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NZDF PFAS Investigation – Summary Report: RNZAF Base Woodbourne, Stage C

New Zealand Defence Force

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Prepared for

New Zealand Defence Force

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Executive Summary

This report documents a sampling investigation undertaken on private properties adjacent to the Royal New Zealand Air Force (RNZAF) Base Woodbourne (the 'site') for the New Zealand Defence Force (NZDF) to investigate the potential for surface water and groundwater contamination relating to the use of per- and poly-fluoroalkyl substances (PFAS) at the site.

Sampling and laboratory analysis of 159 groundwater samples and 30 surface water samples has confirmed the presence of PFAS at some locations.

Groundwater

Groundwater samples were obtained from 150 groundwater bores over two weeks, from 14 May to 24 May 2018. Additional groundwater sampling of nine groundwater supply bores was also undertaken on 23 April 2018.

Of the 159 groundwater samples collected:

- PFAS[1] was reported by the laboratory in 69 samples (43%).
- PFAS was reported in 62 bores where landowners/occupants confirmed that the water is used for drinking water purposes.
- None of the samples were found to contain PFAS concentrations above the interim drinking water guidelines (MoH, 2017).
- 47 samples (30%) reported concentrations of PFAS above the screening value for milk consumption (home grown) (stock watering and fodder irrigation); 30 samples (19%) reported concentrations of PFAS above the screening value for milk consumption (home grown) (stock watering only); none of the samples reported concentrations of PFAS above the screening value for beef consumption (home grown) (stock watering and fodder irrigation or stock watering only); and none of the samples were above the screening value for egg consumption (home grown) (stock watering only).
- Of the samples where PFAS was reported, 18 landowners/occupants reported that the sampled water was used for stock watering, domestic irrigation or other purposes; 17 of these samples exceeded the milk consumption (home grown) screening values for stock watering and fodder irrigation, and 12 of these samples exceeded the milk consumption (home grown) screening values for stock watering only.

[1] For the purposes of this report PFAS refers to the following compounds only: perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perflourohexane sulphonate (PFHxS).

Surface Water

Surface water samples were collected from 30 locations.

Of these:

- PFAS was reported by the laboratory in 15 samples.
- PFAS concentrations in eight surface water samples (27%) were above the adopted screening values for milk consumption (home grown) (stock watering and fodder irrigation), and in six of those surface water samples (20%) PFAS concentrations were above the adopted screening values for milk consumption (home grown) (stock watering only).
- None of the surface water samples reported concentrations of PFAS above the screening values for beef or egg consumption (home grown) for stockwater and/or fodder irrigation.

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1.0 Introduction

Pattle Delamore Partners Ltd (PDP), in conjunction with a number of other Environmental Consultancies, has been engaged by the New Zealand Defence Force (NZDF) to undertake a sampling investigation to assess the potential for surface water and groundwater contamination by per- and poly-fluoroalkyl substances (PFAS) at properties adjacent to the Royal New Zealand Air Force (RNZAF) Base Woodbourne.

Stage A sample results, from sampling undertaken in December 2017, have been reported in a previous Summary Report[2] (PDP, 2018a). Based on the Stage A sample results, an expanded investigation area was proposed (being Stage B) (PDP, 2018b).

The Stage B sampling involved:

- repeat sampling of those locations sampled during Stage A; and
- sampling at additional surface water and groundwater locations identified within the expanded investigation area.

This report provides the results and findings of the sampling undertaken for this May 2018 monitoring round which involves repeat sampling of the Stage B locations, and the sampling of a small number of new surface water and groundwater locations identified within and immediately to the east of the investigation area, Stage C.

Stage C monitoring results for landowners of the properties where sampling was conducted, have been reported in individual landowner reports, with recommendations regarding the ongoing use of the water.

1.1 Project Objectives

The key project objectives for this sampling investigation were:

- To assess groundwater and surface water from sites adjacent to Base Woodbourne and determine if PFAS compounds are present;
- To compare the concentrations of PFAS compounds present against interim drinking water guideline values and applicable screening values; and
- Provide further data to update preliminary estimates of PFAS plume extent in groundwater made following the last sampling round undertaken in February 2018 (PDP, 2018b).

