Forest Practices Board

Logging and Winter Streamflow in Twinflower Creek

Complaint Investigation 110981

FPB/IRC/179

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Table of Contents

Board Commentary

This is the Board's second investigation of a complaint about the effects of pine beetle salvage logging on this watershed. The Board acknowledges the complainant's concern that his property, livelihood and the value of Twinflower Creek to his interests are at risk of harm by the cumulative effect of current weather, climate change, mountain pine beetle, and salvage harvesting. Of these, only salvage harvesting is effectively under human influence. In its 2008 *Mountain Pine Beetle Action Plan*, government indicated its intention to salvage harvest beetle-killed timber "while respecting other forest values."[1] A predictable and consistent supply of water for use by a rancher is a forest value.

The complainant expressed frustration that, under the framework of the *Forest and Range Practices Act* (FRPA), it is the forest licensee that decides whether to proceed with forest activities on Crown land that could negatively affect values on which he depends, as well as his assets and livelihood. As the Board observed in its earlier investigation, *Pine Beetle Salvage Logging and Water Flows near Williams Lake, BC*, it is the complainant that bears the risk of consequence and has no reasonable recourse if problems occur. In such circumstances, it is not surprising that the interests of forest licensees and other potentially affected people periodically collide.

In 2011, the complainant experienced an unexpected loss of water and two floods. The Board concludes that it is not practical to precisely quantify the extent to which forest practices may have contributed to these events; it is enough to know that, to some extent, forest practices likely influenced the situation. In this respect, the case illustrates the Board's concern about the cumulative effects of resource use on BC's landbase, and on the people affected.[2] It also underscores the need for greater knowledge about the effect of forest disturbance on groundwater, winter low flows and stream freezing.

[1] Objective #3: http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/actionplan/2005, accessed October 27, 2011.
[2] Forest Practices Board, "Cumulative Effects: From Assessment Towards Management," http://www.fpb.gov.bc.ca/SR39_Cumulative_Effects_From_Assessment_Towards_Management.htm?__taxonomyid=114, 2011.

The Investigation

In March 2011, the Forest Practices Board received a complaint from a rancher that a stream on his ranch had frozen solid, leaving 300 head of cattle without water for 10 weeks, a situation not previously experienced in the complainant's two decades on the property. The complainant believes that recent logging upstream of the ranch caused the watershed to dry out over the summer of 2010, leaving insufficient water for winter flow.

Background

The complainant's ranch is in the Twinflower Creek drainage, near the community of Big Creek, about 80 kilometres southwest of Williams Lake. On January 14, 2011, the flow in Twinflower Creek at the ranch declined and the stream froze solid to the stream bed, an event not previously experienced by the complainant, who typically waters his cattle by chopping through surface ice to expose the free-flowing water below.[3] Twinflower Creek at the ranch remained solidly frozen until March 21, 2011.

FIGURE 1. Twinflower Creek where it froze at the ranch.
(*photo taken August 2011*)

The complainant has a water licence on Twinflower Creek for power generation, usually obtains drinking water from a well (but uses stream water for drinking when the well is dry), and has a water licence for irrigation from a separate watershed. The complainant does not require a licence to use unrecorded (unlicensed) water from Twinflower Creek for either domestic or industrial purposes, the latter of which includes watering livestock. Prior to experiencing the stream freezing completely, the complainant described the usual supply of water from Twinflower Creek during winter as marginal but adequate for his purposes. Using the power generator as an indicator, the complainant estimated normal winter flow in Twinflower Creek to be about 100 gallons per minute or less.

Upstream of the complainant's ranch, Twinflower Creek is within a 3400 hectare pine-dominated watershed[4] that was extensively logged during the 1970s.[5] The area, recently logged

[3] The complainant has about 150 cow-calf pairs (roughly 300 head) and generally uses insulated water troughs away from stream to water the cattle, but they only operate when there is enough flow in the stream to charge an intake pipe.
[4] The total watershed area is about 8500 hectares.
[5] 1300 hectares were logged upstream of the ranch during the 1970s, 42 during the 1980s and 66 during the 1990s.

by Tolko Industries Ltd. (the licensee), was originally proposed for harvest by a former licensee in the 1990s, but the licensee at the time deferred its plans after the Ministry of Forests (now the Ministry of Forests, Lands and Natural Resource Operations [MFLNRO]) raised concerns about hydrologic risk. The risk was expected to decline as the old cutblocks regenerated. However, since 2004, most of the remaining mature pine has been killed by mountain pine beetle, further elevating the hydrologic risk.

