Water Authority
of Western Australia

WATER RESOURCES DIRECTORATE

Summary Of Denmark River Yield And Salinity Study

Report No. WH 8 Summary

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1. SUMMARY

A hydrological study of the 525 km^2 Denmark River Basin in the south west of Western Australia has been completed. The aim of the study was to produce preliminary estimates of the effects of agricultural clearing on the magnitude and timing of water and salt yields from the Denmark catchment and to evaluate the likely water supply reliabilities and salinities for a range of reservoir sizes at the Mt Lindesay gauging station.

Streamflow salinity at the Mt Lindesay gauging station in a median year is likely to be 725 mg/L total soluble salt (TSS) when the full effects of clearing develop early next century. Monthly salinities are likely to be above 800 mg/L more than 60% of the time and above 1000 mg/L for about 40% of the time. These projected salinities represent an increase of approximately 20% over current salinities.

A major reservoir with a storage of at least 150% of the mean annual flow (37.7 x $10^6 m^3$) would supply more than 23 x $10^6 m^3$ with less than a 1% chance of severe restrictions. Monthly supply salinities would exceed 800 mg/L less than 20% of the time and 1000 mg/L less than 2% of the time.

The water resource will therefore be of marginal quality (500 to 1000 mg/L) on average.

Feasibility studies of agroforestry in the 700 to 800 mm rainfall zone, research into agricultural species for minimization of recharge and a more detailed investigation of strategic tree replanting are recommended.

2. INTRODUCTION

The Denmark River is a major potential water resource for the southern coastal region of south western Western Australia. A major reservoir at the most likely site near the Mt Lindesay gauging station has been estimated to potentially yield 30 x $10^6 m^3$ per annum. Currently less than 0.5 x $10^6 m^3$ is harnessed by a pipehead reservoir for water supply to the town of Denmark.

The salinity in the pipehead (420 000 m^3 capacity) has deteriorated in recent years. Maximum salinities increased from less than 900 mg/L in 1980 to more than 1400 mg/L in the drought year of 1983. In 1984 an alternative source on Scotsdale Brook was developed for substitution for or dilution with Denmark River water.

Legislative controls on clearing for agriculture were enacted in 1979 to protect the water resource from further deterioration in water quality. Approximately 25% of the 567 km^2 of catchment to the pipehead dam is alienated and 17% (95 km^2) was cleared by 1984 (Figure 1).

Development of the water resource with a large reservoir is possible during the next 30 to 40 years. However because of the delay between clearing and the development of the full hydrological effects, stream salinities are expected to continue to increase. An evaluation of the likely magnitude and time scale of salinity increases is required for the planning of the development of the resource and the initiation of catchment rehabilitation and landuse management.

A hydrological study (*) of the Denmark River Basin has recently been completed which makes predictions of stream water yield and salinity and implications for reservoir development. This report summarizes the results of the study and presents implications for management of the catchment.

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* Denmark River Yield and Salinity Study by J.K. Ruprecht, R.A. Stokes and R.B. Pickett.

Hydrology Branch Report WH8, November 1985.

3. APPROACH TO THE STUDY

3.1 Aim

The aim of the study was to produce improved estimates of the magnitude and timing of stream water and salt yields (and hence salinity) in response to agricultural clearing.

With this information the second objective was to evaluate the likely water supply reliability and salinity of a range of large reservoir sizes at the site of the Mt Lindesay gauging station which is a likely site for a reservoir.

3.2 Analysis

To predict the likely stream water and salt loads (salinity) required a model of the relationship between the landuse and the hydrology of the catchment. As these relationships are complex and the analysis was required for a catchment of greater than 500 km^2, a robust, statistical approach was developed. Basic information on rainfall, soil salt storage, stream water and salt yields and landuse (clearing) are required for this analysis.

3.3 Data

Aerial photographs and LANDSAT imagery (for 1984) were used to develop a history of clearing for 1946, 1957, 1965, 1973, 1979 and 1984.

