OceanaGold (New Zealand Ltd) Coronation North Project

Aquatic Ecology Assessment

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1. Introduction

1.1 Background

OceanaGold (New Zealand) Limited (OceanaGold) own and operate an open pit and underground gold mine, known as the Macraes Gold Project, in the Macraes Flat area of East Otago. The company has resource consents to mine what is referred to as the Coronation Project Area, which is located on land in the Shag and Taieri river catchments (Figure 1).

OceanaGold are seeking to extend the mine footprint associated with the Coronation Project and have termed this expansion the Coronation North Project. The key elements of the proposed extension are:

- A new pit (North Pit), partially back-filled;
- Extending the existing consented Pit (consented for 62 ha) to the south, partially back-filled over time;
- A new or merged and extended waste rock stack (WRS) – from a consented size of 94 million tonnes (Mt) existing to an expanded size of 230 Mt;
- An extended haul road to the north – approximately 2km long;
- A 67,000 m^3 freshwater reservoir in the Coal Creek catchment;
- Associated diversion drains, silt and sediment control structures.

The project is expected to extend the mine life by up to 3 years.

1.2 Report content

Ryder Consulting has been engaged by OceanaGold to provide an assessment of the Mare Burn catchment to determine the nature and magnitude of any ecological and water quality effects associated with the proposed Coronation North Project. The assessment includes the following components:

- an overview of the existing aquatic ecology of the Mare Burn catchment;
- an assessment of the relative values of aquatic habitat within sub-catchments of the Mare Burn;
- assessment of potential effects of the proposed Coronation North Project on aquatic ecology and water quality;
- suggested mitigation and monitoring.

1.3 Assessment methodology

A review of published and unpublished literature and relevant databases was undertaken to obtain existing information on aquatic communities within the vicinity of the Coronation Project Area. Aquatic communities in the Mare Burn catchment within the Coronation area were first surveyed in 2011 and 2012 as a part of investigations for the original Coronation Project (e.g., Ryder Consulting 2013). For the Coronation North Project, emphasis was placed on lower sections of the tributary catchments, which have received less attention in the past, and are potentially at risk of being lost or modified through mining.

The approach taken was to survey representative habitats throughout the area. Tributaries were surveyed by walking sections noting physical characteristics such as riparian margin intactness, vegetation cover, bank and bed composition, wetted width, water depth and current. An extensive photo record was collected and only a selection of these are presented in this report (see Appendix One), but many more are available.

Instream habitat was noted and included substrate composition, fine sediment cover, and periphyton and macrophyte cover. Some samples of algae were collected for microscopic identification in the laboratory.

Representative benthic macroinvertebrate samples were collected using the kick-net method (see Appendix two for details of analysis and results). The most recent samples were collected in November 2015, December 2015 and February 2016, with additional samples collected from the Coal Creek catchment in April 2016. Macroinvertebrate community health was assessed by assessing a range of health indices as described in Appendix Two.

Fish have been surveyed using a variety of techniques including electric fishing, minnow traps and visual observations. We found the latter method most suitable over the summer period when flows and water depth were generally too low to effectively sample with electric-fishing and traps. Further, very small juveniles (which are common around November-December) are often difficult to capture using standard nets. Provided the water surface remains calm, fish, including small juveniles, can be observed quite easily and effectively, and this was the primary method used in December 2015 and February 2016.

Crayfish distribution was also assessed using the above methods.

A site known as TC01 on lower Trimbells Gully is surveyed quarterly for benthic macroinvertebrates (using the Surber sampler method – see Appendix Two for details and results), and electric-fished annually, as a part of consents associated with the existing Coronation Project. Some of this data is presented in this report.

Fisheries records from the New Zealand Freshwater Fish Database (NZFFD) for the wider Macraes area, and records for the distribution of non-migratory galaxiids in Otago, were obtained (March 2016) and plotted onto a GIS map of the area.

Some water quality information was collected during the above surveys using a YSI hand-held meter. OceanaGold also monitor water quality in the Mare Burn downstream of all mining operations (at a site known as MB01).

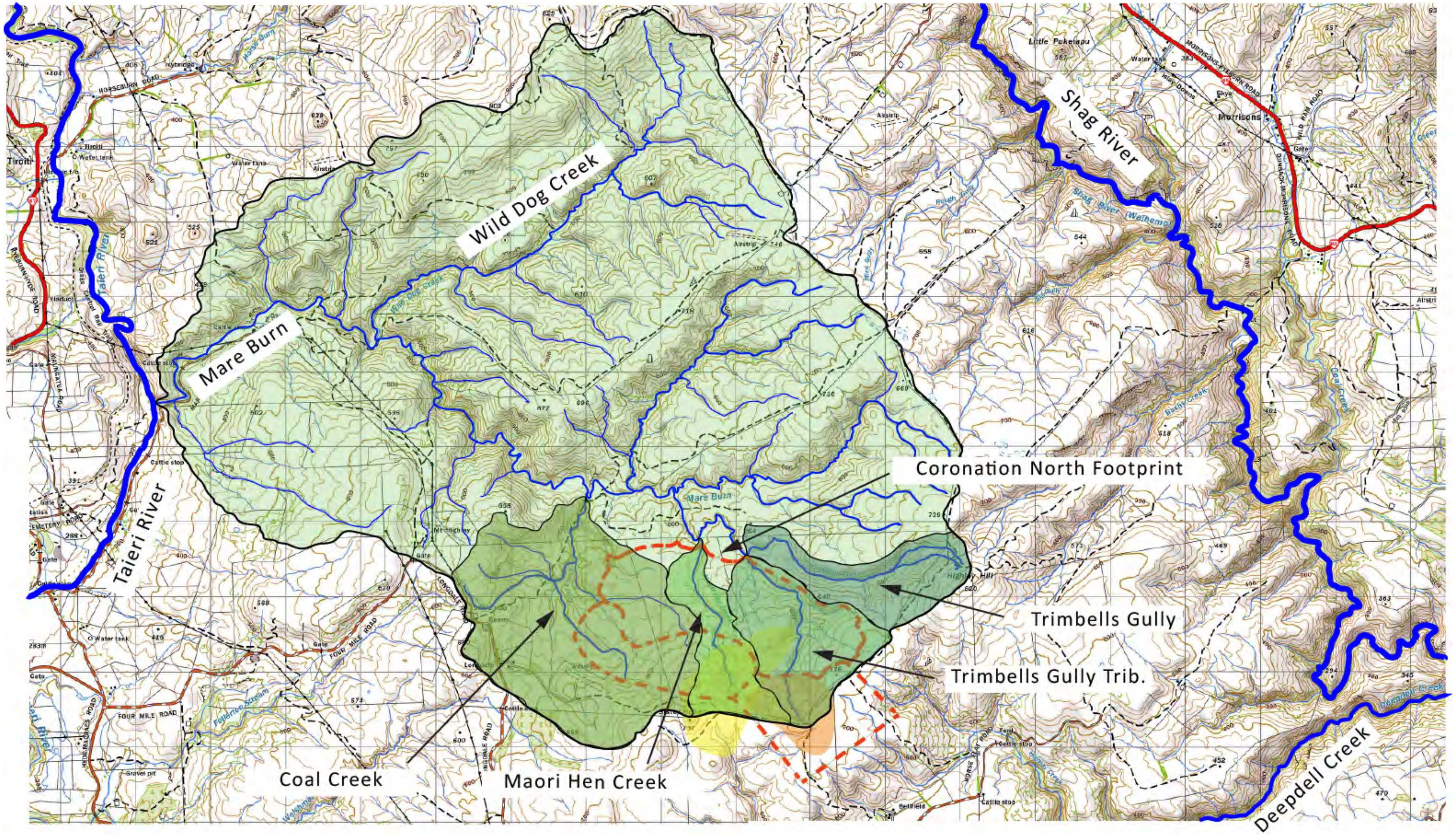

***Figure 1**. Map of Mare Burn catchment and surrounds showing location of key tributaries in relation to the existing (shaded) mining footprint the proposed (dotted line) mining footprintof the Coronation North Project.*

2. Catchment physical & biological descriptions

2.1 General

The existing consented Coronation Project Area is located in the headwaters of Camp Creek, a major tributary of Deepdell Creek, situated adjacent to the existing Macraes Gold Project mining operation, and in the headwaters of Maori Hen Creek and a major tributary of Trimbells Gully, know as Trimbells Gully Tributary (or Trimbells Gully Trib.). Both Maori Hen Creek and Trimbells Gully are tributaries of the Mare Burn, which flows into the Taieri River (Figure 1).

The Coronation North Project is confined to the Mare Burn catchment. While the Coronation Project Area straddles the boundary between the Waitaki District Council (WDC) and the Dunedin City Council (DCC), the Coronation North Project is largely within the DCC boundary. The new pit and waste rock stack are located entirely within the DCC boundary, while the extension of the existing pit will be carried out in both districts.

The headwaters of Maori Hen Creek are situated in the vicinity of the Sister Peaks at an altitude of approximately 680m asl (above sea level). The headwaters of Trimbells Gully Tributary are in the vicinity of Highlay Hill, at elevations up to approximately 820 m asl. Both catchments drain in a north-westerly direction and join several other named and unnamed tributaries flowing into the Mare Burn (Figure 1).

The Mare Burn enters the Taieri River approximately 12 km downstream of the confluence of Maori Hen Creek and Trimbells Gully. The Mare Burn catchment is approximately 6,550 ha in area, or about 1.15 % of the Taieri River catchment.

As noted in section 1.3, tributaries within the Mare Burn catchment have been inspected on repeated occasions since November 2012 as a part of the Coronation Project Area consent process and then as a part of consent monitoring requirements. Most recently, several inspections have occurred between November 2015 and February 2016. The primary purpose of these inspections has been to assess crayfish, macroinvertebrate and fish populations, general habitat quality and flow conditions throughout the summer period (particularly over the 2015-16 summer).

