Water Resources

HORTICULTURE ON LARGE AREA FARMS GROUNDWATER MANAGEMENT ISSUES

A Discussion Paper

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HORTICULTURE ON LARGE AREA FARMS

GROUNDWATER MANAGEMENT ISSUES.

Contents

1. INTRODUCTION

The MIA Land and Water Management Plan aims at identifying a vision for the future in terms of the type of irrigated agriculture that may be developed, possible impacts of this irrigated agriculture and identifying economic and environmentally sustainable means of controlling these impacts. Amongst the various issues to be considered are control of land salinity groundwater control options, and downstream impacts of salt loads generated.

During 1984 an embargo was declared on the further construction of groundwater control works which involve the discharge of effluent to the MIA drainage system. This embargo was effectively reinforced by the MIA LWMP committee during early 1992 when it declared that all salt loads generated in the MIA should be disposed of locally, for as much as possible.

Horticultural development on large area farms is only possible if :

- No waterlogging or salinity problems due to high watertables are likely to occur, or:
- Groundwater levels can be controlled to a satisfactory level.

In the first instance there is no problem, and subsurface drainage is not required, however in the latter instance sub-surface drainage may be (is likely to be) required. For developments to date it is assumed that an evaporation area can be constructed that can receive the effluent and satisfactorily store it, so that the MIA drainage system will not be affected.

The management of evaporation areas, the design criteria, and sustainability of the concept to retain the effluent has been questioned recently, due to some undesirable experiences. This paper provides discussion on the various factors affecting these problem issues and gives recommendations regarding the possible ways by which the problems may be managed.

The problems resulting from ground water table rise, salinity and the installation of sub-surface drainage have been recognised in the past and a system of environmental review prior to development has been in place for several years. There have been deficiencies in the procedures however and even the current system warrants a further review. The methods used for the current system are described in Appendix 1.

2. GROUNDWATER CONDITIONS IN THE MIA.

About 85% of the MIA now has watertable conditions within 2 metres of the surface. Figure 1 shows pressure levels in aquifers underlying the MIA. It shows levels deeper than 2 metres in many places, however it needs to be noted that perched watertable conditions occur in the areas west of Griffith in the Benerembah Irrigation District. It may also be noted that there are many areas where watertables are within 1 metres from the surface. This applies to parts of the Murrami area, north of Gogeldrie, the Kooba and Widgelli area, south and west of Hanwood, and near Lockhart road in the Benerembah district.

The high watertable conditions are caused by several factors, of which percolation from rice fields is the most prominent. Watertables in non rice areas are at the end ofthe rice season are a function of the distance to rice fields, high near a rice field and deeper at greater distances. Between September and March, on average, the watertables rise up to a distance of 400 metres from rice fields, and further away the watertable level drop (in an average rainfall year). The effect is more if aquifer transmissivity is high and the surficial clay permeability is low. For instance in the Bilbul/Yenda area the watertable is likely to drop away more quickly with distance from the rice field than in the south of Hanwood area where aquifers are present.

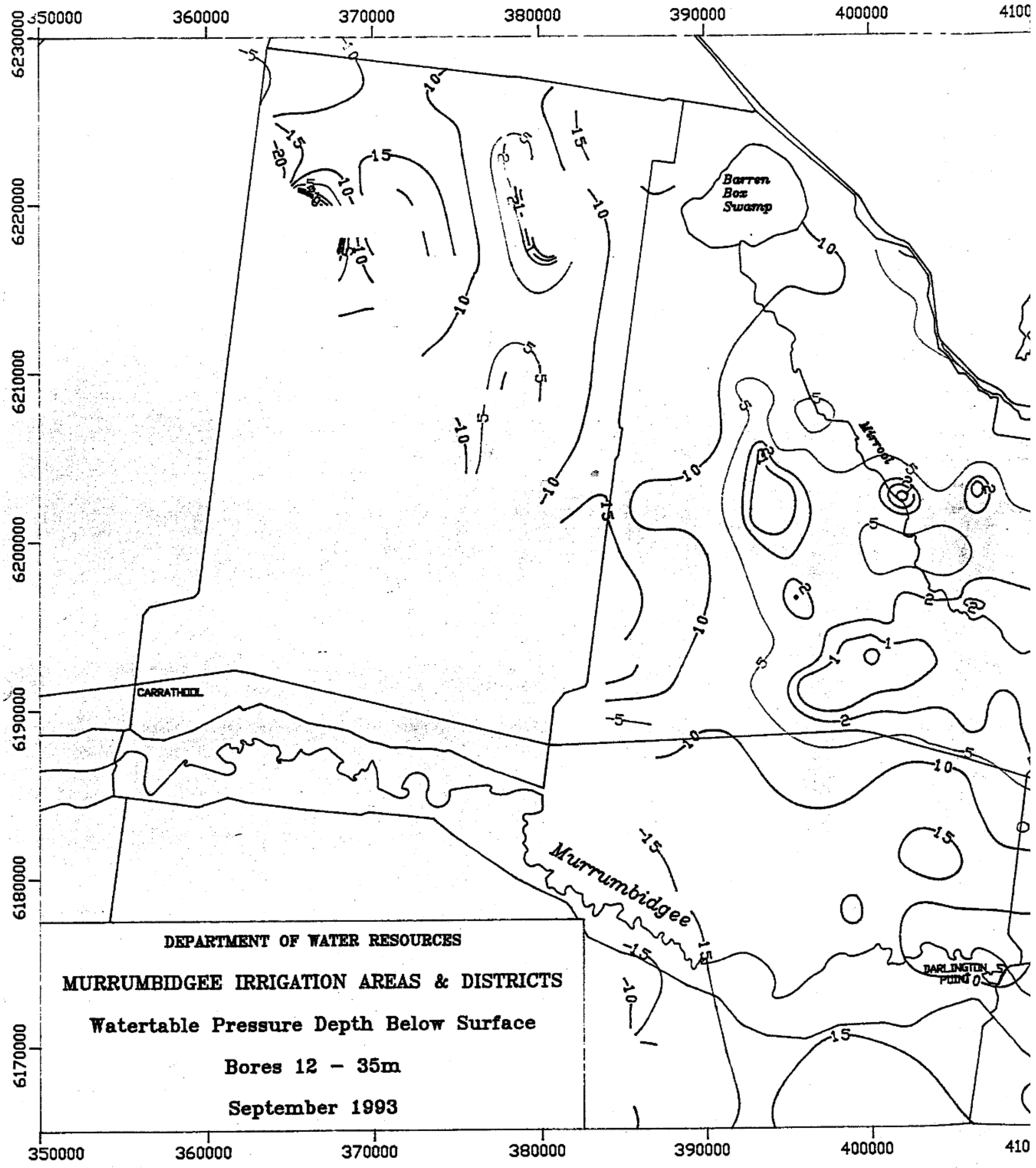
Investigations show that in areas underlain by aquifers and with about 30% of the farm areas under rice the proportion of land located at more than 400 metres away from a rice area is very limited.

The groundwater salinity in the MIA varies considerably, but ranges from about 5 dS/m in the east to over 20 dS/m in the west.

