# Wells and Groundwater in the Selwyn Aquifer

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### Goals of the Exercise

This exercise introduces you to the monitoring wells in the Selwyn aquifer, examines one well in particular so you can see the details of its construction and the water levels recorded in it. Then you'll work with the mesh for a Modflow model of the aquifer and see how this relates to the well you've just studied. You'll make a map of the water level across the Selwyn aquifer and estimate the travel time of groundwater contamination to travel to Te Waihoro/Lake Ellesmere.

## Computer and Data Requirements

To carry out this exercise, you need to have a computer, which runs ArcGIS version 10.5. Version 10.4.1 should work fine also. The data to be used for this exercise are available in the Learn system for Ex5 and at: <a href="http://www.caee.utexas.edu/prof/maidment/Canterbury/Ex5/Ex5Data.zip">http://www.caee.utexas.edu/prof/maidment/Canterbury/Ex5/Ex5Data.zip</a> They consist of two Excel files of Monitoring Well information and an ArcGIS shape file describing a Selwyn aquifer Modflow grid. The monitoring well data were provided by Fouad Alkhaier of Environment Canterbury and the Model Grid by Julian Weir of Aqualinc. Thanks Fouad and Julian!! Modflow is a standard US Geological Survey model used for simulating the flow in groundwater aquifers. <a href="https://water.usgs.gov/ogw/modflow/">https://water.usgs.gov/ogw/modflow/</a> You won't actually run this model but instead use the data compiled to create the model to illustrate the nature of the Selwyn aquifer.

This PC > Documents > Canterbury > Ex5 > Ex5Data				
_ Name	Date modified	Туре	Size	
00_Monitoring_bores	3/16/2018 8:37 PM	Microsoft Excel Work	41 KB	
🔲 🛋 01_Grand_average	3/16/2018 8:37 PM	Microsoft Excel Work	26 KB	
Model_Grid.cpg	3/8/2018 7:51 AM	CPG File	1 KB	
Model_Grid.dbf	3/8/2018 7:51 AM	DBF File	51,113 KB	
Model_Grid.prj	3/7/2018 11:58 AM	PRJ File	1 KB	
Model_Grid.sbn	3/8/2018 7:51 AM	SBN File	2,983 KB	
Model_Grid.sbx	3/8/2018 7:51 AM	SBX File	44 KB	
Model_Grid.shp	3/8/2018 7:51 AM	SHP File	48,953 KB	
Model_Grid.shx	3/8/2018 7:51 AM	SHX File	2,880 KB	

## Procedure

## 1. Map of Observation Wells

Open ArcMap and add Sheet1\$ of the **00\_Monitoring\_Bores.xlsx** spreadsheet to the map display

Add Data			
Look in:	🖴 Data	~ ▲	
<sup> ©</sup> 00_Monitoring_bores.xlsx <sup> ©</sup> 01_Grand_average.xlsx			

Open the Attribute Table of this Spreadsheet and you'll see a lot of details about these wells, at the end of which are the **NZTMX** and **NZTMY** attributes which show the location of the well in New Zealand Transverse Mercator coordinates.

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SI	heet1\$									×
Г	REFERENCE_RL	GROUND_RL	HIGHEST_WATER_LEVEL	LOWEST_WATER_LEVEL	START_READINGS	END_READINGS	NZTMX	NZTMY		^
•	223.251007	-0.42	-1.62	-2.527	5/23/2012 3:00:00 PM	2/8/2018 9:30:00 AM	1527382	5195342		
	222.725006	-0.525	-1.447	-2.069	5/23/2012 1:00:00 PM	2/8/2018 9:20:00 AM	1527439	5195285		
Г	66.858002	-0.5	-23.611	-31.865	10/9/2013	2/7/2018 8:45:00 AM	1556032	5193093		
Г	4.168	-0.3	4.05	2.3	8/8/2015	1/29/2018 8:15:00 AM	1571948	5192875		
Г	22	3	-0.355	-1.755	6/16/2016 12:30:00 PM	7/3/2017 9:25:00 AM	1564320	5196468		
Γ	120.400002	-0.4	-35.847	-58.721001	5/29/2012 11:00:00 AM	2/1/2018 12:30:00 PM	1534121	5174477		
Г	225.339996	-0.4	-95.035004	-102.525002	7/25/2017 4:15:00 PM	2/1/2018 9:45:00 AM	1529097	5189166		
	<null></null>	-0.63	-1.22	-7.681	6/13/2012 12:15:00 PM	1/29/2018 12:00:00 PM	1548303	5158262		
Г	18.65	-0.79	-3.581	-9.331	2/25/2013 2:45:00 PM	1/29/2018 2:00:00 PM	1555938	5167978		
Г	109.790001	-0.71	-50.208	-61.32	7/12/2016 12:00:00 PM	2/1/2018 12:50:00 PM	1541554	5177966		
	73.129997	-0.5	-5.444	-5.968	7/24/2017 2:30:00 PM	1/31/2018 8:15:00 AM	1554245	5187729		~
1	C								>	•
14	· 1 · · · 🗐 🗖	(0 out of 189	Selected)							
S	heet1\$									

