BEFORE ENVIRONMENT SOUTHLAND

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of Lorneville Processing Plant Resource Consent Applications (APP-20158595)

STATEMENT OF EVIDENCE OF PETER CALLANDER ON BEHALF OF ALLIANCE GROUP LIMITED

4 July 2016

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QUALIFICATIONS AND EXPERIENCE

1 My full name is Peter Francis Callander.

2 I am an environmental scientist and a Director of the environmental Consultancy Pattle Delamore Partners Limited (**PDP**). I have over 25 years of experience specialising in groundwater and surface water resources. Prior to my employment at PDP, I had been employed for seven years by the Canterbury Regional Council and its predecessor the North Canterbury Catchment Board. These organisations are now known as Environment Canterbury (**ECan**).

3 I hold the qualifications of BSc (Geology) from the University of Auckland and MSc (Earth Sciences) from the University of Waterloo (Canada). I am a member of the New Zealand Hydrological Society and the USA based National Ground Water Association. I have particular experience in the management of water resources with a specialisation in groundwater. I completed the MfE Commissioner Training Course, "Making Good Decisions" in 2008 and the recertification course in 2012. From time to time I am appointed to hearing panels dealing with consent applications for groundwater abstraction and wastewater discharges to land and to surface waterways.

4 I have been involved in the following relevant investigations and studies:

(a) The management of water resource assessments and investigations for public water supplies and irrigation schemes;

(b) Assessments of contamination issues and management of a range of Assessment of Environmental Effects technical reports and consultation with affected parties; and

(c) Management of the consent applications through the regulatory hearings process.

5 I have visited the Alliance Lorneville processing plant (referred to hereon as "**the Plant**") and am familiar with the site and its surroundings.

6 In preparing this evidence I have reviewed:

(a) The reports and statements of evidence of other experts giving evidence relevant to my area of expertise, including:

(i) The technical report dealing with current and proposed wastewater management at the site (titled *Biosolids Land Disposal Assessment*);

(ii) The technical report detailing the additional groundwater investigations undertaken at the site (titled *Groundwater and Surface Water Monitoring at Alliance Lorneville*); and

(iii) The evidence of Azam Khan.

(b) The Section 42 Officers' Report and the evidence of Rob Potts.

7 I have read and agree to comply with the Code of Conduct for Expert Witnesses (Environment Court Practice Note 2014). This evidence is within my area of expertise except where I state that I am relying on facts or information provided by another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

SCOPE OF EVIDENCE

8 My evidence addresses the following matters:

(a) The potential for seepage from the lagoon-based wastewater treatment plant (**WWTP**) to affect groundwater to the south and east of the WWTP; and

(b) The investigations undertaken to measure groundwater levels, and flow direction, water quality and hydraulic conductivity.

EXECUTIVE SUMMARY

9 On the basis of the information I have reviewed and the assessments carried out, I have come to the following conclusions:

(a) The strata beneath the plant comprises surface soils, silts and clay to depths of up to 2 metres (**m**), underlain by predominately gravel and sand with minor amounts of silt. The thickness of the strata varies from less than 5 m up to 30 m and is underlain by low permeability lignite measures;

(b) Groundwater investigations for this assessment have involved the drilling and installation of five new groundwater monitoring bores, two piezometric surveys and two groundwater and surface water quality monitoring rounds;

(c) Groundwater levels in the monitoring bores were measured around 0.8 – 1.4 m below ground level (**m bgl**) in bores close to the Makarewa River and 2.0 – 4.1 m bgl in bores located at higher elevations. Slug tests indicate that the gravelly strata is relatively permeable with hydraulic conductivities ranging between 4 – 33 m/day;

(d) Water level monitoring at the plant shows that groundwater moves in a general south-westerly and westerly direction away from the main processing plant due to drainage effects from Boiler Ditch, Bateman's Drain and the Makarewa River;

(e) Water level monitoring showed that tidal fluctuations occur in the Makarewa River and lower reaches of the Boiler Ditch which induce a subdued tidal response in adjacent groundwater levels. The fluctuations in groundwater levels from the tidal response result in localised variations in groundwater flow direction. Groundwater levels in the vicinity of the wastewater treatment lagoons are lower than the typical level of wastewater in the lagoons;

(f) Groundwater and surface water samples collected for chemical characterisation generally showed similar characteristics between the monitoring bores and surface water monitoring sites with the exception of some localised variations in particular parameters;

(g) Samples from Bateman's Drain and Boiler Ditch (above the wastewater discharge into Boiler Ditch) show similar characteristics to groundwater in the monitoring bores located in the eastern area of the Plant. Samples from these sites indicate a more aerobic environment; and

(h) The absence of elevated concentrations of various parameters in monitoring bores BHB and BHC immediately to the south of the wastewater treatment lagoons indicates no obvious groundwater effects from the wastewater lagoons were occurring at the time of sampling.

10 The chemical characteristics of one groundwater sample from BHD, located further south of the treatment lagoons and close to the Makarewa River indicated higher concentrations of several chemical species relative to nearby monitoring bores BHB and BHC. The chemical signature of BHD does not match the wastewater treatment lagoon discharge and it is

expected that the elevated concentrations in the monitoring bore are due to naturally occurring anaerobic hydrogeologic conditions:

(a) Based on the results of the groundwater level measurements and groundwater sampling, discharges from the wastewater treatment lagoons were not affecting groundwater to the south and east of the WWTP at the time of the monitoring undertaken. Consequently it can be expected that any leakage from the lagoons is migrating directly to the Makarewa River or to Boiler Ditch; and

(b) Modelling of the proposed application of biosolids to the grazed pasture indicate that nitrate leaching rates will be within the expected range of leaching from a typical sheep grazed pasture within New Zealand and are not expected to result in an adverse effect on groundwater at the Plant greater than background nitrogen leaching.

WASTEWATER TREATMENT PLANT

11 The wastewater treatment plant consists of a series of ponds or lagoons sited in abandoned channels of the adjacent Makarewa River, as described in the evidence of Azam Khan.

12 The current wastewater treatment lagoons at the Plant are not lined and as a result, there is a possibility that leakage of wastewater from the lagoons to groundwater may be occurring. However, the build-up of a sludge layer at the base of the lagoons will lessen any such leakage.

13 Additional groundwater investigations at the Plant were undertaken to determine the effects of any potential leakage of wastewater from treatment lagoons to groundwater that may affect other groundwater users.

14 Treated wastewater from the plant is discharged into the Makarewa River via Boiler Ditch. Currently, additional wastewater management practices involve irrigation of wastewater to parts of the sheep grazed pasture surrounding the Plant.

15 Following the upgrade of the wastewater treatment plant, wastewater irrigation will cease and biosolids will be applied to parts of the surrounding sheep grazed pasture.

16 The current irrigation of wastewater or the proposed application of biosolids to sheep grazed pasture has potential to leach nitrates into the shallow groundwater system beneath the Plant.

17 Onsite measurements and modelling of nitrate leaching rates from the irrigation of wastewater to sheep grazed pasture at the plant are comparable to background leaching rates measured from unirrigated sheep grazed pasture at the Plant.

HYDROGEOLOGIC SETTING

18 The AGL Plant is located on gently undulating topography formed by highly weathered fluvio-glacial outwash of Quaternary period (within the last 1.8 million years). The fluvio-outwash deposits comprise quartz gravel within a weathered clay matrix with varying quantities of silt and sand. The thickness of the strata varies from around 5 m up to 30 m. The greatest thicknesses generally occur beneath the ridges in the undulating topography (Environment Southland, 2014).

19 Underlying the Quaternary deposits are the older, Tertiary Gore Lignite Measures which were deposited between 65 million and 2 million years ago. The Gore Lignite Measures typically consist of low permeability carbonaceous and non-carbonaceous mudstones, lignite seams, sandstones and conglomerates (Turnbull and Allibone, 2003).

20 The groundwater table surface in the shallow Quaternary strata generally follows a pattern that mimics the topographic surface. Groundwater levels are typically close to the surface near streams and rivers but can occur at deeper depths beneath the intervening ridges in the undulating topography. Local variations in the water table can occur close to pumping bores and/or surface waterways and drainage channels.

21 Groundwater recharge in the shallow Quaternary strata is almost solely from rainfall infiltration. Environment Southland (2014) estimate recharge from rainfall infiltration for the area to be around 436 mm/yr. Much of the shallow strata are covered by a network of artificial subsurface drains and surface drainage channels. As a result, a significant proportion of the rainfall that infiltrates into the soil may be intercepted and discharged into surface water courses before it reaches the underlying groundwater table. Notwithstanding that interception, many small streams in the area are fed by groundwater where they occur at a lower elevation than the adjacent groundwater table.

22 A number of bores exist in the area surrounding the AGL Plant and are mostly shallow (<20 m deep with the exception of a few deeper bores used for geological investigation). Figures 1a and 1b show the location of the existing bores within 3 km of the AGL Plant based on their yield and use respectively.

23 Environment Southland (2014) report low yields from bores within the shallow Quaternary strata and the uses including domestic, stockwater and small scale irrigation generally reflect this. Groundwater resources are also present in the underlying Gore Lignite Measures although they are poorly defined and typically low yielding.

