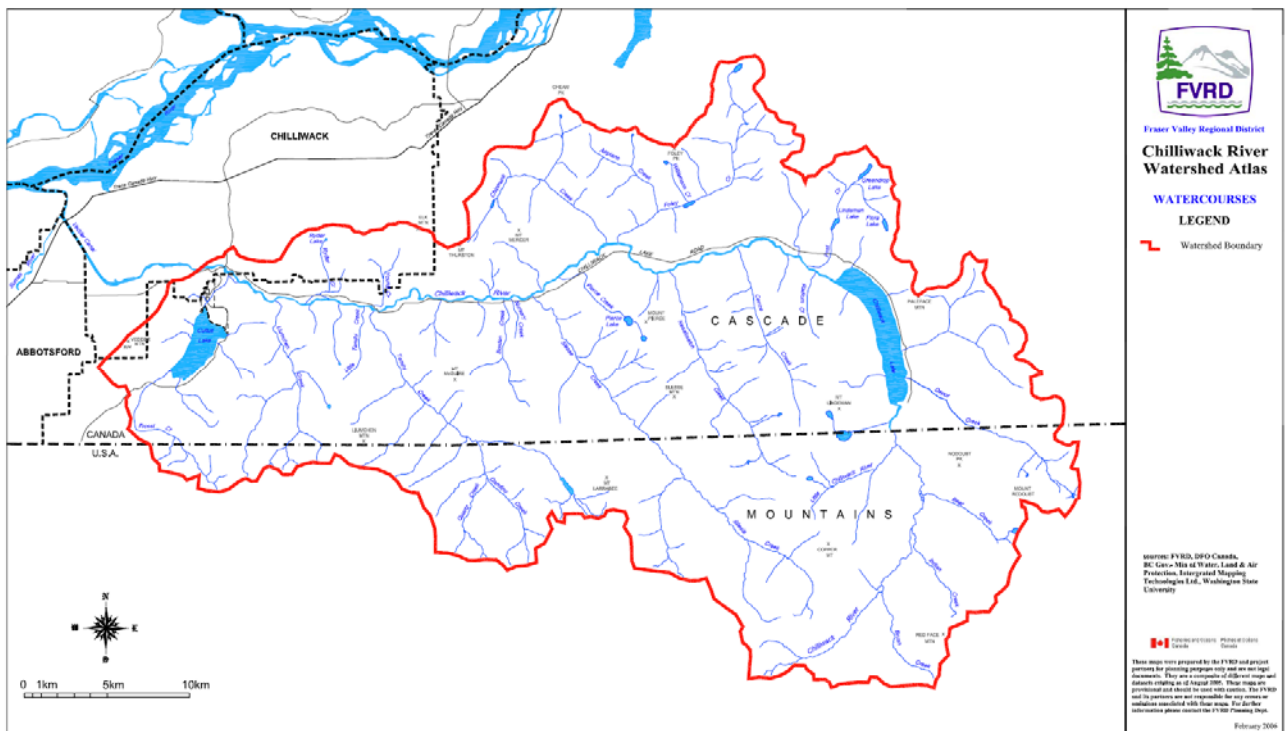


Review of the Chilliwack River Watershed and Forest Practices



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Summary

Scope and objectives

This report evaluates the effects of forest operations on the flooding and channel stability of the Chilliwack River. The report is based primarily on published literature, supplemented by the author's knowledge of the Chilliwack Valley. The specific objectives were to:

- Evaluate the effects of past and future forest operations on flooding and channel stability of the Chilliwack River,
- Summarize the landslide hazards that are present in the lower areas of the valley such as Slesse Park, and
- Summarize the causes and effects of the January 2009 flooding and landslide event.

Findings

- Forest operations that adhere to current regulations and practice will not result in harm to the Chilliwack River.
- Less than 12 per cent of the watershed area has been harvested over many decades of forestry. This is well below the level at which harvesting may increase flooding, even if all the harvesting occurred at once. The largest recorded flood in the Chilliwack River was in 1917, prior to any significant amount of forest harvesting. Recent decades have had large floods that are a result of natural climate cycles or perhaps global warming.
- Significant channel destabilization and loss of bank strength has resulted from riparian (streamside) logging in the lower valley that occurred between the 1920s and 1950s. Settlement and development of the lower valley has resulted in permanent loss of riparian forests, leading to further loss of channel stability.
- Forestry-related landslides are not a significant source of sediment for the Chilliwack River and do not destabilize the channel. Forestry-related landslides could affect some of the Chilliwack River tributaries or could present a safety hazard to users of the watershed, and in rare cases, to residents.
- Landslides in the lower valley (Slesse Park area and downstream) occur on steep slopes composed of glacial lake sediments thousands of years old. Several of the landslide areas are not in, or below, Provincial Crown Forest land, and are therefore not affected by forestry on Crown land. Other landslides are located in, or below, Provincial Crown Land, and these landslides could be affected by forestry operations. Careful attention to forest practices is necessary to prevent landslides in these areas, some of which are located near residential areas.
- The January 2009 flooding and landslide event was the result of intense rain falling on snow, which then melted. Landslides and flooding were limited to low elevation areas. The Chilliwack River had a small flood event, since higher elevation areas of the watershed did not have melting snow. Several landslides occurred in the glacial lake sediments in the lower Chilliwack Valley as a result of the rapid snowmelt and runoff.

