The Effects of Logging Stream and River Reserves on Water Quality Criteria and Streambed Profiles

by

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INTRODUCTION

The Government's decision to reserve the Shannon River Basin and to manage it as if it was a National Park substantially reduced the available timber resource within the Southern Forest Region.

Government has assured the timber industry of alternative sources of timber to those withdrawn by the reservation of the Shannon Basin. The total sawlog volume is estimated at 1.7 million m^3 of which 1.28 million m^3 is karri.

One way to obtain this volume would be to extend cutting into previous burning buffers, to expand existing coupes into some of the uncut buffer strips along stream and river reserves, to rationalize the location of some road reserves and to reduce the width of others to an average of 200m either side, as in the original Impact Statement (Forests Department of Western Australia, 1973).

The Department of Conservation and Land Management (CALM) was directed by Government to commence a series of operational trials to examine the feasibility and consequences of extending cutting coupes into selected road, river and stream reserves. As this constitutes a departure from the Impact Statement (1973), the matter was referred to the Environmental Protection Authority (EPA). Close liaison was maintained with the Shire of Manjimup. Environmental groups and the public were advised of these proposals.

The Premier approved a number of operational trials in road, river and stream reserves in April, 1984. The Environmental Protection Authority was advised of the proposal in August, they requested that a Notice of Intent be prepared and this was submitted to the EPA in November 1984. Following EPA approval, logging commenced in late spring 1984 and summer 1985. On completion of the trials, the operations were to be reviewed and a report prepared. This report discusses the implementation and results obtained from six trial areas, three stream and three river reserves.

BACKGROUND

All trial areas were inspected with officers of the Water Authority. Prescriptions, guidelines and monitoring techniques were discussed, as well as operational needs such as regeneration and protection.

The value of stream buffers in minimizing problems of turbidity in high rainfall areas and salinity in low rainfall areas is recognised (Steering Committee 1987, Borg et. al. 1987). However, the Water Authority has no objection to the progressive removal of timber from these buffers, provided that water quality criteria are maintained.

Comprehensive pre-treatment data was not available. Monitoring techniques suitable to these trials needed to be developed. Monitoring was a co-operative effort between the Water Authority and CALM.

This report deals only with aspects related to water quality. It is recognised that road, river and stream reserves have value from an aesthetic, landscape and wildlife management viewpoint. Consultation with the research branch indicated that existing studies would cater for the conservation aspects. The landscape consideration would to be covered in the road reserve trials and the results reported elsewhere.

AREAS AND TREATMENTS

The six coupes will be identified by their Block names, Sutton, Poole and Crowea (stream reserves), Lockhart 2 and 11 and Mattaband (river reserves). All coupes contained karri in either pure or mixed stands and were clearfelled for regeneration. Soils were karri loams. Details for these coupes and their treatments are provided in Table 1.

Apart from some steep slopes leading onto the Deep river (Lockhart 2) and a small steep section of Sutton, the slopes on the remainder of the coupes were slight to moderate (less than 5°). The Sutton slope was logged but the steep slopes on the southern and eastern boundaries of Lockhart 2 were not.

Logging was carried out by bush crews and contractors from Bunnings and Whittakers, to prescriptions provided by CALM. A sample copy of a prescription is shown in Appendix 1. Supervision by CALM staff indicated that bush operations were carried out conscientiously.

All coupes were burnt and regenerated by standard procedures as soon as cutting was completed. After burning the debris, some were replanted with karri at 4x2m spacing,others regenerated from seed trees. The Sutton coupe was treated differently. Because all of the original stream buffer had been logged, the area was left unburnt over the first winter. The logging debris and slash were then burnt in late spring rather than autumn. This gave maximum time for scrub growth to occur prior to the winter rains. However, some problems were encountered planting in small areas where scrub growth was dense and up to 1 metre in height. It remains to be seen whether planted karri will successfully grow through the scrub layer. Survival counts completed in early 1987 show that there has been an adequate survival and growth of planted karri.

All trials were delineated with roads or unsurfaced 4x4 ungraded tracks. Throughout the trial period the logging roads were maintenance graded and drained only. Tracks were cleared of scrub growth using a Departmental bulldozer. Little emphasis was placed on drainage and no form grading was carried out. No culverts were installed in creek crossings, except for one at Crowea. This technique led to some minor erosion problems due to the concentration of water within earth mounds which confined run-off to the track surface. Cross drains or spoon drains would have avoided this problem. If culverts or all-weather crossings had been installed at all creek crossings, turbid water resulting from intermittant vehicle use would not have entered the cutting trials.

All landings and major snig tracks were ripped during summer. No severe compaction or mixing of soil profiles occurred within cutting trials and it is expected that regeneration on landings and snig tracks will be good. The standard of rehabilitation work was excellent and well within prescribed standards.

The total area for the six trials was 110 ha and yielded 10970 m^3 of sawlog (mainly karri) and 10940 m^3 of chipwood. At current royalties ($17 and $10 respectively) this represents an income of $296,000. In the Sutton trial, an additional resource, estimated at 20m^3 ha of chipwood, from the crown and branches of felled trees, was not recovered. In the prescription it was considered that the removal of this material may have caused additional disturbance to stream banks.

