Appendix C: Sensitivity assessment of bathtub approach

Memo

To:	**Chch CHA Technical Reviewers**	**Job No:**	**1012976**
From:	**T+T technical team**	**Date:**	**20 October 2020**
Subject:	**Comparison of bathtub modelling with hydrodynamic modelling**		

1 Introduction

As part of the Christchurch City Council (CCC) Coastal Hazards Assessment (CHA) study, CCC require technical assessment to identify areas potentially susceptible to coastal inundation around Christchurch City. This memo explores the technical and practical advantages and disadvantages of two flood modelling options which are being considered for the CHA study: "bathtub modelling" and "hydrodynamic modelling".

The focus of the current CHA technical assessment is to produce "base" hazard information that can then feed into community engagement, risk evaluation and risk mitigation and adaptation planning undertaken by CCC in the future. Given the intent of the data usage for high-level public engagement and adaptation planning, and the large number of scenarios to be considered, T+T has proposed to adopt a connected-bathtub modelling approach to assess the approximate potential coastal inundation extents around Christchurch City. This approach is simpler than the alternative hydrodynamic modelling approach that has been previously applied, but the flexibility and responsiveness that it offers means that is considered more suitable for the specific intended purpose of this study (i.e. the initial engagement and risk evaluation stages of adaptation planning).

2 Modelling approach

The previous T+T (2017) assessment utilised a hydrodynamic model to assess the extent of storm tide propagation within the Avon-Heathcote Estuary and Brooklands lagoon. A hydrodynamic model has technical advantages compared to simpler approaches (such as bath tub modelling), because it takes full account of hydraulic performance that can limit the inundation extents based on tidal duration (i.e. there is a limit to how far floodwater can travel before the tide turns). However, the hydrodynamic modelling approach brings with it some practical disadvantages, for example:

- It is reliant on accurate definition of the boundary and forcing conditions such as the tidal boundary, fresh water inflows and wind. A hydrodynamic model requires values for all fresh water inflows whether static or time-varying, and there are numerous permutations that might be considered for joint probability between extreme sea level and stream/river flow.
- Hydraulic performance should be calibrated using data from the area of interest for similar scenarios. This brings in factors such as hydraulic roughness, vegetation growth and channel definition from the DEM that are not considered using a bathtub approach.
- Previous modelling noted difficulties accurately defining the seaward boundary including potential wave set up over Sumner Bar, and in defining the coincident rivers flow and winds. This is notably more complex if these boundaries are time-varying as would normally be applied in a hydrodynamic model. The bathtub approach avoids this.

- It is highly sensitive to the ground elevation model adopted, so results can be substantially impacted by small changes due to natural measurement variability between different ground level surveys (new LiDAR data has become available since the previous T+T hydrodynamic model was developed), and small changes in ground level (e.g. localised earthworks). This is particularly the case where hydraulic performance is dictated by bathymetry and channel dimensions
- The peak levels attained are subject to influence from surface water flow from streams and rivers, and these inflows demand careful consideration to ensure that a robust approach to joint probability between rainfall and sea condition is maintained.

These disadvantages make hydrodynamic analysis less useful than bathtub modelling for assessing scenarios where these future conditions and calibration parameters are unknown or highly uncertain. Furthermore, a more comprehensive city-wide flood model has been developed by CCC (since the 2017 T+T assessment) which can be used when more detailed modelling results are required in a specific location for other purposes (e.g. for setting floor levels or for detailed design of infrastructure). This means that a bathtub modelling approach is being considered as a methodology option for the current high-level coastal hazard assessment.

The bathtub approach would enable the updated coastal inundation assessment to be based on the latest available 2018 LiDAR ground level survey, and be readily updated for future ground surface models or to examine the effectiveness of any physical mitigation options being considered. This could also be achieved through re-development of a hydrodynamic model, but would require substantial time and cost to re-develop and calibrate (limiting the number of adaption scenarios that could practically be considered); and would still leave uncertainty regarding the absolute accuracy of model results because of uncertainty in the input parameters. The bathtub approach also utilises the specific extreme levels derived at gauges within the estuaries (so is directly linked to actual physical observations) rather than having to develop boundary conditions and achieve a match in the model.

The primary disadvantage of a bathtub modelling approach is that all areas across the city below the specified bathtub level are identified as inundated, which does not allow for changes in flood levels further away from the coast and rivers (although connected and unconnected areas can be separately defined). This means that it has a tendency to over-predict the absolute extent of coastal flooding for a specific scenario. It should also be noted that under flood event conditions, the bathtub model may under-predict extreme inundation.

However this tendency for over-prediction can be taken into account during adaptation planning, and the following key concepts clearly communicated in adaptation discussions:

- The bathtub analysis results are indicative rather than precise, so are best used to understand relative changes in risk from different adaptation options, rather than quantifying the absolute level of risk.
- An additional “buffer” should not be applied beyond the modelled areas, as the modelled extent already includes a degree of conservatism at the edges.
- The absolute accuracy of the results can vary across the study area and for different water levels and adaptation scenarios (e.g. the results may be more conservative in some situations, and less conservative in others).
- Uncertainty in future conditions (e.g. sea level and storm events) can have a more significant effect on inundation extent that the modelling approach, so adaptation planning should consider a range of possible future scenarios rather than focussing on a single model output.

In order to assess the suitability of the bathtub modelling method for use on this project, it has been compared with outputs from two different hydrodynamic models. The model comparisons and conclusions are presented within this memo.

3 Model results

The two hydrodynamic models which have been compared with bathtub modelling are the T+T (2017) TUFLOW model used for the previous coastal hazard assessment, and the CCC city-wide flood model which is used for a range of purposes (such as setting minimum floor levels). A description of the models and their assumptions is outlined below.

3.1 T+T (2017) TUFLOW model

T+T (2017) utilised a hydrodynamic model based on a surface water drainage model previously developed for the purpose of flood level estimation in response to rainfall events. Instead of allowing the model to respond to rainfall inputs, the revised model was run with zero rainfall (and hence zero inflow from rivers, drains, streams etc to the estuary) and was used to assess hydrodynamic response to storm tide applied at the seaward boundary. The “zero inflow” assumption was arrived at through agreement, in recognition of this being a simplification of the likely response. It was recognised that extreme sea level conditions were likely to occur concurrently with some rainfall, and whether or not this rainfall would be statistically significant was not able to be confirmed by analysis of past records with the period of record being of insufficient length. This brought into question the joint probability between rainfall and sea level. While a joint probability approach is suggested in the CCC WWDG, there is difficulty in attempting to simulate these events hydrodynamically. The reason for this is the timing between high tide and peak flow. Each of the waterways that contributes flow to the estuary is likely to have its own time of concentration, and it would not be possible to simulate a single tidal time series to make high tide occur concurrently with peak flow from all waterways. Sensitivity assessment indicated that peak water levels close to the coast are dominated by tidal conditions, and that further from the coast the peak levels would be dominated by surface flow. It was recognised that there is a margin within which the combination of flow and sea level gives rise to peak levels, but this was knowingly simplified in the 2017 modelling undertaken.

The model was constructed using the TUFLOW software package. The model includes the Avon, Heathcote and Styx catchments (Figure 3.1). Also shown in Figure 3.1 are the locations of key water level recording sites. For the model terrain, a bare earth digital elevation model (DEM) at 2 m resolution was created using a combination of LiDAR and estuary bathymetry files stitched together to make one DEM. The majority of the model used LiDAR data collected following the December 2011 Christchurch earthquake. Where LiDAR data were not available the model used LiDAR flown following the June 2011 Earthquake. The Avon-Heathcote Estuary bathymetry was based on surveys from March/April 2011 and January 2013 by NIWA.

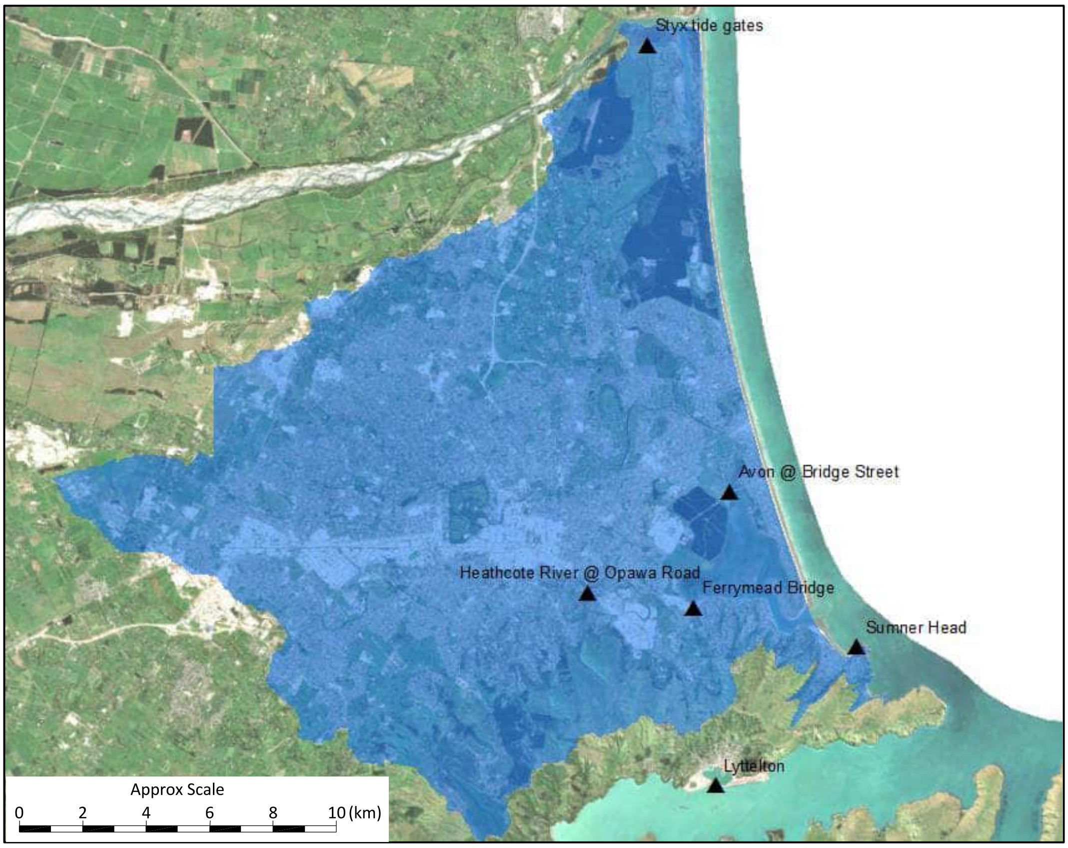

Figure 3.1: Extent of T+T (2017) TUFLOW model.

T+T (2017) applied a dynamic sea level as a downstream boundary condition, using a “building bock” approach which included the effects of astronomical tide, storm surge, an allowance for wave set up over Sumner Bar and sea level rise for future timeframes.

An important consideration with this modelling approach is that the results were mapped with a zero rainfall assumption. This means that there was no flow in the waterways that drain towards the estuary and Brooklands Lagoon at the time of the extreme sea level event. Given that storm surge is a contributor to extreme sea level, and that same storm could also cause rainfall at the same time, it is possible for a rainfall event of some magnitude to occur concurrently with the extreme sea level. In CCC guidance[1] the joint probability between rainfall and extreme sea level is specified, but due to differing response times of the many freshwater inflows, it is difficult to simulate these such that peak discharge and peak sea level occur concurrently. This is why this was not undertaken for the 2017 hydrodynamic modelling approach.

[1] CCC (2003), *Waterways, Wetlands and Drainage Guide – Ko Te Anga Whakaora mo Nga Arawai Repo*, Part B: Design, Christchurch City Council, February 2003.

3.2 CCC city-wide flood model

CCC have been undertaking the City-wide Flood Modelling Project (GHD, 2018). The main aims of the project are to increase the level of detail and produce an integrated city-wide model that includes the Avon, Heathcote, Parklands, Sumner, Styx and Halswell River catchments. Only the Avon catchment model has been provided for this model comparison (Figure 3.2).

In development of this CCC city-wide flood modelling, the models are set up to assess the contributions from both extreme sea level and statistically significant rainfall. Note that this differs from the T+T (2017) TUFLOW modelling approach, which assumed zero rainfall.

The current model is an 'existing' post-quake model calibrated with the March 2014 flood event. The current model is based on 2011 LiDAR, however where there were significant changes between the LiDAR data and the March 2014 model, modifications are understood to have been made. At the coastal boundary where there is no LiDAR the terrain has been artificially extended as a 2% slope down to below -3 mRL (LVD37). This is to ensure it extends below the low tide level of approximately -1 mRL (LVD37). The minimum mesh element is $12m^2$ (road width) and the maximum mesh element is $200m^2$ (flat land).

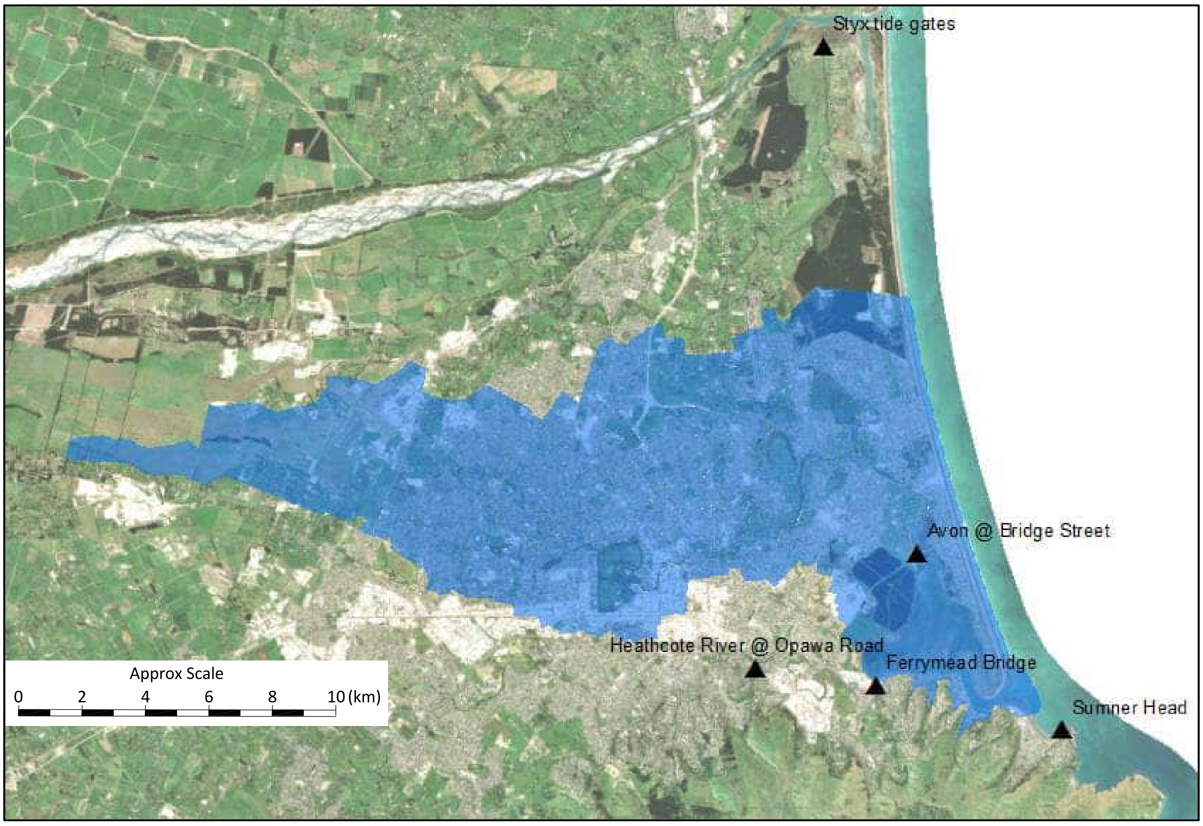

Figure 3.2: Extent of Avon catchment within the city-wide flood model.

The results from this model include both extreme sea level and input rainfall, such that there is not zero freshwater inflow to the coastal areas under design event conditions.

Using CCC guidance[2], the extreme flood levels in coastal areas can be influenced both by extreme rainfall and by extreme sea level. The guidance sets out the differing event likelihoods that should be combined to produce extreme flood level estimates. For example, to establish extreme flood level in response to a 1%AEP event, two separate events are specified, as follows:

- 1%AEP rainfall event, combined with 10%AEP sea level event
- 10%AEP rainfall event, combined with 1%AEP sea level event

The maximum water levels reached across the envelope of the two events above are combined, to yield the 1%AEP water levels. This approach is often termed “max-of-max”, where the results are enveloped.

Rainfall is generally applied to the model as “direct rainfall” or “rain-on-grid” rainfall. This means that every cell in the model receives rainfall and can therefore be classified as “wet”. For this reason it is necessary to adopt a depth threshold, below which flood depths are not considered relevant. In most cases any flood depths predicted, at maximum, to be less than 0.1 m are deleted with only cells where predicted flood depth exceeding 0.1 m being shown to be flood affected.

3.3 Bathtub model

The bathtub model identifies all areas that are below a defined water level connected to the coastline and characterises the depth at these locations. The bathtub also identifies non-connected areas which are below a defined water level. These areas are typically low-lying areas which may be susceptible to flooding through groundwater or through impeded surface water outlets.

The model is driven by a water level which is deemed representative of the inundated areas, in this case from water level gauges at Bridge St, Ferrymead Bridge and the Styx tide gates. Levels identified here will include components driving water levels such as tide, storm surge, river flows, rainfall, local wind effects and wave breaking over the Sumner and Waimakariri Bars. Extreme value analysis undertaken on these water levels implicitly includes these components without them having to be separated out and analysed separately in terms of their magnitude and joint likelihood of occurrence, as would be required for hydrodynamic modelling.

The downside is that only one level is identified for each catchment and so if this level varies significantly across an area in reality, the bathtub approach may under- or over-estimate flooded extents. However, the bathtub approach enables areas inundated under a range of water levels to be rapidly identified which is useful for engagement and adaptation planning where effects of incremental changes in event likelihood and sea level rise are of interest.

The bathtub model used for the following comparisons is based on the latest 2018 topographic LiDAR data which has been sourced as a 1m DEM (Figure 3.3).

[2] CCC (2003), *Waterways, Wetlands and Drainage Guide – Ko Te Anga Whakaora mo Nga Arawai Repo*, Part B: Design, Christchurch City Council, February 2003.

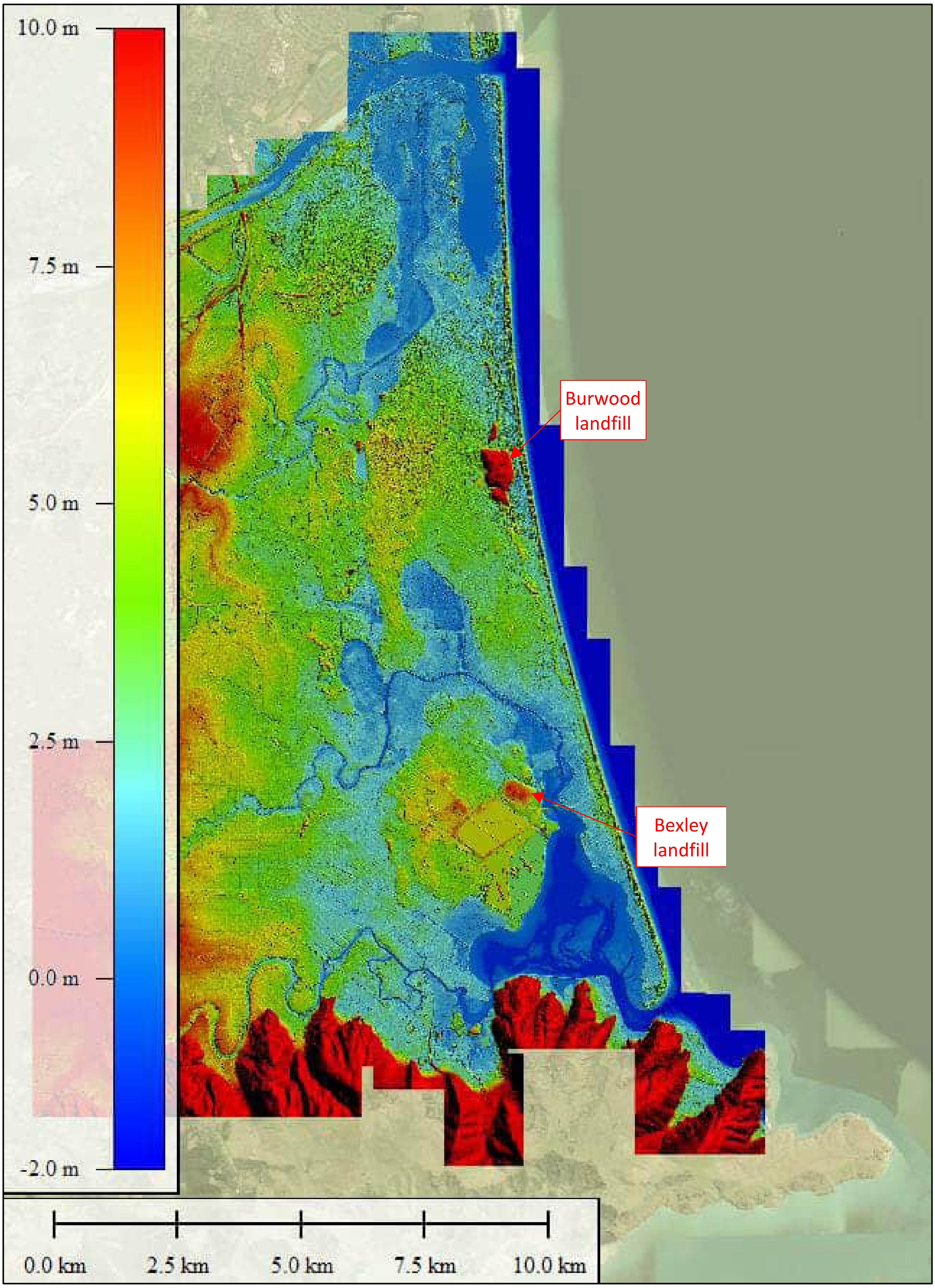

Figure 3.3: Example of 2018 DEM used for bathtub model.

4 Model comparisons

4.1 Comparison methodology

In order to assess the suitability of the bathtub approach for its intended purpose, comparisons were made against both hydrodynamic models. To cover the range of likely outcomes, sample results were taken for both low and high sea level rise scenarios from each of the hydrodynamic models.

Scenarios used for comparison are summarised in Table **4-1**. Peak water levels have been extracted from the hydrodynamic model outputs at three water level gauge locations (Bridge St, Ferrymead Bridge and Styx tide gates) (Table **4-1**). Based on the peak water levels from the two models for each scenario, an equivalent level was then used to drive the connected bathtub model. For the purposes of the comparison presented in this memo, which focusses on the Avon catchment results from the citywide flood model, the same level was applied in all catchments with a greater weighting given to the Bridge St level when setting this equivalent level. For the TUFLOW high sea level rise scenario the water level at Ferrymead Bridge is 0.2 m higher than the water level at Bridge St. For this scenario, a different bathtub level (3.2 m RL) was adopted for the Heathcote catchment. For the final bathtub analysis, levels will be selected separately for each of the three catchments.

Bathtub depths and extents connected to the coast were derived and filtered to show inundation extents for depths greater than 0.1 m. This was to make inundation extents comparable with both the TUFLOW and city-wide hydrodynamic model outputs (which use the same filtering, as discussed in Section 3.2).

For the CCC city-wide flood model, “max of max” water level raster files were provided by CCC for the Avon catchment. As the model results include rainfall it is not directly comparable with the bathtub model (i.e. flooding on every grid cell). The level from the city-wide model was converted to a depth by subtracting the model terrain. The estimated depths were then filtered to show depths greater than 0.1 m. The resultant file presented for model comparison is the maximum water level for areas where depths are greater than 0.1 m and are connected to the coastal margin or Avon River. Due to several differences in the model input and assumptions, the comparison between the bathtub model and city-wide flood model only provides an indicative comparison.

Table 4-1 **Scenarios and water levels for comparison between bathtub and hydrodynamic models**

Hydrodynamic model	**Scenario**	**Peak water level within hydrodynamic model (m LVD37)**			**Adopted water level for bathtub model (m LVD37)**
		Bridge St	**Ferrymead Bridge**	**Styx tide gates**	
T+T (2017) TUFLOW	Low sea level rise 2065 1% AEP RCP4.5	2.5	2.5	2.5	2.5
	High sea level rise 2115 1% AEP RCP8.5H+	3.0	3.2	3.1	3.0[1]
CCC (2020) city-wide flood model, Avon catchment	Present-day 0.2% AEP 0 m SLR	1.7	1.7	N/A	1.7
	High sea level rise 0.5% AEP 1.88 m SLR	4.0	3.9	N/A	4.0

[1]3.2 m bathtub scenario adopted for Heathcote catchment

4.2 DEM comparison

The three different models presented in this memo each use different ground elevation models, because they were developed at different times using the information then available. Slight differences in the DEMs used for each model are likely to contribute to some differences between the model outputs. The vertical accuracy of the 2018 DEM is +/-0.2m and the average difference between the 2018 DEM and the TUFLOW terrain is approximately 0.2m (Figure 4.1). The key differences are through Bottle Lake Forest (south of Brooklands Lagoon) and around the oxidation ponds near the Avon-Heathcote estuary, where the 2018 DEM is on average 0.2 m lower than the TUFLOW terrain.

There are also differences between the city-wide flood model terrain and the 2018 DEM (Figure 4.2). The typical difference is +/-0.2m with some of the key differences occurring due to filling associated with motorway, landfill and subdivision earthworks; along the stopbanks of the Avon River (possibly due to “burning-in” of stopbank crest levels); the Port Hills (possibly erroneous vertical difference caused by horizontal misalignment of the LiDAR survey over steep ground); and areas of changing vegetation in Travis Wetland and plantation forests between Burwood and Kainga.

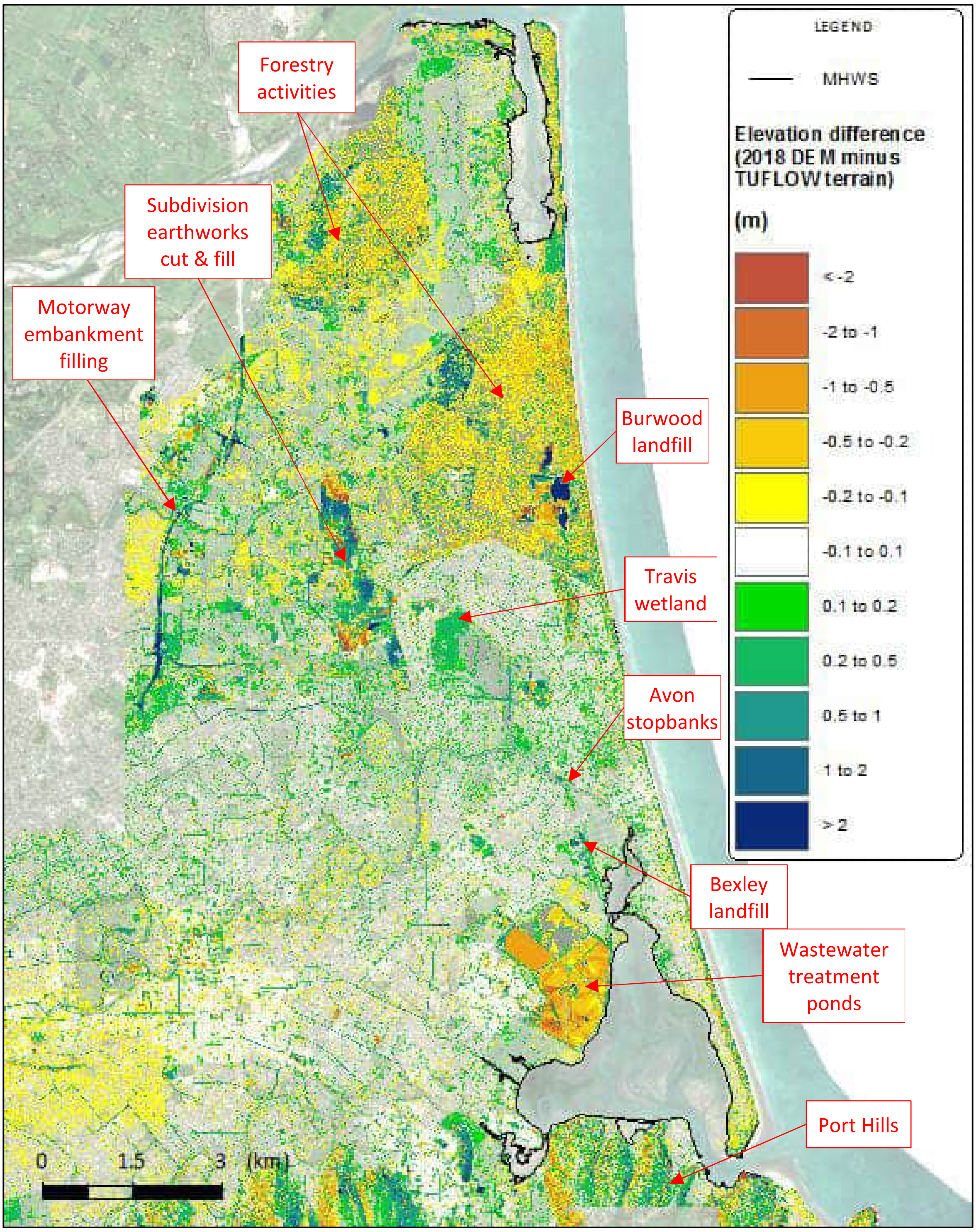

Figure 4.1: Elevation difference between the 2018 DEM used for the bathtub modelling and the terrain grid used within the TUFLOW model.

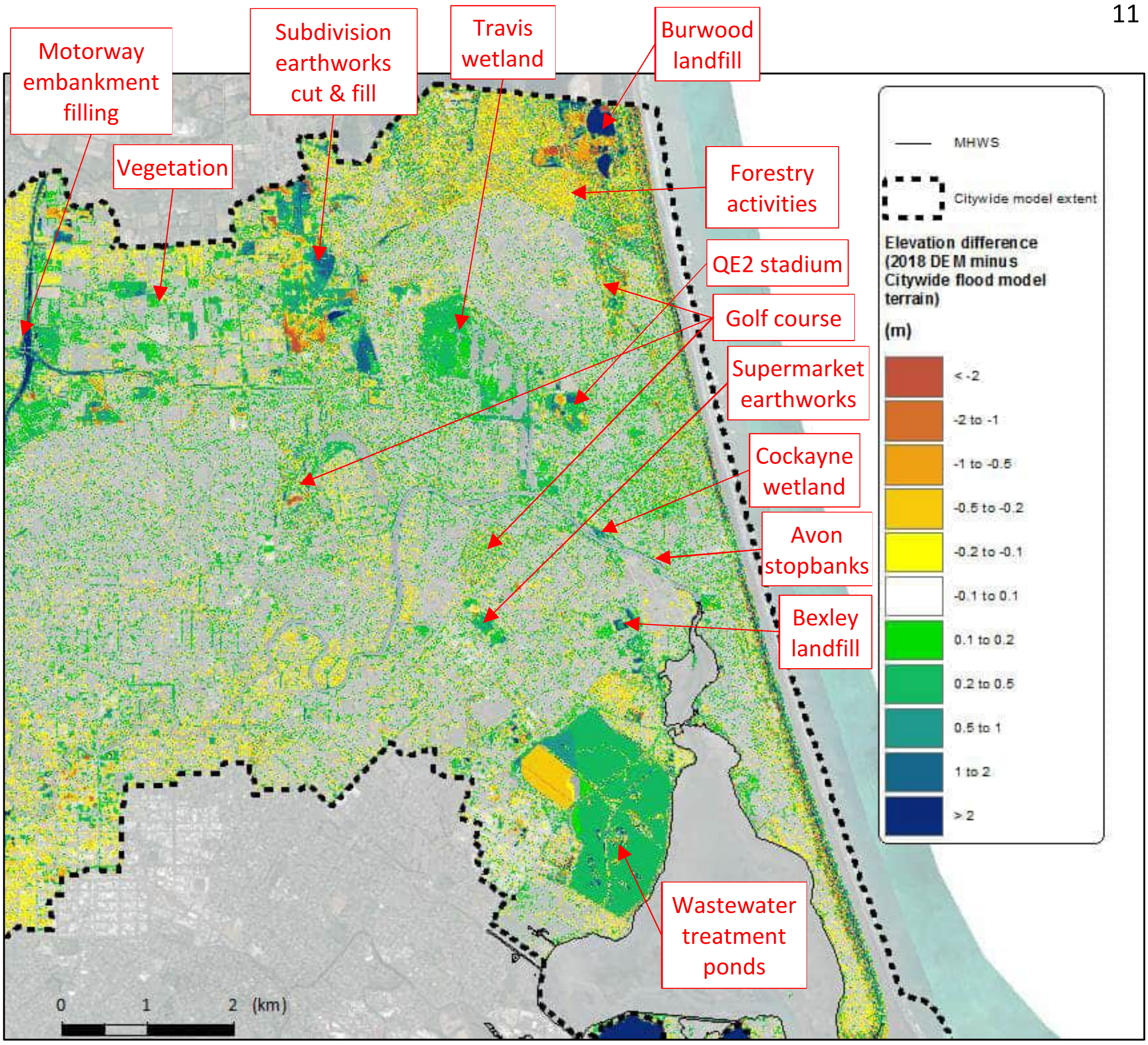

Figure 4.2: Elevation difference between the 2018 DEM used for the bathtub modelling and the terrain grid used within the CCC city-wide flood model.

5 Results

The results from the model comparisons are presented in Appendix A.

5.1 Comparison with T+T (2017) TUFLOW model

5.1.1 Low sea level rise scenario

In the coastal areas (i.e. downstream of Wainoni Road on the Avon River and downstream of Radley St on the Heathcote River) the bathtub model shows good agreement with the T+T (2017) TUFLOW model results. Further upstream of the Avon and Heathcote Rivers there are some differences between the bathtub and TUFLOW model results. These differences are as expected.

For the low SLR scenario (2065 RCP4.5) there is some difference upstream of Wainoni Road on the Avon River where the bathtub model overestimates the inundation extent through some of the low-lying areas around Avondale, Dallington and Linwood (Figure 5.1) compared to the TUFLOW model. Through Dallington the bathtub extent is approximately 350 m further than the TUFLOW inundation extent. These differences are largely due to the lower water elevations reached by the hydrodynamic model in the upstream limits. For example, the TUFLOW model indicates the water level reduces to approximately 2 m LVD37 through Linwood and Richmond, which is 0.5 m less than the water level at Bridge St and subsequently the level used for the bathtub (i.e. the bathtub overestimates inundation depth by up to 0.5 m in some areas upstream of Wainoni Rd).

Compared to the TUFLOW model, the bathtub also overestimates the inundation extent upstream of Radley St on the Heathcote River (Figure 5.2). The TUFLOW model indicates levels within the Heathcote River reduce to approximately 2 m LVD upstream of Rutherford St (Figure 5.2).

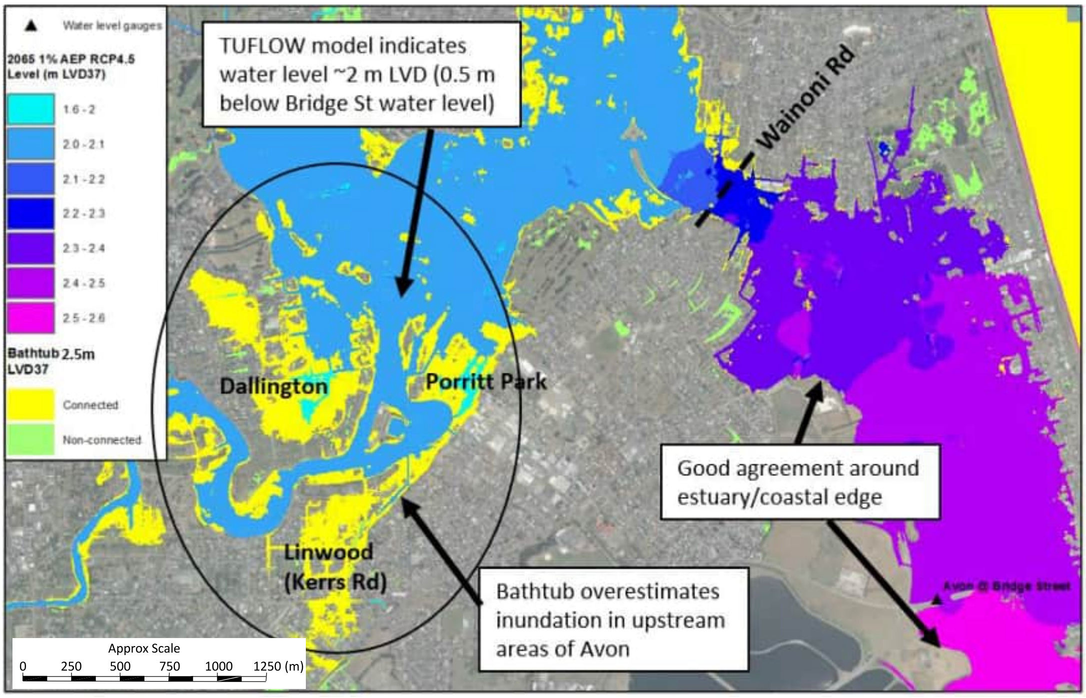

Figure 5.1: Comparison of bathtub and T+T TUFLOW results for a low SLR scenario (2065 1% AEP RCP4.5). Key areas of difference along Avon River (yellow and green shading are where bathtub flood extent is larger).

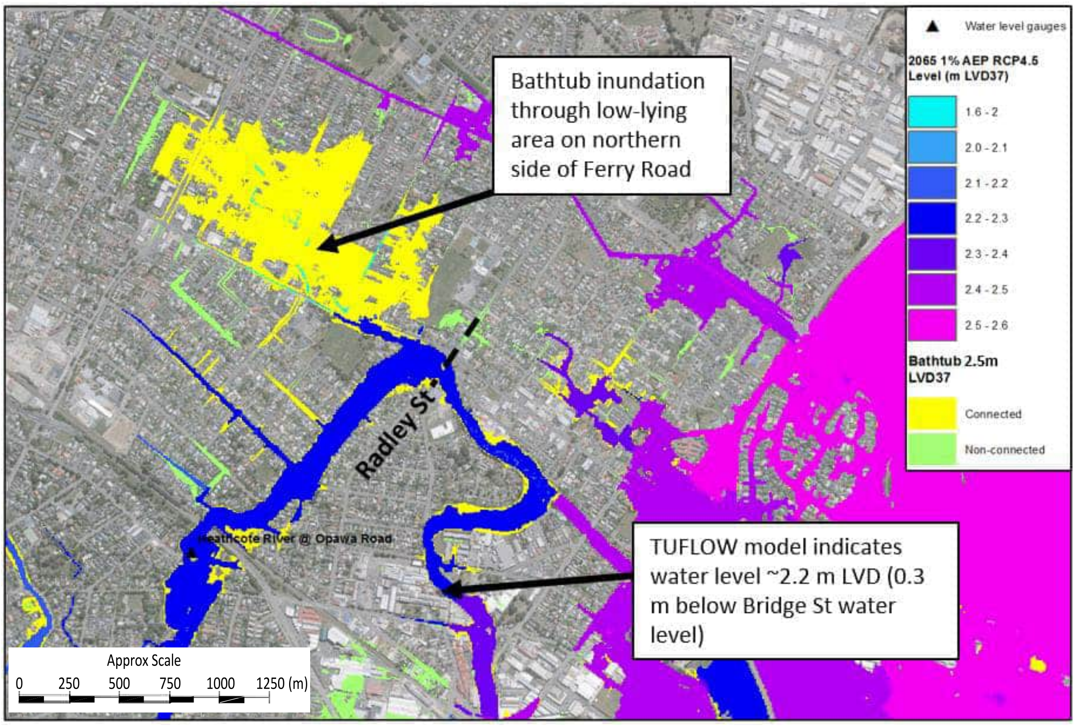

Figure 5.2: Comparison of bathtub and T+T TUFLOW model results for a low SLR scenario (2065 1% AEP RCP4.5). Key areas of difference along Heathcote River (yellow and green shading are where bathtub flood extent is larger).

5.1.2 High sea level rise scenario

For the high SLR scenario (2115 RCP8.5) the differences between hydrodynamic model and bathtub are substantially less. The bathtub slightly overestimates the inundation extent through Linwood compared to the TUFLOW model. The largest difference occurs along Gloucester Street where the bathtub inundation extent is up to 100 m further than the TUFLOW inundation extent (Figure *5.3*). Again, this difference is due to reduction in the water elevation upstream from the coastal margin. The TUFLOW model shows water levels reducing to 2.7 m LVD37 which is 0.3 m below the Bridge St level.

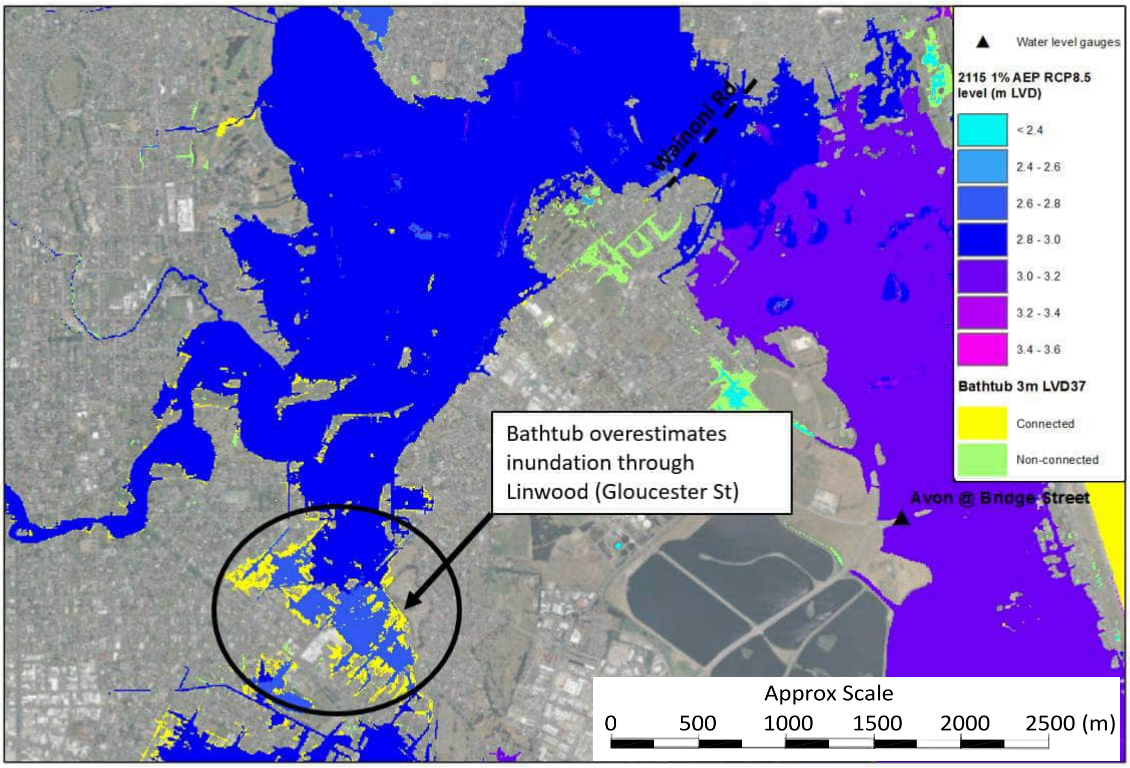

Figure 5.3*: Comparison of bathtub and T+T TUFLOW model results for a high SLR scenario (2115 1% AEP RCP8.5). Key areas of difference along the Avon River (yellow and green shading are where bathtub flood extent is larger).*

The bathtub also overestimates the inundation extent compared to the TUFLOW model (by up to 1 km) at the upstream limit through Bottle Lake Forest south of Brooklands Lagoon, and Chaneys Plantation west of Brooklands Lagoon (Figure 5.4). However, the areas inundated by the bathtub model are patchy indicating very low and uneven terrain (forested dunes). The TUFLOW model indicates the water level reduces rapidly across the uneven terrain. Over a horizontal distance of approximately 600 m the water level reduces from 3 m LVD37 to 2.7 m LVD37 which is 0.3 m less than the water level near the Styx tide gates and subsequently the bathtub level. The 2018 DEM used for the bathtub inundation is also approximately 0.2 m lower than the TUFLOW terrain through Bottle Lake Forest and therefore the bathtub inundation is expected to extend further landward.

