REPORT

Tonkin+Taylor

Kaiapoi Red Zones

Engineering Feasibility of Potential Land Uses - Stage 1 Report

Prepared for
Waimakariri District Council
Prepared by
Tonkin & Taylor Ltd
Date
January 2016
Job Number
52082.030.v3

Exceptional thinking together
www.tonkintaylor.co.nz

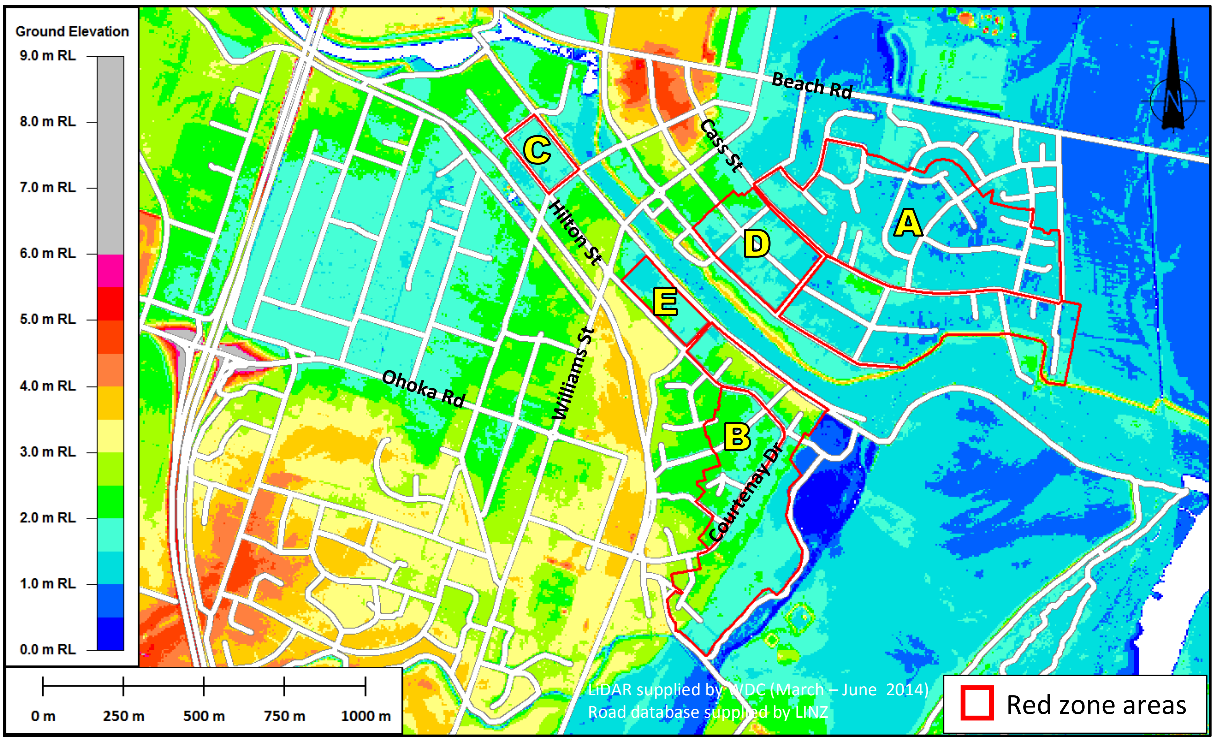
Distribution:

Waimakariri District Council	1 copy
Tonkin & Taylor Ltd (FILE)	1 copy

Table of contents

Executive summary

The primary purpose of this Stage 1 report is to provide an initial assessment of the engineering feasibility of residential land development in the Kaiapoi North and Courtenay Drive red zone areas, and commercial land development in the red zone areas adjacent to the Kaiapoi town centre. These red zone areas are identified as Areas A to E in the figure below.



Overview of Kaiapoi red zone development areas A to E assumed for this initial scoping study, also showing the existing ground elevation (metres above mean sea level, Lyttelton Datum).

The work outlined in this report addresses the technical engineering feasibility aspects only – it does not cover the broader aspects of feasibility (e.g. economic, social, RMA consenting etc.) or whether positive effects outweigh negative effects. We understand these broader aspects will be considered by others in due course. This report considers whether it would be "reasonably practical" to undertake engineering works to enable development, using design approaches and construction techniques that are commonly applied for land development in Canterbury. It does not assess whether it would be financially viable to undertake the work - this would require a broader business case analysis to be developed.

Residential development concepts – Areas A and B

This initial scoping study has not identified any immediate "fatal flaws" regarding the engineering feasibility of land improvement works to enable residential development parts of the North Kaiapoi and Courtenay Drive red zone areas. However, a number of significant technical constraints and potential effects on neighbouring areas have been identified. These include:

- It would be necessary to raise and compact the land to meet flood, TC2 foundation and infrastructure requirements. Preliminary estimates indicate a likely average fill depth of approximately 1.2m for Kaiapoi North, and 1.1m for Courtenay Drive.
- Ground stabilisation would be required to reduce ground deformations resulting from lateral spreading and slope instability in future earthquakes. Preliminary assessment indicates that targeted use of ground improvement and geotextile reinforcement is likely to be effective, however more detailed geotechnical analysis would be required to confirm this.

- Placing this volume of fill has the potential to exacerbate flooding in the surrounding area, due to a reduction in floodplain volume. An initial qualitative assessment suggests it is likely that these effects could be managed, however more detailed flood model analysis and stormwater design would be required to confirm this.
- The large volume of fill material required means that a large number of truck deliveries would be needed. This could cause adverse effects for local traffic, noise and vibration for nearby residents and accelerated wear on local streets.

It appears to be technically feasible to manage these issues, using engineering approaches that are commonly applied for land development in Canterbury - such as earthworks, ground improvement and stormwater management. However, given the significant scale of work that would be required, this would add considerable development cost.

This report presents preliminary estimates of construction costs for the work needed to improve the land to the point where it is suitable for residential subdivision. This is the cost of engineering work that would be incurred over and above normal subdivision servicing. It should be noted that the need for land improvement is not unique to the red zone - much of the land in the Kaiapoi area would require some degree of improvement prior to residential development.

For urban-residential development, the preliminary "most likely" estimate of construction cost over and above normal subdivision servicing corresponds to approximately $90k per lot for Kaiapoi North, and $135k for Courtenay Drive. For rural-residential development (5000m^2 lots) these cost estimates increase to approximately $285k per lot for Kaiapoi North, and $380k for Courtenay Drive. Given the considerable design and market pricing uncertainties at this initial scoping stage, "pessimistic" cost estimates are significantly higher than these values, and "optimistic" estimates are significantly lower. Specific aspects of the work which make significant contributions to cost uncertainty have been identified for further consideration as part of the Stage 2 engineering feasibility assessment.

Alternative residential development concepts have been considered, such as constructing elevated dwellings rather than placing fill to raising the land above flood level. These alternative concepts do not appear to offer significant cost savings and face some potentially significant issues, but they may result in less disruption for surrounding green zone areas.

Commercial development concepts – Areas C, D and E

For red zone Areas C and D, this initial scoping study has not identified any immediate "fatal flaws" regarding the engineering feasibility of land improvement works to enable either a yard-based commercial development or a large-format retail development.

For red zone Area E, this study has identified that exacerbation of flooding elsewhere is likely to be a significant constraint for commercial development. Based on the current qualitative assessment of potential adverse flooding effects from placing fill in Area E, it appears that a yard-based commercial option would be more suitable in this location than a large-format retail option.

In all three red zone areas a number of significant technical constraints and potential effects on neighbouring areas have been identified. These constraints and adverse effects are similar to those outlined above for residential development in Areas A and B. Managing these issues would add considerable development cost.

For the yard-based commercial scenario, the "over-and-above" cost of land improvement works is estimated to be approximately $50 to $80 per square metre of total site area for Areas C and E, or $40 to $60 for Area D.

For the large-format retail scenario, the "over-and-above" cost of land improvement works is estimated to be approximately $220 to $370 per square metre of total site area for Areas C and E, or $160 to $300 for Area D.

1 Introduction

1.1 Background

The Technical Advisory Panel report of April 2015 presented a preliminary assessment of land use capability for the Waimakariri District residential red zone areas. It was identified that there was some potential for built residential or commercial land use in some areas, but that further assessment of the feasibility of this land use was required before this possibility could be considered further.

Waimakariri District Council (WDC) and CERA are now working with their strategic partners to develop a recovery plan for future use of the Waimakariri residential red zone land. To help inform consultation and development of the recovery plan, WDC have requested that T+T provide further advice regarding the engineering feasibility of potential residential and commercial land use options.

1.2 Staged scope of work

In accordance with the scope of services agreed with WDC, as set out in our Offer of Service dated 2nd September 2015, Tonkin + Taylor (T+T) have commenced a staged scope of work for the assessment of engineering feasibility of land improvement for built residential and commercial land use in parts of the Kaiapoi red zones.

The first two stages of this engineering feasibility study are:

Stage 1 – Initial Scoping The aim of this stage is to identify possible "fatal flaws" in potential land improvement options. This is a high-level study, focussing only on the main engineering issues which are considered to pose the greatest risk to the feasibility of land improvement.

Stage 2 – Concept Design The aim of this stage will be to refine the initial scoping work, to address a broader range of technical issues and to provide greater certainty in the estimate of the scope and cost of land improvement work required.

The scope of engineering work outlined in Stages 1 and 2 is expected to be sufficient to progress to plan change application stage. Further engineering work beyond Stages 1 and 2 would be required to progress potential land improvement through to construction, as discussed further in Section 9.

1.3 Purpose of the Stage 1 report

The primary purpose of this Stage 1 report is to provide an initial assessment of the engineering feasibility of residential and commercial land development in parts of the Kaiapoi red zones.

The Stage 1 report is intended to assist WDC determine the next steps in development of the recovery plan and assessment of land use feasibility. It is envisioned that WDC will use this report to determine whether to proceed with Stage 2 of the engineering feasibility assessment, and whether there are potential refinements to the general outline plan they wish to explore (e.g. adjustments to assumed extent or density of built residential land use). WDC may also wish to use the initial construction cost estimates presented in this report as a preliminary input into a business case analysis to assess economic feasibility of potential land uses.

The work outlined in this report addresses the technical engineering feasibility aspects only – it does not cover the broader aspects of feasibility (e.g. economic, social, RMA consenting etc.), which we understand will be considered by others in due course. The initial technical assessment undertaken for Stage 1 is based on the general findings of engineering analysis undertaken for these areas previously, and did not involve any new investigations or new engineering design work.

1.4 Definition of "engineering feasibility"

T+T have assessed the "engineering feasibility" of undertaking works to enable residential or commercial development in parts of the Kaiapoi red zone areas. To some extent, almost anything could be considered possible from an engineering perspective – given enough time and money, and applying highly specialised bespoke design and construction techniques. Therefore T+T have adopted a "reasonably practical" definition of engineering feasibility for this initial scoping study.

For the purposes of this report, engineering works to enable land development are considered "reasonably practical" if all of the following criteria can likely be met **using design approaches and construction techniques that are commonly applied for land development in Canterbury**.

a The geotechnical characteristics of the land can be improved as necessary to meet the target land performance for building foundations and infrastructure (refer Section 2.3).

b Land and floor levels that satisfy minimum consenting requirements for flooding and coastal inundation can be achieved (refer Sections 2.5 and 2.6).

c Stormwater and floodplain management can be implemented to control stormwater runoff from the newly developed area, and to reduce any exacerbation of flooding caused in the surrounding area to a level that would typically be granted consent.

d Land can be remediated or contaminants contained, sufficient to comply with the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health for the assumed type of land use.

e The impact of the construction works on the amenity of surrounding residents can be managed at level that would typically be granted consent.

This assessment of engineering feasibility does not assess whether it would be financially viable to undertake the work. Determining the financial viability would require a broader business case analysis to be developed, and the construction cost estimates presented in this report would be just one of the inputs into this analysis.

This report presents a preliminary estimate of potential adverse effects (such as exacerbation of flooding or disruption from construction traffic) and how they could potentially be managed. As outlined above, the engineering feasibility assessment considers whether these adverse effects could likely be limited to a level where consent has often been granted for similar types of developments in the past. However we are unable to conclusively determine whether or not consent would be granted for residential or commercial development in these red zone areas, as this will depend on a broader judgement of the balance between positive and negative effects considered as part of the consenting process.

2 Key technical assumptions for initial scoping

It has been necessary to make a number of technical assumptions to guide the initial scoping of the preliminary land improvement outline plan. The key assumptions are summarised in the following sections.

These assumptions are not fixed, and may change in future stages of the project as the details evolve and feedback is received from WDC, the steering group and other disciplines. Changes to these assumptions may have positive, negative or neutral impacts on technical feasibility and cost estimates.

2.1 Residential development scenarios

The Stage 1 assessment has assumed two different residential development scenarios for Area A and B, as summarised in Table 2.1

Table 2.1: Residential development scenarios assumed for Stage 1 assessment

Scenario	Key features
Rural-residential	• Land predominantly remains at current ground level, which has a predicted average recurrence interval for flooding shorter than 100 years • Building platforms maybe raised with fill to provide an amenity area around the dwelling, or the land may be left at existing level (depending on the design and consenting approach adopted) • Dwellings constructed with elevated floor levels to manage flood risk, and specialised foundations to manage poor ground conditions • Minimum lot size of $5000m^2$ • Can form part of an integrated flood plain management strategy
Urban-residential	• Land is raised to meet flood and foundation design requirements, providing a low likelihood of flooding and good bearing capacity for foundations • Dwellings constructed at ground level, using normal residential foundations • Similar to pre-earthquake residential density • Requirement to manage stormwater and flood exacerbation effects

The pre-earthquake residential density of red zone Area A and B is summarised in Table 2.2.

Table 2.2: Pre-earthquake residential density

	Pre-earthquake number of lots	Total area, including roads and reserves.	Overall average residential density
Area A - north of Cass St	314	27.5 hectares	11 lots per hectare $670m^2$ per lot
Area B - west of Courtenay Drive	84	6.9 hectares	12 lots per hectare $650m^2$ per lot

2.2 Commercial development scenarios

The Stage 1 assessment has assumed two different commercial development scenarios for each of the three red zone areas adjacent to the Kaiapoi town centre, as summarised in Table 2.3.

Table 2.3: Commercial development scenarios assumed for Stage 1 assessment

Scenario	Example uses	Key features
Yard-based commercial	• Public car parking • Garden centre • Timber yard • Landscape supplies yard • Vehicle sales yard	• Land remains at current ground level, which has a predicted average recurrence interval for flooding shorter than 100 years • Suitable only for uses which can accept or manage risk of flooding • Suitable only for small and simple buildings raised above design flood level with deformation-tolerant foundations • Minor to moderate engineering works required to prepare land • Can form part of an integrated flood plain management strategy
Large-format retail	• Large floor-plan retail • Medium floor-plan retail • Food & beverage • Cinema • Indoor sports centre • Customer car parking	• Land is raised to meet flood and foundation design requirements, providing a low likelihood of flooding • Flooding unlikely to be a significant constraint on potential uses • Suitable for typical single-level buildings of commercial-type construction • Significant engineering works required to prepare land • Requirement to manage stormwater and flood exacerbation effects

2.3 Target land performance

2.3.1 Residential lots

For the Stage 1 assessment the assumed target land performance for residential land development is to improve the ground so that it can support TC2-type foundations (e.g. a waffle slab). This is similar to the target performance typically chosen for residential subdivision development elsewhere in the region at present.

The assumed residential density has an influence on the choice of foundation design approach for managing liquefaction to meet this target land performance:

- As residential density increases it becomes more efficient to undertake large-scale area-wide ground improvements improve the land to reduce ground deformations due to liquefaction.
- As residential density decreases it becomes more efficient to undertake site-by-site ground improvements and specialised foundation design to tolerate ground deformations due to liquefaction.

For the urban residential scenario, the most practical foundation design approach is likely to be construction of a well-compacted ground surface crust across the entire area to manage liquefaction issues on an area-wide basis. In areas with potential for severe lateral spreading to occur, it has been assumed that area-wide perimeter ground improvement would be used to reduce the expected ground deformation to tolerable levels.

For the rural-residential scenario, the most practical foundation design approach is likely to be localised ground improvement beneath building footprints only to manage liquefaction issues on a site-by-site basis. This localised ground improvement is less effective at managing lateral spreading than area-wide perimeter treatment, so for this initial assessment it has been assumed that dwellings will be set back as far as possible from lateral spreading free-faces and the fill platforms will be heavily reinforced with geogrid.

2.3.2 Commercial developments

For this Stage 1 assessment, the assumed target land performance is as follows:

- **Yard-based commercial scenario**
  Ground to provide suitable static bearing capacity for it to support a typical light-duty pavement approximately 250mm thick. No specific performance requirements were assumed for earthquake conditions, so pavement damage would be likely if liquefaction occurs in a large earthquake in future.
- **Carpark areas in the large-format retail scenario**
  As above for the yard-based scenario, however the need to place fill as part of the wider development may provide a minor to moderate improvement in earthquake performance.
- **Building footprints in the large-format retail scenario**
  Ground to provide suitable bearing capacity in both static and earthquake conditions for it to support a post-tensioned concrete floor slab foundation for typical single-level buildings of commercial-type construction.

2.3.3 Underground service corridors

For the urban-residential development scenarios, the Stage 1 assessment has assumed a target land performance for underground service corridors in accordance with the normal public infrastructure guidelines currently applied in Waimakariri District.

These guidelines stipulate maximum allowable deformations in a 500 year earthquake as follows:

- Gravity sewers: 50mm vertical and 100mm horizontal deviation along a 50m length of main
- PVC water supply: 100mm vertical and 200mm horizontal deviation along a 50m length of main

The tolerable deformation for gravity sewers is less than for PVC water supply and TC2 foundations. Therefore it is likely that even if area-wide engineering works are undertaken to bring the red zone land up to the minimum performance required for urban-residential foundations, additional land improvement would still be required along gravity sewer lines to meet the higher standard required for these pipelines.

Therefore this initial scoping study has assumed that additional shallow ground improvement (compacting to a depth of about 4 - 6m) will be undertaken along the lines of the gravity sewer mains for the urban-residential development scenarios in areas where these settlement limits are likely to be exceeded. For future stages of the feasibility assessment alternative sewer systems (e.g. pressurised or vacuum) could be considered if WDC wish to explore other options – this may reduce or eliminate the need for additional ground improvement along service corridors.

For the rural-residential development scenarios, no ground improvement along service corridors has been allowed for. This would require the risk of damage to be accepted for conventional pipelines, or for alternative approaches to be adopted (such as pressurised or vacuum systems).

For the commercial development scenarios it has been assumed that private services would connect directly to the adjacent public network. No specific allowable ground deformation limits have been

applied for the private reticulation system, as it is assumed that pressure systems can be used within the site where necessary, and raising the land will assist gravity drainage to the public network.

2.4 Infrastructure

For this initial scoping study the following assumptions have been made regarding infrastructure:

- Water supply and sewer will reconnect into the network in the adjacent green zone. It is assumed that there is sufficient capacity in the town network to service the re-establishment of this demand.
- Stormwater will drain to new stormwater management areas constructed as part of the land development works.
- For the residential development scenarios the main roads will remain in the same location, but minor roads will be realigned where necessary to be more consistent with current subdivision design practice.
- For the commercial development scenarios, existing public roads within the fill area may be realigned or closed, but good internal and external access will be maintained.
- Where fill will be placed to raise the land, new roads within the fill area will be constructed at the higher level. Roads around the boundaries of the fill area (e.g. Cass St and Courtenay Drive) will remain at their existing level.
- The analysis of the construction costs took into consideration stripping of bituminous material from existing road surfaces, removal of existing light poles and power boxes and enabling works to maintain road access and underground services to adjacent green zone residents.

2.5 Flooding

There are two main mechanisms of flooding relevant to the Kaiapoi red zones:

- Flooding as a result of rain falling on the ground within the local area
- Flooding as a result of rivers further inland (e.g. the Ashley River) breaking out from their channel and flowing across the land

When considering potential land use options, there are three primary options for managing flooding:

1. Implement engineering measures to stop flooding occurring. For example stopbanks to prevent rivers overtopping their banks, and drainage/pumping to collect rain falling on the ground. There are limits to the effectiveness of such measures in larger flood events.
2. Raise the level of the land so that it is above flood level in frequent flood events (i.e. a 50 year event), and construct buildings with floor levels that are above flood level in extreme flood events (i.e. a 200 year event). Raising land levels has the potential to worsen flooding elsewhere, so adverse effects need to be carefully assessed.
3. Choose land uses that are able to tolerate or mitigate the impacts of flooding. For example it is likely that a sports field, garden centre or timber yard could tolerate flooding, or a shop or storage facility could have racks above flood level to reduce losses. This approach allows productive use of land whilst also serving a useful floodplain management role.

For this initial scoping study a combination of options 2 and 3 above has been assumed. For urban-residential or large-format retail areas, the assumed flood management strategy is to place fill to raise the land and impose floor level controls. To manage potential adverse effects, it is assumed that adjacent red zone or yard-based commercial areas will be used for stormwater and floodplain management. For the Stage 1 assessment, flooding effects from development of each of the five red zone areas has been considered separately. Once potential combinations of development scenarios

are established for more detailed consideration, the cumulative effects of all the development areas should also be assessed.

The fill level required to meet consenting requirements for flooding of land and dwellings was estimated based on the WDC flood model results for the 200-year ARI event South Ashley 2015 scenario. As this model is a rain-on-grid model with every cell being “wet”, peak flood level is influenced by land level. For this reason the peak flood level shows some variability over the subject sites (i.e. tops of hills receive rainfall and therefore are shown to be wet, even though not flooded). Therefore over the subject areas flood level where there is a significant flood depth (more than 100mm) were selected, to establish a suitable target fill level.

2.6 Coastal erosion and inundation

In 2015 T+T undertook a study of potential future coastal erosion and inundation for the Christchurch City Council. While this study did not include the Kaiapoi area, it is possible to draw some comparisons by examining ground levels in the Kaiapoi red zone areas.

For the Christchurch City study, assuming 1.0m sea level rise by the year 2115, land near the coast was assessed as being at risk of inundation during 100 year storm events if the ground level was below RL 3.3m (Lyttelton Vertical Datum). Coastal land below a level of RL 2.2m was typically identified as being at risk of coastal erosion.

Much of the land in the Kaiapoi red zone areas lies below RL 2.2m, as does much of the land in green zone areas of Kaiapoi. This suggests that if there was a connection between this land and the sea then coastal erosion and inundation could occur. However, the stopbanks already in place alongside the Kaiapoi and Waimakariri Rivers could be expected to provide a degree of protection against coastal erosion and inundation. The stopbank crest level is approximately RL 3.9m adjacent to the Kaiapoi township, lowering to approximately RL 2.8m near the Waimakariri River mouth.

As the stopbanks already in place protect the wider Kaiapoi township, not just the red zone land, for the purposes of this scoping study it is assumed that these stopbanks will be maintained into the future to provide protection against coastal erosion and inundation. We recommend that further assessment is undertaken in future to confirm the adequacy of the stopbanks to provide this protection.

Accordingly, this initial scoping study has assumed that the governing case for setting minimum ground and floor levels for new residential development will be flooding as outlined in Section 2.5, rather than coastal erosion and inundation due to future sea level rise.

2.7 Tsunami

The potential impact of tsunami on the Kaiapoi red zone areas will depend on how tsunami waves travel up the Waimakariri and Kaiapoi rivers, and whether water levels overtop the existing stopbanks. No detailed information is presently available on these factors, therefore this initial scoping study has assumed that the Kaiapoi red zones fall within a tsunami evacuation zone (along with much of the Kaiapoi green zone area).

It is assumed that this assumed level of tsunami risk will not be a governing constraint for residential development. If the tsunami risk becomes a critical factor for decision making then we recommend that a detailed tsunami impact analysis is undertaken to clarify the actual level of risk.

2.8 Residents remaining in the red zone

There remain several properties in the Kaiapoi red zone areas where the owners have not accepted the Crown’s voluntary offer of purchase. The presence of this privately owned property presents a range of constraints for improvement of the surrounding red zone land. For example there could be

a range of technical and aesthetic challenges if the red zone land was raised to manage the flooding risk, but these private properties remained at the existing level.

It is beyond the scope of the current engineering feasibility assessment to consider how these constraints could be managed. For the purposes of this initial scoping study it has been assumed that all land within these red zone areas will be included in the improvement work, including any private properties. No allowance has been made for any additional costs or delay associated with private ownership.

We recommend that WDC and the steering group consider how private ownership could be managed to allow land improvement to proceed, and make allowance for the associated additional costs. This consideration could be informed by the Stage 2 engineering feasibility assessment – for the meantime it could be appropriate to broadly consider the acceptability or otherwise of treating all land in the red zone in the same way.

2.9 Construction cost estimate for land improvement

2.9.1 Costs "over and above" normal construction work

In the Kaiapoi area, one of the most important factors when considering the feasibility of developing one area of land compared to another is the work needed to improve the land to the point where it is suitable for residential or commercial construction. Once the land has been improved to a suitable standard, the work required for roading, local infrastructure and building construction is broadly similar regardless of location.

Therefore the preliminary cost estimate prepared as part of this initial scoping study includes only the cost of land improvement works. This is the cost of engineering work that would be incurred "over and above" the normal construction work that would be required to develop land that did not have any significant geotechnical or flooding issues.

It should be noted that the need for land improvement is not unique to the red zone. Much of the land in the Kaiapoi area and surrounding region is low-lying and/or potentially susceptible to liquefaction, and so would likely also require the land to be raised and compacted to meet flood and foundation design requirements. Therefore care should be taken when comparing the land improvement costs presented in this report with land prices elsewhere in the region. For example, it would be inappropriate to compare the Kaiapoi red zone land improvement costs directly with nearby land values in Woodend or Belfast – it would first be necessary to add the cost of land improvement that would be needed to build in these other areas. The land improvement cost in these surrounding areas would likely be considerably less than for the red zone, but still significant.

More detail on the land improvement works necessary for land development in the Kaiapoi red zone areas is presented in the following sections of this report, including the need to raise and compact the land to meet flood and foundation design requirements. To place this land improvement work into context, it is useful to compare against other recent residential subdivision developments in the Kaiapoi area, as summarised in Table 2.4.

2.9.2 Confidence range

A confidence range was developed to recognise the uncertainty in estimating the construction costs based on preliminary (pre conceptual) levels of design. The confidence range equates approximately to a 10% to 90% probability of exceedance.

The following cost estimates are presented in this initial scoping study:

- **Pessimistic** – about one time in ten the cost estimate will be exceeded
- **Most Likely** – about half of the time the final cost of the works be less than the estimate and about half the time the final cost will exceed the estimate
- **Optimistic** – about nine times in ten the cost estimate will be exceeded

These three scenarios are incorporated into the cost estimate schedule by varying the quantities for each scenario (to represent uncertainty in the final design) and by varying the unit rates (to represent uncertainties in market pricing).

It is anticipated that the difference between the pessimistic and optimistic cost estimates will decrease as the project progresses through design, tender and construction stages. A simplified example of this evolution over time is presented in Figure 2.1.

Table 2.4: Comparison of ground levels and fill thickness against recent subdivisions in Kaiapoi

Location	Pre-development ground elevation (m RL)	Post-development ground elevation (m RL)	Typical thickness of fill required (m)
Kaiapoi North red zone, north of Cass St	Typically RL 1.0 – 1.5m Average RL 1.2m	Most likely design assumption = RL 2.4m	Typically 0.9 – 1.4m Average 1.2m fill
Courtenay Drive red zone, west of Courtenay Drive	Typically RL 1.5 – 2.3m Average RL 1.9m	Most likely design assumption = RL 3.0m	Typically 0.7 – 1.5m Average 1.1m fill
Beach Grove	Typically RL 0.7 – 1.4m Average RL 1.1m	Approx. RL 2.0m	Average approx. 1.0m fill
Moorcroft	Unknown	Typically RL 2.4 – 3.1m Average RL 2.9m	Unknown
Silverstream	Typically RL 2.6 – 4.0m Average RL 3.3m	Typically RL 3.0 – 4.2m Average RL 3.8m	0.2m cut to 1.3m fill Average 0.4m fill
Sovereign Palms	Typically RL 2.1 – 4.2m Average RL 3.1m	Typically RL 2.6 – 3.2m Average RL 2.9m	1.3m cut to 0.8m fill Average 0.2m cut.
NOTE: Ground elevations are specified as metres above mean sea level, relative to Lyttelton Vertical Datum			

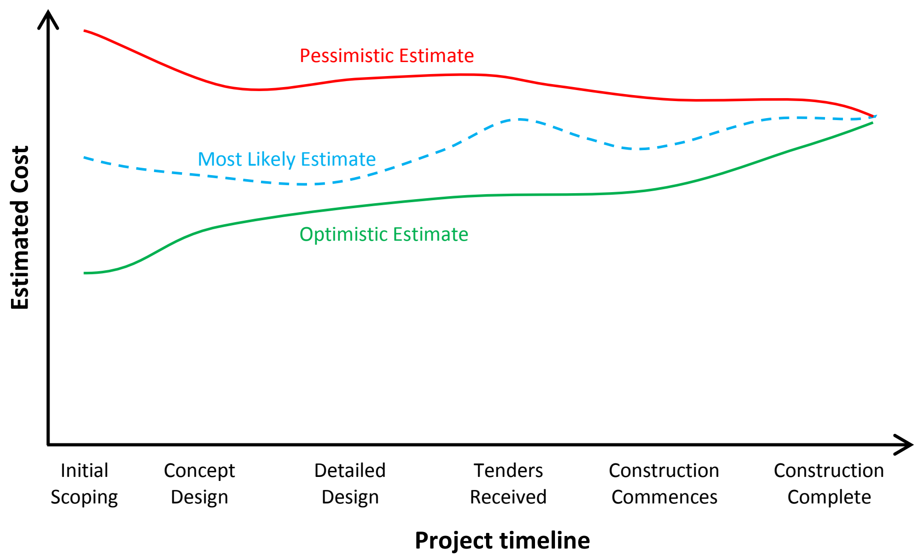


Figure 2.1: Simplified example of cost estimate confidence range over the life a of a project

3 Overview of red zone development areas

Figure 3.1 provides an overview of the five potential development areas considered as part of this initial scoping study. Residential land use has been assumed for areas A and B, and commercial land use has been assumed for areas C, D and E. The two unlabelled red zone areas in Figure 3.1 could potentially be used for stormwater and floodplain management purposes, helping to offset the effects of placing fill in the red zone areas, and improving drainage of the surrounding green zone areas.

As outlined in the Technical Advisory Panel report of April 2015, there are various other land use options that could potentially also be suitable for these areas. Therefore the engineering feasibility of each potential development area has been considered separately, without relying on any specific type of land use in the other areas.