MONITORING TECHNIQUES

Four techniques were used to monitor the effect of logging within the Stream and River Reserve cutting trials.

1. Sediment inflow from boundaries.
2. Stream and bank inspection.
3. Stream bed and bank profiles.
4. Sediment and water sampling.

OBJECTIVES OF MONITORING

1. Sediment Inflow from Boundaries

   - to identify and record sediment deposition moving from outside sources into the cutting trials or the remaining reserve.
   - to ascertain the effect of cutting on changes to deposition within the stream reserve or the trial area.

   Sediment movements from outside areas into the cutting trials were identified. Each deposition point was marked with a numbered peg and its exact location was recorded on a colour aerial photograph. A description and diagram of each site were made. These were supported with photographs.

   The sediment deposition was probed at 5 metre intervals along its length and at 0.3 metre intervals diagonally across the flow using a graduated wooden stake. Sediment depths were recorded on the diagram for each site (Appendix II). This technique was used in all stream and river reserve trials. Data was obtained before cutting commenced and annually thereafter.

2. Stream Bed and Bank Inspection

- to record in detail the condition of stream bed, pools and banks prior to the cutting trials taking place.

- to monitor and record changes to stream bed, pools and banks as a result of cutting trials.

As insufficient resources existed to monitor all streams, specific 50m sections were nominated. Each site was identified with a numbered peg, its location was recorded on a colour aerial photograph and the site was described.

Bank width and height, stream bed description, type of deposition, bank and bed stability were recorded. A diagram and photographs were used to support these descriptions. (Appendix III).

Initial monitoring was done prior to any cutting taking place. This technique was applied to thirteen sites within Sutton and five sites within Poole stream reserve cutting trials.

3. Stream Bed and Bank Profiles

- to record stream bed and bank profiles at a number of permanently fixed points prior to the winter rains, and after cutting had taken place.

- to monitor and record annual changes to stream bed and bank profiles at these points.

At each stream bed and bank inspection point at least one cross sectional profile was taken. Star pickets were placed on opposite banks of the stream at randomly selected points. The top of these pickets were levelled using a clinometer. A graduated tape was fastened to the top of the pickets and pulled tight. Using another graduated tape with a plumb bob attached, the distance to the ground from the horizontal tape was measured, wherever a change in profile occurred.

The horizontal distance from the start point (picket) and the vertical height to the ground were recorded. By repeating this process at every point of change a cross sectional profile of the stream bed and banks was obtained (Appendix IV).

Profiles were taken soon after cutting was completed and were repeated in the summer of 1986 and 1987. This techniques was applied to thirteen sites within Sutton and six sites within Poole.

4. Sediment and Water Sampling

- to record suspended sediment loads in streamflow through:

    a) samples collected automatically at a known time, or manually at the time of a visit;

    b) samples collected at a known river height, but at some unknown time between visits.

Sampling was carried out by hydrographers from the Manjimup office of the Wather Authority of Western Australia. Grab samples were taken during site visits, and automatic pump samples were collected throughout some storm events. Stream water level, which was later converted to flow rate, and time of sampling were recorded. Between visits, samples were collected with rising stage samplers when the stream water level rose beyond a selected height. The collection times for these samples are unknown. All samples were subsequently analysed for suspended sediment less than .063 mm in diameter and turbidity.

One of the Poole sites was located at the western fork of a tributary to Bighill Brook where the remaining stream buffer was deliberately burnt in April 1985 as part of a regeneration burn. The other site was located at the eastern fork of the tributary where the remaining buffer was not burnt. Comparing the data from the two sites thus yields an estimate of the effect of the burn on stream water quality.

Three sites were monitored in the Sutton block along Six Mile Brook , one at Landing Road, one at Strop Road downstream of the Landing Road site, and one at Rope Road still further downstream. The stream buffer between Landing Road and Strop Road was clear- felled between January and May 1985, some 6 years after the adjacent slope had been clear-felled an regenerated. In contrast, the stream and some slope areas between Strop Road and Rope Road were both clear-felled between January and May 1985. Comparing the data for Landing Road and Strop Road and Rope Road, respectively, thus makes it possible to compare the effect on stream water quality of phased and simultaneous logging of stream and slope areas.

RESULTS

a. Boundaries

Little erosion occurred within the cutting trials. However, some early stages of rill erosion were observed in localised areas on the external ungraded tracks.

Any outflow of sediment into the stream reserve was deposited within 5 metres of these tracks. Vegetation will consolidate these tracks until they are maintenance graded and drained in about 5 years time.

b. Depressions and Culverts

Observations in 1985 prior to logging of Sutton showed that there were 23 sites where sediment movement into the cutting trial from outside sources had occurred. These were described and photographed. In 1986 after completion of logging all sites monitored in 1985 had been disturbed, destroying all evidence of sediment movement collected in 1985. No significant deposits were observed in 1986.