Descriptions of individual sub-catchments are presented below.

2.2 Maori Hen Creek

The consented boundary of the current Coronation Project lies within the upper Maori Hen Creek catchment. Potentially, the proposed boundary of the Coronation North Project would envelope almost the entire catchment of Maori Hen Creek (principally by land needed to create an extended waste rock stack).

Maori Hen Creek lies within a relatively narrow gully with steeply-sided faces throughout most of its length (about 1.6 km from the current boundary of the Coronation project to the confluence with Trimbells Gully). Its catchment is approximately 152 ha in size, representing about 2.4 % of the total Mare Burn catchment. The Coal Creek catchment lies to the west of it and the Trimbells Gully Tributary catchment lies to the east.

The wetted channel is narrow throughout most of its length, typically varying from about 50 to 20 cm wide. While the creek typically carries a small flow through summer (a few litres per second), some sections have reasonable water depth due to the confined nature of the channel, brought about by the step sided gully faces often coupled with underlying bedrock. There are some areas where the flow spreads out and the channel becomes unconfined, resulting in little obvious surface flow, and more akin to wetland habitat as opposed to stream habitat. In these places, the bed is typically comprised of damp mud covered with plants capable of tolerating wet feet.

Prior to mining, the upper reaches of Maori Hen Creek were comprised of a tussock and pasture filled basin with low gradient, wetland habitats. Flowing water was not observed in this area, with habitat dominated mainly by boggy ground. These areas had low stream ecosystem values, with wetland areas drying out following periods of low rainfall. This section of the catchment has now been mined.

Further downstream, the creek flows through a gully dominated by tussocks and pasture grasses, grazed by cattle and sheep. Instream habitat through the gully is comprised of shallow riffles, runs and small drops and pools. Bed substrate is dominated by gravels and cobbles, with some areas of boulders and bedrock. There is evidence of stock damage to the channel particularly in the lower reaches.

A kick-net sample collected from the lower section of Maori Hen Creek in December 2015 included 17 invertebrate taxa including seven dipteran taxa. The fauna was dominated by small chironomids and ostracods, and *Potamopyrgus* snails. Other abundant taxa included a small bivalve (Sphaeriidae), a small stonefly larvae (*Zelandobius*), the purse caddisfly *Oxythira* and aquatic worms. *Deleatidium* mayflies were present but uncommon.

Juvenile galaxiids were abundant in small pools and adults were observed also.

The creek was inspected again in February 2016. Water temperature was moderate (16 – 17 °C) given the time of they year, and dissolved oxygen saturation was moderate to good also (8.12 - 8.72 mg/L). The upper area carried a small flow, similar to that observed in December, and patches of filamentous green algae were present. Flow increased slightly downstream and filamentous green algae abundance was less pronounced. The February 2016 survey found the invertebrate community to be heavily dominated by *Potamopyrgus* snails at the two sites sampled. *Deleatidium* mayflies were abundant in the sample collected from the upper site, but uncommon in the sample collected just upstream of the ford. A range of other invertebrate taxa were present (32 in total) and the community was generally indicative of slow moving water and similar to that found in December.

Crayfish were observed in small pools throughout the creek, and, further downstream, both galaxiids and crayfish were observed in pools in significant numbers.

2.3 Trimbells Gully Tributary

The existing footprint of the Coronation mine lies in the headwaters of Trimbells Gully Tributary (Figure 1). This tributary drains a catchment of approximately 250 ha representing about 3.9 % of the total Mare Burn catchment. While technically a tributary of Trimbells Gully, Trimbells Gully Tributary typically has more water in it over the summer period. This appears to be due in part to the tributary having a slightly larger catchment (Trimbells Gully drains a catchment of approximately 197 ha). Potentially, the proposed boundary of the Coronation North Project will envelope the majority of the Trimbells Gully Tributary catchment.

The catchment of this tributary has similar characteristics to other tributaries in this area of the Mare Burn catchment. The sides of the gully are relatively steep and narrow with rocky outcrops in places. The stream channel is typically bordered by tussocks and pasture grasses. Channel morphology varies throughout its length and is governed to some degree by the presence of surface bedrock, which acts to constrain the wetted channel in places. Where bedrock is absent on the surface, the wetted channel is less defined, particularly where the valley floor is wider, and surface flow is often difficult to detect.

Surveys in November and December 2015 found flow to be quite substantial at times, however this was due to the discharge of mine pit water into the upper reaches of the catchment. These discharges last for a limited time and flows recede quite markedly once they cease.

The bed of Trimbells Gully Tributary ranges from bedrock to fine sediment. Visible algae was generally uncommon in December 2015. There was evidence of significant stock pugging of the bed and channel margins.

Further downstream, the stream channel is more defined and incised in places. Several bedrock sections create small waterfalls and steep drops. Small pools (up to 35-45cm deep) form downstream of bedrock sections, however overall, water depth is shallow. The side gullies in December 2015 were generally devoid of surface water.

Kick net samples were collected from three sites in February 2015, ranging from just upstream of the ford in the lower reach to about 500 metres downstream of the existing mine's silt pond.

Thirty three taxa were identified from the three sites, with dipteran larvae being the most diverse group with 15 distinct taxa. Abundant taxa included the mayfly *Deleatidium*, the purse caddis *Oxythira albiceps*, the snail *Potamopyrgus antipodarum*, small crustaceans called ostracods, aquatic worms and the small stonefly *Zelandobius*. The MCI invertebrate community health index[1] ranged between 85 and 92, which can be regarded as indicative

[1] The MCI index of stream invertebrate community health is based on the presence/absence of individual taxa at a site, and theoretically can range between 200 and 0. Scores >120 reflect a community dominated by taxa indicative of pristine conditions while a score of <80 reflects a community indicative of very poor water quality and habitat conditions. There are two well used variations to the MCI, the SQMC, which takes into account the relative abundance of the various taxa found at the site, and the QMCI, which is also takes into account the abundance of each taxa when quantitative sampling methods are employed. Typically, SQMCI scores are calculated when a kick-net sampler is used and QMCI when a Surber sampler is used (see Appendix Two for more detail). These indexes range between 10 and 1.

of 'Fair' habitat quality, however the semi-quantitative version of this index (SQMCI) produced scores ranging between 2.6 and 4.4, which are indicative of 'Fair' to 'Poor' habitat quality.

The follow up survey in February 2016 found that flow in this creek had reduced considerably relative to that observed in December 2015, with an estimated flow of less than 0.5 L/sec. Small pools were still present in places, however in some sections surface water was barely visible. Water temperature was measured at 17.4 °C and dissolved oxygen concentration was healthy at 9.79 mg/L.

Kick-net samples collected in February in the lower section of the creek found a slightly less diverse fauna (30 taxa), but similar in composition, dominated by snails and to a lessor extent by ostracods, *Deleatidium* mayflies, *Oxythira albiceps*, and the stonefly *Zelandobius*.

Crayfish are common throughout most of the length of Trimbells Gully Tributary. Adults and juveniles are observed in most sections often in large numbers.

Galaxiids are also common in Trimbells Gully Tributary. Young juveniles (whitebait-sized and smaller) were observed in most pools in December, along with adults. Galaxiids were also observed in the February 2016 survey, although the low flow meant that available habitat had reduced considerably.

Aside from a much lower flow, the most striking difference to the stream in February compared to earlier in the summer was the extensive rafts of filamentous green algae that were found in many reaches between the confluence with Trimbells Gully and upstream towards the mine's silt pond. An algae sample, collected in December 2015, and identified under the binocular microscope, found the only filamentous algae taxa present was *Parallela*, which is described as found in streams and rivers of 'moderate to good water quality'. However, samples of the filamentous algae collected in February 2016 found they were dominated by *Mougeotia,* with *Oedogonium* also common. *Mougeotia* was previously found in Trimbells Gully Tributary in a November 2012 survey. It is described as being found in slow-flowing waters of moderate to good quality.

2.4 Trimbells Gully

The Trimbells Gully catchment (197 ha) starts at the top of Highlay Hill (820m asl).

In its lower reaches in December 2015, the Trimbells Gully creek had a largely narrow wetted width (30-50 cm wide) and water depths ranging between 5-20 cm. The flow was very sluggish with no discernable flowing water in many places except over shallow bedrock. Flow was estimated by eye to be less than 0.1-0.15 L/sec.

The bed had a thin layer of fine silt or organic matter over rock and gravels. Tussock and grass foliage often spilled over the channel. There was evidence of heavy grazing by cattle and/or sheep, and the margins and channel was well tramped in places.

Crayfish were observed in the lower reaches. Juvenile galaxiids were caught by kick-netting and via electric fishing.

Small shoals of juvenile galaxiids were observed in this creek all the way up to and just above the fence-line at map reference N 4979211 E 1396618, a distance of approximately 1.1 km. Beyond this point, the bed of the watercourse was wet, but with no discernable surface flow.

The benthic invertebrate fauna in Trimbells Gully in December 2015 was varied and dominated by taxa that were suited to slow moving water with variable water quality and fine sediment. Chironomid larvae, small crustaceans (e.g., ostracods) and the stonefly *Zelandobius* were abundant or common at both sampling sites (Appendix Two). *Sigara* beetles were also abundant at the downstream sampling site while *Potamopyrgus* snails were abundant at the upstream sampling site. Nineteen taxa in total were found in samples collected from two sites.

Community health indices were low reflecting the dominance of taxa suited to slow water movement, fine sediment and moderate to low water quality. Higher daily peaks in water temperature at this time of the year may also have played a role in invertebrate community structure. However, on the day of the survey, water temperature was moderate (15.4 – 18.4 °C) and dissolved oxygen concentration was good (8.3 – 9.89 mg/L).

In February 2016, Trimbells Gully creek was virtually dry. Pools of standing water were still present, but appeared stagnant, and sections of dry channel were common. There was evidence of stock disturbance throughout the channel. Water temperature was moderate (14.4 °C).

