# STREAM AND FLOODPLAIN RESTORATION IN GLEN CREEK, DENALI NATIONAL PARK AND PRESERVE

Kenneth F. Karle and Roseann V. Densmore

Technical Report NPS/NRWRD/NRTR-94/17

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## Abstract

The National Park Service is conducting long-term multi-disciplinary research on methods to promote riparian ecosystem recovery on placer-mined sites. The primary study site is located on abandoned claims on lower Glen Creek in the Kantishna Hills region of Denali National Park. One component of this research is a project to develop techniques which will restore proper function to stream channels and floodplains. Project design requirements include a channel capacity for a 1.5-year (bankfull) discharge and a floodplain capacity for a 1.5-to-100 year discharge. The project design included the development of alder brush bars, located on the floodplain to dissipate floodwater energy and encourage sediment deposition. The brush bars, constructed of alder bundles tied together, were designed to offer protection from floods until natural revegetation occurs. Streambank plantings of *Salix alaxensis* cuttings and *Alnus crispa* seedlings were also established to anchor the substrate and catch organic debris. A moderate flood near the end of the two-year construction phase of the project provided data on channel design, stability, and floodplain erosion. The brush bars provided substantial protection, but unconsolidated bank material and a lack of bed armour in some areas led to bank erosion, slope changes, and an increase in sinuosity.

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February 1994

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# INTRODUCTION

Placer mining for gold has severely disturbed many riparian ecosystems in northern regions. Placer mining involves removing vegetation and topsoil, excavating gravel down to bedrock from the active floodplain, old terraces, and/or the active stream channel, and processing the gravel to remove the gold.

Glen Creek, in the Kantishna Hills region of Alaska's Denali National Park and Preserve, is typical of many placer-mined streams in the area. It is characterized by significant stream channel adjustments and disfunctioning riparian zones. Specifically, unstable or excessively confined streambeds, as well as over-steep floodplains are evident along many reaches of the 8 km length. Piles of mine tailings have replaced much of the native streambed material. Riparian vegetation is absent along most channel bank and floodplain reaches. Floodplain soils, necessary for vegetative recovery, are relocated in separate distinct piles, or absent altogether. Soils replenishment, normally a function of annual flooding, is impossible due to confined streambeds.

The importance of a properly functioning riparian zone cannot be overstated. Riparian habitat in undisturbed conditions is characterized by high levels of species diversity, density, and productivity (Van Haveren and Jackson 1987). Evidence indicates that the habitat value of the Glen Creek watershed and other mined drainages of the Kantishna Hills has been severely reduced (USNPS 1990). Long-term habitat loss for grizzly bear, black bear, moose, furbearers, and birds has been documented. Aquatic zone habitat has similarly been disturbed. Populations of many of the macro and microinvertebrates, as well as *Cottus cognatus* (slimy sculpin) and *Thymallus arcticus* (arctic grayling), are suspected to have been severely impacted or eliminated (Myer and Kavanaugh 1983).

With such a disturbed hydrologic regime, riparian ecosystem recovery through natural processes is significantly hindered in the Glen Creek watershed. In channel reaches where the stream bed is incised and straightened, bed scouring continues to occur. During annual flooding, erosion of banks results in excessive sediment loading of the stream. This sediment load is then deposited in the channel downstream in areas of shallower gradient, resulting in additional problems such as cementing of substrates and clogging of benthic invertebrate habitat. Incised stream channels also prevent flood waters from reaching the floodplain, thus interrupting the natural process of floodplain sediment deposition necessary for the enhancement and creation of moist, nutrient rich zones.

Abandoned placer claims on lower Glen Creek represent a unique opportunity for conducting research to improve riparian ecosystem recovery. As part of a National Park Service (NPS) long-term multi-disciplinary research effort, a hydrologic study was begun in 1990 to address the development of techniques for the stabilization and restoration of stream channels and floodplains disturbed by mining activities. The specific goal of this study was to develop restoration techniques which would

(1) reduce erosion, (2) allow the stream to develop floodplains, sinuosity, and pools and riffles similar to premining conditions, and (3) minimize construction needs. Testing of stream restoration techniques took place in 1991 and 1992 along two adjacent reaches of Glen Creek totaling 1400 m in length.

## STUDY AREA

The Glen Creek watershed study area lies within the Kantishna Hills, a group of rugged, low-lying hills located within Denali National Park and Preserve (Figure 1). The watershed is 17.2 $km^2$, with elevations ranging from 648 m at the mouth to 1372 m near Spruce Peak. Glen Creek originates as two forks, south and east of Glacier Peak, in a highly mineralized area. The east fork flows 1.1 km to the confluence, while the west fork flows about 2.4 km to the confluence. The stream then flows 5.6 km to join North Fork Moose Creek. The bedrock geology of the Glen Creek watershed is faulted and folded quartzite and hornblende schist of the Birch Creek formation. The study area on lower Glen Creek was covered in the middle Wisconsin with glacial ice from the Alaska Range, and gravel and rocks deposited by the glacier are mixed with bedrock material in the alluvial gravels.

The Glen Creek watershed is in the continental climatic zone of interior Alaska; however, the continental pattern of light precipitation and extreme temperatures is modified in the Kantishna Hills (Selkregg 1974). The summers are cooler in the study area because of the greater maritime influence and a higher elevation. July, the warmest month, averages 12° C, while January, the coldest month, averages -18° C. Precipitation averages 47.8 cm annually with 72 percent occurring from June through September. Snow accumulation ranges from 50 to 150 cm. Discontinuous permafrost may be found throughout the Kantishna Hills area.

The study area is at treeline, and trees are confined to favorable sites on alluvial terraces and south-facing slopes. Tall shrubs dominate riparian vegetation on the floodplain and younger terraces, and low shrubs and herbs form the tundra vegetation on colder, more exposed sites. The mining severely disturbed the vegetation on the study area, but the predisturbance vegetation can be inferred from remnants and adjacent undisturbed watersheds. On these watersheds the floodplain is dominated by *Salix alaxensis* (feltleaf willow) (Viereck and Little 1972) 3-4 m tall, mixed with varying amounts of *Alnus crispa* (American green alder) 1-2 m tall. The floodplain is vegetated to the bankfull stream level; natural flood or ice events which remove vegetation and initiate primary riparian succession appear to be infrequent. Higher areas have *Populus balsamifera* (balsam poplar) and younger *Picea glauca* (white spruce), and old terraces have open stands of Picea glauca with an understory of *Betula glandulosa* (dwarf birch) and *Salix planifolia* (diamondleaf willow).

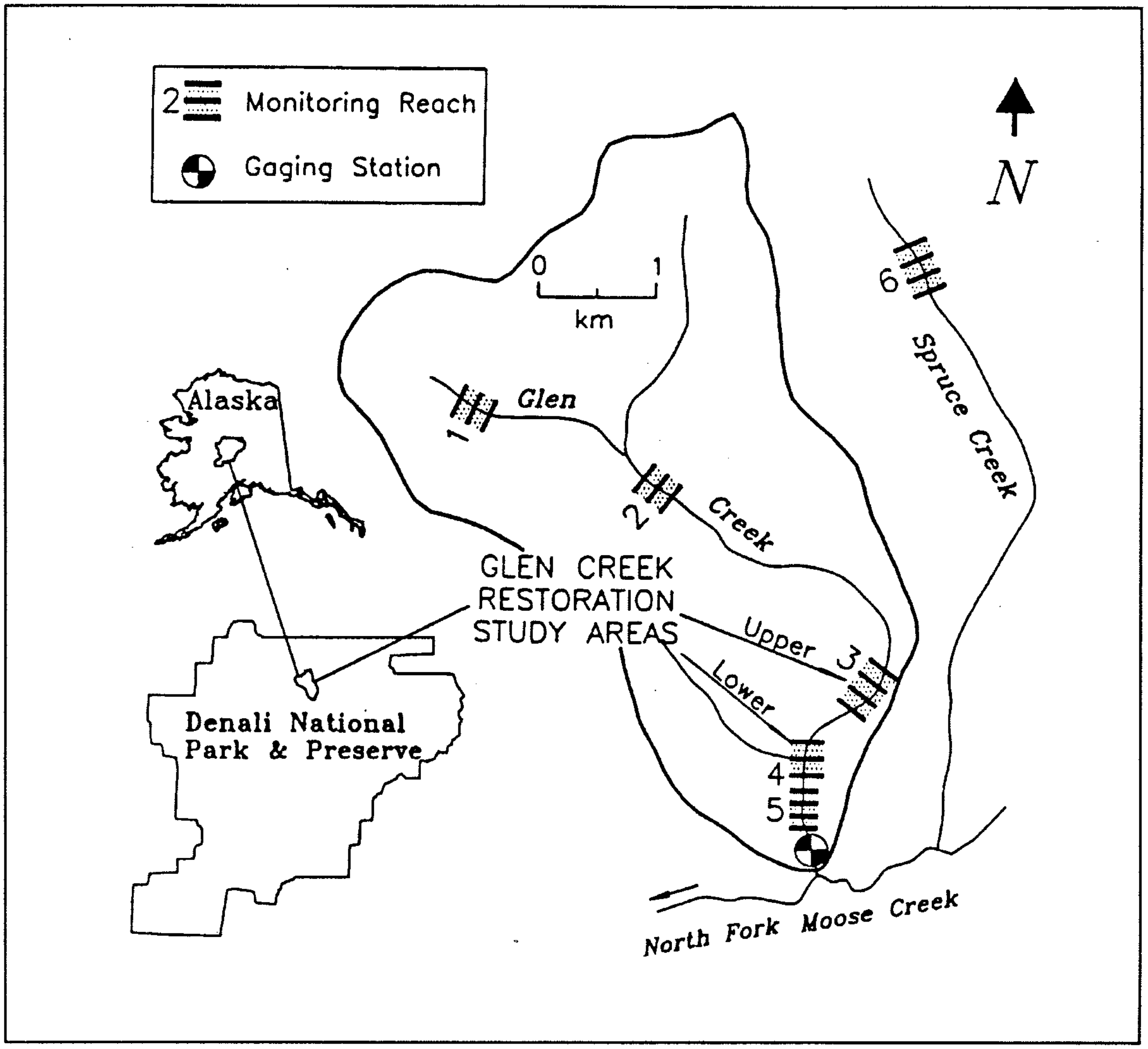


Figure 1. Location of the Glen Creek study area in Denali National Park and Preserve, Alaska.

The Glen Creek watershed was hand-mined from 1906 to 1941. The stream was diverted and dammed, and topsoil and fines were washed away, but the areal extent of disturbance was limited relative to later mining. In the 1970s, the watershed was extensively remined with heavy equipment. The entire west fork, much of the east fork, and most of the entire length from the confluence to the mouth suffered extreme disturbance from this period of mining.

Initial restoration by NPS of the study area began in August 1988, when the area above the active floodplain was recontoured. Excavated material was redistributed to fill excavations, reduce and stabilize slopes, and the available topsoil and fines were spread over some areas of gravel and rock substrate. The work described in this report, the restoration of the active floodplain and stream channel, was initiated in 1991.