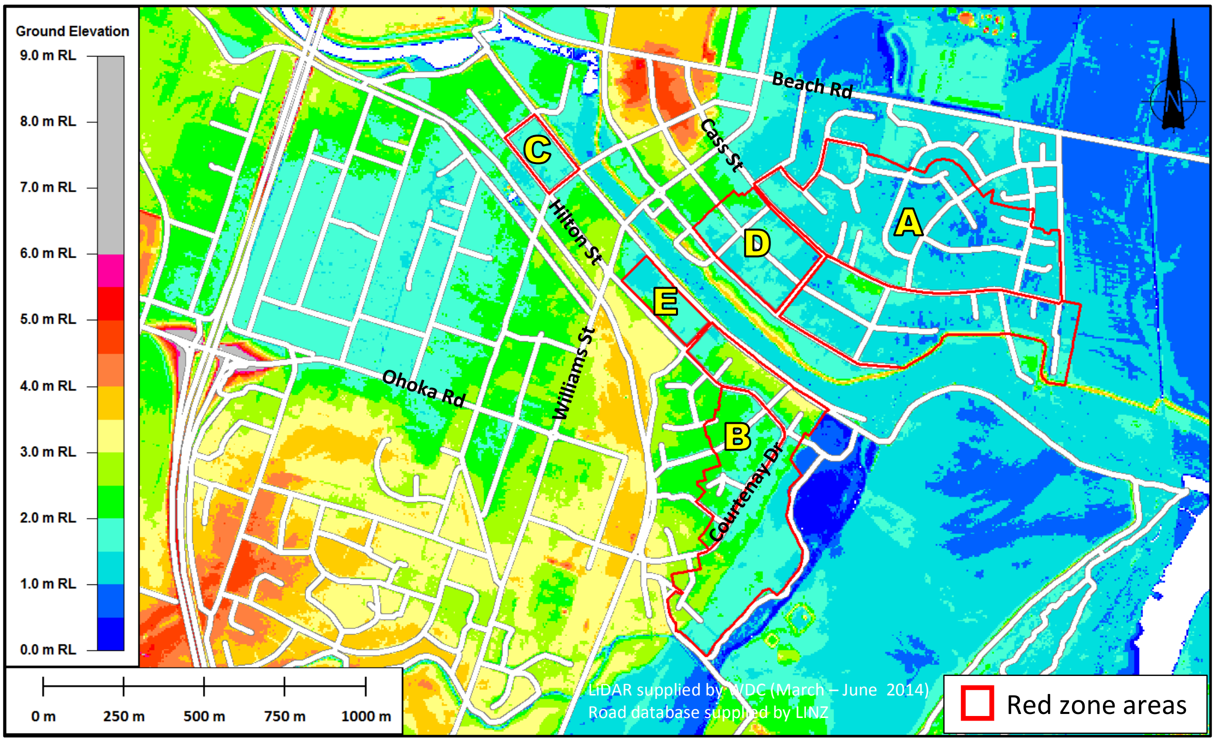


Figure 3.1: Overview of Kaiapoi red zone development areas A to E assumed for this initial scoping study, also showing the existing ground elevation (metres above mean sea level, Lyttelton Datum).

4 Kaiapoi North residential development (Area A)

4.1 Preliminary general land use outline plan

The preliminary general land use outline plan assumed for this initial scoping study is shown in Figure 4.1. This outline plan assumes residential land use for the red zone land north of Cass Street, with average lot sizes of approximately 670m^2 (11 lots per hectare) for the urban-residential scenario and 5000m^2 for the rural-residential scenario. Much of the red zone land south of Cass Street is assumed to be used for floodplain and stormwater management purposes. More detail on the assumed outline plan is presented in Appendix A.

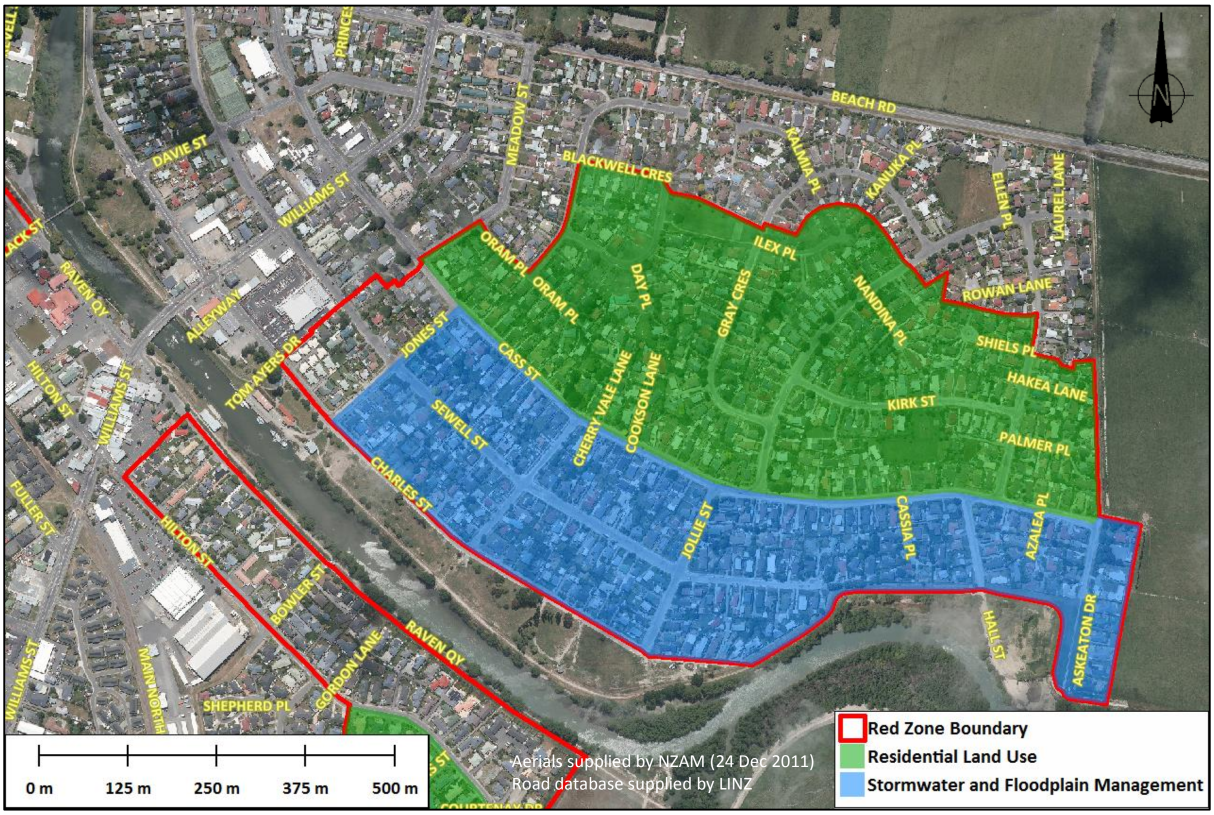


Figure 4.1: Preliminary general land use outline plan assumed for red zone Area A.

4.2 Key technical constraints

4.2.1 Geotechnical

For the red zone area north of Cass Street the primary geotechnical constraint is the thin and weak crust of soil above groundwater level. The depth to groundwater across this area typically ranges between 0.6m and 1.0m. This results in a low load-bearing capacity for conventional residential foundations during earthquakes when the underlying soils may liquefy, and also during normal day to day conditions. It also results in the potential for large volumes of liquefied material to be ejected from the ground during an earthquake, causing large differential ground settlements. Accordingly, this initial scoping study assumes that engineering works would be required to thicken and strengthen this surface crust to meet the target land performance for residential building platforms and infrastructure.

South of Cass Street, in addition to the thin crust there is also potential for lateral spreading to occur towards the Kaiapoi river during moderate earthquakes (return periods greater than approximately 100 years). However the thin crust and lateral spreading risk is unlikely to preclude the use of this

land for floodplain and stormwater management as assumed in this initial scoping study, provided it is accepted that repair works would be required after a moderate earthquake. Therefore this study assumes that no engineering works will be required for the land south of Cass Street to manage thin crust and lateral spreading issues.

4.2.2 Flooding

The existing ground level in the Kaiapoi North red zone north of Cass St typically ranges between 1.0m and 1.5m above mean sea level (Lyttelton Vertical Datum), with an average ground level of 1.2m. The low-lying elevation of this ground means it is susceptible to flooding.

Floodwater is slow to drain from this area because the land is at a similar elevation to the Kaiapoi River, so it can only drain when the flood or tide levels in the river drop. Also, the shallow depth to groundwater in this area (typically 0.6m to 1.0m) means that there is limited capacity for stormwater to seep into the ground.

Modelling undertaken in 2014 by T&T for EQC examined flooding as a result of a 100 year Average Recurrence Interval (ARI) event, based on current sea level and climate. This model showed flooding covering approximately 30% of the Kaiapoi North red zone, with a flood depth of up to 0.4m.

Modelling undertaken in 2015 by WDC incorporated the projected effects of climate change over the next 100 years (1.0m sea level rise and a 16% increase in rainfall intensity). This model showed flooding covering the entire Kaiapoi North red zone, with flood depths typically ranging between 0.5m and more than 1.0m in a 100 year ARI event. Modelling for 200 year and 500 year ARI events shows flood depths of 1.0m or more across the entire Kaiapoi North red zone.

Modelling undertaken in 2008 by Environment Canterbury examined potential effects from various scenarios of the Ashley River breaking out from its channel and flowing across the land between Rangiora and Kaiapoi. This modelling showed flood depths in the Kaiapoi North red zone of up to 0.5m for 100 year and 200 year ARI scenarios, and more than 0.5m for a 500 year ARI scenario.

At this stage there is still considerable uncertainty in the minimum land and floor levels that would be consentable, therefore the construction cost estimate has considered a range of building platform fill levels between an optimistic scenario of RL 2.0m and a pessimistic scenario of RL 2.8m, with a most likely estimate of RL 2.4m (levels are relative to mean sea level, Lyttelton Vertical Datum).

4.2.3 Ground contamination

The Environment Canterbury Listed Land-Use Register (LLUR) does not record any known sites in the Kaiapoi North red zone area where hazardous activities have occurred, however we understand that the assessment programme for the Kaiapoi area is not yet completed.

The Technical Advisory Panel noted anecdotal reports that an orchard was located in this area in the past, which indicates potential for ground contamination from pesticides or horticultural chemicals. Additionally, the majority of dwellings in this area were constructed between 1960 and 1990, so there is potential for asbestos contamination resulting from demolition debris.

Based on the information available at this time, there do not appear to be any “fatal flaws” relating to ground contamination that would preclude residential land use in this area. There may be minor to moderate additional land development costs associated with addressing ground contamination, but it is expected that this work would be technically feasible.

A formal ground contamination assessment (likely including on-site sampling) will still need to be undertaken to assess the presence of asbestos in soil and meet National Environmental Standards before development proceeds. This assessment may also be required for plan change purposes, and

would assist in reducing uncertainties in the construction cost estimate. We will discuss potential contamination assessment options with WDC at the commencement of Stage 2 of this engineering feasibility study.

For this initial feasibility assessment, we have assumed that in some locations it will be necessary to excavate contaminated soil to a depth of 200mm, and dispose offsite at a suitable facility. For the urban-residential assessment the assumed contaminated area ranges from 10% of the total area in the optimistic scenario to 25% in the pessimistic scenario. For the rural-residential assessment the assumed contaminated area ranges from 1% of the building platform area in the optimistic scenario to 5% in the pessimistic scenario.

4.3 Preliminary land improvement outline plan

Figure 4.2 outlines the preliminary land improvement plan assumed for this initial scoping study for the Kaiapoi North red zone for the urban-residential scenario.

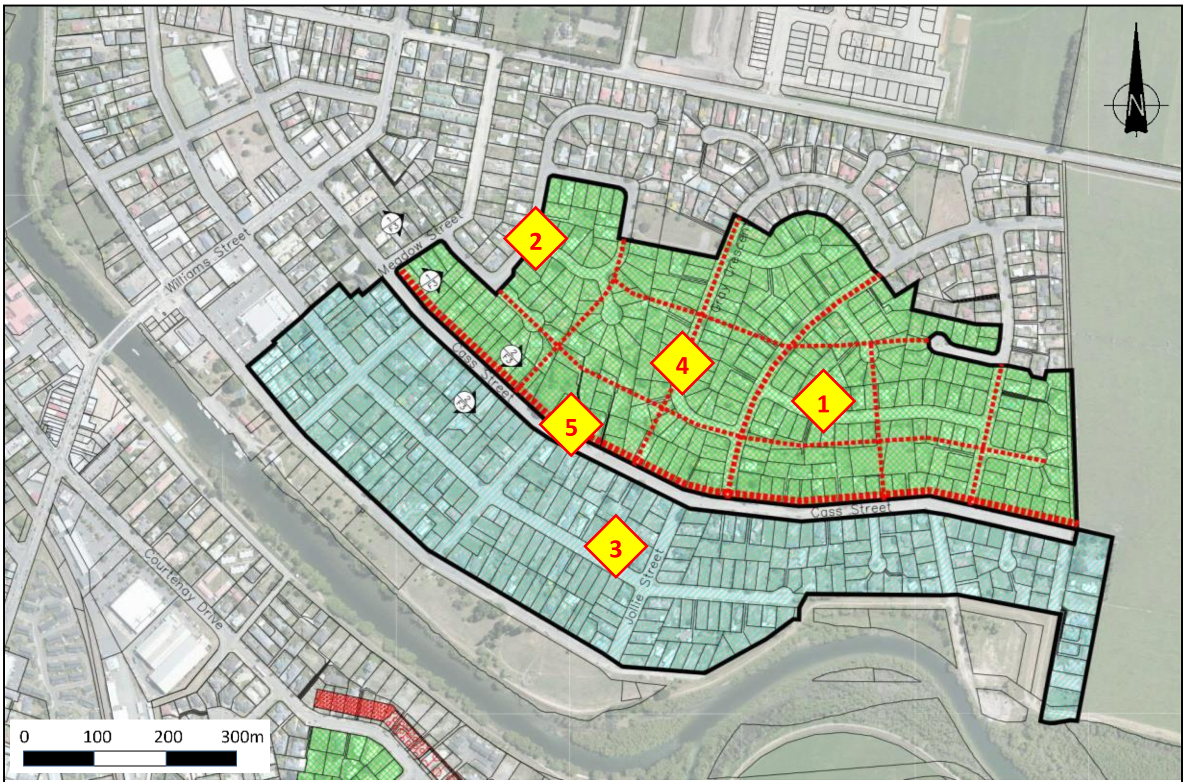
For the rural-residential scenario, no area-wide land improvement is proposed – it is assumed that specialised foundations would be constructed on a site-by-site basis, as outlined in Appendix A. For this initial assessment, it has been assumed that stone column ground improvement would be installed to a depth of 4m beneath the building footprint (extending 4m beyond the edge of the building). It has also been assumed that the land beneath the building (and 4m surrounding) would be raised to provide an amenity area, using geogrid-reinforced engineered fill. An MBIE Type 2B surface structure foundation would likely be required on top of this fill platform to meet flooding and geotechnical requirements (this foundation is not included in the cost estimate).

In accordance with our offer of service dated 2nd September 2015, these preliminary plans are based on the general findings of engineering analysis undertaken for these areas previously, and did not involve any new investigations or new engineering design work.

4.4 Potential civil engineering effects on neighbouring areas

The land improvement work outlined in Section 4.3 has the potential to affect neighbouring areas, in both positive and negative ways. Table 4.1 identifies potential effects related to civil engineering aspects of the land improvement works for the urban-residential scenario. Many of these effects are likely to be less significant for the rural-residential scenario.

There will also be other types of effects related to residential land use of red zone land, such as social, economic, environmental and cultural effects. Identification of these effects is beyond the scope of this initial scoping study – we recommend that these broader aspects are considered by WDC as part of the recovery plan process.



The key features labelled on this preliminary land improvement outline plan are:

1. Construction of a compacted hardfill platform in the red zone area north of Cass Street. This platform raises ground and floor levels above the relevant design flood levels, improves the available bearing capacity for residential foundations, and reduces surface land damage resulting from liquefaction of the underlying soils in future earthquakes. The average thickness of fill needed ranges from 0.8m for optimistic design assumptions to 1.6m for pessimistic assumptions, with a most likely estimate of 1.2m.

2. Installation of a high strength base geotextile and geogrid reinforcement around all edges of the hardfill platform. This reduces the potential for slope failure and lateral spreading of the new fill in future earthquakes.

3. Excavation of stormwater basins and flood flowpaths in the red zone area south of Cass Street. This helps offset adverse flooding effects that might otherwise result from placing fill in the area north of Cass Street, and also assists in the management of stormwater runoff from adjacent green zone areas.

4. Shallow ground improvement along the main underground service corridors (target depth about 4 – 6m). This reduces the ground deformations imposed on buried services.

5. Shallow ground improvement along the southern edge of the hardfill platform. This reduces the potential for lateral spreading towards the stormwater basins and flooding flowpaths south of Cass Street.

Figure 4.2: Preliminary land improvement outline plan for red zone Area A, urban-residential scenario (refer also to Appendix A)

Table 4.1: Potential civil engineering effects of land improvement works on neighbouring areas, for the urban-residential scenario

Potential effects	Potential measures to reduce negative effects and increase positive effects
Flooding and stormwater + Stormwater ponds and flood flowpaths south of Cass Street could be used to improve drainage of green zone areas, as part of the wider floodplain management strategy. − Fill platform may reduce floodwater storage capacity or obstruct flood flowpaths, and this could increase flood depth elsewhere.	• Design stormwater ponds to provide capacity to service existing neighbouring areas in addition to the new residential development. • Use flood model results to shape the extent of the fill platform to reduce obstruction of flood flowpaths north of Cass St, and improve flowpath performance south of Cass St. • Excavate basins and flowpaths for floodwater, to help offset loss of flood capacity due to fill platform. *Refer to Section 4.4.1 for more detail.*
Construction traffic − Gravel for construction of the fill platform would likely be delivered to site using trucks. The large volume of fill material required means that a large number of truck deliveries would be needed. This could cause effects for local traffic and residents and accelerated wear on road pavements.	• Select routes for heavy traffic that reduce the impacts on local traffic, residents and road pavements. *Refer to Section 4.4.2 for more detail.*
Access and services + The potential for revision of road layouts creates an opportunity to provide more direct access routes for green zone properties north of the red zone. − Green zone properties north of the red zone are currently accessed by roads and power/telecommunications services that run through the red zone. These would be decommissioned and rebuilt at a higher level, disrupting normal access routes and services to these properties during construction.	• Provide suitable temporary roads and power/telecommunications services for the green zone properties during the land improvement works.
Relative land levels − Around the border of the new fill platform the new land and dwellings would be at a significantly higher level than the neighbouring green zone properties. The ground level in the adjacent green zone is typically between RL 1.1m and 1.7m, compared to a ground level for the new fill platform ranging from RL 2.0m for the optimistic case to RL 2.8m for the pessimistic case. This may result in an impact on visual aesthetics and privacy, and an unfavourable perception of the lower-lying properties.	• Design the fill platform and subdivision layout to provide a gradual transition from areas of lower to higher land. • Avoid new dwellings constructed immediately overlooking existing lower-lying properties. • A green-space corridor could be provided to transition from lower to higher ground levels.

4.4.1 Exacerbation of flooding elsewhere

A preliminary assessment has been made of the potential for construction of the new fill platform for the urban-residential scenario to exacerbate flooding in the surrounding area, due to a reduction in floodplain volume. For the Stage 1 assessment the potential effects have been evaluated qualitatively, with reference to the flood depth and velocities predicted in the WDC and T+T flood modelling.

Potential effects if red zone Area A was filled have been considered both upstream and downstream:

- **Upstream:** Reduction in floodplain volume can have an upstream effect if it results in higher tailwater level that propagates to an upstream area. However, we expect that this effect upstream of the Kaiapoi North red zone area could be adequately mitigated as part of detailed design.
- **Downstream:** Reduction of floodplain volume can have effects on downstream areas in that a loss of floodwater storage may result in a higher peak discharge to downstream areas, and this can cause higher downstream flood levels. However, inspection of the modelled flood depths and velocities indicates that there may be little loss of floodplain conveyance, and thus little effect on downstream flood level as a result of filling. There is potential for localised flood exacerbation to occur, but it is likely that these effects can be managed as part of detailed design.

For the rural-residential scenario, a preliminary assessment suggests that the isolated fill platforms for each dwelling are unlikely to result in significant exacerbation of flooding elsewhere, provided that excavation is undertaken elsewhere in the red zone area to offset the lost flood storage volume.

This preliminary qualitative assessment indicates that exacerbation of flooding elsewhere is not likely to be an insurmountable impediment for residential development of red zone Area A. It is proposed that a quantitative assessment involving updated flood modelling is undertaken as part of the Stage 2 engineering feasibility assessment.

4.4.2 Construction traffic

The most likely source of gravel material for construction of the fill platform would be from the Waimakariri River, delivered to site by truck & trailer. To deliver the large volume of fill needed for the urban-residential scenario, up to about 20 – 40 truck deliveries per day would be required during peak summer earthworks season, over a period of about three to five years. Each delivery involves two truck movements, one going to the site and one leaving the site – although the route may be slightly different each way. For the rural-residential scenario, only about 10% of this volume of fill is required, so the number and duration of truck deliveries would be significantly less.

The most direct and practical access to site for most construction traffic would likely be to exit the northern motorway at Smith Street and continue east to a right turn onto Cass Street, as outlined in Figure 4.3. However, this route will put additional heavy vehicle demands on sections of Cass Street between Smith Street and Meadow Street which were likely not designed for this level of traffic. This could cause accelerated wear on these roads, resulting in a need for additional maintenance and repair. These additional road network costs have not been included in the land improvement construction cost estimate for this initial scoping study. There may also be noise and vibration effects for the residences along Cass Street due to this increase in heavy traffic.

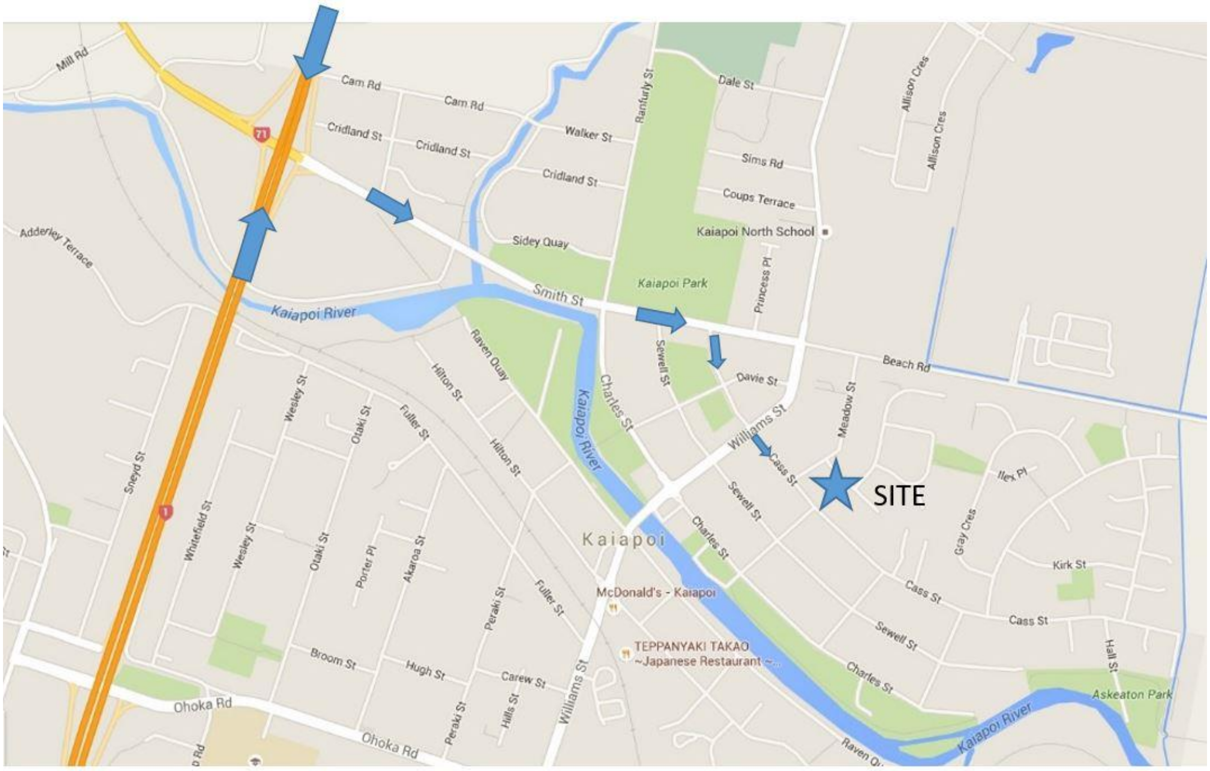


Figure 4.3: Potential construction traffic route to red zone Area A site (map data © 2015 Google)

4.5 Preliminary estimate of land improvement costs and timeframe

As discussed in Section 2.9.1, the preliminary cost estimate prepared as part of this initial scoping study includes only the cost of land improvement works. This is the cost of engineering work that would be incurred "over and above" normal subdivision servicing.

For the urban-residential scenario, significant land improvement works would be required in the North Kaiapoi red zone area to meet the land performance requirements outlined in Section 2.3.

- Depending on design assumptions, between approximately 230,000m^3 and 460,000m^3 of compacted fill with geotextile reinforcement would be required to meet flood and foundation design requirements. It has been assumed that part of the volume of fill required can be sourced from excavation of stormwater basins to the south of Cass St (cut to fill), with the remainder being imported gravel fill.
- Approximately 26,000m^2 of shallow ground improvement (e.g. dynamic compaction) would be required along the main underground service corridors to meet infrastructure performance requirements.

The expected construction timeframe for the area-wide land improvement works for the urban-residential scenario would be approximately three to five years. A residential subdivision of this scale would typically be constructed in stages (about 100 lots per stage), with stages developed progressively depending on market demand. For the rural-residential scenario, the expected construction timeframe for land improvement works for the individual building platforms would be approximately one year.

The preliminary "over-and-above" construction cost estimate for these land improvement works is summarised in Table 4.2. As discussed in Section 2.9.2 these estimates span a confidence range between approximately 10% and 90% probability of exceedance, to represent uncertainty in the

final design and market pricing. This preliminary estimate includes direct engineering design and construction costs only - we suggest that WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.

Table 4.2: Preliminary "over-and-above" cost estimate for Area A land improvement works

	Pessimistic	Most likely	Optimistic
Urban-residential scenario: Cost to strip site, dispose of contaminated soil, raise and stabilise land, excavate to provide stormwater storage south of Cass St, reinstate topsoil and grass.	$44.2M *$140k per lot*	$28.3M *$90k per lot*	$16.6M *$53k per lot*
Rural-residential scenario: Cost to strip site, construct ground improvement and reinforced fill platform beneath building footprints only, excavate to provide equivalent volume of stormwater storage, reinstate topsoil.	$14.9M *$360k per lot*	$11.7M *$285k per lot*	$11.0M *$270k per lot*

NOTE:
1) These estimates include direct engineering design and construction costs only – we suggest WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.
2) Per lot values assume same number of lots as previously for urban-residential (314 lots of average 670m^2) or 41 lots of 5000m^2 each for the rural-residential scenario.
3) These are land improvement costs "over-and-above" normal construction work, as detailed in Section 2.9.1.
4) All cost values exclude GST.

For the urban-residential scenario the main difference in the assumed land improvement design between the optimistic and pessimistic cost estimates is the volume of fill assumed to be necessary to provide suitable ground bearing conditions and meet flood level requirements. At the present preliminary stage of design there is still considerable uncertainty regarding the fill level that would be required, and the volume of excavated material able to be reused as fill (cut to fill). This uncertainty is illustrated in Table 4.3. Each 0.1m increase in the design fill level (or shortfall in suitable cut to fill material) adds approximately 24,000m^3 of fill, and increases costs by approximately $1.1M (based on most likely unit rate cost for imported fill, including overheads & contractors margins) – about $3,400 per lot.

Table 4.3: Estimates of volume of fill required for Area A land improvement works for the urban-residential scenario

Design Scenario	Ground elevation (m RL)	Thickness of fill required (m)	Volume of fill required (m^3)
Pessimistic design assumptions	RL 2.8m	Typically 1.3 – 1.8m Average 1.6m	85,000 m^3 cut to fill 374,000 m^3 imported
Most likely design assumptions	RL 2.4m	Typically 0.9 – 1.4m Average 1.2m	127,000 m^3 cut to fill 241,000 m^3 imported
Optimistic design assumptions	RL 2.0m	Typically 0.5 – 1.0m Average 0.8m	170,000 m^3 cut to fill 63,000 m^3 imported
Current ground level (2014 LiDAR survey)	Typically RL 1.0 – 1.5m, Average RL 1.2m		

NOTE: Ground elevations are specified as metres above mean sea level, relative to Lyttelton Vertical Datum.

For the rural-residential scenario, the main difference between the optimistic and pessimistic cost estimates is due to uncertainty in the required building platform level for flood mitigation, and to a lesser extent uncertainty in the extent of deep ground improvement needed for foundation design.

4.6 Discussion

This initial scoping study has not identified any immediate “fatal flaws” regarding the engineering feasibility of land improvement works to enable urban or rural residential development in the North Kaiapoi red zone north of Cass Street. However, a number of significant technical constraints and potential adverse effects have been identified. It appears to be technically feasible to manage these issues, using engineering approaches that are commonly applied for land development in Canterbury - such as earthworks, ground improvement and stormwater management. However, given the significant scale of work that would be required, this would add considerable development cost.

If WDC wish to better understand the economic feasibility of potential residential land use, then we would recommend that a broader business case analysis be undertaken which includes the estimated range of costs for undertaking these land improvement works. This business case analysis should make allowance for the likelihood that some of the land preparation work included in this cost estimate would be required regardless of the future land use selected (e.g. decommissioning existing roads and managing ground contamination).

4.7 Next steps

If WDC wish to examine in more detail the potential for residential land use in red zone Area A, then we would recommend a second stage of engineering feasibility assessment as outlined in our Offer of Service dated 2nd September 2015.

In particular, the following technical aspects appear to have a significant influence on the engineering feasibility and construction cost estimate:

a One of the most important uncertainties controlling the construction cost estimate appears to be the minimum land level necessary to meet flood and foundation design requirements. The 0.8m difference in level between the optimistic and pessimistic design assumptions corresponds to a difference in cost of approximately $8.8M (based on most likely unit rate cost for imported fill, including overheads & contractors margins) – about $27,000 per lot. The Stage 2 assessment should aim to more precisely define the required fill level – this would involve further analysis of flood model results and consultation with WDC technical and consenting staff.

b Another important uncertainty in the construction cost estimate is the volume of contaminated soil requiring off-site disposal. A preliminary estimate has been made at this initial stage, ranging from 10% of the total area in the optimistic scenario to 25% of the total area in the pessimistic scenario. This corresponds to an estimated cost range of $1.7M to $6.4M for contaminated soil disposal. However, there is currently very little site-specific information to support these assumptions – so the volume of contaminated soil could potentially be under-predicted or over-predicted. The Stage 2 assessment should aim to more clearly identify the potential extent of soil contamination – this would be most effectively achieved by on-site shallow soil sampling and laboratory testing. This assessment could also consider whether it would be possible to manage contaminated soil on-site, rather than disposing off-site.

c The preliminary assessment has assumed that a significant proportion of the soil excavated from the stormwater basins to the south of Cass Street can be re-used as part of the new fill platform north of Cass Street. This results in a cost saving of between $2.9M for pessimistic design assumptions and $5.9M for optimistic design assumptions, compared to the cost of importing fill (based on most likely rates, including overheads and margin). The Stage 2 assessment should aim better estimate the volume of suitable cut-to-fill material – this would be most effectively achieved by on-site shallow soil sampling and laboratory testing.

d It has been assumed that dynamic compaction will be a suitable ground improvement technique for improving the land performance along service corridors. Dynamic compaction is significantly less expensive than alternative techniques such as stone columns, so this has resulted in a saving of several million dollars. However the effectiveness of dynamic compaction can be sensitive to the ground conditions. The Stage 2 assessment should further examine the suitability of the ground for dynamic compaction – however it is unlikely that this uncertainty can be conclusively resolved until field trials are undertaken (e.g. at the commencement of construction).

e The engineering feasibility for the rural-residential scenario has assumed that specialised foundations will be required for each building. The Stage 2 assessment could aim to better define the cost of these foundations, for incorporation into a broader economic analysis.

5 Courtenay Drive residential development (Area B)

5.1 Preliminary general land use outline plan

The preliminary general land use outline plan assumed for this initial scoping study is shown in Figure 5.1. This outline plan assumes residential land use for the red zone land west of Courtenay Drive, with average lot sizes of approximately 650m^2 (12 lots per hectare) for the urban-residential scenario and 5000m^2 for the rural-residential scenario. More detail on the assumed outline plan is presented in Appendix A.

As detailed in Section 5.3, construction of stone column ground improvement is assumed within the red zone land to the east and north of Courtenay Drive. However, as the stone columns will be entirely underground they are unlikely interfere with other potential uses of this land in future, so no specific land use has been assumed in this area for this initial assessment.

