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INTEGRATED BASIN MANEGEMENT STUDIES IN SITANADI BASIN, WESTERN GHATS REGION, KARNATAKA

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ABSTRACT
Sitanadi is one of the west flowing river of Udupi district and drains an area of 650 sq.km. in the taluks of Udupi, Karkala and Kundapura. The eastern part of the basin is partially under western ghats and western part lies in the coastal midan land. Physiographic ally the basin can be broadly divided into three well defined, identifiable and genetically significant units. Soil survey of the basin shows that, based on the morphological characteristics of various soil profiles 18 soil series are established and 24 soil units are recognised which are combinations of sandy clay, silty clay and gravely clay soils. Sitanadi is a sixth order river, the bifurcation ratio is 4.2 indicating mature basin. The drainage density is 1.78km/sq.km. The basin is elongated with a form factor 0.26, circularity ratio 0.30 and elongation ratio 1.06.General pattern of rain fall over the basin was that eastern part received more rainfall compared to the western part of the basin. Based upon the origin, Geological diversities and relative groundwater potentialities in the aquifers belonging to different geological formations two hydrogeological units have been identified as consolidated and unconsolidated formations. Groundwater potential in the basin is evaluated by conducting resistivity surveys in different parts of the basin. Based on apparent resistivity, total longitudinal conductance, specific yield, transitivity and observation well data, the basin is divided into high, medium and low potential regions. The quality of groundwater from both domestic and irrigation wells is generally good and well within the limited both for domestic and irrigation purposes except few wells in the lower reaches during premonsoon periods where quality of water deteriorates due to salt water intrusion. Seasonal variation of water quality shows that there is a significant cyclic variation in quality characteristics between premonsoon and post monsoon period. Salt water Ingression studies indicate that ingression goes up to and beyond 20.5 km from the river mouth. Correlation studies between salinity ingression verses stream discharge as a function of distance indicates that the stream discharge increases as salinity decreases and as stream discharge decreases, salinity increases. Rate of salt water ingression is inversely proportional to the rate of stream flow in the river.

INTRODUCTION

Water is one of the most basic resources of a country. No care or expenditure will be too great to conserve it for the optimum benefit of the nation. Unlike other natural resources, water is a unique resource which renews itself and regains its properties for reuse. Unfortunately, 97.55 of all water resources on earth are salty. Fresh water including the one in glaciers accounts for only 2.5%. Even here the most accessible one is as little as 0.3%.Mpreover, natural distribution is extremely uneven. This unevenness is aggravated by the still greater uneven distribution of human settlements. Integrated basin management is a measure which allows consideration of interrelation between natural resources like water, land and environment as well as consideration of diverse interests and values. Integrated basin management will benefit a region directly through the development of water, land and socio-economic aspects and indirectly through diversification of opportunities and sustainable productivity.

In view of the increasing demand for a planned and optimum utilization of water resources. Although water resources in a basin remain unchanged, the demand for water would always increase. To meet this rapidly increasing demand for water, integrated development of water resources of river basin are planned all over the world. Hydrological, Hydrogeological and Hydro geochemical investigations of a basin are quite essential for development of water resources keeping in view the utility of the resources for different purposes.

Due to uneven distribution of rainfall and unfavorable topography of the area the utilizable surface water is quite limited in extent and quantity. Sitanadi basin area receives heavy rainfall during south-west monsoon. The average rainfall is around 4600mm. Even though the basin area experiences heavy rainfall it faces an acute scarcity of fresh water during summer months. River water in estuarine reaches is prone to salt water ingression from the sea during high tides. Therefore, it cannot serve as dependable sources of fresh water. In such cases groundwater becomes the only alternative source of good quality water for irrigation, industries and drinking purposes. Even the groundwater in the wells gets polluted on account of seepage of water from tidal rivers.

SCOPE FOR STUDY

The river basin selected for basin studies is one of the west flowing rivers of Udupi district in Karnataka state. It is unique in many ways as indicated below:

1. River takes its origin in the westernghats and flows though the area comprises of undulated topography with hilly terrains and flat valleys. The river valleys are shallow in nature and are not able hold the full flow during monsoon season resulting in flooding.
2. Since the river is in orographic geographical location. It experiences very heavy precipitation during south-west monsoon period.
3. Basin area is relatively short in length and river flows in a meandering course on a level ground in plain region and becomes susceptible to salt water ingression during high tides.
4. On the banks of the river and along the sea coast, the wells are deepened for purposes of tapping more groundwater and they suffer from salt water intrusion
5. Most of the basin area consisting of porous lateritic soil, which is unable to hold rainwater for a longer period, results in quick depletion of subsurface water potential. Over irrigation and pesticides are common practices which lead to water quality deterioration.
6. Due to deforestation in the Western Ghats region, high rate of soil erosion and siltation of river courses are experienced, resulting in reduction of carrying capacity of river channels.