By 1987 the soil had consolidated and no abnormal sediment movement from external sources was observed. Some deposits were observed at culverts and spoon drains, however these extended only very short distance into the cutting trial area. No significant sediment deposits were observed or described in 1987.

Observations in Poole during 1986 and 1987 indicate that the only source of major sediment movement into the stream reserve was from a gravel pit described and photographed in 1985. At this site sediment deposits were visible for less than 10 metres into the remaining reserve. It is possible that turbid water from this site may have had some effect on stream turbidity.

In other trial areas there was no evidence of major sediment movement into the uncut stream and river reserves from outside sources. Boundaries were monitored but the erosion was so minor that permanent sites were not required.

2. Visual Observations of 50m Section of Streams

(i) Sutton

a. Visual Observations

Visual observations on 13 sites indicate that there was an increase in heavy wood, twig and leaf material in the stream bed. There also appeared to be increased build up of sand and partially decomposed organic matter. Below road crossings there was an obvious increase of road surfacing materials within the stream bed.

No algae bloom was observed in 1985, however these were observed in all slow moving or stationary water bodies in 1986 and 1987. Algal build up is possibly caused by increased light after canopy removal, impeded flow and increased organic matter.

b. Water Turbidity

In 1985 observation of the stream bed was easily possible as stream water was clear.

In 1986 and 1987 observation of stream bed was impossible in areas that were covered with water. This was largely due to algal blooms. Clays in suspension were also contributing to the cloudiness of the water. Runoff from slushy logging roads is likely to be the major contributing factor.

c. Bank Collapse

No bank collapse caused by water flow was observed, however some bank collapse was caused by falling of trees over the stream bed. This could have caused an increase in water turbidity and bedload. Some merchantable trees were deliberately left standing along stream banks to prevent bank collapse.

(ii) Poole

a. Visual Observations

Visual observations on 6 sites indicate that there was a general increase in white sandy material and partially decayed organic matter in the stream bed. At the site where the major access road crossed the western stream, quantities of white sand were observed in the stream bed. This material appeared to have been washed from table drains beside the road.

b. Water Turbidity

No visible change to water turbidity was observed throughout the monitoring period. The stream was clear with the bed easily visible.

c. Bank Stability

No changes to stream banks were observed.

d. Rise in Water Table

At one site the water table has risen and created a permanently wet area on the boundary track.

3. Stream Profiles

(1) Sutton

The marker pegs from two points were stolen or disturbed during the logging operation making it impossible to collect data from these points. Evaluation of data from remaining eleven sites indicate that there were some changes to stream profile in the two years following the logging operation.

There was no consistent trend of erosion or sedimentation of the stream bed. Some points became deeper and other became shallower (Appendix IV). It is likely that this is due to changes in stream flow due to the increase in heavy wood, twig and leaf material within the stream banks after logging.

(ii) Poole

The pegs were disturbed at 2 sites making it impossible to collect data in 1986 or 1987. Evaluation of data from the remaining 4 sites showed no significant change to the stream bed profile. Variation on initial measurements was + or - 20mm. No consistent trend could be established.

4. Sediment and Water Sampling

Flows ranged between 0 and .66 m^3/second at Poole and from 0 to 3.65 m^3/second at Sutton.

A detailed report on the results of the stream water sampling is currently being prepared by the Water Authority. A summary of the results is given in table 2. The first part of the tables gives flow-weighted mean annual suspended sediment concentrations and turbidity for the five sampling sites considering all data collected at each site. The second part of the table gives the equivalent values for samples which were collected within two hours of each other at the Poole sites, and within two hours of each other at the Sutton sites.

Comparing the data from the two Poole sites shows that burning the buffer at Pool West had no obvious effect on suspended sediment concentrations but there was some increase in turbidity in 1985. This increase was due to one sample of high turbidity at Poole West. About 83% of the samples collected at both sites had turbidities less than 5 NTU, some 14% had values between 5 and 10 NTU, only one sample at Poole East and two at Pool West had turbidities greater than 10 NTU, and none exceeded 25 NTU. About 67% of the samples had suspended sediment concentrations below 5 mg/L, 15% between 5 and 10 mg/L, 13% between 10 and 20 mg/L, only 5% exceeded 20 mg/L, and no samples had concentrations above 50 mg/L.

There was no consistant difference in turbidity between Landing Road and Strop Road, but sediment concentrations tended to be slightly lower at Strop Road. Turbidity and sediment concentrations were similar between Strop Road and Rope Road except for one sample with relatively high

turbidity and sediment concentration which elevated the flow-weighted value for 1985. Some 70% of the samples collected at the three Sutton sites had turbidities below 5 NTU, 22% between 5 and 10 NTU, 6% between 10 and 20 NTU, less than 2% exceeded 20 NTU, and no samples exceeded 40 NTU. In case of the sediment samples about 65% were below 5 mg/L, 21% between 5 and 10 mg/L, 12% between 10 and 20 mg/L, and 3% above 20 mg/L. Except for one sample from Landing Road where 54 mg/L were measured all other contained less than 50 mg/L of suspended sediments.

