EXPLORATION GEOCHEMISTRY – SEDIMENT SUPPLY TO HARRIS CREEK (82L/2)

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INTRODUCTION

Stream sediment geochemical anomalies are often interpreted with reference to an idealized dilution model, based on catchment area, that supposes a smooth exponential decay of the anomaly away from its source (*e.g.* Rose *et al.*, 1979, pages 399-400). The model involves several assumptions, one of which is that supply of sediment to the stream by erosion is constant throughout the catchment. However, in streams in hilly or mountainous terrain, significant amounts of sediment are derived from individual mass-wasting events (*e.g.* debris flows) or are locally stored in the stream channel and only intermittently released. The frequency and distribution of such events is not constant throughout a catchment, and this will clearly influence decay rates for geochemical anomalies both locally and throughout the length of the stream. This has not been studied. Our objectives, therefore, are to investigate the magnitude of these effects and to establish practical limits to the idealized dilution model. We have initiated the study with an investigation of sediment supply in Harris Creek, east of Vernon (Figure 4-2-1), the site of ongoing studies of fluvial processes and transport of gold in streams (Day and Fletcher, 1989, *in press*; Fletcher, 1990; Fletcher and Day, 1988; Fletcher and Wolcott, submitted).

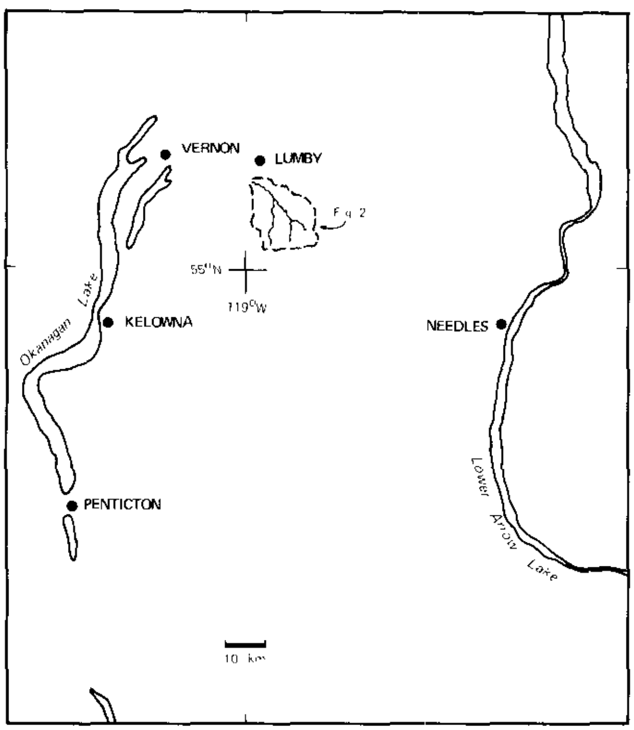

Figure 4-2-1. Location map for Harris Creek study area.

A preliminary inventory of sediment sources has been conducted by terrain mapping of the 225 square kilometre basin of Harris Creek. The 1:20 000-scale terrain map shows the distribution of active mass-wasting and bank erosion, as well as the distribution of surficial materials and landforms. Many mass-wasting sites were examined in the field in order to assess their relation to Harris Creek. Estimation was attempted of the volume of sediment supplied, and the timing of events was investigated by dendrochronology.

PHYSIOGRAPHY OF THE STUDY AREA

Harris Creek basin occupies part of the dissected plateau of the Okanagan Highland. The gently undulating plateau surface, between 1300 and 2000 metres above sea level, constitutes about two-thirds of the catchment (Figure 4-2-2). The downstream sections of Harris Creek and its major tributaries, however, occupy steep-sided valleys that are incised as much as 750 metres below the plateau surface. Mean valley side gradients range from 20° to 38°.

Three types of stream course are clearly differentiated within this physiographic setting (Figure 4-2-2).

- On the plateau surface, stream gradients are gentle, generally between 1° and 5°. Numerous lakes and bogs along the stream courses trap any sediment that is mobile. Consequently, sediment supply from the uplands to points downstream is negligible.
- Streams descend steeply (6° to 17°) from the uplands through V-shaped valleys where colluvial slopes adjoin the stream channel and no valley flat is present.
- On the main valley floor, stream gradients are between 1° and 2°, and a valley flat is present. This type of stream course is restricted to lower Harris Creek.

