University of Canterbury Geography 309

Risk Analysis of Yellow Creek Fan in the Fox Glacier Valley

Annabel Hobson, Dina Chase, Callum O'Brien, Andrew LaCock, Catherine Paul

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Executive Summary

Research Question

What effects do significant rainfall events have on debris flow hazards in the Fox Valley and how can these be mitigated?

Research Context

Fox Glacier is located on the West Coast of the South Island and is a hugely popular tourist attraction. The Fox Glacier Valley is prone to rock fall and debris flow due to its steep slopes and high rainfall. The walking track up to Fox Glacier has been constantly moved over the years due to the risk of rocks falling down and seriously injuring tourists. This research was carried out on the Yellow Creek debris fan due to it being one of the most active in the Valley. The walking track used to be on yellow creek fan but due to the danger of rock fall and debris flow it has currently been moved to the riverbed. The main objective has been to help The Department of Conservation (DOC) and the Glacier Guides to improve the safety and quality of the public walking track up to Fox Glacier. To do so we need to determine and analyze the areas of risk. From here we can then provide information to our Community Partner Wayne Costello so that he and his team from DOC can make a more accurate judgment on track position and closure.

Summary of Method

The first step was to figure out what could be done to answer our research question and what data was necessary to collect in field.

To collect data in the field we used drmble R8 GNSS and measurements were taken of large fTGa8unllers using measuring tapes on and around the Yellow Creek Fan.

We used the data from this to create the fan profile. Using this profile and data we created hazard area maps and debris flow models.

The rainfall and track closure data which was collected by DOC and Glacier Guides was statistically analyzed to predict likelihood of future track closure.

Key Findings

The whole area of the fan is prone to rock fall and debris flow, although the primary and secondary channels are the more likely locations for a debris flow to occur.

Well-established vegetation areas show areas of less rock fall and debris flow activity.

Fan evolution over time could be used to aid and predict future fan evolution, as well as better tract placement and hazard mitigation.

Effect of underground waterways on initiation of debris flow and sediment transport

Introduction

The research question this report focuses on is: What effects do significant rainfall events have on debris flow hazards in the Fox Valley and how can these be mitigated? This project aims to analyse the risk of rock fall and debris flow to the public, then advise The Department of Conservation (DOC) and local glacier guides on the probable hazardous areas around the Yellow Creek fan. DOC can then make better judgement calls on when and where to close the track and provide a safer, more permanent track layout to the public. To achieve these objectives, we had to go to Fox Glacier and use high precision GPS to gather fan profile data along with finding hazardous areas on Yellow creek fan. This data was then put into GIS soft wear and used to model what happens to the fan in debris flow events and create maps showing previous and current hazard areas. Other data used was rainfall and track closure data, provided by DOC. This data was statistically analysed and compared to find what conditions the track had been closed in and how often it was closed due to debris flow risks.

This research matters because it not only concerns the safety of the public but it also

Theory/Concepts/Literature Review

Because no previous research had been carried out on debris flow in the Fox Valley, we studied several broader reports and articles to get a better understanding about rock fall, debris flow and glacial valleys. These reports also help with identifying particular conceptual or methodological points that have contributed to the design of this current research.

It was necessary to gain a better knowledge into the likely depositions created by a debris flow. For this, the paper Depositional Processes in Large-Scale Debris-Flow Experiments by J.J. Major provided a base knowledge of likely depths and extent of a debris flow with specific parameters in a controlled environment. While this information is very simplified in terms of channel profile, and in reality there would be much more impact from variations in the

Brocklehurst, & Gawthorpe, 2010). Any over steepening of these hillslopes will therefore result in slope failure leading to landslides creating alluvial fans and debris flows such as the Gun Barrel fan and the Yellow Creek fan. The Teton Range highlights that a clear interpretation of how topography, climate and erosion interact in glacial mountain ranges is a vital precursor to gaining clearer insights and developing more realistic numerical models of glacial landscape evolution (Foster, Brocklehurst, & Gawthorpe, 2010) which in turn helps us undergo our research project