Soil solute and groundwater salinity were determined from available drilling information and comparison with a more extensive data set in the Manjimup Woodchip Licence Area.

Yearly rainfalls were produced for sub-catchments of the Denmark by Thiessen weighting of daily rainfall between 1910 and 1984.

Daily stream water volume and salt loads were calculated for the Mt Lindesay and the Kompup gauging sites (Figure 1). The Kompup gauging station measures the water and salt yield from the more saline area of the Denmark catchment.

Yearly rainfall-runoff and runoff-salinity relationships were developed for forested and cleared conditions.

3.4 Catchment Model

The yearly, regional, rainfall-runoff-salinity model developed by Loh and Stokes in 1980 in the study of the Wellington catchment was modified for use on the Denmark catchment. The model uses soil solute information, a history of clearing, estimates of the delay between clearing and salinisation and forested and cleared area water and salt load responses to produce yearly water and salt yields for three different catchment zones.

After calibration with historical data the equilibrium conditions were predicted using the 10%, 50% and 90% probabilities of non-exceedance (PNE) of yearly rainfalls to represent typical drought, average flow and flood years respectively.

3.5 Reservoir Model

A monthly water and salt balance model was used to determine the probabilities of reliability of water supply and salinity for a range of reservoir sizes and demand draws.

4. RESULTS

4.1 Clearing

Approximately 18% (94 km^2) of the 525 km^2 catchment to the Mt Lindesay gauging site was cleared by 1984. About 80% of this clearing is in the drier, more saline headwater catchment above the Kompup gauging site (34% of 235 km^2) (Figure 1). Most of the clearing had occurred by 1973.

The area cleared in 1984, as estimated from LANDSAT imagery, was about 9 km^2 less than that estimated from aerial photographs for 1979. Approximately 2/3 of this reduction occurred as a result of forest regrowth on private land upstream of Kompup. Most of the remaining 1/3 is attributed to differences in the interpretation of forest and clearing between the machine processed 1984 LANDSAT imagery and the manually processed 1979 aerial photographs. In calculating stream salinity a conservative approach was followed and the largest estimate of clearing in 1979 was adopted. The effects of smaller areas of clearing will be discussed below.

4.2 Current Situation

4.2.1 Groundwater

Soil solute storage is comparable with that of the Manjimup Woodchip Licence Area for which there is a more extensive and therefore representative data set. Groundwater salinities in the area above Kompup are on average 6000 to 8000 mg/L TSS and stream baseflow salinities approach these values at Kompup during late spring into summer.

4.2.2 Streamflow and Salinity

The median flow and salinity statistics are listed in Table 1.

Table 1 Median Streamflow and Salinity

LOCATION	AREA (km^2)	RECORD	FLOW ($10^6 m^3$)	SALINITY (mg/L TSS)
Kompup	235	1972-84	10.3	Not avail.
Lindesay Gorge	466	1973-84	18.0	Not avail.
Mt Lindesay	525	1962-84	25.1	600

The current annual 10% (drought), 50% (average) and 90% (flood) probability of non-exceedance of stream salinity at Mt Lindesay gauging station were estimated to be 1000, 600 and 300 mg/L TSS respectively.

Streamflow data from 1978 to 1984 indicates that the catchment above Kompup currently contributes about 70% of the stream salt load and about 40% of the water as measured at the Mt Lindesay gauging station.

4.2.3 Rainfall

A 74 year record of daily rainfalls was obtained, commencing in 1910. The mean rainfall for the last half of the record (1940-1983) was 10% to 14% lower than that for the first half (1910-1939) across the Denmark catchment. The period from the mid 1960's has been noticably drier, particularly relative to the very wet period from about 1915 to 1930.

There is some evidence that the rainfall during the early part of this century may not be representative of likely future rainfalls. Therefore the last half of the record was adopted as likely to be more representative of future rainfalls for this study. This is a somewhat conservative approach in that stream water yields are therefore lower than if the whole rainfall record was used.

