REGRESSION ANALYSIS OF WATER QUALITY DATA

6 REGRESSION ANALYSIS OF WATER QUALITY DATA

In this chapter detailed analysis of water quality, RWL and rainfall data monitored by GWRDC and SWDC as well as field investigation for water quality is described.

6.1 Regression Analysis

Water quality data of wells in unconfined aquifer collected from offices have been used to establish the average equations for linear relations between TDS and distance from Kavi. Graphs for wells at equidistance from centre line of river considering equal effect are prepared. The different ranges of equi-distances from river centre line are considered. Similarly water quality data of wells used for establishing the average equations for linear relationship between TDS and distance from centre line of river. The graphs for wells at equidistance from Kavi considering equal effect are prepared. The different ranges of equidistance from Kavi are considered. The average equations for linear relations have been established for wells within each range of distances. Analysis has been carried out to determine correlation coefficient (r) and standard error of estimates (S_{yx}) of average linear equations.

The Multiple Linear Regression Analysis has been carried out for establishing the linear relationships between three parameters such as TDS, Distance from Kavi and RWL. TDS has been taken as dependent variable because the analysis has been carried out to study the variation of salinity in Mahi estuarine area and other two have been taken as independent variables. Using pre-monsoon water quality data of 12 years(1995 to 2006) of 26 unconfined wells the equations for multiple linear relations established and from these year wise equations an average equation has been established. Also the relationships of TDS with RWL and distances from Kavi have been established for the data averaged over number of years. (1995 to 2006). The equations and values of the correlation coefficient (r) and standard error of estimates (S1.23) have been calculated for left bank, right bank and both bank.

The Multiple Linear Regression Analysis has been carried out for establishing the linear relationships between four parameters such as TDS, Distances from Kavi and RWL and rainfall. TDS has been taken as dependent variable because the analysis has been carried out to study the variation of salinity in Mahi estuarine area and other three have been taken as independent variables. Using pre-monsoon water quality data of 12 years(1995 to 2006) of 26 unconfined wells the equations for multiple linear relations established and from these year wise equations an average equation has been established.

The water quality data collected from offices are graphically represented to show the year wise variation in TDS with reference to rainfall for different wells in different talukas in the study area.

6.1.1 Linear Regression Analysis

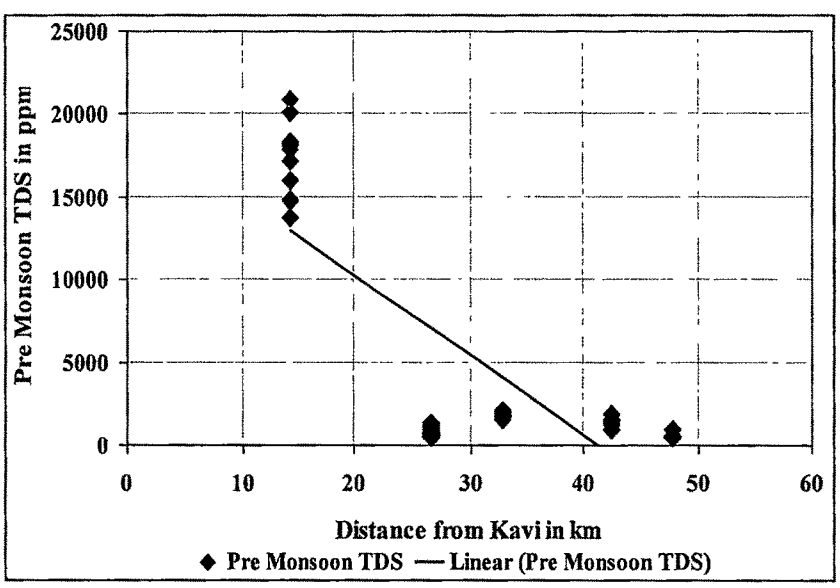
This analysis has been carried out for unconfined wells because the objective of the study is to observe the effect of recharge from surface water due to weir. The water quality data of 12 years (1995 to 2006) of 26 unconfined wells have been arranged in appropriate format to obtain these types of graphs. The maps of Survey of India (1: 50,000) have been used to determine the distances of observation wells from centre line of river. Also these maps have been used to obtain the distances of observation wells from the location of village Kavi, where river Mahi emerges in the Gulf of Cambay (table 4.7). In this analysis graphs have been drawn for pre-monsoon conditions because there is worst condition observed for salinity i.e. more value of Total Dissolved Solids (TDS) in pre-monsoon season. This condition occurs due to less ground water recharge in pre-monsoon season whereas in post-monsoon season, there is more groundwater recharge due to rainfall. This analysis has been carried out in two different ways as described below:

(1) These graphs have been prepared for establishing the relation between TDS (in ppm) and distance from Kavi (in kms). The graphs have been prepared for wells which are at equidistance from centre line of river. So that the effect of recharge of fresh water from the river at the wells under consideration is approximately equal. The range of distances of wells from the centre line of the river for establishing the relation between TDS & Distance from Kavi have been chosen as below:

- ⇨ Equidistance from river centre line: 1.80km to 3.20km (Graph 6.1)
- ⇨ Equidistance from river centre line: 4.20km to 6.90km (Graph 6.2)
- ⇨ Equidistance from river centre line: 8.65km to 12.40km (Graph 6.3)

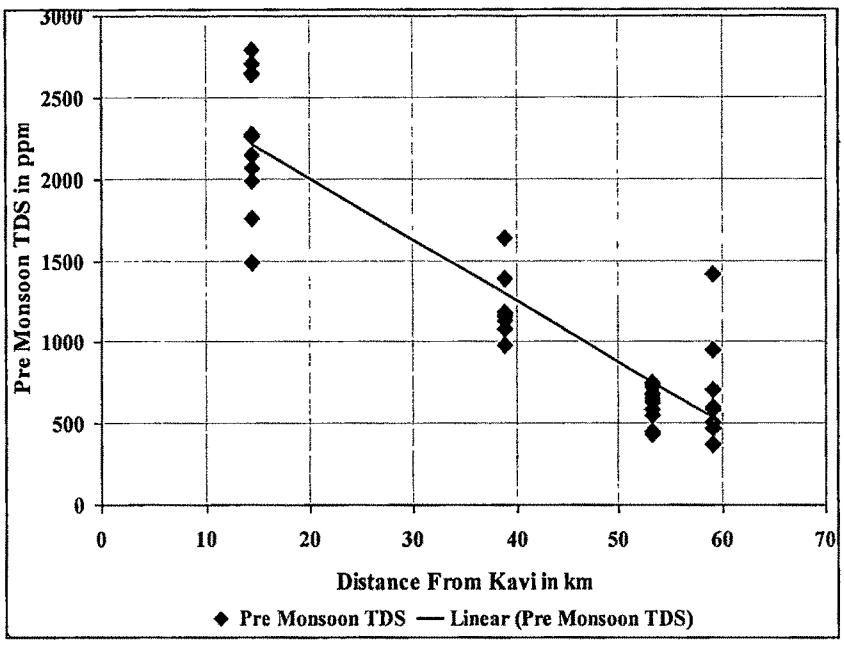
(2) These graphs have been prepared for establishing the relation between TDS (in ppm) and distance from centre line of river (in kms). The graphs have been prepared for wells which are at equidistance from the location of village Kavi. So that the effect of tides from Kavi at the wells under consideration is approximately equal. The ranges of distances of wells from the centre line of the river for establishing the relation between TDS & Distance from centre line of river have been chosen as below:

- ⇨ Equidistance from Kavi: 6.50km to 10.60km (Graph 6.4)
- ⇨ Equidistance from Kavi: 14.25km to 18.40km (Graph 6.5)
- ⇨ Equidistance from Kavi: 24.40km to 30.00km (Graph 6.6)
- ⇨ Equidistance from Kavi: 32.75km to 42.50km (Graph 6.7)
- ⇨ Equidistance from Kavi: 56.75km to 59.45km (Graph 6.8)



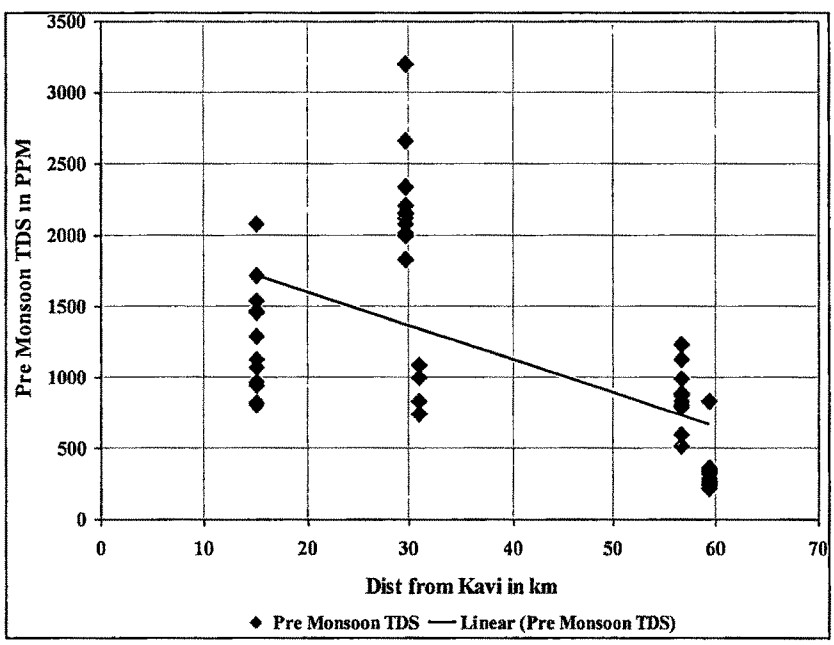
Graph 6.1 Pre-Monsoon TDS V/S Distance from Kavi

Equidistance from River Centre Line 1.80 km to 3.2 km



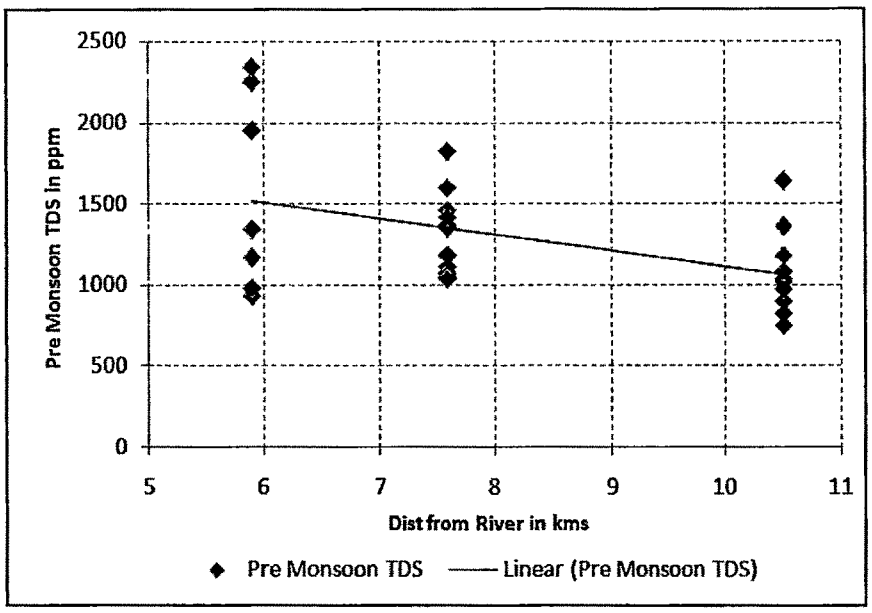
Graph 6.2 Pre-Monsoon TDS V/S Distance from Kavi

Equidistance from River Centre Line 4.20 km to 6.90 km



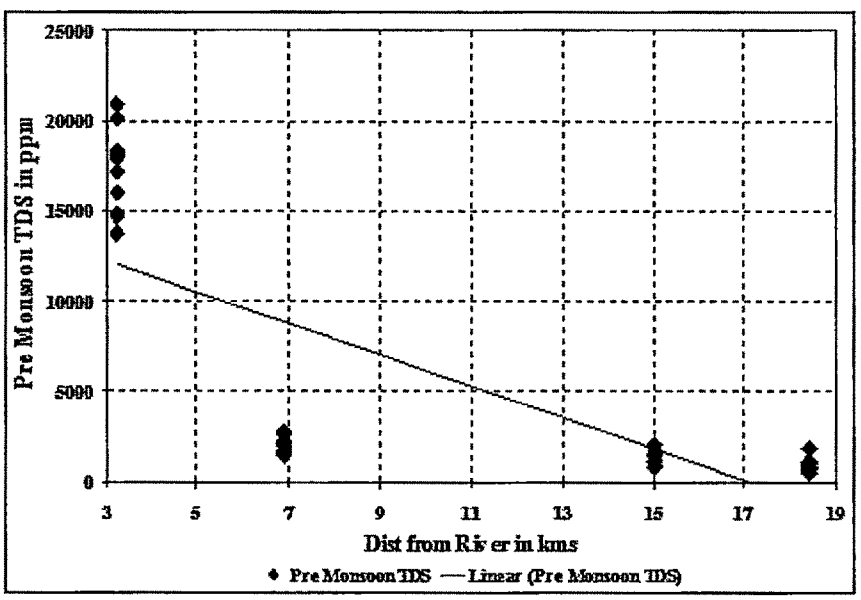
Graph 6.3 Pre-Monsoon TDS V/S Distance from Kavi

