Delineation of drinking water supply catchment protection zones (surface water)

Method to support the Proposed Natural Resources Plan

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1. Background

1.1 National Environmental Standard

The National Environmental Standard (NES) for Sources of Human Drinking Water (2007) directs regional councils to consider the potential impacts of land use activities on community drinking water supplies within its regulatory planning framework.

To give proper effect to the NES it is necessary to know which parts of region, and therefore which activities, the regulations should apply to. An approach to assist with this is to define 'source protection zones' for all relevant community drinking water supply points. These zones describe the area within which an activity might reasonably be expected to impact upon the quality of water at the abstraction point.

1.2 Land use activities and contaminants to be managed

The policies and rules in the Proposed Natural Resources Plan (GWRC in prep) that are relevant to the management of drinking water supplies cover the following activities:

- Pit latrines
- On-site wastewater management units (septic tanks)
- Application of biosolids and treated wastewater to land
- Discharge of animal effluent to land
- Discharge/application of agrichemicals
- Aerial application of vertebrate toxic agents (eg, 1080)
- Farm refuse dumps

The contaminants associated with these activities range from nutrients and pathogens (bacterial and viral) to pesticides and petroleum products. A detailed description of activities and associated contaminant groups is provided in Appendix C of PDP and ESR (2005). Of particular relevance to the management of activities in drinking water supply catchments are contaminants that are especially persistent (long-lived) and/or highly mobile (eg, viruses and petroleum hydrocarcbons).

1.3 Scope of this document

This document describes the method proposed by GWRC to define protection zones for **surface water** community supplies in the Wellington region. The method for delineating protectionzones for groundwater community supplies is defined in a separate report (Toews and Donath 2015).

2. Surface water community supplies

2.1 Number of people serviced

The most stringent regulations in the NES for regional councils to implement, relate to the protection of drinking water for community supply points that routinely deliver water to more than 500 people. GWRC has taken the decision that the delineation of individual protection zones should primarily focus on these larger supply points.

2.2 Source of information

The authoritative source of information on existing water supply points in New Zealand is the Community Drinking-Water Supply Register (administered by ESR on behalf of the Ministry of Health)[1]. Details of all large supplies (ie, those that service >500 people) are contained in this register and were accessed for this project.

2.3 Identified supply points and catchments

There are 13 direct abstractions from rivers and streams in the Wellington region that meet the community drinking water supply criteria described in section 2.1[2]. There are also two shallow groundwater bore supply points that are located directly adjacent to the Otaki and Waiohine rivers. Given their shallow depth and proximity to the rivers they are treated as surface water takes including for the purpose of defining protection areas. This takes the total number of abstraction points under consideration to 15 and associated supply catchments to 14. Abstraction points and associated catchments are listed in Table 2.1 and shown in Figure 2.1.

Eleven of the 14 catchments lie almost entirely within Department of Conservation estate. As such, the risk of contamination at the abstraction points due to human activities is perceived by GWRC as low; and mainly limited to predator and pest management activities. Three of the catchments, for the Waikanae, Otaki and Huangarua rivers, contain areas of land upstream of the supply abstraction points that are in private ownership and put to various uses. Within these catchments the scope for human activities that could potentially impact drinking water quality is relatively broad.

[1] http://www.drinkingwater.esr.cri.nz/general/supplyregistration.asp

[2] A preliminary assessment of the Drinking Water Supply Register indicates that there are about another 20 surface water abstraction points in the Wellington region that are registered as community drinking water supplies (servicing **less** than 500 people). However, there is considerable uncertainty in this estimate due to the lack of consistency between the register and GWRC's own databases.

Table 2.1. Abstraction points and upstream catchments for drinking water supplies in the Wellington region that service 500 or more people.

Catchment (abstraction location)	Area supplied	Consent holder
Otaki River (shallow bores)	Hautere/Te Horo	Kapiti Coast District Council
Waikanae River (WTP)	Waikanae	Kapiti Coast District Council
Wainui Sream (Smiths Creek)	Paekakariki	Kapiti Coast District Council
Hutt River (Kaitoke)	Wellington metropolitan area	Wellington Regional Council
Big Huia River	Wellington metropolitan area	Wellington Regional Council
George Creek	Wellington metropolitan area	Wellington Regional Council
Orongorongo River	Wellington metropolitan area	Wellington Regional Council
Wainuiomata River	Wellington metropolitan area	Wellington Regional Council
Waingawa River	Masterton	Masterton District Council
Kaipatangata Stream	Carterton	Carterton District Council
Huangarua River	Martinborough	South Wairarapa District Council
Waiohine River (Moroa Water Race and shallow bores)	Greytown & Featherston	South Wairarapa District Council
Boar Bush Creek	Featherston	South Wairarapa District Council
Taits Stream	Featherston	South Wairarapa District Council

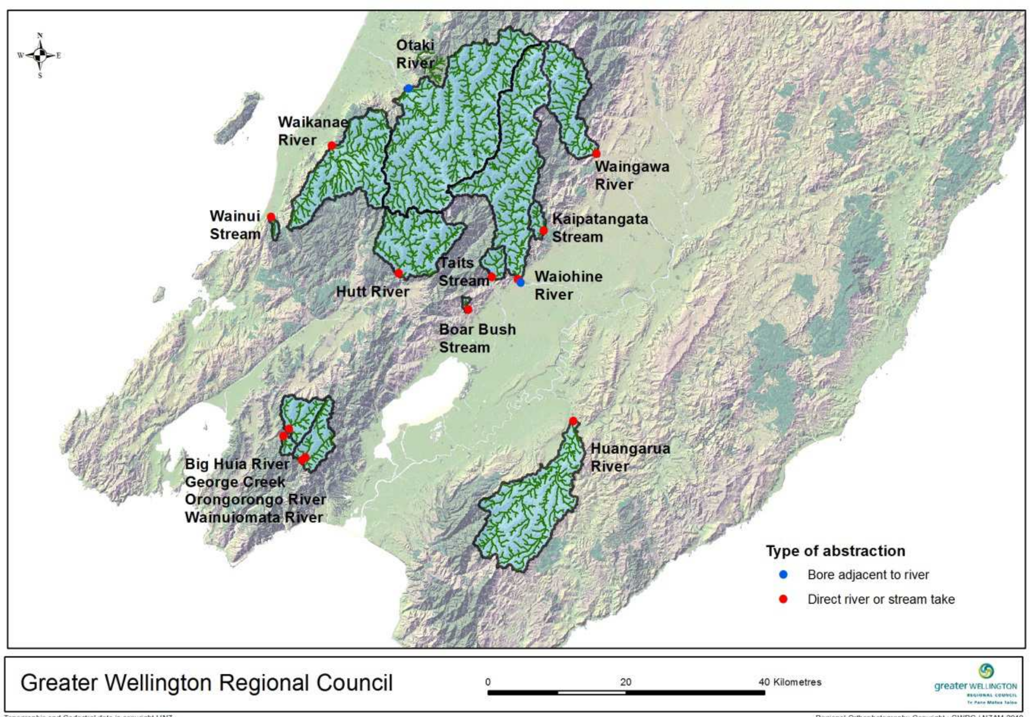

Figure 2.1. Location of abstraction points and upstream catchments for drinking water supplies in the Wellington region that service 500 or more people (see Table 2.1).

3. Defining protection zones

Approaches to protection[3] zone delineation range in their complexity from simple (eg, an arbitrary zone defined for lumped contaminant management) to highly sophisticated (eg, a zone defined by contaminant-specific dispersion and attenuation modelling).