4.3 Stream Water Yield and Salinity Predictions

4.3.1 Yearly Estimates

The full hydrological effects of clearing will have developed by early next century. Based on the 92 km^2 of clearing above Kompup in 1979 the 10%, 50% (median) and 90% probabilities of annual non-exceedance of stream water yield at Mt Lindesay gauging station were calculated to be 12, 32 and 82 x $10^6 m^3$ (the mean annual flow was 37.7 x $10^6 m^3$). The associated 10%, 50% and 90% yearly salinities are likely to be 1080, 725 and 460 mg/L TSS.

These salinities and streamflows were calculated for a cleared area of 92 km^2 above the Kompup gauging station in 1979. The 1984 LANDSAT imagery estimate of clearing for 1984 was 80 km^2 because of some forest regrowth and because of differences between procedures used to estimate clearing.

At the lower, 1984 amount of clearing the median annual stream water yield and salinity at the Mt Lindesay gauging station are likely to be 31 x $10^6 m^3$ and 675 mg/L TSS. This salinity is about 50 mg/L lower than that based on the 1979 clearing estimate.

4.3.2 Monthly Salinities

When the full effects of clearing develops the 10%, 50% and 90% monthly stream salinities were estimated to be 1430, 900 and 460 mg/L. More than 60% of average monthly salinities may be greater than 800 mg/L TSS and almost 40% may be greater than 1000 mg/L TSS. This will represent a 15% to 20% increase in the number of months with salinities above 800 mg/L and 1000 mg/L.

4.4 Reservoir Development

A 500 year sequence of synthetic monthly stream water and salt loads was produced and used as input to simulate the demand, reliability and salinity for various reservoir sizes and draws at the Mt Lindesay gauging site. Reservoir size ranged between 100% and 300% of the mean annual inflow (MAI) of 37.7 x $10^6 m^3$ and draws ranged between 60% and 90% of MAI.

A draw of about 60% of MAI could be achieved with a probability of severe restrictions of less than 1% with a storage of 150% of MAI.

For most reservoir sizes the probabilities of monthly draw salinities being greater than 800 mg/L and 1000 mg/L were less than 20% and 2% respectively.

The median monthly salinity of supply was estimated to be 675 mg/L on the basis of the clearing at 1979.

With the smaller area of clearing at 1984 it is estimated that the median monthly salinity of supply might be 50 mg/L lower at 625 mg/L.

The monthly supply salinities for major reservoirs are significantly less than those possible from a small reservoir such as the existing pipehead. Such essentially run-of-river schemes supply high salinities during early winter flows and store the high salinity at the end of the flow-season which are then supplied over the following summer. Larger storages retain the fresher mid-winter flows which dilute the more saline earlier and later inflows.

5. DISCUSSION

5.1 Future Salinities

The water resources of the Denmark River at Mt Lindesay gauging station are projected to be of marginal quality (in the range 500 to 1000 mg/L TSS) for either run-of-river (small pipehead) or for a major reservoir development. Monthly supply salinity from a large reservoir may be greater than 800 mg/L for about 20% of the time. Community concern is often expressed when salinity levels exceed 800 mg/L and there is increasing pressure for lower sodium levels in water supply for health reasons.

The supply salinity from a large reservoir would in practice be somewhat less than that indicated. Reservoir operation strategies, particularly scouring of saline inflows, could be expected to produce an improvement in the quality of supply by about 10%. However this is relatively small and as standards for water supply quality increase the Denmark resource appears more marginal.

5.2 Management

5.2.1 Existing Pipehead

This study indicates that the water quality problem in the small (420 000 m^3) reservoir supplying Denmark will worsen. There is little potential for management of this problem in the near future other than to develop alternate or conjunctive sources of supply.

