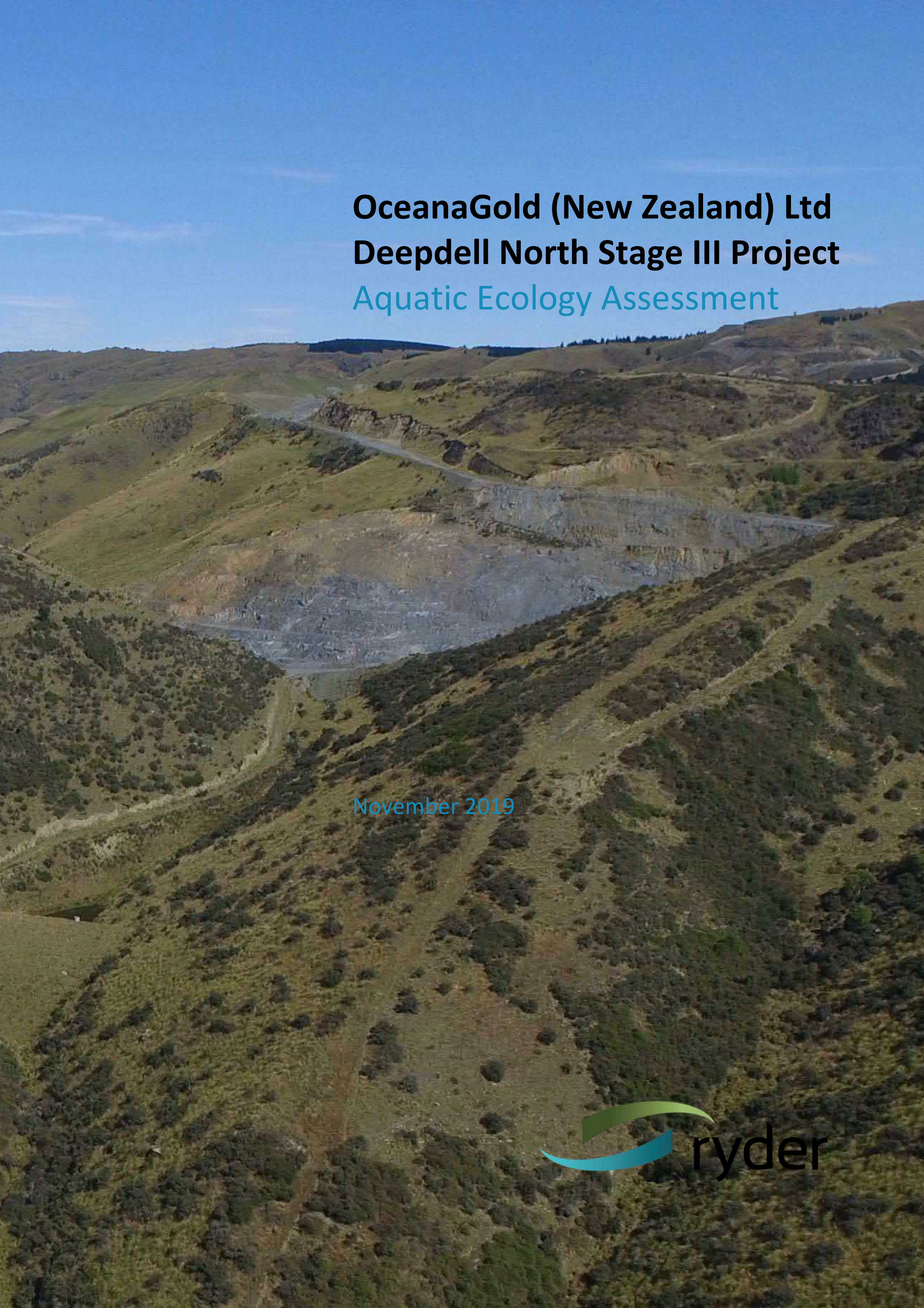

OceanaGold (New Zealand) Ltd
Deepdell North Stage III Project

Aquatic Ecology Assessment

November 2019

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Deepdell North Stage III 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's operation extends into catchments that drain to the Shag, Taieri and Waikouaiti rivers.

OceanaGold are seeking to re-mine the Deepdell North Pit and have named this proposal the Deepdell North Stage III Project (or the Project). The key elements of the proposal are:

- A new pit (Deepdell North Stage III Pit) covering an area of approximately 38 ha, that includes excavation of 18.7 ha of existing rehabilitated waste rock stack. This pit could potentially be expanded if exploration is successful.
- A new waste rock stack (Deepdell East Waste Rock Stack), that would back-fill the existing Deepdell South Pit, extending north from the Deepdell South Pit to beyond Horse Flat Road, covering a total area of 70.8 ha.
- A short haul road will be required between the Deepdell North Pit and the Deepdell East Waste Rock Stack.
- Associated diversion drains, silt and sediment control structures.

The Project footprint of the new pit and waste rock stack are shown in Figure 1, but greater detail of the Project are presented in The Deepdell North Stage III Resource Consent application. Aerials photos of the affected catchments are presented in figures 2 and 3. Potential diversion routes for clean and mine drainage water to surrounding catchments are identified in Figure 4.

1.2 Report content

OceanaGold engaged Ryder Environmental to provide an assessment of the existing aquatic ecology of the area potentially affected by the Deepdell North Stage III Project and to determine the nature and magnitude of any aquatic ecological and water quality effects with the proposal. The assessment includes the following components:

- an overview of the existing aquatic ecology of the Highlay Creek catchment, Camp Creek catchment and Deepdell Creek catchment adjacent to Deepdell South Backfill and downstream of Highlay Creek;
- an assessment of the values of aquatic habitat within these catchments;
- an assessment of the potential effects of the Deepdell North Project on aquatic ecology and water quality;
- suggested mitigation and monitoring.

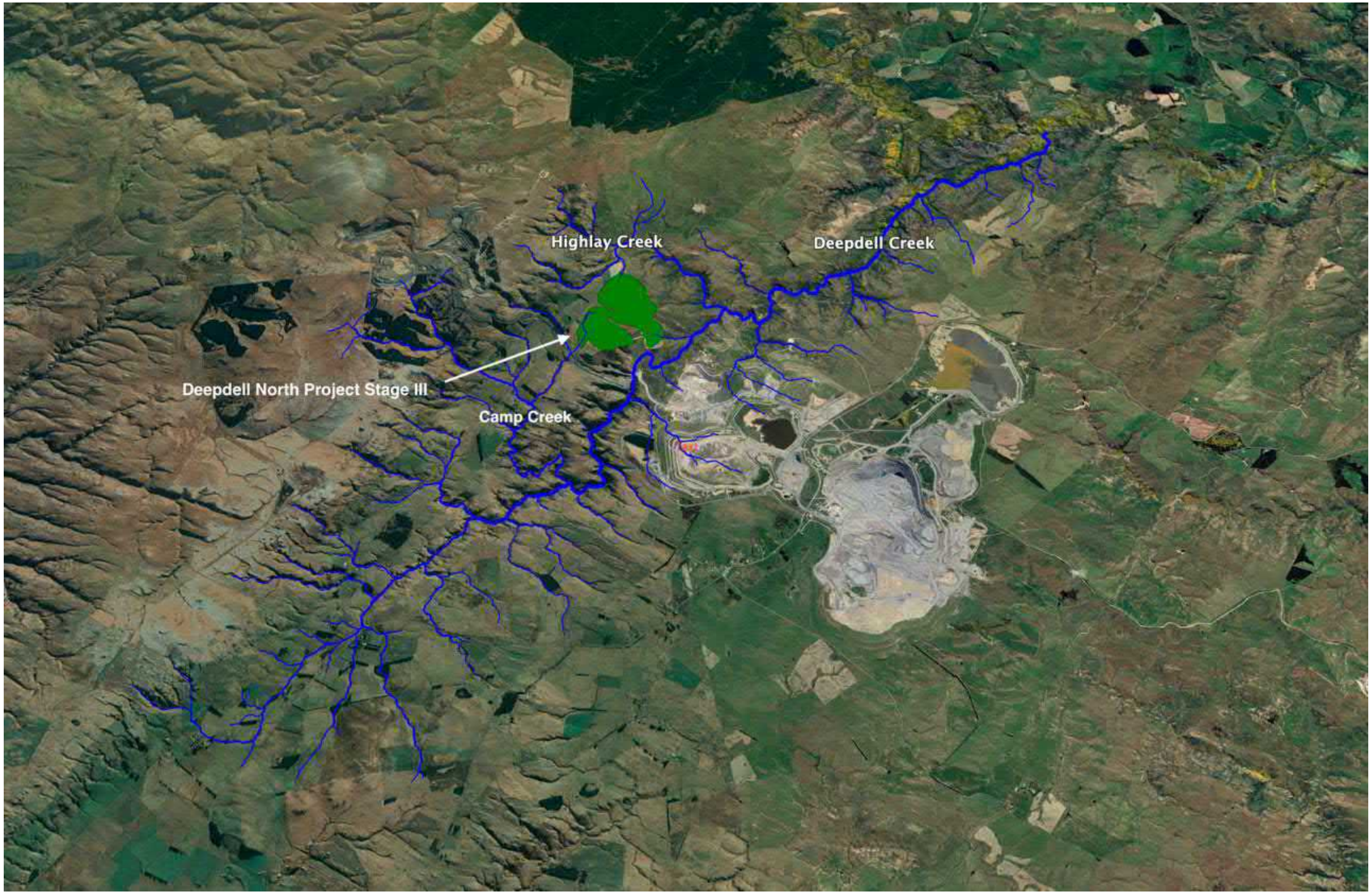

Figure 1 Map showing location of the proposed Deedell North Project area in relation to surface waters of the Deepdell Creek catchment.

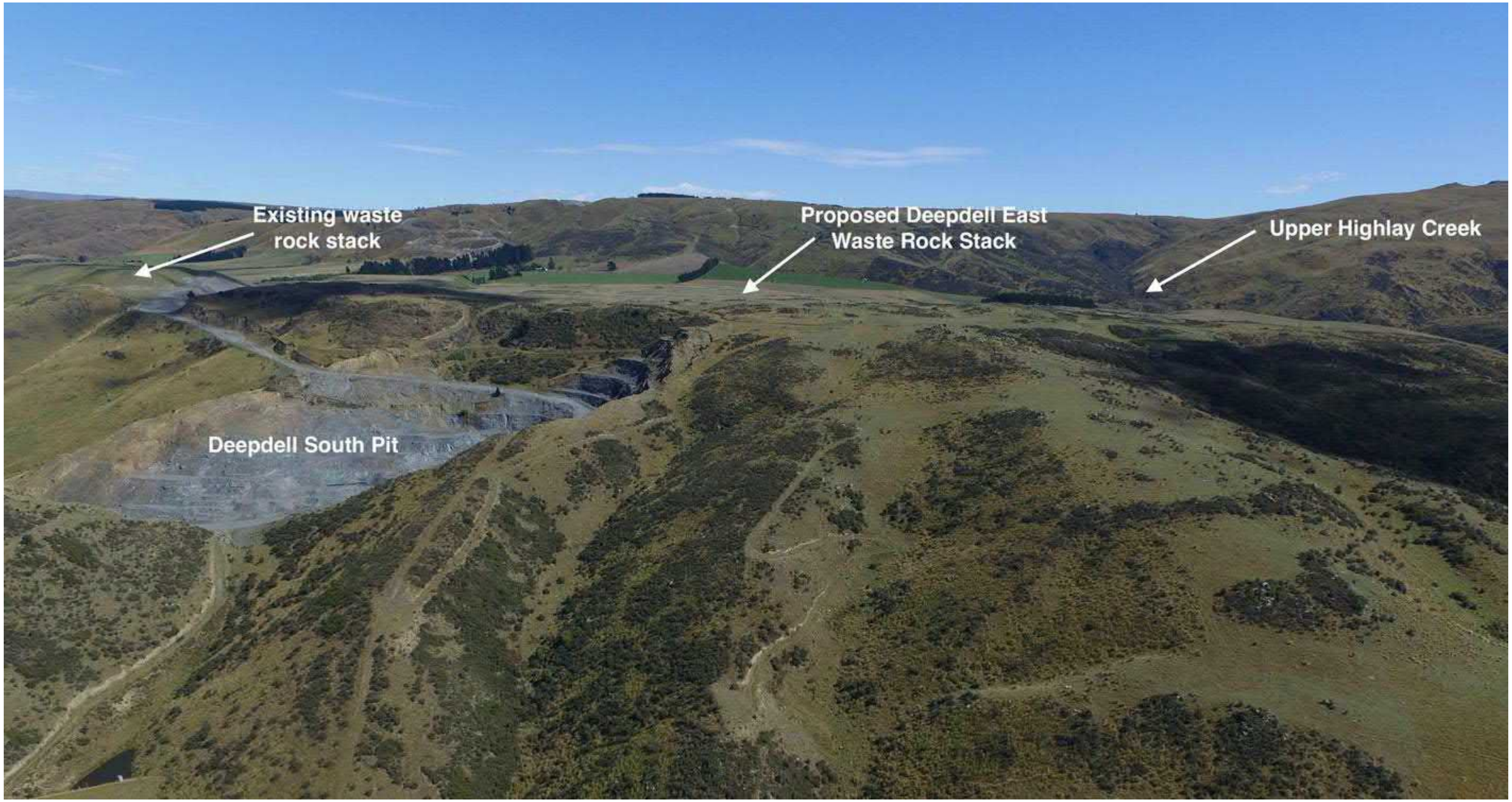

Figure 2 Aerial photo looking across land affected by the Deepdell North III Project (photo: 12 February 2018).

