Preliminary Analysis of Surface Karst Feature Data from Northern Vancouver Island

FREP

Extension Note #37

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Introduction

Forest and Range Evaluation Program (FREP) monitoring evaluates the influences and impacts of resource development on ecological states and dynamics. This information is critical in assisting local resource managers and decision-makers to manage the ongoing balance between ecological, social and economic factors.

On Northern Vancouver Island, managing forested karst landscapes is of particular importance as up to 10-15% of the region is karst or potential karst with a wide range of hydrological, biological, scientific and recreational values (see Figure 1). During 2010-2012, FREP pilot tested the 2010 version of the draft karst field cards and routine monitoring protocol[1] to address the following FREP Priority Evaluation Question:

> ***"Are current forest practices adequately protecting and maintaining the structure, function and ecological integrity of the surface and subsurface elements of karst systems?"***

Staff from the North Island-Central Coast Natural Resources District collected data from 18 cutblocks on Northern Vancouver Island. The 18 cutblocks were selected from a random list that met the harvest date criteria and were known to contain karst as confirmed by the tenure holders.

The pilot test focused on surface karst features[2] such as sinkholes (SH), cave entrances (CE), karst springs (KS), epikarst exposures (EE), sinking streams (SS), sinking watercourses (SW), and other karst features (OT). Field data were collected on the basic characteristics of surface karst features, retention areas,[3] tree retention at the features,[4] and the presence or absence of six disturbance types[5] at the features, including windthrow, exposed bare soil, disturbed ground, burning, introduced material (e.g., logging slash, road debris), and shade alteration (see Figures 2-4). All of these disturbance types have the potential to alter the physical, hydrological and biological functions of karst features and the overall karst system.

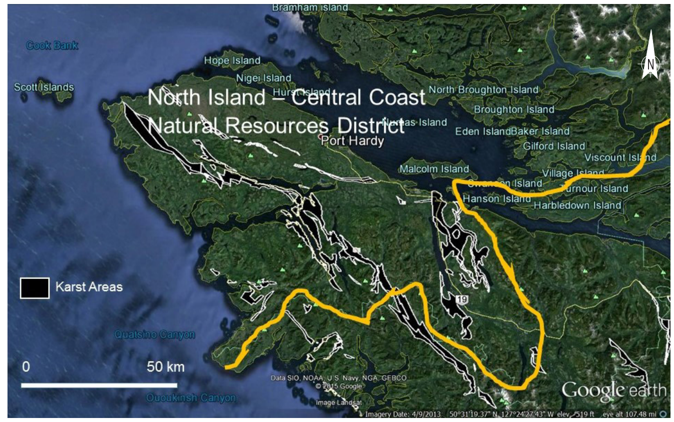

Figure 1: *Distribution of potential karst areas on Northern Vancouver Island. (Based on the Reconnaissance-level 1:250,000-scale karst mapping.)*

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1 An initial set of draft karst field cards were developed in 2004. These were modified between 2006 and 2009, and used for field testing and training with a protocol document. The karst field cards were modified again in 2010 and used to collect the 2010-2012 data. A 2016 version of the karst field cards is currently under development.

2 Strictly speaking, these surface karst features should be considered as 'surface karst feature elements', of which some are individual features (e.g., SH - a sinkhole), while others might combine together to form karst feature complexes (e.g., SH/SS/CE – a sinkhole with a sinking stream and cave entrance).

3 The term 'retention areas' as used in the 2010 karst field cards refers to any trees retained after harvesting. Retention areas can occur in many forms, such as designated karst 'reserves' or karst 'management zones' as described in the *Karst Management Handbook for British Columbia* (BC Ministry of Forests, 2003), wildlife tree patches, riparian reserve zones or management zones, or undesignated areas where trees are retained for a variety of purposes.

4 Note that trees play an integral role in the ecological, hydrologic, and geomorphic functions of surface karst features and the broader karst landscape.

5 Disturbances to surface karst features focus on recent observable changes to environmental conditions due to natural, forestry-related, or other causes.