# METHODS

Jackson and Van Haveren (1984), in an attempt to enhance riparian zone recovery in a portion of Badger Creek, Colorado, developed a methodology for designing stable channels in coarse alluvium based on pertinent geomorphic, hydraulic, and hydrologic principles. This methodology was based on the premise that a channel in coarse alluvium is considered stable if design discharges and sediment loads can be carried without causing excess bank or bed erosion or deposition. This design, with modifications for subarctic conditions, was the basis for the NPS Glen Creek study. A brief outline of this design follows; for specific hydraulic design details, see Jackson and Van Haveren (1984).

## Channel Design

The requirements for channel design include a streambed capacity to contain a 1.5 year (bankfull) discharge, and a floodplain capacity to contain a 1.5-to-100 year flood. Though Jackson and Van Haveren recommended the use of channel controls such as riprap or gabions, NPS felt these controls generally hinder natural stream restoration, and excluded their use.

The design process began with the estimation of design flood flows from regional multiple-regression estimations (Lamke 1979; Kane and Janowicz 1988) (see Figure 2). The estimated bankfull discharge was 1.44 $m^3/s$; however, a value of 1.83 $m^3/s$ was used for the design as a factor of safety.

Manning's equation was applied to determine a range of channel configurations which would carry bankfull discharge. The roughness coefficient, Manning's "n", is computed from hydraulic analysis of previous discharge measurements (Jarrett 1985).

Once a range of bankfull channel configurations was found, shear stress equations were applied to each configuration to determine stability for both bed and bank. Design theory dictates that incipient motion of bed and bank material begin at or just above bankfull discharge. In this manner, a general balance in bedload transport should be achieved. In flooding conditions, material being brought down from steeper reaches upstream should pass through to shallower reaches. At low flow, low shear stresses will not cause erosion, and no deposition will occur. Slope and sinuosity determinations were made by regional comparisons to other Kantishna streams, based on regression with drainage area (USNPS 1991). Typical values for the design channel are found in Table 1.

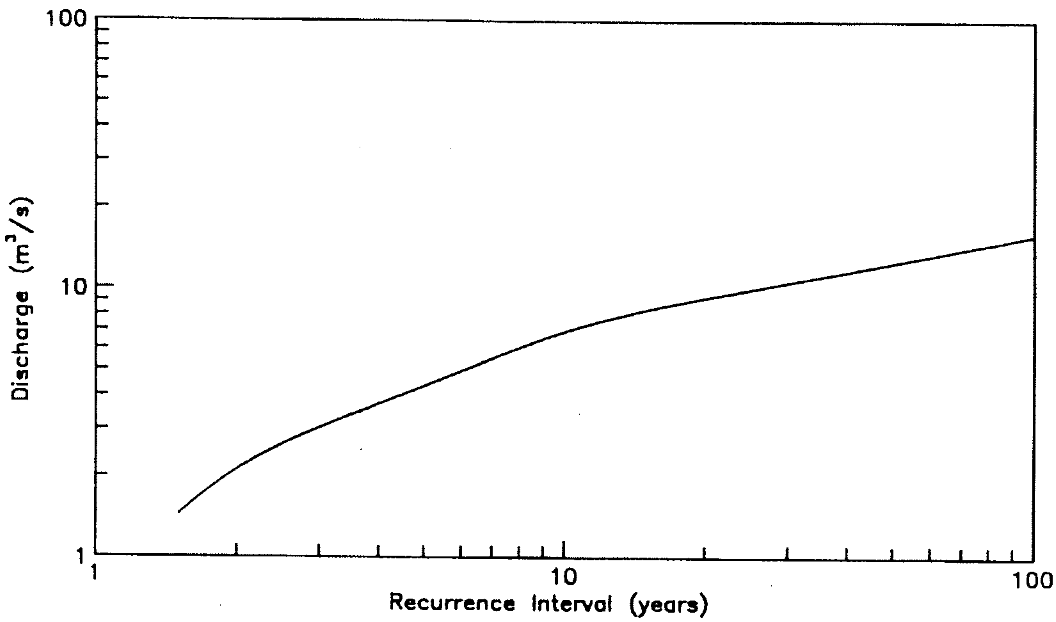


Figure 2. Flood frequency curve for Glen Creek study area.

| | |
|---|---|
| Bankfull discharge | 1.83 $m^3/s$ |
| Slope | 0.0224 m/m |
| Sinuosity | 1.12 |
| Manning's "n" | 0.051 |
| Bankfull width | 6.0 m |
| Bankfull depth | 0.3 m |
| Average bed shear stress | 5.70 $kg/m^3$ |
| Critical bed shear stress | 5.90 $kg/m^3$ |
| Average bank shear stress | 4.39 $kg/m^3$ |
| Critical bank shear stress | 4.91 $kg/m^3$ |

Table 1. Typical values for the Glen Creek design channel.

Floodplain design was achieved in the same manner. Using a 100-year flood discharge estimate of 16.0 $m^3/s$, capacity equations were used to determine floodplain geometry. For many sections of the study reach, the floodplain was designed in a 2-terrace configuration, with the lower terrace designed to carry the 20-50 year flood, and the upper terrace capacity at the 100-year flood. Depending on location along the study reach, floodplains were either situated on one or both sides of the streambed. Floodplains were typically located on the inside of meanders and bends, and on both sides through straight reaches.

Once the design parameters were established and surveyed, earthwork took place along two reaches of Glen Creek, including a 425 m reach in 1991 (upper study area) and an adjacent 975 m reach in 1992 (lower study area). To achieve the design goal of a functioning channel and floodplain, two types of earthwork configurations were constructed along the test reaches. Most of the work involved recontouring over-steepened floodplains to a lower elevation, using a shallow slope to restore natural floodplain processes, and leaving the existing channel undisturbed except for minor bank modifications (Section design 1, upper study area, Figure 3). In one area, an entirely new channel 150 m long was designed and repositioned in the valley center, away from the valley wall where it was previously located (Section design 2, lower study area, Figure 3). Additionally, the floodplains along this reach were constructed with two terrace levels instead of a single slope.

Excavated gravels were used in some areas to fill in settling ponds, old channel beds, and other unnatural depressions. Excess gravels were blended into the valley slope at the floodplain's edge. A crawler-dozer, articulated front-loader, and dump truck were employed to move the ground to the desired configuration.

## Temporary Floodplain Stabilization

In conjunction with these restoration techniques, results from revegetation research currently being conducted in the Glen Creek watershed were applied to facilitate riparian zone recovery. On undisturbed floodplains, the vegetation is an important component of floodplain structure and stability. The root system anchors the substrate, and above-ground plant decreases water velocity, catches organic debris, and promotes sediment deposition. Based on observations in adjacent less-disturbed watersheds, we predicted that the reconstructed floodplains would naturally revegetate within five to ten years.

A major concern for this project was the occurrence of a large flood before revegetation occurs, which could seriously damage the new channel and floodplain. The probability of such an event was calculated in the following manner (Linsley et al. 1982). The probability J that a flood P will be equalled or exceeded in N years is:

$$J = 1 - (1 - P)^N$$

For example, in the five year time period for revegetation to occur, there is a 67 percent probability that a 5-year flood will occur or be exceeded, a 41 percent probability that a 10-year flood will occur or be exceeded, and a 23 percent probability that a 20-year flood will occur or be exceeded.

We predicted that serious damage could occur to the new (unvegetated) floodplains from a 10-year flood or less. Based on the low probability of occurrence for a 50- or 100-year flood, and the difficulty and expense of protecting against such larger discharges, we decided to install protective devices for smaller (5- to 20-year) flood events. An additional goal with such devices was to encourage sediment deposition during flood events.

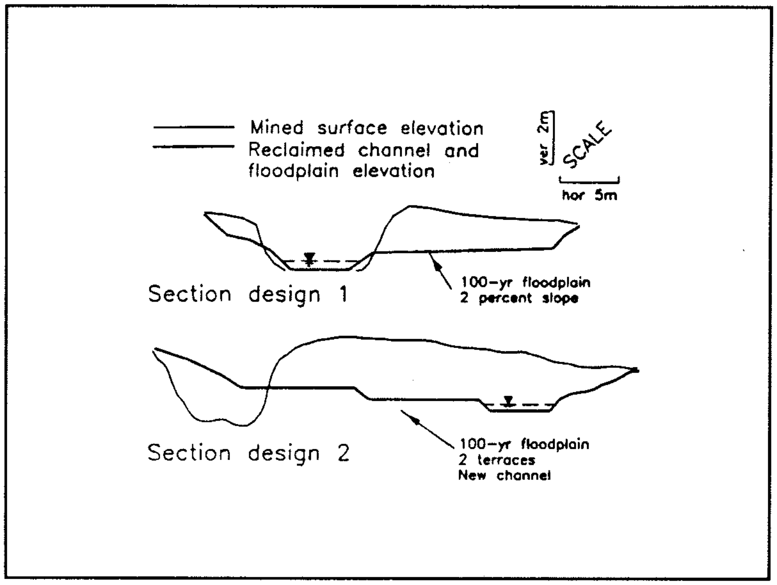


Figure 3. Typical cross-section designs. The channel is designed to carry bankfull discharge (1.5-year flood). Two floodplain configurations (single 2-percent slope, and 2-terrace) were designed to carry the 100-year flood.

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To meet these requirements, a series of alder brush bars were installed on various locations along the study reaches. Designed to slow flood water velocity and encourage sediment deposition, these were bundles of cut alder, approximately 50 to 75 cm in diameter and 4 to 5 m in length. The bundles were installed by first digging a trench into the floodplain perpendicular to the channel. Several rope lengths were placed across the open trench, the lower half of each bundle was set into the trench, and the trench was then backfilled. The top half of the bundle was added, and the ropes were tied around the bundle to anchor the bundle in place (see Figure 4). In 1991, two groups of brush bars were installed on the upper reach. The bars were placed two to three channel-widths apart, with four bars in the first group and 22 bars in the second group. Bars in the first group included one 4 to 5 m long feltleaf willow branch buried in the lower half of the bundle, and five willow cuttings planted into the downstream side of the bundle. For the 1992 project, two groups of brush bars were installed on the lower reach, with the spacing at one channel-width apart. One group contained eight bars, and the second group, installed along the left bank of the new channel construction, contained 25 bars.

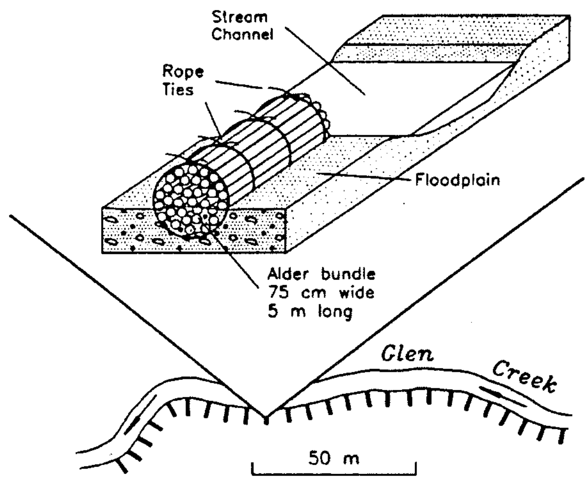


Figure 4. Brush bar pattern, with one channel-width spacing along left bank of new channel reach in lower study area. Inset shows typical installation of alder bundle, adjacent to channel, and anchored to the floodplain.

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Additional techniques were also tested to encourage sediment deposition. Small circular ridges 10 to 20 cm in height and 1 to 2 m in diameter were created by the tracks of a bulldozer running a pattern of tight turns on the new floodplain surfaces. These ridges were designed to capture sediment and precipitation runoff, and catch airborne seeds as they tumble across the roughened surface.