5.2.2 Salt Discharge Reduction

Most (70%) of the stream salt load at the Mt Lindesay gauging station originates upstream of Kompup and a reduction in the salt load from this area could improve the water quality at Mt Lindesay with relatively little reduction in stream water yield. This is shown in Figure 2 where the variations of the 10%, 50% and 90% probabilities of non-exceedance of streamflow and salinity at the Mt Lindesay gauging station are plotted against the area of clearing upstream of the gauging station at Kompup.

From Figure 2 the median salinity (C_{50}) varies approximately linearly with the area of clearing (A) between 20 and 80 km^2.

$$C_{50} = 385 + 5 (A - 20)$$

The median salinity changes by 5 mg/L per square kilometre change in clearing.

A reduction in the area of clearing and hence effectively of the discharge of salt to streams can be accomplished by the minimization of recharge to saline groundwaters or by the minimization of groundwater discharge.

An agricultural approach to controlling recharge to groundwaters would involve a relatively large scale use of alternative agricultural crops and pasture species. Such species have not been identified and demonstrated to be capable of significantly reducing recharge in areas such as the high salt risk, 700 to 800 mm rainfall, area of the Denmark catchment. However some preliminary research has commenced.

Agroforestry, with extensive areas of pine and integrated agriculture, would reduce recharge and also discharge. Encouraging pine growth has been recorded in similar rainfall zones. The economics of pine and agriculture in this area require evaluation. Research into the hydrologic effects of agroforestry is also required.

Discharge minimization involves the strategic planting of permanent, deep-rooted trees along lower parts of the landscape to intercept groundwater before discharge to streams. This management option is being used in the Wellington catchment and typically involves the replanting of 25% to 33% of the landscape.

A preliminary study of the area cleared above Kompup in the Denmark indicates that approximately 20 km^2 of replanting would effectively 'control' the discharge of saline groundwaters from the total of 80 km^2 of clearing. This represents 25% replanting and is based on a 100 m wide belt of trees on both sides of streamlines.

If such a replanting programme was 100% effective then the median salinity at Mt Lindesay would be 260 mg/L TSS. A 100% effective programme of 10 km^2 could control 40 km^2 of clearing and possibly reduce the median salinity to about 500 mg/L TSS (Figure 2).