1.0 Introduction

The following is a summary of available reports and reviews the effect of past and future forest operations on the hydrology and geomorphology of the Chilliwack River and its watershed. The review is focussed primarily on flooding and landslide hazards, but may also be relevant for water quality, fisheries or other ecological resources. This report also summarizes the causes and effects of the January 2009 rain-on-snow event.

The Chilliwack River is located south and east of the City of Chilliwack. A portion of the watershed is within Washington State. The Canadian portion of the Chilliwack River and watershed has a long history of development since European settlement, with forestry as part of that history. In 1922, the Vedder Canal diverted all of the water from the Vedder River and delivered it into the canal (Yarrow Pioneers website). About the same time as the Vedder Canal was constructed, logging began in the Chilliwack Valley upstream of Vedder Crossing (FVRD 2005). Settlement and development of land along the reaches of the river between Vedder Crossing and Slesse Park have resulted in significant permanent losses of riparian forest, and exposes people, property and infrastructure to flooding hazards. In response to floods and bank erosion, sections of the river have been riprapped and diked, further altering the natural course and regime of the river. Wildfire has burned extensive areas of the watershed, particularly in the period from 1925 to 1950 (FVRD - CWS website).

Terraces in the lower Chilliwack Valley are composed of fine-grained glacial lake sediments that were deposited thousands of years ago. These sediments are susceptible to landslides and form a second type of hazard within the watershed. The Chilliwack Watershed Strategy shows a map of the locations of these slides (FVRD 2005). Most of the slides that are hazardous to people and property (Neville Road, Willow Run, Siscoe, Tolmie, and Anderson Run) are located downstream of Slesse Park and are outside of the Provincial Forest, and no Provincial Forest is upslope of the slides. As such, the management of land and landslide risk is outside of Ministry of Forests and Range jurisdiction. The Slesse Park, Anderson Run, Thurston Corrections Camp, Ranger Run, and Slesse Creek landslides are within the Provincial Forest.

2.0 Methods

This report summarizes and interprets several publications that discuss the Chilliwack River and its watershed. No fieldwork was done for this review.

3.0 The Chilliwack River

The Chilliwack River system can be divided into four zones:

1. The Chilliwack River above Chilliwack Lake delivers both water and sediment to the lake. The lake traps the sediment and delivers clear unladen water downstream (Tunncliffe 2008).

2. From Chilliwack Lake to a short distance upstream of Slesse Creek the river is generally a stable single channel. Bed and bank materials are coarse and resistant to erosion, and the river can transport most sediment delivered to it from tributaries such as Centre or Nesakwatch Creek (Ham and Church 2000). Sediment transported downstream from this zone is delivered to the zone between Slesse Creek and Vedder Crossing, and eventually most or all of it is exported past Vedder Crossing.
3. Between Slesse Creek and Vedder Crossing, the river develops zones with large gravel bars. Some sections are braided, which typically indicates a high sediment supply. From Liumchen Creek to Vedder Crossing the river is almost continuously braided. Channel bed and bank materials are easily erodible. The channel location is unstable and wanders across the floodplain during high flood events (Ham and Church 2000; Hay and Company 1992). Engineering works restrict the movement of the channel across the floodplain in some locations (BC MOE map).
4. Below Vedder Crossing, the river flows across its alluvial fan in a highly engineered channel system that includes the Vedder Canal and continuous dikes. Prior to the construction of the Vedder Canal, there was a multi-channel network that had frequent changes in channel locations as water and gravel spread out across the surface of the alluvial fan (Yarrow Pioneers website). Currently, all gravel transported past Vedder Crossing is deposited into the Vedder River and Canal system, and requires periodic excavation to maintain channel flood capacity. Up to 100,000 m³/year of gravel removal is permitted (FVRD 2005). Current practice is to remove gravel in non-pink salmon spawning years (pers. comm. Scott Babakaiff, Fish Protection Hydrologist, MOE).

