2.0.0. STUDY AREA

The study streams are situated in the vicinity of Fundy National Park, New Brunswick (45°37'N, 65°03'W) (Figure 1). Four are located within the park, while the remaining 12 are in clearcuts close to the Park boundaries: within 5 km to the west, 4 km to the north, and 4 km to the northeast. In total, the study area spans approximately 300 km^2. All the study watersheds drain into the Bay of Fundy (Map, Figure 2).

The Park and surrounding area is situated on a rolling plateau, dissected by deep, steep-sided river valleys. The plateau reaches elevations of over 300 m within 4-5 km of the coast, but seldom exceeds 350 m above sea level (Woodley 1985). Most of the plateau is covered by morainic deposits of till, including silt, sand, gravel, and rubble (Woodley 1985). The most common soil type overlying the glacial till is a stony, Lomond loam. The steeper slopes are well-weathered and partially disintegrated, glacially-molded bedrock.

Most of the study area is underlain by highly deformed volcanic and sedimentary rocks of Precambrian age. Streams located to the west and northwest of the Park (including Dustin Bk.,#15, #40, #41, #21 and #45) are underlain by Precambrian deformed granodiorite, granite and minor gabbro, and the remaining streams are underlain by Precambrian basaltic and rhyolitic volcanics deposited in shallow

Figure 1. Map of New Brunswick, Canada, with Fundy National Park in southeast corner.

