5 Portland GMA Results

5.1 Species Tolerance Model

The species tolerance model results for the Glenelg Hopkins CMA region are shown in Figure 12. The colour-ramp indicates the maximum result from each of the 4 species tolerance properties expected to be found in GDE areas. The zonal statistic median value of the species tolerance model for each potential terrestrial GDE polygon in the Portland GMA region is shown in Figure 13. The potential GDE areas with the lowest 15 species tolerance classes are associated with forested areas that are considered generally unlikely to be groundwater dependent although they may include sub-areas of deep-rooted or other groundwater dependent vegetation. Those classes have been excluded from the figure. Some of the remaining potential GDE areas also appear to be associated with non-native vegetation. The distribution of maximum species tolerance model results for the Portland region GDEs is bimodal and highly skewed (Figure 14). The maximum species tolerance value within the Portland GMA region was 45. The highest species tolerance values are associated with small GDE polygons and probably reflect local variability in the model results.

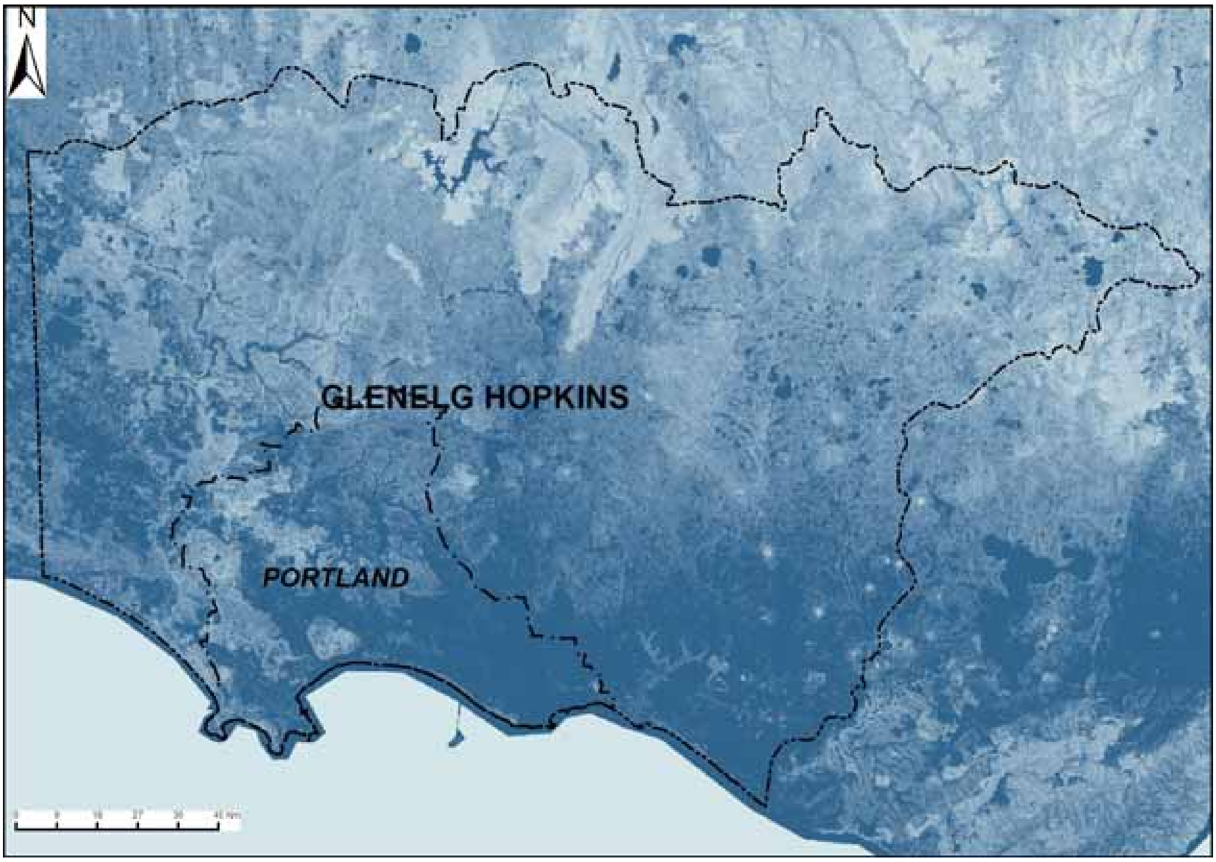

Figure 12 Species tolerance model for Glenelg Hopkins CMA region showing maximum value for overlain tolerance models. Darker colours are higher values.

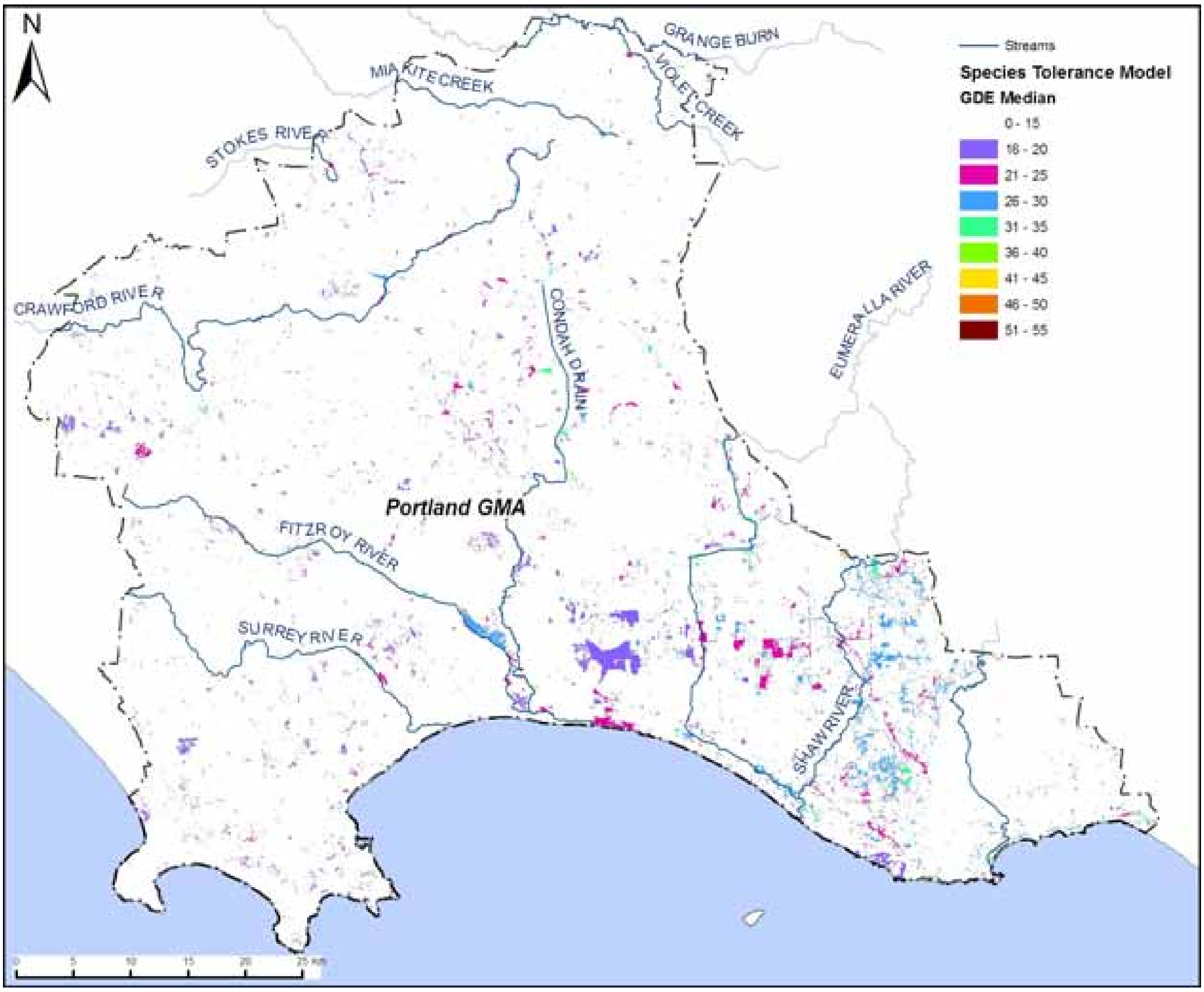

Figure 13 Median value of species tolerance model results within each potential terrestrial GDE in the Portland GMA region

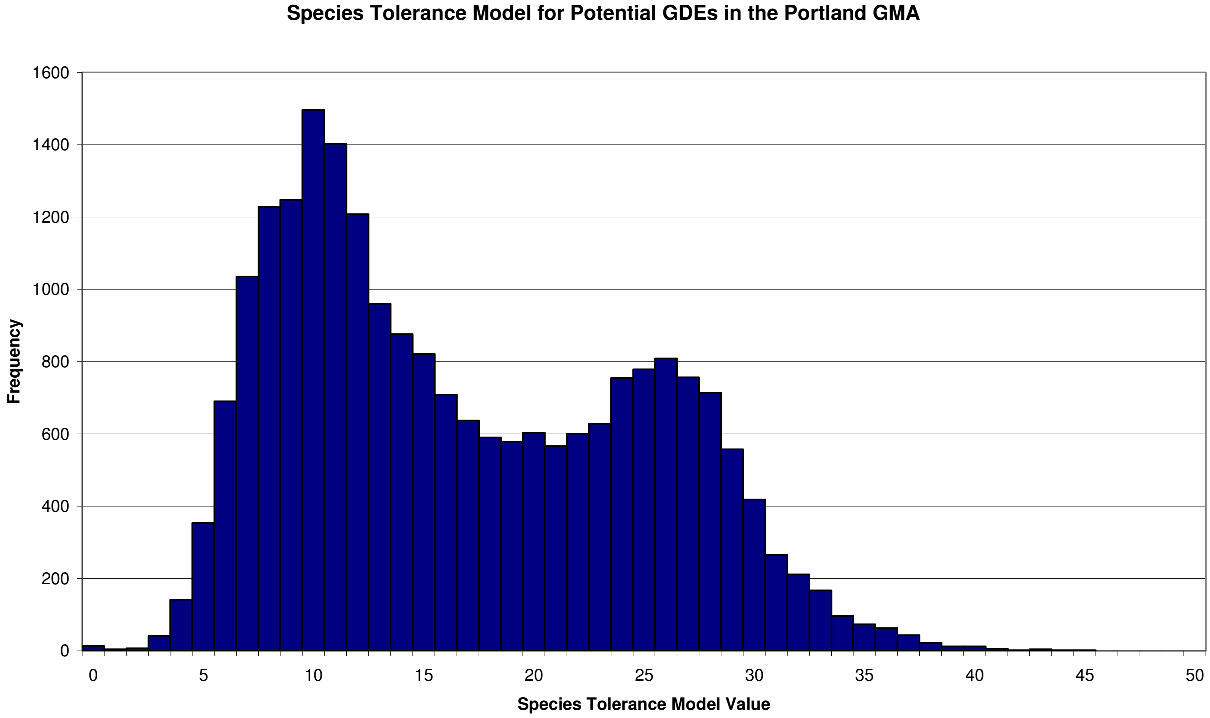

Figure 14 Histogram of median species tolerance model values for potential GDEs in the Portland GMA region.

5.2 NDVI Difference

The calculated NDVI difference between 1995 and 2002 for the Glenelg Hopkins CMA is shown in Figure 15. The general appearance is for decreasing NDVI for treed areas and increasing NDVI for pasture and cropland. A possible explanation is that the deeper-rooted trees are showing stress due to the longer term drought effects while the shallow rooted grasses and crops respond more quickly to the somewhat higher summer rainfall seen in 2002.

The differences in NDVI values for potential GDEs between 1995 and 2002 are shown in Figure 16 with a backdrop indicating different combinations of image dates. There is an obvious change in the magnitude of the difference in the southern Grampians area of the north-central Glenelg Hopkins CMA region but image date effects are not obvious elsewhere. There appears to be generally decreasing NDVI between 1995 and 2002 in the western part of the CMA region and increasing NDVI in the east. This could be due to climatic effects, uncertainties in the calculation of NDVI, or regional differences in vegetation type. Within potential GDE areas, the treed areas show higher NDVI decrease between the 1995 and 2002 composite images than do the non-treed areas, as was seen in the complete difference image (see Figure 15). This suggests possible increased water stress for woody vegetation. As discussed for individual catchments, below, this correlation also is seen within individual GDE polygons. The effect is seen across large areas both within and outside potential GDEs and is not likely the result of changes in groundwater availability, although groundwater may help offset the overall decrease in NDVI that is apparently caused by other factors. At this point no definitive statements can be made about groundwater dependency or sensitivity of deep-rooted tree species in the major forest areas.

