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Frozen debris lobes – Characterizing a potential geologic hazard along the Dalton Highway, southern Brooks Range, Alaska

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101233 NA

162076 NA

FDL-D A-A'

Distance (meters)

areas with south-facing slopes greater than 30 degrees. 5E and 5F) Topographic profiles across FDL-D (see 5C for location of profiles.

Table 4. Tabular data from LiDAR analysis of FDL-D

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ABSTRACT

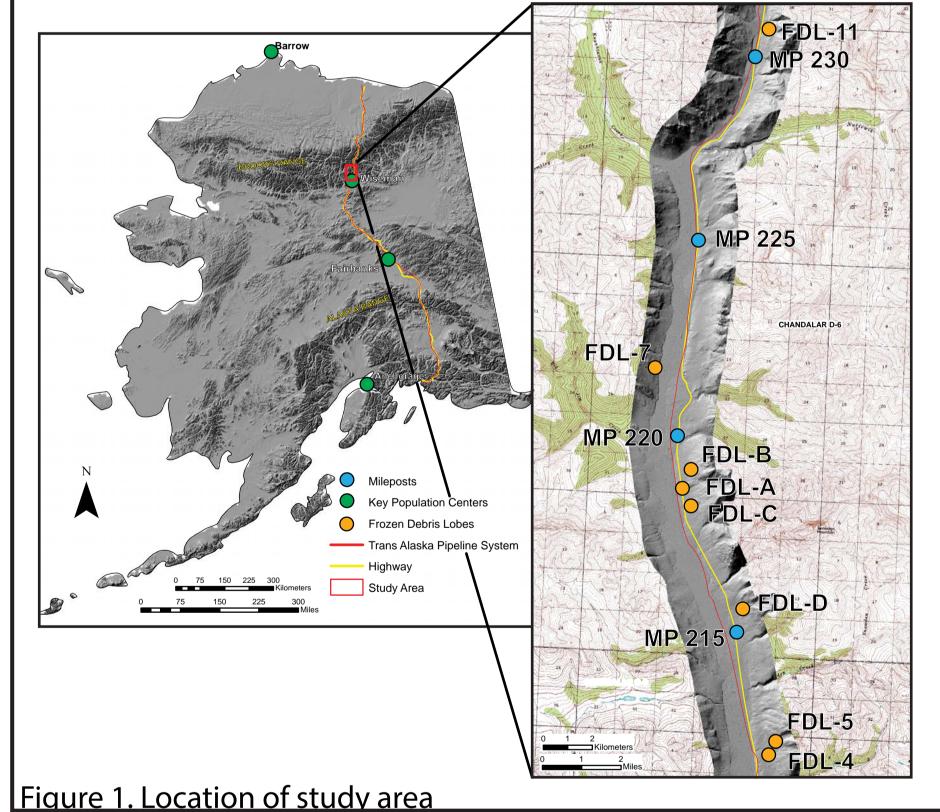
rozen debris lobes are elongated, slow-moving landslides of frozen soil, rock, and debris. As part of geologic hazards investigations along Alaska's major infrastructure corridors, the Alaska Division of Geological & Geophysical Surveys (DGGS), ir conjunction with UAF, is conducting a study of the lobes in close proximity to the Dalton Highway, Trans Alaska Pipeline System (TAPS) and proposed natural gas oipeline corridor between Wiseman and Chandalar Shelf in the southern Brooks Range. This region is characterized by steep terrain, active slope movement, and continuous permafrost. Repeat imagery and previous investigations indicate that some debris lobes are moving rapidly while others lack evidence of significant

The primary goal of this study is to develop a means of classifying the potential geologic hazard of frozen debris lobes. This assessment is being conducted using multi-date remotely-sensed imagery and oblique photography, repeat differential GPS surveys, and multi-year geologic field observations. As part of our work we are measuring the surface rate and direction of movement of eight of these debris lobes. These data will assist us in predicting future movement, including the poten-Itial for increased movement of lobes that are currently less active. Here we present information from our preliminary classification scheme, including distance of the features from the Dalton Highway, rate of movement, slope, aspect, and size of the debris lobe and catchment area. Additionally, we discuss other parameters important for geohazard classification of the lobes. Information and results from our investigations will be important for decision-making related to long-term maintenance of the Dalton Highway and TAPS, and will be useful in planning for potential future development such as a proposed natural gas pipeline.

INTRODUCTION

The Dalton Highway is the main infrastructure connecting Alaska's North Slope to Fairbanks and areas beyond, making it vitally important to have information about potential geologic hazards for maintenance decisions and development planning. The southern Brooks Range section of the highway is characterized by actively Kreig and Reger, 1982; Brown and Kreig, 1983). Recent studies of frozen debris lobes (FDLs: slow-moving landslides of frozen soil, rock, and debris) in this area indicate the FDLs are moving rapidly enough to be problematic to both the Dalton Highway and the adjacent Trans Alaska Pipeline System (TAPS) (Daanen and others, 2012; Darrow and others, 2012).

