

# ASPECT

Definition: ˈas – pekt / 1. a position facing a particular direction  
2. appearance to the eye & mind.

## THE DEGIFS NEWSLETTER

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### The Editors:

Bruce Thomson, P.Geo.  
[brucethomson@shaw.ca](mailto:brucethomson@shaw.ca)

Jennifer Clarke, P.Geo.  
EBA Engineering Consultants Ltd.  
[jclarke@eba.ca](mailto:jclarke@eba.ca)

Julie Orban, P.Geo.  
Land and Water BC  
[julie.orban@gems9.gov.bc.ca](mailto:julie.orban@gems9.gov.bc.ca)

### *The "Editorial" – Warm and Fuzzy*

Yikes - Here I sit with Mr. P.G., faced with the responsibility of compiling a technical editorial to stimulate the ever-advancing unquenchable grey matter of the DEGIFS readership. Quite the intimidating task for one who's job description is riddled with *warm and fuzzy* tasks such as: relationship-building, facilitation, getting-to-yes'ing, liaising, consensus-building, mediating, group-hugging etc. - all that intangible amorphous kinda stuff that doesn't fit into an equation or a sieve.

So, as a deer in the headlights faced with such a daunting task, my natural instincts took over and caused me to flee to safety. Instead, I will leave the technical stimulation to be satisfied at the upcoming AGM and my editor's task will now be to simply recount a conversation. Last week, while indulging in brunch's finest swine and cluck, two fellow DEGIFS types and I were shooting the feces. During this yak-a-thon, we commiserated on the seemingly defenceless battle we are fighting against the exponentially-multiplying forces of the pine beetle battalion. From there, we regressed to discussing our careers in the forestry sector (i.e., 2 of our forestry careers are no longer in existence while the 3<sup>rd</sup> compadre, although still working in forestry, is now engaged in the uplifting task of mapping the extent of pine carcasses falling victim to said beetle). With only mere seconds to go, prior to me uncontrollably blubbing into my cloth napkin, light was shed on the spiralling conversation as DEGIFS saved the day. A positive tone was restored to our mid-morning confabulation as we discussed the upcoming topics and events catered to DEGIFS in the 2004 AGM. When the wind-power presentation (i.e., *Energy Generation in British Columbia: Potential and Issues - Lewis and Duggleby*) came up, we acknowledged our keen interest to attend a presentation that was not forestry-related. This kick-started another tangent to the rap-fest where we explored the possibility of expanding the DEGIFS focus to encompass the natural resource sector instead of limiting it to only forestry. This provided much food for thought as we polished off another round of steaming brown liquid. I will now present this question to those of you who are still reading this drivel – **What are your thoughts on the possibility of becoming the Division of Engineers and Geoscientists in the Resource Sector (DEGIRS - sounds kinda tough if you really resonate on the 'R')?**

To continue along the *warm and fuzzy* vein (non-magmatic) I am also proposing (as per Mr. Guthrie's suggestion) to include an '*Up Close and Professional*' section to profile members. This would involve conducting a 'surprise-interview' on a randomly selected DEGIFS member to briefly glean information to account for a day in their caulks. Yet another reason to invest in the \$4.00 over-bundle cost of call display.

I must also thank those that answered my desperate plea to fill this fall issue with some hearty meat and potatoes. The damsel in distress was rescued by her fellow DEGIFS'ers who promptly rose to the occasion and provided hydrophobicity, log stringers and geo-newsletter goodness. Seek (panic) and ye shall find.

For those of you who have yet to submit tales (i.e., highs, lows, mediums) of your professional journey, I also take this opportunity to encourage you to submit. Letters to the Editor are also always welcome.

See you in Whistler. Bring on the fans, flying mugs and bottle-cap-eye-orthotics!

*The Ed*



## 2004 APEGBC AGM – Whistler, BC DEGIFS AGENDA

Please peruse the **irresistible** schedule of events, catered just for our DEGIFS crew, at the upcoming AGM. Looks like we're in for YET ANOTHER action-packed and knowledge-filled opportunity to learn indoors and out. Many thanks to Heather Blyth, Tracy Frazer and Janet Sinclair for pulling it all together! Sign-up now before it's too late. (-Remember hard hats are MANDATORY in the Frontenac Room!-)

### SPECIAL TECHNICAL TOUR WEDNESDAY, OCTOBER 20, 2004

#### Exploring Fans: Squamish to Pemberton 8:30 am – 4:30 pm

*Division of Engineers and Geoscientists in the Forest Sector*

**Trip leaders: Dave Wilford, PGeo, RPF  
Tom Millard, PGeo**

This field trip will consist of a full day exploring logged and natural fans in the Squamish to Pemberton area. The focus will be on identification of hydrogeomorphically active zones on fans and their implications to forest management practices. The differences between debris flow, debris flood and flood fans will be examined. Participants should wear boots and carry rain gear.

### ENGINEERING AND GEOSCIENCE IN THE FOREST SECTOR

**THURSDAY, OCTOBER 21, 2004**

**Location: Frontenac A Room**

*Coordinated by DEGIFS*

#### A1A Standard Haul Design: Vehicle Configuration for Forest Roads in BC

9:00 – 9:35 am

**Speaker:** Darrel Gagnon, PEng

This presentation will examine the development of revised Design Vehicle Configurations for use in the design of BC Ministry of Forests bridges. These configurations provide a more consistent level of design safety for all bridge spans and are consistent for use with the provisions of CAN/CSA-S6-00 (CHBDC).

