ANALYSIS OF SUSTAINABILITY OF SURAJKUND LAKE AND DETERMINATION OF HYDRODYNAMICS OF DELHI RIDGE WITH SPECIAL REFERENCE TO URBANIZATION IMPACT ASSESSMENT

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ABSTRACT :

The Delhi Ridge is considered to be a water divide between arid climate of Rajasthan and semi-arid to sub-tropical climate of Indo-Gangetic Plains. Also the Delhi Ridge is the main carrier of surface runoff .But due to urbanization, the Delhi Ridge has lost its peripheral runoff, and as a result the water bodies fed by Delhi Ridge are suffering and are losing their identity.

There is an utmost need for the revitalization of these water bodies which is important not only from the microclimatic point of view but also is an essential tool for the replenishment of the ground water resources .The ground water resources with the pace of deterioration of water bodies on one hand and excessive abstraction on the other hand, are getting depleted fastly and has acquired a continuous declining trend. The minimum declining of the water table is in the range of 2.5-3.5 m per year and the maximum of 6.5-7 m per year which clearly indicates need for revitalization of water bodies.

There are number of water bodies in NCR which has saturated within the premises of Delhi Ridge runoff. The present study deals with the Surajkund Lake which was **originally** occupied by

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137.07 acres has been shrunk to 40.51 acres which is 29 % of its original volume .This is because of unplanned urbanization impact. The present study deals with the analysis of revitalization of Surajkund Lake using innovative technique such as Geographical Information System (GIS) for design of watershed and catchment to acquire the requisite amount of runoff for the proper replenishment of Surajkund Lake .This study will be the modal example of revitalization of the water bodies in order to improve the geo environment in general and water resources in particular. Apart from this there are many other ideas which may be used for planners, architects, scientists, administrative officers working in this direction.

Keywords - Revitalization, watershed, Surajkund Lake, GIS, runoff

1. Introduction

1.1, General

Aravalli Range which are the oldest fold mountains and presently forms the hill system of Northern India runs northeasterly for 560 km through Rajasthan, Gujrat, Haryana, Delhi .The Aravalli Range divides the area into two natural divisions N-W and S-E .The NW area is a sandy and water deficient zone characterized by low rainfall with erratic distribution, low humidity and high wind speed while S-E side of Aravalli is covered by Indus River and its tributaries. Aravalli Range captures the southwest monsoon winds rising from Arabian sea, and thus causes the moisture to precipitate in northwestern region .Thus Aravalli Range acts as a barrier for the moisture fed southwestern Arabian sea monsoon winds to precipitate their moisture on the eastern side of the range which is occupied by fertile area covered by cities of Delhi NCR and southeast Rajasthan while the western portion is water deficient region which is represented by deserted landforms(chittorgarh,jaisalmer)

1.2 ,Surajkund Lake

The study area is located at 30 km from Delhi. The Surajkund Lake is located in Faridabad District of Haryana state of NCR. It is a manmade reservoir filled with groundwater and rainwater. Faridabad adjoins Delhi on its south eastern side having total area of 742.90 km2 located in $28^0$25’ N latitude and 77^0 18’ E longitude.

Since the area in Surajkund Lake is surrounded by Tilput range of hard Quartzite terrain and therefore any water body of this magnitude will provide the thermal comfort and good ambience

for the tourists. The Surajkund Lake area is originally occupied by 137.07 acres as evident from SOI Toposheet number 53H/7& 53H/3.However due to the disturbance, its watershed and the catchment the lake has shrunk down to 40.51 which is actually 29% of its original dimension. Currently the lake carries very nominal amount of water and dries in the peak summer season of May and June. Considering the historical factor and the tourism, revitalization of Surajkund Lake is very essential and it may be treated as National Development Activity. Since the state of art at present is governed by the modern technique such as application of GIS, Geophysics, Hydrology and Hydrogeology in order to calculate the catchment delineation, mapping of watershed and losses of the lake water therefore it is imperative to apply the latest knowledge for the subject matter.

2 ,Objectives And Scope Of The Study

The following objectives shall be achieved for the revitalization of water bodies in general and for Surajkund Lake:

1-To delineate the catchment area of Surajkund Lake in present condition.

2-To delineate the drainage system and the modern watershed of this lake

3-To calculate the surface runoff with varying rainfall intensity.

4-To delineate the feasibility and design of rainwater harvesting master plan for development of Surajkund Lake.

5-Finally to provide the sustainability of the Surajkund Lake with the help of delineation of systematic hydrological and hydro geological system.

2.1 ,Scope of the study

The Surajkund Lake is an ancient man-made water body constructed to impound rainwater from the Aravalli Hills. This lake was largely fed by rainwater and need the catchment to be maintained in order to retain good water levels throughout the year. But fast pace of urbanization in close vicinity of the lake have denuded the catchment area which led to soil erosion and increased runoff without recharging the groundwater.