In view of the above factors the water resources available in the region are an adequate to meet the ever growing demand for fresh water. These problems have a great impact on human settlement and their socioeconomic conditions. In order to assess the quantum of water available for utilization, systematic Hydrological, Hydrogeological and Hydro geochemical studies have been carried out in the Sitanadi basin.

PHYSIOGRAPHY

The river Sitanadi is a one of the west flowing river of Udupi district and drains an area of 650 sq.km. in the taluks of Udupi, Karkala and Kundapura.The basin is bounded by north latitudes $13^0$21' – $13^0$35' and east longitudes $74^0$40'- $75^0$10'.Before emptying into Arabian sea it confluences with river Swarna near Hangarkatte village. The river flows towards west for a length of 49 km. The eastern part of the basin is partially under Western Ghats and western part lies in the coastal midan land. Physiographically the basin area is divide into three regions depending upon the terrain features and their altitudes. On the western side the low land region is 2-8 km wide sandy tract running parallel to the coast. It extends up to a distance of about 16 km along the river course. It has small laterite ridges with cultivable low lands in between small exposures of gneiss and laterite hillocks with sparse vegetation. The river takes meandering course with wide channels and some large landmasses in the centre. The mid-land region consists of laterite ridges, mesas and also residual hills composed of gneiss with incised narrow valleys of younger cycle. The laterite ridges exhibit step like topography. The regional elevation varies from 30-70m. This region situated between low land and high land constitutes the largest belt and consists of dissected small hills with or without laterite cappings. High land region consists of dissected high hills and ridges forming part of the foot hills of the Western Ghats. It consists of steep hills and valleys interspersed with thick vegetation. These high hills are mostly Archean gneisses, metavolcanics and metasediments of Dharwar super group of proterozoic age. Scrap faces bounding these hills are steep having a slope of more than 200m.

GEOLOGY, SOILS AND VEGETATION

Major portion of the Sitanadi basin is underlined by crystalline rocks which are overlaid by sedimentary formation along the coastal region. The major lithological units are banded granitic gneisses, laterites and some parts covered by chlorite schist. Some intrusive bodies like dolerite dykes and pegmatite veins are also noticed. The layer of coastal sediments is noticed in the western part f the basin. The granitic gneisses which is wide spread in the basin as prominent hillocks, as isolated outcrops at varying magnitude and along the river courses. The sporadic exposures of crystalline rocks are common within alluvium formation as well as in the seashore. The rocks of the area belong to different period like Archean, Proterozoic, Cretaceous, Tertiary, and Quaternary
Study of the soil is an important aspect of hydrological investigations. The infiltration, which takes place is dependent on physical properties of the soil. Soils influence the chemistry of groundwater. The climate. topography, soil biota, rock type and time factor influence the formation of soils in a region. The infiltration capacity of different soils varies and is dependent upon surface conditions, texture, structure, transmissivity and storage capacity of soils, vegetation and also tanks and reservoirs nearby. In the coastal region three major types of soils namely Oxisol, Entisol and Ultisol are encountered. Entisol is of recent origin and is confined to alluvial coastal plain. It is light and belongs to textural class of sandy clay and loam. The soil is feebly acidic with less than 5.1 PH and with low manganese and boron content. The soil infiltration rate is in the range of 0.76-1.5 cm/hr, with water available for plant use being 2.38cm/ meter. Oxisol is a heavy soil prevalent everywhere, right from upland to the coast in the pedeplain. The soil with high iron content belongs to textural class of clay and

loamy type with coarse sand of 23 to 44% and clay of 25 to 26%.The PH of the soil ranges between 5.2 and 6.1 with soil infiltration rate of 0.7 to 1.00 cm/hr and with 20cm/meter of water available for plant use. The soil has got more capacity to hold hydroscopic water with 35% of moisture not available for plants. Ultisol is the medium soil confined to granitic and gneisses terrain with coarse sand of 53-60% and clay of 47 to 49% belonging to textural class of sandy clay loam with more clay at depth below 22cm, with infiltration rate of 0.80 to 1.25 cm/hr and with 14.25 cm/meter of water available for plant use. It has got more capacity to hold hygroscopic water with loss of infiltration rate. The soil is less acidic (Venkataraman and Rao,1990).To study the soil status in Sitanadi basin with respect to physical and chemical properties, 38 soil samples were collected in the vicinity of wells from which water samples were collected for quantitative analysis, the soil samples were subjected to physical tests like Grain size distribution, Absolute specific gravity, Apparent density, Maximum water holding capacity, Percentage pore spaces ,Volume expansion and permeability, Ph, & EC and Chemical tests like Estimation of available organic carbon , phosphorus and potassium. Physico –Chemical Soil test results were presented below table 1.