#### A1B Leagh Creek Mainline: A Lesson on Murphy's Law

9:35 – 10:15 am

**Speaker:** Eric McQuarrie, PEng

After several attempts to design road access into the Leagh Creek watershed, an alignment was found that was at least not impossible, but still had its share of problems. The measures that were taken to complete this complex project will be discussed.

#### B1A Road Design: Information Taken to Wildly Different Extremes

10:45 – 11:20 am

**Speaker:** Tim Dunne, PEng

Road design in the forest industry is performed for slope stability, construction costs, appraisal, and contract management. This session will examine opportunities to better synchronize survey and design with intended use.

#### B1B Common Problems Associated with Forest Road Bridges

11:20 am - Noon

**Speaker:** Jeremy Araki, EIT

Individuals with a wide range of knowledge levels design forest road stream crossings. This presentation examines the varying degrees of success in the design, construction, and maintenance of these structures.

#### C1A Canadian Highway Bridge Design Code and the Design of Bridges for the Ministry of Forests

1:45 – 2:20 pm

**Speaker:** Julien Henley, PEng

This session will present a review of CSA S6-2000, the Canadian Highway Bridge Design Code for the Ministry of Forests to evaluate applicability of the revised code to forest road bridge structures.

#### C1B Historic Road Construction Techniques vs. New Ones

2:20 – 3:00 pm

**Speaker:** Calvin VanBuskirk, PEng, PGeo

With the current "results-based" code, it may take years or decades to determine if certain practices are meeting the desired results and if they are doing so economically. By undertaking a study of past forest road construction practices to determine what practices work or do not work; it is possible to recommend changes or points to build on.



## D1A The Characterization of Drainage Related Landslides on Gentle Over Steep Terrain of the Southern Interior of British Columbia

3:30 – 4:15 pm

**Speaker:** Doug Stead, Kevin Turner, PEng

Results of recently completed research on gentle-over steep terrain in the Southern Interior will be presented including details of the field investigation, parameters measured, observed important factors, and computer modelling.

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**DEGIFS AGM - 4:15 – 5:30 pm - Location: TBA**  
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## ENGINEERING AND GEOSCIENCE IN THE FOREST SECTOR

FRIDAY, OCTOBER 22, 2004

Location: Frontenac A Room

Coordinated by DEGIFS

### E1A Experiences with Implementing Terrain Stability Assessment Recommendations

9:00 – 9:35 am

**Speaker:** Mark Graf, Limited Licensee (Engineering)

Terrain Stability Assessment recommendations are based on limited subsurface information. Specific project TSA road construction (recommendations and examples) are discussed along with why changes were necessary during construction.

### E1B Landslides and Erosion in the Southern Interior of BC: Implications for Terrain Stability Mapping and Assessments

9:35 – 10:15 am

**Speaker:** Peter Jordan, PGeo

The results of a six-year study on landslides and terrain attributes in southeastern BC give quantitative data on landslide likelihood following road construction and harvesting, and show notable differences from similar studies conducted on the Coast. This presentation will discuss the implications that this and other research projects have on choosing the criteria used to assign hazard classes for terrain stability and erosion.

### F1A Forest Practices Board Investigations and Professional Accountability

10:45 – 11:20 am

**Speaker:** John Pennington, LLB

Professional judgment and environmental management systems take on greater importance under the new forestry legislation. An examination of the work of the Forest Practices Board provides lessons for the future.

### F1B Wind Energy Generation in British Columbia: Potential and Issues

11:20 am - Noon

**Speakers:** Terry Lewis, PGeo, Tony Duggleby

This presentation will provide perspective and current trends for wind power generation on global, North American and Canadian scales. The potential for wind power in BC and current proposals, as well as issues regarding terrain suitability and potential conflicts, will be outlined.

### G1A Fire History, Debris Flows and Geomorphic Process

1:45 – 2:20 pm

**Speakers:** Bill Grainger, PGeo, Dave Wilford, PGeo, RPF

Research in the western U.S. and Canada and dendroecological observations on fans in the Southern Interior of B.C. suggest a relationship between forest fires, watershed sediment supply and debris flow occurrence. Evidence, controls and implications will be discussed.

### G1B The Okanagan Mountain Park Fire 2003: A Post-fire Slope and Hydrologic Hazard Risk Analysis

2:20 – 3:00 pm

**Speakers:** Don Dobson, PEng, Tim Smith, PGeo

The summer of 2003 brought severe drought conditions and wildfires to the Southern Interior of BC. The catchment areas of several watersheds located within the City and Regional District's boundaries were severely burned. This presentation will review the results of a risk analysis undertaken to determine the potential risk to public safety and infrastructure located within these watersheds.

### H1 Fan Research Part II: A Broader Perspective

3:30 – 4:45 pm

**Speakers:** Dave Wilford, PGeo, RPF, Tom Millard, PGeo

The new Forest and Range Practices Act has regulations that can restrict development on alluvial or colluvial fans. This session will discuss recent fan destabilization research results from North-Central BC, the South Coast of BC, and Vancouver Island.



