6. Results and Analysis

6.1 Introduction

This chapter reports and interprets the principal results from the model runs. The chapter contains two major sub-sections. In the first sub section, there are two main objectives. The first is to explore the ability of variable taxes and a flat tax in meeting the environmental standard. The second is to examine the influence of the cost reducing attributes of the variable tax policy modelled in Chapter 4 on a number of key variables. This is done by defining four additional tax policy scenarios and modelling each. In the second sub-section, sensitivity analyses are undertaken for changes in the assumed storage size, environmental standard, changes in the marginal abatement cost curve and changes in the rate of the flat tax. The interaction of each sensitivity analysis with storage size is also examined.

The chapter begins by describing the assumptions used in the base run of the model, for the five different tax policy scenarios considered. The results of these five model runs are presented in both graphical and tabular form, in section 6.3. Section 6.4 contains sensitivity analyses and section 6.5 summarises the key findings.

6.2 The five base run policies described

The first tax scenario considered is that described in section 4.3. It is given the operational name of MINTAX. The benefits of setting a tax on the basis of spill volume and of allowing free discharge to the river were investigated by altering the model in a number of ways. the resulting variants of the model , have been named as alternative policy scenarios, and are outlined below. The tax costs and the treatment costs associated with each policy scenario are used to compare the relative merits of each characteristic of the tax. Each tax policy is examined for its ability to meet the environmental standard without violating it. Details of the five alternative tax policies are discussed below.

6.2.1 The MINTAX policy

The assumptions in the base run for the MINTAX policy include:

- env. std = 420 mg/L;

- NTR = \$100;
- MAC=100+15×SRPM (where SRPM = tonnes of salt removed per ML); and
- storage capacity = 6000 ML.

The storage size of 6000 ML is used for the base run of the model since this is the closest to the actual situation in the Hunter if all mine storages were combined.

The next three policy scenarios are designed to help illustrate the effects of the three cost-reducing features of the MINTAX policy. These scenarios are the same as the MINTAX scenario with one or more cost-reducing features removed.

6.2.2 The MINTAX-NFSD policy

This is the MINTAX policy, without free salt discharge on the component of salt which is released at 420 mg/L (that is, on the zero impact salt). Free discharge is still allowed when total mine water can be assimilated by the river and the zero tax is invoked.

6.2.3 The MAXTAX policy

This policy is named MAXTAX because it involves the removal of all three cost-reducing features and hence is likely to experience the highest costs of the variable taxes. The MAXTAX policy involves setting the tax on total minewater and not on the spill volume (as is done in MINTAX). It also does not allow free discharge when river assimilative capacity can assimilate all of the minewater, and does not allow free discharge of the "zero impact" salt. It is assumed that mine operators will discharge mine contents whenever the tax rate is lowest (that is, \$100). Although the amount of salt discharged under the MAXTAX policy when tax rate equals \$100 would be expected to be the same as the amount discharged under MINTAX policy when tax rate equals zero, the number of occasions when these events may occur may not be the same. Under the MINTAX policy the "zero impact" salt (ZIS TMW) is added to the assimilative capacity of the river, so that the amount of salt which is allowed to be discharged from the mine is higher. Therefore the decision to discharge mine contents could occur more often under the MINTAX policy than under the MAXTAX policy.

6.2.4 The MAXTAX-FD policy

This policy is equivalent to the MAXTAX policy with the two free discharge tax-reducing features of the MINTAX policy included. First, the mine is permitted to discharge the full contents of mine storage (without paying any tax) when this will not violate the environmental standard. Second, the mine does not pay tax on the "zero impact" salt (that is,., the salt associated with the first 420 mg/L) in their discharges. This policy is designed to allow us to determine the impact of setting the tax on the basis of storage contents (rather than on the spill contents alone) by comparing the results from this policy scenario with the results from the MINTAX policy scenario.

6.2.5 The FLATTAX policy

The flat tax scenario is included to allow us to compare the results of the different variable tax scenarios with the results obtained when a simple flat tax is used to achieve the environmental standard. Particular attention will be given to violations of the environmental standards as well as to the costs incurred by the mines. Under the FLATTAX it is assumed that a storage offers no advantage to mine operators. This is because there is no advantage in storing water until a cheaper tax rate occurs and so storages are not used under the FLATTAX policy. For the base run, the FLATTAX is set at $120/T.

The principal features of the above five tax policy scenarios are summarised in Table 6.1 below.

Table 6.1 Summary of the principal features of the five tax policies

Policy	Free discharges permitted	"Zero impact" salt not taxed	NTR may be adjusted	Tax rate set at
MINTAX	yes	yes	yes	MAC of SR_{std} from spill
MINTAX-NFSD	yes	no	yes	MAC of SR_{std} from spill
MAXTAX	no	no	no	MAC of SR_{std} from total minewater
MAXTAX-FD	yes	yes	no	MAC of SR_{std} from total minewater
FLATTAX	no	no	no	a constant level on all discharges

SR_{std} is the optimal level of salt to remove from minewater to meet the environmental standard
MAC = the marginal cost of abatement
NTR = nominal tax rate

6.3 Results and discussion of the five tax policies

The model was run for the five tax policies described in the previous section. The results obtained from these five model runs are reported and comment upon any observed differences is made . The values obtained for the six key variables listed below are considered in detail:

1. river salinity;
2. assimilative capacity;
3. tax rate;
4. salt discharge;
5. tax costs; and
6. treatment costs.

The section contains plots for each of the variables (over the first two years of the data period), and a summary table which presents the means and standard deviations for the full 15 year period.

6.3.1 River salinity and assimilative capacity

The impacts of each policy on weekly river salinity levels are shown for the two year period, 1980-81 in Figures 6.1 and 6.2 below. In these figures Rsalin0 represents the initial salinity of the river, prior to discharges from the mines, and Rsalin1 is the salinity of the river downstream of the mines, after discharge of minewater. The assimilative capacity of the river is the difference between the environmental standard and the initial river salinity (Rsalin0).

One measure of success of a tax policy is that the assimilative capacity of the river is used, while at the same time minimising any violations of the environmental standard. The MINTAX policy in Figure 6.1 has made good use of this assimilative capacity, however, it has also caused river salinity levels to violate the environmental standard in some periods which had initial river salinity levels less than the standard. Compared to the MINTAX, the MINTAX-NFSD policy does not utilise the assimilative capacity of the river as well, although the difference is fairly small. However, the violations of the standard appear to be slightly fewer, and smaller in magnitude than for the MINTAX.

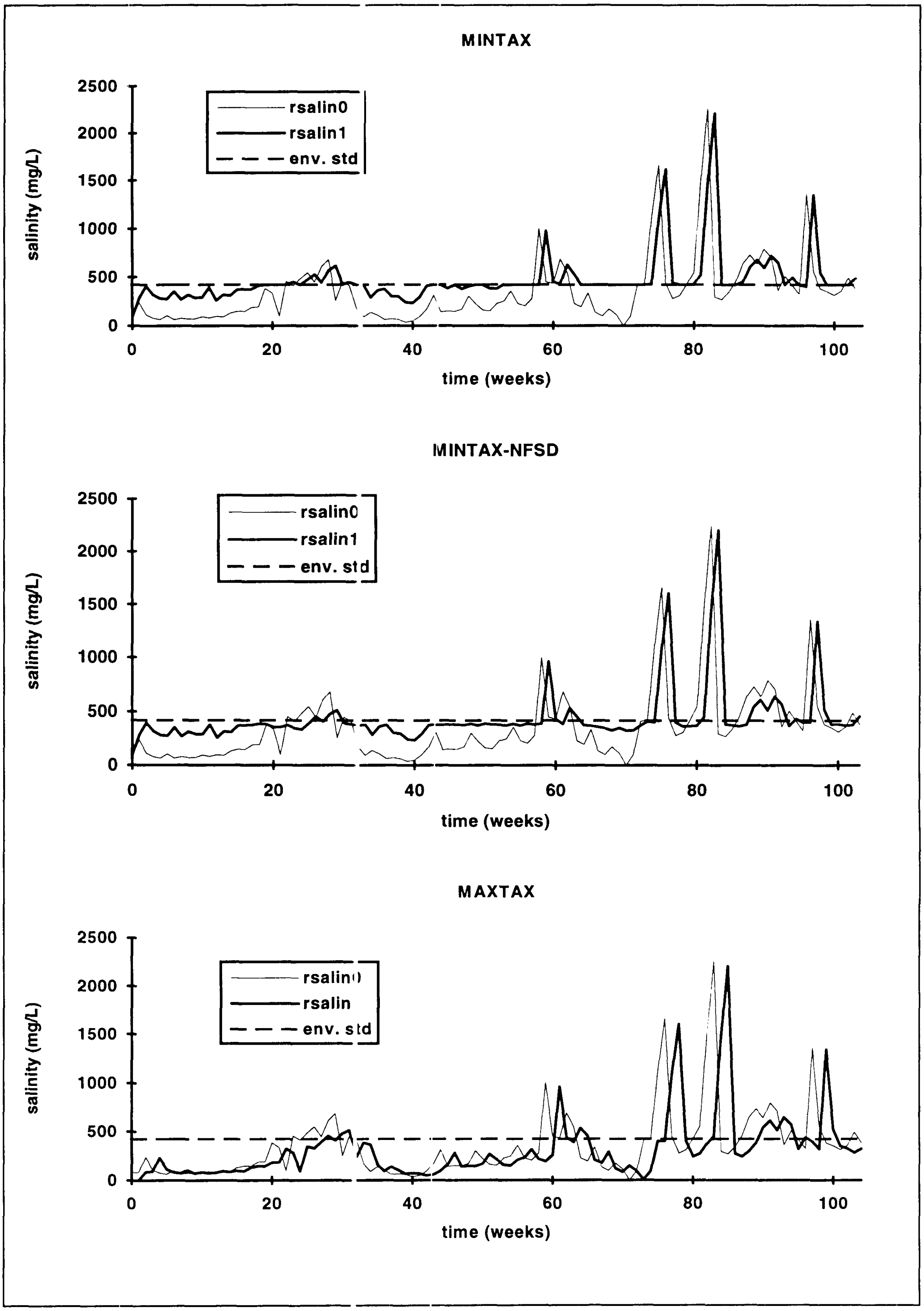

Figure 6.1 Impact of mine discharges on river salinity under MINTAX, MINTAX-NFSD and MAXTAX policies (1980-81)