Note salinity conversions:

1 dS/m = 1000 uS/cm = 600 mg/L = 600 ppm = 600 kg/ML

(deci Siemens per metre, micro siemens per centimetre, milligrams per litre, parts per million, kilograms per megalitre)



DEPARTMENT OF WATER RESOURCES

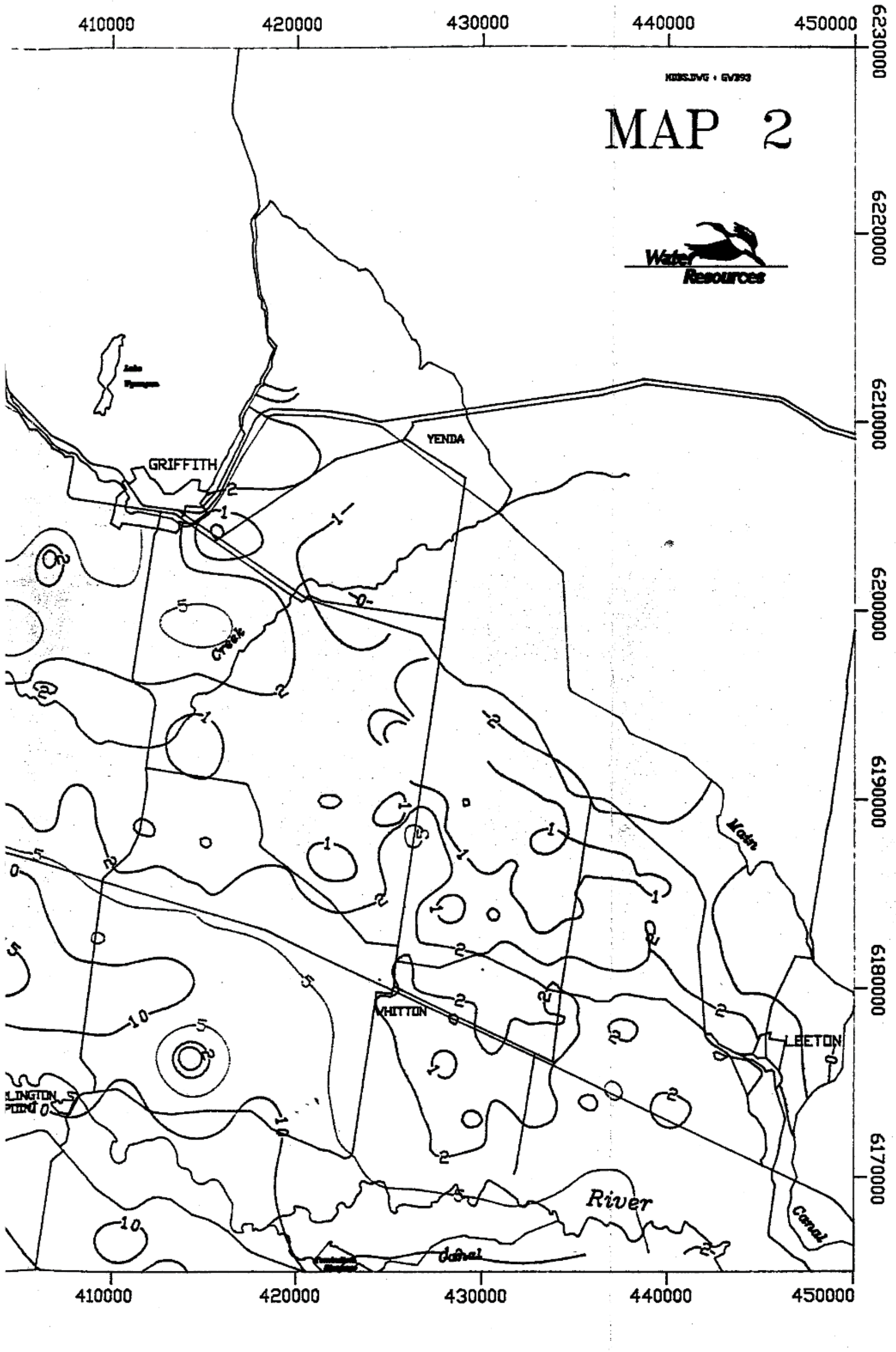
MURRUMBIDGEE IRRIGATION AREAS & DISTRICTS

Watertable Pressure Depth Below Surface

Bores 12 - 35m

September 1993

MAP 2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3. SITE CONDITIONS

Large area farm land previously used for rice growing is usually clayey in nature. The B - horizon of the clay soils (0.1-0.6 metres depth) vary in permeability, from less than 1 mm/day in Transitional Red Brown Earths under flooded condition to over 20 mm/day in some Self Mulching soils and prior stream related soils. Figure 2 shows the range of permeability values under ponded conditions.

The deeper subsoil of the Transitional Red Brown Earths (1.2-2.0 metres) usually also has a low permeability, to the extent that tile drainage may not be feasible. Figure 3 shows the range a values for the MIA derived from a special survey of hydraulic conductivity in the Bilbul area and parts of Kooba . The sefmulching clays on the other hand have higher hydraulic conductivity, which was confirmed after construction of experimental tile drainage.

In some parts of the west of Hanwood area the subsoil rather quickly merges into a more permeable layer, which increases drainability. Such changes to a more permeable layer may occur in all locations. The characteristics of deeper subsoils are not necessarily linked to the soil type. To discover the characteristics of the deeper subsoil bore logs of nearby piezometers may provide a clue, but often extra holes have to be bored and examined before a judgement can be made.

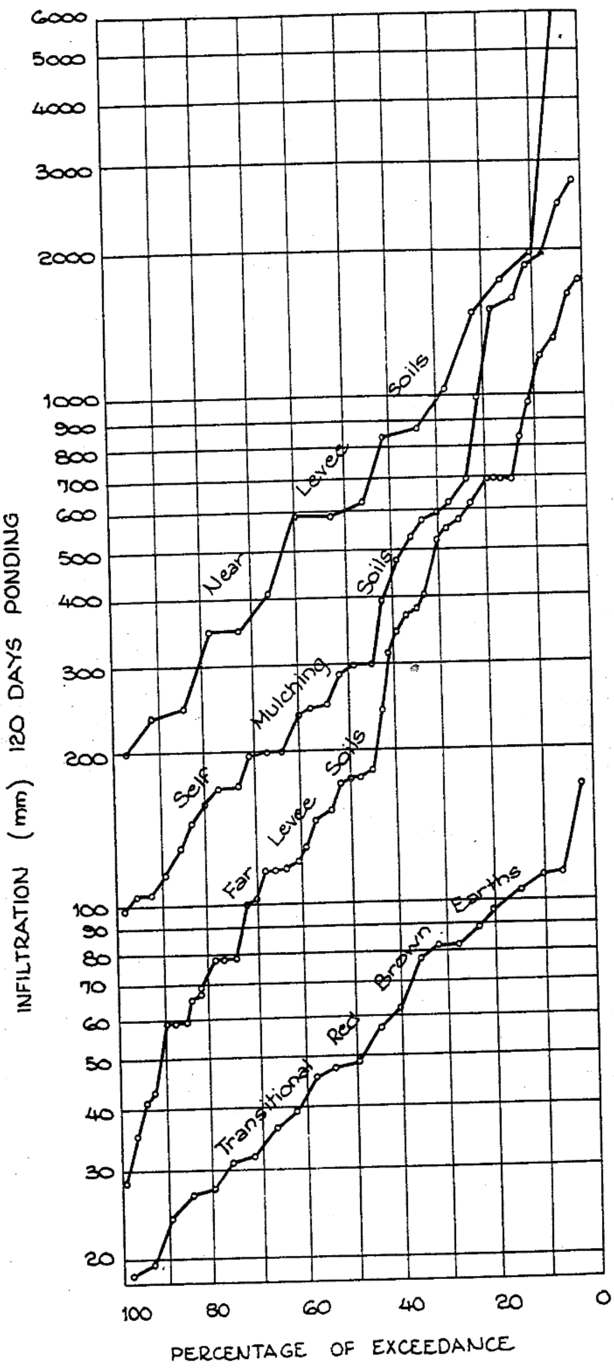
More permeable conditions throughout the profile are likely to promote better vine development, however will reduce the chances for successful construction of evaporation areas without special impervious membrames.