## DEBRIS FLOWS CAUSED BY WATER REPELLENT SOILS IN RECENT BURNS IN THE KOOTENAYS

Peter Jordan, P.Geo., Mike Curran, P.Ag., and Doug Nicol, P.Eng.<sup>1</sup>

Until the past year, the hazard of debris flows, landslides, and floods related to wildfires has not been fully appreciated in British Columbia, especially in the more humid mountain regions. Following the wildfires of 2003 in the southern Interior, there have been several unusual mass movement and flood events which have alerted us to the potential of extreme events following severe burns, and to the role of hydrophobic (water repellent) soils in causing these events. This article reports two events that occurred in August of this year in the Kootenay region (former Nelson Forest Region), and discusses some related issues such as risk assessment and research needs.

Soil erosion, mass movement, and flooding have long been recognized as significant hazards following fires in the western United States (Kalendovsky and Cannon, 1997; Robichaud et al., 2000). Much of the American work has been done in places like the Colorado Front Ranges and southern California, where wildfires are common, and there are consequences to large urban populations. In Canada, most wildfires occur in relatively unpopulated areas, and once the fire is out, further monitoring of conditions in the burns is rare. If erosion events occur following burns, they are likely to be unobserved and unreported. To the knowledge of the authors, no significant wildfire-related events have been reported in southeastern British Columbia before 2003. The last extreme fire season in this region was 1985, when several very large wildfires occurred in the East Kootenays. One of these was the Matthew Creek fire near Kimberley, which was in a community watershed; a water quality research and monitoring project was conducted here for several years. No unusual erosion or mass movement was observed in this burn or in the other large fires. In 1995, another bad fire year, Ministry of Forests research staff were involved in deactivation prescriptions for a number of fires, and again no unusual events were reported. An inventory of landslides in a large study area in the region identified about 1740 landslides; in only 30 of these was wildfire identified as a probable cause.

There are several reasons why severe soil erosion and mass movement following wildfire may be rare in B.C., compared with in the U.S. The hydrology, especially in

mountainous regions, is dominated by snowmelt; as explained below, hydrophobic soils are unlikely to influence runoff during snowmelt or during early-season rainstorms following snowmelt. Rainfall intensities during summer rainfall events tend to be much lower than in the American southwest. Much of our forest land is in a relatively humid environment, where the forest floor is relatively thick and well-shaded by trees and understory vegetation, making it resistant to drying out.

In the 2003 fire season, conditions were unusual. Several large fires happened late in the season, when the soil and fuel were exceptionally dry following a hot, dry summer. This led to unusually intense ground fires, which burned the forest floor to a greater extent than in most years.

### Hydrophobic soils following fire

(from Curran et al., 2004)

Hydrophobicity (or water repellency) is a natural phenomenon that can occur in forest soils when they dry. Water-repellant organic substances, such as waxes and lipids, naturally occur in the forest floor and soil. These come from plant litter and roots, decomposition of these materials, and fungal hyphae. In summer, it is not uncommon for these materials to impart some hydrophobic properties to the surface soil. However, this type of hydrophobicity is usually not of hydrologic significance because it is not as well developed as post-wildfire, and usually does not affect a large, continuous part of the forest soil.

During wildfire, the forest floor can be partially or totally consumed. During and immediately prior to combustion, the waxes, lipids, and other compounds vaporize and diffuse both into the atmosphere above the ground, and into the soil atmosphere. In the soil, these compounds will condense when they reach a lower temperature and vapor pressure, coating the mineral soil particles. This often occurs one or more centimeters below the surface. In order for a continuous coating of hydrophobic compounds on the soil particle surfaces there needs to be:

1. enough heating of the soil to vaporize these organic compounds and move them down into the soil (this implies dry litter & duff that is largely consumed in the wildfire)
2. soil that was dry enough to allow the gaseous vapors to penetrate, and enough of



these vapours to adequately coat all the soil particles at the depth of condensation.

3. Sandy soils, which have the lowest surface area, are more susceptible to hydrophobicity following wildfire, although these layers can form on a range of soil textures.

A hydrophobic layer in the soil may completely stop infiltration of water into the soil with the result that water that would normally soak into the soil now runs over the surface and begins to erode. Soils are hydrophobic immediately after a fire and the first major rainfall events after a fire can cause significant erosion. Hydrophobicity persists for several years (somewhere between 2 and 6 years), but its importance is reduced as sites revegetate and the forest floor builds up. The effects of hydrophobicity are most pronounced after prolonged dry periods (or shortly after a fire). As soils moisten, the effects of the hydrophobic layers lessen and infiltration of water proceeds at normal soil rates. For this reason, hydrophobicity of soil is not a concern during snowmelt or in the spring. However, in the years following a fire, as the soil dries out in summer following snowmelt, hydrophobicity can return.

In October 2003, following the Okanagan Mountain Park fire at Kelowna, a severe rainstorm caused extremely high peak flows and extensive soil erosion and sediment movement in two burned watersheds. This event was documented by Don Dobson and Tim Smith (in Rogers, 2004), who attributed it to hydrophobic soils caused by the fire. Hydrophobic soils are also believed to be a contributing factor in the debris flows that occurred in the Cedar Hills fire near Falkland.