No fish were observed in the creek, but some may have been present in the pools. Habitat was unsuitable to collect invertebrate kick-net samples.

A long-term fish and invertebrate monitoring site (TC01) has been established on Trimbells Gully creek downstream of the confluence with Maori Hen Creek. This site is surveyed for macrophytes, periphyton and fish, and sampled quantitatively for macroinvertebrates. Monitoring commenced in August 2014. The site is very open, with limited shading from surrounding hills and from the riparian vegetation, which consists of tussocks and pasture grass, with some matagouri, sedges and rushes. There is evidence of stock access throughout the site. The substrate consists of small gravels and cobbles, with bedrock in pools immediately upstream of the site.

Surveys were conducted between the winter of 2014 and autumn of 2015. Macrophyte cover was low in both winter and spring (less than 3%). Mat algae cover was very high in winter with 81% cover, although declined to less than 2% in spring. Filamentous algae cover was lower although still reaching 23% cover in spring.

The fauna was found to be dominated in winter and spring by mayflies, snails, small dipteran larvae and worms. In spring 2014, *Oxythira albiceps* caddisfly larvae and *Zelandobius* stonefly larvae were common also. In summer, the site was dry and could not be sampled. In the following autumn (2015), mayflies were absent, and the fauna was less diverse and in lower abundance than in the previous winter and spring. The QMCI health index declined between winter (average of 5.0) and autumn (average of 2.7).

No galaxiids were caught at TC01 in the summer of 2014. In previous years, galaxiids were found to be present in low numbers (two caught in 2012 and five caught in 2013). A large unidentified eel (approximate length 600 mm) was observed at TC01 in 2014. The site was dry in the summer (February 2015) and again in February 2016, and so was not sampled for fish.

2.5 Coal Creek

Coal Creek lies to the immediate west of Maori Hen Creek (Figure 1). Part of the Coronation North project footprint would lie within the eastern side of its catchment and a reservoir to store freshwater is proposed for part of the lower catchment (Figure 2). At approximately 700 ha, its catchment is greater than the total area occupied by the Maori Hen, Trimbells Gully and Trimbells Gully Tributary catchments. Despite this significantly greater catchment area, its flow in the lower catchment is modest and much less than observed in these catchments over the 2015-16 summer. In December 2015, this creek had a very small flow and was almost dry between pools in its lower section.

Galaxiid larvae were observed in the pool immediately downstream of the farm bridge in December 2015, however, by late February 2016, the flow in the lower section of Coal Creek had ceased and the channel was completely dry (Appendix One).

A more extensive survey of the Coal Creek catchment was undertaken on 19 April 2016 with particular emphasis on watercourses within and immediately surrounding the footprint of the proposed freshwater reservoir. Prior to the survey, weather conditions had been relatively stable with only a small amount of rain falling in the weeks prior to the survey.

The April survey involved a walkover of watercourses accompanied by extensive electric fishing and in some cases macroinvertebrate sample collection. The survey area is identified in Figure 2.

The first watercourse examined (labelled as Trib. A in Figure 2) carried the greatest flow and we have assumed this to be the main tributary in the Coal Creek catchment. In its lower reaches, from the reservoir footprint to an upstream distance of approximately 800 metres, the watercourse flowed through a gully floor characterised by grazed sedges, tussock grasses and pasture grasses. There was extensive evidence of historic mining activity and it seemed that significant parts of the channel had been realigned and straightened over time.

We observed flowing water and a continuous wetted channel throughout this reach, although the flow was modest and estimated at less than a 1 litre/second. However, this was sufficient to create small riffle and slow run habitat, and support deeper pool habitat.

One of the main characteristics of the gully floor and associated watercourse channel was the extensive trampling and pugging by stock (see Appendix One). This damage was observed right throughout the length of the channel surveyed and was severe in places, resulting in deep soft muds on the bed that quickly resuspended and discoloured the water when walked on. Cattle were present in the vicinity of the creek on the day of the survey.

Cattle faeces were common in and around the wetted channel and long filamentous green algae was present in some areas.

Despite this physical disturbance, galaxiids (which we assume are flathead galaxias) and crayfish were common throughout the reach surveyed. Some of the fish were large (80-90 mm long) and possibly gravid (carrying eggs). Small and medium sized fish (15- 50 mm long) were also captured indicating that the population was recruiting. Crayfish also varied in size indicating active recruitment to the population. During electric-fishing, most fish were observed to come from under rocks. Few fish were located within the water column or lying above the soft mud sections of the bed.

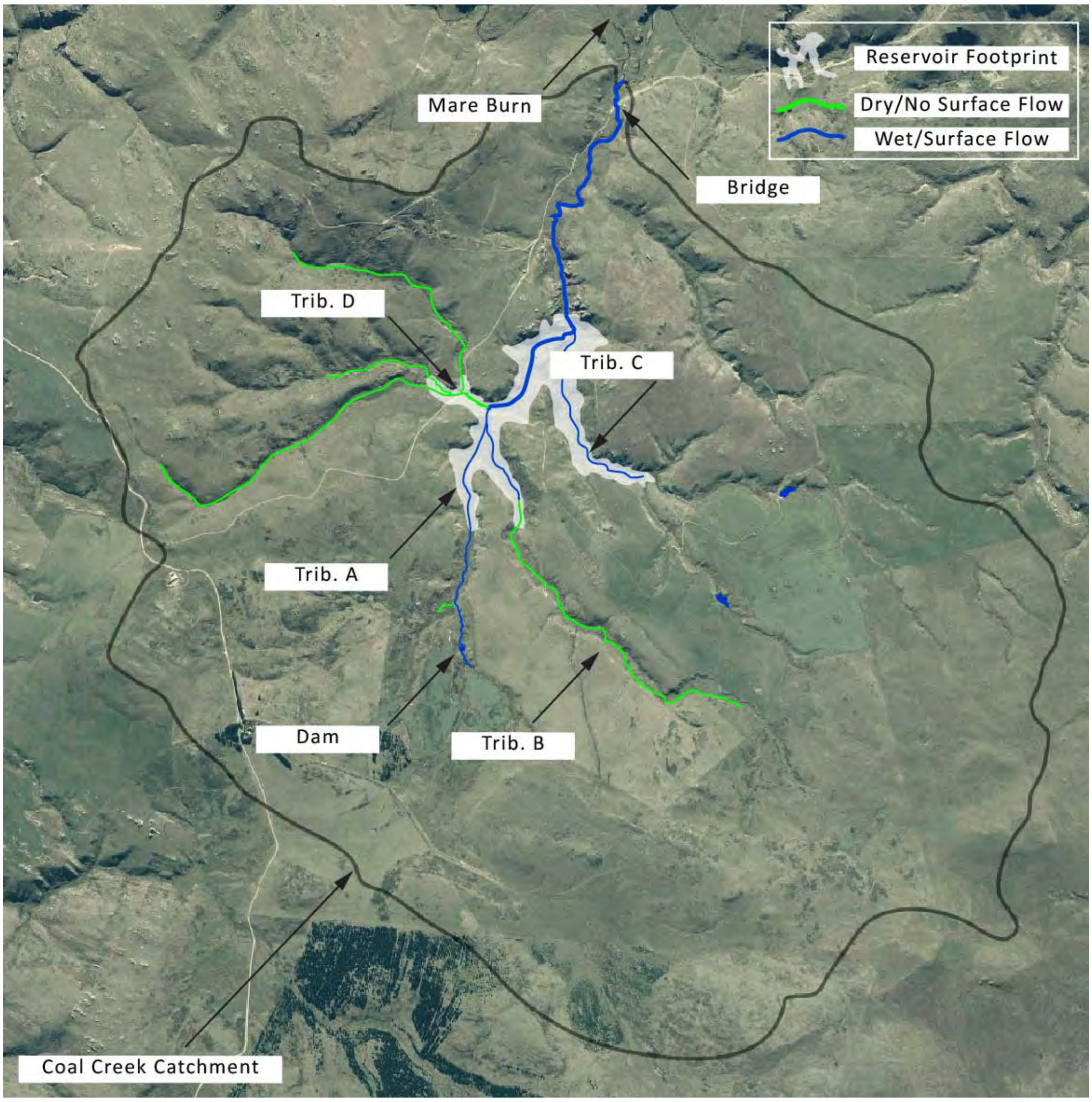

***Figure 2**. Aerial Map of the Coal Creek catchment showing areas surveyed in April 2016 and the approximate footprint of the proposed freshwater reservoir.*

A kick-net benthic invertebrate sample collected from this section of Trib. A was dominated by snails, small crustaceans (ostracods), small Sphaeriidae bivalves and the larval trichopteran *Oxythira albiceps* (purse caddisfly). Other taxa indicative of still water, soft bed, and degraded water quality were common (Appendix Two). Invertebrate community health index scores were low (MCI of 83 and SQMCI of 3.4).

Further upstream of this tributary, an old earth and rock dam was present. There was an outlet on one side of the dam face allowing a small trickle of water to flow out.

The next gully to the southeast (Trib. B, Figure 2) was then surveyed. It was dry throughout its mid reaches and surface water was not observed until some distance downstream toward the reservoir footprint. Even then, there was no obvious surface flow.

The next watercourse surveyed was the reach through the reservoir footprint (Figure 2). The channel in this section of the catchment is confined due to the physical nature of the surrounding land, being dominated by narrow, steep rock faces creating a gorge. Small pool habitat is more common in this reach and these pools were deeper than those further upstream. Having said that, fish (galaxiids) abundance was lower than that found further upstream in Tributary A. Reasons for this were not readily apparent, but may be due to less rock cover relative to that in some pools surveyed upstream. The fish caught ranged in size from small to large. Crayfish abundance appeared similar to that in Tributary A further upstream.

Stock damage to the banks and channel was apparent throughout this reach, however, while significant, it was not as severe as upstream, probably due to the presence of more bedrock and hard surfaces restricting erosion and pugging. Long filamentous algae was common.