Streambank plantings of *Salix alaxensis* cuttings and *Alnus crispa* seedlings were also established to anchor the substrate and catch organic debris. In 1991, on the upper section, willow cuttings collected near the site were planted in rows of five, perpendicular to the stream, in a 0.5 m band bordering the stream channel. A total of 250 cuttings were planted between the first five brush bars in the second group. An additional 130 cuttings were planted on a point bar without brush bars. Greenhouse-propagated containerized alder seedlings (from seed collected on site) were planted in rows of three, perpendicular to the stream between two brush bars. On the lower section, in 1992, feltleaf willow cuttings collected near the site were planted in rows of five, 1 m long, perpendicular to the stream, with three rows between each brush bar.

## Longterm Monitoring

In order to assess the degree of success of the design, a comprehensive long-term monitoring program has been enacted on Glen Creek. Six distinct reaches, each with three or four permanently monumented cross-sections, were established to track changes over time in the channel and floodplain configuration. These reaches are located in both study areas where active restoration took place, as well as upstream and downstream of the restoration work, and in an undisturbed section of Spruce Creek, which is an adjacent watershed to Glen Creek (Figures 5 through 10).

Surface bed material was periodically sampled to track changes in caliber over time. Size analysis was performed by a pebble count, in which the intermediate axis of 100 randomly picked particles are measured, and the size distribution is expressed in percentage by number of particles (Leopold 1970).

Additionally, sampling of benthic invertebrates, water chemistry, streambed material, and suspended sediment was also incorporated into the long-term monitoring, conducted jointly with the U.S. Geological Survey (USGS). A stream-gage and weather station were located in the lower end of the Glen Creek watershed to provide pertinent hydrologic data.

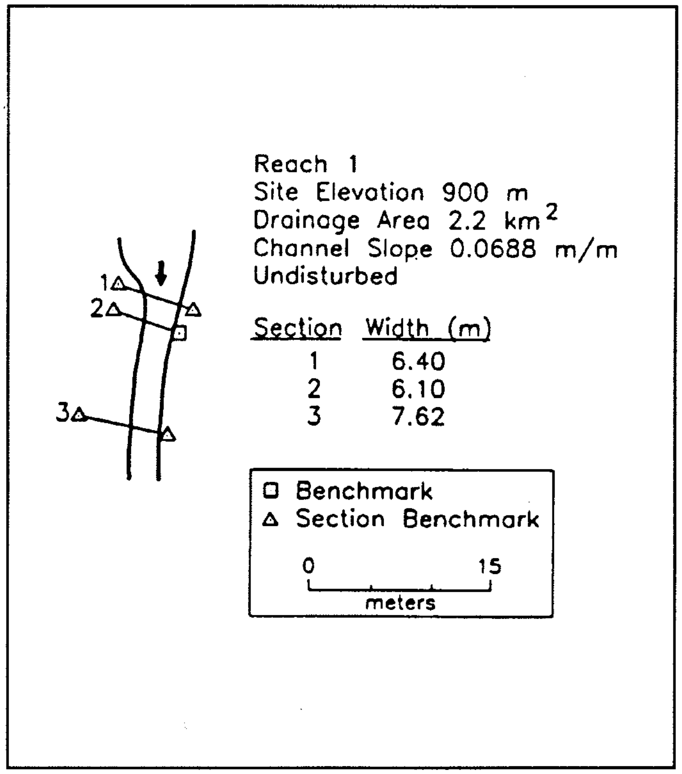


Figure 5. Monitoring reach No. 1, on upper Glen Creek.

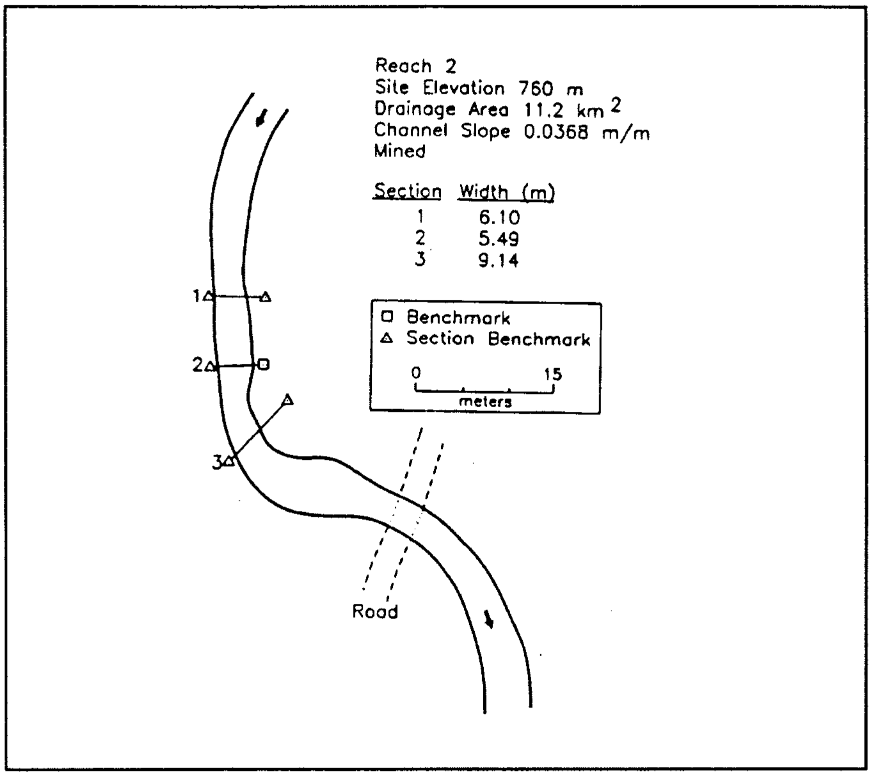


Figure 6. Monitoring reach No. 2, on mid-upper Glen Creek.

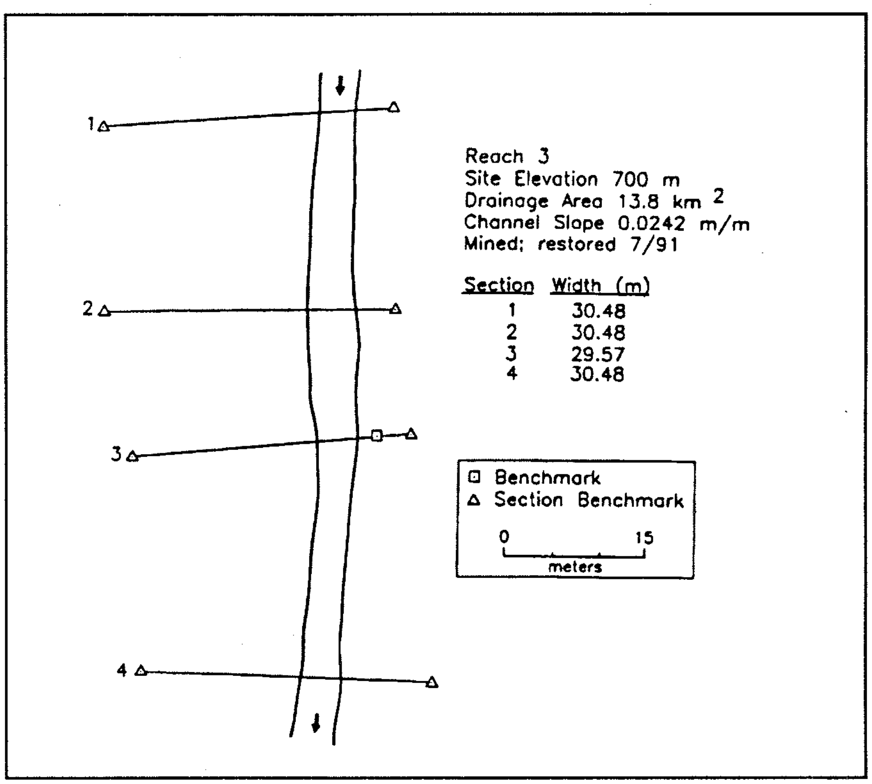


Figure 7. Monitoring reach No. 3, on middle Glen Creek.

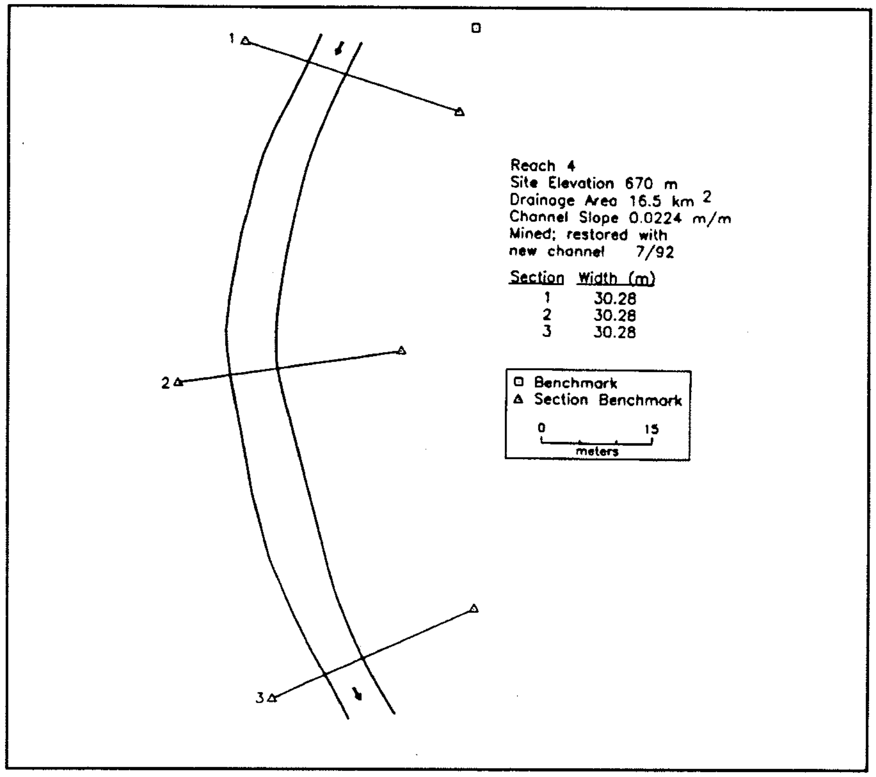


Figure 8. Monitoring reach No. 4, on mid-lower Glen Creek.