The turbidities and suspended sediment concentrations determined for the individual samples and the flow-weighted mean annual values at the five sites were generally low. Differences between the two sites at Poole were minor and not consistent, which indicates that burning of the stream buffer did not significantly influence water quality. Differences between the three sites in the Sutton block were also minor and not consistent. This suggests that stream areas can be logged several years after logging and regeneration of the adjacent slope areas, or even at the same time, without a significant deterioration of stream turbidity or sediment concentration . if the logging and regeneration procedures outlined in Appendix I are followed carefully.

The above results may have been influenced by the below average rainfall in 1985 and 1986. Data from experimental catchments in the Sutton block show that the 1985 and 1986 annual rainfall were some 13 and 21%, respectively, below the long-term mean (Borg et al. 1987). Streamflow rates in these years were also below average. Higher rainfall usually generates more runoff which carried the potential for more erosion and hence higher stream turbidity and sediment concentrations. However, erosion is more affected by short-term rainfall intensities than by the total annual rainfall. Wetter years therefore do not necessarily result in high turbidities and stream sediment concentrations.

DISCUSSION

Generally the slopes in these coupes were slight to moderate. Little evidence of erosion exists where slopes are less than 5°. However some rill erosion has developed on slopes exceeding 5°.

The major source of sediment movement is likely to be from boundary tracks and log road surfaces. Wheel tracks become compacted below the original road level and unless regularly maintained, water concentrates and runs off over longer distances. Concentrated, fast flowing water will carry a higher sediment load than water moving slowly over a wide surface area.

Heavy log truck traffic tends to create a flowable mud on the road surface. The distinct colour of this material was observed below most culverts after road use in wet weather.

Where the stream reserve was clear-felled (Sutton) there was a substantial increase in wood and vegetative debris in stream bed which impeded flow. Some changes to the stream profiles were observed and there was some bank collapse and buildups of sand, and organic matter. Algae growth and cloudiness of the water were noted.

In contrast, where buffers has been reduced but not eliminated, there was no increase in debris, no algae growths, no collapse of banks, and water was clear. However some additional white sand and organic matter were observed in the stream bed adjacent to major roads.

The effects of logging on stream sediment concentration and turbidity were negligible. Most values were below the currently accepted standard for domestic water supply of 25 NTU's.

These conclusions are consistent with data from hydrologic studies initiated in the southern forests in the mid 1970`s (Steering Committee 1987, Borg et al 1987). After logging, stream sediment concentrations increased for 1 to 3 years but returned to pre-logging levels within 5 years after regeneration. The largest observed increase was 35mgl^{-1}. No increases were detected where vegetative buffers were kept along the streams.

A comprehensive review of buffer strip management in forest operations published by Clinnick (1985), concluded that "a buffer strip 30m on either side of a stream provides adequate protection to the stream environment. A 20m buffer may be considered satisfactory in selected situations, for example where soils are highly permeable and slopes are less than 30%".

On all coupes other than Sutton, buffer strips of between 50 and 100m in width were retained. With a wider buffer, an error of demarcation in the field becomes less significant.

Maintenance work on boundary tracks should be limited to drainage works. When the next major boundary upgrade is programmed (suggested in 5 years) tracks should be properly formed and drained. There is little likelihood of any major sediment movement into stream or river reserves if drainage of boundary track is carried out. However, in the event of heavy rains and no drain construction some further erosion is possible.

Casual observation showed that the stream reserves were heavily used by birds for nesting and shelter. This monitoring only considered stability, erosion and water quality criteria and did not take into account aesthetics, fauna values, natural forest ecosystem or habitat preservation. These should be researched prior to making firm recommendations on operational cutting of stream and river reserves.

ACKNOWLEDGEMENTS

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TABLE 1

	COUPE					
	POOLE	SUTTON	CROWEA	LOCKHART	LOCKHART	MATTABAND
Treatment	Coupe expansion by 50m	Clearfell of stream reserve	Coupe expansion by 50m	Coupe expansion by 100m	Coupe expansion by 100m	Coupe expansion by 100m
Buffer remaining on stream or river	50m	Nil	50m	100m minimum	100m	100m
Area within trial	18ha	48ha	12ha	8ha	16ha	8ha
Forest type KMJ JMK	10ha 8ha	48ha	12ha	8ha	16ha	8ha
Estimated volume removed from trial Sawlog Chipwood	1620m3 1490m3	3500m3 4200m3	1900m3 1600m3	1600m3 950m3	1000m3 1350m3	1350m3 1350m3
Operations Cutting commenced Cutting completed	 Dec '84 Mar '85	 Jan '85 May '85	 Dec '85 Jan '86	 Jan '85 Mar '85	 Jan '85 Feb '85	 Dec '85 Feb '86
Regeneration burn SDI on day of burn	Apr '85 1196	Nov '85 500	Feb '87 1650	Mar '85 1513	Mar '85 1401	Mar '86
Replanting (seed trees)	Seed trees 1985	Hand planted 1986	Hand planted 1987	Hand planted 1985	Seed trees 1985	Hand planted 1986
Regeneration January 1987	Good	Good	N/A	Good	Good	Good

TABLE 2

Flow-weighted, mean annual data, all samples.

