COMPARISON OF GROUNDWATER RECHARGE OF THE SAPANCA LAKE IN NORTHERN TURKEY WITH REMOTE SENSING

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In this study, remote sensing (RS) techniques are used as a tool to verify the groundwater recharge of the Sapanca Lake in northern Turkey. It is necessary to work with recent data and with recent Pinder's theory of Groundwater recharge to be able to compare the groundwater recharge with RS method. Sapanca Lake basin area is a polluted catchment because of heavy urbanization and industrial development around it. RS is an important tool to monitor groundwater quality and to compare the pollution area of the lake surface and the Izmit Bay area at Marmara Sea which is not far from Sapanca Lake. There is a seepage recharge between the lake and the bay. For this aim, a project has been initiated at the Technical University Hydraulic Laboratory and at the Remote Sensing Laboratory. The study uses LISS-III satellite data of 1996 for water quality analysis at Part of Sapanca Lake and Izmit Bay. The RS data was converted into the UTM coordinate system and image enhancement and classification techniques are used. As a result of disporsion of the seepage from Sapanca Lake to Izmit Bay recommendations are made for planning and management of the polluted environment of the Sapanca Lake basin. Measuring the groundwater recharge is a very important issue for preventing the pollution sources of the basin and for controlling the future development of the catchment, RS technique is performed and results are compared with theoretical considerations of the groundwater pollution.

Keywords: ***Remote sensing (RS); ground water quality; Pollution; Satellite data.***

1. Introduction

This article provides an overview of the Sapanca Lake water capacity management program, including a description of the hydrologic conditions in the region, an overview of the lake storage system and its water use control capabilities, and salt water intrusion from the Marmara Sea at Izmit Bay at Northwest-Turkey (Fig.1). A description of forecasting procedures and water-use control operating strategy is also given. The development and implementation of water capacity management program, and its role in reducing water amount at the Sapanca Valley are also presented. The article has given th a discussion about the (comparing the prediction of ground water research theory with RS technique) role of water management advances for the future operations. Groundwater flow from Sapanca Lake Basin from the Sea at the Izmit Bay is represented by three governing equations: ground water flow equation representing the fresh water portion of the flow system, a ground water flow equation representing the salt water portion of the flow system, and an equation derived that enables determination of the elevation of the interface as a function of fresh and salt water hydraulic heads which assigned density values.

A three-dimensional finite element code is given that simulates fluid flow and solute transport in saturated porous media. Groundwater flow is represented by three governing equations: ground water flow equation representing the fresh water portion of the flow system, a ground water flow equation representing the salt water portion of the flow system, and an equation derived by Hubbert (1940) that enables determination of the

elevation of the interface as a function of fresh and salt water hydraulic heads and assigned density values . These equations are solved simultaneously for each time step of a model simulation. A description of forecasting procedures and water-use control operating strategy was also given. The article closes with a discussion of the role of water management advances on future operations. As a conclusion, withdrawn water differs with the months. Because Sapanca Lake interact with ground water in three basic ways: some receive groundwater inflow throughout their entire bed, some have seepage loss to ground water throughout their entire bed, but Sapanca Lake receive ground-water inflow through part of their bed from Sakarya river. Although these basic interactions are the same for lakes as they are for streams, the interactions differ in several ways.

Therefore to protect the measure different water quality; remote sensing (RS) and Geographic Information Systems (GIS) are useful techniques with the potential to meet these objectives. Remote sensing techniques provide not only a spatial data connection but it is also a powerful technology for the quantitative analysis of land use and water quality changes and for map updating (Coskun et al., 2005).

Performing these inventories with classical methods is not sufficient as they are time consuming, and take many resources. RS and techniques can be effectively used for determining and updating the land-use changes in the water basin areas and pollution loads on the water that water bodies can then be expressed in terms of suspended sediment concentrations, turbidity, or secci disk depth (Bahrgava and Mariem, 1991, Coskun et al., 1995, 2002, 2005,2006).

The main purpose of this paper is to describe the application of satellite data for dispersion measurements of the Sapanca Lake water quality changes of the Lake using RS techniques. For this aim, a study has been at the Istanbul at Technical University Remote Sensing Laboratory using LISS-III satellite data of 1996 for water dispersion . RS data have been converted into UTM coordinate system. Image enhancement and classification techniques have been applied to the images. Results of dispersion measurement from Sapanca Lake to Izmit Bay are measured and visualized both in graphical representation at Figure 4.

This paper is concerned with the previous study which was explained as above theoretical dispersion results were to present, to what extend is possible on preparation of with remote sensing techniques using satellite data. Whereby two sets of data namely, in the lake the from the starting point to the finishing point on the İzmit Bay of the dispersion distance is calculated. Different water quality ground water measurements such as polluted water and the natural lake water showed from the satellite images. The correlation between each pair of variables in these two sets is sought by the dispersion approach, which is coming to the remote sensing data analysis recently. The study area is chosen as one of the important area as afuture drinking water resorvuar in the northwestern part Marmara Region in Turkey. It has been observed that some significant relations become apparent adaptively by the disporsion approach and this relations help to manage future water management using the satellite data, too.

2.The characteristics of the Study Area

Sapanca Lake is the drinking water source of the Adapazari at the earthquake region of Turkey. The geographical characteristics of this region was given by Yilmaz et.al. (1999). Sapanca lake is situated at the north-west part of Turkey. Sapanca Lake's water shows seepage to the Marmara Sea at Izmit Bay and Sakarya River. Izmit bay is 19 km. far away and the distance from Sakarya River is nearly 5 km. Drinking water and industry water for this environment is taken from this lake. In recent years, at the Sapanca Lake Basin

Area the necessity to the water increased, because of the industry and the growth of the population as the reason of the settlement from the East Anatolia (Fig. 1).

