GIS APPLICATIONS FOR WATER RESOURCES CONSERVATION THROUGH HYDROGRAPHIC SURVEYS IN CHIKARAYAPURAM AND PAMMAL ABANDONED QUARRIES

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Abstract

During the year 2017 the Chennai metropolis was facing a severe drought due to failure of monsoon rainfall and starved even for drinking water. A scientific study has been carried out using geospatial technology and echo sounders for the identified source of water from abandoned quarries towards estimating the quality and quantity. The study has identified the quantity of available water is 26,32,967 m³ from both the quarries and the water quality is suitable for drinking purpose and concluded with the recommendations of collecting the excess water (Floodwater) in Chikarayapuram Quarries, which can hold maximum of 0.55 TMC of water for water starving Chennai City with diversion of overflowing water channels to the abandoned quarries with minimal measures. The water in Quarry No.4, Pammal should be treated with hydrochloric acid and after additional water treatment techniques, the water can be utilized for drinking purposes.

Keywords: Geospatial technology, water treatment, water quality

1. Introduction

Water is vital, for all facets of life and defines the characteristic of our world. Around 97.5% of all water is saline and found to occur in the oceans. Of the remaining freshwater, only one percent is available for extraction and usage. The planet is facing a water quality crisis at the beginning of
the 21st century, exacerbated by continuous population growth, industrialization, food processing practices, amplified living standards and inadequate strategies for water use. Water plays an important role in a nation's economic development[1], especially in a country like India, which has an economy predominantly dependent on agriculture. Indiscriminate surface and subsurface water exploitation has contributed to extreme water shortages and environmental degradation[2]. The issue has been intensified by the spatial–temporal variation in rainfall[3].

Water consumption patterns suggest that household and industrial water demand in developing countries could double as a percentage of total water demand over the next 25 years. Without a fundamental reform in water management, speedy growth in urban demand for water would entail large-scale water transfers from irrigated agriculture, thereby putting food security at risk.

In order to meet domestic, agricultural, industrial and ecosystem needs, sustainable water protection requires the availability of water in sufficient quantity and quality in perpetuity.

In the field of water conservation and sustainable use, some of the urgent steps required are:

- Conserving rainwater through harvesting[4]
- Encouraging coordinated use of river, rain, ground, sewage and sea water in proper permutations
- Evasion of untenable aquifer misuse
- Upholding watersheds and command areas by safeguarding water use through quality, economy and equity by cooperatively
- Regulating the expansion of markets for water
- Introducing constructive steps to eliminate disputes with water

Although global processes and institutions are essential, it is essential for every nation to develop institutional structures to address national and local problems. Water supplies should be designed, created and controlled in an effective manner to meet the challenges of scarcity, increasing demand and depletion of groundwater levels.

2. **Aim and Objectives**

- To estimate the volume of water available in the abandoned quarries in and around Sikarayapuram, Pammal and Tiruneermalai region.
To investigate the possibility of converting abandoned quarries as water storage reservoirs in future for water starving Chennai city.

To evaluate the suitability of quarry water for drinking purpose as per CPCB norms for selected water bodies.

3. **Hydrographic Surveys**

Generally speaking, sound is an air vibration, and when an item vibrates, the surrounding air often vibrates in the same way. Like sound, the vibration spreads and propagates. It is reported that humans can hear are in a wider range of frequencies, 20Hz to 20kHz. Ultra sound is defined as the sound of higher frequencies that 20kHz. Ultrasound attenuates while traveling. Ultrasound can reach shorter distances than audible sound, as the attenuation rate increases with increasing frequency. Reachable distance depends upon a medium. In a homogeneous medium, sound moves straight forward but reflects on an interface between different materials. This characteristic feature is utilized in the fish finders and medical diagnosis scanner. Ultrasound has sharper detectivity than audible sound and gets sharper with increasing frequency[5].