Equidistance from River Centre Line 8.65 km to 15.00 km



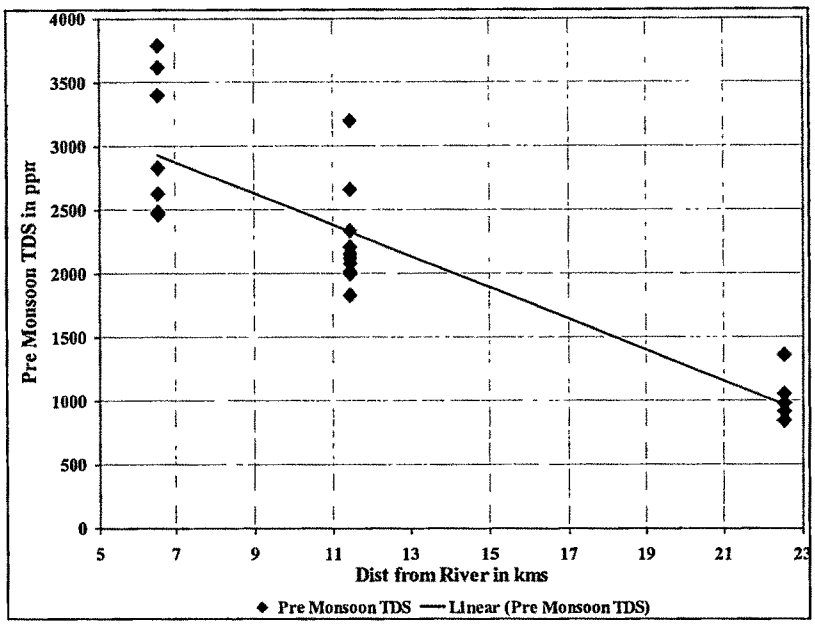
Graph 6.4 Pre-Monsoon TDS V/S Distance from River Centre Line

Equidistance from Kavi 6.50 km to 10.60 km



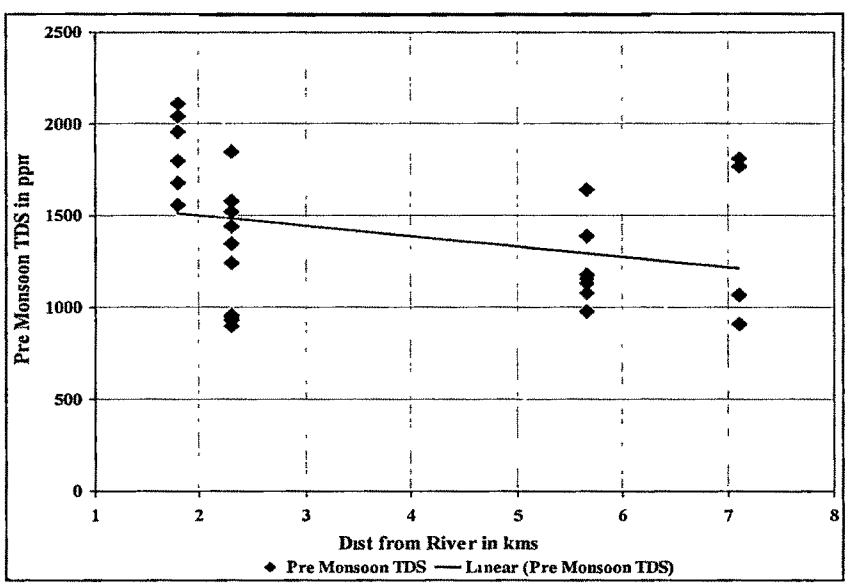
Graph 6.5 Pre-Monsoon TDS V/S Distance from River Centre Line

Equidistance from Kavi 14.25 km to 18.40 km



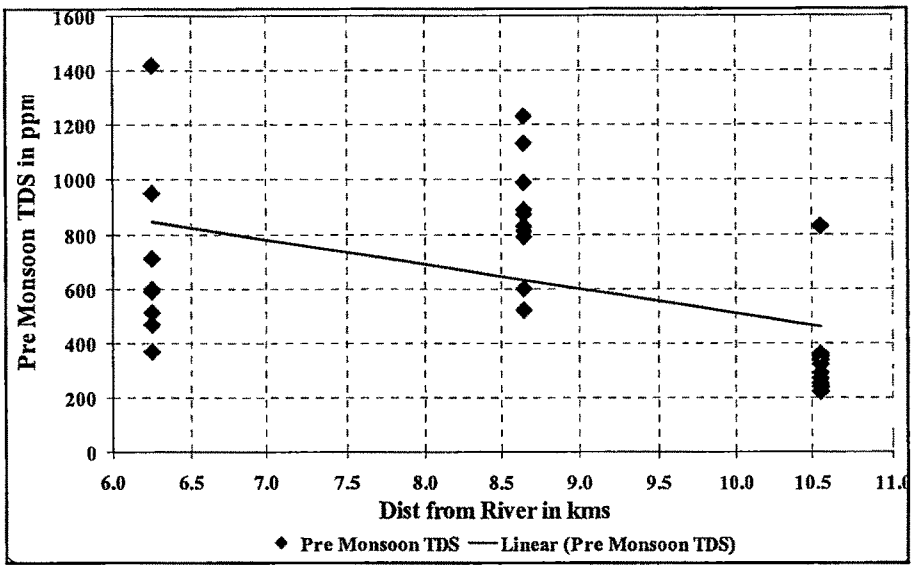
Graph 6.6 TDS V/S Distance from River Centre Line

Equidistance from Kavi 24.40 km to 30.00 km



Graph 6.7 Pre-Monsoon TDS V/S Distance from River Centre Line

Equidistance from Kavi 32.75 km to 42.50 km



Graph 6.8 Pre-Monsoon TDS V/S Distance from River Centre Line

Equidistance from Kavi 56.75 km to 59.45 km

The average equations for Linear relations have been established for wells within each range of distance from centre line of river (graph 6.1 to 6.3) and each range of distance from Kavi (graph 6.4 to 6.8). Analysis has been carried out to determine correlation coefficient (r), Standard Error of Estimate (S_{YX}) of average linear equations and this has been shown in Table 6.1.

Correlation Coefficient (r) is commonly used statistical parameter for measuring the degree of association of two linearly dependent variables x and y. It is defined by

$$r = \frac{\sum(\Delta X * \Delta Y)}{\sqrt{\sum(\Delta X)^2 * \sum(\Delta Y)^2}} \quad \ldots\ldots\ldots\ldots \quad (6.1)$$

$\Delta X = X - \overline{X}$ Where $\overline{X} = \frac{\Sigma X}{N}$

$\Delta Y = Y - \overline{Y}$ Where $\overline{Y} = \frac{\Sigma Y}{N}$

X = Distance from Kavi or River

Y = Observed TDS in ppm

N = No. of observations for X

The correlation coefficient lies between -1 and +1 i. e. $-1 \leq r \leq +1$

r = +1 shows perfect positive correlation between two variables. For such variables an increase in the value of one variable is associated with a proportional increase in the value of the other variables. The points on the scattered diagram for such variables are in a straight line in an increasing order.

r = -1 shows perfect negative correlation between two variables. For such variables an increase in the value of one variable is associated with a proportional decrease in the value of the other variables. The points on the scattered diagram for such variables are in a straight line in the decreasing order.

Standard error of estimate (S_{yx}) is a measure of scatter about the regression line of Y on X. It is given by,

$$S_{yx} = \sqrt{\frac{\sum (Y - Y_{est})^2}{N - 2}} \quad \text{.....(6.2)}$$

Where Y = Observed TDS in ppm

Y_{est} = Estimated TDS in ppm using obtained equation

N = no. of observations

Table 6.1 Linear Regression Equations and Values of "r" & "S_{YX}" for Graphs 6.1 To 6.8

Graph	Graph Title	Equation	Correlation Coefficient r	Standard Error of Estimate S_{YX} ppm
6.1	Equidistance from River Centre Line: 1.80km to 3.20km	Y = -478.43X +19752	-0.7890	4508.159
6.2	Equidistance from River Centre Line: 4.20km to 6.90km	Y = -37.445X + 2748.20	-0.9144	305.540
6.3	Equidistance from River Centre Line: 8.65km to 12.40km	Y = -23.472X + 2066.80	-0.57346	607.039
6.4	Equidistance from Kavi: 6.50km to 10.60km	Y = -99.51X + 2105	-0.47757	347.413
6.5	Equidistance from Kavi: 14.25km to 18.40km	Y = -865.76X + 14815.00	-0.76531	4529.622
6.6	Equidistance from Kavi: 24.40km to 30.00km	Y = -122.79X + 3733.20	-0.87032	408.473
6.7	Equidistance from Kavi: 32.75km to 42.50km	Y = -56.159X + 1610.80	-0.30779	368.898
6.8	Equidistance from Kavi: 56.75km to 59.45km	Y = -90.216X + 1409.90	-0.48656	292.883

In Graphs 6.1 to 6.3	X = Distances From Kavi in kms
	Y = TDS in ppm
In Graphs 6.4 to 6.8	X = Distances from River centre line in kms
	Y = TDS in ppm

It is observed from graph 6.1 to 6.3 that Total Dissolved Solids (TDS) decreases with increased distance from Kavi where Mahi River merges in the Gulf of Cambay. It is also observed from graph 6.4 to 6.8 that TDS decreases with increasing distance from centre line of river.

The correlation coefficient r is a useful measure of the goodness of regression, commonly used to study the degree of statistical relationship between a set of variables. From Table 6.1, for graphs 6.1, 6.2, 6.5 & 6.6 the linear regression equations show that the correlation coefficient r is ranging between -0.76531 to -0.9144 which indicates a close negative linear correlationship between dependent variable TDS of groundwater (Y) and

independent variable, distance from centre line of river or distance from Kavi where Mahi River merges in the Gulf of Cambay (X). An increase in the distance from centre line of river or distance from Kavi is associated with a proportional decrease in the value of TDS of groundwater.

Similarly for graphs 6.3, 6.4 and 6.8 the linear regression equations show that the correlation coefficient r is ranging between -0.47757 to -0.57346 which indicates an average negative linear correlationship between the above two variables. It is also found from regression equation of graph 6.7 that the correlation coefficient r is -0.30779 which indicates poor negative linear correlationship between the above two variables. The dependent variable TDS of groundwater is not significantly influenced by the independent variable, distance from centre line of river or distance from Kavi only. So perfect match is not indicated and analysis by multiple linear regressions with additional independent variables is required.

Standard error of estimate SYX is a measure of scatter about the best fit regression line of TDS of groundwater (Y) on distance from centre line of river or distance from Kavi (X). Its value is found ranging from 292.883 ppm to 4529.622 ppm.

6.1.2 Multiple Linear Regression Analysis for Three Parameters

This analysis has been carried out for establishing the linear relationships between three different parameters in Mahi estuarine area. In this analysis, parameters such as Total Dissolved Solids (TDS in ppm), distances from Kavi (in kms) and Reduced Water Level (RWL in m) have been used for establishing the linear relationship. TDS in ppm has been taken as dependent variable because the analysis has been carried out to study the variation of salinity in Mahi estuarine area. The other two parameter such as Distances from Kavi (in kms) and (RWL in m) have been taken as independent variables. The general form of multiple linear relationships of these parameters follows relationships as given below:

$$X_1 = a + bX_2 + cX_3 \quad .. \quad (6\,3)$$

Where a, b & c = the constants determined by the method of least squares.

X_1 = TDS in ppm

X_2 = Distances from Kavi in kms

X_3 = Reduced Water Level in m

The least square regression plane of X_1 on X_2 and X_3 can be determined by solving simultaneously the three normal equations.

$$\sum X_1 = an + b\sum X_2 + c\sum X_3$$
$$\sum X_1X_2 = a\sum X_2 + b\sum {X_2}^2 + c\sum X_2X_3 \quad (64)$$
$$\sum X_1X_3 = a\sum X_3 + b\sum X_2X_3 + c\sum {X_3}^2$$

Where n is the set of data points (X_1, X_2, X_3)

The coefficient of multiple correlations is given by

$$r_{1.23} = \sqrt{\frac{{r_{12}}^2 + {r_{13}}^2 + 2r_{12}\,r_{13}\,r_{23}}{1 - {r_{23}}^2}} \quad (65)$$

Where
$$r_{12} = \frac{\sum X_1X_2 - n\,\overline{X_1}\,\overline{X_2}}{(n-1)\,\sigma_1\,\sigma_2} \quad (66)$$

r_{12} = the linear correlation coefficient between the variables X_1 and X_2, ignoring the variable X_3; and similarly r_{13} and r_{23}. r_{12}, r_{13}, r_{23} are partial correlation coefficients.

$$\bar{X} = \frac{\sum X}{n}$$

Standard deviation = $\sigma = \sqrt{\frac{\sum (X-\bar{X})^2}{n-1}}$

n = number of set of data points

The Standard error of estimate of X_1 with respect to X_2 and X_3 is given by

$$S_{1.23} = \sqrt{\frac{\sum (X_1 - X_{1est})^2}{n-3}} \quad (67)$$

X_{1est} = value of X_1 for the given values of X_2 and X_3 in equation (6.3).