Right click on this spreadsheet and select Display XY Data



Use NZTMX and NZTMY as the X and Y fields

Display XY Data	Display XY Data X				
A table containing X and Y coordinate data can be added to the map as a layer					
Sheet1\$		• 6			
Specify the field	s for the X, Y and Z coordinates:				
X Field:	NZTMX	$\sim$			
Y Field:	NZTMY	~			
Z Field:	<none></none>	$\sim$			
Coordinate Syste Description: Projected Coo Name: NZGI Geographic C Name: GCS_	em of Input Coordinates rdinate System: D_2000_New_Zealand_Transverse_Mercator pordinate System: NZGD_2000	^			

You'll see a lot of dots appear in the map display and you can see where they are located if you add the **NZ Community Map** as your Basemap.



Click on the **Catalog** tab at the top right of the ArcMap display and establish a **New File Geodatabase** in the folder you are using to store your data in for this exercise.



and let's call this Canterbury. Within this establish a new Feature Dataset called Groundwater

with **NZGD 2000 New Zealand Transverse Mercator** as the horizontal coordinate system and **NZVD2009** as the vertical coordinate system.

New Feature	New Feature Dataset				
Choose the	coordinate system that will be used for Z coordinates in this data.				
Vertical coo define the p	rdinate systems define the origin and linear unit of z coordinates. They also positive direction of values in order to model heights or depths.				
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	Lyttleton				
	🖲 Moturiki				
	NZVD2009 (height)				
	Napier				
	Nelson				
	One Tree Point				
	Stewart Island				

Right Click on the Event feature class and export it to the **Groundwater** Feature Data Set as a new feature class called **Wells**.



Label the Wells feature class with Well\_No as the descriptor

Text Symbol	n	Expression	~			WELL_NO	Text String Label <u>F</u> ield:
A DLV( Z							Text Symbol
AaBbYyZZ B I U Symbol		Symbol	✓ 1	I	rial - B	AaBbYyZz	



Save your map display as Ex5.mxd

To be Turned in: A map of the observation wells over the Selwyn aquifer. How many wells are there? How many observations have been made at these wells (Hint: Use the Reading\_Count attribute). What is the average number of observations per well in the region?

# 2. Story of a Well

Let's zoom in to Highway 1 just south of Burnham and choose well L36/2175.



If we query the attributes of this well, we can see that it was drilled on 23 April 2007. Its horizontal coordinates are

UTMX = 1537887 m

UTMY = 5167030 m

and its Reference level (top of the well pipe) = 67.25m above geodetic datum (Vertical coordinate system)

The well diameter is 150 mm

Measurements have been made since 17 May 2007 and since that time 407 water level measurements have been made for this well which vary in water elevation between -1.39m and -13.356m below the top of the well.