Aquifer conditions near each site are important in so far they these convey groundwater laterally to and from the site. Groundwater movement away from the site in horticulture is only expected near the fringes of the MIA. Elsewhere the reverse is more likely, there will be groundwater movement to the site from the surrounding rice areas, particularly if the general pressure levels are within 1.5 metres from the surface.

The transmissivity of the shallow aquifers that convey the groundwater is in the order of 10 to 200 m^2/day. A median value is likely to be in the range of 15-40 m^2/day. Transmissivity is a term describing the ability of the aquifer to transmit groundwater flow. For instance if the pressure gradient over one kilometre is 1 metre, and the aquifer transmissivity 100 m^2/day then the flow through the aquifer is 1/1000x100=0.1 cubic metre per day per metre cross section. The term is widely used in groundwater hydraulics and groundwater models.

Currently NSW Agriculture is responsible for advice on the suitability of land for horticultural development. In terms of economic viability, the less permeable the clay, the less suitable the site for horticulture, and the more difficult it is to make the site profitable.

The stratigraphical and groundwater conditions data are being consulted as part of the environmental review process, but this has not always resulted in an effective package of preventative measures, or a decision to not proceed with the development. For a discussion of environmental review processes, see Appendix 1.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INFILTRATION (mm) 120 DAYS PONDING
100
80
60
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20
0
PERCENTAGE OF EXCEEDANCE
Near Levee Soils
Self Mulching Soils
Far Levee Soils
Transitional Red Brown Earths

FIG 2

4. EXPECTED GROUNDWATER CONDITIONS

In most of the MIA the watertable levels are now at an equilibrium, and fluctuating seasonally at each point dependent on climatic and irrigation/crop stage conditions. Groundwater movement through aquifers occurs from where pressure levels are higher (relative to sea level) to where they are lower. Gradients for flow therefore are provided by the following factors.

1. gradient in the landscape from east to west (about 0.4 metres per kilometre)
2. gradient in the landscape from high areas to the average landscape (may be 1-2 metres per kilometre)
3. gradient from the average plain level to depressed areas (similar, 1-2 metres per kilometre)
4. gradient from a rice field where 0.15 metres of water is ponded, to an adjacent field, where the watertable may be at say 1.2 metres depth. A typical gradient is about 1.5 m/km.
5. Gradients to DWR drains, or subsurface drainage installations (tubewells, tile drains).

The first of these cannot be controlled, but is relatively small, the second may be (and has been) controlled by prohibiting rice on high land, the third cannot be controlled without eliminating irrigation altogether, the fourth is partially reversible by sensible rice rotations, and the fifth can be partially managed at the design stages of construction

The development of horticulture on large area farms is influenced mostly by the fourth factor. Unfortunately, the management option to rotate rice areas is not possible once horticultural plantings are established, therefore the groundwater flow to the horticultural development may be a one way affair. If the groundwater contains salt then there will be a net salt movement to the horticulture, because in the horticulture the watertable levels on average are likely to be deeper than in the rice areas.

Groundwater conditions on the hill slopes adjacent to the MIA, and on the western, south eastern, and southern fringe areas of the MIA tend to be at about 2 metres and deeper. In many of these areas it is probable that no problems will occur with high watertables over the lifetime of the plantings.

5. IRRIGATION TECHNOLOGY EFFECTS

Very high groundwater conditions more often than not are caused by irrigation or rainfall accessions not far from the site rather than at some remote location. Irrigation accessions are a function of irrigation technology and leaching requirement. Rainfall accessions depend on rainfall intensity, soils, slope and surface drainage management.

Slow steady rainfall in winter cannot usually be overcome by improved surface drainage alone. Summer and autum storms may be diverted to DWR drains if slopes, length of furrow and surface conditions are suitable. It is noted here that in the MIA many horticulturalists in the past have relied on their tile drainage system (and DWR pumps) to remove the excess rainfall. This was despite the repeated advice from the MIA Tile Drainage Committee to improve surface drainage, because the drains were not designed for that purpose.

It is concluded that it is likely there will be some accessions to groundwater from rainfall, even with the adoption of good irrigation and drainage technology.

Irrigation systems are designed to deliver sufficient water to plant roots, for transpiration purposes. If the aim is to supply sufficient water to the all locations on a planted area, then it is likely that most of the orchard will be overwatered. The degree of overwatering depends on the efficiency of the system.

The systems considered are furrows, micro- sprinkler and drip.

Furrow systems can be designed by considering soil infiltration, slope, water deficit in the soil and rate of flow application consistent with furrow shape. During the 1940's a lot of attention was given to these aspects because overwatering was causing waterlogging. (work by CSIRO, Pennefather, etc). After the introduction of tile drainage this became less important, and the efficiency of watering in terms of labour cost became the main factor in deciding furrow length, rather than the danger of waterlogging and accessions. Consequently in the 1990's not much consideration is given to design aspects of furrow systems, the generall idea being that longer furrows are better.

MIA tile drainage systems until about 1991 removed about 16% of irrigation applications, and some of this is due to inadequate furrow design, irrigation management.being the main other factor.

Efforts are being made to get farmers to cut back flows once it reaches say two third distance of the furrow. It is unclear to what degree this will be adopted, because the time spent by busy farmers on this activity may be less productive than other work he may do on his farm. This for instance is a clear outcome of a survey in the Barr Creek area of Victoria, where farmers find it is cheaper to waste some water to the surface drain instead of walking away from milking the cows and do a sterling job on water management. Labour saving is the highest motive for these farmers and water costs (post Dartmouth Dam allocation increases) is a lesser issue.

The water demand of plants vary throughout the season, and it is difficult to adjust furrow systems to match the changing conditions. For instance the flow may need adjustment, but it is not exactly known by how much to achieve even wetting of the whole length of the furrow. There may also be weeds in the furrows, interfering with flow rates in some parts.

It is concluded that significant accessions to the watertable are probable, even with good management. The only way to avoid large accessions is by underwatering the vines. Fortunately, this actually is the case for the early part of the growing season.

Sprinkler systems rely on pumps, pipelines and emitters which have to be balanced in design else there will be differences in water application across the paddock. These differences actually are inevitable. If sufficient water is given to all parts of the paddock accessions to the watertable of 10-20% are not improbable. Again only because underwatering for some parts of the gowing season is a likely strategy the actual accessions may be less.

Drip irrigation systems suffer the same handicaps.

An additional problem is that water requirements of the plants and the volume applied are not easy to match. Some special system based on water watch or neutron probes is necessary for management of subsoil moisture, and many farmers do not use these. Water availability in the channel may be a more important criteria of when to irrigate than the soil moisture content.

Rainfall accessions after irrigation are hard to avoid, particularly if the rainfall is of low intensity.

Comparing the three systems, it is concluded that all systems are likely to result in some accessions, however the furrow systems are likely to be the worst because of the complexities in correct design and changing factors during the season.

It is also claimed that grapes grown on raised beds may reduce accessions.. Raised beds may result in runoff to the intermediate furrow, hence better surface drainage. This, coupled with micro sprinklers or drip and a well designed system may result in the lowest possible accessions. If there is also a tendency to underwater during the earlier parts of the growing season then the volume of accessions may be near zero, particularly on the clay soils selected for grape growing.

6. PROBABILITY OF WATERLOGGING AND SALINITY.

The probability that salinity and waterlogging will be developing in the new horticultural development depends on a number of factors, of which site conditions, irrigation technology and management, and groundwater hydrology are the most significant. Climatic factors also play a role, and these may to a large extent determine the severity and frequency of occurrence.