This analysis has been carried out by using pre-monsoon data of 26 unconfined well. The water quality data of 12 years (1995 to 2006) of 26 unconfined wells have been used to obtain this type of multiple linear relationships. Equations for multiple linear relations have been established by using each year (1995 to 2006) data for 26 wells. From these year wise equations an average equation has been established.

The effect of recharge due to Mahi Right Bank Canal (MRBC) irrigation have been observed in the area on right bank of the river, while in the area on the left bank of the river, the recharge due to irrigation is not observed as there is no left bank irrigation canal in past. So, the analysis for left bank, right bank and for both bank have been carried out separately.

The correlation coefficient (r) and standard error of estimates ($S_{1\,23}$) have been calculated from these equations. The equations and values of "r" and "$S_{1\,23}$" have been shown in Table given below:

- ⇨ For Left Bank i.e. for Vadodara district (Table 6.2)
- ⇨ For Right Bank i.e. for Anand district (Table 6.3)
- ⇨ For Both Banks (Table 6.4)

Table 6.2 Multiple Linear Regression Equations and Values of "r" and "$S_{1.23}$" for Left Bank

Year	Equation	Multiple Correlation Coefficient ($r_{1.23}$)	Standard Error of Estimate ($S_{1\,23}$) in ppm
1995	$X_1 = 1909.88 - 11.02X_2 - 46.80X_3$	0.904	647.00
1996	$X_1 = 2051.64 - 18.04X_2 - 0.74X_3$	0.898	977.46
1997	$X_1 = 2191.30 - 7.97X_2 - 22.53X_3$	0.994	1039.12
1998	$X_1 = 1574.72 - 2.89X_2 - 26.12X_3$	0.956	930.00
1999	$X_1 = 2396.37 - 21.83X_2 + 10.65X_3$	0.951	625.54
2000	$X_1 = 1742.11 - 9.65X_2 - 1.78X_3$	0.905	666.71
2001	$X_1 = 2281.28 - 27.70X_2 + 22.25X_3$	0.998	712.39
2002	$X_1 = 1487.97 - 10.26X_2 - 8.08X_3$	0.910	313.76
2003	$X_1 = 3422.53 - 42.34X_2 + 51.77X_3$	0.951	347.99
2004	$X_1 = 3421.12 - 50.20X_2 + 14.17X_3$	0.999	268.70
2005	$X_1 = 2550.40 - 34.16X_2 + 22.57X_3$	0.913	682.24
2006	$X_1 = 5963.81 - 94.15X_2 + 20.50X_3$	0.985	825.28
Year wise Average Equation	$X_1 = 2582.76 - 27.52X_2 + 2.99X_3$	0.947	740.50
Equation for data averaged over Number of Years	$X_1 = 2087.80 - 17.14X_2 - 6.84X_3$	0.946	733.85

Where, X_1 = TDS in ppm

X_2 = Distances from Kavi in kms

X_3 = Reduced Water Level in m

The multiple linear regression equations for estimating a dependent variable TDS for groundwater (X_1) from two independent variables, distance from Kavi (X_2) and reduced water level (X_3) for left bank of River Mahi of study area are represented in table 6.2. The multiple correlation coefficient $r_{1\,23}$ between the dependent variable TDS of groundwater (X_1) and two independent variable, distance from Kavi (X_2) & reduced water level (X_3) is found from partial correlation coefficients which uses the standard deviation of X_1 and X_2. The value of $r_{1\,23}$ lies between 0 & 1.

It is found from table 6.2 that for the multiple linear regression equations the value of multiple correlation coefficient $r_{1\,23}$ is ranging between 0.898 to 0.999 which indicates a close linear correlationship of (X_2) and (X_3) on (X_1).

The table 6.2 shows the value of standard error of estimate $S_{1\,23}$ of X_1 with respect to X_2 and X_3 for the multiple linear regression equations is ranging between 268.70 ppm to 1039.72 ppm for left bank.

Table 6.3 Multiple Linear Regression Equations and Values of "$r_{1.23}$" and "$S_{1.23}$" for Right Bank

Year	Equation	Multiple Correlation Coefficient ($r_{1.23}$)	Standard Error of Estimate ($S_{1.23}$) in ppm
1995	$X_1 = 1445.51 - 18.44X_2 + 5X_3$	0.953	591.34
1996	$X_1 = 1549.60 - 16.80X_2 + 7.57X_3$	0.927	529.86
1997	$X_1 = 1409.05 - 10.33X_2 - 1.73X_3$	0.9996	492.82
1998	$X_1 = 1129.72 - 18.53X_2 + 16.10X_3$	0.939	273.90
1999	$X_1 = 1753.94 - 17.37X_2 + 5.05X_3$	0.96	594.91
2000	$X_1 = 1377 - 12.83X_2 + 3.83X_3$	0.932	455.59
2001	$X_1 = 1460.05 - 6.49X_2 - 6.23X_3$	0.946	477.16
2002	$X_1 = 1489.40 - 20.63X_2 + 23.47X_3$	0.921	200.79
2003	$X_1 = 1642.51 - 11.22X_2 + 1.00X_3$	0.96	303.09
2004	$X_1 = 1475.36 - 18.73X_2 + 14.13X_3$	0.935	486.35
2005	$X_1 = 1344.38 - 9.03X_2 + 5.70X_3$	0.971	264.65
2006	$X_1 = 1518.84 - 9.98X_2 - 4.90X_3$	0.916	1298.91
Year wise Average Equation	X1 = 1382.95 - 14.20X2 + 5.75X3	0.947	410.23
Equation for data averaged over No. of Years	X1 = 1567.06 - 14.27X2 - 1.82X3	0.992	446.71

Where, X_1 = TDS in ppm

X_2 = Distances from Kavi in kms

X_3 = Reduced Water Level in m

The multiple linear regression equations for estimating a dependent variable TDS for groundwater (X_1) from two independent variables, distance from Kavi (X_2) and reduced water level (X_3) for right bank of River Mahi of study area are represented in table 6.3. It is found from table 6.3 that for the multiple linear regression equations the value of

multiple correlation coefficient r1.23 is ranging between 0.916 to 0.9996 which indicates a close linear correlationship of (X_2) and (X_3) on (X_1). The table 6.3 shows the value of standard error of estimate $S_{1.23}$ of X_1 with respect to X_2 and X_3 for the multiple linear regression equations is ranging between 200.79 ppm to 1298.91 ppm for right bank.

Table 6.4 Multiple Linear Regression Equations and Values of "r" and "$S_{1.23}$" for Both Banks

Year	Equation	Multiple Correlation Coefficient ($r_{1.23}$)	Standard Error of Estimate ($S_{1.23}$) in ppm
1995	$X_1 = 1579.37 + 10.52X_2 - 44.96X_3$	0.961	673.61
1996	$X_1 = 1953.82 - 8.72X_2 - 22.28X_3$	0.932	613.17
1997	$X_1 = 1646.58 + 4.63X_2 - 33.13X_3$	0.921	824.49
1998	$X_1 = 1633.34 + 0.831X_2 - 29.52X_3$	0.958	687.69
1999	$X_1 = 2045.07 - 16.29X_2 - 8.99X_3$	0.907	561.42
2000	$X_1 = 1743.88 + 2.62X_2 - 38.85X_3$	0.994	688.18
2001	$X_1 = 1629.44 - 6.27X_2 - 12.07X_3$	0.991	563.23
2002	$X_1 = 1515.68 - 6.79X_2 - 6.97X_3$	0.888	317.95
2003	$X_1 = 1479.48 - 1.80X_2 - 10.65X_3$	0.816	511.40
2004	$X_1 = 1872.58 - 21.52X_2 - 0.07X_3$	0.985	439.30
2005	$X_1 = 1496.89 + 3.77X_2 - 21.10X_3$	0.977	461.79
2006	$X_1 = 1956.52 - 10.93X_2 - 14.60X_3$	0.946	839.95
Year wise Average Equation	$X_1 = 1712.72 - 4.16X_2 - 20.27X_3$	0.940	520.64
Equation for data averaged over Number of Years	$X_1 = 1666.41 - 3.60X_2 - 21.17X_3$	0.978	478.92

Where, X_1 = TDS in ppm

X_2 = Distances from Kavi in kms

X_3 = Reduced Water Level in m

The multiple linear regression equations for estimating a dependent variable TDS for groundwater (X_1) from two independent variables, distance from Kavi (X_2) and reduced water level (X_3) for both banks of River Mahi of study area are represented in table 6.4. It is found from table 6.4 that for the multiple linear regression equations the value of multiple correlation coefficient $r_{1\,23}$ is ranging between 0.816 to 0.994 which indicates a close linear correlationship of (X_2) and (X_3) on (X_1). The table 6.3 shows the value of standard error of estimate $S_{1\,23}$ of X_1 with respect to X_2 and X_3 for the multiple linear regression equations is ranging between 317.95 ppm to 839.95 ppm for both banks.

6.1.3 Multiple Linear Regression Analysis for Four Parameters

This analysis has been carried out for establishing the linear relationships between four different parameters in Mahi estuarine area. In this analysis, parameters such as TDS in ppm, distances from Kavi (in kms), RWL (in m) and Rainfall (in mm) have been used for establishing the linear relationship. TDS in ppm has been taken as dependent variable because the analysis has been carried out to study the variation of salinity in Mahi estuarine area. The other three parameters such as distance from Kavi (in kms), RWL in m and Rainfall (in mm) have been taken as independent variables. The general form of multiple linear relationships of these parameters follows relationship as given below:

$$X_1 = a + bX_2 + cX_3 + dX_4 \quad . \; . \; . \qquad (6\,8)$$

Where a, b, c & d = the constants determined by the method of least squares.

X_1 = TDS in ppm

X_2 = Distances from Kavi in kms

X_3 = Reduced Water Level in m

X_4 = Rainfall in mm

This analysis has been carried out by using pre-monsoon data of 26 unconfined well. The water quality data of 12 years (1995 to 2006) of 26 unconfined wells have been used to obtain this type of multiple linear relationships. Equations for multiple linear relations have been established by using each year (1995 to 2006) data for 26 wells. From these year wise equations an average equation has been established.

Also the multiple regression analysis has been carried out for the relationships of TDS with RWL, distances from Kavi and rainfall have been established for the data averaged over no. of years (from 1995 to 2006).

The multiple correlation coefficient (r) and standard error of estimates ($S_{1\,234}$) have been calculated from these equations. The equations and values of "r" and "$S_{1\,234}$" have been shown in Table 6.5.

Table 6.5 Multiple Linear Regression Equations and Values of "r" and "$S_{1.234}$" for Both Banks

Year	Equation	Multiple Correlation Coefficient ($r_{1\,234}$)	Standard Error of Estimate ($S_{1.234}$) in ppm
1995	$X_1 = 1543.70 - 3.80X_2 - 20.40X_3 - 0.10X_4$	0.982	646
1996	$X_1 = 1735.10 + 5.90X_2 - 8.20X_3 - 1.30X_4$	0.995	722
1997	$X_1 = 1833.40 + 11.90X_2 - 45.80X_3 - 0.50X_4$	0.942	692
1998	$X_1 = 1254.50 - 2.50X_2 - 14.90X_3 + 0.20X_4$	0.967	678
1999	$X_1 = 2495.40 - 18.50X_2 - 6.30X_3 - 0.50X_4$	0.915	558
2000	$X_1 = 2893.30 + 6.90X_2 + 3.20X_3 + 5.50X_4$	0.956	433
2001	$X_1 = 2608.40 - 0.60X_2 - 10.70X_3 - 3.10X_4$	0.993	777
2002	$X_1 = 2016.20 - 0.30X_2 - 2.90X_3 - 1.60X_4$	0.989	364
2003	$X_1 = 1418.40 - 25.90X_2 + 3.40X_3 + 1.60X_4$	0.967	577
2004	$X_1 = 2211.50 - 14.50X_2 + 4.00X_3 - 0.90X_4$	0.980	510
2005	$X_1 = 770.53 - 24.09X_2 - 4.36X_3 + 1.94X_4$	0.999	495
2006	$X_1 = 1295 - 18.00X_2 - 3.40X_3 + 0.40X_4$	0.997	566
Year wise Average Equation	$X_1 = 1839.62 - 6.96X_2 - 11.30X_3 + 0.14X_4$	0.974	626.28
Equation for data averaged over Number of Years	$X_1 = 2399.40 + 1.70X_2 - 11.40X_3 - 1.60X_4$	0.983	510.48