Methods

The methods used to conduct this research involved both fieldwork and analysis of

Firstly the Yellow Creek fan image was loaded into ArcMap as a raster layer. An 'unknown' geographic coordinate system was used as the image did not have any spatial reference, and therefore could not be projected without the 'unknown' coordinate system. New feature classes were created in order to produce areas that needed to be shown as hazards these were then overlain onto the original image. The final maps identify areas that are vulnerable to debris flow and rock fall at the time the data was collected. Hazard areas will change over time as the main channel avulses across the face of the debris fa

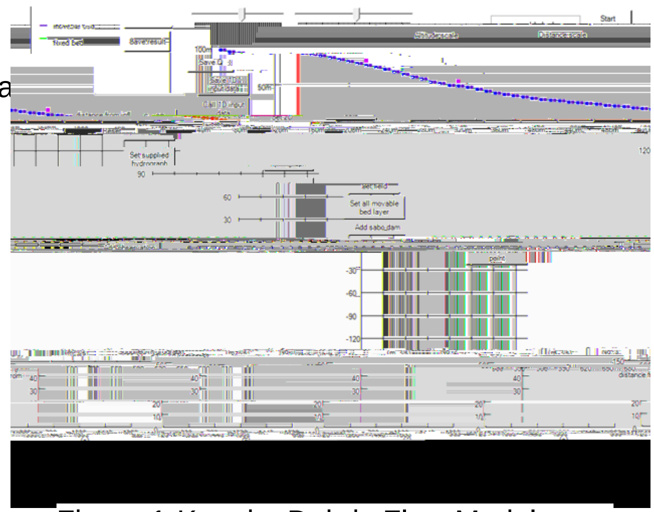

Figure 1-Kanako Debris Flow Model user interface

Debris Flow Modeling

In order to project and predict the potential extent of a debris flow, some form of modelling needed to be done. Initial research and reading of Debris Flows: Mechanics, Prediction and

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initiation and development of debris flow, as well as modelling the flow and extent. This set of equations required very specific input parameters and information which we did not have available, and which would also be very difficult to collect while in the field. For this reason a more simplified version of modelling which displayed potential extent and depth of the debris flow was chosen, this model was the Kanako debris flow model, which was primarily developed by Kana Nakatani at the Kyoto University in Japan. The model was developed with the intention of modelling the effects of Sabo dams on debris flow deposition. It uses a series of partial derivative equations to model different parts of a debris flow. The model user interface is displayed in figure 1.

The information required as an input for this model is a set of hydrograph data, which is a combination of the potential water in the system and the sediments in the system as a percentage of fine and course sediment. The other main part of the information is the profile of the channel which is being modelled as a potential debris flow location.