The range of site conditions were discussed at section 3. Heavy clay soils are prone to surficial waterlogging and management of surface drainage to optimise oxygen levels in the soil will be crucial. The permeability of the soil will determine whether sub-surface drainage using horizontal clay tiles is feasible. If not feasible there are likely to be problems with waterlogging and salinity developing, as the contents of soil salts derived from irrigation water supplies increases. Heavy clay soils inherently have some salts occurring in the sub-soils which may be mobilised and conveyed by capillary flow to the soil surface.

Where some degree of natural leaching occurs, and this is likely where the depth to watertable prognosis is that it will remain below some 1.5-2.0 metres, then the likelyhood of soil salinity is much reduced (if not negligible). If the watertables are low at present, but are likely to increase in the future, then a risk of salinisation must be acknowledged from the outset.

It is only in situations of natural or artifcial through drainage in the order of 1-2 cm per year (0.1-0.2 ML/ha) that there is no long term risk of salinity developing.

Where surrounding rice farms cause a groundwater flow to the horticultural site, then inevitably a problem will occur. The size of the problem will depend on the rate of groundwater movement. Provided reasonable estimates can be made of groundwater gradient, soil permeability and aquifer transmissivity, then the relative risk can also be estimated. Example calculations of this may be found at section 8.

In the MIA large area farms watertable conditions are such that about 50% of the area has a watertable within 1.3 metres from the surface. With horticultural development in these areas it would therefore be expected that there is significant potential problem in much of the MIA. Because of the investments involved it would be sensible if landholders took advise from the outset what the relative risk of their proposal is.

In areas with little aquifer activity and limited scope for groundwater flow it is still probable that problems with salt build up and waterlogging will occur, however because flow rates from the adjacent farms is fairly small to negligible it may be feasible to construct sub-surface drainage systems and evaporation disposal facilities to cope with the problem.

Capillary rise from the ground water table is the process which ultimately will bring the salts into the rootzone. Capillary rise is generally higher in soils with intermediate size pores, such as in loams. These are the more permeable soils of lighter texture. Selfmulching clays, often selected for higher value production, allow a higher rate of capillary rise than the Transitional Red Brown Earths.

The rate of rise also depends on the depth to the watertable and the soil moisture conditions. In clays soils with watertables below 1.2 metres capillary rise is usually small, less than 0.2 mm/day. With watertables at 0.5 metres this may increase to over 1 mm/day, however if the topsoil is very dry the capillary rise is still small (<0.2 mm/day) because the pores for capillary flow are empty. In that situation all moisture loss from the soil is by vapour fluxes, which are of about the 0.1-0.2 mm/day magnitude. Capillary rise will increase if the evaporation rate decreases and if the topsoil becomes more moist, because a moister topsoil allows for many more larger soil pores to participate in the capillary rise process. In grape orchards the objective is to produce moist soils by efficient irrigation practices. The problem therefore is that good irrigation management which achieves zero leaching and keeps the soil moist may result in more rapid capillary rise, hence salting.

As the wetness of the soil increases further eventually the gradient for unsaturated flow reverses and there will be a leaching downward flow to the watertable. This is the situation existing during waterlogging (and ponding).

The issue to be faced is that with higher watertables beneath the horticultural plantings salt accumulation at a lower or higher rate may be inevitable. The question becomes - how much is it, can it be managed effectively and is the horticultural development viable, environmentally and economically.

7. OPTIONS TO CONTROL GROUNDWATER

The options to control groundwater include the following

Preventative measures to reduce accessions

- Careful site selection
- irrigation technology that minimises accessions and provides even application
- appropriate irrigation management (timing, volumes, rate of flow)
- an effective surface drainage system
- Weed/grass management between rows and soil management
- Buffer strips between rice areas and horticultural development
- Interceptor tree lines

Prevention is usually better than the cure. Preventative measures include care with site selection, efficient irrigation systems, the creation of buffer strips, and finally the planting of trees on these buffers to intercept groundwater flow.

Interceptor rows of trees are useful and are capable of removing a large proportion of groundwater seepage. The trees may become a sink for groundwater flow, in which case the land of the trees may become salinised over time (Heuperman, Tatura IRS). The width of trees needed depends on the seepage rate, of which Table 1 in section 8 gives an indication. With a seepage rate of about 0.05 m2/day and effective groundwater removal rates of about 2 mm/day a tree width of about 25 metres would be quite effective. In the average situation a width of about 12 metres may be sufficient. Much will depend however on whether the tree roots are capable of extracting groundwater from the aquifer and this is a function of stratigraphy as well as tree characteristics.

Whilst effective initially, it is probable that trees will eventually become less effective, as salts build up in the root zone. It is uncertain what should be done in that scenario. A probable solution is to irrigate the trees heavily, thereby transferring the salts to under the horticultural area, where it may be removed by the tile drainage system. In this case the trees have acted as a biological concentrator before the salts are passed on.

Groundwater Control Options

- Tubewell or spearpoint drainage (vertical drainage)
- Tile drainage (horizontal drainage)
- Hybrid horizontal and vertical systems
- Mole drainage
- Trees on Farm
- Deep surface drainage ditches that intercept groundwater

Groundwater control options include all measures that remove groundwater artificially, thereby lowering the watertable. The objective may be to control watertables, or to control salt levels building up in the soil. These two objectives have different criteria as far as the rate of groundwater removal per unit time is concerned. Usually, with watertable control the objective of salinity control is also achieved. With salinity control a smaller rate of groundwater removal is sufficient.

Vertical drainage is only possible where aquifer layers occur, and where pumping from the aquifer will result in a lowering of the watertable. Usually, with vertical drainage large volumes of water are removed (up to 3 ML/ha/year), which exacerbates the disposal problem. This option is not considered further in this paper.

Tile drainage in horticultural areas of the MIA typically remove some 1.6 ML/ha/year under furrow management.

The ground water sources to be removed are the accessions to the watertable from rainfall and irrigation and any groundwater flow to the site from surrounding paddocks (not only the neighbour property). It is possible that there is groundwater flow away from the site, in which case the drainage requirement becomes less or zero.

Mole drainage is used in large area farms with some success, however in horticultural farms, where deeper watertables usually result in more yield, this option is largely hypothetical.

Trees on farms usually have benefits over very limited distances only and are not effective for larger plantations. Their main benefit could be in terms of providing an interceptor to groundwater flow from areas grown to rice.

Deep surface drains may collect a fair bit of groundwater, particularly where an aquifer occurs at some depth below the drain bed. Deep drains meeting this criterion however are pretty rare. For instance with Main Drain J the effect of groundwater lowering would be over a distance of some 15-50 metres only, because there is no aquifer.

Tile drainage installed on horticultural farms in amongst large area farms may produce significant volumes of groundwater if an aquifer system is involved. In fact they may cause a lowering of groundwater levels and sub-surface drainage over an area several times larger than the horticultural development itself. This has been found in several experimental installations in the Kooba area and at Kerang.

Hybrid horizontal and vertical spearpoint systems use a 2 metres deep tile drainage installation which drains to a pumping sump, but also have spearpoints to the aquifer installed next to the tile drain, with a T-joint at the tile drain level to releave pressure from the aquifer directly into the tile drain. The advantage is that the flow from individual spearpoints can be easily controlled by insertion of a plug into the pipe. The discharge rate is greatly increased, reducing the need for narrow drain spacings. The disadvantage is that the larger flow rates increase the need for elaborate disposal systems.

