thus, either one-dimensional Cartesian or spherical blocks may be used to approximate the actual matrix geometry. Thus, either one-dimensional Cartesian or spherical geometry may be used for the local matrix equations. In either case, the interior boundary is assumed to be a reflective no-flow boundary. The fracture/matrix interface provides a source r' which is identical to the fracture loss r to within a geometrical scaling factor.

Many of the coefficients of above Equations require further specification. The coefficients of the second-order transport terms are defined as follows:

$$E'_C = D' + D'_m$$
$$D' = \alpha'_L u'$$

For the rock matrix, diffusion is expected to dominate the dispersion E'_C, in contrast to the dispersion E_C for the global simulation. Consequently, the dependence of diffusion upon temperature is expected to be much more significant and is included through the linear relation:

$$D'_m = D'_{mo} [1 + \delta ' (T' - T_o)]$$

Local Transient-state Equations for Flow Within the Rock Matrix:

The flow and transport processes occurring within the rock matrix are conceptualized as being one-dimensional in a lateral direction relative to the movement in the fractures. Thus, it is assumed that the fractures provide the only means for large-scale movements through the entire system while the matrix provides most of the storage of the system. The approach used here to treat the fracture matrix system is similar to that used by Bear and Braester[1972],Huyakorn et al.[1983], Pruess and Narasimhan [1982], Tank et al. [1981], Grisak and Pickens[1980], Streltsova-Adams[1978], and rasmuson et al.[1982].

Conservation equations used here for the matrix are very similar to those presented in Section for global transient equation. They are as follows:

$$-\nabla\cdot(\rho'\underline{u}') + r'_W = \frac{\partial}{\partial t}(\varphi'\rho')$$

conduction   gain from fracture   accumulation

It is anticipated that either parallel fractures or intersecting sets of parallel fractures will be treated. A Prismatic block is invoked in the numerical solution, and for the latter, either prismatic or spherical blocks may be used to approximate the actual matrix geometry. Thus, either one-dimensional Cartesian or spherical geometry may be used for the local matrix equations. In either case, he interior boundary is assumed to be a reflective no flow boundary. The fracture/matrix interface provides a source r' which is identical to the fracture loss r to within a geometrical scaling factor. The flow equation is coupled by following relations for

Darcy flux :

$$\underline{u}' = -(k'/\mu')\nabla p'$$

Porosity :

$$\varphi' = \varphi_o'[1+C_R'(p'-p_o)]$$

Fluid density:

$$\rho' = \rho_o[1+C_W'(p'-p_o)-C_T(T'-T_o)+C_C C']$$

Fluid viscosity:

$$\mu = \mu_R(C^{\wedge\prime})\exp[B(C^{\wedge\prime})((T')^{-1}-T_R^{-1})]$$

Parameter C_c is assumed to have negligible importance in determining Darcy velocities within the matrix.

5.0 MODEL FORMULATION

.1 Conceptualisation:

As part of the development of the numerical model a conceptual flow system model is postulated. The conceptual model provides a framework that describes the flow system geometry and the physical processes to be simulated by the numerical model. Physically the model comprised of 5 hydrostratigraphic formations, which in descending order from ground surface are:

i) black cotton soil
ii)kankar
iii)weathered granitic gneiss
iv)moderately weathered and fractured granitic gneiss
v) sound granitic gneiss bed rock.

Conceptualised flow domain is comprised of middle three layers only , whereas soil moisture condition in first and no flow condition in the fifth layer will act as top and bottom boundary conditions respectively. As depicted in the conceptual flow model, the thickness and lateral continuity of individual hydrostratigraphic layers does not vary much throughout the flow domain. Because the study area lies within the canal command area, undulation in ground surface is possible to limited extent only. Ground levels may change slightly during cropping season due to agricultural activities and swelling of wet black cotton soil layer. Due to various assumptions in conceptualising the flow system in the black cotton layer, it has been found more appropriate, to omit the top layer for the purpose of groundwater flow and contaminant transport simulation and treat it separately as a part of drainage problem elsewhere in future. Vertical recharge enters the first conceptualised layer of Kankar, as a surplus recharge, after deducting the quantity of water retained by the black soil layer from total recharge at the ground level. This is possible as water table normally remains below black soil layer and hardly there can be any horizontal flow in swelling type of soils(Smiles,1972).

Variable recharge to the flow system could have been allowed spatially as per Theissen weightages of the gauging stations and to the extent of difference between command and noncommand area but in the present study it became more uniform as the entire study area falls under the influence of the command area of Nargund only. System heterogeneity has also been restricted to vertically, layer to layer only.

5.2 Spatial Domain:

The Spatial Domain is descretized in 400 grids each of them having a dimension 640.25 ft X 302.5 ft. in each layer. Vertically three layers are considered as per the litholog at the location Alagwadi i.e. Kankar, Weathered Granitic Gneiss and moderately weathered and fractured granitic gneiss having uniform thickness of 50 ft., 30 ft. and 85 ft. respectively. Though the area is being controlled by canals and tanks but this has not been considered looking to the fact that these are mostly confined to black cotton soil layer only. All the 400 blocks are considered as active blocks in each layer as shown in figure 6.

5.3 Boundary Conditions:

The study area is a small part of the Nargund-Navalgund Command area which is hydrologically bounded by rivers and nallas in three sides and by outcrop boundary on one side. Constant head boundary conditions are evaluated by Kriging of the available water table data. Corresponding water levels in Malaprbha river, Bennihalla and Tuprinalla are also considered for this purpose. Top boundary has been simulated through recharge through rainfall and irrigation return flow and the bottom is bounded by an impervious layer. Boundary conditions for two seasons i.e., 1978-79 and 1980-81 are shown in Table 6.

5.3.1 Recharge Rate Estimation:

Infiltration of seasonal precipitation and the irrigation return flows are considered as the source for groundwater recharge. Top layer of the conceptualised model would receive the excess water that would percolate after satisfying the moisture retention capacity of the black cotton soil cover. Average rainfall over the Nargund - Navalgund area is estimated through Theissen polygon of the entire Nargund-Navalgund command area as shown in fig 7. Recharge rate for the year 1978-79 and 1980-81 comes out to be 0.009 and 0.0064 ft/day respectively. It includes rainfall recharge at Nargund station and irrigation returns from the command area.

5.3.2 Well production & Well Index Calculation:

Groundwater utilisation is remarkably less as compared to village tanks and canals. Therefore well production is considered as zero for calibration purpose and well index is calculated by following expression(Ward,1986):

$$WI_o = 2\pi \; K_s \sum_{k} \Delta z_k / \ln(r_1/r_w)$$

TABLE 7. BOUNDARY PRESSURES AT SELECTED BLOCKS.

Blk No.	FLPR78	FLPO78	FLPR80	FLPO80	SLPR78	SLPO78	SLPR80	SLPO80	TLPR78	TLPO78	TLPR80	TLPO80
1	1.663339	24.59467	10.61978	12.24047	18.99334	41.92467	27.94978	29.57047	43.91499	66.84633	52.87143	54.49212
5	2.672716	29.48517	14.6715	16.27798	20.00272	46.81517	32.00151	33.60798	44.92437	71.73683	56.92316	58.52963
10	2.260435	27.56594	14.21657	15.95099	19.59044	44.89594	31.54658	33.281	44.51209	69.81759	56.46823	58.20265
15	3.795825	26.85511	15.4392	17.21627	21.12583	44.18511	32.7692	34.54627	46.04748	69.10676	57.69085	59.46792
20	-2.08984	17.34422	8.956441	10.73351	15.24017	34.67422	26.28644	28.06352	40.16182	59.59587	51.2081	52.98517
81	0.369631	16.12159	4.250755	5.615546	17.69963	33.4516	21.58076	22.94555	42.62129	58.37325	46.50241	47.8672
100	2.047187	11.20266	6.937688	8.444644	19.37719	28.53266	24.26769	25.77465	44.29884	53.45431	49.18934	50.6963
181	-0.6824	5.075317	-2.53055	-1.47852	16.64761	22.40532	14.79945	15.85148	41.56926	47.32697	39.7211	40.77313
200	-12.0272	-1.8908	-1.73442	-0.46915	5.302782	15.4392	15.59558	16.86086	30.22443	40.36085	40.51723	41.78251
281	-7.57743	-5.71506	-7.50635	-6.65336	9.752569	11.61494	9.823652	10.67665	34.67422	36.53659	34.7453	35.5983
300	-0.5971	-3.42619	0.582879	1.677556	16.73291	13.90381	17.91288	19.00756	41.65456	38.82546	42.83453	43.92921
381	-6.9519	-10.5345	-8.70054	-8.07501	10.3781	6.795522	8.62946	9.254989	35.29975	31.71717	33.55111	34.17664
385	-7.02299	-11.9419	-9.05596	-8.40199	10.30702	5.388081	8.274045	8.928008	35.22867	30.30973	33.1957	33.84966
390	-2.00454	-14.3872	-9.80944	-9.09861	15.32547	2.942831	7.520567	8.231396	40.24712	27.86448	32.44222	33.15305
395	-3.45463	-17.4295	-10.8615	-10.0369	13.87538	-0.09952	6.468541	7.293102	38.79703	24.82214	31.39019	32.21475
400	-5.23169	-14.4156	-6.25529	-5.2317	12.0983	2.914397	11.07471	12.0983	37.01996	27.83605	35.99636	37.01996

FL : FIRST LAYER SL : SECOND LAYER TL : THIRD LAYER PR : PRE-MONSOON PO : POST-MONSOON

where K_s is the hydraulic conductivity of the skin and where index k ranges over all layers in which the well is completed. For Cartesian coordinates, radius r_1 is not defined directly, but may be specified in terms of the radius

$$\bar{r} = (\Delta x \ \Delta y / \pi)^{1/2}$$

Mathematically, the relation between the skin radius and the average block radius is given by

$$\ln(r_1/r_w) = r_w \{1 + (\bar{r}/r_w)[\ln(\bar{r}/r_w) - 1]\} / (\bar{r}-r_w)$$

In the present case: x = 640.25 ft.

y = 302.50 ft.

K_s = 2.882 ft/day(Pump test at Alagwadi)

$\Delta z_1, \Delta z_2, \Delta z_3$ = 50,30,85 fts.

r_w = 6.562 ft.

Further calculation yields: r = 248.2919 ft.

$\ln(r_1/r_w) = 2.73194$

WI_o = 331.248 ft^2/day for well in 1st layer

= 1093.095 ft^2/day for fully penetrating well

5.4 Hydraulic Conductivity:

Hydraulic conductivities and porosities for different layers and heterogenities are specified below as a first approximation and later would be finalised through calibration.

S. No.	Heterogeneity	Conductivity in m/sec	Porosity
1	Kankar	$3.0x10^{-4}$ to $3.0x10^{-2}$	0.35
2	Weathered Gr.Gn	$3.3x10^{-6}$ to $5.2x10^{-5}$	0.45
3	Moderately Weathered fractured Gr.Gn	$8.0x10^{-9}$ to $3.0x10^{-4}$	0.01

(after Domenico et. al.,1990)

5.5 Modelling Assumptions:

Conceptualisation of any mathematical model requires certain assumptions to be adhered. In present study following assumptions are implemented.

(1) Flow and Transport is under Unconfined steady state condition.

(2) Only layerwise heterogeneity is entertained.

(3) Darcy,s law is valid and as such there is no influence of layer gradients on the flow system.

