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Sedimentation Analysis and Remedial Measures for Upper Lake Bhopal using Remote Sensing and GIS

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Abstract ***Our Country has a large range of water resources like lakes, wetlands, coastal lagoons and reservoirs. Upper Lake Bhopal is one of significant wellspring of drinking water for the residents of the city, serves 40% of the residents with nearly 30 million imperial gallons (140,000 m^3) of water per dayIt also plays a very important role in history and culture of the population of Bhopal. In the present study sedimentation in lake for the year 2014-17 has been described. In this paper LISS III image of IRS 1C, 1D having Path 97 and Row 55 with 30% shift has been used. From the analysis it was observed that Upper Lake of Bhopal lost its gross storage capacity from 101.6 MCM to 75.72 MCM i.e. 25.88 MCM which is 25.47%. The revised capacity curve developed in the analysis may be used for lake operation and allocation of water for different uses. Considering the uniform loss in the storages, it can be concluded that 0.58 Mm^3 of storage of Upper Lake have been lost each year with average rate of 0.17 Mm^3/100 km^2/ year. Some remedial measures like protection of fringe area, creation of buffer zone, removal of silt and weeds at regular interval and prohibition of sewage disposal and idol immersion have been suggested.***

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Index Terms**: *Fringe area, gross storage capacity, lake operation and remedial measures.***

I.INTRODUCTION

Bhopal is known as city of lakes. With the deposition of sediments and increase in urbanization in the city the most of the lakes are reduced to small size and also the waters of many lakes got polluted with the discharge of domestic and industrial waste products. Land and water are vital Natural resource on which the supporting life systems and socio-economic development depends. For development of city based on urban planning effective and precise understanding of the environmental quality is necessary. Sedimentation in a lake is always been a tedious problem and moreover it is very tough to accurately measure the volume of sediments in a lake. cross-section of lake increases when stream is entering the lake, although the speed of current decreases and thus sedimentation is deposited. Creation of sediments getting from seepage zone depends on erosion, rainwater runoff , and characterstics of sediments transportation along streams. It is most important to have a specialist evaluation for the evaluation of sediments in a drainage area which is flowing in dam position. To calculate the sedimentation a lake and to evaluate its distribution and deposition pattern, remote sensing techniques is convenient and efficient method.

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Remote Sensing Technology, offering information securing over a long period of time and broad spectral range, can give brief, repetitive, and timely information in regards with sedimentation characteristics of a lake. Lake water spread area for a specific elevation can be obtained very precisely from the satellite data. If water spread area reduced in a specific elevation represents the deposition of sediment at that level. When this technique using multi data satellite information gets integrated then it calculates the loss of volume of storage due to sedimentation. In this paper satellite images were tested to evaluate sedimentation in Upper Lake Bhopal in Madhya Pradesh state of India. Jain and Goel (1996) used this SRS technique to determine the capacity and sedimentation of Singoor lake, India. To extract the water spread area of lake using medium resolution multi-spectral image data, both the per-pixel and sub-pixel mehod have been used and it results high resolution panchromatic image data. Thus after determining the lake capacity it concludes that the enabling od precise mapping of terrain features is done by high spatial-resolution of image data[1]. Agarwal et al (2006) assessed the sedimentation in Hirakud Reservoir using digital remote sensing technique. During 44 years, live storage capacity was reduced by nearly 17 % (at the rate of 0.376 % year") of live storage. Silt index for Dive storage area was 2.623 ha m (I00 Sq.KM/Year).[2]Goel et al, (2002) estimated the sedimentation in Bargi reservoir M.P, India using digital image processing data & satellite image data. In this research, digital processing methois performed by using the ERDAS/IMAGINES image processing software. [3]Jain et al (2002) Assessed sedimentation in Bhakra Reservoir in the western Himalayan region using remotely sensed data .study showed that the average sedimentation rate for 32 years (1965-1997) is 25.23 Mm^3 per year whereas ground observations through hydrographic survey provided sedimentation rate of 20.84 Mm^3 for the same period.[4]Jaiswal et al studied Ravishankarsagar reservoir using digital image processing and concluded that 45.93nM cum of gross storage and and 31 M cum of dead storage has been lost in 24 years[5-6]Jeyakanthan(2002) studied Poondi reservoir and Singoor reservoir using Image Processing method.[7-8]Prasad.B (2018) demonstrated that the remote sensing technique is time- and cost-effective and convenient approach to estimate the elevation-area-capacity curves for a reservoir[10].**M**odels have been changed and assessed in a noteworthy way as of late, highlighting the utilization of Remote Sensing and GIS.[11-12]

