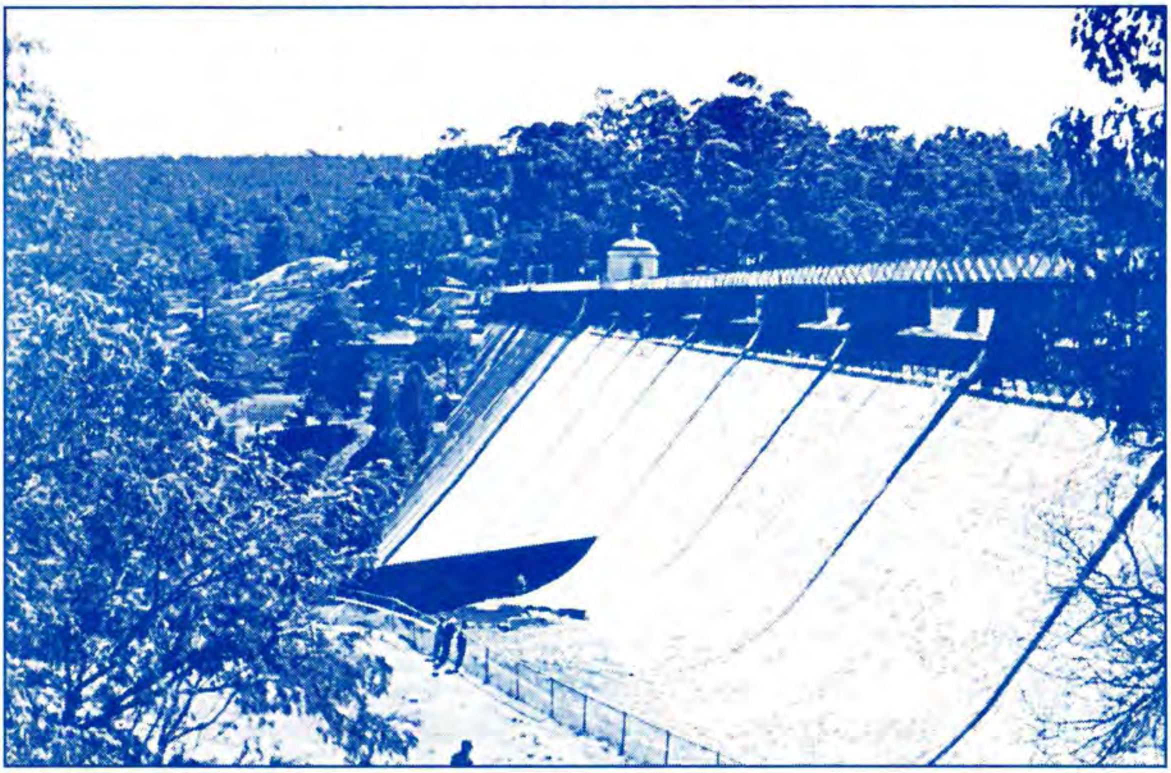
TREES ON FARMS TO REDUCE SALINITY IN THE CLEARING CONTROL CATCHMENTS

VOLUME 4: HELENA CATCHMENT



WATER RESOURCES TECHNICAL SERIES

WATER AND RIVERS COMMISSION REPORT WRT8 1996

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3 PLAIN STREET
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TELEPHONE (09) 278 0300
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Cover:

The Helena Catchment is dammed by the Mundaring Weir, source of water for the Goldfields and Agricultural Water Supply Scheme

TREES ON FARMS TO REDUCE SALINITY IN THE CLEARING CONTROL CATCHMENTS

VOLUME 4: HELENA CATCHMENT

R.N.M. DIXON
ECOWISE HYDROLOGY AND ENVIRONMENTAL SERVICES - W.A.

for
Water and Rivers Commission
Resources Investigations Division
Catchment and Salinity Investigations Section

WATER AND RIVERS COMMISSION
WATER RESOURCES TECHNICAL SERIES
REPORT NO WRT 8

Reference Details

The recommended reference for this publication is:

Water and Rivers Commission 1996, *Trees on Farms to Reduce Salinity in the Clearing Control Catchments, Volume 4: Helena Catchment,* Water and Rivers Commission, Water Resources Technical Series No WRT 8

ISBN 0-7309-7265-8
ISSN 1327 - 8436

Text printed on recycled stock ,
Onyx 100% recycled 100gsm
Cover, Media Satin 250gsm
November, 1996

Contents

Appendices

Summary

Clearing deep rooted natural vegetation from the land and replacing it with shallow-rooted agricultural crops and pastures in the South West of Western Australia has resulted in the salination of streams and land. This has been caused by the rising of groundwater tables and an increase in groundwater recharge (Peck and Williamson 1987). Salt has accumulated in the soil profile from rainfall or dry fallout and is mobilised by the rise in the groundwater level (Schofield et al. 1988).

The Water and Rivers Commission has developed a computing hydrological modelling process, (M.A.G.I.C.), that estimates the steady state deep groundwater discharge associated with vegetation. This model was used on the Helena Catchment situated 30 km east of Perth, Western Australia with a catchment area of 1482 km^2. Various factors in the catchment which have been potential causes of increased salt movement over the years as outlined below:

- The Wundowie Iron and Steel Company extensively cut the forest for use in the charcoal-iron plant from 1960 onwards
- Clearing of private property in the catchment for agriculture started in 1948. Five percent of the catchment area is private property of which approximately half has been cleared for grazing of sheep, cattle and horses and the growing of grain.
- Felling of wandoo (*Eucalyptus wandoo* Blakely) that occurred for the use of industrial extracts
- The death of native species caused by dieback disease

The model of the Helena Catchment identified sites for tree planting (on pasture existing in 1980) that would most effectively reduce groundwater discharge, while still maximising the area available to various forms of agriculture. These results are portrayed as mapsheets in Map Appendix 4B. These maps can be used as a guide when planning tree layouts in farm plans. The model also identified the saline seepage resulting from pasture existing in 1980 (mapsheets in Map Appendix 4A). Methods of analysis and results of the model are outlined in this report.

1. Introduction

The Helena catchment is situated 30 km east of Perth, Western Australia with a catchment area of 1482 km^2 (Figure 1). Helena Reservoir (Mundaring Weir) has a capacity of 77.1 mill. cu. m (Mauger 1989) and was completed in 1903 for water supply to the Eastern Goldfields, some 550 km to the east. The dam is situated in the west of the catchment in the valleys of the Helena and Darkin Rivers.

In the late eighteen hundreds and early this century the Railways Department used dams to collect water supplies for locomotive boilers on the Great Southern Railway. By 1905 the water had become unsuitable for use in the locomotive boilers (>50 mg/l TDS), and a remedy was found by diverting water from cleared land away from the dams (Wood 1924). After two consecutive dry years in 1902-03, native forest in the Helena catchment was ring-barked for the purpose of reducing evapotranspiration and thereby increasing streamflow to fill the dam. The two areas ring-barked included 48 km^2 situated just south of the dam and 18 km^2 north of the dam in the high rainfall zone (Ward 1977). This had the desired effect of increasing runoff but streams draining from the ringbarked areas increased in turbidity and the salinity increased by 300% in some instances. A maximum salinity of 1540 mg/l of total dissolved solids (TDS) was recorded (Water Corporation 1981). The salinity of the Helena reservoir increased to 550 mg/l TSS (Stokes & Batini 1985). To remedy the situation, regrowth forest was allowed to replace the original stand and some pines were planted on parts of the ringbarked areas in the second and third decades. Turbidity and salinity levels in the dam slowly decreased.

Various factors in the catchment have potentially influenced salt movement. The Wundowie Iron and Steel Company extensively cut the forest for use in the charcoal-iron plant from 1960 onwards (Ward 1977). Some clearing of private property in the catchment for agriculture started in 1948. Five percent of the catchment area is private property of which approximately half has been cleared for grazing of sheep, cattle and horses and the growing of grain. Felling of wandoo (*Eucalyptus wandoo* Blakely) has occurred for the use of industrial extracts in the catchment (Batini and Selkirk 1978). The death of native species caused by dieback disease is thought to have influenced salinity and is attributed to *Phytophthora cinnamomi* Rands (Batini, 1973).

Clearing deep rooted natural vegetation from the land and replacing it with shallow-rooted agricultural crops and pastures in the South West of Western Australia has resulted in the salination of streams and land. This has been caused by the rising of groundwater tables and an increase in groundwater recharge (Peck and Williamson 1987). Salt has accumulated in the soil profile from rainfall or dry fallout and is mobilised by the rise in the groundwater level (Schofield et al. 1988).

The Western Australian Government introduced clearing controls legislation for the Mundaring Weir Catchment Area to prevent additional clearing of native forest that would lead to increases in salinity. This was gazetted on 15 December, 1978 as an Amendment Act No 95 of 1978 of the Country Areas Water Supply Act. Salinity levels in the catchment have increased since 1978 due to earlier clearing. The Public Works Department repurchased 12 000 Ha of farmland within the catchment, mostly between 1956 and 1965 from farms which were largely uncleared (Batini & Selkirk 1978). Some of the land has been reforested or planted with pines.

Flynn's Farm is located in the Helena catchment and has a history of forest clearing and pasture development before 1940, mainly on the lower slopes. The soil profile is lateritic and depth of weathering varies from 0 to 20 m. Three experimental sites were established between 1977 and 1979, Flynn's Landscape, Flynn's Hillslope and Flynn's Agroforestry. Flynn's Agroforestry was planted predominantly with pines. The other two sites were planted with predominantly eucalypts. Eight percent of the cleared land was strip planted at Flynn's Landscape in 1977. Extensive planting in 1978-79 at Flynn's Hillslope amounted to 54% of the cleared area. An agroforestry experiment was initiated at Flynn's Agroforestry in 1978, where 58% of the cleared land was planted in wide-spaced plantations with agriculture between trees (Bell et al 1989).

The Water and Rivers Commission has developed a computing modelling process, (M.A.G.I.C.), that estimates the steady state deep groundwater discharge associated with vegetation. A hydrological model of the Helena catchment was developed that identified sites for tree planting that would most effectively reduce groundwater discharge, while still maximising the area available to various forms of agriculture. The methods of analysis and results of the model are outlined in this report. This process was previously applied to the Upper Denmark (Mauger 1994) , Wellington (Arumugasamy and Mauger 1994) and the Kent (Mauger 1996a) catchments. Maps have been produced for areas in the Helena catchment that were not native forest in 1980 that show predicted sites for planting trees. These maps can be used as a guide when planning tree layouts in farm plans.

2.0 Description of Catchment

The average annual rainfall of the catchment varies from 540 mm in the east to 1140 mm in the west. In the lower rainfall areas east of the catchment, the topography is flat and the main tree species is wandoo (*Eucalyptus wandoo* Blakely) with a canopy cover of about 20%. In the west the land consists more of hills and valleys and the main tree species is jarrah (*Eucalytus marginata* Sm). The canopy cover increases to 75% (Ward 1977). Other major species found in the catchment include marri (*Eucalyptus calophylla*), banksia (*Banksia attenuata*), powderbark wandoo (*Eucalyptus accedens*), Christmas *Tree (Nuytsia floribunda*) and Blackboy (*Xanthorrhoeaceae preissii*).

The Helena Catchment is located in the Darling Range which consists of an undulating plateau bounded to the west by an escarpment; to the east it merges into a large peneplain. The soil profile has resulted from the weathering of Precambrian igneous and metamorphic rocks. The rock has been weathered into clay and quartz grains up to depths of 60 m, but usually 20-30 m. The degree of weathering decreases over the bottom few metres, finishing in hard rock.

Soils on the surface vary from sandy to loamy sands with some colluvial and alluvial deposits on the valley floors. Laterisation can occur, generally decreasing with distance downslope. Often solid caprocks may appear in the landscape. The surface soil on the slopes is typically underlain by a duricrust above a sandy loam followed by a mottled zone and a pallid zone. The pallid zone contains a higher proportion of macropores than the mottled zone, which usually contains a higher proportion of clay. However clay layers can occur anywhere within the profile. Over a small scale the permeability can vary significantly, however over the scale of a small catchment the permeability of the soil in bulk can be uniform. Between depths of 1-3 m, there is less clay resulting in a higher permeability than the deeper zone.

3.0 Model of Catchment

The Helena Catchment was modelled using the personal-computer based M.A.G.I.C. (Microstation and Geographic Information Computation) modelling system. Mauger 1996b outlines the principles used in the hydrologic assessment of vegetation in catchments affected by dryland salinity in South Western Australia. A Geographic Information System approach was used in the development of the model. The resulting process can provide information at a scale of tens of metres, useful for planning tree planting on farms, while effects can be integrated for the whole catchment with areas up to hundreds of square kilometres. The whole catchment was sub-divided into sixty sub-catchments of areas from 10 to 40 square kilometres. Each sub-catchment was placed into a Rascal project consisting of separate maps comprised of 25 x 25 m cells.

The catchment boundaries, identifying numbers of each sub-catchment and flow directions are illustrated in Figure 1. Gauging stations run by the Water and Rivers Commission that were used to obtain gauged yearly average rainfall, streamflow and salt load are also shown on this figure. Spreadsheet 1 details the AMG coordinates of outlet locations in the sub-catchments (ie. points at which totals are reported).

The raster processing program, RASCAL computed quantities needed as input into the model of the catchment. Gridded elevation cells were generated from contour linework in MicroStation PC (geographical information drawing software package) format. Slope and drainage distribution information was generated from the elevation map in each Rascal project. Average Annual Pan Evaporation Isopleths and Average Annual Rainfall Isohyets (1926-81) polygons in MicroStation PC format were converted into Rascal maps in each project.

Frequency bands 5 and 7 of the Landsat MSS scene captured in December 1980 were used to classify the tree density in the catchment and areas consisting of water. In rural land, most of the pixels (the area of land which is recorded as a single data point in a Landsat scene) contain three types of reflecting surfaces: green leaves, bare earth and shaded areas. An index referred to as the 'greenness', a percentage of pure green component, was computed by the method outlined in Appendix A of Mauger 1988. This was used to give an indication of the tree density in the catchment.

The model, a two-layer groundwater simulation with inputs of rainfall and evapotranspiration was then executed using RASCAL. The soil profile was represented as two layers of equal slope to the surface slope. Soil depths and permeabilities were constants (Mauger 1996b). The model was run in monthly time steps for three years running. The first year ran the shallow groundwater simulation as a preliminary analysis to get an estimate of the initial water storage in each cell. The lower groundwater level was a "steady state" analysis, ie. the average over a long period of time assuming vegetation cover remained the same throughout. The shallow groundwater simulation was ran for the next two years using the storage loss from the previous year. Ideally, after the third year the final water storage in each cell should have equalled the initial water storage.

The details of the computing processes used in the Kent Catchment are documented in the Volume of Appendices in Mauger 1996a. The computing processes used in the Helena catchment are similar to those used for the Kent, any variations have been documented in the Addendum for Volume 3: Helena Catchment found in the Volume of Appendices in this report.

The results of the model for each sub-catchment are relayed in spreadsheets 2-4. Each spreadsheet has the sums for isolated individual catchments and aggregates for subcatchments including all the upstream catchments.

Spreadsheet 2 contains all of the area statistics, such as catchment area (sq. km), average rainfall (mm), cleared areas (sq. km & % of catchment), forest without upstream clearing (sq. km & % of catchment). The flows for 1980 clearing are in spreadsheet 3. This includes streamflow (cu. m & mm [m^3/m^2 of catchment]), deep groundwater discharge ('seepage') (cu. m & mm), seepage inside and outside forest.

In spreadsheet 4, the model minimum tree planting for a 52% reduction in seepage at gauging station S616216 is reported for each subcatchment. This includes the predicted and review seepages and streamflows that would occur if the trees were planted.

3. Modelling Parameters

The main parameters that determined the estimates of streamflow and seepage rates were:

- Cleared areas were used for annual pasture with a peak Leaf Area Index (LAI) of 2.1.
- The top soil layer throughout the catchment was taken to be 1.5 metres deep with a permeability of 30 m/month/unit hydraulic gradient and a porosity of 0.2.
- The bottom soil layer was 20 metres deep with a permeability of 4 m/year/unit hydraulic gradient.

For all the Water and Rivers gauging stations in the Helena catchment, the positions of the outlet points on some of the Rascal projects were made to coincide. In Table 1, the gauging point column represents the sub-catchment number that has an outlet point on the corresponding Gauging Station. Table 1 also compares the model and gauged rainfall figures for the catchment. The gauged rainfall data for the period between 1970 and 1994 in the Helena Catchment was 90% of the annual average rainfall. The rainfall map in the model contained the average yearly rainfall from 1926-81. So that the model streamflows might match the gauged streamflows for the years 1970-94, the model was run with a rainfall input of 90% of the average annual rainfall.

The streamflow results obtained from the shallow groundwater simulations were compared to historical streamflow records from gauging stations. The results of the comparisons are also illustrated in Table 1. The modelling process overestimated the streamflows. To reduce the streamflows output from the model , at the end of each year in the modelling process, the annual evaporation from lakes and streams was removed. The amount of evaporation removed from the streams was proportional to the width of the stream and 0.7 times the pan evaporation. The factor 0.7 is the assumed lake to pan correction factor. The width of the streams was assumed to be 2m for cells with an upstream catchment area of greater than 100 Ha and less than 500 Ha and 5 m for cells with an upstream catchment area greater than 500 Ha. For cells on streams with an upstream catchment area less than 100 Ha, this process was not applied.

High streamflows were generated in the east of the catchment. The natural vegetation is wandoo woodlands compared with jarrah forest in the west. The differences in vegetation complexes was not accounted for in the model.

The natural 'greenness' of the vegetation was assumed to be 0.0095*Rainfall + 11.5. The coefficients for the natural 'greenness' formula were obtained from Mauger (1988) since the same December 80 Landsat scene was used in that study. The transpiration rate from trees in any cell was computed as:

$$\frac{\text{(actual greenness)}}{\text{('natural' greenness)}} \times \text{('natural' transpiration rate')}$$

where ('natural' transpiration rate) is proportional to annual rainfall. (Mauger 1996b)

If the natural greenness was overestimated, the transpiration rate from the trees would be underestimated leading to an over-estimation of streamflow.

A peak pasture LAI of 2.1 was adopted. This factor had minimal effect on the streamflow results due to the small areas of pasture in the catchment.

In the 1980 Landsat scene it was evident that large areas of the forest had been burnt. To account for this cells where the greenness of the cell was less than nine were replaced with the natural 'greenness' value.

The average monthly rainfall for the years 1970-1994 at Mundaring Weir was used to calculate the monthly rainfall coefficients used in the model. These monthly rainfall figures were obtained form the Reservoir Water Balance Study performed by the Hydrologic Services Section at the Water & Rivers Commission. The average monthly pan evaporation figures for Perth for the years 1970-1994 was used to calculate the monthly pan evaporation coefficients. The gauged pan evaporation monthly figures at Mundaring Weir were incomplete for the years 1970-1994. However, when the monthly pan evaporation coefficients were compared between Perth and Mundaring for available years, they were very similar. Use of the Perth monthly pan evaporation coefficients should have minimal effect on the streamflow.

The model deducted evaporation from free water surfaces for one month only. In swampy forest areas, free water surfaces may last more than one month, leading to an overestimation of streamflow. Photo 3 was taken along Qualen Rd in the east of the catchment on 5/9/96 and is a good example of a waterlogged area in the forest.

The bottom soil layer permeability is usually set by calibrating modelled deep groundwater discharge out of the forest to the value estimated by dividing gauged salt flux by typical deep groundwater salinity (Mauger 1996b). Seepage from forested areas is not counted in contributing to salt output. In order to separate seepage originating from pasture areas from seepage generated within forested areas, a map was generated in which cells were marked as 'outside forest' if more than 2% of the catchment area upstream from them was pasture. Only seepage from 'outside forest' cells was assumed to carry salt. A value of 4 m/year/unit hydraulic gradient was used for the bottom soil layer in the model. It appeared to be consistent with model results on the gauged catchments which is shown in Table 2.

Saltfall decreases with the distance from the coast and is estimated to range between 95 kg/Ha chloride (NaCl) per annum at Mundaring Weir and 24 kg/Ha per annum at the catchment's eastern boundary (Batini and Selkirk 1978). Since the average yearly rainfall at Mundaring Weir is 1140 mm/year and the average yearly rainfall in the east of the catchment is 540 mm/year, this corresponds to a salt concentration in the rain of 8.3 mg/l and 4.4 mg/l respectively. The salt concentration in the rain used in Table 2 was assumed to be proportional to the aggregate average rainfall for the subcatchment and all upstream subcatchments as shown in Spreadsheet 1.

25% of the Salt from rainfall was assumed to infiltrate into the bottom soil layer, thus not entering streamflow in the immediate future. The flow weighted mean salt concentration was assessed from streamflow records. The total amount of salt resulting from the seepage of cleared land in the catchment was estimated by subtracting from the stream's salt load an estimate of the salt contributed directly by rainfall. The amount of salt originating in the rainfall was assumed to be 75% of the salt load input into the stream in one year.

The recorded seepage before treatment had some very small negative values for some catchments, which equated to no salt load emanating from these catchments. Since the recorded salt concentration in these catchments was so low, errors in estimating the salt load from the rain caused the negative values of salt load. Gauging station S616216, "Helena River - Poison Lease" was used to calibrate the bottom soil layer permeability. This station had upstream areas that contained a large proportion of the cleared areas in the catchment.

In the Table 2, a typical deep groundwater salinity of 12000 mg/l was used. Not many deep groundwater salinities have been measured throughout the catchment. At Flynn's Landscape, the groundwater salinity ranged from 330-16600 mg l-1 TSS before the strip planting of trees occurred in 1977. At Flynn's Hillslope the groundwater salinity varied between 2400-12100 mg/l TSS while at Flynn's Agroforestry it varied between 130-8400 mg l^{-1} TSS. Groundwater salinities which are less than 1000 mg l^{-1} TSS indicate the presence of shallow perched water (Bell et al 1989).

Maps showing the location of predicted deep groundwater discharge (seepage), classed by rate of discharge are in Map Appendix 4A. Also shown on the maps is native forest as interpreted from the Landsat MSS data for December 1980; streamlines, property information and contours taken from planimetric maps. A sample of the map is shown in Figure 2.

4 Seepage Reduction Objectives

The stream salinity at the Poison Lease gauge (S616216) is relatively high as a result of upstream agricultural clearing. The overall salinity of water supplied from Mundaring Weir is close to the desirable limit of 500 mg/l. Thus a reduction in salt discharge is desirable, but a target that must be achieved is not identifiable. The target chosen corresponded to the degree of treatment being recommended for other salt affected catchments, that is to plant trees on about 30% of the cleared areas. This should result in a reduction in the mean salinity at Poison Lease from 1299 mg/l to 800 mg/l and a reduction at Mundaring Weir from 500 mg/l to 228 mg/l. The results of this analysis are in Table 2.

