A Tactical Plan for the Recovery of Whitebark Pine in the Omineca Region

Prepared by Alana Clason M.Sc
Bulkley Valley Research Centre

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Bulkley Valley Research Centre
www.bvcentre.ca
Bulkley Valley Centre for Natural Resources Research & Management

TACTICAL PLAN: WHITEBARK PINE IN THE OMINECA REGION

REPORT SUMMARY

Whitebark pine (*Pinus albicaulis*), a subalpine and treeline species of western North America is an important tree species for forest biodiversity, supporting wildlife communities and providing ecosystem services in mountain environments where it is found. The species has declined across its range and is now listed on the Canadian Species at Risk Act (SARA) as "Endangered" due to the cumulative effects of an invasive pathogen (white pine blister rust, *Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosa*) outbreaks, competitive exclusion under fire suppression, and the potential impacts of climate change. The Omineca region of BC contains the most northern stands of whitebark pine, which are as vulnerable to blister rust and mountain pine beetle as their southern counterparts. Maintaining these stands will be important for the recovery of the species, for facilitating future migration north with a changing climate and for maintaining biodiversity, particularly supporting species that rely on whitebark pine so closely. Initiatives to recover whitebark pine outside of federally protected lands in Canada is extremely important for this species as most of its Canadian range falls outside national parks, resulting in little federal protection. The actions outlined in this report will therefore be important contributions to the recovery of the species, particularly in the interim between the designation of whitebark pine as endangered, and the production of federal and provincial recovery plans. This report summarizes the current state of knowledge on the occurrence, threats and status of whitebark pine in the Omineca region, provides guidance on actions to begin the process of species recovery, as well as recommendations for future work. This report should be used in conjunction with higher level recovery planning once available. Recovery planning for whitebark pine is currently underway at the provincial and federal levels, so there should be ongoing review and re-assessment of the recommendations in this report as new information becomes available at the regional, provincial, national and international levels facilitating species recovery.

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Part I - Background

Range

Whitebark pine is found in subalpine and treeline environments from the southern Sierra Mountains in California to northern BC and occurs in both the Rocky and Coastal Mountain Ranges (Figure 14). The current most northern confirmed population for the species occurs in Mt. Blanchet Park and the adjacent Mitchell Range, north of Fort St. James (Figure 2 & Figure 3). Current range maps (Figure 14) do not well represent whitebark pine in northern areas, such as the Omineca, making planning restoration based on the location of populations challenging. For instance, the current provincial forest inventory (vegetation resource inventory, VRI) does not indicate the northern populations on Mt. Blanchet or in the Mitchell range; however the previous forest inventory did contain these polygons. For a full discussion on distribution and range maps, as well as new mapping products for the Omineca Region generated for this report see Part II.

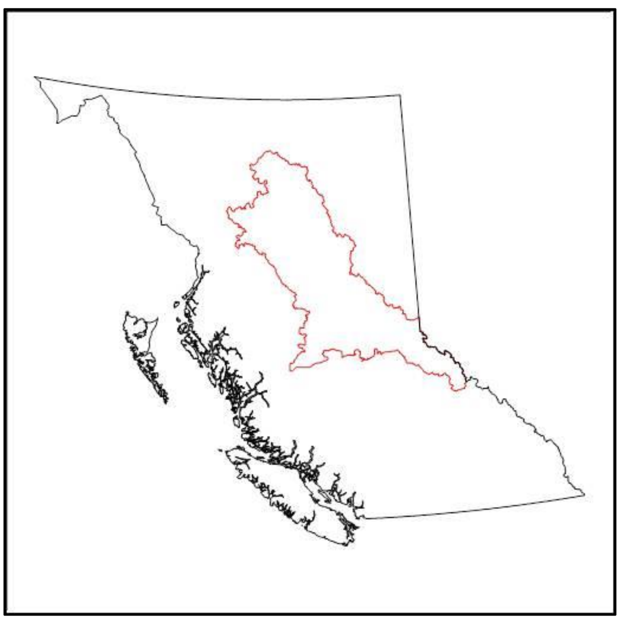

Figure 1 – The Omineca region of British Columbia

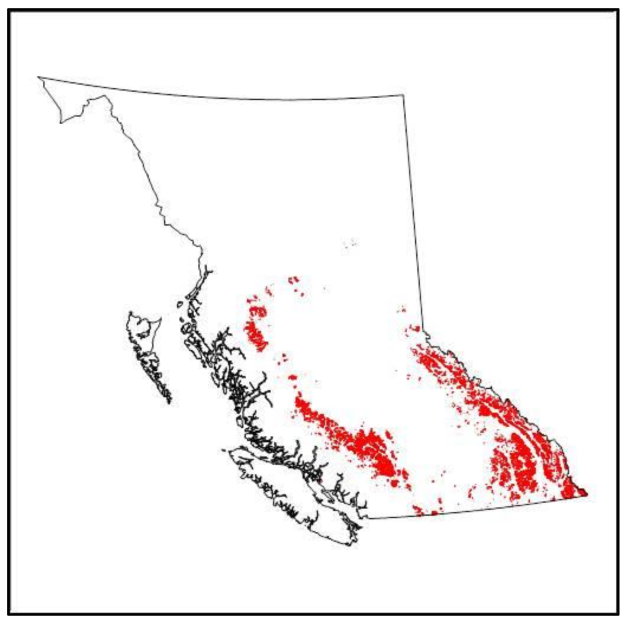

Figure 2- Vegetation Resource Inventory (VRI) forest cover containing whitebark pine in BC in red

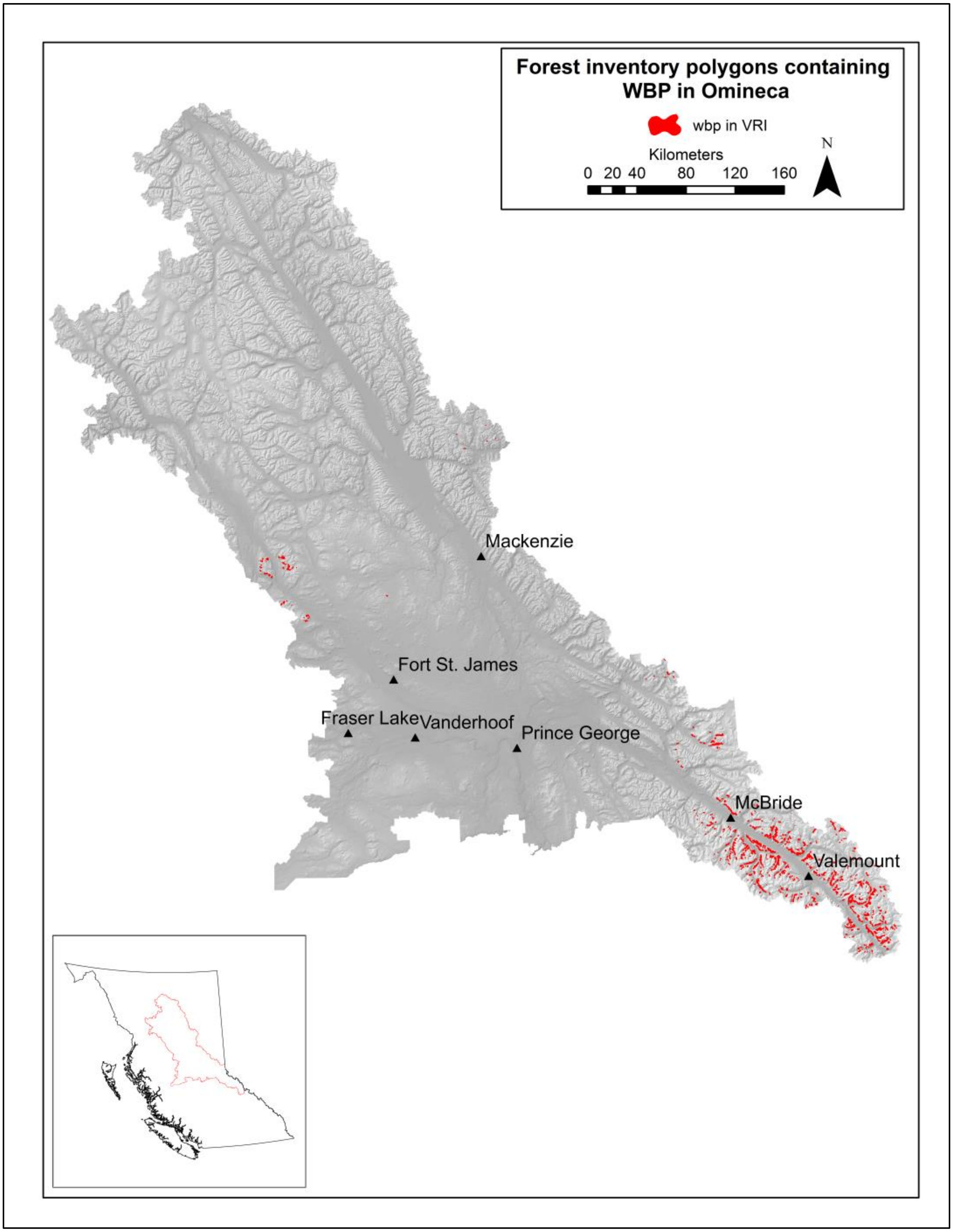

Figure 3 – Whitebark pine distribution for the Omineca region predicted by the VRI

Biology

Whitebark pine can be identified by light green needles found in clumps of five in each fascicle, white/gray bark that tends to be smooth on small diameter trees, upswept branches, red resinous cones that do not open when ripened or by fire, and pollen cones that are purple.

Figure 4 – five needles per fascicle

Figure 5 – resinous cones opened by wildlife

The overall appearance of the tree is brushier with a broader canopy than other species such as lodgepole pine or subalpine fir (Figure 7). As a stone pine, whitebark pine produces large, wingless seeds that are high in fat and adapted for animal dispersal (Figure 4, Figure 5). Whitebark pine also varies in its growth form. For instance, at or above treeline it can grow in a stunted "krummholz" form, but can also be found in mid and lower elevation subalpine and montane forests growing as large diameter, straight stemmed trees (see "Whitebark pine in British Columbia" factsheet (Pigott 2012), Weaver 2001, or McCaughley and Schmidt 2001 for more information on taxonomy and growth forms).

The high caloric, fatty seeds of whitebark pine are specifically adapted to animal dispersal. In particular, Clark's nutcrackers are a co-evolved avian dispersal agent for whitebark pine, adapted to cracking open the ripened cones, collecting the seeds in their sub-lingual pouch and then caching these seeds within their home range. Clark's nutcrackers will return to their cache sites in the spring with their young offspring and forage on the seeds hidden the previous year. As a result of this co-evolved dispersal mechanism, whitebark pine is able to produce seedlings only when the nutcrackers cache and then forget to retrieve the seeds from a suitable microsite within a suitable habitat for whitebark pine germination and establishment. A series of factsheets have been developed by the USDA on nutcracker behaviour that summarizes the most up-to-date information on caching at the landscape, habitat and microsite scales, home range and migratory behaviour, population trends, and the effectiveness of Clark's nutcrackers as a seed dispersal agent for whitebark pine (http://ecoshare.info/projects/whitebark-pine/).

Figure 6 – Clark's nutcracker cracking a cone and retrieving seeds for caching

Figure 7 – Upswept "brushy" branches of whitebark pine

HABITAT AND GROWING CONDITIONS

Whitebark pine is a stress tolerator, found on harsh sites where other species may struggle to survive, such as sites with a short growing season, lack of moisture and poor nutrients. Dry, south-facing slopes, wind exposed treeline and subalpine rock outcrops or rocky sites along the shorelines of subalpine lakes within suitable elevational range are common habitat types for this species. Flatter sites, such as well-drained glacial-fluvial fans also support whitebark pine within its northern range. Being restricted to less productive habitats, whitebark pine has a wide fundamental, but narrow realized niche (Weaver 2001). This means that while there are broader climatic or edaphic conditions that may be suitable for whitebark pine, due to biotic interactions such as competition, whitebark pine is restricted to a much narrower range of sites. This is an important consideration for restoration activities as given suitable disturbance, site and climate, whitebark pine can be planted in a wide range of habitat types.

Whitebark pine occurs exclusively in mixed stands at the northern edge of its range, including the Omineca region. Common associates are subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*). In the southern portion of the Omineca, in the ESSFmm1/mmp south of Valemount, whitebark pine can also be found mixed with Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). Common understory associates in the Omineca include *Vaccinium membranaceum*, *Rhododendron albiflorum*, *Menziesia ferruginea*, *Empetrum nigrum*, *Arctostaphylos uva-ursi*, *Spirea betulifolia*, *Ribes lacustre*, *Orthilia secunda*, *Linnaea borealis*, *Lycopodium annotinum*, *Cladina* spp., *Cladonia* spp., *Pleurozium shreberi*, *Dicranum* spp. and *Stereocaulon* spp. (see Arno and Hoff 1989, Arno 2001, Ogilvie 1990, Weaver and Dale 1974 for more background on community types and vegetation composition across the range of whitebark pine).

A list of potentially suitable environmental habitats described by BEC subzones is found in Table 8 and while suitable site series within each of these subzones have not been identified, whitebark pine is generally found on sub-mesic to xeric and nutrient poor edaphic conditions. Whitebark pine can be found on more productive (mesic) sites if a disturbance such as fire opens up growing space and enables establishment. As a moderately shade tolerant, but very slow growing species, it is expected to be out-competed on these sites over time as faster growing, or more shade-tolerant species begin to dominate. (See Campbell and Antos 2003, Kipfmueller and Kupfer 2005 or Keane 2001 for a more thorough discussion on successional pathways in whitebark pine stands).

Ecosystem services

Whitebark pine is not only a significant food source for Clark's nutcrackers, but also for other species of wildlife such as squirrels and bears; an excellent food source due to the high fat and protein content of the seed. Red squirrels are common foragers of whitebark pine seed, clipping mature cones off the end of branches and storing the cones in their middens for consumption over the winter. Both grizzly and black bears are known to excavate squirrel middens in order to eat whitebark pine seeds. They are efficient at cracking the cone scales and extracting the seed with their tongues. Bears are also known to climb trees to access the seeds (Figure 8).

Figure 9 – Bear scat full of whitebark pine seeds outside of Lillooet, BC

Figure 8 – likely grizzly bear (pers. comm., Tony Hamilton Oct. 30, 2012) claw marks moving up a whitebark pine tree on Mt. Sidney Williams, north of Fort St. James, BC

There are several ongoing research projects to investigate the importance of whitebark pine seeds to grizzly bear diets in the Canadian range (i.e. Foothills Research Institute in Alberta http://foothillsri.ca/program/grizzly-bear-program and Yvonne Patterson, University of Victoria MSc research in the Lillooet area). Research from the Greater Yellowstone Area of the U.S indicates a strong relationship between grizzly bears and whitebark pine when there are enough seeds available for consumption (Mattson *et al.* 1991).

In addition to its importance as a food source for wildlife, whitebark pine can also contribute significantly to the hydrological cycle and treeline dynamics. As an initiator of tree islands, it modifies the harsh treeline environment, enabling the establishment by other species. As a high mountain species, it is also important in modifying the rate of snowmelt in spring (see Tomback *et al.* 2001 and Weaver 2001 for a more thorough discussion on ecosystem services provided by whitebark pine).

SEED PRODUCTION

In order to enhance or supplement the natural process of colonization and survival for restoration and recovery planning, it is important to understand the process of seed production and maturation of whitebark pine. Age of cone production estimates vary between studies, but on average, reproduction may begin somewhere between 30-60 years, with greater cone production associated with larger crowns from stems 125-250 years old (Arno and Hoff 1989). A reproductively mature whitebark pine can house both pollen and seed cones on the same tree, with pollen cones generally found on the lower branches and the female cones found at the tips of branches higher on the tree. With good pollination and adequate growing season for maturation, 40-60 seeds/cone can be expected, however it may be prudent to plan for lower seed/cone estimates on average.

Figure 10 - Seeds in a whitebark pine cone. Photo: Don Pigott

One of the most challenging aspects of conservation planning for whitebark pine is trying to coordinate seed collection effort with seed production in a given year. Whitebark pine is a masting species, which means that trees within a given area will synchronize their seed production, resulting in the production of abundant seed in one year and substantially less in other years. The prediction of masting is challenging as there does not appear to be a simple environmental cue triggering synchronization of seed production (Weaver 2001, Crone *et al.* 2011).

This has significant implications on restoration planning, as having the resources to fund a seed collection in any year will not guarantee that there will be seeds available for collection. Funding sources for restoration would work best if there was flexibility in deadlines for collection.

LANDSCAPE DYNAMICS

Whitebark pine often occurs within islands of suitable habitat in a sea of unsuitable low elevation habitat. Understanding the dynamics between populations as well as the impacts of landscape level processes, such as fire disturbance, will be important to naturally sustain and establish new populations and as a consideration for restoration prioritization. The dependence of whitebark pine on Clark's nutcrackers for dispersal is central to these dynamics and maintaining connectivity between whitebark pine populations for nutcrackers to continue dispersing seed is an important conservation consideration. Better understanding the relationship between Clark's nutcrackers, whitebark pine abundance and cone production, as well as the abundance of alternate food sources for nutcrackers is essential for managing stands of declining whitebark pine and prioritizing restoration resources. There has been little documentation on Clark's nutcrackers in the Omineca region except from a limited number of eBird records, Christmas bird counts, and the BC breeding bird atlas (J. Vinnedge pers. communication). Better understanding how nutcrackers are using northern whitebark pine populations, their alternate food sources, where they are caching seeds, where they are breeding and how successfully they are breeding at the northern edge of the range, will all help to better understand the thresholds in whitebark pine abundance needed to sustain Clark's nutcrackers over time. Given the importance of northern populations of whitebark pine for future species latitudinal migration under climate change, it is essential to understand where management should focus efforts in order to support natural dispersal via Clark's nutcrackers This may also involve the need to manage alternate food sources in certain areas. (See McKinney and Tomback 2007, McKinney *et al.* 2009, Barringer *et al.* 2012 for current understanding of thresholds in whitebark pine to sustain Clark's nutcrackers).

Decline of whitebark pine

Whitebark pine in the Omineca region is declining and susceptible to the same threats found elsewhere in its range. White pine blister rust (WPBR), mountain pine beetle (MPB), fire suppression and climate change are recognized as the primary threats to whitebark pine, however greater recognition of the role of industry as a threat could also be considered.

White pine blister rust

WPBR is a fungal pathogen introduced into North America on both the east and west coasts in the early 20th century from Eurasia, resulting in the decline of five needle pines across North America. It is important to understand the basic biology and spread of this invasive disease, as the recovery of whitebark pine will require facilitating increased rust resistance as one of the main restoration efforts.

To complete its life cycle (Figure 11), WPBR requires a five needle pine as the primary host and most commonly a species within the *Ribes* genus (but also *Castelleja* or *Pedicularis*), as secondary hosts. There are five stages in the rust life cycle, however the two most frequently discussed are the aeciospore stage where the rust is visible on the pine. It is at this stage that the rust travels to its secondary host. At the basidiospore stage the rust travels from *Ribes* back to five needle pines. Aeciospores can travel upwards of 500 km by wind, and basidiospores travel in the order of several kilometres but these spores also require constant high humidity to survive in the wind. Basidiospores enter the pine through its needles and as a result cankers often first form on the branches, moving into the stem over time where the infection can become lethal. Whitebark pine is susceptible to rust from seedling through to mature tree size classes. Identifying rust and monitoring changes in rust infection rates over time is another crucial component of restoration planning.

There was a *Ribes* eradication program in the U.S that proved largely unsuccessful at controlling the spread of rust as a result of the long distance dispersal of aesiospores, the large abundance of *Ribes* across the landscape, long survival of *Ribes* seed in the forest floor and its ability to sucker from rhizomes after removal of the above ground biomass (McDonald and Hoff 2001). A more promising approach might be to obtain seed from rust resistant individuals. There is some native resistance in North American five needle pines to this invasive rust. The whitebark pine genetic restoration program based out of Idaho focuses on producing seedlings that are not immune, but more likely survive infection by rust.

Predicting the probability of infection by blister rust of the stand and individual is an approach to prioritizing seed collection and restoration activities. There are several strategies to selecting candidate trees for rust screening, but one of the ideas is to collect seed from whitebark pine trees that show some degree of resistance (lack of cankers) in a stand that has high infection rates (Mahalovich and Dickerson 2004). This way, there is a high probability that a tree without cankers was exposed to the rust, with the apparent resistance potentially due to genetic factors. Collecting seed from these trees should be prioritized over trees that may not have been fully exposed to rust. Infections rates may vary with microclimate, topography, secondary host distribution or abundance, forest structure. Zeglen (2002) found an increase in infection rate from the Coast Mountains to the Rockies; however, little of this variation may be explained by climatic factors. Zeglen (2002) indicates weak causal relationships between rust incidence and latitude, longitude and elevation. For instance, whitebark pine growing at high elevations as krummholz in treeline environments in Montana had 35% incidence of tree infection (Resler and Tomback 2008), which indicates high rust infection even at high altitudes.

The average plot level infection rate by WPBR in the Omineca region is 28% (Figure 12), with a maximum rate of infection within a plot of 71% on Mt. Sidney Williams (Figure 26, data from Clason (unpublished) and Zeglen (2002)). In total, 88% of all plots surveyed in the Omineca region had at least one individual infected by rust, however there are relatively few sampling points for WPBR in the north (43 plots reported here, but many are spatially continuous, and sampled over a long time period (1998 – 2013)). In comparison, the Kootenays have 14-71% plot level infection (Murray 2010), Smithers area has ≤ 72% infection within plots (Haeussler *et al.* 2009), 98% of plots surveyed had at least one tree infected in the Canadian Rockies with average plot infection rate of 52% (Smith *et al.* 2013), province-wide in BC plot level infection ranged from 0-83% with an average of 31% infection (Zeglen 2002) and another study across BC had an average of 33%, ranging from 0-100% infection rate within plots (Campbell and Antos 2000). (See Hoff 1992, and Tomback *et al.* 2005 for more information on identifying and surveying blister rust. See Van Arsdel *et al.* 1956 for the interactions between rust and climatic factors, and McDonald and Hoff 2001 for a good review of blister rust in whitebark pine).

