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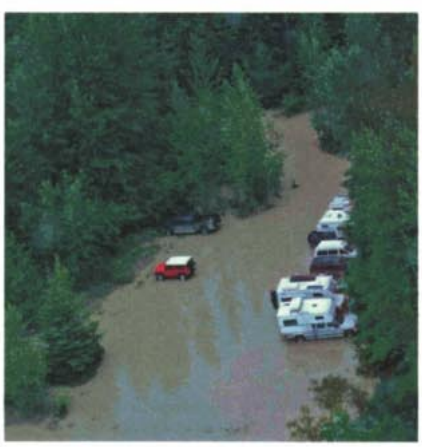
A Field Investigation of Glacial Lake Outburst Potential in the Taiya River Watershed, Skagway, Alaska

Chuck Denton, Larry Standley, and Brent Lewis



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Authors

Chuck Denton is a hydrologist at the BLM's Anchorage District Office. Larry Standley is a hydrologist at the BLM's Alaska State Office. Brent Lewis is a geophysical survey specialist at the BLM's National Science and Technology Center in Denver.

Cover photos

A lateral moraine of West Creek Glacier in the Taiya River watershed near Skagway, Alaska, liquefied in July 2002, causing debris to slide into a glacial lake in front of the glacier's terminus. This event triggered a tremendous flood at Klondike Gold Rush National Historic Park and the community of Dyea, causing extensive damage to bridges, roads and private property. Photos courtesy TEMSCO Helicopters.

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INTRODUCTION

On July 23, 2002, a lateral moraine of the West Creek Glacier liquefied, causing debris to slide into a glacial lake located in front of the glacier's terminus. The debris displaced a large volume of lake water into West Creek, generating a tremendous flood that poured into the Klondike Gold Rush National Historic Park (KLGO) and the community of Dyea, Alaska. This flood caused extensive damage to private property, bridges and roads, and forced the immediate evacuation of Dyea residents and approximately 50 campers from nearby campgrounds. This flood event surpassed the estimated 500-year flood for West Creek, producing a peak discharge of 16,209 cubic feet per second (cfs) (459 cubic meters per second) (Capps, 2004).

In reaction to this event, the KLGO funded a six-month investigation of geologic hazards conducted by a volunteer student geologist. This investigation identified a second lateral moraine, adjacent to West Creek Glacier Lake, which could replicate the results of the first lateral moraine slide. This same study identified a much larger potential threat at the Nourse Glacier, located within a tributary of the Taiya River. Nourse Lake has formed within the past 50years due to the retreat of its glacier. This lake has a surface area of approximately 170 acres (0.69 square kilometers) with a maximum depth of 95 feet (ft) (29 meters (m)). The lake has formed behind a 394-ft (120 m) high terminal moraine. A catastrophic failure of this moraine may result in a peak discharge twice as large as the West Creek glacial flood (Capps, 2004).

On June 10, 2004, a multi-agency teleconference was held to discuss the potential threats of geohazards within the Taiya River watershed. This teleconference (Appendix A) was initiated by the KLGO in response to the July 2002 event and a reconnaissance study performed by a National Park Service (NPS) volunteer in 2003.

Both the West Creek Glacier (latitude -135.5105, longitude 59.5693) and the Nourse Glacier (-135.4250, 59.5693) (Figure 1) are on lands currently administered by the Bureau of Land Management (BLM), but are selected for conveyance by the State of Alaska under Section 6 of the Alaska Statehood Act PL85-508 (72 STAT 339) as amended.

METHODS

An evaluation of the West Creek and Nourse moraines was performed in September 2004 to determine the potential risk of glacial lake outbursts. This evaluation consisted of a site inspection performed by BLM Anchorage Field Office hydrologist Chuck Denton and BLM Alaska State Office hydrologist Larry Standley. The site inspection was intended to provide reconnaissance information of the moraine's stability by assessing its internal structure through surface and subsurface measurements; however, the malfunction of geophysical instrumentation eliminated the acquisition of any subsurface

information. The surface inspection consisted of aerial and on-the-ground observations to inventory sagging or sloughing areas indicative of internal decay and to gather baseline information on surface materials and measurements of distance and slope. Field measurements of distance and slope were accomplished using an inclinometer and a laser range finder.

