

Hydrogeochemical Behavior in the Central Mahaweli Basin of Sri Lanka.

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The chemical behavior of natural waters within the Central Mahaweli basin is examined. Water samples, 49 in 1996 and 46 in 1997, were collected from rivers, surface streams, ponds, dug wells and tube wells in the area for two different seasons and analyzed for number of chemical parameters. Major cations (Na^+ , Ca^{2+} , K^+ , Mg^{2+}) and anions (SO_4^{2-} , CO_3^{2-} , HCO_3^- , Cl^-), total Fe, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Total Hardness (TH) were measured and plotted in several classification diagrams. The geographic distribution of pH in ground and surface waters varies between 5.65 to 8.00 in the dry season and 5.41 to 8.98 for the wet season. EC varies from 20 to 880 $\mu\text{S}/\text{cm}$. Ground water shows higher EC than the surface water specially in the dry season. However, there is no such relation in the wet season. TDS vary between 12 to 608 ppm in the dry season and 19 to 1280 ppm in the wet season. Low TDS may result due to lack of soluble materials in the crystalline hard rock terrain. Semi-logarithmic plots of $\text{Na}^+ / (\text{Na}^+ + \text{Ca}^{2+})$ vs. TDS and $\text{Cl}^- / (\text{Cl}^- + \text{HCO}_3^-)$ vs. TDS for the water samples show high abundance of Ca^{2+} and HCO_3^- . The analytical results show following types of water. During the wet season $\text{Ca}^{2+} + \text{Mg}^{2+}$ and HCO_3^- dominant and during the dry season $\text{Na}^+ + \text{K}^+$ and HCO_3^- dominant. Sulfate content in the dry zone (0 - 54 ppm) is higher than that in the wet zone (0 - 20 ppm), and this may result due to high evaporation. Logarithmic plot of Mg vs. Ca show samples collected in the wet season fall within the range of $\text{Mg}/\text{Ca} = 0.1$ to 1.0 however, in the dry season, they fall within $\text{Mg}/\text{Ca} = 0.1$ to 10.0. The waters in the region can be classified as low salinity - low sodium and medium salinity - low sodium categories. Total hardness varies between 11 to 811 ppm. However, based on the carbonate hardness, 30 % of the samples collected in the wet zone are fallen into very hard water type, while in the dry zone most fallen into moderate soft type.

INTRODUCTION

Analysis of chemical behavior of waters in a region is very important in assessing and understanding the available water quality and in implementing water supply programs. A number of studies related to hydrochemistry of ground and surface waters in the Kandy district have been completed (Dissanayake and Hapugaskumbura, 1980; Weerasooriya and Dissanayake, 1986). However, the effects of different water bodies on the hydrochemical regime have not been investigated. Since, these effects may provide significant indications, which can be used to maintain the total environmental balance of a region, we carry out this study, during the period between 1996 June to 1998 March, to examine the relation.

The study comprises field, laboratory and desktop studies, and aims to discuss the hydrochemical behavior of water in the central Mahaweli Region of Sri Lanka. The study area is characterized by extremely complex and variable patterns of relief. Even though intermittent agricultural land-use is noted, forest cover mainly underlies the study area. This study includes chemical analysis of water samples from six catchments (micro basins and inter basins) which cover an area of about 150 km^2 (about 58 mile^2) within the central part of the country. The study area is located within the coordinates $7^\circ 05'$ to $7^\circ 22'$ N and $80^\circ 37'$ to $80^\circ 61'$ E (Fig. 1).

CONCISE ANALYSIS OF OVERALL HYDROLOGY

Rainfall Pattern and Distribution

The Central Mahaweli region lies in the rain shadow of the Knuckles Range and the main mass of the hill country. This area comprises a greater part of the intermediate climatic zone of Sri Lanka. This section provides an analysis of the total hydrological cycle and its overall behavior both in "Time" and "Space". The data were collected from the Meteorology department, Mahaweli Authority and Upper Mahaweli Forest Conservation Division of Sri Lanka.

The precipitation, controlled by ITCZ (Intra Tropical Convergence Zone) and orographic effects, show distinct bimodal distribution with peaks from December to February (northeast monsoon) and from May to September (southwest monsoon). The distribution shows a tendency to decrease the rainfall from south to north and northeast (Fig 2). The highest rainfall usually receive during the northeast monsoon and preceded inter monsoon convection rains. The average annual rainfall for these areas vary between 2000 to 3400 mm and generally increases northwards in many of the catchments. The average annual temperatures vary between 20.0° and 22.5° C. It decreases towards the Central Highlands with the increase of the altitude.

The sunshine hours are also significant mainly to assess the humidity, evapotranspiration etc. It is noted that the sunshine hours are in the range of 9-10 hrs and may vary in the rainy season some time being very low due to cloud cover. Deciduous, broad leaf trees are common within the wet regions and which replaced by thorny bushes in the northeastern dry part of the project area. This vegetation cover directly affects the amounts of evapotranspiration. However, after the introduction of by laws and the vigorous forestry program, it is noted that the ET is maintained close to potential value. As has been noted that the Kandy has fairly high Potential Evapotranspiration of 1578.63 mm (Dharmasena, 1990), the above factors should be thoroughly examined. In general discharging zones close to lower reaches of small and large stream segments provide water with high EC.

Streams, Perennial and Seasonal

Except Uma Oya, other basins in the study region represented by up to 4th and 5th order streams (based on Strahler, 1957). Most of them flow along the valleys formed by prominent geological structures such as joints, fracture zones, lineaments, and geologically weak rocks such as marble, khondalite and biotite gneiss layers. Development of different morphological features within the area is related to the underlain geology and the prevailing geological structures. Streams belonging to 1st and 2nd orders are either intermittent or depend on seasonal rainfall. Certain 3rd order streams draining within smaller catchment areas or those belong to the dry or the intermediate zone may have seasonal discharges. However, certain 1st and 2nd order streams in the wet highlands have perennial discharges (Suhail, 1997). Based on point discharge observation, the following ranges of values have been obtained for Uma Oya, Kurundu Oya and Belihul Oya basins during the dry season (March to end of September). However, they represent only point values and one may have to select suitable control to obtain more realistic measurements.

1 st order	-	2.5 m ³ /s
2 nd order	-	20 m ³ /s
3 rd order	-	200-250 m ³ /s

In the rainy season (November to February end), the discharge values are very much different and vary with the precipitation intensity and increase by several folds. The measurements as collected by the Upper

Mahaweli Forest Conservation Division indicate an annual discharge value of $56 \times 10^6 \text{ m}^3$ for the Uma Oya catchment. The flood plain deposits are good for crop vegetation. Therefore, number of cash crops or paddy lands are associated with them. The soil moisture is fairly high in the clay rich overburden. The thickness, soil type, soil moisture and cropping pattern within the drainage basins may be changed with the perennial and seasonal streams.

PHYSICAL SETTING

Land use

Several distinctive land-use areas have been identified in the Central Mahaweli Region. The permanently cultivated lands are largely confined to the western end and strips of land occupying the wetter, higher areas on the southern slopes of the Knuckles Range and the northern slopes of the main hill country.

Soil types

Major soil groups in the region are Red Brown Earth (RBE) and Low Humic Gley (LHG). However, some areas consist of Red Yellow Podzolic (RYP) soils (Panabokke, 1996). In general the flood plains have five to nine meters thick alluvial soils which are tapering off close to the adjacent residual soils or rock outcrops. Colluvial soils are also found in certain parts, which usually formed uniform slopes, while hummocky and carved topography occurred in the eroded regions (Suhail, 1997).