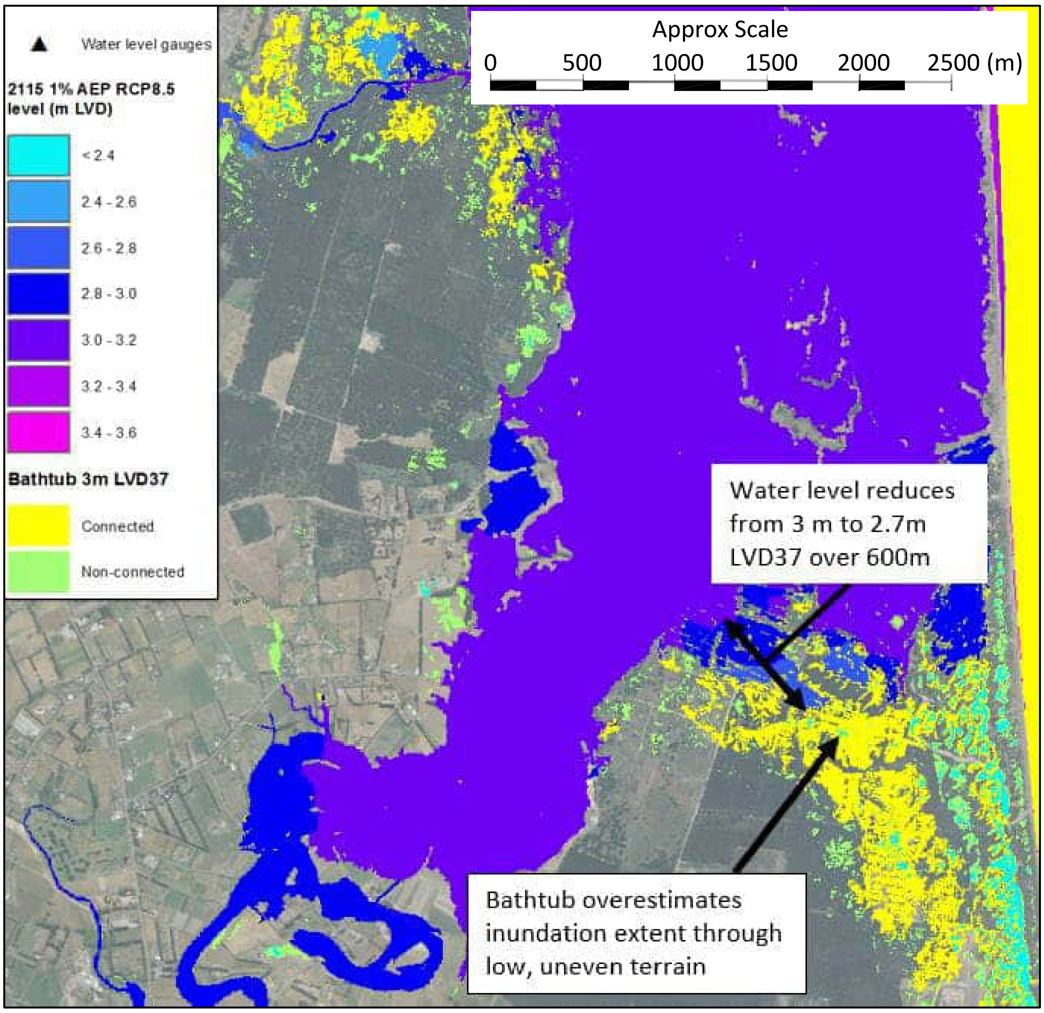

Figure 5.4: Comparison of bathtub and T+T TUFLOW model results for a high SLR scenario (2115 1% AEP RCP8.5). Key areas of difference near Brooklands Lagoon (yellow and green shading are where bathtub flood extent is larger).

On the Heathcote River, the higher SLR scenario generally shows good correlation with the TUFLOW model results (Figure 5.5). The TUFLOW results indicate the water levels reduce to approximately 2.9 m RL upstream of Radley Street which is 0.3 m lower than the water level at Ferrymead Bridge (3.2 m RL). Subsequently the bathtub overestimates the inundation extent by up to 130 m through parts of Phillipstown.

Overall, the bathtub shows better correlation with TUFLOW results for the higher SLR scenario. This is because under higher water levels the hydraulic controls in the catchments have less influence on dampening the upstream levels. For the lower SLR scenarios the bathtub overestimates the upstream inundation levels by approximately 0.3 to 0.5 m for the Heathcote and Avon catchments, respectively. Whereas for higher SLR scenarios the bathtub overestimates the upstream inundation levels by approximately 0.3 to 0.4 m for the Heathcote and Avon catchments, respectively. It should be noted that the upstream areas where these differences are shown, are excluded from the coast hazard maps which are the focus of this study.

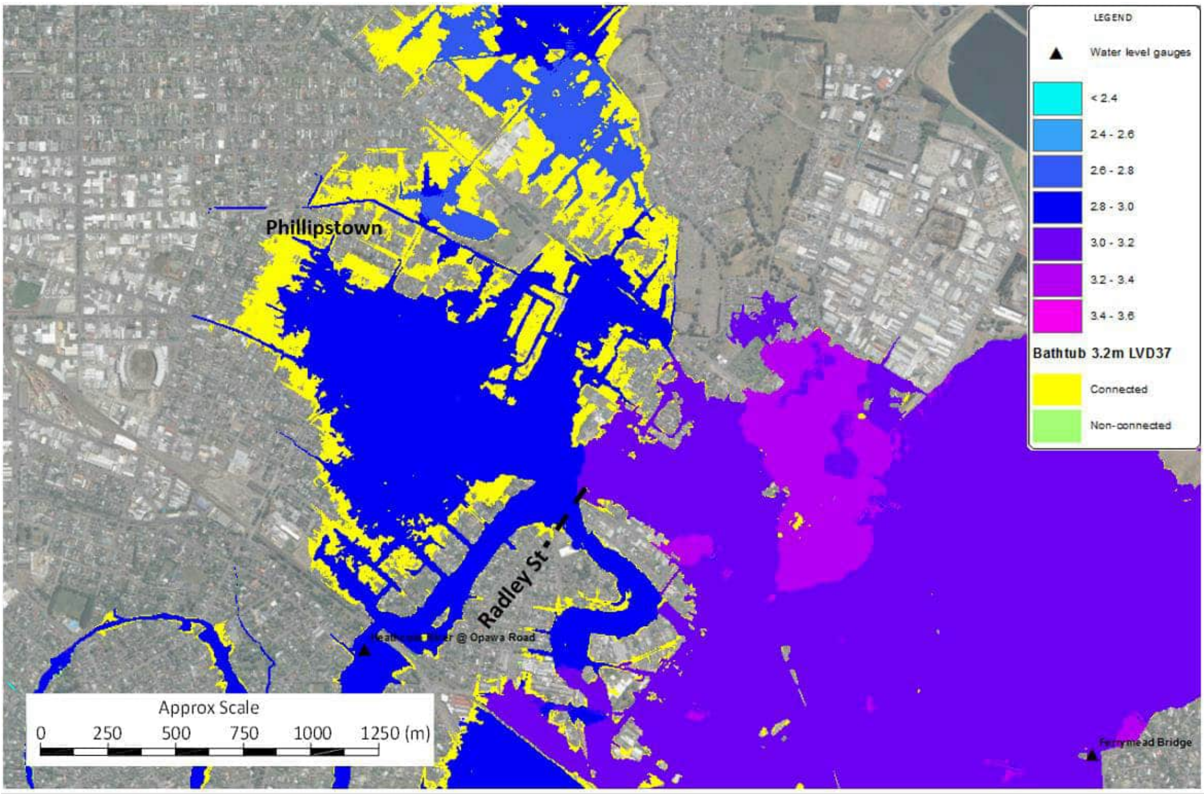

Figure 5.5: Comparison of bathtub and T+T TUFLOW model results for a high SLR scenario (2115 1% AEP RCP8.5). Key areas of difference along the Heathcote River (yellow and green shading are where bathtub flood extent is larger)

5.2 Comparison with CCC city-wide flood model

5.2.1 Present day scenario

In the coastal areas the bathtub model generally shows good correlation with the city-wide flood model for a present-day scenario (Figure 5.6).

The main difference is that the bathtub is non-connected in the areas where the city-wide flood model shows connected inundation (i.e. Travis Wetland, Horseshoe Lake Reserve, Avondale Park and Bexley). This difference is due to the bathtub model not including inundation via culverts or other below-ground infrastructure. While the bathtub does not identify it as being connected inundation, the extent of non-connected inundation is generally consistent with the extent of inundation from the city-wide model.

One other area of difference is through Bexley where the bathtub slightly overestimates the extent of non-connected inundation by up to 100 m and the inundation level by approximately 0.3 m.

The high water levels (>2 m LVD37) shown in pink in Figure 5.6 are likely to either be rainfall-driven ponding or surface water flow influenced. Both of these flood mechanisms are not considered to be "coastal inundation", and it is suggested that differences shown in these areas between the city-wide and bathtub models is not relevant for the coastal adaptation planning purposes of the current CHA study. These mechanisms responsible for these differences are also likely to exist in the Heathcote and Styx catchments, and the conclusion where these differences are deemed not relevant for coastal adaptation would also apply to these areas.

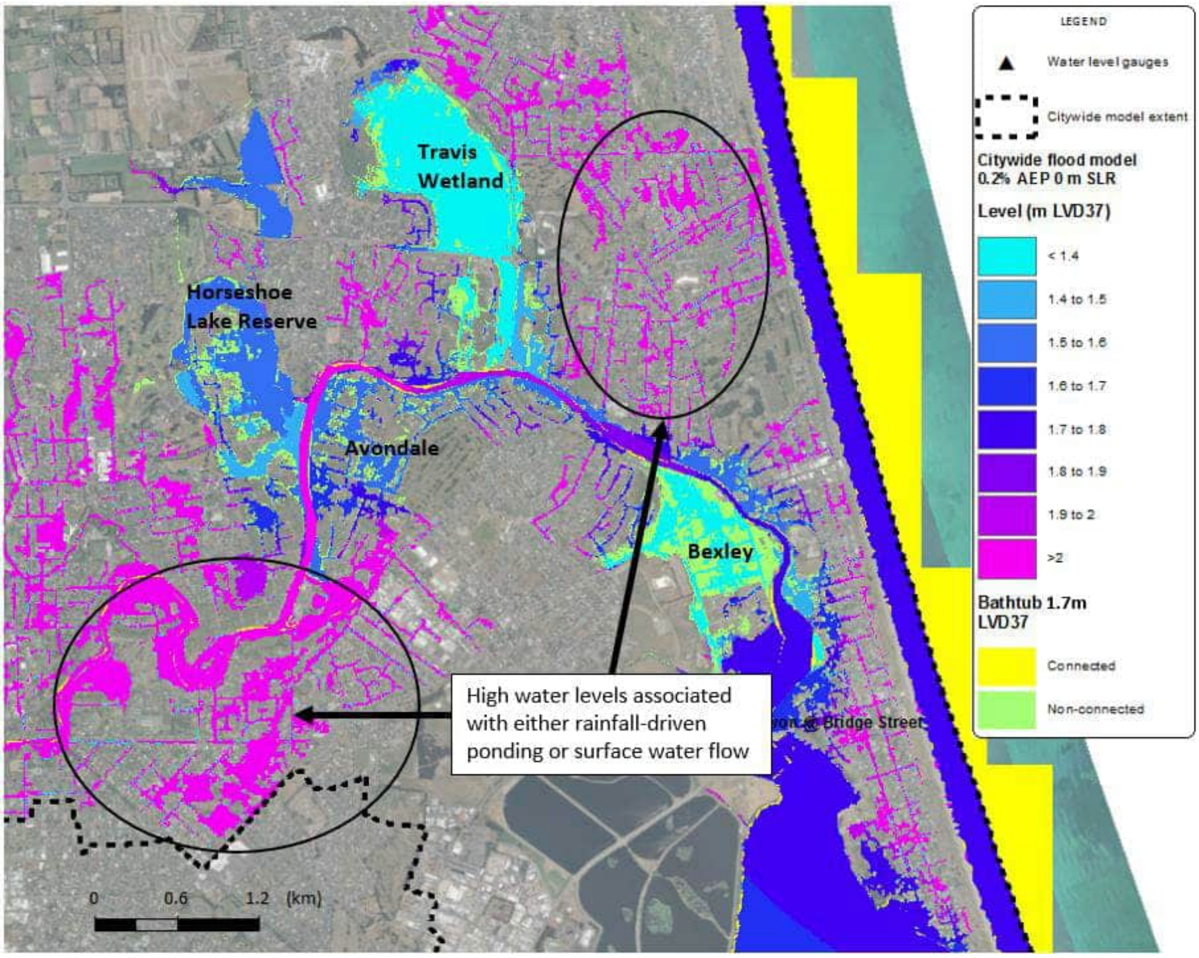

Figure 5.6: Comparison of bathtub and CCC city-wide flood model results for a present-day scenario (0.2% AEP 0 m SLR). Key areas of difference for Avon catchment (yellow and green shading are where bathtub flood extent is larger).

5.2.2 High sea level rise scenario

For a high SLR scenario the bathtub model shows good agreement with the city-wide flood model downstream from Wainoni Road. The city-wide flood model shows approximately a 0.5 m reduction in peak water level between Bridge St and just North of Wainoni Rd. The bathtub does not account for this reduction in water level and subsequently the 4 m LVD37 bathtub overestimates the extent of inundation upstream of Wainoni Rd, such as through North New Brighton, Burwood and Shirley (Figure 5.7). Inundation extents from the bathtub model are up to 500 m landward of the inundation extents from the city-wide flood model. Similar effects are anticipated in the Heathcote and Styx catchments, although the horizontal extent differences will be dependent on local ground slope in each case (ie not necessarily the same 500 m difference in extent, but level differences would be similar).

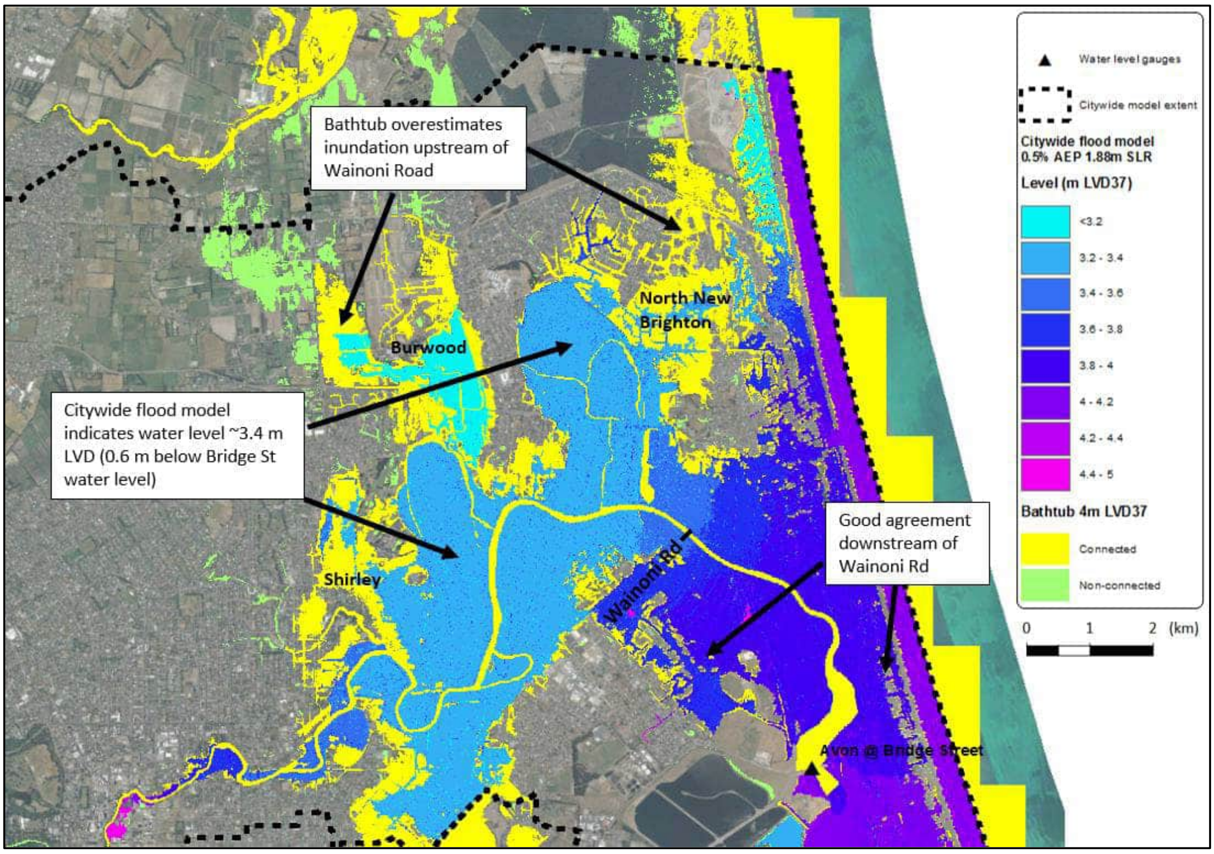

Figure 5.7: Comparison of bathtub and CCC city-wide flood model results for a high SLR scenario (2150 0.5% AEP 1.88 m SLR). Key areas of difference for Avon catchment (yellow and green shading are where bathtub flood extent is larger).

6 Conclusions

6.1 Recommended boundary for bathtub model output

In both the Avon and Heathcote catchments there are locations at which hydraulic control appears to notably affect the inland propagation of coastal inundation. Such hydraulic control would ordinarily tend to suggest that a hydrodynamic modelling approach would be preferred over a bathtub approach. This effect is common to both the city-wide and TUFLOW model results, at similar locations on both of these rivers.

On the Avon River the hydraulic control is approximately around Wainoni Road and on the Heathcote River it is near Radley Street. In these locations the flood plains narrow and subsequently there is a significant reduction in the water levels (via throttled flow). Upstream of the hydraulic controls the bathtub model generally overestimates the extent of inundation because it applies a water level derived at the coast which is too high for the area further inland.

The bathtub model tends to overestimate the landward extent slightly more on the Avon catchment compared with the Heathcote and Styx catchments. This is partly due to the hydraulic controls being less significant on the Heathcote and Styx catchments, but is also linked to local ground elevations and slopes. Similarly, the bathtub is most similar to the hydrodynamic results for the higher SLR scenario compared with the low SLR scenario. This is due to the hydraulic controls having less influence on the higher water levels.

In pursuit of a simple approach suitable for exploring a range of scenarios for adaptation planning, and on the simplification of there being just a single hydraulic control on both river systems, we have identified a boundary where we recommend the bathtub model outputs (e.g. maps) are cut off for the current CHA study. This boundary is shown in red in Figure 6.1 to Figure 6.3. At this boundary the difference between the water level in the bathtub model and hydrodynamic models varies between approximately 0.2m and 0.4m for the various scenarios and models.

Inland of these boundaries the CHA maps would be blanked out, with a note explaining that the interaction between rainfall and sea level rise was more complex in this inland area and so the city wide-flood model is the more appropriate source of information (e.g. via the CCC floor level viewer).

Even though the inland area wouldn't be shown on the maps in the final CHA report, the analysis results for this area would still be available for assessment if needed for some reason (e.g. to identify lower-lying parts of the CHAP adaptation engagement areas). In this case the results for the inland area would need to be used with careful technical guidance and an appreciation that there is increased uncertainty in the hydraulics so the extent and depth of inundation for a given scenario could be overstated. There may also be situations where it could be useful to create a separate bathtub model specifically for the inland area (e.g. using an inland level 0.5m lower than at Bridge Street). In inland areas, recognition of rainfall and surface flow contributions to extreme flood levels needs to be given, and in instances where high precision is required, a site specific peak flood level analysis may be required and would be recommended.

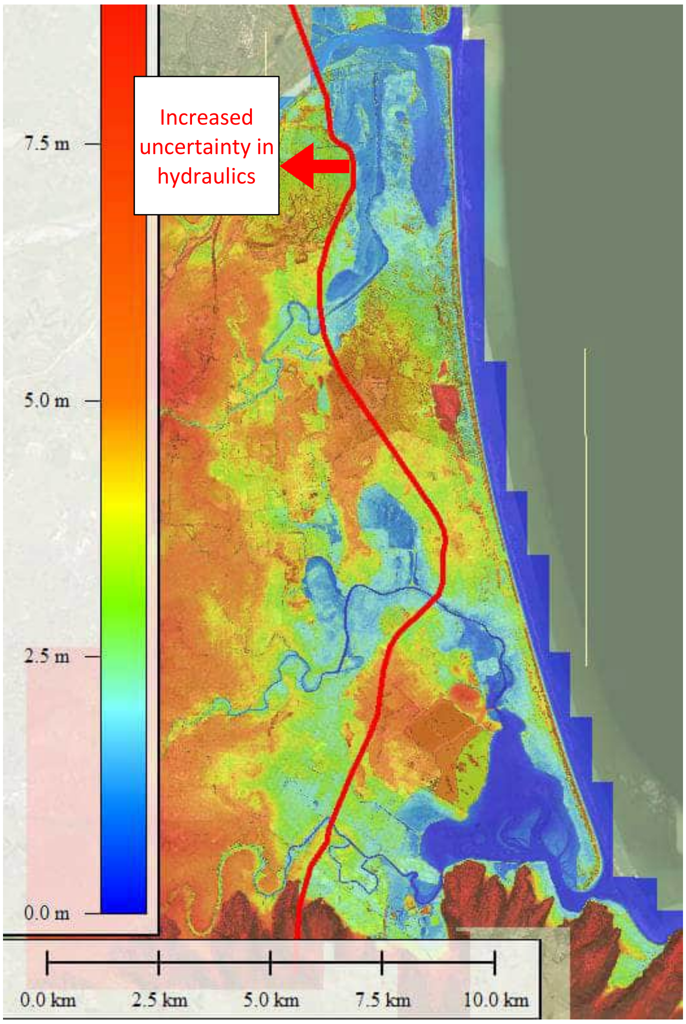

Figure 6.1: 2018 DEM used for bathtub model with the recommended bathtub boundary shown in red.

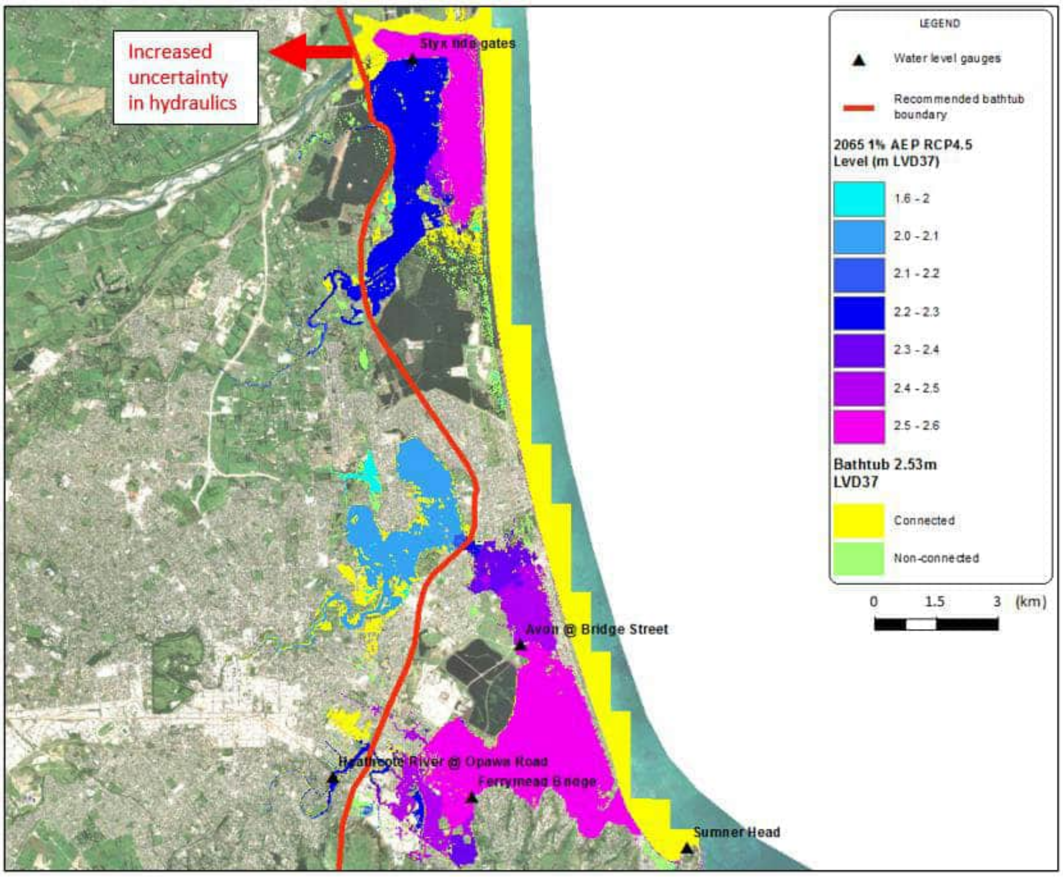

Figure 6.2: TUFLOW and bathtub model comparison with the recommended bathtub boundary shown in red

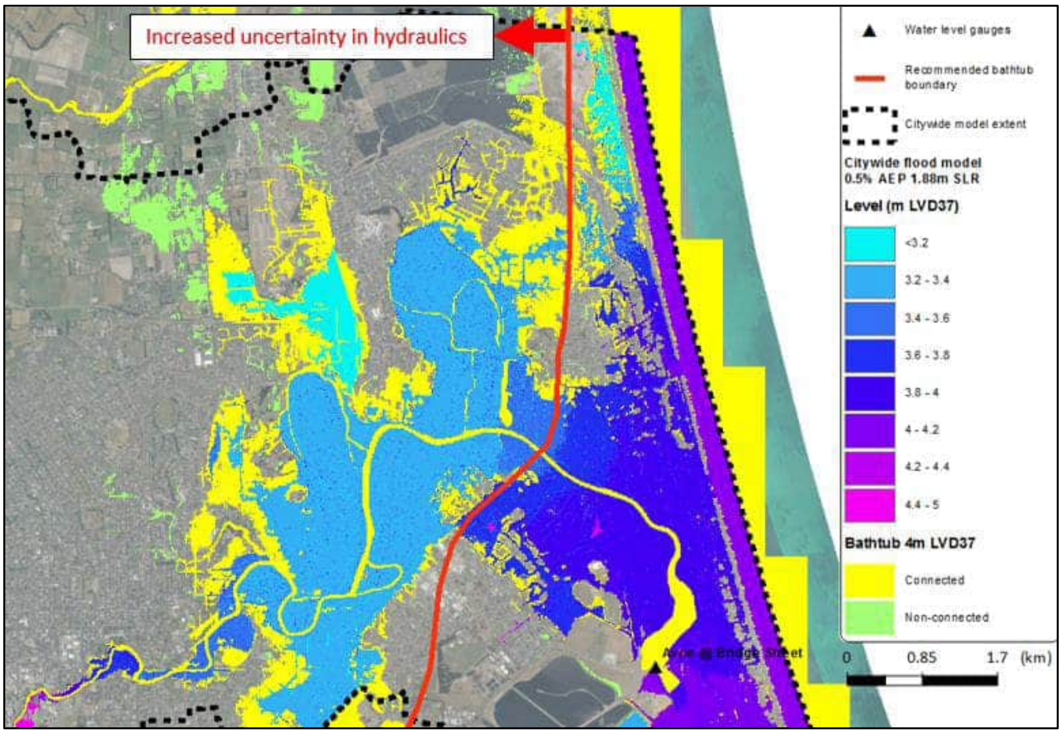

Figure 6.3: CCC city wide flood model and bathtub model comparison with the recommended bathtub boundary shown in red

6.2 Use of bathtub model for current adaptation planning purposes

Overall, there are some differences between the inundation extents derived using a bathtub approach with those derived using hydrodynamic modelling. These differences are negligible near the coastal edge (the Avon-Heathcote Estuary and Waimakariri River) and typically increase with distance inland. The primary reason for this difference is the reduction in water levels away from the coastline which occurs in the hydrodynamic model but is not allowed for in the bathtub modelling. It should be noted that the T+T (2017) TUFLOW modelling did not include river flows or rainfall, but the city-wide flood model does. These contributions may elevate the water levels away from the coast, particularly along the Avon and Heathcote Rivers, partially offsetting this difference. It is also noted that these differences are more pronounced at lower sea level rise scenarios and less pronounced at higher sea level rise scenarios.

Given the intended purpose of the current adaptation planning work and the large number of scenarios to be considered, the bathtub method appears to provide a suitable approach if the limitations are understood and accepted. The bathtub approach enables areas inundated under a range of water levels to be rapidly identified which is useful for engagement and adaptation planning where effects of incremental changes in event likelihood and sea level rise are of interest. For these purposes it is important to explore a wide range of uncertainties in the analysis inputs and outputs, and these uncertainties often have much larger impact on objectives and decision making than differences in modelled flood levels as a result of a more simplified analysis. This means that higher precision in the modelling would provide little, if any, meaningful benefit for engagement and adaptation purposes. More precise modelling might instead bring disadvantages for the adaptation project, if it limited the scope of analysis which could be practically undertaken, or the flexibility to respond quickly to requests for further information to explore particular scenarios of interest.

Furthermore, by basing levels on the most recent extreme values analysis of water level gauges within the estuary and lagoon at Bridge Street, Ferrymead and the Styx, the combined effects of tide, storm surge, river flows, rainfall, local wind effects and wave breaking over the Sumner and Waimakariri Bars are implicitly included in the derived extreme values and they do not need to be defined separately by joint probability analysis. This reduces the number of technical assumptions which might be subject to challenge (e.g. potential “weak links” in the analysis chain) or become superseded by future changes in agreed methodology or extreme water level frequencies, which could unnecessarily undermine public confidence in the results of the coastal hazard assessment.

A comprehensive assessment of joint probability and the various forcing factors is currently underway within the Land Drainage Recovery Programme and could be implemented within the Christchurch city-wide flood model once assessments are complete and there is widespread agreement on the technical assumptions. These more comprehensive models could be used in future stages of the adaptation planning work if more detailed site-specific analysis is required for a particular assessment (e.g. to help understand the effect of a proposed flood protection structure).

6.3 Summary of recommendations

We recommend that:

1. The current coastal hazard assessment utilises a connected bathtub approach based on extreme levels derived for Bridge Street, Ferrymead and the Styx with connected and non-connected areas defined.
2. Due to potential over-estimation of inundated areas upstream of the identified hydraulic control locations, the maps in the final CHA report only show the bathtub model results for the areas downstream of these locations.
3. The specific purpose and limitations of this modelling are clearly communicated, so it is understood that if more precise site-specific flood level information is required for other purposes (e.g. setting Building Consent floor levels, or detailed design of flood protection options as part of more detailed site-specific adaptation planning in future) it would be more appropriate to refer to detailed hydrodynamic models such the city-wide flood model.

30-Jul-21
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Appendix D: Coastal inundation levels

- **Christchurch open coast inundation levels:**
    - **Appendix D Table 1 - Appendix D Table 6:**
- **Major harbours and estuaries inundation levels:**
    - **Appendix D Table 7 - Appendix D Table 11**
- **Regional hazard screening sites inundation levels:**
    - **Appendix D Table 12 - Appendix D Table 16**

Appendix D Table 1: Static inundation levels (m NZVD2016) for Christchurch open coast

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	1.8	2.0	2.2	2.4	2.6	3.0	3.2	3.3	3.8
10 year ARI	2.0	2.2	2.4	2.6	2.8	3.2	3.4	3.5	4.0
100 year ARI	2.3	2.5	2.7	2.9	3.1	3.5	3.7	3.8	4.3

Appendix D Table 2: Dynamic inundation levels (m NZVD2016) for Christchurch open coast

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	3.8	4	4.2	4.4	4.6	5	5.2	5.3	5.8
10 year ARI	4.2	4.4	4.6	4.8	5	5.4	5.6	5.7	6.2
100 year ARI	4.4	4.6	4.8	5	5.2	5.6	5.8	5.9	6.4

Appendix D Table 3: Static inundation levels (m NZVD2016) for Sumner

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	1.8	2.0	2.2	2.4	2.6	3.0	3.2	3.3	3.8
10 year ARI	2.0	2.2	2.4	2.6	2.8	3.2	3.4	3.5	4.0
100 year ARI	2.3	2.5	2.7	2.9	3.1	3.5	3.7	3.8	4.3

Appendix D Table 4: Dynamic inundation levels (m NZVD2016) for Sumner

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	4.5	4.7	4.9	5.1	5.3	5.7	5.9	6.0	6.5
10 year ARI	4.9	5.1	5.3	5.5	5.7	6.1	6.3	6.4	6.9
100 year ARI	5.3	5.5	5.7	5.9	6.1	6.5	6.7	6.8	7.3

Appendix D Table 5: Static inundation levels (m NZVD2016) for Taylor's Mistake

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	1.8	2.0	2.2	2.4	2.6	3.0	3.2	3.3	3.8
10 year ARI	2.0	2.2	2.4	2.6	2.8	3.2	3.4	3.5	4.0
100 year ARI	2.3	2.5	2.7	2.9	3.1	3.5	3.7	3.8	4.3

Appendix D Table 6: Dynamic inundation levels (m NZVD2016) for Taylor's Mistake

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	4.5	4.7	4.9	5.1	5.3	5.7	5.9	6.0	6.5
10 year ARI	4.9	5.1	5.3	5.5	5.7	6.1	6.3	6.4	6.9
100 year ARI	5.3	5.5	5.7	5.9	6.1	6.5	6.7	6.8	7.3

Appendix D Table 7: Static inundation levels (m NZVD2016) for Brooklands Lagoon

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	1.4	1.6	1.8	2.0	2.2	2.6	2.8	2.9	3.4
10 year ARI	1.6	1.8	2.0	2.2	2.4	2.8	3.0	3.1	3.6
100 year ARI	1.8	2.0	2.2	2.4	2.6	3.0	3.2	3.3	3.8

Appendix D Table 8: Static inundation levels (m NZVD2016) for Avon-Heathcote – North

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	1.5	1.7	1.9	2.1	2.3	2.7	2.9	3.0	3.5
10 year ARI	1.7	1.9	2.1	2.3	2.5	2.9	3.1	3.2	3.7
100 year ARI	2.0	2.2	2.4	2.6	2.8	3.2	3.4	3.5	4.0

Appendix D Table 9: Static inundation levels (m NZVD2016) for Avon-Heathcote – South

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	1.5	1.7	1.9	2.1	2.3	2.7	2.9	3.0	3.5
10 year ARI	1.6	1.8	2.0	2.2	2.4	2.8	3.0	3.1	3.6
100 year ARI	1.8	2.0	2.2	2.4	2.6	3.0	3.2	3.3	3.8

Appendix D Table 10: Static inundation levels (m NZVD2016) for Lyttelton Harbour

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	1.6	1.8	2.0	2.2	2.4	2.8	3.0	3.1	3.6
10 year ARI	1.7	1.9	2.1	2.3	2.5	2.9	3.1	3.2	3.7
100 year ARI	1.8	2.0	2.2	2.4	2.6	3.0	3.2	3.3	3.8

Appendix D Table 11: Static inundation levels (m NZVD2016) for Akaroa Harbour

Return period	Present day	Relative sea level rise (m)							
		0.2	0.4	0.6	0.8	1.2	1.4	1.5	2
1 year ARI	1.9	2.1	2.3	2.5	2.7	3.1	3.3	3.4	3.9
10 year ARI	2.1	2.3	2.5	2.7	2.9	3.3	3.5	3.6	4.1
100 year ARI	2.3	2.5	2.7	2.9	3.1	3.5	3.7	3.8	4.3

Appendix D Table 12: Static inundation levels (m NZVD2016) for Banks Peninsula – North

Return period	Present day	Relative sea level rise (m)							
		0.2	0.4	0.6	0.8	1.2	1.4	1.5	2
1 year ARI	2.2	2.4	2.6	2.8	3.0	3.4	3.6	3.7	4.2
10 year ARI	2.5	2.7	2.9	3.1	3.3	3.7	3.9	4.0	4.5
100 year ARI	2.8	3.0	3.2	3.4	3.6	4.0	4.2	4.3	4.8

Appendix D Table 13: Static inundation levels (m NZVD2016) for Banks Peninsula – South

Return period	Present day	Relative sea level rise (m)							
		0.2	0.4	0.6	0.8	1.2	1.4	1.5	2
1 year ARI	2.9	3.1	3.3	3.5	3.7	4.1	4.3	4.4	4.9
10 year ARI	3.4	3.6	3.8	4.0	4.2	4.6	4.8	4.9	5.4
100 year ARI	3.9	4.1	4.3	4.5	4.7	5.1	5.3	5.4	5.9

Appendix D Table 14: Static inundation levels (m NZVD2016) for Wairewa (Lake Forsyth)

Return period	Present day	Relative sea level rise (m)							
		0.2	0.4	0.6	0.8	1.2	1.4	1.5	2
1 year ARI	2.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10 year ARI	2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
100 year ARI	2.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Appendix D Table 15: Extreme lake levels (m NZVD2016) for Kaitorete Spit

Return period	Present day	Relative sea level rise (m)							
		0.2	0.4	0.6	0.8	1.2	1.4	1.5	2
1 year ARI	2.6	2.8	3.0	3.2	3.4	3.8	4.0	4.1	4.6
10 year ARI	2.9	3.1	3.3	3.5	3.7	4.1	4.3	4.4	4.9
100 year ARI	3.3	3.5	3.7	3.9	4.1	4.5	4.7	4.8	5.3

Appendix D Table 16: Extreme lake levels (m NZVD2016) for Te Waihora (Lake Ellesmere)

Return period	Present day	Relative sea level rise (m)							
		0.2	**0.4**	**0.6**	**0.8**	**1.2**	**1.4**	**1.5**	**2**
1 year ARI	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10 year ARI	1.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
100 year ARI	1.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Appendix E: Example maps

- **Coastal erosion maps**
- **Coastal inundation maps**
- **Rising groundwater maps**

To see the full suite of maps for the various scenarios analysed, use the online map viewer at https://ccc.govt.nz/environment/coast/coastalhazards/2021-coastal-hazards-assessment

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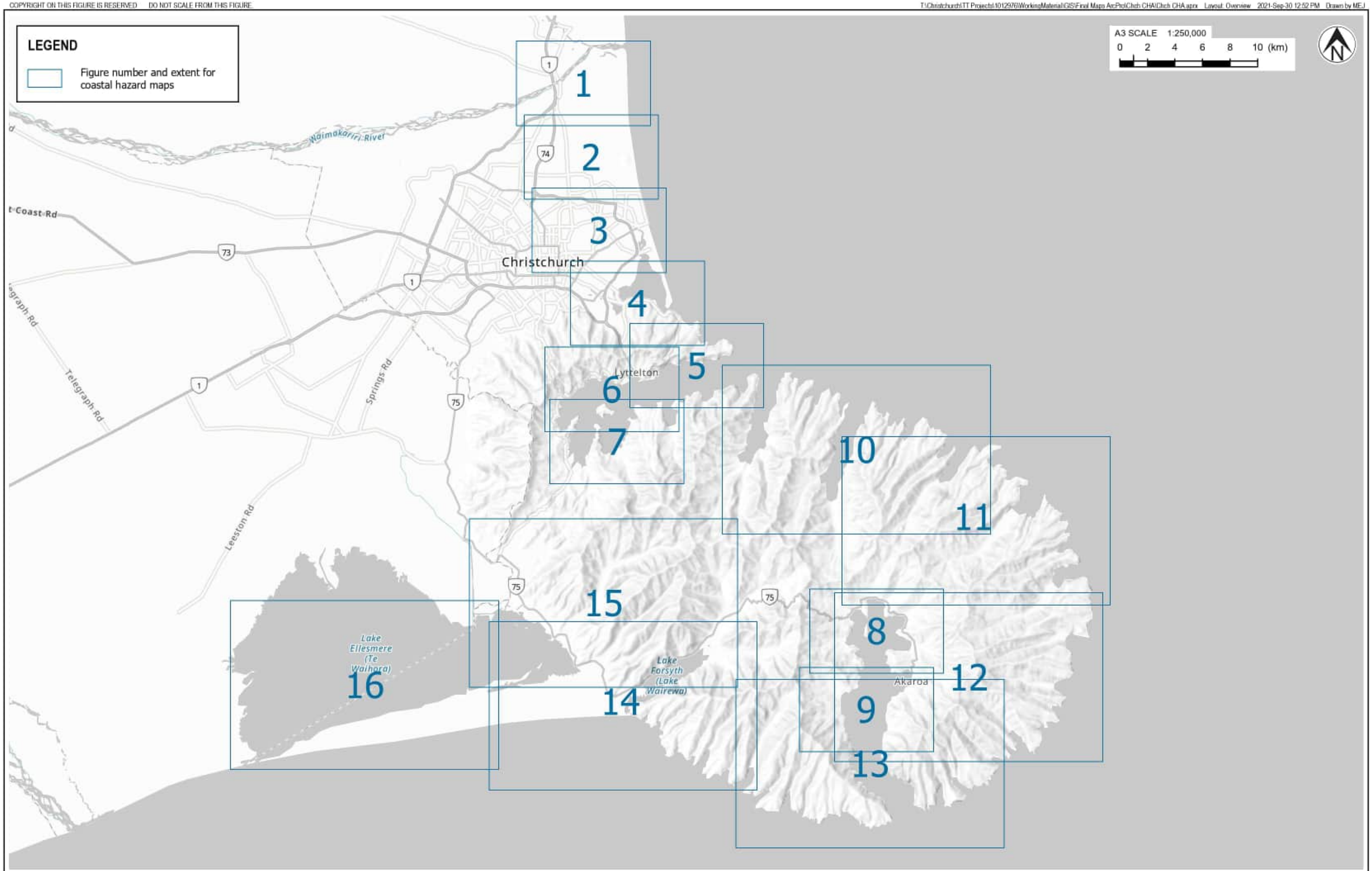

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NOTES:
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1	Report issued	MEJ	RHAU	29/09/21

LOCATION PLAN

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DRAWN	MEJ	SEP.21
CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE MAP LOCATION KEY

SCALE (A3) 1:250,000   FIG No. 17   REV 1

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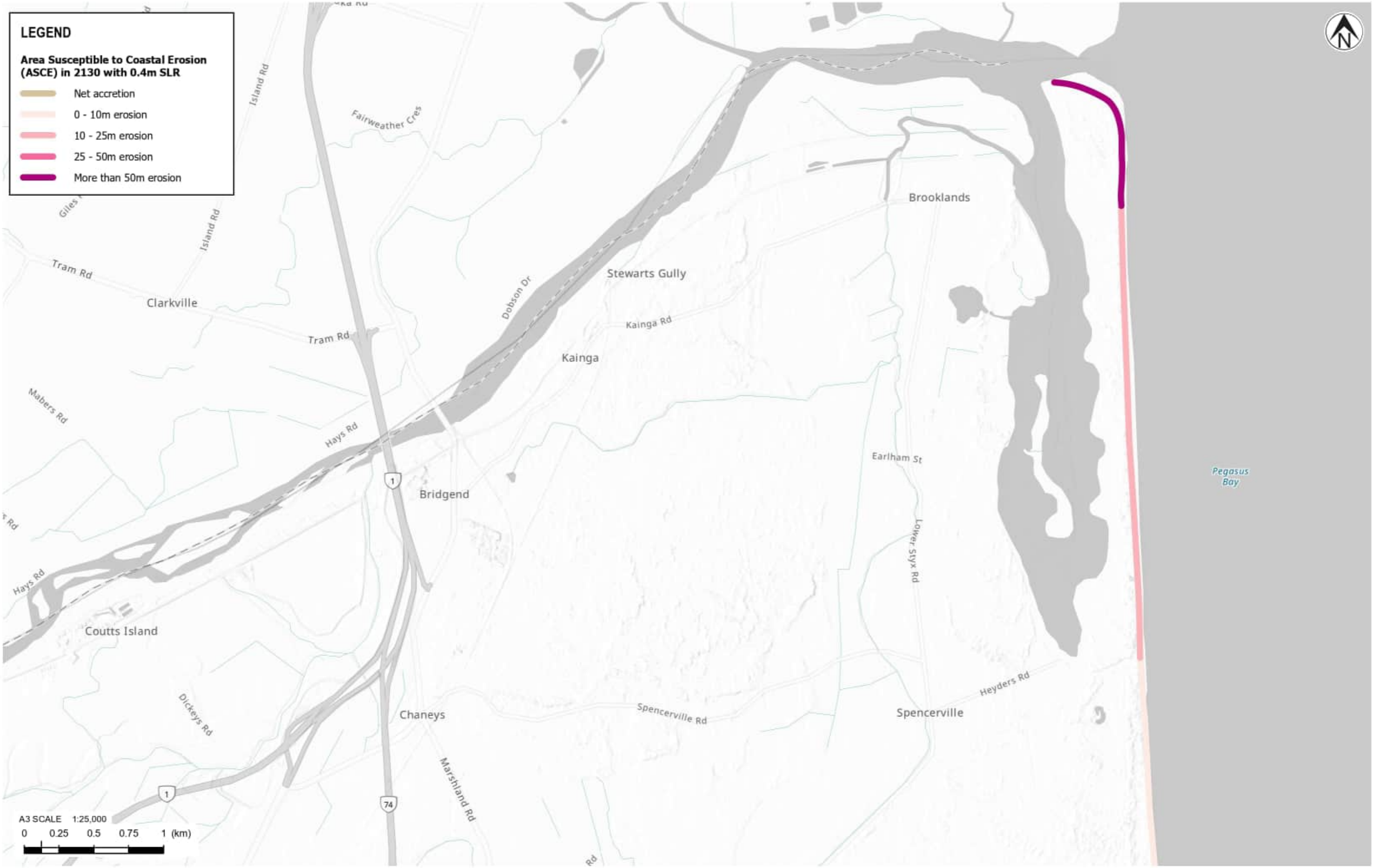

