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Ministry of Energy, Water Resources and Irrigation
Department of Hydrology and Meteorology
Babarmahal, Kathmandu, Nepal

FINAL REPORT

Main Report-Volume I

Preparation of Bathymetric Map of Phoksundo Lake of Dolpa to Update its Inventory

July, 2019

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Acronyms:

BCM : Billions Cubic Meter
CBS : Central Bureau of Statistics
TU : Tribhuvan University
BOD : Biological Oxygen Demand
CDES : Central Department of Environmental Science
COD : Chemical Oxygen Demand
DGPS : Differential Global Positioning System
DHM : Department of Hydrology and Meteorology
DOAD : Department of Agriculture Development
GLOF : Glacial Lakes Outburst Floods
GoN : Government of Nepal
GPS : Global Positioning System
IUCN : International Union for Conservation of Nature
MoFALD : Ministry of Federal Affairs and General Administration
MCM : Million Cubic Meter
NCVST : Nepal Climate Vulnerability Study Team
NHMRCC : Nepal Hydrological and Meteorological Research Center and Consultancy
NLCDC : National Lake Conservation Development Committee
NTNC : National Trust for Nature Conservation
ToR : Term of Reference

Report Preparation, Quality Checkup and Declaration

Project Name: Preparation of Bathymetric Map of Phoksundo Lake of Dolpa to Update its Inventory			
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Consultant: Nepal Hydrological and Meteorological Research Center and Consultancy P. Ltd.			
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I declare the following:

i. I have conducted the study professionally using standard and acceptable methodologies.
ii. The study findings are correct to the best of my knowledge; and have not been altered in any manner.
iii. I myself with the team will be liable for any misunderstanding and errors in the report.

Acknowledgement

On behalf of Nepal Hydrological and Meteorological Research Centre and Consultancy Pvt. Ltd. (NHMRCC), we would like to graciously thank the Department of Hydrology and Meteorology (DHM), Nepal for awarding this contract and providing the opportunity to carry out the work on '***To Prepare Bathymetric Map of Phoksundo Lake of Dolpa to update its Inventory'.*** We would also like to thank all the external expert from Tribhuvan University, Kathmandu University, Ministry of Energy, Water Resources and Irrigation and Water and Energy Commission Secretariat for their comments and inputs to make this report more advanced. We are very much grateful to team leader Mr. Om Ratna Bajracharya for his rigorous work and valuable contribution to carry out this study. Thanks to Mr. Dhruba Lochan Adhikari, for his untiring effort to complete this study. We would like to thank Mr. Ishwor Sharma, Mr. Roshan Bhandari, surveyors; and Mr. Pujan Gurung, boat guide for their work. Special thanks go to Chairman Mr. Tashi Tundup Gurung and Vice Chairman Mr Dhawa Sumduk Gurung of Shey Phoksundo Rural Municipality; Ward Chairman of ward no. 8, Mr. Nima Lama; Chairman Mr. Ringzin Wangyal Budha of Phoksundo Lake Conservation Committee and Mr. Phurba Tenzing Budha, Chairman of Phoksundo Buffer Zone User Group for their valuable support in field work and other aspects. Thanks to Mr. Pramod Kumar Yadav, Warden of Shey Phoksundo National Park. We are equally thankful to Lama Guru and local people who contributed to us by providing local beliefs and cultural background associated with the lake. Finally, special thanks to Mr. Sabin Dangol, Engineer (SEC P. Ltd. team) for his continuous support in data management and map preparation. NHMRCC would also like to thank all the researchers and associates involved.

Nepal Hydrological and Meteorological Research Center and Consultancy P. Ltd
Kathmandu, Nepal
July, 2019

1. Award of Job

As per the agreement signed between the ***Department of Hydrology and Meteorology*** and ***Nepal Hydrological and Meteorological Research Center & Consultancy P. Ltd.*** for consulting services on ***'Preparation of Bathymetric Map of Phoksundo Lake of Dolpa to Update its Inventory'***, the consultant is pleased to submit this Final Report. This report includes introduction, study area, objective and scope of work, literature review, methodology, field work, result and discussion and conclusion.

2. Introduction

2.1 General

Nepal is a small landlocked country that covers an area of 147,181 km^2 located in the centre of Hindu Kush Himalayas between India and china (Figure-1). Nepal stretches from 26º 22' to 30º 27' North latitude and from 80º 04' to 88 º 12' East longitudes. The country looks roughly rectangular in shape with the length from east to west of about 885 km and width ranging from 130 to 260 km from south to north. It contains 8 of the 10 highest mountain peaks in the world, including Mount Everest (8848 m), although some of its low lying areas are only about 80 meters above sea level.

The country is divided into three broad ecological regions, i) The higher Himalayas in the north, ii) Hills and Valleys in the middle, and iii) Terai, an extension of Indo-Gangetic plain, in the south. Nepal is one of the most water-abundant countries in the world with its 6,000 rivers and rivulets, with total mean annual runoff of 224 billion cubic meters (BCM) and per capita water availability of 9,000 cubic meters (Nepal Climate Vulnerability Study Team, 2009) .

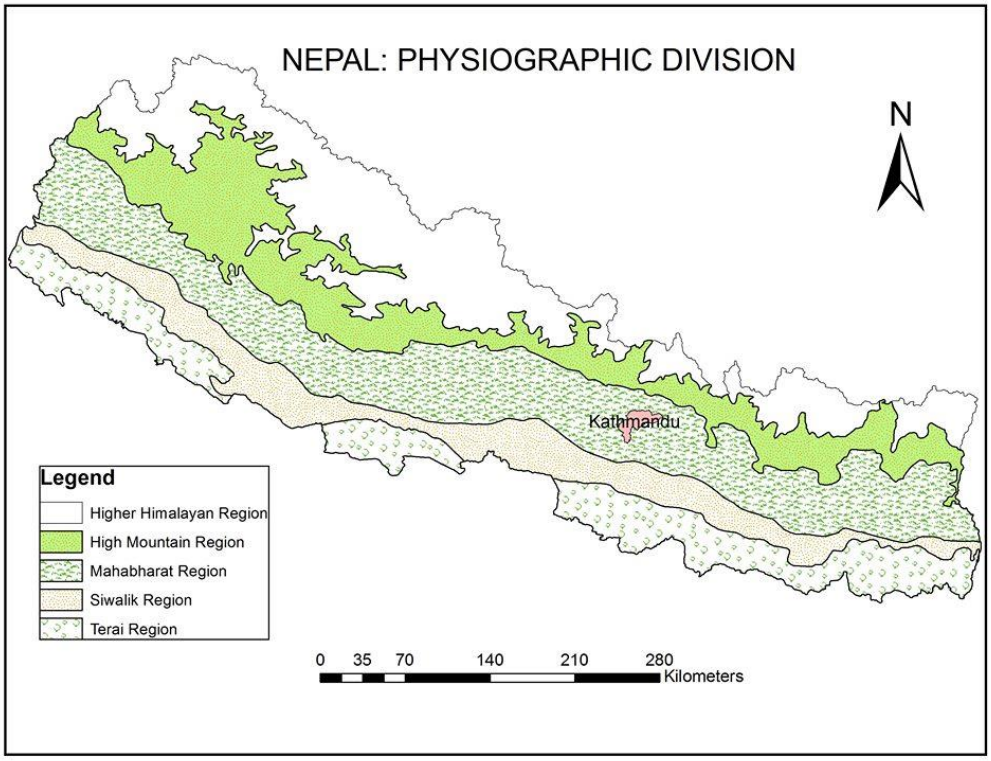


Figure 1: Map of Nepal showing the physiographic region

2.2 Lakes of Nepal

There are many lakes within the country located in low altitudes to the high Himalayas stretching from the east to the west. Lakes are basically natural resources available for multiple uses. A lake consists of two distinct parts, the basin and the water body. A lake, in other words may be defined as an inland basin filled with water. One definition of "lake" is a body of water of 2 hectares (5 acres) or more in area (Source), however others have defined lakes as water bodies of 5 hectares (12 acres) and above, or 8 hectares (20 acres) and above. Charles Elton, one of the founders of ecology, defines lakes as water bodies of 40 hectares (99 acres) or more.

There are different studies and reports that Nepal has more than 6000 rivers, 3,252 glaciers, 2,323 glacial lakes and several tectonic and ox-bow-lakes. Among them, National Lake Conservation Development Committee (NLCDC) has enlisted 5,358 lakes in Nepal in its map based inventory released/prepared conducted program in 2009 (Ministry of Tourism and Civil Aviation, GoN, 2009). Among these lakes, altitude wise over 2,700 lakes (51%) are distributed below 500m, and 2,227 (42%) above 3,000m. Only 419 lakes (<8%) are in the mid hills of altitudinal range between 500m and 2,999m.

The following table shows the altitude-wise distribution of lakes.

Table 1: Altitudinal Distribution of Lakes in Nepal

Altitude (m)	Number of lakes		%
Below 100	1270	2712	50.62
100-499	1442		
500-999	77	419	7.82
1000-1499	69		
1500-1999	125		
2000-2499	114		
2500-2999	34		
3000-3499	56	2227	41.56
3500-3999	60		
4000-4499	418		
4500-4999	762		
5000-5499	764		
above 5500	167		
Total	5358	5358	

Source: NLCDC, 2009

2.3 Objectives and Scopes of the work

The main objective of this study is to prepare scientific report of Phoksundo Lake of Dolpa through detail Bathymetric Survey and Topographic Survey of the lake using standard echo-sounder and total station or theodolites and other hydro-meteorological investigations and available related information. In particular, the study aims to:

- Carry out Bathymetric Survey of the lake to measure depth of the lake using echo-sounder.
- Carry out Topographic Survey around the lake to prepare topographic maps with contour lines with interval of 5m cover at least up to 25 m strip above the lake's water level and up to 10 m strip along the river channel in both banks for up to 500 m downstream from the lake outlet.
- To establish temporary bench marks at the proper site of the lake for reference.
- To carry out Hydrological investigations of the lake including discharge measurements (at least 2 with possible different gauge heights during the stay at the site) and collect water samples for the study of physical parameters including sediment and water quality of the lake.

The scope of the works are as following:

- Carry out water depth survey of the lake and calculated area, volume and other geometrical parameters
- Conduct topographical survey of the lake, cross section survey at Lake outlet and Lake inlet.
- Construct and fix 4 concrete pillar for bench marks at proper site of the lake for reference using DGPS.
- Collect water samples of different time for the study of physical and chemical properties of the water including pH, air temperature, water temperature, dissolved oxygen, turbidity, conductivity, BOD, COD, nitrate, iron sulphate and total hardness.
- Conduct discharge measurement at 2 possible different gauge heights at the outlet of the lake.
- Literature review and compilation of climatic data of the region to summarize the climatic condition of the lake and compilation of different studies
- Involvement of the local government authorities during the study period in coordination with "Shey Phoksundo National Park" office.
- Organize a workshop at MEWRI/DHM for the dissemination of the works done and to receive feedback and suggestion before the draft final report with concerned and related stakeholders.
- Prepare digital GIS map of the lake, preparation of different reports and posters for information dissemination about the findings of the study (including map and other important features of the lake)

3. Study Area

3.1 Phoksundo Lake: Dolpa

Lakes of Nepal are culturally important elements in the higher altitude areas and Phoksundo Lake of Dolpa district is one of them. Lakes/wetlands provide water for irrigation, maintains biodiversity, enhancing livelihoods of people through eco-tourism as the basis for cultural and spiritual development and so on.

Phoksundo Lake lies in Shey Phoksundo Rural Municipality of Dolpa District. The area of this rural municipality is 123.07 km^2 and total population is 3099. This municipality consist of 9 wards. Major part of this municipality belongs to Shey Phoksundo National Park, which is the largest national park of Nepal covering an area of 3,555 km^2. (Figure-2 & 3) (Population Census, 2011)

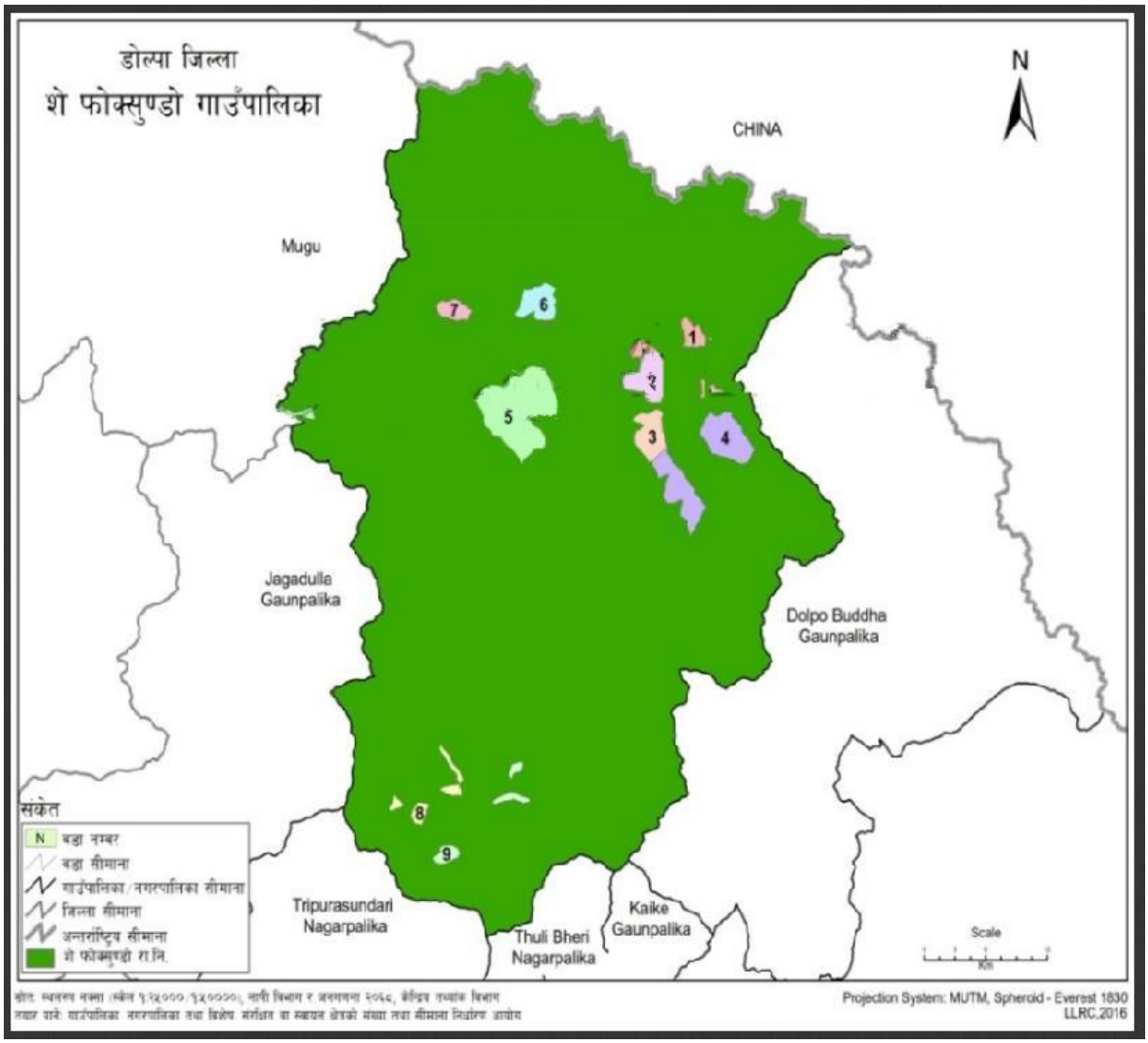


Figure 2: Location of Phoksundo Rural municipality

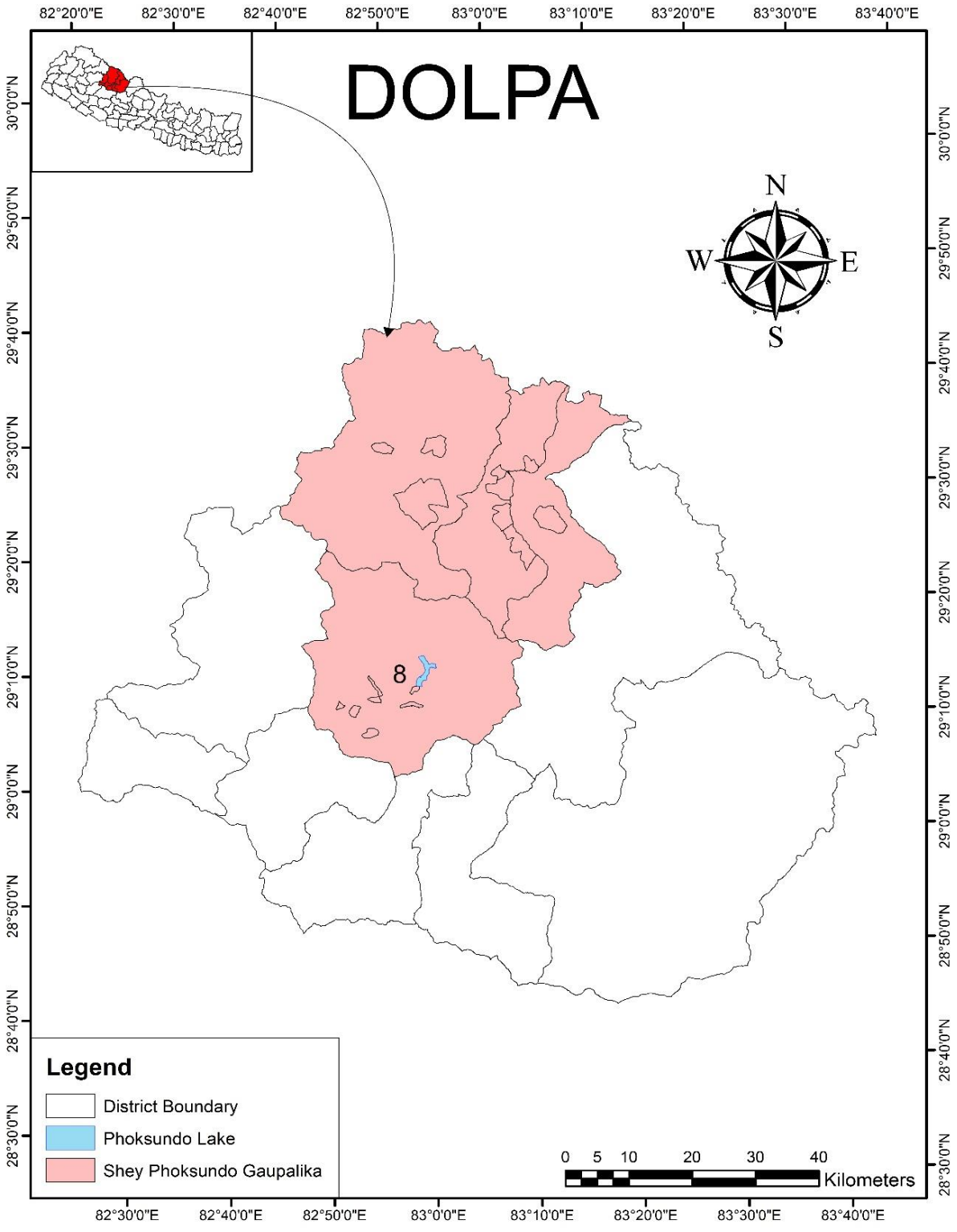


Figure 3: Location map of Phoksundo Lake, Dolpa

Figure 4: Phoksundo Lake (Looking towards Inlet from Outlet, Date: 27 May 2019)

It is remote yet accessible and is one of the most beautiful lakes in Nepal, situated at an altitude of 3588 meters above the mean sea level.

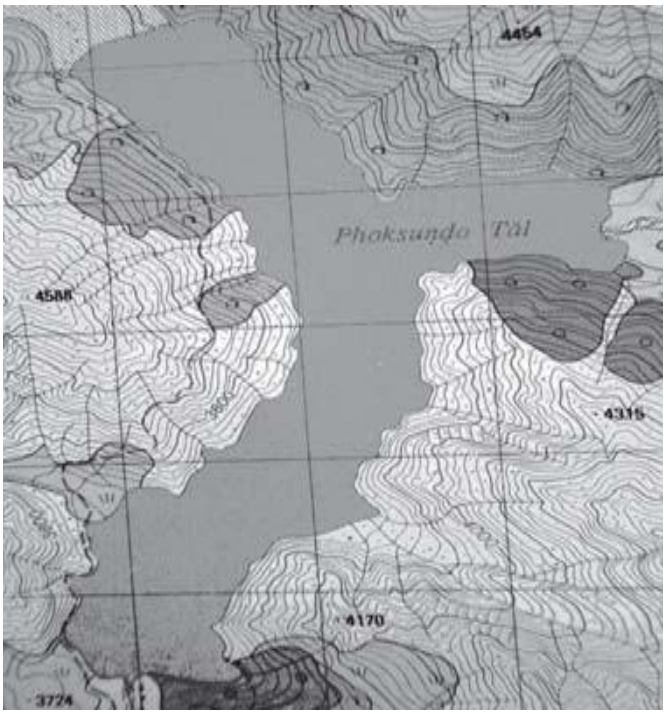


Figure 5: Topographical Map of Phoksundo Lake

3.2 Climate and Geography

Dolpa is the largest district of Nepal covering 5.36% of the total landmass of the country. Its elevation ranges from 1,525 to 7,625 m (5,003 to 25,016 ft). The district borders Tibet (China) on the north and

northeast, Jumla and Mugu districts of Karnali on the west, Myagdi, Jajarkot and Rukum on the south, and Mustang on the east. A large portion of the district is protected by Shey Phoksundo National Park. The name is derived from the 12th century *Shey Monastery* and the *Phoksundo Lake*, both of which are located in the district. The park protects endangered animals like the snow leopard, musk deer and the Tibetan wolf (Wa). *Shey Phoksundo* is the largest and the only trans-Himalayan National Park in Nepal. Dolpa district is one of the driest districts of Nepal. According to the climate station located at Dunai, the annual rainfall has recorded around 500mm. Similarly, the maximum temperature the district has observed is around 29ºC in July and minimum temperature observed is below 0ºC in January. The summary of the climate data is presented in below table.

Table 2: Rainfall and temperature, Station no. 312 (DHM)

Station No.	312	Latitude	28.93333333 (Degrees)
Location	Dunai	Longitude	82.91666667 (Degrees)
Elevation	2058 m		
Month	**Normal Rainfall (mm) (1993-2017)**	**Max Temperature (^{0}C) (1993-2017)**	**Minimum Temperature (^{0}C) (1993-2017)**
January	13.2	10.6	-1.6
February	13.8	13.0	0.7
March	6.9	15.9	6.0
April	8.3	21.3	9.4
May	14.6	25.7	15.5
June	43.1	28.0	20.1
July	79.9	29.2	22.5
August	87.7	27.9	21.3
September	42.3	26.1	19.3
October	11.0	22.5	13.3
November	2.1	17.7	6.8
December	3.7	13.1	1.6

Though the study area (Phoksundo Lake) is located at an elevation of 3588m above mean sea level, the Himalayan ranges, climate of that region is obviously different than the above-presented data. Past study and literature show that this region is highly vulnerable to climate change impact, as warming trends have been observed in most of the Himalayan region and the Middle Mountains (Shrestha, Wake, Mayewski, & Dibb, 1999). Similarly, the mean annual minimum temperature trend is higher in low altitude Terai and Siwalik range and lower in High altitude region while the trend pattern is reverse in mean annual maximum temperature with higher in high altitude region and lower in low lying Terai

plains. Also, most of the mid-western development region showed decreasing annual precipitation trend (Study of Climate and Climatic Variation over Nepal, 2015).

