Installation of GLOF Early Warning System in the Punatsangchhu Basin

UNDER
the Project Reducing Climate Change-Induced Risks and Vulnerabilities from Glacier Lake Outburst Flood in the Punakha-Wangdu and Chamkhar Valleys
(funded by GEF/UNDP under LDC Funding)

Department of Energy
Ministry of Economic Affairs
Thimphu: Bhutan

Purpose

- To make a comprehensive early warning system for the Punatsangchhu basin that not only cater the needs of the people in Punakha-Wangdue valley but also to hydropower and other infrastructures projects downstream.

Demonstration Basin-AWCI

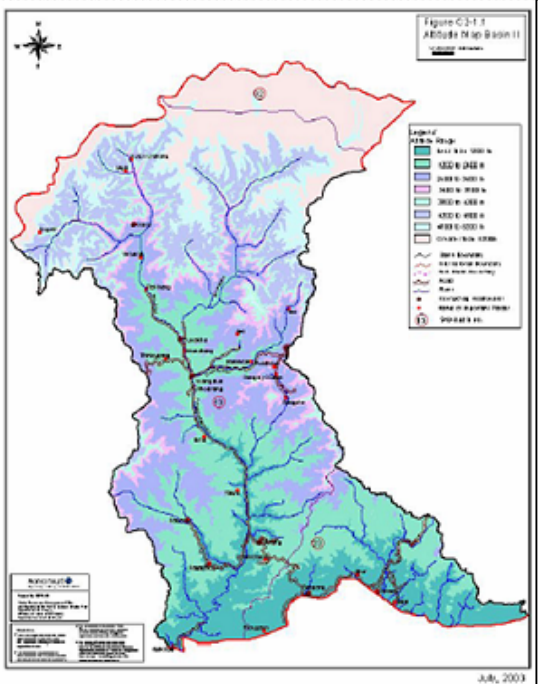
1. **Background, Issues, and Objectives**

The river basin is the second largest in Bhutan and very important from an economic point of view. Punakha-Wangdue is one of the most fertile valleys. In addition, the biggest hydropower plants are also planned in this basin. On the other hand, the frequent glacier melt increases the risk of glacial lake outburst floods (GLOF) and then decreasing flow in the rivers afterwards.

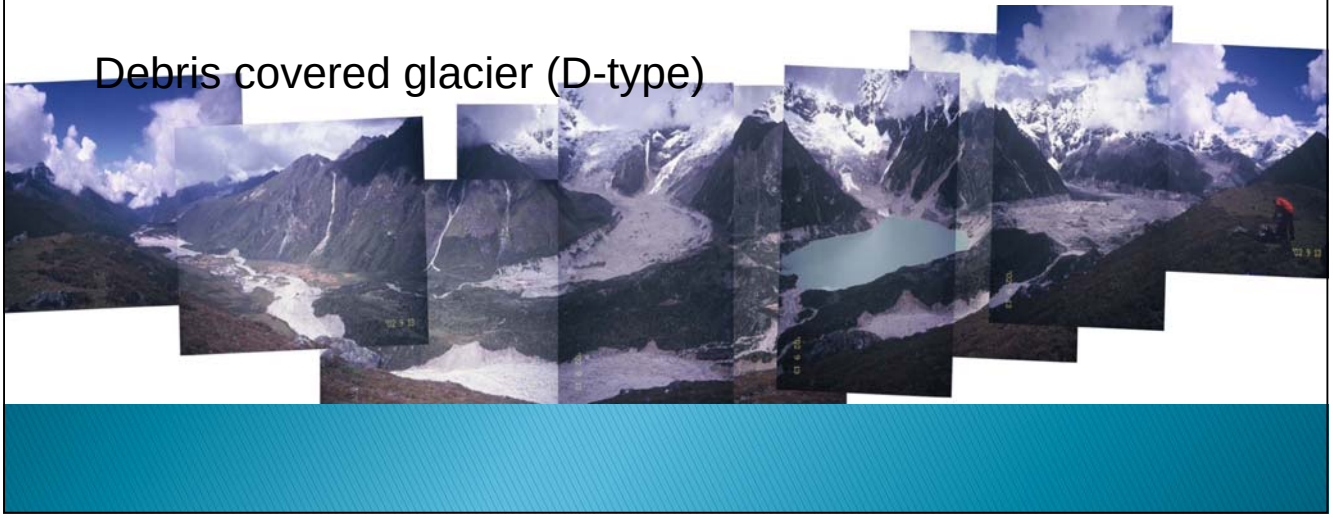
- *River Basin Name:* **Punatsangchhu**
- *River Basin Area:* **13,263 km²**
- *Major Issues:* **Floods**
- *Significant event whent the issues specified above were evident:* **Flood due to glacial outburst in October 1994**
- *Targets to be addressed through demonstration:* **(i) Flood forecast, (ii) Impacts of the hydropower generation, and (iii) A sediment transport study**
- *Objectives:* Determination of **an adequate warning system for floods** and assist in **monitoring the flow regimes** in the rivers due to climate change.