For the remaining evaluation, the species tolerance model was used as a filter on the NDVI difference layer so only the potential GDEs with higher species tolerance values are included. This produces a consistent data set between the NDVI and the species tolerance analysis, including potential GDEs that are most likely to be sensitive to groundwater availability at or near the surface. The species tolerance values greater than 15 were carried forward in subsequent analysis.

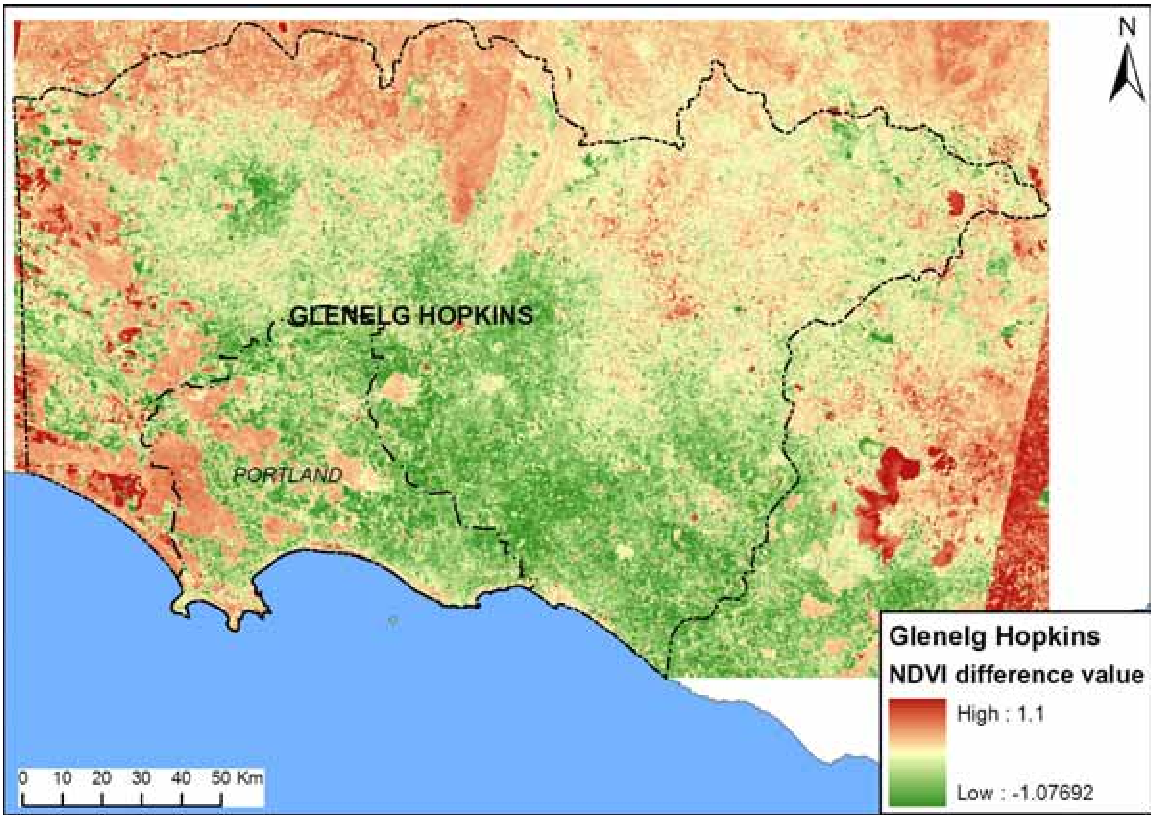

Figure 15 Difference in NDVI value between 1995 and 2002 in the Glenelg Hopkins CMA region. Positive values indicate a decrease in NDVI from 1995 to 2002 and negative values indicate an increase.

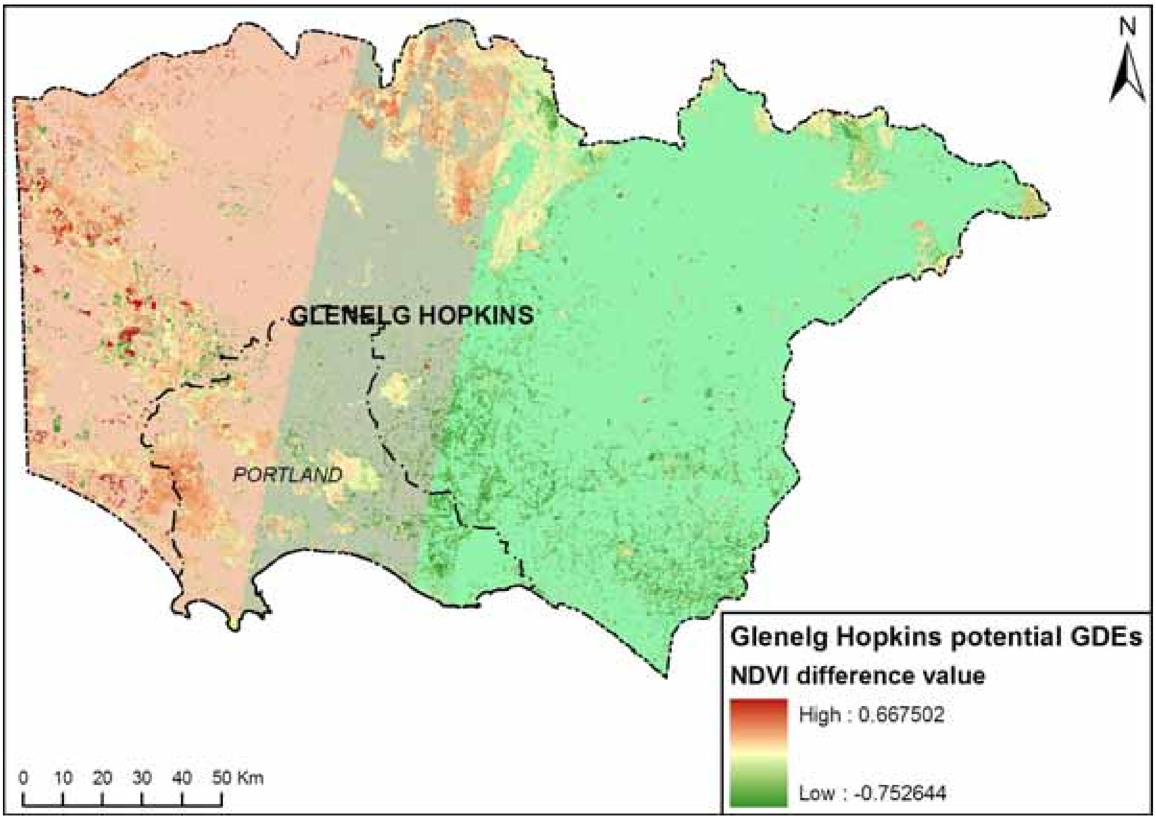

Figure 16 Difference in NDVI value between 1995 and 2002 for potential GDEs in the Glenelg Hopkins CMA region. Positive values indicate a decrease in NDVI from 1995 to 2002 and negative values indicate an increase.

5.3 Hydrogeologic Interpretation

This section describes the hydrogeologic evaluation and integrates the results of the species tolerance and NDVI difference mapping. The assessment is performed generally by catchment areas as described previously (see Figure 10).

5.3.1 Crawford River, Stokes River, Wannon River Catchments

These catchments are located in the northwest part of the study area and have been subject to a significant increase in tree plantations recently. The effect of the plantations on local water resources is unknown but plantations are known to decrease runoff relative to pasture or crop land and, in some cases, use groundwater (Benyon, et al., 2002 and 2009). The increased transpiration from the trees typically decreases recharge to groundwater overall (George, et al., 1999), but that depends on the stage within the growth cycle and on how afforestation affects soil structure and infiltration (van Dijk and Keenan, 2007). Plantation trees that directly access groundwater can transpire sufficient water to lower the watertable and affect groundwater flow direction (Benyon, et al., 2002 and 2009).

Water supply bores in the Crawford River catchment are either in the Condah WSPA or are considered unincorporated (see Figure 3). Water allocations are less than 300 ML. There are no licensed bores in the Stokes River and Wannon River catchment parts of the study area. Thus, current groundwater demands are low. It is likely that there is recharge to the confined aquifers in this part of the Portland GMA. Monitoring bore locations are shown in Figure 17 together with potential GDEs that have species tolerance median values of 15 or higher.

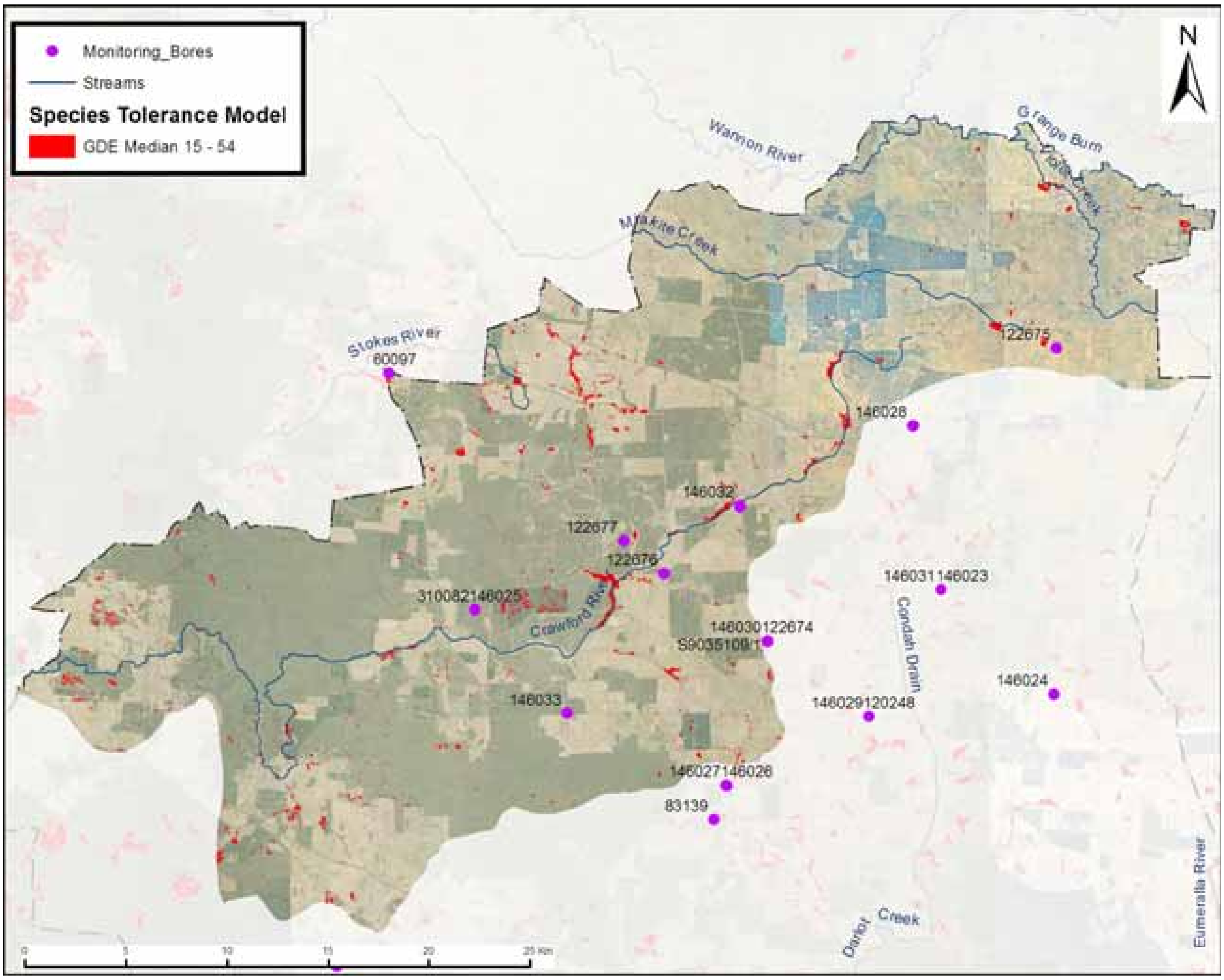

Figure 17 Monitoring bore locations and potential GDEs with median species tolerance values of 15 or higher for the Crawford River, Stokes River, and Wannon River catchments

There is one monitoring bore nest in the Crawford River Catchment, including bore 146025 (drill depth 90 m) developed in limestone (probably Port Campbell Limestone), and 310082 (screened at 222 – 233 m) with no log but probably screened in the lower Tertiary Dilwyn Formation aquifer. The vertical gradient at this location is downward (Figure 18). Both bores are declining through the drought period with the deeper bore declining at a somewhat greater rate than the shallow bore. Both bores show seasonal head fluctuation with a relatively damped response in the lower bore. The seasonal fluctuation and the downward hydraulic gradient indicate that the wells are in or near an area of recharge to the lower Tertiary aquifer. The greater decline in the lower Tertiary bore suggests that groundwater withdrawal may be a more significant factor in its decline compared to the limestone aquifer decline. Also, because of the interconnection, there is some potential for groundwater use of the lower aquifer to impact the water balance in the upper aquifer. The overall decline in both aquifers through the drought period indicates sensitivity to climate change. The bores are at an elevation of ~10 m above the Crawford River, so the water level of ~10 m in the upper well suggests potential interconnection with the surface water. However, further declines may be of concern.

