United States
Department of
Agriculture

Forest Service

Pacific Northwest
Forest and Range
Experiment Station

General Technical
Report
PNW-101

February 1980

EDITOR'S
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Evolution of Large, Organic Debris After Timber Harvest: Maybeso Creek, 1949 to 1978

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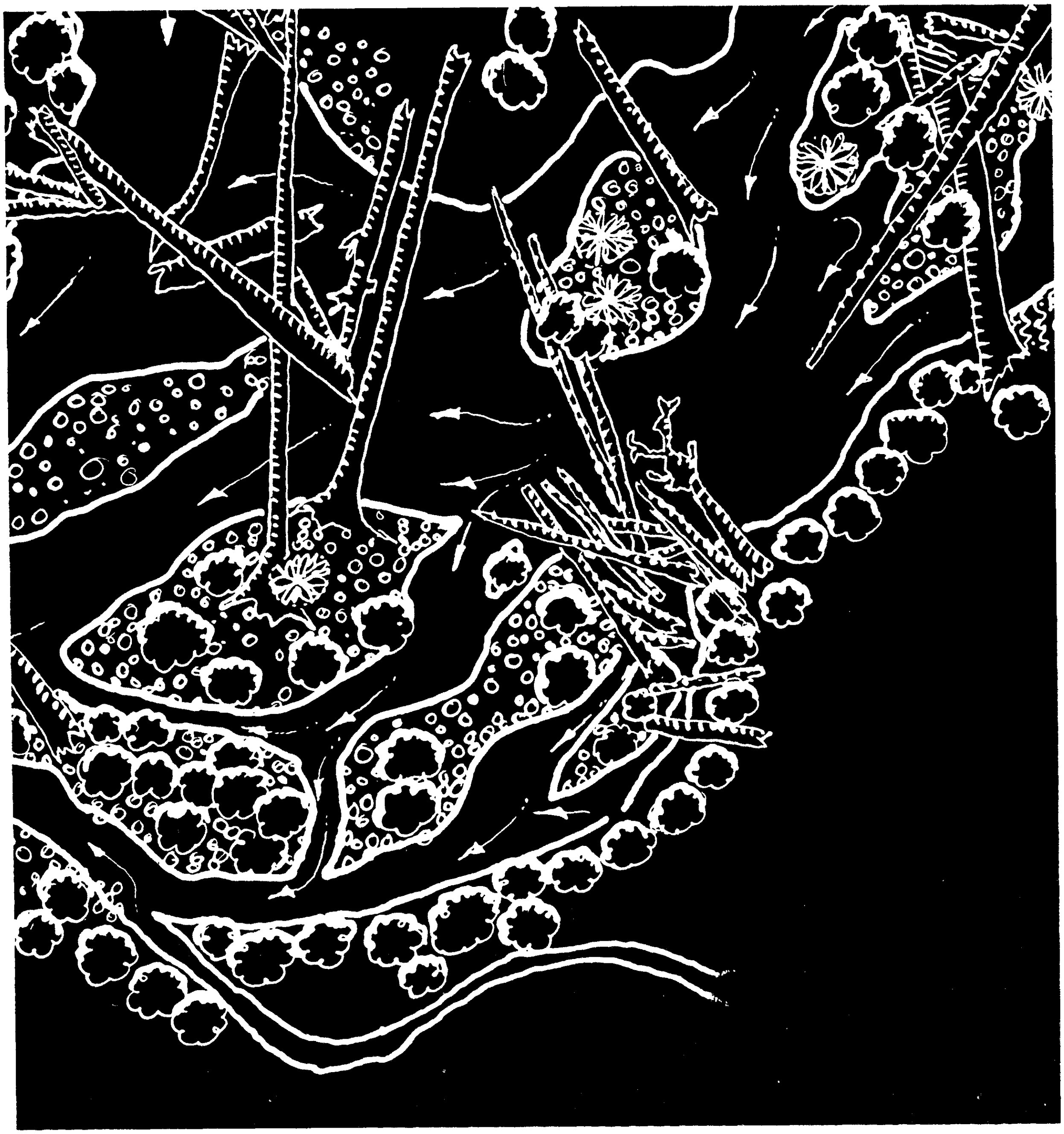

ABSTRACT

The Maybeso Creek valley was logged from 1953 to 1960. Stream maps showing large accumulations of debris and stream channel features were made in 1949 and updated to 1960. The objectives of this paper are to document the effects of natural and logging debris on channel morphometry and to examine the fate of logging debris during and after logging. Map sections from 1949 through 1963 are examined and compared with a ground survey in 1978 of debris accumulations.

Natural conditions before logging revealed sparse accumulations of large debris scattered throughout the stream; these accumulations increased in number and density during logging. Natural material appeared.to be well controlled and stable; whereas, logging debris was floatable. Year-to-year changes in accumulations were noted throughout the period of logging from 1953 to 1969. Fewer accumulations were observed in 1978 than in 1949, before the start of logging. Further studies are needed to quantify physical changes and to relate these changes to salmon habitat.

KEYWORDS: Logging (-erosion, erosion-) forestry methods, sedimentation, morphometry.

CONTENTS

	Page
INTRODUCTION	1
DESCRIPTION OF THE STUDY AREA	2
METHODS	6
RESULTS AND DISCUSSION	6
1949	6
1960	12
1978	17
CONCLUSIONS	28
LITERATURE CITED	29

INTRODUCTION

Most undisturbed stream systems in southeast Alaska flow through predominantly old-growth spruce-hemlock forests. During the natural course of events, these systems are exposed to organic inputs, ranging from needles to material the size of trees. In the past, timber harvest has left substantial amounts of additional organic debris in stream channels.

In this paper I discuss the role of large debris (tree boles and root wads) in the morphological changes in Maybeso Creek, Prince of Wales Island, Alaska. My objectives are to:

1. Document the general changes in morphometry of the stream channel as a result of accumulations of natural and logging debris.
2. Examine the fate of natural accumulations of large debris during and after timber harvest.
3. Discuss the influence of accumulations of natural and logging debris on stability of streams.

The role of large, organic debris in stream channel morphometry in southeast Alaska has not been well documented, but early work on Maybeso Creek provides some baseline information. James (1956) reported some early observations of debris accumulations and their effect on the stream channel in Maybeso Creek. He discussed the role of large debris in creating pools and providing cover for adult salmon.

Bishop and Shapley (1963) created a series of artificial debris jams in Maybeso Creek to examine changes in channel morphometry. Scouring occurred under and around jams, accompanied by downstream deposition of bedload. A flat riffle with an unstable streambed was created after the jam washed out during floods in the autumn. Their work was further reported by Helmers (1966), who concluded that jams increased instability during floods and produced streambed cutting. He found a decrease in fine sediments following washout.

The most recent studies of the role of large, organic debris in streams in the Cascade Ranges of western Oregon show that large debris slows water movement and traps and stores fine, organic material (Swanson and Lienkaemper 1978, Swanson et al. 1976). Large debris can be a stabilizing or destabilizing agent in stream channels, depending on the amount and placement in the stream. The greatest adverse environmental effect of large debris is from debris torrents that completely flush out small, steep streams in western Oregon.

Froehlich (1975) discussed some methods of measuring the quantity of organic debris and the differences in debris loading resulting from different logging systems. In addition, he cited windfall, insect infestations, and wildfire in several areas in Oregon as natural causes of catastrophic inputs of large debris that would otherwise accumulate at a slower rate from natural tree mortality.

From these studies it is apparent that as large pieces of debris enter a channel, gravel streambeds are scoured and banks may be eroded as stream water flows around, under, or over the block. Stable debris can form relatively long-lived bed and bank features by controlling flows. Channel instability increases with increased movement of debris.

Helmers (1966) cited the potential for reduction of fines through increased movement of gravel as a possible benefit for overwinter survival of salmon eggs and embryos. Both Helmers (1966) and Hall and Baker (1975) pointed out the detrimental effects of debris-induced scour during incubation and the mortality of embryos resulting from movement of log jams during floods.

Biological and physical effects of large debris in streams were discussed by Narver (1971) and Hall and Baker (1975). They cited examples of improved habitat when accumulations of large debris increased cover in both rearing habitat and overwintering areas for juvenile coho salmon (Oncorhynchus kisutch).

Although several reports cited debris jams as blocks to passage of fish (Merrell 1951, Howell et al. 1965), many jams do not block fish passage. Narver (1971) pointed out that log jams block fish passage when gravel is dammed behind the block, creating falls. In most circumstances, streams develop channels under or around a jam. Natural accumulations with relatively low concentrations of logs are unlikely to result in a blocking jam.

DESCRIPTION OF THE STUDY AREA

Maybeso Creek is located near Hollis on Prince of Wales Island, approximately 67 km (42 mi) west of Ketchikan, Alaska (fig. 1). The main stem of Maybeso Creek is approximately 8.3 km (5 mi) long and drains about 42 km^2 (16 mi^2) of a U-shaped valley. Mean summer discharge is approximately 2 407 liters/s (85 ft^3/s). Discharge regimes are highly variable, and fall storms frequently result in peak discharges in excess of 22 656 liters/s (800 ft^3/s) (James 1956).