Table. 1: Soil analysis Results of Sitanadi Basin

Sample No	Apparent density (g/cc)	Absolute specific gravity (g/cc)	Maximum water holding capacity (%)	Pore space (%)	Volume expansion (%)	PH	EC (Micro mhos/cm)	Organic carbon (%)	Available potassium (kg/ha)	Available phosphorus (kg/ha)
ST-1	1.39	2.46	33.76	45.86	2.9	4.82	191	0.60	90	96
ST-5	1.65	2.48	21.86	35.14	2.2	4.55	96	0.54	21	58
ST-10	1.30	2.62	40.13	52.76	3.3	5.19	64	0.74	35	140
ST-13	1.28	2.57	38.05	54.09	2.2	5.23	57	0.86	19	152
ST-18	1.38	2.31	33.78	44.59	6.9	4.58	106	1.07	5	128
ST-23	1.11	2.46	52.64	57.89	5.2	4.70	80	1.15	18	152
ST-26	1.11	2.32	5012	55.37	10.0	5.17	39	0.74	3	220
ST-31	1.27	2.34	38.82	48.20	3.0	4.98	151	0.49	45	154
ST-37	1.37	2.33	33.26	44.28	5.0	4.63	60	0.36	25	196
ST-38	1.53	2.43	25.15	38.86	3.0	5.03	63	0.28	47	84

Based on the morphological characteristics of various profiles(soil, colour, texture, depth, erosion,etc.) 18 series of soils have been noticed, based on their texture and combination of soils 24 soil units are recognized in Sitanadi basin(KSDA,1985)

HYDROGEOLOGY

High rainfall and humid climatic conditions favour luxurious growth of vegetation. Nearly 53.86% Sitanadi basin area is covered by forest vegetation. Studies from satellite imagery IRS-LISS-II B1 shows that 233.48 sq.km. area is covered with dense forest vegetation, 71.73 sq.km. area is covered with open forest vegetation and 68.88sq.km. is covered with shrubs type of vegetation (Srinivasa1990).Though the agricultural land is distributed throughout the basin, it is well confined to western portion only. Land use pattern has influenced the hydrological regime in the basin through high surface run-off during monsoon season and decline in groundwater level during non-monsoon season due to groundwater abstraction.

Geo morphological parameters of Sitanadi basin are determined under three heads viz., Linear aspects, Areal aspects & Relief aspects. About 28 basin characteristics were determined and established their relationships with each other. Sitanadi is a sixth order stream. It has 1257, 294,53,13,3 and 1 segments of first, second, third, fourth, fifth and sixth order streams respectively. The bifurcation ratio is 4.2 indicating a mature basin. The average length ratio is 2.70. The departure from linearity of the 2^{nd} and 6^{th} order points on the length order plot is due to the influence of lithology and structure on morphological development. Both elevation and lithology controls the drainage density, stream frequency and length of overland flow. The drainage density is 1.78km/sq.cm. The basin is elongated with a form factor 0.26, circularity ratio 0.30and elongation ratio 1.06. The longitudinal profile is simple concave in nature. The convex part of the profile is occupied by the granitic gneiss which are highly resistant to erosion. The value of ruggedness number (0.39) and relief ratio (0.02) and high value of bifurcation ratio 4.2 indicates maturity of the basin. This is also evidenced by hypsometric integral of the area is 21.08%. This indicates a high level of denudation in the area. Slope map of the basin indicates that the eastern part of the basin has higher slope than the western part. The low slope areas in the basin are potential zones for groundwater accumulation and have been considered for exploration.

Temperature in most parts of the basin is lowest in the beginning of January and increases gradually thereafter. The average monthly maximum temperature of 35.3^{o}C is noticed during March. The average monthly minimum temperature of 19.1^{o} C is recorded during January. Major part precipitation falling over the basin returns to the atmosphere by evaporation. Using modified Penman method, average potential evapotranspiration for the study area is 1652 mm in a year. The soil moisture storage in the study area is observed to be 100mm.There are seven rain gauging stations in the basin. Daily rainfall data from 1972 to 1997for all these stations were collected and analysed. The maximum rainfall is noticed in Agumbe station (7085.90mm) located on the eastern margin of the basin. Kota station recorded lowest rainfall (3425.90mm). The weighted average precipitation over the basin was 4639mm. General pattern of rain fall over the basin was that eastern part received more rainfall compared to the western part of the basin. Seasonal distribution of rainfall was that major portion of the rainfall distribution of rainfall (about 90%) fell during the south-west monsoon period .while about 9.7% during the north-east monsoon period. The areal distribution showed that 30% of rainfall is classified as normal distribution 17% is classified as medium to heavy scattered, 12% is classified as uniformly distributed and rest of the rainfall is classified as medium to very heavy scattered. This wider variation in the distribution of rainfall over the basin is due to its physiographic location i.e. between the west coast and the Western Ghats region. The Sitanadi basin which covers an area of 650 sq.km. has only one river gauging station at Kokkarne. Therefore, rainfall run-off relation studies are carried out in order to find out the relationship between them. A correlation of the type, Q=0.815p-65.37 is developed through linear regression analysis. This model can be used for computing run-off in the ungaged sub-basins of Sitanadi basin for water resource planning, development and management of the sub-basins. The hydrograph analysis (Linsley et al.,1975) is carried out for some typical storms and different flow components are determined. The recession constants for total flow and groundwater flow is 0.25 and 0.89 respectively. From the analysis it is noticed that the base flow is 37% of the total flow. In the present investigations, 13 infiltration tests are carried out using double ring infiltrometer in different soils and locations like cultivated area, uncultivated area and bed stream to study the relative change in infiltration behaviour. Using Horton's (1933) equation, initial rate of infiltration (f_o), final rate of infiltration (f_c)and constant(k) are obtained and are presented in Table 2.