The proposed 2004 subsurface inspection was to consist of using a surface geophysical instrument that induces electromagnetic (EM) waves into the ground. These transmitted waves are then altered by the sediment/geology beneath the instrument, and are then simultaneously recorded with their ground surface location via Global Positioning System (GPS). The degree of alteration is dependent upon the electrical properties of the sediment, e.g., clay being more conductive. The various EM frequencies are capable of penetrating the moraine to various depths with the lower frequencies having the greatest amount of depth penetration. Through the use of specialized computer software, these conductivity values can be used to understand the lateral and vertical geologic structure and cohesiveness, e.g., ice core, of the moraine material.

RESULTS AND DISCUSSION

After inspecting these glaciers and consulting with Brent Lewis (Geophysical Survey Specialist, BLM National Science and Technology Center), we concluded that the West Creek Glacier area has a low potential to cause further flooding, but Nourse Glacier, though currently stable, has the potential to cause flooding from a glacial lake outburst flood.

West Creek Glacier

The 2002 glacial lake outwash event was created by the collapse of Moraine 1 (Figure 2). Moraine 1 is a lateral moraine to the West Creek Glacier that formed perpendicular to the No Name glacier river valley (Figure 2). This configuration created a structure composed of glaciated (fine) material with steep side slopes that were disproportional to its relative height. As the No Name Glacier receded, the area behind the moraine filled in with very fine sediment. This soil class characteristically has a considerable pore space volume, which results in its ability to retain large volumes of water as compared to coarse-textured soils (Miller, 1990). It is also more susceptible to erosional forces due to its small particle size (Miller, 1990). The relatively fine sediment of this moraine was subject to saturation from drainage coming from the No Name valley. Steep, wet and fine sediments created a high potential for slope stability failure.

Dave Herbig of TEMSCO Helicopters reported observing water and debris spewing from the base of the moraine the day prior to its collapse. There is no available information concerning the structural integrity of the moraine before the 2002 event. Considering the characteristics of the fine material that composed the moraine, the annual precipitation of the area, and the witnessed account of the events prior to the collapse, we hypothesized that water drained through the moraine creating a preferential flow path. This path may have resulted in seepage of water at the base of the moraine. As the flow of water through the moraine increased incrementally, this may have resulted in the increased removal of erosive moraine material. This process resulted in the extreme preferential flow path of water and debris that discharged at the base of the moraine.

The removal of material created a sinkhole which resulted in further instability and the catastrophic release of debris into the West Creek glacial lake displacing water into West Creek. This caused a majority of the lake to fill in with debris, which rapidly displaced water into West Creek, and greatly diminished the lake's current holding capacity.

An inspection of lateral Moraine 2 (Figure 2) adjacent to the West Creek Glacial Lakes identifies a different situation compared to that of Moraine 1. Moraine 2 is approximately 520 ft (158 m) high, 150 ft (46 m) thick at the base and 50 ft (15 m) thick at the top. The majority of the moraine has a slope of 35 percent with the top 50 ft (15 m) having 60 percent slope. Moraine 2 is composed of multiple size class sediments which have been pushed against the rocky slope of a mountain side. This rocky slope provides structural support to the underside of the moraine which may prevent a catastrophic collapse similar to that which occurred at Moraine 1. In addition, the location of Moraine 2 makes it much less subject to constant saturation as was the case for Moraine 1. It was evident from the size and composition of the toe of the slope that material from the steeper sections has been sloughing off over time. This is likely to continue until a stable angle of repose is reached.

Nourse Glacier

The surface of the Nourse moraine is composed of multiple size class sediments including large boulders, cobble and sand. The Nourse moraine has a measured length of 2,640 ft (804 m), an average slope of 15 percent, and a calculated height of 396 ft (120 m), confirming Capps (2004) measurements. Two streams have formed that allow water to flow over the moraine (Figure 3). These streams appear to be well armored by small boulders and cobble. Observations revealed no areas of excessive sagging or sloughing.