(4) Velocity calculations are for fully saturated condition and thus approximated for partially saturated blocks.

(5) Following values are assumed for various parameters:

Water Compressibility--------------- 3.00E-09 (1/PSI)
Solid Matrix Compressibility------ 2.20E-09 (1/PSI)
Longitudinal Dispersivity Factor---- 100.00 (FT)
Transverse Dispersivity Factor------ 10.00 (FT)
Effective Molecular Diffusion------- 9.30E-05 (SQ.FT./DAY)
Constant Fluid Density-------------- 62.40 (LB/CU.FT.)
Constant Temperature------- --------- 68.00 (DEG.F)
Constant Viscosity------------------- 1.0 (CP)

(6) Two-line successive-over relaxasation(L2SOR) solution with a backward finite difference approximation in time is sought.

6.0 RESULTS AND DISCUSSIONS

6.1 Groundwater Flow Simulation:

6.1.1 Calibration:

The numerical model was calibrated through an interactive trial and error process. The objective of which was to simulate observed hydraulic head distribution with in the flow system. As a part of this calibration process numerous realizations were performed in which selected physical flow system parameters were systematically altered within realistic ranges.

Observed values were obtained by kriging of the macroscopic level data at various locations using USEPA. Kriging model "GEOPACK". In all 25 nos. of kriged values were available for the local grid system, out of which 16 were used for delineating the boundary conditions and nine inner nodes were selected for simulation purposes. Calibration efforts were focused on the first layer as mostly the water table fluctuates with in that layer.

Comparison of the predicted and observed heads involved minimizing the absolute mean residual as determined by

$$X = n^{-1} \left| H_{obs} - H_{est} \right|$$

Calibration was carried out using the data of year 1980-81. A plot of the absolute head residual as a function of first layer hydraulic conductivity is shown in Figure 8. The minimum value was obtained for a hydraulic conductivity of 885ft/day. The mean and standard deviation for the head residual were 3.52 ft and 0.00663 ft respectively. The potentiometric surface for the first layer for the calibrated care is shown in fig. 9.

A scatter plot of the observed and predicted heads for the calibrated flow model is depicted in fig. 10. In general correlation between estimated and observed heads appears acceptable, as coefficient of correlation comes out to be 0.917, but it is based upon less no. of sample points. There are few points which fall below/above the correlation line, but is acceptable as the observed heads are recorded manually and as such uncertainty would be involved in it as would be with various other parameters and lithologs used for the simulation.

6.1.2 Validation:

The calibrated model was validated for the year 1978-79 for steady state conditions. Only recharge values and boundary conditions are modified in the input data and all other parameters are as per the calibrated model. Head distributions are shown in the fig 11. Table 8 showing the values of observed and computed heads at various nodes well spread over the study mesh. Absolute mean residual comes out to be 4.1 . Which again is acceptable looking to the various uncertainties involved.

Table 8. Model Validation results for season 1978-79.

S. No.	Node No.	Observed (ft)	Predicted (ft)
1	85	17.13	15.774
2	90	16.25	15.163
3	95	14.44	14.093
4	185	5.29	7.39
5	190	3.11	7.35
6	195	-2.60	6.23
7	285	-12.0	-0.16
8	290	-3.41	0.28
9	295	-3.72	-0.28

6.2 Contaminant Transport:

Calibrated flow domain of year 1980 was simulated for steady state contaminant transport for non-reactive and non decaying condition. Chloride plumes were simulated on the basis of specified concentration at the 16 boundary points calculated on the basis of linear interpolation of four well point data at Kanakikop, Nargund, Naganur and Alagwadi. Monitoring well is considered at Jagapur. Mostly the dug wells of the region are partially penetrating and limited to first layer only, therefore, concentration fraction is simulated for the 1st layer with trial and error basis. Calibrated longitudinal dispersivity and transverse dispersivity values comes out to be 150 ft and 15 ft respectively. Absolute error in the monitoring point at Jagapur comes out to be 9.0×10^{-6} mass fraction. Chloride contaminant plumes are shown in Fig. 12.

Possible scenarios have been conceptualised on the calibrated model. It has been argued in general by the concerned that non-consumptive use of surface and ground water may be a reason for deterioration of groundwater quality. Same aspect has been studied here to certain extent, only for academic and model utility point of view. Well productions were simulated on the practical data available assuming some hypothetical background and same is summarised in Table 9.

Table 9. Comparative Concentrations in various scenarios.

S. No.	Scenario Details	Comparative Concentration Index 85 90 95 190 285 290 295
1	No Well Production	2.09 2.90 3.84 2.93 2.72 3.05 3.12
2	10% Irrigation requirement by well (a)Production from one well at C.G. (b)Production from 5 wells at block nos. 85,95,190,285 & 295	 2.09 2.91 3.84 2.94 2.73 3.08 3.11 2.29 2.97 3.84 2.93 2.72 3.05 3.12
3	20% Irrigation requirement by well (a)Production from one well at C.G. (b)Production from 5 wells at block nos. 85,95,190,285 & 295	 2.28 2.97 3.85 3.10 2.79 3.19 2.83 2.09 2.91 3.84 2.93 2.72 3.06 3.12

Comparative concentration index is the value, 1000 times the mass fraction concentration value. There is no appreciable changes in the flow patterns resulted in the above simulations. Hence only the concentration values are depicted here at well spread locations over the study area for the purpose of comparison.

It is evident from the results that certainly conjunctive use of Surface and Ground Water would help in remediating the quality of Groundwater but pumping wells have to be situated well spread over the region rather concentrated at few locations. More precise design of well locations and production rates can be simulated as and when required on the calibrated model. Ground Water abstraction for irrigation may be increased beyond 20 % of local irrigation requirement. Naganur corner of the mesh is more succesptible towards contamination and well pumping.

7.0 SUMMARY AND CONCLUSIONS

Three dimensional finite difference model is formulated for Nargund-Navalgund region of Malaprabha command area which can be utilised for groundwater quality assessment and remediation. The model has been formulated for the most worst affected area that is a rectangular grid of 7.2 sq. km. area bounded by the locations like, Kanakikop, Nargund, Naganur and Alagwadi. Regional Hydrological basin has been considered as an areal extent of 743 sq. km. bounded by rivers at three sides and outcrop boundary at one side.

Groundwater Quality being the aspect of the study it has been preferred to model it locally rather than regionally and as such location considered is the worst affected. Non-point source being the reason behind the contamination and these types of sources differs largely location to location in terms of both quantity and quality, it is justified to attempt mathematical modelling in smaller scale as far as possible and required. Present study deals with the non-reactive pollutant "Chloride" which is the major contaminant constituent of that locality. Other contaminants like Nitrate, Bicarbonate, Sulphate and Sodium can also be tried out on the same model as per the necessity in future. In more broad sense all the application of SWIFT III mentioned in Chapter 4 of this report can be tried out on the model subjected to the data and types of problem available on hand.

Data availability is the major limitation felt during the study as no study has been entrusted over the region in past. Therefore to minimise data uncertainty, various test like Infiltration tests, Permeability tests and Pumping and Recovery Tests were carried out at various locations. Even then nothing could be attempted temporal basis due to lack of proper periodical quality data. Transient conditions can also be attempted as and when enough data is available in future.

Conjunctive use of Surface and ground water is certainly a better prospect available for remedial of ground water quality. Limitted trails in the present report have depicted encouraging results. Wells have to be well spread over the region rather than concentrated at few locations. Design of well locations and its production rates can be simulated on the present model in future.

8.0 RECOMMENDATIONS

The objective of the present study was to generate a finite differences model for Nargund and Navalgund area. Apart from fulfilling that objective following points are recommended.

(i) Detail Drainage Study of Black Cotton Soil layer has to be carried out which would act as a main input for conceptual model.

(ii) Annexure 1 and 2 of this report shows the Physical and Chemical characteristics of vertical soil columns. Like wise Water Quality data of the region at different elevations and formation has to be generated, which would help us to decide the well-depth at various locations and vertical contaminant transport process.

(iii) Valuable data has to be generated for simulating transient conditions so as to predict future scenarios.

(iv) Soil reclamation study and limited fertilizer use may immediately be taken up.

(v) Conjunctive Use of Surface and Ground Water is recommended. Possibility may be explored in terms of using Groundwater for other household purposes if not useful for drinking.

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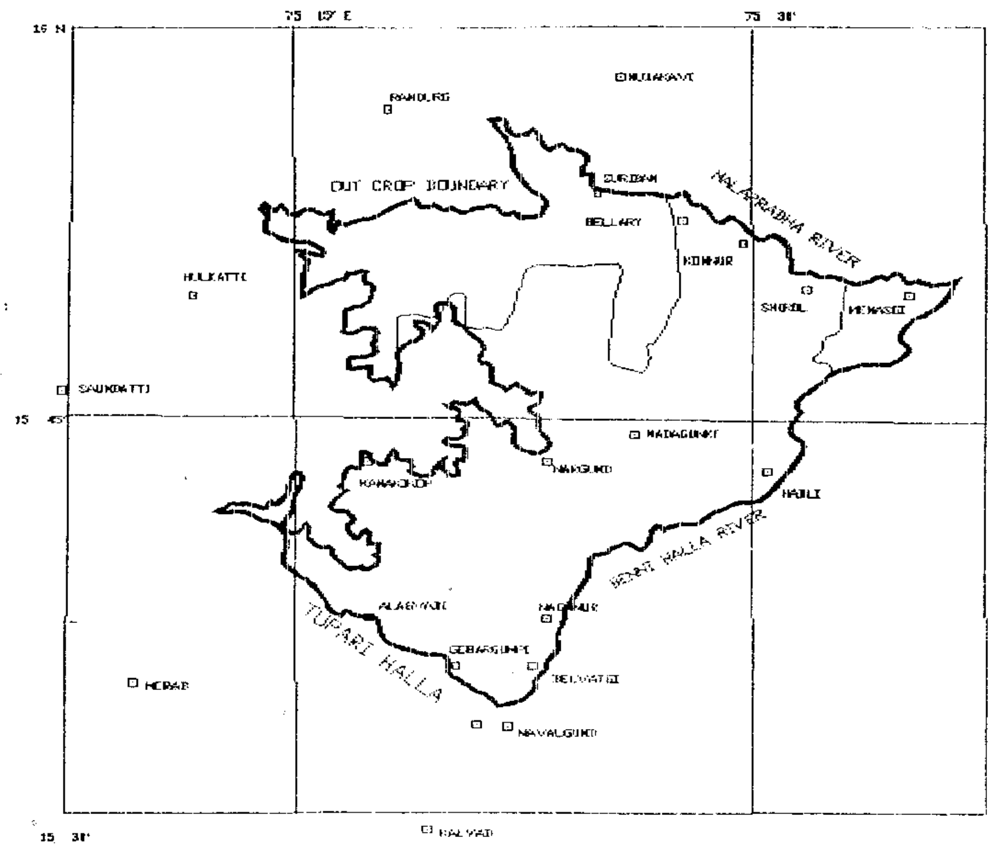


FIG. 1. LOCATION MAP OF NARGUND AND NAVALGUND AREA

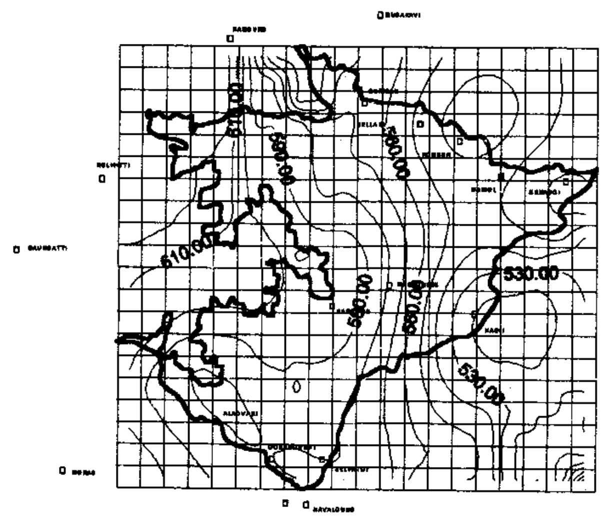


Fig 2. Kriged Ground Level Contours in Nargund-Navalgund area.