3.1 Guidance and NZ application of protection zone methods

While detailed technical guidance on defining groundwater protection zones has recently been developed for New Zealand practitioners (Moreau et al 2014), no comparatively detailed material is available for the same audience to guide the development of surface water zones.

However, when the NES was in development in 2005, a document titled *Methodology for Delineating Drinking Water Catchments* was prepared for the Ministry for the Environment (PDP and ESR, 2005). Notwithstanding the more recent guidance developed for groundwater protection zones, the PDP and ESR (2005) report still represents the best general literature review and NZ-specific advice available. With regard to a review of approaches taken (within NZ and internationally) to delineating surface water supplies, PDP and ESR (2005) conclude that:

"…there is a strong tendency for the delineation of surface water capture zones to take a conservative approach, where management of all parts of the catchment is anticipated or controlled, but with special attention to zones around the intake or immediately adjacent to the surface water body. Many jurisdictions use a response time, to allow resource managers to cope with catastrophic spills within an inner management zone. Overland and in-stream flow velocities have been assessed to factor a time into a distance from the intake point. Most jurisdictions, however, use an apparently arbitrary distance that may not allow for attenuation of potential contaminants…."

More recent observations made by GWRC indicate that there remains a gap in knowledge with respect to setting effects-based protection zones in surface water catchments. There is no uniform approach across regional councils; many do not give specific zone definitions in their main planning documents while others have adopted a range of simple generic criteria. For example, Waikato Regional Council has proposed a "Tier 1" screening method for agricultural effluent discharges that is based on a dilution ratio of 1:100,000 at the point at which drinking water is abstracted. If that dilution ratio cannot be met then a more rigorous assessment of effects on the drinking water supply might be needed. Environment Southland is due to adopt a rule relating to farm dump discharges that specifies it must not occur within either the 'microbial health protection zone' of an abstraction point or within 250 m of a drinking water abstraction point. Environment Canterbury suggested that an 'exclusion zone' should extend for a fixed distance of 3 km upstream of community drinking water abstraction points. This was based on best judgement, mainly related to understanding of microbial dilution rates.

[3] In this document the term 'protection zone' is used to describe the area within which activities are to be managed to prevent contamination of drinking water at a downstream abstraction location. This zone is sometimes referred to in other documents as a 'capture zone'.

3.2 An approach for GWRC

As discussed, there is a relatively low risk of activities leading to contamination in most of the large surface water supply catchments in the Wellington region. Therefore, adoption of a relatively simple approach to protection zone delineation is deemed most appropriate. However, it is also important to recognise the knowledge gaps that exist (relating to contaminant transport pathways and attenuation) and therefore apply criteria in a precautionary manner.

3.2.1 Criteria for zone delineation

The PDP and ESR (2005) report suggests a framework for applying a generic methodology to delineating protection zones (in the absence of catchment-specific information). This framework is summarised in Table 3.1.

Table 3.1: Suggested application of a generic approach to delineating surface water drinking supply protection zones (from PDP and ESR 2005)

Zone	Description
Zone 1 (Intake management)	5 m wide strip extending for up to 1,000 m upstream of the intake
Zone 2 (Immediate buffer)	100 m wide buffer strip extending for a distance of 8 hours travel time at median flow velocity
Zone 3 (Catchment)	Up to an entire upstream catchment

Essentially, Table 3.1 summarises a risk-based approach that provides a filter for determining the level of scrutiny that should be applied to land use activities. The most rigorous scrutiny and control of activities should occur in Zones 1 and 2, with more general consideration of activities beyond those zones (ie, the rest of the catchment). The zone dimensions have been based on a combination of factors including consideration of existing MoH and MfE guidelines for various contaminants and best judgement of the PDP and ESR (2005) report authors and steering panel.

For simplicity it is proposed that a single protection zone is applied by default to manage activities in drinking water catchments of the Wellington region. The default should be based on the Zone 2 criteria (described in Table 3.1) as this represents an appropriate balance between capturing the highest risk activities in the immediate vicinity of the intake (Zone 1) and the lowest risk activities in the outer margins of the catchment (Zone 3).

PDP and ESR (2005) describe this zone as representing an intermediate zone, that allows for considerable attenuation by dilution and dispersion within the flowing water body, and some attenuation within the unsaturated and saturated zone underlying the buffer strip of land either side of the waterway. This intermediate zone of management consists of a buffer strip along the water course for a distance equivalent to 8 hours median water travel time upstream of the intake. The recommended width of the buffer strip is 100 m and is based on a consideration of two factors: surface slope towards the river; and the ability of the land within the buffer to absorb and transmit contaminants to the adjacent waterway. In this regard, reference is made to existing MfE guidelines regarding contaminated sites (Ministry for the Environment 1999) with particular emphasis on the transmission of petroleum hydrocarbons. Petroleum hydrocarbons are highly mobile and are potentially present in a wide range of activities that occur in rural parts of New Zealand (see Tables C-4 to C-6 in PDP and ESR 2005), such as farm dumps.

3.2.2 Defining the protection zones

Defining protection zones for the drinking water catchments in Table 2.1 (based on 'Zone 2' criteria) was undertaken as a desktop exercise using the following approach:

- **Define median flow velocity**. Most of the large rivers in Table 2.1 have automatic flow recorders from which good measurements of median river flow (volume per unit time) could be obtained. The average flow velocity at median flow was then estimated from a sample of spot gauging results from the same site. For the smaller rivers and streams in Table 2.1 (eg, George Creek, Boar Bush Creek) a reliable estimate of median flow velocity could not be made. However, these catchments are so small that it was assumed that Zone 2 would extend to the catchment boundaries irrespective of median flow rate.

- **Define distance travelled in 8 hours at median flow**. Flow velocity was multiplied by 8 hours to determine the distance travelled in that time.

- **Define zone dimensions**. The distance calculated above was then applied using ARC-GIS to all reaches upstream of the abstraction point (main stem and tributaries) to define the upper extent of the protection zone. The lateral extent of the protection zone was defined by applying a 100 m wide buffer strip.

The estimated median flow velocity and upstream distance of the protection zone for each catchment is provided in Table 3.2. A worked example of protection zone calculations is provided in Appendix A.

The River Environment Classification (REC) was used to identify rivers and streams and formed the basis for the zone mapping in ARC-GIS. The REC is a national river network map layer[4] that is based on a digital elevation model. One of the steps in generating the REC network required setting a threshold for 'accumulating drainage cells' for determining the start of a stream segment. A figure of 200 cells (about $0.2km^2$) was chosen by the REC developers, which was seen as a good balance between including too many fine tributaries and too few. This choice of threshold is considered suitable for the purpose of protection zone generation as it is appropriate to exclude very minor tributaries that are less likely to be reliable contributors to the main stem river flow.

[4] https://www.mfe.govt.nz/environmental-reporting/about-environmental-reporting/classification-systems/fresh-water.html

3.2.3 Results – protection zone maps

Appendix B contains maps of each of the surface water catchments that serve >500 people and shows the extent of the protection zone around the river/stream network for each.

3.2.4 Assumptions

One of the assumptions in the approach described above is that the median flow velocity determined for a single point in the main river can be adopted throughout the upstream catchment. This is a relatively coarse assumption given the spatial variation in hydrological properties that control flow velocity – primarily channel slope, water depth (hydraulic radius) and bed roughness.

