Early Warning and Hazard Assessment of Glacial Lake Outburst Floods, Karakoram Mountains, China

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www.geotest.ch
Problem

Flooding along Yarkant River due to Glacial Lake Outbursts Floods (GLOF)

- Threat for > 1 Mio inhabitants
- Annual monetary loss > 10 Mio Euro
Objectives of the Yarkant River Project

> Establishment of an **Early Warning System** for GLOFs

> **Risk management** for the potential flood areas

> **Climate Change monitoring**

The project aim is to **avoid the unmanageable** (mitigation – land-use planning) and to **manage the unavoidable** (adaptation to climate change – Early Warning System).
Area of Interest
<table>
<thead>
<tr>
<th>Length [km]</th>
<th>Average width of glacier tongue in 2011 [km]</th>
<th>Maximum height of the ice dam in 2011 [m]</th>
<th>Area [km²]</th>
<th>Terminal altitude (valley floor) [m a.s.l.]</th>
<th>Altitude of firn line [m a.s.l.]</th>
<th>Highest altitude [m a.s.l.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>1.5 - 2</td>
<td>150</td>
<td>110</td>
<td>4’700</td>
<td>5’400</td>
<td>7’720</td>
</tr>
</tbody>
</table>

Page 5  GWF Geneva, May 9th, 2014  www.geotest.ch
Kyagar Glacial Lake

Length: 5.5 km; Width: 0.5 km

V = 95 million m$^3$

Landsat-TM August 9th, 2002

Page 9 GWF Geneva, May 9th, 2014

GWF Geneva, May 9th, 2014
Kyagar Glacier lake with the damming glacier tongue in the front (1986).
Causes of floods

- **Snowmelt** in the upper catchment area (Karakorum Mountains)

- **Rainfall** in the Yarkant River catchment (approx. 50’000 km²)

- **Glacier Lake Outburst Floods** from the Shaksgam Valley (Keleqin River as tributary of Yarkant River)
Characteristics of Kyagar GLOFs

> 1954 – 2012: 22 floods were classified as GLOFs.

> Most GLOFs had outburst volumes between 40 – 80 million m³.

> GLOFs mostly occurred during late summer to early autumn.

Data redrawn after Zhang (1992) and Chen (2010)
Kyagar Glacial Lake

Outburst mechanism

approx. 40 m

subglacial drainage

East

West

1.3 km

4'810 m a.s.l.

50 m

Ice dam Kyagar Glacier

filled lake

X blocked channel
Early Warning System

Gauge and Warning Station at Kukulangar

Gauge and Warning Station at Cha Hekou

Satellite (SAR) remote sensing

End-user

22 h

Shache

Markit

Zepu

Server

Observation Station at Kyagar Glacier Lake

20 40 60 km

Kelegin River

Yarkant River

Hazard potential

Monitoring

Alarm

IGCIS Beijing, July 29th, 2013
Cha Hekou Station

2 radar sensors

Control unit: data logger, 2 cameras, satellite communication unit, solar panel

GWF Geneva, May 9th, 2014
Kuluklangan Station

> covers a large catchment area

> warning: melt-water, rainstorm and GLOF
Expedition to Kyagar
Kyagar Station

Daily camera images
Kyagar Glacier 2002 - 2011

Surface lowering rate > 5m/year (2002–2011)

Danger of GLOFs in the past and at present

Historic glacial lake volumes: $> 200$ Mio m$^3$

Potential glacial lake volume 2014: 22 Mio m$^3$
Kyagar Glacial Lake

Consequences?

a 2002
154 mio. m³

b 2011
22 mio. m³

Lake
Flux gate
approx. 2 km

Glacier
Flux gate
approx. 2 km
Results: Kyagar Glacier

Ice-flow speed derived from SAR offset tracking

> Highest flow speeds are found below the confluence of the two main branches of Kyagar Glacier.

> Clear **seasonal variation** in ice flow speed is observed along the entire ablation area.

> Slow-down during the winter season.
  → **reduced meltwater input** → basal sliding

> Pattern is typical for a **surge-type glacier** in quiescent phase.

Risk Management

Modeling of floods caused by GLOFs

→ Hazard indication map

→ Land-use planning
Risk Management

> without flooding

> with flooded areas
Risk Management

Modeling results

flood height [m]

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2.5
- 2.5 - 5
- 5 - 10
- 10 - 15
- > 15
Conclusions

- Climate Change adaptation is a global issue and therefore needs a close cooperation on the international level.

- Fully functional Early Warning System (satellite remote sensing and terrestrial observation and alarming stations) was established.

- During the last decade, the height of the ice dam decreased by more than one-third due to strong melt. Hence, the potential maximal glacial lake volumes decreased by more than 80% to approx. 22 million m$^3$ in 2011.

- When a new surge front reaches the glacier tongue, this could lead to a thickening of the ice dam and hence an increase of the GLOF hazard potential in the near future.
Thank you