LEGEND

Area Susceptible to Coastal Erosion (ASCE) in 2130 with 0.4m SLR

- Net accretion
- 0 - 10m erosion
- 10 - 25m erosion
- 25 - 50m erosion
- More than 50m erosion

A3 SCALE 1:25,000

0 0.25 0.5 0.75 1 (km)

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NOTES:
1. For detailed analysis areas, this map shows the P5 erosion distance (5% probability that erosion will be greater for this scenario).
2. For regional screening analysis areas, this map shows the upper envelope erosion distance.
3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

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P. COCHRANE		29/09/21
APPROVED		DATE

CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 1A REV 1

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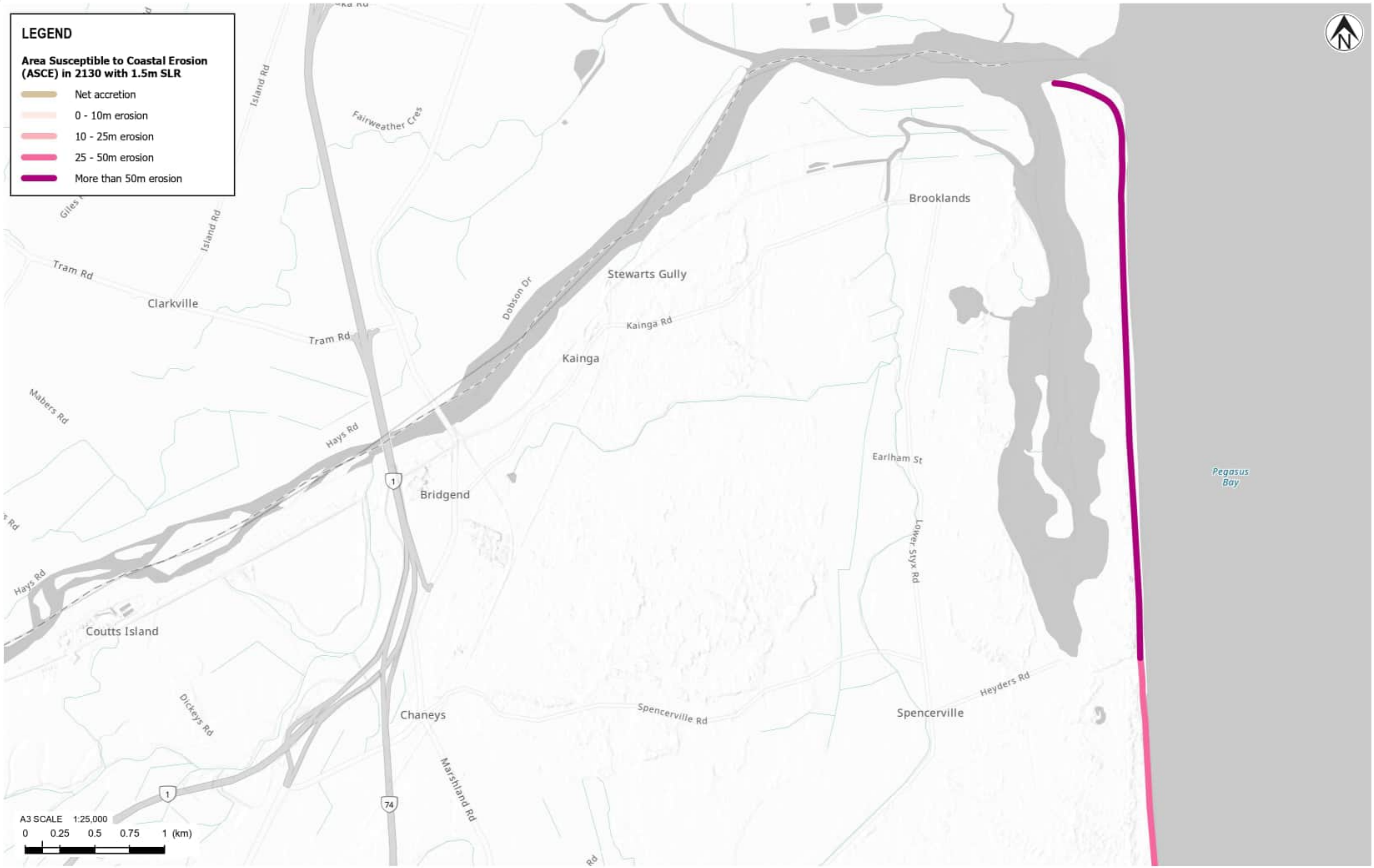

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NOTES:
1. For detailed analysis areas, this map shows the P5 erosion distance (5% probability that erosion will be greater for this scenario).
2. For regional screening analysis areas, this map shows the upper envelope erosion distance.
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APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 1B REV 1

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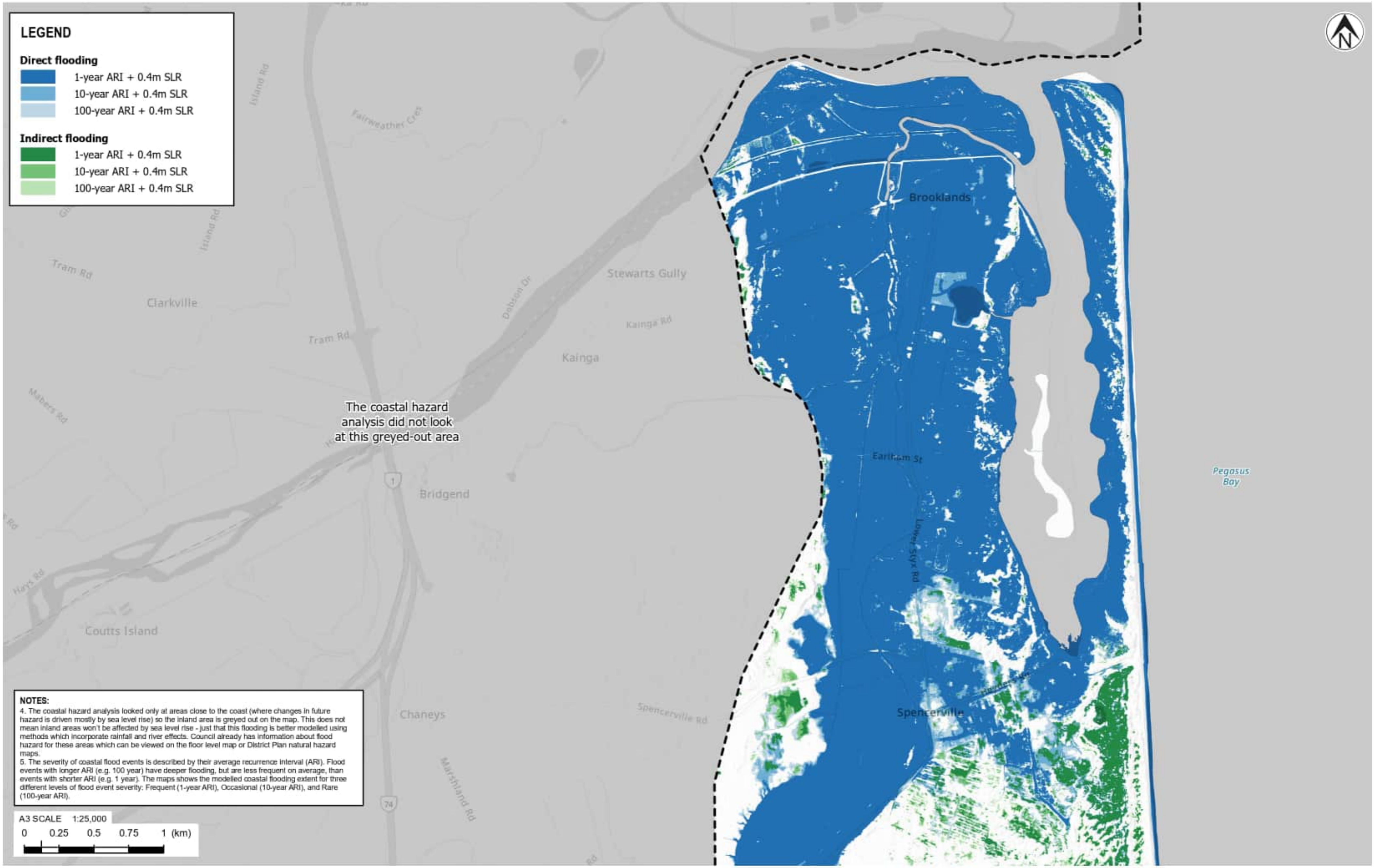

NOTES:

4. The coastal hazard analysis looked only at areas close to the coast (where changes in future hazard is driven mostly by sea level rise) so the inland area is greyed out on the map. This does not mean inland areas won't be affected by sea level rise - just that this flooding is better modelled using methods which incorporate rainfall and river effects. Council already has information about flood hazard for these areas which can be viewed on the floor level map or District Plan natural hazard maps.
5. The severity of coastal flood events is described by their average recurrence interval (ARI). Flood events with longer ARI (e.g. 100 year) have deeper flooding, but are less frequent on average, than events with shorter ARI (e.g. 1 year). The maps shows the modelled coastal flooding extent for three different levels of flood event severity: Frequent (1-year ARI), Occasional (10-year ARI), and Rare (100-year ARI).

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NOTES:

1. 'Direct flooding' is where there is a direct path for water to flow overland from the coast.
2. 'Indirect flooding' is where the ground is below the modelled water level, but there is no direct overland flow path from the coast.
3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

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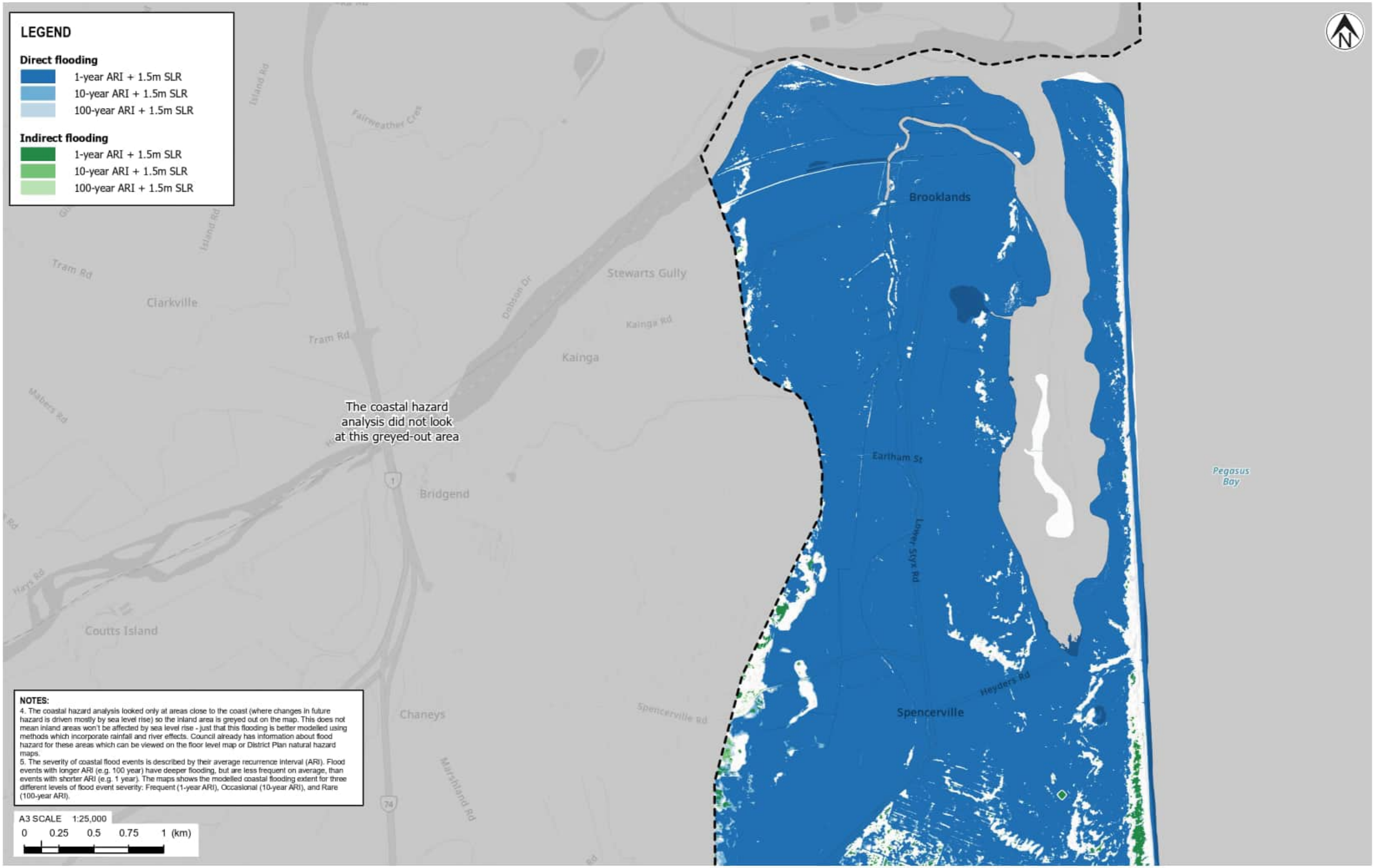

NOTES:

4. The coastal hazard analysis looked only at areas close to the coast (where changes in future hazard is driven mostly by sea level rise) so the inland area is greyed out on the map. This does not mean inland areas won't be affected by sea level rise - just that this flooding is better modelled using methods which incorporate rainfall and river effects. Council already has information about flood hazard for these areas which can be viewed on the floor level map or District Plan natural hazard maps.
5. The severity of coastal flood events is described by their average recurrence interval (ARI). Flood events with longer ARI (e.g. 100 year) have deeper flooding, but are less frequent on average, than events with shorter ARI (e.g. 1 year). The maps shows the modelled coastal flooding extent for three different levels of flood event severity: Frequent (1-year ARI), Occasional (10-year ARI), and Rare (100-year ARI).

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NOTES:

1. 'Direct flooding' is where there is a direct path for water to flow overland from the coast.
2. 'Indirect flooding' is where the ground is below the modelled water level, but there is no direct overland flow path from the coast.
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APPROVED	P. COCHRANE	29/09/21

CLIENT: **CHRISTCHURCH CITY COUNCIL**
PROJECT: **COASTAL HAZARD ASSESSMENT**
TITLE: COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3): 1:25,000   FIG No. FIGURE 1D   REV 1

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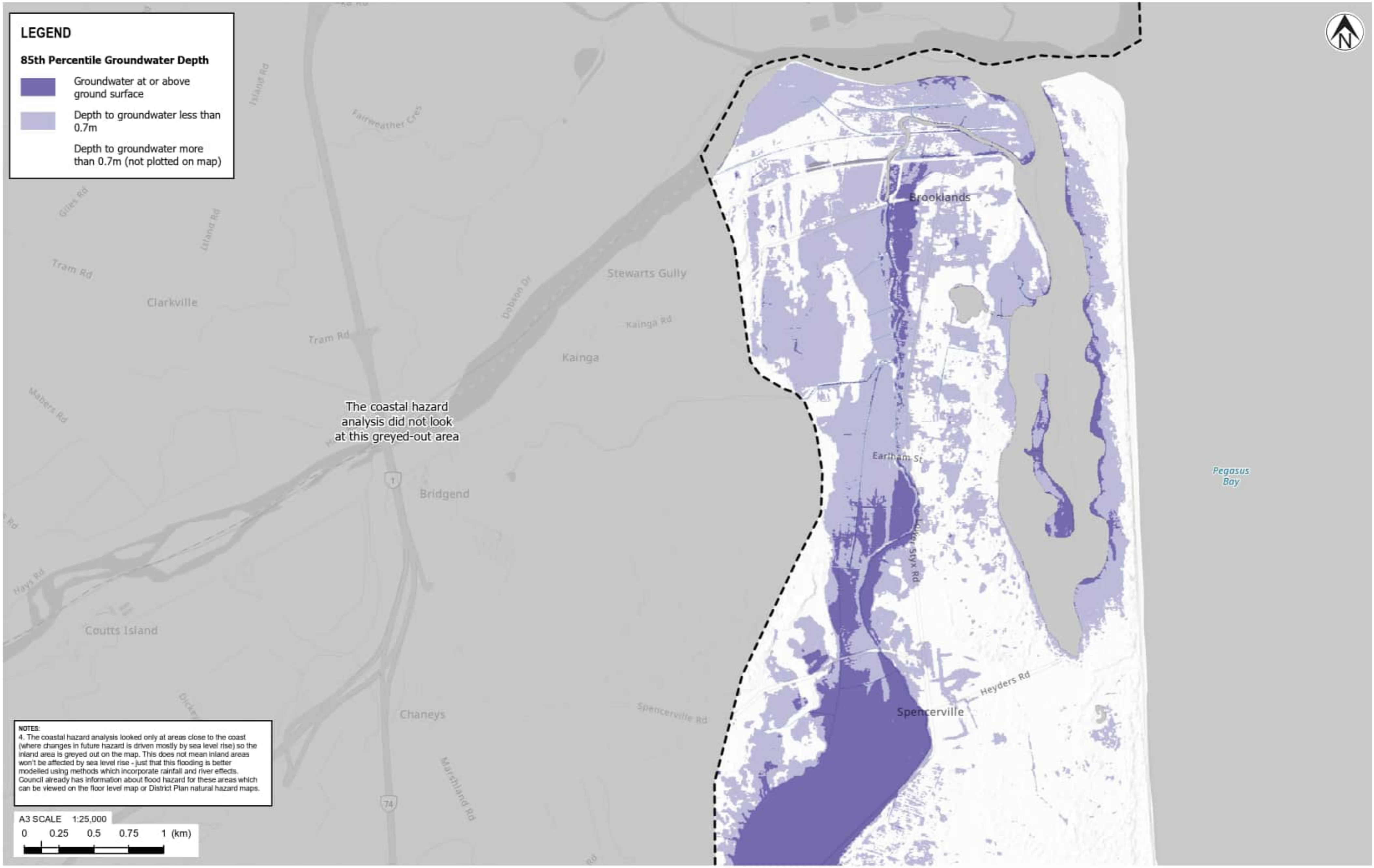

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CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 1E REV 1

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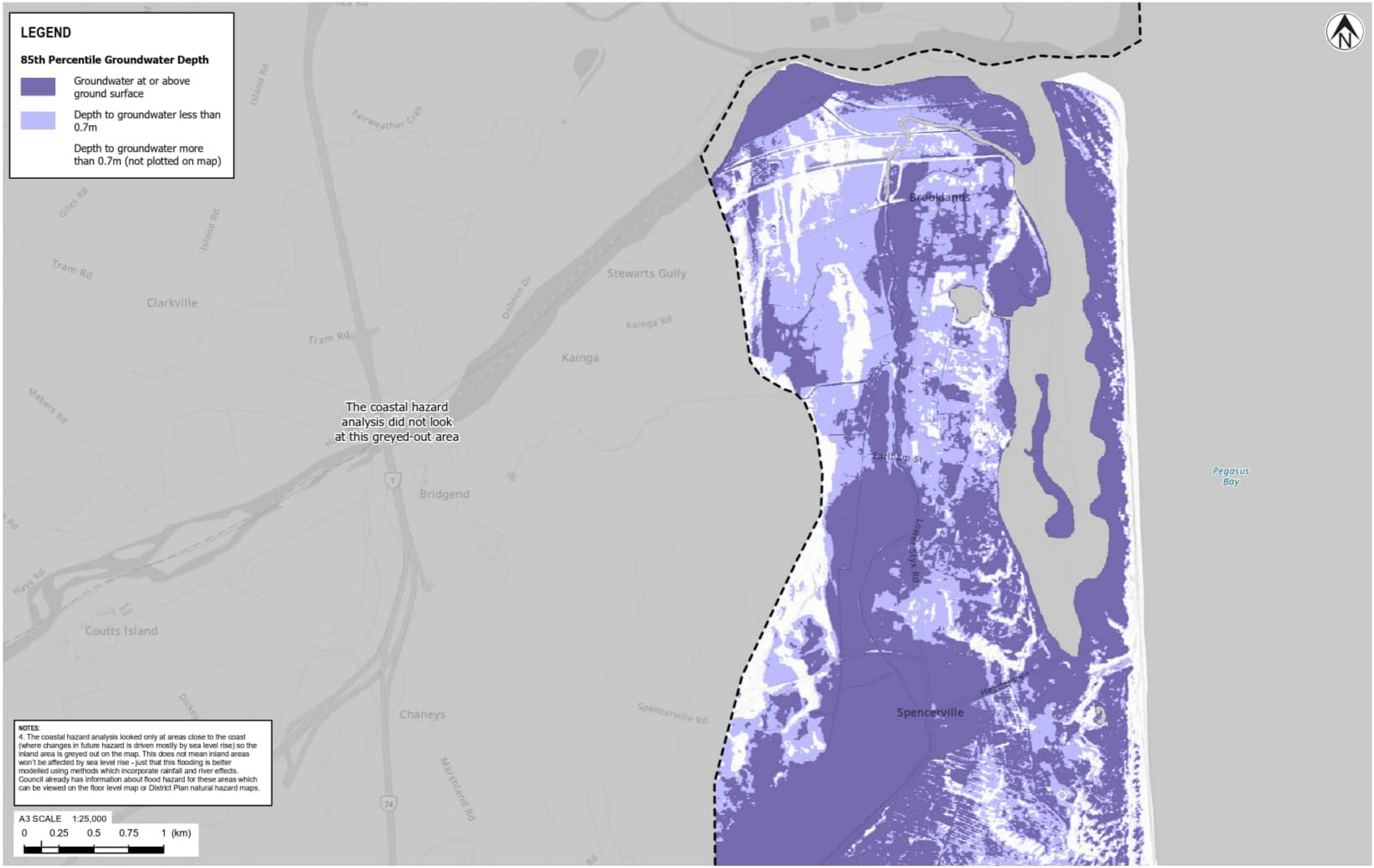

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CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3) 1:25,000   FIG No. FIGURE 1F   REV 1

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CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 2A REV 1

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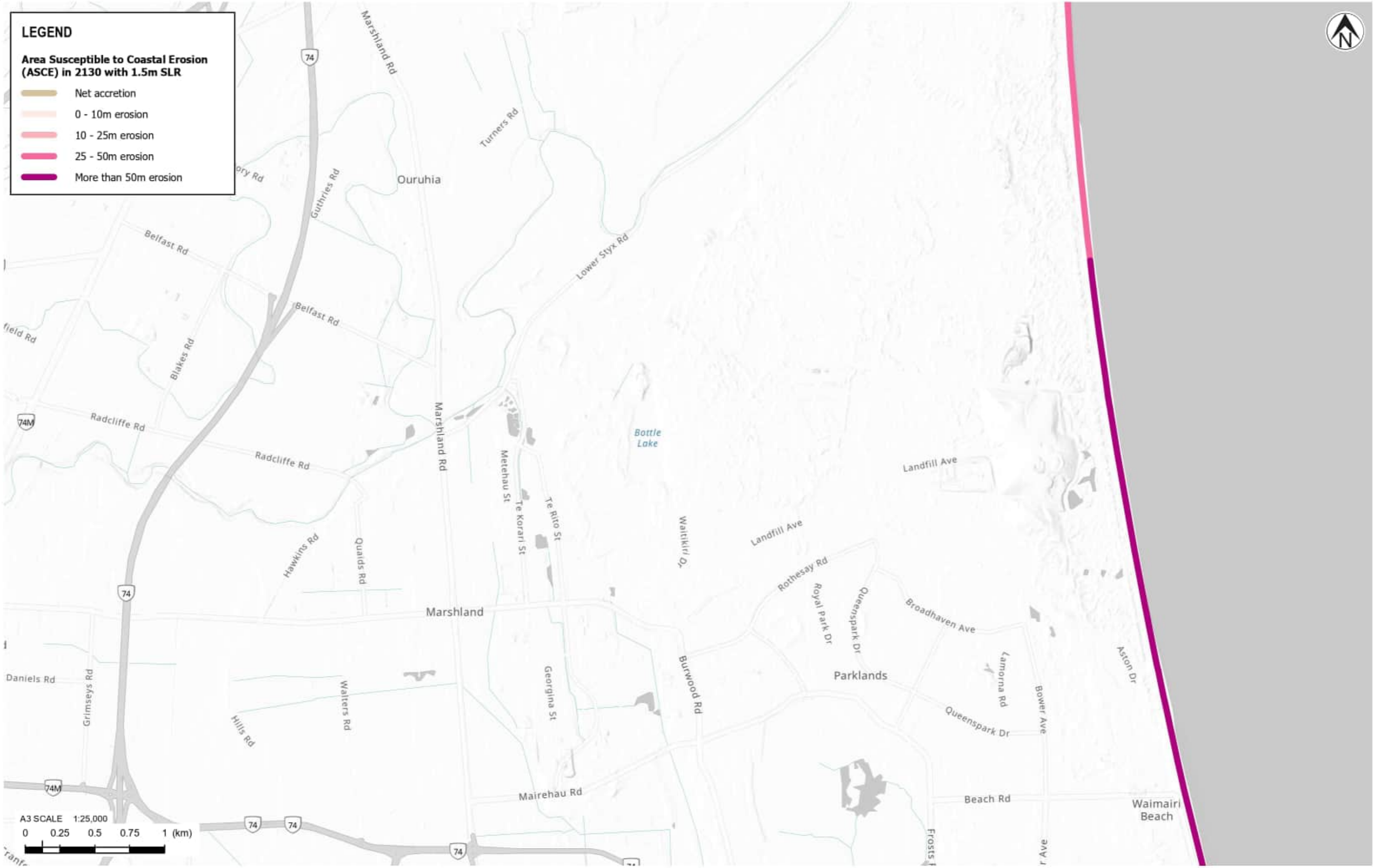

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CLIENT CHRISTCHURCH CITY COUNCIL
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TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 2B REV 1

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CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 2C REV 1

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CLIENT **CHRISTCHURCH CITY COUNCIL**
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TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
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CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3): 1:25,000 FIG No. FIGURE 2E REV 1

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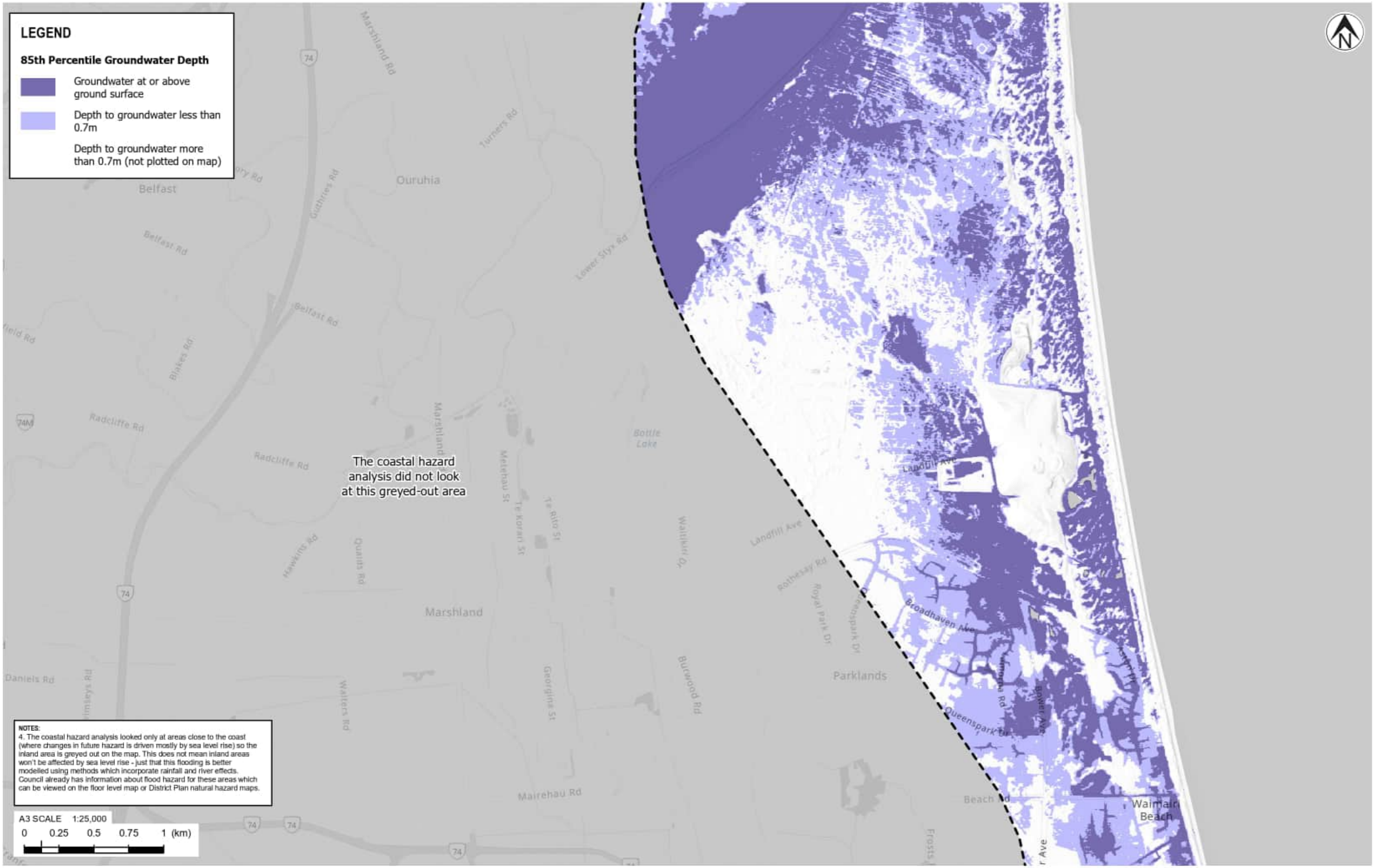

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CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 2F REV 1

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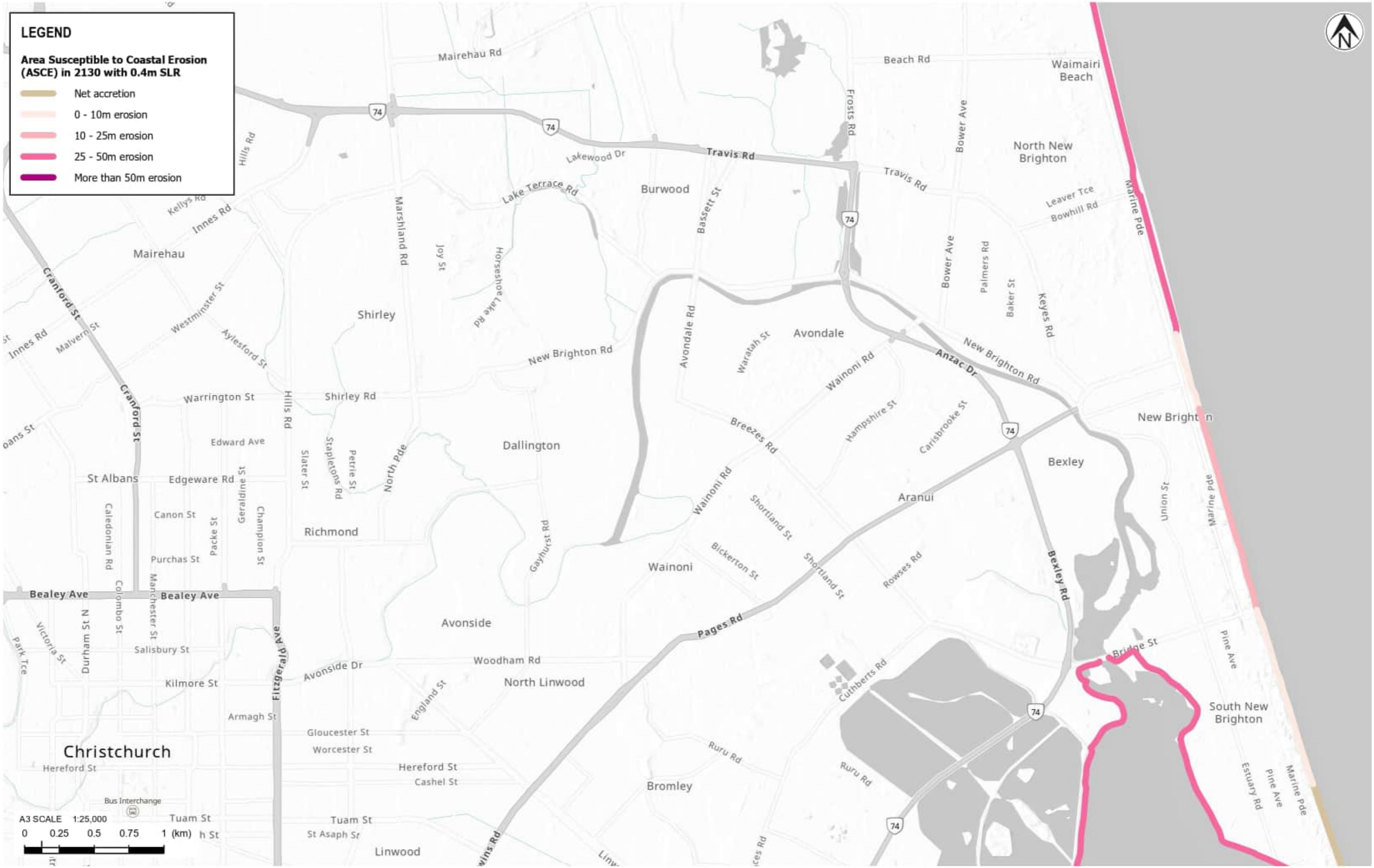

LEGEND

Area Susceptible to Coastal Erosion (ASCE) in 2130 with 0.4m SLR

- Net accretion
- 0 - 10m erosion
- 10 - 25m erosion
- 25 - 50m erosion
- More than 50m erosion

A3 SCALE 1:25,000

0 0.25 0.5 0.75 1 (km)

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CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 3A REV 1

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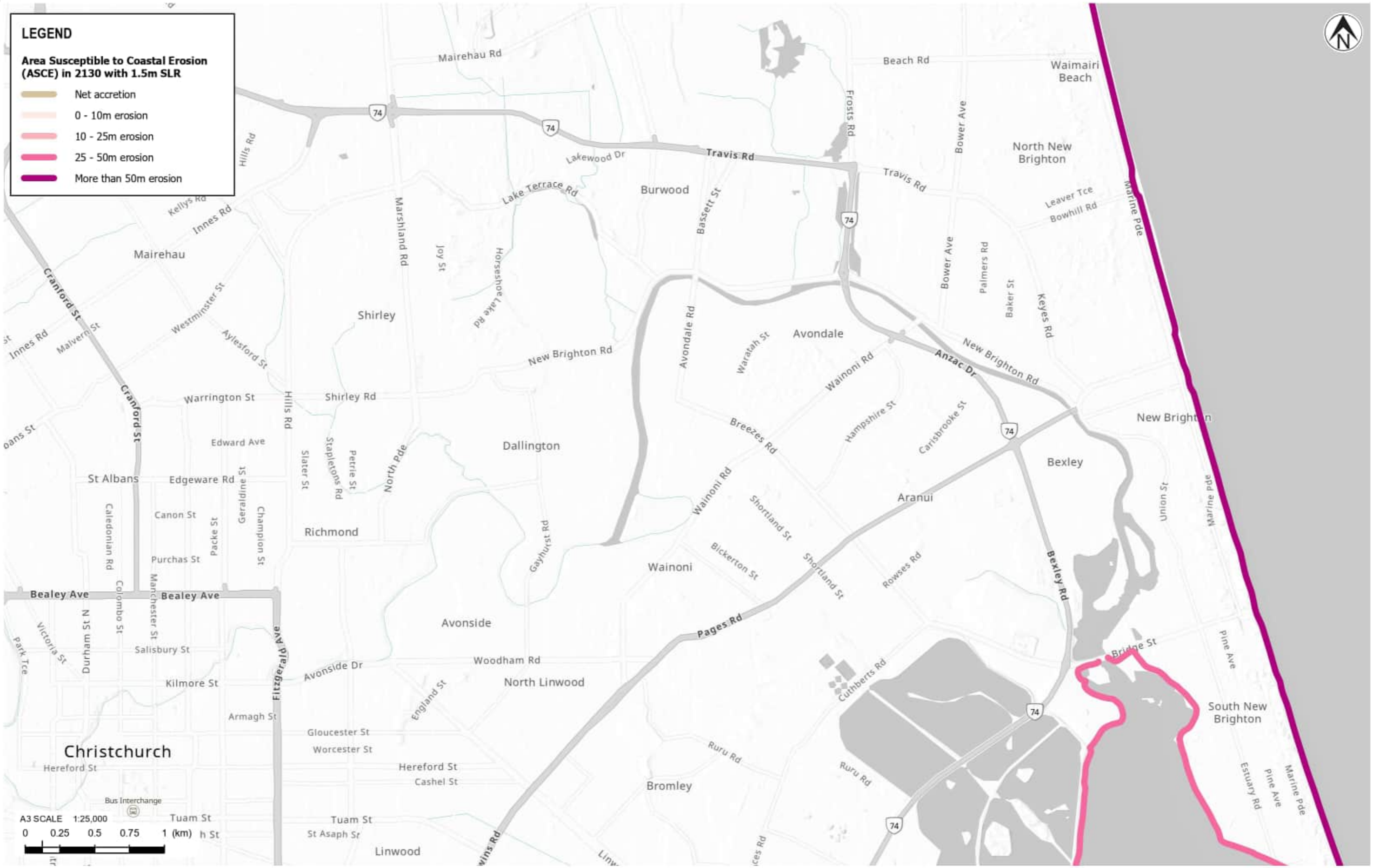

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SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 3B REV 1

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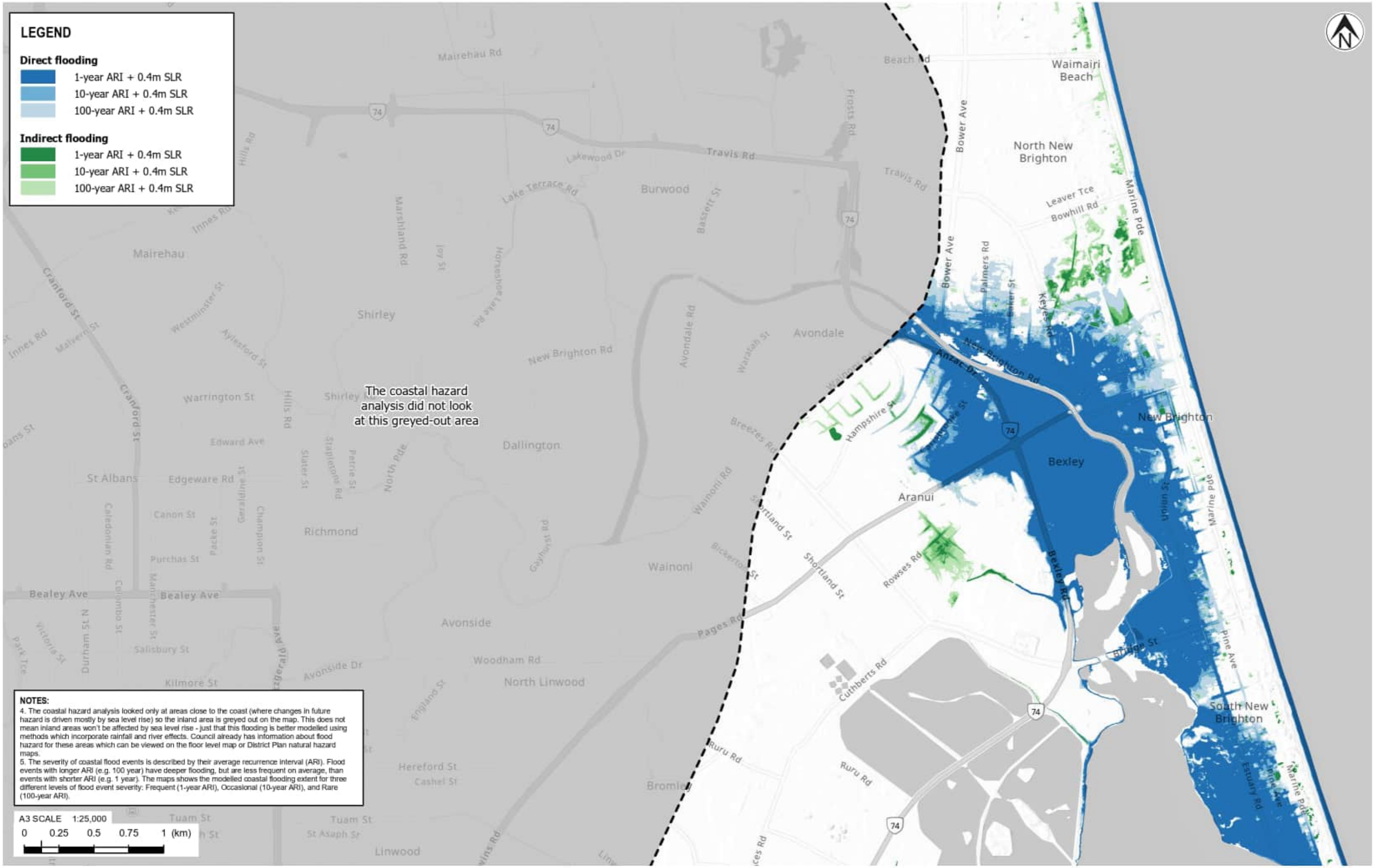

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CLIENT CHRISTCHURCH CITY COUNCIL
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TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 3C REV 1

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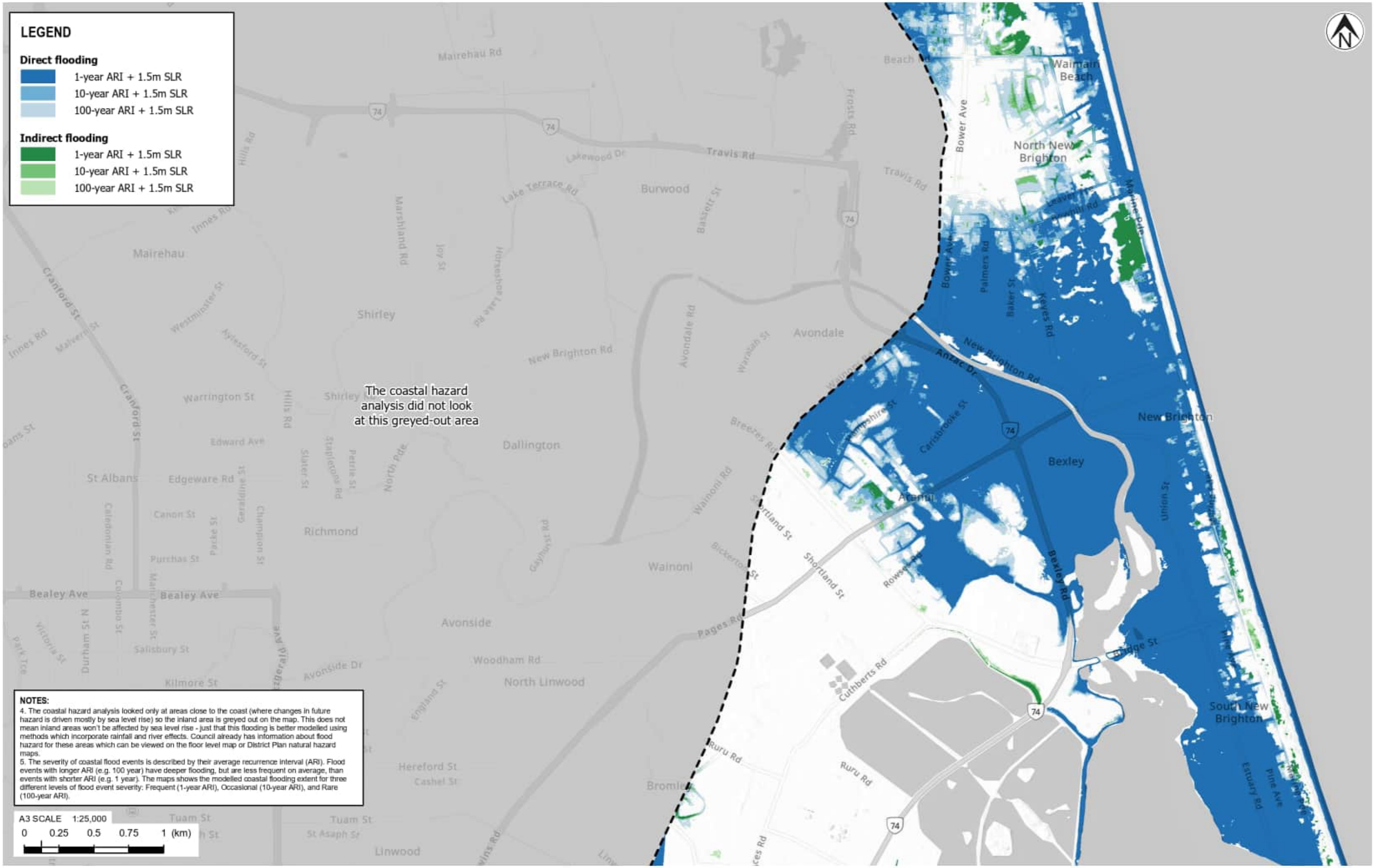