Hence the present study shall be able to solve the above mentioned problem by GIS techniques, modern equipments and tools for the sustainable development of water bodies of Surajkund Lake.

3, Methodology Adopted

The following methodologies were adopted in order to achieve the result for the revitalization of Surajkund Lake:

1-Delineation of watershed of Surajkund Lake area

- The watershed of Surajkund Lake was analysed on the basis of Survey of India Toposheet no 53H/7 and 53H/3 in which all the major drainage system connecting to the Surajkund Lake were analysed on regional basis at a scale of 1:50,000 and then the watershed of the major drainage system were further delineated.
- Once the watershed were analysed the runoff calculation were carried out on the basis of rainfall pattern of the area.

2-The rainfall pattern were analyzed on the basis of Precipitation data available at Meteorological Department sources at different stations such as IGI airport station along with Najafgarh and Safdarjung stations. In this way the data from year 1910 to 2010 was analysed.

3-The climatic data was analyses on the regional basis from Meteorological Department sources as temperature, humidity and evaporation and likewise so that the losses from water bodies such as Surajkund Lake could be calculated.

4-The seepage losses were also calculated on the basis of subsurface geological strata established using the tube well strata charts as well as the borehole logs.

5-The prevention of runoff due to Bhatti mines were also calculated on the basis of self investigation.

6-The groundwater depth to water level for pre and post monsoon season for three years were also considered for the seepage losses of Surajkund Lake which causes infiltration of surface water to the groundwater in downstream direction of Surajkund Lake area.

In this way the hydrologic equation $I \sim O \pm \Delta S$ was considered for the revitalization and sustainability of Surajkund Lake.

The above equation indicates that "I" is the inflow factor which is incoming into Surajkund Lake from surrounding area and "O" is the out flow factor which is outgoing water and losses from the Surajkund Lake area and thus the storage "$\pm \Delta S$" has been considered.

4, Analysis And Discussion

1-Delineation and analysis of watershed of Surajkund Lake area.

2-Hydro meteorological analysis of Surajkund Lake area including climatic conditions

3-Analysis of seepage rate of Surajkund Lake area.

4-Analysis of surface geology of Surajkund Lake area.

5-Hydro geological analysis for the groundwater conditions and behaviour of Surajkund Lake area.

6- Sustainability analysis of Surajkund Lake area to verify the hydrologic equation for storage capacity and enhancement for revitalization of Surajkund Lake area.

5 , Description Of The Study Area

The Surajkund Lake is located at latitude $28^0$24'E longitude $77^0$16'N.Sited at Faridabad district of Haryana State and at a distance of 30 kms from South Delhi, Surajkund Lake is placed in the eastern side of vicinity of southern part of Delhi Ridge of Aravalli Super group. Surajkund Lake is a rainwater nourished lake formed between two hillocks. Surajkund Lake which is a low lying area gets rainfall runoff from northern, western and south western side by Delhi ridge .An embankment is build on it to control it water flow to east and south east side area which is densely urbanized and includes localities like Maharajpur,Aitmadpur,Faridabad New Town and Ballabgarh.

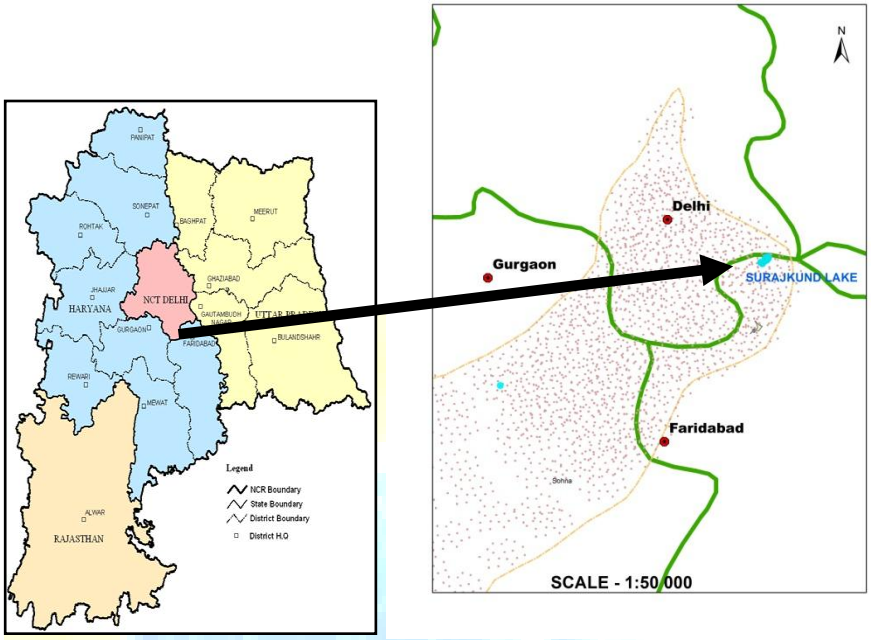


Figure1, The Location Map of Surajkund Lake, Faridabad District, Delhi NCR

SCENE-I (2002) SCENE-II (2012)