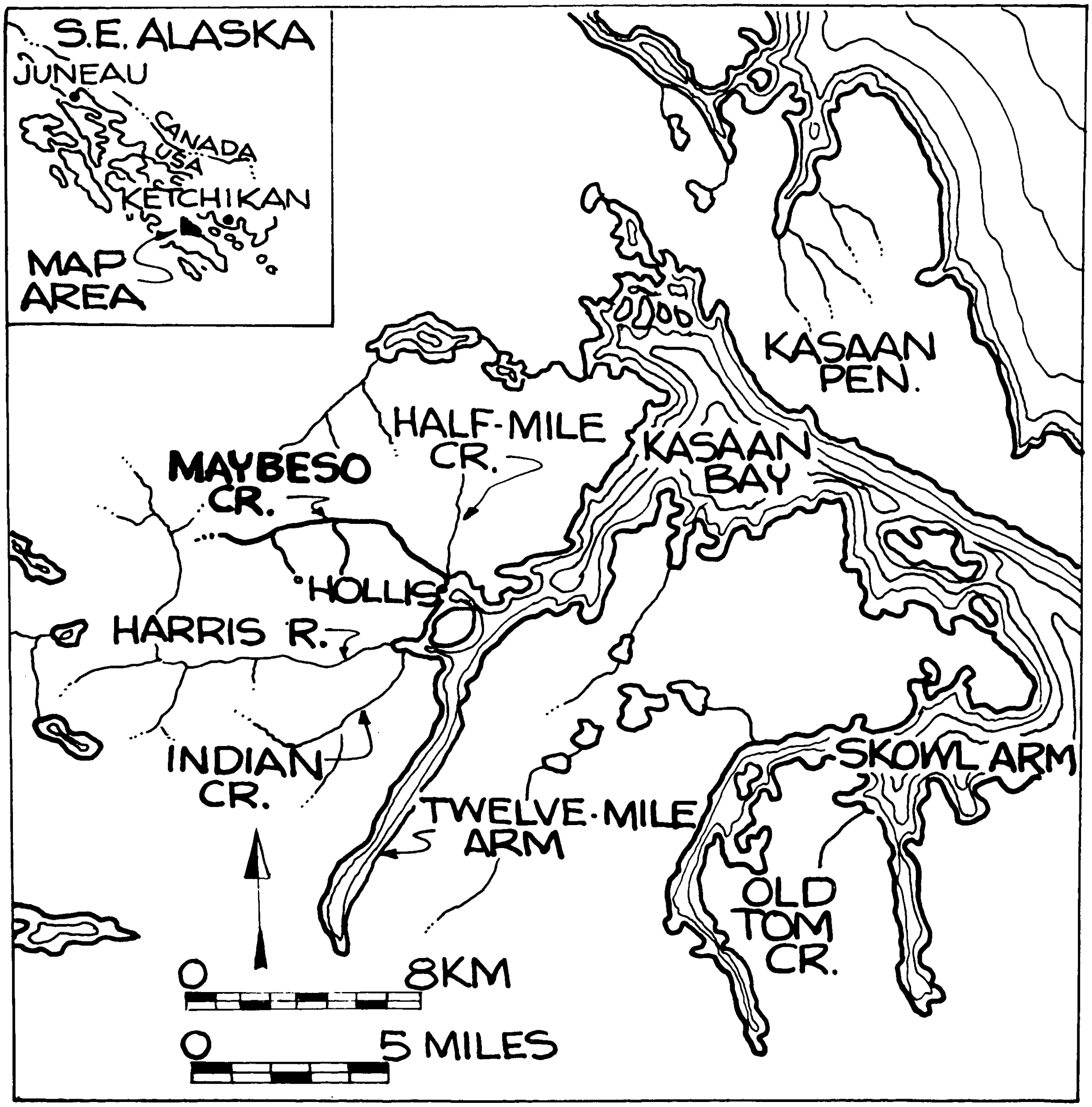

Figure 1.--Location of Maybeso Creek, Prince of Wales Island.

Early studies estimated pink (Oncorhynchus gorbuscha) and chum salmon (O. keta) escapements from 0 to 2,700 (Meehan et al. 1969). Coho salmon and Dolly Varden char (Salvelinus malma) were observed in 1978. Cutthroat trout (Salmo clarki) also occur in Maybeso Creek.

Maybeso Creek from the intertidal zone to about 1 000 m (3,281 ft) upstream is heavily influenced by bedrock. Just below the present location of the main road bridge on the Hollis to Craig road (fig. 2), about 75 m (246 ft) upstream from mean high tide, the channel is constricted through bedrock, which at low flows acts as a partial block to migration of pink and chum salmon.

Logging was begun in the Maybeso Valley in 1953 and continued through 1963 (Meehan et al. 1969); nearly all merchantable timber was removed for a distance of 7.24 km (4.5 mi) along both sides of the stream (shaded area, fig. 2). A small area of large old-growth timber was left along approximately 800 m (2,625 ft) on both sides of the streambank. Remaining uncut areas along the stream were usually muskeg or small unmerchantable trees.

The dominant streamside vegetation is red alder (Alnus rubra), salmonberry (Rubus spectabilis), stink currant (Ribes bracteosum), and thimbleberry (Rubus parviflorus) interspersed with regrowth of Sitka spruce (Picea sitchensis) and western hemlock (Tsuga heterophylla).

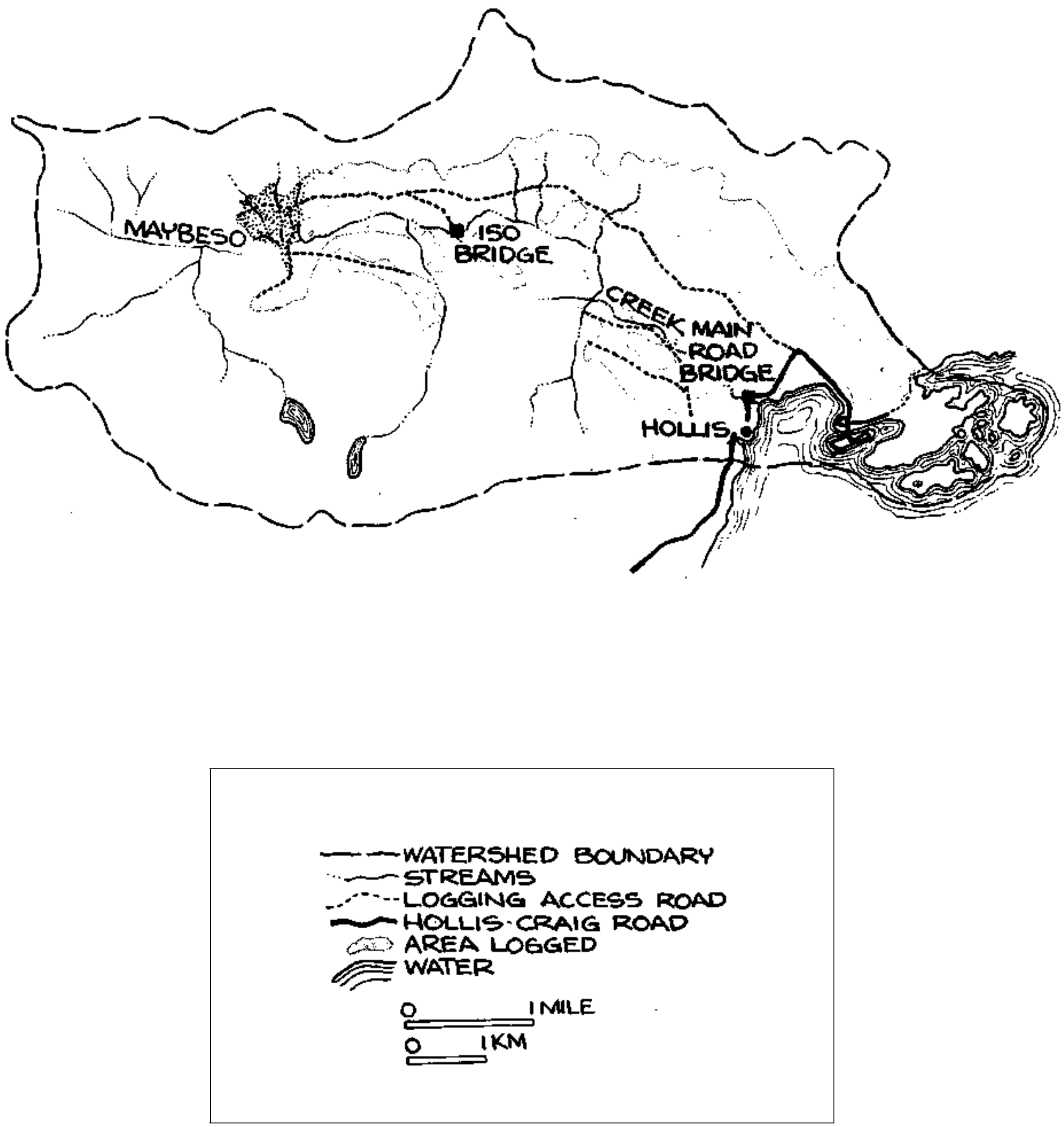

Figure 2.—Maybeso Creek watershed.

METHODS

Mapping of Maybeso Creek was started in 1949. In the following years, these maps were updated annually through 1960. The maps were drawn to 1:600 scale with a plane table and alidade and show locations of large organic debris and primary stream features, such as bedrock, gravel bars, and streamside vegetation. The map sections begin at tidewater and extend upstream approximately 5.5 km (3.4 mi).[1] As logging progressed, changes in the physical features of the stream were noted, and map sections were redrawn. Much of this paper interprets these changes and the influence of logging debris on the stream during this period.

