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EXECUTIVE SUMMARY

Central Hawke's Bay District Council currently hold consent to discharge treated wastewater from the Otane Waste Water Treatment Plant (WWTP) to an un-named farm drain. During dry periods, the treated wastewater infiltrates to groundwater and the drain conducting the effluent to the Te Aute Drain/Kaikora Stream runs dry. The infiltration of effluent to groundwater poses a risk to groundwater and connected surface water bodies. The degree of impact of effluent on local aquifers is dependent on a number of physical and chemical processes that occur during infiltration of the effluent and once within the local aquifer. Hawke's Bay Regional Council (HBRC) contracted GNS Science to conduct a hydrochemical analysis of surface- and ground- water quality datasets to determine the impact of treated effluent disposal on the hydrological system. In this report, the results of the hydrochemical analysis and recommendations for further work are provided.

A hydrochemical assessment of ground- and surface- (drain) waters in the vicinity and down gradient of the Drumpeel Rd drain indicated that the discharge of WWTP effluent is an important source of phosphorous to some local ground- and surface- waters. Impacted bores contained more than ten times, and unimpacted sites contained more than three times, the 0.015 mg/L soluble reactive phosphorous (SRP) level set by the HBRC for lowland streams within the Tukituki River Catchment. Despite evidence of local enrichment in phosphorous derived from WWTP effluent, the concentrations of SRP in local groundwaters were still 33 times lower than that of sampled WWTP effluent. This indicates a large proportion of phosphorous is likely to be retained within soil and subsurface materials. A portion of the WWTP impacted groundwater appears to discharge to the Te Aute Drain/Kaikora Stream. However, the lateral extent of the active WWTP plume is poorly defined. Elevated SRP concentrations at both Te Aute Drain/Kaikora Stream sites may also be partially derived from sources up-gradient of the WWTP. The relative contribution from WWTP effluent to the SRP concentration in stream is difficult to assess without a representative sample of the Te Aute Drain/Kaikora Stream waters from up gradient of the WWTP influence. Up gradient sources of phosphorous likely include both natural (lithological and organic) and land use derived sources.

It is suggested that the existence of a shallow unsaturated zone subject to significant water table fluctuations, reducing soils, and locally reducing aquifers favours higher phosphorous mobility than what occurs in areas where the unsaturated zone is much deeper and not subjected to frequent redox excursions associated with fluctuating water tables. The possibility of a legacy plume of phosphorous-rich water associated with an older discharge at or around the current Otane WWTP is raised, albeit tentatively. The impact of WWTP derived total ammoniacal nitrogen, nitrate and nitrite on local waters is minimal due to natural attenuation processes occurring in the unsaturated zone and shallow aquifer. Similarly, WWTP derived *E.Coli* did not appear to impact on local waters over the sampling period due to effective physical exclusion by the unsaturated zone matrix.

Due to a lack of monitoring bores the exact lateral extent of the phosphorous-rich plume was unable to be defined; and the varying source of phosphorous and the contribution from pastoral and/or natural sources is poorly defined for the Te Aute Drain/Kaikora Stream. Increased resolution of phosphorous sources in the local system and an understanding of the extend of the WWTP plume and its impact on local surface- and ground- waters may be derived from: installation of shallow monitoring bores; completing higher density longitudinal sampling of Te Aute Drain/Kaikora Stream; and further examination of the source and fate of phosphorous in the Papanui Catchment.

1.0 INTRODUCTION

The Otane Waste Water Treatment Plant (WWTP) is located at the end of Lawrence Street on the northern edge of Otane, Central Hawke's Bay, and is operated by Central Hawke's Bay District Council (CHBDC). CHBDC is currently applying to renew their existing resource consents with Hawke's Bay Regional Council (HBRC). The Otane WWTP consent includes provision to discharge treated wastewater to water and to land where it may enter water, in an intermittently flowing un-named farm drain that discharges to Te Aute Drain/Kaikora Stream, a tributary of the Papanui Stream. During dry periods, the treated wastewater entering the drain infiltrates to groundwater and the drain conducting the effluent to the Te Aute Drain/Kaikora Stream runs dry.

The infiltration of effluent from the Otane WWTP to groundwater through the reticulation (open drains) network poses a risk to groundwater and connected surface water bodies. The degree of impact of effluent on local aquifers is however dependent on a number of physical and chemical processes that occur during infiltration of the effluent and once within the local aquifer. Some of these processes include retention by ion exchange, chemisorption, disassociation reactions and redox reactions, among others.

Accordingly, the degree to which chemical and physical reactions attenuate the concentration of contaminants within any effluent is dependent upon the local setting, specifically, the particular combination of soils, geology and hydrology. It is also important to be aware of the range of possible sources of nutrient (nitrogen and phosphorous) species. Within the area of interest this includes losses from intensive land use, natural sources associated with the local geology and aquifer characteristics and WWTP effluent. It is therefore important to discriminate between the various sources.

HBRC contracted GNS Science to conduct a hydrochemical analysis of surface- and ground-water quality datasets to determine the impact of treated effluent disposal on the hydrological system. This work involved the application of specialised techniques to assess the impact of WWTP effluent on the local aquifer systems and connected water bodies. In this report, the results of the hydrochemical analysis and recommendations for further work are provided.

2.0 BACKGROUND AND SITE SETTING

The Papanui Catchment covers an area of approximately 16,400 ha and is one of 16 sub-catchments of the main Tukituki River Catchment (Figure 2.1). The township of Otane (and the WWTP) is located at the centre of the Papanui Catchment (Lynch et al., 2013), and all sites sampled by HBRC as part of this project are located within the Papanui Catchment. The Papanui Catchment is a significant source of phosphorous to the Tukituki River, however, phosphorous sources in the catchment are poorly understood (Lynch et al., 2013). A study completed in June 2012 indicated 'hot spot' sources of phosphorous in the catchment, and trends indicated that the concentration of phosphorous was increasing over time (Lynch et al., 2013).

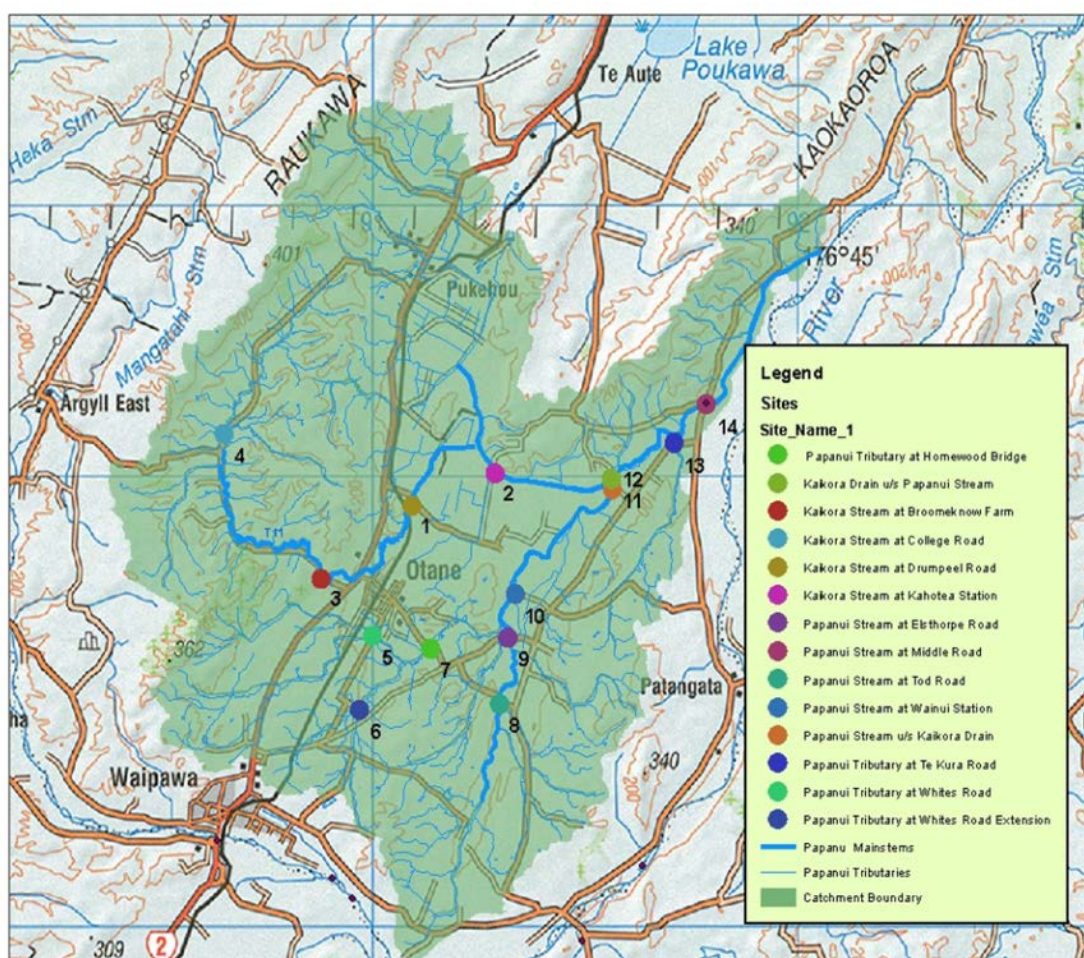


Figure 2.1 Map showing the extent of the Papanui Catchment and location of the fourteen water quality sampling sites (Lynch et al., 2013). Sites 3, 1, 2, and 12 are of particular interest as they are located on Kaikora Stream or Te Aute Drain/Kaikora Stream.

Surface geology of the study site primarily consists of quaternary deposits. The plains area south of Drumpeel Road is composed of late quaternary deposits, with moderately weathered, undifferentiated, poorly-sorted loess-covered alluvial gravels, and fluvial deposits from previous courses of the Waipawa River. The plains area to the north of Drumpeel Road is composed of poorly sorted alluvial gravel, sand and soft, dark brown to black organic swamp mud, muddy peat and woody peat with minor overbank sand, silt and mud (Lee, 2011). The study area is generally overlain with Otane Group soils, which are characterised as light with good natural fertility (Lynch et al., 2013). The Otane soils that are formed on river deposited sediments are slightly acidic, well supplied with lime, and low in phosphate (Lynch et al., 2013). Land use in the study area is a combination of arable and sheep/beef.

Previous hydrogeological studies in the area including assessments of groundwater chemistry (Ludecke, 1988) and hydraulic properties (Luba, 1999) are summarised in Larking (2004), and an environmental characterisation of the Papanui Catchment has been completed by Lynch et al. (2013). Groundwater resources occur in most geological formations in the Papanui Catchment, with the most productive aquifer being associated with Quaternary gravels. These sediments underlie the Waipawa and Papanui rivers, and range from depths of 30 m in the middle of the catchment to 50 m deep in the southern catchment. In the study area near Otane, the aquifer system appears to pinch out and grade into swampy deposits. General flow of groundwater within the aquifer has been interpreted to follow the topographic gradient (e.g., from the south-west to the north-east of the catchment) within paleo-channel sediment of the Waipawa River (Figure 2.2).

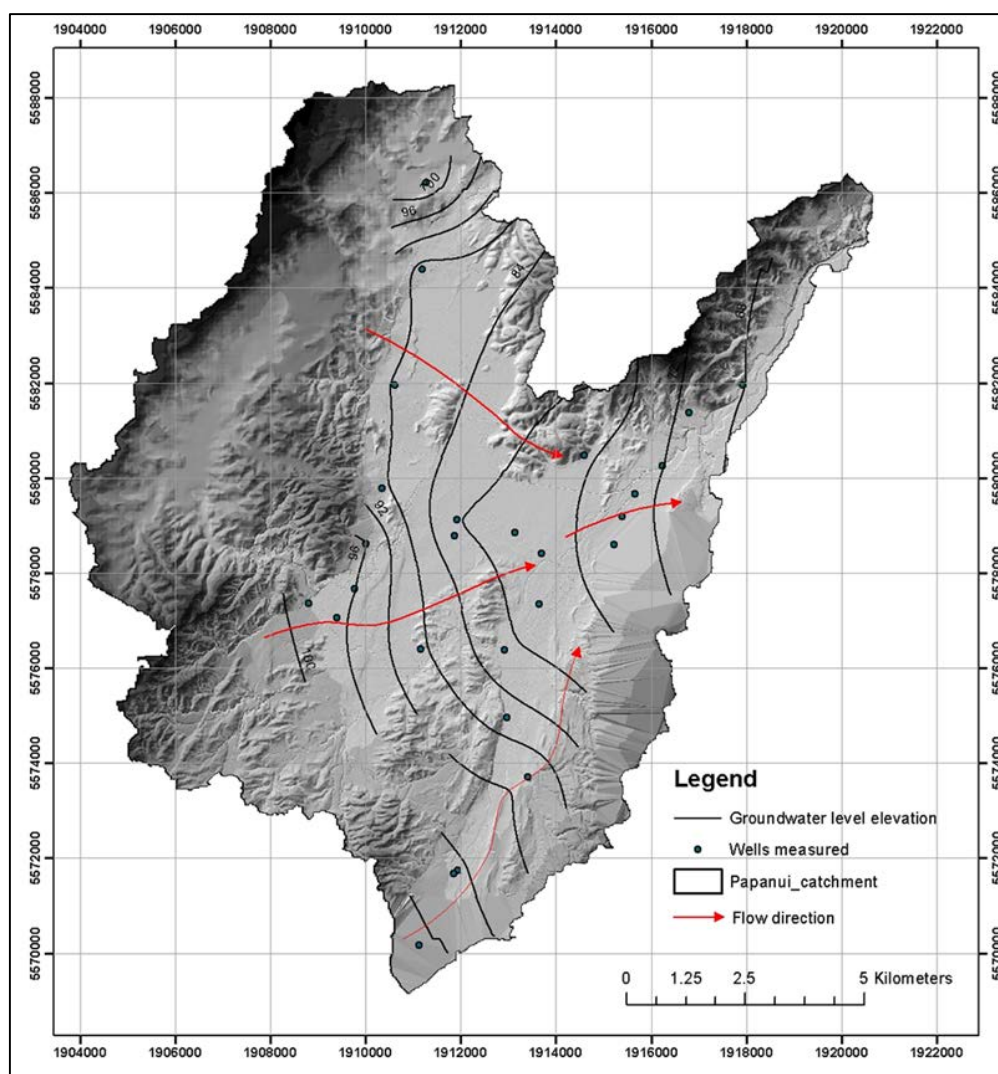


Figure 2.2 Map showing the Papanui catchment boundary, locations of wells measured for groundwater elevation, and inferred groundwater elevation and flow directions (Gordon, 2016).