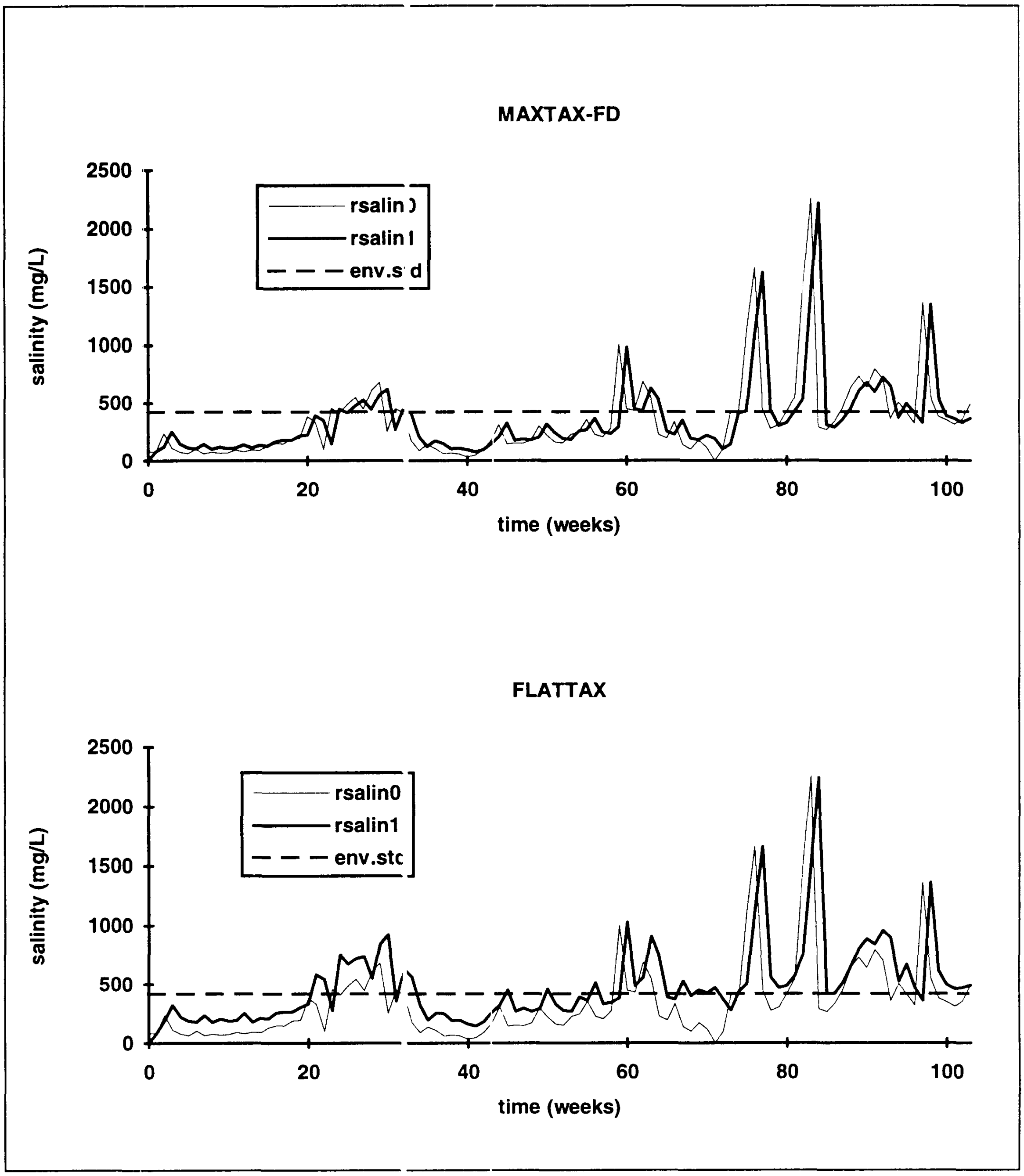

Figure 6.2 Impact of mine discharges on river salinity under MAXTAX-FD and FLATTAX policies (1980-81)

The MAXTAX policy uses very little of the assimilative capacity of the river, keeping the river salinity levels very similar to the initial salinity. In Figure 6.2 the MAXTAX-FD policy (max tax with free salt discharge) allows slightly greater use of the assimilative capacity than the MAXTAX policy, but still rates poorly when compared to the MINTAX results.

A large number of violations of the environmental standard occur under the FLATTAX, with many of the violations large in magnitude. Under the FLATTAX not only is the environmental standard violated, but the assimilative capacity of the river is not utilised. The nature of static flat taxes ensures this result by a set quantity of salt being removed from each megalitre of minewater discharged. For the tax rate of $120/T, 1.33 T/ML of salt is removed.

In all of these diagrams, there is an apparent lagged effect which sometimes causes a violation of the environmental standard when the initial salinity is less than the standard. this occurs when the river salinity is increasing. The reason for this is that the model uses the salinity readings from period (t-1) to set the tax for the current period (t). The lagged effect of Rsalin1 is due to the tax being set on the basis of the previous period salinity. Note also that when discharges occur and Rsalin0 is greater than the env. std, that the effect of the discharge is to lower the river salinity since the discharge water is equal to the env. std and this dilutes the river salinity in the following period.

River salinity under the MINTAX-NFSD policy is lower than for the MINTAX policy because dischargers are taxed on the portion of spill that does not impact on river salinity. The effect is that the salinity of discharges tend to be lower, and so Rsalin1 tends to be lower than in the MINTAX scenario. Similarly, the lagged reaction by dischargers to Rsalin0 results in less severe violations of the environmental standard, because discharges are more dilute.

The tax rate in the MAXTAX policy is set on the basis of the total salt discharge possible (that is., the contents of mine storage), as well as charging for all salt discharges to the river (that is., the salt below the 420 gm/L env. std is not free). The high tax causes the assimilative capacity of the river to be under utilised, with dischargers preferring to treat their discharges rather than paying the tax. In the plot in Figure 6.2 the tax is still set on the basis of full mine discharge potential, but the free discharge makes some discharge of salt more attractive. The impact on river salinity levels of allowing some free discharge is relatively small compared to the impact of setting taxes on the basis of potential mine discharge versus spill discharge. This is demonstrated by comparing the MINTAX plot in Figure 6.1 to the MAXTAX-FD plot in Figure 6.2, where both tax policies involve free salt discharge but one tax rate is set on the basis of spill volume and the other on full potential mine discharge. The impact on river salinity is considerably greater than when free discharge is not allowed under the MINTAX scenario (that is, MINTAX-NFSD), and when free discharge is not allowed as is the case under the MAXTAX scenario.

Figure 6.2 also shows the effect on river salinity of a flat tax rate, where all discharges incur the same tax per unit of salt discharged. This type of tax makes no allowance for assimilative capacity of the river, resulting in regular violations of the environmental standard.

The effect of each tax policy on river salinity levels is driven by the tax rate. Tax rates for each policy are discussed in the following section.

6.3.2 Tax rate

The tax rates which correspond to the river salinity levels shown in the previous section are plotted in Figure 6.3. The tax rates under the MAXTAX and MAXTAX-FD scenarios are high and approaching a flat level of tax. The MAXTAX tax rate is higher than that under the MAXTAX-FD scenario. The MINTAX policy sets the lowest tax in each period, and this rate varies significantly from week to week. The MINTAX-NFSD tax follows a similar pattern to the MINTAX, however, it is slightly higher on average than the MINTAX tax.

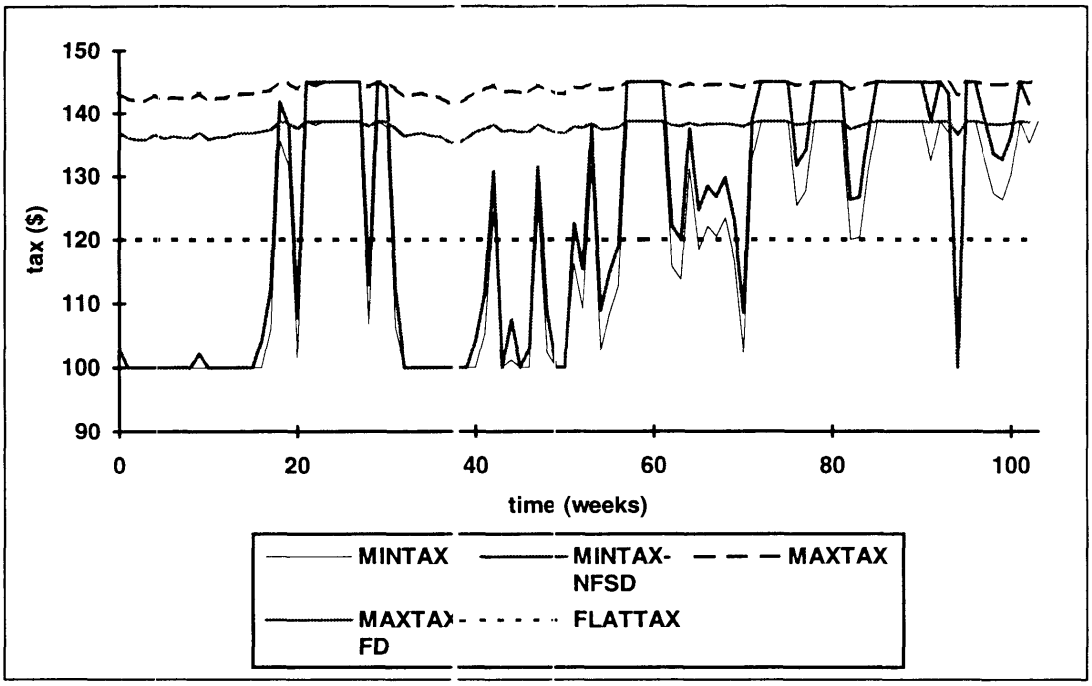

Figure 6.3 Tax rates under the five tax policies (1980-81)

The tax rate is a function of the amount of salt that needs to be removed from the discharge in order for the environmental standard to be satisfied. When the tax rate is set on the basis of spill volume, the amount of salt to be removed is far less than when the total minewater is considered. This is the reason for the high and fairly static tax rates associated with the MAXTAX and MAXTAX-FD policies, and the lower more variable rates of the MINTAX and MINTAX-NFSD tax policies. The tax rate under the MAXTAX policy is higher than that under the MAXTAX-FD policy because, under the latter policy, the volume of water that is discharged by the mine is included in the calculation of the assimilative capacity of the river. Thus the quantity of salt that must be removed is less than the level of salt that must be removed under the MAXTAX scenario.

The tax rate does not equal zero in any week over this two year period. This indicates that the assimilative capacity of the river is never large enough to assimilate all of the minewater available for discharge in any one period. This is due to the fact that a very high stream assimilative capacity would be required to assimilate the contents of a 6000 ML storage which was full. This gives an indication of the difficulty that on-site minewater storages play in this model.

6.3.3 Salt discharge

The salt discharged from the mine under the five tax policies examined is shown in Figure 6.4. The discharge from the MAXTAX policy is considerably lower than the discharge under the MINTAX policy. Under the MINTAX policy salt discharge is always greater than zero, whereas the MAXTAX and the MINTAX-NFSD policies have periods when salt discharge equals zero. This occurs because the free salt discharged to the river under the "zero impact" salt component, occurs even if the assimilative capacity of the river is zero. Therefore, whenever a spill occurs and the assimilative capacity of the river is zero, salt will be discharged to the river at a salinity of 420 mg/L under the MINTAX. The only instance where salt discharge can equal zero is when the on-site storage has space to store water, and the tax is greater than zero.

