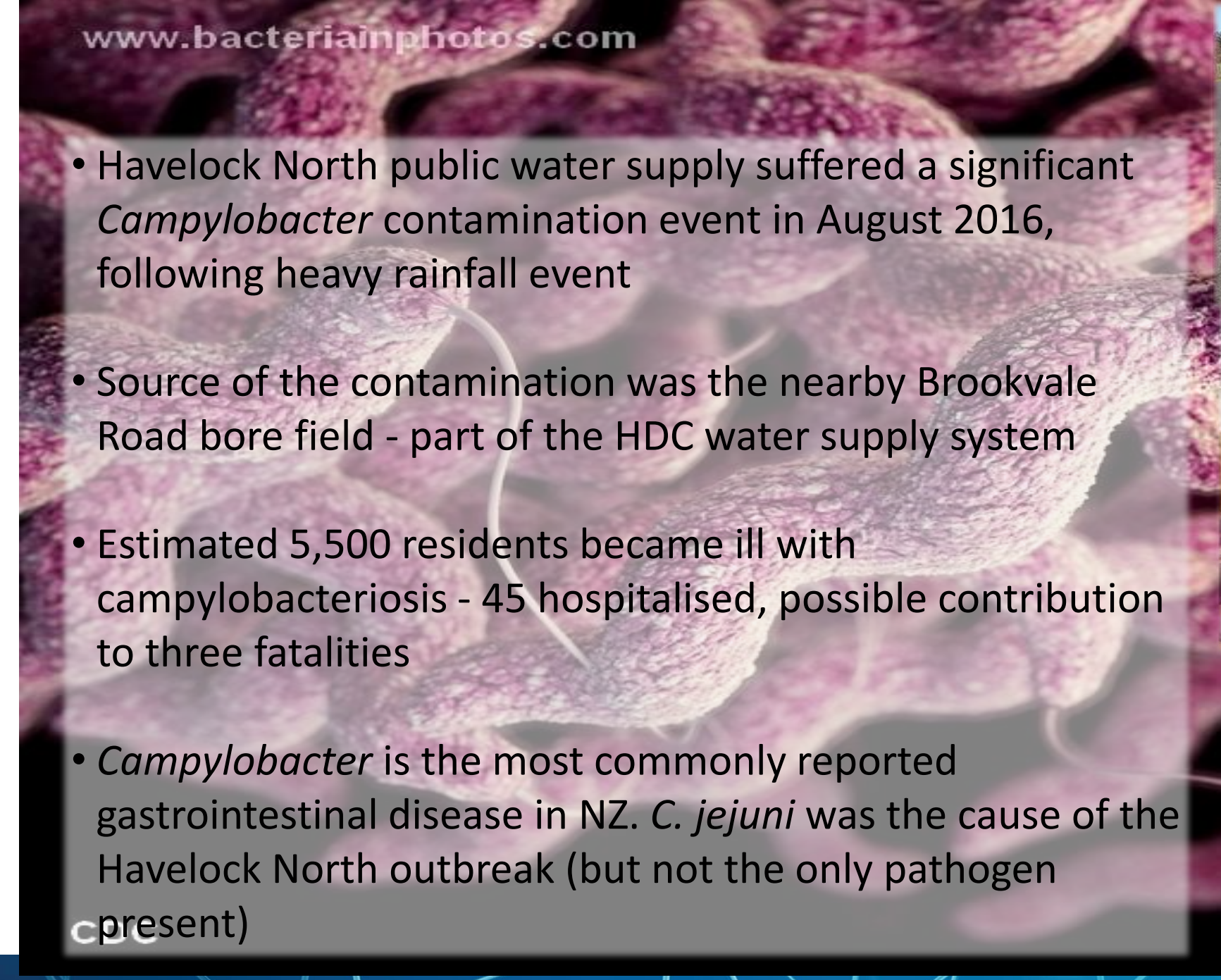
Havelock North Water Supply *Campylobacter* Outbreak – source and ingress investigations

Tony Cussins, Discipline Manager - Hydrogeology, Tonkin + Taylor Group



- Havelock North public water supply suffered a significant *Campylobacter* contamination event in August 2016, following heavy rainfall event

- Source of the contamination was the nearby Brookvale Road bore field - part of the HDC water supply system

- Estimated 5,500 residents became ill with campylobacteriosis - 45 hospitalised, possible contribution to three fatalities

- *Campylobacter* is the most commonly reported gastrointestinal disease in NZ. *C. jejuni* was the cause of the Havelock North outbreak (but not the only pathogen present)

Hastings water supply

- Havelock North is one of six water supply zones - 65,000 people served, 12 M cubic metres p.a.
- Raw water sourced from the gravel aquifers beneath the Heretaunga Plains - abstracted from a total of 12 bores at 6 locations
- Prior to August 2016, Hastings, Havelock North and Flaxmere water supplies were deemed to be secure and were untreated.
- Prior to the 2016 outbreak, water was supplied to Havelock North from the Brookvale Road bore field.
- Brookvale Road Bores 1 and 2 shut down February 2017. Now decommissioned.
- In March 2017, Brookvale Bore 3 brought back into production - 5 log treatment process utilising cartridge filtration and UV disinfection.