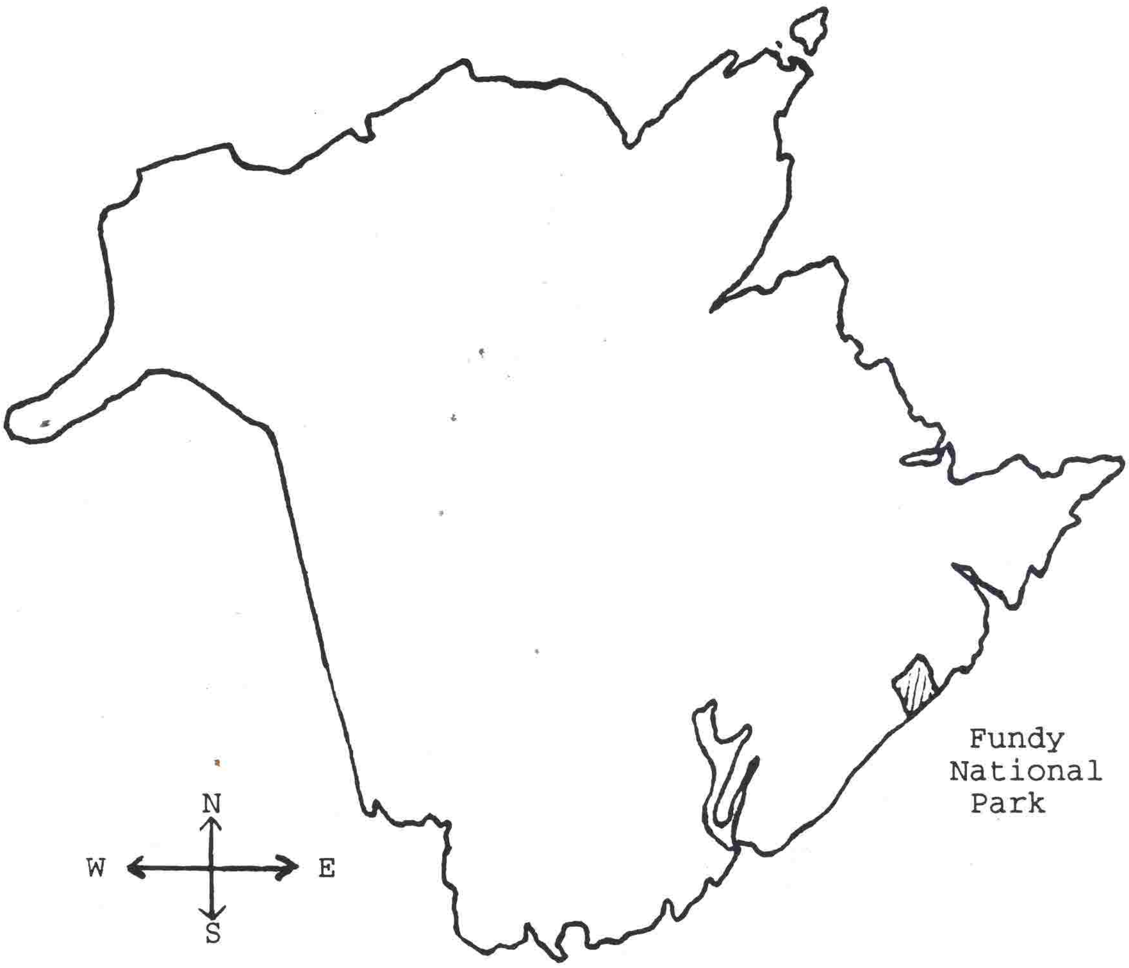
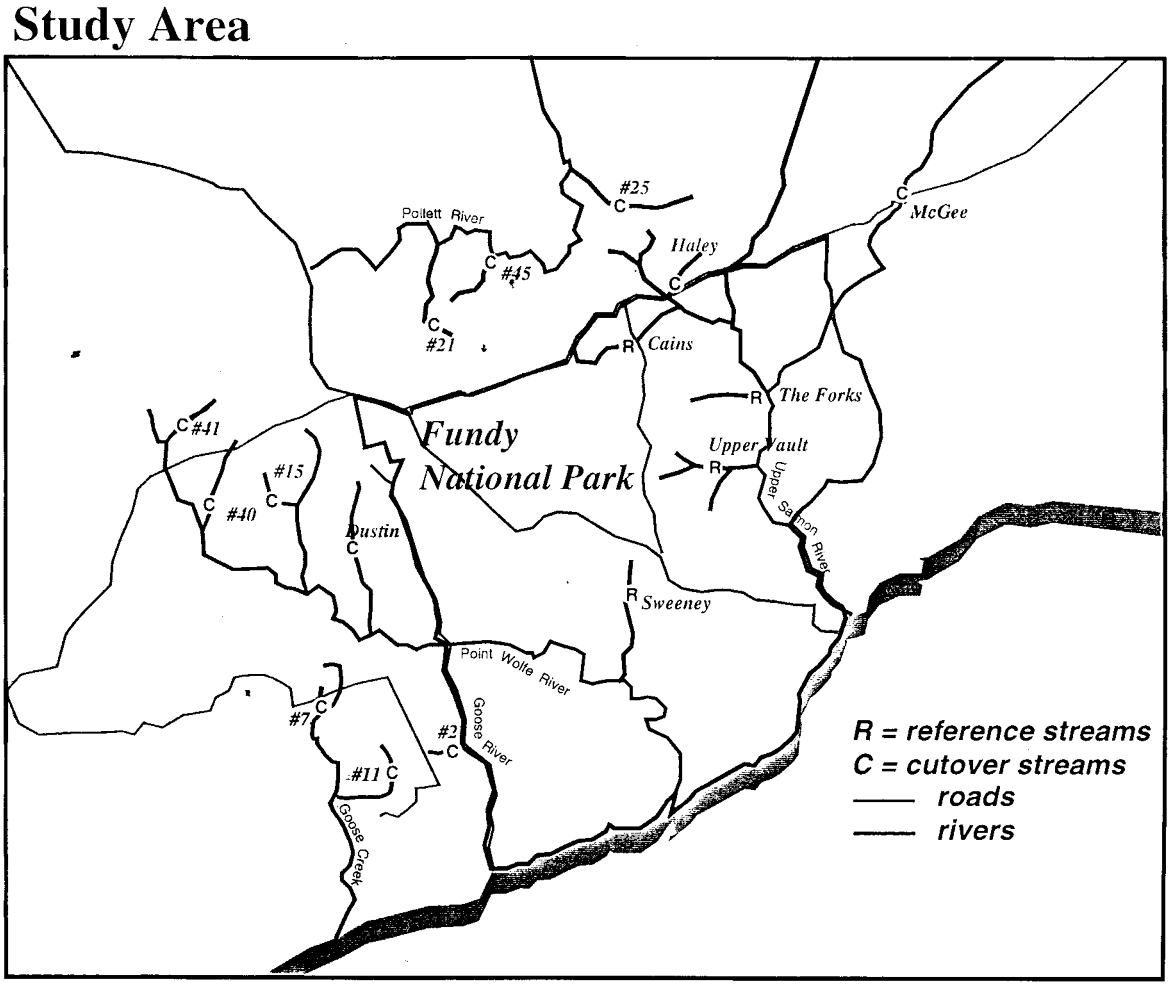


Figure 2. Map of Fundy National Park and surrounding area, including study sites, river systems, and roads.



submarine and subaerial environments (Geological Highway Map of N.B. 1985).

The Park and surrounding clearcuts lie within the Acadian Highlands Natural Region. The forests in the area of study are classified under the Maritimes Uplands Eco-Region of the Sugar Maple-Yellow Birch-Fir Zone. Coastal areas, within 3 or 4 km of the Bay of Fundy, are classified in the Fundy Bay Eco-region of the Spruce-Fir Coast Zone (Woodley 1985). Three streams, Sweeney, #2 and #11, are located in the transitional area between the upland and coastal zones, while the remaining 13 streams are in the Maritime Uplands Eco-Region.

Thirteen of the sixteen streams are located in the Southern New Brunswick climate zone, which is characterized by warm summers, cold winters, and higher precipitation than the Fundy zone. The three streams in the transitional zone may also be affected by the cool summers, mild winters, and high frequency of fog typical of the Bay of Fundy coast (Woodley 1985).