The FREP Mission:
To be a world leader in resource stewardship monitoring and effectiveness evaluations; communicating science-based information to enhance the knowledge of resource professionals and inform balanced decision-making and continuous improvement of British Columbia's forest and range practices, policies and legislation. http://www.for.gov.bc.ca/hfp/frep/index.htm

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Figure 2: *Karst Feature Complex – Sinkhole functioning as a sink point for a sinking stream. Note the old wood debris in the pool in the bottom of the sinkhole. The sunlight that is shining through the trees is likely evidence of shade alteration as harvesting occurred up to the edge of the surrounding retention area.*

Figure 3: *Left: Retention area along a ridge surrounding an epikarst exposure. Below: Grike near the epikarst exposure. Note the logging debris outside the retention area, no apparent windthrow in the retention area, and the absence of trees around the grike.*

Figure 4: *Sinkhole with retained tree on the rim, but no surrounding retention area. Note both old (O) and new (N) logging debris on the sidewalls and rim.*

The goals of this analysis were to firstly provide preliminary results on data collected during the 2010-2012 pilot project, and secondly use this information to refine the 2010 draft karst field cards to improve aspects of the data collection, evaluation methodology, and overall scientific scope. These improvements are currently being incorporated into an updated 2016 version of the karst field cards and monitoring protocol. In addition, the findings in this report are intended to provide useful information on how FREP karst evaluations can assist practitioners and professionals involved in the management of forested karst resources.

METHODOLOGY

The 2010-2012 data collected for the 18 cutblocks were transcribed from hard-copy field cards into an Excel spreadsheet.[6] The following information was analyzed:

- The type and frequency of the surface karst features,[7]
- Whether the surface karst feature was part of a karst feature cluster[8] or feature complex,[9]
- Whether the surface karst feature occurred in low, moderate or high vulnerability karst terrain,
- Whether a retention area surrounded the surface karst feature or not,
- The presence or absence of windthrow in the retention area,
- The total number of disturbance types for each surface karst feature, including tree removal,[10] windthrow, disturbed ground, exposed bare soil, burning, introduced material, and shade alteration, and
- The likely cause of disturbances (e.g., natural, forestry-related, or other).

The total number of disturbances at a surface karst feature provides an indicator as to whether an environmental change has occurred at the site or not. This total number should not be directly linked to the magnitude of the disturbance at the site, as this was not quantified in the analysis. Currently, there are no science-based disturbance thresholds available for surface karst features in BC, but it is anticipated that these will be developed over time.

LIMITATIONS

A number of limitations apply to the field data collected. Firstly, the data are restricted to surface karst features and thus only reflect the condition of this component of the overall karst system. No disturbance information was collected on the broader karst landscape, cave infiltration areas, or road development on karst. Secondly, the total number of disturbance types for a particular surface karst feature is not an accurate indication of the magnitude of the actual disturbance at that site. Thirdly, the data collected provide no indication as to the relative importance or sensitivity of the surface karst features, or if site-specific management prescriptions or practices were used. Fourthly, not all information on tree retention and disturbance types and their causes were included or clearly indicated in the data collected. In some cases, where responses to disturbance indicator questions were left blank, adjustments were made to the data based on supporting information. Finally, the data were analyzed by a series of simple mathematical algorithms applied to the spreadsheets. No in-depth statistical analysis was completed.

RESULTS AND FINDINGS

Data were collected on a total of 142 surface karst features. The main findings are provided below, and summarized in Tables 1-4 and Figures 5-8.

- The 142 surface karst features included: 14 cave entrances, 54 sinkholes, 14 karst springs, 22 sinking streams and sinking watercourses, 11 epikarst exposures, and 27 other surface karst features.
- Of the 54 sinkholes, 17 were small (5 m or less diameter), 32 were medium (>5 m to <20 m diameter), and 5 were large (20 m or greater diameter).
- Of the 142 surface karst features, 66 were part of feature complexes and 56 were part of feature clusters.
- Of the 142 surface karst features, 32 (23%) were in karst areas identified with a low karst vulnerability rating, 33 (23%) were in moderate vulnerability, 56 (39%) were in high vulnerability, and 21 (15%) had no rating established.[11]
- 86 of 142 (60%) surface karst features had retention areas,[12] most of which (80%) reported some level of windthrow.
- Approximately 80% of sinking streams, large sinkholes, and cave entrances had retention areas.
- Most (82%) of the surface karst features in high vulnerability karst areas had retention areas, while 58% of features in moderate vulnerability had retention areas, and 50% of features in low vulnerability areas had retention areas.

