# Risks Associated with Fire Activity in the Cariboo Region, 2017 - A GIS Analysis

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## Abstract

Under current human and climate pressures, forest fires are becoming more and more severe and difficult to contain. Even after a fire is controlled, changes in forest cover, ground surface conditions, and hydrologic processes can lead to ongoing risks downslope of the burned area. Past experience in British Columbia has shown that assessing risk from natural hazards following the wildfire season is the first step in preventing further post-fire disasters (Hope, et al. 2015). One example of such post-fire disasters are landslides. Wildfires can damage the forest canopy, smaller plants, and soil below the trees, resulting in increased runoff and increased risk of landslides (BC Gov.). Furthermore, intense precipitation after a burn event can also trigger landslides due to water's decreased ability to infiltrate fire-altered soils, causing landslides that run down-slope (i.e. debris flows) (BC Gov.). This can have significant adverse effects on downslope riparian watershed ecosystems and habitats, home to many critically endangered or threatened species. Thus, in our report we will assess the impact fires can have on landslide risk by looking at the largest fire in the region Cariboo fire zone in 2017. Furthermore, we will illustrate the consequences of fire triggered landslides on surrounding fish habitat.

## Project Description

The Caribou fire zone is located in the British Columbia Interior surrounding 110 Mile House. This area takes up 10.3 million hectares, stretching from Clinton, north to the Cottonwood River, east to Wells Gray Provincial Park, and west to Tweedsmuir Provincial Park (BC Wildfire Service). It is divided into two main climatic belts: the western dry belt and the eastern wet belt. Due to it's location, the Cariboo zone contains a mixture of thinly grassed meadows, sagebrush, lone coniferous trees and well-spaced forests are found in the west of the region. In the east, there are extensive forests of cedar, hemlock, spruce and balsam trees, along with varied riparian habitat and freshwater ecosystems in valley bottoms (BC Wildfire Service). This combination of vegetation makes the area quite fire prone and is therefore, an interesting area of study on the effects of forest fires.

We will be looking at a specific fire from 2017 in the Caribou fire zone to create a landslide risk classification map from burn severity and slope data. Then we will use this to look at the potential impacts on critical fish habitat that fall in areas of relatively high landslide risk. From here, we will be able to gain a better sense of the significant risks that are associated with wildfire activity in BC. The data will consist of historical fires in BC, the burn severity for these fires, a map of regional fire zones in BC, as well as a Digital Elevation Model of the Cariboo region to get topographic slope and areas of critical fish habitat location data in the region.

## Methodology

**Acquire:**

The data sources we used were 1) *BC Data Catalogue*, 2) *Government of Canada Open Data Catalogue,* and 3) *UBC Department of Geography Database:G:\courses\data\DEMs\CDEM-25m\ CDEM-093.*

**Parse and Filter:**

First we renamed data to appropriate file names, and changed the symbology to an appropriate colour for polygon shapefiles. For example, the fire zones were changed to green, and burn severity was changed to a green-red colour scheme that would match the low-high attributes. We used the intersect and erase tool to create meaningful new layers such as the Cariboo Fire Zone, historical fire polygons for the cariboo zone, and the burn severity for that zone. We selected attributes from these layers to find the largest fire in this zone. This was our 2017 fire we would be analyzing, using its unique burn severity and fire polygon layers.

Because the region we were looking at was not fully covered by one singular DEM, we had to merge the 93b and 93c DEMS using the ‘mosaic to new raster’ tool to create a new DEM that fully covered the largest fire in the cariboo region. This DEM file was created using the ‘extract by mask’ tool from the burn severity layer for the 2017 fire and made into an integer raster file using the ‘int tool’ to create a DEM raster of our 2017 fire.

When creating our map that included the critical fish habitats we followed similar procedures. With our DEM layer we created another layer of slope, next reclassifying it into three categories of low, medium, and high slope. We then converted this layer into vector data. This is so that we would be able to select by attribute for only areas of high slope and create a new layer with this information.

We then took our burn severity layer, reclassifying it into low, medium, high, and extreme and then did another select by attribute to only look at areas of high and extreme burn severity. After this, we had two layers of vector data with which we did an intersect to find areas that would be highly prone to landslides as they were areas of both high and extreme burn severity and slope.

We then added our layer of critical fish habitat and clipped all the data so that it would fit within the burn area of our selected fire.

**Mine:**

For our analysis, we first classified the historical fire polygons in the Cariboo zone by date, using the ‘natural breaks’ method to create the table below (fig.1). We used 5 classes based on the “fire year” attribute. Then, we used selected attributes in this new classified layer to find data for each fire year block:

Next, we used the slope function to create a slope raster file for the 2017 fire. We then reclassified the burn severity layer to a 1, 2, 4, 8 weighting scheme (best representing burn rate), and used ‘raster calculator’ to sum the weight layers, multiplying our slope raster and burn severity layers to create a risk classification layer for landslides in the cariboo zone called ‘Landslide Risk’. At the end we had a layer in which each raster cell contained information about both slope and burn severity.

