PRAGMATIC PRACTICE FOR RIVER MANAGEMENT – THE TONGARIRO AND TAURANGA-TAUPO RIVERS

Ghassan Basheer and Sarah Basheer – Environment Waikato, David Bouma and John Duder – Tonkin & Taylor

ABSTRACT

Best practice for River Management is an idea worth pursuing, but not always attainable. The goals should be kept firmly in view, but invariably the outcome will be a pragmatic combination of achievable components to achieve the Best Practicable Option (BPO).

The two most active contributories flowing into Lake Taupo are the Tongariro and Tauranga-Taupo Rivers, both rising in the greywacke rocks of the Kaimanawa ranges but with significant inputs from volcanic sources, particularly into the Tongariro. Both rivers flow through and impact on the established townships of Turangi and Oruatua/Te Rangiita respectively, and have caused significant flooding in recent years, including floods in excess of the 1% AEP on the Tongariro River.

The prime aims of river management have therefore been pragmatic approaches to protecting assets, in many cases ill advisedly located on the flood plains, by controlling flooding and erosion, and managing gravel deposits.

The physical issues which were evaluated in the extended processes of providing asset protection included remedying uncontrolled river diversions and breakouts, gravel management, upgrading of previous bank works with rock revetments and extended stopbanks, with the design processes assisted by a succession of computer models.

The paper discusses the investigations and designs leading to resource consents and construction, and the requirements for ongoing river management. Reference is also made to the value and limitations on modeling with MIKE 11, MIKE 21 and MIKE FLOOD.

KEYWORDS

Tongariro River, Tauranga-Taupo River, flood protection, erosion protection, modeling

PRESENTER PROFILE

Ghassan W. Basheer BSc. CE (Tech.), HD Urban and Regional Planning.

Ghassan is the Technical Services Programme Manager of Environment Waikato's River and Catchment Services Group. He has more than 30 years of experience covering a wide range of civil and water resources engineering fields, of which the last 13 years was within the Waikato region. His expertise includes investigations, design, implementation and maintenance of irrigation, flood control and drainage projects, as well as leading the hydraulic reviews of the major flood schemes in the region. He was the project manager for both the Tongariro and Tauranga-Taupo flood control schemes.

David Bouma BE (Hons), ME (Environmental Factors)(Dist), MIPENZ, CPEng, IntPE(NZ)

David is a senior civil and environmental engineer with 23 years experience in water resources, civil and environmental engineering projects in 8 countries. David is a director of Tonkin & Taylor and group manager of their Tauranga office.

David has a wide range of experience in water resources engineering including specialist skills in river management and engineering, hydrological and hydraulic analysis, analysis and design of stormwater drainage, and construction management. He was the design engineer and Engineer to Contract for the Tongariro flood control scheme.

1 INTRODUCTION

The recorded histories of the Tongariro and Tauranga-Taupo Rivers provide insight into the opportunities and limitations of managing active gravel rivers. The two rivers are the main contributories into the southern end of Lake Taupo, with greywacke mountain catchments but with a significant volcanic input to the Tongariro (Figure 1).

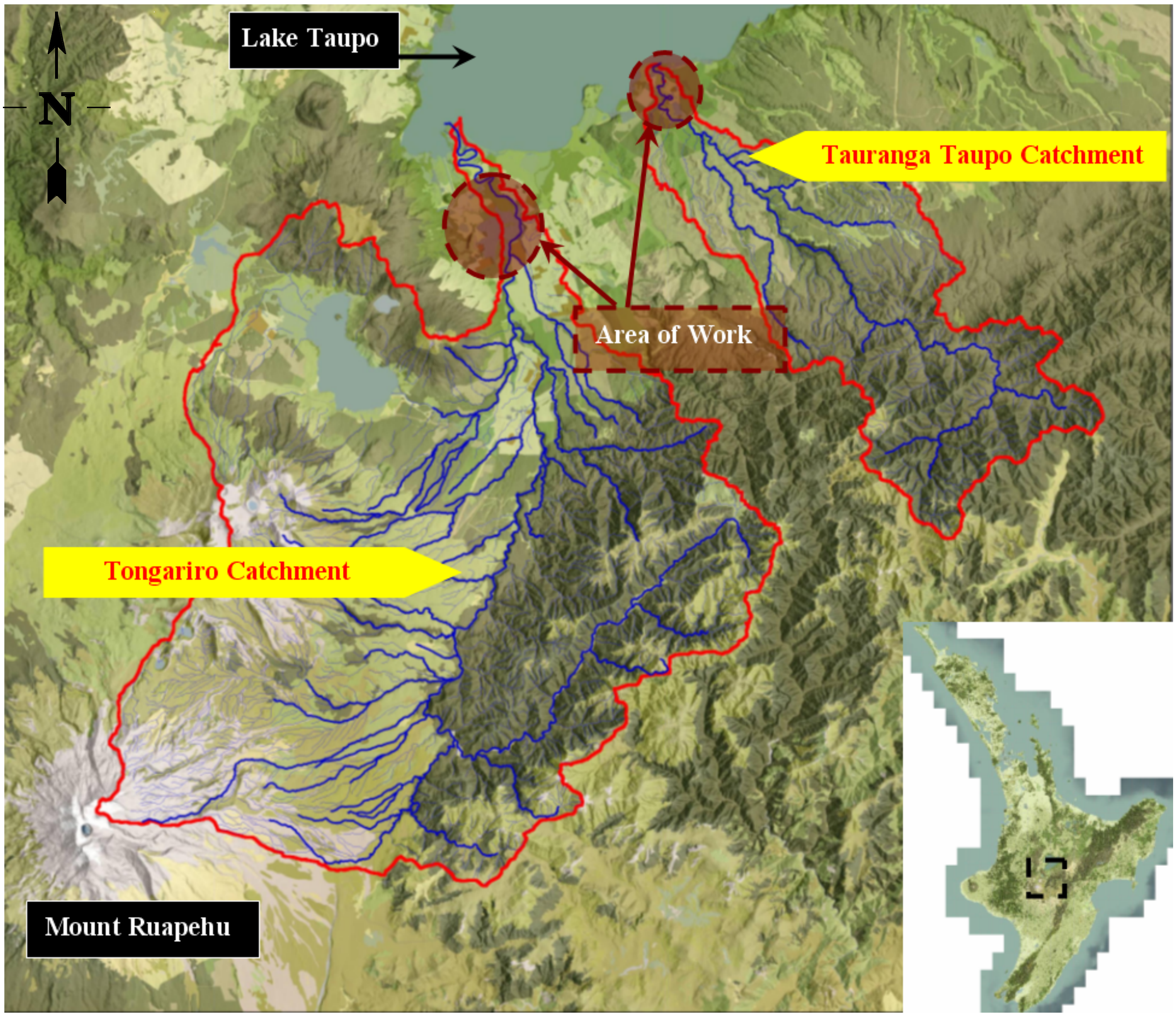

Figure 1: Location plan

Both rivers have been quarried for gravels and both flow through townships built at least partly on their flood plains. Major floods in 1958 for the Tongariro and in 1998 and through the 2000s for both rivers have thrown the issues into clear focus and provided the stimuli for progressive protection works and management plans.