In 1978 we walked the system with copies of the 1949 map series, the 1960 maps, and a set of aerial photographs. During this survey absence or presence of accumulations of debris were noted and comments on general stream morphometry recorded and compared with conditions shown in the map sections. Mapping was not done during this survey.

RESULTS AND DISCUSSION

1949

In the 1949 map sections, no major accumulations of debris that influenced channel morphometry appear in the first 1 000 m (3,281 ft) of Maybeso Creek. Individual pieces were interspersed along the bank and small accumulations of one or two pieces occurred at sharp bends. The first accumulation across the stream occurred at 800 m (2,625 ft). Flows followed a course under the logs; gravel bars formed around the accumulation (fig. 3). This area is influenced primarily by bedrock, indicated by the crosshatch marks on the map.

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[1]The map sections are identified by sheet numbers in figures 3–10 and figure 15. These are the numbers on the original maps, and they remain the same from year to year for each location. They are provided here for comparison with the text and also so a reader could refer to the original maps for study.

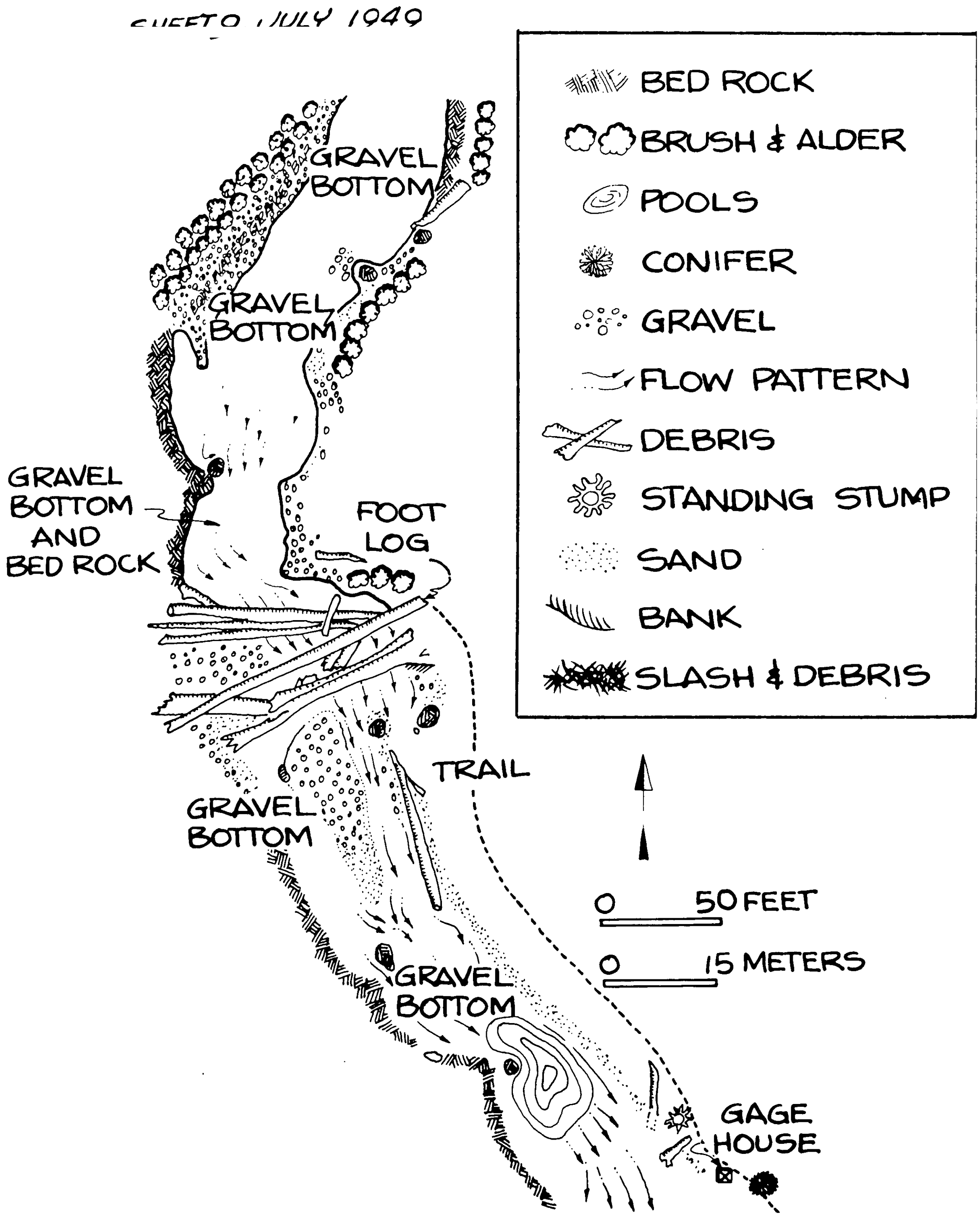

Figure 3.--Lower Maybeso Creek at the gage house, 1949.

The first accumulation of more than five logs occurred at about 1 000 m (3,281 ft) upstream (fig. 4) where eight large trees were across the stream. Although the channel was shown to flow under the log accumulation in the 1949 map, it appears that the immediate influence was to deflect the flow over what is shown in the map as a sand and gravel bar. This accumulation appears to have deflected high flows over parts of the gravel bar. A series of pools and eddies have been formed by the accumulation.

For the next several hundred meters the primary influence of debris was from fallen trees well embedded in the bank acting as deflectors and causing formation of pools and gravel bars (fig. 5). Gravel deposition and storage accompanied by pool formations occurred as debris disrupted flow. Without debris influence, the channel was scoured to bedrock with little or no gravel deposition (fig. 5).

Accumulations of debris at 2 000 m restricted flows and caused the stream to braid or create a series of islets and small channels above and around the accumulation (fig. 6). An alternating pattern of natural blowdown and open areas (figs. 4 and 5) continued upstream for most of the remaining stream sections.

Natural accumulations may begin with blowdown; these in turn erode the bank under root systems. As root systems are undercut, additional blowdown will be directed into the stream, further intensifying inputs of large debris in a restricted area (fig. 6).

Sparse natural accumulations appear to be relatively stable. Where large debris is embedded in the channel bank, year-to-year changes in the channel topography as a result of flooding and erosion decline. These accumulations tend to deflect flows and cause gravel deposition as hydraulic energy is dissipated (fig. 6). These accumulations are stable enough to allow establishment of alder on the gravel depositions. Root systems of alder may further enhance stability of gravel bars. As these areas stabilize, new material falling into the channel as a result of streambank undercutting and blowdown accumulates at a slower rate.

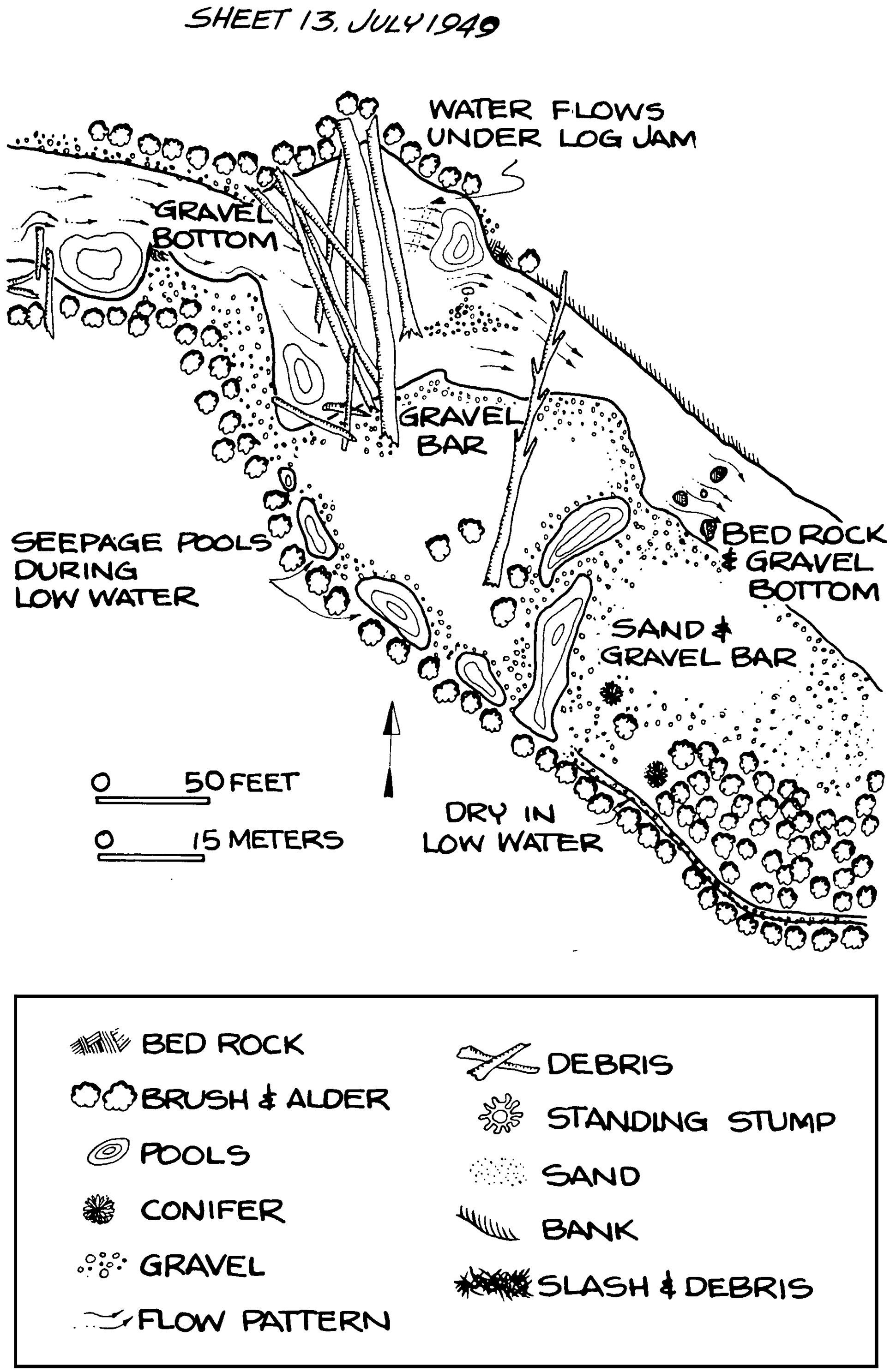

Figure 4.--Pools and eddies formed by large debris, Maybeso Creek, 1949.