There is a poor understanding of groundwater quality in the Papanui Basin, and current knowledge is primarily based on minimal information from a small number of historic monitoring bores. Limited water quality sampling was completed during the period 1997 – 2003. Results indicated that bores 3198 and 2860 had elevated faecal coliform concentrations, and that bores 2718 and 4617 had elevated levels of nitrate-nitrogen ($\text{NO}_3\text{-N}$) (Lynch et al., 2013). However, the location of these bores was not provided in the report. Groundwater level information was available from bore 5006, located near the study site on Drumpeel Road.

Groundwater levels were interpreted to represent a confined gravel aquifer, and displayed a seasonal pattern with higher levels in the winter (c. 0.5 m BGL), and lower levels in the summer (c. 2.5 m BGL) (Lynch et al., 2013).

The upper reach of the Kaikora Stream drains hills to the west of Otane and is characterised by a small gravel bed system with clear water and some macrophyte growth (Lynch et al., 2013). The reach downstream of Otane becomes channelised and flows to the north then to the east until it confluences with Papanui Stream. The reach between Otane and the Papanui Stream confluence is commonly called Te Aute Drain, and for the purposes of this project is named Te Aute Drain/Kaikora Stream. In 2012, fourteen water quality sites in the Papanui Stream catchment were selected for intensive sampling, including four sites on Te Aute Drain/Kaikora Stream (Lynch et al., 2013; Figure 2.1). These sites were located at approximately 2 km intervals, from the upstream site at Kaikora Stream and Broomeknow Farm (Site 1); to Kaikora Stream at Drumpeel Road (Site 3), Kaikora Stream at Kahotea Station (Site 2), and Kaikora Stream upstream of Papanui Stream (Site 12) (Lynch et al., 2013; Figure 2.1).

Overall results of the Papanui Stream catchment water quality sampling indicated nutrient concentrations (e.g., soluble reactive phosphorous (SRP), total phosphorous (TP), NO₃-N, and total nitrogen (TN)) concentrations were relatively high. The Australian and New Zealand Environment and Conservation Council (ANZECC, 2000) trigger level for TP concentration in lowland streams of 0.033 mg/L was exceeded at thirteen of the fourteen sites. In addition, the Regional Resource Management Plan (HBRC, 2006) guideline value for SRP in lowland streams of 0.015 mg/L was exceeded at all fourteen sites (Lynch et al., 2013). In particular, results indicated that there was a considerable increase in SRP and TP concentrations in Te Aute Drain/Kaikora Stream between Drumpeel Road and Kahotea Station. Within this reach, SRP concentration increased by 0.048 mg/L (100%), and TP concentration increased by 0.063 mg/L (103%) (Lynch et al., 2013). When compared to the ANZECC (2000) and Regional Resource Management Plan (HBRC, 2006) trigger values of 0.033 mg/L and 0.015 mg/L respectively, these increases were considered to be substantial (Lynch et al., 2013). In addition, all of the sampling sites were near or above the ANZECC trigger value of 0.614 mg/L for TN concentration in lowland rivers. Between Site 1 and Site 2 (Table 2.1) in the Te Aute Drain/Kaikora Stream, NO₃-N concentration increased by 0.34 mg/L (454%), and TN concentration increased by 2.08 mg/L (400%).

Table 2.1 Summary of water quality results from sampling on Te Aute Drain/Kaikora Stream, adapted from Lynch et al. (2013). Locations of sampling sites are provided in Figure 2.1 (Lynch et al., 2013).

Site (site number)	Flow (m ³ /s)	SRP load (g/day)	TP load (g/day)	NO ₃ -N load (g/day)	TN load (g/day)
Kaikora Stream and Broomeknow Farm (1)	0.025*	95	114	328	1,793
Kaikora Stream at Drumpeel Road (3)	0.045*	187	237	288	2,022
Kaikora Stream at Kahotea Station (2)	0.55*	456	589	1,948	12,355
Kaikora Stream u/s of Papanui Stream (12)	0.14	1,008	1,572	7,441	31,202

* Flow was visually estimated.

Raw and summarised water quality datasets were not supplied in Lynch et al. (2013) in a useable format (e.g., only in graph form); however, calculated instantaneous nutrient loads for the sampling sites were provided (Table 2.1). These results further indicate a considerable increase in SRP, TP, NO₃-N, and TN in Te Aute Drain/Kaikora Stream (in a downstream direction), even when the compounding effects of increased flow were considered.

3.0 HYDROCHEMICAL SAMPLING AND ANALYSIS

For the purposes of this project, HBRC arranged for the collection and analysis of water quality samples from nine bores and four surface water sites located down-gradient from the Otane WWTP discharge (Figure 3.1). Water quality datasets were provided by HBRC at the conclusion of sampling (Gordon, 2016). These datasets were then formatted and an analysis of the hydrochemical and water quality data was undertaken. Analysis included calculation of halide ratios, major ion ratios, mineral saturation indices, and redox assignments. Additional technical detail on these methods is provided in Appendix 1.

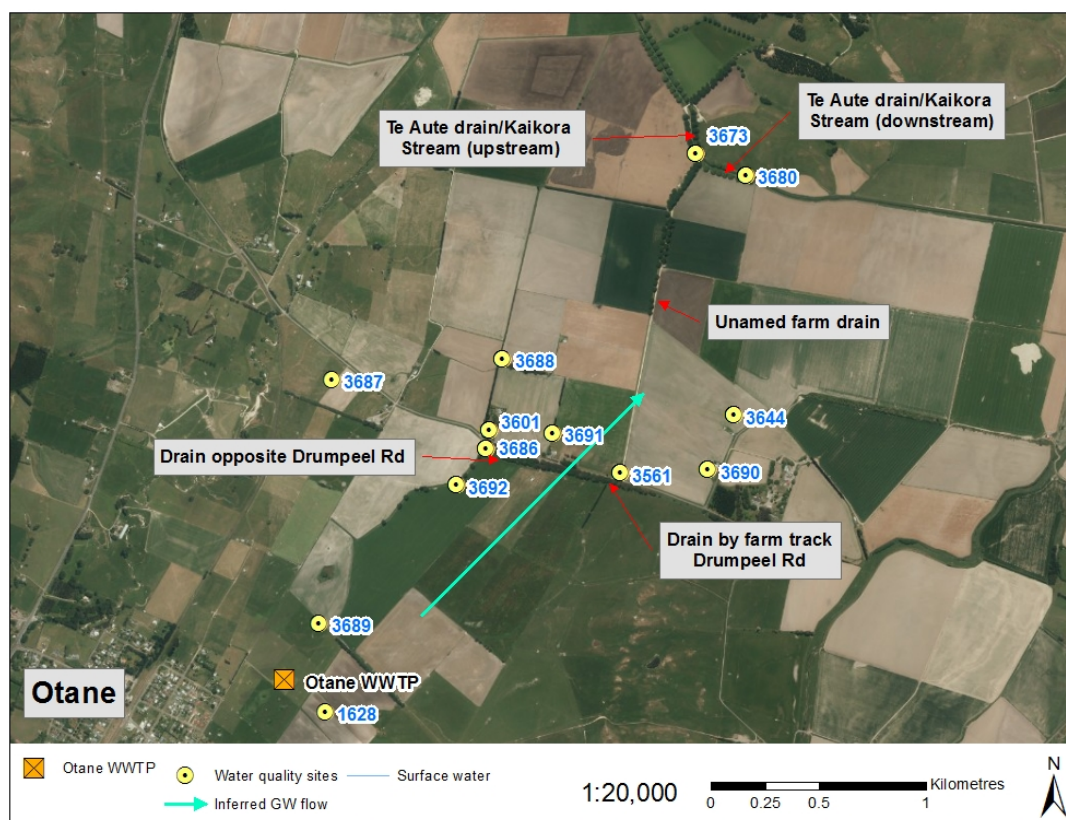


Figure 3.1 Map showing the location of the Otane WWTP, water quality sampling sites, and inferred groundwater flow direction from Lynch et al. (2013) and Gordon (2016).

4.0 HYDROCHEMICAL ASSESSMENT

4.1 WASTE WATER TREATMENT PLANT EFFLUENT

WWTP effluent sampled from the drain adjacent to Drumpeel Rd (sites 3686 and 3561) was characterised by elevated Cl/Br, Cl/I, and Cl/B ratios, anomalous potassium (K), total ammoniacal nitrogen (TAN), and SRP; yet low calcium (Ca) and magnesium (Mg) concentrations relative to local ground- and surface- waters (Figure 4.1 to Figure 4.3; Table 4.1). SRP from the WWTP effluent (median of 3.9 mg/L) is 257 times the Regional Resource Management Plan (HBRC, 2006) guideline value for SRP in lowland streams of 0.015 mg/L. TAN concentration is also elevated (median 15.1 mg/L). The ratio of conservative tracers (halides and boron (B)) are also anomalously elevated and form the basis for tracing WWTP inputs to the local groundwater system and associated streams (e.g., Te Aute Drain/Kaikora Stream). Halide ratios and conservative tracers such as B are widely used to assess contaminant source (Appendix 1). Differences in the major cations noted above, halide and Cl/B and both SRP and TAN are all statistically significance at the 95% level based on application of the non-parametric Wilcoxon–Mann–Whitney test.

Table 4.1 Summary statistics of WWTP effluent and local ground- and surface- waters. Concentration units are in parts per million (ppm), and Electrical Conductivity (EC) is in µs/cm.

WWTP effluent	pH	EC	DO	NO ₃ -N	NO ₂ -N	TAN	SRP	Na ⁺	K ⁺	Mg ⁺⁺	Ca ⁺⁺
Valid Cases	8	8	6	8	8	8	8	8	8	8	8
Mean	7.3	598.1	1.3	0.8	0.050	14.85	3.99	44.4	11.4	4.4	49.8
Median	7.4	594.5	1.3	0.6	0.059	15.05	3.85	44.5	11.5	4.4	49.0
Standard Deviation	0.3	23.4	0.4	0.9	0.031	2.68	0.56	3.0	0.9	0.2	1.9
Geometric Mean	7.3	597.7	1.2	0.2	0.030	14.63	3.95	44.3	11.3	4.4	49.7
Coefficient of Variation	0.0	0.0	0.3	1.0	0.613	0.18	0.14	0.1	0.1	0.0	0.0
Minimum	6.7	564.0	0.7	0.0	0.001	10.60	3.20	41.0	10.1	4.2	47.0
Maximum	7.6	642.0	1.8	2.1	0.083	18.00	4.80	49.0	12.7	4.7	53.0
Range	0.9	78.0	1.1	2.1	0.082	7.40	1.60	8.0	2.6	0.5	6.0

Local ground- and surface-waters	pH	EC	DO	NO ₃ -N	NO ₂ -N	TAN	SRP	Na ⁺	K ⁺	Mg ⁺⁺	Ca ⁺⁺
Valid Cases	55	59	55	59	59	59	59	59	59	59	59
Mean	7.2	529.4	0.6	0.2	0.003	0.85	0.22	32.2	4.7	7.2	85.7
Median	7.4	569.0	0.2	0.0	0.001	0.70	0.12	26.0	4.3	6.8	88.0
Standard Deviation	0.4	116.6	0.8	0.9	0.008	0.75	0.26	13.3	1.2	1.9	12.2
Geometric Mean	7.2	516.7	0.3	0.0	0.001	0.26	0.10	29.7	4.5	7.0	84.9
Coefficient of Variation	0.1	0.2	1.3	5.2	2.801	0.88	1.19	0.4	0.3	0.3	0.1
Minimum	6.1	342.6	0.1	0.0	0.001	0.01	0.00	18.0	2.7	4.4	62.0
Maximum	7.6	819.0	3.1	7.0	0.049	2.00	1.12	55.0	6.9	10.3	108.0
Range	1.5	476.4	3.0	7.0	0.048	2.00	1.12	37.0	4.2	5.9	46.0

WWTP effluent	Cl/Br	Cl/I	Cl/F	Cl/B	Na/K	Ca/K	SRP/Cl	SRP/Br	SRP/I	SRP/F	SRP/B
Valid Cases	8	4	4	4	8	8	8	8	4	4	4
Mean	499.1	42463	348	851	3.9	4.4	0.11	53.1	312.0	32.0	78.2
Median	514.3	43103	350	831	3.9	4.4	0.10	50.1	317.6	32.2	77.9
Standard Deviation	41.8	3393	42	104	0.3	0.3	0.02	11.3	14.3	2.3	2.2
Geometric Mean	497.6	42359	346	846	3.9	4.4	0.10	52.1	311.8	31.9	78.2
Coefficient of Variation	0.08	0.08	0.12	0.12	0.08	0.08	0.18	0.21	0.05	0.07	0.03
Minimum	450.0	38136	300	766	3.6	3.9	0.08	35.6	290.9	29.1	76.2
Maximum	557.1	45512	391	976	4.6	5.0	0.13	68.6	322.0	34.5	80.9
Range	107.1	7376	91	210	1.0	1.1	0.06	33.0	31.1	5.5	4.7