The paper addresses the flood and gravel management history of each river, and evaluates the assets and properties at risk. The design processes used in developing river protection and stopbanks are described, including the sequence of computer modeling using real flood data to the extent available.

The processes and impediments to obtaining consents are discussed, which lead to pragmatic solutions tied as far as practicable to budgets based on rates from affected property owners and stakeholders.

2 SETTING THE SCENE

2.1 THE CATCHMENTS

2.1.1 TONGARIRO RIVER

The river rises predominantly in the Kaimanawa Ranges but with a substantial proportion of its upper catchment on the eastern slopes of volcanoes being Tongariro, Ngaruahoe and Ruapehu. The lower reaches of the river have been influenced by the delta infilling of Lake Taupo since its cataclysmic eruption around AD180. That process formed the land on which Turangi was established and the delta building continues into Lake Taupo with attendant issues of gravel use and management.

Best know since the early days of pakeha settlement for its trout fishing, the Tongariro has been the subject of substantial hydroelectric development not least the construction of the Turangi township partly on its flood plain.

These factors have contributed to the requirements for flood management and river erosion protection works in the lower reaches of the Tongariro.

2.1.2 THE TAURANGA-TAUPO RIVER

While predominantly a greywacke catchment in the Kaimanawa range north of the Tongariro, the lower reaches of the Tauranga-Taupo have been similarly influenced by the formation of Lake Taupo. Settlements on the flood plains have been particularly prone to flooding. Extensive gravel extraction from the Te Rangiita quarry resulted in a river break through which had to be reversed as part of the flood control scheme described in this paper.

2.2 FLOOD HISTORY

2.2.1 TONGARIRO RIVER

The recorded flood history started effectively with the 1958 flood of around 1470 m^3/s which inundated lower parts of Turangi and washed out the south abutment of the highway bridge. The flood peak and water levels were recorded and formed the basis of a sequence of proposals for intermittent erosion control works and stopbanks, not all of which were constructed.

Meanwhile, property development continued closer to the river as the township became established for the Tongariro Power Development and the subsequent Rangipo scheme, and lastly as a tourist and forestry centre.

“Suburban” housing across the river along Herekiekie Street (Fig 2) included areas of flood plain. Progressive erosion of property at the river end of the street was the catalyst for the local office of Taupo County/District Council (TDC) to initiate rock revetment protection. At the same time, a series of gabion basket groynes along Tahawai Street at the upstream end of Turangi were starting to collapse after 30+ years of service and an extensive rockfill revetment and stopbank were implemented by Tonkin & Taylor for Environment Waikato and TDC. The completion of these works was stimulated by two substantial floods a week apart in 1998.

Further development and substantial completion of a comprehensive flood and erosion control scheme received dramatic impetus with a record flood in 2004, estimated at 1420 m^3/s, equivalent to the 1%AEP flood (a 100 year return period) as previously calculated. One of the consequences of this flood was that when the historic flow data was analyzed post 2004 flood, the 1%AEP flood increased to 1,500 m^3/s.

While much publicity has been given by some sectors on the effects of hydroelectric diversion on the Tongariro River and its fishing, namely a minimum and therefore relatively constant flow of around 27 m^3/s through Turangi, those developments have had negligible effects on the flood regimes in the river. That is partly due to the shutdown of diversions at Rangipo and Poutu intakes in flood times, to minimize sediment ingestion, and to the fact that river regimes and changes are caused by floods with attendant gravel and boulder transport, rather than by “fair weather” conditions.