8. EXPECTED VOLUMES OF GROUNDWATER PUMPING.

The volume removed by tile drainage traditionally has been some 1.6 ML/ha/year, with a variation of about 50% up or down. The volumes are derived from rainfall as well as irrigation. The only studies on this (DWR, 1972, 1980) suggests that in either case about 16% of the quantity applied to the land was removed.

For rainfall accessions this means that the typical rainfall contribution in tile flow is about 0.16 x 300 mm =0.48 ML/year (dry year) to 0.16 x 600 mm = 1 ML/year (wet year), average 0.64 ML/year. With net irrigation applications of 6 ML/ha the groundwater accessions, hence tile drainage flow, would be about 1.0 ML/year. This gives a total of 0.6 +1.0 = 1.6 ML/year in an average farm. Citrus farms that use more irrigation water than the average may drain more than the average grape farm which uses less, however this depends on the irrigation efficiency factors, see section 3.

With irrigation systems the efficiency in terms of reducing groundwater accessions may be improved from the traditional norm (which was not good) to zero. It is expected that even efficient irrigation systems result in some accessions however, and therefore the zero target is unrealistic. If the irrigation contribution to accessions was reduced to zero the annual average accessions would be about 0.6 ML/year. It is probable however that the actual accessions with the best possible technology and practices is a little more, say about 0.7 ML/ha.

Added to the volume derived from the irrigated plantings must be added any volume derived from groundwater flow from adjacent areas. The rate of groundwater movement is dependent on:

1. the pressure difference between the two areas,
2. the permeability of the surficial clays, and the
3. transmissivity of the aquifer.

Rates can be calculated if these factors are known. In many areas the value of these factors can be estimated from bore logs and watertable information.

Flow models are used to carry out the assessments. The calculations shown in Table 1 are approximations using analytical models developed for rice land hydrology (Reference: "Wakool ID, Sub-surface flow models to assess groundwater flow from evaporation areas" by A. van der Lely, 1988). Figure 4 shows schematically the groundwater flow conditions on which the numerical model is based.

The main issue in order to calculate estimates is to find suitable values for the three main parameters in the equations. The input values for the examples below are based on typical data derived from groundwater investigations over many years.

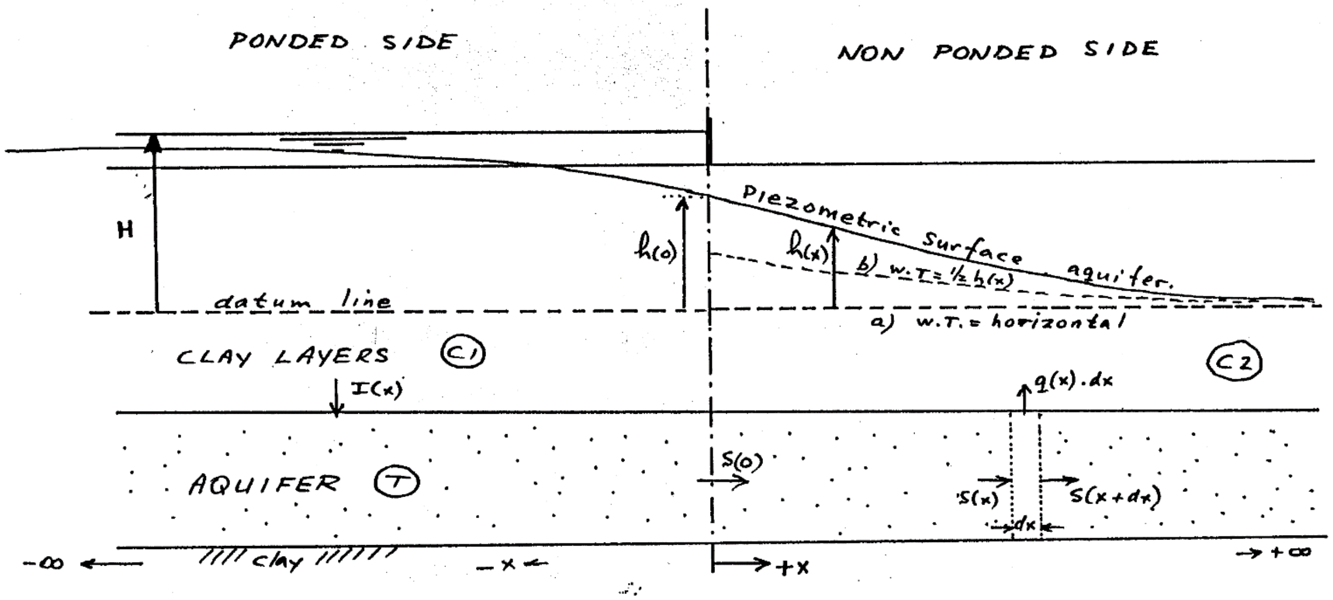


FIGURE ~~25~~ 4 : MAZURE ANALYTICAL MODEL TO ESTIMATE PIEZOMETRIC HEAD, AND FLOWS AT VARIOUS DISTANCES FROM THE BOUNDARY BETWEEN PONDED AND NON PONDED AREAS. (I = DOWNWARD FLOW, q = UPWARD FLOW, S = AQUIFER FLOW)

TWO CONDITIONS : a) WATERTABLE NON PONDED AREA IS HORIZONTAL ;
b) WATERTABLE NON PONDED AREA IS AT $0.5 \times h(x)$

Table 1: Groundwater flow rates in various situations from rice areas to horticultural development.

Situation	WT depth in Rice Farm (m)	WT depth in Horticulture (m)	Transmissivity aquifer m²/day	Resistance to flow in clays (days)	Flow at 50m from rice area boundary m²/m/day	Drainage Rate (*1) ML/ha/ year
Bilbul area	1.3	1.6	<5	1000	0.006	<0.11
Kooba	1.2	1.6	100	500	0.051	0.93
Kooba	1.2	1.6	20	1000	0.018	0.32
Kooba	1.2	1.6	50	1000	0.032	0.60
West Hanwood	1.2	1.6	50	250	0.053	0.97
Whitton	2.0	2.0	200	200	0	0

(*1): Assuming 20 hectares of horticulture, a 1000 metres length of effective perimeter for flow, a buffer area of 50 metres, and a 365 day year.

The flow from the area with higher watertables (the rice farm) is initially calculated in m²/day, which then has to be multiplied with the length of the boundary with the area with higher watertables, A square, 20 ha horticultural block has a perimeter of some 1.8 kilometres. The flow is likely to come from one direction only in any given year, which give an effective perimeter of some 1000 metres. This, and multiplying with 365 days for the year and then dividing in the 20 hectare area gives the volume to be removed by the tile drainage system.

The horticultural area boundary would normally abutt the area generally used for rice growing (at normal rotation). If a buffer strip of 50-100 metres in included the seepage rate will be less by about 25-40%. Since such measure is not unlikely as a measure which will be recommended a 50 metres wide strip is assumed for Table 1.

Table 1 shows that with these assumptions the values may range from less than 0.1 ML/ha/year in the Bilbul area to about 1.0 ML/ha/year in the Kooba area where the transmissivity in the aquifer is highest. Considering that the median transmissivity of aquifers in the latter areas is in the order of 20-50 m²/day it is found that the third and fourth example with an average seepage rate about 0.45 ML/ha/year represents the situation which will be commonly found.

The estimates are based on average observed watertable conditions in the rice farm area. When the rice field is situated close to the horticultural development groundwater flows well in excess of those calculated may occur for the transmissivity and clay permeability conditions indicated (say two and more times higher).

The last line of the table demonstrates that no significant groundwater movement to the horticulture will occur if the gradient is zero, or groundwater level in the rice areas are at a reasonably safe level for capillary rise, which in clay soils is about 1.5 to 2 metres.