A kick-net benthic invertebrate sample collected from the main channel within the reservoir footprint was dominated by aquatic worms and ostracods. Other taxa indicative of still water habitat were common (Appendix Two). Invertebrate community health index scores were low (MCI of 88 and SQMCI of 2.3).

Another gully to the east (Trib. C, Figure 2), which enters the main channel within the gorge, was surveyed. It consisted of a series of small pools separated by sections of channel dominated with grasses and almost no surface flow. Five galaxiids (4 medium size and 1 large size) and one crayfish were caught in four pools surveyed in this tributary. The water in this tributary was very clear relative to that in the other tributaries surveyed (Appendix One).

The bottom end of Coal Creek (downstream of the dam footprint) was previously examined in February 2016. On that occasion, the creek channel at the ford was dry downstream of the bridge (see Appendix One). Upstream of the bridge, the channel was primarily dry also, although there were some isolated pools of water. When this site was visited in April 2016, the channel below the bridge held water again and was relatively deep (Appendix One). Immediately upstream of the bridge, the channel had small pools of water with no discernable flow. These were separated by sections of boggy wetland habitat with little discernable surface flow.

Gullies in the sub-catchment draining the western side of the Coal Creek catchment (we named Trib. D, Figure 2) were dry in April.

In summary, the Coal Creek catchment suffers from heavily degraded physical habitat, due largely to cattle and to a lessor extent sheep trampling and pugging. Historic mining and farming activities also appear to have significantly modified watercourses through straightening and diverting channels, and damming of gullies. Water quality is likely to be characterised by elevated sediment loads (particularly during rain events) and nutrient concentrations. Long filamentous green algae was common and indicative of high nutrient levels. A lack of flowing water is also a characteristic of large parts of this catchment, at least during the summer-autumn seasons, further restricting habitat for fish and invertebrates favouring flowing water.

2.6 Mare Burn catchment above Trimbells Gully confluence

True left tributaries of the Mare Burn upstream of the confluence with Trimbells Gully were inspected in February 2016. This involved a walkover and observation of the creek beds and surrounding riparian margins.

The stream channels were small with good bank and riparian cover dominated by tussock grasses. Sheep had been grazing the surrounding land, but not heavily in the channel. Sections of the channel were dry or consisted of damp mud. Some isolated pools remained. Stream habitat potential appeared high, however a lack of water significantly limits the ability to support valued stream biota all year round.

2.7 Fish distribution in the Mare Burn and surrounding catchments

The New Zealand Freshwater Fish Database (NZFFD) was reviewed to obtain existing information on fish communities in the Mare Burn catchment and five other nearby tributaries of the Taieri River (Table 1). All except one of the records from the Mare Burn catchment are for the mainstem of the Mare Burn within 2 km of the Taieri River confluence and therefore well downstream of the existing Coronation Project and proposed Coronation North Project areas.

Five native and one introduced fish species (brown trout) have previously been recorded in upper Taieri River tributaries. Four of these species have been recorded in the Mare Burn catchment; brown trout, unidentified galaxias (now thought to be Taieri flathead galaxias), longfin eel and shortfin eel. Local NZFF database records for flathead galaxiids are mapped in Figure 4.

With respect to our own fish surveys, galaxiids have been caught or observed in Trimbells Gully, Trimbells Gully Tributary, Maori Hen Creek and Coal Creek. Despite the small size of in these streams, galaxiids appear widespread and abundant in some places, particularly the mid and lower reaches of Trimbells Gully Tributary and Maori Hen Creek. This may be due to our observations that these two tributaries appear to hold surface water for longer throughout the summer period.

We have made one sighting of an adult eel at the TC01 site, but, other than galaxiids, no other fish species have been recorded or observed at sites upstream of the confluence between Trimbells Gully and Maori Hen Creek.

A potential trout barrier exists on Trimbells Gully at a point approximately 230 m downstream of TC01. It consists of a bedrock block with a near vertical downside face approximately 1.5 m high (Figure 3). While the height is not that challenging to trout, the feature is made more of an upstream barrier by having a shallow bedrock platform immediately downstream of it, that provides little opportunity for trout to gain upward momentum when attempting to leap (due to a lack of water depth). This potential barrier, in conjunction with very low flow and potential dry sections for considerable times of the year, may be factors contributing to no trout in this section of the Mare Burn catchment. Other barriers to upstream passage in the Mare Burn are known to exist further downstream.

***Figure 3**. Photo looking upstream showing potential trout barrier on Trimbells Gully (December 2015).*

***Table 1.** Number of NZFFD records for fish species identified in the Mare Burn catchment and five other nearby tributaries of the Taieri River (database accessed February 2016).*

Fish species	Mare Burn	Cap Burn	Filly Burn	Horse Burn	Prices Creek	Scrub Burn
Brown trout (*Salmo trutta*)	4	1			2	1
Flathead galaxias (*Galaxias depressiceps*)	1	5		1		
Galaxias species (unidentified)	1	1				1
Longfin eel (*Anguilla dieffenbachii*)	3		1			
Roundhead galaxias (*Galaxias anomalus*)					1	3
Shortfin eel (*Anguilla australis*)	1					
Upland bully (*Gobiomorphus breviceps*)						1

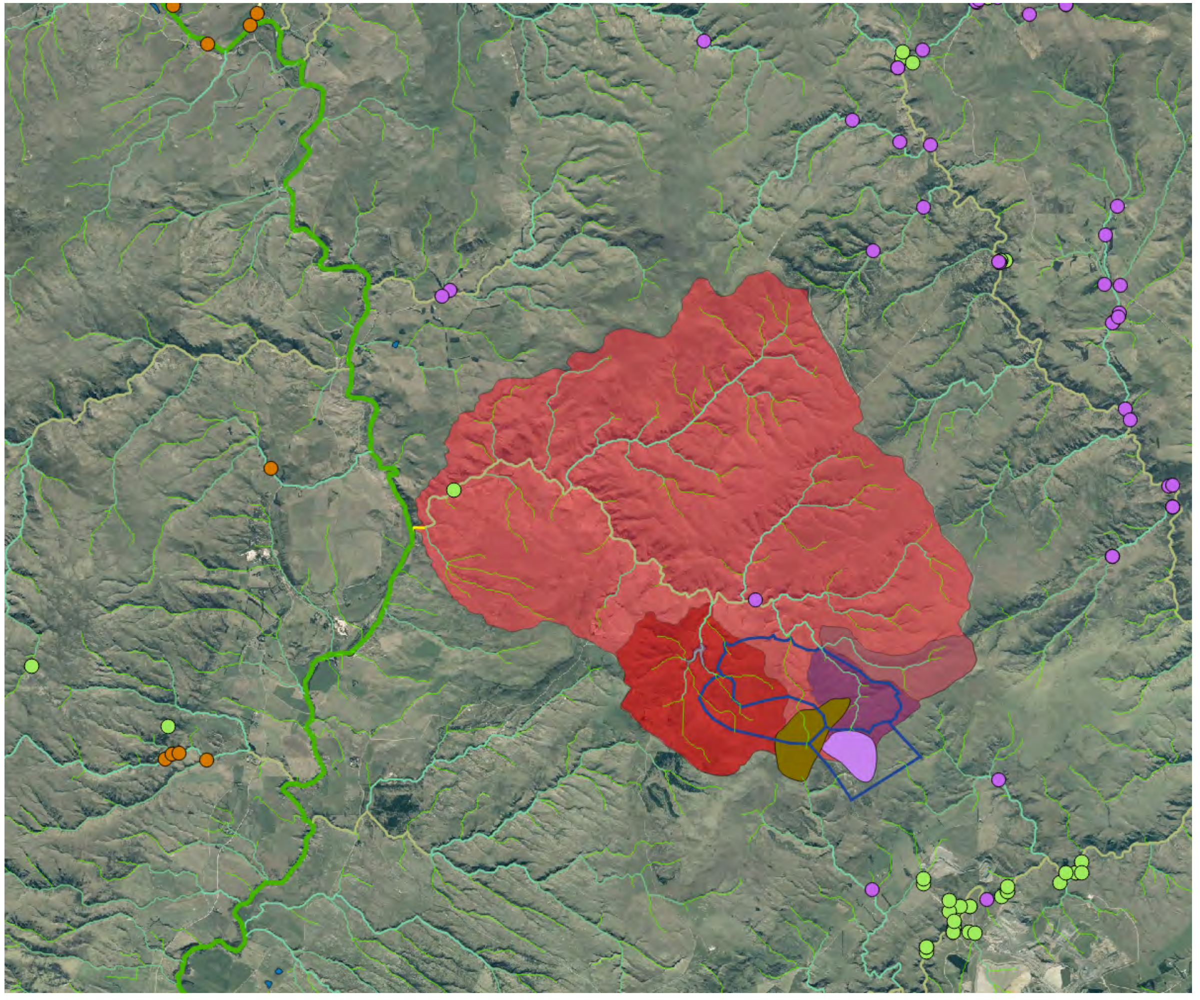

Figure 4. *Known local distribution (purple circles) of* Galaxias depressiceps (Flathead galaxias) *from the NZFF database (March 2016). Green circles are older galaxiid records where the species was classed as unidentified, but are now thought to be* D. depressiceps. *Orange circles are records for* Galaxias anomalus (Roundhead galaxias). *Note that Ryder Consulting fish records are not included on this map – refer to text. Blue lines are Coronation North pit and wastre rock stack. Green and purple areas are consented Coronation pit and waste rock stack areas.*

3. Significance of existing aquatic values

3.1 Salmonids

Significant aquatic values of the Mare Burn catchment identified in the ORC Regional Plan: Water for Otago are the provision of areas for salmonid spawning and development, and the presence of riparian vegetation of significance to aquatic habitats. Our assessments over recent years have not identified the presence of any suitable salmonid spawning habitat, nor were any salmonids caught in Mare Burn tributaries within the areas surveyed. It is likely that this type of habitat is located further downstream in the catchment and well outside of the proposed mine expansion area. Barriers to upstream passage are also likely to restrict the presence of salmonids in the upper Mare Burn catchment.