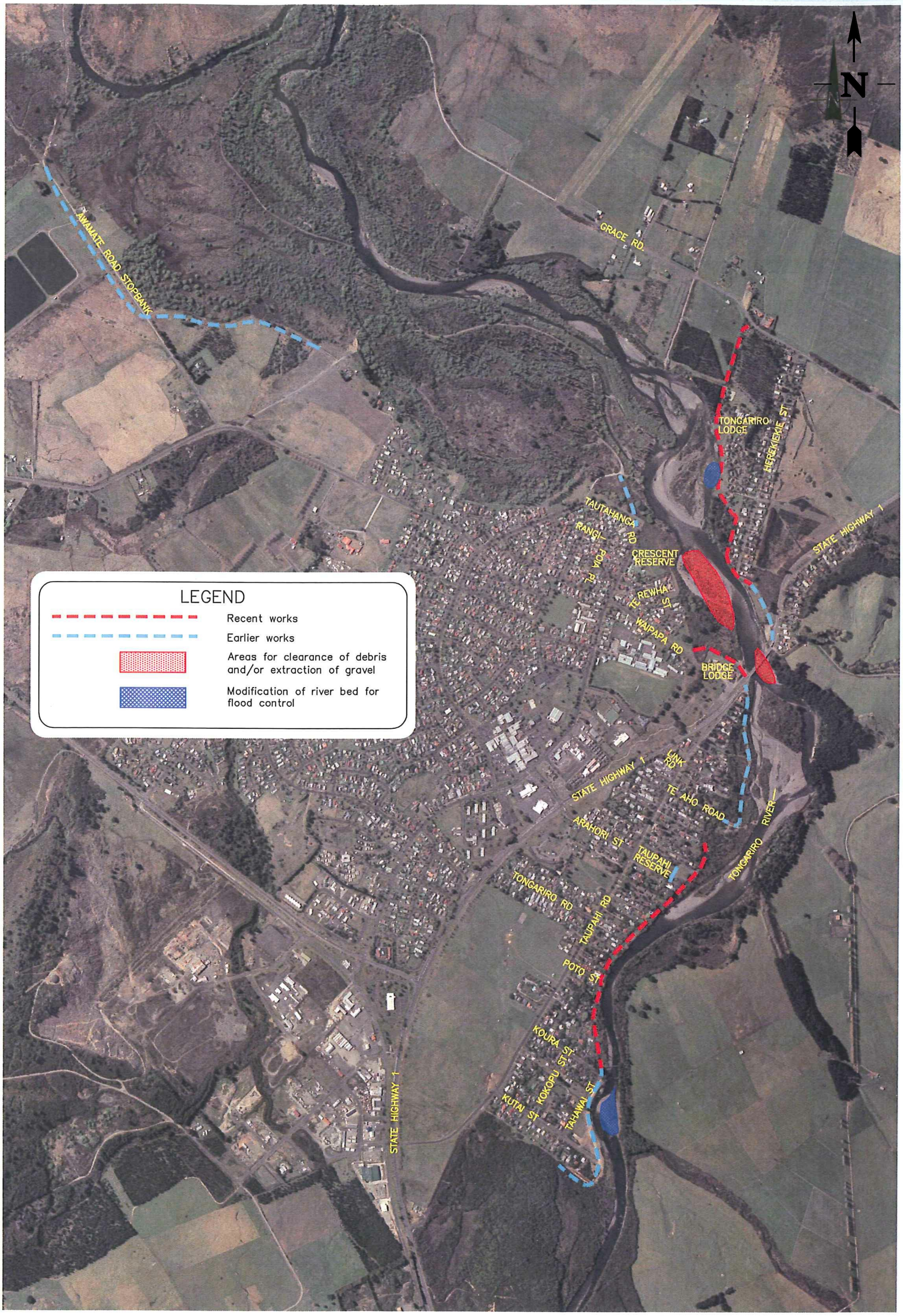

Figure 2: Tongariro River Flood Protection Scheme Layout

2.2.2 TAURANGA-TAUPO RIVER

The lakeside townships of Oruatua and Te Rangiita lie on the flood plains either side of the highway bridge, and have suffered regular flooding in the past decades. The river is deceptively tranquil between the bridge and the lake, presumably providing the safe haven (Tauranga) for Maori waka in the southern part of Lake Taupo. However, the river catchment is steep and produces copious quantities of pumice, sand and shingle under flood conditions, which have been deposited on a triangular flood plain between Kiko Road and Hingapo Road (Fig. 3).

Previous attempts at flood control for the two settlements had been limited to an intermediate stopbank south of Oruatua. The 1998 flood provided the catalyst for a comprehensive scheme for flood control for the settlements and the state highway. planning for this was well advanced when the river diverted itself into the quarry excavation on the right northeast bank through a combination of overland flood flow and underground “piping” through the gravels.

The 2004 floods during the construction period provided further challenges with the river attempting another break out to the south. The modeling and balancing of flood distributions and ponding areas has been one of the key features in the Tauranga-Taupo project, as discussed in more detail below.

2.3 GRAVEL MANAGEMENT ISSUE / HISTORY

2.3.1 TONGARIRO RIVER

The river is relatively constrained through much of its course through Turangi but spreads out into semi braids through and downstream of the highway bridge and finally into a relatively fixed meander pattern before it enters the lake. The braided reach of some 6 kms is the recipient of the bulk of gravel depositions. This was regularly quarried for construction of the Tongariro hydro power projects from the 1960s to 1980s and effectively suppressed the natural delta building process and associated raising of river bed levels. The floods of the 1990s and 2000s most recently in 2004 raised the bed levels downstream of the bridge by around 0.5 m thus potentially reducing freeboard to recently constructed stopbanks.

Gravel management/extraction and ideally its commercial use, remains a challenging component of management of both rivers.

2.3.2 TAURANGA-TAUPO RIVER

Large quantities of gravel were quarried, initially from the centre and more extensively from the right hand side of the river’s flood plain, from the 1950s to the 1990s for highway improvements and the Tongariro power projects. With the cessation of such activities, natural aggradation has recommenced coupled with the associated tendency of such a river to “swing and migrate from the outside of its bends”. Those effects have high significance for ongoing river control.

The key impact of the very extensive gravel quarrying on the right hand side of the flood plain was to cause a breakout of the river and complete dewatering of normal flows from one of the favoured fishing reaches, as shown on Figure 3. Reinstatement of the river required a major closure bank and had implications for works downstream.