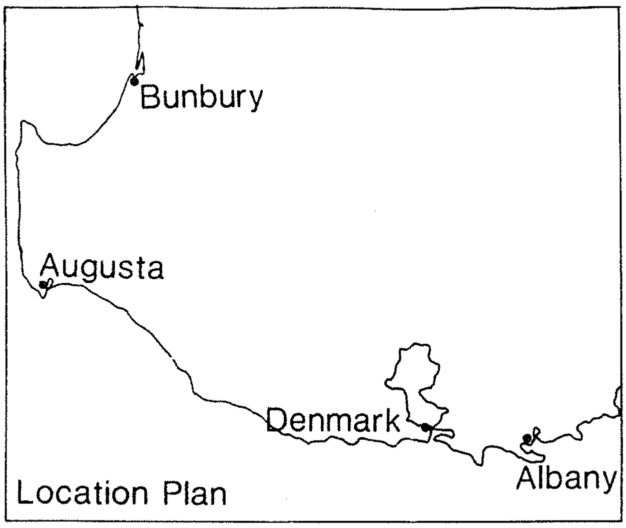
6. RECOMMENDATIONS

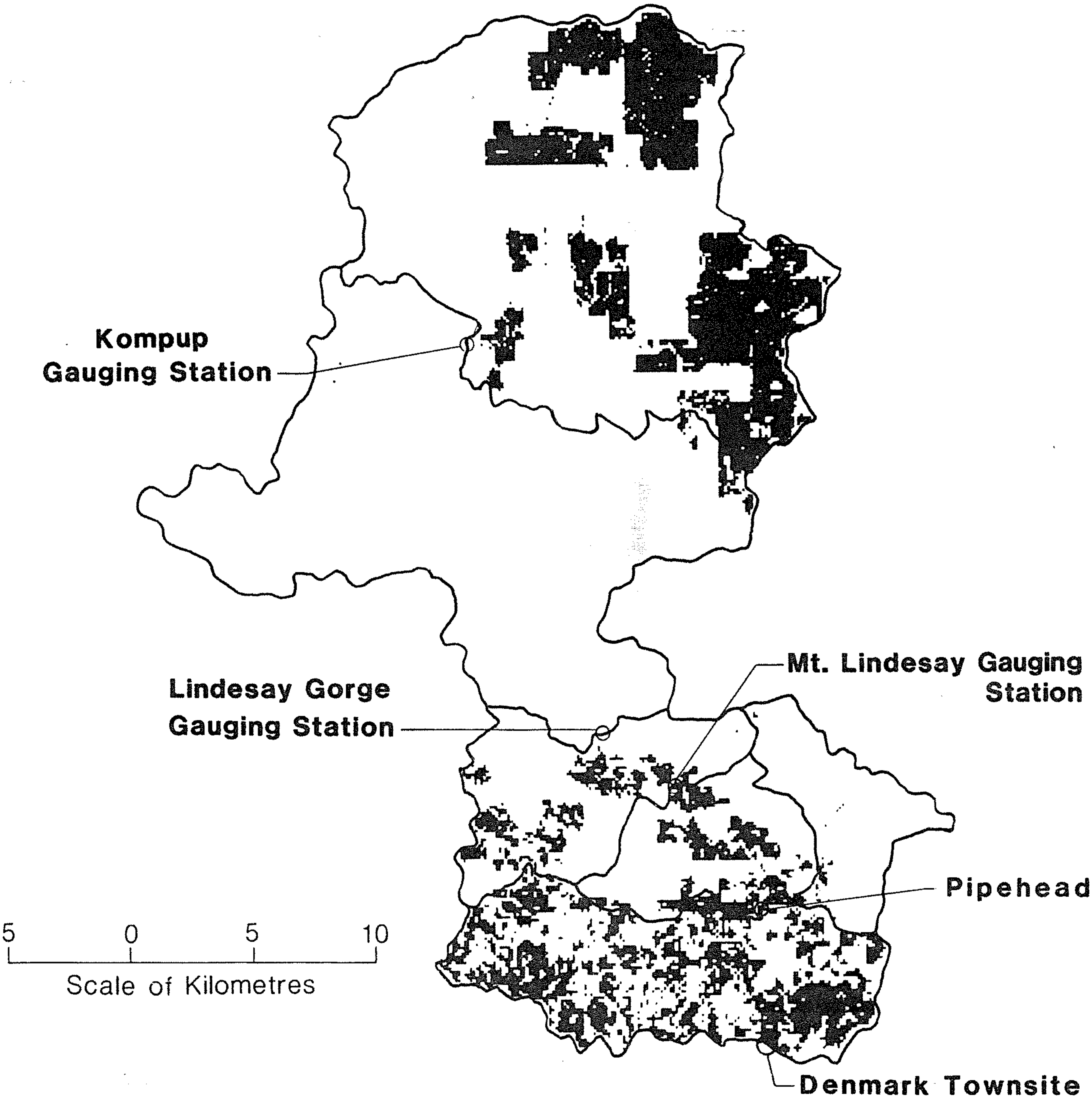
6.1 Review the performance of the current Scotsdale River scheme, particularly its ability to supply sufficient water at the end of summer following a relatively dry previous winter. Alternative schemes to supply the whole or part of the Denmark Town water supply may need to be developed.

6.2 An economic evaluation of the feasibility of pine agroforestry in the 700 to 800 mm rainfall zone of the upper Denmark be undertaken.

6.3 Agronomic research be undertaken to demonstrate alternative agriculturally productive vegetation for widespread use in the upper Denmark for the minimization of recharge.