77	WELL_NO	L36/2175
	WELL_TYPE	Bore or Well
	WELL_STATUS	Active (exist, present)
	LOCALITY	SELWYN
	ROAD OR STREET	STATE HIGHWAY 1
	DEPTH	18.299999
	DIAMETER	150
	DATE_DRILLED	4/23/2007
	USE_CODE_1	Water Level Observation
	USE_CODE_2	<null></null>
	TOP_SCREEN_1	16.799999
36/2175	TOP_SCREEN_2	<null></null>
	BOTTOM_SCREEN_1	18.299999
	BOTTOM_SCREEN_2	<null></null>
	READING_COUNT	407
- en	REFERENCE_RL	67.25
	GROUND_RL	-0.5
$\sim$ $\sim$ $\sim$ $\sim$	HIGHEST_WATER_LEVEL	-1.39
~~~~	LOWEST_WATER_LEVEL	-13.356
	START_READINGS	5/17/2007 2:28:00 PM
	END_READINGS	1/31/2018 7:45:00 AM
	NZTMX	1537887
$\sim$ . $\sim$	NZTMY	5167030



Use the **Select** tool over them. Hold to select Well feature L36/2175 and export it to a new feature class called **SelectWell** and add it to the map display in ArcMap.





To find more descriptive information about this well, go to the web site <a href="https://www.ecan.govt.nz/data/well-search/">https://www.ecan.govt.nz/data/well-search/</a>

and put in L36/2175 as the well number

Regional Council Kaunihera Taiao ki Waitaha	A STOR
HOME / WELL SEARCH	
Well search	
L36/2175	
1 results found for " <b>L36</b>	/2175"
WELL NUMBER	OWNER
L36/2175	CANTERBURY REGIONAL COUNCIL
Water Level Monitorin	g Network All Wells

You'll see one record selected, and indication that this well is in the **Water Level Monitoring Network**, which means that its purpose is to observe water levels not to supply pumped water. Click on the well number and you'll see a category for Bore Log

L36/2175 de	etails		
Back to Well Sea	rch		
SUMMARY	WATER LEVEL GRAPHS	BORE LOG	AQUIFER TESTS
Borelog	for well L36/2175		🙆 Envir

This provides details of the geological strata encountered as the well was drilled, the depth of the well, and where it is screen to permit water entry (at the bottom).

Γ	Bore	og fr	or well	1 36/2175			READING_COUNT	407
	Grid Ro	forono	O (NIZTM	1527007 mE 516702	1 mN	Environmen	REFERENCE_RL	67.25
	Gilu Re	Acou		). 1537667 IIIE, 516703		Canterbury	GROUND RL	-0.5
	Ground	Lovol	Altitudo:	66.9 m +MSD Accuracy	<0.1m	Regional Counci	HIGHEST WATER LEVEL	-1.39
	Drillor	Dynos	Pood Dr	illing	. ~ 0.1111	Kaunihera Taiao ki Waitah	LOWEST WATER LEVEL	-13.356
	Drill Me	thod:	Cable To	ol			START READINGS	5/17/2007 2:28:00 PM
	Boreloc	Denth	183 m	Drill Date: 23-Anr-20	07		END READINGS	1/31/2018 7·45·00 AM
	Dorolog	Dopa	. 10.0 11	- Dim Date. 2074pi 20			NZTMX	1537887
212.3	V	/ater				For	NZTMY	5167030
Sca	ale(m) L	evel	Depth(m	)	Full Drillers Description		The reference les	
				0.0.0.	small- medium sandy grav	/el	The reference lev	el is the top
	0.8	Э		0:0:0			of the well (67.25	im). The
	Н	Δ		D::0::0::0			ground loval ic 0	5 m holow
		10		0:0:0:0:			giounu ievenis -0	.SIII DEIOW
				N.0.00			the top of well, o	r 66.75m
	Н						ahove geodetic d	atum
							above Scoucile a	
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				0=0=0	Sift			
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	r –	ľ					WELL NO	L36/2175
							REFERENCE RI	67.25
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				0=0=0=			The average wate	er level is
			8.00m		and the diversion of th		6.11m below the	top of the
					small-medium gravel wit	n sand	well in the stratu	m labelled
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				D::0::0::0			Small-medium g	raver with
			0.60m	0.00000000000000000000000000000000000			traces of yellow s	ilt".
			9.00m	000000000	small-medium gravel with	h small	,	
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	1			004	- water dropping off	aces of dry sin	TOP_SCREEN_2	<null></null>
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				200000000000000			the well between	16.8m and
			18.30m	200000000000000000000000000000000000000			10 2m from ton -	fwall
							T9 Top Core Teb	n well.

If you switch to **Water Level Graphs**, you'll see a chart of current year levels (in blue compared to the minimum, maximum and average for past years. This year is a relatively wet year with water levels near the highest recorded.



If you scroll down to the next chart, you'll see that the water levels in this well fluctuate between about 2m below top of well to 13m below top of well.