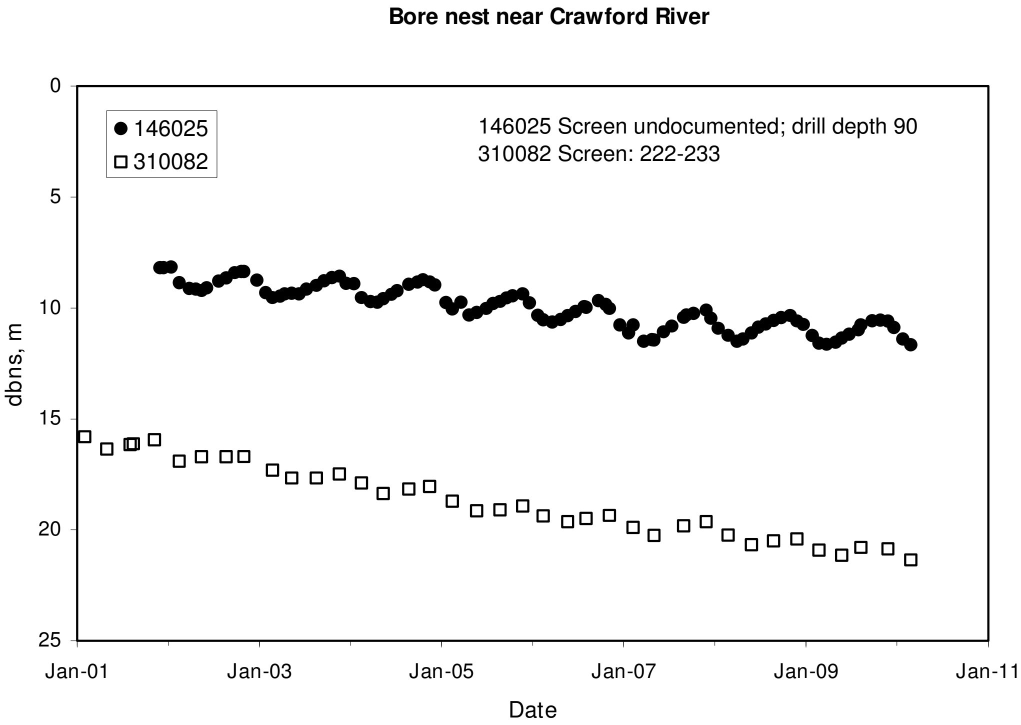

Figure 18 Declining trends in depth to groundwater (below natural surface) in nested bores 146025 and 310082, near the Crawford River, showing seasonal fluctuation with lowest water levels in late summer.

Other monitoring bores in the Crawford River catchment also show declining trends that are probably due to the combined impact of the drought and seasonal groundwater pumping. For example, bore 146032 is at an elevation within ~ 5m of the Crawford River elevation. At the beginning of the record, the water levels were within 5 m of the surface at their highest but are no longer reaching that level (Figure 19). There is a slight suggestion that the rate of decline has decreased in the last 2 years. The declining levels suggest that the regime may be changing from one where the groundwater discharges to the river seasonally to one where it will not and where the groundwater may be declining below the rooting zone of terrestrial vegetation.

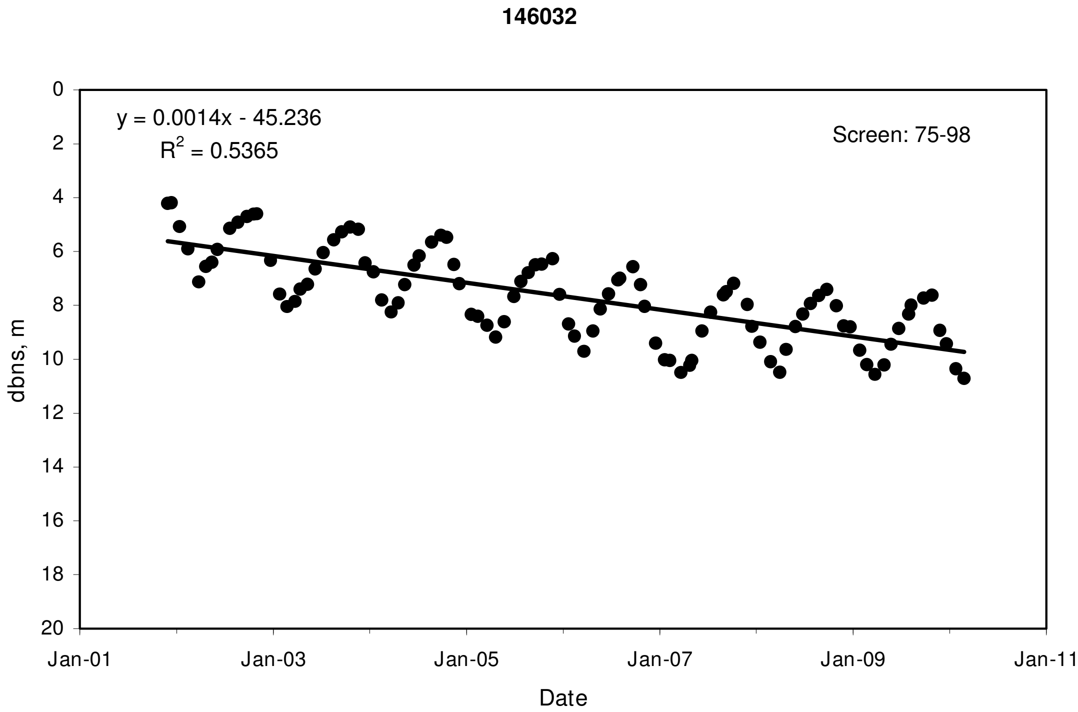

Figure 19 Depth to groundwater hydrograph for bore 146032, near the upper Crawford River, showing seasonal variation with lowest water levels in late summer and declining trend

Species tolerance model values for potential GDEs are generally highest near the Crawford River, suggesting that the most critical and sensitive GDEs are located there (Figure 20). However, the potential GDEs farther up the catchment may be more marginal in that they likely will be affected more rapidly by climatic trends and declines in groundwater level. Thus an assessment of the value of the GDEs needs to be integrated with the sensitivity analysis to make informed management decisions. Figure 20 shows the difference in NDVI value between the 1995 and the 2002 images for an area of potential GDE located along the Crawford River. Areas of NDVI decrease (high values) appear to be associated with woody vegetation while grassy areas appear to show a lower NDVI in the 1995 image. This is in keeping with the overall changes seen in the study area where forests and plantations generally show NDVI decrease while pasture and cropland shows a general NDVI increase. One possible reason for this is that the deeper-rooted woody vegetation is responding to longer term climatic trends while the shallow rooted vegetation is responding to shorter term precipitation events. The grassy vegetation may still be partially dependent on groundwater availability. Analysis of a more complete NDVI data set would be valuable to interpret the long-term effects through the drought period.

Based on the available data, it appears probable that localized GDEs occur along drainages in the Crawford, Stokes, and Wannon River catchments within the study area. The NDVI analysis suggests that the drought period has had at least a temporary impact on the photosynthesis and, by implication, health of some of the vegetation types within those areas. The declining water level trends recorded in monitoring bores indicates that groundwater discharge may be decreasing at some of the GDEs. Possible causes are the climatic changes and the effect of plantation establishment on groundwater recharge. Thus the GDEs in this vicinity should be considered sensitive to perturbation.

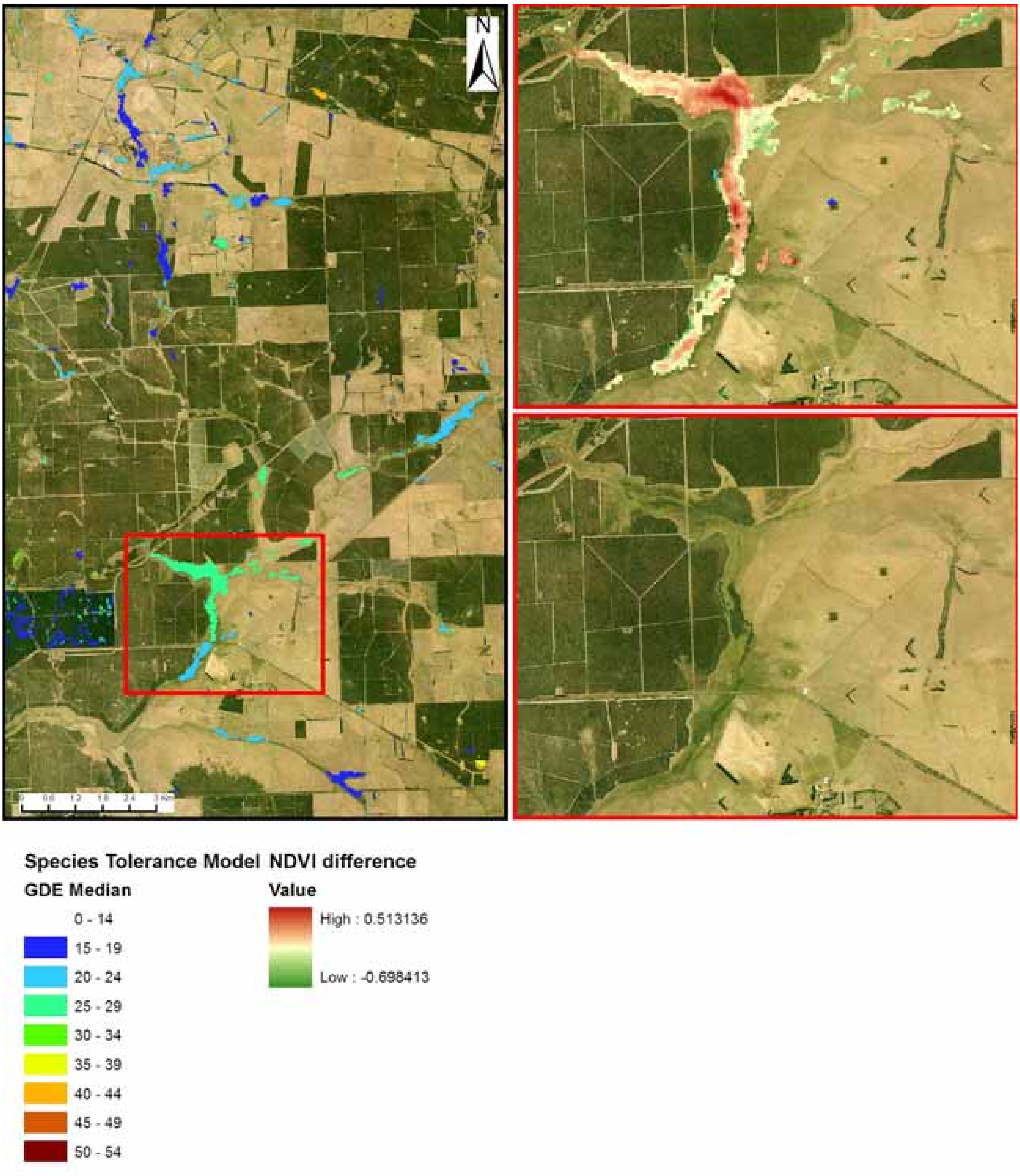

Figure 20 Species tolerance model and NDVI difference values for a portion of the Crawford River catchment.

