Date	10 February 2026
To	Jon Bright, Project Director – Waitaha Hydro Scheme Westpower Ltd
From	Ian Ferrier McCahon
Project advice provided for	*Waitaha Hydro Scheme*
Qualifications	BE (Hons), **Appendix A**
Code of Conduct	**Appendix B**
Documents referred to	*Waitaha Hydro Scheme Substantive Application: Appendix 42 Concept Scheme Design Drawings*
Signature	[redacted]

Introduction

1. I have reviewed the peer review report of Mr Paul Morgan and Dr Jon Tunnicliffe provided to the Waitaha Hydro Fast-track Panel and dated 26 January 2026. I have responded within my area of expertise and based on my involvement in designing the intake concept as an engineer involved in earlier stages of the Waitaha Hydro Scheme (before my retirement). My qualifications and experienced are described in **Appendix A**. My responses below cover both peer reviews.

2. In Mr Morgan's report, he suggested a gap in information with respect to the development of the intake concept (sections 2 & 3). This information may not have been made clear in the application documentation, but at each stage of concept design that I was involved in there was appropriate engineering scrutiny and technical input from other disciplines. I also visited the site numerous times over the years. I have remained involved in peer reviews of key concept design decisions developed by AusHydro who prepared the Concept Scheme Design Drawings submitted with the Application.

3. I became involved with the Waitaha Hydro Scheme in 2005, working on the early pre-feasibility studies (*Waitaha and Kakapotahi Hydro Scheme Civil Pre-Feasibility Report*, May 2005) and the initial assessment of possible intake sites at both the top end of Morgan Gorge and the top end of Kiwi Flat. The location at the top end of Kiwi Flat was clearly preferable from an engineering perspective but environmental considerations meant that this had to be abandoned. I prepared a *Preliminary Concept and Option Report* for a Morgan Gorge intake in April 2013, included here as **Appendix C**. Both a low and high weir option at the gorge entrance were considered, as well as a weir location just downstream of Whirling Water confluence. Again,

environmental considerations ruled out the high weir (effectively a dam) and confluence options, leaving the low weir, for which both a stream bed and side intake configuration were considered.

4. At this early stage, several issues with the site were apparent:

   (a) sediment loads were likely to be high;

   (b) the Morgan Gorge constriction acting as a choke on the river at high flows and drowning the intake site with many metres of water during even moderate floods; and

   (c) limited space within which to construct the intake and river diversions needed.

5. A stream bed intake was the first and obvious type of intake considered, especially given my experience with these on the Branch, Dillmans and Amethyst schemes. However, on this site, a stream bed intake was considered problematic, as outlined in the options report in **Appendix C**, and a side intake was preferred. The side entry design was developed, as described in the Preliminary Headworks Concept Report of August 2013 (relevant parts of which are included as **Appendix D**). At this stage, the main features of the intake were:

   (a) a low weir across the river;

   (b) a channel on the right bank which takes the river flow to the intake gate and a gate to sluice sediment past the intake;

   (c) an intake gate housed at the start of a roofed culvert to convey the flow into the tunnel portal;

   (d) a secondary intake gate mounted in a shaft constructed in the natural rock face, to allow water intake from a level well above the riverbed during high flood periods when the lower gate will be subject to high sediment load;

   (e) an intake tunnel to an underground sediment settling basin; and

   (f) an access tunnel at a high level to allow person and machine access during construction and for ongoing operation and maintenance.

6. This concept formed the basis of the headworks design used for subsequent conferencing with experts around environmental aspects. The secondary higher-level intake and the access tunnel were both later modified to minimise landscape/visual impacts.

7. As the headworks required greater resources than I could provide, as well as the time taken for the project to progress and my pending retirement, I made it clear a few years ago that I could not be responsible for the further development of the design, and AusHydro were engaged by Westpower. I have, however, remained involved as required to help review and comment on ongoing design matters. In early 2025, Westpower brought me in as part of a review of the AusHydro headworks concept. An independent review consultant, Brian Leyland, was of the opinion that a stream bed intake was preferable. The issue was robustly debated and AusHydro compiled a Memo *Alternative Options for Waitaha Intake* (13 February 2025) setting out their perspective on the relative merits of a stream bed intake and side intake. The conclusion of the review, with which I concur, was that a side intake was preferable.

Characteristics of the Intake Site

8. There are some unique characteristics of the Waitaha Intake site that are useful to emphasise in relation to the scheme design:

   (a) It is immediately upstream of the entrance to Morgan Gorge, which is a very narrow slot less than 10m wide cut down about 20m into the schist bedrock.

   (b) A rock "platform" extends about 15 to 20m upstream of the cliffs at the gorge entry. The levels of this rock generally vary between about RL236 and 238. The upstream rock edge abuts the end of the gravel bed making up Kiwi Flat. A 4 m to 8m wide channel is cut through the rock platform and carries the river flow during normal conditions. The rock platform appears to be the hydraulic control on river flows at moderate flows. A steep gravel ramp is present immediately upstream of the rock channel and the upstream bed is clearly graded to the rock platform level (see **Figures 1** and **2**). A cross section of the rock platform is shown on **Figure 3**.

9. The Morgan Gorge entry acts as a natural choke on flood flows. Correlating an approximate flow hydrograph with a series of photographs at 15 minute intervals for a flood event in December 2013 indicates that the choke occurs at a flow of between about 150 and 250 m^3/s, with the hydraulic control shifting from the rock platform to the gorge corresponding to a large increase in water depth and decrease in flow velocity upstream of the gorge entry. This is explained in more detail in Dr Hicks' evidence of 10 February 2026 (including his Figure 2). I have seen fresh sand and flotsam deposits on the banks above the intake site surveyed at RL 250-250.5, or 12 –13m above the rock platform. Flood debris has been reported on the swing-bridge, a further 3m higher, or about 15m above the rock platform (see **Figure 3**).

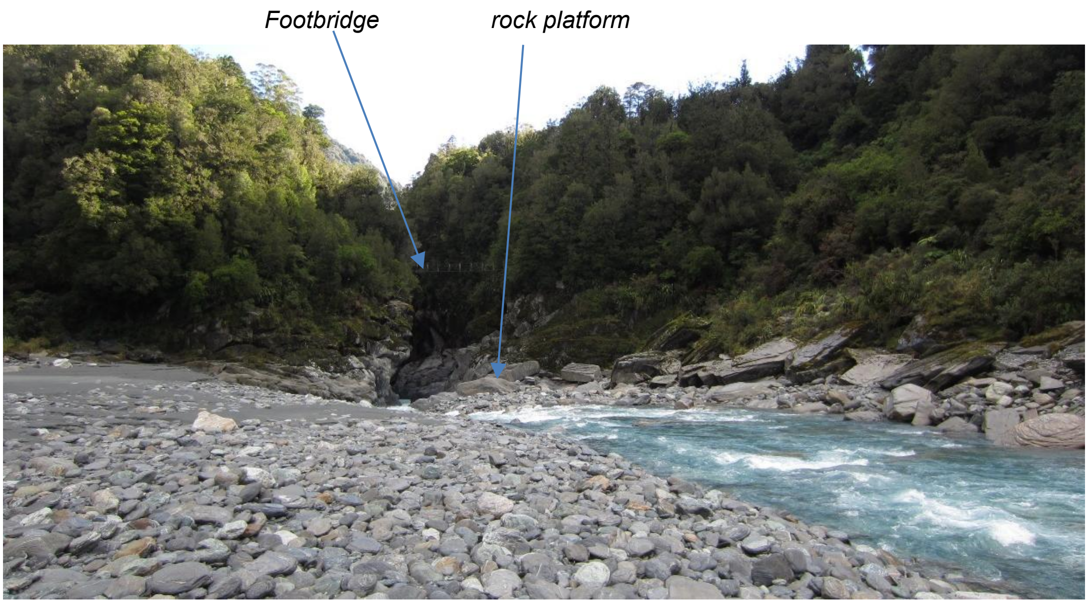

Figure 1: *View to entrance to Morgan Gorge from about 120m upstream of the proposed weir location on the rock platform (24 May 2013). Note steep drop from the gravel bed, which is consistent in level with the rock platform, into the slot through the rock platform and into the gorge. Note height of swing-bridge which has had flood debris observed on it. This indicates 15m water depth in intake area in large but not extreme flood*