Geology and structure

This area occupied high-grade, lithologically and isotopically distinct, Proterozoic metamorphic rocks, which belongs to the Highland Complex of Sri Lanka (Cooray, 1984; Kröner *et. al.*, 1991). Major rock types of this area are:

1. Quartzite and quartz schist
2. Charnockitic Gneisses
3. Garnet-Biotite-Sillimanite Gneiss \pm Graphite
4. Undifferentiated charnockitic biotite gneiss
5. Marble (crystalline limestone)

The general strike of these units aligned in the north-south direction. In general most of the highest order streams usually follow the same trend. Poly-metamorphic structures are common in the area, where Palugama antiform is one major fold with the axis having a same trend as above. Several major lineaments

showing different orientations intersect the study area. A number of pegmatite bodies are also found along the left and right banks of the Randenigala reservoir.

Vegetation

Intermediate dry evergreen forests are present in the study area (Gunathilleke and Gunathilleke, 1990). Since, many parts of the area being degraded by various man made practices, such as chena cultivation and forest fires, secondary forests have been later occupied the region. This sparsely distributed forests show open canopy with savannah grasslands at places, which may quite significant in terms of hydrologic analysis. Riverine vegetation is associated with the streams and rivers.

METHODS OF STUDY

Background Materials

The aerial photographs (1:40,000), topographic and orographic maps (Kandy and Rangala 1 inch sheets) were used to identify major structures, fault zones, geomorphological variations and drainage patterns. The water divide for the drainage basin were later demarcated and several micro and inter basins were identified. Basic geologic analyses were carried out to obtain the overall geologic information.

Water sampling procedure

First batch of sampling was carried out during the dry June/July period, and subsequently second batch of sampling was completed in the wet Nov/Dec period in 1996. These samples were collected from different water bodies, either artificial or natural. In addition, another set of samples was collected with in the more wet areas close to Kandy in the year 1997. The first batch was collected again in the dry June/July and the second batch in Nov/Dec, 1997. In these sampling programs the following water bodies were selected; viz.; the rivers, streams, springs, shallow dug wells, tube wells and major reservoirs. The sampling locations were presented in *fig 1*.

Storage and Preservation

Proper storage and preservation minimizes contamination risk and destabilization of the chemical elements in the water. Hence actual chemical quality of the samples will retain

within the range of acceptable accuracy. Analyses for chemical constituents were carried out within a week of sampling. Sample bottles were thoroughly cleaned by soaking overnight in 2-5 N HCl acid and rinsed out. In addition, they were washed out by respective water during sampling operation. Filtration of the samples was preceded using a filter with pores having diameter of 0.45 μm . Since, pH and EC values are fluctuated with temperature; they were measured as "insitu" tests. For bicarbonate and chloride, samples were acidified with Ultra R grade HCl of 3 ml/l.

Analytical Techniques and Methods

American Standard Testing Methods (ASTM) were adopted to determine the chemical constituents and related parameters. Methods used are given below briefly. EC and pH were measured at the sampling site. EC was measured with a portable conductivity meter (HORIBA-DS-7), which has a facility of adjusting the temperature at desired levels. HANNA-HI 8519-Membrane pH meter with digital display was used to obtain pH. The temperature of the sample was measured using a thermometer having accuracy up to 0.1°C.

Calcium, Magnesium, Sodium, Potassium and Total Ferrous

Major cations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) and Minor cations (Total Fe) were determined using high sensitive atomic absorption spectrophotometer (AAS) – Buck SCIENTIFIC 200-A. The calibration curve of concentration vs. absorption is plotted for known standard solutions of a particular element using the AAS. Absorption value of the sample is measured and corresponding concentration to the sample is obtained using the above calibration curve. If the samples contain high concentration of a particular element, the dilution is preceded before the analysis until the elemental concentration lies within the optimum range.

Sulfate (SO_4^{2-})

Sulfate was determined by turbidimetric method using spectrophotometer. Sulfate ions are precipitated in a HCl / Glycerin medium with BaCl_2 as uniform size of Barium Sulfate (BaSO_4) crystals. The absorbency of this suspension solution is measured spectrophotometrically at 420nm.

Chloride (Cl)

MODEL EE-Cl Iron selective electronic method used in chloride determination. Electric potential of the sample is obtained with respect to chloride concentration, after addition of buffer solution $\text{CH}_3\text{COOH}:\text{CH}_3\text{COOCH}_3$ of 1:1 ratio. Concentration of the sample can be obtained with the calibration curve plotted for known standard of chlorides.

Bicarbonate (HCO_3^-)

Titrimetric method was used to analyze the bicarbonate concentration of the samples. The sample is titrated electrometrically with 0.01 M Sulfuric acid while pH being monitored through out using a digital pH meter (CD-740). The inflection point of the drawn curve for the titration, in the region of pH 4.5 is taken as end point volume. Following equation gives the bicarbonate concentration in mg/l.

$$(\text{HCO}_3^-) = (2440/S)(V_2 - V_1)$$

where,

S = Volume of sample in ml.

V_2 = ml of HCl required for titration to pH 8.3.

V_1 = ml of HCl required for titration (pH 8.3 - 4.5)

Total Dissolved Solids and Hardness (TDS and TH)

Standard formulae were used to obtain TDS and TH as given below.

$$\text{TDS (in ppm)} = 0.64 \text{ EC } (\mu\text{s/cm})$$

$$\text{TH (in ppm)} = 2.497 \text{ Ca (in ppm)} + 4.115 \text{ Mg (in ppm)}$$

Sodium Adsorption Ratio

SAR is calculated using the following formulae. $\text{SAR} = \text{Na} / \sqrt{\{(\text{Ca} + \text{Na})/2\}}$, where, Na and Ca are in milli-equivalents per liter.

Accuracy and Precision of Analytical method

Accuracy and Precision of the complete analysis for the major ions have been estimated by checking the Electronutrality (Powell, 1964).

$$\text{Electronutrality} = \frac{(\text{Sum of cations}) + (-\text{Sum of anions})}{(\text{Sum of cations}) + (-\text{Sum of anions})} \times 100$$

For the above equations, the concentration are given in meq/l and if electronutrality is less than 5.0 %, analysis is considered to be correct and if it is less than 2.0 % it is excellent.

RESULTS AND DISCUSSION

Chemical quality of the water

The analytical results of water samples collected in two seasons for 1996 and 1997 were shown (Appendices I, II, III and IV). The following chemical parameter variations are provided for the interpretations.

Variation of pH in the area

Many natural chemical reactions, such as oxidation, hydrolysis, hydration and carbonation are controlled by the H^+ concentrations in the aqueous media (Hem et al., 1967; Hem, 1985). The chemical and physical quality of water strongly affects the solubility of substances such as iron, aluminum, manganese, which becomes more soluble at different pH values. For instance at pH 6.00 Mn become insoluble and at 8.50 Fe become insoluble (Driscoll, 1986). Soluble iron present in the soil and in river water at pH between 6.5-7.5 will precipitate when it reaches to the sea. The geographic distribution of pH in ground and surface waters varies between 5.65 to 8.00 in the dry season and 5.41 to 8.98 for the wet season.

Table: 1 pH ranges for different seasons and water bodies

Season	Reservoirs	Springs	GW bodies	SW bodies
June/July 1996	7.30-7.80	6.20-7.50	6.50-6.90	6.20-8.00
Nov/Dec 1996	7.53-8.98	7.40-7.96	6.72-8.15	6.20-8.16
June/July 1997	5.65-7.60	6.77-7.28	5.90-7.07	5.65-7.60
Nov/Dec 1997	5.41-8.31	*	5.41-6.84	6.66-8.31

* Springs were not sampled

The above table indicates that the pH range for the wet season collection shows higher values, which indicates the presence of alkaline materials within the system. On the other hand, the groundwater sources for both the years show that the highest value within the range is always lower than that of the surface waters. This may represent the near neutral conditions for the groundwater. Considering the variation of water samples in both seasons, the waters in the Central Mahaweli Region is slight acidic-neutral-slight alkaline type with in the acceptable limits for drinking (WHO, 1984) and irrigation purposes (U.S. Salinity Laboratory, 1954).