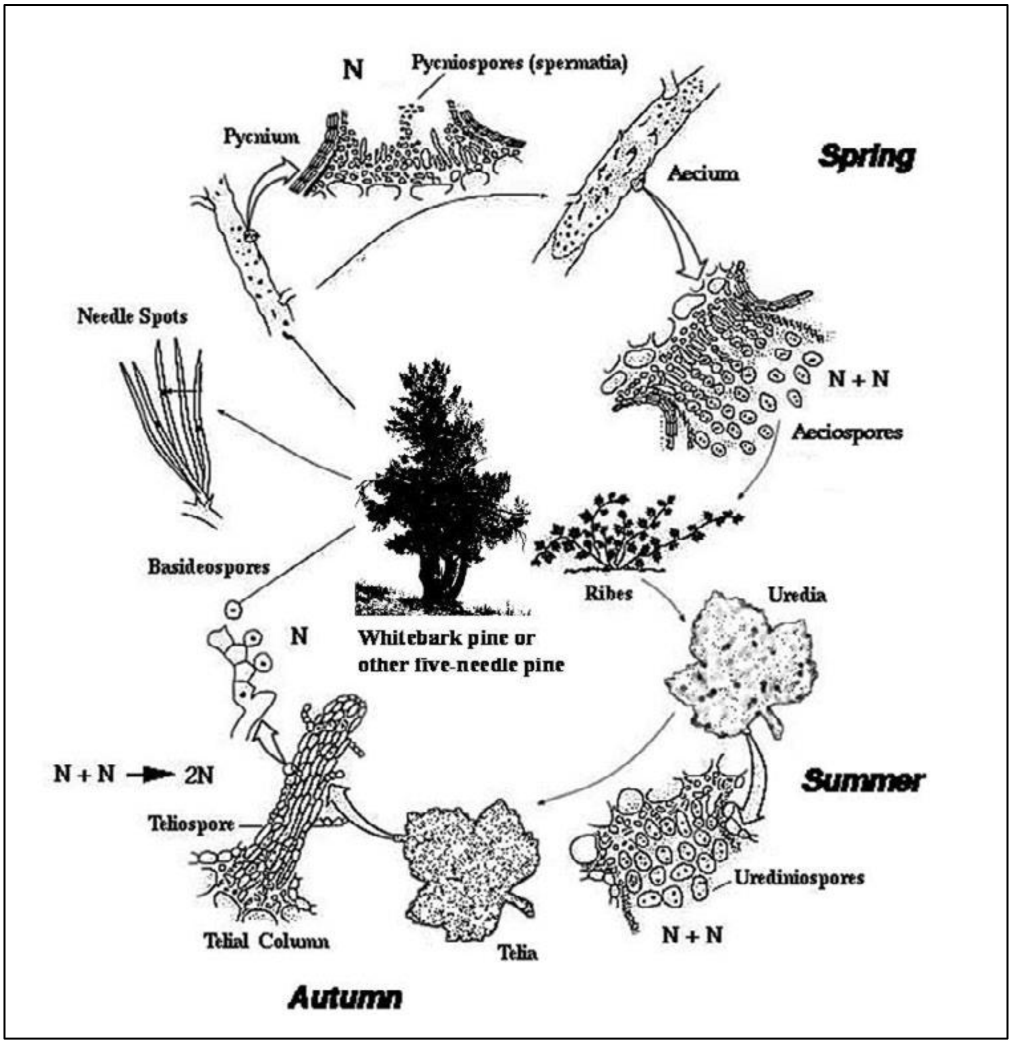

Figure 11 - The life cycle stages of white pine blister rust (McDonald and Hoff 2001)

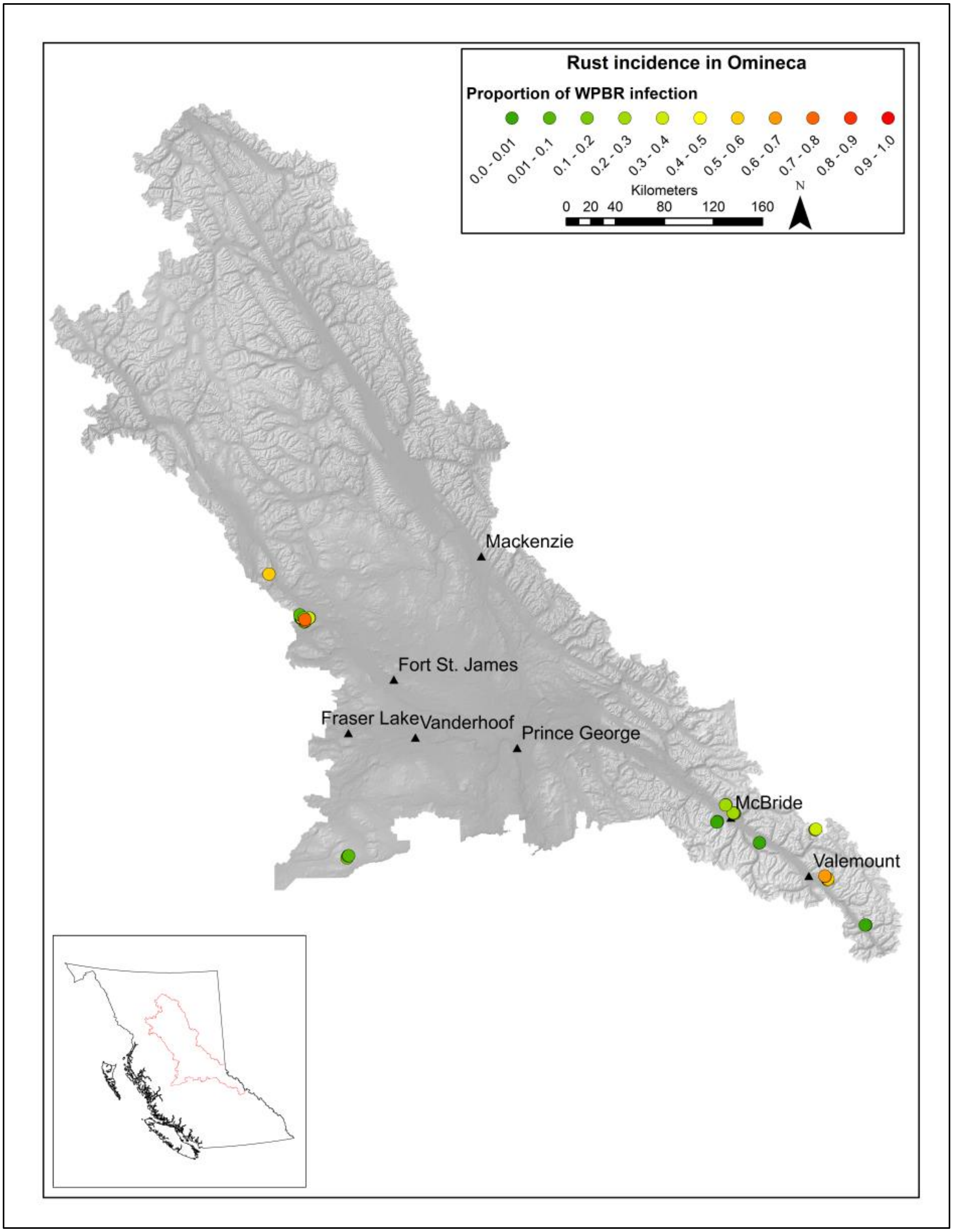

Figure 12 – Relative white pine blister rust infection rate across the Omineca, data from Zeglen (2002) and Clason (unpublished). Healthy sites are in green, sites with high levels of infection in red and intermediate levels of infection in yellow

Mountain pine beetle

The cumulative effects of WPBR and MPB combined with projected climate change are anticipated to result in further reductions in whitebark pine abundance range-wide (Logan *et al.* 2010). There is little specific documentation on the extent of the current MPB outbreak on whitebark pine in the Omineca region. However, MPB mortality is mapped based on overview flights and the provincial MoFLNRO Mountain Pine Beetle Model. It may be possible to overlay MPB mapping with whitebark pine occurrence to determine potential extent of mortality. MPB mortality has been observed in northern whitebark pine ecosystems in the Skeena region (Clason 2010), with significant mortality in the Morice District (average of 81% Haeussler *et al.* 2009). In the Omineca, MPB mortality has been observed in the Cariboo Mountains southwest of Dunster, on Mt. Sidney Williams, and on Mt. Davidson (Clason unpublished data). Further consultation with experts on the extent of MPB-killed whitebark pine across the Omineca region may yield improved mapping, so it is recommended to discuss with these experts to get a better picture of the overall impact MPB may have already had in this region and MPB as a future threat to whitebark pine.

Fire suppression

Fire plays an important role in whitebark pine ecosystems, by opening up growing space for establishment of new seedlings and by maintaining a mix of stand ages on the landscape, such as early successional stands containing whitebark pine. Whitebark pine cones do not open after fire, but there is substantial evidence that the seedbeds available after burns are suitable for whitebark pine germination and establishment (Tomback 1982, Campbell and Antos 2003). The effect of decades of fire suppression in places like Montana has certainly reduced the abundance of young whitebark pine stands across the landscape, increasing the likelihood of successional replacement, and decreasing potential regeneration on these suitable sites (Keane and Arno 2001). The role of fire suppression at the northern edge of whitebark pine's range as an agent of decline is not well understood, but certainly must be considered as a potential threat to the recovery of whitebark pine in this region. (See Keane *et al.* 1990, Keane *et al.* 1994, Keane and Arno 2001, Larson *et al.* 2009 for more information on the potential role of fire and fire suppression on whitebark pine)

Climate change

Whitebark pine in the Pacific Northwest region of the U.S. was recently assessed as the most vulnerable tree species to anticipated impacts of a changing climate (Devine *et al.* 2012). Climate change will directly affect the ability for whitebark pine to persist over time through effects on climate suitability, but changing climate will also result in indirect effects on persistence. For instance, indirect effects could include changes in disturbance regimes, competitive interactions, or changes in dispersal dynamics. As a result, all stands of whitebark pine will not be equally vulnerable to climate change. For example, Haeussler *et al.* (2009) indicate that low elevation whitebark pine-lichen woodlands (primarily associated with glacial-fluvial fans) are more vulnerable to climate change because of increased competition from faster growing, more shade tolerant species. This reduction in suitable habitat through encroachment of species adapted to milder environmental conditions moving upwards in elevation and potentially out-competing whitebark pine in its former habitat is expected to occur significantly faster than whitebark pine is able to migrate north to new climatically suitable habitats (Hamann and Wang 2006). Regardless of changing climate, it appears that there is suitable climate further north than the current northern edge of whitebark pine's range, suggesting that climate may not be the only factor limiting this northern range limit (Figure 13). Whitebark pine can germinate and survive north of its current range within this predicted current climatically suitable habitat (McLane and Aitken 2012). By 2025 with a changing climate, it is predicted that suitable climate will be increasingly lost from southern BC, and increasingly gained in the Omineca region. As a result, conserving populations of whitebark pine in the Omineca region will be important for facilitating future migration north. (See Devine *et al.* 2012, Hamann and Wang 2006, McLane and Aitken 2012 for more information on the potential effects of climate change)

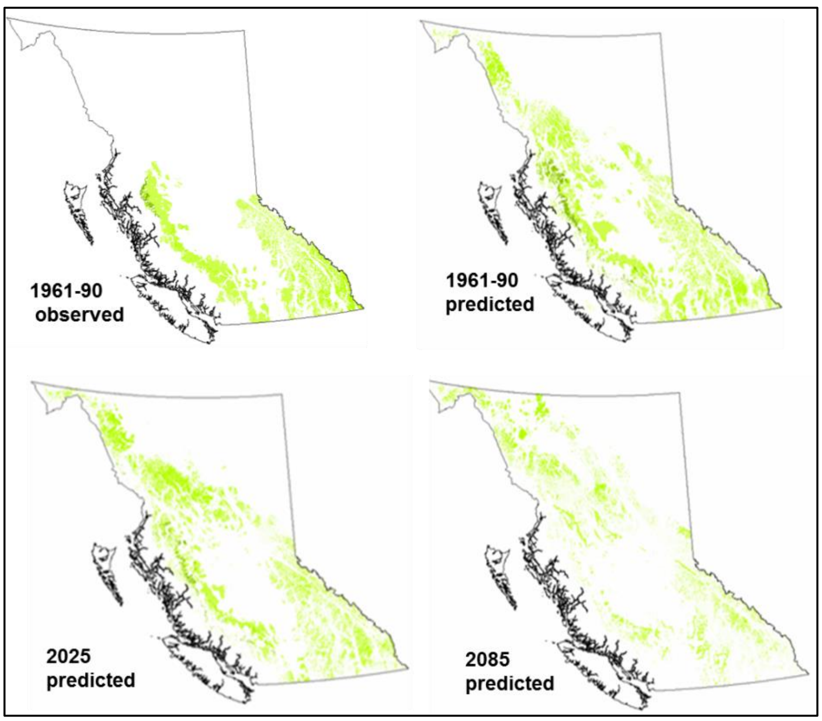

Figure 13 - The two upper maps represent the current observed and current predicted suitable climate in green. The bottom two maps represent future predicted climatically suitable growing space in 2025 and 2085 (Wang *in* McLane and Aitken 2012).

Industrial activities

While the four threats listed above (WPBR, MPB, fire suppression and climate change) are often considered the most important to mitigate in order to recover whitebark pine, industrial development in whitebark pine habitat is another impact that can result in further loss. In the Omineca region, forestry, mining and mineral exploration is a serious concern for the conservation of the species. Industrial activities that may affect whitebark pine should be identified early to minimize potential impacts. Working with companies in the natural resource sectors will be a crucial component of recovery. (See Moody and Clason 2013 for a description of the work with Blackwater mine in the Vanderhoof District and Murray and Krakowski 2013 for mechanisms for collaboration with the forest industry)

Rationale for conservation

The objective of this plan is not to provide high level strategic guidance for the recovery of whitebark pine, as this should be provided by recovery plans (provincial and federal). The recovery planning process has begun for Canadian whitebark pine as a result of the federal listing on the Species-at-Risk Act. The scope of this report is to make recommendations specifically for ongoing whitebark pine restoration planning for the Omineca region. There are other restoration strategies (Genetic Conservation Technical Advisory Committee 2009, GYCCWBPSC 2011, Keane *et al.* 2012 and the Alberta provincial recovery plan: B. Jones pers. communication) currently available that provide different perspectives or higher level planning that cover various aspects of whitebark pine conservation in more detail than what is found in this tactical plan for the Omineca region. For instance, the 16 authors involved in the Range-wide restoration strategy (Keane *et al.* 2012) provide a much more thorough background on the biology, causes of decline, and potential approaches to management across scales than found in this report, which may be of interest to some readers. They also provide a brief discussion on the conceptual framework for active restoration that is worth considering before taking the actions discussed below (pg. 38-39, Keane *et al.* 2012).

Another useful context and rationale for this tactical plan in the Omineca region is the BC Conservation Framework. The goals of the BC Conservation Framework are to "(1) Contribute to global efforts for species and ecosystem conservation, (2) Prevent species and ecosystems from becoming at risk, and (3) Maintain the diversity of native species and ecosystems. Given that a large extent of whitebark pine's global range falls within BC, the species has been identified both provincially (blue-list) and federally (endangered) as at risk, and whitebark pine is an important component of forest biodiversity across the province, the conservation of whitebark pine falls within this Conservation Framework (http://www.env.gov.bc.ca/conservationframework/). The framework provides provincial context for the conservation of whitebark pine. The goal of any actions recommended in this report is to take the first steps towards recovering whitebark pine from “at-risk” in the Omineca region.

Ultimately, while whitebark pine is not widespread across the entire Omineca region, it houses the northern-most whitebark pine stands globally. These northern populations are important for forest biodiversity, genetic diversity, as well as local adaptation to northern climates. The responsibility to conserve and restore these northern populations is in the Omineca region, which will be critical for facilitating future species migration under a changing climate.

PART II – TACTICAL PLAN

The tactical plan for management of whitebark pine in the Omineca Region includes three parts:

- current baseline maps showing known locations of whitebark pine stands,
- management options,
- a summary of potential restoration priorities by forest district.

1. MAPPING WHITEBARK PINE IN THE OMINECA

Developing management strategies for the recovery of WBP in the Omineca region requires a better understanding of the current location and status of WBP populations (Figure 14). The highest resolution inventory currently available for WBP in BC is the provincial Vegetation Resource Inventory (see: http://www.for.gov.bc.ca/hts/vri/intro/index.html; Figure 2 & Figure 3). This forest inventory appears to be of limited use for mapping whitebark pine given its relative low abundance across BC compared to many other tree species. The BEC regional field guides also describe subzones/site series where whitebark pine occurs in other regions of the province but likely because WBP occurrence in the Omineca region is low, it is not described in any of the field guides for this area (land management handbooks 15, 24, 29, 51, 54 produced by the BC Ministry of Forests: Meidinger *et al.* 1998, Delong *et al.* 1993, Delong *et al.* 1994, Delong 2003, Delong 2004). This may result in ongoing misunderstanding about possible occurrence, frequency and even growth form of WBP when it occurs (see Table 5). As a result, whitebark pine maps based on presence within BEC units may also under-represent its occurrence in the Omineca region.

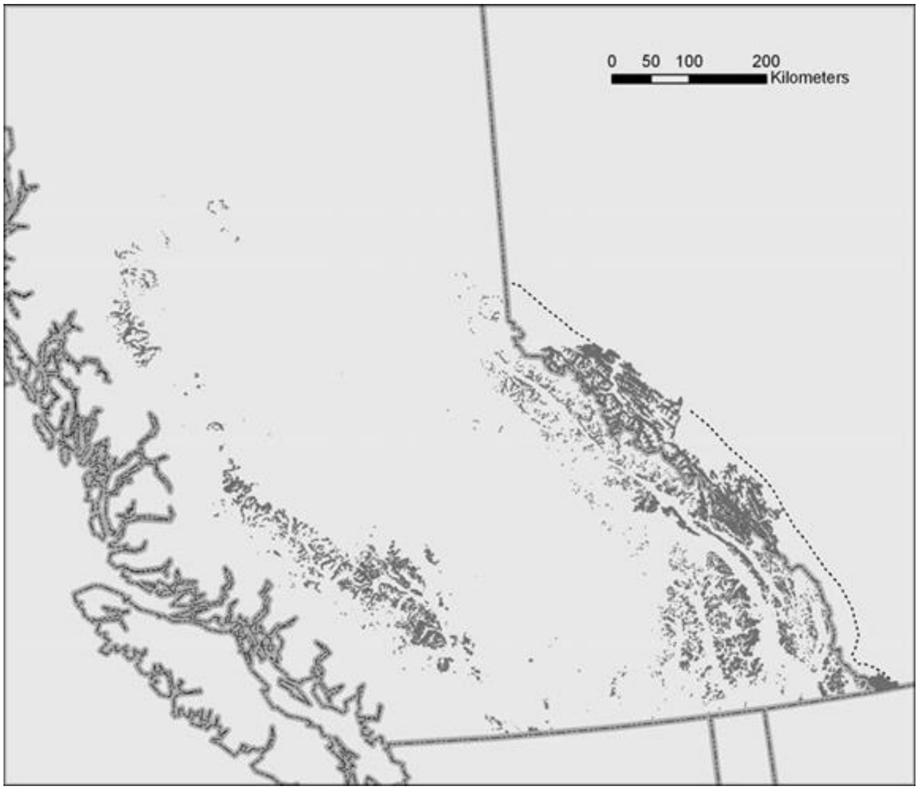

Figure 14 – Current range map for whitebark pine (COSEWIC 2010)

Adequately mapping current locations of whitebark pine is critical for recovery planning and immediate restoration actions. It is important that location mapping be updated periodically and that information about the health and status of whitebark pine is included in mapping updates across the Omineca region. For instance, the Greater Yellowstone Whitebark Pine Subcommittee's most recent WBP mapping (GYCCWBPSC 2011), includes a map indicating dominance, maturity, mortality, resulting in prioritization for restoration of whitebark pine stands across their study region based on this information. Mapping the location and abundance of whitebark pine, as well as the health and reproductive status will help inform prioritization of recovery efforts for this species in the Omineca region. Recommendations to begin the process of mapping populations are outlined below.

Although VRI information about whitebark pine is likely insufficient to use as a starting point for restoration and conservation planning, it is currently one of the only mapping products available. The first step to improving inventory of whitebark pine should be simply determining the accuracy of the VRI using ground plots to create a confusion matrix (under-prediction of presence, over-prediction of absence). Another method of remote mapping that may be more accurate than the VRI for whitebark pine is using remote sensed imagery, identifying the location of whitebark pine based on its spectral signature. Kokaly *et al.* (2003) used hyperspectral (224 bands of 10nm bandwidth, pixel resolution 17.5m) AVIRIS imagery obtained by aircraft fixed with a sensor flying over their study area of Yellowstone Park. They were successful in identifying whitebark pine from this imagery (Kokaly *et al.* 2003).

A potentially more cost effective and rapid mapping product would a predictive map based on larger resolution (25m), but freely available imagery (e.g. LandsatTM, 7 bands instead of 224 above), combined with topographic variables (Digital Elevation Model) to predict probable occurrence of whitebark pine (Landerburg *et al.* 2008, McDermid and Smith 2008). This has proved accurate over relatively large areas, and could be done right now without a great cost investment, however more ground plots then are currently available would be needed to validate/verify the predictive model. For instance, McDermid and Smith (2008) used 145 ground verified whitebark pine presence plots for ~500km^2 area of Waterton National Park. Currently there are 20 BEC program whitebark pine presence plots with GPS coordinates, some of which may be inaccurate, and ~50 from various researchers in the Omineca region which covers ~158,341km^2 (although much of the northern part of the Omineca does not appear to currently support whitebark pine). The drawback to this approach is as a predictive model, it may capture the potential but not actual occurrence of whitebark pine.

Knowing the potential occurrence of whitebark pine may be a useful exercise for restoration planning. Particularly as a first step to determine where to look for the species, a map that widely predicts where whitebark pine is more or less likely to occur can help inform that next step of mapping actual occurrence at finer resolutions. Three types of predictive models were created for this project to identify areas in the Omineca that may be currently environmentally suitable for whitebark pine:

1. a statistical model containing topographic and climatic variables;
2. a statistical model containing only topographic variables; and
3. an overlay of both statistical models on BEC subzones, selecting those intersecting subzones that could conceivably support WBP.

Probability of whitebark pine occurrence based on environmental variables was predicted using a logistic regression in R (R development Core Team 2012). 2840 presence points were generated by taking the centroid of VRI polygons indicating occurrence of whitebark pine within the Omineca region. These models assume the VRI is a reliable source for whitebark pine occurrence, which has not been tested quantitatively. Ground plots of confirmed presence and absence would yield a more accurate representation of suitable environmental conditions for whitebark pine occurrence; however there were not enough of these for the Omineca region. 30,000 absence points were generated by randomly selecting centroids from VRI polygons with no whitebark pine. Topographic variables were derived in ArcGIS 10.0 from a 25m digital elevation model, including slope, aspect and elevation. Site index was extracted for each polygon within the VRI for both presence and absence points as an environmental predictor. Climate variables were generated using ClimateWNA v. 4.70 (Wang *et al.* 2012). Squared values for slope, elevation and site index were included as optimums along those gradients. Stepwise glm model selection in R (package MASS) resulted in a final model that included 5 variables after initially reducing the predictor dataset through pair-wise correlation: elevation, slope, north aspect, east aspect and precipitation as snow. The topography-only model included: elevation, elevation^2, slope, north aspect, east aspect, site index and site inded^2 as predictor variables.

Mapping recommendations:

Although several mapping products were discussed and produced for this report, there is still a need for improved mapping of the location of whitebark pine stands across the Omineca region in order to plan recovery actions for this species.

Table 1 – Recommendations to improve current mapping of whitebark pine in the Omineca. See Table 8 for recommendations by district

Action	Approach	Maps
Quantify the accuracy of the VRI	Ground surveys within/outside of VRI polygon boundaries. Could create a confusion matrix to quantify the accuracy of VRI for whitebark pine. Could do this with the data (plots of known locations) currently available, but some of the BEC plots should be checked for spatial accuracy	Figure 3
Remote sensing whitebark pine locations	Explore the use of advanced remote sensing imagery (e.g. Rapideye, 5m resolution, high resolution aerial photography) to identify whitebark pine	Figure 15
Increase ground plots to verify locations	Regardless of future approach for mapping, more ground plots are required to verify presence/absence of whitebark pine. Add new ground plots to BEC plots database	Ex.) Figure 15
Forest structure	Quantify stand structure (measure of recruitment	n/a

inventory	and abundance of reproductively mature trees)

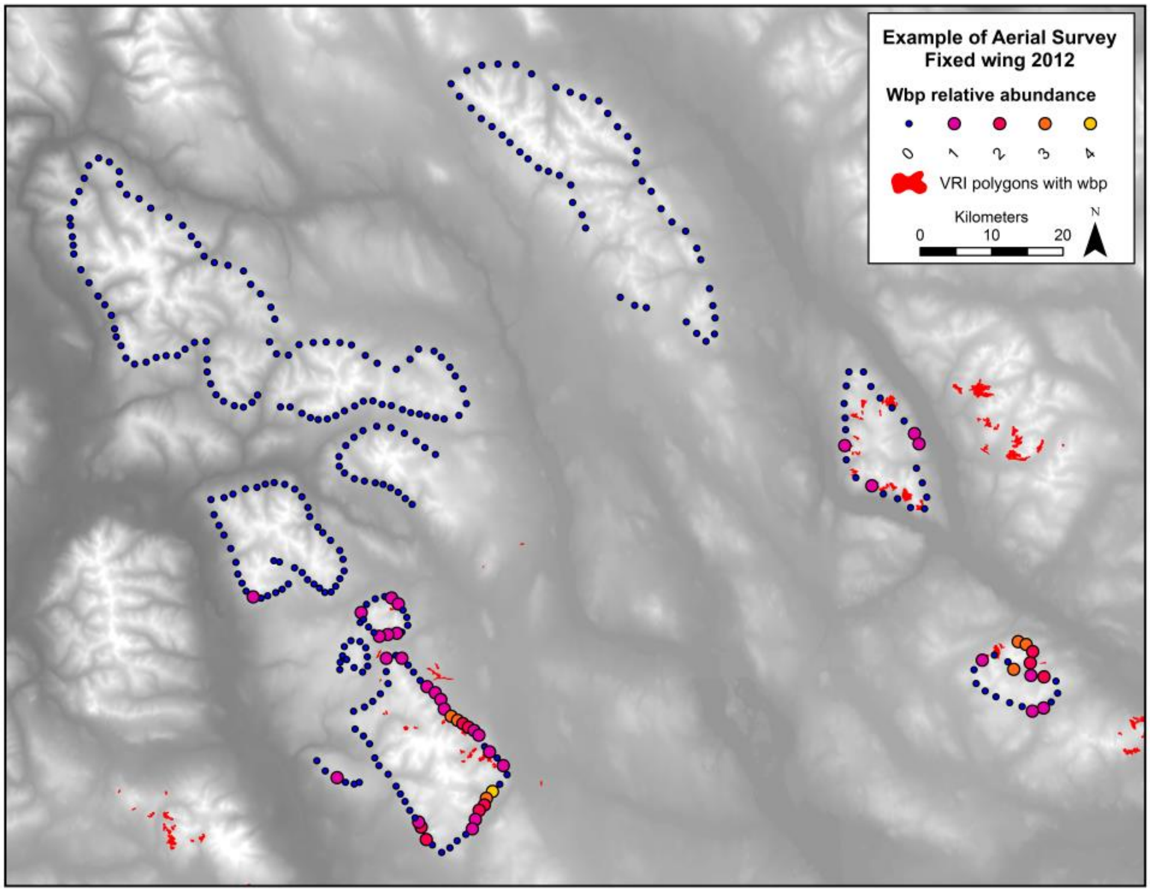

Figure 15 – Example of aerial survey data from fixed wing flight in 2012. Blue dots represent no whitebark pine seen from the aircraft, the rest represent whitebark pine in increasing abundance from 1-4 (low to high wbp abundance).