Where, X_1 = TDS in ppm

X_2 = Distances from Kavi in kms

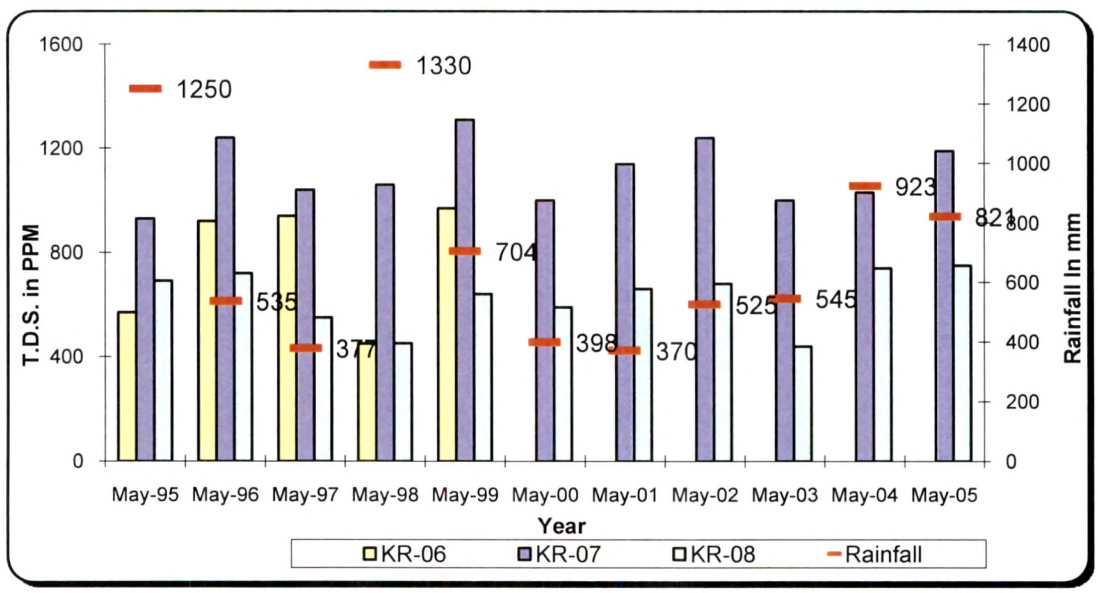
X_3 = Reduced Water Level in m

X_4 = Rainfall in mm

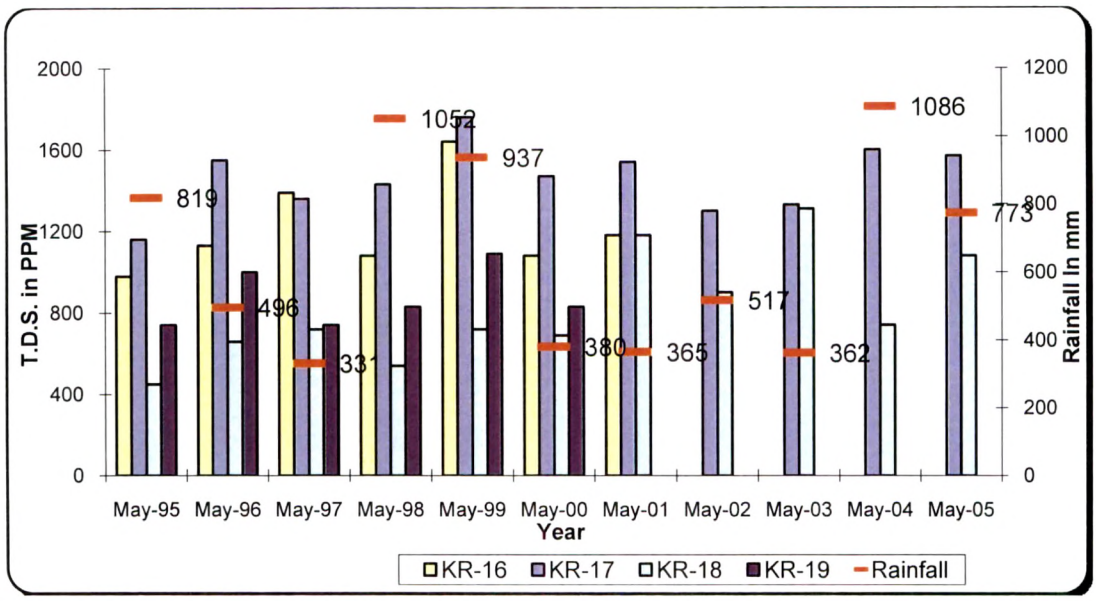
The multiple linear regression equations for estimating a dependent variable TDS for groundwater (X_1) from three independent variables, distance from Kavi (X_2), reduced water level (X_3) and rainfall (X_4) for both banks of River Mahi of study area are represented in table 6.5. It is found from table 6.5 that for the multiple linear regression equations the value of multiple correlation coefficient $r_{1.234}$ is ranging between 0.915 to 0.999 which indicates a close linear correlationship of (X_2), (X_3) and (X_4) on(X_1). The table 6.5 shows the value of standard error of estimate $S_{1.234}$ of X_1 with respect to X_2, X_3 and X_4 for the multiple linear regression equations is ranging between 364 ppm to 777 ppm for both banks.

6.1.4 Year Wise Variation in TDS With Reference to Rainfall

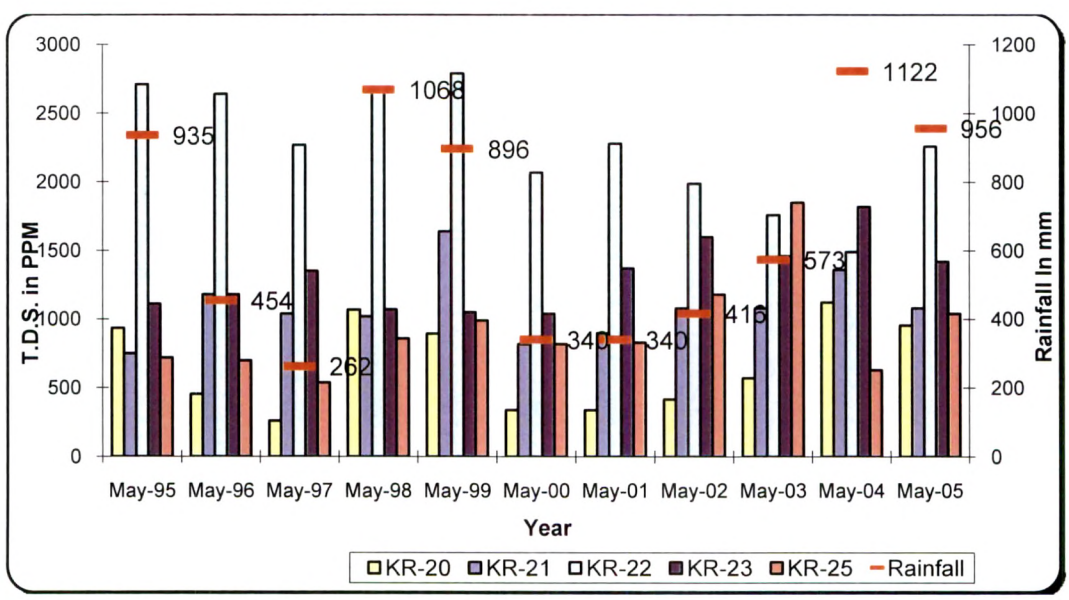
Another analysis which shows the year wise variation in TDS with reference to Rainfall for different wells in different taluka (Graph 6.9 to 6.14) i.e. for Anand taluka (Graph 6.9), for Borsad taluka (Graph 6.10), For Khambhat (Cambay) taluka (Graph 6.11), for Savli taluka (Graph 6.12), for Vadodara taluka (Graph 6.13) and for Padra taluka (Graph 6.14).



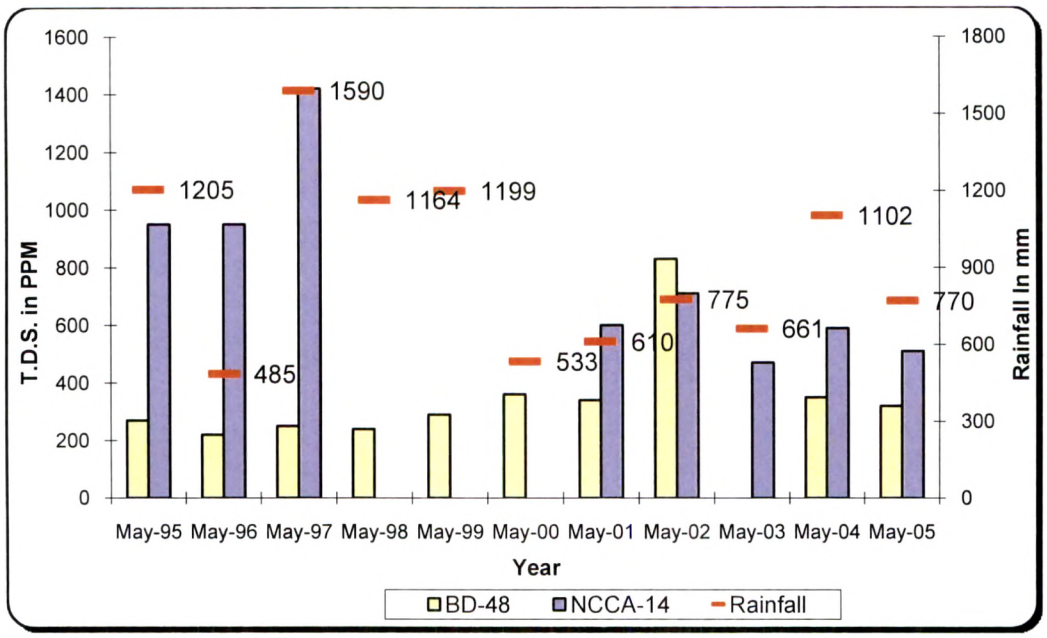
Graph 6.9 Year Wise Variation in TDS With Reference to Rainfall for Different Wells in Anand Taluka



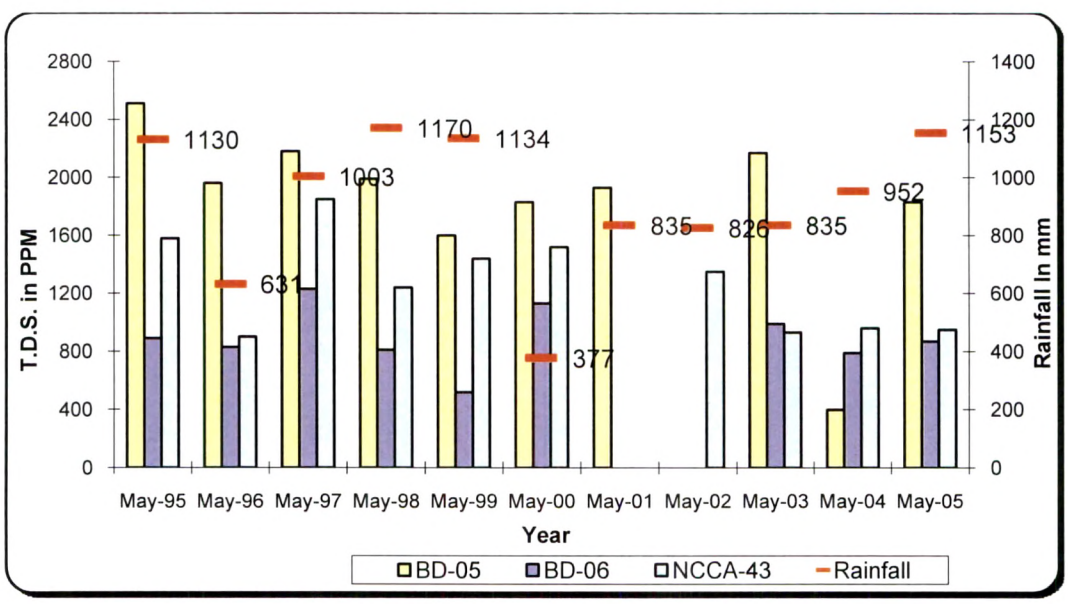
Graph 6.10 Year Wise Variation in TDS With Reference to Rainfall for Different Wells in Borsad Taluka



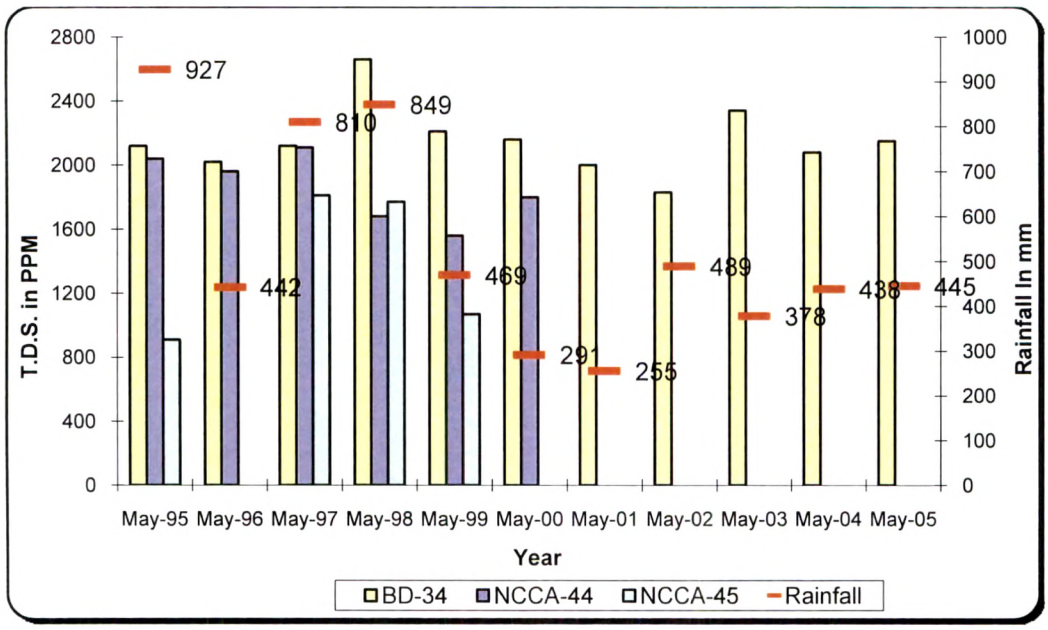
Graph 6.11 Year Wise Variation in TDS With Reference to Rainfall for Different Wells in Khambhat (Cambay) Taluka