Mountain pine beetle has created large forest disturbances across the central interior (subsequent to the image above), as pine-dominated forest stands were killed and then salvage harvested. The potential effects on watershed hydrology from these events include changes to:

- water yield (the total amount of water flowing out of a watershed in a year),
- low flows (the lowest streamflows of the year), and
- peak flows (the highest streamflows of the year).[6]

Flow in a stream is a function of the balance between precipitation, evaporation, transpiration, soil moisture and aquifer storage and release. In a forested watershed, disturbance of the forest stands through timber harvesting, severe fire and/or beetle attack can influence these factors and consequently affect streamflow. Recent studies in BC and elsewhere indicate that removal or thinning of the forest canopy increases snow accumulation, advances the timing and rate of snowmelt, and, because there are no longer live trees that use the water, raises soil moisture and

[6] Forest Practices Board, "The Effect of Mountain Pine Beetle Attack and Salvage Harvesting on Streamflows," http://www.fpb.gov.bc.ca/SIR16_The_Effect_of_MPB_Attack_and_Salvage_Harvesting_on_Streamflows.pdf, 2007.

also potentially raises groundwater levels.[7] In general, water managers believe that more water will be available year-round as runoff following significant disturbances such as clearcut harvesting, fire and beetle attack. Late season low flows are generally found to increase, or not to change, with forest cover removal.[8] However, there are no known studies about the effect of forest harvesting, fire or beetle attack on winter low flow and stream freezing.

This is the Board's second investigation into timber harvesting in the Twinflower Creek drainage. In 2008, the complainant was concerned that the then-proposed harvesting of about 300 hectares of beetle-killed timber would increase peak flows, worsen the potential for flood damage to his property, and reduce the ranch's water supply in summer. In its report, *Pine Beetle Salvage Logging and Water Flows near Williams Lake, BC,*[9] the Board found that peak flow changes in Twinflower Creek were likely even without the harvesting (due to the high proportion of trees killed by mountain pine beetle), and while the proposed harvesting would increase the probability of change, neither the consequences nor the degree to which further harvesting might worsen the situation were clear. The complainant responded that streamflow in Twinflower Creek was already so compromised that, if harvesting proceeded, it would have a large negative effect.

There is a history of periodic flooding and erosion events on the complainant's property. The substantial number of roads and amount of harvesting done in the 1970s altered natural drainage patterns and led to hydrologic concern, following some initial flooding and erosion at the ranch in the 1980s. In 1989, the Ministry of Forests channelized the stream through the ranch at the request of the landowner at the time, who sold the ranch soon after to the complainant. In 1991, runoff from a major storm caused considerable damage by scouring the stream into a deep gully and depositing the eroded material on the complainant's fields; the gully persists today. To control erosion, help restore natural drainage patterns and hasten the opportunity to harvest further timber, a Forest Renewal BC program in the mid-1990s deactivated many of the old forestry roads upstream of the ranch, but not all those repairs proved effective.[10]

[7] R. Winkler et al, "The Upper Penticton Creek Watershed Experiment: Integrated Water Resource Research on the Okanagan Plateau," In: One Watershed-One Water Conference Proceedings, Kelowna, BC, October 2008.
[8] R. Pike and R. Scherer, "Overview of the potential effects of forest management on low flows in snow-melt dominated hydrologic regimes," *BC Journal of Ecosystems and Management*, Vol. 3, No. 1, 2003.
[9] Forest Practices Board, "Pine Beetle Salvage Logging and Water Flows near Williams Lake, BC," http://www.fpb.gov.bc.ca/WorkArea/DownloadAsset.aspx?id=5503, 2010.
[10] P. Teti, "The Twinflower Creek Alluvial Fan, Williams Lake Forest District," unpublished report, Ministry of Forests, 1999.

From October 2009 to April 2010, over the complainant's objections, the licensee harvested 297 hectares in seven cutblocks located from 3 to 10 kilometres upstream of the complainant's ranch. In July 2010, Twinflower Creek at the ranch stopped flowing, but it is not unusual for the creek to go dry in summer. In January 2011, the stream at the ranch froze completely and remained frozen through to March. Later in 2011, two large floods negatively affected the complainant's ability to grow and crop hay, the first during snow melt in May, and the second following a thunderstorm in July.