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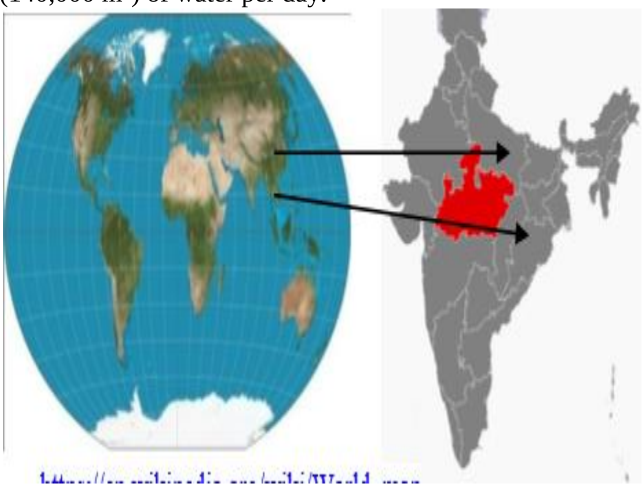
II.STUDY AREA

The Upper Bhopal Lake in the city of Bhopal in the state of Madhya Pradesh is the only source of water for the city of Bhopal. Economic as well as recreational activities of the city of Bhopal is dependent on the water availability in the Upper Bhopal Lake which receives water as surface runoff only during the monsoon period of every year. The Upper Bhopal Lake has a catchment area of 362.35 square km. The land use pattern of about 80% of the catchment is agricultural where as 5% is of forest and the rest is urban. It lies at the latitude of 23˚ 04'N, longitude of 72˚ 18' E, and at an altitude of 508.65 m above mean sea level. The storage capacity is 117.05 million cubic meters. The rain water is the only source of water inthis lake. The main source of drinking water for the residents of the city, serves 40% of the residents with nearly 30 million imperial gallons (140,000 m^3) of water per day.



https://en.wikipedia.org/wiki/World_map,

https://en.wikipedia.org/wiki/Madhya_Pradesh

Fig. 1 Location map of study area, Raja Bhoj statue,

III.METHODOLOGY

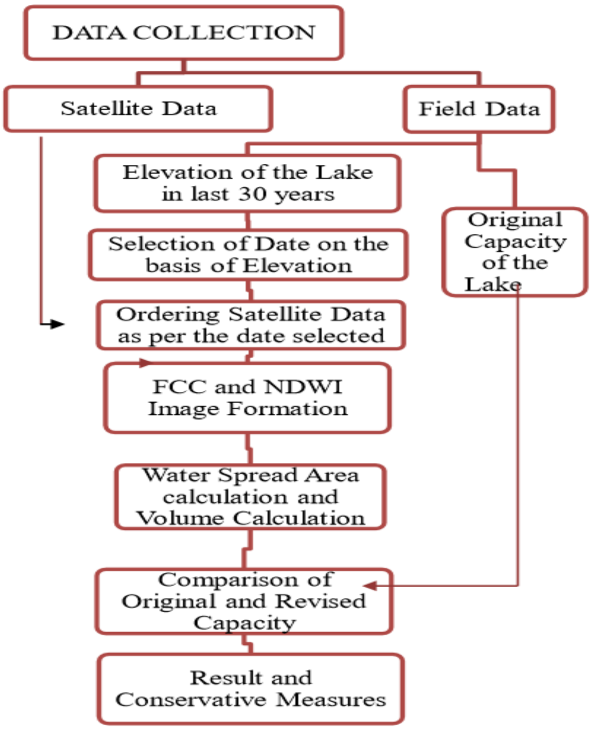


Fig. 2 Flow chart of methodology

3.1 Data Used

3.1.1 Topographical Data

For preparing a base map of SOI Toposheet-55 E/3, 55 E/4, 55 E/7, 55 E/8 (Scale: 1:50,000) has mainly used to to start the process with satellite imageries.