Consideration was given to estimating flow velocities for several points in each catchment and taking the average based on a desktop estimate of bed slope and use of the Mannings equation[5]. However, it was found (see Appendix A) that the velocity increases expected with increasing bed gradient towards catchment headwaters were to a large extent offset when the simultaneous reductions in channel hydraulic radius that occur were taken in to account. Overall, the application of uniform open channel flow calculations to estimate flow velocity at un-gauged and non-uniform flow sections is considered highly theoretical. It would not reduce uncertainty in assumptions relating to flow characterisation enough to warrant further consideration.

In the absence of sufficient data to validate assumptions in the theoretical methods, the adoption of a single-point velocity value based on gauging data is recommended.

[5] For uniform flow in open channels, mean flow velocity can be estimated by relating channel hydraulic radius to channel slope and taking in to account bed roughness (in the form of a Mannings n coefficient). See Appendix B.

Table 3.2. Estimated median flow velocities and upstream distances for drinking water catchments. "n/a" is given for catchments where no flow record is available and since these are exclusively small catchments it is assumed that water from any part of the catchment would reach the intake well within an 8 hour travel time.

Water course	Median flow velocity (metres/second)	Distance upstream from intake (km)
Otaki River	0.48	14
Waikanae River	0.55	16
Wainui Sream (Smiths Creek)	n/a	Assumed catchment boundary
Hutt River	0.32	9
Big Huia Stream	n/a	Assumed catchment boundary
George Creek	n/a	Assumed catchment boundary
Orongorongo River	0.18	5
Wainuiomata River	0.21	6
Waingawa River	0.45	13
Kaipatangata Stream	n/a	Assumed catchment boundary
Huangarua River	0.35	12
Moroa Water Race (Waiohine River)	0.49	14
Boar Bush Creek	n/a	Assumed catchment boundary
Taits Stream	n/a	Assumed catchment boundary

3.3 Summary and recommendations

An approach to defining surface water protection zones in drinking water catchments in the Wellington region has been recommended. The approach is relatively simple and based on general principles and guidance rather than catchment-specific analysis of pollution risk. For this reason, it is suggested that the default protection zones be used as an 'alert' or 'filtering' mechanism only (for certain permitted activities)), rather than in a categorical way to manage land use activities. There may well be activities that fall within the default protection zones that, upon closer analysis, pose little or no risk at the supply point (and conversely, there may be activities in the outer margins of drinking water catchments that need very close scrutiny and management).

Uncertainty about how well the mapped zones reflect actual contaminant pathways and channel characteristics (and therefore risk), will always be present, and especially so in the vicinity of minor tributaries. However, the extent of the protection zones should be reviewed and refined over time as knowledge and methodologies improve.

References

Ministry for the Environment (1999). *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand (Revised 2011)*. ISBN 978-0-478-37261-8. Wellington New Zealand

Moreau M, Nokes C, Cameron S, Hadfield J, Gusyev M, Schritter C and Daughney C (2014). *Capture zone guidelines for New Zealand.* GNS Science report 2013/56.

PDP and ESR (2005). *Methodology for the delineation of drinking water catchments.* Report prepared for Ministry for the Environment by Pattle Delamore Partners Ltd and Environmental Science Research Ltd.

Toews M W and Donath F (2015). *Capture zone delineation of community supply and State of the Environment monitoring wells in the Wellington region.* GNS Science report 2015/6.

Appendix A. Example of protection zone derivation from flow velocity calculation

Below are the workings for the derivation of the protection zone for the Waikanae River. The single point estimate described first is the method that has been adopted. The catchment average method was trialled and discarded.

Single point velocity estimate from gauged data

GWRC operates an automatic flow recorder just upstream of the Water Treatment Plant intake. Median flow recorded at this site (over the period 1975-2014) is 3.0 m^3/sec. The most recent spot flow gaugings undertaken at the same site at a flow similar to the median flow are listed in Table A1. The flow velocity for each gauging is also given and the average across the five gaugings is 0.55 metres/sec.

Table A1. Details of a sample of spot flow gaugings undertaken at the Water Treatment Plant site at a flow similar to median flow (3.0 m^3/sec)

Date of gauging	Flow (m^3/sec)	Flow velocity (metres/sec)
29/09/2005	2.849	0.50
26/09/2008	3.173	0.56
29/07/2010	3.053	0.65
20/03/2013	3.250	0.49
21/05/2014	3.363	0.56
Average	**3.130**	**0.55**

In 8 hours, water moving at 0.55 metres/sec will travel 15.8 km. This distance is used to set the upper extent of the capture zone.

Estimating velocity based on open channel theory

Mean velocity for uniform open channel flow can be estimated using the Mannings equation:

$$v = \frac{1}{n} R^{0.66} S^{0.5}$$

Where:

v = mean flow velocity (m/s)

n = mannings coefficient (dimensionless)

R = hydraulic radius (m)

S = channel slope (m/m)

This equation has been used to (a) estimate flow velocity to compare with velocities measured at median flow at the Water Treatment Plant gauging section and then (b) estimate flow velocity for a location in the uppermost reaches of the main river stem for which some gauging data exists (Mangaone Walkway).

(a) Velocity estimate at gauge location (WTP)

Channel slope (*S*) in the river reach of the abstraction (WTP) is approximately 20 m over 3 km, which equates to 0.0067 m/m. A Mannings *n* coefficient of 0.045 is thought appropriate for the natural stoney bed channel conditions and hydraulic radius (*R*) measurements are available for each gauging occasion listed in Table A1.

Velocity estimates based on the Mannings equation are compared with actual measurements in Table A2. On average, the estimates are almost twice the measured values.

Table A2. Comparison of measurements and estimates (Mannings equation) of mean velocity at flows similar to median flow at the Water Treatment Plant.

Date of gauging	Flow (m^3/sec)	Flow velocity (metres/sec)	
		Measured (Table A2)	Estimated (from Mannings)
29/09/2005	2.849	0.50	0.73
26/09/2008	3.173	0.56	n/a
29/07/2010	3.053	0.65	0.78
20/03/2013	3.250	0.49	1.14
21/05/2014	3.363	0.56	1.30
Average	**3.130**	**0.55**	**0.99**

(a) Velocity estimate at upper catchment location

Channel slope (*S*) in a reach of the main stem Waikanae River near Mangaone Walkway, approximately 16 km upstream from the WTP, is about 20 m over 1 km (0.02 m/m). Assuming a constant Mannings *n* of 0.045 throughout the catchment and adopting a hydraulic radius *R* equating to the average of those measured at median flow at the WTP (0.405 m), flow velocity in equivalent conditions at Mangaone Walkway is initially estimated to be 1.7 m/sec.

However, from the small selection of gauging data available for Mangaone Walkway it appears that the hydraulic radius *R* would be much less than at WTP (0.405 m) during equivalent flow conditions. A more realistic estimate is considered to be 0.150 m[6]. Adopting this reduced value provides a new

[6] Flow at Mangaone Walkway was gauged on 15 October 2008. On this day, flow downstream at the WTP was about 5.5 m^3/sec, almost two times median flow. The hydraulic radius *R* for the gauging section at Mangaone Walkway was 0.184 m, suggesting *R* at the same site during in the median flow range would be significantly lower.

velocity estimate for Mangaone Walkway during median flow conditions of 0.9 m/sec. This Mannings velocity estimate is much closer to the average Mannings estimate for the WTP (0.99 m/sec in Table A2). The inference from this result is that there may be little benefit (over using a single measured value) in calculating flow velocity for multiple catchment locations to derive the extent of the protection zone.