3.2 Eel

The Shortfin eel has been classified as 'Not Threatened' using New Zealand Threat Classification System (NZTCS) criteria (Townsend *et al.* 2008), with the qualifier 'Increasing' (Goodman *et al.* 2014).

The Longfin eel has been classified as 'At Risk - Declining', with criteria C (2/1) (very large population and low to high ongoing or predicted decline, total area of occupancy > 10,000 ha (100 km^2), predicted decline 10–70 %) and the qualifier 'Conservation Dependent' (Goodman e*t al.* 2014).

Eel abundance in the vicinity of the tributaries subject to existing and proposed mining operations is very low to non-existent, with only one eel having been observed (at TC01) since surveying began in 2012. Therefore, significant eel populations are not at risk from existing or proposed mining operations associated with the Coronation Project.

3.3 Non-migratory galaxiids

Galaxiids have also been captured previously in the Mare Burn catchment, however individual species caught in our previous surveys were not confirmed by genetic testing. Both flathead and roundhead galaxias have been recorded in neighbouring catchments (Figure 5).

Flathead galaxiids in the Shag River, Waikouaiti River, and Taieri River catchments are all being managed as *Galaxias depressiceps* K Taieri flathead galaxias. The threat status of New Zealand freshwater fish was updated in 2013 (Goodman *et al.* 2014). The Taieri flathead galaxias has been classified as 'Threatened – Nationally Vulnerable' using New Zealand Threat Classification System (NZTCS) criteria (Townsend *et al.* 2008), with criteria C (3/1) (moderate population, with population trend that is declining, total area of occupancy ≤ 100 ha (1 km^2), predicted decline 10–50 %) and the qualifier 'Conservation Dependent' (Goodman *et al.* 2014). The geographic range of this species has decreased substantially in the last 150 years, since the introduction of invasive fish species (e.g., brown trout) and its distribution is now highly fragmented (Department of Conservation 2004, Jones 2014, NIWA 2013).

Roundhead galaxias have a threat classification of 'Nationally Vulnerable', with criteria C (3/1) (moderate population, and high ongoing or predicted decline, total area of occupancy ≤ 100 ha (1 km^2), predicted decline 50–70 %) and the qualifier 'Extreme Fluctuations' (Goodman *et al.* 2014).

We sent some specimens from our recent surveys to the University of Otago for DNA testing to confirm species identification. All specimens were positively identified as *Galaxias depressiceps* (flathead galaxias).

The ORC Water Plan identifies that some tributaries of the Taieri River contain significant habitat for flathead galaxiids, and this has been confirmed by our current and previous assessments, which have found populations of flathead galaxiids in tributaries of the Mare Burn from Coal Creek up to the confluence with Trimbells Gully. We would expect the distribution of this species within the Mare Burn catchment to be much greater than this.

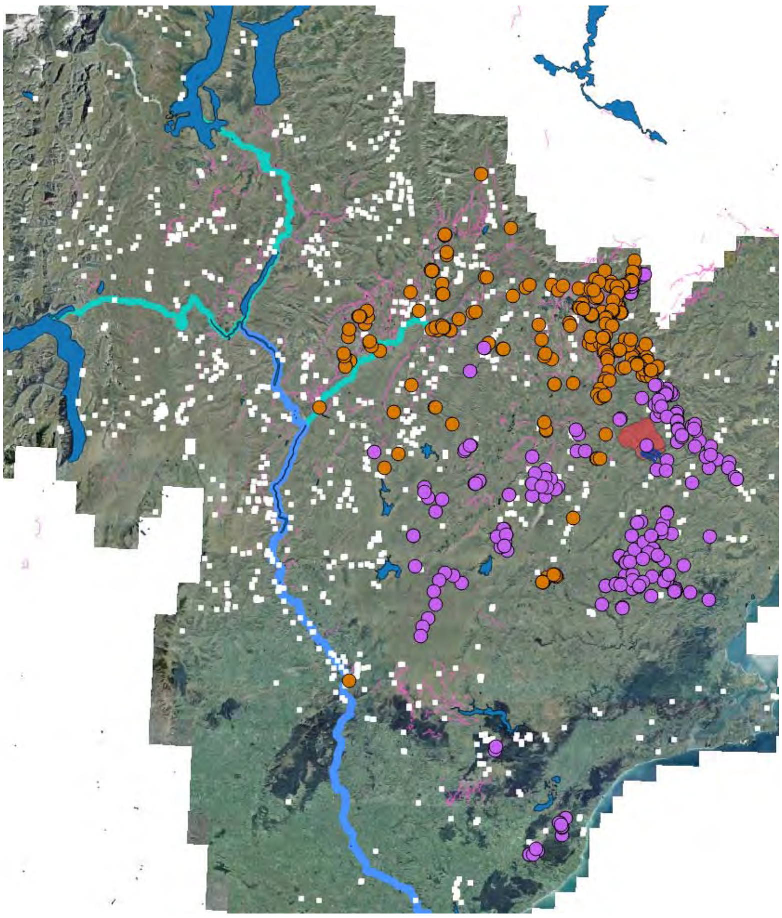

Figure 5. *Known distribution of* Galaxias depressiceps (Flathead galaxias - *purple circles*) and Galaxias anomalus (Roundhead galaxias – *orange circles*). *White squares are survey sites where no fish were found. Mare Burn catchment is shaded. Records from the NZFF database (March 2016).*

3.4 Freshwater crayfish

Freshwater crayfish (*Paranephrops zealandicus*) are widespread and relatively common in Coal Creek, Maori Hen Creek, Trimbells Gully tributary and Trimbells Gully mainstem. Their relatively high abundance in these creeks is surprising given that habitat appears limited by a lack of flow and wetted area. They are likely to be present in other tributaries of the Mare Burn, and in the Mare Burn itself.

Paranephrops zealandicus has been classified as 'At Risk – Declining' using New Zealand Threat Classification System (NZTCS) criteria (Townsend *et al.* 2008), with criteria C (1/1) (very large population and low to high ongoing or predicted decline, >100,000 mature individuals, predicted decline 10 70 %) and the qualifier 'Partial Decline' (Grainger *et al.* 2014).

3.5 Benthic invertebrates

The tributaries of the Mare Burn that we have surveyed contain a surprising number of benthic invertebrate taxa given they are probably impacted by a lack of surface flow at times in most years and their habitats are not protected from grazing stock. This has resulted in significant impacts in tributaries within the Coal Creek catchment in particular. None of the taxa we have identified are uncommon, indeed all are commonly found throughout large areas of the country. However, diversity is relatively high in Maori Hen Creek and Trimbells Gully Tributary given there appears to be nothing particularly unique about their instream character.

4. Potential effects on freshwater ecology associated with the Coronation North Project

4.1 Stream habitat - General

The proposed Coronation North Project will result in the further loss of small stream habitat that supports populations of Taieri flathead galaxias. Most of Maori Hen Creek and Trimbells Gully Tributary catchments, and part of the Coal Creek catchment, will be altered through excavation associated with the pit and deposition associated with the waste rock. Watercourses within these catchments will be lost.

Based on our surveys of the known distribution of flathead galaxiids in the affected catchments, it is estimated that approximately 4.4 km of small stream galaxiid habitat will be lost as a result of Coronation North. The significance of the aquatic habitat loss varies depending on its permanence, with reaches of streams that have permanent flow likely sustaining higher value communities that may include fish. This appears to be the case for Maori Hen Creek, Trimbells Gully Tributary, and parts of the lower Coal Creek catchment, which continued to maintain stream habitat throughout the 2015-16 summer and autumn period, albeit sustained by very low flows. However, these flows were sufficient to support crayfish and galaxiid populations, and maintain relatively diverse benthic invertebrate communities.

The quality of this habitat was quite variable, with the most degraded being in Coal Creek due to ongoing damage from cattle. Stock damage to stream habitat was present in all the other tributaries, but generally not to the same degree.

Similar stream communities are likely to present elsewhere in the Mare Burn catchment, but we did not survey areas outside of land owned by OceanaGold. Therefore it has not been possible to 'rank' the relative habitat quality of these tributaries against that found throughout the catchment. Assuming that other tributaries within the Mare Burn catchment have similar qualities to those we surveyed, and support flathead galaxias populations, it is possible to quantify the loss of galaxiid habitat due to the Coronation North Project.

Using the REC classification[2] data for the Mare Burn catchment, the total length of stream network for stream orders greater than 1 (i.e., stream orders 2 – 4) is 50.7 km. The maximum loss of galaxiid stream habitat due to Coronation North (4.4 km) would be 8.7% of that which potentially exists in the Mare Burn catchment. Order 1 streams were excluded from this analysis as we know that many of the order 1 stream identified in Mare Burn sub-catchments that we have surveyed do not support galaxiid populations (typically because they have no surface flow). However, we know from our surveys that some order 1 streams that do carry surface flow also support galaxiid populations (e.g., Maori Hen Creek). Therefore, if order 1 streams are included in this analysis, 102 km of

[2] River Environment Classification - groups streams into types based on variables derived from geology, climate, source of flow and position in the river network.

stream network is present in the Mare Burn catchment, and the Coronation North Project would result in a 11% loss of 'stream' network, although the actual proportional loss of galaxiid habitat would be less than this. This analysis should be viewed with some caution as only the sub-catchments affected by the Coronation and Coronation North projects have been surveyed for fish distribution in the Mare Burn catchment.

Nonetheless, mitigation is recommended for the direct loss of non-migratory galaxiid fish habitat and associated populations (see section 5).

The creation of a freshwater reservoir in the lower reaches of the Coal Creek catchment would also result in the loss of approximately 1.5-2 km of small stream and ephemeral stream habitat of relatively poor quality, but some sections still supporting small flathead galaxiid and crayfish populations. This loss of habitat may be mitigated by the potential benefits of an augmented flow to the Mare Burn, as discussed below.