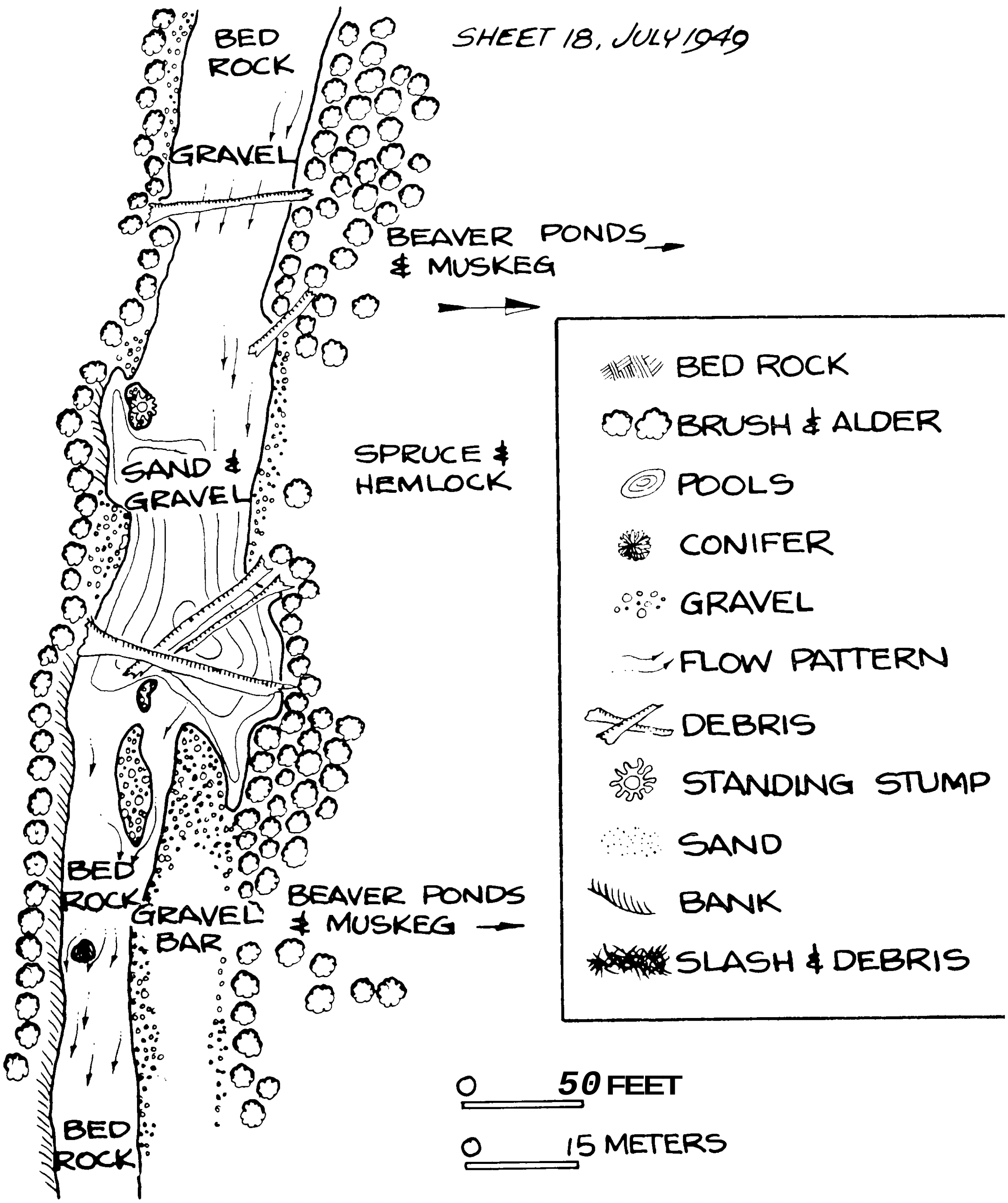

Figure 5.--Pool and gravel formation by natural input of tree-size debris. Maybeso Creek, 1949.

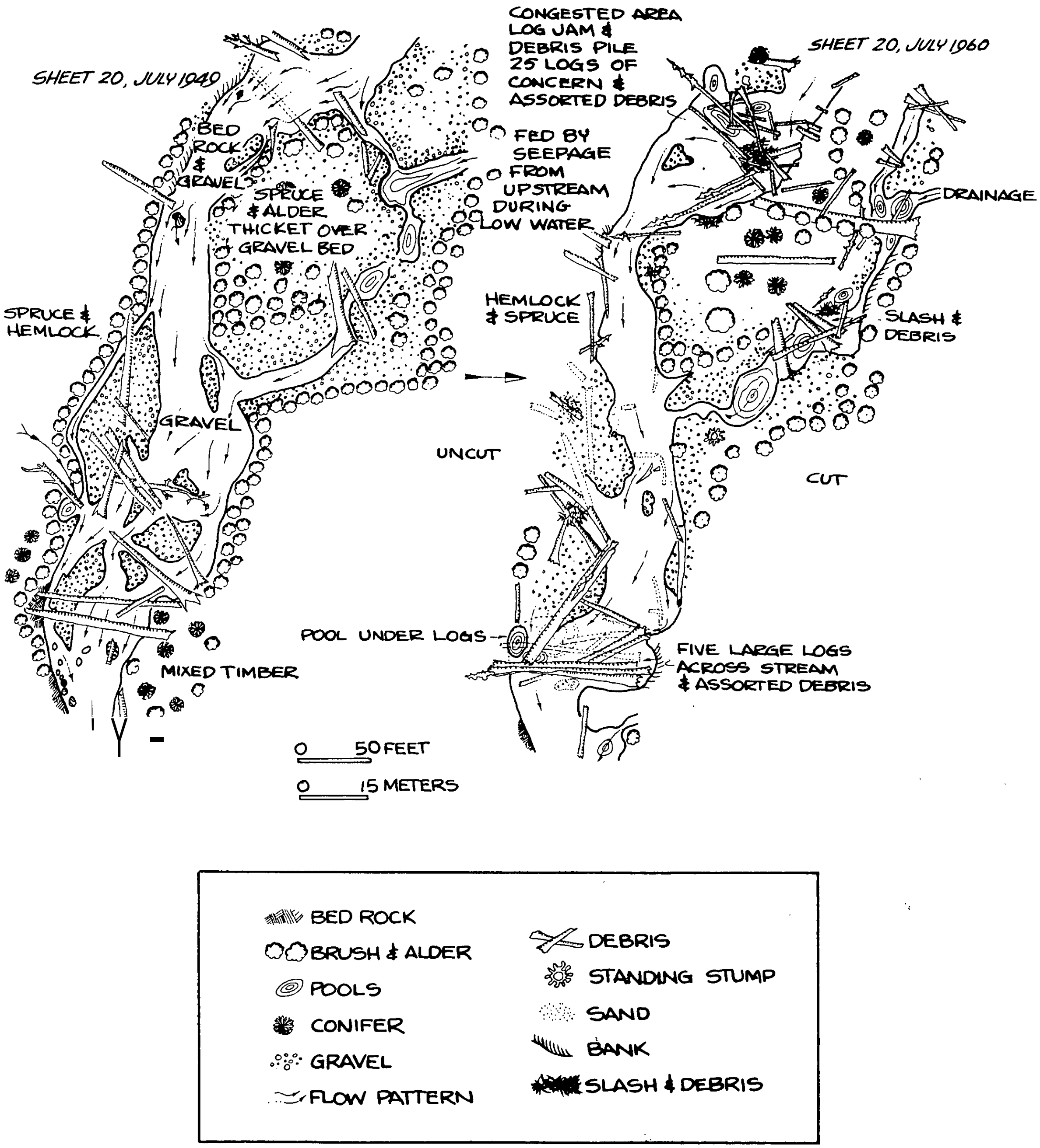

Figure 6.--Side channel and islands formed by natural inputs in 1949 and effects of heavy concentrations of logging debris in 1960.

Seventeen debris accumulations of four or more logs were counted on the 1949 maps between the main road bridge and the 150 road bridge upstream (table 1). James (1956) recorded 9 jams containing 10 or more logs 3 m (9.84 ft) or more in length in 1949 and 16 jams of 10 or more logs in 1953 immediately before logging.