5.3.2 Fitzroy River, Condah Drain Catchment

The Fitzroy River/Condah Drain Catchment is the largest in the study area and contains a number of potentially important GDEs (Figure 21). Condah Swamp and Lake Condah drain to the Fitzroy River through Darlot Creek and almost certainly formed large GDEs under natural conditions but have been highly modified by drains constructed to allow agriculture. Notable potential GDE areas remain along the periphery of the former Condah Swamp (Figure 22). Arrandoovong Creek, Lyne Creek, Scott Creek, and Louth Drain flow into Condah Drain and will also be considered in this section.

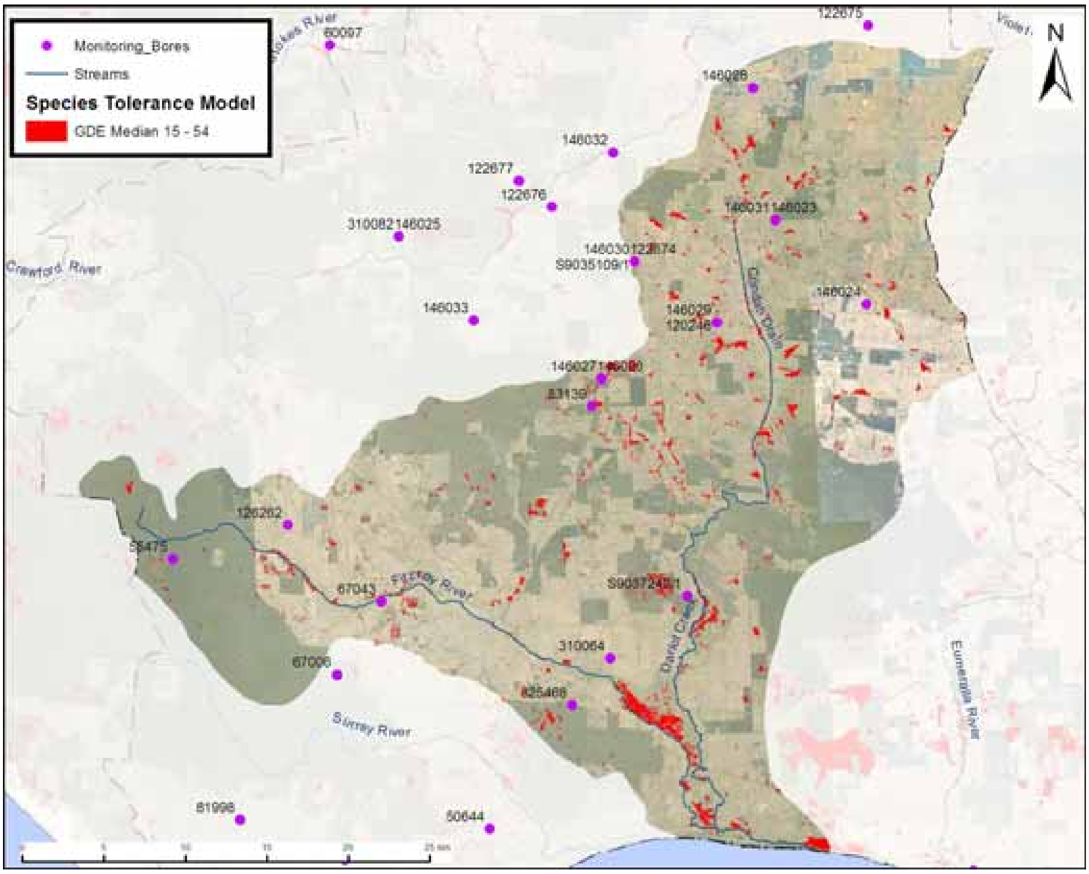

Figure 21 Monitoring bore locations and potential GDEs with median species tolerance values of 15 or higher for the Fitzroy River catchment

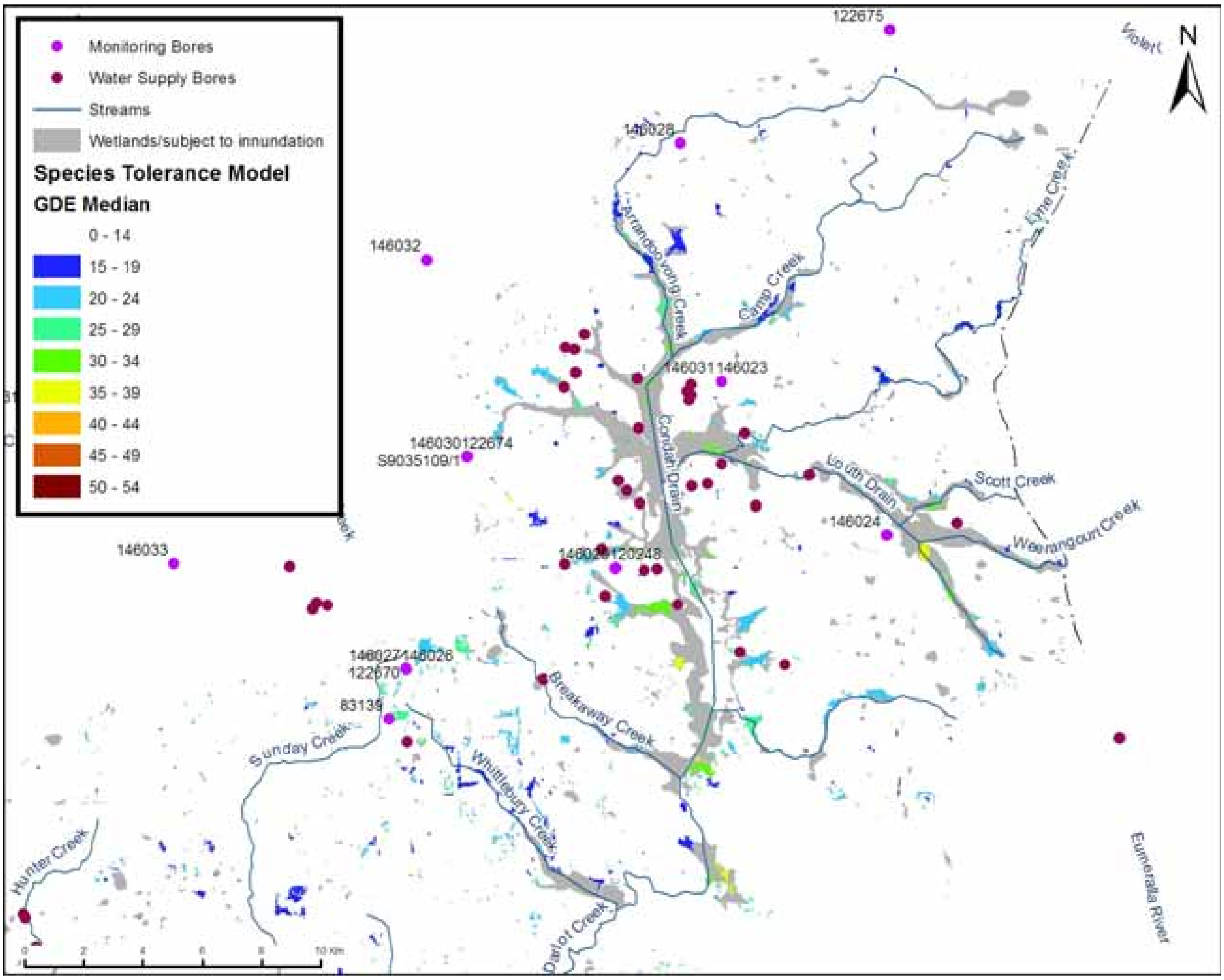

Figure 22 Monitoring bore locations and species tolerance value of potential GDEs in the vicinity of Condah Swamp

Bore nest 146031 and 146023 is located near the northern part of Condah Drain and north of Lyne Creek. The wells are over 10 m above the surface drainage level. The lower bore is completed in the limestone aquifer while the upper is completed in calcareous yellow clay above a grey clay layer. The lack of seasonal response in the upper well indicates either that it is not in good hydraulic connection with recharge or not in a significant aquifer or flow zone (Figure 23). The hydraulic gradient is strongly upward with the lower bore having a static water level in the range of ~5 to 15 m above ground surface. Thus there is strong potential for discharge to surface where the clay aquitard is absent. Although water levels in 146023 declined until ~2005, since then they have been stable or increased slightly. The saw-tooth pattern of the 146023 hydrograph (note the sharp seasonal declines and the rapid initial recovery at the end of summer), together with the amplitude of seasonal change suggests that there is influence from groundwater pumping.

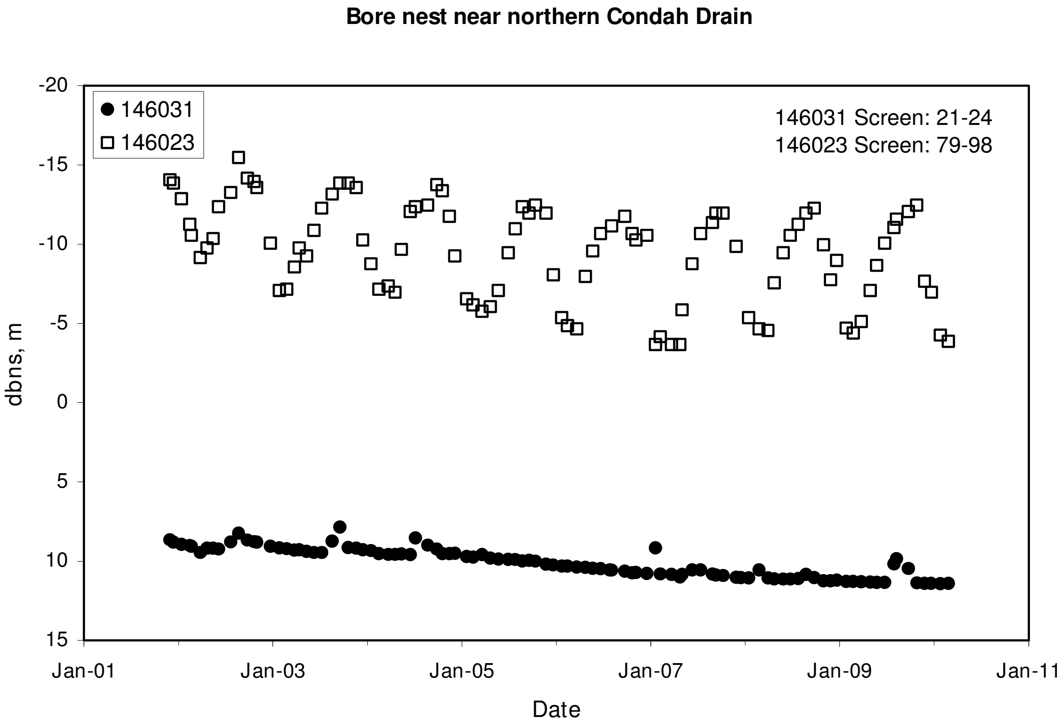

Figure 23 Depth to groundwater hydrograph for nested bores 146031 and 146023, near the Crawford River, showing upward gradient and seasonal fluctuations in 146023 (deeper bore) with lowest water levels in summer.

Bores 120248 and 146029 form a nest completed at different depths west of Condah Drain. The hydraulic gradient at bores 120248/146029 is upward except at the seasonal low water levels in recent years (Figure 24). Deeper bore 120248, however, shows greater seasonal fluctuation of up to 10 m or more. The seasonal variation appears to have increased since 1995 and the lowest static water levels are now below ground surface (Figure 25). The high seasonal variability is due to local groundwater pumping for summer irrigation, which increased from 1999. The overall downward trend in bore 120248 seen prior to 2005 appears to have levelled off but the continued lack of potential discharge to GDEs in summer is of concern.