Table. 2: Results of Infiltration Tests in Sitanadi Basin

SlNo.	Place	Location	Soil type	Duration of infiltration test in mins.	Initial rate of Infiltration f_o(cm/hr)	Final rate of Infiltration fc(cm/hr)	k
1	Matapadi	Stream bed	Clay	135.00	27.81	7.20	0.0713
2	Kokkarne	Stream bed	Lateritic	165.00	57.58	19.20	0.0636
3	Hebri	Cultivated	Lateritic	210.00	45.04	27.52	0.0229
4	Belve	Uncultivated	Clay	90.00	24.23	5.16	0.1343
5	Achaladi	Stream bed	Lateritic	345.00	54.61	19.52	0.0094
6	Tekkatte	Cultivated	Sandy	165.00	20.20	9.60	0.0424
7	Pandeshvara	Uncultivated	Clay with sand	305.00	7.35	4.11	0.0218
8	Hunshemakki	Uncultivated	Sandy clay	195.00	17.09	9.08	0.0286
9	Januvarkatte	Cultivated	Sandy clay	245.00	18.25	7.64	0.0266
10	Baidebettu	Stream bed	Clay	145.00	6.85	2.88	0.0425
11	Albadi	Uncultivated	Sandy clay	180.00	10.89	5.70	0.0386
12	Hebri	Uncultivated	Clay	180.00	4.974	0.90	0.0792
13	Haluvalli	Cultivated	Sandy	240.00	23.84	10.32	0.0154

It is observed that highest infiltration rates are noticed in cultivated lateritic and stream bed locations. In sandy soils also, a considerable infiltration rates (9.6cm/hr) is observed. The nature of the top soil in the basin varies from clayey loam to sandy loam both of which being predominantly iron rich. The fertile top soil in the basin is eroded and the rich nutrients are leached out due to high rainfall and surface run-off. By using USLE (Universal Soil Loss Equation), It is estimated that the average annual soil loss is 5.17 tons per hectare per year.

GROUNDWATER

Based up on the origin, geological diversities and relative groundwater potentialities in the aquifers of different geological formations, two hydrogeological units have been identified (Venkataraman and Rao, 1990) consolidated formations includes granitic gneiss and laterites in pediplain areas between western ghats and coast. The laterite is a porous formation of 7 to 11m thick characterized by vesicular structures and vertical gaping joints which act as channel for conducting water into the deeper levels. Granitic gneiss constituting the major aquifer are traversed by pegmatites and quartz veins which induce secondary porosity into the main rock. Groundwater occurs in crystalline formations and laterite under unconfined conditions. The weathered zone and open fractures below the water table act as good storage for groundwater. The coastal alluvium which are unconsolidated formations occurring all along the coastal belt with a width of 3 to 4 km and length of 25- 30 km has brought out varying thickness of the formations comprising fine to coarse sand, clay, sandy clay, gravel etc. The aquifer ranges in thickness from 2 to 9m.The thickness of clay beds in unconsolidated sediments ranges from 2 to 12m.Groundwater development in the coastal area is through mostly dug wells. Groundwater occurs in unconfined and phreatic conditions. Rainfall is the main source of groundwater. Irrigation also plays an important role in recharging of groundwater. Pumping test and recovery data relating to the eleven dug wells conducted in Sitanadi basin have been analysed by Slicher's conventional method (Narasimhan, 1965) to determine the aquifer parameters. Six wells out of these are in consolidated formations comprising fractured, weathered granitic gneiss and five wells are in unconsolidated formations comprising weathered laterites, coastal alluvium consisting of fine to coarse sand, clay and gravel. The aquifer parameters of eleven test wells are presented in Table. 3 .

