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An Observation on the Interrelationship Between the Gravitational Weight and the Area of a Flat Sheet: A New Concept of Rapid Measurement of Areas Bended by Irregular Outlines

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Abstract: An accurate measurement of a bended flat area with many bends and deflections is practically impossible to perform using any of the existing methods of mensuration. Therefore, an alternative method has been investigated which insists on the measurement of gravitational weight of the portion of paper occupied by the area of a map. However, the map should be drawn on a thin flat sheet having the quality of uniform gravitational weight. A simple method for the selection of an uniform thin sheet has also been discussed. A theorem, $I = W10^2$ has been proposed for the rapid determination of index of any flat surface irrespective of sizes and geometric forms.

Keywords: Uniform gravitational weight, Transparency, Index, Spot-Photograph, Asteroids.

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1. Introduction

The measurement of a flat surface (FS) having a simple form of map can be performed by any of the existing methods of mensuration. But it is difficult to do this measurement when the FS is surrounded by a curved line with numerous deflections and bends (Figures 1 and 2). If a FS is surrounded by a simple bended line, however, one can calculate by plotting the line on a graph paper. In this case of course, visual countings are done of the total graphical squares (small units) surrounded by a boundary line. But this procedure takes longtime to complete a measurement and has possibilities of errors since some presumptions are involved when countings are done at the sites of deflections and bends in the marginal line. Generally simple bounded areas are measured by applying Simpson's formula (1):

$$area = \frac{\text{Common distance}}{3}\{\text{first ordinate}+\text{last ordinate}+2\times(\text{Sum of remaining odd ordinates})+4\times(\text{Sum of even ordinates})\}$$

But it has been noticed, there are some limitations in the use of this formula.In fact, application of this formula in measuring simple bended areas yields approximately correct results. But it is difficult to measure small FS bended by a line of numerous deflections. In certain experiments, measurements of small FS often become an important issue. In the past, I (first author)

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made several attempts to measure small FS. (2), but failed to obtained accurate results. In these experiments however, I used initially the graphical method and subsequently Simpson's formula. As a matter of fact, I noticed that any existing method of measurement of an irregular area requires complicated graphical drawings, land measuring equipments as well as long calculations.

Therefore, I decided to develop a better method of measurement which would be more convenient, prompt and accurate. In order to fulfil my purpose, I attempted an alternative procedure based on the measurements of gravitational weights (GW) of some cut-pieces of a polyethylene sheet (PES) considering these cut-pieces were the representatives of known and unknown areas (Figures 1 and 2). This study reports the details of this method and also focuses it's possible applications in the measurements of FS on the Earth, Planets or Asteroids; In fact, wherever complicated measurements of FS are much in demand.

2. Materials and Methods

In the begining of this study it had been speculated that the measurement of an unknown area bended by many bends and deflections can be done simply by the determination of mass of the F-sheet occupied by the area of the map. Before the use of this alternative method, it was required to choose an F-sheet having the quality of uniform G.W. Therefore ten varieties of F-sheets were examined to select a suitable one which would be used for correct measurements. These were: aluminium foil, polyethylene sheet, brown paper, plastic coated paper, cotton paper, polyvinyl film, art paper, food wrapping paper, copy and print paper, and demy paper.

3. Selection of the F-sheet of Uniform Gravitational Weight (GW)

Twelve different spots were randomly selected from each variety of F-sheet. The size of each spot was $10cm \times 10cm$. These spots were cut off by a sharp paper cutting tool. These cut pieces were individually weighed in a micro electric balance. The average weight of each variety of F-sheet was separately determined and the data were tabulated in ten different groups (Table 1). The data are presented in grams in table i. No significant difference of GW is found in all the individual groups. However an absolute uniform GW is recorded only in polyethylene sheet. Here the uniform GW is meant by the mass per $10cm^2$ of area.

AF	**PES**	**BP**	**PCP**	**CP**	**C & P**	**AP**	**FWP**	**PVF**	**DP**
0.470 $\pm$0.004	0.324 $\pm$0.000	1.240 $\pm$0.008	0.852 $\pm$0.003	0.830 $\pm$0.007	0.873 $\pm$0.009	1.315 $\pm$0.012	0.621 $\pm$0.006	1.045 $\pm$0.005	0.982 $\pm$0.006

Table 1.

