3.3. Current groundwater levels

As illustrated in the previous section, groundwater levels across a majority of the Central Plans have been increasing steadily since 2005 in response to a sequence of years with above normal winter recharge. As a consequence, groundwater levels in many areas were at (or near) record highs during the 2013 winter (certainly compared to levels recorded over the preceding 20 years). **Figure 28** shows a plot of the minimum recorded depth to groundwater during the 2013 year. Comparison with **Figure 19** shows the area with groundwater levels within 5 m of the ground surface was close to the historical maximum, although the extent of areas experiencing groundwater levels less than 2 metres below ground was less extensive than that observed in the historical record.

Figure 29 illustrates the departure of peak groundwater levels recorded in the Central Plains area in 2013 from the average annual maximum level recorded over the 1993 to 2013 period[3]. This plot shows groundwater levels across the entire Central Plains were above average during the 2013 winter, with areas to the west of SH1 generally exhibiting a peak winter level 2 to 4 metres above normal, while areas around the margins of Te Waihora/Lake Ellesmere experienced levels around 1 metre higher than the average winter maximum.

Figure 30 shows a similar plot to **Figure 29** but compares 2013 peak groundwater levels against the maximum level recorded in each monitoring well (over the entire period of record available for sites with >10 years record). The figure shows 2013 peak groundwater levels were within 0.5 metres of historical maximum levels across a broad area fringing Te Waihora/Lake Ellesmere and within 2 metres of the historical maximum in all areas aside from the northern quadrant of the Central Plains (~north of the Selwyn River and west of West Melton).

Figure 31 plots the spatial distribution of groundwater level trends observed across the Environment Canterbury groundwater level monitoring network since 2005. Trends were calculated based on a linear fit with significance determined at the 95% confidence interval. Results of this analysis indicate that, of the 71 wells analysed, 41 exhibited a statistically significant increasing trend, 29 showed no trend and 1 showed a declining trend. Wells showing increasing trends tend to be located in inland areas away from the major rivers, while wells in lowland areas or near constant head boundaries (rivers, springs and Te Waihora/Lake Ellesmere) exhibited no significant trends. The largest increasing trends (> 2m/year) were noted in deep wells (80m+) in the Greendale/Hororata area including L35/0790, L36/0058, L36/0064 and L36/1226. These figures indicate a substantial increase in groundwater storage volume over the past 8 years in inland areas in response to a sequence of years experiencing above average winter recharge.

Due to the relationship between groundwater levels and discharge in lowland streams, temporal variations in groundwater levels in the Central Plains area over recent years are reflected in measured discharge. For example, **Figure 32** shows a plot of mean annual discharge in Doyleston Drain over the period 1987 to 2013 which follows observed variations in land surface recharge (**Figure 6**) and groundwater levels (**Figure 24 to Figure 27**) across the Central Plains area.

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[3] The 1993 to 2013 period was selected as the 'baseline' for this comparison as a compromise between the length of record and the spatial resolution due to the limited number of wells having a record over 20 years. As a consequence, this assessment does not include the period of high groundwater levels recorded during the late 1970's. Figure 30 compares 2013 peak levels against the maximum recorded at each site. For sites with a record exceeding 40 years this includes the late 1970's period.