Under the FLATTAX, salt discharge is high and less variable than under either the MINTAX or the MINTAX-NFSD policies

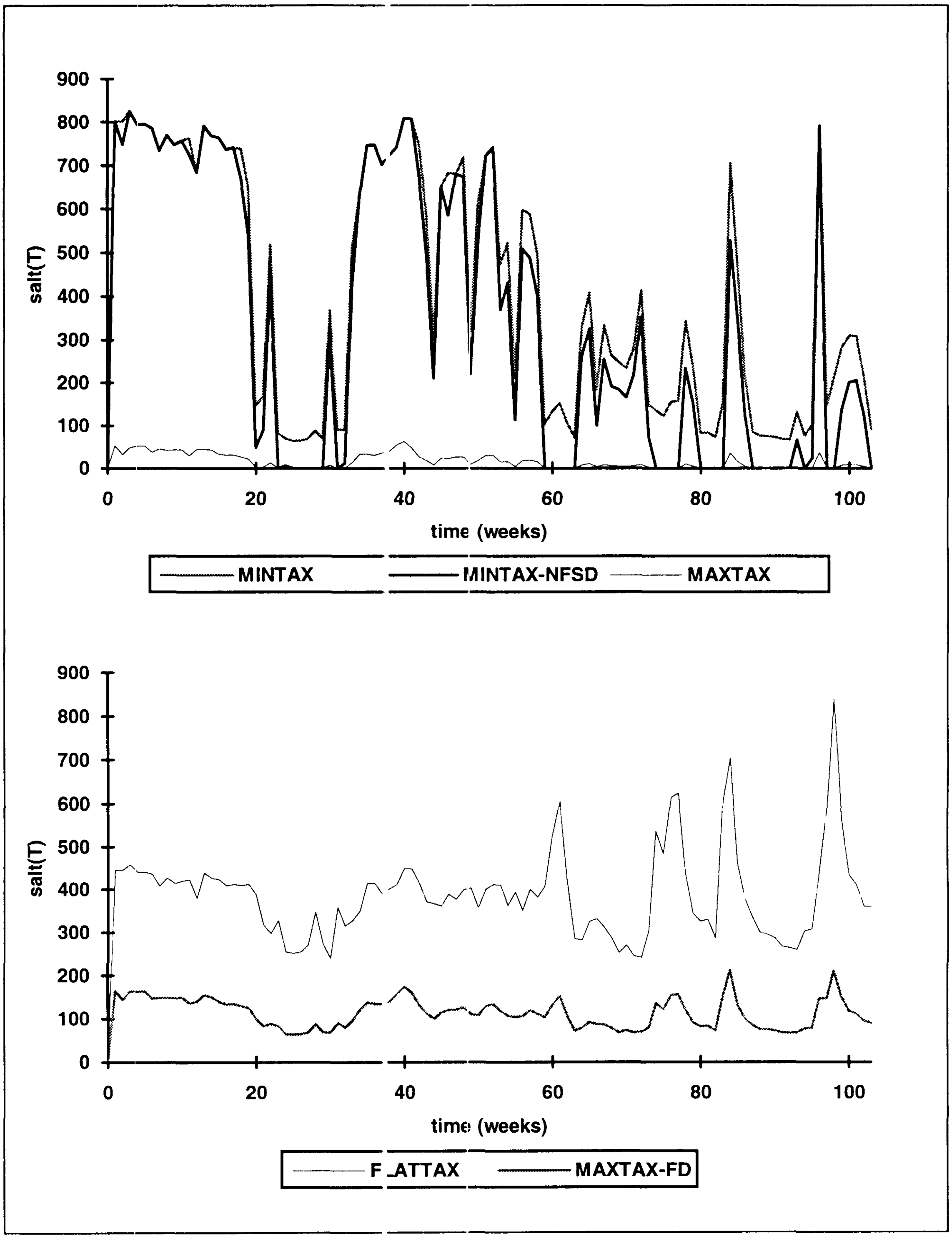

Figure 6.4 Salt discharge from mine under the five tax policies (1980-81)

6.3.4 Tax revenue

The MINTAX policy generates high and variable tax revenue, while the MAXTAX policy produces tax revenues which are consistently low. Although the tax rate is high in the case of the MAXTAX policy, the actual level of salt discharged is low, and so the revenue generated is also low. The MINTAX-NFSD policy displays even greater tax revenue variability than the MINTAX policy. All three policies have periods where zero tax revenue is generated. These periods correspond to periods of either no salt discharge, or discharge of minewater at a salinity of 420 mg/L.

The FLATTAX has tax costs which are on average higher and less variable than the tax costs from any of the other tax policies. The MAXTAX policies display very little difference with both MAXTAX and MAXTAX-FD having relatively low tax costs. The reason for the similarity is because the extra salt discharge which occurs under the MAXTAX-FD policy is free, so that the tax collected from both the MAXTAX-FD and MAXTAX policies are derived from similar levels of salt discharge. A very small difference still occurs, because the tax rate is slightly higher for the MAXTAX policy. The higher tax rate is due to the extra salt which needs to be removed when ZISspill is not allowed, and the salt present in this portion also needs to be removed.

6.3.5 Treatment costs

The MINTAX policy has the lowest treatment costs of the tax policies presented in Figure 6.6. The MAXTAX policy has the highest, and the MINTAX-NFSD treatment costs are only slightly higher than for MINTAX. Both of these latter taxes are set on the basis of the spill volume and have periods where treatment costs equal zero, whereas the flat tax and the taxes set on the total minewater held on-site do not.

The treatment costs for the MAXTAX, FLATTAX and MAXTAX-FD policies all display a similar pattern of variability, with the MAXTAX policy generating the highest treatment costs, followed by the FLATTAX, and finally the MAXTAX-FD policy. All of these policies have treatment costs in every period, since the tax rate is set so high that it is always cheaper to remove some salt than to pay the tax on all salt. Notice that this level of treatment occurs despite the river having positive assimilative capacity (see Figures 6.1 and 6.2).

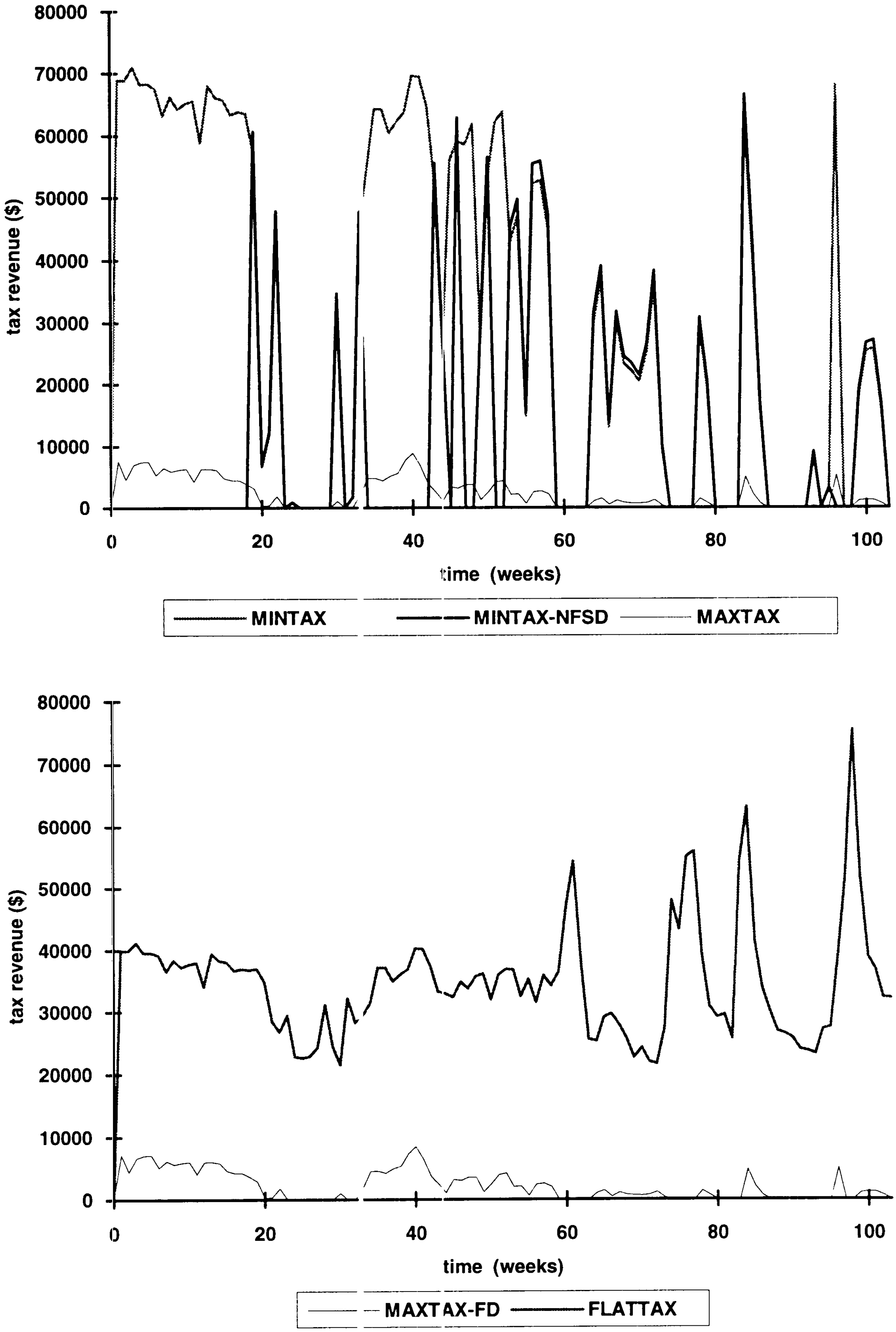

Figure 6.5 Tax revenue generated under five tax policies (1980-81)

