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STREAM AND GROUNDWATER SALINITY LEVELS IN THE SOUTH DANDALUP CATCHMENT OF WESTERN AUSTRALIA

by

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SUMMARY

Results of a stream salinity (Total Dissolved Solids) survey conducted over two years in the South Dandalup Catchment are summarised. Stream salinity during the base-flow period and salinity of water sampled from shallow bores have been used to estimate groundwater salinity throughout the catchment. A research programme which is aimed at quantifying water and salt yield from all sub-catchments within the South Dandalup Catchment is outlined.

INTRODUCTION

There have been numerous reports of increases in stream salinity (Total Dissolved Solids (TDS)) in the south-west of Western Australia following disturbance of the vegetation and these have been summarised by Peck and Hurle (1973). It is generally assumed that increases in stream salinity occur following disturbance of the vegetation because the reduction in permanent canopy reduces evapotranspiration, causing an increase in the proportion of the saline groundwater component of the yield. However, in areas where there has been no accumulation of salts in the profile, a disturbance of the vegetation can have a beneficial effect on water supply. For example, in some western jarrah forest catchments where canopy has been markedly reduced by jarrah dieback, there have been large increases in yield without a significant increase in stream salinity (Havel, 1976). Thus the presence or absence of salt in the soil profile is the major factor determining whether a disturbance of the vegetation will have a detrimental or beneficial effect on water supply.

The impact of a disturbance of the vegetation in any part of a catchment on the quality of water in the reservoir will be determined by—

(1) the quantity and quality of the additional water discharged as a consequence of the disturbance,

(2) the proportion of the total yield which this additional water constitutes,

(3) the quality of the water discharged from other parts of the catchment.

Detailed research into the jarrah forest hydrological cycle is being carried out by Australian and State Government authorities. The principal objective of these studies is to quantify the effect of vegetative disturbance and subsequent rehabilitation on water quality and yield at specific sites within the jarrah forest. Ultimately, however, the effect of a disturbance on any part of a catchment on water quality in the reservoir must be evaluated in the context of the hydrological characteristics of the total catchment.

The South Dandalup Catchment is an important unit in the Perth Metropolitan Water Supply system: the reservoir has a storage capacity of 208 210 000 m^3 which constitutes 41.5% of the total storage capacity of northern jarrah forest Metropolitan Water Supply catchments; annual average water yield is 34 061 000 m^3 which represents 12% of the annual yield of the Metropolitan Water Supply catchments (R. Dartnall, pers. comm.).

There is no evidence that salinity levels in the reservoir are increasing; however, disturbance of the forest vegetation in some other northern jarrah forest catchments has resulted in the discharge of saline groundwater (Shea et al, 1975). The likelihood of disturbance of the vegetation on the South Dandalup Catchment is increasing. *Phytophthora cinnamomi* Rands, a soil-borne fungus which causes mass destruction of the forest (Podger, 1968), is widespread throughout the Catchment and it is planned to extend bauxite mining operations, currently restricted to the western edge of the Darling Range, eastwards onto the Catchment.

In 1973, an extensive stream salinity sampling programme was initiated in the northern jarrah forest to define salt-prone areas. Preliminary results of this survey have been reported (Shea et al, 1975). In this paper, data from two years stream salinity sampling and preliminary results from groundwater sampling within the South Dandalup Catchment are summarised. In addition a research programme to quantify current water and salt yield from all major sub-catchments, and to determine the potential yield of saline water from these sub-catchments, is described.

Catchment characteristics

The South Dandalup Catchment is located 90 km south-east of Perth, on the western boundary (the Darling Fault Scarp) of the Great Plateau of Western Australia (Jutson, 1950) (Figure 1). The Catchment is 341 km^2 in area and is contained within State Forest.