3.1.2 Field Data

Maximum, minimum and daily water level data for the period from 1993 to 2017 were collected from dam site. The salient features of the lake along with original Capacity in 1965, Capacity table of Upper Lake Bhopal based on C.W.P.C report were collected from the Municipal corporation of Bhopal and Bhadbhada west weir Authorities.

3.1.2 Satellite Data

The multi-spectral data from IRS 1C, 1D and IRS P6 Satellites for LISS-III Sensor are available. The data were taken for six different date 13-May-15, 07-Apr-15, 11-Jun-14, 26-Nov-14, 26-Jan-17, 03-Nov-16 which were cloud free at different levels for the year 2014-17. The Upper Lake Bhopal water spread was covered in one scene of Path-97, Row-55 with 30 % shift for IRS 1C, 1D and IRS P6.

IV.ANALYSIS OF RESULT AND DISCUSSION

The reservoir level data and the original reservoir volume at these level were obtained from the dam authorities. Using these original data, the original elevation-area-capacity curves were constructed and are presented in tabular form in table below.

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Table 1: Original reservoir volume and level

RESERVOIR LEVEL (FT)	RESERVOIR LEVEL (M)	VOLUME (MCFT)	VOLUME (MCM)
1657.1	505.08	1217.6	34.48
1658.6	505.54	1362.8	38.59
1660.35	506.07	1741.75	49.32
1662	506.58	2120.5	60.04
1664.05	507.2	2678.05	75.83
1666.2	507.86	3363	95.23

4.1 Import, visualization and Geo-referencing

The National Remote Sensing Centre (NRSC), Indian CD-ROM transmitted the data of IRS-ID satellite and LISS-III sensor for different dates and this information imported in ILWIS system. A visualization false colour composite (FCC) of near infrared (NIR), red and green bands combination has been formed. The waterspread area (except at the periphery) of the lake was different and clear in the FCC. The water-spread areas at different time periods has been observed by using the geo-referenced images.

4.2 Identification of water pixels

NDWI = (Green - NIR)/(Green + NIR)
OR=(BAND2-BAND4)/(BAND2+BAND4) (i)

The slicing operation of the NDWI images is carried out to extract the water pixels from the rest. Slicing is done for all the images so that proper histogram can be generated which further gives the value of revised water spread area

The revised areas obtained from this operation may be used to estimate the revised volume between two consecutive elevations with the help of prismoidal formula. After concluding the water spread area of all images, histogram is constructed and water pixel were recorded. By using the prismoidal formula lake capacity between two consecutive Lake is calculated:

$$V=H\times(A1+A2+\sqrt{A1\times A2})/3 \quad \text{(ii)}$$

V= Volume between two consecutive elevation 1 and 2
A1 and A2= water spread area at consecutive elevation
H = Difference in the elevation between elevation 1 and elevation 2

The revised cumulative capacities will be obtained by adding the revised volumes between consecutive intervals. The cumulative capacities between the consecutive levels were added up so as to reach at the
cumulative original and the revised capacities at the maximum observed level. The difference between the original and the revised cumulative capacity represents the loss of capacity in the zone under study.

Table II: Revised water spread area at elevation

Date of pass satellite	Reservoir level (meter)	Revised water spread area (ha)
########	505.08	1138.12
07-Apr-15	505.54	1438.44
11-Jun-14	506.07	1587.57
########	506.58	1854.89
26-Jan-17	507.2	2380.55
########	507.86	2811.22

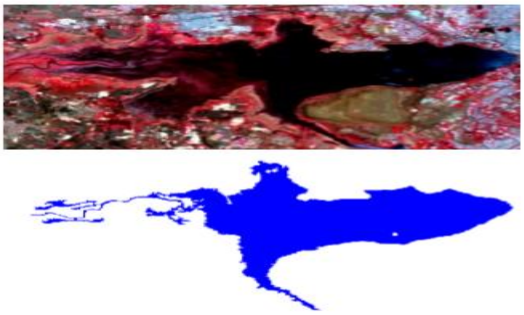

Fig.3(a) False color composite and (b) Extracted water spread on May 13, 2015 (Res. Level: 505.08 m)