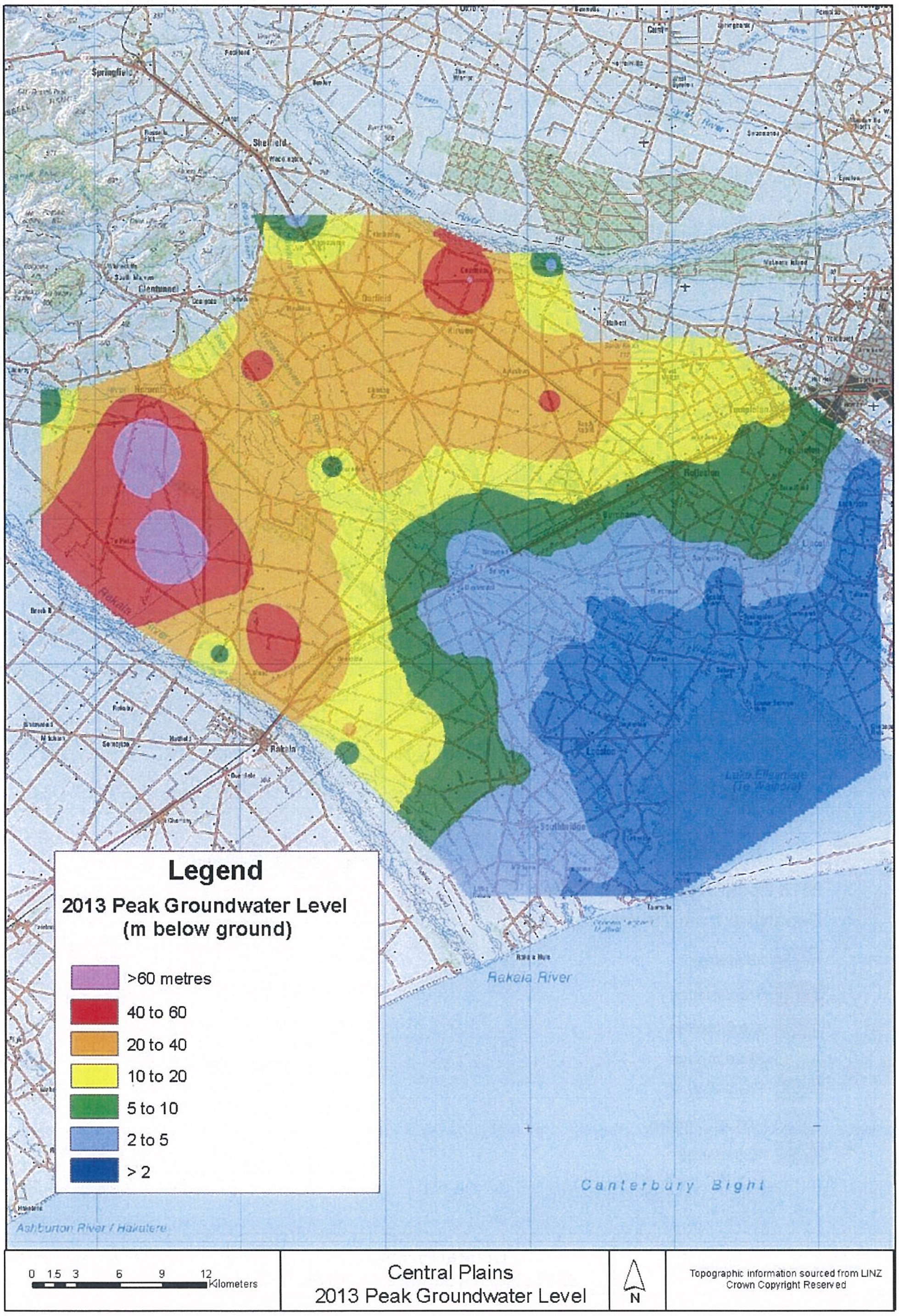

Figure 28. Peak groundwater levels in the Central Plains area during winter 2013

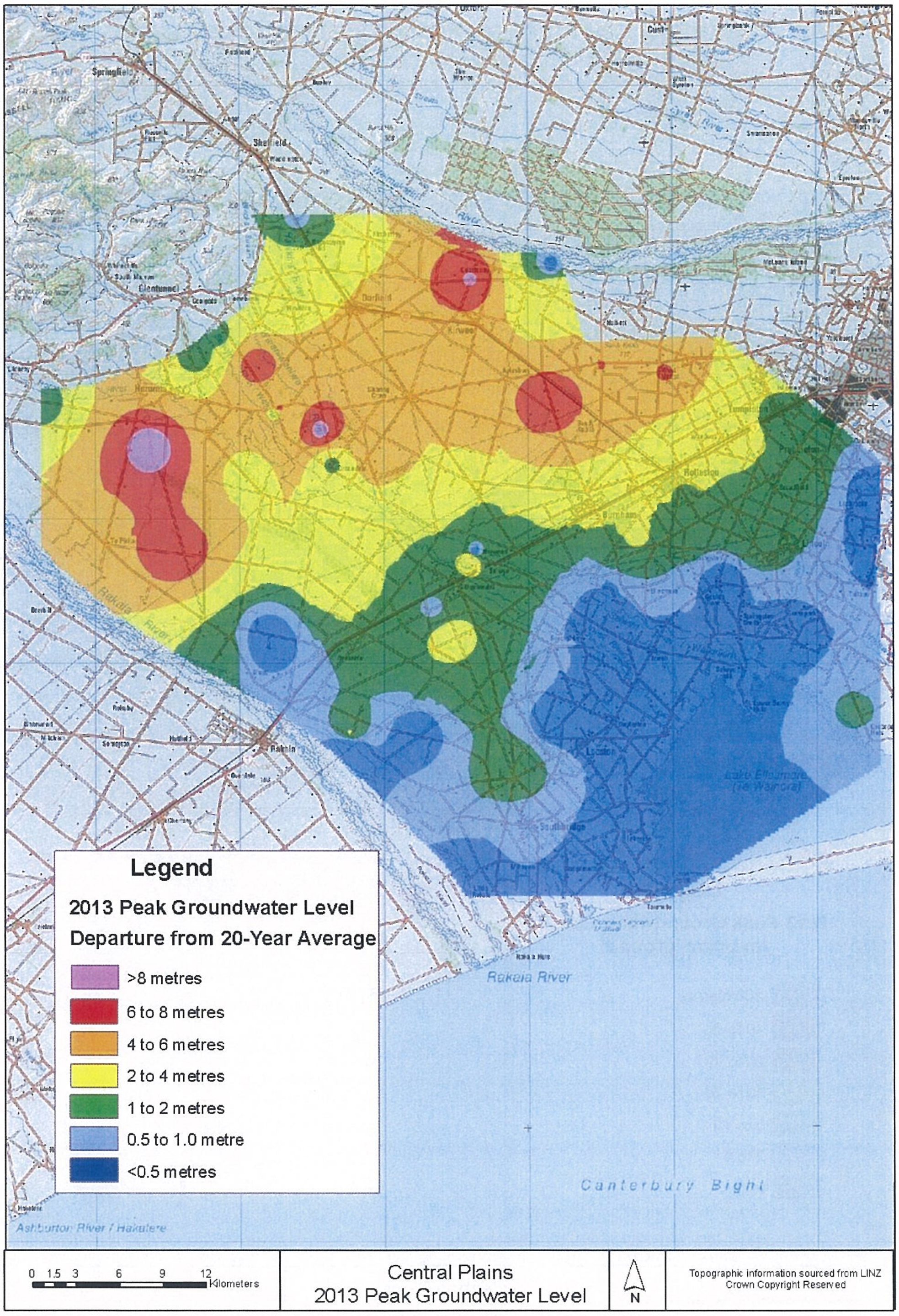

Figure 29. Departure of 2013 peak groundwater levels from the 20-year (1993 to 2013) average annual maximum