The potential significance and sensitivity of GDEs in the vicinity of Condah Swamp, the upward hydraulic gradient, and flowing artesian conditions from the mid-Tertiary aquifer indicate that this is an area where the GDEs are likely to be highly sensitive to perturbation. The groundwater usage from the aquifer and the declining head trends in the last several decades heighten the potential for negative impacts on the ecosystem.

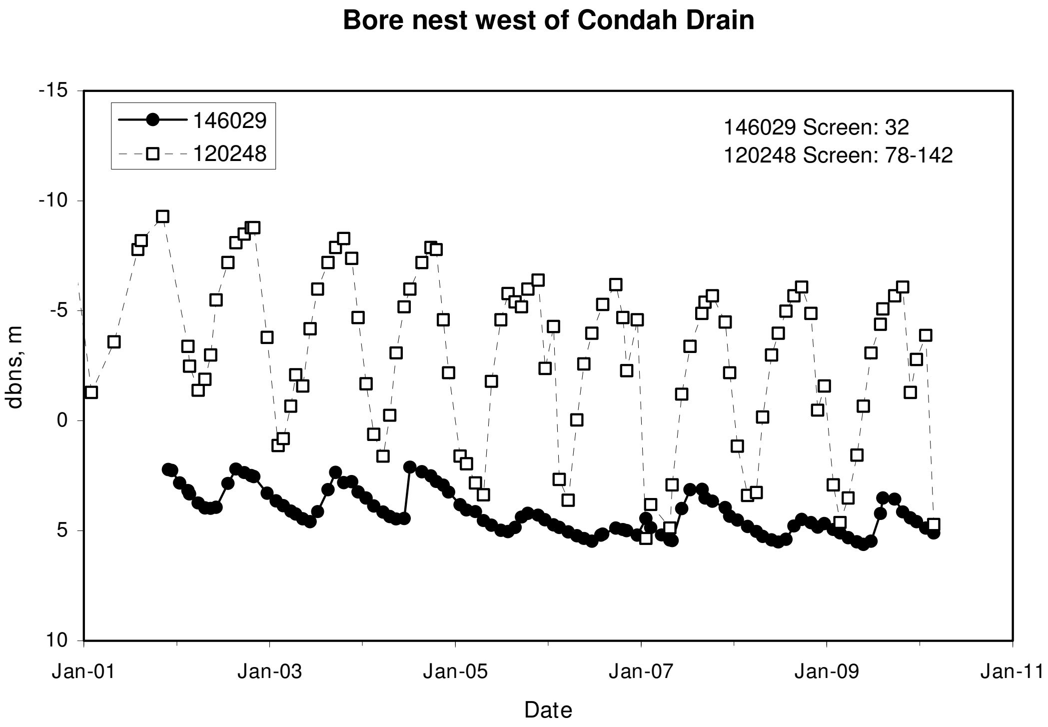

Figure 24 Depth to groundwater hydrograph for nested bores 146029 and 120248, west of Condah drain, showing seasonal fluctuation and an upward hydraulic gradient except in summers since 2007

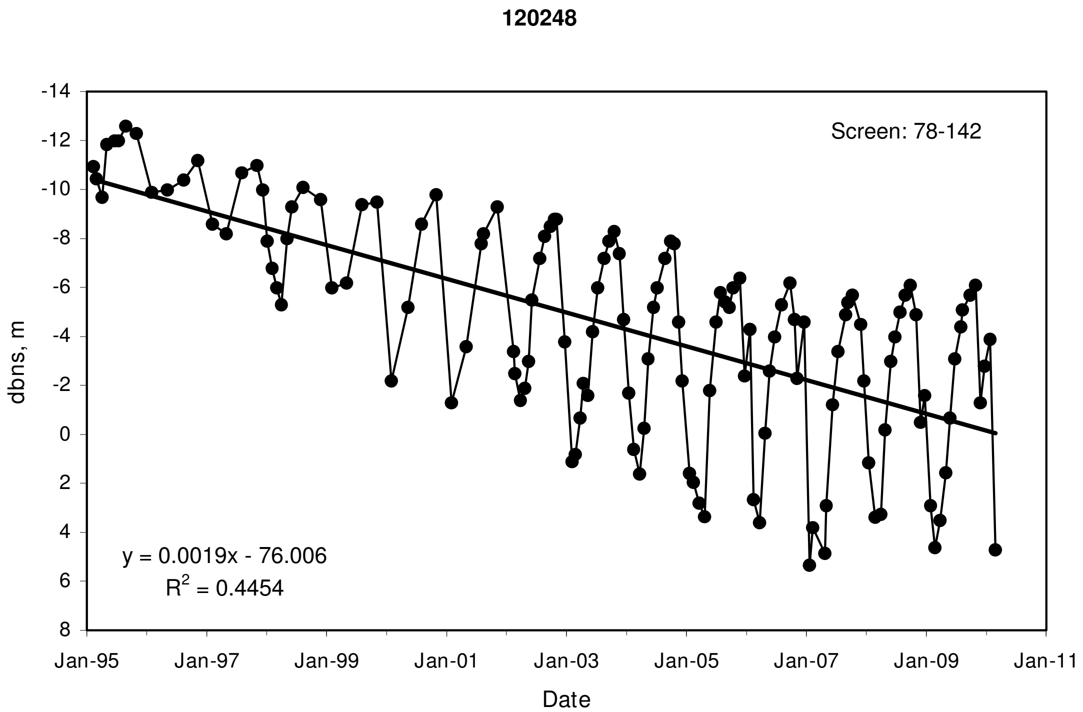

Figure 25 Depth to groundwater hydrograph for bore 120248, west of Condah Drain, showing seasonal variation with lowest water levels in summer and declining trend.

Bores 146026 and 146027 are nested near the head of Sunday Creek, in an area with mapped surficial geology in the Newer Volcanics. The vertical hydraulic gradient is downward and the limestone aquifer bore, 146027, shows greater seasonal variability (Figure 25). Bore 146026 is developed in the Newer Volcanics basalt and its groundwater response indicates it is unlikely to be in a high permeability zone. The data suggest little potential for groundwater dependency in this vicinity.

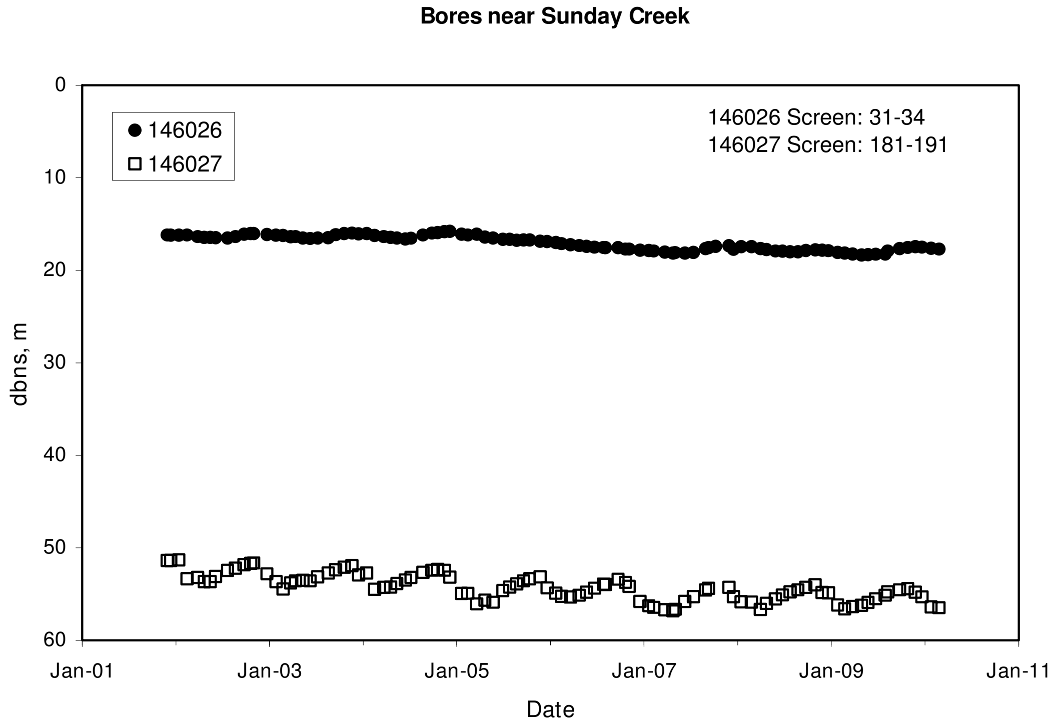

Figure 26 Depth to groundwater hydrograph for nested bores 146026 and 146027, near the head of Sunday Creek, showing a downward hydraulic gradient

Species tolerance model results for the Fitzroy River catchment indicate that the potential GDEs mapped along the river exhibit the characteristics of ecosystems expected to be sensitive to changes in near-surface water availability (Figure 27). However, there is a lack of groundwater monitoring data of sufficient quality to support interpretations of groundwater dependency. Bore 67043 is located very close to the Fitzroy River. The groundwater head is slightly above ground surface suggesting possible groundwater discharge but the well is very shallow, so the relationship to regional aquifers is unknown (Figure 28). Nevertheless, nearby ecosystems may be dependant on the shallow groundwater. In the absence of more definitive data, it appears that GDEs in this area may be moderately sensitive to perturbation in the groundwater regime or to climate changes.

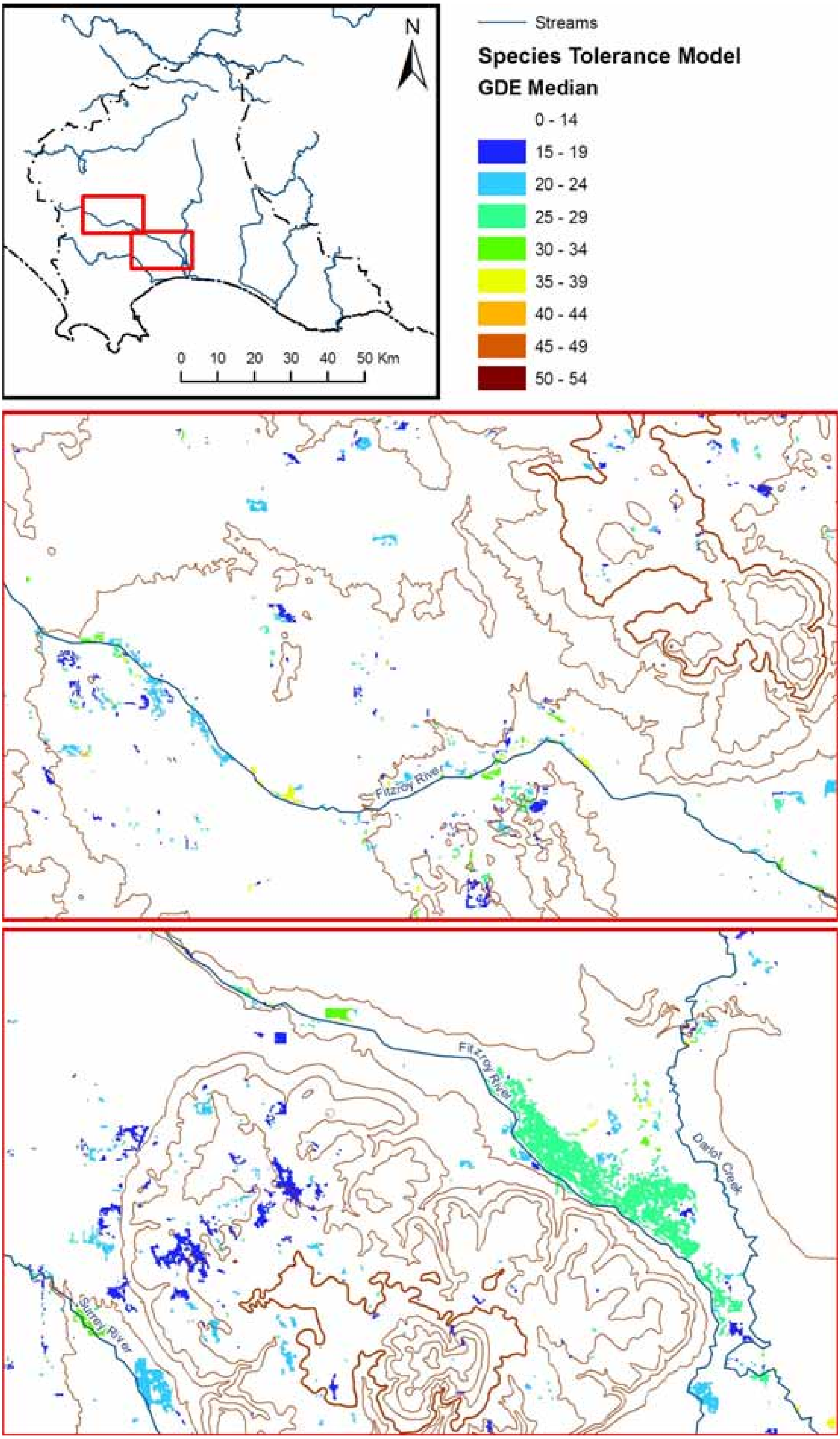

Figure 27 Species tolerance model results for potential GDEs along the Fitzroy River