A large portion of the park and surrounding areas have an extensive history of exploitation. The Old Shepody Road was constructed along the northern border of the Park in the 1820s and was settled shortly thereafter. By the 1870s, the Park area was well-settled. Farming and logging were common throughout. Sawmills sprang up along the Point Wolfe and Upper Salmon Rivers. Dams were built along many tributaries of the Point Wolfe, Upper Salmon, and Goose Rivers for the purpose of driving logs downstream to the mills. These log drives "resulted in scouring of the river bed, erosion of the banks and removal of any large woody debris" (Cooper and Clay 1994). By the late 1890s, the forest industry had virtually destroyed the local fishing industry by preventing the migration of anadromous fishes and by polluting the rivers with sawdust, discarded lumber, and bark (Allardyce 1969).

When Fundy National Park was established in 1948, lots along three of the reference streams were owned as freehold lands by the lumber company Hollingsworth and Whitney, having been purchased from the C.T. White company in 1921 (Cooper and Clay 1994). These freehold lands were primarily old farms which had been partially cleared and cultivated at one time, but had since returned to forest (Prov. of N.B., Registry of Deeds). A year prior to 1948, 80 000 cords of pulp were cut from granted lots, mostly along the Shepody Road, and some from within what was to become the Park area.

2.1.0. Site Selection

Sixteen streams were selected from 46 candidate sites on the basis of their size (approximately 3-m wide), accessibility, and disturbance history. For the twelve cutover watersheds, disturbance history was determined in terms of the year of cutting, and presence of a logging road and buffer zone. Also, streams draining beaver ponds and lakes high in dissolved organic acids were avoided. Preliminary estimates of stream bankfull width and channel area allowed for selection of first-order streams 2.5-3.8 m in width (Upper Vault, however, is a third-order stream, although it is similar in width to the others). Within these criteria, streams were selected over a wide range of sites to capture the natural biophysical variation of the landscape.

A 25-m sampling reach was established along each stream. Each reach had at least one riffle (that is, an area of turbulence with a relatively high proportion of gravel substrates), with depth and width similar among all streams. Sampling reaches through clearcuts were sometimes located below a logging road. When a road or trail crossed a reference stream, however, sampling was carried out upstream of that potential disturbance.

2.2.0. Site descriptions

The following brief descriptions are of each study stream and their sampling reach. The descriptions are arranged in order of cutting history, with the most recently cutover stream listed first, followed by the next most recently cutover stream, etc. The reference streams are the last on the list. Information about each stream is summarized in Table 1.

Table 1. Summary table of stream descriptions. The first group includes streams draining watersheds clearcut in the mid-late 1980s; the second group includes streams draining watersheds clearcut in the early 1980s; and the third group, streams draining watersheds clearcut in the 1970s. The forth group includes streams draining reference watersheds.

Stream	Reference (R) or Cutover (C)	Year of cutover	Gradient (%)	Channel Width (m)	Stream Cover (%)	Maximum Temp. (Celsius)	Dominant Shrub Spp.	Dominant Tree Spp.	Snag Density (per ha)	Special features
#45	C	1987	5.4	2.9	74.2	20.0	Be.allenghan. Ac.spicatum	Pi.rubens Be.allenghan.	49	Wide buffer strip Logging road crossing upstream of sampling reach
#2	C	1987	9.1	3.1	64.2	16.0	Be.allenghan. Ab.balsamea	Ab.balsamea Be.papyrifera	32	Steep gradient Small tributary crosses logging road Wide buffer strip
#11	C	Upper watershed 1984, Lower watershed 1987	5.0	3.1	62.8	18.4	Pi.rubens Ab.balsamea	Pi.rubens Ab.balsamea	170	Drains muddy pond Selective harvesting within wide buffer strip Logging road crossing upstream of sampling reach
#7	C	Upper watershed 1989, Mid watershed 1986, Lower watershed 1982	5.5	2.5	29.3	18.0	Ab.balsamea Pi.rubens	Pi.rubens Ab.balsamea	45	Variable buffer strip width, 0 m to >30 m Logging road crosses upstream of sampling reach Several huge, dense debris dams upstream
#21	C	1986	4.0	3.0	70.1	14.5	Al.rugosa	Pi.rubens Be.allenghan.	35	Well-vegetated logging road crossing approximately 0.5 km upstream of sampling reach Medium width buffer strip, 7 m to >30 m
Haley	C	1984	3.4	2.7	47.6	19.5	Al.rugosa Pr.virginiana	Pi.rubens Ab.balsamea	23	Medium width buffer strip, 0 m to > 30 m Small tributary of Haley Brook
#25	C	1984	3.6	3.3	61.9	23.6	Al.rugosa Ac.rubrum	Pi.rubens Be.allenghan.	108	Large portion of the stream flows unprotected through clearcut, then enters minimum 15 m buffer
Dustin	C	1983, early 1900s?	1.6	3.8	25.1	21.0	Al.rugosa Ab.balsamea	Pi.rubens Ab.balsamea	56	Remains of a splash dam found along channel Large sawed stumps in riparian zone, ill-defined buffer
#41	C	Upper watershed 1984, Lower watershed 1980	1.6	2.5	26.6	22.0	Ab.balsamea Al.rugosa	Pi.rubens Ab.balsamea	41	Very low flows in August and September Many budworm killed trees in riparian zone, ill-defined buffer Washed out logging road approx. 1 km upstream of sampling reach
#15	C	1979	4.6	2.7	5.1	23.8	Ab.balsamea Al.rugosa	Be.allenghan. Ab.balsamea	16	Clearcutting to streambanks Stream channel full of logging slash Stream channel may have been used as a skid trail
McGee	C	1978	1.8	3.7	23.9	23.0	Al.rugosa	Al.rugosa Ac.spicatum	16	Clearcutting to streambanks Stream channel may have been used as a skid trail
#40	C	1973	1.8	3.3	11.5	22.0	Al.rugosa Ab.balsamea	Pi.rubens So.americana	75	Uncertain buffer strip with some harvesting in riparian area Logging road washed out directly above sampling reach
Cains	R	1920s	1.7	2.7	40.6	19.5	Al.rugosa	Al.rugosa	27	Portable mill situated on Cains in the 1920s Logs with sawed ends observed in debris dams Riparian vegetation dominated by alders
Sweeney	R		4.8	2.9	74.2	15.3	Be.allenghan. Ac.pensylvan.	Pi.rubens Be.allenghan.	223	Portable mill site situated near headwaters, sometime before creation of National Park Portion of land upstream used to cultivate christmas trees
Upper Vault	R		3.1	3.7	59.2	15.6	Ac.spicatum Pr.virginiana	Be.allenghan. Pi. rubens	104	Portable mill cut taken from the head of Upper Vault in the 1920s.
Forks	R		11.3	3.3	67.0	13.5	Pi.rubens Be.allenghan.	Pi.rubens Be.allenghan.	65	Steep gradient

