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APPENDIX G

Sediment Assessment – Tonkin & Taylor

REPORT

Motukawa HEPS Consent Renewal

Sediment Assessment

Prepared for
Trustpower Ltd
Prepared by
Tonkin & Taylor Ltd
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Note: Since the lodgement of the resource consent applications for the Motukawa Hydro-Electric Power Scheme in November 2021 (being the application to which this technical assessment relates), the proposal by Manawa Energy has been amended to retain the consented maximum water take from the Manganui River as 5.2 m^3/s. The Assessment of Environmental Effects lodged with the resource consent applications has been amended to reflect this change, but the technical assessments associated with the application (including this one) have not been amended. However, all effects on the environment will either be the same or less than previously assessed in the lodged technical assessments.

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Document Control

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1 Introduction

The Resource Consents for Trustpower Ltd's (Trustpower) Motukawa (MTK) hydroelectric power scheme (HEPS) is due to expire on 1 June 2022.

As part of the reconsenting process, Trustpower is assessing the effects of the existing maximum water take from the Manganui River (5.2 m^3/s) on sediment processes, and how these effects may change with the proposed increase in maximum water take from the Manganui River to 7.5 m^3/s within the MTK HEPS and associated receiving environments.

1.1 Background

The following is a description of the history and layout of the scheme. The various features referred to are shown on Figure 1.1.

The MTK HEPS was commissioned in the 1920s to meet the growing electricity needs of urban and rural communities. Mako Stream was dammed to create a storage lake, Lake Ratapiko. Water is diverted into Lake Ratapiko from the Manganui River through the Motukawa Race.

To allow the diversion of water from the Manganui River, a concrete weir was constructed across the Manganui River downstream from Tariki Road. The weir is approximately 4 m high and was constructed in 1927 (C. England pers. comm). The current consented take from the Manganui River at the weir is 5.2 m^3/s, with residual flows at the weir of 0.4 m^3/s. However, when flow in the Waitara River (at Bertrand Road gauge) falls below 5 m^3/s, all of the Manganui River flow must be passed over the weir or pass continuously through Lake Ratapiko.

There is a settling pond (Silt Pond) located on the Motukawa Race, approximately 280 m from the Manganui River intake. The Silt Pond was constructed prior to 1950 (based on historic aerial imagery), to reduce the amount of fine-grained sediment entering Motukawa Race and ultimately Lake Ratapiko. The Silt Pond has a surface area of approximately 0.01 km^2 with an average depth of 2.5 m, and an approximate volume of 25,000 m^3. The Silt Pond is cleaned out approximately once a year, with roughly 100 m^3 per year extracted (C. England pers. comm.).

The Motukawa Race is approximately 4.6 km long and typically between 3 and 9 m wide. The Motukawa Race was formed in the 1920s by excavating into the in-situ material with three short tunnel sections. The upper section of the race (near the Manganui River) is lined with concrete, while the rest of the race is unlined. The slope of the race varies but has an average slope of 0.3 %. The water level within the Motukawa Race, at least as far as the Mangaotea Aqueduct, can be influenced by high water levels in Lake Ratapiko (backwater effect).

Lake Ratapiko is approximately 0.3 km^2 in area and is split into two 'arms' by Ratapiko Road. The Western Arm is to the west of Ratapiko Road and receives water from the Motukawa Race. The Eastern Arm is to the east of Ratapiko Road, and receives water from the Mako Stream as well as flow from the Western Arm via culverts underneath Ratapiko Road. The consented maximum normal operating water level within Lake Ratapiko is 198.70 m RL, and the consented minimum water level is 194 m RL.

The Motukawa Power Station tunnel intake is located on the Eastern Arm, within the lower reach of the Mako Stream as it enters the lake. The average maximum lake outflow through the Motukawa Power Station tunnel intake is approximately 7.7 m^3/s. Water is diverted by the tunnel into a steel penstock to the Motukawa Power Station, which discharges the water into the Makara Stream, a tributary of the Waitara River.

Trustpower holds a consent to discharge up to 55,000 l/s (55 m^3/s) over the spillway of Ratapiko Dam into the Mako Stream during high lake levels and adverse weather conditions (Resource

Consents 3373 and 5084). Other than when the spillway is activated, there are no flows from Lake Ratapiko to the Mako Stream apart from minor seepage.

Trustpower also holds a consent to dredge within Lake Ratapiko, in order to maintain lake storage capacity (Resource Consents 1166-3), and such dredging has taken place in areas of the lake on multiple occasions in the past. T+T understands that a dredging operation was attempted on the northern edge of the lake, near Ratapiko Road, however this was unsuccessful as the material on the bottom of the lake was not able to be 'dredged' using traditional means (C. England pers. comm). An assessment of the Digital Elevation Model (DEM) (Figure 2.10) for the Lake Ratapiko lake bed shows where this operation was undertaken, with 'scrape' marks still visible on the lake bed.

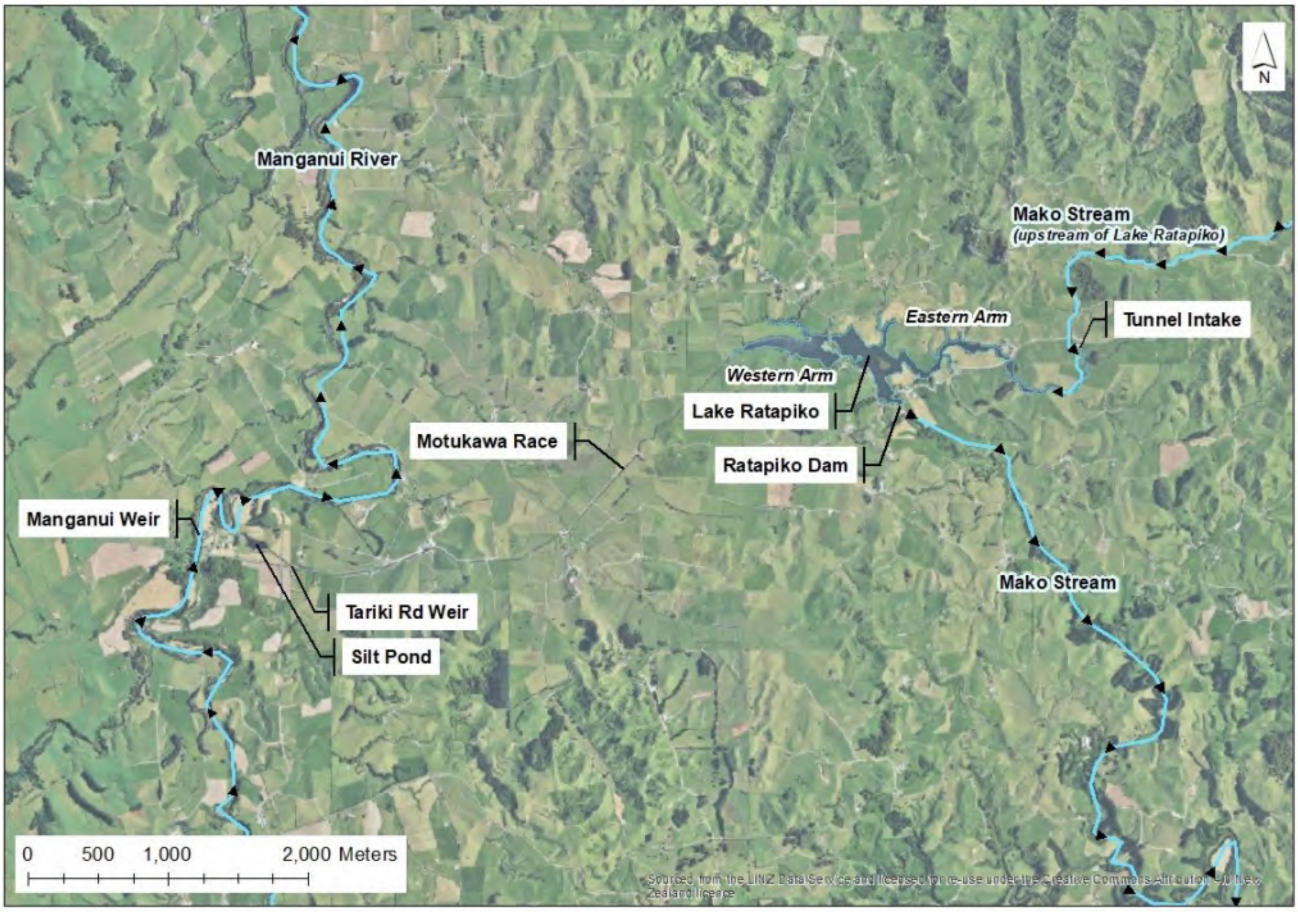

Figure 1.1: Motukawa HEPS features of interest

1.2 Project scope

This 'Motukawa HEPS Consent Renewal – Sediment Assessment' report has been prepared to support reconsenting of the MTK HEPS and the proposed take from the Manganui River of 7.5 m^3/s.

This MTK HEPS sediment report comprises the following three aspects:

1 A description of the existing stream environments associated with the MTK HEPS, focussing on the Manganui River, the Motukawa Race, the Mako Stream, Lake Ratapiko, the Makara Stream and the Waitara River (Section 2).

2 A description of the current sediment regime and processes within the MTK HEPS and associated receiving environments (Section 3).

3 An assessment of the effects of the proposed increase in take of 7.5 m^3/s on sediment processes within the MTK HEPS and associated receiving environments (Section 4).

The assessment of effects of the MTK HEPS on sediment processes is not intended to be a stand-alone effects assessment report, especially in relation to the National Policy Statement for Freshwater Management (NPS FM) (2020) and in particular policy 7 which is associated with "Loss of river extent and values". Loss of river value in the NPS FM specifically relates to:

i. Ecosystem health,
ii. Indigenous biodiversity,
iii. Hydrological functioning,
iv. Māori freshwater values, and
v. *Amenity.*

Sediment, and sediment processes, contribute to several of these values, and as such the 'Motukawa HEPS Consent Renewal – Sediment Assessment' report is intended to inform the effects assessments which have been prepared by other technical specialists in association with the reconsenting of the MTK HEPS.

2 Catchment context

As described in Section 1.1, flows diverted from the Manganui River for the purposes of generating electricity as part of the MTK HEPS, are stored in Lake Ratapiko. Lake Ratapiko is a man-made lake that is fed by the following catchments (Figure 2.1):

- Mako Stream catchment, up to where it joins Lake Ratapiko: 4.7 km^2.
- Lake Ratapiko local catchment with natural tributaries draining directly into the lake: 3.8 km^2.
- Motukawa Race – including water diverted from the Manganui River and any drainage channels entering the race: 3.9 km^2, (excluding Mangaotea Stream which flows underneath the race/aqueduct.
- The Manganui River (via the Motukawa Race) up to the Manganui Weir (24 km stream length), including tributaries such as the Waipuku Stream (18 km stream length) and Te Popo Stream (17 km stream length): 80 km^2.

Flows are diverted from Lake Ratapiko, into the penstock via a tunnel, to the Motukawa Power Station, and then discharged into the Makara Stream (a tributary of the Waitara River). The corresponding catchment areas are as follows:

- Makara Stream catchment up to (above) the Motukawa Power Station: 8 km^2.
- Waitara River catchment up to (above) the confluence with the Makara Stream: 685 km^2.

The Manganui River and contributing waterways drain off the high, steep, unstable slopes of Mount Taranaki and are capable of transporting large amounts of coarse sediment as bed load, as well as fine sediment (TRC, 2011). Additionally, the orographic influence of Mount Taranaki results in high local rainfall and attracts high intensity rainfall events in the headwaters of rivers originating on the Maunga. This means sediment transport rates, and the frequency of sediment transport events, are likely to be relatively high in the Manganui River.

In contrast, the Mako and Makara Stream catchments drain relatively low rolling hill country (approx. 280 m ASL) comprised of sandstone and have significantly lower rainfall exposure. As such, the sediment transport rates, and frequency of transport events, may be relatively low.

The Waitara River is a large river, and considerably different in character and behaviour to all other rivers associated with the MTK HEPS. It is the ultimate receiving environment for the MTK HEPS, receiving flows from both the Makara Stream and the Manganui River.

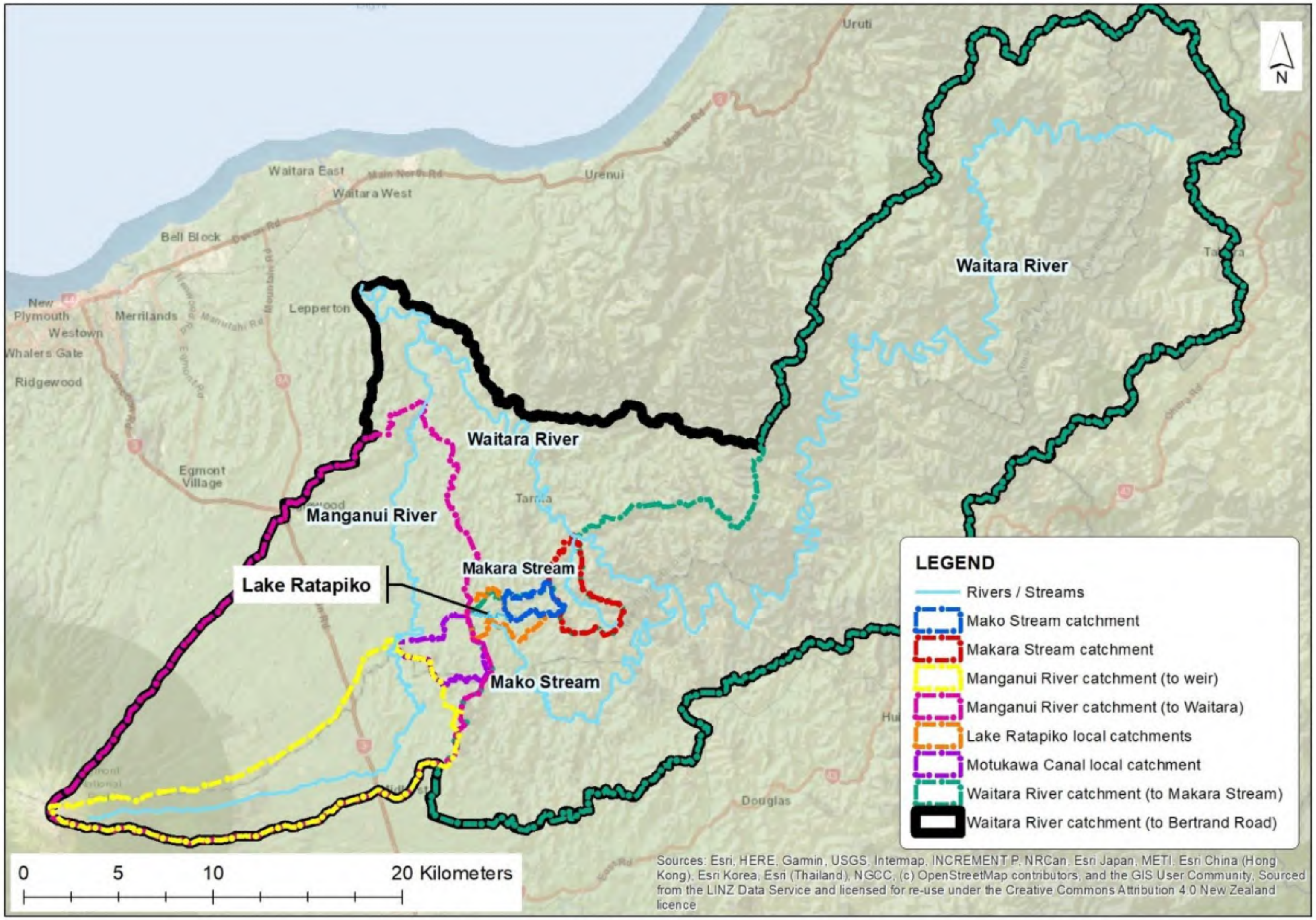

Figure 2.1: Map of the sub-catchments that have been assessed as part of the MTK HEPS sediment assessment

2.1 Catchment descriptions

2.1.1 Geology and soils

The geology is not consistent between the Manganui River catchment and the remaining sub-catchments. This influences the volume and type of sediment available for transport.