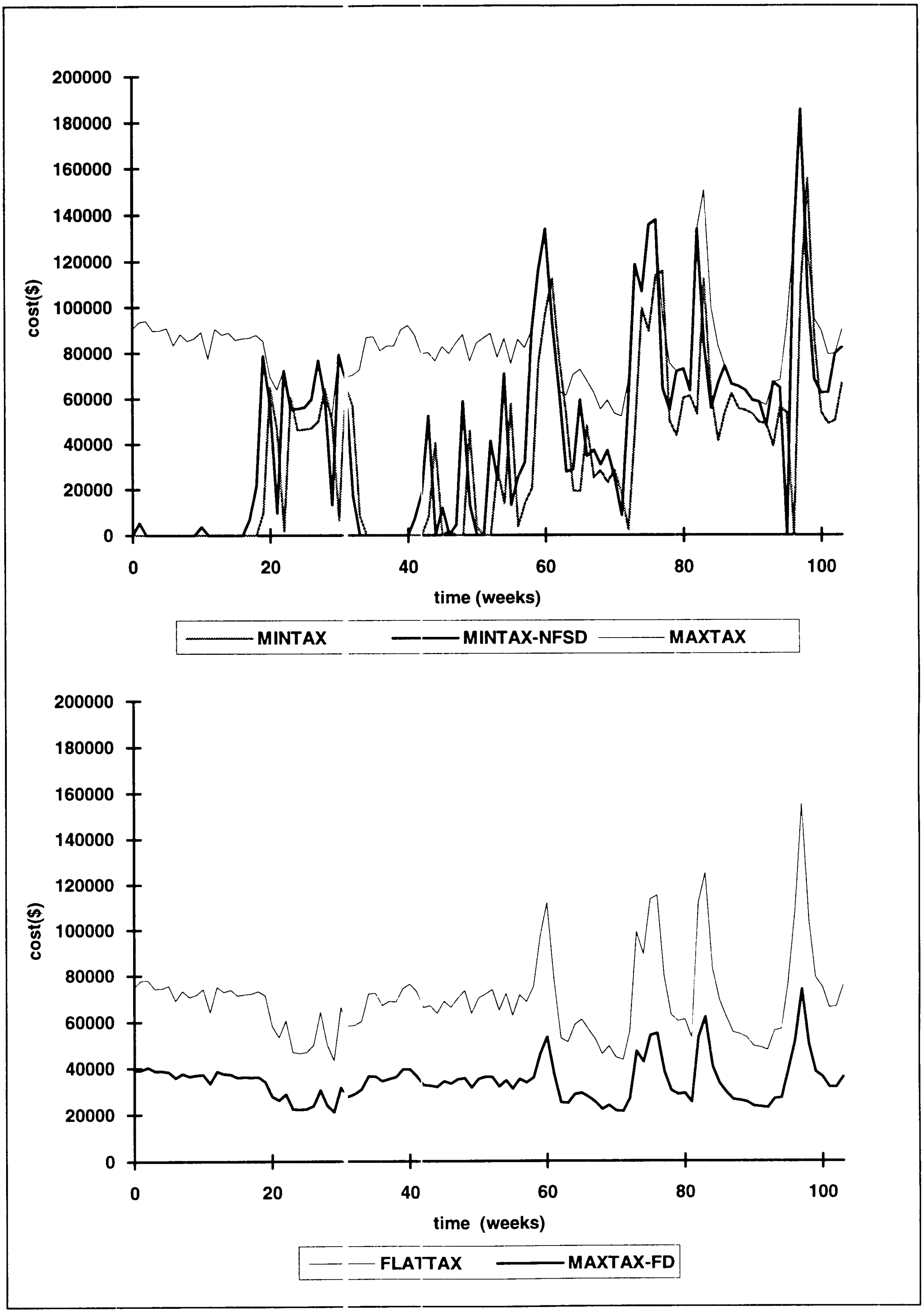

Figure 6.6 Cost of removing salt under the five tax policies (1980-81)

6.3.6 Summary of model results under the five tax policies

Table 6.2 presents the average weekly values from the model for the fifteen years of data available. The "Total Cost" ($/wk) was obtained by adding the average weekly variable costs of treatment to the average weekly tax paid. "Total Variable Cost" ($/wk) is the average value of the variable cost of treatment in each week of the model run. "Tax Revenue" ($/wk) is the average value of the tax paid over each week of the model run. "Salt discharged" (T/wk) is the weekly average of all salt which is discharged from the mine site to the river, it includes free salt and taxed salt alike. The "free salt discharge" (T/wk) is the average weekly quantity of salt which is discharged for free, when tax is zero. It does not include the "zero impact" salt.

The means and standard deviations (in brackets) are presented in Table 6.2. All values have high standard deviations which one would expect given the variability displayed in the figures shown earlier in this chapter.

The MAXTAX policy has the highest total cost associated with it, while the MINTAX policy has the lowest. The costs obtained for the various policies can be compared because all but one of the five policies result in violations of the standard on a similar number of occasions. The one exception to this is the flat tax which is observed to violate the standard on many occasions and therefore does not have the same terms of reference on which comparisons of cost can be made.

It is interesting to note that considerably more money is invested in removal of salt than in paying the tax. Tax revenue is significantly lower than treatment costs for all policies except the flat tax. The flat tax has roughly equal amounts of money spent on tax, as it does on treatment. This is because the tax is set at $120/T, and this represents the mid-point of the marginal abatement cost curve used to set the other taxes.

Table 6.2 Summary of average weekly results from the five policy scenarios (1980-94)

Variable	MINTAX	MINTAX-NFSD	MAXTAX	MAXTAX-FD	FLATTAX
Total cost ($/wk)	76874 (33632)	91777 (40063)	95447 (39029)	79891 (32822)	79629 (30238)
Variable cost ($/wk)	56859 (47310)	69582 (65319)	94098 (39259)	78606 (33045)	39420 (14969)
Tax revenue ($/wk)	20015 (25590)	22195 (28815)	1443 (3507)	1285 (2202)	40208 (15268)
Salt removed (T/wk)	481.83 (394.05)	675.42 (448.35)	769.79 (320.15)	660.70 (275.61)	358.36 (136.09)
Salt discharged (T/wk)*	324.82 (712.26)	231.33 (726.96)	37.29 (679.52)	145.45 (653.63)	447.96 (170.11)
Free salt discharged (T/wk)	27.861 (679.70)	27.861 (679.70)	N/A	26.898 (653.14)	N/A

*Salt discharged includes the quantity recorded as Free salt discharged
Standard deviations are in brackets

The results in Table 6.2 can be used to calculate the effects that each of the cost-reducing features of the MINTAX policy has on the variables in the table (when storage size is 6000 ML).

i) The effect of free zero impact salt is given by;

MINTAX-NFSD - MINTAX

This represents a saving of $14903/wk (91777-76874)

Both the level of treatment as well as discharge are influenced since the tax rate is lower for the MINTAX policy than for the MINTAX-NFSD policy. The tax rate for MINTAX is set allowing for free discharge of this water, while the MINTAX-NFSD tax rate does not allow this. The higher tax rate of the MINTAX-NFSD policy forces higher levels of salt removal and lower levels of discharge by the mines, increasing total costs.

ii) The effect of both zero impact salt and free discharge of all minewater (when tax rate = 0) is given by;

MAXTAX-MAXTAX-FD

which represents a saving in total cost of $15556/wk (95447-79891)

The relative cost savings of zero impact salt to free discharge salt are $14903 and $653 (15556-14903). This is an expected outcome, since there is very little opportunity for free discharge of the total minewater to occur when a volume in excess of 6000 ML must be assimilated.

iii) The effect of setting tax on the basis of spill volume rather than the total minewater is given by ;

MAXTAX-FD - MINTAX

A saving in total cost of $3017/wk (79891-76874) is possible due to this cost-reducing feature.

iv) the fourth cost-reducing feature of the MINTAX policy is the ability to reduce the nominal tax rate. This feature has not been included as a separate model since all results are the same as the MINTAX with the exception of a reduction in the tax revenue generated. For this reason variation of MINTAX has been included in the sensitivity analysis. In order to compare the relative impact of each cost-reducing feature of the tax, however, the result from the third column in Table 6.3 is discussed here.

By reducing the NTR used in the MINTAX from $100/T to $50/T, cost savings of $5123/wk can be made.

v) The combined effects of all four tax reducing features can be calculated from the adding the savings from ii), iii) and iv) above.
This represents a cost saving of $23696/wk (15556+3017+5123)

The above calculations show that for the base run the MINTAX policy is able to save costs of $18573/wk and with an NTR of $50 is able to save $23696/wk. The largest cost savings are due to the release of zero impact salt for free. The NTR represents the next largest saving, followed by setting the tax on the basis of the salt load present in the spill. The smallest cost saving was from free discharge of all minewater.

6.4 Sensitivity analysis

The results from the model runs under the five different tax policies, described in section 6.2, were discussed in deta l in the above section. In this section the sensitivity of these results to a number of alternative assumptions are considered. Since the MINTAX policy is the policy of primary interest, we consider the sensitivity of the MINTAX policy results to changes in storage size, nominal tax rate (NTR), environmental standard and the marginal abatement cost curve in the next four sub-sections. Following this we also investigate the sensitivity of the four variable tax scenarios to changes in storage size in the final sub-section (6.4.5). This is done to illustrate the significant influence that storage size assumptions have upon a number of the tax policies considered.

Table 6.3 considers the MINTAX policy and shows the sensitivity of costs, treatment levels and salt discharges to changes in the assumed storage size, the nominal tax rate (NTR) and the environmental standard. The table reports average weekly values obtained from running the model over a fifteen year horizon.

The MINTAX policy is examined in detail with sensitivity to changes in the environmental standard tested, as well as a reduction in the nominal tax rate (NTR). The values are recorded as units of change from the base run and have not been subjected to more formal sensitivity analysis. Elasticity's were not used because the variables used are discrete with large changes in magnitude, and so the interpretation of the elasticity's would be questionable.

6.4.1 Sensitivity of MINTAX results to changes in the storage size

The results in column 3 (Table 6.3) show that having on-site storage increases the overall cost to the mine operators because the decrease in treatment costs are outweighed by the increase in taxes. The size of the storage, however, affects treatment and tax costs differently. For a storage size of 1000 ML (under the base run), total costs are $78405, while for a 6000 ML storage total costs are reduced by approximately $1500. The major reason for this is the impact that the free salt discharge has. When the assimilative capacity of the river is high enough to assimilate the contents of a large

Table 6.3 Sensitivity of MINTAX results to changes in storage size, NTR and environmental standard (1980-1994)

Variable	Storage size	Base run	Changes relative to the base run		
		NTR=$100 env. std=420	NTR=$50 env. std=420	NTR=$100 env. std=300	NTR=$100 env. std=600
Total cost ($avg/wk)	6000	76874	-5123	5836	-11070
	1000	78405	-5091	6387	-9805
	0	68996	0	14021	-19356
Variable cost ($avg/wk)	6000	56859	0	13814	-22056
	1000	58638	0	14116	-20952
	0	59228	0	13924	-20535
Tax revenue ($avg/wk)	6000	20015	-5123	-7978	10985
	1000	19767	-5091	-7730	11147
	0	9758	0	78	1178
Salt removed (avgT/wk)	6000	481.83	0	111.77	-181.83
	1000	496.62	0	114.29	-171.86
	0	501.67	0	112.7	-168.28
Salt discharged (avgT/wk)*	6000	324.82	0	-111.53	175.51
	1000	310.03	0	-114.05	171.54
	0	304.97	0	-112.45	167.97
Free salt discharged (avgT/wk)	6000	27.861	0	0	30.89
	1000	13.23	0	-4.6	16.60
	0	123.93	0	-94.8	145.76

storage, considerable savings are possible through reduced treatment. It follows that the larger the storage, the greater the assimilative capacity of the river that is needed and hence the fewer occasions possible for free discharge. Figure 6.7 shows that one free discharge occurs from a storage of 6000 ML (for the MINTAX base run) in the fifteen year period. When storage is 1000 ML free discharge occurs on two occasions, as shown in Figure 6.8, but less free salt is discharged in total. Under conditions of no storage, free discharge is possible on a number of occasions, explaining the cost savings when storage is zero.