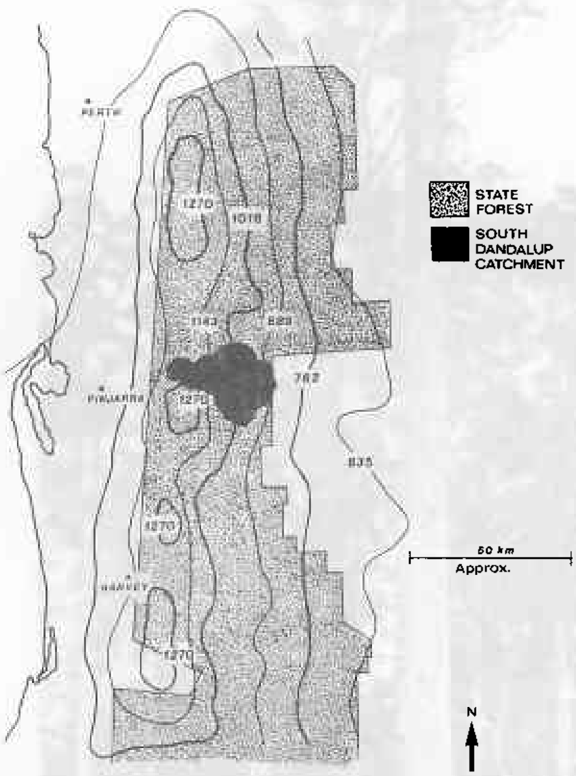

FIGURE 1: Location of the South Dandalup Catchment in relation to the northern jarrah forest and rainfall isohyets (mm)

On passing downstream from east to west in jarrah forest river systems, there is a succession of valley types which reflect different degrees of dissection of the lateritic peneplain (Bettenay and Mulcahy, 1972). In the eastern sections of the Catchment, the valleys are broad and drainage is sluggish. Colluvial deposits of silt and sand occur on the valley floors. The western valleys are steeply incised, particularly on the southern side of the Catchment. In the western edge of the Catchment, the South Dandalup River has dissected the lateritic profile and soils are formed from the original parent material on the valley floors and sides.

Jarrah (*Eucalyptus marginata* Sm.) is the dominant species on the upland freely drained sites throughout the Catchment area. The main associate species is marri (*Eucalyptus calophylla* R.Br.) and the principal understorey component is *Banksia grandis* Willd. with occasional *Persoonia longifolia* R.Br. Logging has occurred in the Catchment continuously over a period of 60 years. Prior to the proclamation of the Forest Act in 1918, clear felling was practised and these areas have regenerated to form dense, relatively uniform pole stands. However, most of the Catchment has subsequently been logged under a selection cut system. In selectively cut areas, trees varying from large over-mature veterans down to saplings are irregularly distributed. In the western valleys, Western Australian blackbutt (*Eucalyptus patens* Benth.) and bullich (*Eucalyptus megacarpa* F. Muell.) form the overstorey. In the eastern valleys, wandoo (*Eucalyptus wandoo* Blakely) and Western Australian flooded gum (*Eucalyptus rudis* Endl.) form a scattered woodland-type forest. The floors of some of these eastern valleys are waterlogged for most of the winter months. No tree cover is present and the vegetation consists principally of dense, shrubby Melaleuca species.

Phytophthora cinnamomi is present in most of the valleys throughout the Catchment. In lowland moisture-gaining sites the disease has progressed to the overstorey mortality stage. Although small infections are present on upland sites, mortality of the overstorey on these sites is rare. The rate of disease development varies on different sites, but the fungus has the potential to kill the majority of the forest vegetation throughout the Catchment.

Annual average rainfall varies from 1311 mm (Dwellingup) in the western section of the Catchment to between 700 and 800 mm (approximation from average rainfalls of Bannister and Duncans Mill) on the eastern Catchment boundary. Total annual average evaporation recorded at Dwellingup is 1598 mm. Prior to damming, the South Dandalup River yielded approximately 13% of precipitation and the weighted average stream salinity was 185 mgl^{-1} (Public Works Department, 1972).

METHODS

Sampling

In the western section of the Catchment, streams were sampled at the entry points to the reservoir. Streams in the eastern section were sampled at the mouths of sub-catchments and micro-catchments, and the main stream was sampled at intervals along its length. Locations of sampling points are shown in Figure 2.