Table 1--Accumulations of large debris extending across Maybeso Creek between the main road and the 150 road bridge before, during, and after logging

Year	4 or more logs	10 or more logs1/
1949 (before logging)	17	4 (9)
1953 (during logging)	24	8 (16)
1956 (during logging	34	20
1960 (after logging)	29	21
1978 (after logging)	4	1

1/Numbers in parentheses are from James (1956).

1960

The number and size of major accumulations of debris increased between 1953 and 1960 (table 1). The 1960 maps showed 29 accumulations of four or more logs extending across the width of the stream between the main road bridge and the 150 road bridge. A jam containing 5-10 logs in 1949 commonly included more than 20-30 logs, trees, and root wads in 1960 after logging (figs. 6 and 7).

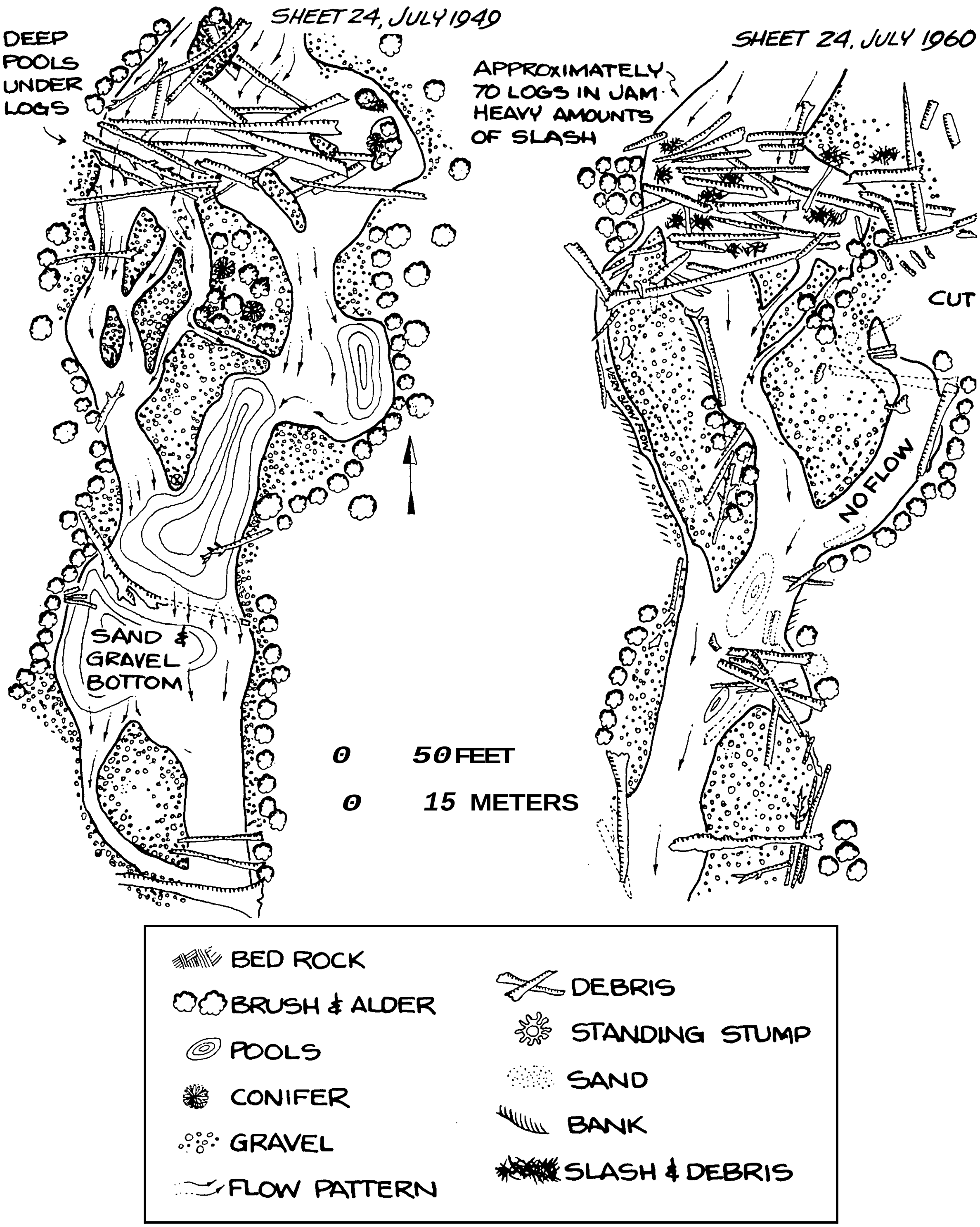

Figure 7.--Concentration of logging debris at a natural debris accumulation.

In the downstream sections, bedrock continued to be the dominant feature. No accumulations reached completely across the stream, but the number of logs and root wads projecting into the stream from the bank increased compared with 1949. Most larger accumulations in this section were probably washed out by floods and the impact of large debris moving downstream during floods. In this area, the bedrock configuration concentrates flows through a relatively restricted area and thus intensifies the effect of floods on any accumulations of debris.

Above the first 1 000 m, accumulations of large debris began to appear on the 1960 maps. Natural jams (as shown in fig. 7) frequently sieved floated debris and formed massive jams. The marginal notes on map section 24 (fig. 7) show a steady increase from 30 logs in 1955 to 70 logs in 1958. A similar situation occurred at map section 13 (fig. 4). In 1956, yarding in and around this section altered the stream drastically (fig. 8). Severe bank cutting along the north edge of the stream as a result of yarding across the stream and removal of debris in the stream caused extensive changes in the channel.

Relatively little change occurred in the upstream area where muskegs and beaver ponds border the bank. Some noticeable downstream movement of debris occurred. Comparison of the 1949 and 1960 map sections (fig. 9) showed little movement of debris or new input.

From 1949 to 1960, jams became larger and more frequent in the upstream sections. Areas with natural blowdown and braiding were completely occluded by debris as small side channels were filled with slash and heavy debris (fig. 7). As a result, the main channel was frequently rerouted and flow diverted away from side channels.

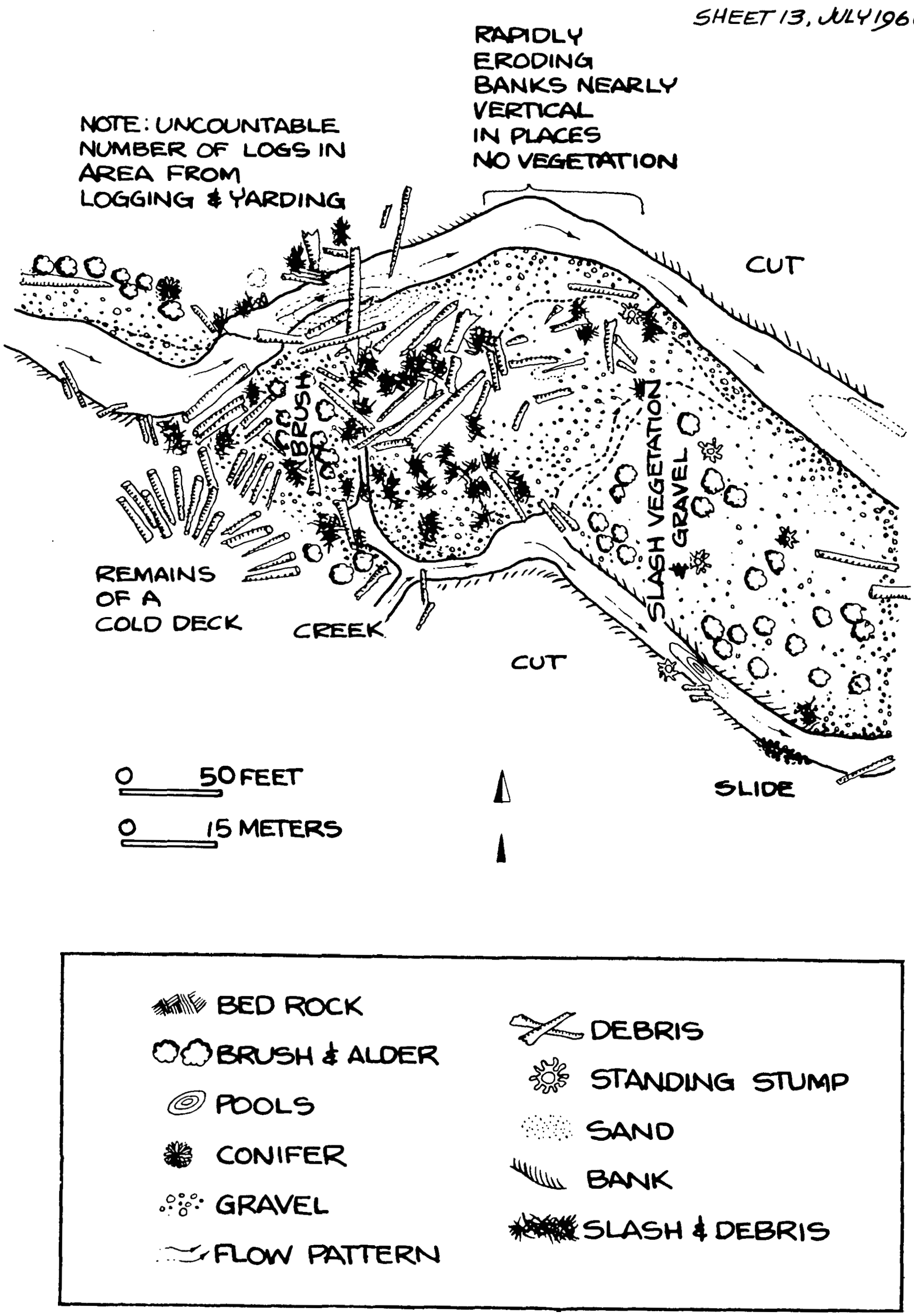

Figure **8.--Map** section 13 in 1960 showing results of yarding and removal of debris in Maybeso Creek. Figure 4 shows 1949 conditions in this section.