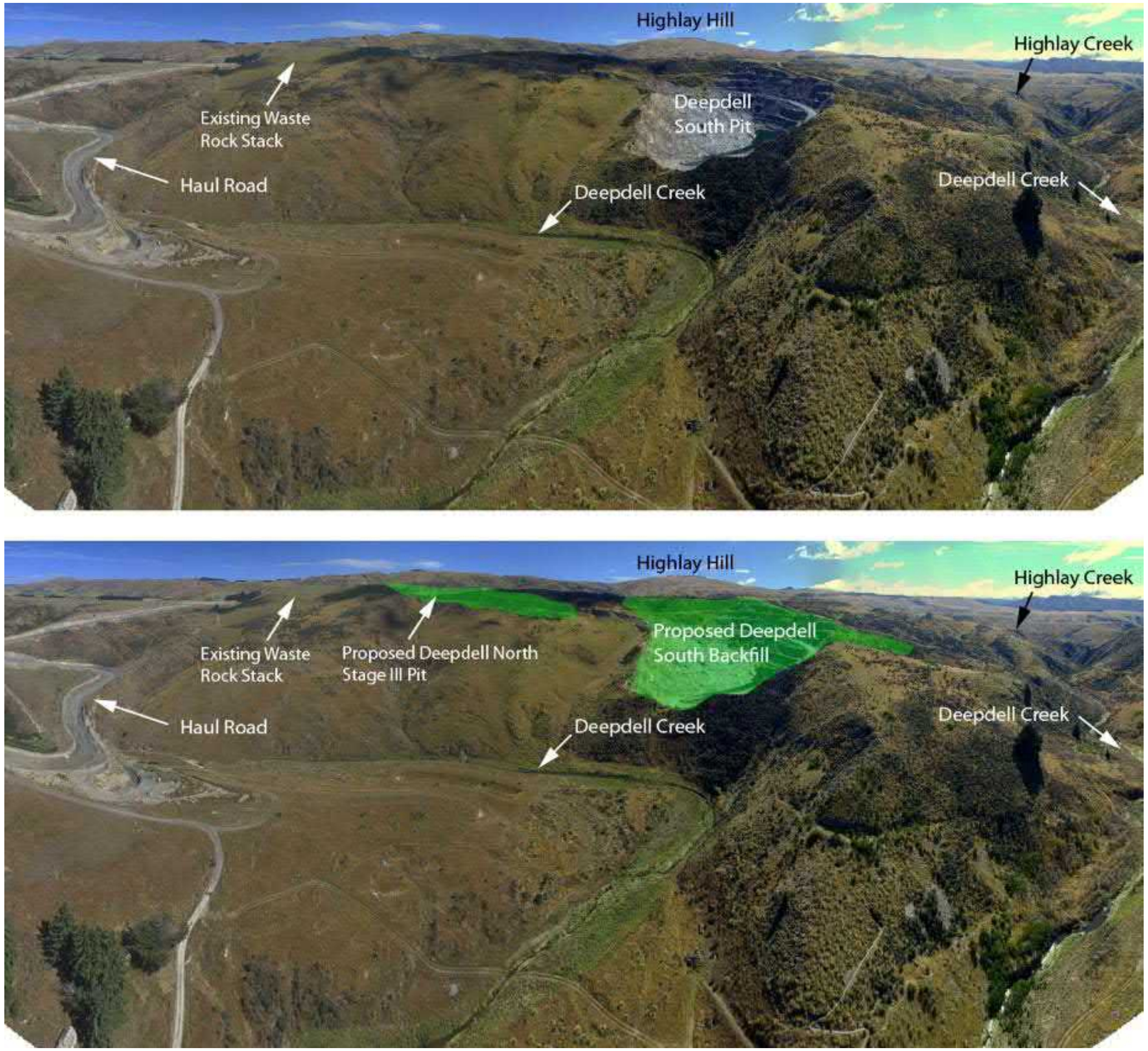

Figure 3 Aerial photo looking west/north-west showing land that drains directly to Deepdeall Creek affected by the proposed Deedell North Project. Highlay Creek catchment can be seen in the distance (photo: 12 February 2018).

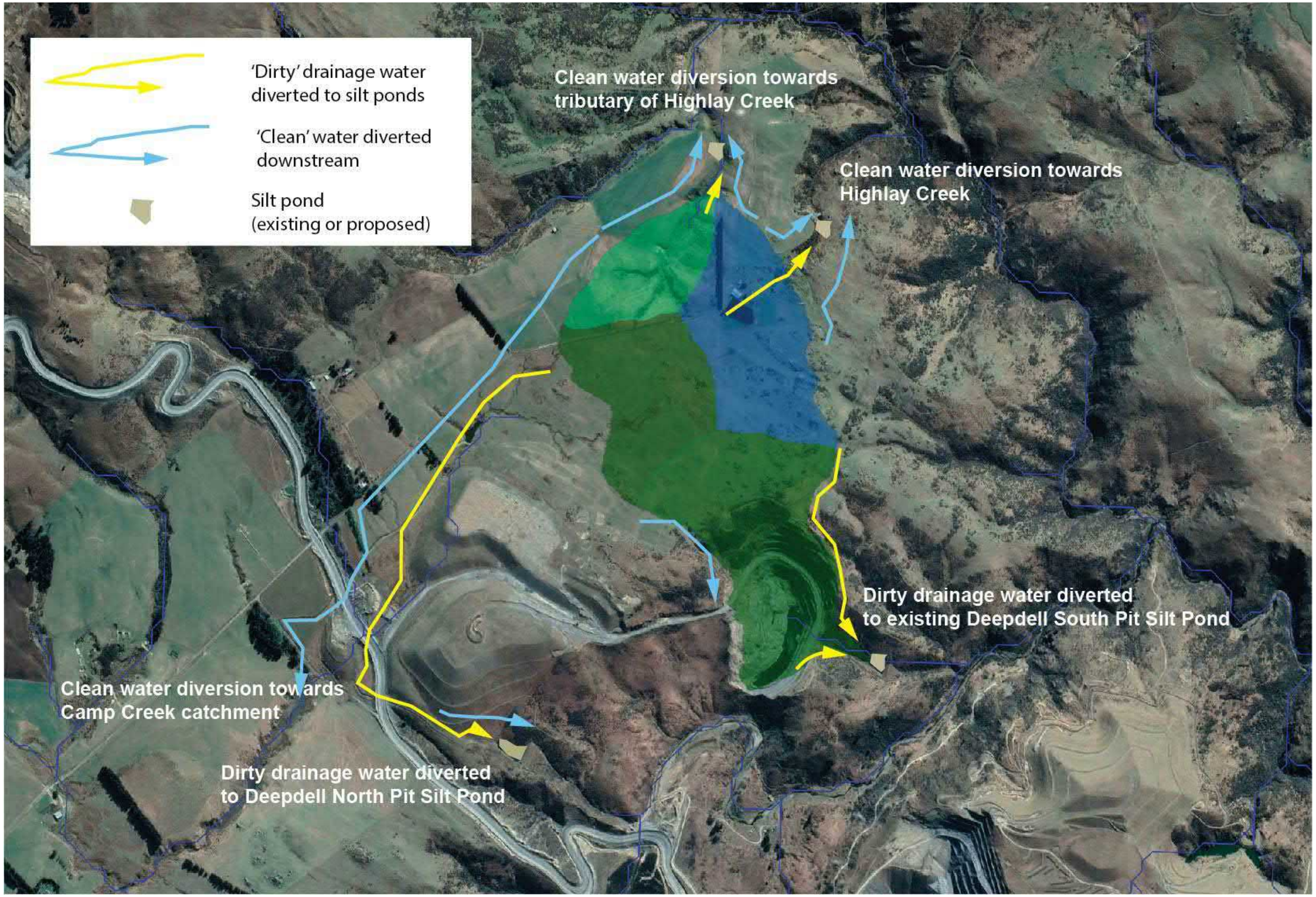

Figure 4 Aerial photo showing existing drainage patterns and proposed diversions of 'clean' water and 'dirty' drainage water on land within and adjacent to the proposed Deepdell North Project.

2. Assessment methodology

Previous freshwater surveys of Camp Creek, Highlay Creek and Deepdell Creek catchments (Ludgate *et al*. 2011, Ryder Consulting 2013, Ryder Consulting 2018) were reviewed to obtain existing information on aquatic communities within the vicinity of the Deepdell North Project Area. Information contained within these surveys was supplemented with surveys and visual inspections of selected sites within the relevant watercourses in February 2018 and September 2019 (Figure 3). For these inspections, instream habitat was noted and described including observations of instream habitat (wetted width and depth, substrate composition, fine sediment cover, periphyton and macrophyte cover) and riparian cover. In addition to the above surveys, sites on Deepdell Creek and Camp Creek have been monitored in 2019 as a part of monitoring requirements associated with Macraes Gold Project existing resource consents. Only some of the data from this most recent monitoring was available for assessment.

Quantitative benthic macroinvertebrate Surber samples were collected from long-term Deepdell Creek monitoring sites throughout 2018 and 2019. These were supplemented with samples collected in February 2018 using the kick-net method. Macroinvertebrate community health was assessed by assessing a range of health indices, as used for previous surveys, and as described in Appendix One.

Over many years now, creeks of the Macraes Flat area have been surveyed for fish largely using electric fishing techniques and visual observations. This latter method was adopted in the February 2018 survey, along with use of a scoop net, as viewing conditions were ideal and many sites contained insufficient channel width and depth of water for effective electric fishing due to low summer flow conditions. Crayfish distribution was also assessed using the above methods. In September 2019, baited minnow traps were deployed over-night at several sites surrounding the Project area.

Fisheries records from the New Zealand Freshwater Fish Database (NZFFD) for the wider Macraes area, and records for the distribution of key non-migratory galaxiids species in Otago, were assessed (5 October 2019) and plotted onto a GIS map of the area. By far the most comprehensive fish survey data for the Macraes Flat area is that associated with surveys undertaken on behalf of OceanaGold. However, fish records from the New Zealand Freshwater Fish Database (NZFFD) are available for other surveys undertaken in the general Macraes area by the Department of Conservation (DOC), Fish and Game Otago, NIWA and the University of Otago.

OceanaGold monitor water quality in Deepdell Creek upstream and downstream of the Highlay Creek confluence and in Highlay Creek at the Horse Flat Road ford (see Figure 5). Water quality data from downstream site DC07 was examined along with monitoring data from two silt ponds: Deepdell North Silt Pond and Deepdell South Silt Pond, which both drain to Deepdell Creek. All water quality and freshwater ecology sampling sites are shown in Figure 5.

When describing surface water features in this report, the Auckland Unitary Plan definitions for surface waters have been adopted for convenience. The relevant definitions are:

Ephemeral stream

Stream reaches with a bed above the water table at all times, with water only flowing during and shortly after rain events. This category is defined as those stream reaches that do not meet the definition of permanent or intermittent.

Intermittent stream

Stream reaches that cease to flow for some periods of the year because the bed can be above the water table at some times.

This category is defined by those stream reaches that do not meet the definition of permanent and meet at least three of the following criteria;

- It has natural pools
- It has a well-defined channel, such that the bed and banks can be distinguished
- It contains surface water more than 48 hours after a rain event which results in stream flow
- Rooted terrestrial vegetation is not established across the entire cross- sectional width of the channel
- Organic debris resulting from flood can be seen on the floodplain
- There is evidence of substrate sorting process, including scour and deposition.

River (or stream or creek)

Means a continually or intermittently flowing body of fresh water; and includes a stream and modified watercourse; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal).

Note that the definition of river is that found in the Resource Management Act and is also contained in the Regional Plan: Water for Otago glossary.

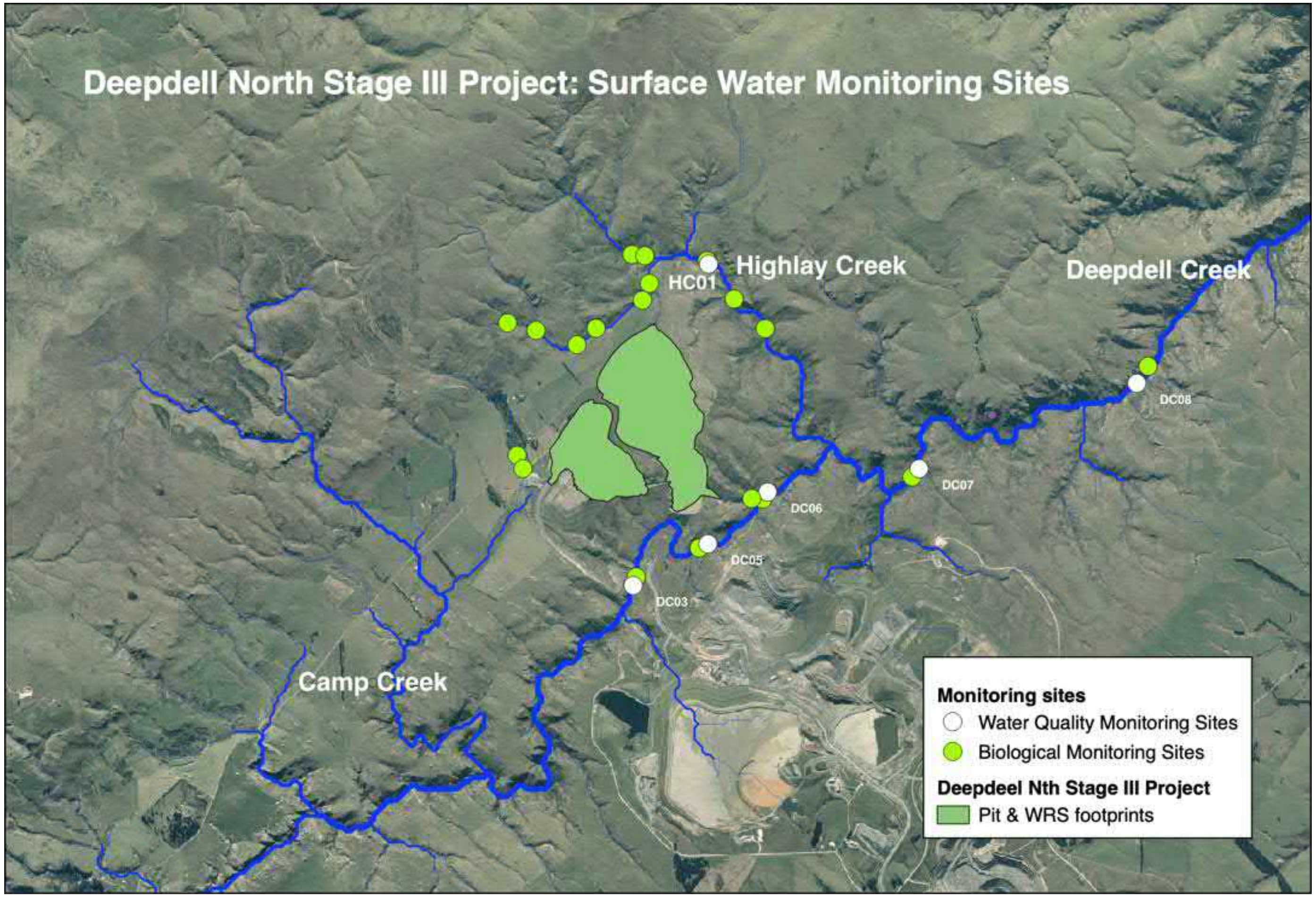

Figure 5 Aerial map showing surface water monitoring sites and biological survey sites in relation to the proposed Deepdell North Stage III Project.

3. Catchment physical & biological descriptions

3.1 General

Part of the proposed Deepdell East Waste Rock Stack is situated in the Highlay Creek catchment (figures 1 and 4). Runoff and seepage from the WRS area will flow into Highlay Creek and a small tributary of Highlay Creek. Depending on how the WRS is contoured, the southern side could also potentially drain to the headwaters of Camp Creek.