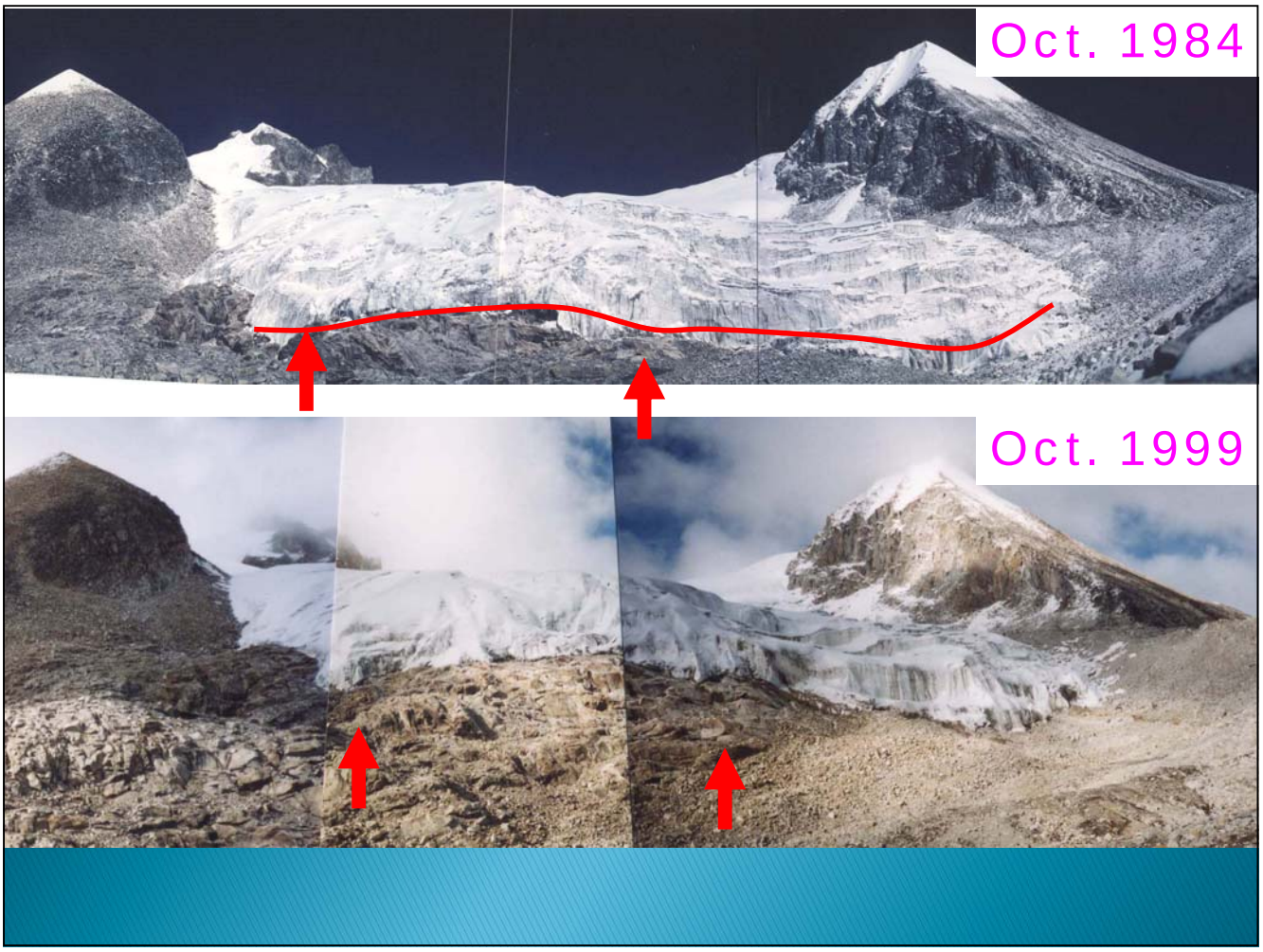
Demonstration Basin-AWCI

- 2. River Basin Characteristics
- *Climate Regime*
  - Temperate
- *– Topography (minimum, maximum, average elevation):*
  - 200 m (min), 6500 m (max)
- *– Annual Average Precipitation:* 500 mm at foothills and above 5000 mm in upper reaches.
- *– Dominant Land Use:*
  - Agriculture
- *– Dominant Soil Type:*
  - Varying
- *– Geographic Coordinates:* 89° 21'– 90° 24E ; 26° 42'– 28° 18N