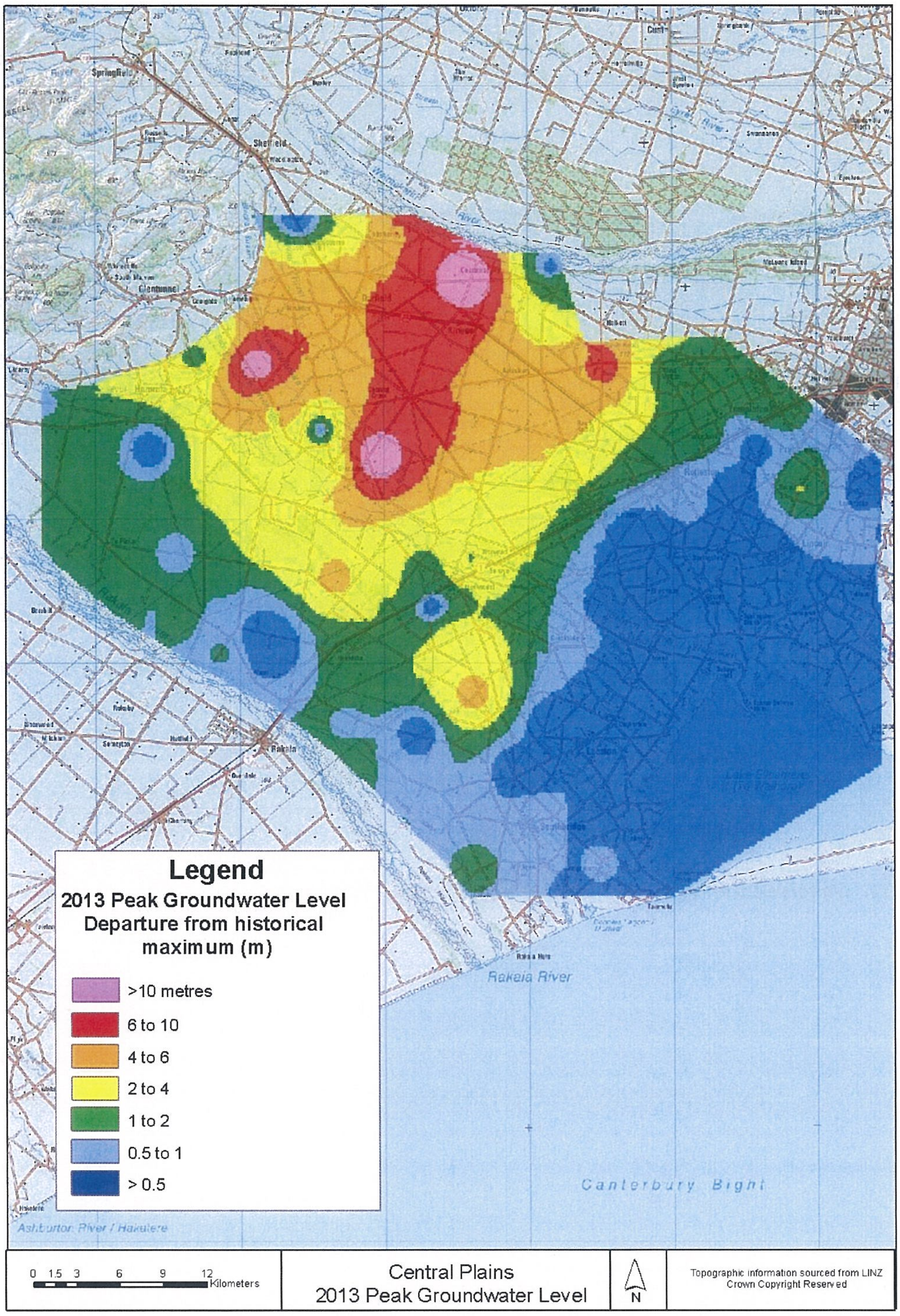

Figure 30. Departure of 2013 peak groundwater levels from the historical maximum recorded at in individual monitoring wells (for sites with record length >10 years)

