3. Inverloch

Occurring to the north of Inverloch in the small catchments of Pound and Screw Creeks, the mapped salinity discharge areas (one shown in **figure 13**) range in size from a few hectares to several tens of hectares (see map, **figure 18**). Of significance for this location is the urban development of Inverloch that potentially overlies some of these areas of high watertables.

Although close to the coastline, the salinity occurrences are far enough and high enough above sea level to not be considered primary salinity coastal features. The small catchments are less than10 kilometres wide and have gentle slopes generally less than 5°.

Figure 13. Looking east from Stuchberry Road across Screw Creek

3.1. Inverloch Climate

As for Rosedale, 50 years of data drill climate data (1950 to July 2006) that includes daily rainfall and evaporation data was obtained from the SILO website for coordinates 38° 40' S and 145° 42' E. Mean annual rainfall is between 900 to 1000 mm and mean annual potential evaporation is between 975 to 1000 mm.

This data was processed in the same way as the Rosedale data, with a plot of daily potential recharge illustrating the variability in rainfall and evaporation over the years. (See Figure 2, Appendix A). Compared to Rosedale, the rainfall is slightly higher and evaporation lower, with no years failing to have recharge periods. The coastal location is probably responsible for this. Daily recharge events were also generally higher, with substantially more 2 - 4 mm/day events than Rosedale. As with Rosedale though, some years had longer and more significant recharge events than other years.

The 'estimated total annual recharge' plot (**figure 14**) shows that in all years, recharge conditions have occurred. The years 1950, 1967 and 1998 are notably the lowest potential recharge years. Any trend towards drying conditions is less obvious here than at Rosedale. The decade to 1960 had an average of 226 mm/year recharge. There has been some decline to 197, 181, 175 then 192mm/year over the next 4 decades, and the past 5 years has an average of 163 mm/year. The 5 year rolling average line shows a less obvious trend here compared to Rosedale.

While the absolute recharge values and the method of their calculation could be debated, the method treats the raw daily rainfall and FAO evaporation data consistently, so there is no doubt that the rainfall and evaporation conditions at Inverloch are conducive to higher overall rates of recharge when compared to Rosedale and Yarram.