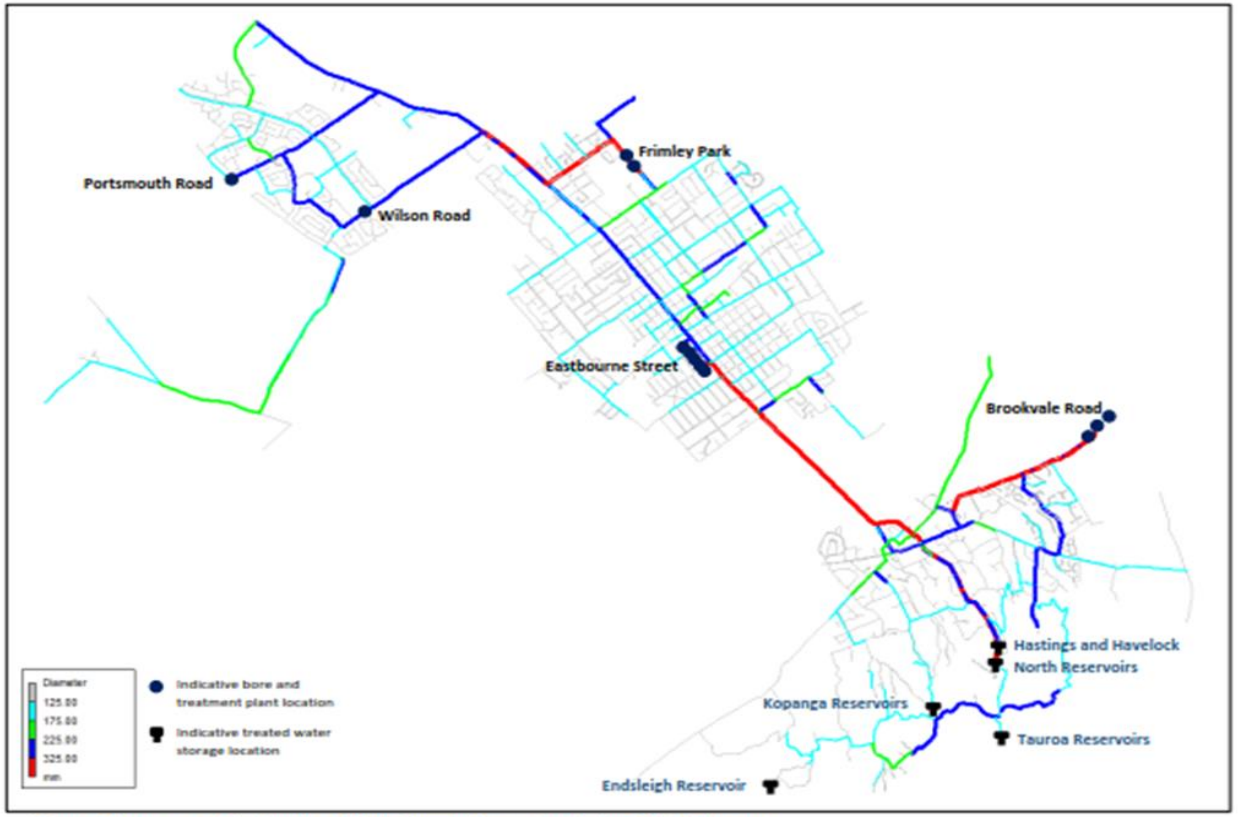
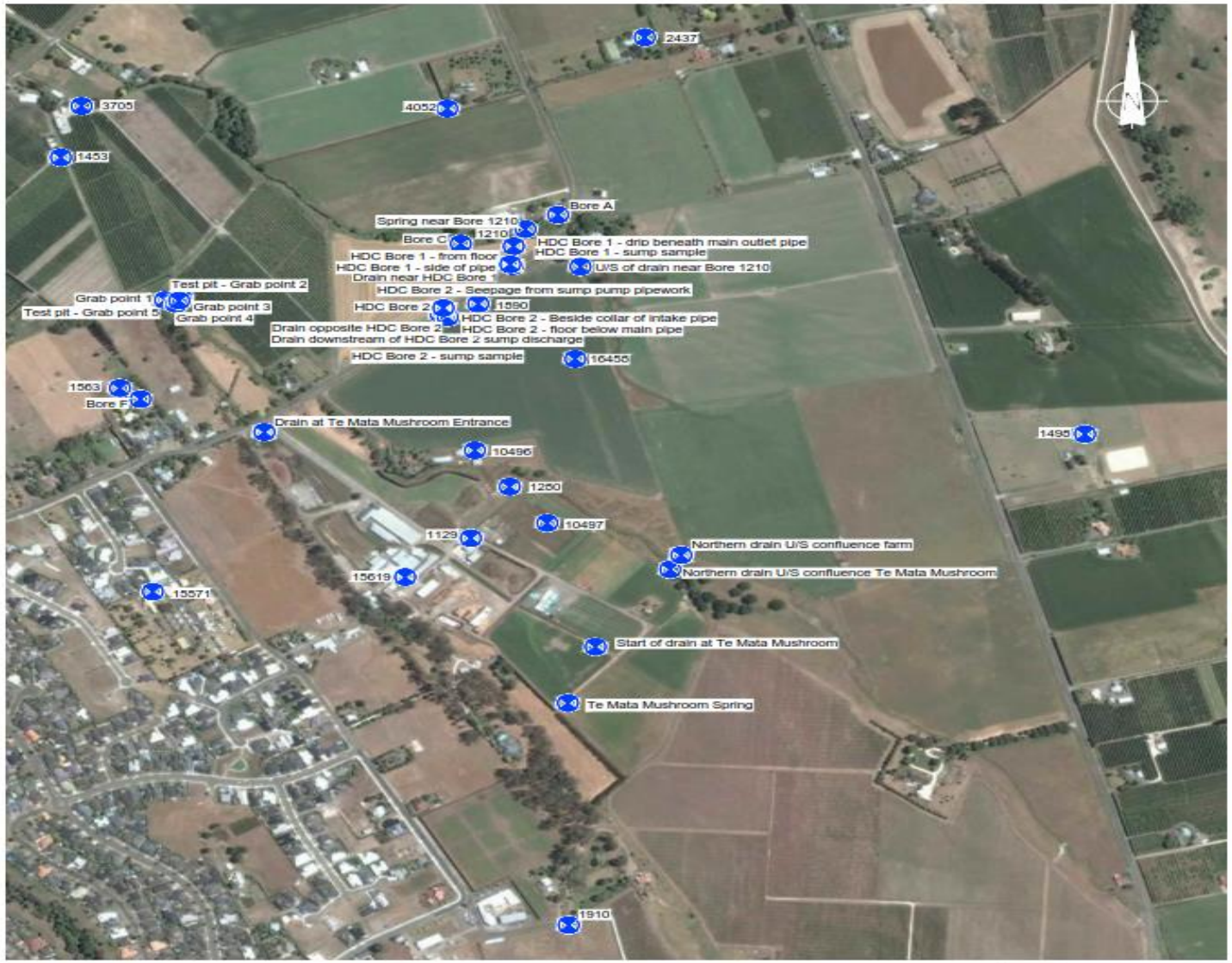
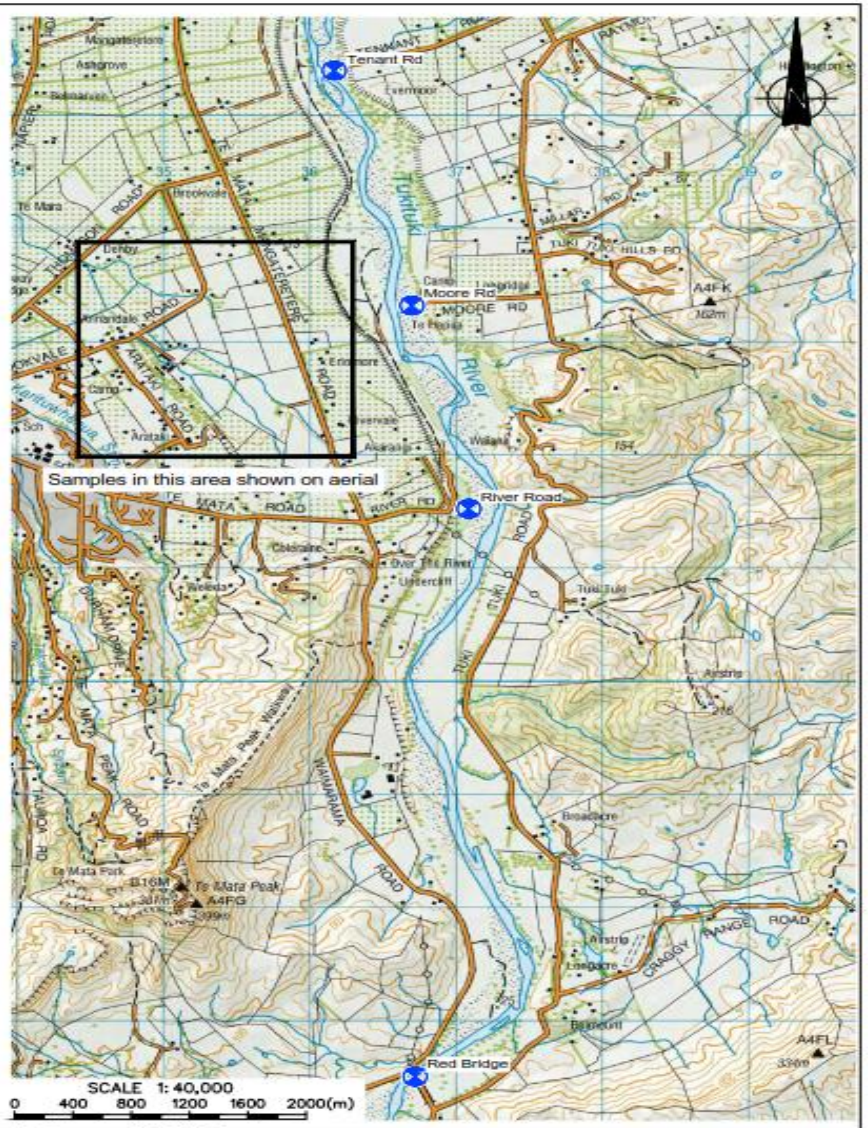


Figure 2-1: Layout of the Hastings Water Supply System (excluding Paki Paki zone)





SCALE 1: 7500
0 100 200 300 400 500 (m)

Aerial photo sourced from Google Earth. Copyright Image©2016 DigitalGlobe. Imagery Date: 15/1/16
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DRAWN	RBS	Nov. 16
DRAFTING CHECKED		
APPROVED		
CADFILE 1	3 1301-BCA-F6.dwg	
SCALES (AT A3 SIZE)	1: 7500, 1: 40000	
PROJECT No.	3 1301. 1000	

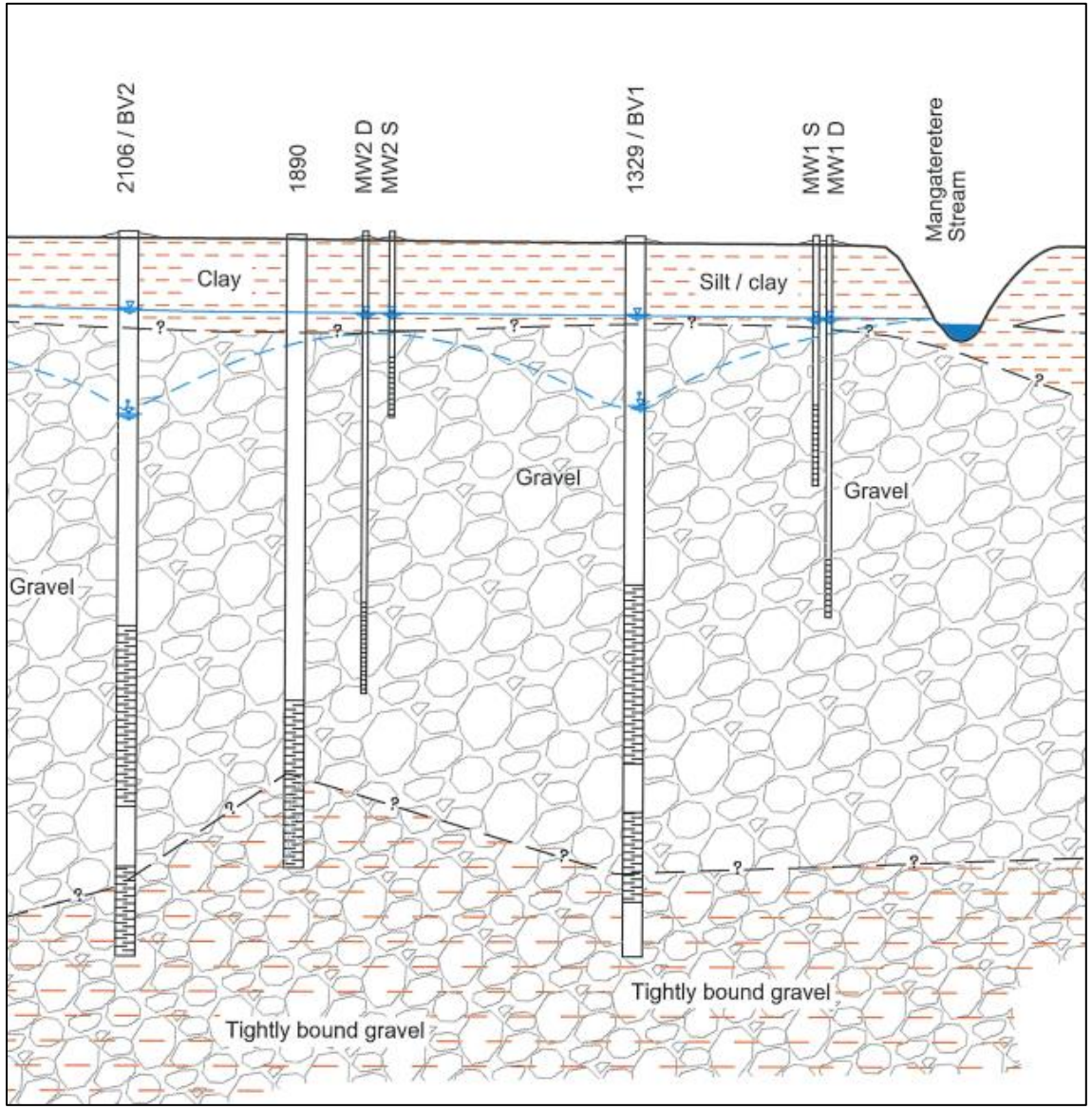
HASTINGS DISTRICT COUNCIL
BACTERIOLOGICAL CONTAMINATION INVESTIGATION
BROOKVALE ROAD WATER SUPPLY BORES
HBRC Sampling Locations