Figure 2: *Rock platform with low flow channel in foreground and upstream gravel bed consistent in level with it (29 February 2024). Note steep drop into rock channel off the gravel bed. The cross section in Figure 3 is over narrow section of channel and hollowed rock at centre*

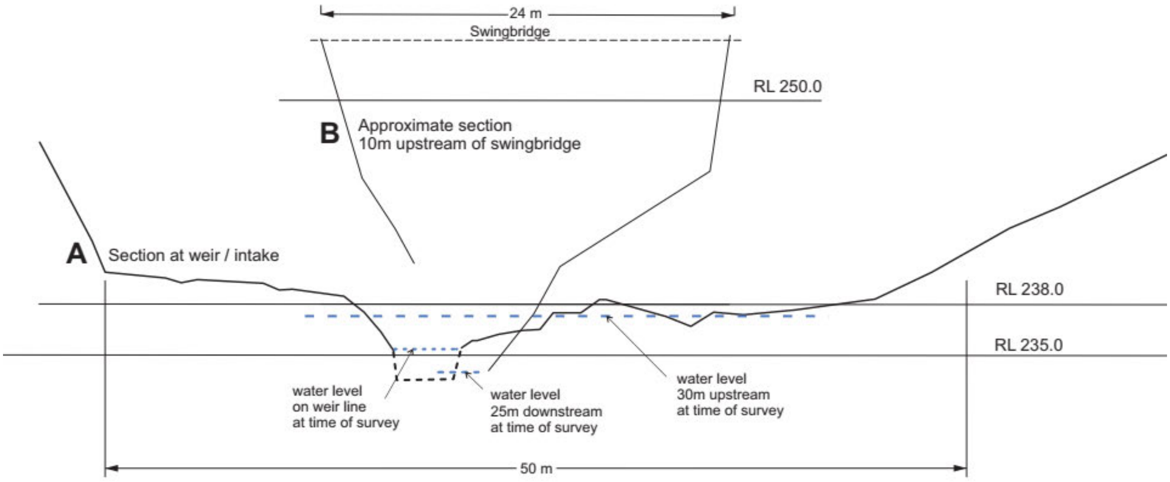

Figure 3: Cross section close to upstream side of rock platform and approximate line of proposed weir. Note RL 238.0 line represents proposed weir crest.

10. The natural Morgan Gorge choke controls the water levels during large floods at least as far upstream as Whirling Water and probably much of Kiwi Flat. Although not so clear on the river talweg1 section, walking down from Kiwi Flat on site it is quite noticeable how the river steepens for the last 300m or so down into the gorge. Larger bedload material clearly gets deposited in a deltaic way when the gorge chokes and a lake-like submergence occurs in this area. This material is then remobilised and carried downstream when river flows and velocities are sufficiently high but not high enough to choke the gorge. This is explained in more detail in Dr Hicks' evidence of 10 February 2026 (including his Figure 2).

11. Thus, the site is subject to:

    (a) a very rapid constriction in river flow conditions from a wide gravel bed to narrow rock gorge (from about 90m width to about 10m width in less than 50m) which is likely to create complex flow patterns during floods; and

    (b) an abnormally high flood rise from the Morgan Gorge choke which moves the hydraulic conditions from near critical flow at low to medium flows to subcritical submergence at high flows.

12. The site is challenging from an engineering perspective, but does offer some benefits, including:

[1] Talweg section is the line of lowest elevation connecting the deepest points along a riverbed.

(a) The exposed rock platform, with only a narrow river channel cut into it, provides a solid foundation for the intake structures and sufficient, even if not generous, room for river diversion.

(b) The cliffs above the platform means only a short transition into the headworks tunnel is needed.

(c) The existing backwater effects caused by the gorge entry choke means that a low weir at the site will have very limited effect upstream. The weir crest level of RL238 is only a little above the average rock level on the platform (see Figure 3) and the sluice gate replicates the existing slot the river flows through. The upstream effects (extent of backwater, aggradation, and associated effects) of the weir compared to what currently occurs should be minimal beyond 300m. As the flow increases, the effects on water levels in the river will extend further upstream but then once the gorge chokes, the effects of the weir should be beyond the immediate area of the intake. The 300m comes from modelling done by Dr Hicks in 3.5 of Appendix 19 of the Application where the weir backwater is estimated to extend about 200m upstream at a low flow of 10 m3/s and aggradation to about 300m upstream. I perceive the rock platform being the major control on sediment movement and upstream bed levels, whereas the modelling as depicted in Figure 3-3 of the Sediment Report indicates the bed level (thalweg) entry to the rock-bound channel as the control. The thalweg profile then gives a 3m height to the weir which clearly has a greater impact than the less than 1m weir height above the rock platform. Survey data from 2012, assumed to be representative, gives an upstream bed slope in 1 vertical in 40 horizontal, whereas the thalweg in Figure 3-3 of the Sediment Report is about 1 in 50. Thus, whether a 3m height to create a flat pond 3x40 = 120 to 3x50 = 150m long or a 1m height of weir, with a 40 to 50m long pond, the effects upstream will not be large and will be limited in extent.

(d) Coarse sediment transport down the river should continue with very little change from what occurs now. The weir will not form any significant pond and thus gravel will continue to pass over it just as it does currently over the rock platform, and the sluice gate will in large part compensate for the blocking off the narrow rock-bound channel. Very little gravel sized material is expected to be moving at flows less than when the river flow is two to three times the abstracted flow and thus the sluice gate can be operated whenever significant gravel movement occurs.

Reasons for Side Intake option

13. My principal reasons for not going with a stream bed (Tyrolean) intake, as the main alternative to the side intake, are detailed below.

(a) A stream bed intake screen would be in the order of 20m wide across the river. On the likely weir line for this option, the total weir width would be about 30m. This is different to other screen bed intakes such as at the Branch, with the screen constituting one third of the weir crest, or Amethyst (with the 2.5m long screen on a 14.5m total crest length). Assuming a uniform distribution of bedload across the river, the screen would unavoidably be subject to about two-thirds of the bedload. A large portion of this would be sand and fine to medium gravel which would be drawn in with the abstracted flow through the screen. How to deal with this high volume of sediment is problematic. Designing the desander for high volumes and fine-to-medium gravel stone sizes rapidly becomes uneconomic and diverting the sediment back to the river at the intake is difficult (and it creates other adverse landscape/visual effects). Closing the intake gate and shutting down the scheme once river flows are high enough to mobilise a significant bed load is in my opinion the only sensible[2] option for a stream bed intake. This shutdown would almost certainly be lower for a bed intake than the side intake, which in turn results in loss of generation. The advantage of the side intake with the sluice channel in front of it is that it should be exposed to a much smaller proportion of coarse bed load.

(b) There is an unavoidable loss of head with the Tyrolean option which results in less power generation.

(c) The depth of channel and extent of structural concrete to precise dimensions needed across the river with the stream bed intake option is substantial and hence the risk of damage and delay from flooding is greatly increased, both from the much longer construction period needed, and the exposure of more complicated construction to damage. The issue of river diversion is considerably more complicated, as is maintenance of the screen bars and intake.

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[2] Following problems at the Branch Hydro, Royds Garden spent considerable effort in developing a double screen intake for a scheme proposed for the Waingawa River in the Wairarapa. The upstream screen intercepts most of the bed load able to pass through the screen and discharges directly downstream back to the river, leaving a much smaller amount of sediment to enter the second screen, which discharges to the desanding basin. In theory this system should work, although to my knowledge has never been built. However it has disadvantages in that the whole weir structure becomes much larger in both width and height.

(d) The stream bed intake does not work well when submerged with reduced longitudinal flow velocity to the headworks and hence increased risk of sediment build up. Also, when shut off for any reason (maintenance, plant shut down, emergency), the intake slot is likely to at least partially fill with sediment, with consequential difficulties in clearing.