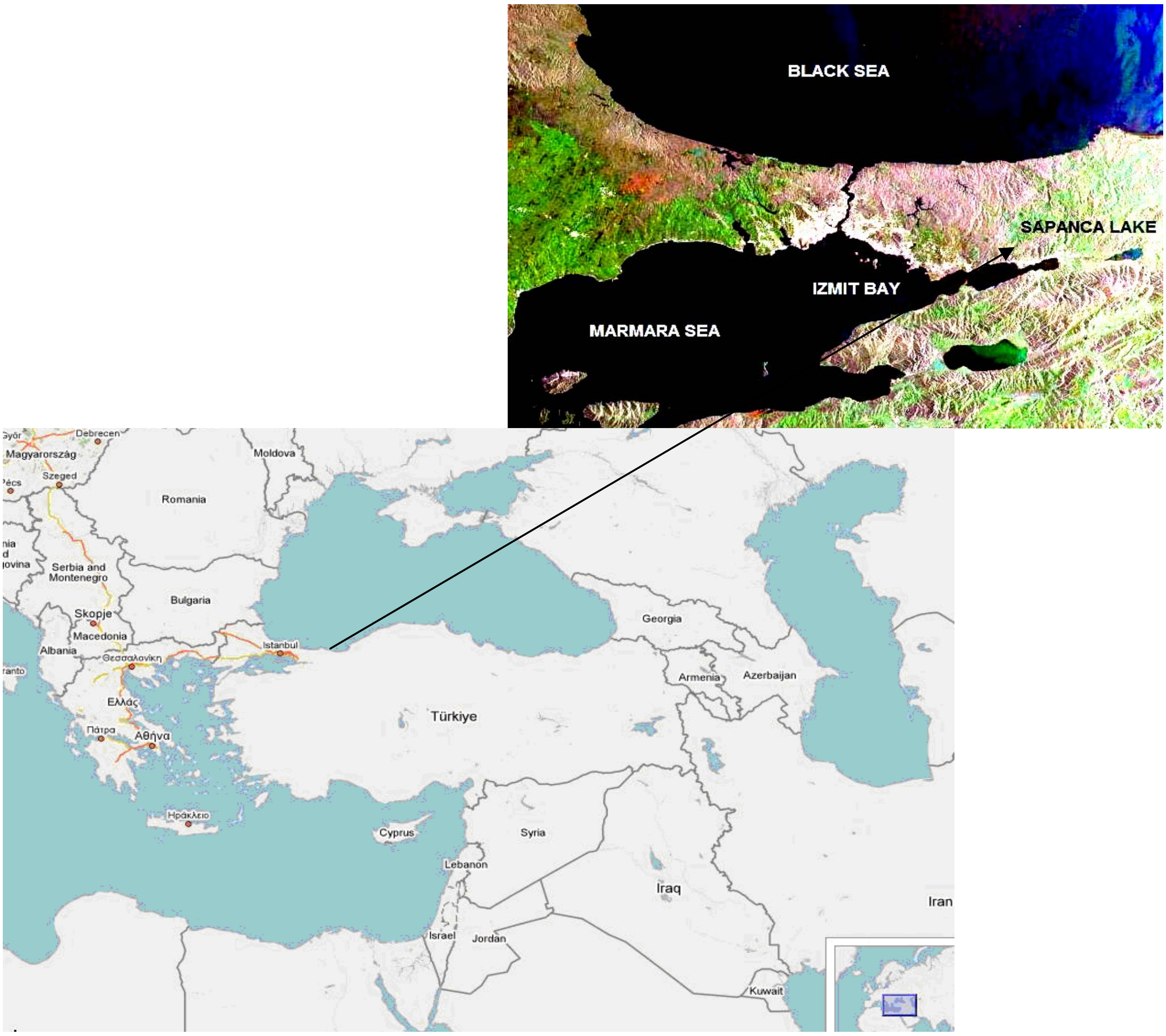

Figure 1. Study area consists of Sapanca Lake and Izmit Bay which is given on georeferenced raster data

At the geological point of view, the formation of this basin consists of the alluvial materials. At the last 30 years in this river – basin, Sakarya River bottom boundary layer degrade oneself nearly 8-10 m. The degradation at the bottom of Sakarya River could affect on the seepage from Sapanca Lake. It is necessary a new estimation of the withdrawn water from Sapanca Lake. Sapanca Lake is planned to be the drinking water supply of the Outside Greater Istanbul Region in the future. Within the framework of the IVth 5-Year Development Plan Execution Plan of the year 1977, item 24S, a water pollution study has been carried out in this lake. Various water quality parameters have been analyzed in the samples taken periodically during the years 1980-1982 from 41 sampling points at 18 sampling stations at different depths in the lake, inflowing streams and outflowing stream.

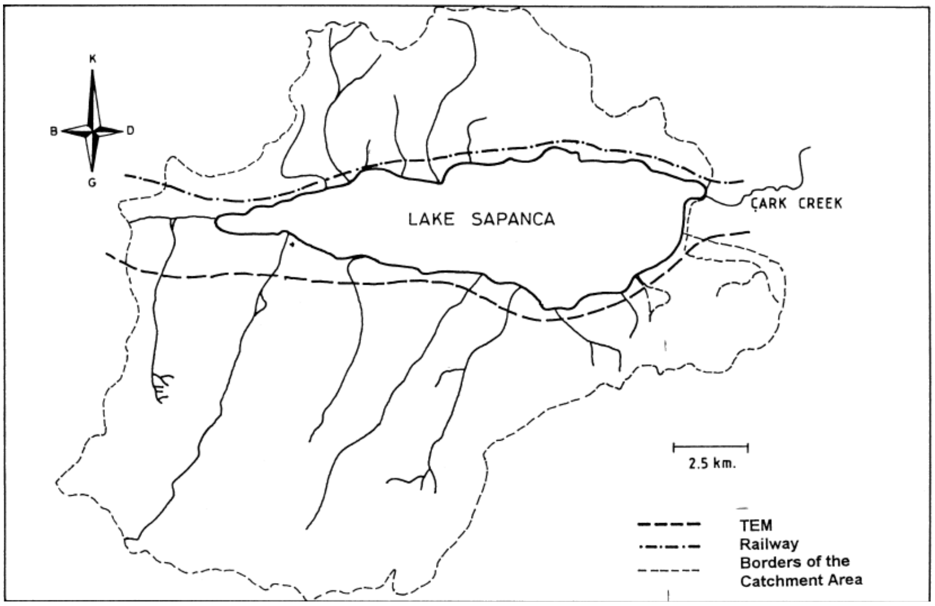

Figure 2. General layout of the study area Sapanca District (Tanık et.al. 1998)

The waste water from the residential regions, commercial and tourist facilities comes to the lake without treatment. Some pollutions occur because of the exhaust gases from the Ankara and Istanbul highway which passes through the north of the lake. Sapanca Lake is situated 30 meter above sea level between Sakarya River and Izmit Bay, which has superfluous waters with a catchment area 311 km^2. The length is 16 km and the other dimension of the Sapanca Lake is nearly 6 km and has a elliptical surface area. The surface area changes between 46 km^2 and 60 km^2 depending on the seasonal water balance. Maximum storage level is changed from 32.00 m. level into the 31.50 m. level.