FIG. No. Figure 6 REV. 0


Mangateretere Stream
Brookvale Bores (BV1 & BV2)
Field Investigation Extent

Conceptual hydrogeological model

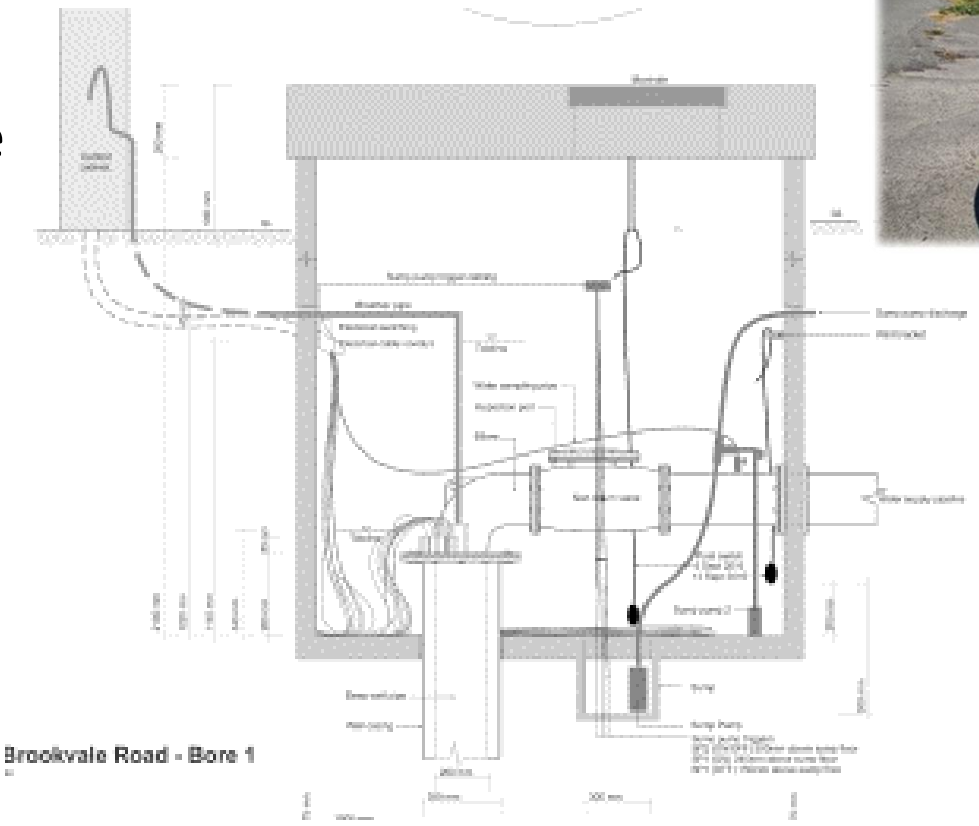
- Relatively thin confining layer overlying Te Mata Aquifer
- Upper screen in Bore 1: 11.4 – 17.4m bgl
- Hydraulic connection - pond/groundwater
- Very high transmissivity in the area – >30,000 m^2/day
- Preferential flow pathways through paleo-channels
- Water level in ponded area observed to be immediately drawn down when Bore 1 turned on (had not been observed before)
- Kh / Kv relationship poorly understood



Key Features:

- 1.8m below ground chamber
- 200mm bore to 35m depth, 2 screens
- Rising main and cable ducts not secure (prosecution)
- Shallow drains adjacent to the bores.
- Stormwater can enter bore chambers during rainfall events
- High level alarm did not activate (separate system).
- HDC considered to be secure based on bore security assessment undertaken by MWH.

Brookvale Bore 1



Outbreak investigation programme

- HBDHB-led Joint Agency Outbreak Investigation Science Group
- Integrated with, and complimentary to the HBRC investigations
- Soil, sediment and groundwater sampling (bacteriological and chemical parameters)
- DTM and flowpath modelling (in conjunction with HBRC)
- Geophysical survey (ScanTec)
- Hydrogeological investigations: piezometer installation – groundwater level/quality, hydraulic parameters
- Fluorescent dye tracer tests (in conjunction with HBRC)
- Bore chamber integrity tests (BV1 and BV2)
- Groundwater modelling and fate & transport modelling

HDC Broad scale Investigation

- 100+ sites documented and evaluated, within a 140ha investigation area
- 10 priority sites identified for more detailed assessment, including:
  - Areas of significant land disturbance, landfilling
  - Numerous uncapped bores - potential for flooding during rainfall/flood events
  - Potential areas of contaminated runoff, and discharges to stormwater and/or the underlying aquifer

Analysis results

Extensive sampling and analysis programmes (HBRC/HDC) - microbial contamination in soils, surface water, sediments and groundwater.

Key results:

- Microbiological contamination is widespread in the catchment area.
- *Campylobacter* identified in a number of locations, including the Mangateretere Stream north of Brookvale Rd, and on TMML land
- *E. coli* in new monitoring wells and in shallow wells adjacent to Stream
- *E. coli* and total coliforms in private landfill to North of borefield, and in SOE bore 10496
- Common signature between Mangateretere Stream (N), T+T's GW monitoring bores, and Brookvale Bores 1 and 2.

Contrasting contaminant pathway theories (HBRC/HDC) – later combined in science caucus convened by the Inquiry

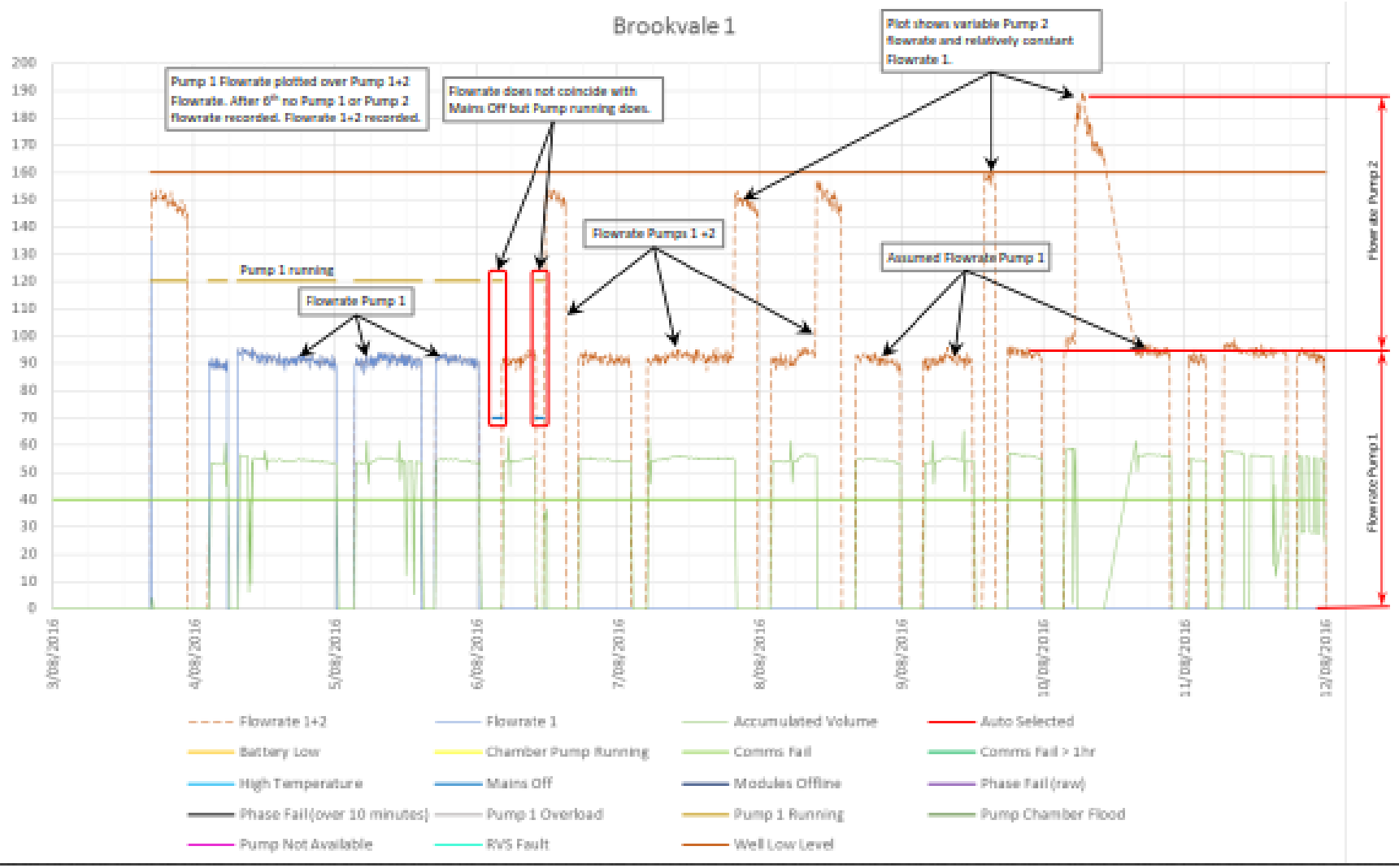
HBRC/ESR work critical to identifying the source of the *Campylobacter* contamination that caused the outbreak