FIGURE 2. A 2010 harvested cutblock and remaining beetle-killed timber.

Discussion

The complainant agrees that snow accumulation increases in forest openings, and that the rate and timing of snowmelt is advanced following forest canopy removal. The complainant noted that even though the weather was cool during the spring of 2011, snowmelt came early and more of the ranch pastures were flooded than usual. This is not unexpected; in its 2007 report, *Effect of Mountain Pine Beetle Attack and Salvage Harvesting on Streamflows*, the Board found, after studying a stream representative of many in the central interior, that the magnitude and timing of flood events were increased as a result of combined beetle attack and timber harvesting.

However, the complainant does not agree with the general belief that forest canopy removal will also typically result in sustained or greater low streamflow, particularly during winter. Instead, the complainant believes that the licensee's road-building and harvesting in Twinflower Creek caused the draining of soil moisture that otherwise would have been available in the ground for later release, and that subsequent runoff and evaporation during the summer and fall of 2010 further dried the area. In his mind, the result was reduced streamflow during winter and consequently an increased risk that Twinflower Creek would freeze completely.

The Board considered:

- What factors might reduce winter streamflow and affect freezing?
- How might these factors have affected Twinflower Creek during the 2010/2011 winter?
- What was the likely cause of Twinflower Creek freezing solid?

To answer these questions, the Board conducted interviews, reviewed available literature, field-visited the area and consulted hydrology and climate experts.

What factors might reduce winter streamflow and affect freezing?

For a stream that is usually ice-covered but flowing in winter to freeze solid (i.e., to have ice anchored to its bed) either: temperatures would have to be unusually cold; streamflow or water depth would have to drop sufficiently to allow typical cold weather to freeze the stream completely; or heat loss from the stream during winter would have to increase. Several factors—acting alone or in combination—could cause streamflows or water depth to decrease, or winter heat loss to increase. These are:

- drought
- cold weather
- lack of snow cover
- changes to natural drainage patterns
- changes to streamside vegetation
- reduced groundwater recharge due to soil compaction
- water extraction
- stream channel change

Most experts identified weather as the primary factor affecting winter streamflow and the potential for winter freezing; other factors were thought to be secondary. Unfortunately, there is no long-term and consistent source of weather data in the vicinity of Twinflower Creek. The nearest year-round official weather station is Williams Lake (80 kilometres northeast), while summer-only information is available from Riske Creek (45 kilometres northeast). The closest available weather information, from 2006 to 2011, was collected and kindly provided by a neighbouring rancher, whose property is located about eight kilometres from the complainant's. While these are the best available sources of weather data, they may not accurately represent the weather at Twinflower Creek.

How might these factors have affected Twinflower Creek during the 2010/2011 winter?

Drought

Changes in precipitation, both long- and short-term, can affect aquifer recharge and thus winter streamflow. The complainant's observation was that rainfall was normal at Twinflower Creek during 2010 (little rain during summer, but the fall was wet).[11] However, records from Riske Creek of summer precipitation for four of the past five years (2005-2010) were substantially below average. For summer 2010, precipitation was 70 millimetres compared to an average of 129 millimetres. Temperatures were slightly warmer than average. At Williams Lake, 2010 was the fifth driest and third warmest year on record (1960-2011). The four driest years all occurred prior to 1990, making 2010 the driest year of the past 20 years. In 2010, the mean annual precipitation at Williams Lake was 299 millimetres compared to an average of 435 millimetres. Temperatures in 2010 were considerably higher than average, and each season was also drier

[11] The complainant generally records rainfall at the ranch but the rain gauge was broken in 2010.

than average.[12] Precipitation records for the period 2005 to 2010, from a neighbour a few kilometres from the complainant's ranch indicated that 2010 was considerably drier than the previous four years.

Though not all streams behave similarly, summer streamflow in other monitored streams west of Williams Lake declined over the past few years—an indication of drought conditions.[13] Pond and lake levels in the surrounding area have also declined over the past few years and have yet to fully recover, another indication of persistent drought. Groundwater well records from Junction Sheep Range Provincial Park, some 40 kilometres east of Twinflower Creek also indicate a generally declining water level since 2008.[14] Reduced precipitation and warmer temperatures in the Twinflower Creek drainage, particularly over several years, would result in reduced low streamflow.