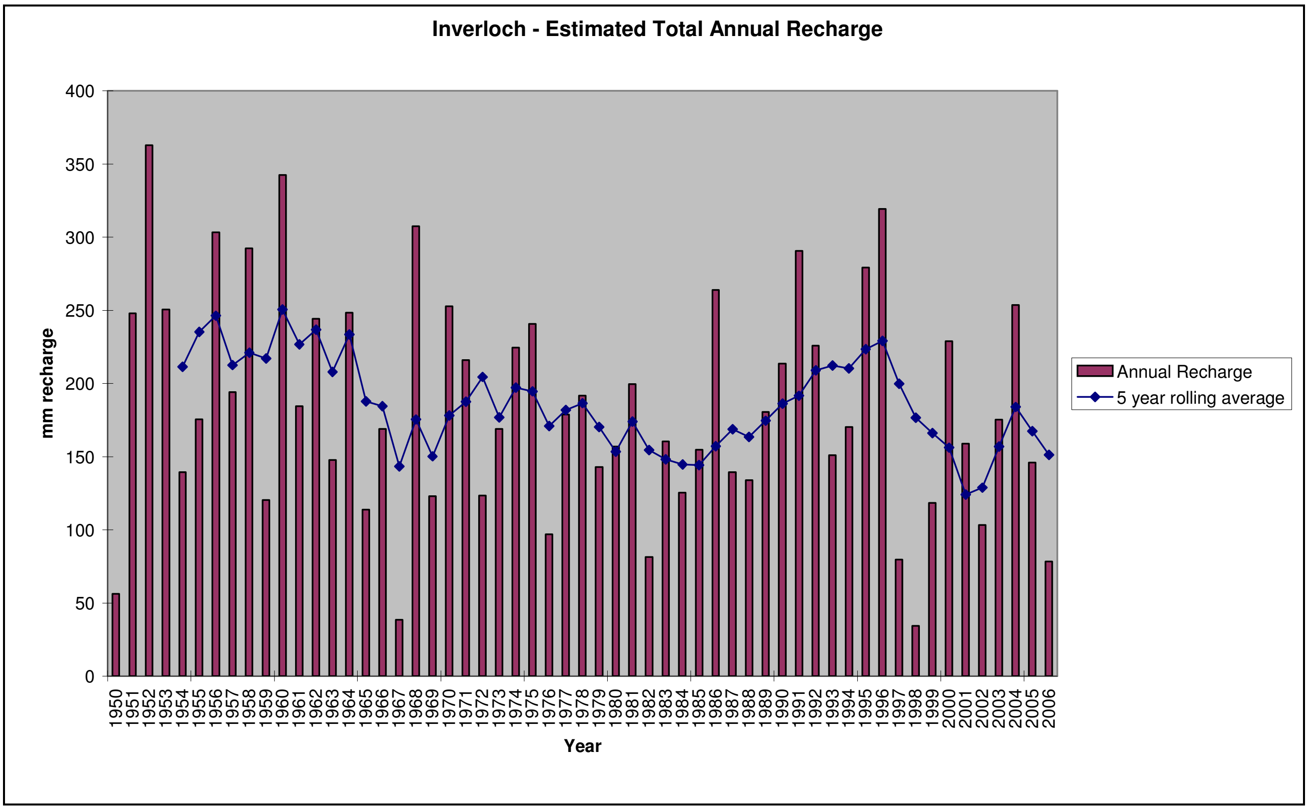

Figure 14. Estimated annual recharge for the Inverloch area

3.2. Inverloch Groundwater Flow System

SKM (2005) defined GFS 5, Tertiary Sediments - general, as the major groundwater flow system in the vicinity of Inverloch. It is considered to be of predominantly local groundwater flow path scale, with some intermediate influence. It overlies Cretaceous bedrock.

For the full characterisation of GFS 5, see SKM (2005). The key characteristics of most importance in this Flowtube modelling exercise (taken from the GFS report) are as follows:

Salinity Process - Recharge likely to be occurring on upper parts of low hills and discharge occurring on lower lying floodplains.

Groundwater Level Trend - Rising in the Inverloch and Yarram areas (hydrographs near Inverloch show discharge conditions have prevailed since monitoring began in 1999 - see **figure 7**).

Groundwater salinity - Generally less than 500 mg/L TDS, with some areas 1000 - 1500 mg/L TDS

Topography - less than 5^{o} slope

Soil Permeability - Large areas of moderate permeability, with remainder having low to high permeability.

Geology - Sands, gravels and yellow and grey clays (Haunted Hills Formation)

Aquifer type - unconsolidated sediments

Aquifer properties (hydraulic conductivity, gradient, transmissivity, storage coefficient) - all unknown

Temporal recharge distribution - follows rainfall pattern

Spatial recharge distribution - Most recharge through permeable soils on upper slopes of rolling hills.

Current landuse – Grazing, annual and perennial pastures.

3.2.1 Inverloch Conceptual Model

The conceptual model developed for GFS5 is that of recharge occurring on the low hills, with local scale flow paths that follow the ground surface gradient, leading to discharge along drainage lines and lower landscape locations. (see **Figure 15**, from SKM, 2005) While groundwater salinities are not high, discharge above a high watertable during hot, dry summers can rapidly increase surface soil salt content. Waterlogging during wet periods in areas with poor drainage can then exacerbate productivity impacts.

Examination of the area and mapped discharge locations suggests some association between poor surface drainage related to original clearance of tea tree wetland areas. Some of the areas of mapped discharge therefore have a geomorphic predisposition to high watertables.

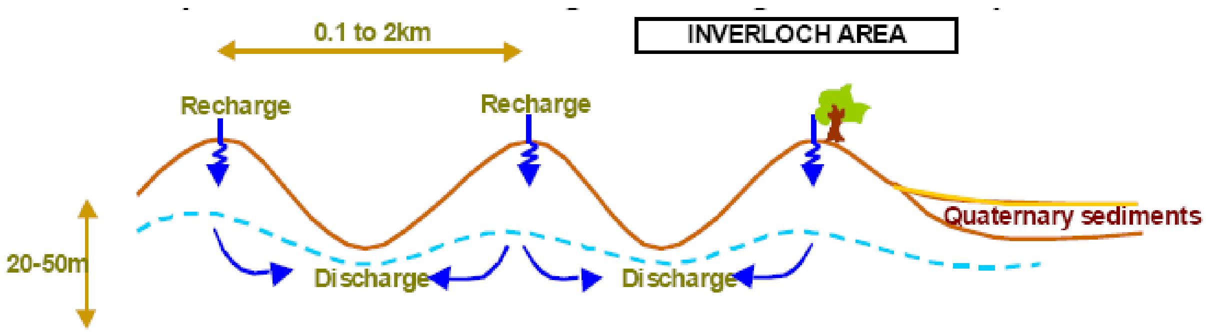

Figure 15. Inverloch GFS5 Conceptual flow system diagram. (taken from SKM 2005)

3.2.2 Shallow groundwater behaviour

Groundwater behaviour has been monitored in the vicinity of Inverloch since May 1999. Monitoring bores are clustered around two discharge sites north east of Inverloch and are positioned up slope and adjacent to the discharge zones. A selection of monitoring bore hydrographs are provided in **Figures 16 and 17**. Bores 14075 (**Figure 16**) and 14079 (**Figure 17**) are adjacent to the discharge sites and show seasonal behaviour with an annual 2 metre oscillation in depth from winter to summer. Depth to groundwater in these bores is between ground surface and 2 metres below surface. Overall, the bores show an upward groundwater trend indicative of a groundwater system that is filling. Bores 14077 (**Figure 16**) and 14078 **(Figure 17)** are upslope of the discharge zones and show a more significant 2 – 3 metre rise during the winter of 2001.