The Manganui River is dominated by volcanic deposits such as Holocene lahar flows and Late Pleistocene debris avalanche deposits (debris deposits in Figure 2.2). Some lavas of the Egmont Volcanic Centre (Igneous Extrusive in Figure 2.2) are present near the headwaters. These volcanic deposits are characterised by multiple beds of unconsolidated layers, mostly of gravel and sands. However, cobbles and boulders are also present. These deposits erode easily, with gravels transported as bed load, and sand to clay sized particles being transported the furthest downstream as wash load or suspended sediment.

The other catchments comprise late Quaternary river deposits (Gravel, Figure 2.2) and Early Pliocene to Late Miocene sandstones interbedded with siltstone (sedimentary weak sandstone in Figure 2.2). The river deposits will be highly erodible as they are likely to be unconsolidated.

The sandstones and siltstones are the least erodible when exposed in the rivers and streams as 'bedrock', as they generally present as interbedded 'rock' as opposed to individual clasts (like the volcanic deposits) or unconsolidated alluvium (like the river deposits). However, they are still erodible, and will contribute large amounts of fine-grained sediment (silts and fine sands) to the river systems through landscape erosion (such as weathering or landslides).

The Waitara catchment has the most variable and erodible geology. This catchment is predominantly comprised of weak sandstone and mudstones on the hillslopes, with recent river deposits on most of the valley floors. As with the sandstone described above, the mudstone is likely to be highly erodible at a landscape level. As such, the Waitara River is likely to have a high suspended sediment load, and is likely to have a different river character and behaviour to those catchments primarily in volcanic geologies.

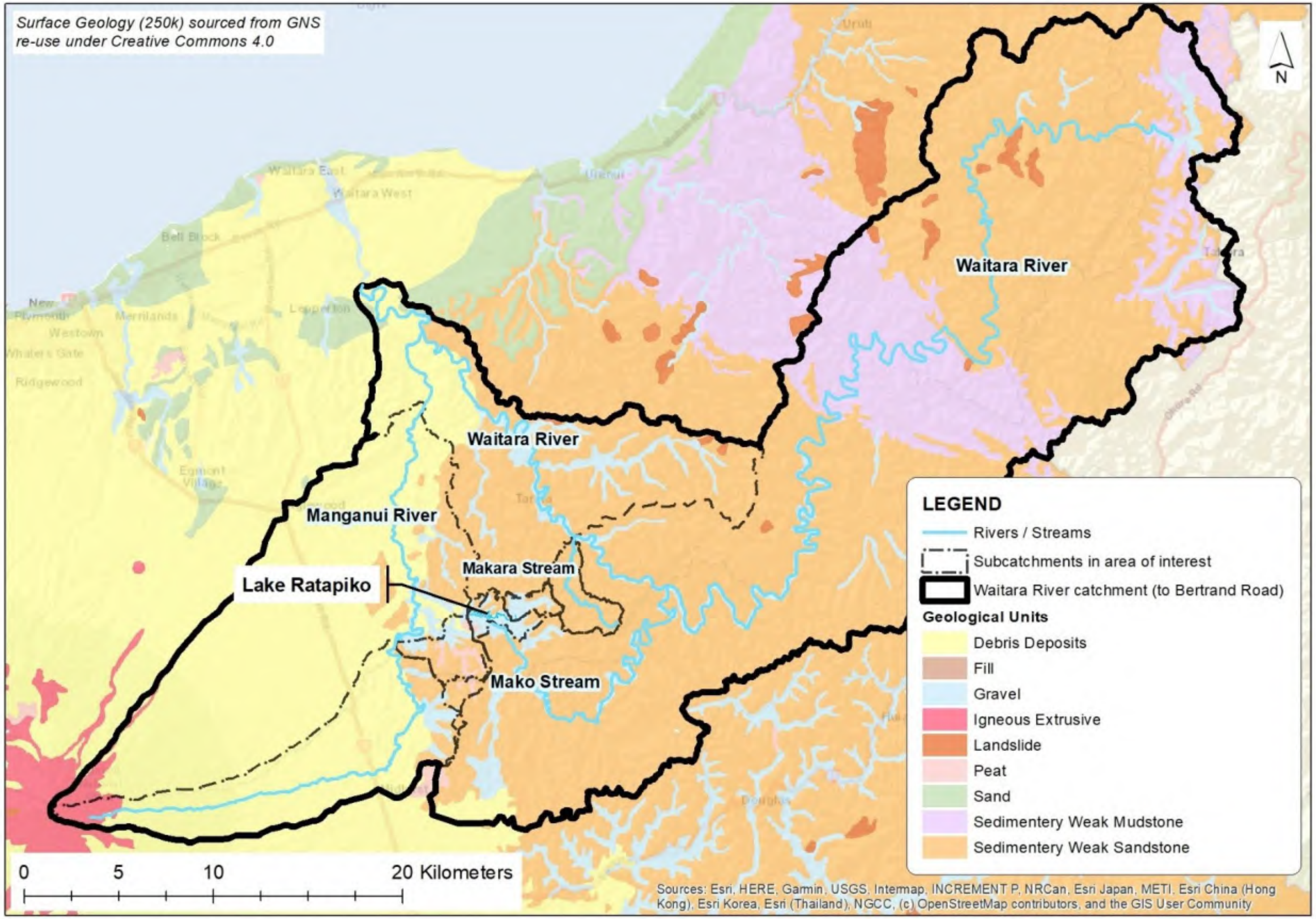

Figure 2.2: Geological map of sub-catchments. Source: GNS 250K

Detailed regional soil maps do not yet exist for the Taranaki area, however the soil orders have been mapped for some parts of the region (Figure 2.3).

Most of the catchments feeding into Lake Ratapiko were identified as having Allophanic soils. These soils are less susceptible to erosion from run-off but are moderately susceptible to fluvial erosion and abrasion due to having weak strength. The Allophanic soils mostly comprise of fines, and in exposed banks will likely erode into waterways as sands, silts and clays.

Recent and raw soils were also mapped in the Manganui River sub-catchment up to the Manganui Weir. Recent and raw soils are formed in areas of high erosion and/or deposition with varied materials, therefore, these soils are made up of boulders to clay size particles. Recent and raw soils show little to no evidence of soil-forming processes; therefore, they are best described geologically and have been defined as the volcanic deposits above (lahar flows, debris avalanche and lava deposits).

Peat type soils were observed during a site visit to the Lake Ratapiko catchment and Motukawa Race catchment. Peats are classified as 'Humic Organic' in the NZSC, but on Figure 2.3, the area where the peats were observed has been instead mapped as 'Orthic Gley Soils'(soils being strongly affected by waterlogging). If confirmed to be present, the peat is likely Holocene swamp deposit (GNS 250K) that is prone to waterlogging and will contain large organic debris (such as tree roots/logs etc). When waterlogged, peats are naturally cohesive and have a low erodibility. However, their erodibility increases as they become desiccated.

The Makara Stream catchment, and to some extent the Waitara River catchment, are approximately 50 % 'Orthic Allophanic' and 50 % 'Acidic Orthic Brown Soils'. Orthic Brown soils are described as being weak soils, commonly on slopes or young land surfaces. These soils are considered to be highly erodible, and will be contributing large amounts of silts and sands to both river systems.

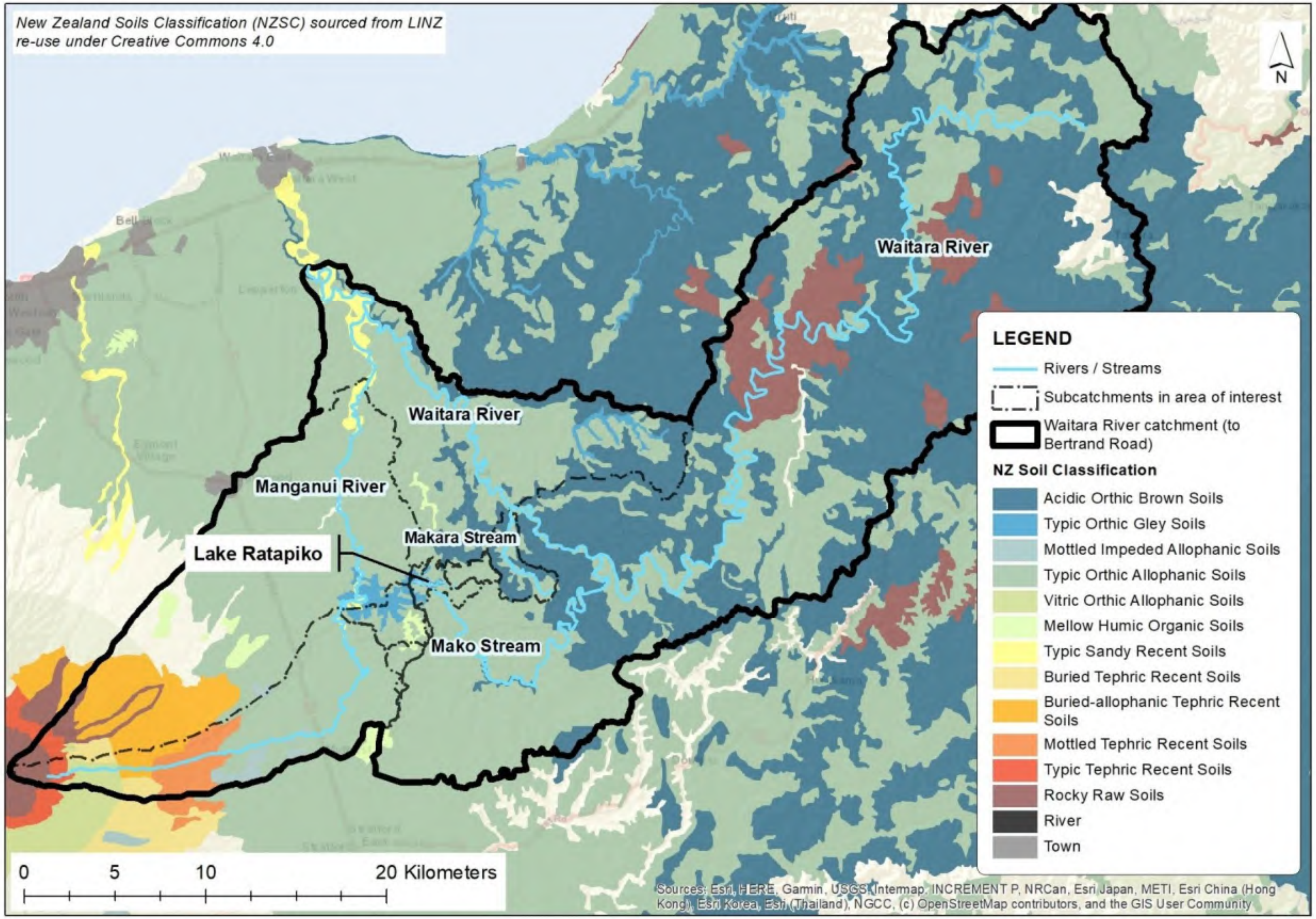

Figure 2.3: Soil classifications for the assessed catchments (from NZ Soil Classification)

2.1.2 Catchment land-cover

Landcover is a key component of landscape change and sediment generation, and changes in landcover can result in substantial changes in sediment regimes.

Streams in pastureland generally have a greater sediment yield than those under forested areas (Davis-Colley, 1997). National literature of erosion rates in New Zealand suggest erosion rates are between 3 – 11 times higher in catchments under pasture than those under forest, and sediment yields are 50 – 80 % higher in pastureland than forested catchments (Basher, 2013). The processes operating on Mount Taranaki may be contrary to this, however, due to the steep slopes and recent volcanic soils, the upper slopes of Mount Taranaki can generate large pulses of sediment during large rainfall events despite being dominated by indigenous forest.

Approximately 70 % of the Manganui River sub-catchment is pastureland, while the other sub-catchments (excluding the Waitara) have approximately 90 % or greater coverage of pastureland.

The Waitara has a greater diversity of landcover, with the headwaters and mid-catchment a mix of native forest and occasional tracts of exotic forestry. Pastureland becomes dominant in the middle to downstream parts of the catchment.