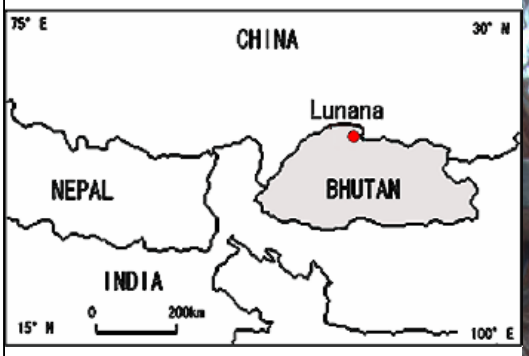


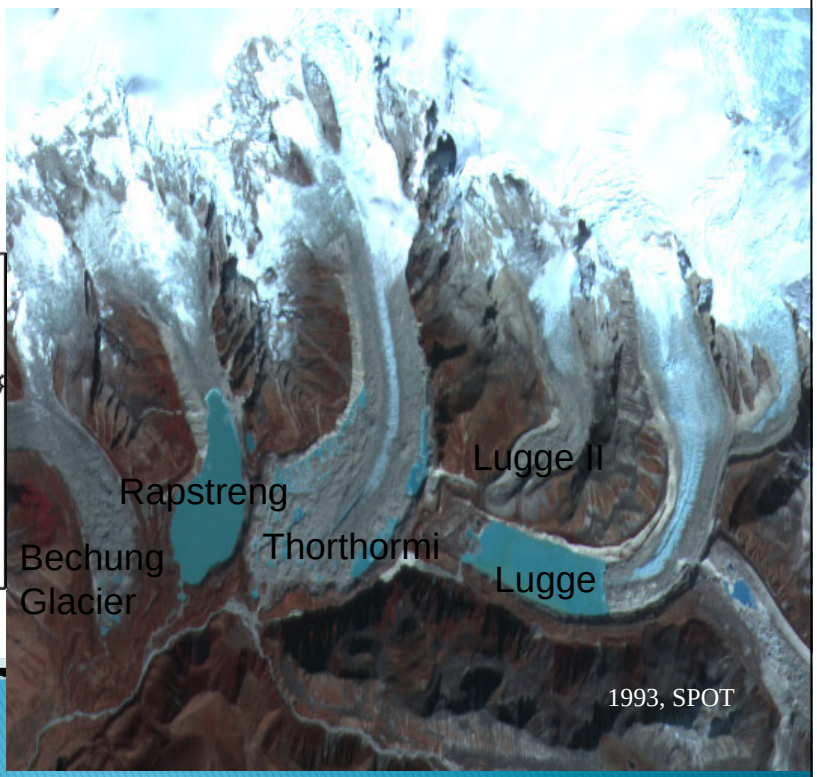
Glacier Types in Bhutan



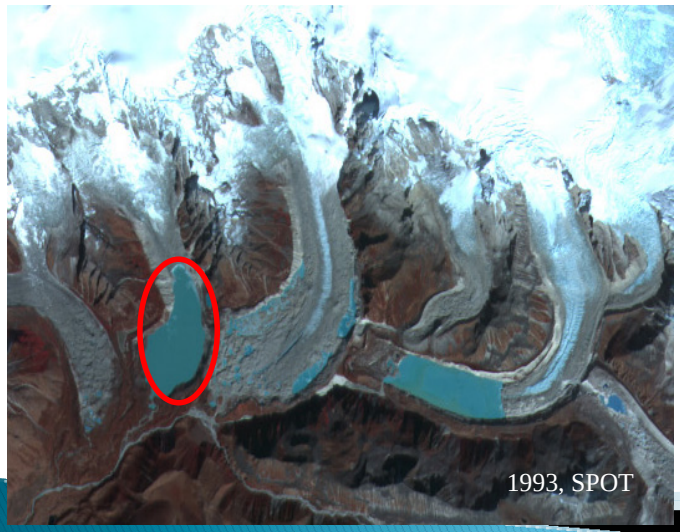


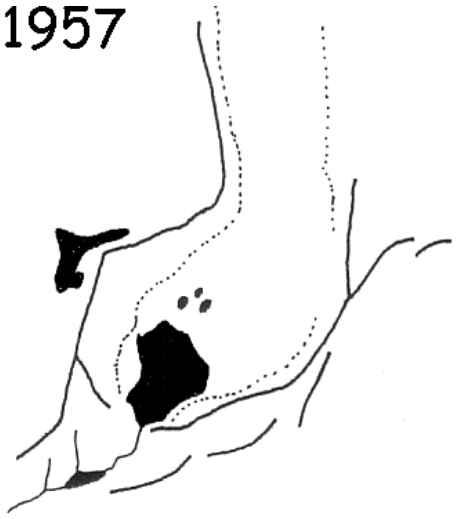
Lunana Complex



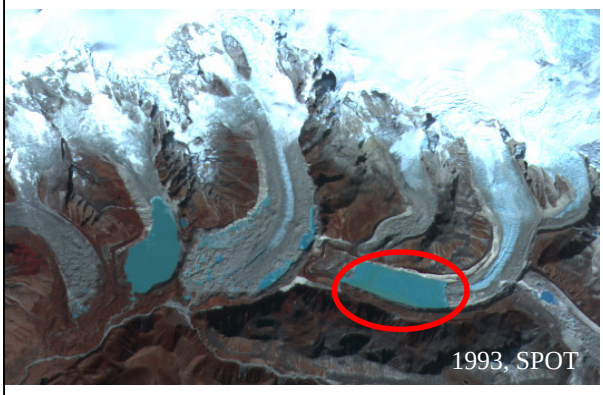


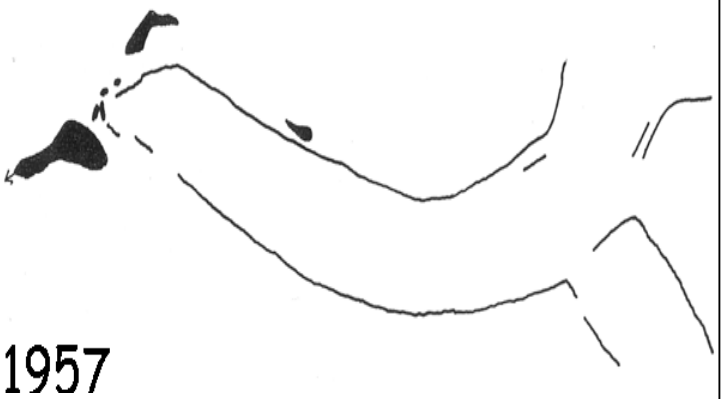
Rapstreng Tso Expansion



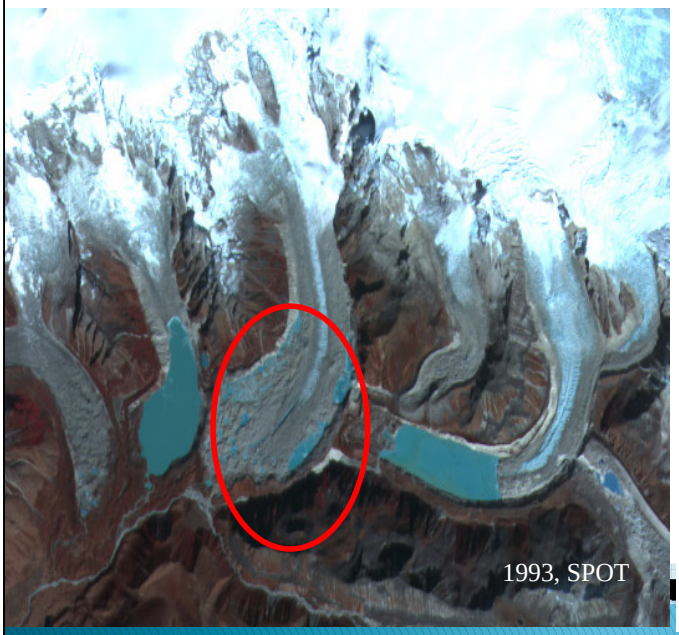


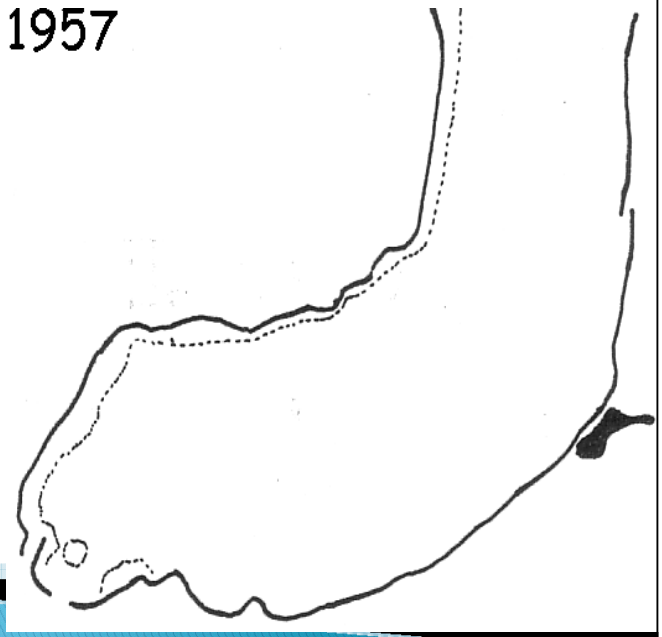
Lugge Tso Expansion



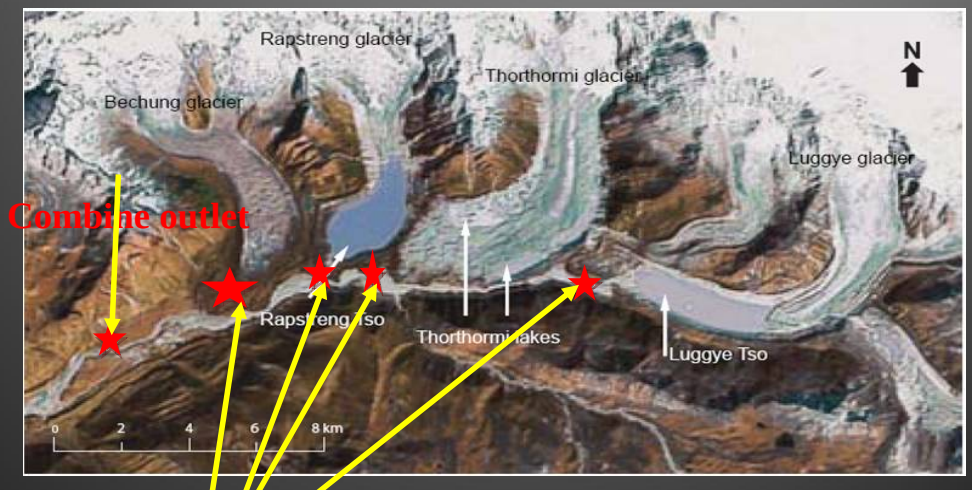


Thorthormi Expansion





Existing GLOF Early Warning System ..



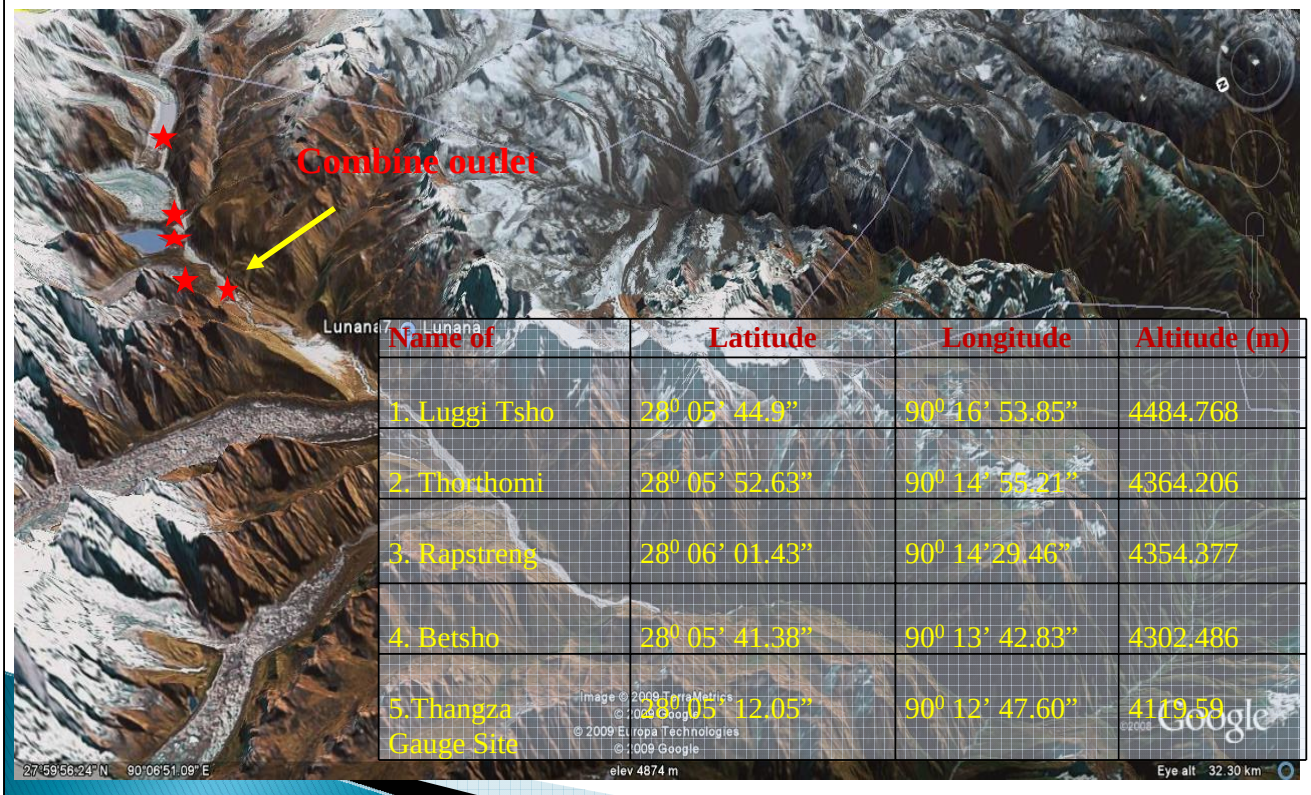
Altitude and GPS Coordinate of Existing GLOF Monitoring Station at Lunana