4.2 Creating a freshwater reservoir in the Coal Creek catchment

General

The proposed dam will result in the conversion of approximately 1.2-1.5 km of small stream and ephemeral stream habitat into lake habitat (approximately 135,000 m^2 when full). Stream habitat within this reach is currently utilised by stream benthic macroinvertebrates, crayfish and flathead galaxiids. The quality of the habitat is relatively poor and has been modified historically through mining activities and more recently by stock having widespread access to the watercourses. The density of fish and crayfish observed in this section of the catchment in April 2016 was relatively modest and lower than that observed further upstream in the main tributary (Trib. A) during the same period, and also lower than that observed in the lower sections of Maori Hen Creek and Trimbells Gully Tributary in February 2016.

The new reservoir habitat will not provide suitable habitat for flathead galaxiids, but will provide habitat for crayfish and benthic invertebrate taxa that prefer still water, macrophytes and/or soft substrate habitat. The edges of the reservoir will provide similar habitat to that found currently in the catchment, although its quality and availability will be affected by how the reservoir is operated (i.e., frequency and rate of drawdown).

Flathead galaxiids are found throughout the Macraes area, and the loss of creek habitat associated with the Coal Creek reservoir is minor relative to the wider galaxiid population. However the loss is cumulative and the distribution of this species is restricted to only a part of the Otago region.

Reservoir stratification

Depending on a number of factors, reservoirs in New Zealand can stratify into layers of markedly different temperatures during the warmer months of the year. Cold water entering the reservoir from the river sinks to the bottom. During warm summer months, the sun warms the upper layer and that layer becomes warmer than the reservoir as a whole. Eventually the reservoir water divides: warm water (called the epilimnion) floating above the cold water (called the hypolimnion) resting below. Between these two layers is a transitional layer, the metalimnion, in which temperature decreases rapidly as one moves deeper. This 'thermocline' is important to the biology and water quality of a reservoir. It acts as a barrier to the movement of dissolved oxygen and dissolved materials (e.g., bioavailable nutrients), and the distribution of heat between the epilimnion and the hypolimnion.

The depth of the epilimnion in the proposed Coal Creek reservoir can be predicted from the area using the following equation:

- Fetch (F) = $A^{0.5}$ (A = surface area, km) (Davies-Colley, 1988)
- Epilimnion depth = $7.69 \times \text{Fetch}^{0.463}$ (m)

  = $7.69 \times 0.367^{0.463}$

  = 4.84 m

The following rule of thumb can be used as a guide to potential stratification of surface outflow lakes (Hoare and Spigel 1987):

1. If the lake depth is more than twice the predicted epilimnion depth the lakes are usually stratified in a stable manner;
2. If the lake depth is between 1 and 2 times the predicted epilimnion depth then stratification occurs, but is often broken by windy periods;
3. If the lake if less than the predicted epilimnion depth, then the lakes are usually mixed, only stratifying in calm periods.

When full, the reservoir would have an average depth of about 0.5 m, indicating that a significant proportion of it would be very shallow. Ignoring other potential influences, the predicted epilimnion depth of 4.84 metres is much greater than the average reservoir depth, but towards the dam face (the embankment will be approximately 25 m high), the water depth deepens significantly, reaching up to 20 m. This suggests there is a small risk that water in the lower end of the reservoir could vertically stratify at times of the year and in doing so potentially create a layer of low oxygen water in the deeper part of the reservoir. This water would be discharged to the lower section of Coal Creek, however, the discharge system can be engineered to ensure the released water gets as much aeration as possible in the area close to the toe of the dam. As the water level in the dam is drawn down over summer, the risk of stratification is reduced as the water depth reduces and wind-induced mixing increases.

Water quality

Given the current state of tributaries in the catchment, reservoir water quality may initially be enriched with nutrients and sediment due to farming practices. Algae blooms may develop and these already occur in the tributaries that would be inundated. Retiring the upper catchment from stock is recommended as this, in the medium to long term, would improve the quality of water entering the dam as well as improve the quality of habitat in the upstream tributaries which are currently significantly impacted.

The temperature of the reservoir water may differ from that in the creek due to the energy buffering capacity of a large body of water relative to water in the creek, which is more likely to closely reflect ambient temperature conditions. The effect of this on downstream fish, crayfish and benthic invertebrates is unlikely to be significant as these are accustomed to a range of temperatures. Potentially cooler water discharged in summer will, if anything, benefit downstream stream communities provided it is sufficiently oxygenated. Introducing oxygen back into the discharge can be achieved by engineering the discharge to fall and dissipate across roughened media prior to entering the downstream channel of the creek.

It is proposed to release a minimum flow of 5 litres/second to the creek below the reservoir. This is significantly higher than what we have currently observed in lower Coal Creek. Given the size of the channel, such a flow would easily be accommodated and would increase the area of flowing water considerably. This is expected to improve the overall physical habitat available for stream biota and reduce the critical extreme low flow periods observed over summer and autumn 2015/2016. It is estimated this would benefit approximately 860 metres of the lower Coal Creek and a significantly greater length of the Mare Burn. This proposed increase in the minimum flow would not increase the risk of trout invasion as the Mare Burn has trout barriers further downstream that would not be affected by a flow increase of this magnitude.

4.3 Sediment mobilisation and run-off

Mining disturbs the land, removes vegetation and soil cover, and so increases the risk of fine sediment discharges to watercourses further down the catchment. Fine sediment is already present in most reaches of the tributaries we assessed, however excessive cover is usually detrimental to stream communities, particularly if flow variability is insufficient to regularly flush the excessive cover away. Therefore, an expanded mining operation poses some risk to downstream communities unless measures are implemented to avoid the introduction and downstream transport of sediment. Such measures are routinely employed by OceanaGold at the Macraes Mine but are worth re-emphasising here.

Specific erosion and sediment control measures will need to include:

- Manage surface water runoff around the pit, waste rock stack and haul road with diversion drains and silt control dams. Permanent silt ponds should be located as close as possible to the disturbed area to minimize effects on downstream aquatic habitats. Service and emergency spillways may be required to pass large flow events. Sediment control should be installed prior to any disturbance within each catchment area;
- Shoulders of waste rock stacks should have benches designed to control runoff;

- Install perimeter surface water drains around waste rock stacks to ensure runoff is conveyed to the base of gullies without erosion. Such drains may need to be lined where necessary and energy dissipation provided at high energy locations.
- Surface water and groundwater collected in the pit during operations may need to be pumped out to a water sump and used for dust control. Any surplus water may need to be discharged to watercourses via silt ponds. Water quality testing of this water is recommended prior to discharge to ensure it meets water quality guidelines that protect stream biota.

4.4 Accidental contaminant spills

The presence of construction machinery in and around waterways always presents a risk of contaminants (e.g., diesel, lubricants) entering watercourses with the potential to harm aquatic life. These issues can be addressed by way of an appropriate on-site contaminant management plan. As a general rule, any possible contaminants stored on site should be kept away from watercourses and bunded. Refuelling of machinery should also take place away from watercourses. Such measures are routinely employed by OceanaGold at the Macraes mine and are addressed by consent conditions for the Coronation Project which will be replicated for the Coronation North Project.

4.5 Nuisance aquatic weed/algae introduction

Machinery and personnel involved in construction can potentially transfer nuisance weeds/algae (e.g., *Didymosphenia geminata* - didymo) to local watercourses. Didymo has been recorded in the Shag River catchment, but has not been recorded in the Taieri River catchment, and we have not found it during our more recent surveys. While didymo has not been recorded in the Taieri River catchment, and many watercourses within the mining area may not be suitable for didymo establishment, if didymo was to enter these streams it may be able to travel downstream to establish at more suitable locations in the lower Taieri River. To address this, OceanaGold complies with notices and guidelines issued by Biosecurity New Zealand regarding didymo, and will continue this practice.

5. Mitigation

5.1 Loss of fish habitat

Previously, we have suggested the transfer of fish and crayfish where their habitat is likely to be lost or significantly affected by mining. It is difficult to assess the effectiveness of such measures without long term monitoring of populations in the areas where fish and crayfish are relocated. Monitoring of populations prior to relocation would also be necessary to determine whether relocations have successfully increased populations.

Transferring to stream habitat where no fish or crayfish are currently present also raises issues around the appropriateness of the new habitat.

Further, finding appropriate habitat requires intensive investigation work, and access to land outside of OceanaGold's control presents further challenges.

Given the above, we are of the view that fish and crayfish translocation may not represent the best form of mitigation for loss of habitat.

Habitat creation and protection in areas that already support flathead galaxiid populations are worth exploring further. The population has a limited distribution and is under threat from invasive fish, particularly brown trout. This threat can be reduced through the establishment of trout barriers.

Protection of existing strong holds of flathead galaxiid populations may also involve measures to enhance riparian protection through stock exclusion and other measures to enhance riparian vegetation, instream and water quality. Fencing with appropriate setbacks is the obvious method that is employed to achieve such outcomes. We are of the view that such measures would have benefits to tributaries within the Mare Burn catchment, particularly in the Coal Creek catchment, however, if this is not possible, there may be opportunity to explore such initiatives elsewhere.

It is recommended the Coal Creek freshwater reservoir be fenced from stock and the development of ungrazed riparian margin encouraged. This will assist in the filtering of sediment and nutrients prior to reaching the reservoir.

Galaxiid habitat in the lower Coal Creek catchment, and in the Mare Burn downstream of the Coal Creek confluence, may benefit from the proposed minimum flow of 5 litres/second released from the proposed Coal Creek reservoir. Providing water quality is reasonable (in particular dissolved oxygen levels are adequate to support fish life stages), the additional water should result in a more stable fish population less affected by a loss of habitat (quality and quantity) and associated stress under summer-autumn low flow periods.