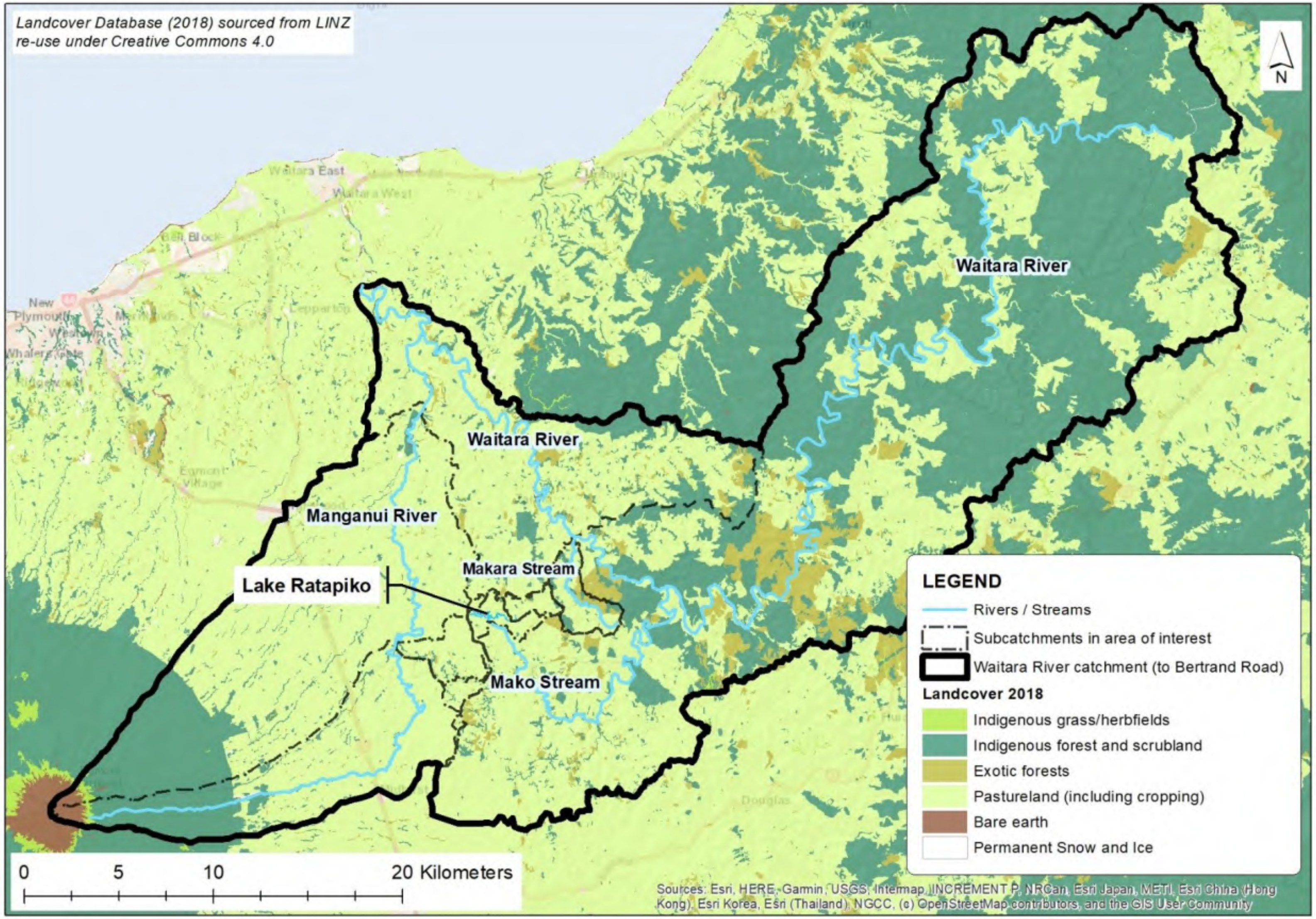

Figure 2.4: Landcover from 2018 for all sub-catchments (Sourced from LINZ and licensed for use under Creative Commons 4.0)

2.2 Stream descriptions

2.2.1 Manganui River

The Manganui River begins near the peak of Mount Taranaki and flows north towards the coast. The gradient of the river varies significantly along its length and is steepest at its headwaters to 5 km downstream, after which it begins to flatten off. The overall grade is approximately 5 % (Figure 2.5).

After leaving the slopes of Mount Taranaki the Manganui River has an approximate width of 20 m and is a meandering gravel river, with a tendency to be incised as it moves away from the slopes of Mount Taranaki. Along the river, riffles, mid-channel islands, point bars and lateral bars are observed.

Bars and islands temporarily store sediment that can be reworked and transported downstream during large bankfull flow events such as the Mean Annual Flow (MAF). These bars typically have a coarse surface layer with sands present underneath, therefore breaking this surface layer could result in fine sediment being available for downstream transport.

Multiple man-made weirs along the Manganui River may disrupt the natural transport processes and downstream conveyance of sediment. This is evident at the Manganui Weir, where sand and pebbles are accumulating behind the weir. Ponding behind the weir appears to be visible up to 500 m upstream of the weir.

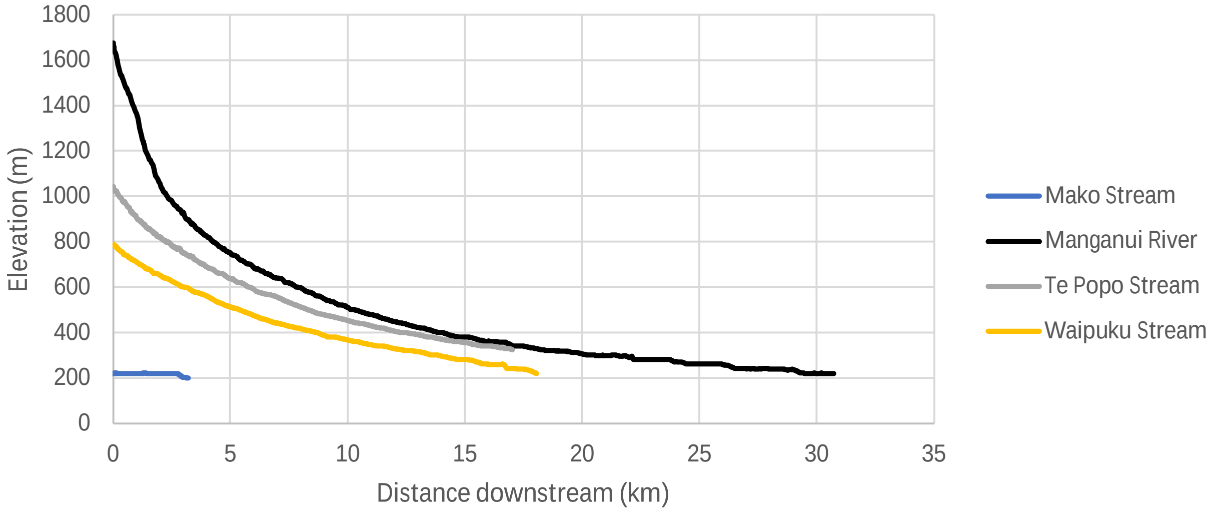

Figure 2.5: Long profile graph of the Manganui River, Te Popo Stream (tributary to Manganui River), Waipuku Stream (tributary to Manganui River) and Mako Stream entering Lake Ratapiko

The banks downstream of the Manganui Weir (Figure 2.6) are near vertical, approximately 6 – 8 m high and comprised of boulders held in a clay matrix. The banks of the Manganui River upstream of the weir are likely to have the same composition as those downstream, given the morphology of the river and the local geology/soils. However, this could not be confirmed during the site visit due to dense vegetation on the banks.

Downstream of the Manganui Weir, there is a large cobble array (meaning unsorted cobbles across the channel floor), with more organised geomorphic units appearing approximately 200 m downstream of the weir. Interestingly, the first geomorphic unit downstream of the weir appears to be a large point bar that looks like it is dominated by finer sediment than other point bars immediately downstream. This suggests that at a 'functional level', bed load may be (or has previously been) partially disrupted, but suspended sediment (and possibly wash load) may be uninterrupted by the weir. The partial interruption of bed load could have triggered historic degradation (Figure 2.6).

The 'cobble array' downstream of the weir has likely resulted from the trapping of some sediment behind the weir, where the finer grained sediment which would normally be present has been 'stripped' away (as seen in Figure 2.6).

However, as the Manganui Weir has been in place for almost 100 years, and effectively now operates as 'run of river' in terms of sediment transport, especially during flood flows. The weir is not expected to interrupt bed load during these events, and the Motukawa Race intake is mostly 'closed' during these events, so only a minor change in suspended sediment loads is expected.

Figure 2.6: Photos of the Manganui River near the Manganui Weir showing the trapping of sediment upstream of the weir (left) and the bank material (right). Note the difference in bank height between upstream and downstream. Source: Author's photos

2.2.2 Mako Stream

The Mako Stream originates at 210 m ASL with an approximate slope of 0.22 % to Lake Ratapiko (Figure 2.5). Desktop analysis shows the Mako Stream to be incised along its extents, both upstream and downstream of Lake Ratapiko. The stream enters Lake Ratapiko approximately 4.5 km downstream from its headwaters at 200 m ASL (Figure 2.7).

Near the entry point to Lake Ratapiko (and the intake structure to the power tunnel), the Mako Stream has a fine-grained bed. Banks are comprised of underlying gravel overlain with finer grained sediment, with the fines being more likely to be erodible. Fine sediment was observed in the channel and surrounding the structures during the site visit. However, there was no apparent aggradation within the channel.

Figure 2.7: Photos of the Mako Stream tributary input to Lake Ratapiko, looking upstream. Source: Author's photos

The Mako Stream downstream of Lake Ratapiko, was only assessed by a desktop assessment. It is likely the Mako Stream in this section has previously incised through sandstone Holocene fan deposits, and would have exhibited deep narrow stream valleys pre-damming. However, no historical photos, or surveys of the pre-dam valley topography were able to be located.

The stream downstream of the dam is still deeply incised, with a smaller secondary channel incised through the valley base. This may indicate stream incision is still occurring when the spillway is activated, albeit at a much slower pace.

The bed material appears to consist mainly of 'bedrock', and occasional gravels, with some fine-grained material. While the secondary channel suggests some incision may be still occurring, the presence of gravels and fine-grained material within the channel suggests that some sediment is still able to pass into the Mako Stream, again, when the spillway is activated.

While sediment transport appears not to be entirely disrupted based on these observations, there is likely to be a substantial reduction in sediment transported into the Mako Stream downstream of Lake Ratapiko. It is highly unlikely that bedload is able to pass over the spillway, and only minor suspended sediment loads are expected when the spillway is activated. As such, some (slow) incision may be occurring as a result of the dam, and some modification of the bed has possibly occurred due to the disruption in sediment transport.

Figure 2.8: Photos of the Mako Stream immediately downstream of the Lake Ratapiko spillway, looking upstream (left) and the Mako Stream downstream of Lake Ratapiko looking downstream (right). Source: R. Goldsmith

2.2.3 Motukawa Race

As previously mentioned, the Motukawa Race is a man-made race, constructed in the 1920s to divert water from the Manganui River to Lake Ratapiko. However, during rainfall events, water also drains from surrounding pastureland, a proportion of which directly enters the Motukawa Race. The current consented diversion flow from the Manganui River to the race is 5.2 m^3/s.

The Motukawa Race intake is on the Manganui River, upstream of the Manganui Weir, so suspended sediment is available to be entrained into the Motukawa Race from the Manganui River. The Silt Pond is situated between the Tariki Weir and the Manganui River intake, and from historic aerial imagery appears to have been in place since at least the 1950's. The efficiency of the Silt Pond in trapping sediment is discussed further in Section 3.3.

From site observations, the banks of the race between the Mangotea in-race generator and Lake Ratapiko (Reaches 6,7 and 8 in Riley Consultants 2021), are comprised of what were observed to be saturated peats with considerable coarse organic debris (Figure 2.9), this is identified as 'clays or organic clays' in Riley Consultants (2021). Peats and organic clays can be considered to be similar in composition and function. The banks are often near vertical, and Riley Consultants (2019) suggests that some bank instability has previously occurred in this section of the race, as well as Reach 3, 4, and 5. Riley Consultants (2021) use the term 'slumping' to describe the erosion.

Almost no deposited fine-grained sediment was observed on the bed of the race. Downstream of the Mangotea in-race generator, the bed appeared to consist primarily of in-situ clays, with some areas of what appeared to be coarse/block material from the bank (e.g. blocks of failed bank, not unconsolidated sediment) which had been unable to be reworked or transported far from the source bank. In some locations, dense patches of submerged macrophytes were present on the bed. All this suggests that the bed of the Motukawa Race is reasonably 'stable' in that there was no obvious sign of recent or severe scour or any type of aggradation (e.g. accelerated deposition of sediment).

Historical Works Consultancy Services Drawings (Appendix A) show the Motukawa Race has a stepped longitudinal profile, with an average overall grade of 0.3 %. Of note is the 1.8 m bed elevation change near Salisbury Road, which has rock rip-rap and cobbles downstream (as shown on the plan drawing). Another steep section is shown after the 'tunnel' noted on the Historical Works Consultancy Services Drawings (Appendix A) with a fall of 3.12 m over 80 m (3.9 % grade). This could indicate historic incisional processes, which has since been remediated, or the steps in grade and rock-riprap could be original design features to manage rapid changes in grade when the race was constructed.

Sediment contributions into Lake Ratapiko from the Motukawa Race will be primarily from the Manganui River, with a smaller contribution from erosion of the race, as well as run-off from the surrounding agricultural landscape. Anecdotally, it is noted that in 2015 there was a sediment slug in the Motukawa Canal near the entry to Lake Ratapiko that was naturally flushed (likely during successive flood events) into the lake (C. England pers. comm.).

As the Motukawa Race was constructed in the 1920s to divert water from the Manganui River to Lake Ratapiko, no natural watercourse existed in this location prior to the 1920s. While some minor erosion was noted by Riley Consultants (2021), the Race had minimal deposited fine sediment, suggesting it is efficient at transporting any sediment in the diverted flow and that the Silt Pond is effective at reducing sediment loads into the Race itself.

Figure 2.9: Photos of the Motukawa Race diverting water from the Manganui River to Lake Ratapiko. Note the pieces of eroded bank still on the bed in the photo on the right. Source: Author's photos

2.2.4 Lake Ratapiko

Lake Ratapiko has a total surface area of approximately 0.3 km^2 and was formed by damming the Mako Stream during the construction of the MTK HEPS in 1927. The lake effectively flooded an existing river valley (Eastern Arm with a surface area of approx. 0.07 km^2) and an old swamp (Western Arm with a surface area of approx. 0.19 km^2) (Figure 2.10). The consented minimum (RL 194 m) and maximum (RL 198.7 m) normal operating levels result in a live storage for Lake Ratapiko of 695,00 m^3[1].