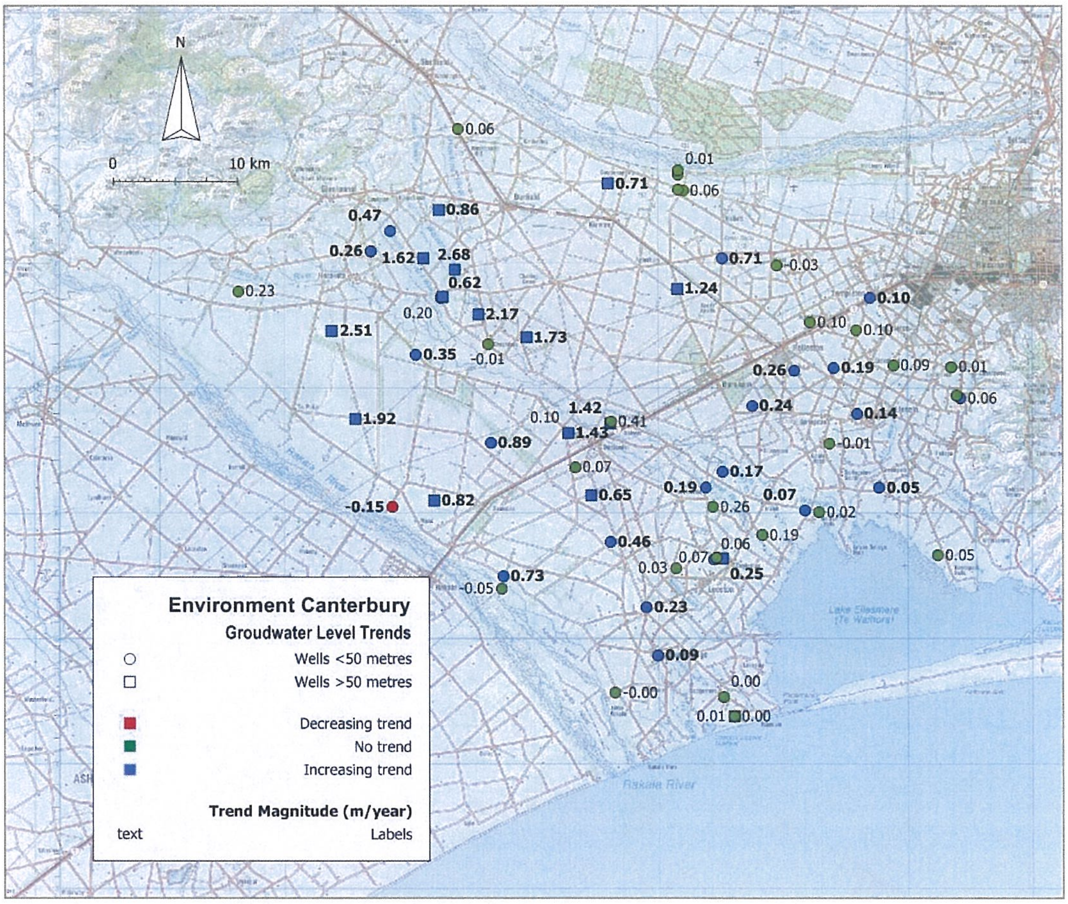

Figure 31. Observed trends in groundwater levels across the Central Plains, 2005 to 2013.

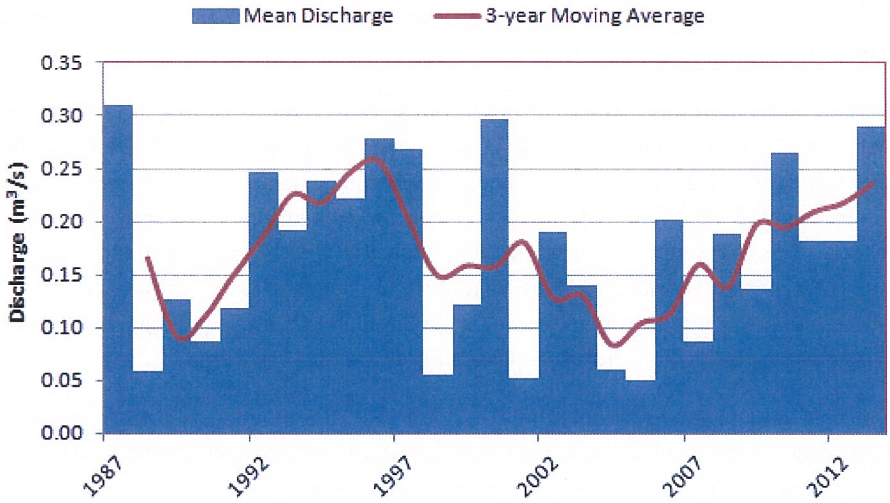

Figure 32. Temporal variation in mean annual discharge in Doyleston Drain, 1987 to 2013