3. The hydrological characteristics of the Sapanca Lake

Some hydrological characteristics of the Sapanca Lake is given (Sumer, 1980):

Yearly Storage Volume: 159x10^6 m^3/year
Yearly mean flow to the Sapanca Lake: 180.27 x 10^6 m^3/year
The total capacity of the Lake : 150x10^6 m^3/year
Maximum pool level: 32.00 m.
Minimum pool level: 28.00 m.

A variety of general interpolation methods is available for areal estimations (Rainbird, 1976; Mendel, 1979; Giesecke et. al., 1983). For water balance studies it is useful to obtain estimates of the error of computed areal means. An overview on this problem is given by Kagan & Poliscuk (1972), Clarke & Edwards (1972). Bras & Rodriguez-Iturbe (1976 a, 1976 b). There is an ever growing need for water balance computations which are required for Sapanca Lake. Different methods are improved for the estimation of the lake capacity. Here , a simple method for the estimation of lake water budget is given from the evaluation of the data between the years 1965 and 1976 (Table 1).

TABLE:1 Graphical values of the monthly used water volumes : x 10^6 m^3

Years	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May.	June	July	Aug.	Sept.
1975	3,62	2,84	1,98	2,63	6,64	22,55	29,06	7,33	4,28	4,85	5,36	6,53
1974	2,25	1,81	3,56	3,37	3,76	4,92	11,75	3,55	8,99	6,76	2,77	4,56
1973	27,14	31,29	20,93	14,88	5,75	4,42	4,52	4,50	4,17	2,85	3,74	3,22
1972	1,50	1,52	9,64	23,59	22,65	2,64	1,15	2,21	8,48	31,47	15,30	24,22
1971	2,64	6,38	18,25	31,00	27,60	21,95	24,75	13,14	4,61	2,88	1,97	1,74
1970	2,03	1,96	2,06	2,20	2,61	8,04	24,42	14,02	3,29	2,23	1,56	2,83
1969	12,57	24,96	40,33	41,21	37,32	32,22	28,54	29,47	18,79	8,71	4,38	2,58
1968	2,95	3,45	5,88	14,64	21,46	24,49	20,84	13,48	11,09	11,09	10,78	10,29
1967	2,93	2,29	2,35	3,08	3,84	5,91	7,93	9,05	5,18	4,04	3,99	3,19
1966	3,81	3,53	4,61	5,88	10,24	16,23	20,32	8,19	5,47	5,34	4,77	3,55
1965	4,95	4,54	20,27	22,68	23,09	29,81	37,58	25,38	10,32	6,35	5,44	4,87
TOT	66,39	84,57	129.86	165,16	164,96	173,18	210,86	130,32	84,67	86,57	60,06	67,00

From Table.1 necessary Total water volume is taken as Tot. V = 118.69 x 10^6 m^3/year

Sapanca lake is a very important water source at this district, but there is no prevention from the pollutions. On the other hand, there is no real key study for the withdrawn water capacity. There is only a key study about the pollution control of the Sapanca Lake and depends on the data about 20 years ago (Sumer, 1980). After this date, at this district the suburb area buildings are increased heavily. The heavy amount of pollution, which comes from the touristic and industry establishments, continue to send pollution sources to the lake.

There is only one key study about the hydrological cycle about the Sapanca Lake. In this study the seasonal water level changes are examined (Aka, 1983). It is necessary to make a water budget management of the Sapanca Lake.

4. Water Budget for Sapanca Lake (Used Method)

After evaluating the collected data, it was seen that the pollution level in the lake, inflowing and outflowing streams was not high and the water quality of the lake was suitable as a raw drinking water and industrial water source and fisheries and aquatic life. It was also determined that the lake has an oligotrophic structure. The results of the study have been evaluated and proposals were developed for the protection of the present water quality of Sapanca Lake.

For this period, lake water levels, precipitations, and evapotranspirations, nearly withdrawn water amount are taken into account for presenting the seepage of the lake. Monthly calculated average seepage data is used to estimate the withdrawn water from the lake between the years 1976 and 1985. These estimations are compared with these withdrawn water amount differences of those years and are examined.

For this subject the classical and simple water budget relationship is given below (Eagleson, 1978)

$$P - E - Y - dS = L, \qquad (1)$$

where P = precipitation; E = evapotranspiration; Y = streamflow (discharge = Cark Creek), dS =change of Sapanca Lake Storage Volume and L = losses of water volume

$$L = S + W \text{ and } S = L - W, \tag{2}$$

where S = real groundwater runoff, L = total loss of storage volume and W = water volume for users. The real water volume for users is given as;

$$W = P - E - Y - dS - S. \tag{3}$$

Water loss can be found with the relationship (2). In this relationship seepage can be found. After determining the seepage, water-use-capacity can be calculated from the Equation 3.

At the Cark Creek which is a discharge of the superfluous water of the Sapanca Lake to the Sakarya River passes through Adapazari has been polluted completely by the sewer of the residential areas and the untreated liquid wastes of the industrial plants. The Cark Creek was a place of recreament in the past, but now it has become a source of embarrassment for the residential areas around.

5. Extension of Darcy's Law to three Dimensions in seepage

Darcy's law can be written in three dimensions as below:

$$V_X = -K_x \frac{\delta H}{\delta X} \quad V_y = -K_y \frac{\delta H}{\delta Y} \quad V_z = -K_z \frac{\delta H}{\delta Z} \tag{4}$$

where *Vx, Vy* and *Vz* are the velocity vector components and δH/δX, δH/δY and δH/δZ are the hydraulic gradients of the phreatic line. For non-homogeneous and anisotropic medium Darcy's Law can be written as (Bear 1972):

$$\begin{aligned} qx &= Kxx\,Jx + Kxy\,Jy + Kxz\,Jz \\ qy &= Kyx\,Jx + Kyy\,Jy + Kyz\,Jz \\ qz &= KzxJx + KzyJy + KzzJz \end{aligned} \tag{5}$$

where *qx, qy* and *qz* are the components of the specific discharge in x, y and z directions respectively. *Jx, Jy,*and *Jz* are the components of the hydraulic gradient, *Kx, Ky* and *Kz* are the permeability tensor coefficients. The permeability tensor is symmentric and hence *kxy = kyx, kxz = kzx and, kyz=kzy*. Thus the principal permeabilities are *kxx, kyy* and *kzz.*

The Dupuit's equation which is derived from *q= -k dh/dx .(h.1)* is a strong artifice that can be used to interpolate the heads within the given two sections of the aquifer, which exhibits two-dimensional heads as is the present case. The equation pre-supposes reasonably less hydraulic gradients for the phreatic surface (U.S.EPA,1988).