The local Lake Ratapiko catchment includes a number of small unnamed tributaries. All of these have small contributing catchments, so are likely to experience small flows (a total mean inflow of approximately 0.3 m^3/s is estimated from the local catchment, excluding the upper Mako Stream). While sediment is still able to be transported off the surrounding hillslopes and into Lake Ratapiko through these tributaries, these are considered to be minor sources of sediment.

The two arms of the lake vary in terms of morphology. The Western Arm is essentially a shallow embayment, with a narrow, constructed channel through the middle of it conveying the flows from the Motukawa Race to the northern most culvert, under Ratapiko Road.

[1] T+T 2021: MTK Hydrology Report.

The Eastern Arm is mostly the old Mako Stream valley. As such, the eastern most portions of the Eastern Arm are narrow, sinuous and deep (Figure 3.1). Flow currents likely move both westward into the lake (from Mako Stream), as well as eastwards out of the lake (towards the intake).

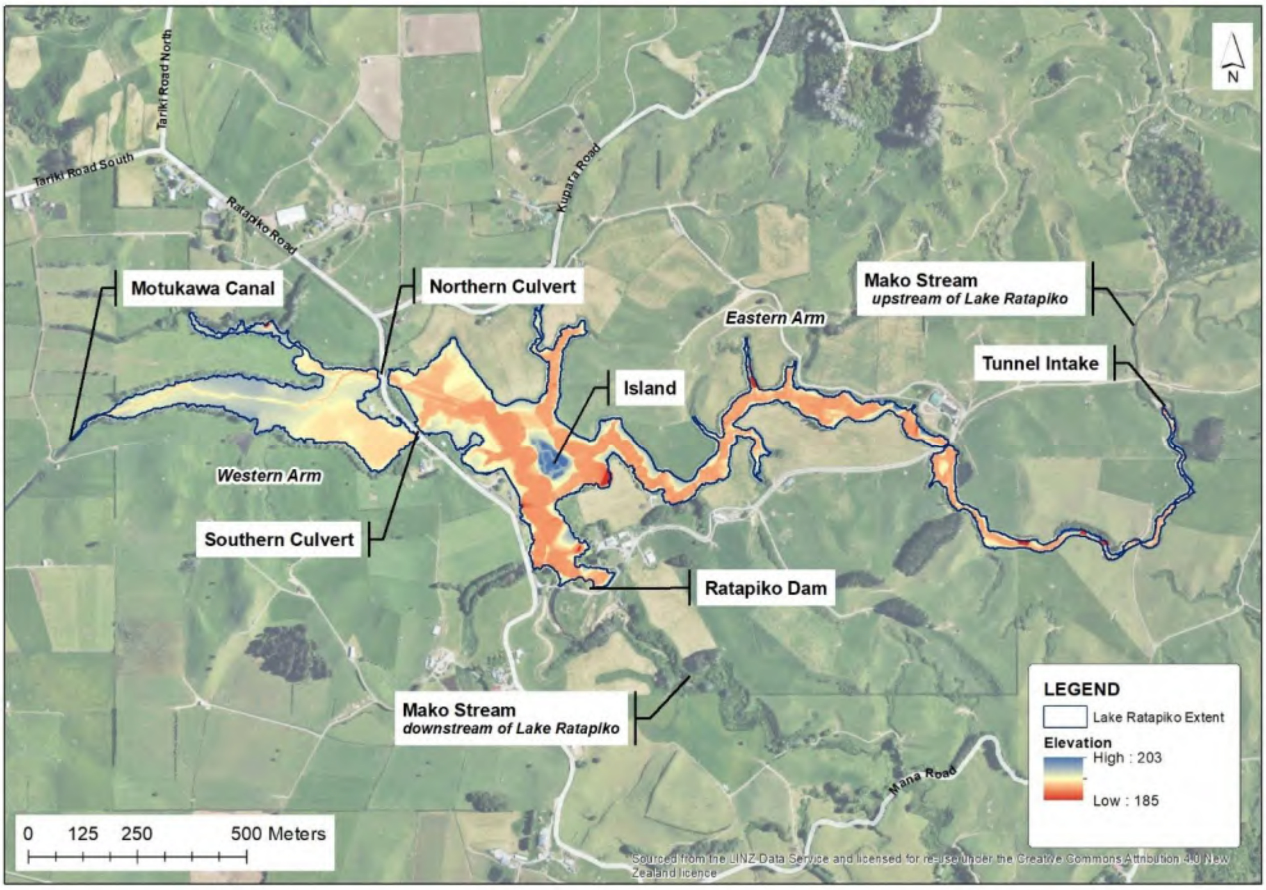

Figure 2.10: 2019 Digital elevation model (DEM) and features of interest at Lake Ratapiko

Observations of sediment deposition were made during the site visit in April 2019 when the lake level was drawn down. At the most western extent of the Western Arm, near where the Motukawa Race enters the lake, a thin layer (approx. 0.3 m) of unconsolidated fine sediment was observed overlying a cohesive clay on the exposed surfaces of the lake (Figure 2.11). This layer of fine sediment reduced further into the Western Arm, with areas near the water ski club that displayed no deposited fine sediment and appeared to be in-situ pre-dam soils. (Figure 2.11).

In the Eastern Arm of the lake, there was an absence of deposited fine sediments around the edge of the lake, with lakebed surfaces adjacent to the grass esplanade a mix of in-situ cohesive clays, or rocks (presumably used to prevent erosion from boat wash). Deposited fine sediment increased away from the edges of the lake, towards the centre of the lake, but remained as a thin layer out to the edge of the deeper channels.

During the site visit, submerged rooted macrophytes were observed to be present where there was deposited fine sediment, and they were absent where there was no deposited fine sediment. This would suggest generally low rates of sedimentation.

Despite the lake being in existence for almost 100 years, there is minimal observable deposited sediment within the lake, with many surfaces exposed during the lake draw-down being characterised as the ‘in-situ’ ground surface present before damming.

	
Example of the thin layer of unconsolidated silts (approx. 0.3 m) overlying a cohesive clay layer on the exposed lakebed in the Western Arm near the Motukawa Race.	*Example of cohesive clay layer on the exposed lakebed in the Western Arm near the water ski club. Note the absence of deposited fine sediment.*

Figure 2.11: Example of the surface sediments on the exposed lakebed during the April 2019 site visit when the lake level was drawn down.

2.2.5 Makara Stream

The Motukawa Power Station is located near, and the tail race discharges to, the Makara Stream, which is a small tributary of the Waitara River. At the location of the Power Station, the Makara Stream is approximately 8 km from its headwaters to the confluence with the Waitara, and has an approximate catchment area of 8 km^2, and an overall grade of 0.01 %. As with the Waitara catchment, the Makara catchment is predominantly underlain with sandstone and siltstone.

The Makara Stream appears to be reasonably incised for most of its length. The upstream reaches and headwaters appear to be potentially ‘overwhelmed’ with fine grained sediment, meaning the stream reach does not have sufficient flow (and thus stream power) to transport the amount of sediment entering it. This is fairly common for small streams in this type of geology.

The character and behaviour of the Makara Stream changes approximately 1 km downstream of the headwaters, where the channel appears to be well defined, incised and clear of sediment.

Downstream of the Power Station, the stream is incised and appears to have a ‘mixed’ bed load, meaning that there is a mix of gravels and fine-grained sediment. From the aerial imagery, where the channel can be seen, the geomorphic units appear to be small instream units such as transverse riffles. As the channel is incised, it is unlikely the channel accesses the floodplain regularly enough to allow for sediment trapping or storage.

The banks appear to be near vertical, with some stable undercutting. Riparian vegetation appears to be dense and dominated by native species (for the most part). Based on the photos supplied by Trustpower and aerial imagery, no bank erosion or stability issues were identified.

Immediately downstream of the Power Station, the bed appears to be stable, with clearly embedded gravels, and no evidence of scour. However, there is also a lack of fines, suggesting that the station discharge is sufficient to entrain and transport fine grained material. As the coarser material is embedded, it is unlikely this material is ‘available’ for transport, without some form of bed disturbance.

This suggests a ‘clear water effect’ where the sediment transport capacity exceeds the sediment supply. Generally, the ‘clear water effect’ results in incision. As the discharge has been ongoing for the last 100 years, any incision arising from the 'clear water effect' is considered to be historic (e.g. it has already happened) and appears to be no longer active.

Figure 2.12: Photos of the tail race immediately downstream of the Power Station (left) and where the tail race joins the Makara River (right), with the Makara River coming from the right of the photo. Source: Trustpower

2.2.6 Waitara River

The Waitara River begins in the Moki Ranges (451 m ASL) and flows generally south before turning west towards the coast near Matau. The Waitara River is reasonably low gradient with an approximate overall grade of 0.18 %.

Unlike the Manganui River, the Waitara River catchment is predominantly underlain by sedimentary rocks, such as siltstone and mudstone. As such, the river is likely to be characterised by predominantly fine-grained sediment (silts and sands) for most of its length.

The width of the Waitara River increases with distance downstream, but maintains a relatively consistent width of between 30 and 50 m after leaving the hill country. The channel is predominantly an incised meandering fine-grained river system. Inset floodplains and benches appear to be the dominant geomorphic unit, but large floodplains capable of trapping large quantities of fine-grained sediment appear to be largely absent. Gullies and landslide scars are a common feature of the landscape, suggesting that periods of incision, and extreme climate events, likely result in large-scale landscape response that generates a lot of sediment.

This all suggests that sediment is readily entrained and rapidly transported downstream during most events smaller than the MAF, with very little opportunity for deposition of storage outside of the main channel.

The Waitara River is the second largest catchment in the Taranaki Region, and the maximum consented Power Station discharge (7.787 m^3/s) is approximately 1.2 % of the Waitara River's Mean Annual Flood (MAF). Accordingly, the Power Station discharge appears to have had no observable effect on the sediment processes in the Waitara River.

3 Sediment regime

A desktop review of existing data sources was undertaken to inform a qualitative assessment of potential sediment sources. The reviewed data sources comprised of:

- Published literature.
- Relevant internal T+T documents.
- Council websites.
- The National Institute of Water and Atmospheric Research (NIWA) River Maps app.
- GNS geological maps of the region.
- Soil maps and land use maps.

A site visit was undertaken by Selene Conn (T+T fluvial geomorphologist) and Michelle Hitchcock (Trustpower hydrologist) on 6 April 2019. Several sites in the Lake Ratapiko and Motukawa Race catchments were visited. The MTK Power Station, Makara Stream, Mako Stream downstream of Lake Ratapiko and Waitara River were not visited. During the site visit, a high-level assessment of stream character and potential geomorphic processes was undertaken. The information gathered during the site visit was used to inform potential sources of fine-grained sediment to Lake Ratapiko, and to develop an understanding of sediment regimes the might effect, or operate within the MTK HEPS.

As noted previously, the catchments assessed as part of the 'Motukawa HEPS Consent Renewal – Sediment Assessment' include:

- Manganui River catchment – up to the Manganui Weir before water is diverted through the Motukawa Race, and up to 500 m downstream of the weir.
- Motukawa Race –water diverted from the Manganui River and any drainage channels entering the race.
- Lake Ratapiko local catchment – with natural tributaries draining directly into the lake.
- Mako Stream catchment – upstream of Lake Ratapiko, and up to 200 m downstream of Lake Ratapiko.
- Makara Stream – upstream of the Power Station and up to 500 m downstream of the Power Station.
- Waitara River – upstream of the Makara Stream confluence and up to 500 m downstream of the Makara Stream confluence.

3.1 Sediment type

In most rivers, sediment can be broadly categorised into two types that have different sediment transport mechanisms: bed load and suspended sediment.

Bed load is the sediment fraction that contributes the most to geomorphic processes in gravel bed rivers (Leopold 1992, Fuller et al 2011). Bed load entrainment is often difficult to predict, with variable sediment sizes, coarse surface armouring, imbrication, and possibly hydrostatic pressure between surface flows and sub-surface flows all playing a role in modulating bed load entrainment (Neverman et al. 2018; Brierley, Reid and Coleman 2011). However, for the purposes of this report, bed load entrainment has been considered to occur during a MAF event or greater.

Suspended sediment loads are the portion of sediment carried in suspension and are usually restricted to the fine-grained particles (sands, silts and clays). Suspended sediments generally have a limited role in morphological processes, especially in gravel bed rivers, but play an integral role in stream health and ecological function.

The focus of this section is primarily on sediment entrained into the MTK HEPS from the Manganui River. As such, only sediment in the Manganui River has been described, but Section 2.2 provides high level descriptions of sediment within the other reaches.

Bed load in the Manganui River consists of rounded grey boulders (> 0.3 m diameter), and large cobbles (between 0.06 m and 0.3 m diameter). Suspended sediment in the Manganui River consists primarily of fine-grained sediment (e.g. sands and silts) derived from volcanic soils and geologies (Section 2.1.1). Bed load is not entrained into the MTK HEPS, and bed load transport is not functionally affected by the Manganui Weir. As such, bed load is not considered any further.

For the purposes of this assessment, four Particle Size Distributions (PSD) from the nearby Waiwhakaiho River and Mangorei Scheme were used to determine the potential proportion of suspended sediment load comprising ‘fine sand’ or coarser (≥0.125 mm diameter) in the Manganui River. The Waiwhakaiho River and the Manganui River both originate on Mt Taranaki, and pass through similar soils and geologies, and as such are likely to have very similar sediment types. From the PSD samples analysed, it was determined that approximately 40 % of the suspended sediment load is ‘fine sand’ or coarser.

3.2 Suspended sediment loads

Estimations of suspended sediment load are often based on a number of catchment variables, such as land cover, rainfall, catchment area and reach scale variables such as erosion and surface armouring. The relationship between suspended sediment concentrations and flow can therefore be extremely complex, and is river (or catchment) specific.

The following sections describe the methods used to determine sediment loads within the catchments of interest, and the potential sediment budgets for each, focussing on sediment entering Lake Ratapiko (Sections 3.2.1 and 3.2.2). A description of the sediment transport dynamics in reaches of interest is also provided, as well as an assessment of where sediment is most likely to end up (fate) (Section 3.3).

3.2.1 Methods

To develop an understanding of suspended sediment loads entrained into the MTK HEPS, three avenues of investigation were used.