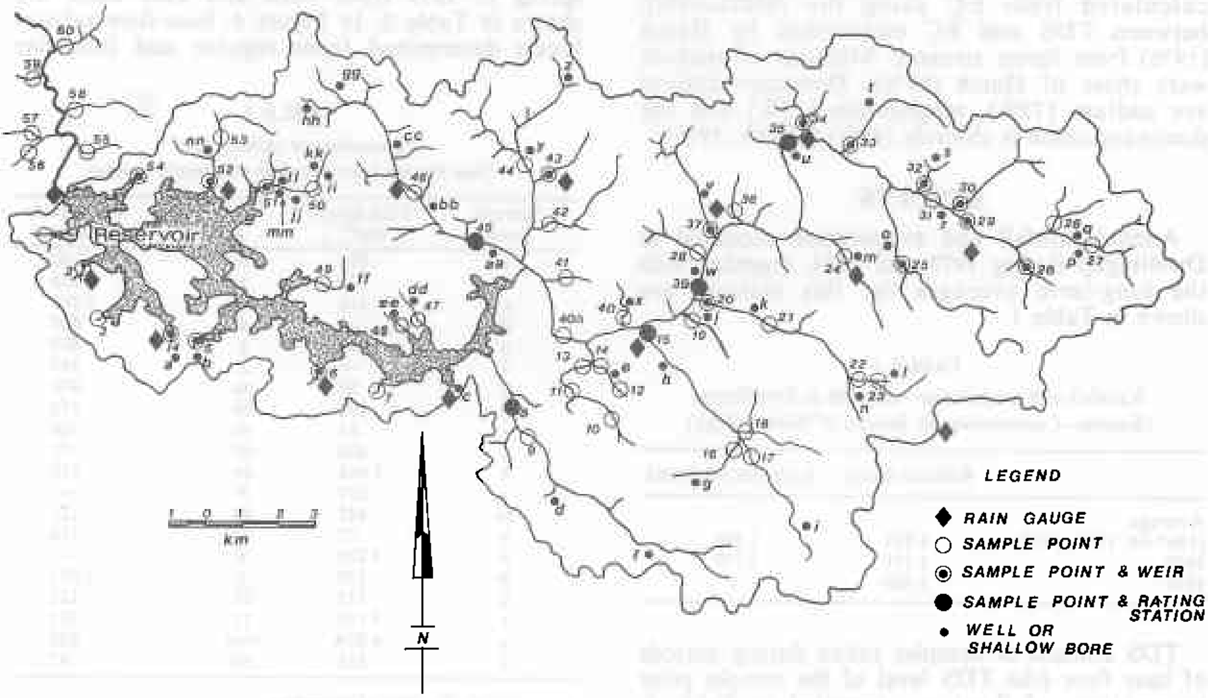

FIGURE 2: Stream, rainfall and groundwater sampling points

Sampling was carried out from July 1973, with the exception of streams in the western section on the north side of the reservoir which were sampled from July 1974. Except for monthly sampling from 19 June 1975 to 4 September 1975, all streams were sampled weekly. From August to December 1974, streams in the eastern third of the catchment were sampled on five occasions at 300 m intervals throughout their lengths.

One disused forestry well in the eastern section of the catchment was sampled weekly from June 1974 to June 1975. In the spring of 1975, additional wells were located from old forestry maps. These were pumped dry and water samples were taken immediately after they had refilled by natural seepage.

The results from the analysis of well water indicated that, particularly in eastern sub-catchments, the groundwater salinity was frequently significantly higher than stream water salinity during periods of base flow. Consequently, a number of shallow, drilled holes were established in selected catchments. The holes were located slightly upslope from valley floors to avoid dilution of the groundwater by surface and sub-surface flow, and were drilled to a depth of approximately 2.5 m. Piezometers, constructed from polyvinyl chloride tubing, were inserted in each hole and sealed with plastic at the soil surface. Samples of the groundwater in the piezometers were taken within twenty-four hours of establishment.

Analysis

Electrical Conductivity (EC) was determined on all samples. TDS measured in mgl^{-1} was calculated from EC using the relationship between TDS and EC established by Hatch (1976) from forest streams. Methods of analysis were those of Hatch (1976). Dominant cations are sodium (72%), magnesium (21%) and the dominant anion is chloride (86%) (Hatch, 1976).

RESULTS

Annual rainfall and evaporation recorded at Dwellingup during 1973 and 1974, together with the long-term averages for this station, are shown in Table 1.