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TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000   FIG No. FIGURE 3D   REV 1

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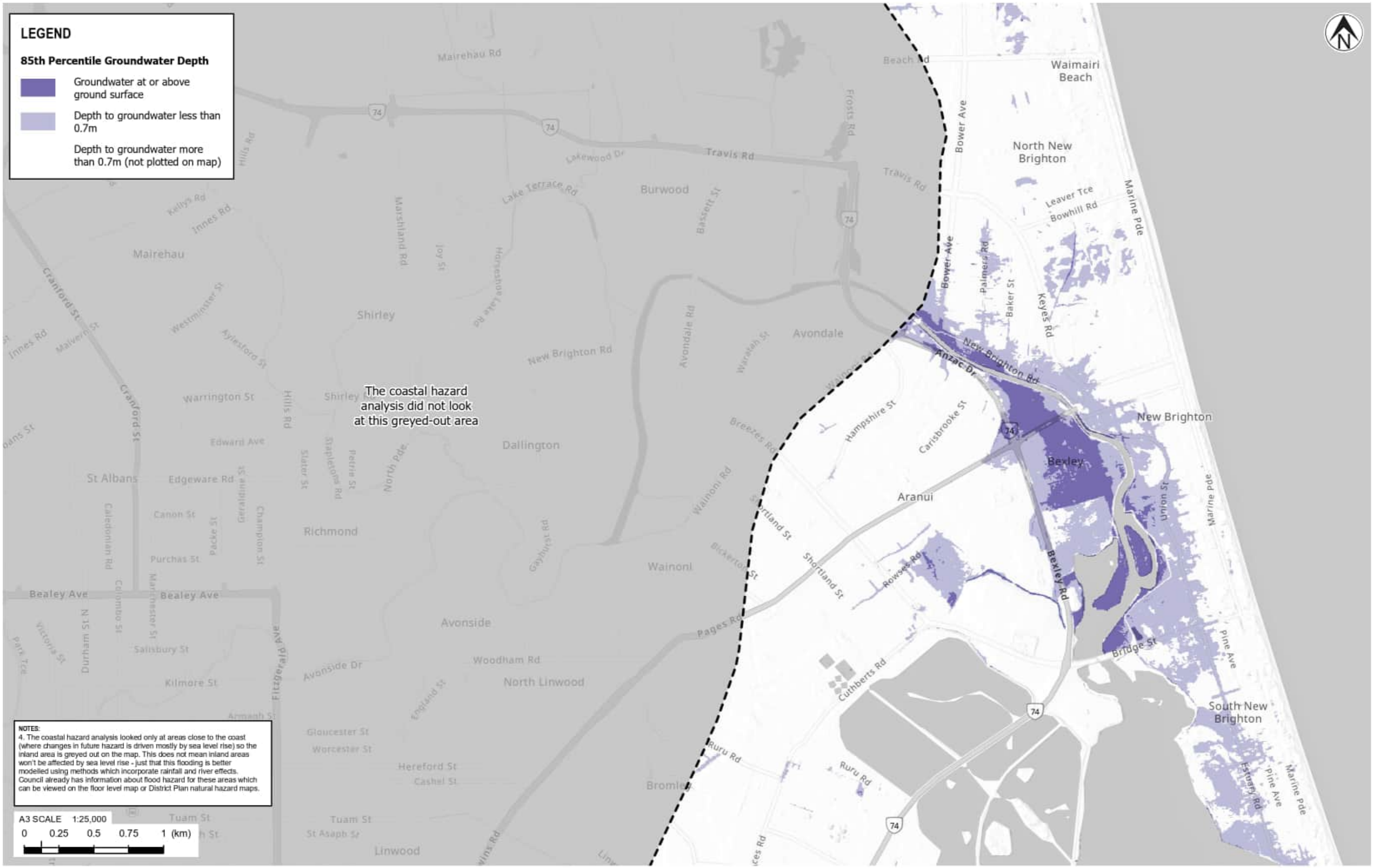

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SCALE (A3) 1:25,000   FIG No. FIGURE 3E   REV 1

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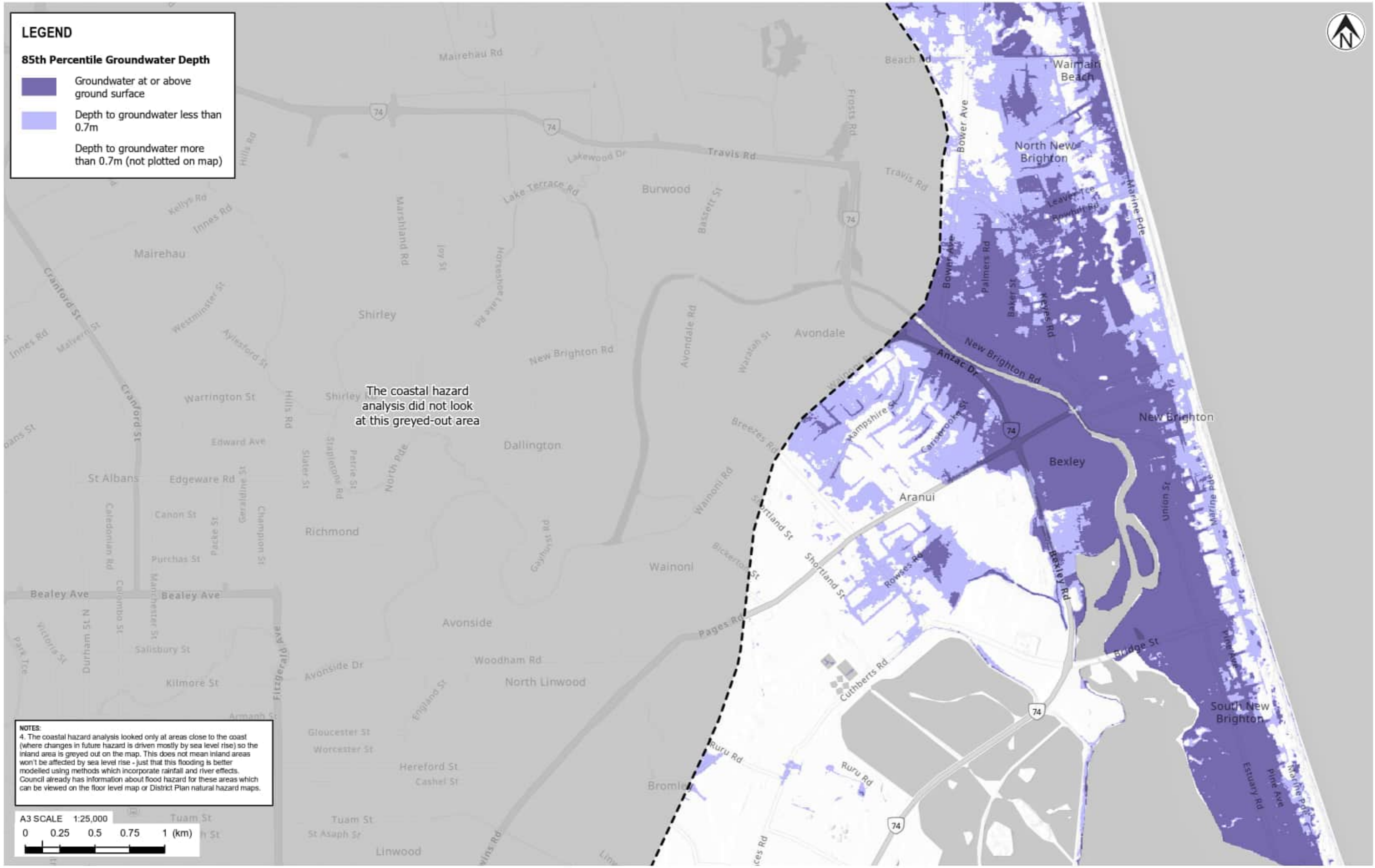

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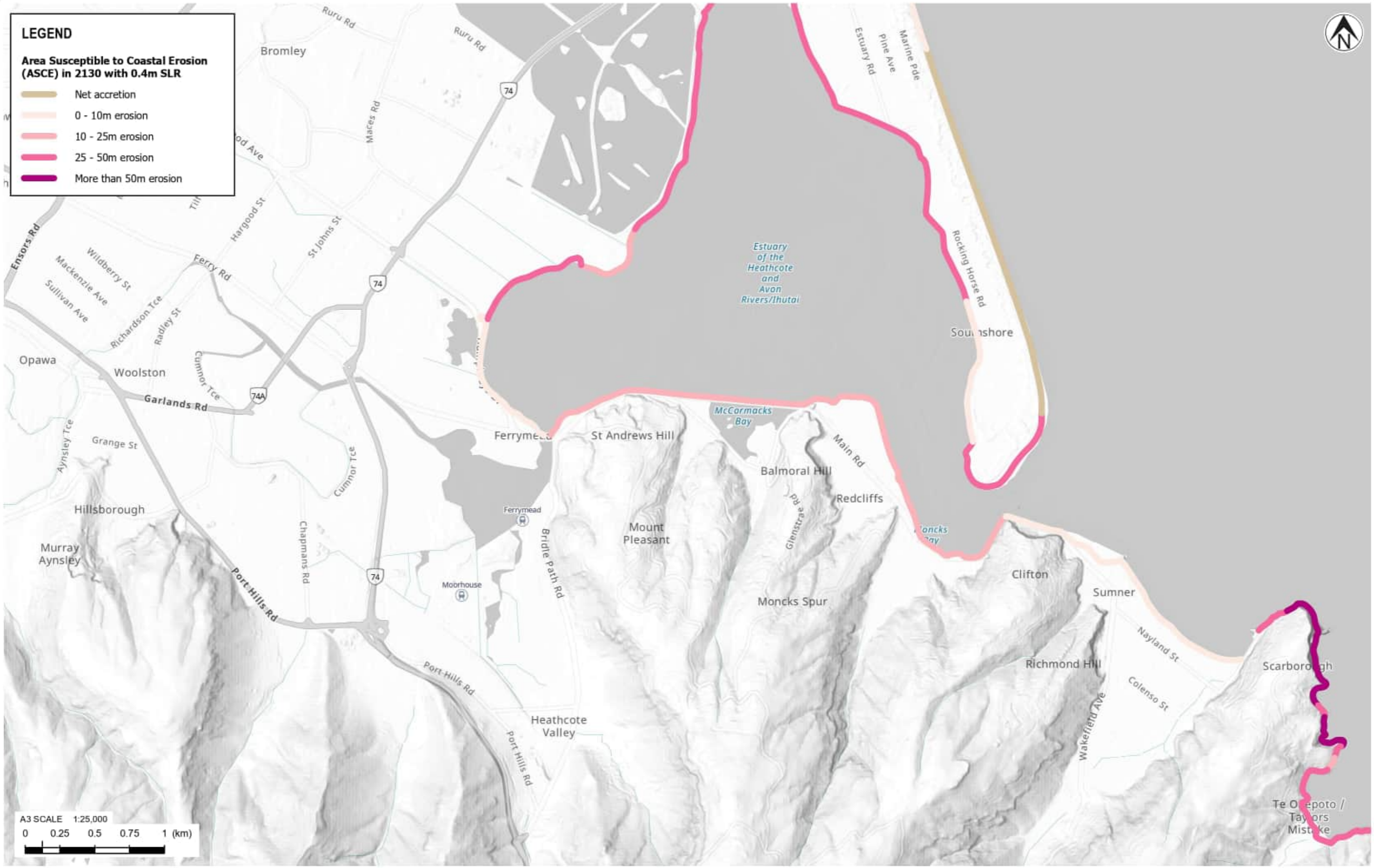

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REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	RHAU	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE
SCALE (A3): 1:25,000 FIG No. FIGURE 4A REV 1

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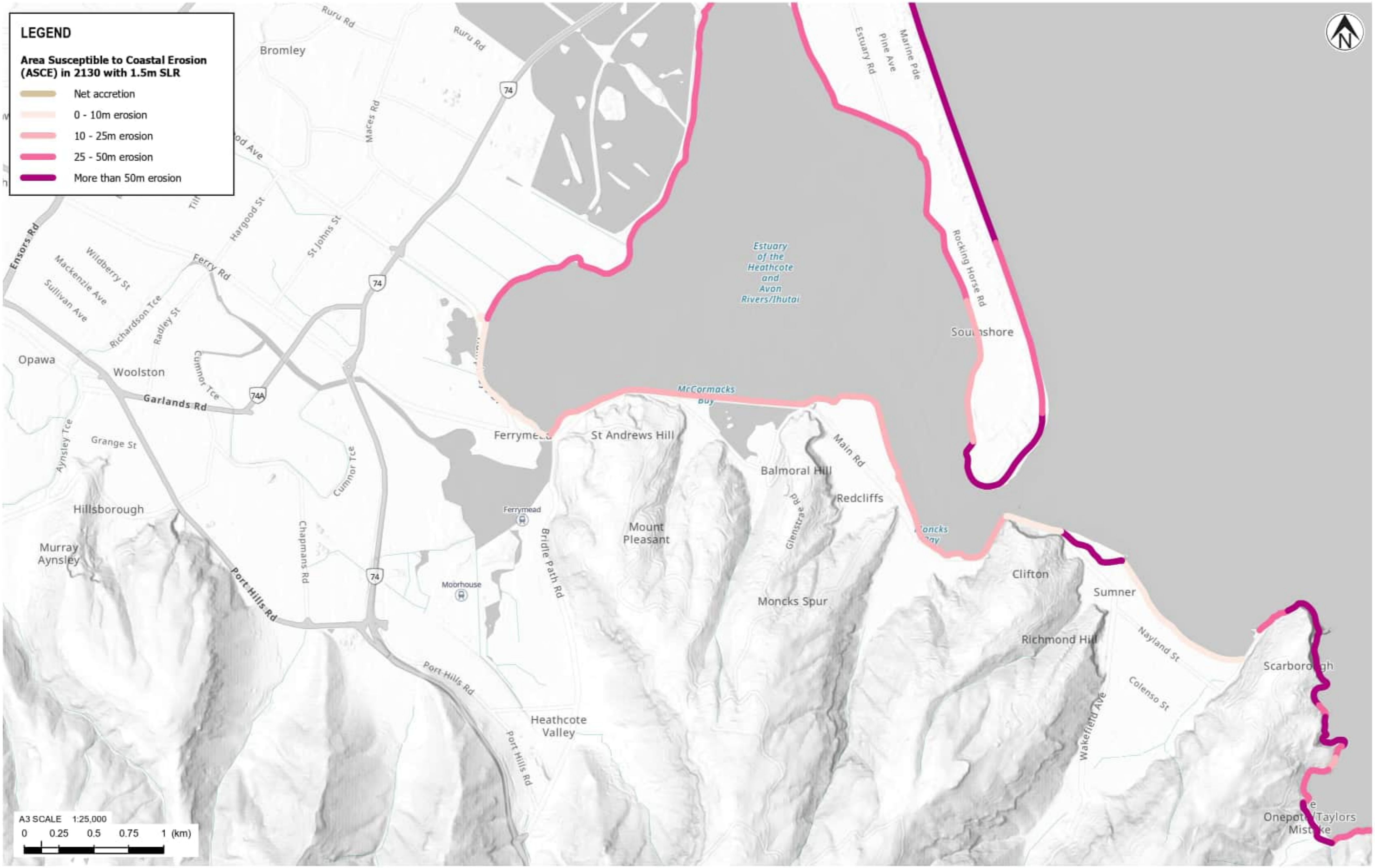

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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000   FIG No. FIGURE 4B   REV 1

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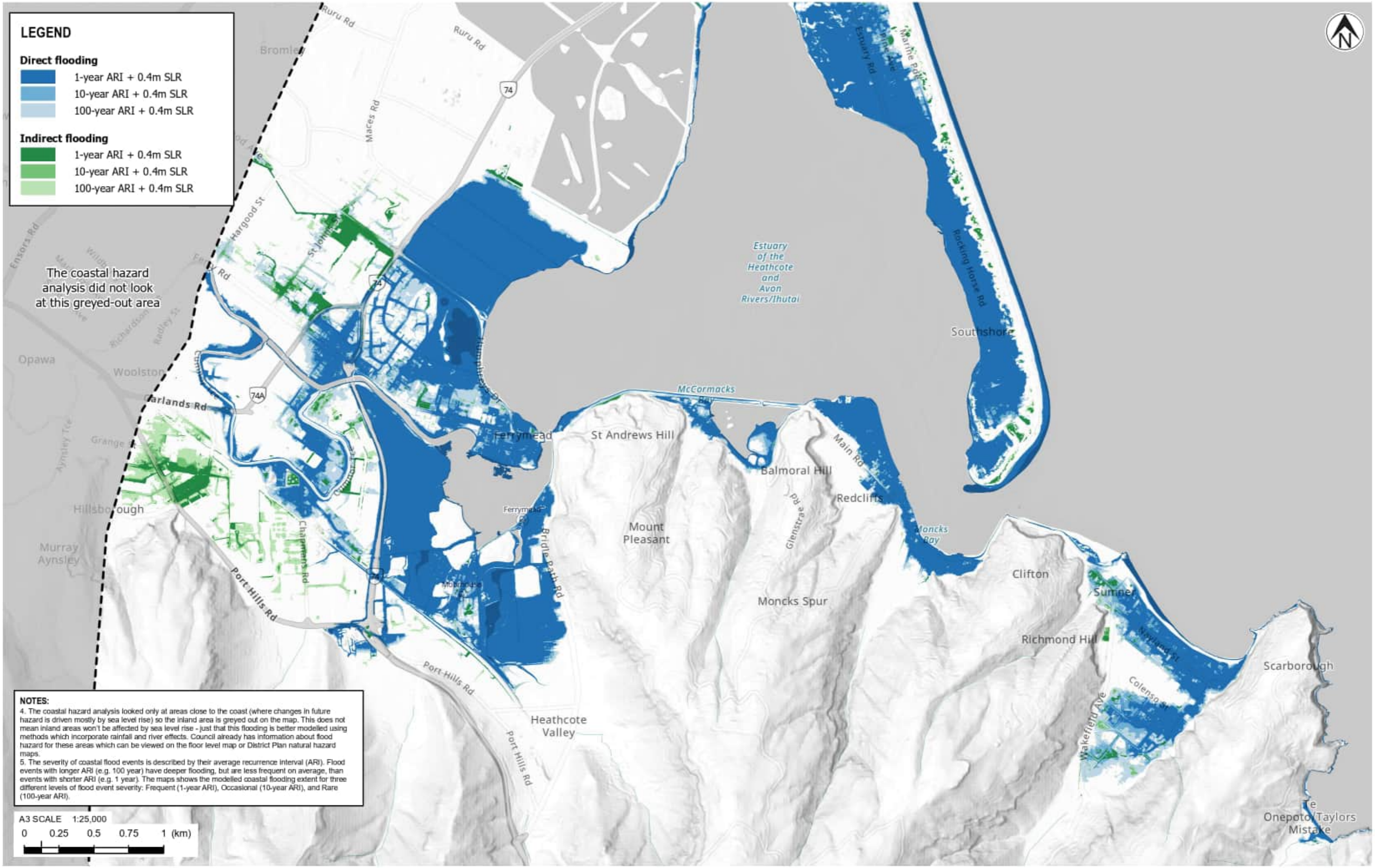

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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 4C REV 1

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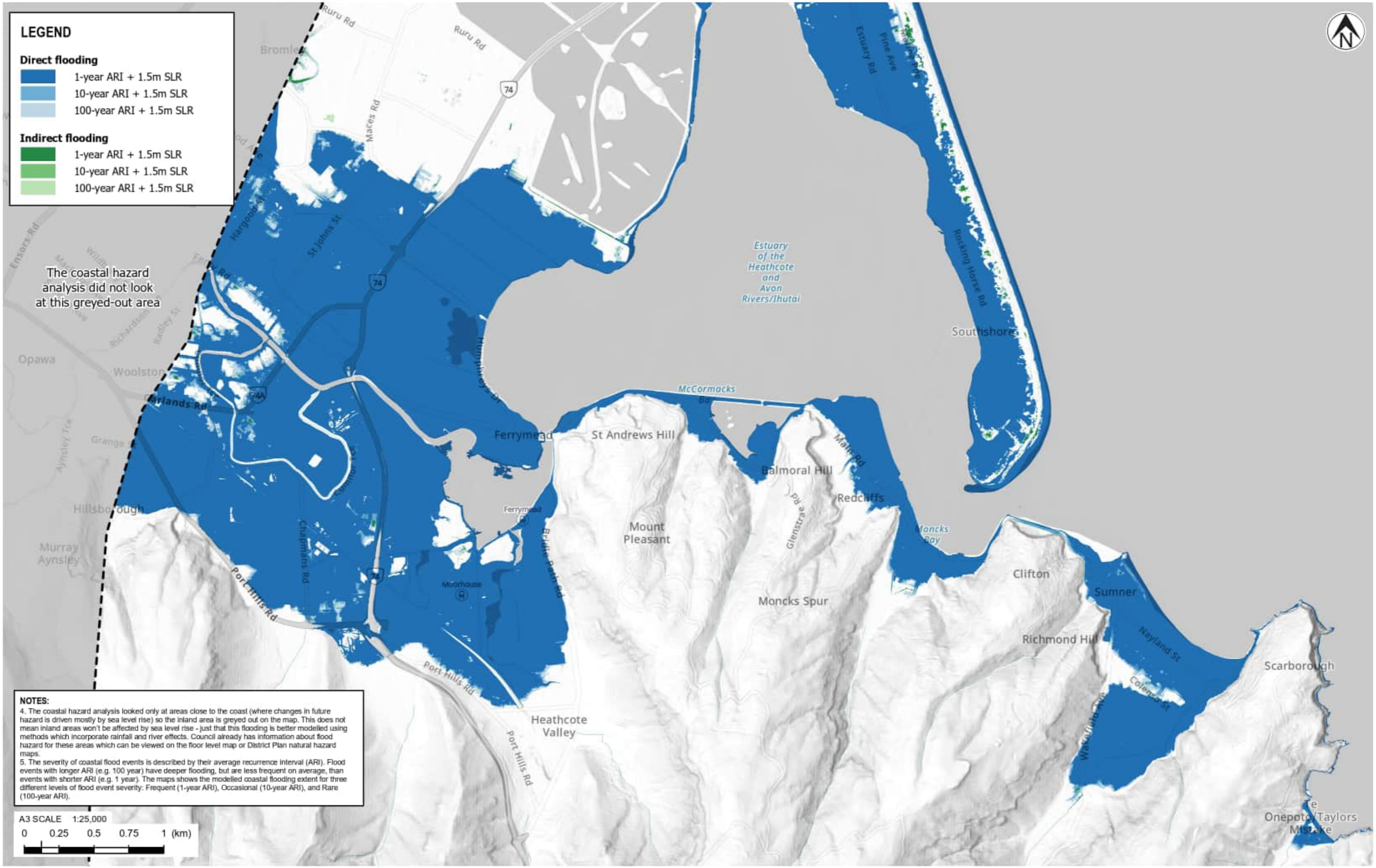

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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 4D REV 1

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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 4E REV 1

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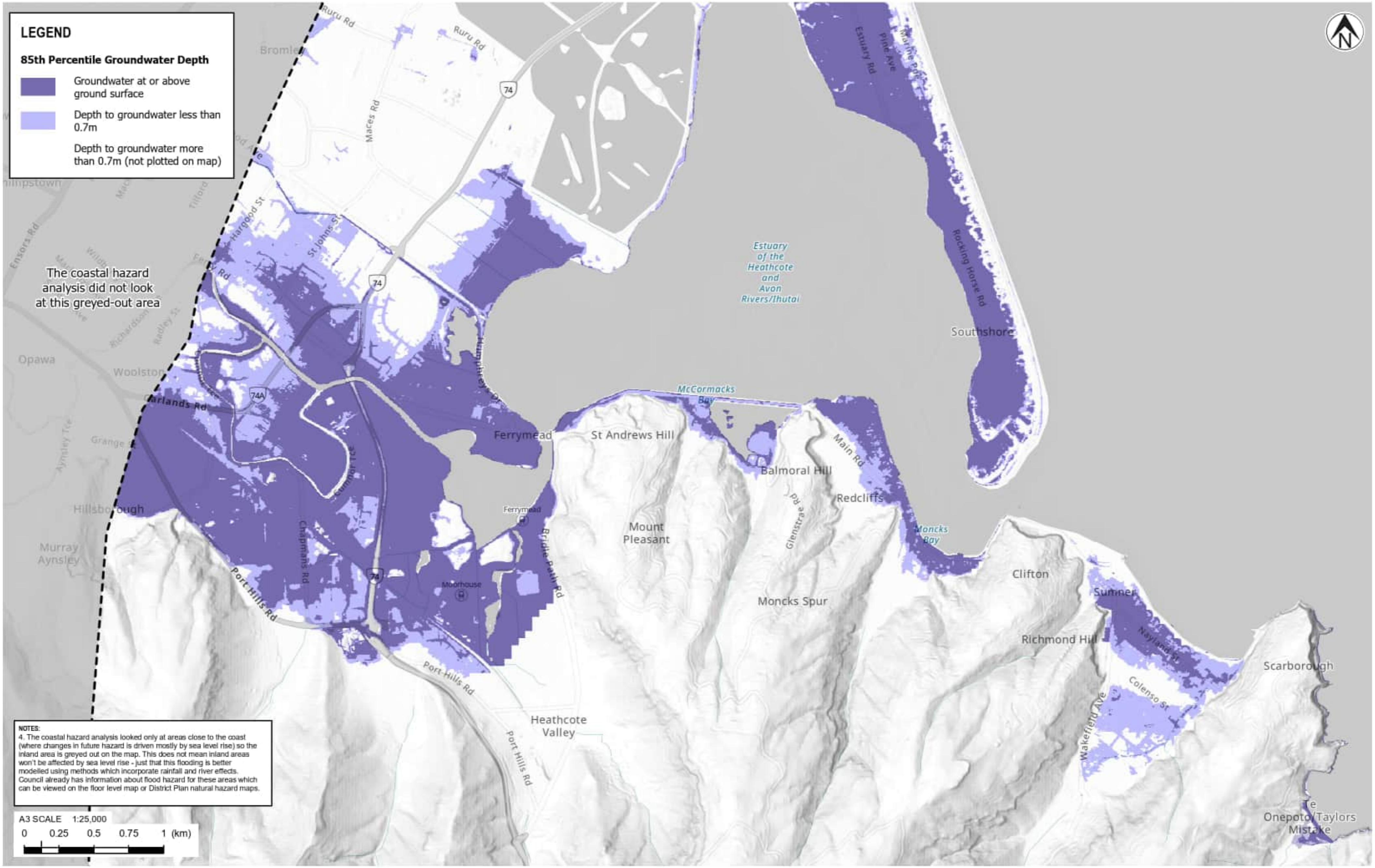

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APPROVED	P. COCHRANE	29/09/21

CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL GROUNDWATER ANALYSIS SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3): 1:25,000 FIG No. FIGURE 4F REV 1

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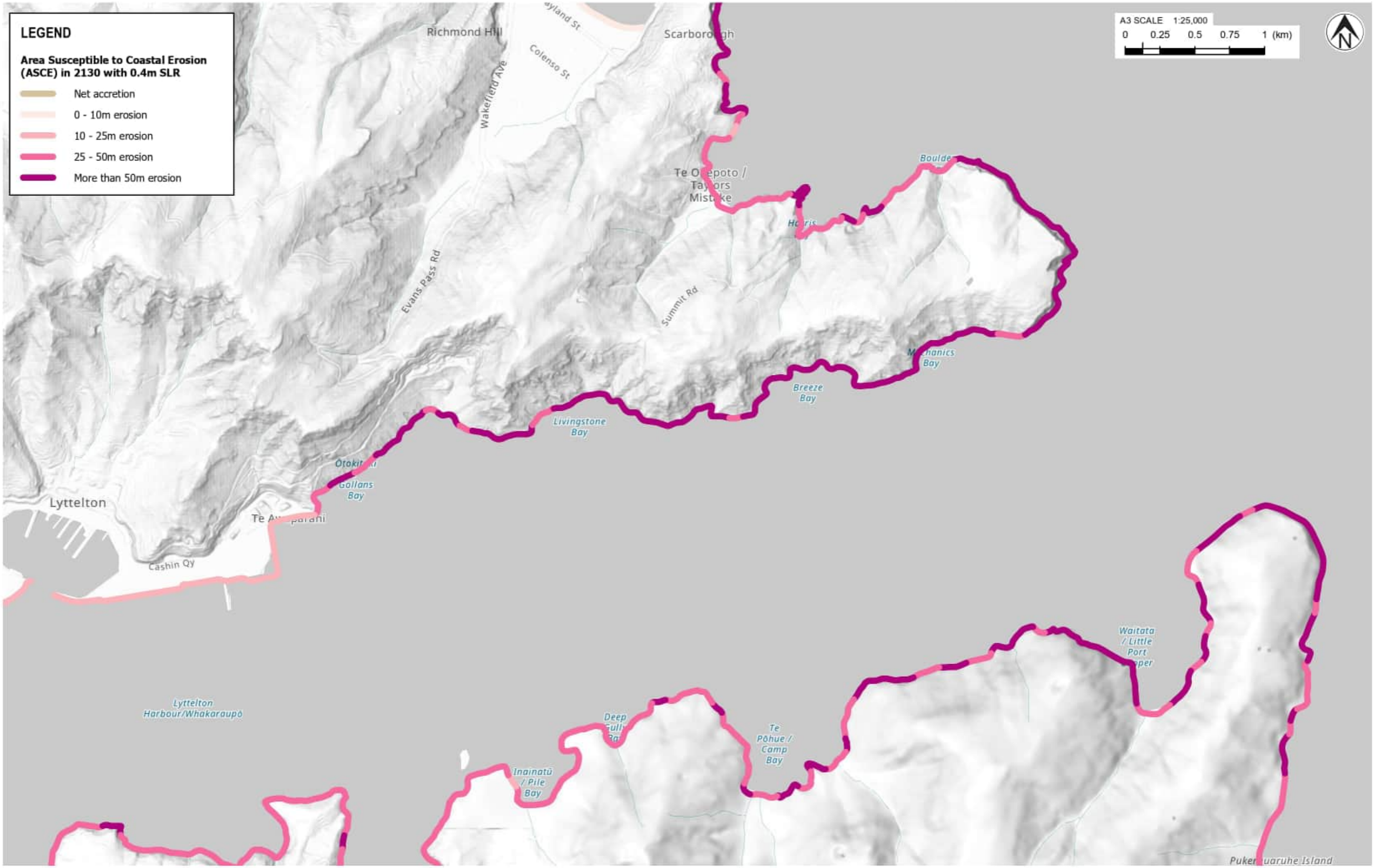

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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 5A REV 1

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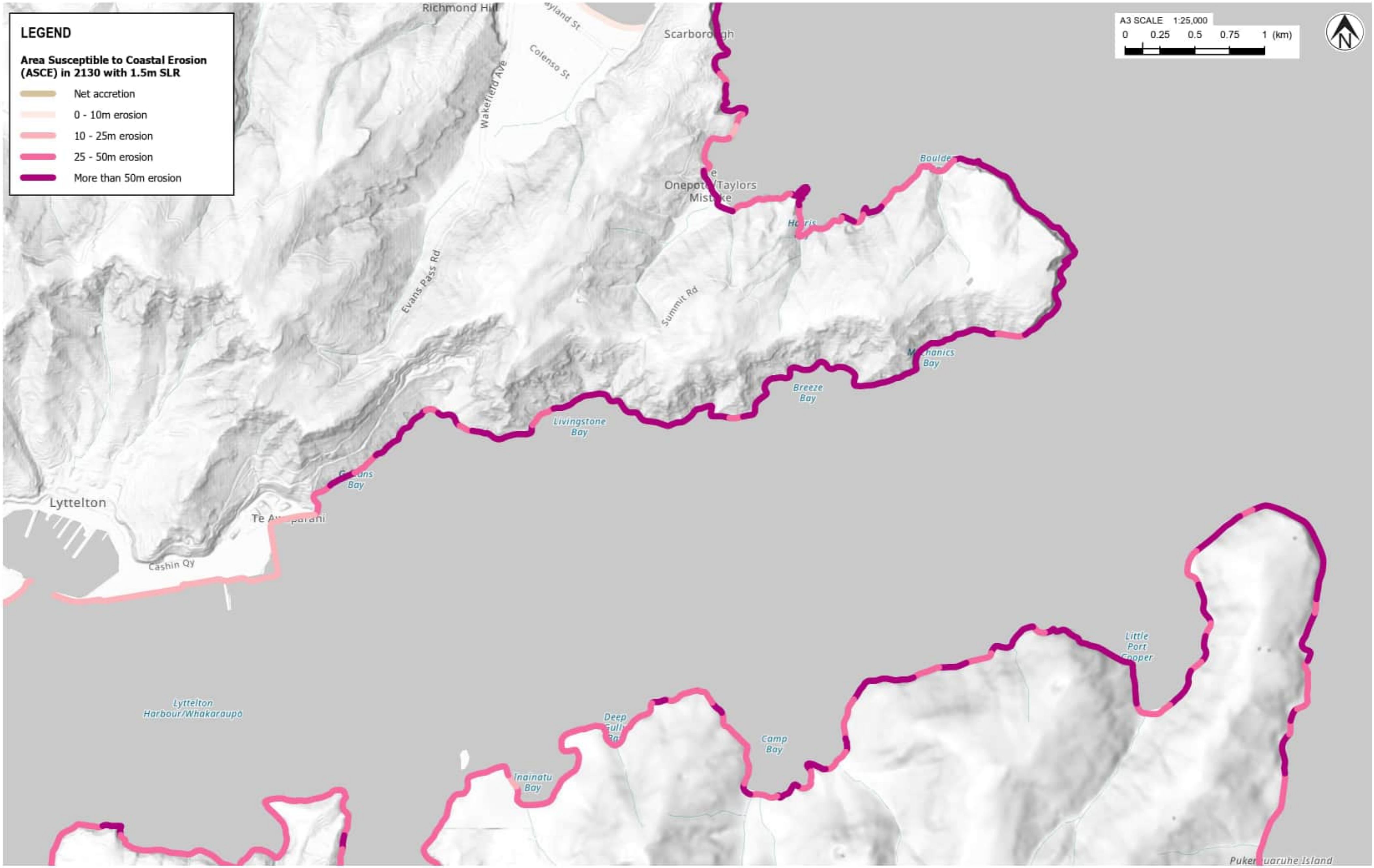

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LOCATION PLAN

PROJECT No.	1012976	
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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 5B REV 1

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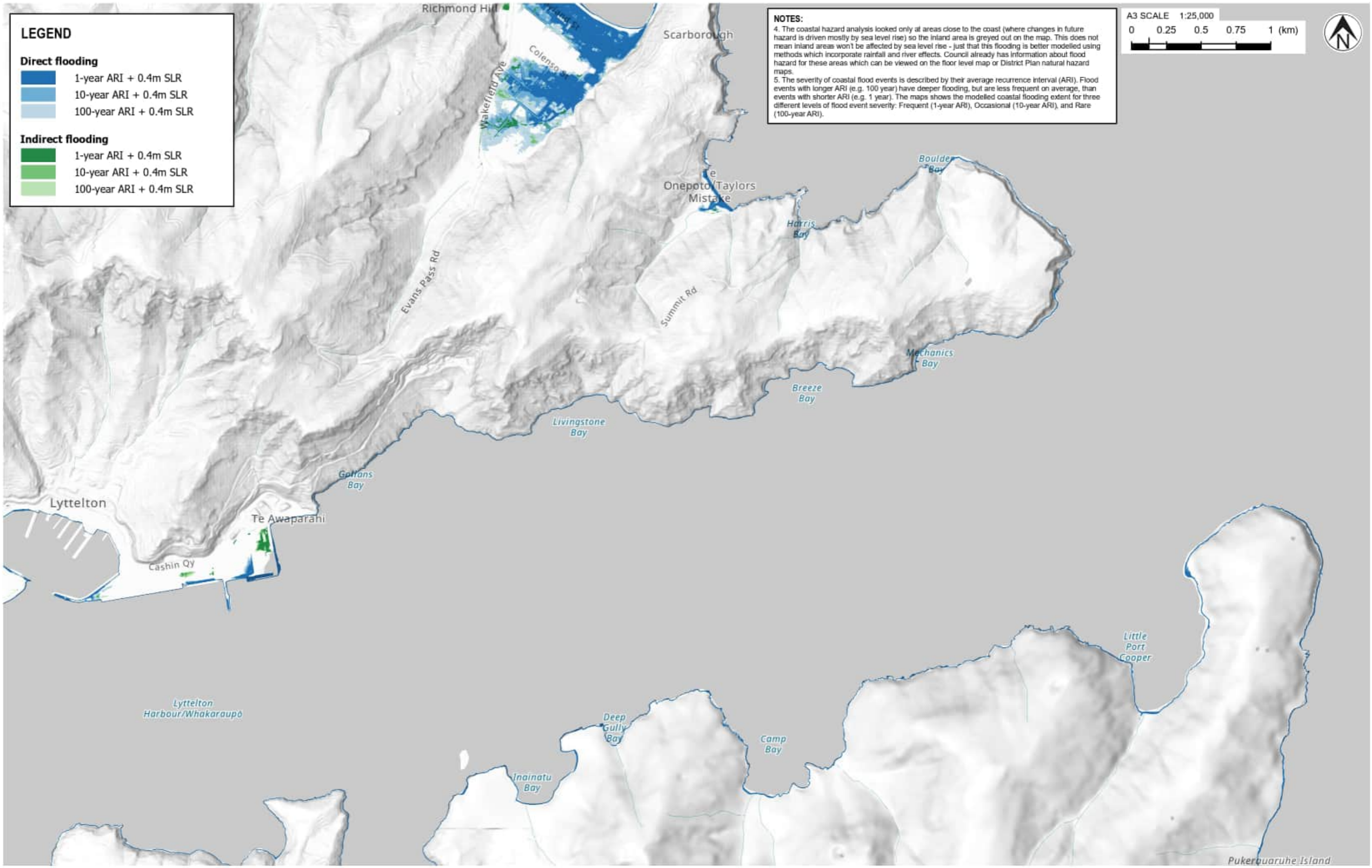

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REV	DESCRIPTION	GIS	CHK	DATE
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PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

LOCATION PLAN

CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3): 1:25,000   FIG No.: FIGURE 5C   REV: 1

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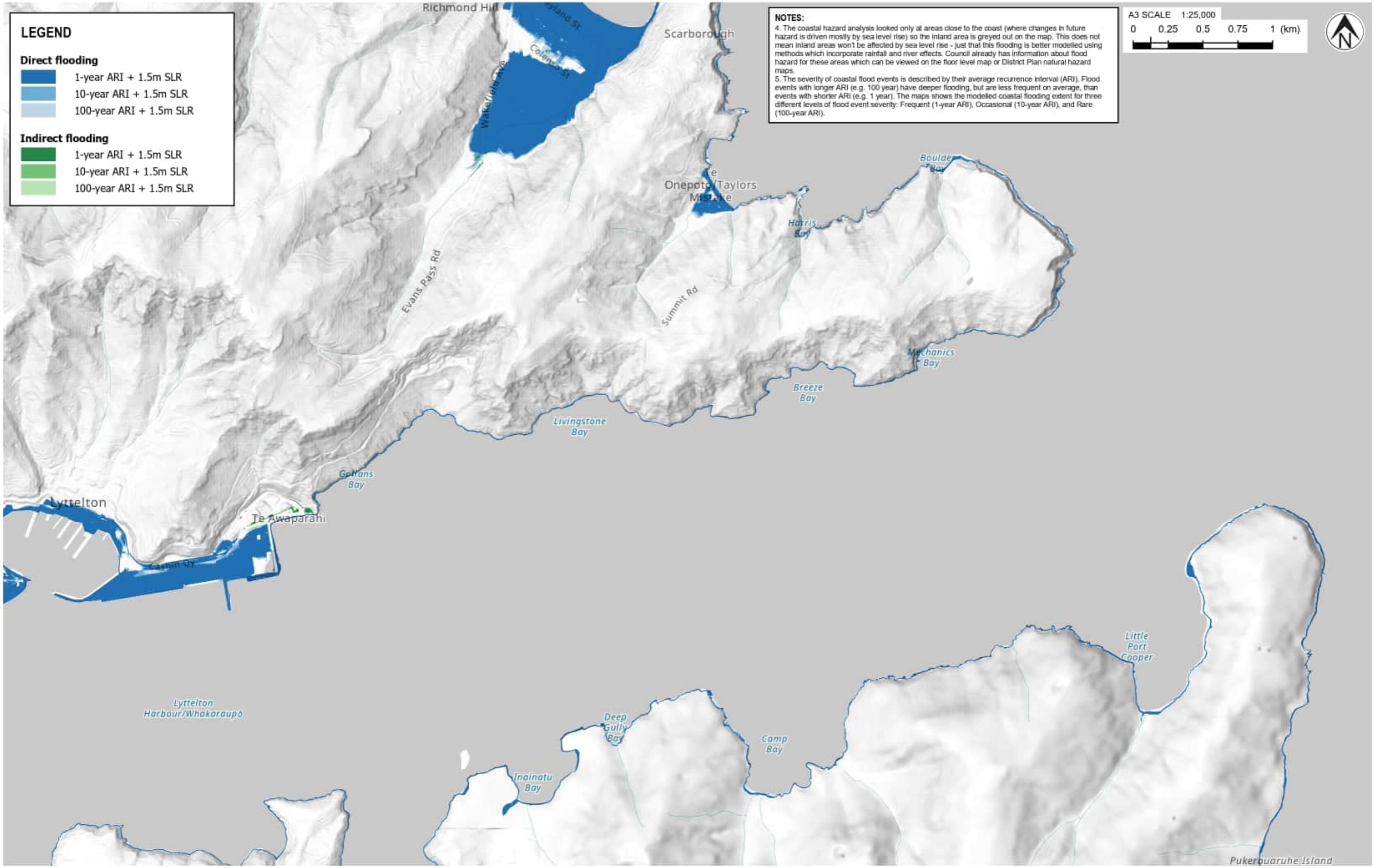

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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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APPROVED	P. COCHRANE	29/09/21

CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3): 1:25,000   FIG No.: FIGURE 5D   REV: 1