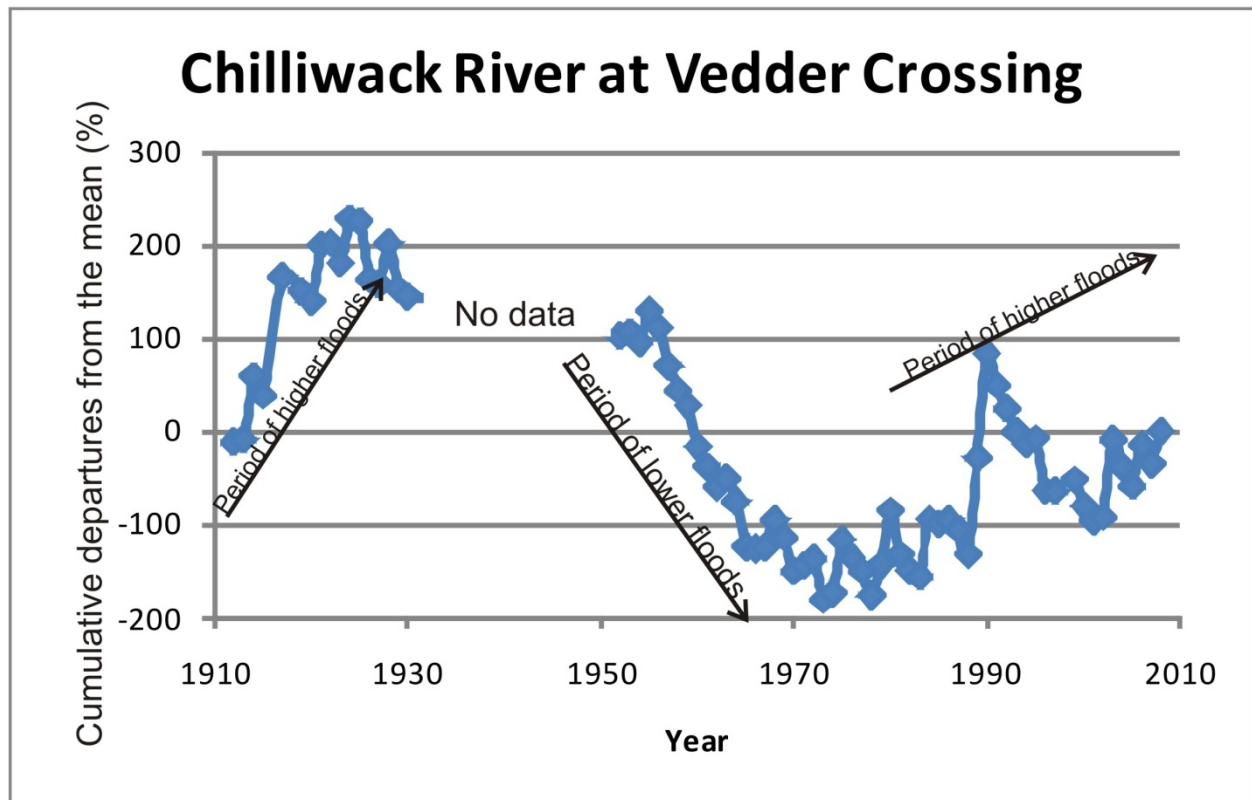
The modern Chilliwack River is strongly influenced by the period after glaciation, which ended about 11,000 years ago (Tunncliffe, 2008). Immediately post-deglaciation, large volumes of sediment were delivered to the Chilliwack River. Beginning about 6000 years ago the sediment supply was reduced and has resulted in the river cutting into previously deposited sediments, particularly in the area between Slesse Creek and Vedder Crossing (Tunncliffe 2008). The most recent decades show a similar pattern of degradation. Ham and Church (2000) examined the movement of sediment through the Chilliwack River from Chilliwack Lake to Vedder Crossing, in the period from 1952 – 1991. Ham and Church's results show:

- For the entire river between Chilliwack Lake and Vedder Crossing, over the entire period, there has been net degradation. That is, the river is cutting into previously deposited valley-bottom sediments and exporting them to the Vedder River.
- Reaches upstream of Slesse Creek had minor changes in all time periods, which reflects their erosion-resistant bed and banks and the capability of the channel to transport most of the sediment introduced by tributaries.
- Most of the channel degradation occurs downstream of Slesse Creek, where finer riparian sediments are easier to erode.
- Degradation below Slesse Creek increased substantially after 1973. The degradation increased in response to large flood flows that occurred in the 1973 – 1991 period, whereas the 1952 – 1973 period was characterized by moderate flood events. The degradation occurs when the river erodes its banks and then exports the bank sediment downstream. The bank erosion results in a high sediment supply, and in response, the river develops a braided pattern.
- Tributaries supply some sediment to the Chilliwack River, but compared to the amount of sediment transported out of the Chilliwack River, the tributary inputs are fairly small. For

example, in 1983 – 1991, Slesse Creek contributed 2900 m³/yr to the Chilliwack River, but transport of sediment past Vedder Crossing was 54,600 m³/yr – a far greater amount. Slesse Creek is the major tributary supplier of sediment to the Chilliwack River, and other tributaries would be even less significant sediment sources. The most significant source of the sediment is bank erosion from the Chilliwack River downstream of Slesse Creek.