Figure 2, Aerial view of Surajkund Lake showing lake condition at a span of 10 years.SOURCE-google earth pro

The wet area of Surajkund Lake is only 40.51 acres left in last 10 years which is actually 29% of its original 137.07 acres. It acts as a barrier for excessive flood water flow and also prevents soil erosion in the area. But its catchment has disturbed due to urbanization factor by interrupting the

continuity of the runoff flow and leading huge debris flow towards the lake ultimately leads to lessening of water content of the lake

6,Micro Climatology Of Surajkund Lake

6.1, Temperature

Temperature data for last six years from 2006 to 2011 was collected from Indian Meteorological Department and an average rainfall of these six years was considered for calculation of water losses due to high temperature ,which depicted that Pre-monsoon months are the hottest months recorded with a maximum temperature of 41.5 C in the months of June, July and August which is generally followed by rain and thus lowering the peak temperatures which otherwise causes heavy water losses due to evaporation and evapotranspiration.

6.2,Humidity

Humidity data for last six years from 2006 to 2011 was collected from Indian Meteorological Department. Humidity is highest during the rainy months. Highest humidity of 81%has been recorded in the month of August and a minimum of 24% in the month of May has been recorded. Thus May is the driest month when humidity is least.

Months	Temperature Mean daily in degree centigrade		Relative Humidity in %	
	Max.	Min.	Max.	Min.
January	13.4	4.7	74	45
February	19.5	7.2	68	43
March	28.5	11.4	62	37
April	35.3	19.4	44	27
May	40.3	24.7	45	24
June	41.5	27.7	55	37
July	35.5	26.4	78	64
August	34.3	24.1	81	73
September	35.3	21.8	71	57
October	34.8	16.6	60	41
November	28	11.7	63	41
December	23.7	5.1	70	45

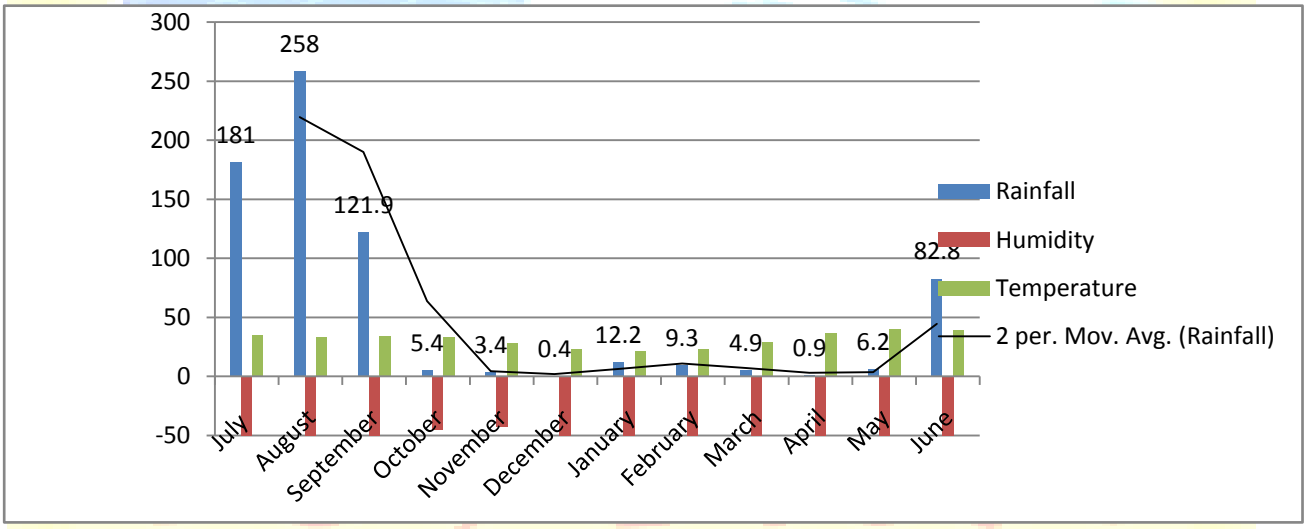
Table 1, Temperature, Relative Humidity in Faridabad District (2006-2011)

SOURCE: IMD

6.3, Rainfall

The southwest monsoon cases heavy rain to fall in the region in rainy months starting from Last week of June to End of September. Frequency of rain is highest in the months of July and August reaching up to 338.8 mm in the month of August in 2010 causing flooding in many low lying areas.

The study of rainfall data of last 6 years as depicted from graph 1 shows that there is a sharp decline in the temperature factor after rainfall .Only 80% of the runoff generated by the Aravalli Ridge reaches the study area lake while rest is lost due to many natural processes like evaporation, evapotranspiration, seepage, and man-made activities like construction and mining activity.