Table. 3: Aquifer Parameters of Sitanadi Basin

Site Name	Diameter(m)	Depth(m)	Specific capacity (m3/min/m) C	Transmissivity (m2/day) T	Permeability (m/day) K	Specific yield (%) Sy	Discharge (m3/min) Q
Pandeshwar	1.90	6.915	0.012	51.78	10.35	1.21	0.4393
Yedyadi-Matyadi	7.35	9.570	0.166	104.67	21.58	2.40	0.0571
Januvarkatte	2.00	6.635	0.082	320.41	96.95	4.40	0.3762
Baidebettu	6.55	3.420	0.412	248.19	24096	6.00	0.4607
Sitanadi	6.61	5.85	0.048	584.61	167.03	6.60	0.3891
Shedimane	2.75	2.64	0.118	283.71	177.98	6.60	0.3831
Hebri	5.30	5.15	0.107	47.08	29.42	0.36	0.4280
Haluvalli	5.60	6.00	0.112	91.82	19.83	1.04	0.0480
Varamballi	5.93	5.25	0.880	197.80	5073	6.50	0.0170
Handadi	2.31	4.52	0.410	13.11	1.96	0.32	0.0860
Belve	3*5.7	1.79	5.720	302.16	385.04	4.98	3.8330

Transmissivity ranges from 13.11 to 584.61m2/day. Specific yield ranging from 0.32 to 6.6%.It is found to be 4.4 to 6.6% in unconsolidated laterites and found to be 0.32 to 4.98% in consolidated granitic gneisses. Thickness of the aquifer in unconsolidated formations ranged between 2m to 9m. The thickness of weathered zone in the consolidated formation ranged between 2m to 15m beyond which it was fractured. The wells piercing consolidated crystalline formations have a depth range of 4 to 17m.Most of the wells are shallow in the depth range of <3m to 7.5m.Only small percentage of wells was in the depth range of more than 7.5 up to 17m.The water balance studies have been employed to estimate the dynamic water resource of the basin. Both climatic water balance and groundwater balance studies are carried out for the entire Sitanadi basin by Thornthwaite and Mather method modified by Subramanyam et. al. (1970). Climatic water balance study shows that the maximum values of precipitation and surface run-off are recorded during July. Whereas the maximum underground flow (base flow) is observed in the month of August. The base flow and the surface flow are almost equal from February to May. The potential evapotranspiration is more than precipitation from November to May in the basin. The shows enormous surplus water during south-west monsoon period (June- September) but during rest of the year it shows deficit. This is due to the torrential rains, topography and the lithology of the basin which are not favourable for the storage of water for a long period.

Groundwater development is semi critical as indicated by the latest groundwater resource assessment (CGWB, DMG, 2010).The resources estimated by using GEM-97 methodology for the period 2008-09. As per the estimation net groundwater available is 7356ham. Which is about 87% of groundwater development. From this it is evident that more attention has to be focused for future groundwater development. Keeping in view of a fairly favourable hydrogeological situation, basin area can be divided into two hydro geological units as hard rock terrain where mostly pediplain in the form of valley fill material, moderately thick weathered residuum, open fractures and criss crossed by lineaments over an area of about 450 sq.km. The other one is coastal alluvial area and valley fills in the basin along the coast which constitute about 200sq.km area of the basin. Based on hydrogeological conditions of the area, generally two modes of development are feasible in this terrain. They are traditional dug wells of 7*12m tapping weathered residue and fracture crystalline formation are feasible. In respect of the area where weathered and fractured crystalline formations are underlain by laterite and thick bed of clay, deep dug wells piercing clay to tap the underlying crystalline formation can be constructed. If the clay bed encountered is of considerable thickness dug-cum- borewell can be constructed. Bore wells are feasible over the entire stretch of pediplain but in view of heterogeneity the design of well will be site specific. The exploration of CGWB in this basin has shown feasibility of low to medium duty bore wells. These wells can be drilled over the entire pediplain area with depth range of 60-90m depth, taping weathered and fractured crystalline formation.

Groundwater potential in the basin is evaluated by conducting 41 resistivity surveys in different parts of the basin. Based on apparent resistivity, total longitudinal conductance, specific yields, transmissivity and observation well data, the basin is divided into three regions namely high, medium and low potential regions. The high potential zones are characterized by high density of lineaments, high longitudinal conductance, high transmissivity, high specific yield. Low apparent resistivity and low water table fluctuations. The low potential zones have high apparent resistivity, low values of longitudinal conductance and high water table fluctuations. The high and moderate potential zones are good areas for future exploration and development of groundwater in the basin. Based on geological, geomorphological, remote sensing and resistivity data the groundwater potential map of Sitanadi basin is prepared. The map indicates coastal alluvium and some of the weathered and fractured granitic gneiss patches all over the basin area are potential zones, where compact granitic gneisses are moderate potential zones. The low potential zones are noticed in patches where massive granitic gneiss hills are exposed. Presence of saline water intrusion results in low resistivity along lower river reaches.