Bedrock in the study area was mapped by Jones (1959). The eastern part of the basin is underlain by Tertiary volcanic rocks of the Kamloops Group. Tuffs and breccias are widespread, as well as basalt and other lavas. Tertiary gravels (conglomerates) were noted in a few places. These various lithologies contribute a range of detritus, including a silty till matrix and abundant pebbles, to overlying Quaternary sediments. The volcanic rocks, particularly breccias, form prominent scarps along the plateau margins. In several places, topographic features downslope from the scarps suggest that massive slope movements within the volcanic rocks have affected many square kilometres of the study

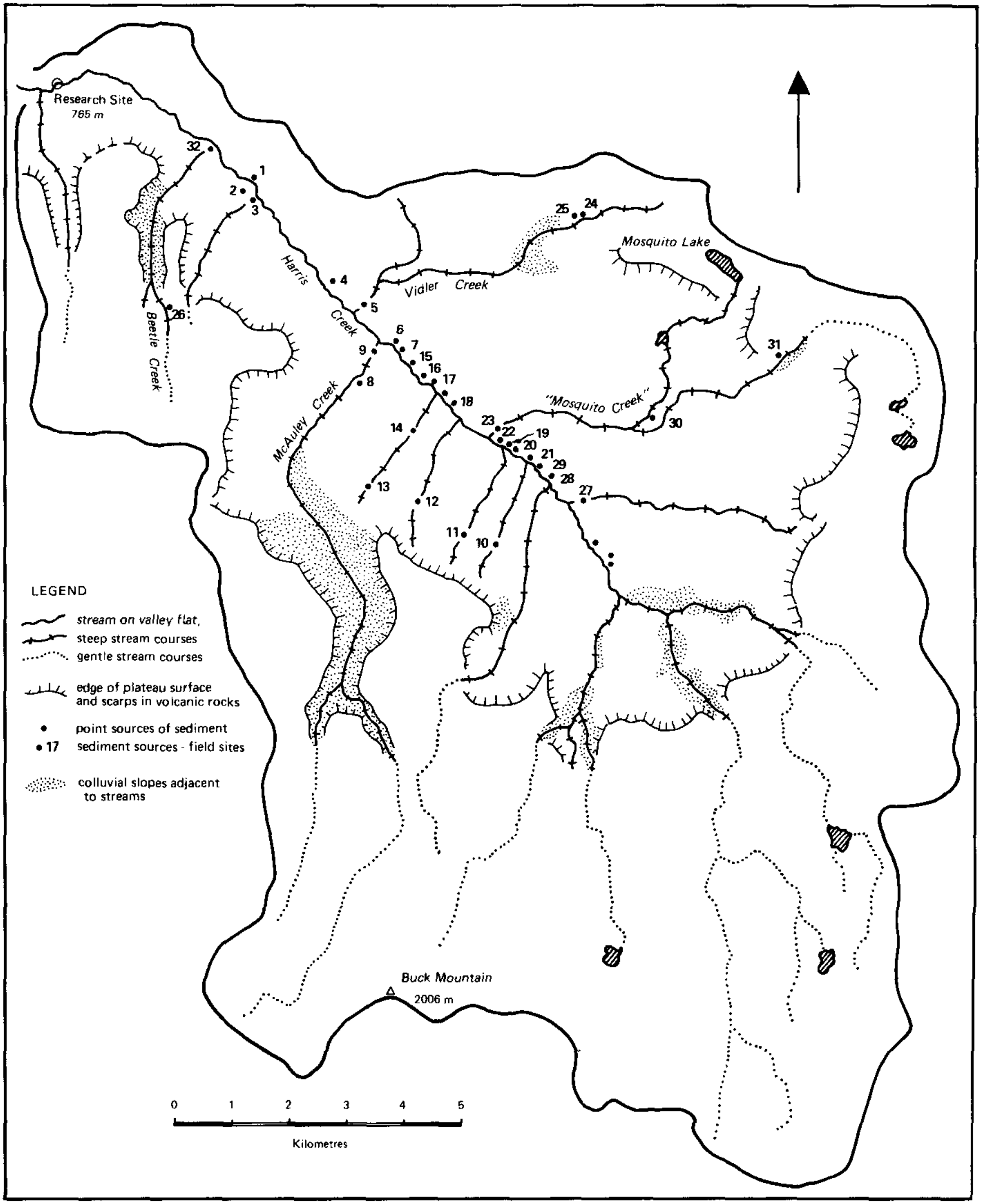

Figure 4-2-2. Harris Creek basin: physiographic features and field sites.

area. The features are till covered, however, suggesting that they predate the last glaciation.