The variation of EC

Electrical Conductivity (EC) is a measure of dissolved ions in water. EC varies from 20 to 880 $\mu\text{s}/\text{cm}$, except few anomalous samples that show 1000 $\square\text{s}/\text{cm}$ for a spring and 2000 $\square\text{s}/\text{cm}$ for dug well. Generally ground water shows higher EC than the surface water bodies such as streams and rivers. This is quite significant in the dry season. However, in the wet season, there is no such relation. The EC of samples collected from Kimbulantota where marble rock was found closer to the locations show general higher values. In addition the Ca contents are also higher in these samples. Therefore, it can be concluded that the dissolution of marble has contributed for the high EC in such areas. Samples collected from same locations but with different sources show different EC values. The high EC values in the stagnant bodies or ground water may attribute to the fact that these sources show accumulation of chemical constituents with in the system than the flowing water.

Distribution of TDS

Physical and chemical properties of water mainly depend on TDS content. If TDS is greater than 1000 ppm, the water is not acceptable for drinking. In irrigation practices, the TDS is extremely important and sensitive to crop patterns. TDS in water of Central Mahaweli Region is relatively low. This may be due to the fact that lack of soluble material in the crystalline hard rock terrain or due to rapid runoff along the drainage network.

TDS content mainly dependent on evaporation rate and precipitation. In general, waters from quartzite and marble pose fairly low TDS content whereas basic and ultrabasic rocks have high TDS. The composition of groundwater naturally reflects the underlying geology and the residence time where the water in contact with the rock through the flow path.

TDS varies from 12.8 to 457.6 for the samples collected in June/July while it varies from 20.61-1280.0 for the samples collected during Nov/Dec. Since, the EC is closely related to TDS, The localities, which pose the higher EC, show the higher TDS. The semi-logarithmic plots of TDS vs. $\text{Na}^+(\text{Na}^++\text{Ca}^{2+})$ and TDS vs. $\text{Cl}/(\text{Cl}^++\text{HCO}_3^-)$ for all the water samples collected from different sources are shown in the *Figures 3a, 3b, 3c and 3d*.

Gibbs, 1970, stated that if the ratios of

$\text{Na}^+(\text{Na}^++\text{Ca}^{2+})$ and $\text{Cl}/(\text{Cl}^++\text{HCO}_3^-)$ for the water are close to 1.0 or the TDS content is close to 10 ppm, the chemical constituents in natural waters usually reflect the chemistry of atmospheric precipitation. However, streams having higher TDS (70-300 ppm) or have the above ratios of 0.5 or less show the maximum influence of interaction with rock or the results of evaporation and precipitation of CaCO_3 from the solution. These figures (Corbett, 1979) show that the analytical results for water samples are highly skewed towards the TDS axis indicating high concentration of HCO_3^- with respect to Cl^- .

Piper Trilinear diagram

The piper diagram is a multiple-trilinear diagram for graphical representation of the major chemical constituents of water. It sufficiently portrays analytical data of dissolved constituents also used to classify a sample as a water type. Major cation and anion distributions in the Central Mahaweli Region are illustrated in *figures 4a, 4b, 4c and 4d* for the dry and wet seasons during 1996 and 1997. The prominent fact shown by the diagrams is that the SO_4^{2-} content in the water samples is very low, especially in Nov/Dec season. Ca^{2+} and Mg^{2+} correlate very closely with HCO_3^- , and the greater proportion of CaHCO_3^- reflects the influence of reaction with the geologic terrain.

According to the Piper (1944) diagram the waters can be classified as Ca dominant type, Na^++K^+ dominant or Mg dominant type with cation concentration, $\text{CO}_3^{2-} + \text{HCO}_3^-$ type or non-dominant $\text{SO}_4^{2-} + \text{Cl}^-$ type with the anion concentration. The waters in the Central Mahaweli Region can classify as Ca and Mg dominant type with $\text{CO}_3^{2-} + \text{HCO}_3^-$. This is clearly shown in *Fig. 4b and 4d* for the Nov/Dec season. However, about 40% of the samples collected for June/July season are shown that they are Na^++K^+ dominant types with mainly $\text{CO}_3^{2-} + \text{HCO}_3^-$ (*Fig. 4a and 4c*).

Quality class ratings of water for Drinking and Irrigation purposes

As shown in the Na - Salinity hazard diagrams (U.S. Salinity laboratory Staff, 1954) samples for all locations have fallen into Low-Salinity Low-Sodium (C1-S1) and Medium-Salinity Low-sodium (C2-S1) categories. There is one sample falls into C3-S1 category where it was collected during Nov/Dec 1996 (*Figs. 5a, 5b, 5c and 5d*). The sample collected from a marshy land where no irrigation is taking place.

However, the adjacent lands have been irrigated through good water management and by proper drainage systems, which control the salinity.

Lithology that is in contact with water will add inorganic chemical constituents to the waters (Jayasena and Dissanayake, 1995). However, the wet climate in the region may dilute these constituents and control the salinity producing good quality water for drinking and irrigation purposes (WHO, 1984).

Distribution of Hardness

Hardness in water is primarily the result of interaction between water and geological formations. Water either flowing through or over the bedrock may provide the necessary elements for the hardness. Carbonate (CO_3) equilibrium in the water system greatly controls the abundance of Ca and the value of pH in water. Hardness is calculated in many ways,

- (1) CO_3 Hardness [$(\text{CO}_3^{2-} + \text{HCO}_3^-)$ ppm]
- (2) (Ca+Mg) Hardness

Carbonate Hardness

Carbonate hardness is varies from 10.90 to 811.30 ppm in the Central Mahaweli Region. Observing the data, 30% of the samples are fallen into very hard water type. 50% - 60% of the samples are of soft to moderately soft water. In the Nov/Dec period, the CO abundance is quite higher than the June/July period.

Total Hardness

Total hardness is mainly depending on the presence of alkaline elements of Ca and Mg. Other elements such as Sr, Ba, Fe, Mn and Al, though present, are not normally detectable at sufficient quantities to affect the hardness.

Total hardness is calculated from Mg and Ca concentration. In the Central Mahaweli Region, the TH is varying within 17.80 - 156.0 ppm for June/July period and 9.13 - 611.37 for Nov/Dec. The maximum desirable level is 250.0 ppm as CaCO_3 and maximum permissible level is 600.0 ppm (SLS is 614 in 1983). Except several samples, most are within the maximum desirable level. But the L6 is a shallow dug well directly overlies on CO deposit soil layer, which shows 611.37 ppm.

Log-Log plot of Mg vs. Ca (Figs. 6a, 6b, 6c and 6d) shows the Mg/Ca ratio and relative positions of water samples. All the samples collected except few springs in Nov/Dec season

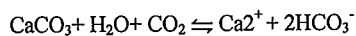
are fallen into $\text{Mg/Ca} = 0.1$ to 1.0 . This indicates higher Ca content than Mg in the wet season. However, for June/July season more samples within the $\text{Mg/Ca} = 1$ to 10 . Therefore, during the dry period, Mg existence or accumulation may pronounce.

Sulfate (SO_4^{2-})

Sulfate SO_4^{2-} content of water samples is not quite considerable. High amounts are expected where water draining areas are underlain by volcanic rocks or the oxidized zones of sulfide ore deposits such as Sphalerite (ZnS), Galena (PbS) and specially Pyrite (FeS). The study area though underlain by Precambrian metamorphic rocks, intermittent sulfide enrichments associated with pegmatite bodies are noted. It is well seen that the SO_4^{2-} content in the groundwater is fairly low, however, in several locations in the wet region, it has significant concentrations. It has been observed in the other parts of the world that SO_4^{2-} is not significant in the surface waters and ground waters (Hem, 1985).