In conjunction with efforts to map the current location of whitebark pine, collecting more information on the health status of whitebark pine trees across the Omineca region is of utmost importance. There is a paucity of data on mortality and infection rates from WPBR in this region (see section on white pine blister rust in the Omineca above). There are only 4 long-term rust monitoring installations in the entire region (2 in McBride and 2 in Valemount, established by Parks Canada in 2009). Rust incidence data from those 4 transects is not included in this report as it was not available at the time of writing. Knowledge on the infection and mortality rates from rust is crucial for restoration planning as it informs (1) prioritization of sites for restoration planting, (2) prioritization of sites for seed collection and screening for rust resistance. At the moment, it is difficult to set priorities for seed collection and restoration without this baseline information on the spatial variation in health of whitebark pine across the region.

Quantifying MPB-related mortality to date and identifying stands at risk of future attack is also important for planning. Collecting and potentially protecting trees that show some level of rust resistance may be important for maintaining genetic variation in natural populations. MPB caused mortality of potentially genetically rust resistant trees is a significant loss for conservation, given the need to increase the abundance of rust resistant seedlings on the landscape through natural and/or artificial selection and screening processes. Given the magnitude of the most recent MPB outbreak it may not have been practical to attempt to mitigate this disturbance agent, however in the future, if potentially rust-resistant candidate trees are identified for screening, it is important to attempt to protect those trees from additional disturbance, such as fire or mountain pine beetle.

INVENTORY RECOMMENDATIONS:

Table 2 – Actions and approach to improving the assessment of blister rust and mountain pine beetle disturbance

Action	Approach
Survey blister rust	Use aerial or ground surveys as appropriate. This is a high priority for the Omineca region. Better assessment of the spatial variation in health of whitebark pine is essential for restoration prioritization including seed collection and restoration treatments. See Table 7 for monitoring recommendations and Table 9 for recommendations by district
Survey MPB mortality	There may already be resources available as a starting point to compile this information, but potentially not at an appropriate scale for restoration planning. It is important to identify the intensity and location of MPB mortality as a data layer in restoration prioritization

2. MANAGEMENT OPTIONS

Prioritization is a significant component of where on the landscape any one of the following restoration treatments is applied. The range-wide restoration strategy (Keane *et al.* 2012) lists three priority stand conditions warranting restoration in order of importance: high blister rust infection and mortality, high levels of MPB mortality, and stands in late successional stages. The Greater Yellowstone Area plan (GYCCWBPSC 2011) prioritized protection and/or restoration based on the health of stands (rust and MPB), abundance of cone bearing trees, stand density, value of the stand as grizzly bear habitat, access and land ownership as well as potential genetic diversity and rust resistance as this information becomes available. In the Omineca region, however, all these data layers are not available or may not be at the same resolution available for regions like the Greater Yellowstone Area. Table 3 describes the layers that could be available for the Omineca region with some additional investment in information gathering (see Table 1 and Table 2 for inventory needs).

Table 3 – Proposed data layers for prioritization of restoration in the Omineca

Rust infection rate and level of mortality
Level of MPB mortality
Industrial activities (recent past and current planned)
Fire history
Habitat suitability
Stand successional status (cone-bearing density)
Access (site and trees)

For the purposes of this tactical plan, systematic decision making (e.g. Jenkins 2005) was not possible due to lack of information on many of the layers outlined in Table 3. Engaging a wider range of experts in establishing restoration priorities is recommended as a next step for the Omineca region.

PLANNING RECOMMENDATIONS:

Following the completion of this report for the Omineca region, a meeting with all those interested in whitebark pine management in the Omineca could be set to seek wider consultation, discuss prioritization of activities and future work by a broader range of people with different specializations. This recommendation should not overshadow the need for action on the ground as soon as possible.

SEED COLLECTION, SEEDLING PRODUCTION AND RUST SCREENING

Producing rust resistant seedlings is a top priority for restoration of whitebark pine. Seed should be collected in order to screen for rust-resistance and to use in restoration treatments. Screening is the process of testing select seed for rust resistance, generally in a nursery setting, by artificially inoculating seedlings with rust spores. Those seedlings identified as having higher resistance to rust are then prioritized for collection and restoration planting in the future, increasing the amount of rust resistant stock on the landscape. In the Omineca region, where there are few long term monitoring plots for blister rust (Figure 12), it is difficult to prioritize collection areas, as ideally collections occur from areas of high rust infection, looking for trees with no cankers or only a few inactive branch cankers. See Table 10 for recommended seed collection and screening prioritization by district. Seed collection can be costly given the need to cage cones and return in the fall for collection and the difficulty in accessing many whitebark pine stands. A rough estimate of up to $1/seed for a collection may be appropriate if helicopter access is required. Details on methods for cone collection can be found elsewhere (See Murray 2006 and Burr *et al.* 2001 for cone collecting techniques).

There is currently a lack of facilities in BC for blister rust screening for whitebark pine so the options available for screening in BC are to (1) ship seeds of candidate trees to USDA facilities where they are screened or (2) conduct field trials. The first scenario will provide the most rigorous assessment of rust resistance, however the seedlings produced during the screening trial cannot be shipped back to Canada. For instance, once a candidate tree has been identified as having some degree of resistance during screening, seeds would have to be collected again and seedlings grown in Canada for restoration planting. The second option of field trials would be less expensive, but may take longer to determine genetic resistance as a result of having to wait for the seedlings to be exposed to rust in order to assess their response. This would involve careful documentation of origin of the seed (parent), and monitoring of out planted seedlings over time (until the seedlings are exposed to rust) to determine the potential resistance of the parent tree. In this case, it is important to ensure that the location of planting sites is likely to be exposed to blister rust inoculum in order to more rapidly assess resistance.

Planting seedlings

Once seedlings are grown in a nursery for restoration planting, it is important to plant these seedlings carefully on sites identified as a priority for restoration (see Table 10 for potential restoration priorities for districts where there is enough available information to discuss prioritization). Seed transfer zones are relatively far given the dispersal and subsequent genetics of seeds dispersed long distances by a bird. Current seed transfer zones are more restricted in the U.S Rocky Mountains (1.0˚C mean annual temperature (MAT) in US Rocky Mountains), but general recommendations for seed transfer is of 80km, with no restrictions in elevation (Hoff *et al.* 2001), or within 1.9˚C in MAT in northern regions of species range (Bower and Aitken 2008). (See Burr *et al.* 2001 for growing techniques, and McCaughey *et al.* 2009 for planting guidelines)

Site treatments

In addition to planting seedlings, other site treatments may be appropriate depending on tree health, successional status of the stand, historical disturbance regime, site access and availability of funds. Table 4 summarizes silvicultural treatment options potentially useful as tools for whitebark pine restoration.

Silvicultural treatment options for restoration

Table 4 – Treatment options for restoration of whitebark pine with a description of potential benefits and drawbacks of each method

Treatments	When and Where?	Potential benefits	Potential drawbacks	Information Sources
Planting rust resistant seedlings	Highest priority sites first, but all sites would benefit	-The best (and potentially only) action to increase rust resistance across the landscape ensuring long term survival of whitebark pine	- Slow - Facilities are not currently available in Canada, but capacity is under development at Kalamalka	Keane *et al.* 2012, Tomback *et al.* 2001, many others
Pruning	Accessible young whitebark pine stands	- Can potentially save trees from stem cankers, reducing the likelihood of mortality from rust while waiting for rust resistant seedlings to be produced - Good way to engage local community in hands on restoration	- May not be successful in saving the tree - May negatively impact the tree - May enable survival of genes that are less rust resistant - Likely difficult to operationalize at a large scale due to cost and access	Don Pigott
Forest clearing and/or thinning	Forests where a prescribed fire is inappropriate, but want	- Opening the canopy for natural regeneration ("nutcracker openings) or planting	- Expensive - Need collaboration with operators	Keane and Parsons 2010, Keane *et al.* 2012, Keane *et al.* 2007

	openings to increase regeneration	rust resistant seedlings - Can also be useful in combination with prescribed fire to manage fuels etc.	- May require ongoing management to ensure survival of seedlings to maturity (e.g. brushing)	
Seed collection area	Stand with high genetic value, rust resistance and accessibility (potential Critical Habitat under SARA)	- Reduce competition, increase access of whitebark pine to above and below ground resources, hopefully producing seed earlier and more frequently	- Potentially expensive - Need to have good access to site - Need to have trees that are worth investing in (rust resistance)	Don Pigott (set up a trial site in the east Kootenays)
Use Verbanone or carbaryl on trees identified as potentially rust resistant	Sites with potential (or known) rust resistant trees	- Reducing the probability of a rust-resistant candidate tree dying from MPB	- Logistically challenging - Potentially difficult to achieve success at a large scale due to potential extend of MPB outbreaks	GYCCWBPSC 2011
Manage Clark's nutcracker food sources	Adjacent to critical or high value whitebark stands	-need to maintain sufficient alternate food sources on landscape (as well as minimum whitebark threshold) to keep nutcrackers in sufficient numbers to be able to propagate whitebark.	- threshold levels not known here in north - Poor understanding of alternate food sources, other than Ponderosa pine and possibly Douglas fir	n/a

FIRE

The role of fire in whitebark pine ecosystems and the decline of whitebark pine under extensive fire suppression have been primarily studied in the U.S. (i.e. Keane *et al.* 1994, Keane and Arno 2001, Keane *et al.* 2012, Murray *et al.* 1997), but has also been studied in Canada (Moody 2006, Campbell and Antos 2003). The primary mechanism by which fire benefits the regeneration of whitebark pine is by opening up growing space and enabling establishment in this early successional stage. As a slow growing species, whitebark pine is often out-competed when growing in more moderate conditions. Canopy openings on both moderate and harsh sites provided by fire can enhance the ability of whitebark pine to regenerate, with seedlings able to capitalize on above and below ground resources. Fire suppression for the past several decades may be contributing to the decline of whitebark pine regeneration because such sites are no longer created and there is increased successional replacement. Fire can be used as a restoration tool to create openings suitable for caching and establishment of seedlings, increasing the frequency of young stands containing whitebark pine. Prescribed fire can be combined with silvicultural treatments (see Table 4) to produce suitable caching habitat for nutcrackers (Keane and Parsons 2010). It is also possible to restore sites burnt by wildfire. Wildfire can enable natural regeneration establishment, but these sites can also be used to plant rust resistant seedlings (see Figure 20 for an example of how overlaying wildfires can inform restoration sites). Before using prescribed burning as a restoration tool, it may be more beneficial to make use of subalpine sites recently (within the last 2-3 years) burnt for planting rust resistant seedlings.

Regardless of the fire origin, it is important to protect seed-producing trees and possibly other important alternate nutcracker food sources. Without a seed source, neither a prescribed or natural fire will be useful for the establishment of seedlings by nutcrackers or seed collection for planting. Natural establishment post-fire may occur anywhere from a few years after up to 40 years following the burn, depending on the severity of the site, i.e. soil stability (Arno and Hoff 1989) and episodic recruitment events (Tomback *et al.* 1993). Careful consideration of whitebark pine needs to be reflected in District fire management plans. Fire data used here was the historic fire database

Fire recommendations

While it is accepted that fire produces highly suitable regeneration habitat for whitebark pine, there should be careful consideration of the use of fire as a restoration tool. For instance, there may be adequate early seral habitat for whitebark pine across the landscape, but a lack of rust resistant seedlings to plant on these sites. The recommendation for fire in this report is to have a discussion about the potential use of prescribed burning (of different intensities) with a wider group of experts, placed within a broad landscape disturbance context for this and other species that would be affected by prescribed burning. See Keane and Parsons 2010 for management guide to restoration using fire including severity and fuels management.

Industrial activities

The impact of industrial development as described above should be mitigated as much as possible given the extent of the decline by other threats (WPBR, MPB, climate change etc.). Engagement with industry to protect whitebark pine could be encouraged with policies on industrial cooperation, but also by educating field workers on identification and techniques for minimizing damage to whitebark pine. In addition, it is possible to take advantage of access created by industrial activities such as forestry or mining to collect seed, screen and plant improved rust resistant whitebark pine seedlings (see Murray and Krakowski 2013 for recommendations on available actions to protect and improve whitebark pine conservation with the forestry industry in BC, Moody and Clason 2013 for collaboration with mining industry).

Industrial Recommendations:

Table 5 – Recommended actions for improved whitebark pine resources and as well as potential policy tools for mitigating industrial impacts

Action	Approach
Revise BEC land management handbooks	Update the field guides to indicate the presence of whitebark pine, at minimum at the zone/subzone level. For example, this could be simply a single page (or less) at the beginning of the appropriate guides
Revise BC "Tree species selection tool"	Discuss with regional ecologists. Currently, whitebark pine is identified as suitable on ESSFmk 02/03 (Pr.Rupert), ESSFwc3 02(Cariboo), and ESSFwk1 02(Pr. George & Cariboo) in the tree species selection tool. Review and update to more accurately represent where whitebark pine could be planted as a suitable species (see: http://www.for.gov.bc.ca/hfp/silviculture/TSS/tss.htm)
Evaluate policy options for minimizing and mitigating industrial impacts	What are the policies surrounding protection of whitebark pine on provincial land? What are the mechanisms in place that can be used to address current policy barriers (e.g. establishing wildlife habitat areas)? What are the mechanisms for engaging with industry (forest licensees, mining companies) that would aid moving past any current policy barriers

Climate change

Climate change adaptation recommendations:

Given that areas not currently occupied by whitebark pine within the Omineca are potentially currently climatically suitable, and are likely to become more so over time, assisted migration may be appropriate for whitebark pine in the Omineca region. Threats related to climate change, such as competitive exclusion and changing disturbance regimes (e.g. mountain pine beetle) should be considered when undertaking restoration. For instance, whitebark pine could be planted at higher elevations in anticipation of the upward movement of treeline, planted after fire (prescribed or wild), or planted at lower elevations to reach cone-bearing age sooner, however management of those plantings may be required (e.g. thinning/brushing). Continued research on the effects of climate change on whitebark pine persistence in the Omineca is required in order to anticipate vulnerabilities not previously identified. These vulnerabilities should be reflected in prioritization of stands for seed collection and restoration. (See McLane and Aitken 2012 for discussion on assisted migration and Keane *et al.* 2012).

Knowledge Gaps

While many actions should be undertaken immediately to improve the likelihood of persistence of whitebark pine across the Omineca region, supporting research in whitebark pine ecosystems will continue to inform management and improve our understanding of the decline and survival of the species.

Research Recommendations:

Table 6 – Areas of active or recommended research to improve management of whitebark pine in the Omineca region

Clark's nutcrackers	Population estimates, feeding behaviour (on whitebark pine and alternate food sources), caching behaviour, breeding success etc. Understanding how nutcrackers are surviving and using whitebark pine at the northern edge of its range will be important for managing stands to maintain future natural dispersal processes
Mapping	See Table 7 for recommendations by district and above for alternative approaches to future mapping
Health	How healthy is whitebark pine in this region? Are there any strong predictors of vulnerability to blister rust? In order to determine where to collect seed and where to

	restore, better information on current levels of rust is required in order to make informed prioritization decisions.
Ecosystem Services	How important is whitebark pine for bears in this region? Does whitebark pine increase habitat quality for grizzly bears?
Seed production	How reliable is seed production? How often does a masting event occur in the Omineca? What are the seed threshold levels to mitigate losses to seed predation and maintaining nutcracker populations?
Fire	Investigate the role fire suppression may have played in the decline of whitebark pine in the Omineca (e.g. what is the historical range of variability in fire regimes for the Omineca region and how significant is fire suppression as a threat to whitebark pine, e.g. Larson *et al.* 2009))
Climate change	How will climate change directly and indirectly affect persistence of whitebark pine in the Omineca region
Sensitive ecosystems	What is the relationship between whitebark and soils in the Omineca? Can a soil layer (e.g. ultramafic) be used as a predictor of occurrence and should these sites be managed differently?
Decision support tools	With increasing information and availability of appropriate data layers, formal decision support and prioritization tools should be developed

Monitoring Recommendations:

Table 7 – Monitoring needs to improve management of whitebark pine in the Omineca region

Action	Approach

Establish health monitoring installations	Higher priority in areas that are protected from industrial activity (e.g. BC Parks) and are accessible. Locations should be stratified across variation in climate and mountain ranges (see Table 9 for suggested monitoring sites by district; Dr. Michael Murray MFLNRO pathologist Nelson for details on installations)
Clark’s nutcracker population trends	Monitor population dynamics and caching behaviour of Clark’s nutcrackers in northern whitebark pine ecosystems

3. Restoration Prioritization for the Omineca

The final section of this report summarizes current available data on whitebark pine in the Omineca region, discussing options for future inventory, monitoring and preliminary recommendations for restoration prioritization. Tables 8-10 refer to the maps that follow (Figures 17 – 44).

Table 8 – Interpretation of current whitebark pine mapping resources, and priorities for future surveys for whitebark pine locations across the five districts within the Omineca region

District	Predictive models (topography, topography & climate)	VRI	Potential occurrence in BEC subzones	Population confirmation priorities	Maps
Vanderhoof	Both predictive models indicate a low probability (max ~30% climate + topography model; ~60% topography model) of occurrence in this region. However, both identify highest probability in this district on Mt. Davidson (where there is	There are no VRI polygons indicating WBP anywhere in this district, however there is at least one known population (on Mt. Davidson) Anecdotal reports of WBP on Fawnie range – needs confirmation	The following BEC zones have been identified as potentially containing whitebark pine in this district: BAFA, SBSmc2, ESSFmv, ESSFxv, ESSFmvp, MSxv	All three models indicate that Polygon 1 has the highest probability of WBP in this district. This area is top priority for ground or aerial surveys. Little is known of WBP in this region, and with confirmed populations on Mt. Davidson, as well as the greater proximity at the southern edge of the Vanderhoof District to larger populations of WBP	Figure 19

	known WBP) and nearby Fawnies			further south, this area warrants investigation. The potential occurrence in Entiako Park should be determined, whether through consultation with those that know the area, and/or by ground/aerial surveys. Potential collaboration on surveys with Blackwater mine	
Fort St. James	Both predictive models indicate high probability (however the climate & topography model more than the topography model alone) of occurrence in the northern portion of the region. There are no known occurrences north of Blanchet	The new VRI changed many of the polygons from whitebark pine to subalpine fir (in this region, but maybe others as well?). Many of the polygons shown here in the Fort St. James area are from the forest inventory (fc1) preceding the VRI. UPDATE: the VRI polygons in	The potentially suitable BEC zones also predict whitebark pine occurrence in the far north of this district. The subzones identified as potentially suitable are: BAFA, ESSFmv3, ESSFmvp, ESSFmc, ESSFmcp	Aerial surveys should be targeted to the ranges directly north and east of the current known occurrences on Mt. Sidney Williams, Blanchet Park and the Mitchell range within Polygon 1. Ground surveys should confirm locations and assess health in areas not previously surveyed on the ground (Mitchells, E-side Blanchet)	Figure 24

	Park/Mitchell Range	the Witch drainage (east of current known occurrence) were flown by A. Tait and confirmed that there is no whitebark pine there (subalpine fir)			
Mackenzie	Both predictive models indicate high probability of occurrence in this district, and there is probability in the far north, beyond what is the current understanding of the northern edge of the range	The only indication of occurrence in this district is in several VRI polygons just north of the Peace arm of the Williston Lake Reservoir. UPDATE: J. Vinnedge and A. Clason surveyed these polygons by air, and no whitebark pine	The potentially suitable BEC zones also predict whitebark pine occurrence in the far north of this district. The subzones identified as potentially suitable are BAFA, ESSFmc, ESSFmcp, ESSFmv3, ESSFmv4, ESSFmvp, ESSFwc3, ESSFwcp, ESSFwk2, BWBSwk2	It may be worthwhile to survey by air the mountainous areas south of Mackenzie, but this may be a lower priority than surveys in the Prince George District NW of current known distribution	Figure 30, Figure 31

		was found			
Prince George	Both predictive models indicate high probability of occurrence in the Kakwa Provincial Park area, decreasing towards the west.	The VRI indicates whitebark pine occurrence in and south of Kakwa park, and again around the southern edge of Waipiti Provincial Park, towards Monkman Provincial Park with little in between Kakwa and these areas. None of the VRI polygons in the Prince George District are confirmed by ground plots (BEC plots, A.Clason, S.Zeglen), UPDATE: photograph and UTM confirmation	The subzones identified as potentially suitable habitat are ESSFwk1, ESSFwc3, ESSFwcp, ESSFwk2, ESSFmvp, ESSFmm1, ESSFmmp, ESSFmv2, ESSFmv3, ESSFmv1, BAFA, IMA	The area starting from Kakwa Provincial Park following the Rockies northwest, ending around the southern edge of Monkman and Waipiti should be flown to determine whether there are any populations in that area. These would be the northern-most confirmed populations in the Rockies if found. If there are populations confirmed, ground surveys should verify location and assess health (Polygon 1, Figure 35) South of Kakwa in both the Rockies and Cariboos (Polygon 2, Figure 35) should be surveyed by air. There are a few VRI polygons and lower probability of occurrence	Figure 35, Figure 36, Figure 37

		in Mt Dezaiko area		based on the predictive models (climate and topography) in these areas	
Robson Valley	Both models (climate & topography, topography alone) predict high probability (up to 99%) of occurrence in this district within the subalpine and alpine areas. This is unsurprising given the models were built using VRI data, which has far greater coverage (presumably accurately representing greater distribution of WBP) in the Robson Valley	The VRI coverage here is extensive, however ground truthing and particularly on the south-side of the Robson valley has far fewer data points. Given how widely distributed the VRI predicts WBP in this district, it warrants assessment to determine accuracy	Many areas of the Robson Valley likely have suitable environmental conditions as represented by the large number of potentially suitable subzone habitats: ESSFmm1, ESSFmm2, ESSFmmp, ESSFwc2, ESSFwc3, ESSFwcp, ESSFwk1, ESSFwk2, IMA, BAFA	Focus on the areas east of McBride, and potentially greater ground surveys on the Cariboo mountain side of the Robson valley.	Figure 41

Table 9 – Summary of rust infection rates (average across plots and min-max plot level infection), as well as prioritization for future rust surveys and monitoring within each of the Omineca Districts

District	Rust data available?	Avg % infection (min-max)	Priority area for rust monitoring	Maps
Vanderhoof	Yes	15% (0- 36%)	If populations of WBP occur in the Entiako area, monitoring transects should be prioritized in this area. Partnership with Blackwater mine on Mt. Davidson may lead to a rust monitoring transect there as well	Figure 19, Figure 20
Fort St. James	Yes	31% (1-71%)	Mt. Blanchet Provincial Park as one of the northern-most populations of whitebark pine should prioritize assessing extent and health of the population in the park. A rust monitoring transect could be established in this park as well. Assessment of rust in the Mitchell range is also recommended	Figure 24, Figure 25, Figure 26
Mackenzie	No	n/a	No current confirmed populations in Mackenzie.	Figure 30, Figure 31
Prince George	No	n/a	If populations are confirmed in the PG area, rust surveys and monitoring will be based on this. It is very likely that there is whitebark pine in Kakwa park, so this should be a priority area for establishing a monitoring site	Figure 35, Figure 36, Figure 37
Robson valley	Yes	29% (0-62%)	There are 4 monitoring transects already in the Robson valley (2 on McBride peak and 2 on Mt. McKirdy), however greater coverage of health across this region, including new monitoring installations on the Cariboo mountain side of the Robson Valley is recommended	Figure 41, Figure 42, Figure 43