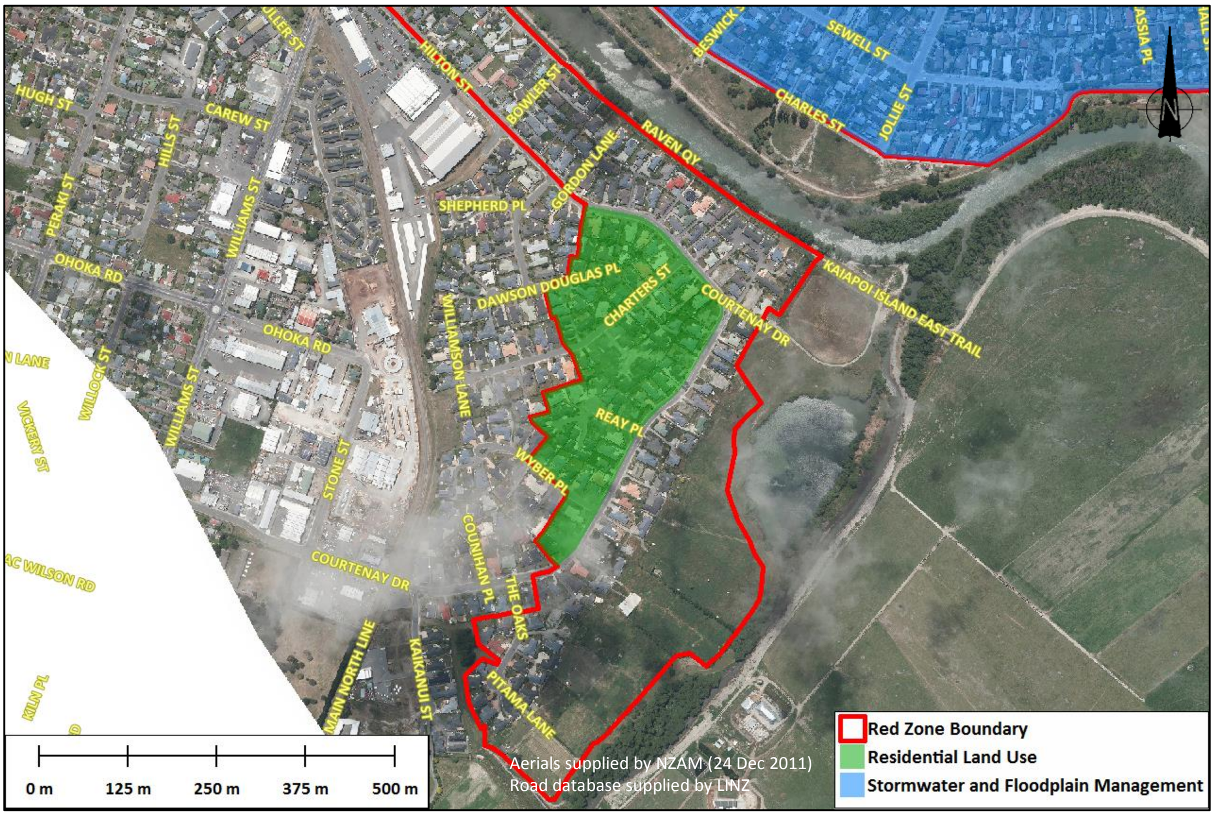


Figure 5.1: Preliminary general land use outline plan assumed for red zone Area B

5.2 Key technical constraints

5.2.1 Geotechnical

For the red zone area west of Courtenay Drive the primary geotechnical constraint is the potential for area-wide lateral spreading to occur towards the lower terrace area to the east of Courtenay Drive.

The depth to groundwater across this area typically ranges between 1.0m and 1.9m. Typically this would provide moderate load-bearing capacity for conventional residential foundations during earthquakes when the underlying soils may liquefy. However, the occurrence of lateral spreading causes cracking in the load-bearing crust which exacerbates ejection of liquefied soil, which can result in large differential ground settlement.

Accordingly, this initial scoping study assumes that engineering works would be required to reduce lateral spreading ground deformations to meet the target land performance for residential building platforms and infrastructure. It is also assumed that work would be required to thicken and strengthen the surface crust to improve the load-bearing capacity during earthquakes.

5.2.2 Flooding

The existing ground level in the Courtenay Drive red zone west of Courtenay Drive typically ranges between 1.5m and 2.3m above mean sea level (Lyttelton Vertical Datum), with an average ground level of 1.9m. The low-lying elevation of this ground means it is susceptible to flooding. The roadway along Courtenay Drive forms an important floodwater conveyance path, carrying stormwater runoff from west to east towards Courtenay Lake, NCF Reserve, and Courtenay Stream.

Modelling undertaken in 2014 by T&T for EQC examined flooding as a result of a 100 year Average Recurrence Interval (ARI) event, based on current sea level and climate. This model showed flooding covering approximately 70% of the Courtenay Drive red zone west of the centreline of Courtenay Drive, with a typical flood depth of 0.8m – 1.7m along the roadway and up to 0.4m on residential lots.

Modelling undertaken in 2015 by WDC incorporated the projected effects of climate change over the next 100 years (1.0m sea level rise and a 16% increase in rainfall intensity). This model showed flooding covering the entire Courtenay Drive red zone west of Courtenay Drive, with typical flood depths in a 100 year ARI event of more than 1.0m along roadways and up to 0.75m on residential lots. Modelling for 200 year and 500 year ARI events shows flood depths of more than 0.5m and 0.75m respectively across the entire Courtenay Drive red zone west of Courtenay Drive.

Modelling undertaken in 2008 by Environment Canterbury examined potential effects from various scenarios of the Ashley River breaking out from its channel and flowing across the land between Rangiora and Kaiapoi. This modelling showed only localised flooding of roadways in the Courtenay Drive red zone for the 100 year and 200 year ARI scenarios, but more than 1.5m depth of flooding for a 500 year ARI scenario.

At this stage there is still considerable uncertainty in the minimum land and floor levels that would be consentable, therefore the construction cost estimate has considered a range of building platform fill levels between an optimistic scenario of RL 2.6m and a pessimistic scenario of RL 3.5m, with a most likely estimate of RL 3.0m (levels are relative to mean sea level, Lyttelton Vertical Datum).

5.2.3 Ground contamination

The Environment Canterbury Listed Land-Use Register (LLUR) does not record any known sites in the Courtenay Drive red zone area where hazardous activities have occurred, however we understand that the assessment programme for the Kaiapoi area is not yet completed.

The Technical Advisory Panel noted that a freezing works occupied this area until the Courtenay Downs subdivision was developed in the 1990's. Development of this subdivision included stripping of the land and placing new fill. Therefore this initial scoping study has assumed that no contamination issues remain from this historic landuse that would significantly impact the feasibility of residential development. As the dwellings in this area were constructed in the 1990's, it has been assumed that there is little potential for asbestos contamination resulting from demolition debris.

Based on the information available at this time, there do not appear to be any "fatal flaws" relating to ground contamination that would preclude residential land use in this area. There may be minor additional land development costs associated with addressing localised ground contamination, but it is expected that this work would be technically feasible.

A formal ground contamination assessment (likely including on-site sampling) will still need to be undertaken to confirm the absence of asbestos in soil and meet National Environmental Standards before development proceeds. This assessment may also be required for plan change purposes, and would assist in reducing uncertainties in the construction cost estimate. We will discuss potential contamination assessment options with WDC at the commencement of Stage 2 of this engineering feasibility study.

For this initial feasibility assessment, we have assumed that in some locations it will be necessary to excavate contaminated soil to a depth of 200mm, and dispose offsite at a suitable facility. The assumed contaminated area ranges from 1% of the total area (urban-residential) or building platform area (rural-residential) in the optimistic scenario to 5% in the pessimistic scenario.

5.3 Preliminary land improvement outline plan

Figure 5.2 outlines the preliminary land improvement plan assumed for this initial scoping study for the Kaiapoi North red zone for the urban-residential scenario.

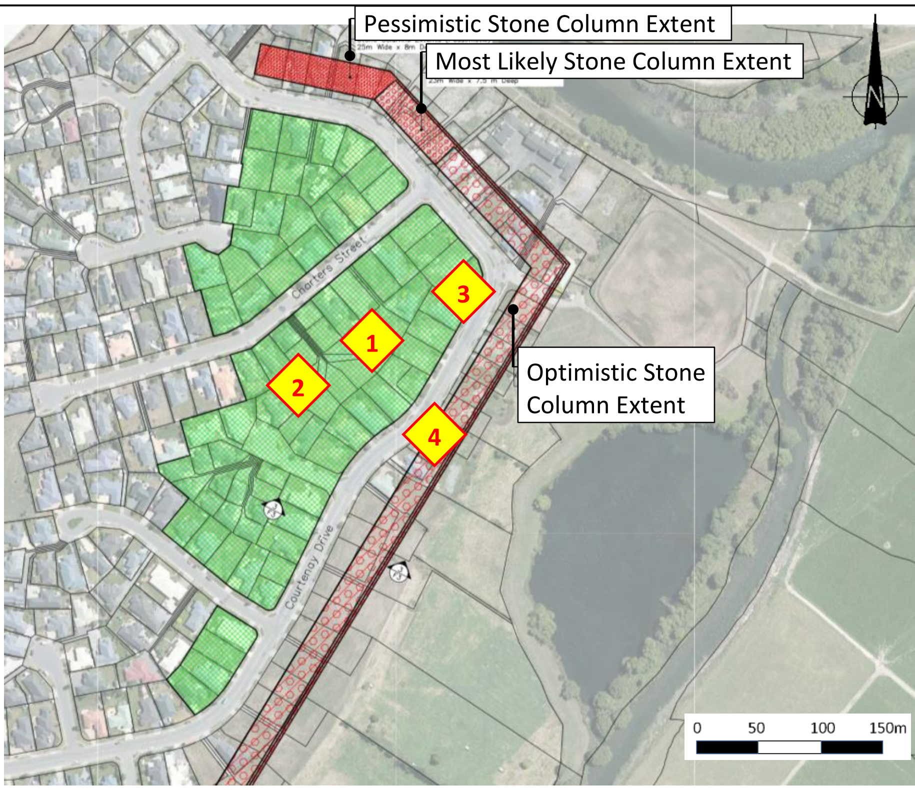
For the rural-residential scenario, no area-wide land improvement is proposed – it is assumed that specialised foundations would be constructed on a site-by-site basis, as outlined in Appendix A. For this initial assessment, it has been assumed that stone column ground improvement would be installed to a depth of 8m beneath the building footprint (extending 4m beyond the edge of the building). It has also been assumed that the land beneath the building (and 4m surrounding) would be raised to provide an amenity area, using geogrid-reinforced engineered fill. An MBIE Type 2B surface structure foundation would likely be required on top of this fill platform to meet flooding and geotechnical requirements (this foundation is not included in the cost estimate).

In accordance with our offer of service dated 2nd September 2015, these preliminary plans are based on the general findings of engineering analysis undertaken for these areas previously, and did not involve any new investigations or new engineering design work.

5.4 Potential civil engineering effects on neighbouring areas

The land improvement work outlined in Section 5.3 has the potential to affect neighbouring areas, in both positive and negative ways. Table 5.1 identifies potential effects related to civil engineering aspects of the land improvement works for the urban-residential scenario. Many of these effects are likely to be less significant for the rural-residential scenario.

There will also be other types of effects related to residential land use of red zone land, such as social, economic, environmental and cultural effects. Identification of these effects is beyond the scope of this initial scoping study – we recommend that these broader aspects are considered by WDC as part of the recovery plan process.



The key features labelled on this preliminary land improvement outline plan are:

1 Heavy earthworks compaction of the existing ground surface across the red zone area west of Courtenay Drive, to repair ground cracking from lateral spreading.

2 Construction of a compacted hardfill platform in the red zone area west of Courtenay Drive. This platform raises ground and floor levels above the relevant design flood levels, improves the available bearing capacity for residential foundations, and reduces surface land damage resulting from liquefaction of the underlying soils in future earthquakes. The average thickness of fill needed ranges from 0.7m for optimistic design assumptions to 1.6m for pessimistic assumptions, with a most likely estimate of 1.1m.

3 Installation of a high strength base geotextile and geogrid reinforcement around all edges of the hardfill platform. This reduces the potential for slope failure and lateral spreading of the new fill in future earthquakes.

4 Deep ground improvement along the northern and eastern side of Courtenay Drive, potentially using stone columns to a depth of 7 – 8m (other ground improvement techniques may also be suitable). This reduces the potential for area-wide lateral spreading towards the lower terrace level.

Figure 5.2: Preliminary land improvement outline plan for red zone Area B, urban-residential scenario (refer also to Appendix A)

Table 5.1: Potential civil engineering effects of land improvement works on neighbouring areas, for the urban-residential scenario

Potential effects	Potential measures to reduce negative effects and increase positive effects
Flooding and stormwater + New stormwater ponds and widened or additional flood flowpaths to the north and east of Courtenay Drive could be used to improve drainage of upstream green zone areas, as part of the wider stormwater and floodplain management strategy. − Fill platform west of Courtenay Drive may reduce floodwater storage capacity or obstruct flood flowpaths, and this could increase flood depth elsewhere.	• Design stormwater ponds to provide capacity to service existing neighbouring areas in addition to the new residential development. • Use flood model results to shape the extent of the fill platform, and shape the red zone land north and east of Courtenay Drive, to reduce obstruction of flood flowpaths and improve flowpath performance. • Excavate basins and flowpaths for floodwater, or flatten the terrace slope east of Courtenay Drive, to help offset loss of flood capacity. *Refer to Section 5.4.1 for more detail.*
Construction traffic − Gravel for construction of the fill platform would likely be delivered to site using trucks. The large volume of fill material required means that a large number of truck deliveries would be needed. This could cause effects for local traffic and residents and accelerated wear on road pavements.	• Select routes for heavy traffic that reduce the impacts on local traffic, residents and road pavements. *Refer to Section 5.4.2 for more detail.*
Access, services and amenity + The proposed works would restore the original access and service corridors for green zone properties west of the red zone, and reduce potential damage in future earthquakes. + Construction of new dwellings may substantially restore the original residential density and corresponding amenity. − Green zone properties west of the red zone are accessed by roads and services that run through the red zone. It is envisioned that these would not be disrupted during the works as the roads would be left at the existing level. However access to these properties would be through the earthworks construction site.	• Ensure that access and services for the green zone properties are maintained during the land improvement works, or provide suitable alternatives.
Relative land levels − Around the border of the new fill platform the new land and dwellings would be at a moderately higher level than the neighbouring green zone properties. Ground level in the adjacent green zone is typically between RL 2.1m and 2.4m, compared to ground level for the new fill platform ranging from RL 2.6m for the optimistic case to RL 3.5m for the pessimistic. This may result in an impact on visual aesthetics and privacy, and unfavourable perception of the lower-lying properties.	• Design the fill platform and subdivision layout to provide a gradual transition from areas of lower to higher land. • Avoid new dwellings constructed immediately overlooking existing lower-lying properties. • A green-space corridor could be provided to transition from lower to higher ground levels.

5.4.1 Exacerbation of flooding elsewhere

A preliminary assessment has been made of the potential for construction of the new fill platform for the urban-residential scenario to exacerbate flooding in the surrounding area, due to a reduction in floodplain volume. For the Stage 1 assessment the potential effects have been evaluated qualitatively, with reference to the flood depth and velocities predicted in the WDC and T+T flood modelling.

Potential effects if red zone Area B was filled have been considered both upstream and downstream:

- **Upstream:** Reduction in floodplain volume can have an upstream effect if it results in higher tailwater level that propagates to an upstream area. However, we expect that this effect upstream of the Courtenay Drive red zone area could be adequately mitigated as part of detailed design.
- **Downstream:** Reduction of floodplain volume can have effects on downstream areas in that a loss of floodwater storage may result in a higher peak discharge to downstream areas, and this can cause higher downstream flood levels. Inspection of the modelled flood depths and velocities indicates that there may be some loss of floodplain conveyance, and so potentially some exacerbation of downstream flood levels as a result of filling. However, it is likely that these effects can be managed as part of detailed design.

For the rural-residential scenario, a preliminary assessment suggests that the isolated fill platforms for each dwelling are unlikely to result in significant exacerbation of flooding elsewhere.

This preliminary qualitative assessment indicates that exacerbation of flooding elsewhere is not likely to be an insurmountable impediment for residential development of red zone Area B. It is proposed that a quantitative assessment involving updated flood modelling is undertaken as part of the Stage 2 engineering feasibility assessment.

5.4.2 Construction traffic

The most likely source of gravel material for construction of the fill platform would be from the Waimakariri River, delivered to site by truck & trailer. To deliver the large volume of fill needed for the urban-residential scenario, up to about 6 – 13 truck deliveries per day would be required during peak earthworks season, over a period of about two to three years. Each delivery involves two truck movements, one going to the site and one leaving the site – although the route may be slightly different each way. For the rural-residential scenario, only about 10% of this volume of fill is required, so the number and duration of truck deliveries would be significantly less.

The most direct and practical access to site for most construction traffic would likely be to exit the northern motorway at Ohoka Road and continue east to turn onto Stone Street then Courtenay Drive, as outlined in Figure 5.3. However, this route will put additional heavy vehicle demands on sections of Stone Street and Courtenay Drive which were likely not designed for this level of traffic. This could cause accelerated wear on these roads, resulting in a need for additional maintenance and repair. These additional road network costs have not been included in the land improvement construction cost estimate for this initial scoping study. There may also be noise and vibration effects for the residences along Ohoka Road and Courtenay Drive due to this increase in heavy traffic.

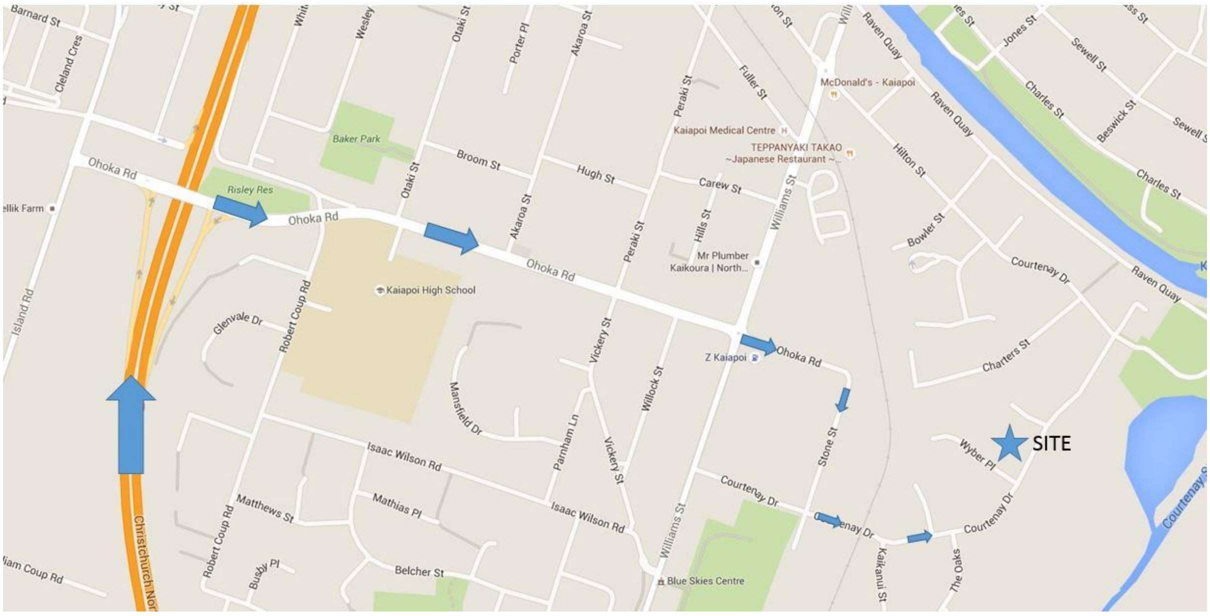


Figure 5.3: Potential construction traffic route to red zone Area B site (map data © 2015 Google)

5.5 Preliminary estimate of land improvement costs and timeframe

As discussed in Section 2.9.1, the preliminary cost estimate prepared as part of this initial scoping study includes only the cost of land improvement works. This is the cost of engineering work that would be incurred "over and above" normal subdivision servicing.

For the urban-residential scenario, significant land improvement works would be required in the Courtenay Drive red zone area to meet the land performance requirements outlined in Section 2.3.

- Depending on design assumptions, between approximately 14,000m^2 and 21,000m^2 of deep ground improvement (e.g. stone columns) would be required to the north and east of Courtenay Drive to reduce ground deformation due to area-wide lateral spreading in future earthquakes.
- Depending on design assumptions, between approximately 38,000m^3 and 76,000m^3 of compacted fill with geotextile reinforcement would be required to meet flood and foundation design requirements. At this stage it has been assumed that all fill will be imported gravel material, however in future stages to possibility of reshaping the terrace in red zone land to the east of Courtenay Drive could be considered as a source of cut to fill material.
- Approximately 69,000m^2 of ground surface compaction (e.g. a heavy roller) would be required across the entire area to repair ground cracking from lateral spreading and prepare the subgrade for filling.

The expected construction timeframe for the area-wide land improvement works for the urban-residential scenario would be approximately two to three years. A residential subdivision of this scale would typically be constructed in stages (about 40 lots per stage), with stages developed progressively depending on market demand. For the rural-residential scenario, the expected construction timeframe for land improvement works for the individual building platforms would be less than one year.

The preliminary "over-and-above" construction cost estimate for these land improvement works is summarised in Table 5.2. As discussed in Section 2.9.2 these estimates span a confidence range between approximately 10% and 90% probability of exceedance, to represent uncertainty in the final design and market pricing. This preliminary estimate includes direct engineering design and

construction costs only - we suggest that WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.

Table 5.2: Preliminary "over-and-above" cost estimate for Area B land improvement works

	Pessimistic	Most likely	Optimistic
Urban-residential scenario: Cost to strip site, dispose of contaminated soil, raise and stabilise land, reinstate topsoil and grass.	$16.5M *$195k per lot*	$11.3M *$135k per lot*	$8.4M *$100k per lot*
Rural-residential scenario: Cost to strip site, construct ground improvement and reinforced fill platform beneath building footprints only, reinstate topsoil and grass.	$5.3M *$480k per lot*	$4.2M *$380k per lot*	$3.8M *$350k per lot*

NOTE:
1) These estimates include direct engineering design and construction costs only - we suggest WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.
2) Per lot values assume same number of lots as previously for urban-residential (84 lots of average 650m^2) or 11 lots of 5000m^2 each for the rural-residential scenario.
3) These are land improvement costs "over-and-above" normal construction work, as detailed in Section 2.9.1.
4) All cost values exclude GST.

For the urban-residential scenario the main differences between the optimistic and pessimistic cost estimates are due to design uncertainties at the present preliminary stage of design. There is still considerable uncertainty regarding the extent of deep ground improvement needed to manage lateral spreading (refer Table 5.3), and the volume of new fill for flood and foundation requirements (refer Table 5.4). For example, each 0.1m increase in the design fill level adds approximately 5,500m^3 of fill, and increases costs by approximately $250k (based on most likely unit rate fill cost, including overheads & contractors margins) – about $2,900 per lot.

Table 5.3: Estimates of extent of stone columns required for Area B land improvement work

Design scenario	Ground improvement extent	Stone column depth (m)	Stone column area replacement ratio	Number of 0.9m diameter stone columns needed
Pessimistic design assumptions	21m wide x 660m long	8.0m	19%	3,700
Most likely design assumptions	23m wide x 740m long	7.5m	17%	5,000
Optimistic design assumptions	25m wide x 840m long	7.0m	16%	6,400

Table 5.4: Estimates of volume of fill required for Area B land improvement works

Design scenario	Ground elevation (m RL)	Thickness of fill required (m)	Volume of fill required (m^3)
Pessimistic design assumptions	RL 3.5m	Typically 1.2 – 2.0m Average 1.6m	76,000 m^3 imported
Most likely design assumptions	RL 3.0m	Typically 0.7 – 1.5m Average 1.1m	56,000 m^3 imported
Optimistic design assumptions	RL 2.6m	Typically 0.3 – 1.1m Average 0.7m	38,000 m^3 imported
Current ground level (2014 LiDAR survey)	Typically RL 1.5 – 2.3m, Average RL 1.9m		
NOTE: Ground elevations are specified as metres above mean sea level, relative to Lyttelton Vertical Datum.			

For the rural-residential scenario, the main differences between the optimistic and pessimistic cost estimates are due to uncertainty in the required building platform level for flood mitigation, and the extent of deep ground improvement and geogrid reinforcement needed for foundation design.

5.6 Discussion

This initial scoping study has not identified any immediate “fatal flaws” regarding the engineering feasibility of land improvement works to enable urban or rural residential development in the Courtenay Drive red zone west of Courtenay Drive. However, a number of significant technical constraints and potential adverse effects have been identified. It appears to be technically feasible to manage these issues, using engineering approaches that are commonly applied for land development in Canterbury - such as earthworks, ground improvement and stormwater management. However, given the significant scale of work that would be required, this would add considerable development cost.

If WDC wish to better understand the economic feasibility of potential residential land use, then we would recommend that a broader business case analysis be undertaken which includes the estimated range of costs for undertaking these land improvement works. This business case analysis should make allowance for the likelihood that some of the land preparation work included in this cost estimate would be required regardless of the future land use selected (e.g. decommissioning existing roads and managing ground contamination).

5.7 Next steps

If WDC wish to examine in more detail the potential for residential land use in the Courtenay Drive red zone, then we would recommend a second stage of engineering feasibility assessment as outlined in our Offer of Service dated 2nd September 2015.

In particular, the following technical aspects appear to have a significant influence on the engineering feasibility and construction cost estimate:

a One of the most important uncertainties controlling the construction cost estimate appears to be the extent and intensity of deep ground improvement required to reduce the potential for area-wide lateral spreading. The difference between the optimistic and pessimistic design assumptions corresponds to a difference in cost of approximately $3.9M (including overheads & contractors margins) – about $47,000 per lot. The Stage 2 assessment should aim to more precisely define the required extent of ground improvement – this would involve specific geotechnical stability analysis.

b Another important uncertainty in the construction cost estimate is the minimum land level necessary to meet flood and foundation design requirements. The 0.9m difference in level between the optimistic and pessimistic design assumptions corresponds to a difference in cost of approximately $1.7M (based on most likely unit rate cost for imported fill, including overheads & contractors margins) – about $20,000 per lot. The Stage 2 assessment should aim to more precisely define the required fill level – this would involve further analysis of flood model results and consultation with WDC technical and consenting staff.

c For this initial assessment it has been assumed that only a small proportion of contaminated soil will require off-site disposal. A preliminary estimate has been made at this initial stage, ranging from 1% of the total area in the optimistic scenario to 5% of the total area in the pessimistic scenario – resulting in only minor estimated costs. However, there is currently very little site-specific information to support these assumptions – so the volume of contaminated soil could potentially be under-predicted. The Stage 2 assessment should aim to more clearly identify the potential extent of soil contamination – this would be most effectively achieved by on-site shallow soil sampling and laboratory testing.

d The engineering feasibility for the rural-residential scenario has assumed that specialised foundations will be required for each building. The Stage 2 assessment could aim to better define the cost of these foundations, for incorporation into a broader economic analysis.

e The roadway along Courtenay Drive forms an important floodwater conveyance path, carrying stormwater runoff from west to east towards Courtenay Lake, NCF Reserve, and Courtenay Stream. An initial qualitative assessment suggests it is likely that flood exacerbation effects could be managed as part of detailed design. This may require reshaping the red zone land north and east of Courtenay Drive, to reduce obstruction of flood flowpaths and improve flowpath performance. The Stage 2 assessment should aim to provide more certainty that flood exacerbation effects can be managed – this would involve specific flood modelling of the new fill and land reshaping.

f The estimated per-lot land improvement construction costs are relatively high in the Courtenay Drive red zone area, in part because a large extent of deep perimeter ground improvement is required to protect a comparatively small number of lots to the west of Courtenay Drive. However, this ground improvement will also protect the access and services to the adjacent green zone, as well as protecting up to 21,000m^2 of red zone land to the north and east of Courtenay Drive for which no specific land use has been assumed at this stage. WDC may wish to consider these other benefits as part of a broader business case analysis to assess the financial viability of potential residential development. WDC may also wish to consider whether the Stage 2 engineering feasibility should include assessment of potential residential land use on top of the deep ground improvement to the north and east of Courtenay Drive.

6 Kaiapoi West commercial development (Area C)

6.1 Preliminary general land use outline plan

The preliminary general land use outline plan assumed for this initial scoping study is shown in Figure 6.1. This outline plan assumes commercial land use for the red zone land between Rich Street and Black Street, with both yard-based and large-format retail scenarios considered as outlined in Section 2.2. More detail on the assumed outline plan is presented in Table 6.1 and Appendix A.

Figure 6.1: Preliminary general land use outline plan assumed for red zone Area C

Table 6.1: Development footprint options for Area C

Development footprint option	Total site area (m^2)	Assumed building footprint area for large-format retail scenario (m^2)
Option C: Area C only	20,000	6,430

6.2 Key technical constraints

6.2.1 Geotechnical

For the red zone Area C the primary geotechnical constraint is the potential for area-wide lateral spreading to occur towards the Kaiapoi River to the east during moderate earthquakes (return periods greater than approximately 100 years). Additional localised lateral spreading has also been observed towards the stormwater channel that runs southwest/northeast across the area.

A further geotechnical constraint is the deep thickness of weak liquefiable soil at this location. This results in a low load-bearing capacity for conventional wide and shallow commercial-type foundations during earthquakes. It also results in the potential for large volumes of liquefied material to be ejected from the ground during an earthquake, causing large differential ground

settlements. The occurrence of lateral spreading causes also cracking in the load-bearing crust which further exacerbates ejection of liquefied soil and ground settlements.

Accordingly, this initial scoping study assumes that engineering works would be required to provide a robust non-liquefying block of ground beneath each building. The objective is for the entire block of improved ground to move together as one when the surrounding soil liquefies and lateral spreading occurs. The ground improvement would be designed to reduce the severity of lateral ground stretching and differential settlement to a level that is tolerable for conventional shallow commercial-type foundations.

For the carparking areas away from the building footprints, engineered fill is likely to be required as part of the wider site works. This is expected to increase the strength of the non-liquefiable surface crust, and thus provide a minor to moderate reduction in the severity of differential ground settlements in these areas due to liquefaction of the underlying soil.

6.2.2 Flooding

The existing ground level in the red zone Area C typically ranges between 1.7m and 2.0m above mean sea level (Lyttelton Vertical Datum), with an average ground level of 1.8m. The low-lying elevation of this ground means it is susceptible to flooding.

Modelling undertaken in 2014 by T&T for EQC examined flooding as a result of a 100 year Average Recurrence Interval (ARI) event, based on current sea level and climate. This model showed flooding covering the entire Area C red zone, with a typical flood depth of 1.3m.

Modelling undertaken in 2015 by WDC incorporated the projected effects of climate change over the next 100 years (1.0m sea level rise and a 16% increase in rainfall intensity). This model showed flooding covering the entire Area C red zone for events with an ARI of 100 years or greater, with typical flood depths of more than 1.0m.

Modelling undertaken in 2008 by Environment Canterbury examined potential effects from various scenarios of the Ashley River breaking out from its channel and flowing across the land between Rangiora and Kaiapoi. This modelling showed only localised flooding of roadways for the 100 year and 200 year ARI scenarios, but more than 1.5m depth of flooding for a 500 year ARI scenario.

At this stage there is still considerable uncertainty in the minimum fill level that would be consentable, therefore the construction cost estimate for the large-format retail scenario has considered a range of bulk fill levels between RL 3.45m for the optimistic and most likely scenarios, and RL 3.7m for the pessimistic scenario (levels are relative to mean sea level, Lyttelton Vertical Datum). In addition to this bulk hardfill, a pavement of approximately 0.25m thickness will be required (not included in this cost estimate), and it has been assumed that building floor levels will be set 400mm above the top of the bulk fill.