3.4. Future Groundwater Levels

Construction of the CPWL scheme has the potential to have a significant impact on the overall water balance of the Central Plains groundwater system due to a combination of:

- Increased land surface recharge due to a doubling of the currently irrigated area of approximately 30,000 Ha to 60,000 Ha; and
- Substitution of current groundwater abstraction for irrigation with surface takes from CPWL reticulation.

The resulting net increase in land surface recharge and decrease in groundwater abstraction has the potential to result in an increase in groundwater levels across the Central Plains area. While a majority of direct effects on groundwater levels will occur within the scheme area, the resulting change groundwater throughflow has the potential to raise groundwater levels downgradient of the scheme as the increased recharge flux moves through the aquifer system to the lowland/coastal discharge area.

The potential increase (or 'mounding') of groundwater levels within the scheme area has the potential to improve access (and reliability of supply) and decrease pumping costs for groundwater users within the scheme area (where the existing water table is typically deep and is currently affected by significant seasonal and long-term variations). Downgradient of the scheme, potential increases in both median and peak groundwater levels have the potential to result in a range of adverse effects in areas where the water table already occurs at shallow depths including:

- Soils becoming waterlogged with a consequent reduction in productivity;
- Impediments to the proper functioning of existing wastewater and stormwater discharges to ground
- Capacity issues in the lowland drainage network

However, groundwater level increases in lowland areas also have the potential to increase baseflow in spring-fed streams in the Te Waihora/Lake Ellesmere catchment with consequent beneficial effects on flow sensitive values.

Estimates of the likely magnitude and extent of groundwater mounding were prepared by Aqualinc Research Ltd (Weir, 2008, Weir 2009) for the CPWL consent hearing process. This assessment utilised a numerical groundwater flow model to simulate the potential effect of scheme operation under a range of climate scenarios representing both 'wet' and 'dry' years. **Figure 33** and **Figure 34** show the modelled extent and magnitude of groundwater mounding resulting from the CPWL scheme during a wet year. **Figure 35** and **Figure 36** present equivalent figures illustrating the modelled extent of areas experiencing groundwater levels less than 1 metre and 5 metres below ground during a dry year respectively, with the CPWL scheme in operation. Key findings from this assessment include:

- Maximum predicted groundwater mounding in a dry year was 6.5 metres, increasing to around 7 metres in a wet year. The extent of 'significant' groundwater mounding was limited to the scheme area with smaller increases (<2m) in water levels occurring down gradient;
- Flows in lowland stream flows are predicted to increase by approximately 60% (in terms of mean annual low flow).

More recently, scenario modelling undertaken for the Selwyn-Waihora water management zone limit setting process[4] has provided a more up to date estimate of potential effects of the CPWL scheme in its current configuration. The modelling, also undertaken using the Aqualic Research Central Plains groundwater model, considered three scenarios relevant to this assessment:

- Scenario 0 - no groundwater abstraction in the catchment
- Scenario 1 - based on the estimated 2011 irrigated area (essentially representing status quo water and land use); and
- Scenario 2 - essentially equivalent to the current CPWL development involving irrigation of up to 60,000 Ha comprising 30,000 Ha of new irrigation combined with replacement of a portion of existing groundwater takes with surface water

[4] Available from http://ecan.govt.nz/publications/Plans/selwyn-tewaihora-groundwater-quantity-draft-report.pdf (not referenced)