Table 10 – Summary of seed collection and restoration recommendations across the Omineca Districts based on current available data

District	Current seed collection	Current restoration	Priority for collection	Priority for restoration	Maps
Vanderhoof	No (but one collection planned on Mt. Davidson)	No (but planned for Mt. Davidson)	- None at present - However, if populations occur in the Fawnies, or in Entiako Park, collections could be prioritized for those areas	- None at present - Depending on whether there are new occurrences confirmed, priorities will be determined	Figure 20
Fort St. James	Yes – Mt. Sidney Williams, 2007	No	- Screen seeds already in storage from Mt. Sidney Williams from trees identified in 2012 as candidates (Table 11) - Collect from Blanchet Park for future restoration in the park - collect from Mitchell range for genetic conservation and future restoration in the	- There should be discussion about possible restoration on Mt. Sidney Williams, or in areas further north outside the immediate impact of mining activity (e.g. Forfar creek, Gluskie drainage) given development in the area and high rust infection	Figure 25, Figure 26

			area - Assess and prioritise upper Forfar creek, which appears to still have a sizeable population.	rates	
Mackenzie	No	No	-none	- none unless through assisted migration	n/a
Prince George	No	No	- Potentially in Kakwa Park, but priorities for collection would be best made with better health data	- Not enough information for this district to make recommendations	n/a
Robson valley	No	No (but planned restoration spring 2013 on McBride peak)	- McBride peak. Not a very healthy population, so possible to find candidate trees for screening - Potentially McKirdy peak	- McBride peak, given the access and declining health - other locations to be determined	Figure 42, Figure 43

VANDERHOOF MAPS

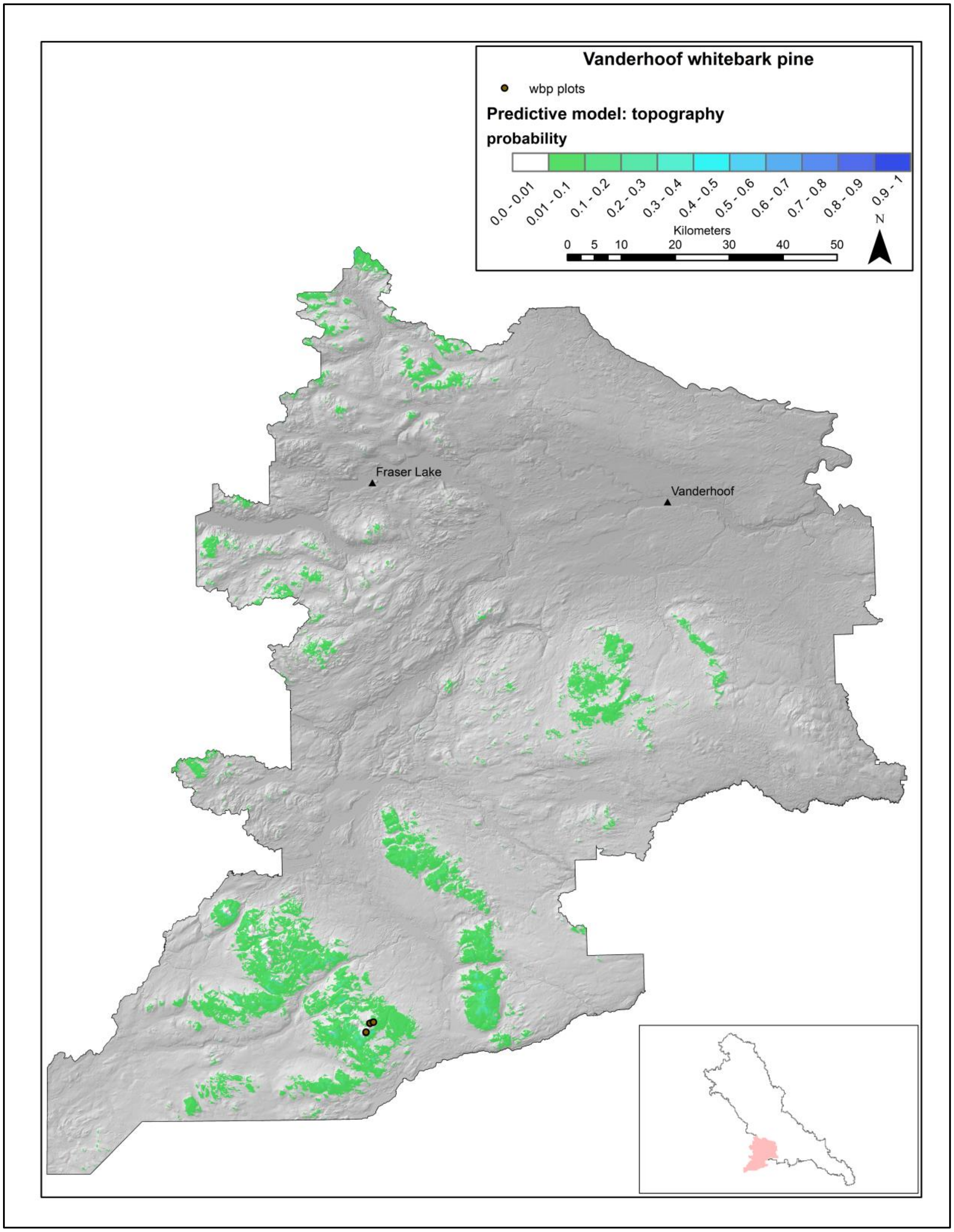

Figure 16 - Potential whitebark pine habitat in the Vanderhoof District based on topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography.

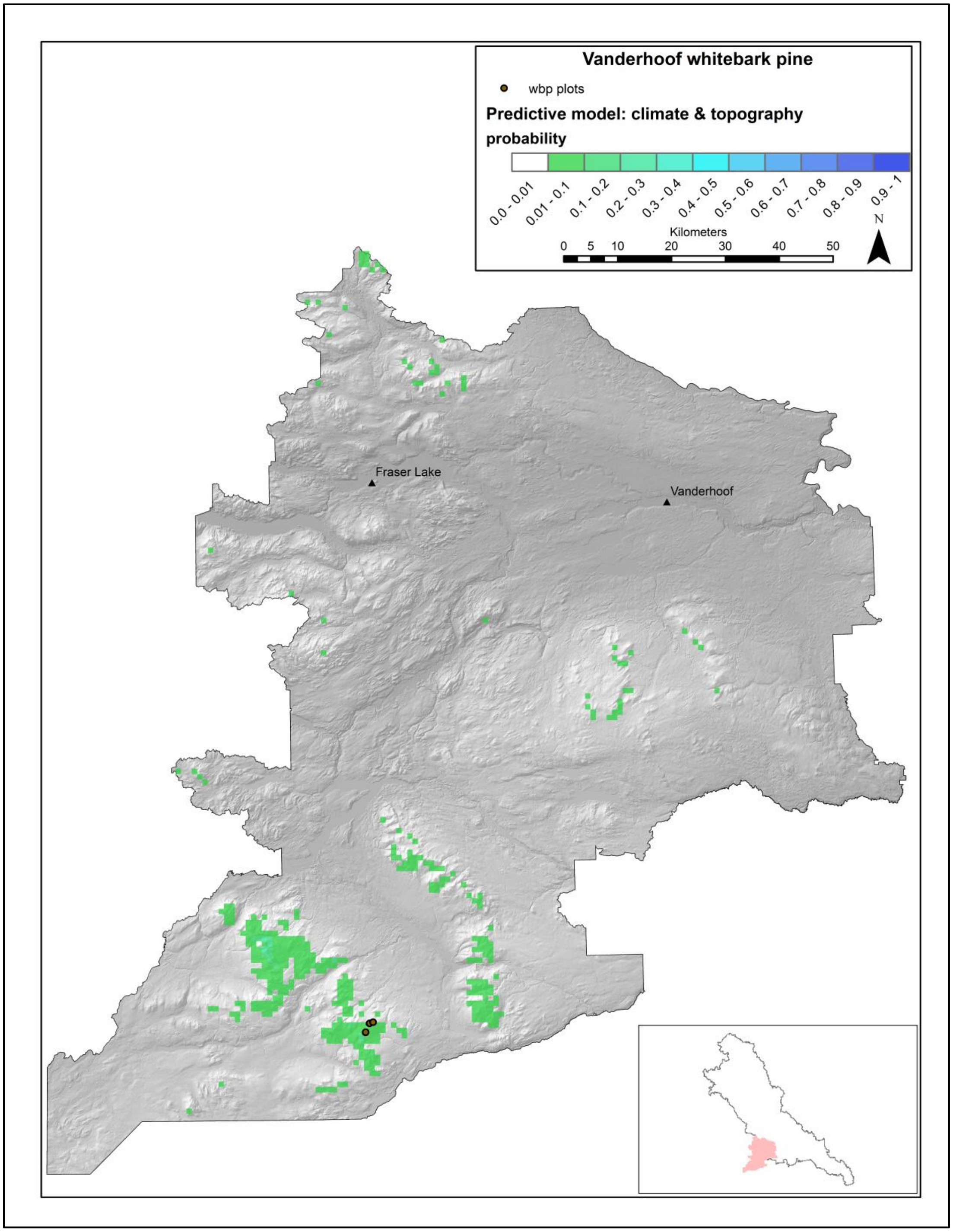

Figure 17 – Potential whitebark pine habitat in the Vanderhoof District based on climatic and topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography and climate.

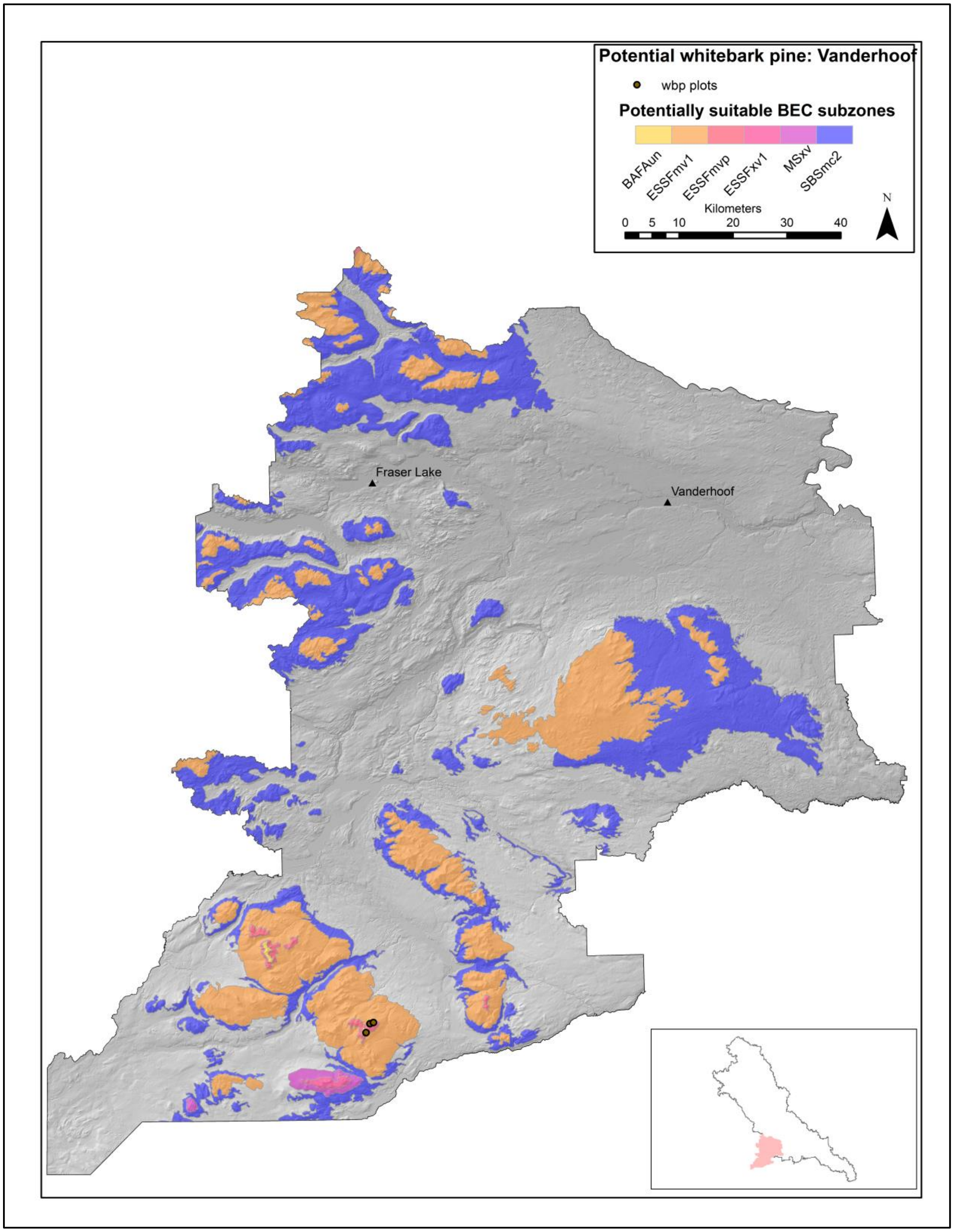

Figure 18 –Potentially suitable BEC subszones. Areas coloured other then grey are potentially suitable based on BEC subzones for whitebark pine in the Vanderhoof District.

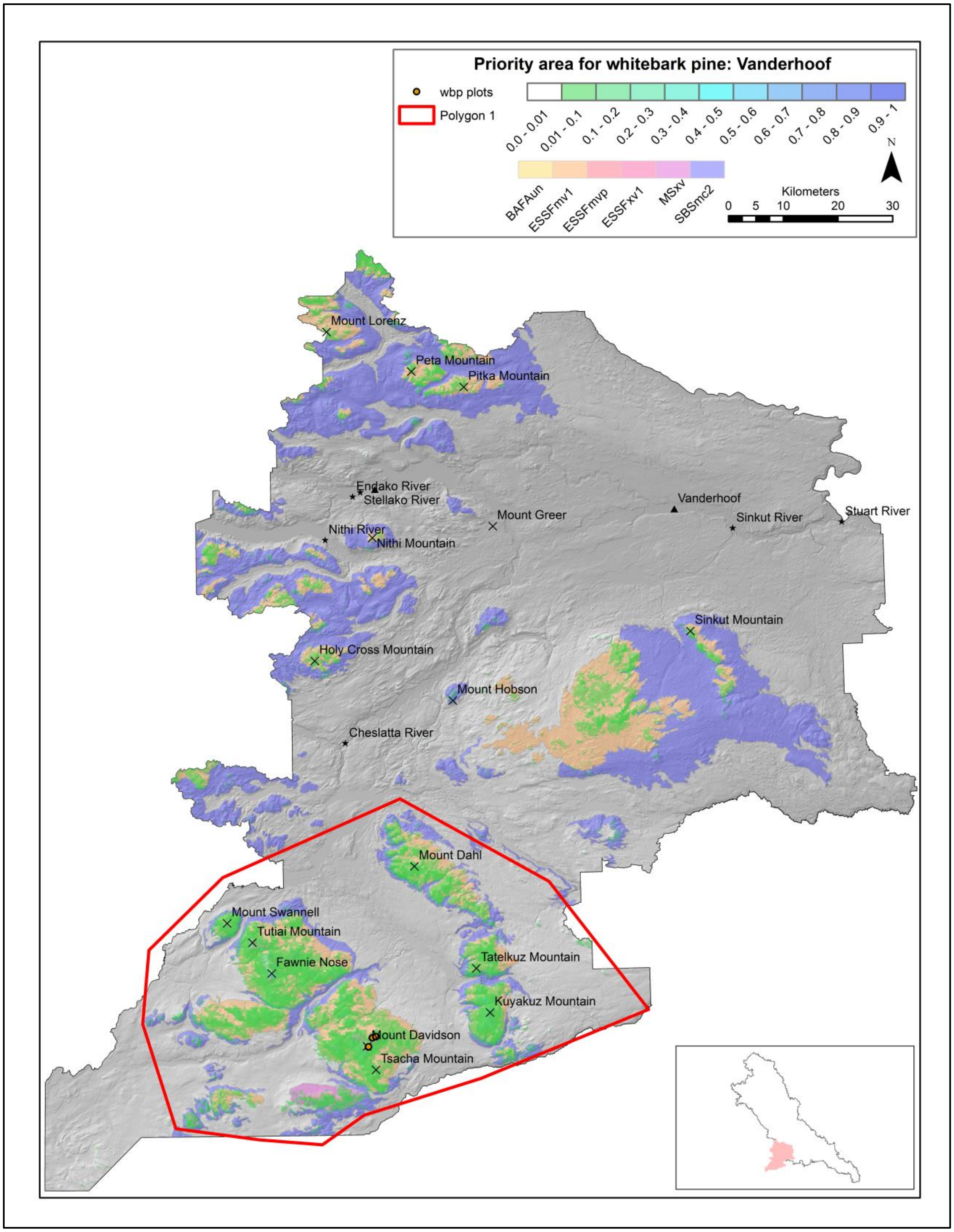

Figure 19 – Red polygon indicates the area of interest to confirm populations, survey rust and establish long term rust monitoring installation in the Vanderhoof District.

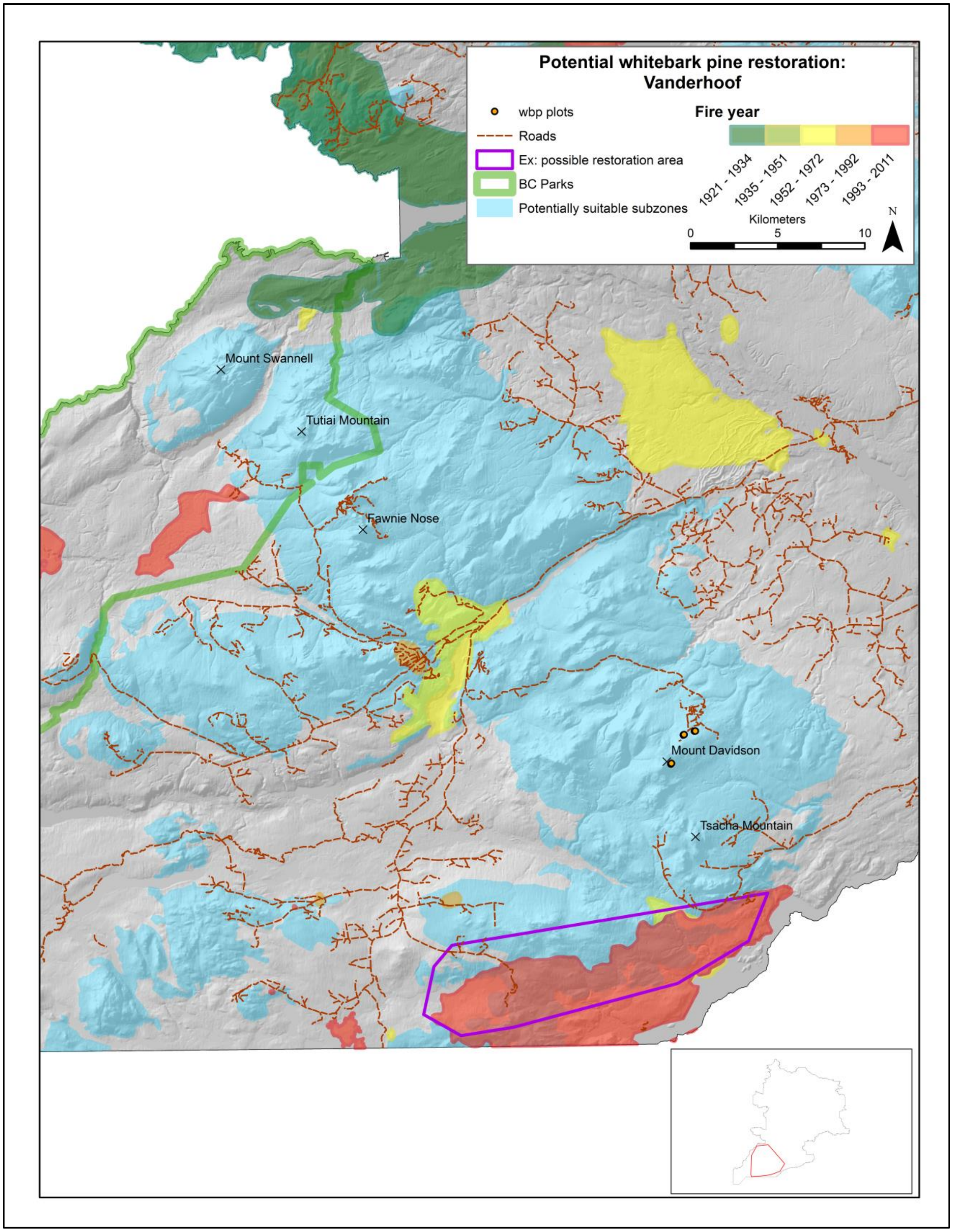

Figure 20 – Example of area selected (purple polygon) for restoration based on suitable habitat, recent disturbance (fire in 2010), proximity to known WBP and potential road access.

FORT ST. JAMES MAPS

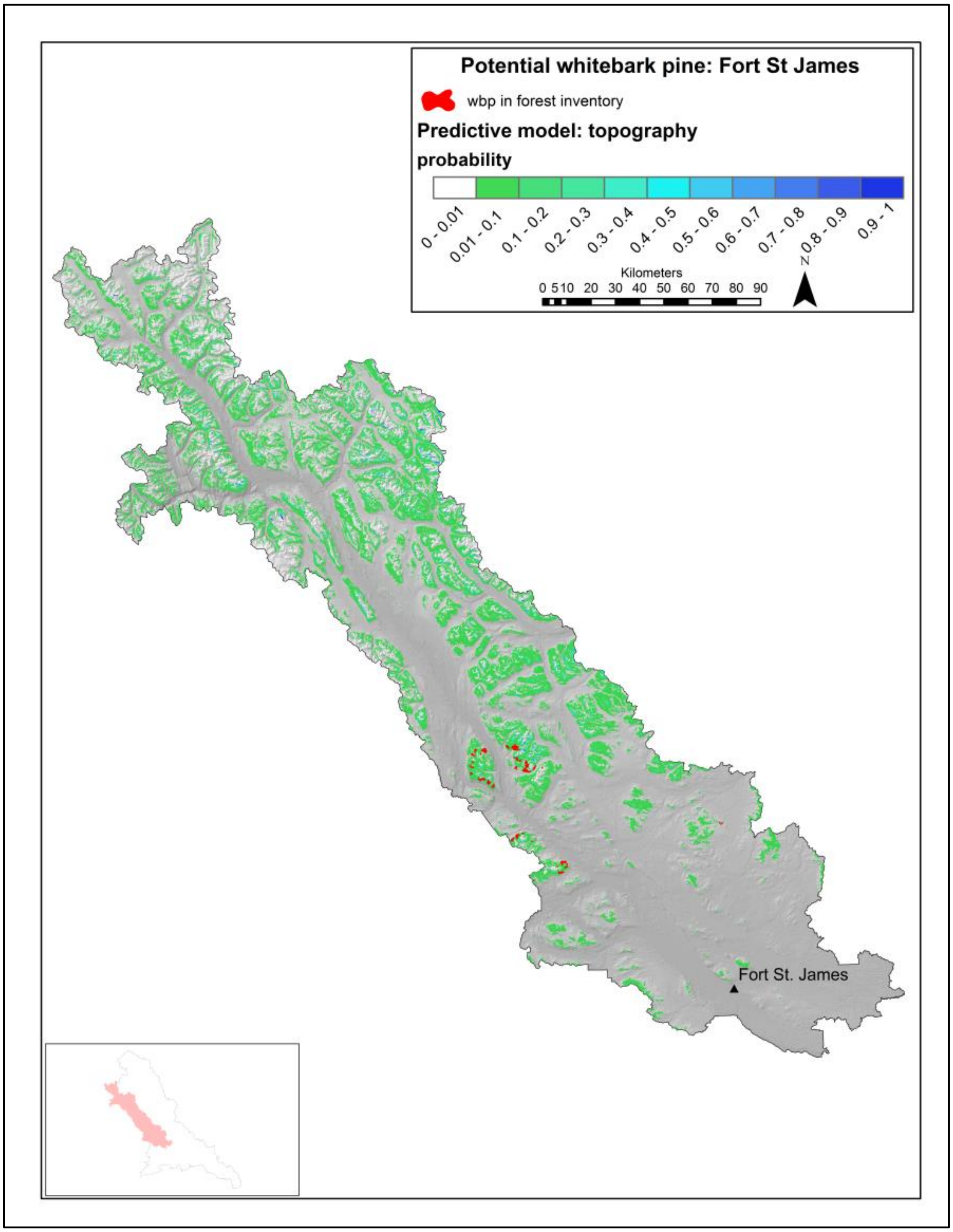

Figure 21 - Potential whitebark pine habitat in the Fort St. James District based on topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography.