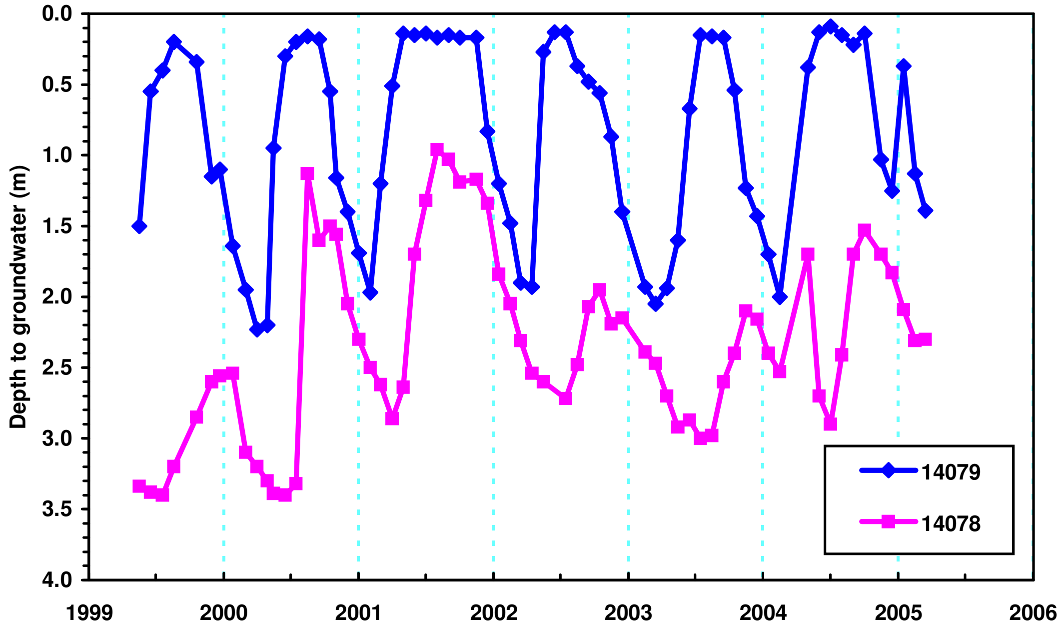

Figure 16. Hydrograph of selected groundwater monitoring bores at Inverloch

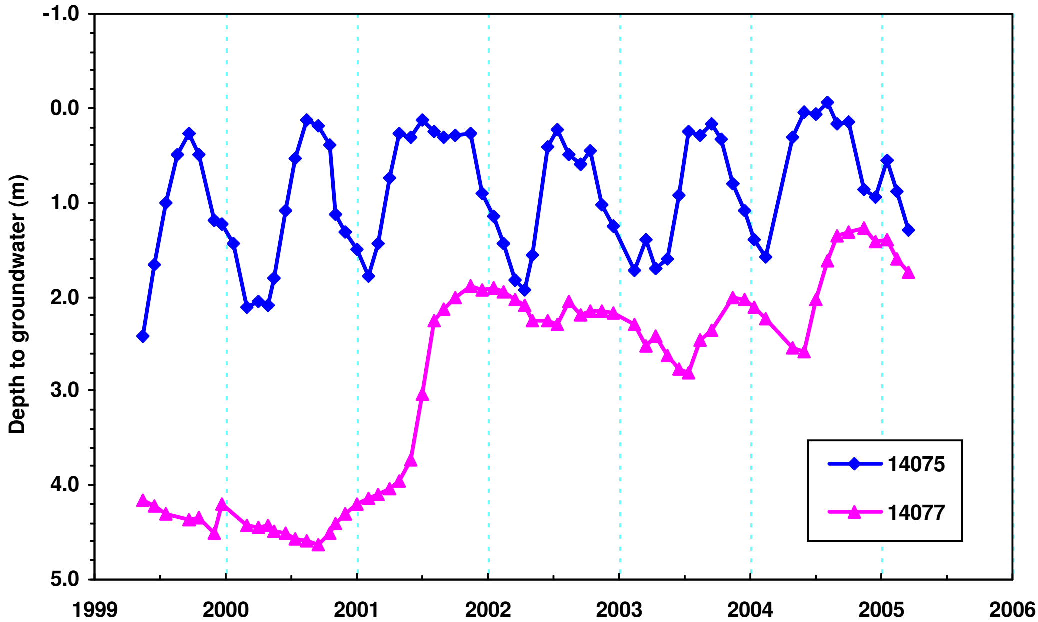

Figure 17. Hydrograph of selected groundwater monitoring bores at Inverloch

3.3. Inverloch - Results of modelling

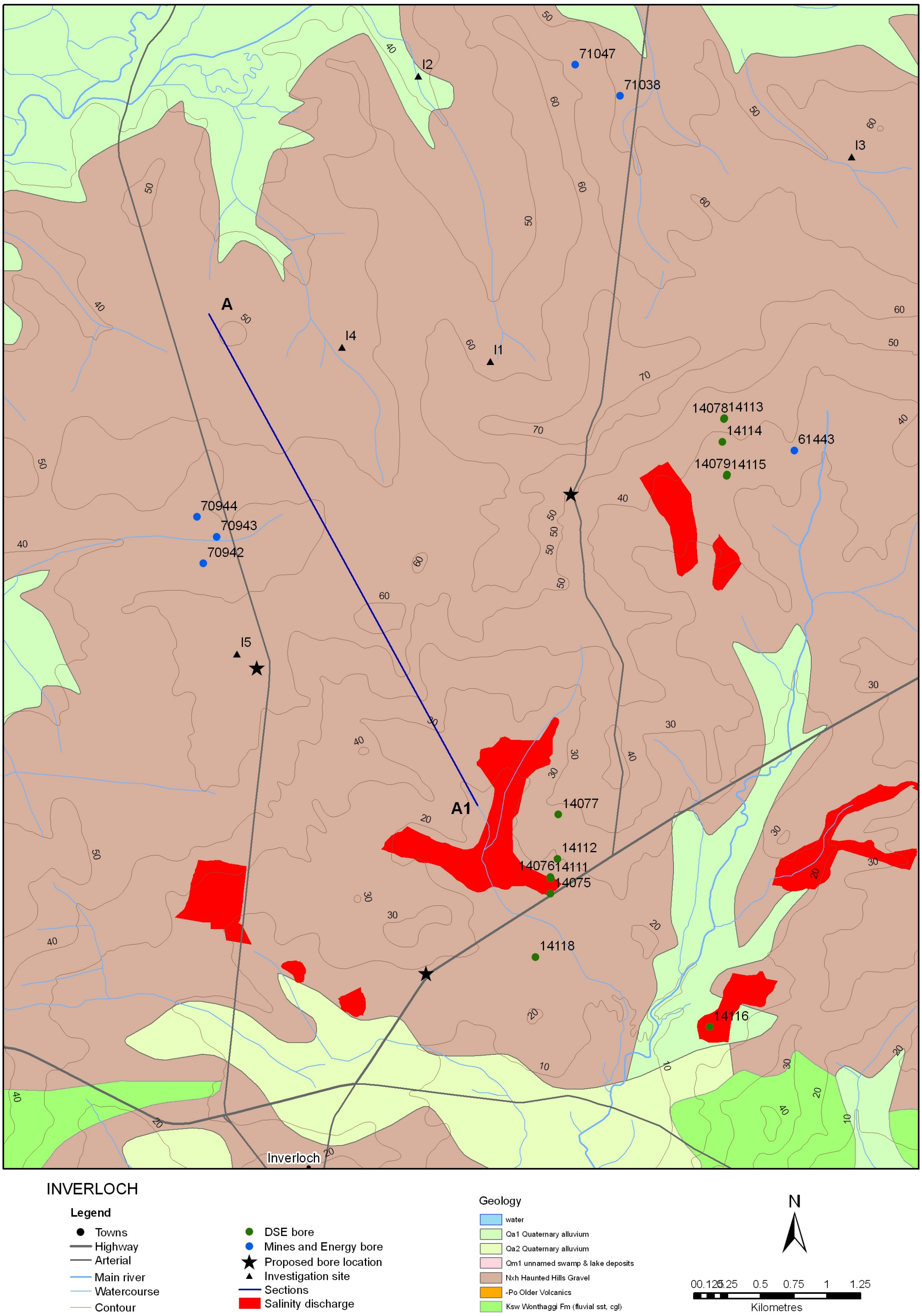

Figure 18. Inverloch Locality Plan

The southern third of the section line A-A', (**Figure 18**) up-gradient of the larger of the Inverloch discharge sites to the 60 metre hill was created in FLOWTUBE. This is based on topography, groundwater flow system information and the limited groundwater bore data. A schematic of the modelled cross-section is shown in **Figure 19**. The available geological logs for the three bores to the west of the section line did not indicate much variation in transmissivity down the profile, with clay, mudstone, coal and grey sandstone present. Stratigraphically, it is likely that the Haunted Hills formation is a relatively thin layer overlying the Cretaceous age sedimentary sequence (that contains the locally mined coal seams). Note also the presence of the Quaternary alluvium to the south (probably coastal aeolian sand deposits) that appears to have had some impact on the surface drainage in the area.

Based on the drilling data (that suggested little hydraulic variation with depth) and GFS5, the Flowtube model for the groundwater flow system north of Inverloch has been constructed as a dual layer section thinning towards the coast. A slight rise in groundwater level near the discharge end to reflect the coastal dune aquifer under Inverloch has been surmised.