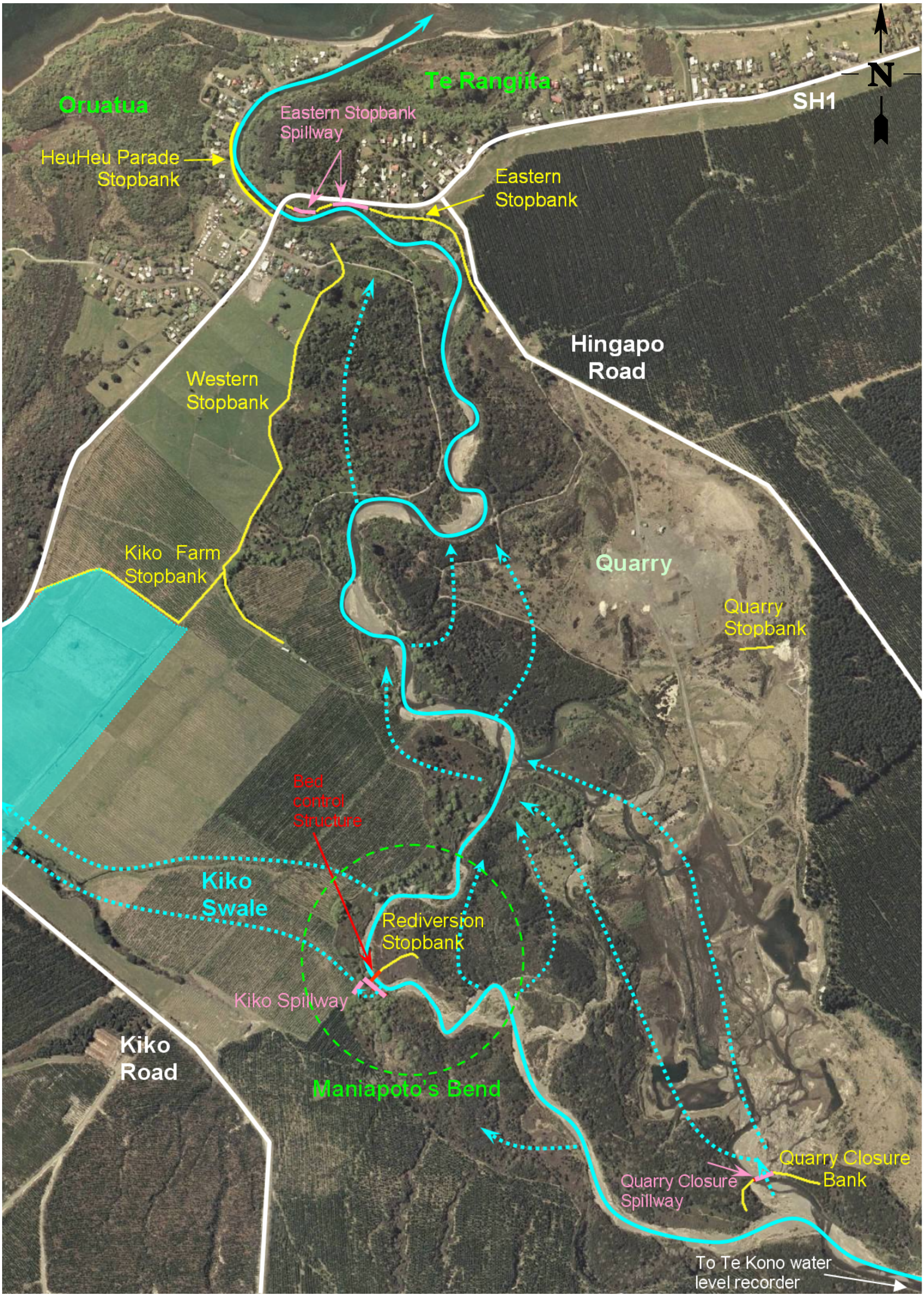

Figure 3: Tauranga-Taupo River Flood Protection Scheme Layout

2.4 ASSETS AND PROPERTIES AT RISK

2.4.1 TONGARIRO RIVER

The 1958 flood gave warnings of properties at risk which despite county council plans for stopbank protection were not followed through. Apart from the highway bridge on a key national arterial road, the properties at most risk were private residences along the lower lying left bank areas of older Turangi and the more recent houses on Herekiekie Street below the bridge on the right bank. Also at risk have been the Bridge Lodge on the left bank and lower lying houses associated with Tongariro Lodge on the right bank. These have all been protected up to a 1.0% AEP flood by stopbanks fronted by rockfill revetments where appropriate. However, their efficiency is dependent on river bed gravel management as noted above.

The highway bridge reconstructed after the 1958 flood is prone to blockage with flood debris. Overflow at abutments and possible highway breach remains a possibility in the event of a flood and/or blockage greater than that experienced to date.

Further downstream, the municipal sewage treatment ponds remains at risk while negotiations continue to gain access to upgrade the Awamate Rd stopbank. Arguments have been presented for protection of farm land between Turangi and the river mouth delta. However, these pastures have always flooded historically and flows across them to the lake are part of the natural flood dispersal system. Hence no further works are seen as economically justified apart from willow maintenance and possible unblocking of the delta river mouth.

2.4.2 TAURANGA-TAUPO RIVER

Most properties in the smaller settlement of Oruatua had over the years experienced or were at risk from flooding and with the breakout diversion of the river into the quarry area, that risk was potentially extended northwards through Te Rangiita and so those properties were included in the cost sharing apparatus discussed below.

The principal public asset at risk was the highway bridge with its limited capacity and adjacent bank erosion. Further south the natural overflows from the river caused ponding and overtopping of the highway at the so-called Kiko culvert to the west of Kiko swale. Upgrading of that culvert was done by Transit New Zealand to ease the upstream flooding from spillage out of the river.

Other assets at lesser risk were pine plantations and pasture south of the river, which were able to be given a degree of protection by the scheme which was basically developed to address township flooding.

2.4.3 RATING BASES FOR FUNDING THE PROJECTS

For both rivers a differential rating base was struck by Environment Waikato, with regional and ‘district’ base contributions made up by differential levies based on the proximity of properties to the respective river and the associated risk of flooding and hence the benefit afforded by the protection works.

Environment Waikato developed a funding system for the whole Waikato River catchment to fund soil conservation, river management and flood protection services. The system recognizes the beneficiaries of these services and the contributors to the need for such services. This approach made implementation of these works affordable for the local communities.

3 DESIGN PROCESS

3.1 MODELLING

3.1.1 TONGARIRO MODEL

The Tongariro River was modeled using a 1-Dimensional model (DHI's MIKE11) in 2003, with surveyed river cross sections from 2002/2003, however following the 2004 flood, the model was updated with new cross sections (to capture bed level changes) and more consideration was given to the effects of bridge blockage. The new model was also compared and calibrated to the 2004 event.

Following community consultation, the design event was chosen to be the 1%AEP (1400m^3/s). This was updated following the 2004 flood, where the 1%AEP was recalculated to be 1500 m^3/s. Over design events were also modeled to understand the associated residual risk.

The scheme was designed based on the results of the model for 1% AEP event with freeboard.

3.1.2 TAURANGA-TAUPO MODEL

The Tauranga-Taupo River was originally modeled using a 1-D model (DHI's MIKE11) in 2002-2004, with surveyed river cross sections, and most of the scheme was designed using this model. However to gain a better understanding of the extensive channel/floodplain interaction, 2-Dimensional models (MIKE21, MIKEFLOOD) using a LiDAR survey, were developed. The level of the bed control structure at Manaipoto's bend was designed using the 2-D model (2009 Stormwater Conference Paper).

Following community consultation, the design event was chosen to be the 2%AEP (315 m^3/s) and the scheme was designed using modeled water levels with freeboard.

Over-design events were also modeled to understand the associated residual risk and parts of the scheme were updated (SH1 bund, eastern stopbank spillways) to minimize effects of such events.

3.2 CONCEPT DEVELOPMENT

The MIKE11 models were used to develop design concepts for the flood protection works. For the Tongariro River this involved stopbanks on the left bank upstream of the highway bridge, and on the right bank downstream of the bridge. The height of the stopbank was designed to provide freeboard from the 1%AEP flood. Due to significant changes in river bed levels, (up to 1m depth of gravel deposited outside Tongariro Lodge), a policy for gravel management to manage bed levels in critical areas was required before stopbank height could be determined. The concept developed included significant gravel extraction from critical areas as part of the Stage 1 works.

The concept developed for the Tauranga-Taupo River was based around utilizing the natural overflow and storage mechanisms in the flood plain upstream of the villages. This required the river to be locked into Maniapoto's bend where a natural spillway allows peak flows to bypass the townships via the Kiko swale. The MIKE11 model was used to develop the concepts and design for the stopbanks through Oruatua and Te Rangiita together with the Maniapoto's bend works. The MIKEFLOOD model was developed toward the end of the project and used to confirm levels for the grade control at Maniapoto's bend.

3.3 CONSENT PROCESS / CONSULTATION

The consenting process for works on both rivers was difficult, time consuming and represented a significant portion of the costs for the projects. Local residents, iwi and landowners, all had strong views on the level of protection to be provided, and the design of the scheme with their views often quite different. Much of the land on which scheme components were built is owned by the Crown and administered by the Department of Conservation (DOC). The DOC representative had very strong views on protection of local vegetation that resulted in specific design constraints in some areas.

The local knowledge from the residents, especially local iwi who have the longest history in these areas, was very useful in understanding the complexities of these rivers, and the natural historic changes that have occurred.

A few individual residents objected to the idea of a stopbank across their river frontage, and caused significant interruption and cost to the consenting and design stages of the project before innovative solutions could be found to meet their concerns.

However, an interactive design process was developed for the Tongariro River stopbank works to develop a range of solutions to match individual site constraints and desires of landowners and immediate neighbors.