Large flood events on the Chilliwack River occurred more frequently prior to 1925 and then after about 1973. Figure 1 shows an updated version of a graph of flood events for the Chilliwack River (Ham and Church 2000). In this type of graph, a period of generally lower floods than average is shown as a declining line, whereas a period of higher than average floods is shown as an ascending line. The period from 1912 – 1924 had generally higher than average floods, the period from 1952 – 1973 had almost consistently lower than average floods, and the post 1973 period is characterized by mostly higher than average floods.

Figure 1. Long-term trends in size of floods, Chilliwack River, from 1912 – 2008¹.



1) Estimated values for 1984, 1989 and 1990 are taken from Hay and Company 1992

Ham and Church (2000) identify the larger flood events in the period of 1973 – 1991 as causing the extensive sediment movement and degradation that has occurred in that period. The response of the river in the post-1973 period is likely the first period of higher than average flows since development of

the watershed began (we don't know the exact pattern of flows in the Chilliwack River from 1928 – 1952, but Western Canada was generally in a dry period).

4.0 Effect of past forestry practices

Stream channels respond to changes in the environment, particularly changes in vegetation, sediment supply and water supply. These changes may be natural or from human activities in the watershed. For example, wildfires can change the vegetation, alter stream flows and cause landslides that lead to an increase in the sediment supply to a channel. Forest practices may affect stream channels and flooding in the following manners:

1. **Streambank logging** can reduce bank strength, causing bank erosion, channel widening, and increase the supply of sediment into the channel.
2. Roads and harvesting on steep slopes can cause **landslides**, increasing the sediment supply to stream channels.
3. There is a potential for **increased peak flows** (floods) when a large percentage of the watershed is "Equivalent Clearcut Area" (ECA, recently harvested).
4. For water quality and habitat concerns, **fine sediments** can enter the stream system from roads, skid trails, or yarding disturbance in addition to landslides. Evaluating the extent of introduction of fine sediment is beyond the scope of this report as it requires different methods and field investigation.

4.1 Streambank logging

Historically, logging typically harvested trees from along stream banks and often used machinery in channels or cross-stream yarded. In the Chilliwack Valley, most of the mainstem of the Chilliwack River was harvested by the 1950s. Low elevation floodplain areas of most of the major tributaries (Liumchen, Tamihi, Slesse, Nesakwatch, and Centre Creeks) were burned or had streambank logging by 1965.

Following streambank logging alongside Slesse Creek in the 1950/60s period, Slesse Creek increased in width by five times and changed from a primarily single-thread channel to a braided channel morphology (Millar 2001). As noted above, the increased width and change in channel pattern in Slesse Creek potentially could be a result of riparian logging, landslides, or increased peak flows. However, by 1992 less than 6% of the watershed had been logged. This is far too small an amount of harvesting to lead to peak flow changes, so the changes are not caused by the amount of harvesting that occurred. Also, there are few logging-related landslides in Slesse watershed, so increased sediment supply from landslides has not destabilized Slesse Creek. The destabilization of Slesse Creek is almost certainly from streambank logging. **Similarly, the Chilliwack River downstream of Slesse Creek was most likely destabilized from streambank logging.**

4.2 Logging-related landslides

The Chilliwack Valley was one of the first areas in British Columbia with logging on steep slopes. Between 1952 and 2002, logged steepland areas of the Chilliwack Valley had a landslide frequency nine times higher than the natural steepland frequency of landslides (frequency is the number of landslides

per year, accounting for the amount of logged steep land area compared to natural steep land areas). Another measure of the impact of logging on landslides is to add up the amount of area (in m² or in hectares) that landslides occupy, from the uppermost location at which the landslide initiated to the lowest deposition area. When the area occupied by landslides is measured, logged steep land areas have three times more area occupied by landslides than natural steep land areas (Wolter, Ward and Millard in press). Logging-related landslides are typically much smaller than natural landslides, and this explains the difference when measuring the effect of logging on landslide frequency compared to the area occupied by landslides.