3.3 Hydrology and Drainage Pattern

Phoksundo Lake, an alpine fresh water oligotrophic lake (having poor nutrient supply), situated in Shey Phoksundo National Park, located at an elevation of 3,588 m above mean sea level at Dolpa District. According to the previous study, this lake has an area of 494 ha (1.91 sq mi) in size with water volume of 409,000,000 m^3 (1.44×1010 cu ft) and discharge of 3.715 m^3/s (131.2 cu ft/s). (Nepal Biodiversity Resource Book: Protected Areas, Ramsar Sites, and World Heritage Sites, 2007)

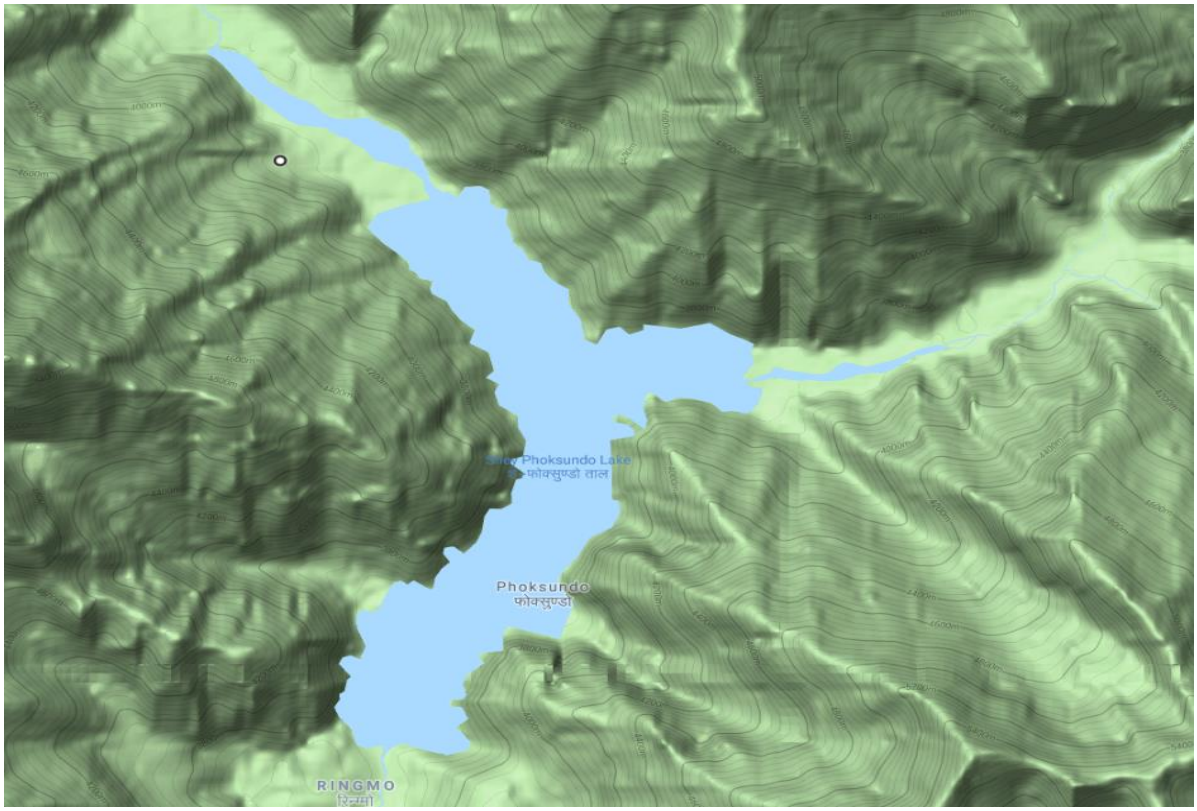


Figure 6: Map of topography and elevation of basin of Phoksundo (thick line 100m interval)

(Source: https://www.google.com/maps/place/Shey+Phoksundo+Lake/)

In September 2007, Phoksundo Lake has been designated a Ramsar site (Bhandari, 2009). On the lake' southern end, the village of *Ringmo* sits on the 30,000- to 40,000-year-old landslide dam that formed the lake. Past the dam, the waters of the lake plunge over a 167 m (548 ft) high waterfall (Weidinger, 2005).

3.4 Geology

The Phoksumdo lake (3600 m asl.; area of 4.5-to-5 km^2) is the second largest lake of Nepal; it owes its origin to the damming of the Suli Gad River by the large (4.5 km^3) collapse of a mountain wall

(Dhaulagiri limestone) culminating at 5148 m, SE of the lake (Fort, Braucher, Bourles, Guillou, & Rimal, 2014).

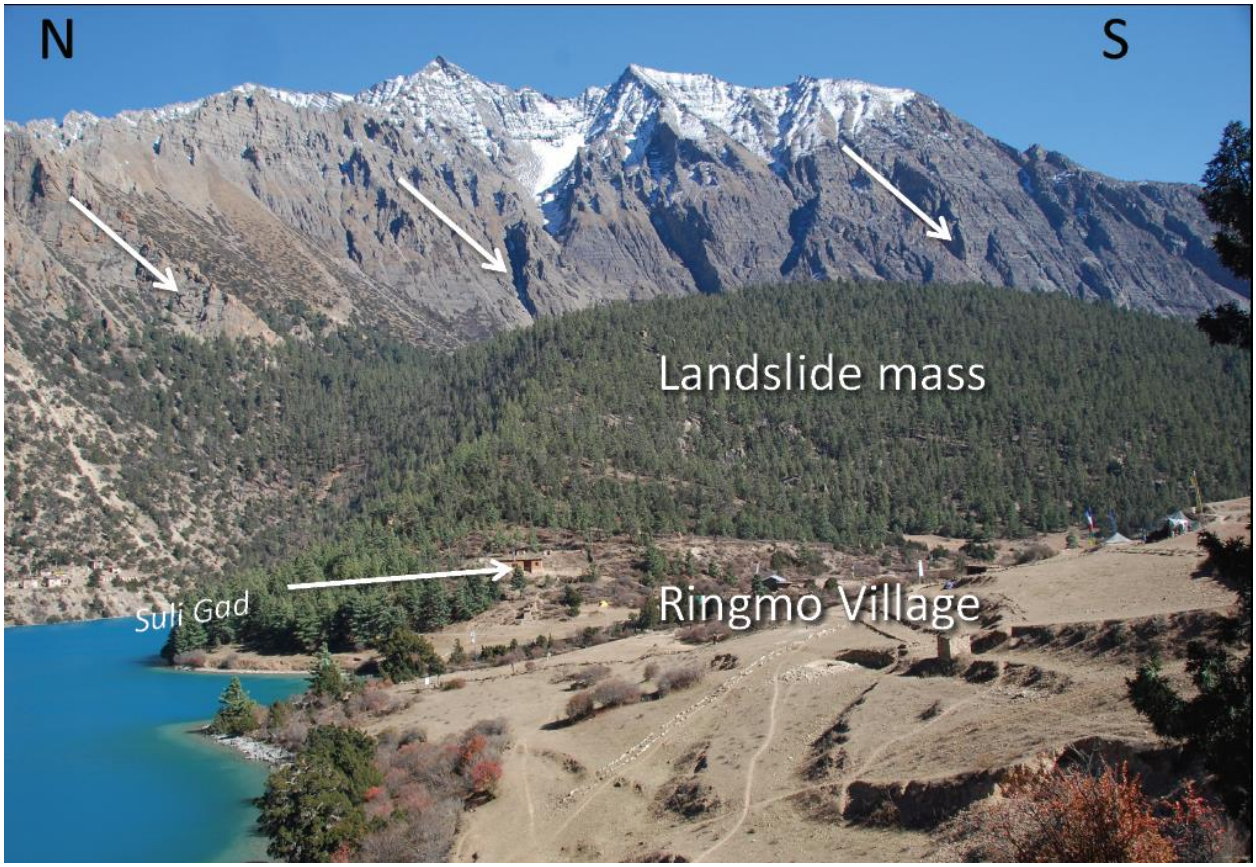


Figure 7: Ringmo-Phoksundo site

The damming of the lake was caused by rockslides bodies derived from different parts of the rocky face bounding the lake in its SE part.

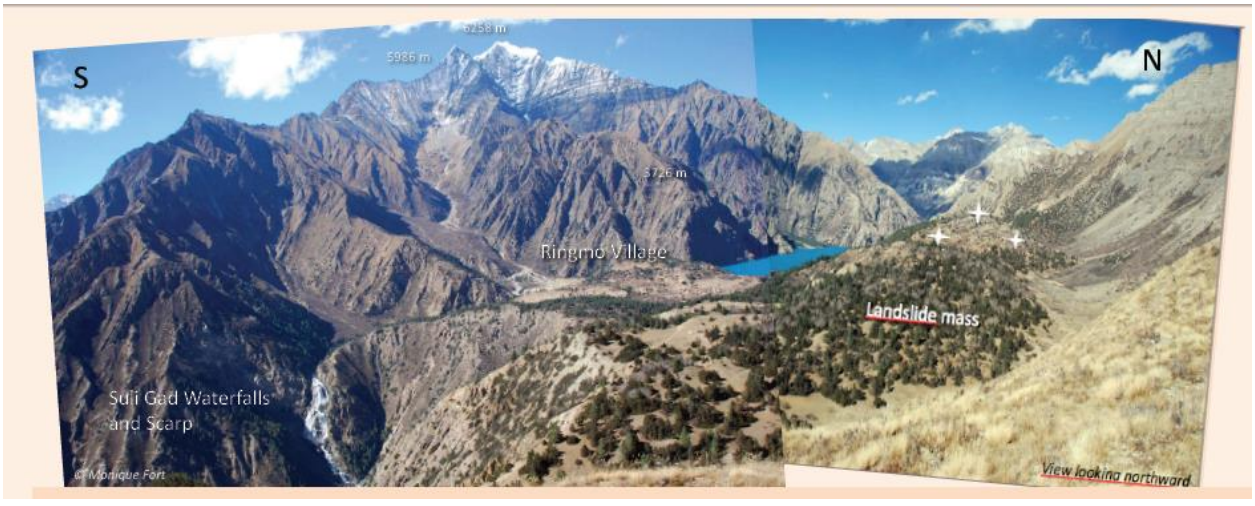


Figure 8: View looking Northwards

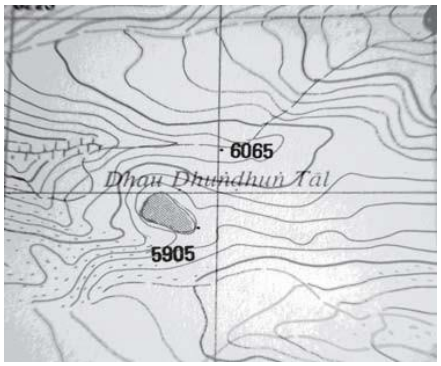
The survey team walked around the periphery of the lake to collect information about the soil type and other condition of the lake around the area. Around the outlet area the land is almost flat where *Rigmo* Village is located. The bank of the lake is formed by rocky area in many parts. There is gravel and boulder mixed soil at the upper part of the lake. The shape of the lake is observed to be north-south elongated with a slight bend at the central part. The lake is surrounded by steep mountain slope composed of bedrocks along its eastern, northern and western sides. There are few ragged mounds observed on the right bank of the river where *Gonpa* (colloquially Gumba) is situated. The water drains out of the lake from the southern end through a 167 m high waterfall which is considered as the highest waterfall in Nepal.

4. Literature Review

A lake is a large body of water that is surrounded by land. The lakes are considered as natural reservoirs and they are important from diverse perspectives like water cycle, biological diversity, economic and social fame, tourism and biogeochemical cycle. Lake history shows the close relation between development of human civilization and the Lake. In addition, they are the important habitat for amphibian as well as aquatic lives and also important for religious values, festivals, sports, recreational activities etc. In addition, Lakes/wetlands also harmonize temperature, precipitation and absorbing greenhouse gases to moderate the climate change, accumulate water, soil and nutrient for agriculture and manage flood, drought and landslide to control natural disaster. Therefore, lake plays an important role to maintain and balance the ecological system. Loss, degradation, change and fragmentation of lakes are caused by both natural and anthropogenic factors. Climate change, outbursts of lakes due to landslides and siltation, watershed dried out are some natural factors whereas encroachment and unplanned land use are anthropogenic causes for the degradation of the lakes which in turn disrupt the entire ecosystem.

In Nepal, the study of lake was conducted in 2009 by researchers of Nepal Lake Conservation Development Committee (NLCDC), which is a government body established under the Ministry of Tourism and Civil Aviation in 2007. Experts were involved from the International Union for Conservation of Nature (IUCN) Nepal office, Nepal Academy of Sciences and Technology (NAST), National Trust for Nature Conservation (NTNC), and the Tribhuvan University, Central Department of Environmental Studies (TU-CDES). The initial study using topographic map showed altogether 5358 lakes across the country. DOAD (1993) reported 5000 lakes, 1380 reservoirs and 5183 village pond (National fisheries development plan-1992/93, 1993) while IUCN (1996) reported 163 wetlands in Terai and 79 in the hills and mountains (An Inventory of Nepal's wetlands, 1996). Similarly 3,808 glaciers and 1,466 glacial lakes have been identified in the high mountain region (Mool, Bajracharya, & Joshi, 2001). The inventory of glacial lakes was conducted from the perspectives of the potential Glacial Lakes Outburst Floods (GLOF). ICIMOD (2009) updated glacial lakes and found significant different in number and area of lakes. The total number of glaciers are found to be 3808 whereas number of glacial lakes decreased from 2,323 to 1,466, a reduction of 37%; and area decreased to 14%, whereas the average lake area increased by 33%. Among the significant lakes, Rara is the largest one covering an area of 800 ha, and Phoksundo is the longest one with its length 5.15km. Similarly, *Dhau Dhundhun* Tal is the highest placed lake in Mustang at an altitude of 5905m, and an unnamed lake is at 59 m altitude in Dhanusha district. (Lakes of Nepal: 5358 - A Map Based Inventory, 2009). The following maps and table shows high altitude lake in Nepal.

Table 3: High altitude lakes in Nepal



Name of Lake:	Dhau Dhundhun Tal
Topo- Sheet no:	2983-16
Code:	MS52
District:	Mustang
VDC:	Charan
Nearby City/Village:	Saukre (20Km)
Area:	4.75ha
Length:	350m
Breadth:	150m
Perimeter:	900m
Altitude:	5905m

In Nepal, there are few studies carried out for the bathymetric survey of Lakes. Tsho Rolpa, Imja, Thulagi glacial lakes were studied as these lakes were identified as potentially dangerous. In the early 1990, bathymetric studies were carried out for Lower *Barun* glacier lake (Kadota and Mool, 1993), the Imja glacier lake (Yamada, 1998; Department of Hydrology and Meteorolgy, 2014; Topographic and Bathymetric Survey of Imja Glacier Lake, 2009), Tsho Rolpa Glacier Lake (Mool et al., 1993; Kadota. 1994) and Thulagi glacier lake (Mool et al., 1995). More detailed investigation were carried in Tsho Rolpa glacier lake (Yamada, 1996), Thulagi glacial Lake (DHM, 1997). A. B. Shrestha et al, 2004 studied bathymetric survey of Tsho Rolpa Glacier Lake carried out in 2002 shows that the maximum depth measured was 140 m and volume of lake was 97.7×10^6 m^3 before the lake lowering. Echo sounder was used for the first time in Tsho Rolpa Glacier Lake to determine the depth of the Lake. Similarly, the bathymetric survey of Imja Glacier Lake was carried with the help of inflatable boat with outboard motor and Echo sounder mounted on boat (Samos-Valenzuela et al., 2013).

DHM carried out "Bathymetric Survey of Phoksundo Lake in Dolpa District, Mid-Western Development Region of Nepal" in 2004 AD assuming the deepest lake, using echo-sounder instrument. Points were selected along lines of random positions to measure the depth of the lake. During this bathymetric survey, the maximum depth of the lake was found to be 145 m and the equipment used was Echo Sounder Bathy 500 (Analog). The frequency used for that echo-sounder Bathy 500 was 200 kHz transducer and further indicated that the frequencies set at 200 kHz in the transducer would reflect off Lake bottom's layer of underlying materials such as silt, vegetation or weeds and "fluid mud" as shown in the chart given in **Annex X** (DHM,2004). It was concluded that the depth of underlying deposited materials at the lake bottom would be 6 to 7 meter of fluid mud, silt type, vegetation etc. as mentioned in a reply letter sent by Mr. Frank Budz, the US Company (Syqwestinc) to queries of Mr. Jagat Bhusal, then DHM's section head of river hydrology, on 11 Aug 2004 concerning the interpretation of Phoksundo's bathymetric chart given in the **Annex X**.

The area of the lake was obtained as 4.95 km^2 and lake volume as 408.599 MCM. For the topographical survey theodolite was used. During this survey, details on the ground such as Lake boundary, outlet position, and details of end moraine dam, rocks etc. and all other important physical features, hydrographic features such as; streams was depicted from the ground, recorded in the field book. Sufficient spot heights were taken to draw contour lines.

Similarly, again in 2008 AD "Preparation of Bathymetric Map of Phoksundo Lake" survey was carried out. Bathymetric survey was carried out using echo-sounder. Only 36 random points of depth had been measured assuming that these measurements were sufficient to draw bathymetric map including the deepest point of the lake. GPS was used to locate the points of the measured depth. The maximum depth of the lake was found to be 202.41 m. The total area and volume of the lake was obtained as 5.1861 km^2 and 0.21 km^3 respectively (Preparation of Topographic and Bathymetric Map of Phoksunod Lake, 2004, 2008). The following table shows the detail findings of both studies.

Table 4: Morphological Parameters of Phoksundo Lake 2008 and 2004 (DHM)

Parameters	Value (2008)	Value (June, 2004)
Maximum depth, m	202.41	145
Surface area, km^2	5.1861	4.95
Shoreline, km		17.29
Maximum length, km	5.78	5.935
Maximum Width, km	1.052	1.807
Water volume, Mm^3	213.6	408.599

In 2010, DHM carried out “Preparation of Bathymetric Map of Phewa Lake” using tape, thread and weight and depth. The study measured 380 points of whose locations, latitudes and longitudes, which were recorded from GPS. The result showed that maximum depth of Phewa Lake was found to be 19.9 m at a location 28º 14’ 46.1” and 83º56’29.8”E. The total area and volume of Phewa Lake was obtained as 411.51 ha and 30.49 million m^3 with maximum width and maximum length as 1.81 km and 4.92 km respectively (Preparation of Bathymetric Map of Phewa Lake, 2010).

In continuation of the bathymetric survey of lakes, DHM carried out study on bathymetric map of Begnas Lake, east of Pokhara in Kaski district. The maximum and mean depths of Begnas Lake were found to be 11.2 m and 6.8 m respectively with lake surface area and volume of 3.16 km^2 and 21.5 million m^3. The maximum length and width of lake were found to be 3.30 km and 1.76 km respectively (Preparation of Bathymetric Map of Begnas Lake, 2011). This lake was also studied by several other institutions and researchers in the past.

Similarly, DHM carried out bathymetric survey of Rupa Lake including topographic survey in 2015. The maximum depth was found to be 4.0m at a point 511404.8 E and 3115154.82N with an area, volume and mean depth of lake as 1.106 km^2, 2.548 million m^3 and 2.3 m respectively. These findings were based on the measurement of 30 cross sections of the lake (Bathymetric Survey of Rupa Lake, 2015).

The study on Impact of Land Use on Water Quality of *Phewa* Lake Pokhara, Nepal mainly based on quantitative determination of selected physical and chemical parametric values that present in the water, where various intervention have been implemented (discharge from hotel and restaurants, fish farming, outlet of *Seti* channel in the lake and tributaries). The study indicates that the average sedimentation rate in the *Phewa* Lake for the period from March 1998 to 2004 is about 180000 cu. m. The total estimate average sediment contribution rate from the watershed was about 15cu.m. for the sample period. If this average annual sedimentation rate continues, 80% of the *Phewa* lake capacity would be silted up in the next 190 years virtually making the *Phewa* Lake useless. The authors further indicated that physio-chemical parameters are destructive as found in natural surface water bodies (Raya, Sharma, & Gurung, 2008). Other study on the physio-chemical parameters of *Deepang* Lake in Pokhara Valley, Nepal (August 2009-January 2010) showed that the PH values were found mostly alkaline and were generally between 6.7 and 7.5; the concentration of free CO_2 ranged between 1.8 mg/l and 5.6 mg/l; dissolved oxygen value were found to be gradually increased from 6.4 mg/l in August to 8.7 mg/l in January; the maximum and minimum transparency were observed at 2.5 m (January) and 1.4 m (August); the maximum and minimum temperature of Lake were observed 25.6^{o}C (August) and 17.7^{o}C (January) during the investigation period. It was concluded all measured physicochemical parameter meet WHO Standard of Water Quality (Bastola, 2013).

DHM (2016) studied measurement of water quality and hoarding board installation at some of the rivers and lakes of Kathmandu, Pokahara, Butwal, Birgunj and Narayangadh. The studied lakes were *Taudaha* (Kathmandu), *Phewa* and *Begnas* Lakes (Pokhara). The water parameter measured were pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand, total dissolved solid, electrical conductivity, nitrate, total hardness, magnesium, ammonia, iron, total coliform and E.coli. The study shows that there were spatial variation within lakes of Kathmandu Valley, and Pokhara. Most of the water quality parameters measured were within the desired limit given by national drinking water quality standard, 2062. In case of *Taudaha;* ammonia, iron, total coliform and E.coli, all the four sites were beyond the desired limit. *Begnas* and *Phewa* lakes were found to be within the desired limit given by national drinking water quality standard. However coliform and E.coli were detected beyond the desired limit. It was concluded that the agriculture and urban land use are the most contributing factors to the pollution of Lake water system.

5. Methodology

Bathymetry is the study of underwater depth of lake or ocean floors. In other words, bathymetry is the underwater equivalent to hypsometry or topography. A multi-beam echo sounder attached to a boat sends out a wide array of beams across a "swath" of the water body floor. Bathymetric (or hydrographic) charts are typically produced to support safety of surface or sub-surface navigation, and usually show bottom floor relief or terrain of lake as contour lines (called depth contours or isobaths) and selected depths (soundings), and typically also provide surface navigational information. Bathymetric maps (a more general term where navigational safety is not a concern) may also use a Digital Terrain Model and artificial illumination techniques to illustrate the depths being portrayed.

For the purpose of this study, the lake was divided into 50m x 50m grid. The measurement was followed the tentative grid point lines based on its geographical position. Section from S-N and N-S was surveyed; when one whole grid line is completed, a marking like flag was placed in the end point so it clearly indicated the surveyed area to move forward and continued the work. As well as a path was followed making an interval of 50 m using SW maps an android based apps. A continuous recording of latitude, longitude and depth were done at around 50m interval. The displayed depth from echo-sounder was recorded in GPS with its respective latitude and longitude. The different depths measured was also verified using the tag reel. Near the *Chholupu khola* at 14 m depth, the depth was tallied using tag reel with depth shown in echo-sounder. Next to this, a depth of 40.8 m was also verified using tag reel and was tallied with the eco-sounder depth near *Gumba*. A standard echo-sounder, GPS, boat, tag reel, measuring tape was used for bathymetric survey. Besides, measurements were carried out twice at the deepest point of the Lake for verification.

Topographic survey was carried out to third order precision and the admissible error of closure were not exceed 12 K mm, where K is the distance in KM. The survey was carried out as described in ToR. In case of establishing permanent benchmark, the six bench marks at possible accessible and visible area were established according to the site condition in permanent boulders using steel rod drilled in boulder. The instruments and accessories that were used for the topographical survey included DGPS, total station (reflector and reflector less), GPS, paint etc.

6. Field Works

6.1 Preparatory Meeting at DHM

A meeting was held at DHM on 20th May 2019 to discuss about preparation and departure of fieldwork to be carried in Phoksundo Lake. The discussion meeting focused on the following essential points:

i) Life insurance of all field members

ii) Boat for bathymetric survey and its transportation from airport to Phoksundo lake site.

iii) Generator required for equipment's battery recharge

iv) Contact of local person for porter arrangement

v) Start of field work

a) Inspection of all equipments

b) Lake Pooja to be performed by *Lama Gurus* for its religious values and cultural beliefs linked to the lake.

c) Briefing to different local stakeholders, local people including Village Chief and other related local institutions.

d) Reconnaissance survey of Phoksundo Lake and its surroundings for bathymetric and topographic surveys.

e) Observation air temperature during the field work.

f) Bench mark setting at a suitable place for topographic survey.

g) Water sampling at selected sites and Lake Outlet.

h) Discharge measurement at Lake Inlet and Outlet using Current Meter.