Name of	Latitude	Longtitude	Altitude (m)	ZRL of Gauge (m)	Remarks
1. Luggi Tsho	28^0 05' 44.9"	90^0 16' 53.85"	4484.768	4477	Gauge site located about 400 m downstream of lake outlet.
2. Thorthomi	28^0 05' 52.63"	90^0 14' 55.21"	4364.206	4357	Gauge site at lake outlet.
3. Rapstreng	28^0 06' 01.43"	90^0 14'29.46"	4354.377	4346	Gauge site located about 400 m downstream of lake outlet.
4. Betsho	28^0 05' 41.38"	90^0 13' 42.83"	4302.486	4309	Gauge site 50 m upstream
5.Thangza Gauge Site	28^0 05' 12.05"	90^0 12' 47.60"	4119.59	4111	Gauge site located at temporary footbridge connecting Thanza and Tenchey village.

Existing GLOF Early Warning System....

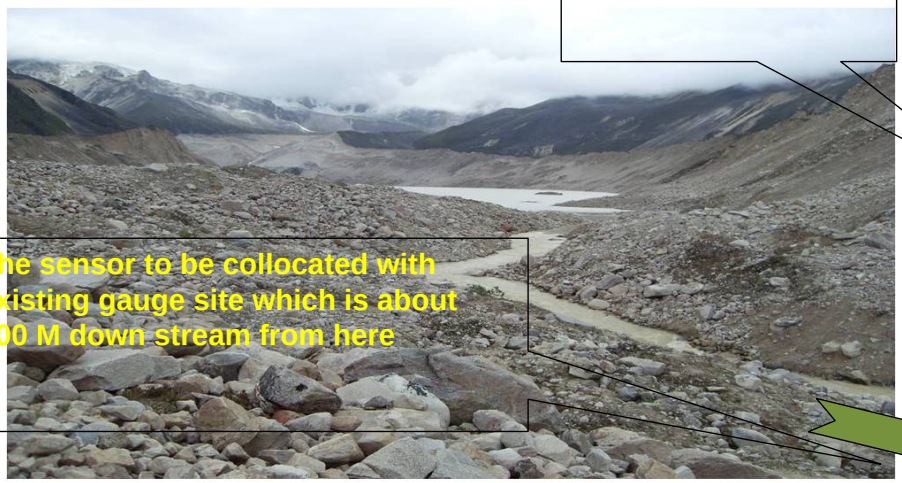
17 siren stations have been set up across the basin. Sirens are triggered as stream thresholds are exceeded

Sensor Site at Thanza, Lunana



Name of	Latitude	Longitude	Altitude (m)
1. Luggi Tsho	28^0 05' 44.9"	90^0 16' 53.85"	4484.768
2. Thorthomi	28^0 05' 52.63"	90^0 14' 55.21"	4364.206
3. Rapstreng	28^0 06' 01.43"	90^0 14'29.46"	4354.377
4. Betsho	28^0 05' 41.38"	90^0 13' 42.83"	4302.486
5.Thangza Gauge Site	28^0 05' 12.05"	90^0 12' 47.60"	4119.59

Water Level Sensor location on Luggi Tsho

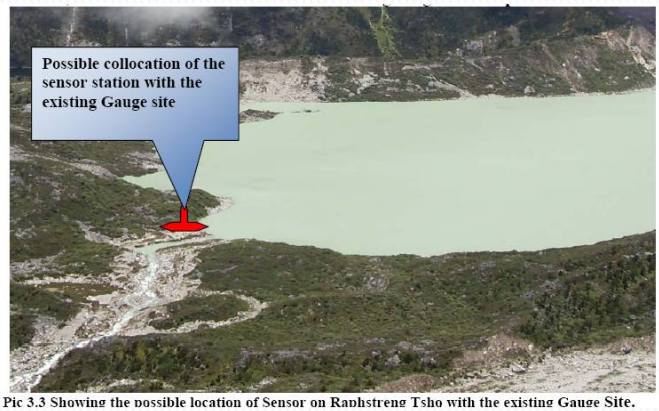


Pic:3.1 showing the unstable out let of the Luggi Tsho

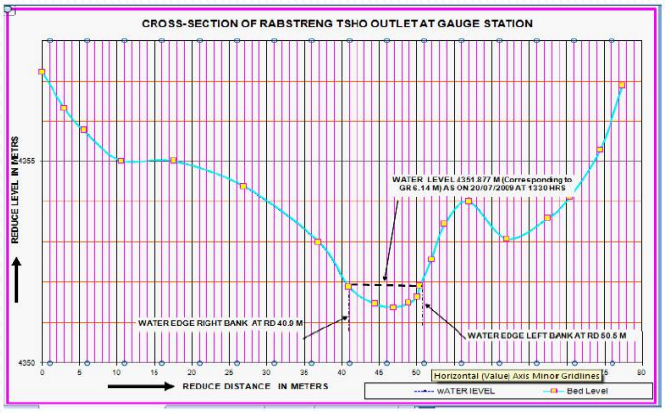
WL Sensor Site for Thorthomi lake

Pic 3.2 showing the possible location of sensor and the existing gauge Station

Sensors Site for Raphstreng



Pic 3.3 Showing the possible location of Sensor on Raphstreng Tsho with the existing Gauge Site.