6 Note that the transcribing of information from hand-written field cards into a digital format has the potential for introducing errors.

7 Sinkholes (SH) were subdivided into three categories based on their average diameter – small (SHs: 5 m or less), medium (SHm: >5 m to <20 m), and large (SHl: 20 m or greater). See Figures 5 and 6.

8 A feature cluster is where two or more surface karst features are separated by a distance no greater than twice the greatest dimension of the closest neighbour.

9 A feature complex is a combination of two or more surface karst features that are touching or overlapping each other, such as a cave entrance in the bottom of a sinkhole.

10 For this analysis, tree retention values were converted into a seventh disturbance type 'tree removal' – which is also used in the 2016 version of the karst field cards. Any karst features with 100% tree retention were assigned a 'No' response for tree removal, while those with <100% or a blank response were assigned a 'Yes' response.

11 The determination of whether a surface karst feature occurs in an area of low, moderate or high vulnerability rating is based on an estimate of the sensitivity of the broader karst landscape in which the feature occurs (RISC, 2003). However, the available vulnerability ratings in the data did not always appear to be reliable, as they varied in consistency as to how the rating was determined.

12 Note that this percentage is likely slightly biased, as 46% of the 142 surface karst features were part of a karst feature complex. In these cases, a single retention area might surround two or more surface karst feature elements.

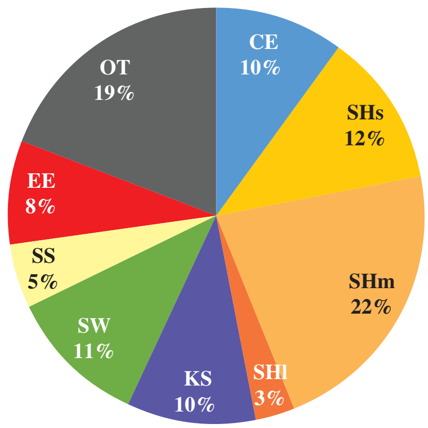

Figure 5: Distribution of surface karst features. Note the three categories of sinkholes (SH) based on their average diameters (SHs: 5 m or less, SHm: >5 m to <20 m, SHl: 20 m or greater). (See page 1 for surface karst feature abbreviations.)

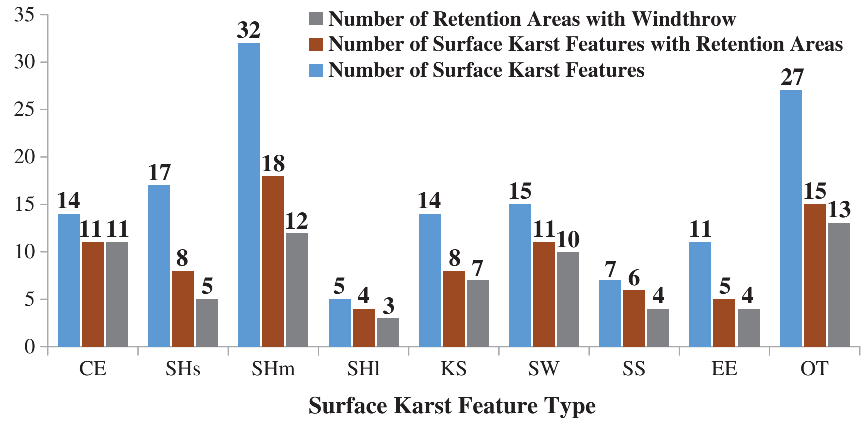

Figure 6: Number of surface karst features, number of surface karst features with retention areas, and number of retention areas with windthrow.