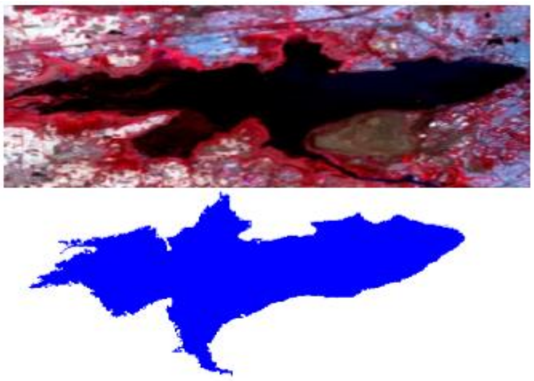

Fig 4(a) False color composite and (b) Extracted water spread on Apr 07, 2015 (Res. Level: 505.54 m)

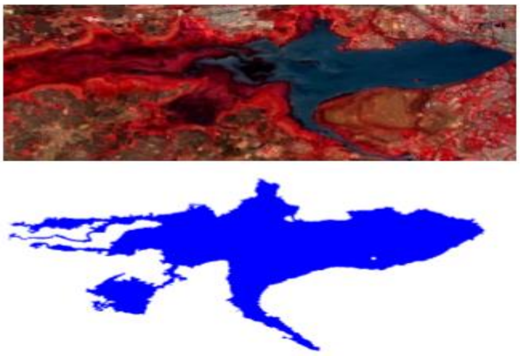

Fig 5 (a) False color composite and (b) Extracted water spread on Jun 11, 2014 (Res. Level: 506.07 m)

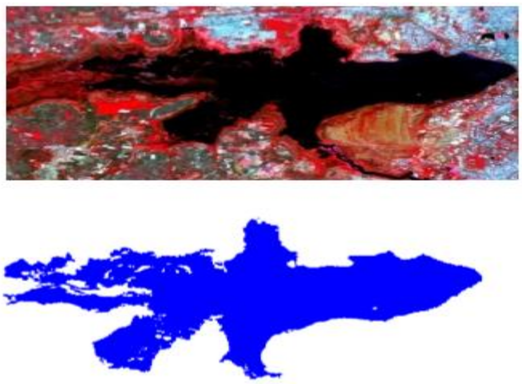

Fig 6(a) False color composite and (b) Extracted water spread on Nov 26, 2014 (Res. Level: 506.58 m)

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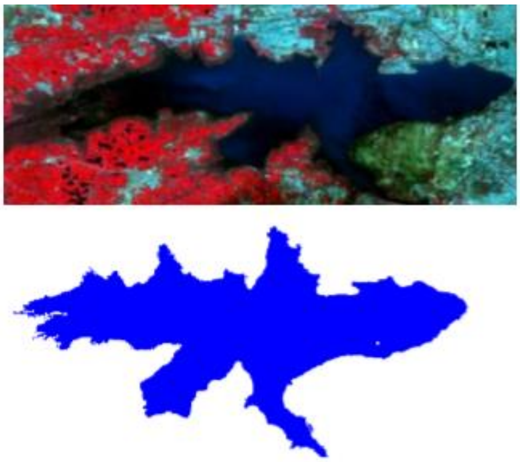

Fig 7(a)False color composite and (b) Extracted water spread on Jan 26, 2017 (Res. Level: 507.20 m)

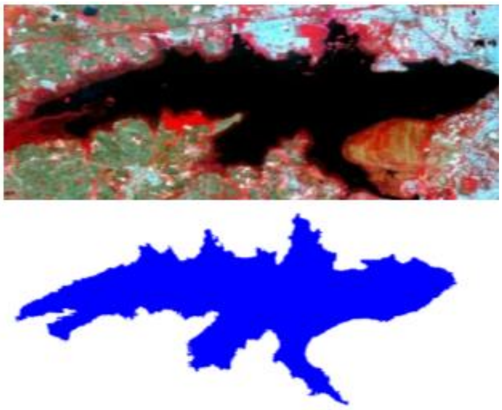

Fig 8:(a) False color composite and (b) Extracted water spread on Nov 03, 2016 (Res. Level: 507.86 m)

In order to calculate the sedimentation loss ,it is essential to compute the revised area at the river bed level and the revised river bed level and their values were calculated using best fit curve. Their value was further use in the analysis to compute the loss of capacity of reservoir and sedimentation loss as well.