Discharge in CuM/Sec
= 2.350 CuM/Sec

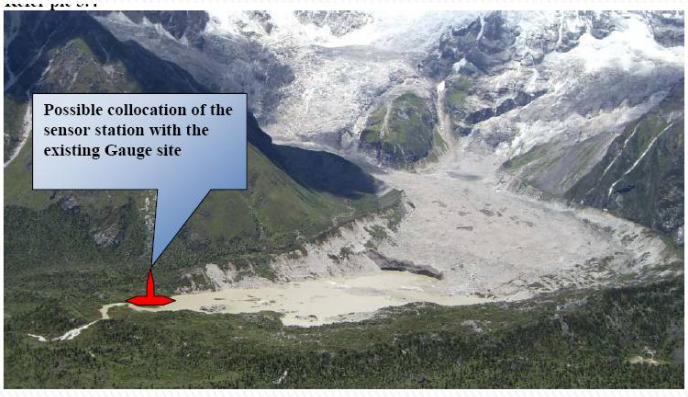
Aveg. Velocity M/Sec
= 0.687 M/Sec

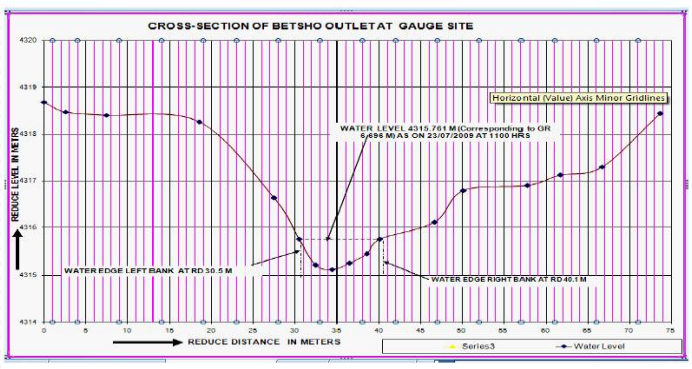
Water Width
= 9.60 M

Area = 3.42 SqM

Mean Gauge reading
= 6.70M

Sensor Site for Bay-tsho





Discharge in CuM/Sec
=2.512 CuM/Sec

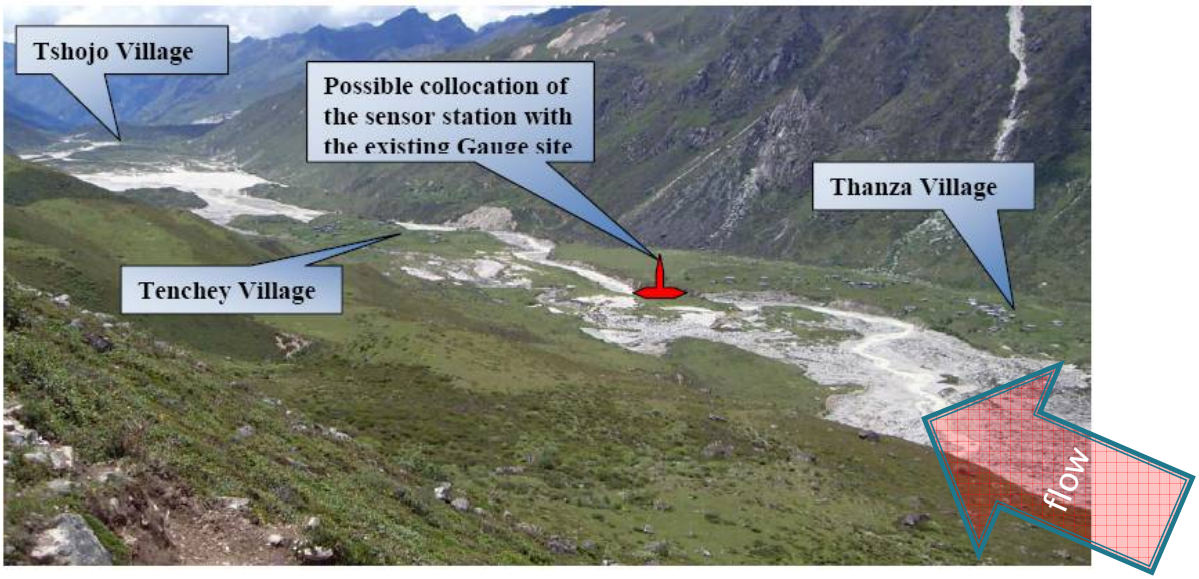
Aveg. Velocity M/Sec
= 0.609 M/Sec

Water Width
= 9.60 M

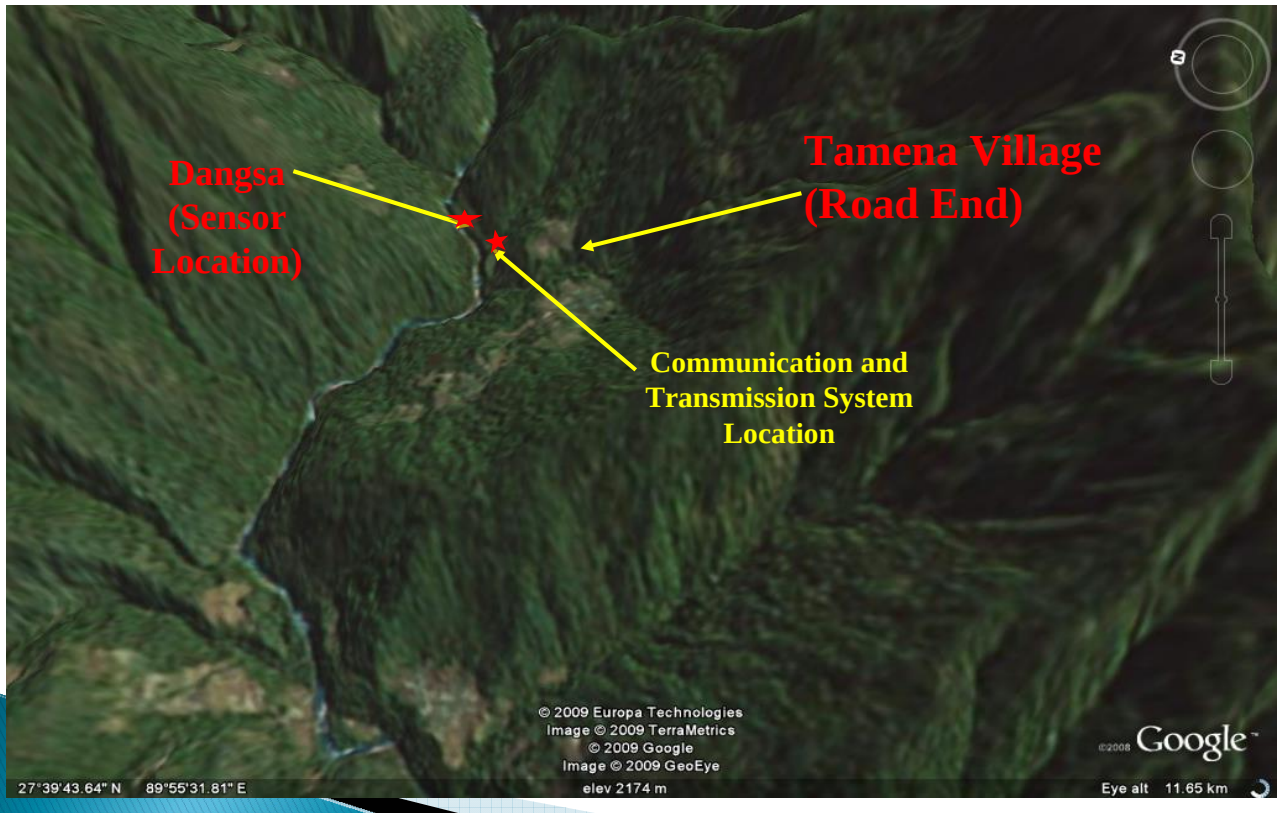
Area
= 4.14 SqM

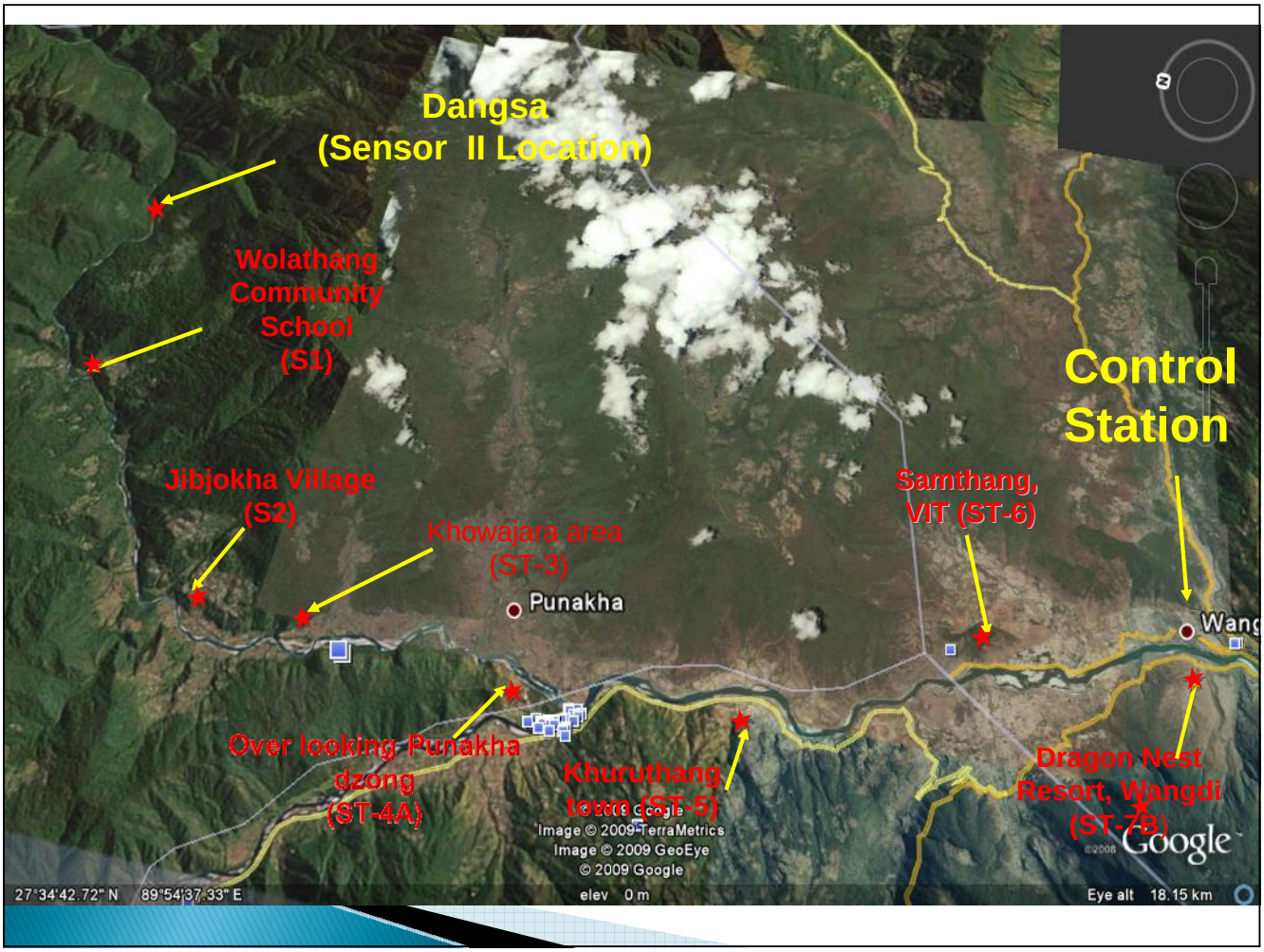
Mean Gauge reading