To be Turned in: Choose another observation well from the dataset and prepare a similar description of it like the one presented above for L36/2175. How does your well compare with L36/2175? [Hint make sure this well is upstream of Te Waihora/Lake Ellesmere because this is important for Question 4].

# 3. Description of the Selwyn Aquifer

The physical and flow properties of the hydrogeology of the Selwyn aquifer are contained in a data set developed to support Modflow groundwater modeling of the aquifer, compiled by Julian Weir and colleagues at Aqualinc. Go to the dataset you downloaded for this exercise and add the **Model\_Grid** shape file to your map display.

Add Data		
Look in:	🖴 Ex5Data	
<sup>™</sup> 00_Monitoring_bores.xlsx <sup>™</sup> 01_Grand_average.xlsx <sup>™</sup> Model_Grid.shp		

Turn off the Wells feature class but leave the **SelectWell** feature displayed.



Now, let's get a geology map to add to this display. Select Add Data from ArcGIS Online

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And search for **Geological Map of New Zealand** You'll see that a map becomes available produced by the project **QMAP** of the Crown Research Institute: **Geological and Nuclear Sciences** (GNS)



If you add this map to your display, you'll see a coloured image of the geology of this region. The purple areas are volcanic rocks of Banks Peninsula (Lyttleton Harbour and Akaroa Harbour are flooded calderas of ancient volcanos). The white areas are regions where river gravel depositions dominate the surface geology – in the case of the Selwyn aquifer, these are the Waimakariri River to the north, the Rakaia River to the south and the Selwyn River in the center of the model grid.



A three-dimensional view of the Selwyn groundwater system is shown below.



Three-Dimensional Model of the Selwyn Groundwater System Source of Image: Julian Weir, Aqualinc

And if you zoom in to Well L36/2175, and use the **Identify** tool to query the Model\_Grid cell in which this well is located, you'll see parameters **I**, **J**, **K**, which refer to the **row, column** and **layer** indices of the Modflow model. In the display shown below, the "Top" elevation of 67.5 meters refers to the ground surface elevation for layer 1 (K = 1). The white colour in the map below represents the gravels in and around the Selwyn River bed.



Use **Select** to select the grid cell containing well L36/2175, open the **Model\_Grid** attribute table, and hit the **Show Selected Records** in the tab at the bottom of the table display

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<mark>،</mark> 9	151	Polygon	265	11	10	1	1	61.677	267.882	28.428	63.666	67.528	55.827	
26	975	Polygon	713	11	10	2	1	54.827	415.695	5.277	63.661	55.827	53.827	
44:	304	Polygon	116	11	10	3	1	52.827	415.695	5.277	63.658	53.827	51.827	
61	381	Polygon	160	11	10	4	1	50.827	415.695	5.277	63.655	51.827	49.827	
78	168	Polygon	205	11	10	5	1	48.827	415.695	5.277	63.653	49.827	47.827	
94:	390	Polygon	250	11	10	6	1	46.827	415.695	5.277	63.652	47.827	45.827	
11(	015	Polygon	294	11	10	7	1	44.827	10.569	0.001	63.036	45.827	43.827	
12	577	Polygon	339	11	10	8	1	42.827	10.569	0.001	61.963	43.827	41.827	
14	130	Polygon	384	11	10	9	1	40.827	10.569	0.001	60.986	41.827	39.827	
15	682	Polygon	428	11	10	10	1	38.827	10.569	0.001	60.061	39.827	37.827	
17:	232	Polygon	473	11	10	11	1	36.827	10.569	0.001	59.174	37.827	35.827	
18	783	Polygon	518	11	10	12	1	34.827	10.569	0.001	58.298	35.827	33.827	
20:	299	Polygon	563	11	10	13	1	31.277	232.8	6	57.855	33.827	28.728	
21	794	Polygon	607	11	10	14	1	25.132	232.8	6	57.854	28.728	21.537	
23	278	Polygon	652	11	10	15	1	18.263	232.8	6	57.853	21.537	14.989	
24	737	Polygon	697	11	10	16	1	11.756	232.8	6	57.853	14.989	8.524	
26	162	Polygon	741	11	10	17	1	7.388	161.292	0.001	58.51	8.524	6.253	
27	565	Polygon	786	11	10	18	1	5.253	161.292	0.001	58.58	6.253	4.253	
28	966	Polygon	831	11	10	19	1	3.239	161.292	0.001	57.832	4.253	2.226	
30	333	Polygon	876	11	10	20	1	1.143	161.292	0.001	55.979	2.226	0.061	
31	616	Polygon	920	11	10	21	1	-13.486	114.547	5.172	54.439	0.061	-27.032	
32	897	Polygon	965	11	10	22	1	-40.084	114.547	5.172	54.437	-27.032	-53.137	