TABLE 1

Rainfall and evaporation recorded at Dwellingup (Source—Commonwealth Bureau of Meteorology)

	Rainfall (mm)	Evaporation (mm)
Average (1967-69, 1971, 1972)	1 311	1 589
1973	1 571	1 530
1974	1 549	—

TDS content of samples taken during periods of base flow (the TDS level of the sample prior to cessation of flow) are recorded in Table 2.

TABLE 2

Stream salinity during base flow

Sample point	TDS levels mgl^{-1}		Sample point	TDS levels mgl^{-1}	
	1973/74	1974/75		1973/74	1974/75
1	122	129	31	957	1 629
2	130	148	32	511	410
3	138	144	33	ND	1 060
4	172	156	34	1 101	743
5	127	151	35	1 935	2 821
6	161	189	36	ND	714
7	153	225	37	ND	ND
8	290	318	38	ND	710
9	423	300	39	ND	ND
10	368	348	40	ND	ND
11	368	415	40a	ND	1 620
12	410	333	41	ND	ND
13	405	354	42	ND	276
14	660	1 436	43	ND	203
15	458	553	44	ND	402
16	259	249	45	ND	ND
17	585	569	46	ND	293
18	315	392	47	ND	ND
19	453	261	48	ND	ND
20	ND	ND	49	ND	ND
21	560	726	50	ND	175
22	395	371	51	ND	ND
23	ND	ND	52	ND	ND
24	334	501	53	ND	91
25	584	714	54	ND	ND
26	262	525	55	ND	242
27	425	572	56	ND	189
29	ND	ND	57	ND	101
30	ND	ND	58	ND	106
30a	329	430	59	ND	158
30b	ND	412	60	ND	186

ND = No Data

Weekly TDS levels of representative streams throughout the catchment are plotted in Figure 3. The TDS levels of water samples taken in the spring of 1975 from wells and bore holes are shown in Table 3. In Figure 4, base-flow salinity levels determined from regular and intensive

TABLE 3

Groundwater salinity data (See Figure 2 for location of sample points)

Sample point	TDS levels mgl^{-1}	Sample point	TDS levels mgl^{-1}
a	193	u	246
b	175	v	1 536
c	116	w	1 346
d	—	x	605
e	460	y	402
f	—	z	597
g	96	aa	474
h	192	bb	172
i	83	cc	168
j	400	dd	171
k	1 968	ee	150
l	397	ff	—
m	342	gg	121
n	77	hh	114
o	3 239	ii	—
p	730	jj	1 051
q	153	kk	122
r	3 148	ll	531
s	4 823	mm	229
t	313	nn	97

— = dry at the time of sampling.