= 6.14M

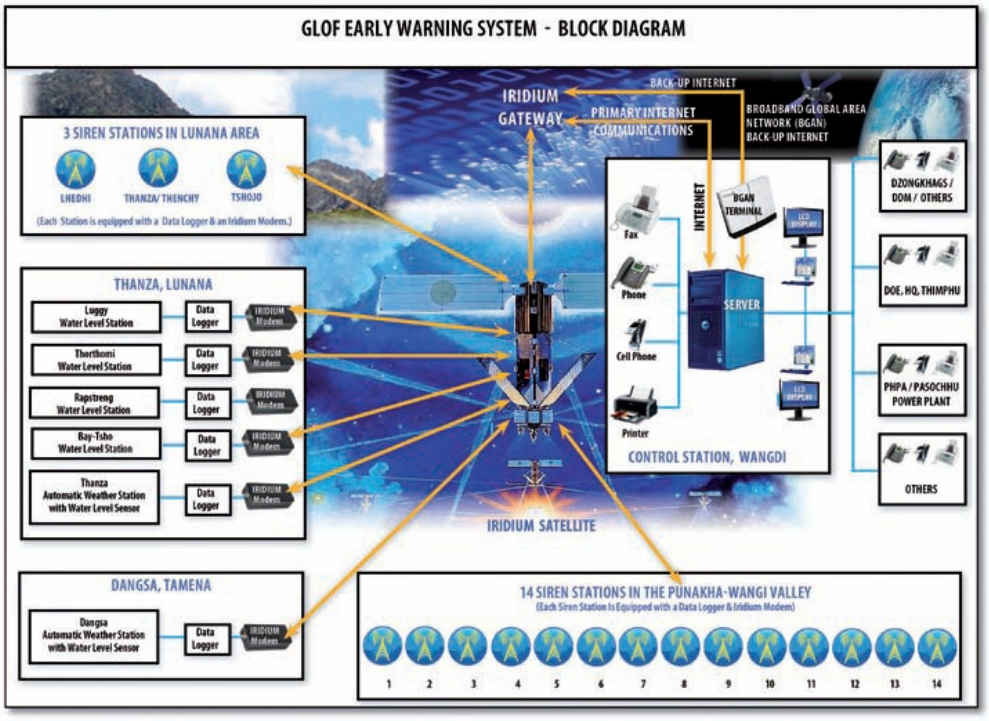
Sensor Site at Confluence



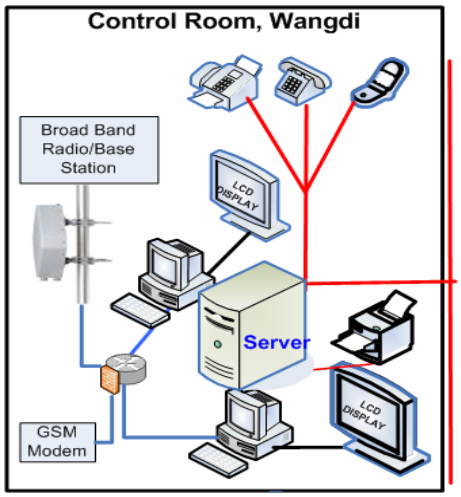
Sensor site Dangsa




Dangsa
(Sensor II Location)
Wolathang
Community
School
(S1)
Control
Station
Jibjokha Village
(S2)
Khowajara area
(ST-3)
Punakha
Samthang,
VIT (ST-6)
Over looking Punakha
dzong
(ST-4A)
Khuruthang
town (ST-5)
Dragon Nest
Resort, Wangdi
(ST-7B)
Image © 2009 TerraMetrics
Image © 2009 GeoEye
© 2009 Google
27°34'42.72" N 89°54'37.33" E
elev 0 m
Eye alt 18.15 km