6.2 Testing of Echo sounder prior to field work

Testing of echo sounder was carried out at Indra Sarobar Lake in Kulekhani on 8th May 2019. The depths measured by echo sounder were verified manually using tag reel tied with iron weight. Both results showed the same depths at several points as shown in table 5.

Figure 9: Testing of Echo sounder at *Indra Sarobar* Lake, Kulekhani

Table 5: Test and verification of Echo-Sounder

Location: *Indra Sarobar*, Kulekhani

Date	Depth measured by Echo sounder (m)	Depth measured by tag reel (m)
2019.05.08	19.2	19
2019.05.08	11	11
2019.05.08	16	16

6.3 Bathymetric Survey

For determining geometric parameters and preparation of bathymetric map, the field survey was conducted from 26 May to 04 June 2019. The depth of Phoksundo Lake were measured using digital Echo Sounder CVS 126 made of Japanese company Koden Electronics. The depth measuring range of the echo sounder was up to 800m and the accuracy was ±0.1%. The instrument was operated in dual frequency of 50 kHz and 200 kHz for depth measurement. Basically, low frequency have more

accuracy in higher depth and higher frequency is reliable for lower depth. The detail can be found in the link as follow.

http://www.raymarine.com/view/?id=197&fbclid=IwAR1s3ndk1rsHr99M-ZIfEs9zQXxqnakJxU0rzWWeNsZ_gBJ-qzUg8FF03xY#Frequency. This model of echo sounder is more advanced than analog echo sounder in terms of the method of processing and displaying received signals. The detail specification of the echo sounder is presented in **Annex IV**.

The first line was followed by the centerline of the lake. The other measurements were based on the reference of first line by maintaining 50 m distance. The measured depth points were used to create the path line of that day. With its reference the next path line was created for other day. The same process was repeated continuously till the end of the work. GIS tools were used to carry out this process. The lines were converted to shape file and inserted in SW maps, an android based app of mobile phone, which made easier to take a path line in the lake for survey. Almost 4000 sites of nearly 50 m x 50 m grid point of the lake were located and tracked using GPS (Global Positioning System) to record the depth of the lake. The depth of the lake was also verified manually using the tag reel. The depth measured by echo sounder and the depth using tag reel was found to be exact. To find the deepest part of the lake, around 5 times the boat was moved making a big circle, then small circle in different places. The deepest part of lake was verified measuring the depths near and around twice.

6.4 Topographic Survey

All the members of the survey team walked around the lake, where accessible to select perfect location for the establishment of permanent benchmark, to overview general layout of the lake and vegetation cover around the lake. The team also thoroughly studied the 1:50,000 scale topographical map of sheet number 2982 16 published by the Survey Department of Nepal for the general overview of the lake and its location. The overview of general layout and vegetation of the inaccessible location was carried out through boat. Easily accessible locations were selected for the placement of permanent benchmarks using DGPS. The topographical survey work started establishing the DGPS benchmark. The benchmarks are established at accessible and visible sites.

The established benchmark becoming far though visible and straight from edge of the lake, the survey was delayed around 5 hours because of communication problem. The topographical survey was conducted as per the standards required and as per the scope of works according to ToR. Necessary Bench Marks were fixed at the accessible location using the Sanding DGPS, Topcon total station. DGPS benchmark point coordinates are picked by observing 6 hrs data from satellite on each base point. Traverse is carried out by total station within given accuracy. Errors on total station and DGPS were already calculated and eliminated. The accuracy of the DGPS was horizontal ±8 mm + 0.5 ppm and

vertical ±15 mm + 0.5 ppm. The number of connecting satellite were observed as 20 to 37 in different stations. The cut off angle was 15^0. Sanding DGPS, Topcon and Sokia were used to carry out the survey work from upstream of the lake to the farthest downstream outlet of the lake. Traversing was done using DGPS 1, DGPS 2 and cp1. The errors calculated was -0.019 m in easting and -0.012 in northing. Adjustment made in 3 benchmarks was +0.006 m easting and +0.004 m in northing.

The data obtained was in WGS 84. So this data was projected to Modified UTM 84 with an overlay on topo sheet which was basis for further calculation. Nepal has greater East-West expansion so as to increase accuracy for cadastral survey and various other purpose, UTM has been modified to MUTM (Modified UTM); Gauss-Krueger projection-based coordinate system, thus the "modified" designation. In this projection system Earth is divided in 120 zones each of $3^{\mathbf{0}}$. Nepal has central meridian of $81^{\mathbf{0}}$,$84^{\mathbf{0}}$and $87^{\mathbf{0}}$. The scale factor of 0.9999 is used for central meridian normally for $84^{\mathbf{0}}$ and 00 55' east or west of central meridian has the scale factor of 1 (meaning no distortion). False Easting at central meridian is 500 000 m in order to keep all the coordinates within the country positive, and False Northing at the Equator is 0 m.

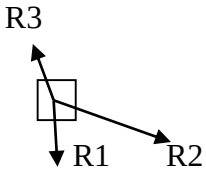
The topographic survey was conducted using total station and DGPS covering an area of approximately 91.40 hectares, which includes lake surroundings and river cross sections. The area of the lake was surveyed using DGPS. For the calculation of area, the DGPS base was fixed near the army camp, located at the edge of the lake. And the rover was used to survey the lake. The boat was propelled about 2 m far from the edge of the lake and the survey was carried out using DGPS. The area, length and width of the lake were calculated using CAD software.

For establishing the benchmarks, all the permanent ground control stations were fixed/marked with a cross-mark on permanent boulders with center 16 mm dia. Steel Rod and marking with paint. The detail of the established benchmark is as follows:

PHOKSUNDO LAKE SURVEY PROJECT DOLPA
DETAIL SURVEY (Bathymetry & Topo)

DESCRIPTION CARD OF GROUND CONTROL POINT

Station Name: DGPS-1
No. of satellite connection: 37
Date: 2019. 05.26
Time: 06-11 AM
Station Type: Permanent



Location

District: Dolpa

Rural Municipality: Shey Phoksundo

Ward No: 8

Land Type: Peg on boulders

R1 →	3.75m	Tree
R2 →	1.34m	Boulder
R3 →	2.42m	Boulder

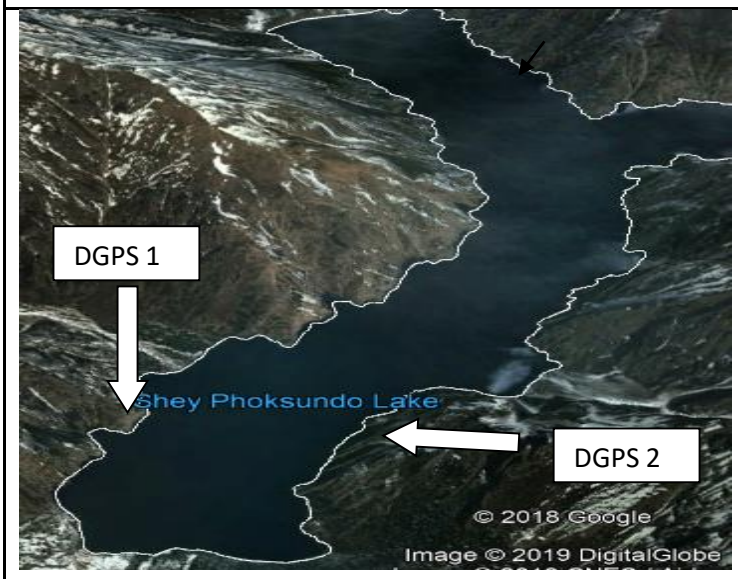
Description:

This DGPS permanent B.M point is located in right bank of lake at 2nd nose of hill opposite side of Gumba.

Co-Ordinates

Northing: 3229162.140 m Easting: 396794.693m Elevation:3590.253 m

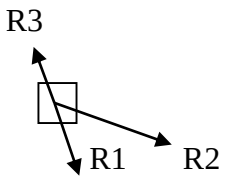
Location Sketch



Photograph

DESCRIPTION CARD OF GROUND CONTROL POINT

Station Name: DGPS-2
No. of satellite connection: 37
Date: 2019. 05.26
Time: 06:45-11 AM
Station Type: Permanent



Location

District: Dolpa

Rural Municipality: Shey Phoksundo

Ward No: 8

Land Type: Peg on boulders

R1 →	2.75m	Boulder
R2 →	2.34m	Boulder
R3 →	3.42m	Boulder

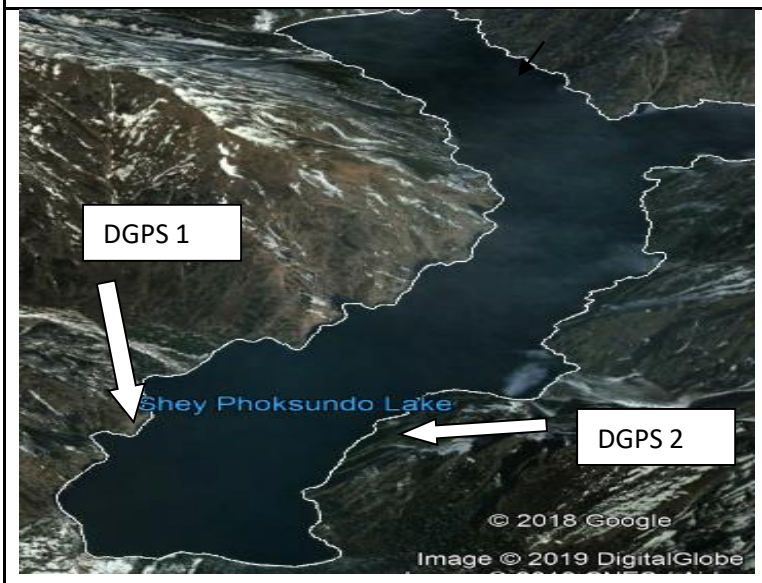
Description:

This DGPS permanent B.M point is located in left bank of lake at front side of Gumba.

Co-Ordinates

Northing:3228552.149 m Easting: 397491.746m Elevation: 3609.779m

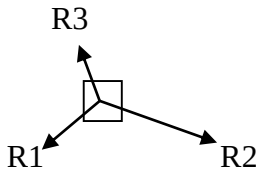
Location Sketch



Photograph

DESCRIPTION CARD OF GROUND CONTROL POINT

Station Name: DGPS-3
No. of satellite connection: 22
Date: 2019. 05.28
Time: 06:30-12 Noon
Station Type: Permanent



Location

District: Dolpa

Rural Municipality: Shey Phoksundo

Ward No: 8

Land Type: Peg on boulders

R1 →	3.7m	Tree
R2 →	1.84m	Boulder
R3 →	2.42m	Boulder

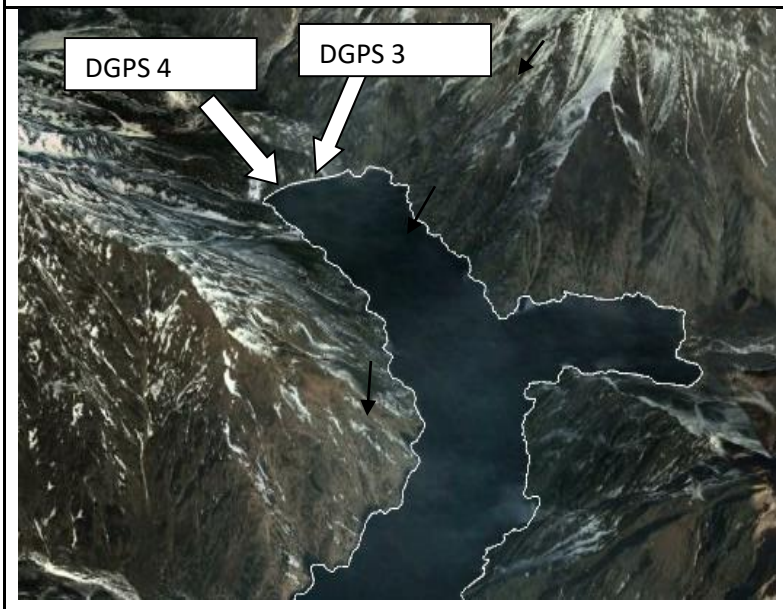
Description:

This DGPS permanent B.M point is located in inlet at Chholupu. DGPS 4 is visible from here.

Co-Ordinates

Northing:3233074.611 m Easting: 396884.201m Elevation: 3591.512m

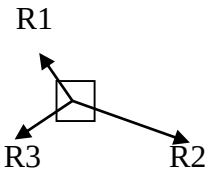
Location Sketch



Photograph

DESCRIPTION CARD OF GROUND CONTROL POINT

Station Name: DGPS-4
No. of satellite connection: 22
Date: 2019. 05.28
Time: 07:00-12 Noon
Station Type: Permanent



R1 → 2.389m Tree
R2 → 1.66m Boulder
R3 → 2.49m Boulder

Location

District: Dolpa

Rural Municipality: Shey Phoksundo

Ward No: 8

Land Type: Peg on boulders

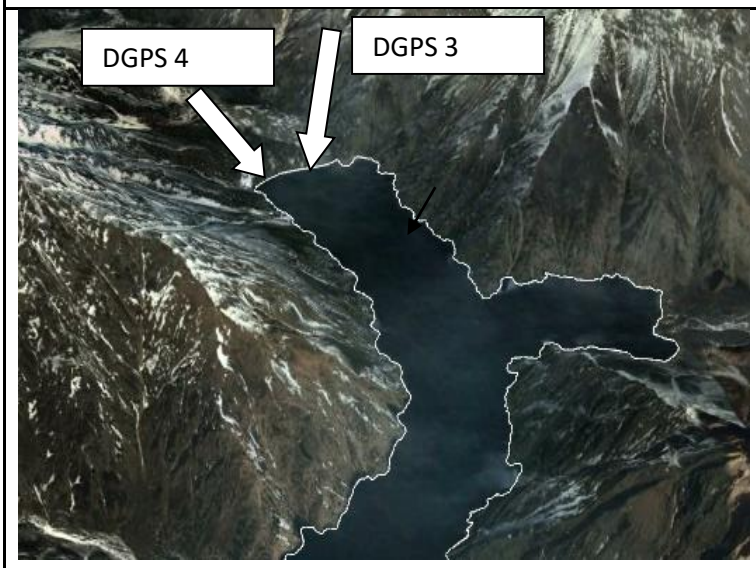
Description:

This DGPS permanent B.M point is located in inlet area Chholupu.

Co-Ordinates

Northing: 3233033.858 m Easting: 396883.832m Elevation: 3591.576m

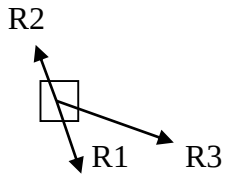
Location Sketch



Photograph

DESCRIPTION CARD OF GROUND CONTROL POINT

Station Name: DGPS-5
No. of satellite connection: 20
Date: 2019. 05.29
Time: 07:00-11 AM
Station Type: Permanent



Location

District: Dolpa

Rural Municipality: Shey Phoksundo

Ward No: 8

Land Type: Peg on boulders

R1 →	2.75m	Tree
R2 →	1.34m	Boulder
R3 →	0.42m	Boulder

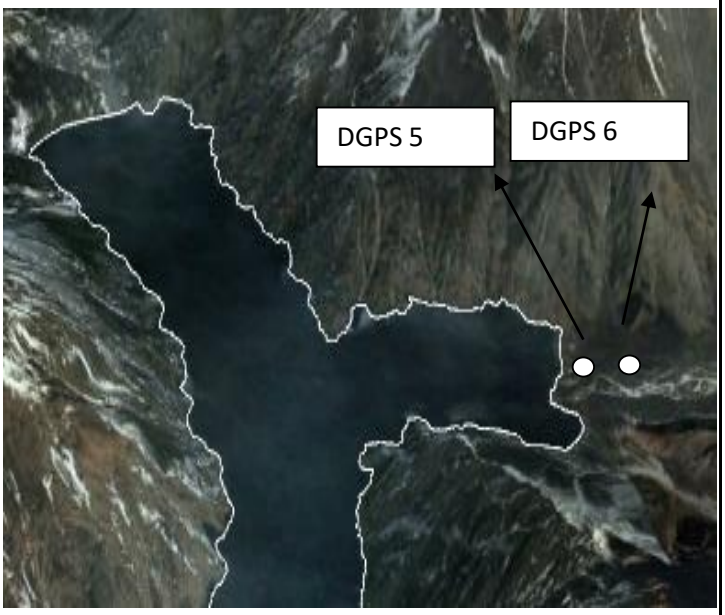
Description:

This DGPS permanent B.M point is located in *Sagar Lek* intake area, and 100m away from lake edge.

Co-Ordinates

Northing: 3231969.774m Easting: 399764.772m Elevation: 3591.590m

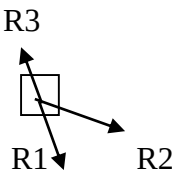
Location Sketch



Photograph

DESCRIPTION CARD OF GROUND CONTROL POINT

Station Name: DGPS-6
No. of satellite connection: 20
Date: 2019. 05.29
Time: 07:15-11 AM
Station Type: Permanent



Location

District: Dolpa

Rural Municipality: Shey Phoksundo

Ward No: 8

Land Type: Peg on boulders

R1 →	3.75m	Tree
R2 →	1.34m	Boulder
R3 →	2.42m	Boulder

Description:

This DGPS permanent B.M point is located in Sagar Lek, around 50 m away from fifth B.M.

Co-Ordinates

Northing: 3231972.668 m Easting: 399791.813m Elevation: 3592.070m

Location Sketch

Photograph

6.5 Possible Errors in Survey and Bathymetry

The term Global Navigation Satellite Systems (GNSS) refers to a satellite constellation used to provide geospatial position, navigation and timing. Global Positioning System (GPS) of the US, the GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (GLONASS) of Russia, Galileo of Europe, Compass/BeiDou Navigation Satellite System (CNSS) of China and NAVigation with Indian Constellation (NAVIC) of India are examples of Global/Regional - Navigation Satellite Systems (NSS). Atmospheric delay in the ionosphere and neutral atmosphere are major error sources of GNSS measurements. Ionospheric errors are mostly eliminated by observing at two or more frequencies. But the tropospheric delay is a valuable meteorological information. Ground based GNSS receivers are used to measure geospatial position.

GPS signals can also be affected by multipath issues, where the radio signals reflect off surrounding terrain; buildings, canyon walls, hard ground, etc. These delayed signals **cause** measurement **errors** that are different for each type of **GPS** signal due to its dependency on the wavelength.

The arrangement of satellites in the sky also affects the accuracy of GPS positioning. The ideal arrangement (of the minimum four satellites) is one satellite directly overhead, three others equally spaced nearer the horizon (but above the mask angle). Imagine a vast umbrella that encompasses most of the sky, where the satellites form the tip and the ends of the umbrella spines.

GPS coordinates calculated when satellites are clustered close together in the sky suffer from **dilution of precision** (DOP), a factor that multiplies the uncertainty associated with User Equivalent Range Errors (UERE - errors associated with satellite and receiver clocks, the atmosphere, satellite orbits, and the environmental conditions that lead to multipath errors). The calculation of DOP results in values that range from 1 (the best case, which does not magnify UERE) to more than 20 (in which case, there is so much error the data should not be used). According to Van Sickle (2001), the lowest DOP encountered in practice is about 2, which doubles the uncertainty associated with UERE.

GPS receivers report several components of DOP, including Horizontal Dilution of Precision (HDOP) and Vertical Dilution of Precision (VDOP). The combination of these two components of the three-dimensional position is called PDOP - position dilution of precision. A key element of GPS mission planning is to identify the time of day when PDOP is minimized. Since satellite orbits are known, PDOP can be predicted for a given time and location.

Total station is a device used in surveying. Like any other devices, total station also have some sources of error which can affect the surveying report. Total station measure angles with some degree of

imperfection. These imperfections result from the fact that no mechanical device can be manufactured with zero error.

In the past very specific measuring techniques were taught and employed by surveyors to compensate for minor mechanical imperfections. With the advent of electronic total station, the mechanical errors still exist but are related to in a different way.

Horizontal collimation error exists when the optical axis of the instrument is not exactly perpendicular to the telescope axis. The two most common errors are reading an angle incorrectly and/or entering incorrect information into the field book. Another common (and potentially disastrous) error is an incorrect instrument or rod height. The optical plummet or tribrachs must be periodically checked for misalignment. This would include total stations with laser plummets. (Source: https://www.e-education.psu.edu/geog160/node/1924)

There may be some errors occurred during bathymetry. Such errors are mainly due to handling of transducer while in operation. If the submerged transducer could not place vertically and stably, the value of the depth may observe different in the same location. These are because of water current, moving boat and installation of transducer in the boat.

6.6 Water Sample Collection and handling

Before taking the water sample, both hands were washed. The bottles used for water sample was 500ml. The bottle was plunged into the water (lip of bottle first) to a depth of approximately 20 cm to 30 cm (~1foot) below the surface of water. In case of bottle overfilled, small amount of water was poured leaving at least 2cm to 3cm of air space at top of bottle to allow for adequate mixing and replaced the lid tightly. Date and time of sampling was noted along with bottle numbering and sample location. The collected samples were then carefully safely packed in the box. The collected sample were then transported to Kathmandu and delivered to the laboratory for detail analysis.

Water Temperature, pH, turbidity, conductivity were measured in the field. For other properties like dissolved oxygen, BOD, COD, nitrate, iron, sulphate and total hardness; collected water sample were tested in the laboratory at Kathmandu. The samples collected at different locations is given in the following table and map. Altogether four different sites were selected for water sampling. The measured values of pH and EC were found be within the standard range as specified by National Drinking Water Quality Standard, 2062.

Table 6: Location and measurement of physical parameters measured at the site

Sample site	Location	Latitude (Degrees)	Longitude (Degrees)	pH (6.5-8.5)*	EC, µS/cm (<1500)*	Water Temp ^{0}C	Time
1	Near Chholupu	29.215268	82.943667	8.2	254	8.3	8:30 AM
2	Near Sagar *Lek*	29.205047	82.962359	8.3	256	7.7	9:50 AM
3	Near Center	29.193204	82.950438	7.9	254	8.6	3:15 PM
4	Near Gumba	29.179394	82.941184	8.3	254	6.9	5:25 AM

National Drinking Water Quality Standard, 2062

Table 7: Location of site for water sample collection

Sample site	Location	Latitude (Degrees)	Longitude (Degrees)	Date	Time
1	Chholupu *Lek* inlet	29.21762	82.942171	31.05.2019	8.00 AM
2	Sagar *Lek* inlet	29.20466	82.965537	01.06.2019	7.30 AM
3	Near Center	29.198394	82.952359	01.06.2019	9.00 AM
4	Lake Outlet	29.174307	82.936966	04.06.2019	6.30 AM

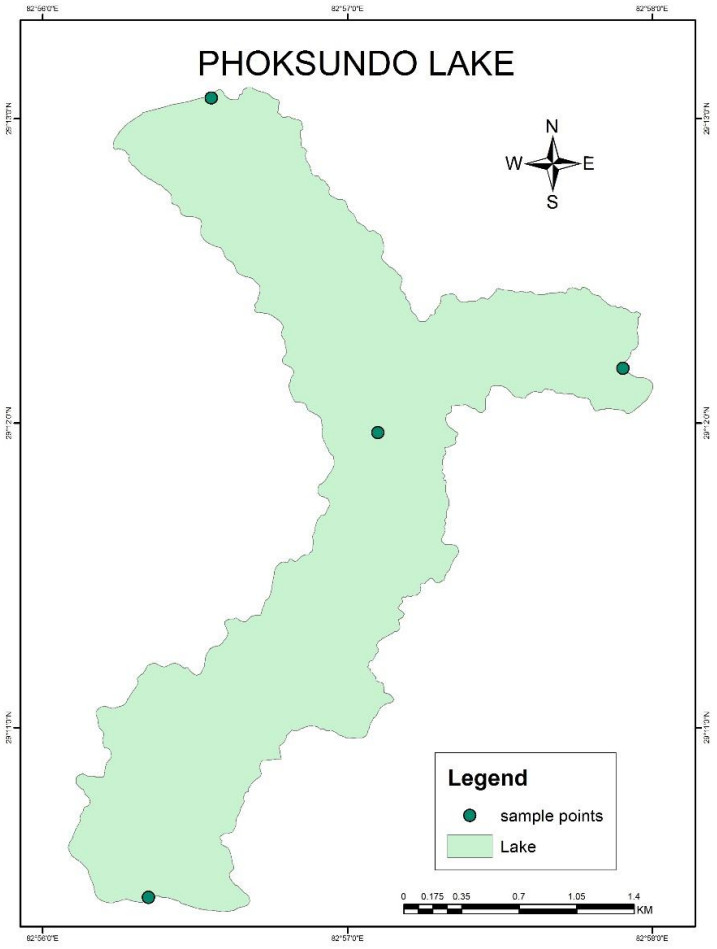


Figure 10: Water Sample Collection Points

6.7 Discharge Measurement

Phoksundo Lake is the important source of water for Thuli Bheri River. The released water about after 500 m south of lake, forms the majestic fall of about 167 m. Discharge measurement at outlet and inlets of Phoksundo lake were carried out using price type current meter by wading method. Two discharge measurements were carried out at the outlet of lake on May 28 and 30, 2019, whereas one measurement each at Chholupu and Sagar *Lek* inlets of Lake, were carried out on May 29. The suitable sites were selected at both inlets and outlet of the Lake. The number of sections taken at inlets were 14 and 16 whereas at the outlet it was 34 sections. The discharge were measured by current meter using wading method as the water depth was less than 1m. The discharge were measured at 0.6 depth.