Summer 2013 fieldwork focused on collecting real-time kinematic global positioning system (GPS) data to calculate rates of surface movement of eight FDLs in close proximity to the Dalton Highway while examining the geologic characteristics of the FDLs and associated debris catchment areas (Figure 1). The extent of existing LiDAR coverage allows us to make an initial assessment of geologic hazard potential for five of the eight FDLs along this corridor that are closest to the road and TAPS (FDLs A, B, C, D, and 11) by combining our field data with desktop evaluations. Assessment of FDL-D was limited because of incomplete LiDAR coverage in the catchment area. Existing inch-to-the-mile maps were used when pos-



METHODS

Slopeshade images (Figures 2A–6A), showing variation in surface slope, aspect images (Figures 2B-6B) showing variation in slope orientation, and flow accumulation images (not shown here) showing areas of surface water accumulation were generated for each FDL area using high-resolution LiDAR (Hubbard and others, 2011).

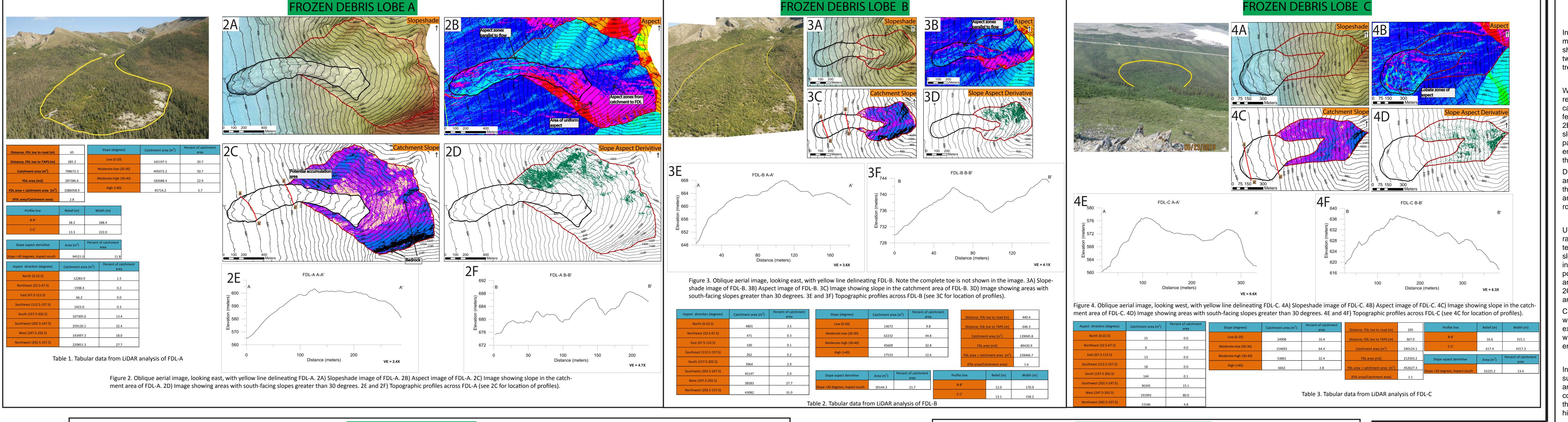
Based on interpretation of LiDAR images, ArcGIS was used to create polygons outlining FDLs and associated debris catchment areas (Figures 2–6). While most debris-catchment areas and FDL boundaries were easily discernible using slopeshade and aspect images, flow accumulation images helped differentiate boundaries in lower catchment areas where it was difficult to determine where water, and thus debris, are added to the FDLs.

After polygons were created, areas were calculated for each FDL and debris catchment, and FDL area/FDL debris catchment area were determined. Additionally, distances from the toe of each FDL to the road and TAPS were calculated (Tables 1-5).

LiDAR-derived slope data were used to calculate the percentage of each debris catchment, with low, moderate-low, moderate-high, and high slope angles (Tables 1–5); results are displayed visually in catchment slope images (Figure 2C–6C). Similarly, LiDAR-derived aspect data were classified according to geographic orientation and percentage calculated for each class, with a given range of aspect values (Tables 1-5). The distribution of aspect for each FDL and catchment area are shown in the aspect images (Figure 2B–6B).

Aspect and slope-derived LiDAR data were combined to calculate the percentage of each debris-catchment area with high slope values and southerly aspect (Tables 1–5); results are displayed visually in slope-aspect derivative images (Figures 2D-6D).

LiDAR digital elevation models (DEMs) and functionality in Grapher were used to construct topographic profiles for each FDL to examine variability in slope and relief along cross sections in the lower and middle regions of each lobe (Figures 2E–6E and 2F–6F). Locations of profile lines are shown in Figures 2C–6C.