34(	050	Polygon	101	11	10	23	1	-66.813	114.547	5.172	54.437	-53.137	-80.489	
35	146	Polygon	105	11	10	24	1	-116.761	1	0.01	54.253	-80.489	-153.033	
36	242	Polygon	109	11	10	25	1	-189.304	1	0.01	54.014	-153.033	-225.576	
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In the top left corner of the Attribute Table, with the rows selected as shown above, you can export this table

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If you look in the Excel file, you'll see two columns labeled **HKPARAMET** and **VKPARAMET** that refer to values of the horizontal and vertical **Hydraulic Conductivity** of the aquifer in meters per day. This is a measure of the "ease of flow" of the water in the aquifer. Notice that the water flows much more readily in the horizontal direction than it does in the vertical, and also that some hydrogeological layers are much more free flowing than others are. The free flowing layers are "aquifers" and the slow flowing layers are "aquitards".

FID	ID	I	J	К	CELLACTIVE	ELEVATION	HKPARAMET	VKPARAMET	HEAD	ТОР	BOTTOM
9151	26588	110	101	1	1	61.677	267.882	28.428	63.666	67.528	55.827
26975	71300	110	101	2	1	54.827	415.695	5.277	63.661	55.827	53.827
44304	116012	110	101	3	1	52.827	415.695	5.277	63.658	53.827	51.827
61381	160724	110	101	4	1	50.827	415.695	5.277	63.655	51.827	49.827
78168	205436	110	101	5	1	48.827	415.695	5.277	63.653	49.827	47.827
94390	250148	110	101	6	1	46.827	415.695	5.277	63.652	47.827	45.827
110155	294860	110	101	7	1	44.827	10.569	0.001	63.036	45.827	43.827
125775	339572	110	101	8	1	42.827	10.569	0.001	61.963	43.827	41.827
141307	384284	110	101	9	1	40.827	10.569	0.001	60.986	41.827	39.827
156820	428996	110	101	10	1	38.827	10.569	0.001	60.061	39.827	37.827
172325	473708	110	101	11	1	36.827	10.569	0.001	59.174	37.827	35.827
187830	518420	110	101	12	1	34.827	10.569	0.001	58.298	35.827	33.827
202994	563132	110	101	13	1	31.277	232.8	6	57.855	33.827	28.728
217948	607844	110	101	14	1	25.132	232.8	6	57.854	28.728	21.537
232781	652556	110	101	15	1	18.263	232.8	6	57.853	21.537	14.989
247371	697268	110	101	16	1	11.756	232.8	6	57.853	14.989	8.524
261622	741980	110	101	17	1	7.388	161.292	0.001	58.51	8.524	6.253
275657	786692	110	101	18	1	5.253	161.292	0.001	58.58	6.253	4.253
289663	831404	110	101	19	1	3.239	161.292	0.001	57.832	4.253	2.226
303330	876116	110	101	20	1	1.143	161.292	0.001	55.979	2.226	0.061
316166	920828	110	101	21	1	-13.486	114.547	5.172	54.439	0.061	-27.032
328978	965540	110	101	22	1	-40.084	114.547	5.172	54.437	-27.032	-53.137
340505	1010252	110	101	23	1	-66.813	114.547	5.172	54.437	-53.137	-80.489
351465	1054964	110	101	24	1	-116.761	1	0.01	54.253	-80.489	-153.033
362420	1099676	110	101	25	1	-189.304	1	0.01	54.014	-153.033	-225.576

Effectively, you can see that there are 7 hydrogeological layers at this location denoted by the colours. I have summarized the data in the following table on the following page to show the properties of the layers. If you multiply the horizontal Conductivity, K, by the layer thickness, B, you get a quantity called Transmissivity, T, which indicates how much flow can pass though this layer.

T = KB

Adding all the Transmissivity values for the 7 layers,  $T_i$ , i= 1,2,...7, a total Transmissivity of 24,020 m<sup>2</sup>/day is obtained.

$$T_{tot} = \sum_{i=1}^{7} T_i = 24,020 \ m^2/day$$

I've used this value to compute the % of the total transmissivity and in the final column and you can see that layers A, B, D, and F are the aquifers in this system while C, E and G are aquitards. Similarly, the total thickness of the hydrogeological system at this location is the sum of the individual layer thicknesses:

$$B_{tot} = \sum_{i=1}^{7} B_i = 293m$$

We can get an average value for the horizontal conductivity = Total Transmissivity/Total Thickness:

$$K_{avg} = \frac{T_{tot}}{B_{tot}} = \frac{24020}{293} = 82 m/day$$

We'll use this value later in the exercise.

Layer	Тор	Bottom	Conductivity (m/day)	Thickness (m)	Transmissivity (m²/day)	% of Transmissivity
А	67.5	55.8	267	12	3124	13.0
В	55.8	45.8	416	10	4160	17.3
С	45.8	33.8	11	12	132	0.5
D	33.8	8.5	233	25	5895	24.5
E	8.5	0.1	161	8	1352	5.6
F	0.1	-80	115	80	9212	38.3
G	-80	-225	1	145	145	0.6