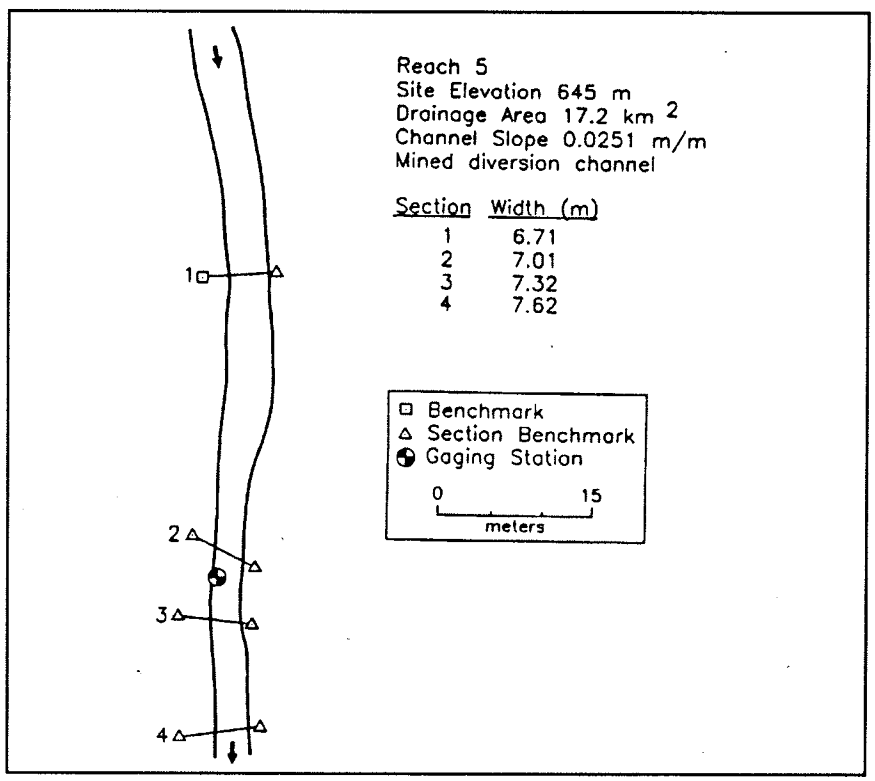


Figure 9. Monitoring reach No. 5, on lower Glen Creek.

## RESULTS

As the channel and floodplain work for the 1992 project neared completion, the Glen Creek study area experienced a moderate flood event. Flood peak discharge was calculated at 4.7 $m^3/s$ on August 5, 1992 (the 5-year flood discharge is estimated at 4.4 $m^3/s$). This flood event and the resultant changes to the newly constructed channel and flood-plains generated important preliminary information for this design project.

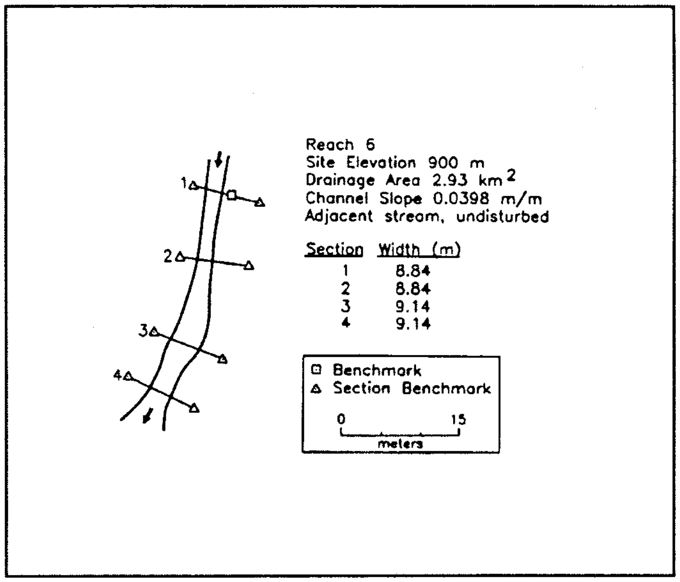


Figure 10. Monitoring reach No. 6, on upper Spruce Creek.

As mentioned above, six reaches were established, each with three or four monumented cross-sections, to track changes in channel geometry. These cross-sections were each surveyed during August in 1990, 1991, and 1992. Appendix A contains the figures of all cross-sections surveyed, and should be referred to in the following section.

The major design goal was bed stability, which does not require bed immobility but rather occasional material movement and fluctuations in channel geometry about a long-term stable average (Andrews 1982; Heede 1986). However, at the time of construction we were concerned about bed instability and erosion potential in areas which had unconsolidated bank material and/or lacked an armor layer. Two areas presented special problems. In the lower study area, construction of the new channel segment passed through a section of undersized processed mine tailings, markedly decreasing the average size of the bed material and effectively eliminating the old bed armor layer which it replaced. Floodplain lowering in the upper study area uncovered additional sites of fine unprocessed tailings on the right bank adjacent to the stream channel. Both sites were protected with brush bars.

The passage of the August 5, 1992 flood event caused several significant changes to the channels in these areas. Severe bank erosion, channel widening, and lateral migration of the channel were noted in both study areas. In the lower area along the new channel segment, enough erosion and lateral movement of this reach occurred, to result in a slope decrease of almost 5 percent, with a corresponding increase in channel sinuosity. The erosion took place along the right bank, which was unprotected by alder brush bars. See Cross-section 1 in Reach 4 (Appendix A).

Cross-section 1-4 in Reach 3 also shows channel changes in the upper study area, which suffered bed and bank erosion and channel widening.

The first few brush bars in each group took the brunt of the flood. In the upper reach, the flood water eroded the floodplain in front of, and the streambank under the end of, the first brush bar in each group, and bent the brush bar around the resulting corner. This brush bar configuration prevented further erosion and remained stable throughout the remainder of the season, although the stream flow was now channeled against the front of the bar. On the lower reach, the first brush bar in the first group was entirely washed out, and the second bar was bent around and stabilized the remainder of the floodplain. The first bar in the last group remained in place, but demonstrated the size and volume of bedload material moving during the flood. Cobbles (to 20 cm) and gravel were deposited in front of and over the bar, to a depth of 0.5 m.

Floodwater cut behind most of the brush bars on the upper section, where the bars were three stream widths apart. The floodplain area containing the last three bars on the upper section was highly erodible tailing material. In this section a new channel was cut behind the brush bars, creating an island. Some deposition occurred in the upper reach, but much of the material was reworked and eroded by the floodwater flowing behind the bars and back into the stream between bars.

Floodwater cut behind only the first few brush bars in each group on the lower reach, where the bars were only one stream width apart. Substantial amounts of sediment were deposited on the floodplain where water did not run behind the bars. Cross-section 1 in Reach 4 (Appendix A) shows substantial deposition on the left bank (where the bars were located). Figure 11 depicts the average deposition of material adjacent to brush bars installed along the new channel section.

In mined reaches where no active floodplain or channel restoration took place, bed and bank instability was apparent, with significant channel movement during the first two years of monitoring (Cross-sections 1-4, Reach 5, Appendix A). The two control reaches in upper Glen and Spruce Creeks remained relatively stable during this same period (Cross-sections in Reaches 1 and 6, Appendix A). Inundated circular depressions were very effective at trapping sediment, and average particle size was smaller than the sediment trapped by the brush bars.

The bed material caliber changed significantly as a result of the flood. Bed material sampling was conducted just before and after the flood at the lower study area, and annually at all other monitoring reaches. The changes in the particle size distribution, including the $D_{16}$, $D_{50,}$ and $D_{84}$ (diameters at which 16 percent, 50 percent, and 84 percent, respectively, of the bed particles are finer by size), are shown for the six reaches before and after the flood in Table 2. The complete particle size distribution curves may be found in Appendix B.

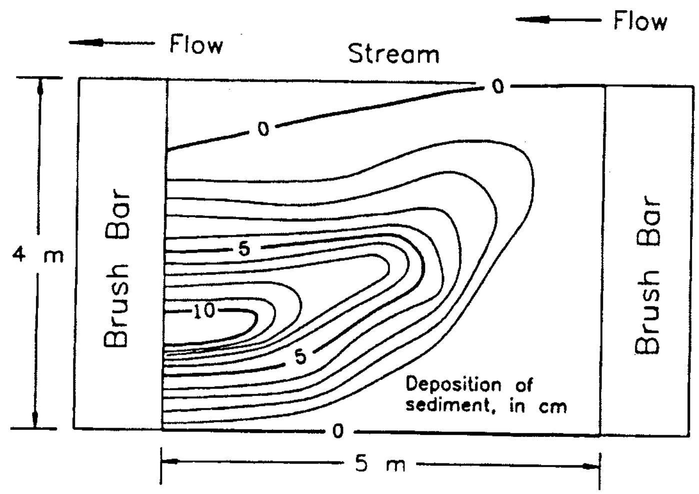


Figure 11. Typical sediment deposition depths, in centimeters, for brush bars spaced one channel-width apart, along new channel reach.

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Before the flood, one year after planting, the willows and alders had high survival (78 percent and 92 percent, respectively) and well-developed root systems. Nevertheless, all the willows on the point bar without brush bars were washed out. All of the willows between the first and second brush bar, and approximately 40 percent of the willows between the second and third brush bar were washed out, but willows further down the point bar were not affected. One-third of the alder seedlings were washed out. The willow cuttings effectively captured leaves, twigs, and other organic debris.

## DISCUSSION

Natural river channels (disturbed and undisturbed) are extremely dynamic in nature, and present a number of difficulties when designing for channel and floodplain restoration projects. Six independent variables are considered to control the dimensions of natural channels. They include discharge, bed load discharge, bed material size, bank material characteristics, valley-slope, and bank vegetation (Hey 1978). As these variables change during mining and reclamation, changes in channel geometry should be expected.

For example, our original design did not account for the severe change in bed caliber for the new channel repositioned through the undersize sorted mining tailings. Investigators have found that slope changes may be attributed to bed material changes

| Reach | 1 | | | 2 | | | 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | $D_{16}$ | $D_{50}$ | $D_{84}$ | $D_{16}$ | $D_{50}$ | $D_{84}$ | $D_{16}$ | $D_{50}$ | $D_{84}$ |
| 1990 | 4 | 23 | 95 | 3 | 14 | 78 | 2 | 16 | 81 |
| 1991 | 10 | 36 | 90 | 8 | 29 | 63 | 6 | 33 | 94 |
| 1992 | 3 | 24 | 116 | 5 | 17 | 81 | 10 | 22 | 92 |
| **Reach** | **4** | | | **5** | | | **6** | | |
| Year | $D_{16}$ | $D_{50}$ | $D_{84}$ | $D_{16}$ | $D_{50}$ | $D_{84}$ | $D_{16}$ | $D_{50}$ | $D_{84}$ |
| 1990 | -- | -- | -- | 2 | 23 | 81 | 4 | 25 | 68 |
| 1991 | 6[a] | 18[a] | 60[a] | 11 | 32 | 104 | 10 | 29 | 62 |
| 1992 | 17 | 43 | 100 | 2 | 17 | 80 | 4 | 24 | 62 |

Table 2. Stream bed material size distribution (in mm) for six monitoring reaches for August 1990, 1991, and 1992.

[a] Sampled July 1992, immediately after construction of new channel.

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(Hey and Thorne 1986). This may reflect the slope and sinuosity changes of the new channel reach, in which much coarser material was deposited as a result of the August 5, 1992 flood (Table 2).

The development and use of alder brush bars in this project served two purposes. The first purpose was to encourage sediment deposition in areas where riparian area fines were absent as a result of mining processes. The second purpose was to stabilize and protect newly constructed and unvegetated floodplains during large flood events.

A dominant discharge is one of a given magnitude occurring at a given recurrence interval which shapes the river channel to accommodate it. Leopold and Wolman (1957) attribute the dominant discharge to the bankfull discharge. Through such smaller flood discharges, and with the removal of the "incised" condition, the channel has the ability for adjustments not accounted for in the design and construction process. We do not wish to impede this ability for self-adjustment by building permanent, rigid control structures such as rock-filled gabions on the floodplains. However, larger 10-20 year floods have enough erosive potential to cause major damage to newly constructed channels and floodplains, and must be protected against until floodplain vegetation is reestablished. The alder brush bars seem to provide an adequate solution to this problem, offering some floodplain protection and a means to encourage sediment deposition while remaining a temporary structure constructed of native, biodegradable materials. The "bulldozer circular depressions" were effective at trapping sediment, but will not provide much erosion protection in a large flood.

