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Dear Raymond

## **DEPTH TO GROUNDWATER IN THE CULVERDEN BASIN**

### **1.0 Introduction**

Environment Canterbury (ECan) have engaged Pattle Delamore Partners Ltd (PDP) to prepare a map of the Culverden Basin showing the average depth of groundwater from the land surface. The work is being carried out to assist ECan staff with the preparation of NRRP Variation 27 – Managing non-point source discharges.

This letter presents the methodology for deriving the depth to groundwater contours, the assumptions made and the limitations encountered during the study.

### **2.0 Background**

The Culverden Basin is the largest of three inland basins (Cheviot Basin, Culverden Basin and Lees Valley) in North Canterbury. The Culverden Basin is located approximately 90 km north of Christchurch and 35 km inland, with an area of approximately 81,000 ha (Figure 1). Four main rivers cross the basin in a general west-to-east direction: (from north to south) Waiau; Pahau; Hurunui; Waitohi.

The study area for this project is the Culverden Plain, which comprises the area of alluvial gravels that extends from the Waitohi catchment in the south, to just north of the Waiau River. Figure 2 shows the study area along with the major rivers and the location of Leonard Mound.

A number of previous studies have considered groundwater levels in the Culverden Basin. In 1984, Weeber and Talbot wrote a preliminary report on the groundwater resource of the Culverden Plain. They presented a map showing 10 m and 20 m depth to groundwater contours between the Hurunui and Waiau Rivers. Their map showed that the groundwater table is shallow near the main rivers and along the eastern boundary of the basin near the Lowry Peaks Range, with the greatest depths to groundwater found in the west of the basin approximately halfway between the main rivers.

Close (1985) used pre-1980 mean groundwater levels from 37 wells to produce a piezometric contour map between the Hurunui and Waiau Rivers. Close noted that groundwater flows from the upstream section of the Waiau River into

the centre of the basin, at which point the Leonard Mound splits the flow, with one branch flowing to the northeast to discharge back into the Waiau River, and the other branch flowing southwards to discharge into the Hurunui River.

Tonkin and Taylor Ltd (1985) carried out a study to evaluate the nature and extent of drainage problems caused by the Waiau Irrigation Scheme. The irrigation scheme, established in the late 1970s, is sourced from both the Waiau and Hurunui Rivers. Excess irrigation, especially during the summer months, resulted in localised surface flooding, particularly along the western edge of the Leonard Mound where the groundwater is particularly close to the surface (Armstrong, 2000).

Tonkin and Taylor Ltd (1985) produced a depth to water contour map between the Pahau and Waiau Rivers; although with a lot more detail than Weeber and Talbot (1984). Tonkin and Taylor Ltd showed contours for the following depths: 0.1, 1, 2, 3, 5, 10, 12 and 15 m.

### 3.0 Methodology

ECan's GIS database was used to obtain information on all the wells in the Culverden Basin. Well information was then sorted by the number of water level measurements on record. Wells with a depth of greater than 40 m were excluded from the project, as they were less likely to represent water table conditions. Weeber and Talbot (1984) noted that groundwater exists at shallow depths between 7 and 30 m in the gravels of the Culverden Plain. The well depths used in the project ranged from 2.7 to 36 m deep. The next well depth greater than 36 m was 54 m deep, which may indicate a deeper aquifer, rather than the strata in which the water table occurs.

A total of 65 wells (from the ECan GIS database) had depths less than 40 m and at least one water level measurement. The entire record of water level data for each of these wells was downloaded from ECan's Well Card Search. Time series of the individual water level records were plotted for each well, and mean and median depths to water were calculated. A mean depth to water was used, rather than a median value, because this better represented the average depth for the available data, especially for wells with a smaller number of water level readings.

Time series data for wells with the most water level records was closely examined to determine whether it was possible to adjust the mean depth to water for wells with less than 20 measurements. However, there was simply not enough data to determine whether on a given date the water table was above or below the long-term average. Instead of excluding wells with only a few water level measurements, all wells with any readings were used in the project because of the paucity of water level data available and since the range of water level fluctuations within the Culverden Basin was typically only around four metres. Therefore, if a well with only one water level record was measured at a time when the water table was at its maximum (or minimum) height, then the mean depth to water for that well would only be out by around two metres.

Water levels from an additional four shallow wells, located at the Fonterra Satellite Milk Concentration plant near Culverden, were included in the project. The wells were measured on three occasions between April and May 2007.

The mean depths to groundwater for all wells were converted to mean water table elevations using the known reduced level of the measuring point, as recorded in the ECan GIS database.

It was assumed that the Waitohi, Hurunui, Pahau and Waiau Rivers were connected to groundwater within the Culverden Basin. Tonkin and Taylor Ltd (1985) reported that the Amuri Plains groundwater system receives recharge from rivers (namely the Waiau and Pahau). In addition, depth to water measurements for wells near these four rivers were very shallow, indicating a likely connection between groundwater and surface water. These four rivers were accounted for by a series of points along the riverbed, where the depth to water at each point was assumed to be zero metres below ground level at the riverbed. The x, y coordinates for these points and their elevations were obtained from Freshmap V10.0 mapping software (data for Freshmap is sourced from the NZTopo database).

The location of springs was obtained from the ECan GIS database. There were six springs within the Culverden Basin. As for the rivers, it was assumed that the depth to water at each spring was zero metres below ground level. The reduced levels for these springs were obtained from Freshmap V10.0.

Using each of the data sources mentioned above, a piezometric contour map of the average (mean) groundwater table was produced using Surfer Version 9 surface mapping system. The gridding method used to produce the contour map was the Kriging method.