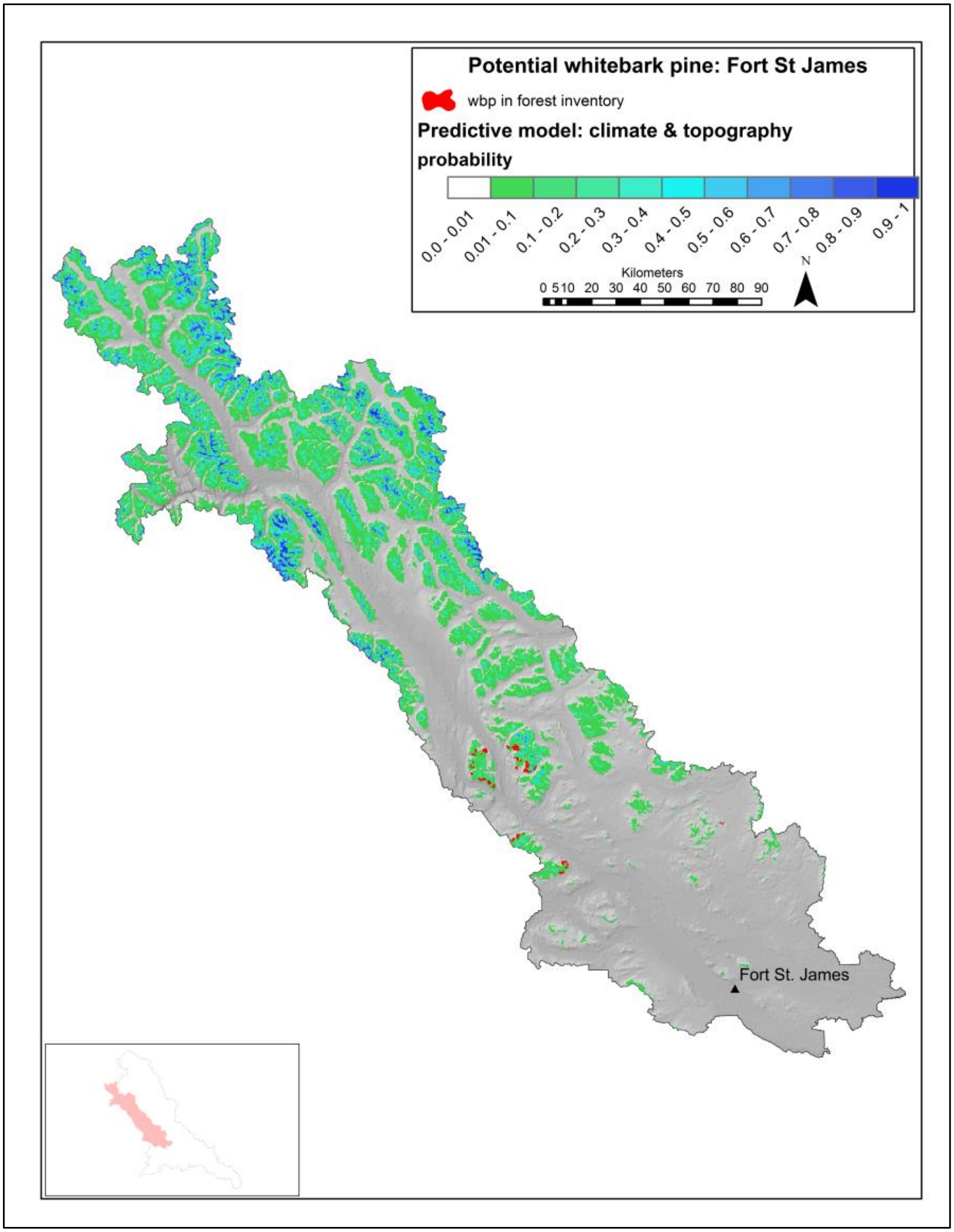

Figure 22 - Potential whitebark pine habitat in the Fort St. James District based on climatic and topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography and climate.

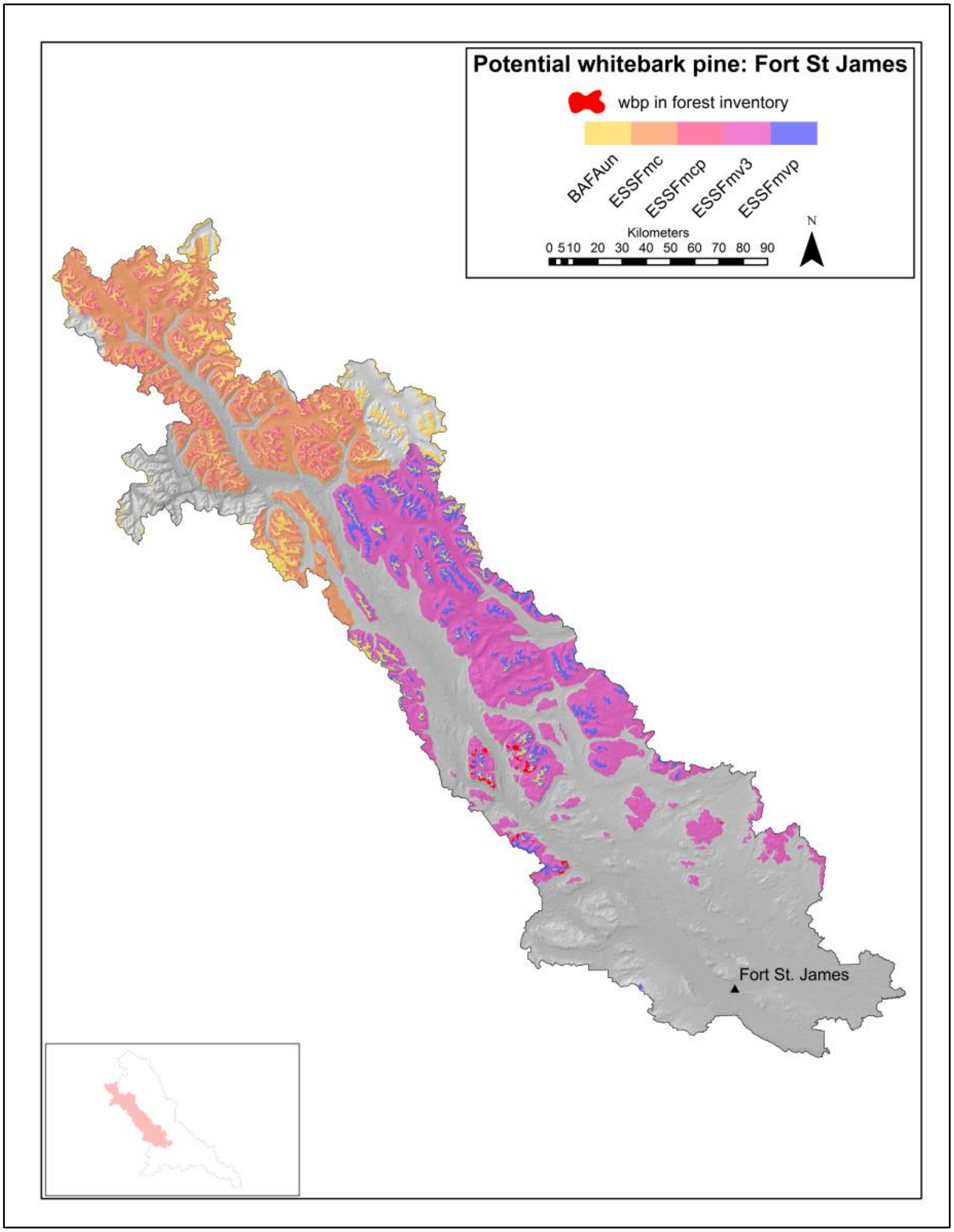

Figure 23 - Potentially suitable BEC subszones. Area coloured other then grey are potentially suitable based on BEC subzones for whitebark pine in the Fort St. James District.

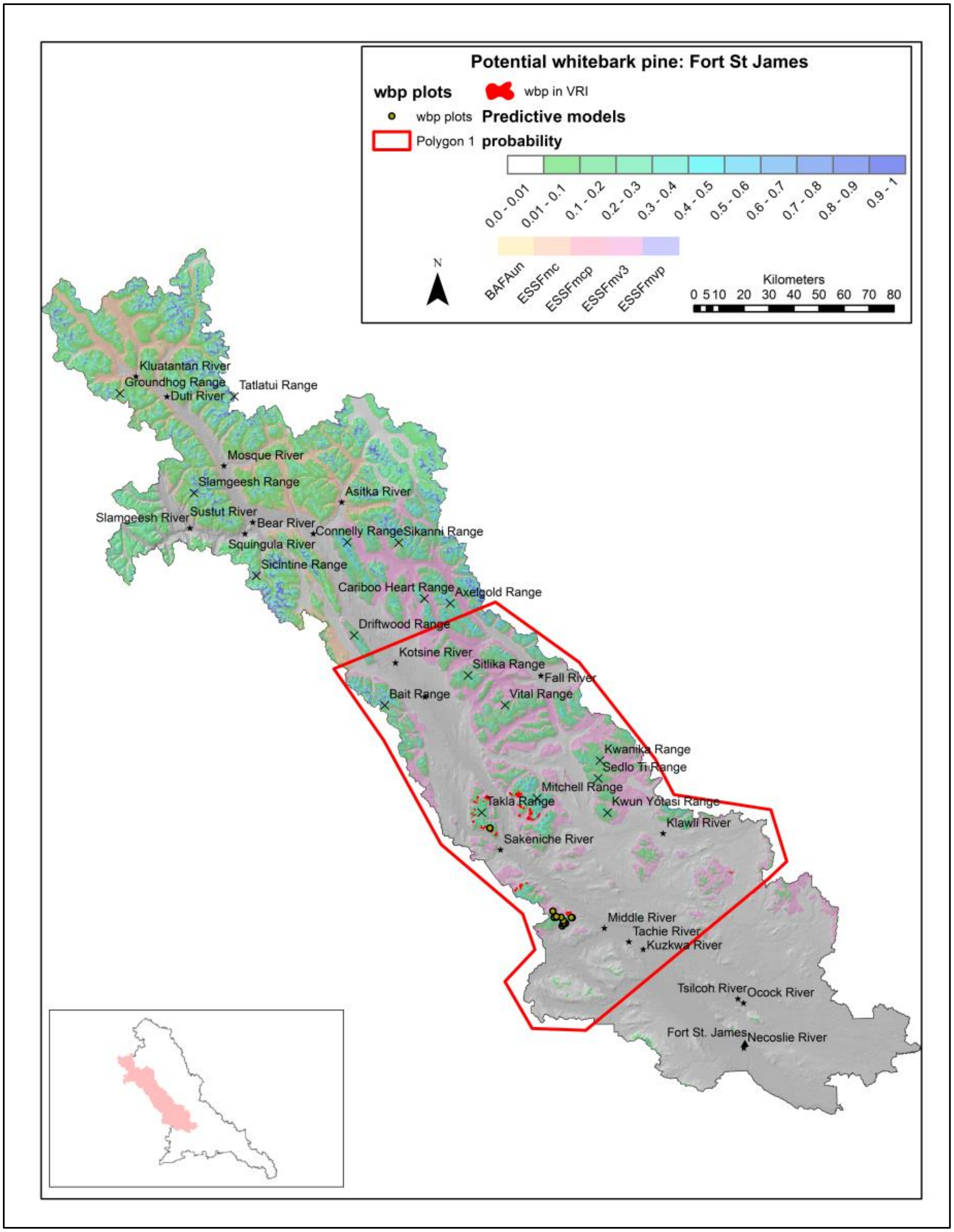

Figure 24 – Polygon 1 (red) indicates the area of interest for surveying for new populations (east and north of confirmed populations) and focusing rust surveys and long-term rust monitoring installations (Blanchet, Mitchells, Sidney Williams) in the Fort St. James District.

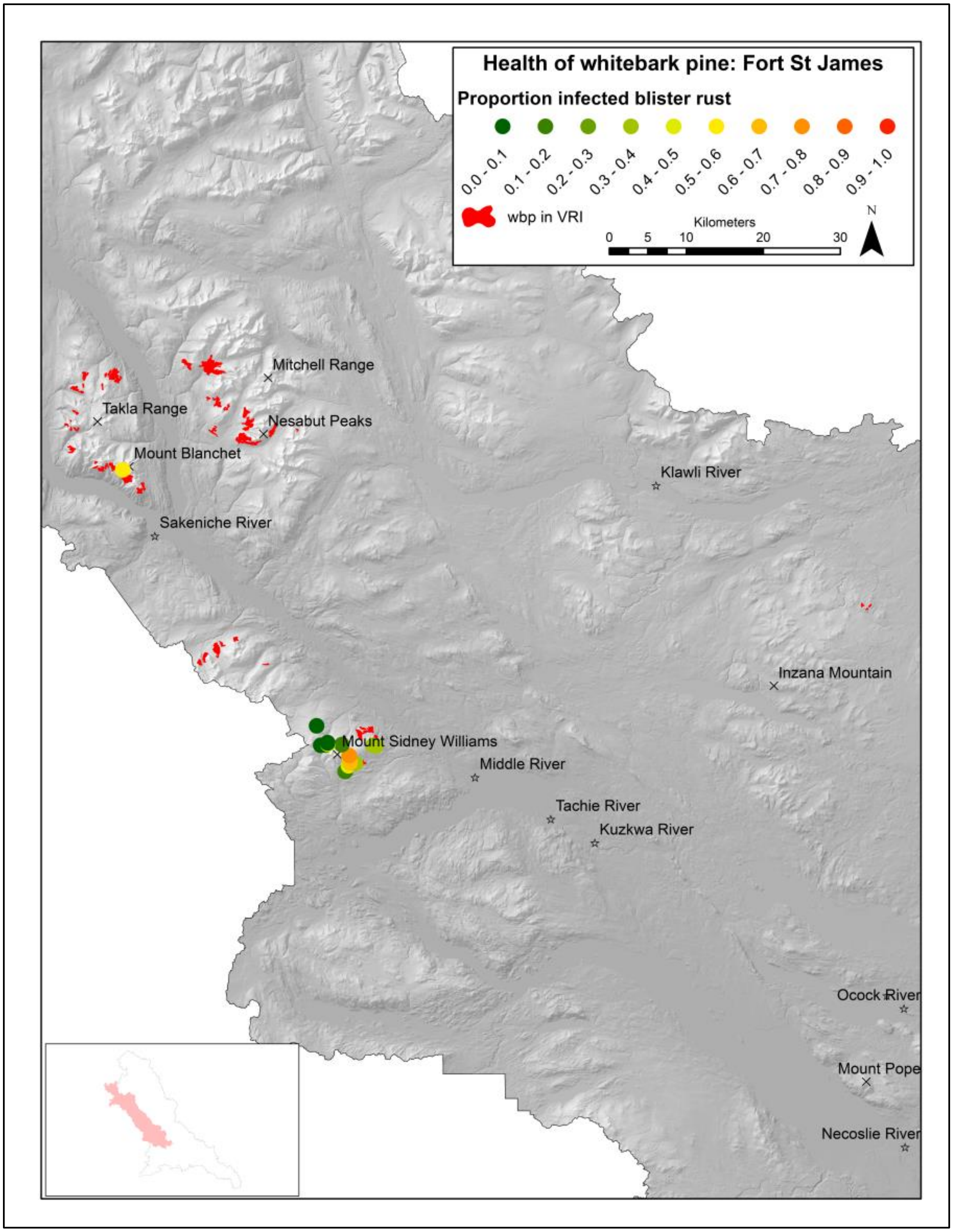

Figure 25 – Health of whitebark pine in the northern-most confirmed stands in Canada (Mt. Blanchet, Mt. Sidney Williams) also showing forest cover polygons that contain whitebark pine.

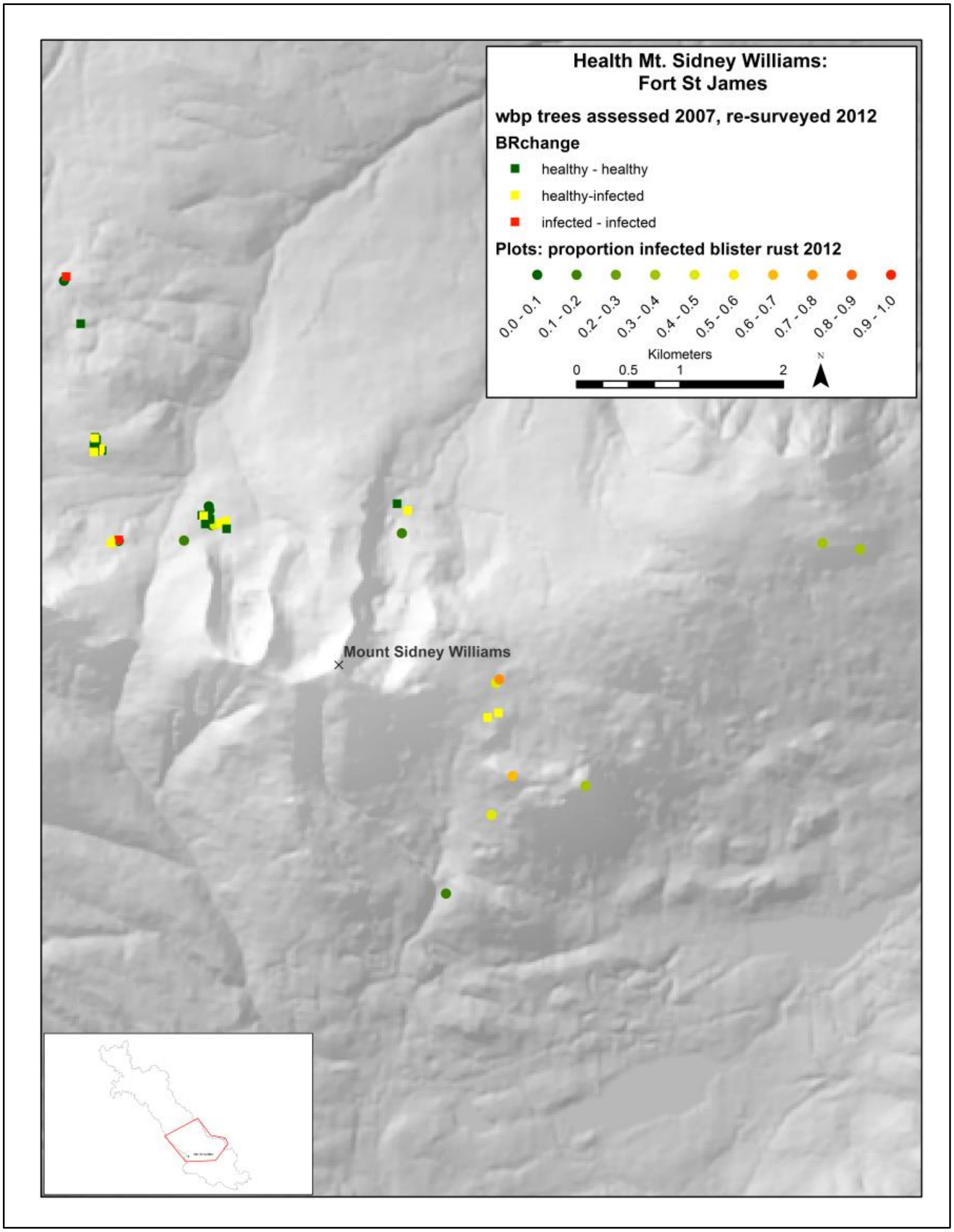

Figure 26 – Blister rust infection rates on Mt. Sidney Williams. Square points indicate individual trees that were assessed in 2007 and re-assessed in 2012, circles indicate infection rates on transects (~50m long). See also Table 11.

MACKENZIE MAPS

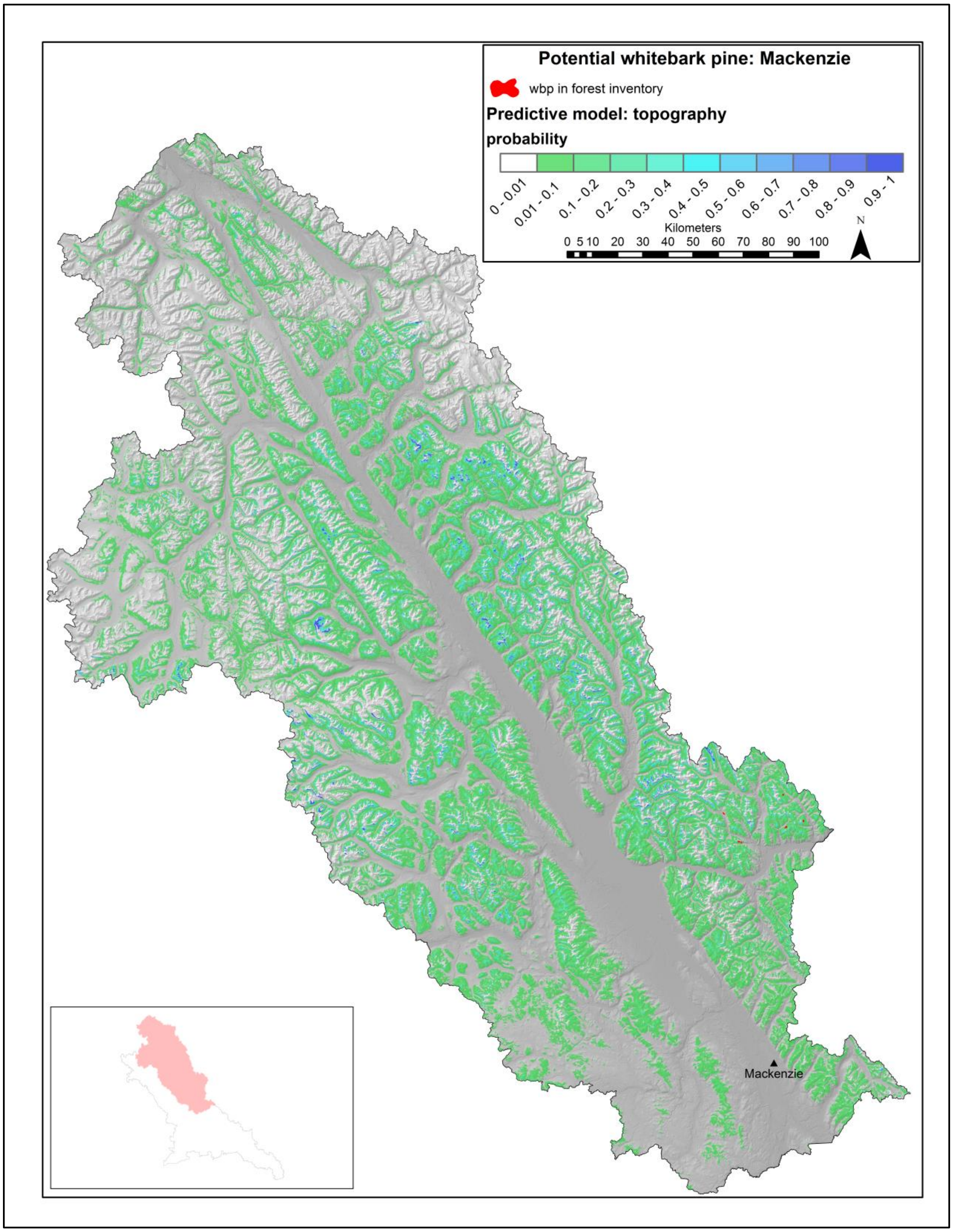

Figure 27 - Potential whitebark pine habitat in the Mackenzie District based on topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography.

