Wells and Groundwater in the Selwyn Aquifer

Prepared by David R. Maidment
Waterways Centre for Freshwater Research
University of Canterbury

March 2018

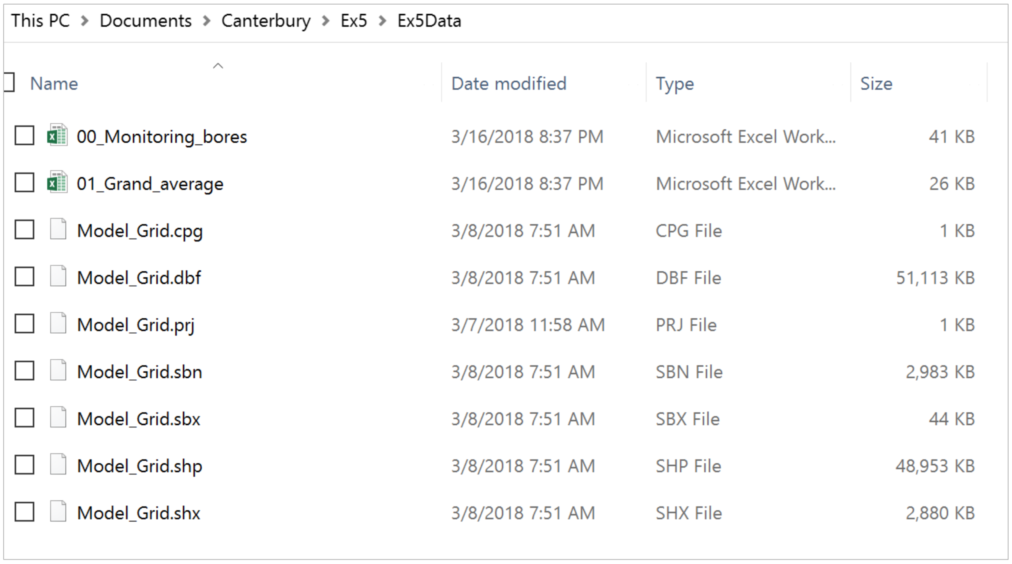
Table of Contents

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: http://www.caee.utexas.edu/prof/maidment/Canterbury/Ex5/Ex5Data.zip 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. https://water.usgs.gov/ogw/modflow/ 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.



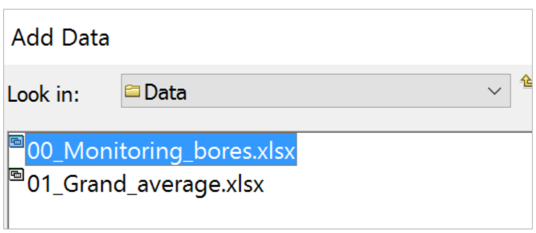
This PC > Documents > Canterbury > Ex5 > Ex5Data

Name	Date modified	Type	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

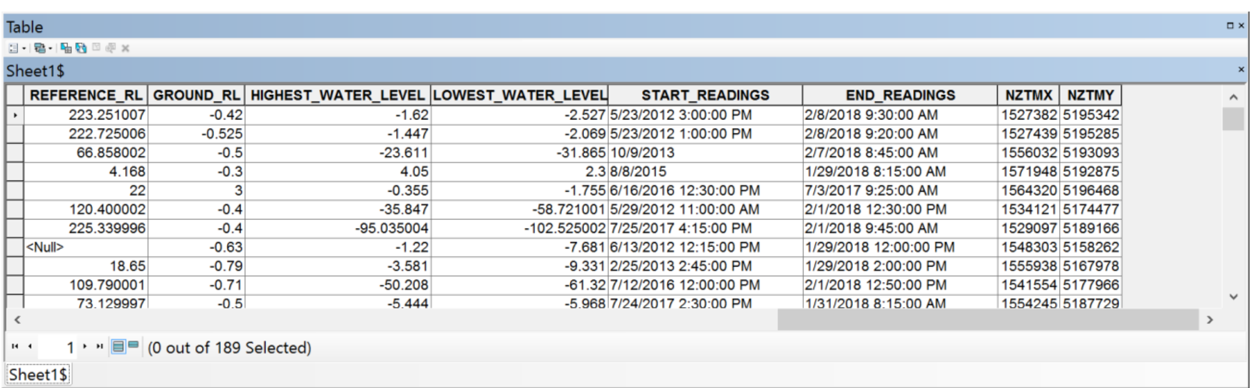
Procedure

1. Map of Observation Wells

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



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.



Table

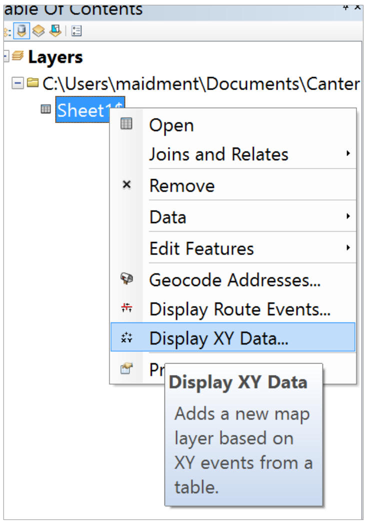
Sheet1$

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
66.858002	-0.5	-23.611	-31.865	10/9/2013	2/7/2018 8:45:00 AM	1556032	5193093
4.168	-0.3	4.05	2.3	8/8/2015	1/29/2018 8:15:00 AM	1571948	5192875
22	3	-0.355	-1.755	6/16/2016 12:30:00 PM	7/3/2017 9:25:00 AM	1564320	5196468
120.400002	-0.4	-35.847	-58.721001	5/29/2012 11:00:00 AM	2/1/2018 12:30:00 PM	1534121	5174477
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>	-0.63	-1.22	-7.681	6/13/2012 12:15:00 PM	1/29/2018 12:00:00 PM	1548303	5158262
18.65	-0.79	-3.581	-9.331	2/25/2013 2:45:00 PM	1/29/2018 2:00:00 PM	1555938	5167978
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

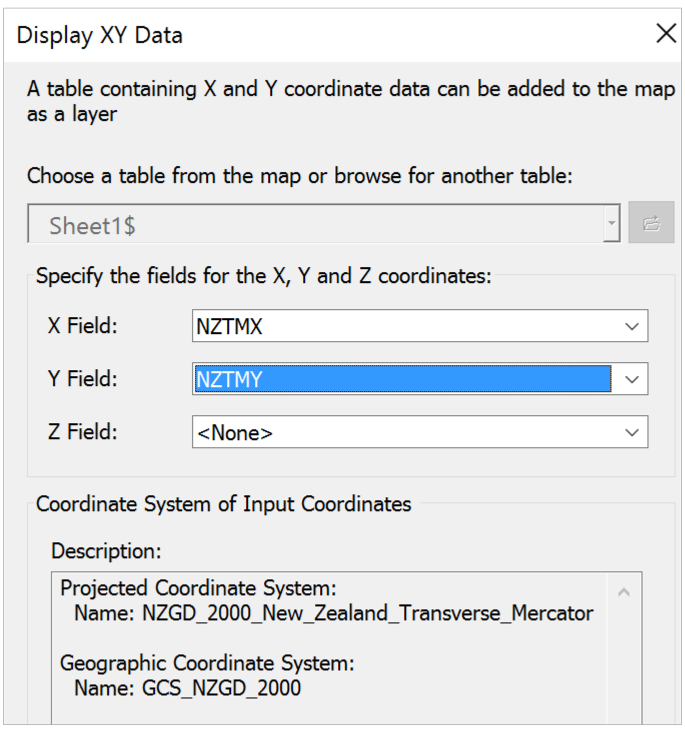
1 (0 out of 189 Selected)

Sheet1$

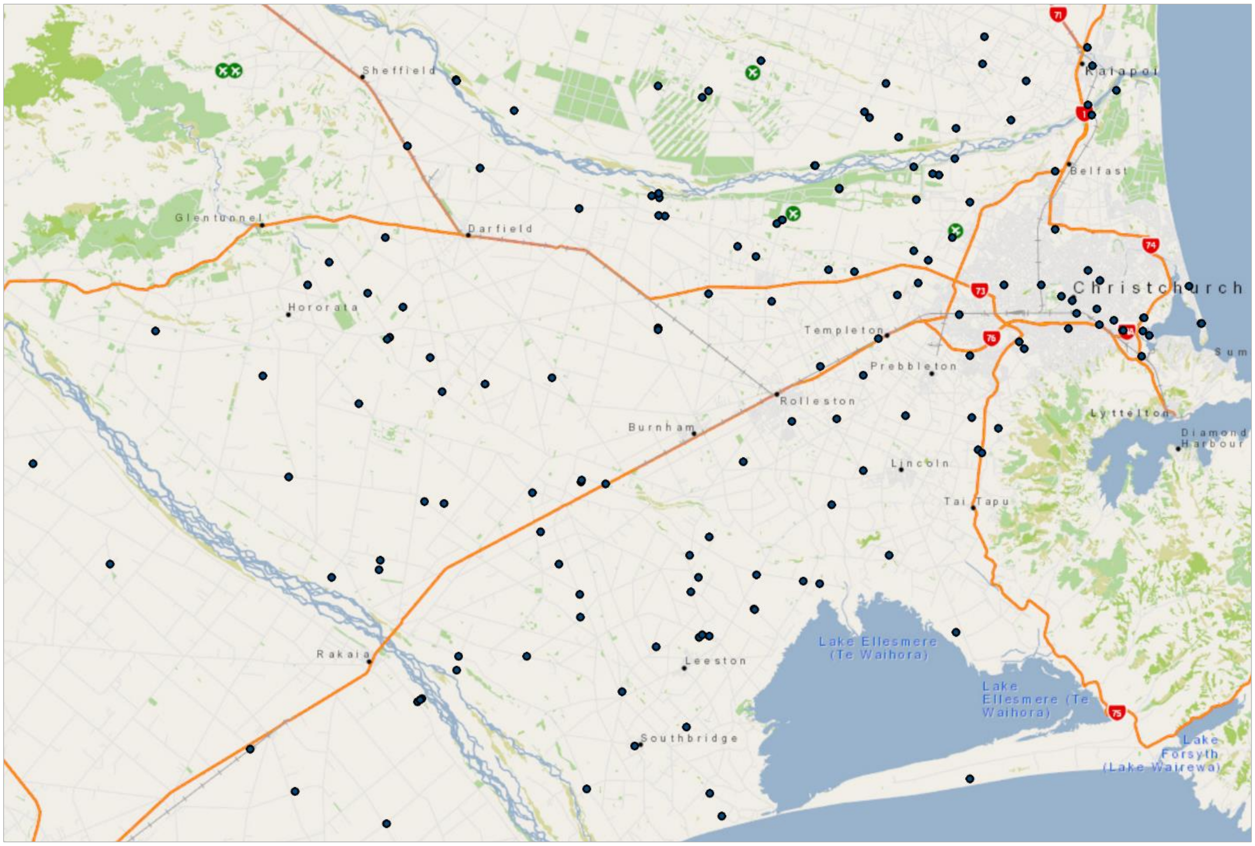
Right click on this spreadsheet and select **Display XY Data**



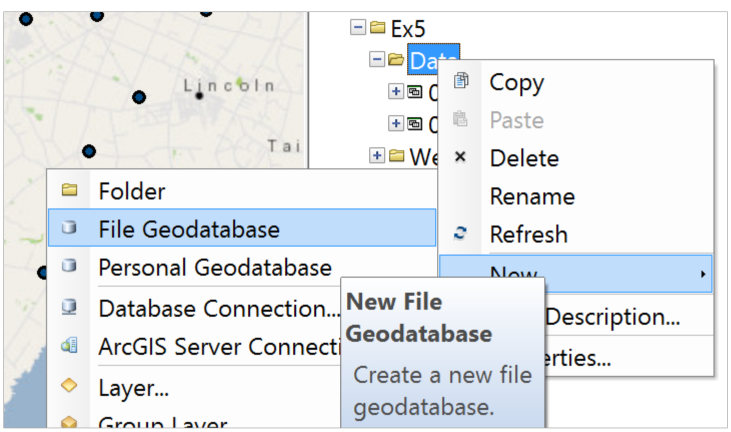
Use NZTMX and NZTMY as the X and Y fields

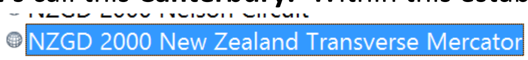


You'll see a lot of dots appear in the map display and you can see where they are located if you add the **NZ Community Map** as your Basemap.