The effect of logging-related landslides on sediment supply to the Chilliwack River can be assessed using the area occupied by landslides and some estimates of the depth of landslides and the amount of landslide sediment that reaches the Chilliwack River. If all the surface areas of all logging-related landslides are added together, and an average depth of erosion of 0.3 m is applied (to obtain a total volume of logging-related landslide sediment), and assuming 100% of the sediment is introduced into the Chilliwack River (an overestimate), the yield is approximately 9000 m³/yr of landslide-derived sediment. This generous overestimate is about one-quarter of the amount of sediment the Chilliwack River actually exported (Ham and Church 2000), and indicates that logging-related landslide sediment is not a major factor in the behaviour of the Chilliwack River. The highest rate of logging-related landslides occurred in the 1973-1983 period, and since then the rate has declined (Wolter, Ward and Millard, in press). **Based on the above results, logging-related landslides do not appear to alter the morphology or hazard level in the river.**

Millard et al. (2002) investigated what types of terrain logging-related landslides occurred on. They examined steep slopes in the Chilliwack Valley that were logged between 1975 and 1989. Gullies, and in particular deep gullies, had the most frequent landslides. For areas without gullies, terrain steeper than 38° (78%) had elevated rates of landslides.

One of the legacies of historical logging in the Chilliwack Valley is the road network. Many of these roads were constructed before there was a strong understanding of road construction techniques in landslide-prone terrain, and these roads are responsible for many of the logging-related landslides that have occurred. Although road deactivation has reduced the number of such roads that still exist, there remain a number of roads that are still potentially unstable. An example is the set of landslides that occurred along the Tamahi mainline road during the extreme rain-on-snow event in January 2009. Eighteen slides occurred along a 3 km section of road.

The glacial lake sediment landslides located in the lower valley (Slesse Park, Anderson Run, Thurston Correction Camp, Ranger Run and Slesse Creek) are locations of recurrent landsliding and are not typical of landslides in other areas of the watershed. Undercutting of the base of the landslide by the Chilliwack River is an important factor in the recurrent nature of these landslides. In addition, land use and hydrological effects on areas immediately upslope of the slides may be a factor in their movement (B. Thomson, pers. comm.). **Forest operations that increase the amount of water delivered to a glacial lake sediment slide location, whether from roads or harvesting, may cause further landslides.**

4.3 Increased peak flows from forest harvesting

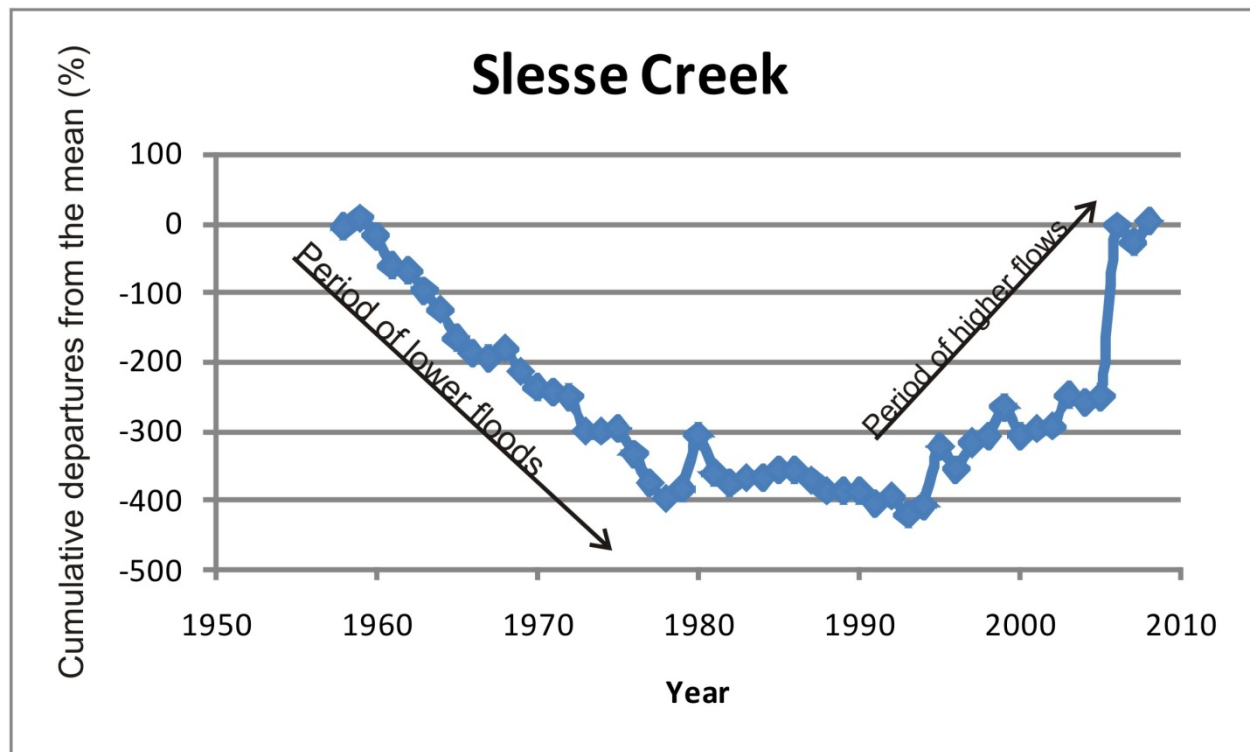
Increased peak flows may become measureable when 30% of a watershed is in Equivalent Clearcut Area (ECA), and 20% ECA is generally considered a conservative maximum level to prevent increased peak flows (Church and Eaton 2001, Alila and Schnorbus 2005, Grant et al. 2008). The American portion of the Chilliwack River watershed is essentially unlogged, and in addition, a significant portion of the watershed is alpine or not economical for forestry. By 2008, about 145 km² of the 1230 km² watershed area had been harvested (Hayco 1992 and Mike Smith, Chilliwack District). This totals <12% of watershed area, and ECA is likely to be much lower, since many of the previously logged areas will have recovered hydrologically as regenerating stands have achieved tree heights of 15 – 20 m. **Forest harvesting has not changed peak flows in the Chilliwack River.**