First, suspended sediment load values (in tonnes/year) were obtained from NIWA (2017) for four catchments likely to be contributing sediment to Lake Ratapiko (Manganui River, Motukawa Race, Lake Ratapiko local catchments and Mako Stream). These values represent the long-term averages and are generally for terrestrially derived sediment (e.g. from run-off). These estimates likely do not include sediment contributed to the systems through bed and bank erosion. For the purposes of this report, the solid tonnage per year value was then converted to a volumetric value by using the in-situ bulk density (1.46 tonnes/m^3) estimated from the sediment cores taken at site (refer to Figure 3.1).

Secondly, the flow gauging data supplied to T+T by NIWA contained, inter alia, four grab sample suspended sediment results for the Manganui River flow recording site at SH3. These grab samples were collected between 1987 and 1992, as detailed in Table 3.1.

Table 3.1: Suspended sediment (SS) grab samples from Site 39508 Manganui at SH3

Stage height (mm)	Flow (l/s)	Q/Q_{mean}	Mean velocity (mm/s)	SS concentration (mg/l)	Date	Time
2685	48242	31.05	2635	1133	13/10/1987	2:15:00 PM
1584	6150	3.964	754	9	23/04/1991	2:45:00 PM
2346	37548	24.17	2317	727	21/02/1992	2:07:00 PM
1314	1488	0.96	393	4	19/03/1992	1:00:00 PM

From these data points, a sediment rating curve was developed. The following equation was used to relate the recorded suspended sediment concentration data to the non-dimensionalised flow (Q/Q_{mean}):

$$\textit{Suspended sediment (SS) concentration (mg/l)} = 2.25\,(Q/Q_{mean})^{1.81}$$

The equation above was then converted into a suspended sediment flux rating curve that relates the sediment transport rate (in grams per second units) to the river flow (in litres per second units). This suspended sediment flux curve was then applied to the recorded flows for the Manganui River at SH3 to determine a corresponding time series of suspended sediment concentration/load in the Manganui River at SH3.

An average flux of 153 g/s was determined for the full record period 1972 to 2020, which corresponds with an annual average suspended sediment load of 4835 tonnes/year. This value was then compared to the suspended sediment load determined from the desktop assessment using data from NIWA (2017), to see if there was agreement of the values (which there was). Despite the good agreement, there is inherent significant uncertainty in the sediment load estimates presented in this report, which is typical for all quantitative sediment assessments.

The catchment area and mean flow at the Manganui Weir (80 km^2 and 6.9 m^3/s, per T+T, 2021) are much larger than at the SH3 gauge (13.0 km^2 and 1.68 m^3/s, per T+T, 2021). Sediment yield per unit catchment area (and per unit water volume) is expected to be lower in the larger catchment at the weir compared with the upper catchment to SH3. This is supported by both the qualitative catchment assessments presented in Section 2 and also by the SS yield estimates from NIWA (2017). The latter indicates that the suspended sediment yield at the Manganui Weir is 69 % (0.69) of that at SH3 on a unit water volume basis.

Factoring suspended sediment concentrations by 0.69 in the non-dimensionalised sediment rating curve for the Manganui Weir resulted in a predicted suspended sediment yield of 9750 tonnes/year. If the yield per unit flow is assumed the same as at SH3 (i.e. no reduction factor applied), the estimated yield is 14,150 tonnes/year, which agrees better with the NIWA (2017) value. For subsequent assessments, this higher suspended sediment yield estimate (i.e. without a reduction factor) has been adopted.

Lastly, sediment cores were collected by T+T on 11 and 12 April 2019 when Lake Ratapiko was dewatered. A total of nine core sites were planned, but only four sites were able to be accessed due to persistent rain and rising lake levels. No samples were able to be taken in the Western Arm due to this.

Sediment cores were between 2 – 3 m deep and were collected using hand augers in the four locations indicated in Figure 3.1. All four locations were in the Eastern Arm of Lake Ratapiko, to the east of Ratapiko Road.

The sediment cores were assessed for unconsolidated, stratified sediments (indicative of sediment deposited in a lake environment), or consolidated, clays/peats indicative of pre-lake in-situ soils.

Figure 3.1: Sediment core locations in the dewatered Lake Ratapiko in April 2019

3.2.2 Indicative suspended sediment load results

Using the long-term average suspended sediment loads (NIWA 2017), the estimated total suspended sediment load entering Lake Ratapiko from the catchments (via the Motukawa Race, Lake Ratapiko and Mako Stream) is 693 tonnes/year (Table 3.2). This equates to a volume of 475 m^3/year[2].

Sediment loads entrained into the Motukawa Race from the Manganui River have also been estimated using the suspended sediment rating curve and the synthetic hourly inflows (T+T 2021) at the Manganui Weir (Section 3.2.1). To generate the estimate, it is assumed that, at any given instance, the flow diverted into the race has the same suspended sediment concentration as the flow approaching the weir. This assumption slightly overestimates the sediment input to the race under low to moderate flow conditions as some settlement might occur in the pondage behind the weir. However, little sediment is present in such flow conditions. Using this approach, it is estimated that about 805 tonnes of suspended sediment a year is transported into the Motukawa Race, based on a maximum consented take of 5.2 m^3/s.

Should the take capacity increase to 7.5 m^3/s, using the same calculation, this value is predicted to increase to approximately 1075 tonnes/year.

In addition, roughly 100 m^3/year of sediment is extracted from the Silt Pond (C. England pers. comm). This material is assumed to be mostly fine (0.125 mm diameter) to coarse (1 mm) sands, characteristic of the 'fine grained' suspended and wash load for the Manganui River (as described in Section 3.1). This represents roughly 18 % of the estimated annual sediment load (under the existing

[2] Based on a wet density of silty sand and gravel of 1.46 tonnes/m^3

maximum take of 5.2 m^3/s) entering the Motukawa Race though the Manganui River intake. An assessment of the effectiveness of the Silt Pond is discussed further in Section 3.3

When the estimated suspended sediment load from Manganui River is included in the sediment budget, the annual suspended sediment load for Lake Ratapiko increases to approximately 1,350 tonnes/year, or approximately 930 m^3/year. These estimates do not include sediment contributed from any erosion within the Motukawa Race, nor do they include bed load[3].

Table 3.2: Estimated suspended sediment load for each sub-catchment entering Lake Ratapiko

Sediment source	Annual suspended sediment load (tonnes/year)	Annual sediment volume[4] (m^3/year)
Motukawa Race catchment	270[5]	185
Lake Ratapiko catchment	70[5]	50
Mako Stream catchment	360[5]	245
Subtotal (excluding Manganui River)	*700*	*480*
Estimated SS load entrained from Manganui River	805[6]	551
The Silt Pond	-146[4]	-100[7]
Total for all sources	1360	930

The sediment cores appear to support the sediment loads presented in Table 3.2. The surface material retrieved in the sediment cores was a loose, unconsolidated dark brown silt with extensive organic material (predominantly fine roots from aquatic plants). This material is assumed to represent the 'deposited sediment' that's been entrained into the Motukawa Race (or local lake catchments) and transported all the way through into Lake Ratapiko. Below this material, there was a distinct cohesive clay layer, which is assumed to be the 'in situ' ground surface, present before the Mako Stream was dammed to form Lake Ratapiko (Figure 3.2).

These results suggest that in the four sampled sites, there was between 0.05 – 0.2 m of sediment deposited since the formation of the lake (period of 92 years). The greatest amount of deposition is in Location 4 near Ratapiko Road (Figure 3.1).

These levels of deposition, over a 92 year period spanning the life of Lake Ratapiko, represents an annual elevation change of 0.001 m in the Eastern Arm, or an annual sediment volume of 220 m^3 in the Eastern Arm only.

[3] No bed load is expected to be entrained into the Motukawa Race from the Manganui River, or from the Motukawa Race itself. A very small amount of bed load may enter Lake Ratapiko from the local lake catchment and Mako Stream, but these loads are likely to be minimal.
[4] Based on a wet density of silty sand and gravel of 1.46 tonnes/m^3.
[5] Source of data from NIWA Shiny Maps (NIWA 2017).
[6] Generated using the suspended sediment flux rating curve described in Section 3.2.1
[7] C. England pers. comm

	
Example of in-situ soils exposed in the banks of Lake Ratapiko, predominantly characterised as red-brown clays.	*Example of one of the sediment sample locations. Note the loose dark brown silts characterising the top layer (deposited silts) and the red-brown clays beneath (in-situ soils).*

Figure 3.2: Example of in-situ soils and material forming the bed of Lake Ratapiko observed during the 2019 site visit

On a long term average basis, the estimated suspended sediment entrainment into the Motukawa Race from the Manganui River is approximately 6 % of the overall suspended load in the Manganui River at the weir. This leaves 94 % of the 'natural' suspended sediment load to continue downstream of the weir.

In addition, it is assumed that no sediment is entrained into the Power Station tunnel at the Lake Ratapiko intake (located in the Eastern Arm). This is largely confirmed by operations staff who have reported that sediment is not an issue within the Motukawa Power Station infrastructure (C. England pers. comm). This indicates that the Motukawa Power Station discharge into the Makara Stream is 'clear water' without sediment.

3.3 Sediment transport

As stated in Section 3.2.2 (Table 3.2), the potential load of sediment entering Lake Ratapiko is approximately 1,360 tonnes/year (or 930 m^3/year). This would equate to an approximate annual depositional rate of 0.004 m per year within Lake Ratapiko, or 0.33 m of deposited sediment over the 92 year life of Lake Ratapiko. This is reasonably consistent with observations on site (described in Section 3.2.2).

However, there are two other processes within the MTK HEPS which may impact on sediment deposition rates within Lake Ratapiko

1. The Silt Pond (Figure 1.1) is likely to be trapping and storing sediment; and
2. Suspended sediment transported into Lake Ratapiko is potentially being preferentially stored in the deepest part of the lake where no assessments have been undertaken.

In regard to point 1 above, the volume of sediment removed from the Silt Pond has been estimated to be roughly around 100 m^3 per year on average or 146 tonnes per year (Section 1.1 and Table 3.2). This would suggest that the Silt Pond is capturing at least approximately 18 % of the total sediment load entering Motukawa Race.

Ministry for Agriculture and Forestry (MAF) produced a 'best management practice' guidance note for the sizing and construction of a coarse sediment trap (Appendix B). Figure 1 in Appendix A uses surface area (m^2)/discharge (m^3/s) to predict the trapping efficiency of a sediment trap for different sediment sizes. Generally, sediment traps are designed to a specific trapping efficiency for a target sediment size (e.g. 90 % of sediment ≥0.125 mm).

As identified in Section 3.1, approximately 40 % of the suspended sediment load entering the Motukawa Race from the Manganui River is likely to be 'fine sand' or coarser (≥0.125 mm diameter).

Given the size of the Silt Pond, and the modelled velocities through the Silt Pond (Appendix C), it is expected that 90 % of sediment ≥0.125 mm would drop out of suspension and be stored in the Silt Pond. This equates to approximately 290 tonnes/year (or 200 m^3/year) of suspended sediment (≥0.125 mm diameter) trapped and stored in the Silt Pond, of which approximately 100 m^3 of this material is excavated annually.

The storage volume of the Silt Pond is not known, but a maximum storage volume of 25,000 m^3 has been assumed for the purposes of this report[8]. With 200 m^3 of sediment deposited annually, and 100 m^3 of this excavated annually, the Silt Pond has an estimated life >100 years (until full).

The remaining sediment not trapped in the Silt Pond (approximately 510 tonnes per year) is assumed to pass through the Silt Pond and into the race. In addition, approximately 270 tonnes per year of sediment is potentially contributed to the race from the local race catchments. This equates to approximately 780 tonnes per year (530 m^3) available for transport within the Motukawa Race, and into Lake Ratapiko.

The average velocities modelled in the Motukawa Race (Riley Consultants 2021) are between 1.0 m/s and 1.8 m/s. These velocities are on average, higher than the predicted 'scouring velocities' for coarse sands (Appendix C), which suggests that most of the sediment entrained into the Motukawa Race is constantly in flux. Where the slope of the race is steeper, channel narrow, or the channel lined with concrete, more sediment will be able to be transported. This suggests that the Motukawa Race will be efficient at transporting sediment through the race and into Lake Ratapiko, with minimal 'storage' of sediment within the race itself.

The lower suspended sediment loads entering Lake Ratapiko from the Motukawa Race (due to the effectiveness of the Silt Pond) equates to an annual average sediment depth across the lake of 0.003 m. Over a 92 year period, the accumulated areal averaged sediment depth in the lake is estimated to be 0.29 m (Table 3.3). This is in reasonable agreement with the sediment depths identified in the sediment cores taken from the Eastern Arm (Section 3.2.2), which showed between 0.05 – 0.2 m of sediment deposited since the construction of the lake (period of 92 years).

[8] Assuming the Silt Pond has an average depth of 2.5 m (which would be an over estimation) over a 10,000 m^2 surface area.

Table 3.3: Indicative volumetric change (m^3), annual sediment deposition rates (m) and total sediment deposition rates (m) within Lake Ratapiko with consideration of the effectiveness of the Silt Pond taken into account

	Estimated sediment loads entering Lake Ratapiko, including 100 m^3 extracted, but no consideration of additional storage in Silt Pond			Estimated sediment loads entering Lake Ratapiko, including 100 m^3 extracted, and taking into account additional storage in Silt Pond (assuming 90% effective)		
	Annual volumetric change (m^3)	Annual sediment deposition rates (m)	Total sediment depths over life of lake (m)	Annual volumetric change (m^3)	Annual sediment deposition rates (m)	Total sediment depths over life of lake (m)
Western Arm						
Motukawa race and local lake catchments only	640	0.009[9]	0.84	540	0.008	0.71
Eastern Arm						
Excluding Motukawa race inputs	290	0.0015[10]	0.14	290	0.0015	0.14
Total Lake						
	930	0.004	0.33	830	0.003	0.29

In regard to point 2 above, Lake Ratapiko is a sediment sink, meaning it does not have sufficiently high flow velocities to flush out sediment that is being contributed from the tributaries (i.e. Motukawa Race, Mako Stream and surrounding tributaries). When turbid water from the tributaries reaches the slower flowing lake water, the sediment begins to be deposited in the area where the tributary enters the lake (Figure 3.3). This process starts with the coarser sediment depositing first, followed by the finer sediment as the water moves further into the body of Lake Ratapiko.