### The Kuskonook Creek debris flow

On the night of 6-7 August 2004, a large debris flow occurred in the channel of Kuskonook Creek, a steep mountain drainage about 25 km north of Creston (Kootenay Lake Forest District). There was substantial damage on the fan, including the destruction of two houses, and Highway 3A was closed for several days. A smaller debris flow occurred at about the same time on Jansen Creek about 1.5 km north, which caused only minor damage. A heavy rain shower was reported in the area on the evening of August 6-7, which apparently was quite localized, as weather data from nearby stations did not show any unusual amounts of rainfall. The rain event followed a month of very dry weather.

In 2003 a wildfire burned most of the Kuskonook and Jansen Creek watersheds. The area of most severe burn occurred in the upper part of the watersheds, and can be recognized from the air a year after the fire as being grey in colour, with little greenup by grass or other vegetation. The areas of severe burn are patchy, and probably occupy only about 10% of the watershed area.

The authors (together with Dwain Boyer, P.Eng., of the Ministry of WLAP in Nelson, and Dr. David Scott of Okanagan University College) inspected the area on the ground and from the air soon after the event. We found hydrophobic soils throughout the drainage area contributing to the debris flow, especially in the most severely burned areas. The soils are sandy, derived from granite and granitic till, which may make them especially susceptible to developing a hydrophobic layer. We did not observe any landslides (except for one small slide in a tributary gully, unrelated to the main debris flow source). There was fairly extensive, shallow, soil erosion due to overland flow.

In the most intensely burned areas, there was abundant evidence of overland flow, generated as rainfall was impeded by the hydrophobic layer. This evidence was in the form of shallow erosion rills, areas where the overlying ashy layer had been washed or floated off, accumulations of ash and sediment in low-lying areas, small debris buildup in vegetation, and flattened grass. The greatest amount of overland flow was produced in the most intensely burned areas, a lesser amount was produced in areas of lighter burn, and there was no evidence of overland flow from areas of unburned forest.

Most of the overland flow was produced in fairly gently sloping areas near the top of the watershed, at about Elevation 1800 to 2050 m. The flow then cascaded over steep slopes below, towards the incised gully of the creek channel. On these slopes, erosion rills and flattened grass indicate that flowing water covered about 50% of the width of the slope, in an area where there are no pre-existing channels. In the adjacent creek channel, the high-water mark from the running water is several times as wide as the natural channel width. As the creek channel steepened downslope to 60% or more, its flow began to erode the bank and bed, and entrain coarse gravel and boulders. Below this point, it appears that the channel bed and banks failed, and the flood became a fully developed debris flow.



Although this channel is naturally subject to debris flows, as far as we know it had not experienced a large debris flow event in the last century. (The community of Kuskonook has existed on the fan for that long, and a 100 year old building was damaged by this event.) As the debris flow progressed downstream, it entrained the sediment, soil, and wood debris which had accumulated, stripping the channel to bare bedrock and becoming larger in the process. On the fan, the event deposited an estimated 10,000 m<sup>3</sup> or more of debris. The debris is coarse, typical of granitic-source debris flows, but it includes a lot of fine black organic material, derived from charcoal and burned litter from the burn, which gives the debris a dark colour.

In the adjacent Jansen Creek, evidence of overland flow from severely burned areas at its headwaters was clearly visible from the air, and it appears the cause of the debris flow in its channel was the same as in Kuskonook Creek.

In summary, we concluded that these debris flows were caused by exceptionally high peak flow, generated by overland flow on hydrophobic soils covering a relatively small area of severe burn near the headwaters of the creeks.

Photo 1. Debris flow deposit on Kuskonook Creek fan.



Photo 2. Aerial view of Kuskonook drainage basin and fire. Salvage logging is underway on right; Jansen Creek is on the left. The start of the debris flow is faintly visible just right of centre.



Photo 3. Shallow soil erosion from overland flow, headwaters of Kuskonook Creek.





## The Lamb Creek debris flow and flood

On the afternoon of 19 August 2004, a local rainstorm initiated several debris slides and debris flows in drainages located within and downstream of the Lamb Creek Fire, southwest of Cranbrook (Rocky Mountain Forest District). In Gold Hill Creek, a tributary of Lamb Creek, the event washed out a Forest Service road and stranded 7 vehicles until road access could be re-established. Heavy local rainshowers and hail were observed; however, the nearest weather stations did not record any significant accumulations. Reconnaissance flights the next day did however note significant hail accumulations at high elevations. In 2003 a wildfire (11,000 hectare) burned most of the Lamb Creek and upper Moyie River drainages. To date, little green up has occurred in the upper portions of the drainages where the fire severity was high.