For our analysis of high risk landslide areas and critical fish habitats we performed a proximity analysis by adding a 180 m buffer around all the areas of high and extreme slope and burn severity. We chose this amount because this was the maximum length that the average landslide would travel in previous studies (Finlay 1999). Our use of buffers helped us to visualize the movement of sediment and its potential effect on any nearby critical fish habitat.

**Represent:**

When preparing our maps, it was important to use colour schemes that were intuitive to the user. Normal risk classification schemes follow a green-yellow-orange-red colour progression to represent areas of associated risk, so we decided to use this colour scheme for our landslide risk map. Choosing colours that best represent land use was very important to us, such as green for forested/unburned areas, as we wanted to make our maps easy for any reader to understand.

Original Datasets:

| Layer name | Source | Uses | Data model | Attributes | Modifications |
|---|---|---|---|---|---|
| ***Original / renamed*** | ***Agency, date compiled, data extracted*** | ***For example DEM to determine slope*** | ***Vector polygon/raster*** | ***Item names or general if big file with many columns*** | ***Changes: project, clip out project area, delete attributes..*** |
| *DRPMFFRZNS_polygon_1 / BC Fire Zones* | *BC Data Catalogue, 2018-05-09, custom download fire zone boundaries* | *To find and deliniate the cariboo fire zone* | *Vector polygon* | *MOF_FIRE_ZONE_ID, FEATURE_AREA_SQM, MOF_FIRE_ZONE_NAME* | *Changed colour symbology* |
| *BURN_SVRTY_polygon__2__1 / Burn Severity* | *BC Data Catalogue, 2011-06-29, BC Geographic Warehouse Custom Download* | *To model the burn severity for the 2017 fire, and then use in conjunction with slope layer to create a risk classification* | *Vector Polygon* | *FIRE_YEAR, BURN_RATE_SHAPE_AREA* | *Intersected with 2017 fire boundaries, changed colour symbology* |
| *H_FIRE_PLY_polygon / Hist_Fire_Polygons* | *BC Data Catalogue, 2018-05-16, Fire Perimeters - Historical -* | *To create summary table of fires in the caribou zone* | *Vector Polygon* | *FIRE_YEAR, SHAPE_AREA* | *Intersected with cariboo fire zone to find all fires in that zone* |

| | | | | | |
|---|---|---|---|---|---|
| | *Custom Download* | | | | |
| *Cdem_093c_25m / BC_DEM_93c_25m* | *UBC Department of Geography, G Drive* | *Used to create slope raster layer* | *Raster* | *N/A* | *Joined with 93b* |
| *Cdem_093b_25m / BC_DEM_93b_25m* | *UBC Department of Geography, G Drive* | *Used to create slope raster layer* | *Raster* | *N/A* | *Joined with 93c* |
| *Crit_Fish / Crit_FishHabitat* | *BC Data Catalogue, 2017-01-10, BC Geographic Warehouse Custom Download* | *Used to see location of critical fish habitat.* | *Vector Polygon* | *N/A* | *Unioned with slope burn buffer (SlopeBurn_Buff). Then colour and symbology was changed.* |

**Discussion and Results**

The specific 2017 fire in question was what the BC Wildfire Service is calling the “Plateau Complex of Fires” on the Chilcotin Plateau, which covered a combined area of 545,151 hectares; the largest fire in B.C.’s recorded history (about the same size as Prince Edward Island). The plateau complex was the result of nearly 20 separate fires merging together. We will be referring to this fire as the ‘2017 fire’ for the purposes of simplicity. In the Cariboo region alone, we are seeing dramatic changes in the number of fire events. *Fig. 1* shows that the past two decades have seen an unprecedented area burned. This table allows us to point out that our risk analysis should incorporate a fire in this time period.

In our analysis of landslide risk, it is evident that there are indeed locations of elevated or “extreme” landslide risk. Looking at our landslide risk map, there are several clusters of 5-10 kilometer wide zones where there is a high slope in surface topography and high burn severity. These zones in red are the areas of interest to us, as they point out the possible locations of fire-induced landslides that would result from a large precipitation event. The majority of these at-risk areas are located in the north-west region of this fire, with some others located centrally, and a smaller portion to the east.

Using a raster calculator, we were able to multiply the slope and burn severity rasters to create our new classification scheme. We wanted the scheme for the burn severity raster layer to be representative of the weight that these classes would have. For example, the government of British Columbia states in the *Post-wildfire Natural Hazards Risk Analysis in British Columbia* that a higher burn severity was much more weight than a lower burn severity, yet the "post-wildfire landslide hazard increases approximately in proportion to soil burn severity" (Hope, et al. 2015). Therefore, it seemed necessary to weight each class unequally, but not by too much, so we chose a 1, 2, 4, 8 weight when multiplying the slope and burn severity raster layers to create our risk analysis. This will be further discussed in 'error and uncertainty'. The *Post-wildfire Natural Hazards Risk Analysis in British Columbia* also mentions that landslides preceding a wildfire event are far more likely to occur in channel gullies, alluvial fans, and unsupported (convex) slopes (Hope, et al. 2015). This was not taken into account in our assessment for simplicity, however it should be noted.