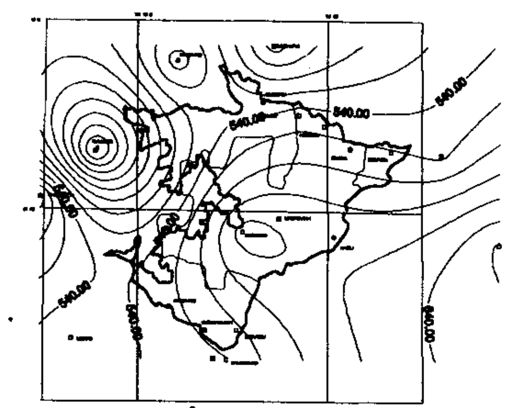


Fig 3(a) Isohytal Map of Nargund - Navalgund Area for year 1978.

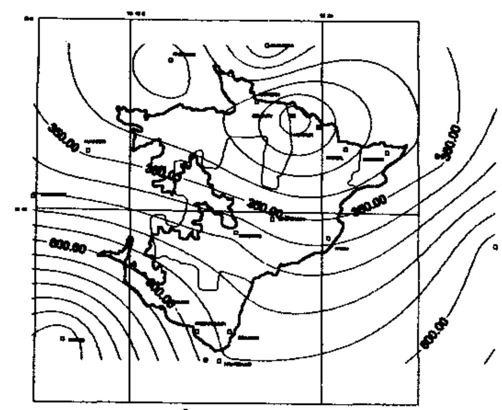


Fig 3(b) Isohytal Map of Nargund - Navalgund Area for year 1980.

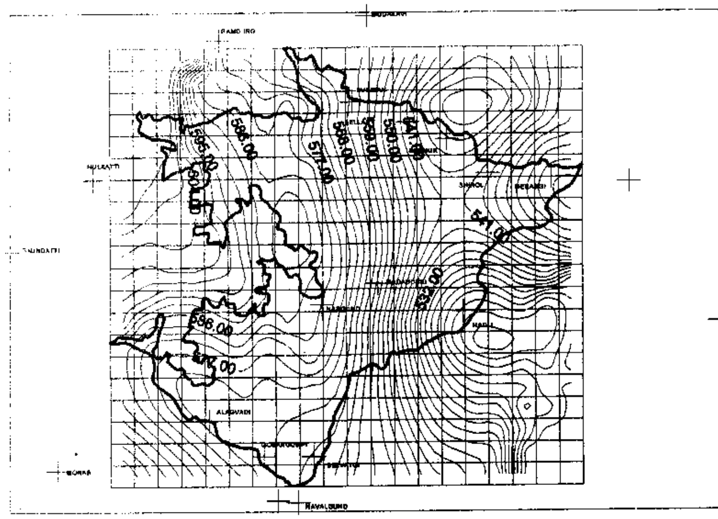


Figure 4 (a) Groundwater Table Contours for Pre-monsoon 1978-79.

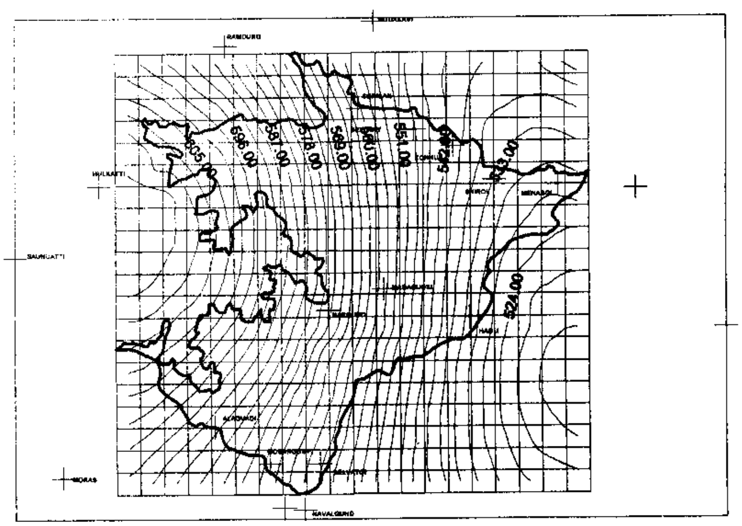


Figure 4 (b) Ground Water Table Contours for Post-monsoon 1978-79

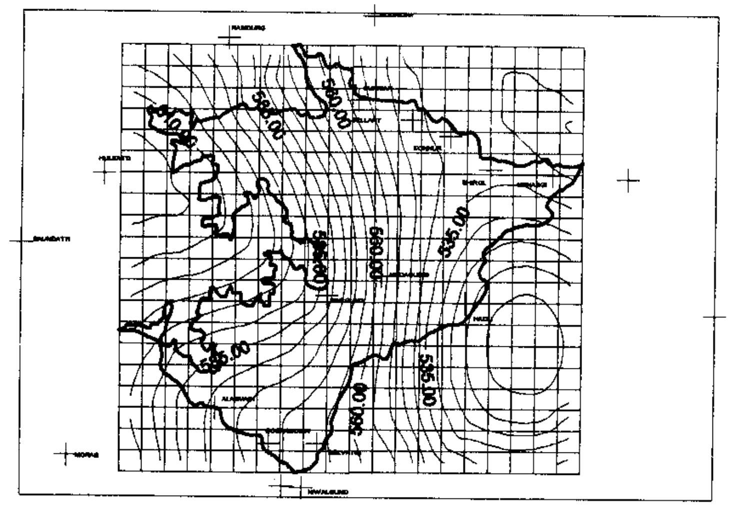


Fig. 4 (C). Kriged Pre-monsoon Water Table in Nargund - Navalgund Area for the year 1980

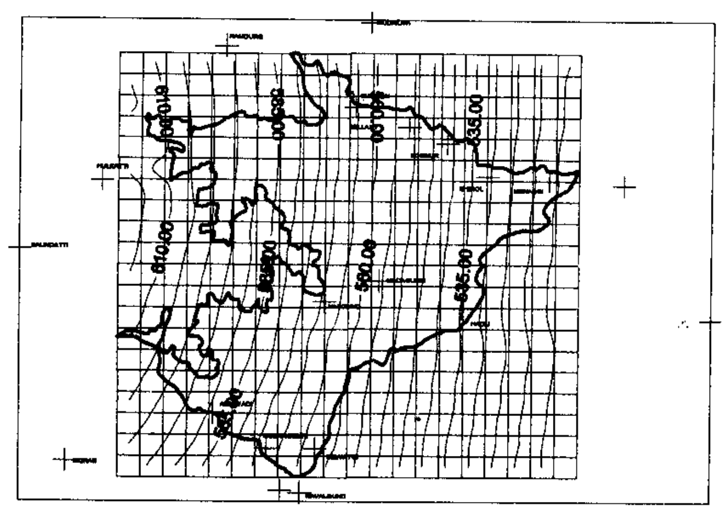


Fig. 4(D). Kriged Post-monsoon Water Table in Nargund - Navalgund Area in 1980

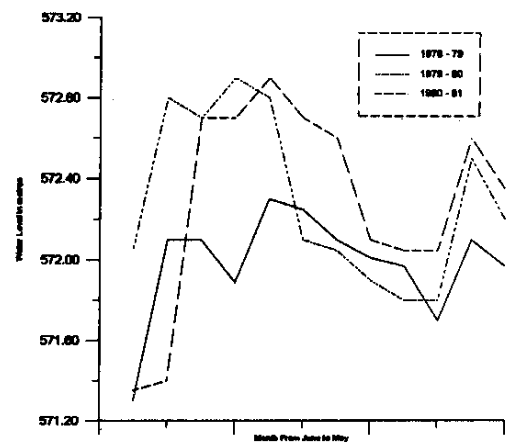


Fig. 6 (a). Seasonal Water Table Fluctuation in Alagwadi

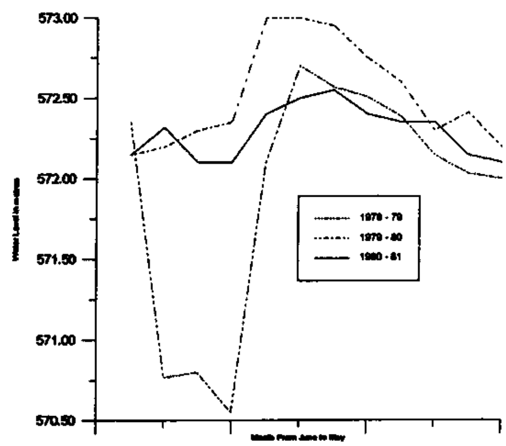


Fig. 6 (b). Seasonal Water Table Fluctuation in Gobargumpi

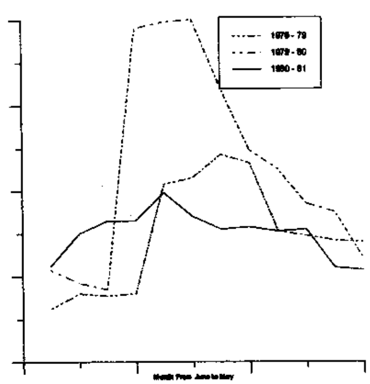


Fig 5(c) Seasonal Water Level Fluctuations in Nargund

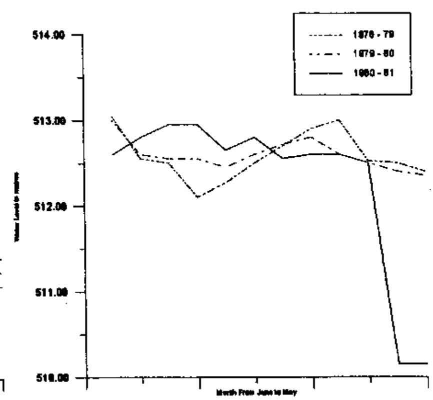


Fig. 5 (d). Seasonal Water Table Fluctuation in Hadli.