The drainage most severely impacted by the rain/hail event was Gold Hill Creek, which comprises a 500 hectare area that drains into Lamb Creek. On 19 August, three debris slides occurred at about the 1900m elevation within a severely burned bowl shaped area of the upper portion of the Gold Hill Creek drainage. The runoff distance from the slides to the height of land was only 300 to 400 m. The slides did not directly impact Gold Hill Creek. However, there was evidence of significant overland flows within the burned areas, which produced concentrated runoff within the bowl (area of concentration about 100 hectares), and initiated a debris flood at the bowl outlet. As the Gold Hill Creek channel steepened and the volume of entrained sediment increased (from continued channel erosion) the flood was transformed into a debris flow. After about a kilometre the channel gradient flattened to approximately 10% and deposition of about 5,000 m<sup>3</sup> occurred. Further downstream the channel steepened in several segments to 15% whereby the flood once again transported significant debris and bedload. When the channel gradient dropped to 10% the bedload once again dropped out (effectively plugging the channel for distances of 200 to 300m). This change between transport and deposition occurred several times throughout the 4.5 km transport zone. The total volume transported/deposited is estimated at 30,000 to 50,000 m<sup>3</sup>.

Approximately 10,000 m<sup>3</sup> was deposited at the confluence of Gold Hill Creek and Lamb Creek, whereby the larger creek was dammed by a debris plug that was several metres deep. The subsequent

breach of the dam flooded Lamb Creek for a distance of 7 km to its outlet in Moyie Lake.

Given the extreme runoff volumes from a summer thunderstorm, the relatively small drainage areas and the extent of the fire severity, it was concluded that the debris flows and floods were caused by the soil hydrophobic effects resulting from the 2003 fire.

Photo 4. Small landslide in upper basin of Gold Hill Creek, Lamb Creek watershed.



Photo 5. Scour by debris flow in the channel of Gold Hill Creek.

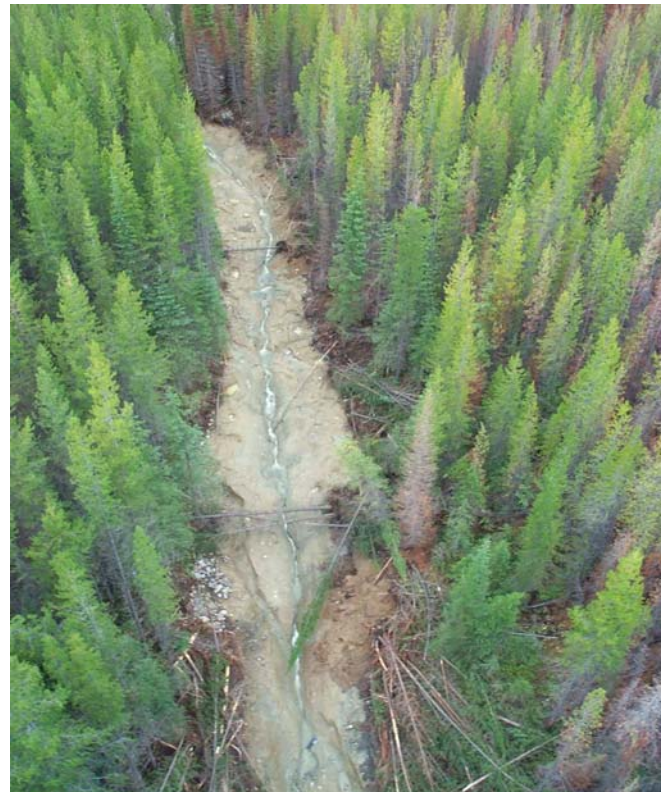




Photo 6. Confluence of Gold Hill Creek debris flow and Lamb Creek.



## Hazard and risk assessment

Following the 2003 fires, the Ministry of Forests conducted a risk assessment of fires in southeastern B.C. (the former Nelson Forest Region), aimed at identifying risks to public safety that might result from possible landslides or erosion following the fires. This process was separate from, and additional too, the more basic risk assessment which is part of the procedure for deactivation of roads, trails, and fireguards on all fires.

The methodology used for this risk assessment is summarized here, with the objective that it might be useful for similar risk assessments in the future.

1. Identification of any high values located below/adjacent to 2003 fires in the region. High values were defined as being residences, private property, high use transportation corridors, railways or where there was significant exposure of human life. At this stage 16 fires were identified as being upslope/upstream of one of the values noted.
2. Conduct preliminary review at the district level to determine if any of the fires can be dropped from the list, due to their limited size, limited consequences or inability of slides to impact any of the values noted. As a result of this review the list was reduced to 10 fires.
3. Review of detailed maps with fire boundaries, contours, and location of downslope values. Helicopter review of the

10 fires – review of fire severity, fire size, and connectivity to consequence values.

4. Given the results of step 3, conduct a preliminary partial risk analysis which combines the likelihood of an adverse effect (whether it be flooding, debris flow, debris flood, rockfall, or creek avulsion)  $P(H)$  with the spatial and temporal exposure ( $P(S:H)$  and  $P(T:S)$ ) of the elements at risk.
5. For any elements identified as being of high risk as per step 4, notification of the risk along with possible mitigation strategies proceeded with respective stakeholders (Regional Districts, MOT, CP Railway etc). Of the initial 16 fires identified, 5 were assessed as having hazards that pose a high risk to identified values, including the Kuskonook fire.

This process was reasonably successful at identifying the fires that presented a risk from debris flows or other events, despite the fact that the severity of the hazard presented by hydrophobic soils was not fully recognized at the time.