Consideration should also be given to off-site mitigation in the form of enhancement and/or protection measures of other endangered non-migratory Otago galaxiid populations, such as roundhead galaxias. This species has a shorter life-span than the Taieri flathead galaxias and some stronghold populations are at risk from trout invasion.

5.2 Loss of crayfish habitat

As already noted above, crayfish relocations may have limited benefit. Crayfish are more widespread in their distribution than flathead galaxiids, and are able to inhabit both stream and pond environments. Consequently, their population can be maintained and enhanced through habitat creation (e.g., man-made ponds), and this has shown to be successful in the South Island.

We also note that crayfish and flathead galaxiids appear to co-exist quite well in tributaries of the Mare Burn, and so the mitigation recommended above for these fish are likely to have benefits for local crayfish populations as well. A number of small ponds already exist in the Coal Creek catchment. These could be protected and enhanced to improve habitat for crayfish. De-stocking the catchment would have significant benefits to pond and stream habitat. Such measures would also act to improve downstream water quality.

5.3 Spills and sediment management

Recommended mitigation measures to avoid effects on downstream ecosystems due to accidental spills and sediment losses have been identified above in sections 4.2 and 4.3.

5.4 Contaminants and nuisance weed/algae introduction

To ensure didymo and nuisance weeds are not introduced or spread it is recommended that, wherever possible, equipment and other items to be used in or near waterways are first inspected and if necessary cleaned prior to use. Such measures are already in place with the existing Coronation Project consent conditions and would continue for the Coronation North Project.

6. References

Allibone, R., David, B., Hitchmough, R., Jellyman, D., Ling, N., Ravenscroft, P. and Waters, J. 2010. Conservation status of New Zealand freshwater fish, 2009. *New Zealand Journal of Marine and Freshwater Research*. **44**: 271-287.

Boothroyd, I.G. and Stark, J.D. 2000. Use of invertebrates in monitoring. Chapter 14 in Collier, K.J. and Winterbourn, M.J. eds. New Zealand stream invertebrates: ecology and implications for management. New Zealand Limnological Society, Christchurch. Pp. 344-373.

Davies-Colley, R. 1988. Mixing depths in New Zealand lakes. *New Zealand Journal of Marine & Freshwater Research.* **22**: 517-528 .

Department of Conservation. 2004. New Zealand non-migratory galaxiid fishes recovery plan 2003-13. Threatened Species recovery Plan 53. New Zealand Department of Conservation, Wellington.

Goodman, J.M., Dunn, N.R., Ravenscroft, P.J., Allibone, R.M., Boubee, J.A.T., David, B.O., Griffiths, M., Ling, N., Hitchmough, R.A., and Rolfe, J.R. 2014. Conservation status of New Zealand freshwater fish, 2013. New Zealand Threat Classification Series **7**. Department of Conservation, Wellington. 12p.

Grainger, N., Collier, K., Hitchmough, R., Harding, J., Smith, B. and Sutherland, D. 2014. Conservation status of New Zealand freshwater invertebrates, 2013. New Zealand Threat Classification Series 8. Department of Conservation, Wellington, New Zealand.

Hoare, R. and Spigel, R. 1987. Water balances, mechanics and thermal properties. In: A Viner (ed.). Inland Waters of New Zealand. DSIR bulletin **241**. DSIR, Wellington.

IUCN. 2014. The IUCN Red List of Threatened Species. Version 2014.3. Available at: www.iucnredlist.org. (Accessed: March 2016).

Jones, P.E. 2014. Life history variation in the *Galaxias vulgaris c*omplex: implications for interactions with invasive salmonids. A thesis submitted for the degree of Doctor of Philosophy in Zoology. Department of Zoology, University of Otago.

NIWA. 2013. NIWA Atlas of NZ Freshwater Fishes. Available at: https://www.niwa.co.nz/freshwater-and-estuaries/nzffd/NIWA-fish-atlas.

Ryder Consulting. 2013. Coronation Project: Ecological Assessment. Prepared for OceanaGold NZ Ltd.

Stark, J.D. 1993. Performance of the Macroinvertebrate Community Index: effects of sampling method, sample replication, water depth, current velocity, and substratum on index values. *New Zealand Journal of Marine and Freshwater Research*. **27**: 463-478.

Stark, J.D. 1998. SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research*. **32**: 55-66.

Stark, J.D. and Maxted, J.R. 2007. A biotic index for New Zealand's soft-bottomed streams. *New Zealand Journal of Marine and Freshwater Research*. **41**: 43-61.

Stark, J.D., Boothroyd, I.K.G., Harding, J.S., Maxted, J.R. and Scarsbrook, M.R. 2001. Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. **1**. Prepared for the Ministry for the Environment.

Townsend, A.J., de Lange, P.J., Norton, D.A., Molloy, J., Miskelly, C. and Duffy, C. 2008. The New Zealand Threat Classification System manual. Wellington, Department of Conservation.

Winterbourn, M.J., Gregson, K.L.D. and Dolphin, C.H. 2006. Guide to the aquatic insects of New Zealand. *Bulletin of the Entomological Society of New Zealand*. **14**.

Appendix One: Site photos

Trimbells Gully

December 2015

February 2016

Trimbells Gully Tributary

December 2015

February 2016

February 2016

Maori Hen Creek

December 2015

February 2016

Coal Creek

Bridge - December 2015

Bridge - February 2016

Bridge - April 2016

Trib. A. looking upstream

Trib. A small pool

Large galaxiid caught from trib. A.

Trib. A. Stock pugging

Trib. bank erosion

Small pond in upper Trib. A.

Trib. B. looking downstream

Channel within gorge section (reservoir inundation area)

Channel within gorge section (reservoir inundation area)

Channel within gorge section (reservoir inundation area)

Lower end of Trib. C (reservoir inundation area)

Lower end of Trib. D (reservoir inundation area)

Mare Burn (MB01)

December 2015

February 2016

Appendix Two: Benthic macroinvertebrate data

Field collection

Benthic macroinvertebrates were sampled at TG01 using a quantitative Surber sampler. At all other sites, samples were collected using a qualitative kick-net sampler with a 500 µm diameter mesh, following Ministry for the Environment's 'Protocols for sampling macroinvertebrates in wadeable streams' (Stark *et al.* 2001). Samples were collected by disturbing the substrate in a representative area immediately upstream of the net. Two samples were collected from each sampling site on each occasion. Samples were preserved in 70% ethanol and returned to the Ryder Consulting laboratory for processing.

Laboratory analysis

For kick-net samples, macroinvertebrate samples were processed for species identification and relative abundance using the semi-quantitative protocols outlined in Stark *et al.* (2001). Protocol 'P1: Coded abundance' was used, which is summarised briefly below.

Samples were passed through a 500 µm sieve to remove fine material. Contents of the sieve were then placed in a white tray for observation. Each taxon present in a sample was assigned to one of five coded abundance categories using the codes established by Stark (1998) (Table A1). Up to 20 individuals representative of each taxon were removed from each sample to confirm their identification under a dissecting microscope (10-40x). Identifications were carried out using keyed guidelines from Winterbourn *et al.* (2006).

Table A1 *Coded abundance scores used to summarise semi-quantitiative macroinvertebrate data (after Stark 1998).*

Abundance (in sample)	Coded Abundance	Weighting factor
1 - 4	Rare (R)	1
5 - 19	Common (C)	5
20 - 99	Abundant (A)	20
100 - 499	Very abundant (VA)	100
> 500	Very very abundant (VVA)	500

For sites apart from TG01, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: A measurement of the number of distinct taxa present which provides an indication of community diversity.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, and percentage of EPT taxa (% EPT taxa): These insect groups are generally dominated by pollution sensitive taxa. In stony bed rivers, these indexes usually increase with improved water quality and increased habitat diversity.

Macroinvertebrate Community Index (MCI) (Stark 1993): The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxon scores are between 1 and 10, 1 representing species highly tolerant to organic pollution (e.g., worms and some dipteran species) and 10 representing species highly sensitive to organic pollution (e.g., most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national standards (Table 2). For example, a low site score (e.g., 40) represents 'probable severe pollution' and a high score (e.g., 140) represents very 'clean' conditions.

$$MCI = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

Semi-quantitative MCI (SQMCI) (Stark 1998): The SQMCI uses the same approach as the MCI but weights each taxa score based on how abundant the taxa is within the community. Abundance of all taxa is recorded using a five-point scale (i.e., rare = 1-4 animals per sample, common = 5-19, abundant = 20-99, very abundant = 100-499, very very abundant = >500). As for MCI, SQMCI scores can be interpreted in the context of national standards (Table A2).

$$SQMCI = \frac{\text{Sum of (Taxa coded abundance x Taxa score)}}{\text{Sum of coded abundances for sample}}$$

Quantitative Macroinvertebrate Community Index (QMCI) (Stark 1985): This method was used for analysing community health in samples collected with a Surber sampler. Similar to the SMCI, the QMCI assigns taxa scores based on their sensitivity to organic pollution. However, unlike the SMCI, the QMCI takes into account the abundance of each taxa collected in a sample and weights each sample score accordingly. Sample scores range between 0 and 10. A score of 1 represents 'poor' conditions and 10 represents 'excellent' conditions (Table A2).

$$QMCI = \sum_{i=1}^{i=S} \frac{(n_i \times a_i)}{N}$$

Where S = the total number of taxa in the sample, n_i is the number of invertebrates in the ith taxa, a_i is the score for the ith taxa, and N is the total number of invertebrates for the entire sample.