67043

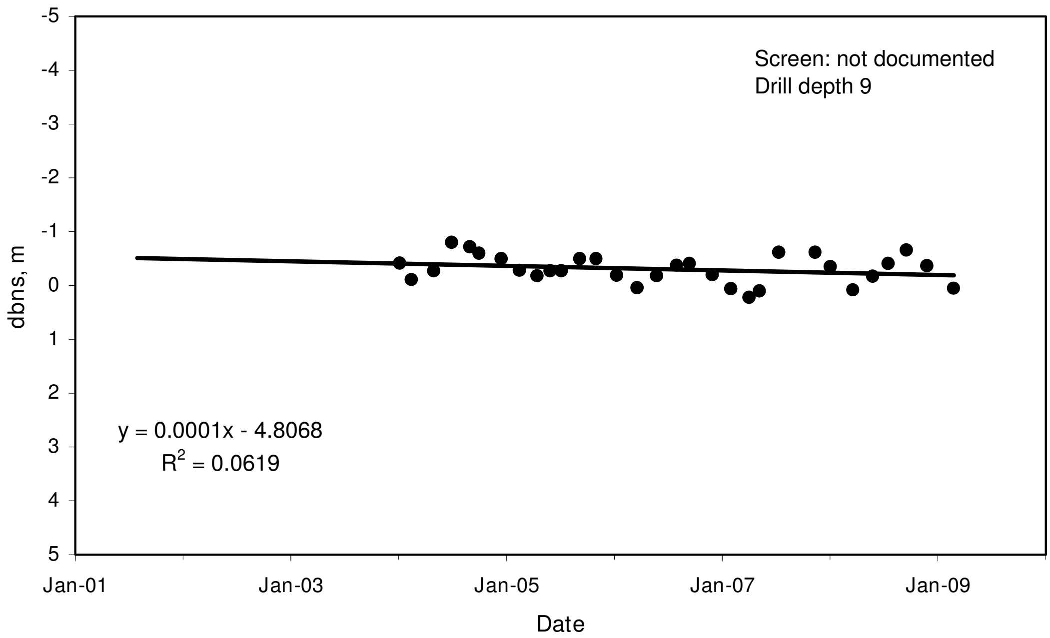

Figure 28 Depth to groundwater hydrograph and regression analysis for shallow bore 67043, near the Fitzroy River, showing slightly artesian head

5.3.3 Eumeralla River, Shaw River, Moyne River Catchments

The Eumeralla, Shaw, and Moyne Rivers flow through the eastern part of the study area. Relief is low and large areas are mapped as wetland or subject to inundation, particularly in the volcanic flows between the Shaw and Moyne Rivers (Figure 29). Groundwater is used extensively. The species tolerance model indicates conditions are generally favourable for species compatible with GDEs (dark colours in Figure 12). The NDVI difference map shows generally lower NDVI in 1995 than in 2002 (see Figure 15).

Species tolerance model results for these catchments show highest values in the volcanic terrain between the Shaw and Moyne Rivers (Figure 30).

In spite of the amount of groundwater use, few monitoring bores are located in this area, with the majority being within the 5 km coastal buffer. Bore nest 111522 and 111523 is located in the upper part of the Shaw River catchment. There is minimal vertical hydraulic gradient seen in the data and water table decline has been less than 1 m since 1992 (Figure 31).

The water level trend for Bore 141306 near Murray Brook shows a seasonal trend in most years but the trend is unusual in that the lowest water levels are seen sometimes in the winter (Figure 32). Similar trends in this catchment are seen in bores 141302 and 141305, but the seasonal variation is considerably lower in bore 141305 (Figure 33, Figure 34). Water levels are increasing slightly over time in all 3 bores.

The data available from these catchments are not sufficient to provide definitive assessment of the GDE sensitivity but indicate that summer evapotranspiration and irrigation demands are not major influences on groundwater levels in the southern part of the catchments. GDEs in this area may be of significant interest but no evidence of threat from climatic change or groundwater use has been identified as yet. The middle reaches of the Eumeralla River show similarities to the Condah Swamp area but lack groundwater monitoring data (Figure 35). Given the similarities in geomorphology, species tolerance values, and the groundwater use, GDEs in the area should be considered sensitive and further evaluation is warranted.

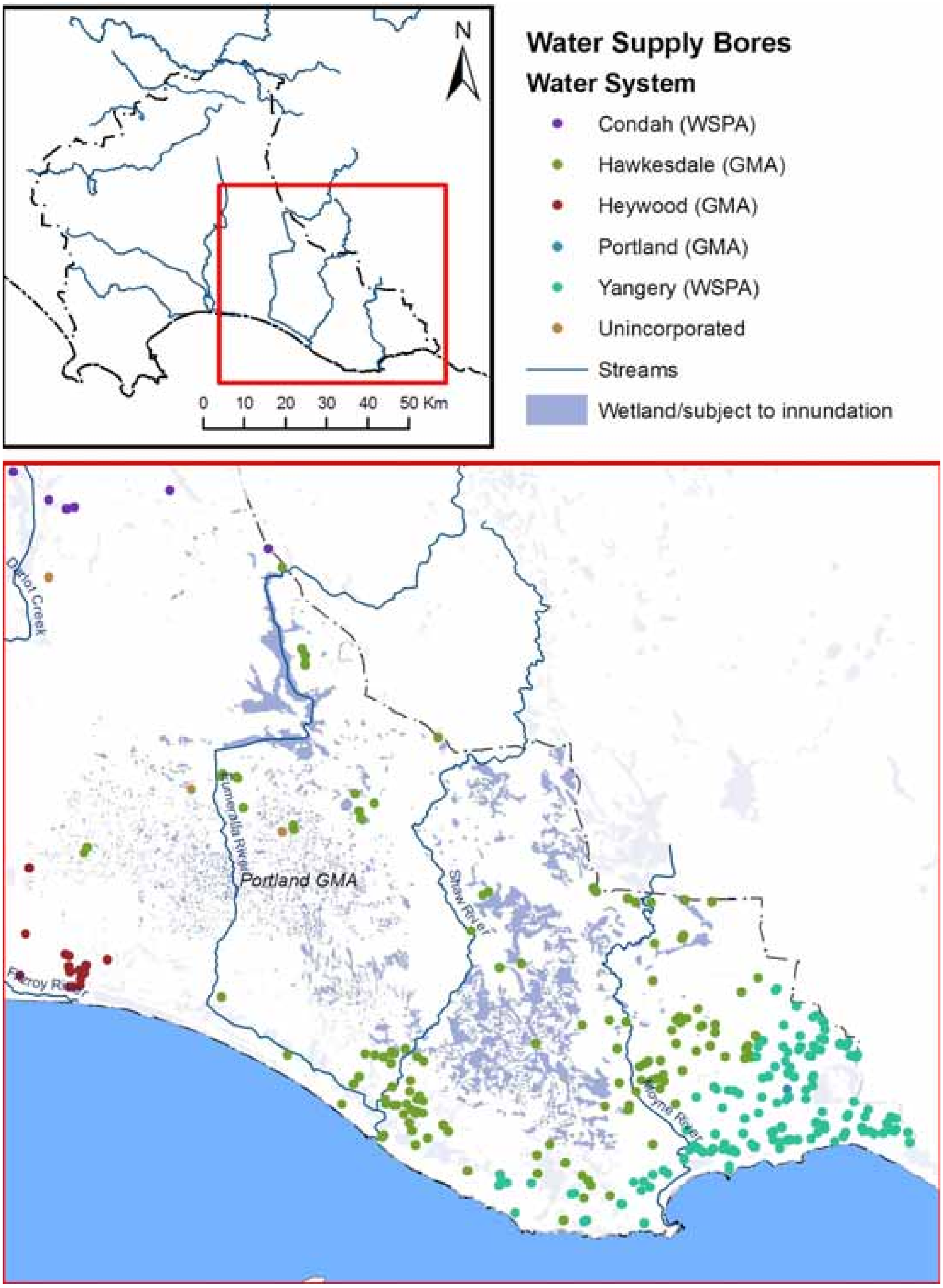

Figure 29 Eumeralla, Shaw, and Moyne River catchments showing water supply bore locations

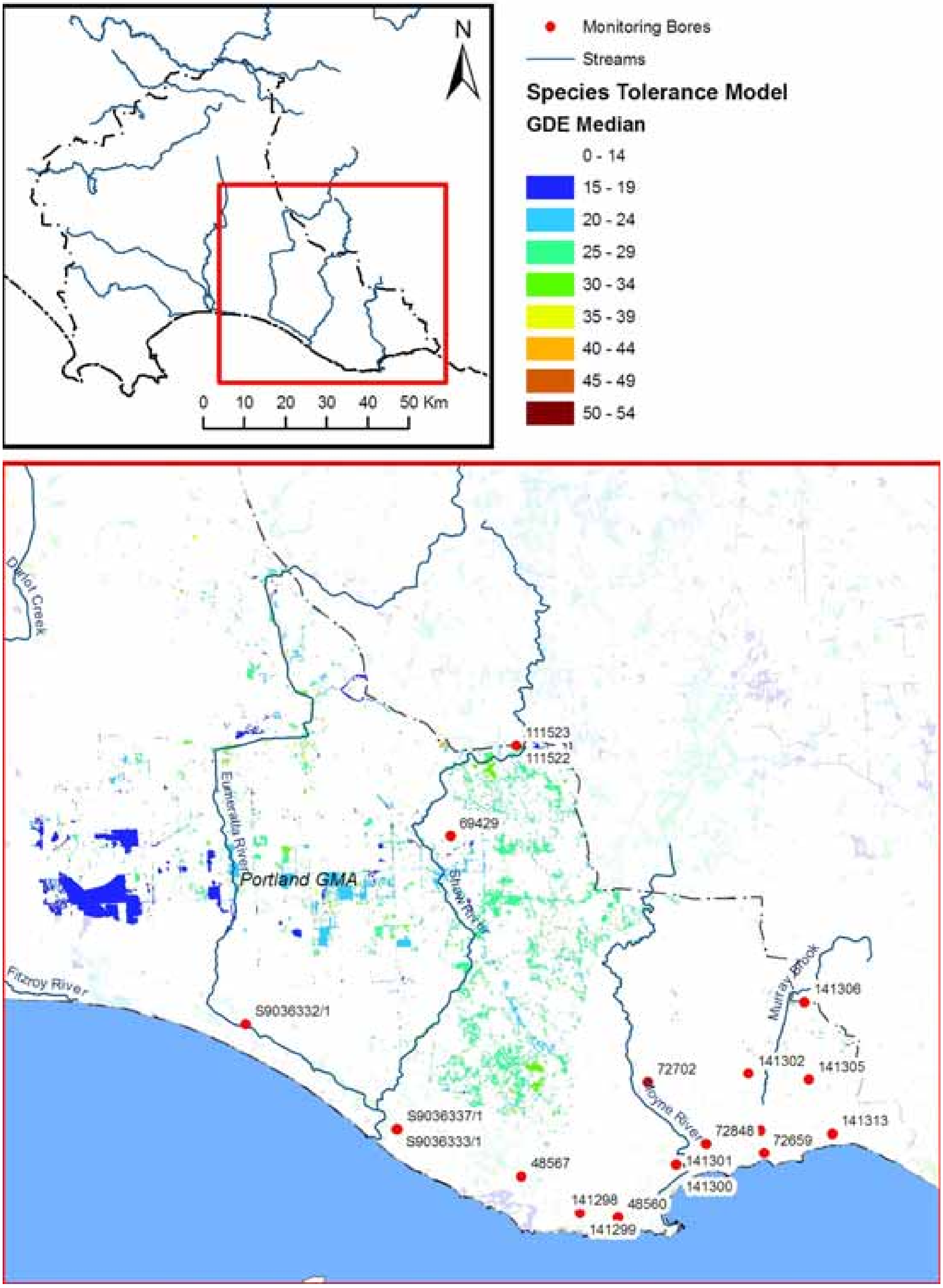

Figure 30 Species tolerance model results for the Eumeralla River, Shaw River, Moyne River, and Murray Brook catchments showing location of bores with water level data