(e) The idea of the stream bed intake orientated parallel to the bank was considered as it should reduce the bed load entering it, and it is easier for river diversion, but the other aspects remain the same. There is a significant issue in how it could be designed with any degree of confidence given the steep river gradient at the site. I have severe reservations as to whether it could be made to work.

14. Given the similarity in overall scheme layout, it is worth commenting on why the stream bed intake as used at Amethyst was not selected here:

(a) the Amethyst has less than 10% of the diverted flow (1.6 m^3/sec), making the screen and intake channel sizes much smaller;

(b) the screen length to weir length ratio is relatively small (17%), the high head scheme meant that the loss of head associated with a stream bed intake was not significant;

(c) the intake was located at the top of a very steep cataract which meant that submergence of the screen would not occur; and

(d) the geometry of the site allowed for a deep gravel trap immediately downstream of the intake, outside and upstream of the de-sanding bay on the tunnel, such that trapping and sluicing of larger sediment could be very easily achieved.

Response to Peer Review Questions on Weir

15. My response to the question of a weir being the “best” intake type for this location as presented by Mr Morgan in his section 3 is:

(a) The weir will not be a significant barrier to sediment transport and will not be greatly different to what is currently there with the rock platform. There will be little change to gravel bed levels upstream and very little volume to be filled.

(b) Adopting Dr Hicks’ more conservative assessment, at low flows the weir will not create a backwater for more than about 200m upstream and will not permanently flood areas currently flooded in high flows only.

(c) The area immediately upstream will fill with sediment and regrade to some extent as indicated by Dr Hicks modelling (3.5 of the Sediment Report). Typically, this will be less than 1m maximum depth close to the intake but outside the immediate area of the rock channel and zero depth at about 300m upstream extent, using Dr Hicks numbers. This is only a small modification occurring to a highly dynamic environment and is not beyond what naturally occurs.

(d) A 7m inferred weir height is in fact the height of the sluice gate structure, which will cut into the rock a similar amount. As seen on Figure 3, the weir itself will be about 3m above rock level across the existing river channel, but generally less than about 1m across the right side and 1m below the highest rock level profile on the left side.

16. To re-iterate, early in the project I started with a Tyrolean stream bed intake as my preferred concept, but for similar reasons to those above I decided the side intake was preferable, and by a wide margin. Revisiting the question again in 2025 only confirmed my previous conclusion.

Ian McCahon

Appendix A: Qualifications and Experience

1. I retired from my professional life in 2024, but previously worked for fifty years as a civil and geotechnical engineer. My qualifications are BE (Hons) from University of Canterbury 1975. I was a chartered professional engineer from 1979 until 2024 and a Fellow of IPENZ. I worked for Royds Sutherland McLeay and that firm's successors from 1979 until 1999 in a variety of roles from design engineer to principal, and for Geotech Consulting Ltd as director from 1999 until 2024.

2. I have worked on hydro power and irrigation schemes throughout my career since 1979, although geotechnical engineering became my main focus from the late 1980s.

3. I have worked on a number of hydro schemes on the West Coast, including civil and hydraulic design of Waihapo Hydro (1989-93), a feasibility study on Taipo River (1997), Dillmans Hydro upgrade (1989-90), a feasibility study for upgrade of Arnold Hydro (1996-98), design of desanding basin at Haast hydro (1989), intake site selection and design for Inchbonnie Hydro (2011-14), feasibility studies for Kakapotahi, Amethyst & Waitaha hydro (2005-2014) and feasibility study and design of the headworks for Amethyst Hydro (2005-15).

4. Other detailed design work has included the 7m high concrete weir with crest gates at Paerau (1983), replacement of the Waihopai dam spillway (2005), debris flow and flood protection works on very steep rivers at Mt Cook village in 1998-99, intake and desanding basin at Clearwater (2009) and a low weir on sheet-pile cells with crest gates on Sarawak River for Kuching water supply (2000-03).

5. I have also carried out feasibility studies for three hydro schemes in Indonesia (1985), three in Laos (1997), and a 68MW scheme in the Philippines (1996-1998). Technical reviews include 8 small hydro in Australia (1992-95,) 6 in New Zealand, and 2 in Taiwan. I assessed the impact of probable maximum floods on the 8 Waikato River dams in 1997. My experience with river channel design has included 2 x 2km diversions on the Fraser river and one on the Waikaka River around mine sites (1998 – 2002), Harper River (1997), Tekapo Canoe Course (1997-98) and Training works at Waihopai Hydro (2014).

6. Of most relevance to the Waitaha Intake are the following

    (a) Branch Hydro Scheme (1983-84): I was design engineer for the 11m high buttress dam incorporating a 20m wide stream bed intake screen, intake culvert and desanding basin. The design incorporated a physical hydraulic model of the desanding basin, as the limited head required a wide basin relative to its depth and length. My involvement extended through commissioning and the early period of operation which gave me insight as to how well the intake functioned.

(b) Haast Hydro (Turnbull River) 1989: The low-pressure pipeline fed from a side intake in a natural river pool had to be replaced because of sediment erosion to the invert, and a desanding basin was installed. I was responsible for the hydraulic and structural design of the twin basin to allow continuous power generation during flushing. The basin has worked as expected and very successfully.

(c) Clearwater Hydro (Rakaia Gorge) 2009: Design of stream bed intake and settling basin on very steep gravel alpine riverbed subject to debris flow.

(d) Wainihinihi Intakes (Dillmans Hydro Scheme): I was the designer for small settlement basins added to the Ahahura intakes and the rebuilding of the Big Wainihinihi Intake weir following damage from rockfall. All the intakes are stream bed intakes.

(e) Amethyst Hydro Scheme (2005-2015): I was responsible for feasibility studies, selection of alternative intake sites and tunnel alignments, and the concept design of the intake with stream bed screen, gravel trap and settling basin inside the tunnel.

Appendix B: Code of Conduct

As an expert witness I have read, and I am familiar with, the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2023. This memorandum has been prepared in compliance with that Code. In particular:

- my overriding duty is to assist the decision-maker impartially on matters within my expertise;
- unless I state otherwise, my assessment is within my area of expertise, and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express; and
- I have not, and will not behave as, an advocate for the Applicants.

Appendix C

Intake Preliminary Concept and Options - 2013

Waitaha Hydro Scheme

Morgan Gorge Intake

Preliminary Concept and Options

DRAFT

1 Introduction

This preliminary report outlines the possible intake options for the proposed Waitaha Hydro-power scheme with a flow of 20 m3/s diverted from the Waitaha River at the downstream end of Kiwi Flat through a tunnel to a powerhouse below Morgan Gorge.

2 Intake area

This site is immediately upstream of the entrance to Morgan Gorge. The site has some unusual features

- Morgan Gorge is a very steep sided slot gorge which appears in places to be as narrow as 6 – 7m and 20m deep close to the top end and deeper further downstream.
- Upstream of the gorge, the river flows over a wide gravel bed within Kiwi Flats. About 0.5km upstream of Morgan Gorge, the whirling Water enters at a rock bluff on the true left, and the active river channel is restricted to about 100m width. Within a short distance the river bed gradient increases and falls an estimated 10m into the gorge entrance.
- At the gorge entrance, the river channel extends through a platform of rock on each side, about 2 – 3m above normal water levels for about 20m upstream of the gorge proper.
- There is clear evidence in vegetation lines, fine sediment deposits and debris, that in large floods, the river ponds upstream of the gorge and this backwater effect extends up to about the Whirling water confluence. The flood depth at the gorge entrance is estimated to be 8 – 9m above the normal water level.
- The bed levels in the section of river upstream of the gorge are likely to controlled by the combination of the backwater effects of the flood levels and sediment load. During large floods, when the bulk of sediment transport occurs, the backwater will reduce the flow velocities and bedload is likely to be dropped by the flow, almost as a delta formation. Once the flood recedes, the river is then able to remobilize this material because of the steep gradient down the “delta” face. The bed levels in the 400m upstream of the gorge are therefore likely to fluctuate considerably during and following large floods.

Any intake must allow for this substantial flood rise. Earlier work suggested that the backwater effect at the gorge entrance was the result of a partial constriction with a rock fall in the gorge, and that some work could be done to remove the constriction. Flow analysis of the narrow gorge section now indicates that the backwater is explained simply by the narrow width, and there is unlikely to be any way of reducing the flood depth.