Typically, moraines such as that found at the Nourse Glacier are held together by the presence of an ice core (Souchez, R.A., 1971, Reynolds, 1998, Moorman, et al.2000). As average annual temperatures increase, these ice cores become susceptible to degradation. A failure may occur when the moraine structure becomes too weak to hold back the force created by the large volume of water trapped behind the moraine.

The malfunction of the EM equipment prevented a subsurface inspection of the Nourse moraine. The composition and surface slope (15 percent) of this moraine does not indicate a high potential for instability or failure. However, the large volume of water trapped behind this moraine has the potential to cause significant downstream damage if catastrophically released. According to Hal Pranger (geomorphologist, National Park Service), seven different dam failure equations were used to estimate peak discharge in the event of a catastrophic moraine failure. All seven equations estimate an at-the-moraine discharge in the 250,000 (cfs) range. Five equations estimate the peak discharge at Dyea to be in excess of five times the estimated 500-year flood event on the Taiya River.

RECOMMENDATIONS

The overall integrity of the Nourse moraine should be determined in order to provide improved information concerning geohazards on public lands. It remains extremely important to fully understand the subsurface structural integrity of this moraine, and specifically the presence or absence of an ice core, in order to more accurately predict hazard potential.

This information may assist downstream land managers in deciding the best course of action to mitigate damages caused by flooding. These inspections should include a surface inspection to identify any seepage locations and rates and an evaluation of the internal composition and integrity of the moraine through the use of geophysical instrumentation.