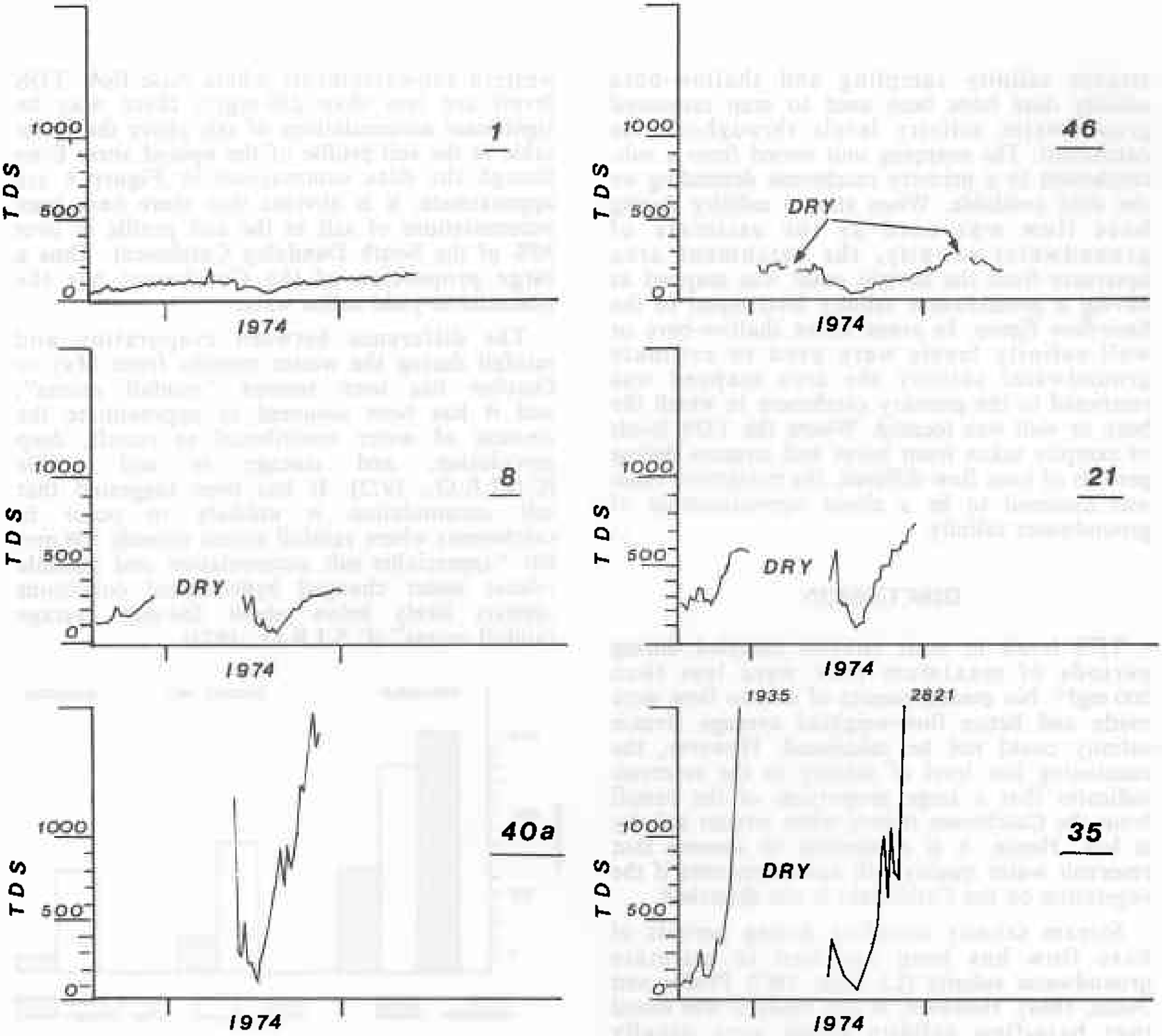

FIGURE 3: Variations in weekly TDS (mgl⁻¹) levels of representative streams in the South Dandalup Catchment