The Deepdell North Stage III Pit and Deepdell South Backfill footprints lie within the Deepdell Creek catchment and surface water from these sites would flow into Deepdell Creek via the existing Deepdell North Silt Pond and the Deepdell South Silt Pond.

Routes for flow of 'clean' water and 'dirty' drainage water from the project areas are shown in Figure 4.

Descriptions of individual sub-catchments are described in Thorsen (2019).

3.2 Highlay Creek catchment

3.2.1 Physical description

Highlay Creek is a third order tributary of Deepdell Creek (Figure 1). Its headwaters are in the vicinity of Highlay Hill, starting at elevations up to approximately 750m above sea level. The catchment drains steep slopes with several small tributaries that join upstream of Horse Flat Road. Below Horse Flat Road the creek flows in a south-easterly direction through a 2km long gorge before entering Deepdell Creek on its true left.

The area of catchment within the Project footprint consists largely of gently sloping land, with shallow ephemeral gully systems, and watercourses that may have once had a natural channel but since been channelled to divert surface flows. The gullies and watercourse drain to small tributaries of Highlay Creek located outside of the Project footprint. The watercourses are likely to be ephemeral in their upper reaches and have intermittent flow in their lower reaches, or at least carry very little surface flow in drier months of the year, given the very small size of their watersheds.

Surrounding land is a mixture of open pasture and matagouri with tussock grasses and native shrubs surrounding the watercourses (see Thorsen 2019). Cattle, deer and sheep graze much of the area.

Surface waters in the general area of the Project were inspected in February 2018 and September 2019. In the Highlay Creek catchment, under summer conditions, surface flow in small tributaries of the upper catchment (upstream of the project footprint) was minimal and barely covered the bed of the gully. Stock trampling was evident at many sites along the gully, often resulting in pugging and surface mud, although remnant native stream-side vegetation was present in most places. Tracks where stock had crossed the creek areas were common. Schist gravels, large rocks and occasional bedrock were common, often covered with moss. Bedrock often created short, steep waterfalls although the movement of water over these was more of a slow trickle than a steady flow. Further downstream, as gullies joined, surface flow increased to an estimated 0.1 – 0.15 L/sec (Figure 6 left).

Figure 6 Left: Highlay Creek tributary upstream of the Project footprint, upper reach over bedrock, with an estimated flow of 0.1 – 0.15 L/sec. Right: True left gully in section with no flow. February 2018.

In its lower reaches, but still upstream of the Project footprint (see Figure 4), this tributary of Highlay Creek remains confined within a small, narrow gully (Figure 7). In this reach, the tributary is bordered by open pasture with open stock access to the creek, and a ford for a farm access track. The creek channel appears to have been historically modified in places, with contoured banks on both creek banks confining the channel (Figure 7, top). The creek in this reach contains large beds of grasses, *Juncus* and the introduced grass *Glyceria fluitans*. Note that *Glyceria fluitans* is on Biosecurity New Zealand's Schedule of Prohibited Plant Species. Wetland habitat is also present characterised by diffuse flow through a poorly defined channel choked with grass-like species. Some riffle habitat is present where the channel is incised, but the majority of the surface flow is through grass beds.

Still further downstream, about 250-300 metres upstream of the confluence with Highlay Creek, the tributary remains in a confined channel that is grazed to the water's edge (Figure 7, bottom).

The gully that would receive runoff and seepage water from the northern part of the WRS is described by Thorsen (2019) as a shallow ephemeral drainage system and seepage habitat. These gullies are contained within farmed land and stock have access to them.

Severe pugging was observed in them during the September 2019 site inspection (Figure 8, top).

Figure 7 Lower reaches of the tributary of Highlay Creek potentially receiving runoff and seepage from the Deepdell East Waste Rock Stack. In the top photo (February 2018), this section of the channel looks to have been engineered in the past. In the bottom photo (September 2019), further downstream, the channel is open with grazing to the edge. The gully with seepage water can be seen in the lower left of the photo.

The tributary joins Highlay Creek approximately 450 metres upstream of Horse Flat Road ford. The Highlay Creek reach upstream of Horse Flat Road is bordered by open areas of pasture grass with isolated patches of *Coprosma* and matagouri that completely shade the creek (Figure 9). Stock presence is evident throughout the area, although stock numbers appeared low when the site was inspected in February 2018 and September 2019. The creek has been modified in places by historic mining activities, with stone walls concentrating river flows through chutes. Instream habitat is dominated by riffles, with few runs and pool sections. Bed substrate is dominated by small boulders and cobbles with gravels and fine sediment deposits in slower flowing areas.

Figure 8 Top: Heavily pugged upper reaches of a gully that drains part of the proposed Deepdell East WRS. Bottom: Lower reaches of the same gully system just upstream of the confluence with the Highlay Creek tributary shown in Figure 7.

The middle reaches of Highlay Creek, in the vicinity of the Horse Flat Road ford, are bordered by *Coprosma* and matagouri away from the banks, with generally open sections of pasture and isolated *Carex* along the creek edges (Figure 9). The creek is generally very open with limited shading. Instream habitat is dominated by riffles, with few runs and pool sections. Bed substrate is dominated by small boulders and cobbles with gravels and fine sediment deposits in slower flowing areas. Some extensive sections of bedrock are present. The creek forms a well-defined, confined channel with a bed of large cobbles and occasional large slabs of bedrock.

Figure 9 Highlay Creek middle reach in the vicinity of the Horse Flat Road ford.

In April 2013, a site was surveyed approximately 750 m downstream of the Horse Flat Road ford (NZTM E 1399031 N 4976644). This section of Highlay Creek is narrow (0.5 – 1.0 m wide) and bordered by matagouri and other native shrubs away from the banks, with sections of pasture and isolated tussocks, *Carex* and rushes along the creek edges (Figure 10). The channel is mainly open although shaded in places by overhanging vegetation. Stock have access to the watercourse. At the survey site the creek is dominated by riffles, with occasional short run and pool sections. The water level appeared to be lower than normal and water depths ranged from 0.10 – 0.15 m in the riffles. The bed substrate is dominated by small boulders and cobbles with gravels and fine sediment deposits in slower flowing areas including within vegetation on the channel edges.

Figure 10 Highlay Creek survey site, April 2013.

In general, the quality of habitat in Highlay Creek is superior to that in its tributary that would be potentially affected by runoff and seepage from the proposed WRS. Aquatic habitat is of similar quality in the middle and upper reaches of Highlay Creek.

3.2.2 Highlay Creek water quality

As noted above, part of the proposed WRS (18.8ha) will drain towards Highlay Creek. There has been no regular water quality monitoring of Highlay Creek until recently. Previous spot readings collected during previous surveys in summer found reasonably low water temperatures (for summer), good dissolved oxygen levels (all readings above 9 mg/L) suitable for sensitive fish species, relatively low conductivity levels indicative of low nutrient enrichment, but increasing with distance down the catchment (Table 1). GHD (2019) report that 17 samples taken from Highlay Creek at site HC01 (Figure 5) had a median sulphate concentration below 10 g/m^3 and a maximum recording of 70 g/m^3. The median Nitrate-N value was 0.09 g/m^3 and the maximum reading was 0.49 g/m^3. Current and projected increases in nitrate and sulphate are discussed further below in Section 5.

Table 1 Water quality in Highlay Creek, February 2011.

Site	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	Conductivity (µS/cm)
Highlay Creek - upper reaches	8.11	13.7	10.42	100.3	53.2
Highlay Creek tributary	7.83	17.0	9.05	93.2	65.8
Highlay Creek - middle reaches	8.54	15.8	9.83	98.8	65.7

3.2.3 Stream biota

Benthic communities

In support of a proposed Highlay Creek Storage dam, aquatic communities within the Highlay Creek area were surveyed in February 2011. The approach taken was to sample representative habitats throughout the area. Refer to Appendix One for descriptions of sampling techniques.

Periphyton communities in the upper reaches of Highlay Creek have been previously found to include diatoms (e.g., *Synedra*, *Encyonema*, *Melosira*, *Cymbella*, and *Gomphoneis*) and cyanobacterial mats (*Oscillatoria / Phormidium*). Small areas of the felt-like mats of *Vaucheria* have also been observed. These algal communities are found in a wide range of conditions, from pristine headwater streams to more enriched lowland locations.

The February 2018 survey of Highlay Creek found a significant algae bloom in the creek in the vicinity of the Horse Flat Road ford (Figure 11). A sample of the algae was identified in the lab to be *Melosira varians*, a filamentous diatom, found throughout New Zealand in slow to medium flowing open lowland streams. It can dominate the periphyton community in moderately enriched situations, although it is reported as both a "clean water species" and "moderately polluted water species" in Cassie (1989).

Not surprisingly, algal abundance appears to be higher in open areas where sunlight can reach the creek bed, providing more suitable conditions for growth. Algal communities present in the creek are commonly found throughout New Zealand in a range of conditions, with the filamentous algae typically found in open, unshaded situations.

*Figure 11 Algae bloom (*Melosira varians*) in Highlay Creek just upstream of the Horse Flat Road ford, February 2018.*

Benthic invertebrate surveys of Highlay Creek catchment in February 2011 found a total of 32 invertebrate taxa. *Deleatidium* mayflies and *Potamopyrgus* snails (Figure 12) were numerically abundant at all sites (Appendix One). 'High quality' taxa were also present, including *Stenoperla* stonefly larvae. Invertebrate community health index scores were calculated using tolerances developed for hard-bottomed habitats for the upper and middle reaches of Highlay Creek, and soft-bottomed habitats for the tributary of Highlay Creek (Appendix One). The average hard-bottomed and soft-bottomed MCI and SQMCI score was indicative of 'fair' water quality, using Stark's narrative categories (Table A1.2).

Figure 12 Potamypyrgus antipodarum *snails on stones surface of Highlay Creek, February 2018.*

A survey of Highlay Creek downstream of the Horse Flat Road ford in April 2013 found and identified 20 invertebrate taxa from six benthic samples (Appendix One). *Deleatidium* mayflies numerically dominated the community. *Neozephlebia* mayflies, the megalopteran *Archichauliodes*, *Potamopyrgus* snails, oligochaete worms, and the caddisflies *Aoteapsyche* and *Polyplectropus* species were also common. MCI scores were indicative of 'good' or 'excellent' habitat quality (using Stark and Maxted's (2007) narrative terminology). The SQMCI and average QMCI scores were both indicative of 'excellent' habitat quality (Appendix One).

Surveys of the Highlay catchment in February 2018 found similar macroinvertebrate communities to that found in the February 2011 surveys (Appendix One). A total of 41 taxa were found from three sites, with beetle taxa being more diverse relative to the lower creek. Community health was good in the upper tributaries (SQMCI scores of 6.9 and 7.0) and indicative of good water quality, although MCI scores suggested doubtful quality (MCI scores of 111 and 108).

Crayfish (*Paranephrops zealandicus*, Figure 13) have been observed throughout the Highlay Creek catchment, having been recorded at all survey sites. *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).

Figure 13 Crayfish and crayfish eggs from Highlay Creek.

Overall, macroinvertebrate communities are relatively healthy throughout Highlay Creek, with communities dominated by sensitive mayflies and *Potamopyrgus* snails. Invertebrate communities were of poorer quality in the tributary that would receive runoff and seepage water from part of the Project's proposed WRS.

3.2.4 Fish communities

NZFFD records for surface waters draining the Macraes Gold Project area are presented in Figure 14.

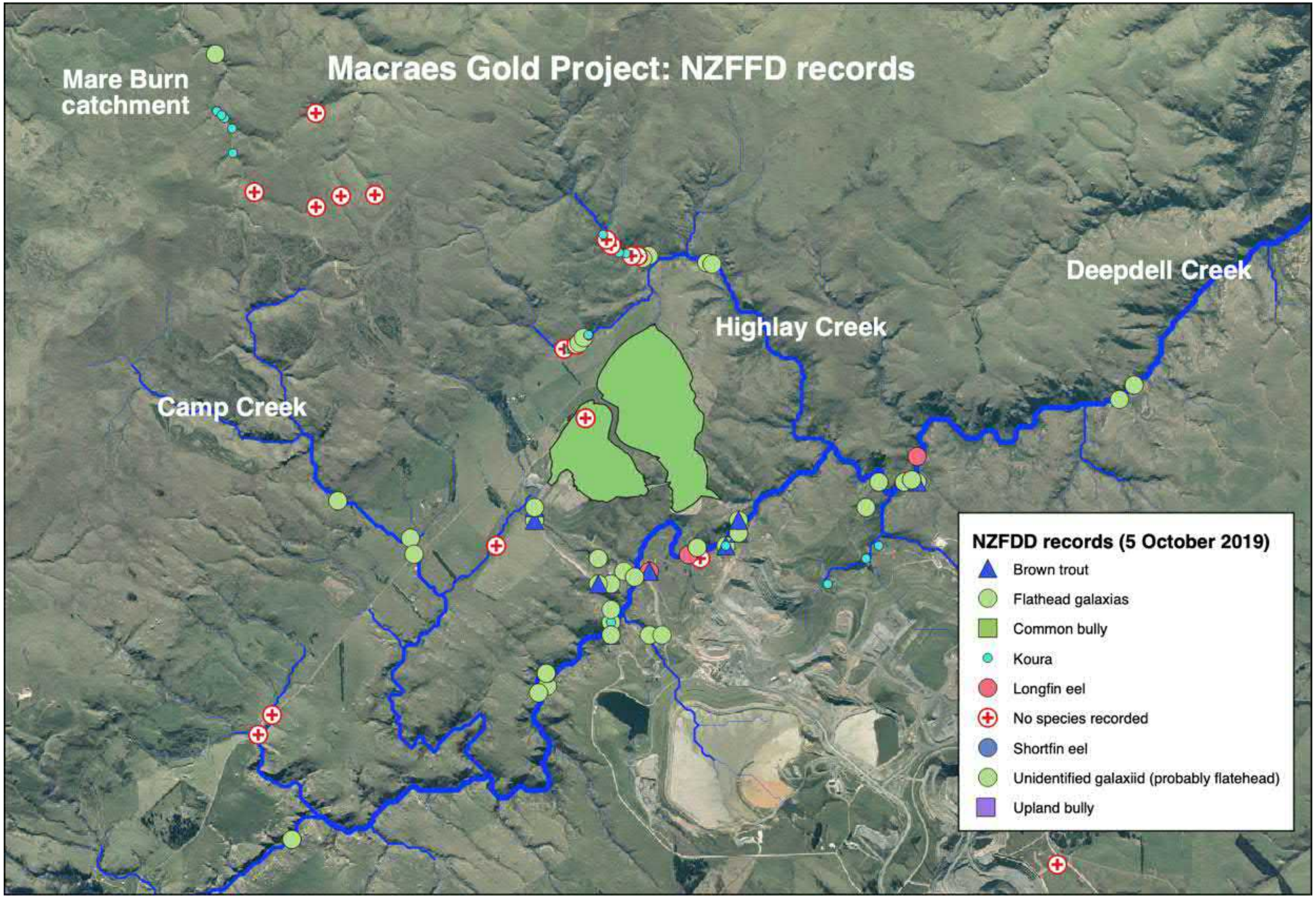

Figure 14 NZ freshwater fisheries database records for receiving waters surrounding the Macraes Gold Project (accessed 5 October 2019).