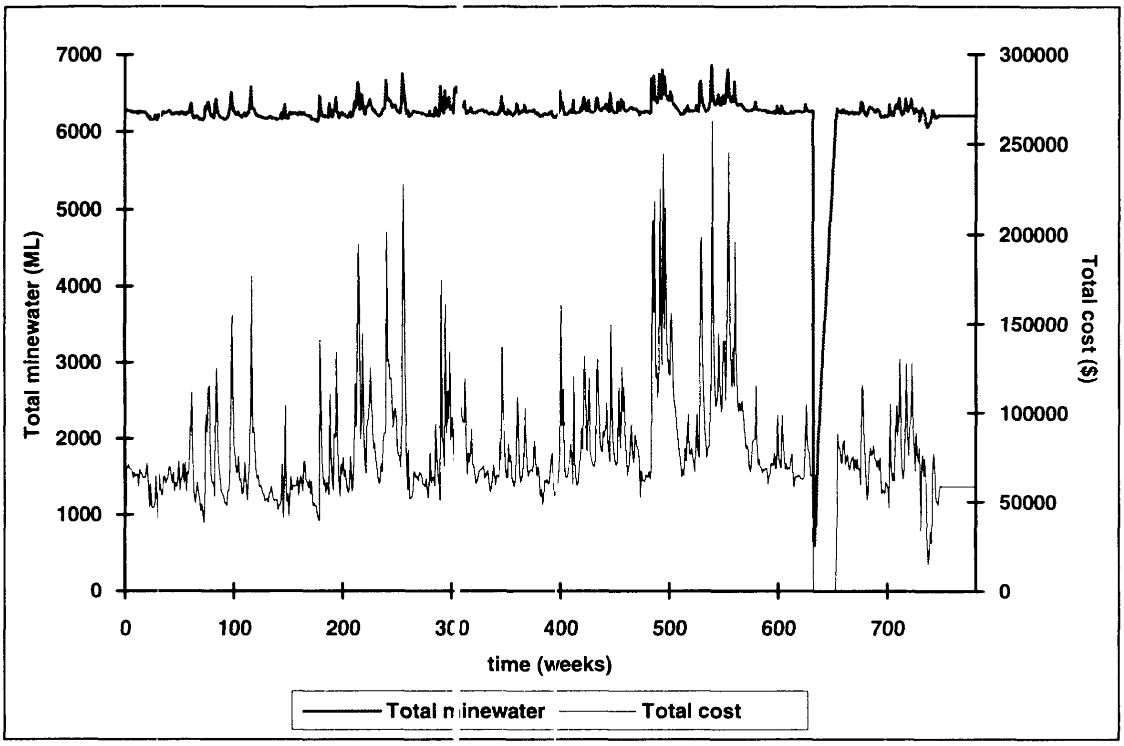

Figure 6.7 Total minewater and treatment costs for a storage size of 6000 ML under MINTAX (1980-94)

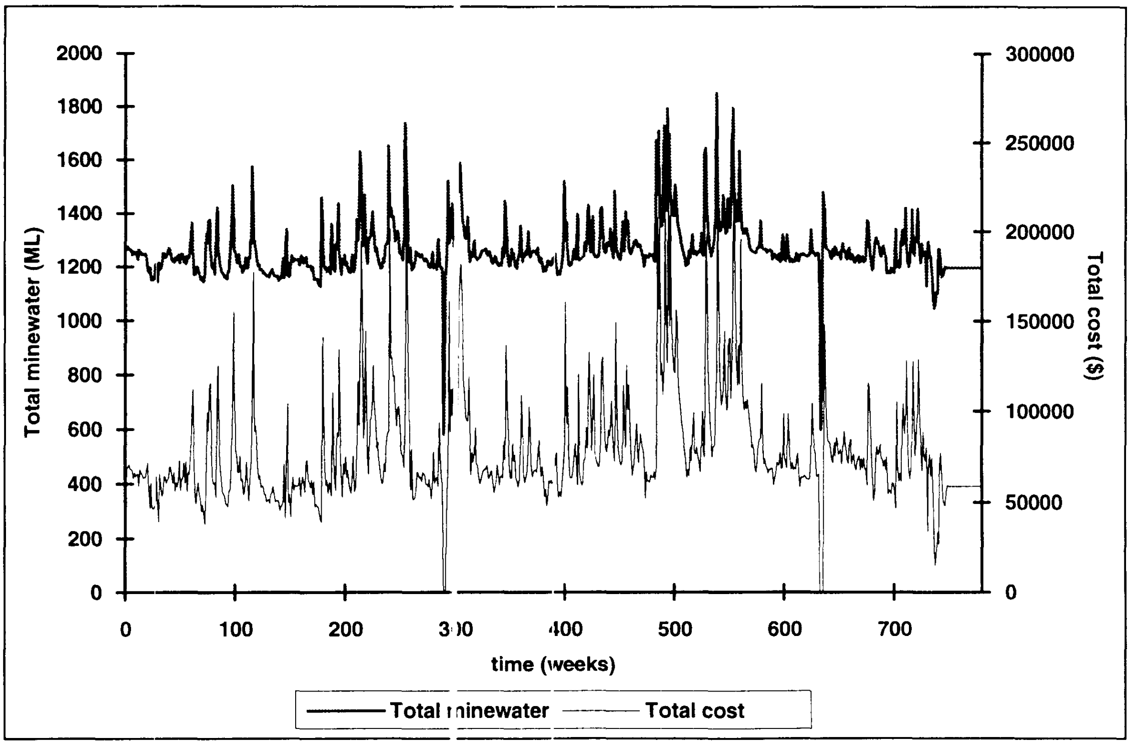

Figure 6.8 Total minewater and treatment costs for a storage size of 1000 ML under MINTAX (1980-94)

6.4.2 Sensitivity of MINTAX results to changes in the nominal tax rate (NTR)

From Table 6.3, column 4, we observe that reducing the nominal tax rate (NTR) to $50 results in no cost savings when on site storage equals zero. This is because the NTR only applies when the spill discharge can be assimilated by the river and the contents of the storage cannot. A lower NTR goes some way to addressing the problems that the model experiences in dealing with storages due to the assumption that future tax rates would not be anticipated by mine operators. The average weekly cost savings (tax savings) gained by reducing the NTR from $100 to $50 are $5123 when storage size is 6000 ML and $5091 when storage size is 1000 ML. Altering the NTR makes no difference on mine discharge and treatment behaviour.

6.4.3 Sensitivity of MINTAX results to changes in the environmental standard

From Table 6.3, column 5, we observe that reducing the environmental standard to 300 mg/L increases the total costs by an average of $5836 per week for a storage size of 6000 ML and $6387 per week for a storage of 1000 ML. When storage is not used, the cost increases by over $14000 per week. The higher costs are due to increased levels of treatment needed to meet the lower environmental standard. The interaction that storages display with the costs is due to the considerable reductions in the possibility for free discharge.

Increasing the river environmental standard to 600 mg/L (refer to the final column in Table 6.3) results in significant cost savings For a storage size of 6000 ML, $1170/wk are saved, for a storage of 1000 ML $9805/wk are saved and when storage is not used, the cost savings are in excess of $19000/wk. Once again the free discharge is the dominant factor influencing the differences in costs between the storage sizes. The value of free discharge therefore, is of increased importance when storage size is small or non-existent. It is also of greater value when the salinity of the environmental standard is higher.

6.4.4 Sensitivity of MINTAX results to changes in the specification of the marginal abatement cost curve

The nature of the marginal abatement cost curve was explained in section 4.3.3. This section presents an analysis of the sensitivity of results to changes in the intercept and slope of the MAC curve in equation (4.2). Two new cost curves are applied to the MINTAX policy. These cost curves maintain the same mid-point abatement cost (that is, $120), they are:

$$MAC = 110 + 7.5 \times SRPM \tag{6.1}$$

$$MAC = 90 + 22.5 \times SRPM \tag{6.2}$$

The results in Table 6.4 illustrate the impact that the alternative cost curves have on the costs to polluters. The new cost curves, have no impact on the level of treatment or discharge of salt, but it causes changes in the tax revenue generated and total treatment costs incurred. Tax revenue increases (decreases) 3 times more than the treatment costs. Note that the NTR used for the respective curves was equal to the intercept on the cost axis, that is $110/T and $90/T.

Table 6.4 Sensitivity of MINTAX results to changes in the marginal abatement cost curve and storage size (1980-94)

Variable	Storage size	Base run	Change relative to base run	
		MAC= 100+15×SRPM	MAC= 110+7.5×SRPM	MAC= 90+22.5×SRPM
Total cost ($avg/wk)	6000	76874	1820	-1820
	1000	78405	1796	-1796
	0	58996	697	-697
Variable cost ($avg/wk)	6000	56859	468	-468
	1000	58638	456	-456
	0	59228	468	-468
Tax revenue ($avg/wk)	6000	20015	1352	-1352
	1000	19767	1339	-1339
	0	9768	229	-229
Salt removed (avgT/wk)	6000	481.83	0	0
	1000	496.62	0	0
	0	501.67	0	0
Salt discharged (avgT/wk)*	6000	324.82	0	0
	1000	310.03	0	0
	0	304.97	0	0
Free salt discharged (avgT/wk)	6000	27.86	0	0
	1000	13.23	0	0
	0	23.93	0	0

The marginal abatement cost curve, although largely arbitrary, is based on information supplied by the staff at Pacific Power, which operate a plant which has a processing capacity of 80T of salt removed per day, or 560T per week. The requirements for salt removal in the model suggest between 480 and 580T of salt per week, so the plant size is appropriate for approximating operating and capital costs alike.

6.4.5 Sensitivity of the four variable tax policies to changes in storage size

In this section we consider the sensitivity of the results from the four variable tax policies introduced in section 6.2. Table 6.5 shows sensitivity of the results to storage size for the MINTAX and the MINTAX-NFSD policies. The effect that free discharge has on the costs is measured by subtracting the values obtained under MINTAX from the values obtained under the MINTAX-NFSD policy. These differences are presented in the final column of Table 6.5, for different storage sizes. The column shows any interaction that occurs between the savings due to zero impact salt and storage size.