24 The AGL Plant is located within the Makarewa Groundwater Zone as defined by Environment Southland and the allocation status of the Makarewa Groundwater Zone is 'low', implying there is groundwater resource available for allocation in the area.

GROUNDWATER MONITORING BORES

25 To complement the existing bores in the area used by AGL to monitor groundwater levels and groundwater quality, five additional monitoring bores were installed by McNeill Drilling between 4 and 5 November 2014.

26 The locations of the bores are displayed in Figures 2a and are labelled BHA, BHB, BHC, BHD and BHE.

27 All five additional monitoring bores are 50 mm diameter PVC piezometers and were installed between depths of 5.7 and 8.4 m bgl.

28 The purpose of the monitoring bores was to determine groundwater flow directions to the south and east of the waste water treatment lagoons and the bores were used to collect groundwater samples.

29 Borelogs for the five bores indicate alluvial gravels and sands with varying amounts of silt between approximately 3.8 and 5.3 m.

30 The more permeable sediments are overlain by less permeable silts and clays up to 2 m thick, in particular at the area to the south of the wastewater treatment lagoons.

31 A cap of top soil between 0.2 and 0.8 m thick overlies the less permeable silt and clay strata.

HYDRAULIC CONDUCTIVITY

32 To provide an estimate of in situ hydraulic conductivity of the shallow strata beneath the Plant, slug tests were undertaken in groundwater monitoring bores BHA, BHB, BHC, BHD and BHE on 11 December 2014 by PDP. Slug tests provide an estimate of the hydraulic conductivity of the strata occurring locally around each bore.

33 Two rising head and falling head tests were undertaken in each bore. Water levels were measured using pressure transducers installed in each bore recording changes in water pressure at 1 second intervals.

34 Hydraulic conductivities were calculated from the slug test data using the Bouwer and Rice (1976) method.

35 The results indicate that that average hydraulic conductivity is around 20 m/day with a range of around 4 m/day to around 30 m/day.

36 The range in hydraulic conductivities is likely due to the depositional environment of the shallow strata and indicates that some bores may intersect lenses of high permeability material.

37 The slug tests represent the strata surrounding the screened section of each bore which are typically around 6 m long.

38 Therefore, transmissivity of the tested strata could be estimated to be around 60 m^2/day, which is relatively low and reflects the silty strata within the gravels.

GROUNDWATER LEVELS AND FLOW DIRECTION

39 Piezometric surveys of groundwater levels and surface water levels were undertaken by PDP and Bonisch Environmental on 9 December 2014 and again by PDP on 19 March 2015.

40 The purpose of the surveys was to determine the direction of shallow groundwater flow across the Plant and how the shallow groundwater system interacts with surface water ways including the wastewater treatment lagoons. The March 2015 survey was timed to target minimum groundwater and surface water levels in the area.

41 Groundwater levels were measured in the nine bores (the five monitoring bores, two bores monitored by AGL and two neighbouring private bores located off the Plant site) and surface water levels were measured at

twelve surface water sites which included four sites in the wastewater treatment lagoons.

42 All water levels measured during the surveys were converted to water level elevations relative to local mean sea level for the area which is the Bluff 1955 Datum. Spatial coordinates were also recorded during the survey.

43 Indicative groundwater contours for each piezometric survey are shown in Figures 2a and 2b.

44 The groundwater contours from both the December 2014 and March 2015 surveys show a general south westerly flow direction from the main processing plant which appears to be influenced by Bateman's Drain.

45 West of Bateman's Drain, groundwater flow has a more westerly flow component which appears to be influenced by drainage of groundwater into Boiler Ditch and Makarewa River.

46 Surface water levels are generally lower than the levels in nearby surrounding groundwater monitoring bores with the exception of some variations caused by tidal influences.

47 Flow gauging of Bateman's Drain confirmed the drainage effect of this surface water way on shallow groundwater flow. Flow gauging at two sites in Bateman's Drain was undertaken on 9 December 2014 and showed that the drain gained flow by approximately 4 L/s along a 560 m reach of the drain from the shallow groundwater system.

48 Water levels measured during the March 2015 survey were lower than the levels measured during the December 2014 survey. Water levels during the December 2014 survey were around 0.5 m higher towards the Makarewa River and around 1 m higher at the eastern extent of the survey area compared to the March 2015 piezometric survey.

49 At all times, the water levels in the wastewater lagoons were higher than surrounding groundwater levels.

50 The section of Makarewa River that flows past the AGL Plant is tidally influenced. Groundwater levels near Makarewa River and surface water levels in Makarewa River and Boiler Ditch were monitored to determine the influence of tidal effects.

51 Continuous water level measurements using automated electronic pressure transducers were used to record fluctuations in groundwater levels in monitoring bores BHC and BHD and surface water level fluctuations in Boiler Ditch (BD3) and Makarewa River (MR1) to determine the influence of tidal fluctuations. Water levels were measured at 15 minute intervals for the period between 8 December 2014 and 11 December 2014. Figure 3 shows the tidal fluctuations monitored at the Plant during this period as well as the tidal data recorded at Bluff for the same period.

52 Water levels in Makarewa River displayed a full range of tidal fluctuation, approximately half of the amplitude that occurred at sea.

53 Boiler Ditch maintained a base flow at approximately 0.8 metres above mean sea level (**m amsl**) but rises above that for the higher part of the tidal cycle to match the Makarewa River when water levels in these two water ways are above 0.8 m amsl.

54 Groundwater levels in BHC and BHD show a subdued response to tidal fluctuations in both the Boiler Ditch and Makarewa River.

55 During the continuous monitoring period, groundwater levels in BHC were higher than BHD. Water levels in both bores were at a higher elevation than nearby surface water levels with the exception of a short period at the highest tidal peak in the Makarewa River.

56 As a result of the tidal fluctuations, mean surface water levels will likely provide the main influence on groundwater levels. The data shows that groundwater levels are higher than average levels in both the Boiler Ditch and Makarewa River indicating that groundwater will typically flow towards those surface water ways.

GROUNDWATER AND SURFACE WATER QUALITY

57 To check for any effect from the AGL wastewater treatment lagoons on surrounding groundwater quality, samples were collected from five groundwater monitoring bores and five surface water sites. Figure 4 shows the locations of the sites.

58 Groundwater and surface water samples were collected by PDP on 10 December 2014 and 18 March 2015.

59 Groundwater samples were collected using a bailer dedicated to each bore during the December 2014 sampling round and a small submersible

electric pump with dedicated downhole tubing for each bore during the March 2015 sampling round. The submersible pump allowed dissolved oxygen (**DO**) and oxidation / reduction potential (**ORP**) to be measured during the March 2015 round in the field during purging and sampling of the monitoring bores.

60 Field measurements of pH, electrical conductivity and temperature were recorded at each surface water sampling site during both sampling rounds. Field DO and ORP measurements were also recorded during the collection of samples during the March 2015 sampling round.

61 All surface water samples were collected around low tide to lessen any localised influence from surface waterways.

62 The sampling of Boiler Ditch (BD3 and BDA) during both sampling rounds occurred when controlled wastewater discharge from the wastewater lagoons into Boiler Ditch was occurring.

63 Groundwater quality results for the December 2014 and March 2015 sampling rounds are displayed in Tables 1 and 2 (**Appendix A**) respectively.

64 Surface water quality results for the December 2014 and March 2015 sampling rounds are displayed in Tables 3 and 4 (**Appendix A**) respectively.

65 Surface water quality results show that site BD3 in Boiler Ditch had the highest concentrations of most chemical parameters during both sampling rounds due to its location downstream of the controlled wastewater discharge point from the lagoons. BD3 had much higher total ammoniacal-N and TKN concentrations during both sampling rounds than BDA located in Boiler Ditch upstream of the wastewater discharge point.

66 BDA had slightly elevated nitrate-nitrogen concentrations compared to BD3 which had low nitrate-nitrogen concentrations.

67 Surface water samples from the Makarewa River show the effect of the wastewater discharge in the river via the Boiler Ditch during both sampling rounds. MR1 (located downstream of the Boiler Ditch confluence and the wastewater lagoons) had elevated concentrations of similar parameters to those from samples at BD3 when compared to the results of MR2 (located upstream of the wastewater lagoons).

68 Bateman's Drain had recorded slightly lower concentrations than other surface water sites but had elevated concentrations of ammoniacal-N and nitrate-N during both sampling rounds. Concentrations of ammoniacal-N and nitrate-N increased at this site between the December 2014 and March 2015 sampling rounds, which may reflect seasonal variations in nitrogen inflow to the stream as well as in-stream processes.

69 Groundwater sampling results from the five monitoring bores were compared against the New Zealand Drinking-water Standards (**NZDWS**) (2005) (Revised 2008).

70 The majority of the parameters analysed from the groundwater quality samples for both sampling rounds were generally below their respective maximum acceptable value (**MAV**) and/or guideline value (**GV**) with the exception of both field pH and laboratory pH which were below the GV range of 7.0 to 8.5 in all five bores during both sampling rounds and manganese occurred above the MAV in three bores and the GV in one additional bore.