Graph 1, Graph showing Average of Rainfall, humidity, Temperature variation for six years (2006-2011) of Faridabad District

The Microclimatic Analysis clearly indicates that the response of the rainfall much higher in the months of rainy days but the temperature is also very high in that period by the increase of temperature the humidity increases and rate of Evaporation and Evapotranspiration increases which is one of the major reason for the loss of water in the Surajkund Lake area.

7,Geological Interpretation of Surajkund Lake area

The geological mapping for the watershed area of the Surajkund Lake was carried with the help of survey of India Toposheet no. H43X3 and H43X7 on a scale of 1:50 000 as well as reconoiscence survey which was carried out in the field followed by detailed geological survey in which the rock sampling was done at an interval of every 100 m or change of lithology on a grid pattern .

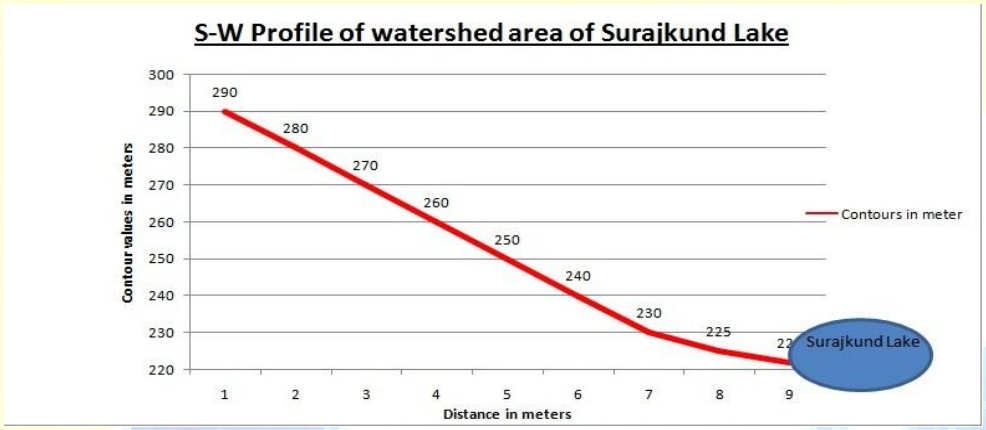


Figure 3,Profile showing S-W profile of the watershed area of Surajkund Lake

A relief profile as evident from Figure 3 was drawn from south-west direction starting from the Aravalli ridge area towards Surajkund lake area along with their relief and their respective area occupied in square kilometers .These physiographic units were particularly analyzed with reference to different lithological units. The maximum mean sea level recorded were 290 m in Aravalli Ridge area and a minimum of 222 m at Surajkund lake reservoir .In this way, it is evident that a steep gradient is established which is about 68m in 4.2 km land which indicates the average gradient which is about 16.1m/km . The average gradient shows that the area has got hilly topography, by virtue of which the existence of lake was possible.

In this way, all the lithologies were covered for entire watershed area of Surajkund Lake and were analyzed for the response of runoff on various lithological units present in the area .The following lithologies have been encountered in the water shed area and its topographical relief was also measured to acquire the complete physiography of the watershed area.