We chose a 'low, moderate, high and extreme' classification scheme for the landslide risk map because it is a very easy and readable legend for the map user, as well as universal recognition. It was the most intuitive option, since the users eye would be drawn to the deeper, darker colours on our map, and focus on these areas first. As for the colours, it is universally understood that green is associated with safety and red is associated with danger, which is why we used this coulour scheme in our classification.

Overall, we can say that there was a presence of areas that would be at high risk of landslides due to the largest fire in 2017 in the Cariboo region. We are not able to make assumptions about whether this is a relatively large presence of high risk areas, however, we could look at the effect of other burns in the area to make inferences about this.

In order to further assess the effects of our specific 2017 fire and landslide risk in the Cariboo zone, we looked at high risk landslides in association to critical fish habitat data. By looking at only areas of both 'high burn severity' and 'high slope' we were able assess only the areas that would be of the greatest risk of landslide for the 2017 fire and see how these areas would affect critical fish habitat, if at all. We thought this analysis would be relevant, because in BC, specifically in the Cariboo Region, there are many different species of fish that are listed under SARA as threatened or considerable concern (Haas, 1998).

Furthermore, landslides are events that can have huge impacts and consequences for watersheds and and the ecosystems that inhabit them (Arriagada 2016, Grewer, 2018). As landslides displace the soil and sediment they are able to change or even halt the flow of a waterway, change structure and composition of the streambed, as well as make numerous other habitat modifications (Grewer, 2018). For smaller and more sensitive ecosystems, entire populations can be at risk of extirpation due to landslides (Vincenzi 2016). Thus, when concerning ourselves with these ‘species at risk’, it is imperative that their habitat and the effects that they may be subject to are thoroughly understood. In this case, we are looking at the effect of a fire and its ability to trigger events that cause massive shifts in ecosystem dynamics.

Before assessing and discussing the effect that fires can have on watersheds containing critical fish habitats, we should note that in our assessment, we were only looking at the effect of one particular fire. More specifically, the largest fire in the cariboo region during 2017 (The Plateau Complex). As such, our analysis shows the unique effect of only one particular burn event. Other burn events in the future will most likely have a different distribution of burn severity, meaning that the areas at high risk of landslide will differ as well. However, we still deemed this assessment important as it illustrates the effects that a fire may have on critical fish habitat in the selected area. The effect of a singular fire event can be assessed through the determination of high risk areas by comparing burn severity and high slope areas, like we did using the ‘raster calculator’. With different fires, this assessment will result in a different and unique prevalence of high risk landslide areas affecting fish habitats more or less depending on this prevalece. Despite these differences, we decided that by looking at the effect that just one fire event has on a critical fish habitat, we can tap into a deeper understanding of the relation between the habitats and ecosystems of species at risk and forest fires and the landslides that they have the ability to cause.

We looked at the effect of landslides on fish by finding areas of high landslide risk through looking at areas of *only* high slope *and* high burn severity. We then created a 180 meter buffer around these high risk areas. We chose a 180 meter buffer because of previous studies finding this to be the maximum travel length of a landslide measured from its foot (Finlay et al. 1999).

Overall, when looking at only areas of the highest landslide risk there were three main clusters with high frequency of areas that met our conditions. Other areas that met our conditions for high landslide risk were scattered in smaller clusters throughout the rest of the total burn area. Of these small clusters, there were two in particular that intersected with the critical fish habitat polygon that is over top of our total burn area. It is these two locations that we will be paying the most attention to (see fig. 4). For the rest of the critical fish habitat zone, none of the areas of high landslide risk seemed close enough to make a significant impact.

When looking at the two areas in the critical fish habitat that had the highest associated landslide risk, it can be seen that a landslide event would have considerable negative effects on the water channel. If a landslide were to slide within the 180 m buffer, the watershed would become extremely narrow. This change would have sizable impacts on the ecosystem as a whole, especially the 'at risk' fish species. The long travel distance of these landslides would mean the possibility for other impacts mentioned above, such as changes in the structure and sediment composition of the streambed (Grewer, 2018). Additionally, these high risk landslide areas are distributed along the coasts of water bodies, meaning that there would also be implications for riparian ecosystems (Arriagada 2016, Grewer 2018). This is important to note as these ecosystems and their health are often closely intertwined with that of the fish habitats (Arriagada, 2016). From these results we determined that the event of a fire has the ability to considerably change the geography of a critical fish habitat and ecosystem and thus, high potential to change the overall dynamics of a fish population.

## Error and Uncertainty

Throughout the entire process, from data retrieval, to the analysis, and final map creation, we feel it necessary to disclose the fact that there are many possible sources of error, and that this assessment of landslide risk and its effects on fish habitat carries with it, a degree of uncertainty.