Appendix B. Protection area maps for drinking water supply catchments (surface water)

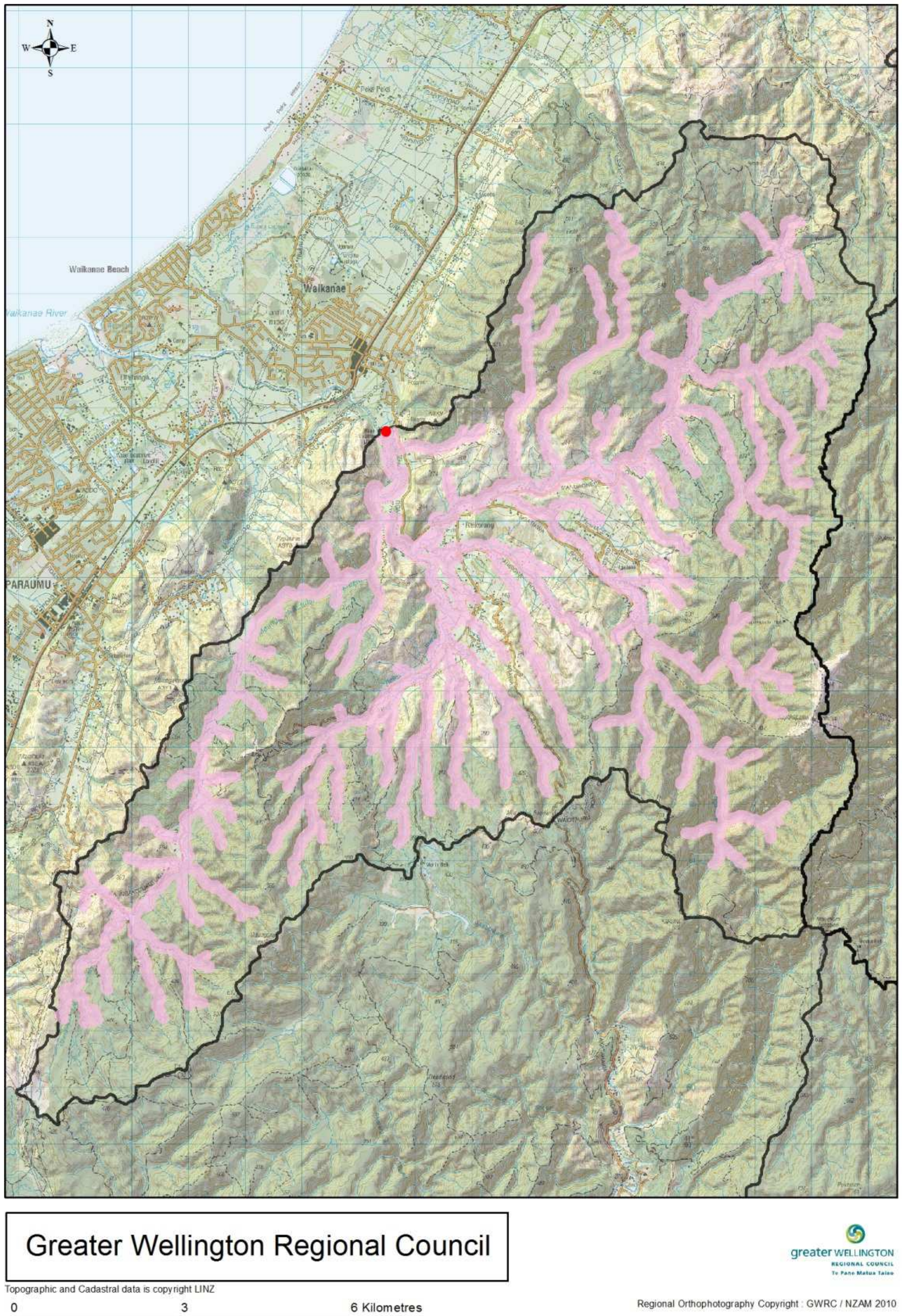

Figure B1. Waikanae River catchment drinking water supply protection area. The catchment boundary is depicted by the black line and the pink shading indicates the extent of the buffer zone around the river/stream network. The location of the abstraction point is shown by the red dot

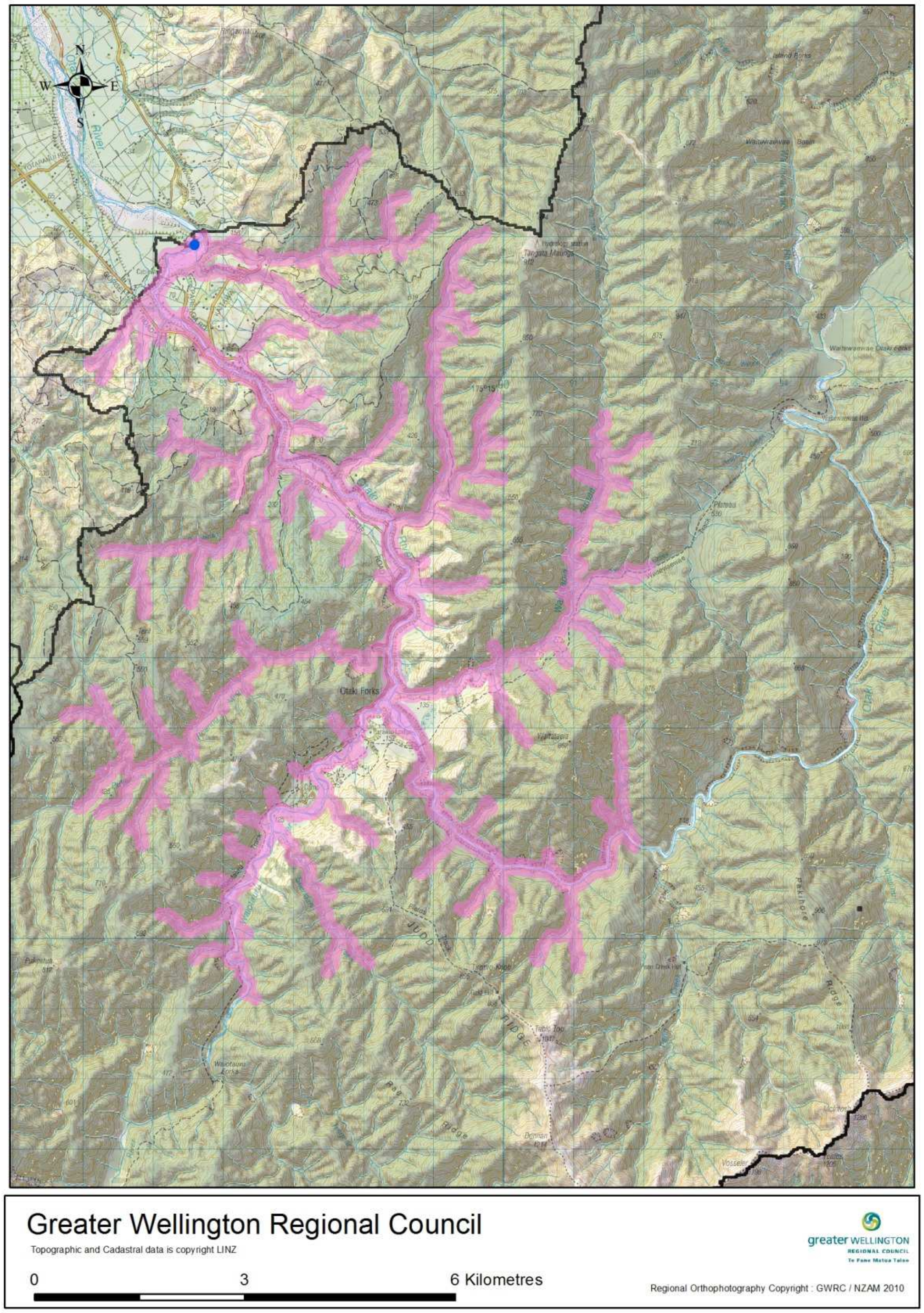

Figure B2. Otaki River catchment drinking water supply protection area. The catchment boundary is depicted by the black line and the pink shading indicates the extent of the buffer zone around the river/stream network. The location of the abstraction bores adjacent to the river is shown by the blue dot.