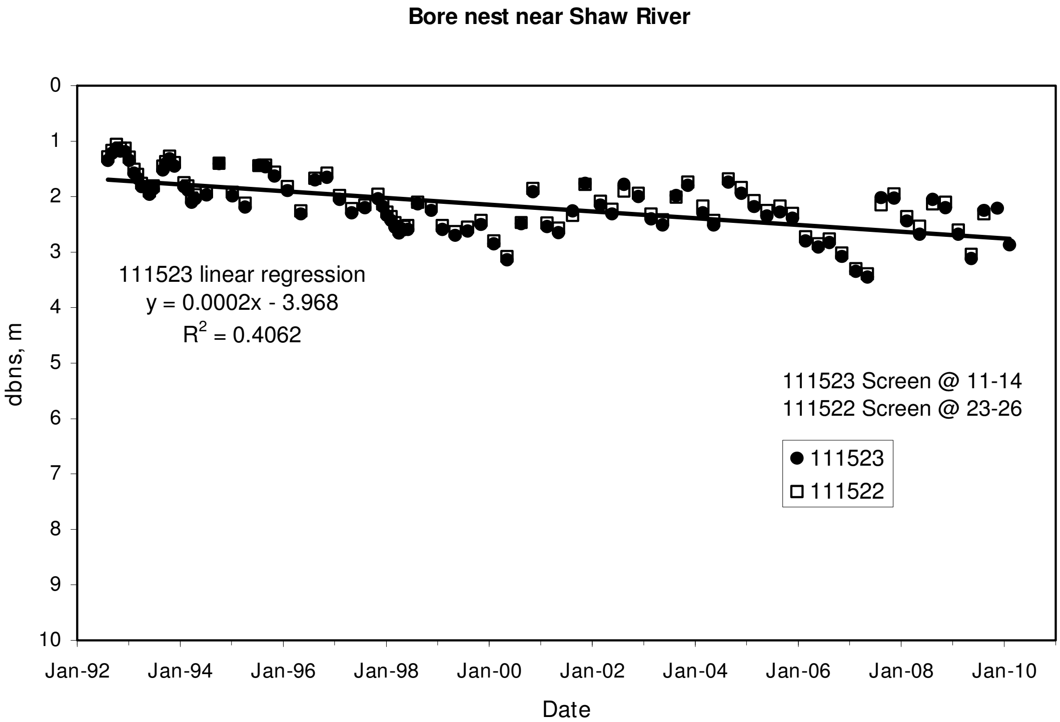

Figure 31 Hydrograph plot and regression analysis for nested bores near the upper Shaw River showing minimal vertical hydraulic gradient

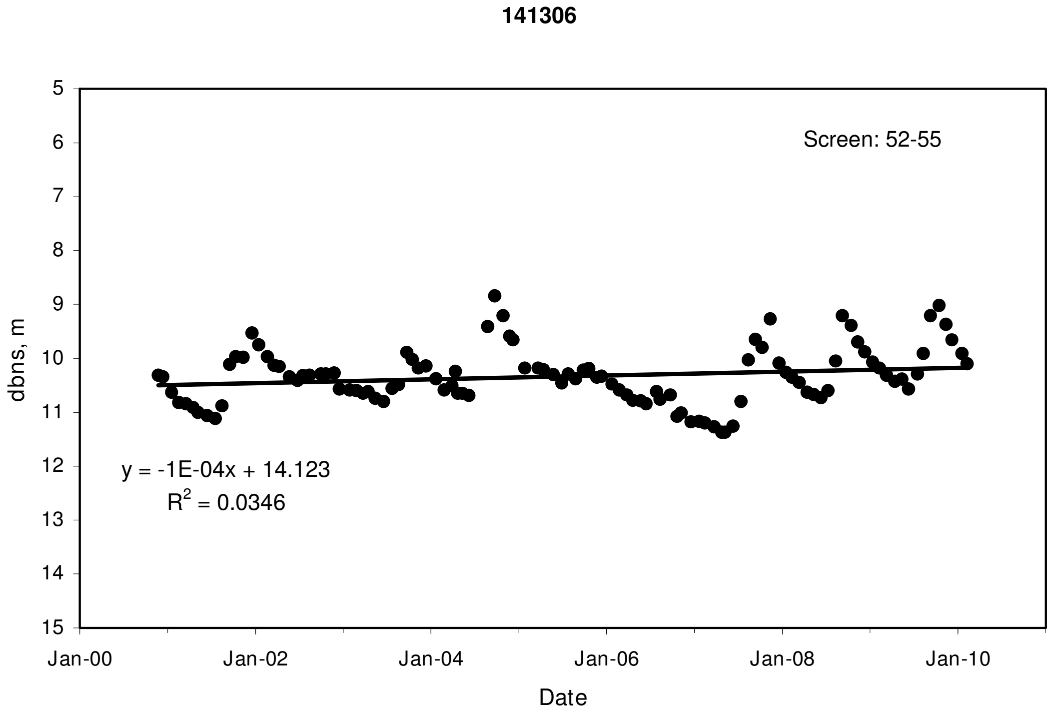

Figure 32 Plot of depth to groundwater and regression analysis for bore 141306, located in the upper part of the Murray Brook catchment, showing lowest water levels in winter and highest in spring, reflecting a relatively stronger rainfall pattern influence.

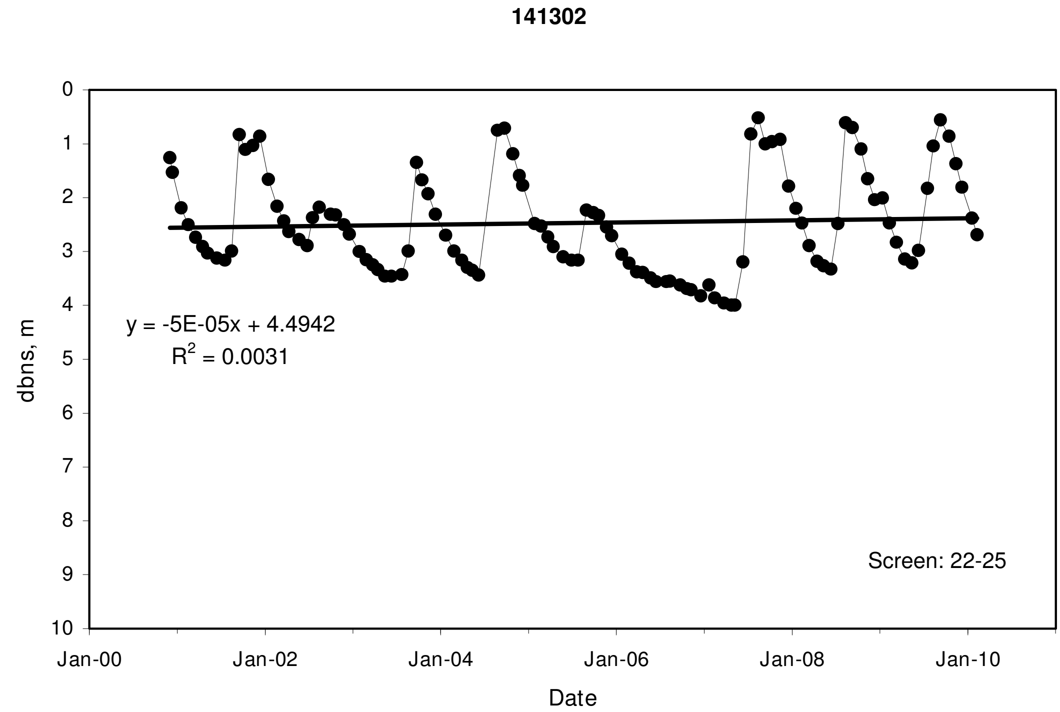

Figure 33 Plot of depth to groundwater and regression analysis for bore 141302, located in the upper part of the Murray Brook catchment, showing similar trend and behaviour to bore 141306 (Figure 32).

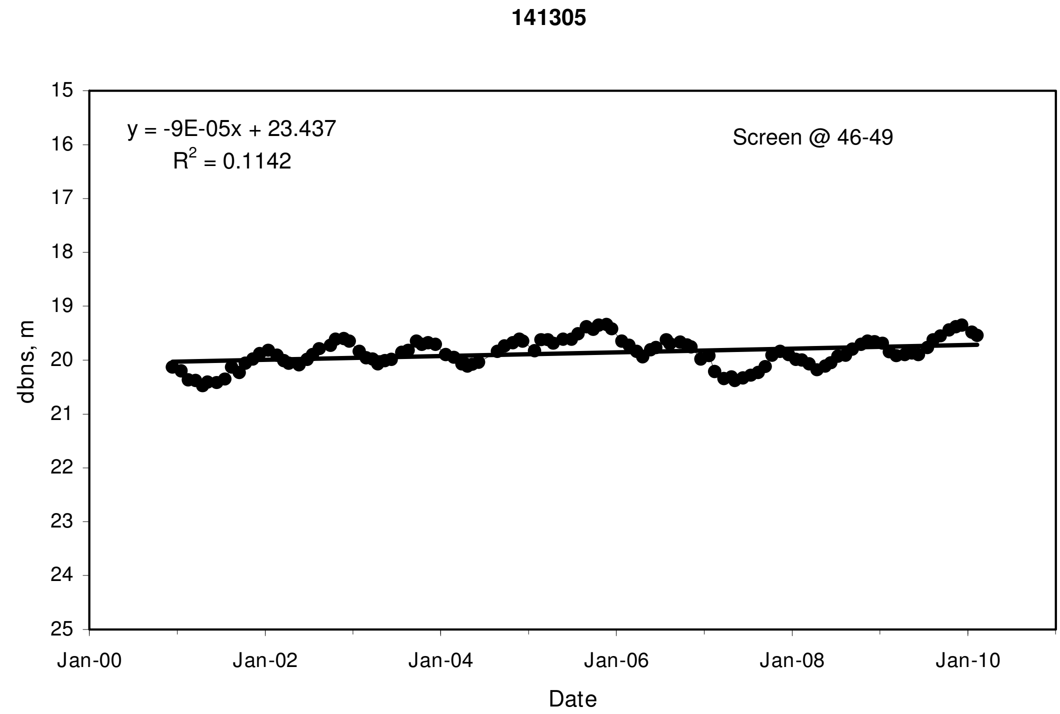

Figure 34 Hydrograph and regression analysis for bore 141305, located in the upper part of the Murray Brook catchment, showing lowest water levels in autumn/winter and a damped seasonal variability.