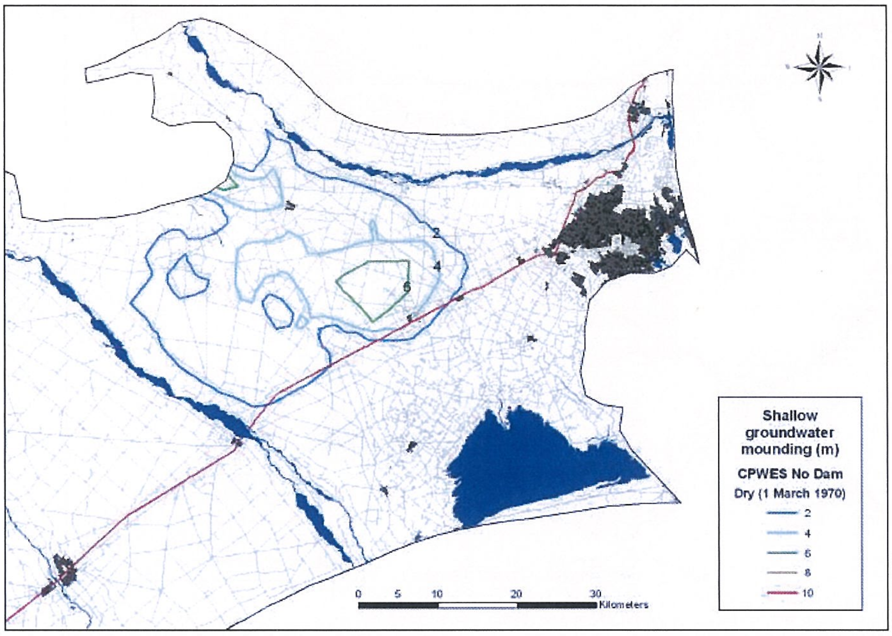

Figure 33. Estimated magnitude of water table mounding resulting from the CPWL scheme in a dry year (1971), reproduced from Weir (2009)

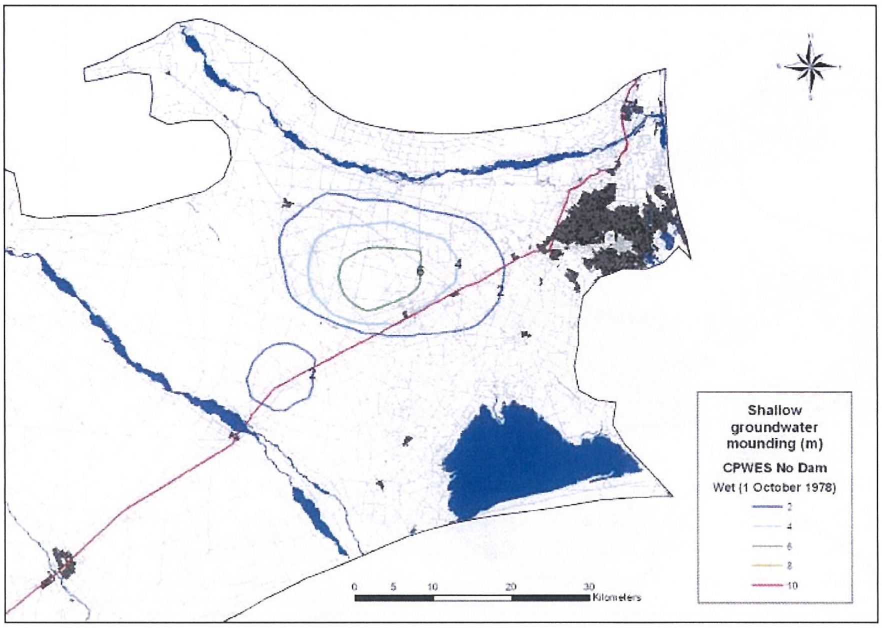

Figure 34. Estimated magnitude of water table mounding resulting from the CPWL scheme in a wet year (1978), reproduced from Weir (2009)

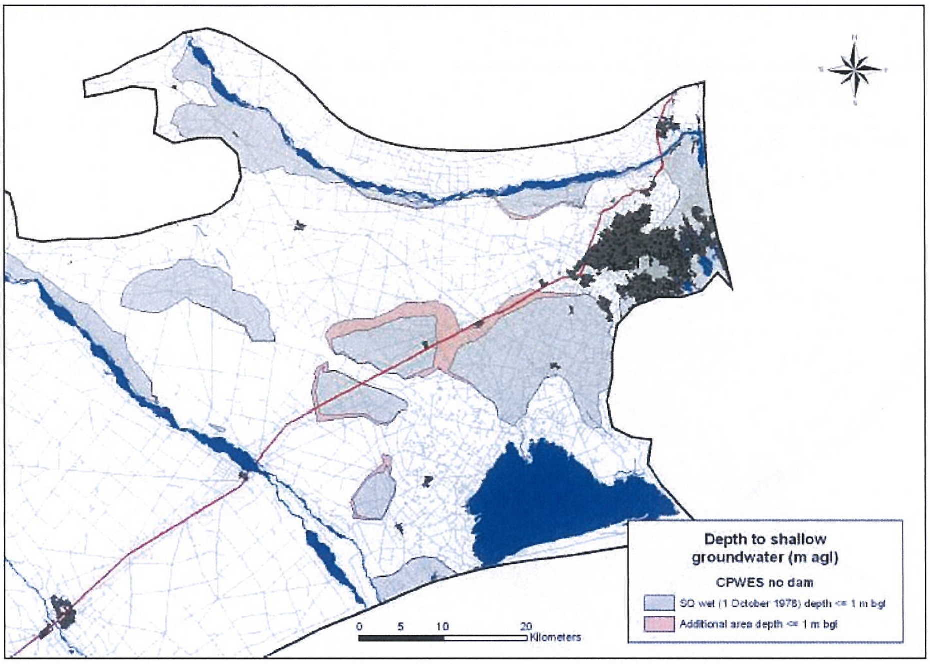

Figure 35. Extent of area with groundwater levels (<1 m) during a wet year following CPWL development, reproduced from Weir (2009)