[2] It is noted that the February 2018 summary report refers to the 'Stage 1' sampling area. The Stage 1 sampling area has subsequently been renamed 'Stage A'.

1.2 Scope of Summary Report

The scope of work undertaken to achieve the project objectives involved:

- Collecting representative samples of groundwater and surface water from sites adjacent to RNZAF Base Woodbourne, and analyses of these samples for PFAS.
- Comparison of the laboratory results to guideline and screening value criteria (where available).
- Update of the area in the Woodbourne sampling investigation with PFAS concentrations above the limit of reporting.

2.0 Background

PFAS compounds, such as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are a group of manufactured chemicals used since the 1950s. PFAS have been and continue to be used in a wide range of industrial and commercial products including aqueous film forming foam (AFFF) used for fighting fuel fires. Recently PFAS have gained increasing scientific and regulatory interest due to their widespread use, their environmental persistence and because some PFAS (primarily PFOS and PFOA) display bio accumulative and toxic properties to humans and wildlife (CONCAWE, 2016).

PFAS are emerging contaminants. NZDF is investigating the potential for contamination of ground and water associated with the use and storage of AFFF containing PFAS at its camps and bases. Investigations at Woodbourne have identified PFAS in the water on the base.

Woodbourne is surrounded by productive land, predominantly vineyards. Shallow (and deep) groundwater is used relatively extensively surrounding the base for water supply. Grape sampling was undertaken in a separate investigation and the concentration of PFAS in the grape samples collected were not above the laboratory limit of reporting. A description of the geology and hydrogeology for the area is contained within Appendix A.

3.0 Methodology

Groundwater and surface water sampling was undertaken in groundwater supply wells and surface water at selected locations adjacent to the base following the methodology outlined in the *Sampling Protocols for Monitoring Per and Poly-fluorinated Compounds in Groundwater and Surface Water for New Zealand Defence Force* (PDP, 2018c) and the guidance documents referenced therein.

A majority of the sampling was undertaken over two weeks, from 14 May to 24 May 2018. Additional groundwater sampling of nine groundwater supply bores was also undertaken on 23 April 2018. All samples were sent to

AsureQuality laboratories, Wellington, under standard chain of custody procedures and analysed for their PFAS suite.

4.0 Guidelines and Screening Values

The interim guidelines for drinking water and non-potable water/contact recreation currently used in New Zealand to compare with the water sample data collected during this project are presented in Table 1. Additional screening criteria have been prepared by NZDF consultants EnRisks, for water supply for animals/products grown and consumed at home (home-grown produce).

Guidelines are provided for three PFAS compounds only. These compounds are known to be associated with certain types of AFFF. Henceforth results are discussed for these three compounds only. Results for the full analytical suite of 28 PFAS are available in the laboratory reports. These are provided in a separate electronic file.

Table 1: Environmental and Human Health Guidelines

Media	Sum of Total PFOS + PFHxS	PFOA	Total PFHxS	Total PFOS	Source
Drinking Water	0.07 µg/L	0.56 µg/L	-	-	MoH[1], AGDoH [2]
Non-potable water/contact recreation	0.7 µg/L	5.6 µg/L	-	-	AGDoH [2]
Stock Watering Only (home grown consumption)	-	Beef 150 µg/L	Beef 0.1 µg/L	Beef 0.1 µg/L	EnRisks [3]
	-	Milk 30 µg/L	Milk 0.02 µg/L	Milk 0.02 µg/L	
	-	Eggs 4 µg/L	Eggs 0.2 µg/L	Eggs 0.09 µg/L	
Stock Watering and Fodder Irrigation (home grown consumption)	-	Beef 60 µg/L	Beef 0.06 µg/L	Beef 0.05 µg/L	EnRisks [3]
	-	Milk 14 µg/L	Milk 0.008 µg/L	Milk 0.008 µg/L	

Notes:

1. *Ministry of Health (MoH, 2017) Interim Guidance Level for Drinking Water, PFOA, PFOS and PFHxS.*
2. *Australian Government Department of Health (AGDoH, 2017) Health Based Guidance Values for PFAS for Use in Site Investigations in Australia.*
3. *Site specific screening values from Livestock Uptake Modelling and Screening Criteria Development for PFAS. EnRisks, November 2017. Screening values calculated using a scenario of 10% of the tolerable daily intake. This is the most conservative scenario developed.*

5.0 Quality Assurance / Quality Control

5.1 Project Data Quality Objectives

The project data quality objectives (DQOs) were to:

1. Determine the presence or absence (less than 0.005 µg/L) of PFASs in groundwater from groundwater bores.
2. Determine the presence or absence (less than 0.005 µg/L) of PFASs in surface water.