Graph 6.12 Year Wise Variation in TDS With Reference to Rainfall for Different Wells in Savli Taluka



Graph 6.13 Year Wise Variation in TDS With Reference to Rainfall for Different Wells in Vadodara Taluka



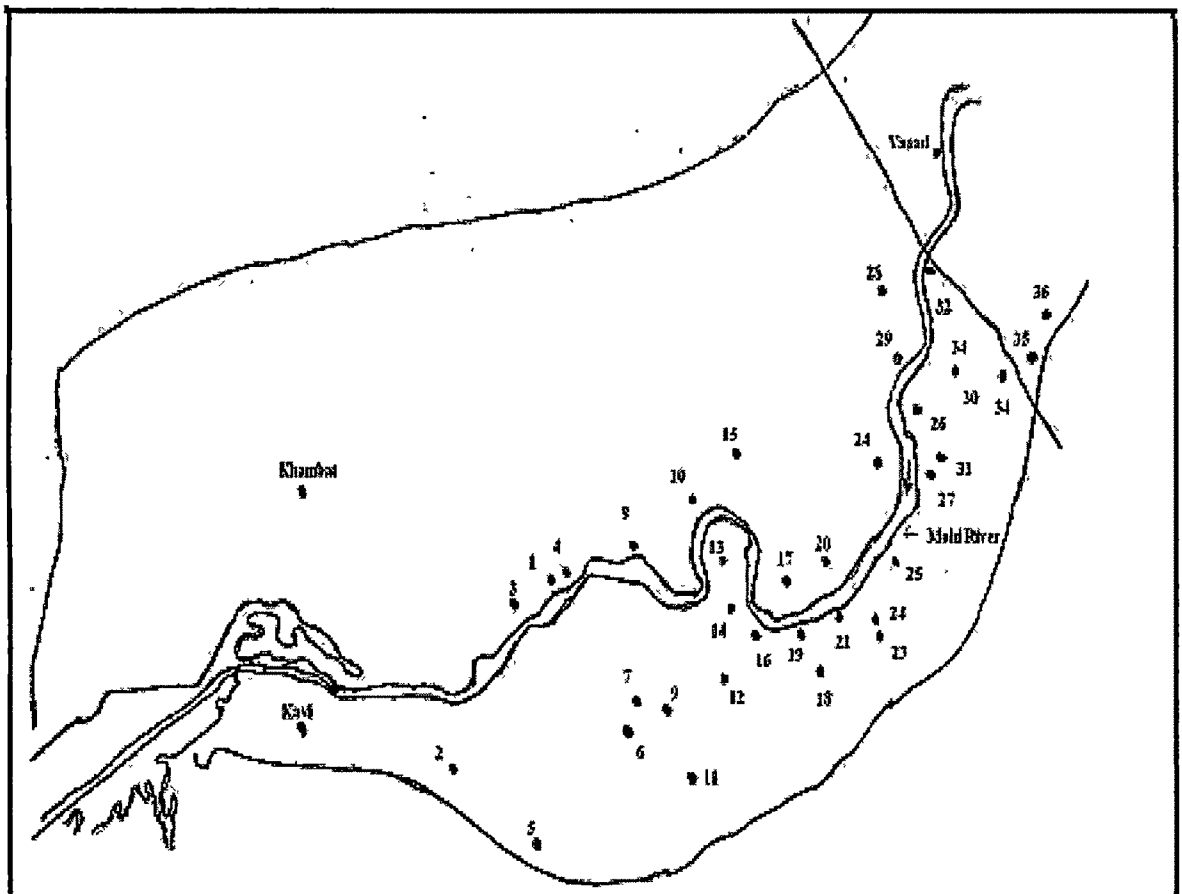
Graph 6.14 Year Wise Variation in TDS With Reference to Rainfall for Different Wells in Padra Taluka

It is observed from Graphs 6.9 to 6.14, that impact of rainfall on TDS is inversely proportional i.e. high value of rainfall shows less value of TDS and less value of rainfall shows high values of TDS for different taluka in Mahi estuarine area.

6.2 Lab Analysis for Water Quality

To get the comprehensive picture of ground water quality changes in Mahi estuarine area in pre and post monsoon season, the sampling was done in a specific manner. The sampling was carried out for ground water quality in the affected area from wells parallel to the Mahi River on both sides within 10 km distance from river. The representative water samples of 36 wells were collected in Plastic containers in May-June for pre-monsoon and in November for post-monsoon period of year 2003. The locations of wells for water samples are shown in figure 6.1. Samples analyzed in the laboratory for different parameters and also analyzed them graphically.

The water samples then were analyzed using standard methods (Lenore et al., 1998), for different important chemical parameters like pH, EC, TDS, Cl, CO_3, HCO_3, TH, Na, Ca, Mg, K and So_4 to evaluate water quality both in pre and post monsoon period in the Environmental Engineering Laboratory, Civil Engineering Department, Faculty of Technology and Engineering, The M. S. University of Baroda, Vadodara.



Well No	Village	Well No	Village	Well No	Village
1	Kankapura	13	Mahmad pura	25	Jaspur
2	Sarod	14	Sultanpura	26	Kotana
3	Badalpur	15	Khedasa	27	Sindhrot
4	Dahevan	16	Dabka	28	Bhetasi Talpad
5	Uber	17	Gambhira	29	Kahanvadi
6	Kareli	18	Dhobi kuva	30	Angadh
7	Tithor	19	Mujpur	31	Sherkhi (Sonafarm)
8	Sarol	20	Bamangam	32	Fajal pur
9	Karakhadi	21	Ekalbara	33	Nandesari
10	Walvod	22	Dabhasa (Pasand)	34	Karachia
11	Kahanva	23	Dabhasa	35	Dashrath
12	Chokari	24	Umeta	36	Ajod

Figure 6.1 Locations of Wells for Water Samples

Results obtained in the laboratory are recorded as statement of different chemical analysis of Mahi estuarine area (distance from Kavi and distance from centre line of river) (Table 6.6).

6.2.1 Graphical Analysis

These laboratory results are also represented graphically as TDS, Cl and TH V/S distances from Kavi and distances from centre line of river to see at a glance the change of ground water quality in Mahi estuarine area in pre monsoon and post monsoon season.

(1) TDS (Total dissolved solids) v/s distance from Kavi. (Graphs 6.15, 6.16 &6.17)

(2) Cl (Chlorides) v/s distance from Kavi (Graphs 6.18, 6.19 &6.20)

(3) TH (Total hardness) v/s distance from Kavi (Graphs 6.21, 6.22 &6.23)

(4) TDS (Total dissolved solids) v/s distance from river. (Graphs 6.24, 6.25&6.26)

(5) Cl (Chlorides)v/s distance from river (Graphs 6.27, 6.28 & 6.29)

(6) TH(Total hardness)v/s distance from river (Graphs 6.30, 6.31&6.32)

Table 6.6 Statement of Chemical Analysis of Water Samples in Mahi Estuarine Area (Dist. from Kavi and Dist. from Centre Line of River)

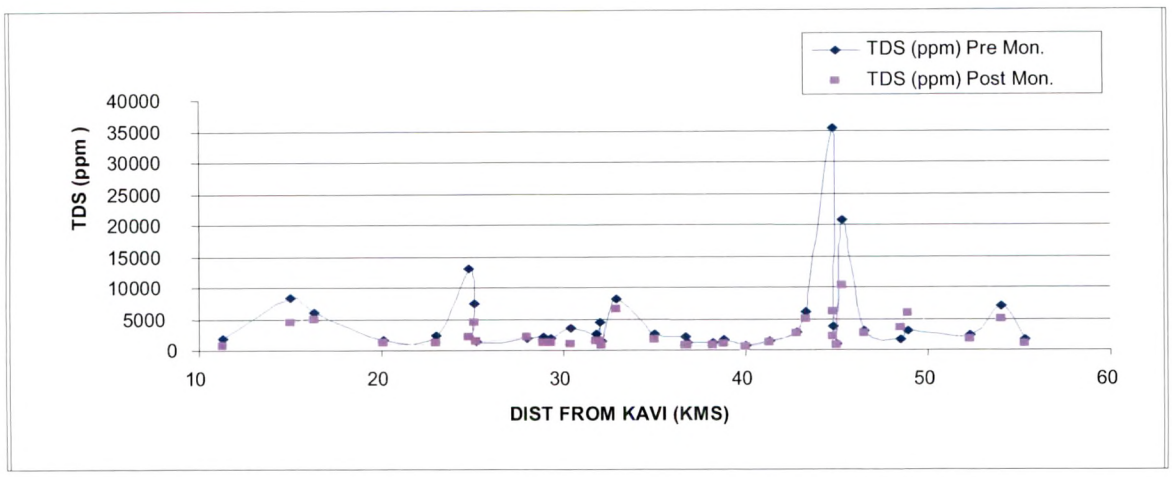
Sample No.	Dist. from kavi km	Dist. from river km	Village	EC (m mhos/cm		pH		TDS (ppm)	
				Pre Mon soon	Post Mon soon.	Pre Mon soon.	Post Mon soon.	Pre Mon soon.	Post Mon soon.
18	11.35	6	Kankapura	502	1041	7.9	8 93	1746	798
21	15	3 3	Sarod	3250	5950	7.6	8.27	8472	4436
23	16.25	5.75	Badalpur	2560	5390	7.6	8.22	5962	4916
13	20.15	6.25	Dahevan	681	1440	8.6	8.78	1712	1168
28	23	8	Uber	1358	1385	7.7	8 47	2272	1258
15	24 8	5.15	Kareli	4050	3410	7.5	8.26	13036	2074
19	25 05	4	Tithor	3400	5780	6.9	8 2	7352	4438
32	25.2	3.5	Sarol	872	1690	8.4	8.58	1504	1404
29	27.95	4.15	Karakhadi	1090	2980	8	8.55	1906	2152
31	28.85	7	Walvod	1290	1447	8.5	8 53	2208	1262
4	29.3	7.65	Kahanva	874	1513	7.6	8.45	1748	1096
6	30.4	4.5	Chokari	2840	1235	7 5	8.45	3390	900
20	31.75	0.45	Mahmad pura	1300	1836	7.8	8.44	2564	1480
26	32	1.7	Sultanpura	1990	1651	7.6	8.69	4398	1476
12	32.1	6.5	Khedasa	473	998	8.3	8.6	1428	752
35	32.9	2.5	Dabka	4190	6900	7.4	8.32	8076	6442
16	35	1.35	Gambhira	1250	2860	7 9	8.45	2556	1662
11	36.7	3 65	Dhobi kuva	632	993	7.8	8.97	2006	736
17	36.75	1.6	Mujpur	400	911	7.9	8.38	1128	602
5	38.15	1.05	Baman gam	456	947	8.4	8 4	1088	706
3	38 75	1.15	Ekalbara	443	1113	7 8	8.29	1554	966
7	40	3.5	Dabhasa (Pasand)	333	709	7.8	8.5	654	494
1	41.25	3.65	Dabhasa	833	1444	8	8.62	1448	1062
34	42.75	1.2	Umeta	1270	2950	7 8	8.11	2808	2570
8	43 25	2.4	Jaspur	2410	6120	7.3	7.76	6062	4966
14	44.75	0.65	Kotana	16400	3220	7.6	8.44	35414	1978
30	44.8	0.85	Sindhrot	1976	6030	7.8	8.15	3630	5968
9	45	2.75	Bhetasi Talpad	430	912	7.4	8.63	960	630
22	45	0.85	Kahanvadi	328	797	8	8.38	842	644
36	45.25	0.7	Angadh	12100	10630	7.2	7.85	20812	10312
33	46.5	2.55	Sherkhi (Sonafarm)	1420	2820	7.9	8.37	2968	2634
2	48 5	0.35	Fajal pur	1210	4970	7.6	8.51	1610	3502
27	48.9	1 6	Nandesari	1260	6790	7.6	8 19	3072	5796
10	52 25	6.35	Karachia	955	2910	7.5	8.21	2408	1704
25	54	7.75	Dashrath	2200	5120	6.6	8.2	7042	4962
24	55 25	8.5	Ajod	578	1153	7.8	8.39	1712	994