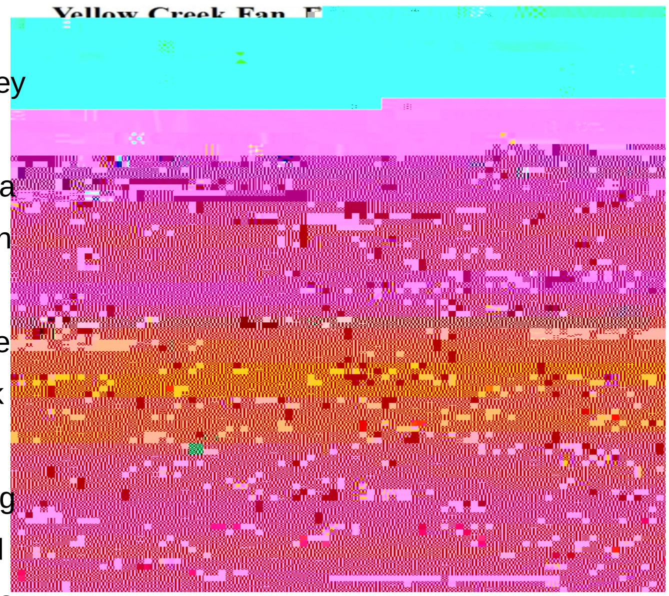
Statistical Analysis

As rainfall is considered a primary risk fa

Results

Hazard Maps

To access the Fox Glacier on the West Coast, a track has been constructed on the side of the valley and has been moved over the years due to rock fall in order the keep the public safe. The image below is the Yellow Creek debris fan on the West Coast and it is one of the most active areas in the Fox Valley and is particularly vulnerable to debris flow and rock fall. This area is also where the current research was carried out. The whole area shown on the image is very active and prone to debris flow and rock fall, which is why it can be a real threat to human life. When looking at the image, one can see the old walking track (brown line that runs through the fan, as well as the Fox River (blue thick line), the Yellow Creek River (thin blue line) that runs through the fan, and small old river channels (black lines) on the fan as well. The areas that are shaded in red indicate the areas that are mostly affected by erosion from the Yellow Creek River and from the Fox River.



During our feildworkon the Yellow Creek debris fan two months ago, we noticed that most of the areas were covered with shrubs, mosses and red algae (areas shada7 Tw [5g5(t).6(

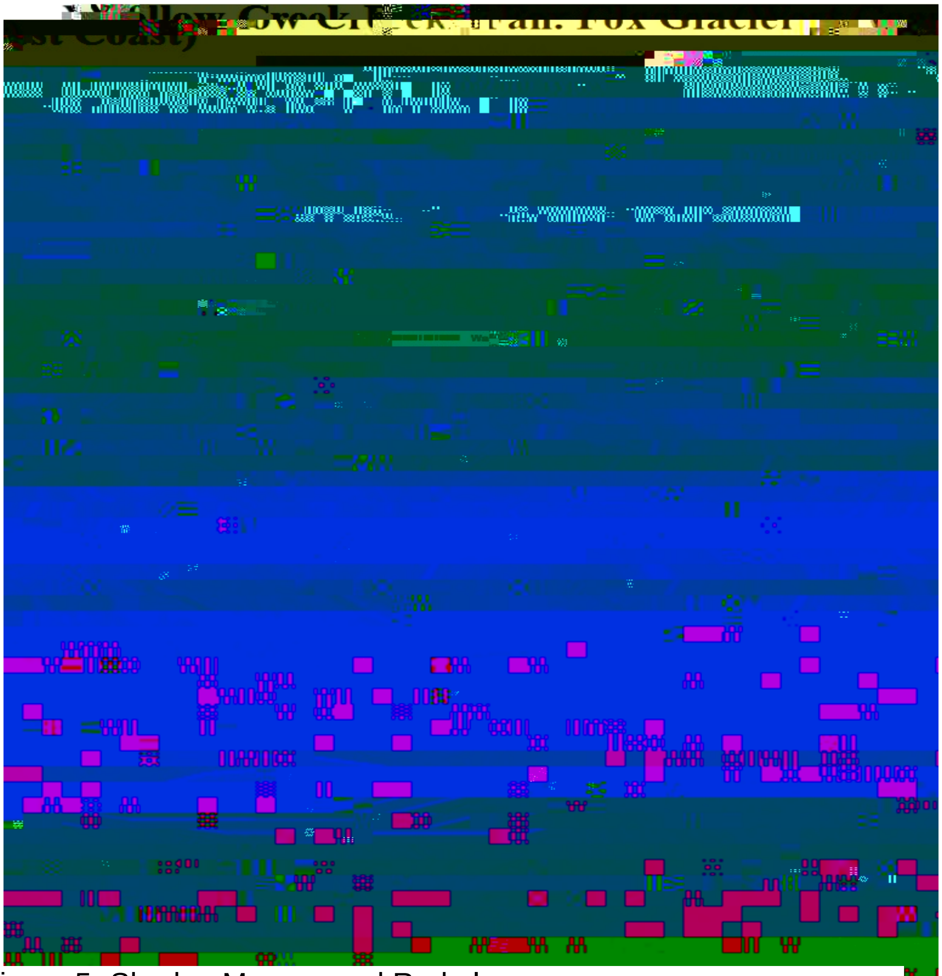


Figure 5- Shrubs, Mosses and Red algae

From the fan profiles produced we found the left side of the fan (the area shaded in orange) is much higher than the area to the right of the main channel. This tells us that the left hand side of the fan, which is one of the main routes DOC uses when they change the track layout, has the potential to be highly active with both debris flow and rock fall.