6.2.3 Ground contamination

The Environment Canterbury Listed Land-Use Register (LLUR) does not record any known sites in the Area C red zone where hazardous activities have occurred, however we understand that the assessment programme for the Kaiapoi area is not yet completed. The Area C red zone land was initially developed for housing over the period of 1900 – 1950, with redevelopment between 1990 and 2010, so there is potential for asbestos contamination resulting from historic or recent demolition debris.

Based on the information available at this time, there do not appear to be any “fatal flaws” relating to ground contamination that would preclude commercial land use in this area. There may be minor to moderate additional land development costs associated with addressing ground contamination, but it is expected that this work would be technically feasible.

A formal ground contamination assessment (likely including on-site sampling) will still need to be undertaken to assess the presence of asbestos in soil and meet National Environmental Standards before development proceeds. This assessment may also be required for plan change purposes, and would assist in reducing uncertainties in the construction cost estimate. We will discuss potential contamination assessment options with WDC at the commencement of Stage 2 of this engineering feasibility study.

For this initial feasibility assessment, we have assumed that the majority of soil potentially contaminated with asbestos can be managed on site and covered with a suitable capping layer to meet the requirements for commercial land use. However, in some locations the nature of the contamination may mean that offsite disposal at a suitable facility is necessary. For this initial assessment, it has been assumed that a 200mm depth of topsoil will require offsite disposal over an area ranging from 1% of the total area in the optimistic scenario to 5% in the pessimistic scenario.

6.3 Preliminary land improvement outline plan

Figure 6.2 outlines the preliminary land improvement plan assumed for this initial scoping study for the Area C large-format retail scenario.

For the yard-based commercial scenario, less work would be required, but some land improvement would be necessary to provide a suitable subgrade for a lightweight pavement. For this initial assessment, the assumed land improvement works for a yard-based development are:

- Excavate topsoil (approximately 0.2m deep), and shape as landscaping bunds around the site. This landscaping reduces the area available for pavement by approximately 20%, but reduces costs associated with disposal of contaminated topsoil.
- Place compacted AP100 hardfill (approximately 0.2m thick on average).
- Place compacted GAP65 hardfill (0.25m thick).
- As an alternative to this hardfill, cement-stabilisation of the subgrade could be considered, but this option has not been assessed as part of the current study.
- Construct lightweight pavement (approximately 0.25m thick) – this is not included in the cost estimate, as it is not an “over-and-above” cost (refer Section 2.9.1).

In accordance with our offer of service dated 2nd September 2015, this preliminary plan is based on the general findings of engineering analysis undertaken for these areas previously, and did not involve any new investigations or new engineering design work.

6.4 Potential civil engineering effects on neighbouring areas

The land improvement work outlined in Section 6.3 has the potential to affect neighbouring areas, in both positive and negative ways. Table 6.2 identifies potential effects related to civil engineering aspects of the land improvement works.

There will also be other types of effects related to residential land use of red zone land, such as social, economic, environmental and cultural effects. Identification of these effects is beyond the scope of this initial scoping study – we recommend that these broader aspects are considered by WDC as part of the recovery plan process.

The key features labelled on this preliminary land improvement outline plan are:

1. Heavy earthworks compaction of the existing ground surface across the entire site, to repair ground cracking from lateral spreading.

2. Construction of a compacted platform of bulk hardfill across the entire site. This platform helps to raise ground and floor levels above the relevant design flood levels, improves the available bearing capacity for pavements and building foundations, and reduces surface land damage resulting from liquefaction of the underlying soils in future earthquakes. The average thickness of fill needed beneath building footprints ranges from 1.8m for optimistic and most likely design assumptions to 2.05m for pessimistic assumptions. In addition to this bulk hardfill, a pavement of approximately 0.25m thickness will be required (not included in this cost estimate, as it is not an “over-and-above” cost).

3. Installation of a high strength base geotextile and geogrid reinforcement around all edges of the hardfill platform. This reduces the potential for slope failure and lateral spreading of the new fill in future earthquakes.

4. Deep ground improvement beneath the footprint of all major buildings, potentially using stone columns to a depth of 7 – 8m (other ground improvement techniques may also be suitable). The ground improvement would be designed to reduce the severity of lateral ground stretching and differential settlement to a level that is tolerable for conventional shallow commercial-type foundations. Ground improvement would likely be required to extend approximately 5m beyond the edge of the building footprint.

Figure 6.2: Preliminary land improvement outline plan for Area C – large-format retail scenario shown (refer also to Appendix A)

Table 6.2: Potential civil engineering effects of land improvement works on neighbouring areas

Potential effects	Potential measures to reduce negative effects and increase positive effects
Flooding and stormwater – Fill platform may reduce floodwater storage capacity or obstruct flood flowpaths, and this could increase flood depth elsewhere.	• Use flood model results to shape the extent of the fill platform, to reduce obstruction of flood flowpaths. • Consider the feasibility of using parts of the Courtenay Drive red zone to construct stormwater basins to help offset flooding effects from the new fill in Kaiapoi West. *Refer to Section 6.4.1 for more detail.*
Construction traffic – Gravel for construction of the fill platform would likely be delivered to site using trucks. The large volume of fill material required means that a large number of truck deliveries would be needed. This could cause effects for local traffic and residents and accelerated wear on road pavements.	• Select routes for heavy traffic that reduce the impacts on local traffic, residents and road pavements. *Refer to Section 6.4.2 for more detail.*
Amenity – Deep ground improvement works for building foundations could cause noise and vibration effects for nearby green zone residents to the south and west.	• Consider lower-vibration methods of ground improvement and/or optimise the site layout to locate buildings away from the existing residents on Hilton St and Rich St.
Relative land levels – Around the border of the new fill platform the new land and buildings would be at a moderately higher level than the neighbouring green zone properties. Ground level in the adjacent green zone is typically between RL 1.3m and 2.2m, compared to ground level for the new fill platform (including pavement) ranging from RL 3.45m for the optimistic and most likely case to RL 3.7m for the pessimistic. This may result in an impact on visual aesthetics and privacy, and unfavourable perception of the lower-lying properties.	• Design the fill platform and layout to provide a gradual transition from areas of lower to higher land. • Avoid new buildings constructed immediately overlooking existing lower-lying properties. • A green-space corridor could be provided to transition from lower to higher ground levels.

6.4.1 Exacerbation of flooding elsewhere

A preliminary assessment has been made of the potential for construction of the new fill platform to exacerbate flooding in the surrounding area, due to a reduction in floodplain volume. For the Stage 1 assessment the potential effects have been evaluated qualitatively, with reference to the flood depth and velocities predicted in the WDC and T+T flood modelling.

Flooding of this area is largely attributable to overflow from flooding on the southern side of the Main North Railway line, backing up slightly at William Street as floodwaters pass through the area in a generally south-east direction. This combines with locally generated runoff that is not able to be discharged to the Kaiapoi River. The potential fill platform does not obstruct any significant overland flow paths, although there is some general sheet flow at low velocity in the area as a whole. A

corridor will remain between Hilton Street and Main North Line through which this general low velocity flow can occur.

Potential effects if red zone Area C was filled have been considered both upstream and downstream:

- **Upstream:** Possible slight increase in peak flood level in the area north and west of Area C, between the Kaiapoi River stopbank and the Main North Line. This increase is expected to be small to insignificant.
- **Downstream:** Provided that adequate provision of an overland flow path between Hilton Street and Main North Line is made, the flood-related effects downstream are likely to be minor.

This preliminary qualitative assessment indicates that exacerbation of flooding elsewhere may result in some constraints on commercial development of red zone Area C, but it should be possible to manage these issues if adequate overland flow paths can be provided. It is proposed that a quantitative assessment involving updated flood modelling is undertaken as part of the Stage 2 engineering feasibility assessment.

6.4.2 Construction traffic

The most likely source of gravel material for construction of the fill platform would be from the Waimakariri River, delivered to site by truck & trailer. To deliver the large volume of fill needed, up to about 10 truck deliveries per day would be required over the main earthworks period of about 9 months for the large-format retail option or 3 months for the yard-based commercial option. Each delivery involves two truck movements, one going to the site and one leaving the site – although the route may be slightly different each way.

The most direct and practical access to site for most construction traffic would likely be to exit the northern motorway at Ohoka Road and continue east to turn onto Peraki Street, as outlined in Figure 6.3. However, this route will put additional heavy vehicle demands on sections of Peraki Street which were likely not designed for this level of traffic. This could cause accelerated wear on these roads, resulting in a need for additional maintenance and repair. These additional road network costs have not been included in the land improvement construction cost estimate for this initial scoping study. There may also be noise and vibration effects for the residences along Ohoka Road and Peraki Street due to this increase in heavy traffic.

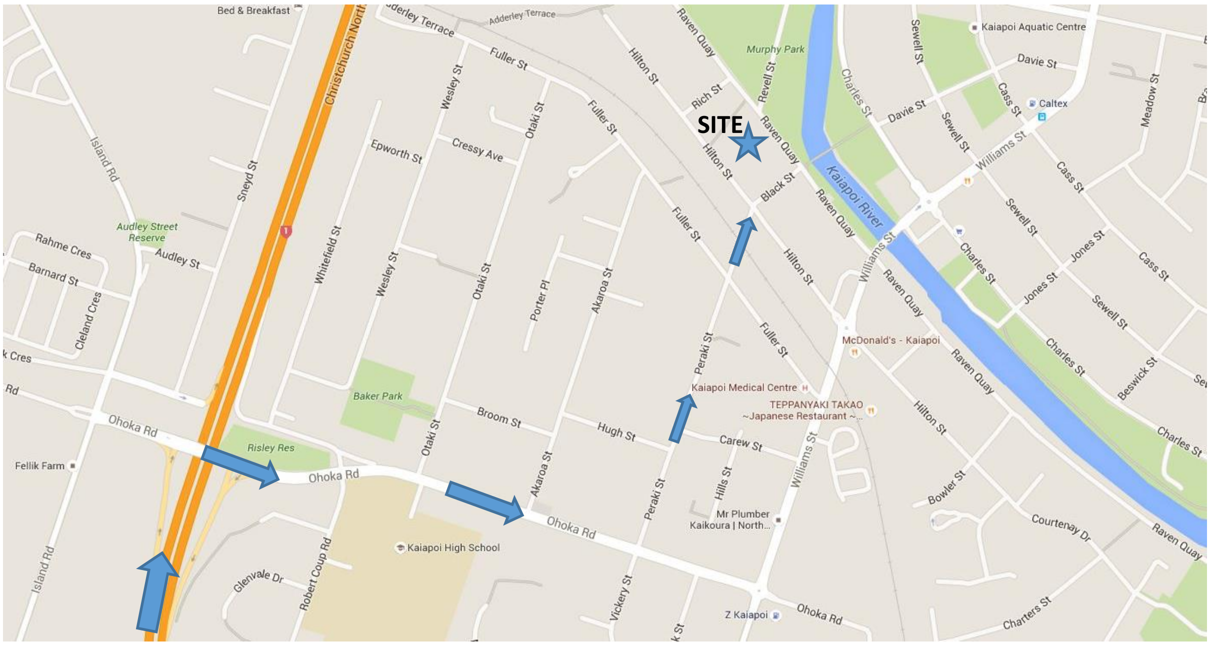


Figure 6.3: Potential construction traffic route to Area C red zone site (map data © 2015 Google)

6.5 Preliminary estimate of land improvement costs and timeframe

As discussed in Section 2.9.1, the preliminary cost estimate prepared as part of this initial scoping study includes only the cost of land improvement works. This is the cost of engineering work that would be incurred “over and above” normal construction work.

Significant land improvement works would be required in red zone Area C to meet the land performance requirements outlined in Section 2.3.

- For the large-format retail scenario, approximately 8,800m^2 of deep ground improvement (e.g. stone columns) would be required beneath and surrounding building footprints to reduce the severity of lateral ground stretching and differential settlement in future earthquakes.
- For the large-format retail scenario, depending on design assumptions, between approximately 25,000m^3 and 32,000m^3 of bulk fill with geotextile reinforcement would be required to meet flood and foundation design requirements.
- For the yard-based commercial scenario, between approximately 7,200m^3 and 8,600m^3 of bulk fill would be required to provide a suitable pavement subgrade.
- It has been assumed that all bulk fill will be imported gravel material.
- For both development scenarios, approximately 20,000m^2 of ground surface compaction (e.g. a heavy roller) would be required across the entire area to repair ground cracking from lateral spreading and prepare the subgrade for filling.

The expected construction timeframe for the land improvement works would be approximately one to two years for the large-format retail scenario, or less than one year for the yard-based commercial scenario.

The preliminary “over-and-above” construction cost estimate for these land improvement works is summarised in Table 6.3. As discussed in Section 2.9.2 these estimates span a confidence range between approximately 10% and 90% probability of exceedance, to represent uncertainty in the final design and market pricing. This preliminary estimate includes direct engineering design and construction costs only - we suggest that WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.

Table 6.3: Preliminary "over-and-above" cost estimate for Area C land improvement works

	Footprint Option	Pessimistic	Most likely	Optimistic
Yard-based commercial: Cost to strip site, manage contaminated soil, and prepare land for pavement.	C (20,000m^2)	\$1.6M	\$1.2M	\$1.1M
Large-format retail: Cost to strip site, manage contaminated soil, raise and stabilise land.	C (20,000m^2)	\$7.2M	\$5.5M	\$5.0M

NOTE: 1) These estimates include direct engineering design and construction costs only - we suggest WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.
2) These are land improvement costs "over-and-above" normal construction work, as detailed in Section 2.9.1.
3) All cost values exclude GST.

The main differences between these three scenarios are due to design uncertainties at the present preliminary stage of design, along with uncertainties in market pricing for construction work and materials. There is still considerable uncertainty regarding the level of new fill required for flood, foundation and pavement design requirements (refer Table 6.4). The volume of fill required will also depend on the degree to which it is possible to refine the development layout and gradients to make efficient use of fill material while still retaining a well-functioning operational layout.

Table 6.4: Estimates of volume of fill required for Area C large-format retail scenario

Design scenario	Elevation of top of bulk fill below buildings (m RL)	Fill height required below buildings (metres above current average ground level)	Volume of fill required (m^3)
Pessimistic design assumptions	RL 3.7m	2.05m	32,000 m^3 imported
Most likely design assumptions	RL 3.45m	1.8m	25,000 m^3 imported
Optimistic design assumptions	Same as most likely design assumptions		
Current ground level (2014 LiDAR survey)	Typically RL 1.4 – 1.8m, Average RL 1.65m		

NOTE: 1) Ground elevations are specified as metres above mean sea level, relative to Lyttelton Vertical Datum.
2) Specified elevation of fill below buildings assumes a 400mm thick slab foundation.

6.6 Discussion

This initial scoping study has not identified any immediate "fatal flaws" regarding the engineering feasibility of land improvement works to enable commercial development in the Area C red zone. However, a number of significant technical constraints and potential adverse effects have been identified. It appears to be technically feasible to manage these issues, using engineering approaches that are commonly applied for land development in Canterbury - such as earthworks, ground improvement and stormwater management. However, given the significant scale of work that would be required, this would add considerable development cost.

Careful assessment and management of the wider floodplain would also be required to provide flooding flow paths. An initial qualitative assessment suggests that this will require careful attention, but should be feasible.

If WDC wish to better understand the economic feasibility of potential commercial and use, then we would recommend that a broader business case analysis be undertaken which includes the estimated range of costs for undertaking these land improvement works. This business case analysis should make allowance for the likelihood that some of the land preparation work included in this cost estimate would be required regardless of the future land use selected (e.g. decommissioning existing roads and managing ground contamination).

6.7 Next steps

If WDC wish to examine in more detail the potential for commercial land use in red zone Area C, then we would recommend a second stage of engineering feasibility assessment as outlined in our Offer of Service dated 2nd September 2015.

In particular, the following technical aspects appear to have a significant influence on the engineering feasibility and construction cost estimate:

a For this initial scoping study, it has been assumed that deep ground improvement would be required beneath and beyond the entire footprint of all major buildings in Area C, to reduce the severity of lateral ground stretching and differential settlement. This deep ground improvement work accounts for about 60% of the estimated “over-and-above” construction costs for the large-format retail scenario. The Stage 2 assessment should aim to more precisely define the required extent and depth of ground improvement – this would involve specific geotechnical stability and foundation analysis. This assessment could also consider whether there are any specific types of structure that could use an alternative more economical type of foundation system instead of deep ground improvement.

b Another uncertainty in the construction cost estimate is the minimum land level necessary to meet flood and foundation design requirements. This is of less importance for the commercial development areas than for the residential areas, because the minimum land level only applies beneath the building footprint and it is possible to reduce the fill thickness by having carpark areas slope downwards away from buildings. Nonetheless, the Stage 2 assessment should aim to more precisely define the required fill level – this would involve further analysis of flood model results and consultation with WDC technical and consenting staff.

c For this initial assessment it has been assumed that only a small proportion of contaminated soil will require off-site disposal, with the remainder of the existing topsoil able to be managed on site within landscaping areas. A preliminary estimate of offsite disposal volume has been made at this initial stage, ranging from 1% of the total area in the optimistic scenario to 5% of the total area in the pessimistic scenario – resulting in only minor estimated costs. However, there is currently very little site-specific information to support these assumptions – so the volume and/or severity of contaminated soil could potentially be under-predicted. The Stage 2 assessment should aim to more clearly identify the potential extent and severity of soil contamination, and the ability for it to be managed on site. This would be most effectively achieved by on-site shallow soil sampling and laboratory testing.

d An initial qualitative assessment suggests it is likely that flood exacerbation effects could be managed as part of detailed design. This may require management of the wider floodplain to provide flood flow paths. The Stage 2 assessment should aim to provide more certainty that flood exacerbation effects can be managed – this would involve specific flood modelling of the new fill.

e It has been assumed that stone columns will be a suitable ground improvement technique for improving the land performance beneath building footprints, as it is a technique that is typically widely applicable. Stone column costs make up about 60% of the estimated “over-and-above” construction costs for the large-format retail scenario. There are alternative ground improvement techniques that could be considered instead of stone columns. Dynamic compaction is significantly less expensive than stone columns, however its effectiveness can be sensitive to the ground conditions, and the associated ground vibrations may be unacceptable if there are neighbours nearby. Soil-cement mixing is applicable for a wide range of ground conditions and results in little ground vibration, but is more expensive than stone columns. The Stage 2 assessment should further examine the suitability of alternative ground improvement methods – however it is unlikely that this uncertainty can be conclusively resolved until field trials are undertaken (e.g. at the commencement of construction).

7 Kaiapoi North commercial development (Area D)

7.1 Preliminary general land use outline plan

The preliminary general land use outline plan assumed for this initial scoping study is shown in Figure 7.1. This outline plan assumes commercial land use for the red zone land between Cass Street and Charles Street, with both yard-based and large-format retail scenarios considered as outlined in Section2.2.

Three different development footprint options were considered, a smaller-sized option (Option D1), a medium-sized option (Option D2), and a larger-sized option (Option D3). More detail on each of these options is presented in Table 7.1 and Appendix A.

If necessary, it may be possible to use the red zone land to the east of Beswick Street for stormwater and floodplain management, to help offset the effects of placing fill and also improve stormwater drainage in the wider area. This potential stormwater basin has not been scoped as part of the current feasibility assessment as it may not be necessary, so the costs (or potential savings from cut-to-fill) have not been included in the cost estimate.

Figure 7.1: Preliminary general land use outline plan assumed for red zone Area D

Table 7.1: Development footprint options for Area D

Development footprint option	Total site area (m^2)	Assumed building footprint area for large-format retail scenario (m^2)
Option D1: Area D1 only	20,900	4,060
Option D2: Areas D1 & D2 combined	48,700	14,840
Option D3: Areas D1, D2 & D3 combined	76,000	22,090

7.2 Key technical constraints

7.2.1 Geotechnical

For the red zone Area D the primary geotechnical constraint is the thin and weak crust of soil above groundwater level (typically between 0.7 and 1.4m depth), and the deep thickness of weak liquefiable soil. This results in a low load-bearing capacity for conventional wide and shallow commercial-type foundations during earthquakes. It also results in the potential for large volumes of liquefied material to be ejected from the ground during an earthquake, causing large differential ground settlements.

A further geotechnical constraint is the potential for area-wide lateral spreading to occur towards the Kaiapoi River to the south during moderate earthquakes (return periods greater than approximately 100 years). While the most severe lateral spreading during the Canterbury Earthquakes was observed in the reserve land south of Charles Street, moderate to major lateral ground stretching was observed to extend as far north as Cass Street or beyond. The occurrence of lateral spreading causes also cracking in the load-bearing crust which further exacerbates ejection of liquefied soil and ground settlements.

Accordingly, this initial scoping study assumes that engineering works would be required to provide a robust non-liquefying block of ground beneath each building. The objective is for the entire block of improved ground to move together as one when the surrounding soil liquefies and lateral spreading occurs. The ground improvement would be designed to reduce the severity of lateral ground stretching and differential settlement to a level that is tolerable for conventional shallow commercial-type foundations.

For the carparking and road areas away from the building footprints, engineered fill is likely to be required as part of the wider site works. This is expected to increase the strength of the non-liquefiable surface crust, and thus provide a minor to moderate reduction in the severity of differential ground settlements in these areas due to liquefaction of the underlying soil.

7.2.2 Flooding

The existing ground level in the red zone Area D typically ranges between 1.2m and 1.9m above mean sea level (Lyttelton Vertical Datum), with an average ground level of 1.6m. The low-lying elevation of this ground means it is susceptible to flooding.

Modelling undertaken in 2014 by T&T for EQC examined flooding as a result of a 100 year Average Recurrence Interval (ARI) event, based on current sea level and climate. This model showed flooding in localised lower-lying parts of the D red zone, with a typical flood depth of up to 0.4m.

Modelling undertaken in 2015 by WDC incorporated the projected effects of climate change over the next 100 years (1.0m sea level rise and a 16% increase in rainfall intensity). This model showed flooding covering the entire Area D red zone for events with an ARI of 100 years or greater, with flood depths typically ranging between 0.1m and 1.0m for the 100 year ARI model, increasing to more than 1.0m for the 200 year and 500 year ARI models.

Modelling undertaken in 2008 by Environment Canterbury examined potential effects from various scenarios of the Ashley River breaking out from its channel and flowing across the land between Rangiora and Kaiapoi. This modelling showed flood depths in the Kaiapoi North red zone of up to 0.5m for 100 year and 200 year ARI scenarios, and more than 0.5m for a 500 year ARI scenario.

At this stage there is still considerable uncertainty in the minimum fill level that would be consentable, therefore the construction cost estimate for the large-format retail scenario has considered a range of bulk fill levels between an optimistic scenario of RL 2.0m and a pessimistic scenario of RL 2.8m, with a most likely estimate of RL 2.4m (levels are relative to mean sea level,

Lyttelton Vertical Datum). In addition to this bulk hardfill, a pavement of approximately 0.25m thickness will be required (not included in this cost estimate), and it has been assumed that building floor levels will be set 400mm above the top of the bulk fill.

7.2.3 Ground contamination

The Environment Canterbury Listed Land-Use Register (LLUR) does not record any known sites in the Area D red zone where hazardous activities have occurred, however we understand that the assessment programme for the Kaiapoi area is not yet completed. The majority of dwellings in this area were constructed between 1950 and 1990, so there is potential for asbestos contamination resulting from demolition debris.

Based on the information available at this time, there do not appear to be any "fatal flaws" relating to ground contamination that would preclude residential land use in this area. There may be minor to moderate additional land development costs associated with addressing ground contamination, but it is expected that this work would be technically feasible.

A formal ground contamination assessment (likely including on-site sampling) will still need to be undertaken to assess the presence of asbestos in soil and meet National Environmental Standards before development proceeds. This assessment may also be required for plan change purposes, and would assist in reducing uncertainties in the construction cost estimate. We will discuss potential contamination assessment options with WDC at the commencement of Stage 2 of this engineering feasibility study.

For this initial feasibility assessment, we have assumed that the majority of soil potentially contaminated with asbestos can be managed on site and covered with a suitable capping layer to meet the requirements for commercial land use. However, in some locations the nature of the contamination may mean that offsite disposal at a suitable facility is necessary. For this initial assessment, it has been assumed that a 200mm depth of topsoil will require offsite disposal over an area ranging from 1% of the total area in the optimistic scenario to 5% in the pessimistic scenario.

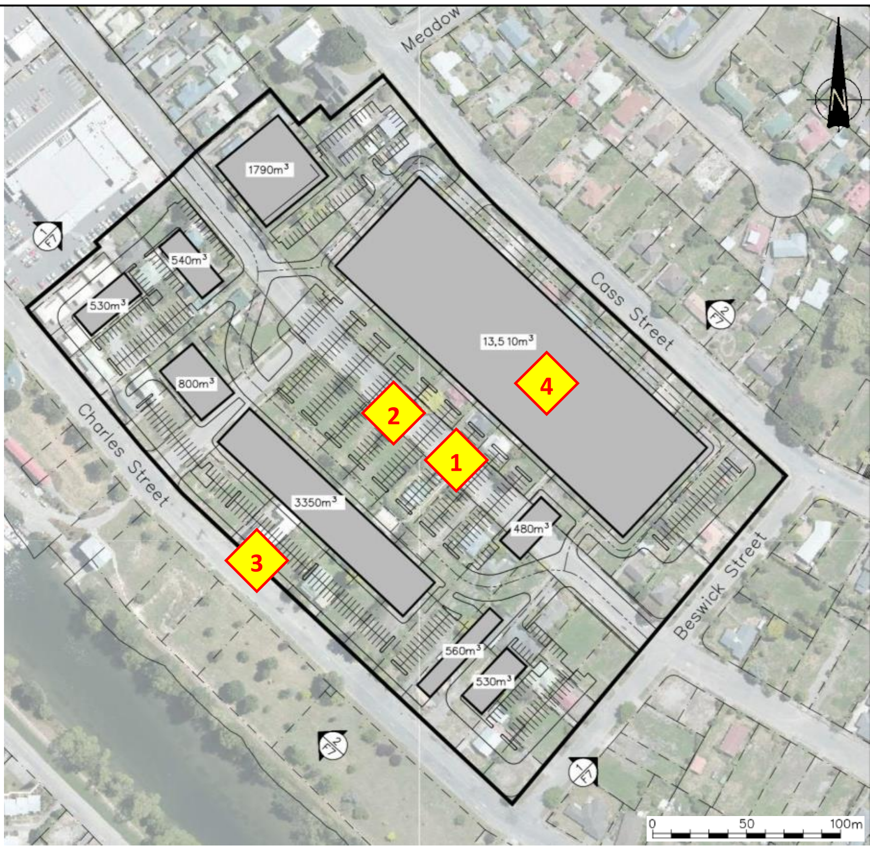
7.3 Preliminary land improvement outline plan

Figure 7.2 outlines the preliminary land improvement plan assumed for this initial scoping study for the Area D large-format retail scenario.

For the yard-based commercial scenario, less work would be required, but some land improvement would be necessary to provide a suitable subgrade for a lightweight pavement. For this initial assessment, the assumed land improvement works for a yard-based development are:

- Excavate topsoil (approximately 0.2m deep), and shape as landscaping bunds around the site. This landscaping reduces the area available for pavement by approximately 20%, but reduces costs associated with disposal of contaminated topsoil.
- Place compacted AP100 hardfill (approximately 0.2m thick on average).
- Place compacted GAP65 hardfill (0.15m thick).
- As an alternative to this hardfill, cement-stabilisation of the subgrade could be considered, but this option has not been assessed as part of the current study.
- Construct lightweight pavement (approximately 0.25m thick) – this is not included in the cost estimate, as it is not an "over-and-above" cost (refer Section 2.9.1).

In accordance with our offer of service dated 2nd September 2015, this preliminary plan is based on the general findings of engineering analysis undertaken for these areas previously, and did not involve any new investigations or new engineering design work.



The key features labelled on this preliminary land improvement outline plan are:

1 Heavy earthworks compaction of the existing ground surface across the entire site, to repair ground cracking from lateral spreading.

2 Construction of a compacted platform of bulk hardfill across the entire site. This platform helps to raise ground and floor levels above the relevant design flood levels, improves the available bearing capacity for pavements and building foundations, and reduces surface land damage resulting from liquefaction of the underlying soils in future earthquakes. The average thickness of fill needed beneath building footprints ranges from 0.4m for optimistic design assumptions to 1.2m for pessimistic assumptions, with a most likely estimate of 0.8m. In addition to this bulk hardfill, a pavement of approximately 0.25m thickness will be required (not included in this cost estimate, as it is not an “over-and-above” cost).

3 Installation of a high strength base geotextile and geogrid reinforcement around all edges of the hardfill platform. This reduces the potential for slope failure and lateral spreading of the new fill in future earthquakes.

4 Deep ground improvement beneath the footprint of all major buildings, potentially using stone columns to a depth of 7 – 8m (other ground improvement techniques may also be suitable). The ground improvement would be designed to reduce the severity of lateral ground stretching and differential settlement to a level that is tolerable for conventional shallow commercial-type foundations. Ground improvement would likely be required to extend approximately 5m beyond the edge of the building footprint.

Figure 7.2: Preliminary land improvement outline plan for Area D – Option D3 large-format retail shown (refer also to Appendix A)

7.4 Potential civil engineering effects on neighbouring areas

The land improvement work outlined in Section 7.3 has the potential to affect neighbouring areas, in both positive and negative ways. Table 7.2 identifies potential effects related to civil engineering aspects of the land improvement works.

There will also be other types of effects related to residential land use of red zone land, such as social, economic, environmental and cultural effects. Identification of these effects is beyond the scope of this initial scoping study – we recommend that these broader aspects are considered by WDC as part of the recovery plan process.

Table 7.2: Potential civil engineering effects of land improvement works on neighbouring areas

Potential effects	Potential measures to reduce negative effects and increase positive effects
Flooding and stormwater + Stormwater ponds and flood flowpaths south of Cass Street could be used to improve drainage of green zone areas, as part of the wider floodplain management strategy. – Fill platform may reduce floodwater storage capacity or obstruct flood flowpaths, and this could increase flood depth elsewhere.	• Design stormwater ponds to provide capacity to service existing neighbouring areas in addition to the new commercial development. • Use flood model results to shape the extent of the fill platform to reduce obstruction of flood flowpaths and improve downstream flowpath performance. • Excavate basins and flowpaths for floodwater, to help offset loss of flood capacity due to fill platform. *Refer to Section 7.4.1 for more detail.*
Construction traffic – Gravel for construction of the fill platform would likely be delivered to site using trucks. The large volume of fill material required means that a large number of truck deliveries would be needed. This could cause effects for local traffic and residents and accelerated wear on road pavements.	• Select routes for heavy traffic that reduce the impacts on local traffic, residents and road pavements. *Refer to Section 7.4.2 for more detail.*
Amenity – Deep ground improvement works for building foundations could cause noise and vibration effects for nearby green zone residents to the north and west.	• Consider lower-vibration methods of ground improvement and/or optimise the site layout to locate buildings away from the existing residents between Cass and Sewell Streets.
Relative land levels – Around the border of the new fill platform the new land and buildings would be at a moderately higher level than the neighbouring green zone properties. Ground level in the adjacent green zone is typically between RL 1.4m and 2.2m, compared to ground level for the new fill platform (including pavement) ranging from RL 2.0m for the optimistic case to RL 2.8m for the pessimistic. This may result in an impact on visual aesthetics and privacy, and unfavourable perception of the lower-lying properties.	• Design the fill platform and layout to provide a gradual transition from areas of lower to higher land. • Avoid new buildings constructed immediately overlooking existing lower-lying properties. • A green-space corridor could be provided to transition from lower to higher ground levels.

7.4.1 Exacerbation of flooding elsewhere

A preliminary assessment has been made of the potential for construction of the new fill platform to exacerbate flooding in the surrounding area, due to a reduction in floodplain volume. For the Stage 1 assessment the potential effects have been evaluated qualitatively, with reference to the flood depth and velocities predicted in the WDC and T+T flood modelling.

Area D is located in an area which has been shown to be an overland flow path, linking the floodable area of Wylie Park (corner of Smith Street and Ranfurly Street with flooding predicted for the area around Jollie Street. If this area were to be filled then this overland flow would need to pass via Charles Street, in a south-easterly direction. Allowance for this would need to be made in the design of the fill platform and site layout.