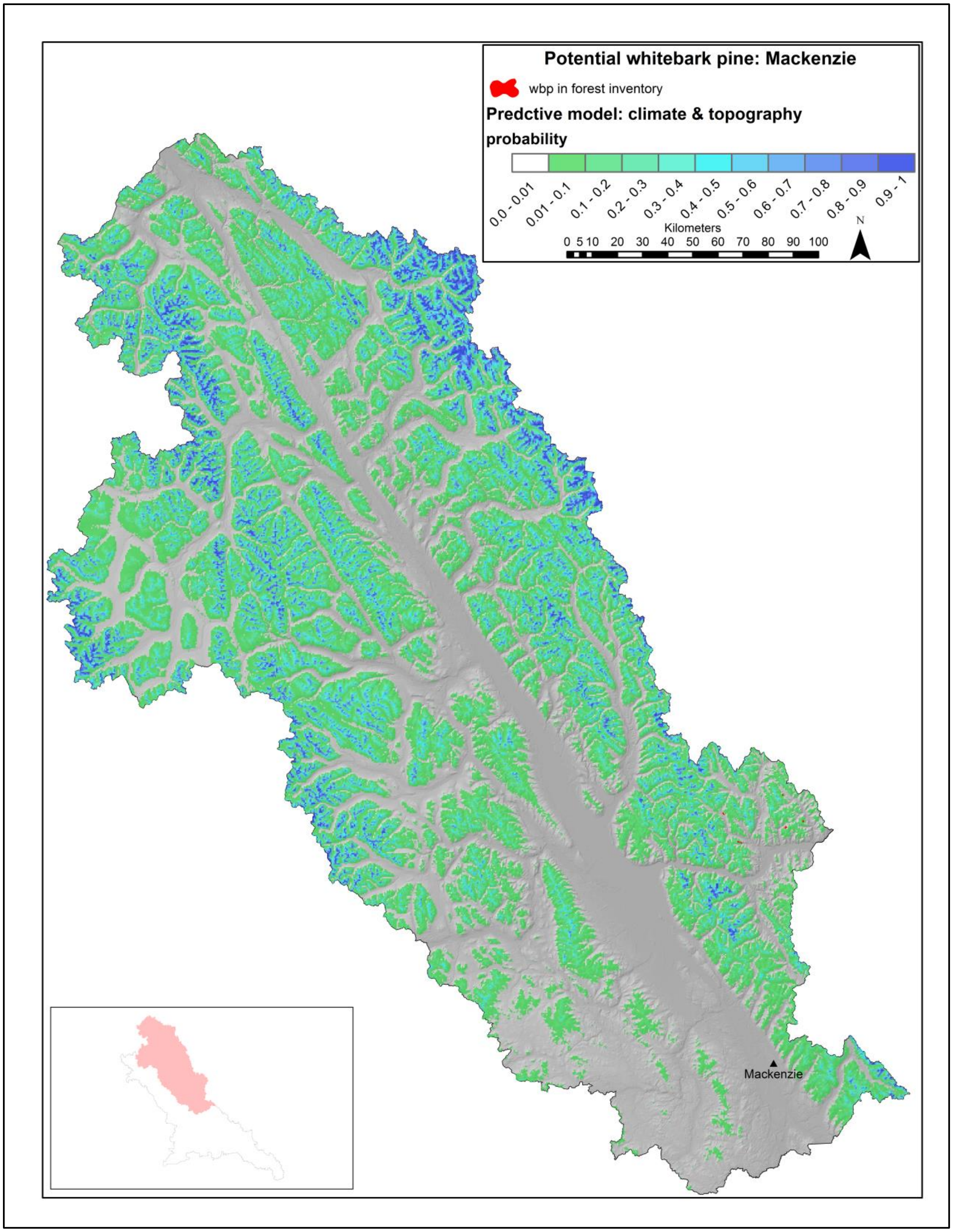

Figure 28 - Potential whitebark pine habitat in the Mackenzie District based on climatic and topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography and climate.

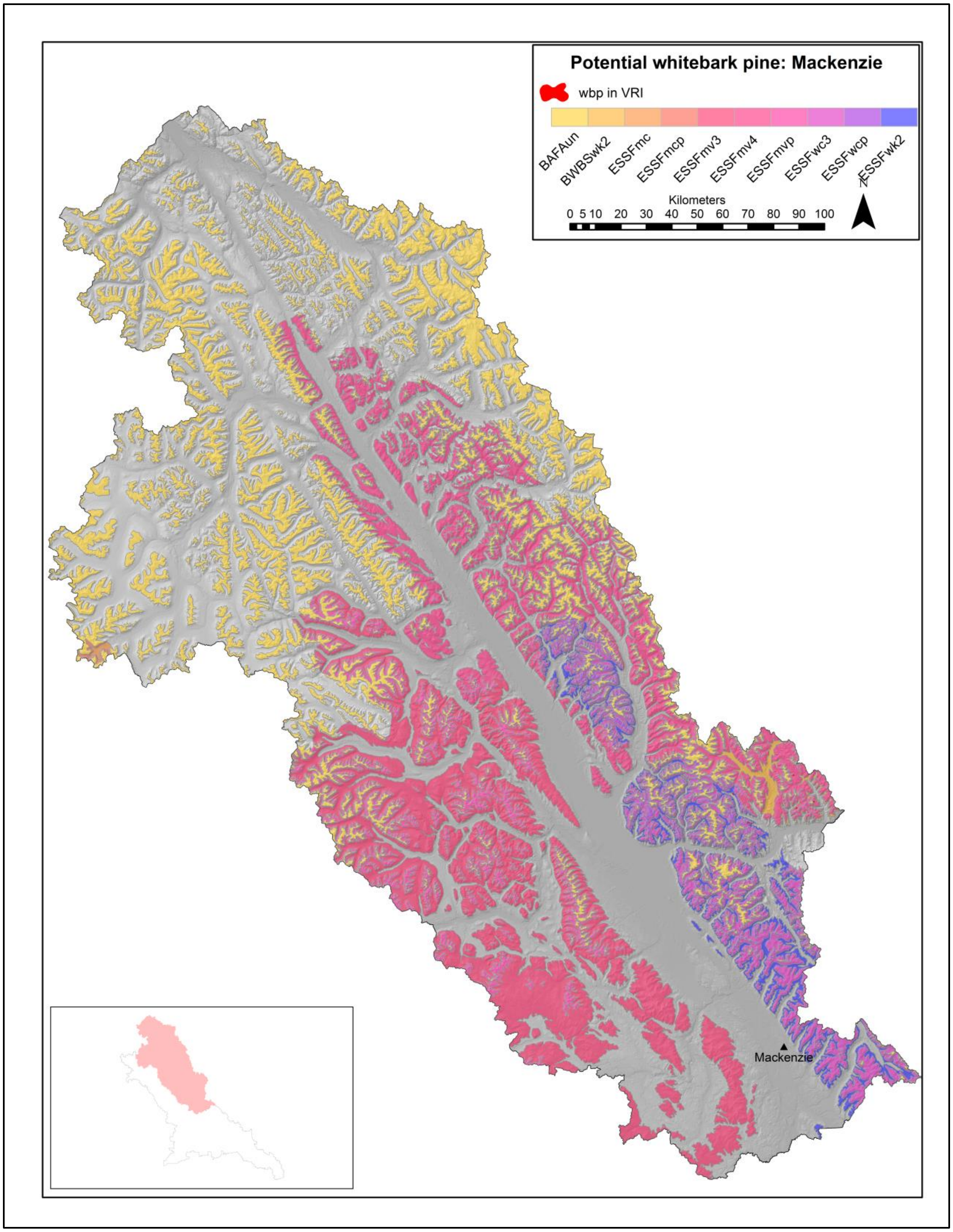

Figure 29 – Potentially suitable BEC subzones. Areas coloured other then grey are potentially suitable based on BEC subzones for whitebark pine in the Mackenzie District.

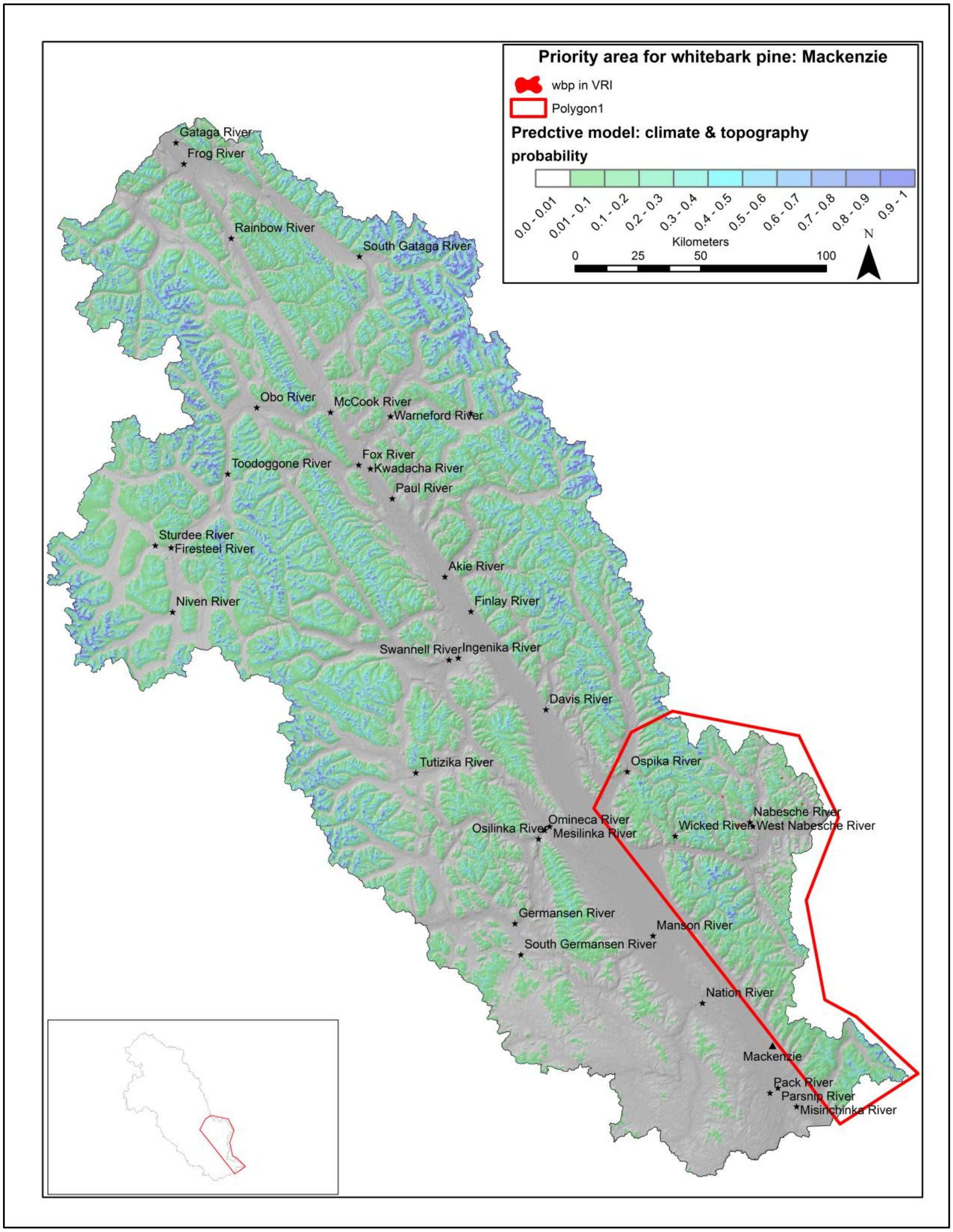

Figure 30 – Polygon 1 (red) indicates the area of interest for surveying for new populations in the Mackenzie District.

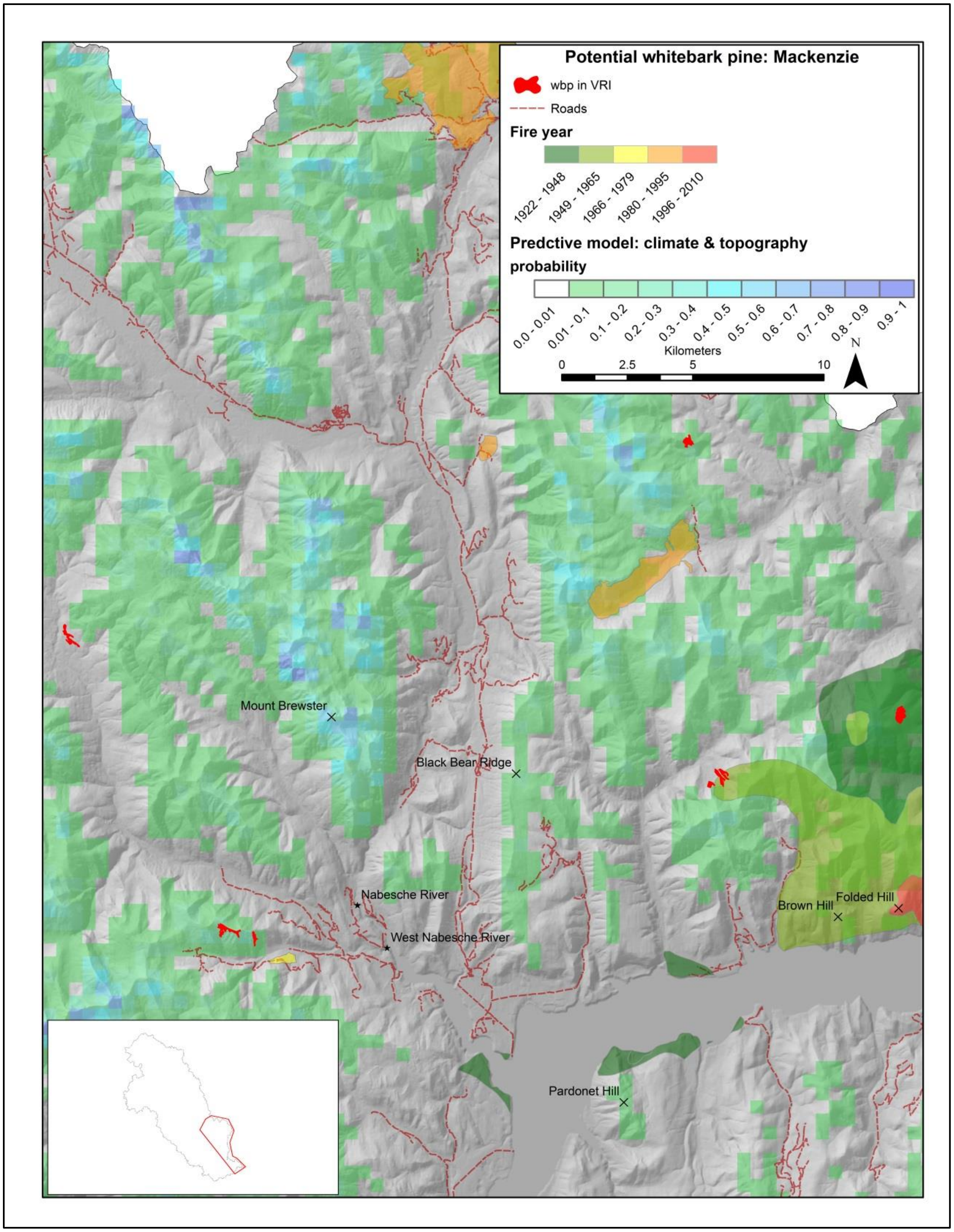

Figure 31 – Northern-most potential whitebark pine stands in the Mackenzie District with fire and road access overlaid. UPDATE: March 28, 2013, polygons surveyed by air, and confirmed that they contained lodgepole pine, not whitebark pine.

PRINCE GEORGE MAPS

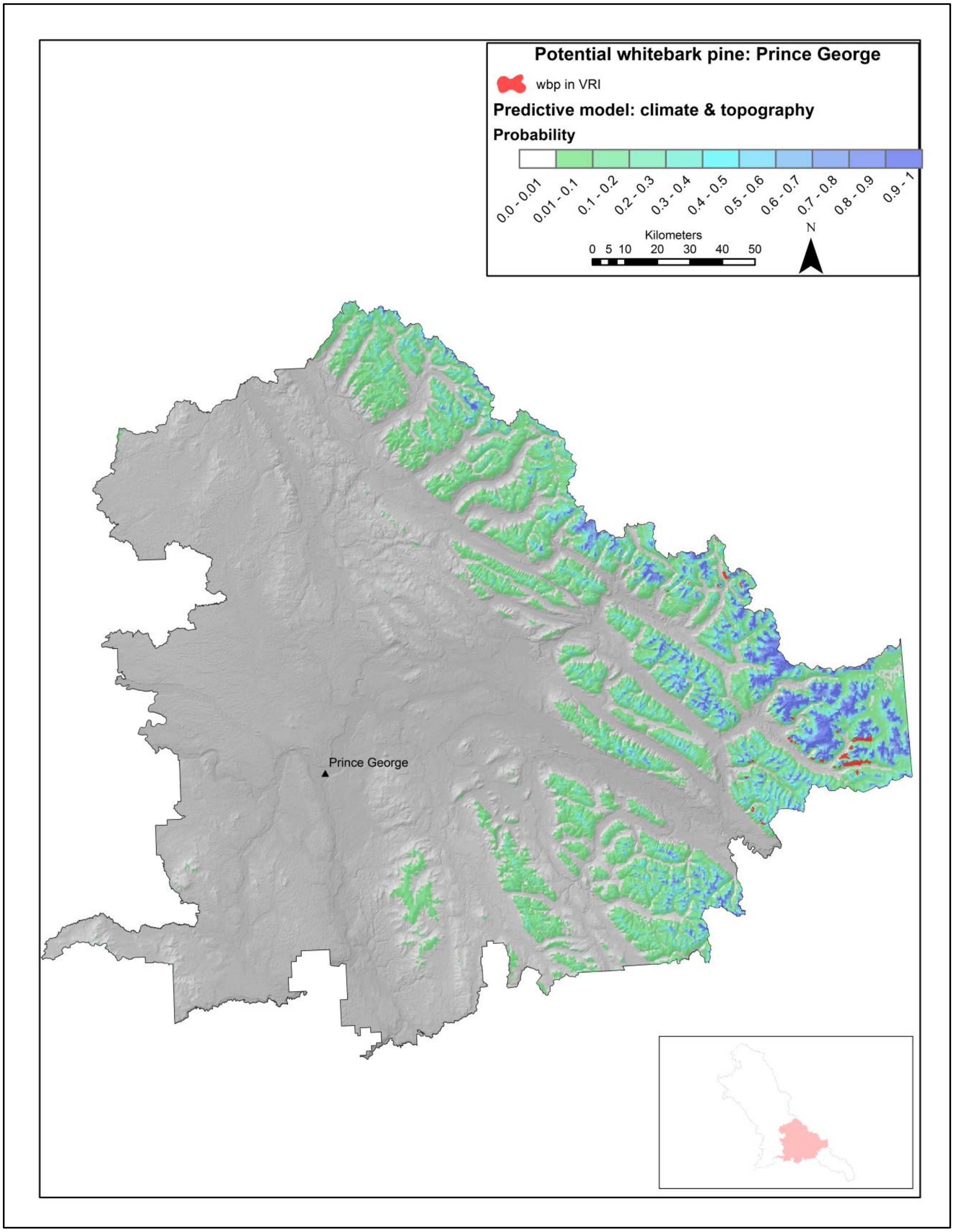

Figure 32 - Potential whitebark pine habitat in the Prince George District based on climatic and topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography and climate.

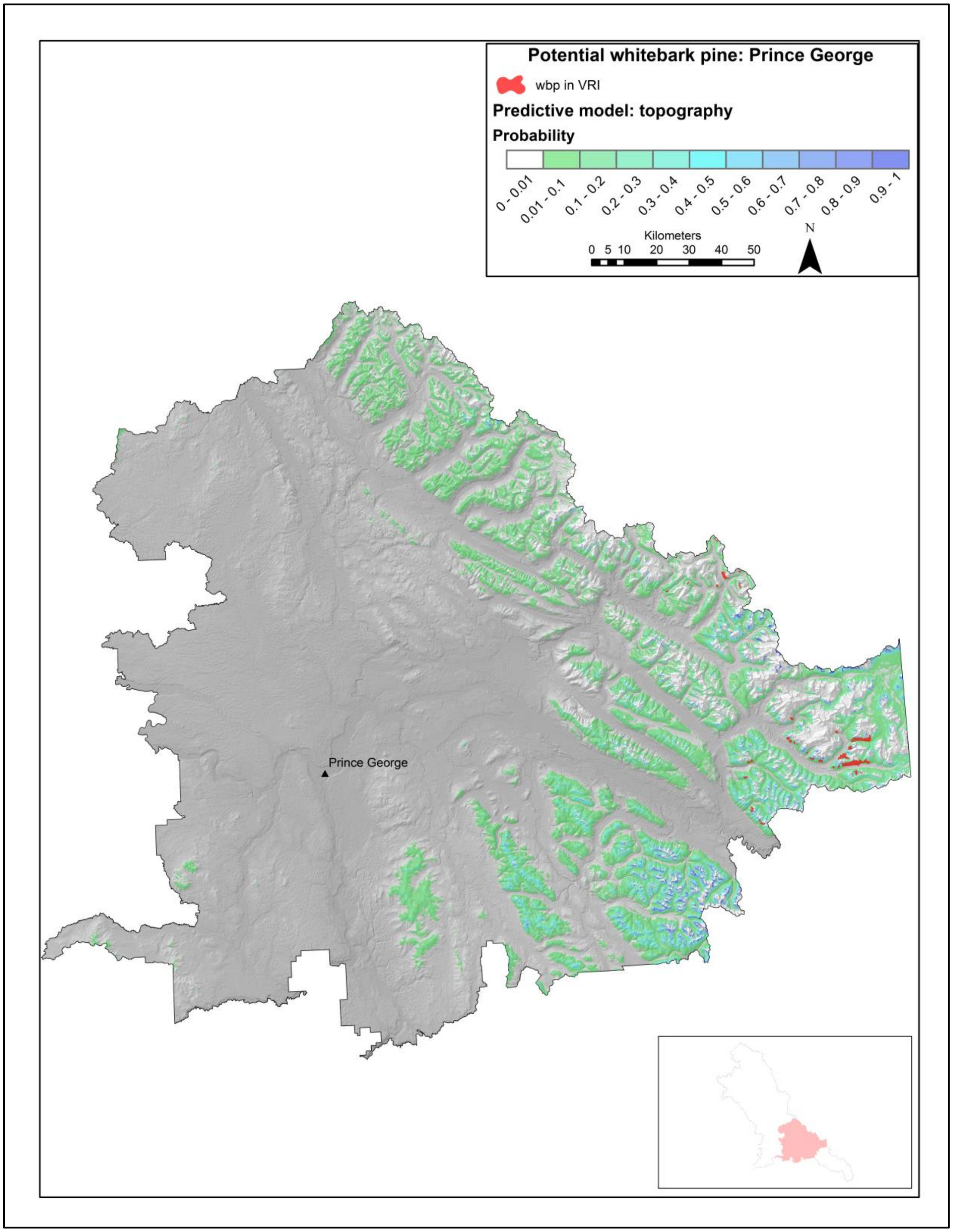

Figure 33 – Potential whitebark pine habitat in the Prince George District based on topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography.