We alsofound that the Yellow Creek channel changes direction once it reaches the Fox River bed. This is due to a levee that has been built on this area in order to prevent the Yellow Creek River from flowing onto the current track location. Further human influence is seen in the Yellow Creek channel where DOC has removed debris so they do not block the channel.

sort of blockage or other protection method could have on the depositional profile and extent of a debris flow in each of the channels.

Firstly the output of the 1d model which was run using the default hydrograph data and a Sabo dam added to the channel profile approximately half way up the modelled channel. This model output for the main channel displayed a depositional depth of over 10 metres behind the Sabo dam, meaning the dam was overtopped and there was some deposition in front of the Sabo dam. This deposition was however very shallow, showing that a large percentage of the debris flow material was actually trapped by the Sabo dam. This output was very similar when the model was run on the secondary channel profile. The main difference being that there was a deeper deposition at the bottom of the secondary channel model output. The amount of sediment which overtopped the Sabo dam in the secondary channel was very similar to that of the main channel, the difference in deposition is most likely due to the difference in steepness of the channel.

The 2d model was run without the addition of Sabo dams in order to determine the likely outflow extent and depth of a debris flow event. This model gave outputs, which are displayed on the following page, to show extent. As can be seen from these model outputs the extent of possible debris flow extends at least 240 metres from the end of the channel, This is enough to extend well past the position of the current track, at its deepest the deposition of the pr