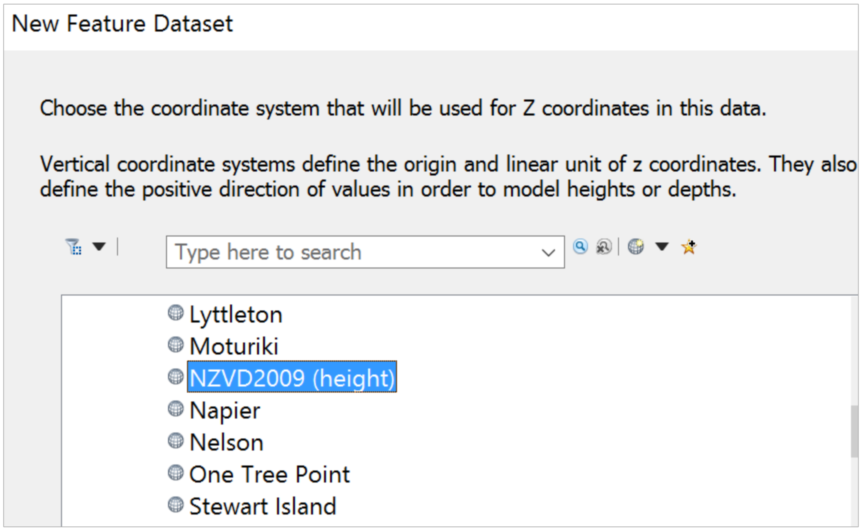


Click on the **Catalog** tab at the top right of the ArcMap display and establish a **New File Geodatabase** in the folder you are using to store your data in for this exercise.

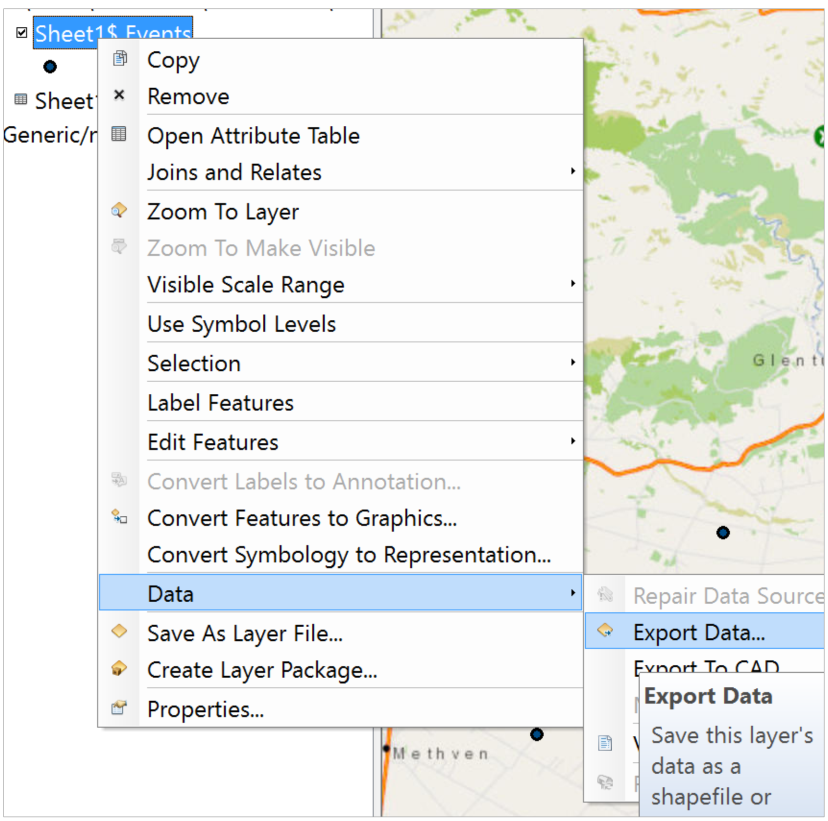


and let's call this **Canterbury.** Within this establish a new Feature Dataset called **Groundwater** with 

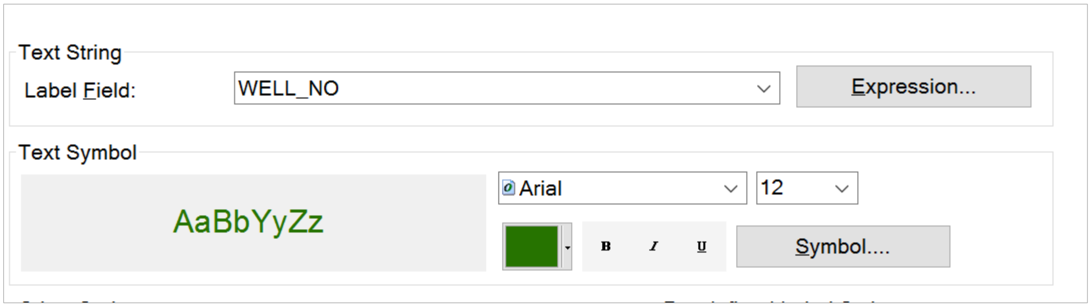
as the horizontal coordinate system and **NZVD2009** as the vertical coordinate system.

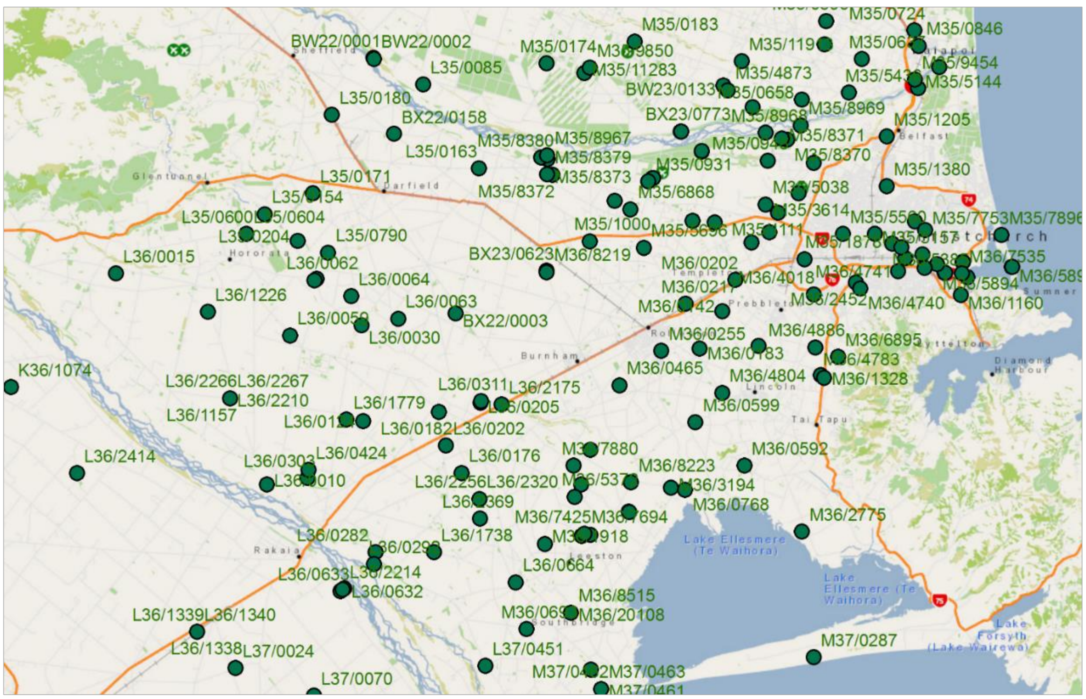


Right Click on the Event feature class and export it to the **Groundwater** Feature Data Set as a new feature class called **Wells**.



Label the Wells feature class with **Well_No** as the descriptor



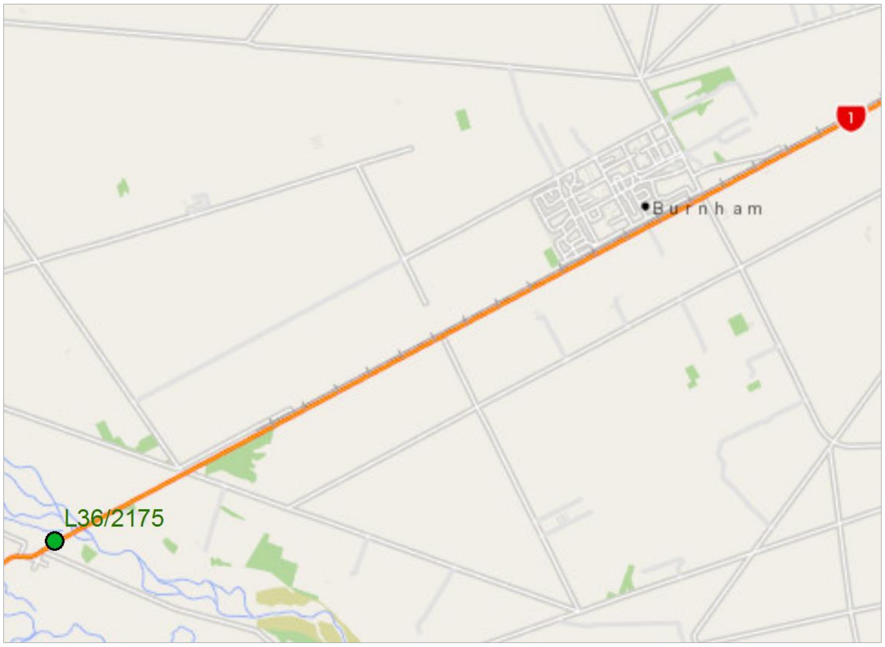


Save your map display as **Ex5.mxd**

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

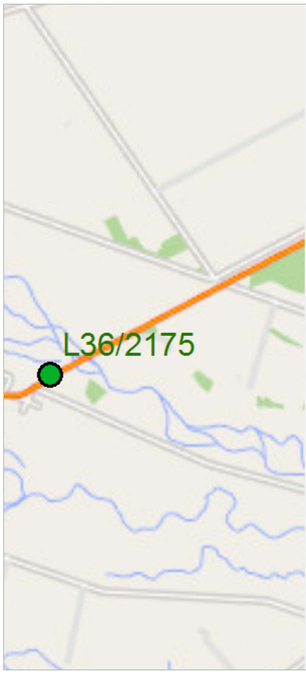
UTMX = 1537887 m

UTMY = 5167030 m

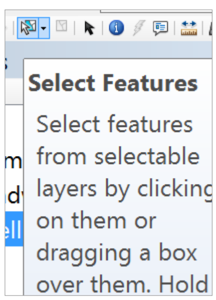
and its Reference level (top of the well pipe) = 67.25m above geodetic datum (Vertical coordinate system)