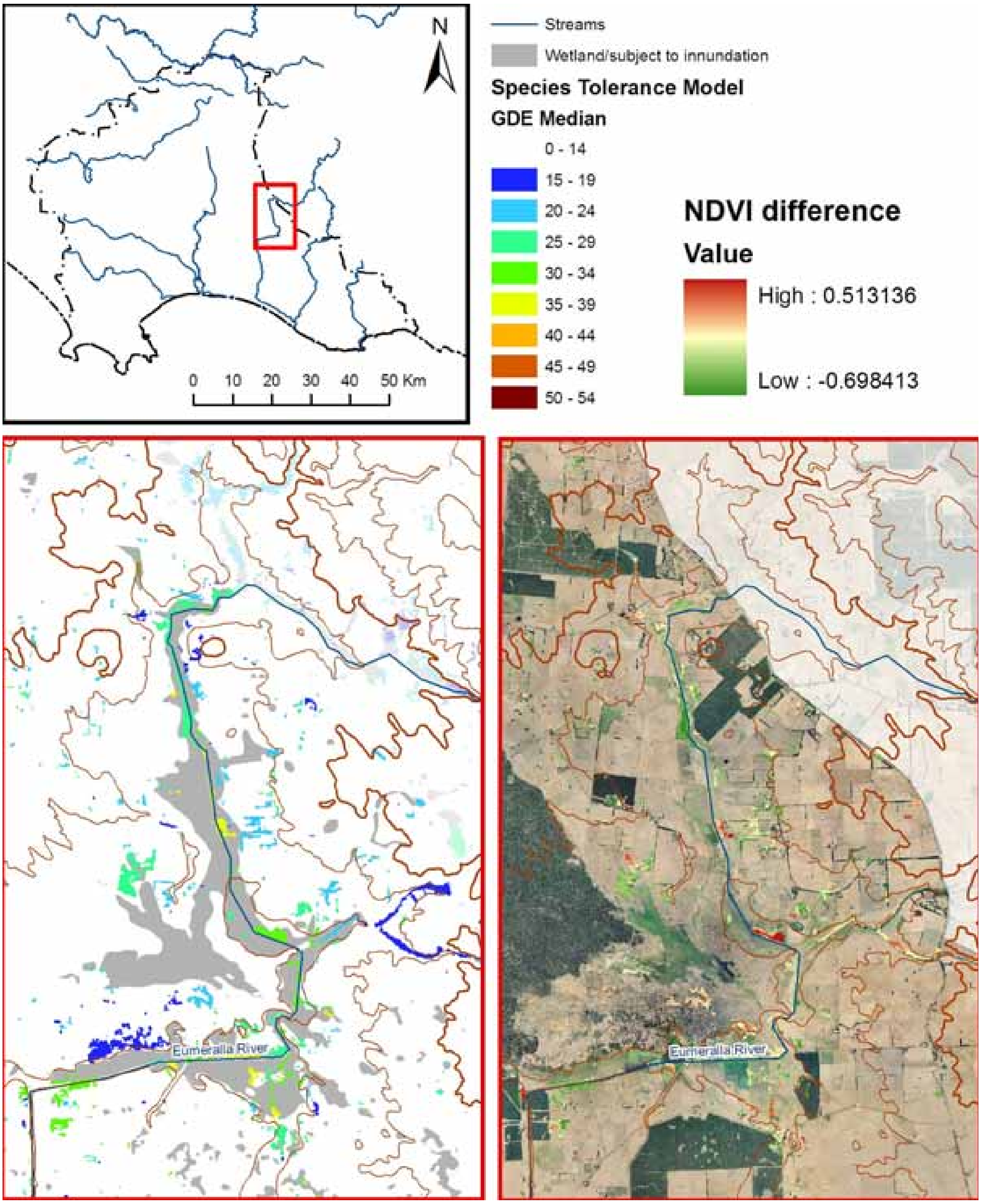

Figure 35 Species tolerance model and NDVI difference results for potential GDEs in a portion of the middle Eumeralla River Catchment, showing similarities to Condah Swamp.

5.3.4 Surrey River Catchment

Few potential GDEs were mapped in the Surrey River Catchment and there is little bore control to evaluate the hydrogeology. The proximity to the coast suggests tentatively that precipitation is more important than groundwater for ecosystem health but additional data would be needed to provide a more technically-based assessment.

5.3.5 Coastal Zone

The coastal zone was defined by an arbitrary 5 km buffer along the coast. In contrast to inland areas, there is no obvious correlation between treed or woody areas and a decline in NDVI from the 1995 to 2002 images. Mapped potential GDE areas are mainly located in dune areas and at the periphery of lagoons and streams.

Several deep monitoring bores are found in the coastal zone within the boundary of the Portland Groundwater Management Area. Completion depths ranging from approximately 520 to over 1200 m and static water levels less than 35 m below surface indicate that they monitor confined aquifers. Bores are presumably in the Dilwyn Formation (Lower Tertiary) aquifer or the Clifton Formation (Lower-Mid Tertiary) Aquifer. Available groundwater level data indicate generally declining heads since the 1970s. Geologic or drillers logs are not available on the Victorian Groundwater Management System (GMS) data base. On the available evidence, these bores are not likely to have any direct implications for groundwater discharges to GDEs but still provide an important part of the overall hydrogeologic picture.

Bores in the coastal zone with depths of less than approximately 100 m show water level behaviour that is typically seasonal with maximums in winter-spring and minimums in autumn. Where logs are available, they show that bores are usually completed in limestone, with some in basalt or sand. Vertical hydraulic gradients are near 0 to approximately 1 m upward (Figures 36 to 38). The overall groundwater trend for these bores is flat to slightly rising, despite the drought years. This suggests that the groundwater levels, and by implication any GDEs, are not sensitive to climatic conditions in the coastal areas. If groundwater extraction is causing the decline in deeper bores, then the impacts have not been seen in the shallow data suggesting resilience to current levels of groundwater exploitation. The observed rising trends themselves are interesting and seem counter-intuitive but require closer analysis beyond the scope of this project to assess possible causes.

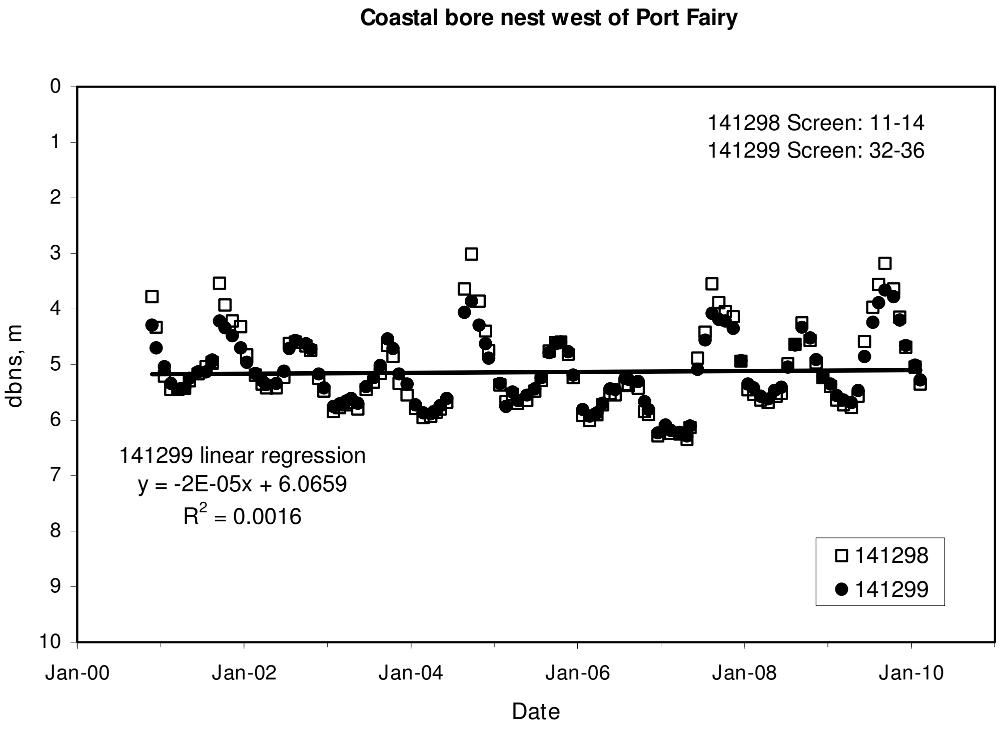

Figure 36 Hydrographs of nested bores west of Port Fairy showing seasonal variation with lowest water levels in summer-autumn and minimal vertical hydraulic gradient.

Coastal Bore Nest North of Port Fairy

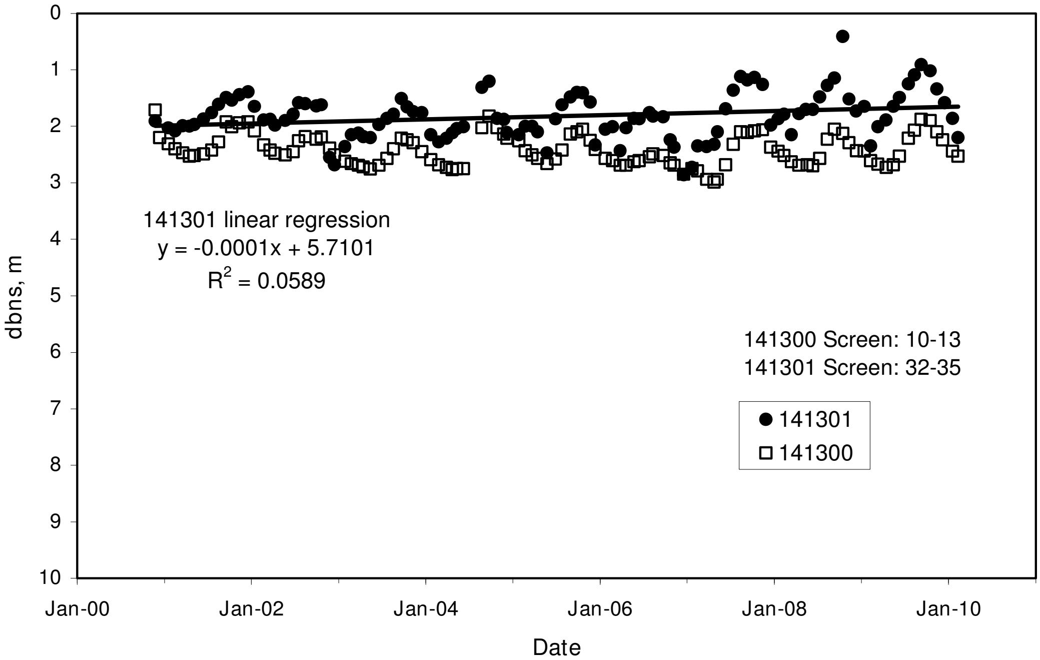

Figure 37 Hydrographs of nested bores north of Port Fairy showing seasonal variation with lowest water levels in summer-autumn and slight upward vertical hydraulic gradient.

Coastal bore nest north east of Port Fairy

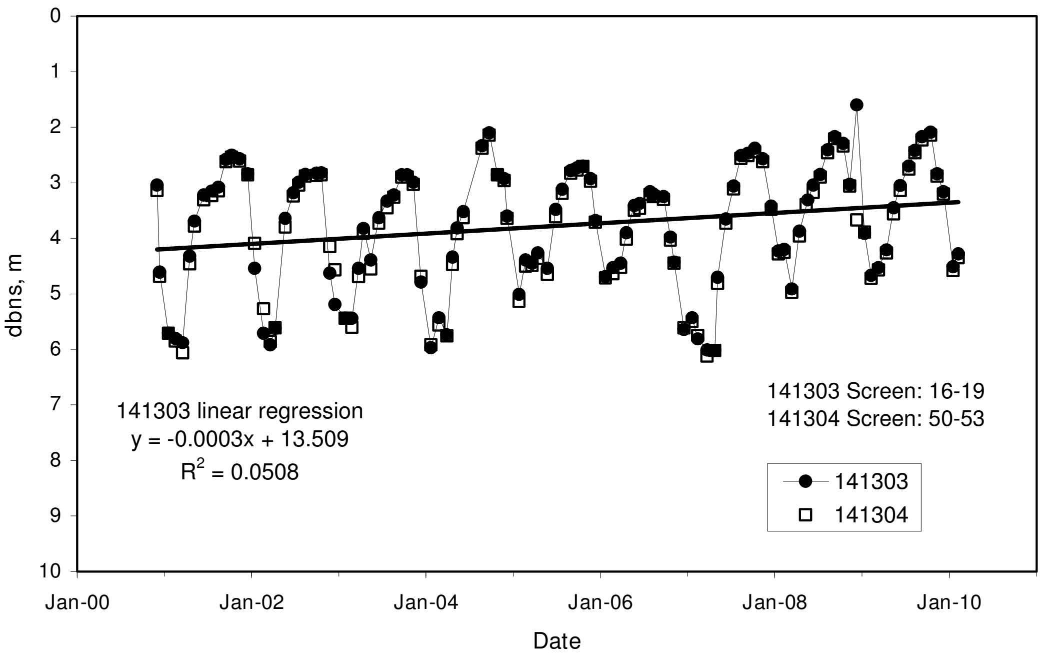

Figure 38 Hydrographs of nested bores west of Port Fairy showing seasonal variation with lowest water levels in summer and minimal vertical hydraulic gradient.