Potential effects if red zone Area D was filled have been considered both upstream and downstream:

- **Upstream:** Unless adequate overland flow provision were made along Charles Street, there is a potential for increased flood depth upstream (north-west) of Area D (in the vicinity of Williams Street).
- **Downstream:** As the area to be filled does not provide for a notable attenuation effect on flood flows (it mainly provides flood flow conveyance), there is low probability that fill in this area would adversely affect flood levels downstream.

This preliminary qualitative assessment indicates that exacerbation of flooding elsewhere is not likely to be an insurmountable impediment for commercial development of red zone Area D, provided that flowpaths are provided as part of design. It is proposed that a quantitative assessment involving updated flood modelling is undertaken as part of the Stage 2 engineering feasibility assessment.

7.4.2 Construction traffic

The most likely source of gravel material for construction of the fill platform would be from the Waimakariri River, delivered to site by truck & trailer. To deliver the large volume of fill needed, depending on the footprint and design assumptions, up to about 8 – 13 truck deliveries per day would be required over the main earthworks period of about 3 months to 2 years for the large-format retail option or 3 – 9 months for the yard-based commercial option. If an accelerated program was desired it could be possible to complete the 58,000m^3 pessimistic fill estimate for Option D3 in a year, however this would require about 20 truck deliveries per day. Each delivery involves two truck movements, one going to the site and one leaving the site – although the route may be slightly different each way.

The most direct and practical access to site for most construction traffic would likely be to exit the northern motorway at Smith Street and continue east to a right turn onto Cass Street, as outlined in Figure 7.3. However, this route will put additional heavy vehicle demands on sections of Cass Street between Smith Street and Meadow Street which were likely not designed for this level of traffic. This could cause accelerated wear on these roads, resulting in a need for additional maintenance and repair. These additional road network costs have not been included in the land improvement construction cost estimate for this initial scoping study. There may also be noise and vibration effects for the residences along Cass Street due to this increase in heavy traffic.

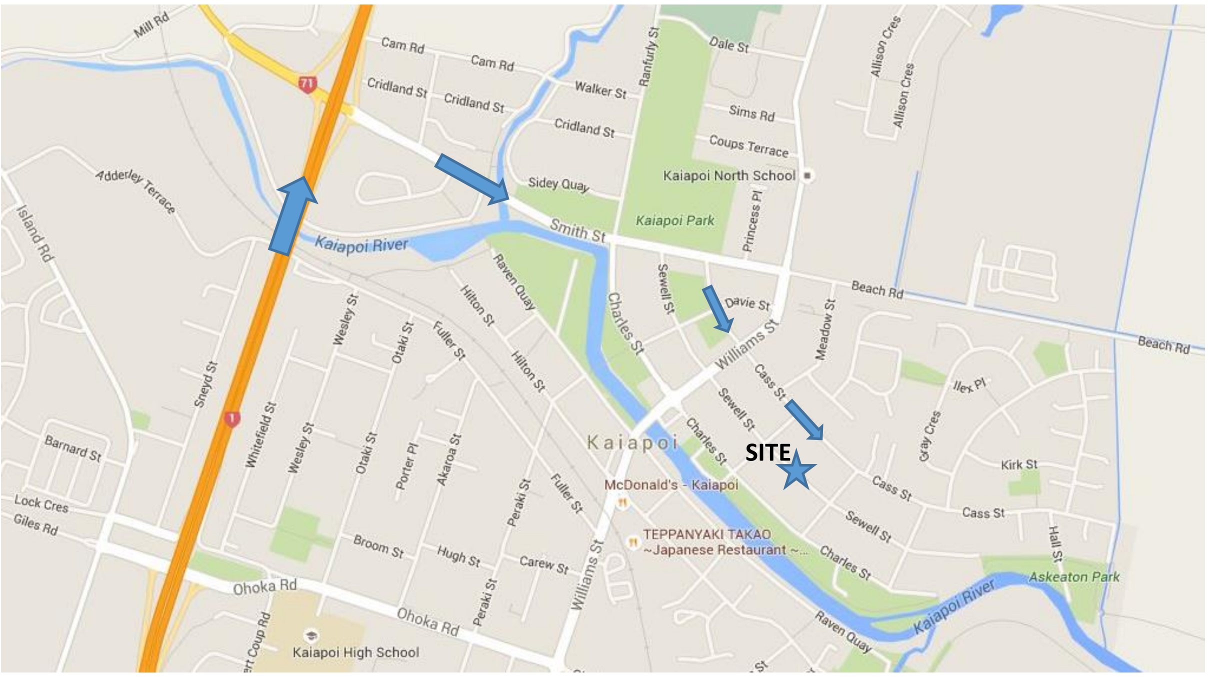


Figure 7.3: Potential construction traffic route to Area D red zone site (map data © 2015 Google)

7.5 Preliminary estimate of land improvement costs and timeframe

As discussed in Section 2.9.1, the preliminary cost estimate prepared as part of this initial scoping study includes only the cost of land improvement works. This is the cost of engineering work that would be incurred "over and above" normal construction work.

Significant land improvement works would be required in red zone Area D to meet the land performance requirements outlined in Section 2.3.

- For the large-format retail scenario, depending on the footprint option, between approximately 7,000m^2 and 33,000m^2 of deep ground improvement (e.g. stone columns) would be required beneath and surrounding building footprints to reduce the severity of lateral ground stretching and differential settlement in future earthquakes.
- For the large-format retail scenario, depending on design assumptions and the footprint option, between approximately 7,000m^3 and 72,000m^3 of bulk fill with geotextile reinforcement would be required to meet flood and foundation design requirements.
- For the yard-based commercial scenario, depending on the footprint option, between approximately 6,000m^3 and 24,000m^3 of bulk fill would be required to provide a suitable pavement subgrade.
- At this initial stage it has been assumed that all bulk fill will need to be imported, but if stormwater basins are constructed in the red zone land to the east then this may provide some of the necessary material (cut to fill).
- For both development scenarios, depending on the development footprint option, between approximately 21,000m^2 and 76,000m^2 of ground surface compaction (e.g. a heavy roller) would be required across the entire area to repair ground cracking from lateral spreading and prepare the subgrade for filling.

The expected construction timeframe for the land improvement works, depending on the footprint and design assumptions, would be approximately one to three years for the large-format retail scenario, or less than one year for the yard-based commercial scenario.

The preliminary "over-and-above" construction cost estimate for these land improvement works is summarised in Table 7.3. As discussed in Section 2.9.2 these estimates span a confidence range between approximately 10% and 90% probability of exceedance, to represent uncertainty in the final design and market pricing. This preliminary estimate includes direct engineering design and construction costs only - we suggest that WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.

Table 7.3: Preliminary "over-and-above" cost estimate for Area D land improvement works

	Footprint Option	Pessimistic	Most likely	Optimistic
Yard-based commercial: Cost to strip site, manage contaminated soil, and prepare land for pavement.	D1 (20,900m^2)	$1.2M	$1.0M	$0.9M
	D2 (48,700m^2)	$2.7M	$2.1M	$2.0M
	D3 (76,000m^2)	$4.2M	$3.2M	$3.1M
Large-format retail: Cost to strip site, manage contaminated soil, raise and stabilise land.	D1 (20,900m^2)	$5.1M	$3.9M	$3.4M
	D2 (48,700m^2)	$13.1M	$10.1M	$8.7M
	D3 (76,000m^2)	$22.8M	$17.5M	$15.2M

NOTE: 1) These estimates include direct engineering design and construction costs only - we suggest WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.
2) These are land improvement costs "over-and-above" normal construction work, as detailed in Section 2.9.1.
3) All cost values exclude GST.

The main differences between these three scenarios are due to design uncertainties at the present preliminary stage of design, along with uncertainties in market pricing for construction work and materials. There is still considerable uncertainty regarding the level of new fill required for flood, foundation and pavement design requirements (refer Table 7.4). The volume of fill required will also depend on the degree to which it is possible to refine the development layout and gradients to make efficient use of fill material while still retaining a well-functioning operational layout.

Table 7.4: Estimates of volume of fill required for Area D large-format retail scenario

Design scenario	Elevation of top of bulk fill below buildings (m RL)	Fill height required below buildings (metres above current average ground level)	Volume of fill required (m^3)
Pessimistic design assumptions	RL 2.8m	1.2m	Option D1: 18,000 m^3 Option D2: 38,000 m^3 Option D3: 72,000 m^3
Most likely design assumptions	RL 2.4m	0.8m	Option D1: 12,000 m^3 Option D2: 22,000 m^3 Option D3: 43,000 m^3
Optimistic design assumptions	RL 2.0m	0.4m	Option D1: 7,000 m^3 Option D2: 13,000 m^3 Option D3: 29,000 m^3
Current ground level (2014 LiDAR survey)	Typically RL 1.2 – 1.9m, Average RL 1.6m over entire Area D On average, Area D1 is 0.2m higher than Area D2 and 0.35m higher than Area D3		

NOTE: 1) Ground elevations are specified as metres above mean sea level, relative to Lyttelton Vertical Datum.
2) Specified elevation of fill below buildings assumes a 400mm thick slab foundation.

7.6 Discussion

This initial scoping study has not identified any immediate “fatal flaws” regarding the engineering feasibility of land improvement works to enable commercial development in the Area D red zone. However, a number of significant technical constraints and potential adverse effects have been identified. It appears to be technically feasible to manage these issues, using engineering approaches that are commonly applied for land development in Canterbury - such as earthworks, ground improvement and stormwater management. However, given the significant scale of work that would be required, this would add considerable development cost.

Careful assessment and management of the wider floodplain would also be required to provide flooding flow paths, but an initial qualitative assessment suggests that this should be feasible.

If WDC wish to better understand the economic feasibility of potential commercial land use, then we would recommend that a broader business case analysis be undertaken which includes the estimated range of costs for undertaking these land improvement works. This business case analysis should make allowance for the likelihood that some of the land preparation work included in this cost estimate would be required regardless of the future land use selected (e.g. decommissioning existing roads and managing ground contamination).

7.7 Next steps

If WDC wish to examine in more detail the potential for commercial land use in red zone Area D, then we would recommend a second stage of engineering feasibility assessment as outlined in our Offer of Service dated 2nd September 2015.

In particular, the following technical aspects appear to have a significant influence on the engineering feasibility and construction cost estimate:

a For this initial scoping study, it has been assumed that deep ground improvement would be required beneath and beyond the entire footprint of all major buildings in Area D, to reduce the severity of lateral ground stretching and differential settlement. This deep ground improvement work accounts for about 60% of the estimated “over-and-above” construction costs for the large-format retail scenario. The Stage 2 assessment should aim to more precisely define the required extent and depth of ground improvement – this would involve specific geotechnical stability and foundation analysis. This assessment could also consider whether there are any specific types of structure that could use an alternative more economical type of foundation system instead of deep ground improvement.

b Another uncertainty in the construction cost estimate is the minimum land level necessary to meet flood and foundation design requirements. This is of less importance for the commercial development areas than for the residential areas, because the minimum land level only applies beneath the building footprint and it is possible to reduce the fill thickness by having carpark areas slope downwards away from buildings. Nonetheless, the Stage 2 assessment should aim to more precisely define the required fill level – this would involve further analysis of flood model results and consultation with WDC technical and consenting staff.

c For this initial assessment it has been assumed that only a small proportion of contaminated soil will require off-site disposal, with the remainder of the existing topsoil able to be managed on site within landscaping areas. A preliminary estimate of offsite disposal volume has been made at this initial stage, ranging from 1% of the total area in the optimistic scenario to 5% of the total area in the pessimistic scenario – resulting in only minor estimated costs. However, there is currently very little site-specific information to support these assumptions – so the volume and/or severity of contaminated soil could potentially be under-predicted. The Stage 2 assessment should aim to more clearly identify the potential extent and severity of soil contamination, and the ability for it to be managed on site. This would be most effectively achieved by on-site shallow soil sampling and laboratory testing.

d An initial qualitative assessment suggests it is likely that flood exacerbation effects could be managed as part of detailed design. This may require management of the wider floodplain to provide flood flow paths. The Stage 2 assessment should aim to provide more certainty that flood exacerbation effects can be managed – this would involve specific flood modelling of the new fill.

e It has been assumed that stone columns will be a suitable ground improvement technique for improving the land performance beneath building footprints, as it is a technique that is typically widely applicable. Stone column costs make up about 60% of the estimated “over-and-above” construction costs for the large-format retail scenario. There are alternative ground improvement techniques that could be considered instead of stone columns. Dynamic compaction is significantly less expensive than stone columns, however its effectiveness can be sensitive to the ground conditions, and the associated ground vibrations may be unacceptable if there are neighbours nearby. Soil-cement mixing is applicable for a wide range of ground conditions and results in little ground vibration, but is more expensive than stone columns. The Stage 2 assessment should further examine the suitability of alternative ground improvement methods – however it is unlikely that this uncertainty can be conclusively resolved until field trials are undertaken (e.g. at the commencement of construction).

f For this initial scoping assessment, it has been assumed that all fill material would be imported gravel. If stormwater basins are excavated in the red zone land to the east of Area D, then it may be possible to re-use some of this excavated material as part of the new fill platform (cut-to-fill). If WDC wish to explore this option, then the Stage 2 assessment should aim to better estimate the volume of suitable cut-to-fill material – this would be most effectively achieved by on-site shallow soil sampling and laboratory testing.

g There may be an opportunity to arrange the site layout so that a continuous wide strip of ground improvement was constructed along the river-side boundary of the site, with a row of buildings on top. It may be possible to design this strip of perimeter ground improvement to control lateral spreading to a level where other buildings on the site could use an alternative more economical type of foundation system instead of deep ground improvement. If WDC wish to explore this option, then the Stage 2 assessment should aim to more precisely define the required perimeter ground improvement and alternative foundation options – this would involve specific geotechnical stability and foundation analysis.

8 Kaiapoi Southeast commercial development (Area E)

8.1 Preliminary general land use outline plan

The preliminary general land use outline plan assumed for this initial scoping study is shown in Figure 8.1. This outline plan assumes commercial land use for the red zone land between Williams Street and Bowler Street, with both yard-based and large-format retail scenarios considered as outlined in Section2.2. More detail on the assumed outline plan is presented in Appendix A.

Two different development footprint options were considered, a smaller-sized option (Option E1) and a larger-sized option (Option E2). More detail on each of these options is presented in Appendix A.

Figure 8.1: Preliminary general land use outline plan assumed for red zone Area E

Table 8.1: Development footprint options for Area E

Development footprint option	Total site area (m^2)	Assumed building footprint area for large-format retail scenario (m^2)
Option E1: Area E1 only	14,700	3,990
Option E2: Areas E1 & E2 combined	31,300	10,420

8.2 Key technical constraints

8.2.1 Geotechnical

For the red zone Area E the primary geotechnical constraint is the potential for area-wide lateral spreading to occur towards the Kaiapoi River to the north during large earthquakes (return periods of approximately 500 years).

A further geotechnical constraint is the deep thickness of weak liquefiable soil at this location. This results in a low load-bearing capacity for conventional wide and shallow commercial-type foundations during earthquakes. It also results in the potential for large volumes of liquefied material to be ejected from the ground during an earthquake, causing large differential ground settlements. The occurrence of lateral spreading causes also cracking in the load-bearing crust which further exacerbates ejection of liquefied soil and ground settlements.

Accordingly, this initial scoping study assumes that engineering works would be required to provide a robust non-liquefying block of ground beneath each building. The objective is for the entire block of improved ground to move together as one when the surrounding soil liquefies and lateral spreading occurs. The ground improvement would be designed to reduce the severity of lateral ground stretching and differential settlement to a level that is tolerable for conventional shallow commercial-type foundations.

For the carparking and road areas away from the building footprints, engineered fill is likely to be required as part of the wider site works. This is expected to increase the strength of the non-liquefiable surface crust, and thus provide a minor to moderate reduction in the severity of differential ground settlements in these areas due to liquefaction of the underlying soil.

8.2.2 Flooding

The existing ground level in the red zone Area E typically ranges between 1.3m and 2.0m above mean sea level (Lyttelton Vertical Datum), with an average ground level of 1.6m. The low-lying elevation of this ground means it is susceptible to flooding. The roadway along Courtenay Drive forms an important floodwater conveyance path, carrying stormwater runoff from west to east towards Courtenay Lake, NCF Reserve, and Courtenay Stream.

Modelling undertaken in 2014 by T&T for EQC examined flooding as a result of a 100 year Average Recurrence Interval (ARI) event, based on current sea level and climate. This model showed flooding covering the majority of the Area E red zone, with a typical flood depth of 0.5 - 1.1m.

Modelling undertaken in 2015 by WDC incorporated the projected effects of climate change over the next 100 years (1.0m sea level rise and a 16% increase in rainfall intensity). This model showed flooding covering the entire Area D red zone for events with an ARI of 100 years or greater, with typical flood depths of more than 1.0m.

Modelling undertaken in 2008 by Environment Canterbury examined potential effects from various scenarios of the Ashley River breaking out from its channel and flowing across the land between Rangiora and Kaiapoi. This modelling showed only localised flooding of roadways for the 100 year and 200 year ARI scenarios, but more than 1.5m depth of flooding for a 500 year ARI scenario.

At this stage there is still considerable uncertainty in the minimum fill level that would be consentable, therefore the construction cost estimate for the large-format retail scenario has considered a range of bulk fill levels between RL 3.45m for the optimistic and most likely scenarios, and RL 3.7m for the pessimistic scenario (levels are relative to mean sea level, Lyttelton Vertical Datum). In addition to this bulk hardfill, a pavement of approximately 0.25m thickness will be required (not included in this cost estimate), and it has been assumed that building floor levels will be set 400mm above the top of the bulk fill.

8.2.3 Ground contamination

The Environment Canterbury Listed Land-Use Register (LLUR) does not record any known sites in the Area E red zone where hazardous activities have occurred, however we understand that the assessment programme for the Kaiapoi area is not yet completed. The Area E red zone land was initially developed for housing over the period of 1920 – 1960, with redevelopment between 1980 and 2010, so there is potential for asbestos contamination resulting from historic or recent demolition debris.

Based on the information available at this time, there do not appear to be any "fatal flaws" relating to ground contamination that would preclude commercial land use in this area. There may be minor to moderate additional land development costs associated with addressing ground contamination, but it is expected that this work would be technically feasible.

A formal ground contamination assessment (likely including on-site sampling) will still need to be undertaken to assess the presence of asbestos in soil and meet National Environmental Standards before development proceeds. This assessment may also be required for plan change purposes, and would assist in reducing uncertainties in the construction cost estimate. We will discuss potential contamination assessment options with WDC at the commencement of Stage 2 of this engineering feasibility study.

For this initial feasibility assessment, we have assumed that the majority of soil potentially contaminated with asbestos can be managed on site and covered with a suitable capping layer to meet the requirements for commercial land use. However, in some locations the nature of the contamination may mean that offsite disposal at a suitable facility is necessary. For this initial assessment, it has been assumed that a 200mm depth of topsoil will require offsite disposal over an area ranging from 1% of the total area in the optimistic scenario to 5% in the pessimistic scenario.

8.3 Preliminary land improvement outline plan

Figure 8.2 outlines the preliminary land improvement plan assumed for this initial scoping study for the Area E large-format retail scenario.

For the yard-based commercial scenario, less work would be required, but some land improvement would be necessary to provide a suitable subgrade for a lightweight pavement. For this initial assessment, the assumed land improvement works for a yard-based development are:

- Excavate topsoil (approximately 0.2m deep), and shape as landscaping bunds around the site. This landscaping reduces the area available for pavement by approximately 20%, but reduces costs associated with disposal of contaminated topsoil.
- Place compacted AP100 hardfill (approximately 0.2m thick on average).
- Place compacted GAP65 hardfill (0.25m thick).
- As an alternative to this hardfill, cement-stabilisation of the subgrade could be considered, but this option has not been assessed as part of the current study.
- Construct lightweight pavement (approximately 0.25m thick) – this is not included in the cost estimate, as it is not an "extra-over" cost (refer Section 2.9.1).

In accordance with our offer of service dated 2nd September 2015, this preliminary plan is based on the general findings of engineering analysis undertaken for these areas previously, and did not involve any new investigations or new engineering design work.

8.4 Potential civil engineering effects on neighbouring areas

The land improvement work outlined in Section 8.3 has the potential to affect neighbouring areas, in both positive and negative ways. Table 8.2 identifies potential effects related to civil engineering aspects of the land improvement works.

There will also be other types of effects related to residential land use of red zone land, such as social, economic, environmental and cultural effects. Identification of these effects is beyond the scope of this initial scoping study – we recommend that these broader aspects are considered by WDC as part of the recovery plan process.

8.4.1 Exacerbation of flooding elsewhere

A preliminary assessment has been made of the potential for construction of the new fill platform to exacerbate flooding in the surrounding area, due to a reduction in floodplain volume. For the Stage 1 assessment the potential effects have been evaluated qualitatively, with reference to the flood depth and velocities predicted in the WDC and T+T flood modelling.

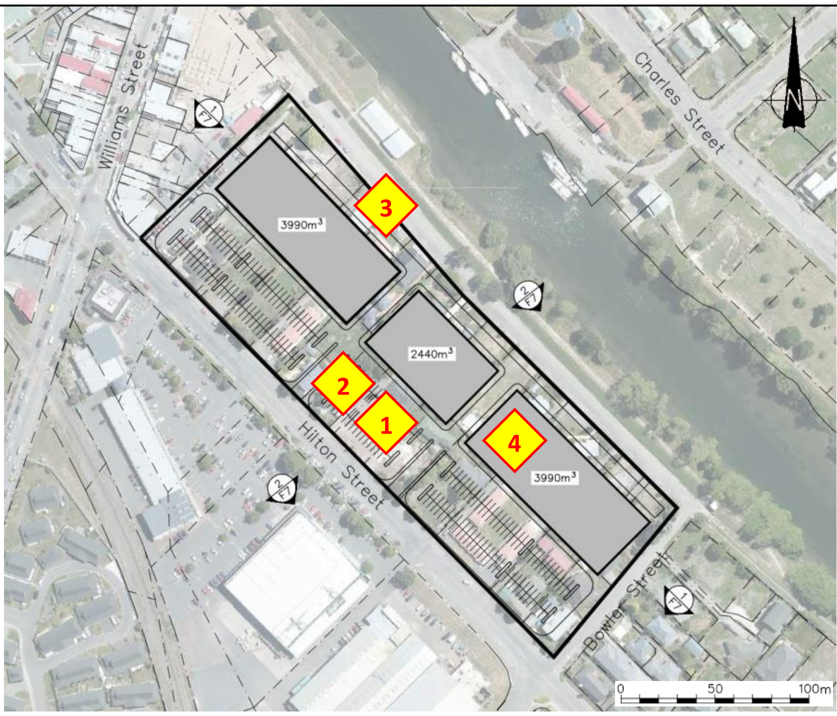
It should be noted that flooding that currently occurs in Area C passes downstream to Area E. There is a high likelihood of adverse flooding effects if both areas C and E are filled, as an alternative flood flow path will be required.

The extent of the potential fill platform for Area E would obstruct the overland flow that would otherwise pass through this area in a south-easterly direction. If this area were completely filled then overland flow across Williams Street would be diverted elsewhere, with likely consequent adverse effects.

Potential effects if red zone Area E was filled have been considered both upstream and downstream:

- **Upstream:** Due to hydraulic grade across Williams Street, it is possible that filling of Area E might not have a notable effect on flood levels upstream.
- **Downstream:** Filling of Area E would require that flood water passing over Williams Street be diverted to the area south and west of Hilton Street, with likely increases in flood depth occurring as a result.

This preliminary qualitative assessment indicates that exacerbation of flooding elsewhere is likely to be a significant constraint for commercial development of red zone Area E. It is proposed that a quantitative assessment involving updated flood modelling is undertaken as part of the Stage 2 engineering feasibility assessment.



The key features labelled on this preliminary land improvement outline plan are:

1 Heavy earthworks compaction of the existing ground surface across the entire site, to repair ground cracking from lateral spreading.

2 Construction of a compacted platform of bulk hardfill across the entire site. This platform helps to raise ground and floor levels above the relevant design flood levels, improves the available bearing capacity for pavements and building foundations, and reduces surface land damage resulting from liquefaction of the underlying soils in future earthquakes. The average thickness of fill needed beneath building footprints ranges from 1.8m for optimistic and most likely design assumptions to 2.05m for pessimistic assumptions. In addition to this bulk hardfill, a pavement of approximately 0.25m thickness will be required (not included in this cost estimate, as it is not an "extra-over" cost).

3 Installation of a high strength base geotextile and geogrid reinforcement around all edges of the hardfill platform. This reduces the potential for slope failure and lateral spreading of the new fill in future earthquakes.

4 Deep ground improvement beneath the footprint of all major buildings, potentially using stone columns to a depth of 7 – 8m (other ground improvement techniques may also be suitable). The ground improvement would be designed to reduce the severity of lateral ground stretching and differential settlement to a level that is tolerable for conventional shallow commercial-type foundations. Ground improvement would likely be required to extend approximately 5m beyond the edge of the building footprint.

Figure 8.2: Preliminary land improvement outline plan for Area E – Option E2 large-format retail shown (refer also to Appendix A)

Table 8.2: Potential civil engineering effects of land improvement works on neighbouring areas

Potential effects	Potential measures to reduce negative effects and increase positive effects
Flooding and stormwater + The carparking area alongside Hilton Street could create a more efficient flood flowpath to improve drainage of upstream green zone areas, as part of the wider floodplain management strategy. – Fill platform may reduce floodwater storage capacity or obstruct flood flowpaths, and this could increase flood depth elsewhere.	• Use flood model results to shape the fill platform and the rest of the red zone land north of Courtenay Drive, to reduce obstruction of flood flowpaths and improve flowpath performance. • Excavate basins and flowpaths for floodwater, or flatten the terrace slope east of Courtenay Drive, to help offset loss of flood capacity. *Refer to Section 8.4.1 for more detail.*
Construction traffic – Gravel for construction of the fill platform would likely be delivered to site using trucks. The large volume of fill material required means that a large number of truck deliveries would be needed. This could cause effects for local traffic and residents and accelerated wear on road pavements.	• Select routes for heavy traffic that reduce the impacts on local traffic, residents and road pavements. *Refer to Section 8.4.2 for more detail.*
Amenity – Deep ground improvement works for building foundations could cause noise and vibration effects for nearby commercial properties on Williams St and Hilton St.	• Consider lower-vibration methods of ground improvement and/or optimise the site layout to locate buildings away from the existing commercial properties.
Relative land levels + The Area E red zone is currently 1.1 – 1.5m lower than most of the surrounding green zone land. Placing fill to raise the land would make the ground level more uniform in this area. – The carpark and medical centre between Williams Street and Raven Quay have a ground level of RL 1.5 – 1.8m. If the ground level was raised in Area E (to a level ranging from RL 3.45m for the optimistic and most likely case, to RL 3.7m for the pessimistic) then this would leave a small area surrounded on all sides by higher ground. This may result in an impact on visual aesthetics and privacy, stormwater drainage issues and unfavourable perception of the lower-lying properties.	• Design the fill platform and layout to provide a gradual transition from areas of lower to higher land. • Avoid new buildings constructed immediately overlooking existing lower-lying properties. • A green-space corridor could be provided to transition from lower to higher ground levels. • Implement measures to control stormwater runoff.

8.4.2 Construction traffic

The most likely source of gravel material for construction of the fill platform would be from the Waimakariri River, delivered to site by truck & trailer. To deliver the large volume of fill needed, depending on the footprint and design assumptions, up to about 10 truck deliveries per day would be required over the main earthworks period of about 1 – 2 years for the large-format retail option or 2 – 4 months for the yard-based commercial option. If an accelerated program was desired it could be possible to complete the 46,000m^3 pessimistic fill estimate for Option E2 in a year, however this would require about 20 truck deliveries per day. Each delivery involves two truck movements, one going to the site and one leaving the site – although the route may be slightly different each way.

The most direct and practical access to site for most construction traffic would likely be to exit the northern motorway at Ohoka Road and continue east to turn onto Stone Street then Courtenay Drive, as outlined in Figure 8.3. However, this route will put additional heavy vehicle demands on sections of Courtenay Drive which were likely not designed for this level of traffic. This could cause accelerated wear on these roads, resulting in a need for additional maintenance and repair. These additional road network costs have not been included in the land improvement construction cost estimate for this initial scoping study. There may also be noise and vibration effects for the residences along Ohoka Road and Courtenay Drive due to this increase in heavy traffic.

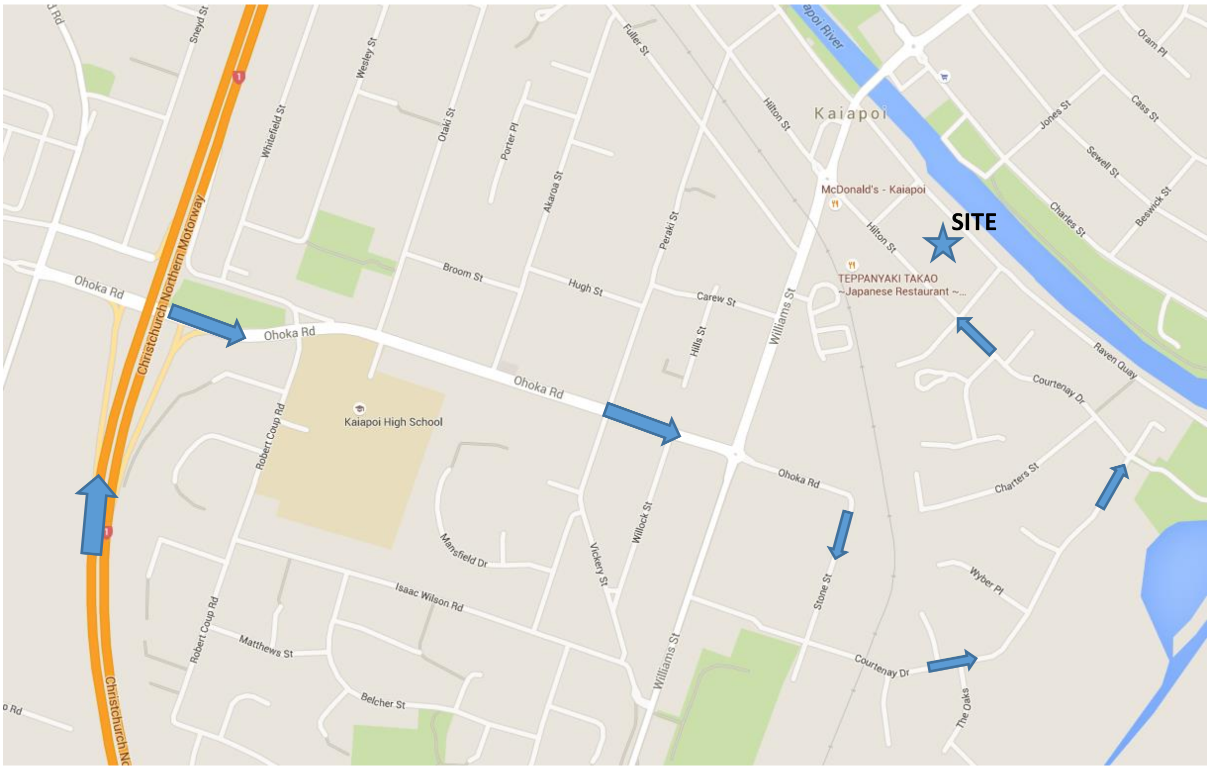


Figure 8.3: Potential construction traffic route to Area E red zone site (map data © 2015 Google)

8.5 Preliminary estimate of land improvement costs and timeframe

As discussed in Section 2.9.1, the preliminary cost estimate prepared as part of this initial scoping study includes only the cost of land improvement works. This is the cost of engineering work that would be incurred "over and above" normal construction work.

Significant land improvement works would be required in red zone Area E to meet the land performance requirements outlined in Section 2.3.