Local ground- and surface waters	Cl/Br	Cl/I	Cl/F	Cl/B	Na/K	Ca/K	SRP/Cl	SRP/Br	SRP/I	SRP/F	SRP/B
Valid Cases	51	27	27	27	59	59	59	51	27	27	27
Mean	262.7	11621	177	588	6.8	19.4	0.01	1.4	6.3	0.8	2.5
Median	250.0	10743	167	389	7.0	19.5	0.00	1.0	4.6	0.8	2.2
Standard Deviation	61.8	5997	39	390	1.8	4.4	0.01	1.2	5.2	0.5	1.8
Geometric Mean	256.2	10099	173	485	6.6	18.9	0.00	0.8	3.2	0.4	1.3
Coefficient of Variation	0.24	0.52	0.22	0.66	0.26	0.23	0.98	0.85	0.82	0.66	0.72
Minimum	161.5	3922	111	193	3.9	14.1	0.00	0.0	0.1	0.0	0.0
Maximum	414.3	22371	250	1304	10.6	31.7	0.03	4.8	19.2	1.8	5.7
Range	252.7	18450	139	1111	6.7	17.6	0.03	4.7	19.1	1.8	5.7

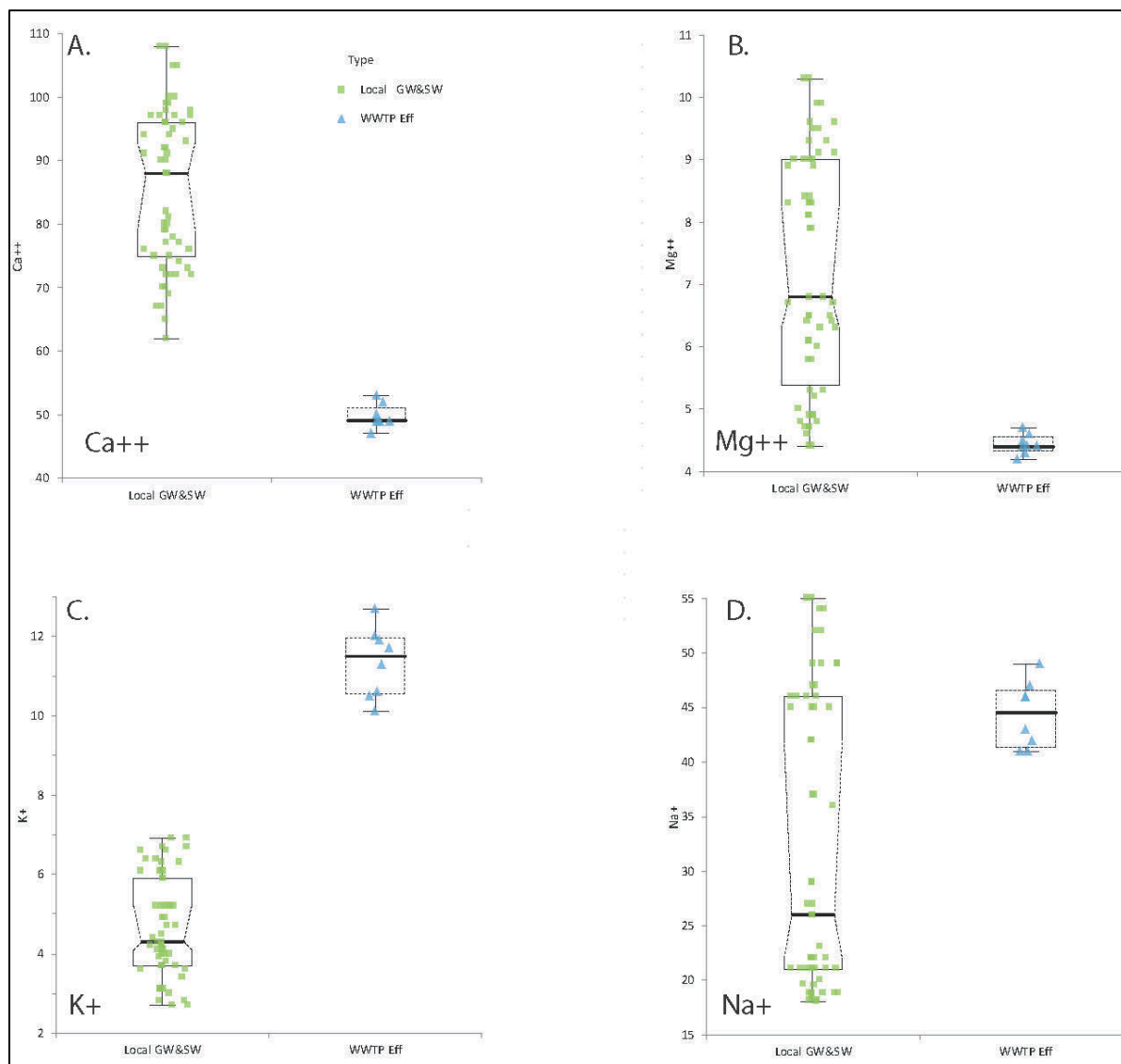


Figure 4.1 Box and whisker plots comparing the Ca, Mg, K, and Na concentrations (ppm) between WWTP effluent from sites 3686 and 3561, and concentrations in local ground- and surface- waters sampled for this project. Medians are the black horizontal line and whiskers extend to the 95% confidence interval. It is readily apparent that Ca and Mg are much lower in the WWTP effluent and K is much higher than local ground and surface waters. Na shows some overlap but has a higher median concentration for the WWTP effluent relative to local ground- and surface- waters.

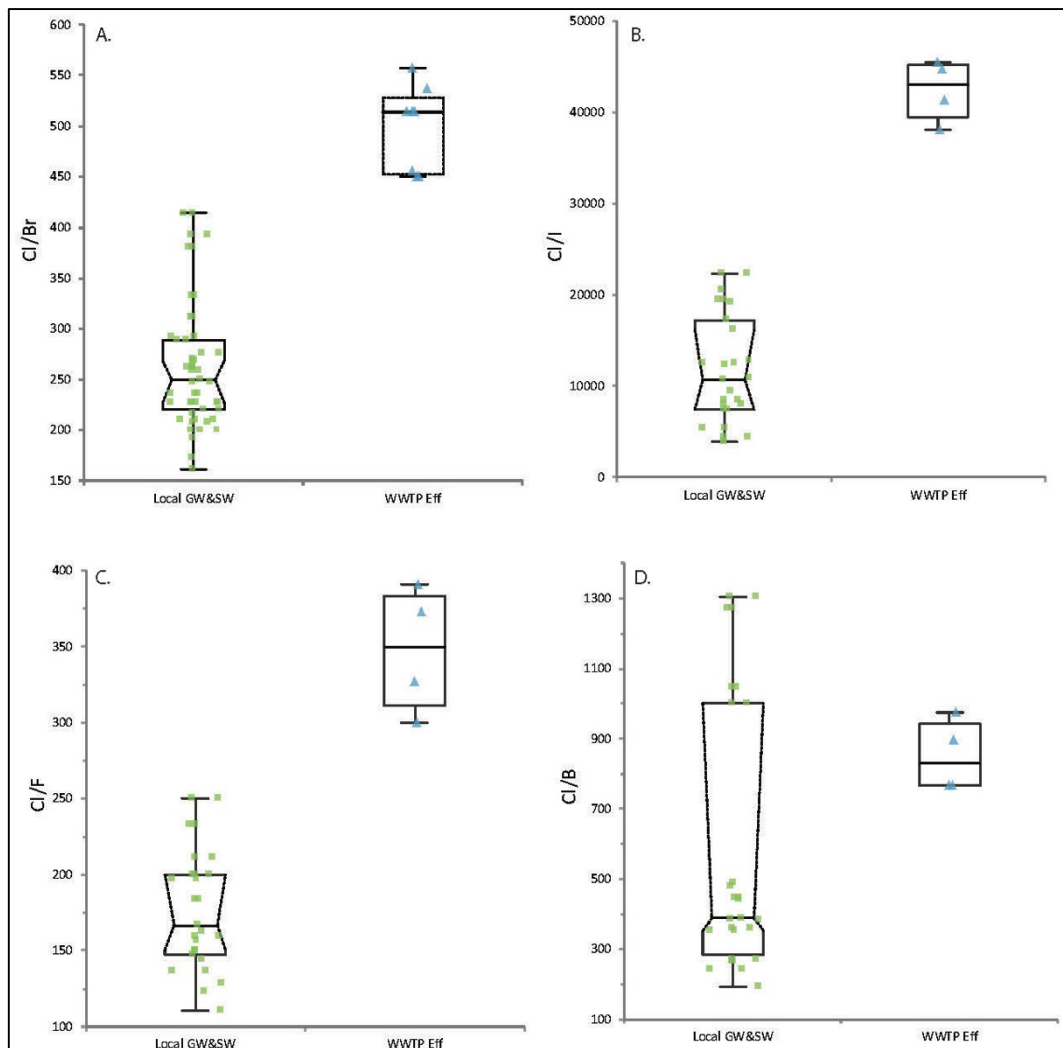


Figure 4.2 Box and whisker plots comparing halide ratios, and Cl/B ratios (D) between WWTP effluent from sites 3686 and 3561 and those of local ground- and surface- waters. Halide and Cl/B ratios are elevated in WWTP effluent relative to local ground- and surface- waters.

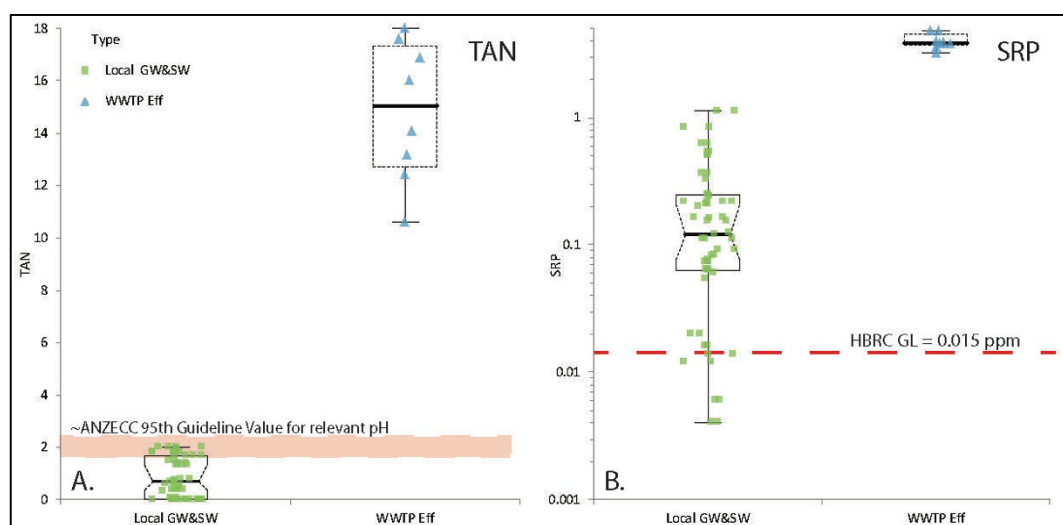


Figure 4.3 Box and whisker plots comparing TAN and SRP concentrations (ppm) between WWTP effluent from sites 3686 and 3561 and concentrations in local ground- and surface- waters sampled for this project. GV's are shown and SRP represented by a log scale. NO₃-N (not shown here) is negligible and shows little difference in concentration between WWTP effluent and local ground- and surface- waters.

4.2 TOTAL AMMONIACAL NITROGEN (TAN) AND *E. COLI* SOURCE, TRANSFORMATION AND TRANSPORT

TAN concentrations in the WWTP effluent are high (median = 15.05 mg/L) relative to local ground- and surface- waters (median = 0.7 mg/L). However, TAN concentrations in the Te Aute drain/Kaikora Stream are low (median = 0.0105 mg/L, NH₃-N) as are NO₃-N concentrations (median = 0.0010 mg/L, NO₃-N) indicating little transfer of TAN, ammonium or NO₃-N from groundwater contaminated with WWTP effluent.

The attenuation of TAN concentrations from WWTP discharge is likely due to significant aerobic and or anaerobic oxidation of ammonium to nitrate within the unsaturated zone underlying the drain or in the shallow aquifer (Desimone et al., 1998; Buss et al., 2004; Böhlke et al., 2006; Moore et al., 2011). At the circumneutral pH of local sub-soils and unsaturated zone materials, ammonia is likely ionised to ammonium which is positively charged and retained by negatively charged surfaces within the unsaturated zone. Retention is followed by the oxidation of ammonium to oxidisable nitrogen within the unsaturated zone by bacteria which use O₂ or potentially Mn^{IV} as electron acceptors (Buss et al., 2004; Moore et al., 2011). Significant unsaturated zone oxidation of WWTP derived ammonia is a common feature of some land based disposal systems (Buss et al., 2004 and references therein) and can lead to the decoupling of TAN and dissolved P species where receiving waters are reducing. In summary, WWTP TAN is firstly ionised to ammonium followed by nitrification and leaching of nitrate and nitrite into locally reduced groundwaters. Oxidisable nitrogen is then rapidly denitrified. Fluctuating water tables are known to play an important role in the above process (Burt et al., 2002; Hefting et al., 2004).

Elevated *E.coli* (> 100 cfu/ml) counts are primarily associated with surface water sites and waste water reticulation drains. Of the two groundwater sites with detectable *E.Coli* one was associated with a WWTP impacted site (bore, 3692) the other an unimpacted site (bore, 3690). Elevated *E.coli* in surface waters but not in groundwaters is commonly caused by poor well head protection being the primary reason for *E.Coli* contamination of groundwater. In most instances *E.Coli* is effectively removed by unsaturated zone and or saturated zone filtration. The low *E.coli* counts found in impacted groundwaters are up-gradient of the Te Aute/Kaikora Stream, and the fact that the drain was not discharging to the stream over the sampling period, indicates elevated *E.coli* in the stream is unlikely to be derived from groundwater contaminated with WWTP effluent.