To determine if the DQOs were met, the internal quality assurance/quality control (QA/QC) function ('QAChecker') in the environmental database software ESdat was used to calculate relative percent differences (RPDs) between sample duplicates and to check for detections of PFAS in blanks.

The results of the QA/QC check indicate that all samples meet the DQOs. No PFAS compounds were detected in the field, trip or rinsate blanks. The duplicate sample pairs reported RPDs within the acceptable reporting range.

A summary of the QA/QC check is provided in Appendix B. Additional information relating to the QA/QC results can be provided upon request.

5.2 PFAS Concentrations at the Limit of Reporting

Where low detections (sum of total PFHxS + PFOS < 0.005 µg/L) have been reported in groundwater and surface water samples, this may not represent a real presence of PFAS in the sampled water but may reflect uncertainty of measurement or sampling and/or analysis error. Where appropriate the presence of at PFAS near the limit of reporting has been, or will be, confirmed by re-sampling.

6.0 Results

A total of 159 groundwater samples and 30 surface water samples were collected during this sampling investigation.

The groundwater and surface water results are summarised in Sections 6.1 and 6.2 respectively.

6.1 Groundwater Samples

A summary of the groundwater sample results is presented below along with a comparison of the results to the interim drinking water guidelines, the non-potable guidelines and the screening values for stock watering and fodder irrigation developed by EnRisks (2017). Screening values defined for beef would also be conservative for the consumption of home-grown sheep meat (EnRisks, 2017).

6.1.1 Drinking Water Interim Guideline Value

Of the 159 groundwater samples collected:

- PFAS was detected in 69 samples (44%).
- None of the groundwater samples were found to exceed the interim drinking water guideline for PFAS (sum of total PFOS + PFHxS and PFOA) (MoH, 2017).
- 69 samples (44%) returned concentrations of the sum of total PFOS + PFHxS above the LOR but below the interim drinking water guideline (MoH, 2017).
- 46 samples (29%) returned concentrations of PFOA above the LOR but below the interim drinking water guideline (MoH, 2017).
- 89 samples (56%) were reported as less than the LOR for the sum of total PFOS + PFHxS.
- 113 samples (71%) were reported as less than the LOR for PFOA.

6.1.2 Non-potable, Stock Watering and Fodder Irrigation Screening Values

Of the 159 samples tested:

- 47 samples (30%) reported concentrations of PFAS above the screening value for milk consumption (home grown) (stock watering and fodder irrigation).
- 30 samples (19%) reported concentrations of PFAS above the screening value for milk consumption (home grown) (stock watering only).
- No samples reported PFAS concentrations above the screening value for non-potable/contact recreation, beef consumption (home grown) (stock watering only, stock watering and fodder irrigation), or egg consumption (home grown) (stock watering only).

6.1.3 Groundwater Results Summary Table

A summary of the results described in Sections 6.1.1 and 6.1.2 is provided in Table 2 below. It is noted that changes in the numbers, and percentages of samples found to exceed guideline or screening values must be considered in the context of the lesser number of samples obtained and new sample locations during the May 2018 sampling event (Stage C) compared to the previous February 2018 (Stage B) sampling event (159 in Stage C vs 162 in Stage B). Values in brackets denote results from the previous February 2018 sampling event (PDP, 2018b).