## SUMMARY

Reclamation project design involves deciding where to rely on natural recovery, and where and how to manage recovery by altering or avoiding controlling factors to modify the pattern or increase the rate of ecosystem development. Effective reclamation requires knowledge of the structure and function of mined and unmined riparian ecosystems and the pattern and rate of natural recovery from natural and mining disturbances. This project design attempts to balance technique effectiveness with cost efficiency. The risk of failure will decrease with time, as revegetation occurs and channel banks and floodplains evolve to a stable condition.

Much of the existing information on mine reclamation is not applicable to national parks, and many common mine reclamation practices are inappropriate for national parks. The mandates of the NPS emphasize minimum interference in natural ecosystem processes. This design has been guided by those mandates.

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## ACKNOWLEDGEMENTS

The original version of this manuscript will appear in *Ecological Engineering The Journal of Ecotechnology*, 1994 (in press). The authors would like to thank William W. Emmett (U.S. Geological Survey) for his field assistance and advice on this project. They would also like to thank the NPS Alaska Regional Office Mining and Minerals Division, and the NPS Water Resources Division for helping to fund this project.

# APPENDIX A

Figures 12 through 17.

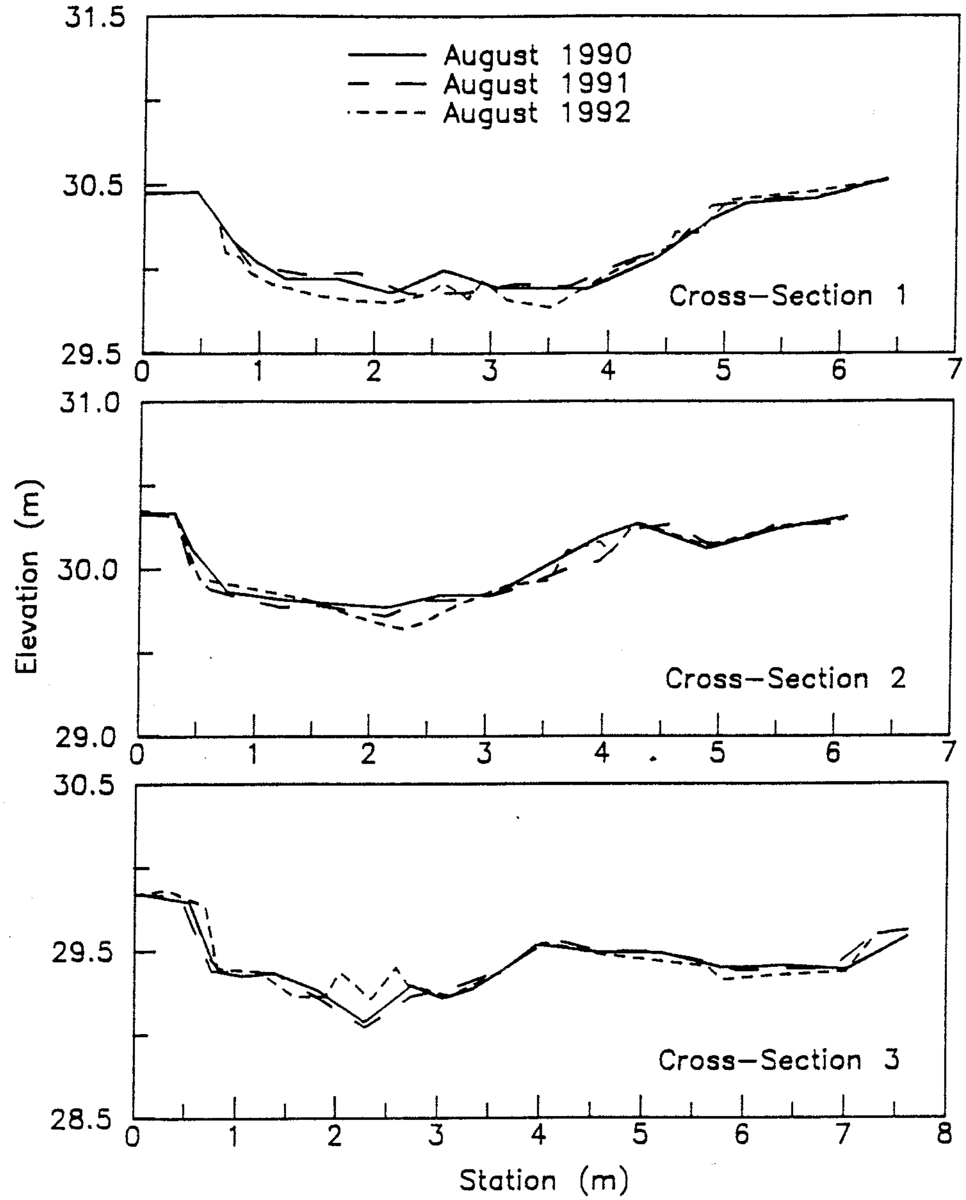


Figure 12. Cross-sections for Reach No. 1.

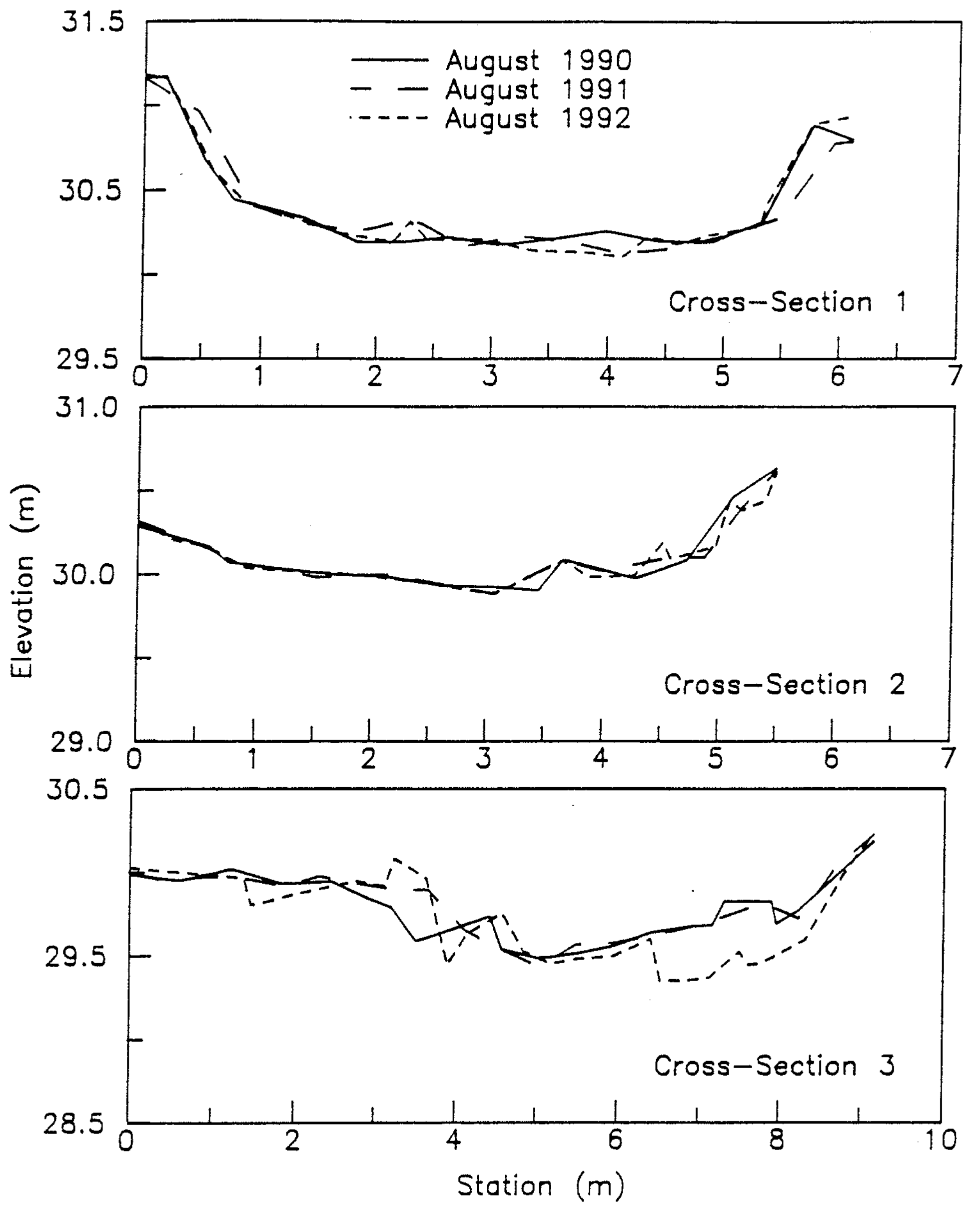


Figure 13. Cross-sections for Reach No. 2.