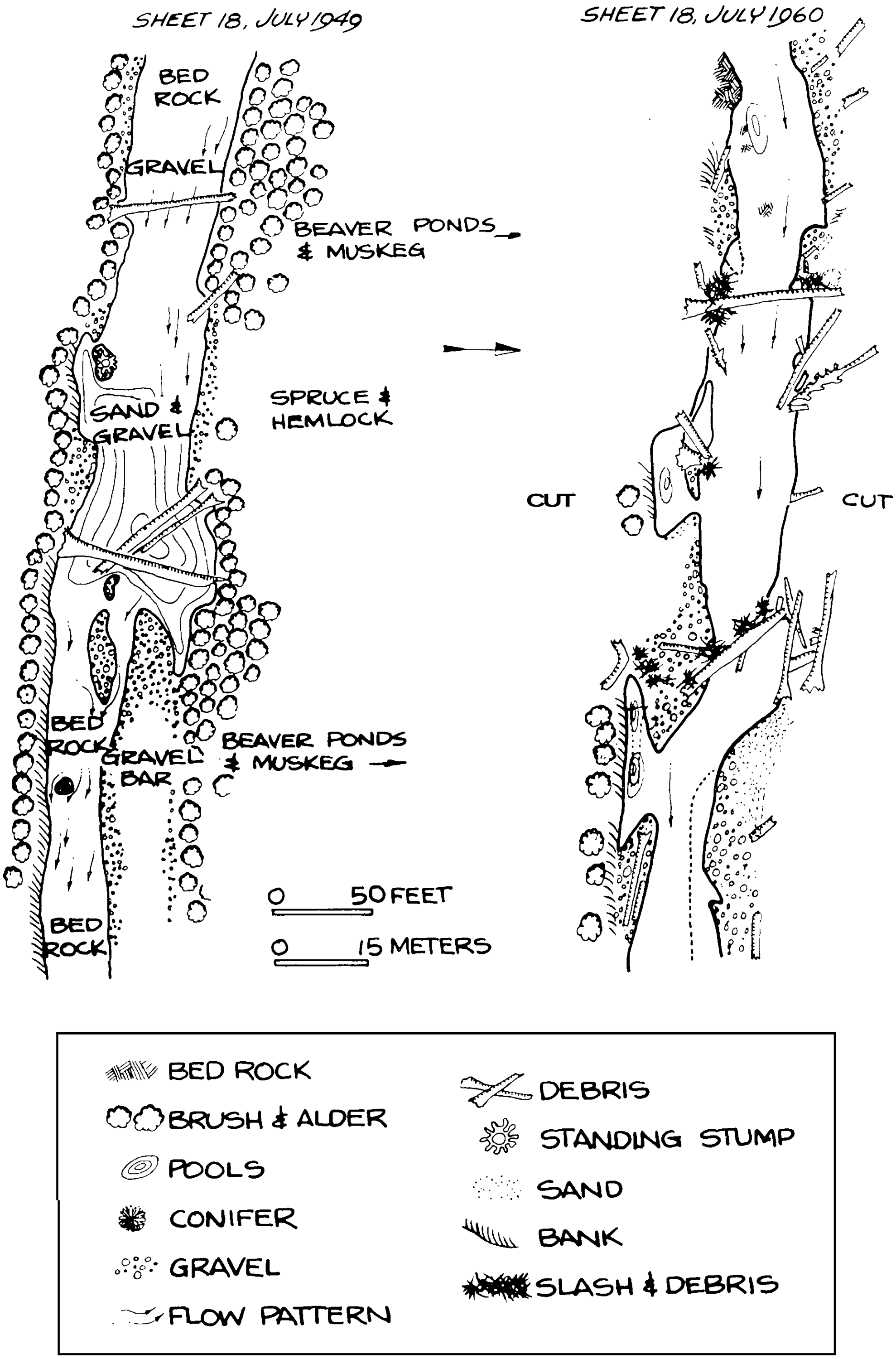

Figure 9.--Maybeso Creek, 1949 and 1960, at low levels of debris loading.

Although new jams were recorded on the 1960 maps, the largest accumulations occurred at points where natural debris had accumulated. Most new jams occurred at gravel bars. Jams generated by logging debris generally appeared to be less stable on a year-to-year basis than those created naturally. The relative instability of logging debris is illustrated by the map section series in figure 10. Logging debris began to accumulate in 1953. After the first addition of debris, the jam and channel began to gradually shift. Another channel was cut along the north bank with substantial gravel movement as flows were redirected. Over the 11-year period shown in figure 10, considerable movement occurred within the jam as individual pieces moved into and out of it. Most of the debris accumulation shown in figure 11 was floatable, large tree-size material. During fall floods, this material becomes highly mobile.

The major effects of logging debris jams were changes in the channel, bank erosion, and scour, aggravated by washout of accumulations of unstable large debris. After 1961, logging in the valley was reduced and new inputs of debris decreased accordingly.

1978

The observations are based on a personal on-the-ground reconnaissance. Because mapping was discontinued with the 1960 map series, no comparable maps were available for conditions in 1978. Copies of the 1949 and 1960 series were used as references during the reconnaissance. Where changes were observed, notes were made on the map sheets. Aerial photographs taken at various times before and after logging were also used as references.

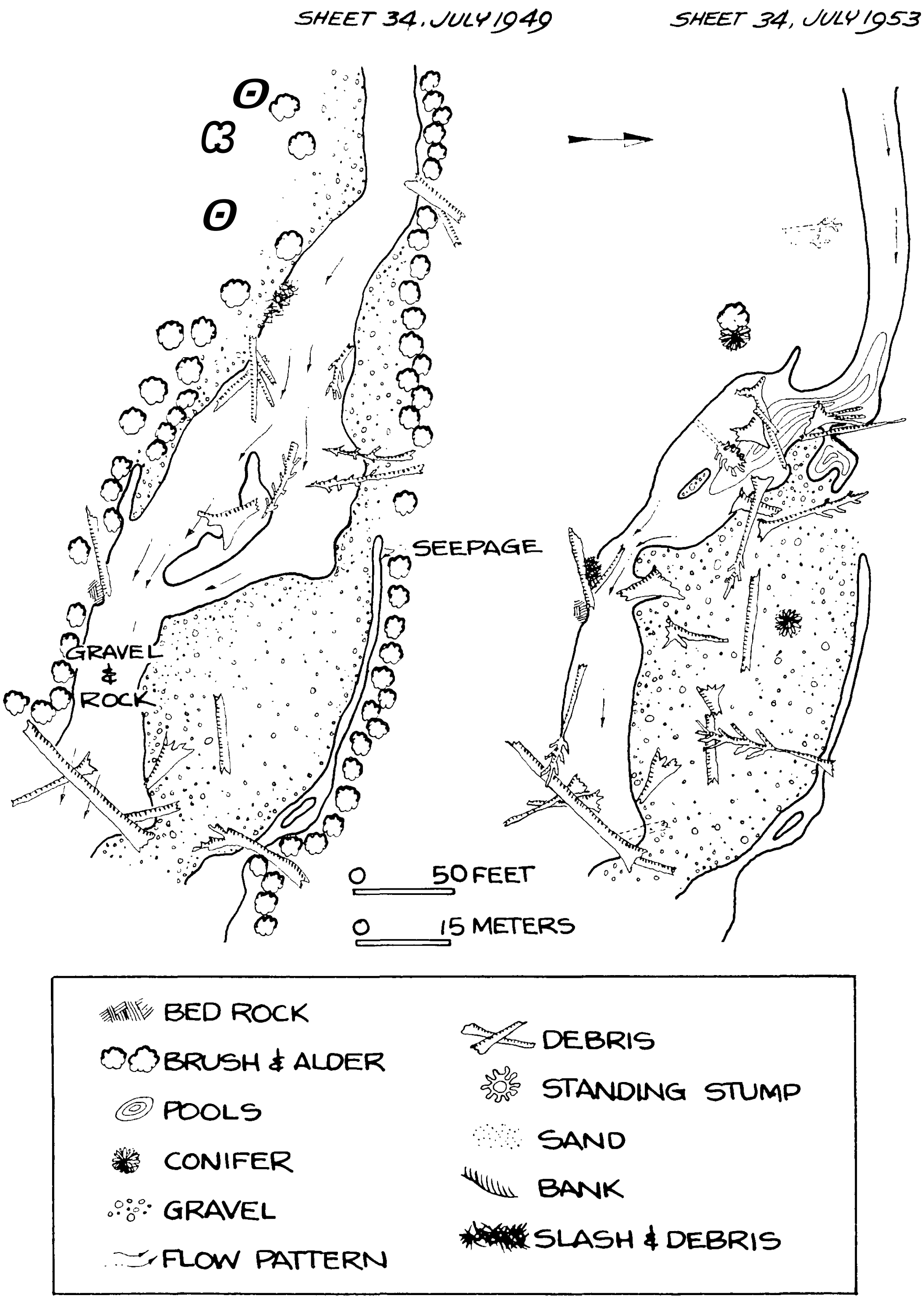

Figure 10.--Evolution of logging debris jam, 1949–60.