Telemetry system

T+T / ERGO completed an independent assessment of the telemetry system – both the hardware functionality and the data collected:

- Bore pumps on/off, volumes
- Sump pump operation
- High level alarms functioned or not

Verified that the data collected was accurately represented in system



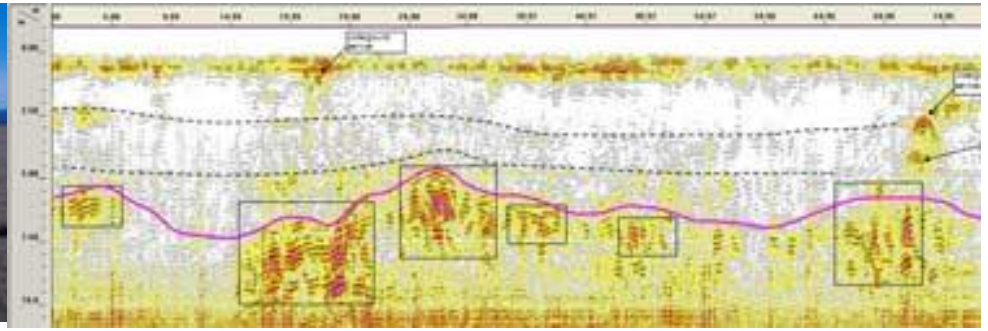
Geophysical survey

ScanTec – specialised geophysical equipment / techniques:

- Ground Penetrating Radar (GPR)
- Electromagnetic Induction (EM-34)
- Electrical Resistivity Imaging (ERI)

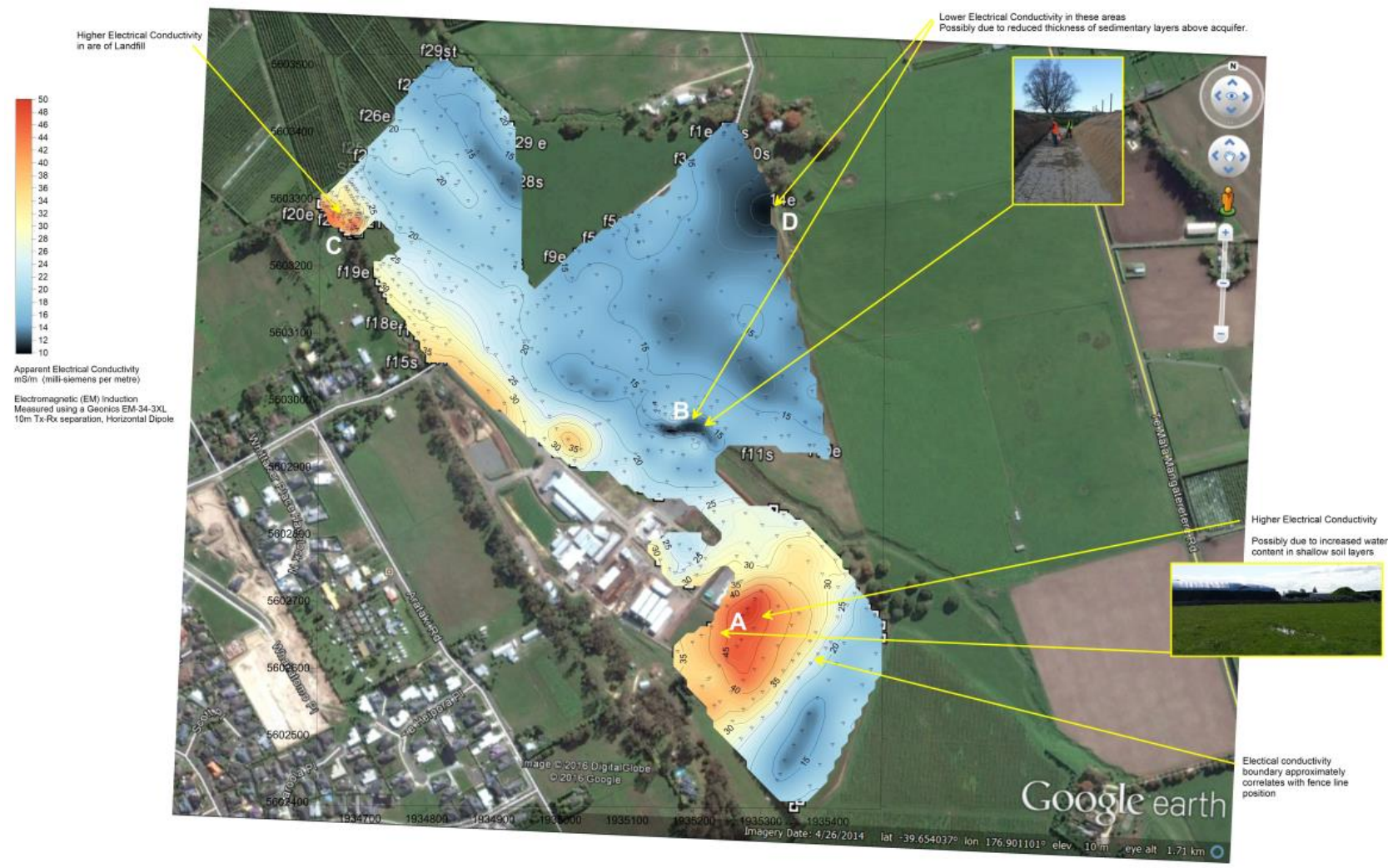
Objectives:

- Characterise the near surface geology within the area of interest (15m depth), including the upper Te Mata Aquifer
- Increase knowledge about the confining layer (or aquitard) in the vicinity of the Brookvale Rd borefield
- Total area of approx. 140 ha
- Included land disturbance or fill



Electromagnetic Induction (EM-34)

- Electrical Conductivity (EC) in the 0-10m depth range (bulk average)
- Elevated areas of EC correspond to the very wet (boggy) areas of the paddocks.
- Possible elevated EC due to a combination of moisture content and shallow geological conditions. Note the NW-SE trend with the elevated EC.
- Low EC level in the NE boundary - very close to ponded area in Mangateretere Stream, and on TMML watercourse.
- SCANTEC speculated that this could be due to reduced thickness of the aquitard in these areas.
- Lack of calibration a problem



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PROJECT Geophysical Surveys
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Figure 3
Apparent Conductivity Map (Average values for 0-10m depth range)
Measured using Electromagnetic Induction (EM-34)

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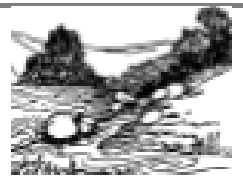
Table 1 Summary of key genotypes of *Campylobacter* observed among samples from Havelock North.

Genotype Cluster	Source (numbers indicate the number of isolates analysed by MBiT, with in brackets, the number of those whole genome sequenced)							
	Human[1]	Reticulated water (12/8)	#	Bore	#	Animal Faecal (23/8)	#	Environmental	#
									
CJ-16-001 ST42A/B	98 (38) 49%	41 Hikanui Dr 31 Endsleigh Library	1 (1) 7 (3) 3 (1)	Bore 1 (19/8)	2 (1)	Sheep 96, Paddock 2 Sheep 98, Paddock 2	2 (1) 3 (1)	Drain 55204 (30/8)	3 (1)
CJ-16-002 ST3610-A	47 (19) 23%	-	-	-	-	Sheep 84, Paddock 2 Sheep 97, Paddock 2 Sheep 100, Paddock 2	3 (1) 3 (1) 2 (1)	Drain 55077 (16/8)	4 (1)
CJ-16-003 ST8398-A	-			Bore 1 (12/8) Bore 2 (12/8)				Drain 55151 (24/8) Pit 54536 (23/8)	3 (1) 5 (1)
CJ-16-005 ST1517-A	9 (4) 4%	92 Endsleigh Library	4 (1) 1 (0)	Bore 1 (24/8)	11 (1)	-	-	-	-
CJ-16-006 ST474-A	9 (2) 4%	-	-	-	-	Sheep 93, Paddock 1	1 (1)	-	-
CJ-16-007 ST50-A	3 (1) 2%	41 Hikanui Dr	6 (2)	-	-	-	-	-	-