WATER QUALITY

To study the quality of groundwater, 200 water samples were collected from both irrigation & domestic wells in different season and subjected to physico-chemical analysis. The results of analysis show that the pH values of most of the water samples during post-monsoon period range between 4.95 to 7.36 and during premonsoon period between 3.84 to 7.43. EC values range between 13 to 1287 micromhos/cm and 50 to 9500 micromhos/cm during post-monsoon and premonsoon respectively. The chloride content of the water samples generally fluctuate. However, it ranges from 0.15mg/l to 10.31mg/l during post monsoon period and ranges from 0.20mg/l to 85.62mg/l during premonsoon period and other parameters K, Na.Mg, Ca, SO4, NO_3, HCO_3 are found to be well within the limits. Results of water quality analysis are presented in table 4&5.

Table. 4: Drinking groundwater quality analysis results

Constituent	Season	Range of values	
		Minimum	Maximum
pH	Pre monsoon	3.84	7.36
	Post monsoon	4.15	7.36
EC (micromhos/cm)	Pre monsoon	38	9500
	Post monsoon	20	1980
TDS	Pre monsoon	25	6175
	Post monsoon	20	1287
TH	Pre monsoon	7	1336
	Post monsoon	4	341
Cl (mg/l)	Pre monsoon	0.20	85.62
	Post monsoon	0.15	10.31
HCO3 (mg/l)	Pre monsoon	0.22	5.28
	Post monsoon	0.09	4.83
SO4 (mg/l)	Pre monsoon	0.03	4.23
	Post monsoon	0.00	2.76
NO3 (mg/l)	Pre monsoon	0.00	1.40
	Post monsoon	0.00	0.92
Na (mg/l)	Pre monsoon	0.22	60.22
	Post monsoon	0.11	9.30
K (mg/l)	Pre monsoon	0.00	1.28
	Post monsoon	0.00	0.87
Ca (mg/l)	Pre monsoon	0.19	14.80
	Post monsoon	0.08	3.65
Mg (mg/l)	Pre monsoon	0.05	18.53
	Post monsoon	0.08	6.02

Table. 5 : Irrigation Water quality results

Constituent	Season	Range of values	
		Min	Max
SAR	Pre monsoon	0.29	14.75
	Post monsoon	0.30	5.01
RSC	Pre monsoon	-30.16	0.18

(meq/l)	Post monsoon	-5.63	0.23
ESP	Pre monsoon	-0.55	-17.01
	Post monsoon	-0.75	5.17
SSP	Pre monsoon	26.03	76.63
	Post monsoon	62.00	71.43
Mg Hazard (%)	Pre monsoon	17.86	71.32
	Post monsoon	6.67	70.00
Potential salinity (meq/l)	Pre monsoon	0.22	87.73
	Post monsoon	0.13	11.69
P.I.	Pre monsoon	52.56	155.53
	Post monsoon	49.17	178.77
Mg/Ca	Pre monsoon	-0.46	2.49
	Post monsoon	0.07	2.11
RSBC (meq/l)	Pre monsoon	-11.63	1.37
	Post monsoon	-0.33	1.18
SCAR	Pre monsoon	0.41	16.12
	Post monsoon	0.13	`4.36
Kellay's ratio	Pre monsoon	0.38	3.90
	Post monsoon	0.13	4.36

The water quality is generally good and well within the limited both for domestic and agricultural purposes except few wells in the lower reaches where the quality of water deteriorates due to salt water intrusion during premonsoon period. Irrigation water quality parameters such as SAR, RSC, RSBC, Potential salinity, percent sodium, ESP,(Mg)/(Ca) ratio, Mg hazard, SCAR, permeability index and Kelley's ratio are well within the prescribed limit and effectively used for rating the water quality for irrigation. Seasonal variation of water quality shows that there is a significant cyclic variation in quality characteristics between premonsoon and post-monsoon period. The relationship of chemical properties of the samples of groundwater in piper trilinear diagram shows almost similar geochemical environment. The chemical properties of groundwater are generally dominated by alkaline earths and strong acids. This may be due to circulation of water in coastal lithology. Interpretation of chemical properties of groundwater by modified Hill-Piper diagram indicates that about 70-80% of water samples are non-carbonate waters and 20-30% of water samples are carbonate waters. The plot in the second parallelogram which indicates the salinity and sodium hazard show that majority of the water samples falls in the alkaline group and low salinity- low alkalinity group. However, some of the premonsoon water samples in the lower reaches show high salinity concentration.