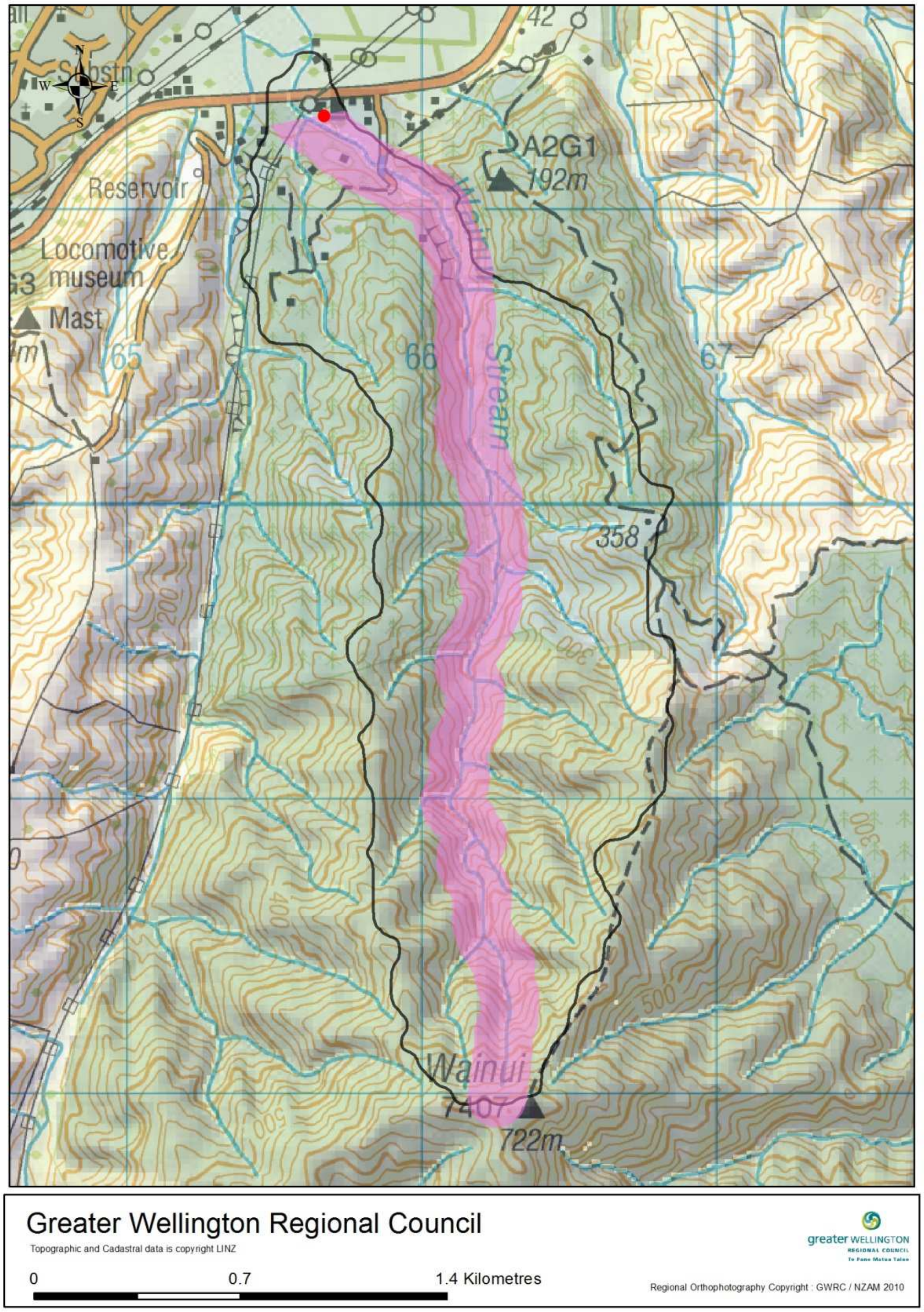

Figure B3. Wainui Stream catchment drinking water supply protection area. The catchment boundary is depicted by the black line and the pink shading indicates the extent of the buffer zone around the river/stream network. The location of the abstraction point is shown by the red dot