GLOF EARLY WARNING SYSTEM - BLOCK DIAGRAM
3 SIREN STATIONS IN LUNANA AREA
LHEDHI
THANZA/ THENCHY
TSHOJO
(Each Station is equipped with a Data Logger & an Iridium Modem.)
THANZA, LUNANA
Luggy Water Level Station
Thorthormi Water Level Station
Ragotreng Water Level Station
Bay-Tsho Water Level Station
Thanza Automatic Weather Station with Water Level Sensor
Data Logger
IRIDIUM Modem
DANGSA, TAMENA
Dangsa Automatic Weather Station with Water Level Sensor
IRIDIUM GATEWAY
BACK-UP INTERNET
PRIMARY INTERNET COMMUNICATIONS
BROADBAND GLOBAL AREA NETWORK (BGAN) BACK-UP INTERNET
INTERNET
BGAN TERMINAL
SERVER
Fax
Phone
Cell Phone
Printer
CONTROL STATION, WANGDI
IRIDIUM SATELLITE
DZONGKHAGS / DOM / OTHERS
DOE, HQ, THIMPHU
PHPA / PASOCHHU POWER PLANT
OTHERS
14 SIREN STATIONS IN THE PUNAKHA-WANGI VALLEY
(Each Siren Station is Equipped with a Data Logger & Iridium Modem)
1 2 3 4 5 6 7 8 9 10 11 12 13 14

Control Station



Thank You

by Daren B. Tagg, PE

GLACIAL MELTDOWN

Implementation of a flood EWS in Bhutan

Remote applications: Bhutan's Glacial Lake Outburst Flood (GLOF) Iridium-based early warning system

On October 7, 1994, a glacial lake outburst flood (GLOF) occurred on Lake Luggy in the Kingdom of Bhutan, sending a flood wave down the Phochhu and Punatsangchhu rivers that claimed 22 lives and caused massive property and livestock damage. Although major flooding had occurred in the past, the 1994 GLOF was the catalyst for the government of Bhutan to establish an early warning system (EWS) giving downstream inhabitants time to evacuate.

Bordered by China's glacial Tibetan Plateau in the north, the Indian states of Sikkim in the west, Assam and West Bengal in the south, and Arunachal Pradesh in the east, the Kingdom of Bhutan is in the eastern Himalayas where the terrain rises to over 7,000m.

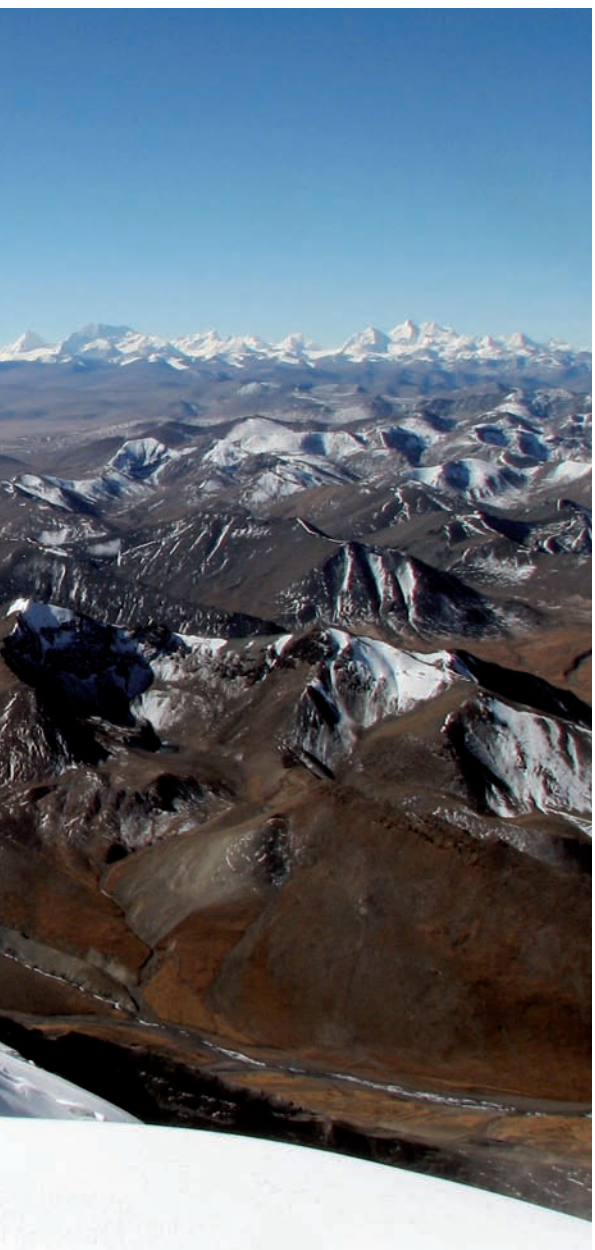
Bhutan's glacier lake-fed rivers carry large volumes of water during the monsoon season. Glacial lakes, which form behind unconsolidated glacial debris (moraine) as the glaciers melt, will periodically produce a GLOF when water previously dammed by moraine or a glacier suddenly breaks through.

In 2001, the International Center for Integrated Mountain Development (ICIMOD) identified 24 of Bhutan's glacial lakes as potentially dangerous. Eight of these lakes are in the headwaters of the Punakha-Wangdu Valley.

After the 1994 event, Bhutan implemented a basic early flood warning system at strategic points in the Phochhu sub-basin. In 2004, simple staff gauges were installed at four glacial lakes and at their confluence in the headwaters of the Phochhu River. Currently, the system depends on two personnel from the Hydro-Met Services Division reading the gauges

The climate in Bhutan varies with altitude, from subtropical in the south to temperate in the highlands and polar-type climate snow, in the north

"Four AWLS and one AWS are located at elevations reaching 14,000ft, accessible only by pack animal"



manually and reporting their results via HF radio to the control station in Wangdu. When radio communication fails, they use a Thuyara satellite phone.

To provide a comprehensive, reliable solution to the problem, the early flood warning project was funded by the Global Environment Facility of the United Nations Development Programme (GEF-UNDP). It has three components: lowering the water level in Lake Thorthormi; installation of an EWS along Punatsangchhu Valley; and improving disaster management and community awareness.

The Sutron Corporation, a leader in providing real-time data collection, remote monitoring systems, and hydrological/meteorological monitoring equipment, was awarded the project to supply the early warning system in March of 2010. Testing, training, and installation are underway and the system will be operational by mid-2011.

The Solution: Iridium Communications

Iridium Satellite Communications were chosen as the telemetry backbone for Bhutan's GLOF early warning project. Iridium's fully-meshed constellation of 66 satellites enables worldwide continuity of service, regardless of how remote the location. The satellites fly in formation in near-polar orbit, in six orbital planes, with 11 evenly spaced satellites per plane. These Iridium satellites circle the earth every 100 minutes.

Sutron recommended the Iridium system as the most economical, the most reliable, and the best suited for Bhutan's remote, rugged terrain and extreme climate. Other communications were ruled out for the following reasons: INSAT (over India) communications are only one way; VSAT are not economical; HF radio communications have reliability issues; and line-of-sight (LOS) radio would need several repeater stations crossing the terrain that would be too costly in terms of time and money.