The Principal component analysis of water quality data shows three important sub- components. The first principal component has been influenced by the variables like chlorides, total dissolved salts, total hardness, sodium, sulphate, magnesium and electric conductivity with more or less uniform loadings. This accounts for 80% of the total variance and indicates the importance of major ions contributing to total dissolved solids. The second principal component, which accounts for 19.97% of the total variance, is mainly loaded by the ions of electric conductivity, nitrate, and potassium. The third principal component accounts for 3.47% of the total variance is mainly loaded by the ions of total hardness, magnesium, total dissolved solids, electrical conductivity and potassium. In general, the major variations in the chemical quality of water are due to the abundance of all the ions of Mg, Cl, Na, K, Ca, SO4 and HCO3.Large variations in the total dissolved solids and major ions may be due to high rate of evaporation and mineralization of groundwater influenced by different litho units in the area viz., coastal alluvium, laterites with granitic gneisses, climatic and environmental conditions in the area (i.e., sea water ingress and saltwater intrusion) can also account to some extent for these variations(Chachadi and Mahapatra,1982).

In order to study the tidal variations and quality of river water over a tidal period of 12 hours, at every one hour interval samples are collected simultaneously at five sections along the river course on higher high water days. Water samples are collected at depths viz., surface, 0.6d, bottom and are analysed for EC and chloride content. The results of analysis are presented in table.6.

Table.6: River water Quality of Sitanadi

Distance from The river mouth (km)	23rd may 1989 Pre-monsoon period		26th October 1989 Post-monsoon period		26th February 1990 Pre-monsoon period	
	EC (micromhos/cm)	Chloride (mg/l)	EC (micromhos/cm)	Chloride (mg/l)	EC (micromhos/cm)	Chloride (mg/l)

-1.0 (S_1)	54000	21908	49000	18270	54000	21984.67
-5.5 (S_2)	54000	21093	26000	9213	53000	21122.53
-9.5 (S_3)	53000	20667	360	81.71	49000	20260.38
-15.5(S_4)	39000	14889	66	16.43	29000	10776.80
-20.5(S_5)	16900	9678	52	12.61	2700	548.00

The result shows significant variation in chloride and electrical conductivity values. It is also noticed that the sea water ingression has beyond 20.5km from the river mouth. This polluted river water gradually seeps normal to the river flow and reaches the groundwater, thus polluting the wells situated on the banks of the river. The relationship between stream discharge and saline water ingression as a function of distance in Sitanadi basin in different seasons on higher-high water days, is found to be:

$Q = 12.6681+0.2119S_1 - 0.4088S_2 + 0.1347S_3 - 0.945S_4 + 0.00000057S_5$ with r = 0.82

Where, Q = stream discharge in m^3/sec at Kokkarne gauging station.

S_1, S2, S3, S4, S5 = salinity levels in different sites along the river course.

Correlation studies between salinity ingression Vs stream discharge as a function of distance indicates that the stream discharge increases, salinity decreases and as stream discharge decreases, salinity increases. Rate of salt water ingression is inversely proportional to the rate of stream flow in the river. So, while attempting to utilize the available surface water and groundwater, care is required to be exercised to preserve their quality. To preserve fresh water quality of rivers, temporary salt water exclusion dams are necessary across the tidal river so that ingression of seawater during high tides can be prevented. To avoid salt water intrusion in to the wells situated along the coast they should not be deepened. Instead of deepening the wells o tap more water, the technique of horizontal galleries can be adopted. The well diameter can be increased too to store more water.

In order to know the seasonwise soil- water- crop relation in Sitanadi basin area, typical computations are carried out on representative water and soil samples. The water is collected from selected wells and soil samples are collected from the area nearby the inventoried wells. Studies on compatibility show that soil- water-crop compatibility is generally good during post-monsoon season. However, poor compatibility is found in some locations during premonsoon season. Soil-Water-Crop compatibility assessment reveals that the first and second crops of rise are profitable. The yield of the third crop is poor due to increase in salinity of the water. The available water resources should not be used for growing water intensive crops like rice or sugarcane, instead they should be used for irrigation lands with less water demanding crops like groundnut, pulses etc. It is recommended that measures like rotation of crop, intercropping etc. are adopted in order to preserve the soil-moisture environment in the basin area.

CONCLUTIONS

The river Sitanadi is a one of the west flowing river of Udupi district and drains an area of 650 sq.km. The river flows towards west for a length of 49 km. physiographically the basin area is divide into three regions depending upon the terrain features and their altitudes. Major portion of the Sitanadi basin is underlined by crystalline rocks which are overlaid by sedimentary formation along the coastal region. The major lithological units are banded granitic gneisses, laterites and some parts covered by chlorite schist. Based on the morphological characteristics of various profiles (soil, colour, texture, depth, erosion,etc.) 18 series of soils have been noticed, based on their texture and combination of soils, 24 soil units are recognized in Sitanadi basin. Studies from satellite imagery IRS-LISS-II B1 shows that 233.48 sq.km. area is covered with dense forest vegetation, 71.73 sq.km area is covered with open forest vegetation and 68.88sq.km. is covered with shrubs type of vegetation. Geo morphological parameters of Sitanadi basin are determined under three heads viz., Linear aspects, Areal aspects & Relief aspects. About 28 basin characteristics were determined and established their relationships with each other. The value of ruggedness number (0.39) and relief ratio (0.02) and high value of bifurcation ratio 4.2 indicates maturity of the basin. This is also evidenced by hypsometric integral of the area is 21.08%. This indicates a high level of denudation in the area. Slope map of the basin indicates that the eastern part of the basin has higher slope than the western part. The average monthly maximum temperature of 35.3^{o}C is noticed during March. The average monthly minimum temperature of 19.1^o C is recorded during January. Using modified Penman method, average potential evapotranspiration for the study area is 1652 mm in a year.