CONCLUSION

The present study examined an area covering six major basins, within which sampling for two different seasons were performed. It is noted that certain specific ion enrichments present within different water bodies of the region have direct relationship to the season and the rock types. It is very clear that $\text{HCO}_3^- \gg \text{Cl}^- > \text{SO}_4^{2-}$. The latter relation is obliterated when water collected from the wet zone. For cations $\text{Ca}^{2+} > \text{Mg}^{2+} \gg \text{Na}^+$ however, in certain location and Mg^{2+} may have higher vales than Ca^{2+} . Abundant Ca^{2+} and Mg^{2+} in the water directly related to the marble and secondary calcite formation. Calcite is more soluble under earth surface conditions and produced Ca^{2+} and HCO_3^- into 1:1 equivalent ratio by the following equation.



On the other hand $\text{Na}^+ \gg \text{K}^+$ indicating that the Na^+ bearing mineral percentage than the K^+ bearing ones. The abundant charnockite and biotite gneiss may produce the necessary Na^+ while the K-Feldspar may provide the K^+ . EC, TDS and TH show linear relationship. Based on the salinity diagram waters can be used for agricultural purposes. However, for more realistic interpretations, we proposed to carry out a detailed investigation supported by a controlled sampling program.

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APPENDIX I - CHEMICAL ANALYTICAL DATA OF WATER SAMPLES COLLECTED IN JUNE-JULY 1996

Sam-no	Temp	PH	EC	TDS	HCO	CL	SO	Ca	Mg	Na	K	Fe	T.H	SAR
S1	25.5	6.7	205	131	99.02	10	5.5	2.75	19	9.1	1.08	0.2	84.78	0.431
S2	25.6	7.2	180	115	66.26	5	5.55	2.53	11.6	8.5	0.34	0.2	53.89	0.493
S3	25	7.5	295	119	113.06	3.9	5.6	4.05	18.85	8.8	3.28	0.7	87.41	0.407
S4	25	8	350	224	13024	4.2	4.1	2.75	1.9	2.7	2.34	1.5	14.67	0.308
S5	25.4	7.8	275	176	16.41	4.4	8	2.7	3.3	2.92	2.34	0.3	20.28	0.282
H1	26.2	6.2	670	426	45.64	4.4	10	9.45	3.92	8.4	2.03	0.1	39.69	0.629
T2	25.5	7.3	90	58	41.67	3.4	10.6	4.7	4.89	8.08	2.26	2	31.8	0.629
WF2	24.5	7.5	90	57	2.25	3.8	2.02	0.55	0.35	2.8	0.46	2	2.81	0.718
WF4	25.4	7.5	145	93	2.92	4.2	10.6	0.5	0.3	3.15	0.26	0	2.48	0.856
BA1	26	7.5	430	275	72.91	7	7.02	5	12.1	7.72	2.76	5	62.11	0.425
HA1	26	7.5	920	589	39.66	3	7	4.4	6.05	5.12	1.64	0	35.8	0.372
RB3	25.6	6.5	520	333	101.89	4.6	4.6	7.55	13.5	8.32	2.04	2.5	74.23	0.421
RB2	26	7.6	400	256	98.31	2.1	3.2	15.57	11.32	3.44	2.1	0	85.34	0.162
RB1	25.5	6.5	900	576	173.65	7	10.75	45.78	10.78	3.55	2.4	0	158.65	0.123
WF3	25.5	7.8	240	154	60.31	5.64	2.1	13.45	5.23	3.21	2.1	0	55.07	0.188
K1	26.5	7.8	180	115	63.72	4.2	11.91	15.67	6.25	2.31	2.3	0.2	64.8	0.125
ME1	25.5	7	120	77	53.64	3.2	11.91	11.9	4.56	5.63	2.1	0	48.45	0.352
ME2	25.6	6.5	90	58	73	4.75	14.81	14.78	8.32	4.62	2.6	0	71.06	0.238
ME3	25.6	6.5	85	54	66.14	4.75	3.2	10.78	5.21	6.53	2.1	2	48.31	0.409
ME4	26	6.5	84	54	51.83	4.77	5.2	9.67	4.36	4.56	2.3	0	42.05	0.306
ME5	25.6	7	40	26	42.23	2.31	4.2	5.98	5.25	2.22	2.5	0	36.48	0.161
SU1	26.5	6.9	300	192	86.38	8.45	22.41	20.89	9.32	6.23	2.3	2	90.44	0.285
SU2	25.6	6.7	360	230	105	9.4	20.41	25.67	11.23	4.52	3.4	0	110.22	0.187
H2	25.5	6.5	950	608	168.52	9.87	23.71	45.78	12.36	6.12	8.1	0	165.13	0.207
T1	26.5	6.2	110	70	37.72	8.45	13.17	13.89	4.23	2.11	2.33	0	52.07	0.127

APPENDIX II - CHEMICAL ANALYTICAL DATA OF WATER SAMPLES COLLECTED IN NOV-DEC 1997

Sam-no	Temp	PH	EC	TDS	HCO	CL	SO	Ca	Mg	Na	K	Fe	T.H	SAR
L1	22	7.57	41.6	27	12.99	2.56	4.56	2.4	1.52	2.4	1.3	0.02	18.23	0.298
L2	25.6	7.66	56.6	36	22.76	4.75	3.64	6	1.68	2.4	1.9	0	21.89	0.223
L3	23.6	7.55	148.7	95	37.11	1.15	8.18	4.4	4.88	3.1	2.5	0.02	31.01	0.242
L4	23.7	8.16	162.5	104	22.78	4.41	15.94	4.8	5.08	3	2.05	0.02	32.83	0.227
L5	22.6	7.21	47.4	30	11.9	2.89	0.7	2	0.88	2.5	0.3	0.07	8.61	0.371
L6	21.6	7.88	63.1	40	16.1	4.13	5.13	4	1.56	2.45	2	0.02	16.4	0.263
L7	21.9	7.56	29.8	19	8.82	1.42	1.82	1.2	0.92	1.7	0.6	0.02	6.77	0.284
L8	24	7.72	63	40	12.34	4.83	2.43	3.6	1.08	2.45	0.9	0	13.43	0.291
L9	24.5	6.2	39.5	25	10.55	0.55	0.35	1.2	1	2.45	0.4	0.02	7.1	0.4
L10A	26.5	6.72	391	250	144.97	4.79	9.08	37.76	8.8	2.8	1.65	0.02	130.48	0.106
L10B	26.4	7.96	340	218	172.2	8.34	14.52	37.6	15.88	2.8	2.65	0	159.48	0.096
L11	25	7.77	184.5	118	44.06	5.8	3.7	8.8	4.4	2.9	1.75	0.02	40.04	0.199
L12	25.6	8.15	525	336	222.64	5.69	9.63	49.6	17	2.8	2.05	0.02	196.16	0.087
L13	25.6	7.51	490	314	210.43	5.82	23.66	57.6	12.8	2.8	2.3	0.02	196.48	0.086
L14	25.6	7.4	259	166	82.36	5.04	13.65	20	4.4	2.8	2.6	0.02	84.44	0.133
L15	27.5	7.53	79.5	51	19.79	0.9	7.55	4	2.08	2.2	1.95	0.07	18.53	0.223
L16	27.3	7.82	264	169	61.66	9.82	16.44	17	6.12	2.8	6.2	0.07	67.59	0.148
L17	27.6	8.98	89.4	57	21.68	3.26	10.11	6	2.64	2.3	1.9	0.07	25.82	0.2
L18	23.6	7.7	63.4	41	10.18	3.81	4.63	2	1.68	2.65	0.75	0.02	11.89	0.334
L19	23.7	7.86	103.3	66	23.09	7.32	4.96	6.4	2.68	2.4	1.75	0	26.99	0.2
L20	25.8	6.92	438	280	71.09	11.26	55.96	16	21.92	2.85	0.95	0	129.87	0.108
L21	24.6	8	136.9	88	43.55	4.63	1.25	8.8	3.56	2.45	1.4	0	36.6	0.176
S11	25.4	7.22	71	45	9.74	4.02	7.6	2	2.32	2.3	1.45	0.01	14.51	0.262
S22	25.4	6.42	69	44	9.79	6.11	3.28	2.4	1.36	2.5	2.25	0.07	11.58	0.319
S33	25.4	7.41	49.4	32	5.86	4.89	3.17	1.2	1.16	2.5	1.3	0.1	7.76	0.39