71 Low pH is a natural occurrence that is not uncommon in many shallow groundwaters in New Zealand that receive recharge from rainfall infiltration through soils.

72 High total suspended solid concentrations (>3000 g/m^3) were recorded in all bores during the December 2014 sampling round. Total suspended solid concentrations in all bores were significantly lower (<1,100 g/m^3) during the March 2015 sampling round. The difference in total suspended solid concentrations is likely to be due to the difference in sampling methods between each sampling round. A submersible pump provides a constant abstraction whereas a bailer causes a degree of disturbance in the bore as it is lowered into the bore and pulled out. Furthermore, the initial sampling round would have helped to develop the bores and remove some of the loose sediment adjacent to the screen.

73 The results of both groundwater sampling rounds indicate that the groundwater samples generally show similar composition with the following exception of BHE (lower bicarbonate and alkalinity than the other bores), BHA (higher nitrate than the other monitoring bores) and BHD (higher concentrations of bicarbonate, hardness, manganese and sulphate).

74 Ammoniacal-N was detected at low concentrations (<0.2 g/m³) in all bores with the exception of BHE in which Ammoniacal-N was not detected.

75 Nitrate-nitrogen was detected in monitoring bore BHA and BHE at concentrations up to 5.2 mg/L during both sampling rounds. Nitrate-N was not detected in BHB, BHC and BHD. The presence or lack of nitrate-nitrogen is indicative of oxidising (nitrate-nitrogen present) or reducing environments (ammoniacal-N present). Nitrogen species is converted to nitrate-nitrogen in oxidising conditions and to ammoniacal-N in reducing conditions.

76 The chemical characteristics in the groundwater bores do not match the chemical characteristics of the wastewater. This indicates that the groundwater to the south and east of the wastewater ponds is not affected by leakage or discharge of wastewater to the Boiler Ditch. If any leakage from the ponds is occurring it can be expected to discharge to the Makarewa River or to Boiler Ditch.

77 The results of the December 2014 and March 2015 sampling rounds were also used for major ionic chemical analysis to determine different water types at the Plant.

78 Stiff plots and equivalents analysis were used to analyse the major ionic water chemical data.

79 Stiff plots display the pairs of major cations and anions on individual horizontal axes with all major cations on one side and the anions on the other. The ionic concentrations for each cation and anion are plotted in units of milliequivalents per litre and a polygonal shape is created that will be indicative of that particular water sample.

80 Figures 5a and 5b (**Appendix B**) display Stiff plots for all sample sites for the December 2014 and March 2015 sampling rounds respectively. The colours represent the type of sample (i.e. groundwater or surface water).

81 Based on their shape, Stiff plots can be grouped, providing an indication of a common water source. The Stiff plots in Figures 5a and 5b are grouped based on shape and the groups are summarised in Table 5 below.

Table 5: Stiff Plot Groups Based on Shape		
Group	**Bore Number/Surface Water Sample Site**	**Dominant Water Source**
Group 1	BD3	Wastewater from treatment lagoons
Group 2	MR1 and MR2	Makarewa River
Group 3	BHA, BHE, BDA and S4	Shallow groundwater and surface water receiving significant input from that shallow groundwater
Group 4	BHB, BHC and BHD	Western shallow groundwater

82 Group 1 is dominated by discharge from the wastewater treatment lagoons into Boiler Ditch and has elevated concentrations, particularly of bicarbonate, sodium, potassium, chloride and ammoniacal-nitrogen, as a result of the discharge.

83 Group 2 (Makarewa River sites MR1 and MR2) are dominated by sodium, potassium, bicarbonate and carbonate with a secondary component of calcium and chloride.

84 Group 3 consists of BHA, BHE, BDA and S4. Stiff plots for these bores and surface water sites indicate groundwater to the east and south east of the wastewater treatment lagoons is generally of similar ionic chemistry and that the Boiler Ditch (above the wastewater treatment lagoons) and Bateman's Drain receive inflows from the shallow groundwater system.

85 Group 4 consists of BHB, BHC and BHD which have less of a chloride component when compared to the groundwater bores in Group 3. In addition, BHD has greater sulphate concentration. None of these changes are related to patterns in the Boiler Ditch at BD3 or the Makarewa River as can be seen in the Stiff plots.

86 There are some differences in the water chemistry between BHB, BHC and BHD, although this is most likely to be related to different geological conditions in the strata around these monitoring bores.

87 A further evaluation of the water quality data allows groupings of samples using major ionic data (hydrogeochemical facies) based on their equivalent weight (Rosen, 2001).

88 The molecular weight of each major ionic species is converted from milliequivalent per litre to percentages and grouped to together by listing the ionic species greater than 10 % in decreasing order starting with the cations.

89 The groupings using the equivalents method based on the water quality data from the December 2014 sampling round are outlined in Table 6 below.

Table 6: Stiff Plot Groups Using the Equivalents Method - 10 December 2014

Group	**Bore Number/Surface Water Sample Site**	**Hydrogeochemical Signature**
Group 1	BD3	Na + K, NH_4, Ca – Cl, HCO_3, SO_4
Group 2	MR1 and MR2	Na + K, Ca, Mg – HCO_3, Cl, SO_4
Group 3	BDA and S4	Na + K, Ca, Mg – Cl, HCO_3, SO_4
Group 4	BHB, BHC and BHD	Na + K, Mg, Ca – Cl, HCO_3, SO_4
Group 5	BHA	Na + K, Mg, Ca – Cl, HCO_3
Group 6	BHE	Na + K, Mg, Ca – Cl, SO_4

90 Equivalents method analysis was also applied to the water quality data from the March 2015 sampling round and showed a similar result. The groupings in Table 6 are considered to be representative of both sampling rounds.

91 The equivalents method generally form groupings similar to the groups described using the Stiff plots with the exception of BHA and BHE which form groups of their own as they have different anions in their hydro-geochemical signature (BHA - HCO3, BHE – SO4). With this exception,

the equivalents methods indicate similar chemical signatures to those in Group 4.

92 Based on the water chemistry data, the eastern bores BHA and BHE generally show similar chemistry to surface water (spring-fed) samples BDA and S4 although there are minor variations in concentrations in BHA and BHE.

93 Minor variations in water chemistry between BHB, BHC and BHD are not likely to be due to seepage or controlled discharge from the wastewater lagoons and any differences are most likely reflect changes in the natural hydrogeological environment.

INTERACTION WITH SURFACE WATERWAYS

94 Monitoring data collected to date indicate groundwater levels between the main AGL Plant and the Makarewa River decrease in a general westerly and south westerly direction.

95 Drainage effects caused from surface water ways (Boiler Ditch, Bateman's Drain and the Makarewa River) likely affect groundwater flow at the Plant. Bateman's Drain and the Boiler Ditch are known to be spring–fed and receive shallow groundwater inflows. Groundwater levels in the vicinity of the surface water ways are generally higher than the nearby surface ways.

96 Water levels in BHC and BHD are generally higher than the Makarewa River indicating that the river causes a drainage effect on the local groundwater environment.

97 Based on the groundwater flow directions, monitoring bores BHC and BHD allow for the sampling of groundwater closest to the wastewater lagoons.

98 There is potential for a hydraulic gradient from the Wastewater lagoons toward monitoring bores BHB and BHC, however any significant seepage losses from the lagoons could also be intercepted by Boiler Ditch or would drain directly into the Makarewa River.

99 Groundwater chemistry indicate a generally similar chemistry in the eastern bores (BHA and BHE) and the nearby spring fed streams (Bateman's Drain and the reach of the Boiler Ditch above the wastewater lagoons).

100 All the groundwater bores are dominated by sodium, potassium, magnesium, calcium and chloride, and any differences between bores are likely to be related to localised effects of the variations in the strata and/or nearby land-use.

101 The chemical signature of the wastewater (as indicated by the sample from BD3) does not appear to be present in the groundwater monitoring bores.

102 Based on the information from both the groundwater levels and groundwater chemistry suggests that at the time of the two piezometric surveys and sampling rounds, any seepage from the wastewater lagoons (via seepage and controlled discharge) was primarily directed towards the Makarewa River.

103 Therefore, controlled discharge of wastewater into the Boiler Ditch and any seepage from the wastewater lagoons do not appear to be resulting in an adverse effect on groundwater at the AGL Plant.

104 Regarding the area that has up until recently been used for wastewater irrigation, modelling of the proposed wastewater management practice (i.e. application of biosolids) indicate that nitrate leaching to the groundwater system is within the expected range of leaching rates from a typical sheep grazed pasture in New Zealand, as described in the evidence of Azam Khan.

COMMENTS ON THE COUNCIL SECTION 42A REPORT

105 I have reviewed the groundwater comments in the memorandum prepared by Rob Potts as a part of the Section 42A Officers' Report. Mr Potts concludes that the effects from wastewater irrigation on soils and groundwater have been less than minor and will continue to be minor. He also concludes that the proposed application of WAS is likely to have less than minor effects on soils and groundwater.

106 Mr Potts' memorandum indicates a similar understanding of the groundwater system as described in my evidence. The monitoring data indicates that any leakage from the ponds is not migrating into groundwater to the south and east of the ponds. Consequently if any leakage is occurring it can be expected to seep into the Makarewa River, either directly or via Boiler Ditch. The effects of any such leakage will be demonstrated by the monitoring of the Makarewa River.