Table 6.5 Sensitivity of MINTAX and MINTAX-NFSD results to changes in storage size

Variable	Storage size	MINTAX		MINTAX-NFSD		Change
Total cost ($avg/wk)	6000	76874	(33632)	91777	(40063)	14903
	1000	78405	(31914)	93603	(38001)	15198
	0	68996	(43366)	82759	(51477)	13763
Variable cost ($avg/wk)	6000	56859	(47310)	69582	(55319)	12723
	1000	58638	(46892)	71676	(54736)	13038
	0	59228	(47027)	72409	(54886)	13181
Tax revenue ($avg/wk)	6000	20015	(25590)	22195	(28815)	2180
	1000	19767	(25466)	21926	(28695)	2159
	0	9768	(17627)	10350	(18650)	582
Salt removed (avgT/wk)	6000	481.83	(394.05)	575.42	(448.35)	93.59
	1000	496.62	(390.25)	592.36	(443.17)	95.74
	0	501.67	(391.39)	598.5	(444.4)	96.83
Salt discharged (avgT/wk)	6000	324.82	(712.26)	231.33	(726.96)	-93.49
	1000	310.03	(313.25)	214.39	(343.33)	-95.64
	0	304.97	(263.91)	209.44	(298.57)	-95.53
Free salt discharged (avgT/wk)	6000	27.86	(679.70)	27.86	(679.70)	0
	1000	13.23	(214.09)	13.23	(214.09)	0
	0	123.90	(290.84)	123.93	(290.84)	-0.03

Standard deviations are in brackets.

In section 6.2 the cost savings due to the zero impact salt was shown to be $14903/wk (this is the same as the first value in column 7 of Table 6.5) Storage size has a relatively small effect on the change in total costs with savings of $15198 for a storage size of 1000 ML and $13763 when no storage is used. However, the reverse is true for the change in tax costs where a storage of 6000 ML causes tax costs to reduce by $2180/wk but only $582/wk result when no storage is used.

Table 6.6 presents the sensitivity of the MAXTAX and MAXTAX-FD to changes in storage size. The difference between MAXTAX and MAXTAX-FD is the cost savings due to both free zero impact salt and free (total) salt discharge (final column of Table 6.6). The sensitivity of free discharges to storage size is obtained from this column.

Table 6.6 Sensitivity of MAXTAX and MAXTAX-FD results to changes in storage size

Variable	Storage size	MAXTAX		MAXTAX-FD		Change
Total cost ($avg/wk)	600(	95447	(39029)	79891	(32822)	-15556
	100(	97108	(36612)	81186	(30930)	-15922
	(	94992	(38377)	68996	(43366)	-25996
Variable cost ($avg/wk)	600(	94098	(39259)	78606	(33045)	-15492
	100(	90894	(39233)	75344	(33424)	-15550
	(	72409	(54886)	59228	(47027)	-13181
Tax revenue ($avg/wk)	600(	1443	(3506)	1285	(2201)	-158
	100(	6307	(9977)	5843	(9034)	-464
	(	22673	(30497)	9768	(17627)	-12905
Salt removed (avgT/wk)	600(	769.79	(320.15)	660.70	(275.61)	-109.09
	100(	748.54	(316.76)	637.40	(276.05)	-111.14
	(	598.5	(444.40)	501.67	(391.39)	-96.83
Salt discharged (avgT/wk)	600(	37.29	(679.52)	145.45	(653.63)	108.16
	100(	58. 5	(223.25)	168.05	(195.99)	109.55
	(	208.26	(296.62)	304.97	(263.91)	96.71
Free salt discharged (avgT/wk)	600(	N/A		26.90	(653.14)	26.90
	100(	N/A		11.51	(185.40)	11.51
	(	N/A		106.58	(250.13)	106.58

Standard deviations are in brackets.

The change from the base MAXTAX shows that free salt discharge saves $15556 and $15922 for storage sizes of 6000 ML and 1000 ML, respectively. When storage size is zero the savings are significantly larger, $25996. The main savings in cost are due to reduced treatment costs, that is, $15492, $15550, and $13181 for storage sizes of 6000 ML, 1000 ML and zero, respectively. As was the case for the MINTAX policy, the main determinant for differences in costs between the storage sizes are due to large savings in taxes paid. Tax revenue is $12905/wk less under the MAXTAX-FD policy than it is under the MAXTAX policy when storage is zero, compared to savings of $158/wk when a 6000 ML storage is assumed and $464 per week for a 1000 ML storage. The savings in tax costs are due to the increased discharge of free salt when storage is zero. That is, 106 (T/wk) compared to 26.9 (T/wk) 6000 ML storage and 11.51 Tonnes per week for the 1000 ML storage.

6.4.6 Sensitivity of the FLATTAX to changes in the level of tax

Table 6.7 shows the results from the FLATTAX policy for changes in the level of the flat tax. Total cost is highest for the tax rate of $140/T. Under this tax rate all of the salt is removed and none discharged to the river. No taxes are paid. The reverse of this is true for the tax rate of $100/T which causes all salt to be discharged to the river, with high tax costs and no treatment costs. The results shown in Tables 6.7 highlight the inflexibility of the static flat tax.

Table 6.7 Sensitivity of the FLATTAX policy to two levels of tax

Variable	Baserun (tax=$120/T)	TAX=$100/T	TAX=$140/T
Total cost (avg$/wk)	78540	68395	84831
Variable cost (avg$/wk)	38881	0	84831
Tax revenue (avg$/wk)	39659	68395	0
Salt removed (avgT/wk)	333.46	0	795.29
Salt discharged (avgT/wk)*	441.83	795.29	88.37
Free salt discharged (avgT/wk)	N/A	N/A	N/A

*Salt discharged includes the quantity recorded as Free salt discharged

A summary of the major findings from this chapter is included in Chapter 7

7. Summary and conclusions

7.1 Introduction

In this chapter, the taxes formulated and modelled in Chapter 4 are examined in the light of the objectives outlined in Chapter 1. The chapter begins by summarising the results from the model in section 7.2. This section highlights the relative merits of load based variable tax permits versus flat taxes, in terms of the ability to utilise assimiltaive capacity of the river. Section 7.3 discussed the feasibility of the tax in terms of the informational requirements. The practical limitations of these tax policies are critically appraised in section 7.4 and the implications for the design and implementation of a system in transferable discharge permits made. The limitations of the model are discussed in section 7.5 and section 7.6 contains suggestions for further research.

7.2 Summary of the study

The tax (MINTAX) policy formulated in this project attempts to meet the environmental standard at low cost using a load based tax policy. The stochastic nature of the river and hence the assimilative capacity is addressed through using a tax rate which varies weekly. The cost minimising features of taxes which rely on using price control and never quantity control are used in the formulation of this tax, but are not tested in the analysis. The tax and treatment costs incurred when achieving the environmental standard, were reduced due to four features of the MINTAX tax policy.

i) free discharge of the first 420 mg/L of salt discharged to the river, (zero impact salt),

ii) free discharge of all minewater when this can be assimilated by the river,

iii) setting the tax on the basis of spill volume and not all minewater

iv) reducing the tax rate to a nominal tax rate (NTR) whenever all of the spill can be assimilated but total minewater cannot.

The model used in the analysis predicts the assimilative capacity of the river at the start of each week and sets the tax rate in order that discharges from the mine will not exceed the assimilative capacity of the river. Model results showed that the environmental standard can be met due to a variable tax rate, but the assimilative capacity of the river was only utilised fully when storages were not used. When onsite minewater storages were used, setting the tax on the basis of spill volume used most of the river assimilative capacity.

The effect on costs of using each of the cost saving features of the tax are summarised below.

i) The savings from zero impact salt, when tax rate was set on spill volume was $14903, and were primarily due to savings in treatment costs because less salt was removed.

ii) the savings from free discharge and zero impact salt together when tax rate was set on total minewater volume were on average $1556/wk

iii)Setting the tax on the basis of spill volume rather than total minewater saves an average of $3017/wk. This was due to a reduction in treatment costs which outweighed the increases in tax costs paid.

iv) savings due to using a NTR of $50/T were an average of $5123/wk.

Storage size had a significant effect on treatment and tax costs for the various policies tested, as well as on the variables tested in the sensitivity analysis. Storage size did not significantly affect the savings due to zero impact salt, but was significant for free discharge (Table 6.6).

Sensitivity of the results to changes in the environmental standard, and marginal cost of abatement were tested. Total costs increased by $5836/wk when the environmental standard was reduced to 300 mg/L, and cost savings of $11070/wk were recorded when the standard was increased to 600 mg/L. When an environmetal standard of 300 mg/L was used, the increased costs were due to high treatment costs because more salt needed to be removed. These increased costs outweighed savings in tax costs. The reverse was true for the environmental standard of 600 mg/L.

Storage size showed interaction with changes in the environmental standard such that the greatest changes in cost occurred for storage size of zero.

The results showed that setting the tax on the basis of all minewater stored in the mine (that is, the MAXTAX policy) led to a high tax rate which caused excessive removal of salt. The high costs associated with this level of tax were reduced considerably when the tax was set on the basis of spill volume, and greater use was made of the assimilative capacity of the river.

The tax revenue raised from the MINTAX policy was $20015/wk when a NTR of $100 was used and $14892/wk when the NTR was $50.

7.3 Information required by the regulator

A single discharging firm was used to model the tax in Chapter 4. The firm was based on an aggregate of nine mines in the upper Hunter Valley. The information required by the regulator and already identified in Chapters 2 and 3, is listed below.

- the environmental standard
- the aggregate MAC curve
- the total mine water excess and the average salinity level
- the total storage capacity
- the assimilative capacity of the river each week
- total salt and volume discharges from the mine each week

Each requirement will be examined using the following terms of reference:

1. how is the information obtained?
2. how reliable is the information likely to be?
3. how much effort is involved in updating information from one week to the next?
4. what are the likely consequences of incorrect information?

Although the model in Chapter 4 is for a single discharging firm, the following discussion applies largely to multiple discharging firms too. In instances where the discussion may not apply to the multiple discharger case attention is drawn to this fact.

7.3.1 Environmental standard

There are a number of different ways that the environmental standard could be obtained. One way is to use a consultative process with the community, including water users and dischargers alike. Another option is to undertake a cost-benefit study which looks at the impact of several different salinity levels on all water users, including dischargers, irrigators, municipalities, environmental and recreational uses, etc. Alternatively the standard that is recommended by the EPA could be used, as seen in this project.

The information obtained in this manner should be reliable but would also be subject to political pressure from special interest groups. Environmentalists would want the salinity lowered while mine operators would prefer it to be raised.

Updating information weekly is not strictly applicable to this information requirement, however an environmental standard which alters according to season may be worth considering. For instance in winter when irrigation is not as important, it may be worth while raising the level of the river salinity threshold, since this would have considerable cost savings, as was shown in the sensitivity analysis of Chapter 6.

Incorrect information in setting the environmental standard may cause the standard to vary considerably from the social optimum. Since the objective is to have the standard set as close as possible to this point the result would be a missallocation of resources, especially if the tax was efficient in achieving the environmental standard, as is its purpose.

7.3.2 Aggregate MAC curve

Estimating the aggregate marginal abatement cost curve is perhaps the most difficult task in setting a tax. The marginal abatement cost curve would need to be set on the basis of knowledge of likely abatement processes available to discharger(s). The regulator will not be able to gain accurate information of this curve but should be able to make good estimates from knowledge of available processes. Asking the discharging firm(s) themselves would probably result in estimates less than the actual cost of treatment, as the firms are likely to attempt to lower the tax rate below the marginal cost of treatment and therefore save the cost of treatment. Therefore cost information would need to be gained from alternative sources.