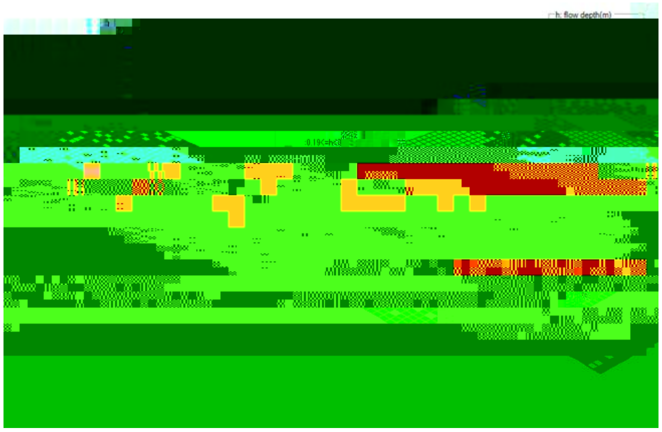


Figure 7 - Extent and depth of debris flow from main channel

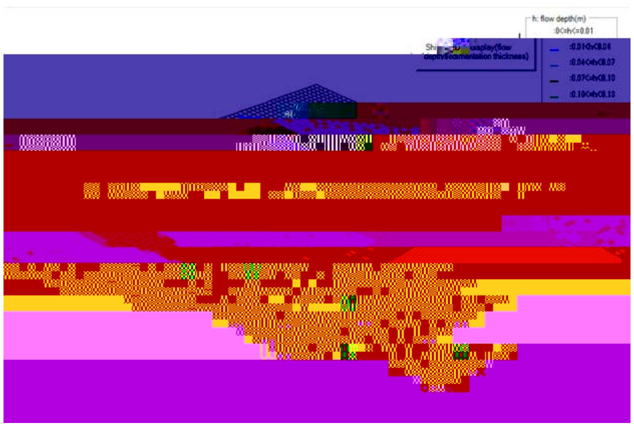


Figure 8 - Extent of a debris flow from the secondary channel

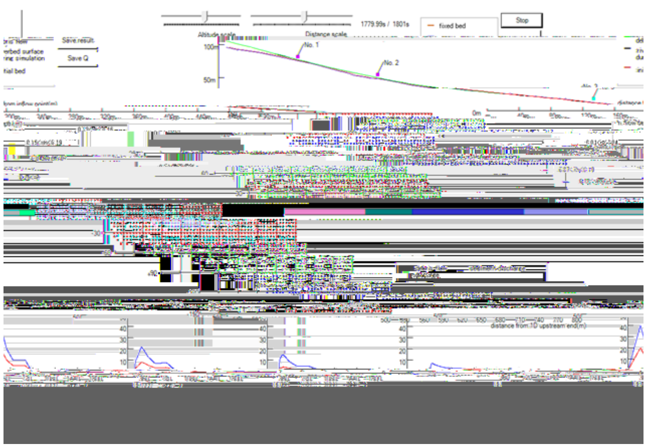


Figure 9 - 2d model showing area of debris deposition from main channel.

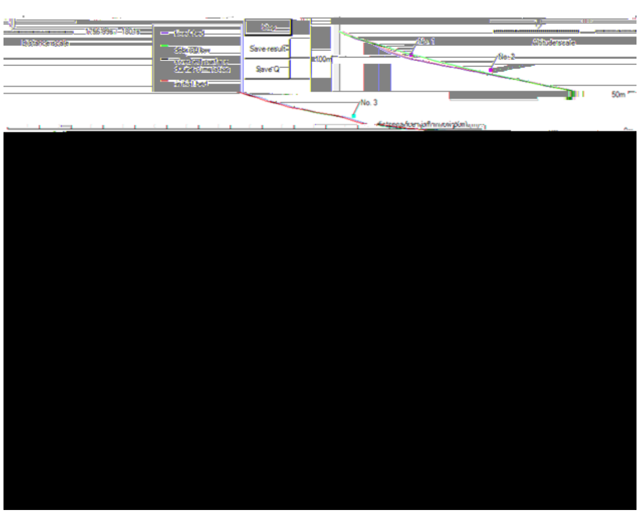


Figure 10 - 2d model showing area of debris deposition from main channel.

Statistical Analysis

Department of Conservation data from 2009 to present day generated annual rainfall amounts from between 4500 and 6089 mm per annum (Figure 6).

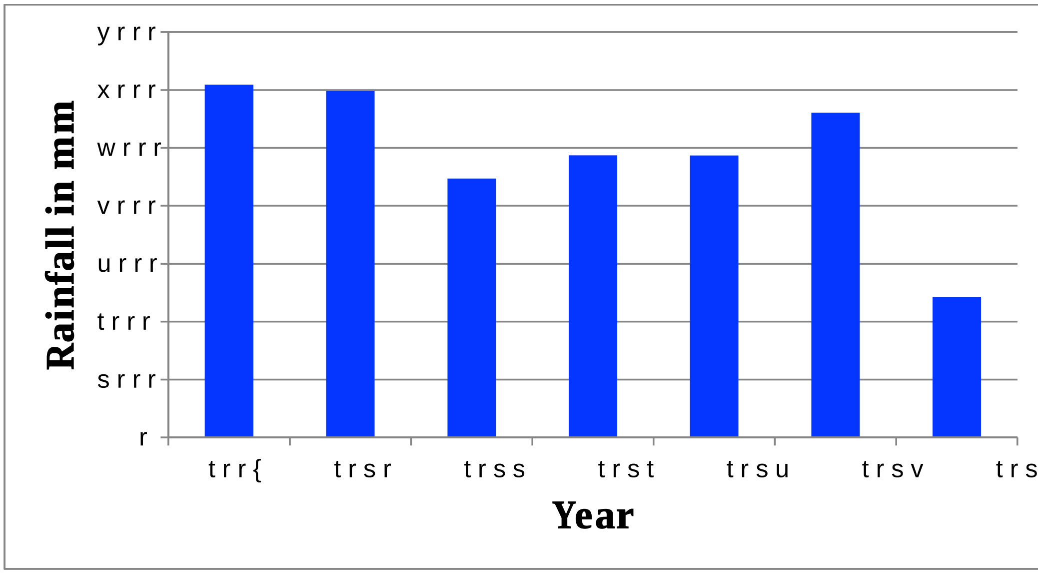


Figure 11 – Graph shows the amount of rainfall the Fox Glacier valley received from 2009-July 2015.