#### 4.0 Results

The piezometric contour map shows that groundwater in the Culverden Basin generally flows from west to east, parallel to the four main rivers. The map also shows that the Leonard Mound divides groundwater flow, with a portion flowing to the northeast to discharge into the Waiau River, and the rest flowing southwards to discharge into the Hurunui River. This observation was also noted by Close (1985).

Two errors (or inaccuracies) were observed in the draft piezometric contour map. Firstly, well N32/0008, which is located approximately 5 km west of the Waiau township and just south of the Waiau River, created a mound (or high point) in the piezometric contour map because of its relative elevation difference compared with the nearby riverbed. This caused all the contours to bunch around well N32/0008. However, the 1:250,000 Geological Map for the Kaikoura Area (Rattenbury *et al.*, 2006) shows that well N32/0008 draws water from a much older formation than the rest of Culverden Basin. Therefore, the shallow depths to water experienced in this well are likely to be indicative of perched water that is not connected to the alluvial gravels found in the rest of the basin. To correct for this error in the piezometric contour map, well N32/0008 was removed from the data set. This had the effect of removing the mound in the map at Isolated Hill and spacing out the contours.

The second error in the draft piezometric contour map was near Leonard Mound, at the eastern edge of the Culverden Basin, halfway between the Waiau and Hurunui Rivers. The mean water table elevation for well N33/0005 is much higher than the surrounding wells, due to the relative elevation differences, which caused a mound in the piezometric contours around the Leonard Mound. This effect appears to be correct, since the Leonard Mound diverts groundwater north and south; however, the spatial extent of the mounding is incorrect. The groundwater mounding extended too far to the west, due to the limited number of wells near the Leonard Mound, which resulted in the mean groundwater table being above the land surface. To correct for this, several additional artificial points were added to the data set to lower the water table in this area. The updated piezometric contour map is shown in Figure 3.

To compute depth to water contours, the average (mean) water table elevations (represented by the piezometric contours) were subtracted from the land surface elevations. In order to carry out this subtraction, two grid files (a file made up of square cells, each with a unique elevation) were required – one file representing the land surface elevations across the basin, and the second file of the average (mean) water table elevations.

A grid file of land surface elevations was generated by converting 20 m contours to 20 by 20 m cells, with the elevation for each cell being interpolated from the contours. The 20 m contours were sourced from the Land Information New Zealand (LINZ) 1:50,000 NZTopo database.

A second grid file containing the average water table elevations was generated from the data sources discussed above. This second grid file also contained 20 by 20 m cells and these cells matched exactly spatially with the land surface cells.

SAGA (System for Automated Geoscientific Analyses), which is a GIS software package, was used to subtract the average water table elevations from the land surface elevations and create a grid file containing the average depth to water values. This resulting grid file was used to generate average depth to groundwater contours.

These SAGA-generated average depth to water contours were imported into ArcMap GIS and displayed with points showing the known average depths to groundwater (i.e. for the wells, rivers and springs). The final average depth to groundwater contours were drawn over the top of the SAGA-generated contours with some modifications, where appropriate, to reflect the locations of the four major rivers (Waiau, Pahau, Hurunui and Waitohi), the springs and the wells.

## 5.0 Limitations

The major limitation in producing a map of average depth to groundwater contours for the Culverden Basin is the scarcity of water level measurements. Not a single well in the ECan GIS database had a long-term record ranging from the 1960s (or even 1980s) to present date. This meant that it was not possible to account for any changes (or trends) in groundwater level movements in the last few decades.

Given that all of the wells had different periods of record (e.g. some wells only have water level records in the 1950s, while others only have records in the 1980s), inaccuracies are formed by comparing mean depths from different periods. One event that may have had a significant effect on groundwater levels in the Culverden Basin is the introduction of the Waiau Irrigation Scheme. Close (1985) predicted that the mean rise in groundwater levels following the full development of the irrigation scheme would be 0.7 m. This event could not be accounted for due to the lack of long-term water level records.

There are also spatial limitations in the data set. In some areas of the Culverden Basin, there are no, or very few, wells with water level records. This includes the Balmoral Forest and the area north of the Waiau River. In one of the maps that is attached to this letter, the wells that have been used to formulate the contours have been colour coded to show the number of water level measurements that were available. The location of these wells and the number of measurements provide an indication of the reliability of the judgment of water level data at any particular point. In particular, no contours have been drawn for most of the area north of the Waiau River (other than a 5 m contour near the Waiau River), as there is no data available. The 15 m depth to groundwater contours within Balmoral Forest were drawn, even though no water level information was available, to reflect the relative elevation differences between the ground surface contours and the interpolated piezometric contours.

## 6.0 Outputs

Based on the assessment described above, we enclose the following maps:

- ∴ A piezometric contour map showing the average groundwater table elevations (Figure 3)
- ∴ A map showing the average depth to groundwater contours (Figure 4)
- ∴ A map showing the depth to groundwater contours in relation to the data sources (Figure 5)

## 7.0 Recommendations for Future Work

It is recommended that Environment Canterbury should gather more information on groundwater levels in the Culverden Basin. In particular, future work should focus on a central location within the basin where there is an existing historical record so that current levels can be compared against previous values. It would also be useful to gather water level readings in those areas where few, or no, water level measurements are currently available; namely:

- ∴ Balmoral Forest
- ∴ The area north of the Waiau River (i.e. the Emu Plain)

## 8.0 References

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Yours sincerely

**PATTLE DELAMORE PARTNERS LIMITED**



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Encl.