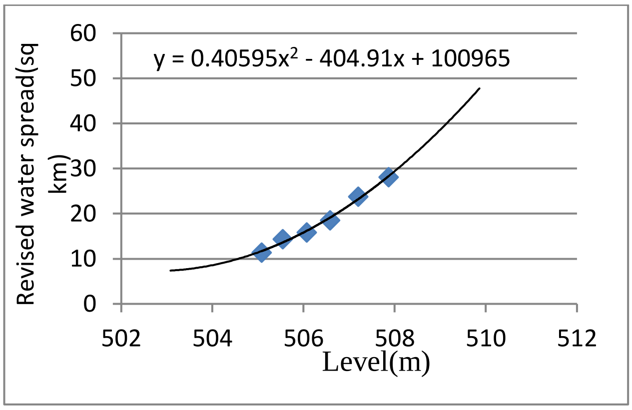

Fig 9 Graph for computation of revised water spread area

Table III Original and revised capacity with cumulative loss

Date of Passing Satellite	Reservoir Elevation (m)	Original Capacity (MCM)		Revised Capacity (MCM)		Loss in Cum .Capacity	% Loss in CumCapacity
		Volu	Cum Cap	Vol	Cum Capacity	MCM	
Origina	500.50						
Revised	501.00						
DSL	503.5	14.1	14.1	5.25	5.25	8.91	62.92
13-May-15	505.08	17.1	31.27	12.47	17.72	13.55	43.33
07-Apr-15	505.54	7.32	38.59	5.91	23.63	14.96	38.77
11-Jun-14	506.07	11.3	49.32	7.71	31.34	17.98	36.45
26-Nov-14	506.58	10.7	60.04	8.77	40.11	19.93	33.19
26-Jan-17	507.20	15.7	75.83	13.09	53.2	22.63	29.84
03-Nov-16	507.86	19.4	95.23	17.11	70.31	24.93	26.17
FSL	508.04	6.37	101.6	5.41	75.72	25.88	25.47

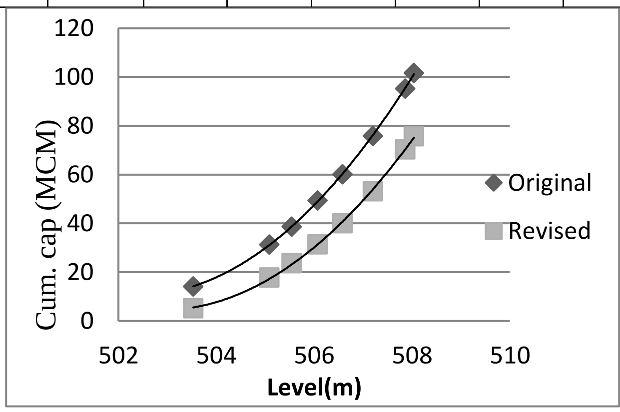

Fig 10: Original and revised capacity curves of Upper Lake Bhopal.

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4.3 Remedial Measures for excessive sedimentation.

4.3.1 Fringe area should be protected

The construction within 50-75 m of the Full Tank Level (FTL) of the Upper Lake, Bhopal should be prohibited. It should be strictly followed and public awareness program should be conducted at regular interval.

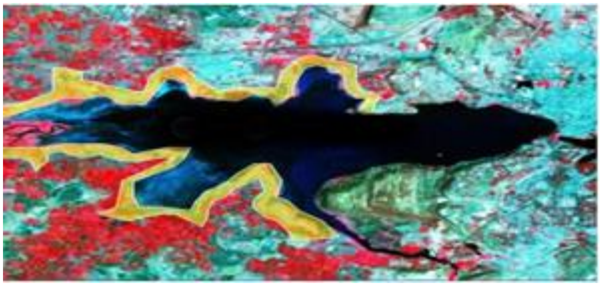

Fig 11: Fringe Area Protection in Upper Lake Bhopal

4.3.2 Buffer zones should be created

Human settlements, cultivation and grazing within the lake area, siltation and plantation are going on in the lake area so buffer zones have to be created, particularly in the western, southern and northern fringes of the Upper Lake. Many times government of Bhopal has created buffer zones so proper care should be taken on it. We should motivate farmers to plant fruit yielding trees along their crop fields and marginal lands.