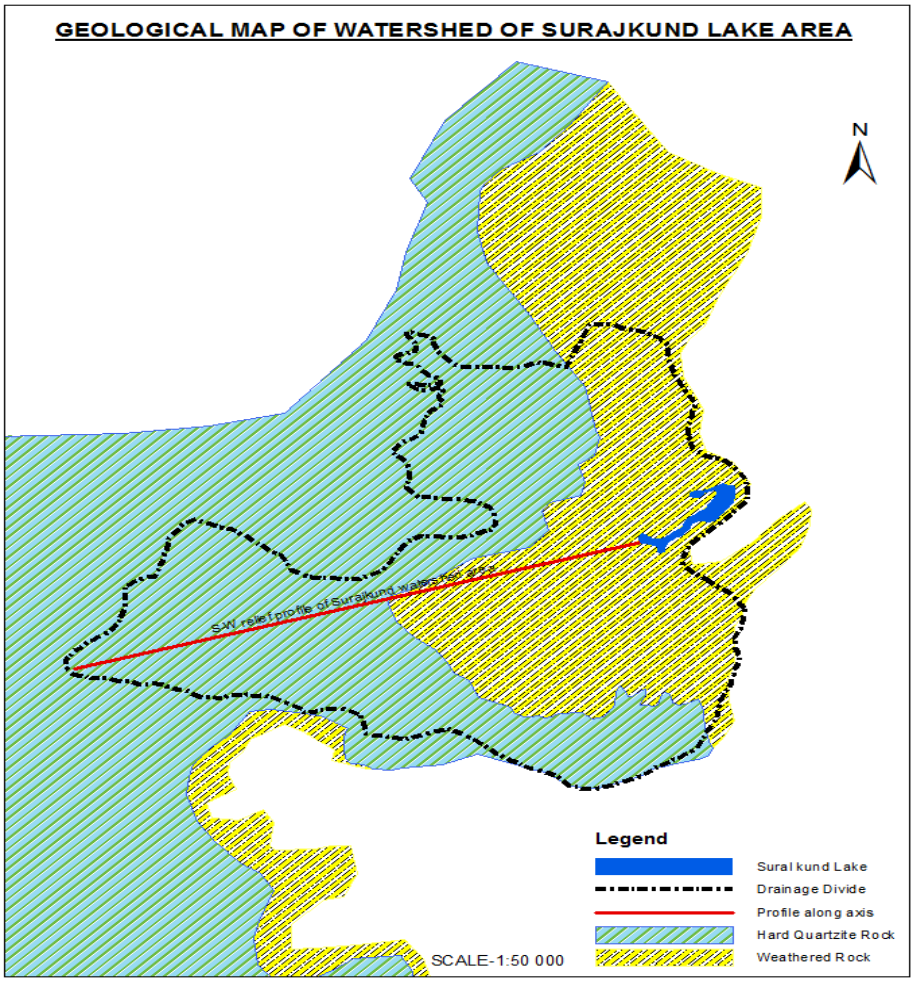


Figure 4,Geological map of watershed area of Surajkund Lake

S.No.	Label	Lithology	Area(km2)	Relief(in meters)
1.	B	Solid Quartzite Rock	9.75	290-240
2.	C	Fractured Quartzite Rock	7.62	240-220

Table2, The lithological units of watershed area of Surajkund Lake

These physiographic units were particularly analyzed with reference to different lithological units starting from the Aravalli ridge area towards Surajkund Lake area along with their relief and their respective area occupied in square kilometers. The maximum mean sea level recorded for Solid Quartzite Rock were 290 m to 240m stretched in 2.7 km of area in Aravalli Ridge area and in Fractured Quartzite Rock area a maximum elevation of 240m to 222 m is covered in 2.18 km of area at Surajkund Lake reservoir .Thus Solid Quartzite Rock is found to have very steep gradient of 18.5 m/km whereas Fractured Quartzite Rock has a comparatively less but still steep gradient of 8.2 m/km.In this way, it is evident that overall on an average a steep gradient is established and average gradient shows that the area has got hilly topography, by virtue of which the existence of lake was possible. Further details of each lithological unit is demarcated in table no- which - indicates that the Solid Quartzite Rock occupies 9.75 km2 area with a relief starting from 290m to 240m with a very steep gradient .Further, the Solid Quartzite Rock is followed by fractured quartzite which occupies a major portion of the area which is about 7.62 km2 with a relief of 240-220 m with a steep gradient .However, pace of urbanization is very fast in this portion of watershed area and a lots of construction activity is going on by virtue of which the runoff have been effected greatly and may be analyzed as one of the major reason for the deterioration of Surajkund Lake. This aspect of watershed seems to be irreparable .However, the local ditches recharge the ground water and ultimately the groundwater gets diverted to Yamuna River.

8,Analysis of watershed and Drainage system of Surajkund Lake

The watershed analysis was carried out for entire watershed of the Surajkund lake area for the calculation of response of the rainfall on various lithological units encountered on the watershed area of the lake and its drainage system has also been developed-

The perusal of the map indicates the major runoff comes from N-W and S-W direction in which it is found that the drainage follows the relief pattern in general.However, the regular dendrtitic drainage pattern gets disturbed due to local stone quarries and mining along with the roads and settlements .It is seen that the watershed is mostly disturbed due to urbanization factor by virtue of which the adequate amount of runoff does not reach to the Surajkund Lake. The local stone quarries and mining activity in the close vicinity of the lake has also increase the sediment flow to the Surajkund Lake. Thus the volume of the lake has also reduced due to excessive sedimentation

.The analysis of the runoff generated in the watershed area of Surajkund Lake as per lithology variance and gradient are as follows

S.No.	Lithology	Runoff Coefficient (c)	Intensity of rainfall for year 2011 (in mm)	Area(km2)	Runoff Potential in mcm Q=CIA
1	Hard quartzite	0.7	617.7	9.75	4.21 m3
2	Fractured quartzite	0.4	617.7	7.62	1.8 m3
					Total=6.2 m3

Table3, Analysis of Run-off potential of watershed area of Surajkund Lake

C=Runoff Coefficient

I=Intensity of Rainfall

A=Area in km2

Q=Total available runoff

The analysis of runoff potential of watershed area indicates that there are number of local drainage generated from Aravalli area to Surajkund Lake .However, the density of discharge seems to be very low as compared to watershed area of Surajkund Lake which is the main concern of the present watershed and drainage system. The empirical relation has been established by applying the formula

$$Q=CIA$$

Where Q is the total runoff and C is taken as coefficient of runoff and I is taken as intensity of rainfall, A=Area in km2 .It is found that there are two lithological units which are already

described with their occupied area in Table---.The runoff generated from the individual litho-units were calculated with the assumption that the watershed is undisturbed .It was analyzed that the runoff generated from