The maximum rainfall is noticed in Agumbe station (7085.90mm) located on the eastern margin of the basin. Kota located on the western margin of the basin station recorded lowest rainfall (3425.90mm). Seasonal distribution of rainfall was that major portion of the rainfall distribution (about 90%) fell during the southwest monsoon period. while about 9.7% during the northeast monsoon period. The areal distribution showed that 30% of rainfall is classified as normal distribution 17% is classified as medium to heavy scattered, 12% is classified as uniformly distributed and rest of the rainfall is classified as medium to very heavy scattered. The Sitanadi basin which has only one river gauging station at Kokkarne. Therefore, rainfall run-off relation studies are carried out in order to find out the relationship between them. A correlation of the type, Q=0.815p-65.37 is developed through linear regression analysis. This model can be used for computing run-off in the ungaged sub-basins of Sitanadi basin for water resource planning, development and management of the sub-basins. The recession constants for total flow and groundwater flow is 0.25 and 0.89 respectively. Hydrograph analysis indicates that the base flow is 37% of the total flow. It is observed that highest infiltration rates are noticed in cultivated lateritic and stream bed locations. In sandy soils also, a considerable infiltration rates (9.6cm/hr) is observed. By using USLE (Universal Soil Loss Equation), It is estimated that the average annual soil loss is 5.17 tons per hectare per year.

Transmissivity ranges from 13.11 to 584.61m2/day. Specific yield ranging from 0.32 to 6.6%.It is found to be 4.4 to 6.6% in unconsolidated laterites and found to be 0.32 to 4.98% in consolidated granitic gneisses. Thickness of the aquifer in unconsolidated formations ranged between 2m to 9m. The thickness of weathered zone in the consolidated formation ranged between 2m to 15m beyond which is fractured. Climatic water balance study shows that the maximum values of precipitation and surface run-off are recorded during July. Whereas the maximum underground flow (base flow) is observed in the month of August. The base flow and the surface flow are almost equal from February to May. The potential evapotranspiration is more than precipitation from November to May in the basin. As per the (GEM-97) estimation net groundwater available in the basin is 7356ham. Which is about 87% of groundwater development. Groundwater potential in the basin is evaluated by conducting 41 resistivity surveys in different parts of the basin. Based on apparent resistivity, total longitudinal conductance, specific yields, transmissivity and observation well data, the basin is divided into three regions namely high, medium and low potential regions.

The water quality analysis show that the pH values of most of the water samples during post-monsoon period range between 4.95 to 7.36 and during premonsoon period between 3.84 to 7.43. EC values range between 13 to 1287 micromhos/cm and 50 to 9500 micromhos/cm during post-monsoon and premonsoon respectively. The chloride content of the water samples generally fluctuate. However, it ranges from 0.15mg/l to 10.31mg/l during post monsoon period and ranges from 0.20mg/l to 85.62mg/l during premonsoon period and other parameters K, Na.Mg, Ca, SO4, NO_3, HCO_3 are found to be well within the limits. Irrigation water quality parameters such as SAR, RSC, RSBC, Potential salinity, percent sodium, ESP,(Mg)/(Ca) ratio, Mg hazard, SCAR, permeability index and Kelley's ratio are well within the prescribed limit and effectively used for rating the water quality for irrigation. Interpretation of chemical properties of groundwater by modified Hill-Piper diagram indicates that about 70- 80% of water samples are non-carbonate waters and 20-30% of water samples are carbonate waters. The plot in the second parallelogram which indicates the salinity and sodium hazard show that majority of the water samples falls in the alkaline group and low salinity- low alkalinity group. However, some of the premonsoon water samples in the lower reaches show high salinity concentration. Large variations in the total dissolved solids and major ions may be due to high rate of evaporation and mineralization of groundwater influenced by different litho units in the area viz., coastal alluvium, laterites with granitic gneisses, climatic and environmental conditions in the area The result shows significant variation in chloride and electrical conductivity values. It is also noticed that the sea water ingression has beyond 20.5km from the river mouth. Correlation studies between salinity ingression Vs stream discharge as a function of distance indicates that the stream discharge increases, salinity decreases and as stream discharge decreases, salinity increases. Rate of salt water ingression is inversely proportional to the rate of stream flow in the river.

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