Slope Profile Lines

Debris Lobe Outline

Northeast (22.5-67.5)

Southeast (112.5-157.5)

Southwest (202.5-247.5)

Northwest (292.5-337.5)

South (157.5-202.5)

West (247.5-292.5)

North (337.5-360)

Slope aspect derivitive

Catchment slope

Slope (degrees)

>20- 30

East (67.5-112.5)

Slope Aspect Derivat

0 100 200 400 Meters

140173 NA

225373 NA

72234 NA

FDL-D B-B'

Distance (meters)

Figure 5. Oblique aerial image, looking south, with yellow line delineating FDL-D. 5A) Slopeshade image of FDL-D. 5B) Aspect image of FDL-D. 5C) Image showing slope in the catchment area of FDL-D. 5D) Image showing

Contour Interval = 20 meters

FDL-11 A-A' VE = 4.4XSlope > 30 degrees, Aspect 90-270 degrees Figure 6. Oblique aerial image, looking east, with yellow line delineating FDL-11. 6A) Slopeshade image of FDL-11. 6B) Aspect image of FDL-11. 6C) Image showing slope in the catchment area of FDL-11. 6D) Image showing areas with south-facing slopes greater than 30 degrees. 6E and 6F) Topographic profiles across FDL-11 (see 6C for location of profiles). Table 4. Tabular data from LiDAR analysis of FDL-11. Aspect direction (degrees) Catchment area (m²) Percent of catchmene 11483 4.3 24030 8.9 56496 21.0 Table 5. Tabular data from LiDAR analysis of FDL-11

RESULTS/DISCUSSION SURFACE MOVEMENT

Initial analysis of GPS measurements from summer fieldwork indicates FDL-D moved the greatest amount. FDLs 7 and A moved less and FDLs 4, 5, 11, B, and C, showed little movement. Our measurements only account for movement over a two-month period; additional measurements are needed to determine meaningful trends and rates.

rection and style of movement of surface material within each FDL and debris catchment, as well as the information about the type of weathering patterns of different material. Faster-moving frozen debris lobes such as FDLs A and D (Figures 2B and 5B) have distinct zones that parallel their general flow direction, while in slower-moving FDLs these zones are less distinct. FDL-C lacks zones of aspect parallel to flow but does have lobate zones of aspect, perhaps representing a different style of downslope movement (Figure 4C). FDL-D has elongate zones of aspect that parallel flow as well as zones perpendicular to flow (Figure 3D).

Distinct zones of aspect can be traced from most FDLs to the debris-catchment areas (e.g., Figures 3B and 6B) that indicate how material is being transported from the FDL catchment areas. Then, considering rock type and what kinds of materials are being contributed, distinct zones of aspect also may be related to differences in rock weathering (Spangler and others, 2013).

rstanding slope angle variations in FDL debris catchments is important as rates of slope movement may be directly related to slope angle, with material potentially moving downhill faster on steeper slopes and accumulating on more gentle slopes. The percentage of catchments with steeper and gentler slopes may be an indication of the rate at which material can be delivered to an FDL as well as the potential for material accumulation. Areas of low slope (possible accumulation areas) can be found near the tops of lobes of faster-moving FDLs A and D (Figures 2C and 5C) but are generally absent in the catchments of slower-moving FDLs C and 11 (Figures 4C and 6C).

weathers differently. A distinct break in slope occurs at the base of a large bedrock exposure in the southern and central portions of the catchment area of FDL-A, where field examination of the rocks reveals a difference in composition and weathering pattern (Figure 2C).

SLOPE AND ASPECT

susceptible to increased slope movement (Figures 2D-6D). Identifying these areas and their percentage of the total debris catchment (Tables 1-5) is important when considering future slope movement and contribution of material to FDL; however, the amount and type of vegetation cannot be ignored. Consider FDL-A, where high-angle, south-facing slopes (Figure 2D) occur in an area of mature vegetation

TOPOGRAPHIC PROFILES

Examination of topographic profiles can provide information about surface morphology that is important when considering the amount and style of material movement in frozen debris lobes. Cross sectional profiles show the width, amount of relief, slope variability, and morphology of FDLs (Figures 2E–6E and 2F–6F). Summary data are provided in Tables 1–5.

In general the profiles across the upper parts of the lobes are more irregular than the profiles across the lower parts of the lobes, although both upper and lower profiles for faster-moving FDL-D are irregular. Perhaps variation in morphology such as is seen in the upper profiles of FDL-A and B reflects differential flow on the sur-

CONCLUSIONS AND IMPLICATIONS FOR HAZARDS ANALYSIS

In assessing the geologic hazard potential of FDLs, their rate of movement and distance to infrastructure is important, but one must also consider the overall geologic character of the FDLs and their catchment areas. LiDAR-derived slope and aspect images, as well as topographic profiles, provide information about how material moves from catchment areas to FDLs and within FDLs. By quantifying LiDAR-derived information and combining it with field observations we aim to develop a hazard classification scheme describing the potential geologic hazards related to FDLs. Developing a hazard classifi cation scheme will result in a better understanding of FDL dynamics, facilitating informed decisions regarding infrastruc-

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