The well diameter is 150 mm

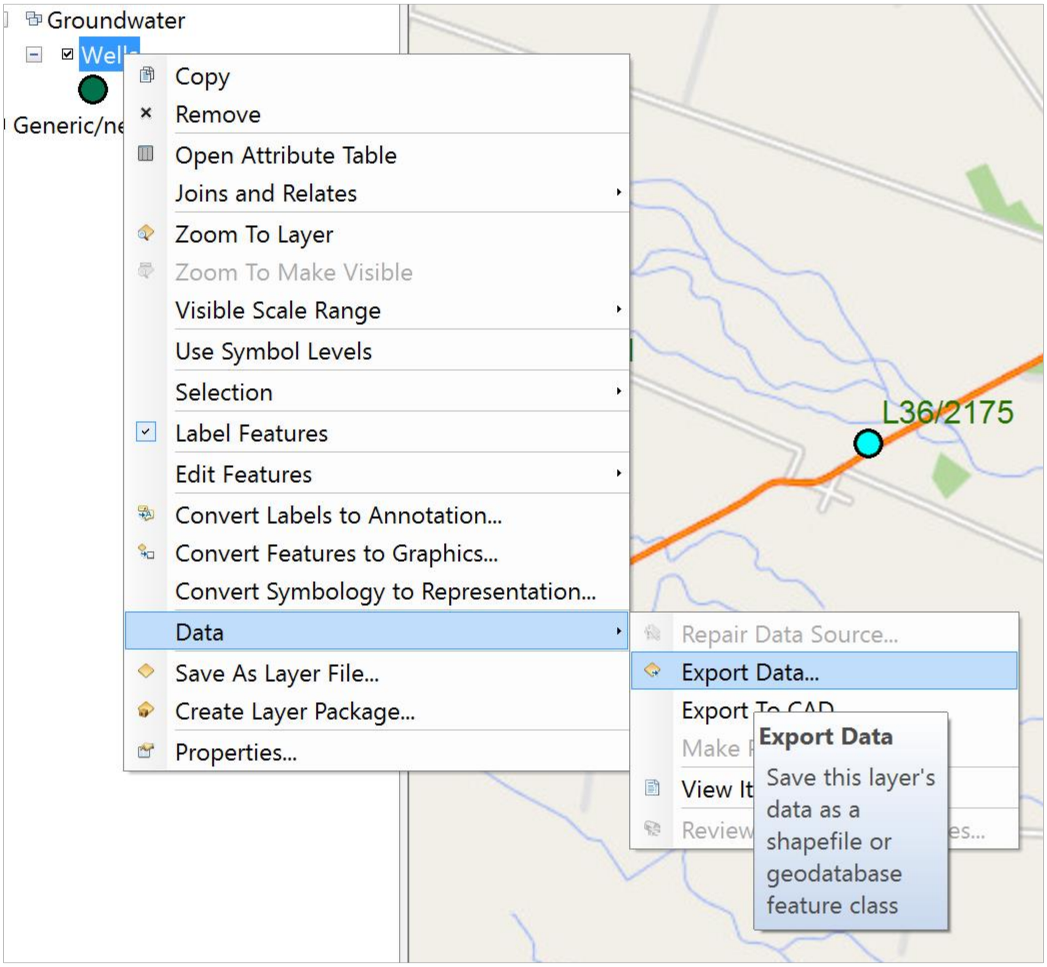
Measurements have been made since 17 May 2007 and since that time 407 water level measurements have been made for this well which vary in water elevation between -1.39m and -13.356m below the top of the well.

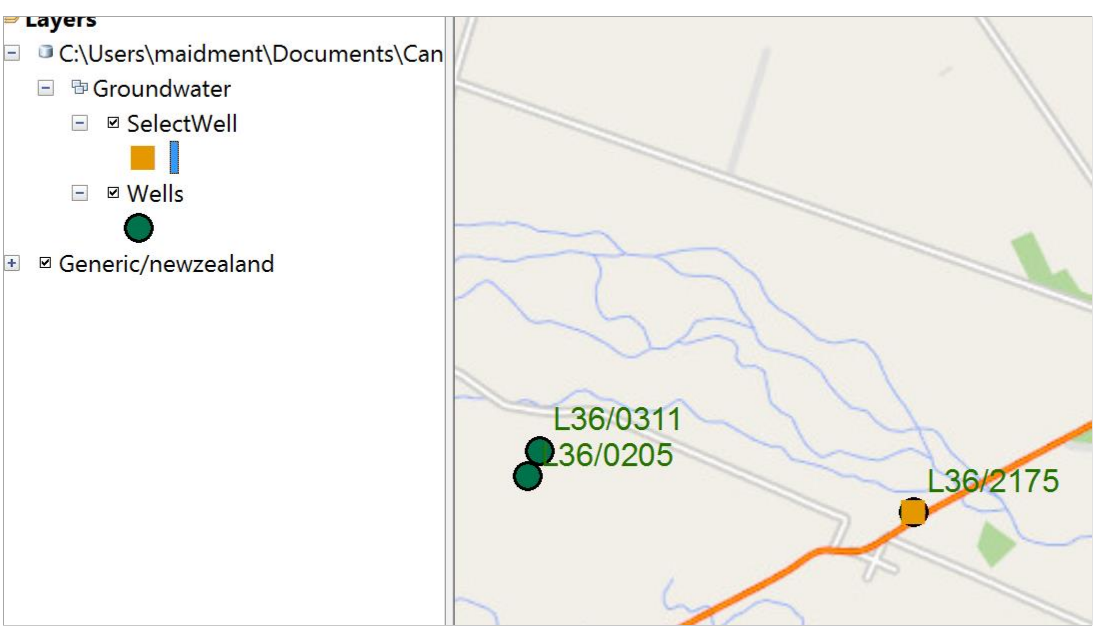


WELL_NO	L36/2175
WELL_TYPE	Bore or Well
WELL_STATUS	Active (exist, present)
LOCALITY	SELWYN
ROAD_OR_STREET	STATE HIGHWAY 1
DEPTH	18.299999
DIAMETER	150
DATE_DRILLED	4/23/2007
USE_CODE_1	Water Level Observation
USE_CODE_2	<null>
TOP_SCREEN_1	16.799999
TOP_SCREEN_2	<null>
BOTTOM_SCREEN_1	18.299999
BOTTOM_SCREEN_2	<null>
READING_COUNT	407
REFERENCE_RL	67.25
GROUND_RL	-0.5
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
NZTMY	5167030

Use the **Select** tool 

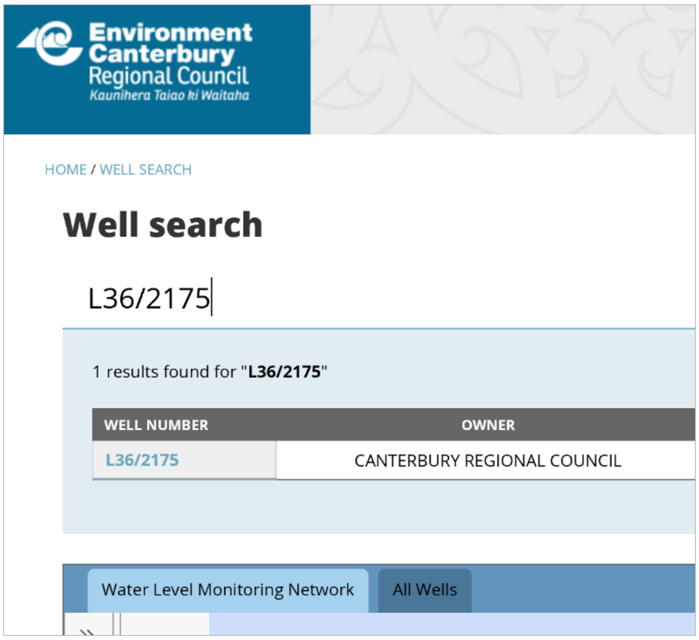
to select Well feature L36/2175 and export it to a new feature class called **SelectWell** and add it to the map display in ArcMap.


Groundwater
Wells
Generic/ne
Copy
Remove
Open Attribute Table
Joins and Relates
Zoom To Layer
Zoom To Make Visible
Visible Scale Range
Use Symbol Levels
Selection
Label Features
Edit Features
Convert Labels to Annotation...
Convert Features to Graphics...
Convert Symbology to Representation...
Data
Save As Layer File...
Create Layer Package...
Properties...
Repair Data Source...
Export Data...
Export To CAD
Export Data
Save this layer's data as a shapefile or geodatabase feature class
L36/2175

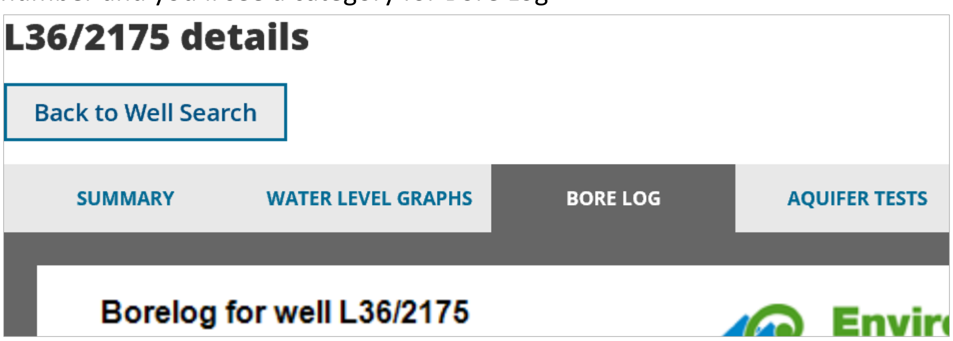

Layers
C:\Users\maidment\Documents\Can
Groundwater
SelectWell
Wells
Generic/newzealand
L36/0311
36/0205
L36/2175