	Concentration of suspended sediment <0.063mm in diameter mgl			Turbidity NTU's		
	1985	1986	Both Years	1985	1986	Both Years
Poole buffer burnt	6	7	6	8	4	7
(n=107) buffer unburnt	4	8	5	2	4	3
Sutton upper site no buffer	11	6	9	4	4	4
(n=510) central site	5	10	5	4	8	4
lower site	11	7	10	8	7	7

Flow-weighted, mean annual data, samples collected within two hours of each other.

	Concentration of suspended sediment <0.063mm in diameter mgl			Turbidity NTU's		
	1985	1986	Both Years	1985	1986	Both Years
Poole buffer burnt	4	4	4	11	3	9
(n=22) buffer unburnt	3	9	5	2	4	2
Sutton upper site no buffer	8	6	8	4	4	4
(n=26) central site	5	4	4	'3	6	4
lower site	11	3	8	10	4	8

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SUTTON 4, 8, 10 - TRIAL CUTTING IN STREAM BUFFER

LOGGING PRESCRIPTION MARK II

1. BOUNDARY

The coupe will be extended to cut the stream buffer on Six Mile Brook and a tributary to the south of the Six Mile Brook. The western boundary will be a northern tributary of the Six Mile Brook. The eastern boundary will be Six Mile Road.

2. OPERATIONS

a) Logging will be conducted between October 1984 and April 1985 when soil conditions are most favourable. A crew briefing will be conducted before logging commences.

b) Scrub rolling prior to falling will be confined to an absolute minimum preferably using a rubber tyred or FMC machine. Soil disturbance will be avoided. Scrub will be rolled, and not bladed out.

c) During falling tree crowns will be directed away from stream beds. The forest officer in charge will toemark any trees leaning over a stream bed. Some trees may be left standing if potential damage is unacceptable. A critical zone 10 m either side of the watercourse will be recognized for special care.

d) Machines will not snig across any stream bed. Ground salvage logs in stream beds will not be extracted.

e) No landings or loading areas will be located within 50 m of the stream bed. Snig tracks will parallel the stream where possible. Roads may be used for snigging. Landing sites will be selected in advance by the forest officer and Industry representative. Snig tracks will enter the landing from the sides.

f) On completion of logging, cross drains will be installed on all snig tracks to direct water into clumps on ground debris. Drainage from landings and loading areas will be directed into clumps of debris. Log barriers may be installed at the back of landings.

g) All karri areas will be cut to a clearfall prescription to avoid a second entry.

h) On completion of cutting the regeneration burn in the former river buffer will be held over for one winter to allow run-off to be trapped in ground debris. Bracken and other scrub species which regenerate from rootstocks will assist to slow run-off and minimize erosion and siltation.

i) Mild regeneration burning will be programmed for the following early summer.

j) Rehabilitation of landings and snig tracks will be programmed to immediately follow completion of logging. All ripping to be strictly on the contour.

k) Small chip logs in crowns will be left uncut, under supervision of the forest officer.

l) During the first winter, patrols to monitor water movement will be conducted. Erosion control work will be implemented where problem sites are recognized.