Tributary watersheds are more likely to have large portions of the watershed recently harvested, but the highest ECA levels noted by Hay and Company (1992) were the Little Tamahi with an ECA of 16% and Chipmunk Creek with an ECA of 12%. These are still moderate levels of harvest and very unlikely to result in peak flow changes.

4.4 Changes in peak flows unrelated to forest harvesting

When flood discharges on Slesse Creek are examined, they indicate that flood levels have increased since about 1994, and this increase is not attributable to forest harvesting. Figure 2 is equivalent to Figure 1, except the graph shows the trends in flood events for Slesse Creek for the period of 1958 (start of gauging) to 2008. It shows a similar pattern to Figure 1, in that the period from 1958 – 1978 had generally lower than average floods, and since 1994 there has generally been higher than average floods. Slesse Creek ECA likely never exceeded 4%, a figure far too low to have a measurable effect on flood flows. The changes in peak flows in the Chilliwack River strongly resemble those changes in peak flow for Slesse Creek. Both watersheds have modest or very low levels of harvesting, and the changes in peak flows in both watersheds are almost certainly not a result of logging. Natural climate cycles or global climate change are likely to be the cause of changes in floods in both Slesse Creek and the Chilliwack River. **The Chilliwack Watershed has a low rate of forest harvest, and so even if climate change increases peak flows, forest harvesting is unlikely to result in any significant effect on peak flows.**

Figure 2. Long-term trends in size of floods, Slesse Creek, from 1958 – 2008.



5.0 Discussion on flooding and instability on the Chilliwack River

Loss of riparian forests from natural events, forestry or other human causes, can lead to major changes in the location, width and type of channel, even if flood levels do not change. Increased supply of sediment, whether natural or human-caused, can aggrade (fill up) the channel. In response to the excessive sediment, the channel may widen and the channel pattern may change (i.e. from a single-thread channel to a braided channel), or the location of the channel can become more unstable. In contrast, if only increased peak flows occur, the likely result is modest increases of channel width and channel depth and an increase in sediment transport (assuming erodible channel bed and banks). However, if increased peak flows are combined with loss of riparian forests or increased sediment supply, the cumulative effects can be significant. It is likely that streambank logging and increased sediment supply from landslides are the most damaging results of forest practices, and that increases in peak flows are not as much of a problem as the first two effects (Grant et al. 2008).

Slesse Creek and the Chilliwack River downstream of Slesse Creek appear to have similar histories. In the case of Slesse Creek, riparian logging (and some wildfire) resulted in a very destabilized and wider channel. Similarly, it is likely that loss of riparian forest on the Chilliwack River resulted in easily erodible banks. Large flood events, most of which occurred in the last 30 years, now result in extensive bank erosion and channel location changes. The Chilliwack River now requires riprap, dikes, and excavation of sediment to minimize flood damage. In the case of Slesse Creek, the loss of riparian forest resulted in a

destabilized channel, but since there is a forest regrowing on the floodplain of Slesse Creek, it will eventually become a more stable channel.

Logging-related landslide sediment supply to the Chilliwack River appears to result in a minor increase in the amount of sediment moving through the system. In part, this is due to the average size of logging-related landslides being small, and in part because the Chilliwack River can accept an increase in sediment supply without a negative effect in its channel form. In addition, landslides appear to account for a small volume of sediment when compared to the amount of sediment derived from bank erosion in the lower portion of the Chilliwack River. **The logging-related sediment does not appear to affect the level of flooding hazard on the Chilliwack River.**

Increased peak flows from forest harvesting almost certainly have not contributed to flooding and instability in the mainstem Chilliwack River. Tributary watersheds did not have high ECAs in 1992 and it is unlikely peak flows have been significantly affected in tributary watersheds as well.