Up until 2006, there was only one confirmed NZFFD record of a fish survey in Highlay Creek, undertaken as part of a survey throughout the Macraes area by DOC. The survey included a site in Highlay Creek in January 2006 and was undertaken at the Horse Flat Road ford. The survey recorded Flathead galaxias, ranging in length from 22 to 93mm (data sourced from the NZFFD).

The February 2011 survey undertaken on behalf of OceanaGold found flathead galaxias throughout Highlay Creek and in the lower section of the tributary that would receive runoff and seepage from the new waste rock stack (Table 2). Abundance was similar at both sites surveyed in Highlay Creek, indicating an abundant population probably present throughout the creek. Only one galaxiid was caught in the Highlay Creek tributary.

Table 2 Number of fish (length range in mm), Highlay Creek catchment, February 2011.

Site	Flathead galaxias (*Galaxias depressiceps*)
Highlay Creek - upper reaches	19 (36–81mm)
Highlay Creek tributary	1 (45mm)
Highlay Creek - middle reaches	19 (36–81mm)

Flathead galaxias were also captured in lower Highlay Creek in April 2013. Fish were common, with seven individuals caught and several others observed, but not caught. Individuals ranged in length from 60 to 88 mm, indicating an absence of juveniles. A lack of juveniles may have been related to the low flows in the creek at the time, with smaller fish having temporarily moved into less confined habitats elsewhere to avoid larger individuals.

Numerous adults and sub-adult galaxiids were observed and caught in the February 2018 survey at the Horse Flat Road ford. No fish were found in the headwaters of the tributary that would receive runoff and seepage water from the proposed WRS. These headwaters are steep and carried very little water in late summer. Some gullies had no surface flow.

The Department of Conservation surveyed sections of the Highlay Creek catchment in May 2018 (Jack 2018). Ten g-minnow traps were placed in the second order tributary in a section just upstream of the Project's proposed WRS, and another ten traps were placed in the mainstem of Highlay Creek just downstream of the confluence of the second order tributary, but still upstream of the WRS area (Figure 5). The Highlay Creek tributary traps captured two adult flathead galaxias (89 and 92 mm long), along with 14 adult and juvenile koura. The Highlay Creek mainstem traps captured two Taieri flathead galaxias (47 and 75 mm long) and 10 adult koura.

A further 8 baited minnow traps were set in the second order tributary overnight by Ryder Environmental in September 2019, downstream of Jack's (2018) traps (Figure 5). No flathead galaxias or Koura were captured in this early spring survey. Water temperature was very cold.

3.3 Camp Creek

3.3.1 General

Camp Creek is a major tributary of Deepdell Creek. Its catchment is situated upstream of the OceanaGold's mining operations, on the true left (Figure 1). Camp Creek headwaters are set in the vicinity of the Sister Peaks, at an elevation of 737m above sea level. The catchment drains steep slopes and the creek flows in a south-easterly direction to a plateau at approximately 500m elevation near Horse Flat Road. Below Horse Flat Road the creek enters a 3km long gorge before entering Deepdell Creek on its true left.

In 2011, OceanaGold gained consents to construct a storage dam in the Camp Creek catchment. The purpose of the storage dam is to augment flows in lower Deepdell Creek to guarantee adequate dilution of future leachate from the waste rock stacks and tailings impoundment.

3.3.2 Description of surface waters associated with the Project

Several small watercourses associated with the Camp Creek catchment are situated within or adjacent to the proposed Project footprint. The mid reaches of a modified watercourse that runs close to and parallel to the existing haul road (Figure 15) will be surrounded by the Project footprint. Within the proposed Project footprint area, the watercourse below Horse Flat Road has been straightened (Figure 16, top left) and flows into a cut-off drain that has been constructed around the upper perimeter of the existing waste rock stack (Figure 16, top right). It then discharges into a small ponding area on the northern side of the haul road (Figure 17, top). Discharge into the upper Camp Creek catchment is then via a small culvert under the haul road (Figure 17, top).

This small tributary in the Camp Creek catchment was surveyed by Ryder Consulting in the general vicinity of the haul road in October 2010 (Ludgate, Ryder & Dale 2011), as a part of Macraes Gold Project Phase III investigations (and prior to the establishment of the haul road and other mining activities in this area of the catchment). At that time, the tributary was described as having a low gradient, bordered by pasture grasses and with unrestricted stock access (Figure 16, bottom). Very little water was present in the channel with only occasional sections having visible surface water. Some areas are dominated by wet areas of soft sediment with pasture grasses and tussocks. Beds of *Glyceria fluitans* were present throughout the channel.

This watercourse was inspected again in September 2018 . The channel is willow-infested (Figure 16, top left) down as far as the cut-off drain, and significant cover of algae covered with iron-staining bacterial flocs were present in September (Figure 17, bottom). The bed was also clogged with willow branches and willow roots.

This watercourse will not be physically modified by the Project and will continue to drain to the Camp Creek catchment under the Project design.

A man-made pond is located on between Horse Flat Road and the existing waste rock stack. It discharges into a cut-off drain which runs for approximately 460 metres before reaching the confluence of the modified watercourse described above (Figure 16 top right). Approximately 100 metres of its lower section will be lost due to pit infrastructure.

The pond is fed by a small catchment (currently in pasture) that contains several gullies that potentially support ephemeral watercourses (Figure 23). The pond will be surrounded by the Deepdell North Pit to the east and additional pit infrastructure to the west (towards Horse Flat Road). These gullies will be lost to the new pit and some stockpile area. The loss of these ephemeral watercourses is estimated at 450 metres.

The cut-off drain into which the pond flows into will be converted to a drain for the diversion of 'dirty' drainage water to the existing Deepdell North Silt Pond (Figure 4) and will cease flowing towards the Camp Creek catchment. The loss of this highly modified intermittent flowing drain is estimated at approximately 360 metres.

3.3.3 Stream biota

The aquatic ecology of Camp Creek is similar to that found elsewhere in the Macraes area. The quality of benthic macroinvertebrate communities is variable, but generally healthy throughout, with some degradation in community health in the small tributaries that flow through farm land.

3.3.4 Benthic invertebrates

Thirty four invertebrate taxa were identified at the Camp Creek monitoring site CC02 in 2018 (Appendix One). The most taxonomically diverse group was trichopterans (caddisflies), following by dipterans (true flies) and plecopterans (stoneflies). Overall taxonomic diversity and diversity of EPT taxa were similar in summer and winter, however densities were lower in winter, due mainly to a reduction in snail abundance, which typically dominate the invertebrate fauna at site CC02. Invertebrate health index scores (QMCI) in summer 2018 were indicative of 'fair' quality conditions, while in winter the higher average score was indicative of 'good' quality conditions, using the narrative terminology of Stark and Maxted (2007).

The October 2011 survey found macroinvertebrate communities were relatively healthy throughout Camp Creek, however communities in the middle and lower reaches were generally of higher quality than those upstream of Horse Flat Road. Invertebrate communities in the tributaries such as the one adjacent to the haul were expected to be dominated by low quality taxa more typical of those found in soft bottomed habitat (Ludgate, Ryder & Dale 2011).

3.3.5 Fish

Flathead galaxias are present throughout Camp Creek with higher abundance in the lower and middle reaches. Some longfin eel are also present in the lower and middle reaches of Camp Creek, however eels have not been found further upstream.

Old NZFFD records from 1996 and 1987 recorded brown trout, koura and an unidentified galaxiid (most likely flathead galaxias) in the tributary beneath what is now the haul road, but no fish captured a further 300-400 metres downstream (Figure 15). In September 2019, four baited minnow traps were set overnight in deeper water within the tributary below Horse Flat Road (Figure 15). No fish or crayfish were captured.

The October 2010, a survey by Ryder Consulting included the tributary of Camp Creek at Golden Point Road, and was at a similar location as the Fish and Game Otago NZFFD record described above. However, habitat in the creek was described as very poor, with low water clarity and no suitable habitat for fish. Ludgate, Ryder & Dale (2011) concluded that the brown trout, flathead galaxias and crayfish found in the area by Fish and Game are probably no longer present due to local changes in habitat.

Figure 15 Aerial map showing the location of the modified watercourse adjacent to the haul road described in section 5.1.1. The thick light blue line indicates the watercourse flow path from top of the aerial down to the left towards Camp Creek (piped under the culvert. The finer dark blue lines are imported REC shape files. Note that fish and koura records for the tributary running through the middle of the map pre-date (1991-1987) the existing haul road and adjacent waste rock stacks.

Figure 16 Camp Creek tributary within the Project footprint. Top left: willow infested, channelled section immediately below Horse Flat Road (September 2019). Top right: Cut-off drain that receives tributary water and flows towards the haul road culvert (September 2019). Bottom: Same tributary in October 2010 looking downstream from Golden Point Road.

Figure 17 Top: Ponded area between the cut-off drain and haul road. Note the haul road culvert in upper centre of the photo. Bottom: Flocs of iron-staining bacteria over filamentous algae in the Camp Creek tributary downstream of Horse Flat Road.

3.4 Deepdell Creek catchment

The Deepdell North Stage III Project includes backfilling the existing Deepdell South Pit and creating a new pit on a rehabilitated rock stack (Figure 2). These areas border land that drains into Deepdell Creek (figures 1 and 4). The section of Deepdell Creek that would potentially receive runoff and seepage water from this land, and the discharge of Highlay Creek water, has been monitored at several sites (Figure 5) for many years, and thus the creek environment in this area is well understood.

3.4.1 General habitat

Deepdell Creek in the vicinity of the Project is contained within a confined channel that is surrounded by relatively steep-sided land throughout most of its length (figures 3 and 18). Riparian vegetation is dominated by pasture grasses, broom and matagouri, with occasional tussocks and *Carex* sedges along the edges. Shading is common due to the steep topography and overhanging riparian vegetation. Stock and pig disturbance is evident in places.

Figure 18 Aerial view of Deepdell Creek looking downstream (right of photo), with the Deepdell South Pit in the upper left corner.

In summer, the flow in Deepdell Creek can drop significantly, however even under these low flow events, the creek is punctuated with deep, very slow moving sections (Figure 19 left). Small riffle and run sections are also present (Figure 19 right). In riffle and run sections the substrate is dominated by cobbles with gravels and occasional boulders. Softer sediment is present in the slow moving glides and pools. These habitats support significant macrophyte cover, particularly in the warmer months and following periods of stable flow (Figure 20). Algae growth can be significant also.

Figure 19 Examples of pool (left) and riffle (right) habitat in Deepdell Creek in the vicinity of the Deepdell North project area.

Figure 20 Submerged macrophytes including Myriophyllum*, Deepdell Creek, February 2018.*

3.4.2 Water quality

Deepdell Creek typically has a pH above 7 and relatively high conductivity (average of 546 µS/cm). Dissolved inorganic nitrogen levels are elevated (particularly nitrate, average of

0.54 mg/L at DC07) and concentrations in Deepdell Creek at DC08 over the period 2018-2019 peaked at 0.6 mg/L, but generally much lower. Nitrate concentrations in the Shag River at Loop Road were slightly less than 0.5 mg/L over the same period. Although no recent phosphorus monitoring data are available, past monitoring suggests there is sufficient dissolved phosphorus in Deepdell Creek to promote algae and plant growths. Water clarity is generally very good under average and low flow conditions.

3.4.3 Benthic biota

Biological surveys of Deepdell Creek and tributaries were first undertaken in 1987 (Dungey 1988). Following on from these initial surveys, aquatic monitoring has been undertaken on a quarterly basis in Deepdell Creek since 1990 as part of resource consent monitoring for the Macraes Mine (e.g., OFGC 1990, Bioresearches 1991, Ryder 1995, Ludgate and Goldsmith 2004, 2006, 2007, Ludgate 2008, Ryder Consulting 2009a, Ryder Consulting 2010). This monitoring has included surveys of fish (since 1990), benthic macroinvertebrate (since 1991) communities and plant and periphyton cover.

The most recently completed analysis of Deepdell Creek monitoring data (March 2019) found the invertebrate community composition at monitoring sites DC03, DC05 and DC07 to be dominated by snails (particularly *Potamopyrgus antipodarum* but also *Physa*), chironomid larvae and various Trichoptera, with lessor contributions from small crustaceans, mayflies and worms. This assemblage is broadly similar to that observed in recent years. Benthic invertebrate health index scores are typically indicative of 'poor' to 'fair' water quality using the narrative terminology of Stark and Maxted (2007). This ranking reflects the dominance of taxa (e.g., snails) that are relatively insensitive to poor water quality and habitat conditions (although see further below in relation to nitrate toxicity). Koura have been observed at sites DC03, DC05 and DC07.

Flathead galaxiids are by far the dominant fish in Deepdell Creek, and site DC07, located downstream of the Highlay Creek confluence, typically supports a large population (Figure 19). In the most recently completed fish survey of Deepdell Creek (February 2017), 32 galaxiids were caught at DC07, 11 at DC05 and 27 at DC03.

3.4.4 Fish communities

Electric fishing was undertaken at two Deepdell Creek monitoring sites in late summer 2018 and at all sites in winter 2018. The community at each site was dominated by galaxiids in the 40-50 mm size class. At DC07 in summer, 61 galaxiids were caught, ranging in size from 38 to 90 mm long (Figure 21). Freshwater crayfish were also caught during electric fishing at DC07.

The highest populations of galaxiids in winter 2018 were found at DC01 and DC02, followed by DC03 and DC05 (Figure 21, Table 3). The population estimate for DC01 was the highest since 2014, and estimates for all sites except DC07 and DC08 were higher than 2017 estimates. Natural annual fluctuations in the galaxiid population are expected, and relate to variations in reproduction, food availability and physical habitat. Error associated with sampling efficiency and model assumptions also affect population estimates. With the sampling being undertaken in winter 2018, rather than the usual summer monitoring period, variation when compared to previous sampling results is also expected.