The distribution of rainfall by month (Figure 7) and season (Figure 8) demonstrate that spring and winter have higher daily rainfall. The individual months show that the increased likelihood of closure for spring and winter was consistent across all associated months.

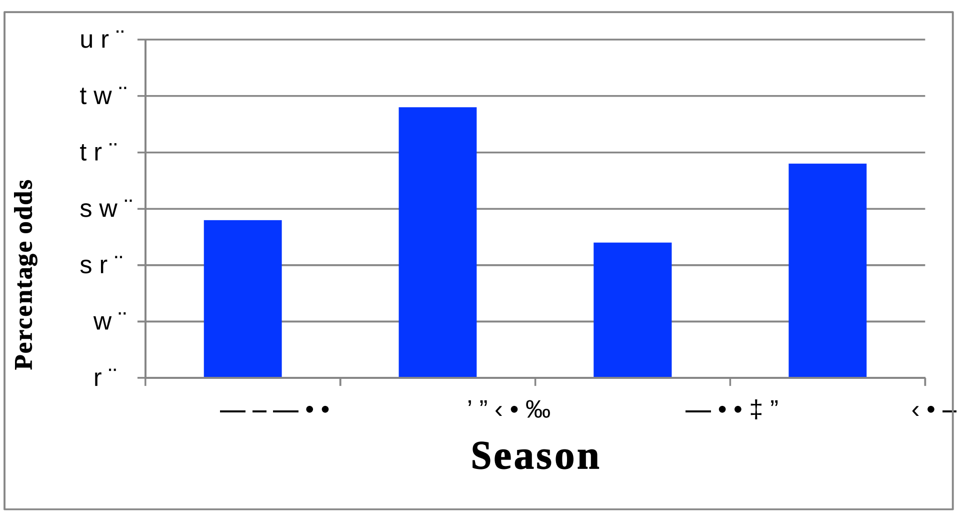


Figure 12- Graph shows the percentage of days closed at Yellow Creek fan per season

based on the quantities of rainfall recorded and size of catchment area of the yellow creek. If the research were to be repeated, the use of sediment data and potential water in the system would give a more accurate model of a potential debris flow.

With the purpose of the study bring to determine conditions required for track closure and the possible extents of a debris flow event in the area, the data and methods could only be used to produce theoretical results, and with the time and previous knowledge constraints the depth of this analysis could not be done as thoroughly as would be possible with more time. The modelling of possible debris flows is very limited due to the complexity of this form of analysis and the lack of previous knowledge of group members in this field. For this purpose the Kanako modelling software was used, this software does not have any input for modelling the topography of the land after the channel ends, this area is modelled as flat which on the Yellow Fan is not accurate to the true topography. The logistical regression model created from the historic rainfall data is a more accurate prediction method due to the availability of all the required variables for an accurate model. The accuracy of the statistical modelling can be much more certain than that of the physical model in this situation due to the number of variables, and the availability of the data. The mae e . Th5(ta)7rd5.7(l).4(a.8(e)6.6a7.3(n)95n1(e)-o) understanding debris fan morphology and potential hazard areas. Through use of debris flow modelling, potential debris flow extents and depositions were modelled that highlighted possible threats to the track. Statistical analysis of rainfall and track closure data demonstrated that the probability of future track closures could be predicted with almost 100 percent certainty. We applied these methods to help DOC and glacier guides improve the safety of tourists as they walk the track to the glacier terminus, we have researched and analyzed areas of risk, and provided information and data that can be utilized in the future, in order to help ensure visitor safety.

Acknowledgments

Throughout this research we were fortunate enough to have the help and support from a number of important people. We would like to acknowledge the following people that have put time and effort into helping us with this research process. Thank you to;

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