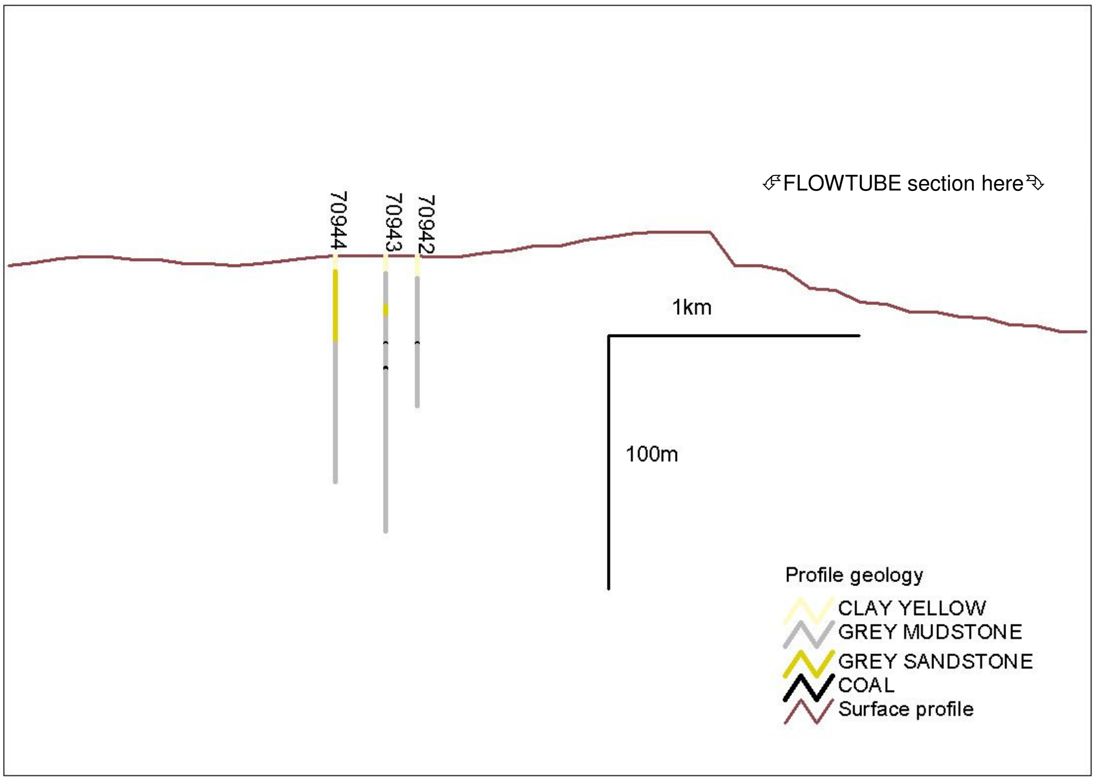

Figure 19. Geological cross section though the Inverloch site.

The 'initial' model was designed and input to the program to replicate existing groundwater conditions, **Figure 20**. The model consists of 5 sections, each of which have been assigned aquifer parameters according to **Table 3.** The end of the "Flowtube" has been designated as a partial aquifer boundary with a hydraulic head value of 1m below the ground surface. The groundwater surface was initially based upon the recorded waterlevels from the existing mining bore data. However, these levels resulted in a flat watertable surface that was considered to be unlikely. The watertable surface for the model was then redeveloped based upon the assumption that the watertable is a subdued reflection of the land surface and assigned a level that accorded with levels seen in local observation bores. However, this is not ideal and should be redone if actual groundwater data from new bores becomes available.

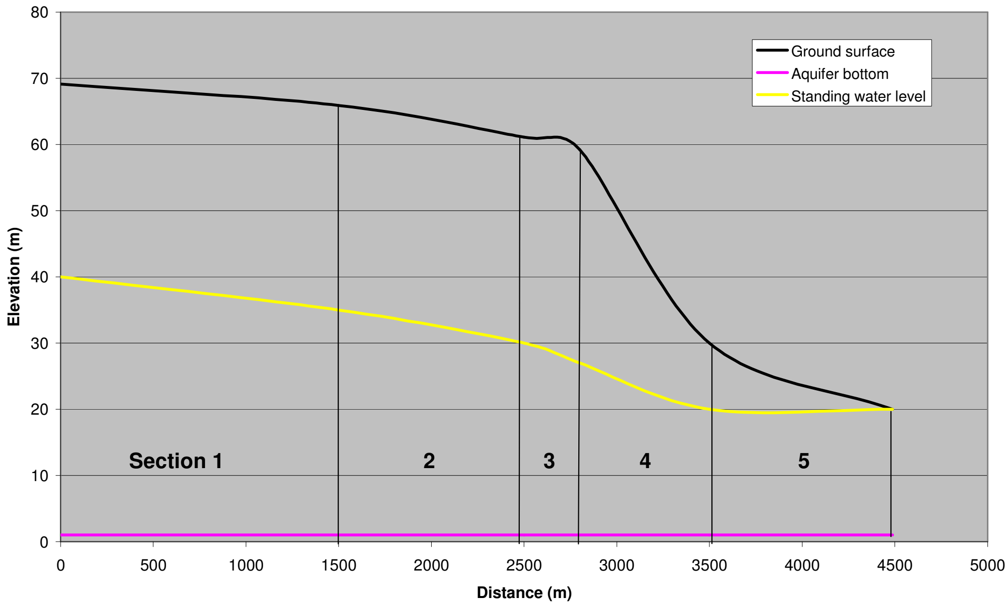

Figure 20. Initial groundwater conditions at the Inverloch site showing model design and current standing water level