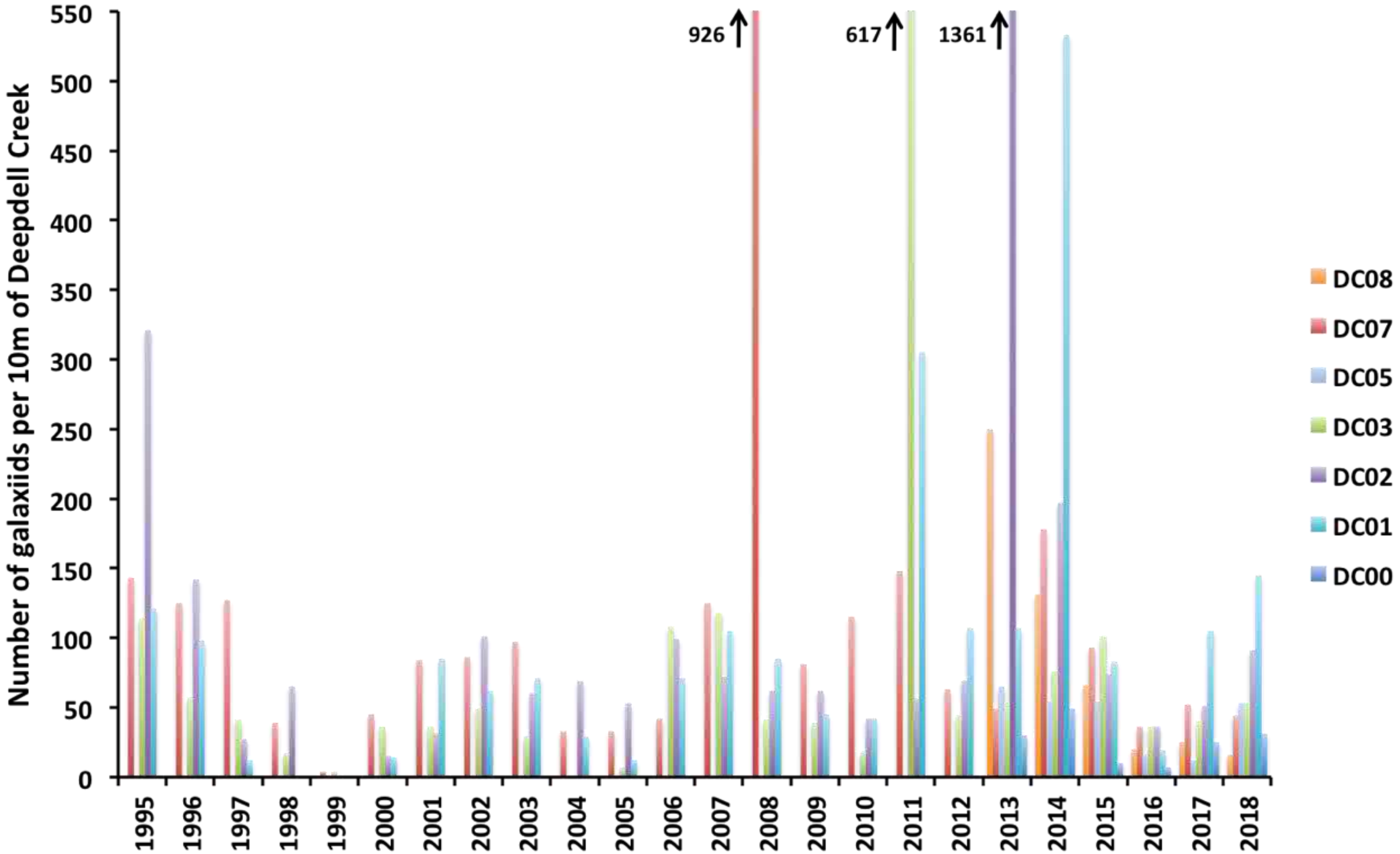

Figure 21 Number of flathead galaxiids (per 10 m reach) found in summer surveys of Deepdell Creek, 1995 to 2018. Summer sampling in each year, except winter 2018.

Table 3 Results of fish surveys and fish population estimates, Deepdell catchment sites, 1998-2018. – = unable to be sampled due to low flows. Note 2018 data is from fishing undertaken in winter 2018.

Year	Downstream of mine operations								Upstream of mine operations					
	DC08		DC07		DC05		DC03		DC02		DC01		DC00	
	Count	Pop'n estimate	Count	Pop'n estimate	Count	Pop'n estimate	Count	Pop'n estimate	Count	Pop'n estimate	Count	Pop'n estimate	Count	Pop'n estimate
1990														
1991			30	-			19	-	62	-	45	-		
1992			43	-			15	-	37	-	68	-		
1993			56	-			15	-	48	-	105	-		
1994			21	-			2	-	38	-	30	-		
1995			155	143			55	114	126	321	72	121		
1996			84	125			43	57	115	142	88	98		
1997			47	127			52	41	37	27	14	12		
1998			42	39			14	17	37	65	7	*		
1999			3	4			3	4	-	-	-	-		
2000			15	45			13	36	5	15	7	14		
2001			40	84			20	36	20	31	24	85		
2002			81	86			25	49	48	101	38	62		
2003			53	97			25	29	62	60	41	71		
2004			27	33			6	*	34	69	13	29		
2005			18	33			4	7	35	53	7	12		
2006			21	42			35	108	43	99	18	71		
2007			38	125			50	118	57	72	35	105		
2008			70	926			26	41	62	62	62	85		
2009			31	81			20	39	28	62	27	45		
2010			58	115			10	18	14	42	16	42		
2011			37	148			46	617	14	56	32	305		
2012			32	63			42	44	43	69	76	107		
2013	29	250	33	49	24	65	22	53	69	1361	70	107	24	30
2014	57	131	105	178	39	54	49	76	131	197	108	533	39	49
2015	29	66	53	93	45	54	70	101	66	74	70	83	7	10
2016	9	20	26	36	16	16	26	36	28	36	14	19	5	7
2017	15	25	32	52	11	12	27	40	33	51	78	105	15	25
2018	14	16	31	44	48	53	22	53	70	91	76	145	24	31

4. Significance of existing aquatic values

4.1 Natural values

According to the Otago Regional Council (ORC) Regional Plan: Water for Otago (2004), Deepdell Creek contains significant natural values including the absence of aquatic pest plants and significant habitat for galaxiids (Table 4). 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 in the Macraes Flat area.

There are no values listed in the regional water plan for Camp Creek or Highlay Creek, however it is expected that the values present in Deepdell Creek would also be relevant for these creeks.

Table 4 Natural values for Deepdell Creek. Schedule 1A, Otago Regional Council Regional Plan: Water for Otago (2004).

Water body	Ecosystem values	Significant indigenous vegetation and significant habitat of indigenous fauna
Deepdell Creek	No aquatic pest plants Presence of indigenous fish species threatened with extinction	Significant habitat for flathead galaxias

4.2 Non-migratory galaxiids

Flathead galaxiids are common and widely distributed in the Highlay Creek catchment and to a lesser extent in Camp Creek. Headwaters of both creeks drain small catchments, are very steep and carry little surface water under normal summer flow conditions. Indeed, some sections of the Highlay Creek catchment were dry in the February 2018 inspection despite recent rain. Further downstream, where channels are more creek-like in appearance and have stony beds, fish are more common, despite significant algae and plant growth smothering the bed in places. However, it has been our experience that fish can be quite common amongst significant periphyton growths in creeks of the Macraes Flat area.

Flathead galaxiids are common in the mainstem of Deepdell Creek and monitoring over many years has indicated that the population is large and resilient to algae blooms, disturbance (e.g., large floods and stock damage) and drought conditions (Table 3).

Flathead galaxiids found 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 2018 (Dunn *et al.* 2018). The Taieri flathead galaxias has been classified by the Department of Conservation as 'Threatened – Nationally Vulnerable', with criteria C (3) (moderate population, with population trend that is declining, total area of occupancy ≤ 100 ha (1 km^2), predicted decline 10–50%) and the qualifiers 'Conservation Dependent' and 'Data Poor' (Dunn *et al.* 2018). 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) (Figure 22).

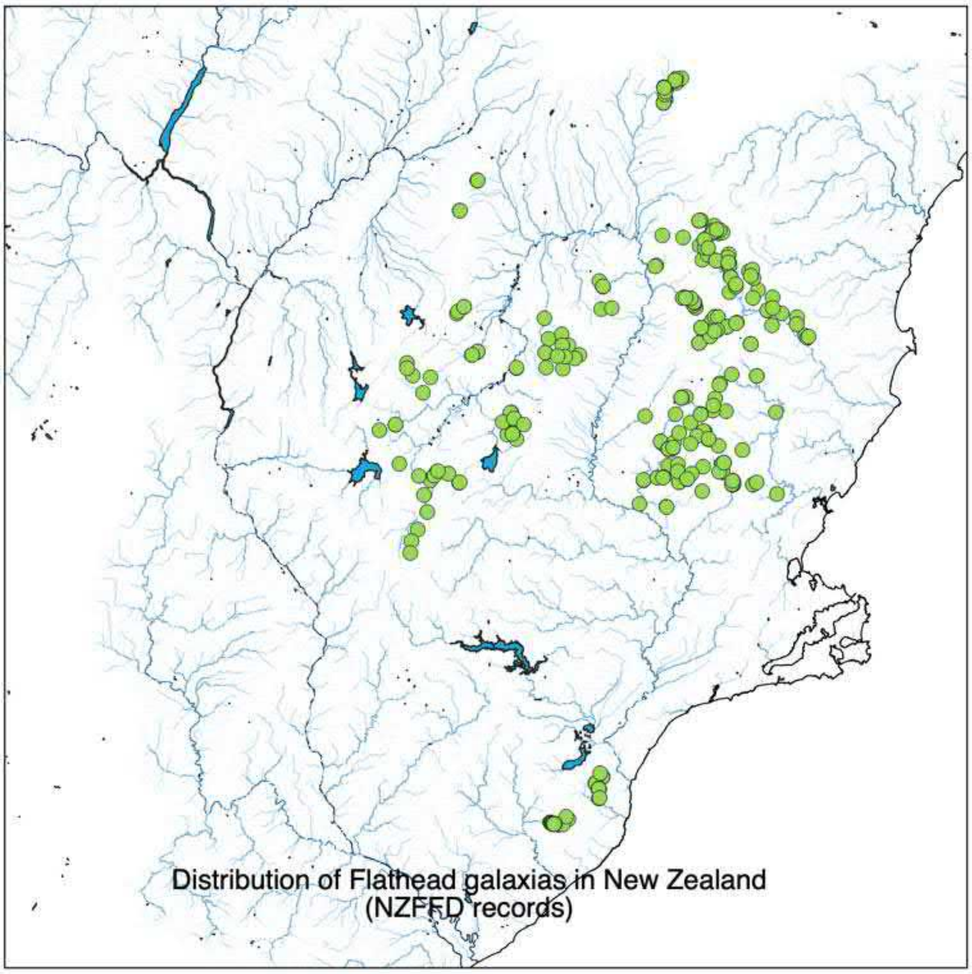

*Figure 22 Map showing the known national distribution of flathead galaxias (*Galaxias depressiceps) using NZFFD records.

4.3 Other fish species

Brown trout and longfin eel have occasionally been caught in Deepdell Creek since regular monitoring commenced in the 1990s, however they are uncommon. This is probably due to limited access from downstream populations (Deepdell Creek often flows underground in a short section near monitoring site DC08) and frequent low flows in summer provide limited habitat availability. Longfin eel are classified by the Department of Conservation as 'At Risk – Declining' (Dunn *et al.* 2018).

4.4 Freshwater crayfish

Freshwater crayfish or koura (*Paranephrops zealandicus*) are widely distributed throughout the Highlay Creek catchment and in the mainstem of Deepdell Creek, and they are generally common in many of the small streams of the Macraes Flat area. They are also likely to widespread in the Camp Creek catchment. Their relatively high abundance in these creeks is surprising given that habitat appears limited by a lack of flow and wetted area at times, particularly during late summer and into autumn. A lack of predators (trout and birds – both restricted by a lack of suitable foraging habitat and, in the case of trout, upstream passage) and good cover amongst the schist slab substrate may in part explain the success of crayfish at Macraes.

4.5 Benthic macroinvertebrates

Approximately sixty benthic invertebrate taxa have been identified from three benthic invertebrate surveys of the Highlay Creek catchment (Ludgate *et al*. 2011, Ryder Consulting 2013, this report). This is a relatively high number by New Zealand standards, but reflects the sampling effort in the catchment. Scarsbrook *et al.* (2000) found 18 was the national median number of taxa per site based on 66 sites located throughout New Zealand. The most recent survey (February 2018) of the Highlay catchment found the number of taxa per site ranged between 17 and 25 (Appendix One).

Benthic invertebrate habitat is variable in the Highlay Creek catchment, ranging from small seepages through to creeks. Habitat is widely affected by algal blooms and stock damage. No taxa we have identified are uncommon, and most are commonly found throughout large areas of the country.

The benthic invertebrate community of Deepdell Creek is similar to that of Highlay Creek, but composition varies between sites and seasons, often influenced by climate, flow history and local physical habitat features. Again, as for Highlay Creek, most taxa in Deepdell Creek are common and found throughout the country.

5. Potential effects on freshwater ecology associated with the Project

5.1 Stream habitat - General

5.1.1 Within the Project footprint

The proposed Deepdell North Stage III Project will result in some loss of shallow ephemeral drainage systems and small seepage habitat in the Highlay Creek catchment (see Figure 23 of this report and Figure 2 of Thorsen 2019). Arguably, some of this habitat may be intermittent in character than ephemeral (as shown in Figure 23), however, based on (wet) September observations, it is difficult to distinguish where watercourses change from being ephemeral to intermittent. It is unlikely that they carry surface flow during warmer months of the year. A rough estimate using maps of the proposed project area and GIS tools indicates that approximately 350 metres of ephemeral seepage watercourses and 130 metres of possibly intermittent watercourse would be lost in the Highlay Creek catchment. Because they are small, very shallow surface water systems at best, and appear to be largely ephemeral in nature, they do not support fish or typical stream invertebrate habitat and associated communities. Further, given that they lie within farmed land, and historically stock have had direct access to this habitat, they are also likely to be a source of nutrients, sediment and faecal pathogens to watercourses located further downstream. Inspections of some of these areas in September 2018 found them to be heavily modified and subject to considerable pugging from stock (Figure 8). Consequently, other than some very minor flow contribution, it is considered that these drainage networks provide little to support downstream stream communities of the Highlay Creek tributaries or Highlay Creek itself. 'Clean' water will be diverted downstream of the proposed silt pond (Figure 4). The establishment of a silt pond in this part of the catchment may potentially help improve downstream water quality relative to the current situation.