Cold weather

Excessively or prolonged cold weather might result in a stream that is usually ice-covered but flowing in winter to freeze solid. The complainant observed that the stream at the ranch froze solid on January 14, 2011. During the winter of 2010/2011, temperatures at Williams Lake were below average, the result of two persistent cold snaps. Mean temperature in November was twice as cold as usual (-4.3° Celsius compared to -2.4° Celsius), December and January were near normal, and February was twice as cold as usual (-8.9° Celsius compared to -4.2° Celsius).

Temperature records from a neighbour a few kilometres from the complainant's ranch showed a cold snap from November 21 to 24, 2010, of -14° to -29° Celsius. According to those records, typical temperatures during November from 2005 to 2011 ranged from 0° to -14° Celsius. A cold snap similar to November 2011 also occurred in November 2006.

Temperatures were about normal when the stream froze at the ranch in January, but the cold snap in November could have frozen upper elevation water sources earlier or more completely than usual, and thus prematurely reduced the flow of water that would otherwise have contributed to later winter flow in Twinflower Creek.

Snow cover

Observations from northwestern BC suggest that the depth of snow can influence stream freezing.[15] For example, at -35° Celsius, and without snow cover, a stream flowing through coniferous forest and an adjacent clearcut was observed to have frozen solid. However, after a one metre-plus snowfall event, the section of stream through the clearcut began to flow again below the surface ice and snow. Presumably, the combination of warm groundwater inputs and the insulating effect of the snow thawed the ice anchored to the stream bed. Conversely, in the

[12] Weather record summaries provided by provincial climatologist V. Foord, MFLNRO, Prince George.
[13] MFLNRO, Williams Lake.
[14] Observation well #376 http://a100.gov.bc.ca/pub/gwl/disclaimerInit.do (see Riske Creek records, accessed October 16, 2011).
[15] MFLNRO, Smithers.

forested section of the stream, the tree canopy had intercepted much of the snow, leaving the stream channel below largely snow-free; it remained solidly frozen.

The complainant described snow cover at Twinflower Creek as being shallow for many years with no substantive snowfall during the winters of 2009/2010 and 2010/2011. Photos taken by the licensee during both winters confirm there was little snow cover. Reduced snow cover (during the November cold snap) could have contributed to upper elevation surface waters freezing more completely than usual, thus reducing water input to the main stream channel during winter.

Changes to natural drainage patterns

If natural drainage patterns were disrupted in the watershed such that water normally held in the soil was intercepted (e.g., by a road cutbank and ditchline) and discharged from the drainage early, less water might be available during low flow periods.[16] The complainant considers that groundwater seepage from road cutbanks drained and helped dry the hillsides that, when forested, maintained a steady flow of groundwater to the stream in winter.

The *Forest and Range Practices Act* (FRPA) requires that a forest licensee maintain natural surface drainage patterns during and after construction of roads and other access structures.[17] Several of the licensee's road cutbanks and ditchlines intercepted subsurface flows,[18] concentrated the water in ditches and discharged the flows to soak into the forest floor nearby, but nothing was outside the range of typical forest practices. Overall, the licensee maintained natural surface drainage patterns.[19]

The subsurface flows intercepted by the licensee's road cutbanks and ditches, though not individually excessive, were of relatively steady and continuous volume.[20] Although the intercepted water was returned to the forest floor down slope, the timing and rate of delivery of that water to the main channel below was likely altered. Intercepted and concentrated subsurface flows could augment low streamflow in summer but, in the absence of normal precipitation, it would serve to reduce streamflow in winter as soil moisture in the affected areas decline and/or the cutbank seepage areas later freeze.

FIGURE 3. Cutbank seepage in road ditch (August 2011).

[16] Carver, M, "Using indicators to assess hydrologic risk," *i*n: Watershed Assessment in the Southern Interior of British Columbia: Workshop Proceedings, Penticton, March 9-10, 2000. Ministry of Forests working, 2001, p. 57.
[17] Section 39(1) of the *Forest Planning and Practices Regulation*.
[18] The Board inspected the licensee's harvesting and roads in the Twinflower Creek drainage on May 31 and August 9, 2011.
[19] There was one minor exception concerning a wet area near Cutblock 8.
[20] Based on the Board's spring and summer visits, and the complainant's observations of ice "tongues" on the cutbanks (indicating seepage over winter).