D J Keene
A|Regional Manager
Southern Forest Region

AWW:CB

SHANNON ALTERNATIVE RESOURCE

CUTTING TRIALS IN STREAM AND RIVER BUFFERS

DEPRESSION & CULVERT OBSERVATIONS

TRIAL CUTTING AREA: SUTTON 4

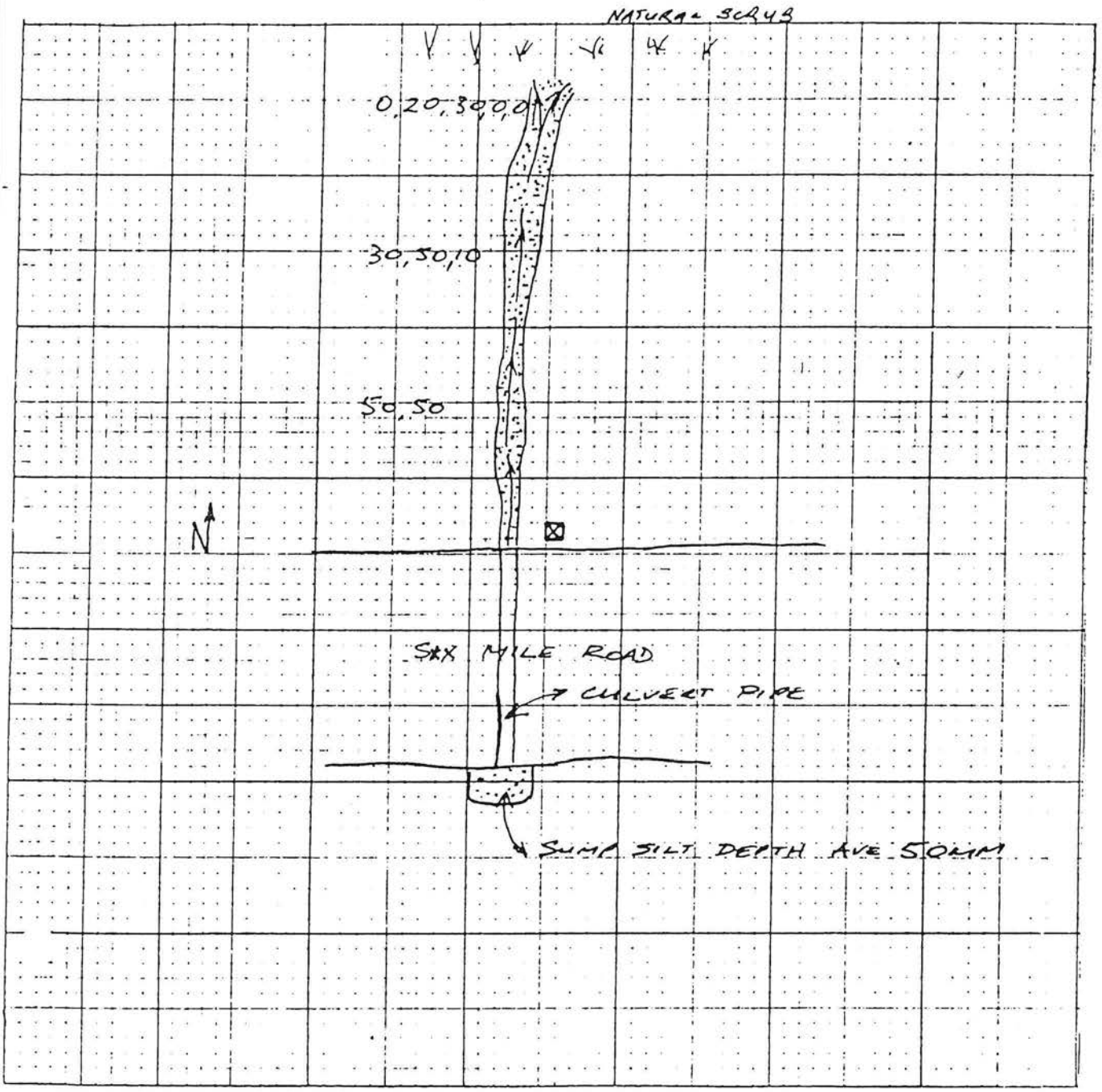
DATE: 24/10/84 POINT NO: 1

OBSERVER: A. HORDACRE

DESCRIPTION OF SITE:

- 375MM CULVERT PIPE, SIX MILE ROAD.
- CULVERT OPEN.
- VERY STABLE AND SEDIMENT FREE SITE.
- RE-VEGETATION OF NATURAL SCRUB BEGINNING.
- SEDIMENT DISPERSAL AND DEPTH (SEE DIAGRAM OVER PAGE).
- VERY LITTLE HEAVY SILT OBSERVED.
- NO SEDIMENT OBSERVED BELOW MAIN CHANNEL OR WITHIN VEGETATED AREA.

DIAGRAM:

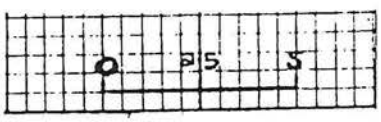


NOTE: All sediment probing was done diagonally across direction of movement. Depth records shown were all probed at 30cm intervals.

LEGEND:

Marker Peg	⊠
Lowest Point	→ → →
Fine Sediment	⬭
Heavy Sediment	⬭
Trees or Stumps	⊗
Sediment Depths	20, 30, 40 ETC.

SCALE:



SHANNON ALTERNATIVE RESOURCE

CUTTING TRIALS IN RIVER AND STREAM BUFFERS

STREAM BED AND BANK OBSERVATIONS

TRIAL CUTTING AREA: SUTTON 4

OBSERVER: A. HORDACRE DATE: 13/11/84

POINT NUMBER: 1M

BANK TO BANK WIDTH: AVE 4M

BANK HEIGHT: POINT 1 1.3M POINT 3 1.0M

POINT 2 0.8M POINT 4 1.0M

STREAM BED DESCRIPTION:
- WATER CLEAR.
- SOFT AND OF AN UNEVEN NATURE.
- HEAVY BUILD UP OF TRASH.
- MODERATE-DENSE GROWTH OF WATER WEED.
- VERY LITTLE SEDIMENT DEPOSITION OBSERVED.

DESCRIPTION OF VISIBLE DISPERSAL OR BUILD UP:

- A SMALL BANK OF WHITE SAND DEPOSITION OBSERVED WHERE A LOG IMPEDES FLOW.
- SMALL AREA OF WHITE SAND DEPOSITION WHERE BANK OVERFLOW ONTO FLOOD PLAIN HAS OCCURRED.
- SUSPENDED ORGANIC MATTER OBSERVED WHERE WATER FLOW WAS NEGLIGIBLE.