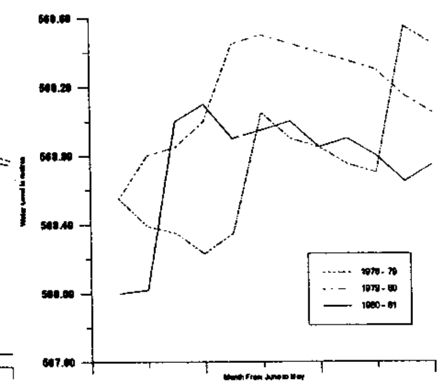
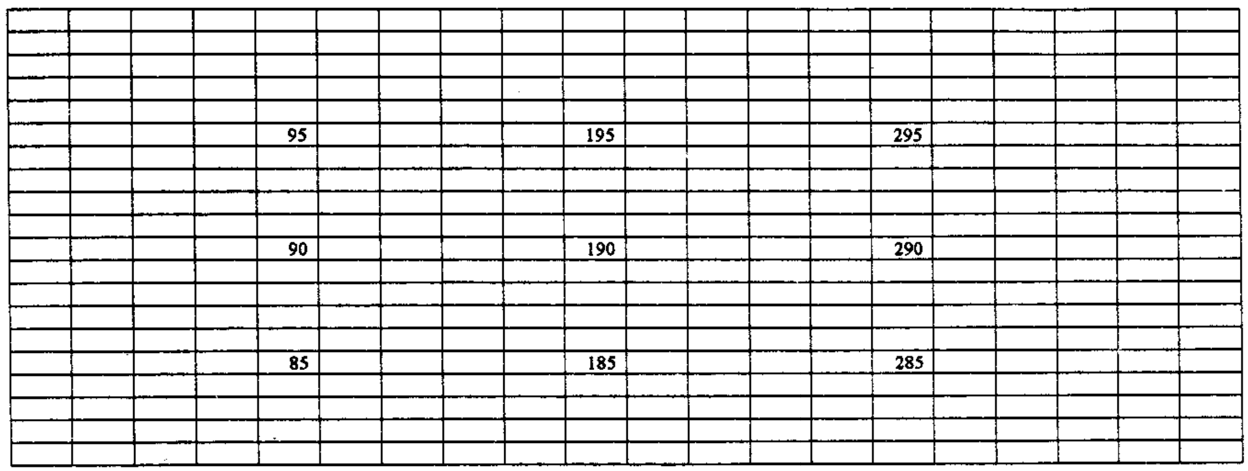


Fig. 5 (e). Seasonal Water Table Fluctuation in Navalgund



No. of Rows : 21, No. of Columns : 21, No. of Blocks in each layer : 400

$\Delta X = 640.25\,ft$

$\Delta Y = 302.50\,ft$

FIGURE 6. FINITE DIFFERENCE MESH FOR THE STUDY AREA

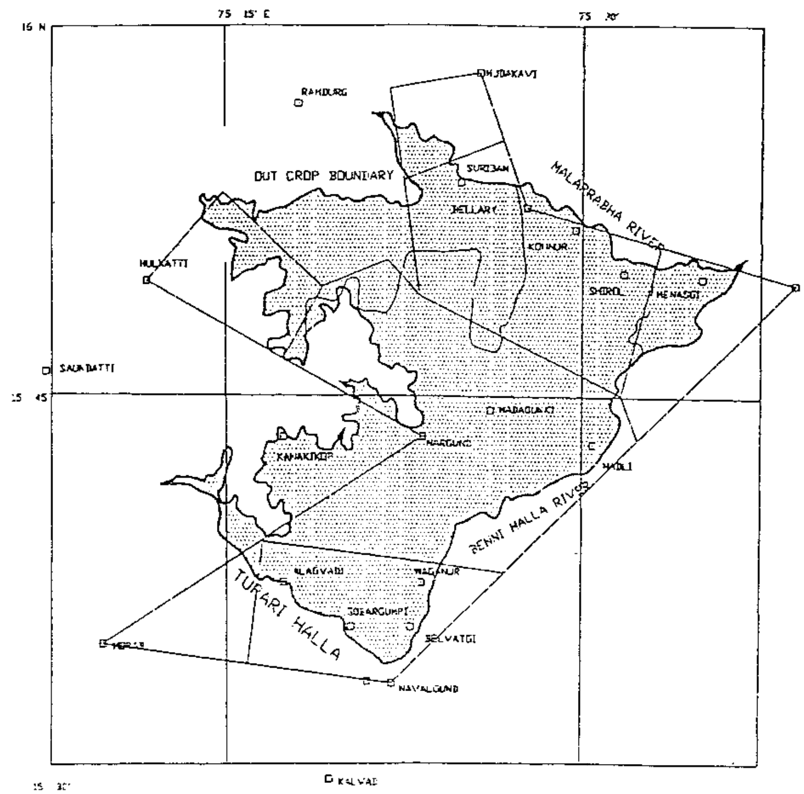


FIG. 7. THEISSEN POLYGON MAP OF NARGUND - NAVALGUND AREA

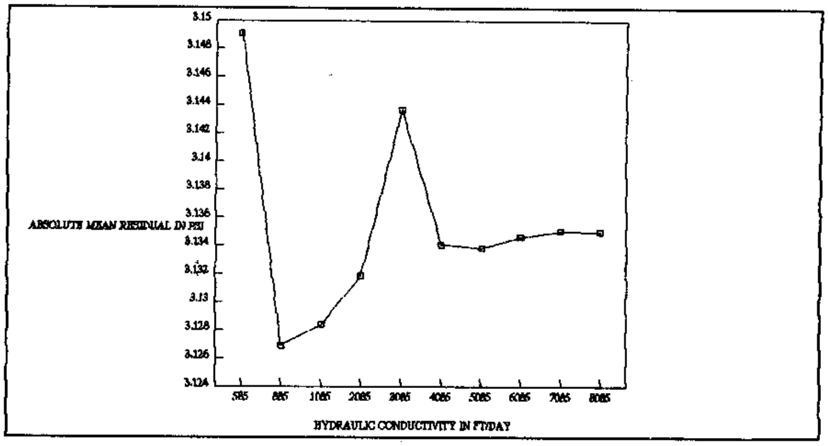


Fig. 8. Plot between Hydraulic Conductivity & Absolute Residuals.

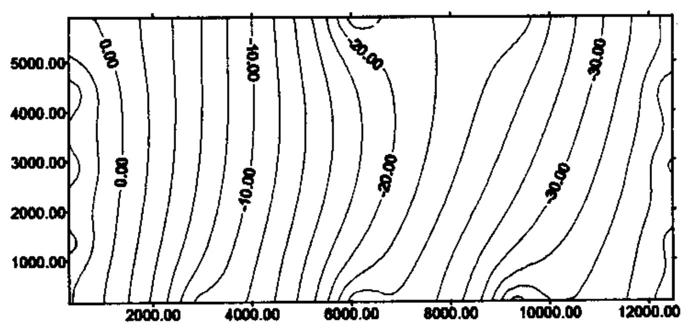


Fig 9. Calibrated Head Distribution in the Study Area

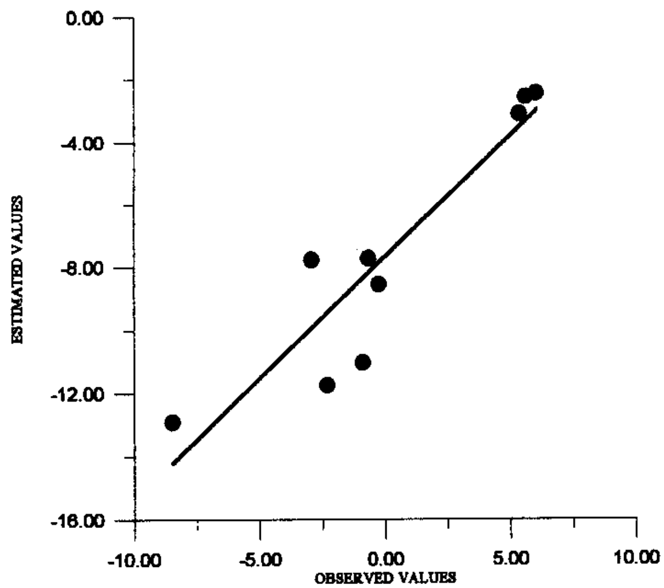


FIGURE 10. PLOT BETWEEN OBSERVED HEADS Vs ESTIMATED HEADS

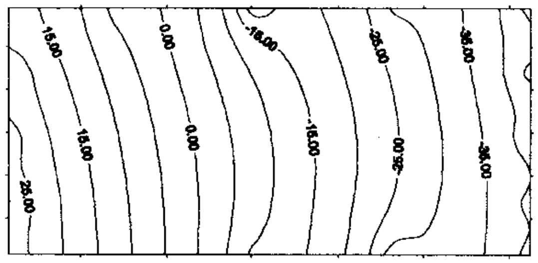


Fig 11. Validated Head Distribution of the Model.

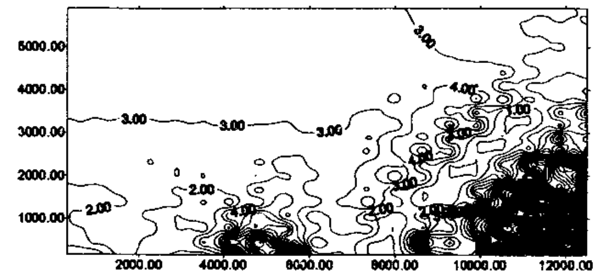


Fig. 12. Chloride Contaminant Plumes for Calibrated Model

ANNEXURE - 2

Some physical and chemical properties of soils of Malaprabha Command Area.

Sl. No.	Soil series	Soil depth (cm)	pH	EC (ds/m)	Exchangeable cations (me/100g)			Water soluble cations & anions mg/l							
					Na+	K+	Ca+	Na	K	Ca	Mg	Hco3	Cl	CEC	EEP
1	**Jamakhandi Series**	**0-20**	**7.4**	**0.37**	**1.04**	**0.99**	**17.4**	**1.95**	**0.2**	**0.50**	**1.00**	**3.0**	**2.0**	**20.16**	**5.16**
		20-40	**7.6**	**0.21**	**0.87**	**0.43**	**19.8**	**1.84**	**0.5**	**0.25**	**1.25**	**3.0**	**3.0**	**19.07**	**4.56**
		40-60	**7.1**	**0.15**	**1.04**	**0.42**	**16.4**	**1.70**	**0.5**	**0.40**	**1.00**	**2.0**	**2.5**	**19.62**	**5.30**
		60-90	**8.0**	**0.24**	**0.79**	**0.40**	**15.2**	**1.83**	**0.6**	**0.50**	**0.25**	**2.5**	**1.0**	**21.80**	**3.58**
		90-120	**8.5**	**0.32**	**0.44**	**0.28**	**16.4**	**2.17**	**0.6**	**1.00**	**0.50**	**3.5**	**2.0**	**21.80**	**2.02**
2	**Chimmanakatti series**	**0-20**	**7.8**	**0.32**	**2.34**	**0.91**	**24.6**	**----**	**0.9**	**0.25**	**0.75**	**5.0**	**2.0**	**27.25**	**8.59**
		20-40	**8.2**	**0.31**	**1.32**	**0.89**	**24.6**	**1.53**	**0.5**	**0.50**	**0.90**	**3.5**	**2.0**	**30.52**	**3.99**
		40-60	**8.3**	**0.27**	**1.13**	**0.91**	**24.6**	**1.41**	**0.6**	**0.50**	**0.70**	**3.5**	**2.0**	**34.88**	**3.24**
		60-90	**8.1**	**0.25**	**1.04**	**0.96**	**30.0**	**1.41**	**0.9**	**1.00**	**0.40**	**3.5**	**1.5**	**32.70**	**3.18**
		90-120	**8.2**	**0.22**	**1.22**	**0.94**	**34.2**	**1.84**	**1.1**	**1.00**	**1.50**	**4.0**	**3.0**	**37.06**	**3.29**
3	**Hanchinal Series**	**0-20**	**8.4**	**0.35**	**3.91**	**1.09**	**55.4**	**04.76**	**0.7**	**0.75**	**0.75**	**6.0**	**2.0**	**61.04**	**6.41**
		20-40	**8.5**	**0.51**	**7.04**	**0.91**	**53.6**	**08.47**	**0.9**	**0.25**	**0.75**	**10.0**	**2.0**	**61.56**	**11.43**
		40-60	**8.7**	**0.60**	**8.26**	**0.79**	**56.0**	**06.95**	**0.9**	**0.25**	**0.50**	**6.5**	**2.0**	**64.31**	**12.84**
		60-90	**7.9**	**0.66**	**9.14**	**0.91**	**54.0**	**10.25**	**0.5**	**0.30**	**0.80**	**7.5**	**3.0**	**61.04**	**14.97**
		90-120	**7.8**	**0.88**	**9.74**	**1.04**	**56.2**	**18.47**	**1.1**	**0.50**	**0.85**	**13.5**	**5.5**	**67.58**	**14.41**

(Source : U A S Dharwad.)