6. Governing Equation for 2-D Groundwater

The 3-dimensional equation governing groundwater flow is obtained by integrating the 2-D equation along the vertical Z, which mathematically eliminates variations along z dimension. The resultant head is termed as piezometic head, instead of total head. For a confined aquifer, this equation may also yield the values of transmissivity and storage coefficients. Therefore

$$\frac{\partial}{\partial X}\left[K_{xx} b \frac{\partial H}{\partial X}\right] + \frac{\partial}{\partial Y}\left[K_{yy} b \frac{\partial H}{\partial Y}\right] + K_{zz} b \frac{\partial}{\partial Z}\Big|_{z=b} - K_{zz} b \frac{\partial}{\partial Z}\Big|_{z=0} + \sum_{i=1}^{N} Q_i \partial(X - X_i)\partial(Y - Y_i)$$
$$= S_s b \frac{\partial \overline{H}}{\partial t} \qquad (6)$$

7. Spatial Velocities in the Unconfined Aquifer

The artifice of Pinder and Abriola (1982) is used for the case of São Bento-PB, which involve two- and three dimensional heads from piezometers placed in an aleatory manner which form a tetrahydron.(Fig 1). In matric notation, the components of velocity are expressed as follows :

$$\begin{bmatrix} V_x \\ V_y \end{bmatrix} = \frac{1}{\theta}\begin{bmatrix} K_{xx} K_{xy} & \frac{\partial h}{\partial x} \\ K_{yx} K_{yy} & \frac{\partial h}{\partial y} \end{bmatrix} \qquad (7)$$

where V = velocity, θ= effective porosity of the aquifer material, K = permeability coefficient and h = piezometric head. Pinder and Abriola (1982) adopted their systematic method to estimate the velocity components in three dimensions in an anisotrpoic aquifer as:

$$Vx = \frac{1}{\theta}\left(K_{xx}\frac{\partial h}{\partial x} + K_{xy}\frac{\partial h}{\partial y} K_{xz}\frac{\partial h}{\partial z}\right) \qquad (8a)$$

$$Vy = \frac{1}{\theta}\left(K_{yx}\frac{\partial h}{\partial x} + K_{yy}\frac{\partial h}{\partial y} + K_{yz}\frac{\partial h}{\partial z}\right) \qquad (8b)$$

$$Vx = \frac{1}{\theta}\left(K_{zx}\frac{\partial h}{\partial x} + K_{zy}\frac{\partial h}{\partial y} K_{xz}\frac{\partial h}{\partial zz}\right) \qquad (8c)$$

where h = hydraulic head [L]; Kxx, Kxy and Kxz = components of the permeability tensor, K [LT^{-1}]; Vx, Vy,and Vz = directional velocity components, V [LT^{-1}]; n_{ef} = θ = effective porosity of the soil which is non-dimensional With K and θ known, one can calculate the velocity components with the algebraic expressions as given in Table 1.

8. Pinder's Theory Applied to the Tetrahydron

The configuration adopted is in the form of a tetrahydron (ABCD) reduced to a triangle (ABC') because the two points that are in the viscinity of Well N^o. 3 (C & D) have equal heads, thus reduce to a single point C'. The radius of influence of Well N^0. 3 is 18 m. The input data included the coordinates at the 4 corner points of the tetrahydron (Fig. 2), namely x,y and z at the four points, the respective piezometric heads registered, the permeability coefficients in x, y and z directions and effective porosity of the aquifer medium. The corresponding velocity components, their resultants in the x-y and x-z planes the angles these resultants make with the planes are the outputs. The simulated dischares for the test pumping rates of 20.90, 40.00 and 80.80 m^3/h as performed by the CDRM are 1Q, 2Q, 3Q and 4Q.The permeability value in the z-diretion (Kzz) is taken as

Kh/Kv=1000 (Rushton and Redshaw, 1979; Sarma and Silva, 1987). Hereunder three examples are presented to show the differences that occur with changes in two-dimensional hydraulic heads at the four corners of the tetrahydron (Tab. 2) .

Table 2 – Algebraic Expressions for Three Dimensional Velocity Components

Node Coeffts.	B_j x 6_v	c_j x 6_v	d_j x 6_v
01	$Z_1Y_3+Z_3Y_4+Y_2Z_4$ $-Y_3Z_4-Y_2Z_3-Z_2Y_4$	$Z_2X_4+X_2Z_3+X_3Z_4$ $-X_2Z_4-Z_3X_4-Z_2X_3$	$Y_3X_4+Y_2X_3+X_2Y_4$ $-X_2Y_3-X_3Y_4-Y_2X_4$
02	$Y_3Z_4+Y_1Z_3+Z_1Y_4$ $-Z_1Y_3-Z_3Y_4-Y_1Z_4$	$X_1Z_4+Z_3X_4+Z_1X_3$ $-Z_1X_4-Z_4X_3-X_1Z_3$	$X_1Y_3+X_3Y_4+Y_1X_4$ $-Y_3X_4-X_3Y_1-X_1Y_4$
03	$Z_1Y_2+Z_2Y_4+Y_1Z_4$ $-Y_2Z_4-Y_1Z_2-Z_1Y_4$	$Z_1X_4+X_1Z_2+X_2Z_4$ $-X_1Z_4-Z_2X_4-Z_1X_2$	$Y_2X_4+Y_1X_2+X_1Y_4$ $-X_1Y_2-X_2Y_4-X_4Y_1$
04	$Y_2Z_3+Y_1Z_2+Z_1Y_3$ $-Z_1Y_2-Z_2Y_3-Y_1Z_3$	$X_1Z_3+Z_1X_2+Z_2X_3$ $-Z_1X_3-X_1Z_2-X_2Z_3$	$X_1Y_2+X_2Y_3+X_3Y_1$ $-Y_2X_3-Y_1X_2-Y_3X_1$

Note: 6^v = b1+b2x2+b3x3

Table 3 - Convention adopted for the Coordinate System in theTrapezoidal Irrigation Lot - x,y,z and H

Data	Xm	Ym	Zm	Hm	Comments
Point 1	-200	0	-5	16	Refer to the
Point 2	-260	0	+3	18	Figure for
Point 3	-260	+160	+4	15	Coordinate
Point 4	-200	+160	-3	16	System

Calculation of the Spatial Velocities:

H_1 (m) =16: H_2 (m) = 18 : H_3(m) = 15: H_4(m) = 16

Permeabilities (m/day): $K_{xx} = K_{yy}$ = 26.144 : K_{zz} = 0.026144

Vx = Velocity in X direction = 31.953 m/day

Vy = Velocity in Y direction = 3.268 m/day

Vz = Velocity in Z direction = -2.614 m/day

Resultant = $\sqrt{(Vx^2 + Vy^2)}$ = 32.120 m/day

θ in degrees = 5.87 to the longitudinal direction of flow

Thus, Pinder's artifice as modified by Sarma and Alex (1997) served well to obtain the spatial velocities and their components, and also their inclination to the x-y and y-z planes.