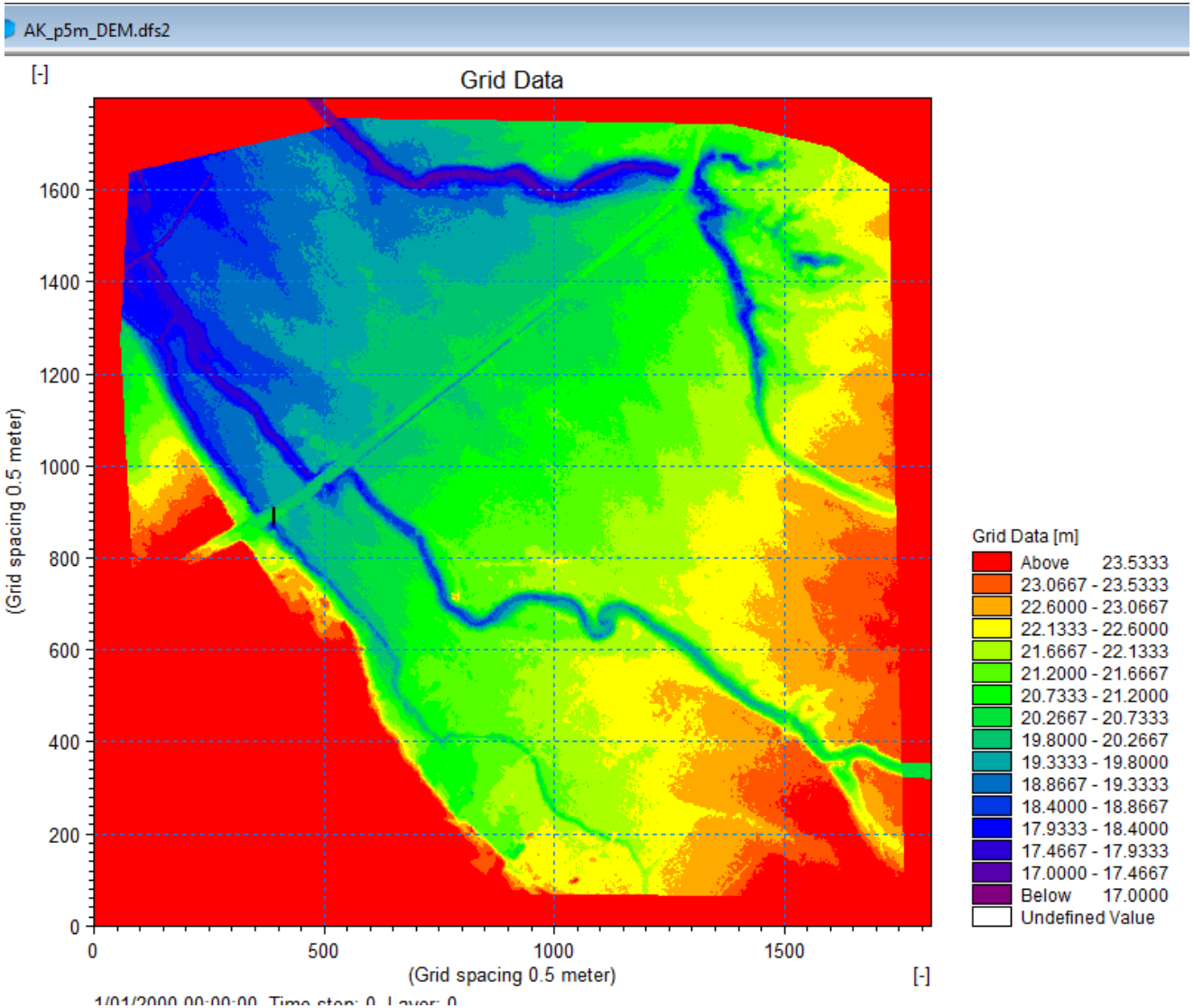
[1]Only emaining cases may also

Source: ESR Evaluation of water and animal faecal samples from Havelock North, August & September 2016.

Hydrodynamic modelling

Hydrodynamic modelling was carried out for the period August 5-August 7 by HBRC, using a rain on grid approach. It showed:

- Flooding would have reached 10 mm or greater over much of paddocks 1, 2 and 3 during the August event
- Maximum flood depth models show that flooding would have exceeded 1 m in the pond upstream of the Mangateretere Stream, and in some of the Brookvale Road drains.

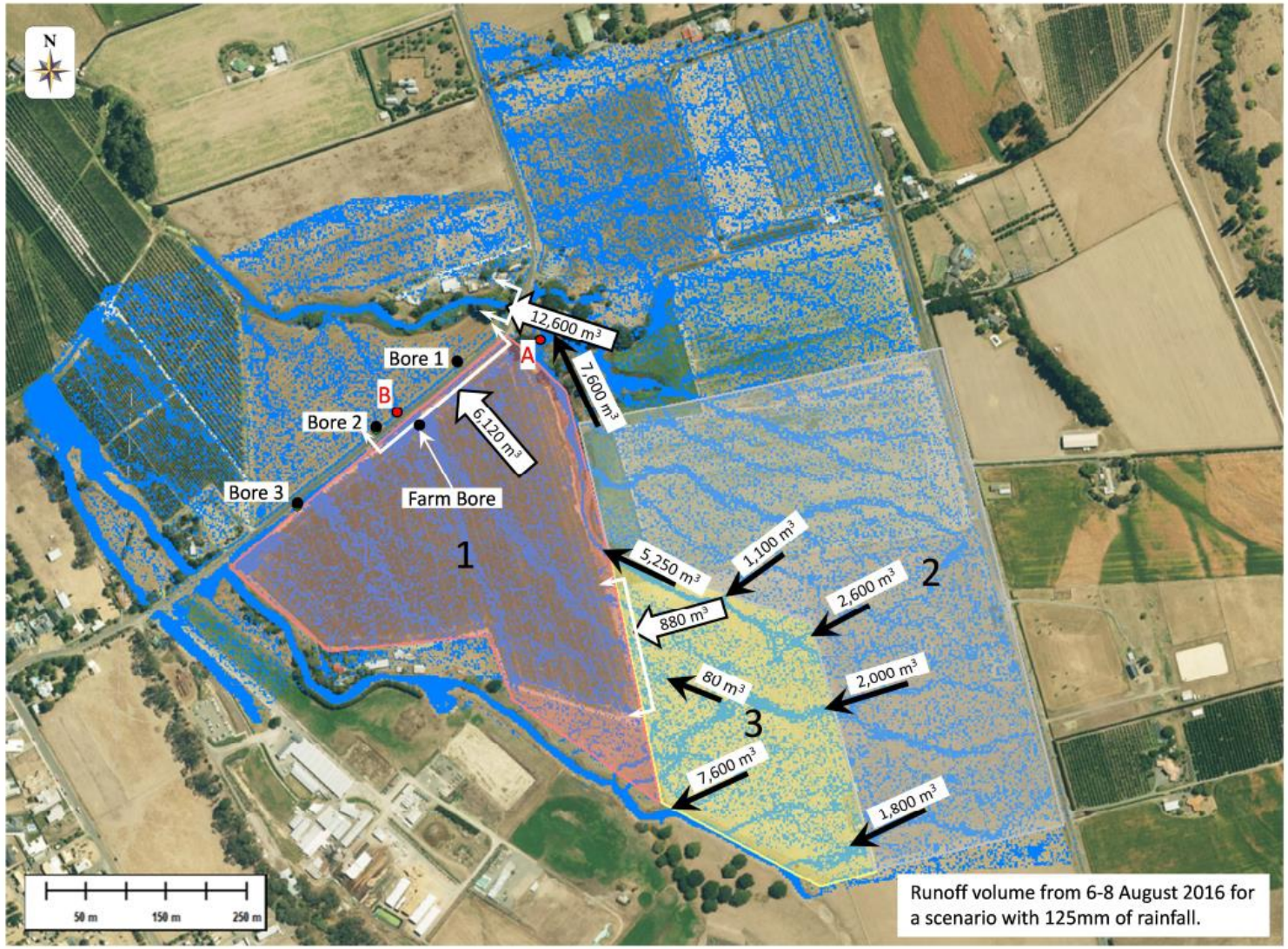


Rainfall runoff

ESR had demonstrated that sheep in Paddocks 2 and 3 were the likely source of the *Campylobacter*

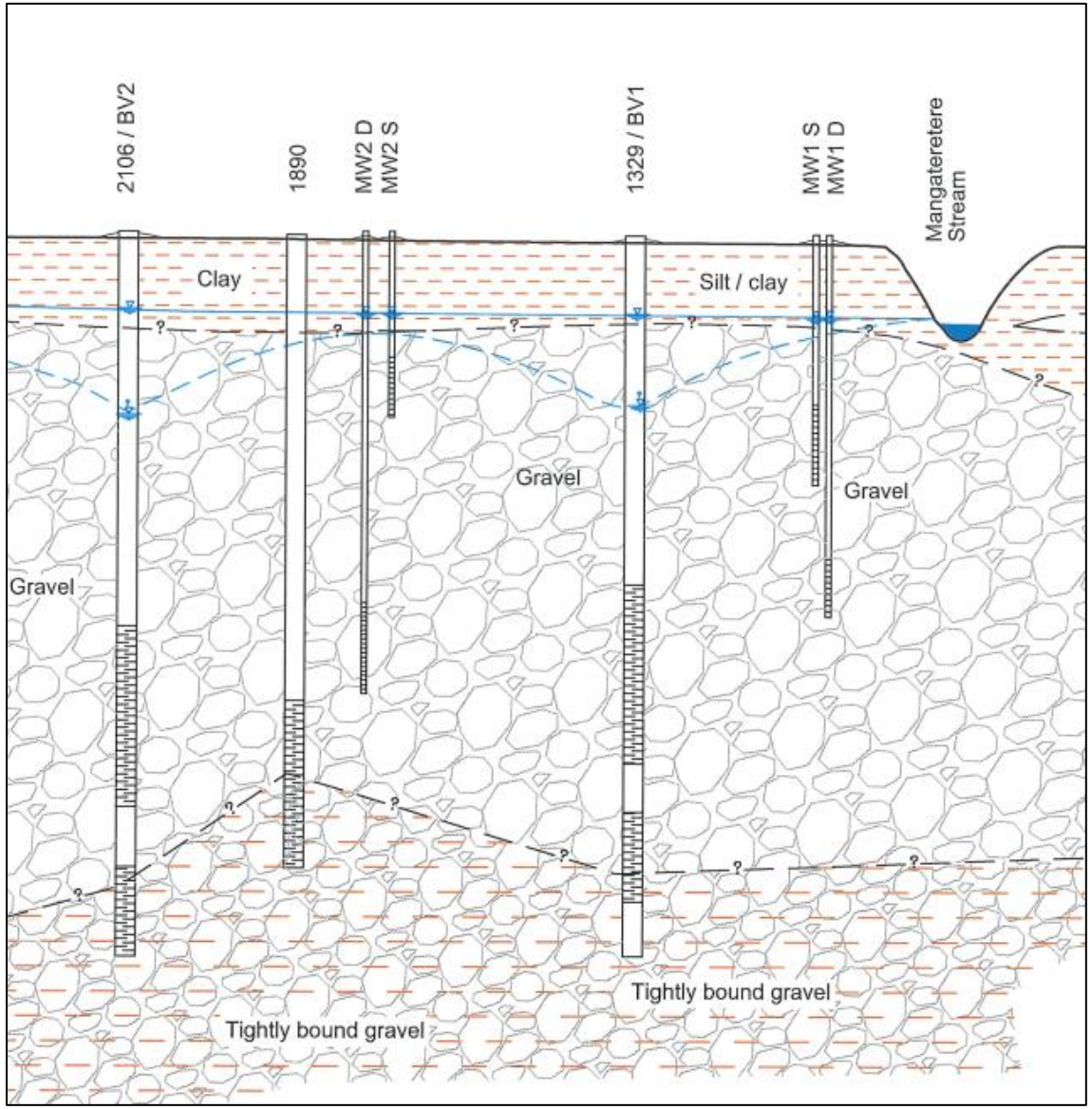
T+T then assessed the likely volumes of runoff during 5-6 August, which showed:

- Runoff from paddocks 2 and 3 would have been predominantly toward the Mangateretere Stream, with a total of 15,000 m^3 and 6,100 m^3 generated respectively
- A lesser amount to the stream through Te Mata Mushrooms and a small amount into Paddock 1 and towards the Brookvale Water Supply Bores



Key question was: “Could viable pathogenic micro-organisms have travelled from the Mangateretere Stream to Bore 1?”:

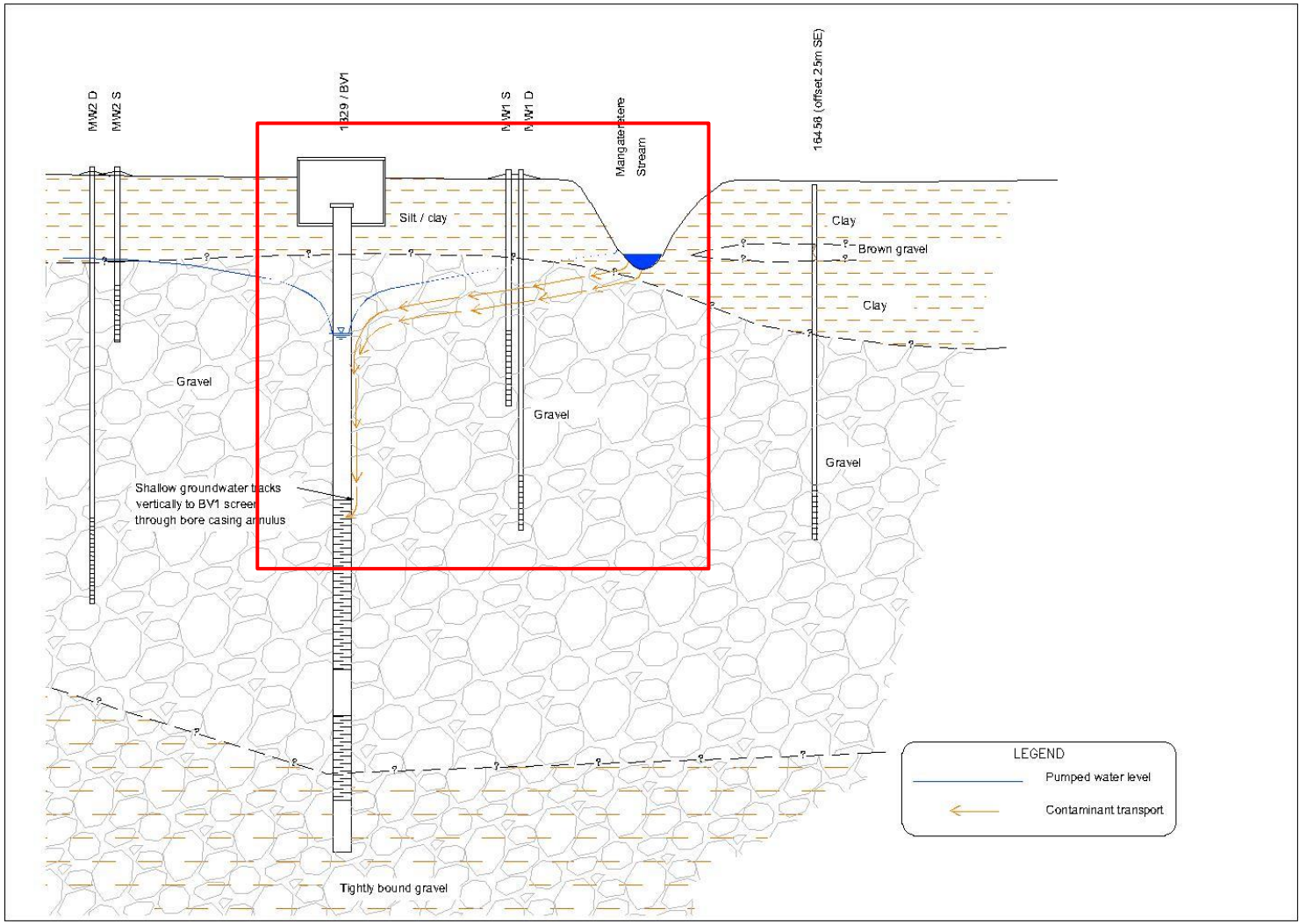
- Within the outbreak timeframe to match epidemiology and have caused the outbreak
- Concentration of > 5 MPN/100ml such that caused the outbreak (Dr Brent Gilpin, ESR’s estimate)
- Pathogenic micro-organisms were frequently recorded in the monitoring bores, and including *E. coli*, *Campylobacter* total coliforms. O157:H7 recorded during the tracer tests.



Revised hydrogeological model

Refined hydrogeological model – inputs to numerical model for the Te Mata aquifer.

- Likely a direct hydraulic connection between Mangateretere Stream ponded area and the source aquifer for Bore 1
- Very high hydraulic conductivity
- 95m separation with preferential flowpaths
- Initial modelling suggest a travel time in groundwater in the order of 1-2 days



Groundwater modelling (Dr Mark Gyopari / T+T)

- Groundwater numerical modelling using MODFLOW and MODPATH
- Modelling results indicated a 1-2 day travel time between the Mangateretere Stream and Bore 1
- Contaminant fate & transport indicated *Campylobacter* survival
- Supported by ESR (Dr Brent Gilpin)

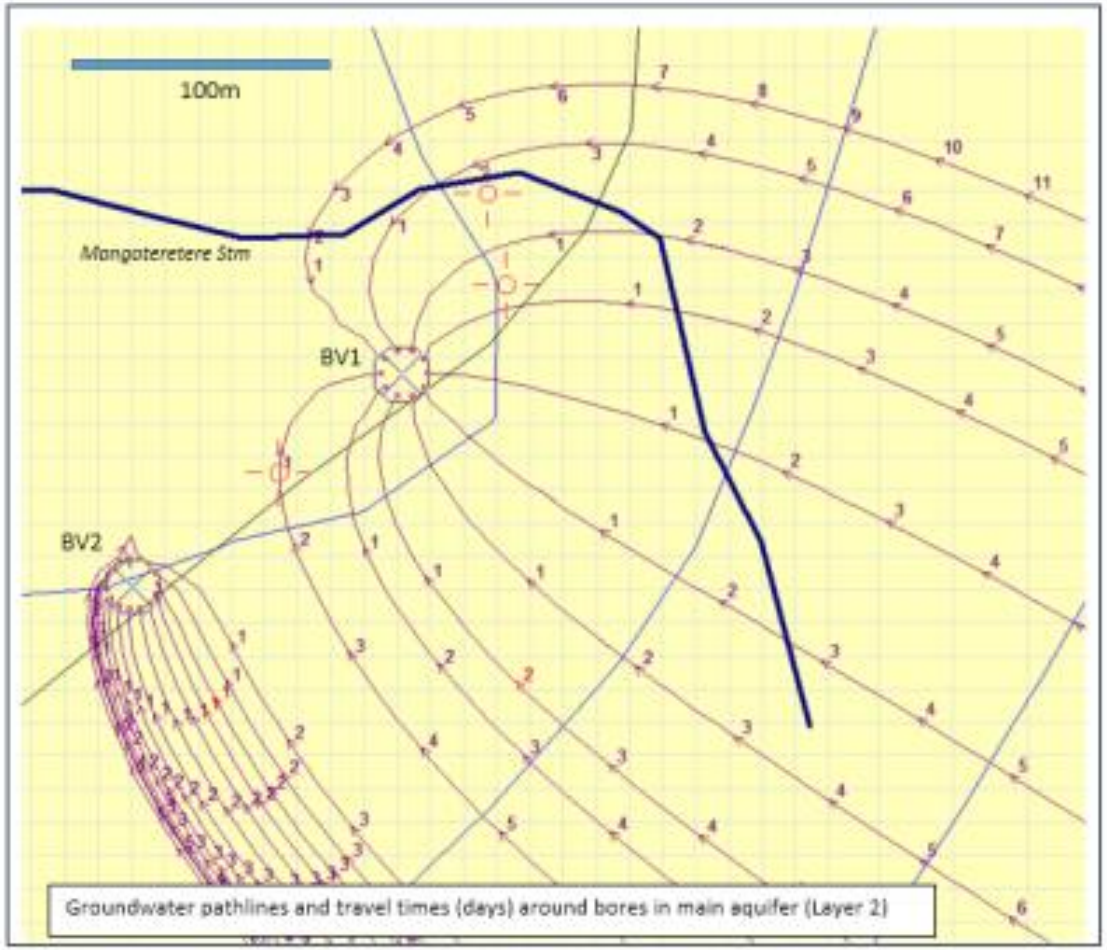


Figure 16: Simulated path lines and captures zones and travel times for BV1 and BV2 using an effective porosity of 0.02. BV 1 pumping at 90 L/sec, BV2 pumping at 15 L/sec.