Total				293	24020	

#### Aquifer Layer Table for Model\_Grid Cell (I,J) = (110,101)

To be turned in: Prepare an aquifer layer table like the one above for the Model\_Grid cell that contains the observation well that you chose for Question 2.

## 4. Water Level Map and Travel Time in the Aquifer

When water levels are measured in wells, the Reference Level is the level of the top of the well. This elevation is measured above Geodetic Datum, using a GPS unit or land surveying. From that point, all measurements are made down from the top of the well. The water level in the well reflects the hydraulic pressure that exists in the aquifer in which the well screen is located.



We are going to make a water level map (or piezometric head map) from the average water levels recorded in the ECan monitoring wells. These levels are averaged through time over the period of record of measurements from each well. We are also not allowing for different hydraulic pressures that

may exist in the difference aquifers. Please bear in mind these simplifications as we do this part of the exercise.

From the original data provided for the exercise, add the Excel Spreadsheet **01\_Grand\_average** to ArcMap. Choose worksheet **Query\$4**.

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Selectivell		🗄 • 📳	□ - m - m · m · m · m · m · m · m · m · m								
-		Query	/4\$								
C:\Users\maidment\Documents\Can	e.	V	VellIndex	WELL_NO	REFERENCE_RL	AVERAGE_WATER_LEVEL	StandardDeviation	Maximum	Minimum	Count	
Model_Grid		•	1	BW22/0001	223.251007	-2.308093	0.186337	-1.62	-2.527	75	
	-		2	BW22/0002	222.725006	-1.825131	0.17	-1.447	-2.069	268	
C:\Users\maidment\Documents\Can	1		3	BW23/0133	66.858002	-28.315934	2.204338	-23.611	-31.865	258	
	1		4	BW24/0274	4.168	3.411747	0.30964	4.05	2.763	79	
= GridData.txt			5	BW24/0321	22	-1.0005	0.399183	-0.355	-1.755	10	
C:\Users\maidment\Documents\Can	~		6	BX22/0003	120.400002	-47.264526	7.534162	-35.847	-58.721001	266	
■ Query4\$			7	BX22/0158	225.339996	-97.836889	2.589155	-95.035004	-102.525002	9	
Geological Map Of New Zealand	1		8	BX23/0044	<null></null>	-3.432125	1.822846	-1.22	-7.681	320	
B Conomia (november and	1		9	BX23/0157	18.65	-6.064796	1.481356	-3.581	-9.331	260	
Seneric/newzealand			10	BX23/0623	109.790001	-55.570334	3.540266	-50.208	-61.32	15	
			11	BX23/0761	73.129997	-5.7074	0.151839	-5.444	-5.968	25	
			12	BX23/0762	72.989998	-20.403875	0.35566	-19.983	-21.087999	24	
		14 4	1 י י 🗉	📒 (0 out d	of 189 Selected)						

Right click on this table and Export the Table as **AverageLevel** in the **Canterbury** geodatabase (cannot put this in the Groundwater feature dataset because that only holds feature classes not simple tables).

Saving Data	a	×
Look in:	] Canterbury.gdb 🗸 🍐 🎕 🕼 🗮 ▼   🖄 🛍 🖏 🐓 🦻	
Name:	AverageLevel Save	:
Save as type	E: File and Personal Geodatabase tables	el

Now, we've got a Feature Class of Wells and a Table that stores the AverageLevel recorded in each well.



Now let's Join these two tables using the **WellIndex** field present in both tables as a common key field.

	🖃 🖻 Ground	lwa	ter	100	Less in
	-	۳ ×	Copy Remove	5	
			Open Attribute Table		and the second s
	Averag		Joins and Relates	•	Join
-	□ C:\Users\r	¢	Zoom To Layer		Romoura Lain(a)
	🖃 🗆 Model		Zoom To Make Visible		RJoin
			Visible Scale Range	•	R Join data to this
-	C:\Users\r		Use Symbol Levels		standalone table
4	GridDa     Goologica		Selection	•	based on a
+	□ Geologica ☑ Generic/n		Label Features	common attribute, spatial	

Right click on the Wells feature class and select Joins and Relates/Join

Use **AverageLevel** as the Table you want to join and **WellIndex** as the field with common values between the two tables that will establish their association.

Join Data	×
Join lets you append additional data to this layer's attribute table so you can, f example, symbolize the layer's features using this data.	or
What do you want to join to this layer?	
Join attributes from a table	$\sim$
1. Choose the field in this layer that the join will be based on:	
WellIndex	
2. Choose the table to join to this layer, or load the table from disk:	
AverageLevel	
Show the attribute tables of layers in this list	