## Conclusions and recommendations

An important question that arises from these incidents is: How prevalent is the phenomenon of increased mass movement and flood hazard due to hydrophobic soils? The lack of evidence of previous extreme events in this region suggests it is not very common in southeastern B.C. However, a number of the 2003 fires have now experienced mass movement or flood events, suggesting that, given the weather and soil moisture conditions of last summer, the hazard is widespread. Normally, forest soils generate no overland flow during summer rainstorm events. If only a small area of a watershed has reduced infiltration capacity due to hydrophobic soils, and generates overland flow, the peak flow of a small stream during a rainstorm event can be increased many times over what would occur under pre-fire conditions. From our experience, it appears that the vast majority of wildfires in most years do not produce this hazard. But when the unusual conditions of very dry soil and forest floor, and intense ground fires, occur then many fires in a region may produce hydrophobic soils. In 2003, several of these fires were in interface areas with populated areas downslope or downstream, resulting in some high risks.



In order to conduct effective risk assessments on these fires, we must address these questions:

1. How can we identify where hydrophobic soils may have developed after a fire?
2. How long do the hydrologic effects persist?
3. How can we assess the likelihood of landslides and debris flows following fire?
4. How can we make reasonable estimates of peak discharge of streams draining burns?

A useful step in dealing with the first two questions might be to prepare maps classifying the severity of a burn, something not normally done at present. It is possible that air photos or some other form of remote sensing might be useful for this purpose. Some form of monitoring the recovery of the soil and vegetation in the years following a fire would also be useful. The U.S. Forest Service has a "Burned Area Emergency Response" policy which includes risk assessment, stabilization, monitoring, and funding. The extent of both the hazard, and the consequence of large populations in affected areas, is probably much greater in the U.S. than in B.C.; still, there is much that we could learn from their practices. It is worth noting that the U.S. Forest Service has many times the staff of its B.C. counterpart, to conduct research and monitoring, and to manage a similar land base and timber resource.

To some large extent, the scientific nature of the hazard is poorly understood. Further research is needed in B.C. on several topics. These include the formation and properties of hydrophobic soils, the recovery of soil function and vegetation after a fire, and hydrologic processes such as infiltration and runoff generation. There is a need for both fundamental research on processes, and applied work such as monitoring of selected burns for several years following a fire. For risk assessment, predictive tools are needed; there are some from the U.S. and elsewhere that should be tested here.

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<sup>1</sup> All authors are with B.C. Ministry of Forests, Southern Interior Forest Region (Kootenay Lake Forestry Centre), Nelson, BC.  
E-mail addresses:

[peter.jordan@gems4.gov.bc.ca](mailto:peter.jordan@gems4.gov.bc.ca)

[mike.curran@gems5.gov.bc.ca](mailto:mike.curran@gems5.gov.bc.ca)

[doug.nicol@gems3.gov.bc.ca](mailto:doug.nicol@gems3.gov.bc.ca)

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## 2004 DEGIFS BURSARY APPLICANT - RESEARCH PAPER SUBMISSION

Matt Lansdowne applied for the 2004 DEGIFS Bursary. Matt is a M.Sc. candidate in the Forest Resources Management (Forest Operations) Department at UBC. Matt provided the following paper as a component of the bursary application. We are pleased to present this paper which contains relevant information for the DEGIFS membership. Best of luck to Matt as he completes his academic pursuits.

## LOAD SHARING BETWEEN LOG STRINGERS IN GRAVEL DECKED LOG BRIDGES

*Matt Lansdowne, M.Sc. Candidate  
University of British Columbia - Forest Resources Management*

## INTRODUCTION

In British Columbia bridge designers for logging roads have shifted to using steel or concrete for more permanent structures. For temporary structures gravel decked log stringer bridges can still be a cost effective alternative. However, as companies move into smaller second growth timber, load sharing between the stringers becomes an important consideration. There are many ways that load sharing between log stringers is achieved. Examples of methods used to distribute the live loads between the log stringers are gravel



surfaces, cedar cross puncheon, needle beams, and cable lashing.

If the stringers are assumed to act independently of each other there will still be a sharing of the live load between the stringers. This sharing of the live load is a function of the angle of shearing resistance and the depth of the gravel used for surfacing. As the thickness of the layer of gravel is increased the load will be spread over a larger surface on the stringers; however, a thicker layer of gravel will also increase the dead load that must be supported by each stringer.

For companies working with smaller timber it is desirable to design for thinner gravel decks on log bridges in order to reduce the dead load on the bridge so that the live loads can be maximized. However, this will reduce the number of stringers that share the live load through the angle of shearing resistance of the gravel. In the case of using smaller diameter stringers and thinner gravel layers it will be necessary to rely on other methods such as lashing to share live loads between stringers.

The objectives of this project are to:

1. Develop a Finite Element Model (FEM) of a log stringer bridge in Visual Basic
2. Perform a parameter analysis to determine if it possible for lashing to maintain the load sharing between log stringers when the depth of the gravel surface material is reduced.
3. Distribute the FEM to practitioners.