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

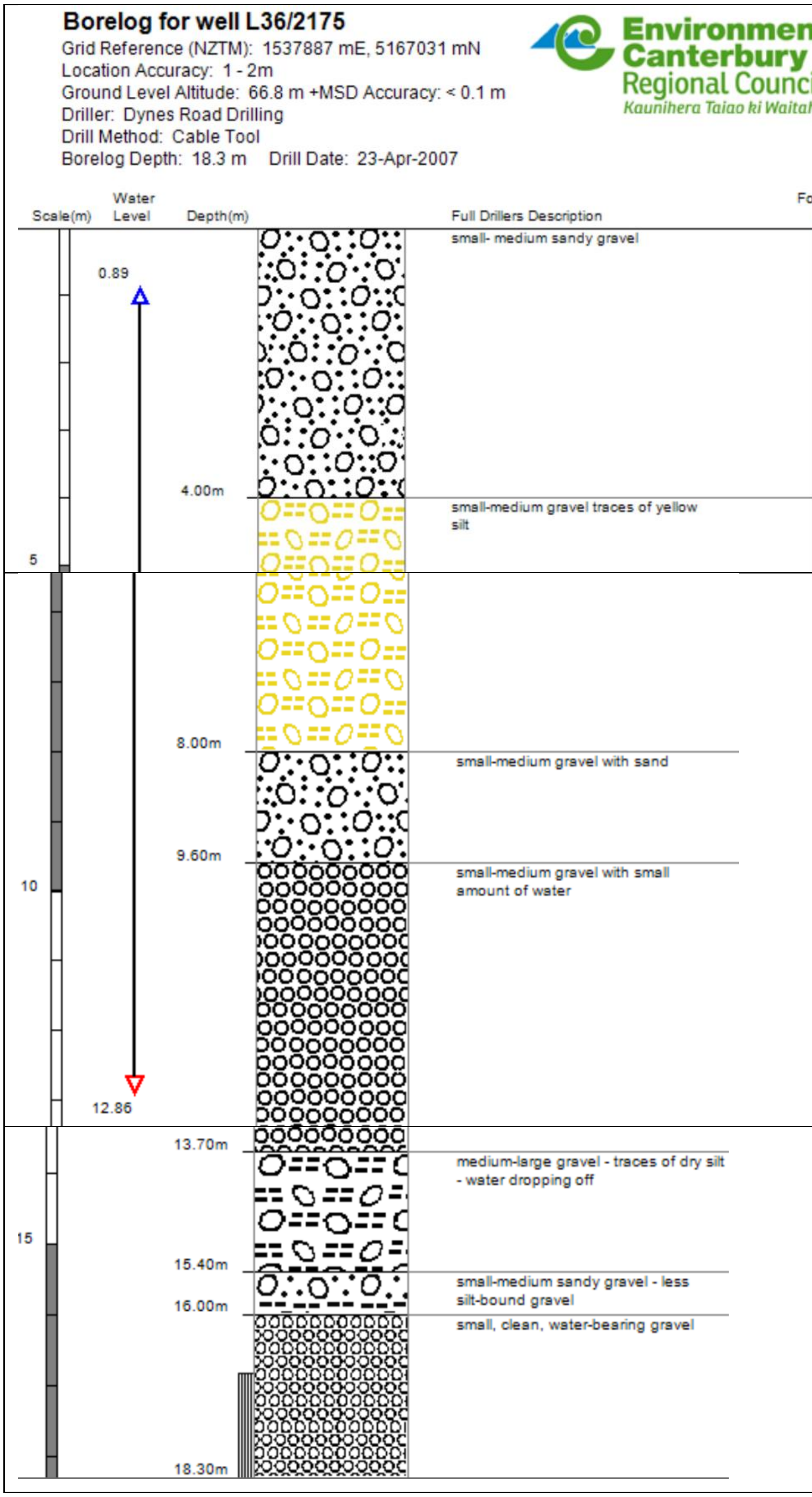
and put in L36/2175 as the well number



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



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).



READING_COUNT	407
REFERENCE_RL	67.25
GROUND_RL	-0.5
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
NZTMY	5167030

The reference level is the top of the well (67.25m). The ground level is -0.5m below the top of well, or 66.75m above geodetic datum.

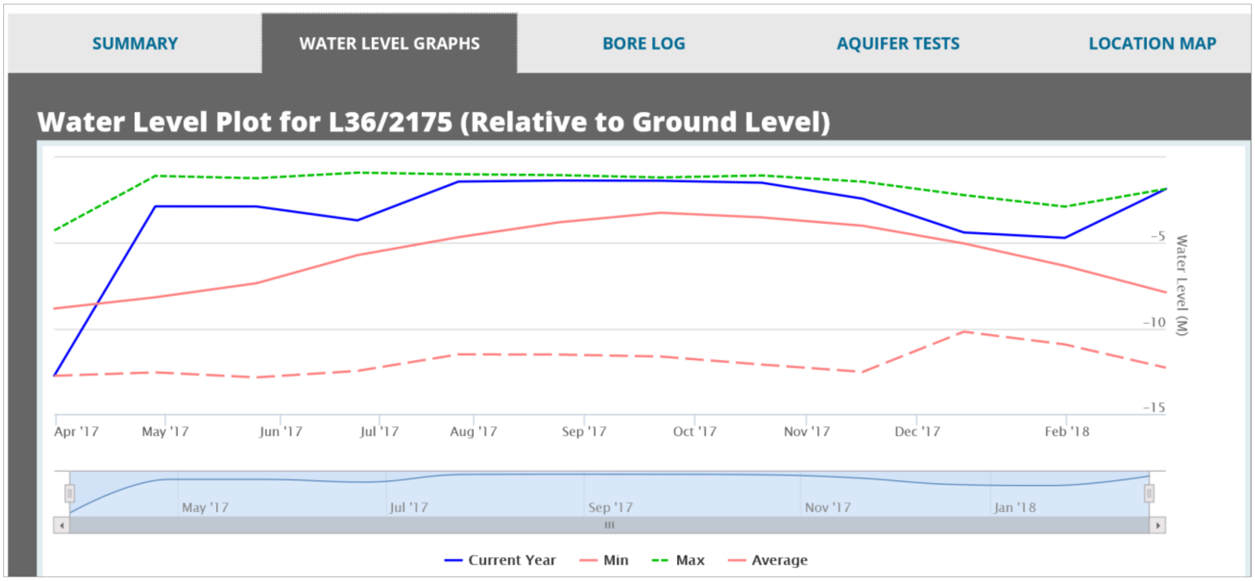
WELL_NO	L36/2175
REFERENCE_RL	67.25
AVERAGE_WATER_LEVEL	-6.113755

The average water level is 6.11m below the top of the well in the stratum labelled “Small-medium gravel with traces of yellow silt”.

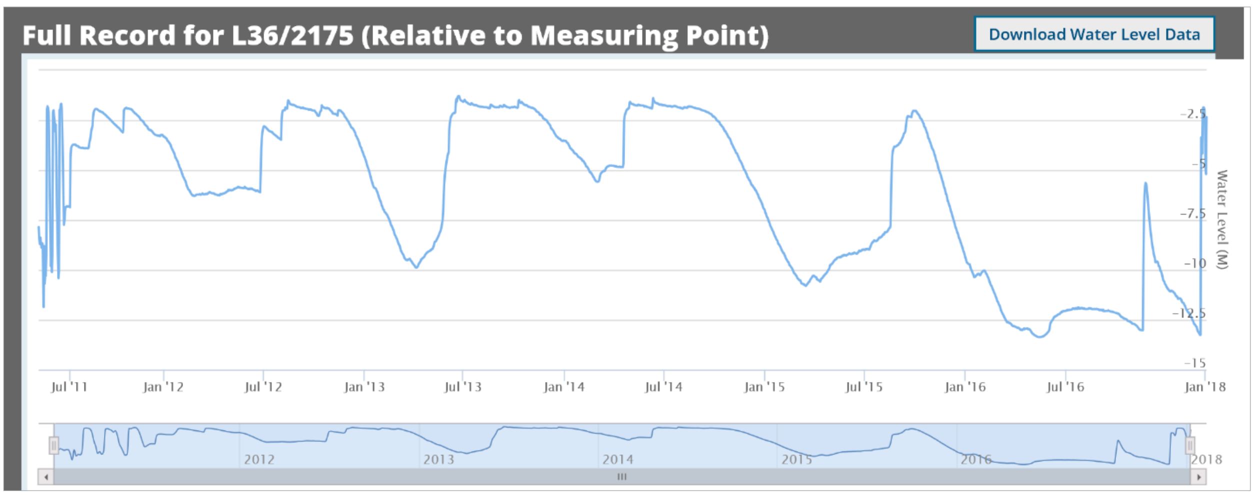
TOP_SCREEN_1	16.799999
TOP_SCREEN_2	<null>
BOTTOM_SCREEN_1	18.299999

The well is screened for entry of water right at the bottom of the well between 16.8m and 18.3m from top of 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.



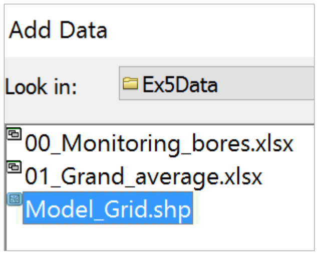
If you scroll down to the next chart, you'll see that the water levels in this well fluctuate between about 2m below top of well to 13m below top of well.



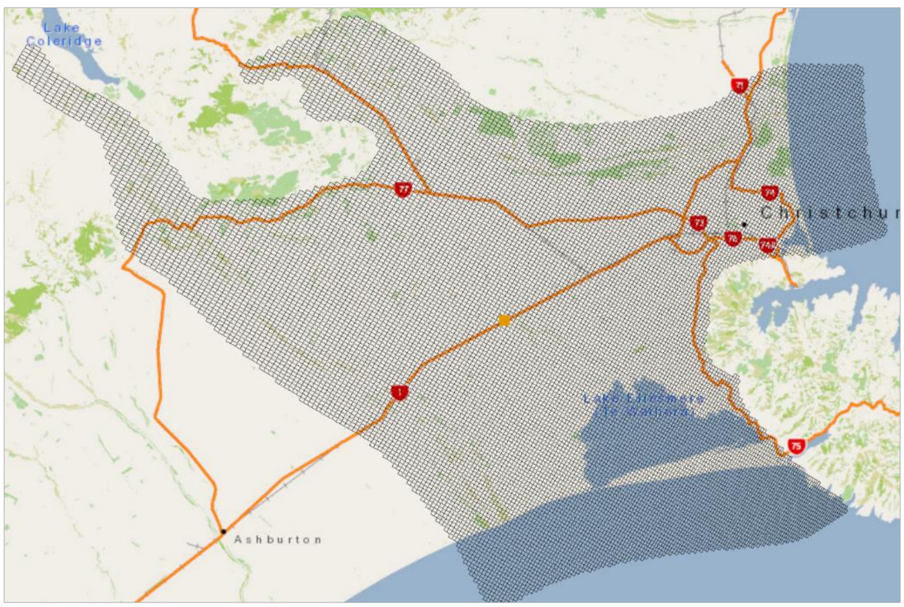
To be Turned in: Choose another observation well from the dataset and prepare a similar description of it like the one presented above for L36/2175. How does your well compare with L36/2175? [Hint make sure this well is upstream of Te Waihora/Lake Ellesmere because this is important for Question 4].