First of all, the DEM files that were retrieved from The Department of Geography at the University of British Columbia are subject to a certain degree of inaccuracy due to collection errors, which would compound throughout our entire analysis. Although we consider the data to be from a trusted source, from which data would be checked and updated, we must consider the possibility that there are minor inaccuracies, even if the data itself is precise. Also, the burn severity and critical fish habitat data retrieved from the BC Data Catalogue are subject to the same sort of scrutiny.

Another source of error in our analysis could come from the classification methods chosen for sorting the historical fire polygon data by ‘fire_year’ (fig.1), as we chose natural breaks to better represent the unequal data distribution (i.e., majority of the fire polygons occured in the last 10 years). Another classification method, for example, using equal intervals, would represent the data differently, and would not take into account the distribution. The same goes for the weighting scheme we chose to reclassify our burn severity raster layer. The 1, 2, 4, 8 weighting was chosen as a generalization from our sources, and is not entirely representative of the actual weighting value. We wanted a high burn severity to have more weight then a low burn severity due to the relative impact and risk associated with a fire event as this would allow us to really focus on areas in the ‘extreme risk’ category. It is important for us to disclose that our maps are dependant on these generalizations, and the map user should take this into account.

As previously mentioned in our discussion, another source of error could be in the buffer width chosen for looking at areas at high risk of landslides. We chose a 180 meter buffer due to the tendencies of various studies of landslides and their effects. We chose the specific number, 180 meters, after a particular study by Finlay et al. deemed this as the maximum length a landslide would travel from its foot (1999). Additionally, there could have been many different ways to measure the extent of sediment travel by measuring the reach of a landslide from where it initially faults or by measuring travel distance from the end of the landslide foot which is what we chose to do. These different variations of measurement methods would mean different ways of summarizing the effects of the landslides. Our specific buffer was chosen to best visualize the *potential* effects and reach of a landslide, however other buffer widths may be more adequate if wanting to represent average travel distance.

## Further Research and Recommendations

There are a number of other things that could be looked into further. For example, looking at precipitation and the effects that it has on an area in terms of landslide risk, since precipitation has such a large impact on slope stability. Large precipitation events are a primary contributor to the causation of landslides on steep slopes, especially after a fire event (Hope et al. 2015). It is not very easy, however, to try and predict extreme precipitation events. That being said, the collection of precipitation data one month after a fire event, along with slope data and burn severity data, could reveal more information about the varying risk of landslides throughout the area due to precipitation.

Additionally, there is also further research required, regarding the impacts of forest fires and the landslides they cause on fish. It would be interesting to look at an entire stream network and be able to see where landslides might affect stream network locations. Going further on this, it would be revealing to take these areas in which landslides affect the stream network and look at what lies downstream of these areas as a landslide would significantly impact stream flow. This impact on stream flow would result in large scale consequences on any habitat or ecosystem downstream that is part of the network, thus, a river network system would be interesting to include in a study. We highly recommend that the risks associated with wildfires in BC be further researched, as there exists a massive potential for detrimental risks to not only fish habitat and freshwater ecosystems, but to humans as well.

**Works Cited**

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**Maps and Figures:**

Fig. 1: *Summary table of Historical fires in the Cariboo Region*

| **Time Period** | **Total # Fires** | **# Caused by Humans** | **# Caused Lightening** | **# Unknown Cause/Other** | **Total Area Burned (km^2)** |
|---|---|---|---|---|---|
| **1919-1935** | **532** | **457** | **75** | **0** | **1436** |
| **1936-1953** | **577** | **531** | **46** | **0** | **1219** |
| **1954-1974** | **846** | **724** | **122** | **0** | **2160** |
| **1975-1999** | **313** | **285** | **28** | **0** | **2178** |
| **2000-2017** | **1153** | **409** | **735** | **9** | **7893** |