The reduction in salt was achieved by reducing the seepage outside the forest by 52% at gauging stations with areas that contained resonably sized cleared areas suitable for tree planting. After the planting treatment the resulting reduction in streamflow was calculated to be around 2%. The seepage to be reduced is shown in Spreadsheets 4. Gauging stations S616008, S616009, S616010, S616012, S616016 and S616017 did not contain large cleared areas suitable for tree planting in 1980. The records obtained from gauging stations S616002, S616008, S616009, S616010, S616012, S616016 and S616017 suggested that most of the salinity was due to the rainfall contribution.

5. Tree Planting to Reduce Seepage

In order to identify sites and areas for tree planting, the following criteria was used:

- minimise the areas to be planted in order to reduce seepage to the required degree
- plant in areas currently not native forest

The computer analyse process selected the areas of highest seepage rate first, and then progressively lower seepage rates until the total reduction in seepage target was met. Cells with deep groundwater discharge rates in the bottom soil layer that exceeded 15 mm/year were selected to be planted. The results of the analysis are presented as 'denoted sites for trees' as shown in the mapsheets titled 'Recommended sites for tree planting' in Map Appendix 4B. A sample of one of these maps is shown in Figure 3. The principles outlined in Appendix A result in a pattern of tree planting in belts of trees being situated in zones where deep groundwater discharge is to be utilised.

The numerical results of the analysis is tabled in Spreadsheets 4. Firstly, an estimate was made of the effect the tree planting would have on the seepage. The results are under the heading 'PREDICTED SEEPAGE'. The density of planting to achieve the predicted seepage is also estimated. The review process then puts the planted trees in the model, and the steady state modelling of the streamflow and seepage is re-analysed. The results are labelled 'REVIEW STREAMFLOW' and 'REVIEW SEEPAGE'. The review streamflow was used as an estimate of the effect of planting on the mean streamflow in Table 2.

The reviewed seepage was used to confirm the predicted seepage estimate. A summary of the model, predicted and reviewed seepages are presented in Table 3. The average Review/Predicted seepage was 82% for the whole catchment (Gauging Point 53 at Mundaring Weir). To reach the target reduction in seepage the percentage of planted over cleared areas should be on the average 31%. The predicted seepage should be used as the guide when estimating the reduction in seepage that would result from the tree planting, since the reviewed estimate may not be that precise.

In the modelling process, planted tree densities were assigned to a cell 25 metres square. The 'AREA PLANTED @ 1xNATIVE' in Spreadsheets 4 is the area planted with trees at a density equal to that of native forest. It is possible to achieve the same effect by planting narrower strips at a higher density.

6. Conclusion

The hydrological modelling of the Helena Catchment identified the saline seepage resulting from pasture existing in 1980. The results from this process are portrayed as mapsheets in Map Appendix 4A. Since 1980, more privately owned land has been cleared, so in the future it might be worthwhile updating the model with a more recent Landsat scene.

It was estimated that the saline seepage from the pasture in 1980, needs to reduced by 52% on average to meet the target flow weighted average salinity of 228 mg/l (down from 500 mg/l) at Mundaring Weir. The model was re-run with the suggested trees planted, and the resulting seepage volume was compared to the target reduction in seepage volume. This comparison suggested that the initial criteria chosen for tree planting was appropriate. Trees need to be planted where the seepage exceeds 15 mm/year (based on a bottom soil layer permeability of 4 m/year/unit hydraulic gradient) to meet the target. The results of the predicted sites of tree planting at native density are portrayed as mapsheets in Map Appendix 4B. If all of the suggested trees were planted, it was estimated that a decrease in flow into Mundaring Weir of 1.8% would result.

The streamflows generated from the model where higher than the gauged results. This was mainly caused by not accounting for differences in vegetation complexes in the model. To improve the model, the System Six Study maps of vegetation classification could be incorporated into the model. Different transpiration rates could then be applied to the different vegetation complexes. However, overestimating the streamflow should not have a large effect on the tree planting results. The percentage reduction in seepage is the main criteria used when predicting the density and location of tree planting and an overestimation of streamflow does not effect this a great deal.

The mapsheets in Map Appendix 4B can be used as a guide when planning tree layouts in farm plans. Actual plans should also incorporate farm objectives and operational constraints. If farm plans are prepared, then their effectiveness in reducing salinity should be reviewed by modelling them.

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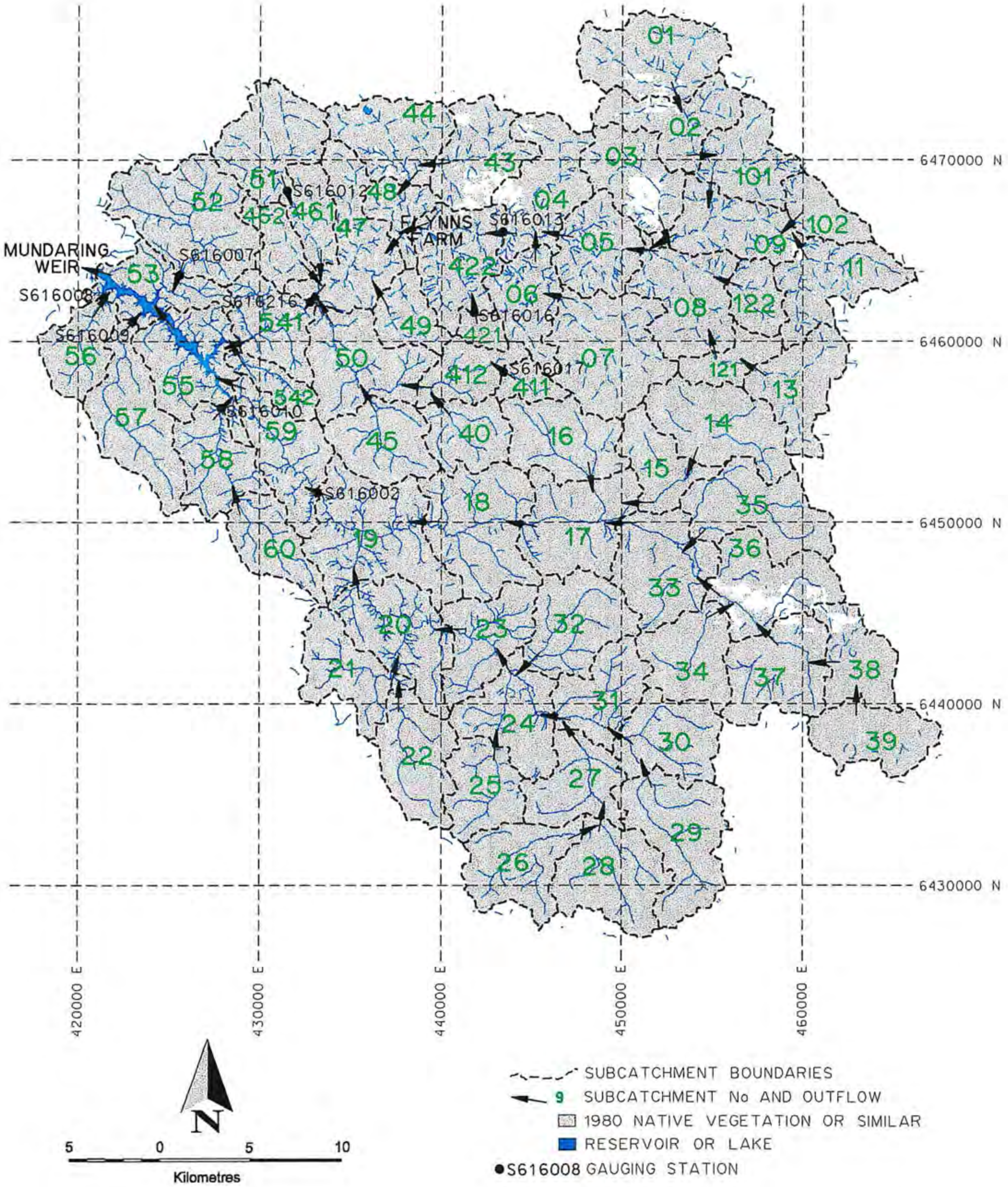
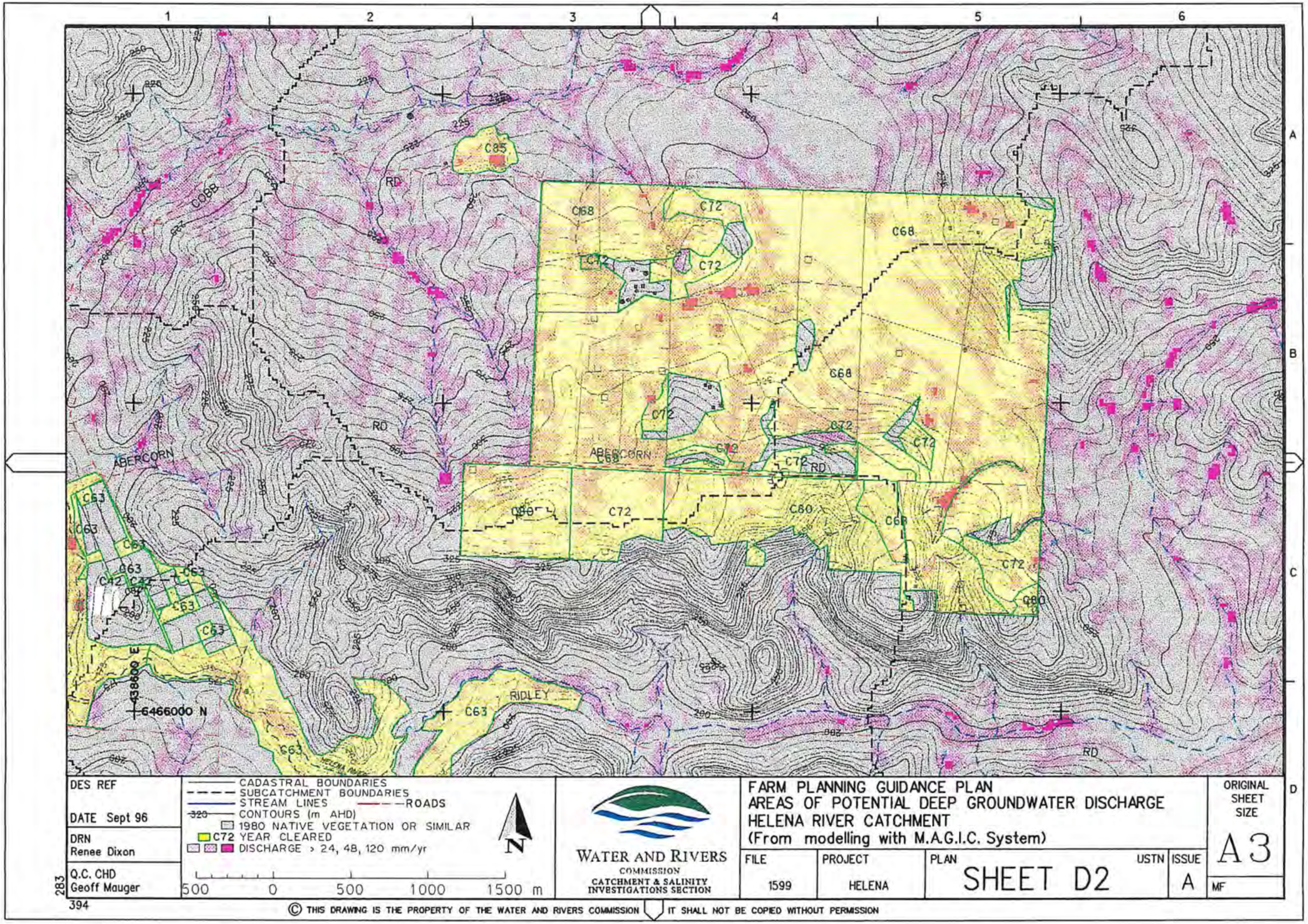


FIGURE 1 : Helena Catchment Showing Sub-Catchments and Gauging Stations

FIGURE 2: Sample of Map from Map Appendix 4A



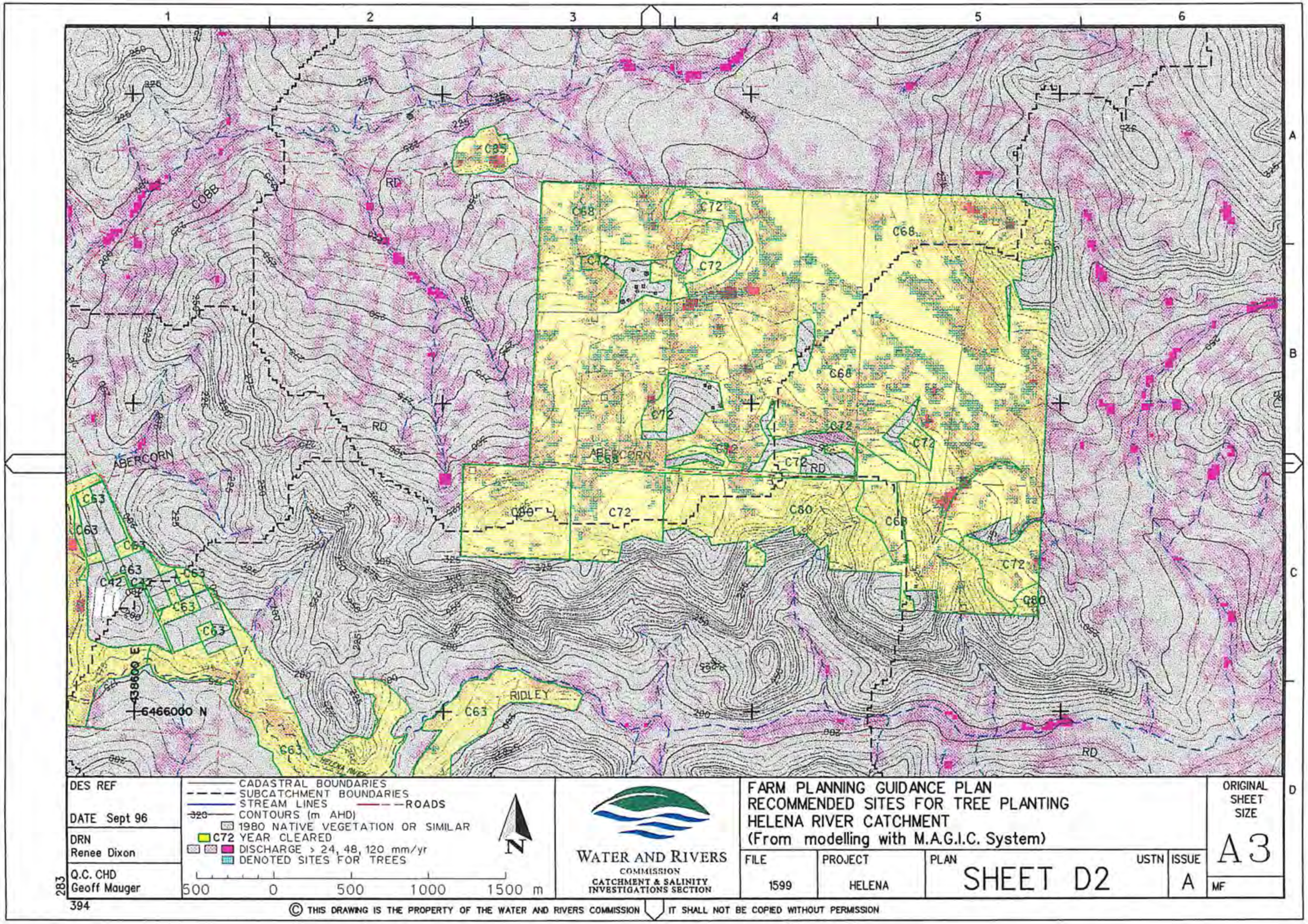


FIGURE 3: Sample of Map from Map Appendix 4B

TABLE 1 : RAINFALL AND STREAMFLOW RESULTS

MODEL AND GAUGED RAINFALL

Catchment	Station Number	Gauging Point	Catch. Area km^2	Years Gauged	Model Rainfall mm	Gauged Rainfall mm	Gauged/ Model Rainfall
Darkin River, Pine Plantation	M509256	19	665.1	74-87	842	787	93%
Rushy Creek, Byford Road	M509161	52	39.3	74-88	976	843	86%
Hay Creek, Reservoir Road		56	16.0		1046		
Pickering Brook, Slavery Lane		57	29.5		1009		
Liitle Darkin River, Hairpin Bend	M509159	58	59.0	73-94	924	854	92%
Helena Brook ,Trewd Road	M509157	51	26.4	74-94	836	775	93%
Helena River, Ngangaguringuring	M510017	4	327.9	73-93	690	625	91%
Helena River Trib., Wellbucket Road	M510221	421	4.7	75-81	708	615	87%
Helena River Trib., Yarra Road		411	6.2		706		
Helena River, Poison Lease		47	553.3		807		
Mundaring Weir	*	53	1459.4	70-94	1049	943	90%

MODEL AND GAUGED STREAMFLOWS

CATCHMENT	STATION NUMBER	Gauging Point	Catch. Area km^2	Years Gauged	Model Stream Flow mm	Review Stream Flow mm	Gauged Stream Flow mm	Model Stream Flow $x10^6$ m^3	Review Stream Flow $x10^6$ m^3	Gauged Stream Flow $x10^6$ m^3	Review / Model Stream Flow
Darkin River, Pine Plantation	S616002	19	665.1	74-87	30.66	29.78	7.14	20.395	19.806	4.750	97.11%
Rushy Creek, Byford Road	S616007	52	39.3	74-88	39.41	38.77	36.00	1.548	1.523	1.414	98.38%
Hay Creek, Reservoir Road	S616008	56	16.0	69-72	38.92	38.92	50.67	0.623	0.623	0.811	100.00%
Pickering Brook, Slavery Lane	S616009	57	29.5	70-94	22.19	22.19	66.82	0.655	0.655	1.973	100.00%
Liitle Darkin River, Hairpin Bend	S616010	58	59.0	73-94	21.45	21.45	21.30	1.266	1.266	1.257	100.00%
Helena Brook ,Trewd Road	S616012	51	26.4	74-94	33.90	33.91	35.64	0.896	0.897	0.942	100.03%
Helena River, Ngangaguringuring	S616013	4	327.9	73-93	38.30	37.58	6.01	12.557	12.321	1.971	98.12%
Helena River Trib., Wellbucket Road	S616016	421	4.7	75-81	7.51	7.51	2.34	0.035	0.035	0.011	100.00%
Helena River Trib., Yarra Road	S616017	411	6.2	74-82	8.91	8.91	6.22	0.055	0.055	0.038	100.00%
Helena River, Poison Lease	S616216	47	553.3	67-94	37.59	37.06	11.70	20.800	20.504	6.474	98.57%
Mundaring Weir	*	53	1459.4	70-94	35.08	34.46	14.25	51.197	50.286	20.801	98.22%

Note: * Gauged results obtained from Reservoir Water Balance Study, Hydrologic Services Section, Water & Rivers Commission

TABLE 2 : CALCULATION OF SALINITY REDUCTION TARGETS

RAIN

CATCHMENT	STATION	AREA (sq.km)	VOLUME mill.cu.m	mm	SALT mg/l	tonnes
Darkin River, Pine Plantation	616002	665.1	539.10	810.6	5.4	2641
Rushy Creek, Byford Road	616007	39.3	37.98	966.5	7.2	246
Hay Creek, Reservoir Road	616008	16	17.90	1118.6	8.2	132
Pickering Brook, Slavery Lane	616009	29.5	31.32	1061.6	7.8	220
Liitle Darkin River, Hairpin Bend	616010	59	51.82	878.3	6.6	309
Helena Brook ,Trewd Road	616012	26.4	22.95	869.2	6.6	135
Helena River, Ngangaguringuring	616013	327.9	220.89	673.7	5.0	994
Helena River Trib., Wellbucket Road	616016	4.7	3.33	707.7	5.5	16
Helena River Trib., Yarra Road	616017	6.2	4.33	698.4	5.4	21
Helena River, Poison Lease	616216	553.3	429.36	776.0	5.4	2080
Mundaring Weir	N/A	1459.4	1076.44	737.6	5.6	5378

STREAM

		Before Treatment					After Treatment				
		VOLUME			SALT		VOLUME			SALT	
		Model	Records		Records		Model	Estimate			
		mill.cu.m	mill.cu.m	mm	mg/l	tonnes	mill.cu.m	mill.cu.m	mm	mg/l	tonnes
Darkin River, Pine Plantation	616002	20.395	4.75	7	396	1880.05	19.801	4.61	6.93467	131.782	607.813
Rushy Creek, Byford Road	616007	1.587	1.41	36	688	969.80	1.563	1.39	35.3397	338.663	470.352
Hay Creek, Reservoir Road	616008	0.623	0.81	51	269	217.89	0.623	0.81	50.625	187.568	151.93
Pickering Brook, Slavery Lane	616009	0.655	1.97	67	247	486.31	0.655	1.97	66.7797	190.942	376.157
Liitle Darkin River, Hairpin Bend	616010	1.266	1.26	21	380	478.61	1.266	1.26	21.3559	257.408	324.334
Helena Brook ,Trewd Road	616012	0.896	0.94	36	814	765.16	0.894	0.94	35.6061	741.98	697.461
Helena River, Ngangaguringuring	616013	12.557	1.97	6	1790	3527.09	12.319	1.93	5.89378	877.919	1696.64
Helena River Trib., Wellbucket Road	616016	0.045	0.01	2	70	0.77	0.045	0.01	2.34043	-678.2	-7.4602
Helena River Trib., Yarra Road	616017	0.055	0.04	6	92	3.53	0.055	0.04	6.19355	-183.92	-7.0626
Helena River, Poison Lease	616216	22.157	6.65	12	1299	8633.15	21.833	6.55	11.8434	**800**	5242.36
Mundaring Weir		52.594	20.80	14	* 500	10400.50	51.651	20.43	13.9966	228.096	4659.23

SEEPAGE (SALT LOAD = SALT IN STREAM - 75% SALT IN RAIN)