Ultrasonic pluses transmitted from the transducer into the water are reflected from fish school or the bottom and then they are received by transducer as indicated in the Figure 1.
4. **Methods and Field data collection**

The bathymetric survey covered the entire water body and its adjacent regions with distinct control points covering depth variations reflecting the terrain’s underwater topography. (Initially 25 m Grids were planned however due to field conditions the number of readings were apart increased). The survey included the alignment of the long-lines and two external radial profile boundaries. A Hondex portable echo sounder connected with the Global Positioning System (GPS) was able to collect depth measurements.

4.1 **Reservoir Boundary**

Establishing a reservoir boundary is one of the initial steps in planning for a hydrographic survey. Boundaries are digitized from satellite images and available aerial photographs from NRSC and Landsat data's along with Google Earth data[6].

4.2 **Planned Survey Lines**

Every survey takes place along pre-planned range lines perpendicular to the original river channels’ presumed location and spaced approximately 75 feet apart.
4.3 Spatial Interpolation of Reservoir Bathymetry and GIS mapping

We have used various anisotropic spatial interpolation techniques to improve the accuracy of the bathymetry representation between survey lines[7]. In this study, we have used natural neighborhood method for creating the 3D profile of the underwater terrain using Geographical Information system (GIS) further the TIN model is generated for the study area with cross sectional profiles. A fundamental principle is that there is an upstream and downstream similarity in the reservoir profile in the vicinity of a specific site.

4.4 Dual frequency Depth Sounder

For comprehensive bathymetric surveys, we have used a multiple-frequency depth sounder integrated with a differential global positioning system (DGPS). A standard volumetric survey is an easy, reliable, and inexpensive way of obtaining the current capacity of a reservoir. Modified elevation-area-capacity tables are included in a volumetric survey report and a bathymetric contour map of the study region is described below.

4.5 Evaluation of suitability of quarry water for drinking purpose

The lake in Quarry No.4 of the Pammal is selected as study area for evaluating the suitability of quarry water for drinking purpose. Water samples were taken at seven different locations along the lake. The sampling locations with their latitude and longitude were represented in table below.

| Sampling Locations | Latitude   | Longitude  |
|--------------------|------------|------------|
| 1                  | 12.96635   | 80.12208   |
| 2                  | 12.96700   | 80.12197   |
| 3                  | 12.96781   | 80.12252   |
| 4                  | 12.96760   | 80.12342   |
| 5                  | 12.96716   | 80.1225    |
| 6                  | 12.96663   | 80.12227   |
| 7                  | 12.96631   | 80.12252   |
The parameters like pH, salinity and TDS (total dissolved solids) were estimated by using water quality probes in the field. Dissolved oxygen and chlorophyll content and sampling locations were estimated by Wrinkler's method[8] and Spectrophotometric method as follows,

Winkler method:

Reagents:

1. Winkler-A (WA) - 400g manganese chloride dissolved in 1000ml distilled water and stored in polyethylene bottle.
2. Winkler-B (WB) - 360g potassium iodide and 100g sodium hydroxide dissolve din 1000ml distilled water and stored in polyethylene bottle.
3. 50% HCl (50 ml conc. HCl in 50 ml distilled water)
4. Sodium thiosulphate solution, 0.01N (2.5g sodium thiosulphate dissolved in 1000 ml distilled water)
5. Starch indicator.

Procedure:

1. 1 ml of WA and WB were added to the water samples in the DO bottle.
2. Precipitate was allowed to form.
3. 3 ml of 50% HCl was added to the DO bottles. The bottles were stoppered and shaken vigorously, till the precipitate dissolve.
4. 50 ml of the solution from the DO bottle was titrated against thiosulphate solution, using starch indicator. The burette reading was noted.

Calculation:

\[
\text{Do (mg/l)} = \text{titration value} \times \text{Normality} \times \text{Atomic number of O}_2 \times \frac{1000}{\text{Volume of sample}}
\]

Spectrophotometric method for estimation of Chlorophyll a:

Reagents:

1. 90% Acetone : 100 ml of distilled water in 1l volumetric flask and made upto 1000 ml, with analytical grade acetone[9].
2. Magnesium carbonate: 1 g of MgCO₃ dissolve in 100 ml distilled water and transferred to wash bottle.