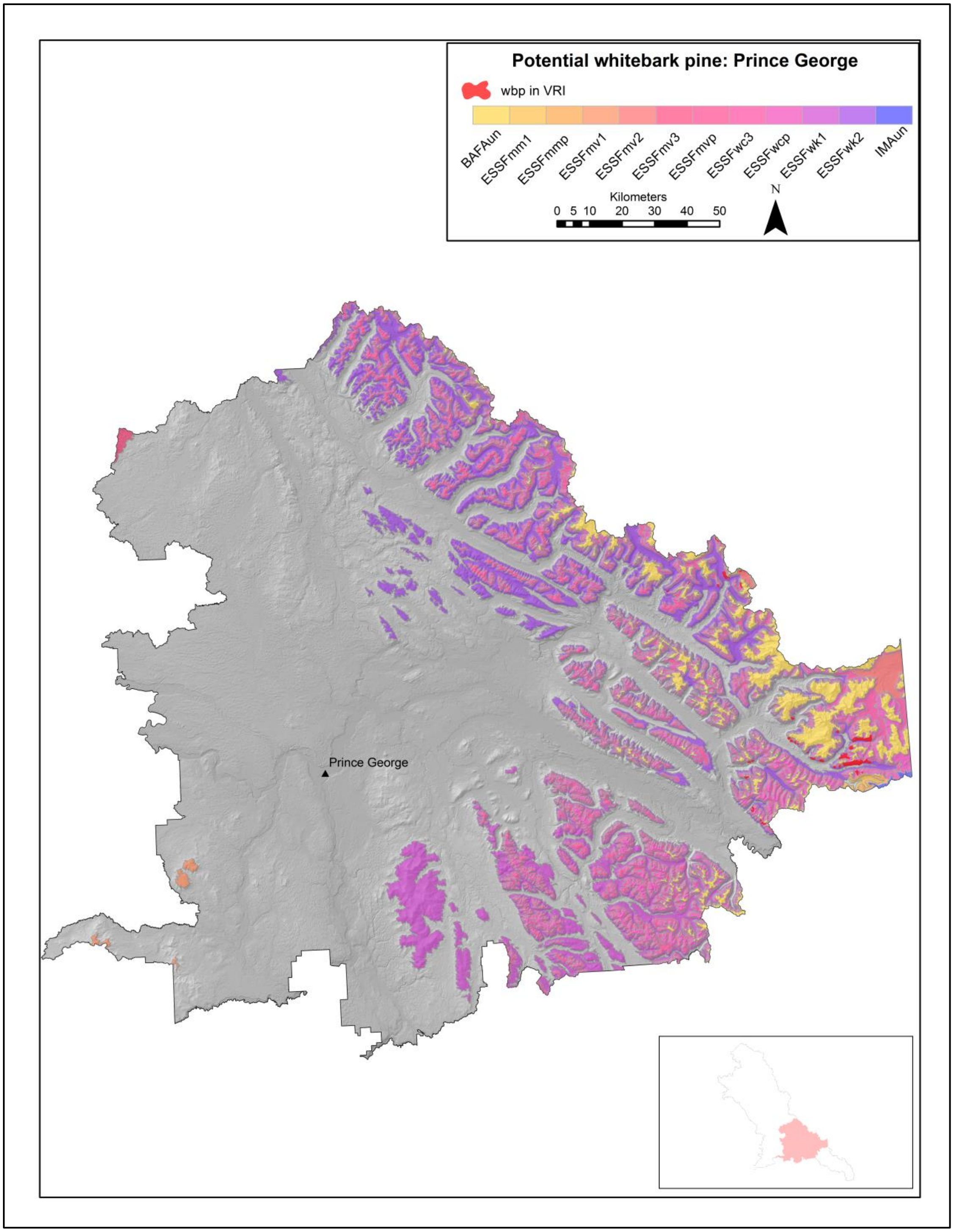

Figure 34 – Potentially suitable BEC subszones. Coloured areas other then grey are potentially suitable based on BEC subzones for whitebark pine in the Prince George District.

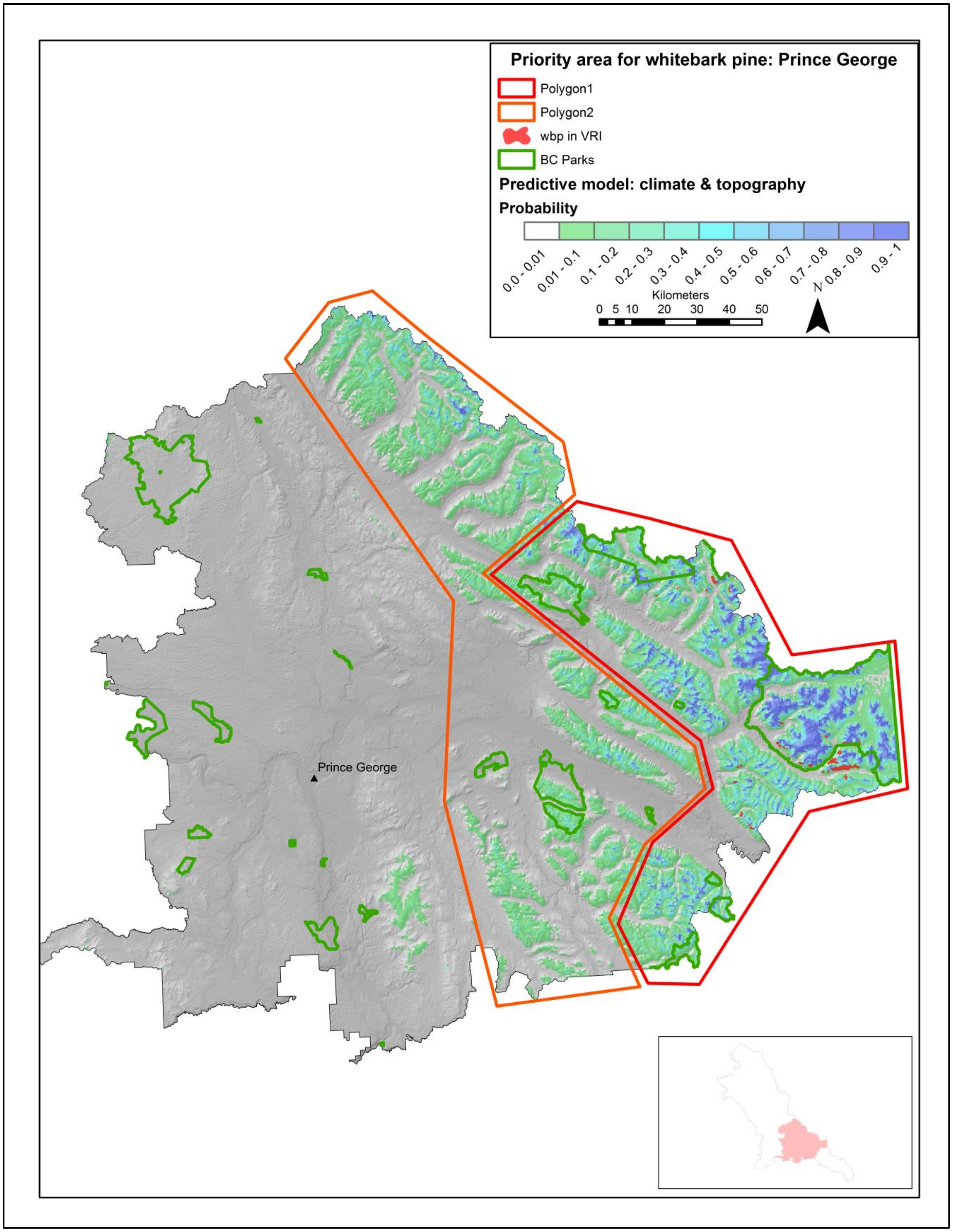

Figure 35 – Potential areas to focus whitebark pine location reconnaissance efforts and future rust surveys if locations are confirmed in the Prince George District.

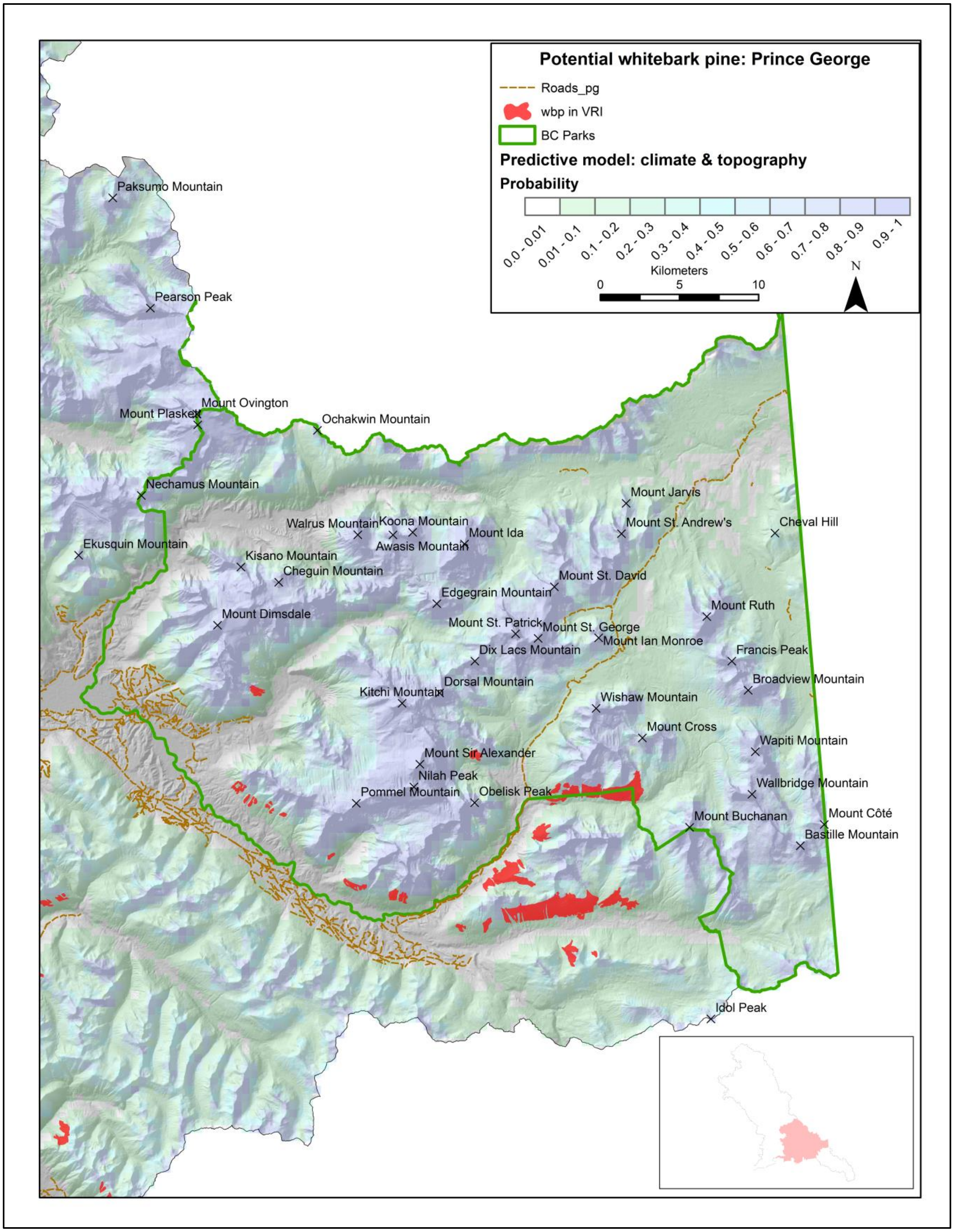

Figure 36 – The VRI and predictive model indicate the areas in and south of Kakwa Provincial Park as potentially having whitebark pine.

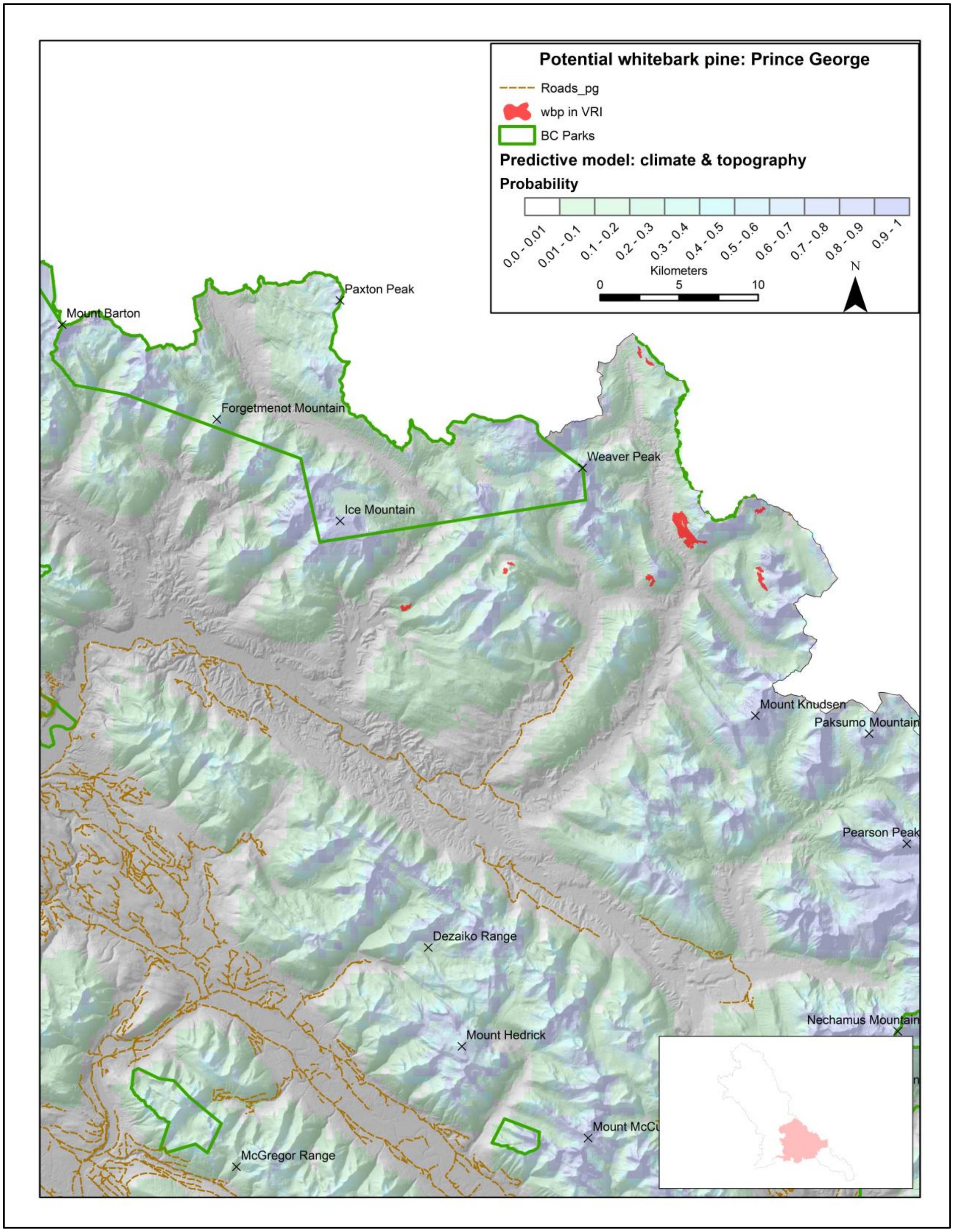

Figure 37 – the VRI and predictive model indicate areas south of Monkman and Wapiti Parks as potentially having whitebark pine. UPDATE April 26, 2013: new confirmed location in the Dezaiko Range (Bonnie Hooge).

ROBSON VALLEY MAPS

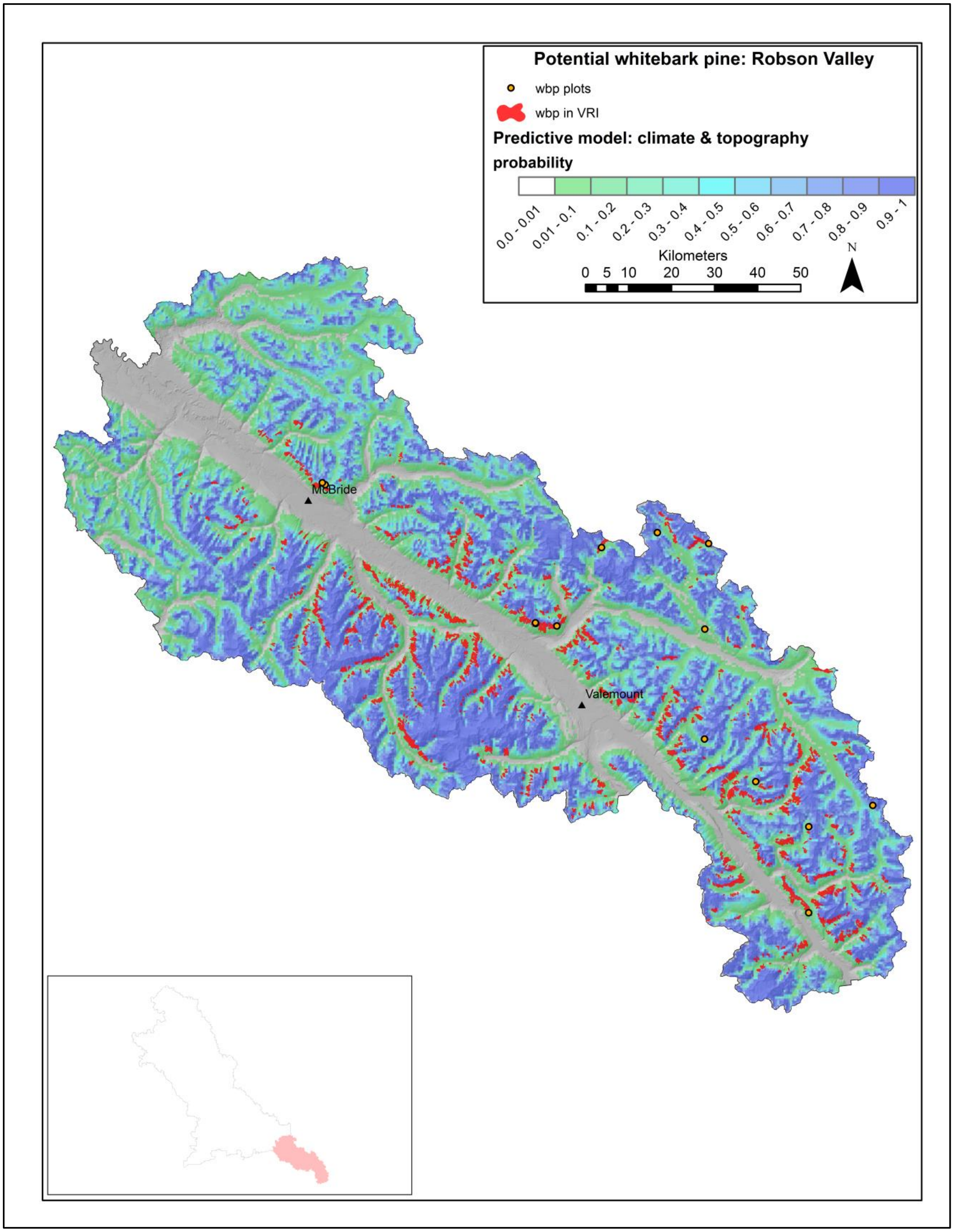

Figure 38 - Potential whitebark pine habitat in the Robson valley based on climatic and topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography and climate.

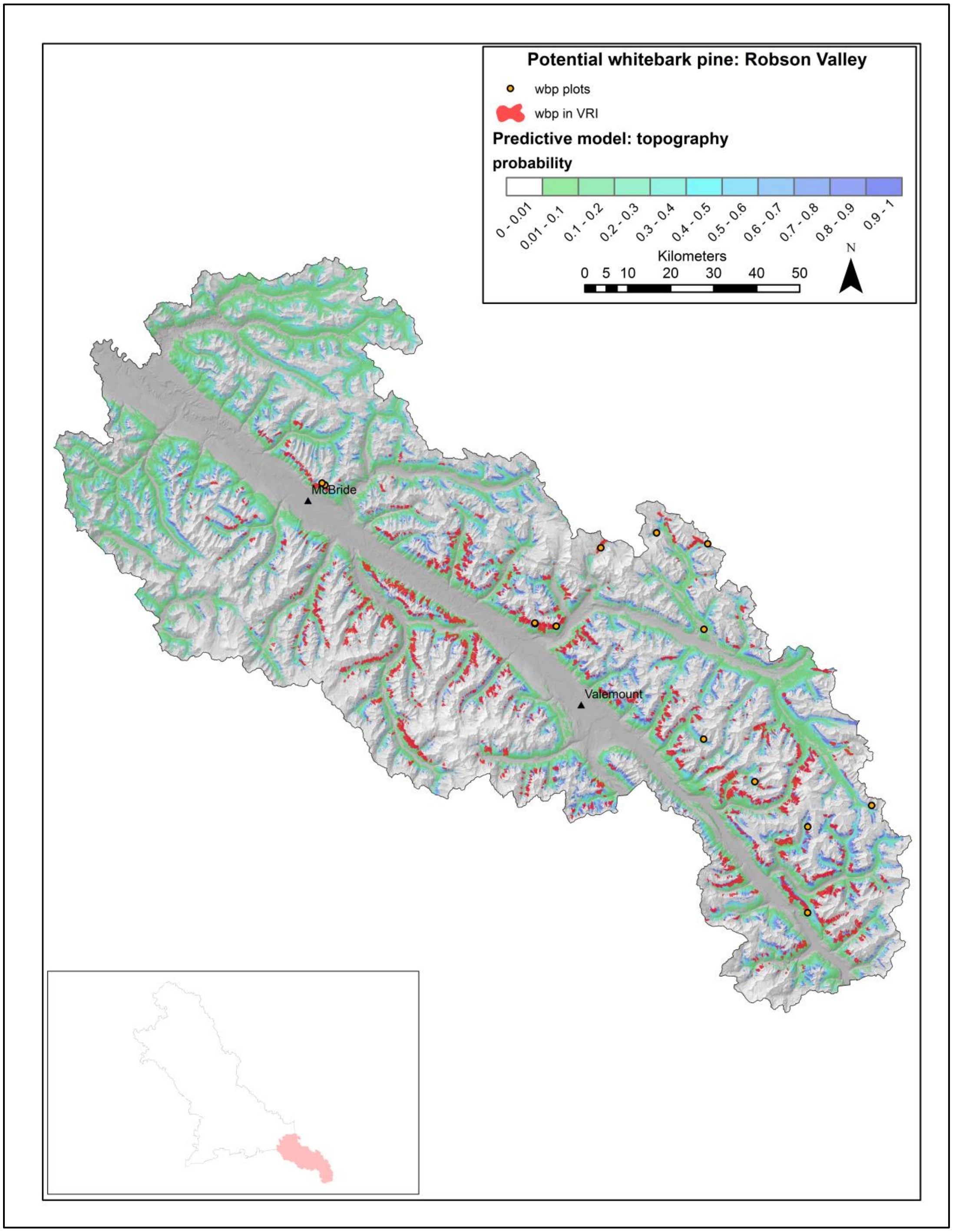

Figure 39 - Potential whitebark pine habitat in the Robson valley based on topographic predictive model. Area coloured in green (low) to blue (high) have a probability of supporting whitebark pine based on topography.

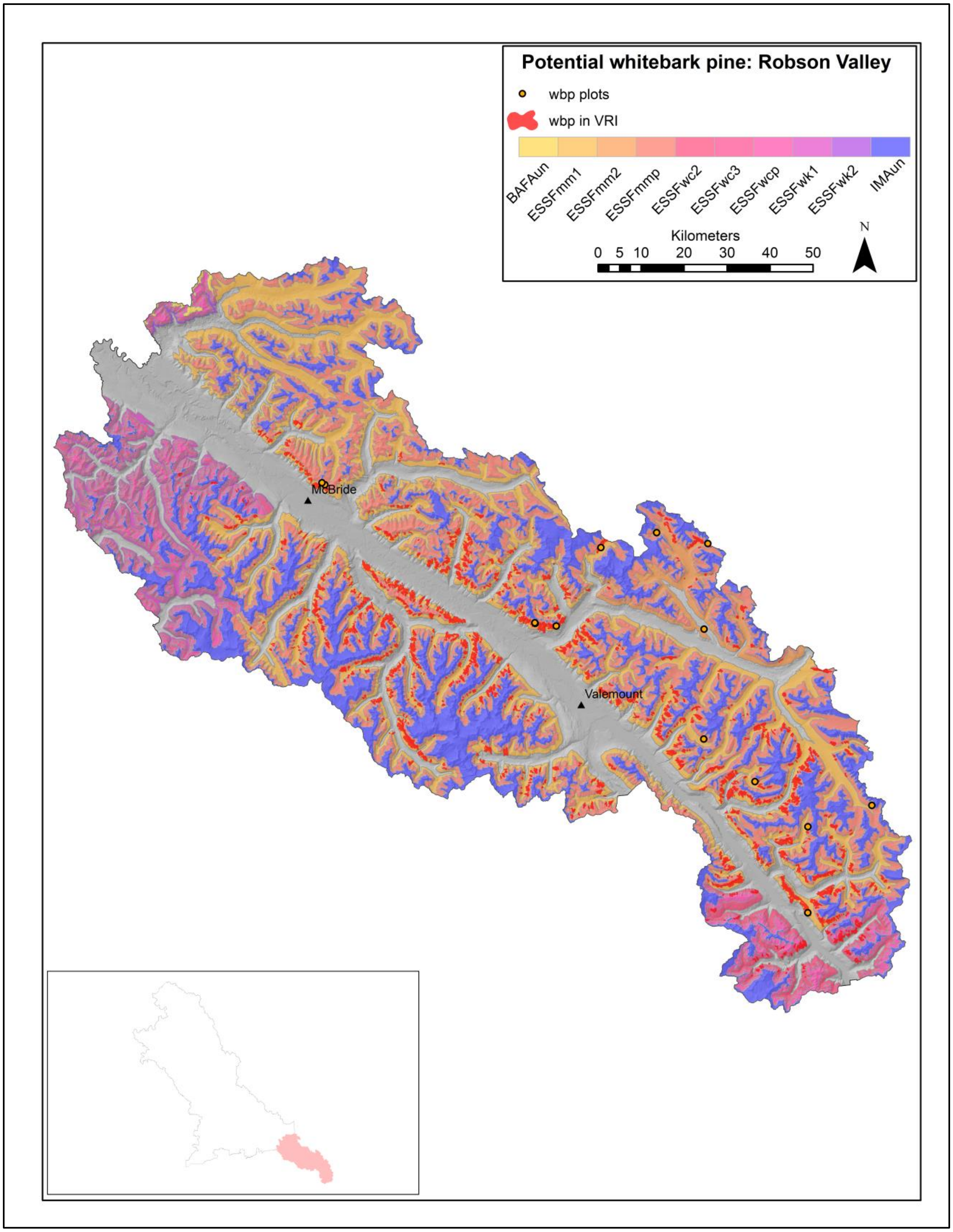

Figure 40 - Potentially suitable BEC subszones. Areas coloured other then grey are potentially suitable based on BEC subzones for whitebark pine in the Robson valley District.