3. Description of the Selwyn Aquifer

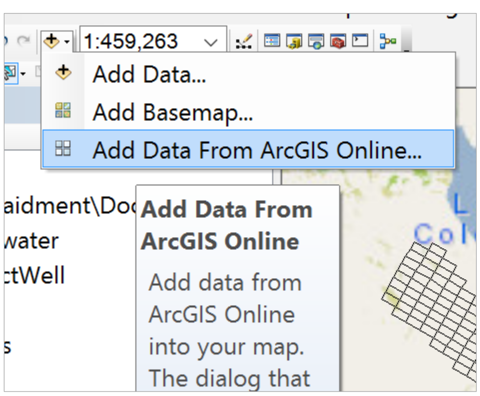
The physical and flow properties of the hydrogeology of the Selwyn aquifer are contained in a data set developed to support Modflow groundwater modeling of the aquifer, compiled by Julian Weir and colleagues at Aqualinc. Go to the dataset you downloaded for this exercise and add the **Model_Grid** shape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



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

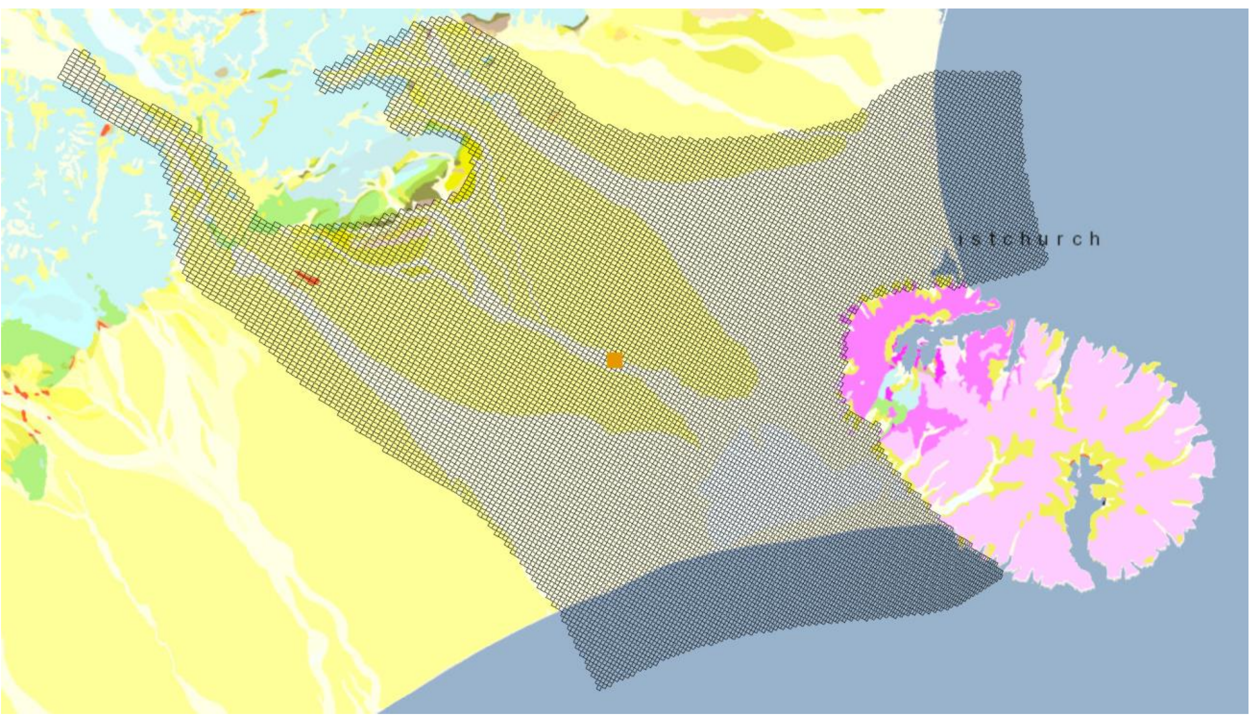


Now, let's get a geology map to add to this display. Select **Add Data from ArcGIS Online**

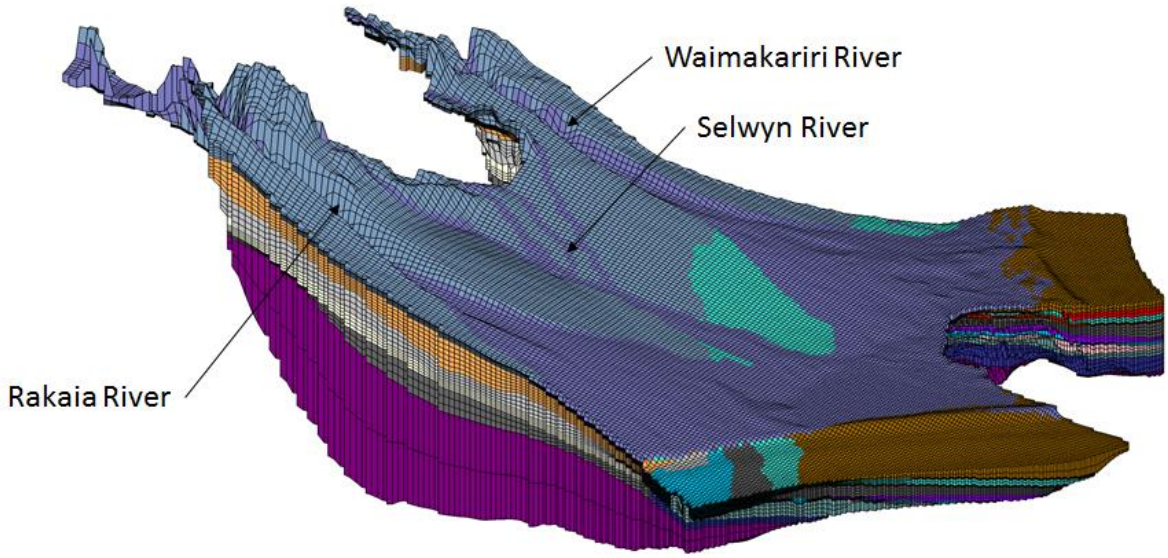


And search for **Geological Map of New Zealand** You'll see that a map becomes available produced by the project **QMAP** of the Crown Research Institute: **Geological and Nuclear Sciences** (GNS)

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.

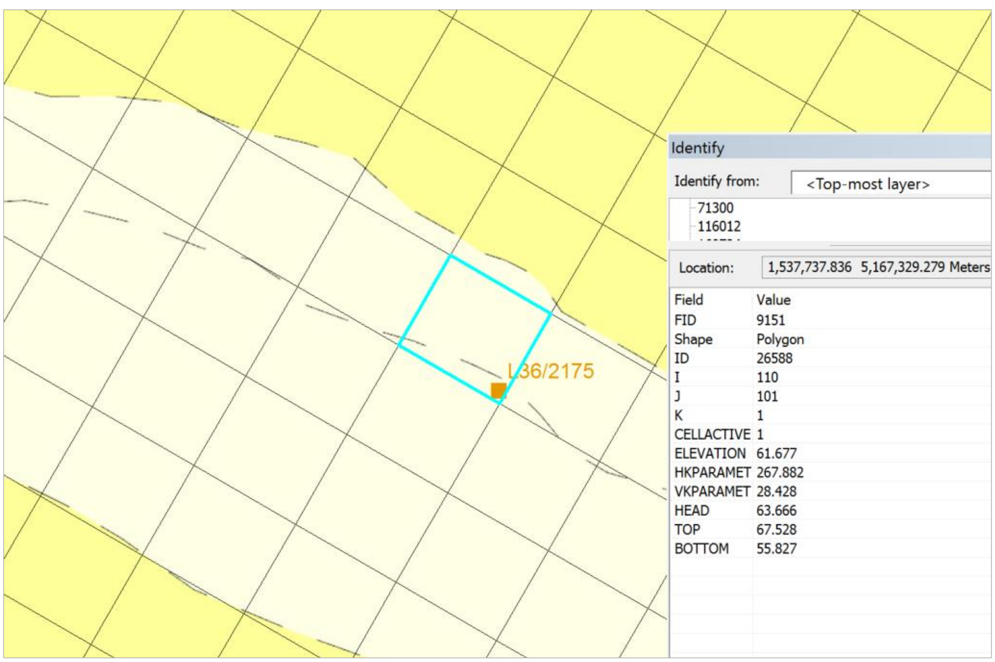


A three-dimensional view of the Selwyn groundwater system is shown below.



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

Table

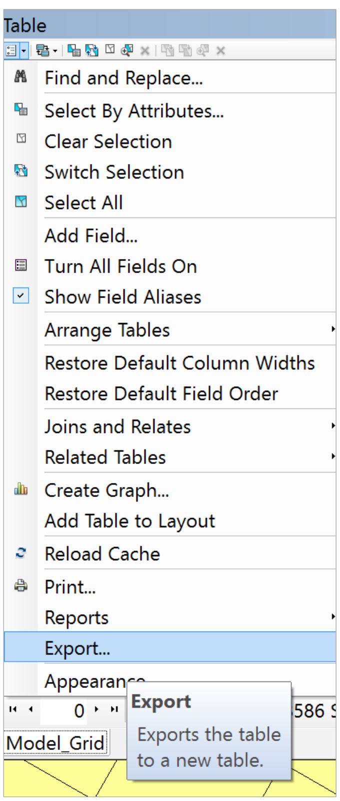
Model_Grid

FID	Shape *	ID	I	J	K	CELLACTIVE	ELEVATION	HKPARAMET	VKPARAMET	HEAD	TOP	BOTTOM
9151	Polygon	265	11	10	1	1	61.677	267.882	28.428	63.666	67.528	55.827
26975	Polygon	713	11	10	2	1	54.827	415.695	5.277	63.661	55.827	53.827
44304	Polygon	116	11	10	3	1	52.827	415.695	5.277	63.658	53.827	51.827
61381	Polygon	160	11	10	4	1	50.827	415.695	5.277	63.655	51.827	49.827
78168	Polygon	205	11	10	5	1	48.827	415.695	5.277	63.653	49.827	47.827
94390	Polygon	250	11	10	6	1	46.827	415.695	5.277	63.652	47.827	45.827
11015	Polygon	294	11	10	7	1	44.827	10.569	0.001	63.036	45.827	43.827
12577	Polygon	339	11	10	8	1	42.827	10.569	0.001	61.963	43.827	41.827
14130	Polygon	384	11	10	9	1	40.827	10.569	0.001	60.986	41.827	39.827
15682	Polygon	428	11	10	10	1	38.827	10.569	0.001	60.061	39.827	37.827
17232	Polygon	473	11	10	11	1	36.827	10.569	0.001	59.174	37.827	35.827
18783	Polygon	518	11	10	12	1	34.827	10.569	0.001	58.298	35.827	33.827
20299	Polygon	563	11	10	13	1	31.277	232.8	6	57.855	33.827	28.728
21794	Polygon	607	11	10	14	1	25.132	232.8	6	57.854	28.728	21.537
23278	Polygon	652	11	10	15	1	18.263	232.8	6	57.853	21.537	14.989
24737	Polygon	697	11	10	16	1	11.756	232.8	6	57.853	14.989	8.524
26162	Polygon	741	11	10	17	1	7.388	161.292	0.001	58.51	8.524	6.253
27565	Polygon	786	11	10	18	1	5.253	161.292	0.001	58.58	6.253	4.253
28966	Polygon	831	11	10	19	1	3.239	161.292	0.001	57.832	4.253	2.226
30333	Polygon	876	11	10	20	1	1.143	161.292	0.001	55.979	2.226	0.061
31616	Polygon	920	11	10	21	1	-13.486	114.547	5.172	54.439	0.061	-27.032
32897	Polygon	965	11	10	22	1	-40.084	114.547	5.172	54.437	-27.032	-53.137
34050	Polygon	101	11	10	23	1	-66.813	114.547	5.172	54.437	-53.137	-80.489
35146	Polygon	105	11	10	24	1	-116.761	1	0.01	54.253	-80.489	-153.033
36242	Polygon	109	11	10	25	1	-189.304	1	0.01	54.014	-153.033	-225.576

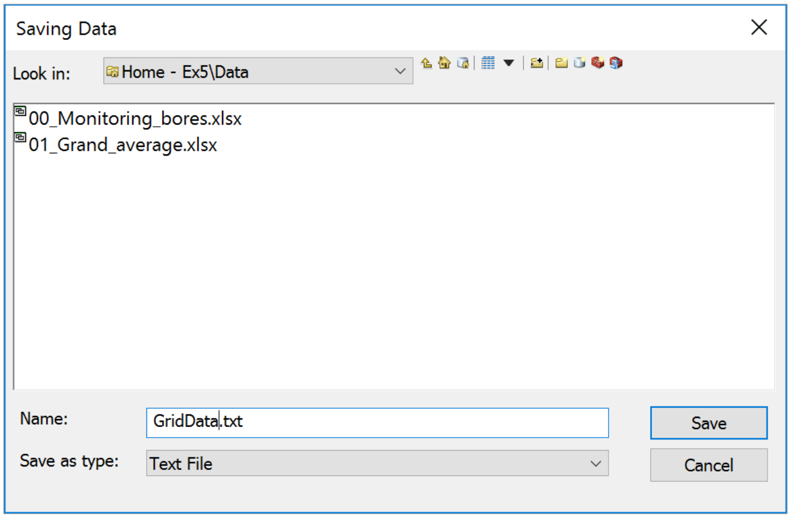
1 (25 out of 368586 Selected)