Procedure:

1. 500 ml of water sample was filtered through a Millipore filter paper. Two to three drops of MgCO₃ was added while the sample was being filtered.
2. After filtration, the filter paper was removed and placed in 15 ml centrifuge tube and 15 ml of 90% acetone was added and shaken vigorously.
3. The centrifuge tube, preferably inside a refrigerator, was closed tightly and allowed to
stand overnight.
4. The tubes were taken out of the fridge and allowed to heat up to room temperature.
5. The contents of the tubes are then centrifuged for 10 minutes at room temperature.
6. The supernatant is decanted into 10 cm path length spectrophotometer cuvette.
7. The readings are taken at wavelengths 750, 664, 647 and 630 nm.

Calculation:

Chlorophyll a, μg/ml = 11.85*E_{664} – 1.54*E_{647} – 0.08*E_{630}

Where E is the absorbance at different wavelengths.

Chlorophyll, mg/m³ = C * \( \frac{\upsilon}{V} \) * 10

Where
- \( U \) is the volume of acetone in ml (15ml)
- \( V \) is the volume of water sample in liters (500 ml)
- \( C \) is the chlorophyll a value in μg/ml

5. Results and Discussions

The results for quantity of water available from the estimated echosounders are presented in
Table 2 to Table 4 and the estimated with the total availability of 26,32,967 cubic meters (figures 1
and 2) due to high risk and safety concerns of human life the table 3 is arrived based on single
observations by sending a diver with the transducer to find one minimal depth for each
waterbody which is extended to few hectares and from that observations the approximated
factors for each quarry was fixed and the expected minimum volume in m³ were arrived and
presented to the Board and Government for further action. The figures 4 and 5 presented in the
article is marked with the estimated quantity of available water during 2017. The cross section of
quarry number 8 is indicated in the figure 2 and 3. Based on the hydrographic study estimations
and due to the proximity of the location (Chikarayapuram) is close to the largest water supplying
reservoir (Chemparambakkam), during rainy season the excess water (Flood water) can be
collected in Chikarayapuram Quarries which can hold maximum of 0.55 TMC of water for water
starving Chennai City with diversion of overflowing water channels to the abandoned quarries
with minimal measures. The quarry water is pumped at few locations for agriculture and a few
locations by private lorry tankers. So, this may be checked by fencing the area with appropriate
measures. The people living around the region may be permitted to use the water resources
without restrictions for bathing and fishing with full freedom since they are safeguarding the
resources as of now.

Table 2: Estimated Volume of Fresh water available in and around
Chikarayapuram Quarries
| Quarry No | Area in Ha | Estimated Volume in m³ |
|-----------|------------|------------------------|
| 1         | 6.05       | 588736.73              |
| 10        | 4.14       | 282186.94              |
| 23        | 0.52       | 36933.27               |
| 8         | 5.55       | 1094603.38             |
| Expected min volume in m³ with output from Hydrographic survey | | 20,02,460.32 |

**Table 3 : Approximated Volume of Fresh water available in and around Chikarayapuram Quarries**

| Quarry No | Area in Ha | Approximate estimated Volume in m³ | Approximation Factor Used in meters |
|-----------|------------|-----------------------------------|-----------------------------------|
| 2         | 0.28       | 11081.20                          | 4                                 |
| 3         | 0.93       | 55794.59                          | 6                                 |
| 4         | 1.89       | 113327.91                         | 6                                 |
| 5         | 0.41       | 24702.68                          | 6                                 |
| 6         | 0.04       | 1682.14                           | 4                                 |
| 7         | 1.57       | 62999.80                          | 4                                 |
| 9         | 2.23       | 133873.44                         | 6                                 |
| 11        | 0.29       | 11408.63                          | 4                                 |
| 12        | 0.34       | 13673.47                          | 4                                 |
| 13        | 0.15       | 6142.43                           | 4                                 |
| 14        | 0.58       | 23267.25                          | 4                                 |
| 15        | 0.53       | 31530.83                          | 6                                 |
| 16        | 0.11       | 4386.08                           | 4                                 |
| 17        | 0.36       | 14254.19                          | 4                                 |
| 18        | 0.48       | 19288.10                          | 4                                 |
| 19        | 2.39       | 95403.14                          | 4                                 |
Expected min volume in m³ with single representative hydrographic observation and based on field conditions.