The northwestern and southwestern parts of the study area are underlain, respectively, by acidic plutonic rocks and gneiss of the Shuswap complex. These provide relatively large clasts and coarse sand to the sediment system.

During Fraser Glaciation, the entire study area was buried beneath southward-flowing ice, and all but the steepest slopes still retain a drift cover. In many places, the characteristics of this material determine the mode of sediment supply to Harris Creek. Till is widespread on valley sides. Its texture and lithology are variable, being strongly influenced by the proximity and type of the underlying bedrock. Pockets of stratified drift are scattered throughout the till.

Within about 150 metres elevation of the valley floor along lower Harris Creek, terraces and undulating benches at several levels are underlain by thicker drift consisting of glaciofluvial gravels, glaciolacustrine silt and fine sand, and till. The till is sandwiched between two units of glaciolacustrine sediments, suggesting that Harris Creek drainage was impounded by ice during both early and late phases of Fraser Glaciation. Well-defined terraces are underlain by glaciofluvial sand and gravel.

Relatively little modification of the landscape has occurred during the past 10 000 years. A broad floodplain (now forested) has developed along lower Harris Creek, and small alluvial fans have formed at the mouths of the larger tributaries. Mass movements such as rockfall and debris flows on the steepest slopes have resulted in the accumulation of talus and colluvial fans. Widespread rock slumps (much smaller than the preglacial features mentioned above) have been active along the volcanic rock scarps during Holocene time. A few of these may influence sediment input to the steep middle courses of some streams.

THE SEDIMENT CASCADE

A framework for the analysis of sediment supply to lower Harris Creek is represented schematically in Figure 4-2-3. This demonstrates that sediment mobilization on valley sides does not necessarily coincide with sediment supply to a stream channel. For example, material moved in debris flows and landslides may reach a creek or it may be temporarily stored on lower valley sides and fans. Sediment that is transported by tributary creeks may accumulate on alluvial fans, rather than being entrained by the trunk stream. Remobilization of stored sediment may occur after a few years (*e.g.* trunk stream erosion of the toe of a fan), or it may not occur until the next regional glaciation (*e.g.* sediment buried beneath the apical part of a fan). The diagram also indicates that sediment supply from the upstream to the downstream reaches of lower Harris Creek is not a continuous process, but that channel material may be temporarily stored in the old floodplain or in channel bars for time periods ranging from one year to several millenia.

In view of these processes, and since research on sediment transport has, so far, been concentrated at the downstream end of Harris Creek, particular attention was paid to sediment supply to lower Harris Creek.

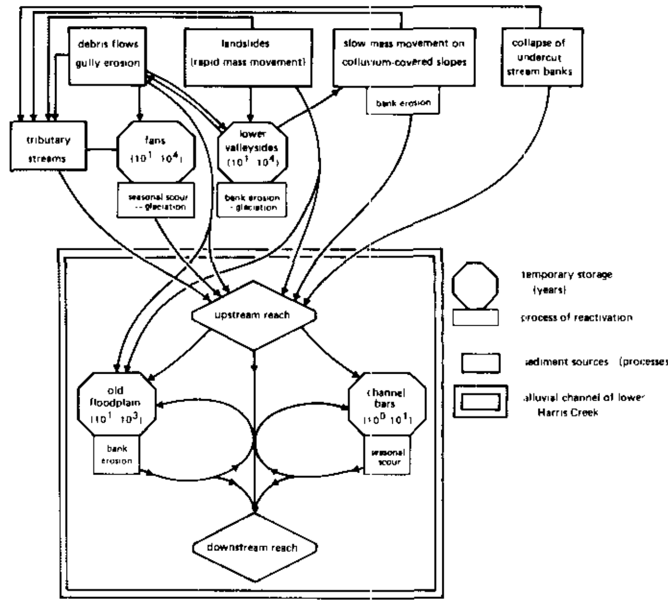

Figure 4-2-3. Sediment cascade for Harris Creek.