6.8 Instruments used in the field and their features

1. Echo Sounder

   Instrument : Echo Sounder
   Company : Koden (Japan)
   Frequency Used : Dual Frequency (Checked with 50 kHz and 200 kHz time and again)
   Model : CVS 126
   Depth Range : up to 800 m
   Accuracy : ± 0.1%

2. GPS

   Instrument : GPS
   Company : Garmin
   Model : Oregon 700
   Accuracy : ±3m
   GPS Signal Received : GPS + GLONASS dual mode

3. Total Stations
4. DGPS

   Instrument : DGPS
   Model : Sanding T66
   Satellite Visible : >37
   Cut off Angle : 15^{o}
   P Dop : 1.32
   Accuracy: Horizontal : ±8 mm + 0.5 ppm
   Vertical : ±15 mm + 0.5 ppm
5. EC Meter and pH meter
6. Price Type current meter
7. Rope and Inflated boat

7. Results and Discussion

7.1 Topographic, L and X Section Map

Based on the survey data the topographic, L and X section and other map are prepared. The topographic map of the lake is shown in figure 11. The A0 size printed map are placed in **Annex VI**.

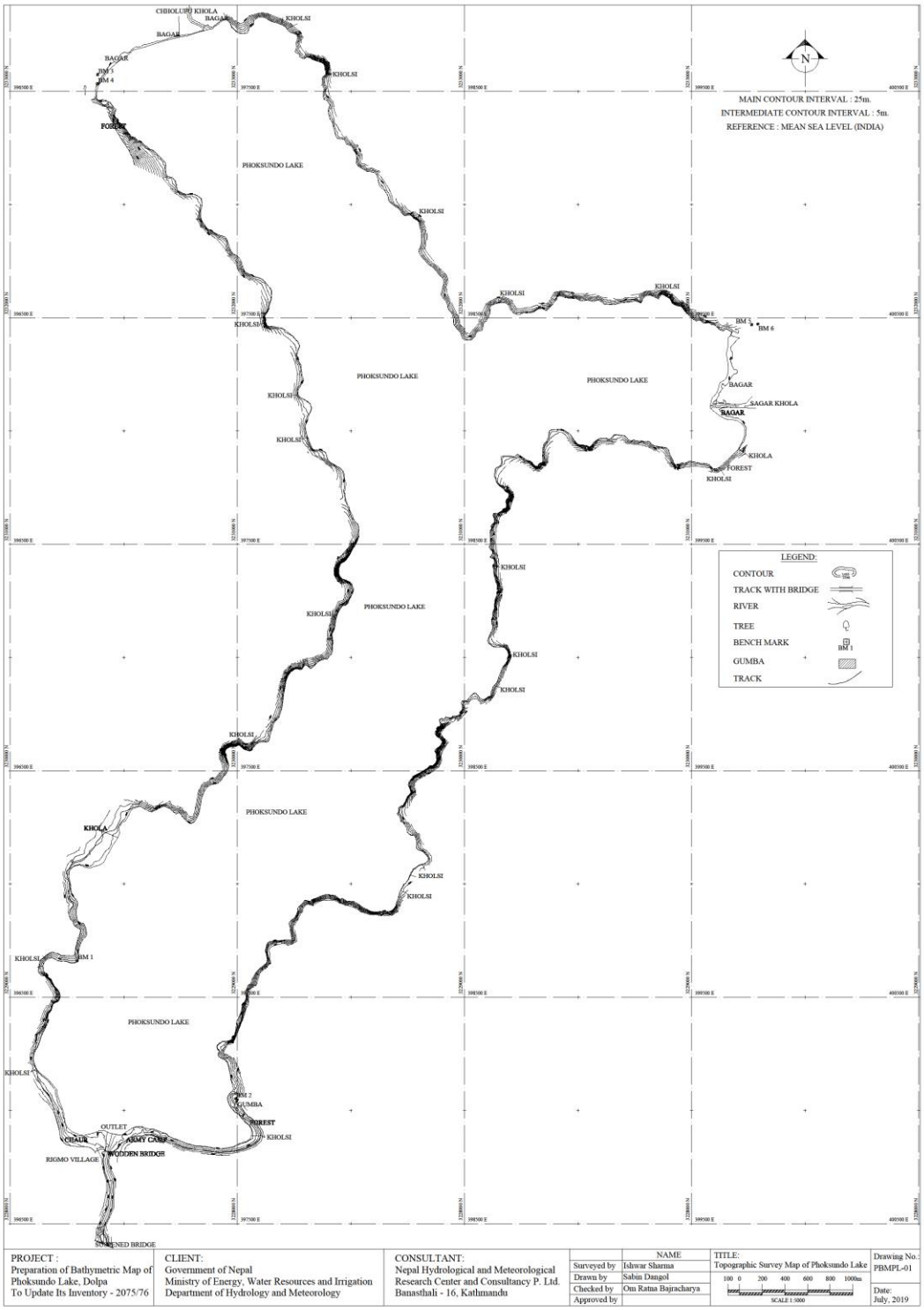


Figure 11: Topographic map of Phoksundo Lake

The width of the lake were calculated along the cross sections. The length of the lake has been calculated joining the center point of each cross section perpendicular to it. The length and width are as shown in Figure 12.

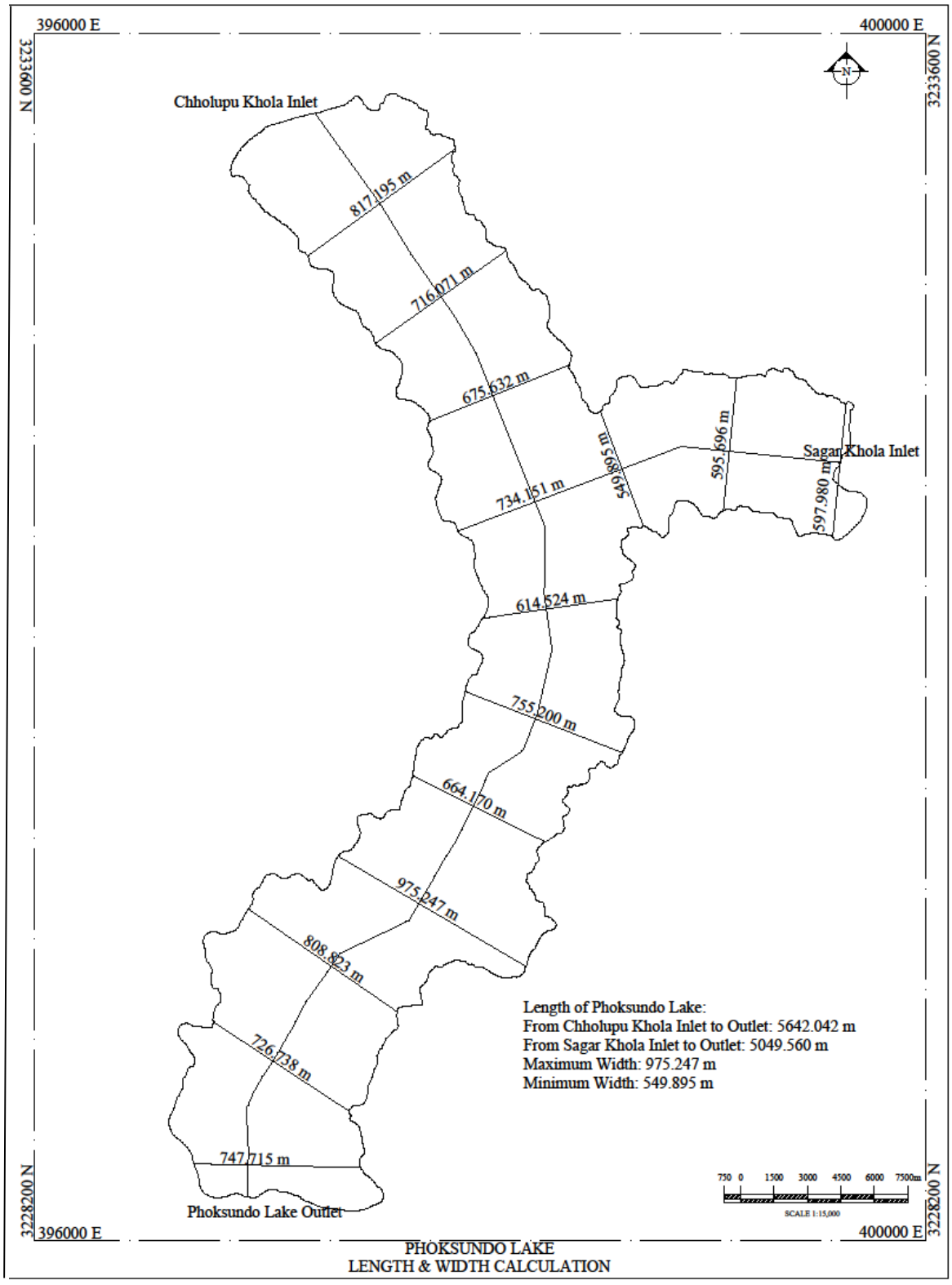


Figure 12: Calculated Length and width of Lake from survey data

The following morphometric parameters of Lake are calculated from the survey.

Table 8: Morphometric parameters of Phoksundo Lake

Parameters	**Value**
Shape	Y- Shape
Maximum depth (m)	**136.20** Location: 29.18369^0 and 82.94256^0
Elevation (m)	3588.85 (Outlet)
Surface area (km^2)	4.849
Shoreline (m)	18295.269
Length of Lake (m) Chholupu khola inlet to outlet	5642.042
Length of Lake (m) Sagar khola inlet to outlet	5049.560
Minimum Width (m)	549.895
Maximum Width (m)	975.247
Volume (MCM)	398.73

The printed L-section and X-section of Phoksundo Lake and X-section of inlet and X-section of outlet map are presented in **Annex VII**.

7.2 Bathymetric Survey

7.2.1. Bathymetric map of Phoksundo Lake

The measured and recorded depth points of lake are shown in figure 13. The point highlighted in red color indicate the location of the deepest point of the lake. The deepest part of the Lake was recorded as **136.20m** at location with latitude and longitude 29.18369^0 and 82.94256^0 respectively. The measured horizontal distances and the corresponding depths were plotted on the topographic map of the lake. The contour lines were drawn using interpolation and extrapolation techniques. The contour lines were drawn at an interval of 5 meters. The map are generated with ARC GIS software. Figure 14 shows the bathymetric map of Phoksundo Lake and A0 size bathymetric map is attached in **Annex VIII**.

Raw data from the survey was converted to Triangular Irregular networks (TIN) and then to 20m * 20m grid size raster file, which is a digital means to represent surface morphology using ArcGIS software. The parameters like contour, volume and area were all computed from the TIN using Surface Contour and Surface Volume tool respectively in ArcGIS. Above computed values were then used to prepare Hypsometric curve, and Elevation-Area- Volume Curve.

The other method for volume calculation like kriging interpolation and IDW were also tested but TIN was found more reliable and commonly used technique. Some references who has also adopted the same tools in calculation of volume and area in bathymetry.

http://lakes.chebucto.org/DATA/morphology.html?fbclid=IwAR3f5yNISqf4nd-lworIcCdL20O78aAkyCVcANYvLYgjKnfbynpCtY6BigA#lmax

http://resources.esri.com/help/9.3/arcgisengine/java/gp_toolref/3d_analyst_tools/how_surface_volume_3d_analyst_works.htm

The reference level of water surface for bathymetry is calculated by averaging the different reference level of water surface from inlet to outlet of the Lake calculated in L-section.

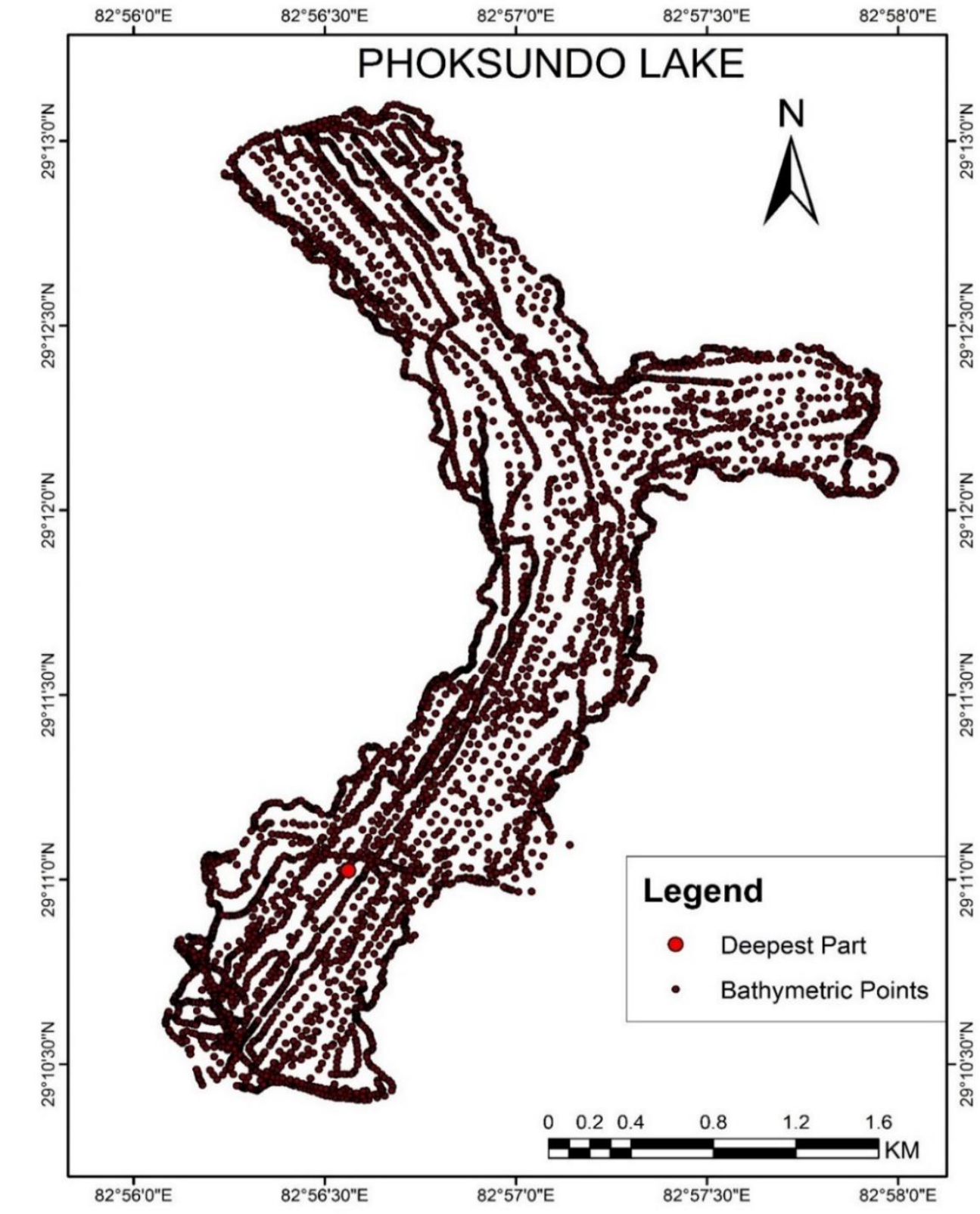
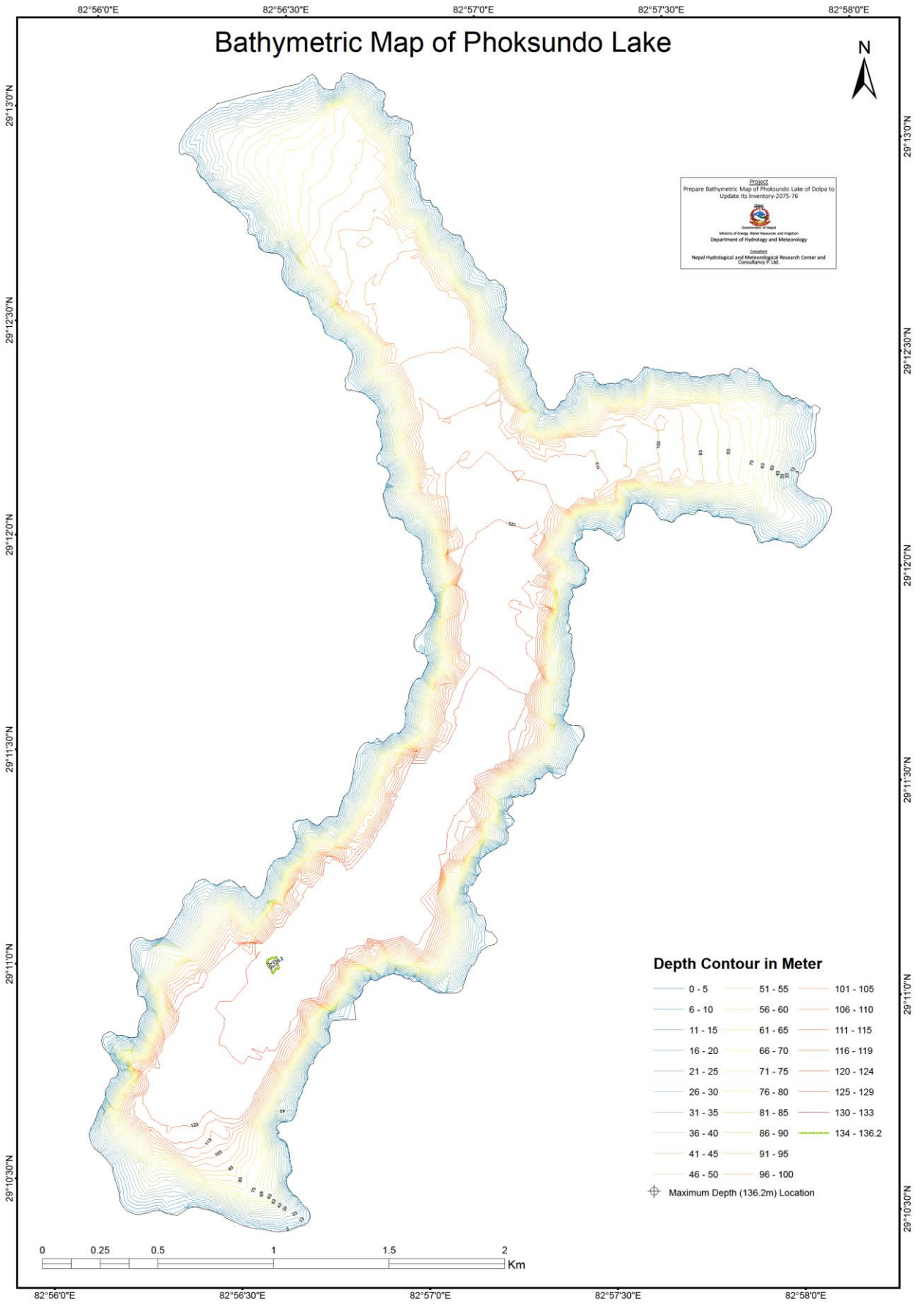


Figure 13: Measurement points of Bathymetric Survey


Bathymetric Map of Phoksundo Lake
N
82°56'0"E
82°56'30"E
82°57'0"E
82°57'30"E
82°58'0"E
29°13'0"N
29°12'30"N
29°12'0"N
29°11'30"N
29°11'0"N
29°10'30"N
Project
Prepare Bathymetric Map of Phoksundo Lake of Dolpa to Update Its Inventory-2075-76
Department of Hydrology and Meteorology
Consultant
Nepal Hydrological and Meteorological Research Center and Consultancy P. Ltd.
Depth Contour in Meter
0 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 35
36 - 40
41 - 45
46 - 50
51 - 55
56 - 60
61 - 65
66 - 70
71 - 75
76 - 80
81 - 85
86 - 90
91 - 95
96 - 100
101 - 105
106 - 110
111 - 115
116 - 119
120 - 124
125 - 129
130 - 133
134 - 136.2
Maximum Depth (136.2m) Location
0
0.25
0.5
1
1.5
2
Km

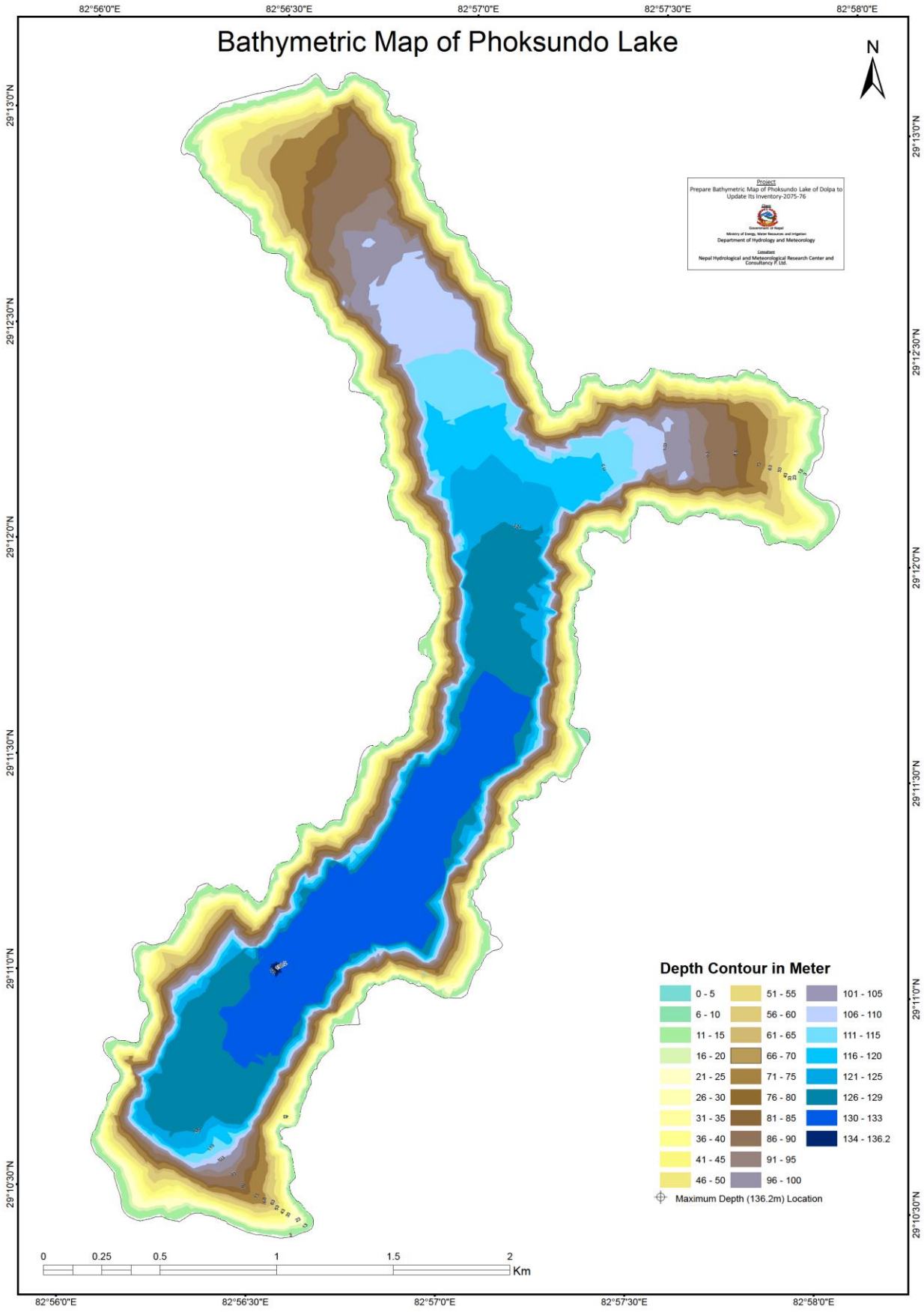


Figure 14: Bathymetric map of Phoksundo Lake

7.2.2. Depth-Volume Relationship

The area of the Lake and the area between two consecutive contour lines were determined from GIS data base of bathymetric map of Lake. The area between two consecutive contour lines was measured and GIS data base was prepared using software Arc Info and Arc View. The volumes of lake were then calculated by multiplying the measured area with the average depth. Table 9 below shows the relation of depth ranges with area and volume between two consecutive contour lines. The depth–volume, depth-area and depth-area-volume relationship of the lake is shown in figure 15, 16 and 17 respectively. The total water volume of the Lake is about 398.73 million cubic meter.