		Before Treatment						After Treatment				
		VOLUM			SALT		REDUCE	VOLUME			SALT	
		Model	Records		Records		SEEPAGE	Model	Estimate			
		mill.cu.m	mill.cu.m	mm	mg/l	tonnes	TO	mill.cu.m	mill.cu.m	mm	mg/l	tonnes
Darkin River, Pine Plantation	616002	0.2378	-0.0084	-0.013	12000	-100.756		0.1228	-0.0044	-0.00657	12000	-52.455
Rushy Creek, Byford Road	616007	0.0066	0.06545	1.6653	12000	785.3689		0.0025	0.03407	0.867	12000	408.876
Hay Creek, Reservoir Road	616008	0	0.00991	0.6195	12000	118.9505		0	0.00991	0.61953	12000	118.951
Pickering Brook, Slavery Lane	616009	0.0016	0.02676	0.907	12000	321.0777		0.0016	0.02676	0.907	12000	321.078
Liitle Darkin River, Hairpin Bend	616010	0	0.0206	0.3491	12000	247.1968		0	0.0206	0.34915	12000	247.197
Helena Brook ,Trewd Road	616012	0.0039	0.0553	2.0947	12000	663.6115		0.0037	0.0553	2.09473	12000	663.611
Helena River, Ngangaguringuring	616013	0.3786	0.2318	0.7069	12000	2781.588		0.1724	0.12068	0.36803	12000	1448.14
Helena River Trib., Wellbucket Road	616016	0	-0.001	-0.205	12000	-11.5753		0	-0.001	-0.20524	12000	-11.575
Helena River Trib., Yarra Road	616017	0	-0.001	-0.166	12000	-12.3602		0	-0.001	-0.16613	12000	-12.36
Helena River, Poison Lease	616216	0.4547	0.58944	1.0653	12000	7073.226	**52%**	0.2399	0.30687	0.55462	12000	3682.44
Mundaring Weir		0.7007	0.53057	0.3636	12000	6366.808		0.3668	0.27622	0.18927	12000	3314.66

LEGEND

sq.km =	square kilometres	Pas. =	Pasture
mm =	millimetres	Nat. =	Native
mill.cu.m	million cubicmetres	Conc. =	Concentration
mg/l =	milligrams per litre	Vol. =	Volume
*	Estimated		

TABLE 3: COMPARISON OF MODEL, PREDICTED AND REVIEWED SEEPAGES

CATCHMENT	STATION NUMBER	Gauging Point	Model Seepage Out For x10^6 m^3	Review Seepage Out For x10^6 m^3	Predicted Seepage Out For x10^6 m^3	Review/ Predicted Seepage Out For	Predicted/ Model Seepage Out For	Planted / Cleared Areas %
Darkin River, Pine Plantation	S616002	19	0.2378	0.1057	0.1228	86%	52%	27%
Rushy Creek, Byford Road	S616007	52	0.0066	0.0016	0.0025	62%	38%	43%
Hay Creek, Reservoir Road	S616008	56	0.0000	0.0000	0.0000	100%	100%	0%
Pickering Brook, Slavery Lane	S616009	57	0.0016	0.0016	0.0016	100%	100%	0%
Liitle Darkin River, Hairpin Bend	S616010	58	0.0000	0.0000	0.0000	100%	100%	0%
Helena Brook ,Trewd Road	S616012	51	0.0039	0.0030	0.0037	81%	94%	33%
Helena River, Ngangaguringuring	S616013	4	0.3786	0.1406	0.1724	82%	46%	34%
Helena River Trib., Wellbucket Road	S616016	421	0.0000	0.0000	0.0000	100%	100%	0%
Helena River Trib., Yarra Road	S616017	411	0.0000	0.0000	0.0000	100%	100%	0%
Helena River, Poison Lease	S616216	47	0.4547	0.1902	0.2399	79%	53%	34%
Mundaring Weir		53	0.7007	0.2991	0.3668	82%	52%	31%

PHOTOGRAPHS: Taken 5/9/96 in Helena Catchment

1. Fresh waterlogged area in forest along Qualen Rd

2. Wandoo Forest along Qualen Rd

PHOTOGRAPHS: Taken 5/9/96 in Helena Catchment

3. Farm west of Wandabiniring Rd

4. Stream with saline water (approx 5500 mg/l TDS) from runoff from farm shown in Photograph 3

PHOTOGRAPHS: Taken 5/9/96 in Helena Catchment

5. Waterlogging on farm opposite Darkin Swamp

6. Darkin Swamp

SPREADSHEETS

SHEET 1

Locations and Sizes of Rascal Projects for Sub-Catchments of the Helena Catchment

Project	SW Corner		NE Corner		Rows	Columns	Cell Length	Catchment	Gauging Point	
	Easting	Northing	Easting	Northing				Number	Easting	Northing
HEL01	447000	6472500	456500	6478500	240	380	25	1	453062	6473112
HEL02	448000	6469000	457500	6475500	260	380	25	2	454387	6470237
HEL03	447250	6465250	453750	6472500	290	260	25	3	452512	6465837
HEL04	442250	6463750	449000	6473250	380	270	25	4	443362	6465937
HEL05	445500	6462000	451500	6469000	280	240	25	5	446462	6465887
HEL06	441500	6457500	448000	6465750	330	260	25	6	445237	6465312
HEL07	445500	6455000	453250	6463750	350	310	25	7	446562	6462337
HEL08	449750	6457500	457250	6466750	370	300	25	8	451037	6464937
HEL09	451000	6463750	461000	6469750	240	400	25	9	451787	6465187
HEL10	453500	6465000	466500	6474000	360	520	25	101	454837	6468712
"								102	459337	6466462
HEL11	458000	6459000	466500	6466250	290	340	25	11	459887	6465162
HEL12	452750	6456750	459500	6465000	330	270	25	121	454987	6459487
"								122	455812	6463287
HEL13	456250	6453250	463000	6461250	320	270	25	13	457212	6458587
HEL14	450500	6451750	460250	6458500	270	390	25	14	454312	6453187
HEL15	449250	6450000	456250	6456750	270	280	25	15	450837	6451087
HEL16	442750	6451500	450750	6457500	240	320	25	16	448212	6452312
HEL17	444000	6446000	451250	6453500	300	290	25	17	444362	6449962
HEL18	438250	6445000	446000	6454000	360	310	25	18	438987	6450187
HEL19	431500	6444500	442000	6454250	390	420	25	19	433187	6451637
HEL20	433500	6438750	441000	6447500	350	300	25	20	435337	6446687
HEL21	431250	6437500	439250	6445750	330	320	25	21	437362	6441787
HEL22	435500	6432250	441500	6441500	370	240	25	22	437662	6440837
HEL23	439500	6438500	446000	6447250	350	260	25	23	440487	6444162
HEL24	440000	6435000	447500	6444000	360	300	25	24	443562	6442462
HEL25	439750	6431750	445000	6438750	280	210	25	25	442962	6437762
HEL26	440750	6426750	448500	6434250	300	310	25	26	448012	6432912
HEL27	444000	6432500	451000	6439250	270	280	25	27	446962	6438637
HEL28	445500	6426500	453500	6434250	310	320	25	28	448862	6433612
HEL29	449000	6427250	456500	6436500	370	300	25	29	451412	6436137
HEL30	449000	6435000	456000	6441250	250	280	25	30	449737	6438337

Project	SW Corner		NE Corner		Rows	Columns	Cell Length	Catchment	Gauging Point	
	Easting	Northing	Easting	Northing				Number	Easting	Northing
HEL31	445250	6436750	452250	6444500	310	280	25	31	446287	6439187
HEL32	444000	6440750	451500	6447750	280	300	25	32	444612	6442037
HEL33	448000	6443000	456000	6452000	360	320	25	33	449912	6450162
HEL34	450250	6438750	456500	6446500	310	250	25	34	455662	6445212
HEL35	452500	6446750	462500	6454000	290	400	25	35	453787	6448687
HEL36	454000	6442250	463000	6450000	310	360	25	36	454737	6446687
HEL37	454000	6438000	462500	6445750	310	340	25	37	458012	6443737
HEL38	460000	6438500	466000	6446000	300	240	25	38	461337	6443062
HEL39	460000	6435500	468250	6441500	240	330	25	39	462837	6440237
HEL40	438000	6452000	444500	6457750	230	260	25	40	439812	6456787
HEL41	438000	6456000	447750	6461000	200	390	25	411	443462	6458312
"								412	438712	6457512
HEL42	437750	6458500	444000	6468000	380	250	25	421	441862	6461537
"								422	438187	6466087
HEL43	439000	6466500	446000	6474000	300	280	25	43	439487	6469787
HEL44	432250	6467750	441250	6474500	270	360	25	44	438012	6468637
HEL45	432500	6451500	440500	6457500	240	320	25	45	435937	6456937
HEL46	428250	6462250	434750	6470250	320	260	25	461	433312	6464112
"								462	433137	6463637
HEL47	430750	6460750	438500	6471500	430	310	25	47	432812	6462212
HEL48	435250	6463500	440750	6469250	230	220	25	48	437437	6465437
HEL49	435500	6458500	441000	6464500	240	220	25	49	436637	6462637
HEL50	432000	6455250	440500	6462500	290	340	25	50	433312	6461962
HEL51	426500	6466750	434250	6475500	350	310	25	51	431462	6468262
HEL52	421000	6462500	430500	6471000	340	380	25	52	425587	6463712
HEL53	420000	6460000	429000	6466250	250	360	25	53	420962	6463912
HEL54	427500	6455250	433500	6464250	360	240	25	541	428937	6459812
"								542	428762	6459537
HEL55	422500	6453500	430000	6462500	360	300	25	55	424662	6461462
HEL56	417400	6456250	422500	6463000	270	204	25	56	421412	6462412
HEL57	420000	6450000	426500	6461500	460	260	25	57	423012	6461062
HEL58	424500	6450000	431250	6457000	280	270	25	58	427912	6456312
HEL59	427750	6448500	434500	6458500	400	270	25	59	428737	6456812
HEL60	427750	6444750	434250	6452000	290	260	25	60	428737	6451312

SHEET 2

Areas for Sub-Catchments of the Helena Catchment

AREAS

Sub-catchments	1	2	101	3	102	11	9
Drains to	2	101	9	9	9	9	8
SUMS FOR ISOLATED SUBCATCHMENTS							
Areas (sq.km)	30.11	21.72	20.51	22.43	11.50	24.83	23.26
Total Rainfall (m3)	1.91E+07	1.37E+07	1.24E+07	1.45E+07	6.55E+06	1.41E+07	1.43E+07
Average Rainfall (mm)	634.21	629.10	605.69	645.33	569.52	567.57	616.80
AS AT 1980							
CLEARED AREA (sq.km)	4.54	1.59	0.00	4.16	0.00	0.27	0.34
CLEARING (%)	15%	7%	0%	19%	0%	1%	1%
FOREST W/O U/S CLEARING	24.63	19.78	20.51	17.86	11.50	24.54	22.72
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS							
Areas (sq.km)	30.11	51.83	72.34	22.43	11.50	24.83	154.37
Total Rainfall (m3)	1.91E+07	3.28E+07	4.52E+07	1.45E+07	6.55E+06	1.41E+07	9.47E+07
Average Rainfall (mm)	634.21	632.07	624.59	645.33	569.52	567.57	613.15
AS AT 1980							
CLEARED AREA (sq.km)	4.54	6.13	6.13	4.16	0.00	0.27	10.90
CLEARING (%)	15%	12%	8%	19%	0%	1%	7%
FOREST W/O U/S CLEARING	24.63	44.40	64.91	17.86	11.50	24.54	141.52

Abbreviations:
sq.km = square kilometres
W/O = without
U/S = upstream

AREAS

Sub-catchments	9	122	13	121	8	5	7	6	4	421	422
Drains to	8	8	121	8	5	4	6	4	422	422	48
SUMS FOR ISOLATED SUBCATCHMENTS											
Areas (sq.km)		10.53	22.29	10.18	27.73	20.67	35.98	18.40	27.73	4.69	26.41
Total Rainfall (m3)		6.43E+06	1.32E+07	6.33E+06	1.76E+07	1.36E+07	2.39E+07	1.26E+07	1.87E+07	3.32E+06	1.88E+07
Average Rainfall (mm)		610.20	591.84	622.07	635.14	659.54	664.97	686.17	673.65	707.72	711.10
AS AT 1980											
CLEARED AREA (sq.km)		0.00	0.00	0.00	0.00	0.05	0.00	0.00	2.70	0.00	0.39
CLEARING (%)		0%	0%	0%	0%	0%	0%	0%	10%	0%	1%
FOREST W/O U/S CLEARING		10.53	22.29	10.18	27.73	20.54	35.98	18.40	23.96	4.69	25.30
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS											
Areas (sq.km)	154.37	10.53	22.29	32.47	225.10	245.78	35.98	54.37	327.88	4.69	358.98
Total Rainfall (m3)	9.47E+07	6.43E+06	1.32E+07	1.95E+07	1.38E+08	1.52E+08	2.39E+07	3.65E+07	2.07E+08	3.32E+06	2.29E+08
Average Rainfall (mm)	613.15	610.20	591.84	601.32	614.02	617.85	664.97	672.14	631.57	707.72	638.41
AS AT 1980											
CLEARED AREA (sq.km)	10.90	0.00	0.00	0.00	10.90	10.95	0.00	0.00	13.65	0.00	14.04
CLEARING (%)	7%	0%	0%	0%	5%	4%	0%	0%	4%	0%	4%
FOREST W/O U/S CLEARING	141.52	10.53	22.29	32.47	212.26	232.80	35.98	54.37	311.14	4.69	341.12

Abbreviations:
sq.km = square kilometres
W/O = without
U/S = upstream

AREAS

Sub-catchments	422	43	44	48	49	45	40	411	412	50	47
Drains to	48	44	48	47	47	50	412	412	50	47	541
SUMS FOR ISOLATED SUBCATCHMENTS											
Areas (sq.km)		23.04	24.28	10.02	12.25	21.17	16.37	6.18	14.09	28.61	27.79
Total Rainfall (m3)		1.61E+07	1.84E+07	7.43E+06	9.12E+06	1.67E+07	1.21E+07	4.31E+06	1.02E+07	2.25E+07	2.16E+07
Average Rainfall (mm)		699.21	758.88	741.48	743.94	788.32	737.61	698.41	724.29	785.33	775.99
AS AT 1980											
CLEARED AREA (sq.km)		3.84	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
CLEARING (%)		17%	3%	0%	0%	0%	0%	0%	0%	0%	0%
FOREST W/O U/S CLEARING		18.04	22.74	10.02	12.25	21.17	16.37	6.18	14.09	28.61	27.75
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS											
Areas (sq.km)	358.98	23.04	24.28	393.28	12.25	21.17	16.37	6.18	20.26	70.04	553.29
Total Rainfall (m3)	2.29E+08	1.61E+07	1.84E+07	2.55E+08	9.12E+06	1.67E+07	1.21E+07	4.31E+06	1.45E+07	5.37E+07	3.82E+08
Average Rainfall (mm)	638.41	699.21	758.88	648.48	743.94	788.32	737.61	698.41	716.40	766.30	689.99
AS AT 1980											
CLEARED AREA (sq.km)	14.04	3.84	0.85	14.88	0.00	0.00	0.00	0.00	0.00	0.00	14.97
CLEARING (%)	4%	17%	3%	4%	0%	0%	0%	0%	0%	0%	3%
FOREST W/O U/S CLEARING	341.12	18.04	22.74	373.88	12.25	21.17	16.37	6.18	20.26	70.04	533.71

Abbreviations:
sq.km = square kilometres
W/O = without
U/S = upstream

AREAS

Sub-catchments	14	15	16	35	39	38	37	34	36	33	17
Drains to	15	17	17	33	38	37	36	36	33	17	18
SUMS FOR ISOLATED SUBCATCHMENTS											
Areas (sq.km)	29.49	15.94	24.44	29.21	21.15	19.04	26.90	21.96	27.73	28.28	29.87
Total Rainfall (m3)	1.85E+07	1.04E+07	1.69E+07	1.79E+07	1.19E+07	1.08E+07	1.63E+07	1.42E+07	1.69E+07	1.87E+07	2.08E+07
Average Rainfall (mm)	628.08	654.77	692.38	612.95	564.54	569.76	604.33	648.26	608.98	659.70	696.96
AS AT 1980											
CLEARED AREA (sq.km)	0.00	0.00	0.00	0.00	0.05	1.64	0.75	0.32	6.71	0.12	0.00
CLEARING (%)	0%	0%	0%	0%	0%	9%	3%	1%	24%	0%	0%
FOREST W/O U/S CLEARING	29.49	15.94	24.44	29.21	21.02	16.82	25.37	21.37	19.35	28.13	29.87
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS											
Areas (sq.km)	29.49	45.43	24.44	29.21	21.15	40.18	67.08	21.96	116.77	174.26	274.00
Total Rainfall (m3)	1.85E+07	2.90E+07	1.69E+07	1.79E+07	1.19E+07	2.28E+07	3.90E+07	1.42E+07	7.02E+07	1.07E+08	1.73E+08
Average Rainfall (mm)	628.08	637.44	692.38	612.95	564.54	567.01	581.98	648.26	600.85	612.43	632.92
AS AT 1980											
CLEARED AREA (sq.km)	0.00	0.00	0.00	0.00	0.05	1.69	2.44	0.32	9.47	9.59	9.59
CLEARING (%)	0%	0%	0%	0%	0%	4%	4%	1%	8%	6%	3%
FOREST W/O U/S CLEARING	29.49	45.43	24.44	29.21	21.02	37.84	63.21	21.37	103.94	161.28	261.02

Abbreviations:
sq.km = square kilometres
W/O = without
U/S = upstream

AREAS

Sub-catchments	29	30	26	28	27	31	32	25	24	23
Drains to	30	31	28	27	31	24	24	24	23	20
SUMS FOR ISOLATED SUBCATCHMENTS										
Areas (sq.km)	32.13	23.04	24.57	28.41	20.77	20.08	25.92	18.85	24.37	22.32
Total Rainfall (m3)	2.11E+07	1.52E+07	1.84E+07	1.98E+07	1.49E+07	1.40E+07	1.84E+07	1.45E+07	1.82E+07	1.69E+07
Average Rainfall (mm)	657.53	661.23	750.20	697.16	716.01	698.00	708.11	768.99	748.51	758.15
AS AT 1980										
CLEARED AREA (sq.km)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CLEARING (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
FOREST W/O U/S CLEARING	32.13	23.04	24.57	28.41	20.77	20.08	25.92	18.85	24.37	22.32
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS										
Areas (sq.km)	32.13	55.17	24.57	52.97	73.74	148.99	25.92	18.85	218.12	240.45
Total Rainfall (m3)	2.11E+07	3.64E+07	1.84E+07	3.82E+07	5.31E+07	1.03E+08	1.84E+07	1.45E+07	1.55E+08	1.71E+08
Average Rainfall (mm)	657.53	659.08	750.20	721.76	720.14	694.55	708.11	768.99	708.62	713.22
AS AT 1980										
CLEARED AREA (sq.km)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CLEARING (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
FOREST W/O U/S CLEARING	32.13	55.17	24.57	52.97	73.74	148.99	25.92	18.85	218.12	240.45

Abbreviations:
sq.km = square kilometres
W/O = without
U/S = upstream

AREAS

Sub-catchments	23	17	22	21	20	18	19	59
Drains to	20	18	21	20	19	19	59	55
SUMS FOR ISOLATED SUBCATCHMENTS								
Areas (sq.km)			23.88	21.01	28.86	35.92	41.00	23.68
Total Rainfall (m3)			1.93E+07	1.76E+07	2.32E+07	2.69E+07	3.32E+07	2.04E+07
Average Rainfall (mm)			806.27	839.05	805.51	747.50	810.55	862.86
AS AT 1980								
CLEARED AREA (sq.km)			0.00	0.00	0.00	0.00	0.00	0.00
CLEARING (%)			0%	0%	0%	0%	0%	0%
FOREST W/O U/S CLEARING			23.88	21.01	28.86	35.92	41.00	23.68
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS								
Areas (sq.km)	240.45	274.00	23.88	44.89	314.20	309.92	665.12	688.80
Total Rainfall (m3)	1.71E+08	1.73E+08	1.93E+07	3.69E+07	2.32E+08	2.00E+08	4.65E+08	4.86E+08
Average Rainfall (mm)	713.22	632.92	806.27	821.62	737.18	646.20	699.31	704.93
AS AT 1980								
CLEARED AREA (sq.km)	0.00	9.59	0.00	0.00	0.00	9.59	9.59	9.59
CLEARING (%)	0%	3%	0%	0%	0%	3%	1%	1%
FOREST W/O U/S CLEARING	240.45	261.02	23.88	44.89	314.20	296.94	652.13	675.81

Abbreviations:
sq.km = square kilometres
W/O = without
U/S = upstream

AREAS

Sub-catchments	59	47	542	541	51	461	462	60	58	55
Drains to	55	541	55	55	461	47	47	58	55	53
SUMS FOR ISOLATED SUBCATCHMENTS										
Areas (sq.km)			8.60	17.36	26.44	12.29	11.18	17.36	20.28	28.26
Total Rainfall (m3)			7.43E+06	1.67E+07	2.30E+07	9.92E+06	9.48E+06	1.53E+07	1.89E+07	2.68E+07
Average Rainfall (mm)			864.68	960.04	869.18	806.57	847.49	880.13	933.67	950.12
AS AT 1980										
CLEARED AREA (sq.km)			0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
CLEARING (%)			0%	0%	0%	0%	0%	0%	0%	0%
FOREST W/O U/S CLEARING			8.60	17.36	26.31	12.29	11.18	17.36	20.28	28.26
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS										
Areas (sq.km)	688.80	553.29	8.60	570.65	26.44	38.74	11.18	38.74	59.02	1355.32
Total Rainfall (m3)	4.86E+08	3.82E+08	7.43E+06	3.98E+08	2.30E+07	3.29E+07	9.48E+06	3.29E+07	5.18E+07	9.70E+08
Average Rainfall (mm)	704.93	689.99	864.68	698.21	869.18	849.31	847.49	849.31	878.30	715.78
AS AT 1980										
CLEARED AREA (sq.km)	9.59	14.97	0.00	14.97	0.06	0.06	0.00	0.06	0.06	24.63
CLEARING (%)	1%	3%	0%	3%	0%	0%	0%	0%	0%	2%
FOREST W/O U/S CLEARING	675.81	533.71	8.60	551.07	26.31	38.60	11.18	38.60	58.88	1322.62