MASS MOVEMENTS

SLUMPS AND SLIDES IN DRIFT

Landslides in till and glaciolacustrine sediments (Figure 4-2-4) are common on the scarp of a more or less continuous bench that extends along the north side of lower Harris Creek. Conditions contributing to slope failure include steep slopes, thick and weak materials (silt with minor fine sand and clay, and silty diamicton), and saturation by groundwater. Slope movements appear to have been triggered by undercutting by Harris Creek, because a stream channel (either the present channel or a recently abandoned channel) abuts the toe of almost every landslide.

Of the fourteen landslides of this type that were examined in the field (Figure 4-2-4, Table 4-2-1), only four appear to be active (moving slowly) at present: one of these (SS18) debouches into an abandoned channel, but the other three (SS1b, SS7a, SS28) feed directly into Harris Creek. Of ten inactive features, nine are adjacent to abandoned channels and one (SS17) is being undercut by the active channel of Harris Creek. Minor gully erosion and very small debris flows (<10 m^3) have occurred on the toes of some of the inactive features within the past one or two years.

Preliminary results from the analysis of increment cores from trees on stationary slump blocks suggest that they have not moved significantly for intervals that vary from 25 to 80 years. Trees on inactive (but sparsely vegetated) slide scars and on the slump toes indicate that sites have been stable for 6 to 80 years. Thus it appears that slumping occurs intermittently (Table 4-2-1). Consequently, the significance of these landslides as sediment sources (in the short term) depends upon whether or not a period of active slope movement coincided with the presence of an active channel at the toe of the slump. More dendrochronological dating of both slumps and fluvial features would possibly allow a more precise assessment of the frequency of sediment input to Harris Creek. Success of such a dating program would depend upon the presence of pioneer trees on the critical sites.

Measurements were made of the approximate dimensions of most slump blocks and slide scars (Table 4-2-1) in order to attempt estimates of the volume of material displaced by slope movement. Determination of potential volumes contributed to the bedload (*i.e.* sand and gravel) of Harris Creek is complicated by the fact that the landslide materials include a high proportion of finer material that would be rapidly removed from the creek as wash load after a landslide event. Proportional clast content in till was estimated visually and the relative volumes of till and glaciolacustrine sediments involved in a slope failures were estimated according to the area of their outcrops in the slide scar. These data were used to calculate approximate gravel volume equivalents for a few sites. Individual slump blocks appear to contain in the order of hundreds of cubic metres of gravel; total volumes of gravel that have been displaced from landslide scars, that is the volume of the empty concavities, range from hundreds to thousands of cubic metres.

TABLE 4-2-1
LANDSLIDES IN DRIFT ADJACENT TO LOWER HARRIS CREEK
CHARACTERISTICS AND RATING AS SEDIMENT SOURCES

Number[1]	Description[2]	Material involved	Relation to stream[3]	Width[4] (m)	Height (m)	Age[5] (yr)	Rating[6]
SS1a	slump	till, silt	ic	107	58	>10	H
SS1b	slide/fall*	till, silt	ac	56	24	A	P
SS4	slide scar	silt	of	20	30	>3	h
SS6	slide scar	till, silt	ic	17	36	>30	h
SS7a	slide scar*	till, silt	ac	34	36	A	P
SS7b	slide scar	till, silt	of	20	36	>60	h
SS8	slump	till, silt	of[m]	25	20	>25	h
SS15	slump	till, silt	of	60-100	68	>80?	H
SS17	slump	till, stil	ac	50?	70	A	P
SS18	slump*	silt	ic	60	61	A	H
SS19	slide scar	till, silt	ic	30-40	40?	(–)	h
SS20	slide scar	till, silt	ic	30-40	40?	(–)	h
SS21	slide scar	till, silt	ic	40?	40?	(–)	h
SS28	slump*	gravel	ac	30?	24	A	P

[1] SS=sediment source.
[2] *=active or partly active landslide.
[3] landslide descends to: ic=inactive (abandoned) channel; ac=active channel; of=old floodplain; m=lower McAuley Creek.
[4] ? indicates approximate.
[5] estimate only: based on age of one or two trees; (–)=no data; A=active.
[6] H=former (historic) major source; h=former minor source; P=major source at present; p=minor source at present.

Debris Flows

Evidence of recent debris-flow activity was found at only one site (25 on Figure 4-2-2), although the presence of gullies cut into drift on steep slopes (both mountainsides and terrace scarps) suggests either that this process operates very sporadically or that it was more effective at some past period of time. Debris flows may also be contributing sediment to Harris Creek indirectly if debris-flow fans are being undercut by bank erosion (Figures 4-2-3), but no such sites were specifically noted.