Table 9: Depth-Volume relationship

RL (m)	Depth Contour (m)	Incremental Area (Km^2)	Cumulative Area (Km^2)	Incremental Volume (MCM)	Cumulative Volume (MCM)
3453.08	0	0	0	0	0
3459.08	10	0.23	0.23	0.35	0.35
3469.08	20	0.24	0.48	8.77	9.12
3479.08	30	0.25	0.72	14.50	23.62
3489.08	40	0.25	0.97	19.19	42.81
3499.08	50	0.25	1.22	23.19	66.00
3509.08	60	0.25	1.47	26.48	92.48
3519.08	70	0.26	1.73	29.51	121.99
3529.08	80	0.29	2.02	32.23	154.22
3539.08	90	0.31	2.33	34.68	188.89
3549.08	100	0.31	2.64	37.10	225.99
3559.08	110	0.34	2.98	39.48	265.47
3569.08	120	0.46	3.44	41.87	307.34
3579.08	130	0.48	3.93	44.37	351.71
3589.08	136.2	0.92	4.85	47.02	398.73

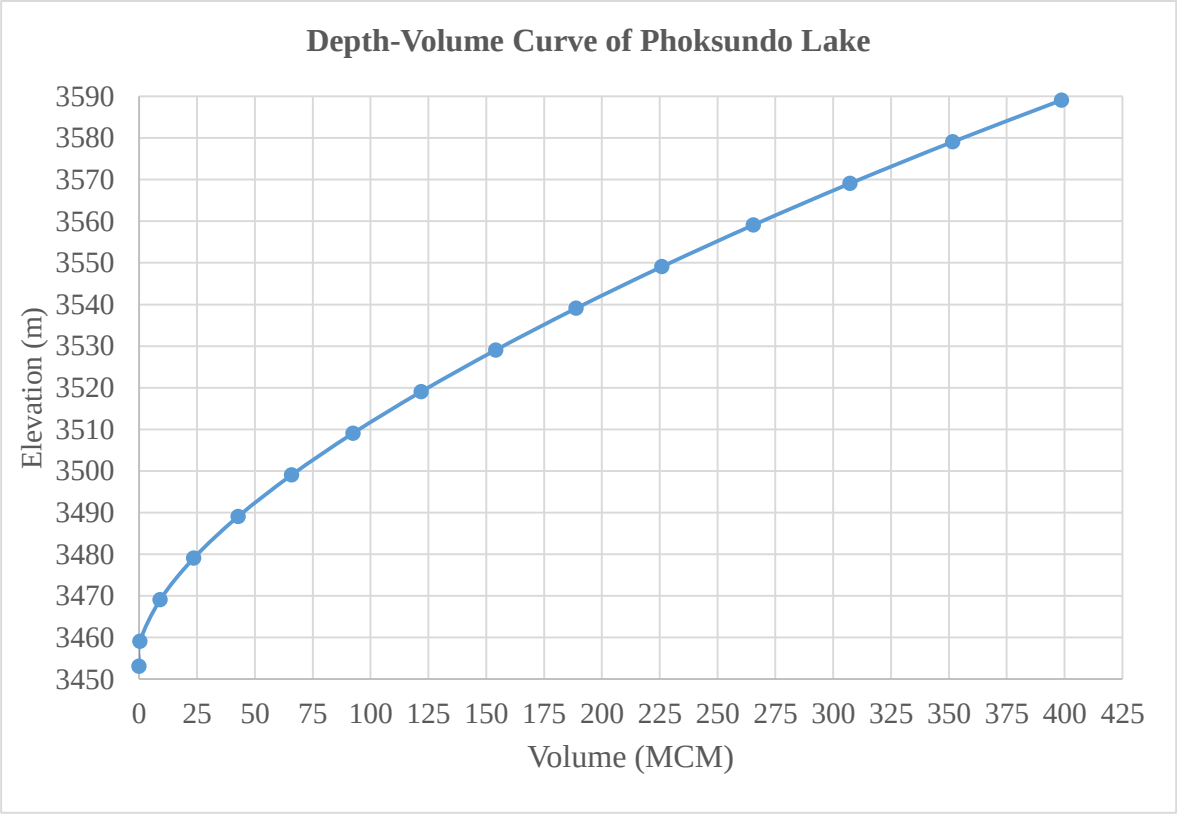


Figure 15: Depth-Volume Curve

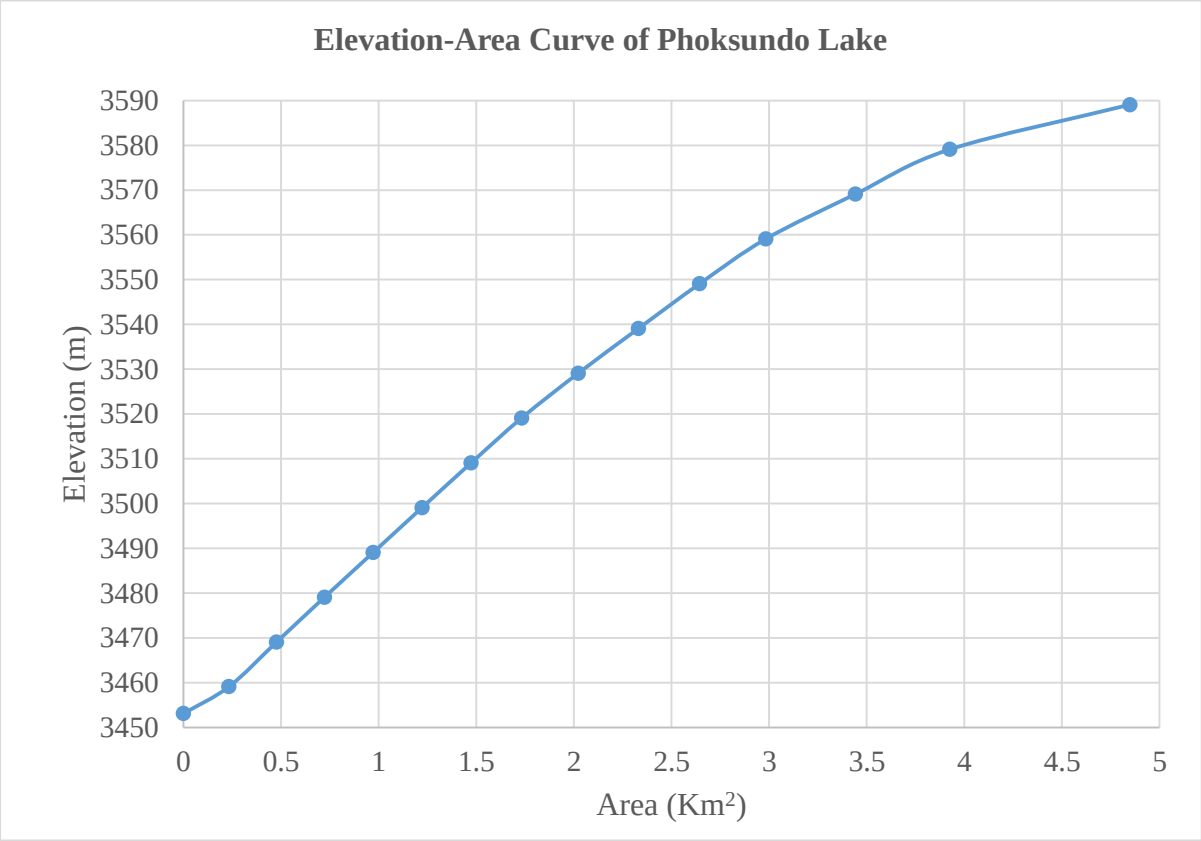


Figure 16: Elevation-Area Curve

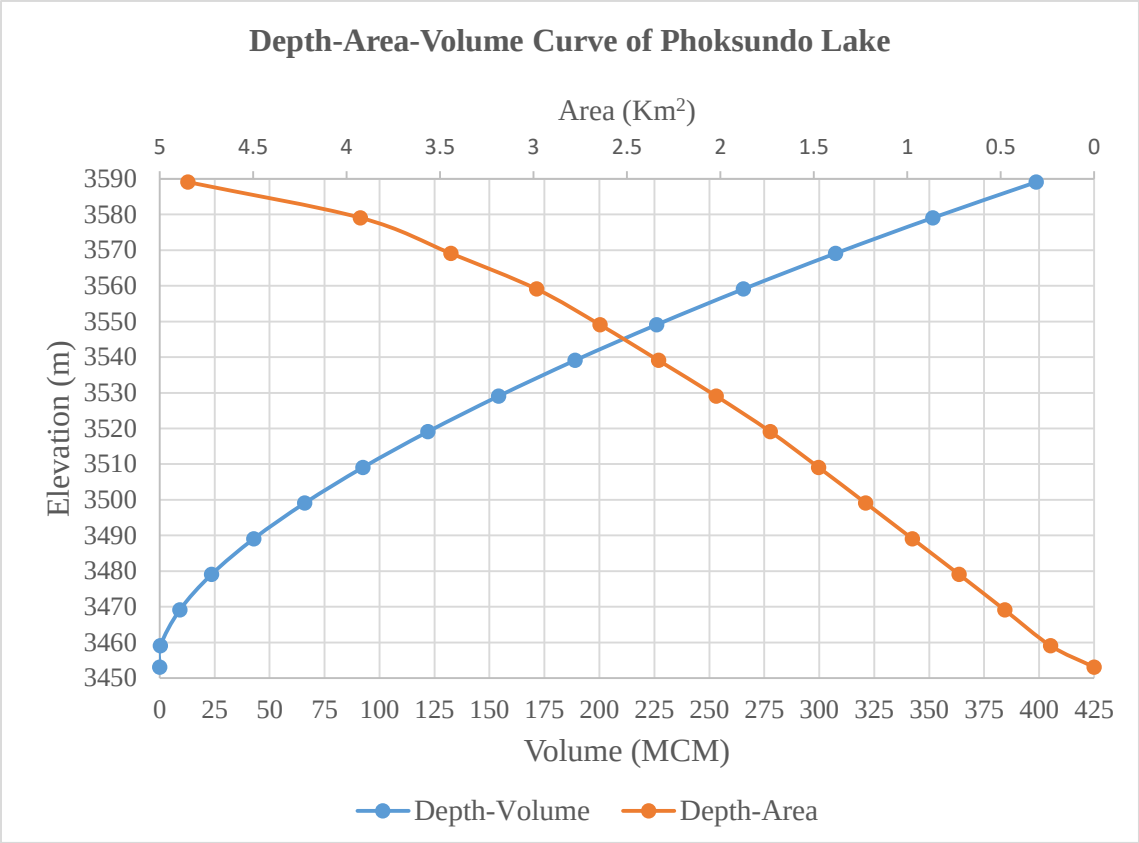


Figure 17: Depth-Area and Volume Curve

7.2.3. Hypsometric Curve

The relation between cumulative depths of the Lake with its respective area in percentage is shown in figure 18.

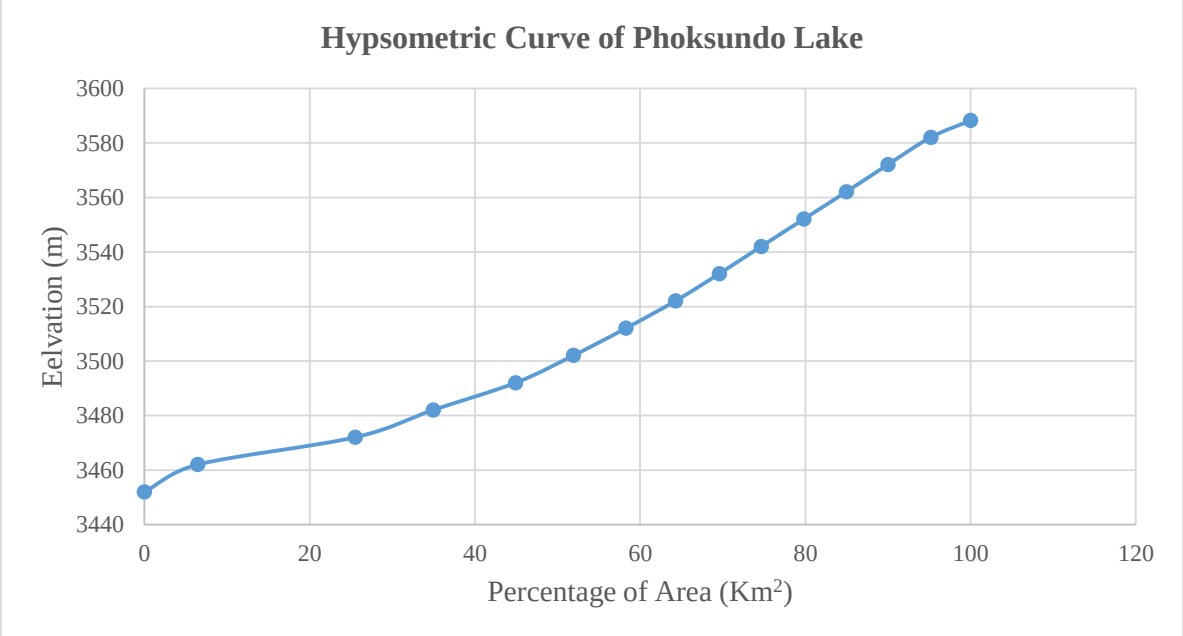


Figure 18: Hypsometric Curve

7.3 Discharge Calculation

The locations of discharge measurement and discharge volume of different sections are presented in table 10.The results showed that outlet discharge is 3 to 4 times more than the inlet discharges. This differences might have been due to several reasons like: Phoksundo Lake is surrounded by snow - capped-mountain in all directions. The sources of water to the lake are small streams originated from the surrounding Himalayas. The seepage of the melt water from snow-capped mountain play an important role in contribution to the lake which was also seen in field. Also, during winter season, snow gets accumulated and melts during summer season. Snowmelt has great contribution to stream flow in a river. Similarly groundwater contribution to river flow, generally called base flow, often accounts for a significant proportion of total flow rate, especially during the dry season. The main reason for higher discharge at the lake outlet of Phoksundo Lake compared to Lake Inlet can be attributed to these factors of occurrence of snowmelt and base flows. The study of snowmelt contribution using snow cover area data and monitoring of hourly/daily water level of lake at the inlet and outlet are necessary for detail investigation for the differences seen in the lake outlet discharge.

The discharge calculated data sheet are presented in **Annex I**.

Table 10: Summary of discharge measurements at three different locations of Phoksundo Lake

Location	Measurement date & time	Latitude (degrees)	Longitude (degrees)	Gauge Height (m)	Width (m)	Area (m^2)	Mean Velocity (m/s)	Discharge (m^3/s)
Inlet 1, Chholupu	29.05.2019 7: 10AM 9:30 AM	29.2195	82.94114		14	5.42	0.789	**4.274**
Inlet 2, Saagar Paas		29.2034	82.96674		16	7.02	0.932	**6.543**
Outlet	28 and 30, May 2019 11:30AM	29.1743	82.93696	1.07	34	16.92	1.069	**18.094**
				1.09	34	17.18	1.075	**18.477**

7.4 Water Quality and Sediment Analysis

The values of concentration of suspended sediment measured at Chholupu Lek intake, and Sagar Lek intake are given in the following table 11 and 12.

Table 11: Suspended sediment, Chholupu Lek Intake

Source: Chholupu Lek, Intake			
Location : Phoksundo Lake	Latitude : 29.21762 degrees		Longitude: 82.942171 degrees
Parameters	Units	Result	Methods used
Sand & Silt	mg/l	3.2	2540 D. ALPHA 23rd EDITION

Table 12: Suspended sediment, Sagar Lek Intake

Source: Sagar Lek Intake Location : Phoksundo Lake	Latitude: 29.20466 degrees		Longitude: 82.965537 degrees
Parameters	Units	Result	Methods used
Sand & Silt	mg/l	3.8	2540 D. ALPHA 23rd EDITION

The following table 13 shows the values of biological properties of Lake Water measured at center of the Lake. All the measured values were found to be within the standard range as specified by National Drinking Water Quality Standard, 2062 (2004) and WHO Guideline Values.

Table 13: Biological Properties of Lake Water

Source: Center of Lake Location : Phoksundo Lake Latitude: 29.198394 degrees Longitude: 82.952359 degrees					
Parameters	Units	WHO GV	NOWQS	Result	Methods used
CHEMICAL					
Dissolved Oxygen	mg/l	>5	>5	5.7	4500-OA, APHA, 23rd EDITION
Biological Oxygen Demand	mg/l	<30	<30	4.7	5210 B., APHA, 23rd EDITION
Chemical Oxygen Demand	mg/l	<250	<250	12	5220 B., APHA, 23rd EDITION

The values of water quality parameters measured at the outlet of lake as given in the table 14 were found to be within the standard range as specified by National Drinking Water Quality Standard, 2062 (2004) and WHO Guideline Values.

Table 14: Chemical Properties of Lake water

Source: Outlet Location : Phoksundo Lake		Latitude 29.174307 degrees			Longitude 82.936966 degrees
Parameters	Units	WHO GV	NDW QS	Result	Methods used
PHYSICAL					
Turbidity	NTU	5	5 (10)	2	2130 B, APHA, 23rd EDITION
Sand & Silt	mg/l			<1.0	2540 D. APHA, 23rdEDITION
CHEMICAL					
Total Hardness	mg/l as CaCO3	500	500	132	2340 C, APHA, 23rd EDITION
Nitrate	mg/l	50	50 (Max)	0.9	4500-NO3- B., APHA, 23rd EDITION
Sulphate	mg/l	250	250 (Max)	41.9	4500-SO4. APHA, 23rd EDITION
Iron	mg/l	0.3	0.3 0	0.04	3111 B, APHA, 23rd EDITION

The laboratory results on water quality and sediment analysis is presented in the **Annex II**.

8. Conclusion and Recommendation

This study concludes that the deepest point of the Lake is **136.20 m**. The echo sounder used for this survey was KODEN CVS 126 of whose frequency of transducer was set at 50 kHz and 200 kHz. This echo sounder has capacity to measure water depth of 2.5 m to 800 m. The bathymetric map of Phoksundo Lake is prepared based on the measured data. The total volume of water stored in the Lake is calculated as 398.73 MCM.

The surface area, perimeter (shoreline), length from Chholupu khola inlet to outlet and Sagar khola inlet to outlet, maximum width and minimum width of the lake are calculated as 4.849 km^2, 18.29km, 5642.042m, 5049.560m, 975.247m and 549.895m respectively.

The topographic map of Phoksundo Lake is prepared showing its shoreline and different locations. L-section and X-section map of Lake is prepared. Similarly, L-section and X-section map of inlet and outlet of Lake are prepared.

The suspended sediment measured at two inlet points are calculated as 3.2 mg/l and 3.8 mg/l respectively. Further study on sedimentation should be essential to calculate the sediment deposition.

Chemical analysis of lake water demonstrated that the measured chemical parameters like, DO, BOD, COD, Nitrate, Iron, Sulphate, total hardness are found to be within standard range as specified by National Drinking Water Quality Standard, 2062 (2004) and WHO Guidelines Values.

Local people are using the lake water for drinking and other domestic purposes.

Discharge measurement carried at the outlet of the Lake shows higher values compared to inlet flow. The high discharge value at lake outlets can be attributed to snowmelt and base flow contributions. Phoksundo Lake is snow and rain- fed lake and sources of water to the lake are small streams originated from the surrounding Himalayas.

The study of snowmelt contribution using snow cover area data and monitoring of hourly/daily water level of lake at the inlet and outlet by establishing automatic water level recorder as well as meteorological stations including snow gauges are necessary for detail investigation.

Routine field investigation to determine water equivalent of snow and snow depth are also recommended.

Additional test for chemical parameters of Lake Water are required.

It is also recommended to produce a leaflet or booklet of Phoksundo incorporating summary of the results of this study.

Annex I

Discharge Sheet

Station No.:		Meas. No.:	3
River No.:	Phoksundo Lake	Computed:	
Location:	Intake	Date:	
Date:	5/29/2019	Checked:	
	Discharge Measurement Notes	Date:	

Width in m:	14.00	Area in m^2:	5.42	Mean velocity in m/s:	0.789	Discharge in m^3/s:	4.274

Party: BJ Counter No.: Meter No.: Price Type 622 Rated on:

Weight: Distance from currentmeter to the bottom of the weight in m:

Location of measuring site: m. upstream/downstream of gauge

Time			7:10		7:50			Weather:
G. Ht.								