Table 3. Inverloch aquifer parameters

Section	Aquifer thickness (m)	Upper layer K* (m/day)	Lower layer K (m/day)	Mean specific yield %
1	70	0.1	0.5	0.03
2	70	0.1	0.5	0.03
3	60	0.1	0.5	0.03
4	40	0.1	0.5	0.03
5	30	0.1	0.5	0.03

*K = hydraulic conductivity

The "do nothing" scenario was modelled using a recharge value of 50mm under annual pasture across each section, excluding the discharge site. This model output suggests only a minor increase of the standing water level of 0.5 metres below the discharge site will occur (**Figure 21**). The model was run for 50 years, with output profiles for ten, twenty and 50years. This 0.5 metre rise equates to only a small increase in size of the discharge area over the 50 years. This means that if nothing further is done to control recharge rates, the area affected by salinity will not greatly increase from the currently affected area. This also suggests the system may be close to equilibrium, with the discharge area water loss almost equal to recharge.

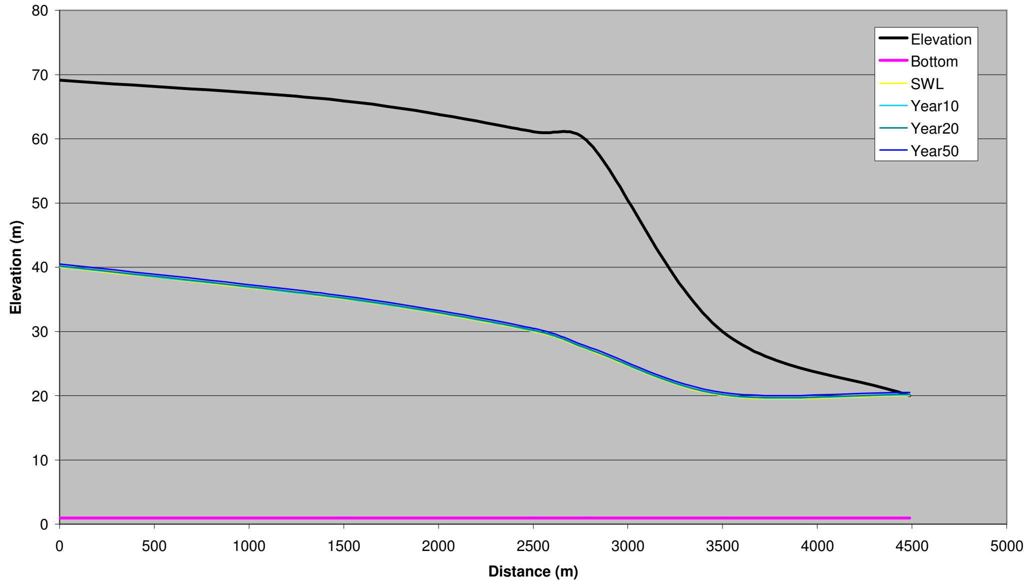

Figure 21. Inverloch site modelled groundwater behaviour under a "do nothing" scenario

To assess the effect of reducing recharge a number of scenarios have been run based on a standardised volume of recharge beneath various vegetative options. The recharge values assigned to each scenario are based on previous modelling studies conducted by the FLOWTUBE developers and may or may not be appropriate for the West Gippsland area.

Figure 22 shows the replacement of annual pasture with perennial pasture with over total length of the model domain using a recharge of 5mm/year under perennial pasture. The model was run for a 20 year period with two year output frequency plots. These show a lowering of the standing water level below the discharge site of approximately 7 metres at 20 years. However, it should be noted that the model assumes an instantaneous reduction of recharge of 90% at year 1 and does not allow for an establishment period to achieve maximum plant-water use.