3. Choose the field in the table to base the join on:	
WellIndex	

Now, when you navigate over to the right hand side of the Wells Attribute table, you'll see more fields that have been added since the Join was made.

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W	Nells												
Г	NZTMX	NZTMY	Shape *	OBJECTID *	WellIndex *	WELL_NO	REFERENCE_RL	AVERAGE_WATER_LEVEL	StandardDev 🔨				
F	1527382	5195342	Point	1	1	BW22/0001	223.251007	-2.308093					
	1527439	5195285	Point	2	2	BW22/0002	222.725006	-1.825131					
	1556032	5193093	Point	3	3	BW23/0133	66.858002	-28.315934					
	1571948	5192875	Point	4	4	BW24/0274	4.168	3.411747					
	1564320	5196468	Point	5	5	BW24/0321	22	-1.0005	(				
	1534121	5174477	Point	6	6	BX22/0003	120.400002	-47.264526					
Г	1529097	5189166	Point	7	7	BX22/0158	225.339996	-97.836889					
Г	1548303	5158262	Point	8	8	BX23/0044	<null></null>	-3.432125					
	1555938	5167978	Point	9	9	BX23/0157	18.65	-6.064796					
	1541554	5177966	Point	10	10	BX23/0623	109.790001	-55.570334					
Е	1554245	5187729	Point	11	11	BX23/0761	73.129997	-5.7074	V				
<	Σ.								>				
н	• 1	· • •	(0 out of 18	39 Selected)									
N	Vells												

Now, let's make a new field to compute the Water Level above geodetic datum.

In the top left of the Attribute Table, Select Add Field

Tabl	e			
:= +   !	a •   🖫 🌄 🖾 🐗 🗙			
A	Find and Replace			
5	Select By Attributes	TID *	WellIndex *	WELL_NO
	Clear Selection		1	1 BW22/0001
-	ologi bologion		2	2 BW22/0002
	Switch Selection		3	3 BW23/0133
	Select All		4 4	4 BW24/0274
			5 !	5 BW24/0321
	Add Field		6 6	6 BX22/0003
:	Turn Add Field		7	7 BX22/0158
~	Show		8 8	3 BX23/0044
	Adds a new field		9 9	BX23/0157
	Arrar to the table.	, 1	0 10	BX23/0623
	Restore Default Column	Widths 1	1 1	1 BX23/0761
	Postoro Dofault Field Or	dor		

Call this field WaterLevelAboveGD and make its Type Double.

Add Field				×	<
<u>N</u> ame:	WaterLevelAbo	oveGE	)		
<u>Т</u> уре:	Double			$\checkmark$	
Field Prop	erties				
Alias	11 L \/=b		/		
Allow NU	JLL Values	ľ	es		
Default	/aiue				
		ОК		Cancel	

In this new field, open the Field Calculator

Wells.Water	Lovol	AboveGD
5 <null></null>	1	Sort Ascending
3 <null></null>	7	Sort Descending
3 <null></null>		Advanced Serting
) <null></null>		Advanced Softing
) <null></null>		Summarize
δ <null></null>	Σ	Statistics
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) <null></null>		Field Calculator
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5 <null></null>		Field Calculator
5 <null></null>		Populate or
		F undate the
		update the
	×	values of this
		- field by

And add together the **Reference\_RL** (elevation of top of well above Geodetic Datum) and the **Average\_Water\_Level** (drop from top of well to the water level as a negative number).

Show Codeblock	*	1	&		+
Wells.WaterLevelAboveGD =		'			
[AverageLevel.REFERENCE_RL] + [AverageLevel.AVERAGE	WA	TER_I	LEVE	L]	

Now we have Average Water Level in the well above Geodetic datum.

	Wells.WaterLevelAboveGD
75	220.942914
68	220.899875
58	38.542068
79	7.579747
10	20.9995
66	73.135475
9	127.503107

#### In Customize/Extensions make sure the Spatial Analyst extension is turned on



Select the ex	tensions you want to use
🗹 3D Anal	yst
- ArcScan	I
Geostati	istical Analyst
□ Network	Analyst
- Publishe	ər
□ Schema	tics
Spatial A	Analyst
Tracking	j Analyst

Now let's draw a water level map using the **Inverse Distance Weighting (IDW)** method. Search for IDW in the Search tab at the top right of ArcMap.



Open the IDW tool and use Wells as the Input Point Features, and Z value field as WaterLevelAboveGD.

R	N IDW
	Input point features
	Wells
	Z value field Wells.WaterLevelAboveGD
	Output raster
	C:\Users\maidment\Documents\ArcGIS\Default.gdb\Idw_Wells4
	Output cell size (optional)
	244.6



Color the map in shades of Blue and make the Display have 50% transparency so you can see other things below the map.



And you'll get a rather nice map that shows how groundwater levels are higher near the mountains and diminish towards the coast in a fairly uniform pattern.

Export the **WaterLevelMap** grid to the Canterbury geodatabase.

Use Colormap	NoData as: -3.402823e+03
Name	Property
Bands	1