Mean Gauge height: Air temperature: Water temperature:

Remarks:

5 Verticals >10 % of Discharge

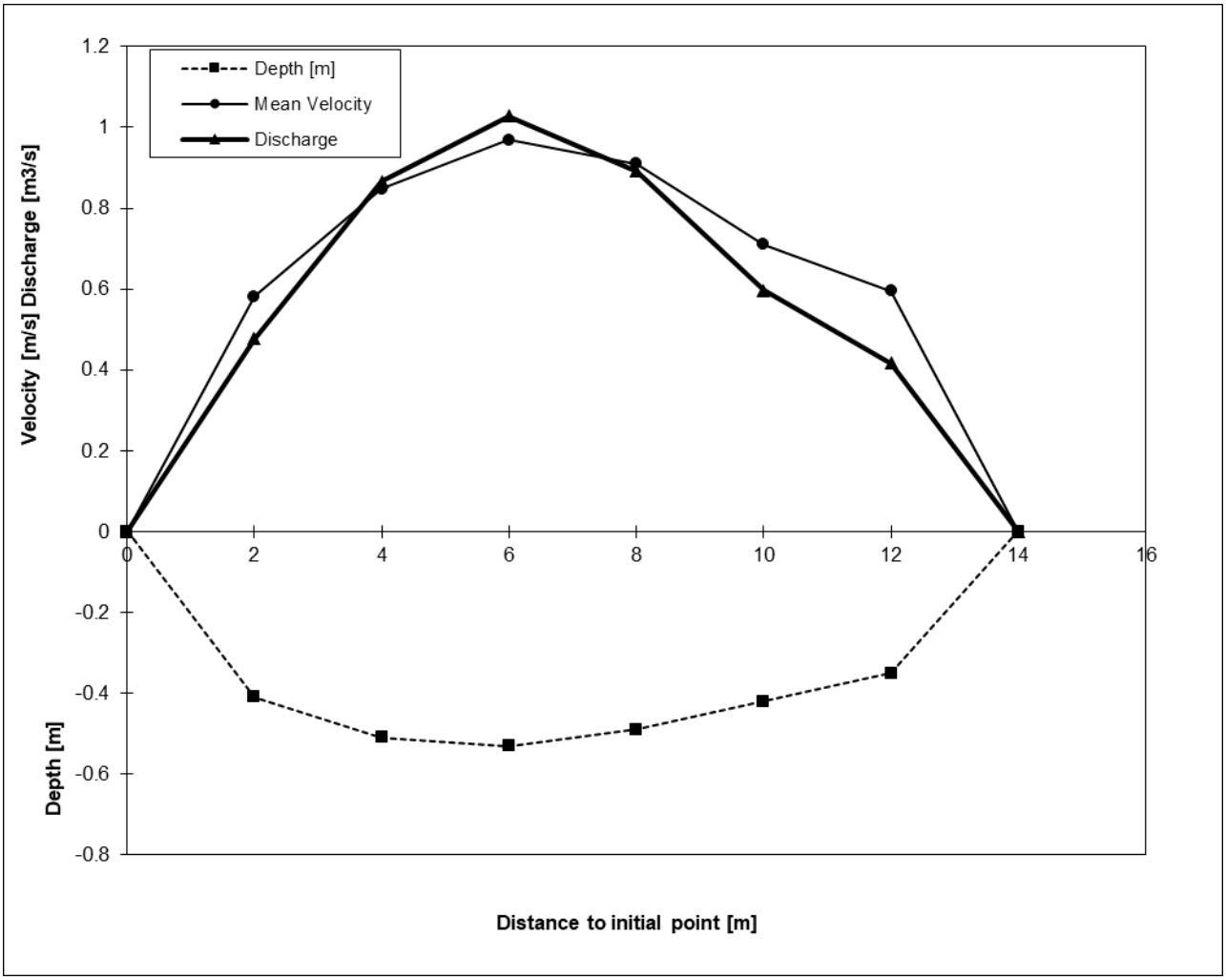
0 Verticals with missing angle correction

Vert. angle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coeff. f1	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.997	0.996	0.995	0.994	0.993	0.991	0.990	0.989
Coeff. f2	0.000	0.001	0.001	0.002	0.004	0.005	0.007	0.010	0.012	0.015	0.019	0.022	0.026	0.030	0.035

Coefficients f1, f2 for vertical angle correction

Vert. angle	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Coeff. f1	0.987	0.985	0.984	0.982	0.980	0.978	0.976	0.973	0.971	0.969	0.966	0.963	0.961	0.958	0.955
Coeff. f2	0.040	0.045	0.051	0.057	0.063	0.070	0.077	0.084	0.092	0.100	0.109	0.118	0.127	0.137	0.148

Ser No.	Dist. to initial point	Width	Height	Meas. depth	Vert. angle	Obs. Depth	Rev	Time	Vel. at point	Mean vel.	Hor. angle coeff.	Vert. angle coeff. f1	Meas. depth *f1 (13*5)	Vert. angle coeff. f2	Height *f2 (15*4)	Adj. depth (14-16)	Area (17*3)	Discharge (11*18*12)
	m	m	m	m	deg	m		sec	m/s	m/s			m		m	m	m2	m3/s
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.0	1.00	1.00	0.00	0.0	0.6	0	0			1.000	1.000	0.000	0.000	0.00	0.00	0.00	
2	2.0	2.00	1.00	0.41	0.0	0.6	35	41	0.581	0.581	1.000	1.000	0.410	0.000	0.00	0.41	0.82	0.477
3	4.0	2.00	1.00	0.51	0.0	0.6	50	40	0.848	0.848	1.000	1.000	0.510	0.000	0.00	0.51	1.02	0.865
4	6.0	2.00	1.00	0.53	0.0	0.6	60	42	0.969	0.969	1.000	1.000	0.530	0.000	0.00	0.53	1.06	1.028
5	8.0	2.00	1.00	0.49	0.0	0.6	55	41	0.910	0.910	1.000	1.000	0.490	0.000	0.00	0.49	0.98	0.892
6	10.0	2.00	1.00	0.42	0.0	0.6	45	43	0.710	0.710	1.000	1.000	0.420	0.000	0.00	0.42	0.84	0.596
7	12.0	2.00	1.00	0.35	0.0	0.6	35	40	0.595	0.595	1.000	1.000	0.350	0.000	0.00	0.35	0.70	0.417
8	14.0	1.00	1.00	0.00	0.0	0.6	0	0			1.000	1.000	0.000	0.000	0.00	0.00	0.00	
										0.789							5.42	4.274


Depth [m]
Mean Velocity
Discharge
Velocity [m/s] Discharge [m3/s]
Depth [m]
Distance to initial point [m]
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
2
4
6
8
10
12
14
16

Station No.:		Meas. No.:	4
River No.:	Phoksundo Lake	Computed:	
Location:	Saagar Paas Intake	Date:	
Date:	5/29/2019	Checked:	
		Date:	

Discharge Measurement Notes

Width in m:	16.00	Area in m^2:	7.02	Mean velocity in m/s:	0.932	Discharge in m^3/s:	6.543

Party: BJ Counter No.: Meter No.: Price Type 622 Rated on:

Weight: Distance from currentmeter to the bottom of the weight in m:

Location of measuring site: m. upstream/downstream of gauge

Time			9:30		10:00			Weather:
G. Ht.								

Mean Gauge height: Air temperature: Water temperature:

Remarks:

6 Verticals >10 % of Discharge

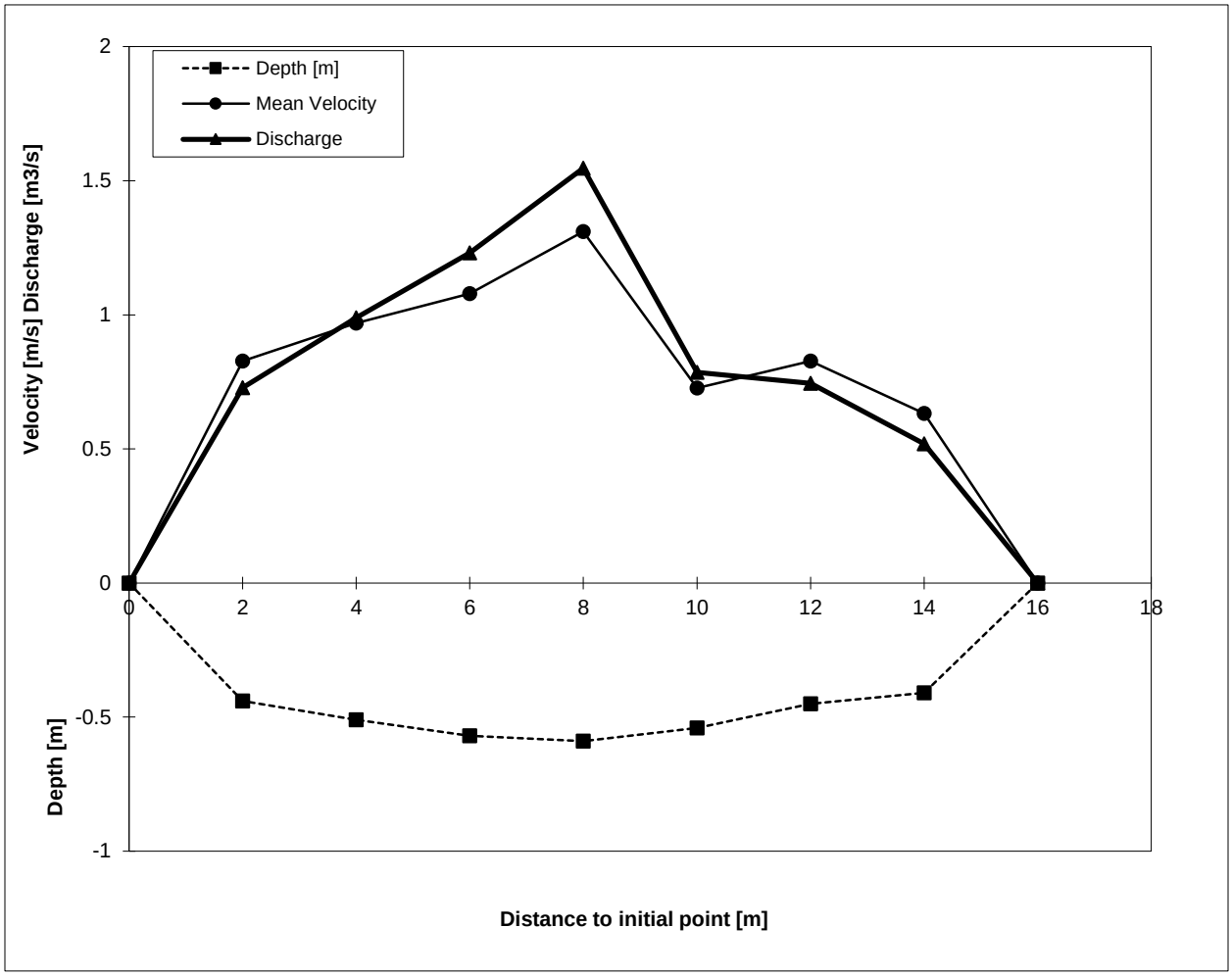
0 Verticals with missing angle correction

Vert. angle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coeff. f1	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.997	0.996	0.995	0.994	0.993	0.991	0.990	0.989
Coeff. f2	0.000	0.001	0.001	0.002	0.004	0.005	0.007	0.010	0.012	0.015	0.019	0.022	0.026	0.030	0.035

Coefficients f1, f2 for vertical angle correction

Vert. angle	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Coeff. f1	0.987	0.985	0.984	0.982	0.980	0.978	0.976	0.973	0.971	0.969	0.966	0.963	0.961	0.958	0.955
Coeff. f2	0.040	0.045	0.051	0.057	0.063	0.070	0.077	0.084	0.092	0.100	0.109	0.118	0.127	0.137	0.148

Ser No.	Dist. to initial point m	Width m	Height m	Meas. depth m	Vert. angle deg	Obs. Depth m	Rev	Time sec	Vel. at point m/s	Mean vel. m/s	Hor. angle coeff.	Vert. angle coeff. f1	Meas. depth *f1 (13*5) m	Vert. angle coeff. f2	Height *f2 (15*4) m	Adj. depth (14-16) m	Area (17*3) m2	Discharge (11*18*12) m3/s
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.0	1.00	1.00	0.00	0.0	0.6	0	0			1.000	1.000	0.000	0.000	0.00	0.00	0.00	
2	2.0	2.00	1.00	0.44	0.0	0.6	50	41	0.827	0.827	1.000	1.000	0.440	0.000	0.00	0.44	0.88	0.728
3	4.0	2.00	1.00	0.51	0.0	0.6	60	42	0.969	0.969	1.000	1.000	0.510	0.000	0.00	0.51	1.02	0.989
4	6.0	2.00	1.00	0.57	0.0	0.6	70	44	1.080	1.080	1.000	1.000	0.570	0.000	0.00	0.57	1.14	1.231
5	8.0	2.00	1.00	0.59	0.0	0.6	85	44	1.311	1.311	1.000	1.000	0.590	0.000	0.00	0.59	1.18	1.547
6	10.0	2.00	1.00	0.54	0.0	0.6	45	42	0.727	0.727	1.000	1.000	0.540	0.000	0.00	0.54	1.08	0.785
7	12.0	2.00	1.00	0.45	0.0	0.6	50	41	0.827	0.827	1.000	1.000	0.450	0.000	0.00	0.45	0.90	0.745
8	14.0	2.00	1.00	0.41	0.0	0.6	40	43	0.632	0.632	1.000	1.000	0.410	0.000	0.00	0.41	0.82	0.518
9	16.0	1.00	1.00	0.00	0.0	0.6	0	0			1.000	1.000	0.000	0.000	0.00	0.00	0.00	
										0.932							7.02	6.543


Depth [m]
Mean Velocity
Discharge
Velocity [m/s] Discharge [m3/s]
Depth [m]
Distance to initial point [m]
2
1.5
1
0.5
0
-0.5
-1
0
2
4
6
8
10
12
14
16
18

Station No.:		Meas. No.:	1
River No.:	Phoksundo Lake	Computed:	
Location:	Outlet	Date:	
Date:	019/05/28	Checked:	
		Date:	

Discharge Measurement Notes

Width in m:	34.00	Area in m^2:	16.92	Mean velocity in m/s:	1.069	Discharge in m^3/s:	18.094

Party: BJ Counter No.: Meter No.: Price Type 622 Rated on:

Weight: Distance from currentmeter to the bottom of the w eight in m:

Location of measuring site: m. upstream/dow nstream of gauge

Time			11:20		12:05		
G. Ht.			1.07				

Weather:

Mean Gauge height: 1.07 Air temperature: Water temperature:

Remarks:

1 Verticals >10 % of Discharge

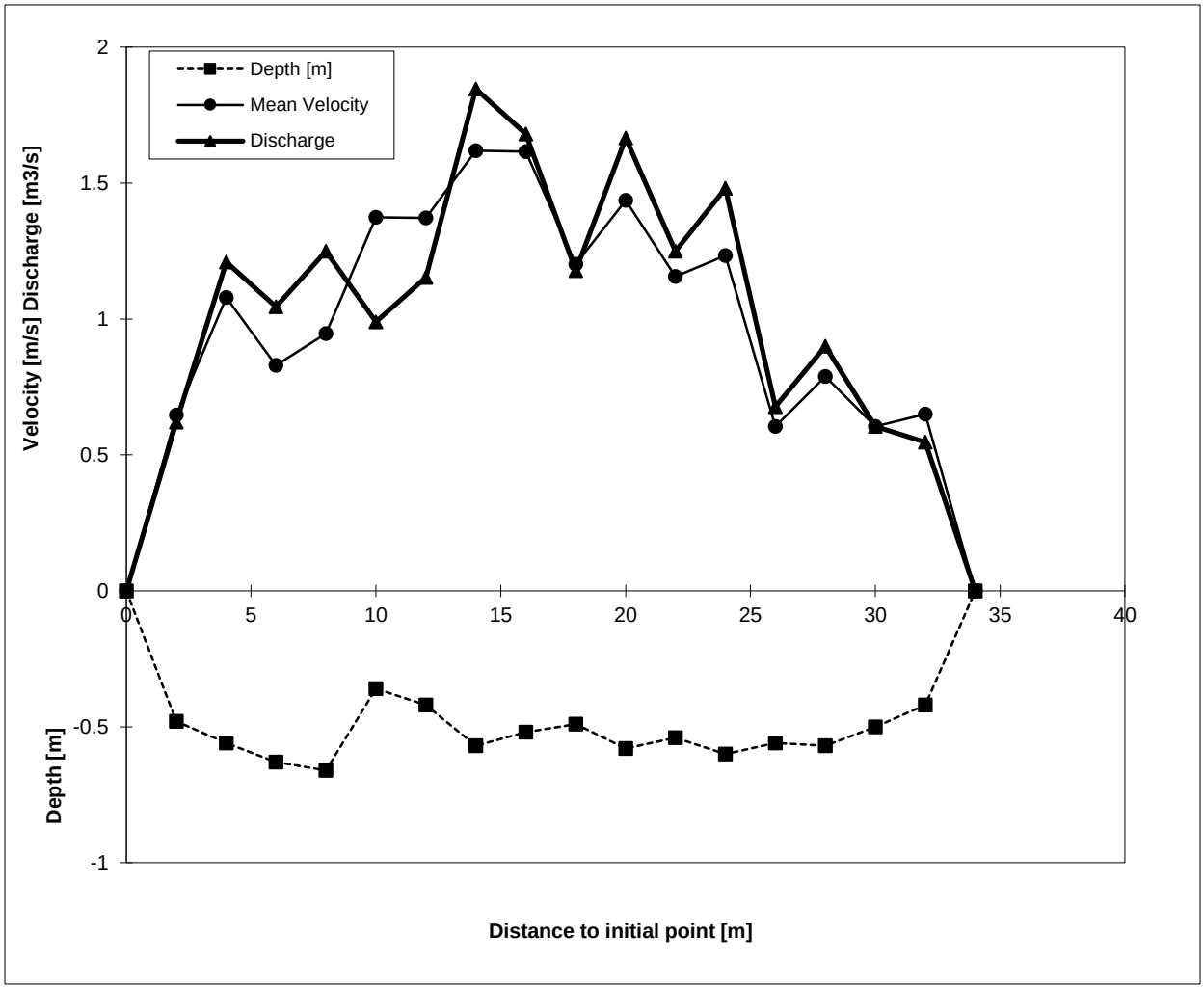
0 Verticals w ith missing angle correction

Vert. angle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coeff. f1	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.997	0.996	0.995	0.994	0.993	0.991	0.990	0.989
Coeff. f2	0.000	0.001	0.001	0.002	0.004	0.005	0.007	0.010	0.012	0.015	0.019	0.022	0.026	0.030	0.035

Coefficients f1, f2 for vertical angle correction

Vert. angle	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Coeff. f1	0.987	0.985	0.984	0.982	0.980	0.978	0.976	0.973	0.971	0.969	0.966	0.963	0.961	0.958	0.955
Coeff. f2	0.040	0.045	0.051	0.057	0.063	0.070	0.077	0.084	0.092	0.100	0.109	0.118	0.127	0.137	0.148

Height	Meas. depth	Vert. angle	Obs. Depth	Rev	Time	Vel. at point	Mean vel.	Hor. angle coeff.	Vert. angle coeff. f1	Meas. depth *f1 (13*5)	Vert. angle coeff. f2	Height *f2 (15*4)	Adj. depth (14-16)	Area (17*3)	Discharge (11*18*12)
m	m	deg	m		sec	m/s	m/s			m		m	m	m2	m3/s
4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.00	0.00	0.0	0.6	0	0			1.000	1.000	0.000	0.000	0.00	0.00	0.00	
1.00	0.48	0.0	0.6	40	42	0.647	0.647	1.000	1.000	0.480	0.000	0.00	0.48	0.96	0.621
1.00	0.56	0.0	0.6	70	44	1.080	1.080	1.000	1.000	0.560	0.000	0.00	0.56	1.12	1.209
1.00	0.63	0.0	0.6	55	45	0.829	0.829	1.000	1.000	0.630	0.000	0.00	0.63	1.26	1.045
1.00	0.66	0.0	0.6	60	43	0.947	0.947	1.000	1.000	0.660	0.000	0.00	0.66	1.32	1.250
1.00	0.36	0.0	0.6	85	42	1.374	1.374	1.000	1.000	0.360	0.000	0.00	0.36	0.72	0.989
1.00	0.42	0.0	0.6	95	47	1.372	1.372	1.000	1.000	0.420	0.000	0.00	0.42	0.84	1.153
1.00	0.57	0.0	0.6	105	44	1.619	1.619	1.000	1.000	0.570	0.000	0.00	0.57	1.14	1.846
1.00	0.52	0.0	0.6	100	42	1.616	1.616	1.000	1.000	0.520	0.000	0.00	0.52	1.04	1.680
1.00	0.49	0.0	0.6	85	48	1.202	1.202	1.000	1.000	0.490	0.000	0.00	0.49	0.98	1.178
1.00	0.58	0.0	0.6	110	52	1.436	1.436	1.000	1.000	0.580	0.000	0.00	0.58	1.16	1.666
1.00	0.54	0.0	0.6	75	44	1.157	1.157	1.000	1.000	0.540	0.000	0.00	0.54	1.08	1.249
1.00	0.60	0.0	0.6	80	44	1.234	1.234	1.000	1.000	0.600	0.000	0.00	0.60	1.20	1.481
1.00	0.56	0.0	0.6	40	45	0.605	0.605	1.000	1.000	0.560	0.000	0.00	0.56	1.12	0.677
1.00	0.57	0.0	0.6	50	43	0.789	0.789	1.000	1.000	0.570	0.000	0.00	0.57	1.14	0.899
1.00	0.50	0.0	0.6	40	45	0.605	0.605	1.000	1.000	0.500	0.000	0.00	0.50	1.00	0.605
1.00	0.42	0.0	0.6	45	47	0.650	0.650	1.000	1.000	0.420	0.000	0.00	0.42	0.84	0.546
1.00	0.00	0.0	0.6	0	0			1.000	1.000	0.000	0.000	0.00	0.00	0.00	
							1.069							16.92	18.094


Depth [m]
Mean Velocity
Discharge
Velocity [m/s] Discharge [m3/s]
Depth [m]
Distance to initial point [m]
2
1.5
1
0.5
0
-0.5
-1
0
5
10
15
20
25
30
35
40

Station No.:		Meas. No.:	2
River No.:	Phoksundo Lake	Computed:	
Location:	Outlet	Date:	
Date:	5/30/2019	Checked:	
		Date:	

Discharge Measurement Notes

Width in m:	34.00	Area in m^2:	17.18	Mean velocity in m/s:	1.075	Discharge in m^3/s:	18.477

Party: BJ Counter No.: Meter No.: Price Type 622 Rated on:

Weight: Distance from current meter to the bottom of the weight in m:

Location of measuring site: m. upstream/downstream of gauge

Time			12:00		1:15			Weather:
G. Ht.			1.09					

Mean Gauge height: 1.09 Air temperature: Water temperature:

Remarks:

0 Verticals >10 % of Discharge

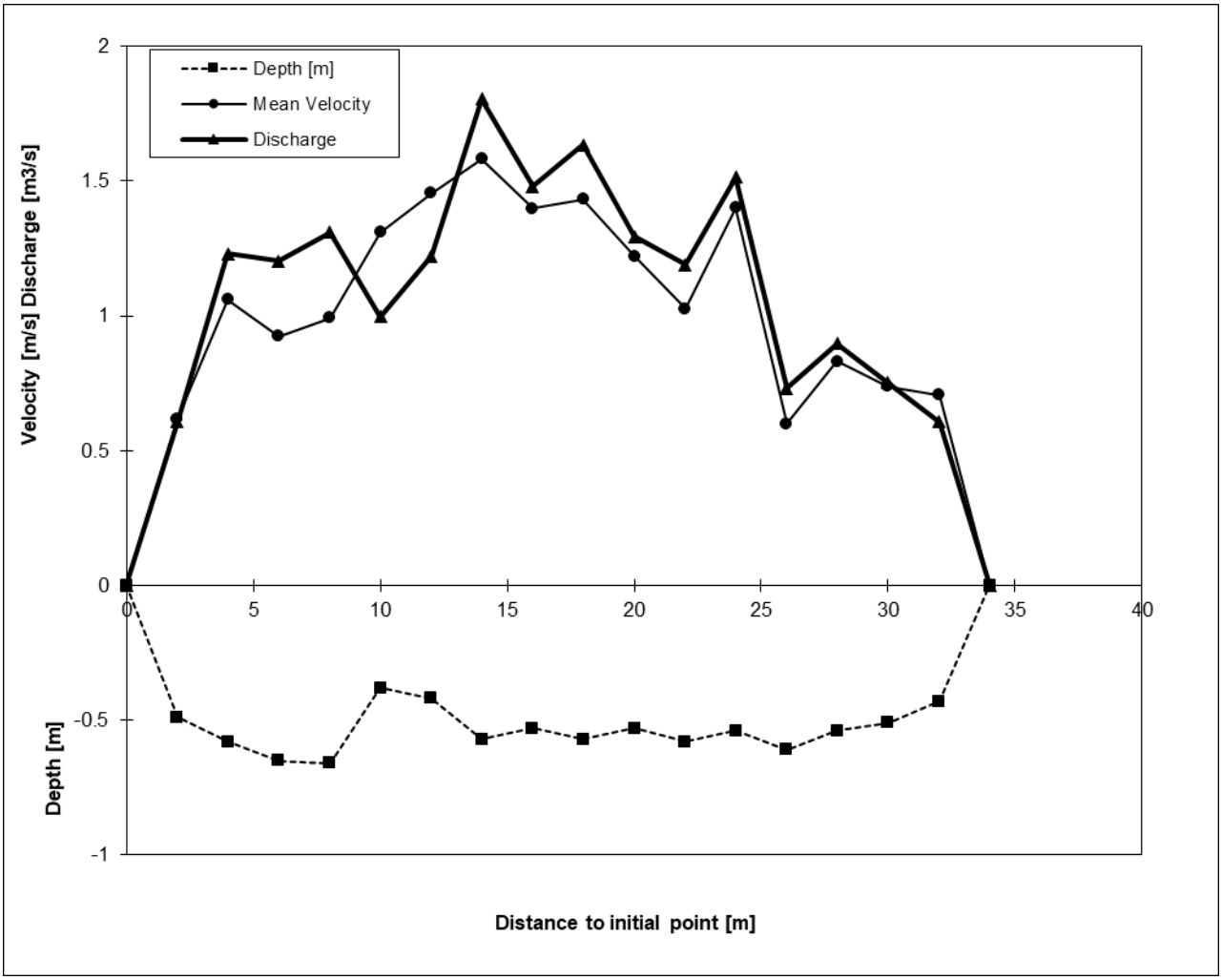
0 Verticals with missing angle correction