Adding the two sources of sub-surface drainage together the following table may be compiled, giving estimated probable volumes of sub-surface drainage.

Table 2: Drainage flow (q) resulting from internal and external sources combined (ML/ha/year)

Irrigation Technology in Horticulture	Low k and T	Median k and T	High k and T
Low effiency	1.7	2.05	2.6
Medium efficiency	1.3	1.65	2.2
High efficiency	0.8	1.15	1.8

From this it would follow that for locations with high watertable conditions in the adjacent rice areas the installation of tile drainage systems would lead to the removal of large volumes of groundwater. This is further discussed in section 10.

The volumes of table 2 will not be realised if buffer strips of trees are planted to intercept seepage. The transpiration of the trees has to match the groundwater flow. If this is achieved the effluent volume woul be closer to the values in the left hand column of table 2. It needs to be remembered though that when rice is grown close to the buffer strip the seepage rates will be higher and the trees probably less effective. Winter transpiration rates are less, may may reduce effectiveness for that season.

9. ALTERNATIVE DISPOSAL METHODS.

The discussion below initially assumes that no interceptor tree lines are planted.

Various alternatives exist for disposal of effluent, once it leaves the sub-surface drainage system.

- disposal to the DWR drain
- permanent disposal to an evaporation area
- temporary disposal to an evaporation area
- disposal to areas of saltbush on the same farm.
- reuse of effluent.

Disposal to DWR drains has already been recommended as an unsuitable option because it causes damage to the productivity of downstream landholders who reuse the water. It is also harmful to the downstream environment, e.g. the river and the lower Mirrool Creek wetlands.

The "Ranking of Options" paper by Chris Stanton, Appendix 2 concludes on basis of a preliminary assessment discusses that the cost to downstream landholders is in the order of $40/tonne of salt. The cost may increase as a result of the proposed cattle feedlot at Tabita. If the quantity of salt in a farm in the top 3-4 metres is in the order of 100 tonnes, a cost of several thousand dollars per hectare needs to be considered by the time all the salt is discharged to the drains, which may be over a period of some 25 years. Where groundwater flow from rice farms occurs the process could be on-going forever and a day. Without having done analysis this option appears uneconomic. It certainly is undemocratic.

Permanent or temporary disposal to an evaporation area may be feasible technically, and this is discussed further at sections 10 and 11.

Permanent disposal implies that the salts are to be permanently stored in the receiving evaporation basin. The permanent site may be located on the farm where the effluent originates, or it may be stored on one of the neighbouring farms, where several landholders have ageed on a group scheme. A group scheme may include 2 to 10 farms. If one of the farmers has land less suitable for higher value crops, but suitable for evaporation area construction, then he could offer his services to the others and, for a fee, become a specialist effluent disposer. It is likely that short pipelines would be constructed from the effluent producing farm to the permanent site.

Temporary disposal assumes a transfer of the stored groundwater to a selected permanent site to the west during for instance the winter months. This may be feasible and has been considered from time to time, e.g. with sub-surface drainage investigation in the Kooba area. However the following problems exist: (next page)

- practical transfer of the saline flows as a salt slug through the channel system, control of flow rates from other sources at that time
- dilution with other winter drainage flows (e.g. low salinity horticultural tile drainage existing farms) will add to the volumes to be disposed off at the permanent site further west

- unpreparedness of western landholders to have an evaporation area constructed on their farm. It will not be easy to buy land in small parcels just for this purpose.
- the idea that MIA farmers prefer to export their problem rather than solve it.
- general potential problems with leakage from almost any selected site in areas with aquifer activity.

The only way this option could proceed would be by having the permanent site located at close proximity to the MIA, perhaps in the Barren Box Swamp area. Benerembah farms however attract values not less than in the MIA, and Wyvern station is unlikely to cooperate.

Irrigation of saltbush or agroforestry could be attractive. If the salinity of the effluent is below 8-10 dS/m then up to 4 ML of effluent could be used by a hectare of saltbush. If the salinity is below say 4 dS/m a larger volume could be used on a hectare of salt tolerant Eucalypts. If these irrigations are augmented by fresh channel supplies and or the salinity of the effluent is less, then the option could be quite sustainable. The land selected would usually be the less productive (but non salne) parts of the farm, therefore the productive loss overall may be small.

Saline land should not be selected for this option, because that type of land is on the way out , and even saltbush will not survive in the long run. The longevity of the option depends on the quantity of salt that may be added to the soil system before the plantings will start to suffer from salinity. If there is some leaching this could be quite long.

Sound advice should be gathered before embarking on this option, but it may be more sustainable and cost effective than evaporation areas.

Reuse is mentioned but only practical where the groundwater salinity is below 3 dS/m (2000 ppm). This is a rare situation in the MIA, but not uncommon in the area west of Hanwood.

10. SIZING OF DISPOSAL/EVAPORATION AREAS

If it is decided to dispose of effluent to a permanent site two critical design aspects need to be considered:

- rate of discharge of effluent from the tile drainage installation
- ability of the evaporation area to store and dissipate effluent

The first of these two aspects has been discussed at section 8. It was concluded that volumes of effluent may vary between 0.8 and 2.6 ML/ha/year (80-260mm/year), median values being about 1.2-1.6 ML/year. The qualification is that in some locations where groundwater movement away from the horticultural site occurs the drainage rate may be less than 0.8 ML/ha/year and even negative.

The evaporation rate of a class A pan in the Griffith area is 1800 mm/year. The coefficient applicable to get the evaporation rate from a small lake is 0.7-0.8. Using the lower value shows that about 1300 mm would evaporate in an average year. In a 90% cool year the evaporation rate is in the order of 1200 mm. Rainfall has to be deducted. This varies from 300 to 600 mm, the latter value applying for a wetter (cool?) year. The conclusion is that the net evaporation rate would range from about 700 to 1100mm/year, the average being about 900 mm/year.

A wet year may be followed by a drier year, therefore if the evaporation area is constructed to allow for a 200 mm carryover from one year to the next, then the average evaporation rate may be used for design of the area.

A safety margin is also required if it is likely that from time to time rice will be grown at close proximity to the horticultural development. In those conditions the groundwater flow to the site will be larger than shown at Table 1 (section 8), and this flow will end up in the evaporation area.

Combining the volume of effluent from Table 2 (section 8) with the evaporation volume it is found that the size of the evaporation area would vary from one hectare in twelve to one hectare in four hectares of horticultural plantings, with a median of about 1 in 8 ha. The lower proportion (1:12) applies for very efficient systems without groundwater recharge and very low groundwater flow to the site and the larger proportion applies for the more problematic sites with high groundwater recharge rates. For each case a decision needs to be made regarding the appropriate value.

If trees are planted in a 50 metres buffer strip between the horticulture and the areas grown to rice the evaporation area may be reduced, however ratios of less than one in ten hectares will not be easy to achieve, even with efficient irrigation technology.

With groundwater movement away from the site ratios of 1:20 hectares and less are a possibility.

Percolation from the evaporation area should not be included as a design consideration, because it needs to be assumed that all percolated water will be returned by means of an interceptor tile drain. If there is a probability of leakage from the evaporation area then an impervious membrame needs to be included in the design and construction cost.

Most effluent with efficient systems will be pumped during the winter months. This means that the height of the banks will need to be designed having in mind of this extra height (say about 50 cm). Other height considerations are the year to year carry over requirement (about 30 cm) and the free board safety requirement (about 50 cm). These heights are not necessarily 100% additive and generally a 1.2 metre high bank will be sufficient.