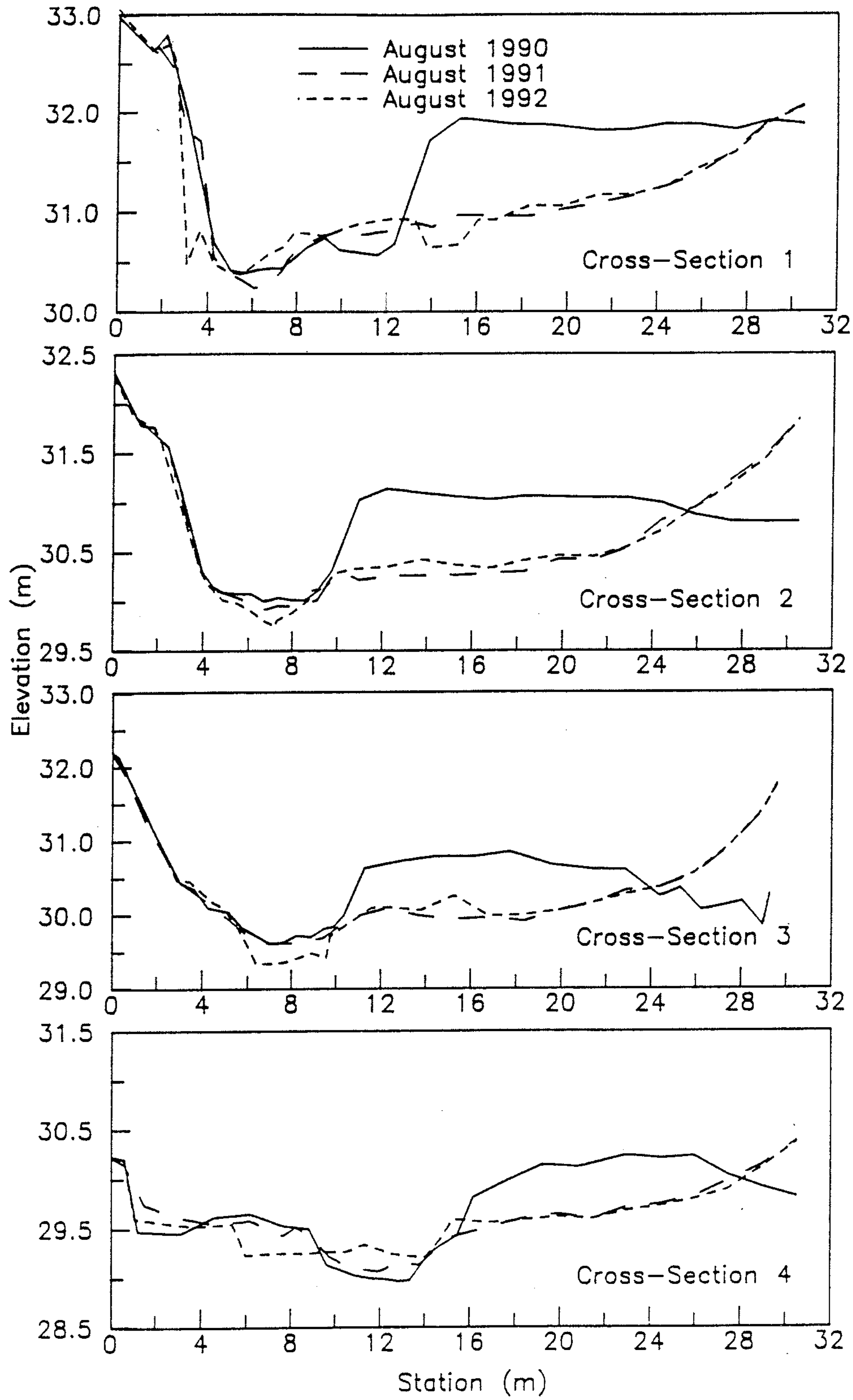


Figure 14. Cross-sections for Reach No. 3. These cross-sections are located in the Upper Study Area, which was restored in July 1991.

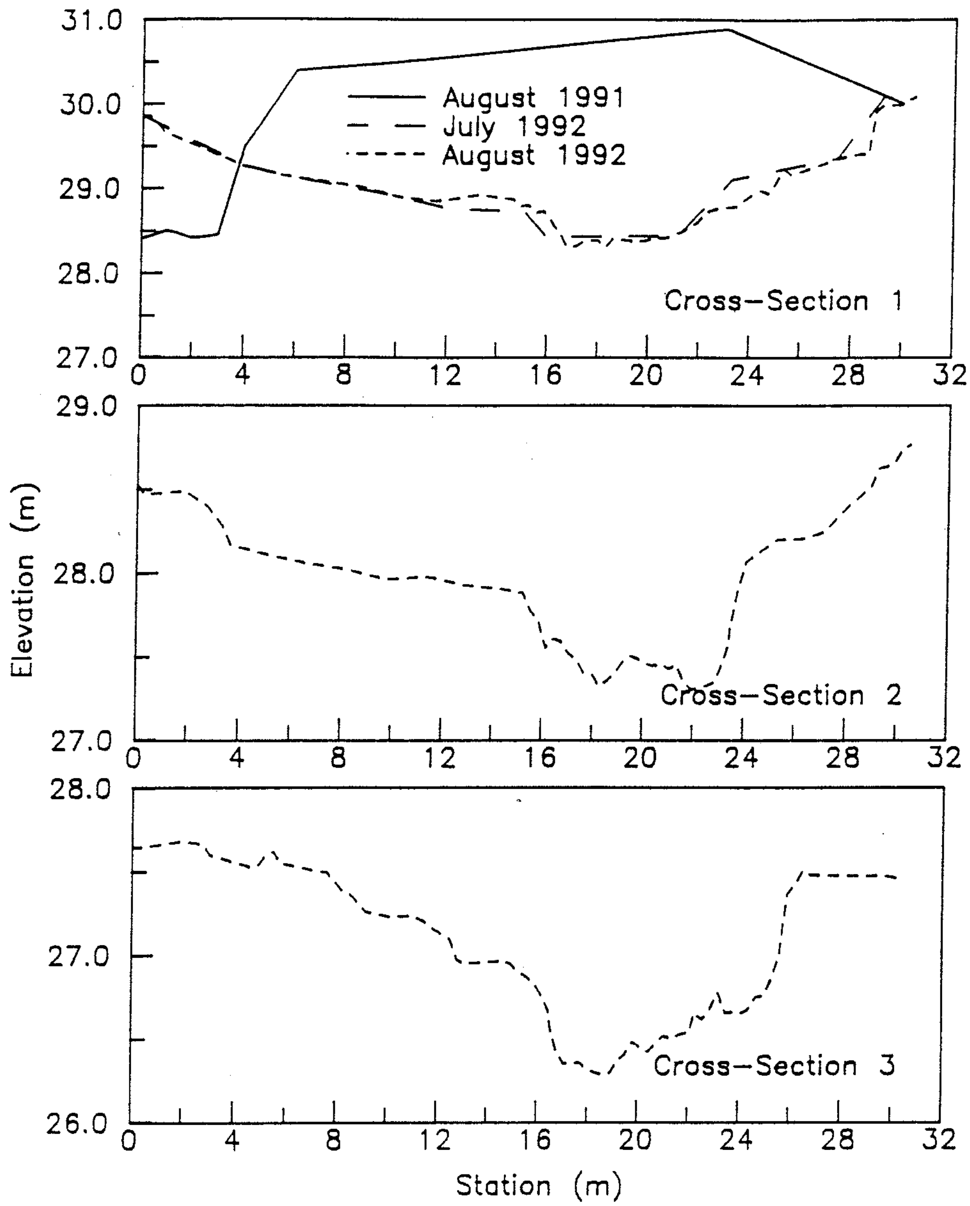


Figure 15. Cross-sections for Reach No. 4. These cross-sections are located in the Lower Study Area, which was restored in July 1992. Cross-section 1 was established in 1991. Cross-sections 2 and 3 were established after construction in 1992.

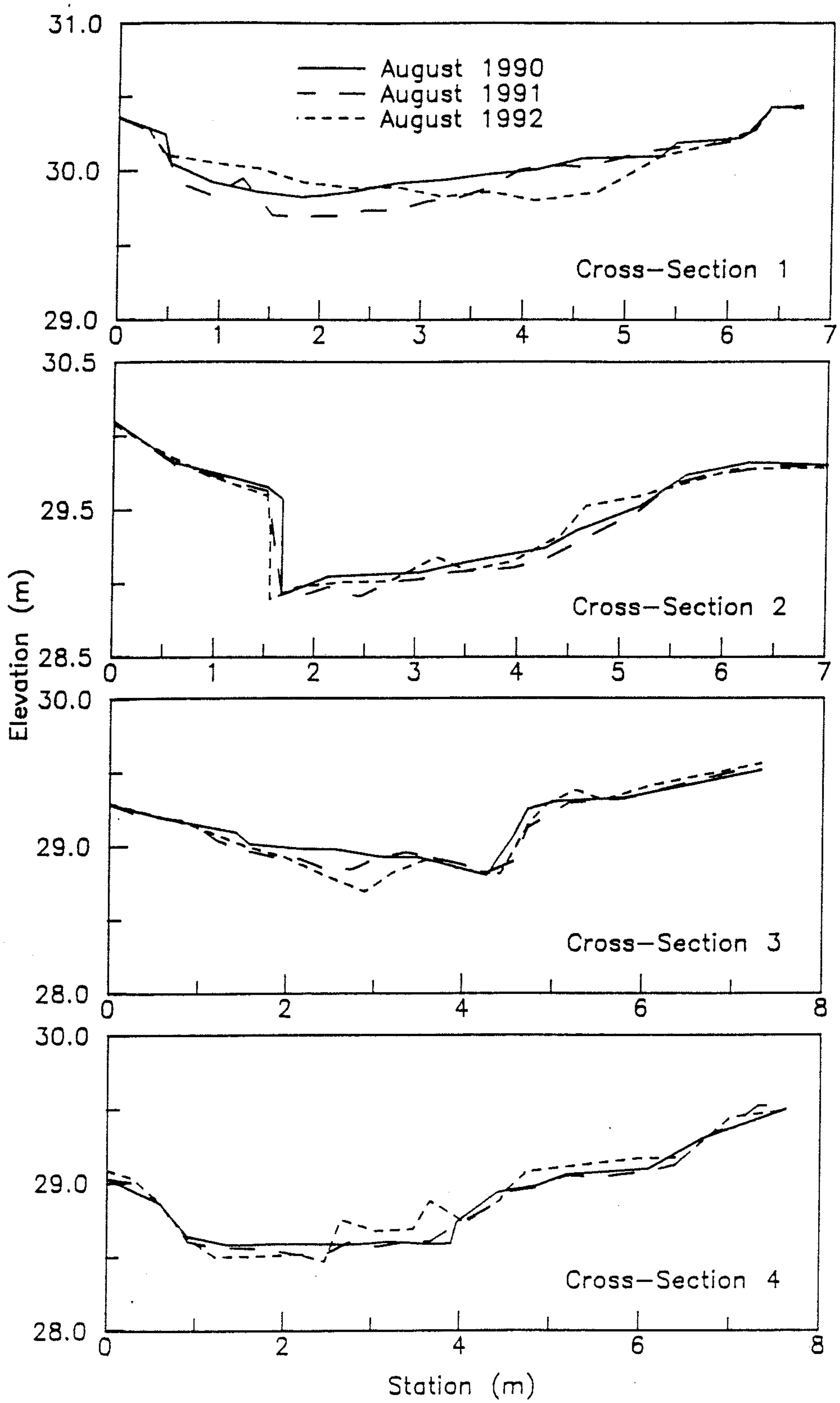


Figure 16. Cross-sections for Reach No. 5.