17 siren stations have been set up across the kingdom. Sirens are triggered as stream thresholds are exceeded

Sending data from remote locations

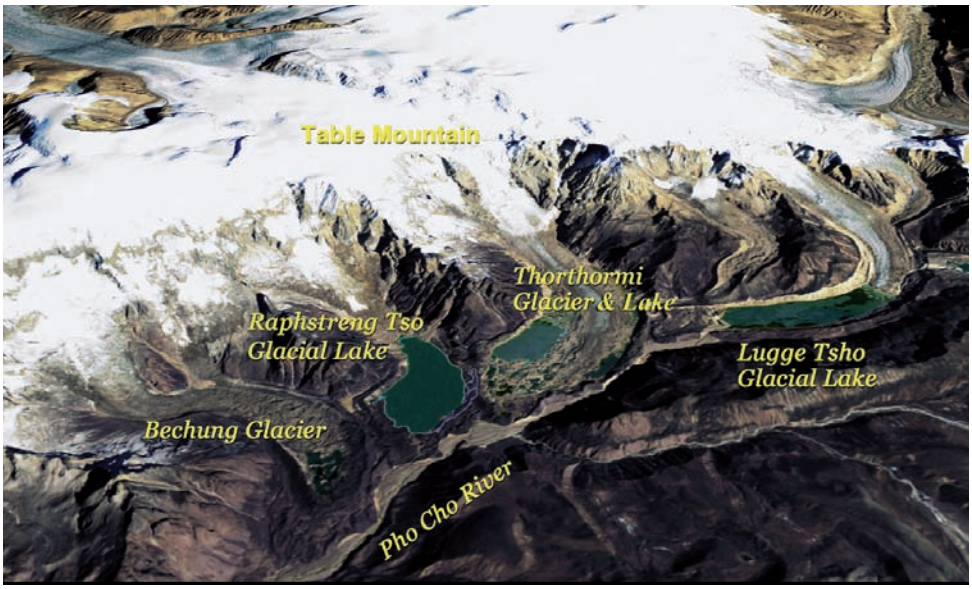
When a remote hydro-met station sends data via its Iridium modem, it connects to the Iridium satellite that is overhead at the time. Data traffic is routed along the chain of satellites until it reaches the satellite above the Iridium Earth Gateway, which downlinks the data to the internet. Data is immediately available through the internet at the control station in Wangdu. Because the Iridium Constellation uses low earth orbit (LEO) satellites, data delays are virtually unnoticeable.

Sutron's early warning system consists of one central control station, 17 siren stations and six hydro-met monitoring stations, of which four check water levels (AWLS) and two monitor both water levels and weather (AWS). The system is divided into two geographical areas: the upper sites near the glacial lakes at the source of the GLOF, and the lower sites in the Punakha-Wangdu Valley where the majority of the population lives.

Four AWLS and one AWS are at 14,000ft (4,267m) and are only accessible after traveling by pack animal for nine days. Maintenance visits to these stations are time consuming so two-way communications, remote diagnostics and back-up sensors, and dataloggers had to be built into the system.

Automatic Water Level Stations (AWLS)

Automatic water level stations at the glacial lakes of Luggy, Thorthormi,



A map of all Bhutan's glacial lakes and plateaus

Rapstreng, and Bay Tsho measure river levels every 15 minutes (from November to February) and every five minutes (from March to October) and transmit their data every hour. When a user-selectable parameter threshold for river stage or rate of change is detected, an Iridium message is instantly transmitted to the control station to activate the upper sirens and to verify conditions prior to activating the lower sirens. Water level stations house a durable, reliable XLite Datalogger, iridium modem, AC/DC power supply for future connection, and Sutron's Dual-Orifice Constant Flow Bubbler with Logger for simultaneous sensor measurements and data back-up. The stations are powered by a 50W solar panel and a 100Ah 12V battery and solar regulator.

Global early warning flood system – a topographical map of Bhutan

Automatic Weather and Water Level Stations (AWS)

Automatic weather and water level stations at Dangsa and Thanza measure weather parameters and river levels every 15 minutes and transmit data every hour. Like the AWLS, user-selected alarm parameters trigger an instant iridium message to the control station for verification and siren activation.

The AWS house a reliable XLite Datalogger, iridium modem, AC/DC power supply for future connection, Sutron's Dual-Orifice Constant Flow Bubbler with Logger, barometric pressure sensor, ultrasonic wind sensor, solar radiation sensor, air temperature and relative humidity sensor, a Total Precipitation Gauge (Thanza), and a tipping bucket rain gauge (Dangsa). The stations are powered by a 50W solar panel with a 100Ah 12V battery and solar regulator.

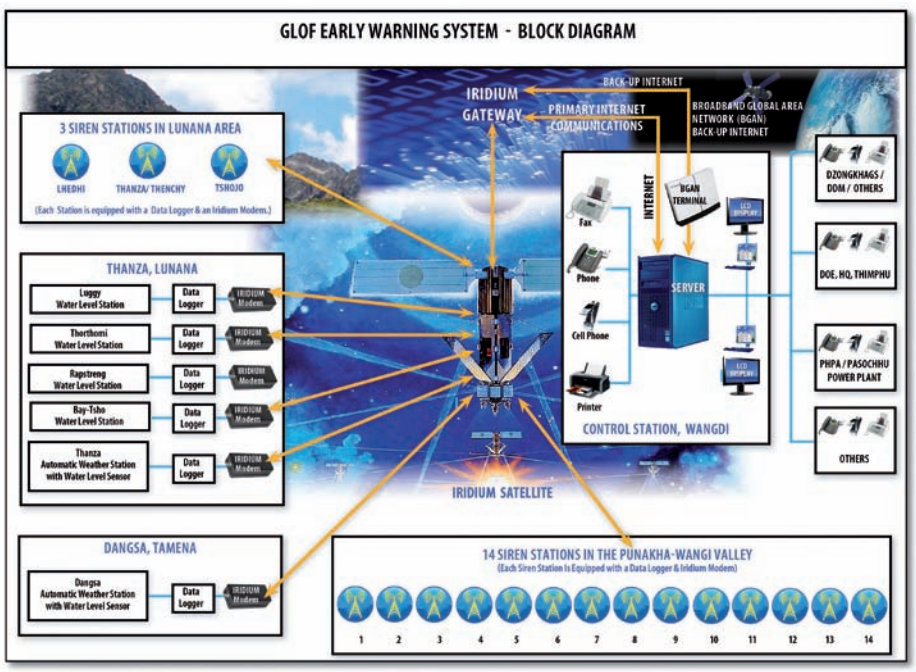
Siren stations

The siren stations are positioned near the population centers, usually above the villages on the mountainside for maximum projection. Siren stations transmit diagnostics such as battery voltage and siren status to the control station once a day. The siren stations include an XLite Datalogger, Iridium modem, AC/DC power supply for future connection, and a Whelen OA-1 siren with siren amplifier. To ensure continuous operation, the siren stations are powered by two 80W solar panels with two 75Ah 12V batteries connected in series.

The control station

The Wangdu control station has a server and two work stations. Data from the remote stations flows into the custom database via the Iridium satellite telemetry. Control station operators can view the latest data from any of the 23 stations using custom software, databases, and graphical interfaces developed by Sutron.

Designated users (power companies, disaster management agencies etc) will be given access to a custom system webpage so they can view river stage and weather data. In addition to managing scheduled and on-demand data collection, control center staff will oversee siren activation. Since river travel times to the upper villages can vary from 20-60 minutes, the upper three sirens will activate as soon as the user-selected thresholds are exceeded. Before activating the 14 lower sirens, control center staff will verify that a



The global early warning system – diagram

GLOF event has happened. If it is a confirmed false alarm, they will then deactivate the sirens.

Project status and future systems

Construction and installation of the GLOF early warning system in the lower sites of the Punakha-Wangdu Valley is going well. Work in the upper sites will resume in spring 2011. All the equipment for the 23 remote stations has been assembled and tested. The control center software has been developed, integrated, and tested with all systems. The GLOF EWS will be fully operational during 2011.

The success of this entire project is attributable to the foresight and hard work of the Bhutanese government, the generosity of the donors, the technical expertise of Sutron, and the local knowledge of the partner in Bhutan, USD Enterprises. This system is expected to be the first of many early warning systems in the Kingdom of Bhutan. ▮

Daren B. Tagg, PE, is senior water resources engineer for Integrated Systems, the Sutron Corporation, and project manager in Bhutan.