AF : Aluminium foil
PES : Polyethylene sheet
B.P. : Brown paper
PCP : Plastic coated paper
CP : Cotton paper
C & P : Copy & print paper
AP : Art paper
FWP : Food wrapping paper

PVF : Polyvinyl film

DP : Demy paper

4. The Statistical Procedure

The standard deviations of the means, and the t-tests for the significance at the level of $P < 0.5$ were determined adopting the procedure described in **SPSS** Computer program (3). Each figure is the mean value of twelve cut pieces taken randomly from different locations of the same type of F-sheet. ± SD of the mean. Since the GW of the PES was found to be uniform, therefore this F-sheet was selected for the measurement of areas. A reduced size map of a natural water-land surrounded by a border line with numerous bends and deflections was marked for the determination of it's area (Figure 3). Four straight lines were drawn on the four sides of this map to form a rectangle. The lenghths of these lines were measured and written in centimeters. The scale of this map shows the exact ratio between the size of the map and that of the original water-land.

A photographic transparency of this map was made which was vertically projected on to a large piece of PES ($90cm \times 60cm$) affixed flat on a wooden board. The projected light was focused on the board until the map was clearly seen. The enlarged outline of the rectangular area as well as the map of the unknown area of the water-land were carefully traced on the PES with a fine black marker pen. The rectangular area and the unknown bended area-both the pieces of PES were cut smoothly by the light touch of an electrically heated needle tip (custom made simulated planimeter). These two pieces of PES were weighed together in a micro electric balance. The unknown bended area also was weighed. All these weights were recorded.The above procedure was repeated five times and the average numbers were used for the calculation of areas.

5. Results

The length of the rectangle in the projected photograph was $52cm$ and the breadth was $44cm$. The area of the rectangle was 2288^2cm. The weight of this portion of **PES** was $7.413gm$. The weight of the unknown bended portion of the **PES** was $3.602gm$. If $7.413gm$ of **PES** was represented by 2288^2cm of area, then $3.602gm$ of **PES** would be equivalent to 1111.742^2cm of area. So the unknown area of the **PES** was 1111.742^2cm. It appeared from the results, that any mass of the **PES** could be converted to an equivalent size of an area and vice versa.

6. Proportional Weight of the Unknown Area of the PES

The weight of the unknown area of **PES** is $3.602gm$. which is marked as W_1, and the weight of known area of the **PES** i.e., the rectangular area is $7.413gm$, which is marked as w_2. The ratio of the weights of unknown and known areas will be $\frac{W_1}{W_2}$, this is marked as W. So, $W = \frac{W_1}{W_2} = \frac{3.602}{7.413} = 0.4859$.

The Index of the unknown bended area is briefly written as "I", which is expressed as the percentage of the total known area, that is the area of the rectangle. So, $I = \frac{W_1}{W_2} \times 100$, or briefly $W10^2$. Since, $W = 0.4859$, so, $I = W10^2 = 0.4859 \times 10^2 = 48.59\%$. The above calculation for the determination of index can be written precisely in the form of a theorem: $I = W10^2$, when the GW of the **F**-sheet is uniformly constant.

7. The Relation Between the Gravitational Weight and the Area of a F-Sheet

After computing the data of GW of unit area of different kinds of **F**-sheets (Table 1) it has always been noticed, that an **F**-sheet of uniform GW only maintains the same comparative relation between the GW (or G) and the area (A) of any portion of the **F**-sheet. So, this conclusive observation is written in the form of a principle (Bhattacharya and Ghosh's Principle):

GW or $G \propto$ A when the **F**-sheet is constant.

8. Discussion

The measurements of an irregularly bended FS with many deflections can easily be done now using the proposed method described in this paper. In practice, this procedure appears to be simple, short and closely accurate. Furthermore, unlike the regular method it never needs any complicated calculations and presumptions as required in graphical countings. Another advantage of this new method is that it can be used to measure any kind of FS irrespective of sizes and geometric forms. It has been noticed that the projected image which is formed through transparency is exactly similar figure of the actual FS, part by part although on a reduction scale. Therefore a projected photographic transparency of any map shows the exact ratio between the size of the projected map and that of the original size of the FS.