Other Forms of Rapid Mass Movement

Collapse of undercut valley sides and rockfalls appear to contribute minor amounts of bed material to Harris Creek. Where the creek occupies a broad valley flat, it rarely impinges on the valley sides (except at sites where landslides have occurred as described above). Only two undercut banks in unconsolidated materials were identified; the one of these that was examined in the field had supplied about 1000 cubic metres of sediment directly to Harris Creek, but the time span over which this had occurred is not known. Along much of lower Harris Creek, the southern side of the valley flat is flanked by a bedrock scarp. Where the creek flows against the toe of this scarp, which is commonly a near-vertical cliff in such locations, angular blocks in the stream channel indicate where minor rockfalls (no more than a few cubic metres) have occurred. Very little mobile sediment seems to be contributed by this process.

In a few places, mostly along tributary streams, minor (100s of cubic metres) amounts of logging road materials have moved downslope to a stream channel (Figure 4-2-2, sites 21, 22, 39).

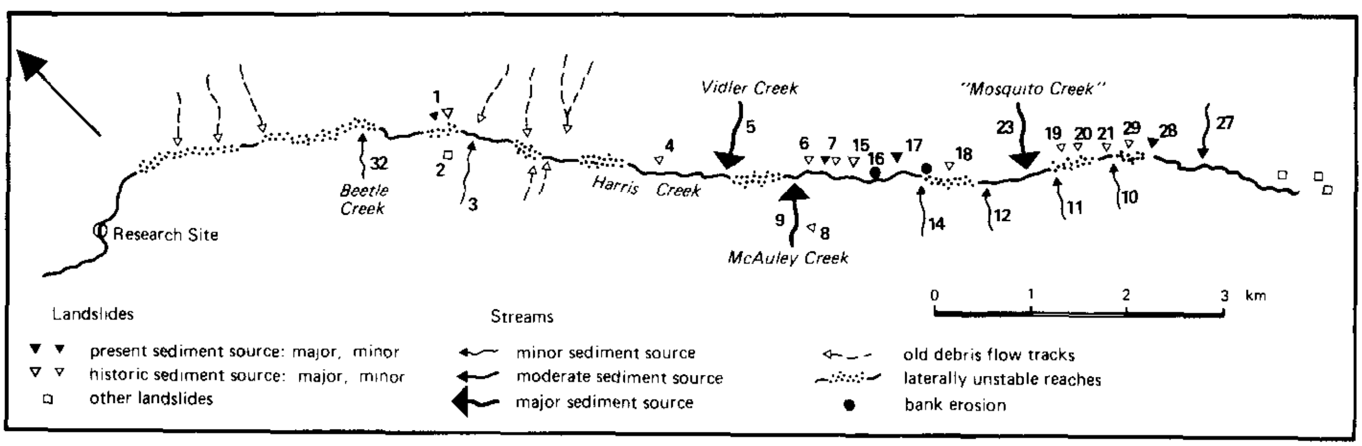

Figure 4-2-4. Sediment sources along lower Harris Creek.

Slow Mass Movement on Colluvial Slopes

Slow mass movement of colluvium toward stream channels is occurring along the steep, mid-courses of Harris Creek and its tributaries (Figures 4-2-2 and 3).

Sediment Input From Tributary Streams

Bedload transport in tributary streams that enter lower Harris Creek was assessed visually at sites adjacent to Harris Creek and, for some creeks, at more distant locations. Volumes of sediment contributed were rated qualitatively according to the width of the stream channel and active floodplain, the apparent freshness of gravel in the channel, and the presence of features such as pools and riffles, bars, and logjams (Table 4-2-2, Figure 4-2-4). Fortuitous deposition upstream of a culvert at Vidler Creek allowed an estimate of at least 120 cubic metres bedload transport during a recent flood.