This means that sediment introduced to Lake Ratapiko from the various inflows is most likely to remain in the embayment closest to the location of the inflow. For example, sediment brought into the system from the Motukawa Race is most likely to remain within the Western Arm. This process is likely to be exacerbated by the presence of submerged, rooted macrophytes.

There are lake processes that will affect this generalised pattern, however. When, the lake is drawn down, there is a high likelihood that some sediment deposited within the Western Arm will be transported through into the Eastern Arm. The amount of connectivity between the Western and Eastern arms when the lake is full was not assessed as part of this assessment, as initial site observations made when the lake was drawn down suggested sediment deposition was not excessive in the lake (and therefore understanding this connectivity was largely immaterial to the scope of the assessment). However, it is likely that sediment, especially suspended fine silt and clay particles, is being transported from the Western Arm into the Eastern Arm during 'normal' flow conditions.

Given all of the above, it is highly likely that a proportion of the sediment entering Lake Ratapiko from all sources, is subsequently deposited in the deeper areas of the Eastern Arm in Lake Ratapiko.

[9] Based on 70,000 m^2 surface area of the Western Arm, and sediment contributions only from the Motukawa Race (including sediment entrained from the Manganui River) and local lake catchments only. Sediment transfer between the arms (through the Ratapiko Road culverts) has not been accounted for.
[10] Based on a surface area of 190,000 m^2 in the Eastern Arm, and sediment contributions from Mako Stream and local lake catchments only. Sediment transfer between the arms (through the Ratapiko Road culverts) has not been accounted for.

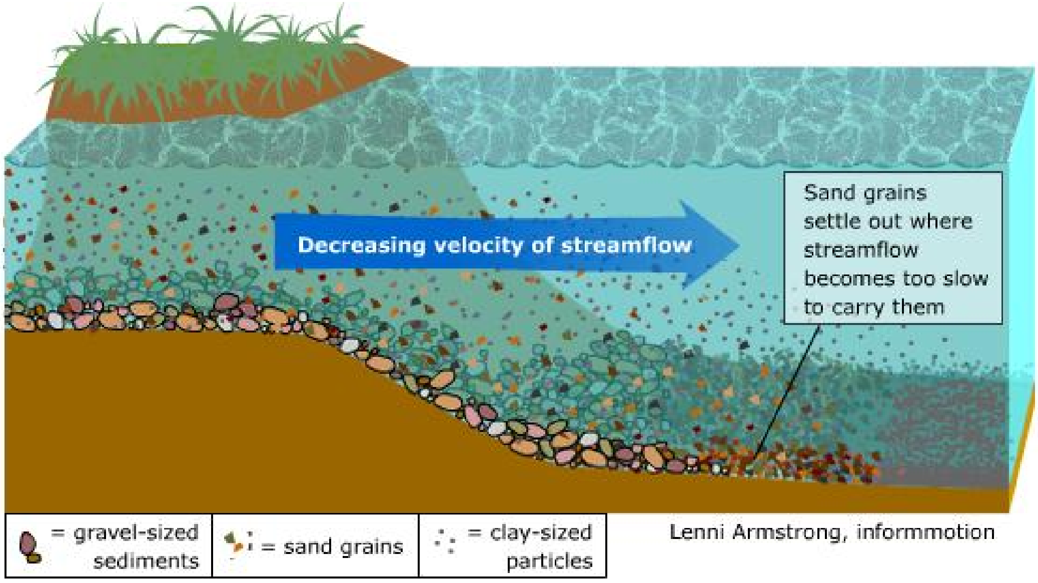

Figure 3.3: Schematic demonstration the settlement of sediment when a stream enters a lake. Source: Exploring Earth Visualizations website

4 Effects assessment

An assessment of effects of the proposed 7.5 m^3/s take from the Manganui River on sediment processes has been undertaken.

The assessment of effects of the MTK HEPS on sediment processes is intended to inform the effects assessments prepared by other technical specialists. This effects assessment is not intended to be a stand-alone effects assessment report, especially in relation to the NPS FM (2020) provisions relating to "Loss of river extent and values".

The effects assessment has been undertaken on the following reaches:

- Manganui River downstream of the race intake and the Manganui Weir.
- Motukawa Race.
- Lake Ratapiko.
- Mako Stream downstream of the Lake Ratapiko Dam.
- Makara Stream downstream of the Motukawa Power Station.
- Waitara River downstream of the Makara Stream confluence.

For the last two reaches (Makara Stream and Waitara River), the effects assessment is directly related to the Motukawa Power Station discharge.

The effects assessment is provided in Table 4.1, and has been based largely on the 'existing environment' as described in earlier sections of this report. Where no change to the existing environment is expected as a result of the increased take of 7.5 m^3/s, the effects assessment may refer to the descriptions of the existing environments presented in Section 2.2.

Some additional assessments have been made in regard to predicted sediment loads under the proposed 7.5 m^3/s take, using the methods outlined in Section 3.2.1. These results are presented in the 'description of effects' column of Table 4.1, and are not presented elsewhere in this report.

Table 4.1: Assessment of the effects of the proposed maximum 7.5 m^3/s take from the Manganui River on the identified reaches

Reach	Description of effects on sediment processes	Level of effect	Comment
Manganui River downstream of the race intake and the Manganui Weir	• The proposed maximum take of 7.5 m^3/s represents about 4% of the MAF. • Potential increase in suspended sediment entrained into the Motukawa Race from the Manganui River (increased to 1075 tonnes/year from 805 tonnes/year currently). • Potential 8% reduction in annual suspended sediment loads passing over the weir into the downstream reach. • No change in bed load transport expected.	Very low	The effects associated with the proposed increase in take to 7.5 m^3/s is unlikely to result in any observable change from the existing conditions in the Manganui River downstream of the Manganui Weir, as described in Section 2.2.1

Reach	Description of effects on sediment processes	Level of effect	Comment
Motukawa Race	· Increase in suspended sediment load entrained into Motukawa Race (1075 tonnes/year from 805 tonnes/year currently). · The Silt Pond is expected to trap and store up to 90% of fine grained sediment (≥0.125 mm) entrained into the Race from the Manganui River. · Increase in sediment passing through the Silt Pond into the Motukawa Race (up to 690 tonnes per year from 510 tonnes per year currently). · Velocities in the Motukawa Race expected to increase in some reaches, resulting in an increase in sediment transport capacity. · No expected change in deposited fine sediment within the Motukawa Race.	Very low	The effects associated with the proposed increase in take to 7.5 m^3/s is unlikely to result in any observable change from the existing conditions in the Motukawa Race as described in Section 2.2.3.
Lake Ratapiko	· Increase in sediment entering Lake Ratapiko from the Motukawa Race (estimated at 690 tonnes per year compared with 510 tonnes per year currently). · Increased sediment entering Lake Ratapiko is expected to have minimal change to annual deposition rates (0.0037 m annually across the whole lake compared with 0.0032 m per year currently). · Increased sediment entering Lake Ratapiko is expected to result in minimal loss of live lake storage. · No change to sediment loads entering Lake Ratapiko from the Mako Stream and local lake catchments. · No change in sediment dynamics expected within the lake itself.	Very low	The effects associated with the proposed increase in take to 7.5 m^3/s is unlikely to result in any observable change from the existing conditions in Lake Ratapiko as described in Section 2.2.4, and Section 3.3.

Reach	Description of effects on sediment processes	Level of effect	Comment
Makara Stream downstream of the Motukawa Power Station	· No change in proposed maximum consented discharge from Motukawa Power Station as a result of the proposed increase in take from the Manganui River. · No expected change in sediment dynamics from existing conditions.	Very low	The effects associated with the proposed increase in take to 7.5 m^3/s is unlikely to result in any observable change from the existing conditions in the Makara Stream, as described in Section 0.
Mako Stream downstream of the Lake Ratapiko Dam	· No change in sediment processes to those described for the existing environment.	Very low	The effects associated with the proposed increase in take to 7.5 m^3/s is unlikely to result in any observable change from the existing conditions in the Mako Stream downstream of Lake Ratapiko, as described in Section 2.2.2.
Waitara River downstream of the Makara Stream confluence	· No change in proposed maximum consented discharge from Motukawa Power Station as a result of the proposed increase in take from the Manganui River. · No expected change in sediment dynamics from existing conditions.	Very Low	The effects associated with the proposed increase in take to 7.5 m^3/s is unlikely to result in any observable change from the existing conditions in the Waitara River, as described in Section 2.2.6.

5 Summary

Trustpower's MTK HEPS Resource Consents expire on 1 June 2022.

To support the reconsenting process Trustpower is seeking to understand the effects of the existing maximum water take from the Manganui River on sediment processes within the MTK HEPS and associated receiving environments, and how these effects may change with the proposed increase in maximum water take from the Manganui River to 7.5 m^3/s. As such, T+T have provided the following for the MTK HEPS:

1. A description of the existing stream environments associated with the MTK HEPS, focussing on the Manganui River, the Motukawa Race, the Mako Stream, Lake Ratapiko, the Makara Stream (below the Lake Ratapiko) and the Waitara River (Section 2).
2. A description of the existing sediment regime and processes within the MTK HEPS and associated receiving environments (Section 3).
3. An assessment of the effects of the proposed increase in take of 7.5 m^3/s on sediment processes within the MTK HEPS and associated receiving environments (Section 4).

A site visit was completed, alongside a desktop analysis of catchment properties that influence sediment regimes, including land use, geology and soils. Sediment cores were also collected from Lake Ratapiko when the lake was drawn down in April 2019. The cores were used to assess the degree of sedimentation within Lake Ratapiko, and to corroborate estimations of sediment deposition rates. Finally, a suspended sediment flux rating curve was developed using historic suspended sediment samples from the Manganui River. This rating curve was then applied to flows recorded for the Manganui River to determine how much sediment is likely to be entrained into the Motukawa Race from the Manganui River, on average, over a year.

The amount of sediment estimated to be entering the Motukawa Race from the Manganui River is 805 tonnes per year. This represents 6 % of the potential annual suspended sediment yield for the Manganui River, suggesting this 6 % of suspended sediment is effectively removed from the Manganui River (downstream of the weir).

There are multiple waterways entering Lake Ratapiko. To the west, the Motukawa Race enters the lake, delivering water diverted from the Manganui River. Approximately 1075 tonnes per year is estimated to be entrained into the Motukawa Race from the Manganui River and local race catchments.

The Motukawa Race showed no signs of aggradation (suggesting there is not an over-supply of sediment), and modelled velocities within the race suggest fine sediment would be constantly in flux. This would suggest that any sediment entering the race is carried rapidly through the system and into Lake Ratapiko.

There is a Silt Pond at the start of the Motukawa Race, and this has been assessed as having a 90% trapping efficiency for sediment ≥0.125 mm. In addition, in most years roughly 100 m^3 of sediment is extracted from the Silt Pond. This reduces the potential sediment load entering Lake Ratapiko to approximately 780 tonnes per year.

The small catchments draining directly into Lake Ratapiko were assessed as having a small annual sediment yield (70 tonnes per year), while the Mako Stream was estimated to contribute up to 360 tonnes per year. In total, an estimated 1,200 tonnes per year is estimated to currently enter Lake Ratapiko. This equates to an annual sediment deposition rate of 0.003 m, or approximately 0.3 m over the whole life of the lake to date. This is in reasonable agreement with the observed sediment deposited within Lake Ratapiko, and the sediment cores, which suggested between 0.05 – 0.2 m of sediment has been deposited since the formation of the lake. Due to the morphology of the lake, it is also likely that sediment is being preferentially stored in the deepest part of the lake where no assessments were able to be undertaken.

The discharge from the Motukawa Power Station into the Makara Stream is considered ‘clean water’ with no sediment associated with it. This may have resulted in a ‘clear water effect’ where the sediment transport capability exceeds the sediment supply. While the Makara Stream downstream of the Power Station is incised, the incision appears to be historic and no longer active.

The Waitara River is the second largest catchment in the Taranaki Region, and originates in the Moki Ranges. The Waitara River is different in character and behaviour to the rivers which originate on Mount Taranaki. The Motukawa Power Station discharge ultimately ends up in the Waitara River, via the Makara Stream, but the discharge represents a small increase in mean flow in the Waitara River and is considered to contain no additional sediment.

As the MTK HEPS has been in operation for almost 100 years, some of the current sediment effects associated with the scheme are considered historic (e.g. the processes have already happened and are no longer active). The remaining sediment effects associated with the MTK HEPS are associated with slight changes in suspended sediment loads within the Manganui River, and the effects of sediment entrained into the Motukawa Race (from the Manganui River) and being deposited within Lake Ratapiko.

The proposed increase in take from the Manganui River to 7.5 m^3/s is likely to result in a very small change to suspended sediment loads entering the Motukawa Race, and subsequently Lake Ratapiko. This change in suspended sediment load is unlikely to result in any observable change in annual deposited sediment, or annual volumetric change within Lake Ratapiko.

6 Applicability

This report has been prepared for the exclusive use of our client Trustpower Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that this report will be used by Taranaki Regional Council in undertaking its regulatory functions in connection with the reconsenting of the MTK HEPS.