Model_Grid

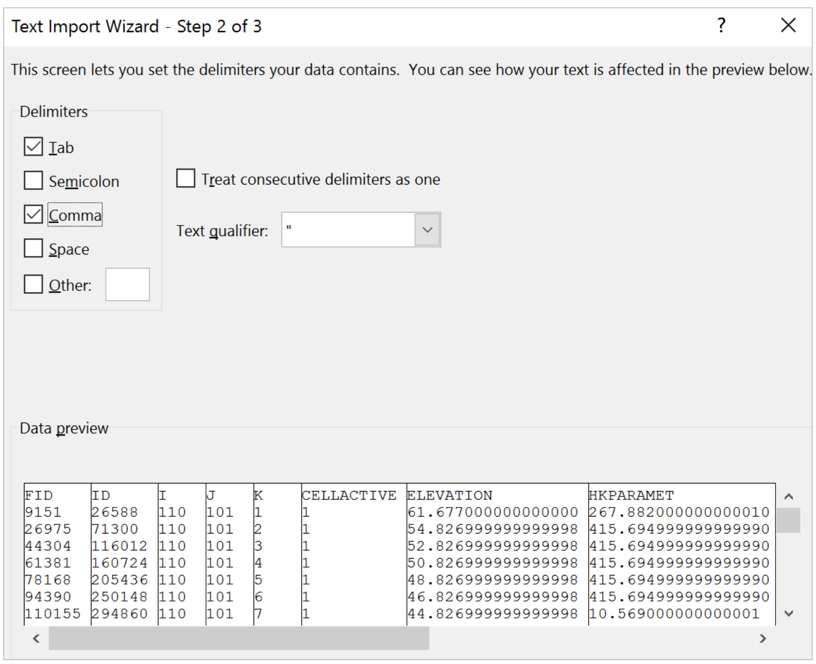
In the top left corner of the Attribute Table, with the rows selected as shown above, you can export this table



Export this as a text file **GridData.txt**



Import this table into Excel as a Comma Delimited text file



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	K	CELLACTIVE	ELEVATION	HKPARAMET	VKPARAMET	HEAD	TOP	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^2/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:

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

We'll use this value later in the exercise.

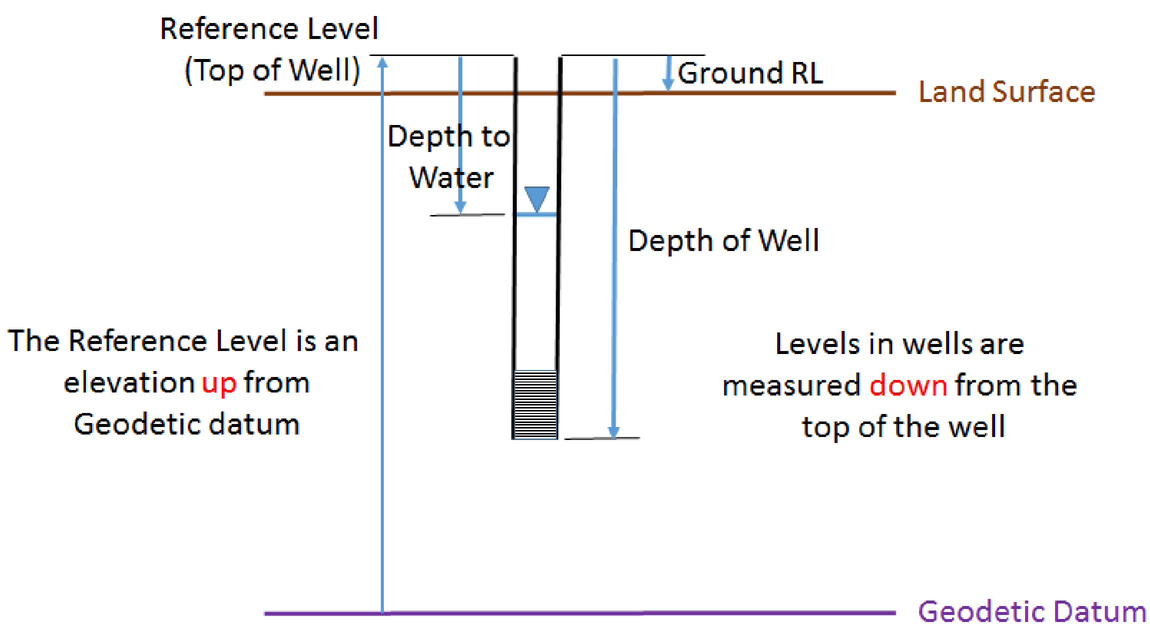
Layer	Top	Bottom	Conductivity (m/day)	Thickness (m)	Transmissivity (m^2/day)	% of Transmissivity
A	67.5	55.8	267	12	3124	13.0
B	55.8	45.8	416	10	4160	17.3
C	45.8	33.8	11	12	132	0.5
D	33.8	8.5	233	25	5895	24.5
E	8.5	0.1	161	8	1352	5.6
F	0.1	-80	115	80	9212	38.3
G	-80	-225	1	145	145	0.6
Total				293	24020	

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.

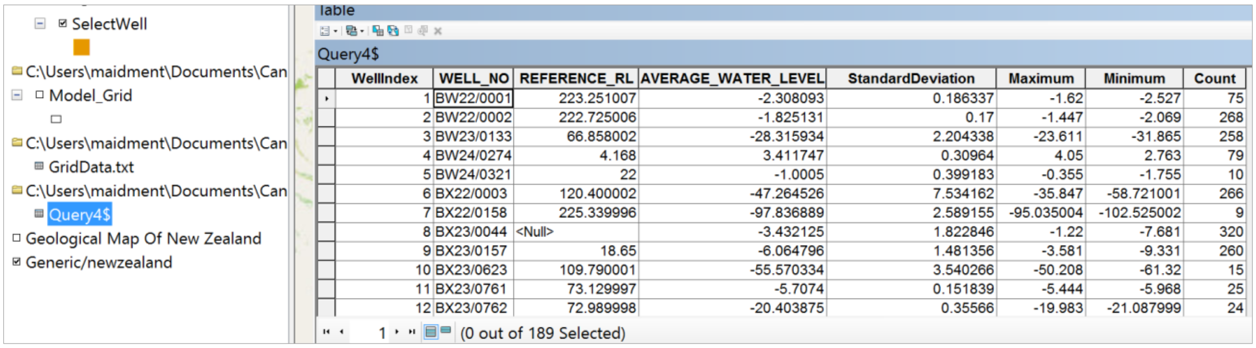
4. Water Level Map and Travel Time in the Aquifer

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.



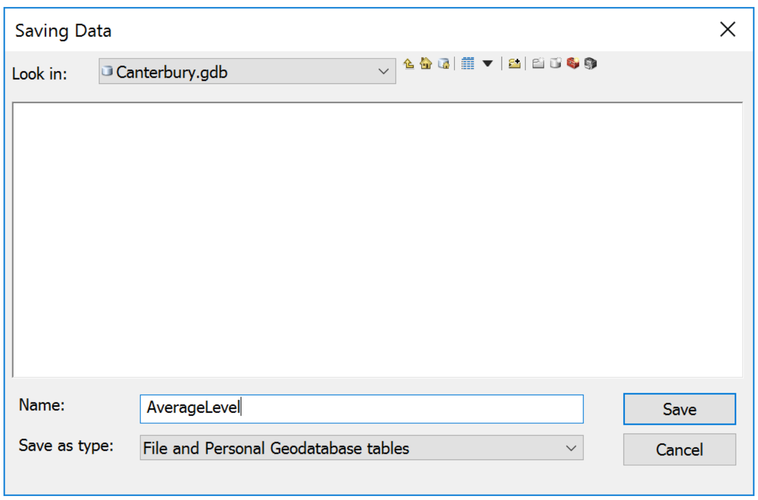
We are going to make a water level map (or piezometric head map) from the average water levels recorded in the ECan monitoring wells. These levels are averaged through time over the period of record of measurements from each well. We are also not allowing for different hydraulic pressures that may exist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

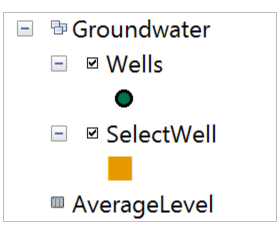


WellIndex	WELL_NO	REFERENCE_RL	AVERAGE_WATER_LEVEL	StandardDeviation	Maximum	Minimum	Count
1	BW22/0001	223.251007	-2.308093	0.186337	-1.62	-2.527	75
2	BW22/0002	222.725006	-1.825131	0.17	-1.447	-2.069	268
3	BW23/0133	66.858002	-28.315934	2.204338	-23.611	-31.865	258
4	BW24/0274	4.168	3.411747	0.30964	4.05	2.763	79
5	BW24/0321	22	-1.0005	0.399183	-0.355	-1.755	10
6	BX22/0003	120.400002	-47.264526	7.534162	-35.847	-58.721001	266
7	BX22/0158	225.339996	-97.836889	2.589155	-95.035004	-102.525002	9
8	BX23/0044	<Null>	-3.432125	1.822846	-1.22	-7.681	320
9	BX23/0157	18.65	-6.064796	1.481356	-3.581	-9.331	260
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

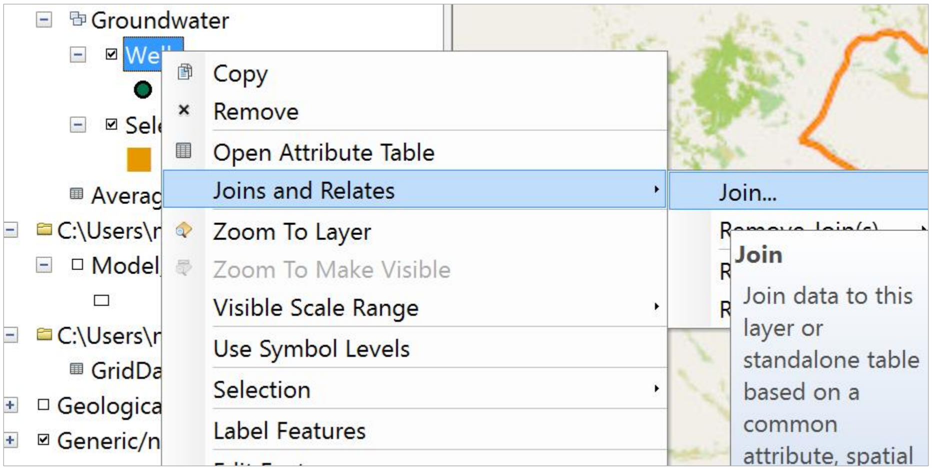
Right click on this table and Export the Table as **AverageLevel** in the **Canterbury** geodatabase (cannot put this in the Groundwater feature dataset because that only holds feature classes not simple tables).