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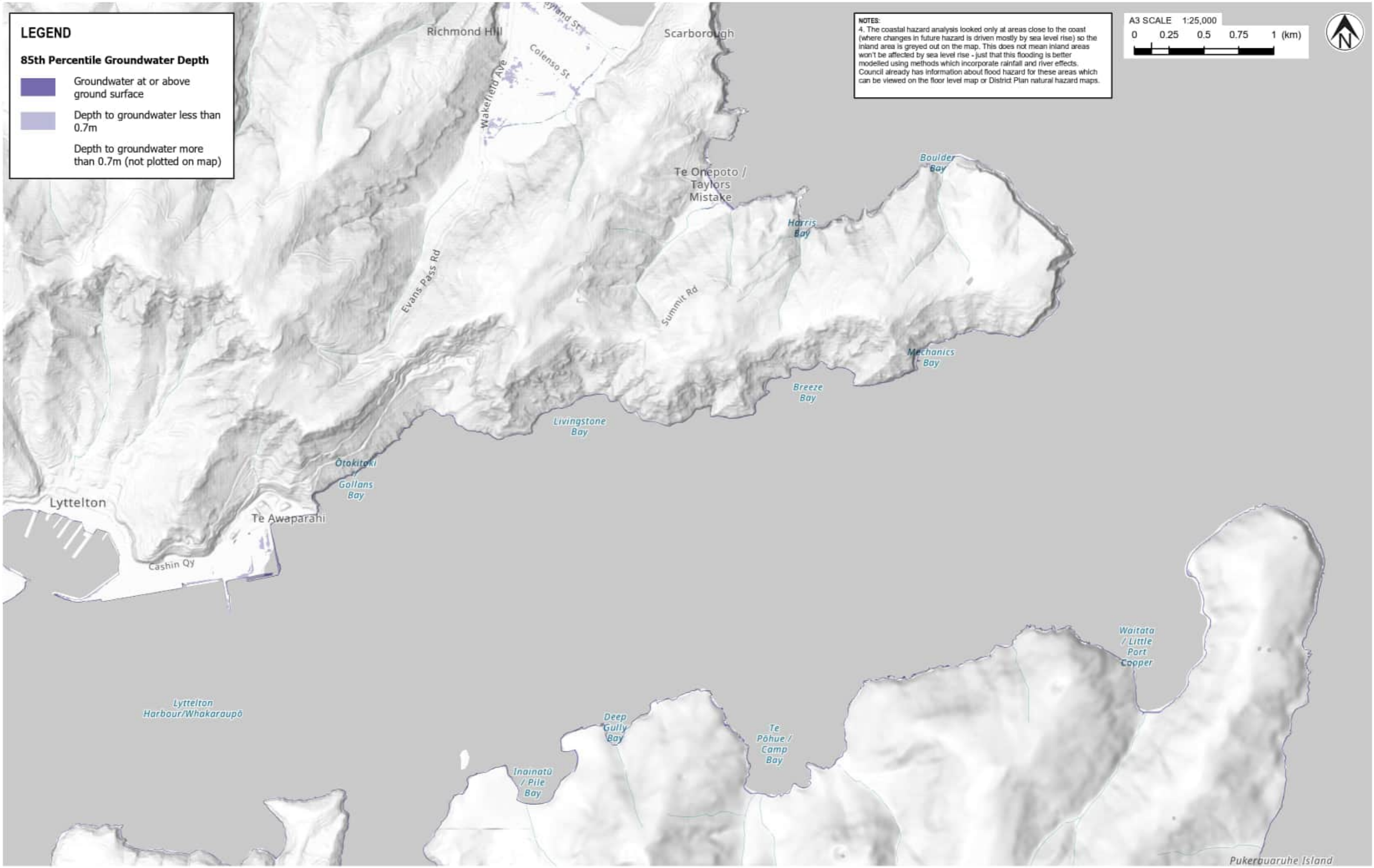

LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
- Depth to groundwater more than 0.7m (not plotted on map)

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CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 5E REV 1

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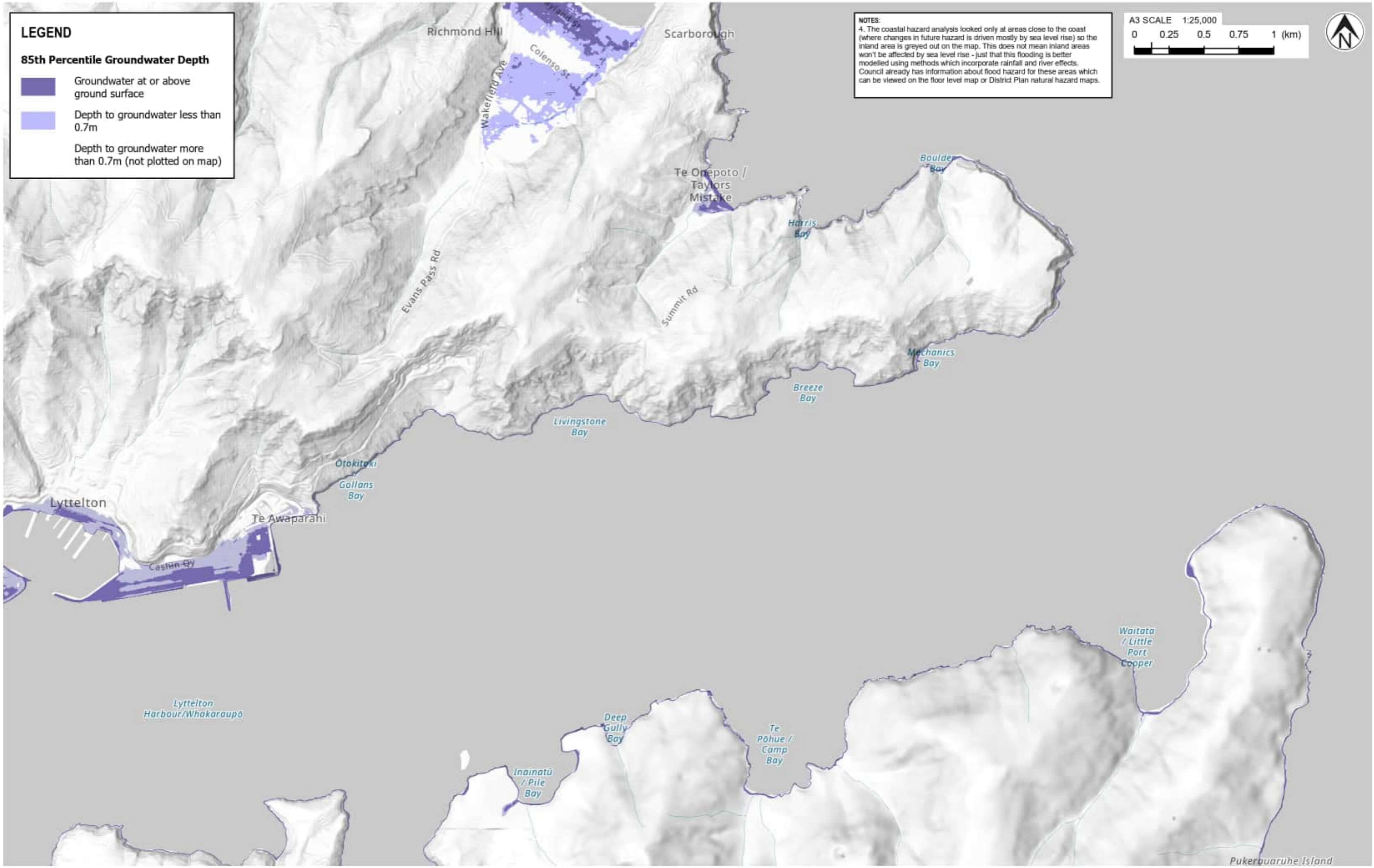

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CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL GROUNDWATER ANALYSIS SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3): 1:25,000   FIG No. FIGURE 5F   REV 1

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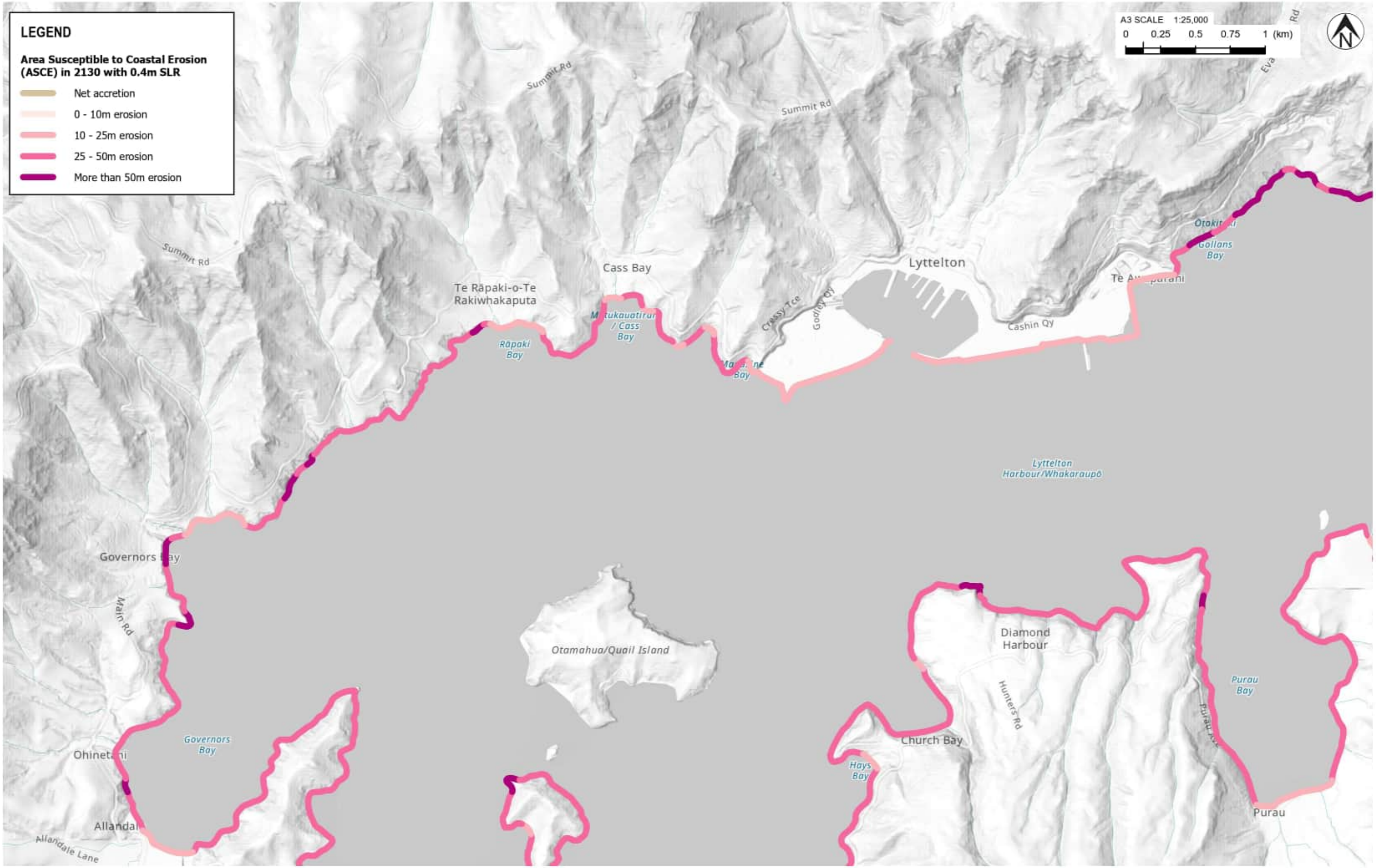

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LOCATION PLAN

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CLIENT CHRISTCHURCH CITY COUNCIL
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TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000   FIG No. FIGURE 6A   REV 1

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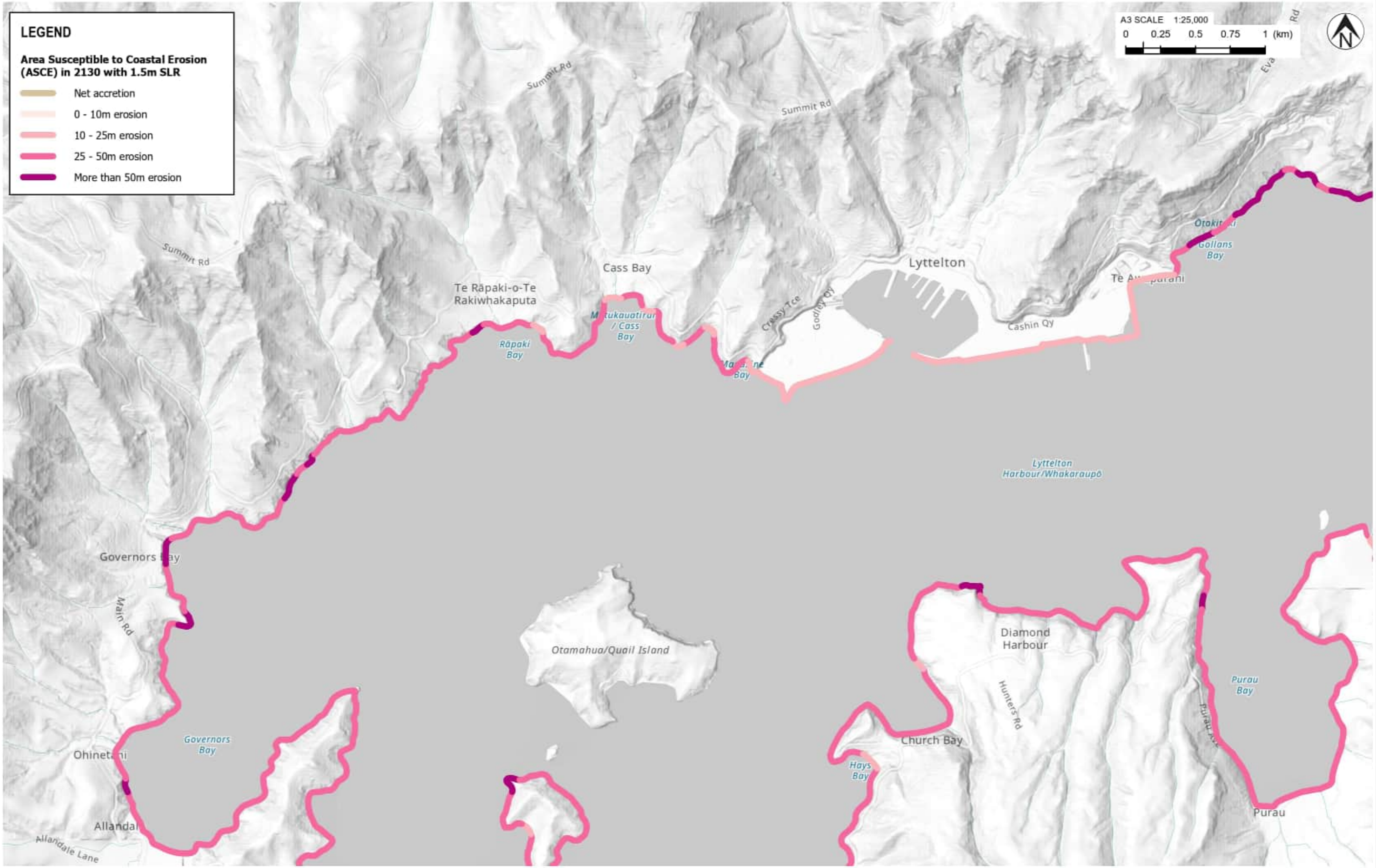

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CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 6B REV 1

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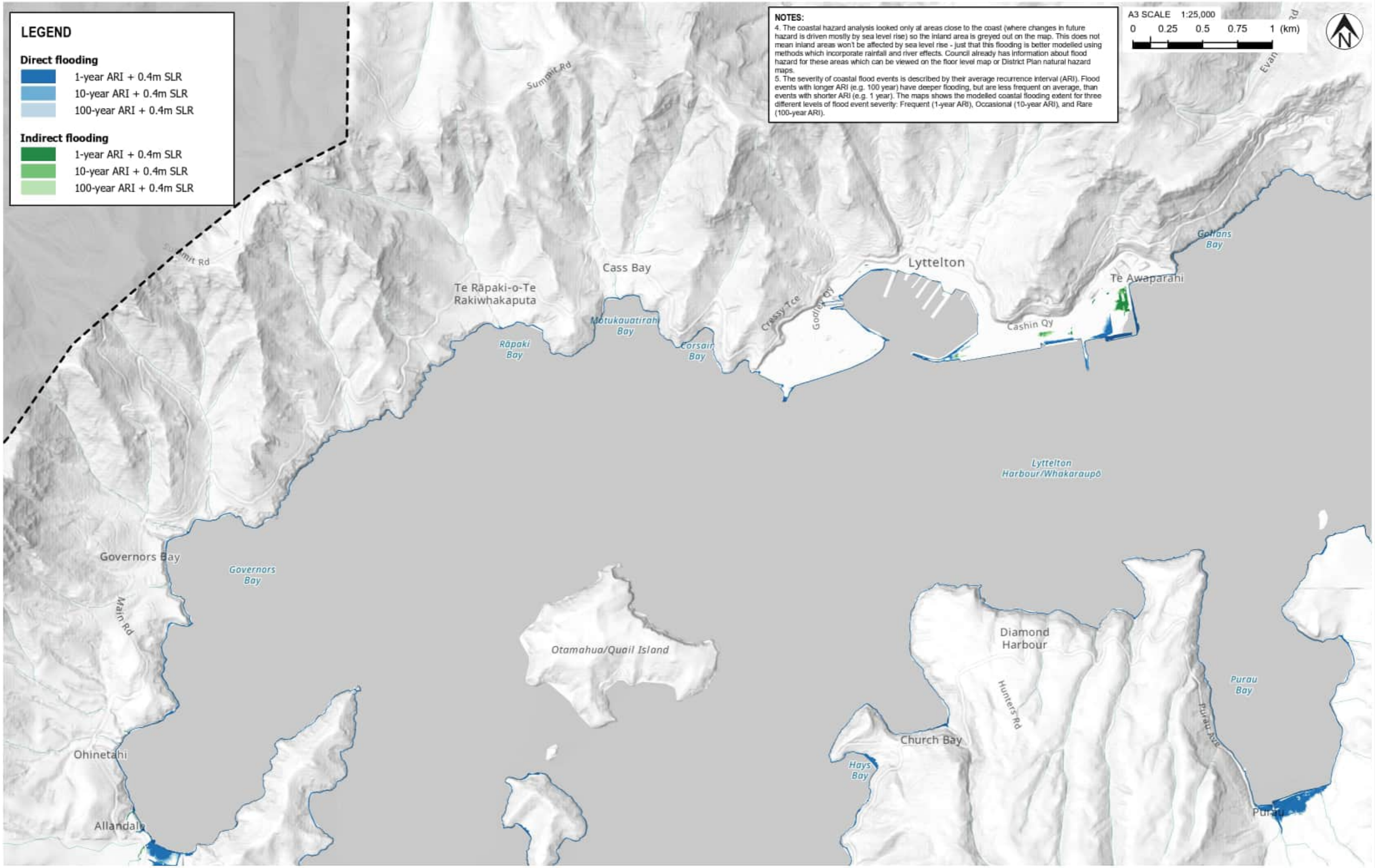

NOTES:

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REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	PPK	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 6C REV 1

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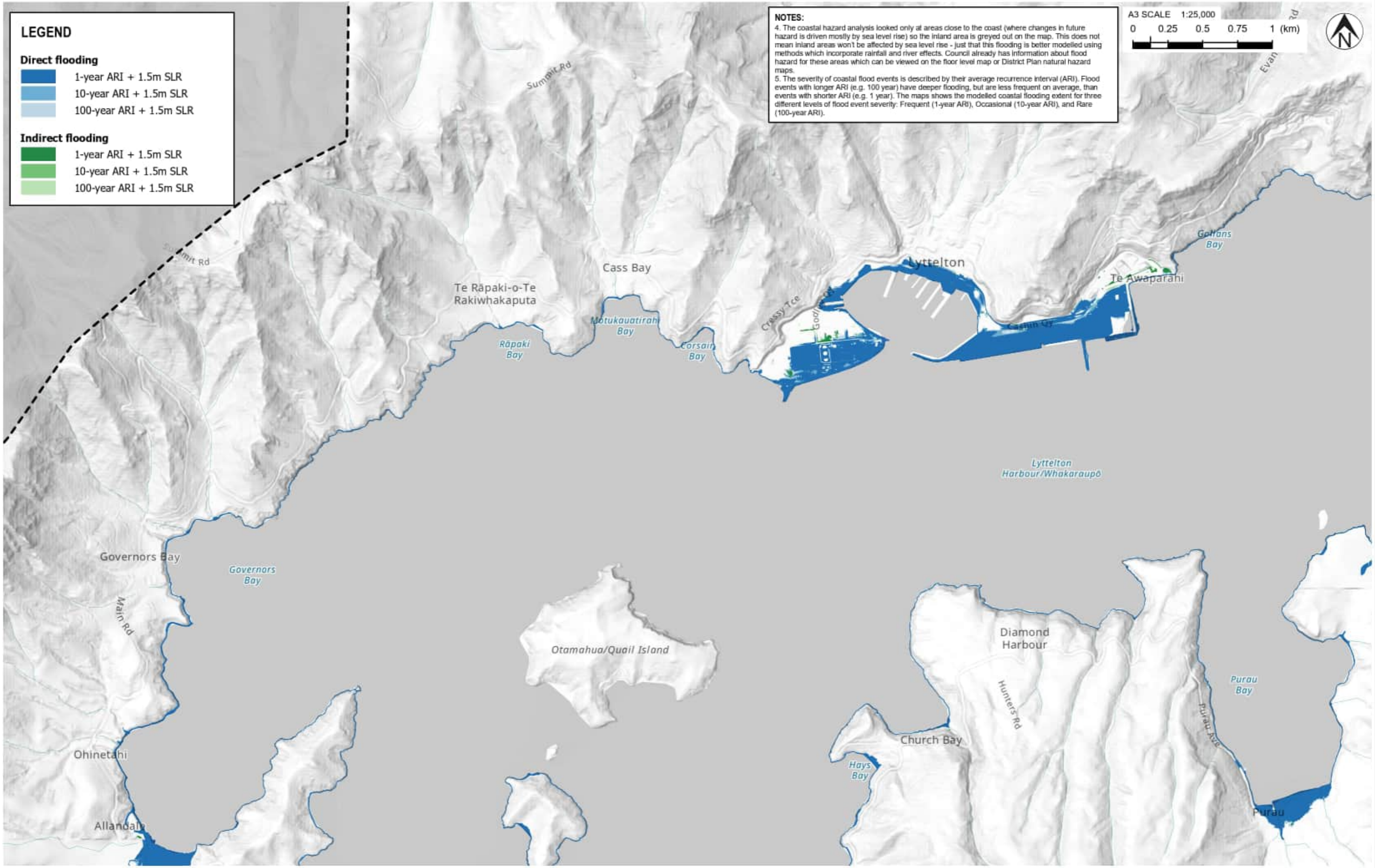

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LOCATION PLAN

PROJECT No.	1012976	
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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000   FIG No. FIGURE 6D   REV 1

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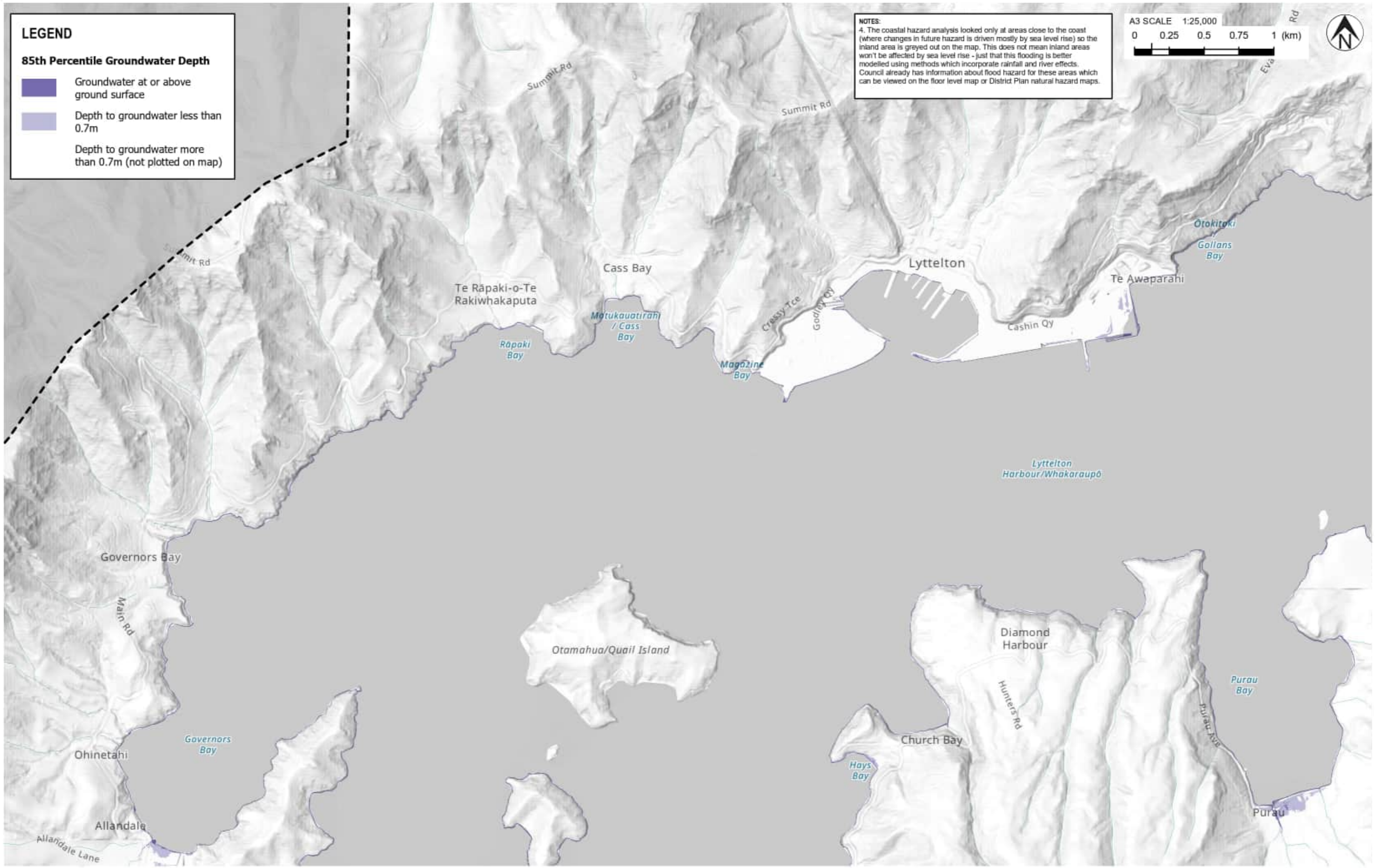

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APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 6E REV 1

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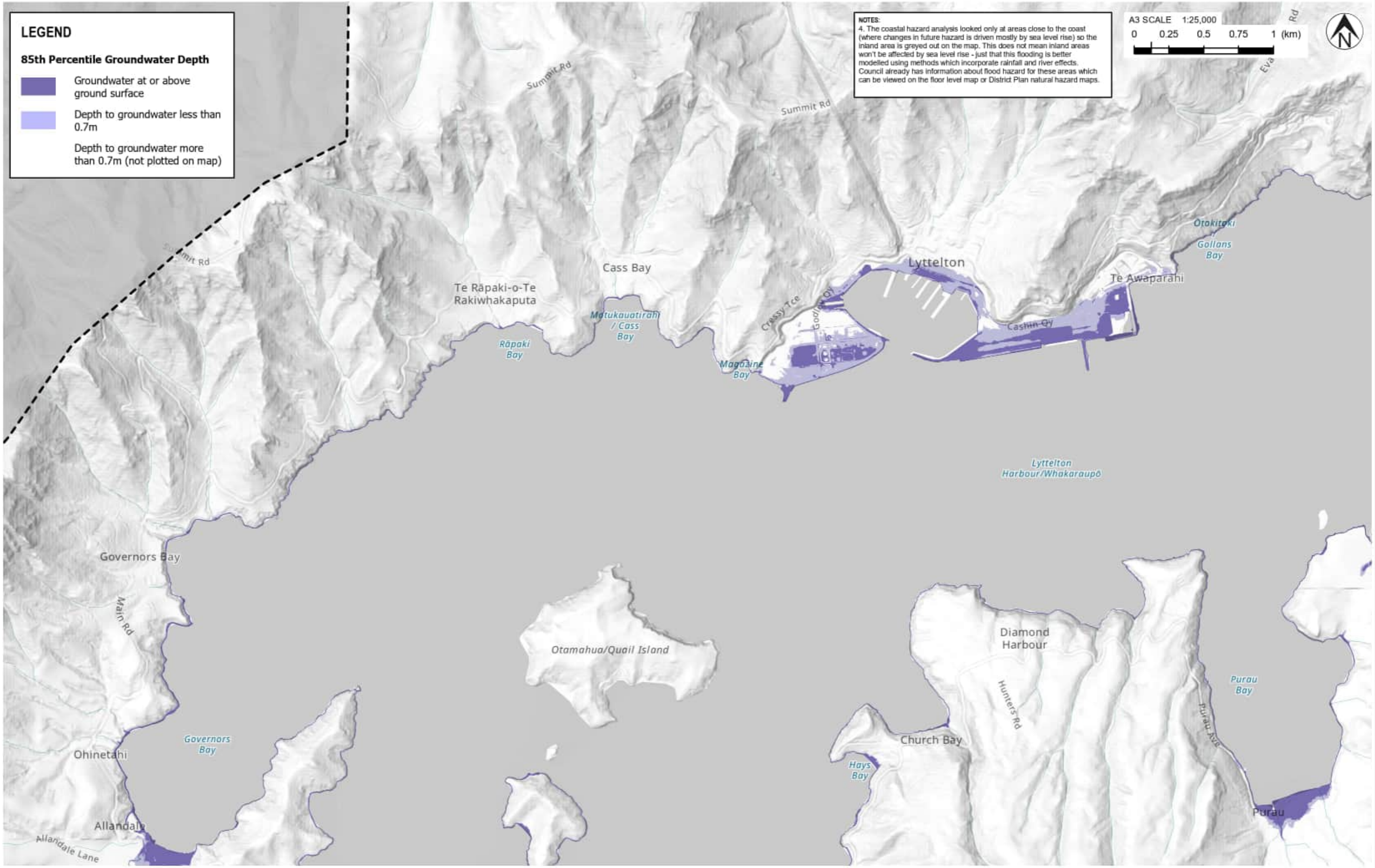

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CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL GROUNDWATER ANALYSIS SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 6F REV 1

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1	Report issued	MEJ	RHAU	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
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APPROVED	P. COCHRANE	29/09/21

CLIENT: **CHRISTCHURCH CITY COUNCIL**
PROJECT: **COASTAL HAZARD ASSESSMENT**
TITLE: COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000   FIG No. FIGURE 7A   REV 1

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APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 7B REV 1

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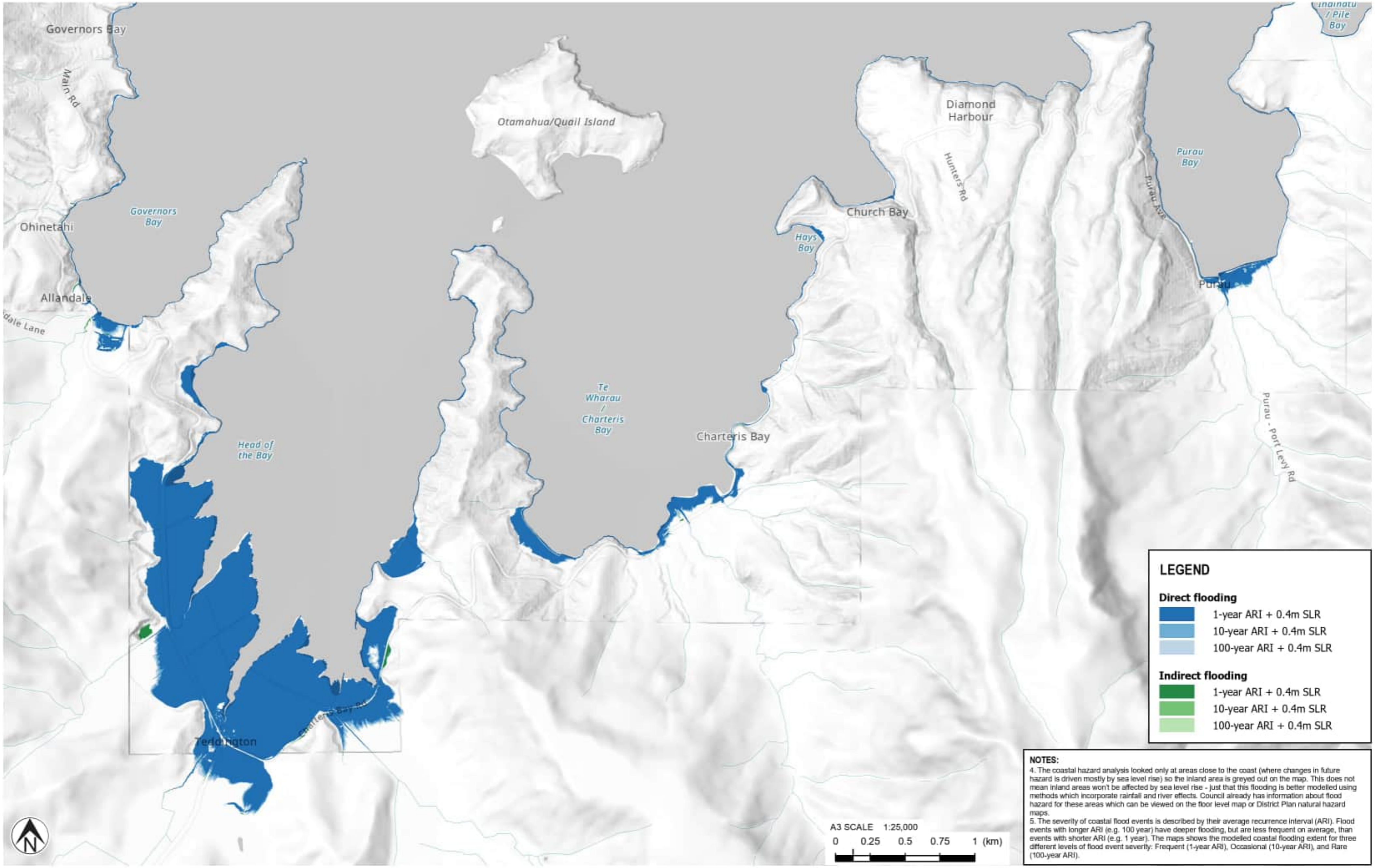

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CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 7C REV 1

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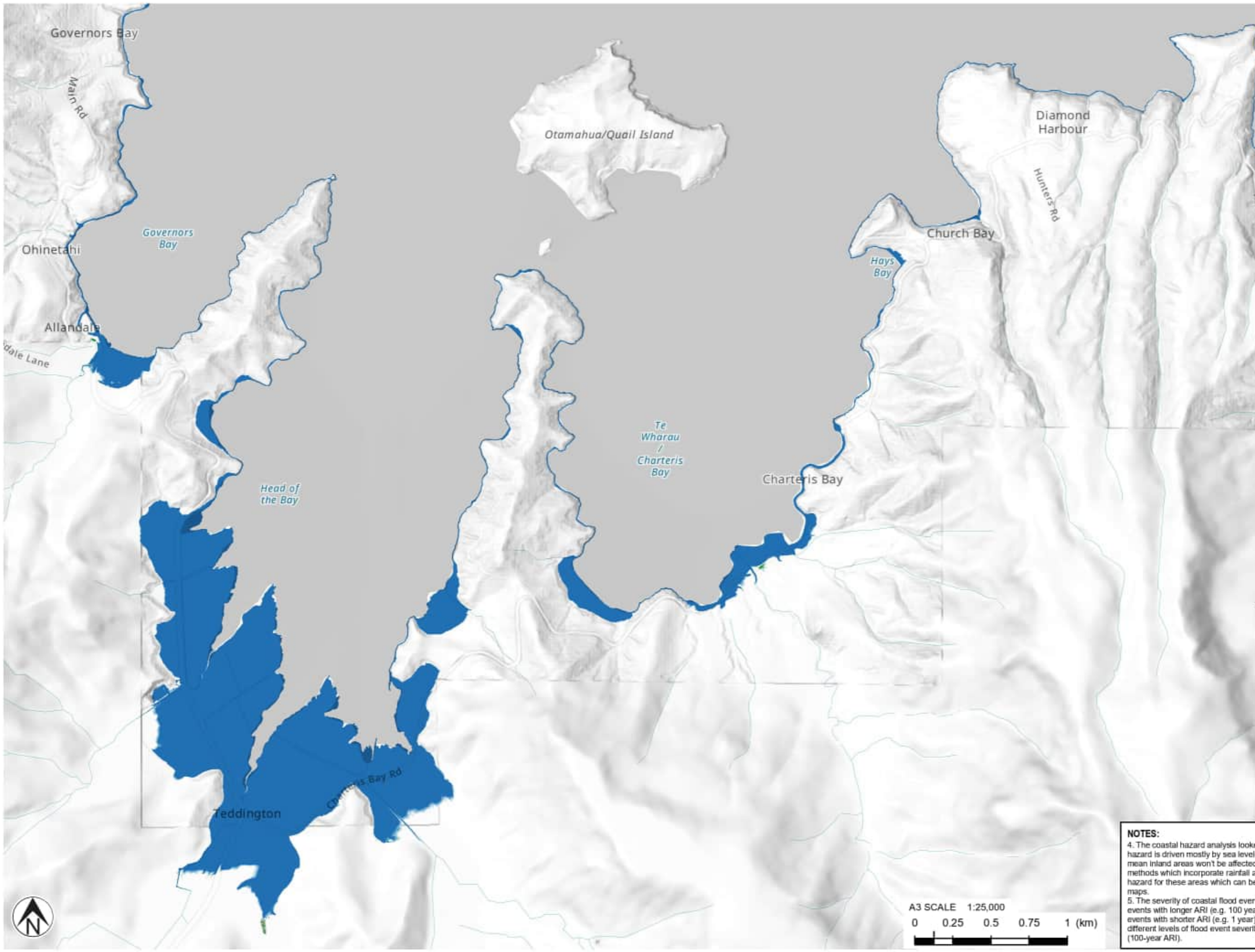

LEGEND

Direct flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

Indirect flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

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A3 SCALE 1:25,000
0 0.25 0.5 0.75 1 (km)

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LOCATION PLAN

PROJECT No.	1012976	
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DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 7D REV 1

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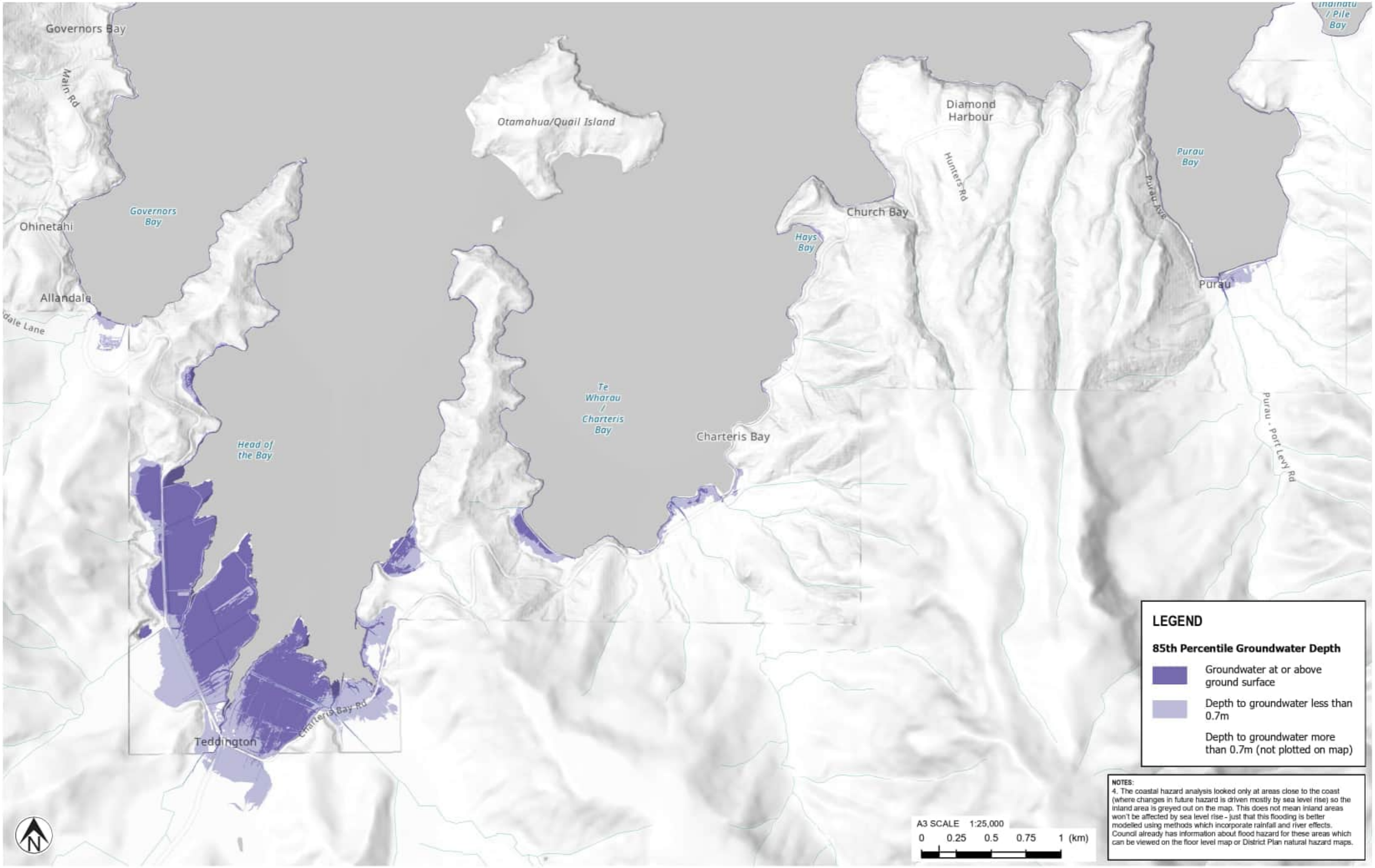

LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
- Depth to groundwater more than 0.7m (not plotted on map)

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1	Report issued	MEJ	PPK	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
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CLIENT CHRISTCHURCH CITY COUNCIL
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TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 7E REV 1

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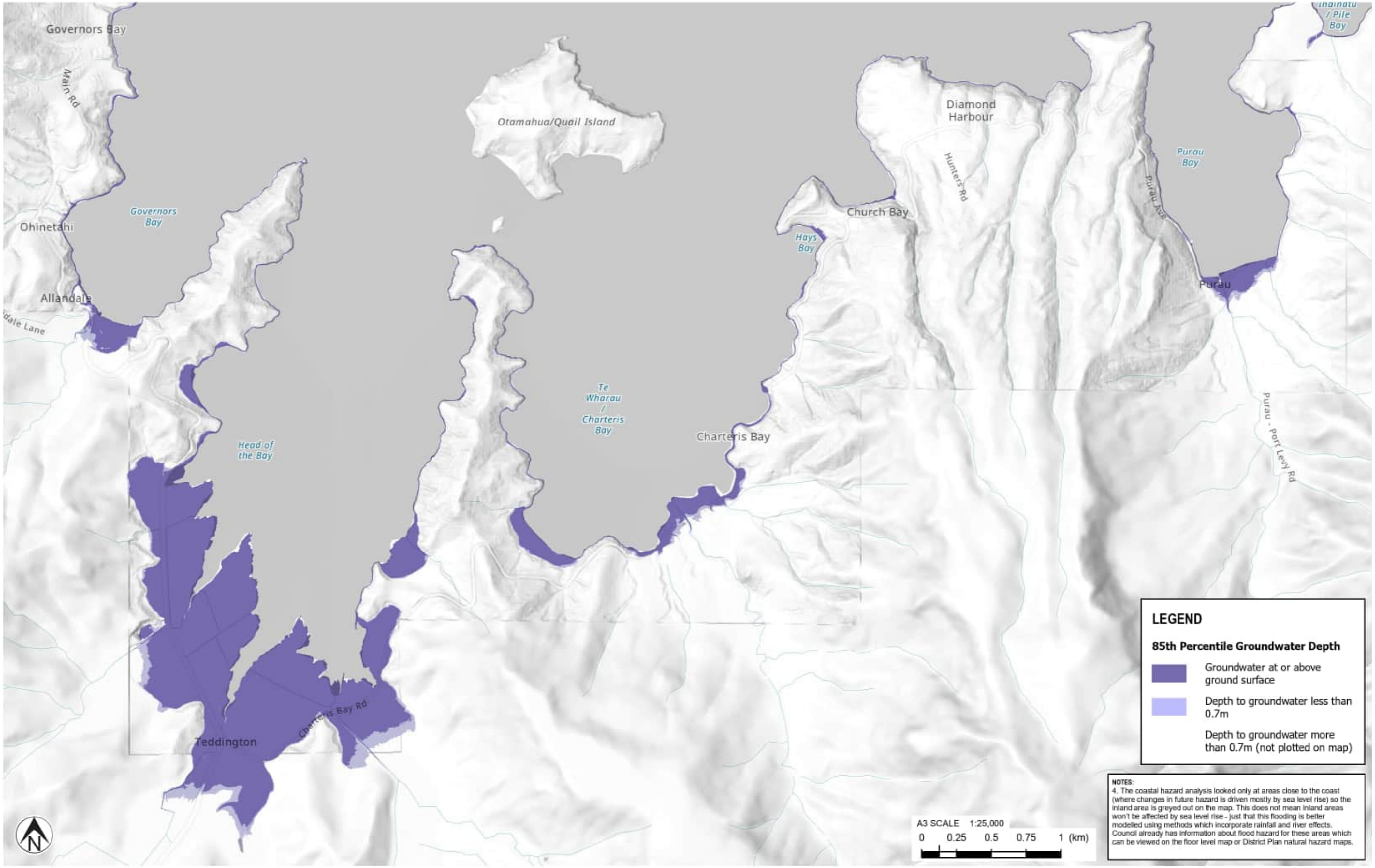

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CLIENT: **CHRISTCHURCH CITY COUNCIL**