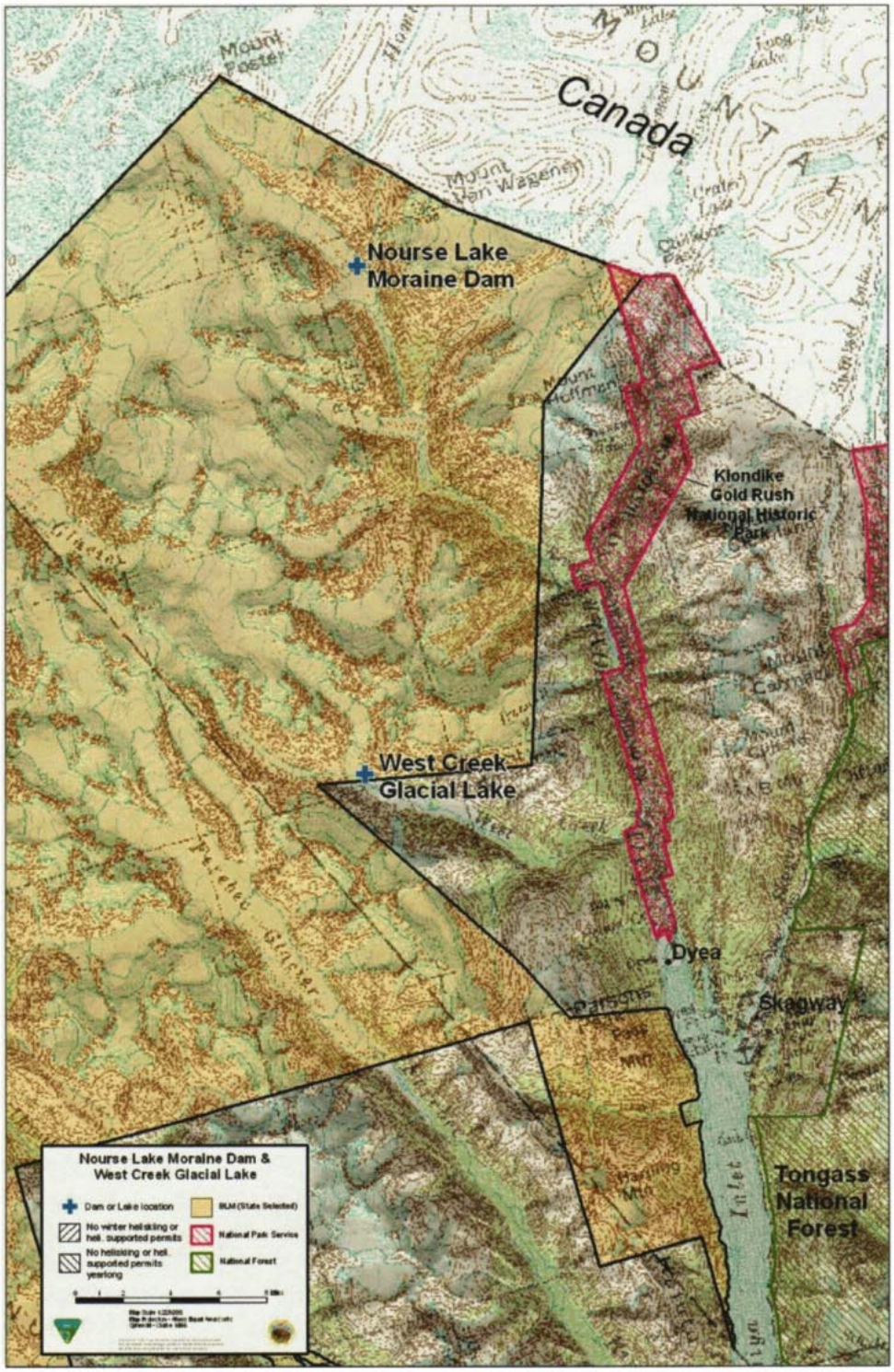

Figure 1. Haines/Skagway regional topography and land ownership map showing locations of West Creek and Nourse glaciers.

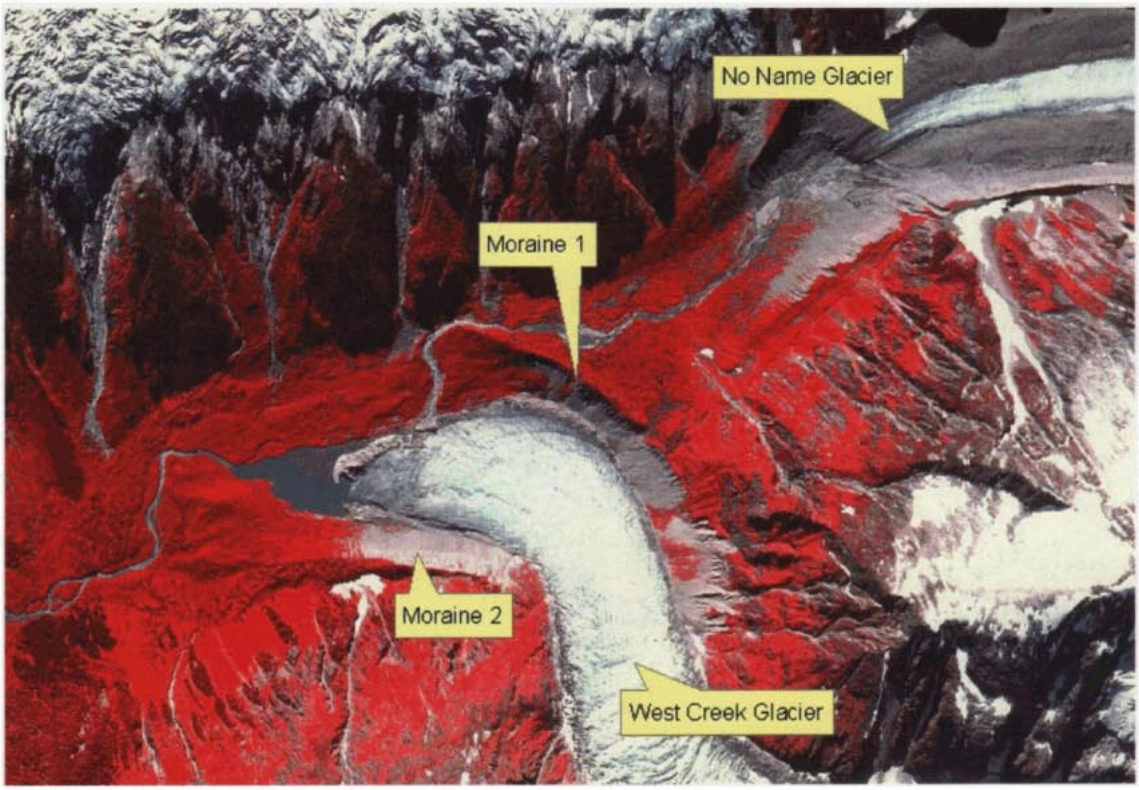

Figure 2. Infrared aerial photo of the West Creek Glacier area, August 1979.