All groundwater samples were assessed against the New Zealand Drinking Water Standards Guideline Values (GV's) (Ministry of Health, 2008). This assessment indicated that the only exceedances (other than one *E.Coli* impacted bore) were aesthetic in nature due to elevated Mn^{II} and Ca + Mg, which are typical of reduced groundwaters in areas of carbonate or alkali parent materials (see Gordon, 2016).

4.3 PHOSPHORUS SOURCE AND TRANSPORT

Unlike TAN and *E.Coli*, WWTP derived SRP appears to locally impact ground- and surface-waters. Unlike, TAN, P is not subject to assimilation by reduction. However, P is normally poorly mobile due to a high affinity for exchange sites associated with clay minerals (both structured and poorly ordered). Absorption is a two stage process, firstly electrostatic attraction followed by a slower process of chemisorption (bond formation) between the P molecule/ion and exchange sites. Normally, there is more than enough sorptive capacity to retain P within

the soil or unsaturated zone. However, when P loads are high, as with WWTP effluent and application occurs over an extended period, the sorptive capacity can be locally overwhelmed (Robertson et al., 1998; Siemens et al., 2004; Hu et al., 2005; Spiteri et al., 2007; Heredia et al., 2007; Leader et al., 2008). The latter is more common in areas of shallow water table and for areas with reducing soils or aquifers which tend to have a lower mass of highly sorptive Fe and Mn oxides and oxy-hydroxides (Villapando and Graetz, 2001; Leader et al., 2008; Obour et al., 2011; Domagalski and Johnson, 2012). Accordingly, over time, a large concentration gradient develops between sorption sites and the local pore waters driving an increase in P concentrations in solution. Soluble P then migrates in solution to down-gradient sites with available sorptive capacity. Over a period of time much of the sorptive capacity in an area down gradient of a WWTP loading area is overwhelmed and a P plume may extend through the unsaturated zone and into the shallow aquifer and down gradient to any hydrologically connected surface water (Holman et al., 2008; Domagalski and Johnson, 2012).

Binary plots of halide and B normalised SRP concentrations versus Ca and Mg concentrations are displayed in Figure 4.4 and Figure 4.5. These plots indicate varying degrees of mixing and dilution between P-enriched WWTP effluent and both local ground- and surface- waters (e.g., Te Aute/Kaikora Stream). Of the sites sampled, site 3690 (bore, 63.0 m BGL; screen 9.03 – 10.33 m BGL) and site 3644 (bore, 9.37 m BGL; screen 7.17 – 9.6 m BGL) located to the east of the Drumpeel Road farm drain are compositionally distinct from the WWTP effluent signature, with little to no signatures of WWTP contamination (i.e., normalised SRP or halide ratios). Both these sites have low median SRP concentrations of 0.006 mg/L and 0.015 mg/L respectively¹. Accordingly, for the purposes of this study both of these sites constitute a local hydrochemical 'end member', being most consistent with what is expected of local groundwaters that are unimpacted by WWTP effluent.

¹However, of the seven replicate samples for site 3690, SRP ranges between the lower detection limit of 0.004 mg/L to as high as 0.53 mg/L on one sampling occasion. Assuming the SRP measures are correct, the variation in SRP often occurs in response to local water table fluctuations that drive associated changes in redox conditions that govern P solubility (Villapando and Graetz, 2001; Niedermeier and Robinson, 2009; Obour et al., 2011). It is noted that the majority of sites including both Te Aute Drain/Kaikora Stream sites show considerable fluctuation in SRP concentrations.

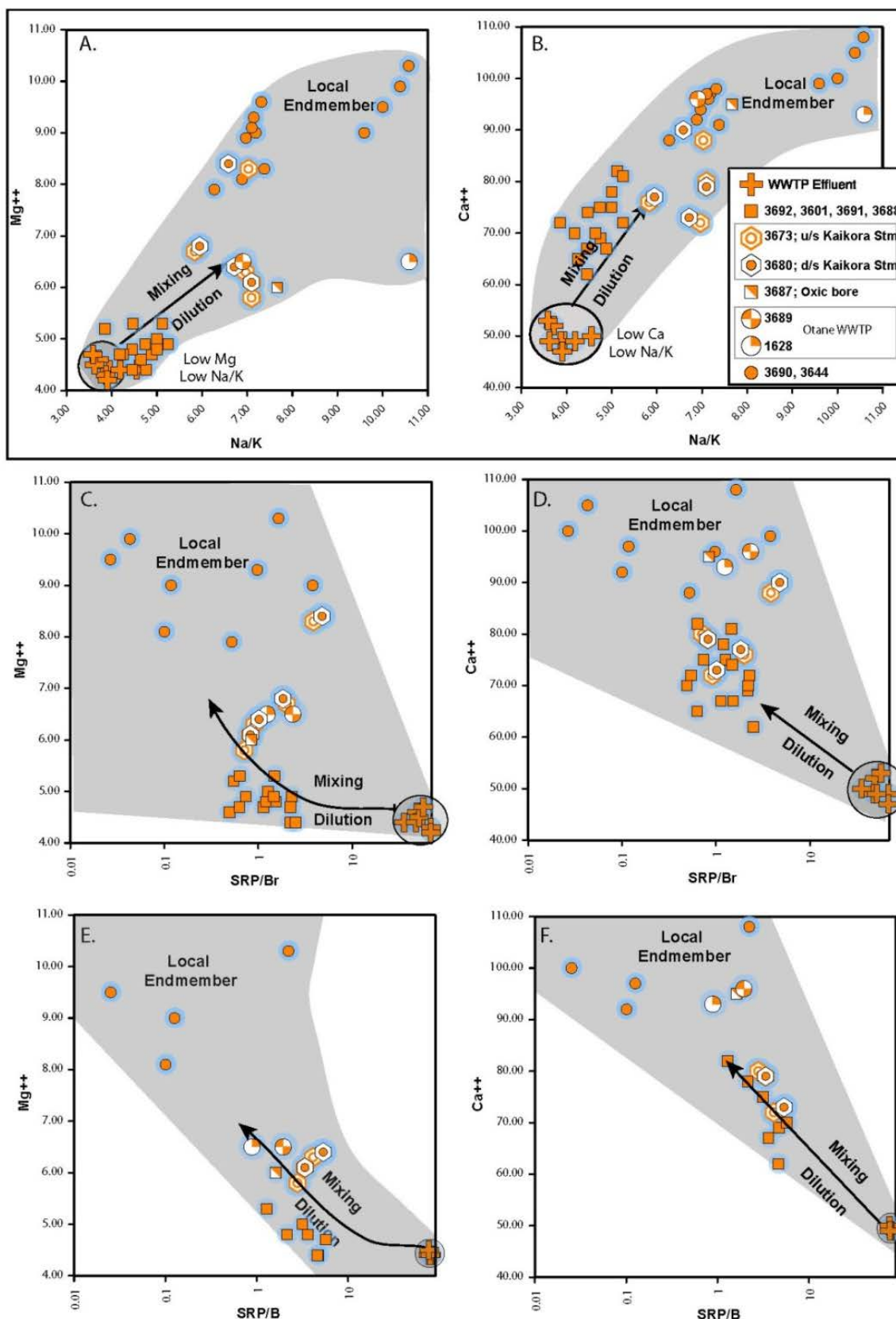


Figure 4.4 A) and B): Binary plots of Mg and Ca versus Na/K ratio displays the relationship between the low Mg, Ca, and Na/K ratios of WWTP effluent and local ground- and surface- waters. There is some evidence for a mixing trend between WWTP and local ground- and surface- waters although the degree of WWTP influence declines towards the NE quadrants of each figure. C) to F): Binary plots of Br and B normalised SRP concentrations versus Ca and Mg concentrations. Normalised SRP values suggest significant WWTP mixing with local groundwaters of sites 3692, 3601, 3691 and 3688. Where: 'local end member' refers to the unimpacted groundwaters sites 3690 and 3644 that for the purposes of this study constitute natural background.

Groundwater sites 3692, 3601, 3688 and 3691 are of broadly similar composition to the WWTP group albeit variably diluted (Figure 4.4 and Figure 4.5). These sites appear most impacted by WWTP effluent as is consistent with their immediate proximity down gradient of the Drumpeel Road Drain (Figure 3.1). The median SRP concentrations for these four sites is 0.161 mg/L or c. 3.5 times the median of the local background of 0.047 mg/L based on unimpacted sites 3690 and 3644². Impacted bores are 10.7 times and unimpacted 3.1 times the 0.015 mg/L SRP level set by the HBRC for lowland streams.

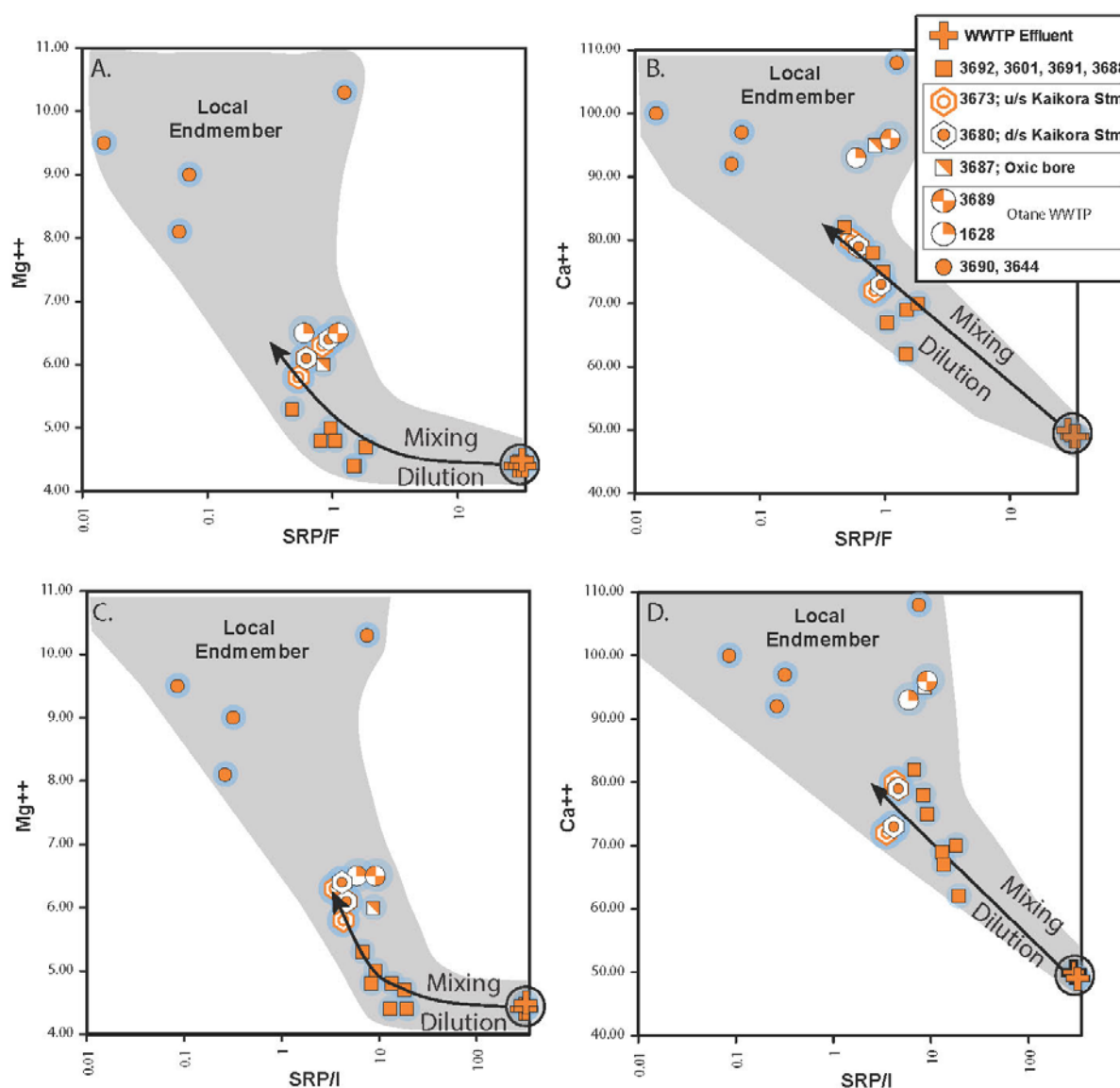


Figure 4.5 Binary plots of halide normalised SRP concentrations versus Ca and Mg concentrations. Again, varying degrees of mixing and dilution is evident between WWTP effluent and local ground and surface waters. Where: 'local end member' refers to the unimpacted groundwaters sites 3690 and 3644 that for the purposes of this study constitute natural background.

Both of the Te Aute/Kaikora Stream sites show a degree of WWTP impact in Figure 4.4 and Figure 4.5. However, they show a greater degree of dilution with local background waters relative to contaminated groundwaters (sites 3692, 3601, 3688, and 3691). A higher degree of dilution is consistent with the larger drainage area associated with pastoral land use that occurs up gradient of the sampling sites. Importantly, the hydrochemical metrics for upstream (site

² For reference, sites 3601 (bore of unknown depth) and 3691 (bore of unknown depth) both contain median SRP concentrations that are 10.9 and 13.5 times the HBRC guideline value of 0.015 mg/L for lowland streams.

3673) and downstream (site 3680) of the WWTP drain confluence do not vary significantly. The similarity of WWTP effluent indicators is consistent with a diffuse groundwater plume that is not restricted to the vicinity of the farm drain. The flaring or broadening of a contaminant plume from its source (i.e., Drumpeel Road Drain) is typical of advection and dispersion processes within aquifers. The longitudinal distance between the two sites was small and the drain was not discharging to the Te Aute Drain/Kaikora Stream during the sampling period.

Overall, SRP for both Te Aute/Kaikora Stream sites is 10.9 times the HBRC guideline value of 0.015 mg/L for lowland streams. However, the relative contribution from WWTP to the SRP concentration in stream is difficult to assess without a representative sample of the Te Aute Drain /Kaikora Stream waters from up gradient of the WWTP influence. Up gradient samples of Te Aute Drain/Kaikora Stream samples are important given the possibility that a proportion of the P within the stream is derived from sources associated with intensive land use.