TABLE 4-2-2
TRIBUTARIES OF LOWER HARRIS CREEK
SEDIMENT SOURCE RATINGS

Tributary (number)	Width of channel/ active zone (m)	Qualitative estimate of bedload transport	Rating as sediment source
1 km east of Beetle Cr. (SS3)	1.0	inactive	minor
Vidler Cr. (SS5)	2.0	very active*	major*
McAuley Cr. (SS9)	3.0/7.0	very active	major
(SS10)	1.0	inactive	minor
(SS11a)	1.5	mod. active	} minor
(SS11b)	2.0	inactive	
(SS12)	1.3	inactive	minor
(SS13/14)	1.5	inactive	minor
"Mosquito Cr." (SS23)	3.6	very active	major
(SS27)	3.3	mod. active	moderate
Beetle Cr. (SS32)	1	mod. active	minor

* Sediment transport to Harris Creek currently restricted by culvert.

FLUVIAL PROCESSES ALONG LOWER HARRIS CREEK

Lower Harris Creek occupies an active channel zone that is flanked by an extensive old floodplain. In places gravel is being supplied to the active channel from the old feature, and this appears to be a significant source of sediment for lower Harris Creek.

The old floodplain, which, together with the active channel zone, constitutes a valley flat that varies in width from about 100 to 350 metres, typically stands 0.5 to 1.5 metres above the gravel bars of the active channel zone. It is occupied by mature forest, suggesting an age of at least several hundred years. The floodplain surface is underlain by overbank sediments, 0.5 to 1.5 metres of thinly interbedded silt and sand, which commonly contain paleosols, layers of forest litter, charcoal or wood fragments (Plate 4-2-5). Channel gravels underlie the overbank sediments along a contact which ranges in elevation from below present stream level to approximate high-water levels.

Preliminary assessment of the characteristics of the active channel zone suggest that it consists of alternating reaches of relatively active and less active sediment (largely bedload) transport (Figure 4-2-4). In active reaches, the stream channel is laterally unstable; the active channel zone is several times as wide as the stream channel and includes recently deposited (or reworked) gravel bars. The presence of numerous fallen trees attests to recent severe bank erosion and broadening of the active zone at the expense of the old floodplain. Such instability progresses downstream, leaving behind partly eroded bars that are above normal flood levels and undergoing recolonization by vegetation. Detailed surveys of fluvial features and dendrochronological dating could be used to estimate the magnitude and timing of sediment movement in these reaches. It is possible that instability in initially stable reaches could be triggered by the development of logjams or by a sudden influx of

Plate 4-2-1. Overbank sediments exposed by recent erosion of Harris Creek about 1 km upstream from Research Site (Figure 4-2-2). Note well-defined paleosol at 31-35 cm, lower discontinuous paleosol (faintly defined at 50 cm), and underlying channel gravels (>60 cm).

sediment from a landslide, as well as by downstream progression. Estimates based on a few measurements at one site suggest that from several hundred to a few thousand cubic metres of sediment could be mobile in a single unstable reach. This quantity is of similar order of magnitude as estimates of the total volume of gravel represented by a single landslide scar, and an order of magnitude greater than the volume of gravel likely to be contained in a single slump block or a single landslide event.

In less active, laterally stable reaches, the active channel zone is relatively narrow, commonly no wider than the stream channel during floods. Bank erosion occurs on bends, resulting in the transfer of relatively minor amounts of sediment — no more than a few cubic metres per site per flood event — from the old floodplain to the active channel.

SUMMARY OF SEDIMENT SOURCES

A preliminary classification of sediment sources adjacent to lower Harris Creek is indicated in Tables 4-2-1 and 2 and Figure 4-2-4. Sources are rated according to their relative magnitudes, and in the case of landslides, according to their proximity to the present channel of Harris Creek. Landslide and tributary sources cannot be compared directly, however, since the dates and magnitude of specific landslide events and the volumes of stream sediment transport are not known.

CONCLUSIONS

Sediment supply to Harris Creek is discontinuous both spatially and temporally. Sediment that is mobilized on slopes or along tributary streams may be supplied to the trunk stream or it may be stored temporarily on lower valley sides, in fans, or on the old floodplain and abandoned channels of lower Harris Creek; storage times range from one to tens of thousands of years. Only four of fourteen landslides along lower Harris Creek are currently supplying sediment to the trunk stream; other landslides are stable at present or debouch into inactive channels. Only the three largest tributaries appear to regularly contribute significant bedload to the trunk stream. Along lower Harris Creek, relatively large volumes of bedload material are being derived from the old floodplain by bank erosion in several laterally unstable reaches. The volume of mobile gravel within each unstable reach may be similar to the total volume of gravel supplied by a single landslide.

ACKNOWLEDGMENTS

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