For instance, if a map is drawn on a graph paper to scale of 20 meters to a 1 centimeter; it means that $20m$ in length on the original FS is reduced to $1cm$ in length in the map (Figure 3). It emerges from this study that proper selection of a **F**-sheet bearing the property of uniform GW is actually required for accurate measurements. As a matter of fact, the availability of such product is uncommon at present. However in the future it is expected to find more through research. At present **PES** of thin quality is considered as the right product which is practically useful for the said procedure. As soon as we realized the utility of this **PES**, we became interested to see the possibility of quick measurements of various bended lands; such as, damaged lands due to earthquakes and some flood affected areas caused by heavy rainfalls, oil spilled areas in the river water, etc.

9. Conclusions

So it is suggested that the theorem (Bhattacharya's Theorem) $I = W10^2$ may be used for the determination of any types of areas not only on earth surfaces but also on the planets or the asteroids during the voyage of the astronauts. The possibilities of land measurements on the earth from the spot photographs of various FS which have been taken vertically from the high altitude have also been included in our recent investigations. We hope to report the results soon in the form of part two as the continuation of this paper.

Acknowledgements

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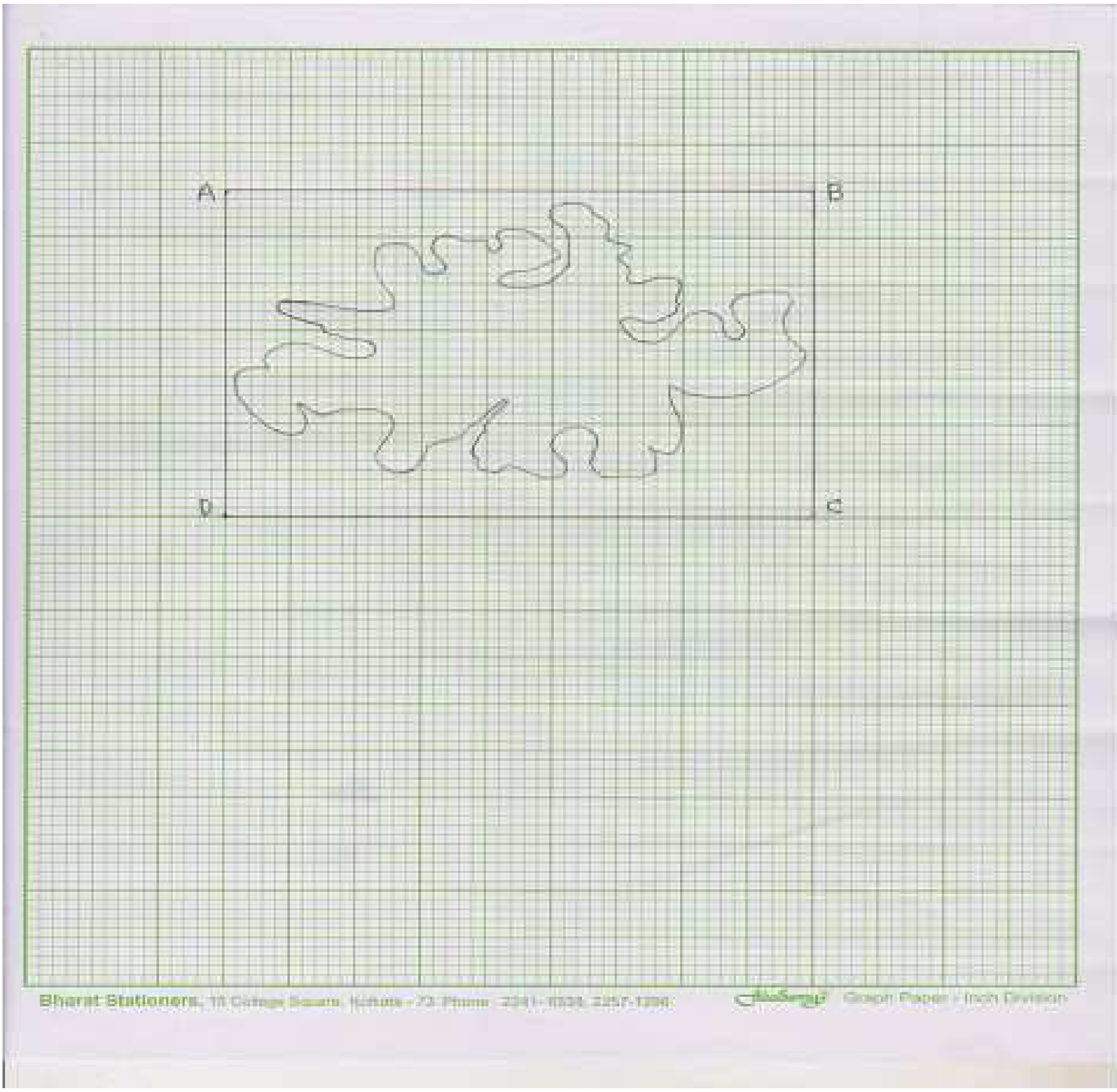