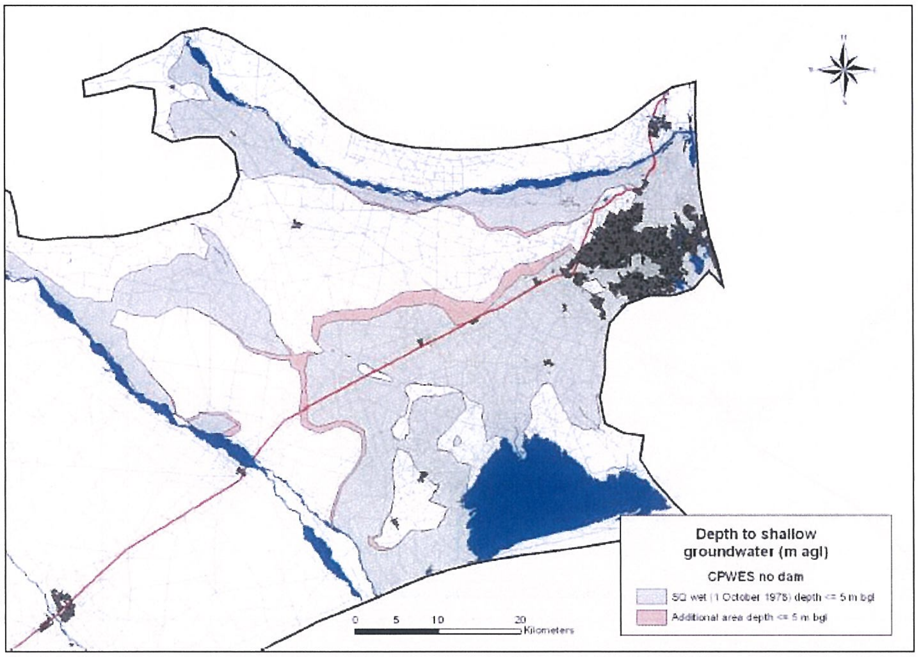

Figure 36. Extent of area with groundwater levels (<5 m) during a wet year following CPWL development, reproduced from Weir (2009)

Results of this assessment indicate that:

- Under Scenario 1 (status quo) groundwater levels east of SH1 are up to 2 metres lower that would likely occur under Scenario 0 (i.e. no groundwater abstraction);
- High (i.e. >90th percentile) groundwater levels under Scenario 2 (CPWL) are predicted to increase by up to 5 metres in inland areas compared to the status quo. Under this scenario, groundwater levels east of SH1 do not increase by more than 1 metre due to increased drainage via lowland streams and the existing drainage network;
- Under Scenario 2 (CPWL) long-term average flows in lowland streams are approximately equal to those predicted under Scenario 0 (i.e. no groundwater abstraction)

Figure 37 shows the calculated difference in 90 percentile groundwater levels between Scenario 2 (CPWL) and Scenario 1 (status quo). The figure shows the maximum increase in groundwater levels occurring within the scheme area while a range of less than 2 metres occurring across the remainder of the scheme area.