Sample No.	Dist. from kavi km	Dist. from river km	Village	Ca++ (ppm)		Mg++ (ppm)		Na+ (ppm)	
				Pre Mon soon.	Post Mon soon.	Pre Mon soon.	Post Mon soon.	Pre Mon soon.	Post Mon soon.
18	11.35	6	Kankapura	33.65	56	33.02	14.33	-	-
21	15	3.3	Sarod	180.3	356	177.3	81.11	-	-
23	16.25	5.75	Badalpur	220.3	184	179.7	183.6	1723	671.6
13	20.15	6.25	Dahevan	28.04	32	33.99	15.3	-	-
28	23	8	Uber	92.14	120	63.13	20.64	-	-
15	24.8	5.15	Kareli	248.4	228	206.4	66.05	-	-
19	25.05	4	Tithor	192.3	92	211.2	161	-	-
32	25.2	3.5	Sarol	36.85	144	52.65	13.6	-	-
29	27.95	4.15	Karakhadı	43.26	96	56.34	30.11	-	-
31	28.85	7	Walvod	40.06	72	212.4	73.58	-	-
4	29.3	7.65	Kahanva	60.09	182	58.28	47.97	-	-
6	30.4	4.5	Chokari	220	52	218.6	43.22	1774	237
20	31.75	0.45	Mahmad pura	35.25	44	39.34	16.03	-	-
26	32	1.7	Sultanpura	120.2	68	145.7	22.34	-	-
12	32.1	6.5	Khedasa	32.04	64	58.28	34.24	-	-
35	32.9	2.5	Dabka	204.3	410	272	245.3	3878	311.25
16	35	1.35	Gambhira	56.08	52	21.85	33.51	-	-
11	36.7	3.65	Dhobi kuva	36.05	44	46.14	12.38	1787	244.5
17	36.75	1.6	Mujpur	60.09	128	48.56	19.91	-	-
5	38.15	1.05	Baman gam	26.03	59.7	57.06	42.58	-	-
3	38.75	1.15	Ekalbara	80.12	214	97.13	56.09	-	-
7	40	3.5	Dabhasa (Pasand)	24.03	60	21.85	13.36	-	-
1	41.25	3.65	Dabhasa	86.53	56.1	42.25	47.08	-	-
34	42.75	1.2	Umeta	132.2	256	106.9	90.82	-	-
8	43.25	2.4	Jaspur	212.3	480	182.1	201.6	-	-
14	44.75	0.65	Kotana	681	72	655.5	83.29	-	-
30	44.8	0.85	Sindhrot	156.2	400	123.9	170	-	-
9	45	2.75	Bhetasi Talpad	52.07	68	48.56	49.05	-	-
22	45	0.85	Kahanvadi	76.11	48	43.71	38.13	-	-
36	45.25	0.7	Angadh	1302	1120	1105	480.8	-	-
33	46.5	2.55	Sherkhi (Sonafarm)	196.3	424	221	137.5	-	-
2	48.5	0.35	Fajal pur	240.4	267	194.2	27.52	-	-
27	48.9	1.6	Nandesarı	216.3	408	109.3	124.3	-	-
10	52.25	6.35	Karachia	152.2	128	104.4	87.91	-	-
25	54	7.75	Dashrath	641	980	330.3	408	-	-
24	55.25	8.5	Ajod	64.09	44	46.13	40.31	-	-

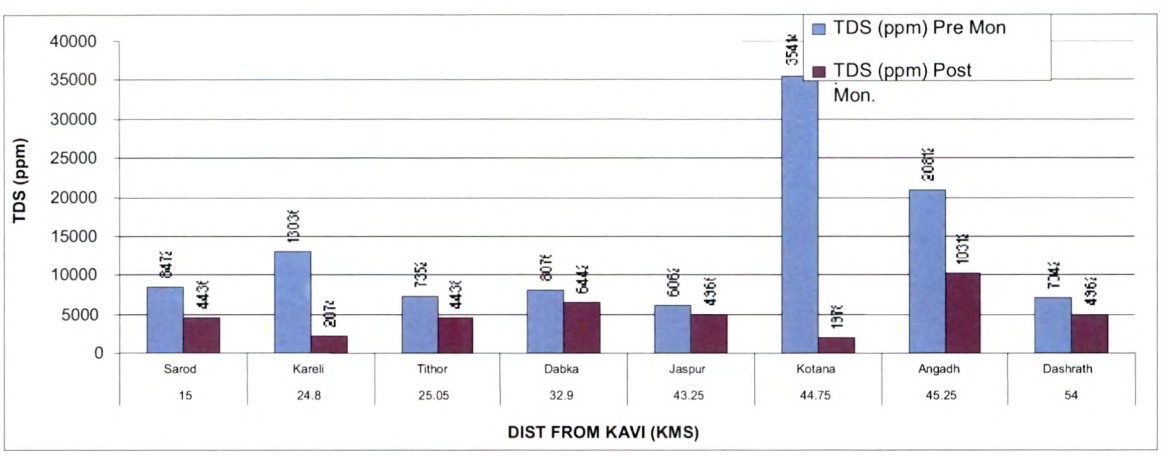
Sample No.	Dist. from kavi km	Dist. from river km	Village	Co3 (ppm)		HCO3 (ppm)		Cl- (ppm)	
				Pre Mon soon.	Post Mon soon.	Pre Mon soon.	Post Mon soon.	Pre Mon soon.	Post Mon soon.
18	11.35	6	Kankapura	Nil	Nil	707.6	420	999.69	259.92
21	15	3.3	Sarod	Nil	Nil	793	280	5248.37	2199.32
23	16.25	5.75	Badalpur	Nil	Nil	536.8	130	4398.63	2149.33
13	20.15	6.25	Dahevan	18	Nil	1024.8	690	299.9	319.9
28	23	8	Uber	Nil	Nil	671	280	1449.53	449.86
15	24.8	5.15	Kareli	Nil	Nil	732	380	5498.29	1099.66
19	25.05	4	Tithor	Nil	Nil	707.6	260	7747.59	2374.26
32	25.2	3.5	Sarol	Nil	Nil	817.4	480	999.69	459.86
29	27.95	4.15	Karakhadi	Nil	Nil	915	600	1399.56	974.7
31	28.85	7	Walvod	Nil	Nil	793	470	1199.62	309.9
4	29.3	7.65	Kahanva	Nil	Nil	805.2	300	659.8	579.82
6	30.4	4.5	Chokari	Nil	Nil	585.6	420	3099.03	349.89
20	31.75	0.45	Mahmad pura	Nil	Nil	896.6	540	1799.44	439.86
26	32	1.7	Sultanpura	Nil	Nil	695.4	490	2199.31	459.86
12	32.1	6.5	Khedasa	Nil	Nil	902.8	510	399.87	299.907
35	32.9	2.5	Dabka	Nil	Nil	610	210	7197.76	2924.09
16	35	1.35	Gambhira	Nil	Nil	878.4	510	1999.38	519.84
11	36.7	3.65	Dhobi kuva	Nil	Nil	805.2	510	549.82	179.94
17	36.75	1.6	Mujpur	Nil	Nil	805.2	330	1199.62	219.93
5	38.15	1.05	Baman gam	Nil	Nil	780.2	350	280	269.92
3	38.75	1.15	Ekalbara	Nil	Nil	549	170	359.88	419.87
7	40	3.5	Dabhasa (Pasand)	Nil	Nil	585.6	300	199.9	269.92
1	41.25	3.65	Dabhasa	Nil	Nil	488	340	434.86	419.87
34	42.75	1.2	Umeta	Nil	Nil	646.6	150	1499.53	824.74
8	43.25	2.4	Jaspur	Nil	Nil	549	110	1999.4	2649.18
14	44.75	0.65	Kotana	Nil	Nil	488	230	15995.1	909.72
30	44.8	0.85	Sindhrot	Nil	Nil	549	130	3398.94	2499.23
9	45	2.75	Bhetasi Talpad	Nil	Nil	658.8	380	474.85	249.92
22	45	0.85	Kahanvadi	Nil	Nil	695.4	330	599.81	199.94
36	45.25	0.7	Angadh	Nil	Nil	451.4	100	14995.3	6697.92
33	46.5	2.55	Sherkhi (Sonafarm)	Nil	Nil	707.6	170	1199.62	824.74
2	48.5	0.35	Fajal pur	Nil	Nil	524.6	170	2199.3	2024.37
27	48.9	1.6	Nandesari	Nil	Nil	622.2	140	1249.61	2924.09
10	52.25	6.35	Karacha	Nil	Nil	793	340	799.75	669.79
25	54	7.75	Dashrath	Nil	Nil	475.8	180	499.84	399.88
24	55.25	8.5	Ajod	Nil	Nil	732	280	999.69	369.89

Sample No.	Dist. from kavi km	Dist. from river km	Village	SO4 (ppm)		K (ppm)		TH (ppm)	
				Pre Mon soon.	Post Mon soon.	Pre Mon soon.	Post Mon soon.	Pre Mon soon.	Post Mon soon.
18	11 35	6	Kankapura	-	-	-	-	169.62	115
21	15	3.3	Sarod	-	-	-	-	910.26	690
23	16.25	5.75	Badalpur	8.8	381.395	13.68	4.7	960.29	940
13	20.15	6.25	Dahevan	-	-	-	-	168.01	95
28	23	8	Uber	-	-	-	-	352.1	205
15	24.8	5.15	Kareli	-	-	-	-	1098.37	500
19	25.05	4	Tithor	-	-	-	-	1062.08	755
32	25.2	3.5	Sarol	-	-	-	-	253.66	200
29	27.95	4.15	Karakhadi	-	-	-	-	275.26	220
31	28.85	7	Walvod	-	-	-	-	914.76	375
4	29.3	7.65	Kahanva	-	-	-	-	300.08	380
6	30.4	4.5	Chokari	82.25	12.34	17.25	6.65	1120.02	230
20	31.75	0.45	Mahmad pura	-	-	-	-	197.25	110
26	32	1.7	Sultanpura	-	-	-	-	720.17	160
12	32.1	6.5	Khedasa	-	-	-	-	272.03	205
35	32.9	2.5	Dabka	317.9	268.38	7.36	4.66	1324.31	1420
16	35	1.35	Gambhira	-	-	-	-	146.05	190
11	36.7	3.65	Dhobi kuva	256.5	23.4	4.709	1.522	226.05	95
17	36.75	1.6	Mujpur	-	-	-	-	260.06	210
5	38.15	1.05	Baman gam	-	-	-	-	261	235
3	38.75	1.15	Ekalbara	-	-	-	-	180.1	445
7	40	3.5	Dabhasa (Pasand)	-	-	-	-	114	115
1	41.25	3.65	Dabhasa	-	-	-	-	260.51	250
34	42.75	1.2	Umeta	-	-	-	-	572.19	630
8	43.25	2.4	Jaspur	-	-	-	-	962.27	1310
14	44.75	0.65	Kotana	-	-	-	-	3380.37	415
30	44.8	0.85	Sindhrot	-	-	-	-	666.24	1100
9	45	2.75	Bhetasi Talpad	-	-	-	-	252.04	270
22	45	0.85	Kahanvadi	-	-	-	-	256.1	205
36	45.25	0.7	Angadh	-	-	-	-	5851.93	3100
33	46.5	2.55	Sherkhi (Sonafarm)	-	-	-	-	1106.29	990
2	48.5	0.35	Fajal pur	-	-	-	-	1040.08	380
27	48.9	1.6	Nandesari	-	-	-	-	666.27	920
10	52.25	6.35	Karachia	-	-	-	-	582.11	490
25	54	7.75	Dashrath	-	-	-	-	2000.93	2660
24	55.25	8.5	Ajod	-	-	-	-	254.05	210

Note: - Indicate chemical analysis not done.

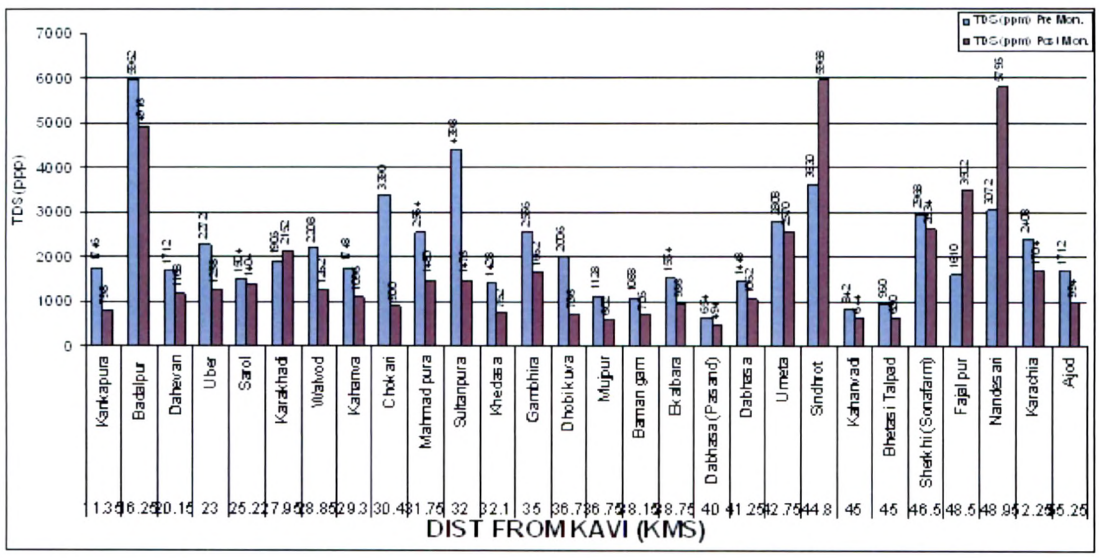


Graph 6.15 Total Dissolved Solids V/S Distance from Kavi



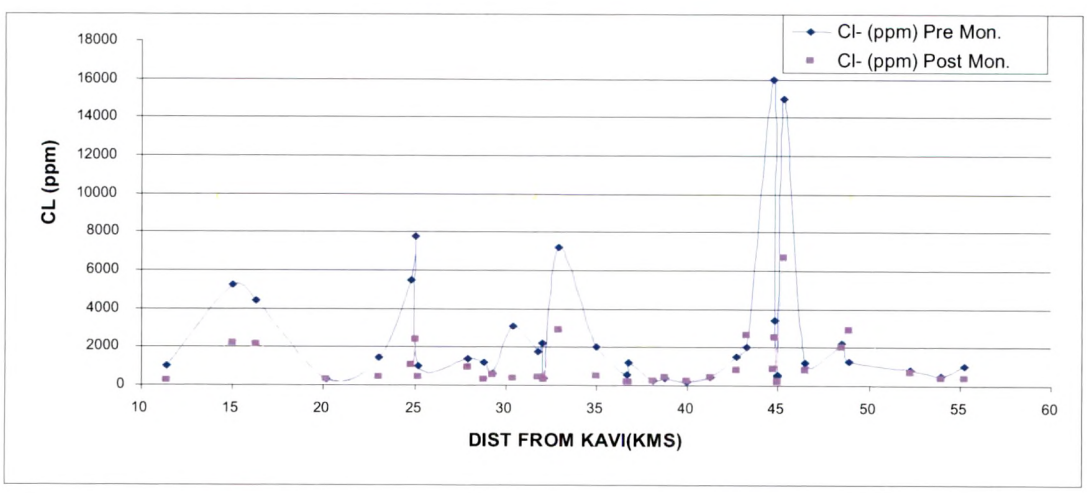
Graph 6.16 Total Dissolved Solids V/S Distance from Kavi