Table 2: Guideline and Screening Value Exceedences – Groundwater Samples (n=159)			
Guideline	**Number Exceeding the Relevant Guideline**	**Percent Exceeding the Relevant Guideline**	**Source**
Interim Drinking Water Guidelines	0 (1 during previous sampling event)[1]	0% (0.6% during previous sampling event)	MoH[1]
Non-potable water/contact recreation	0 (0 during previous sampling event)	0% (0% during previous sampling event)	AGDoH [2]
Site Specific Screening Value – Beef Consumption (home grown)			
Stock Watering and Fodder Irrigation	0 (1 during previous sampling event)	0% (0.6% during previous sampling event)	EnRisks [3]
Stock Watering Only	0 (0 during previous sampling event)	0% (0% during previous sampling event)	EnRisks [3]
Site Specific Screening Value – Milk Consumption (home grown)			
Stock Watering and Fodder Irrigation	47 (51 during previous sampling event)	30% (30% during previous sampling event)	EnRisks [3]
Stock Watering Only	30 (28 during previous sampling event)	19% (16% during previous sampling event)	EnRisks [3]
Site Specific Screening Value – Egg Consumption (home grown)			
Stock Watering Only	0 (0 during previous monitoring event)	0% (0% during previous monitoring event)	EnRisks [3]

Notes:

1. *The bore with the reported exceedance of the interim drinking water guidelines during the previous monitoring event was unavailable for resampling during the Stage C monitoring round as it was not operational during the winter period.*
2. *Ministry of Health (MoH, 2017) Interim Guidance Level for Drinking Water, PFOA, PFOS and PFHxS.*
3. *Australian Government Department of Health (AGDoH, 2017) Health Based Guidance Values for PFAS for Use in Site Investigations in Australia.*
4. *Site specific screening values from Livestock Uptake Modelling and Screening Criteria Development for PFAS. EnRisks, November 2017.*
5. *The same locations were not necessarily sampled in each round, therefore a direct comparison of the number of exceedances with the previous monitoring event may not be applicable.*

6.1.4 Comparison with Stage B February 2018 Groundwater Sampling Results

In general, the bores where PFAS was detected during the previous February 2018 Stage B sampling event also showed detects of PFAS during the May 2018 Stage C sampling event (where resampling of the bores occurred: it is noted that 25 sites from the February 2018 monitoring round were unavailable for re-sampling during May 2018 monitoring round as the bores were not operational

during the winter period). A comparison of the groundwater analysis data from the February 2018 and May 2018, where the same bores were re-sampled, shows that:

- 31 samples have decreased in concentration (with a median decrease of 26% and a median absolute decrease of 0.0033 ug/L);
- 41 samples have increased concentration (with a median increase of 19% and a median absolute increase of 0.005 ug/L);
- Three samples displayed no change between sampling rounds (i.e. remained non-detect).

The notable changes between the February 2018 and May 2018 monitoring rounds with respect to individual groundwater bores were:

- Nine bores were found to contain PFAS at concentrations above LOR during Stage B, but concentrations in these bores have decreased to below the LOR during Stage C;
- Two bores were found to contain PFAS at concentrations below LOR during Stage B, but concentrations in these bore have increased to above the LOR during Stage C;
- No samples in Stage C exceeded the interim drinking water guideline values; and
- The single bore which was found to contain PFAS at concentrations above the potable guideline value during Stage B February monitoring round was not able to be resampled in May because the bore is not operational over the winter period.

6.2 Surface Water Samples

A summary of the surface water sample results is presented below. It is likely that surface water sampled within the investigation area is not used for drinking water (based on landowner feedback). Therefore, results have been compared to the non-potable guideline and the stock watering and fodder irrigation screening values.

Of the 30 surface water samples collected:

- Concentrations of total PFHxS, and / or total PFOS, and / or total PFOA, and / or the sum of total PFHxS + PFOS were above the LOR in 15 samples (50%).
- PFAS concentrations in eight surface water samples (27%) were above the adopted screening values for milk consumption (home grown) (stock watering and fodder irrigation), and for milk consumption (home grown) (stock watering only) in six of the surface water samples (20%).

- PFAS concentrations in all samples where it was detected were below the adopted screening values for non-potable / contact recreation, beef consumption (home grown) (stock watering only) and beef consumption (home grown) (stock watering and fodder irrigation), or egg consumption (home grown) (stock watering only).