Hard quartzite about =4.21 m3

Fractured quartzite was= 1.8 m3

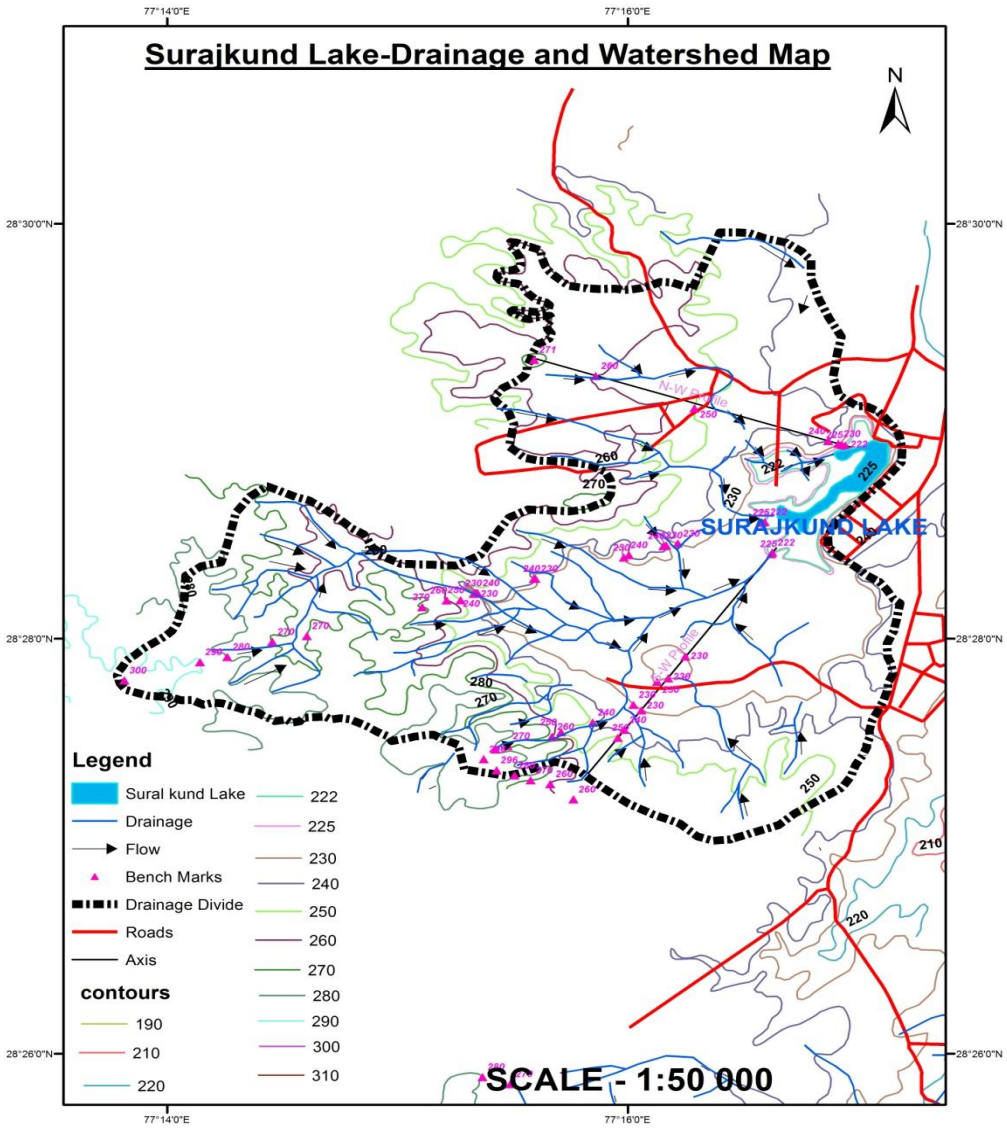


Figure 5,Watershed and Drainage map of Surajkund Lake area

In totality, the runoff was generated as 6.2 m3. However, it is found that the area is highly disturbed by the construction of urbanization projects such as roads, bunding and houses which has disturbed the runoff and only 25-30 % of the runoff remains for the replenishment of Surajkund Lake which may be taken as 2.7-3m3 as a final total runoff to reach Surajkund Lake. In this way, it may be analyzed that the runoff for the watershed area are good enough for the Surajkund Lake with the help of training of drainage system using the innovative technique such as continuous connectivity of the small reservoir of mining and provision of aqueducts or subsurface waterways from the tangent of the watershed in order to replenish the Surajkund Lake.