6.0 Expected effects of current forestry practices

Within the Chilliwack Watershed, the Forest Planning and Practices Regulations (FPPR) require that forest licensees:

- Maintain riparian reserves zones on all large streams and most smaller streams (unless the minister approves an alternate strategy);
- “must ensure that the primary forest activity does not cause a landslide that has a material adverse effect”;
- “must ensure that the primary forest activity does not cause a gully process that has a material adverse effect”; and
- “must ensure that the primary forest activity does not cause fan destabilization that has a material adverse effect”.

The effect of riparian harvesting that occurred early in the history of forestry in the Chilliwack Valley has likely had the greatest negative effects on the Chilliwack River and its tributaries. **Under current regulations, this type of harvesting would not be allowed.**

Historical logging has increased the number of landslides that have occurred, although it appears that the overall effect to the channel network has not been significant. Current regulations and current practices are both aimed at reducing the number of landslides. Better identification of terrain susceptible to post-logging landslides is used to help avoid harvesting on terrain likely to have landslides (Millard et al. 2002). Improved road construction practices have dramatically reduced the number of road-related landslides on newer roads. The reduction in landslide rates in the Chilliwack Valley were noticeable by 2002 (Wolter, Ward and Millard, in press), indicating practices were likely changing before the introduction of the Forest Practices Code in 1995. Current forestry practices will almost certainly reduce landslide rates far below historical forestry-related rates and are unlikely to significantly affect the Chilliwack River. However occasional landslides will likely still occur. Some of these landslides may

occur due to inadequate practices by forest companies and should be addressed through Compliance and Enforcement actions. Other slides may occur naturally, or because there are always unknown conditions when operating in steep terrain. **Of the factors that affect the hydrology and geomorphology of the Chilliwack Watershed, landslides will require the most active management.**

Despite the minor effect of logging-related landslides to the Chilliwack River, these landslides can present significant hazards to fish habitat and water quality in smaller streams, or a safety hazard to users of the valley. Since these effects are site-specific, evaluation of these issues is outside the scope of this report. Site specific issues such as this are typically addressed during forest development planning.

The limited amount of land available for forest harvest in the Chilliwack Watershed suggests that peak flows in the mainstem Chilliwack River are very unlikely to be affected by forest harvesting. In part, this is due to the extensive parks in the American portion of the watershed, and in part due to the alpine and non-operable forest areas in the Canadian portion. Although the Chilliwack River itself is unlikely to be affected by changes in peak flows due to harvesting, some tributary watersheds could be affected by forestry-related peak flow changes due to their smaller size and possibly greater sensitivity.

Overall, current forestry practices and regulations should result in no increased hazards on the Chilliwack River. Smaller scale impacts are possible, such as landslides within a local area affecting a smaller stream channel, or presenting hazards to users of the valley.

The recurrent slides in glacial lake sediments (Slesse Park, Thurston Correction Camp, Ranger Run and Slesse Creek) may initiate new movement in response to forest development. Any plans for forest operations upslope of these slides should include an evaluation of the potential effect on the landslide. **Forest professionals may choose to restrict forest operations near these landslide sites as the development may present too great a hazard to people living downslope.**

Forest operations in the Chilliwack Valley should consider the potential for climate change. The discharge records of the Chilliwack River and Slesse Creek indicate the valley is currently experiencing higher than average flood flows. This is consistent with climate change models that predict southwest B.C. will become wetter as a result of increased atmospheric carbon dioxide content (Pike et al, 2008). Although the current flood flows are within the range of historic variability (the greatest flood in the record of the Chilliwack River occurred in 1917), climate change may result in new extremes of weather. **Forest operators should consider how their roads and forest harvesting will respond to greater extremes of precipitation.**

7.0 January 2009 rain-on-snow event

Much of southwestern B.C. experienced cold temperatures and substantial snow through late December 2008 and early January 2009. Starting on January 4th, temperatures moderated and rain began to fall, with heavy rain on January 6th and 7th. The weather conditions caused rapid snowmelt and in combination with the rain, there were large water inputs into the soil. Numerous landslides occurred in the Chilliwack Valley and flooding was common in Fraser Valley areas.