Extra height is not a substitute for area. If the area is insufficient the pond will get fuller and fuller. The area must be sufficient. It pays to over design the area by say 20%. Area in this sense can be a substitute for bank height. A larger area will give more tolerance for the bank heigth requirements and it will ensure that most years parts of the ponds will be empty, which may be important from a maintenance point of view.

If saltbush is contemplated the volumes to be disposed off should have a salinity of less then about 8-10 dS/m. About 2-4 ML/ha maybe disposed off, and the means the area of saltbush should be about three times larger than an equivalent evaporation area. The benefits are that some grazing value may be obtained, which may suit farmers who also run sheep.

If Agroforestry is contemplated the salinity of the effluent should be less the about 3-5 dS/m. Aboout 5-10 ML/ha may be disposed off, but part of this should be fresh. Depending on circumstances an area would be required equivalent to the size of an evaporation area, to 50% larger.

The volume of the evaporation area will always be sufficient to store the salt that will enter the basins from the evaporation areas. Typically only a couple of hundreds of tonnes are stored in the soil underneath the horticultural plantings. This salt load may be augmented by the groundwater flow process, as described, as well as the salts in the irrigation water. However a 0.5 metre layer of salt in one hectare of evaporation basin would contain about 10,000 tonnes. Therefore, even with a one in ten ratio of evaporation area to horticulture there is sufficient storage space. The only concern would be that eventually the horticulture may be abandoned and the salt in the evaporation basin no longer cared for by regular maintenance of banks.

In cases without impervious membrames much of the salt may end up in the groundwater system beneath the site. This would occur anywhere where the seepage rate is above about 0.5 mm/day. This applies anywhere in the Riverine plain where an aquifer is present within 15 metres from the surface. Where the permeability is less at present it will increase due to the saline nature of the ponded water. The feature of losses to the groundwater system is not necessarily a problem for sustainability. Interception drainage would return the concentrated groundwater flow.

11. EVAPORATION AREA CONSTRUCTION METHODS.

The DWR has produced a handout for evaporation area construction and this is attached to this discussion paper. The main issues are that banks are to be constructed properly and capable of allowing traffic, which will aid in compaction. Side slopes need to be small enough to avoid wave erosion. There needs to be enough safety margin.

Where seepage from the evaporation area is a possibility an impervious membrame must be included. The impervious membrame may be plastic based but needs to be strong enough to avoid rupturing during construction and compaction of the overburden (of some 30 cm of soil). The seams need to be watertight.

Consideration also needs to be given to the future maintenance aspect and the ultimate fate of the evaporation area after abandonment (perhaps) of the horticultural venture.

12. BENEFIT/COST ANALYSIS.

AS the problems with seepage from surrounding areas grown to rice increase the cost of remedial measures increase. A full benefit cost analysis may be carried out to establish a cut off point whereby it is not economic to proceed with horticulture in given situations. This may be carried out over the next few months. The various factors to be analysed are given below.

- The gross and net profit margins of the horticulture to be established. This will provide an idea as to the ability of the enterprise to include tile drainage and construction of evaporation areas in the cost structure.
- Cost of tile drainage installation and operational cost. This is a variable depending on the rate of groundwater to be removed. Typical costs may be in the order of $2,500-5,000/ha. Some land may not be drainable. Other land does not require tile drainage.
- Cost of other preventative measures, such as buffer strips and interceptor tree plantings
- Cost of evaporation area construction. This is also variable dependent on rate of groundwater removal. A typical cost per hectare may be decided upon (could be about $10,000/ha with plastic membrame, and $5,000 without membrame)

The above analysis should give a cost per hectare for several situations, and this may be compared with the marginal profitability to give a break even point.

A preliminary assessment indicates that where evaporation area to horticultural area ratios of more than 1 in 10 are needed the horticultural enterprise may no longer be economic. This means that landholders are ill advised to proceed with low efficiency irrigation methods in conditions of high watertables in rice areas underlain by transmissive aquifers.

No matter which type of scenario is the break even point, the fact remains that situations where no tile drainage is needed are the most profitable.

A mechanism is needed whereby prospective large area farm horticulturalists are forewarned about the consequences of high watertables and the problems of effluent disposal. The current EIS processes are insufficient in this regard, as it is based on an interview, and the filling out of a form based on checking of available data only

13. CONCLUSIONS AND RECOMMENDATIONS.

About 85% of the MIA now has watertable conditions within 2 metres of the surface. Only the hill slope areas and southern fringe areas are not likely to be subject to possible problems with watertables, hence have no need for sub-surface drainage.

In most parts of the MIA aquifer conditions occur which will allow groundwater flow from the areas grown to rice to the horticultural developments. Because of watertable gradients these flows will tend to be one way, and will cause transport of groundwater salts to the selected sites.

Improved irrigation techniques may reduce groundwater accessions, reducing the subsurface drainage requirement to about 0.7 ML/ha/year. However the groundwater flow component may add another volume, which may range from negative at the naturally well drained sites, to 1.0 ML/ha at sites where aquifer activity and soil permeability are high. At sites where no aquifers of substance occur the groundwater component may be as little as 0.1 ML/ha/year.

The volumes of groundwater seepage to the horticultural site may be reduced by rows of interceptor trees and buffer strips, however some of th groundwater and perhaps most of the salts will eventually find their way to the horticulture.

No matter what the efficiency of the irrigation system, if there is groundwater flow to the site from surrounding areas, then it is likely that salinity transport into the rootzone via capillary rise will eventually occur. This will increase the demand for a sub-surface drainage system to be installed.

The effluent volume should be estimated for each site separately to establish the design criteria for the tile drainage system and the evaporation area. Alternatively the effluent may be disposed to areas of saltbush and/or agroforestry on the same farm or a farm belonging to a group.

Tubewell drainage and other means of groundwater control appear not feasible, for various reasons. As far as disposal methods are concerned, it was found that the preferred option is to dispose of effluent on or near the farm that originates the effluent.

The effluent volumes will vary between sites and this will affect the size of the evaporation area. If is probable that a ratio in area of horticulture to area of evaporation area below 10 is no longer viable economically, because expensive impervious membrames are likely to be needed in most instances.

It is recommended that economic analysis is carried out for the break even ratio of horticulture over evaporation area. If current guesses are correct landholders who embark on horticulture in high watertable areas underlain by aquifer systems are ill advised to proceed.

A mechanism is needed whereby prospective large area farm horticulturalists are forewarned about the consequences of high watertables and the problems of effluent disposal. The current EIS processes are insufficient in this regard, as it is based on an interview and the completion of a form and not on a proper independent assessment.

Appendix 1: Current Environmental Review Procedures.

Before establishing horticulture the volumetric water entitlement of the holding needs to be converted from low security to high security. The responsibiltiy for this rests with the Commercial Arm of DWR. The process includes an environmental review of the changed land use, which to date has been referred to the State Arm of DWR.

Until 1993 the review was mostly concerned with the sub-surface drainage issue, and the need to dispose groundwater to evaporation areas rather than the drain. DWR (State Arm) charged a fee, carried out investigations and decided whether the proposal could proceed. This led to special requirements being put into the approval and the conditions for water supply to the converted holding.

The disadvantage was that the conditions were imposed rather than volontarily adopted by the proponent. The proponent was not necessarily committed to the measures to be implemented, e.g. he could disagree with the sizing of the evaporation area. To achieve volontary compliance the procedure was changed during early 1993, causing the proponent to become responsible for supply of sufficient information that would satisfy the DWR Regional Environmental Officer (on behalf of: Regional Director) that no environmental harm would occur. This procedure is in accordance with Part V of the EP&A act 1979 and principles of environmental law making.