4.3.3 Sewage treatment should be done

Main reason of pollution and water quality deterioration lakes with 14 drains carrying 15 million liters/day of sewage entering the Upper Lake is sewage. Greater treatment plants are required t0o be developed for diversion and treatment of domestic sewage.

4.3.4 Solid waste management

Solid waste generated from the 18 wards in that area were mostly thrown in the lake. Proper transport facility and heavy equipments are also required. Due to Swachh Bhopal Abhiyan the solid waste management in the area has been improved.

4.3.5 Removal of Silt from Lake

after constructing earthen cofferdams and dewatering the area, Silt is removed from Upper Lake The excavated materials were transported to wastelands transforming them into beneficial agrarian and ranch lands.

Fig 12 Removal of Silt in Upper Lake Bhopal

4.3.6 Weed removal

Supplement enhancement of the lakes due to influx of untreated sewage, natural waste-containing runoff from urban ranges in
lakeand agrarian buildups from provincial ranges around the Upper Lake have caused excessive aquatic vegetation development inside the lake range. We need to Regularly remove weeds from the submergence zone of the Upper Lake.

Fig 13 Removal of Weed from Upper Lake Bhopal

4.3.7 Public awareness campaign

We need to regularly arrange seminar, campaign, workshop to educate the people of Bhopal regarding the awareness of Upper Lake so that they can understand the importance of Upper Lake and they did not spoil the lake surrounding. As an starting action, we can give an overview to evaluate people's reactions with respect to the preservation and lake administration endeavors. Based on this we can motivate the individuals of all strolls of life. Different public awareness program should be conducted in the form of painting, drama, debate, group discussion in the Upper Lake Bhopal area so as to motivate the Local public to make the lake clean and healthy.

1.3.8 Control of idol immersion activities.

Religious activities are very important in India. Religious celebration of submerging idol in water is practiced all over the nation. Idol drenching activities are also performed within upper lake which might be consumable water source for the individuals of Bhopal. This idol is made from wood, bamboo, feed, clay and printed with shinning colors thus lake accepts the sediments and harmful for the water. So, idol immersing should be ban in lake

V.CONCLUSIONS

Land and water are vital Natural resource on which the supporting life systems and socio-economic development depends. Sedimentation in a reservoir is always been a tedious problem and moreover it is very tough to accurately measure the volume of sediments in a reservoir. Traditionally assessment of reservoir sedimentation was done by hydrographic method. But, by the introduction of Remote sensing techniques it becomes quite easy to compute reservoir sedimentation with less error time. The present investigation of Upper Lake shows that the remote sensing technique is a time- and cost-effective and advantageous for the elevation area capacity curves for a lake. The merhod to expel the discontinuous pixels and the derivation of contours has been significantly computerized.

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In a present study work an ILWIS 3.0 GIS software was used for image processing. From the analysis it was observed that Upper Lake of Bhopal reservoir lost its gross storage capacity from 101.6 MCM to 75.72 MCM i.e. 25.88 MCM which is 25.47% The revised capacity curve developed in the analysis may be used for reservoir operation and allocation of water for different uses. Considering the uniform loss in the storages, it can be concluded that 0.58 $Mm^3$of storage of Upper Lake have been lost each year with average rate of 0.17 Mm^3/100 km^2/year. As the silt deposition is increasing in the lake every year it is a matter of great concern for all of us. Some of the remedial measures like protection of fringe area, creation of buffer zone, proper disposal of sewage, solid waste management, removal of silt from the lake, removal of weed from the lake, stopping idol immersion in the lake and regularly doing public awareness program should be done at regular interval so as to maintain the capacity and purity of lake.

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