(Pre-Monsoon TDS > 6000 ppm)

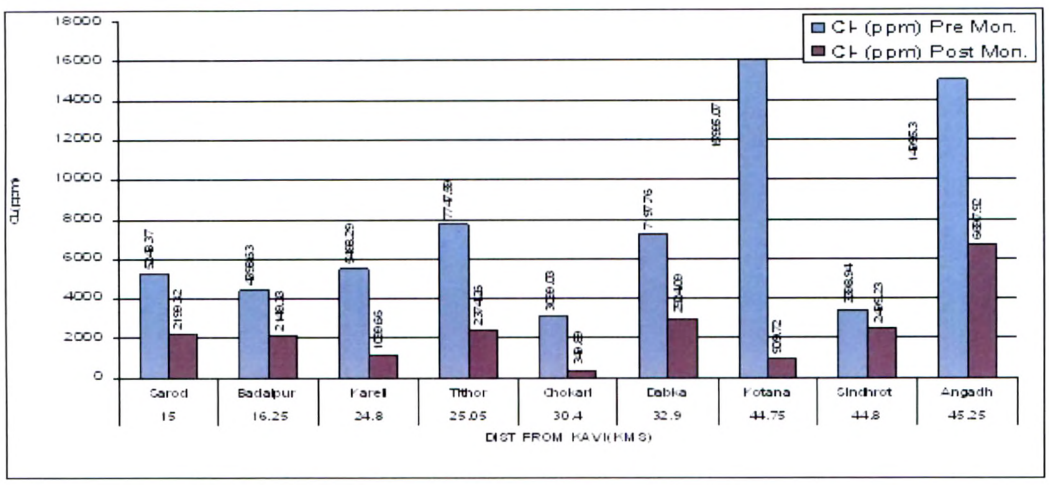


Graph 6.17 Total Dissolved Solids V/S Distance from Kavi

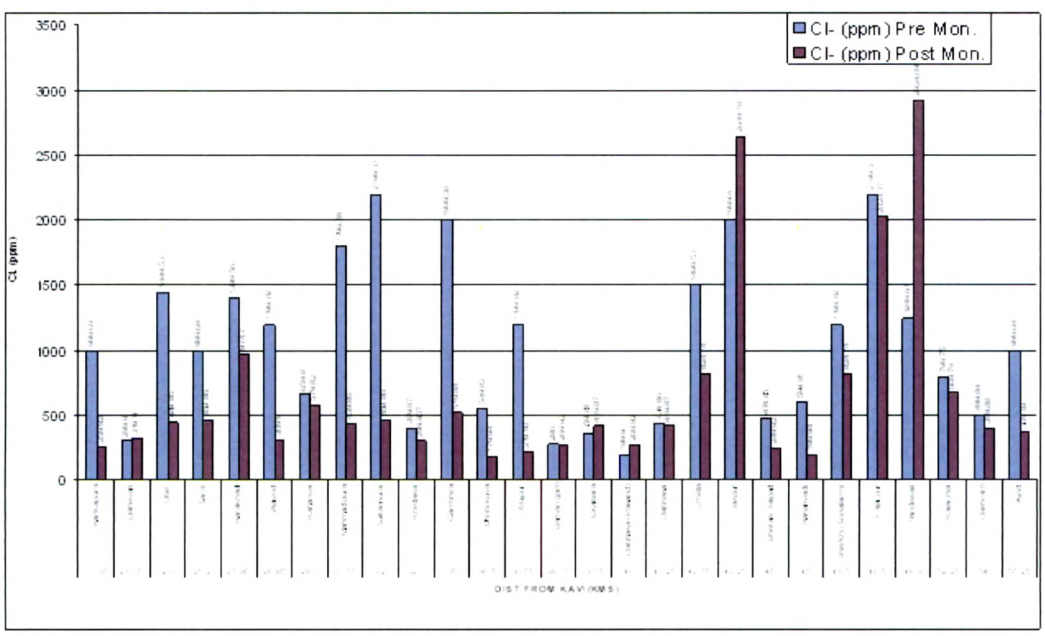
(Pre-monsoon TDS < 6000 ppm)



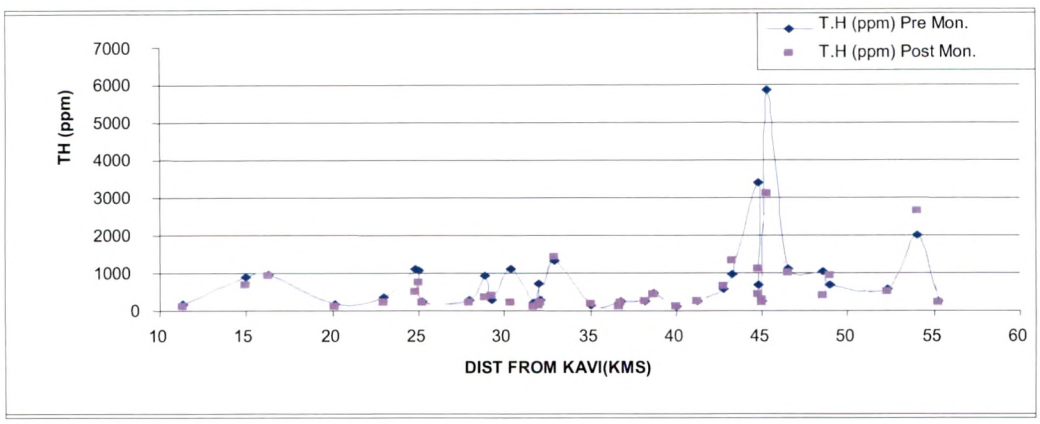
Graph 6.18 Chlorides V/S Distance from Kavi



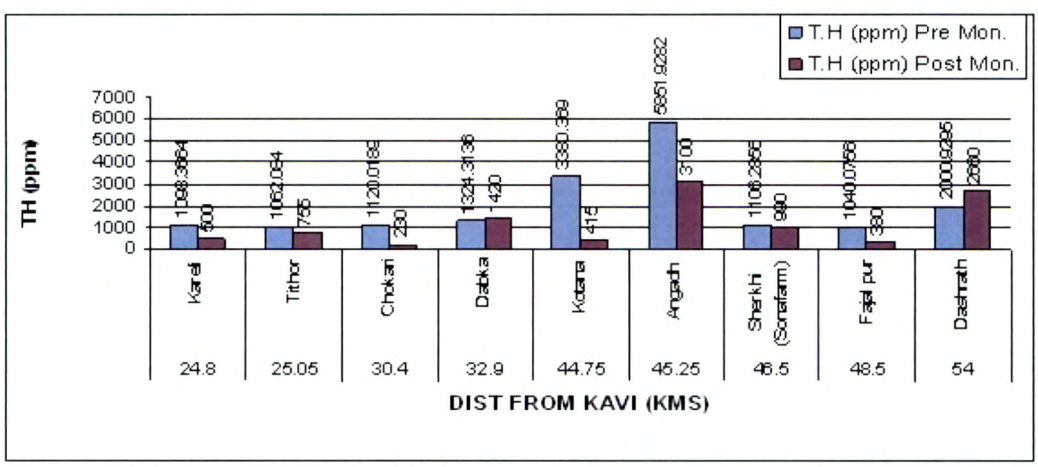
Graph 6.19 Chlorides V/S Distance from Kavi (Pre-Monsoon Cl > 3000 ppm)



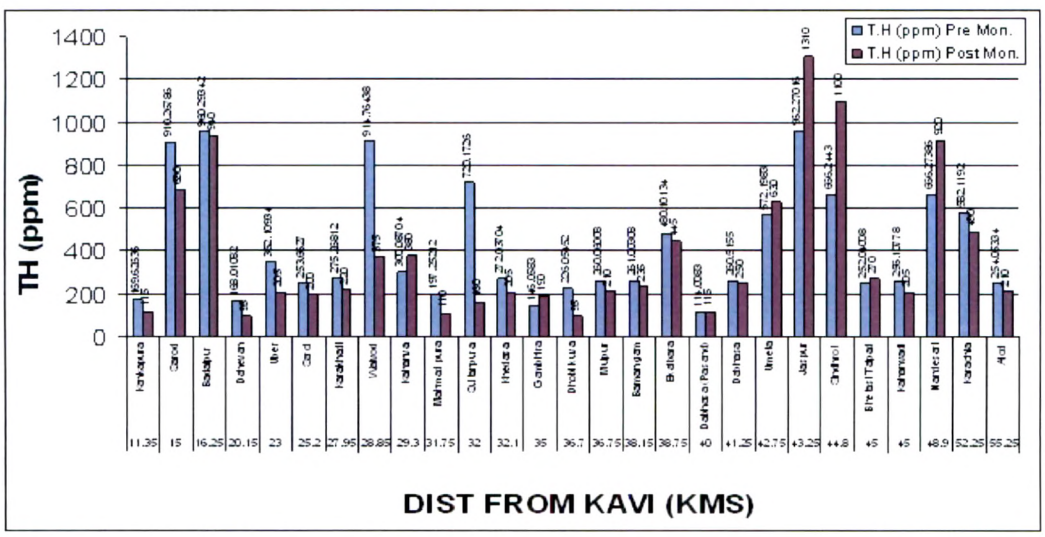
Graph 6.20 Chlorides V/S Distance from Kavi (Pre-Monsoon Cl < 3000 ppm



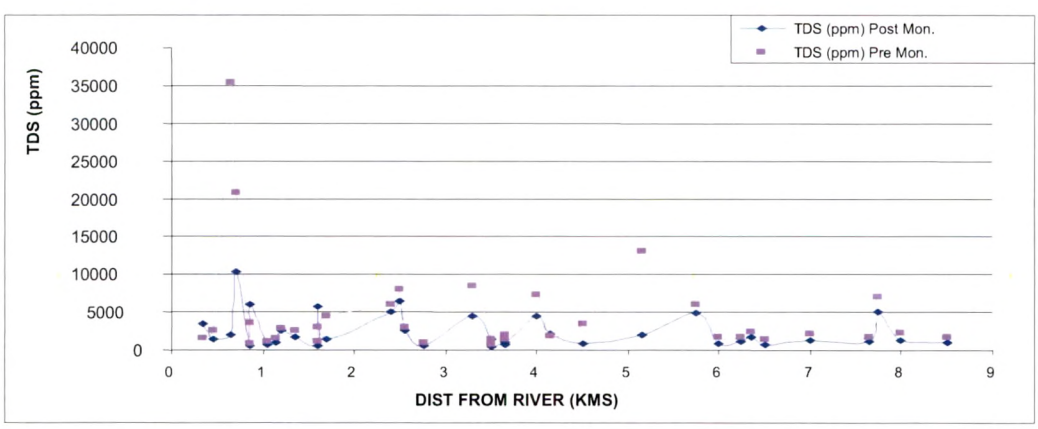
Graph 6.21 Total Hardness V/S Distance from Kavi



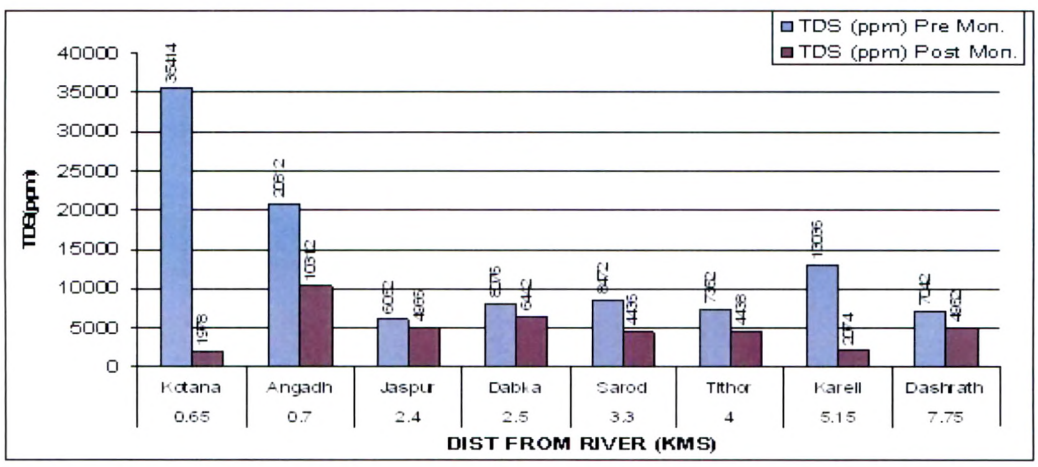
Graph 6.22 Total Hardness V/S Distance from Kavi (Pre-Monsoon TH > 1000 ppm)