Although the new procedure was introduced the report with information submitted by the landholder in fact was still being prepared by a section within DWR as a contract job for the landholder. On completion of the document the landholder would peruse the document and sign it, and take ownership of the measures proposed before forwarding the document to the reviewing officer, also in DWR.

DWR State Arm was seen to be the determining authority for the process but the new procedure had a short life as in May 1993 an embargo was declared on processing applications following submissions by the Griffith City Council and others. This concerned a view that social economic factors were not considered properly during the procedure.

The embargo was lifted during September 1993 and since that time the processing of applications has followed a different procedure, including the completion of a form consistent with Part V of the EPA act, but without investigations regarding tile drainage feasibility, volumes of effluent and identification of areas suitable for evaporation pond construction. As far as the latter is concerned it was considered that impervious membrames would normally be needed, therefore soil investigations were unnecessary. The proponent is required to clearly state his intentions regarding the development and the measures that will be put in place should problems with high watertables develop. Depending on the case certain aspects are referred to other agencies, e.g. regarding the Pesticde Act or other issues. Surrounding landholders are given an opportunity to object to the proposal and state their views. Finally DWR passes judgement whether the proposal is to be approved or not.

Following the discussion in this paper it may be concluded that more detailed site investigations and examination of prevailing groundwater conditions etc probably should be carried out before completing the process.

CURRENT GUIDELINES

DEPARTMENT OF WATER RESOURCES

Murrumbidgee Region

HORTICULTURE ON LARGE AREA FARMS

Future need for Sub-Surface Drainage

Since the de-regulation of the growing of horticulture on large area farms there have been quite a few enquiries to get approval to go ahead. This involves consideration of water allocation aspects, subdivision, winter water supply and other aspects, but also environmental considerations.

With intensive irrigation, even with preferred systems such as drip and microjet systems, it is inevitable that a proportion of the water supplied or rainfall will reach the watertable. The watertable will eventually rise and may cause problems. There is a likely need for sub-surface drainage in most cases, particularly where the land is basically flat.

The current D.W.R. policy is to not allow sub-surface drainage effluent from any farm to enter D.W.R. drains, excepting horticultural farms, or farms with plantings existing before 1984.

This means all new horticultural development is subject to having to retain drainage effluent, now or in the future, on their own farm. Since recirculation is feasible in only limited circumstances, evaporation disposal may be the only means which can allow sub-surface drainage to go ahead.

As part of the approval process the environmental aspect is to be investigated, including the possibility to construct evaporation areas which will not leak excessively and affect other farms by the seepage process. A fee is charged by D.W.R. for these investigations.

Currently the requirement is that a minimum area equal to 10% of the land proposed for horticultural plantings be set aside for evaporation area construction. The nominated area must not be planted up. The 10% is a minimum and is sufficient if drainage is not more than 1 ML/ha/year from the area planted. Please note that most orchards in the M.I.A. drain about 2 ML/ha/year through the tile drainage pump.

It is very important to properly construct the evaporation ponds. The guidelines below have been compiled by the Resource Assessment Group of the D.W.R. in the M.I.A. and should be followed as closely as possible. If enquiries exist please do not hesitate to contact Mr. R.L. Ellis, Field Officer of the D.W.R. at Griffith (069 624408).

Manager
Murrumbidgee Region.

GENERAL REQUIREMENTS FOR CONSTRUCTION OF EVAPORATION PONDS FOR DISPOSAL AND STOARGE OF SALINE WATER

1) Most important is the selection of a suitable site. Ponds located on light soils will leak resulting in movement of salt out from the pond perimeter or into the local groundwater body.

2) Banks should be about 1 metre in height and 2.4 metres wide at the crest so as to allow passage of light vehicles.

3) To minimise bank erosion an inside slope of 1:5 is recommended (See diagram). This will absorb much of the wave energy.

4) The outside of the bank can be constructed at a 1:2 slope.

5) Before bank construction, the top soil should be pushed out from the area where the bank is to be located. This will key the bank into the less permeable subsoil and reduce through bank seepage. It is also important that the inside of the bank is formed from the subsoil or at least lined with subsoil (See diagram).

   The topsoil can be pushed up against and onto the bank crest as a final step, this will encourage vegetation reducing erosion.

6) The bank should be compacted during construction by passage of machinery and compacting roller (Sheepsfoot or vibrating).

7) An interceptor tile line should be installed around the pond perimeter at a depth of 1.5 to 2 metres. This line will carry out a critical role in returning seepage water to the pond. This seepage rate will increase as the salt levels in the pond increase due to the effect of the salts on the clay.

8) A buffer at least 10 metres wide from the outside of the bank around the pond will provide access. This buffer with the intercepting tile line below it will minimise seepage into Department channels and neighbouring farms.

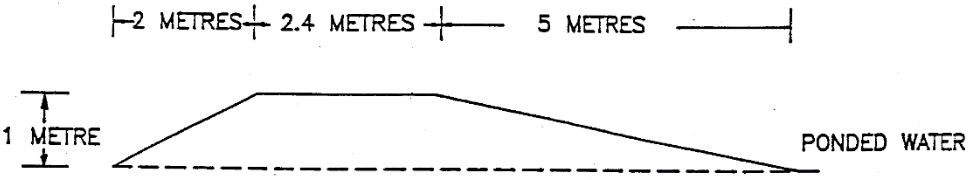
9) The bed of the pond should be compacted as a final step. This will reduce seepage through the pond bottom.

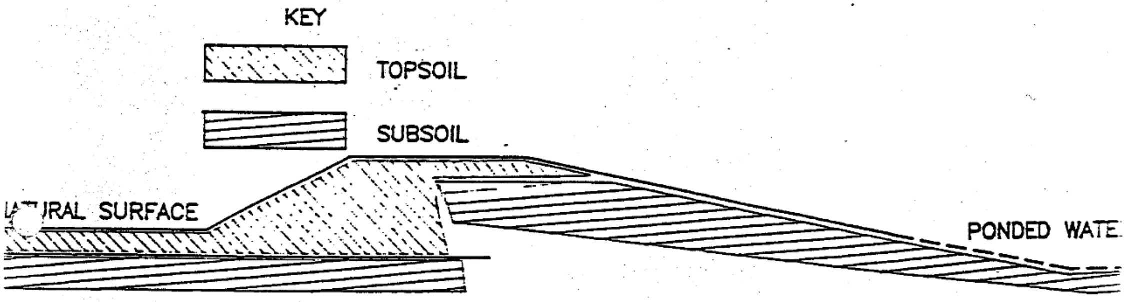
10) Ponds should be divided into smaller ponds, about 1 hectare in area with internal banking. This will reduce wave action and bank erosion.

11) Connecting pipes between ponds should be set below 300mm from the pond bottom (as low as possible). This will increase the evaporation surface and limit wave activity.

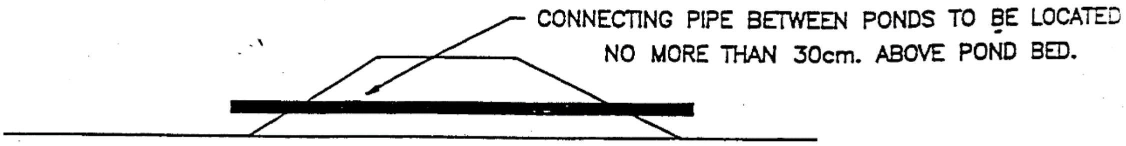
DEPARTMENT WATER RESOURCES
GRIFFITH.

ON—FARM EVAPORATION PONDS — DIMENSIONS OF OUTSIDE BANK





INTERNAL BANKS


CONNECTING PIPE BETWEEN PONDS TO BE LOCATED NO MORE THAN 30cm. ABOVE POND BED.