APPENDIX III - CHEMICAL ANALYTICAL DATA OF WATER SAMPLES COLLECTED IN JUNE-JULY 1997

Sam-no	Temp	PH	EC	TDS	HCO	Cl	SO	Ca	Mg	Na	K	Fe	T.H	SAR
DWL1	23	6.11	125	80	70.92	7.7	0	3.65	17.37	6.92	0.87	0.1	80.58	0.612
STL2	22.8	7.39	215	137.6	225.41	5.15	0.1	21.37	7.69	7.55	3.3	0.1	85	0.393
STL3	22.4	5.65	20	12.8	13.72	1.78	8	0.67	3.92	2.27	1.5	0	17.8	0.384
TWL4	23.7	6.88	275	176	162.13	5.48	0	20.65	9.8	6.3	3.92	0	91.89	0.059
OYL5	22.8	6.28	30	19.2	10.9	5.15	0.1	1.12	4.73	3.4	2.01	0	22.26	0.463
STL6	22	6.64	35	22.4	38.27	4.76	0.3	1.01	2.01	3.4	1.15	0.9	10.79	0.47
DW7	24.5	5.9	125	80	64.75	2.71	0.1	2.66	6.24	7.02	0.43	0	28.17	0.652
CAL8	27	6.98	135	86.4	78.79	2.74	0	10.23	3.89	4.37	1.83	0	41.55	0.321
TWL9	26.9	6.37	470	300.8	242.56	18.4	6	27.28	21.06	15.97	2.05	0.1	154.78	0.685
TWL10	27	6.77	715	457.6	272.79	22.1	0	32.01	15.65	33.6	3.95	0	144.32	1.182
CAL11	25.9	6.85	370	236.8	222.6	21	20	27.5	21.35	14.95	3.98	0	156.52	0.647
TWL12	27	7.07	520	332.8	119.7	16.6	18	30.3	4.72	32.4	1.43	0	95.08	1.166
DWL13	26	6.24	275	176	136.52	15.25	6	17.87	10.67	9.4	1.64	0	88.53	0.507
TWL14	25	6.89	180	115.2	253.26	24.3	0.1	57.33	4.62	13.72	4.14	0	162.16	0.454
SPL15	24	6.77	175	112	92.24	6.62	0.4	3.38	8.89	7.2	1.78	1.56	46.15	0.238
SPL16	24.6	7.28	75	48	34.86	13	0	2.48	2.88	5.9	1.92	1	18.04	0.588
REL17	24.4	6.62	100	64	40.4	9.03	0.2	6.69	4.26	4.01	2.5	0	34.23	0.346
TWL18	25.5	6.47	320	204.8	219.2	19.8	1	26.23	3.75	31.15	8.58	0	80.93	1.174
STL19	25.2	7.6	315	201.6	166.18	12.15	0	23.44	11.97	11.97	3.22	0	107.79	0.566
OYL20	25.7	7.15	60	38.4	22.32	4.01	0.1	2.97	4.24	6.92	1.15	0	24.86	0.635
OYL21	25	6.82	210	134.4	94.64	10.02	6.25	3.76	17.52	8.72	1.73	0.2	81.48	0.712
DWL22	24.6	6.06	160	102.4	37.65	4.7	5.63	8.03	4.7	3.27	0.85	0.1	39.39	0.457
OYL23	25.1	6.27	98	62.72	69.92	12.6	11.72	4.24	5.21	0.67	1.72	0.1	32.03	0.06
STL24	26.3	6.75	120	76.8	42.63	8.93	12.02	16.92	4.65	2.71	3	0.5	61.38	0.17
REL25	25.8	7.26	93	59.52	54.25	4.76	10.93	8.65	3.73	3.47	1.93	2.7	36.95	0.28

APPENDIX IV - CHEMICAL ANALYTICAL DATA OF WATER SAMPLES COLLECTED IN NOV-DEC 1997

Sam-no	Temp	PH	EC	TDS	HCO	Cl	SO	Ca	Mg	Na	K	Fe	T.H	SAR
DWL1	24.5	6.63	880	204.82	544.42	19.2	12.6	34.62	11.94	19.86	3.01	0.1	563.2	3.804
STL2	24	7.57	415	114.41	262.3	24.12	3	28.63	10.43	20.53	1.69	0.1	265.6	4.141
STL3	23	7.2	370	93.4	179.95	16.93	0	18.38	7.65	17.7	3.21	0	236.8	4.167
STL4	24	7.34	240	71.48	162.56	16.05	2.3	19.35	5.63	15.32	2.63	0.1	153.6	3.688
TWL5	25	5.98	465	156.02	268.4	24.25	0	36	16.07	23.05	1.94	0	297.6	4.242
DWL6	25	6.84	2000	611.37	811.3	90.9	20.6	134	67.26	35.01	12.01	1.9	1280	8.89
STL7	24.7	7.28	645	187.96	411.75	29.61	4	43.37	19.36	22.3	2.75	0	412.8	3.892
OYL8	23	7.42	345	85.65	122	15.5	0.9	23.11	6.8	17.9	1.58	0	220.8	3.953
DWL9	23.5	6.47	400	82.69	207.4	18.01	0.7	25.6	4.56	15.06	6.01	0.1	256	3.34
DWL10	24.2	6.77	76.2	129.6	455.97	14.32	0	29.9	13.35	20.3	3.2	0.1	48.77	4.052
DWL11	24	6.7	450	118.04	267.23	24.12	0.4	34.65	7.66	23.16	4.27	0	288	4.308
STL12	24.6	7.39	255	70.63	154.02	13.9	0.2	19.27	5.47	12.46	2.01	0.3	163.2	3.128
STL13	23	7.01	130	45.93	76.25	6.25	0.1	11.44	4.2	9.65	1.38	0	83.2	2.972
STL14	24	8.31	59	19.64	42.7	0.93	0	6.4	0.89	1.08	0.24	0.1	37.76	0.558
STL15	21	6.66	37	9.13	19.82	0.42	0	2.98	0.41	0.17	0.1	0.1	23.68	0.135
STL16	24	7.22	120	26.22	59.65	5.4	0.3	8.95	40.94	3.21	0.2	0.2	76.8	1.302
STL17	24.2	6.68	32.2	9.59	21.3	0.41	0	3.2	0.94	0.26	0.04	0	20.61	0.047
DWL18	24.1	5.41	115	39.38	51.85	5.12	0.2	7.78	0.39	1.25	0.62	0	73.6	0.588
DWL19	23.7	5.54	110	28.28	59.47	1.5	0.7	8.92	4.85	0.9	0.17	0.1	70.4	0.406
STL20	22.1	6.88	57.5	17.11	38.12	0.7	0.1	5.7	1.46	0.4	0.26	0	36.8	0.229
STL21	23.1	6.7	35	13.47	31.1	0.46	0	4.67	0.7	0.1	0.15	0	22.4	0.664