4 PRAGMATIC SOLUTIONS

4.1 TONGARIRO RIVER

As noted above the sequence of works over the last past two decades started with localized provision of conventional rockfill bank protection (Figure 4) in areas of active erosion, initially at Tahawai and Herekiekie Streets. Preparations for the work involved extensive consultation, not all of it proceeding smoothly as noted in the previous section. Particular attention had to be paid to issues raised by DOC regarding protection of relatively minor areas of native vegetation. These measures eventually led in some places to timber flood walls (Figure 6) rather than conventional earth stopbanks which also assisted in negotiating congested areas and private properties (Figure 5).

DOC requested that an agglomerate rock bar remain at Tahawai Street to provide shelter for fish. This produces standing waves and an eddy to thrill unwary kayakers.

The potential for the river to change course was dramatically demonstrated in 1998 and 2004 in several areas well upstream of Turangi, and just upstream of the highway bridge. Along the Tahawai Street stretch, a well vegetated island isolated by breakouts in the last century was completely wiped out in 2004, causing the flood to “bounce” across the river and overtop the recently completed stopbank to the distress of recently “protected” properties. However, the stopbank was shown to have been constructed somewhat higher than designed, so the residents realized matters could have been much worse.

Stopbanks were constructed of well compacted local brown ash, usually set back from the main river course so that vegetation plantings were sufficient to provide protection from flood overflows. As the stopbanks effectively become polders of low lying areas, underdrains were provided with flap valves on the river side to ensure drainage of local runoff. Most stopbanks have public crest walkways, dressed with compacted pumice and were well vegetated with plantings.

Timber flood walls were used in various configurations where space was insufficient for stopbank construction. In some places these floodwalls were located on property boundaries and designed as an integral component of the boundary fence. This has enabled the works to have minimal visual impact for the adjoining landowners, and users of the river walkway.

Downstream of the highway bridge, the semi-braided river has swung from side to side as a series of alternative gravel bars and intermediate reaches favoured by fishers. As noted previously the accumulation of gravels in recent decades exacerbated the development of distributaries and the consequential foci of erosion, particularly in the vicinity of Tongariro Lodge. In addition to some 80m of rockfill revetment to protect the southern end of Herekiekie St, a permeable groyne was formed adjacent Tongariro Lodge to divert flood flows while maintaining a local amenity flow.

Gravel extraction of some 45,000 m^3 in recent years has been targeted to control flood levels downstream of the highway bridge. This is expected to be an ongoing requirement as future flood events are expected to deposit more gravel in this area.