107 There are two minor points of difference I have with the comments provided by Mr Potts. In the last paragraph of page 12 of his memo he notes that not all the bores are screened at the water table and that the most concentrated plume from any seepage may not be observed. However I do not think that is likely. There are only two boreholes with slightly deeper screens, BH B and BHD, although at times of low water level the BHD screen does intercept the water table. BHB and BHC are located closest to the WWTP ponds to detect any seepage effects. The water levels in BHB are higher than the surface water level in the adjacent Boiler Ditch. Consequently any seepage from the ponds would be intercepted by Boiler Ditch rather than migrate at a shallower level in the vicinity of BHB.

108 Mr Potts also suggests that ongoing monitoring should be undertaken to confirm the groundwater effects in the vicinity of the ponds, particularly during low flow conditions. I agree that there could be some different monitoring results if lower flow conditions occur but I do not think that requires regular ongoing sampling. Such circumstances could be checked by occasional groundwater monitoring during dry conditions. If groundwater levels declined to particularly low levels, and were lower than the surface water level in Boiler Ditch, that would be a time when a check on groundwater quality could be undertaken and compared to the currently available monitoring data. In my view such an approach would be a more efficient targeted monitoring regime than regular ongoing monitoring.

CONCLUSION

109 The AGL Plant is underlain by silts and clays which is in turn underlain by gravelly strata.

110 Current waste water management practices at the Plant involve the irrigation of wastewater on dedicated sheep grazed pasture areas.

111 Modelling of the proposed application of biosolids to sheep grazed pasture at the Plant will result in nitrate leaching rates comparable to leaching rates expected from sheep grazed pasture in New Zealand. Therefore, the proposed wastewater management practices will not result in an adverse effect on groundwater at the Plant.

112 Wastewater irrigation will cease when the application of biosolids begins.

113 Groundwater levels decrease from east to west due to drainage effects of groundwater into Boiler Ditch, Bateman's Drain and the Makarewa River.

114 Groundwater quality samples from the monitoring bores generally show similar characteristics, with some variations in particular parameters.

115 Sampling from monitoring bores BHB and BHC (closest to the wastewater treatment lagoons) do not show any significantly elevated concentrations or consistent chemical patterns from wastewater in the treatment lagoons.

116 Therefore, controlled discharge of wastewater into the Boiler Ditch and any seepage from the wastewater lagoons do not appear to be resulting in an adverse effect on groundwater at the AGL Plant. Any seepage is expected to enter the Makarewa River, either directly or via Boiler Ditch.

Peter Callander
4 July 2016

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APPENDIX A – TABLES

Table 1: Groundwater Quality Sampling Results collected on 10 December 2014							
Site (Time of Sample Collection)	**BHA** (14:20)	**BHB** (15:40)	**BHC** (16:50)	**BHD** (17:55)	**BHE** (10:25)	**NZDWS GV**	**NZDWS MAV**
Sum of Anions (meq/L)	3.1	1.76	2.1	3.4	1.85	-	-
Sum of Cations (meq/L)	3.3	2	2.3	3.7	1.9	-	-
pH – Laboratory Measurement	**6.7**	**6.6**	**6.5**	**6.8**	**5.9**	7.0 - 8.5	-
pH – Field Measurement	**5.66**	**6.22**	**5.6**	**6.06**	**5.13**	7.0 - 8.5	-
Total Alkalinity (g/m³ as $CaCO_3$)	38	37	49	83	3.8	-	-
Carbonate (g/m³ as $CaCO_3$)	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	-	
Bicarbonate (g/m³ at 25°C)	46	45	60	102	4.6	-	-
Total Hardness (g/m³ as $CaCO_3$)	69	48	50	100	52	200	-
Electrical Conductivity (EC) (mS/m)	34.8	19	21.6	34.4	21.5	-	-
Total Suspended Solids (g/m³)	8,600	4,400	3,000	7,400	6,100	-	-
Dissolved Calcium (g/m³)	13	9	8.3	18.6	8.6	-	-
Dissolved Magnesium (g/m³)	8.9	6.2	7	13	7.3	-	-
Dissolved Potassium (g/m³)	2.1	1.28	1.09	2.1	1.42	-	-
Dissolved Sodium (g/m³)	42	23	29	38	19	200	-
Chloride (g/m³)	60	25	29	34	45	250	-
Total Nitrogen (g/m³)	8.8	1.47	1.13	2.7	4.9	-	-
Total Ammoniacal-N (g/m³)	0.014	0.122	0.013	0.085	< 0.010	1.2	-
Nitrite-N (g/m³)	0.007	< 0.02	< 0.002	< 0.02	< 0.002	-	0.06^{+}
Nitrate-N (g/m³)	4.8	< 0.02	< 0.002	< 0.02	1.98	-	11.3
Nitrate-N + Nitrite-N (g/m³)	4.8	< 0.02	< 0.002	< 0.02	1.98	-	-
Total Kjeldahl Nitrogen (TKN) (g/m³)	4	1.47	1.13	2.7	2.9	-	-
Dissolved Reactive Phosphorus (g/m³)	< 0.004	0.004	< 0.004	< 0.004	< 0.004	-	-
Sulphate (g/m³)	13.3	15.6	14.6	37	17.5	250	-

Notes: New Zealand Drinking-water Standards (NZDWS) 2000 (Revised 2008) guideline value (GV) for aesthetic effects and maximum acceptable value (MAV) for the protection of human health. $^{+}$ *More stringent long term MAV for Nitrite - N. Short term Nitrite - N MAV = 0.91 g/m³.* ***Bold*** *values indicate value outside of GV.*

Table 2: Groundwater Quality Sampling Results Collected on 18 March 2015

Site (Time of Sample Collection)	**BHA** (9:32)	**BHB** (11:51)	**BHC** (13:33)	**BHD** (12:43)	**BHE** (10:31)	**NZDWS GV**	**NZDWS MAV**
Sum of Anions (meq/L)	3.2	2.4	2.5	3.8	2	-	-
Sum of Cations (meq/L)	3.4	2.2	2.6	3.9	2.2	-	-
pH – Laboratory Measurement	**6.4**	**6.8**	**6.7**	**6.8**	**5.8**	7.0 - 8.5	-
pH – Field Measurement	**5.40**	**6.03**	**5.64**	**5.82**	**4.75**	7.0 - 8.5	-
ORP (mV) – Field Measurement	200.1	69.5	152.6	109.1	365.9	-	-
DO (mg/L) – Field Measurement	2.61	0.29	0.39	0.25	8.94	-	-
DO (% Sat.) – Field Measurement	24.3	2.8	3.9	2.3	83.1	-	-
Electrical Conductivity (mS/m) – Field Measurement	39.9	29.4	29.2	42.5	26.1		
Electrical Conductivity (mS/m) – Lab Measurement	36.8	25	26.3	38.6	24	-	-
Total Alkalinity (g/m³ as $CaCO_3$)	38	53	65	94	5	-	-
Bicarbonate (g/m³ at 25°C)	47	64	79	114	6.2	-	-
Total Hardness (g/m³ as $CaCO_3$)	72	45	57	102	57	200	-
Total Suspended Solids (g/m³)	169	48	9	1,100	20	-	-
Dissolved Calcium (g/m³)	13.5	8	10	18.7	7.8	-	-
Dissolved Iron (g/m³)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02		
Dissolved Magnesium (g/m³)	9.3	6.2	7.8	13.4	9.2	-	-
Dissolved Manganese (g/m³)	0.091	0.7	0.97	1.28	0.023		
Dissolved Potassium (g/m³)	1.87	1.16	1.32	2.2	1.82	-	-
Dissolved Sodium (g/m³)	44	27	32	41	22	200	-
Chloride (g/m³)	64	32	31	35	50	250	-
Total Nitrogen (g/m³)	5.3	0.3	< 0.3	0.9	2.4	-	-
Total Ammoniacal-N (g/m³)	0.01	0.116	0.029	0.1	< 0.010	1.2	-
Nitrite-N (g/m³)	0.002	< 0.2	< 0.2	< 0.2	< 0.002	-	0.06^{+}
Nitrate-N (g/m³)	5.2	< 0.2	< 0.2	< 0.2	2.3	-	11.3
Nitrate-N + Nitrite-N (g/m³)	5.2	< 0.2	< 0.2	< 0.2	2.3	-	-
Total Kjeldahl Nitrogen (TKN) (g/m³)	0.15	0.22	0.13	0.79	< 0.10	-	-
Dissolved Reactive Phosphorus (g/m³)	< 0.004	0.109	0.018	0.009	< 0.004	-	-
Sulphate (g/m³)	14.6	19.9	18	43	17.5	250	-

*Notes: New Zealand Drinking-water Standards (NZDWS) 2000 (Revised 2008) guideline value (GV) for aesthetic effects and maximum acceptable value (MAV) for the protection of human health. $^{+}$ More stringent long term MAV for Nitrite - N. Short term Nitrite - N MAV = 0.91 g/m³. **Bold** values indicate value outside of GV. DO – Dissolved Oxygen and ORP – Oxidation/Reduction Potential*