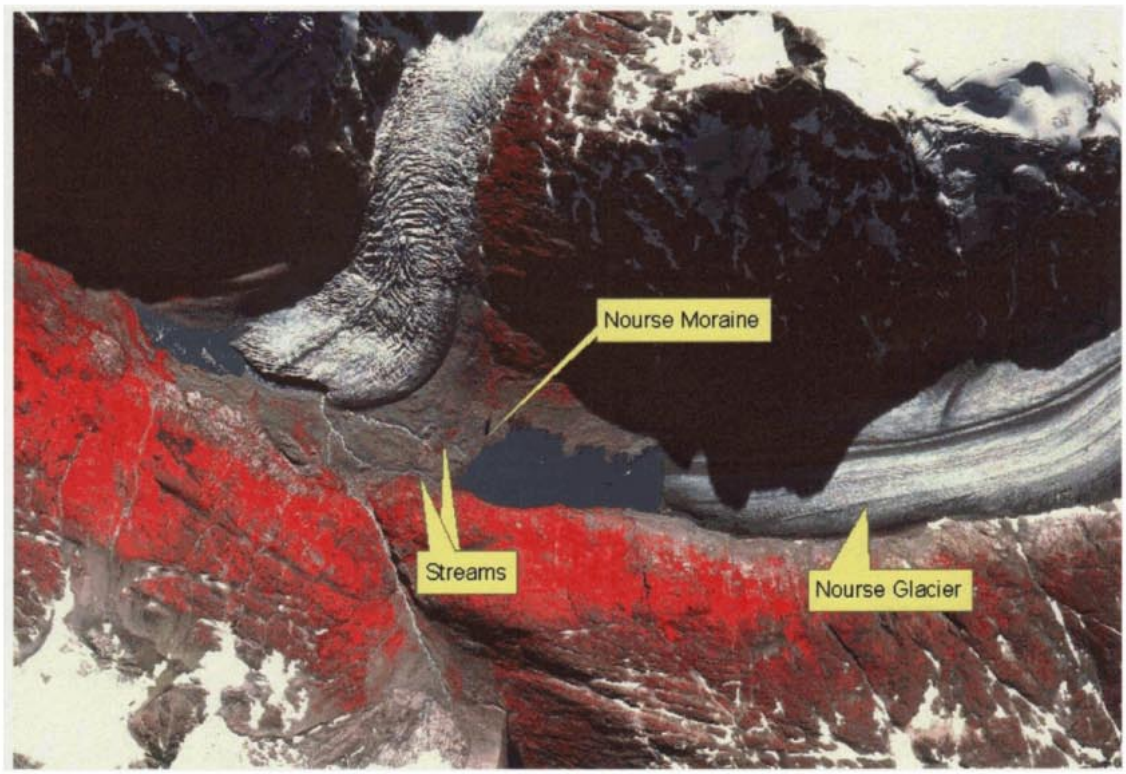

Figure 3. Infrared aerial photo of the Nourse Glacier area, August 1979.