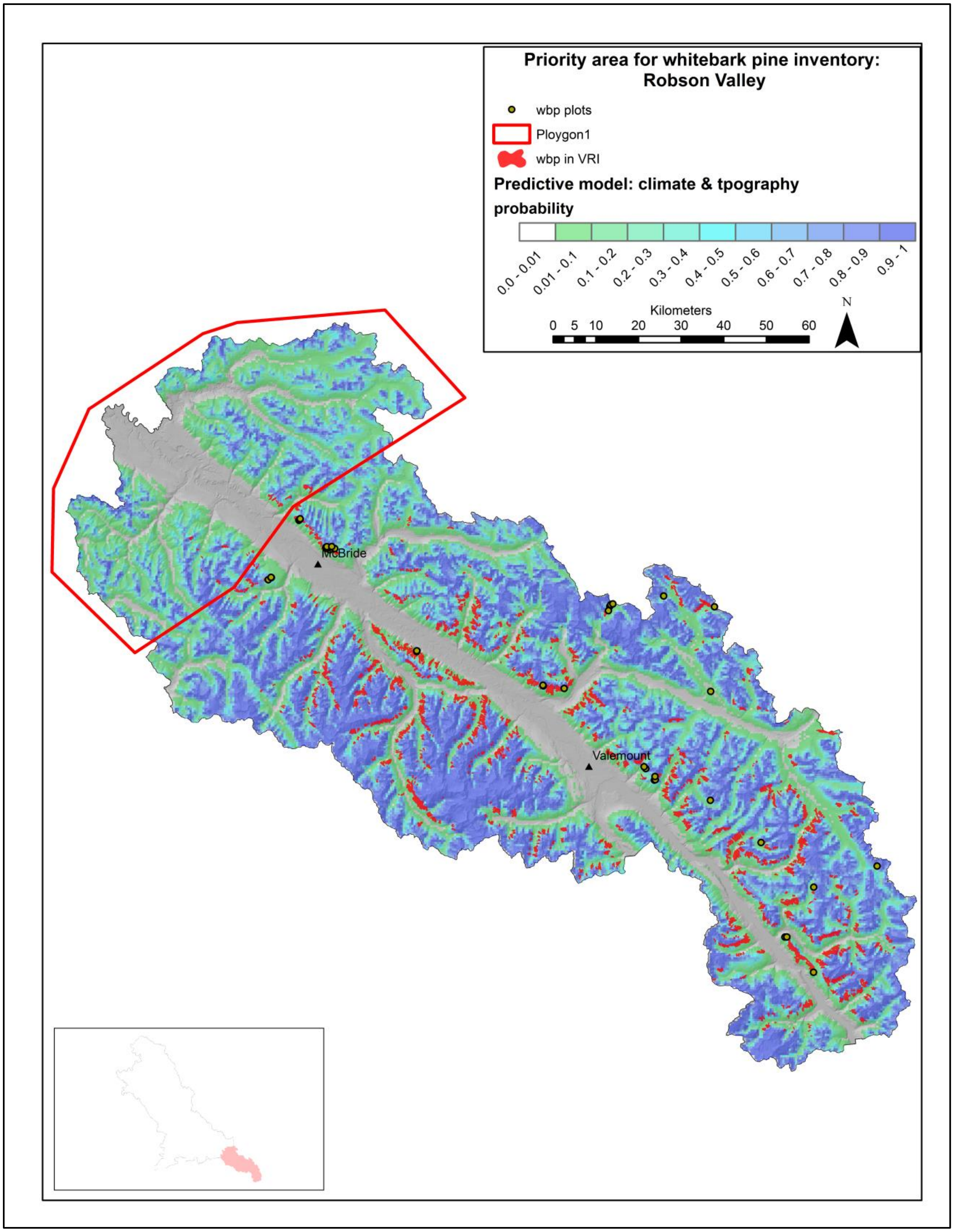

Figure 41 - Red polygon indicates the area of interest to confirm populations in the Robson valley District.

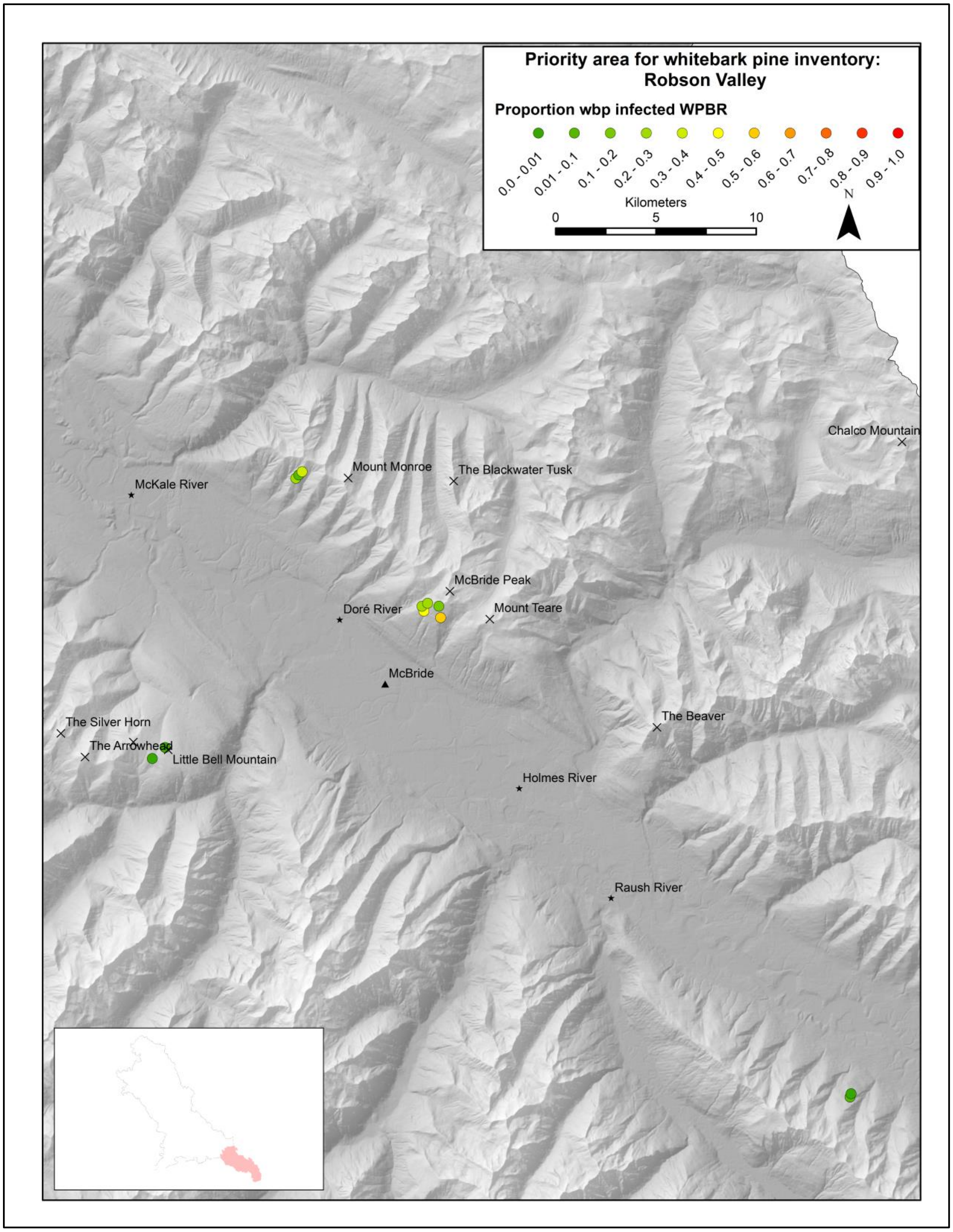

Figure 42 – Rust infection rates at sites in the McBride area of the Robson valley. Priority for cone collection and monitoring installations could be informed by these sites.

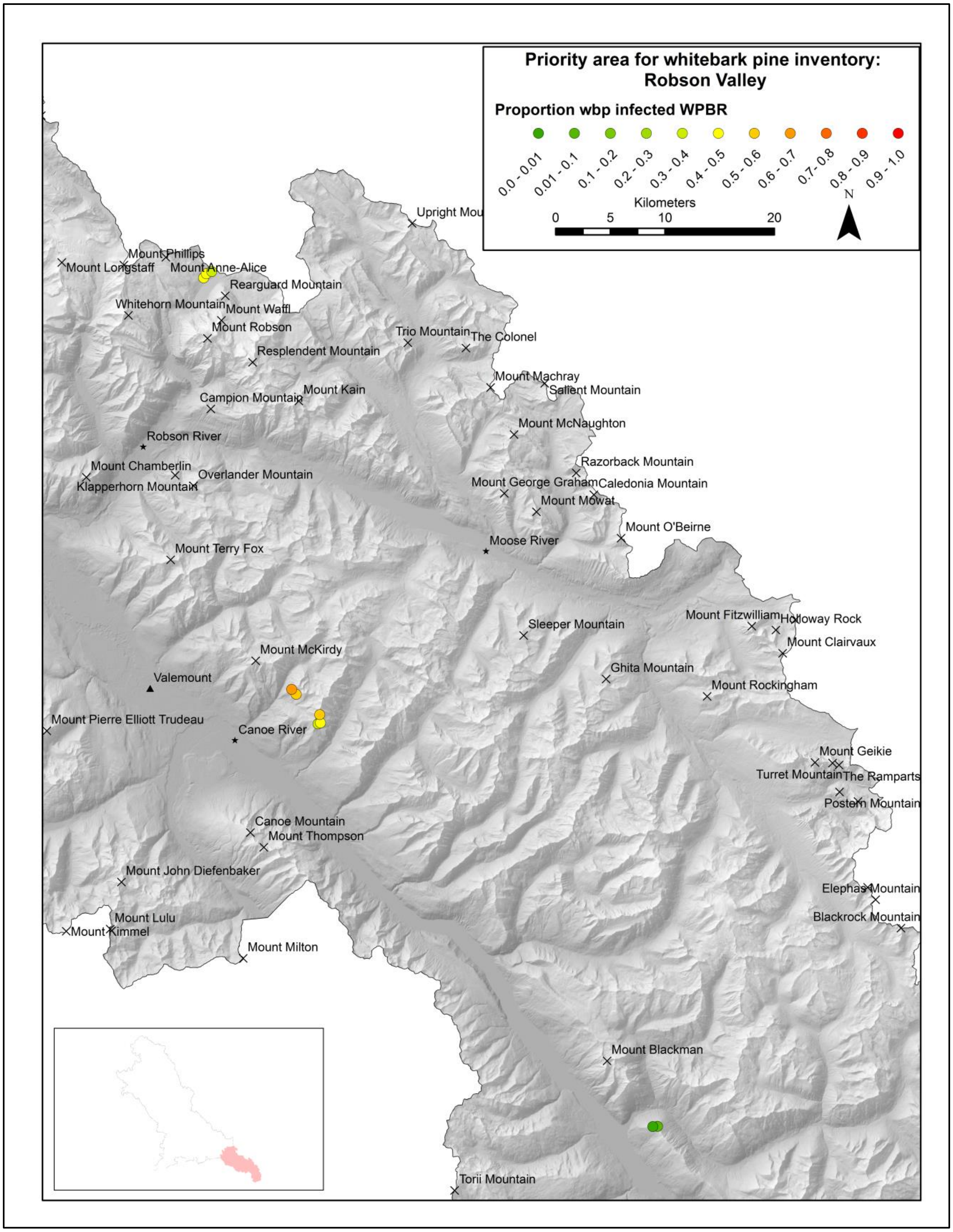

Figure 43 – Rust infection rates at sites in the Valemount area of the Robson valley. Priority for cone collection and monitoring installations could be informed by these sites.

Table 11 – Summary of trees on Mt. Sidney Williams with seeds collected and health surveyed in 2007 and re-surveyed in 2012 to determine whether seeds in storage may be suitable for screening.

Tree Num 2007	Clump Num 2012	Stem Num 2012	Stems 2007	Age	Easting	Northing	Elev (m)	MPB 2007	MPB 2012	BR 2007	BR1 2012	BR2 2012	BR3 2012	Status 2012	Hgt (m) 2007	Δ in BR	Stand level BR infection
a1	1	1	1	-	344104	6087037	1602	N	N	0	InB	AcB	n/a	healthy	20	healthy-sick	0.074074
a1	1	2	2		344104	6087037	1602	N	N	0	InS	InB	n/a	D3	.	healthy-sick	0.074074
a1	1	3	3		344104	6087037	1602	N	N	0	AcB	InB	n/a	healthy	.	healthy-sick	0.074074
a1-2	2	1	4		344104	6087037	1602	N	N	0	InS	AcB	InB	D2	.	healthy-sick	0.074074
a1-2	2	2	5		344104	6087037	1602	N	N	0	AcB	n/a	n/a	declining	.	healthy-sick	0.074074
a1-2	2	3	6		344104	6087037	1602	N	N	0	AcB	InS	n/a	D3	.	healthy-sick	0.074074
a2	3	1	7	-	344119	6087038	1612	N	N	0	AcB	n/a	n/a	declining	12	healthy-sick	0.074074
a2	3	2	8		344119	6087038	1612	N	N	0	AcB	InB	n/a	declining	.	healthy-sick	0.074074
a2	3	3	9		344119	6087038	1612	N	N	0	AcB	InB	n/a	declining	.	healthy-sick	0.074074
a3	4	1	10	-	344133	6087037	1604	N	N	1	AcB	n/a	n/a	healthy	12	sick-sick	0.074074
a3	4	2	11		344133	6087037	1604	N	N	1	InS	n/a	n/a	D2		sick-sick	0.074074
a3	4	3	12		344133	6087037	1604	N	N	1	AcS	n/a	n/a	healthy		sick-sick	0.074074
a4	5	2	13	-	344056	6087010	1607	N	N	0	AcB	n/a	n/a	healthy	10	healthy-sick	0.074074
a4	5	1	14		344056	6087010	1607	N	N	0	AcB	AcS	n/a	declining	.	healthy-sick	0.074074
a4	5	3	15		344056	6087010	1607	N	N	0	AcS	InB	n/a	D3	.	healthy-sick	0.074074

b1	6	1	16	92	345010	6087196	1517	N	N	0	N	n/a	n/a	healthy	3.8	healthy-healthy	0.173
b1	6	2	17		345010	6087196	1517	N	N	0	InB	n/a	n/a	healthy		healthy-sick	0.173
b2	7	1	18	42	345026	6087199	1520	N	N	0	N	n/a	n/a	healthy	5	healthy-healthy	0.173
b2	7	2	19	.	345026	6087199	1520	N	N	0	N	n/a	n/a	healthy	.	healthy-healthy	0.173
b2	7	3	20	.	345026	6087199	1520	N	N	0	N	n/a	n/a	healthy	.	healthy-healthy	0.173
b2	7	4	21	.	345026	6087199	1520	N	N	0	N	n/a	n/a	healthy	.	healthy-healthy	0.173
b3	8	1	22	99	345123	6087157	1525	N	N	0	InB	n/a	n/a	healthy	8	healthy-sick	0.173
b3	8	2	23	.	345123	6087157	1525	N	N	0	AcB	n/a	n/a	healthy	.	healthy-sick	0.173
b3	8	3	24	.	345123	6087157	1525	N	N	0	PB	n/a	n/a	healthy	.	healthy-sick	0.173
b4	9	1	25	98	345179	6087174	1530	N	N	0	InB	AcS	AcB	healthy	7	healthy-sick	0.173
b5	10	1	26	90	345182	6087099	1536	N	N	0	N	n/a	n/a	healthy	10	healthy-healthy	0.173
c1	11	1	27	61	344986	6087196	1516	N	N	0	N	n/a	n/a	healthy	8.3	healthy-healthy	0.173
c1	11	2	28		344986	6087196	1516	N	N	0	N	n/a	n/a	healthy		healthy-healthy	0.173
c1	11	3	29		344986	6087196	1516	N	N	0	N	n/a	n/a	healthy		healthy-healthy	0.173
c1	11	4	30		344986	6087196	1516	N	N	0	N	n/a	n/a	healthy		healthy-healthy	0.173
c2	12	1	31	100+	344986	6087221	1516	N	**Y**	0	InB	n/a	n/a	D2	7	healthy-sick	0.173
c2	12	2	32		344986	6087221	1516	N	N	0	N	n/a	n/a	D1		healthy-healthy	0.173

c2	12	3	33		344986	6087221	1516	N	**Y**	0	N	n/a	n/a	D2		healthy-healthy	0.173
c2	12	4	34		344986	6087221	1516	N	N	0	N	n/a	n/a	D3		healthy-healthy	0.173
c3	13	1	35	118	344950	6087231	1515	N	N	0	AcB	AcS	n/a	healthy	8.7	healthy-sick	0.173
c4	14	1	36	120	344948	6087240	1506	N	N	0	InB	n/a	n/a	healthy	8.6	healthy-sick	0.173
c5	15	1	37	30+	344948	6087240	1506	N	N	0	AcB	n/a	n/a	healthy	4	healthy-sick	0.173
c5	15	2	38		344948	6087240	1506	n/a	N	0	N	n/a	n/a	healthy		healthy-healthy	0.173
c6	16	1	39	100+	344965	6087233	1516	N	N	0	N	n/a	n/a	healthy	8.6	healthy-healthy	0.173
c6	16	2	40		344965	6087233	1516	N	N	0	InS	InB	n/a	healthy		healthy-sick	0.173
c7	17	1	41		344978	6087154	1511	N	N	0	InB	n/a	n/a	healthy		healthy-sick	0.173
c7	17	2	42		344978	6087154	1511	N	N	0	N	n/a	n/a	healthy		healthy-healthy	0.173
c7	17	3	43	100+	344978	6087154	1511	N	N	0	N	n/a	n/a	healthy	8.3	healthy-healthy	0.173
d1	18	1	44	-	343931	6087942	1580	N	N	0	N	n/a	n/a	healthy	6.5	healthy-healthy	n/a
d2	19	1	45	-	343952	6087919	1577	N	N	0	N	n/a	n/a	healthy	6	healthy-healthy	n/a
d2	19	2	46		343952	6087919	1577	N	N	0	N	n/a	n/a	healthy	6	healthy-healthy	n/a
d2	19	3	47		343952	6087919	1577	N	N	0	N	n/a	n/a	healthy	6	healthy-healthy	n/a
d3	20	1	48	-	343952	6087919	1577	N	N	0	InB	n/a	n/a	healthy	6.3	healthy-sick	n/a
d3	20	2	49		343952	6087919	1577	N	N	0	AcB	n/a	n/a	healthy		healthy-sick	n/a

d4	21	1	50	-	343984	6087928	1575	N	N	0	N	n/a	n/a	healthy	7	healthy-healthy	n/a
d4	21	2	51		343984	6087928	1575	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
d4	21	3	52		343984	6087928	1575	N	N	0	PS	n/a	n/a	D2		healthy-sick	n/a
d4	21	4	53		343984	6087928	1575	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
d4	21	5	54		343984	6087928	1575	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
d5	22	1	55		344007	6087907	1571	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
d5	22	2	56	-	344007	6087907	1571	N	N	0	N	n/a	n/a	healthy	7	healthy-healthy	n/a
d5	22	3	57		344007	6087907	1571	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
d5	22	4	58		344007	6087907	1571	N	N	0	PB	n/a	n/a	healthy		healthy-sick	n/a
d5	22	5	59		344007	6087907	1571	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
d5	22	6	60		344007	6087907	1571	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
e1	23	1	61	-	343932	6087958	1583	N	N	0	N	n/a	n/a	healthy	8	healthy-healthy	n/a
e2	24	1	62	-	343959	6087936	1577	N	N	0	InS	InB	n/a	healthy	8	healthy-sick	n/a
e3	25	1	63	-	343980	6087906	1573	N	N	0	InB	n/a	n/a	healthy	8	healthy-sick	n/a
e3	25	2	64		343980	6087906	1573	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
e3	25	3	65		343980	6087906	1573	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
e3	25	4	66		343980	6087906	1573	N	N	0	InB	AcB	n/a	healthy		healthy-sick	n/a

e4	26	1	67		343993	6087926	1579	N	N	0	AcB	InB	n/a	healthy		healthy-sick	n/a
e4	26	2	68	-	343993	6087926	1579	N	N	0	N	n/a	n/a	healthy	8	healthy-healthy	n/a
e4	26	3	69		343993	6087926	1579	N	N	0	InS	InB	n/a	D1		healthy-sick	n/a
e4	26	4	70		343993	6087926	1579	N	N	0	InS	n/a	n/a	D2		healthy-sick	n/a
e4	26	5	71		343993	6087926	1579	N	N	0	InS	n/a	n/a	healthy		healthy-sick	n/a
e4	26	6	72		343993	6087926	1579	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
f1	27	1	73	76	343931	6087964	1566	N	N	0	PS	n/a	n/a	healthy	11	healthy-sick	n/a
f2	28	1	74	73	343953	6088005	1575	N	N	0	N	n/a	n/a	healthy	8	healthy-healthy	n/a
f3	29	1	75	63	343958	6088016	1577	N	N	0	N	n/a	n/a	healthy	7	healthy-healthy	n/a
f4	30	1	76	59	343945	6088036	1580	N	N	0	N	n/a	n/a	healthy	9	healthy-healthy	n/a
f5	31	1	77	-	343941	6088026	1580	N	N	0	InS	InB	n/a	D2	7	healthy-sick	n/a
f6	32	1	78	-	343940	6087946	1578	N	N	0	N	n/a	n/a	healthy	7	healthy-healthy	n/a
f6	32	2	79		343940	6087946	1578	N	N	0	N	n/a	n/a	healthy		healthy-healthy	n/a
f6	32	3	80		343940	6087946	1578	N	N	0	InB	n/a	n/a	healthy		healthy-sick	n/a
f7	33	1	81	-	343936	6087900	1573	N	N	0	N	n/a	n/a	healthy	8	healthy-healthy	n/a
f8	34	1	82	-	343928	6087896	1575	N	N	0	AcB	InB	n/a	healthy	8	healthy-sick	n/a
r1	35	1	83	70+	346845	6087271	1497	N	N	0	N	n/a	n/a	healthy	7.7	healthy-healthy	0.103448

r2	36	1	84	75+	346943	6087200	1501	N	N	0	InS	n/a	n/a	declining	7.7	healthy-sick	0.103448
r3	37	1	85	80+	347740	6085211	1652	N	N	0	InB	InS	n/a	healthy	5.7	healthy-sick	0.607
r3	37	2	86		347740	6085211	1652	N	N	0	InB	InS	n/a	D3		healthy-sick	0.607
r4	38	1	87	80	347634	6085171	1643	N	N	0	AcS	AcB	n/a	declining	5	healthy-sick	0.607
r4	38	2	88		347634	6085171	1643	N	N	0	InB	AcB	n/a	declining		healthy-sick	0.607
r4	38	3	89		347634	6085171	1643	N	N	0	InS	InB	n/a	D3		healthy-sick	0.607
i1	39	1	90		343731	6089599	1517	N	N	1	N	n/a	n/a	healthy		healthy-healthy	0.090909
i1	39	2	91	175	343731	6089599	1517	N	N	1	InB	n/a	n/a	healthy	11	sick-sick	0.090909
i1	39	3	92		343731	6089599	1517	N	N	1	InB	n/a	n/a	healthy		sick-sick	0.090909
i2	40	1	93	130	343853	6089138	1532	N	N	0	N	n/a	n/a	healthy	7.8	healthy-healthy	n/a

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