Within the Chilliwack Watershed, the following landslides, or similar type events, were reported:

- Road fill failure at Branch 11, Army FSR (Stephen Ngo email).
- Washout of road fill along Army FSR at 0.3 km (Stephen Ngo email).
- A series of 18 landslides along the Tamihi FSR between 2.5 km and 5.15 km (Stephen Ngo email).
- A landslide that impacted a house at Slesse Road and Bench Road (email from Betty Snerle to Allan Johnsrude August 29, 2009).
- A small slide in the vicinity of Slesse Road (email from Betty Snerle to Allan Johnsrude August 29, 2009).
- Numerous slides along the glaciofluvial escarpment between Vedder Crossing and Slesse Park on the north side of the Chilliwack River (Jim Dunkley pers comm. Jan 7, 2009).

Caine (1980) shows that, worldwide, landslides may occur when 48-hour water inputs exceed 157 mm. Table 1 shows 48-hour rainfall and estimated snowmelt totals for weather stations in the Fraser Valley area. The combined rainfall and estimated snowmelt are recorded as “total water input.” All of the stations with both rainfall and snow depth data (unfortunately the Chilliwack River Hatchery weather site does not have snow depth data) show total water inputs exceeded Caine’s threshold of 157 mm by substantial amounts. Given the very large amounts of rainfall and snowmelt, landslides would be expected.

Table 1. January 6th and 7th, 2009 rainfall and snowmelt totals¹

Station	Elevation (m)	Rainfall (mm)	Snowmelt ² (mm)	Total water input
Chilliwack River Hatchery	213	101	No data	NA
Abbotsford Airport	59	107	69	176
Agassiz	15	154	66	220
Mission West	221	138	120	258
Maple Ridge Kanaka Creek	76	119	66	185

1) Data from Environment Canada

2) Snowmelt is estimated from changing snow depths, and assumes a 30% density of snow

The BC Ministry of Environment snow pillow in the Chilliwack Valley is located at 1621 m elevation, and temperatures at the snow pillow during the rain-on-snow event barely exceeded 0°C (data from Allan Chapman, MOE River Forecast Centre). Significant snow melt was limited to lower elevation areas and this limited the extent of landslides and flooding. Slides appeared to be limited to low-elevation areas. Widespread flooding in low elevation, low lying areas occurred and appeared to be primarily a result of local ditches unable to handle the water generated from snow melt and rain. Flood flows on larger

streams such as Slesse Creek or the Chilliwack River was not significant, reflecting the limited portions of their watersheds that generated high volumes of streamflow. The flood level on Slesse Creek was slightly higher than the mean annual flood size ($95 \text{ m}^3/\text{s}$ compared to $89 \text{ m}^3/\text{s}$, respectively), and the flood level on the Chilliwack River at Vedder Crossing was much smaller than the mean annual flood ($308 \text{ m}^3/\text{s}$ compared to $480 \text{ m}^3/\text{s}$, respectively).

Wind speed is an important factor during rain-on-snow events. During rain-on-snow events, open areas such as subdivisions, farm fields, and clearcut areas typically have greater water inputs into the soil than forested areas since the trees reduce the wind speed, and therefore forested areas have lower snow melt rates. Individual landslides downslope of such openings may have been affected by increased water inputs. Landslides originating at roads may be related to drainage diversions or to unstable fill slopes. The location of many of the landslides in the lower Chilliwack Valley, and away from any Provincial Forest areas, would indicate that forest practices were not involved in these landslides. Other landslides occurred within or downslope of Provincial Forest areas and may have been a result of forest practices. Further comment on the causes of the landslides would require field work and is therefore not within the scope of this document.

8.0 Summary

In examining the effect of forestry on the Chilliwack River and its watershed, historical harvesting of riparian areas that would not be allowed today appears to have had a significant effect on the stability of the river and has likely resulted in extensive bank erosion. Landslide rates increased as a result of forest operations, particularly during 1973 – 1983. Since then logging-related landslide rates have declined, but are still elevated compared to natural landslide rates. The effect of logging-related landslides on the Chilliwack River appears to be minor as the average size of logging-related landslides is small, and therefore the total amount of sediment input into the Chilliwack River from logging-related landslides is also relatively small. In contrast, the amount of bank erosion far exceeds landslide sediment inputs. No changes in peak flow in the Chilliwack River have likely occurred, and are unlikely to occur in the future.

Although forestry-related landslides and peak flow issues do not appear to be significant for the mainstem Chilliwack River, within the smaller tributary watersheds these issues may become significant. FPPR regulations could restrict some forestry activities that can occur within these watersheds.

In all cases where people are exposed to landslides, the landslides present a safety hazard. **Forest operators should ensure that landslides do not occur where the landslide may result in a safety hazard or material adverse effect.** Slides in glacial lake sediments that occur in the lower valley have the potential to present the greatest risk to public safety, particularly in the area of Slesse Park. These areas warrant exceptional care.

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