Further, it is also analyzed that the drainage system in the downstream direction are weathered quartzite and alluvial zone needs the repairing and broadening of drainage system with the help of connectivity of RCC drain to Surajkund Lake area .The rainwater harvesting master plan from the settlement to Surajkund Lake will further improve the replenishment condition of Surajkund Lake .

S.No	Months	Average runoff coefficient	Average intensity of rainfall For last six years(mm)	Area of watershed for all lithologies Of the watershed area(m2)	Average monthly runoff potential in m2
1	January	0.55	1.53	17.37	14.61
2	February	0.55	20.06	17.37	190.5
3	March	0.55	13.06	17.37	124.07
4	April	0.55	6.5	17.37	61.75
5	May	0.55	59.03	17.37	560.78
6	June	0.55	64.81	17.37	615.6
7	July	0.55	151.36	17.37	1437.7
8	August	0.55	185.3	17.37	1760.3
9	September	0.55	157.76	17.37	1498.7
10	October	0.55	3.9	17.37	37.05
11	November	0.55	3.9	17.37	37.05
12	December	0.55	0.616	17.37	5.8

Table 4, Average monthly runoff potential available to Surajkund Lake from its water shed.

9 - Seasonal Response OfSurajkund Lake With Its Expansion And Shrinkage

Seasonal response of Surajkund Lake's original extent occupies a vast area of 137.07acres in which the remaining wet area has been analyzed as 40.51 acres which clearly indicates that about 29% of the area remains as wet area .This is because of the urbanization factors such as roads and settlements around Surajkund Lake area.

For the simplicity of calculation study of seasonal response with the expansion and shrinkage of Surajkund Lake has been carried out which is shown in the table no-6

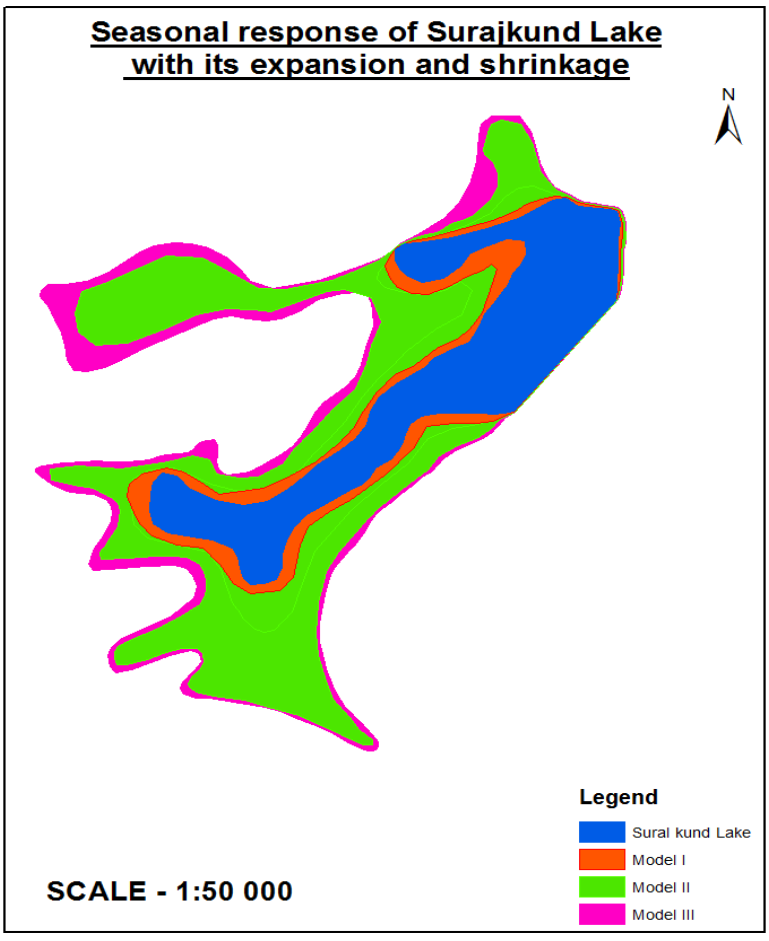


Figure 6,Seasonal response of Surajkund Lake with its expansion and shrinkage

It is found that Surajkund Lake may be divided into three models namely model I,II,III.It is found that since zone of present wet area of the lake which is 0.1645 m2 has got the maximum depth of 6.5 m on an average which occupies the volume of the water as 1.06 m3which is a conformity to our previous calculation that only this amount of water through runoff is reaching to the lake and so the present condition of the lake represented by the shed volume .However, in order to develop the model I of the lake which occupies an area of 0.2140 m2with an average depth of 5.2m will require about 1.11 m3of water. likely to develop model II which occupies an area of 0.4709 m2 with an average depth of 3.8 m will require the volume of runoff as 1.78 m3 and lastly in order to develop the model III of the lake which occupies an area of 0.5424 m2 in an average depth of 2.5m will require 1.35 m3 of runoff .