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

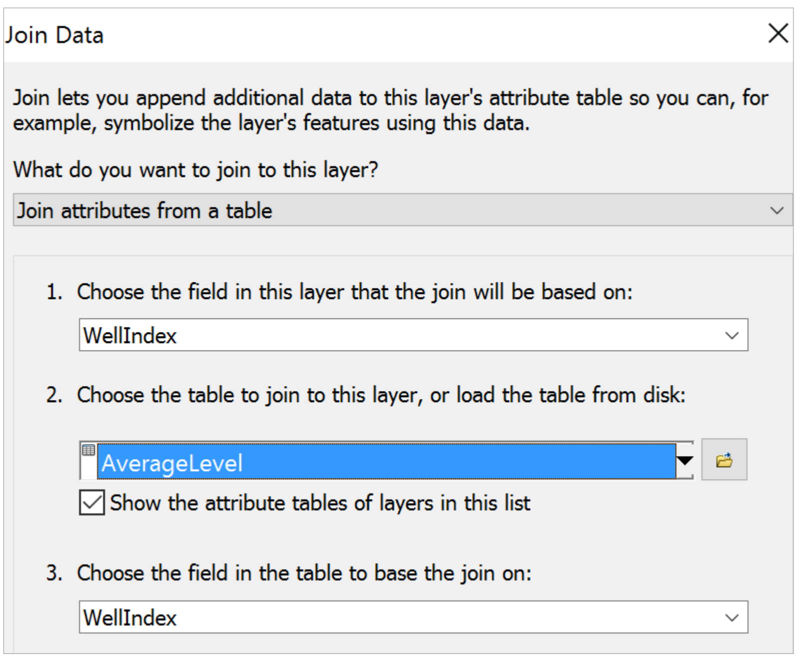


Now let’s Join these two tables using the **WellIndex** field present in both tables as a common key field.

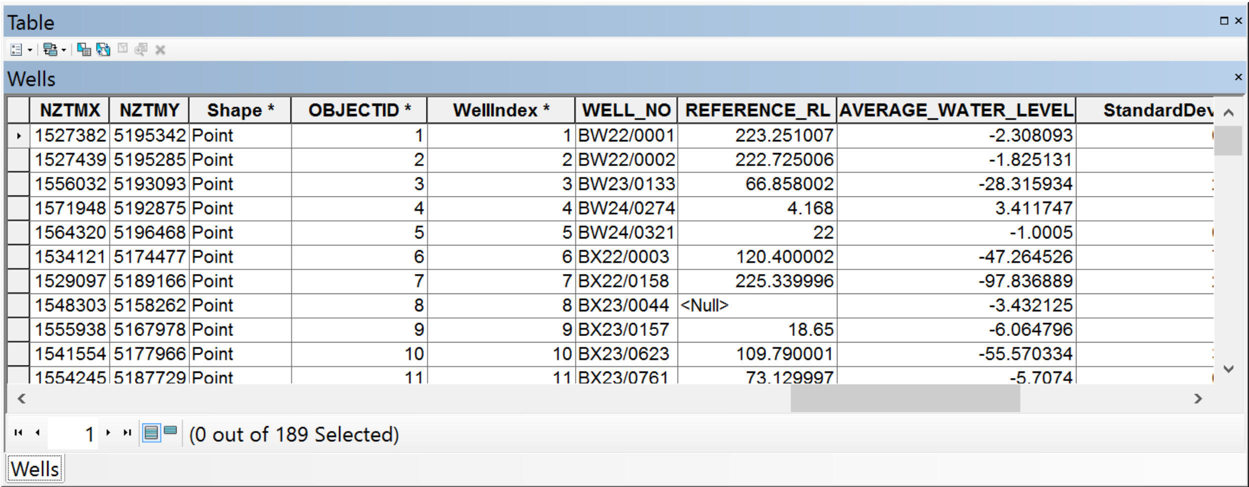


Right click on the Wells feature class and select **Joins and Relates/Join**

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.



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.



Table

Wells

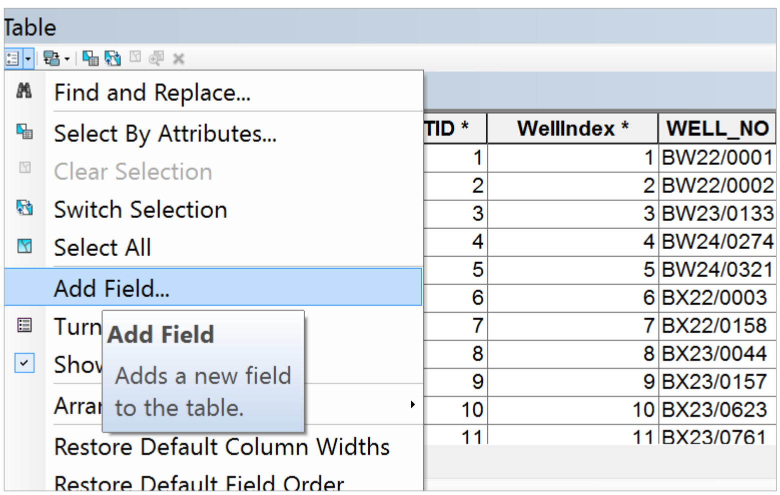
	NZTMX	NZTMY	Shape *	OBJECTID *	WellIndex *	WELL_NO	REFERENCE_RL	AVERAGE_WATER_LEVEL	StandardDev
▸	1527382	5195342	Point	1	1	BW22/0001	223.251007	-2.308093	
	1527439	5195285	Point	2	2	BW22/0002	222.725006	-1.825131	
	1556032	5193093	Point	3	3	BW23/0133	66.858002	-28.315934	
	1571948	5192875	Point	4	4	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	
	1529097	5189166	Point	7	7	BX22/0158	225.339996	-97.836889	
	1548303	5158262	Point	8	8	BX23/0044	<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	
	1554245	5187729	Point	11	11	BX23/0761	73.129997	-5.7074	

1 (0 out of 189 Selected)

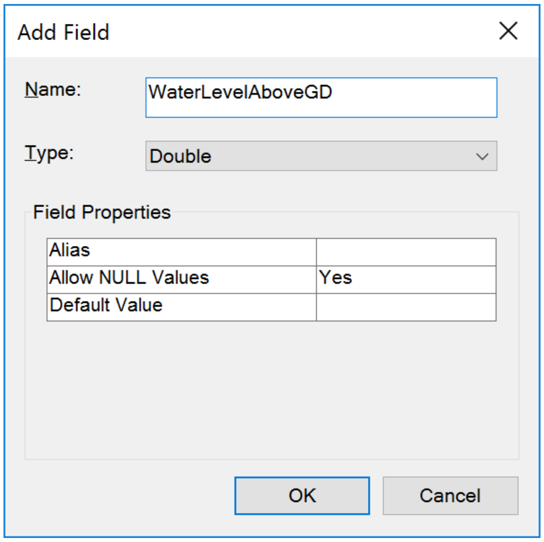
Wells

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

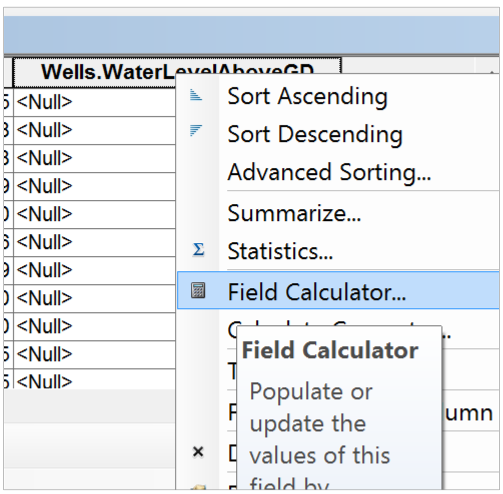
In the top left of the Attribute Table, Select **Add Field**



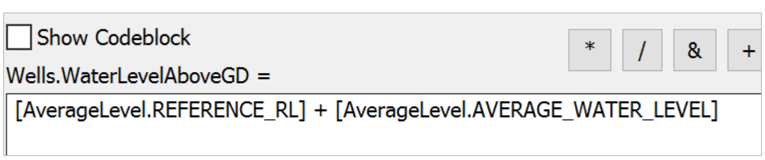
Call this field **WaterLevelAboveGD** and make its **Type Double**.



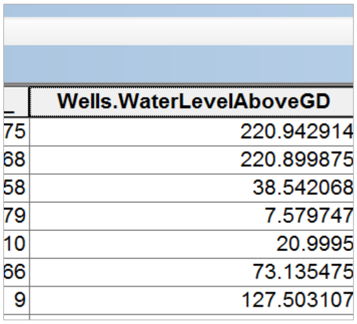
In this new field, open the **Field Calculator**



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).

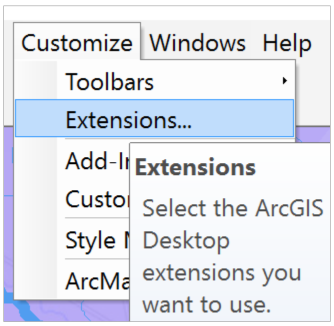


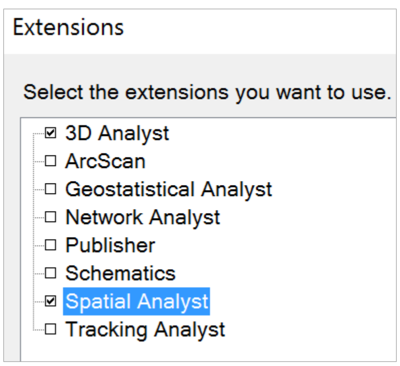
Now we have Average Water Level in the well above Geodetic datum.



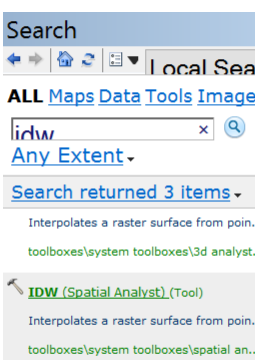
	Wells.WaterLevelAboveGD
75	220.942914
68	220.899875
58	38.542068
79	7.579747
10	20.9995
66	73.135475
9	127.503107

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

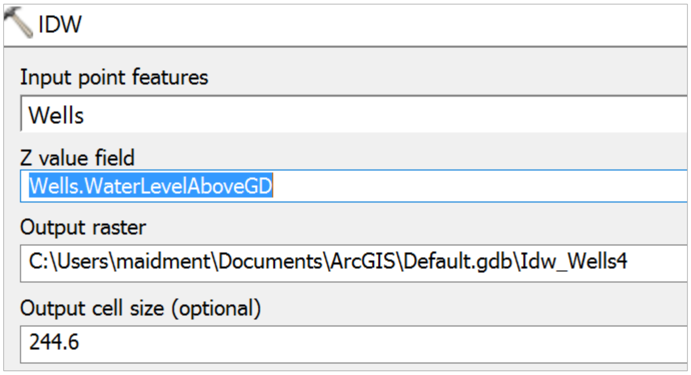


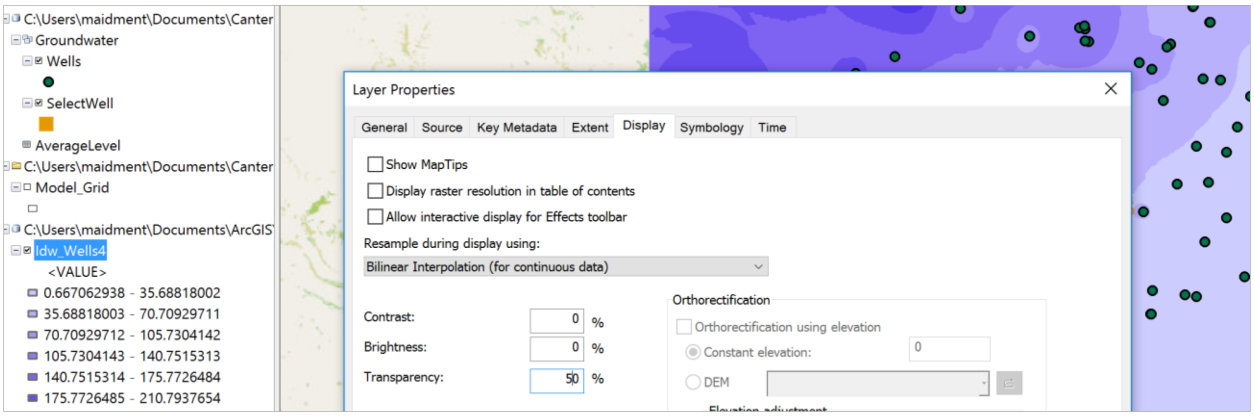


Now let's draw a water level map using the **Inverse Distance Weighting (IDW)** method. Search for IDW in the Search tab at the top right of ArcMap.