Tonkin & Taylor Ltd

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Selene Conn	David Leong
Technical Director – Fluvial Geomorphology	Project Director

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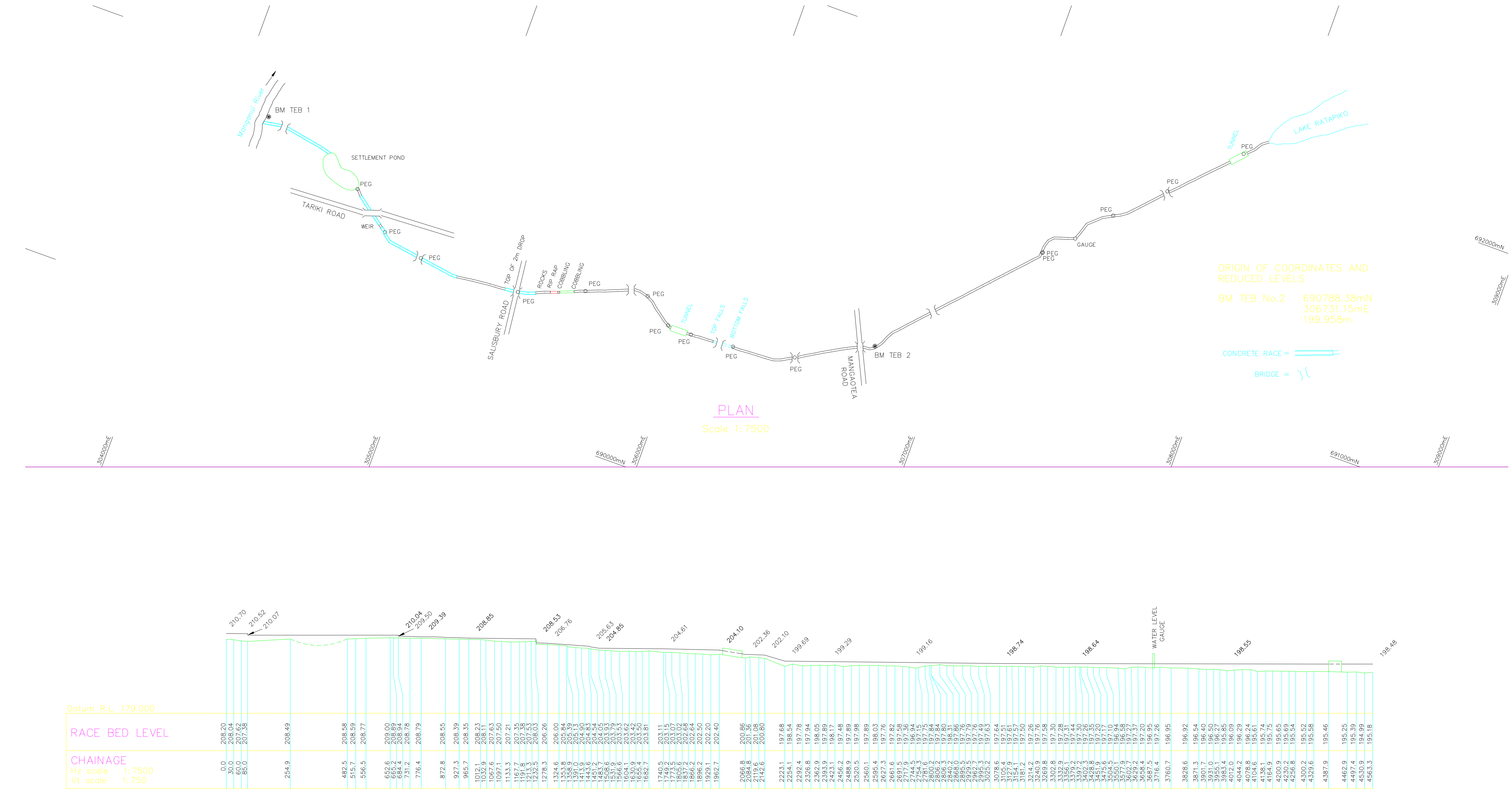
Appendix A: Historical race drawing



TARANAKI GENERATION

MOTUKAWA RACES

PLAN & SECTION OF RACE, RIVER TO LAKE

1 1 0

As Shown

Works Consultancy Services

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Appendix B: Best management practice guidance note for the sizing and construction of a coarse sediment trap

In-channel coarse sediment trap
Best Management Practice

By Henry R. Hudson
Environmental Management Associates Ltd., Christchurch

July 2002

Complexity		
Low	Moderate	High

Environmental Value		
Low	Moderate	High

Cost		
Low	Moderate	High

Definition

Coarse sediment traps are excavations in the bed of a watercourse designed to limit the downstream movement of sand and gravel from upstream sediment sources. Depending on trap design and stream characteristics, lesser amounts of fine sediments (the fine sand, silts and clays that move in the flow rather than along the bed) can be trapped. A coarse sediment trap is required as the upstream component of a constructed wetland system. The trap is for sedimentation of solids down to coarse and medium silt; and the wetland removes the fine sediment, and dissolved and finely dispersed contaminants.

Purpose

1) Instream sediment traps are used in conjunction with other sediment control measures to reduce excessive sediment in watercourses: For upland sediment sources, the most desirable strategy is to implement land management practices that reduce erosion and transport of sediment and associated contaminants (e.g. conservation tillage; critical area planting). The second strategy is to retain sediments on the land before they get to the drainage network (e.g. filter strips, sediment retention ponds). For channel sources, streamflow should be retarded to protect the channel (e.g. vegetated banks); eroding banks should be repaired (e.g. contour and vegetate); and livestock that cause erosion should be removed from the channel and banks. If these measures are not undertaken, then continuous in-channel sediment problems will occur. In some cases, the in-channel sediment trap is the first line of defence (e.g. multiple, uncontrollable sediment sources).
2) Excessive sediment deposition is common, destabilises channels, and reduces instream habitat quality and quantity: Excessive sediment reduces channel capacity and causes drainage and flooding problems. Aggrading channels tend to have bank erosion. Pools are infilled and finer material accumulates in the gravel bed reducing habitat quality and quantity. Trout populations (and presumably other species that require clean gravel bed channel) are significantly reduced with sand deposition in a gravel stream.
3) Sediment traps confine sediment deposition to a small reach of channel and reduce excavation costs: Sediment traps are relatively wide, short and deep excavations in the bed. Trapped sediment does not progress downstream where deposition would reduce channel capacity. The trap itself has to be episodically excavated (after major storms) rather than a much greater length of the stream. Further monitoring is required, but preliminary indications are that in appropriate situations maintenance costs are reduced to about half or less of regular downstream channel excavation. Widespread use internationally indicates the economic and environmental benefits of sediment traps.
4) Environmental benefits result from limiting downstream disturbance: Excavating channels causes modification or loss of habitat; re-suspension of sediment and sediment associated contaminants; and removes invertebrates, fish, eels and crayfish from the channel. This may have long-term impacts.
5) Trapping excessive sediment improves physical habitat: Habitat for fish and food production are damaged by excessive sediment. Stopping excessive inputs of sediment into channels and trapping sediment improves habitat. However, erosion of the channel may occur if the natural sediment supply is cut off, or if the bed at the trap is unstable.

6) Establishing and maintaining good bank vegetation is a priority: Appropriate vegetation provides bank protection, shade and nutrients, with improvements in channel stability and habitat quality.
7) It may take years before channel changes are apparent: The damage from excessive sediment inputs can take years to work there way downstream. Recovery by trapping sediment is rapid immediately below the sediment trap, but it takes time for a wave of sediment to move through the system (or to be trapped in other places downstream) and for conditions to improve.
8) A plume of sediment will be released from the channel during excavation of the sediment trap and with re-excavation of the trap: Sediment Control measures must be used to minimise sediment washing into the channel from tracks and stockpiles of spoil. During excavation a plume of sediment will be released from the channel, but this usually results in a short duration discolouration of water without biological impact.
9) Channel diversions may be an effective means of reducing sediment plumes during excavations: In particularly sensitive areas where large quantities of fine sediment are trapped, it might be prudent to divert flow around the sediment trap during excavation. However, these diversions may also introduce a sediment plume.
10) A vegetated by-pass channel may be an effective means of reducing sediment plumes during excavations: A permanent low flow bypass channel could be constructed and stabilised with vegetation prior to excavation of the in-channel sediment trap. The bypass channel could be temporarily re-activated when the sediment trap is to be re-excavated (e.g. block the main channel with straw bales to divert the flow into the grassed waterway bypass channel). (See the Grassed Waterways BMP).

Location

1) A long relatively straight channel reach with good access, room to operate an excavator, room to stockpile or dispose of sediment, and suitable ground conditions are required.
2) Sediment traps should not cause channel instability and endanger infrastructure, and public health and safety.
3) Sediment traps to enhance fisheries should be constructed where the potential for downstream recovery from excessive sediment exists (e.g. gravel bed channels with excessive sand deposition).

Work Window

1) Establish which fish and birds use the channel and channel margins.
2) Establish which times and places are sensitive to disturbance by consulting the "Work Windows" management practice.
3) Avoid in-channel works during sensitive times (e.g. trout spawning and incubation in gravel bed streams).

Performance Indicators

1) Design objectives are stated and followed in the construction and maintenance of the sediment trap. As-built surveys will be undertaken.
2) Sediment control management measures are followed in the construction and maintenance of the sediment trap, which includes delineation and protection of sensitive places on the channel banks and berms.
3) Construction and maintenance costs are documented.
4) Design trapping efficiencies are achieved.
5) After a period of adjustment, channel conditions approach reference reach conditions, and the channel should be in dynamic equilibrium.

6) After a period of adjustment, biological conditions approach reference reach conditions.

7) The sediment trap does not endanger infrastructure, such as bridges and water intakes.

8) The banks of the sediment trap are vegetated with species that promote bank stability, trap sediment and provide habitat.

9) Sensitive times and places of fish and wildlife (e.g. trout spawning in riffles; bird nesting) are avoided during construction and maintenance.

10) Sediment traps should not endanger infrastructure or public safety. Sediment traps should be well signposted and secured from inadvertent access (e.g. the access track to the trap is gated).

Procedures

These procedures are not a substitute for expert advice on the particular conditions prevailing at the site. Get expert advice on the design requirements (e.g. the river engineers at the Regional Council).

Planning

1) Consult with experts at the regional or district council regarding the location and design of in-channel sediment traps, paying particular attention to channel stability and public health and safety.

2) Develop a construction, operational and maintenance plan, and obtain the necessary resources consents and access agreements. This plan will include Sediment Control measures. As part of this plan consult with Fish and Game, Department of Conservation and the Work Windows guidelines to avoid sensitive times and places for construction and maintenance. Flag or signpost sensitive areas and make operators aware of the need to avoid these areas. Consult to see if fish salvage is required.

3) Assess if a diversion channel or vegetated bypass channel will provide significant benefit in the construction and on-going maintenance of the sediment trap.

4) Assess if grade control structures are required.

5) Plan and undertake construction activities following the Sediment Control guidelines. The sediment control plan will avoid and/or control discharge of sediment to the channel and other sensitive areas (e.g. wetlands). The plan must emphasise minimising soil disturbance and source control of sediment.

Construction

6) All embankments and structures must be constructed in accordance with accepted engineering practice, and with appropriate materials.

7) Determine the design flow for the channel where the sediment trap is to be located and establish the viability of creating a trap (see location).

8) Determine the target size of material to be trapped, and the trapping efficiency required. Fine sand (i.e. sediment ≥0.125 mm) and 90% trapping are often used.

9) Determine the surface area of the sediment trap from Equation 1 or Figure 1. For example, for a design flow (Q) of 1 m^3/s, fine sand (w= 0.10 m/s), and an efficiency (E) of 90%; the required surface area (A) is 222 m^2.

$$A = -\frac{\ln(1-E)}{w} Q \qquad (1)$$

10) Use a rule of thumb for the initial trap size estimate: 1.5 times wider than the channel; length to width ratio of 4:1 to 10:1; and a depth 1.5 m below the average bed level. For a 5 m wide channel, the trap width is 7.5 m, and the trap length 30 m to 75 m long.

11) Check the depth required to prevent re-suspension of the trapped sediment (the cross section average velocity is used). From Figure 2, for a design flow of 1 m^3/s a cross sectional area (CSA) of 5.6 m^2 is required to stop fine sand re-suspension (a velocity of 0.18 m/s – Table 1). For a 7.5 m wide trap, the minimum depth to prevent re-suspension is 0.75 m (i.e. the trap is effectively full when sediment is 0.75 from the design water surface). A 1.5 m deep excavation provides more than 0.75 m of effective storage because the depth of flowing water, which is determined by the outlet control, provides additional settling capacity. This additional depth can be used as a factor of safety.

12) Trap length:width ratios are normally 4:1 to 10:1. The trap should gradually widen downstream. Trap size is determined by the input of bedload and the desired frequency of cleaning. An estimate can be made from historic channel cleaning records. At 4:1 the gross storage is ~340 m^3; and the effective storage is ~170 m^3. At 10:1 the gross storage is ~840 m^3 and the effective storage is ~420 m^3.

13) Excavation would preferably be undertaken with a dragline or hydraulic excavator operating from the bank. The cross section of the trap should be uniform, to limit flow separation, and gradually expand in the downstream direction.

14) Channel side slopes should be 1 vertical: 3 horizontal, or more gentle if possible.

15) Suitable vegetation should be planted to stabilise the banks and berms, and provide food and habitat for fish and wildlife. Locally sourced native species are preferred, and these may be inter-planted with exotic vegetation to promote rapid re-vegetation and channel stabilisation.

16) Construct grade control structures if required.

Maintenance

17) Work within the planning guidelines developed for this particular site (e.g. the Sediment Control plan for the site).

18) Regular inspections should be carried out as part of an overall system maintenance programme, and after floods. The inspections will determine when the trap should be re-excavated; and to detect potential problems (e.g. scour; bank failure).

19) Vegetation should be maintained in good condition (See the Sediment Control guidelines).

Sediment Removal and Stockpiles

20) The design depth of the sediment trap should be marked in the sediment trap (e.g. a stage gauge board). Once the effective capacity of the sediment trap is reached, the trap effectiveness declines, and the sediment trap should be re-excavated.

21) If a diversion channel or grassed waterway has been installed, divert flow into the by-pass before excavating the sediment trap.

22) It is preferable to undertake re-excavation of the sediment trap operating from the bank rather than from in the channel. This will be determined by the sediment trap dimensions, and size and type of excavator.

23) Stockpiles must not be left in the channel where they impede flow or are likely to be eroded by flowing water. Overburden, vegetation or other debris should not be deposited into a watercourse or left in a position where that material could fall into or be washed away. This material may be removed from the site, buried or levelled.

24) Excavated materials should not be placed in wetlands with significant habitat value. Grading should not occur in significant wetlands.

25) Clean spoil can be used to build an embankment along the channel. Embankments may be used as access lanes for future maintenance. Embankments should not confine or direct overbank flows to cause instability of the channel or other structures (e.g. roads, bridges, and culverts).

26) Direct water accumulating on or behind spoil areas or embankments to protected outlets (See Grassed Waterways).

Decommissioning

27) In many cases a sediment trap can be de-commissioned merely by not removing sediment deposits. The bed will build up, and the edges will infill as vegetation encroaches and traps sediment. The channel will eventually be indistinguishable from the adjacent channel.

28) Once stockpiles have been removed, the site should be levelled and re-vegetated. Unless agreements have been made to retain access tracks, tracks should be covered in soil and re-vegetated. These requirements should be explicitly stated in the plans for the site.

Related BMPs

Channel Diversions (Hudson, 2001); Grassed Waterways (Hudson, 2001).