Fig. 2 - Cariboo Fire Zone Reference Map

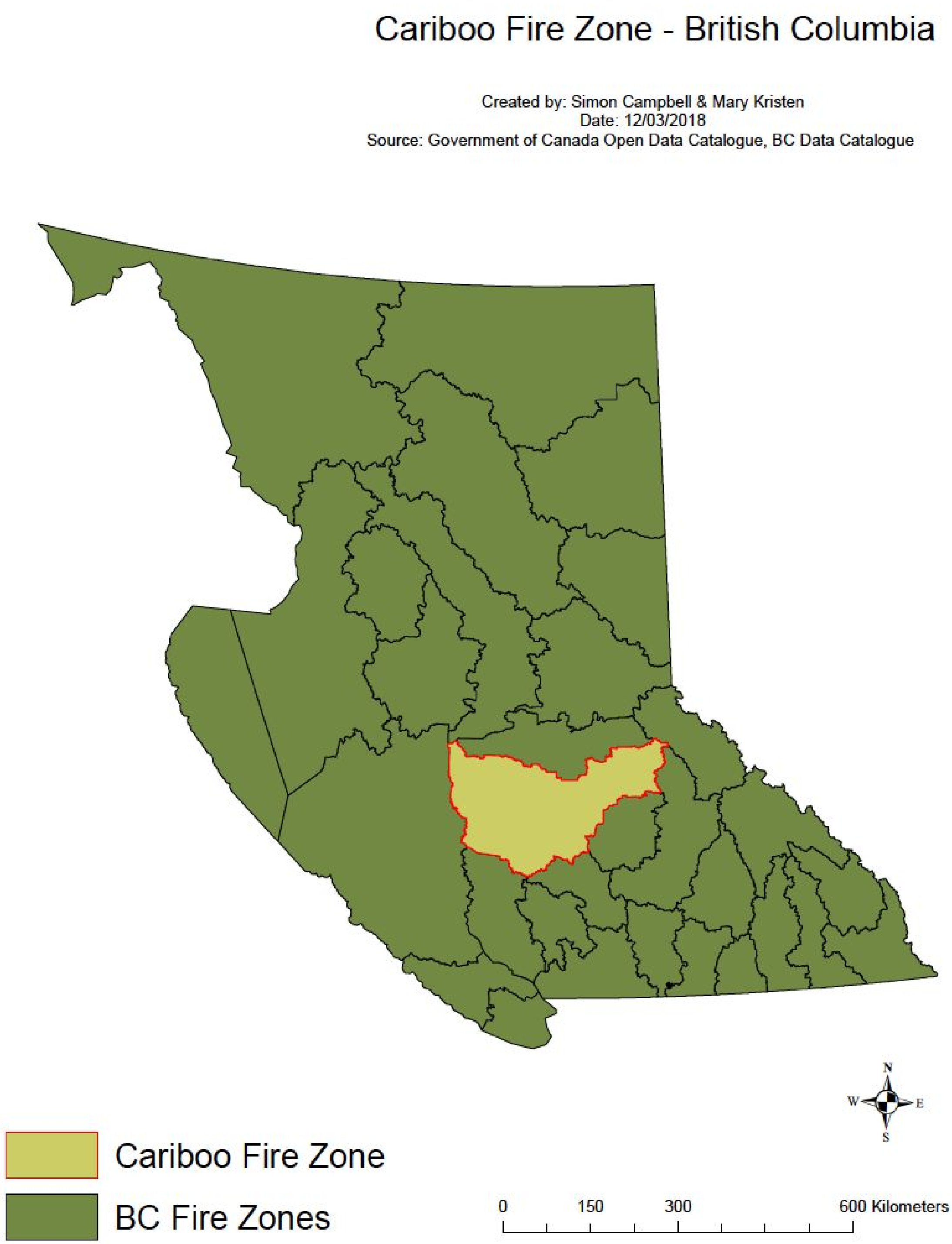