Figure 1. Diagram of a rectangular piece of Polyethylene sheet which includes an unknown area bended by an irregular outline

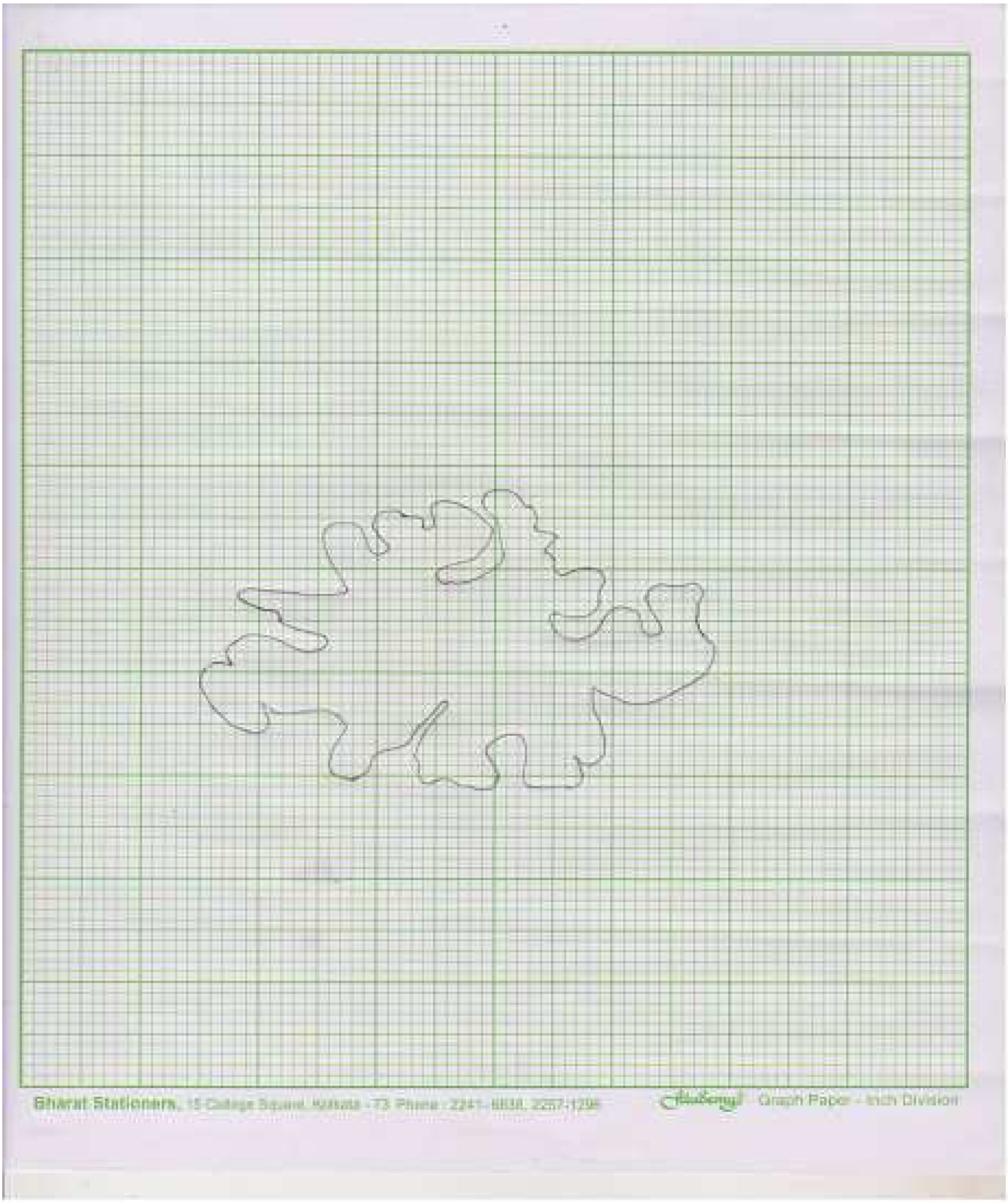

Figure 2. **The unknown area is separated from the rectangle for the determination of gravitational weight**