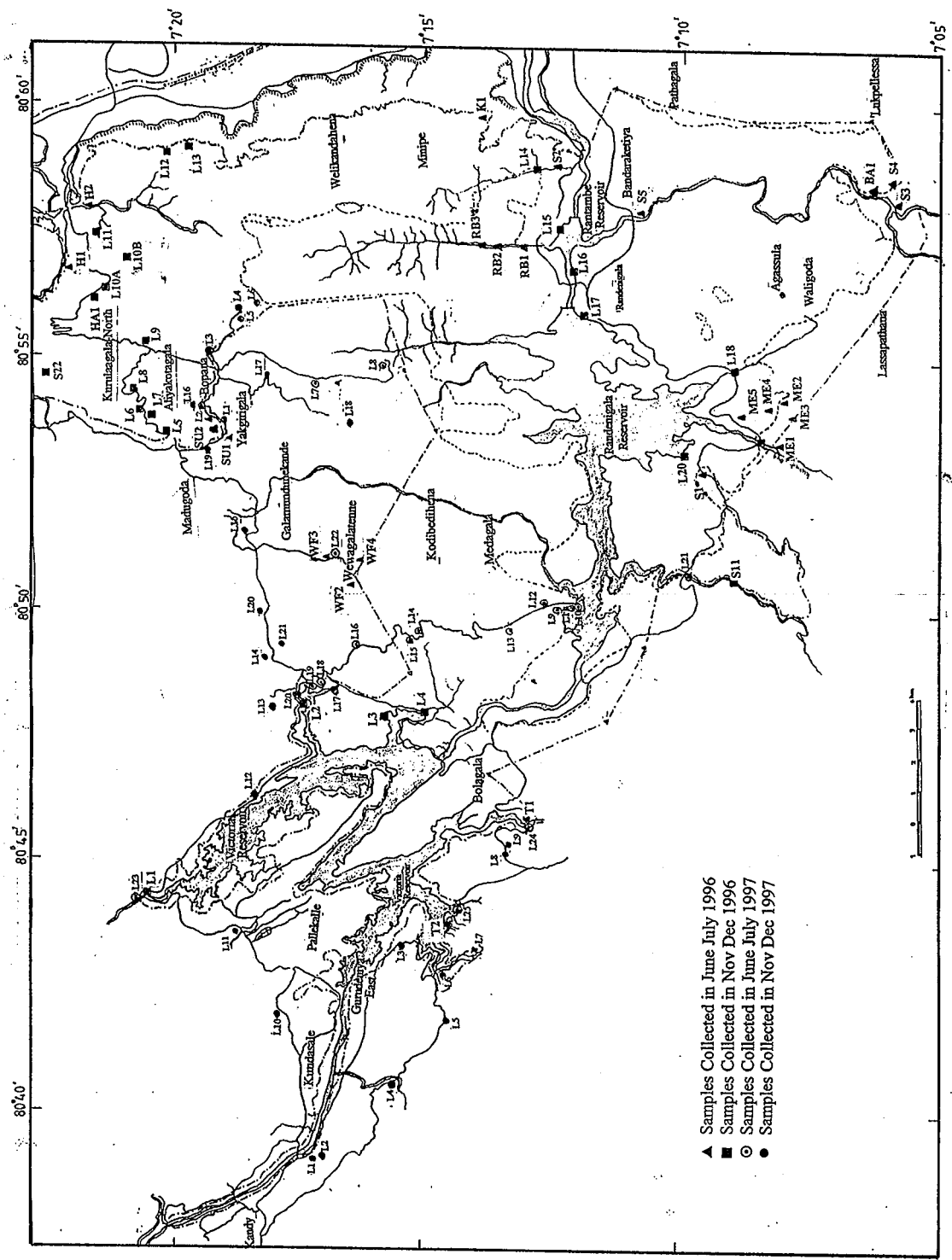
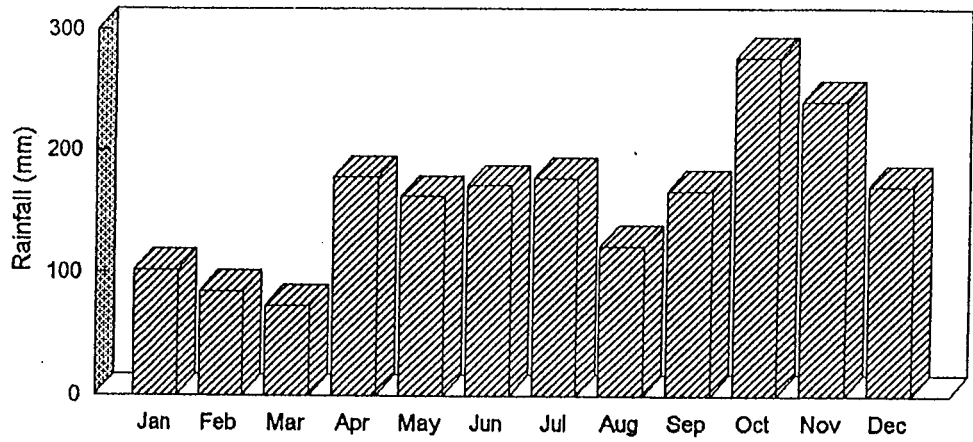


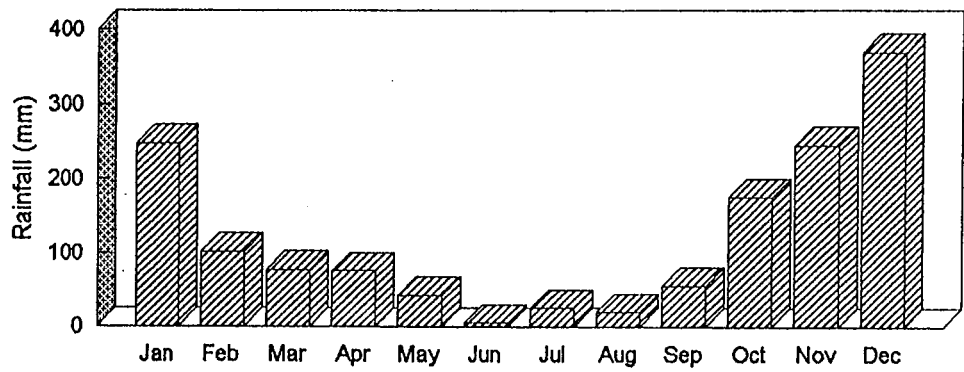
Fig. 1. Location Map of the study area.

Monthly normal average rainfall - Kirimetiya
30 years average



(a)

Monthly normal average rainfall - Kandeketiya
30 year average



(b)

Fig.2. Normal rainfall distribution for a). Kirimetiya in the wet zone, b).Kandeketiya in the dry zone