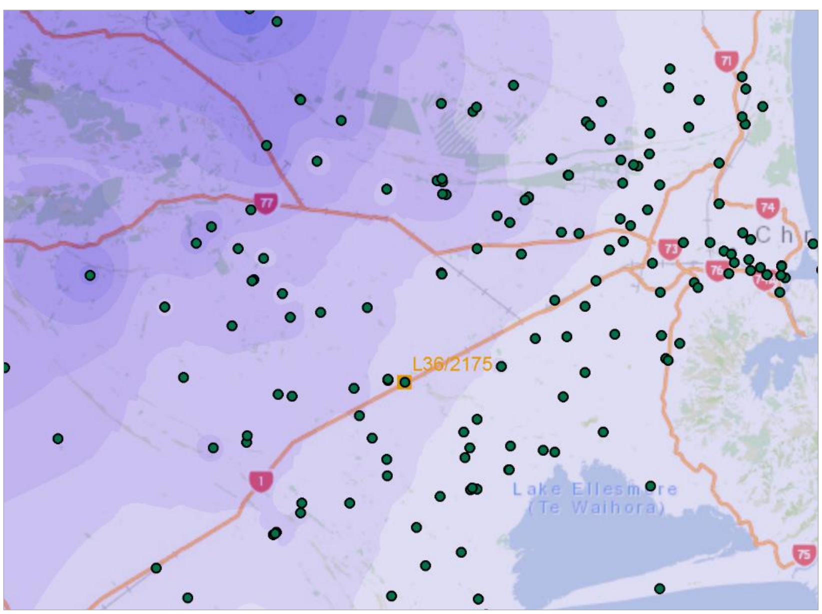


Open the IDW tool and use **Wells** as the Input Point Features, and Z value field as **WaterLevelAboveGD.**



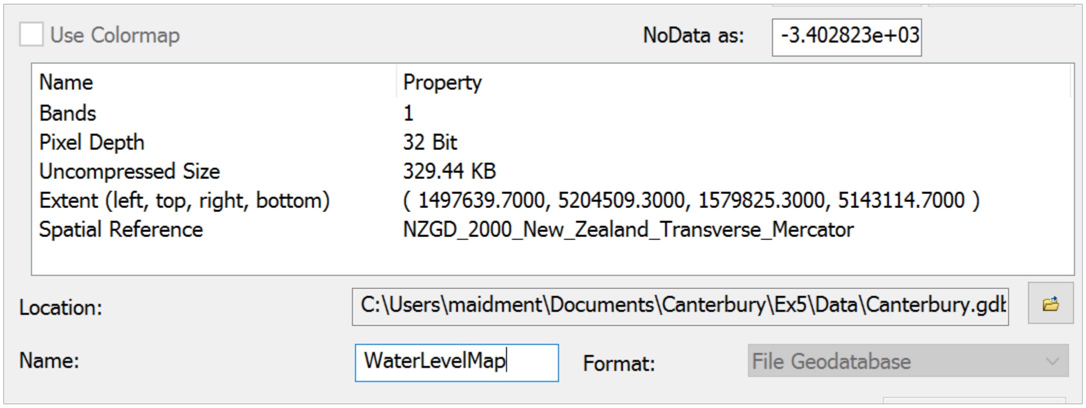


Color the map in shades of Blue and make the Display have 50% transparency so you can see other things below the map.

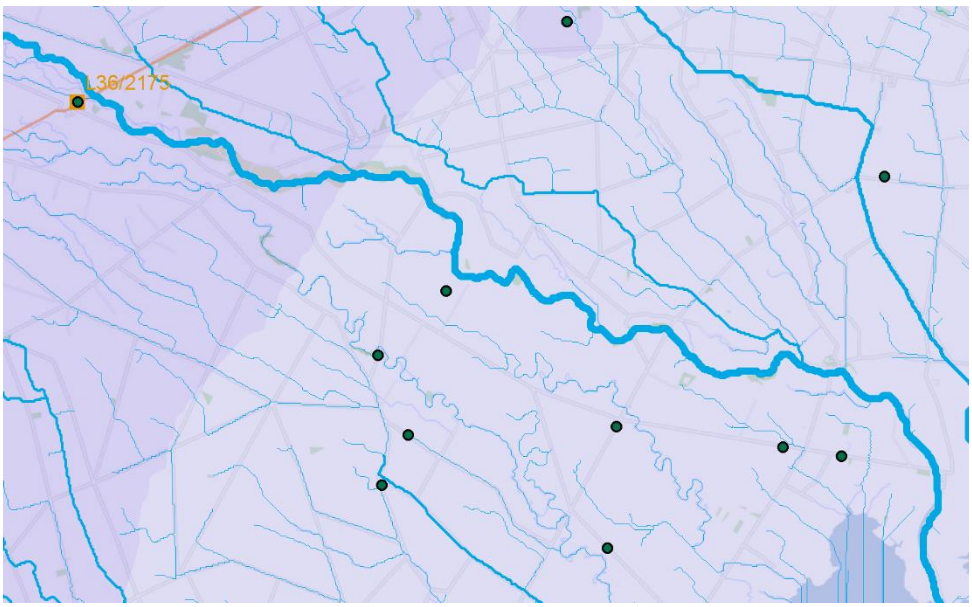


And you'll get a rather nice map that shows how groundwater levels are higher near the mountains and diminish towards the coast in a fairly uniform pattern.

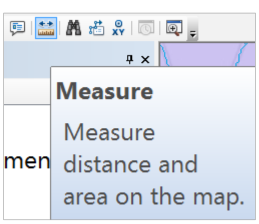
Export the **WaterLevelMap** grid to the Canterbury geodatabase.



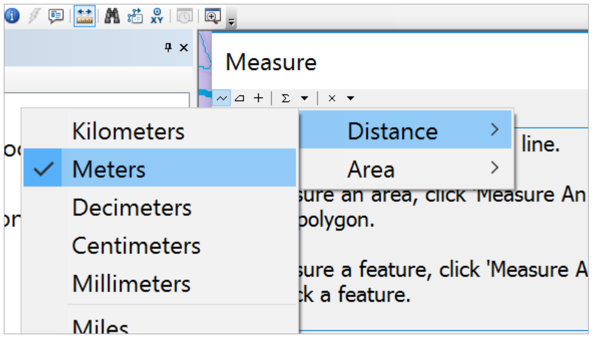
Add the **RiverLines** for the Selwyn catchment that we used in Exercise 3. Zoom in again to the area downstream of well **L36/2175**



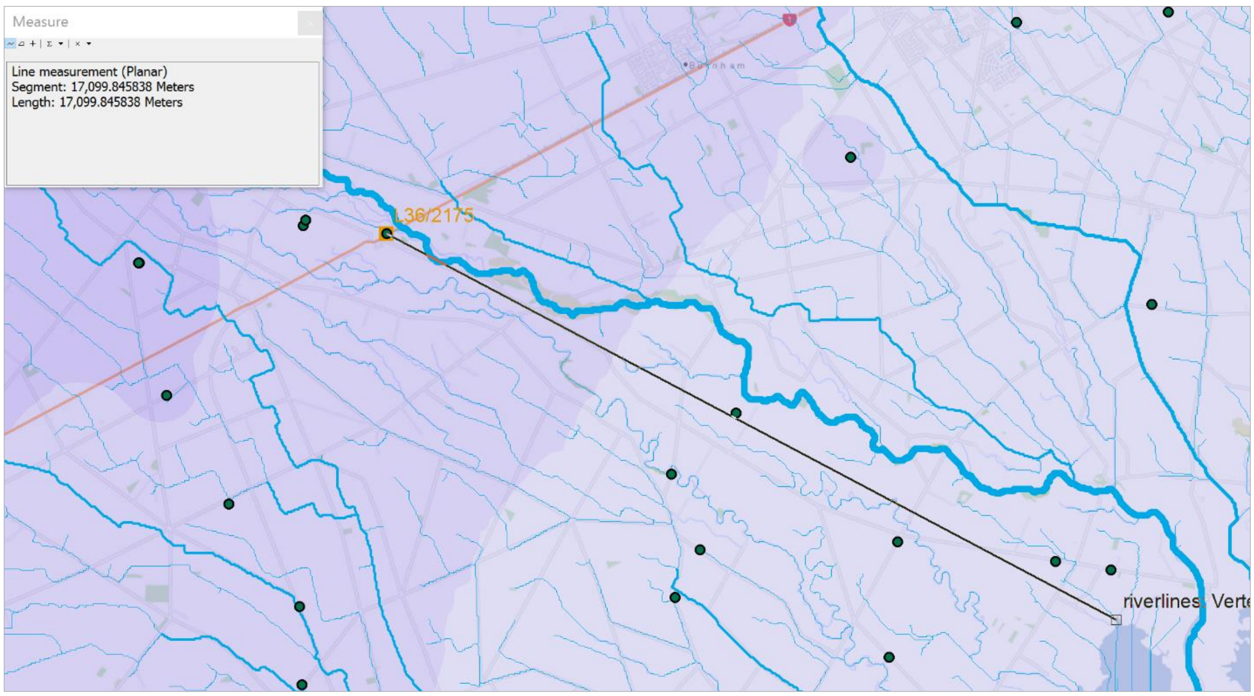
Open the **Measure** tool in ArcMap



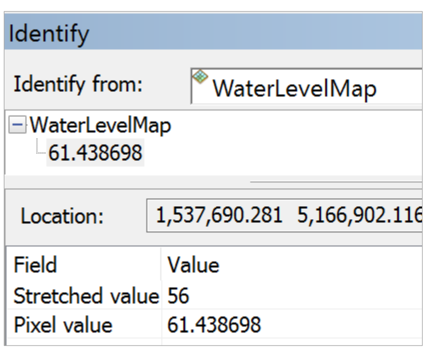
and set the **Distance** measure in **meters**.



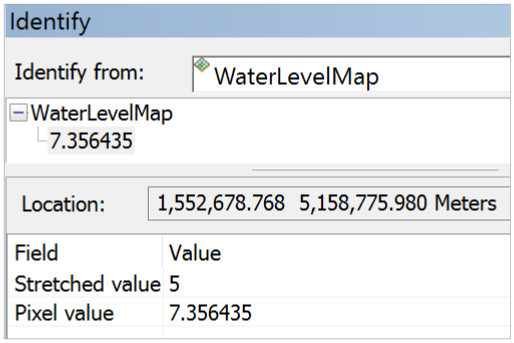
The straight line measure between this well and Te Waihora/Lake Ellesmere is **17,099 meters**



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



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.



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_s 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.*