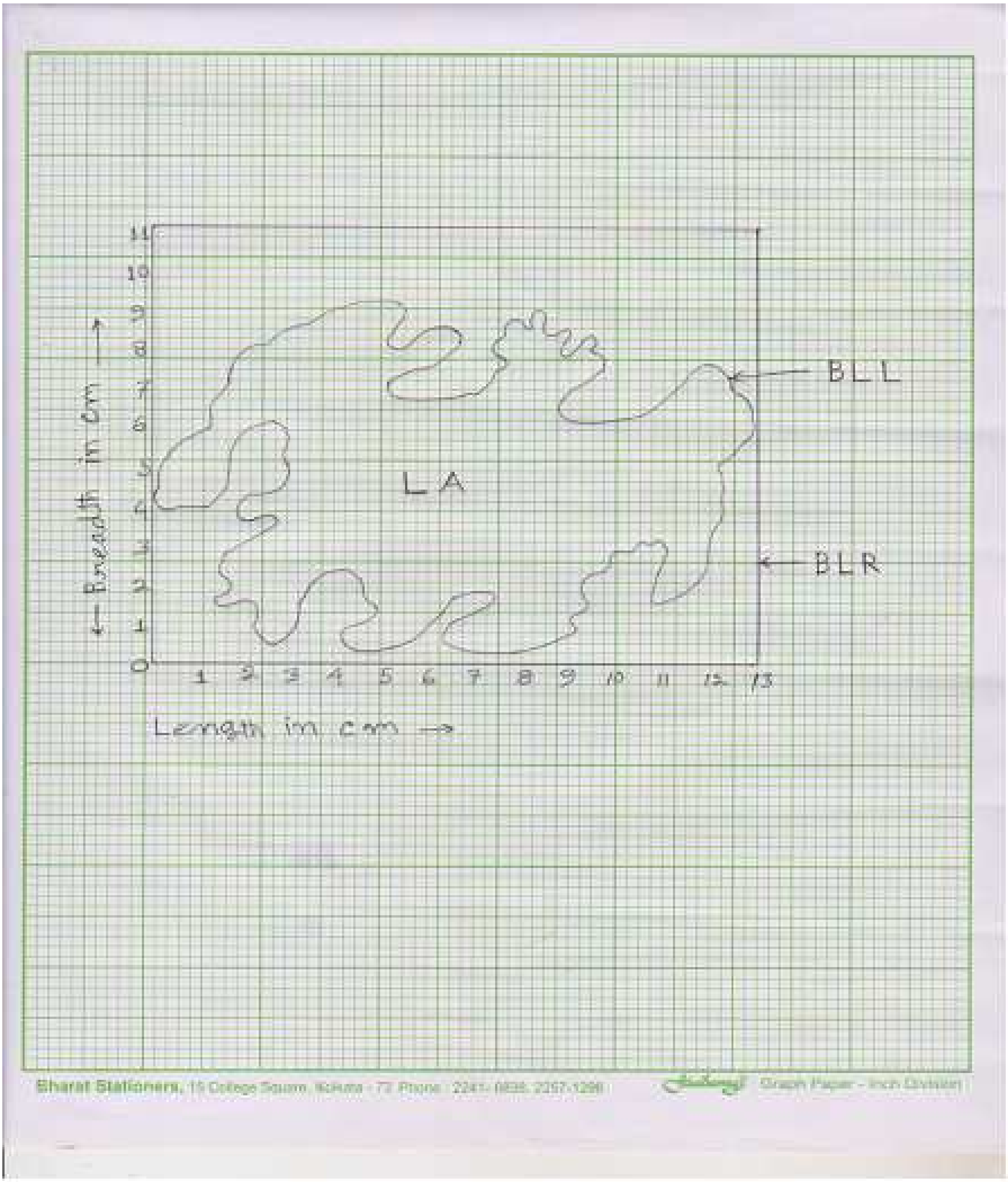

Figure 3. A reduced size map of a natural water-land. A transparency of this map was made and then projected on a PES($90cm \times 60cm$). $1cm = 20m$ (measurement of the original land). BLL : Boundary line of the lake. BLR : Boundary line of the rectangle. LA : Lake area.

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