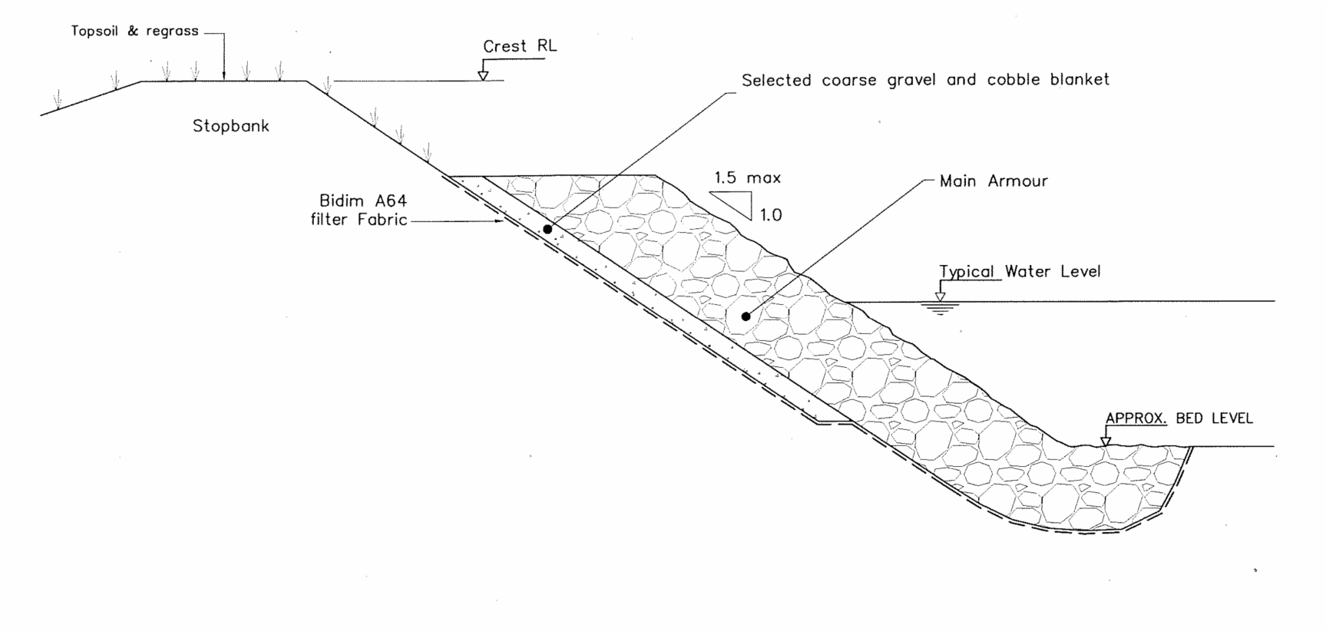

Figure 4: Typical rock revetment, Tongariro and Tauranga-Taupo Rivers

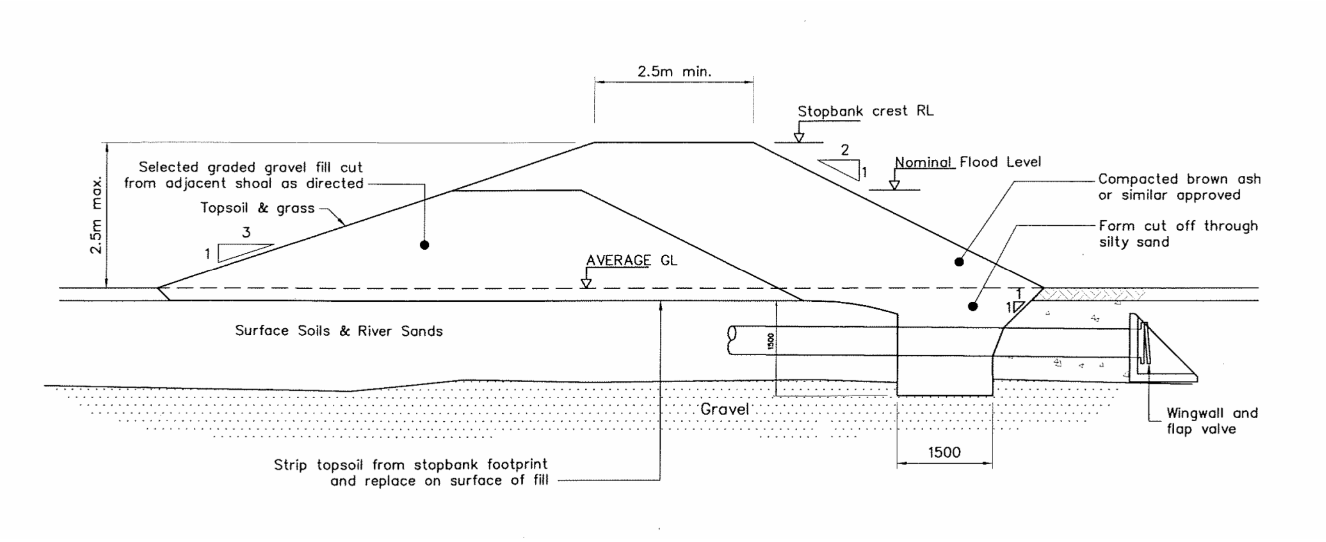

Figure 5: Typical stopbank and drainage culvert, Tongariro and Tauranga-Taupo Rivers

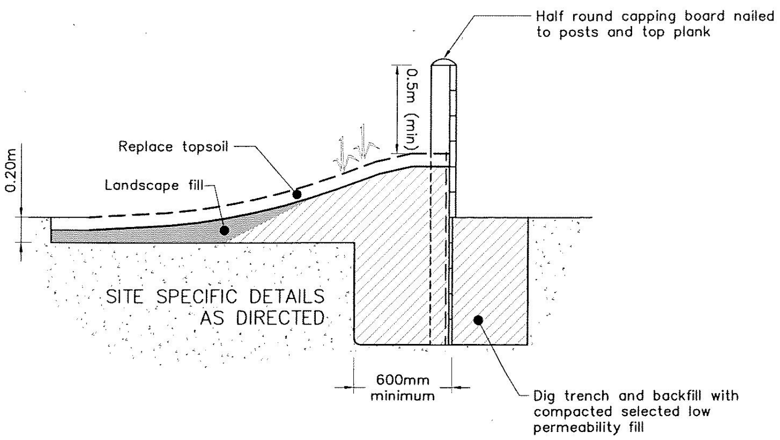

Figure 6: Timber floodwall, Tongariro and Tauranga-Taupo Rivers

4.2 TAURANGA-TAUPO RIVER

The flood control works for protection of Oruatua and Te Rangiita were designed initially for a 2% AEP, 1 in 50 year return period. The key element in the design process was to limit the design flood at Oruatua to the capacity of the highway bridge, nominally set at 250 m^3/s. This was to be achieved by a combination of attenuation ponding of flood peaks in the right bank quarry area and the left side Oruatua scenic reserve (Figure 3), coupled with control of naturally occurring spillage through pine forests and the Kiko culverts under the highway also on the left bank.

During the process of design and preparing applications for resource consents the river broke into the quarry in 2002 necessitating its rediversion by constructing a substantial closure bank with integral spillway. A further design modification was required during formation of the Kiko spillway with an unseasonal flood in May 2003 and consequent erosion which required inclusion of a rockfill weir at the head of the overflow channel at Maniapoto’s bend. That critical and complex flood alleviation facility included a rock armoured training bank closing off the right bank temporary diversion channel (Figure 7), a balancing spillway area between the river and the rockfill weir and finally a rockfill grade control in the river channel (Figure 8).