Table 3: Surface Water Quality Sampling Results Collected on 10 December 2014

Site (Time of Sample Collection)	**MR1** (11:50)	**MR2** (11:30)	**BD3** (12:15)	**BDA** (11:00)	**S4** (8:50)
Sum of Anions (meq/L)	2.5	1.79	12.6	3.4	2.4
Sum of Cations (meq/L)	2.7	1.94	13.3	3.8	2.6
pH – Laboratory Measurement	7.8	7.7	8.1	7.1	7.3
pH – Field Measurement	6.58	6.66	7.43	6.11	6.12
Total Alkalinity (g/m³ as $CaCO_3$)	63	48	260	52	35
Carbonate (g/m³ as $CaCO_3$)	< 1.0	< 1.0	1.9	< 1.0	< 1.0
Bicarbonate (g/m³ at 25°C)	76	58	320	63	43
Total Hardness (g/m³ as $CaCO_3$)	62	56	112	69	59
Electrical Conductivity (EC) (mS/m)	26.3	18.9	133.7	37.7	26.2
Total Suspended Solids (g/m³)	9	4	48	10	< 3
Dissolved Calcium (g/m³)	16.9	15	36	19.3	14
Dissolved Magnesium (g/m³)	4.8	4.6	5.7	5	5.8
Dissolved Potassium (g/m³)	3.1	1.69	25	2.5	2.8
Dissolved Sodium (g/m³)	27	17.5	175	53	30
Chloride (g/m³)	31	19.8	191	60	41
Total Nitrogen (g/m³)	4.4	1.39	43	3.1	4.2
Total Ammoniacal-N (g/m³)	2.6	0.066	39	0.22	0.88
Nitrite-N (g/m³)	0.02	0.016	0.081	0.03	0.067
Nitrate-N (g/m³)	0.87	0.9	0.42	2	2.7
Nitrate-N + Nitrite-N (g/m³)	0.89	0.91	0.5	2.1	2.8
Total Kjeldahl Nitrogen (TKN) (g/m³)	3.6	0.48	42	1.01	1.41
Dissolved Reactive Phosphorus (g/m³)	0.34	0.024	5.2	0.066	0.012
Sulphate (g/m³)	13.1	10	67	27	14.3

Table 4: Surface Water Quality Sampling Results Collected on 18 March 2015

Site (Time of Sample Collection)	**MR1** (14:45)	**MR2** (14:25)	**BD3** (15:05)	**BDA** (14:10)	**S4** (11:00)
Sum of Anions (meq/L)	3.5	1.6	28	13	4.4
Sum of Cations (meq/L)	3.5	1.81	29	12.8	4.6
pH – Laboratory Measurements	7.9	7.8	8.3	7.1	7.2
pH – Field Measurements	7.45	7.23	8.12	6.39	5.68
Oxidation/Reduction Potential - ORP (mV)	136.9	110.6	123.6	86.5	266.9
DO (mg/L) – Field Measurement	8.58	9.68	9.98	3.45	4.14
DO (% Sat.) – Field Measurement	83.3	93.2	101.9	36.6	40.2
Electrical Conductivity (mS/m) – Field Measurement	40.9	20.1	342.4	169.9	53.3
Electrical Conductivity (mS/m) – Lab Measurement	36.8	17.5	283	146.2	50.2
Total Alkalinity (g/m³ as $CaCO_3$)	88	44	700	50	63
Bicarbonate (g/m³ at 25°C)	107	53	840	60	77
Total Hardness (g/m³ as $CaCO_3$)	54	51	144	89	76
Total Suspended Solids (g/m³)	10	5	99	9	5
Dissolved Calcium (g/m³)	14.2	12.7	48	28	17.9
Dissolved Iron (g/m³)	0.26	0.32	0.13	0.58	0.07
Dissolved Magnesium (g/m³)	4.6	4.7	6	4.8	7.6
Dissolved Manganese (g/m³)	0.0012	0.0013	0.099	0.031	0.023
Dissolved Potassium (g/m³)	6.5	1.58	79	2.6	6
Dissolved Sodium (g/m³)	39	16.8	340	250	58
Chloride (g/m³)	43	18.9	360	360	83
Total Nitrogen (g/m³)	9.9	0.76	140	5.2	10.7
Total Ammoniacal-N (g/m³)	8.1	0.026	131	0.74	5.7
Nitrite-N (g/m³)	0.102	0.011	0.78	0.074	0.22
Nitrate-N (g/m³)	0.57	0.33	0.47	2	4.4
Nitrate-N + Nitrite-N (g/m³)	0.67	0.34	1.25	2.1	4.6
Total Kjeldahl Nitrogen (TKN) (g/m³)	9.2	0.42	139	3.2	6.1
Dissolved Reactive Phosphorus (g/m³)	0.97	0.03	14.7	0.43	0.184

APPENDIX B – FIGURES

FIGURE 1A

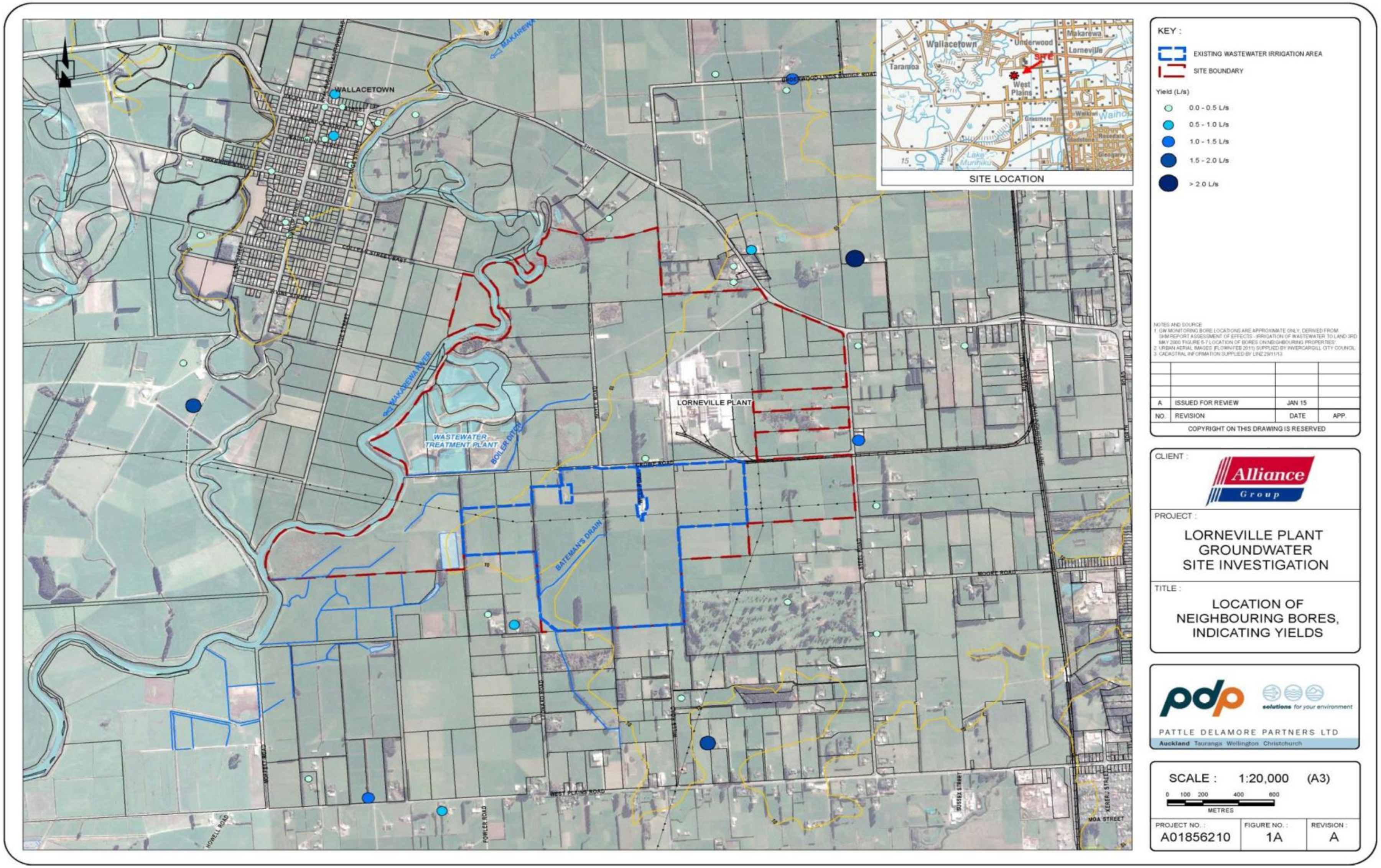

Figure 1a: Map showing location of yields of neighbouring bores neighbouring and surface water ways.