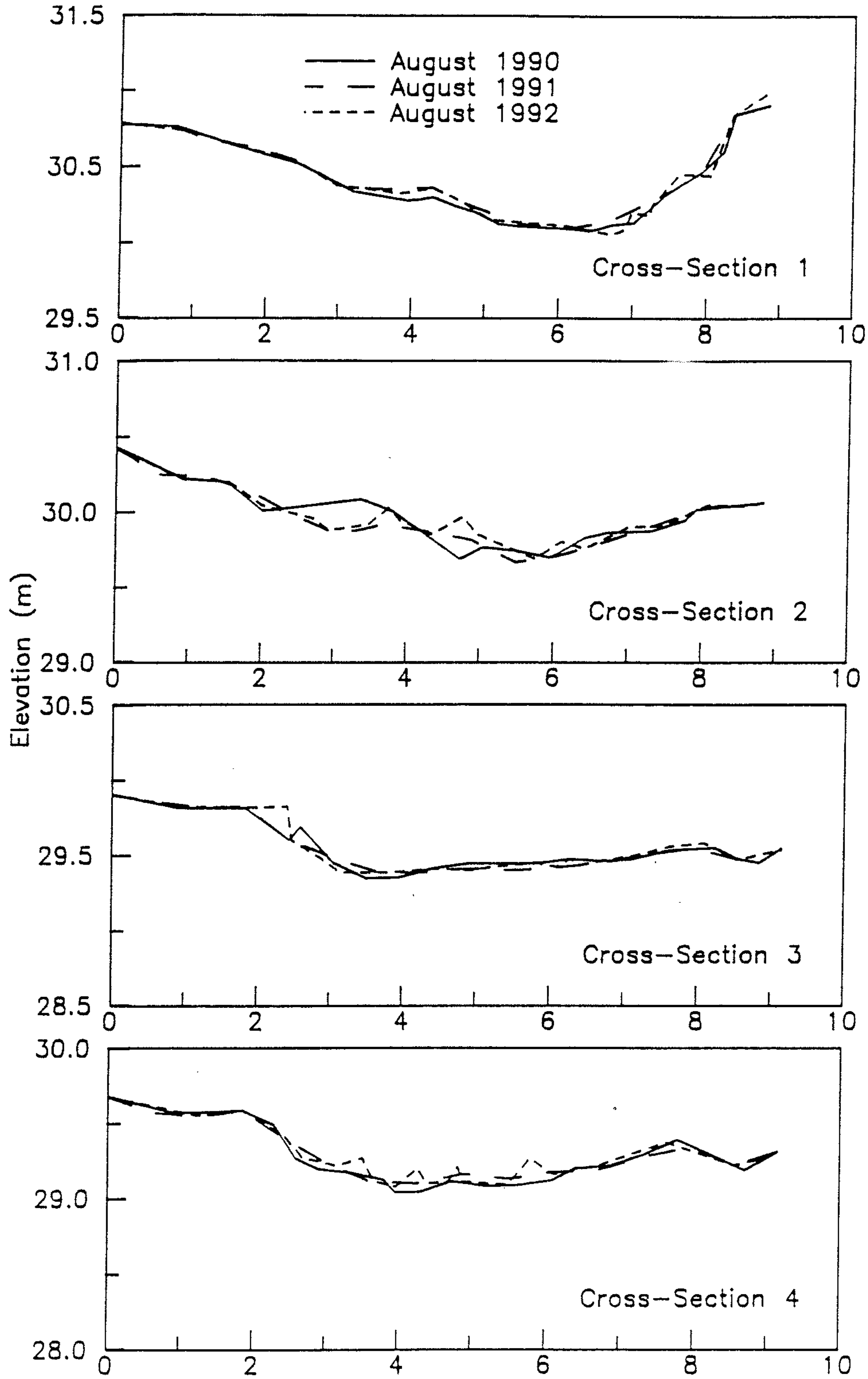


Figure 17. Cross-sections for Reach No. 6.

# APPENDIX B

Figures 18 through 23.

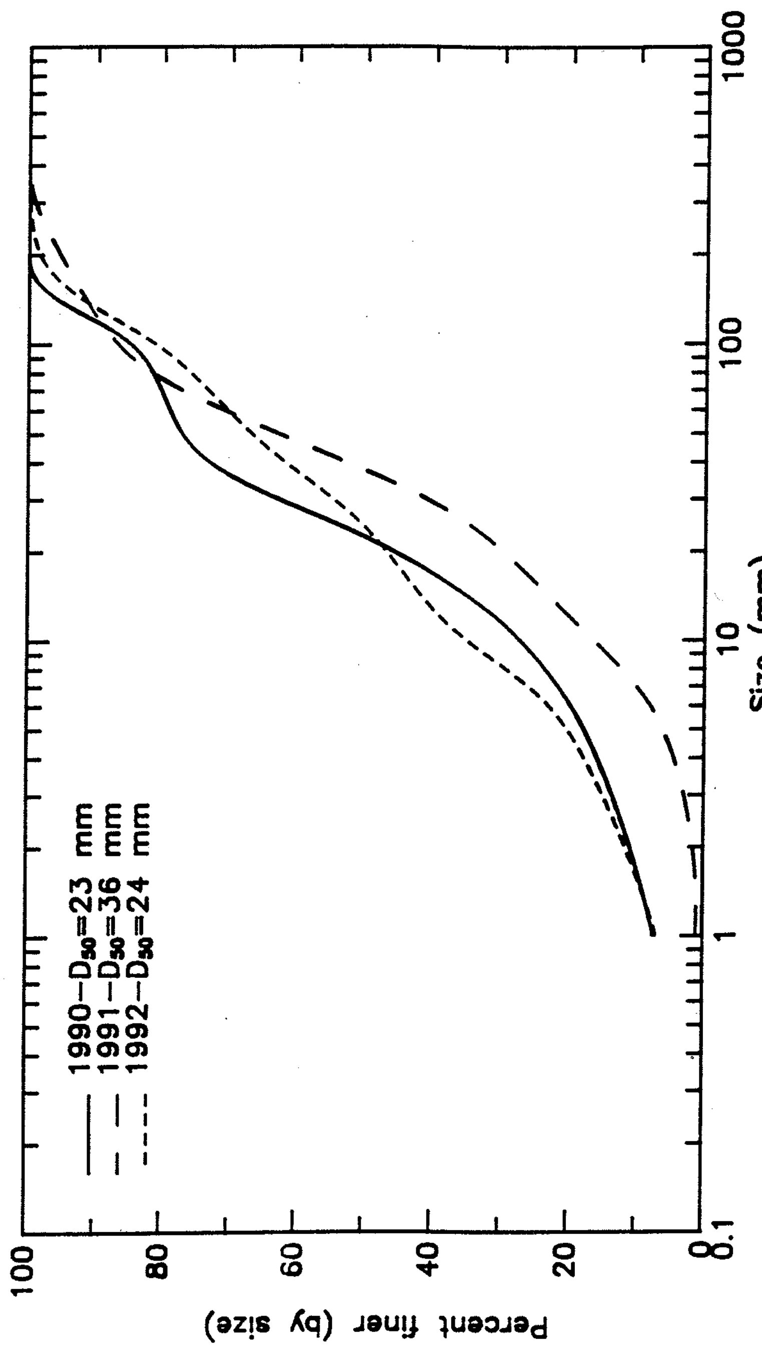


Figure 18. Particle size distribution curve for Reach No. 1.

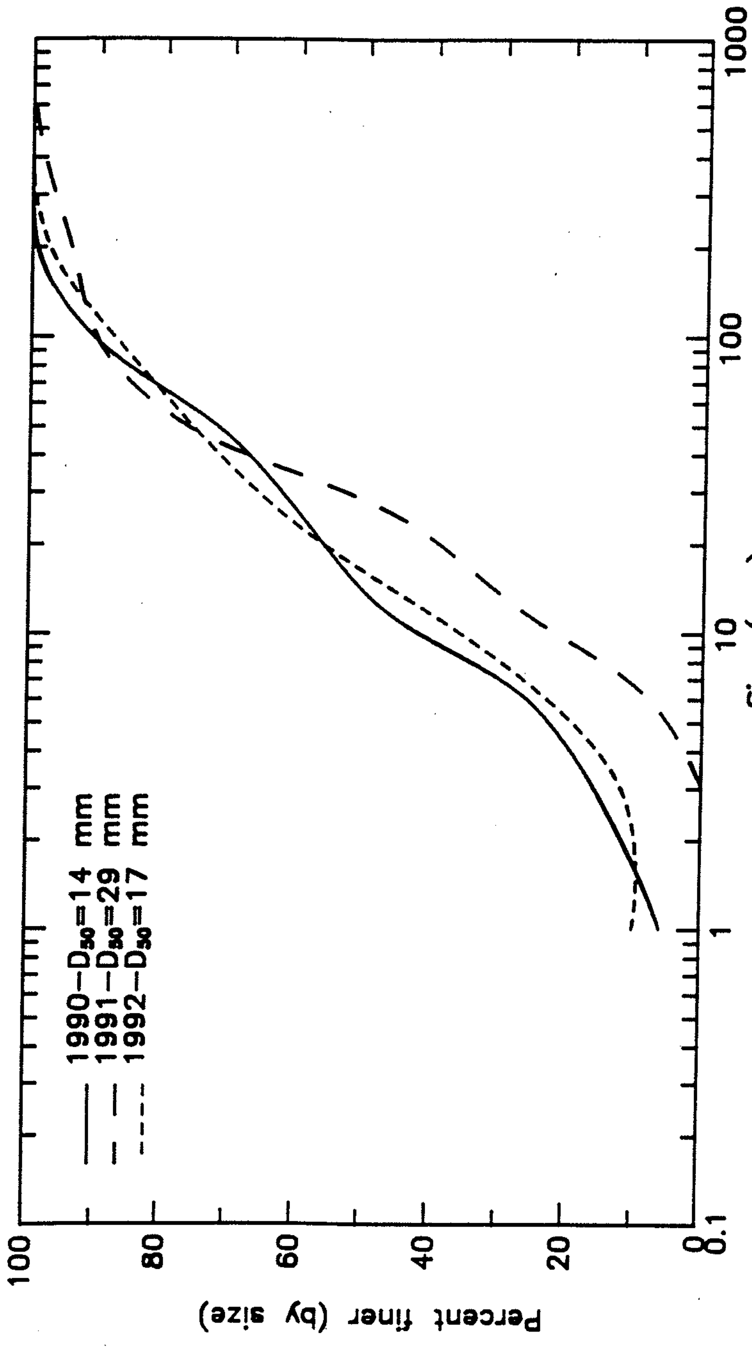


Figure 19. Particle size distribution curve for Reach No. 2.

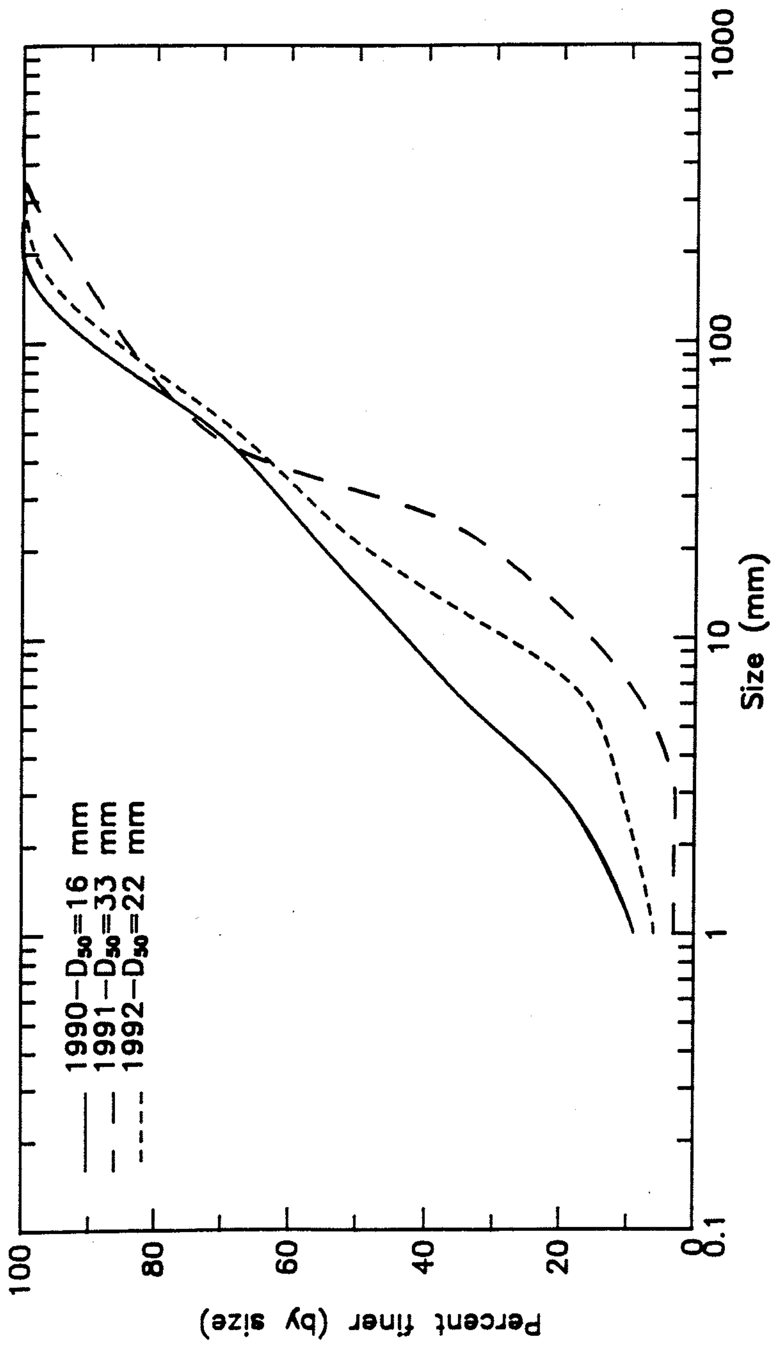


Figure 20. Particle size distribution curve for Reach No. 3.