ANNEXURE - 2

Some physical and chemical properties of soils of Malaprabha Command Area.

Sl. No.	Soil series	Soil depth (cm)	Mechanical analysis				pH	EC (ds/m)	CaCo3 (%)
			Coarse	Fine	Silt	Clay			
1	**Jamakhandi Series**	**0-20**	**57.00**	**20.10**	**4.50**	**10.50**	**7.4**	**0.37**	**0.60**
		20-40	**55.40**	**20.00**	**7.00**	**11.00**	**7.6**	**0.21**	**0.95**
		40-60	**50.10**	**21.50**	**12.00**	**15.10**	**7.1**	**0.15**	**1.00**
		60-90	**46.00**	**25.00**	**12.10**	**16.00**	**8.0**	**0.24**	**0.98**
		90-120	**43.00**	**24.90**	**14.50**	**16.50**	**8.5**	**0.32**	**1.00**
2	**Chimmanakatti Series**	**0-20**	**60.46**	**26.90**	**4.20**	**9.98**	**7.8**	**0.32**	**1.05**
		20-40	**61.90**	**27.00**	**4.90**	**10.10**	**8.2**	**0.31**	**1.15**
		40-60	**57.20**	**21.69**	**7.50**	**12.25**	**8.3**	**0.27**	**1.61**
		60-90	**49.10**	**18.15**	**16.21**	**23.23**	**8.1**	**0.25**	**2.00**
		90-120	**42.30**	**19.00**	**16.20**	**22.30**	**8.2**	**0.22**	**2.10**
3	**Hanchinal Series**	**0-20**	**13.10**	**10.15**	**17.15**	**47.10**	**8.4**	**0.35**	**8.60**
		20-40	**11.35**	**08.72**	**13.12**	**52.60**	**8.5**	**0.51**	**10.25**
		40-60	**9.25**	**09.00**	**11.25**	**53.00**	**8.7**	**0.60**	**13.00**
		60-90	**9.00**	**08.25**	**11.00**	**55.32**	**7.9**	**0.66**	**15.61**
		90-120	**8.10**	**08.00**	**10.21**	**56.11**	**7.8**	**0.88**	**18.28**

(Source : U A S Dharwad.)

ANNEXURE - 3

```
Geopack input
well data for nargund-navalgund
jan 07,1997
    5   12    790.000
    1    2     3    4     5    6     7    8
      surf        pr80        po80        pr78        po78
(I5,1P7E12.5)
    1 2.79404E+04 3.40623E+04 5.47000E+02 5.41650E+02 5.42800E+02 5.41400E+02 5.42250E+02
    2 3.16412E+04 3.24694E+04 5.37000E+02 5.32000E+02 5.34000E+02 5.32420E+02 5.33750E+02
    3 3.54945E+04 2.92274E+04 5.47800E+02 5.43400E+02 5.44750E+02 5.43350E+02 5.44600E+02
    4 2.51374E+04 1.90531E+04 5.79500E+02 5.61800E+02 5.64020E+02 5.61500E+02 5.62090E+02
    5 1.98623E+04 1.70922E+04 5.97000E+02 5.84250E+02 5.84400E+02 5.83250E+02 5.86850E+02
    6 3.31510E+04 1.64447E+04 5.19500E+02 5.14350E+02 5.14950E+02 5.12890E+02 5.15050E+02
    7 9.21975E+03 0.61944E+04 5.80000E+02 5.72150E+02 5.73700E+02 5.72820E+02 5.73100E+02
    8 1.44034E+04 2.80965E+03 5.80000E+02 5.73100E+02 5.73550E+02 5.71550E+02 5.73700E+02
    9 0.00000E+00 2.87420e+04 6.25250E+02 6.21100E+02 6.22600E+02 6.11750E+02 6.19950E+02
   10 0.00000E+00 1.55000E+03 6.09000E+02 6.02500E+02 6.03300E+02 6.01450E+02 6.02810E+02
   11 1.76010E+04 1.43800E+03 5.79000E+02 5.68420E+02 5.69300E+02 5.68500E+02 5.69500E+02
   12 1.02360E+04 4.18440E+04 8.55450E+02 8.55450E+02 8.50150E+02 8.50000E+02 8.50000E+02
```

```
**********************************************************************
*
*                     LINEAR ESTIMATOR CALCULATION
*                 ***********************************
*                 DATE: 02/26/1997        TIME: 15:10 pm
*
*   Geopack input
*   well data for nargund-navalgund
*   jan 07,1997
*
*
*                         *****  KRIGING  *****
**********************************************************************
```

INPUT PARAMETERS
================

```
NUMBER OF RANDOM FUNCTIONS......................          1
NUMBER OF DATA POINT READ.......................         12
NUMBER OF NEAREST NEIGHBORS FOR   surf..........         10
MAXIMUM ALLOWED VALUE FOR         surf..........    790.000
MAXIMUM ALLOWED RADIUS.......................... 19722.000
```

COVARIANCE/VARIOGRAM COEFFICIENTS
=================================

VARIOGRAMS	MODEL	NUGGET	SILL-NUGGET	
surf/ surf	GAUSS	.0000	852.0000	1140

SITE	X	Y	surf
1	2.7940E+04	3.4062E+04	5.47000E+02
2	3.1641E+04	3.2469E+04	5.37000E+02
3	3.5495E+04	2.9227E+04	5.48000E+02
4	2.5137E+04	1.9053E+04	5.79500E+02
5	1.9862E+04	1.7092E+04	5.97000E+02
6	3.3151E+04	1.6445E+04	5.19000E+02
7	9.2198E+03	6.1944E+03	5.80000E+02
8	1.4403E+04	2.8096E+03	5.80000E+02
9	0.0000E+00	2.8742E+04	6.25250E+02
10	0.0000E+00	1.5500E+03	6.09000E+02
11	1.7601E+04	1.4380E+03	5.79000E+02
12	1.0236E+04	4.1844E+04	8.55450E+02

ESTIMATED VALUES
================

X0	Y0	surf	VARIANCE	N1
1.1090E+03	1.0295E+03	6.0790E+02	1.5596E+01	4
1.1090E+03	3.0885E+03	6.0476E+02	2.2969E+01	4
1				
1.1090E+03	[illegible]	[illegible].0047E+02	9.0819E+01	4
1.1090E+03	7.2065E+03	5.9584E+02	1.9846E+02	4
1.1090E+03	9.2655E+03	5.9477E+02	3.2593E+02	5
1.1090E+03	1.1325E+04	5.9447E+02	4.6029E+02	6
1.1090E+03	1.3384E+04	6.0258E+02	6.6034E+02	5
1.1090E+03	1.5443E+04	6.0523E+02	7.2274E+02	5
1.1090E+03	1.7502E+04	6.0805E+02	7.2213E+02	4
1.1090E+03	1.9561E+04	6.1227E+02	6.2806E+02	4
1.1090E+03	2.1620E+04	6.1553E+02	4.7613E+02	3

1.1090E+03	2.3679E+04	6.1991E+02	2.9475E+02	2
1.1090E+03	2.5738E+04	6.2525E+02	1.2932E+02	1
1.1090E+03	2.7797E+04	6.2525E+02	2.7621E+01	1
1.1090E+03	2.9856E+04	6.2525E+02	3.2077E+01	1
1.1090E+03	3.1915E+04	6.2525E+02	1.4184E+02	1
1.1090E+03	3.3974E+04	6.2525E+02	3.3658E+02	1
1.1090E+03	3.6033E+04	6.2525E+02	5.8265E+02	1
1.1090E+03	3.8092E+04	6.2525E+02	8.4252E+02	1
1.1090E+03	4.0151E+04	6.2525E+02	1.0840E+03	1
3.3270E+03	1.0295E+03	6.0335E+02	8.1766E+01	4
3.3270E+03	3.0885E+03	5.9966E+02	5.4035E+01	4
3.3270E+03	5.1475E+03	5.9508E+02	6.6317E+01	4
3.3270E+03	7.2065E+03	5.9013E+02	1.1374E+02	5
3.3270E+03	9.2655E+03	5.8685E+02	2.0829E+02	5
3.3270E+03	1.1325E+04	5.8914E+02	3.2861E+02	6
3.3270E+03	1.3384E+04	5.9144E+02	4.6567E+02	6
3.3270E+03	1.5443E+04	6.0191E+02	6.5514E+02	5
3.3270E+03	1.7502E+04	6.0605E+02	6.8159E+02	5
3.3270E+03	1.9561E+04	6.0985E+02	6.4018E+02	4
3.3270E+03	2.1620E+04	6.1373E+02	5.1941E+02	3
3.3270E+03	2.3679E+04	6.1797E+02	3.6580E+02	3
3.3270E+03	2.5738E+04	6.2245E+02	2.2765E+02	2
3.3270E+03	2.7797E+04	6.2350E+02	1.4345E+02	2
3.3270E+03	2.9856E+04	6.2525E+02	1.5398E+02	1
3.3270E+03	3.1915E+04	6.2525E+02	2.5574E+02	1
3.3270E+03	3.3974E+04	6.2525E+02	4.3629E+02	1
3.3270E+03	3.6033E+04	6.2525E+02	6.6441E+02	1
3.3270E+03	3.8092E+04	6.2525E+02	9.0533E+02	1
3.3270E+03	4.0151E+04	6.2525E+02	1.1292E+03	1
5.5450E+03	1.0295E+03	5.9797E+02	1.4501E+02	4
5.5450E+03	3.0885E+03	5.9396E+02	8.2115E+01	4
5.5450E+03	5.1475E+03	5.8862E+02	4.1204E+01	5
5.5450E+03	7.2065E+03	5.8469E+02	4.5140E+01	5
5.5450E+03	9.2655E+03	5.8207E+02	1.0611E+02	5
5.5450E+03	1.1325E+04	5.8441E+02	2.1913E+02	6
5.5450E+03	1.3384E+04	5.8733E+02	3.6834E+02	6
5.5450E+03	1.5443E+04	5.9194E+02	5.0793E+02	6
5.5450E+03	1.7502E+04	6.0555E+02	6.4638E+02	6
5.5450E+03	1.9561E+04	6.1053E+02	6.4103E+02	6
5.5450E+03	2.1620E+04	6.1107E+02	5.8790E+02	3
5.5450E+03	2.3679E+04	6.1509E+02	4.8471E+02	3
5.5450E+03	2.5738E+04	6.2004E+02	3.9218E+02	2
5.5450E+03	2.7797E+04	6.2116E+02	3.3310E+02	2
5.5450E+03	2.9856E+04	6.2151E+02	3.4243E+02	2
5.5450E+03	3.1915E+04	6.2525E+02	4.5924E+02	1
5.5450E+03	3.3974E+04	6.2525E+02	6.1441E+02	1
5.5450E+03	3.6033E+04	6.2525E+02	8.1049E+02	1
5.5450E+03	3.8092E+04	6.2525E+02	1.0176E+03	1
5.5450E+03	4.0151E+04	6.2525E+02	1.2099E+03	1