| Quarry No | Area in Ha | Estimated Volume in m³ |
|------------|------------|------------------------|
| 20         | 0.08       | 3210.76                |
| 21         | 0.17       | 10088.11               |
| 22         | 0.04       | 1619.36                |
| 24         | 0.09       | 3776.59                |
| 25         | 2.69       | 161400.18              |

Table 4: Estimated volume of Fresh water available in and around Pammal quarries

| Quarry No | Area in Ha | Estimated Volume in m³ |
|------------|------------|------------------------|
| 1          | 2.2141     | 2,11,127.35            |
| 3          | 1.868659   | 2,01,271.68            |
| 4          | 2.529219   | 2,18,107.74            |

Expected min volume in m³ with output from Hydrographic survey: 6,30,506.77
Table 5: Values of various parameters on the sampling points along the lake

| Sampling Locations | pH  | TDS | Salinity | Dissolved oxygen, mg/l | Chlorophyll a, mg/m³ |
|--------------------|-----|-----|----------|------------------------|----------------------|
| 1                  | 8.25| 130 | 0.2      | 7.68                   | 3.25455              |
| 2                  | 8.41| 140 | 0.2      | 5.12                   | 1.96422              |
| 3                  | 8.48| 150 | 0.2      | 7.52                   | 2.42544              |
| 4                  | 9.22| 160 | 0.2      | 7.52                   | 3.214545             |
| 5                  | 9.11| 150 | 0.2      | 9.76                   | 3.820245             |
| 6                  | 9.51| 140 | 0.2      | 7.84                   | 3.2739               |
| 7                  | 9.47| 130 | 0.2      | 8.16                   | 4.163925             |

Fig 2. 3D Views of the Chikarayapuram Quarries along section A-B

Fig 3. Cross section of the Chikarayapuram Quarries along section A-B
Fig. 4. Map showing water depth for all quarry around Chikarayapuram region.
Fig 5. Map showing water depth for quarry no 4. around Pammal region.
If the water level is maintained / stored up to 0 meter MSL the estimated volume of storage upon all the combined quarries is 32,11,971.62 m$^3$ (Currently available water based on Hydrographic Surveys and single point diver assumptions).

- Upto 5 m of MSL – 50,59,130.64 m$^3$
- Upto 10m of MSL – 71,0,3941.70 m$^3$
- Upto 20m of MSL – 1,56,54,703.79 m$^3$

Since the ground level elevation is close to 23 m from the MSL it is possible to store at least 0.55 TMC of water for water starving Chennai City.

The greatest estimation of chlorophyll a, acquired at the examination zone is 4.163925 mg/m$^3$. Since the chlorophyll values ranges beneath 20mg/m$^3$, the investigation region goes under the classification of Mesotrophic[10] Lake, which is portrayed as away from with medium degree of nutrients and lowered aquatic plants. As the assessed pH values at some testing locations surpass 8.5, hydrochloric acid ought to be added to eliminate chlorine.

6. **Conclusion** The study concluded with the conclusion of collecting the excess water (Floodwater) in Chikarayapuram Quarries, which can hold maximum of 0.55 TMC of
water for water starving Chennai City with diversion of overflowing water channels to the abandoned quarries with minimal measures. The water in Quarry No.4 in Pammalvillage should be treated with hydrochloric acid and other water treatment techniques since a few places the pH values are basic as indicated in the resultant table. The water can be utilized for drinking purposes. Based on our scientific study and recommendations the government has promulgated an ordinance to convert the existing abandoned quarries as reservoirs and have directly implemented the measures to tap the available water and has utilized 30 Mld of water per day for 100 days during the year 2017 from this study and has supplied drinking water for Chennai city.

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