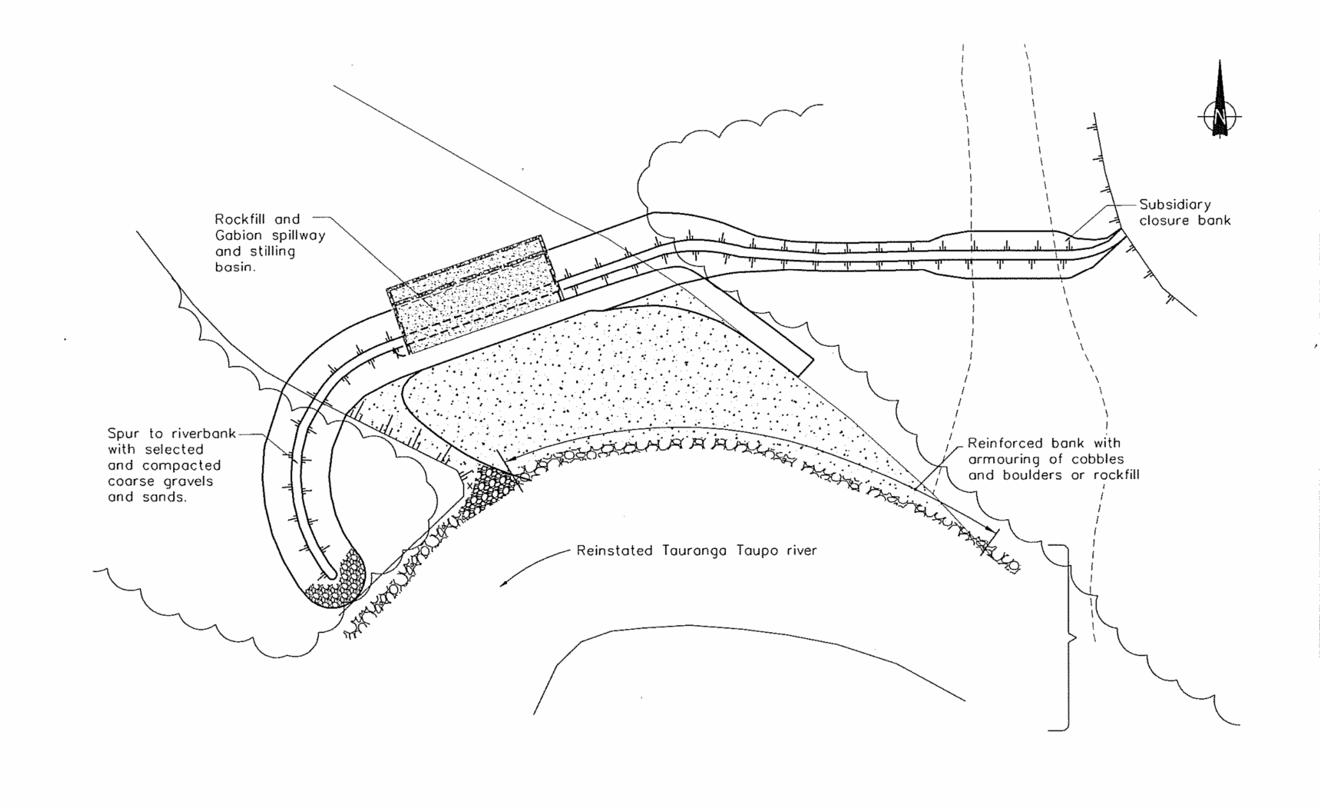

Figure 7: Quarry closure bank, Tauranga-Taupo River

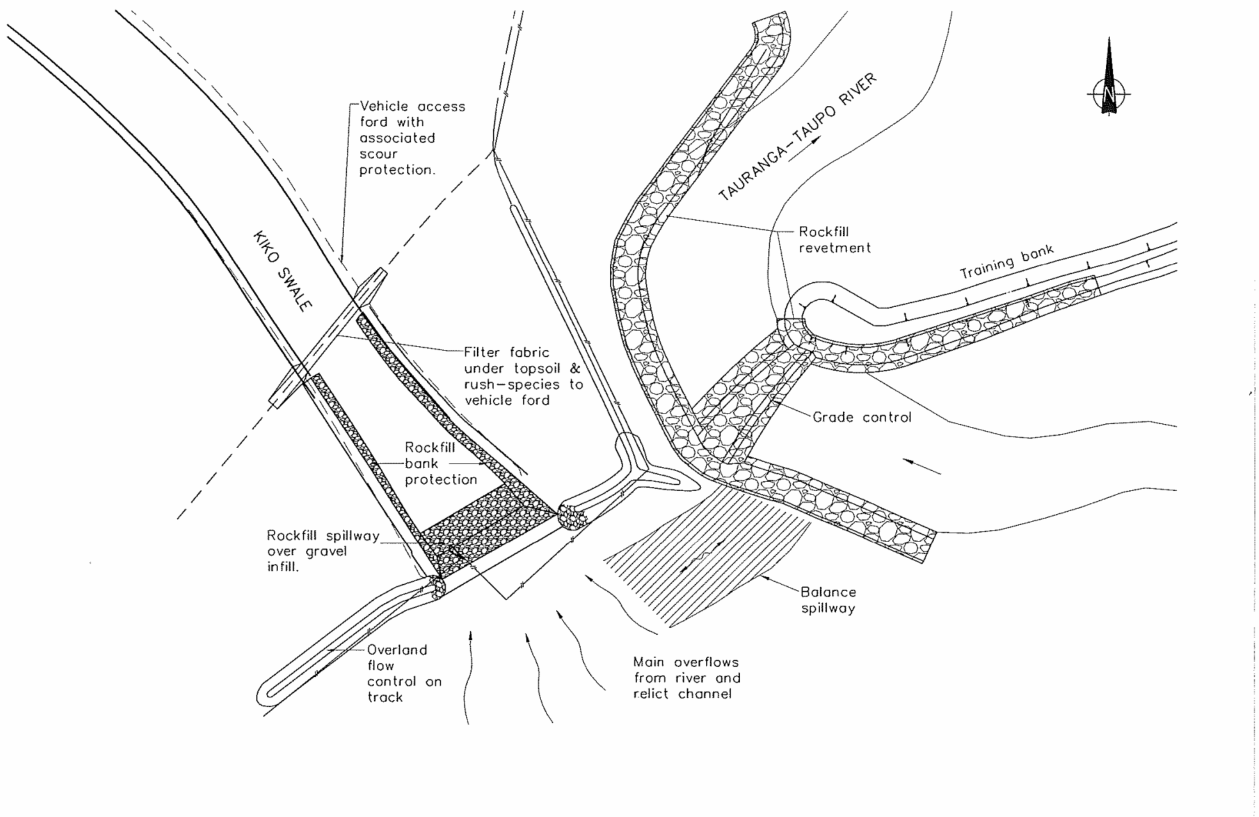

Figure 8: Maniapoto’s bend, Tauranga-Taupo River

While bank erosion continues in other less critical areas downstream of Maniopoto's bend, ongoing river management is being focused on the continuing erosion control upstream at the outside of bends, caused in part by the ongoing deposition of gravel and the consequent tendency of the river to lengthen its course and dissipate energy by erosion at bends.

A critical factor in that management is prevention of right bank breakout bypassing the Maniapoto's bend (Kiko) spillway and hence exceeding the highway bridge flood capacity.

The third area of major works was bank protection and stopbanking both sides of the bridge and provision of timber walling where room for conventional stopbanking was limited. Upstream of the bridge the wall can also be overtopped to spill excessive flood peaks across the highway clear of properties. Downstream, a similar timber wall provides a measure of protection to properties along Heuheu Parade (Figure 9). Some residents objected to the loss of their river view but were eventually persuaded that dry houses were preferable.

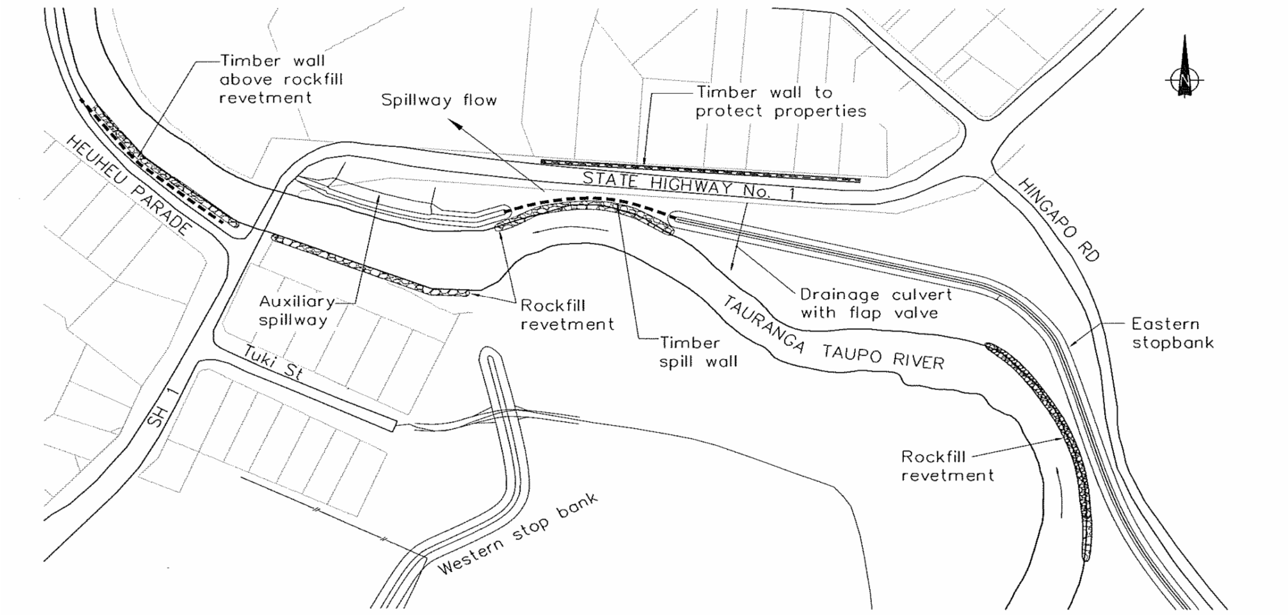

Figure 9: Oruatua / Te Rangiita flood protection works, Tauranga-Taupo River

In between the two critical locations of Maniapoto's bend and the highway bridge, an earlier short stopbank was extended to control the significant flood breakouts which had regularly flooded Oruatua and the highway. Setting the crest level of this western stopbank depended on identifying ponded flood levels in the Oruatua reserve. This has been done to an interim standard by a combination of observed levels in minor floods and the modeling described above. Some overtopping of a section of that stopbank may occur in extreme flood and for that reason emphasis has been placed on maintaining a good grass cover and excluding stock.