Fig. 3 - Landslide Risk Map

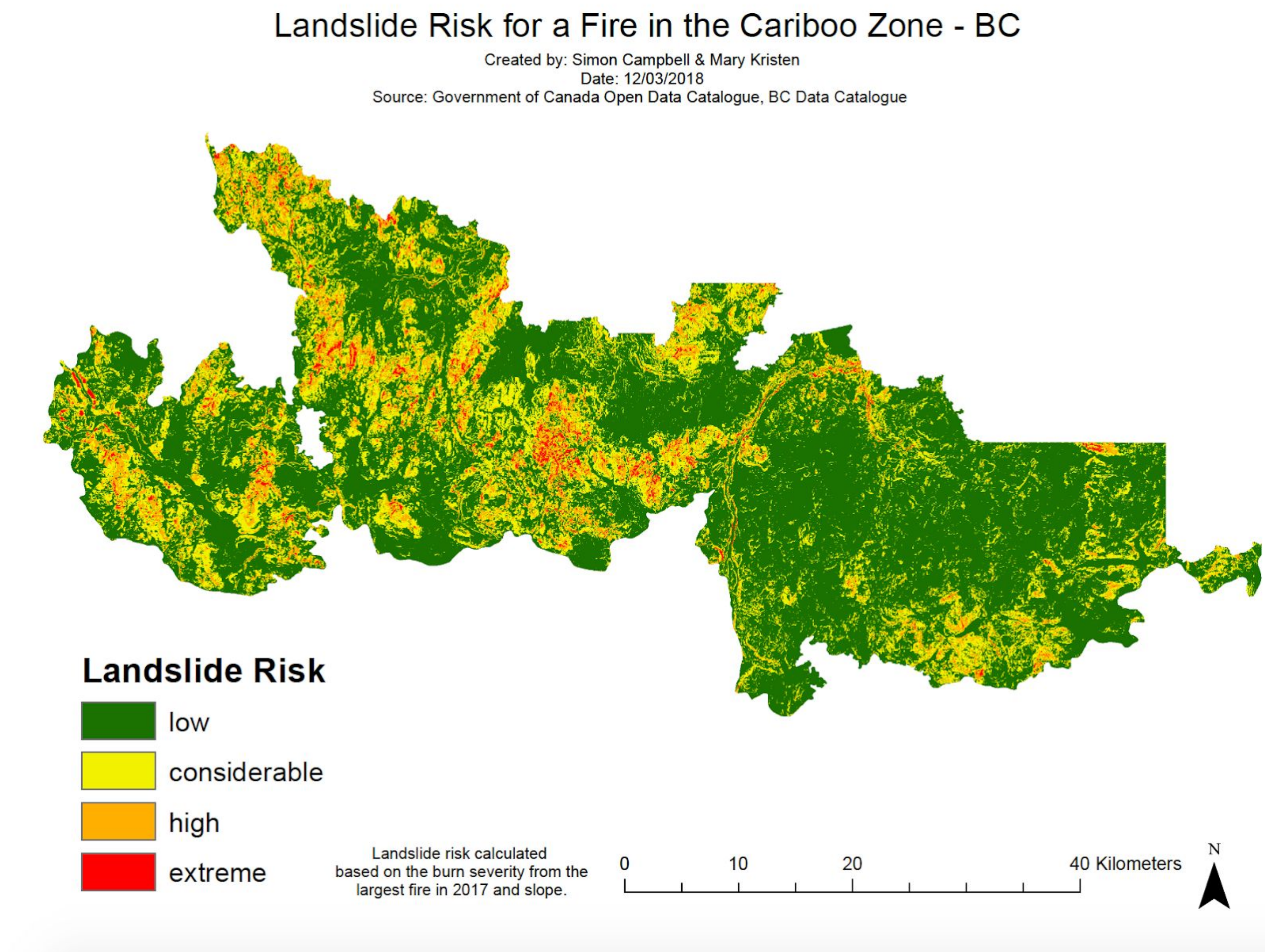
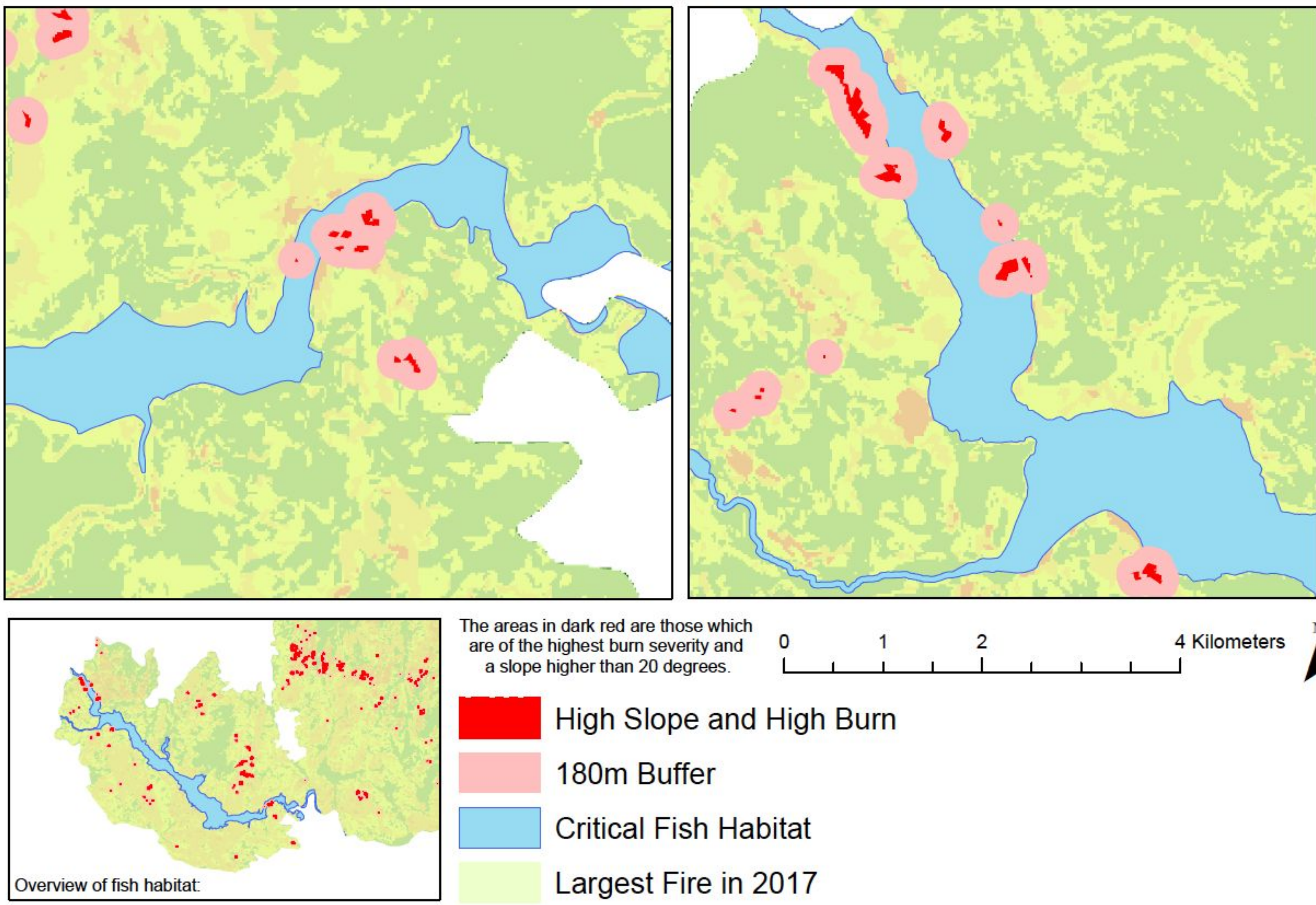