3 Possible intake configurations

There are several possible intake configurations for the scheme.

- Low weir at the gorge entrance, founded on the rock platform, and diverting water directly into a tunnel and sediment settling basin in an underground chamber at the top end of the penstock tunnel
- High weir at the gorge entrance, which could allow for a settling basin on the flats upstream of the gorge, or in a rock cut to the side of the gorge
- Weir at the rock bluff at the Whirling Water confluence, with settling basin on the terrace on the true right bank.

4 Low weir at Gorge entrance

4.1 Stream bed intake

A weir would be constructed across the river between and over the rock platform upstream of the gorge proper. The weir would have a crest of about 35 m, with a stream bed intake taking up about 20m of this. It could be about 5m height above the exposed rock with a crest level at the screens of about RL242 and 8 – 9m high across the river channel.

The intake chamber in the weir leads to a culvert about 3.5m wide which enters a tunnel bored into the steep rock face on the right abutment. The tunnel portal will need to be protected with a high gate structure to prevent flooding. As soon as rock quality and geometry allow, the culvert widens into a settling basin to remove the sand and gravel in the flow. The topography of the site is such that there is no alternative to siting the settling basin in a cavern below ground. The settling basin can be made narrower and deeper than the basin planned for the upper site, but allowing an access roadway alongside the basin between the gate structure and the penstock intake, a cavern width of 16 – 18m. The rock is sound, but extensive roof support is likely to be necessary. A weir at the downstream end of the settling basin takes the flow into a penstock intake and the penstock. A small tunnel about 130m long will be driven from the downstream end of the settling basin to return flushing flow to the river. The tunnel length is subject to detailed study, as it will be necessary for the tunnel exit to remain above flood levels in the gorge, which could remain very high for a considerable distance through the gorge.

The stream bed intake has been proven to be effective on steep mountain rivers with high bed load, but there can be problems with the amount of sediment entering through the screens requiring intake shut down during periods of high flow and high sediment transport. This is likely to be an issue at this site as the width of the site means that the intake grill will extend over a large proportion of the weir crest, and a similarly large proportion of the bed load will pass over or into the screens. Therefore a double stream bed intake is proposed, with two intake slots and screens, one immediately upstream of the other. At low flows the upstream intake is shut and all the flow enters the second downstream intake. When flow increases past a threshold where appreciable bedload is moving, the upstream intake is opened and the bulk of the bedload finer than the screen size enters this intake and is flushed back into the river immediately downstream of the weir. The water closer to the water surface will enter the second intake and pass through to the culvert and settling basin. This double screen significantly increases the size and complexity of the weir which would be a minimum of 9m wide.

The stream bed intake system requires a tunnel portal invert little above normal water levels at the gorge entrance, and the portal is thus exposed to even minor flood inundation. The intake gate structure has to be built prior to the tunnel break through. This will necessitate a short access tunnel to be built from the penstock tunnel to a second portal well above conceivable flood level to provide construction access and access for maintenance and operation. A road will need to link the second portal and the weir site.

The height of weir needed for a stream bed intake is likely to make the weir the hydraulic control rather than the gorge, and thus flood levels could be raised by 4 – 5m upstream of the weir. This will extend the flooding a further 300 – 400m up the river (taking an average bed slope of about 1:80 above the Whirling Water confluence. There would be aggradation of the river bed by about 5m at the weir, and while major aggradation is likely to be confined to the step bed section within about 400m of the weir, the increased flood levels could have a long term effect on bed levels through a large portion of the Kiwi Flat.

The stream bed intake is normally used in an open river situation, such as applies at normal flows. However, with the choking effect of the gorge, during floods, the intake becomes completely submerged in slower flowing water. The effectiveness of the system is questionable under these circumstances. In addition the double screen arrangement adds probably 2m to the weir height, and the impact of the weir could be significant in terms of aggradation and flood levels well upstream from the intake. For these reasons an alternative side entry intake is probably better, as discussed below.

4.2 Side Entry Intake.

This option is similar to 4.1 in overall arrangement and the tunnel and settling basin remain the same but the weir becomes a simple concrete wall to control the river level. The works in the river are:

- The weir is a simple shape approximately 30m crest length and a crest level of about RL238m, making it less than 2m height over most of the rock platform and perhaps 5 – 6m high through the river channel.
- A channel is cut through the rock platform on the right bank. An opening in the side wall, about 1m above the channel invert, takes flow into the tunnel. The channel is fitted with a sluice gate downstream of the intake opening to allow bed sediment to be flushed past and below the intake, and the channel walls extend upstream to provide flow alignment . This channel can be sized to act as diversion while the weir across the river channel is constructed.
- A tall structure is required to prevent flood water entering the tunnel; this could also be fitted with an additional intake opening at a higher level to be operated during floods to take the water from further away from the bed load.

With this option, it is expected that the weir would have little impact on the flood levels which would be still controlled by the gorge, and thus the impact of the intake on the river flow would be confined to within less than 100m of the weir. Aggradation is expected at the weir itself but is unlikely to extend more than 100 – 200m upstream, within the steep section of bed controlled by drawdown after floods.

This option is considered to be the better arrangement for a low level weir at the gorge as it is likely to operate better during large floods, be simpler and easier to build, and have significantly lower potential impact on the river upstream.

A second access tunnel and portal and road to the weir will still be needed. The structure around the intake tunnel portal must be built prior to tunnel break out to protect the works from flooding.

5 High level weir at Gorge

It would be possible to build a structure about 10m above the rock platform, or an estimated 15m above the river channel invert across the river just upstream of the gorge entrance. The concept would be include large gates in the structure to pass flood flows and thus reduce the impact on water and bed levels upstream. The intake to the scheme would be at the high level. This should allow:

- Settling basin to be constructed in a deep open cut rather than being confined to within a tunnel
- Alternative settling basin on the terrace upstream of the gorge, with much less earthworks but an intake race about 200m long
- Places the tunnel portal above normal flood levels thus eliminating the need for a second access portal
- Increases the head on the scheme by about 10m
- Flushing through the flood gates, or a specific sluice gate near the base of the dam, would provide a small l to provide a small buffer in operation and reduce the sediment issues into the scheme.

This option would increase water levels well upstream of the weir and well into Kiwi Flat with consequent aggradation impacts. For a major structure such as this, river diversion may require a diversion tunnel rather than an open channel across the rock platform. The structure would be potentially subject to strong seismic shaking in the event of an Alpine Fault earthquake and this loading may require a substantial structure section.

The environmental impacts of this option are such that it is unlikely to be acceptable, but is included here for completeness and as an alternative with significant engineering advantages in terms of scheme output and construction of the settling basin.

6 Weir at Confluence

An alternative site for the intake is opposite the rock bluff just downstream of the confluence with Whirling Water. The rock provides a good abutment on the left bank, and a vegetated terrace on the right bank suggests a stable flow regime that limits the width of river bed to about 100m. A low weir could be built across the river with a stream bed intake incorporated in the right end. River training could reduce the overall width of structure to perhaps 50m. The alluvial bed would mean that some flow would bypass the intake but this could contribute to the residual flow.

A structure 2 – 3m high is likely to be required. This would pond water up to 250m upstream and cause bed aggradation which could ultimately effect the whole of the river through Kiwi Flat. The better option would be to design the weir as a gate structure such that in large floods the gates open and the existing bed levels are maintained.

A culvert would carry the abstracted water into a settling basin located on the terrace on the right bank. The location of the tunnel portal could then be chosen to best suit the geology rather than the geometry of the headworks, and there is no need for a settling basin within the tunnel. This location would provide 5 – 7m more head on the turbine than the low weir option at the gorge.

Major issues with this option are:

- How to design an economic weir structure across a wide alluvial bed
- Increase in river water levels upstream of the weir
- Potential bed aggradation well upstream of the weir

7 Conclusion

The high level and Confluence options both have considerably greater environmental impacts than a low weir at the gorge entrance, although they also have some significant benefits on the engineering side and increased generation.