Second dye tracer test

- Second dye tracer test undertaken to correct deficiencies in 1st test
- Undertaken in January 2017, with the following refinements:
    - Water levels in pond raised to approximately 18.08mRL - replicate outbreak conditions in August 2016
    - Greater mass of fluorescein dye (8kg) was used
    - Pumping regimes (BV1 and BV2) synchronised to commence 5-6 August 2016 rainfall through to outbreak
    - Testing of a range of parameters including *E. coli, Campylobacter*, total coliforms


Dye Injection
Brookvale Bore 1
Approx. 95m

Rhodamine tracer

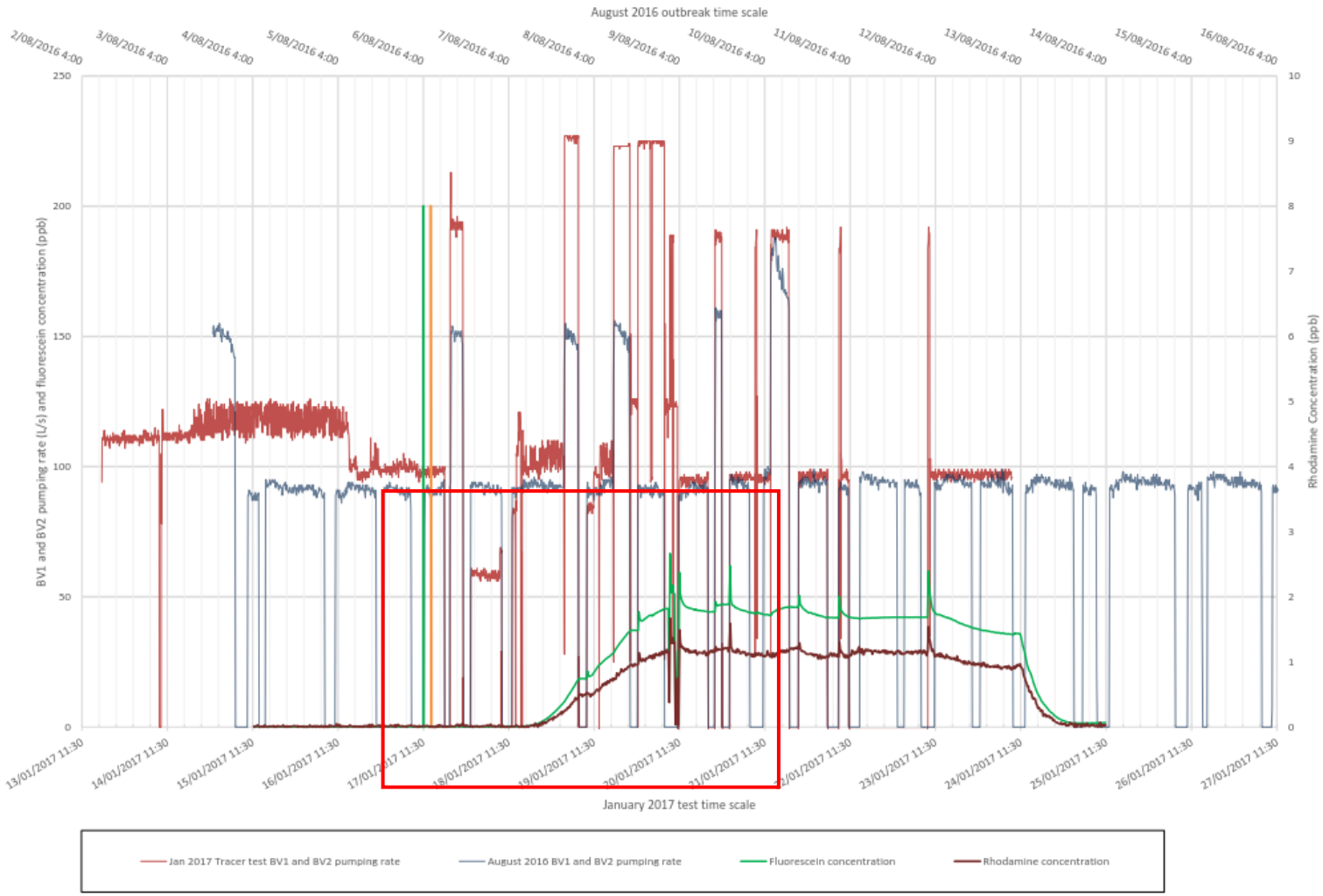
- Rhodamine WT dye was used to assess a potential contaminant migration pathway adjacent the BV1 bore head
- Concurrent with the fluorescein dye tracer test in the Mangateretere pond.
- No clear evidence of pathway from the surface to the bore screen

Results of tracer test

Fluorescein dye first appeared in Bore 1 approximately 29 hours after injection into the Mangateretere pond.

Strongly supported by contaminant data, including:

- *E.coli*
- *Campylobacter*
- *Total coliforms*
- O157:H7 pathogenic *E.coli* strain



High level float switch operation

- Focus on float switch cable attachment - critical
- MWH Bore Head Security Report (2014) - float in exactly the same position as 2016
- No interference with the float cable between 2014 and 6 September 2016
- Inquiry accepted that high level float switch had likely operated as required

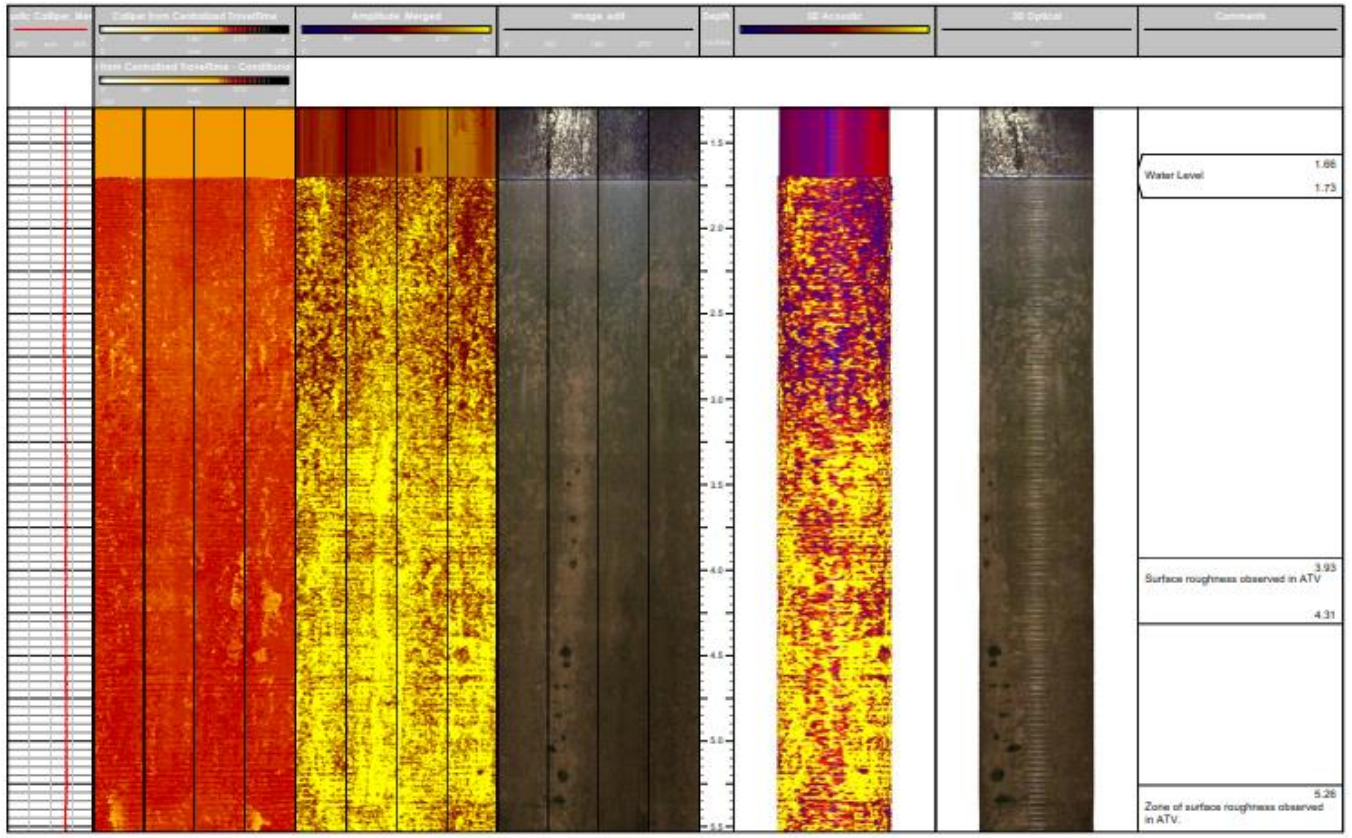
Bore / casing assessments

- Bore 1: 1982 – 2017 (35 years)
- Electrolysis nodulation – top of lower screen (nearby transformer)
- Condition of pump string and pump – reflective of 10 years (replacement).