2.2.1. Cutover streams

2.2.1.1. Clearcut in the mid-late 1980s

(1) Stream #45, to the north of the Park, flowed into the Pollett River (Figure 2). Approximately 100 m upstream of the sampling reach, the stream was channeled through several culverts under an actively eroding logging road. Further up, the stream substrates were dominated by fines and small-sized logging debris. Pools were frequent and the thalwag well-defined. Brook trout (Salvelinus fontinalis) were observed in this stream.

Approximately 90% of the watershed was cut in 1987. Along the sampling reach, the buffer strip was at least 30 m in width (buffer strip widths in Appendix 1). Upstream (about 250 m), buffer width was variable and sometimes quite narrow. In places it appeared to have been selectively harvested.

(2) Stream #2, to the southwest of the Park and approximately 4 km from the coast, descended rapidly into the Goose River (Figure 2). Stream #2 had many pools, large boulders and cobbles, and a large proportion of exposed bedrock.

Ninety five percent of site #2's watershed was clearcut in 1987. The wide buffer strip provided intact forest for at least 30 m on each side of the streambank. A small tributary of stream #2 flowed through a culvert below an actively-eroding logging road.

(3) Stream #11, to the southwest of the Park, drained a muddy pond and flowed southward, then descended rapidly from the upland plateau into Goose Creek (Figure 2). Above the sampling reach, the stream divided into many channels with muddy bottoms, crossed under an actively-eroding logging road through several culverts, and then became ill-defined, pond-like, and boggy.

In 1984, 35% of the watershed was cut, and in 1987, 30%. Along the sampling reach, it was forested on one side, though old sawn stumps were observed within 10 m of the streambank. On the other side of the streambank, there was a wide but variable-sized buffer strip (>20 m), dipping to 6 m at one point. Selective cutting was done within this buffer. Debris dams in the stream channel have logs with sawn ends, indicating either streambank cutting in the past, an old dam, or input of felled trees during road construction upstream.

(4) Stream #7, to the west of the Park, rapidly descended into Goose Creek (Figure 2). A number of huge, dense, debris dams were upstream.

Approximately 35% of this watershed was cut in 1982, 25% in 1986, and 30% in 1989. The buffer zone was greater than 20 m on one side, and ranged from 0-13 m on the other.

In the older cut, stumps were found along stream margins. The sampling reach was situated more than 500 m downstream of a road crossing through a culvert that was at least 12 years old, and still eroding into the stream channel.

(5) Stream #21 was situated north of the Park and flowed into the Pollett River (Figure 2). Upstream, the channel widened and narrowed many times, and the stream bottom was primarily organic fines strewn with small woody debris. There were few pools, and many overhanging banks and pieces of woody debris. Trout were observed in this stream.