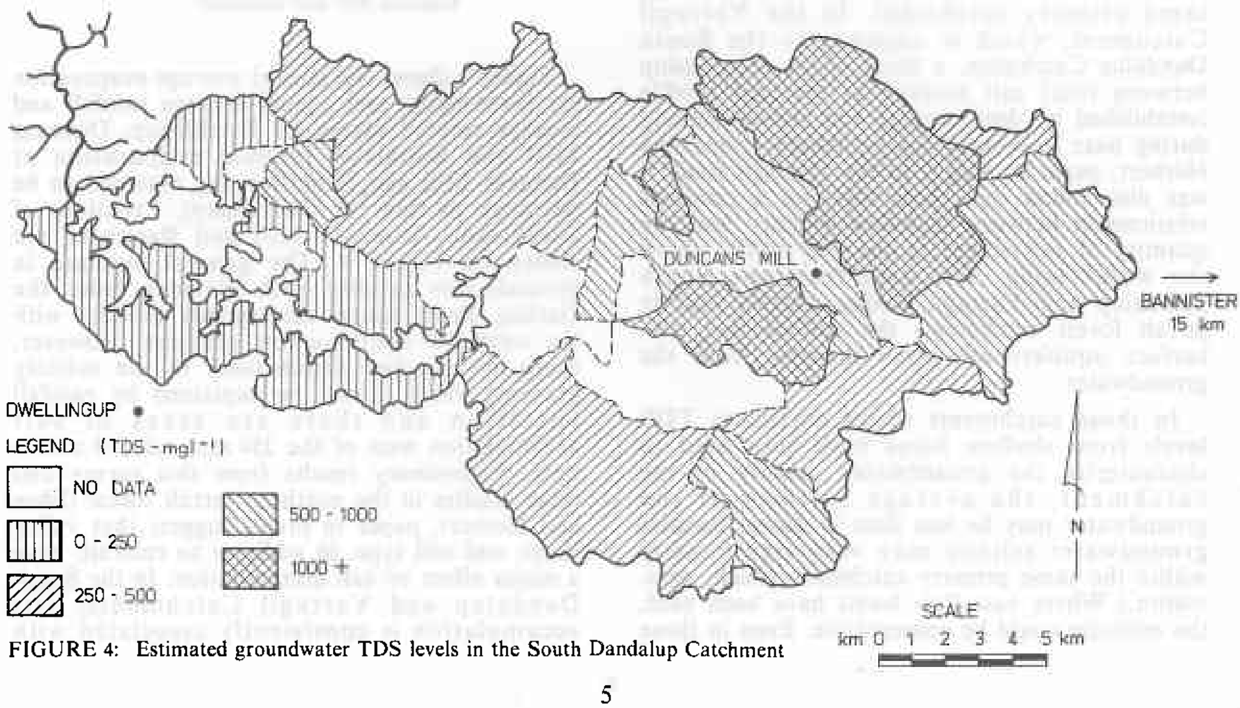

FIGURE 4: Estimated groundwater TDS levels in the South Dandalup Catchment

stream salinity sampling and shallow-bore salinity data have been used to map *estimated* groundwater salinity levels throughout the catchment. The mapping unit varied from a sub-catchment to a primary catchment depending on the data available. When stream salinity during base flow was used as the estimate of groundwater salinity, the catchment area upstream from the sample point was mapped as having a groundwater salinity level equal to the base-flow figure. In areas where shallow-bore or well salinity levels were used to estimate groundwater salinity the area mapped was restricted to the primary catchment in which the bore or well was located. Where the TDS levels of samples taken from bores and streams during periods of base flow differed, the maximum value was assumed to be a closer approximation of groundwater salinity.

DISCUSSION

TDS levels in most streams sampled during periods of maximum flow were less than 200 mgl^{-1}. No measurements of stream flow were made and hence flow-weighted average stream salinity could not be calculated. However, the continuing low level of salinity in the reservoir indicates that a large proportion of the runoff from the Catchment occurs when stream salinity is low. Hence, it is reasonable to assume that reservoir water quality will not deteriorate if the vegetation on the Catchment is not disturbed.

Stream salinity sampling during periods of base flow has been assumed to estimate groundwater salinity (La Sala, 1967; Pinder and Jones, 1969). However, in this study it was found that base-flow salinity levels were usually significantly lower than the salinity of water from bores less than 2 m deep in the valley of the same primary catchment. In the Yarragil Catchment, which is adjacent to the South Dandalup Catchment, a study of the relationship between total salt storage in the soil profile (established by deep coring) and stream salinity during base flow gave similar results (Shea and Herbert, paper in prep.). In the Yarragil study it was also found that there was not a constant relationship between base-flow salinity and the quantity of salt stored in the soil profile above the water table. The data from the South Dandalup and Yarragil studies suggest that in jarrah forest catchments the surface and sub-surface aquifers are often discrete from the groundwater.

In those catchments where maximum TDS levels from shallow bores have been used to characterize the groundwater salinity of the catchment, the average salinity of the groundwater may be less than is shown because groundwater salinity may vary significantly within the same primary catchment (Peck, pers. comm.) Where base-flow levels have been used, the estimate could be conservative. Even in those western sub-catchments where base-flow TDS levels are less than 250 mgl^{-1}, there may be significant accumulations of salt above the water table in the soil profile of the upland sites. Even though the data summarised in Figure 4 are approximate, it is obvious that there have been accumulations of salt in the soil profile in over 50% of the South Dandalup Catchment. Thus a large proportion of the Catchment has the potential to yield saline water.

The difference between evaporation and rainfall during the winter months from May to October has been termed "rainfall excess", and it has been assumed to approximate the amount of water contributed to runoff, deep percolation, and storage in soil profile (C.S.I.R.O., 1972). It has been suggested that salt accumulation is unlikely to occur in catchments where rainfall excess exceeds 508 mm but "appreciable salt accumulation and possible release under changed hydrological conditions appears likely below about 254 mm average rainfall excess" (C.S.I.R.O., 1972).