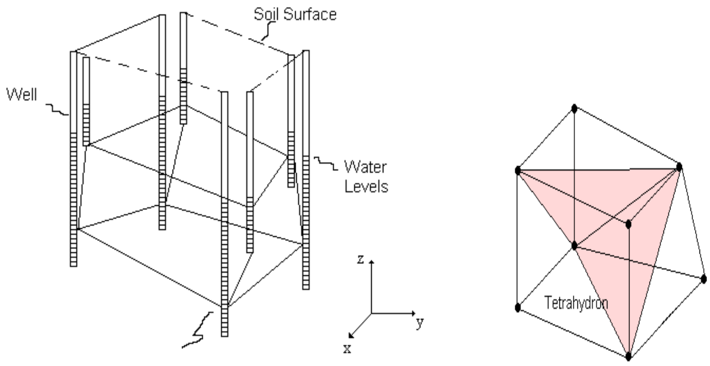

Figure 3. Tetrahydron

9. Method of Remote Sensing

For the location images of Sapanca Lake Basin at North Turkey the digital satellite data set IRS-LISS respectively dated year of 1996 were used. Firstly, digital satellite data set was transformed into UTM coordinate system that the geometric registration process using 1/5000 digital topographic maps. Taking 40 ground control points using the maps, the images are registered and than geometrically corrected before the image classification. Coordinate transformation has done in order by polynomial transformation equation and by resolution using cubic convolution technique. After the test of registration accuracy on test points and the result root mean error (RSME) is given as $\pm$0.5 pixels. (Figure 4).

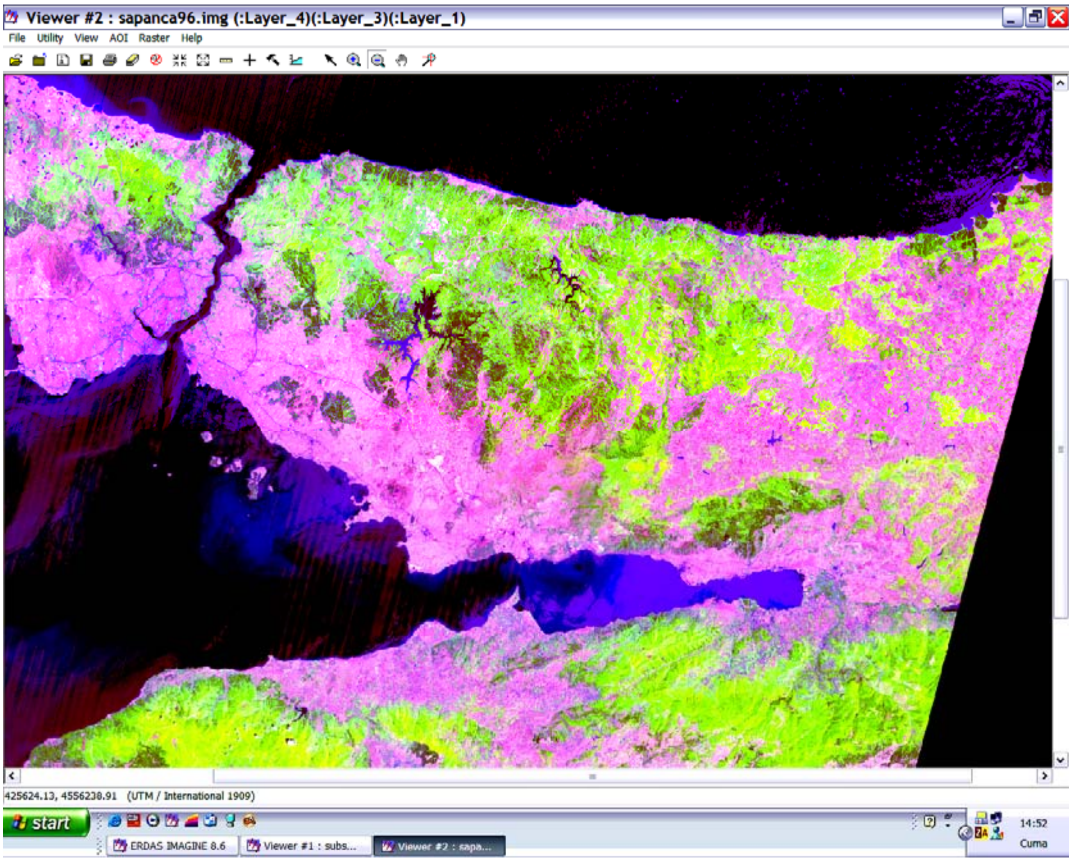

Figure 4. IRS-LISS satellite image of dated 1996 that is obtained ERDAS 8.6 software at the Sapanca Lake basin area using UTM coordinate system.

The distance of dispersion is taken at the local points which can be seen on the Figures 5 and 6, while the beginning of the dispersion can be met at the entrance of Izmit Bay. The other dispersion loads after the Izmit Bay entrance are secondary currents of the seepage from the Lake to the Izmit Bay. This theoretical used data considerations belonged to the year of 1995, but the used satellite data has sensed year of 1996. If the both measurements are consisting of the same year, accuracy assessment would be higher then the last result.

The result images have been given on Fig. 5 and 6 which were obtained using one of important RS techniques that called ISODATA classification method working with reflection of different type of water body on different sensed wavelight interval bands . Adapted to the UTM coordinate system image(Figs 5 and 6) can provide different water bodies and measure distances which is chosen by us.