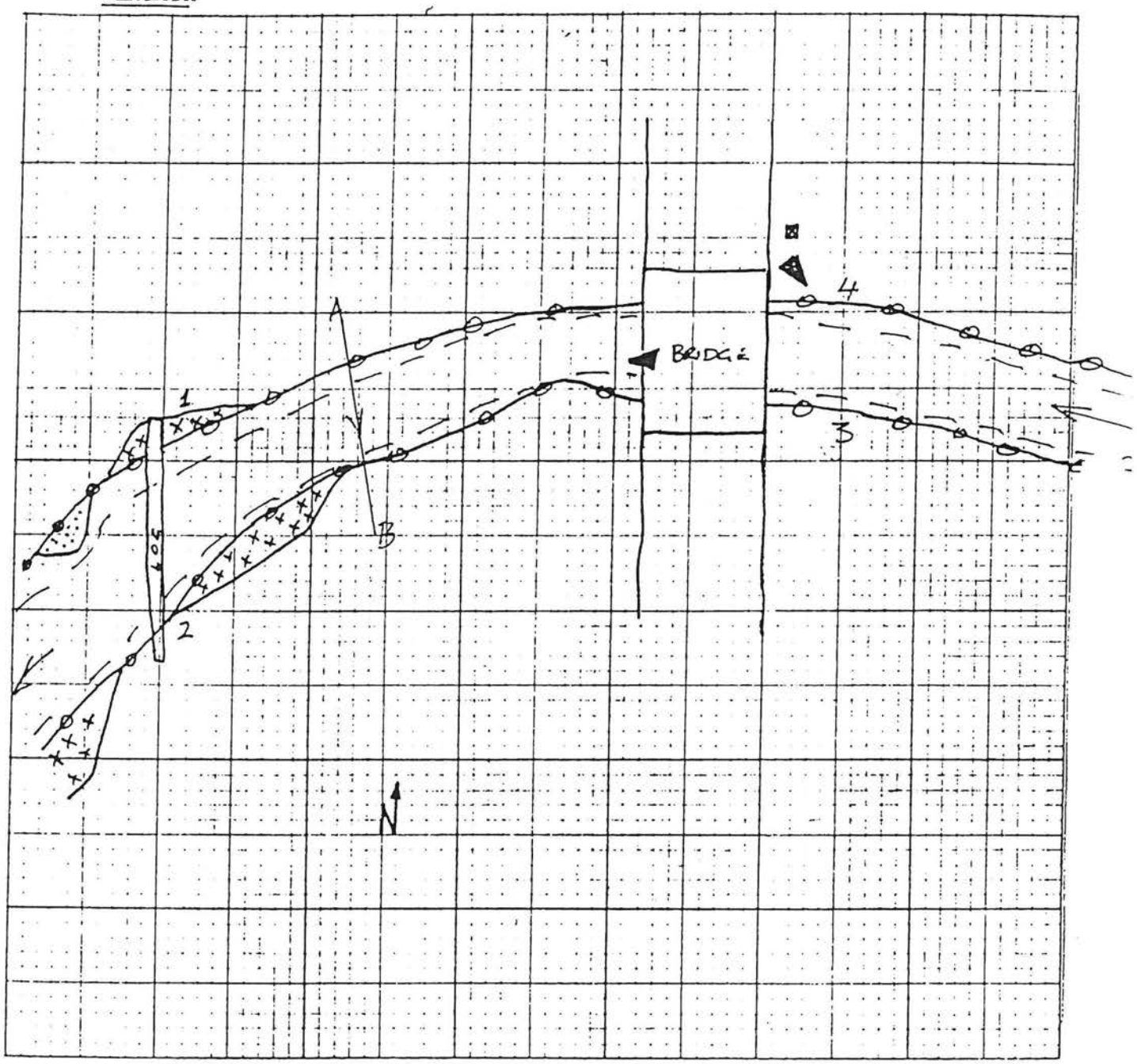
TYPE OF DEPOSITION:

- WHITE SANDS.
- ORGANIC MATTER.

BANK AND BED STABILITY:

- BANK IN NATURAL STATE WITH DENSE VEGETATION COVER OFFERING STABILITY.
- BED IS COVERED BY WATER WEED AND IS IN A VERY STABLE STATE.

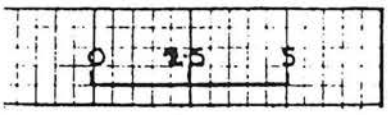
DIAGRAM:



LEGEND:

- Sediment Deposition
- Gravel Deposition
- Water Level
- Photograph Position
- Permanent Marker Pegs
- Tree or Stump
- Sediment Deposition Bank Overflow
- Stream Bank
- Stream Bed Profile Survey

SCALE:

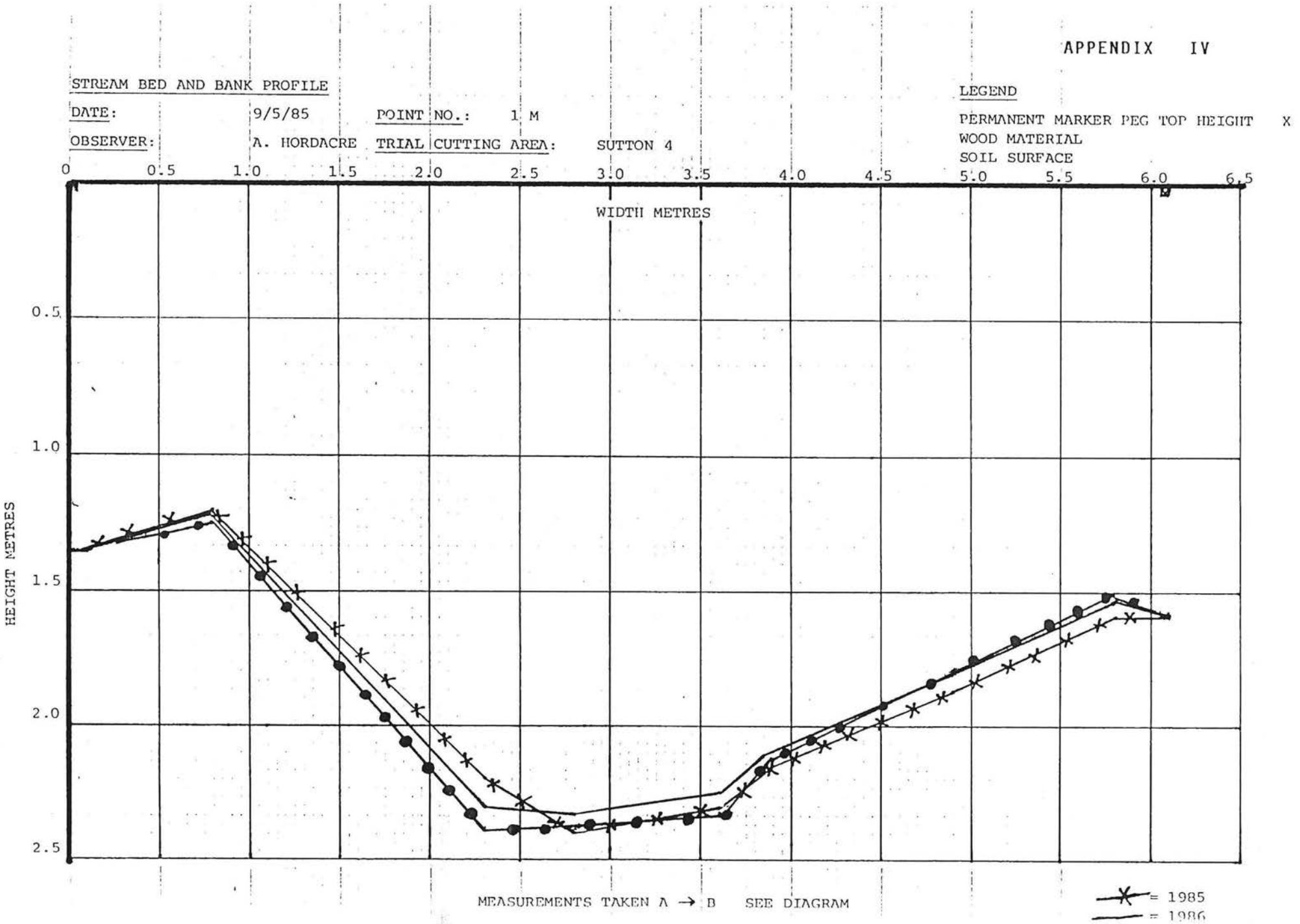


APPENDIX IV

STREAM BED AND BANK PROFILE

DATE: 9/5/85 POINT NO.: 1 M

OBSERVER: A. HORDACRE TRIAL CUTTING AREA: SUTTON 4



SUTTON STREAM RESERVE CUTTING TRIAL PRIOR TO LOGGING

Typical dense vegetation growth and debris.
This site is very stable.

SUTTON STREAM RESERVE CUTTING TRIAL PRIOR TO CUTTING

Spoon drain from Six Mile Road containing
quantities of sediment washed from road surface.

SUTTON STREAM RESERVE CUTTING TRIAL PRIOR TO CUTTING

Streambed below a bridge on Six Mile Road.
Debris from roads surfacing material obvious
in streambed.

MATTABAND RIVER RESERVE CUTTING TRIAL

Rill erosion resulting from poor track techniques.
Earth mound at track side and no side drainage
confined water runoff to track.

POOLE PARTIAL CUTTING OF STREAM RESERVE CUTTING TRIAL

Sediment resulting from gravel pit runoff deposited on disturbed area adjacent to uncut Reserve.

Deposit movements were impeded by vegetation and woody debris.

SUTTON STREAM RESERVE CUTTING TRIAL AFTER CUTTING

Woody debris resulting from logging over stream banks.

SUTTON STREAM RESERVE CUTTING TRIAL

Dense scrub growth 1 year old after regeneration burn.

Established karri regeneration outside trial area is in the background.

LOCHART 2 RIVER RESERVE CUTTING TRIAL

Two years after regeneration, cutover area and boundary track are well stabilized by vegetative growth.