Abbreviations:
sq.km = square kilometres
W/O = without
U/S = upstream

AREAS

Sub-catchments	55	57	56	52	53
Drains to	53	53	53	53	
SUMS FOR ISOLATED SUBCATCHMENTS					
Areas (sq.km)		29.52	16.00	39.27	19.31
Total Rainfall (m3)		3.13E+07	1.79E+07	3.80E+07	1.92E+07
Average Rainfall (mm)		1061.62	1118.59	966.47	992.12
AS AT 1980					
CLEARED AREA (sq.km)		0.06	0.00	0.18	0.00
CLEARING (%)		0%	0%	0%	0%
FOREST W/O U/S CLEARING		29.35	16.00	39.11	19.31
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS					
Areas (sq.km)	1355.32	29.52	16.00	39.27	1459.42
Total Rainfall (m3)	9.70E+08	3.13E+07	1.79E+07	3.80E+07	1.08E+09
Average Rainfall (mm)	715.78	1061.62	1118.59	966.47	737.59
AS AT 1980					
CLEARED AREA (sq.km)	24.63	0.06	0.00	0.18	24.86
CLEARING (%)	2%	0%	0%	0%	1.70%
FOREST W/O U/S CLEARING	1322.62	29.35	16.00	39.11	1426.39

Abbreviations:
sq.km = square kilometres
W/O = without
U/S = upstream

SHEET 3

Flows for 1980 Clearing For Sub-Catchments of the Helena Catchment

FLOWS FOR 1980 CLEARING

Sub-catchments	1	2	101	3	102	11	9
Drains to	2	101	9	9	9	9	8

SUMS FOR ISOLATED SUBCATCHMENTS

STREAM FLOW (cu.m)	755558	725463	1066799	649928	608620	1007550	1233093
STREAM FLOW (mm)	25	33	52	29	53	41	53
SEEPAGE (cu.m)	601051	489040	501580	472561	309188	609013	577156
SEEPAGE (mm)	20	23	24	21	27	25	25
SEEPAGE/STREAM FLOW (%)	80%	67%	47%	73%	51%	60%	47%
SEEPAGE INSIDE FOREST (cu.m)	539059	431447	501580	354360	309057	600635	562089
SEEPAGE INSIDE FOREST (mm)	22	22	24	20	27	24	25
SEEPAGE OUTSIDE FOREST (cu.m)	61992	57593	0	118201	131	8377	15066
SEEPAGE OUTSIDE FOREST (mm)	11	30	0	26	21	29	28
STORAGE LOSS (cu.m)	-246182	-225393	-267980	-90667	-170826	-343875	-189340

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

STREAM FLOW (cu.m)	755558	1481021	2547820	649928	608620	1007550	6047011.26
STREAM FLOW (mm)	25	29	35	29	53	41	39
SEEPAGE (cu.m)	601051	1090091	1591671	472561	309188	609013	3559588.71
SEEPAGE (mm)	20	21	22	21	27	25	23
SEEPAGE/STREAM FLOW (%)	80%	74%	62%	73%	51%	60%	59%
SEEPAGE INSIDE FOREST (cu.m)	539059	970505	1472085	354360	309057	600635	3298227.81
SEEPAGE INSIDE FOREST (mm)	22	22	23	20	27	24	23
SEEPAGE OUTSIDE FOREST (cu.m)	61992	119586	119586	118201	131	8377	261360.90
SEEPAGE OUTSIDE FOREST (mm)	11	16	16	26	21	29	20
STORAGE LOSS (cu.m)	-246182	-471575	-739554	-90667	-170826	-343875	-1534261.63

Abbreviations:
cu.m = cubic metres
mm = millimetres

Assumptions
Lower soil layer 20m deep with permeability 4m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.1

FLOWS FOR 1980 CLEARING

Sub-catchments	9	122	13	121	8	5	7	6	4	421	422
Drains to	8	8	121	8	5	4	6	4	422	422	48

SUMS FOR ISOLATED SUBCATCHMENTS

STREAM FLOW (cu.m)		418514	644624	182566	1035796	1158004	998062	808545	1263550	35244	1249723
STREAM FLOW (mm)		40	29	18	37	56	28	44	46	8	47
SEEPAGE (cu.m)		259235	499749	191006	571214	427475	656527	257530	526217	52657	185467
SEEPAGE (mm)		25	22	19	21	21	18	14	19	11	7
SEEPAGE/STREAM FLOW (%)		62%	78%	105%	55%	37%	66%	32%	42%	149%	15%
SEEPAGE INSIDE FOREST (cu.m)		259235	499749	191006	571214	421895	656527	257530	414534	52657	171089
SEEPAGE INSIDE FOREST (mm)		25	22	19	21	21	18	14	17	11	7
SEEPAGE OUTSIDE FOREST (cu.m)		0	0	0	0	5580	0	0	111683	0	14378
SEEPAGE OUTSIDE FOREST (mm)		0	0	0	0	43	0	0	30	0	13
STORAGE LOSS (cu.m)		-132479	-344394	-152184	-283058	-99522	-236091	4118	-60674	-20887	6034

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

STREAM FLOW (cu.m)	6047011	418514	644624	827190.14	8328510.88	9486515.26	998062.13	1806607.06	12556672.57	35244.20	13841639.37
STREAM FLOW (mm)	39	40	29	25	37	39	28	33	38	8	39
SEEPAGE (cu.m)	3559589	259235	499749	690755.27	5080792.54	5508267.63	656526.81	914057.24	6948541.97	52656.60	7186665.38
SEEPAGE (mm)	23	25	22	21	23	22	18	17	21	11	20
SEEPAGE/STREAM FLOW (%)	59%	62%	78%	84%	61%	58%	66%	51%	55%	149%	52%
SEEPAGE INSIDE FOREST (cu.m)	3298228	259235	499749	690755.27	4819431.64	5241327.02	656526.81	914057.24	6569918.69	52656.60	6793663.81
SEEPAGE INSIDE FOREST (mm)	23	25	22	21	23	23	18	17	21	11	20
SEEPAGE OUTSIDE FOREST (cu.m)	261361	0	0	0.00	261360.90	266940.61	0.00	0.00	378623.28	0.00	393001.57
SEEPAGE OUTSIDE FOREST (mm)	20	0	0	0	20	21	0	0	23	0	22
STORAGE LOSS (cu.m)	-1534262	-132479	-344394	-496578.47	-2446377.14	-2545899.34	-236091.03	-231973.52	-2838546.73	-20887.50	-2853400.38

<u>Abbreviations:</u>
cu.m = cubic metres
mm = millimetres

<u>Assumptions</u>
Lower soil layer 20m deep with permeability 4m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.1

FLOWS FOR 1980 CLEARING

Sub-catchments	422	43	44	48	49	45	40	411	412	50	47
Drains to	48	44	48	47	47	50	412	412	50	47	541
SUMS FOR ISOLATED SUBCATCHMENTS											
STREAM FLOW (cu.m)		702807	875254	407197	331294	636438	442442	55009	437135	1085232	1113691
STREAM FLOW (mm)		31	36	41	27	30	27	9	31	38	40
SEEPAGE (cu.m)		443677	261139	63388	57375	229157	170656	66810	168619	292728	101669
SEEPAGE (mm)		19	11	6	5	11	10	11	12	10	4
SEEPAGE/STREAM FLOW (%)		63%	30%	16%	17%	36%	39%	121%	39%	27%	9%
SEEPAGE INSIDE FOREST (cu.m)		289316	204161	63388	57375	229157	170656	66810	168619	292728	100882
SEEPAGE INSIDE FOREST (mm)		16	9	6	5	11	10	11	12	10	4
SEEPAGE OUTSIDE FOREST (cu.m)		154362	56979	0	0	0	0	0	0	0	786
SEEPAGE OUTSIDE FOREST (mm)		31	37	0	0	0	0	0	0	0	18
STORAGE LOSS (cu.m)		-75205	-15560	3409	-3041	-12991	3136	-14617	-4739	-10024	7519
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS											
STREAM FLOW (cu.m)	13841639	702807	875254	15124090.27	331294	636438	442442	55009	492144.07	2213813.39	20800378.75
STREAM FLOW (mm)	39	31	36	38	27	30	27	9	24	32	38
SEEPAGE (cu.m)	7186665	443677	261139	7511192.56	57375	229157	170656	66810	235429.23	757314.49	8553452.71
SEEPAGE (mm)	20	19	11	19	5	11	10	11	12	11	15
SEEPAGE/STREAM FLOW (%)	52%	63%	30%	50%	17%	36%	39%	121%	48%	34%	41%
SEEPAGE INSIDE FOREST (cu.m)	6793664	289316	204161	7061212.49	57375	229157	170656	66810	235429.23	757314.49	8098747.93
SEEPAGE INSIDE FOREST (mm)	20	16	9	19	5	11	10	11	12	11	15
SEEPAGE OUTSIDE FOREST (cu.m)	393002	154362	56979	449980.07	0	0	0	0	0.00	0.00	454704.78
SEEPAGE OUTSIDE FOREST (mm)	22	31	37	23	0	0	0	0	0	0	23
STORAGE LOSS (cu.m)	-2853400	-75205	-15560	-2.87E+06	-3041	-12991	3136	-14617	-19355.89	-42370.88	-2899578.03

Abbreviations:
cu.m = cubic metres
mm = millimetres

Assumptions
Lower soil layer 20m deep with permeability 4m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.1

FLOWS FOR 1980 CLEARING

Sub-catchments	14	15	16	35	39	38	37	34	36	33	17
Drains to	15	17	17	33	38	37	36	36	33	17	18
SUMS FOR ISOLATED SUBCATCHMENTS											
STREAM FLOW (cu.m)	743353	471303	811189	1074714	499008	309088	702122	393706	653929	739790	1451180
STREAM FLOW (mm)	25	30	33	37	24	16	26	18	24	26	49
SEEPAGE (cu.m)	561319	269335	443528	661645	380100	297851	475552	345758	508291	384510	453842
SEEPAGE (mm)	19	17	18	23	18	16	18	16	18	14	15
SEEPAGE/STREAM FLOW (%)	76%	57%	55%	62%	76%	96%	68%	88%	78%	52%	31%
SEEPAGE INSIDE FOREST (cu.m)	561319	269335	443528	661645	375450	246498	454510	335300	360114	382417	453842
SEEPAGE INSIDE FOREST (mm)	19	17	18	23	18	15	18	16	19	14	15
SEEPAGE OUTSIDE FOREST (cu.m)	0	0	0	0	4649	51353	21042	10458	148177	2092	0
SEEPAGE OUTSIDE FOREST (mm)	0	0	0	0	37	23	14	18	18	14	0
STORAGE LOSS (cu.m)	-319213	-153351	-79818	-369561	-370880	-310746	-491724	-219454	-295800	-335140	-99120
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS											
STREAM FLOW (cu.m)	743353	1214656.22	811189	1074714	499008	808096.09	1510218.09	393706	2557853.34	4372357.34	7849382.31
STREAM FLOW (mm)	25	27	33	37	24	20	23	18	22	25	29
SEEPAGE (cu.m)	561319	830653.88	443528	661645	380100	677950.79	1153503.04	345758	2007552.01	3053706.90	4781730.12
SEEPAGE (mm)	19	18	18	23	18	17	17	16	17	18	17
SEEPAGE/STREAM FLOW (%)	76%	68%	55%	62%	76%	84%	76%	88%	78%	70%	61%
SEEPAGE INSIDE FOREST (cu.m)	561319	830653.88	443528	661645	375450	621947.97	1076458.13	335300	1771872.59	2815935.19	4543958.41
SEEPAGE INSIDE FOREST (mm)	19	18	18	23	18	16	17	16	17	17	17
SEEPAGE OUTSIDE FOREST (cu.m)	0	0.00	0	0	4649	56002.82	77044.91	10458	235679.42	237771.72	237771.72
SEEPAGE OUTSIDE FOREST (mm)	0	0	0	0	37	24	20	18	18	18	18
STORAGE LOSS (cu.m)	-319213	-472563.81	-79818	-369561	-370880	-681626.13	-1173349.75	-219454	-1688604.08	-2393304.27	-3044805.81

Abbreviations:
cu.m = cubic metres
mm = millimetres

Assumptions
Lower soil layer 20m deep with permeability 4m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.1

FLOWS FOR 1980 CLEARING

Sub-catchments	29	30	26	28	27	31	32	25	24	23
Drains to	30	31	28	27	31	24	24	24	23	20
SUMS FOR ISOLATED SUBCATCHMENTS										
STREAM FLOW (cu.m)	564638	882606	181249	343368	506023	897385	1088157	295777	523995	661476
STREAM FLOW (mm)	18	38	7	12	24	45	42	16	22	30
SEEPAGE (cu.m)	462777	519711	107447	274426	239475	421229	527181	75334	287718	339870
SEEPAGE (mm)	14	23	4	10	12	21	20	4	12	15
SEEPAGE/STREAM FLOW (%)	82%	59%	59%	80%	47%	47%	48%	25%	55%	51%
SEEPAGE INSIDE FOREST (cu.m)	462777	519711	107447	274426	239475	421229	527181	75334	287718	339870
SEEPAGE INSIDE FOREST (mm)	14	23	4	10	12	21	20	4	12	15
SEEPAGE OUTSIDE FOREST (cu.m)	0	0	0	0	0	0	0	0	0	0
SEEPAGE OUTSIDE FOREST (mm)	0	0	0	0	0	0	0	0	0	0
STORAGE LOSS (cu.m)	-80300	-147204	-11262	-37679	-41420	-117321	-76538	631	-135044	-87744
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS										
STREAM FLOW (cu.m)	564638	1447243.69	181249	524617.31	1030640.25	3375269.00	1088157	295777	5283197.44	5944673.88
STREAM FLOW (mm)	18	26	7	10	14	23	42	16	24	25
SEEPAGE (cu.m)	462777	982487.38	107447	381872.24	621347.16	2025063.57	527181	75334	2915296.07	3255165.57
SEEPAGE (mm)	14	18	4	7	8	14	20	4	13	14
SEEPAGE/STREAM FLOW (%)	82%	68%	59%	73%	60%	60%	48%	25%	55%	55%
SEEPAGE INSIDE FOREST (cu.m)	462777	982487.38	107447	381872.24	621347.16	2025063.57	527181	75334	2915296.07	3255165.57
SEEPAGE INSIDE FOREST (mm)	14	18	4	7	8	14	20	4	13	14
SEEPAGE OUTSIDE FOREST (cu.m)	0	0.00	0	0.00	0.00	0.00	0	0	0.00	0.00
SEEPAGE OUTSIDE FOREST (mm)	0	0	0	0	0	0	0	0	0	0
STORAGE LOSS (cu.m)	-80300	-227503.44	-11262	-48940.49	-90360.52	-435184.91	-76538	631	-646135.37	-733879.53

Abbreviations:
cu.m = cubic metres
mm = millimetres

Assumptions
Lower soil layer 20m deep with permeability 4m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.1

FLOWS FOR 1980 CLEARING

Sub-catchments	23	17	22	21	20	18	19	59
Drains to	20	18	21	20	19	19	59	55

SUMS FOR ISOLATED SUBCATCHMENTS

STREAM FLOW (cu.m)			268962	531395	1921283	1566728	2313002	1986154
STREAM FLOW (mm)			11	25	67	44	56	84
SEEPAGE (cu.m)			75140	33667	85736	519303	258464	62370
SEEPAGE (mm)			3	2	3	14	6	3
SEEPAGE/STREAM FLOW (%)			28%	6%	4%	33%	11%	3%
SEEPAGE INSIDE FOREST (cu.m)			75140	33667	85736	519303	258464	62370
SEEPAGE INSIDE FOREST (mm)			3	2	3	14	6	3
SEEPAGE OUTSIDE FOREST (cu.m)			0	0	0	0	0	0
SEEPAGE OUTSIDE FOREST (mm)			0	0	0	0	0	0
STORAGE LOSS (cu.m)			10162	3394	7473	-29562	-26854	-4331

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

STREAM FLOW (cu.m)	5944674	7849382	268962	800357	8666313.36	9416111	20395425	22381579
STREAM FLOW (mm)	25	29	11	18	28	30	31	32
SEEPAGE (cu.m)	3255166	4781730	75140	108806	3449708.08	5301033	9009205	9071575
SEEPAGE (mm)	14	17	3	2	11	17	14	13
SEEPAGE/STREAM FLOW (%)	55%	61%	28%	14%	40%	56%	44%	41%
SEEPAGE INSIDE FOREST (cu.m)	3255166	4543958	75140	108806	3449708.08	5063261	8771433	8833803
SEEPAGE INSIDE FOREST (mm)	14	17	3	2	11	17	13	13
SEEPAGE OUTSIDE FOREST (cu.m)	0	237772	0	0	0.00	237772	237772	237772
SEEPAGE OUTSIDE FOREST (mm)	0	18	0	0	0	18	18	18
STORAGE LOSS (cu.m)	-733880	-3044806	10162	13556	-712850.43	-3074368	-3814072	-3818402

Abbreviations:
cu.m = cubic metres
mm = millimetres

Assumptions
Lower soil layer 20m deep with permeability 4m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.1

FLOWS FOR 1980 CLEARING

Sub-catchments	59	47	542	541	51	461	462	60	58	55
Drains to	55	541	55	55	461	47	47	58	55	53
SUMS FOR ISOLATED SUBCATCHMENTS										
STREAM FLOW (cu.m)			487881	1431015	896389	638356	482746	447650	818481	812628
STREAM FLOW (mm)			57	82	34	52	43	26	40	29
SEEPAGE (cu.m)			22747	23411	80352	26667	18883	9611	1056	71239
SEEPAGE (mm)			3	1	3	2	2	1	0	3
SEEPAGE/STREAM FLOW (%)			5%	2%	9%	4%	4%	2%	0%	9%
SEEPAGE INSIDE FOREST (cu.m)			22747	23411	76414	26667	18883	9611	1056	71239
SEEPAGE INSIDE FOREST (mm)			3	1	3	2	2	1	0	3
SEEPAGE OUTSIDE FOREST (cu.m)			0	0	3938	0	0	0	0	0
SEEPAGE OUTSIDE FOREST (mm)			0	0	29	0	0	0	0	0
STORAGE LOSS (cu.m)			-930	706	905	2890	72	1212	98	644
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS										
STREAM FLOW (cu.m)	22381579.05	20800378.75	487881	22231394	896389	1534744	482746	447650	1266132	47179613.27
STREAM FLOW (mm)	32	38	57	39	34	40	43	12	21	35
SEEPAGE (cu.m)	9071574.78	8553452.71	22747	8576863	80352	107019	18883	9611	10667	17753092.03
SEEPAGE (mm)	13	15	3	15	3	3	2	0	0	13
SEEPAGE/STREAM FLOW (%)	41%	41%	5%	39%	9%	7%	4%	2%	1%	38%
SEEPAGE INSIDE FOREST (cu.m)	8833803.07	8098747.93	22747	8122159	76414	103081	18883	9611	10667	17060615.53
SEEPAGE INSIDE FOREST (mm)	13	15	3	15	3	3	2	0	0	13
SEEPAGE OUTSIDE FOREST (cu.m)	237771.72	454704.78	0	454705	3938	3938	0	0	0	692476.50
SEEPAGE OUTSIDE FOREST (mm)	18	23	0	23	29	29	0	0	0	21
STORAGE LOSS (cu.m)	-3818402.04	-2899578.03	-930	-2898872	905	3795	72	1212	1310	-6716249

Abbreviations:
cu.m = cubic metres
mm = millimetres

Assumptions
Lower soil layer 20m deep with permeability 4m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.1

FLOWS FOR 1980 CLEARING

Sub-catchments	55	57	56	52	53
Drains to	53	53	53	53	

SUMS FOR ISOLATED SUBCATCHMENTS

STREAM FLOW (cu.m)		654958	622706	1547971	1192157
STREAM FLOW (mm)		22	39	39	62
SEEPAGE (cu.m)		60495	3627	69142	34595
SEEPAGE (mm)		2	0	2	2
SEEPAGE/STREAM FLOW (%)		9%	1%	4%	3%
SEEPAGE INSIDE FOREST (cu.m)		58871	3627	62569	34595
SEEPAGE INSIDE FOREST (mm)		2	0	2	2
SEEPAGE OUTSIDE FOREST (cu.m)		1623	0	6573	0
SEEPAGE OUTSIDE FOREST (mm)		10	0	39	0
STORAGE LOSS (cu.m)		-3487	-330	-2152	1378486

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

STREAM FLOW (cu.m)	47179613.27	654957.88	622706	1547971	51197405.60
STREAM FLOW (mm)	35	22	39	39	35
SEEPAGE (cu.m)	17753092.03	60494.66	3627	69142	17920951.13
SEEPAGE (mm)	13	2	0	2	12
SEEPAGE/STREAM FLOW (%)	38%	9%	1%	4%	35%
SEEPAGE INSIDE FOREST (cu.m)	17060615.53	58871.47	3627	62569	17220278.19
SEEPAGE INSIDE FOREST (mm)	13	2	0	2	12
SEEPAGE OUTSIDE FOREST (cu.m)	692476.50	1623.19	0	6573	700672.94
SEEPAGE OUTSIDE FOREST (mm)	21	10	0	39	21
STORAGE LOSS (cu.m)	-6716249	-3486.81	-330	-2152	-5343731

Abbreviations:
cu.m = cubic metres
mm = millimetres

Assumptions
Lower soil layer 20m deep with permeability 4m/yr/unit hydraulic gradient
Peak leaf area index for pasture = 2.1

SHEET 4

Model Minimum Tree Planting

MODEL MINIMUM TREE PLANTING

Target: 52% reduction in seepage
Criteria: Plant on pasture land where
seepage > 15 mm/yr
Allow draw to 30% depth of bottom soil layer

Sub-catchments	1	2	101	3	102	11	9
Drains to	2	101	9	9	9	9	8

SUMS FOR ISOLATED SUBCATCHMENTS

AREA PLANTED @ 1xNATIVE (sq.km)	0.75	0.71	0.00	1.73	0.00	0.14	0.12
PLANTED/CLEARED AREA (%)	17%	45%	0%	42%	0%	50%	36%
PREDICTED SEEPAGE (cu.m)	562504	449752	501580	384653	309057	600065	569074
" OUT.FOR. SEEPAGE (cu.m)	29734	23781	0	35799	0	1898	10619
% OF 1980 SEEPAGE	94%	92%	100%	81%	100%	99%	99%
% OF 1980 OUT.FOR. SEEPAGE	48%	41%	100%	30%	0%	23%	70%
REVIEW SEEPAGE (cu.m)	562349	449525	501580	383051	309057	600832	569820
REVIEW OUT.FOR. SEEPAGE (cu.m)	25942	20597	0	31120	0	1907	8425
REVIEW STREAMFLOW (cu.m)	727193	690060	1066799	578259	608620	998632	1226471