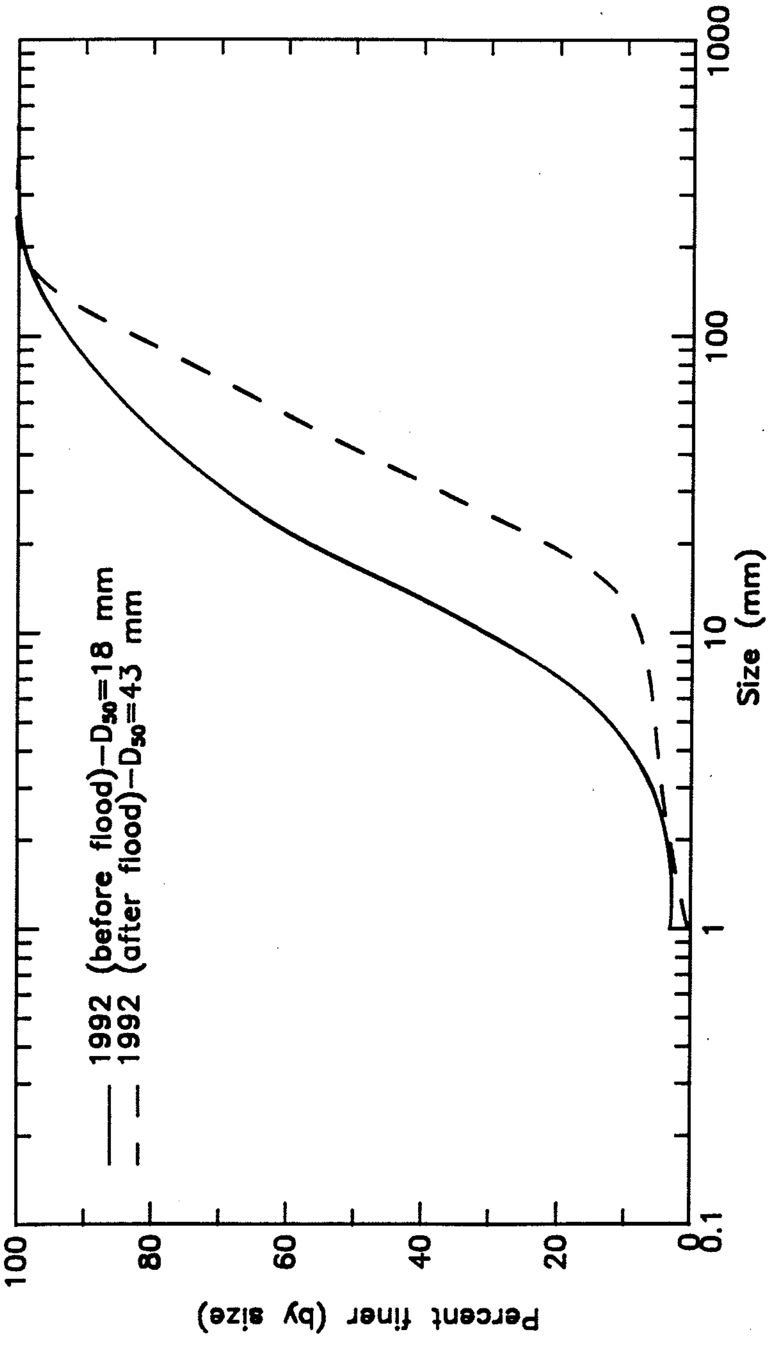


Figure 21. Particle size distribution curve for Reach No. 4.

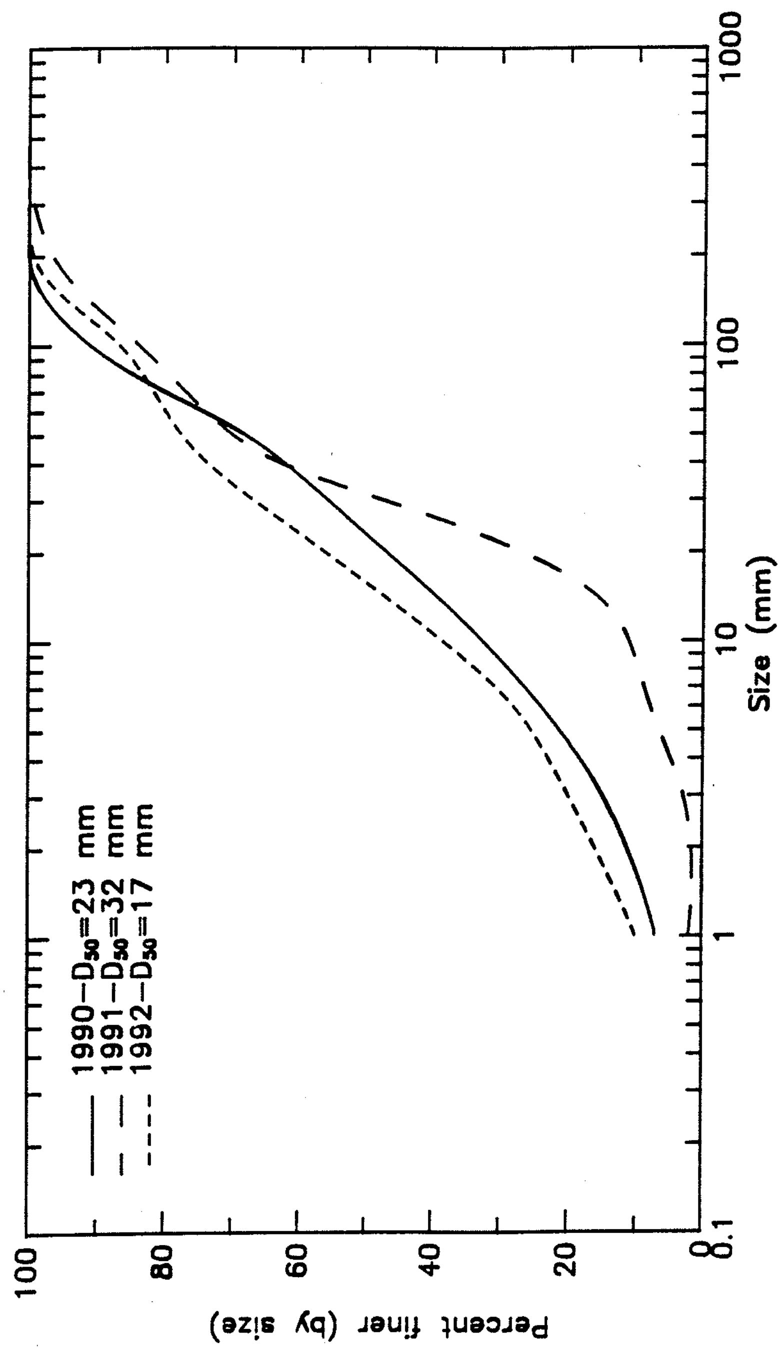


Figure 22. Particle size distribution curve for Reach No. 5.

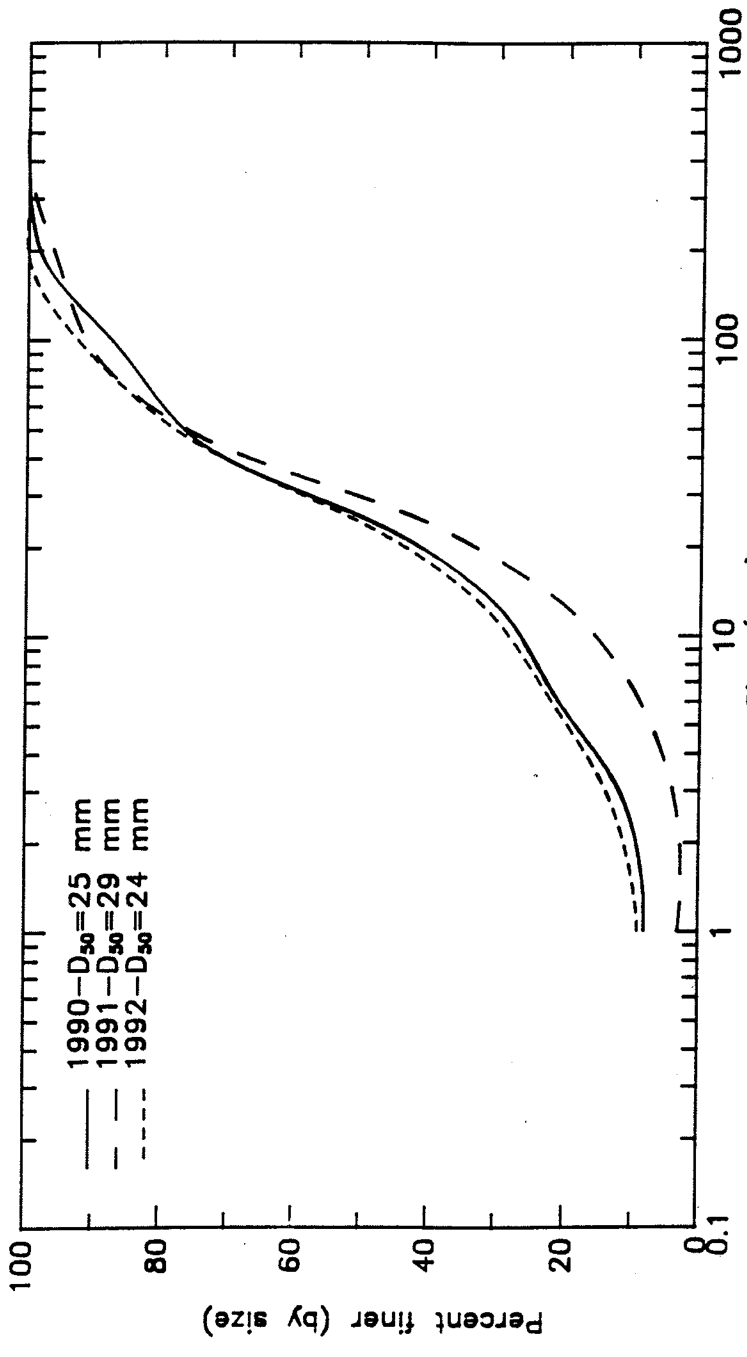


Figure 23. Particle size distribution curve for Reach No. 6.

As the nation's principal conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental an cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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