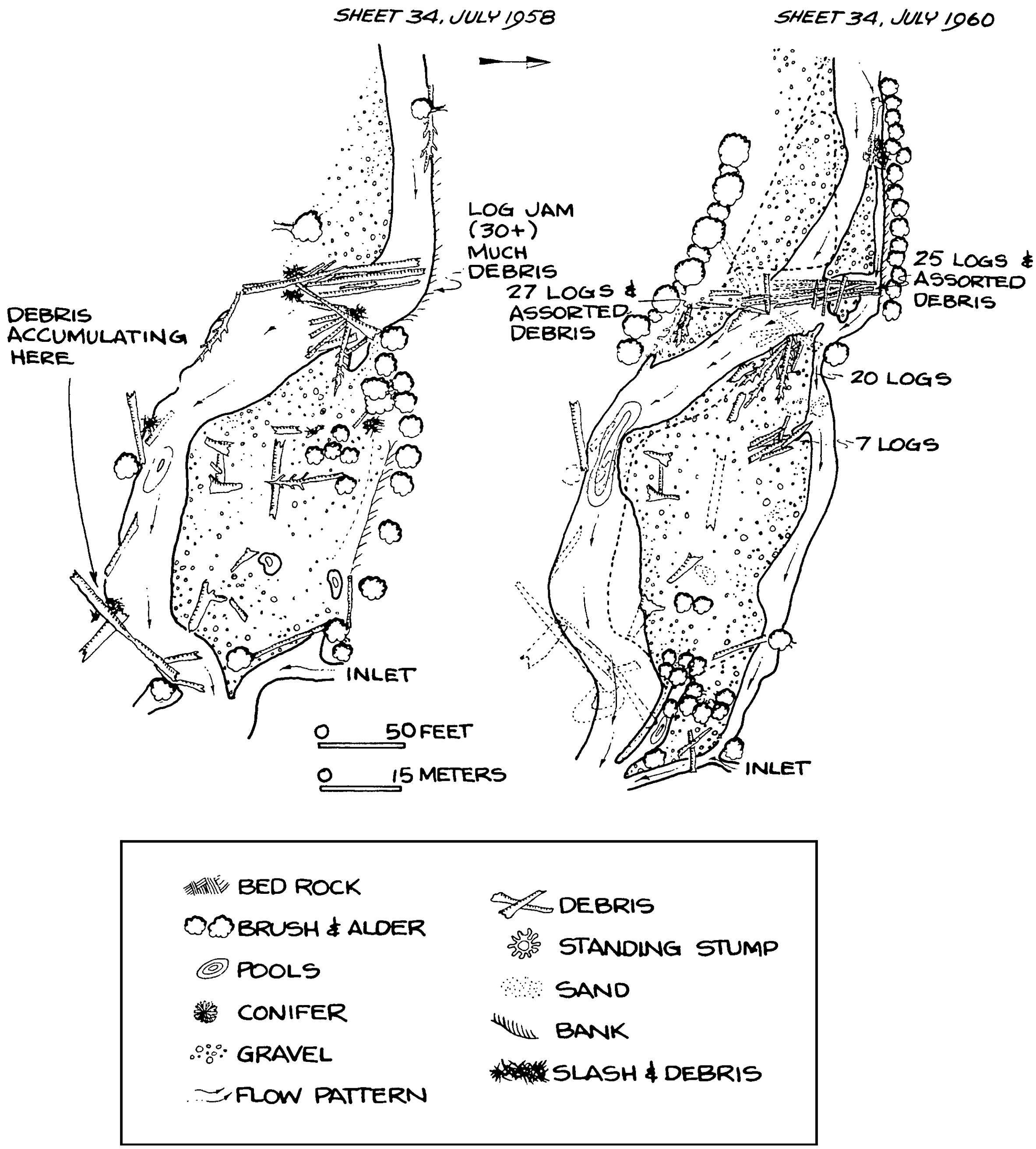

Figure 10.--Continued.

Figure ll.--Aerial photograph of map section 34, Maybeso Creek, 1961.

In 1978, many of the large debris jams shown in the 1960 map sections were absent. Furthermore, there were fewer accumulations in 1978 than in 1949 (table 1). In some places, changes were so great that it was difficult to locate ground position with either set of maps. Sections where a jam was shown in the 1960 map would commonly be replaced by a straight riffle area with overgrown banks.

Inspection of streambank areas revealed that substantial amounts of debris had been incorporated into the present bank structure. Most of this material had been thrown up on the bank during floods and was subsequently buried by flood plain deposits or regrowth of shrubs along the bank. As gravel was anchored by debris, regrowth of alder further obscured debris.

In 1978, the stream channel in the lower section was still predominantly bedrock. Accumulations of debris shown along the bank in 1960 appeared to have been either washed downstream or assimilated into the bank and flood plain. In several instances, pieces shown projecting into the stream on the 1960 map were well decayed and embedded in the bank. For the most part, there were no remarkable changes in this section.

Of the few remaining jams in 1978, all were originally natural accumulations that had increased in size as logging debris was washed downstream. Accumulations caused by logging were not evident in 1978. These appeared to have been washed out or, in some instances, may have been removed during the logging operation.

Above the first 1 000 m (3,281 ft) of stream, sparse (with respect to 1960) tree-size debris accumulations occurred on gravel bars (fig. 12). These were generally above water during low or moderate flows. They appeared to be stable and, in some cases, were partially buried. It is possible that similar pieces may be embedded beneath the gravel bars (fig. 13).

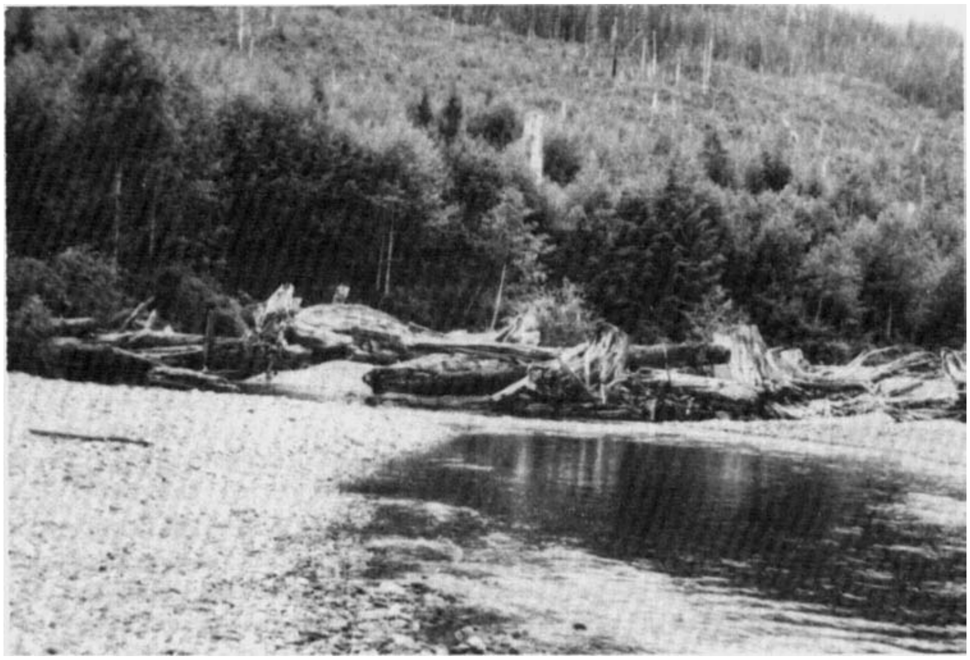

Figure 12.--Remnant accumulation of debris on a gravel bar in 1974.

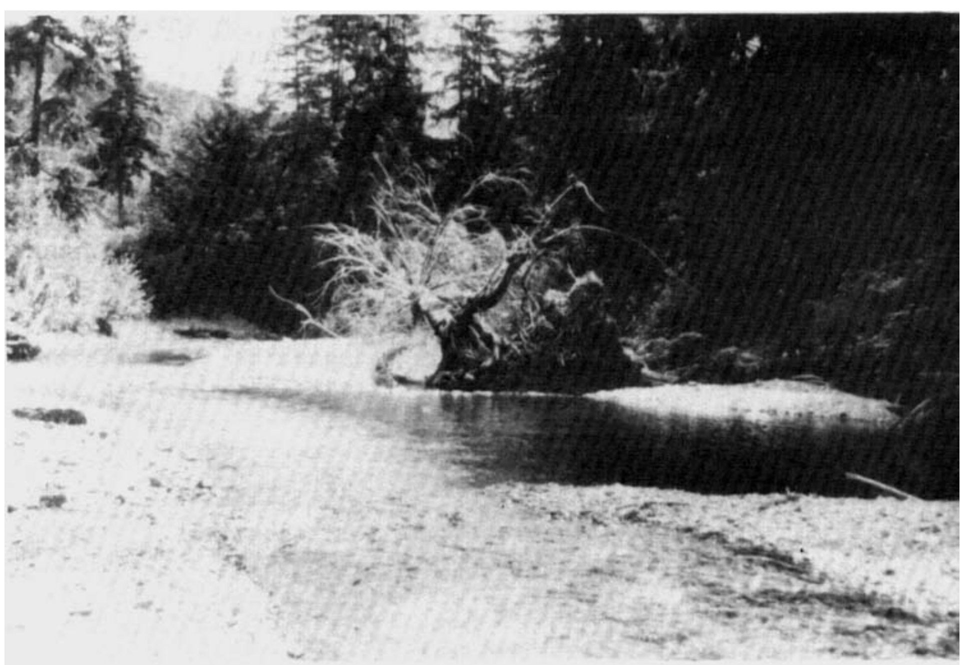

Figure 13.--Gravel bank anchored by partially buried roots of a down tree.