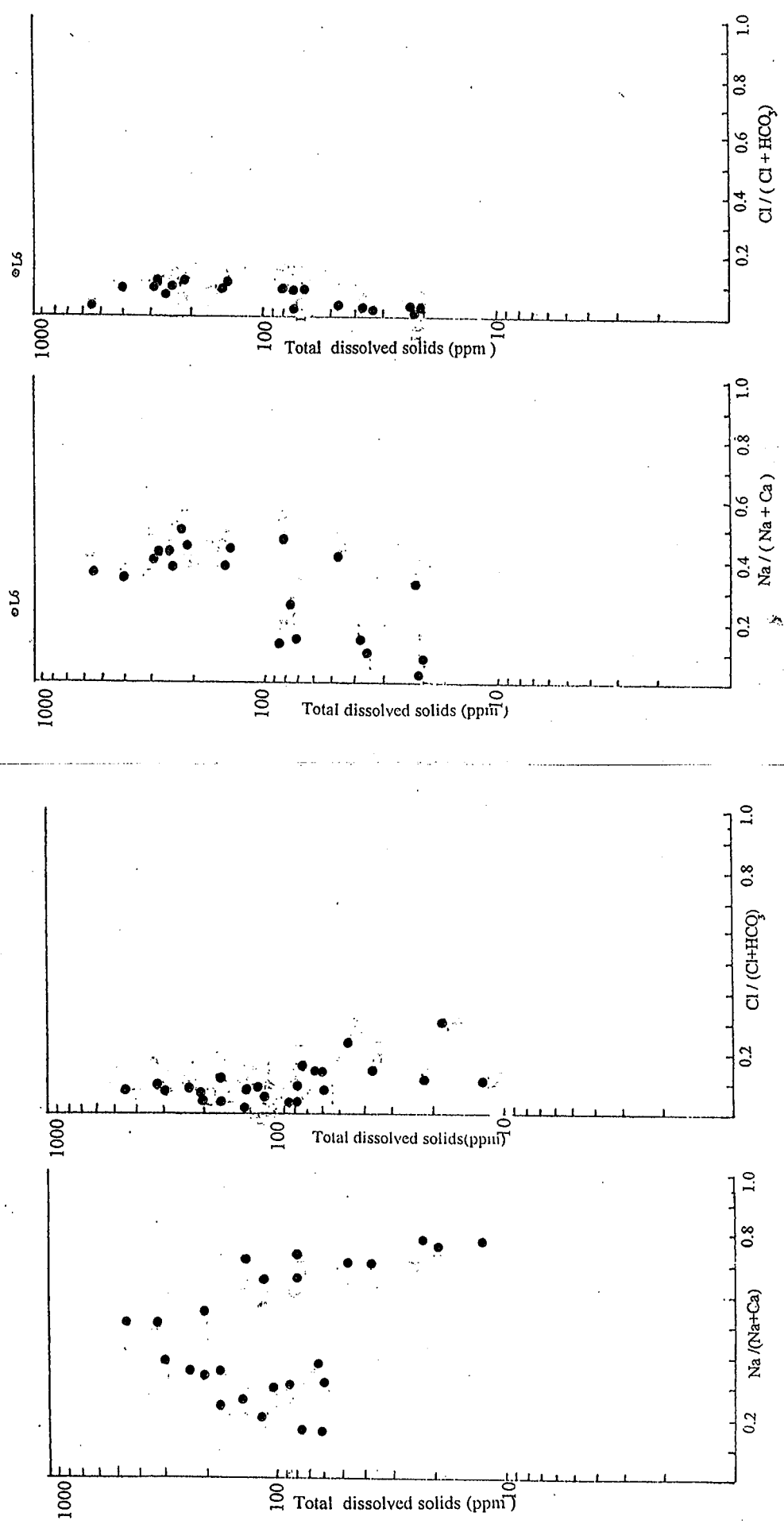


Fig. 3. Graphs for the TDS vs. $\text{Na}/(\text{Na} + \text{Ca})$ and TDS vs. $\text{Cl}/(\text{Cl} + \text{HCO}_3)$; (c). June July 1997 (d). Nov Dec 1997.

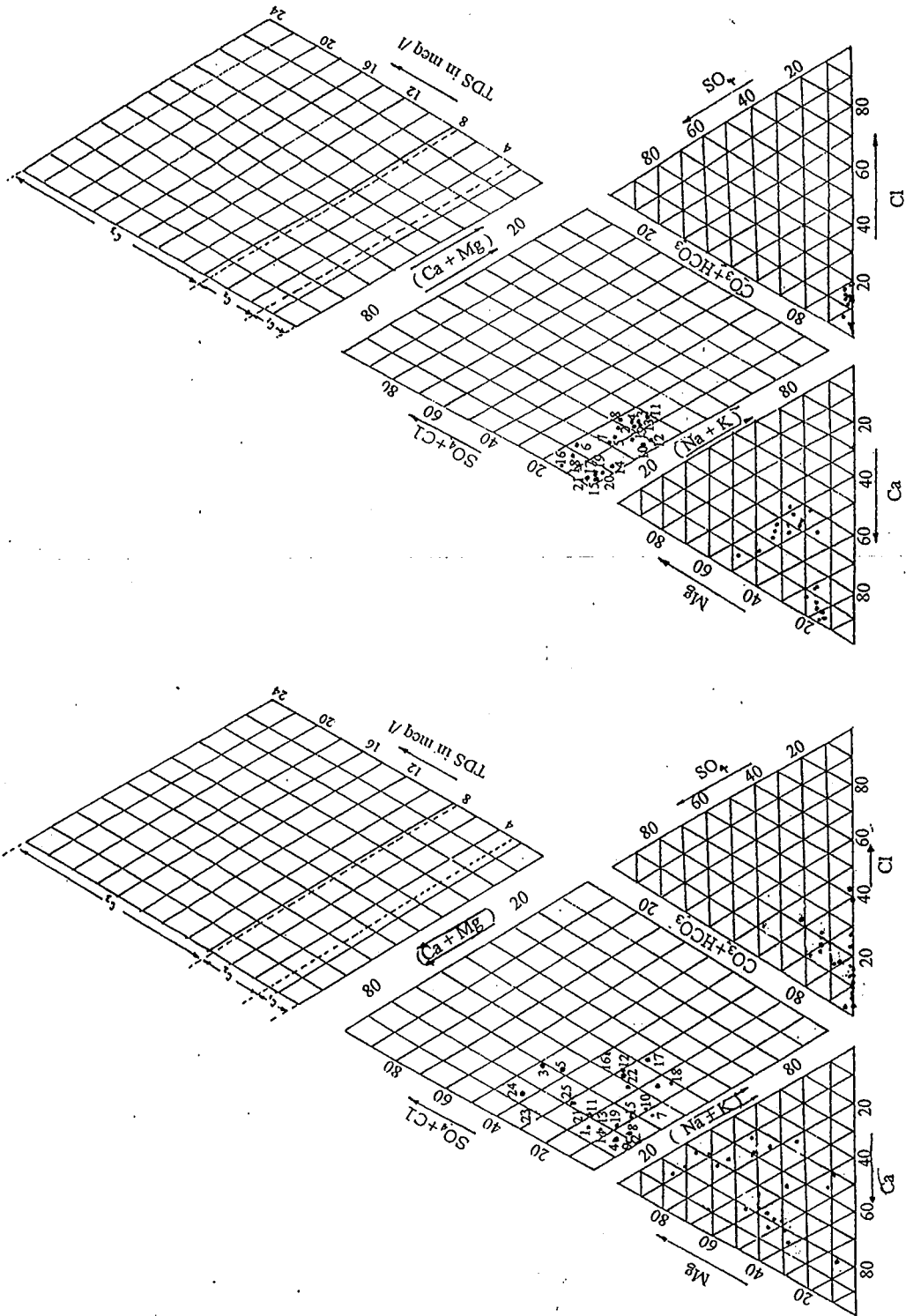


Fig 4. Piper Diagram representing major cations and anions distribution of water samples; (c). June July 1997 (d). Nov Dec 1997.