Table 4.2 Statistical Summary of hydrochemisry from both Te Aute Drain/Kaikora Stream sites.

	NO ₃ -N	NO ₂ -N	Mg ⁺⁺	Ca ⁺⁺	Cl/Br	Cl/I	Cl/F	Cl/B	TAN	SRP
Valid Cases	16	16	16	16	16	8	8	8	16	16
Mean	0.0010	0.0013	6.9	79.4	252.9	14421.2	216.7	1156.2	0.02	0.24
Median	0.0010	0.0010	6.6	78.0	244.4	13953.0	216.7	1160.2	0.01	0.17
Standard Deviation	0.0000	0.0004	0.9	6.3	46.9	7033.6	28.2	143.1	0.02	0.20
Coefficient of Variation	0.0000	0.3578	0.1	0.1	0.2	0.5	0.1	0.1	1.12	0.86
Minimum	0.0010	0.0010	5.8	72.0	200.0	7407.4	183.3	1000.0	0.01	0.06
Maximum	0.0010	0.0020	8.4	90.0	333.3	22371.4	250.0	1304.3	0.06	0.62
Range	0.0000	0.0010	2.6	18.0	133.3	14964.0	66.7	304.3	0.06	0.56
Lower Quartile	0.0010	0.0010	6.2	74.5	214.2	7934.5	191.7	1023.8	0.01	0.08
Upper Quartile	0.0010	0.0015	7.6	84.0	286.3	20907.9	241.7	1288.5	0.02	0.36
Interquartile Range	0.0000	0.0005	1.4	9.5	72.2	12973.4	50.0	264.7	0.01	0.28

The groundwater sampling sites 1628 (bore, 3 m BGL) and 3689 (bore, 65 m BGL; screen 2.01 – 65.0 m BGL) occur adjacent to, and down gradient of the Otane WWTP but up gradient of the Drumpeel Road drain which is the current site of effluent disposal. Hydrochemical signatures for both sites suggest some minor influence from WWTP effluent perhaps reflecting a legacy signature that developed prior to reticulation and or lining of the effluent pond. A similar assessment is made for groundwaters from site 3687 that lies to the NE of the Drumpeel Road Drain but down gradient of the Otane Plant³. The possibility of a legacy WWTP is consistent the persistence of P plumes in groundwater systems for many decades after a P-rich effluent source has been curtailed or relocated (Robertson et al., 1998; Hu et al., 2005; Spiteri et al., 2007). However, the WWTP effluent signature for these three groundwater sites is subdued relative to groundwaters immediately down gradient of the Drumpeel Road Drain and those of the Te Aute Drain/Kaikora Stream sites.

³ Groundwaters from site 3687 constitute the only strongly oxidised waters with elevated NO₃-N that most likely reflects a local pastoral land signature as oxidisable nitrate is likely to have been denitrified long before reaching this site.

In summary, analysis of the WWTP signature in WWTP effluent and local ground- and surface-waters indicates variable contamination with P-rich effluent from the Otane WWTP. More specifically, three WWTP signatures are apparent: (i) a clear WWTP signature on groundwaters immediately adjacent to or down gradient of the Drumpeel Road Drain through which the WWTP effluent percolates (groundwater sites 3601, 3692, 3688, 3691); (ii) a more dilute but still recognisable WWTP signature in both Te Aute Drain/Kaikora Stream sites (3673 and 3680), and; (iii) a possible legacy signature associated with historic disposal practices (i.e., pre-reticulation and plant upgrade) occurring in the groundwaters of sites 1628, 3689 and 3687. Of the three signatures, the legacy signatures are the most uncertain. Within the context of this study, groundwater sites 3644 and 3690 show little evidence of WWTP contamination, legacy or current.

5.0 INTERPRETATION

Hydrochemical analysis of water quality results from bores and surface water sites sampled by HBRC revealed localised elevated groundwater enriched in WWTP derived P. Specifically, three WWTP signatures are apparent: (i) a clear WWTP signature on groundwaters immediately adjacent to or down gradient of the Drumpeel Road Drain through which the WWTP effluent percolates (groundwater sites 3601, 3692, 3688, 3691); (ii) a more dilute but still recognisable WWTP signature in both Te Aute Drain/Kaikora Stream sites (3673 and 3680), and; (iii) a possible legacy signature associated with historic disposal practices (i.e., pre-reticulation and plant upgrade) occurring in the groundwaters of sites 1628, 3689 and 3687. Of the three signatures, the legacy signatures are the most uncertain.

The possibility of the overprinting of a legacy plume of P-rich WWTP by a more recent WWTP source signature is raised. The more recent (active) signature appears to extend north of the east-west trending Drumpeel Road drain (Sites 3686 and 3561) with a proportion of the local WWTP impacted groundwater discharging as base flow to the Te Aute Drain/Kaikora Stream (Figure 5.1). It is likely that the active plume extends up gradient of the upstream site and down gradient of the downstream site. Sites 3690 and 3644 lie immediately to the west-north-west of Drumpeel Road and show little evidence of contamination from the WWTP. Site 3690 is a deep bore (63 m BGL) but screened at a shallow depth of 9.03 – 10.33 m BGL and site 3644 is a shallow bore (9.3 m BGL; screen 7.17 – 9.3 m) and so provide some gross restriction on the eastern lateral extent of the plume. Site 3687 (22.6 m BGL; screen 15.09 – 16.92 m BGL) located to the east-north-east shows some signs of a legacy WWTP signature but little evidence for recent or active contamination from disposal through the Drumpeel Road Drain.

Finally, sites 1628, 3689 and 3687 show some signs of legacy contamination that may have migrated down gradient of the original WWTP disposal area parallel to the prevailing groundwater flow direction. The flaring or broadening of a contaminant plume down gradient of its source is typical of advection and dispersion processes within aquifers. However, the existence of a legacy plume associated with an older or legacy discharge remains a tentative hypothesis. Much more certainty is given to the active signature down gradient of the Drumpeel Road drain where WWTP effluent percolates into the shallow local aquifer system.

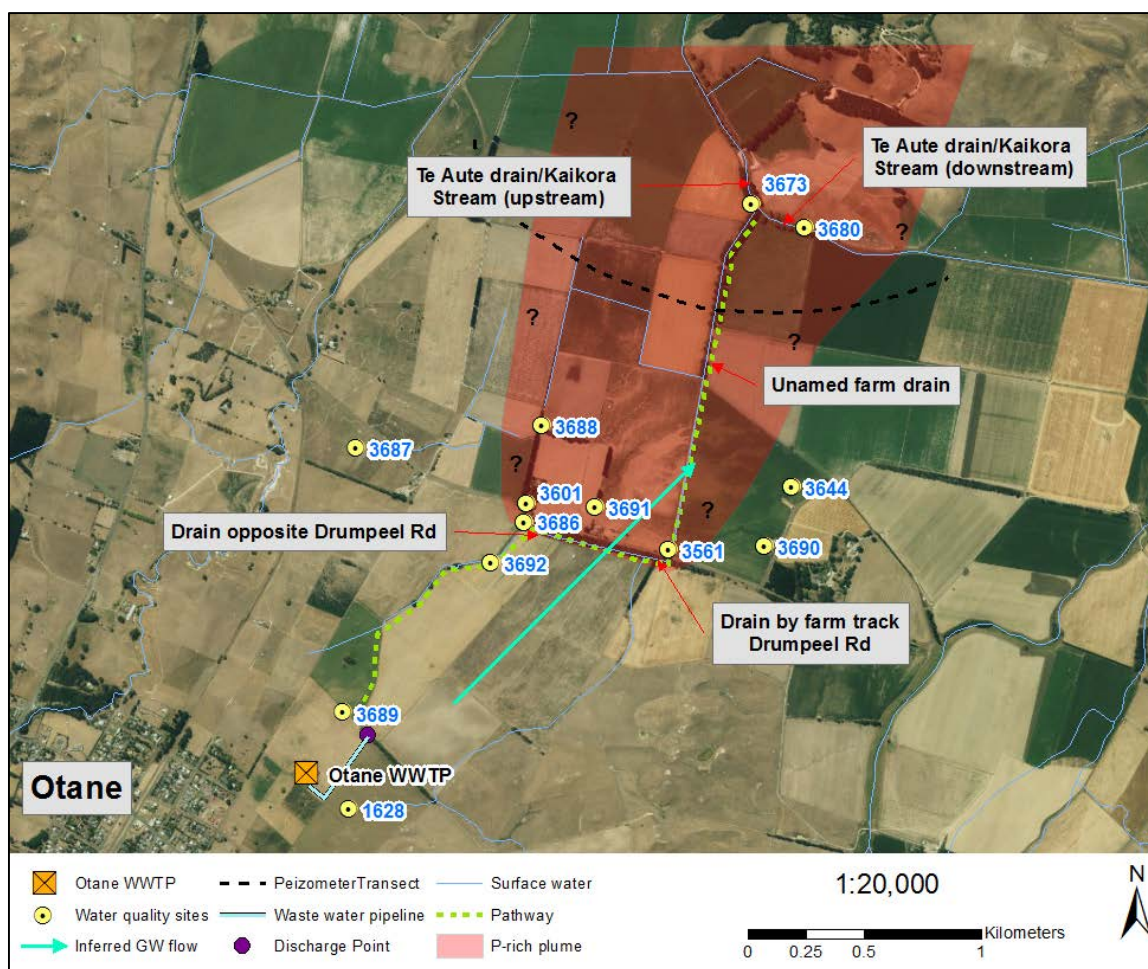


Figure 5.1 Map showing the effluent contaminant drain pathway, possible extent of the WWTP plume containing WWTP derived P, inferred groundwater flow direction (Lynch et al., 2013; Gordon, 2016), and a potential piezometer transect line for further investigation of the plume. Lateral extent of the plume and whether it extends beyond Te Aute Drain/Kaikora stream is poorly understood.

The mobility of P within the study area is likely a feature of the sorptive capacity of the shallow unsaturated zone and unconfined aquifer being overwhelmed by ongoing WWTP effluent rich in P. Whether or not P sorptive capacity is overwhelmed is a feature of the loading rates, duration of loading, the sorptive capacity of unsaturated and saturated zone materials and the redox status of local aquifers. At Otane it is suggested that the existence of a shallow unsaturated zone subject to significant water table fluctuations, reducing soils and locally reducing aquifers favours higher P mobility than in areas where the unsaturated zone is much deeper and not subjected to frequent redox excursions associated with fluctuating water tables. Furthermore, aside from site 3687, redox assignments indicate that all groundwater samples are reducing (Anoxic $\text{Fe}^{\text{III}}/\text{SO}_4$ and/or CO_2 - reducing with fewer Mixed (oxic-anoxic) waters; Appendix 1). This includes bores unimpacted by WWTP effluent. Due to reducing conditions within local aquifers all of the groundwaters sampled exhibit saturation with respects to manganese phosphate ($\text{MnHPO}_4(\text{c})$) and a few show saturation with respects to Vivianite ($\text{Fe}^{2+}\text{Fe}_2^{+2}(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$). Vivianite is an iron phosphate mineral that is known to occur as colloids (1 nm – 1000 nm) that are mobile in reduced aquifers (Gschwend and Reynolds, 1987)⁴. The presence of natural aquifer conditions that favour phosphate transport equates to an elevated water quality risk to ground- and surface- waters from P rich WWTP effluent.

⁴ The observation of reducing groundwaters and elevated P concentrations raises a broader question around P sources within the Papanui Catchment.

6.0 CONCLUSIONS

Phosphorus within the ground- and surface- waters of the Otane area may come from multiple sources including natural (lithological or organic), pastoral land-use, and WWTP effluent. However, a hydrochemical assessment of ground- and surface- (drain) waters in the vicinity and down gradient of the Drumpeel Road drain indicates that the discharge of WWTP effluent is an important source of P to some local ground- and surface- waters. Impacted bores contain 10.7 times, and unimpacted sites contain 3.1 times the 0.015 mg/L SRP level set by the HBRC for lowland streams. Despite evidence for local enrichment in P derived from WWTP effluent the concentrations of SRP in local groundwaters are still 33 times lower than that of sampled WWTP effluent. This indicates a large proportion of P is retained within soil and subsurface materials. Confidence that a proportion of the anomalous SRP is associated with the WWTP comes from multiple lines of evidence including evidence of mixing and dilution of WWTP effluent with local ground- and surface- waters.

A portion of the WWTP impacted groundwater appears to discharge to the Te Aute Drain/Kaikora Stream. However, currently the lateral extent of the active WWTP plume is poorly defined. Elevated SRP concentrations at both Te Aute Drain/Kaikora Stream sites may also be partially derived from up gradient sources. The relative contribution from WWTP effluent to the SRP concentration in stream is difficult to assess without a representative sample of the Te Aute Drain/Kaikora Stream waters from up gradient of the WWTP influence. Up gradient sources of P likely include both natural (lithological and organic) and land use derived sources.

The high mobility of P within the study area is likely a feature of the sorptive capacity of the shallow unsaturated zone and unconfined aquifer being overwhelmed by sustained discharge of P rich WWTP effluent and the typically greater mobility of P in reduced aquifer systems. Whether or not P sorptive capacity is overwhelmed is a feature of the loading rates, duration of loading, the sorptive capacity of unsaturated and saturated zone materials and the redox status of local aquifers. At Otane, it is suggested that the existence of a shallow unsaturated zone subject to significant water table fluctuations, reducing soils, and locally reducing aquifers favours higher P mobility than what occurs in areas where the unsaturated zone is much deeper and not subjected to frequent redox excursions associated with fluctuating water tables. The possibility of a legacy plume of P-enriched water associated with an older discharge at or around the current Otane WWTP was raised but remains a tentative hypothesis.