Casing Inspections – geophysical assessments / video camera

Downhole geophysical data indicate:

- The as-built record of construction (drillers log) is accurate
- No evidence of perforation (hole) in the casing, or significant void behind the casing wall
- Evidence suggests casing performing as designed



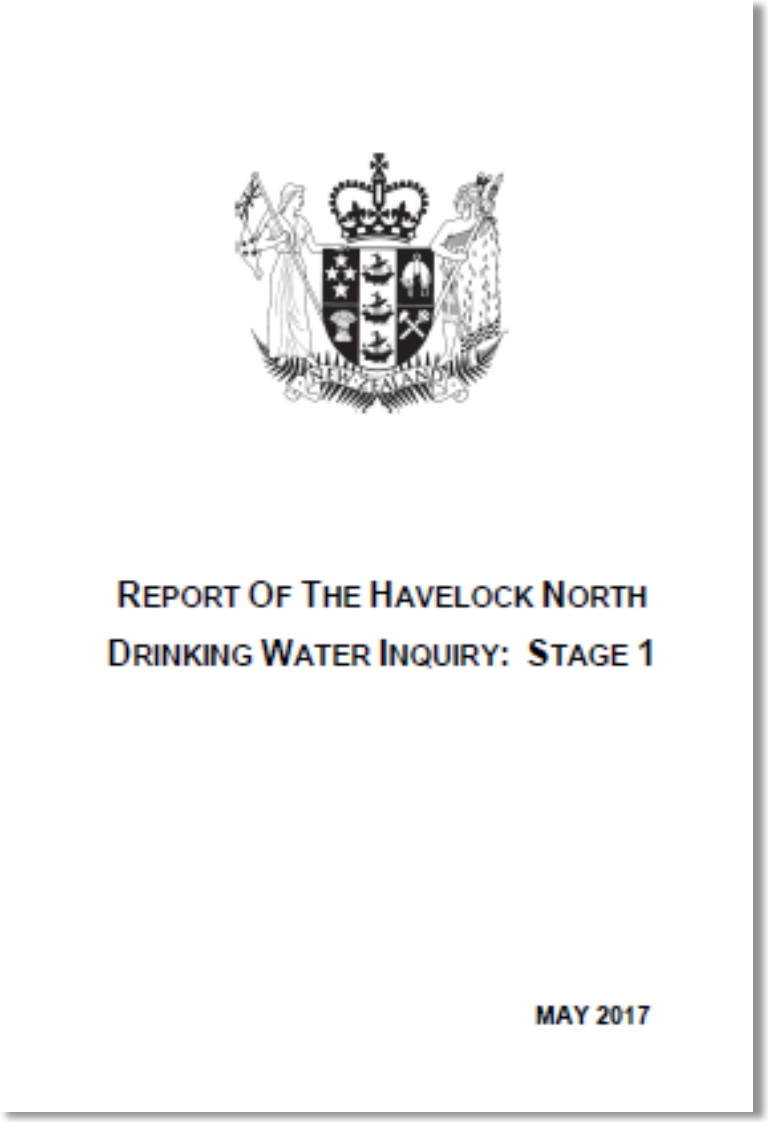
Havelock North Drinking Water Inquiry – Stage 1 report key findings (s10)

(a) Contaminated drinking water was the source of the campylobacter bacterium. Sheep faeces were the likely source of the campylobacter.

(b) Highly likely that after heavy rain on 5 and 6 August 2016, contaminated water in the pond entered the aquifer and flowed across to Brookvale Road bore 1.

(c) Contamination may also have entered drains adjacent to Brookvale Road bores 1 and/or 2, but much less likely.

REPORT OF THE HAVELOCK NORTH DRINKING WATER INQUIRY: STAGE 1, May 2017



Implications for Water Supply

- Compliance with DWSNZ 2005 (2008)
- Secure groundwater confirmation by age-tracer analysis (GNS) in 2011
- 2016 minimum and mean residence time – significantly lower than 2011 results (which confirmed GW was not secure by definition with proportion of young fraction (< 1 year) to be greater than 0.005%)
- Chemical data in the aquifer suggesting the influence of surface water in the aquifer

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Table 4.1 Groundwater mean residence time (MRT) and young fraction (i.e., water less than one year old).

Well name	Exponential mixed flow %	MRT [years]	Minimum residence time [years] [2]	Young Fraction <0.005%
Waipatiki	50	115	58	Yes
Whirinaki	72	10	2.8	Yes
Omahu	50	0.2	0.1	No
Portsmouth Road	19	2.1	1.7	Yes
Wilson Road	56	2.1	0.9	No
Pakipaki	71	149	43	Yes
Parkhill	BMM [1]	20.8	3.3	Yes
Beach Rd, Haumoana	53	73	34	Yes
Tucker Lane, Clive	BMM [1]	26.6	5.4	Yes
Ferry Road, Clive	BMM [1]	34.1	5.0	Yes
Whakatu	BMM [1]	29.9	2.0	Yes
Waipatu	BMM [1]	29.9	2.0	Yes
Brookvale No.1	BMM [1]	4.3	0.1	No
Lyndhurst No.5	50 BMM [1]	5 9.0	2.5 1.0	Yes No
Eastbourne No.5	BMM [1]	25.0	2.4	Yes

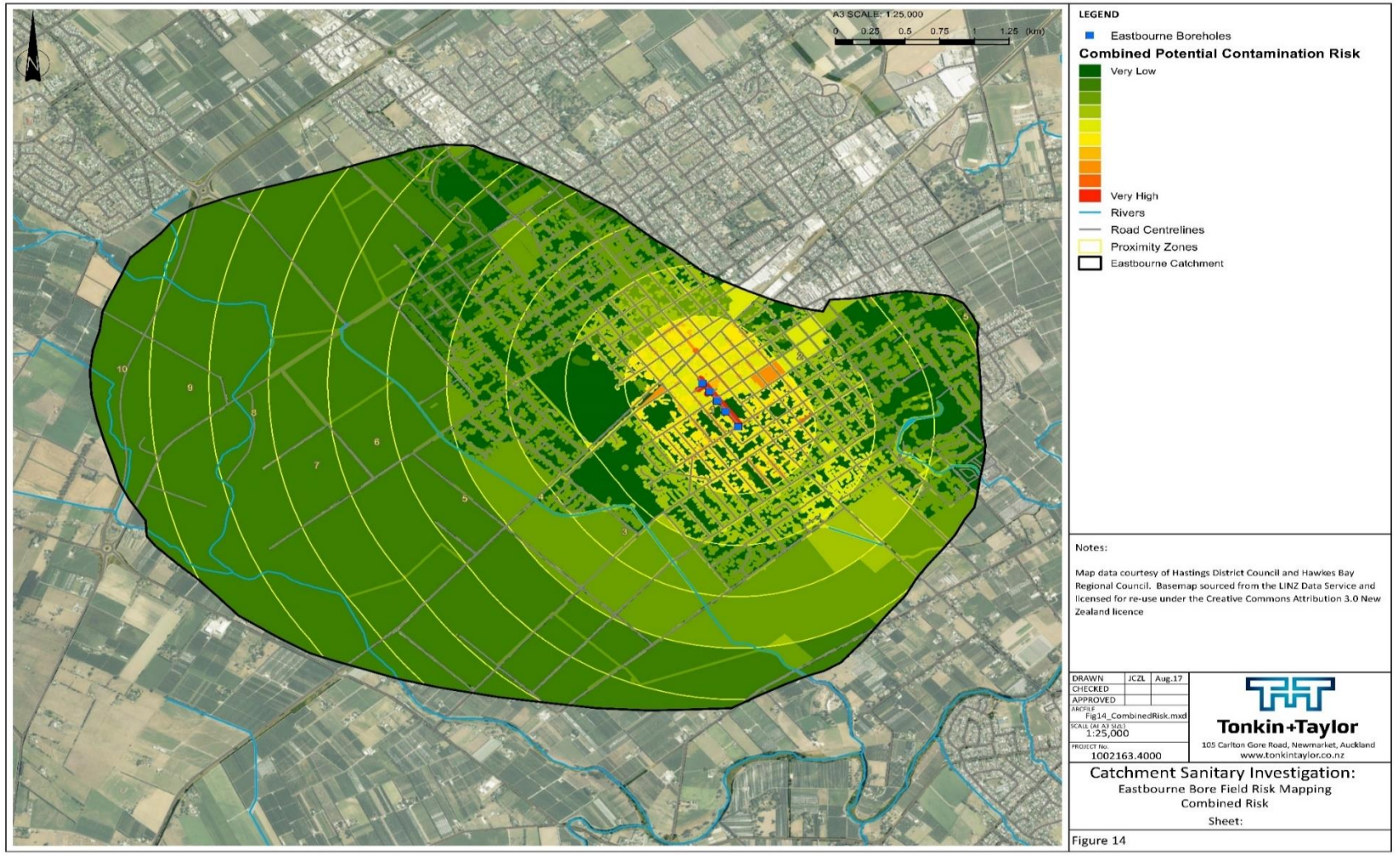
1. BMM denotes a binary mixing model.
2. Minimum residence time is the age of the youngest water present in the well outflow. Values in red indicate non-compliance with the DWSNZ:2005 residence time criterion.

Inquiry Stage 2 - implications

- Water Safety Plans enhanced – risk-based, multiple barrier approach
- Critical control points / Process control summaries
- Enhanced compliance testing
- Source Protection Zones / Catchment risk profiling
- Drinking Water Assessors / Operators – competency/training
- Treatment mandatory in some circumstances
- Secure groundwater definition

Risk based Source Protection zones

- Catchment Sanitary Investigation (CSI)
- Source protection zone (SPZ)
- Identify existing land uses and activities that may pose a risk to drinking water safety
- Develop risk matrix
- Heat map of cumulative risk
- Tool to allow HDC and HBRC to implement statutory controls to manage activities within each bore catchment, commensurate to the level of risks posed to the drinking water supplies



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- Tonkin + Taylor consultancy staff