Of the low weir options, the side entry intake is clearly the better choice in terms of likely performance, simpler construction, particularly while working in the river, and minimal environmental impacts. This option does require the siting of the settling basin inside an enlarged tunnel or tunnels (depending on rock quality, it may be best to divide the basin into two parallel parts each within its own tunnel rather than attempt a single basin in a tunnel which could be 15 – 20m wide).

Ian McCahon
Geotech Consulting Ltd

17 April 2013

Appendix D

Preliminary Headworks Concept – August 2013

Waitaha Hydro Scheme

Morgan Gorge Intake

Preliminary Headworks Concept

Contents

Attachments

Ian McCahon
Geotech Consulting Ltd
Issue 3
1 August 2013

1 Introduction

This preliminary report outlines the concept design of the headworks for the proposed Waitaha Hydro-power scheme. The hydro scheme is to divert a flow of up to 23 m^3/s from the Waitaha River, with the intake located at the upstream end of Morgan Gorge where the river discharges from the wide gravel bed across Kiwi Flats into a narrow rock walled slot gorge. From the headworks the scheme flow is taken through a penstock in a tunnel to a powerhouse well below Morgan Gorge to develop about 100m of head. The selection of the intake configuration is outlined in a previous intake options report.

The proposed arrangement includes:

- A low weir across the river
- An intake channel on the right bank which takes the river flow to the intake gate and incorporates a channel and gate to sluice sediment past the intake
- An intake gate housed at the start of a roofed culvert to convey the flow into the tunnel portal
- A second intake gate mounted in a shaft constructed in the natural rock face, to allow water intake during high flood periods when the lower gate will be subject to high sediment load
- An underground sediment settling basin
- Collection channel and penstock intake
- Sediment flushing tunnel
- Tunnel to access basin for maintenance
- Tunnel to access portal and intake

The concept is shown in the attached drawings A-1 to A-5.

2 Intake area

This site is immediately upstream of the entrance to Morgan Gorge. The site has some unusual features

- Morgan Gorge is a very steep sided slot gorge which appears in places to be as narrow as 6 – 7m, is 20m deep close to the top end, and deeper further downstream.
- Upstream of the gorge, the river flows over a wide gravel bed within Kiwi Flats. About 0.5km upstream of Morgan Gorge, the Whirling Waters tributary enters at a rock bluff on the true left, and the active river channel is restricted to about 100m width. Within a short distance downstream of this point, the river bed gradient increases and falls an estimated 10m into the gorge entrance.
- At the gorge entrance, the river channel extends through a platform of rock on each side, about 2 – 3m above normal water levels for about 20m upstream of the gorge proper.
- There is clear evidence in vegetation lines, fine sediment deposits and debris, that in large floods, the river ponds upstream of the gorge and this backwater effect extends up to about the Whirling Waters confluence. The flood depth at the gorge entrance is estimated to be 8 – 9m above the normal water level.
- The bed levels in the section of river upstream of the gorge are likely to controlled by the combination of the backwater effects of the flood levels and sediment load. During large floods, when the bulk of sediment transport occurs, the backwater will

reduce the flow velocities and bedload is likely to be dropped by the flow, almost as a delta formation. Once the flood recedes, the river is then able to remobilize this material because of the steep gradient down the "delta" face. The bed levels in the 400m upstream of the gorge are therefore likely to fluctuate considerably during and following large floods.

Any intake must allow for this substantial flood rise. Earlier work suggested that the backwater effect at the gorge entrance was the result of a partial constriction with a rock fall in the gorge, and that some work could be done to remove the constriction. Flow analysis of the narrow gorge section now indicates that the backwater is explained simply by the narrow width, and there is unlikely to be any way of reducing the flood depth.

3 Weir

The weir is shown in plan on A-2 and in long section on A-3. It is a simple concrete wall with a crest level of RL238, which is generally 1 – 2m above the rock level on the right abutment (looking downstream). A reinforced concrete structure of about 1m width is envisaged, secured with rock anchors. The section across the river channel is likely to be 4 – 5m high, but at the chosen location, the channel is only about 4m wide, so that the structure will span horizontally as well as vertically.

It is envisaged that this channel section will have a depressed crest at RL 237.35m. This will pass the residual flow, assumed to be 3.5 m3/s with the upstream water level at RL 238. This arrangement concentrates the residual flow into a chute and thus allows kayakers use of the river at all times. Other arrangements are also possible, including having one crest level throughout, or an irregular crest level or weir partially constructed from large boulders bolted and concreted into place to provide a more natural appearance.

The section of weir across the channel can only be constructed with the river diverted. It is likely to be impractical to determine the depth of the channel or bed material until after dewatering, given the very turbulent flow at this location. Construction will require the diversion of the river through the completed intake channel to allow a coffer dam to be built across the river channel both upstream and downstream of the weir. This will be an unavoidably high risk part of the construction very exposed to flooding. It must be well planned and resourced to minimize the time in the river and exposure to flooding and damage.

4 Intake Channel

This channel is designed to fulfill three functions

- Act as a diversion during construction of the weir across the river channel
- Divert the river flow in an appropriate flow alignment to the scheme intake
- Provide a sluicing channel in front of the intake to prevent most of the larger bedload entering the intake.

The rock platform on the right bank provides an excellent location for this channel. Blasting will be required to cut the channel into the rock by generally about 3m and the upstream corner of the gorge will have to be trimmed with a 6m high cut to provide a suitable alignment.

The floor will be concreted to provide better hydraulic conditions for sluicing sediment and the channel confined with side walls about 4.5m high.

The alignment has been sketched to keep the channel sufficiently back from the river channel to allow the rock between to remain with low risk of being inadvertently damaged during excavation and thus allow the channel construction to continue with some security from flooding. A gravel bank is assumed to be built across the upstream end to keep small to moderate floods away from the site. The curved alignment assists in setting up a secondary flow which helps pull sediment away from the intake when the sluicing gate is operated. The channel is sized at 4m width at the gate to keep flow velocities high enough to entrain bed material and move it past the intake.

The concept is for the intake channel to be completed prior to the weir construction. When the weir is to be built, the temporary stopbank would be removed and the river diverted into the channel. On completion of the weir, the gate can be shut and the intake becomes operable.

5 Intake

The intake has been sized as a 5m wide passage out of the side of the intake channel. This opening will be controlled with a radial gate housed within the structure at the upstream end. The structure has been kept deliberately low and thus will be covered with a roof and removable hatch to allow infrequent maintenance access. The top of the structure will be subject to about 7m head of water during large floods and thus the structure will need to be substantial to withstand the imposed loading.

A second auxiliary intake is to be located in a short shaft constructed within a slot cut into the rock face at the tunnel portal. This shaft will also be fitted with an access hatch at the top, and will house a second intake gate. The gate will normally be kept close, and will only open during periods of flood, when the sediment load likely at the lower intake level is likely to be too high to be handled effectively. Thus by shutting the lower gate and using the higher one, it should be possible to minimize bed load entrainment into the scheme.

The intake structure is envisaged as integral with the tunnel portal. Because of the flood risk, the intake structure, higher level intake shaft and portal must be built before the tunnel is broken out.

6 Settling basin

The water taken from the river will carry suspended sediment, and at times some bed load. To prevent undue wear on the turbine and penstock, as much of the coarser sediment as possible should be removed. The current concept is for a traditional settling basin designed to allow the flushing of sediment back to the river. This arrangement is proven but there are a number of other arrangements possible, with a potential for a reduction in amount of tunneling needed.

From the portal the flow is taken by a 5m wide channel for about 25m into the hillside. At this point the tunnel and channel splits before widening and deepening to provide two ten metre wide settling basins. As the channels are 2.5m wide, and as the tunnel itself will need to be wider to provide access for tunneling plant during construction, the channels will need to be formed with side walls to about 1m height. The invert will also need to be concreted to provide the hydraulic smoothness required, unless a steeper gradient is adopted with an increase in head loss.

The two basins are adopted as this allows flushing of one basin while still generating off the other, and reduces the width of the underground excavation. There is limited cover above the settling basin and two narrower tunnels are likely to encounter fewer problems with tunnel support than a single much wider cavern. The settling basin has been provisionally dimensioned at 60m long. No optimization has been carried out, and the length could change to be either shorter or longer (perhaps a range of +/- 20m). The floors will probably need to be concreted to provide the right hydraulic conditions for flushing, and the walls may need shotcreting to reduce water loss.