The impact of WWTP derived TAN and WWTP derived nitrate and nitrite on local waters is minimal due to natural attenuation processes occurring in the unsaturated zone and shallow aquifer. Similarly, WWTP derived *E.Coli* did not appear to impact on local waters over the sampling period due to effective physical exclusion by the unsaturated zone matrix.

7.0 RECOMMENDATIONS

Due to a lack of bores immediately south, south-west, and south-east of Te Aute Drain/Kaikora Stream, the exact lateral extent of the P-enriched plume was unable to be defined. Furthermore, the varying source of P and the contribution from pastoral and/or natural sources is poorly defined for the Te Aute Drain/Kaikora Stream. Better resolution over the source of P in local ground and surface waters as well as the extent of the WWTP plume and its impact on local aquifers and the Te Aute Drain/Kaikora Stream may be derived from:

1. Drilling and sampling of shallow monitoring bores immediately south, south-west, and south-east of Te Aute Drain/Kaikora Stream.
2. Completion of higher density longitudinal sampling up gradient and down gradient of the two Te Aute Drain/Kaikora Stream sampling sites. The two objectives are to: (i) characterise the hydrochemical signature of the stream up gradient of any WWTP influence, and; (ii) better define the lateral extent of the active WWTP on the stream. This work should be completed during a period of low flow.
3. Further examination of the source and fate of P in the Papanui Catchment is recommended in terms of assessing natural sources associated with local lithologies and reducing conditions. This could include analysis of P isotopes to determine the source of P in the catchment (e.g., WWTP effluent, lithological/natural, or agricultural).

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APPENDICES

APPENDIX 1: METHODOLOGY

A1.1 REDOX ASSIGNMENT

Assignment of redox state is based on the methodology of McMahon and Chapelle (2008), as implemented in the excel spread sheet of Jurgens et al. (2009). This approach involves comparison of the concentrations of selected redox-sensitive substances to the thresholds listed in Table A 1.1.

Table A 0.1: Redox category and dominant redox process for groundwater and surface water as determined from measured concentrations of water quality parameters (after Jurgens et al., 2009)

Redox Category	Redox Process	Criteria for Assigning Redox State					
		D.O. ≥ 0.5 mg/L	NO ₃ -N ≥ 0.5 mg/L	Mn(II) ≥ 0.05 mg/L	Fe(II) ≥ 0.01 mg/L	SO ₄ ≥ 0.5 mg/L	Fe/H ₂ S ≥ 0.3 (mass ratio)
Oxic	O ₂	Y	NA	N	N	NA	NA
Suboxic	O ₂	N	N	N	N	NA	NA
Mixed (oxic-anoxic)	O ₂ -Mn(IV)	Y	NA	Y	N	NA	NA
Mixed (oxic-anoxic)	O ₂ -Fe(III)	Y	N	NA	Y	Y	Y
Mixed (oxic-anoxic)	O ₂ -Fe(III)-SO ₄	Y	N	NA	Y	Y	Y
Mixed (oxic-anoxic)	O ₂ -SO ₄	Y	N	NA	Y	Y	N
Mixed (oxic-anoxic)	O ₂ -CH ₄ gen.	Y	N	NA	Y	N	NA
Mixed (anoxic)	NO ₃ -Mn(IV)	N	Y	Y	N	NA	NA
Mixed (anoxic)	NO ₃ -CH ₄ gen.	N	Y	NA	Y	N	NA
Anoxic	NO ₃	N	Y	N	N	NA	NA
Anoxic	Mn(IV)	N	N	Y	N	NA	NA
Anoxic	Fe(III)	N	N	NA	Y	Y	Y
Anoxic	SO ₄	N	N	NA	Y	Y	N
Anoxic	CH ₄ gen.	N	N	NA	Y	N	NA

It is recognised that redox reactions are usually not at chemical equilibrium in low temperature groundwaters. Hence this approach for assignment of redox state is based on the widely observed ecological succession of electron-accepting processes. Redox assignment for each sample includes identification of the dominant redox state (i.e., oxic, suboxic, or mixed (oxic-anoxic)) and the principal terminal electron accepting process operating within that groundwater. If the required data are available, iron reducing conditions are differentiated from SO₄ reducing conditions by measuring the mass ratio of Fe(II) to total sulphide (Jurgens et al., 2009).

A1.2 MINERAL SATURATION INDICES

Mineral dissolution reactions can play an important role in governing the hydrochemistry of surface water and groundwater. Consider the generic reaction where the mineral A_nB_m dissolves to produce the ions A⁺ and B⁻:



The solubility product K_{SP} is a constant that is specific for the mineral in question and that defines the relationship between A⁺ and B⁻ at chemical equilibrium:

$$K_{SP} = [A^+]^n [B^-]^m \quad (A2)$$

where square brackets represent the activities⁵ of the enclosed ions and n and m are the stoichiometric coefficients in the dissolution reaction. The saturation index (SI) provides an evaluation of whether a given solution is at chemical equilibrium with respect to a given mineral:

$$SI = \log\left(\frac{[A^+]^n [B^-]^m}{K_{sp}}\right) \quad (A3)$$

If SI = 0 then the system is at chemical equilibrium and the solution is saturated with respect to the given mineral; if SI < 0 the solution is under-saturated and the mineral is expected to dissolve; and if SI > 0 the solution is oversaturated and the mineral is expected to precipitate.

Measurement of the dissolved concentrations of several different elements allows the saturation indices for a wide variety of minerals to be calculated by comparison to published tables of mineral solubility products (Langmuir, 1997). This information on mineral saturation state can provide useful information on what types of minerals natural water has reacted with, which in turn can provide insight into hydrological processes and flow paths (Hem, 1985).

In this study, saturation indices are calculated with respect to a limited set of minerals. All calculations of saturation indices were performed using AquaChem 2014 software (Schlumberger Water Services) and the phreeqc thermodynamic database (Pankhurst and Appelo, 2013) and are based on either calculated median concentrations or sample-specific analytical results for the relevant elements.

A1.3 ADDITIONAL HALIDE REFERENCES

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⁵ In thermodynamics, activity defines the amount of a substance that is available for reaction. For most natural waters, activity is approximately equal to concentration in moles per litre of solution.

A1.4 ADDITIONAL PHOSPHATE TRANSPORT REFERENCES

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A1.5 AMMONIA AND NITRATE DYNAMICS REFERENCES

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APPENDIX 2: FULL DATASET

SiteID	Date	BoreNo	Sample ID	Easting	Northing	Well Depth	Screen	Type	Observation	SiteDesc	General Redox Category	Redox Process
3692	19/02/2016	16446	58959	2821681	6140209	3.6		Local GW&SW	Shallow well immediately adjacent to WWTP open drain	Well 16446	Anoxic	Fe(III)/SO4
3692	12/04/2016	16446	59600	2821681	6140209	3.6		Local GW&SW	Shallow well immediately adjacent to WWTP open drain	Well 16446	Anoxic	Fe(III)/SO4
3692	19/01/2016	16446	58673	2821681	6140209	3.6		Local GW&SW	Shallow well immediately adjacent to WWTP open drain	Well 16446	Anoxic	Fe(III)/SO4
3692	17/03/2016	16446	54749	2821681	6140209	3.6		Local GW&SW	Shallow well immediately adjacent to WWTP open drain	Well 16446	Mixed(anoxic)	NO3-Fe(III)/SO4
3680	19/01/2016		54684	2823026	6141647			Local GW&SW	Te Aute/Kaikora Stream d/s conf with WWTP outfall	Kaikora Drain 200m DS Otane Sewerage Scheme Drain TLB	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
3680	19/01/2016		54684	2823026	6141647			Local GW&SW	Te Aute/Kaikora Stream d/s conf with WWTP outfall	Kaikora Drain 200m DS Otane Sewerage Scheme Drain TLB	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
3680	19/02/2016		54685	2823026	6141647			Local GW&SW	Te Aute/Kaikora Stream d/s conf with WWTP outfall	Kaikora Drain 200m DS Otane Sewerage Scheme Drain TLB	Mixed(oxic-anoxic)	O2-Mn(IV)
3680	19/02/2016		54685	2823026	6141647			Local GW&SW	Te Aute/Kaikora Stream d/s conf with WWTP outfall	Kaikora Drain 200m DS Otane Sewerage Scheme Drain TLB	Mixed(oxic-anoxic)	O2-Mn(IV)
3680	17/03/2016		54758	2823026	6141647			Local GW&SW	Te Aute/Kaikora Stream d/s conf with WWTP outfall	Kaikora Drain 200m DS Otane Sewerage Scheme Drain TLB	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3680	17/03/2016		54758	2823026	6141647			Local GW&SW	Te Aute/Kaikora Stream d/s conf with WWTP outfall	Kaikora Drain 200m DS Otane Sewerage Scheme Drain TLB	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3680	12/04/2016		54754	2823026	6141647			Local GW&SW	Te Aute/Kaikora Stream d/s conf with WWTP outfall	Kaikora Drain 200m DS Otane Sewerage Scheme Drain TLB	Oxic	O2
3680	12/04/2016		54754	2823026	6141647			Local GW&SW	Te Aute/Kaikora Stream d/s conf with WWTP outfall	Kaikora Drain 200m DS Otane Sewerage Scheme Drain TLB	Oxic	O2
3673	19/01/2016		54683	2822796	6141750			Local GW&SW	Te Aute/Kaikora Stream u/s conf with WWTP outfall	50m us of confluence on the TRB of the Kaikora Drain	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
3673	19/01/2016		54683	2822796	6141750			Local GW&SW	Te Aute/Kaikora Stream u/s conf with WWTP outfall	50m us of confluence on the TRB of the Kaikora Drain	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
3673	19/02/2016		54695	2822796	6141750			Local GW&SW	Te Aute/Kaikora Stream u/s conf with WWTP outfall	50m us of confluence on the TRB of the Kaikora Drain	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3673	19/02/2016		54695	2822796	6141750			Local GW&SW	Te Aute/Kaikora Stream u/s conf with WWTP outfall	50m us of confluence on the TRB of the Kaikora Drain	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3673	17/03/2016		54757	2822796	6141750			Local GW&SW	Te Aute/Kaikora Stream u/s conf with WWTP outfall	50m us of confluence on the TRB of the Kaikora Drain	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3673	17/03/2016		54757	2822796	6141750			Local GW&SW	Te Aute/Kaikora Stream u/s conf with WWTP outfall	50m us of confluence on the TRB of the Kaikora Drain	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3673	12/04/2016		54768	2822796	6141750			Local GW&SW	Te Aute/Kaikora Stream u/s conf with WWTP outfall	50m us of confluence on the TRB of the Kaikora Drain	Anoxic	Mn(IV)
3673	12/04/2016		54768	2822796	6141750			Local GW&SW	Te Aute/Kaikora Stream u/s conf with WWTP outfall	50m us of confluence on the TRB of the Kaikora Drain	Anoxic	Mn(IV)
3687	4/05/2016	1492	59602	2821100	6140700	22.56	15.09-16.92	Local GW&SW	Well - high TON/Ox	Well 1492	Mixed(oxic-anoxic)	O2-Mn(IV)
3644	14/04/2016	16256	59469	2822970	6140534	9.3	7.17-9.10	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	14/04/2016	16256	59469	2822970	6140534	9.3	7.17-9.10	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	8/03/2016	16256	59413	2822970	6140534	9.3	7.17-9.8	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	8/03/2016	16256	59413	2822970	6140534	9.3	7.17-9.8	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	19/02/2016	16256	58954	2822970	6140534	9.3	7.17-9.4	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	Fe(III)/SO4
3644	19/02/2016	16256	58954	2822970	6140534	9.3	7.17-9.4	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	Fe(III)/SO4
3644	19/01/2016	16256	58668	2822970	6140534	9.3	7.17-9.3	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	19/01/2016	16256	58668	2822970	6140534	9.3	7.17-9.3	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	17/03/2016	16256	54751	2822970	6140534	9.3	7.17-9.6	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	17/03/2016	16256	54751	2822970	6140534	9.3	7.17-9.6	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	12/04/2016	16256	59598	2822970	6140534	9.3	7.17-9.5	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	12/04/2016	16256	59598	2822970	6140534	9.3	7.17-9.5	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	14/01/2016	16256	58648	2822970	6140534	9.3	7.17-9.7	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	14/01/2016	16256	58648	2822970	6140534	9.3	7.17-9.7	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	10/02/2016	16256	58779	2822970	6140534	9.3	7.17-9.9	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3644	10/02/2016	16256	58779	2822970	6140534	9.3	7.17-9.9	Local GW&SW	Well 16256 east of unamed drain	Drumpeel Road, Otane	Anoxic	CH4gen
3689	4/05/2016	4325	59601	2821043	6139567	65	2.01-65.0	Local GW&SW	Well adjacent (N-W) to WWTP	Well 4325	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3689	4/05/2016	4325	59601	2821043	6139567	65	2.01-65.0	Local GW&SW	Well adjacent (N-W) to WWTP	Well 4325	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
1628	4/05/2016	16493	59603	2821071	6139155	3		Local GW&SW	Well adjacent (S-W) to WWTP	Elsthorpe road, Otane	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3601	19/02/2016	16126	58951	2821833	6140464	Unknown		Local GW&SW	Well just N of 3686 WWTP water	203 Drumpeel Road	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3601	12/04/2016	16126	59595	2821833	6140464	Unknown		Local GW&SW	Well just N of 3686 WWTP water	203 Drumpeel Road	Anoxic	Fe(III)/SO4
3601	17/03/2016	16126	54747	2821833	6140464	Unknown		Local GW&SW	Well just N of 3686 WWTP water	203 Drumpeel Road	Anoxic	Fe(III)/SO4
3601	19/01/2016	16126	58665	2821833	6140464	Unknown		Local GW&SW	Well just N of 3686 WWTP water	203 Drumpeel Road	Anoxic	Fe(III)/SO4
3691	19/02/2016	15035	58952	2822127	6140450	Unknown		Local GW&SW	Well N of Drumpeel Rd drain and sites 3686 and 3561	Well 15035 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3691	19/01/2016	15035	58666	2822127	6140450	Unknown		Local GW&SW	Well N of Drumpeel Rd drain and sites 3686 and 3562	Well 15035 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3691	12/04/2016	15035	59596	2822127	6140450	Unknown		Local GW&SW	Well N of Drumpeel Rd drain and sites 3686 and 3563	Well 15035 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3688	12/04/2016	3159	59599	2821896	6140797	15.8	9.1-15.8	Local GW&SW	Well north of 3686 and WWTP drain	Well 3159	Anoxic	Fe(III)/SO4
3688	17/03/2016	3159	54748	2821896	6140797	15.8	9.1-15.8	Local GW&SW	Well north of 3686 and WWTP drain	Well 3159	Anoxic	Fe(III)/SO4
3688	19/02/2016	3159	58957	2821896	6140797	15.8	9.1-15.8	Local GW&SW	Well north of 3686 and WWTP drain	Well 3159	Anoxic	Fe(III)/SO4
3688	19/01/2016	3159	58671	2821896	6140797	15.8	9.1-15.8	Local GW&SW	Well north of 3686 and WWTP drain	Well 3159	Anoxic	Fe(III)/SO4
3690	19/01/2016	5314	58667	2822851	6140280	63	9.03-10.33	Local GW&SW	Well west of 3561 and WWTP drain	Well 5314 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3690	19/01/2016	5314	58667	2822851	6140280	63	9.03-10.33	Local GW&SW	Well west of 3561 and WWTP drain	Well 5314 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3690	17/03/2016	5314	54750	2822851	6140280	63	9.03-10.33	Local GW&SW	Well west of 3561 and WWTP drain	Well 5314 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3690	17/03/2016	5314	54750	2822851	6140280	63	9.03-10.33	Local GW&SW	Well west of 3561 and WWTP drain	Well 5314 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3690	19/02/2016	5314	58953	2822851	6140280	63	9.03-10.33	Local GW&SW	Well west of 3561 and WWTP drain	Well 5314 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3690	19/02/2016	5314	58953	2822851	6140280	63	9.03-10.33	Local GW&SW	Well west of 3561 and WWTP drain	Well 5314 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3690	12/04/2016	5314	59597	2822851	6140280	63	9.03-10.33	Local GW&SW	Well west of 3561 and WWTP drain	Well 5314 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3690	12/04/2016	5314	59597	2822851	6140280	63	9.03-10.33	Local GW&SW	Well west of 3561 and WWTP drain	Well 5314 @ Drumpeel Road	Anoxic	Fe(III)/SO4
3561	19/01/2016		54682	2822443	6140265			WWTP Eff	WWTP water in drain/trib	Kaikora Tributary at Drumpeel Road	Mixed(anoxic)Or(oxic-anoxic)	Fe(III)/SO4-O2?OrNO3
3561	19/02/2016		54696	2822443	6140265			WWTP Eff	WWTP water in drain/trib	Kaikora Tributary at Drumpeel Road	Mixed(oxic-anoxic)	O2-Mn(IV)
3561	12/04/2016		54720	2822443	6140265			WWTP Eff	WWTP water in drain/trib	Kaikora Tributary at Drumpeel Road	Mixed(oxic-anoxic)	O2-Mn(IV)
3561	17/03/2016		54756	2822443	6140265			WWTP Eff	WWTP water in drain/trib	Kaikora Tributary at Drumpeel Road	Oxic	O2
3686	19/01/2016		54681	2821820	6140380			WWTP Eff	WWTP water in drain/trib	Farm Drain opposite 203 Drumpeel Road	AnoxicOrMixed(oxic-anoxic)	Fe(III)/SO4-O2?
3686	19/02/2016		54686	2821820	6140380			WWTP Eff	WWTP water in drain/trib	Farm Drain opposite 203 Drumpeel Road	Mixed(oxic-anoxic)	O2-Fe(III)/SO4
3686	17/03/2016		54753	2821820	6140380			WWTP Eff	WWTP water in drain/trib	Farm Drain opposite 203 Drumpeel Road	Mixed(oxic-anoxic)	O2-Mn(IV)
3686	12/04/2016		54769	2821820	6140380			WWTP Eff	WWTP water in drain/trib	Farm Drain opposite 203 Drumpeel Road	Oxic	O2