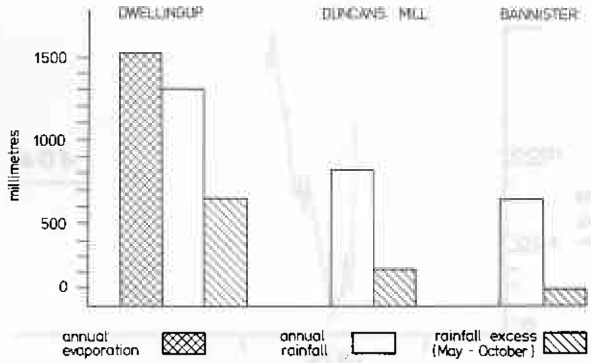

FIGURE 5: Annual average evaporation of Dwellingup, and rainfall and rainfall excess levels of Dwellingup, Duncans Mill and Bannister

Figure 5 shows the annual average evaporation for Dwellingup, and annual average rainfall and average rainfall excess for Dwellingup, Duncans Mill and Bannister (annual evaporation at Duncans Mill and Bannister was assumed to be the same as that for Dwellingup). Locations of Dwellingup, Duncans Mill and Bannister are shown on Figure 4. The general increase in groundwater salinity with distance from the Darling Fault Scarp corresponds broadly with the west-east rainfall-excess gradient. However, there are marked disjunctions in the salinity gradient which cannot be explained by rainfall variation and there are areas of salt accumulation west of the 254 mm rainfall excess level. Preliminary results from this survey and other studies in the northern jarrah forest (Shea and Herbert, paper in prep.) suggest that valley shape and soil type, in addition to rainfall, have a major effect on salt accumulation. In the South Dandalup and Yarragil Catchments, salt accumulation is consistently associated with valleys which have broad floors and moderately sloped sides, or with catchments where the pallid zone clay is heavy textured.

The presence of saline groundwater in sub-catchments with "rainfall excess" greater than 254 mm has important implications. Maintenance of the groundwater component of the yield in potentially saline catchments, at a level which maintains high water quality, is theoretically dependent on evapotranspiration of the rainfall excess so that the groundwater discharge is minimal. The larger the rainfall excess, the higher must be the proportion of the land surface which has permanent canopy. Eastern catchment areas are likely to have more highly saline groundwater but they have a relatively low rainfall excess level (Figure 5). Hence, the degree of disturbance necessary to cause a significant discharge of groundwater is less in catchments with a large rainfall excess than in eastern catchments where the rainfall excess level is low.

FUTURE RESEARCH

It is likely that disturbance of the vegetation in sub-catchments within the South Dandalup Catchment which have a saline groundwater table will cause an increase in stream salinity. However, it is impossible to quantify the impact of a disturbance of the vegetation in any sub-catchment on water quality in the reservoir without data on—

(1) the relationship between degree of canopy disturbance and stream salinity for different site types (this is being investigated by Australian and State Government authorities and has been mentioned in the introduction),

(2) the water and salt yield characteristics of different parts of the landscape within sub-catchments and from different sub-catchments within the total catchment.

The principal objective of the South Dandalup Catchment study is to determine the salt and water yield of the contributing areas of an operational catchment. This will permit the effect of changes in the yield of salt and water from a particular part of the catchment, caused by changes in land use or disease, to be assessed in terms of the yield of salt and water from the total catchment.

Combination "V"-notch weirs or rating stations have been located throughout the catchment (Figure 2). Stage height and maximum flow are recorded at each of these stations three times a week (estimates of total annual flow based on thrice-weekly records of stage height were within 10% of estimates based on continuous recording (Forests Department, unpublished data)). Water samples are taken from flow-measuring sites and other key sample points for conductivity determinations. The major cations (Ca^{++}, Mg^{++}, K^{+} and Na^{+}) and anions (HCO_3^- and Cl^-) are determined from weekly samples taken from five zones of the catchment (sample points 7, 8, 15, 29 and 37). Check analyses of nitrate, sulphate and ammonia levels are carried out periodically on water samples collected from these points. Fourteen rain gauges have been established throughout the catchment and rainfall is recorded weekly. It is planned to determine the Total Soluble Salts content of the soil profile and groundwater in selected sub-catchments by continuous coring to basement rock.

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