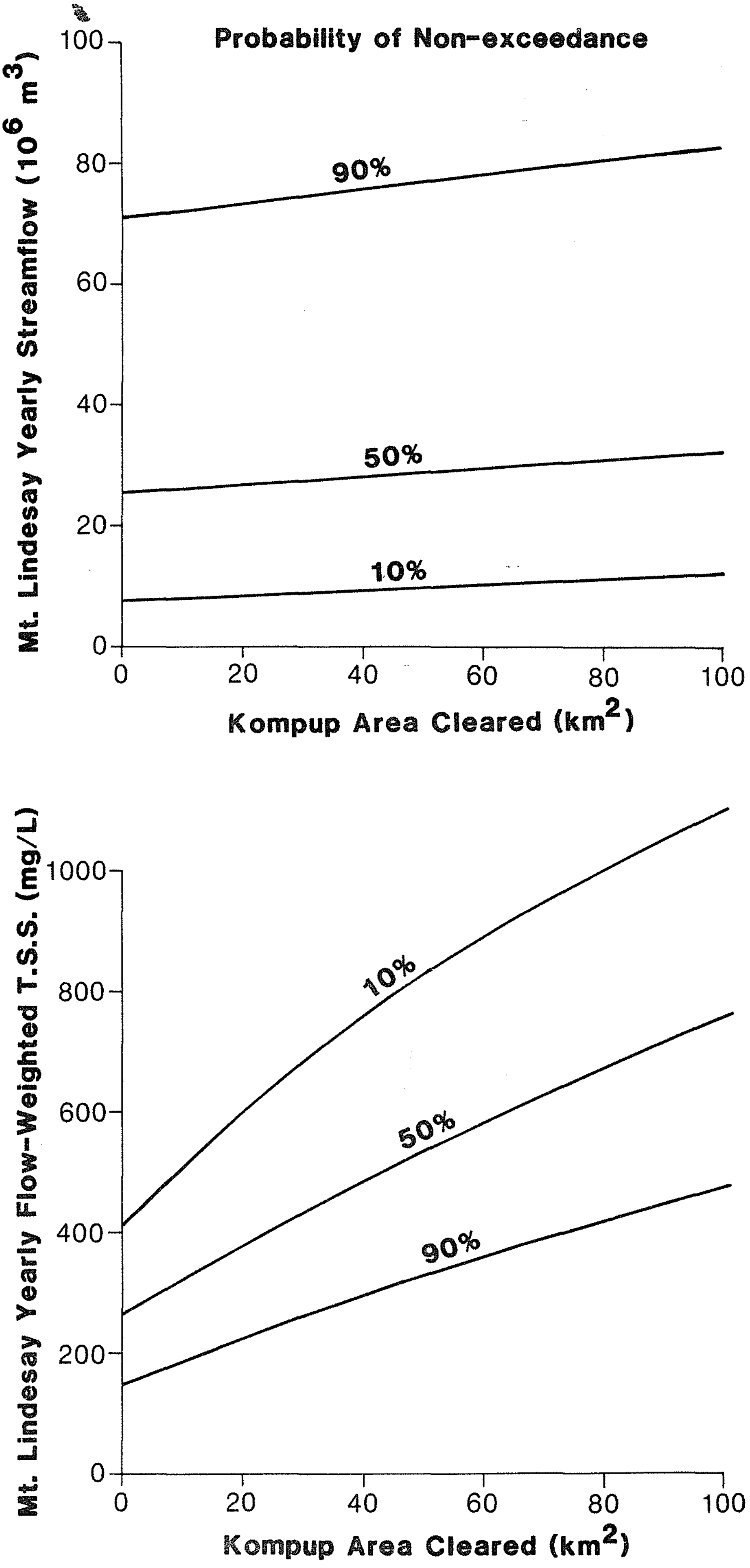
6.4 A more detailed assessment of the feasibility of strategic replanting along water courses in the upper Denmark should be made.





Clearing at 1984

Figure 1



Variation of Streamflow and Salinity at Mt. Lindesay
With Area Cleared Above Kompup

FIGURE