Populations of Taieri flathead galaxiids are present throughout Highlay Creek catchment, but not in gullies that would be inundated by the proposed Deepdell East Waste Rock Stack. Galaxiid populations are present in the Highlay Creek tributary into which these gullies drain into and in Highlay Creek itself. Streams in Highlay Creek catchment that support fish and crayfish populations cannot be regarded as pristine. They are subject to physical disturbance through stock trampling and support nuisance algae growths. However, they obviously have characteristics that are favourable to these species. One of the likely key features responsible for robust crayfish and galaxiid populations in Highlay Creek catchment is the lack of predatory species, in particular brown trout.

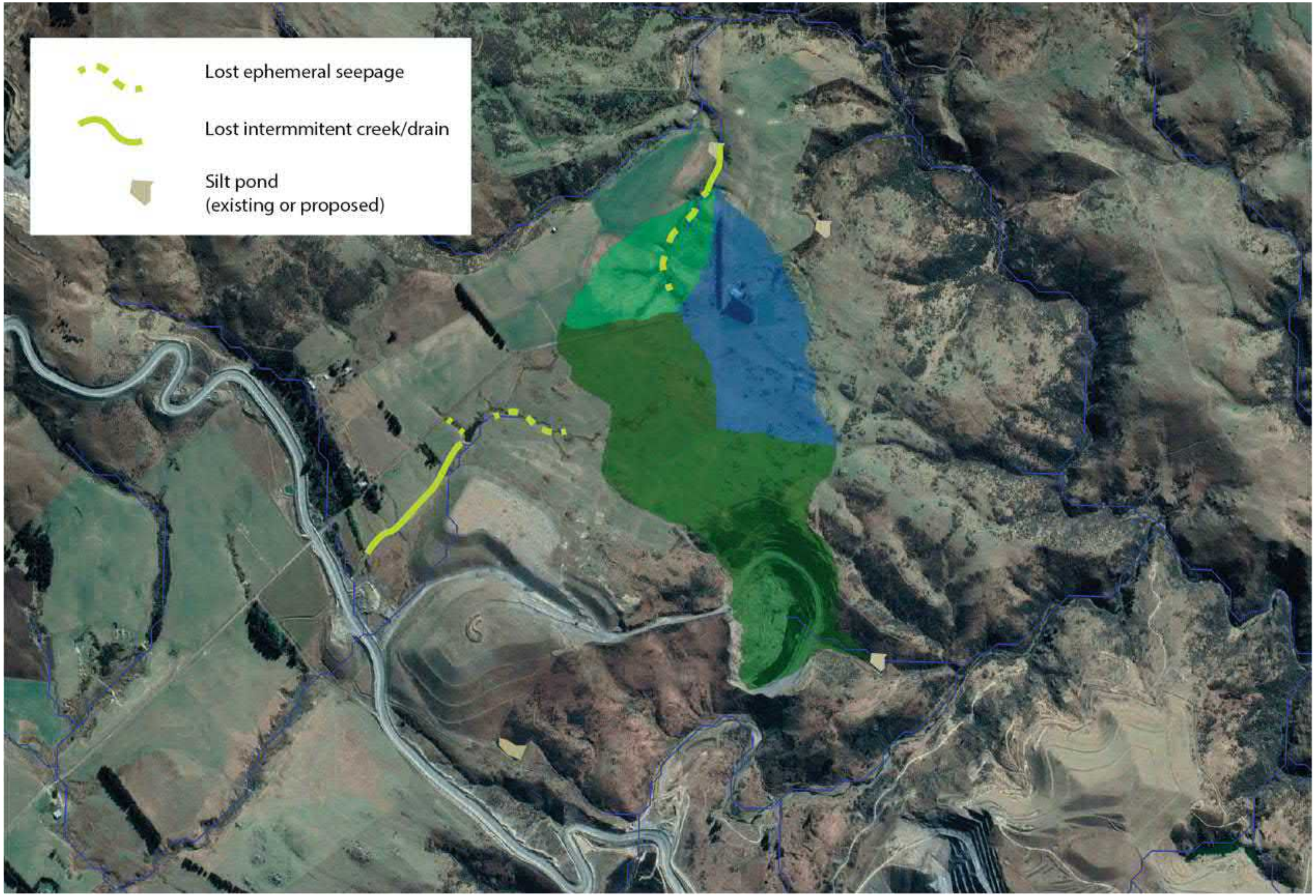

Figure 23 Map showing locations and approximate extent of surface water habitat loss associated with the Deepdell North Stage III Project.

The existing watercourse adjacent to the haul road that drains into the Camp Creek catchment appears devoid of fish, and it is possible the watercourse flows intermittently, which would limit habitat potential even further. Although no fish or crayfish were captured in September, it is possible that crayfish may still be present in the system, given the habitat observed in September 2019. Crayfish were found in the general vicinity as part of a Fish & Game surveys around 1987-1996. Under the proposed Project, this modified watercourse would not be affected, however approximately 480 metres of an intermittently flowing cut-off drain, located between the confluence with the above watercourse and the man-made pond to east of Horse Flat Road, would be lost to pit infrastructure (figures 23 and 24). Although highly modified and likely to carry little flow even in the cooler months of the year, it potentially may provide some crayfish habitat if surface water persists throughout all year-round. New drains are proposed to divert 'clean' water away from the mine footprint, and sections of these could be constructed in a way that provided habitat for crayfish (see section 6.1).

An estimated 450 metres of gullies that may support ephemeral watercourses will be lost due to the new pit and associated mine earthworks. These gullies are currently in grazed catchments and are unprotected. They do not support fish habitat.

Figure 24 Centre of photo is looking upstream to the cut-off drain that receives from the man-mdae pond that lies east of Horse Flat Road. The modified watercourse within the Camp Creek catchment that flows parallel to the haul road enters from the left.

The mainstem of Deepdell Creek is also a stronghold for flathead galaxiids and a large population exists in the reach downstream of gullies draining the Deepdell South Pit and the Highlay Creek confluence.

There will be no physical disturbance to Deepdell Creek as a result of the Project. Provided that the project does not exacerbate low flows, sediment load and water quality, downstream crayfish and fish populations should be unaffected by the Project. Sediment and water quality are discussed further below.

5.2 Sediment mobilisation

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 tributaries of Highlay Creek, and also present in the mainstem of Highlay Creek and in slow runs and pools in Deepdell Creek. Excessive fine sediment cover is usually detrimental to stream communities, particularly if flow variability is insufficient to regularly flush excess material away. Measures to avoid the introduction and downstream transport of sediment are therefore necessary. 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 stacks 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. Sediment control should be installed prior to any disturbance within each catchment area. Any silt pond in the Highlay Creek catchment should be situated well upstream of Highlay Creek mainstem and in any tributary that supports fish. Existing silt ponds associated with the Deepdell South Pit should be assessed to ensure they are appropriately sized for any expansion associated with the Project and in particular to avoid additional transport of fine sediment to Deepdell Creek.

- 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.

- Ensure any catchment runoff associated with the Project is directed into the tributaries they currently feed. This will help minimise any potential effect on downstream crayfish and crayfish communities. At best, ensure that low flows are not exacerbated.

5.3 Water quality

Nitrate and sulphate have been identified as two water quality parameters that have increased in downstream receiving water environments due to the effects of the mining operations at Macraes. The nitrate and sulphate character of Deepdell Creek and the Shag River is discussed in the report prepared by GHD for the Deepdell North Stage III Project (GHD 2019).

The project will result in these two contaminants reaching Deepdell Creek and Highlay Creek via silt ponds and consequently some level of treatment can be expected as a result of flow retention and sediment deposition. Potential ecological effects of these contaminants in these two creeks can be expected to be similar given they have similar freshwater communities and drain catchments with similar physical and land use characteristics. Camp Creek will receive clean water only.

5.3.1 Sulphate

Golder (2011) reported that sulphate concentrations would likely exceed receiving water resource consent limits seasonally at the Macraes Gold Project, with a risk of increasing over time due to the delayed release associated with geochemical reactions of waste rock material. In recent years, OceanaGold OGL has initiated changes in its waste rock stack construction and management in order to better control sulphate in seepage. Sulphate leaches from waste rock stacks over time and recent consenting processes associated with the Macraes Gold Project have considered the effects of sulphate on local surface water quality and ecology.

Sulphate concentrations have been monitored in Deepdell Creek for a number of years now, as have fish populations. Both sulphate concentrations and flathead galaxiid fish population estimates are presented in Figure 25 for the period 1990 to 2018 (note regular fish monitoring of Deepdell Creek commenced in 1995). The data for sulphate in Figure 25 show that concentrations have increased from 2006 onwards. Fish population estimates over that period have not altered relative to pre-2006 estimates. While the population varies widely from year to year, the post 2006 median population estimate of 87 fish/10m^2 compares closely to the pre-2006 estimate of 64 fish/10m^2.

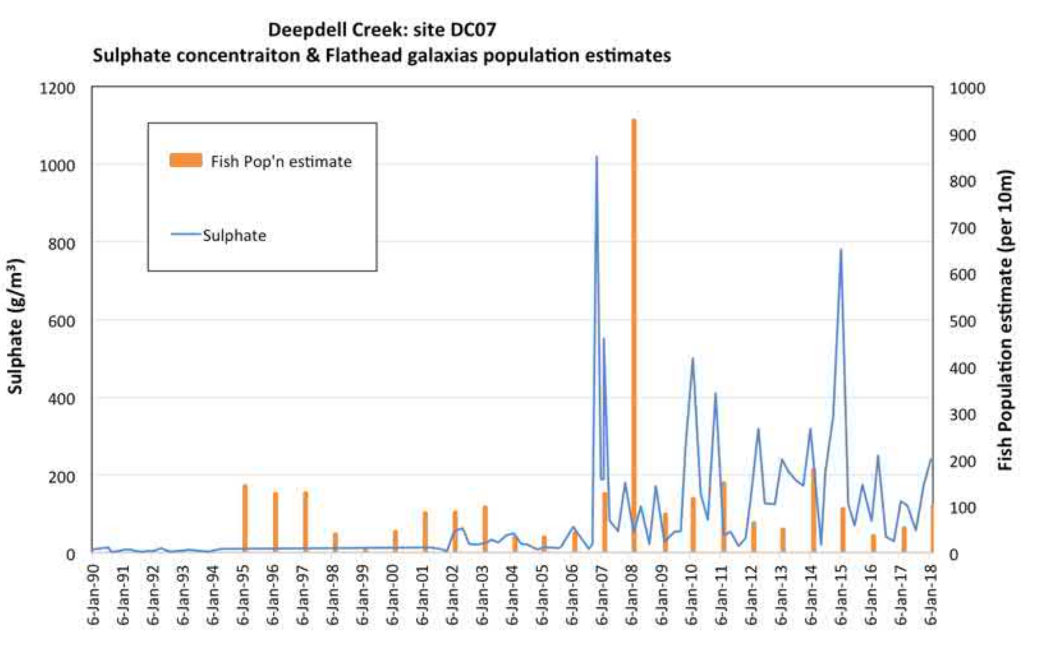

Figure 25 Flathead galaxiid population estimates (per 10 m reach) and sulphate concentrations over time at Deepdell Creek site DC07, 1990 to 2018.

Elevated levels of sulphate in recent years have not resulted in changes to the typical fish population or size classes found in Deepdell in late summer, with the median population estimate in recent years slightly higher than that prior to sulphate levels increasing at DC07.

Recently, toxicity testing has been conducted using Taieri flathead galaxias (OceanaGold 2018). The most sensitive stages of the flathead galaxias (eggs and larvae) were exposed to a range of concentrations of Macraes mine waste rock seepage diluted with Mare Burn creek water over a 50 day period. The principal constituent of seepage is sulphate and the testing used sulphate concentrations ranging from 100 to 3,000 mg/L. No impact was identified on ova. There was no evidence of a toxicity effect during any of the egg development stages. Eggs that developed fungus appeared to have been unfertilised and were distributed across the test concentrations. Actual mortally effects did not occur until sulphate concentrations of between 1,640 and 1,920 mg/L. No effects were observed at 1000 mg/L sulphate, which OceanaGold has proposed as a compliance limit for Deepdell Creek.

GHD (2019) predict that sulphate values will increase in Deepdell Creek (DC08) from the baseline condition over time to a median of 100 to 200 g/m^3 (seasonal variation). This prediction aligns with the gradual increase in sulphate concentrations in waste rock stack seepage, however concentrations will remain consistently under the current compliance limit. For the Shag River downstream of the Deepdell Creek confluence (at Loop Road), the predicted median sulphate concentration is also predicted to stay within compliance over the 40 year time period run in the model (GHD 2019). Modelling did identify potential to exceed the 95th percentile guidance values for sulphate from 2045 onwards, but with a low probability of occurrence.

5.3.2 Nitrate

The GHD (2019) report notes that investigations by OceanaGold have determined that unburnt ammonium nitrate from explosives and source rock are sources of nitrate to receiving waters draining the mine site. GHD (2019) undertook further modelling to predict the potential changes in receiving water nitrate concentrations based on the development of Deepdell North Stage III Project proceeding as summarised in section 1 of this report.

Nitrate nitrogen is a nutrient that is necessary for algae and macrophyte (plant) growth. In excessive concentrations in freshwater, it can result in nuisance growths of these plant forms, particularly if sufficient phosphorus is also available for growth (along with other factors such as sufficient temperature and water clarity for light penetration). At even higher concentrations, nitrate can be toxic to aquatic life to various degrees.

5.3.3 Nitrate toxicity

The 2014 National Policy Statement for freshwater (updated 2017) contains attribute bands for nitrate toxicity. These are presented as concentration bands and are accompanied by a narrative description of each band, as set out in Table 5.

An obvious question to be asked in this report is, are there nitrate-sensitive species in the Deepdell catchment and if so, what is an appropriate attribute state for their protection?

The three aquatic species identified in the catchment are freshwater crayfish (koura), longfin eel and the flathead galaxias, of which the latter species has a relatively narrow geographical distribution (Figure 22). Longfin eel are widely distributed throughout New Zealand and are very uncommon in the Deepdell Creek catchment. This catchment does not appear to be favourable to them and any protection afforded to them is likely to be met by that provided for other species, as described below.

The Taieri flathead galaxiids have not been tested specifically for sensitivity to nitrate. However, the waste rock stack seepage described above that focused on sulphate toxicity most likely contained elevated levels of nitrate also, given the seepage leachate was sourced from areas known to contain high nitrate. This can be seen in Table 6, which are laboratory test results for Back Road Waste Rock Stack seepage leachate collected between May and September 2018. This leachate was used in toxicity testing described above. A sulphate limit of 1,000 mg/L, which testing showed to have no effect on flathead galaxias eggs and larvae, is equivalent to a nitrate-N concentration of approximately 7-8 mg/L N, going by the ratios of sulphate to nitrate in Table 6. This range is below the NPS-FW National Bottom Line concentration identified in Table 4.

Table 5 Nitrate (Toxicity) attribute states from the 2014 NPS-fW (updated 2017).