Changes to streamside vegetation

Overhanging streamside vegetation can influence the rate of radiation loss and thus affect the cooling of water in the stream, and the amount of soil moisture and frost adjacent to the stream.

During harvesting, the licensee removed merchantable conifers along several small drainage areas in some cutblocks. In addition, some proportion of the remaining trees retained in several of those areas blew down subsequent to logging. Reduced coniferous cover overhanging surface drainages in the cutblocks may have increased heat loss through radiation and contributed to those drainages freezing earlier or more completely, thus reducing flows that would otherwise have augmented winter flow in Twinflower Creek.

One way that coniferous forest cover removal has been linked to reduced late season low flow is through deciduous colonization of disturbed riparian areas. In an Oregon study, water use by rapidly growing deciduous trees apparently exceeded the increase in flow that resulted from the initial logging, so summer streamflow declined.[21] Rapid deciduous growth, should it occur in the small logged drainage areas in the Twinflower Creek watershed, may affect summer flow in those areas. Where the stream froze at the ranch, there are few streamside deciduous trees and shrubs. These have grown larger, but have not otherwise changed for at least 20 years.

Reduced groundwater recharge due to soil compaction

Soil compaction during road-building and timber harvesting could redirect and reduce infiltration of precipitation and cause it to runoff instead of recharge soil moisture and area aquifers. Soil compaction would have to be extensive to affect streamflow or groundwater recharge within an entire watershed, so FRPA puts a limit on the amount of soil disturbance (temporary roads, gouges, ruts, scalps and compacted areas) and permanent access structures allowed during timber harvesting. Some rutting occurred in one of the Twinflower Creek cutblocks,[22] but in that and the other cutblocks, the licensee's road and harvesting practices were within FRPA's limits for soil disturbance. It is unlikely that soil compaction contributed to reduced streamflow or the freezing of Twinflower Creek.

Water extraction

If a large amount of water was extracted from the Twinflower Creek watershed upstream of the complainant's ranch, winter streamflow at the ranch could be reduced. There is no indication that any major water extraction occurred, so this factor did not contribute to streamflow decline or the stream freezing.

Stream channel change

Water depth can influence how completely a stream might freeze; the shallower the water, the more likely it is to freeze solid. The complainant observed that streamflow above the ranch

[21] Hicks, B.J., R.L. Beschta and R.D. Harr "Long-term changes in streamflow following logging in Western Oregon and associated fisheries implications," *Water Resources Bulletin*, 17:217-226, 1991.
[22] An area of moderate compaction hazard within Cutblock 6.

declined in mid-November. An additional drop in streamflow occurred in mid-January prior to the stream at the ranch freezing solid.

Changes to the stream channel, such as aggradation, widening or other erosion could affect water depth. Channel aggradation occurs when materials deposit in the stream channel. If the deposited material is sufficiently porous it may diminish surface flow. If not, the stream channel may overfill and widen, ultimately reducing water depth.

No recent changes to channel condition were apparent upstream of the ranch. Neither aggradation nor significant widening of the stream channel is apparent in the area that froze in 2011. However, this part of the stream flows in a gully over an alluvial fan, laid down over thousands of years by earlier stream deposits. The porous nature of the sands, gravels and cobbles that make up the fan might allow water to flow subsurface at anytime anywhere within the fan. Therefore, water depth in the stream channel could be influenced as gully conditions change and the stream channel encounters old deposits of varying porosity. However, gully change was not apparent through 2010, so this factor is unlikely to have contributed to streamflow decline or the stream freezing.

What was the likely cause of Twinflower Creek freezing solid?

There is no obvious answer to this question so it is likely that several of the factors above combined to cause Twinflower Creek to freeze solid. Temperatures in mid-January were not particularly cold, so the stream freezing at that time was more likely related to reduced streamflow and shallow water depth—as observed by the complainant in mid-November and again in mid-January. But, what caused these drops in flow?

Climate is an important factor that influences low streamflow.[23] Drought and lower than usual snowfall before and during 2010 would have reduced water input to the watershed. Reduced water input would eventually result in reduced streamflow, with or without forest harvesting. Such a finding is confounded, however, by the increased soil moisture to be expected following removal of forest cover, in this case, by beetle attack and logging.