Eighty to ninety percent of the watershed of stream #21 was cut in 1986. A buffer strip ranging in width from 7-28 m was left standing. Stream #21 flowed through a culvert under the old Grassy Lake Road, approximately 500 m upstream of the sample reach. The streambanks along the road crossing were well-vegetated.

2.2.1.2. Clearcut in the early 1980s

(6) This tributary of Haley Brook flowed southwest into the Park toward the Upper Salmon River (Figure 2). Despite frequent patches of dry streambed by late summer, trout were observed in several pools, protected by the abundant overhanging vegetation.

In 1984, 70-80% of this watershed was clearcut. The buffer strip was typically greater than 20 m in width, though in places was less than 10 m.

(7) Stream #25, north of the Park, flowed west into the Pollett River, which drains into the Petitcodiac (Figure 2).

Seventy five percent of the watershed was cut in 1984. On the north side of the sampling reach, the forest was uncut. On the south side, the buffer strip varied in width from 14-28 m. Further up, the stream flowed unprotected from the clearcut. Trout were observed in the deep fast flowing section through the cut. Downstream, logging slash in the stream channel formed several debris dams and pools.

(8) Dustin Brook, to the west of the Park, slowly descended the upland plateau and plunged toward the Point Wolfe River (Figure 2). Below the sampling reach, the stream widened and was full of woody debris and debris dams with logging slash.

Stumps in the riparian zone indicated recent selective logging or earlier logging in the area. The latter was suggested by remains of a splash dam in the stream valley. This watershed had been the property of Hollingsworth and Whitney. Most recently, 70-80% of the watershed was clearcut in 1983. The buffer strip was difficult to distinguish; it was usually greater than 20 m in width but consisted of alders with larger trees beyond.

(9) Stream #41, located to the west of #15, gradually descended the upland plateau into the Point Wolfe River (Figure 2). Trout were observed in many of the long, deep pools when other parts of the streambed had dried up. Little cover was provided by large woody debris or overhanging vegetation.

Approximately 30% of the watershed was cut in 1984, and another 40% in 1980. The riparian zone consisted of many spruce- budworm killed trees, such that the stream was protected by a thin forest canopy. Approximately 1 km above the sampling reach, a logging road crossing had been washed out, and was still eroding into the stream channel. An old log bridge crossed the stream above the sampling reach, indicating some past disturbance. Also, old logs with sawn ends were seen in the stream channel.

2.2.1.3. Clearcut in the 1970s

(10) Stream #15, to the northwest of the Park, flowed down the high plateau into the Point Wolfe River (Figure 2). The stream channel was full of logging slash, and the bottom was covered by a layer of dark, organic mud. Debris dams of logging slash were frequent. In some places, the main channel divided into two parallel smaller channels, indicating the probable use of skidders within the stream.

This land was once freehold owned by the lumber company Hollingsworth and Whitney. In 1979, 80-90% of the watershed of stream #15 watershed was clearcut. No buffer strip was left.

(11) McGee Brook, to the northeast of the Park, flowed southward toward the Forty Five River (Figure 2). The sampling reach had many overhanging banks and large cobbles. Upstream, however, there were few deep pools and the channel was unusually straight and shallow. In some places, the stream divided into two evenly spaced channels, suggesting that skidders may have used the stream channel as a trail. Trout were observed in McGee Brook.

While 60-70% of the McGee watershed was cut in 1978, it is likely that it was also cut when the plot granted to J. McGee was sold to Alma Lumber and Shipbuilding Co. in the 1800s. No buffer strip was left along the stream during the 1978 harvest. Sawed stumps were observed in and next to the streambank.

(12) Stream '#40' flowed under Shepody road, to the northwest of the Park, and descended to the Point Wolfe River (Figure 2). Stream #40 had few pools, but abundant woody debris and many cobbles and boulders. Trout were observed in this stream.

Eighty to ninety percent of the watershed of stream #40 was clearcut in 1973. From 70 m above to 70 m below the sampling reach, there was a buffer strip greater than 20 m in width (each side), with evidence of selective harvesting. A logging road was washed out directly above the sampling reach.

2.2.2. Reference streams

(13) Cains Brook, at the north end of the Park, flowed along the wet plateau into Haley Brook (Figure 2). The sampling reach was located approximately 100 m upstream of the Laverty Auto Trail. Cains provided good habitat for brook trout (*Salvelinus fontinalis*), including undercut banks, overhead cover by alders and woody debris, and moderately abundant pools.

Lands originally granted to M. Quigley and F.O. Talbot along Cains were later sold to the Alma Lumber and Shipbuilding Co. (1886), and finally to Hollingsworth and Whitney in 1921 (Registry of Deeds, Albert Co., N.B.). A portable mill was situated on Cains in the 1920s (Cooper and Clay 1994). Logs with sawn ends were observed in debris dams along Cains.

(14) Sweeney Brook, in the southern half of the Park, flowed down the high rolling plateau to the steep river valley of the Point Wolfe River (Figure 2). The sampling reach was located just upstream of the Rat Tail Trail crossing.