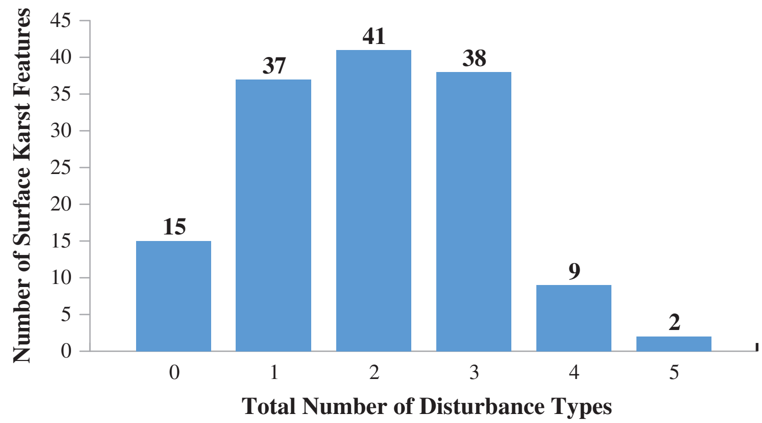

Figure 7: Number of surface karst features compared to the total number of disturbance types.

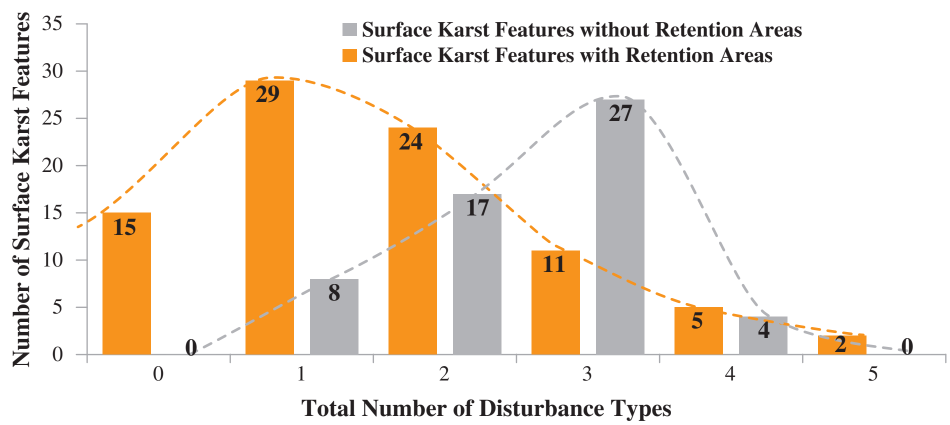

Figure 8: Number of surface karst features with and without retention areas compared to the total number of disturbance types.

Surface Karst Feature	SKF Number	Feature Complex	Feature Cluster	Retention Areas	Windthrow in Retention Areas	Low KVR	Mod KVR	High KVR	No KVR
CE	14	13	7	11	11	1	2	10	1
SHs	17	3	6	8	5	1	3	8	5
SHm	32	9	17	18	12	6	7	12	7
SHl	5	5	3	4	3	1	0	4	0
KS	14	6	3	8	7	5	6	2	1
SW	15	10	5	11	10	1	6	6	2
SS	7	5	1	6	4	3	0	4	0
EE	11	3	4	5	4	3	3	5	0
OT	27	12	10	15	13	11	6	5	5
Total	**142**	**66**	**56**	**86**	**69**	**32**	**33**	**56**	**21**

Table 1: *Surface karst features (SKF), retention areas, windthrow, and karst vulnerability rating (KVR). Note that the KVR is determined for the broader karst landscape within which the surface karst feature is located. (See page 1 for surface karst feature abbreviations.)*