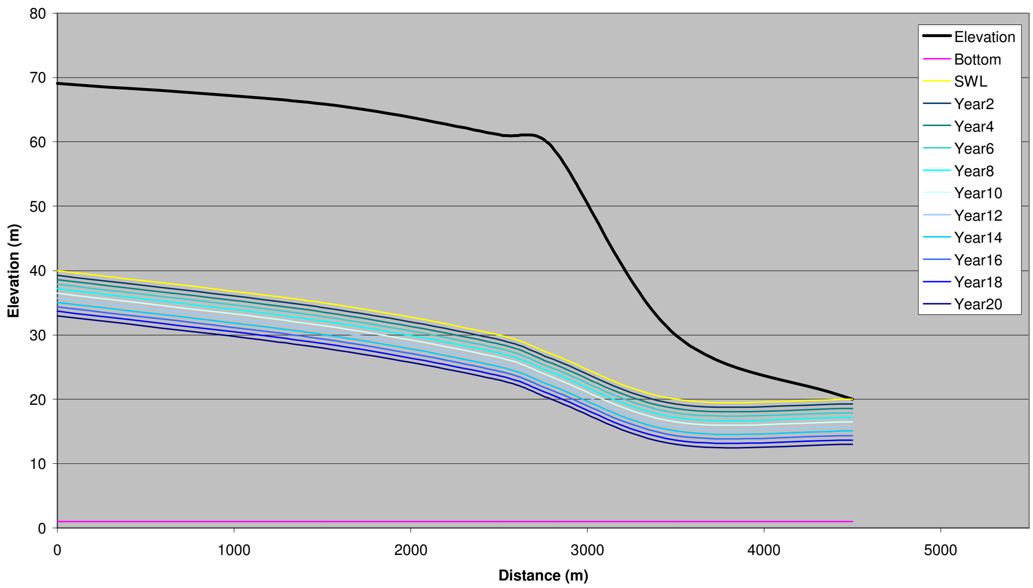

Figure 22. The Inverloch site modelled under perennial pasture with 5mm / year recharge

The model was also run to simulate a tree/pasture scenario of 50% of the landscape with trees and 50% with perennial pasture (**Figure 23**). Trees were positioned in the upper landscape and assigned a recharge value of 3mm / year. Perennial pasture on the slope leading to the discharge site was assigned a recharge value of 5mm / year.

The groundwater response for this scenario shows a fall in water level below the trees of approximately 10 metres, whilst under the perennial pasture the standing water level remains similar to the all perennial scenario of over 6 metres.

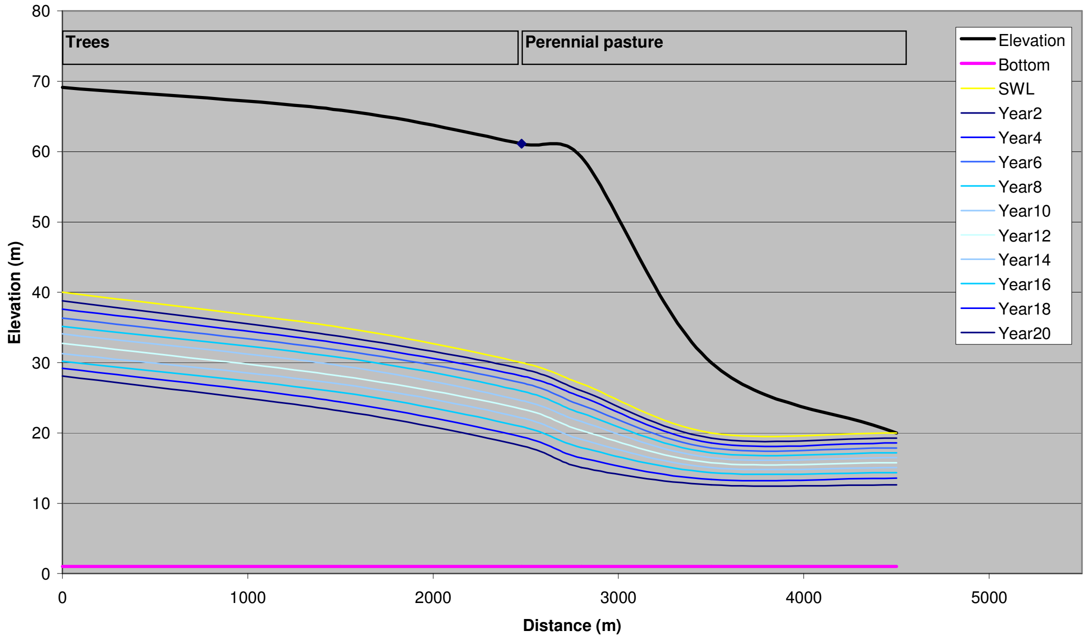

Figure 23. The Inverloch site modelled under 50% trees and 50% perennial pasture

The model was then run simulating an alley farming scenario with 2 rows of trees at 100m spacing with annual pasture between (using the model default recharge values for alley farming, which are 3mm /year for the tree rows and 50mm / year recharge for the annual pasture). The output for this scenario is presented in **Figure 24**.

The groundwater response for this scenario shows a fall in water level below section 1 and 2 with the water level below the discharge site falling by approximately 5 metres. This response in groundwater levels is similar to the all perennial scenario. A summary of the various modelled waterlevel changes is provided in **Table 4**.