Lying between the highway and the lake is an ecological reserve administered by the Te Punawhakaata Trust. It was realized that the area's ecology benefitted from periodic flood overflows and so a diversion pipe was incorporated in the stopbank near the public footpath crossing to provide up to 2 m^3/s flood flow down to and under the highway by way of existing culverts.

5 ONGOING ISSUES

5.1 TONGARIRO & TAURANGA-TAUPO RIVERS REGIME CHANGES

Apart from regular inspections at least annually, and any consequent maintenance of stopbanks and rockfill revetments, the schemes should be inspected after any significant flood which flows outside the normal river course. The inspections need to include gravel shingle deposits as discussed below.

An overall catchment management plan for the Tongariro River is being developed which includes regular gravel extraction as required to maintain flood capacity through the township.

Of particular significance will be the potential if not the reality of major changes in river course due to erosion at bends. Upstream of Turangi the Tongariro River has experienced major changes in course with attendant production of tree debris and shingle.

Similar changes have the potential to occur below Turangi from the semi braided reaches until the river course takes on the meandering section which has been relatively stable since earliest records of the 19th century.

The current river management plan for the Tauranga-Taupo River recognizes that it is particularly active in terms of regime changes and the associated gravel movements, particularly in the areas of the main scheme components i.e. quarry closure bank, Maniapoto's bend and the sections immediately above the highway bridge. The effectiveness of the overall scheme for flood control at Oruatua and Te Rangiita is dependent on the spilling of water at Maniapoto's bend through the Kiko spillway and highway culverts and attenuating flows through the left and right bank ponding areas. These controls are in turn influenced by deposition and remobilisation of gravels, as discussed below, and also by control of willows and other vegetation.

5.2 BRIDGE CAPACITIES

One of the most significant issues at Turangi is the ultimate flood capacity of the highway bridge, not so much from available waterway as from the risk of significant blockage by full tree debris. With the solid old style of bridge parapet railing, there is no effective overtopping capacity. Abutment breakout is most likely to occur across the left (south) stopbank. It could affect adjacent houses before crossing the highway into the Bridge Lodge property that has a protective stopbank with a flap valved culvert which would only drain under positive head i.e. lower river level.

For the Tauranga-Taupo River the highway bridge capacity must be maintained at the design flood by limiting flow primarily via the Kiko spillway and also by the overflow spillways across the Highway immediately upstream of the bridge.

The present flood profile extends through the bridge without undue backwater effect from the lake and ensures much of the bed load reaches the lake.

5.3 GRAVEL MANAGEMENT

Gravel extraction from the Tongariro River has been started in collaboration with local iwi Turangitukua. Continuance of gravel extraction operations will depend in part on the commercial demand for quality aggregates. However, if this could not be achieved, gravel will need to be removed and/or shifted to the sides in some critical locations every few years depending on river surveys. Currently Environment Waikato and Tonkin & Taylor are establishing mean bed levels that trigger gravel removal.

The quarry off Hingapo Road has been shut down. Recent regime controls through the so-called Pump Pool immediately upstream of Maniapoto's bend (the scene of previous limited river extractions) have entailed rechanneling to keep the river away from a right bank erosion which threatens to bypass the Maniapoto's bend/Kiko spillway system. These measures are essentially short term and will be reviewed in the light of successive flood events.

Gravel accumulations in both rivers are kept under observation by regular inspections and by periodic cross section surveys.

6 CONCLUSION / LESSONS LEARNT

Flood risk assessments were initially undertaken for both Tongariro and Tauranga-Taupo Rivers. The risk assessment, supported by community demand was the basis for implementing flood protection measures on these rivers. Flood protection has been provided to a design standard of 1% AEP for Turangi properties along the Tongariro River and to a 2% AEP standard for the settlements either side of the Tauranga-Taupo River.

Implementation of the flood control schemes on both rivers required extensive consultation with residents, tangata whenua, DOC and other parties. In hind-sight there was not enough interaction with the potentially affected parties during the conceptual design stage before the consent applications were lodged. Where flood protection schemes are being developed through urban areas, the affected residents need to be involved in an interactive process where they are fully informed about the risks they face, the options available to mitigate these risks, the associated costs and how these costs will be shared including rate increases. For this process to be effective there needs to be a high level of detail invested in the surveying, modeling, and concept development prior to starting discussions with the affected parties. Supporting information needs to be well founded, based on real data from observed flood levels and a series of computer modeling. The consultation may well result in different concepts being developed or in some cases an acceptance of risks without protection.

Computer modeling has been used to design the schemes, providing understanding of the different options considered and their effects as well as improved understanding of the extent of over design events. Advances in survey techniques such as LIDAR, and the use of 2-D modeling software such as MIKE21 and MIKEFLOOD have enabled more detailed modeling with an increased level of confidence in the results.

The levels of flood protection provided have been a function of cost-benefit balances. Flood protection works have focused on protecting assets including residential housing, and state highways. Residents living in a flood hazard zone need to be made aware that while flood protection schemes will provide protection up to the design flood, there remains a risk of property damage in an extreme event with a return period greater than the design standard.

Design of key control structures has been such that overtopping or bypassing in an over design events should not result in catastrophic failure.

The highway bridge on each river has been a key element in flood management and remains a critical factor in future maintenance of the rivers. The Tongariro bridge capacity is vulnerable to debris blockage and consequential outflanking on the Turangi side, while the limited Tauranga-Taupo bridge capacity requires flood attenuation in ponding areas and the assured functioning of the Kiko bypass spillway system, and a spillway around the right abutment.

Ongoing gravel management is required to limit flood rises and erosion against stopbanks on the Tongariro River, and to maintain the function of the Kiko spillway by preventing bypassing caused by erosion on the Tauranga-Taupo River.

The future effectiveness of the flood control schemes will depend on implementation of river management plans, including control of gravel deposits and river vegetation. Catchment management is also a critical factor with primary issues being land use changes that may affect peak floods, and riparian vegetation that will help control river bank stability.

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