1

7.7630E+03	1.0295E+03	5.9268E+02	1.5888E+02	4
7.7630E+03	3.0885E+03	5.8792E+02	7.0907E+01	5
7.7630E+03	5.1475E+03	5.8381E+02	1.8073E+01	5
7.7630E+03	7.2065E+03	5.8055E+02	7.8312E+00	5
7.7630E+03	9.2655E+03	5.7876E+02	5.7124E+01	5
7.7630E+03	1.1325E+04	5.8388E+02	1.5888E+02	7
7.7630E+03	1.3384E+04	5.8858E+02	2.9866E+02	7
7.7630E+03	1.5443E+04	5.9445E+02	4.3716E+02	7
7.7630E+03	1.7502E+04	6.0061E+02	5.4164E+02	7
7.7630E+03	1.9561E+04	6.0998E+02	6.2605E+02	6
7.7630E+03	2.1620E+04	6.1226E+02	6.2556E+02	4
7.7630E+03	2.3679E+04	6.1484E+02	5.8712E+02	4
7.7630E+03	2.5738E+04	6.1631E+02	5.4650E+02	4
7.7630E+03	2.7797E+04	6.1895E+02	5.3392E+02	3
7.7630E+03	2.9856E+04	6.1875E+02	5.5366E+02	2
7.7630E+03	3.1915E+04	6.1863E+02	6.2013E+02	2

7.7630E+03	3.3974E+04	6.2525E+02	8.3579E+02	1
7.7630E+03	3.6033E+04	6.2525E+02	9.9203E+02	1
7.7630E+03	3.8092E+04	6.2525E+02	1.1570E+03	1
7.7630E+03	4.0151E+04	6.2525E+02	1.3103E+03	1
9.9810E+03	1.0295E+03	5.8757E+02	1.2042E+02	5
9.9810E+03	3.0885E+03	5.8395E+02	3.8917E+01	5
9.9810E+03	5.1475E+03	5.8063E+02	2.7353E+00	5
9.9810E+03	7.2065E+03	5.7937E+02	1.1467E+01	6
9.9810E+03	9.2655E+03	5.8015E+02	6.3453E+01	6
9.9810E+03	1.1325E+04	5.8259E+02	1.5390E+02	6
9.9810E+03	1.3384E+04	5.9025E+02	2.5572E+02	7
9.9810E+03	1.5443E+04	5.9616E+02	3.6416E+02	7
9.9810E+03	1.7502E+04	6.0185E+02	4.6026E+02	7
9.9810E+03	1.9561E+04	6.0719E+02	5.3750E+02	6
9.9810E+03	2.1620E+04	6.1149E+02	6.0777E+02	5
9.9810E+03	2.3679E+04	6.1240E+02	6.4108E+02	4
9.9810E+03	2.5738E+04	6.1290E+02	6.6093E+02	4
9.9810E+03	2.7797E+04	6.0675E+02	6.6226E+02	4
9.9810E+03	2.9856E+04	6.0504E+02	6.9090E+02	4
9.9810E+03	3.1915E+04	6.0253E+02	7.3763E+02	3
9.9810E+03	3.3974E+04	6.0022E+02	7.9999E+02	3
9.9810E+03	3.6033E+04	5.9504E+02	9.2465E+02	2
9.9810E+03	3.8092E+04	5.9253E+02	1.0026E+03	2
9.9810E+03	4.0151E+04	5.9035E+02	1.0749E+03	2
1.2199E+04	1.0295E+03	5.8408E+02	6.8481E+01	5
1.2199E+04	3.0885E+03	5.8133E+02	8.2608E+00	5
1.2199E+04	5.1475E+03	5.7983E+02	8.1698E+00	6
1.2199E+04	7.2065E+03	5.8043E+02	4.7665E+01	6
1.2199E+04	9.2655E+03	5.8264E+02	1.0396E+02	6
1.2199E+04	1.1325E+04	5.8618E+02	1.6179E+02	6
1.2199E+04	1.3384E+04	5.9326E+02	2.1125E+02	7
1.2199E+04	1.5443E+04	5.9876E+02	2.6636E+02	7
1.2199E+04	1.7502E+04	6.0499E+02	3.3847E+02	6
1.2199E+04	1.9561E+04	6.0726E+02	4.2424E+02	6
1.2199E+04	2.1620E+04	6.0985E+02	5.3421E+02	5
1.2199E+04	2.3679E+04	6.0308E+02	6.0697E+02	5
1.2199E+04	2.5738E+04	6.0223E+02	6.8018E+02	4
1.2199E+04	2.7797E+04	6.0018E+02	7.3332E+02	4
1.2199E+04	2.9856E+04	6.0053E+02	7.6925E+02	5
1.2199E+04	3.1915E+04	5.9871E+02	8.0736E+02	5
1.2199E+04	3.3974E+04	5.9697E+02	8.5109E+02	4
1.2199E+04	3.6033E+04	5.8876E+02	9.7396E+02	2

1

1.2199E+04	3.8092E+04	5.8735E+02	1.0283E+03	2
1.2199E+04	4.0151E+04	5.8633E+02	1.0841E+03	2
1.4417E+04	1.0295E+03	5.8149E+02	2.8687E+01	5
1.4417E+04	3.0885E+03	5.7998E+02	6.5695E-01	6
1.4417E+04	5.1475E+03	5.8059E+02	3.7218E+01	6
1.4417E+04	7.2065E+03	5.8260E+02	1.0055E+02	6
1.4417E+04	9.2655E+03	5.8594E+02	1.5027E+02	6
1.4417E+04	1.1325E+04	5.8185E+02	1.5284E+02	7
1.4417E+04	1.3384E+04	5.8481E+02	1.3922E+02	7
1.4417E+04	1.5443E+04	5.9357E+02	1.4189E+02	7
1.4417E+04	1.7502E+04	5.9664E+02	1.7835E+02	7
1.4417E+04	1.9561E+04	5.9907E+02	2.7504E+02	7
1.4417E+04	2.1620E+04	5.9606E+02	4.0105E+02	7
1.4417E+04	2.3679E+04	5.9995E+02	5.4174E+02	6
1.4417E+04	2.5738E+04	5.9847E+02	6.5095E+02	5
1.4417E+04	2.7797E+04	5.9664E+02	7.2402E+02	5
1.4417E+04	2.9856E+04	5.9487E+02	7.6718E+02	5
1.4417E+04	3.1915E+04	5.9326E+02	7.9553E+02	5
1.4417E+04	3.3974E+04	5.9182E+02	8.2437E+02	5
1.4417E+04	3.6033E+04	5.9104E+02	8.6386E+02	4
1.4417E+04	3.8092E+04	5.8616E+02	9.8313E+02	3
1.4417E+04	4.0151E+04	5.8522E+02	1.0430E+03	3
1.6635E+04	1.0295E+03	5.7967E+02	6.5430E+00	5

1.6635E+04	3.0885E+03	5.7986E+02	1.4778E+01	6
1.6635E+04	5.1475E+03	5.8165E+02	8.2571E+01	6
1.6635E+04	7.2065E+03	5.8015E+02	1.5558E+02	7
1.6635E+04	9.2655E+03	5.8211E+02	1.8742E+02	7
1.6635E+04	1.1325E+04	5.8516E+02	1.5910E+02	7
1.6635E+04	1.3384E+04	5.9263E+02	1.0225E+02	6
1.6635E+04	1.5443E+04	5.9482E+02	5.0797E+01	6
1.6635E+04	1.7502E+04	5.9597E+02	6.6953E+01	6
1.6635E+04	1.9561E+04	5.9811E+02	1.5422E+02	8
1.6635E+04	2.1620E+04	5.9805E+02	3.0127E+02	8
1.6635E+04	2.3679E+04	6.0136E+02	4.4765E+02	8
1.6635E+04	2.5738E+04	5.9999E+02	5.6260E+02	7
1.6635E+04	2.7797E+04	5.9371E+02	6.2617E+02	6
1.6635E+04	2.9856E+04	5.9260E+02	6.3759E+02	6
1.6635E+04	3.1915E+04	5.9195E+02	6.2406E+02	6
1.6635E+04	3.3974E+04	5.9167E+02	6.1557E+02	6
1.6635E+04	3.6033E+04	5.8623E+02	7.4503E+02	5
1.6635E+04	3.8092E+04	5.8298E+02	8.6438E+02	3
1.6635E+04	4.0151E+04	5.4919E+02	1.2152E+03	2
1.8853E+04	1.0295E+03	5.7851E+02	1.9151E+00	6
1.8853E+04	3.0885E+03	5.7836E+02	4.3003E+01	7
1.8853E+04	5.1475E+03	5.7892E+02	1.3465E+02	7
1.8853E+04	7.2065E+03	5.8030E+02	2.1733E+02	7
1.8853E+04	9.2655E+03	5.8617E+02	2.4608E+02	6
1.8853E+04	1.1325E+04	5.8938E+02	1.9457E+02	6
1.8853E+04	1.3384E+04	5.9278E+02	9.9711E+01	6
1.8853E+04	1.5443E+04	5.9583E+02	2.0324E+01	6
1.8853E+04	1.7502E+04	5.9729E+02	8.9268E+00	8
1.8853E+04	1.9561E+04	5.9916E+02	8.1732E+01	9
1.8853E+04	2.1620E+04	5.9848E+02	2.1646E+02	8
1.8853E+04	2.3679E+04	6.0143E+02	3.5872E+02	7
1.8853E+04	2.5738E+04	5.9900E+02	4.6832E+02	7
1.8853E+04	2.7797E+04	5.9568E+02	5.1624E+02	7
1.8853E+04	2.9856E+04	5.9221E+02	5.0412E+02	7
1.8853E+04	3.1915E+04	5.8528E+02	4.6274E+02	6
1				
1.8853E+04	3.3974E+04	5.8574E+02	4.2749E+02	6
1.8853E+04	3.6033E+04	5.7965E+02	4.6251E+02	5
1.8853E+04	3.8092E+04	5.7363E+02	5.7249E+02	3
1.8853E+04	4.0151E+04	5.5128E+02	9.8879E+02	2
2.1071E+04	1.0295E+03	5.7675E+02	3.4913E+01	6
2.1071E+04	3.0885E+03	5.7761E+02	9.6270E+01	6
2.1071E+04	5.1475E+03	5.7863E+02	2.0169E+02	6
2.1071E+04	7.2065E+03	5.8014E+02	2.8903E+02	6
2.1071E+04	9.2655E+03	5.8240E+02	3.0941E+02	6
2.1071E+04	1.1325E+04	5.8547E+02	2.5166E+02	6
2.1071E+04	1.3384E+04	5.8908E+02	1.4594E+02	6
2.1071E+04	1.5443E+04	5.9265E+02	4.5906E+01	6
2.1071E+04	1.7502E+04	5.9560E+02	2.1241E+00	9
2.1071E+04	1.9561E+04	5.9763E+02	3.9440E+01	9
2.1071E+04	2.1620E+04	5.9769E+02	1.4251E+02	7
2.1071E+04	2.3679E+04	5.9535E+02	2.6840E+02	6
2.1071E+04	2.5738E+04	5.9115E+02	3.6702E+02	6
2.1071E+04	2.7797E+04	5.8632E+02	4.0118E+02	6
2.1071E+04	2.9856E+04	5.8181E+02	3.6644E+02	6
2.1071E+04	3.1915E+04	5.7820E+02	2.9522E+02	6
2.1071E+04	3.3974E+04	5.7443E+02	2.4058E+02	5
2.1071E+04	3.6033E+04	5.7562E+02	2.4781E+02	5
2.1071E+04	3.8092E+04	5.7366E+02	3.4720E+02	4
2.1071E+04	4.0151E+04	5.7221E+02	5.1434E+02	3
2.3289E+04	1.0295E+03	5.7398E+02	1.3512E+02	6
2.3289E+04	3.0885E+03	5.7391E+02	1.9465E+02	6
2.3289E+04	5.1475E+03	5.7384E+02	2.9120E+02	6
2.3289E+04	7.2065E+03	5.7418E+02	3.6762E+02	6
2.3289E+04	9.2655E+03	5.7534E+02	3.8042E+02	6
2.3289E+04	1.1325E+04	5.7754E+02	3.1921E+02	6