Surface Karst Feature	Disturbance Types Present at Karst Feature							
	SKF Number	Tree Removal	Windthrow	Disturbed Ground	Burning	Exposed Bare Soil	Introduced Material	Shade Alteration
CE	14	1	0	0	1	9	9	6
SHs	17	9	1	0	1	1	12	15
SHm	32	13	4	1	1	10	22	26
SHl	5	1	1	1	1	2	3	3
KS	14	5	1	0	2	3	4	4
SW	15	2	3	2	1	10	6	8
SS	7	1	0	0	1	1	4	3
EE	11	6	0	3	2	1	1	7
OT	27	10	4	6	6	5	7	10
Total	**142**	**48**	**14**	**13**	**16**	**42**	**68**	**82**

Table 2: *Surface karst features (SKF) and disturbance types present at the karst feature.*

Surface Karst Feature Type	Total Number of Disturbance Types at the Karst Feature						Number
	0	1	2	3	4	5	
CE	1	3	8	1	1	0	14
SHs	1	3	5	8	0	0	17
SHm	2	4	11	10	5	0	32
SHl	0	1	1	3	0	0	5
KS	5	3	2	4	0	0	14
SW	1	3	6	4	0	1	15
SS	1	3	2	1	0	0	7
EE	1	4	2	4	0	0	11
OT	3	13	4	3	3	1	27
Total	**15**	**37**	**41**	**38**	**9**	**2**	**142**

Table 3: *Surface karst features (SKF) and the total number of disturbance types present at the karst feature.*

Total Number of Disturbance Types	Surface Karst Features with Retention Areas	Surface Karst Features without Retention Areas	Total Surface Karst Features
0	15	0	15
1	29	8	37
2	24	17	41
3	11	27	38
4	5	4	9
5	2	0	2
	86	**56**	**142**

Table 4: *Total number of disturbance types and surface karst features with and without retention areas.*

- The total number of disturbance types for the 142 surface karst features varied from 0 to 5, with 15 features having no disturbance types, 37 having 1 disturbance type, 41 having 2 disturbance types, 38 having 3 disturbance types, 9 having 4 disturbance types, and 2 having 5 disturbance types.
- The most frequent disturbance types for surface karst features were shade alteration (82/142), followed by introduced material (68/142), tree removal (48/142), and exposed bare soil (42/142). The frequency of burning, windthrow and disturbed ground was much less at 16/142, 14/142 and 13/142, respectively.
- In terms of causes of disturbance, most of the shade alteration and tree removal disturbances at surface karst features were attributed to harvesting, while most instances of exposed bare soil, disturbed ground, and burning were attributed to natural causes. Introduced material and windthrow were equally attributed to harvesting-related and natural causes.[13]

DISCUSSION

A number of preliminary inferences can be drawn from the above findings. Firstly, sinkholes appear to be the most frequent (54/142) surface karst feature sampled in the cutblocks, comprising almost 40% of the total (see Figure 5). Sinkholes are important surface components of karst landscapes and are often sites of concentrated recharge to the subsurface (Ford and Williams, 2007). Sinkholes therefore warrant careful attention.

The total number of disturbances to surface karst features varies from 0 to 5 and forms a bell-shaped curve distribution, with the majority of features having 1, 2 or 3 disturbance types (see Figure 7). Interpretation of this curve, in terms of the overall impacts to surface karst features, is difficult as no disturbance thresholds have yet been developed for karst features or the broader karst landscape.

Shade alteration was the most frequent disturbance type and was largely attributed to timber harvesting and windthrow. Even karst features with surrounding retention areas can be expected to undergo some change in shade level as trees removed or windthrown along the outside edge of retention areas would allow for some penetration of sunlight. Introduced material was the next most frequent disturbance, which might in part be explained by the possible inclusion of introduced material from previous harvests into the data set.[14]

The third highest disturbance type was tree removal where trees have been harvested from within or near a karst feature. Next came exposed bare soil in which the data may have included both soil exposed during harvesting operations and possible instances of naturally occurring soil failures on the side slopes of some features. The lowest three disturbance types were burning, followed by windthrow and disturbed ground.[15]

Approximately 60% of the surface karst features had retention areas. In general, it appears that surface karst features with retention areas have lower total numbers of disturbance types as compared to those without retention areas (see Figure 8). However, most (80%) of the retention areas surrounding surface karst features have undergone some level of windthrow. Overall, these results suggest that the retention areas have limited the total number of disturbances and therefore helped maintain natural conditions at the surface karst features.