Value (and component)	Ecosystem Health (water quality)	
Freshwater Body Type	Rivers	
Attribute Unit	**NO_3-N** mg/L (milligrams nitrate-nitrogen per litre)	
Attribute band and description	**Numeric Attribute State**	
	Annual Median	Annual 95th Percentile
A High conservation value system. Unlikely to be effects even on sensitive species.	≤1.0	≤1.5
B Some growth effect on up to 5% of species.	>1.0 and ≤2.4	>1.5 and ≤3.5
C Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.	>2.4 and ≤6.9	>3.5 and ≤9.8
National Bottom Line	**6.9**	**9.8**
D Impacts on growth of multiple species, and starts approaching acute impact level (ie risk of death) for sensitive species at higher concentrations (>20 mg/L).	>6.9	>9.8

Note: This attribute measures the toxic effects of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes will be more stringent.

Table 6 Laboratory test results for Back Road Waste Rock Stack seepage leachate collected between May and September 2018. (source: OceanaGold 2018).

Date	**Sulphate** (mg/L)	**Nitrate-N** (mg/L)	**Ammoniacal-N** (mg/L)	**Hardness-Total** (mg/L as $CaCO_3$)
2-May-18	2,500	21	<0.01	3,000
1-Jun-18	2,900	20	<0.01	3,400
1-Jul-18	2,900	21	0.25	3,300
1-Aug-18	3,000	21	0.23	3,400
1-Sep-18	3,000	24	<0.10	3,600

Hickey (2013) described toxicity testing for another galaxias species (the inanga or *Galaxias maculatus*) and the ubiquitous, yet relatively sensitive *Deleatidium* mayfly, which is relatively common in Deepdell Creek and Highlay Creek. The chronic mayfly test was for a 20 day exposure and measured survival of the larvae. A no observed effect concentration (NOEC[1]) sensitivity values for *Deleatidium* was 20.3 mg/L NO_3-N in low hardness (soft) water (40 mg/L $CaCO_3$). A geometric mean value of 11.2 mg/L NO_3-N was calculated for inanga from the low and medium hardness water NOEC values and used by Hickey for

[1] The NOEC is the highest measured continuous concentration of an effluent or a toxicant that causes no observed effect on a test organism. NOEC is determined by a statistical test comparison with control concentrations.

guideline derivation.

Only one reference to nitrate toxicity testing using koura has been identified. That work was reported on by Hickey (2018). He found that the third most sensitive New Zealand native species to nitrate were juvenile koura, which were measured over a 60 day test on one occasion. The most sensitive thresholds[2] were growth at 2.2 and 2.3 mg/L NO_3-N for length and weight respectively, with a survival threshold of 17.4 mg/L NO_3-N (i.e., approximately 8x above the growth threshold).

Hickey (2018) found the most sensitive invertebrate species was the New Zealand snail (*Potamopyrgus antipodarum*), which is abundant in Deepdell Creek. Long-term (31-40 day) chronic tests were used and a range of endpoints measured. The most sensitive endpoint was for morbidity (averaged 1.9 mg/L NO_3-N), followed by growth (2.3 mg/L NO_3-N), and a reproduction endpoint of 8.6 mg/L NO_3-N. The survival threshold averaged 15.5 mg/L NO_3-N (i.e., approximately 8x safety factor for the survival threshold above the morbidity threshold). The long-term 50% survival value averaged 56 mg/L NO_3-N (range 16.8 to 194 mg/L NO_3-N) (Hickey 2018).

Hickey (2018) also noted a that a number of studies had identified water hardness as a factor affecting both acute and chronic nitrate toxicity in some species. For example, chronic toxicity studies with *Potamopyrgus antipodarum* showed a decrease in sensitivity as hardness increased for both survival and morbidity endpoints (Hickey 2016). Hardness is high in Macraes waste rock stack seepage (Table 5).

Given all of the above, for toxicity purposes, applying the NPS-FW Band B would appear to provide ample protection for the aquatic community in the Deepdell Creek catchment. The Attribute Band B values for nitrate (and ammonia) are:

- Nitrate-N g/m3 (NO3-N) – Annual median [>1.0 and ≤2.4] and Annual 95th percentile [>1.5 and ≤3.5]
- Ammoniacal-N g/m3 (NH4-N) – Annual median[>0.03 and ≤0.24] and Annual 95th percentile [>0.05 and ≤0.40]

The narrative description for the NPS-FW B Band is "*95% species protection level: Starts impacting occasionally on the 5% most sensitive species*". Hickey (2013) described this level of nitrate management as "*very good*" and for *"Environments which are subject to a range of disturbances from human activities, but with minor effects*".

5.3.4 Nitrate as a nutrient for algae and plant growth

The Regional Water Plan for Otago contains water quality schedules that are relevant to nitrate concentrations that are aimed to curb the development of nuisance algae and macrophyte (aquatic plant) growth. The NPS-FW contain attribute states that provide

[2] Measuring EC10 and LC10 values (the effect concentration or lethal concentration for a 10% effect).

guidance to manage the effects of nitrate toxicity, and are thus set at considerably higher levels than management for the protection against nuisance algae and plant growths. It is important to note that ammoniacal nitrogen is also potentially toxic to freshwater aquatic life and has an NPS-FW attribute state of its own. However, ammoniacal nitrogen concentrations in the Deepdell catchment do not appear to be anywhere near at a level that may cause toxic effects to aquatic life.

The Otago Regional Plan: Water (RPW) Schedule 15 describes the characteristics of good water quality in lakes and rivers along with numerical water quality limits and targets for waterbodies across Otago. The targets and limits specified in this table are to protect against nuisance plant growth as opposed to protection against toxicity.

Table 7 below sets out the numerical water quality limits/targets for receiving water groups (RWGs) in the Shag River catchment. The limits/targets in Schedule 15 are not limits/targets that apply to any potential discharge, but rather set out the long-term water quality objectives for receiving waters. These limits/targets apply as 5-year, 80th percentiles when flow is below the median flow at the relevant flow reference site. That is, 80% of values collected when flows are at or below the median flow at the appropriate flow reference site over a 5-year period should be below the Schedule 15 limit.

Table 7 Numerical limits and targets for good water quality in rivers in the Shag River catchment from Schedule 15 of the Otago Regional Plan: Water. RWG = receiving water group, NNN = nitrate-nitrite nitrogen, DRP = dissolved reactive phosphorus.

RWG	NNN (mg/L)	DRP (mg/L)	Ammoniacal nitrogen (mg/L)	*E. coli* (cfu/100 mL)	Turbidity (NTU)	Catchment
2	0.075	0.01	0.1	260	5	Shag

Currently, Deepdell Creek does not meet the Schedule 15 target concentration for nitrate-nitrite nitrogen, and, not surprisingly, would not do so if the NPS-FW B-Band (or A-Band) was adopted to protect the river ecosystem against nitrate toxicity. The Regional Plan Water Schedule 15 targets are not consistent with the NPS attribute bands for nitrate toxicity, and require much lower levels of nitrate to manage nuisance algae and plant growths. A concentration target of under 0.075 mg/L to achieve this seems overly ambitious for the Deepdell catchment given current concentrations are almost an order of magnitude higher.

Given a highly significant reduction in typical nitrate concentrations in the creek are unlikely, it is recommended that focus on managing phosphorus losses to water be given greater attention in the catchment. Both nitrate and dissolved phosphorus are necessary to stimulate algae and plant growth. The pathway for phosphorus to reach surface waters is primarily via overland flow (and direct through stock access to water), whereas nitrate can reach surface waters via subsurface seepage and groundwater.

This is not to say that management of waste rock stacks at Macraes will be not required to avoid adverse effects on freshwater ecology, but rather dual nutrient management be considered.

5.4 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 should be replicated for the Deepdell North Stage III Project.

5.5 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.

6. Recommended mitigation & monitoring

6.1 Loss of crayfish and fish habitat & water quality

No stream habitat that supports fish populations are proposed to be disturbed or lost as a part of the Deepdell North Stage III Project. Gullies draining parts of the Highlay Creek catchment that would be lost due to the Deepdell East Waste Rock Stack are very small, heavily impacted, probably ephemeral (potentially intermittent in the lower section) and do not support stream communities (including crayfish). The estimated length of this habitat that would be lost is approximately 480-500 metres, of which approximately 130 metres of this may have intermittent flow. Provided the measures described above in section 5 relating to sediment mobilisation and runoff, and the management of contaminants and machinery, are appropriately addressed, effects on stream populations located further downstream are not anticipated. A proposed silt pond (Deepdell East Silt Pond 1) could potentially be suitable for crayfish and riparian planting around the margins would further enhance habitat potential. Additional mitigation for direct physical effects on crayfish and fish habitat and their populations for loss of these habitats is not considered necessary.

The loss of approximately 380 metres of a cut-off drain that may potentially support some koura could be replaced by constructing an equivalent length of drain to divert 'clean' water around the western side of Project footprint near the haul road and into Camp Creek (see Figure 4). To be of net benefit to koura and other aquatic life, the drain, or sections of it, would need to maintain a permanently submerged bed (it need not be flowing continually, although some turnover of water is desirable) and be of sufficient quality to ensure adequate dissolved oxygen levels. Koura are found in most substrate types, often associated with abundant refuge (e.g. woody vegetation and riparian plant cover). Higher densities are associated with substrate that they can burrow in (e.g., clay) with overhanging riparian vegetation. Habitat could also be enhanced by planting tussocks or other overhanging vegetation along the margins and creating shelter through placement of schist slabs and woody debris on the bed.

Potential water quality effects have been described above. Applying the NPS-FW Band B attribute state for nitrate would appear to provide ample protection for the aquatic community in the Deepdell Creek catchment with respect to nitrate toxicity.

OceanaGold propose to construct a freshwater dam in the Camp Creek catchment (operating by January 2022) to provide a base flow to Deepdell Creek to manage and effectively mitigate sulphate concentrations in Deepdell Creek and in the Shag River as far as the confluence with McCormicks Creek (GHD 2019). It is anticipated that this will also act to mitigate nitrate concentrations. It is recommended that this dam also be assessed for potential to provide periodic flushing flows down Deepdell Creek to remove nuisance algae and plant biomass that may accrue over summer stable low flow periods. Additional stream shading may also reduce the need to reduce instream nitrogen.

6.2 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 section 5.

6.3 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 existing consent conditions associated with the Macraes Gold Mine and should continue for the Deepdell North Project.

6.4 Monitoring

Regular monitoring of fish and invertebrate populations in Deepdell Creek and Highlay Creek should continue as a check against potential effects on freshwater biota due to potential changes in water quality. Regular nitrate and phosphorus monitoring should commence in Highlay Creek and at the existing Deepdell Creek monitoring sites if it hasn't already done so.

Investigating the potential to provide effective flushing flows from the Camp Creek dam is recommended.

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Appendix One: Benthic macroinvertebrate data

Field collection

Benthic macroinvertebrates were sampled using either a Surber sampler or 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 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

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

Macroinvertebrate taxa in samples collected from Highlay Creek, February 2011.

			Highlay Creek				
			Upper reaches		Middle reaches		Tributary
TAXON	MCI score	MCI-sb score	1	2	1	2	1
COLEOPTERA							
Elmidae	6	7.2	A	A	C	A	
Ptilodactylidae	8	7.1		C			
CRUSTACEA							
Ostracoda	3	1.9	A	A	C	VA	A
Paracalliope fluviatilis	5	5.5					C
Paranephrops zealandicus	5	8.4			R		R
DIPTERA							
Aphrophila species	5	5.6	R				
Austrosimulium species	3	3.9	R		A	C	C
Empididae	3	5.4	R				
Maoridiamesa species	3	4.9	A			C	
Mischoderus species	4	5.9		R			
Orthocladiinae	2	3.2	VA	A	A	A	C
Paralimnophila skusei	6	7.4					C
Tanypodinae	5	6.5	C	C			
Tanytarsini	3	4.5		C		C	
Zelandotipula species	6	3.6		R			
EPHEMEROPTERA							
Deleatidium species	8	5.6	VA	VA	VA	VA	A
MEGALOPTERA							
Archichauliodes diversus	7	7.3	C	A	A		
MOLLUSCA							
Gyraulus species	3	1.7					VA
Potamopyrgus antipodarum	4	2.1	VA	VA	VVA	VA	VVA
Sphaerium novaezelandiae	3	2.9					C
NEMATODA	3	3.1	R				
OLIGOCHAETA	1	3.8	A	C	C	C	A
PLECOPTERA							
Stenoperla species	10	9.1		R			
Zelandobius species	5	7.4	C	A	C		
Zelandoperla species	10	8.9		R		C	
TRICHOPTERA							
Aoteapsyche species	4	6.0	C	VA	VA	VA	
Hudsonema amabile	6	6.5			C	C	
Hydrobiosis umbripennis group	5	6.7	R	C	R	C	
Oxyethira albiceps	2	1.2	C		C	C	C
Polyplectropus species	8	8.1	A			A	A
Psilochorema species	8	7.8	R			R	
Zelolessica species	10	6.5		C			
Number of taxa			19	18	14	16	13
Number of EPT taxa			7	7	6	8	3
% EPT taxa			33	46	50	44	3
MCI score			89	112	87		
SQMCI score			4.6	5.2	4.5		
MCI-sb score						95	86
SQMCI-sb score						4.8	4.0

Benthic macroinvertebrate communities at the Highlay Creek survey site, April 2013. Quantitative Surber samples (Samples 1 – 5) and one composite qualitative kicknet sample (Kicknet). Surber sample data presented as number of invertebrates per sample. Kicknet sample data presented as coded abundance categories from Stark (1998).

		Highlay Creek					
TAXON	**MCI score**	1	2	3	4	5	Kicknet
COLEOPTERA							
Elmidae	6	1		1	2		R
COLLEMBOLA	6					1	
CRUSTACEA							
Paranephrops zealandicus	5	1				1	
DIPTERA							
Aphrophila species	5			2			
Orthocladiinae	2			1	1		
Tanypodinae	5		2	1			R
EPHEMEROPTERA							
Deleatidium species	8	197	86	113	128	123	V A
Neozephlebia scita	7	8	4	9	2	4	C
Zephlebia species	7			2	1		R
MEGALOPTERA							
Archichauliodes diversus	7	10	10	11	3	1	C
MOLLUSCA							
Potamopyrgus antipodarum	4	20	4	2	2	21	C
OLIGOCHAETA	1	2	12		3	16	C
PLECOPTERA							
Stenoperla species	10					1	
Zelandoperla species	10	1					
TRICHOPTERA							
Aoteapsyche species	4	2	1	5	2	7	C
Olinga species	9					1	
Polyplectropus species	8			1			C
Psilochorema species	8	1			1		R
Pycnocentria species	7	1			1		R
Pycnocentrodes species	5	1					
Number of invertebrates (per sample)		245	119	148	146	176	-
Number of invertebrates (per m^2)		6125	2975	3700	3650	4400	-
Number of taxa		12	7	11	11	10	12
Number of EPT taxa		7	3	5	6	5	7
% EPT		86	76	88	92	77	-
MCI score		120	103	115	111	122	120
QMCI score		7.5	7.0	7.5	7.6	6.7	-
SQMCI score		-	-	-	-	-	7.3
Average QMCI score		7.3					-

Macroinvertebrate taxa from kicknet samples collected from Highlay Creek and Deepdell Creek, February 2018.