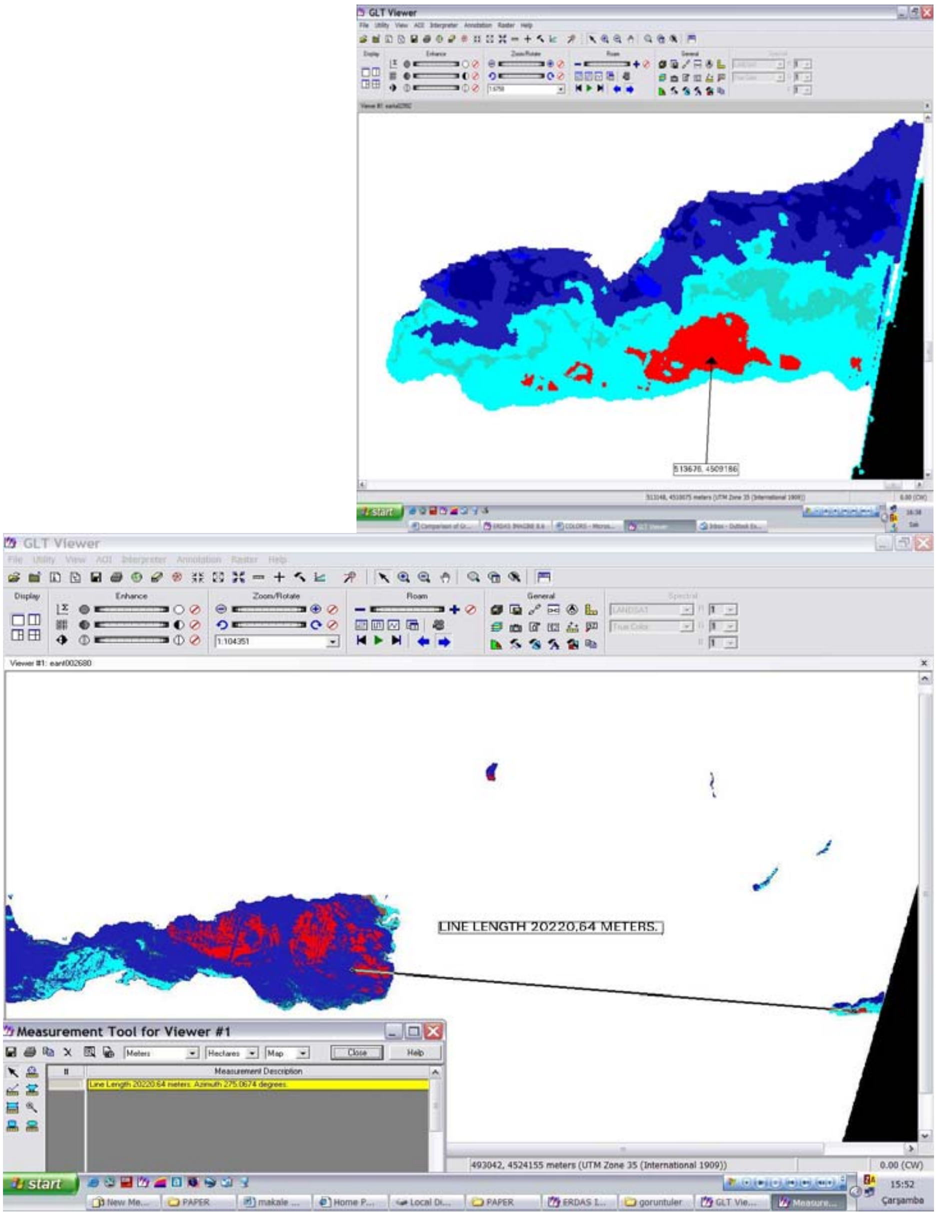

Figure 5. IRS-LISS uncontrolled satellite image of dated 1995 that is obtained ERDAS 8.6 software at the Sapanca Lake basin area which contains dark blue for conventional pollution, red contains industrial pollution and cyan contains house-hold pollution

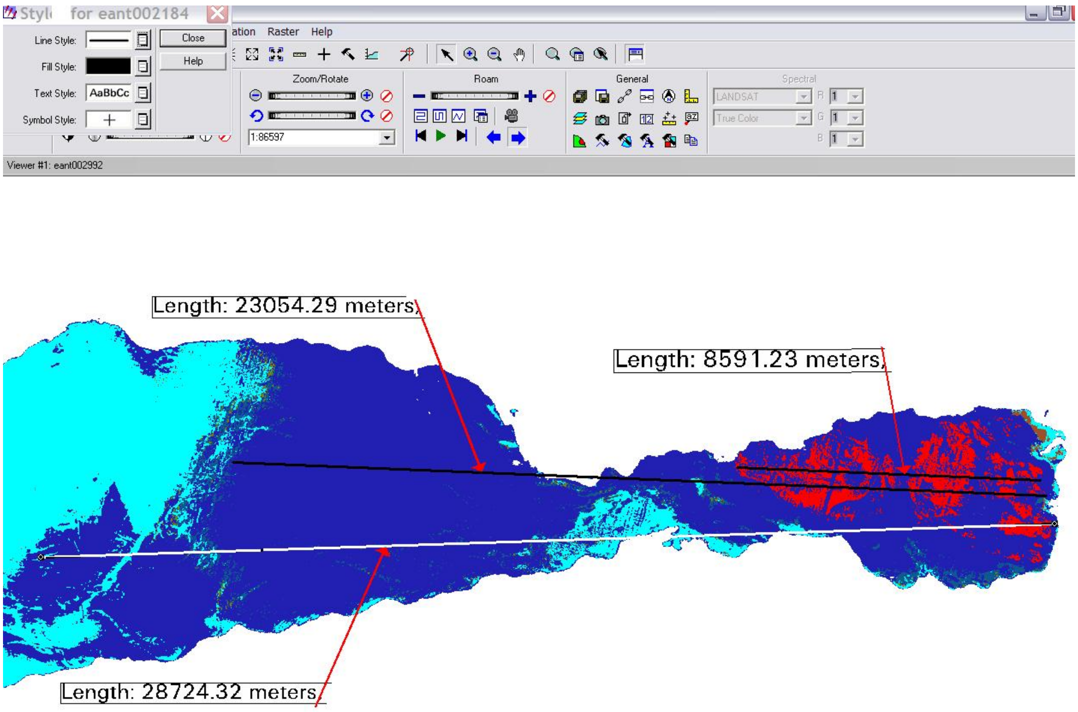

Figure 6. IRS-LISS satellite image of dated 1995 that is obtained ERDAS 8.6 software at the Sapanca Lake basin area using UTM coordinate system.

There is no direct pollution discharge from urban, industry and forestry sources in the study area, but small streams carry this pollution loads to the Sapanca Lake, where agriculture takes place nitrogen pollution sources transported with seepage to the small streams, especially during the rainy seasons. Also, seepage has pollution effect to the Izmit Bay. In the resulting classified colourful images for each pollution loads can be shown with different color. This classified resulting images are compatible with the ground samples (Figs 4, 5 and 6).