S.No.	Zone Area	Area(in acres)	Area in Kilometers square	Average depth of the zone(in meters)	Water Requirement (in m3)	Cumulative water requirement (in m3)
1	Present surajkund lake	40.51	0.1645	6.5	1.06	1.06
2	Model I	54.16	0.214	5.2	1.11	2.17
3	Model II	116.02	0.4709	3.8	1.78	3.95
4	Model III	137.07	0.5424	2.5	1.35	5.3
		Total=1.2 km2			Total=5.30 mcm	

Table 5, Seasonal response of Surajkund Lake with its growth and shrinkage

In all it seems that the total runoff generated by the watershed is about 6.2 m3 and the total requirement of all zones is about 5.30m3 .It is clear from the runoff calculation and water requirement calculation that almost 1 m3 extra amount of water has been generated by the watershed of Surajkund Lake .Also, taking 50% due to seepage ,evaporation and evapotranspiration even then the requisite amount of rainfall runoff is available to the watershed of the Surajkund Lake area which proves that the revitalization of Surajkund Lake is possible with careful engineering design .

10.Conclusions

The Delhi Ridge starts from Jaipur area in the form of eskers and is responsible for the local aggradations of land area which in turn known as water right from desert area of Rajasthan and that of NCR in Delhi onwards.

The Delhi Ridge is the main Hydroboundry and which divide to Yamuna basin and Indus basin. The southern part of Delhi Ridge forms many water bodies at the southern part of Delhi and NCR.

The pace of urbanization has disturbed the Delhi ridge in general and the catchment in particular by virtue of which the water bodies of historical importance started vanishing. The matter became more worse with the advent of new drilling technology such as Down Throw Hammer which drills the tube wells quite deep in the hard rock area .With the development and growth of population in and around Delhi ridge and in historical water bodies the rate of abstraction of groundwater gradually increased by virtue of which the grated gravel in and around historical water bodies started declining. As a result water table goes very deep and seepage losses from these water bodies gradually increased with the pace of declining water level. In this way the water shed declining of water bodies and seepage losses both are responsible for deterioration of water level of historical importance such as Surajkund Lake which has shrunken about 25-29% of its original Shape

The Surajkund Lake is located in Faridabad District and it is the most important tourist place maintained by Haryana tourism. Since the area in SurajkundLakel area is surrounded by Tilput range of hard Quartzite terrain and therefore any water body of this magnitude will provide the thermal comfort and good ambience for the tourists. The Surajkund Lake area is originally occupied by 137.07 acres has been shrunk to 40.51 acres .Surajkund Lake is one of the prominent water bodies in Faridabad and is deteriorating because of the disturbed catchment and watershed due to mining and urbanization. Hence the present study shall be able to solve the above mentioned problem by innovative techniques using modern equipments and tools for the sustainable development of water bodies of Surajkund Lake.

The watershed analysis was carried out for entire watershed of the Surajkund Lake area for the calculation of response of the rainfall on various lithological units and drainage system

It is seen that the watershed is mostly disturbed due to urbanization factor by virtue of which the adequate amount of runoff does not reach to the Surajkund Lake .The local stone quarries and mining activity in the close vicinity of the lake has also increase the sediment flow to the Surajkund Lake. Thus the volume of the lake has also reduced due to excessive sedimentation In all it seems that the total runoff generated by the watershed is about 27.74 mcm and the total requirement of all zones is about 12.53 mcm .It is clear from the runoff calculation and water requirement calculation that more than double amount of water has been generated by the watershed of Surajkund Lake .Also, taking 50% due to seepage ,evaporation and evapotranspiration even then the requisite amount of rainfall runoff is available to the watershed of the Surajkund Lake area which proves that the revitalization of Surajkund Lake is possible with careful engineering design .

11.Suggestions

The Following suggestions have been made with reference to revitalization of Surajkund Lake.

i. The complete Watershed of the Surajkund Lake must be obtained using old records of maps and literature.

ii.The impact on original watershed due to Urbanization must be redefine and redesign

iii.The drainage system of Latest watershed with mixed drainage combindly such as manmade storm water drain due to urbanization and natural drainage such as nallah and gullies must be combined together to get proper amount of run off to Surajkund Lake.

iv. The Rainwater Harvesting Master Plan with the pace of development of the surrounding area at least for 50 years future growth must be taken for Feasibility and Design of Rainwater Harvesting master Plan.

v. The Four Zones of the Surajkund Lake must be replenished as per the latest watershed using Rin Water harvesting Master Plan.

v. The Desilting and Evaporation and Evapotranspiration losses must controlled using Check dams, Cascades and Non Evaporative and harmless chemicals.

vii. The Surplus amount of water from the water logged areas available in the drains due to monsoon run off must be considered.

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