Fig. 4 - Fish Impacts Map

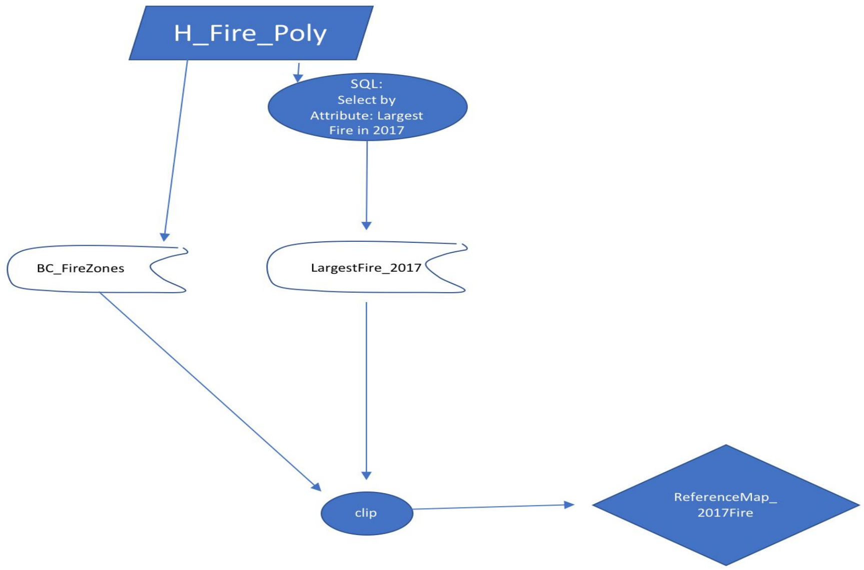
High Risk Landslides in Relation to Fish Habitat - Cariboo Region, BC

Created by: Simon Campbell & Mary Kristen
Date: 12/03/2018
Source: Government of Canada Open Data Catalogue, BC Data Catalogue