APPENDIX A

Interagency Taiya Watershed Geohazard Teleconference
June 10, 2004
Meeting Facilitator and Notes Preparer:
Theresa Thibault, NPS

ParticipantsJanet Curran, Hydrologist, USGS, Anchorage
Ed Josberger, Glaciologist, USGS, Tacoma, WA
Chuck Denton, Hydrologist, BLM, Anchorage
Deanne Stevens, Geologist, AK DNR, Fairbanks
Bob Ward, Skagway City Manager
Bob Dill, Skagway LEPC (Local Emergency Planning Committee)
Amber Bethe, Taiya Inlet Watershed Council

Hal Pranger, Fluvial Geomorphologist, NPS Geologic Resources Division
Reed McCluskey, Chief Ranger, KLGO
Nancy Swanton, Superintendent, KLGO
Theresa Thibault, Chief of Resources, KLGO
Meg Hahr, Natural Resources Program Manager, KLGO
Dan Lawson, Glaciologist, CRREL*
Steve Arconi (sp?) CCREL
*CCREL (Cold Regions Research and Engineering Lab, Corps of Engineers)

Meeting Summary
Klondike Gold Rush NHP called this meeting for the purpose of bringing stakeholders together in order to inform everyone about the issue, to learn whether there was any expertise available at other agencies in support of this project, and what potential funding might be available. The park also wanted to get guidance from the stakeholders regarding the urgency involved in responding and to determine who the appropriate lead should be.

Background
Hal Pranger summarized the situation for the group. Klondike Gold Rush National Historical Park (KLGO) identified a potential geohazard in the vicinity of Nourse Lake. Nourse Lake and Nourse River empty into the Taiya River where the famed Chilkoot Trail corridor lies. The issue of geohazards was brought to the park's attention through earlier visits by Hal Pranger, geomorphologist with the NPS Geologic Resources Division (GRD), and Rick Inglis of the Water Resource Division (WRD). During the course of their work they located historic photographs from the late 1800s (1894 and 1897) showing evidence of catastrophic flooding below the confluence of the Taiya River and Nourse Creek that devastated the lower river. In 2002, a catastrophic lateral moraine failure up West Creek, the next major drainage to the south of Nourse Creek, produced another significant flood that impacted private landowners and flooded the lower trail and the park's campground.

The park, through the GRD, brought a GeoScientist-in-the-Parks (GIP) volunteer to survey the park for potential geohazards. This recentl-graduated masters student produced a report that indicated that we might have a serious geohazard up Nourse Lake. Apparently there is moraine-dam that, if it failed, could produce catastrophic flooding down the Taiya River. Very crude estimates of the potential magnitude of the flood suggest it could be twice a 500-year flood level.

Dan Lawson of CRREL was enlisted to assist in determining how significant of a hazard we might be facing. He was provided the written report and a number of photographs taken on-site.

Based on his examination of the photographs and his extensive background and expertise in the analysis of ice margins and glacial moraines, he concluded that the probability of an ice core in the moraine-dam was at least 50 percent, with a 60-65 percent probability in some areas of the moraine. This has implications for future stability of the moraine. He suggested that an on-the-ground study needs to be undertaken to verify his preliminary conclusions. Dan has outlined a four-stage approach with limited funding for data-gathering:

1. Site visit to assess requirements for a geophysical study. First order approximation for flood and potentially the installation of an early warning system.

2. Geophysical analysis, potentially including ground penetrating radar, near surface seismic - immediately offshore, and lake acoustics, depending on assessment completed in stage 1, to ascertain mechanism and probability of failure.

3. Flood frequency analysis and LIDAR mapping

4. Set up a full-scale early warning system

Theresa Thibault explained that the park's interest in this situation is threefold with the primary concern being the safety of park visitors and staff in the Taiya Valley. Private residents and park staff live in the townsite of Dyea at the mouth of the Taiya River. Several thousand people visit Dyea and hike the Chilkoot Trail each summer. Second, the park is responsible for the historic sites, features and objects that line this historic trail. And third, the park has a significant amount of infrastructure along the trail corridor and at the historic townsite of Dyea. We need to understand whether this is a significant hazard that requires action in order to ensure the safety of park visitors, local residents, property, and resources.

Complicating factors include land ownership issues. The Nourse Lake and River are located on BLM-managed public lands while the Chilkoot Trail and a significant portion of land surrounding the trail belong to the State of Alaska. The City of Skagway owns property within the park boundaries at the upper end of the Chilkoot Trail (on Taiya River) and at the lower end in the townsite of Dyea. Private property owners have parcels within the park boundaries as well. The park manages the Chilkoot Trail through an Interagency Land Management Agreement with the State of Alaska and owns very little of the land within the park boundaries, most of it being in Dyea.