Upstream, a plot originally granted to M. Sweeney (Lot

121) was later sold to E. Hogan (1893), C.T. White (1899), and Hollingsworth and Whitney (1921). When the Park was established in 1948, a portion (18.2 hectares) of Hogan's land was being used to cultivate Christmas trees. This area has since been allowed to regenerate naturally. At one time, a portable mill was located near the headwaters of Sweeney Brook (Cooper and Clay 1994).

(15) Upper Vault (U.V.), or Third Vault Brook, was located directly south of the Forks. As this stream descended the plateau, it received several other small streams and flowed toward the Upper Salmon River (Figure 2). The sampling reach was located along a third order stream on the high plateau. Woody debris and moss-covered substrates were abundant, debris dams common, pools and overhanging banks frequent, and channel width highly variable.

A portable saw mill cut was taken from the head of Upper Vault in the 1920s (Cooper and Clay 1994). A splash dam, used to drive logs, was located downstream of the sampling reach (Cooper and Clay 1994).

(16) "The Forks", located in the northeast corner of Fundy National Park, descended rapidly from the high rolling plateau to the steep sloping valley walls of the Broad River (Figure 2). The sampling reach was located near the outlet to Broad River, above a hiking trail crossing. The Forks

had a high frequency of pools and debris dams.

The location of a logging brow close to the outlet of the Forks was the only obvious indication of past disturbance near this stream. Otherwise, the Forks was not obviously disturbed by logging or agriculture.

3.0.0. METHODS

Except when noted (Section 3.6.0) all data were collected within the 25-m sampling reaches.

3.1.0. Water Quality

Temperature

Stream water temperature was measured with five Hobo recording thermographs in each of Sweeney, Upper Vault, Stream s/#11, #25 and #15; and with 1 maximum/minimum thermometers in each of the remaining 11 study streams. The temperature recorders were placed in streams from the beginning of June to the middle of November, 1993. The thermometers were read and reset every 4 or 5 days from June to early September, and once a month in October and November. Over that period, the thermographs were downloaded in July, September and November. The thermograph on stream #25 operated well in June, but malfunctioned from July to November. The mean, range, and maximum temperatures for stream #25 in July, August, and September were extrapolated using the temperatures measured in June. This was done by calculating the mean range, overall mean, and mean maximum temperature for June for the four other streams with thermographs, then calculating the percent difference between these and the values for stream #25. The differences were then used to estimate the mean, range and maximum temperatures for stream #25 for the months of July, August and September.

Dissolved oxygen

Dissolved oxygen was measured sporadically in sampling reaches in early September, 1993. Sampling was done using a YSI instrument, with a Clark-Type, membrane-covered polarographic sensor. Due to equipment malfunctions, I was unable to measure dissolved oxygen earlier in the season.

Stream chemistry

Nutrient concentrations were measured in water samples collected from each stream in early July, early August, and early September, 1993. Water for phosphorus analysis was collected in a separate acid-washed container, and the water for remaining nutrients was collected in a 1-litre nalgene bottle. All samples were collected while wearing well-rinsed rubber gloves and refrigerated until the time of analysis. The samples were analyzed by the Inland Waters Directorate (Environment Canada, Moncton) for total nitrogen (including nitrate), phosphate, potassium, chloride, magnesium, calcium, sodium, pH, alkalinity, and specific conductance.

Sedimentation

Sedimentation was measured with three 500 ml nalgene bottles, dug into each sampling riffle such that the mouth, which was 45-mm in diameter, was flush with the streambed. Each bottle, or pot, had 2-3 stones (32-64 mm in diameter) weighting it down. The pots were left in the streambed from June until early October. The contents, excluding the gravel weights, were dried, sieved, and weighed into two categories, fines (< 3.3 mm) and larger (> 3.3 mm).

3.2.0. Substrates

Stream substrates were measured using substrate cores in mid-late June, 1993 and by surface estimation of size frequency in late August, 1993. With the former technique, 5 pairs of double-digit numbers were selected from a random number table. Each was translated into a coordinate and assigned a location in the sampling riffle. This spot was then sampled with a metal cylinder, 15 cm in diameter, that was driven 15 cm into the stream bottom. The substrates within the cylinder were emptied into a bucket. Cobbles more than half the way into the cylinder were placed with the rest of the sample in the bucket. An estimation was made of the percent of the core obstructed by bedrock or boulder.

Substrates in the bucket were wet sieved into the following categories described by Hamilton and Bergensen (1984): large cobble (128-256 mm), small cobble (64-128 mm), very coarse gravel (32-64 mm), coarse and medium gravel (8-

32 mm)[a], and fine gravel (3.3-8 mm)[b]. Each category was weighed with a spring balance. Fines (<3.3 mm in diameter) were stored and brought to the lab, where each sample was air dried and mechanically sorted for 20 minutes in a shaker machine. These substrates were sorted into very fine gravels (2-3.3 mm), coarse and very coarse sands (0.5-2 mm), medium sands (0.25-0.5 mm), fine and very fine sands (0.053-0.25 mm), and silt and clay (<0.053 mm).