At the downstream end there will be a weir to take the generation flow from the top of the basin into a cross channel which leads to the upper end of the main tunnel. The cross channel floor will be a concrete slab spanning over four channels, forming a continuation of the settling basin floor leading to four flushing gates. When open these discharge into the flushing tunnel to return sediment to the river (see 8, below).

7 Penstock intake

The cross tunnel channel (refer A-1) takes the generation flow to the penstock intake. The channel will curve around to meet the top end of the main tunnel, where the penstock intake will be located. This is envisaged as a simple wall across the full section of the tunnel, fitted with a gate and penstock entry. This wall seals the settling basin from the main tunnel so that if the settling basin did become completely flooded, it would not spill to the main tunnel. The intake in the cross tunnel allows this feature, which also provides support to the wall on all sides and thus reduces the wall thickness requirements.

The penstock will be located on the right hand side of the main tunnel to allow support directly to the tunnel wall at a bend likely to be needed towards the downstream end.

The cross channel levels are determined by depth of flow and flushing channel height in the settling basin chambers, and the depth of submergence needed for the penstock intake.

8 Flushing tunnel

The flushing gates will discharge into extensions of the main settling basin chambers and then into narrower adits which merge into one tunnel which curves to return to the river. The outlet to this tunnel is about half way down the gorge, downstream of one sharp bend at the downstream end of the very narrow gorge section, and on the outside a second bend, with the gorge becoming wider still downstream. The river bed has probably dropped about 15m from the top of the gorge to this point and this should mean the tunnel invert is about 10m above the river bed. The adit outlet should be above even extreme flood levels. Additional investigation, survey and modeling is needed before the location of the adit outlet can be confirmed.

Flushing would normally be carried out during floods or on their recession when the river is already turbid and at relatively high levels. It is not envisaged that there will be any significant impact on river turbidity or that the discharged sediment will build any appreciable fan at the outlet.

The flushing tunnel has been shown as 4m wide and a similar height, with a gradient of about 1 in 70. The actual dimensions will depend on what tunneling equipment is available; it may be more economical to create a larger cross section.

A short drive is shown connecting the flushing tunnel and the main tunnel. This may be of use in allowing the flushing tunnel to be constructed independently of the settling basin area, but its primary role is to provide long term access for plant to the flushing tunnel and the settling basins for maintenance, repair, or clearing of blockages, should they occur. Small plant should be able to access the basins through the flushing gate openings. This short drive will need to be aligned vertically to prevent any water from the flushing tunnel flowing into the main tunnel, which will be at a lower level.

9 Access Tunnel

Because of the need to construct the intake before breaking out the settling basin tunnel for both programming and risk reasons, a separate tunnel to a high level portal is needed. For a number of reasons, including the need for the penstock to be on the right hand side of the main tunnel and therefore access on the left, providing access to the flushing tunnel, clearance to the cross tunnel to the penstock intake, and maintaining a usable road gradient, the access tunnel will need to start about 60m downstream of the penstock intake and climb at about 1 in 8 gradient to pass over the cross tunnel. The alignment of this tunnel can be determined by the best location for the portal. It is assumed that a 5m by 5m cross section would be adequate; again the actual size may be determined by economics and available equipment.

10 Access Road.

A short road is needed between the access tunnel portal and the intake structure for construction and maintenance. The alignment has been sketched as indicative only on Figure 1. It will necessitate some tree clearance, earthworks on a steep hillside, and river protection at the toe.

11 Construction sequence

The following is a possible order of construction:

a) Form main tunnel to end of penstock
b) Continue with access tunnel and high level portal. As well as providing access to the intake, this also provides through tunnel ventilation and a second tunnel egress
c) Excavate cross drive and access drive to flushing tunnel, construct access road to intake
d) Start intake structure and channel in the river bed
e) Excavate settling basins, using the cross drive as access. The grade in the cross drive is kept to an acceptable level to allow plant access.

f) Concrete work to one settling basin
g) Construct flushing tunnel
h) Complete intake structure to safeguard portal from flooding
i) Break out hydraulic tunnel to the portal and completed intake structure
j) Complete concrete work in settling basins
k) Construct penstock intake
l) Complete intake works and weir
m) Lay penstock

Note: it is assumed that all tunneling work involved with the excavation of the settling basins would involve mucking out to the downstream entrance. Two alternatives are possible: mucking out through the high level portal to a dump site in the bottom end of Kiwi Flat, or dumping out the flushing tunnel into the river. It is assumed that the latter is unacceptable. The former is possible but requires a longer road either through bush or up the river bed.

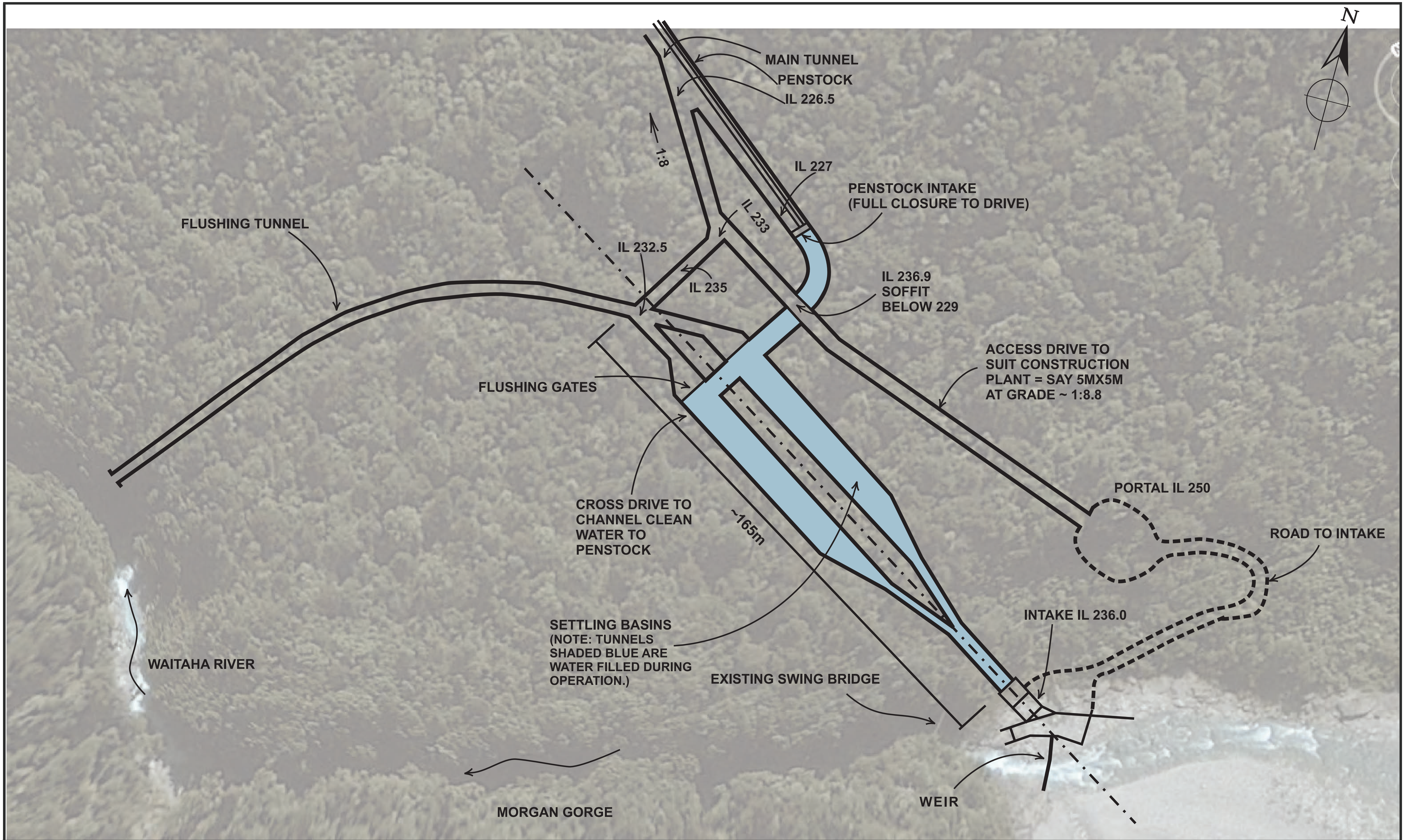
12 Operation

The operation of the headworks may be quite complex. The following are some initial comments.