FIGURE 1B

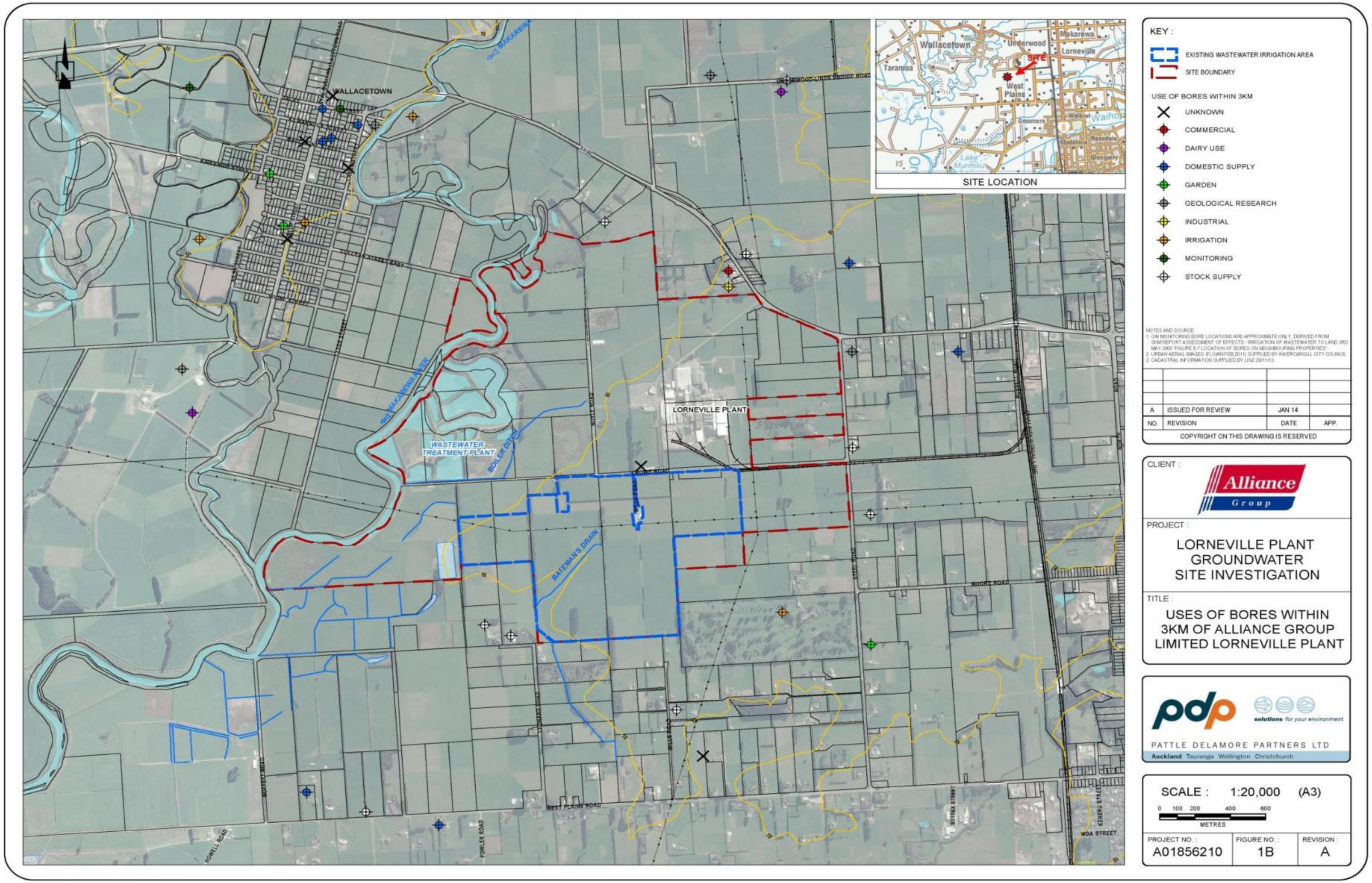

Figure 1b: Map showing the uses of neighbouring bores within 3 km of the AGL Plant