- For the large-format retail scenario, depending on the footprint option, between approximately 5,500m^2 and 14,000m^2 of deep ground improvement (e.g. stone columns) would be required beneath and surrounding building footprints to reduce the severity of lateral ground stretching and differential settlement in future earthquakes.
- For the large-format retail scenario, depending on design assumptions and the footprint option, between approximately 18,000m^3 and 55,000m^3 of bulk fill with geotextile reinforcement would be required to meet flood and foundation design requirements.
- For the yard-based commercial scenario, depending on the footprint option, between approximately 5,000m^3 and 13,000m^3 of bulk fill would be required to provide a suitable pavement subgrade.
- At this initial stage it has been assumed that all bulk fill will need to be imported, but if stormwater basins are constructed in the red zone land to the east then this may provide some of the necessary material (cut to fill).
- For both development scenarios, depending on the development footprint option, between approximately 15,000m^2 and 31,000m^2 of ground surface compaction (e.g. a heavy roller) would be required across the entire area to repair ground cracking from lateral spreading and prepare the subgrade for filling.

The expected construction timeframe for the land improvement works, depending on the footprint and design assumptions, would be approximately one to three years for the large-format retail scenario, or less than one year for the yard-based commercial scenario.

The preliminary "over-and-above" construction cost estimate for these land improvement works is summarised in Table 8.3. As discussed in Section 2.9.2 these estimates span a confidence range between approximately 10% and 90% probability of exceedance, to represent uncertainty in the final design and market pricing. This preliminary estimate includes direct engineering design and construction costs only - we suggest that WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.

Table 8.3: Preliminary "over-and-above" cost estimate for Area E land improvement works

	Footprint Option	Pessimistic	Most likely	Optimistic
Yard-based commercial: Cost to strip site, manage contaminated soil, and prepare land for pavement.	E1 (14,700m^2)	\$1.1M	\$0.9M	\$0.8M
	E2 (31,300m^2)	\$2.2M	\$1.7M	\$1.6M
Large-format retail: Cost to strip site, manage contaminated soil, raise and stabilise land.	E1 (14,700m^2)	\$4.7M	\$3.6M	\$3.3M
	E2 (31,300m^2)	\$11.4M	\$8.8M	\$8.1M

NOTE: 1) These estimates include direct engineering design and construction costs only - we suggest WDC seeks advice from the full range of relevant disciplines to estimate a turn-out-cost that includes all aspects of the project.
2) These are land improvement costs "over-and-above" normal construction work, as detailed in Section 2.9.1.
3) All cost values exclude GST.

The main differences between these three scenarios are due to design uncertainties at the present preliminary stage of design, along with uncertainties in market pricing for construction work and materials. There is still considerable uncertainty regarding the level of new fill required for flood, foundation and pavement design requirements (refer Table 8.4). The volume of fill required will also depend on the degree to which it is possible to refine the development layout and gradients to make efficient use of fill material while still retaining a well-functioning operational layout.

Table 8.4: Estimates of volume of fill required for Area E large-format retail scenario

Design scenario	Elevation of top of bulk fill below buildings (m RL)	Fill height required below buildings (metres above current average ground level)	Volume of fill required (m^3)
Pessimistic design assumptions	RL 3.7m	2.05m	Option E1: 25,000 m^3 Option E2: 55,000 m^3
Most likely design assumptions	RL 3.45m	1.8m	Option E1: 18,000 m^3 Option E2: 41,000 m^3
Optimistic design assumptions	Same as most likely design assumptions		
Current ground level (2014 LiDAR survey)	Typically RL 1.3 – 2.0m, Average RL 1.65m over entire Area E On average, Area E1 is 0.25m lower than Area E2		
NOTE: 1) Ground elevations are specified as metres above mean sea level, relative to Lyttelton Vertical Datum. 2) Specified elevation of fill below buildings assumes a 400mm thick slab foundation.			

8.6 Discussion

This initial scoping study has identified that exacerbation of flooding elsewhere is likely to be a significant constraint for commercial development in the Area E red zone. Based on the current qualitative assessment of potential adverse flooding effects from placing fill in Area E, it appears that a yard-based commercial option would be more suitable in this location than a large-format retail option. If WDC wish to explore either of these options further then we recommend that a quantitative assessment involving updated flood modelling is undertaken as part of the Stage 2 engineering feasibility assessment.

Additionally, a number of significant geotechnical constraints and potential adverse effects have been identified. It appears to be technically feasible to manage these issues, using engineering approaches that are commonly applied for land development in Canterbury - such as earthworks and ground improvement. However, given the significant scale of work that would be required, this would add considerable development cost.

If WDC wish to better understand the economic feasibility of potential residential land use, then we would recommend that a broader business case analysis be undertaken which includes the estimated range of costs for undertaking these land improvement works. This business case analysis should make allowance for the likelihood that some of the land preparation work included in this cost estimate would be required regardless of the future land use selected (e.g. decommissioning existing roads and managing ground contamination).

8.7 Next steps

If WDC wish to examine in more detail the potential for commercial land use in red zone Area E, then we would recommend a second stage of engineering feasibility assessment as outlined in our Offer of Service dated 2nd September 2015.

In particular, the following technical aspects appear to have a significant influence on the engineering feasibility and construction cost estimate:

a For this initial scoping study, it has been assumed that deep ground improvement would be required beneath and beyond the entire footprint of all major buildings in Area E, to reduce the severity of lateral ground stretching and differential settlement. This deep ground improvement work accounts for about 60% of the estimated "over-and-above" construction costs for the large-format retail scenario. The Stage 2 assessment should aim to more precisely define the required extent and depth of ground improvement – this would involve specific geotechnical stability and foundation analysis. This assessment could also consider whether there are any specific types of structure that could use an alternative more economical type of foundation system instead of deep ground improvement.

b Another uncertainty in the construction cost estimate is the minimum land level necessary to meet flood and foundation design requirements. This is of less importance for the commercial development areas than for the residential areas, because the minimum land level only applies beneath the building footprint and it is possible to reduce the fill thickness by having carpark areas slope downwards away from buildings. Nonetheless, the Stage 2 assessment should aim to more precisely define the required fill level – this would involve further analysis of flood model results and consultation with WDC technical and consenting staff.

c For this initial assessment it has been assumed that only a small proportion of contaminated soil will require off-site disposal, with the remainder of the existing topsoil able to be managed on site within landscaping areas. A preliminary estimate of offsite disposal volume has been made at this initial stage, ranging from 1% of the total area in the optimistic scenario to 5% of the total area in the pessimistic scenario – resulting in only minor estimated costs. However, there is currently very little site-specific information to support these assumptions – so the volume and/or severity of contaminated soil could potentially be under-predicted. The Stage 2 assessment should aim to more clearly identify the potential extent and severity of soil contamination, and the ability for it to be managed on site. This would be most effectively achieved by on-site shallow soil sampling and laboratory testing.

d An initial qualitative assessment suggests that exacerbation of flooding elsewhere is likely to be a significant constraint for commercial development in the Area E red zone. The Stage 2 assessment should aim to provide more certainty as to whether or not flood exacerbation effects from placing fill can be managed by providing flow paths and careful floodplain management. This would involve specific flood modelling of the new fill and flowpaths.

e For the yard-based commercial scenario, the Stage 1 cost estimate assumes that it would be permissible to raise the land slightly (less than 0.5m) to construct a pavement. If even this slight increase in ground level is not allowable because of adverse flooding effects, then an alternative (potentially more expensive) subgrade improvement or pavement design would be required. Depending on the flood model results, the Stage 2 assessment may need to consider an alternative construction methodology for the yard-based commercial scenario.

f It has been assumed that stone columns will be a suitable ground improvement technique for improving the land performance beneath building footprints, as it is a technique that is typically widely applicable. Stone column costs make up about 60% of the estimated "over-and-above" construction costs for the large-format retail scenario. There are alternative ground improvement techniques that could be considered instead of stone columns. Dynamic compaction is significantly less expensive than stone columns, however its effectiveness can be sensitive to the ground conditions, and the associated ground vibrations may be unacceptable if there are neighbours nearby. Soil-cement mixing is applicable for a wide range of ground conditions and results in little ground vibration, but is more expensive than stone columns. The Stage 2 assessment should further examine the suitability of alternative ground improvement methods – however it is unlikely that this uncertainty can be conclusively resolved until field trials are undertaken (e.g. at the commencement of construction).

g For this initial scoping assessment, it has been assumed that all fill material would be imported gravel. If stormwater flowpaths are excavated in the red zone land to the east of Area E, then it may be possible to re-use some of this excavated material as part of the new fill platform (cut-to-fill). If WDC wish to explore this option, then the Stage 2 assessment should aim to better estimate the volume of suitable cut-to-fill material – this would be most effectively achieved by on-site shallow soil sampling and laboratory testing.

9 Conceptual options for alternative residential building approaches

9.1 Background

The engineering feasibility assessment summarised in Sections 4 and 5 for residential development on red zone land has been based on the concept of placing fill to raise the land to manage building foundation and flooding issues.

This concept has been adopted for most of the red zone assessment work to date because it is a relatively robust option suitable for the range of ground conditions possible across the red zones. It is also consistent with the approach typically adopted for residential land development in flood-prone areas in the region.

The choice of a concept which raises the land has been partially driven by an implicit assumption that there would be consenting difficulties and little market demand for flood-prone land which required highly bespoke foundations. The project team are now giving further thought to this assumption, and have asked T+T to outline alternative engineering approaches that could be considered without the need to raise the land.

This section of the report outlines several alternative engineering concepts for residential development. T+T has not undertaken any detailed analysis of these options at this time, so at this stage it is uncertain whether they would be technically feasible, cost-effective and consentable. We would be happy to work with the project team to explore any of these options in more detail if desired.

For examples of alternative construction approaches that have been adopted in flood-prone areas elsewhere in the world, it may be useful to refer to the elevated dwelling concepts used in New Orleans (http://makeitright.org/see/new-orleans/)

9.2 Concept 1: Land raised by filling, with dwellings at new ground level

This is the engineering concept assumed to date for the urban residential scenarios for Area A and Area B (refer Sections 4 and 5).

The key features of this concept are:

- Gravel fill, reinforced with geogrid, is placed to raise the land beneath and surrounding dwellings to at least the 50 year flood level. This fill would extend across the entire area, including roads, to provide a continuous improved surface crust to reduce the consequences of liquefaction of the underlying soils.
- Deep area-wide perimeter ground improvement undertaken where necessary to manage lateral spreading (Area B).
- The area-wide engineering works would be designed to enable construction of dwellings using standard TC2 foundation concrete slab or timber floor details similar to other subdivisions recently constructed in Kaiapoi and Christchurch.

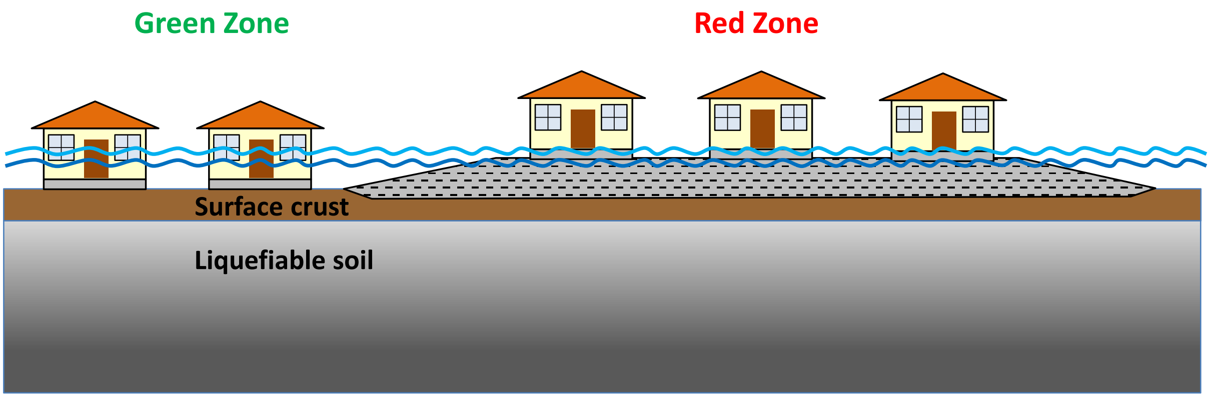


Figure 9.1: Concept 1 - Land raised by filling, with dwellings at new ground level. Dark blue line is 50 year flood level, light blue line is 200 year flood level. New dwellings have standard TC2-type foundations.

9.3 Concept 2: Elevated dwellings with piled foundations

The key features of this concept are:

- Piles installed to reach non-liquefiable sand or gravel soils at depth. Pile founding depth is likely to be approximately 8 – 15m in Area A (North of Cass St) and 5 – 10m in Area B (Courtenay Drive).
- Piles either support a ground-level concrete slab upon which framing is constructed to lift the floor level to the necessary height, or the piles extend up out of the ground and connect directly to the elevated floor joists.
- Deep area-wide perimeter ground improvement undertaken where necessary to manage lateral spreading (Area B).

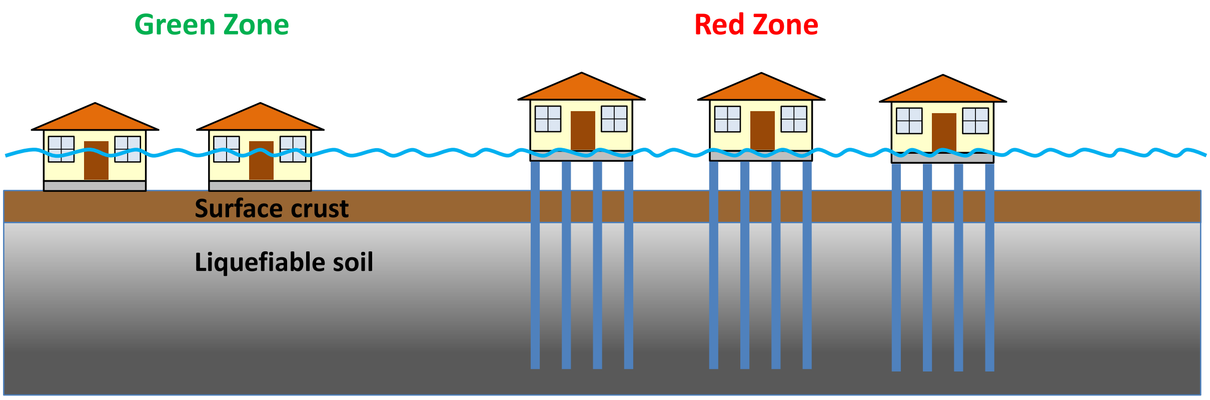


Figure 9.2: Concept 2 - Elevated dwellings with piled foundations. Light blue line is 200 year flood level.

9.4 Concept 3: Elevated dwellings with ground improvement & surface-structure foundations

The key features of this concept are:

- Undertake area-wide ground improvement across the entire area, or localised ground improvement beneath and around each dwelling footprint.
- MBIE "surface structure" type foundation constructed to lift the floor level to the necessary height. This is based on a well-reinforced concrete underslab, out of which rise timber posts which support the floor joists. The robustness of the foundation required will depend on the approach taken for ground improvement.

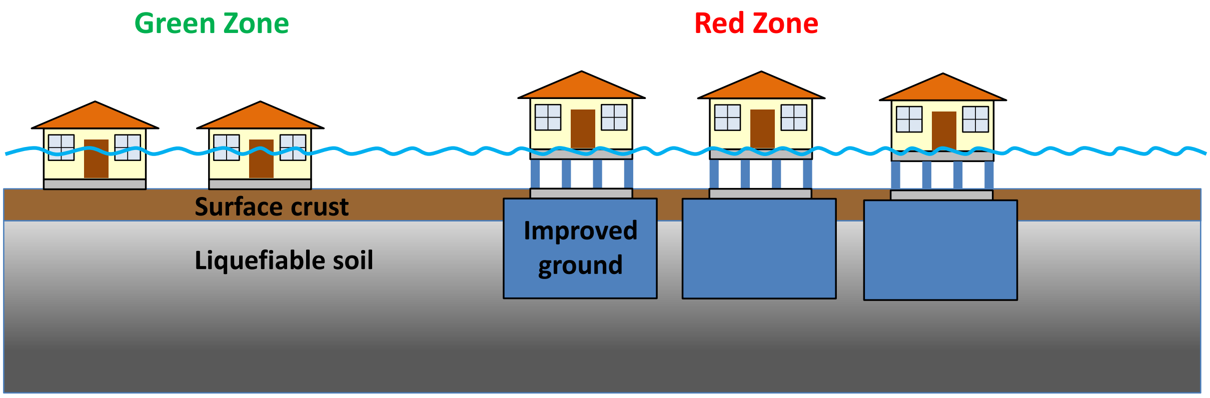


Figure 9.3: Concept 3 - Elevated dwellings with ground improvement & surface-structure foundations. Light blue line is 200 year flood level.

9.5 Concept 4: Flood mitigation with ground improvement & dwellings at ground level

The key features of this concept are:

- Area-wide flood mitigation works undertaken to protect the red zone land (and potentially also existing green zone areas) up to 200-year flood events.
- Undertake area-wide ground improvement using dynamic compaction, or localised ground improvement for each dwelling footprint.
- Deep perimeter ground improvement undertaken where necessary (depending on approach taken for area-wide ground improvement and foundations) to manage lateral spreading.
- Dwellings constructed only slightly above ground level, similar to typical residential construction (floor level at 0.3m above ground for waffle slab foundations, or 0.6m for suspended timber floor options). The robustness of the foundation required will depend on the approach taken for ground improvement.

We note that it may be very technically challenging to provide sufficient flood protection to meet consenting requirements for dwelling floor levels.

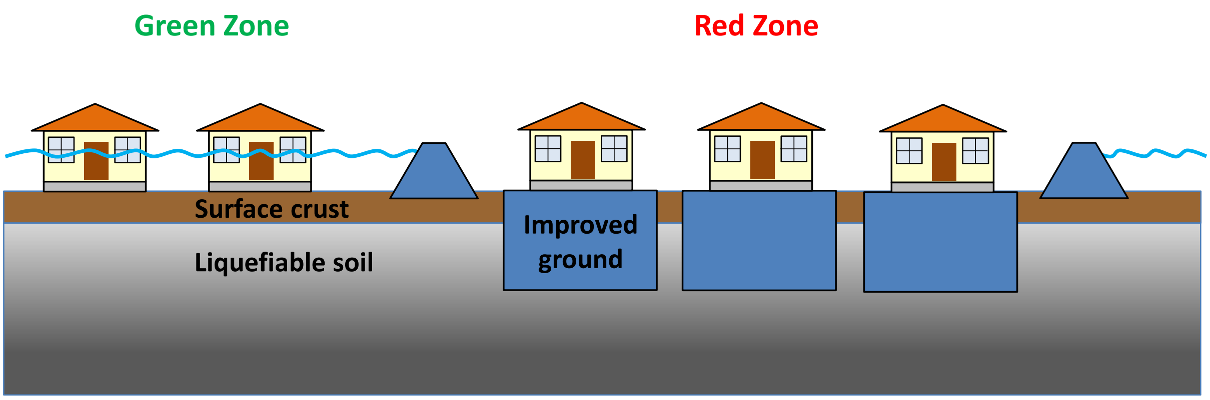


Figure 9.4: Concept 4 - Flood mitigation with ground improvement & dwellings at ground level. New dwellings have standard TC2-type foundations. Light blue line is 200 year flood level.

9.6 Resource consent considerations

The WDC resource consent team has been consulted regarding the consentability of these concepts. The following considerations were noted:

- The primary resource consent considerations would be the Plan rules on maximum earthworks volumes, and National Environmental Standards regarding ground contamination.
- It would be important to ensure that the approach taken in the red zone is consistent with the wider council strategies and plan objectives, and does not conflict with the rights of the local community and individuals. All four concepts appear to have potential for such conflicts to occur.
- For Concept 1, a key aspect would be ensuring that flood flowpaths would be maintained, and managing stormwater flows from the raised platform. Amenity issues may arise due to the raised fill platform.
- For Concepts 2 and 3, as well as specifying a minimum floor level for flood protection, it would also be important to specify a maximum floor level to avoid dwellings becoming the dominant feature in the landscape. Consideration would need to be given to aspects such as privacy, overlooking and amenity.
- For Concept 4 there could be practical consenting difficulties if the work involved multiple land parcels and works on public land and land subject to other considerations (e.g. reserve act, road vesting etc.). Flood flowpaths would need to be maintained, and the amenity and environmental effects of bunding, ongoing pumping and other flood protection works would need to be considered.

9.7 Building consent considerations

The WDC building consent team has been consulted regarding the consentability of these concepts. The following considerations were noted:

- A hazard notice under Section 72 of the Building Act (2004) may be issued where building work is being carried out on land that is “likely” to be subject to a natural hazard. Determinations regarding natural hazards indicate that a 1 in 100 year event should be considered when assessing whether a hazard is “likely”.
- This natural hazard test is applied to the land beneath the building, and also the land immediately surrounding the building (as this land is required for access and amenity).
- Flood modelling indicates that much of the red zone land in Areas A and B is subject to flooding in a 1 in 100 year event for current climate and sea level, and this increases to the entire area when projected climate change and sea level rise over the next 100 years is included. So if the land remains at its current level, then WDC may issue a Section 72 hazard notice when building work is carried out.
- A Section 72 hazard notice does not prevent consent for building work being granted, provided that adequate provision is made to protect the building, land and other property. In this case application can be made for a waiver of part of Section E1 of the Building Code. But a Section 72 notice usually means that insurance and mortgage finance for the property is difficult to obtain.
- For Concept 1, the land improvement and filling will need robust verification and engineering signoff to confirm it is suitable for building on. Stormwater falling on the property would need to be managed, and the fill platform would need to avoid diverting surface water onto other properties.

- For Concepts 2 and 3 a Section 72 hazard notice may be issued as discussed above. The WDC building consent team note that these options appear to be significantly more complex and expensive than the residential building work that is typically undertaken in the district.
- For Concept 4, any area-wide flood protection works would need to be approved by the WDC engineering team, including agreement on who would meet the up-front and ongoing costs.

9.8 Cost estimates

A preliminary cost estimate has previously been prepared for Concept 1, as summarised in Sections 4 and 5:

- For medium residential density (lot sizes of about 650m^2) with the fill platform covering the entire red zone area, the preliminary "most likely" estimate of construction cost over-and-above normal residential subdivision servicing corresponds to approximately $90k per lot for Area A (Kaiapoi East), and $135k per lot for Area B (Courtenay Drive).
- For rural-residential type development (lot sizes of about 5000m^2 and dwelling floor areas of about 300m^2) with fill platforms and ground improvement located only under and immediately surrounding each dwelling, the preliminary over-and-above cost estimate is approximately $285k per lot for Area A (Kaiapoi East), and $380k for Area B (Courtenay Drive).
- Given the considerable design and market pricing uncertainties at this initial scoping stage, "pessimistic" cost estimates are significantly higher than these values, and "optimistic" estimates are significantly lower.

Formal cost estimates have not been prepared for Concepts 2 to 4 at this time. These concepts are more difficult to estimate costs for, as they require bespoke design and non-standard construction techniques (as opposed to Concept 1 where the majority of cost relates to straightforward bulk earthworks and ground improvement). However, our initial impression is that these concepts are unlikely to be significantly less expensive that Concept 1 (or they may be more expensive):

- Based on reported costs for constructing TC3 type foundations and ground improvement, it appears likely that building foundations for Concepts 2 and 3 would cost approximately $100k to $200k per dwelling more than standard TC2 foundations (or possibly more for large dwelling floor areas).
- It is uncertain what flood mitigation works would be required for Concept 4, but this work is likely to be relatively expensive. For example, flood bypass works have recently been approved for Dudley Creek in Christchurch with a budget of $26M (this work benefits about 585 properties). In addition to this flood protection work, there would also be a need for ground improvement and/or specialised foundations to manage the poor ground bearing capacity, at an additional cost of approximately $50k to $100k per dwelling.
- In addition to these extra foundation costs above, perimeter ground improvement would likely be required for medium residential density in Area B for Concepts 2 and 4, to manage lateral spreading (an additional cost of approximately $80k per lot).

9.9 Summary of advantages and disadvantages

Table 9.1 provides a qualitative comparison between the four residential development concept options considered. This indicates that all the concepts face potentially significant issues – there is no option that is clearly preferable to the others. The alternative concepts 2 to 4 do not appear to offer significant cost savings compared to concept 1 (the option assumed for Areas A and B in Sections 4 and 5). However, it appears that these alternative concepts may result in less disruption for surrounding green zone areas.

Table 9.1: Summary of advantages and disadvantages of residential development concepts

Concept options
Concept 1: Land raised by filling, with dwellings at new ground level
Concept 2: Elevated dwellings with piled foundations
Concept 3: Elevated dwellings with ground improvement & surface-structure foundations
Concept 4: Flood mitigation with ground improvement & dwellings at ground level

Advantages	**Concept option**			
	1	**2**	**3**	**4**
Protects land surrounding dwellings from flooding.	✓			✓
Requires no more than a small volume of fill to be imported to site.		✓	(✓)	(✓)
Requires no more than a moderate volume of fill to be imported to site.		✓	✓	✓
Does not rely on area-wide engineering works to improve the surface crust, allowing work to proceed on a site-by-site basis.		✓	(✓)	
Much of the additional construction cost is incurred later in the programme, during final dwelling construction rather than as an up-front cost during initial subdivision construction.		✓	(✓)	
Also reduces the effects of sea level rise on the land.	✓			(✓)
End result is similar to conventional subdivisions elsewhere in Canterbury, assisting with market appeal.	✓			(✓)

(✓) = Depends on the details of the construction method selected

Disadvantages	**Concept option**			
	1	**2**	**3**	**4**
Requires a large volume of fill material to be imported to site.	✗			
The land and streets surrounding the dwellings remain prone to flooding and/or permanent ground wetness issues.		✗	✗	(✗)
Does not manage severe lateral spreading issues, so deep perimeter ground treatment still required for Area B (Courtenay Drive).	✗	✗	(✗)	(✗)
High overall construction costs likely.	✗	✗	✗	✗
May have difficulties with resource consent, building consent, or ongoing insurability.	✗	✗	✗	✗
Potential amenity concerns (e.g. visual or accessibility)	✗	✗	✗	(✗)

(✗) = Depends on the details of the construction method selected

10 Future engineering work required

The scope of engineering work outlined in Stages 1 and 2 of the T+T Offer of Service dated 2nd September 2015 is expected to be sufficient to progress to plan change application stage, or the equivalent stage in the Recovery Plan process. We understand that this is the end-point of the engineering work that WDC wish to commission at this time, and that if the land is zoned for residential or commercial land use then the actual development of the land may be undertaken by other parties.

We consider it is important at this initial stage for us to outline the further engineering work beyond Stages 1 and 2 that would be required to progress potential land improvement works through to construction. This is intended to help develop a consistent understanding across the various parties involved, and reduce the likelihood of these additional stages in the process (and the associated time and cost implications) being overlooked during initial evaluation and decision-making.

Depending on how the details of potential land improvement options evolve, we envision that further engineering work required in future could include:

- Additional geotechnical investigations, laboratory testing and analysis, targeted at reducing uncertainty or conservatism in key technical aspects of the proposed concept design.
- On-site ground contamination investigations.
- Developed design and detailed assessment of effects, suitable to inform full cost/benefit or business case analysis, RMA processes, or for due-diligence assessment by prospective commercial partners.
- Technical peer review.
- Detailed design and cost estimate for land improvement works, suitable to finalise funding arrangements and proceed to construction.
- Preparation of construction specifications and drawings.
- Land improvement construction observation, design verification, and certifications.
- Final subdivision design, consenting, construction and servicing.
- Design, consenting and construction of suitable building foundations.

11 Applicability

This report has been prepared for the exclusive use of Waimakariri District Council (WDC) in accordance with the scope of services set out in the contract between T+T and WDC. T+T accepts no liability or responsibility in respect of any use of, or reliance upon, this report by any person other than WDC.

Tonkin & Taylor Ltd

Report prepared by:

....

Mike Jacka | Russell Brents

Senior Geotechnical Engineer | Senior Civil Engineer

Authorised for Tonkin & Taylor Ltd by:

....

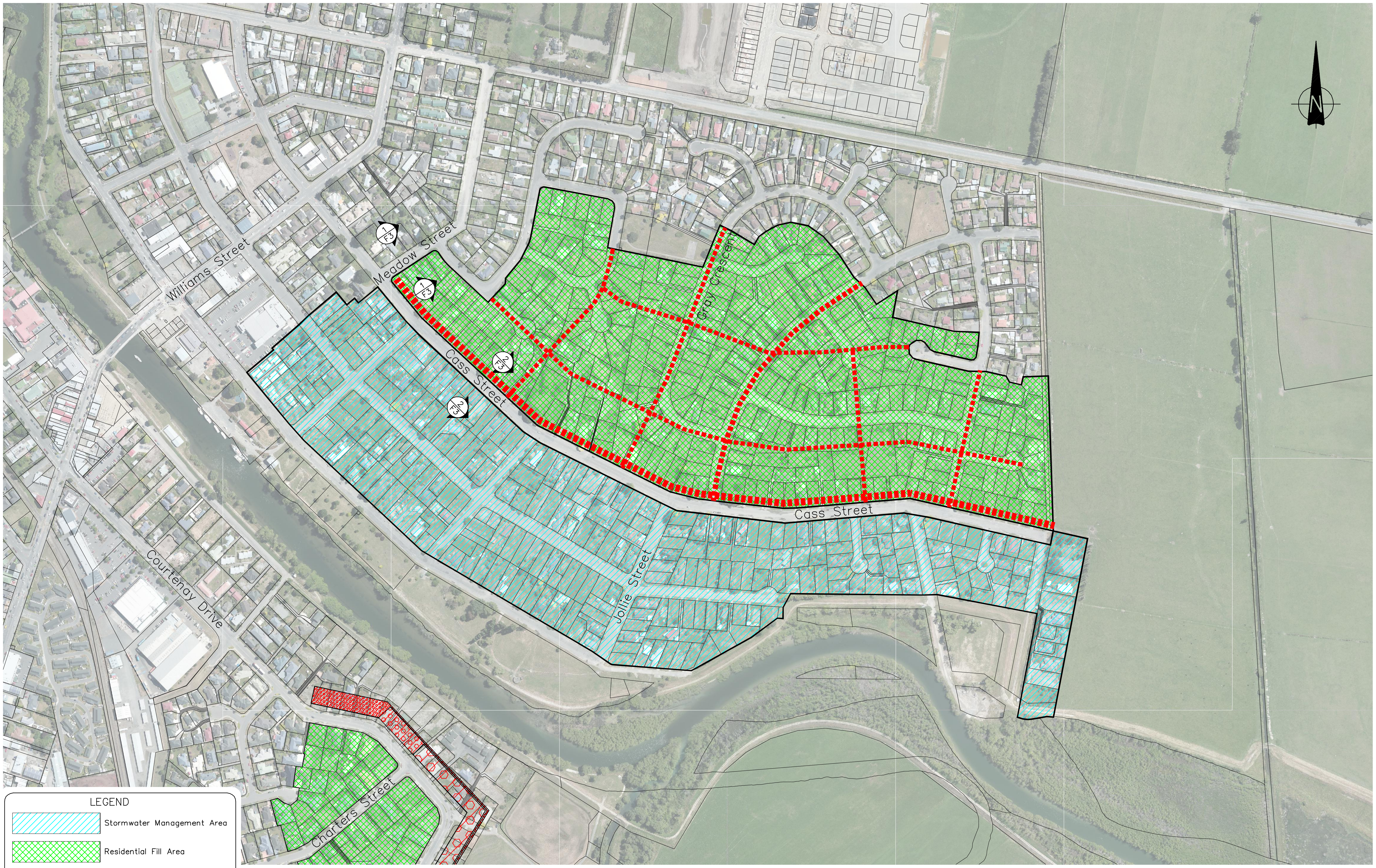
Chris Bauld

Project Director

MEJ
p:\52082\52082.0300\workingmaterial\reports\2015-12-.mej.stage1report-v3.docx

Appendix A: Preliminary concept sketches

- **Figure 1: Site layout plan – Kaiapoi North (Area A)**
- **Figure 2: Site layout plan – Courtenay Drive (Area B)**
- **Figure 3: Earthworks sections**
- **Figure 4: Preliminary commercial concept for Areas C, D and E**
- **Figure 5: Site layout plan, Areas C, E1 and E2**
- **Figure 6: Site layout plan, Areas D1, D2 and D3**
- **Figure 7: Commercial concept earthworks sections**
- **Figure 8: Rural-residential site layout plan -– Kaiapoi North (Area A)**
- **Figure 9: Rural-residential site layout plan -– Courtenay Drive (Area B)**
- **Figure 10: Rural-residential earthworks sections**



LEGEND

- Stormwater Management Area
- Residential Fill Area
- Stone Column Area
- Property Boundaries
- Dynamic Compaction Corridor

A3 SCALE 1:5000

0 50 100 150 200 250 (m)

ORIGINAL IN COLOUR

NOTES:

1. Aerial photo sourced from Linz Data Service <https://data.linz.govt.nz/layer/Canterbury 0.4m Rural Aerial Photos (2012–2013)> , licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence (CC BY 3.0 NZ)
2. Property boundaries sourced from Terralink International (Copyright 2002–2005 Terralink International Limited and its licensors).