Vert. angle	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Coeff. f1	1.000	1.000	1.000	0.999	0.999	0.998	0.998	0.997	0.996	0.995	0.994	0.993	0.991	0.990	0.989
Coeff. f2	0.000	0.001	0.001	0.002	0.004	0.005	0.007	0.010	0.012	0.015	0.019	0.022	0.026	0.030	0.035

Coefficients f1, f2 for vertical angle correction

Vert. angle	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Coeff. f1	0.987	0.985	0.984	0.982	0.980	0.978	0.976	0.973	0.971	0.969	0.966	0.963	0.961	0.958	0.955
Coeff. f2	0.040	0.045	0.051	0.057	0.063	0.070	0.077	0.084	0.092	0.100	0.109	0.118	0.127	0.137	0.148

Height	Meas. depth	Vert. angle	Obs. Depth	Rev	Time	Vel. at point	Mean vel.	Hor. angle coeff.	Vert. angle coeff. f1	Meas. depth *f1 (13*5)	Vert. angle coeff. f2	Height *f2 (15*4)	Adj. depth (14-16)	Area (17*3)	Discharge (11*18*12)
m	m	deg	m		sec	m/s	m/s			m		m	m	m2	m3/s
4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1.00	0.00	0.0	0.6	0	0			1.000	1.000	0.000	0.000	0.00	0.00	0.00	
1.00	0.49	0.0	0.6	40	44	0.618	0.618	1.000	1.000	0.490	0.000	0.00	0.49	0.98	0.606
1.00	0.58	0.0	0.6	75	48	1.060	1.060	1.000	1.000	0.580	0.000	0.00	0.58	1.16	1.230
1.00	0.65	0.0	0.6	60	44	0.925	0.925	1.000	1.000	0.650	0.000	0.00	0.65	1.30	1.203
1.00	0.66	0.0	0.6	60	41	0.993	0.993	1.000	1.000	0.660	0.000	0.00	0.66	1.32	1.311
1.00	0.38	0.0	0.6	85	44	1.311	1.311	1.000	1.000	0.380	0.000	0.00	0.38	0.76	0.996
1.00	0.42	0.0	0.6	90	42	1.455	1.455	1.000	1.000	0.420	0.000	0.00	0.42	0.84	1.222
1.00	0.57	0.0	0.6	105	45	1.583	1.583	1.000	1.000	0.570	0.000	0.00	0.57	1.14	1.805
1.00	0.53	0.0	0.6	105	51	1.398	1.398	1.000	1.000	0.530	0.000	0.00	0.53	1.06	1.482
1.00	0.57	0.0	0.6	95	45	1.433	1.433	1.000	1.000	0.570	0.000	0.00	0.57	1.14	1.634
1.00	0.53	0.0	0.6	90	50	1.221	1.221	1.000	1.000	0.530	0.000	0.00	0.53	1.06	1.295
1.00	0.58	0.0	0.6	65	43	1.026	1.026	1.000	1.000	0.580	0.000	0.00	0.58	1.16	1.190
1.00	0.54	0.0	0.6	95	46	1.402	1.402	1.000	1.000	0.540	0.000	0.00	0.54	1.08	1.514
1.00	0.61	0.0	0.6	45	51	0.600	0.600	1.000	1.000	0.610	0.000	0.00	0.61	1.22	0.732
1.00	0.54	0.0	0.6	60	49	0.831	0.831	1.000	1.000	0.540	0.000	0.00	0.54	1.08	0.897
1.00	0.51	0.0	0.6	50	46	0.738	0.738	1.000	1.000	0.510	0.000	0.00	0.51	1.02	0.752
1.00	0.43	0.0	0.6	50	48	0.707	0.707	1.000	1.000	0.430	0.000	0.00	0.43	0.86	0.608
1.00	0.00	0.0	0.6	0	0			1.000	1.000	0.000	0.000	0.00	0.00	0.00	
							1.075							17.18	18.477


Depth [m]
Mean Velocity
Discharge
Velocity [m/s] Discharge [m3/s]
Depth [m]
Distance to initial point [m]
2
1.5
1
0.5
0
-0.5
-1
0
5
10
15
20
25
30
35
40

Annex II
Water Quality and Sediment Analysis

NS Lab Accreditation No.: 08/065-66
VAT/PAN No.: 300124309
Regd. No. 5180/052/053

"Training For Success"

SAVE WATER

Water Engineering & Training Centre (P.) Ltd.

Tel : 977-1-4475674, 4418156
Fax No: 977-1-4479642

Laboratory, R & D on Total Water Management, Treatment & Consultancy

Test Report/Certificate

WATER ENGINEERING & TRAINING CENTER (P) LTD. DILLIBAZAR 2048

Name of Sender: NHM Research Centre				**Source: Sagar Lake Intake**	
Sample No: 4144 /075/076				**Analyzed date : 09/06/2019 - 15/06/2019**	
Date of Receipt: 09/06/2019				**No. of Samples: 01**	
Sampled by : Client				**Location : Phoksundo Lake**	
Parameters	**Units**	**WHO GV**	**NDWQS**	**Result**	**Methods used**
PHYSICAL					
Sand & Silt	mg/l	-	-	**3.8**	2540 D. APHA, 23rd EDITION

APHA: American Public Health Association, Standard Methods for the Examination of Water & Waste Water,
WHO GV: World Health Organization Guideline Value, 2006 Update, NDWQS: National Drinking Water Quality Standard, 2062 (Nepal),
* These values show lower and upper limits, () Values in the parenthesis refers the acceptable values only when alternative is not available.

WATER ENGINEERING & TRAINING CENTRE (P.) LTD. SAVE WATER, SAFE WATER 2048

Nepal Laboratory Accreditation Scheme Accredited Laboratory

Analyzed by *Checked by* *Authorized Signature*

Note: 1. The result refer only to the parameters tested of the samples provided to our laboratory or collected by us for analysis as specified. Endorsement of the product is neither inferred nor implied.
2. Any duplication of this report can not be used as evidence in the court of law and should not be used in any advertising media without prior written permission to us.
3. The total liability of our company for the product is limited to the invoiced amount only.

132, Ratopul, P O Box # 8975 EPC 5205, Kathmandu, Nepal. E-mail : info@wetcpl.com.np, wetcpl@gmail.com

NS Lab Accreditation No.: 08/065-66
VAT/PAN No.: 300124309
Regd. No. 5180/052/053

"Training For Success"

SAVE WATER

Water
Engineering & Training Centre (P.) Ltd.

Tel : 977-1-4475674, 4418156
Fax No: 977-1-4479642

Laboratory. R & D on Total Water Management, Treatment & Consultancy

Test Report/Certificate

WATER ENGINEERING & TRAINING CENTER (P.) LTD. DILLIBAZAR 2048

Name of Sender: NHM Research Centre				**Source: Chholupu Lake Intake**	
Sample No: 4143 /075/076				**Analyzed date : 09/06/2019 - 15/06/2019**	
Date of Receipt: 09/06/2019				**No. of Samples: 01**	
Sampled by : Client				**Location : Phoksundo Lake**	
Parameters	**Units**	**WHO GV**	**NDWQS**	**Result**	**Methods used**
PHYSICAL					
Sand & Silt	mg/l	-	-	**3.2**	2540 D. APHA, 23rd EDITION

APHA: American Public Health Association, Standard Methods for the Examination of Water & Waste Water,
WHO GV: World Health Organization Guideline Value, 2006 Update, NDWQS: National Drinking Water Quality Standard, 2062 (Nepal),
* These values show lower and upper limits, () Values in the parenthesis refers the acceptable values only when alternative is not available.

WATER ENGINEERING & TRAINING CENTRE (P.) LTD. • SAVE WATER, SAFE WATER • 2048 •

Nepal Laboratory Accreditation Scheme — Accredited Laboratory No. L-365-66

Analyzed by *Checked by* *Authorized Signature*

Note: 1. The result refer only to the parameters tested of the samples provided to our laboratory or collected by us for analysis as specified. Endorsement of the product is neither inferred nor implied.
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3. The total liability of our company for the product is limited to the invoiced amount only.

132, Ratopul, P O Box # 8975 EPC 5205, Kathmandu, Nepal. E-mail : info@wetcpl.com.np, wetcpl@gmail.com

NS Lab Accreditation No.: 08/065-66
VAT/PAN No.: 300124309
Regd. No. 5180/052/053

"Training For Success"

SAVE WATER

Water Engineering & Training Centre (P.) Ltd.

Tel : 977-1-4475674, 4418156
Fax No: 977-1-4479642

Laboratory. R & D on Total Water Management, Treatment & Consultancy

Test Report/Certificate

Name of Sender: NHM Research Centre	**Source: Center of Lake**
Sample No: 4145 /075/076	**Analyzed date : 09/06/2019 - 17/06/2019**
Date of Receipt: 09/06/2019	**No. of Samples: 01**
Sampled by : Client	**Location : Phoksundo Lake**

Parameters	Units	WHO GV	NDWQS	Result	Methods used
CHEMICAL					
Dissolved Oxygen	mg/l	-	-	**5.7**	4500-O A, APHA, 23rd EDITION
Biochemical Oxygen Demand (BOD)	mg/l	-	-	**4.7**	5210 B., APHA, 23rd EDITION
Chemical Oxygen Demand (COD)	mg/l	-	-	**12.0**	5220 B., APHA, 23rd EDITION

APHA: American Public Health Association, Standard Methods for the Examination of Water & Waste Water,
WHO GV: World Health Organization Guideline Value, 2006 Update, NDWQS: National Drinking Water Quality Standard, 2062 (Nepal),
* These values show lower and upper limits, () Values in the parenthesis refers the acceptable values only when alternative is not available.

Analyzed by *Checked by* *Authorized Signature*

Note: 1. The result refer only to the parameters tested of the samples provided to our laboratory or collected by us for analysis as specified. Endorsement of the product is neither inferred nor implied.
2. Any duplication of this report can not be used as evidence in the court of law and should not be used in any advertising media without prior written permission to us.
3. The total liability of our company for the product is limited to the invoiced amount only.

132, Ratopul, P O Box # 8975 EPC 5205, Kathmandu, Nepal. E-mail : info@wetcpl.com.np, wetcpl@gmail.com

NS Lab Accreditation No.: 08/065-66
VAT/PAN No.: 300124309
Regd. No. 5180/052/053

"Training For Success"

SAVE WATER

Water

Engineering & Training Centre (P.) Ltd.

Tel : 977-1-4475674, 4418156
Fax No: 977-1-4479642

Laboratory. R & D on Total Water Management, Treatment & Consultancy

Test Report/Certificate

WATER ENGINEERING & TRAINING CENTER (P.) LTD. BULLIBAZAR 2048

Name of Sender: NHM Research Centre	**Source: Outlet of Lake**
Sample No: 4146 /075/076	**Analyzed date : 09/06/2019 - 17/06/2019**
Date of Receipt: 09/06/2019	**No. of Samples: 01**
Sampled by : Client	**Location : Phoksundo Lake**

Parameters	Units	WHO GV	NDWQS	Result	Methods used
		PHYSICAL			
Turbidity	NTU	5	5 (10)	**2.0**	2130 B, APHA, 23rd EDITION
Sand & Silt	mg/l	-	-	**<1.0**	2540 D. APHA, 23rd EDITION
		CHEMICAL			
Total Hardness	mg/l as $CaCO_3$	500	500	**132.0**	2340 C, APHA, 23rd EDITION
Nitrate	mg/l	50	50 (Max)	**0.9**	4500-NO3- B., APHA, 23rd EDITION
Sulphate	mg/l	-	250 (Max)	**41.9**	4500-SO4. APHA, 23rd EDITION
Iron	mg/l	0.3	0.3 (3)	**0.04**	3111 B, APHA, 23rd EDITION
Dissolved Oxygen	mg/l	-	-	**5.7**	4500-O A, APHA, 23rd EDITION
Biochemical Oxygen Demand (BOD)	mg/l	-	-	**3.3**	5210 B., APHA, 23rd EDITION
Chemical Oxygen Demand (COD)	mg/l	-	-	**8.0**	5220 B., APHA, 23rd EDITION

APHA: American Public Health Association, Standard Methods for the Examination of Water & Waste Water,
WHO GV: World Health Organization Guideline Value, 2006 Update, NDWQS: National Drinking Water Quality Standard, 2062 (Nepal),
* These values show lower and upper limits, () Values in the parenthesis refers the acceptable values only when alternative is not available.

Comment: The tested physical and chemical parameters are within WHO guideline value.

Nepal Laboratory Accreditation Scheme — Accredited Laboratory No. 065-66

Analyzed by *Checked by* *Authorized Signature*

Note: 1. The result refer only to the parameters tested of the samples provided to our laboratory or collected by us for analysis as specified. Endorsement of the product is neither inferred nor implied.
2. Any duplication of this report can not be used as evidence in the court of law and should not be used in any advertising media without prior written permission to us.
3. The total liability of our company for the product is limited to the invoiced amount only.

132, Ratopul, P O Box # 8975 EPC 5205, Kathmandu, Nepal. E-mail : info@wetcpl.com.np, wetcpl@gmail.com

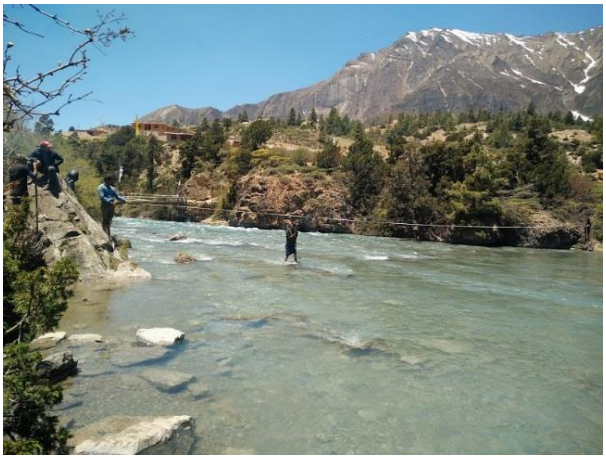
Annex III

Field Photographs

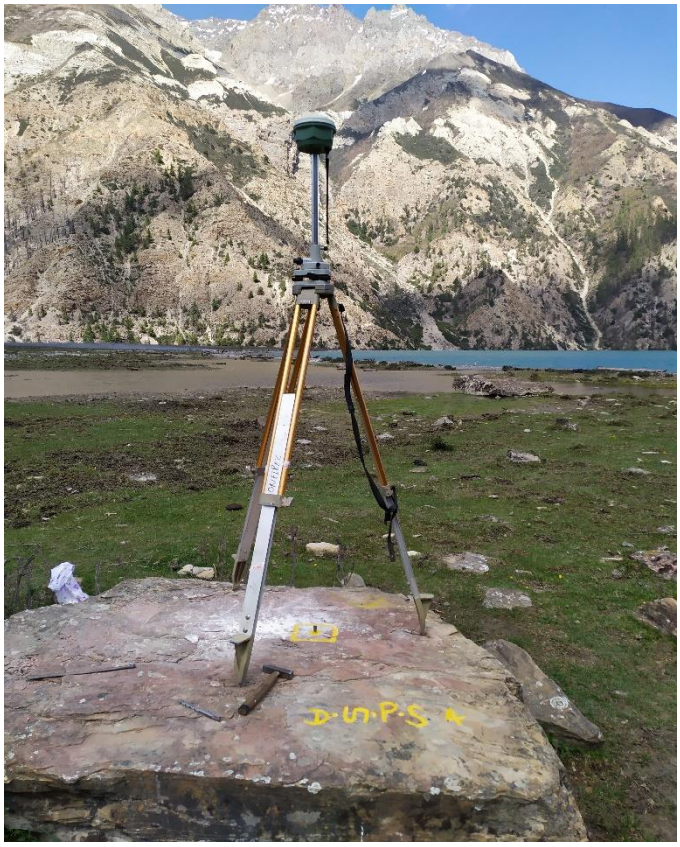
Performing ritual Pooja by Lama Guru with local people before starting Bathymetric Survey of Phoksundo Lake

Inauguration of Boat in Lake with Lama

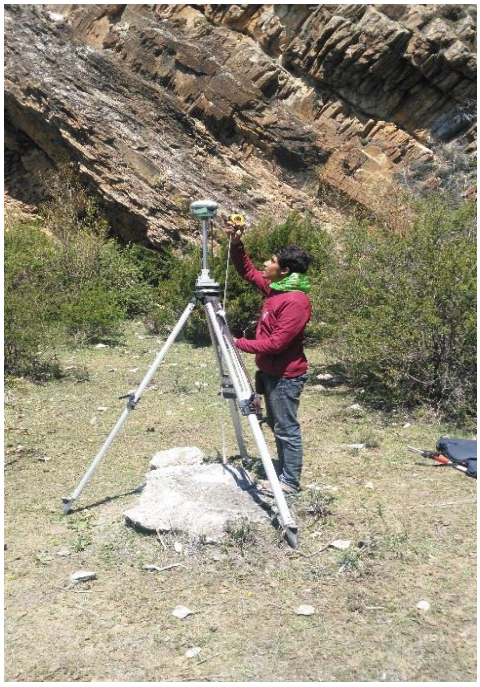
Discharge measurement

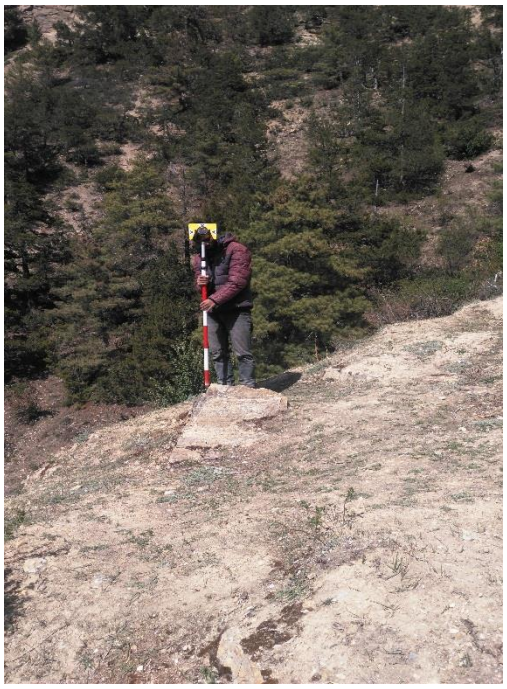


Discharge measurement



Establishing Benchmark in permanent boulder near the Lake





Conducting survey using total station

Conducting survey of the lake using rover

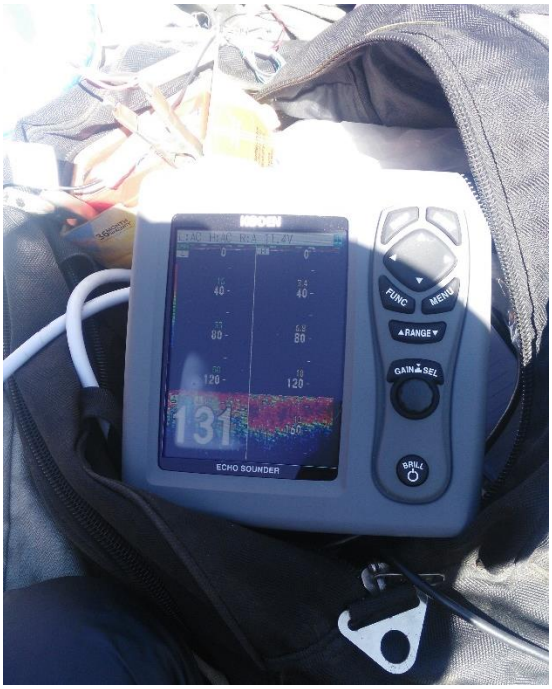
Conducting survey of the lake

Bathymetric survey with Chairman of Shey Phoksundo Ward No. 8

Obstruction on bathymetric survey due to strong wind and sitting nearby fire

Communicating through Walkie Talkie in the village

Conducting Bathymetric Survey with DHM Expert



Depth of the lake shown by echo-sounder

Highest Depth of the Phoksundo Lake Observed by Echo Sounder during the Bathymetric Survey

Annex IV

Instrument Specification:

Echo Sounder

Model	CVS-126	CVS-128
Output power (RMS)	600 W	600W or 1kW
Output frequency	50 kHz and 200 kHz	
Output method	Single or Alternate	
Display size and type	5.7 inch color TFT LCD	8.4 inch color TFT LCD
Display resolution	320 x 240 pixels (QVGA)	640 x 480 pixels (VGA)
Basic range	2.5 to 800 (m), 10 to 2800 (ft), 2.5 to 600 (fm / l. fm) (8 ranges can be set to users choice)	2.5 to 1200 (m), 10 to 3600 (ft), 2.5 to 700 (fm / l. fm) (8 ranges can be set to users choice)
Zoom range	2.5 to 200 (m), 10 to 650 (ft), 2.5 to 150 (fm / l. fm)	
Range unit	m, ft, fm, l. fm	
Shift step	1m, 10m, 1/8, 1/4	
Presentation modes	High frequency, Low frequency, Dual frequency, Zoom image (Bottom lock, Bottom discrimination, Bottom zoom, Zoom, Bottom follow zoom), Nav mode, Vertical split, Horizontal split, A-scope can be displayed at all above modes	
Presentation colors	64 colors, 16 colors, 8 colors, Monochrome	
Back ground color	Marine blue, Blue, Black, White, Nighttime color, Other 5 colors	
Alarms	Bottom, Fish, Temperature *, Speed**, Arrival***, XTE ***	
Image speed	9 steps & stop	
Functions	Interference rejection, Color rejection, VRM, Noise rejection, White line, Draft correct, Water temperature correct, Boat speed correct, Store image (10 images), Sona-Tone™, Fishing Hot Spot, Event memory, Simple plotter, Panel illumination, Power reduction, Fish information, Detection area display etc.	
Auto functions	Range, Shift, Gain	
Language	Traditional Chinese, English, French, Greek, Italian, Japanese, Korean, Spanish, Thai, Danish, (Simplified Chinese CVS-128 only)	
Input data format and sentences	NMEA0183 Ver.1.5 / 2.0 / 3.0	
	GGA, GLL, HDT, MTW, MWV, RMC, VHW, VTG, ZDA	
Output data format and sentences	NMEA0183 Ver.2.0 (DBT: Ver.1.5)	
	DBT, DPT, GGA, GLL, HDT, MTW, MWV, RMC, TLL, VHW, VTG, ZDA	
NMEA port(s)	Total 1 : input and output	
Power supply	10.8 to 31.2 V DC	