Obtaining information from secondary sources can be risky. In the case of desalination plants, it is not possible to directly translate costs of desalinating seawater in the middle east, for example, to desalinating minewater in the Hunter. Minewater in the Hunter is highly alkaline and so incurs greater desalination costs, additionally different mineral salts are present and the desalination of minewater deals with a different range of salinities to those where seawater is being purified for drinking water.

The reliability of the information will depend on its source. Reasonably reliable information may be gained from canvassing a range of sources and combining this information. When multiple dischargers are considered, there is a need to regularly update the MAC curve to take account of new mines as well as being aware of advances in cost saving techniques for removing salt from water.

Whether for individual or multiple discharging firms, the marginal abatement cost curve needs to be updated regularly, so that any change to the aggregate MAC curve can be included. Updating on a weekly basis, however, may not be warranted. Given the degree of confidence in the derived marginal abatement cost curve, the MAC curve may only need to be reviewed on a monthly or perhaps quarterly basis. Updating the MAC would also benefit from comparison of expected, with actual mine abatement levels, as a guide to the accuracy of the curve.

For the multiple discharger case, if firms know that by adopting cheaper technology they will benefit not only from reduced costs of treatment but also from lower taxes, then the use of new cost saving technologies will be encouraged. Firms that are smaller and not able to adopt new and expensive technology, however, may experience a windfall gain in the form of lower taxes. The gap between the individual marginal cost curves of polluters would then be larger, increasing the cost efficiency gains of a tax.

If the MAC curve is inflated, then the level of salinity abatement will be too high causing the assimilative capacity of the river to be under-utilised, and resulting in river salinity readings lower than the standard. If the MAC curve is under-estimated then the tax rate will be too low, and discharge rates to the river too high, causing the river salinity to exceed the threshold level.

7.3.3 Total minewater excess

The method for obtaining total minewater excess could be used for either a single mine or for multiple mines. Each mine would be surveyed for information regarding storage size and the minewater excess carried over from the previous week. This information could be used in conjunction with a minewater balance model, similar to that used in AGC Woodward-Clyde (1992), to verify the likely carryover and to estimate inflows. Periodic onsite checks could be made to ensure that storages contained the amount of water claimed by the survey results.

Survey results would not be reliable if this were the sole source of information. However, used in conjunction with the minewater balance model, a reasonably accurate estimate of total minewater excess could be obtained. The minewater balance model could be developed for each mine in close consultation with the mine operator so that when the operator provides information to the survey, he/she knows that the minewater balance model is going to be used as a check.

The survey could be administered by a central computer, where the mine operator enters their estimate of minewater excess each week. The water balance model could also be updated easily by updating the actual water discharges, together with rainfall recordings from selected sites. The use of computers linked to the databases from these recording stations would simplify an otherwise time consuming task, although considerable investments in time and money would be required in the initial setup.

If minewater excess is under-estimated, then the likelihood of discharging too much salt and exceeding the river salinity standard is high. Under-estimating the minewater excess may result in a zero tax being charged, triggering discharge of mine contents when it otherwise would not occur, causing violation of the environmental standard. Similarly If this error does not cause a zero tax, but causes the NTR (nominal tax rate) to be used when the variable tax rate should have been used, then too much salt will be released to the river, (that is the spill will be untreated when some level of treatment may have been required).

Over-estimating the minewater excess will cause tax rates to be increased and may not make use of free discharges when they would otherwise occur. It is most likely to cause over treatment of minewater, leaving surplus water quality in the river.

7.3.4 Mine salinity level

Mine salinity level is assumed to be 3000mg/L. This is consistent with average mine salinity readings used in the AGC Woodward-Clyde (1992) report, and is slightly higher than 2220 mg/L which was the average salinity level recorded by the DWR (1994) in the staged discharge trial conducted early in 1993.

It would not be necessary to update mine salinity information weekly. However, the salinity measurements of mine discharge water used to tax the mine could be used to check whether 3000 mg/L was an accurate reflection of the potential salt discharge.

7.3.5 Assimilative capacity of the river

The assimilative capacity of the river is a function of salt load and river flow. The model uses upstream gauging stations which provide mean daily streamflow and salinity readings from the previous period to predict the river assimilative capacity downstream. The model assumes that this prediction is accurate (that is, the regulator has perfect knowledge of what assimilative capacity will be in period t). The stream assimilative capacity at the mine discharge site prior to discharge would, in practice, be difficult to estimate. Predictive tools could be used which model the river system comprehensively. A complex model is currently being developed by the DWR in conjunction with EPA (E. Harris 1995, pers.comm.). These models include simulation of regulated and unregulated flows, and the effects of releases of water from instream storages for the purposes of irrigation and town water supply. By setting the tax on the basis of the predicted river assimilative capacity, the dischargers know the tax rate in advance, and can plan their action for the week. In order to improve the predictive ability of the model, a monitoring point just above the mine discharge point should be used to measure streamflow and salinity of the river. This would allow the predictive ability of the model to be refined and improved, and perhaps to be used in a data base for further modelling of the system.

The salinity measurements used in the model were generated using an infinite distributed lag model based on two years of actual streamflow and conductivity data. These data were generated to allow the model to be run over a greater time horizon than the actual data permitted.

Assimilative capacity is more difficult to estimate when multiple discharge sites are considered because tributaries may contribute to river salinity or alternatively help to dilute it, thus influencing the assimilative capacity at different locations along the river.

The assimilative capacity information used in the model cannot be checked for predictive ability, since downstream monitoring sites do not coincide with that what would be necessary for the single discharging mine. The observed measurements of streamflow and conductivity are very reliable. The generated conductivity data is somewhat less precise, but nevertheless is a fair guide to the fluctuations that can be expected in river assimilative capacity over the longer term. A more sophisticated model could reduce the error in estimating assimilative capacity.

With the current model, actual river salinity and streamflow data at the upstream site could easily be used to update the assimilative capacity for the following week. More sophisticated models would have a higher informational load, such as rainfall in different areas of the catchment, stream gauging information from tributaries, releases from dams etc. Nevertheless, after considerable effort in setting up the model initially this data could be supplied regularly without too much effort. This is especially true as the monitoring network of stream gauging stations which monitor both streamflow and conductivity levels is comprehensive enough to accommodate this type of model.

The consequences of incorrect information on assimilative capacity are obvious. If assimilative capacity is estimated as being higher than it actually is, then the environmental threshold will most likely be exceeded when salinity is measured further downstream. Under-estimating assimilative capacity will cause potential discharges to be either stored or treated, when it may have been optimal to discharge them.

7.3.6 Monitoring mine discharge

All mines would need to install meters which measure water discharge, and which can give some indication of average salinity.

Depending on the type of water wheel or salinity monitoring device chosen this could be highly reliable information. The cost of the monitoring device would play a large part in the reliability of information. The monitoring device would need to be under the control of the regulating authority, to ensure that accurate, reliable, and consistent measurements between dischargers were made.

The recordings from the monitoring devices could be read by an inspector (similar to the way electricity meters are read). The need for the regulator to have the information (in order to update the mine water balance equation) means that the reading of meters would be time consuming, and would need to occur weekly. Alternatively, the inspector could read metres less regularly, if the information were used solely to issue tax bills, and not to set taxes.

Incorrect information may cause the tax rate to be set incorrectly in following periods, although there is a double check in terms of the mine operator survey on minewater storage levels. The possibility exists that incorrect information may lead to the dischargers not being charged the appropriate level of tax for their discharges, causing incorrect price signals to be sent.

7.4 Implications for policy design and implementation

7.4.1 Examining the MINTAX policy for its application to the control of salinity in the Hunter River

The tax formulated in this project demonstrates that a tax can be varied on a weekly basis, albeit with very high informational demands. A tax which is set using knowledge of all the minewater available for discharge will be high and cannot make use of the assimilative capacity of the river, leading to unecessarily high levels of treatment. The tax policy, however, represents the potential to save costs through free discharge of zero impact salt and free discharge whenever the assimilative capacity of the river is large enough to assimilate all of the minewater. The sensitivity of free discharge to storage size was demonstrated, and shows the difficulty that onsite storages create in designing a policy to utilise the assimilative capacity of the river.

The assumptions made in the model which make costs of storing minewater equal zero and ignore speculation by mine operators about future tax rates, limit the practicality of setting a variable tax on the basis of spill volume and introducing a nominal tax rate.

While striving to meet the objective of designing a tax to meet an environmental standard at least cost it is important to take a step back from the picture and consider how the policy fits in to the more complete picture of salinity in the Hunter River Valley. The following comments attempt to do this.

7.4.2 Salt concentrates and more salt disposal problems

The process of desalination is a process of moving salt from one solution to another, more concentrated one. The water from which the salt is removed can be discharged to the rive but the concentrated salts need to be stored elsewhere. Currently, Pacific Power have brine storage dams. This highly saline water is a potential environmental risk if seepage from storages occurs. The options for disposal of this salt could include evaporation pans, which would involve considerably less area than if used as the sole treatment process. Similarly, other techniques such as deep-well injections or transportation to the ocean could be used to lessen the risk of salt spills. The possibility of using the salts to produce other saleable products may also exist. Gypsum, for example, is currently a biproduct salt generated by pacific power, and is a useful soil improver in areas where soils are hard setting, acidic and lack structure. Novel ideas such as soap powders are other alternatives, but are only in experimental stages. A tax policy however, must account for this potential environmental hazard, and make sure guidelines are in place for appropriate action to be taken in the event that these salts, accidentally or otherwise, end up in the river system.

7.4.3 Catchment wide sources of salt

A policy maker designing a salinity tax in the Hunter River needs to consider not only the discharges from a single industry, such as coal mines, but also the discharges from other point sources, such as municipal waste water and development sites, and from diffuse non-point sources, such as farming. There are obvious difficulties in measuring the relative contributions of salts, especially from diffuse sources of pollution; however, even if reasonably accurate estimates could be made, a single load-based tax is extremely difficult to set efficiently

Setting the appropriate tax would become increasingly difficult with the number of different abatement techniques available for different industries. In farming, for example, the methods of reducing salt discharges to the river would include alternative farming practices and possibly reduced levels of production. The difficulty in obtaining the appropriate marginal abatement cost curve and the large information requirement, lends support to a permit system, which is able to avoid these informational and administrative requirements by offering the appropriate number of permits for sale. Taxes used in Europe have sometimes been implemented with the objective of altering the level of tax over time, so that eventually the cost efficient tax rate is achieved. This, however, has implications for investment decisions, especially in terms of delaying or not investing in expensive cost-saving methods of reducing salt. Experimental tax levels are also unsuitable for the type of system proposed in this project, which aims to accommodate highly variable river conditions by altering the tax rate on a weekly basis.