Presently, scientific water researches need combining of Remote Sensing (RS) image data that give a new scope of observations. RS is based on joint processing and evaluation of both graphichal (vector) data integrated with raster data, spesifically, to seperate the ground water dispersion and recharge to Izmit Bay and the water quality seapage through aquifer that can monitor for analyzing that subject.

Water quality analyses through ground water recharge with RS methods was estimated for the Sapanca Lake basin area; and a basin ground truth data sampling model was formed using ground truth attribute data taken from the Theoretical Model. Classified satellite result images interpreted with theoretically esteblished model which contains dark blue for conventional pollution, orange contains industrial pollution and light green contains house-hold pollution (Figure 5,6).

In water quality image processing natural water of Sapanca Lake and Izmit Bay has taken as light blue. In addition water color which is affected by agricultural and forest, industry, urbanization is taken as different colors. In this study, multitemporal Sapanca Lake basin raster data is integrated into a single coverageas region subclasses that are fitted as georeferenced streams and ground water recharge as processed satellite data of basin.

10. Recommendations

Sapanca Lake is one of the important drinking water area of Izmit industrilization district which has an acceptable water quality according to Izmit Bay. Sapanca Lake catchment area includes many summer houses and a few industry. Both industrialized and urbanized areas must be controlled with almost care to protect as ground water recharge and also as natural water drinking resource for good water quality of lake. After the observation of ground water recharge from Sapanca Lake to Izmit Bay the recharge distance was measured from the satellite data L = 22,832 km and from the theoretical considerations the horizontal velocity component has the value of 31.9 meter /day and the distance was measured as 19 km on the given map that can be computed by using velocity equation(Vx = Velocity in x direction = 31.953 m/day and Tx=19000m/31,9m/day=666,6 day) is observed as dispersion time between two points. It must not be allowed any kind of industries on majority Sapanca Lake protection zone, also in the short and medium range protection zones the urban activities must be controlled by Istanbul Water and Severage Administration (abbrevited as ISKI in Turkish) regulation.ISKI is responsible to maintain the water quality of water supply from all catchment areas of North Marmara district. It should be completed the infrastructure before any new activities start. A systematic monitoring and control programme must be prepared and seriously implemented. Efficient and timely control of ground water recharge should be monitored using high geometric resolution satellite data. This is also possible to protect the lake basin areas fom destroying.

To monitor the ground water quality quickly and correctly it is another alternative which can be used. Remote Sensing (RS) is the tool having this responses. Sustainable decisions that connected RS data and statistical data has several advantages, and thus information is not only be maximized but ground water recharge is based and accepted analyses of water quality changes and map updating.

The local goverments and the relevant administrations, municipalities planning and environmental protection agencies must protect the lake basin area. They must cooperate with universities and scientific organizations, working in harmony under good coordination, rather than attempting solutions on an individual basis.

A well-planned properly controlled regional management strategy for the basin area , within the context of a holistic system approach, covering as much of the significant elements as possible, will a key issue accomplishing this. Within this framework controlling ground water recharge polution at the source before it is generated streams to be the best management strategy.

To combine the ground truth measurements on ground water recharge quality with RS method needed also point measurements for pattern recognitions on water classes. In terms of non point sources, which belongs to ground water pollution for instance forests, agricultural activities, residential areas, fields, roads, etc. must be handled with care. Within this context, pertinent information and education programmes along with technical assistance is needed.

11. Results and analysis

The main distance between the Sapanca Lake and Izmit Bay is given from the map 19 km. After the theoretical investigations of the year 1995, the velocity in x-distance Vx = 31.9 m/day in aquifer is measured. The region of the theoretical investigation is given by the Satellite Images. The result images have obtained accordingly from the behaviour of light into the water on the real infrared region that reflectance value is taken on the study area using ISO-DATA classification method. In the region three different types of water quality was investigated. The image shows us that three types of water quality in the study area. in

which blue is natural Sapanca Lake Water, red is the polluted substence water which belongs to Sapanca Lake and Cyen is the natural Izmit Bay water. Also, the natural water of Izmit Bay is observed in the Sapanca Lake. From the previous works (Yilmaz et al, 1990) there are two different stratified flows at the two opposite directions. After this research, the dispersion length can be measured from the satellite image. The minimum dispersion of the the polluted water from the Sapanca Lake is 20220,64 metres (Figure 6) and the maximum dispersion distance in the Izmit Bay ise 8591.23 metres from the entrance of the Izmit Bay. The natural Sapanca Lake water at Izmit Bay dispersion contains between the 23 054 metres and 28 724 metres which are taken from the satellite images (Figure. 6).

The study area is Izmit Bay and Sapanca Lake District in the north Marmara Region.

In this study the seepage from the Sapanca Lake to the Izmit Bay and the distribution of the dispersion in the Izmit Bay shows us the groundwater flow in aquifer which shows the dispersion in hydrodynamical point of view. For pollution control at the Basin the classical method of seepage investigation is used with Pinder Method for theoretical considerations and the results are compared with the methods of Remote Sensing.

The study conducted in Sapanca Lake Basin, Adapazari situated in the earthquake Region Northwest Turkey is aimed at applying Pinder's(1982) artifice to obtain the spatial velocities, their components and their angles with the x-y and xy-z planes. Realistic Data is used to demonstrate Pinder method which helps the small and medium farmers to plan use water for irrigation purposes. For the four piezometric heads and base levels differences, the velocity components and their resultants could be determined. This study is useful in determining the direction of flow so that inundation in irrigation fields could be avoided and leaching of fertilizers and other chemicals can be planned.

Keeping a good ground water quality for the health of the human beings needs to have an updated systematic information on the ground water recharge. As a solution to the update information system RS technology is a helpful tool for controling and improving of urban environment. This study reports theoritical considerations about ground water recharge from the lake basin to the seabay and as a comparison the satellite data using RS techniques for urban development in lake basin, is ground water recharge analyzing dated at the year of 1996 which consists of IRS-LISS satellite data.

Firstly, digital satellite data was transformed into UTM coordinate system. Images registered and than geometrically corrected by using polynomial transformation equation. The accuracy of the registration is evalated on 40 points and yielded root mean error (RMSE) of +- 0.5 pixel. This dataset is digitally registered as database. after having Maximum Likely-hood classification method is utilized to get results. The multispectral dataset is classified using min-distance uncontrolled classification to get the result images.