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

AREA PLANTED @ 1xNATIVE (sq.km)	0.75	1.46	1.46	1.73	0.00	0.14	3.46
PLANTED/CLEARED AREA (%)	17%	24%	24%	42%	0%	50%	32%
PREDICTED SEEPAGE (cu.m)	562504	1012256	1513836	384653	309057	600065	3376685.34
" OUT.FOR. SEEPAGE (cu.m)	29734	53515	53515	35799	0	1898	101830.59
% OF 1980 SEEPAGE	94%	93%	95%	81%	100%	99%	95%
% OF 1980 OUT.FOR. SEEPAGE	48%	45%	45%	30%	0%	23%	39%
REVIEW SEEPAGE (cu.m)	562349	1011874	1513455	383051	309057	600832	3376215.09
REVIEW OUT.FOR. SEEPAGE (cu.m)	25942	46540	46540	31120	0	1907	87991.25
REVIEW STREAMFLOW (cu.m)	727193	1417253	2484053	578259	608620	998632	5896035.38

Abbreviations:
cu.m = cubic metres
mm = millimetres
@ 1xNATIVE = at one times native forest density
OUT.FOR. = outside forest

MODEL MINIMUM TREE PLANTING

Target: 52% reduction in seepage
Criteria: Plant on pasture land where
seepage > 15 mm/yr
Allow draw to 30% depth of bottom soil layer

Sub-catchments	9	122	13	121	8	5	7	6	4	421	422
Drains to	8	8	121	8	5	4	6	4	422	422	48

SUMS FOR ISOLATED SUBCATCHMENTS

	9	122	13	121	8	5	7	6	4	421	422
AREA PLANTED @ 1xNATIVE (sq.km)		0.00	0.00	0.00	0.00	0.02	0.00	0.00	1.18	0.00	0.08
PLANTED/CLEARED AREA (%)		0%	0%	0%	0%	39%	0%	0%	44%	0%	20%
PREDICTED SEEPAGE (cu.m)		259235	499749	191006	571214	425147	656527	257530	459008	52647	180519
" OUT.FOR. SEEPAGE (cu.m)		0	0	0	0	7362	0	0	63252	0	14580
% OF 1980 SEEPAGE		100%	100%	100%	100%	99%	100%	100%	87%	100%	97%
% OF 1980 OUT.FOR. SEEPAGE		100%	100%	100%	100%	132%	100%	100%	57%	100%	101%
REVIEW SEEPAGE (cu.m)		259235	499749	191006	571214	425775	656527	257530	460156	52657	181013
REVIEW OUT.FOR. SEEPAGE (cu.m)		0	0	0	0	3973	0	0	48610	0	10588
REVIEW STREAMFLOW (cu.m)		418513.844	644623.938	182566	1035795.63	1159082	998062.125	808544.938	1177873.25	35244	1244782

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

	9	122	13	121	8	5	7	6	4	421	422
AREA PLANTED @ 1xNATIVE (sq.km)	3.46	0.00	0.00	0.00	3.46	3.48	0.00	0.00	4.66	0.00	4.73
PLANTED/CLEARED AREA (%)	32%	0%	0%	0%	32%	32%	0%	0%	34%	0%	34%
PREDICTED SEEPAGE (cu.m)	3376685	259234.94	499749.09	690755.27	4897889.17	5323036.05	656526.81	914057.24	6696101.32	52646.82	6929266.75
" OUT.FOR. SEEPAGE (cu.m)	101831	0.00	0.00	0.00	101830.59	109192.25	0.00	0.00	172443.94	0.00	187024.15
% OF 1980 SEEPAGE	95%	100%	100%	100%	96%	97%	100%	100%	96%	100%	96%
% OF 1980 OUT.FOR. SEEPAGE	39%	100%	100%	100%	39%	41%	100%	100%	46%	100%	48%
REVIEW SEEPAGE (cu.m)	3376215	259234.94	499749.09	690755.27	4897418.92	5323193.78	656526.81	914057.24	6697406.91	52656.61	6931076.63
REVIEW OUT.FOR. SEEPAGE (cu.m)	87991	0.00	0.00	0.00	87991.25	91964.73	0.00	0.00	140575.13	0.00	151163.41
REVIEW STREAMFLOW (cu.m)	5896035	418513.84	644623.94	827190.14	8177534.99	9336617.24	998062.13	1806607.06	12321097.55	35244.24	13601123.80

Abbreviations:
cu.m = cubic metres
mm = millimetres
@ 1xNATIVE = at one times native forest density
OUT.FOR. = outside forest

MODEL MINIMUM TREE PLANTING

Target: 52% reduction in seepage
Criteria: Plant on pasture land where
seepage > 15 mm/yr
Allow draw to 30% depth of bottom soil layer

Sub-catchments	422	43	44	48	49	45	40	411	412	50	47
Drains to	48	44	48	47	47	50	412	412	50	47	541
SUMS FOR ISOLATED SUBCATCHMENTS											
AREA PLANTED @ 1xNATIVE (sq.km)		1.74	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
PLANTED/CLEARED AREA (%)		45%	40%	0%	0%	0%	0%	0%	0%	0%	34%
PREDICTED SEEPAGE (cu.m)		342731	238381	63388	57375	229157	170656	66810	168619	292728	100944
" OUT.FOR. SEEPAGE (cu.m)		73954	48576	0	0	0	0	0	0	0	551
% OF 1980 SEEPAGE		77%	91%	100%	100%	100%	100%	100%	100%	100%	99%
% OF 1980 OUT.FOR. SEEPAGE		48%	85%	100%	100%	100%	100%	100%	100%	100%	70%
REVIEW SEEPAGE (cu.m)		340767	236467	63388	57375	229157	170656	66810	168619	292728	101243
REVIEW OUT.FOR. SEEPAGE (cu.m)		54130	35490	0	0	0	0	0	0	0	527
REVIEW STREAMFLOW (cu.m)		568704.188	821816.938	407197	331293.84	636437.688	442441.75	55009	437135.281	1085232	1110933

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

	422	43	44	48	49	45	40	411	412	50	47
AREA PLANTED @ 1xNATIVE (sq.km)	4.73	1.74	0.34	5.08	0.00	0.00	0.00	0.00	0.00	0.00	5.11
PLANTED/CLEARED AREA (%)	34%	45%	40%	34%	0%	0%	0%	0%	0%	0%	34%
PREDICTED SEEPAGE (cu.m)	6929267	342730.88	238380.81	7231035.57	57375	229157	170656	66810	235429.23	757314.49	8270412.17
" OUT.FOR. SEEPAGE (cu.m)	187024	73954.23	48576.14	235600.29	0	0	0	0	0.00	0.00	239869.06
% OF 1980 SEEPAGE	96%	100%	96%	96%	100%	100%	100%	100%	100%	100%	97%
% OF 1980 OUT.FOR. SEEPAGE	48%	48%	85%	52%	100%	100%	100%	100%	100%	100%	53%
REVIEW SEEPAGE (cu.m)	6931077	340766.73	236467.37	7230932.01	57375	229157	170656	66810	235429.23	757314.49	8271775.88
REVIEW OUT.FOR. SEEPAGE (cu.m)	151163	54130.05	35490.45	186653.86	0	0	0	0	0.00	0.00	190188.43
REVIEW STREAMFLOW (cu.m)	13601124	568704.19	821816.94	14830137.32	331294	636438	442442	55009	492144.07	2213813.39	20503918.93

Abbreviations:
cu.m = cubic metres
mm = millimetres
@ 1xNATIVE = at one times native forest density
OUT.FOR. = outside forest

MODEL MINIMUM TREE PLANTING

Target: 52% reduction in seepage
Criteria: Plant on pasture land where
seepage > 15 mm/yr
Allow draw to 30% depth of bottom soil layer

Sub-catchments	14	15	16	35	39	38	37	34	36	33	17
Drains to	15	17	17	33	38	37	36	36	33	17	18

SUMS FOR ISOLATED SUBCATCHMENTS

AREA PLANTED @ 1xNATIVE (sq.km)	0.00	0.00	0.00	0.00	0.03	0.67	0.17	0.09	1.71	0.00	0.00
PLANTED/CLEARED AREA (%)	0%	0%	0%	0%	53%	41%	22%	27%	25%	0%	0%
PREDICTED SEEPAGE (cu.m)	561319	269335	443528	661645	377639	261531	467691	341647	426670	382417	453842
" OUT.FOR. SEEPAGE (cu.m)	0	0	0	0	4529	18862	18624	7924	77408	0	0
% OF 1980 SEEPAGE	100%	100%	100%	100%	99%	88%	98%	99%	84%	99%	100%
% OF 1980 OUT.FOR. SEEPAGE	100%	100%	100%	100%	97%	37%	89%	76%	52%	0%	100%
REVIEW SEEPAGE (cu.m)	561319	269335	443528	661645	378574	261352	468253	341734	424851	382417	453842
REVIEW OUT.FOR. SEEPAGE (cu.m)	0	0	0	0	3523	15948	14317	6999	68454	0	0
REVIEW STREAMFLOW (cu.m)	743353	471303	811189	1074714	498987	289303	696613	390572	591570	739790	1451180

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

AREA PLANTED @ 1xNATIVE (sq.km)	0.00	0.00	0.00	0.00	0.03	0.67	0.83	0.09	2.63	2.63	2.63
PLANTED/CLEARED AREA (%)	0%	0%	0%	0%	53%	40%	34%	27%	28%	27%	27%
PREDICTED SEEPAGE (cu.m)	561319	830653.88	443527.53	661645.38	377638.50	261531.14	729222.02	341646.88	1497539.28	2541601.87	4269625.09
" OUT.FOR. SEEPAGE (cu.m)	0	0.00	0.00	0.00	4528.57	18862.24	37486.11	7924.04	122818.50	122818.50	122818.50
% OF 1980 SEEPAGE	100%	100%	100%	100%	99%	39%	63%	99%	75%	83%	89%
% OF 1980 OUT.FOR. SEEPAGE	100%	100%	100%	100%	97%	34%	49%	76%	52%	52%	52%
REVIEW SEEPAGE (cu.m)	561319	830653.88	443527.53	661645.38	378574.40	261352.05	729605.24	341734.34	1496190.88	2540253.48	4268276.69
REVIEW OUT.FOR. SEEPAGE (cu.m)	0	0.00	0.00	0.00	3522.53	15947.99	30264.58	6998.74	105717.01	105717.01	105717.01
REVIEW STREAMFLOW (cu.m)	743353	1214656.22	811188.50	1074714.25	498986.53	289303.28	985916.66	390571.81	1968058.84	3782562.84	7259587.81

Abbreviations:
cu.m = cubic metres
mm = millimetres
@ 1xNATIVE = at one times native forest density
OUT.FOR. = outside forest

MODEL MINIMUM TREE PLANTING

Target: 52% reduction in seepage
Criteria: Plant on pasture land where
 seepage > 15 mm/yr
 Allow draw to 30% depth of bottom soil layer

Sub-catchments	29	30	26	28	27	31	32	25	24	23
Drains to	30	31	28	27	31	24	24	24	23	20

SUMS FOR ISOLATED SUBCATCHMENTS

AREA PLANTED @ 1xNATIVE (sq.km)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PLANTED/CLEARED AREA (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
PREDICTED SEEPAGE (cu.m)	462777	519711	107447	274426	239475	421229	527181	75334	287718	339870
" OUT.FOR. SEEPAGE (cu.m)	0	0	0	0	0	0	0	0	0	0
% OF 1980 SEEPAGE	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% OF 1980 OUT.FOR. SEEPAGE	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
REVIEW SEEPAGE (cu.m)	462777	519711	107447	274426	239475	421229	527181	75334	287718	339870
REVIEW OUT.FOR. SEEPAGE (cu.m)	0	0	0	0	0	0	0	0	0	0
REVIEW STREAMFLOW (cu.m)	564638	882606	181249.031	343368.281	506022.938	897385.063	1088156.63	295776.906	523995	661476

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

AREA PLANTED @ 1xNATIVE (sq.km)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PLANTED/CLEARED AREA (%)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
PREDICTED SEEPAGE (cu.m)	462777	982487.38	107447	381872.24	621347.16	2025063.57	527180.56	75333.94	2915296.07	3255165.57
" OUT.FOR. SEEPAGE (cu.m)	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% OF 1980 SEEPAGE	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% OF 1980 OUT.FOR. SEEPAGE	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
REVIEW SEEPAGE (cu.m)	462777	982487.38	107447	381872.24	621347.16	2025063.57	527180.56	75333.94	2915296.07	3255165.57
REVIEW OUT.FOR. SEEPAGE (cu.m)	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
REVIEW STREAMFLOW (cu.m)	564638	1447243.69	181249	524617.31	1030640.25	3375269.00	1088156.63	295776.91	5283197.44	5944673.88

Abbreviations:
cu.m = cubic metres
mm = millimetres
@ 1xNATIVE = at one times native forest density
OUT.FOR. = outside forest

MODEL MINIMUM TREE PLANTING

Target: 52% reduction in seepage
Criteria: Plant on pasture land where
seepage > 15 mm/yr
Allow draw to 30% depth of bottom soil layer

Sub-catchments	23	17	22	21	20	18	19	59
Drains to	20	18	21	20	19	19	59	55
SUMS FOR ISOLATED SUBCATCHMENTS								
AREA PLANTED @ 1xNATIVE (sq.km)			0.00	0.00	0.00	0.00	0.00	0.00
PLANTED/CLEARED AREA (%)			0%	0%	0%	0%	0%	0%
PREDICTED SEEPAGE (cu.m)			75140	33667	85736	519303	258464	62370
" OUT.FOR. SEEPAGE (cu.m)			0	0	0	0	0	0
% OF 1980 SEEPAGE			100%	100%	100%	100%	100%	100%
% OF 1980 OUT.FOR. SEEPAGE			100%	100%	100%	100%	100%	100%
REVIEW SEEPAGE (cu.m)			75140	33667	85736	519303	258464	62370
REVIEW OUT.FOR. SEEPAGE (cu.m)			0	0	0	0	0	0
REVIEW STREAMFLOW (cu.m)			268961.906	531394.688	1921283	1566728	2313001.5	1986153.63
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS								
AREA PLANTED @ 1xNATIVE (sq.km)	0.00	2.63	0.00	0.00	0.00	2.63	2.63	2.63
PLANTED/CLEARED AREA (%)	0%	27%	0%	0%	0%	27%	27%	27%
PREDICTED SEEPAGE (cu.m)	3255165.57	4269625.09	75139.57	108806.14	3449708.08	4788928.03	8497099.63	8559469.75
" OUT.FOR. SEEPAGE (cu.m)	0.00	122818.50	0.00	0.00	0.00	122818.50	122818.50	122818.50
% OF 1980 SEEPAGE	100%	89%	100%	100%	100%	90%	94%	94%
% OF 1980 OUT.FOR. SEEPAGE	100%	52%	100%	100%	100%	52%	52%	52%
REVIEW SEEPAGE (cu.m)	3255165.57	4268276.69	75139.57	108806.14	3449708.08	4787579.63	8495751.23	8558121.36
REVIEW OUT.FOR. SEEPAGE (cu.m)	0.00	105717.01	0.00	0.00	0.00	105717.01	105717.01	105717.01
REVIEW STREAMFLOW (cu.m)	5944673.88	7259587.81	268961.91	800356.59	8666313.36	8826316.06	19805630.92	21791784.55

Abbreviations:
cu.m = cubic metres
mm = millimetres
@ 1xNATIVE = at one times native forest density
OUT.FOR. = outside forest

MODEL MINIMUM TREE PLANTING

Target: 52% reduction in seepage
Criteria: Plant on pasture land where
seepage > 15 mm/yr
Allow draw to 30% depth of bottom soil layer

Sub-catchments	59	47	542	541	51	461	462	60	58	55
Drains to	55	541	55	55	461	47	47	58	55	53
SUMS FOR ISOLATED SUBCATCHMENTS										
AREA PLANTED @ 1xNATIVE (sq.km)			0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
PLANTED/CLEARED AREA (%)			0%	0%	33%	0%	0%	0%	0%	0%
PREDICTED SEEPAGE (cu.m)			22747	23411	78193	26667	18883	9611	1056	71239
" OUT.FOR. SEEPAGE (cu.m)			0	0	3718	0	0	0	0	0
% OF 1980 SEEPAGE			100%	100%	97%	100%	100%	100%	100%	100%
% OF 1980 OUT.FOR. SEEPAGE			100%	100%	94%	100%	100%	100%	100%	100%
REVIEW SEEPAGE (cu.m)			22747	23411	79362	26667	18883	9611	1056	71239
REVIEW OUT.FOR. SEEPAGE (cu.m)			0	0	3008	0	0	0	0	0
REVIEW STREAMFLOW (cu.m)			487880.781	1431015.38	896640	638355.625	482745.625	447650.375	818481.25	812627.688
AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS										
AREA PLANTED @ 1xNATIVE (sq.km)	2.63	5.11	0.00	5.11	0.02	0.02	0.00	0.00	0.00	7.73
PLANTED/CLEARED AREA (%)	27%	34%	0%	34%	33%	33%	0%	0%	0%	31%
PREDICTED SEEPAGE (cu.m)	8559469.75	8270412.17	22747.09	8293822.94	78193.24	104859.85	18883	9610.97	10667.40	16957946.46
" OUT.FOR. SEEPAGE (cu.m)	122818.50	239869.06	0.00	239869.06	3717.77	3717.77	0	0.00	0.00	362687.56
% OF 1980 SEEPAGE	94%	97%	100%	97%	97%	98%	100%	100%	100%	96%
% OF 1980 OUT.FOR. SEEPAGE	52%	53%	100%	53%	94%	94%	100%	100%	100%	52%
REVIEW SEEPAGE (cu.m)	8558121.36	8271775.88	22747.09	8295186.65	79361.76	106028.37	18883	9610.97	10667.40	16957961.76
REVIEW OUT.FOR. SEEPAGE (cu.m)	105717.01	190188.43	0.00	190188.43	3007.88	3007.88	0	0.00	0.00	295905.44
REVIEW STREAMFLOW (cu.m)	21791784.55	20503918.93	487880.78	21934934.31	896640.00	1534995.63	482746	447650	1266131.63	46293358.95

Abbreviations:
cu.m = cubic metres
mm = millimetres
@ 1xNATIVE = at one times native forest density
OUT.FOR. = outside forest

MODEL MINIMUM TREE PLANTING

Target: 52% reduction in seepage
Criteria: Plant on pasture land where
seepage > 15 mm/yr
Allow draw to 30% depth of bottom soil layer

Sub-catchments	55	57	56	52	53
Drains to	53	53	53	53	

SUMS FOR ISOLATED SUBCATCHMENTS

AREA PLANTED @ 1xNATIVE (sq.km)		0.00	0.00	0.08	0.00
PLANTED/CLEARED AREA (%)		0%	0%	43%	0%
PREDICTED SEEPAGE (cu.m)		60495	3627	63772	34595
" OUT.FOR. SEEPAGE (cu.m)		1623	0	2515	0
% OF 1980 SEEPAGE		100%	100%	92%	100%
% OF 1980 OUT.FOR. SEEPAGE		100%	100%	38%	100%
REVIEW SEEPAGE (cu.m)		60495	3627	63206	34595
REVIEW OUT.FOR. SEEPAGE (cu.m)		1623	0	1561	0
REVIEW STREAMFLOW (cu.m)		654957.875	622706.25	1522834.25	1192157

AGGREGATES FOR SUBCATCHMENTS AND ALL UPSTREAM SUBCATCHMENTS

AREA PLANTED @ 1xNATIVE (sq.km)	7.73	0.00	0.00	0.08	7.81
PLANTED/CLEARED AREA (%)	31%	0%	0%	43%	31%
PREDICTED SEEPAGE (cu.m)	16957946.46	60494.66	3626.98	63772	17120435.66
" OUT.FOR. SEEPAGE (cu.m)	362687.56	1623.19	0.00	2515	366825.43
% OF 1980 SEEPAGE	96%	100%	100%	92%	96%
% OF 1980 OUT.FOR. SEEPAGE	52%	100%	100%	38%	52%
REVIEW SEEPAGE (cu.m)	16957961.76	60494.66	3626.98	63206	17119884.19
REVIEW OUT.FOR. SEEPAGE (cu.m)	295905.44	1623.19	0.00	1561	299089.87
REVIEW STREAMFLOW (cu.m)	46293358.95	654957.88	622706.25	1522834	50286014.33

Abbreviations:
cu.m = cubic metres
mm = millimetres
@ 1xNATIVE = at one times native forest density
OUT.FOR. = outside forest

APPENDIX A - DETAILS OF COMPUTING PROCESSES

The M.A.G.I.C. computing processes used for the Helena Catchment were very similar to those used for the Kent Catchment, documented in Appendix B of Mauger 1996a. Any differences are outlined below.