Tonkin+Taylor

33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

DRAWN	NSW	Sep. 15
DRAFTING CHECKED	TM	9/15
APPROVED	MEJ	9/15
CADFILE : \\52082.0300–F1_F2.dwg		
SCALES (AT A3 SIZE) 1:5000		
PROJECT No. 52082.0300		

WAIMAKARIRI DISTRICT COUNCIL

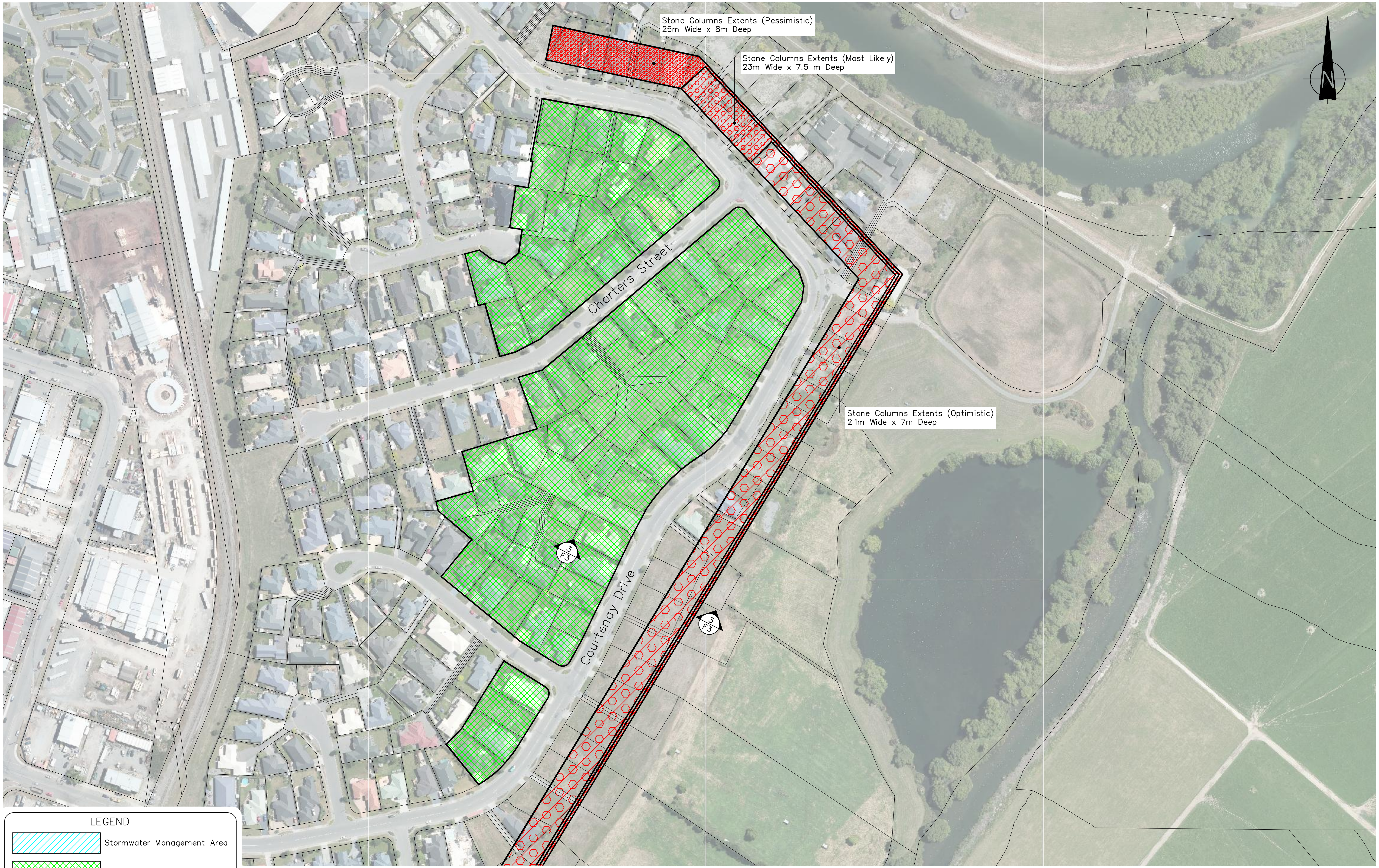
KAIAPOI RESIDENTIAL RED ZONE PRELIMINARY CONCEPT KAIAPOI NORTH & COURTENAY DRIVE

Site Layout Plan (Sheet 1 of 2)

FIG. No. 52082.0300–F1

REV. 0

P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300-F1_F2.dwg, Layout1, 24/09/2015 2:44:29 p.m., NSW



LEGEND

- Stormwater Management Area
- Residential Fill Area
- Stone Column Area
- Property Boundaries

A3 SCALE 1: 2500

0 50 100 150 (m)

ORIGINAL IN COLOUR

NOTES:

1. Aerial photo sourced from Linz Data Service <https://data.linz.govt.nz/layer/Canterbury 0.4m Rural Aerial Photos (2012–2013)> , licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence (CC BY 3.0 NZ)
2. Property boundaries sourced from Terralink International (Copyright 2002–2005 Terralink International Limited and its licensors).

Tonkin+Taylor
33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

DRAWN	NSW	Sep. 15
DRAFTING CHECKED	TM	9/15
APPROVED	MEJ	9/15
CADFILE : \\52082.0300-F1_F2.dwg		
SCALES (AT A3 SIZE) 1: 2500		
PROJECT No. 52082.0300		

WAIMAKARIRI DISTRICT COUNCIL

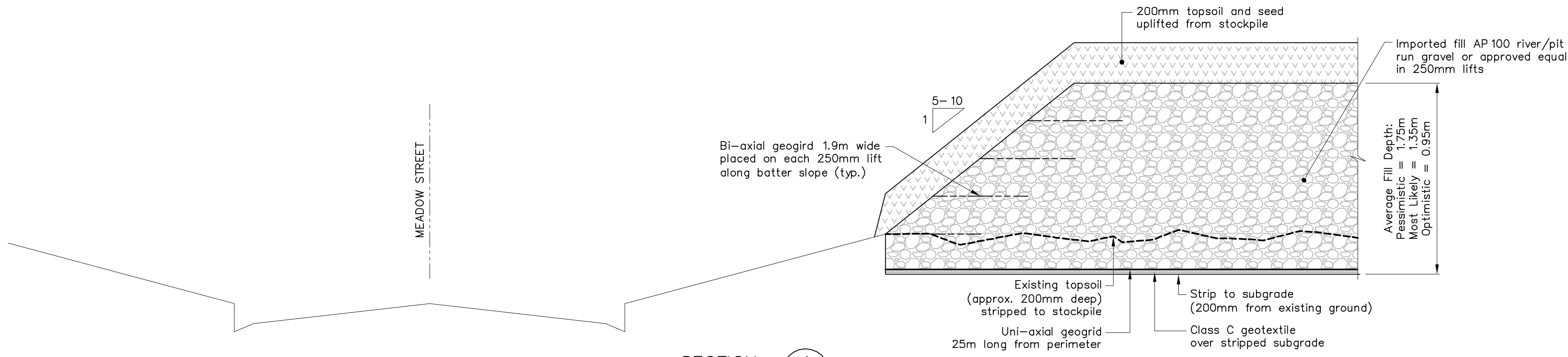
KAIAPOI RESIDENTIAL RED ZONE PRELIMINARY CONCEPT KAIAPOI NORTH & COURTENAY DRIVE

Site Layout Plan (Sheet 2 of 2)

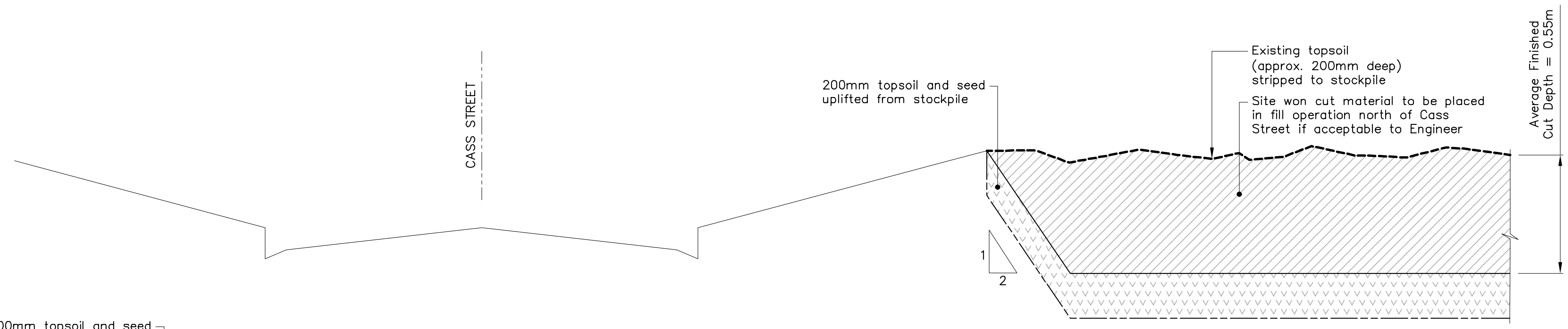
FIG. No. 52082.0300–F2

REV. 0

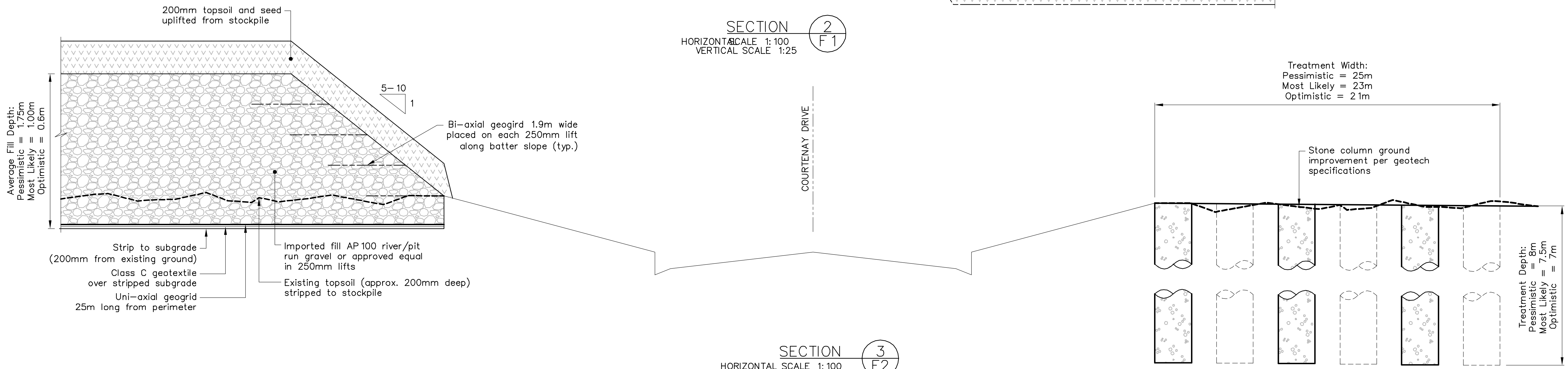
P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300-F1_F2.dwg, Layout1 (2), 24/09/2015 2:44:07 p.m., NSW



SECTION 1/F1
HORIZONTAL SCALE 1:100
VERTICAL SCALE 1:25



SECTION 2/F1
HORIZONTAL SCALE 1:100
VERTICAL SCALE 1:25



SECTION 3/F2
HORIZONTAL SCALE 1:100
VERTICAL SCALE 1:25

NOTE: EXAGGERATED VERTICAL SCALE.

A3 SCALE 1:100
0 1 2 3 4 5 (m)

A3 SCALE 1:25 VERTICAL
0 0.25 0.50 1 1.25 1.50 (m)

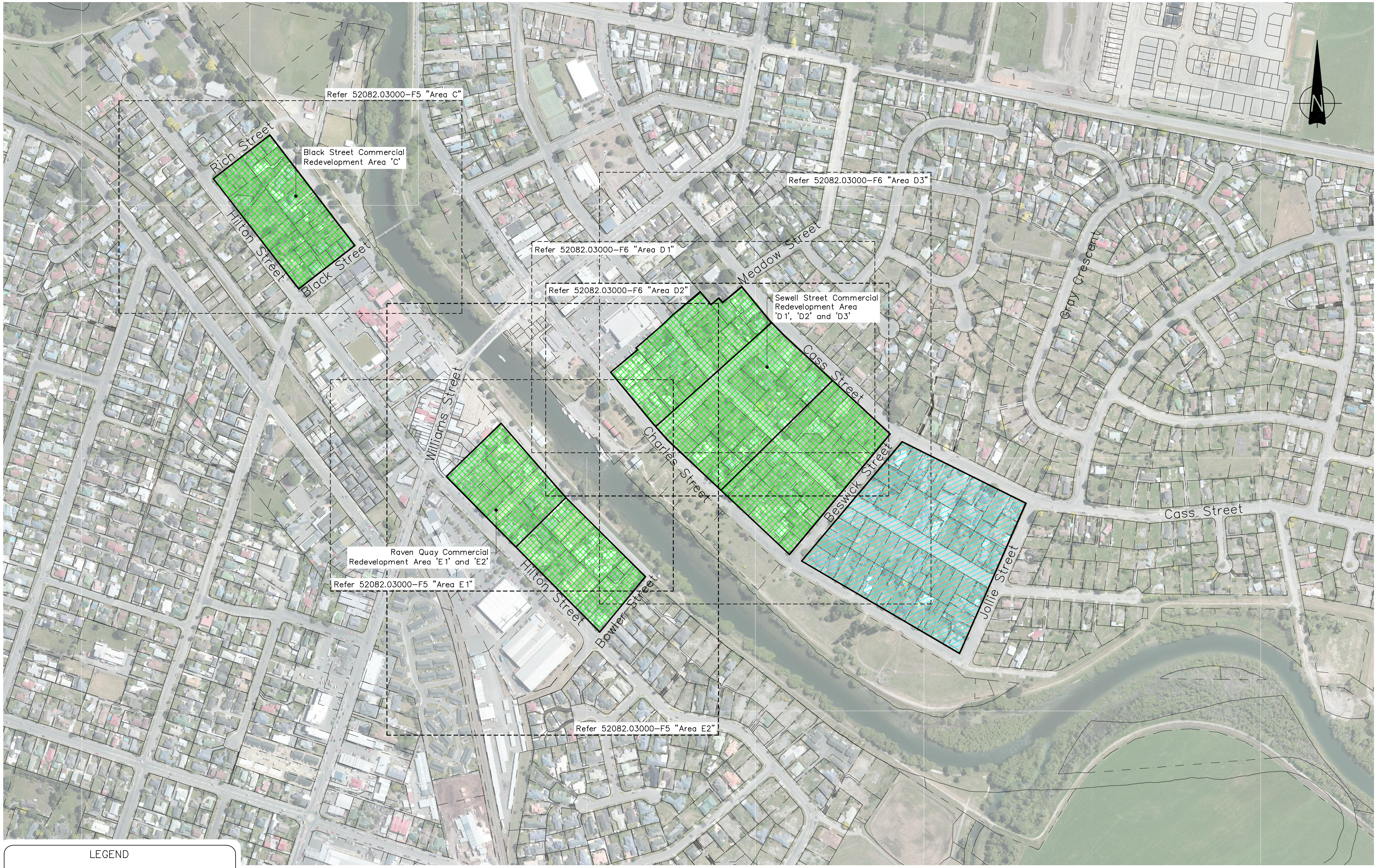
P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300-F3.dwg, Layout1, 24/09/2015 2:42:13 p.m., NSW

Tonkin+Taylor
33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

DRAWN	NSW	Sep. 15
DRAFTING CHECKED	TM	9/15
APPROVED	MEJ	9/15
CADFILE : \\52082.0300–F3.dwg		
SCALES (AT A3 SIZE) (V) 1:25 (H) 1:100		
PROJECT No. 52082.0300		

WAIMAKARIRI DISTRICT COUNCIL
KAIAPOI RESIDENTIAL RED ZONE PRELIMINARY CONCEPT KAIAPOI NORTH & COURTENAY DRIVE
Earthworks Sections

FIG. No. 52082.0300–F3
REV. 0



LEGEND

- Commercial Fill Area
- Stormwater Management Area

A3 SCALE 1:5000

0 50 100 150 200 250 (m)

ORIGINAL IN COLOUR

NOTES:
1. Aerial photo sourced from Linz Data Service <https://data.linz.govt.nz/layer/Canterbury 0.4m Rural Aerial Photos (2012–2013)>, licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence (CC BY 3.0 NZ)
2. Property boundaries sourced from Terralink International (Copyright 2002–2005 Terralink International Limited and its licensors).

Tonkin+Taylor
33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

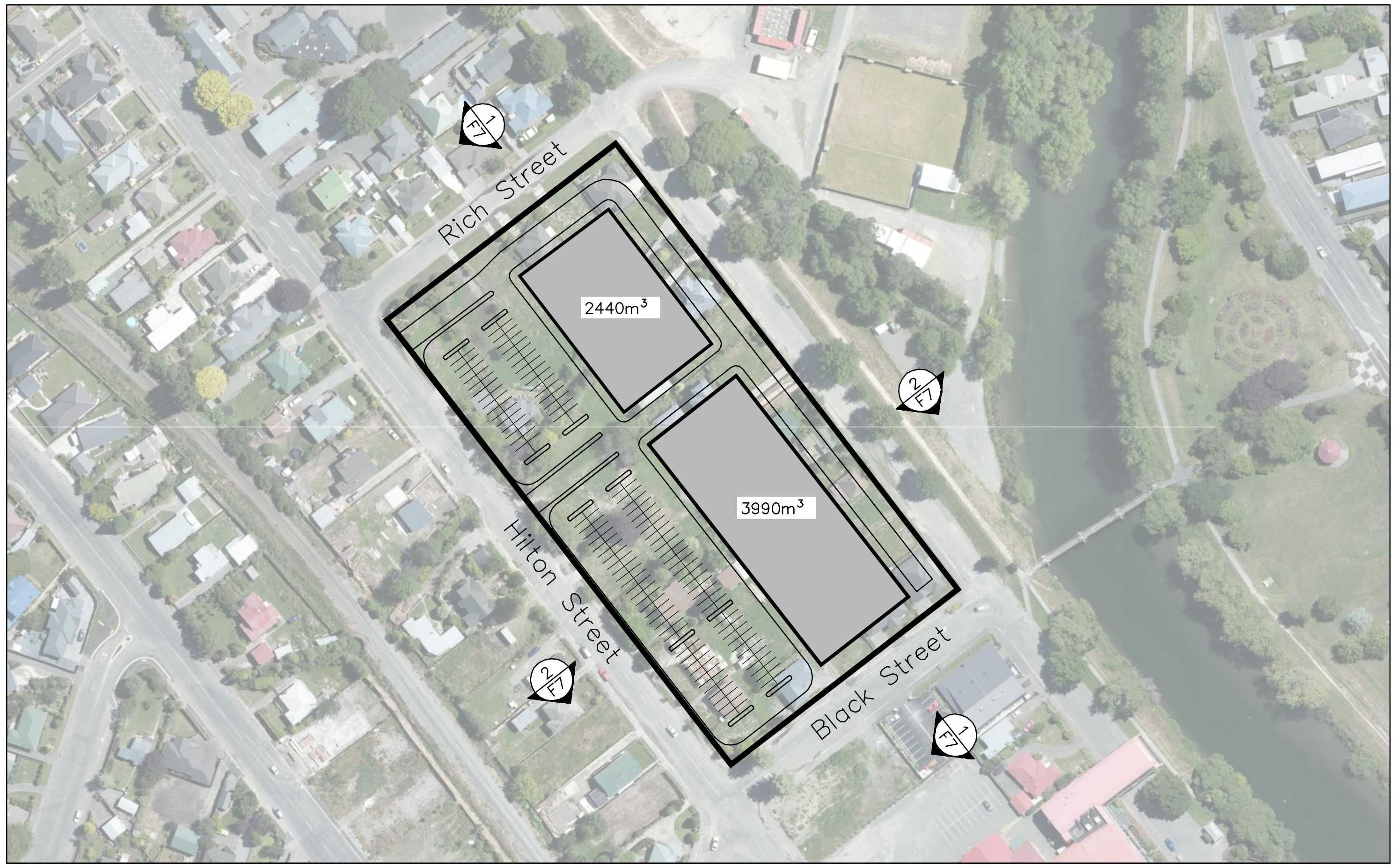
DRAWN	NSW	Jan. 16
DRAFTING CHECKED	TM	1/16
APPROVED	MEJ	1/16
CADFILE: \\52082.0300–F4_F5.dwg		
SCALES (AT A3 SIZE) 1:5000		
PROJECT No. 52082.0300		

WAIMAKARIRI DISTRICT COUNCIL

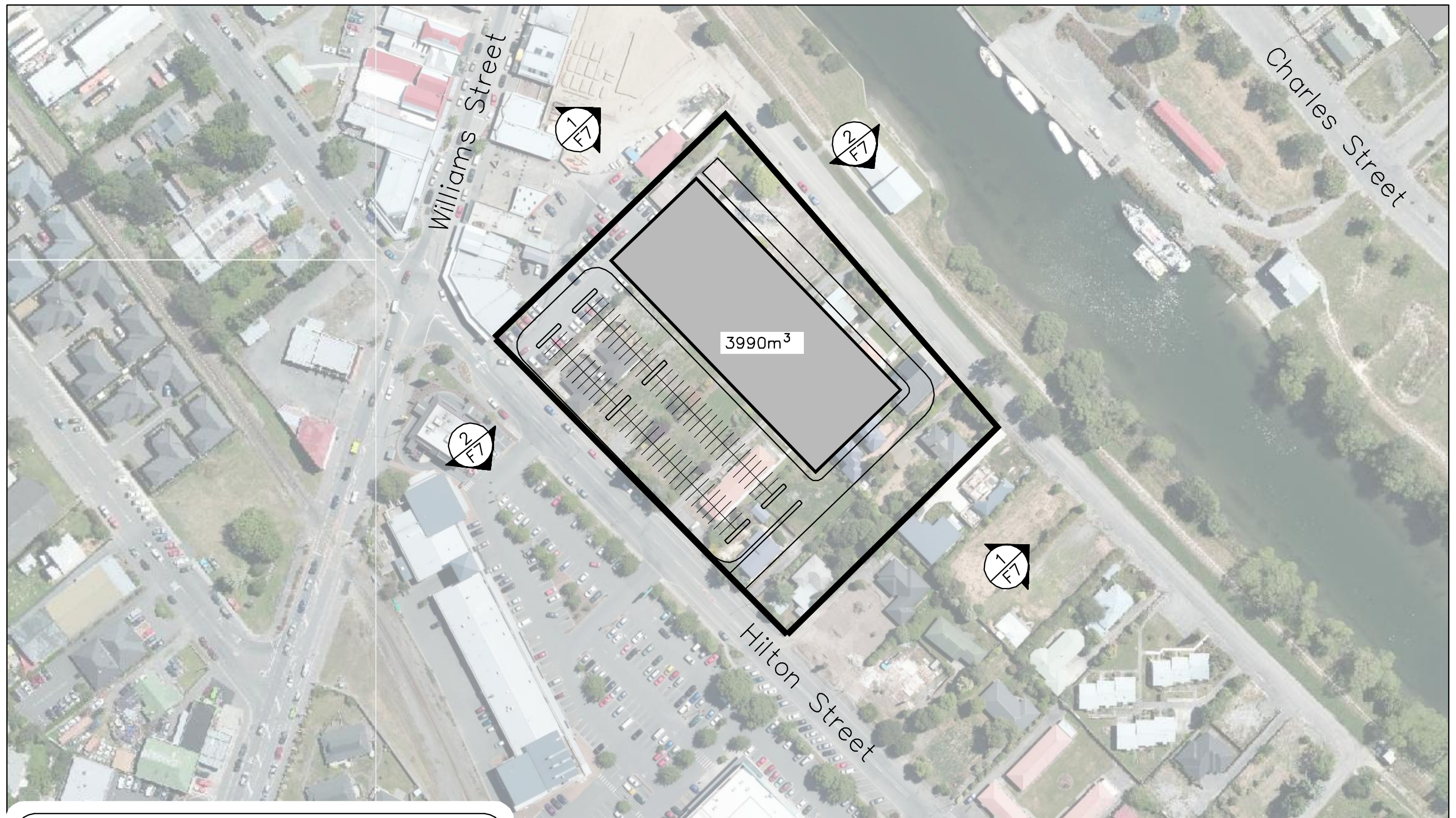
KAIAPOI COMMERCIAL RED ZONE PRELIMINARY CONCEPT OVERALL AREAS C, D1–3, AND E1–2

Site Layout Plan

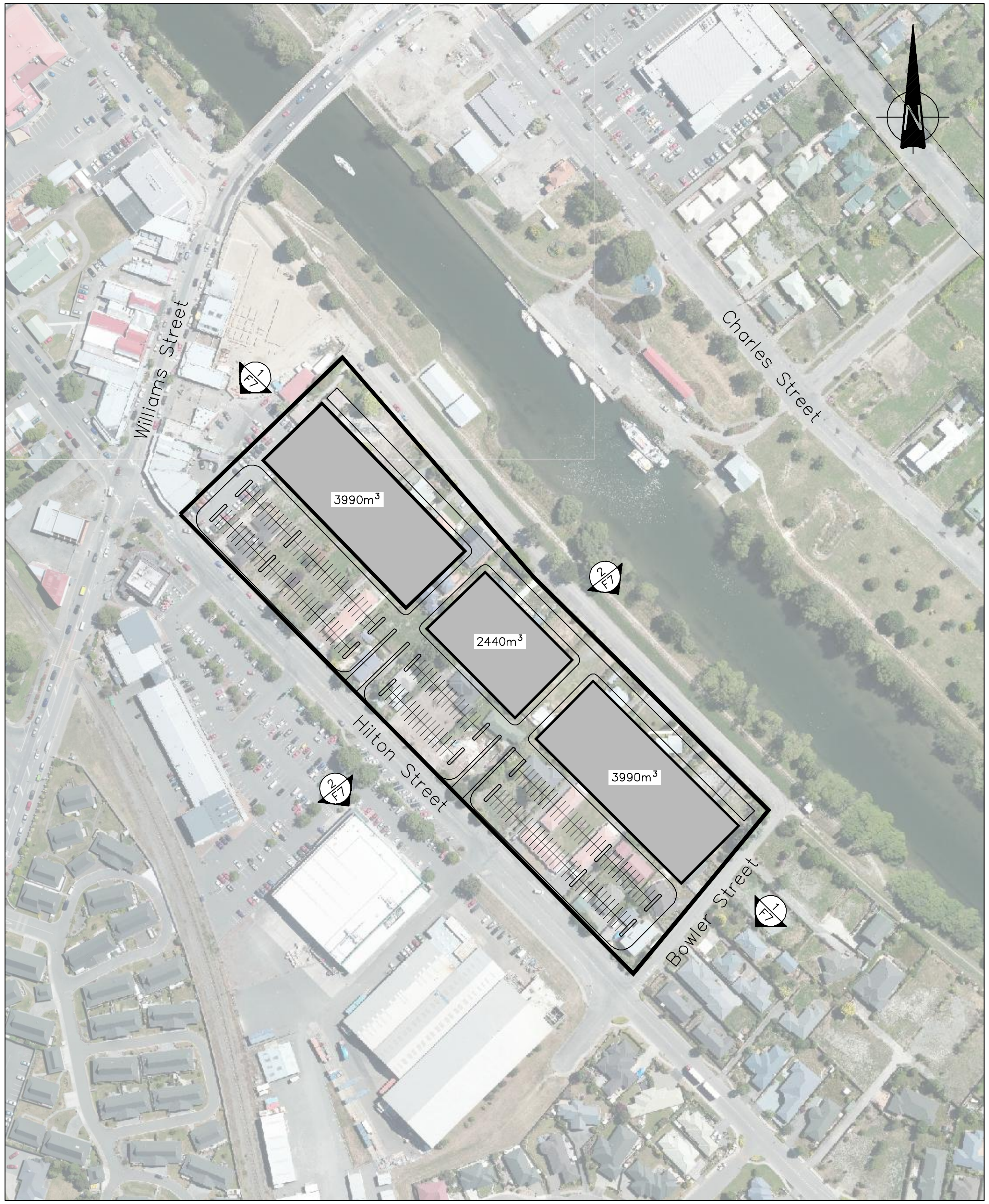
FIG. No. 52082.0300–F4 REV. 0



AREA C



AREA E1



AREA E2

LEGEND

- Proposed Building Location
- Site Extents
- Property Boundaries

A3 SCALE 1: 2500

0 50 100 150 (m)

ORIGINAL IN COLOUR

NOTES:
1. Aerial photo sourced from Linz Data Service <https://data.linz.govt.nz/layer/Canterbury 0.4m Rural Aerial Photos (2012–2013)> , licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence (CC BY 3.0 NZ)
2. Property boundaries sourced from Terralink International (Copyright 2002–2005 Terralink International Limited and its licensors).