7.0 Discussion

Results from this groundwater and surface water sampling investigation indicate that a 'plume' of PFAS contaminated groundwater exists to the east of the RNZAF Base Woodbourne. The Stage C sample results have been used to produce an interpreted 'plume' extent of concentrations of PFAS above LOR within the shallow groundwater system at Woodbourne (note that the approach taken for the RNZAF Base Ohakea investigation was to assess the plume extent total PFOS + PFHxS concentration ≥0.05 µg/L). Albeit the majority (67%) of sample results (total = 189) were below the adopted guideline values, 52% of samples tested in this investigation showed detectable concentrations of PFAS compounds, in a predominantly easterly direction beyond the RNZAF Base.

7.1 Groundwater Users

Where the landowner/occupant specified that bore water was not used for drinking water / domestic supply, or for stock watering purposes, the presumed use of the bore water is for produce / crop irrigation.

7.1.1 Drinking Water

Of the 159 groundwater samples tested, 69 samples (43%) reported concentrations of PFAS above the LOR. Of these 69 samples, 62 samples were collected from bores that landowners/occupants indicated were used for potable or domestic supply.

None of the groundwater samples exceeded the interim drinking water guidelines (MoH, 2017) for PFAS.

7.1.2 Non-potable Stock Watering and Fodder Irrigation

Sample results have been compared to the site specific screening values (EnRisks, 2017) (refer Table 2). These screening values are used to assess the risk of on-farm consumption of farm grown products (e.g. home kill) only, which is a more conservative exposure pathway given the potential for consumption of larger quantities of beef, milk or eggs from a single animal. These screening values are not applicable for produce supplied to the general market. Screening values defined for beef would also be a conservative screening value for the consumption of sheep meat (EnRisks, 2017).

Of the 69 samples where PFAS was reported above the LOR, 18 samples were collected from bores that landowners/occupants indicated were used for stock watering or domestic irrigation.

Of the 30 samples (out of 159 groundwater samples) obtained from bores where a stock watering use was specified, 17 were found to contain concentrations of PFAS which exceed the screening values for Milk Consumption (home grown) for stock watering and fodder irrigation), and 12 samples exceeded the screening values for Milk Consumption (home grown) for stock watering only.

7.2 Surface Water Receptors

PFAS concentrations in surface water samples from eight locations were found to exceed the adopted screening values for milk consumption (home grown) (stock watering and fodder irrigation), and six of those locations were found to exceed the screening values for milk consumption (home grown) (stock watering only). The surface water at these locations is not known to be utilised for stock watering purposes (based on landowner feedback).

Surface water is not known to be utilised for drinking water / domestic use within the investigation area (based on landowner feedback).

7.3 Discussion of Detection of PFAS in Groundwater

The results of the groundwater samples collected during the May 2018 Stage C monitoring round in comparison with results from previous round (February 2018) continues to show a predominant easterly flow direction, with the highest concentrations occurring in the vicinity of the Old Fairhall Creek/ Yelverton Stream. The sampled bores in this area tend to be shallower than those that occur further to the west and closer to RNZAF Base Woodbourne. It is expected that the highest PFAS concentrations will occur in the shallowest groundwater given that the source of PFAS originates from the ground surface and this difference in sampling depth may explain the higher concentrations that are observed around Old Fairhall Creek, with lower concentrations in the deeper water supply bores closer to the Base.

Compared to the Stage B sampling this most recent sampling tends to show lower concentrations in the area of PFAS detections to the northeast of the Base (around Old Renwick Road) and higher concentrations in the Old Fairhall Creek area. These differences may reflect differences in the groundwater flow patterns at the time of, and in the weeks prior to, the time of sample collection. The pattern of detections suggests that at the time of the Stage C sampling the groundwater was showing less influence from Southern Valleys runoff, which would push the contaminants in a north easterly direction (towards Old Renwick Road), and more influence from the typical easterly flow direction that occurs across this area of the Wairau Plain. Although at a localised scale on the order of 10s' to 100's of metres, variable flow directions can occur due to meandering

alluvial processes that have shaped the zones of differing permeability within the strata. This localised variability in flow contributes to differing concentrations between different bores in close proximity to each other.

The Old Fairhall Creek and Yelverton Stream are springfed streams that occur within the eastward moving PFAS plume. These springfed streams act as a drain on the local groundwater system and will draw shallow groundwater towards their watercourses. That is the likely reason for the clustering of higher concentrations in that area.

Further east, within the Blenheim urban area, the May 2018 sampling shows no elevated concentrations of concern in the sampled bores.