B.2 CONVENTIONS

Table B2: Map Number Assignments

RAW DATA	DERIVED DATA	CATCHMENT MODEL	PLANTING PREDICTION	SCRATCH MAPS
1 2 3 4 5 LANDSAT MSS BAND 5 6 7 LANDSAT MSS BAND 7 8 9 10 11 RAINFALL 12 PAN EVAPORATION 13 : 20 21 ELEVATION 22 LAKE=25, STREAM = WIDTH, OTHER =0 23 24 25 CLEARED IN 95 26 27 28 29 30 31 32 33 34 : 49 50 GAUGING LOCATIONS 51 : 54 55 56 : 100	101 102 ASPECT 103 PLAN CURVATURE 104 SLOPE CURVATURE 105 DRAIN REDUCED SLOPE 106 107 SLOPE 108 : 115 LAKE=0, OTHER=1 116 DRAINAGE DIRECTIONS 117 DISPERSED DRAINAGE 118 NON-DISPERSED DRAINAGE RESIDUAL 119 NOS OF CELLS 120 GREENNESS 121 SHADE 122 123 GREENNESS > 0 124 FULL PASTURE LAI=2.1 125 NEGLIGIBLE PASTURE UPSTREAM = 1 126 : 129 130 SMOOTHED INFIL RATE 131 : 149 150 CATCHMENTS 151 : 200	201 CUMULATIVE RUN-OFF 202 TOTAL PASTURE ET 203 STREAMFLOW 204 MINIMUM SHALLOW+DEEP STORE 205 STORAGE LOSS 206 FINAL SHALLOW STORAGE 207 FINAL DEEP STORE 208 : 210 211 NET RECHARGE 212 FINAL DEEP DRAINAGE 213 THROUGHFLOW 214 SURPLUS RECHARGE 215 SMOOTHED SEEPAGE VOLUME 216 SMOOTHED DEEP DISCHARGE 217 SMOOTHED THROUGHFLOW 218 SMOOTHED SURPLUS RECHARGE 219 SEEPAGE AREA *[MAPS 201-219 ARE SAVED RESULTS FROM INITIAL ANALYSIS]* 220 : 240 241 CUMULATIVE RUN-OFF 242 TOTAL PASTURE ET 243 STREAMFLOW 244 MINIMUM SHALLOW+DEEP STORE 245 STORAGE LOSS 246 FINAL SHALLOW STORAGE 247 FINAL DEEP STORE 248 : 250 251 NET RECHARGE 252 FINAL DEEP DRAINAGE 253 THROUGHFLOW 254 SURPLUS RECHARGE 255 SMOOTHED SEEPAGE VOLUME 256 SMOOTHED DEEP DISCHARGE 257 SMOOTHED THROUGHFLOW 258 SMOOTHED SURPLUS RECHARGE 259 SEEPAGE AREA *[MAPS 241-259 ARE RESULTS FROM LAST ANALYSIS]* 260 : 300	301 302 303 TREE GREENNESS FOR CURRENT MODEL 304 ANNUAL PASTURE FOR CURRENT MODEL 305 : 330 331 DEEP G/W DRAWN BY PLANTED TREES 332 PLANTED DISCHARGE 333 PLANTED TREE GREENNESS 334 335% PLANTING OVER NATIVE DENSITY 336 : 400	401 : 409 410 POSSIBLE PASTURE OVERDRAW 411 412 CURRENT SHALLOW STORE 413 RUN-OFF 414 INFILTRATION 415 : 419 420 CURRENT DEEP STORE 421 CURRENT PASTURE ET, OR ASEARCH CELL COUNT 422 SURPLUS DEEP STORE 423 NET RECHARGE TO DEEP STORE 424 REQUIRED DEEP DRAINAGE 425 : 435 436 ANNUAL TREE TRANSPIRATION (MM) 437 438 PERENNIAL PASTURE TRANSPIRATION (MM) 439 PASTURE MAX. TRANSPIRATION (MM) 440 INITIAL STORAGE LOSS 441 CURRENT DEEP STORE, NET RECHARGE TO DEEP G/W 442 POTENTIAL RECHARGE & DISCHARGE 443 : 446 447 FINAL +VE DEEP DRAINAGE 448 449 INTEGRATED STORAGE LOSS 450 : 510

3. MAJOR STAGES OF ANALYSIS

3.1 CONVERT RAW DATA TO EQUIVALENT MAPS IN A RASCAL PROJECT

A. PREPARE RASCAL PROJECTS TO RECEIVE DATA

RASCAL < RASCAL.IN [5.1] Create a series of 15 RASCAL projects in strips to hold basic maps of ground elevation. Also create a low resolution RASCAL project(cell side length = 200m) that covers the whole catchment to hold maps of annual rainfall and pan evaporation.

C. GENERATE GRIDDED THEMATIC MAPS FROM DIGITISED POLYGONS

Used to define areas cleared in 1995.

USTATION	[5.2.2]	Create MicroStation patterning file (CLEAR95.PAT) and convert to text file (CLEAR95.ASC) for input to LISTIN
LISTIN < LISTIN.IN	[5.5]	Import polygons to POLYANA file format
	[5.6]	This step is not required
POL2RAS < POL2RAS.IN	[5.7]	Generate gridded thematic maps in RASCAL project

D. LOAD LANDSAT THEMATIC MAPPER DATA FROM BULK SOURCE

A Rascal project containing the Landsat MSS scene of December 1980 already existed on the server (PSE80.RAS) with cell length of 46.78 m containing Landsat MSS Bands 5 and 7.

3.2 COMPUTE MAPS REQUIRED AS INPUT TO THE HYDROLOGIC MODEL

A. PREPARE BASE MAPS

The greenness and shade maps were created in the existing PSE80 Rascal project.

RASCAL < GRNHEL.IN	[5.8]	Create Greenness and Shade map in PSE80 Rascal project

B. PREPARE SUBCATCHMENT RASCAL PROJECTS

Generation of drainage data is best done on relatively small areas due to the search for drainage outlets when sinks are identified. The small areas are complete subcatchments that will be used to report results of modelling, generally having areas of about 30 sq. km. Before the drainage is analysed, boundaries of subcatchments will only be known approximately by inspecting contour data. The recommended process described here is to create an over-sized RASCAL project for each subcatchment so that the boundary will not fall outside the project limits. After the boundary has been defined by analysis, a smaller project that fully contains the subcatchment can be specified. The smaller project is created and all the maps from the larger project copied to it so that surplus computing in the modelling process will be minimised. If the subcatchment mapped in the larger project lies within 2 cells of the project boundary at any point, the subcatchment could actually extend beyond the project. In such cases, the process should be repeated using a new project with more clearance on that side.

LOADSC	[6.2]	Copy from Rascal project PSE80, Landsat MSS Bands 5 and 7, greenness and shade into individual RASCAL projects. Some of the resulting maps needed to be scaled up by a factor .
INIT *HEL01*	[6.3]	Batch run to prepare initial maps for each subcatchment project. Includes GRPASHEL or BURNT depending whether the project contained burnt areas or not.
RASCAL < MAP22.IN	[6.7]	Create a Lake Map 115 and a map to account for evaporation on streams (Map22).

At this stage, each subcatchment project contains the following maps:

5 LANDSAT MSS BAND 5
7 LANDSAT MSS BAND 7
11 RAINFALL
12 PAN EVAPORATION
21 ELEVATION
22 LAKE=25, STREAM=WIDTH, OTHER =0
50 GAUGING LOCATIONS
102 ASPECT
103 PLAN CURVATURE

104 SLOPE CURVATURE
105 DRAIN REDUCED SLOPE
107 SLOPE
115 LAKE=0, OTHER=1
116 DRAINAGE DIRECTIONS
117 DISPERSED DRAINAGE
118 NON-DISPERSED DRAINAGE RESIDUAL
119 NOS OF CELLS
120 GREENNESS 33,180,15,24,240,180
121 SHADE 33,180,15,24,240,180
123 GREENNESS > 0
124 FULL PASTURE LAI=2.1
125 NEGLIGIBLE PASTURE UPSTREAM = 1
130 SMOOTHED INFIL RATE
150 CATCHMENTS

(Map 120 is GREENNESS based on values of Landsat MSS bands 5 and 7 shown in title for pure components of greenness(33,180), shade(15,24), and bare soil(240,180).

3.3 PERFORM HYDROLOGIC MODELLING ON EACH SUBCATCHMENT

To automate the processing of all subcatchments, the batch files RUNLBURN.BAT and RUNLAK contain the functions of initial modelling [7.2]. REVIEW.BAT contains the functions in the review process [7.4]. They include labelling output files with the subcatchment id number, and compressing the RASCAL projects to remove scratch maps and archive the final files. RUNLBURN and RUNLAK processes one subcatchment whose id no. is the parameter. A higher level batch file, RUNALL.BAT, runs RUNLBURN and RUNLAK. Similarly REVIEWALL runs REVIEW for all subcatchments that require reviewing.

RUNALL	[7.1.0]	Execute RUNLBURN or RUNLAK
REVEWALL	[7.6]	Execute REVIEW

3.4 PREPARE DATA FOR PRESENTATION OF OUTPUT

A. CLASSIFY RASTER MAPS

For classification of seepage and sites for planted trees :

RASCAL < CLASS.IN	[8.1]	Generate maps of: 3 rates of seepage (15, 30 & 75 cu.m/yr) Proposed sites for planted trees

Use on subcatchment Rascal projects

For classification of native forest:

The Landsat MSS Rascal project PSE80.RAS was used to generate the native forest design file. First of all, the following steps were done on the file to prepare it for classification:

POL2RAS < POL2RAS.IN	[5.7]	Generate Map 25 'Cleared in 95' in PSE80.RAS from CLEAR95.PAN
CALL COPYIN3 PSE80 ISO	[6.2.1.3]	Copy Map 11 "RAINFALL' from ISO.RAS into PSE80.RAS
COPYRAS < COPYRAS.IN		
CALL PMIN SCALE2.DAT *DUMMY* PSE80	[6.2.3]	Scale Map 11 by 64
RASCAL < PMIN.DAT		

Modify CLASS.IN accordingly.

5. FLOW OF MAP GENERATION IN RASCAL PROJECTS

The following table summarises the maps required as input and the maps produced as output for the processes involving RASCAL projects:

INPUT MAPS	PROCESS	REF	OUTPUT MAPS
	<u>**Interpolate from isolines**</u> **USTATION** **GRIDSF** **STORE**	 [5.2] [5.3] [5.4]	 11 Rainfall 12 Pan Evaporation 21 Elevation
	<u>**Grid polygon themes**</u> **USTATION** **LISTIN** **POL2RAS**	 [5.2.2] [5.5] [5.7]	 25 Cleared in 95
 5 MSS Band 5 7 MSS Band 7	<u>**Prepare Base Maps**</u> **GRNHEL**	 [5.8]	 120 Greenness labelled by coords of pure components, i.e. 33 180, 15 24, 240 180 121 Shade labelled by coords of pure components, i.e. 33 180, 15 24, 240 180
	<u>**Prepare Subcatchments**</u> **INIT**	 [6.3]	
5 MSS Band 5 7 MSS Band 7 11 Rainfall 12 Pan Evaporation 120 Greenness	**GRPASHEL** **OR** **BURNT**	[6.3.0]	303 Green > 0 304 Full Pasture LAI = 2.1
21 Elevation	**TERRAIN**	[6.3.1]	102 Aspect 103 Plan Curvature 105 Slope
21 Elevation 102 Aspect	**DRAIN**	[6.3.2]	116 Drainage Directions
102 Aspect 103 Plan Curvature 116 Drainage Directions	**DISPER**	[6.3.3]	117 Dispersed Drainage
105 Slope 116 Drainage Directions 117 Dispersed Drainage	**INFRATE**	[6.3.4]	130 Smoothed Infiltration Rate 118 Non-dispersed Drainage Residual 107 Actual Slope 105 Drain Reduced Slope
116 Drainage Directions	**INTDRA**	[6.3.5]	119 Drain Integral of Nos of Cells
116 Drainage Directions 304 Full Pasture LAI = 2.1	**RELG**	[6.3.6]	125 Negligible Pasture Upstream =1
	BLANK	[6.3.7]	50 Blank Map for Gauging Locations
	SEERAS	[6.4]	50 Gauging Locations
116 Drainage Directions 50 Gauging Locations	**CATCH**	[6.5]	150 Catchments
116 Drainage Directions 117 Dispersed Drainage 118 Non-dispersed Drainage	**TRIM**	[6.6]	116 Drainage Directions 117 Dispersed Drainage 118 Non-dispersed Drainage

INPUT MAPS	PROCESS	REF	OUTPUT MAPS
Residual 150 Catchments			Residual
123 Green > 0 119 Drain Integral of Nos of Cells	**MAP22**	[6.7]	115 Lake =0, Other =1 22 Lake =25, Stream = width, other = 0
	Hydrologic modelling **GWMODEL**	[7.1]	
As Above	**GRPASHEL OR BURNT**	[6.3.0]	As Above
11 Rainfall 12 Pan Evaporation 105 Drain Reduced Slope 116 Drainage Directions 117 Dispersed Drainage 118 Non-disp. Drain Resid 150 Catchments 303 Green > 0 304 Full Pasture LAI=2.7	**GWLMYS**	[7.2.1]	253 Deep Throughflow 254 Surplus Recharge to deep 411 Rain Minus ET 412 Final Shallow Storage 413 Run-off 414 Infiltration to Deep in Month 421 Pasture ET in Month 436 Annual Tree Transpiration 439 Pasture Max. Transpiration 441 Net Recharge to Deep 442 Potential Recharge, Discharge
As for GWMLYS Plus: 412 Final Shallow Storage 436 Annual Tree Transp. 439 Pasture Max. Transp. 442 Deep Recharge, Discharge	**GWLMY2**	[7.2.2]	As for GWMLYS Plus: 241 Run-off adjusted for Lakes 242 Total Pasture ET 243 Streamflow 244 Minimum Storage 245 Storage Loss 251 Total Net Recharge to Deep 252 Final Deep Drainage 420 Current Deep Store 422 Surplus Deep Store 423 Net Recharge in Month 440 Initial Storage Loss 447 Final +ve Deep Drainage 449 Integrated Storage Loss
As for GWMLY2	**GWLMY3**	[7.2.3]	As for GWMLYS Plus: 246 Final Shallow Store 247 Final Deep Store
252 Final Deep Drainage 253 Deep Throughflow 254 Surplus Recharge to deep	**SMDISCH**	[7.2.4]	255 Smoothed Seepage Volume 256 Smoothed Deep Discharge 257 Smoothed Throughflow 258 Smoothed Surplus Recharge 259 Seepage area
241 Run-off adj. for Lakes 242 Total Pasture ET 243 Streamflow 244 Minimum Storage 245 Storage Loss 251 Total Net Rech. to Deep 252 Final Deep Drainage 253 Deep Throughflow 254 Surplus Recharge to deep 255 Smoothed Seepage Vol. 256 Smoothed Deep Disch. 257 Smoothed Throughflow 258 Smoothed Surplus Rech.e	**SAVORIG**	[7.2.5]	201 Run-off adj. for Lakes 202 Total Pasture ET 203 Streamflow 204 Minimum Storage 205 Storage Loss 211 Total Net Rech. to Deep 212 Final Deep Drainage 213 Deep Throughflow 214 Surplus Recharge to deep 215 Smoothed Seepage Vol. 216 Smoothed Deep Disch. 217 Smoothed Throughflow 218 Smoothed Surplus Rech.e

INPUT MAPS	PROCESS	REF	OUTPUT MAPS
303 Green > 0 304 Full Pasture LAI=2.7			123 Green > 0 124 Full Pasture LAI=2.7
11 Rainfall 12 Pan Evaporation 105 Drain Reduced Slope 117 Dispersed Drainage 118 Non-disp. Drain Resid 123 Green > 0 124 Full Pasture LAI=2.1 125 Neg. Past. U/s = 1 201 Run-off adj. for Lakes 202 Total Pasture ET 212 Final Deep Drainage 213 Deep Throughflow 214 Surplus Recharge to deep 216 Smoothed Deep Disch.	**PLANT**	[7.3]	331 Deep G/W Drawn by Planted Trees 332 Smoothed Planted Discharge 333 Planted Tree Greenness 334 Planted Seepage Volume 335 % Planting Over Native Density 421 Planted Tree Criterion
	REVIEW	[7.4]	
123 Green > 0 124 Full Pasture LAI=2.1 333 Planted Tree Greenness	**NEWPAST**	[7.4.1]	303 Green > 0 304 Full Pasture LAI=2.1
119 Drain Int. of Nos of Cells 123 Green > 0 227 Smoothed Deep Disch. 333 Planted Tree Greenness	Make maps for plotting **CLASS** **MAP** **USTATION**	[8.1] [8.2] [8.3]	425 Classed Seepage Rates 426 Original Tree Cover 427 Proposed Sites for Planting

5. CONVERT RAW DATA TO EQUIVALENT MAPS IN A RASCAL PROJECT

5.2.2 USTATION - CREATE &EXPORT 'CLEARED IN 95' PATTERN FILE FOR LISTIN

The 'Cleared in 95' information was input into each individual Rascal project, to help in the classification of pasture. First of all the MicroStation file 'HELCLR95.DGN' was created by merging files 'CLEAR.DGN'(contains cleared history of Helena Catchment) and REFORST.DGN'(contains reforestation history of Helena Catchment) linework onto the same level. These files were created by Ian Logan. The history of these files covers the years 1945, 65, 72, 85, 95. The labelling text from both files was also put on the same level.

Use the MDL 'POLY' created by the Water Corporation to perform the following functions. Clean the linework by using LINE BREAK. This will create a new file (HELCLR95.OVL) with cleaned linework for the levels specified (specify level containing cleared and reforested linework). Open this file and then create a polygon file by using POLYGON CREATE. Use the next option LOAD POLY ID to create a database file HELCLR95.DBF linking the polygons with the labels. Exist MicroStation. HELCLR95.DBF needs to be edited using the database software DBASE. Use the following REPLACE command to combine the classifying fields.

replace all POLY_ID with '1' for CLEAR = '*****' .and. REFORST <> '*****'

Open the MicroStation file HELCLR95.OVL and use the PATTERN DESIGN option of the MDL 'POLY' with the area exclusive option to create a patterning file CLEAR95.PAT. The following pattern definition file was used:

HELCLR95.DAT

1 4 50
DEFAULT 0 0

Use the MDL TAGGING to tag the polygons with a nominal value of 10, then use the Polygon Utility MDL DGN2ASC to export the polygons in the pattern file to text format which can be read by M.A.G.I.C. programs.

5.5 CONTENTS OF LISTIN.IN

CLEAR95.ASC	Text format file created by DGN2ASC
CLEAR95.PAN	POLYANA file of same data
OUT.PRN	File for messages generated by program
5	Consider joining if if distance between ends < 5m
Y	Update default filenames

Refer HOW LISTIN.

5.7 CONTENTS OF POL2RAS.IN

P	Gridding polygons
CLEAR95.PAN	Input POLYANA file
HEL01	Receiving RASCAL project
OUT.PRN	File for messages
25	Map no. for output
CLEARED IN 95	Title of output map
I2	Data type of output map
99	Map no. for recording irregular results
ERROR MAP	Title of map " " "
I2	Data type of map " " "
Y	Update default filenames

Refer HOW POL2RAS for more information.

5.8 CONTENTS OF GRNHEL.IN

PSE80		RASCAL project containing Landsat MSS data
GRNHEL.DAT	[5.8.1]	
OUT.PRN		File for messages generated by program
N		Is extra data file to be nominated?
Y		Update default filenames

5.8.1 CONTENTS OF GRNHEL.DAT

```
120EXPR R4                                      5/7 GREENNESS 33 180 15 24 240 180
100/((180-180)*(15-240)-(33-240)*(24-180)) :     GREEN  SHADE BARE
 *((M7-180)*(15-240)-(M5-240)*(24-180))
121EXPR R4                  5/7                 SHADE    33 180 15 24 240 180
100/((180-180)*(15-240)-(33-240)*(24-180)) :     GREEN  SHADE BARE
 *(-(33-240)*(M7-180))
  END
```

Generates the greenness and shade map. Map title records values of MSS data in Bands 5 and 7 corresponding to pure green leaf, shade, and bare soil respectively. Formula computes % of green leaf in cell and % of shade in cell assumed to contain a mixture of these components. Refer (Mauger 1996b).

Refer [HOW EXPR] for details about writing an expression.

6. COMPUTE MAPS REQUIRED AS INPUT TO THE HYDROLOGIC MODEL

6.1 CONTENTS OF PREMODEL.BAT

This step is not required.

6.2 CONTENTS OF LOADSC.BAT

CALL COPYBASE HEL*01* [6.2.1] Load maps into subcatchment project HEL01
Also scales MSS data by factor 3.5019 & Maps 11 &

12

by 64.

Repeat this line in file LOADSC.BAT, changing the number in the subcatchment project name each time, so that the command is performed on every subcatchment.

6.2.1 CONTENTS OF COPYBASE.BAT

CALL COPYIN %1 417421 [6.2.1.1] Prepare input file for COPYRAS, to copy from the first 'base project'. Then execute COPYRAS.
Repeat for each base project.

First set of base projects contain M21 (Elevation)
The numerical title of the Elevation Projects gives the range of AMG eastings covered by the project.
e.g. 417421 is a strip between 417000E and 421000E that spans the Helena catchment from North to South.

```
CALL COPYIN %1 417421
COPYRAS < COPYRAS.IN
CALL COPYIN %1 421425
COPYRAS < COPYRAS.IN
CALL COPYIN %1 425429
COPYRAS < COPYRAS.IN
CALL COPYIN %1 429432
COPYRAS < COPYRAS.IN
CALL COPYIN %1 432435
COPYRAS < COPYRAS.IN
CALL COPYIN %1 435438
COPYRAS < COPYRAS.IN
CALL COPYIN %1 425429
COPYRAS < COPYRAS.IN
CALL COPYIN %1 429432
COPYRAS < COPYRAS.IN
CALL COPYIN %1 432435
COPYRAS < COPYRAS.IN
CALL COPYIN %1 435438
COPYRAS < COPYRAS.IN
CALL COPYIN %1 438442
COPYRAS < COPYRAS.IN
CALL COPYIN %1 442445
COPYRAS < COPYRAS.IN
CALL COPYIN %1 445449
COPYRAS < COPYRAS.IN
CALL COPYIN %1 449452
COPYRAS < COPYRAS.IN
CALL COPYIN %1 452456
COPYRAS < COPYRAS.IN
CALL COPYIN %1 456460
COPYRAS < COPYRAS.IN
CALL COPYIN %1 460464
COPYRAS < COPYRAS.IN
CALL COPYIN %1 464468A
COPYRAS < COPYRAS.IN
CALL COPYIN %1 464468B
CALL COPYIN2 %1 PSE80
```

[6.2.1.2] This base project contains Maps 5,7,120,121

```
COPYRAS < COPYRAS.IN
```

CALL COPYIN2 %1 ISO [6.2.1.3] This base project contains Maps 11 and 12
COPYRAS < COPYRAS.IN
CALL PMIN SCALE.DAT DUMMY %1 [6.2.2] Scales some of the copied maps that use the sum of fraction method

RASCAL < PMIN.DAT

6.2.1.1 CONTENTS OF COPYIN.BAT

ECHO %2 > COPYRAS.IN	Donor project name
ECHO %1 >> COPYRAS.IN	Project receiving maps
ECHO OUT.PRN >> COPYRAS.IN	Output file for messages
ECHO N >> COPYRAS.IN	Take value of 'nearest neighbour' cell
ECHO ALL >> COPYRAS.IN	Copy to whole area of receiving maps
ECHO 21 21 >> COPYRAS.IN	Copies Map 21
ECHO 21 >> COPYRAS.IN	Map numbers of copies to start at 21
ECHO 2 1 >> COPYRAS.IN	No more ranges of map numbers to copy
ECHO Y >> COPYRAS.IN	Update default file names from this run

Refer [HOW COPYRAS] for details of running program COPYRAS.