To maintain the residual flow, the water level at the intake during low flow periods will need to be maintained at RL238. Therefore for river flows less than 25 m^3/s, operation will need to be by means of the intake gate to control the inflow into the scheme and thus the water level at the weir and residual flow in the river. For flows above 25 m^3/s, the water level could be controlled by the sluice gate, and for flows above 40 to 50 m^3/s (this is indicative only and will depend on actual behavior of the river and intake) when bedload movement might be expected, the sluice gate should be opened to provide constant flushing past the intake. For flows higher than about 25 m^3/s, the upstream water level is of little consequence and the intake gate operation would be better controlled by the water level in the settling basin. While excess flow through the basin would safely spill over the end weir and out the flushing channel, the higher than design flow would adversely impact on the settling basin performance – at a time when sediment is higher and the basin is really needed. Therefore it is desirable to keep the basin flow to the design level.

As the river flow increases to above about RL243, the lower (main) intake gate might be best closed and the higher auxiliary gate opened, to reduce the entrainment of bed load into the intake, as discussed in section 4.

The settling basins are set out so that they operate independently of each other. One can be flushed and the other operated. The generation flow is best controlled from the penstock intake. As drawn this channel has a water surface area of about $450m^2$. For an increase in generation flow of 1 m3/s, this gives little more than 20 seconds of storage to draw down 1m, if the inflow was constant. Additional volume may be needed to ease operational tolerances. If both settling basins could be incorporated into the buffer this would provide a total area of about 2000 m^2. However, to do this would require the end weirs to be lowered with the effect that single basin operation would not be possible as water would flow out of the full basin and back into the drawn down basin. It may also be possible to move the penstock intake further down the main tunnel and increase the cross channel storage in this way.

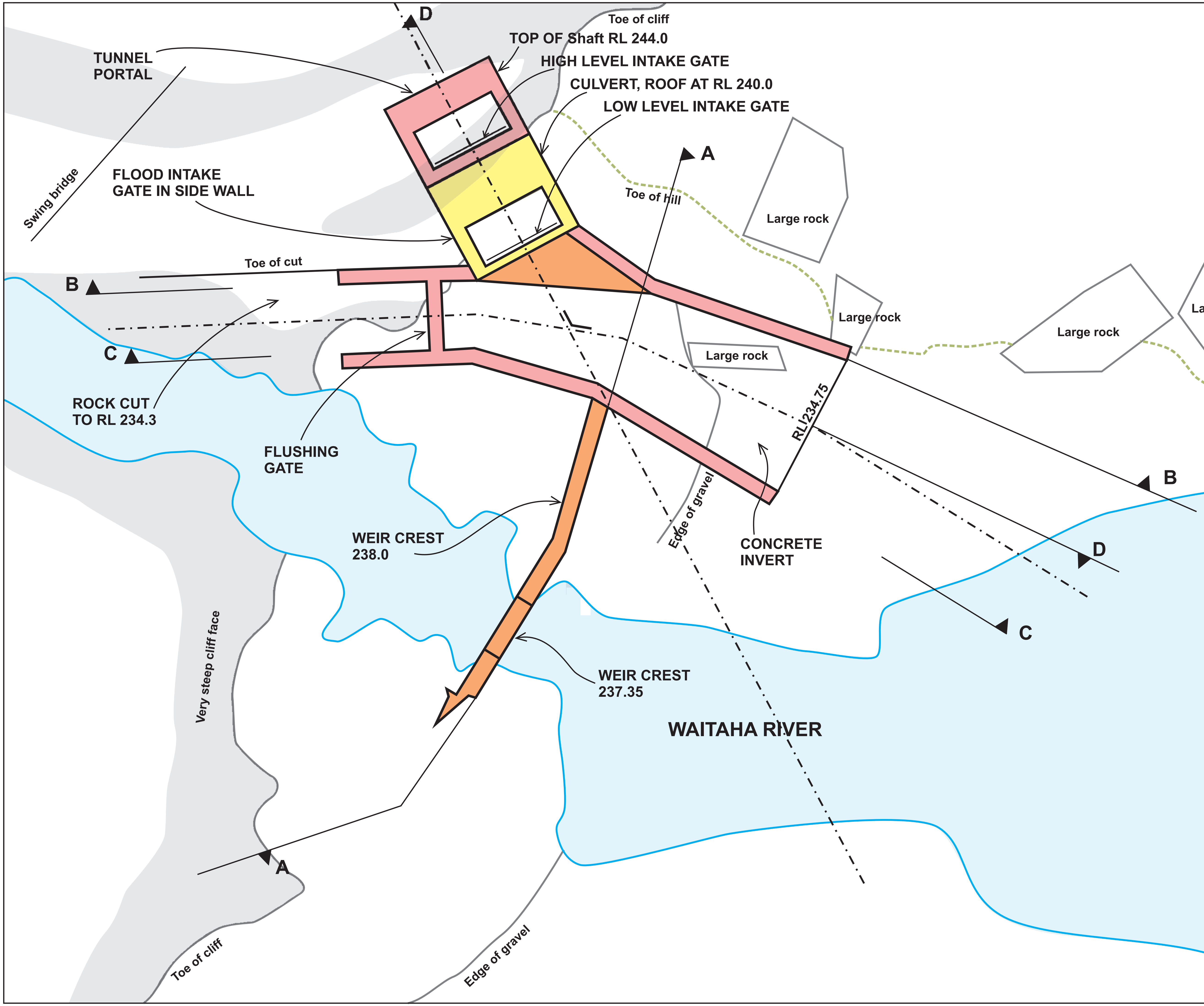


GEOTECH

Waitaha Hydro

Concept Plan of Headworks at Morgan Gorge

SCALE:	1:4000 (Approx.)
DRAWN BY:	RJT
DATE DRAWN:	09/05/2013
CHECKED BY:	IMC
FIGURE No .:	2818 - A1



Waitaha Hydro Scheme
Headworks Concept

Intake Plan

SCALE:	1:200 (Approx.)
DRAWN BY:	RJT
DATE DRAWN:	8 May 2013
CHECKED BY:	IMC
FIGURE No .:	2818

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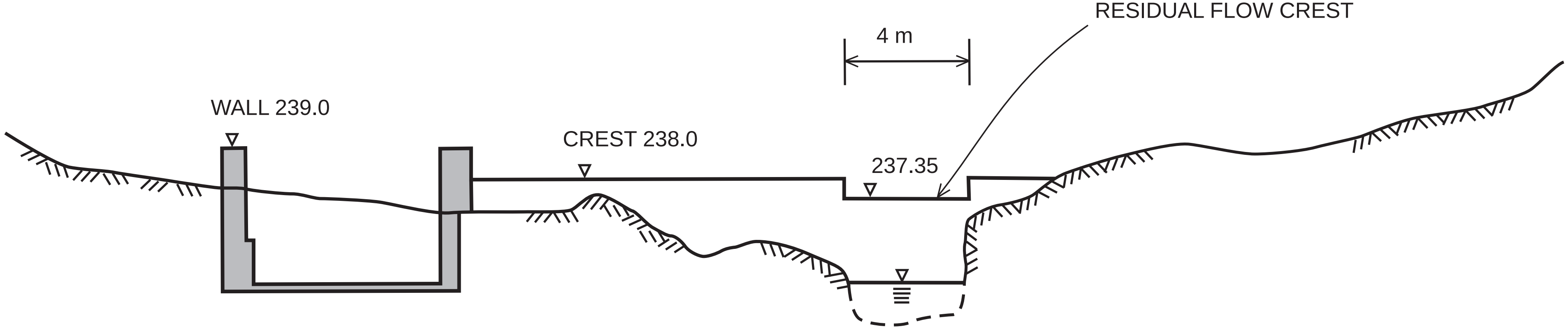
Waitaha Hydro - Headworks Concept