## RELEVANCE

Sustainable forest management in British Columbia has resulted in 1) smaller cutblock sizes, 2) increased use of partial retention silviculture systems where the volume per hectare of wood removed is less than the total volume of merchantable wood per hectare, and 3) larger areas of forest in reserves. These management strategies have resulted in more active road being required for a given volume of timber produced. Therefore, to limit the increase in development cost it is necessary to reduce the cost of access roads. One way to reduce the cost of access roads is to reduce the cost of new bridges and to avoid unnecessarily replacing existing bridges.

The deliverables from this project will allow engineers working with log bridges to reduce access costs to

forests by reducing the cost of bridges, while maintaining the performance and safety of the structures. Reducing the access costs to forests will maintain or enhance the economic viability of both timber and non-timber resources.

Log stringer bridges used for temporary crossings require only local materials. For a 6.1 m span the initial cost of a gravel decked log stringer bridge is \$7,600, while, an equivalent steel bridge is \$17,300. The steel bridge will have a residual value for the girders of \$7,600 not taking into account dismantling and transportation cost (Bradley and Pronker, 1994). Therefore, in some applications it is more cost effective to use log stringer bridges. The deliverable from this project will help engineers to design reliable log stringer bridges from smaller diameter logs while using thinner gravel surfaces.

There are many existing log stringer bridges. The logs in these bridges decay over time; therefore, it is necessary to take into account the reduction in the area of the log cross sections due to rot when performing bridge inspections (Moody et al, 1979). In addition, the lashing can slacken as a bridge ages and this may affect the load sharing between the log stringers. The deliverable from this project will permit engineers to easily factor out the sap rot from the log stringers where it actually occurs in the logs. This will allow for more accurate estimates of the load capacity of the bridge.

## METHODOLOGY

Nagy et al (1980, p 45) states:

*It is difficult to assess the strength and load sharing of several unequal logs placed top to butt. There is no practical way to calculate this accurately but a suitable approximation of performance can be made if the designer can picture how the load-sharing takes place.*

*The stiffest members of a structural group do most of the work since all members must deflect the same amount. The more elastic members will not deflect enough to develop their potential fiber stresses, but they do make some contribution. If the mid-diameters of the stringers are similar, a design based on the average mid-diameter will be reasonably accurate.*



The first paragraph in this statement by Nagy et al (1980) does not take into account the availability of the finite element method for structural analysis. Logan (1993) notes the finite element method allows analysts to consider structures composed of members with differing material properties. Authors such as Saravi and Lyons (2003) have used the finite element method to successfully model structures composed of cable, wood, and spring elements. Using the finite element method it is also possible to include the actual geometry of the individual structural members.

The second paragraph in this statement by Nagy et al (1980) assumes the stringers in a log bridge act as a structural group. This may not be true for gravel decked bridges. Load sharing between log stringers in gravel decked log bridges, with out needle beams, is a function of the gravel surface and the lashing. Therefore, it is necessary to first determine the extent of the load sharing between the stringers before it can be assumed that the stringers are acting as a structural group.

The model that will be developed in this project will be based on theory that has already proven to be effective in analyzing log structures. The model will use a similar formulation as presented by Weaver and Gear (1980). This formulation was used by Ammeson et al (1987) to model trees used for guyed logging spars and Ammeson's model was shown by Connor (1989) to agree well with full size test data.

A stringer in a log bridge that is designed to operate in the linear range of deflections undergoes a simpler motion than a guyed logging spar. Therefore, the theory used by Ammeson et al (1987) to model trees used as logging spars should work well for a log bridge.

The deliverable from this project will be a FEM of a log stringer bridge. The FEM will have two immediate uses.

- 1) The FEM will be used to perform a parameter analysis which will determine if it is possible for lashing to maintain the load sharing between log stringers when the depth of the gravel surface material is reduced.
- 2) The FEM will allow engineers to estimate the strength of in-situ bridges by;
  - i) factoring the log stringer cross sections where sap rot is found, and

- ii) factoring the spring constants for the lashing.

## EXPERIMENTAL DESIGN

### Model construction

This project will produce a FEM of a log stringer bridge. The FEM will be written in Visual Basic using the stiffness method. The log stringers will be modeled using beam elements and the lashing will be modeled as spring elements.

The load applied to the log stringers will be calculated with a separate routine (Load Routine). The Load Routine will determine the nodal forces applied to each stringer. The Load Routine will first calculate the contact area and the wheel load applied to the surface of the road using methods outlined by Jewel (1996). The load applied to the nodes on the stringers will then be calculated through the angle of shearing resistance of the gravel and the depth of the gravel deck.

The FEM of the log stringers and cable lashing will be formulated using the stiffness method (Weaver and Gear, 1980). In the stiffness method the global structure stiffness matrix is formed by combining the individual element stiffness matrixes. The global structure stiffness matrix links the structure force vector to the structure displacement vector in global coordinates. Once the global structure stiffness matrix is formed the unknown nodal displacements can be expressed as a function of the known nodal loads and the known nodal displacements. After solving this function for the unknown displacements, the unknown nodal loads can be expressed as a function of the nodal displacements.

The models of the individual log stringers will use the data from the full size bending tests performed by FERIC and INTERFOR. In the future, in-situ tests of log stringer bridges will be performed by FERIC and INTERFOR and these tests will be used to validate the lashing model.