Need for action
There was some discussion regarding the site visit as proposed, with the installation of an early warning system and additional data gathering for future flood modeling exercises. The group was queried as to what they felt would be the appropriate approach and what a minimum first step would be in resolving whether or not a hazard exists. They all agreed that now that the issue had been raised, it was prudent to follow through and gather additional data. They agreed that at a minimum another site visit was warranted, as proposed by Dan Lawson, but without the installation of the early warning system. All agreed that LIDAR data would be desirable, as would more data collection.

Potential funding
Janet Curan offered that the USGS, in cooperation with KLGO, has been working to get funding for a major study of the Taiya River watershed which would include an analysis of geohazards. It is possible that if funding becomes available this year, the project could be modified slightly to include more study of the Nourse Lake area and the potential geohazards that have been identified. She stated that Dan Lawson could provide complimentary expertise that the USGS currently does not have on its staff. She also said that flood modeling assistance could be provided.

Bob Dill offered that there might be funding after FY06 (City's fiscal year runs July to June) for the installation of an early warning system through LEPC, if such a system is warranted.

Deanne agreed that the State could search for potential funding. The earliest funding could be made available would be after July 1, 2004. She also said that an engineer/geologist could be provided from the State to assist in an on-site visit. She indicated that the State would welcome a letter requesting assistance from KLGO and the City of Skagway.

Bob Ward said that the city could potentially provide funding, but would need information by June 30 in order to get it into the City's budget this year.

Chuck Denton indicated that a BLM helicopter would be in the area during this summer, and could potentially be used for accessing the site as a cost sharing method if a one-day site visit could be accomplished. He also indicated that the Corps had emergency response funding, and that he would check into it.

Amber stated that the Taiya River Watershed Council could assist in obtaining funding.

Identification of appropriate lead
The group discussed briefly the land ownership issues involved. Nourse Lake and River are located on the BLM-managed public lands. The Nourse Lake empties into the Taiya River, which is on State property. Other landowners within the affected area include the NPS, the City of Skagway, and private landowners. As the primary landowner, Chuck agreed that the BLM could take the lead in coordinating the site visit for an on the ground evaluation of the potential hazard.

Tasks
Chuck agreed to take the lead in coordinating the project and working with Deanne to identify funding.

Dan agreed to prepare a Scope of Work (SOW) which would focus only on the first stage, a site visit to gather data necessary for conducting a first-order approximation of an outburst flood and assess requirements for conducting a geophysical assessment and installation of lake/stream level monitoring equipment. The SOW will include the objective, expected accomplishments, and deliverables (end product). Dan indicated that he could have a report prepared within one-to-two weeks of a site visit. The SOW will be prepared within the next week, and finalized by June 25, 2005. The first draft of the SOW is to be sent to Chuck, Janet, Hal, Deanne, Ed, Meg and Theresa by June 16. Dan will also prepare cost estimates.

Ed will also review Landsat 7 images from last year of the area to see what he can learn.

Letters requesting assistance will be sent from the park and the City to BLM and the State DNR

Taiya River Watershed Council will send a letter indicating their interest in being a partner in the project, and their services in identifying further funding.

Meg will send the packet of available data to Chuck for his review.

Future
The group did not set a date for a future meeting, however it agreed to keep in email contact and keep everyone informed as to developments.

In summary, the meeting went very well, with all parties participating in the discussion and agreeing that a minimum first step in the form of a site visit was necessary. Chuck from the BLM agreed to coordinate this initial first visit and to work with the Deanne from State DNR in identifying funding. The site visit is expected to be planned for this summer with information available to all parties within two weeks of the site visit. Letters of support will be forthcoming to the BLM and the State from the park, the City, and the Taiya River Watershed Council. A SOW will be prepared for the site visit by Dan Lawson from CCREL and will be reviewed by several members of the group prior to going forward. The first draft will be expected by the end of the week of June 14.

APPENDIX B

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