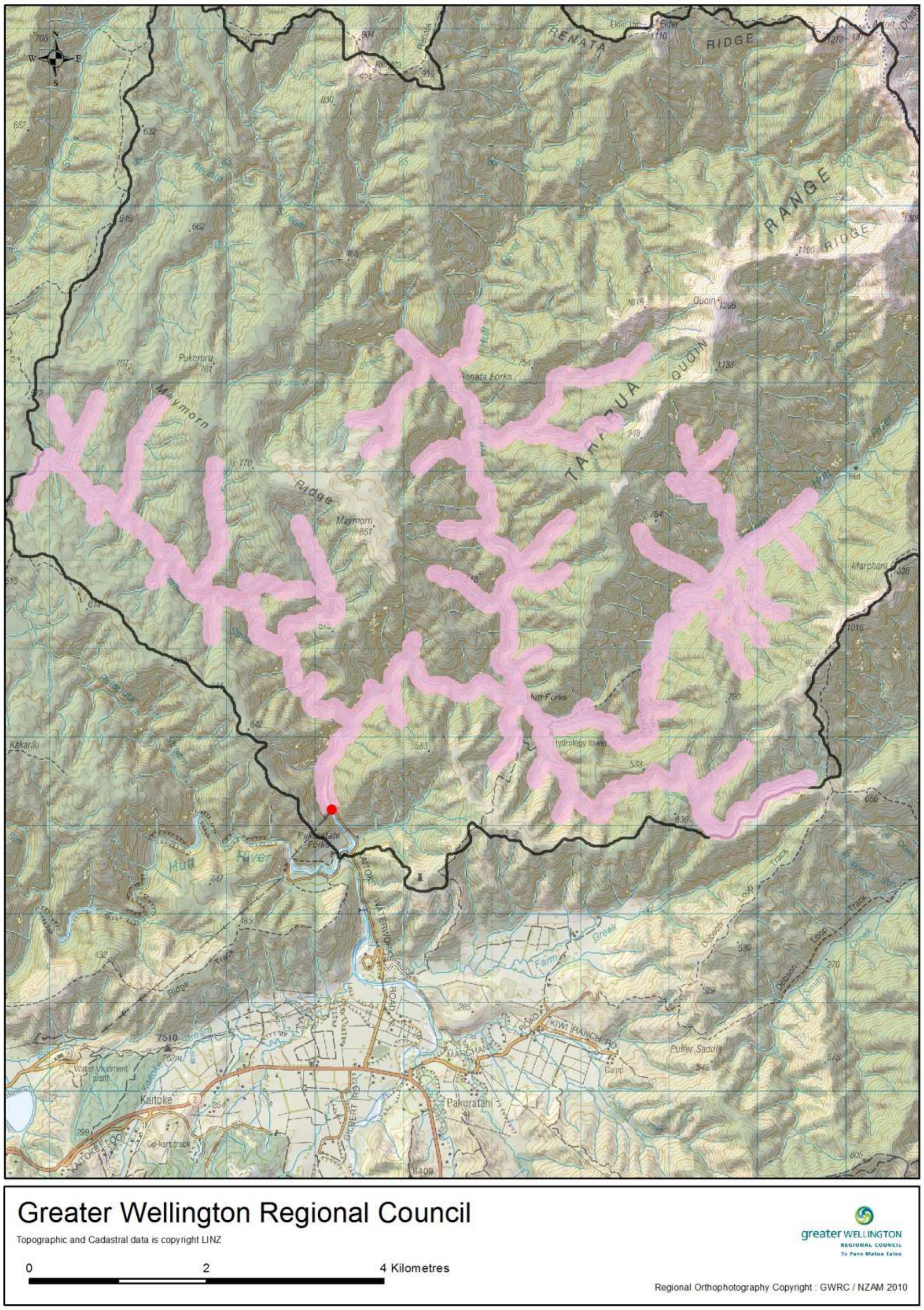

Figure B4. Hutt River catchment drinking water supply protection area. The catchment boundary is depicted by the black line and the pink shading indicates the extent of the buffer zone around the river/stream network. The location of the abstraction point is shown by the red dot

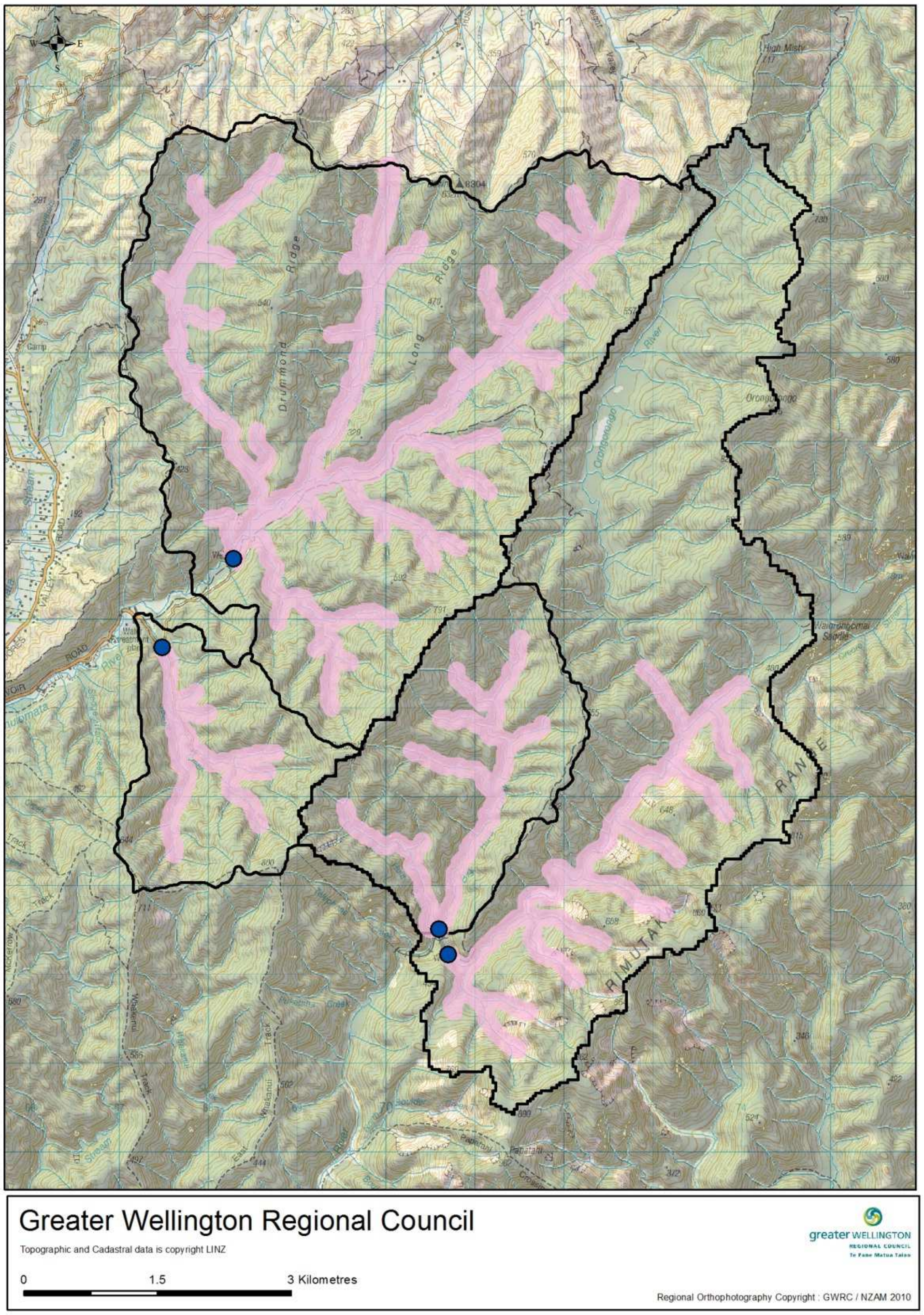

Figure B5. Drinking water supply protection area for the Wainuiomata River, Orongorongo River, Big Huia River and George Creek. The catchment boundaries are depicted by the black lines and the pink shading indicates the extent of the buffer zone around the river/stream networks. The locations of the abstraction points are shown by the red dots