Some of the licensee's road segments intercepted subsurface flows and discharged them nearby to the forest floor down slope, where they could continue on their way, subsurface, to the stream channel below. The influence of the new roads and resulting cutbank and ditch drainage on streamflow in Twinflower Creek is impossible to gauge without detailed hydrologic study beyond the scope of this investigation. The complainant holds the opinion that because the licensee's roads traverse much of the water-producing valley slope, they are a significant factor affecting streamflow. However, the roads were built to proper standards and, while there are some locations that intercept and concentrate groundwater, they are not widespread. Hence, the Board considers road drainage to be a contributing, but not a primary factor affecting streamflow in Twinflower Creek.

[23] R. Pike and R. Scherer, "Overview of the potential effects of forest management on low flows in snow-melt dominated hydrologic regimes," *BC Journal of Ecosystems and Management*, Vol. 3, No. 1, 2003.

FIGURE 4. Frozen groundwater seepage, observed by the complainant in February 2010.

The cold snap in mid-November, lack of insulating snow cover and reduced coniferous cover from beetle attack, road construction, logging and subsequent windthrow likely caused the upper elevation surface streams and road cutbanks with groundwater seepages to freeze. Water in these locations, with little to no insulating snow, would have continued to freeze and remain frozen until the spring thaw, confining soil moisture and groundwater that would otherwise have contributed to later winter flow.[24]

There is no apparent reason for the mid-January drop in streamflow that occurred just before the stream froze completely at the ranch. Likely, the remaining upstream groundwater and soil moisture reserves declined beyond the threshold needed to maintain surface flow at the ranch. With no further groundwater input or surface runoff from above, and continued sub-freezing weather through February, surface flows at the ranch could not recover and remained frozen for the remainder of the winter.

The complainant disagrees with the potential significance of the November cold snap because the stream at the ranch did not freeze completely following a similar temperature drop in November 2006, but in the Board's view, there are too many variables—amount of precipitation, the status of coniferous cover at the time, and depth of snow to name a few—and not enough data about them and how they interact to make a definitive comparison. The complainant commented that such uncertainty suggests a need for further study. In response to such concerns, early in 2011, the Ministry of Forests, Lands and Natural Resource Operations began collecting data to assess streamflow and stream condition relative to timber harvesting in an area that includes Twinflower Creek[25].

In summary, this investigation indicates that there was no one factor that caused Twinflower Creek to freeze solid in January 2011. Ultimately, it was a succession of unfortunate events:

- a dry year,
- a disturbed landscape,
- a slow but steady depletion of soil moisture, and
- an early-winter cold snap that reduced water input to the main stream channel.

[24] Kane, D.L., R.F. Carlson, and C.E. Bowers, "Groundwater pore pressure adjacent to subarctic streams," North American contribution, 2nd International Conference on Permafrost, Yakutsk, U.S.S.R. National Academy of Sciences, Washington, DC, 1973, pp. 453-458.
[25] MFLNRO, Williams Lake.

Conclusions

Hydrologic processes are complex; there are many confounding and inter-related factors that may affect them. Assessing the influence of various land conditions and land use activities on low winter flow and stream freezing is particularly vexing, as these processes are not well understood.

On balance, Twinflower Creek froze solid in January 2011 because of a succession of events:

- the year 2010 was drier than normal;
- the watershed was disturbed and its hydrologic processes affected by past timber harvesting, substantive beetle attack and the recent salvage harvesting;
- road construction had intercepted some subsurface flows, potentially altering the timing and rate of delivery of that water to the stream below; and
- an early-winter cold snap likely froze higher elevation surface waters and the intercepted groundwater seepages that would otherwise have contributed to the usually marginal winter streamflow.

As upstream water reserves declined, so did streamflow, thus increasing the risk that Twinflower Creek would freeze solid. With no further groundwater input or surface runoff from above, and continued sub-freezing weather, the stream at the ranch could not recover and remained frozen for the remainder of the winter.

The complainant asserted that the recent logging upstream of the ranch caused the watershed to dry out, leaving insufficient water for winter flow. However, in the Board's opinion, it was the preceding weather, specifically drought conditions and an early cold snap that primarily affected the normally marginal winter streamflow, and the recent timber harvesting activities added to the hydrologic issues already affecting the watershed. This is a cumulative effect—any further forest harvesting proposed in the Twinflower Creek watershed should first be assessed through a professionally-conducted hydrological review to identify and mitigate any potential negative impacts on downstream values, including potential effects on seasonal water supply and private property. Such assessments should also consider whether there are opportunities to improve the condition of the watershed in association with forest development.

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