		Highlay Creek			Deepdell Creek 1
TAXON	**MCI score**	**Trib. A**	**Trib. B**	**Horse Flat Road ford**	
ACARINA	5		R		
COLEOPTERA					
Elmidae	6	C	C	C	
Hydraenidae	8	C	R		
Ptilodactylidae	8		R		
Scirtidae	8	R	R		
Staphylinidae	5	R			
CRUSTACEA					
Ostracoda	3			C	VA
Paracalliope fluviatilis	5				C
Paraleptamphopus species	5	R			
Paranephrops zealandicus	5		R		
DIPTERA					
Austrosimulium species	3			C	R
Corynoneura scutellata	2			R	
Ephydridae	4			R	
Nothodixa species	4	C			
Orthocladiinae	2		R	C	R
Paradixa species	4	R	R		
Polypedilum species	3	R			
Stratiomyidae	5		R	R	
EPHEMEROPTERA					
Coloburiscus humeralis	9				R
Deleatidium species	8	VA	VA	VA	
HEMIPTERA					
Microvelia macgregori	5		R	R	R
Sigara species	5			R	
LEPIDOPTERA					
Hygraula nitens	4				R
MECOPTERA					
Nannochorista philpotti	7	R			
MEGALOPTERA					
Archichauliodes diversus	7			R	
MOLLUSCA					
Gyraulus species	3			R	VA
Physa / Physella species	3			R	VA
Potamopyrgus antipodarum	4	A	A	VVA	VVA
Sphaeriidae	3	R		C	A
NEMATODA	3			C	
OLIGOCHAETA	1	R	R	C	C
PLATYHELMINTHES	3			R	
PLECOPTERA					
Spaniocerca species	8	R			
Zelandobius species	5			C	
TRICHOPTERA					
Aoteapsyche species	4		R	A	A
Hudsonema alienum	6	A	C		
Hudsonema amabile	6			R	VA
Hydrobiosella species	9	R			
Hydrobiosidae early instar	5			R	
Hydrobiosis umbripennis group	5	R	C		
Neurochorema species	6	R			
Oxyethira albiceps	2			A	C
Psilochorema species	8		R	R	R
Pycnocentrodes species	5			C	R

Macroinvertebrate taxa in samples collected from Camp Creek, October 2010. 'VVA' = very, very abundant, 'VA' = very abundant, 'A' = abundant, 'C' = common, and 'R' = rare.

		Camp Creek					
		Upstream of Horse Flat Road		Middle reaches		Lower reaches	
TAXON	MCI score	1	2	1	2	1	2
COLEOPTERA							
Elmidae	6	C	R	A	A	A	C
Scirtidae	8			C		C	
CRUSTACEA							
Ostracoda	3		C				
DIPTERA							
Aphrophila species	5	C			A	C	R
Austrosimulium species	3	A	VA		C	A	R
Ceratopogonidae	3						R
Maoridiamesa species	3					A	R
Orthocladiinae	2		A	C	C	A	A
Tabanidae	3					R	
Tanypodinae	5				C		R
Zelandotipula species	6		R				
EPHEMEROPTERA							
Deleatidium species	8	VVA	VA	VVA	VVA	VVA	VA
HEMIPTERA							
Sigara species	5				R		
MEGALOPTERA							
Archichauliodes diversus	7				C	R	R
MOLLUSCA							
Potamopyrgus antipodarum	4	A	A	A	C	VA	C
Sphaerium novaezelandiae	3				R		
OLIGOCHAETA	1	VA	VA	A	A	A	C
PLECOPTERA							
Zelandobius species	5		A	C	A	C	C
Zelandoperla species	10		C			C	
TRICHOPTERA							
Aoteapsyche species	4		C	C	C	A	C
Hudsonema alienum	6		R				
Hudsonema amabile	6			R		C	
Hydrobiosis umbripennis group	5	C				A	
Oxyethira albiceps	2		C				R
Polyplectropus species	8		R				
Psilochorema species	8		R	R	C		
Pycnocentria species	7			C	C		
Pycnocentrodes species	5	A		A	C	R	C
Number of taxa		8	15	12	16	17	15
Number of EPT taxa		3	8	7	6	7	5
% EPT		60	49	86	84	50	84
MCI score		93	101	107	98	100	84
SQMCI score		6.5	4.0	7.4	7.3	6.6	6.3
Average MCI score		97		102		92	
Average SQMCI score		5.3		7.3		6.5	

Macroinvertebrate taxa from kicknet samples collected from Camp Creek (CC02) and Deepdell Creek, February 2018.

Summer 2018			**DC07**					**DC00**					**CC02**				
TAXON	**MCI score**	**NG01**	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
ACARINA	5	1											1				
COLEOPTERA																	
Dytiscidae	5												1				
Elmidae	6													1	1	1	
Hydraenidae	8							1					1			10	1
Staphylinidae	5												1				
COLLEMBOLA	6	1										1					
CRUSTACEA																	
Ostracoda	3		2	33	93	9		6	2	26	46			1	1	1	
Paracalliope fluviatilis	5	148	5	9	69	45	1	4	1				5	2			2
DIPTERA																	
Aphrophila species	5																1
Austrosimulium species	3						1	2									
Ceratopogonidae	3														1		
Chironomidae	2		3	12	34	21	9	2	2	11	28	2	21	73	1	2	4
Limonia species	6	1															
Mischoderus species	4												1				
Muscidae	3			2													
Psychodidae	1												1				
Sciomyzidae	3						1										
EPHEMEROPTERA																	
Deleatidium species	8	2	1	3	2	1	1	378	47	96	97	42	9	31	6	45	31
HEMIPTERA																	
Microvelia macgregori	5			1			2					5					
MEGALOPTERA																	
Archichauliodes diversus	7		1			1	4							1	2		
MOLLUSCA																	
Gyraulus species	3		59	9	22	18	78	1		6	17						
Physa / Physella species	3	1	11	16	21	25	17	6	4	7	40	4					
Potamopyrgus antipodarum	4	458	934	465	540	271	348	509	55	103	590	74	898	539	552	515	201
Sphaeriidae	3		2			1	1	2	1		2						
NEMATODA	3													1			
NEMERTEA	3		2		1	1	1										
ODONATA																	
Xanthocnemis zealandica	5								1	1	3						
OLIGOCHAETA	1	5	1	15	17	23	6	20	4	3	18	3	1	2	11		
PLECOPTERA																	
Austroperla cyrene	9													1	1		
Spaniocerca species	8	1															
Stenoperla species	10												1	1	1	3	
Zelandobius species	5						1			1			4	6	5	8	8
TRICHOPTERA																	
Hudsonema amabile	6	2	3	3	25	20	15	15	1		2		1	1			1
Hydropsyche - Aoteapsyche group	4		250	35	41	14	150	2				3	25				
Olinga species	9					3							10	1	4	4	4
Oxyethira albiceps	2		12	12	26	7	7	7	5	3	9	1	10	64		8	6
Paroxyethira species	2		1							1			1	1	2		
Polyplectropus species	8	1			1						4			16	1		
Psilochorema species	8		1	1		2	3	2	1				4	2		2	1
Pycnocentria species	7		1	1	5	3	4						26	11	3	128	18
Pycnocentrodes species	5		1	3	4	11							119	24	22	176	84
Number of invertebrates		621	1290	620	901	476	650	957	124	258	856	135	1141	779	614	903	362
Number of taxa		11	18	16	15	18	19	15	12	11	12	9	21	20	16	13	13
QMCI score		4.3	3.9	3.8	3.8	3.9	3.9	5.5	5.3	5.2	4.2	5.2	4.2	4.0	4.1	4.9	4.8

Macroinvertebrate taxa from kicknet samples collected from Camp Creek (CC02) and Deepdell Creek, August 2018.

Winter 2018		**DC02**					**DC01**					**DC00**					**CC02**				
TAXON	**MCI score**	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
ACARINA	5					1															
COLEOPTERA																					
Berosus species	5			1																	
Elmidae	6		1						1	1						1	1	1	2	2	6
Hydraenidae	8																3	7	9	7	5
Scirtidae	8																				
Staphylinidae	5						1														
COLLEMBOLA	6																				
CRUSTACEA																					
Ostracoda	3	3	2				2		2	4		1		2	8						
Paracalliope fluviatilis	5						1		1	1					1			4		1	6
Paraleptamphopus species	5																				
DIPTERA																					
Aphrophila species	5	1	1		3	1		1			1		1		1		1	1			
Austrosimulium species	3	2	17		6	4	16	13	13	4	9	7	7		1	12					
Ceratopogonidae	3																				
Chironomidae	2	10	10	10	14	16	58	111	83	29	40	18	56	6	23	16	3	16	5	4	7
Empididae	3						2														
Ephydridae	4																				
Hexatomini	5																				
Limonia species	6						1														
Mischoderus species	4																				
Muscidae	3												1								
Paradixa species	4																				
Paralimnophila skusei	6																				
Stratiomyidae	5																				
EPHEMEROPTERA																					
Ameletopsis perscitus	10																1				
Deleatidium species	8	216	230	185	227	351	348	348	808	438	224	204	313	119	216	111	50	49	87	151	55
Neozephlebia scita	7							2													
HEMIPTERA																					
Microvelia macgregori	5																				
HIRUDINEA	3																				
MEGALOPTERA																					
Archichauliodes diversus	7	3				2		15	3	2	2						1	1	1		3
MOLLUSCA																					
Gyraulus species	3														3						
Physa / Physella species	3				1										2						
Potamopyrgus antipodarum	4	38	14	23	19	54	49	104	30	82	39	127	196	23	240	45	90	208	78	157	49
Sphaeriidae	3														1						
NEMATODA	3																				
NEMATOMORPHA	3																				
NEMERTEA	3																				
ODONATA																					
Xanthocnemis zealandica	5																				
OLIGOCHAETA	1	5	2	2	3	6	11	51	12	30	9	11	67	2	14	5	2	4	2	3	
PLATYHELMINTHES	3																				
PLECOPTERA																					
Acroperla species	5																		1	4	1
Stenoperla species	10																5		2	2	
Zelandobius species	5			1	1	1	2	1	2	5			1	1	1		10	6	8	5	1
Zelandoperla species	10																	1			
TRICHOPTERA																					
Hudsonema alienum	6																				
Hudsonema amabile	6	4	1	2	3			2		5		2									
Hydrobiosidae early instar	5					3	1		4	2	1							1			
Hydrobiosis umbripennis group	5							2		1			3							1	
Hydropsyche - Aoteapsyche group	4	1		2	2		1	6	3	1	1	1	1			1		10	2		1
Oeconesidae	9																				
Olinga species	9																7	7	9	9	4
Oxyethira albiceps	2				2	1	1	2	1	2					2						
Polyplectropus species	8																8				
Psilochorema species	8	1	1	1	2	2	2	2	3	4	1			1	1		1	1	4	3	1
Pycnocentria species	7																	9	4		4
Pycnocentrodes species	5	37	9	14	8	10	4	8	4	1	3				2		36	46	58	65	71
Number of invertebrates		321	288	241	291	452	500	668	970	612	330	371	646	154	516	191	219	372	272	414	214
Number of taxa		12	11	10	13	13	16	15	15	17	11	8	10	7	15	7	15	17	15	14	14
QMCI score		6.8	7.1	7.1	7.0	7.0	6.5	5.6	7.1	6.7	6.4	6.0	5.4	7.0	5.5	6.0	5.6	4.8	5.9	5.8	5.7

Macroinvertebrate taxa from Surber samples collected from Deepdell Creek, March 2019.

March 2019	**DC08**					**DC07**					**DC05**					**DC03**				
Taxon	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
ACARINA	1																			
CNIDARIA																				
Hydra species												1								
COLEOPTERA																				
Elmidae						1														
Hydraenidae	1																			
COLLEMBOLA		1			1		1						1					1		
CRUSTACEA																				
Ostracoda					1	4		4	26	3					4		7	7	3	4
Paracalliope fluviatilis	1		2		1	200		5	47	11		5	7		30		2	3	2	5
DIPTERA																				
Austrosimulium species							1					1	2	1	1				1	
Chironomidae		3	16	1	1	13	41	24	100	25	7	46	27	12	34	68	730	190	507	880
Ephydridae			1	1					1	3										
Muscidae	5	3	11	8		22	10	3	13	15	4	2	13		5		3	3	13	14
EPHEMEROPTERA																				
Deleatidium species			9	4		1	3	4	2	1	17	87	13	23	35	19	130	116	95	156
HEMIPTERA																				
Saldidae					1															
Microvelia macgregori											7							2		
MEGALOPTERA																				
Archichauliodes diversus				1		2		2				6		2			5			1
MOLLUSCA																				
Gyraulus species		1	1	1	2		1	15	7	2		2		1	3					
Physa / Physella species	2	2	14	6	17	70	5	120	280	4	2	39	6	6	64	1	5	6	11	12

March 2019	**DC08**					**DC07**					**DC05**					**DC03**				
Taxon	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Potamopyrgus antipodarum	4	45	11	31	40	2480	39	980	1640	28	87	1040	300	210	395	42	265	133	39	320
Sphaeriidae						20	1	9	10			4		1						
NEMERTEA						2		1				1	1		1					
OLIGOCHAETA	3		2	1		1360	13	40	480	17	5	24	160	10	34	1	7	21	4	8
PLATYHELMINTHES						3		1				2	1		9					
PLECOPTERA																				
Zelandoperla species														1						
TRICHOPTERA																				
Hudsonema amabile			1	1		2		2	3	1	4	11		1	5	2	3	11	4	9
Hydrobiosidae early instar						3	1	3			2	3			7		11	2		
Hydrobiosis species						4	3		9		1	11	7	5	5	2	25	14	6	20
Hydropsyche - Aoteapsyche group		38	41	77	2	129	330	180	64	17		24	34	20	10	5	5	1	22	131
Oxyethira albiceps		2	1	2		40	5	56	235	29	19	53	49	51	122	4	6	67	90	43
Psilochorema species				1		8	2	3	12	6		8	2	3	12	1	19	12	4	15
Pycnocentria species						4		3											2	
Pycnocentrodes species					2	7		10	1	1		1		1	5	2	11	5	6	10