A separate area of PFAS detections continues to be present to the south-east of Base Woodbourne, around New Renwick Road. This is not expected to be associated with RNZAF Base Woodbourne as the groundwater elevations and the geological strata do not indicate that groundwater flow from the Base would occur in that direction. It suggests that a separate localised source of PFAS may occur in this vicinity of New Renwick Road.

7.4 Discussion of Detection of PFAS in Surface Water

The May 2018 sampling of surface waters shows detections being limited to Old Fairhall Creek, the Fairhall Co-op Drain and the reach of Doctors Creek immediately downstream of its confluence with the Fairhall Co-op Drain. The highest concentrations occur in the Old Fairhall Creek, which shows increasing concentrations from its headwaters in the west through to Battys Road. This indicates a zone where groundwater affected by elevated PFAS concentrations is continuing to supply water into the creek. Sampling sites downstream of Battys Road show lower concentrations which reflect diluting inflows of surface waterways and groundwater with lower PFAS concentrations (i.e. the Southern Valleys reach of Doctors Creek and the Taylor River).

Concentrations in the Fairhall Co-op Drain show lower concentrations, as would be expected given that its location is further from the centre of the main area of groundwater contamination. The changes in concentration along the Fairhall Co-op Drain/ Doctors Creek reach will also represent the different inputs between groundwater and surface waterways with differing PFAS concentrations.

7.5 Results Interpretation Limitations

Due to their physiochemical properties, the fate and transport of PFAS is complicated and poorly understood. As such, extrapolation of these results, particularly to locations down-gradient, is uncertain and may not represent the actual conditions present. On this basis any assessment of risk to receptors located outside the current investigation area is limited.

8.0 References

AGDoH, 2017. *Final Health Based Guidance Values for PFAS for use in site investigations in Australia.* The Department of Health, Australian Government, Canberra, Australia. Sourced 15/05/2017 https://www.health.gov.au/internet/main/publishing.nsf/Content/2200FE086D480353CA2580C900817CDC/$File/fs-Health-Based-Guidance-Values.pdf

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Appendix A

Site Description

Appendix A: Site Description

Geology – the Wairau Plain

RNZAF Base Woodbourne occurs on the Wairau Plain, which is an extensive deposit of unconsolidated sediments formed by glacial and river processes and derived primarily from the sediments of the Wairau River Valley, with smaller contributions from the valleys along the southern margin of the Wairau Plain.

The deposited sediments are originally derived from the erosion of rock fragments from mountainous catchments, and therefore cover a wide range of particle sizes, from gravels and larger sizes down to sands, silts and clay sized particles.

The Wairau Plain has built up over deposits formed throughout the ice ages over the last several hundred thousands of years, which comprised a successive sequence of colder glacial periods, separated by warmer interglacial periods. During the glacial periods, large volumes of gravel, sand, silt and clay were eroded from the Wairau River's mountainous catchment in the south-west and deposited as a poorly sorted mixture of grain sizes over the area by the alluvial processes of gravel bed rivers. During the interglacial periods, the contribution of new sediment to the plain was significantly less and many of the glacial deposits were reworked by the gravel bed river processes of the Wairau River and the Southern Valley rivers.

These gravel bed rivers are characterised by multiple, interlinking braided channels of flowing water within a broad active bed. Course changes over time periods of hundreds of thousands of years have built up the Wairau Plain, which contain gravelly strata extending to thicknesses of a few hundred metres.

As a result of these processes, the Wairau Plain is comprised of a complex mixture of gravels, sand, silt and clay originating from the higher catchment areas to the west and south of the Plain. These sediments are sorted to varying degrees ranging from poorly sorted mixtures of all grain sizes, through to better sorted deposits with gravels and coarse sand (with a lesser amount of finer sized particles) in some zones and fine sand, silt and clays in other zones.

Geological units in the vicinity of, and downgradient of, Woodbourne

The upper 50 m of strata in the Woodbourne area comprises three geologic formations – the older Speargrass Formation, and the overlying Early Rapaura Formation and Late Rapaura Formation.