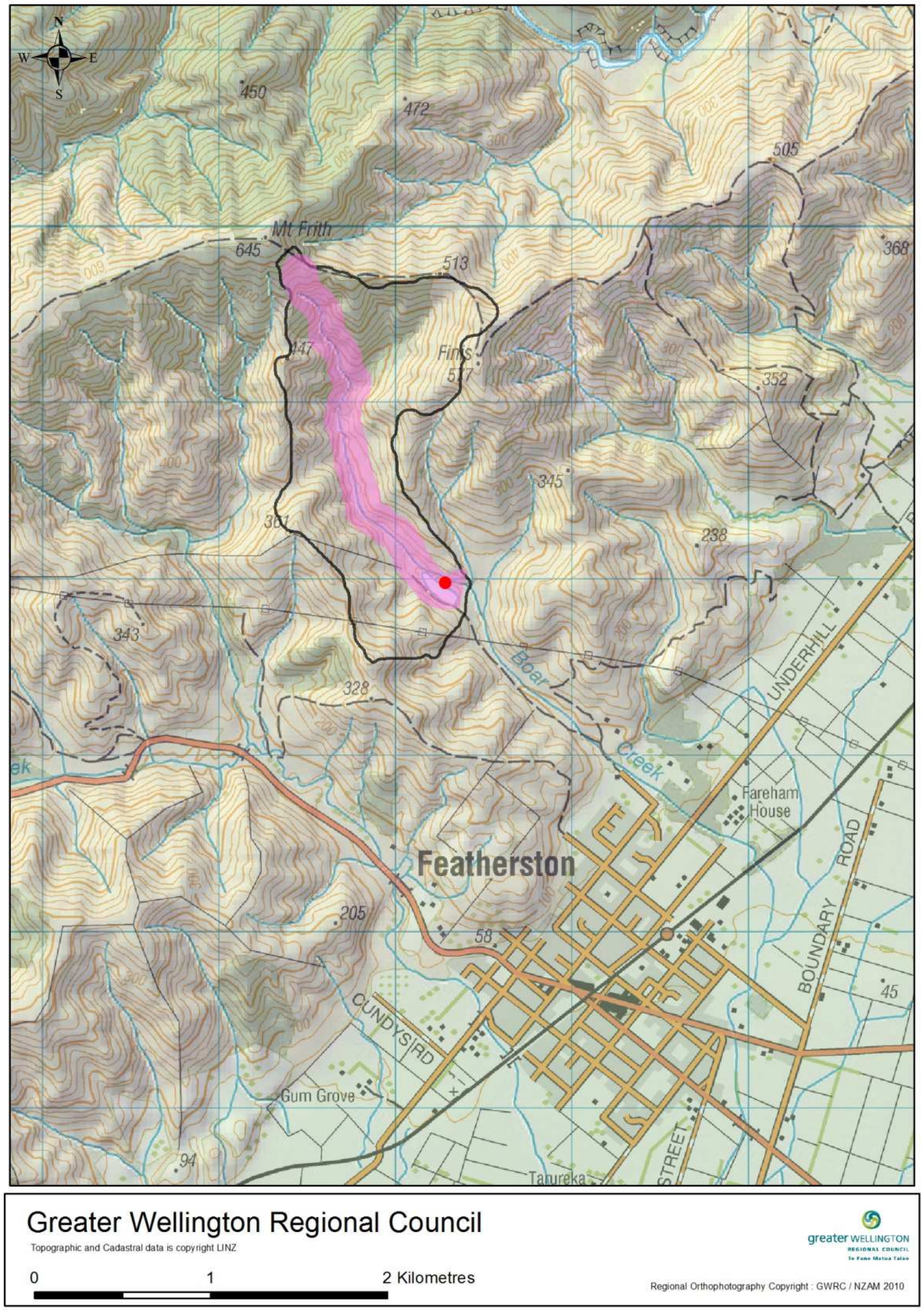

Figure B6. Boar Bush Creek catchment drinking water supply protection area. The catchment boundary is depicted by the black line and the pink shading indicates the extent of the buffer zone around the river/stream network. The location of the abstraction point is shown by the red dot

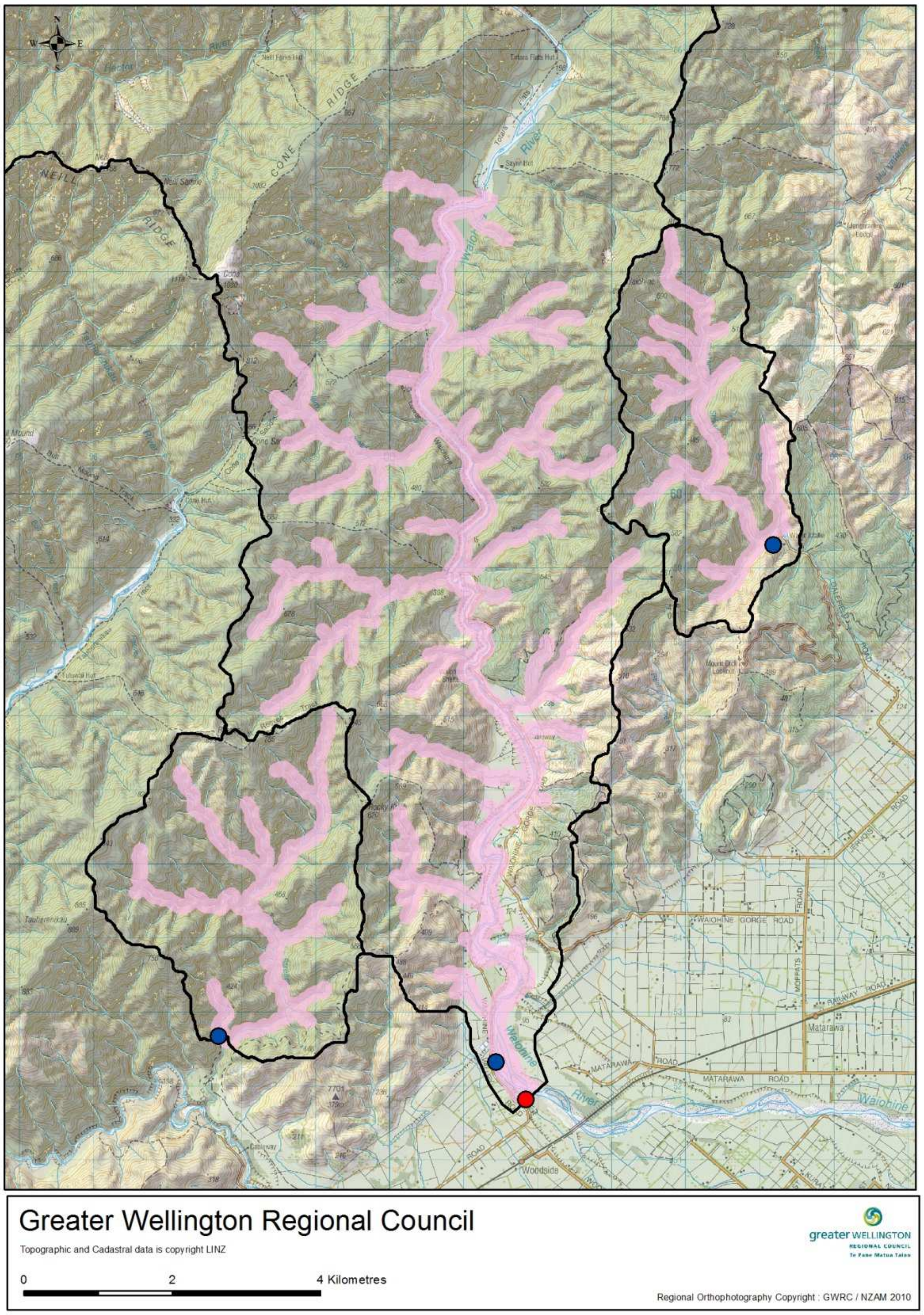

Figure B7. Drinking water supply protection areas for Taits Creek, Waiohine River and Kaipatangata Stream. The catchment boundaries are depicted by the black lines and the pink shading indicates the extent of the buffer zone around the river/stream networks. The locations of the surface water abstraction points are shown by the red dots and groundwater bore abstraction by the blue dot