2.3289E+04	1.3384E+04	5.8067E+02	2.0787E+02	6
2.3289E+04	1.5443E+04	5.8339E+02	8.3563E+01	9
2.3289E+04	1.7502E+04	5.8755E+02	1.2571E+01	9
2.3289E+04	1.9561E+04	5.9043E+02	1.2473E+01	9
2.3289E+04	2.1620E+04	5.9127E+02	8.0838E+01	6
2.3289E+04	2.3679E+04	5.8929E+02	1.8346E+02	6
2.3289E+04	2.5738E+04	5.8532E+02	2.6851E+02	6
2.3289E+04	2.7797E+04	5.8037E+02	2.9170E+02	6
2.3289E+04	2.9856E+04	5.7553E+02	2.4334E+02	6
2.3289E+04	3.1915E+04	5.7166E+02	1.5676E+02	6
2.3289E+04	3.3974E+04	5.6684E+02	9.1671E+01	5
2.3289E+04	3.6033E+04	5.6889E+02	9.7318E+01	5
2.3289E+04	3.8092E+04	5.6869E+02	2.0498E+02	4
2.3289E+04	4.0151E+04	5.6899E+02	3.8883E+02	3
2.5507E+04	1.0295E+03	5.7022E+02	3.0546E+02	6
2.5507E+04	3.0885E+03	5.6892E+02	3.4322E+02	6
2.5507E+04	5.1475E+03	5.6733E+02	4.0702E+02	6
2.5507E+04	7.2065E+03	5.6594E+02	4.5037E+02	6
2.5507E+04	9.2655E+03	5.6531E+02	4.3868E+02	6
2.5507E+04	1.1325E+04	5.6588E+02	3.6405E+02	6
2.5507E+04	1.3384E+04	5.6855E+02	2.3329E+02	7
2.5507E+04	1.5443E+04	5.6948E+02	1.0655E+02	9
2.5507E+04	1.7502E+04	5.7405E+02	2.1807E+01	8
2.5507E+04	1.9561E+04	5.7782E+02	2.0251E+00	6
2.5507E+04	2.1620E+04	5.7961E+02	4.8941E+01	6
2.5507E+04	2.3679E+04	5.7878E+02	1.3307E+02	6
2.5507E+04	2.5738E+04	5.7555E+02	2.0431E+02	6
2.5507E+04	2.7797E+04	5.7083E+02	2.1843E+02	6
2.5507E+04	2.9856E+04	5.6584E+02	1.6544E+02	6
2.5507E+04	3.1915E+04	5.6174E+02	7.8982E+01	6
2.5507E+04	3.3974E+04	5.5922E+02	1.8229E+01	6
2.5507E+04	3.6033E+04	5.5888E+02	3.6567E+01	4
2.5507E+04	3.8092E+04	5.6138E+02	1.5403E+02	4
2.5507E+04	4.0151E+04	5.6332E+02	3.4884E+02	3
2.7725E+04	1.0295E+03	5.6598E+02	5.0943E+02	6
2.7725E+04	3.0885E+03	5.6328E+02	5.1439E+02	6
2.7725E+04	5.1475E+03	5.5992E+02	5.2922E+02	6
2.7725E+04	7.2065E+03	5.5644E+02	5.2049E+02	6
2.7725E+04	9.2655E+03	5.5355E+02	4.6566E+02	6
2.7725E+04	1.1325E+04	5.5270E+02	3.5109E+02	7
2.7725E+04	1.3384E+04	5.5135E+02	2.1939E+02	7
2.7725E+04	1.5443E+04	5.5215E+02	9.7772E+01	8
2.7725E+04	1.7502E+04	5.5704E+02	2.5359E+01	7
2.7725E+04	1.9561E+04	5.6183E+02	1.4134E+01	6
2.7725E+04	2.1620E+04	5.6527E+02	5.7689E+01	6
2.7725E+04	2.3679E+04	5.6613E+02	1.2593E+02	6
2.7725E+04	2.5738E+04	5.6419E+02	1.7595E+02	6
2.7725E+04	2.7797E+04	5.6011E+02	1.7388E+02	6
2.7725E+04	2.9856E+04	5.5516E+02	1.1726E+02	6
2.7725E+04	3.1915E+04	5.5079E+02	4.1143E+01	6
2.7725E+04	3.3974E+04	5.4810E+02	2.8208E-01	6
2.7725E+04	3.6033E+04	5.4960E+02	4.2047E+01	4
2.7725E+04	3.8092E+04	5.5293E+02	1.7839E+02	4
2.7725E+04	4.0151E+04	5.5612E+02	3.8245E+02	3
2.9943E+04	1.0295E+03	5.5888E+02	8.0348E+02	5
2.9943E+04	3.0885E+03	5.5523E+02	7.4981E+02	5
2.9943E+04	5.1475E+03	5.5067E+02	6.8508E+02	5
2.9943E+04	7.2065E+03	5.4569E+02	5.9373E+02	5
2.9943E+04	9.2655E+03	5.4106E+02	4.6994E+02	5
2.9943E+04	1.1325E+04	5.3813E+02	3.1422E+02	6
2.9943E+04	1.3384E+04	5.3454E+02	1.6468E+02	7
2.9943E+04	1.5443E+04	5.3490E+02	6.0524E+01	7
2.9943E+04	1.7502E+04	5.3983E+02	1.9616E+01	6
2.9943E+04	1.9561E+04	5.4614E+02	3.6724E+01	6
2.9943E+04	2.1620E+04	5.5154E+02	8.7624E+01	6

2.9943E+04	2.3679E+04	5.5452E+02	1.3861E+02	6
2.9943E+04	2.5738E+04	5.5433E+02	1.5917E+02	6
2.9943E+04	2.7797E+04	5.5127E+02	1.3433E+02	6
2.9943E+04	2.9856E+04	5.4656E+02	7.4513E+01	6
2.9943E+04	3.1915E+04	5.4190E+02	1.5792E+01	6
2.9943E+04	3.3974E+04	5.3879E+02	4.5422E+00	6
2.9943E+04	3.6033E+04	5.4142E+02	8.1177E+01	4
2.9943E+04	3.8092E+04	5.4522E+02	2.4182E+02	4
2.9943E+04	4.0151E+04	5.4898E+02	4.5795E+02	3
3.2161E+04	1.0295E+03	5.5471E+02	9.6102E+02	4
3.2161E+04	3.0885E+03	5.5119E+02	8.5710E+02	5
3.2161E+04	5.1475E+03	5.4521E+02	7.5697E+02	5
3.2161E+04	7.2065E+03	5.3849E+02	6.2106E+02	5
3.2161E+04	9.2655E+03	5.3188E+02	4.5283E+02	5
3.2161E+04	1.1325E+04	5.2684E+02	2.6709E+02	6
3.2161E+04	1.3384E+04	5.2084E+02	1.0543E+02	6
3.2161E+04	1.5443E+04	5.2077E+02	1.8192E+01	6
3.2161E+04	1.7502E+04	5.2650E+02	8.6962E+00	6
3.2161E+04	1.9561E+04	5.3409E+02	5.2317E+01	6
3.2161E+04	2.1620E+04	5.4152E+02	1.0655E+02	6
3.2161E+04	2.3679E+04	5.4679E+02	1.3578E+02	6
3.2161E+04	2.5738E+04	5.4860E+02	1.2557E+02	6
3.2161E+04	2.7797E+04	5.4685E+02	8.2903E+01	6
3.2161E+04	2.9856E+04	5.4260E+02	3.0366E+01	6
3.2161E+04	3.1915E+04	5.3767E+02	5.0136E-01	6
3.2161E+04	3.3974E+04	5.3332E+02	2.9599E+01	5
3.2161E+04	3.6033E+04	5.3141E+02	1.3864E+02	5
3.2161E+04	3.8092E+04	5.3919E+02	3.2793E+02	3
3.2161E+04	4.0151E+04	5.4361E+02	5.5346E+02	3
3.4379E+04	1.0295E+03	5.4763E+02	1.0560E+03	2
3.4379E+04	3.0885E+03	5.4784E+02	9.6947E+02	3
3.4379E+04	5.1475E+03	5.4247E+02	8.1783E+02	4
3.4379E+04	7.2065E+03	5.3470E+02	6.5801E+02	4
3.4379E+04	9.2655E+03	5.2682E+02	4.6471E+02	4
3.4379E+04	1.1325E+04	5.2023E+02	2.6338E+02	5
3.4379E+04	1.3384E+04	5.1127E+02	9.4296E+01	5
3.4379E+04	1.5443E+04	5.1313E+02	1.6046E+01	6
3.4379E+04	1.7502E+04	5.1914E+02	2.0265E+01	6
3.4379E+04	1.9561E+04	5.2782E+02	6.8733E+01	6
3.4379E+04	2.1620E+04	5.3699E+02	1.0942E+02	6
3.4379E+04	2.3679E+04	5.4432E+02	1.1032E+02	6
3.4379E+04	2.5738E+04	5.4808E+02	7.4566E+01	6
3.4379E+04	2.7797E+04	5.4775E+02	2.8636E+01	6
3.4379E+04	2.9856E+04	5.4415E+02	1.8522E+00	6
3.4379E+04	3.1915E+04	5.3865E+02	1.8049E+01	5
3.4379E+04	3.3974E+04	5.3359E+02	9.5674E+01	5
3.4379E+04	3.6033E+04	5.3076E+02	2.3608E+02	5
3.4379E+04	3.8092E+04	5.3715E+02	4.4123E+02	3
3.4379E+04	4.0151E+04	5.4120E+02	6.6608E+02	3
3.6597E+04	1.0295E+03	5.4639E+02	1.1087E+03	2
3.6597E+04	3.0885E+03	5.4717E+02	1.0246E+03	3
3.6597E+04	5.1475E+03	5.4028E+02	9.1497E+02	3
3.6597E+04	7.2065E+03	5.2988E+02	7.7053E+02	3
3.6597E+04	9.2655E+03	5.2291E+02	5.5618E+02	3
3.6597E+04	1.1325E+04	5.1678E+02	3.4542E+02	4
3.6597E+04	1.3384E+04	5.0874E+02	1.7259E+02	5
3.6597E+04	1.5443E+04	5.0963E+02	9.8766E+01	5
3.6597E+04	1.7502E+04	5.1832E+02	9.2416E+01	6
3.6597E+04	1.9561E+04	5.2762E+02	1.2044E+02	6
3.6597E+04	2.1620E+04	5.3789E+02	1.2957E+02	6
3.6597E+04	2.3679E+04	5.4666E+02	9.7413E+01	6
3.6597E+04	2.5738E+04	5.5195E+02	4.2927E+01	6
3.6597E+04	2.7797E+04	5.5285E+02	6.0872E+00	5
3.6597E+04	2.9856E+04	5.4965E+02	1.8794E+01	5
3.6597E+04	3.1915E+04	5.4422E+02	9.0802E+01	5