The Speargrass Formation represents sediments that are generally of a lower permeability compared to the overlying, better sorted Rapaura Formation. The Speargrass Formation has a thickness of around 40 m in the area east of Woodbourne. Some of the older sedimentary deposits on the Wairau Plain were reworked by river processes to form the Rapaura Formation which varies from around 0–15 m thick in the area east of Woodbourne.

The shallowest geological unit in the area is the recent gravel deposits associated with the present day river channels.

Hydrogeology

With regard to groundwater flow, more rapid movement occurs through the more permeable coarser grained well-sorted zones of strata, whilst slower movement occurs through the sandy and silty zones.

Due to the nature of the river depositional processes these strata typically have a greater permeability in the direction of flowing water at the time of sediment deposition, with a lower permeability at right angles to the direction of deposition and the lowest permeability in the vertical direction.

These river-derived zones of strata are laid down in lenses parallel to the topography at the time of deposition (i.e. roughly horizontal). The lenses of finer grained sand and silt restrict the vertical permeability, but do not totally inhibit it, due to their lack of consistency and lateral continuity. This depositional behaviour encourages lateral groundwater flow through the strata, particularly in the direction in which the strata were deposited.

Due to the meandering pattern of many of these river processes, there can be variable orientations of the deposited strata on a small to medium scale (e.g. less than around 200 m). However, on a larger scale of a few hundred metres and more, the general direction of the highest permeability is expected to coincide with the direction of strata deposition.

Hydrology

The rate and direction of groundwater flow through these gravel deposits is determined by the location and rate of inflow to the aquifer (recharge), the location and rate of discharge from the aquifer and the hydraulic conductivity (related to permeability) of the strata through which the groundwater flows between the recharge and discharge areas.

At the eastern (downgradient) end of the Woodbourne Road area, the groundwater originates from seepage losses from surface waterways and infiltration of rainfall on the gravel plain. Sources of river seepage come primarily from the Southern Valley outflows from the Omaka River, Mill Stream, the Fairhall River, Golf Course Creek and Doctors Creek. Surface flows in these rivers readily infiltrate water to the aquifers and the length of flowing water in the surface channel varies depending on the amount of flow in the upper catchment and the groundwater level surrounding the river channel.

At a more localised scale, seasonal variations in groundwater flow direction will occur. Davidson and Wilson (2011) address seasonally varying groundwater flow directions entering the Woodbourne area. During wetter months, the groundwater flow direction reflects the contour of the land, i.e. southwest to northeast. During the summer months, the source of recharge to the

Woodbourne area changes from the southwest to the northwest, and creates a more easterly groundwater flow direction.

A further influence to groundwater flow direction is the springfed streams that typically emerge east of Bells Road. These flow at rates of a few tens of L/s to 100s of L/s and act as drains which draw groundwater towards them.

Consequently the typical groundwater flow direction leaving RNZAF Base Woodbourne, as determined by groundwater elevations and the orientation of the strata is expected to be in a general easterly direction with the potential for variations due to heterogeneity of the strata and the variable influences of streams, seasonal variations and pumping bores.

References

Davidson, P and Wilson, S, 2011, Groundwaters of Marlborough, ISBN 978-1-927159-03-3, Published by Marlborough District Council.

Appendix B

Quality Assurance / Quality Control Summary

ESDAT QA Checker
Project:A02684802_Combined_Database
Filter: [Sampled_Date-Time] >= #01 Apr 2018# and [Sampled_Date-Time] <= #28 May 2018#

Overview Summary
- Count of Samples
- Count of Results

Holding Times

Blanks
- Field Blanks
- Detects in Lab Blanks (0)

Duplicates
- All Field Duplicates (2304)
- All Field Inter-lab Duplicates (0)
- Field Duplicates with high RPDs (0)
- Field Inter-lab Duplicates with high RPDs (0)
- Lab Duplicates with high RPDs (0)

Lab Control Samples
- SDG's without a Laboratory Control Sample (0)
- Laboratory Control Samples, Error > 25% (0)

Certified and Standard Reference Materials
- Certified Reference Materials - Error > 25% (0)

Matrix Spikes
- Trip Spikes with invalid Control Sample (0)
- Matrix Spike Recoveries outside lab LCL or UCL (0)

Inorganic

Other
- OriginalChemNames Requiring Validation (0)
- Samples with no Results (0)