SiteID	Date	BoreNo	Sample	Easting	Northing	Temp.	pH	EC	Dissolved	O2(aq)	NO ₃ -N	NO ₂ -N	TAN	SRP	Mn++	Fe++	SO ₄ --	Cl-	Br-	I-	F-	B	HCO ₃ -	Carbonate	Na+	K+	Mg++	Ca++	Hardness	SiO ₂ (aq)
3692	19/02/2016	16446	58959	2821681	6140209	15.6	7.33	404.8	330	0.2	0.001	0.001	0.45	0.161	0.191	1.47	2.7	26	0.11				329	0.5	21	4	4.9	81	85.9	37
3692	12/04/2016	16446	59600	2821681	6140209	15.3	6.56	412.1	340	0.3	0.091	0.001	0.38	0.12	0.153	0.6	10.5	25	0.1	0.014	0.15	0.056	342	0.5	20	4	4.8	78	82.8	37
3692	19/01/2016	16446	58673	2821681	6140209	14.4	7.03	390.6	320	0.1	0.126	0.003	0.49	0.081	0.198	1.83	2.2	26	0.11				329	0.5	18	3.8	4.9	75	79.9	37
3692	17/03/2016	16446	54749	2821681	6140209	15.1	7.16	417.3	350	0.3	0.92	0.001	0.36	0.076	0.15	0.57	15.1	26	0.12	0.011	0.16	0.059	329	0.5	21	4.1	5.3	82	87.3	35
3680	19/01/2016		54684	2823026	6141647		7.5	613	410			0.001	0.002	0.062	0.62	0.61	0.32	26	34	0.13			366	0.5	27	4.1	8.4	90	98.4	32
3680	19/01/2016		54684	2823026	6141647		7.5	613	410			0.001	0.002	0.062	0.62	0.61	0.32	26	34	0.13			366	0.5	27	4.1	8.4	90	98.4	32
3680	19/02/2016		54685	2823026	6141647	19.9	7.5	415.1	340	1.84	0.001	0.001	0.005	0.22	0.129	0.08	7.3	25	0.12				317	0.5	22	3.7	6.8	77	83.8	43
3680	19/02/2016		54685	2823026	6141647	19.9	7.5	415.1	340	1.84	0.001	0.001	0.005	0.22	0.129	0.08	7.3	25	0.12				317	0.5	22	3.7	6.8	77	83.8	43
3680	17/03/2016		54758	2823026	6141647	16.1	6.98	460	320	3.1	0.001	0.001	0.019	0.112	0.39	0.13	4.4	22	0.11	0.027	0.12	0.021	305	0.5	18.8	2.8	6.4	73	79.4	39
3680	17/03/2016		54758	2823026	6141647	16.1	6.98	460	320	3.1	0.001	0.001	0.019	0.112	0.39	0.13	4.4	22	0.11	0.027	0.12	0.021	305	0.5	18.8	2.8	6.4	73	79.4	39
3680	12/04/2016		54754	2823026	6141647	15.4	7.41	512.3	350	2.61	0.001	0.001	0.005	0.074	0.028	0.06	6.9	28	0.09	0.016	0.12	0.022	317	0.5	22	3.1	6.1	79	85.1	30
3680	12/04/2016		54754	2823026	6141647	15.4	7.41	512.3	350	2.61	0.001	0.001	0.005	0.074	0.028	0.06	6.9	28	0.09	0.016	0.12	0.022	317	0.5	22	3.1	6.1	79	85.1	30
3673	19/01/2016		54683	2822796	6141750		7.5	602	400			0.001	0.002	0.005	0.5	0.47	0.31	24	34	0.13			366	0.5	26	3.7	8.3	88	96.3	32
3673	19/01/2016		54683	2822796	6141750		7.5	602	400			0.001	0.002	0.005	0.5	0.47	0.31	24	34	0.13			366	0.5	26	3.7	8.3	88	96.3	32
3673	19/02/2016		54695	2822796	6141750	19.4	7.41	487.3	330	1.19	0.001	0.001	0.016	0.22	0.32	0.1	6.7	25	0.11				317	0.5	21	3.6	6.7	76	82.7	43
3673	19/02/2016		54695	2822796	6141750	19.4	7.41	487.3	330	1.19	0.001	0.001	0.016	0.22	0.32	0.1	6.7	25	0.11				317	0.5	21	3.6	6.7	76	82.7	43
3673	17/03/2016		54757	2822796	6141750	16.1	7.01	448	310	1.1	0.001	0.001	0.016	0.091	0.31	0.16	4.1	22	0.1	0.026	0.11	0.022	305	0.5	18.8	2.7	6.3	72	78.3	38
3673	17/03/2016		54757	2822796	6141750	16.1	7.01	448	310	1.1	0.001	0.001	0.016	0.091	0.31	0.16	4.1	22	0.1	0.026	0.11	0.022	305	0.5	18.8	2.7	6.3	72	78.3	38
3673	12/04/2016		54768	2822796	6141750	14.9	7.4	513.6	350	0.45	0.001	0.001	0.005	0.064	0.142	0.05	6.2	30	0.09	0.015	0.12	0.023	317	0.5	22	3.1	5.8	80	85.8	31
3673	12/04/2016		54768	2822796	6141750	14.9	7.4	513.6	350	0.45	0.001	0.001	0.005	0.064	0.142	0.05	6.2	30	0.09	0.015	0.12	0.023	317	0.5	22	3.1	5.8	80	85.8	31
3687	4/05/2016	1492	59602	2821100	6140700	15.9		575	370	0.7	7	0.043	0.019	0.084	0.053	0.07	20	20	0.1	0.010	0.1	0.052	329	0.5	23	3	6	95	101	25
3644	14/04/2016	16256	59469	2822970	6140534	14.3	6.62	571	470	0.2	0.001	0.001	1.7	1.12	1.21	4.7	0.25	42					464	0.5	49	6.9	9.1	97	106.1	30
3644	14/04/2016	16256	59469	2822970	6140534	14.3	6.62	571	470	0.2	0.001	0.001	1.7	1.12	1.21	4.7	0.25	42					464	0.5	49	6.9	9.1	97	106.1	30
3644	8/03/2016	16256	59413	2822970	6140534	14.8	7.57	718	480	0.1	0.001	0.001	1.8	0.83	1.12	4.3	0.25	43					476	0.5	45	6.1	8.3	91	99.3	31
3644	8/03/2016	16256	59413	2822970	6140534	14.8	7.57	718	480	0.1	0.001	0.001	1.8	0.83	1.12	4.3	0.25	43					476	0.5	45	6.1	8.3	91	99.3	31
3644	19/02/2016	16256	58954	2822970	6140534	14.9	7.25	577	460	0.1	0.095	0.001	1.7	0.156	1.23	5.1	0.6	44	0.16				476	1	45	6.3	9.3	96	105.3	30
3644	19/02/2016	16256	58954	2822970	6140534	14.9	7.25	577	460	0.1	0.095	0.001	1.7	0.156	1.23	5.1	0.6	44	0.16				476	1	45	6.3	9.3	96	105.3	30
3644	19/01/2016	16256	58668	2822970	6140534	14.9	7.5	566	450	0.1	0.001	0.001	1.9	0.073	1.07	4.4	0.25	41	0.14				451	0.5	37	5.9	7.9	88	95.9	30
3644	19/01/2016	16256	58668	2822970	6140534	14.9	7.5	566	450	0.1	0.001	0.001	1.9	0.073	1.07	4.4	0.25	41	0.14				451	0.5	37	5.9	7.9	88	95.9	30
3644	17/03/2016	16256	54751	2822970	6140534	14.6	7.52	576	480	0.2	0.001	0.001	2	0.02	1.15	4.6	0.25	42	0.17	0.063	0.28	0.159	451	0.5	46	6.4	9	97	106	31
3644	17/03/2016	16256	54751	2822970	6140534	14.6	7.52	576	480	0.2	0.001	0.001	2	0.02	1.15	4.6	0.25	42	0.17	0.063	0.28	0.159	451	0.5	46	6.4	9	97	106	31
3644	12/04/2016	16256	59598	2822970	6140534	14.7	6.59	575	470	0.1	0.003	0.001	1.8	0.016	1.14	4.4	0.25	43	0.16	0.061	0.27	0.159	476	0.5	42	6.1	8.1	92	100.1	29
3644	12/04/2016	16256	59598	2822970	6140534	14.7	6.59	575	470	0.1	0.003	0.001	1.8	0.016	1.14	4.4	0.25	43	0.16	0.061	0.27	0.159	476	0.5	42	6.1	8.1	92	100.1	29
3644	14/01/2016	16256	58648	2822970	6140534	14.3	7.6	569	470	0.2	0.029	0.001	2	0.014	1.32	5.1	0.25	45					464	0.5	49	6.7	9.6	98	107.6	32
3644	14/01/2016	16256	58648	2822970	6140534	14.3	7.6	569	470	0.2	0.029	0.001	2	0.014	1.32	5.1	0.25	45					464	0.5	49	6.7	9.6	98	107.6	32
3644	10/02/2016	16256	58779	2822970	6140534	14.6	6.86	575	470	0.2	0.004	0.001	1.8	0.012	1.24	4.7	0.25	42					464	0.5	46	6.6	8.9	94	102.9	28
3644	10/02/2016	16256	58779	2822970	6140534	14.6	6.86	575	470	0.2	0.004	0.001	1.8	0.012	1.24	4.7	0.25	42					464	0.5	46	6.6	8.9	94	102.9	28
3689	4/05/2016	4325	59601	2821043	6139567	14		603	390	1.1	0.099	0.004	0.7	0.21	0.2	1.55	17.3	26	0.09	0.023	0.19	0.108	390	0.5	29	4.2	6.5	96	102.5	23
3689	4/05/2016	4325	59601	2821043	6139567	14		603	390	1.1	0.099	0.004	0.7	0.21	0.2	1.55	17.3	26	0.09	0.023	0.19	0.108	390	0.5	29	4.2	6.5	96	102.5	23
1628	4/05/2016	16493	59603	2821071	6139155	15.7		617	400	1.61	1.19	0.049	0.022	0.124	0.077	0.24	30	27	0.1	0.021	0.21	0.14	366	0.5	36	3.4	6.5	93	99.5	26
3601	19/02/2016	16126	58951	2821833	6140464	14.8	7.01	375.2	310	0.5	0.039	0.001	0.38	0.25	0.21	2	3.7	25	0.11				305	0.5	21	4	4.9	72	76.9	39
3601	12/04/2016	16126	59595	2821833	6140464	16.7	6.78	401.1	320	0.2	0.01	0.001	0.36	0.24	0.21	1.92	4.6	25	0.11	0.019	0.16	0.051	317	0.5	19.5	4.1	4.4	69	73.4	39
3601	17/03/2016	16126	54747	2821833	6140464	14.5	6.6	376.3	320	0.2	0.008	0.001	0.33	0.164	0.21	1.94	4.1	25	0.13	0.018	0.17	0.052	305	0.5	21	4.2	5	75	80	39
3601	19/01/2016	16126	58665	2821833	6140464	14.9	7.21	370.2	310	0.2	0.006	0.006	0.37	0.054	0.197	1.93	3.5	25	0.11				305	0.5	18.1	3.9	4.6	70	74.6	39
3691	19/02/2016	1503																												