GPS

DGPS

Surveying Performance	**T66**
Channel	220 Channels
Signal Tracking	BDS B1, B2, B3
	GPS L1C/A, L1C, L2C, L2E, L5
	GLONASS L1C/A, L1P, L2C/A, L2P, L3
	SBAS L1C/A, L5 (only for the satellites supporting L5)
	Galileo GIOVE-A, GIOVE-B, E1, E5A, E5B
	QZSS, WAAS, MSAS, EGNOS, GAGAN, SBAS
GNSS Features	Positioning output rate: 1Hz~50Hz
	Initialization time: < 10s
	Initialization reliability: >99.99%
Positioning Precision	
Code Differential GNSS	Horizontal: ±0.25 m + 1 ppm
Positioning	Vertical: ±0.50 m + 1 ppm
	SBAS positioning accuracy: typically<5m 3DRMS
Static GNSS Surveying	Horizontal: ±2.5 mm + 0.5 ppm

	Vertical: ±5 mm + 0.5 ppm
Real-Time Kinematic Surveying	Horizontal: ±8 mm + 1 ppm
(Baseline<30km)	Vertical: ±15 mm + 1 ppm
Network RTK	Horizontal: ±8 mm + 0.5 ppm
	Vertical: ±15 mm + 0.5 ppm
	RTK initialization time: 2~8s
Physical	
Dimension	12.9 cm X 11.2cm
Weight	970g (including installed battery)
Material	Magnesium aluminum alloy shell
Environmental	
Operating	-45℃ ~ +60℃
Storage	-55℃ ~ +85℃
Humidity	Non-condensing
Waterproof/Dustproof	IP67 standard, protected from long time immersion to depth of 1m
	IP67 standard, fully protected against blowing dust
Shock and Vibration	OFF Status: Withstand 2 meters pole drop onto the cement ground naturally.
	ON Status: Withstand 40G 10 milliseconds sawtooth wave impact test.
Electrical	
Power Consumption	2W
Battery	Rechargeable, removable Lithium-ion battery
Battery Life	Single battery: 7h (static mode)
	5h (internal UHF base mode)
	6h (rover mode)
Communications and Data Storage	
I/O Port	5PIN LEMO external power port + RS232
	7PIN LEMO RS232 + USB
	1 network/radio data link antenna port
	SIM card slot
Wireless Modem	Integrated internal radio receiver and transmitter 0.5W/1W
	External radio transmitter 5W/25W
Working frequency	410-470MHz
Communication protocol	TrimTalk450s, TrimMark3, PCC EOT, SOUTH

Cellular Mobile Network	WCDMA 3.5G module, GPRS/EDGE compatible, CDMA2000/EVDO 3G optional
Double Module Bluetooth	BLEBluetooth 4.0 standard, supports connection with Android and iOS.
	Bluetooth 2.1 + EDR standard
NFC Communication	Realizing close range (<10cm) automatic pair between R6 and controller
	(controller equipped with NFC wireless communication module is required.)
Data Storage/Transmission	4GB internal storage, more than 3 years' raw observation data (about 1.4M/day),
	based on recording from 14 satellites plug and play mode of USB data transmission.
Data Format	Differential: CMR+, CMRx, RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1, RTCM 3.2
	GPS output: NMEA 0183, PJK plane coordinates, binary code
	Network model support: VRS, FKP, MAC, supporting NTRIP protocol
Inertial Sensing System	
Tilt Survey	Built-in tilt compensator, correcting coordinates automatically according to the tilt direction and angle of the centering rod
Electronic Bubble	Controller software display electronic bubble, checking leveling status of the centering rod real time
User Interaction	
Buttons	One-button operation, visual operation

Annex V

Field itinerary

Date	Travel	Mode of travel	Elevation
Day 1 – Jestha 8	Kathmandu – Nepalgunj	Air plane	
Day 2 – Jestha 9	Nepalgunj – Juphal	Air plane	
Day 2 – Jestha 9	Juphal - Suligad	Travel by jeep	
Day 3 – Jestha 10	Suligad to Sankta	Trek	
Day 4 – Jestha 11	Sankta to Jharna	Trek	
Day 5 – Jestha 12	Jharna to Rigmo	Trek	3,608 m, Rigmo village
Day 5 – Jestha 12	Rigmo - Phoksundo Lake	5 min walk	3588 m, Lake

Subash Tuladhar, DHM	Senior Divisional Hydrologist
Dinkar Kayastha, DHM	Hydrologist Engineer
Binod Parajuli, DHM	Hydrologist Engineer
Mausam Bhandari, DHM	Hydrologist Engineer
Dhruba Lochan Adhikari, NHMRCC	Hydrologist
Bhushan Joshi, NHMRCC	Assistant Hydrologist
Ishwor Sharma, NHMRCC	Surveyor
Roshan Bhandari, NHMRCC	Surveyor
Pujan Gurung, NHMRCC	Boat Guide

Outline of Daily Activities on the Site

The field measurements were performed as prepared field plan but implementation difficulties were experienced due to strong wind effect every day. After having a recce survey of the lake on the first day, the consultant team and DHM technical supervision team seated together to review the pre-planning and changed the plan to survey the lake.

The overall activities carried out are described below:

1) Day One Activities

DGPS and Total Stations survey near outlet started.

2) Day Two Activities

DGPS and Total Station survey continued.

Bathymetric measurement started after an inauguration program followed by Puja according to local tradition. The first line followed was the centerline of the lake. It took 2 hours to reach at the cholupu inlet. The strong valley wind moving up from the down valley obstructed while returning from the right 50m line from the bank. The team waited till 7PM for wind to be weak then started returning with measurement.

3) Day 3 Activities

Total Station and DGPS survey continued.

Bathymetric survey team mobilized and started survey early in the morning at 5 am. There was light mountain wind early in the morning, which prevented the boat for easy movement. Around 7:00 am – 7:30 am there were no winds in the lake but soon a mild valley wind gets started which become stronger as time forwards. The locals informed to us that the wind gets stronger at around 10 am and if the team couldn't cross the central section of the lake at the time it gets obstructed till evening.

Discharge measurement at the outlet using current meter was conducted.

4) Day 4 Activities

Total Station and DGPS survey continued.

X-section of the river outlet was conducted.

Bathymetric survey team was mobilized and started survey early in the morning at 5 am.

Discharge measurement at the outlet using current meter was conducted.

5) Day 5 Activities

Bathymetric survey team mobilized and started survey early in the morning at 5 am.

DGPS survey continued to find out the perimeter of the lake using boat.

Discharge measurement at the inlet using current meter was conducted.

6) Day 6 Activities

Bathymetric survey team mobilized and started survey early in the morning at 4:45 am.

7) Day 7 Activities

Bathymetric survey team mobilized and started survey early in the morning at 4:45 am.

8) Day 8 Activities

Bathymetric survey team mobilized and started survey early in the morning at 4:30 am.

The chairman of Lake Conservation Committee also moved to see the survey work conducted.

9) Day 9 Activities

Bathymetric survey team mobilized and started survey early in the morning at 4:30 am.

The chairman of Shey Phoksundo Ward No. 8 also moved to see the survey work conducted.

10) Day 10 Activities

Bathymetric survey team mobilized and started survey early in the morning at 4:30 am.

The chairman of Shey Phoksundo Ward No. 8 also moved to see the survey work conducted. The survey of the lake completed this day.

11) The villagers as well as ward Chairman farewell the survey team while returning.

Annex: VI

Topographic Map
In Volume III

Annex: VII

L-Section and X-section map

In Volume III

Annex VIII
Bathymetric Map
In Volume III

Annex IX

Meetings Minute

With Local Leader at Ringmo Village, Phoksundo

आज मिति २०७६ साल जेठ महिना
को १२ गतेका दिन यस शे-फोक्सुण्डो गाउँपालिका
वडा नं ८ का वडा अध्यक्ष श्री निमा लामा
ज्यूको प्रमुख आतिथ्य र फोक्सुण्डो ताल संरक्षण
समिति का अध्यक्ष श्री रिन्जीन वाङ्गेल गुरुङ
अध्यक्षतामा बसेको निर्णय गरियो।

उपस्थिति

श्री निमा लामा (वडा अध्यक्ष)
" रिन्जिन वाङ्गेल गुरु (ताल संरक्षण
" छिवाङ [illegible] लामा (उपाध्यक्ष
" [illegible] गुरु (कोषाध्यक्ष
" चाइङ्गा छिरिङ बैजी
" छुवा वाङ्जेल गुरु
" छिरि बैजी
" लाक्पा लामा
" सुभाष उपाध्याय (जल तथा
" मौसम विज्ञान विभाग)
" मौसम भण्डारी (जल तथा मौसम वि. विभाग)
" दिवाकर कायस्थ (" " " " ")
" विनोद पराजुली (" " " " ")
" पुजन गुरुङ (सेफटीक गार्ड)
" भुवन जोशी (Discharge)
" ईश्वर शर्मा (सर्वेयर)
" रोशन भण्डारी (सर्वेयर)
" ध्रुव लोचन अधिकारी (NHM Research Cen
& Consultency P.Ltd.)
" राजकुमार बिष्ट (जमदार)
"

विशेष आमन्त्रित

श्री तासि [illegible] गुरुङ (गाउँपालिका अध्यक्ष)
" छेवाङ [illegible] गुरुङ (" उपाध्यक्ष)

~~प्रस्ताव~~ निर्णय

(क) २०७६ साल जेठ महिनाको १३ गतेका दिन
(ख) विहान स्थानीय परम्परा अनुसार ताल पूजा
गरि ताल सर्वेक्षणको कार्य शुरु गर्ने निर्णय
गरियो।

०७६/१/१२

Field Report Presentation

Participant Attendance List

Project: 'To Prepare Bathymetric Map of Phoksundo Lake of Dolpa to update its Inventory'
Client: Department of Hydrology and Meteorology
Consultant: Nepal Hydrological and Meteorological Research Centre and Consultancy P. Ltd.
Year: 2075/76
Meeting: Presentation on Field Report
Date: 2076.03.13 ***Venue: Department of Hydrology and Meteorology***

S.N.	Name	Organization	Designation	Signature
1	Tirtha Raj Adhikari	COHM, TU	Associate Prof.	
2	Maheswor Shrestha	WECS	SDE	
3	Binod Parajuli	DHM	Hydrologist	
4	Sristy Mahajan	DHM	Hydrologist Engineer	
5	Subash Tuladhar	DHM	SDH	
6	Dinkar Kayastha	DHM	Hydrologist	
7	Rudra parajuli	DHM	Hydrologist	
8	Saket Kr. Karn	DHM	Hydrologist	
9	Ishwor Sharma	NHM - Consultancy	Surveyor	
10	Om Ratna Bajracharya	DHM-Consultancy	Hydrologist	
11	Dhruba Lochan Adhikari	DHM Consultancy	Hydrologist	
12	Santosh Regmi	NHM consultancy	Chairman	Regmi
13				
14				
15				
16				
17				
18				
19				
20				

Draft Report Presentation

Participant Attendance List

Project: 'To Prepare Bathymetric Map of Phoksundo Lake of Dolpa to update its Inventory'
Client: Department of Hydrology and Meteorology
Consultant: Nepal Hydrological and Meteorological Research Centre and Consultancy P. Ltd.
Year: 2075/76
Meeting: Presentation on Draft Report
Date: 2076-03-18 ***Venue: Department of Hydrology and Meteorology***
Babarmahal, Kathmandu

S.N.	Name	Organization	Designation	Signature
1	Saraju Kumar Baidya	DHM	D.G.	
2	Ram Gopal Kharbuja	MOEWRI	J.S.	
3	Bikram Shrestha Zoor	DHM	SDH	
4	Subash Tuladhar	DHM	SDH	
5	Dinkar kayastha	"	Hydrologist	
6	Niraj S. Pradhanang	"	Ass. Meteorologist	
7	Maheshwor Shrestha	WECS	S.D.E.	
8	Dhruba Lochan Adhikari	NHMRCC	Hydrologist	
9	Om Katna Bajracharya	"	Sr. Hydrologist	
10	Santosh Regmi	NHMRCC	Chairman	
11				
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Consultative Workshop

Participant Attendance List

Meeting: Consultative Workshop on Draft Report

Project: "To prepare Bathymetric Map of Shey Phoksundo Lake of Dolpa to update it's Inventory."

Client: Department of Hydrology and Meteorology

Consultant: Nepal Hydrological and Meteorological Research Centre and Consultancy P. Ltd.

Year: 2075/76

Date: 2076-03-19 ***Venue: Department of Hydrology and Meteorology Babarmahal, Kathmandu***

S.N.	Name	Organization	Designation	Signature
1	Saraju K. Baidya	DHM	D G	
2	Jagadishwor Karmacharya	"	DDG	
3	Rishi R. Sharma	WECS	J.S.	
4	Suresh Markey	WECS	SDH	
5	Rajendra Sharma	DHM	S.D.H	
6	Sharad Joshi	ICIMOD	Glacier Associate	
7	Niraj S. Pradhanang	DHM	AS. Meteorologist	
8	Chiranjibi Bhetuwal	DHM	Meteorologist	
9	Indira Kadel	DHM	SDM	
10	Hare Ram Lamichhane	"	Hydrologist	
11	Hari Krishna Shrestha	Nepal Engineering College	Principal	
12	Binod Parajuli	DHM	Hydrologist	
13	Deepak KC	UNDP	Senior Prog. Officer	
14	Sunil Pokharel	DHM	Hydrologist	
15	Sristy Maharjan	DHM	Hydrologist	
16	Bikram Shrestha	DHM	SDH	
17	KAMAL A. JOSHI	MOEWRI	SDH	
18	Rita Ku. Mahato	DHM	Meteorologist	
19	Biju Pradhan	DHM	SDM.	
20	Bikash Nepal.	"	Meteorologist	

21	Sakat kr. kam	DHM	Hydrologist	
22	Pratibha Manandhar	"	SDM	
23	Ganesh Prasad Guragain	"	Account Officer	
24	Subash Tuladhar	"	SDH	
25	Dhruba Lochan Adhikari	NHMRCC	Hydrologist	
26	Santosh Regmi	NHMRCC	Chairman	Regmi
27	Om Ratna Bajracharya	NHMRCC	Team leader	
28				
29				

Workshop Photos

Annex X

2004 Bathymetric Survey Chart and Interpretation

From: Frank Budz
Date: Monday, August 09, 2004 10:18:27
To: 'jagat@dhm.gov.np'
Subject: FW: Request for bathy CHT interpretation

Dear Jagat,
I will again try to help answer your questions as best I can.

Thank you very much for reviewing Bathy Chart. The Chart I sent to you is only a part. Please read chart as - The Bathy-500 appears to track correctly and clearly displays the slope on the chart while traveling down (from shallow water to deep water and not from deep to Shallow). Please note that the transducer face was probably not parallel to the water surface at all times as boat was towed by manually and period was windy.

[Frank Budz] If the transducer was not mounted securely so that it was swaying back and forth during survey you will get erroneous data that is difficult to interpret.

Our problem major problem is while interpreting the horizontal part of the Chart. The horizontal part of the Chart while sounding lake bottom is not ZIG-ZAG at some part as it should be like that of traveling from shallow water to deep water. You will notice upward part and downward part not of the graph different.

[Frank Budz] I don't see any upward part on the chart because it is cut off at the end (right side). Is that where the upward part is supposed to be? It would be helpful to us if you included in the picture of the chart arrows to use as pointers and label them as point A, point B etc so that we can better understand your questions.

Other problem is to read depth from graph. Should we read the average point of the graph as graph is not a single sharped lined ? But the digital displayed data matches with upward edge of the graph. Your suggestion is needed. That is why I requested you to read the graph and email us some (two or three points) depths of lake bottom shown by each graph

[Frank Budz] For this I can say that the digital depth will always follow the very top of the horizontal line while tracking the bottom. This is how echosounders work. The very top is where the sound waves first penetrate the seafloor, thus making it the most accurate measurement of the top of the sea floor. The rest of it is simply sound waves penetrating into the seafloor. I don't understand how I can do this. It would have been helpful for you to annotate the chart (mark button).

For your information I have indicted some depth as read by us. There is 137 meter indicated in graph-2 is it Ok?

[Frank Budz] Where is graph-2 ? I have only one section of chart record from you.

Maximum depth shown by graph-1 is 140 meter or 138 meter or more than that.? Similiarly is 88 meter and 137 meter indicted in graph -3 are correctly interpreted ?

[Frank Budz] Again, I have only one chart you sent me and no points indicated for me to reference.

==========

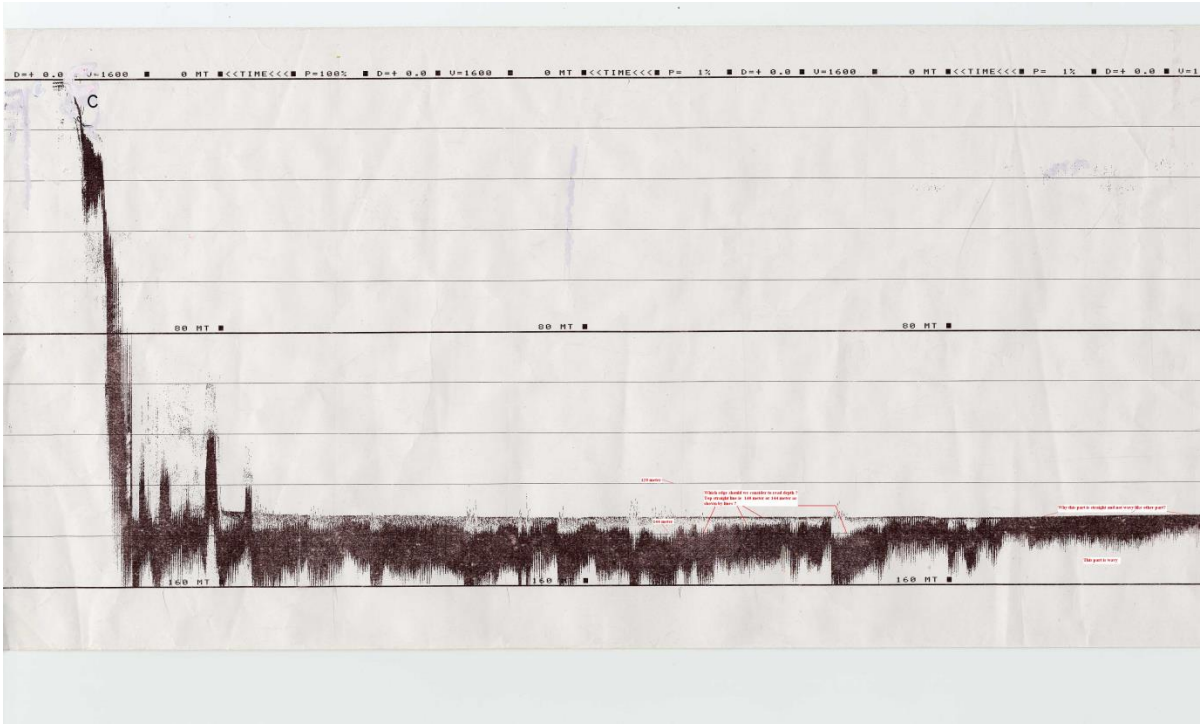
Email to Budz with attached files (one part of graph related to max depth is given below)

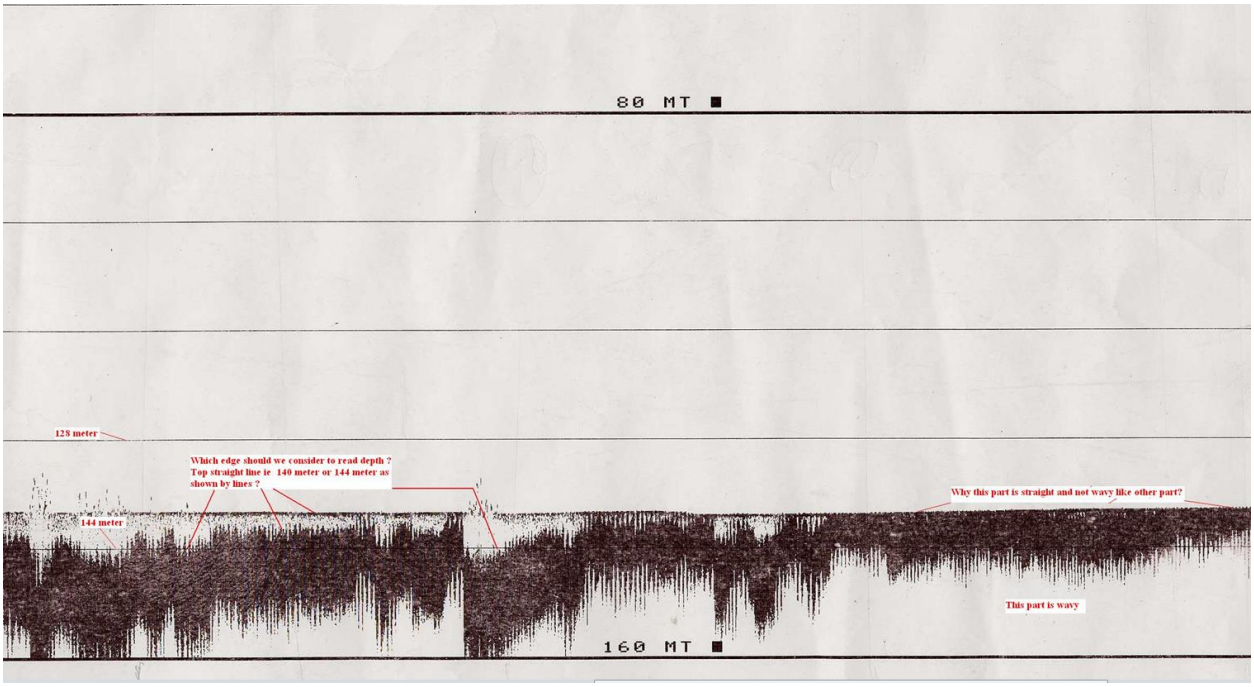
Dear Budz

Thank you for your reply. Your email answered one major query. But still we need your remarks on chart. I have attached zip file and try to clear you my questions indicating by red texts on chart itself. Please send email if it is not downloaded properly. Please view that the very bottom of the horizontal line touched 160-meter line that is the maximum depth that the bathy 500 can read. Does it make any doubt that the bathy might not have measured depth properly at such condition? Pls note that the boat movement was disturbed by wind to this section.

Sincerely yours

Jagat K. Bhusal





From: f.budz@syqwestinc.com Add to Address Book
To: bhusaljagat@yahoo.com
CC: r.philibert@syqwestinc.com
Subject: RE: Cht interpretation
Date: Wed, 11 Aug 2004 11:35:00 -0400

Dear Jagat,

I did receive your attachment and the chart with your notes. I now better understand what your questions are.

For your question "what do we consider is the real depth", I would say the answer is the 144 meter line. Basically, the wavy lines with jagged edges are typically what you will see as the bottom. This is a result of boat motion and uneven terrain. On your chart there is the almost straight (on the horizontal plane) line that seems to follow the bottom but is just above it and occurs almost right on the 140m mark. I assume this is the anomaly that you question about.

My answer to that is that I can't be totally sure why it is there but it looks like a type of silt layer or maybe fluid mud. Because you are using a 200khz transducer, those frequencies will reflect off materials such as silt, vegetation or weeds and "fluid mud". The reflection is less than what you would see from the bottom but will show up on chart record. At the end of your chart record is seems as though the bottom may be just hard sand or such where you no longer have the spikes.

To be perfectly honest we are not expert surveyors here. We obviously do understand how our equipment works but expert data interpretation requires years of true field experience, which we simply don't have.

I would suggest that when you see data that doesn't quite make sense you run over the area a second time to see if the data is repeatable. Also, as I mentioned before you need to try to keep the transducer from swaying as much as possible.

To answer your other question about the Bathy having a max depth of 160m and if that maybe contributed I would say no to that question.

I hope this helps.

Best Regards,
Frank Budz

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