Composition of surface substrates was visually estimated along transects placed across the stream at 10, 20 and 40 m above and below the sampling reach, and every 5 m within the sampling reach. Along each transect, three 30 cm x 30 cm quadrats were placed at 1/4, 1/2, and 3/4 the distance across the stream channel. Following a methodology outlined by Hamilton and Bergensen (1984), within each quadrat estimates were made of the most dominant and second most dominant substrate, as well as the percent embeddedness (the degree to which the larger particles are surrounded or covered by sediments < 4 mm in size). The latter is a measurement of how much of the surface area of the largest size particles is covered by fine sediment. Substrates were

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[a] For the substrate cores, coarse and medium gravels were grouped together as one category.

[b] In the substrate core analysis, 'fines' included substrates less than 3.3 mm in diameter. For the estimates of surface substrates, fines included all substrates less than 4 mm in diameter. Both measures are commonly used.

broken down into 11 categories: wood; bedrock; boulder (>256 mm); large cobble (128-256 mm); small cobble (64-128 mm); very coarse gravel (32-64 mm); coarse gravel (16-32 mm); medium gravel (8-16 mm); fine gravel (4-8 mm); and very fine gravel, sand, silt and clay (<4 mm). The (percent) frequency of occurrence of each substrate type was used to show the proportion of the total stream covered by, for example, large cobble. Similarly, the frequency of occurrence of each embeddedness class was used to show the proportion of the streambed reach covered with, for example, 50% fines. In each quadrat, macrophyte and moss cover were also estimated.

Surface estimation of stream substrates differs from the substrate cores in that the former technique estimates surface substrates only, includes wood, separates medium and coarse gravels into two categories, combines all fines into one category, and defines fines as all substrates <4 mm in diameter (whereas in the substrate core analysis, fines included all substrates <3.3 mm, because no 4 mm sieve was available).

Organic matter

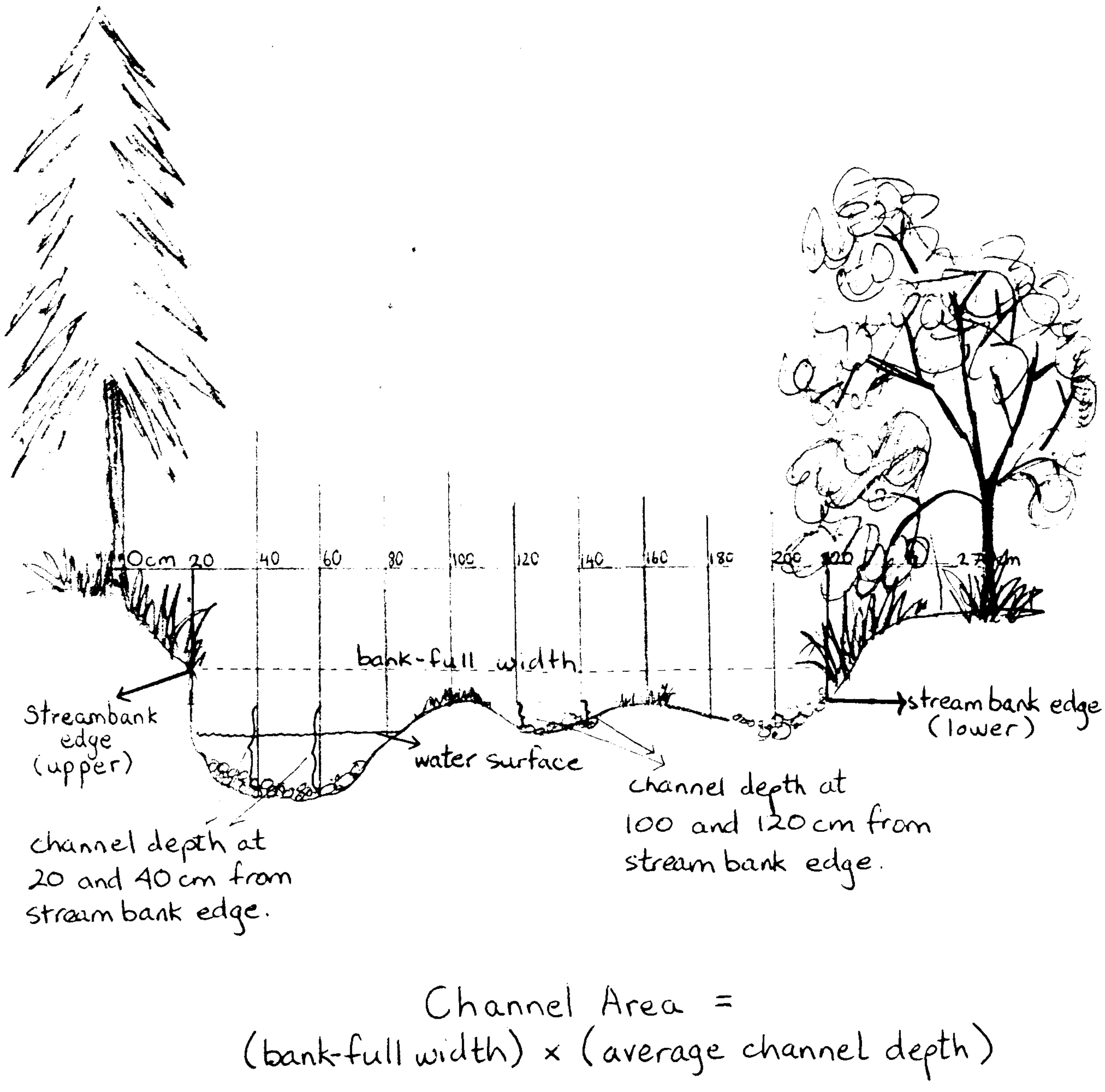
Substrate core samples were used to calculate the organic carbon content of the streambed. Samples taken back to the lab for dry sieving were picked through for pieces of organic matter greater than 2 mm in size. These larger pieces were fed into a grinder then remixed with the portion of each sample less than 2 mm in size. Two subsamples of 2 g each (for a total of 10 per stream) were placed in a beaker and the organic carbon content determined using the Walkley-Black method of wet oxidation (Page *et al.* 1982).