All major concentrations of natural debris were affected by logging debris; therefore, it was difficult to directly determine residence time of accumulations of natural debris in Maybeso Creek. Trees growing on blowdowns across the Shaheen River, located north of Hollis, were aged at over 70 years in a natural accumulation of large debris.

Accumulations remaining in 1978 in Maybeso Creek appeared relatively stable. The jam shown in the 1960 map section in figure 6 appeared little changed in 1978 (fig. 14). These areas were typically characterized by deep pools with large gravel deposits above and below the accumulations. In some cases side channels were formed, but this did not appear to be as common as indicated in the 1949 map section (fig. 6). Although local movement of gravel is likely, the major pieces of debris appeared to be well embedded, and waterflow was not severely constricted.

Figure 14.--Residual accumulation in 1978. Area corresponds to jam shown in the lower section in figure 6.

Logging debris commonly destabilized existing natural accumulations of debris. As a result, many natural accumulations were either washed out or became so clogged that a new channel was formed. An example of this process is shown in figures 15 and 16. The 1949 map section shows a relatively sparse, extensive accumulation with a series of side channels and islands. In 1960 this section was completely choked with debris. By 1978 this area was rechanneled into a relatively straight riffle section shown by the dashed line in figure 15. Figure 16 shows a view of the area in 1978.

Investigation of the bank area revealed evidence of the side channels and islands. Islands were identified by patches of spruce and hemlock. Tree cores taken during the 1978 survey showed that many of these trees were at least 60 years old. Surrounding areas were overgrown by alder of various ages, but usually these were less than 25 years old. Side channels were filled with gravel. The evidence seen in this case and residence times observed elsewhere indicate that undisturbed natural accumulations, such as those seen in the 1949 map section in figure 15, are relatively stable features.

Throughout the cut areas, only negligible amounts of new debris after logging were observed. In the uncut timbered area, new blowdown was evident (fig. 17). New debris was restricted to less than 20 m of the stream length but extended completely across the channel. The effect on the stream is partly illustrated in figure 17 by the buildup of gravel in the foreground. In addition, logging debris was collecting in the jam. Individual logs from the 150 road bridge, which was located approximately 2 000 m (6,562 ft) upstream, were observed in the jam. The area around the jam appeared to be active, with bank cutting along the north side and scour under the jam. No evidence of braiding was observed.

Alder appeared to be most effective in maintaining gravel bars and gravel banks but was ineffective in cut bank areas and was easily undercut. Where active cutting occurred, alder did not appear to contribute to stability.

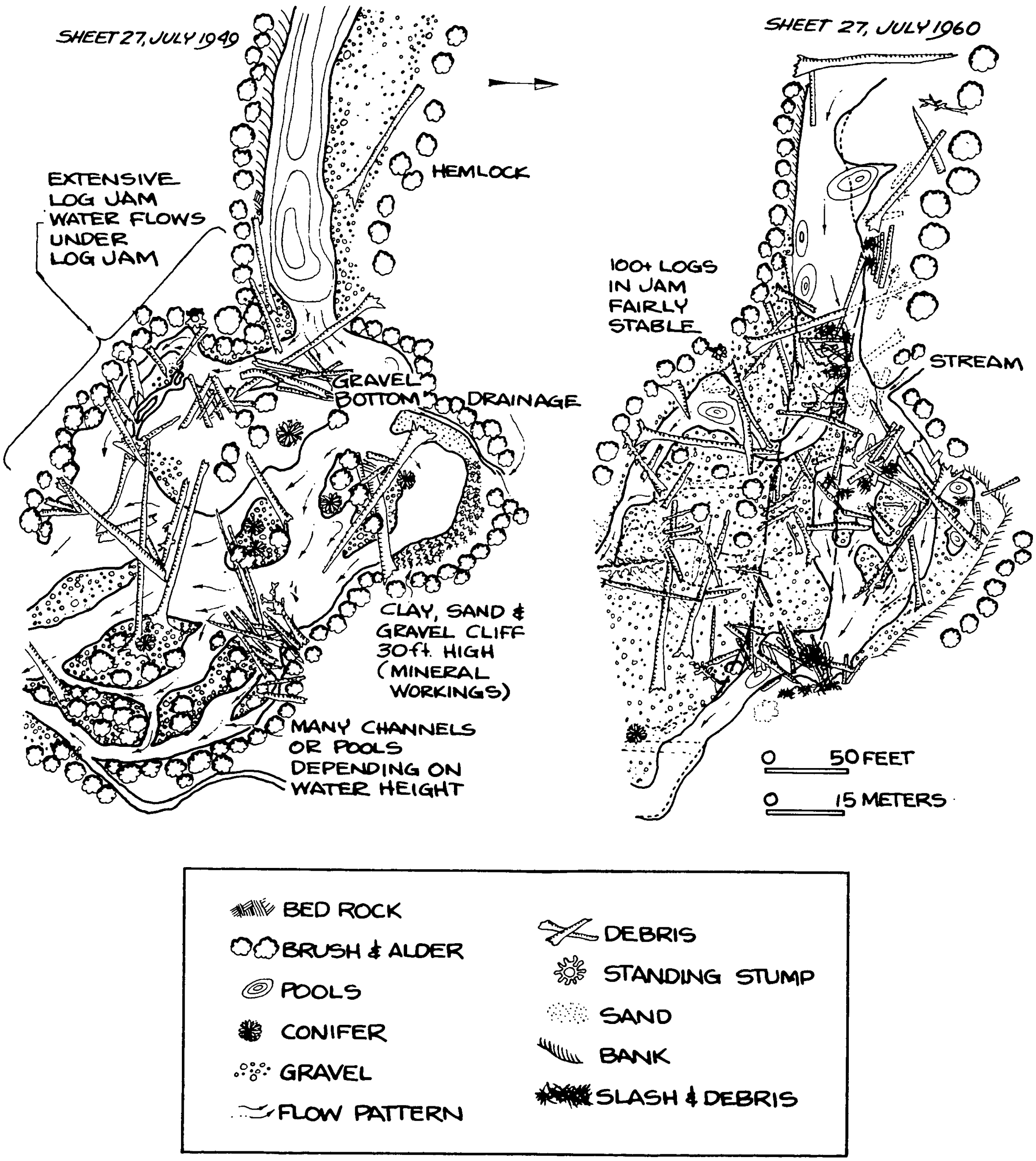

Figure 15.--Map sections of Maybeso Creek showing effects of logging debris on natural accumulation and change in channel.

Figure 16.--View from downstream into the area shown on the map sections in figure 15.

Figure 17.--Input of large debris to Maybeso Creek observed in 1978.

Figure 18 shows the primary large debris input to Maybeso Creek following logging. Bank cutting has tipped small hemlock into the stream. This material is easily floated and will not appear as a stable feature as did the large spruce and hemlock blowdown shown throughout the 1960 map sections. It is apparent that small, young hemlock and alder do not replace old-growth Sitka spruce and hemlock as a source of large debris.

Figure 18.--Illustration of streambank undercutting along Maybeso Creek in 1978.

CONCLUSIONS

Timber harvest has caused extensive changes in the stream channel of Maybeso Creek. Some of these changes may have been imposed by equipment operating in the stream, but most were related to accumulations of large debris. Natural accumulations appeared stable compared with those created by logging debris. Throughout logging, natural accumulations collected large amounts of logging debris and subsequently washed out.

The absence of old-growth forest along the streambank effectively eliminated new accumulations. The decrease in the number of accumulations of large debris after logging is apparent in table 1. As these accumulations are dissipated, pools formed around accumulations of large debris will be replaced by riffles; thus, there will be a net increase in riffle areas. As these areas stabilize, the stream channel morphology will be determined by rock formations and streambank.

It was evident that large quantities of tree-size material had been assimilated between 1960 and 1978, either within the stream or along the banks. Although amount of debris throughout the active channel has decreased, debris along the bank and projecting into the channel still plays a role in channel morphometry. In some cases, it will contribute to bank stability. These areas will also contribute to the formation of pool areas important to juvenile salmonids.

The observations of events following logging on Maybeso Creek show that accumulations of large natural debris play an active role in channel morphometry and form relatively stable features, such as pools and side channels. Natural debris accumulations are most severely affected by large floatable logging debris, whereas bedrock areas are generally unaffected.

Natural debris accumulations sieved floatable logging debris which created massive jams that became unstable and washed out. After logging, accumulations of large debris decreased in size and number. The few remaining in Maybeso Creek are remnants of old natural accumulations.

For a full understanding of the significance of these changes, additional work remains: (1) remapping the stream to provide a complete picture of the changes in channel morphometry in the last 20 years, (2) analyzing organic and fine sediments in remaining accumulations, (3) comparing the invertebrate and fish populations of debris-formed pools and riffle areas, and (4) determining the suitability of riffle areas as spawning sites for pink and chum salmon. Such studies should relate the physical changes observed over the past 30 years to the productivity of the system.

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