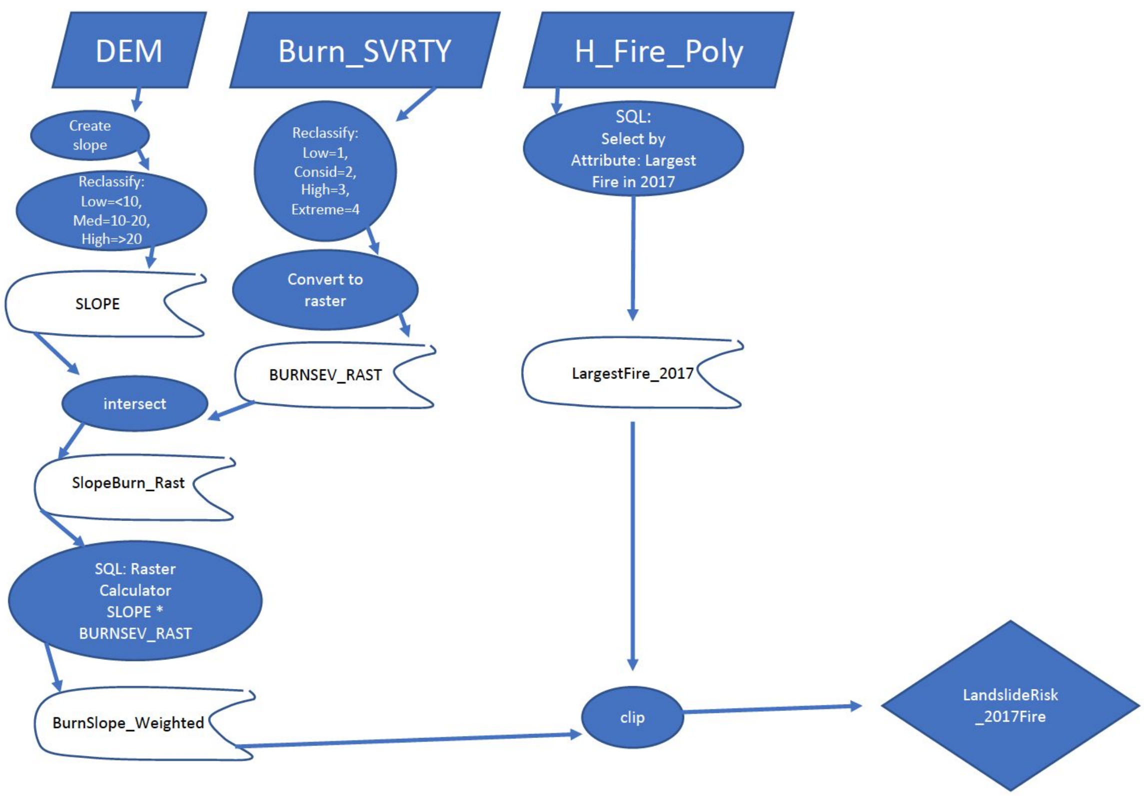



iii) Flowcharts

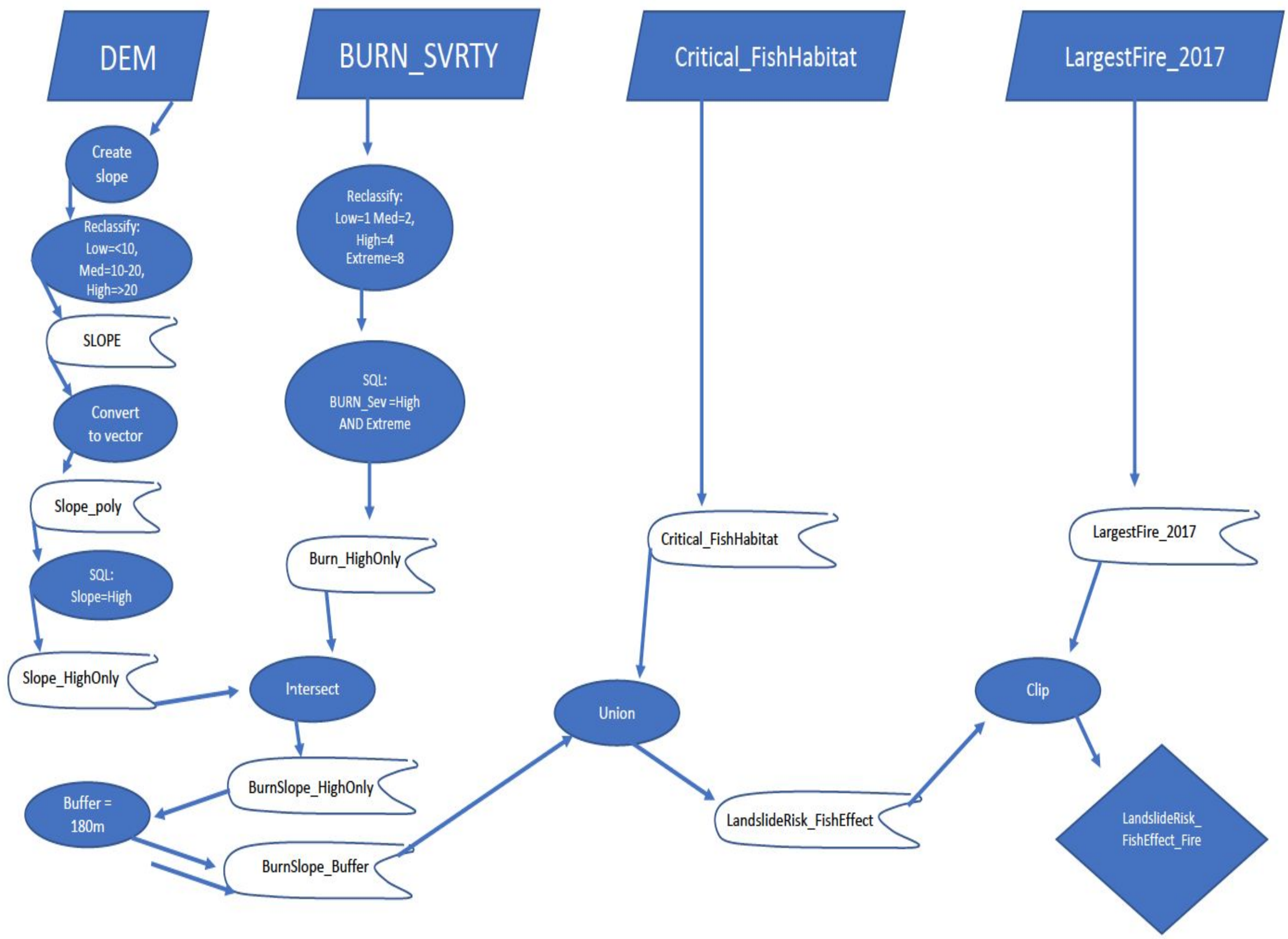
a) Flowchart for Fig. 2




b) Flowchart for Fig. 3




c) Flowchart for Fig. 4


DEM
BURN_SVRTY
Critical_FishHabitat
LargestFire_2017
Create slope
Reclassify: Low=<10, Med=10-20, High=>20
SLOPE
Convert to vector
Slope_poly
SQL: Slope=High
Slope_HighOnly
Reclassify: Low=1 Med=2, High=4 Extreme=8
SQL: BURN_Sev =High AND Extreme
Burn_HighOnly
Intersect
BurnSlope_HighOnly
Buffer = 180m
BurnSlope_Buffer
Critical_FishHabitat
Union
LandslideRisk_FishEffect
LargestFire_2017
Clip
LandslideRisk_ FishEffect_Fire