3.3.0. Channel dimensions

Using a technique described by Hamilton and Bergensen (1984), channel measurements were made along transects placed 10, 20, and 40 m above and below the sampling reach, and every 5 m within the sampling reach in early September, 1993. At each sampling point, a measuring tape was secured level above and across the stream channel. At 20 cm intervals from the edge of the streambank, the distance from the measuring tape to the streambed was recorded. The stream channel was defined as the cross-sectional area under water at bank-full depth, which was estimated as the cross-sectional area below the line of permanent vegetation. In the calculation of stream channel cross-sectional area, the distance below the lowest stream edge was subtracted from the vertical distance between the measuring tape and the streambed (Figure 3). Any boulders projecting above the lower stream edge were assigned zero depth. The average channel depth was multiplied by the channel width to derive channel area. Channel width was divided by average channel depth to estimate width:depth ratios for each stream.

Figure 3.

Diagram showing measurements of channel dimensions. A level tape was secured across the stream channel, and the vertical distance from the tape to the streambed recorded at 20 cm intervals along the tape. Stream channel cross-sectional area was approximated as the area below the lower streambank edge. This was calculated by multiplying the bank-full width by the average channel depth.



Channel gradient above and along the sampling reach was estimated from a 1:50,000 topographical map by dividing the horizontal distance by the drop in elevation, measured by contour lines.

3.4.0. Riparian vegetation

Riparian vegetation was sampled in July and August, 1993, using the point-centred quarter method (Smith 1980). This is a useful technique for sampling communities in which the dominant plants are large shrubs or trees (Smith 1980). Transects were set up approximately 1.5 m from the streambank along both sides of the stream, beginning at the downstream end of the sampling reach and extending 95 m upstream. Data from the streambank side of the transect were ignored. Sampling points were established every 5 m along the sampling reach, and 10, 20 and 40 m above the sampling reach. The distances from the point to the nearest shrub (<5 cm diameter at breast height [DBH]), tree ($\geq$5 cm DBH), and snag ($\geq$5 cm DBH, >4 m tall) were measured in both 90° sectors around the sampling point on the non-streambank side of the transect. Shrub-sized species and tree species were recorded, and the diameter at breast height of shrubs, trees, and snags. Due to time constraints, plants beyond 15 m of the sampling point were not measured. Plants were measured more than once when they were nearest to more than one sampling point. Following Cox (1990), calculations of basal area per hectare, average dominance, density, relative density, dominance, relative dominance, frequency, relative frequency, and importance value were made for all shrub and tree species. Density was calculated by assigning a distance of 25 m to those plants beyond 15 m from the sampling point (thereby overestimating the density of trees and snags in areas with no buffer strip). Shrub and tree diversity were calculated using Brillouin's Index of species diversity, following the methodology described by Krebs (1989) in Ecological Methodology.

Riparian canopy cover was estimated at each sampling point. A funnel was positioned approximately 1 m above the ground, and an estimate of overhanging vegetation, or cover, was made by looking up through the funnel. Overhead cover was estimated at each quarter distance across the stream channel, along the same 12 transects set up for channel measurements.

3.4.1. Buffer strip width

Buffer strip width was measured along streams draining cutovers at each of the transects set up for channel measurements. Width was measured to a maximum of 30 m from the streambank in either direction.

3.5.0. Stream Invertebrates

Stream invertebrates were sampled using 'rockballs',