Pixel Depth	32 Bit
Uncompressed Size	329.44 KB
Extent (left, top, right, bottom)	( 1497639.7000, 5204509.3000, 1579825.3000, 5143114.7000 )
Spatial Reference	NZGD_2000_New_Zealand_Transverse_Mercator
Location:	C:\Users\maidment\Documents\Canterbury\Ex5\Data\Canterbury.gdł
Name:	WaterLevelMap         Format:         File Geodatabase

Add the **RiverLines** for the Selwyn catchment that we used in Exercise 3. Zoom in again to the area downstream of well **L36/2175** 



### Open the Measure tool in ArcMap



and set the **Distance** measure in **meters**.

1	Ø 📮	🔛 🗛 🟥 🕺 🗔 🗔 📮		
		* × Measu	re	
-		+   Σ	•   × •	
		Kilometers	Distance	> line
0	$\checkmark$	Meters	Area	>
br		Decimeters	sure an area, click polygon.	Measure An
		Centimeters		
		Millimeters	k a feature, click Measure A	
		Miles		

The straight line measure between this well and Te Waihora/Lake Ellesmere is 17,099 meters



If you query the WaterLevelMap near the L36/2175 well, you'll get a value of approximately 61 meters

Identify			
Identify from:	<sup>♥</sup> WaterLevelMap		
WaterLevelMap			
Location:	1,537,690.281 5,166,902.116		
Field	Value		
Stretched value	56		
Pixel value	61.438698		

And if you similarly query the WaterLevelMap near Te Waihora/Lake Ellesmere, you'll get a value of about 7 meters. Since Te Waihora/Lake Ellesmere is at approximately sea level (Geodetic Datum ~ 0), what this means is that the aquifer is artesian and water flows freely from wells without being pumped when you are near the coast.

Identify			
Identify from:	<sup>♥</sup> WaterLevelMap		
□WaterLevelMap □7.356435			
Location:	1,552,678.768 5,158,775.980 Meters		
Field Value			
Stretched value	5		
Pixel value	7.356435		

We can compute the slope of the WaterLevelMap along this line as

$$\frac{dh}{dL} = \frac{61.43 - 7.35}{17099} = 0.003163 \, m/m$$

This means that the fall of the water level (dh) is about 3 meters per km of flow distance (dL). If we take this gradient and multiply it by an estimate of the average conductivity that we worked out earlier (82 meters/day), you get a measure of the Darcy Velocity

$$q = K_{avg} \frac{dh}{dL} = 82 * 0.003163 = 0.259 \, m/day$$

and if we divide the Darcy Velocity by the average porosity, n, of about 0.1, we get an estimate of the actual seepage velocity V<sub>s</sub> of water in this aquifer

$$V_s = \frac{q}{n} = \frac{0.259}{0.1} = 2.59 \, m/day$$

This means that water seeping through the aquifer from the area of Well L36/2175, would reach Te Waihora/Lake Ellesmere:

*Travel Time* = 
$$\frac{L}{V_s} = \frac{17099}{2.59} = 6593 \ days = 18.1 \ years$$

If you compare this to the estimate of travel time in the adjacent Selwyn River that we did in Exercise 3, of about **2 hours** you can see the huge difference in travel times of contaminants in surface and groundwater systems. Please bear in mind that the Selwyn aquifer is a 3D flow system and many approximations have been made to get the travel time estimate we've made here. More detailed modeling using Modflow and related programs is needed to get a more accurate estimate of this time.

To be turned in: Make a WaterLevelMap of the Selwyn aquifer and estimate the travel time to Te Waihora/Lake Ellesmere from the well you chose in Question 2.

#### (5) Items to be Turned In

- (1) Make a map of the observation wells over the Selwyn aquifer. How many wells are there? How many observations have been made at these wells (Hint: Use the Reading\_Count attribute). What is the average number of observations per well in the region?
- (2) Choose another observation well from the dataset and prepare a similar description of it like the one you've seen above for L36/2175. How does your well compare with L36/2175? [Hint make

sure this well is upstream of Te Waihora/Lake Ellesmere because this is important for Question 4].

- (3) Prepare an aquifer layer table like the one above for the Model\_Grid cell that contains the observation well that you chose for Question 2. Does your cell have a greater or lesser transmissivity than the one I selected?
- (4) Make a WaterLevelMap of the Selwyn aquifer and estimate the travel time to Te Waihora/Lake Ellesmere from the well you chose in Question 2.