3.6597E+04	3.3974E+04	5.3870E+02	2.1500E+02	5
3.6597E+04	3.6033E+04	5.3767E+02	3.8456E+02	3
3.6597E+04	3.8092E+04	5.3884E+02	5.8633E+02	3
3.6597E+04	4 0151E+04	5.4198E+02	7.9566E+02	3
3.8815E+04	1.0295E+03	5.1900E+02	1.4901E+03	1
3.8815E+04	3.0885E+03	5.1900E+02	1.3666E+03	1
3.8815E+04	5.1475E+03	5.3207E+02	1.1719E+03	2
3.8815E+04	7.2065E+03	5.2593E+02	1.0043E+03	2
3.8815E+04	9.2655E+03	5.1964E+02	8.0850E+02	2
3.8815E+04	1.1325E+04	5.1474E+02	5.8669E+02	3
3.8815E+04	1.3384E+04	5.1535E+02	3.5187E+02	4
3.8815E+04	1.5443E+04	5.1208E+02	2.7202E+02	5
3.8815E+04	1.7502E+04	5.1623E+02	2.6112E+02	5
3.8815E+04	1.9561E+04	5.3210E+02	2.3580E+02	6

1

3.8815E+04	2.1620E+04	5.4258E+02	2.0796E+02	6
3.8815E+04	2.3679E+04	5.5119E+02	1.5122E+02	5
3.8815E+04	2.5738E+04	5.5741E+02	8.4448E+01	5
3.8815E+04	2.7797E+04	5.5925E+02	6.0795E+01	5
3.8815E+04	2.9856E+04	5.5699E+02	1.0764E+02	5
3.8815E+04	3.1915E+04	5.5207E+02	2.2061E+02	5
3.8815E+04	3.3974E+04	5.4425E+02	3.7643E+02	4
3.8815E+04	3.6033E+04	5.4319E+02	5.5771E+02	3
3.8815E+04	3.8092E+04	5.4327E+02	7.4825E+02	3
3.8815E+04	4.0151E+04	5.4523E+02	9.3066E+02	3
4.1033E+04	1.0295E+03	5.1900E+02	1.5343E+03	1
4.1033E+04	3.0885E+03	5.1900E+02	1.4362E+03	1
4.1033E+04	5.1475E+03	5.1900E+02	1.3083E+03	1
4.1033E+04	7.2065E+03	5.1900E+02	1.1562E+03	1
4.1033E+04	9.2655E+03	5.2421E+02	9.8809E+02	2
4.1033E+04	1.1325E+04	5.2024E+02	7.8750E+02	3
4.1033E+04	1.3384E+04	5.1673E+02	6.6705E+02	3
4.1033E+04	1.5443E+04	5.1308E+02	5.8028E+02	4
4.1033E+04	1.7502E+04	5.1715E+02	5.4494E+02	4
4.1033E+04	1.9561E+04	5.3697E+02	4.4706E+02	5
4.1033E+04	2.1620E+04	5.4709E+02	3.8195E+02	5
4.1033E+04	2.3679E+04	5.5629E+02	2.9830E+02	5
4.1033E+04	2.5738E+04	5.6264E+02	2.2736E+02	5
4.1033E+04	2.7797E+04	5.6509E+02	2.1085E+02	5
4.1033E+04	2.9856E+04	5.6368E+02	2.7051E+02	5
4.1033E+04	3.1915E+04	5.5641E+02	3.9733E+02	4
4.1033E+04	3.3974E+04	5.4992E+02	5.5730E+02	4
4.1033E+04	3.6033E+04	5.4966E+02	7.3401E+02	3
4.1033E+04	3.8092E+04	5.4888E+02	9.0284E+02	3
4.1033E+04	4.0151E+04	5.4971E+02	1.0533E+03	3
4.3251E+04	1.0295E+03	5.1900E+02	1.5791E+03	1
4.3251E+04	3.0885E+03	5.1900E+02	1.5070E+03	1
4.3251E+04	5.1475E+03	5.1900E+02	1.4129E+03	1
4.3251E+04	7.2065E+03	5.1900E+02	1.3009E+03	1
4.3251E+04	9.2655E+03	5.1900E+02	1.1812E+03	1
4.3251E+04	1.1325E+04	5.2726E+02	9.7123E+02	3
4.3251E+04	1.3384E+04	5.2442E+02	8.8847E+02	3
4.3251E+04	1.5443E+04	5.2321E+02	8.2518E+02	3
4.3251E+04	1.7502E+04	5.2350E+02	7.8506E+02	4
4.3251E+04	1.9561E+04	5.2893E+02	7.5431E+02	4
4.3251E+04	2.1620E+04	5.3570E+02	7.0822E+02	4
4.3251E+04	2.3679E+04	5.6028E+02	5.0843E+02	5
4.3251E+04	2.5738E+04	5.6607E+02	4.4445E+02	5
4.3251E+04	2.7797E+04	5.6654E+02	4.3202E+02	4
4.3251E+04	2.9856E+04	5.6409E+02	4.8749E+02	4
4.3251E+04	3.1915E+04	5.5940E+02	5.9884E+02	4
4.3251E+04	3.3974E+04	5.5804E+02	7.4511E+02	3
4.3251E+04	3.6033E+04	5.5545E+02	8.9538E+02	3
4.3251E+04	3.8092E+04	5.5418E+02	1.0346E+03	3
4.3251E+04	4.0151E+04	5.5417E+02	1.1527E+03	3

```
Nargund-Navalgund area
groundwater flow  and contaminant modelling year1980
    5    0    0    1    0    0    0    0    0
   20   20    3    2    0    1    3   -1    0  240  400    1    0    0
    0    0    0    0
 .3000E-08 .2200E-08 .0000E+00 .9980E+00 .2700E+02
 .3180E+02 .3180E+02 .3180E+02 .1000E+01 .1500E+03 .1500E+02 .9300E-04
 .1710E+03 .1000E+03 .1000E+03 .6240E+02 .6240E+02
    0    0    0    2
 .6800E+02 .1000E+01 .6800E+02 .1000E+01
   -20.000      98.000
   165.000      98.000
    0    0
 .6800E+02 .0000E+00  -15.0     .0000E+00
20*640.25/
20*302.5/
50.  30.  85./
 1.0        1.0       1.0        0.3       .0000E+00 .0000E+00    25.
    1   20    1   20    1    1
0885.0     0885.0    088.50     0.35        0.0        0.0      0.0
    1   20    1   20    2    2
 8.836      8.836    0.8836     0.45        0.0        0.0      0.0
    1   20    1   20    3    3
 42.25      42.25    4.2250     0.01        0.0        0.0      0.0


    4    1
    1    1    1   01    1    1
    1.0      12.24      68.00    .000048
    1    1    5    5    1    1
    1.0      16.28      68.00    .001976
    1    1   10   10    1    1
    1.0      15.95      68.00    .002964
    1    1   15   15    1    1
    1.0      17.22      68.00    .003952
    1    1   20   20    1    1
    1.0      10.73      68.00    .004
   20   20    1   01    1    1
    2.0      -8.07      68.00    .000686
   20   20    5    5    1    1
    2.0      -8.4       68.00    .000899
   20   20   10   10    1    1
    2.0      -9.1       68.00    .001113
   20   20   15   15    1    1
    2.0     -10.04      68.00    .001326
   20   20   20   20    1    1
    2.0      -5.23      68.00    .001540
    5   05    1    1    1    1
    3.0       5.62      68.00    .000159
   10   10    1    1    1    1
    3.0      -1.48      68.00    .000367
   15   15    1    1    1    1
    3.0      -6.65      68.00    .000526
    5   05   20   20    1    1
    4.0       8.44      68.00    .003385
   10   10   20   20    1    1
    4.0      -0.47      68.00    .002770
   15   15   20   20    1    1
    4.0       1.68      68.00    .002115
    1    1    1   01    2    2
    1.0      29.57      68.00    .000048
    1    1    5    5    2    2
    1.0      33.60      68.00    .001976
    1    1   10   10    2    2
    1.0      33.28      68.00    .002964
    1    1   15   15    2    2
```

```
1.0     34.54     68.00    .003952
1    1    20    20    2    2
1.0     28.06     68.00    .004
20    20    1    01    2    2
2.0     9.25     68.00    .000686
20    20    5    5    2    2
2.0     8.93     68.00    .000899
20    20    10    10    2    2
2.0     8.23     68.00    .001113
20    20    15    15    2    2
2.0     7.29     68.00    .001326
20    20    20    20    2    2
2.0     12.10     68.00    .001540
5    05    1    1    2    2
3.0     22.95     68.00    .000159
10    10    1    1    2    2
3.0     15.85     68.00    .000367
15    15    1    1    2    2
3.0     10.68     68.00    .000526
5    05    20    20    2    2
4.0     25.77     68.00    .003385
10    10    20    20    2    2
4.0     16.86     68.00    .002770
15    15    20    20    2    2
4.0     19.01     68.00    .002115
1    1    1    01    3    3
1.0     54.49     68.00    .000048
1    1    5    5    3    3
1.0     58.53     68.00    .001976
1    1    10    10    3    3
1.0     58.20     68.00    .002964
1    1    15    15    3    3
1.0     59.47     68.00    .003952
1    1    20    20    3    3
1.0     52.98     68.00    .004
20    20    1    01    3    3
2.0     34.18     68.00    .000686
20    20    5    5    3    3
2.0     33.85     68.00    .000899
20    20    10    10    3    3
2.0     33.15     68.00    .001113
20    20    15    15    3    3
2.0     32.21     68.00    .001326
20    20    20    20    3    3
2.0     37.02     68.00    .001540
5    05    1    1    3    3
3.0     47.87     68.00    .000159
10    10    1    1    3    3
3.0     40.77     68.00    .000367
15    15    1    1    3    3
3.0     35.60     68.00    .000526
5    05    20    20    3    3
4.0     50.69     68.00    .003385
10    10    20    20    3    3
4.0     41.78     68.00    .002770
15    15    20    20    3    3
4.0     43.92     68.00    .002115

1    0    0
1    20    1    20    1    3    0.0

1    1    1    0    0    0    0    0    0    1    0
2    0.5
1    20    1    20 0.006400
```

```
    5
01836.36  1836.36    1836.36   1836.36   1836.36
   1    5    5    1    1    1
 331.25      10.83     68.00     .0005
   2    5   15    1    1    1
 331.25      10.83     68.00     .0005
   3   10   10    1    1    1
 331.25      10.83     68.00     .0005
   4   15    5    1    1    1
 331.25      10.83     68.00     .0005
   5   15   15    1    1    1
 331.25      10.83     68.00     .0005

   0.0       0.0       0.0       0.0       0.0       0.0       0.0
   0    0    0    0   -1    0  010    0 0100    1   11    0    0    0
   0    0    0
  10.0      5.53
   1   20    1   20    1    3  -3.4666   5.20
   0    0    0    1
```

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