Intake sections A-A Weir

Intake Channel

SCALE: **1:200** (approx)

DRAWN BY: RJT
CHECKED BY: IMCC
DATE DRAWN: 17/05/2013
JOB No.: 2818
FIGURE No.: A-3



A-A' SECTION ON UPSTREAM FACE OF WEIR
(VIEW TO UPSTREAM)

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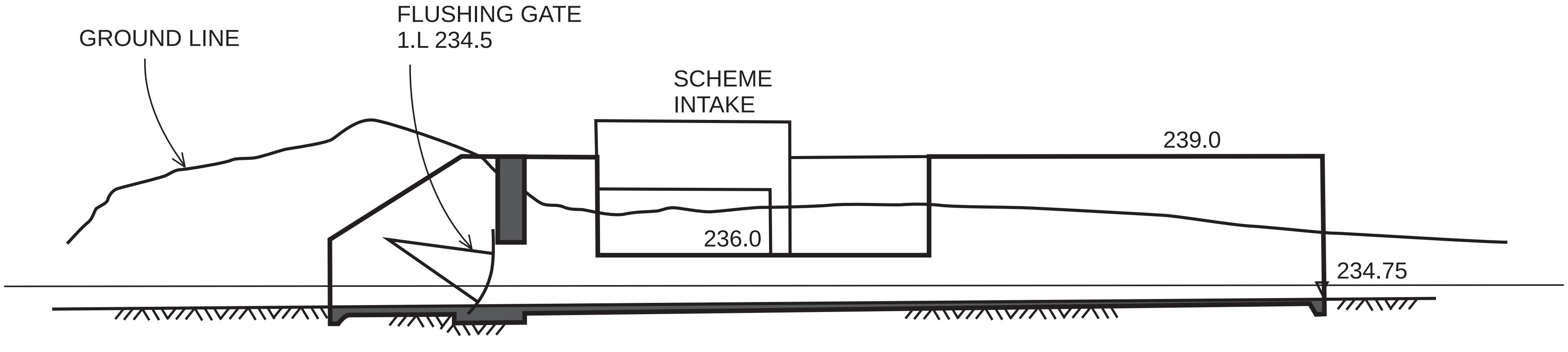
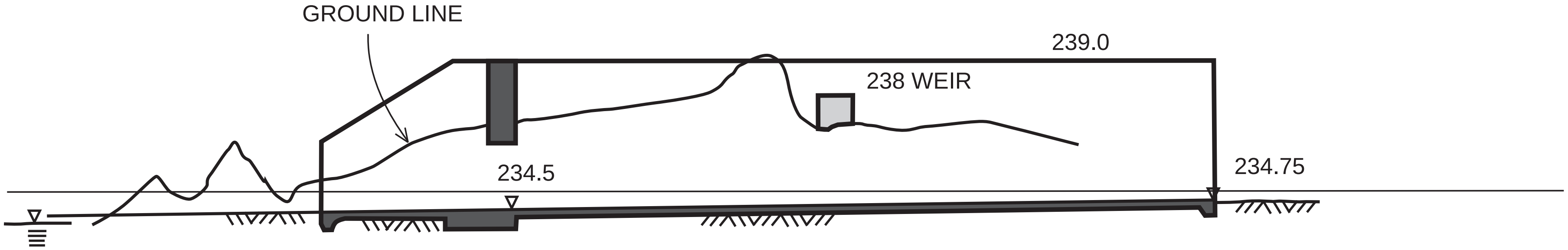
Waitaha Hydro - Headworks Concept

Intake sections B & C
Intake Channel



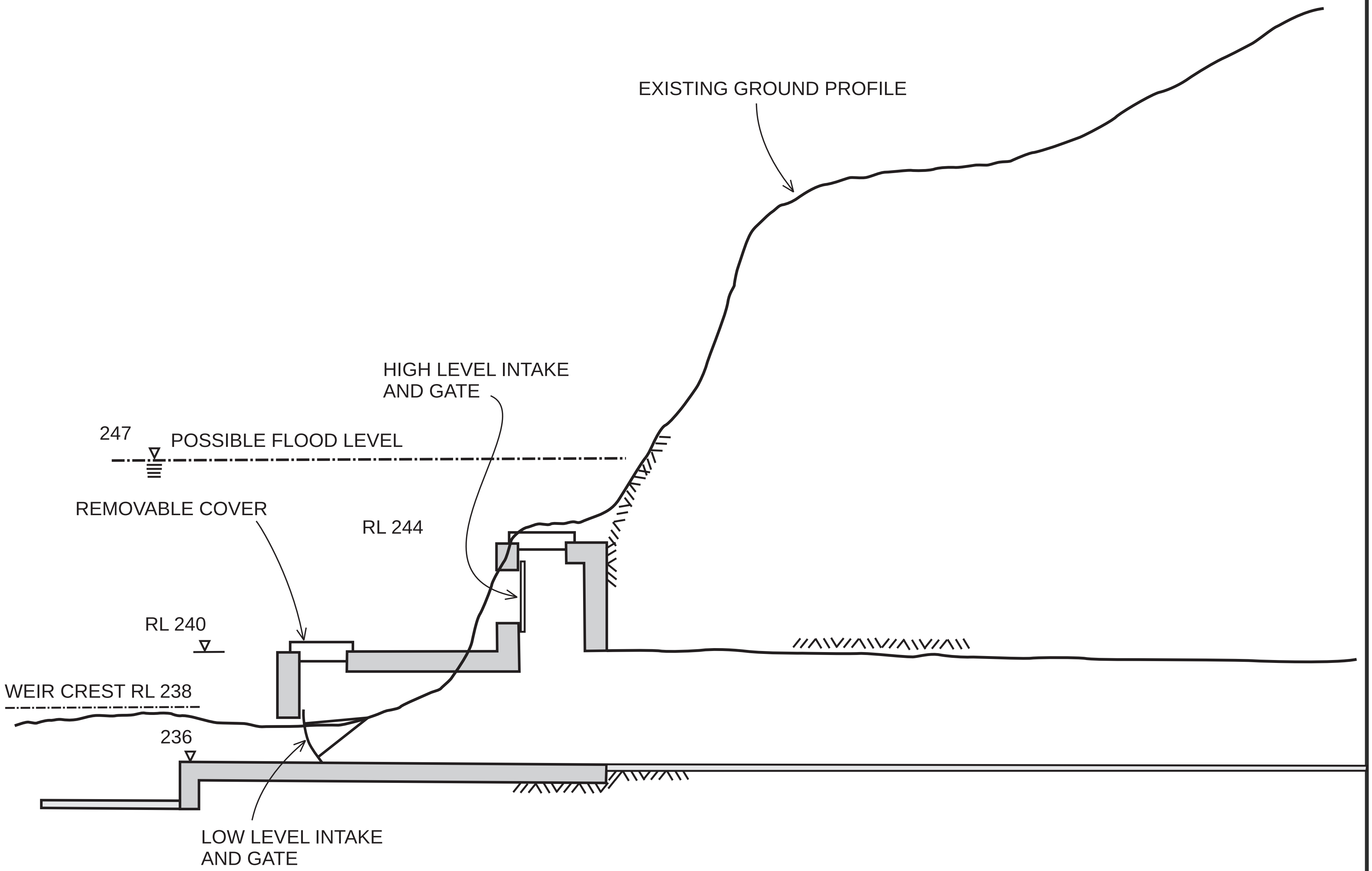
B-B' SECTION ON RIGHT HAND WALL



B-B' SECTION ON LEFT HAND WALL

SCALE: **1:200** (approx)

DRAWN BY: RJT
CHECKED BY: IMCC
DATE DRAWN: 17/05/2013
JOB No.: 2818
FIGURE No.: A-4



D-D' SECTION ON INTAKE CENTRELINE

GEOTECH

Waitaha Hydro - Headworks Concept

Intake sections D-D'

Intake Channel

SCALE: **1:200** (approx)

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CHECKED BY:	IMCC
DATE DRAWN:	17/05/2013
JOB No.:	2818
FIGURE No.:	A-5c