6.2.1.2 CONTENTS OF COPYIN2.BAT

ECHO %2 > COPYRAS.IN	Donor project name
ECHO %1 >> COPYRAS.IN	Project receiving maps
ECHO OUT.PRN >> COPYRAS.IN	Output file for messages
ECHO S >> COPYRAS.IN	Add sum of fraction of donor cells in receiving cell
ECHO ALL >> COPYRAS.IN	Copy to whole area of receiving maps
ECHO 5 7 >> COPYRAS.IN	Copy maps numbered 5 through to 7
ECHO 5 >> COPYRAS.IN	Map numbers of copies to start at 5
ECHO 120 121 >> COPYRAS.IN	Copy maps numbered 120 through to 121
ECHO 120 >> COPYRAS.IN	Map numbers of copies to start at 120
ECHO 2 1 >> COPYRAS.IN	No more ranges of map numbers to copy
ECHO Y >> COPYRAS.IN	Update default file names from this run

6.2.1.3 CONTENTS OF COPYIN3.BAT

ECHO ISO > COPYRAS.IN	Donor project name
ECHO PSE80 >> COPYRAS.IN	Project receiving maps
ECHO OUT.PRN >> COPYRAS.IN	Output file for messages
ECHO S >> COPYRAS.IN	Add sum of fraction of donor cells in receiving cell
ECHO ALL >> COPYRAS.IN	Copy to whole area of receiving maps
ECHO 11 12 >> COPYRAS.IN	Copy maps numbered 11 through to 12
ECHO 11 >> COPYRAS.IN	Map numbers of copies to start at 11
ECHO 2 1 >> COPYRAS.IN	No more ranges of map numbers to copy
ECHO Y >> COPYRAS.IN	Update default file names from this run

6.2.2 CONTENTS OF SCALE.DAT

*5***EXPR** *I2*	*LANDSAT MSS BAND 5*	
NINT(M5*3.5019)		Multiply Map 5 by $46.78^2/25^2=3.5019$
*7***EXPR** *I2*	*LANDSAT MSS BAND 7*	
NINT(M7*3.5019)		Multiply Map 7 by 3.5019
*120***EXPR** *R4*	*5/7 GREENNESS 33 180 15 24 240 180*	
M120*3.5019		Multiply Map 120 by 3.5019
*121***EXPR** *R4*	*5/7 SHADE 33 180 15 24 240 180*	
M121*3.5019		Multiply Map 121 by 3.5019
*11***EXPR** R4	RAINFALL	

```
M11*64                                                  Multiply Map 11 by 200^2/25^2=64
12EXPR R4              PAN EVAPORATION
M12*64                                                  Multiply Map 12 by 64
  END
```

6.2.3 CONTENTS OF SCALE2.DAT

```
11EXPR R4              RAINFALL
M11*64                                                  Multiply Map 11 by 200^2/25^2=64
  END
```

6.3 CONTENTS OF INIT.BAT

```
CALL PMIN GRPASHEL.DAT DUMMY %1     [6.3.0.1]  Generate greenness > 0 of native vegetation
RASCAL < PMIN.DAT                              and the peak leaf area index of pasture
                                               for projects with no burnt areas
                                                          OR
:CALL PMIN BURNT.DAT DUMMY %1       [6.3.0.2]  Generate greenness > 0 of native vegetation
:RASCAL < PMIN.DAT                             and the peak leaf area index of pasture
                                               for projects with burnt areas
CALL PMIN TERRAIN.DAT DUMMY %1      [6.3.1]  Make slope etc from elevation
RASCAL < PMIN.DAT
CALL PMIN DRAIN.DAT DUMMY %1        [6.3.2]  Make simple, sink-free drainage directions
RASCAL < PMIN.DAT
CALL PMIN DISPER.DAT DUMMY %1       [6.3.3]  Make dispersed drainage codes
RASCAL < PMIN.DAT
CALL PMIN INFRATE.DAT DUMMY %1      [6.3.4]  Infiltration rate to bottom soil layer
RASCAL < PMIN.DAT
CALL PMIN INTDRA.DAT DUMMY %1       [6.3.5]  # cells in catchment from simple drainage
RASCAL < PMIN.DAT
CALL PMIN RELG.DAT DUMMY %1         [6.3.6]  Cells with negligible upstream clearing
RASCAL < PMIN.DAT
CALL PMIN BLANK.DAT DUMMY %1        [6.3.7]  Make blank map for catchment outlets
RASCAL < PMIN.DAT
```

'CALL PMIN' will execute the batch file PMIN.BAT [6.1.3] which contains the commands used to generate a file called 'PMIN.DAT' [6.1.3.1] containing appropriate keyboard responses to run RASCAL. The file 'PMIN.DAT' is used as input to RASCAL on the subsequent line ('RASCAL < PMIN.DAT'). Parameter DUMMY has no effect in these RASCAL runs.

6.3.0.1 CONTENTS OF GRPASHEL .DAT

```
303EXPR R4                   GREEN > 0
 IF(M120<0 OR (M5>=70 AND M25=10),0, : WATER, PASTURE OR CLAY
 M120 : NATIVE VEGETATION
)
304EXPR R4                   FULL PASTURE LAI= 2.1
 IF( M5<70 OR M120<0 OR M25=0,0, : WATER  OR CLAY OR UNCLEARED
  : PASTURE LAI=2.1 WITH NO TREES
 2.1*(1 - M303 / (.0095*M11+11.5)): COMBINATION OF PASTURE AND TREES
)
  END
```

Generates the greenness > 0 of native vegetation, and the peak leaf area index of pasture. The natural 'greenness' of the vegetation was assumed to be 0.0095*Rainfall + 11.5. The coefficients for the natural 'greenness' formula were obtained from Mauger (1988) since the same December 80 Lansat scene was used in that study.

6.3.0.2 CONTENTS OF BURNT .DAT

```
303EXPR R4                    GREEN > 0
 IF(M120<0 OR (M5> =70 AND M25=10),0, : WATER,  PASTURE OR CLAY
 IF(M120< =9,0.0095*M11+11.5,M120) : NATIVE VEGETATION OR NATIVE WHERE BURNT
 )
304EXPR R4                    FULL PASTURE LAI= 2.1
 IF( M5<70 OR M120<0 OR M25=0,0, : WATER  OR CLAY OR UNCLEARED
  : PASTURE LAI=2.1 WITH NO TREES
 2.1*(1 - M303 / (.0095*M11+11.5)): COMBINATION OF PASTURE AND TREES
 )
  END
```

6.7 CONTENTS OF MAP22.IN

```
CALL PMIN MAP22.DAT DUMMY %1        [6.7.1]
RASCAL < PMIN.DAT
```

Create maps 115 and 22

'CALL PMIN' will execute the batch file PMIN.BAT [6.1.3]

6.7.1 CONTENTS OF MAP22.DAT

```
115EXPR I2                  LAKE=0,OTHER=1
IF(M123=0,0,1)
 22EXPR I2                  LAKE =25, STREAM =WIDTH, OTHER=0
IF(M119>8000, 5, : MAJOR STREAMS
IF(M119>1600, 2, : MINOR STREAMS
0))
  END
```

Lakes occured when the greenness was negative

Accounting for evaporation along major streams

7. HYDROLOGIC MODELLING

7.1.0 CONTENTS OF RUNALL.BAT

CALL RUNLAK 01 [7.1.3]
CALL RUNLAK 02
CALL RUNLAK 03
CALL RUNLAK 04
CALL RUNLAK 05
CALL RUNLAK 06
CALL RUNLAK 07
CALL RUNLAK 08
CALL RUNLAK 09
CALL RUNLAK 10
CALL RUNLAK 11
CALL RUNLAK 12
CALL RUNLAK 13
CALL RUNLAK 14
CALL RUNLAK 15
CALL RUNLAK 16
CALL RUNLAK 17
CALL RUNLAK 18
CALL RUNLAK 19
CALL RUNLAK 20
CALL RUNLAK 21
CALL RUNLBURN 22 [7.1.1]
CALL RUNLAK 23
CALL RUNLAK 24
CALL RUNLBURN 25
CALL RUNLBURN 26
CALL RUNLAK 27
CALL RUNLAK 28
CALL RUNLAK 29
CALL RUNLAK 30
CALL RUNLAK 31
CALL RUNLAK 32
CALL RUNLAK 33
CALL RUNLAK 34
CALL RUNLAK 35
CALL RUNLAK 36
CALL RUNLAK 37
CALL RUNLAK 38
CALL RUNLAK 39
CALL RUNLAK 40
CALL RUNLAK 41
CALL RUNLBURN 42
CALL RUNLAK 43
CALL RUNLAK 44
CALL RUNLAK 45
CALL RUNLBURN 46
CALL RUNLBURN 47
CALL RUNLBURN 48
CALL RUNLBURN 49
CALL RUNLAK 50
CALL RUNLBURN 51
CALL RUNLBURN 52
CALL RUNLAK 53
CALL RUNLBURN 54

```
CALL RUNLAK 55
CALL RUNLAK 56
CALL RUNLBURN 57
CALL RUNLAK 58
CALL RUNLAK 59
CALL RUNLAK 60
```

7.1.1 CONTENTS OF RUNLBURN.BAT

```
CALL GWMLB HELI %1          [7.1.2] Perform modelling, including renaming and
COPY *.Y? RESULT                    COMPRAS on catchments with burnt areas
COPY *.SM RESULT
COPY *.OVR RESULT                   Archive output files,
DEL *.Y?                            delete redundant files
DEL *.SM
DEL *.OVR
DEL HEL%1.MAP
DEL HEL%1.RAS
PKZIP HELI%1 HELI%1.*
PKZIP2EXE HELI%1
DEL HELI%1.*
```

7.1.2 CONTENTS OF GWMLB.BAT

```
CALL PMIN BURNT.DAT ZZ.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMYS.DAT ZZ.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMY2.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMY3.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN SMDISCH.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN SAVORIG.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
:CALL PMIN PLANT.DAT Y2.OUT %1%2
:RASCAL < PMIN.DAT
COPY ??.Y? ??BS%2.Y?
COPY ??.SM ??BS%2.SM
COPY ??.OVR ??BS%2.OVR
:CALL REVIEW %1%2
:COPY ??.Y? ??TR%2.Y?
:COPY ??.SM ??TR%2.SM
CALL COMPRIN %1 %2
COMPRAS < COMPRIN.DAT
```

7.1.3 CONTENTS OF RUNLAK.BAT

```
HELI%1
DEL HELI%1.EXE
RENAME HELI%1.MAP HEL%1.MAP
RENAME HELI%1.RAS HEL%1.RAS
CALL GWML HEL %1            [7.1.4]
COPY *.Y? RESULT
COPY *.SM RESULT
COPY *.OVR RESULT
DEL *.Y?
```

```
DEL *.SM
DEL *.OVR
DEL HEL%1.MAP
DEL HEL%1.RAS
PKZIP HELI%1 HELI%1.*
PKZIP2EXE HELI%1
DEL HELI%1.ZIP
DEL HELI%1.MAP
DEL HELI%1.RAS
DEL HEL%1.MAP
DEL HEL%1.RAS
```

7.1.4 CONTENTS OF GWML.BAT

```
CALL PMIN GRPASHEL.DAT ZZ.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMYS.DAT ZZ.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMY2.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMY3.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN SMDISCH.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN SAVORIG.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
:CALL PMIN PLANT.DAT Y2.OUT %1%2
:RASCAL < PMIN.DAT
COPY ??.Y? ??BS%2.Y?
COPY ??.SM ??BS%2.SM
COPY ??.OVR ??BS%2.OVR
:CALL REVIEW %1%2
:COPY ??.Y? ??TR%2.Y?
:COPY ??.SM ??TR%2.SM
CALL COMPRIN %1 %2
COMPRAS < COMPRIN.DAT
```

7.2.1 CONTENTS OF PWLMYS.DAT

```
:RUN SHALLOW GROUNDWATER SIMULATION FOR 12 MONTHS AS A PRELIMINARY
:ANALYSIS TO GET ESTIMATE OF INITIAL WATER STORAGE FOR PROJECTS
:WHICH CONTAIN LAKES.
SET DRY 20
:304COPY   124
:303COPY   123
:Convert pan evap and LAI to transpiration. PAN/LEAF = .352
439EXPR R4                    PASTURE MAX. TRANSPIRATION(MM)
  .352*M12*M304
436EXPR R4                    ANNUAL TREE TRANSPIRATION (MM)
 : NET RAIN / NATURAL GREENNESS       * ACTUAL GREENNESS
   1.50*.85*.9*M11 / (.0095*M11+11.5) *  M303
412EXPR R4                    INITIAL WET STORAGE
 187
441EXPR R4                    INITIAL DEEP STORAGE
 0
PROC MONTH RAIN EVAP GROWTH
412EXPR R4                    ADD RAIN
        M412 + M11*.9*RAIN
421EXPR R4                    PASTURE ET
: PASTURE ET CANNOT CAUSE STORE TO BECOME LESS THAN -DRY
```

```
        MAX(0, MIN(M412+ DRY, EVAP*GROWTH*M439))
412EXPR R4                    SHALLOW STORE - PASTURE - TREES
        M412 - M421 -  EVAP*1.0*M436
412INTDRR4412117105      11
 1.5 30 .2  0  0  0  0
412INTDRR4412118105  0     1
 1.5 30 .2  0  0  0  0
414EXPR R4                    INFILTRATION
        MAX(0,MIN(M412,M130))
441EXPR R4                    DEEP STORE
: OLD STORE + INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
      M441 +M414  + .6 * MIN(0,M412+DRY)
412EXPR R4                    STORAGE AFTER INFILT & ET
        MAX(-DRY , M412 - M414)
413EXPR R4                    RUN-OFF
        IF(M412>187,M412-187,0)
412EXPR R4                    FINAL STORAGE
        M412 - M413
ENDPROC
PROC MARCHAPRIL RAIN EVAP NAME
412EXPR R4                    ADD RAIN
        M412 + M11*.9*RAIN
412EXPR R4                    SHALLOW STORE - TREES
        M412 - M421 - EVAP*1.0*M436
412INTDRR4412117105      11
 1.5 30 .2  0  0  0  0
412INTDRR4412118105  0     1
 1.5 30 .2  0  0  0  0
414EXPR R4                    INFILTRATION
        MAX(0,MIN(M412,M130))
441EXPR R4                    DEEP STORE
: OLD STORE + INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
      M441 +M414  + .6 * MIN(0,M412+DRY)
412EXPR R4                    STORAGE AFTER INFILT & ET
        MAX(-DRY , M412 - M414)
413EXPR R4                    RUN-OFF
        IF(M412>187,M412-187,0)
412EXPR R4                    FINAL STORAGE
        M412 - M413
ENDPROC
 MONTH      .056 ; .037 ;  1  ; SEPTEMBER
 MONTH      .031 ; .054 ;  1  ; OCTOBER
 MONTH      .020 ; .067 ; .93 ; NOVEMBER
 MONTH      .005 ; .083 ; .74 ; DECEMBER
 MONTH      .008 ; .090 ; .37 ; JANUARY
 MONTH      .012 ; .077 ; .07 ; FEBRUARY
 MARCHAPRIL .010 ; .068 ;       MARCH
 MARCHAPRIL .029 ; .044 ;       APRIL
 MONTH      .068 ; .030 ; .07 ; MAY
 MONTH      .103 ; .023 ; .37 ; JUNE
 MONTH      .105 ; .023 ; .74 ; JULY
 MONTH      .082 ; .029 ; .93 ; AUGUST
442INTDRR4441117105      12         INITIAL DEEP DRAINAGE
20. 4 0 0 0 0
253 254
442INTDRR4254118105      2          INITIAL DEEP DRAINAGE
20. 4 0 0 0 0
-253 254
```

```
: COMPUTE CAPACITY OF SITE TO ACCEPT INFILTRATION IF NOT DISCHARGE
442EXPR R4                    POTENTIAL RECHARGE & DISCHARGE
: DISCH< =0, SURP RECH - NET RECH + (-VE) DISCH, ELSE +VE DISCH
 IF(M442< =0,M254 - M441 + M442 , M442)
150OVROUT 442                  DD.Y1
150OVROUT 441                  NR.Y1
  END
```

7.2.2 CONTENTS OF PWLMY2.DAT

```
SET DRY 20
SET DEPTH 1.5
SET K 30
SET POROSITY .2
440EXPR I2                    INITIAL STORAGE LOSS
 187 - M412
420EXPR R4                    INITIAL DEEP STORE
 0
251COPY   420                 CUM. NET RECHARGE
241COPY   420                 INITIAL CUMULATIVE RUN-OFF
242COPY   420                 INITIAL PASTURE ET TOTAL
442EXPR R4                    MONTHLY DISCHARGE
        M442/12
PROC MONTH RAIN EVAP GROWTH
420EXPR R4                    ADD DISCHARGE TO DEEP STORE
        MIN(0,M420) + M442
422EXPR R4                    SURPLUS DEEP STORE
        MAX(0,M420)
412EXPR R4                    ADD RAIN & +VE DISCHARGE
        M412+ M422 + M11*.9*RAIN
421EXPR R4                    PASTURE ET
: PASTURE ET CANNOT CAUSE STORE TO BECOME LESS THAN -20
        MAX(0, MIN(M412+DRY, EVAP*GROWTH*M439))
242EXPR R4                    TOTAL PASTURE ET
      M242 + M421
412EXPR R4                    SHALLOW STORE - TREES
        M412 - M421 - EVAP*M436
412INTDRR4412117105      11
 1.5 30 .2  0  0  0  0
412INTDRR4412118105  0    1
 1.5 30 .2  0  0  0  0
414EXPR R4                    INFILTRATION
        MAX(0,MIN(M412,M130))
423EXPR R4                    NET RECHARGE
: INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
        M414  + .6 * (MIN(0,M412+DRY))
420EXPR R4                    DEEP STORE
      M420 + M423 -M422
251EXPR R4                    CUM. NET RECHARGE
      M251 + M423
412EXPR R4                    STORAGE AFTER INFILT & ET
        MAX(-DRY , M412 - M414 + MAX(0,M420))
413EXPR R4                    RUN-OFF
        IF(M412>187,M412-187,0)
241EXPR R4                    CUMULATIVE RUN-OFF LESS EVAP
        M241 + MAX(M413-M115*MAX(.7*EVAP*M12-M421,0),0)
412EXPR R4                    FINAL STORAGE
        M412 - M413
```

```
 ENDPROC
PROC MARCHAPRIL RAIN EVAP NAME
420EXPR R4                  ADD DISCHARGE TO DEEP STORE
      MIN(0,M420) + M442
422EXPR R4                  SURPLUS DEEP STORE
      MAX(0,M420)
412EXPR R4                  ADD RAIN MARCH
      M412+ M422 + M11*.9*RAIN
242EXPR R4                  TOTAL PASTURE ET
     M242 + M421
412EXPR R4                  SHALLOW STORE - TREES MARCH
      M412 - M421 - EVAP*M436
412INTDRR4412117105    11
 1.5 30 .2  0  0  0  0
412INTDRR4412118105  0    1
 1.5 30 .2  0  0  0  0
414EXPR R4                  INFILTRATION
      MAX(0,MIN(M412,M130))
423EXPR R4                  NET RECHARGE
: INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
      M414  + .6 * (MIN(0,M412+DRY))
420EXPR R4                  DEEP STORE
     M420 + M423 -M422
251EXPR R4                  CUM. NET RECHARGE
     M251 + M423
412EXPR R4                  STORAGE AFTER INFILT & ET
      MAX(-DRY , M412 - M414 + MAX(0,M420))
413EXPR R4                  RUN-OFF
      IF(M412>187,M412-187,0)
241EXPR R4                  CUMULATIVE RUN-OFF LESS EVAP
      M241 + MAX(M413-M115*MAX(.7*EVAP*M12-M421,0),0)
412EXPR R4                  FINAL STORAGE
      M412 - M413
 ENDPROC
 MONTH      .056 ; .037 ;  1  ; SEPTEMBER
 MONTH      .031 ; .054 ;  1  ; OCTOBER
 MONTH      .020 ; .067 ; .93 ; NOVEMBER
 MONTH      .005 ; .083 ; .74 ; DECEMBER
 MONTH      .008 ; .090 ; .37 ; JANUARY
 MONTH      .012 ; .077 ; .07 ; FEBRUARY
 MARCHAPRIL .010 ; .068 ;       MARCH
 MARCHAPRIL .029 ; .044 ;       APRIL
245COPY   412               END OF APRIL SHALLOW STORAGE
 MONTH      .068 ; .030 ; .07 ; MAY
 MONTH      .103 ; .023 ; .37 ; JUNE
 MONTH      .105 ; .023 ; .74 ; JULY
 MONTH      .082 ; .029 ; .93 ; AUGUST
241EXPR R4                  RUN-OFF ADJUSTED FOR LAKES
:For cells in lakes, remove annual evaporation (M22 has width of water surface)
    M241-25/1000*.7*M12*M22
:sum run-off over catchment and print to file SF.Y2
150OVROUT 241                SF.Y2
244EXPR R4                  STORAGE LOSS
    187 - M440 - M412
150OVROUT 244                SL.Y2
252INTDRR4251117105    12       FINAL DEEP DRAINAGE
20. 4 0 0 0 0
253 254
```

```
252INTDRR4254118105       2          FINAL DEEP DRAINAGE
20. 4 0 0 0 0
-253 254
447EXPR R4                        FINAL +VE DEEP DRAINAGE
        IF(M252 > 0,M252,0)
150OVROUT 251                       NR.Y2
150OVROUT 447                       DD.Y2
  END
```