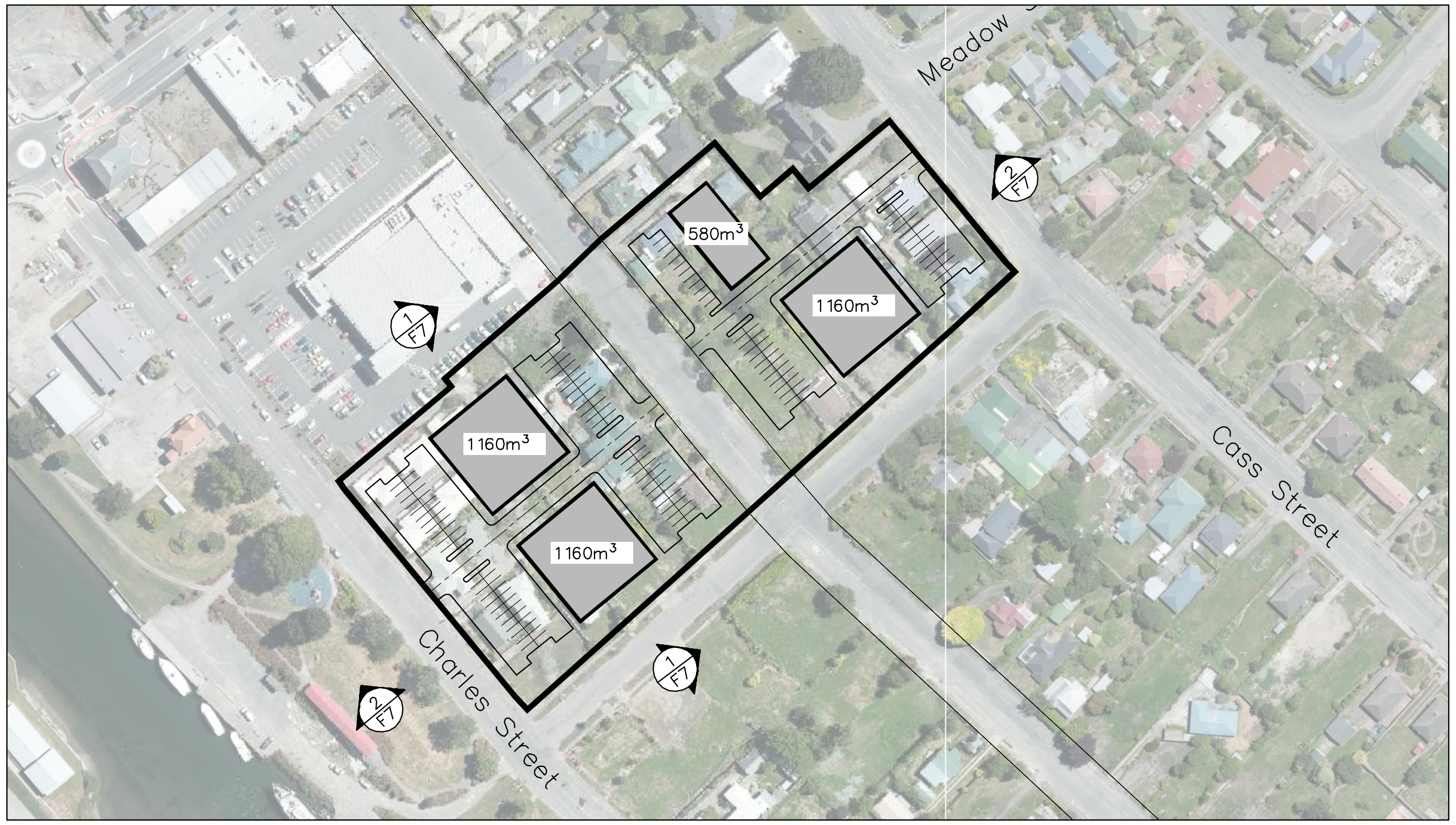
Tonkin+Taylor
33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

DRAWN	NSW	Jan. 16
DRAFTING CHECKED	TM	1/16
APPROVED	MEJ	1/16
CADFILE : \\52082.0300–F4_F5.dwg		
SCALES (AT A3 SIZE) 1: 2500		
PROJECT No. 52082.0300		

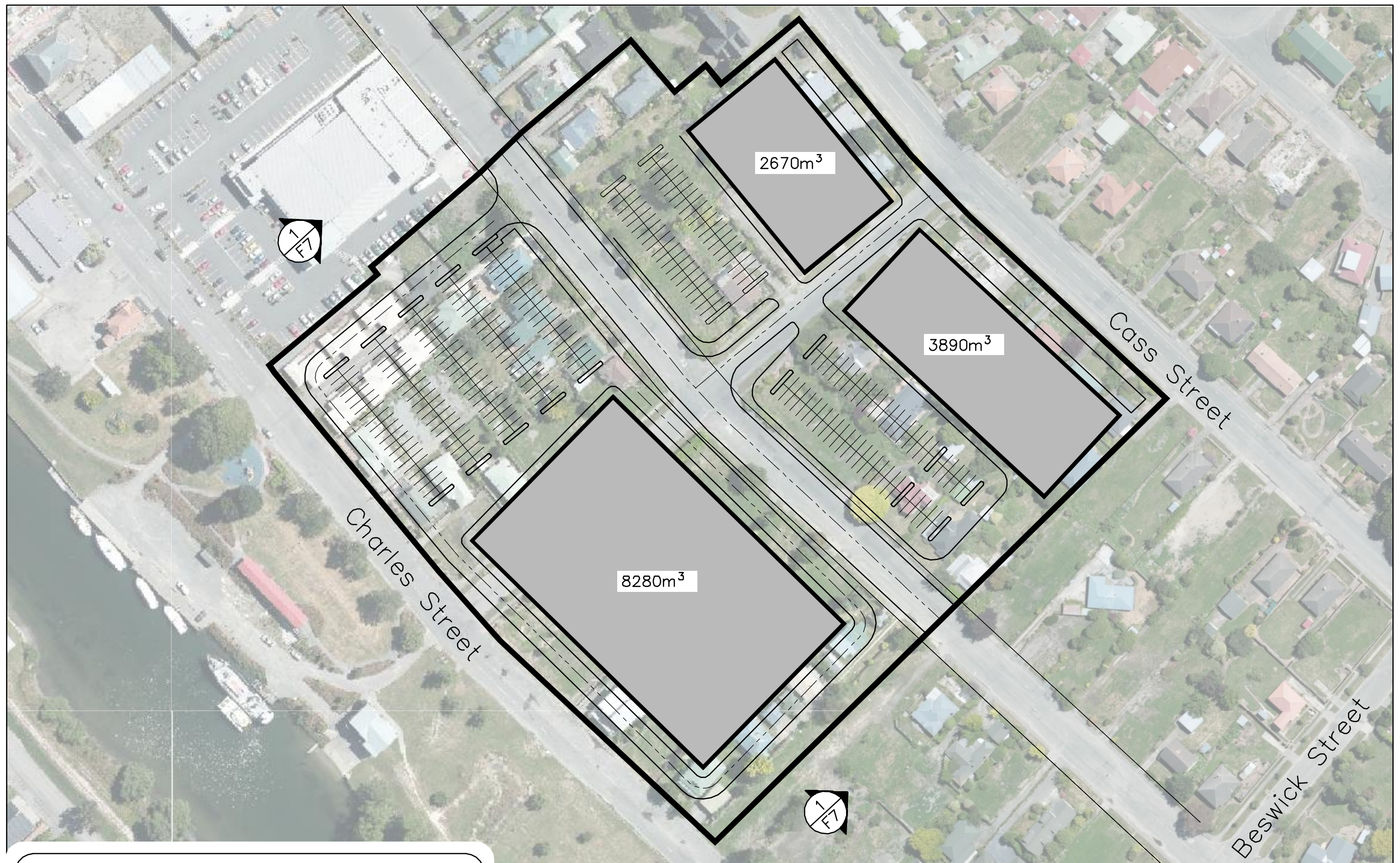
WAIMAKARIRI DISTRICT COUNCIL
KAIAPOI COMMERCIAL RED ZONE PRELIMINARY CONCEPT OVERALL AREAS C, D1–3, AND E1–2
Detailed Site Layout Plan (Areas 'C', 'E1' and 'E2')

FIG. No. 52082.0300–F5
REV. 0

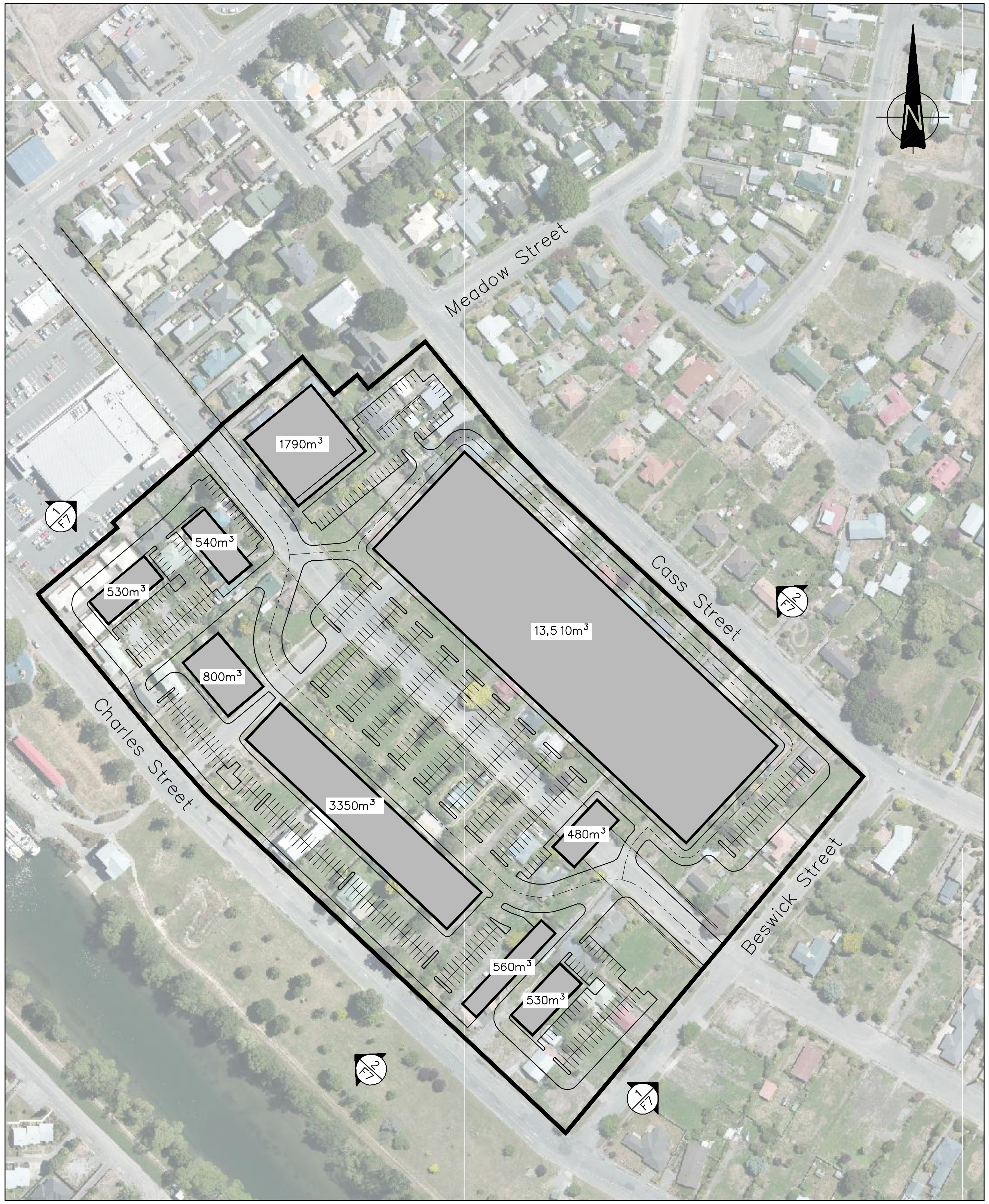
P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300-F4_F5.dwg, F5, 29/01/2016 1:12:08 p.m., raxb



AREA D1



AREA D2



AREA D3

LEGEND

- Proposed Building Location
- Site Extents
- Property Boundaries

A3 SCALE 1:2500

0 50 100 150 (m)

ORIGINAL IN COLOUR

NOTES:

1. Aerial photo sourced from Linz Data Service <https://data.linz.govt.nz/layer/Canterbury 0.4m Rural Aerial Photos (2012–2013)>, licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence (CC BY 3.0 NZ)
2. Property boundaries sourced from Terralink International (Copyright 2002–2005 Terralink International Limited and its licensors).

Tonkin+Taylor

33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

DRAWN	NSW	Jan. 16
DRAFTING CHECKED	TM	1/16
APPROVED	MEJ	1/16
CADFILE : \\52082.0300–F4_F5.dwg		
SCALES (AT A3 SIZE) 1:2500		
PROJECT No. 52082.0300		

WAIMAKARIRI DISTRICT COUNCIL

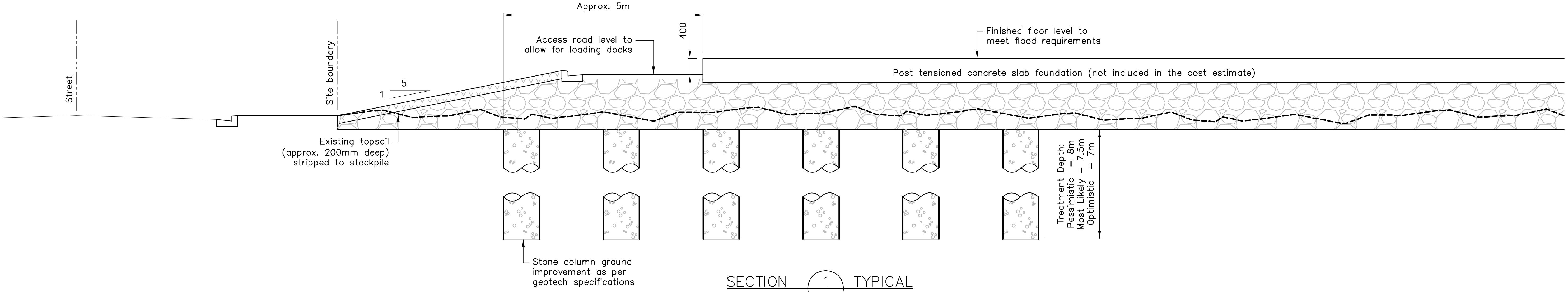
KAIAPOI COMMERCIAL RED ZONE PRELIMINARY CONCEPT OVERALL AREAS C, D1–3, AND E1–2

Detailed Site Layout Plan (Areas 'D1', 'D2', and 'D3')

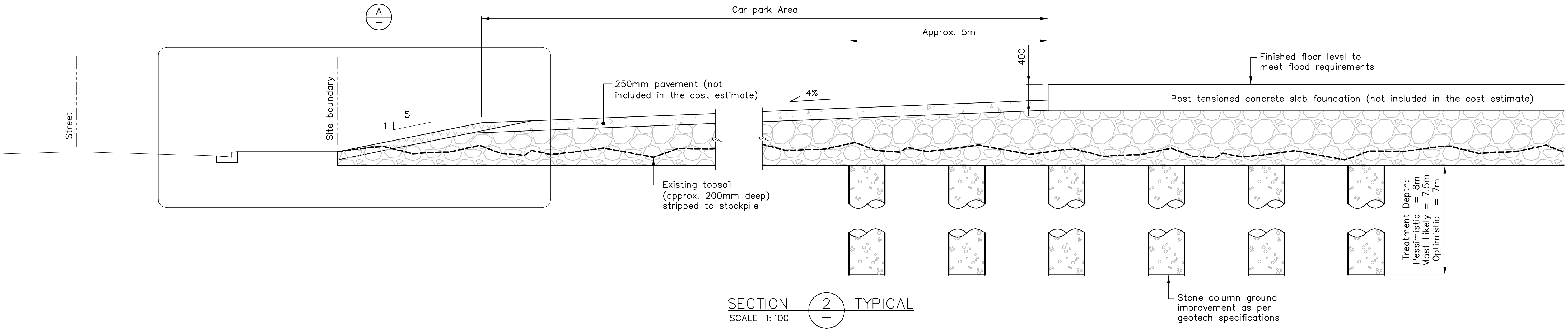
FIG. No. 52082.0300–F6

REV. 0

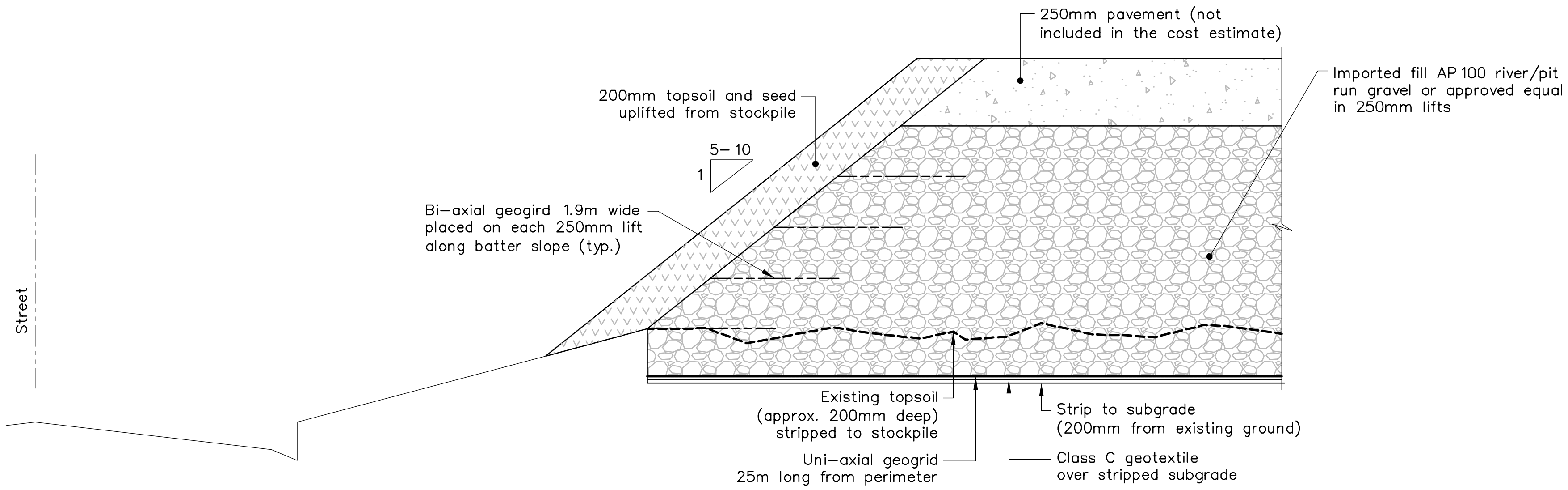
P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300–F4_F5.dwg, F6, 29/01/2016 1:12:35 p.m., raxb



SECTION 1 TYPICAL
SCALE 1: 100



SECTION 2 TYPICAL
SCALE 1: 100



DETAIL A
HORIZONTAL SCALE 1: 100
VERTICAL SCALE 1:25

A3 SCALE 1: 100
0 1 2 3 4 5 (m)

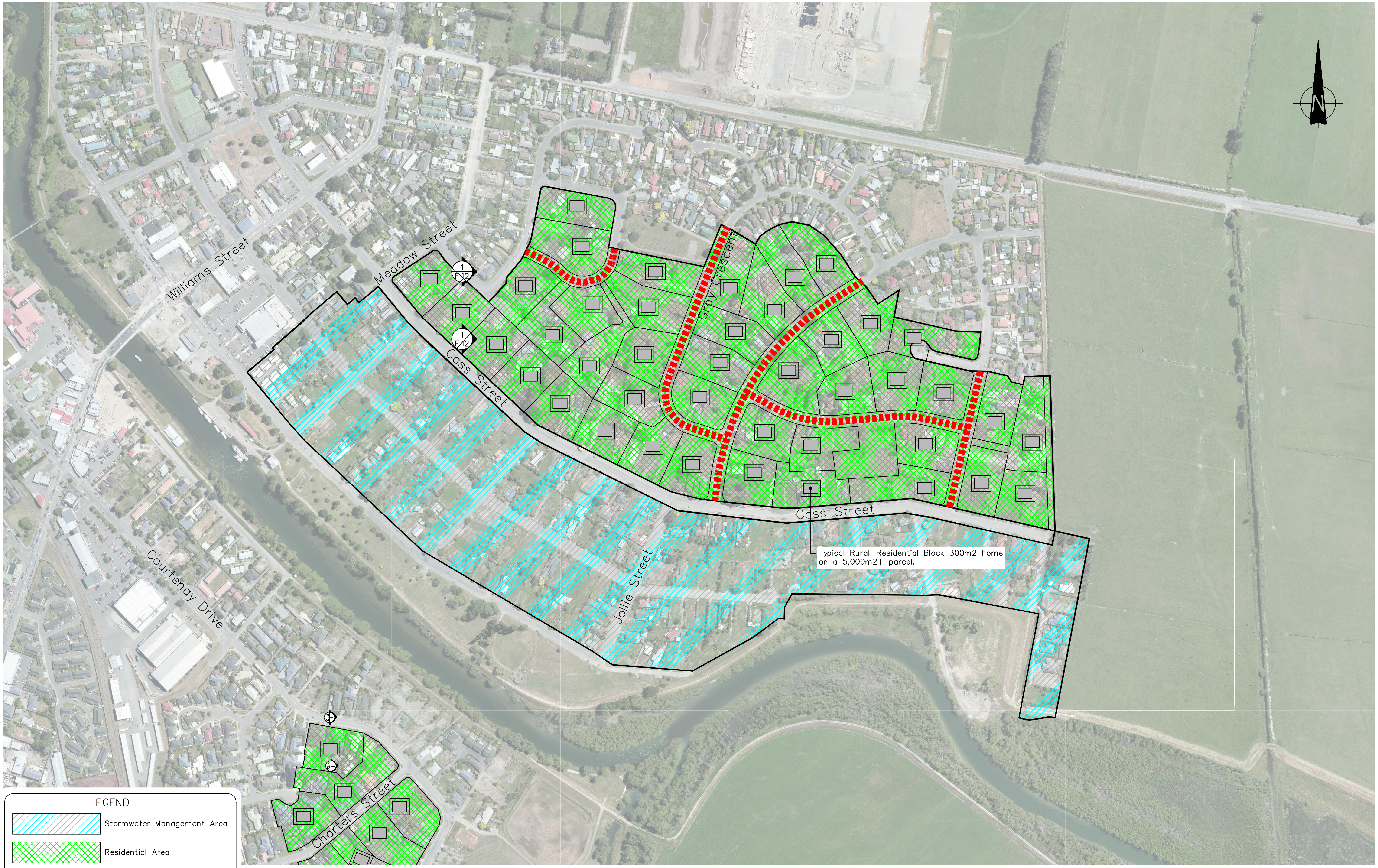
P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300-F7.dwg, Layout1, 29/01/2016 1:13:01 p.m., raxb

Tonkin+Taylor
33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

DRAWN	NSW	Jan. 16
DRAFTING CHECKED	TM	1/16
APPROVED	MEJ	1/16
CADFILE : \\52082.0300–F7.dwg		
SCALES (AT A3 SIZE) 1: 100		
PROJECT No. 52082.0300		

WAIMAKARIRI DISTRICT COUNCIL
KAIAPOI COMMERCIAL RED ZONE PRELIMINARY CONCEPT OVERALL AREAS C, D1–3, AND E1–2
Earthworks Sections

FIG. No. 52082.0300–F7
REV. 0



ORIGINAL IN COLOUR

NOTES:
1. Aerial photo sourced from Linz Data Service <https://data.linz.govt.nz/layer/Canterbury 0.4m Rural Aerial Photos (2012–2013)> , licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence (CC BY 3.0 NZ)
2. Property boundaries sourced from Terralink International (Copyright 2002–2005 Terralink International Limited and its licensors).

Tonkin+Taylor
33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

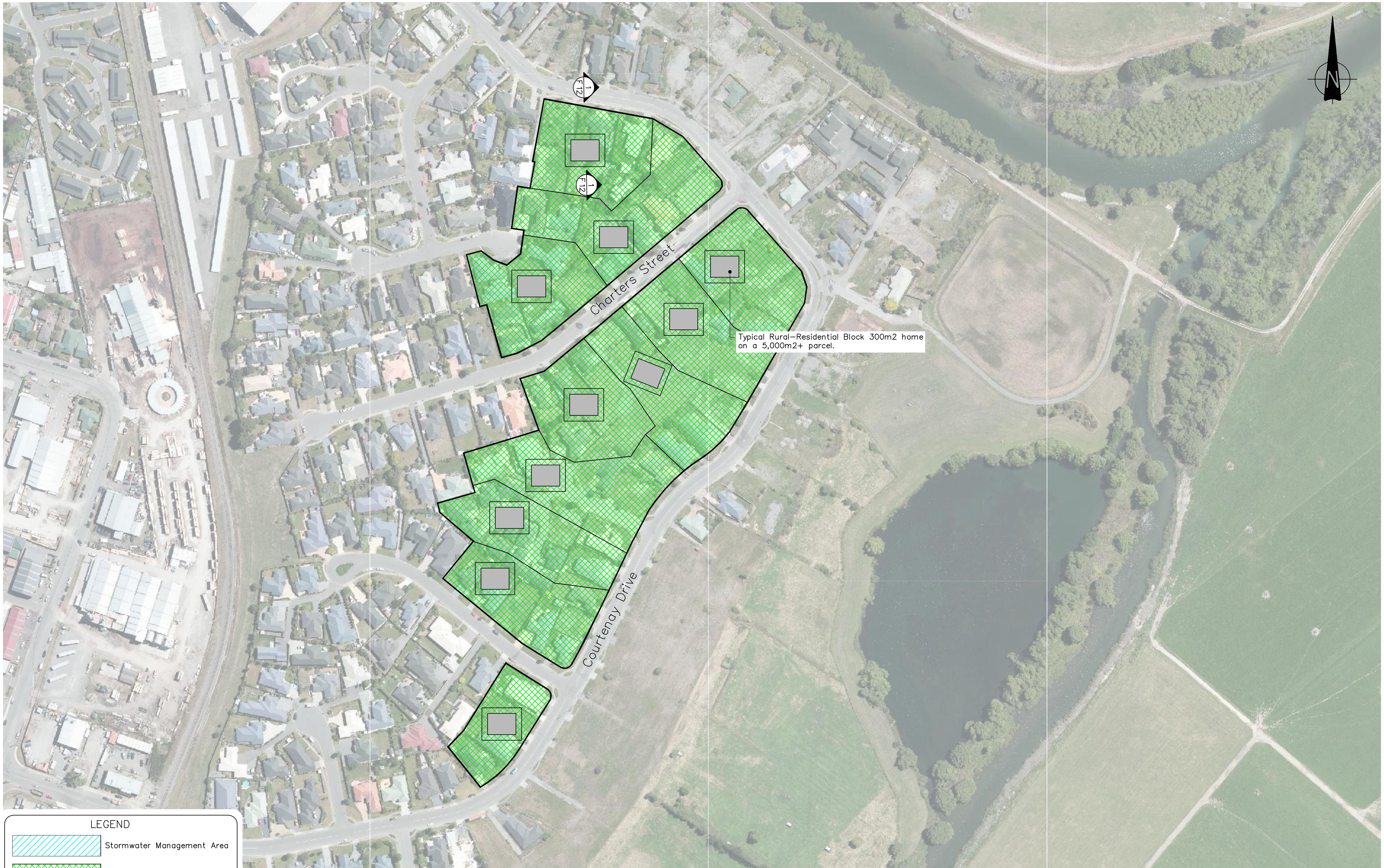
DRAWN	NSW	Jan. 16
DRAFTING CHECKED	TM	1/16
APPROVED	MEJ	1/16

CADFILE : \\52082.0300–F8_F9.dwg
SCALES (AT A3 SIZE) 1:5000
PROJECT No. 52082.0300

WAIMAKARIRI DISTRICT COUNCIL
KAIAPOI RESIDENTIAL RED ZONE PRELIMINARY CONCEPT KAIAPOI NORTH & COURTENAY DRIVE
Rural–Residential Site Layout Plan (Sheet 1 of 2)

FIG. No. 52082.0300–F8
REV. 0

P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300-F8_F9.dwg, Layout1, 29/01/2016 1:13:20 p.m., raxb



LEGEND

- Stormwater Management Area
- Residential Fill Area
- Property Boundaries

A3 SCALE 1: 2500

0 50 100 150 (m)

ORIGINAL IN COLOUR

NOTES:

1. Aerial photo sourced from Linz Data Service <https://data.linz.govt.nz/layer/Canterbury 0.4m Rural Aerial Photos (2012–2013)> , licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence (CC BY 3.0 NZ)
2. Property boundaries sourced from Terralink International (Copyright 2002–2005 Terralink International Limited and its licensors).

Tonkin+Taylor

33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

DRAWN	NSW	Jan. 16
DRAFTING CHECKED	TM	1/16
APPROVED	MEJ	1/16
CADFILE : \\52082.0300–F8_F9.dwg		
SCALES (AT A3 SIZE) 1: 2500		
PROJECT No. 52082.0300		

WAIMAKARIRI DISTRICT COUNCIL

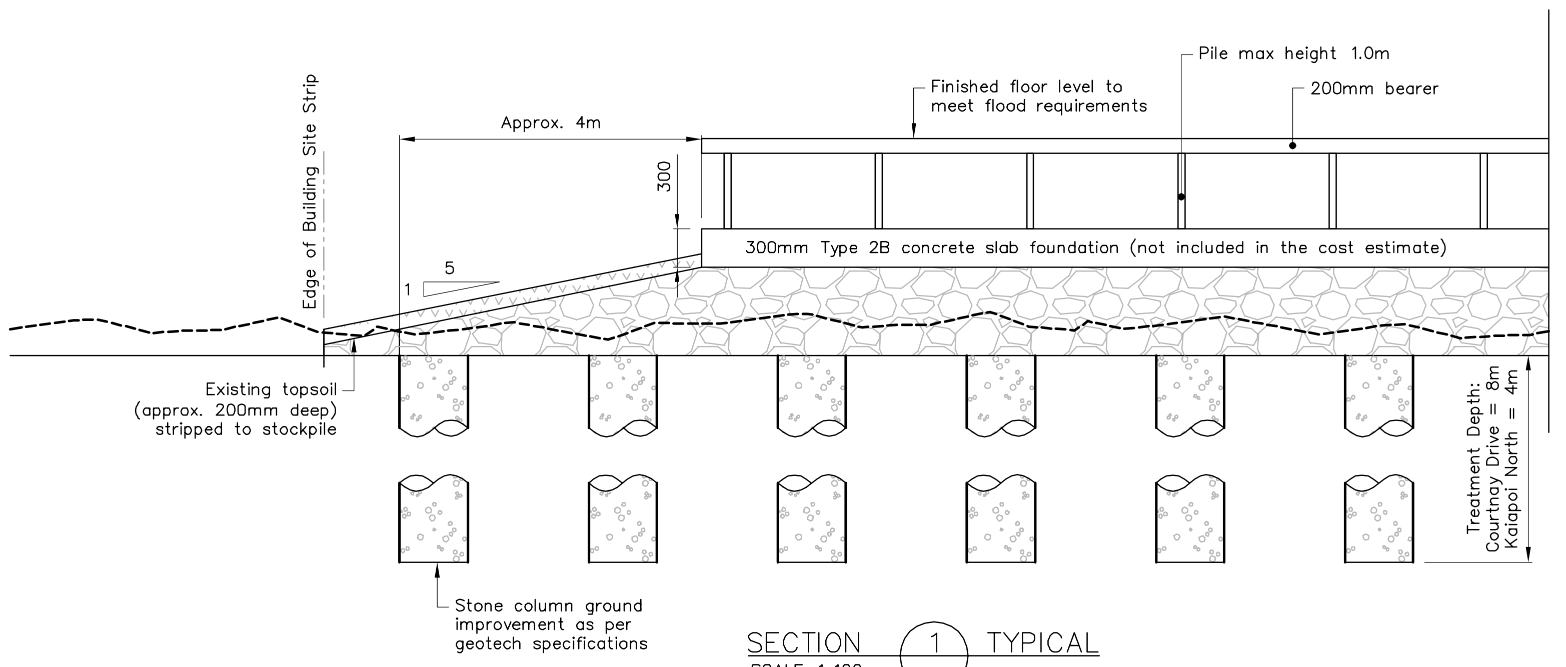
KAIAPOI RESIDENTIAL RED ZONE PRELIMINARY CONCEPT KAIAPOI NORTH & COURTENAY DRIVE

Rural–Residential Site Layout Plan (Sheet 2 of 2)

FIG. No. 52082.0300–F9

REV. 0

P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300-F8_F9.dwg, Layout1 (2), 29/01/2016 1:13:50 p.m., raxb



SECTION 1 TYPICAL
SCALE 1:100

A3 SCALE 1:100
0 1 2 3 4 5 (m)

DRAWN	NSW	Jan. 16
DRAFTING CHECKED	TM	1/16
APPROVED	MEJ	1/16
CADFILE : \\52082.0300–F10.dwg		
SCALES (AT A3 SIZE) 1:100		
PROJECT No. 52082.0300		

Tonkin+Taylor
33 Parkhouse Road, Wigram, Christchurch
www.tonkintaylor.co.nz

WAIMAKARIRI DISTRICT COUNCIL
KAIAPOI RESIDENTIAL RED ZONE PRELIMINARY CONCEPT KAIAPOI NORTH & COURTNAY DRIVE
Rural–Residential Blocks Earthworks Sections

FIG. No. 52082.0300–F10
REV. 0

P:\52082\52082.0300\WorkingMaterial\CAD\FIGS\52082.0300-F10.dwg, Layout1, 29/01/2016 1:14:20 p.m., raxb

www.tonkintaylor.co.nz