Table A2 *Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).*

Quality Class A	Quality Class B	MCI	SQMCI	QMCI
Clean water	Excellent	> 120	> 6.00	> 6.00
Doubtful quality	Good	110 - 119	5.00 – 5.99	5.00 – 5.99
Probable moderate pollution	Fair	80 - 99	4.00 – 4.99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00	< 4.00

Data

TG01 – Winter 2014

Winter 2014 TAXON	MCI score	TG01 1	2	3	4	5
COLEOPTERA						
Ptilodactylidae	8	1				
CRUSTACEA						
Ostracoda	3	2		1		7
Paracalliope fluviatilis	5		1	4	5	
DIPTERA						
Aphrophila species	5	15	4	13	23	3
Austrosimulium species	3	7		6		
Chironomidae	2	18	29	27	40	29
EPHEMEROPTERA						
Deleatidium species	8	96	114	58	37	115
MEGALOPTERA						
Archichauliodes diversus	7				1	
MOLLUSCA						
Potamopyrgus antipodarum	4	95	5	175	177	31
OLIGOCHAETA	1	24	19	44	39	12
PLATYHELMINTHES	3	4			2	
PLECOPTERA						
Stenoperla species	10	1				
Zelandobius species	5	16	6	6	2	2
TRICHOPTERA						
Aoteapsyche species	4	9	3		2	
Hydrobiosidae early instar	5				1	
Hydrobiosis umbripennis group	5		1	1	1	1
Oxyethira albiceps	2	1	1			
Psilochorema species	8		1	2	1	3
Number of invertebrates		289	184	337	331	203
Number of taxa		13	11	11	13	9
QMCI score		5.0	5.9	4.2	4.0	5.9

TG01 – Spring 2014

Spring 2014		**TG01**				
TAXON	**MCI score**	1	2	3	4	5
COLEOPTERA						
Hydraenidae	8					1
Scirtidae	8	1			2	
CRUSTACEA						
Ostracoda	3	1	2	18		3
Paracalliope fluviatilis	5	14	3	6	57	6
DIPTERA						
Aphrophila species	5	3	1	2	4	
Austrosimulium species	3	5	5		25	14
Chironomidae	2	113	21	18	138	27
EPHEMEROPTERA						
Deleatidium species	8	125	54	40	60	129
MEGALOPTERA						
Archichauliodes diversus	7	1	1		1	2
MOLLUSCA						
Potamopyrgus antipodarum	4	268	27	110	149	25
ODONATA						
Xanthocnemis zealandica	5		1			
OLIGOCHAETA	1	139	2	4	218	17
PLECOPTERA						
Stenoperla species	10		1			
Zelandobius species	5	29	22	17	40	3
TRICHOPTERA						
Hydrobiosis umbripennis group	5				3	3
Oxyethira albiceps	2	126	180	27	202	53
Polyplectropus species	8			1		
Psilochorema species	8		1	2	3	
Number of invertebrates		825	321	245	902	283
Number of taxa		12	14	11	13	12
QMCI score		3.6	3.5	4.3	2.9	5.1

TG01 – Autumn 2015

Autumn 2015		TG01				
TAXON	**MCI score**	1	2	3	4	5
COLEOPTERA						
Scirtidae	8			1		
CRUSTACEA						
Ostracoda	3	1	17	349	4	5
DIPTERA						
Aphrophila species	5	2	1			13
Austrosimulium species	3		4	1	8	3
Chironomidae	2	3	5	6		11
Molophilus	5					1
Muscidae	3			1		1
MOLLUSCA						
Potamopyrgus antipodarum	4		1	2		4
ODONATA						
Xanthocnemis zealandica	5		1		1	
OLIGOCHAETA	1	6	9	12	5	18
PLECOPTERA						
Zelandobius species	5	1	2	1	10	3
TRICHOPTERA						
Hydrobiosis umbripennis group	5	1	2	1	2	
Oxyethira albiceps	2	5	20	9	14	3
Number of invertebrates		19	62	383	44	62
Number of taxa		7	10	10	7	10
QMCI score		2.4	2.5	2.9	3.0	2.8

Mare Burn catchment tributaries – December 2015

21-Dec-15		Trimbells Gully tributary			Maori Hen Creek	Trimbells Gully	
TAXON	**MCI score**	**2**	**3**	**Ford**	**at ford**	**1**	**2**
ACARINA	5	R					
ARACHNIDA							
Dolomedes species	5	R					R
COLEOPTERA							
Hydrophilidae	5		R	R			
Rhantus pulverosus	5						R
Scirtidae	8	R		C	R		R
COLLEMBOLA	6				R		
CRUSTACEA							
Ostracoda	3	C	A	A	VVA	A	A
DIPTERA							
Austrosimulium species	3	C	R	R	C		C
Ceratopogonidae	3			R			R
Chironomus species	1			R	A	A	A
Corynoneura scutellata	2			R	C	C	C
Ephydridae	4	R	R				
Hexatomini	5	R					
Limonia species	6	R		C			
Maoridiamesa species	3	A	C	C			
Mischoderus species	4				R		
Muscidae	3	C		C	A		R
Orthocladiinae	2	C	R	A	VA	A	VA
Paralimnophila skusei	6						R
Polypedilum species	3		R				
Sciomyzidae	3	R					
Stratiomyidae	5	R					
Tanypodinae	5	R		R			
Tanytarsini	3		R		VA	C	
EPHEMEROPTERA							
Deleatidium species	8	VA	C	A	R		R
HEMIPTERA							
Sigara species	5					A	
MECOPTERA							
Nannochorista philpotti	7	C		R			
MEGALOPTERA							
Archichauliodes diversus	7			R			
MOLLUSCA							
Potamopyrgus antipodarum	4	VVA	A	VVA	VA	R	A
Sphaeriidae	3				A		
ODONATA							
Austrolestes colensonis	6		R				C
OLIGOCHAETA	1	A	A	VA	A	C	R
PLECOPTERA							
Austroperla cyrene	9	R					
Zelandobius species	5	A	C	A	A	C	A
TRICHOPTERA							
Aoteapsyche species	4			R			
Hudsonema alienum	6		R				
Hydrobiosidae early instar	5	R					
Hydrobiosis umbripennis group	5		R	C	R		
Oeconesus species	9		R	R			
Oxyethira albiceps	2	A	VA	A	A		C
Number of taxa		22	17	22	17	9	17
Number of EPT taxa		5	6	6	4	1	3
% EPT taxa		23	35	27	24	11	18
MCI score		92	85	87	74	58	79
SQMCI score		4.4	2.6	3.6	2.9	2.8	2.7

Mare Burn catchment tributaries – February 2016

		Maori Hen	Maori Hen	TGT	TGT	TGT	MB01
TAXON	MCI score	Upper	Lower	Crayfish Pool'	Ford	WS site	
ACARINA	5		R				
CNIDARIA							
Hydra species	3						A
COLEOPTERA							
Ptilodactylidae	8				R		
Rhantus pulverosus	5			R			
Scirtidae	8	R	A	C	C	C	R
COLLEMBOLA	6		C	R	R	R	R
CRUSTACEA							
Ostracoda	3	C	A	A	A	A	A
Paracalliope fluviatilis	5	C					
DIPTERA							
Aphrophila species	5	R					R
Austrosimulium species	3		R	R	R		
Chironomus species	1						C
Corynoneura scutellata	2		R		R	C	R
Ephydridae	4				R		
Muscidae	3	R			R		
Orthocladiinae	2	A	C	R	C	C	A
Paradixa species	4	R	R				
Paralimnophila skusei	6	R				R	
Polypedilum species	3	R				R	
Sciomyzidae	3			R			
Stratiomyidae	5		C	R			
Tanypodinae	5		R				A
Tanytarsini	3		A		R	C	VA
Zelandotipula species	6		R			R	
EPHEMEROPTERA							
Deleatidium species	8	A	R	C	A	C	C
HEMIPTERA							
Sigara species	5	R	R	R			R
MECOPTERA							
Nannochorista philpotti	7	R					
MEGALOPTERA							
Archichauliodes diversus	7						R
MOLLUSCA							
Gyraulus species	3						R
Potamopyrgus antipodarum	4	VVA	VVA	VA	VA	VA	VA
Sphaeriidae	3	C	C				R
ODONATA							
Xanthocnemis zealandica	5			R		R	C
OLIGOCHAETA	1	A	A	C	C	A	VVA
PLECOPTERA							
Zelandobius species	5	C	C	R	C	A	A
TRICHOPTERA							
Aoteapsyche species	4	R			R		
Hudsonema alienum	6	R				R	
Hudsonema amabile	6	R	R		R		R
Hydrobiosidae early instar	5	C			R		R
Oeconesidae	9	R					
Olinga species	9			R			
Oxyethira albiceps	2	A	C	C	A		C
Paroxyethira species	2						R
Plectrocnemia maclachlani	8						R
Polyplectropus species	8	C	R	R			C
Psilochorema species	8	C	C		R		R
Number of taxa		24	22	17	19	15	26
Number of EPT taxa		10	6	5	7	3	9
% EPT taxa		42	27	29	37	20	35
MCI score		100	93	96	89	91	91
SQMCI score		4.0	4.0	4.0	4.1	3.8	2.1

Coal Creek catchment – April 2016.

TAXON	MCI score	Coal Creek	
		Dam Site	S.I.
CNIDARIA			
Hydra species	3	R	R
COLEOPTERA			
Hydrophilidae	5	R	
Scirtidae	8	R	R
CRUSTACEA			
Ostracoda	3	VA	VVA
Paranephrops zealandicus	5	R	
DIPTERA			
Austrosimulium species	3		A
Corynoneura scutellata	2	C	
Orthocladiinae	2		C
Paradixa species	4		R
Paralimnophila skusei	6		C
Zelandotipula species	6		R
HEMIPTERA			
Sigara species	5		R
MOLLUSCA			
Potamopyrgus antipodarum	4	C	VVA
Sphaeriidae	3		VA
ODONATA			
Austrolestes colensonis	6	C	
Xanthocnemis zealandica	5	R	R
OLIGOCHAETA	1	VA	R
PLECOPTERA			
Zelandobius species	5	R	R
TRICHOPTERA			
Hudsonema amabile	6		R
Oxyethira albiceps	2	R	A
Polyplectropus species	8	C	
Number of taxa		13	16
Number of EPT taxa		3	3
% EPT taxa		23	19
MCI score		88	83
SQMCI score		2.3	3.4