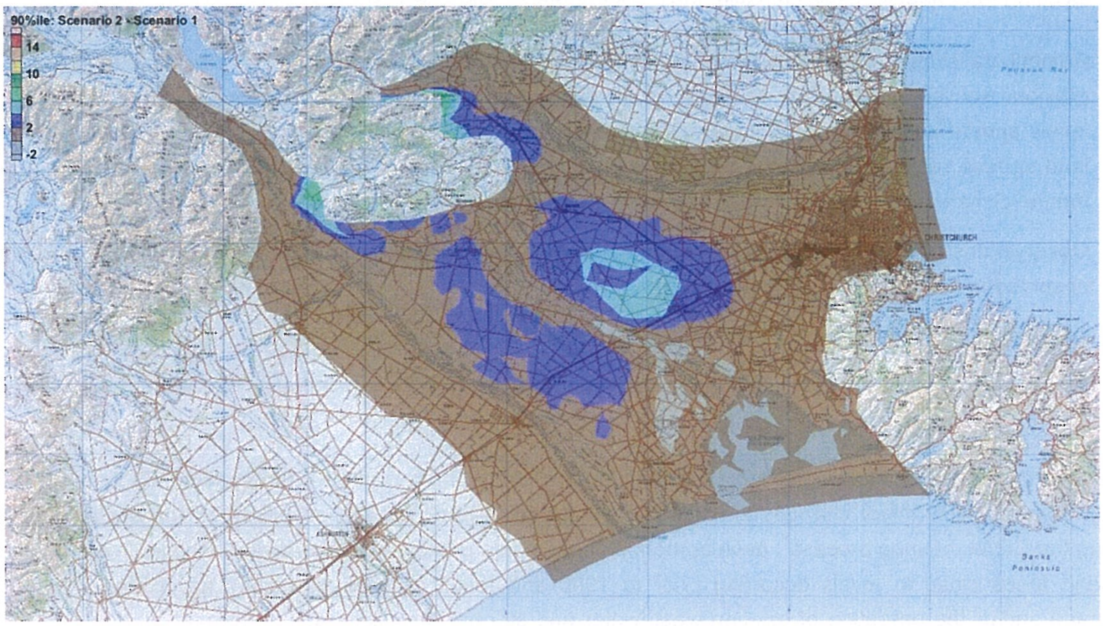

Figure 37. Modelled difference between Scenario 2 (CPWL) and Scenario 1 (status quo) 90 percentile groundwater levels (reproduced from Environment Canterbury, unreferenced)[5]

Overall, modelling of potential effects of CPWL scheme development on groundwater levels across the Central Plains area the magnitude of mounding is likely to be greatest (up to 7 metres) within the scheme area. Smaller increases in groundwater levels (<1 metre) are predicted to occur in lowland areas where the effects of increased groundwater throughflow are moderated by increased discharge to lowland

[5] http://ecan.govt.nz/publications/Plans/selwyn-tewaihora-groundwater-quantity-draft-report.pdf

streams and the existing drainage network. However, given the heterogeneity of the hydrogeological environment and the sensitivity of potential adverse effects associated with relatively small increases in groundwater levels (particularly around the margin of Te Waihora/Lake Ellesmere) it is difficult to reliably quantify the projected effects of CPWL development with any significant degree of accuracy.

It is however noted that modelling suggests that CPWL development will return baseflow in lowland streams (and by inference contributing groundwater levels) close to that occurring under natural (i.e. unpumped) conditions. As a consequence, initiatives to further augment lowland stream flow (for example by managed aquifer recharge) may serve to further exacerbate issues associated with a high water table in lowland areas.

3.4.1. Characterising future changes in baseline groundwater levels

A key consideration in terms of quantifying potential effects associated with the CPWL scheme is the resulting effects on downgradient groundwater levels. Due to the relatively deep water table, this can likely be achieved in most inland areas by analysis of basic water level and hydrological statistics from the existing monitoring network. Key metrics to differentiate natural variability in groundwater levels from that resulting from effects associated with the CPWL Scheme may include:

- Rainfall statistics and calculated (dryland and irrigated) land surface recharge. As illustrated in the previous section, land surface recharge is the primary driver of long-term variations in groundwater levels across a majority of the Central Plains area. Updated assessment of rainfall departure and land surface recharge will assist differentiation of those changes in groundwater level arising from natural climate variability from those associated with development of the CPWL scheme;
- Observations of spatial variations in the timing, rate and magnitude of groundwater level fluctuations observed in individual monitoring wells;
- Changes in springfed stream flow and flows entering drainage schemes; and
- Statistical measures of water levels and springfed stream flows (e.g. minimum, maximum, median and 90th percentile) observed across the entire monitoring network.

However, due to the shallow water table in many lowland areas, both positive and negative effects may result from relatively minor changes to existing groundwater levels. As acknowledged by the applicant during the CPWL hearing process[6], development of the scheme is likely to increase groundwater levels in lowland areas close to levels occurring prior to 1990 and result in localised issues associated with drainage and/or the operation of existing wastewater and stormwater discharges. However, due to the heterogeneous hydrogeological environment and the spatial resolution of modelling (combined with natural climate variability) it is not possible to accurately characterise the exact nature and extent of areas and infrastructure adversely affected by groundwater mounding. It was therefore proposed that an adaptive approach be adopted to manage potential effects associated with groundwater mounding[7].

In order to inform decision-making regarding potential effects of groundwater mounding in lowland areas additional monitoring of groundwater levels, stream and drain flows may be required to characterise 'baseline' groundwater levels and drainage flows in lowland areas on a sufficiently fine (spatial) scale.

[6] http://ecan.govt.nz/publications/Consent%20Notifications/S92responsegroundwatermounding.pdf

[7] One of the functions identified for the Groundwater and Surface Water Expert Review Panel (GSWERP)

This process may also require characterisation of existing infrastructure and activities potential affected by projected changes an groundwater levels including assessment of the effects of 'natural' groundwater level variation (such as the high groundwater levels during the 2013 winter) on their current function. Characterisation of natural variability in groundwater levels within and down gradient of the CPWL command area may be aided by the application of analytical modelling tools such as the eigen model technique documented by Bidwell (2003) and Williams (2011). Use of such modelling techniques may be utilised to establish the natural relationship between recharge and groundwater levels using historical data (i.e. pre-CPWL), thereby enabling quantification of the likely magnitude of changes associated with CPWL development.