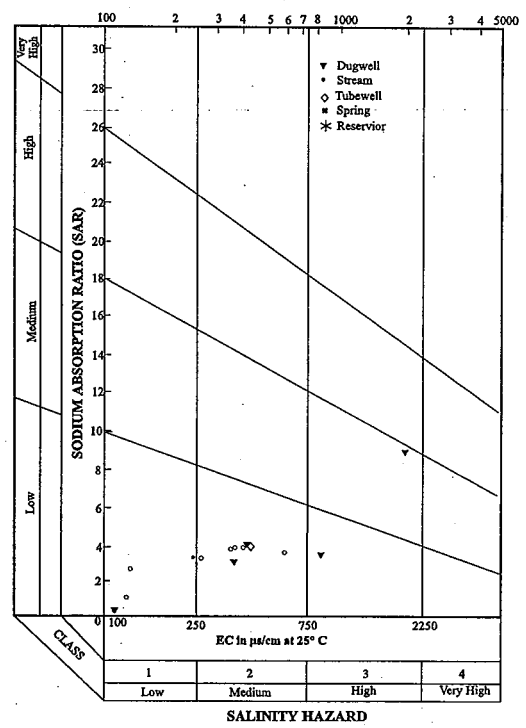
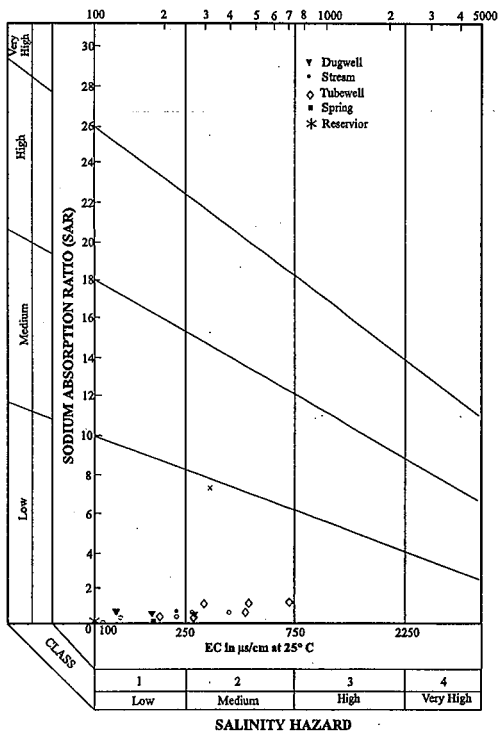
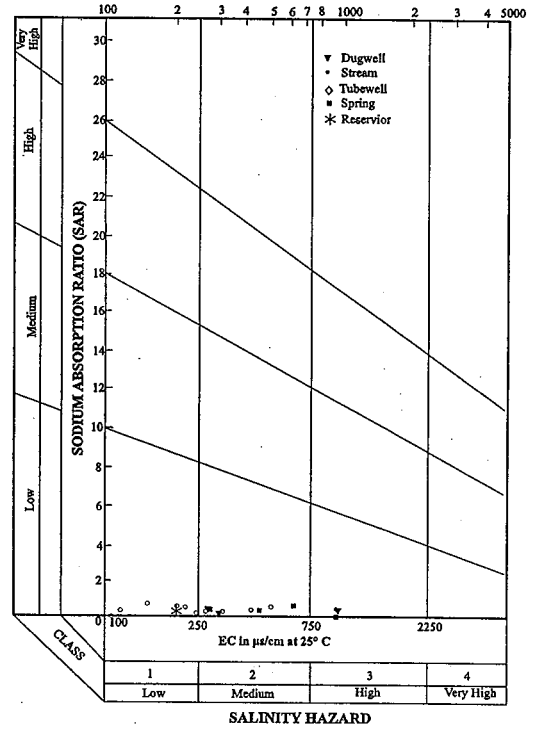
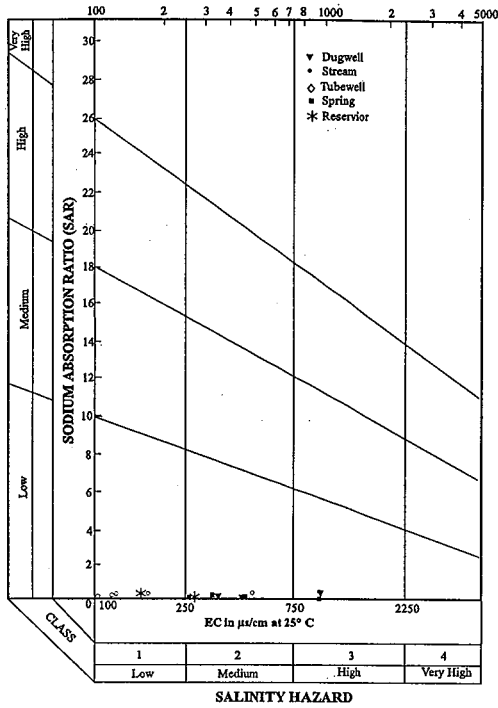
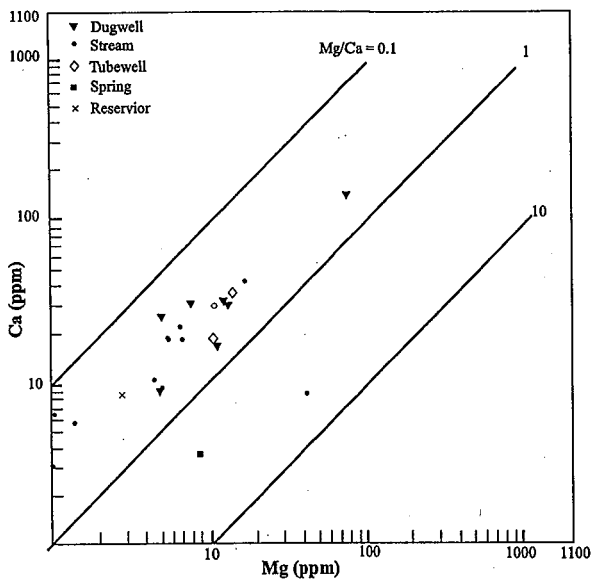
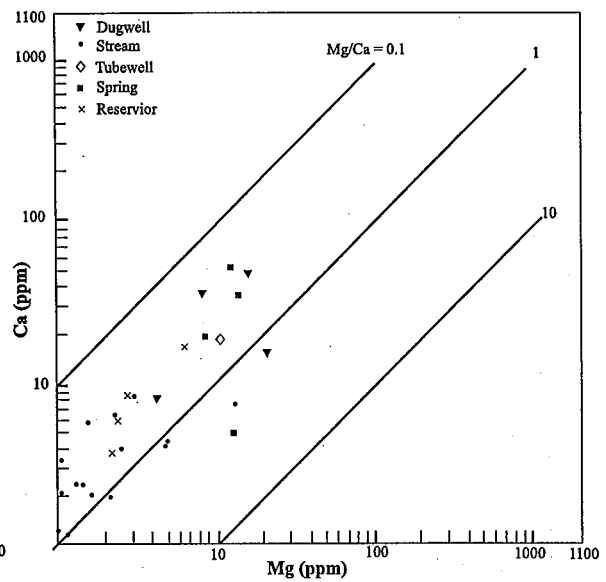


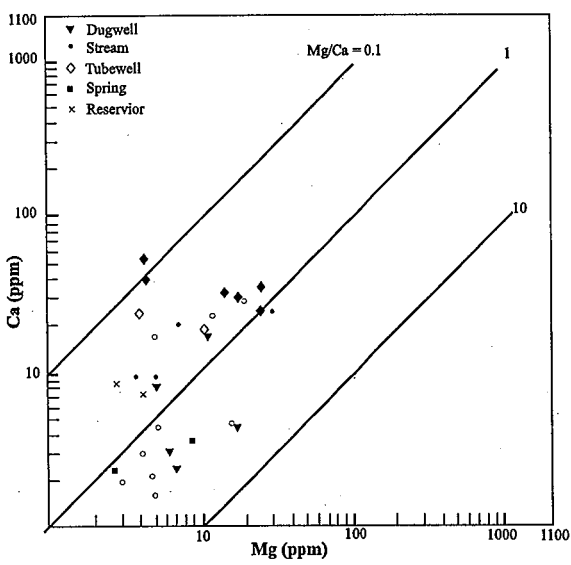
Fig. 5: Na- Salinity Hazard Diagrams
 (a) June July 1996 (b) Nov Dec 1996 (c) June July 1997 (d) Nov Dec 1997



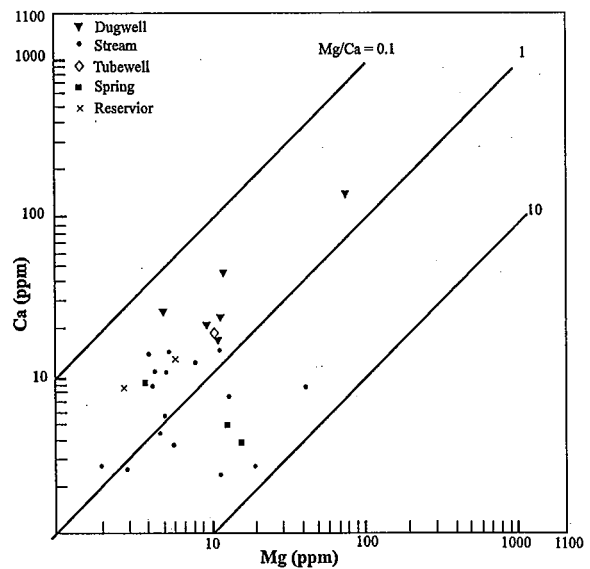
(a)



(b)



(c)



(d)

Fig. 6: Log-Log Plots of Mg vs Ca Distribution for Different Seasons.
 (a) June July 1996 (b) Nov Dec 1996 (c) June July 1997 (d) Nov Dec 1997