Graph 6.23 Total Hardness V/S Distance from Kavi (Pre-Monsoon TH < 1000 ppm)

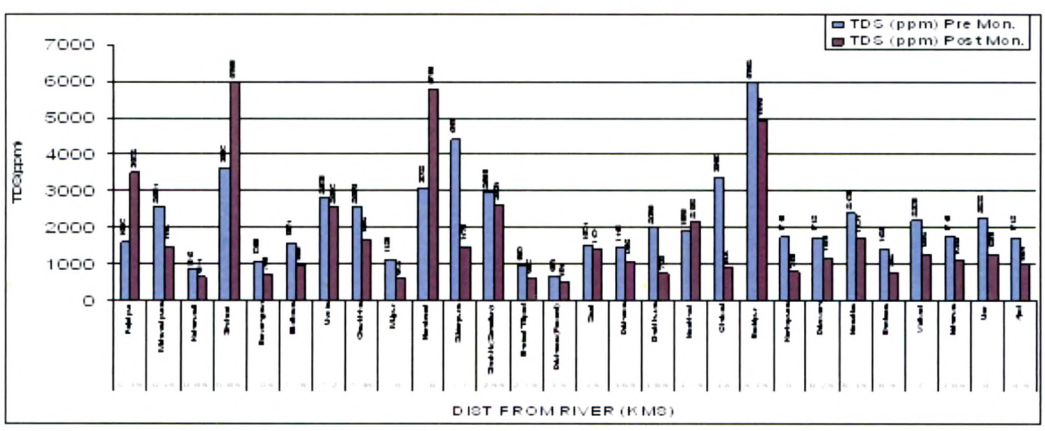


Graph 6.24 Total Dissolved Solids V/S Distance from River



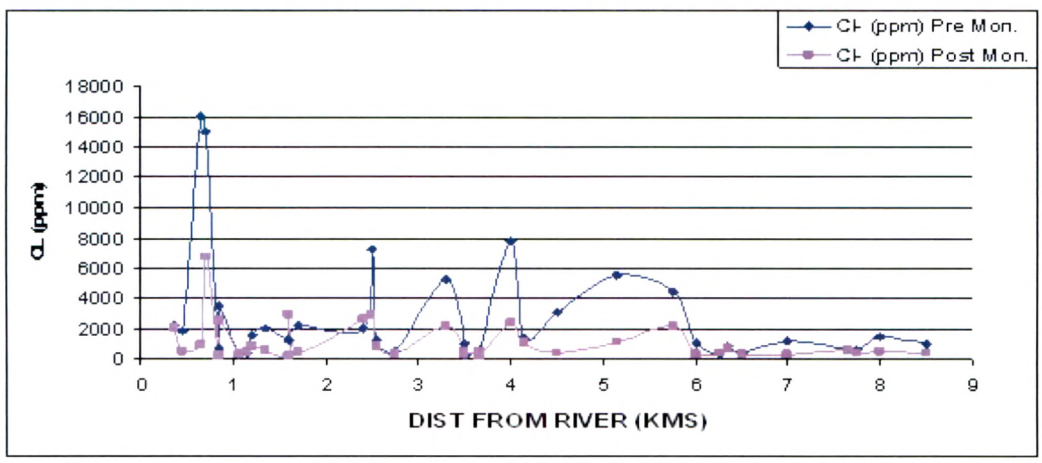
Graph 6.25 Total Dissolved Solids V/S Distance from River

(Pre-Monsoon TDS > 6000 ppm)

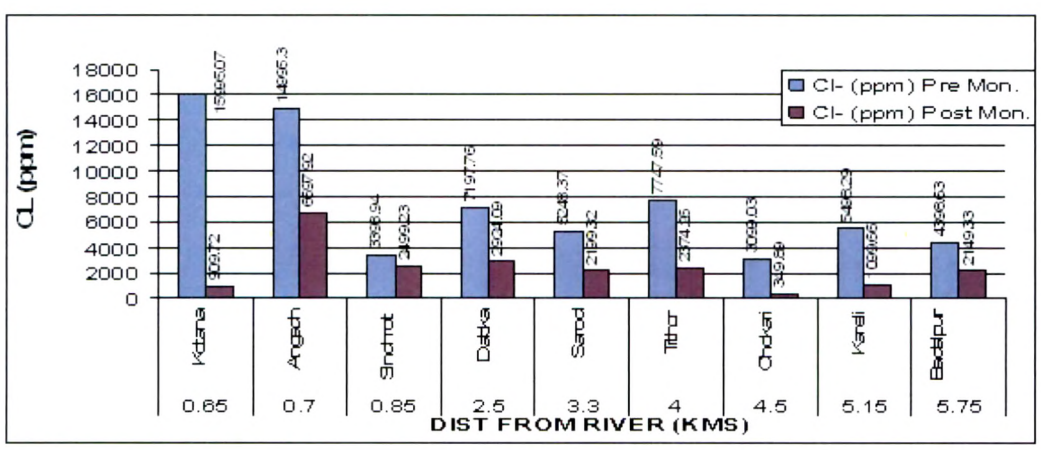


Graph 6.26 Total Dissolved Solids V/S Distance from River

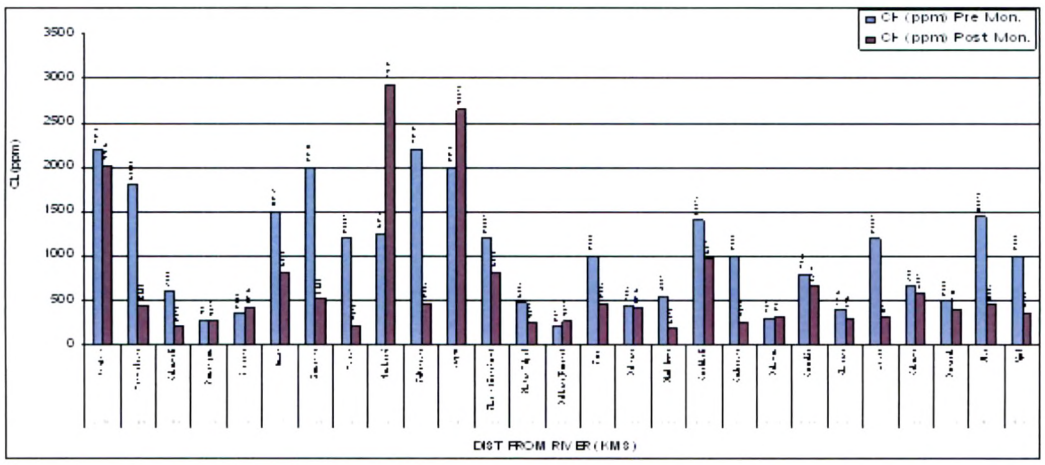
(Pre-monsoon TDS < 6000 ppm)



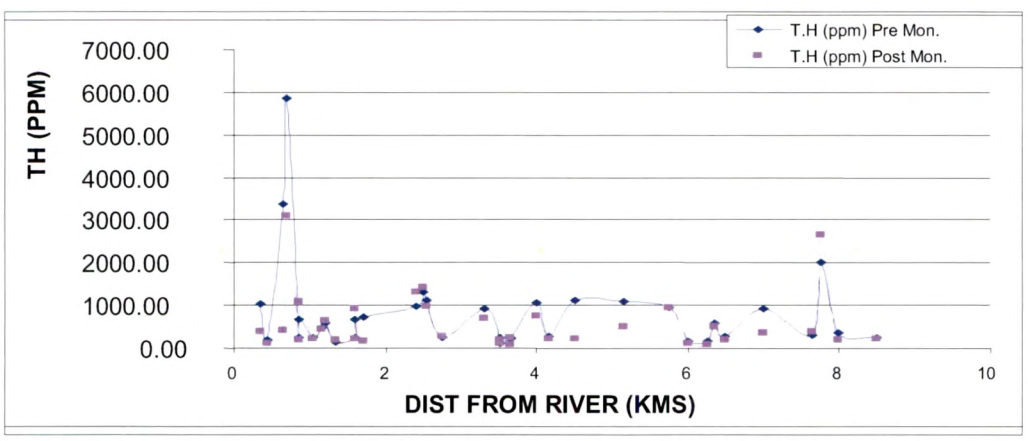
Graph 6.27 Chlorides V/S Distance from River



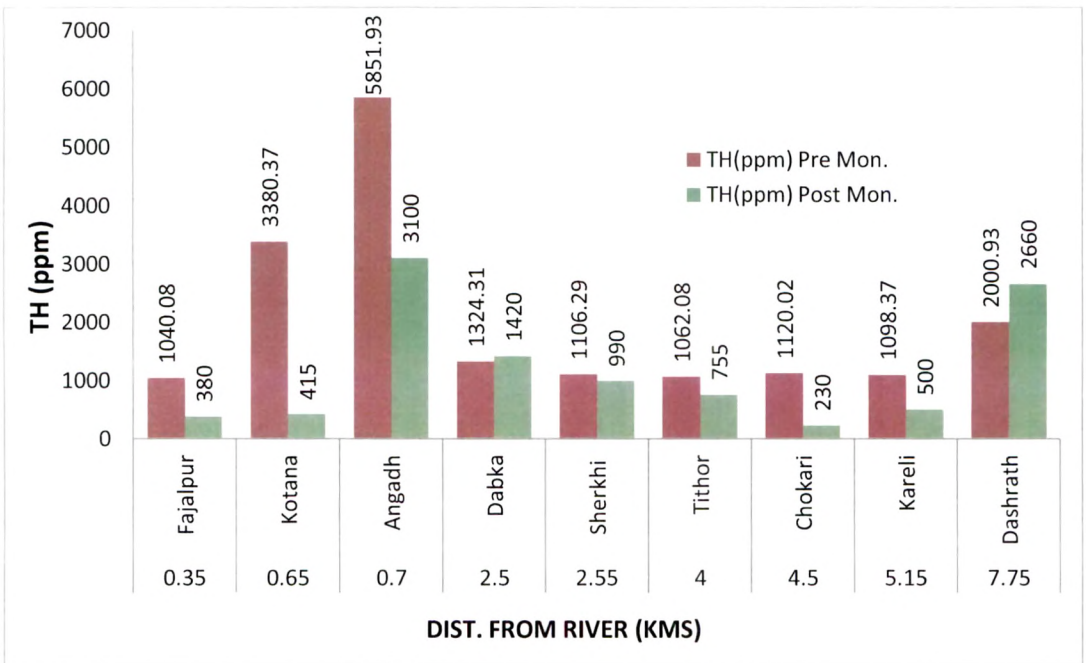
Graph 6.28 Chlorides V/S Distance from River (Pre-Monsoon Cl > 3000 ppm)



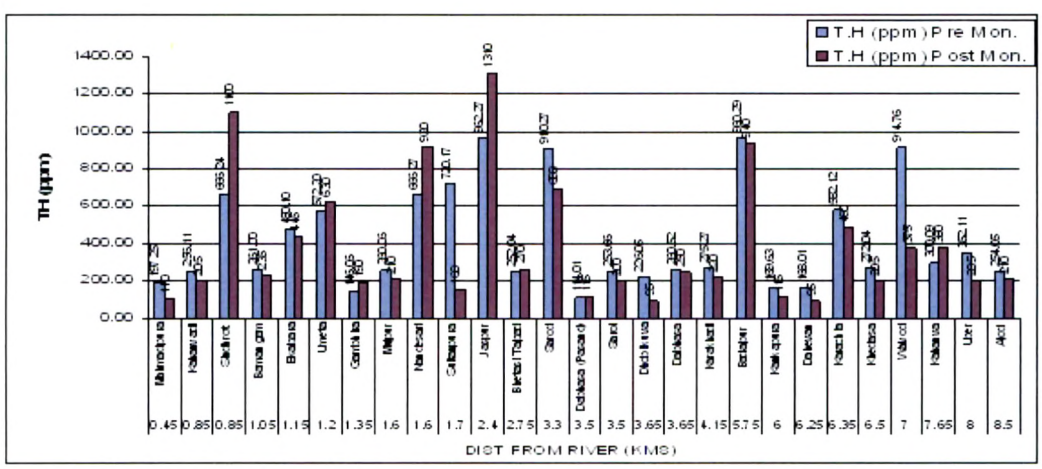
Graph 6.29 Chlorides V/S Distance from River (Pre-Monsoon Cl < 3000 ppm)



Graph 6.30 Total Hardness V/S Distance from River



Graph 6.31 Total Hardness V/S Distance from River (Pre-Monsoon TH > 1000 ppm)



Graph 6.32 Total Hardness V/S Distance from River (Pre-Monsoon TH < 1000 ppm)