FIGURE 2A

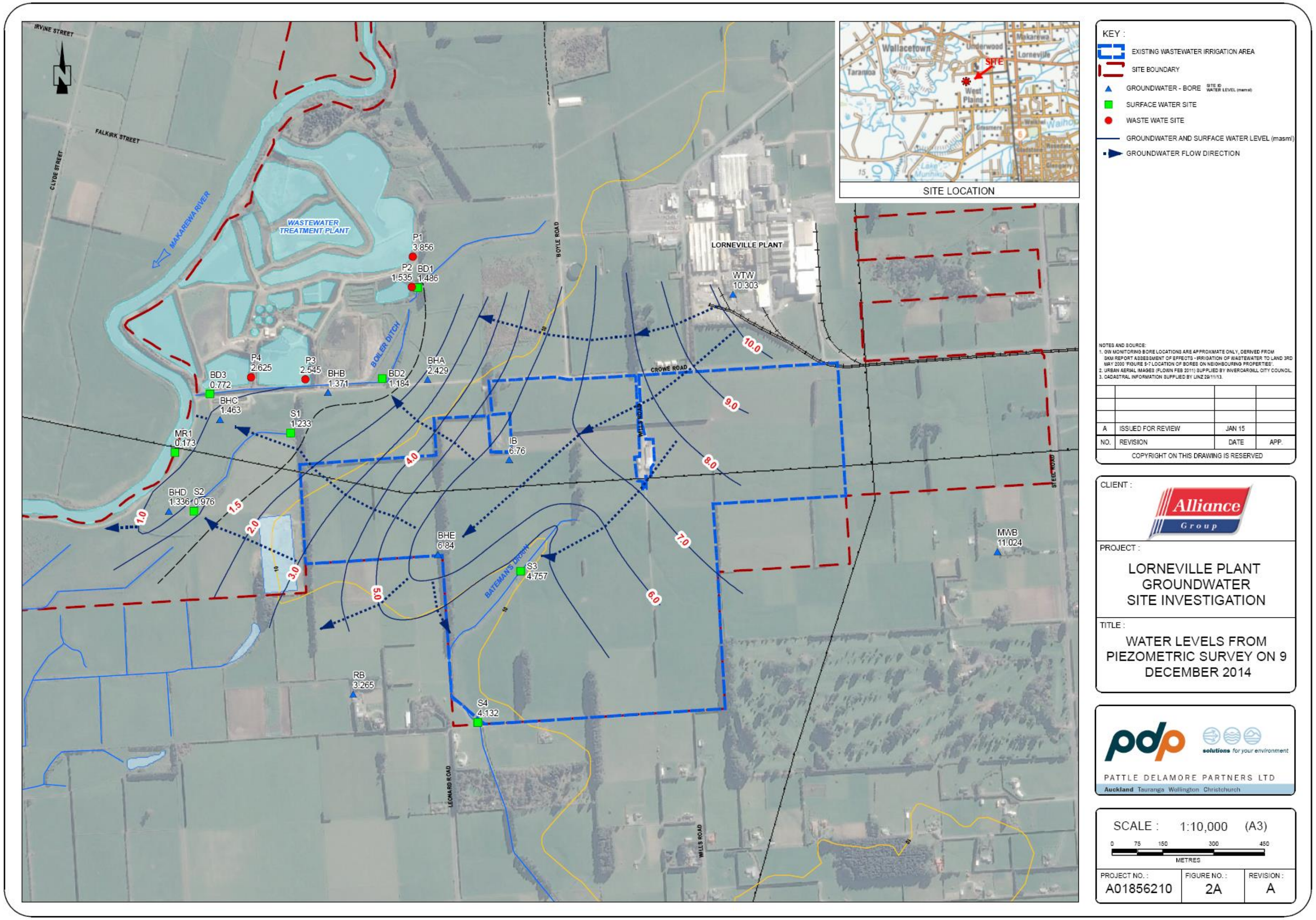

Figure 2a: Water levels from piezometric survey on 9 December 2014

FIGURE 2B

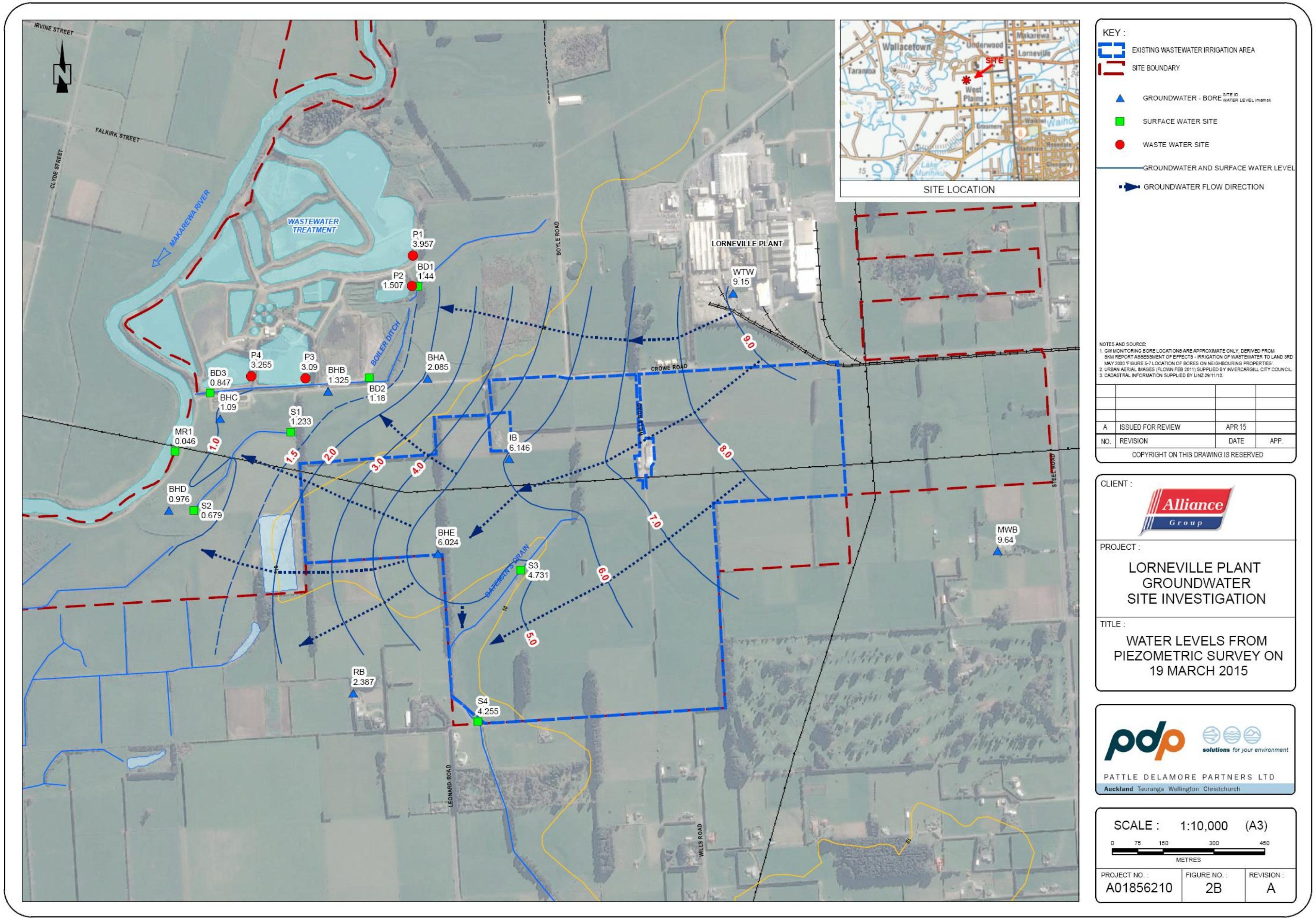

Figure 2b: Water levels from piezometric survey on 19 March 2015

FIGURE 3

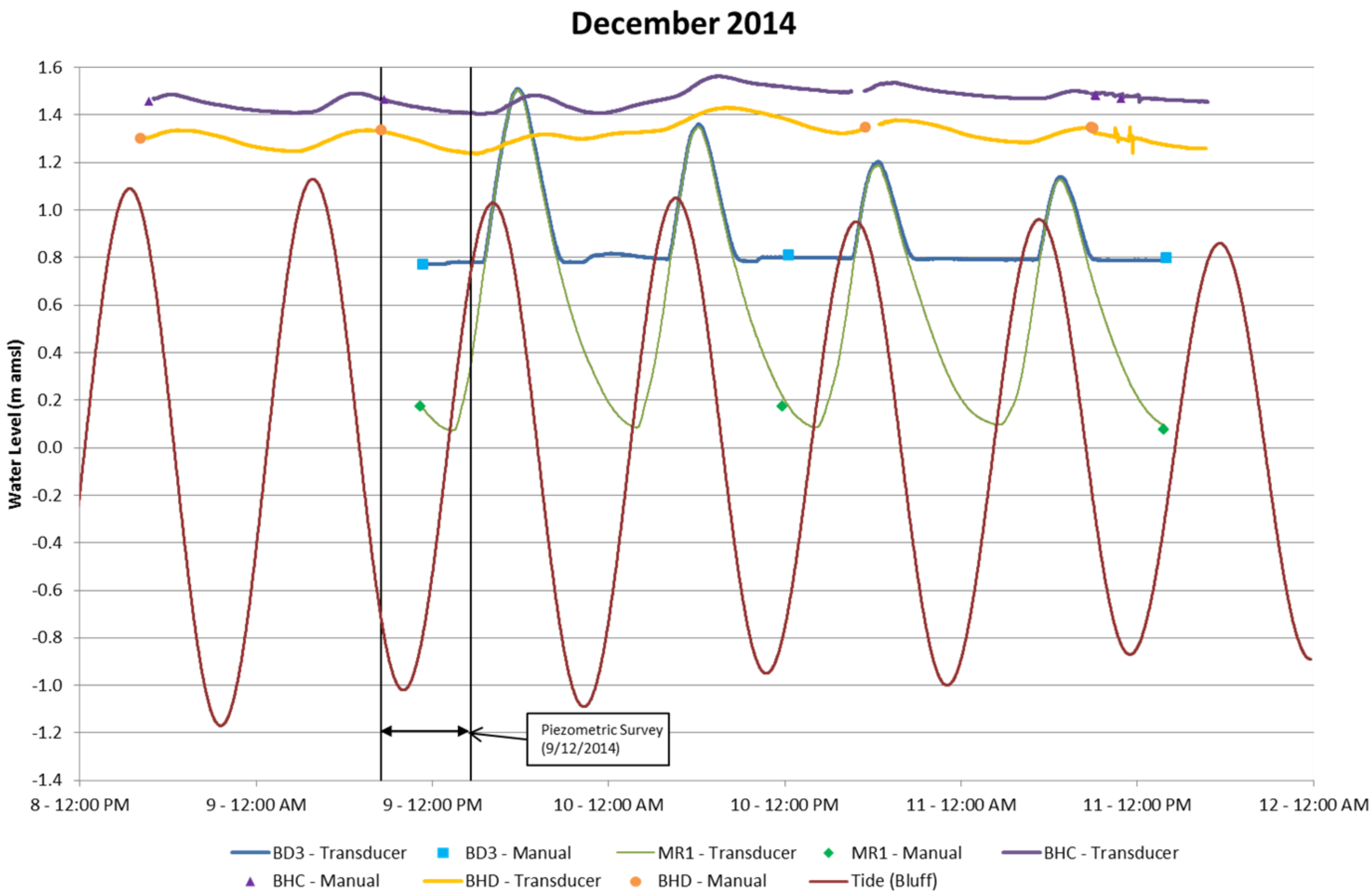

Figure 3: Continuous water levels monitoring records for the Makarewa River (MR1), Boiler Ditch (BD3), bores BHC and BHD and tidal fluctuations.