The result images were obtained using RS techniques are in good agreement with ground truth measurements and with theoretical considerations.

12. Discussion

The groundwater monitoring is very important for different aspects. In this study the comparison between the theoretical aspects and the RS technique is given in which the maximum likelihood classification was taken and the pattern which were taken from Sapanca Lake showed us as observations from the Figures (4, 5, 6) that they are in the same classifications with the Izmit Bay water quality. This result shows us that the seepage from Sapanca Lake to the Izmit Bay is the dispersion in the surface waters. In the classical

hydromechanical methods in 4 different points the seepage is calculated and the distance D = 23.054 m is calculated.

Sapanca catchment area includes low population and limited industry. Both industrialized and urbanized areas must be controlled with almost care to protect as natural drinking water resource for good water quality of dam. It must not be allowed any kind of industries on majority protection zone, also in the short and medium range protection zones the urban activities must be controlled by ISKI regulation. It should be completed the infrastructure before any new activities starts. A systematic monitoring and control program must be prepared and seriously implemented. Efficient and timely control of new housing areas should be monitored using high geometric resolution satellite data. This is also possible to protect the forest areas from the destroying.

To monitor the water quality quickly and correctly it is another alternative can be used. Remote sensing (RS) is the tool having these responses. Sustainable decisions that connected remote sensing data and statistical data has several advantages, and thus information is not only be maximized, but land use planning is based and accepted analysis of land uses changes and map updating.

The local governments and the relevant administrations, municipalities planning and environmental protection agencies must protect the catchment area for conservation of good drinking water supply.

A well planned and properly controlled regional management strategy for the catchment area, within the context of a holistic system approach, covering as much of the significant elements as possible, will be a key issue in accomplishing this. Within this framework, controlling pollution at the source before it is generated, seems to be the best management strategy.

REFERENCES

Bear J. Hydraulics of Groundwater. (1972)New York, McGraw-Hill Book Co., pp 567.

Bhargava D.S. and Mariam D.W., (1991) Effects of suspended particle size and concentration on reflectance measurements. Photogrammetric Engineering and Remote Sensing, American Society for Photogrammetry & Remote Sensing , Maryland , USA, 57(5): 519-529

Bras R.L., and Rodriguez-Iturbe I., (1976 a) Evaluation of mean square error involved in approximating the areal average of a rainfall event by a discrete summation, Water Resources Research, 12 (2), pp. 181-184,

Bhargava D.S., and Mariam, D.W., (1991) Effects of suspended particle size and concentration on reflectance measurements. Photogrammetric Engineering and Remote Sensing, American Society for Photogrammetry & Remote Sensing , Maryland , USA, 57(5): 519-529

Bras R.L. and Rodriguez-Iturbe I., (1976 a) Evaluation of mean square error involved in approximating the areal average of a rainfall event by a discrete summation, Water Resources Research, 12 (2), pp. 181-184,

Coskun (Aydogdu) H.G. (1995) Monitoring of Bosphorus and the Golden Horn Using Landsat-TM Data. I T C (International Institute for Aerospace Survey and Earth Sciences) Journal, 1 : 38-42.

Coskun H.G.: (2002) "Satellite Data Usage to Describe the Differences of Istanbul Concerning Settlement on Water Basin and Water Quality on Drinking Water Dams and Bosphorus".(in Turkish), submitted to Istanbul Water and Discharge Administration, Project no:103, Assoc.Prof.Dr. H.Gonca COSKUN has the project manager

Coskun H.G., Ö. Bayraktar, L.Yilmaz, (2006) Monitoring of protected bands of Terkos drinking water reservoir of metropolitan Istanbul near the Black Sea coast using satellite data. International Journal of Applied Earth Observation and Geoinformation, Volume 8, Issue 1 , Pages 49-60.

Clarke R.T. and K.A. Edwards, (1972) ,The application of the analysis of variance to mean rainfall estimation, Journal of Hydrology, 15, pp. 97-112,

Giesecke J., Schmidt P. and H. Meyer, (1983), Vergleich von Rechenmethoden für Gebietsniederschlaege, Wasserw. 73 (1),

Hubbert M.K., (1940) The Theory of Ground- Water Motion, The Journal of Geology, Vol. 48, # 8, Part-I, Nov-Dec.

Kagan R.L. and Poliscu, A.I., (1972) New Approaches in Water Balance Computations, IAHS, Publication No. 148.,

Mendel H.G.,(1979) Zur Berechnung von Gebietsniederschlaegen aus Punletmessungen, Mitt. Nr. 41, Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie der ETH Zürich,

Pinder G.F. (1982) Finite Element Simulation in Surface and Subsurface Hydrology, Gallegher, Vol. 4.,

Pinder G.F. and L.M.Abriola, (1982) Calculation of Velocity in three space dimensions from hydraulic head measurements, Groundwater, 20, pp. 205-213.

Rainbird A.F. (1976)Methods of Estimating Areal Average Precipitation, WMO/IHD Report No: 3.

Rushton, K. R., and S. C. Redshaw, (1979) Seepage and Groundwater Flow, Wiley, Whichester, UK, 339 pp.

Sarma S.V.K. e Silva T.C.,(1987) Hydraulic Response to Pumping in Free Aquifers, ABAS, n. 11, pp. 26-32.

Sarma K.V.S. and e Antonio A. P.Alex ,(1997)"Decontamination of Pollutants from Aquifers using the Concept of Induced Flow from Adjacent Rivers", International Conference on Large Scale Water Resources Projects, 20 - 23 Oct. 97, Kathmandu, Nepal, pp. EI 17-24.,

Sumer B., (1980) The Determination of Water Quality at the Sapanca Lake, TUBITAK, Project. No: QA6-4, Sakarya

Tanik A., Baykal B.B, Gonenc I.E., Meric S. and Oktem Y., (1998) The effect and control of pollution in the catchment area of Lake Sapanca- Turkey, Environmental Management, Springer-Verlag New York, 22(3):407–114

U.S. Envirommental Protection Agency., (1988) "Model Assessment for Delineating Wellhead Protection Areas", Office of Groundwater Protection, Wahtington, D.C.. 210 p.

Yilma, L., Agiralioğl, N. and L.Saltabas, (1999) The Determination of the Water-Use Capacity of the Sapanca Lake in Turkey, Proceedings of the International Conference on Water, Environment, Ecology, Socia-economics and Health Engineering (WEESHE), October 18-21, Seoul National University, Seoul, Korea, Water Resources Publications, LLC, pp. 162-166., 1999.