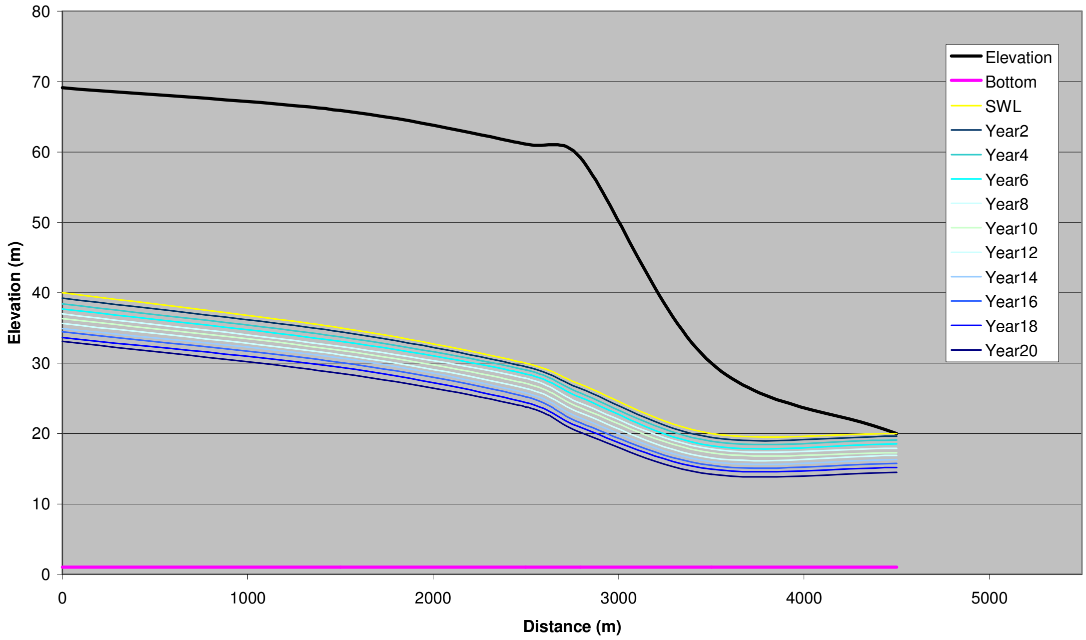

Figure 24. The Inverloch site modelled under 100 metre spacing tree alleys with annual pasture

Table 4. Summary of Inverloch FLOWTUBE results.

Scenario	**Change in depth to groundwater from initial conditions (m)**								
Landscape position	**Ridge**			**Mid slope**			**Discharge zone**		
Time step (years)	**10**	**20**	**50**	**10**	**20**	**50**	**10**	**20**	**50**
"do nothing"	0.10	0.20	0.50	0.10	0.20	0.50	0.11	0.21	0.51
Time step (years)	**10**	**15**	**20**	**10**	**15**	**20**	**10**	**15**	**20**
All perennial pasture	-2.80	-4.93	-7.01	-2.86	-4.93	-7.01	-2.91	-4.94	-7.03
50% tree 50% perennial	-5.48	-8.22	-12.3	-2.88	-4.95	-7.06	-2.94	-4.97	-6.66
100m tree alleys	-5.34	-7.47	-10.6	-3.83	-5.36	-7.66	-2.83	-3.96	-5.67

3.4. Discussion of Inverloch FLOWTUBE results

The Inverloch study area was modelled from the larger mapped discharge zone towards a northern ridge. Depth to groundwater levels were investigated at the site, with groundwater level recorded at less than 2 metres deep along the drainage lines. Groundwater levels recorded in some existing mineralogical bores were initially used to construct the current watertable surface, but these resulted in a flat groundwater surface that was considered unrealistic. It is likely the levels recoded were not correct. Using an assumed 'subdued reflection of topography' basis for current groundwater conditions, several perennial plant options were investigated.

The modelled 'do-nothing- scenario suggests that there will not be much change in groundwater levels in the 50 year timeframe simulated. This may be an indication that the location may already be in a higher recharge – discharge equilibrium state. However, while the 'do-nothing' scenario suggested only a marginal 0.5 metre rise in level at the discharge area, due to the flat topography, this equates to an increase in extent of the discharge zone up slope of approximately 100 metres. The modelling assumes a strong relationship between recharge and discharge along the 'Flowtube'. Without more detailed stratigraphic and hydrogeological analysis at this location, the model results are based on significant unknowns.

Various vegetative salinity mitigation options were simulated to ascertain their possible impact on groundwater levels over time. In this instance, the establishment of perennial pastures over the entire model domain resulted in lowering of the groundwater level at the discharge zone by around 7 metres at the 50 year time step. A combination of 50% trees and 50% perennial pastures established over the flow system only slightly increased the ability to lower groundwater levels at the discharge site compared to the perennial pastures only.

A key aspect of most of the mapped salinity is that the position of the mapped discharge zones appears to be controlled by the combination of topography, surface drainage and possibly by a groundwater mound developed in the coastal sand deposits in the vicinity of Inverloch. The mapped 'discharge' areas topographic location also suggests the areas are naturally poorly drained and hence prone to a high watertable.