FIGURE 4

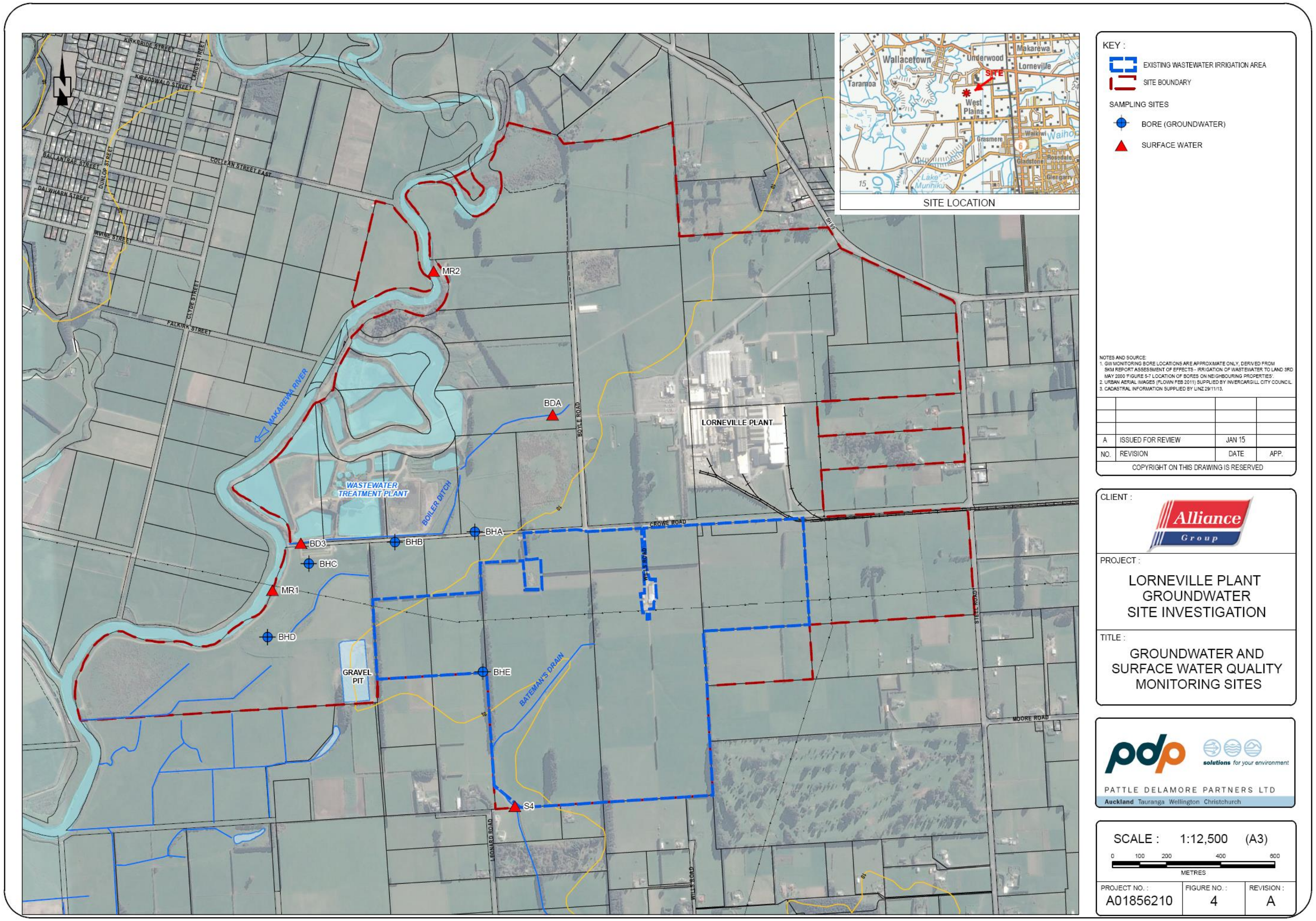

Figure 4: Groundwater and surface water monitoring sites at the Plant

FIGURE 5A

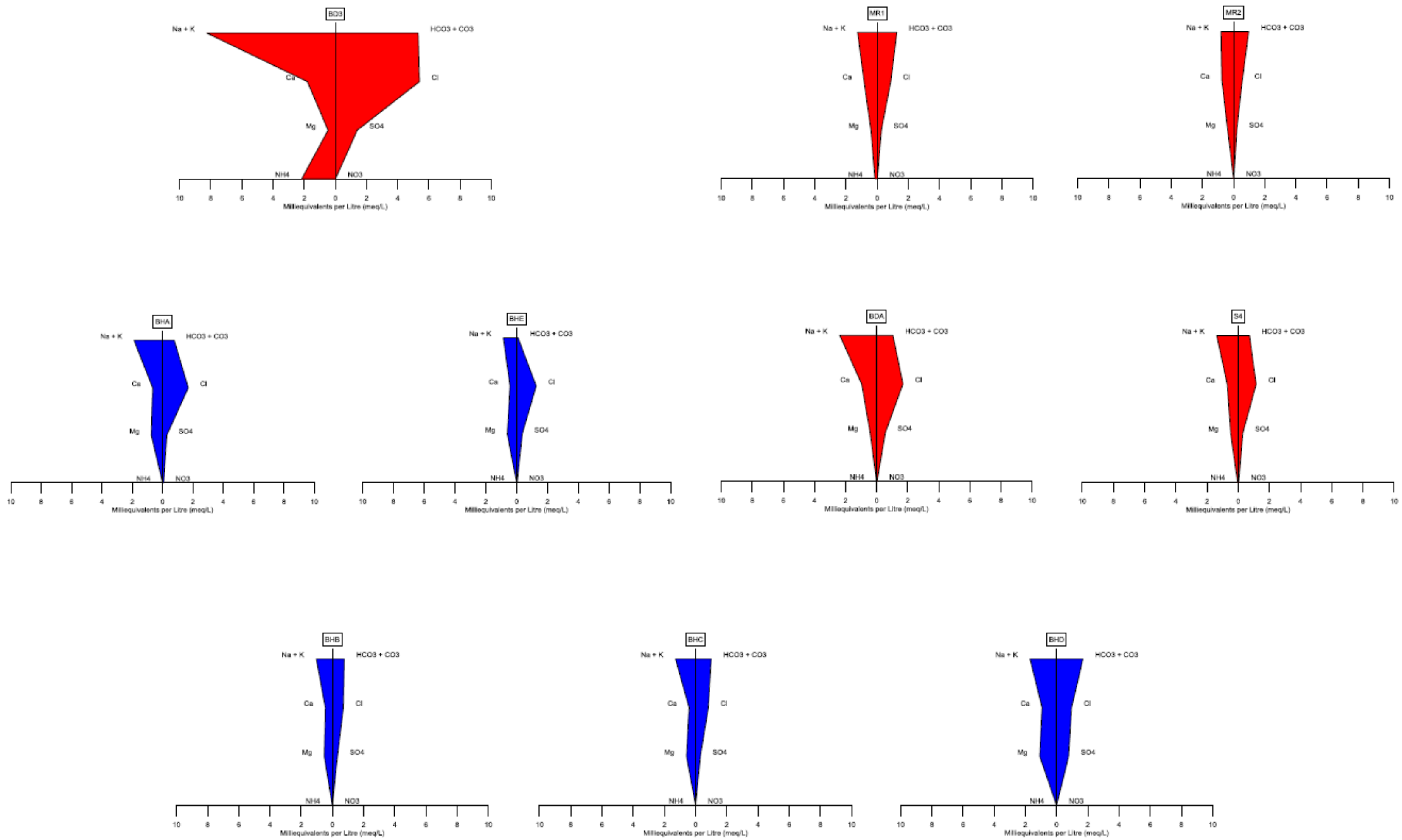

Figure 5a: Stiff plots of major cation and anion data from water samples collected on 10 December 2014. Blue plots indicate groundwater samples and red plots indicate surface water samples.

FIGURE 5B

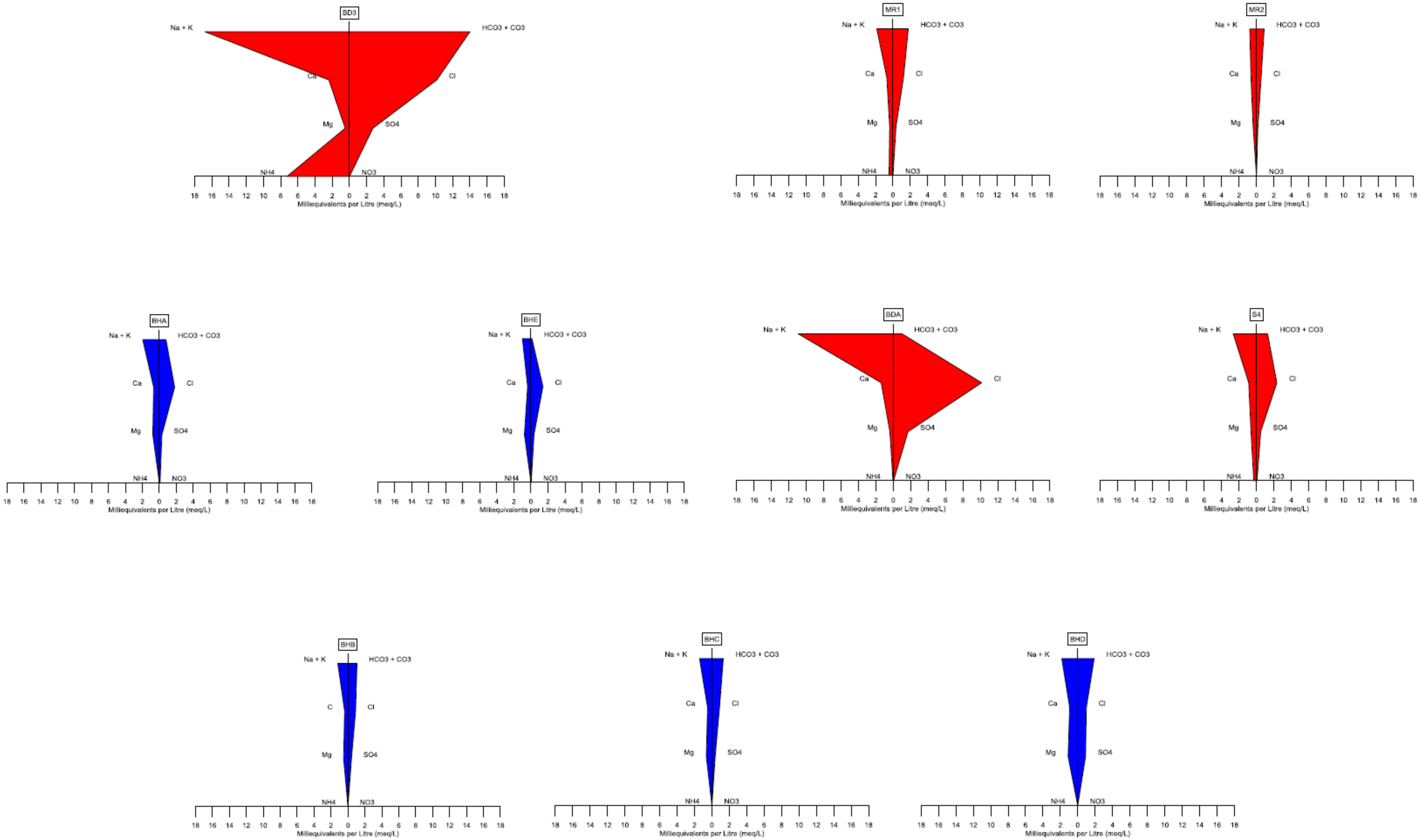

Figure 5b: Stiff plots of major cation and anion data from water samples collected on 18 March 2015. Blue plots indicate groundwater samples and red plots indicate surface water samples.