A few (11/142) surface karst features experienced 4 or 5 total number of disturbance types. Seven of these were linked to karst features with retention areas. This higher total number of disturbance types is, in some cases, attributed to sites where higher levels of windthrow occurred within the retention areas and at the karst features. This increased windthrow and uprooting of trees would have likely led to the occurrence of other disturbance types (e.g., shade alteration, exposed bare soil, introduced material).

[13] Note that not all causes of disturbances were identified on the karst field cards. Multiple causes were sometimes indicated, suggesting caution in the interpretation of the causal data.

[14] Note that in the 2014 Forest Practices Board report, *Management of Karst Resource Features on Northern Vancouver Island, Special Investigation*, logging debris was observed in 40% of sinkholes (i.e., 21 out of 49).

[15] For comparison, the 13/142 (9%) of surface karst features identified with ground disturbance in this analysis is similar to findings in the 2014 Forest Practices Board report, where 4 out of 45 (9%) of sinkholes had evidence of disturbance related to machine tracks (within 5 m of sinkhole rims).

CONCLUSIONS AND RECOMMENDATIONS

The 2010-2012 pilot test and this preliminary analysis have demonstrated that the draft 2010 FREP karst field cards were able to collect useful information about harvesting disturbances as they relate to surface karst features.

The findings suggest that standing trees in the retention areas surrounding 60% of the surface karst features in this study provided a reasonable measure of protection and likely limited the total number of disturbances at the feature. However, high levels of windthrow in the retention areas can contribute to the occurrence of other disturbance types. This reinforces the need for carefully designed and adequately sized retention areas to limit the potential effects of windthrow.

Further analysis of the 2010-2012 data could be carried out to:

- Exclude questionable data,
- Separate surface karst feature complexes from individual features,
- Examine the dimensions and types of retention areas, and percentage of windthrow,
- Group surface karst features into dimensionally minor and major categories, and
- Investigate the causal factors for disturbance types.

There are, however, limitations to how much more information can be extracted from the existing data set. In particular, the differences between natural and harvesting-related disturbances were not always clear; likewise for the distinction between past and recent disturbances.[16]

Completion of this analysis has highlighted the need to ensure that the 2016 version of the karst field cards contain a number of improvements to the data collection system, such as specific procedures for evaluating: tree removal, the broader karst landscape and its vulnerability rating (see RISC, 2003), the extent and nature of road-related disturbances, the extent and type of retention areas, and cave infiltration areas.[17] These improvements will help broaden the scope of data collection to include disturbances to other components of the karst system, rather than limit it to surface karst features.

The 2016 version of the karst field cards will also include a summary table of disturbances and a qualitative procedure for the field worker to assess each karst sample unit (or cutblock). The data collected for each site will be linked to a more extensive and quantitative analytical procedure that will examine the karst and disturbance information for multiple cutblocks and/or for different regions. The use of digital field forms with drop-down menus will be explored to assist with the ease and reliability of data collection and analysis.

Further research is needed to investigate the nature of cumulative disturbances to the biological, hydrological and geomorphic functions of karst systems at the feature and broad karst landscape scales, and to develop disturbance thresholds based on limits of acceptable change. The gradual collection of data on the types and magnitude of these disturbances over time will assist with this research. Other research, such as: examining natural disturbances in unlogged forested karst sites; monitoring geomorphic, hydrological and biological attributes of karst under pre- and post-harvesting conditions; and investigating the disturbance of karst systems at the catchment scale would also be very valuable.

ACKNOWLEDGEMENTS

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[16] In the 2016 version of the karst field cards, efforts will be made to differentiate between recent and past disturbances and better identify the specific causes of disturbances (e.g., natural, forestry-related, other). This will ensure that the disturbances identified more accurately reflect current forest practices under the *Forest and Range Practices Act* (FRPA).

[17] Determining the infiltration area above a cave requires subsurface mapping to establish the depth and location of the cave relative to the surface. This should generally be done as part of a karst field assessment (KFA).