### Model Parameter Analysis

The objective of the parameter analysis is to determine if it is possible for lashing to maintain the load sharing between the log stringers when the depth of the gravel surface is reduced.

To perform the parameter analysis the log stringer geometry and MOE will be taken from the



FERIC/INTERFOR full size test data. This will ensure the log stringers are being modeled with realistic properties. The MOR data from the FERIC/INTERFOR full size tests will be used to ensure the loads applied to the bridge do not exceed allowable limits. The MOR data will be factored to produce an allowable stress according to the Canadian Highway Bridge Design Code (CSA, 2000).

Logging trucks can have many different axle configurations and resulting axle loads. Jokai (2003) gives a comprehensive list of models including vehicle specifications. A five axel pole trailer will be used for the parameter analysis as it is common and generally has higher axle loads for a given gross vehicle weight. The limiting position of the truck on the bridge will be defined as the position of the truck that produces the bending moment of greatest magnitude in the bridge. With the truck positioned in the limiting position, the loads applied to the nodes of the stringers will be determined.

Once the loads applied to the nodes of the stringers are determined the spring constant of the springs representing the lashing will be increased until an increase in load sharing between the stringers is observed. Once an increase in load sharing is observed the load supported by the lashing elements will be compared to the working load for the cable to determine if it is possible for the lashing to assist in load sharing between the stringers.

The sensitivity of load sharing between the stringers will be determined with respect to the MOE of the logs, the depth of the gravel fill, and the shear angle of the gravel fill.

## LITERATURE CITED

Not included in this revised Aspect publication. Please contact the author (Matthew Lansdowne) for this information: [mlansdow@hotmail.com](mailto:mlansdow@hotmail.com)

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## NEWSLETTER ANNOUNCEMENT:

### **ISLAND GEOSCIENCE** **Contact: Rick Guthrie**

Island Geoscience is a new quarterly newsletter that seeks to keep readers informed of recent geoscience issues related to water, land and air protection on Vancouver Island, and coastal British Columbia.

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[Richard.Guthrie@gems6.gov.bc.ca](mailto:Richard.Guthrie@gems6.gov.bc.ca)



## Who We Are

### EDITORIAL BOARD

Iain Blown

Ph: (250) 837-3743 / Fx: (250) 837-3783

Email: [blown@rctvonline.net](mailto:blown@rctvonline.net)

Shelley Higman

Ph: (250) 775-3550 / Fx: (250) 755-3421

Email: [shelley.higman@weyerhaeuser.com](mailto:shelley.higman@weyerhaeuser.com)

Eric McQuarrie

Ph: (250) 721-1665 / Fx: (250) 721-1665

Email: [emcquarrie@shaw.ca](mailto:emcquarrie@shaw.ca)

Bob Patrick

Ph: (250) 756-2256 / Fx: (250) 756-2686

Email: [bpatrick@eba.ca](mailto:bpatrick@eba.ca)

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### DEGIFS EXECUTIVE

Calvin VanBuskirk, P.Eng., P.Geo., Chair

Ph. (250) 832-3933 / Fx. (250) 832-1117

Email: [calvinvb@sunwave.net](mailto:calvinvb@sunwave.net)

Brian Chow, P.Eng., Vice Chair, Bursary Co-ordinator

Ph. (250) 387-8615 / Fx. (250) 387-6445

Email: [brian.chow@gems2.gov.bc.ca](mailto:brian.chow@gems2.gov.bc.ca)

Tim Dunne, RPF, P.Eng., Secretary

Ph. (250) 832-3366 / Fx. (250) 832-3811

Email: [tdunne@forsite-sa.com](mailto:tdunne@forsite-sa.com)

Deepa Filatow, P.Geo., Co-Treasurer

Ph. (250) 764-5266

Email: [deepa@telus.net](mailto:deepa@telus.net)

Bill Grainger, P.Geo., Co-Treasurer, Affiliate Liaison

Ph. (250) 833-0901 / Fx. (250) 833-0901

Email: [bgrainger@telus.net](mailto:bgrainger@telus.net)

Doug Nicol, P.Eng., Guideline Subcommittee Chair

Ph. (250) 825-1100 / Fx. (250) 825-9657

Email: [doug.nicol@gems3.gov.bc.ca](mailto:doug.nicol@gems3.gov.bc.ca)

Heather Blyth, P.Geo., Workshops / AGM Coordinator

Ph. (250) 339-0690 / Fx. (250) 339-0690

Email: [hblyth@shaw.ca](mailto:hblyth@shaw.ca)

Eric McQuarrie, P.Eng., Past Chair

Ph. (250) 721-1665 / Fx. (250) 721-1665

Email: [emcquarrie@shaw.ca](mailto:emcquarrie@shaw.ca)

### APEGBC LIAISON

Peter Mitchell, P.Eng., APEGBC Liaison, Alternate JPB Liaison

Ph. (604) 430-8035 / Fx. (604) 430-8085

Email: [mitchell@apeg.bc.ca](mailto:mitchell@apeg.bc.ca)

### WEB PAGE CONTACT

Heather Blyth, P.Geo.

Ph. (250) 339-0690 / Fx. (250) 339-0690

Email: [hblyth@shaw.ca](mailto:hblyth@shaw.ca)