Channel Stability Assessment (recommended guideline); Constructed riffle (recommended BMP);

Rock weir (recommended BMP); Vegetative bank protection (recommended BMP)

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Design Guides

Table 1. Average fall velocities for naturally worn quartz grains in 20^{0}C water (based on relations in Raudkivi, 1993); and scouring velocities (from VSC, 1999).

Size Class	Nominal Diameter (mm)	Settling Velocity (m/s)	Scouring Velocity (m/s)
Very coarse sand	2.00	0.193	0.72
Coarse sand	1.00	0.121	0.51
Medium sand	0.50	0.064	0.36
Fine sand	0.250	0.029	0.25
Very fine sand	0.125	0.010	0.18
Coarse silt	0.062	0.0026	0.13
Medium silt	0.031	0.00064	0.09
Fine silt	0.016	0.00016	0.06
Very fine silt	0.008	0.00004	
Clay	0.004	0.00001	

The upper end of each size class is listed (e.g. very coarse sand is 1-2 mm; coarse sand 0.5-1 mm)

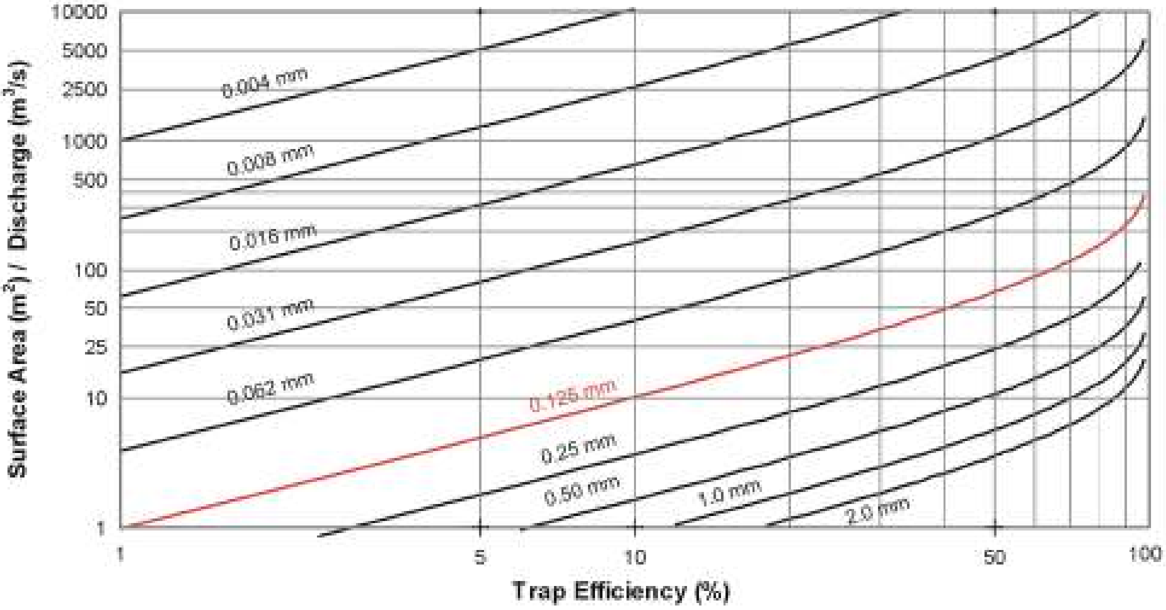


Figure 1. Percent of sediment retained for different sediment trap areas, sediment sizes and discharges.

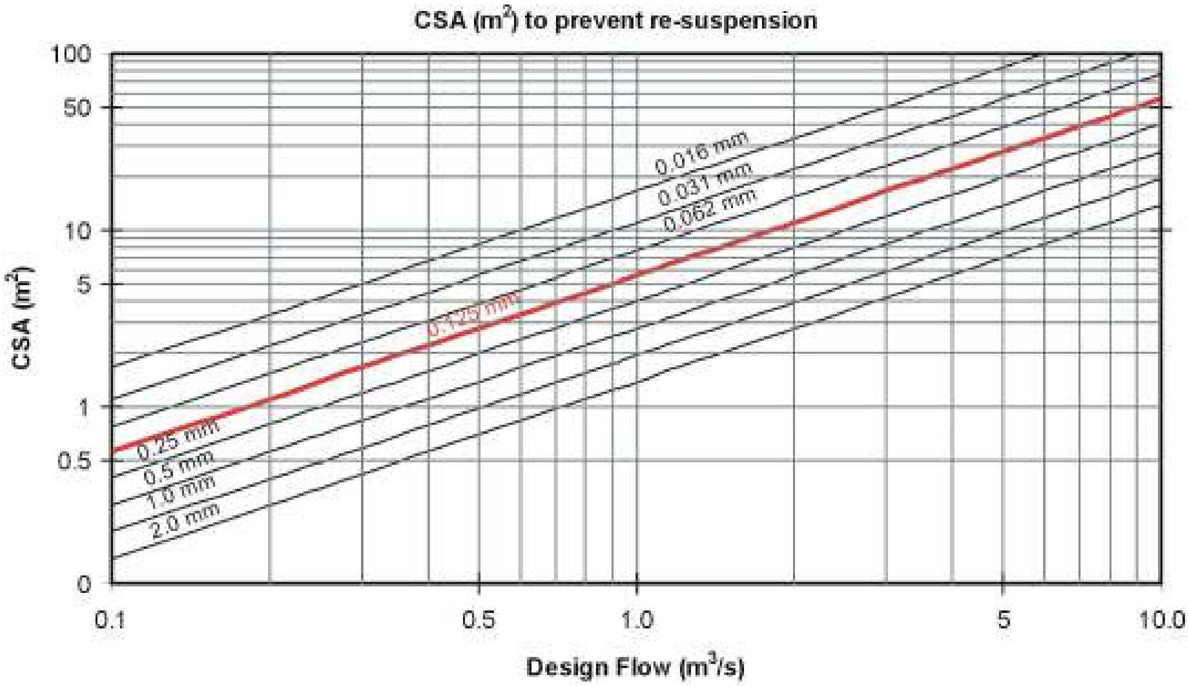
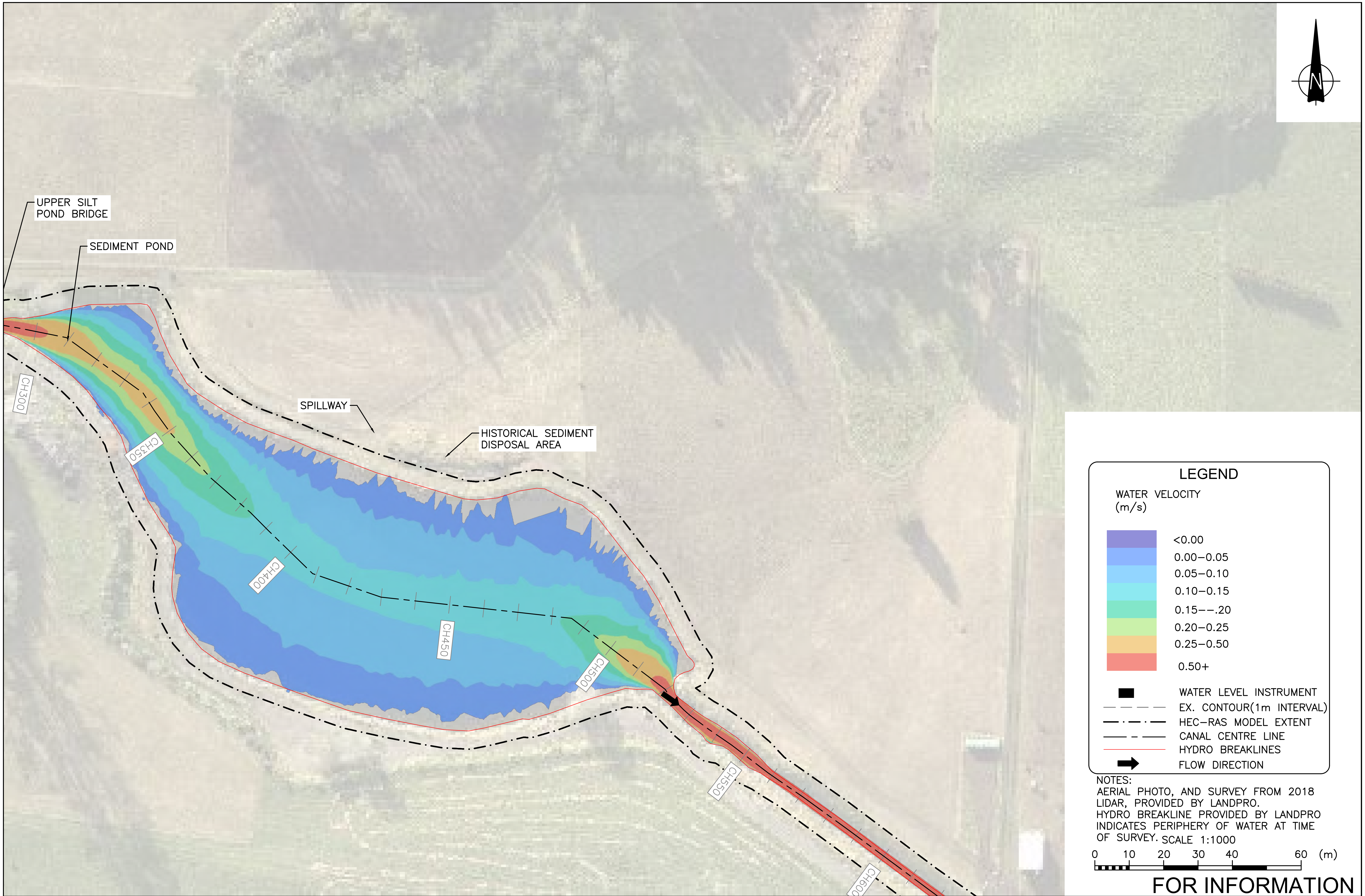


Figure 2. Cross sectional areas required for preventing re-suspension for different sediment sizes and discharges.

Appendix C: Velocity maps for the Silt Pond



NOTES:
AERIAL PHOTO, AND SURVEY FROM 2018 LIDAR, PROVIDED BY LANDPRO.
HYDRO BREAKLINE PROVIDED BY LANDPRO INDICATES PERIPHERY OF WATER AT TIME OF SURVEY.

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TRUSTPOWER LTD
MOTUKAWA HYDRO ELECTRIC POWER SCHEME
CANAL ENHANCEMENT EXISTING FLOW- FIGURE A

CADFILE 18MTK_ENH–FIGA
SCALES (A3) 1:1000
ACENZ
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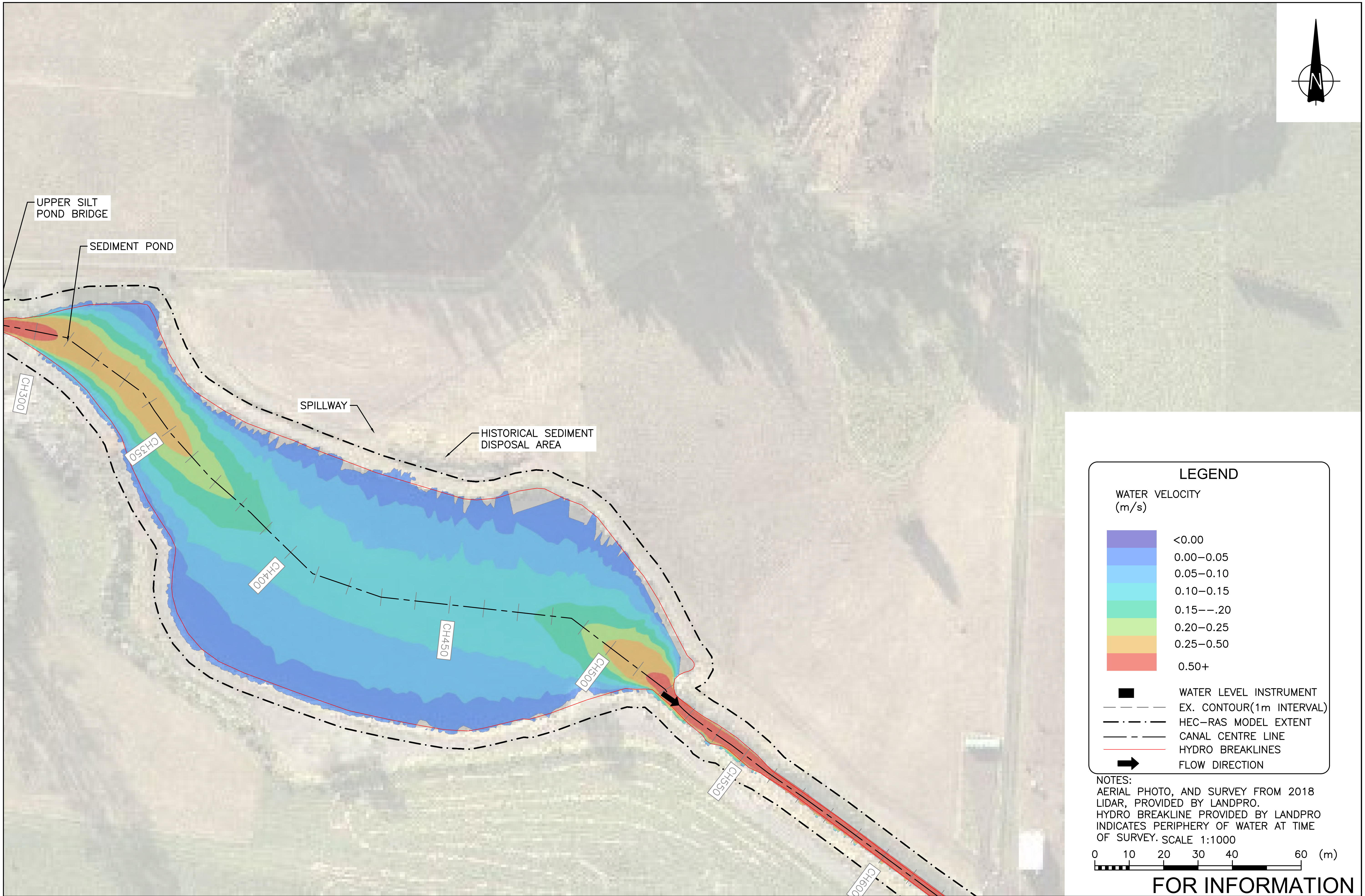
REV. 1



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CANAL ENHANCEMENT RAISED FLOW- FIGURE B

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