SiteID	Date	BoreNo	Sample	Easting	Northing	Cl/Br	Cl/I	Cl/F	Cl/B	Na/K	Ca/K	SO4/Cl	SRP/Cl	SRP/Br	SRP/I	SRP/F	SRP/B	Amrph ^{silica}	Aragonite	Calcite	Chalcedony	Gypsum	MnHPO4(c)	Quartz	Rhodochrosite	Siderite	Vivianite
3692	19/02/2016	16446	58959	2821681	6140209	236				5.3	20.3	0.10	0.006	1.5				-0.40	-2.56	-2.39	0.68	-3.16	1.08	0.96	-3.18	-3.71	-4.93
3692	12/04/2016	16446	59600	2821681	6140209	250	17361	167	446	5.0	19.5	0.42	0.005	1.2	8.3	0.8	2.1	-0.40	-3.35	-3.18	0.69	-2.59	0.48	0.97	-4.05	-11.96	-29.92
3692	19/01/2016	16446	58673	2821681	6140209	236				4.7	19.7	0.08	0.003	0.7				-0.39	-2.90	-2.74	0.70	-3.27	0.69	0.98	-3.47	-3.12	-3.62
3692	17/03/2016	16446	54749	2821681	6140209	217	19174	163	441	5.1	20.0	0.58	0.003	0.6	6.7	0.5	1.3	-0.42	-2.74	-2.57	0.66	-2.42	0.58	0.95	-3.47	-12.38	-31.50
3680	19/01/2016		54684	2823026	6141647	262				6.6	22.0	0.76	0.018	4.8				-0.57	-2.24	-2.07	0.45	-2.19	2.14	0.72	-2.43	-2.73	-1.22
3680	19/01/2016		54684	2823026	6141647	262				6.6	22.0	0.76	0.018	4.8				-0.57	-2.24	-2.07	0.45	-2.19	2.14	0.72	-2.43	-2.73	-1.22
3680	19/02/2016		54685	2823026	6141647	208				5.9	20.8	0.29	0.009	1.8				-0.38	-2.35	-2.19	0.67	-2.76	1.07	0.95	-3.13	-13.68	-34.77
3680	19/02/2016		54685	2823026	6141647	208				5.9	20.8	0.29	0.009	1.8				-0.38	-2.35	-2.19	0.67	-2.76	1.07	0.95	-3.13	-13.68	-34.77
3680	17/03/2016		54758	2823026	6141647	200	7407	183	1048	6.7	26.1	0.20	0.005	1.0	4.1	0.9	5.3	-0.39	-2.94	-2.77	0.69	-2.98	1.11	0.97	-3.21	-13.15	-33.48
3680	17/03/2016		54758	2823026	6141647	200	7407	183	1048	6.7	26.1	0.20	0.005	1.0	4.1	0.9	5.3	-0.39	-2.94	-2.77	0.69	-2.98	1.11	0.97	-3.21	-13.15	-33.48
3680	12/04/2016		54754	2823026	6141647	311	19444	233	1273	7.1	25.5	0.25	0.003	0.8	4.6	0.6	3.4	-0.49	-2.50	-2.33	0.59	-2.77	-0.08	0.87	-3.94	-13.83	-35.98
3680	12/04/2016		54754	2823026	6141647	311	19444	233	1273	7.1	25.5	0.25	0.003	0.8	4.6	0.6	3.4	-0.49	-2.50	-2.33	0.59	-2.77	-0.08	0.87	-3.94	-13.83	-35.98
3673	19/01/2016		54683	2822796	6141750	262				7.0	23.8	0.71	0.015	3.8				-0.57	-2.24	-2.08	0.45	-2.23	1.94	0.72	-2.54	-2.74	-1.43
3673	19/01/2016		54683	2822796	6141750	262				7.0	23.8	0.71	0.015	3.8				-0.57	-2.24	-2.08	0.45	-2.23	1.94	0.72	-2.54	-2.74	-1.43
3673	19/02/2016		54695	2822796	6141750	227				5.8	21.1	0.27	0.009	2.0				-0.38	-2.45	-2.29	0.68	-2.80	1.45	0.96	-2.83	-13.46	-34.04
3673	19/02/2016		54695	2822796	6141750	227				5.8	21.1	0.27	0.009	2.0				-0.38	-2.45	-2.29	0.68	-2.80	1.45	0.96	-2.83	-13.46	-34.04
3673	17/03/2016		54757	2822796	6141750	220	8462	200	1000	7.0	26.7	0.19	0.004	0.9	3.5	0.8	4.1	-0.40	-2.91	-2.75	0.68	-3.02	0.93	0.96	-3.27	-12.97	-33.11
3673	17/03/2016		54757	2822796	6141750	220	8462	200	1000	7.0	26.7	0.19	0.004	0.9	3.5	0.8	4.1	-0.40	-2.91	-2.75	0.68	-3.02	0.93	0.96	-3.27	-12.97	-33.11
3673	12/04/2016		54768	2822796	6141750	333	22371	250	1304	7.1	25.8	0.21	0.002	0.7	4.3	0.5	2.8	-0.47	-2.51	-2.34	0.61	-2.81	0.56	0.90	-3.25	-13.71	-35.75
3673	12/04/2016		54768	2822796	6141750	333	22371	250	1304	7.1	25.8	0.21	0.002	0.7	4.3	0.5	2.8	-0.47	-2.51	-2.34	0.61	-2.81	0.56	0.90	-3.25	-13.71	-35.75
3687	4/05/2016	1492	59602	2821100	6140700	200	20619	200	385	7.7	31.7	1.00	0.004	0.8	8.7	0.8	1.6	-0.58	-2.24	-2.07	0.50	-2.26	0.25	0.78	-3.48	-13.78	-35.90
3644	14/04/2016	16256	59469	2822970	6140534					7.1	14.1	0.01	0.027					-0.48	-3.23	-3.07	0.61	-4.17	2.33	0.89	-3.13	-2.79	-0.48
3644	14/04/2016	16256	59469	2822970	6140534					7.1	14.1	0.01	0.027					-0.48	-3.23	-3.07	0.61	-4.17	2.33	0.89	-3.13	-2.79	-0.48
3644	8/03/2016	16256	59413	2822970	6140534					7.4	14.9	0.01	0.019					-0.47	-2.30	-2.14	0.62	-4.19	2.53	0.90	-2.21	-1.80	2.03
3644	8/03/2016	16256	59413	2822970	6140534					7.4	14.9	0.01	0.019					-0.47	-2.30	-2.14	0.62	-4.19	2.53	0.90	-2.21	-1.80	2.03
3644	19/02/2016	16256	58954	2822970	6140534	275				7.1	15.2	0.01	0.004	1.0				-0.49	-2.30	-2.13	0.60	-3.80	1.77	0.88	-2.18	-1.77	-0.09
3644	19/02/2016	16256	58954	2822970	6140534	275				7.1	15.2	0.01	0.004	1.0				-0.49	-2.30	-2.13	0.60	-3.80	1.77	0.88	-2.18	-1.77	-0.09
3644	19/01/2016	16256	58668	2822970	6140534	293				6.3	14.9	0.01	0.002	0.5				-0.49	-2.38	-2.22	0.60	-4.19	1.45	0.88	-2.29	-1.85	-0.18
3644	19/01/2016	16256	58668	2822970	6140534	293				6.3	14.9	0.01	0.002	0.5				-0.49	-2.38	-2.22	0.60	-4.19	1.45	0.88	-2.29	-1.85	-0.18
3644	17/03/2016	16256	54751	2822970	6140534	247	3922	150	264	7.2	15.2	0.01	0.000	0.1	0.3	0.1	0.1	-0.47	-2.33	-2.17	0.62	-4.17	0.91	0.90	-2.25	-1.91	-1.50
3644	17/03/2016	16256	54751	2822970	6140534	247	3922	150	264	7.2	15.2	0.01	0.000	0.1	0.3	0.1	0.1	-0.47	-2.33	-2.17	0.62	-4.17	0.91	0.90	-2.25	-1.91	-1.50
3644	12/04/2016	16256	59598	2822970	6140534	269	4406	159	270	6.9	15.1	0.01	0.000	0.1	0.3	0.1	0.1	-0.50	-3.27	-3.11	0.59	-4.18	0.44	0.87	-3.17	-2.76	-4.09
3644	12/04/2016	16256	59598	2822970	6140534	269	4406	159	270	6.9	15.1	0.01	0.000	0.1	0.3	0.1	0.1	-0.50	-3.27	-3.11	0.59	-4.18	0.44	0.87	-3.17	-2.76	-4.09
3644	14/01/2016	16256	58648	2822970	6140534					7.3	14.6	0.01	0.000					-0.46	-2.26	-2.09	0.64	-4.17	0.82	0.92	-2.12	-1.79	-1.51
3644	14/01/2016	16256	58648	2822970	6140534					7.3	14.6	0.01	0.000					-0.46	-2.26	-2.09	0.64	-4.17	0.82	0.92	-2.12	-1.79	-1.51
3644	10/02/2016	16256	58779	2822970	6140534					7.0	14.2	0.01	0.000					-0.51	-3.00	-2.83	0.58	-4.18	0.51	0.86	-2.87	-2.55	-3.64
3644	10/02/2016	16256	58779	2822970	6140534					7.0	14.2	0.01	0.000					-0.51	-3.00	-2.83	0.58	-4.18	0.51	0.86	-2.87	-2.55	-3.64
3689	4/05/2016	4325	59601	2821043	6139567	289	12560	137	241	6.9	22.9	0.67	0.008	2.3	9.1	1.1	1.9	-0.60	-2.26	-2.10	0.50	-2.32	1.22	0.78	-2.93	-12.49	-31.19
3689	4/05/2016	4325	59601	2821043	6139567	289	12560	137	241	6.9	22.9	0.67	0.008	2.3	9.1	1.1	1.9	-0.60	-2.26	-2.10	0.50	-2.32	1.22	0.78	-2.93	-12.49	-31.19
1628	4/05/2016	16493	59603	2821071	6139155	270	12857	129	193	10.6	27.4	1.11	0.005	1.2	5.9	0.6	0.9	-0.56	-2.36	-2.19	0.52	-2.10	0.56	0.80	-3.43	-13.25	-33.89
3601	19/02/2016	16126	58951	2821833	6140464	227				5.3	18.0	0.15	0.010	2.3				-0.37	-2.93	-2.77	0.72	-3.06	1.21	1.00	-3.46	-11.72	-28.45
3601	12/04/2016	16126	59595	2821833	6140464	227	12285	156	490	4.8	16.8	0.18	0.010	2.2	13.0	1.5	4.7	-0.39	-3.15	-2.98	0.68	-2.98	1.07	0.96	-3.66	-3.39	-3.55
3601	17/03/2016	16126	54747	2821833	6140464	192	10743	147	481	5.0	17.9	0.16	0.007	1.3	9.2	1.0	3.2	-0.37	-3.33	-3.16	0.72	-3.00	0.78	1.00	-3.87	-3.59	-4.50
3601	19/01/2016	16126	58665	2821833	6140464	227				4.6	17.9	0.14	0.002	0.5				-0.37	-2.74	-2.58	0.72	-3.09	0.60	1.00	-3.28	-2.97	-3.57
3691	19/02/2016	15035	58952	2822127	6140450	236				4.5	15.7	0.09	0.006	1.5				-0.34	-2.52	-2.35	0.75	-3.26	1.25	1.03	-2.96	-2.61	-1.63
3691	19/01/2016	15035	58666	2822127	6140450	227				3.9	15.3	0.09	0.002	0.5				-0.32	-2.63	-2.46	0.77	-3.27	0.77	1.05	-3.08	-2.51	-2.15
3691	12/04/2016	15035	59596	2822127	6140450	173	9472	144	448	4.2	15.6	0.08	0.013	2.2	18.0	1.8	5.7	-0.34	-3.89	-3.72	0.75	-3.33	0.69	1.03	-4.36	-4.38	-6.60
3688	12/04/2016	3159	59599	2821896	6140797	210	16154	124	389	4.5	14.8	0.24	0.012	2.5	19.2	1.5	4.6	-0.37	-3.47	-3.30	0.73	-2.96	0.94	1.01	-3.93	-11.39	-27.53
3688	17/03/2016	3159	54748	2821896	6140797	162	10989	111	382	4.5	15.2	0.23	0.														



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