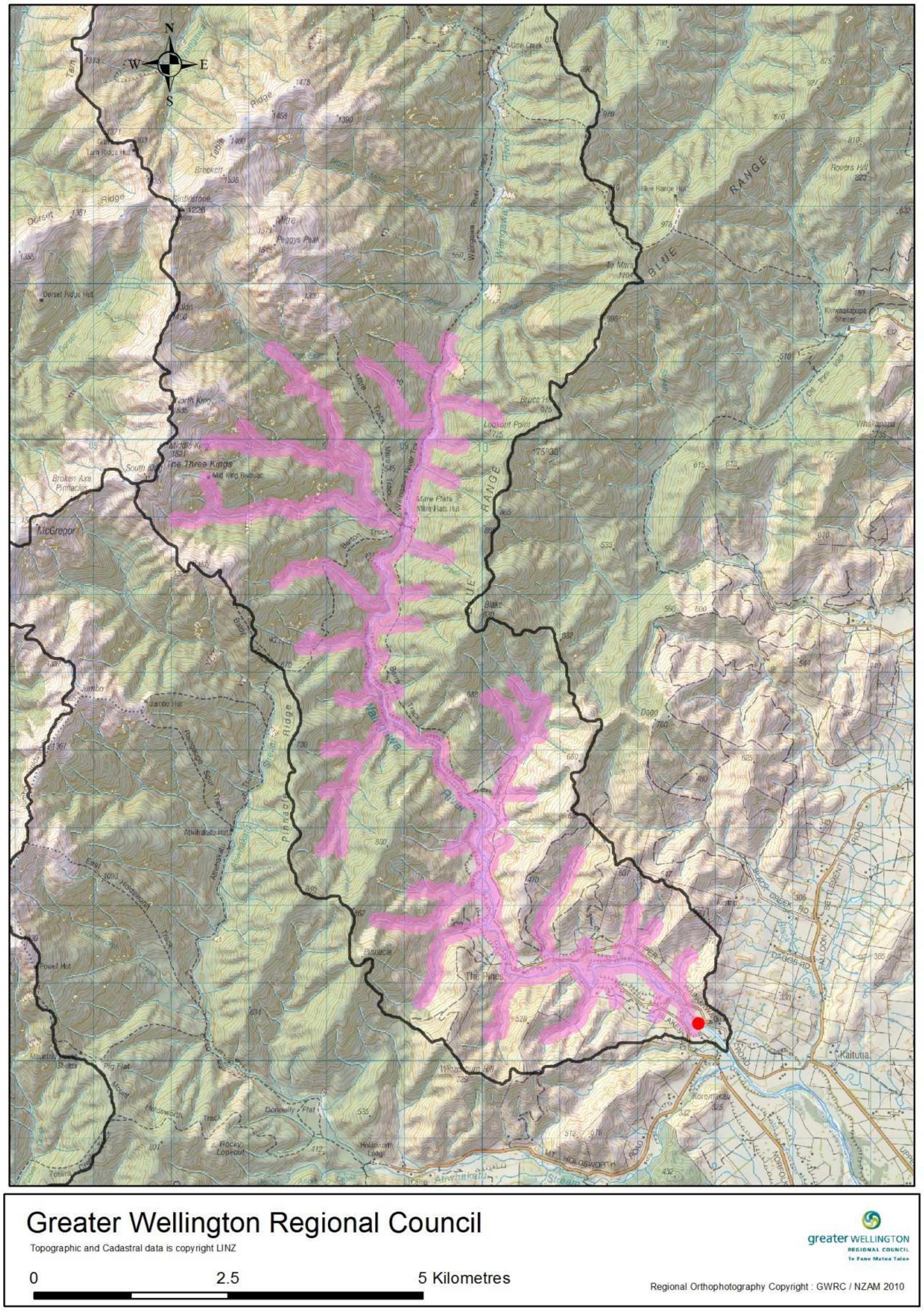

Figure B8. Waingawa River catchment drinking water supply protection area. The catchment boundary is depicted by the black line and the pink shading indicates the extent of the buffer zone around the river/stream network. The location of the abstraction point is shown by the red dot

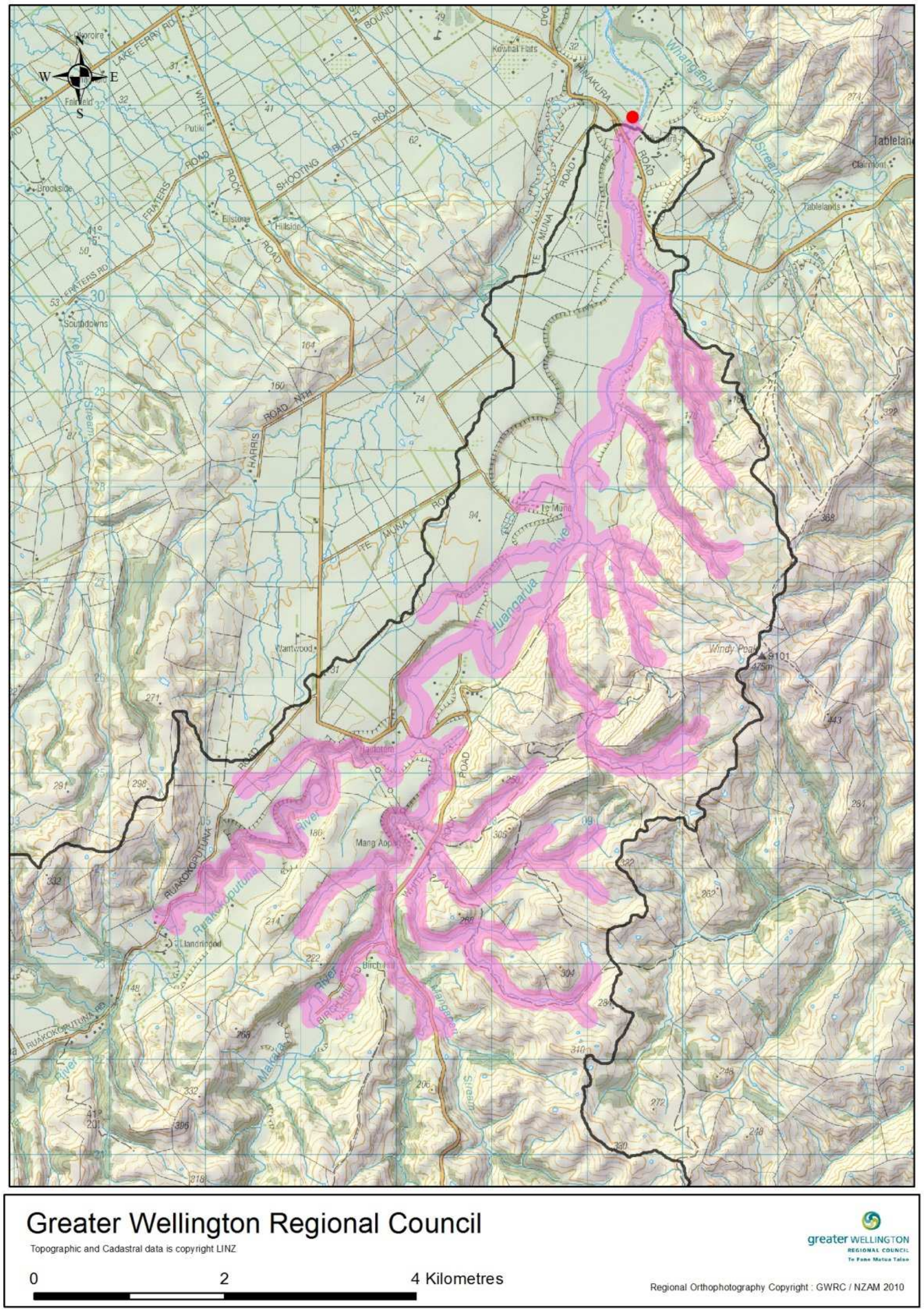

Figure B9. Huangarua River catchment drinking water supply protection area. The catchment boundary is depicted by the black line and the pink shading indicates the extent of the buffer zone around the river/stream network. The location of the abstraction point is shown by the red dot