In addition to the difficulty in setting the rate of tax which will achieve the environmental threshold cost efficiently, an equity problem arises as to how the assimilative capacity should be used by all dischargers of salt. The tax policy explored in this study essentially allows salt to be discharged unchecked from any source other than mines. This is because the assimilative capacity is calculated for mines after other sources have already discharged to the river, any assimilative capacity remaining is left to the mines. A more equitable system may be to establish the natural base load of salts, and to allow the remaining assimilative capacity to be distributed between all industries. For a tax policy this would involve setting the tax on the basis of this total assimilative capacity and charging all industries the same tax rate per tonne of salt discharged. For transferable discharge permits, the permits would be offered for sale to all dischargers alike.

7.4.4 Disused mine sites

The contribution of salt discharges from disused mine sites should be examined and taxes charged to the companies for any salts being released to the river. Taxing mines on these discharges is necessary if the discharges from current mines are to be minimised once coal production from them ceases.

7.4.5 Tax revenue

Tax revenue raised from a tax policy designed to reduce river salinity levels, would be accepted more readily by dischargers if it could be used to contribute to lowering future tax rates. One way of achieving this would be to use the money to assist research into cheaper methods of reducing salt levels in minewater. This is an ideal use of the money, the dischargers would gain in the long run from the taxes they pay, and society would gain from salinity levels which are closer to the threshold than was the case in the past. Using the money for research into cost saving methods of treatment also avoids the wrong price signals which are sent when taxes are used to subsidise end of pipe treatment plants, as has occurred in Denmark (see section 2.7).

Another alternative use of revenue raised from taxes to clean up the environment, is to reduce income tax. The nature of environmental taxes which spiral downward as the level of emissions are reduced, shows that this type of tax may not be able to sustain a continued subsidy of income tax. Furthermore, a tax on salt discharges from one segment of the Hunter River would hardly be able to sustain a significant reduction in income tax, and so this alternative would not be worthwhile unless a number of environmental taxes were used.

7.4.6 Implications for a market in transferable discharge permits

There are two main implications which can be drawn from these results for transferable discharge permits. First, the amount by which the salt discharged to the river needs to fluctuate indicates that permits which are issued to allow a set quantity of salt discharge would not meet the environmental standard, as they would suffer from the same problems as static flat taxes. The permits would need to be designed so that the quantity of allowed discharge was varied regularly or may even be set on the basis of a percentage share in the assimilative capacity of the river. The second implication is that the fluctuation in tax rate needed to drive the appropriate level of treatment under a tax policy indicates that the price of permits would fluctuate very widely. Dischargers who have very little ability to store water will be forced to purchase permits in a market where the value of a permit from one week to the next would be largely unpredictable and highly variable. A third implication is that the amount of information that dischargers would be required to have in order for each individual to purchase the optimal number of permits is very large. Dichargers would need to know their own marginal costs of abatement, be able to accurately estimate the assimilative capacity of the river, and to know their own marginal costs relative to others in order to estimate what price the permits are likely to be. This level of knowledge may not be realised and would mean that the market would not achieve the optimal distribution of permits. Even so, the distribution that is achieved may still represent an improvement on other methods.

7.5 Limitations of the study

Some limitations of the model are discussed in the subsections which follow.

- the model does not account for risk preferences of mine operators
- mine operators are assumed to not consider future tax rates in their decisions
- decision rules in the model do not optimise mine revenue
- a single mine is modelled, which essentially represents nine of the mines in the Hunter as an aggregate
- lack of data to estimate the marginal cost of abatement curve accurately

7.5.1 Relaxing the assumption of a single discharging firm

Relaxing this assumption would possibly realise greater gains from a tax policy over a more direct regulatory approach, however it would also mean that the model would need to be expanded to reflect the many different types of mines which represent the different marginal abatement cost curves- this would then present another problem for the regulators, in that they would need to accurately determine the aggregate marginal abatement cost curve in order to effectively set the tax.

The benefits of the MINTAX policy, and even the MAXTAX policy have been understated by modelling the tax on a single discharging firm. The cost advantages in allowing individual firms to remove different levels of salt from discharges were discussed in section 2.5 The likely sources of differences in individual abatement cost curves, which would drive these cost savings, include the different levels of salinity which would be likely to occur between mine sites, different access to treatment costs due to size and fixed cost ratios of mines, and different ability to develop and adopt new technology.

Relaxing the assumption of a single discharging firm has many implications. The main problem is how to accurately set the mintax when individual mine sites have different storage sizes and entirely different minewater balance equations. Given that the NTR and the tax rate itself are set on the basis of whether or not a spill exists, there seem to be only two possible options. Either to only introduce these aspects of the tax when all mine sites have full storages, or to essentially follow the MAXTAX policy except that the free discharge could be maintained for zero impact salt as well as for total release of minewater. Using the MAXTAX policy would entail ignoring NTR and setting a tax on the basis of total mine salt, not just that in the spill. If the MINTAX policy were maintained, then only when all mine storages were full would the NTR and tax set on the basis of spill apply.

The mines with a greater proportion of spills would be disadvantaged, because not only would the tax be increased by the storage capacity of the other mines, but they would be forced to either pay the tax or treat the spill while the dischargers with unused storage capacity have the option to store. The alternative of always setting the tax on the basis of potential discharge, would once again give dischargers with greater storage capacity the advantage over others, since dischargers without storage capacity available would always face the higher tax rate, with no option to store, while the sites with storage space available could avoid both the tax and treatment costs.

7.5.2 Relaxing the assumption that future tax rates are not anticipated by dischargers

When mine operators are permitted to anticipate future tax rates, discharger response to a NTR would be expected to be vastly different from that under the assumptions of the current model. If the river assimilative capacity is predicted to decline, instead of encouraging storage of minewater so that a tax rate can be set on the basis of spills only, the NTR would present the opportunity to discharge a major portion (and possibly all) of their stored water in order to avoid higher tax rates in the future. The decision to only discharge the spill would be likely if assimilative capacity were increasing, and the promise of free discharge in the future were likely. Given that total free discharge relies on rare high flow events, and is virtually non-existent when storage is 6000ML, it is more likely that the storage would be emptied when NTR applies. This would result in the environmental standard of the river being violated.

7.5.3 Relaxing the assumption of zero storage costs

When the storage costs are no longer zero, the optimal decision rule is considerably more complex, and the model needs to include an optimising component. The nominal tax rate (NTR) would not be a legitimate option in such a model since the mine operators would nearly always empty the storage under a NTR. Under thisscenario, storage costs would represent the costs incurred by having to forego storage in the future, possibly when tax rates are much higher, for storing water in the present. Thus whenever tax rates are reasonably low dischargers would discharge as much of the storage contents as possible, especially if the outlook was for future high tax rates.

7.5.4 Limitations of data availability for the marginal abatement cost curve

The marginal cost curve is relied on for setting the level of tax. The exact nature and location of the curve have not been calculated in this project. For this tax policy to be effective, considerable work would need to be done in obtaining a representative marginal abatement cost curve

7.6 Further research needs

There are two main areas in which future work could contribute to this research. The first is to develop the model further to include more than one discharger, with optimal decision processes, and assumptions about future tax rates and storage costs relaxed. This would provide more accurate estimates of tax and treatment costs that could be expected from the variable tax.

The development of an optimising model for mine discharge decisions, would provide further insights into problem, particularly if the assumptions regarding future tax rates and costs of storage are relaxed Under these conditions the mine twill face an opportunity cost for storing water a tax for releasing water to the river and a MAC curve. The objective function would be to minimise costs by storing (c_s), treating (c_t) or discharging saline water (c_d).

$$\text{minimise } c_s+c_t+c_d \tag{5.1}$$

Possible decision variables include

- volume of minewater to store
- volume of minewater to discharge
- quantity of salt to discharge
- quantity of salt to treat

Possible state variables include:

- contents of onsite storage
- tax rate

A further question of interest arises with the inclusion of more than one discharger, when the variable tax is set on the basis of total minewater. Namely, to what extent are the cost advantages of a tax over direct regulation, offset by not utilising the assimilative capacity of the river fully?

The second area of further research is to investigate the policy options for including water releases for the purpose of dilution, and the associated benefits and costs that would arise from this. Assuming that a market for water is operational, the dischargers could purchase water for dilution, and receive a tax rebate when this water is discharged. The tax (MINTAX) policy developed in this project, allows discharge of any quantity of salt providing it is discharged at a salinity which is less than or equal to the environmental threshold. Considerable work would need to go into coordinating the timing of releases and discharges so that a salt spike does not proceed down the river, with a rush of pure water following it. A market for water which allowed dischargers to purchase water for dilution would increase the demand for water, and together with a higher willingness to pay for water, may cause the price of water to rise significantly.

The impact of significant increases in water prices on the current water users of the Hunter may cause irrigation reliant industries, such as dairying and viticulture, to become unviable. However, the prospects for water markets may not be all bad if irrigators downstream of the mines are able to organise water release sequences for dilution which coincide with their irrigation needs. In this way, the water purchased for dilution can also be used for irrigation, since the water quality standard should mean that the salinity of the river is low enough for the purposes of irrigation. Under this situation, irrigators and mine operators should be able to organise water releases which satisfy their respective needs with mutual benefits.

7.7 Conclusions

The problem of saline discharges from coal mines in the Upper Hunter Valley is complex. Setting a load based tax at a rate which will lead dischargers to reduce the level of discharge from the mines such that the environmental standard of river salinity can be met is difficult. Salt taxes must be variable to cater for the stochastic nature of the river. This requires large amounts of information (some of which may even be unobtainable), which continually needs to be updated. While continual updating may allow close control over discharges of salt, the resources required for setting the tax may far exceed the benefits.

The tax formulated and modelled in this project has demonstrated the difficulty that storages create in attempting to set a tax which allows the assimilative capacity of the river to be used. If all the potential minewater available for release is included in the calculation of the tax rate, then the tax will be high and discharge will be discouraged, leaving large amounts of assimilative capacity unused. If the tax rate is set on the basis of spill (overflow) volume from the onsite storages, then the assimilative capacity could be utilised to a much greater extent, reducing the costs of both treatment and tax. However, setting the tax on the spill volume would not be expected to work when various limiting assumptions used in the model are relaxed. This also discounts the use of the nominal tax rate (NTR) which attempted to reduce the tax paid when discharge was from the spill volume only, and did not cause the level of salinity in the river to violate the environmental standard.

The benefits of allowing free discharge of salt for the first 420 mg/L (zero impact salt), represent cost savings without adversely affecting the river salinity. Benefits arising from the use of free salt discharge of all minewater stored, whenever river assimilative capacity is high enough are also of benefit. The benefits from free discharge of the zero impact salt are high for a storage size of 6000 ML. Setting the tax on the basis of spill volume provides an additional saving in costs, although this is considerably smaller than the saving due to free zero impact salt. Free discharge of all minewater may be extended further to include the free discharge of all minewater whenever a predetermined level of assimilative capacity occurs, even if this will not fully assimilate all the discharge.

The tax policy formulated in this study is not recommended as an appropriate policy tool for meeting the environmental standard cost-efficiently in the Hunter River System. However, the free discharge components of the tax could be incorporated with other policy tools such as transferable discharge permits, with considerable potential benefits in both cost savings and use of the assimilative capacity of the river.