7.2.3 CONTENTS OF PWLMY3.DAT

Because the storage loss in the year 2 simulation is usually significant, a third year is simulated with soil moisture starting at the final values for year 2. The storage loss in the year 3 simulation is usually acceptably small, as reported in file SL.Y3. The third year simulation of deep groundwater discharge is practically the same as for the second year, but streamflow is markedly different. If further convergence to the steady state was required, PWMLY3.DAT should be run again.

```
SET DRY 20
: COMPUTE CAPACITY OF SITE TO ACCEPT INFILTRATION IF NOT DISCHARGE
442EXPR R4                        POTENTIAL RECHARGE & DISCHARGE
: DISCH< =0, SURP RECH - NET RECH + (-VE) DISCH, ELSE +VE DISCH
 IF(M252< =0,M254 - M251 + M252 , M252)
440EXPR I2                        INITIAL STORAGE LOSS
        187-M412
420EXPR R4                         INITIAL DEEP STORAGE
 0
251COPY   420                      CUM. NET RECHARGE
241COPY   420                      INITIAL CUMULATIVE RUN-OFF
242COPY   420                      INITIAL PASTURE ET TOTAL
442EXPR R4                        MONTHLY DISCHARGE
        M442/12
PROC MONTH RAIN EVAP GROWTH
420EXPR R4                        ADD DISCHARGE TO DEEP STORE
        MIN(0,M420) + M442
422EXPR R4                        SURPLUS DEEP STORE
        MAX(0,M420)
412EXPR R4                        ADD RAIN & +VE DISCHARGE
        M412+ M422 + M11*.9*RAIN
421EXPR R4                        PASTURE ET
: PASTURE ET CANNOT CAUSE STORE TO BECOME LESS THAN -20
       MAX(0, MIN(M412+DRY, EVAP*GROWTH*M439))
242EXPR R4                        TOTAL PASTURE ET
      M242 + M421
412EXPR R4                         SHALLOW STORE - TREES
        M412 - M421 - EVAP*M436
412INTDRR4412117105       11
 1.5 30 .2  0  0  0  0
412INTDRR4412118105  0    1
 1.5 30 .2  0  0  0  0
414EXPR R4                        INFILTRATION
        MAX(0,MIN(M412,M130))
423EXPR R4                        NET RECHARGE
: INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
        M414  + .6 * (MIN(0,M412+DRY))
420EXPR R4                        DEEP STORE
      M420 + M423 -M422
251EXPR R4                        CUM. NET RECHARGE
```

```
      M251 + M423
412EXPR R4                    STORAGE AFTER INFILT & ET
        MAX(-DRY , M412 - M414 + MAX(0,M420))
413EXPR R4                    RUN-OFF
        IF(M412>187,M412-187,0)
241EXPR R4                    CUMULATIVE RUN-OFF LESS EVAP
        M241 + MAX(M413-M115*MAX(.7*EVAP*M12-M421,0),0)
412EXPR R4                    FINAL STORAGE
        M412 - M413
 ENDPROC
PROC MARCHAPRIL RAIN EVAP NAME
420EXPR R4                    ADD DISCHARGE TO DEEP STORE
        MIN(0,M420) + M442
422EXPR R4                    SURPLUS DEEP STORE
        MAX(0,M420)
412EXPR R4                    ADD RAIN MARCH
        M412+ M422 + M11*.9*RAIN
242EXPR R4                    TOTAL PASTURE ET
      M242 + M421
412EXPR R4                    SHALLOW STORE - TREES MARCH
        M412 - M421 - EVAP*M436
412INTDRR4412117105     11
 1.5 30 .2  0  0  0  0
412INTDRR4412118105  0     1
 1.5 30 .2  0  0  0  0
414EXPR R4                    INFILTRATION
        MAX(0,MIN(M412,M130))
423EXPR R4                    NET RECHARGE
: INFILTRATION + .6 OF EXCESS ET ON SHALLOW STORE
        M414  + .6 * (MIN(0,M412+DRY))
420EXPR R4                    DEEP STORE
      M420 + M423 -M422
251EXPR R4                    CUM. NET RECHARGE
      M251 + M423
412EXPR R4                    STORAGE AFTER INFILT & ET
        MAX(-DRY , M412 - M414 + MAX(0,M420))
413EXPR R4                    RUN-OFF
        IF(M412>187,M412-187,0)
241EXPR R4                    CUMULATIVE RUN-OFF LESS EVAP
        M241 + MAX(M413-M115*MAX(.7*EVAP*M12-M421,0),0)
412EXPR R4                    FINAL STORAGE
        M412 - M413
 ENDPROC
 MONTH      .056 ; .037 ;  1  ; SEPTEMBER
 MONTH      .031 ; .054 ;  1  ; OCTOBER
 MONTH      .020 ; .067 ; .93 ; NOVEMBER
 MONTH      .005 ; .083 ; .74 ; DECEMBER
 MONTH      .008 ; .090 ; .37 ; JANUARY
 MONTH      .012 ; .077 ; .07 ; FEBRUARY
 MARCHAPRIL .010 ; .068 ;       MARCH
 MARCHAPRIL .029 ; .044 ;       APRIL
245COPY   412                 END OF APRIL SHALLOW STORAGE
 MONTH      .068 ; .030 ; .07 ; MAY
 MONTH      .103 ; .023 ; .37 ; JUNE
 MONTH      .105 ; .023 ; .74 ; JULY
 MONTH      .082 ; .029 ; .93 ; AUGUST
: SAVE FINAL SHALLOW STORE
246SWAP   412
```

```
241EXPR R4                    RUN-OFF ADJUSTED FOR LAKES
:For cells in lakes, remove annual evaporation (M22 has width of water surface)
    M241-25/1000*.7*M12*M22
150OVROUT 241                   SF.Y3
243INTDRI4241117   0   10        STREAMFLOW
243INTDRI4243118   0   0         STREAMFLOW
244EXPR R4                    STORAGE LOSS
    187 - M440 - M246
150OVROUT 244                   SL.Y3
252INTDRR4251117105     12         FINAL DEEP DRAINAGE
20. 4 0 0 0 0
253 254
252INTDRR4254118105     2          FINAL DEEP DRAINAGE
20. 4 0 0 0 0
-253 254
447EXPR R4                    FINAL +VE DEEP DRAINAGE
     IF(M252>0,M252,0)
150OVROUT 251                   NR.Y3
150OVROUT 447                   DD.Y3
  END
```

7.2.5 CONTENTS OF SAVORIG.DAT

This command file is used to copy maps that will be changed in 'PLANT.DAT' [7.3] and 'REVIEW.BAT' [7.4], enabling comparisons to be made before and after reforestation.

```
303SWAP  123
:TREES GREEN>0
304SWAP  124
:PASTURE LAI
241SWAP  201
:CUMULATIVE RUN-OFF LESS EVAP
242SWAP  202
:TOTAL PASTURE ET
243SWAP  203
:STREAMFLOW
244SWAP  204
:STORAGE LOSS
245SWAP  205
:END OF APRIL SHALLOW STORE
246SWAP  206
:FINAL SHALLOW STORE
251SWAP  211
:NET RECHARGE
252SWAP  212
:FINAL DEEP DRAINAGE
253SWAP  213
:THROUGHFLOW
254SWAP  214
:SURPLUS RECHARGE
255SWAP  215
:SMOOTHED SEEPAGE VOLUME
256SWAP  216
:SMOOTHED DEEP DRAINAGE
257SWAP  217
:SMOOTHED THROUGHFLOW
258SWAP  218
```

```
:SMOOTHED SURPLUS RECHARGE
259SWAP   219
:SEEPAGE AREA
  END
```

7.3 CONTENTS OF PLANT.DAT

Commands used to estimate the amount of reforestation required to minimise discharge and predict the location of reforestation in the catchment.

```
:USE MAPS FROM 'SAVE ORIGINAL' POSITIONS
: To get good correspondence between predicted discharge and reviewed discharge, calculated :greenness must be based on unsmoothed deep groundwater maps.
: To avoid over-fragmenting recommended sites for planting, constrain planting to areas where :smoothed discharge exceeds a specified value, then use unsmoothed maps to plant trees wherever :unsmoothed discharge is greater than zero in the constrained areas.
:
USE MAPS FROM 'SAVE ORIGINAL' POSITIONS
: PLANT CELLS THAT ARE PASTURE AND WHERE SMOOTHED DISCHARGE > 15
421EXPR I2                    PLANTED TREE CRITERION
 IF(M124=0 OR M216<15,0,1)
332INTDRR4212117105     13        PLANTED DISCHARGE
20. 4 0 .3  0 0 0 0
213 214 421 331
332INTDRR4212118105     3         PLANTED DISCHARGE
20. 4 0 .3  0 0 0 0
-213 214 421 331
333EXPR R4                    PLANTED TREE GREENNESS
:Tree must use required g/w + total pasture ET + run-off
 IF(M331>0,(M331+M202+M201)  :
:compare to use by nat. veg i.e. total rain less interception less summer stress
 /(.5*M11)  :
: greenness relative to natural veg
  *(.0095*M11+11.5),0)
150OVROUT 125    1332            PD.OVR
150OVROUT 333                    PG.OVR
150OVROUT 421                    PA.OVR
  END
346EXPR R4                    PLANTED TREE GREENNESS
 : REQD NEW MIN STORE TO GIVE NET RECHARGE = DRAW ON DEEP G/W
 IF(M341>0,(M341+20+.83*M258+M130*6+M256)  :
: greenness relative to natural veg
  *(.0095*M11+11.5)/(.8*.625*.85*1.5)/M11,0)
  END
```

7.4 CONTENTS OF REVIEW.BAT

```
CALL PMIN NEWPAST.DAT DUMMY %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMYS.DAT ZZ.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMY2.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN PWLMY3.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
CALL PMIN SMDISCH.DAT Y2.OUT %1%2
RASCAL < PMIN.DAT
COPY ??.Y? ??TR%2.Y?
COPY ??.SM ??TR%2.SM
DEL ??.Y?
DEL ??.SM
```

7.6 CONTENTS OF REVEWALL.BAT

```
CALL REVIEW 01          [7.4]
CALL REVIEW 02
CALL REVIEW 03
CALL REVIEW 04
CALL REVIEW 05
CALL REVIEW 09
CALL REVIEW 11
CALL REVIEW 34
CALL REVIEW 36
CALL REVIEW 37
CALL REVIEW 38
CALL REVIEW 39
CALL REVIEW 42
CALL REVIEW 43
CALL REVIEW 44
CALL REVIEW 47
CALL REVIEW 51
CALL REVIEW 52
```

The PLANT and REVIEW processes are only applied to catchments containing pasture.

8. CONVERT RASTER MAPS TO POLYGONS FOR PRESENTATION IN MICROSTATION

8.1 CONTENTS OF CLASS.IN

HEL01		
CLASS.DAT	[8.1.1]	For use with subcatchment projects (Seepage & Sites for Planting)
:CLASS2.DAT	[8.1.2]	When input file is PSE80 (Native forest)
OUT.PRN		
N		
Y		

8.1.1 CONTENTS OF CLASS.DAT

```
425EXPR                       CLASSED SEEPAGE
IF(M216>15 & M216<=30,1,          :SEEPAGE 15-30 CU.M/YR
IF(M216>30 & M216<=75,2,          :SEEPAGE 30-75 CU.M/YR
IF(M216>75,3,                 :SEEPAGE >75 CU.M/YR
-99)))
427EXPR                       PROPOSED SITES FOR PLANTING
```

```
IF(M333 > 0,1,-99)
  END
```

8.1.2 CONTENTS OF CLASS2.DAT

```
426EXPR                          ORIGINAL TREE COVER
IF(M303 > 0 & M304=0,1,                :NATIVE FOREST
IF(M303 > 0 & M304 > 0,2,              :SCATTERED PADDOCK TREES
-99))
  END
```

8.3.2 CONTENTS OF MICORSTATION MACRO (HELDRAW.BAS) TO PLOT MAPS OF RESULTS

This Macro is run in the design file 'HELBASE.DGN' to create a series of plots for Maps Appendix 4A and 4B. All the correct reference files levels and displays must be turned on in View 5 before running. It is important to close all tool boxes before running this macro, otherwise it may not run properly.

```
' Helena catchment plotting
' choose levels to show drawing, create plot file,
' step through all drawing positions

Sub main
   Dim startPoint As MbePoint
   MbeSendCommand "LOCK FENCE VOID OUTSIDE "
  Coordinates are in master units
   startPoint.x = 421400.000000#
   startPoint.y = 6466000.00000#
   startPoint.z = 0.000000#
   plotpair "a2", "2", startPoint
   startPoint.x = 427000.000000#
   startPoint.y = 6470200.000000#
   startPoint.z = 0.000000#
   plotpair "b1", "3", startPoint
   startPoint.x = 430200.000000#
   startPoint.y = 6460800.000000#
   startPoint.z = 0.000000#
   plotpair "b3", "1", startPoint
   startPoint.x = 434600.000000#
   startPoint.y = 6469300.000000#
   startPoint.z = 0.000000#
   plotpair "c1", "4", startPoint
   startPoint.x = 434600.000000#
   startPoint.y = 6463300.000000#
   startPoint.z = 0.000000#
   plotpair "c2", "4", startPoint
   startPoint.x = 441000.000000#
   startPoint.y = 6469300.000000#
   startPoint.z = 0.000000#
   plotpair "d1", "3", startPoint
   startPoint.x = 438600.000000#
   startPoint.y = 6466000.000000#
   startPoint.z = 0.000000#
   plotpair "d2", "2", startPoint
   startPoint.x = 447200.000000#
   startPoint.y = 6471500.000000#
   startPoint.z = 0.000000#
   plotpair "e1", "2", startPoint
   startPoint.x = 446500.000000#
   startPoint.y = 46465000.000000#
```

```
    startPoint.z = 0.000000#
    plotpair "e2", "1", startPoint
    startPoint.x = 454300.000000#
    startPoint.y = 6463300.000000#
    startPoint.z = 0.000000#
    plotpair "f2", "3", startPoint
    startPoint.x = 451500.000000#
    startPoint.y = 6443300.000000#
    startPoint.z = 0.000000#
    plotpair "f4", "2", startPoint
    startPoint.x = 458500.000000#
    startPoint.y = 6443300.000000#
    startPoint.z = 0.000000#
    plotpair "g4", "1", startPoint
    startPoint.x = 460500.000000#
    startPoint.y = 6436000.000000#
    startPoint.z = 0.000000#
    plotpair "g5", "1", startPoint
end sub
sub plotpair(sheet as string, layer as string,startPoint As MbePoint)
    Dim point As MbePoint
'   Turn on levels in helframe.dgn for series 1
    MbeSendKeyin "reference levels off"
    MbeSendKeyin "frame"

    MbeSendKeyin "1-63"

'   Send a data point to the current command
    point.x = startPoint.x
    point.y = startPoint.y
    point.z = startPoint.z
    MbeSendDataPoint point, 5%
'   Turn on levels in helframe.dgn for series 1
    MbeSendKeyin "reference levels on"
    MbeSendKeyin "frame"

    MbeSendKeyin layer + "0," + layer + "3," + layer + "4"

'   Send a data point to the current command
    point.x = startPoint.x
    point.y = startPoint.y
    point.z = startPoint.z
    MbeSendDataPoint point, 5%

'   Clip boundaries for sheet, then set fence for plot
    setclip startPoint

    MbeSendKeyin "reference display off"
    MbeSendKeyin "plant"
'   Turn on levels in helframe.dgn for series 1
    MbeSendKeyin "reference levels on"
    MbeSendKeyin "frame"

    MbeSendKeyin layer + "1"

'   Send a data point to the current command
    point.x = startPoint.x
    point.y = startPoint.y
```

```
   point.z = startPoint.z
   MbeSendDataPoint point, 5%

   MbeSendKeyin "uc=c:\proj\helena\mdl\dgn\ucm\autoplot"
   FileCopy "c:\plots\helbase.000", "c:\plots\" + sheet + "d.000"

' Turn on levels in helframe.dgn for series 1
   MbeSendKeyin "reference levels off"
   MbeSendKeyin "frame"

   MbeSendKeyin layer + "1"

' Send a data point to the current command
   point.x = startPoint.x
   point.y = startPoint.y
   point.z = startPoint.z
   MbeSendDataPoint point, 5%
' Turn on levels in helframe.dgn for series 1
   MbeSendKeyin "reference levels on"
   MbeSendKeyin "frame"

   MbeSendKeyin layer + "2"

' Send a data point to the current command
   point.x = startPoint.x
   point.y = startPoint.y
   point.z = startPoint.z
   MbeSendDataPoint point, 5%

   MbeSendKeyin "reference display on"
   MbeSendKeyin "plant"
   MbeSendKeyin "uc=c:\proj\helena\mdl\dgn\ucm\autoplot"
   FileCopy "c:\plots\helbase.000", "c:\plots\" + sheet + "p.000"
end sub
sub setclip(startPoint As MbePoint)
   Dim point As MbePoint, point2 As MbePoint

   MbeSendCommand "PLACE FENCE"

   point.x = startPoint.x - 437.000000#
   point.y = startPoint.y - 427.000000#
   point.z = startPoint.z
   MbeSendDataPoint point, 5%

   point.x = startPoint.x + 7437.000000#
   point.y = startPoint.y + 4427.000000#
   point.z = startPoint.z
   MbeSendDataPoint point, 5%
   MbeSendKeyin "REFERENCE CLIP BOUNDARY tree"
   MbeSendKeyin "REFERENCE CLIP BOUNDARY top"
   MbeSendKeyin "REFERENCE CLIP BOUNDARY scbndy"
   MbeSendKeyin "REFERENCE CLIP BOUNDARY seep"
   MbeSendKeyin "REFERENCE CLIP BOUNDARY cont"
   MbeSendKeyin "REFERENCE CLIP BOUNDARY plant"

   MbeSendCommand "PLACE FENCE"
   point.x = startPoint.x - 840.000000#
   point.y = startPoint.y - 1370.000000#
```

```
   point.z = startPoint.z
   MbeSendDataPoint point, 5%

   point.x = startPoint.x + 7560.000000#
   point.y = startPoint.y + 4570.000000#
   point.z = startPoint.z
   MbeSendDataPoint point, 5%

End Sub
```

8.4.1 CONTENTS OF TABALL.BAT

CALL TABIN SFBS Y3 1	[8.4.1.1]	Streamflow Base (One way table)
CALL TABIN DDBS Y3 1	[8.4.1.1]	Deep Discharge Base (One way table)
CALL TABIN PSBS SM 2	[8.4.1.1]	Streamflow Base (Two way table)
CALL TABIN SLBS Y3 1	[8.4.1.1]	Storage loss Base (One way table)
CALL TABIN PDBS OVR 2	[8.4.1.1]	Predicted discharge (Two way table)
CALL TABIN PSTR SM 2	[8.4.1.1]	Streamflow Base (One way table)
CALL TABIN SFTR Y3 1	[8.4.1.1]	Streamflow Treated (One way table)

8.4.1.1 CONTENTS OF TABIN.BAT

Prepares input data file and runs program TABLIST

ECHO %1#.%2 > TABIN.DAT		The template for OVROUT file names
ECHO HELLST.DAT >> TABIN.DAT	[8.4.1.2]	
ECHO *R5*%1.TXT >> TABIN.DAT		Output filename to be read by Excel
ECHO %3 >> TABIN.DAT		Select one-way or two-way table
ECHO Y >> TABIN.DAT		Update default file names
TABLIST < TABIN.DAT		

8.4.1.2 CONTENTS OF HELLST.DAT

In the actual file, each entry is on a new line. The number sequence is that used in the spreadsheet, that reflects the drainage structure of the catchment. X provides a break between data for different sheets within the spreadsheet workbook.

01 02 101 03 102 11 09 X 122 13 121 08 05 07 06 04 421 422 X 43 44 48 49 45 40 411 412 50 47 X 14 15 16 35 39 38 37 34 36 33 17 X 29 30 26 28 27 31 32 25 24 23 X 22 21 20 18 19 59 X 542 541 51 461 462 60 58 55 X 57 56 52 53

8.4.2 CONTENTS OF EXCEL MACRO 'DATAIN'

```
'
' datain Macro
' Macro recorded 27/3/96 by Geoff Mauger
' Modified 17/7/96 by Renee Dixon
' load data from text file generated by program TABLIST (in RASCAL\EXE)
'
' Keyboard Shortcut: Ctrl+d
'
Sub all()
   txtdir = "S:\RID\CSI\HELENA\MDL\XCEL\"
'   txtfile = "ca.TXT"
'   load2 txtdir & txtfile
'     storeOne txtfile, "D", 139
```

```
'   txtfile = "fc.TXT"
'   load2 txtdir & txtfile
'     storeOne txtfile, "D", 140
'   txtfile = "R5sfbs.TXT"
'   load2 txtdir & txtfile
'     storeOne txtfile, "D", 141
'   txtfile = "R5psbs.TXT"
'   load2 txtdir & txtfile
'     storeOne txtfile, "D", 144
'     storeOne txtfile, "E", 143
'   txtfile = "R5slbs.TXT"
'   load2 txtdir & txtfile
'     storeOne txtfile, "D", 145
'  txtfile = "rain.TXT"
'    load2 txtdir & txtfile
'    storeOne txtfile, "D", 155
'    storeOne txtfile, "C", 138
   txtfile = "RV5pa.TXT"
    load2 txtdir & txtfile
    storeOne txtfile, "D", 147
   txtfile = "RV5pd.TXT"
     load2 txtdir & txtfile
     storeOne txtfile, "D", 149
     storeOne txtfile, "E", 150
   txtfile = "RV5sftr.TXT"
   load2 txtdir & txtfile
     storeOne txtfile, "D", 154
   txtfile = "RV5pstr.TXT"
   load2 txtdir & txtfile
     storeOne txtfile, "D", 152
     storeOne txtfile, "E", 153

End Sub
Sub storeOne(ByVal txtfile As String, ByVal scol As String, orow)
   cutpaste txtfile, "CAT09", scol, 1, 7, "B", orow
   cutpaste txtfile, "CAT422", scol, 9, 18, "C", orow
   cutpaste txtfile, "CAT47", scol, 20, 29, "C", orow
   cutpaste txtfile, "CAT17", scol, 31, 41, "B", orow
   cutpaste txtfile, "CAT23", scol, 43, 52, "B", orow
   cutpaste txtfile, "CAT59", scol, 54, 59, "D", orow
   cutpaste txtfile, "CAT55", scol, 61, 68, "D", orow
   cutpaste txtfile, "CAT53", scol, 70, 73, "C", orow

End Sub
Sub load2(ByVal strFileName As String)
    Workbooks.OpenText Filename:=strFileName, Origin:= _
       xlWindows, StartRow:=2, DataType:=xlDelimited, TextQualifier _
       :=xlNone, ConsecutiveDelimiter:=True, Tab:=False, Semicolon _
       :=False, Comma:=False, Space:=True, Other:=False, FieldInfo _
       :=Array(Array(1, 1), Array(2, 1), Array(3, 1), Array(4, 1))
 End Sub
Sub cutpaste(ByVal txtfile As String, ByVal xlsheet As String, _
         ByVal scol As String, srow1, srowl, ocol As String, orow)
   Windows(txtfile).Activate
   Range(Cells(srow1, scol), Cells(srowl, scol)).Select
   Selection.Copy
   Windows("HELSUM.XLS").Activate
   Sheets(xlsheet).Select
```

```
  Range(ocol & orow).Select
  Selection.PasteSpecial Paste:=xlAll, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=True
End Sub
```

8.4.3 CONTENTS OF EXCEL MACRO 'PRINTALL'

```
'' Macro1 Macro
' Macro recorded 27/3/96 by Geoff Mauger
' Modified 24/9/96 by Renee Dixon
'
Sub printall()
'   printtabl ("a2:m30")
'   printtabl ("a44:m81")
  printtabl ("a89:m127")
End Sub
Sub Print2(ByVal cat As String, ByVal table As String)
  Sheets(cat).Select
  Range(table).Select
  Selection.PrintOut Copies:=1
End Sub
Sub printtabl(ByVal table As String)
  Print2 "CAT09", table
  Print2 "CAT422", table
  Print2 "CAT47", table
  Print2 "CAT17", table
  Print2 "CAT23", table
  Print2 "CAT59", table
  Print2 "CAT55", table
  Print2 "CAT53", table
End Sub
```