PROJECT: **COASTAL HAZARD ASSESSMENT**

TITLE: COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE

SCALE (A3) 1:25,000   FIG No. FIGURE 7F   REV 1

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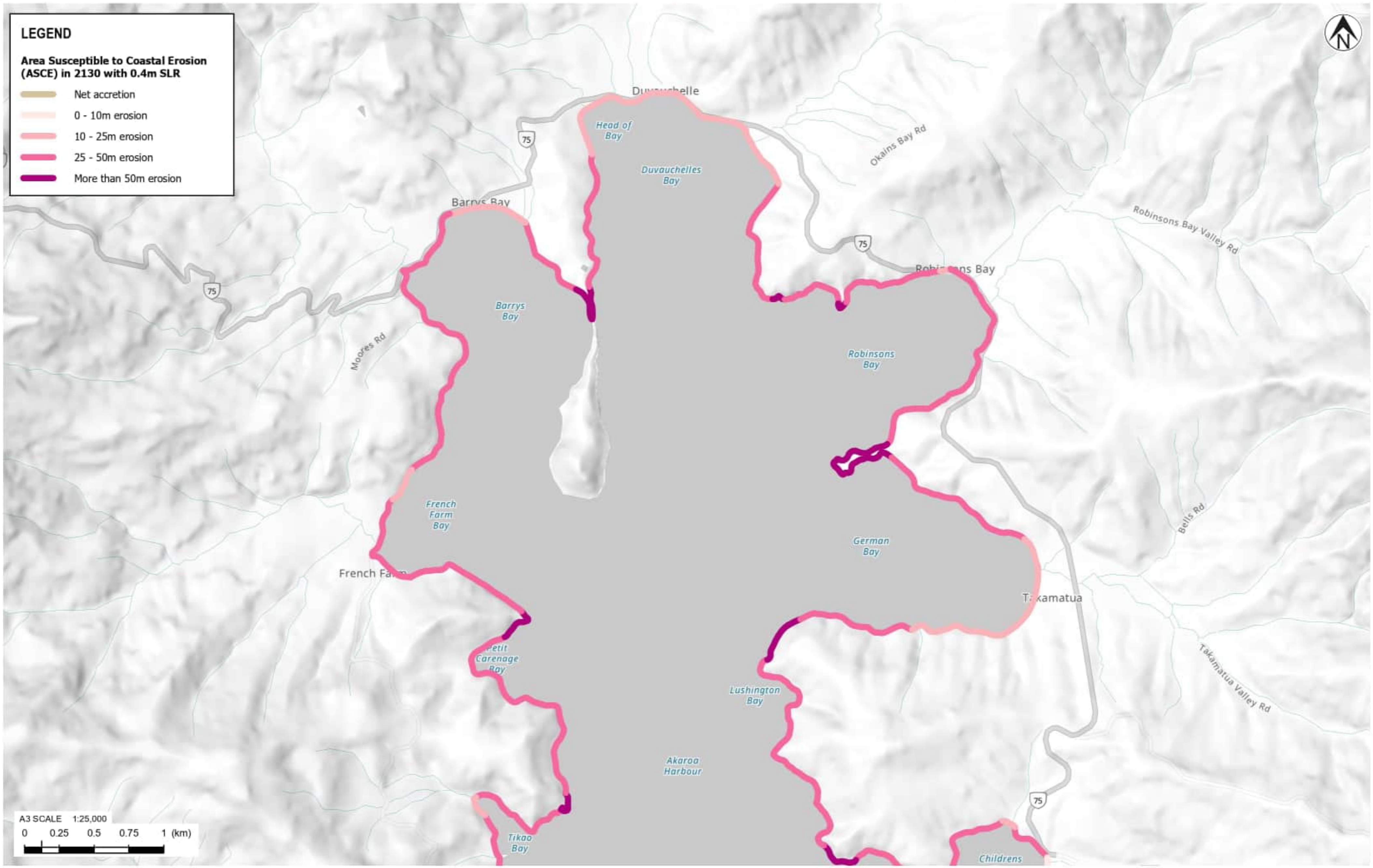

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LOCATION PLAN

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CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 8A REV 1

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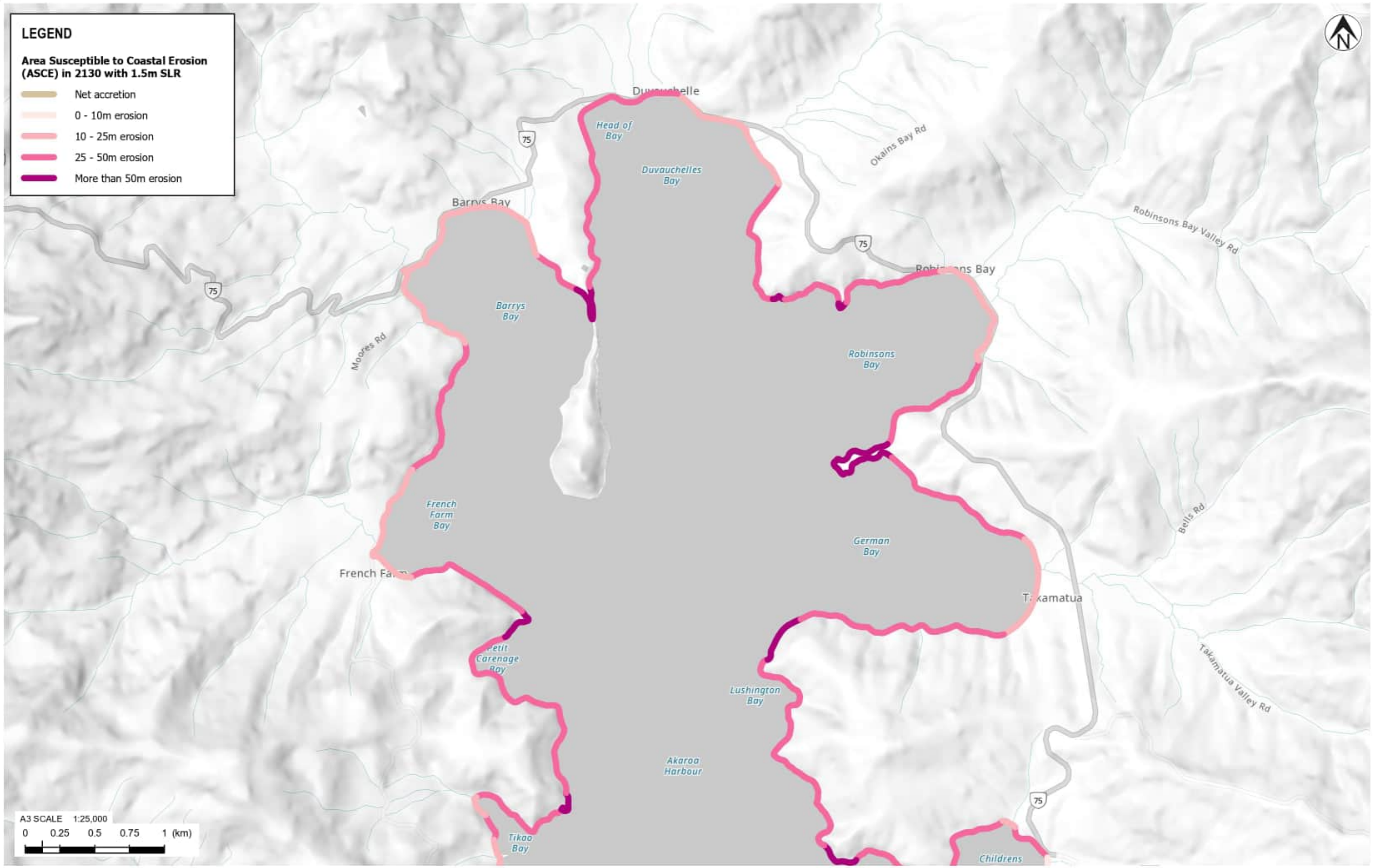

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SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 8B REV 1

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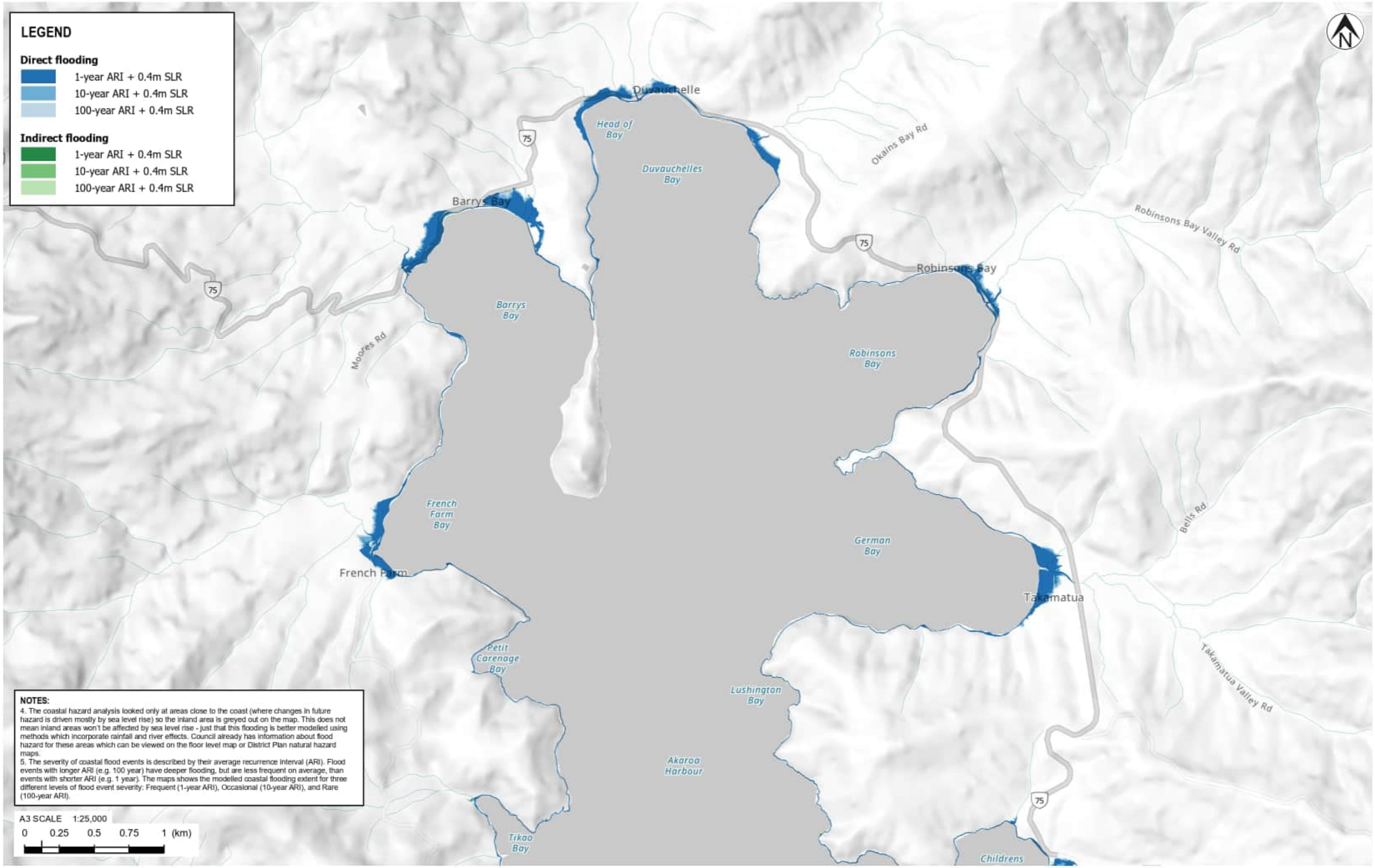

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CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 8C REV 1

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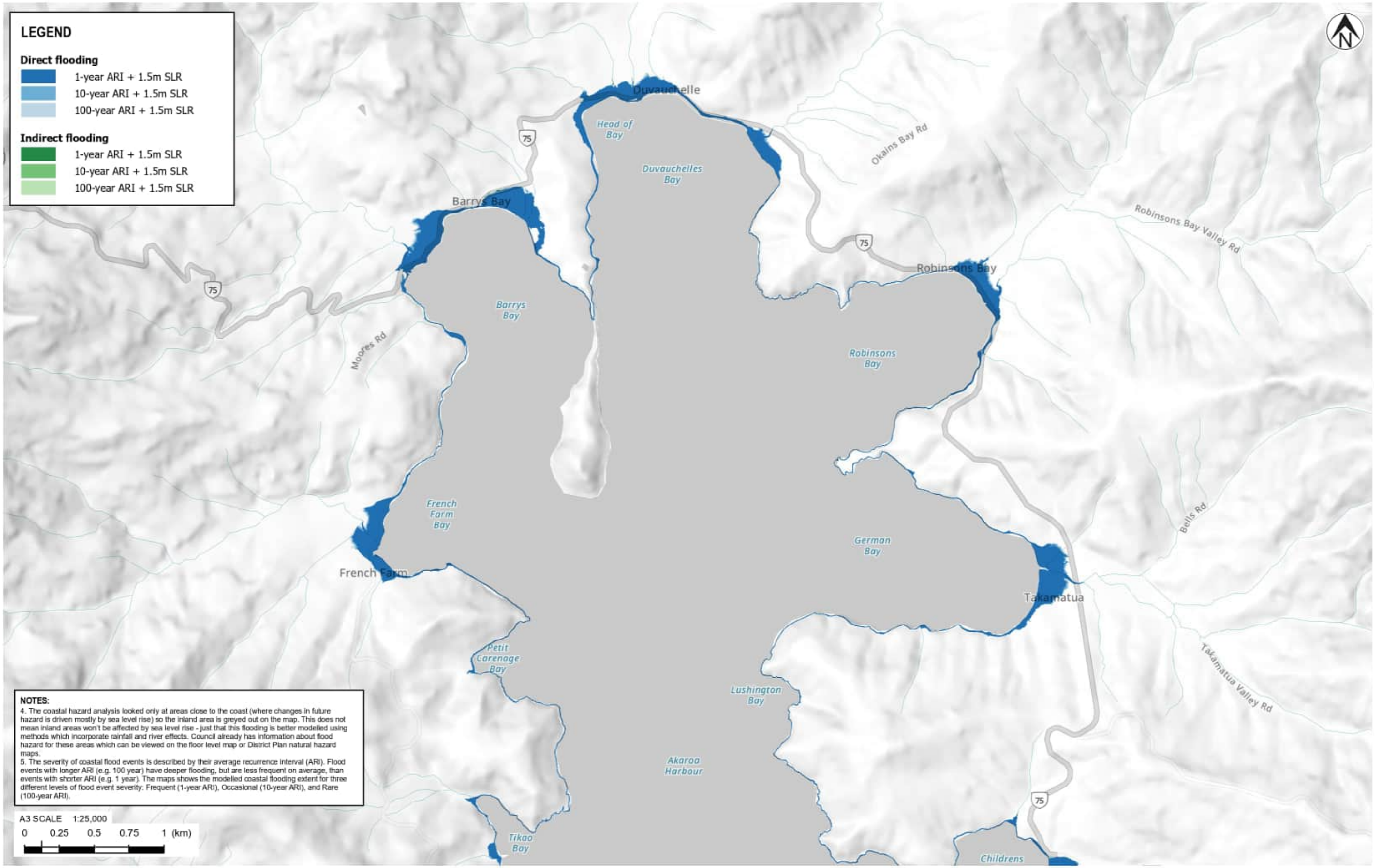

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REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	PPK	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
P. COCHRANE	29/09/21	
APPROVED	DATE	

CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 8D REV 1

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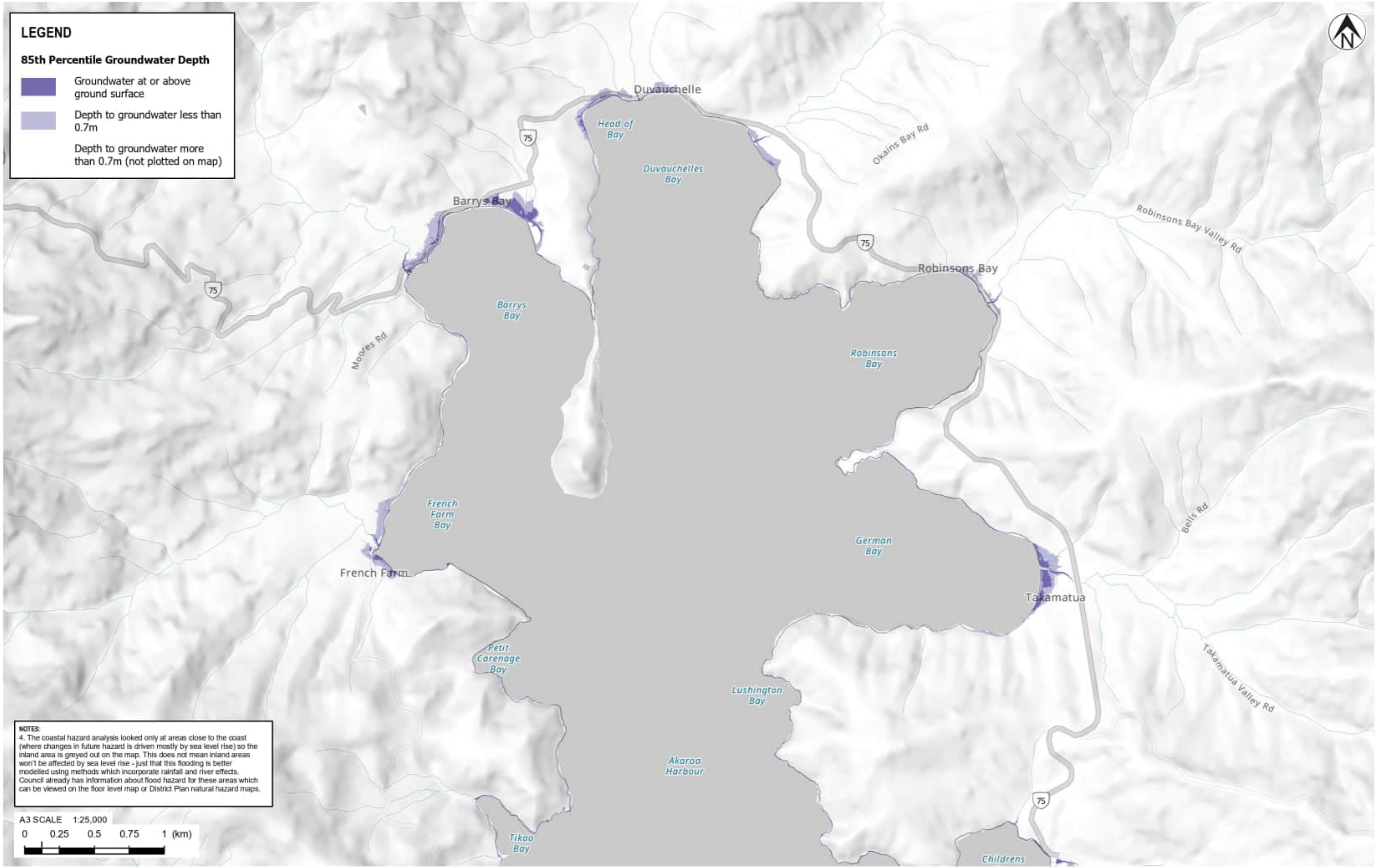

LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
- Depth to groundwater more than 0.7m (not plotted on map)

NOTES:
4. The coastal hazard analysis looked only at areas close to the coast (where changes in future hazard is driven mostly by sea level rise) so the inland area is greyed out on the map. This does not mean inland areas won't be affected by sea level rise - just that this flooding is better modelled using methods which incorporate rainfall and river effects. Council already has information about flood hazard for these areas which can be viewed on the floor level map or District Plan natural hazard maps.

A3 SCALE 1:25,000

0 0.25 0.5 0.75 1 (km)

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NOTES:
1. For Christchurch urban flatland area, map shows 85th percentile groundwater model from Aqualinc (2020) "LDRP45: Impacts of earthquakes and sea level rise on shallow groundwater levels." Report prepared for Christchurch City Council, August-2020.
2. For Banks Peninsula, map assumes that 85th percentile groundwater level is approximately equal to MHWS high tide level.
3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ.

REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	PPK	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 8E REV 1

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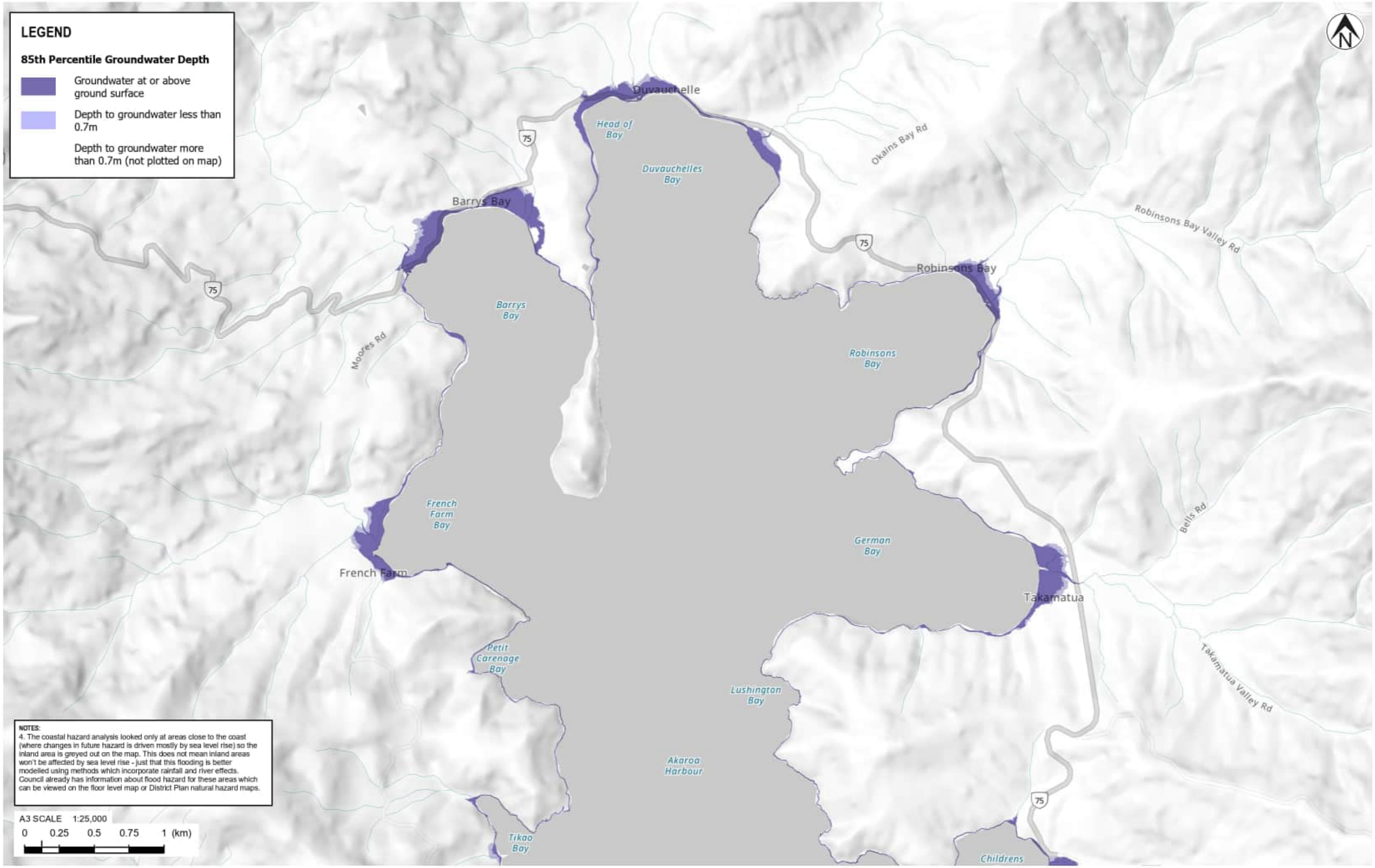

NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	PPK	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
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DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 8F REV 1

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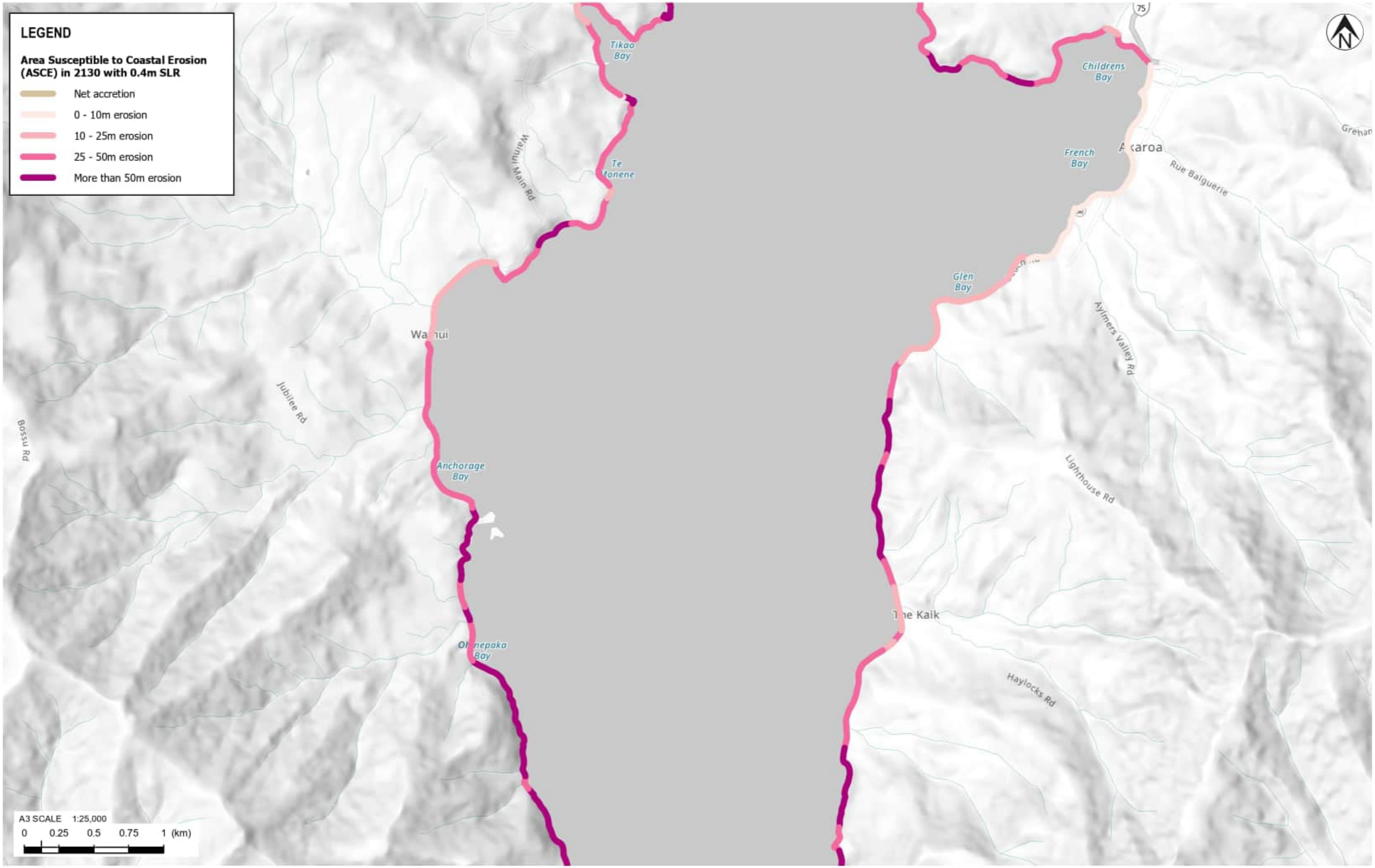

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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE
SCALE (A3): 1:25,000 FIG No. FIGURE 9A REV 1

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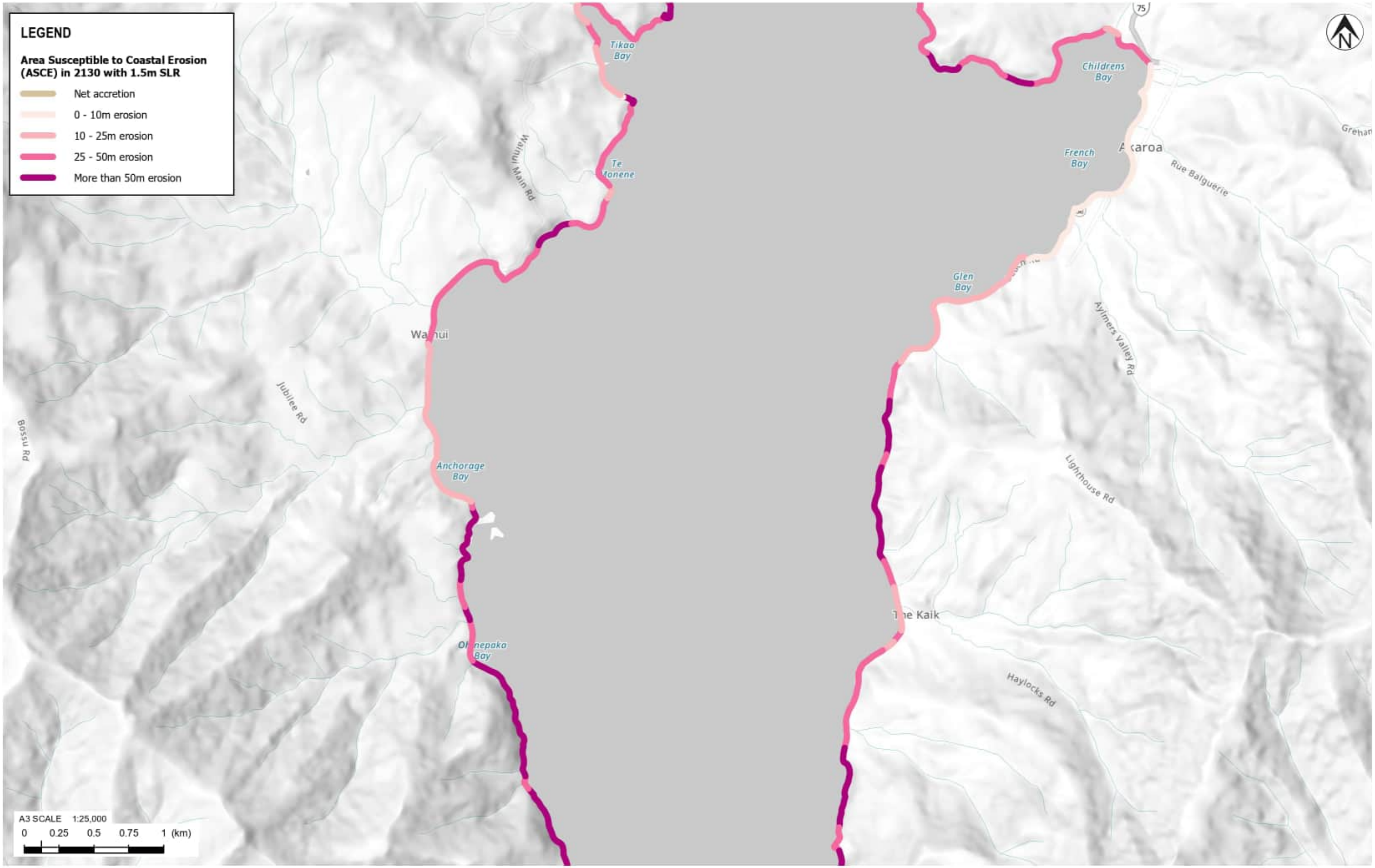

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NOTES:

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3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

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1	Report issued	MEJ	RHAU	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 9B REV 1

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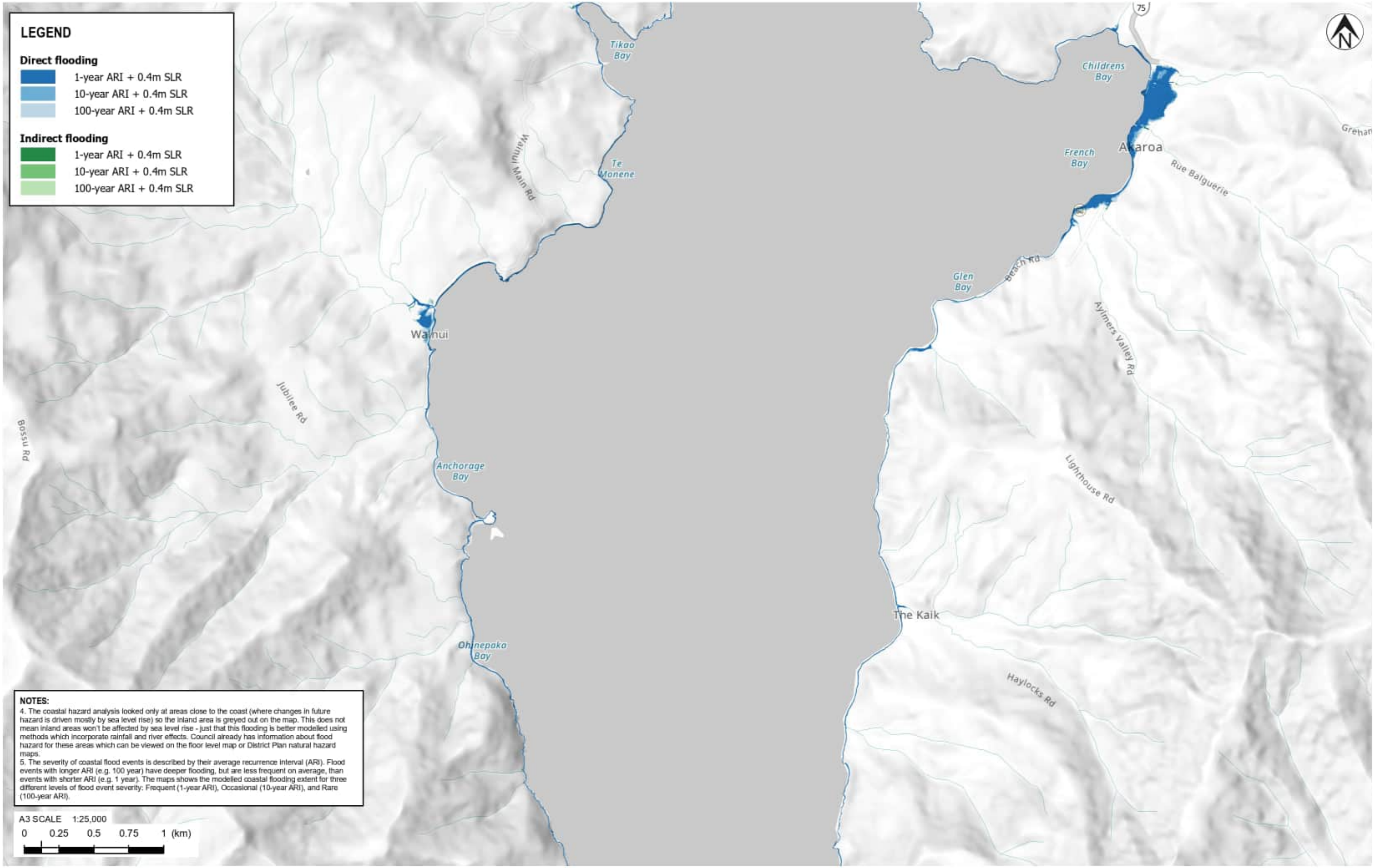

NOTES:

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5. The severity of coastal flood events is described by their average recurrence interval (ARI). Flood events with longer ARI (e.g. 100 year) have deeper flooding, but are less frequent on average, than events with shorter ARI (e.g. 1 year). The maps shows the modelled coastal flooding extent for three different levels of flood event severity: Frequent (1-year ARI), Occasional (10-year ARI), and Rare (100-year ARI).

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NOTES:

1. 'Direct flooding' is where there is a direct path for water to flow overland from the coast.
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CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 9C REV 1

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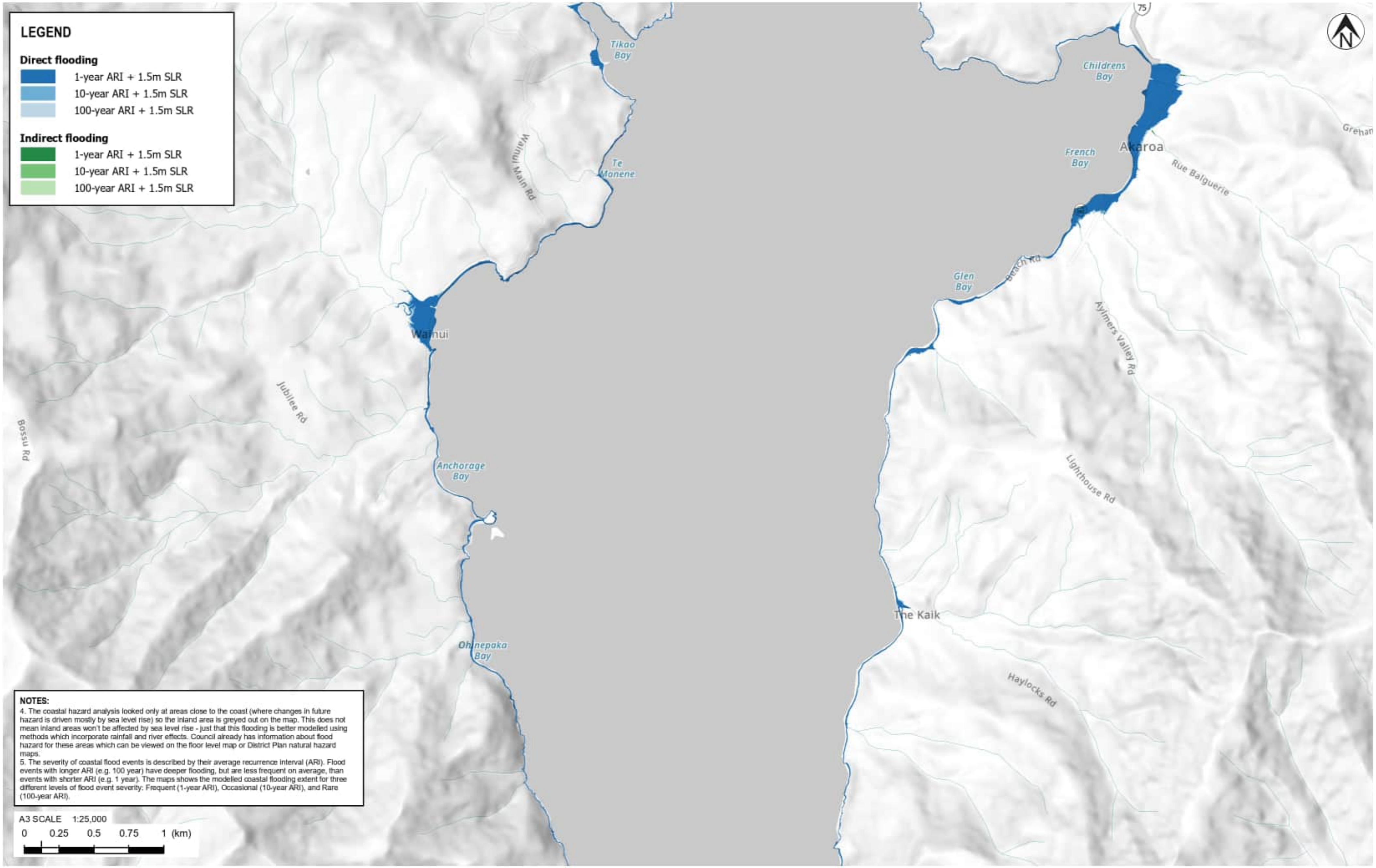

LEGEND

Direct flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

Indirect flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

NOTES:

4. The coastal hazard analysis looked only at areas close to the coast (where changes in future hazard is driven mostly by sea level rise) so the inland area is greyed out on the map. This does not mean inland areas won't be affected by sea level rise - just that this flooding is better modelled using methods which incorporate rainfall and river effects. Council already has information about flood hazard for these areas which can be viewed on the floor level map or District Plan natural hazard maps.

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A3 SCALE 1:25,000

0 0.25 0.5 0.75 1 (km)

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REV	DESCRIPTION	GIS	CHK	DATE
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CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE

SCALE (A3) 1:25,000 FIG No. FIGURE 9D REV 1

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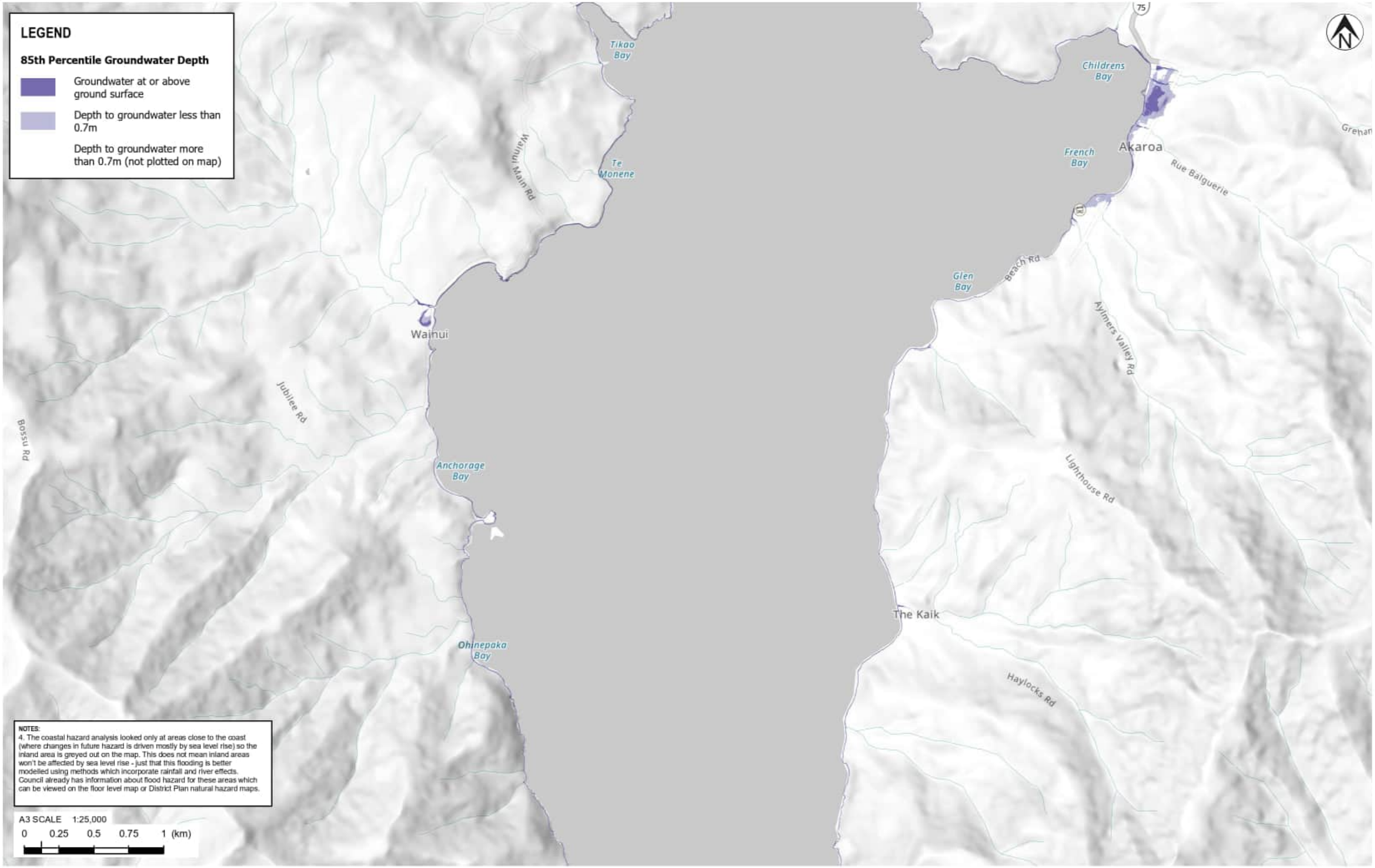

LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
- Depth to groundwater more than 0.7m (not plotted on map)

NOTES:
4. The coastal hazard analysis looked only at areas close to the coast (where changes in future hazard is driven mostly by sea level rise) so the inland area is greyed out on the map. This does not mean inland areas won't be affected by sea level rise - just that this flooding is better modelled using methods which incorporate rainfall and river effects. Council already has information about flood hazard for these areas which can be viewed on the floor level map or District Plan natural hazard maps.

A3 SCALE 1:25,000
0 0.25 0.5 0.75 1 (km)

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NOTES:
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3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ.

REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
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DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:25,000 FIG No. FIGURE 9E REV 1

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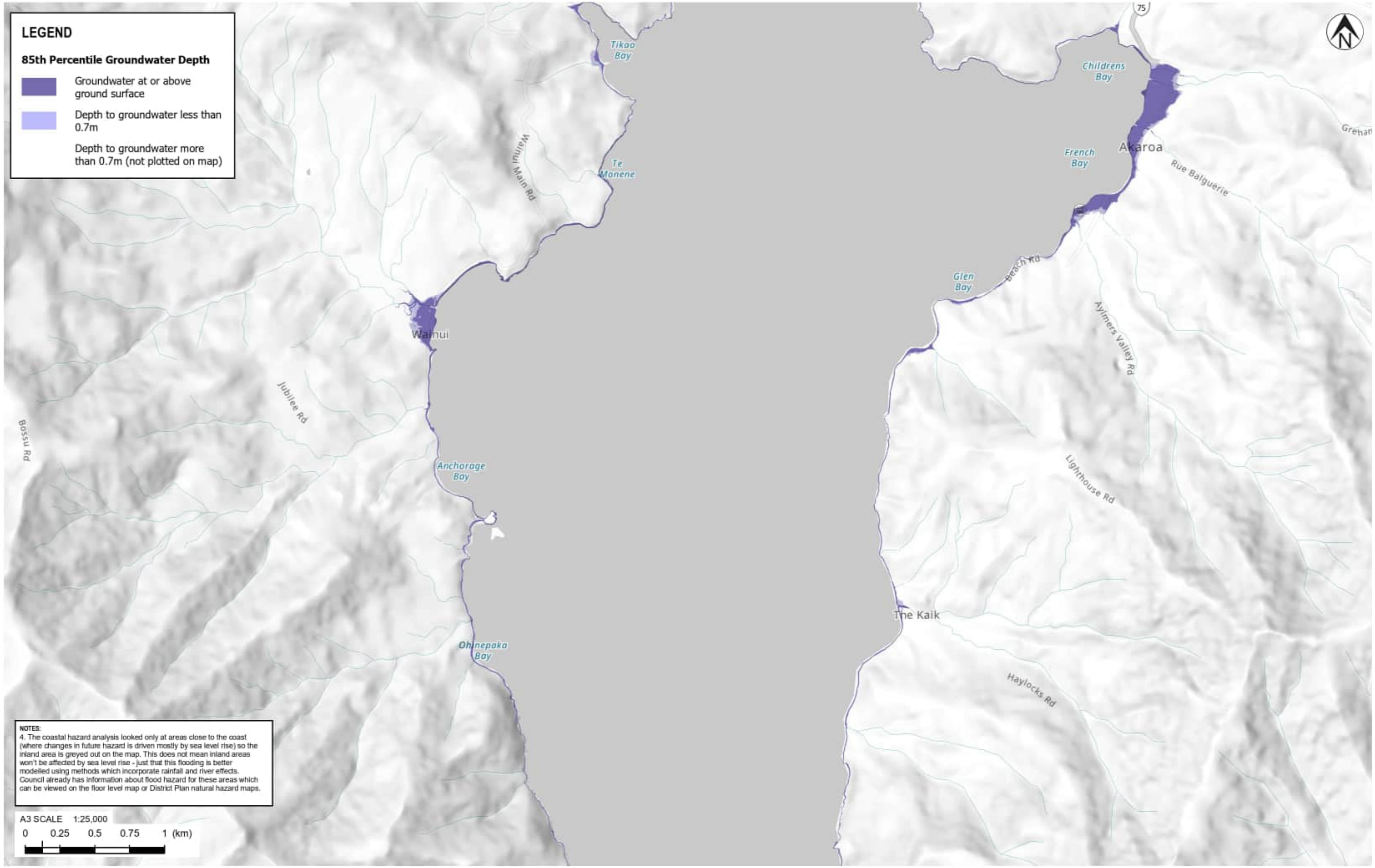

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1	Report issued	MEJ	PPK	29/09/21

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PROJECT No.	1012976	
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CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3) 1:25,000   FIG No. FIGURE 9F   REV 1

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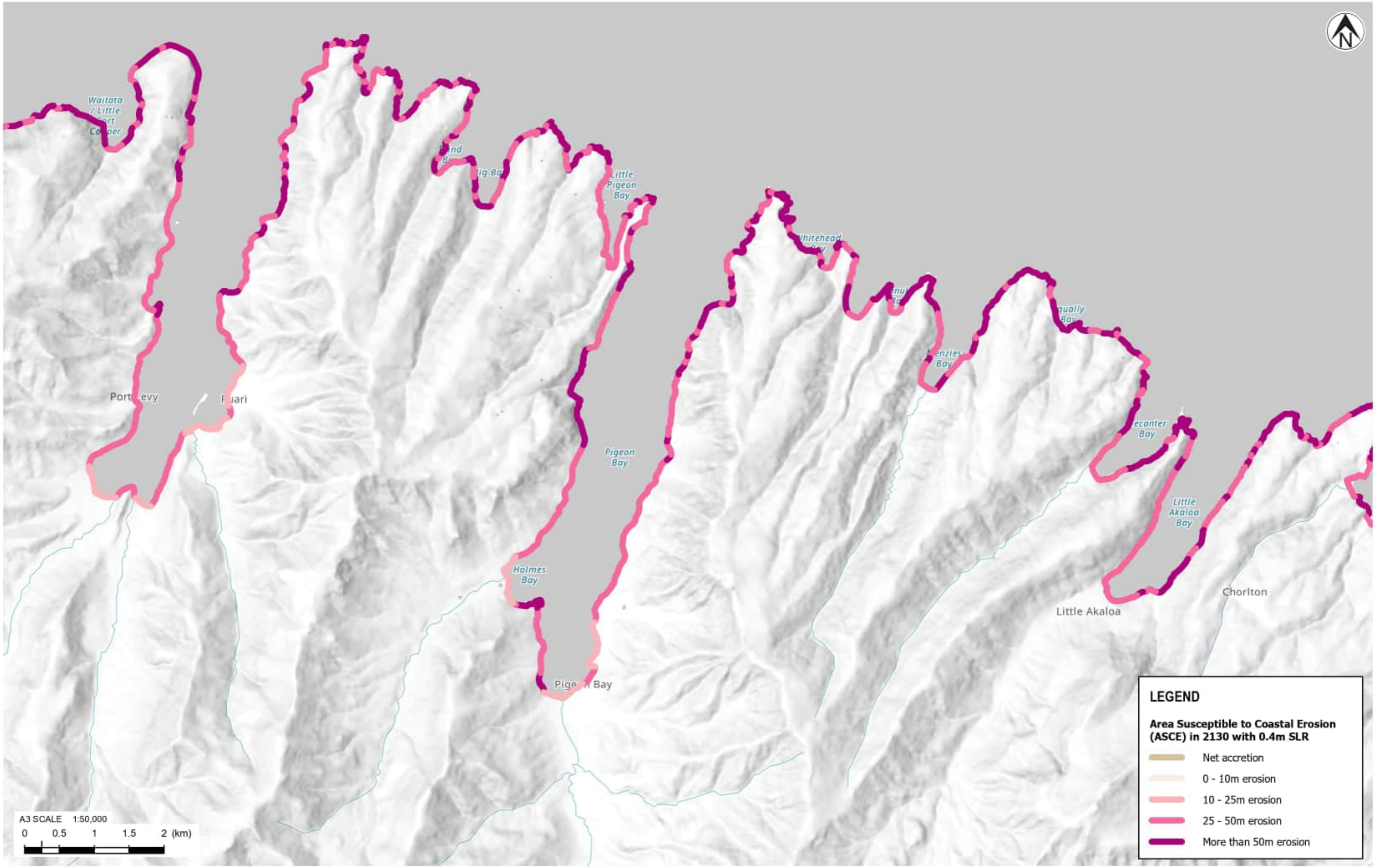

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NOTES:

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REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	RHAU	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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CHECKED	RHAU	SEP.21
APPROVED: P. COCHRANE		DATE: 29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL EROSION ANALYSIS

SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 10A REV 1

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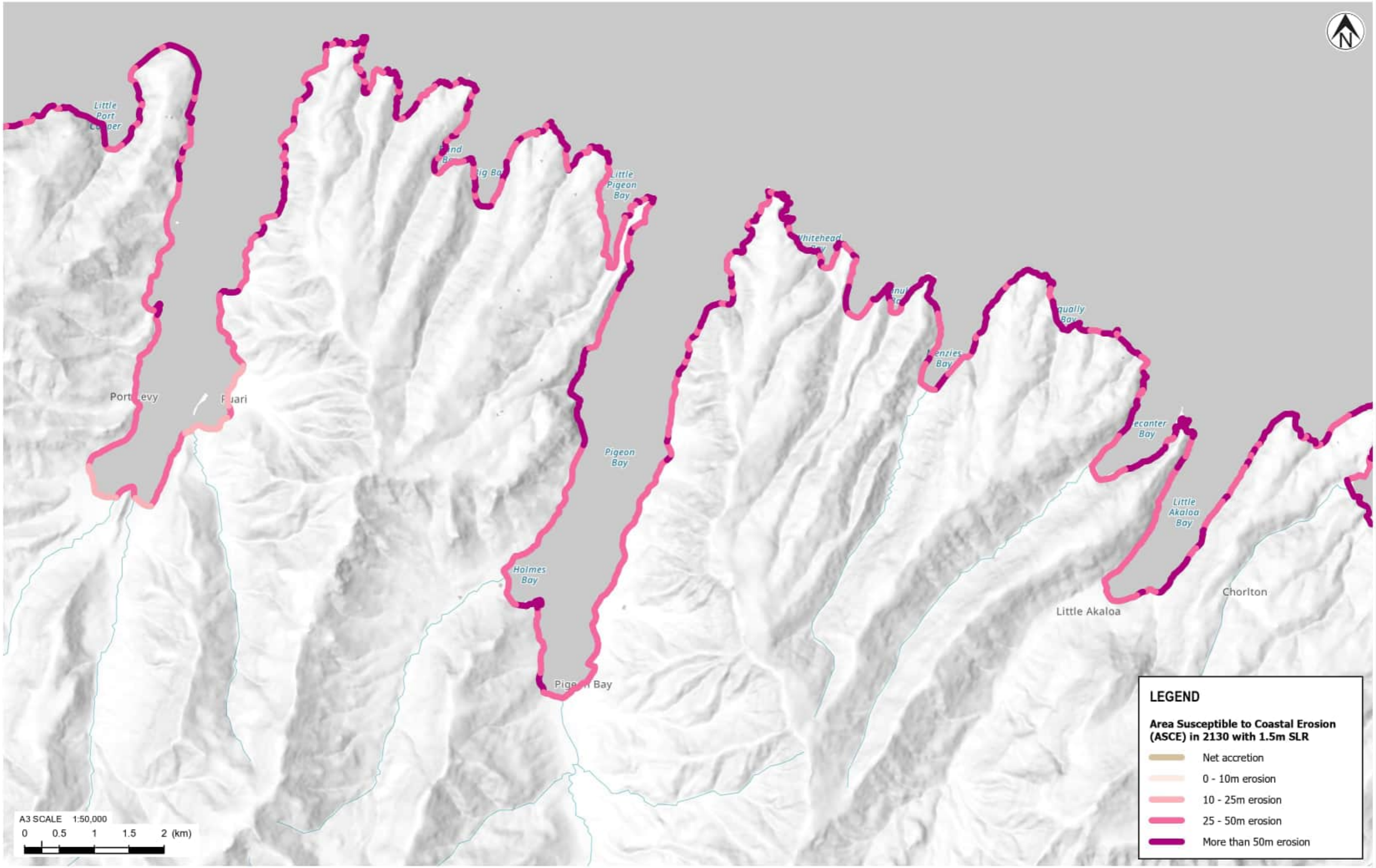

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PROJECT No.	1012976	
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CHECKED	RHAU	SEP.21
P. COCHRANE	29/09/21	
APPROVED	DATE	

CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL EROSION ANALYSIS

SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 10B REV 1

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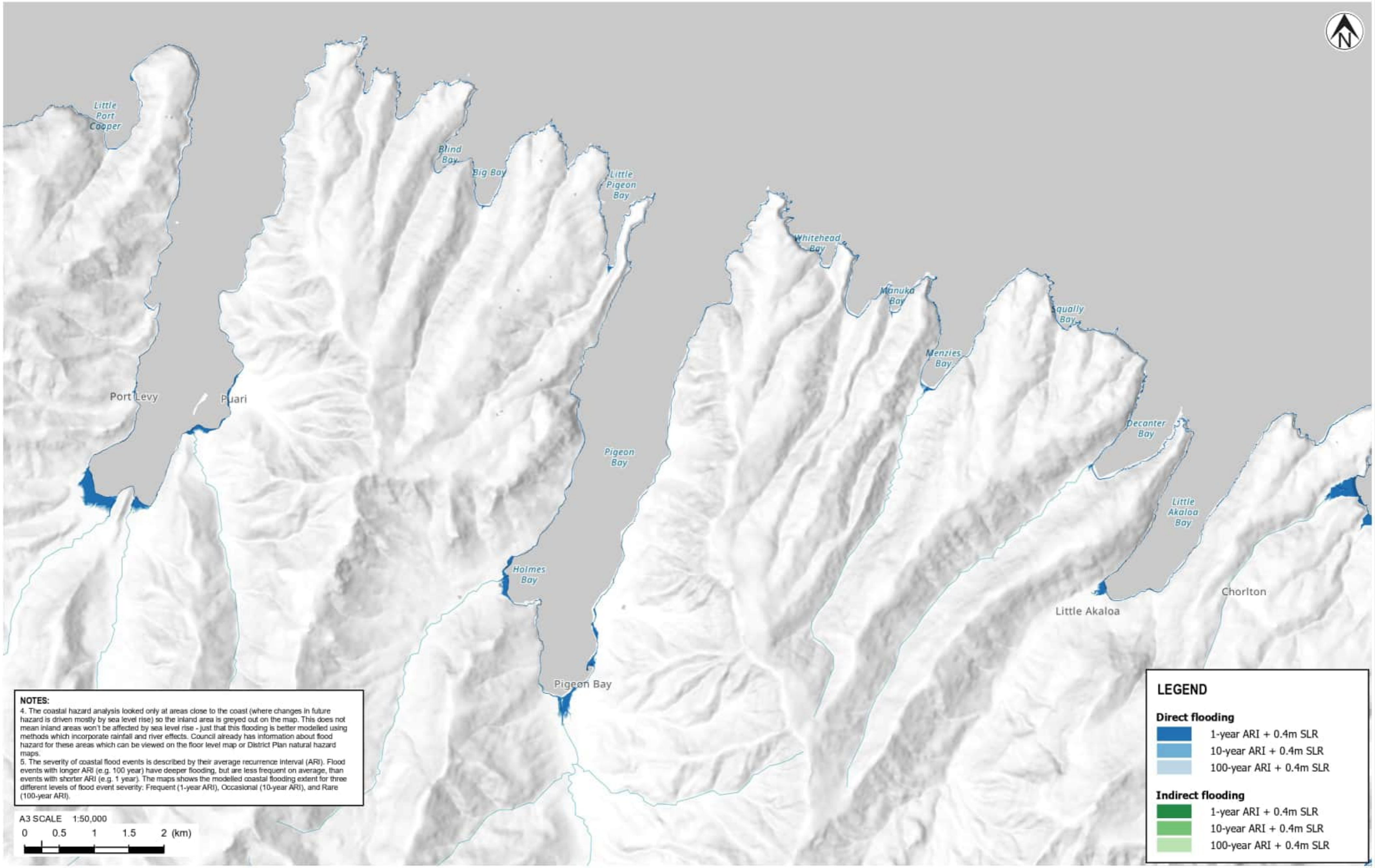

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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 10C REV 1

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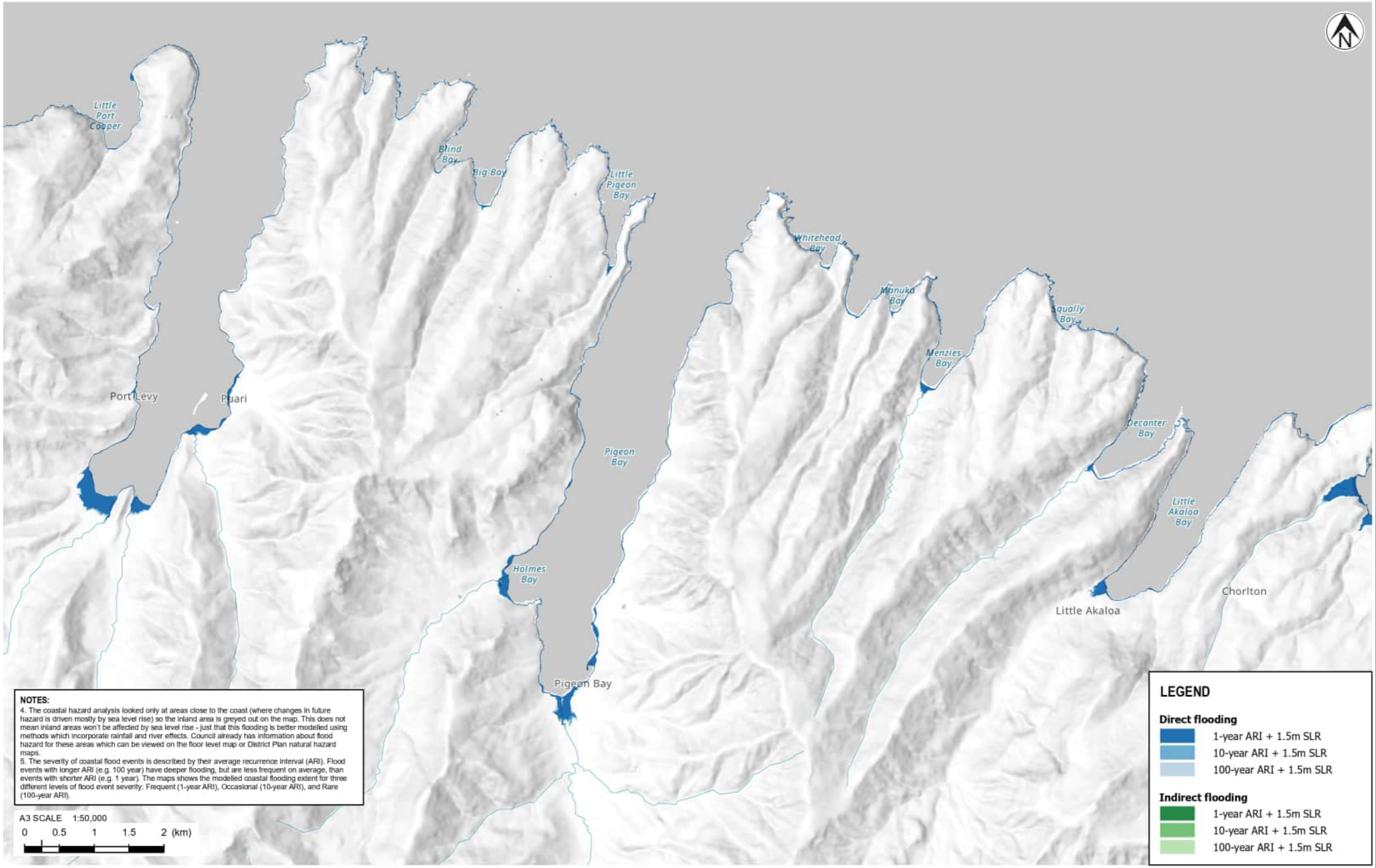

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A3 SCALE 1:50,000
0 0.5 1 1.5 2 (km)

LEGEND

Direct flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

Indirect flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

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NOTES:
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PROJECT No.	1012976	
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CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 10D REV 1

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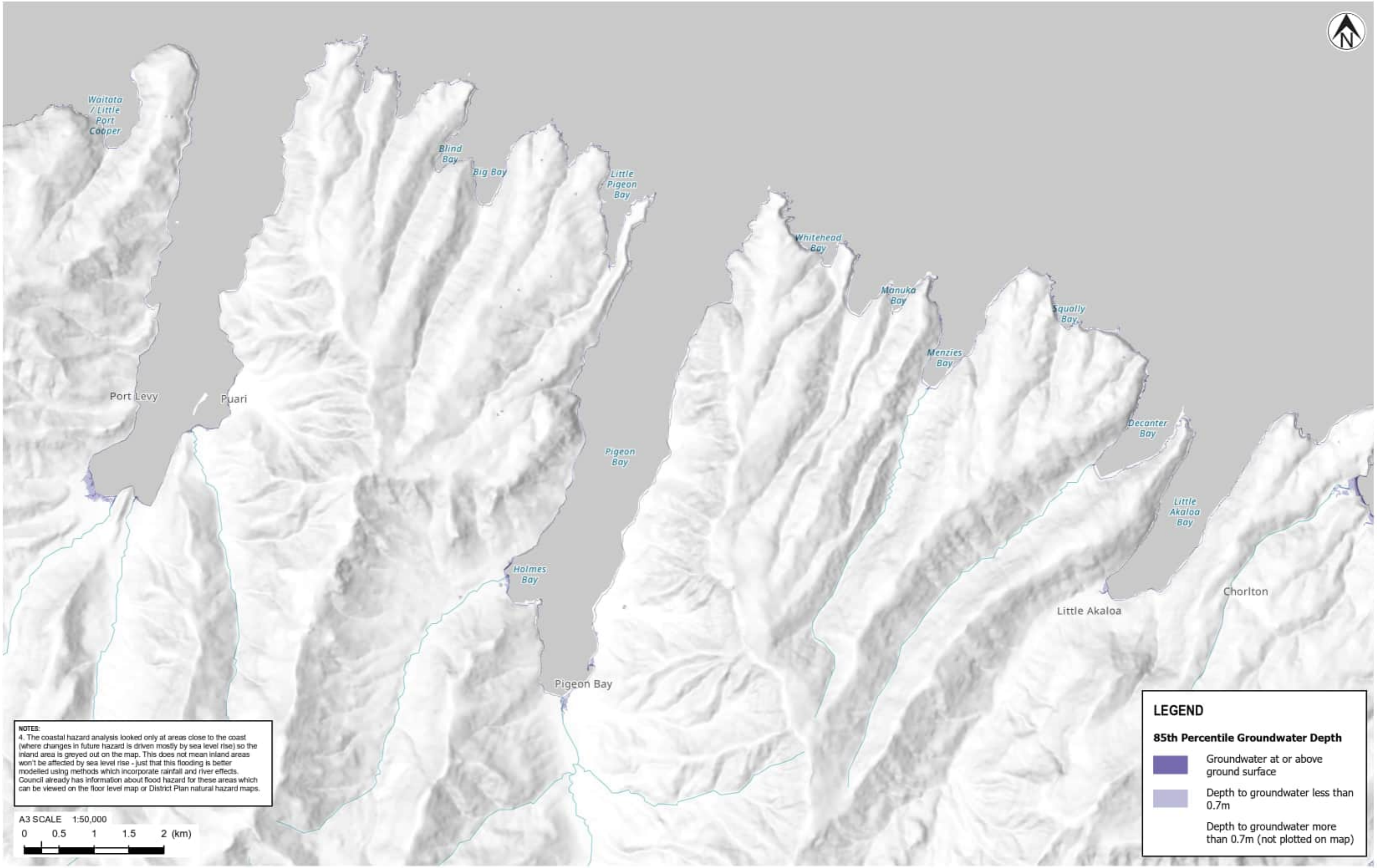

NOTES:
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NOTES:
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2. For Banks Peninsula, map assumes that 85th percentile groundwater level is approximately equal to MHWS high tide level.
3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ.

REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	PPK	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 10E REV 1

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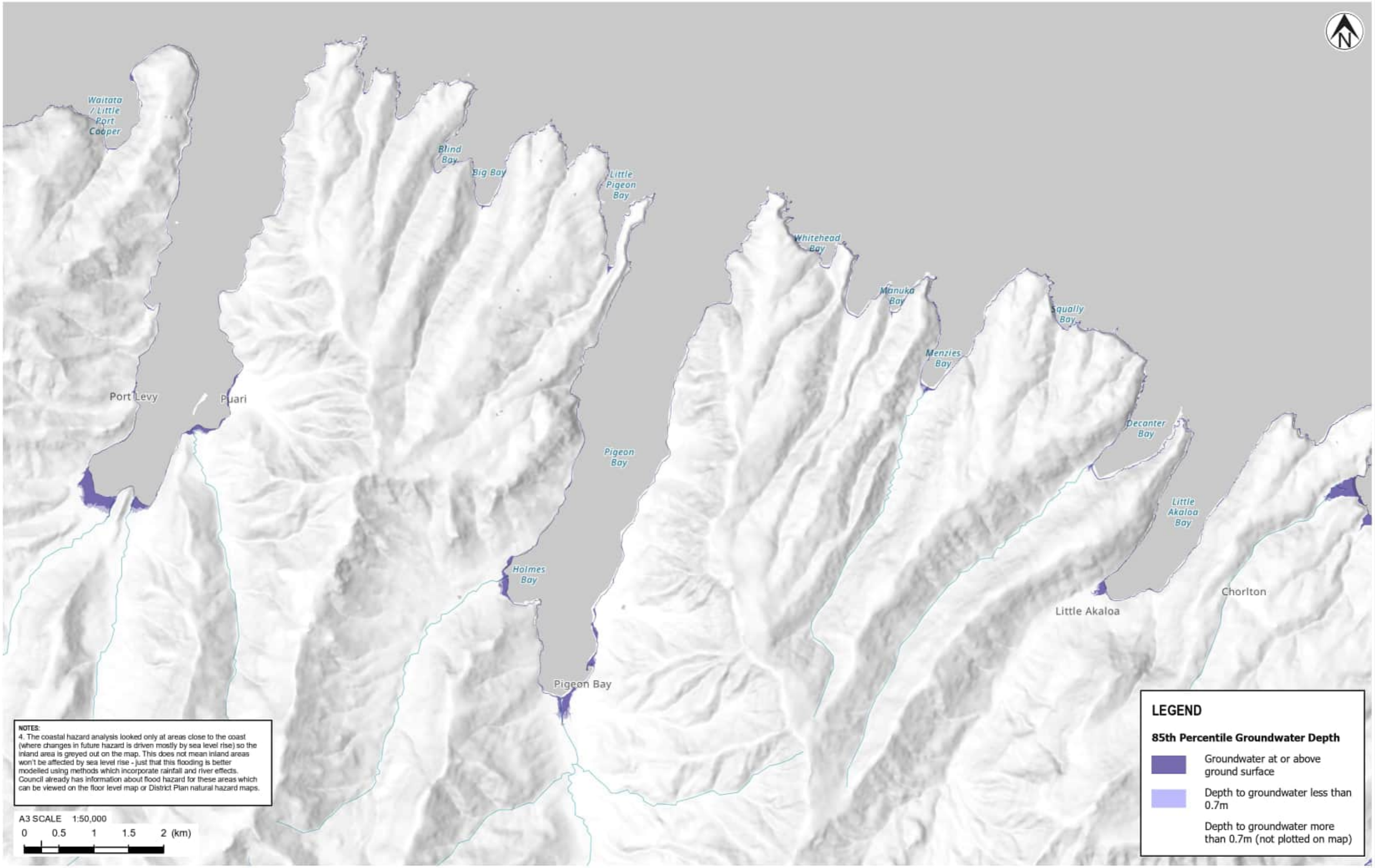

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A3 SCALE 1:50,000
0 0.5 1 1.5 2 (km)

LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
- Depth to groundwater more than 0.7m (not plotted on map)

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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
P. COCHRANE	29/09/21	
APPROVED	DATE	

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL GROUNDWATER ANALYSIS SCENARIO: 1.9M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 10F REV 1

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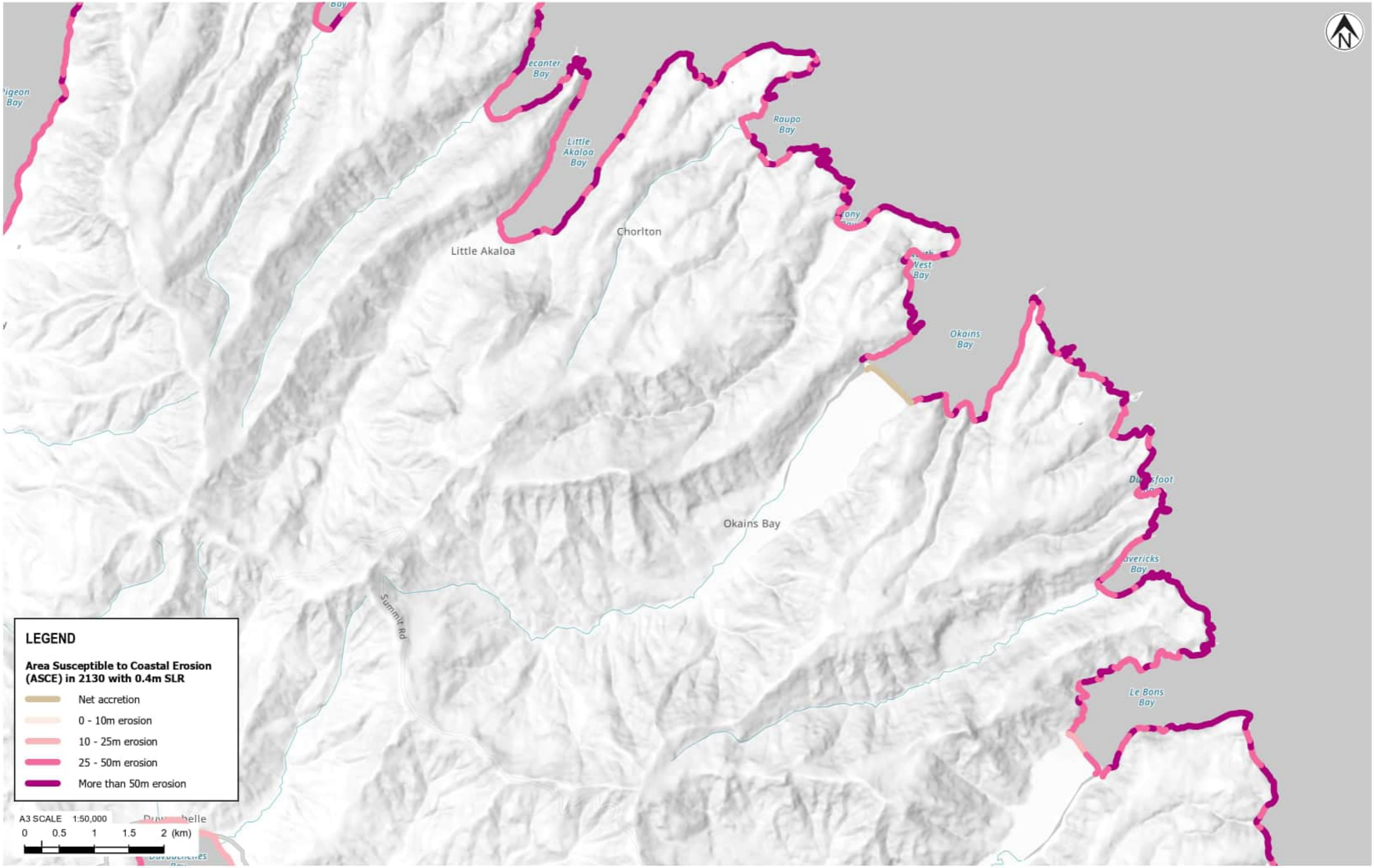

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NOTES:
1. For detailed analysis areas, this map shows the P5 erosion distance (5% probability that erosion will be greater for this scenario).
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3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	RHAU	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE

SCALE (A3): 1:50,000 FIG No. FIGURE 11A REV 1

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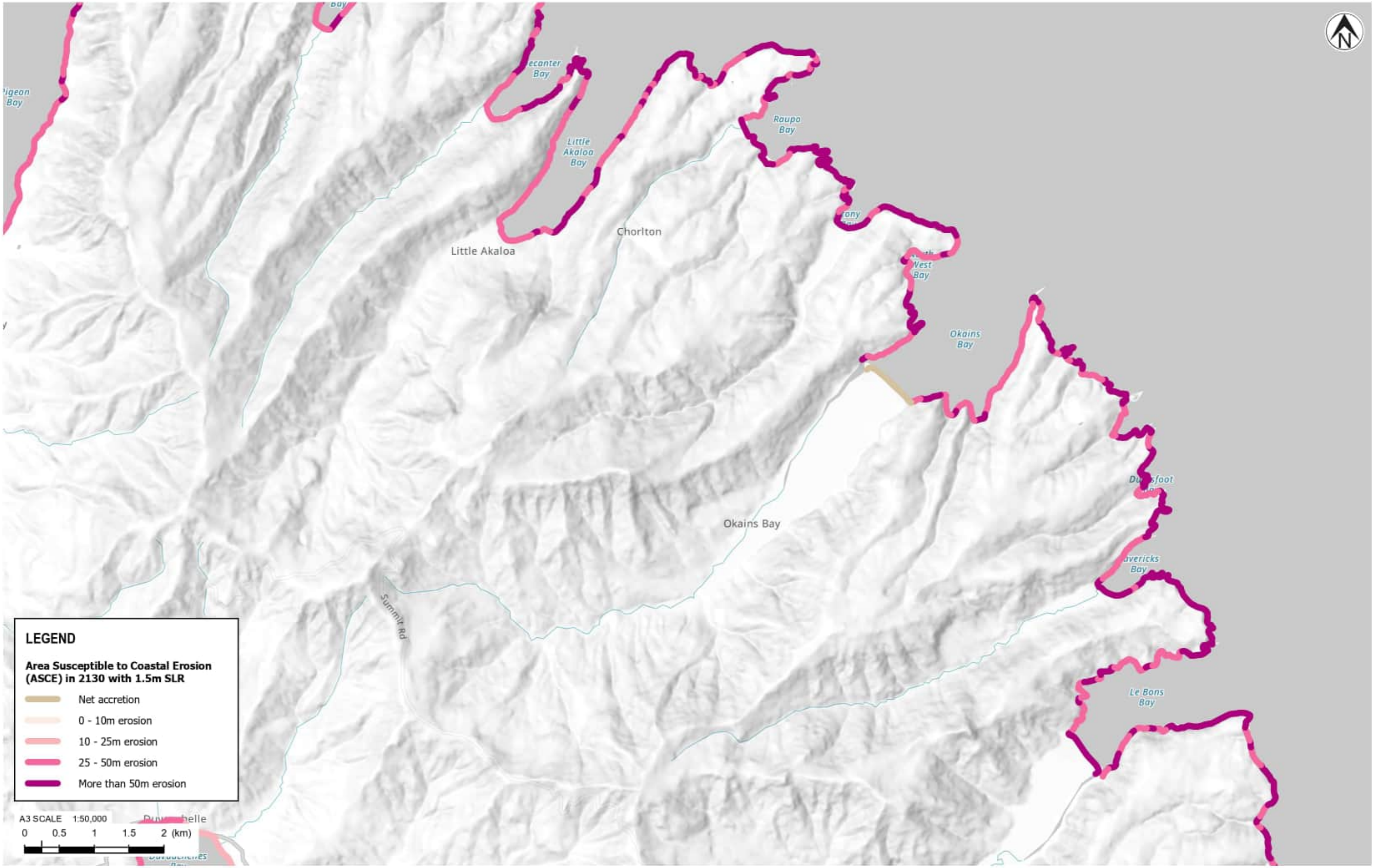

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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 11B REV 1

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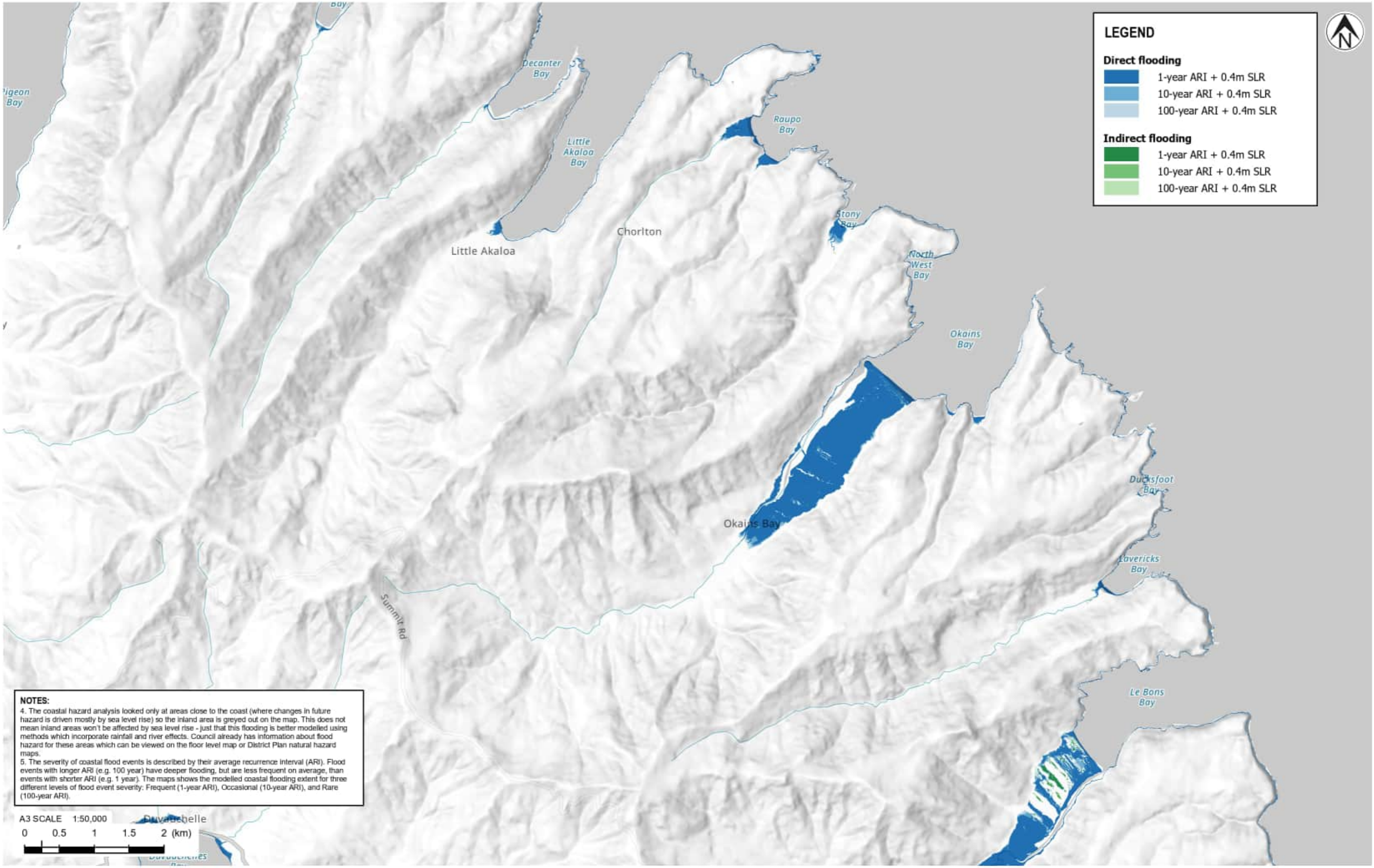

NOTES:

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LOCATION PLAN

PROJECT No.	1012976	
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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 11C REV 1

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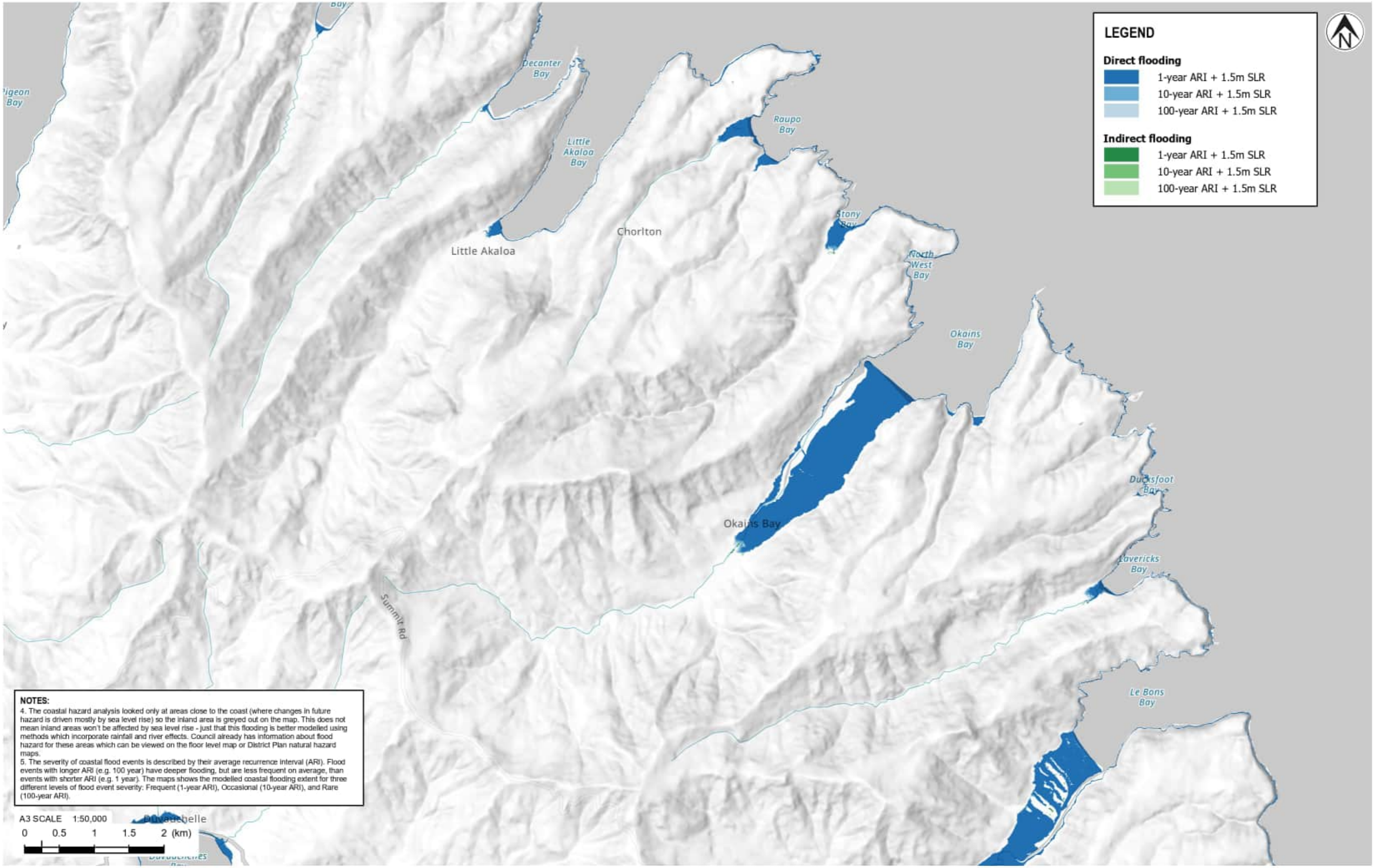

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LOCATION PLAN

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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3) 1:50,000   FIG No. FIGURE 11D   REV 1

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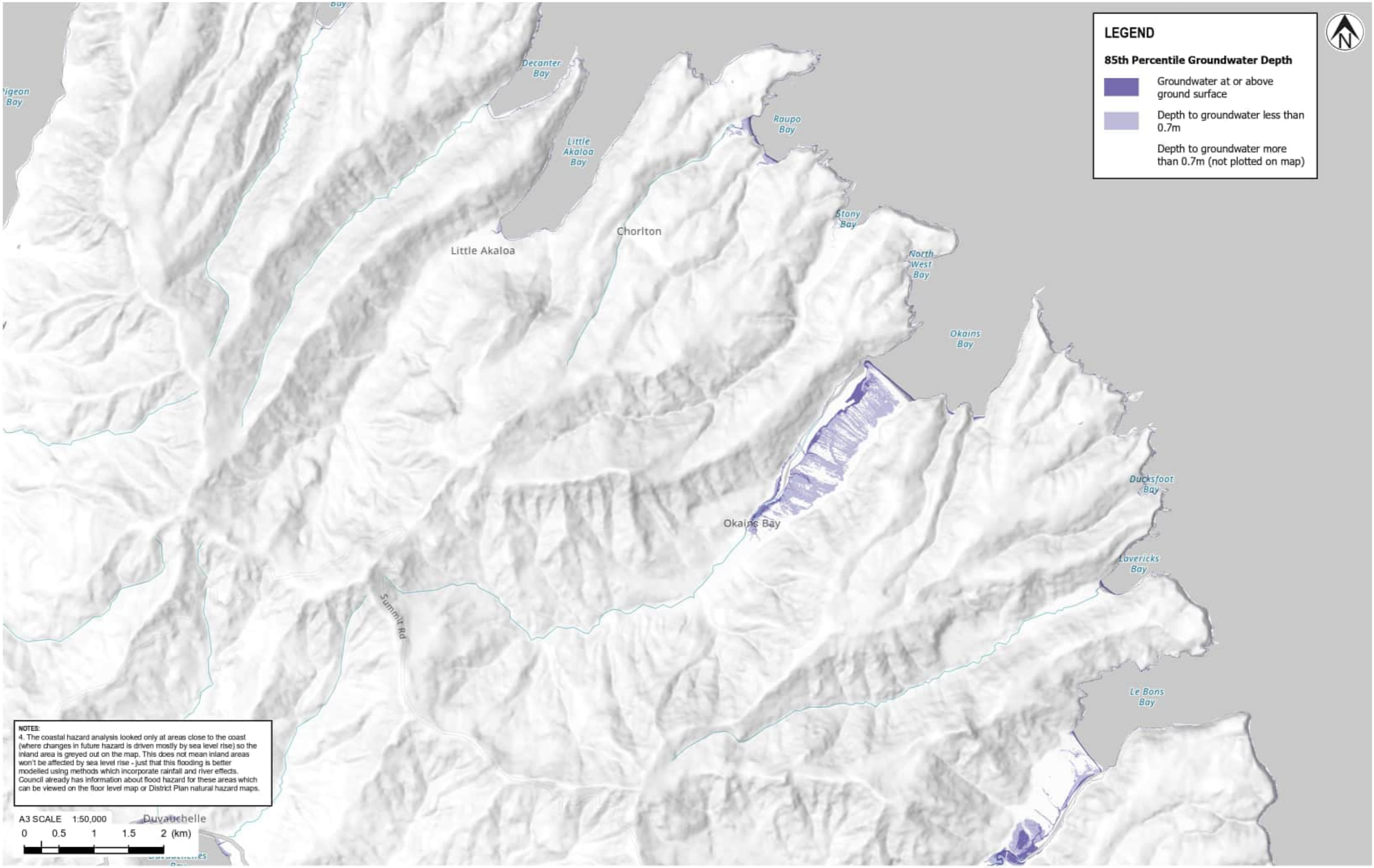

NOTES:
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NOTES:
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3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ.

REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
APPROVED: P. COCHRANE		29/09/21

CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3): 1:50,000 FIG No. FIGURE 11E REV 1

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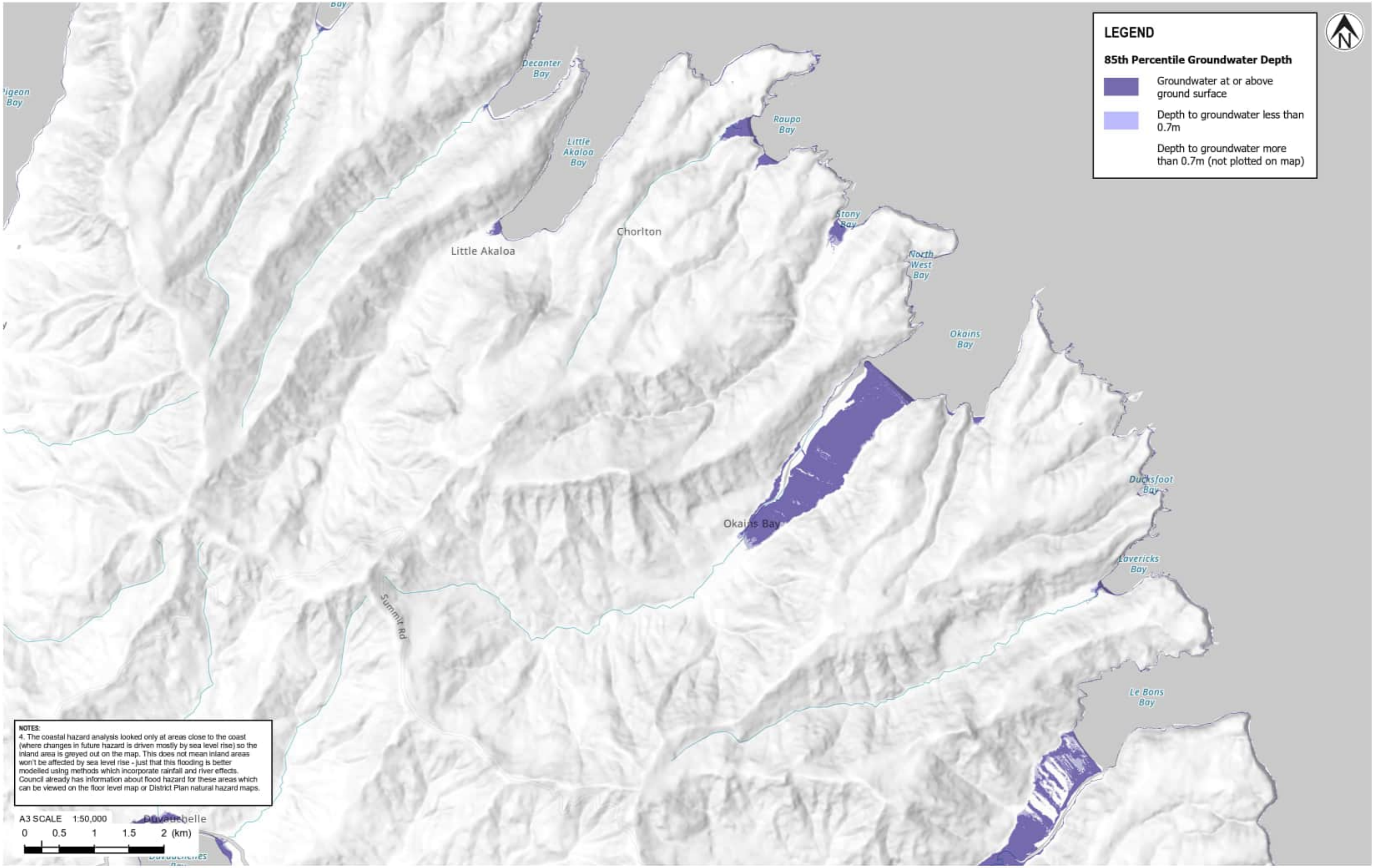

LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
- Depth to groundwater more than 0.7m (not plotted on map)

NOTES:
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A3 SCALE 1:50,000

0 0.5 1 1.5 2 (km)

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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	PPK	29/09/21

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PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 11F REV 1

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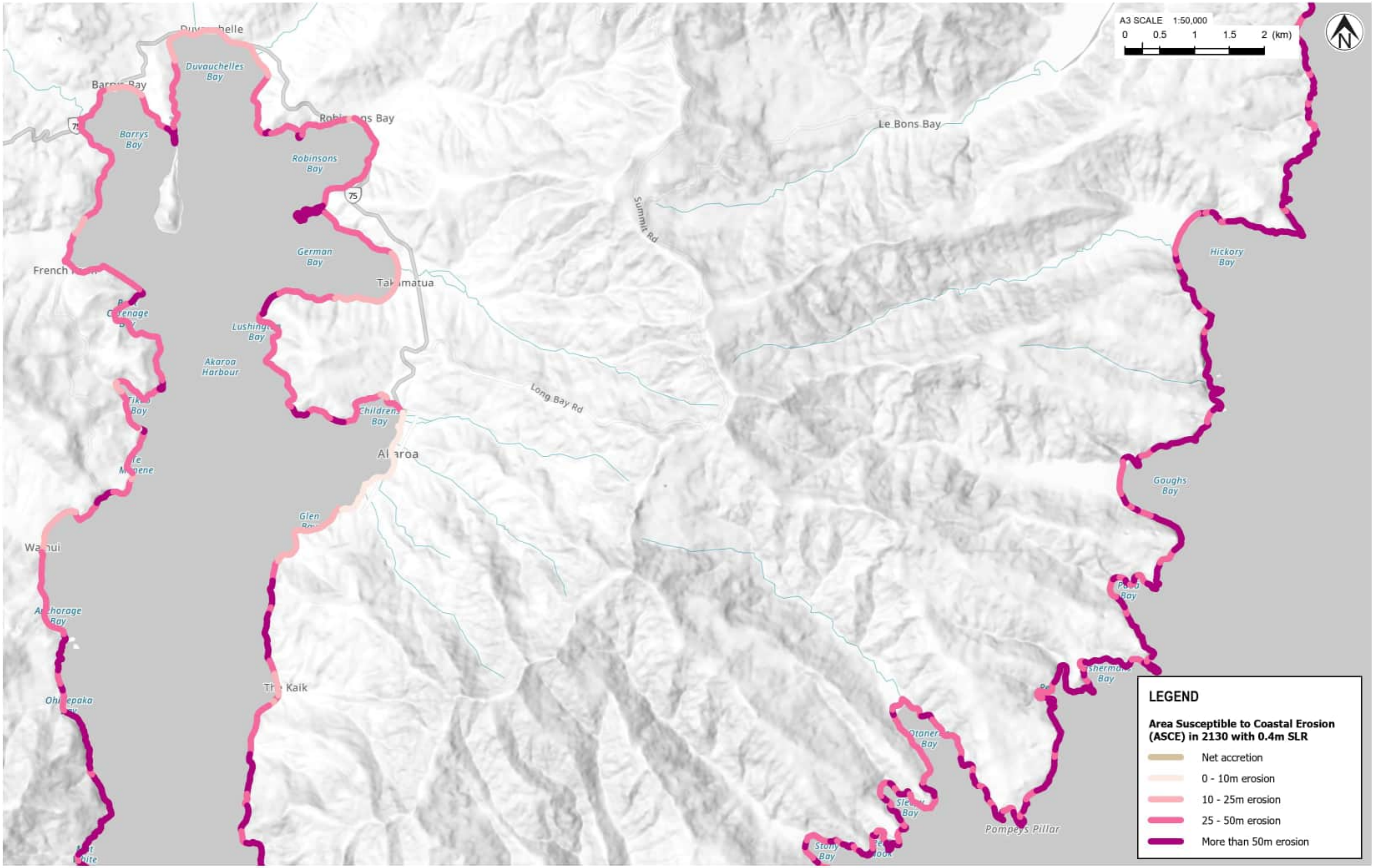

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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 12A REV 1

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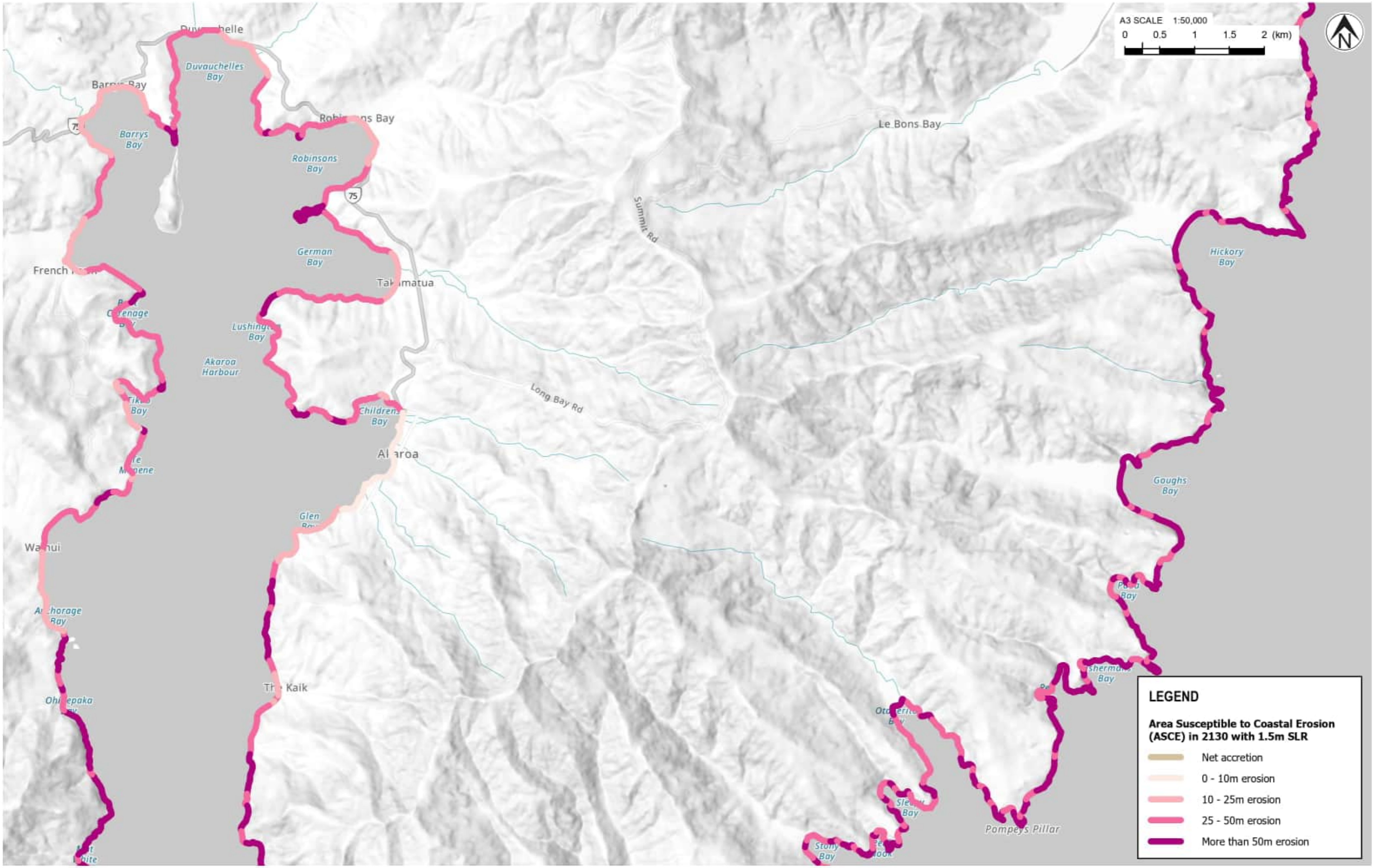

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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 12B REV 1

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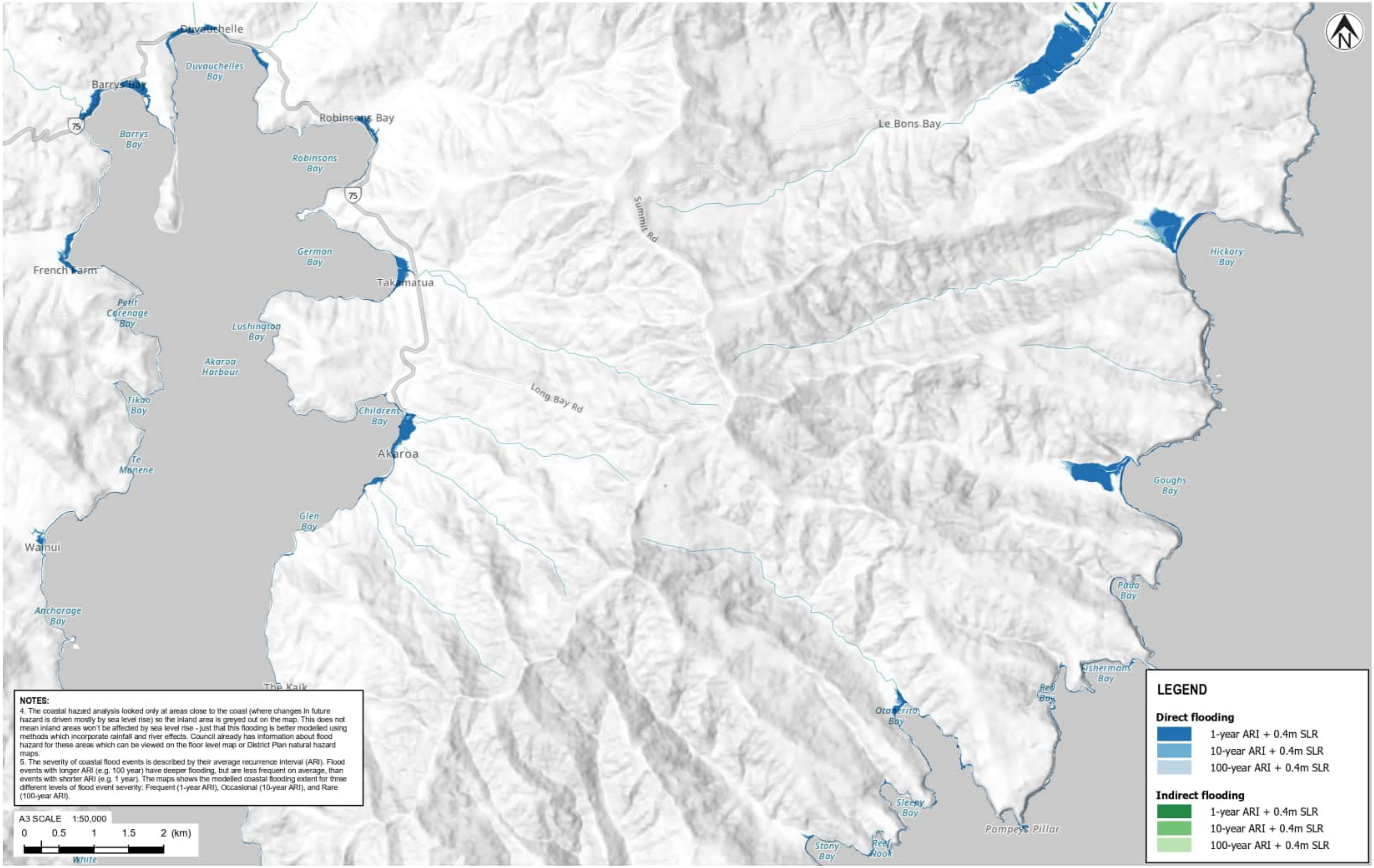

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A3 SCALE 1:50,000

0 0.5 1 1.5 2 (km)

LEGEND

Direct flooding
- 1-year ARI + 0.4m SLR
- 10-year ARI + 0.4m SLR
- 100-year ARI + 0.4m SLR

Indirect flooding
- 1-year ARI + 0.4m SLR
- 10-year ARI + 0.4m SLR
- 100-year ARI + 0.4m SLR

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NOTES:
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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 12C REV 1

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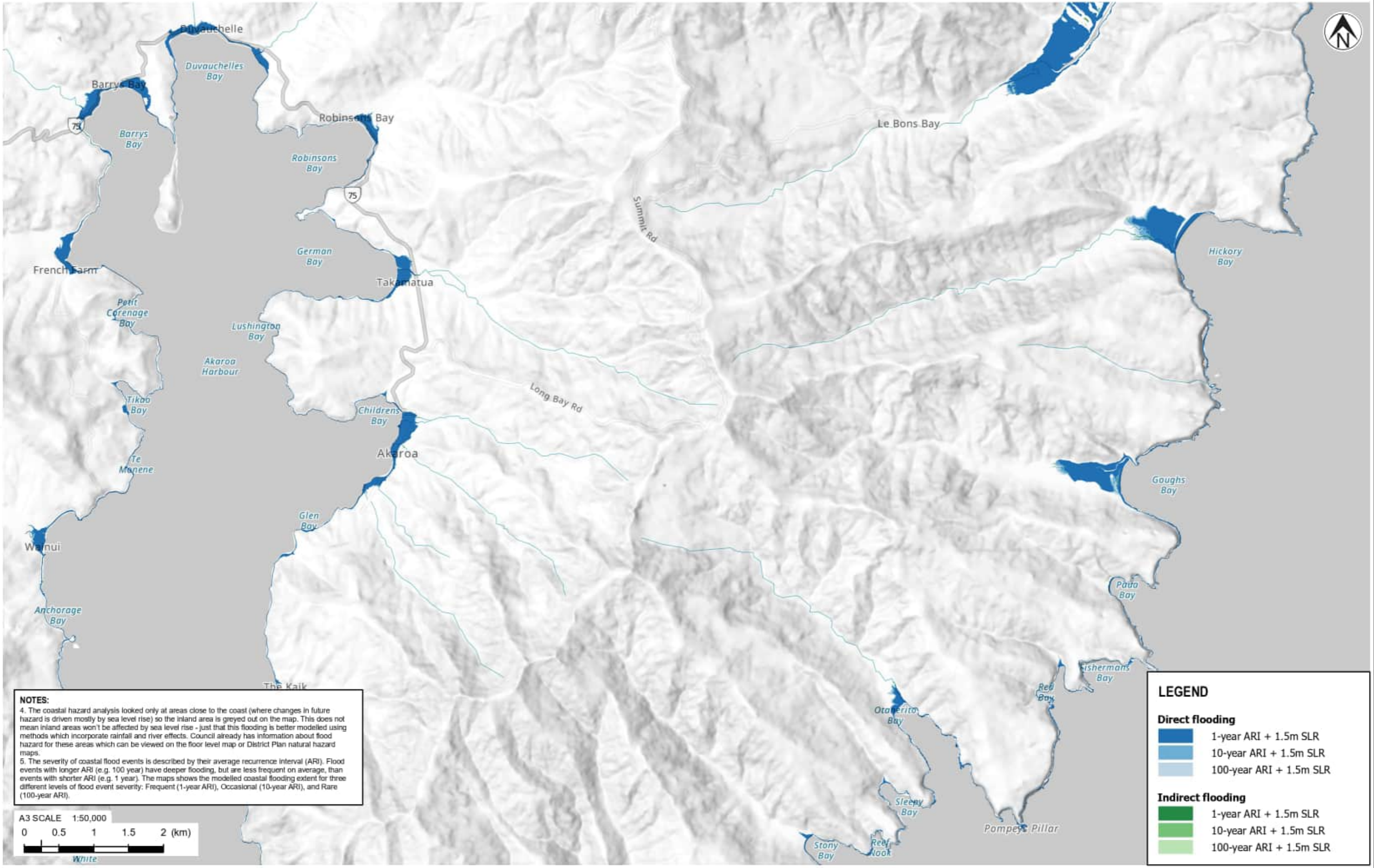

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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 12D REV 1

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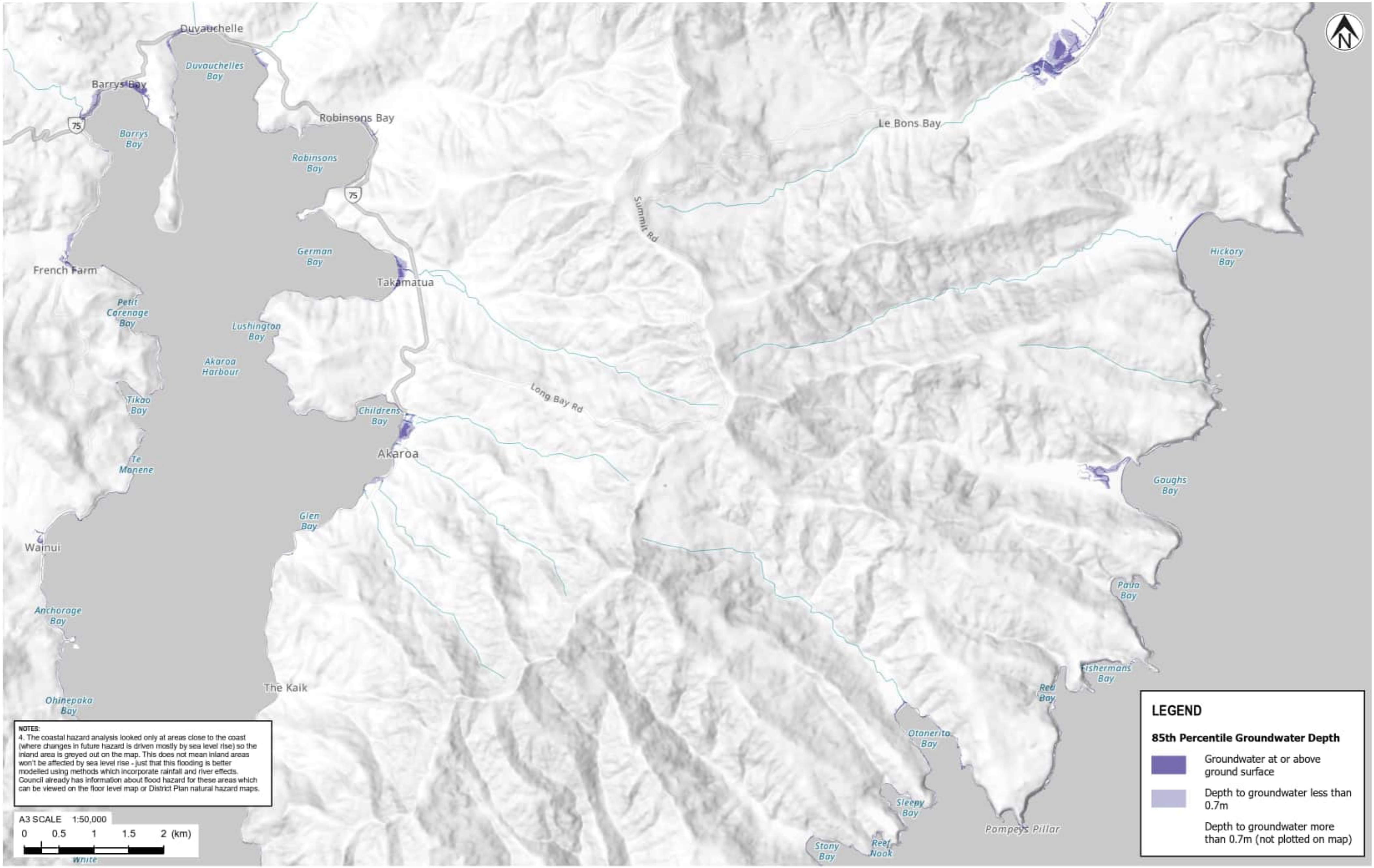

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A3 SCALE 1:50,000

0 0.5 1 1.5 2 (km)

LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
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CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 12E REV 1

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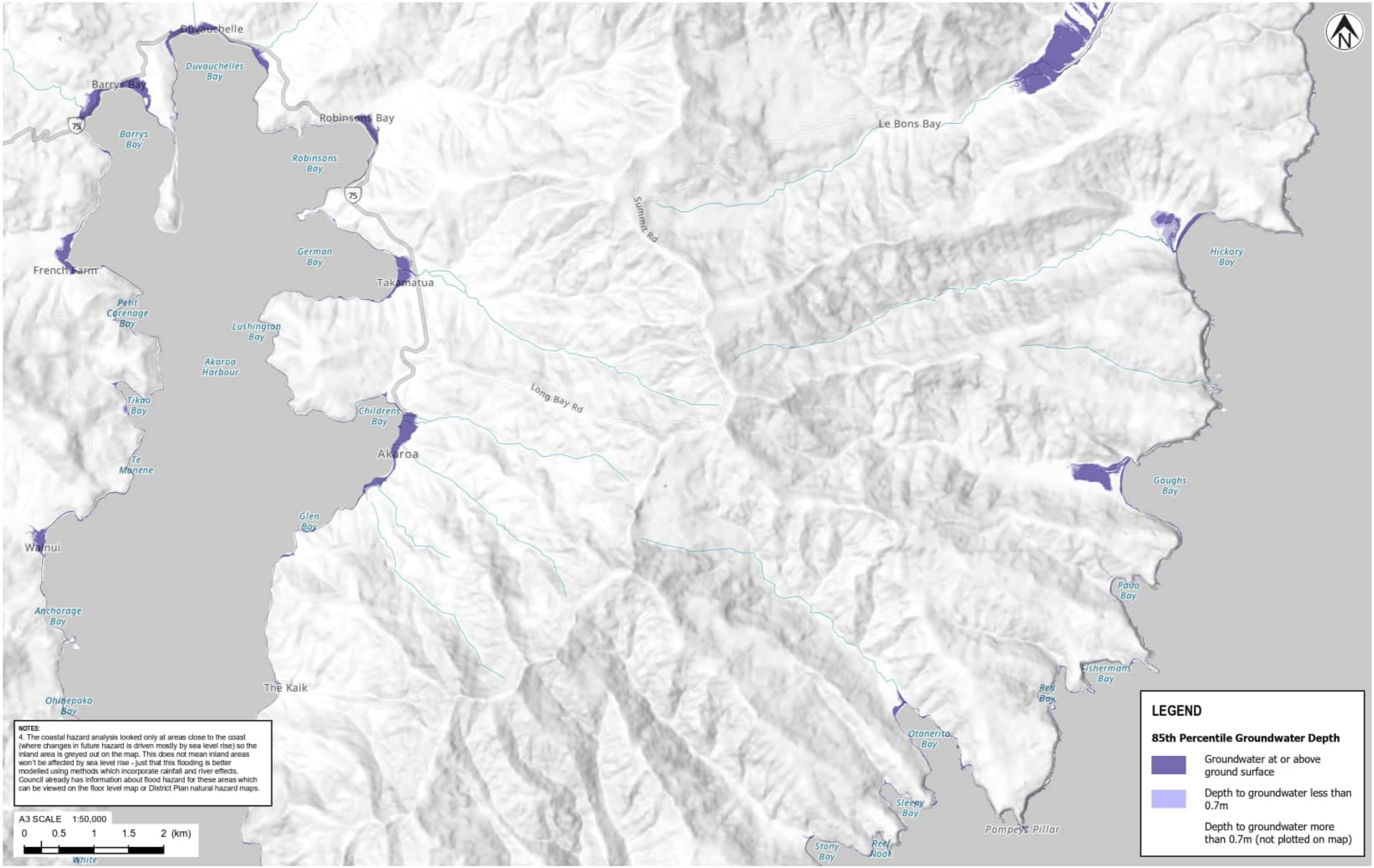

NOTES:
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NOTES:
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3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ.

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LOCATION PLAN

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CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 12F REV 1

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NOTES:
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3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	RHAU	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE
SCALE (A3) 1:50,000   FIG No. FIGURE 13A   REV 1

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LOCATION PLAN

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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21 (DATE)

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 13B REV 1

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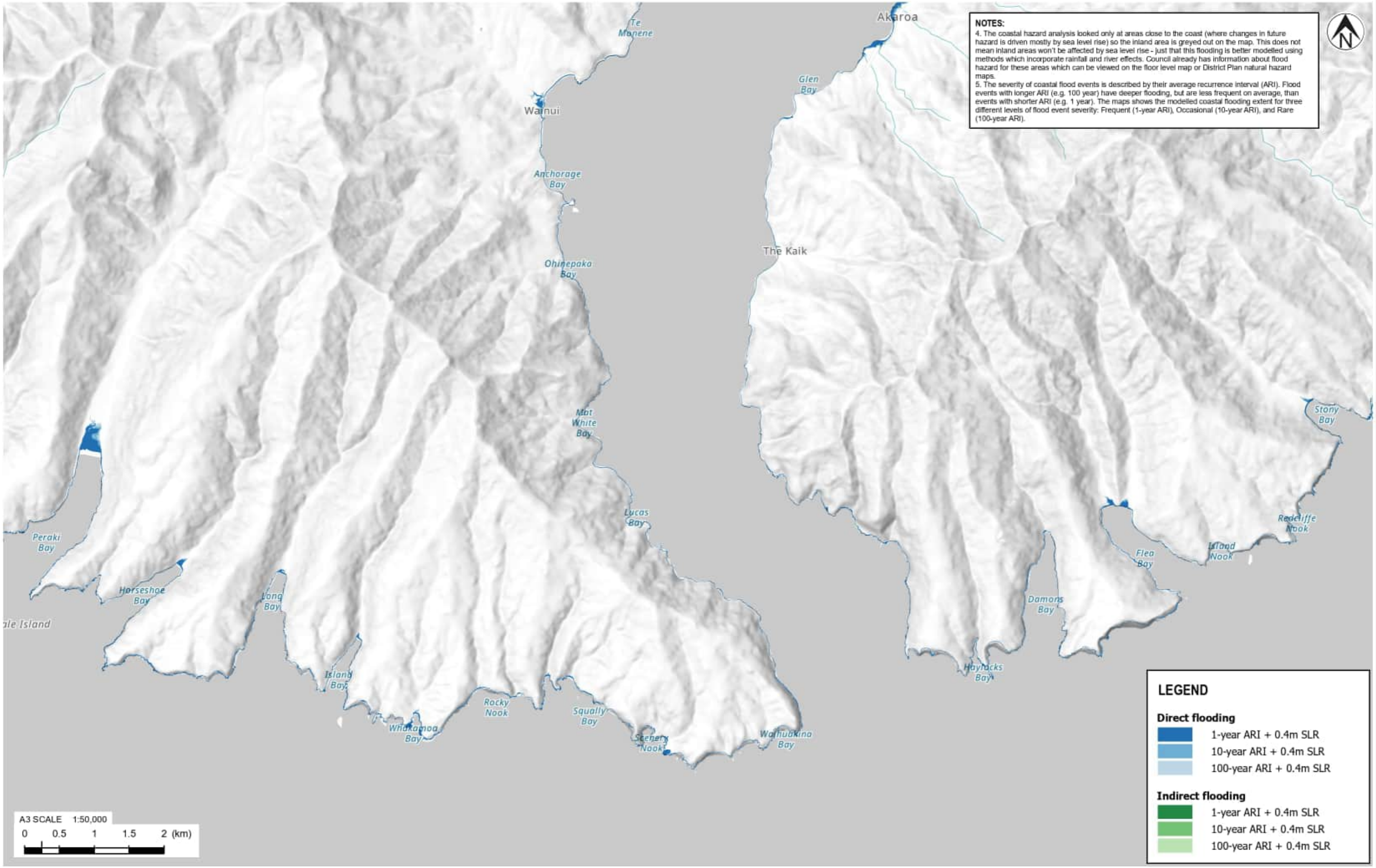

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LEGEND

Direct flooding
- 1-year ARI + 0.4m SLR
- 10-year ARI + 0.4m SLR
- 100-year ARI + 0.4m SLR

Indirect flooding
- 1-year ARI + 0.4m SLR
- 10-year ARI + 0.4m SLR
- 100-year ARI + 0.4m SLR

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NOTES:
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CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:50,000   FIG No. FIGURE 13C   REV 1

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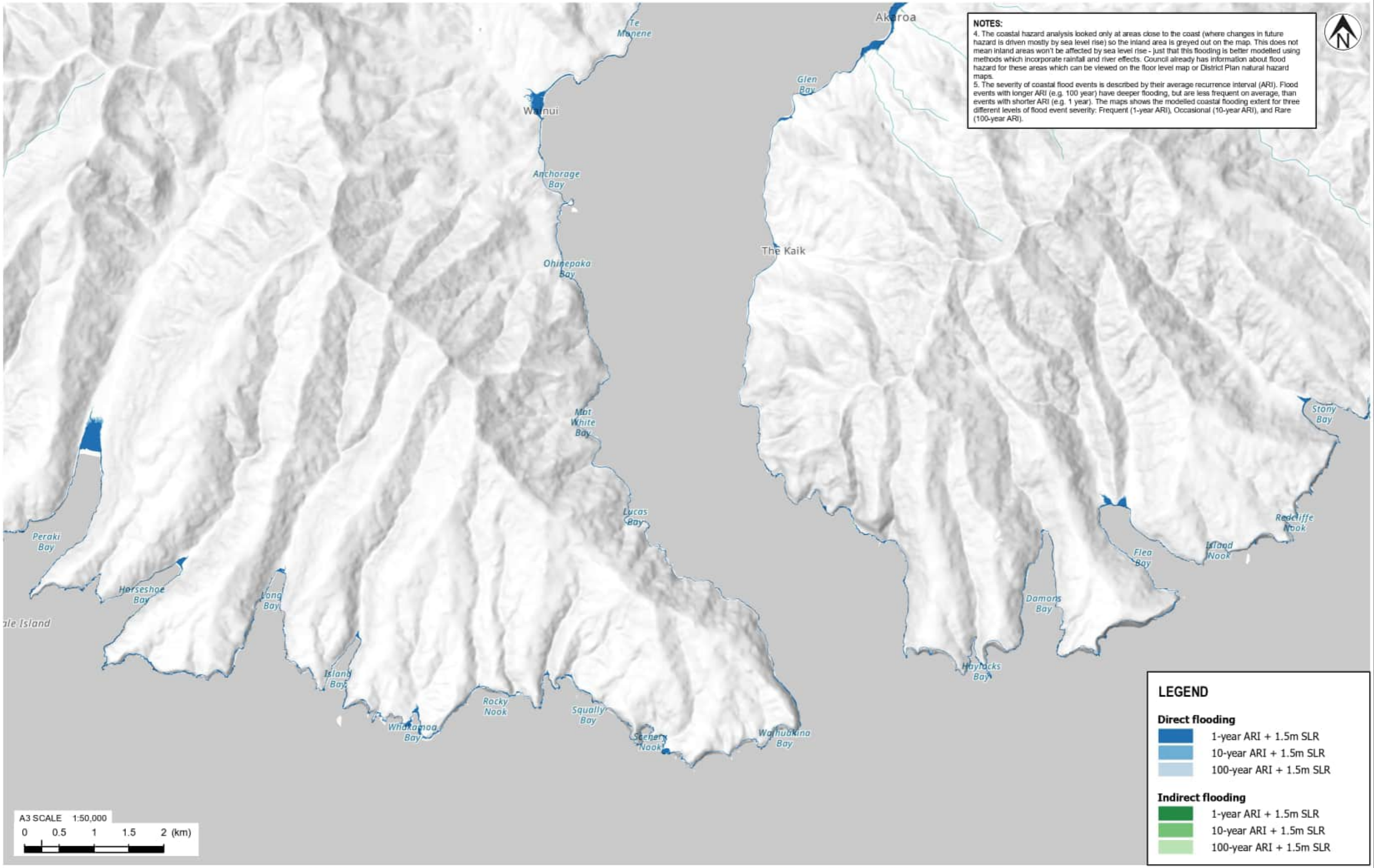

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LEGEND

Direct flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

Indirect flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

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CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3): 1:50,000   FIG No. FIGURE 13D   REV 1

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APPROVED	P. COCHRANE	29/09/21 (DATE)

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 13E REV 1

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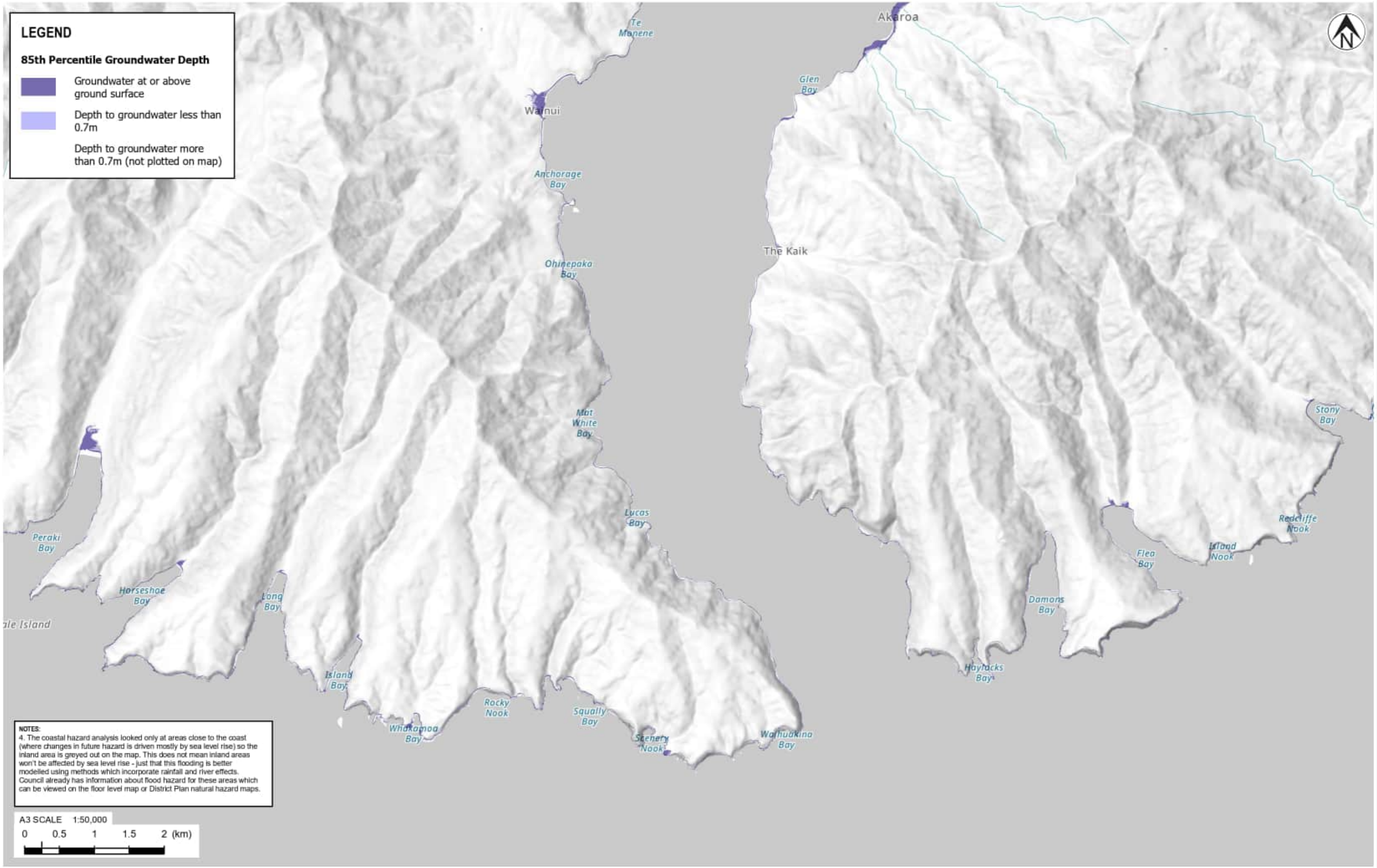

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APPROVED	P. COCHRANE	29/09/21

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PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 13F REV 1

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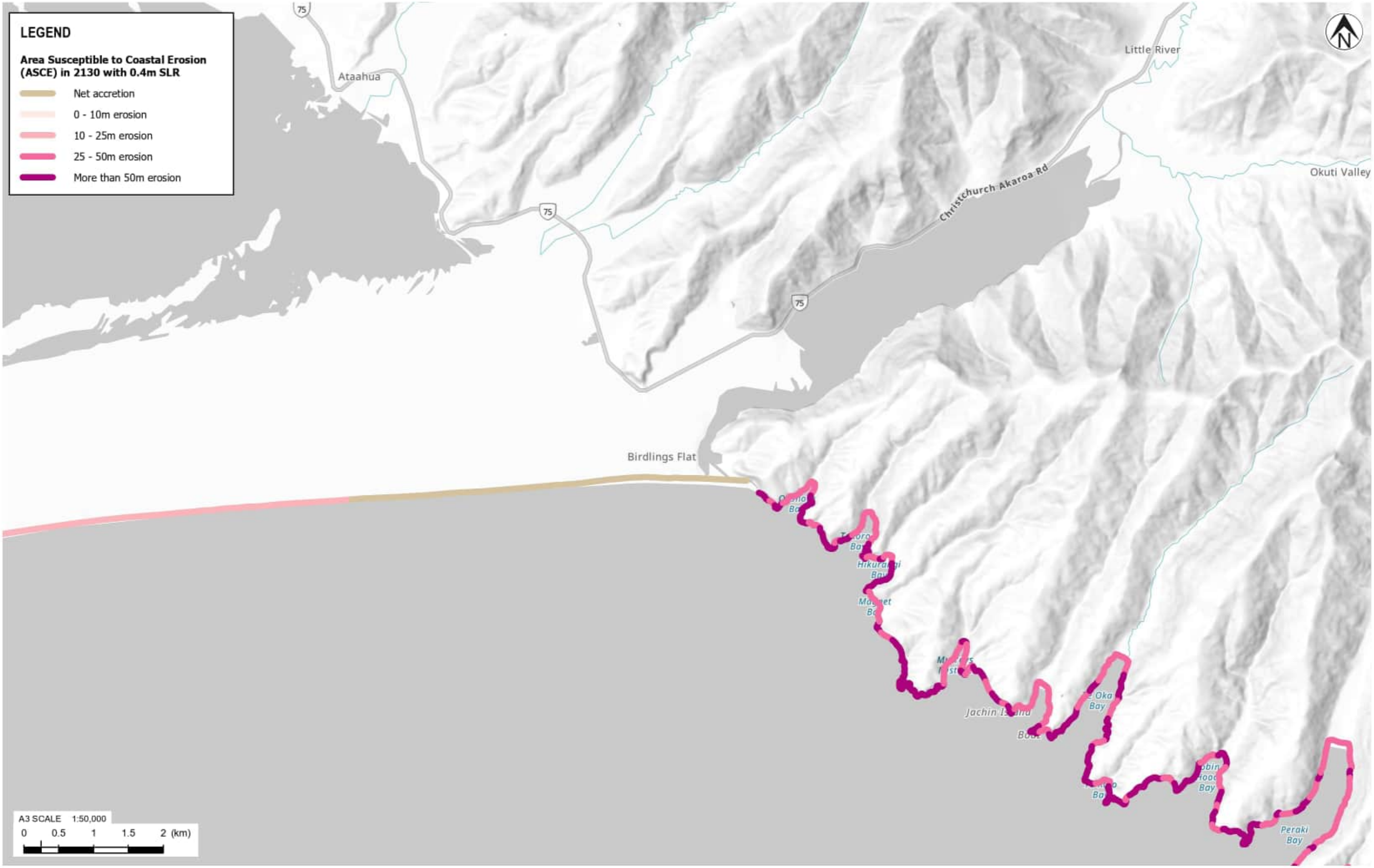

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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 14A REV 1

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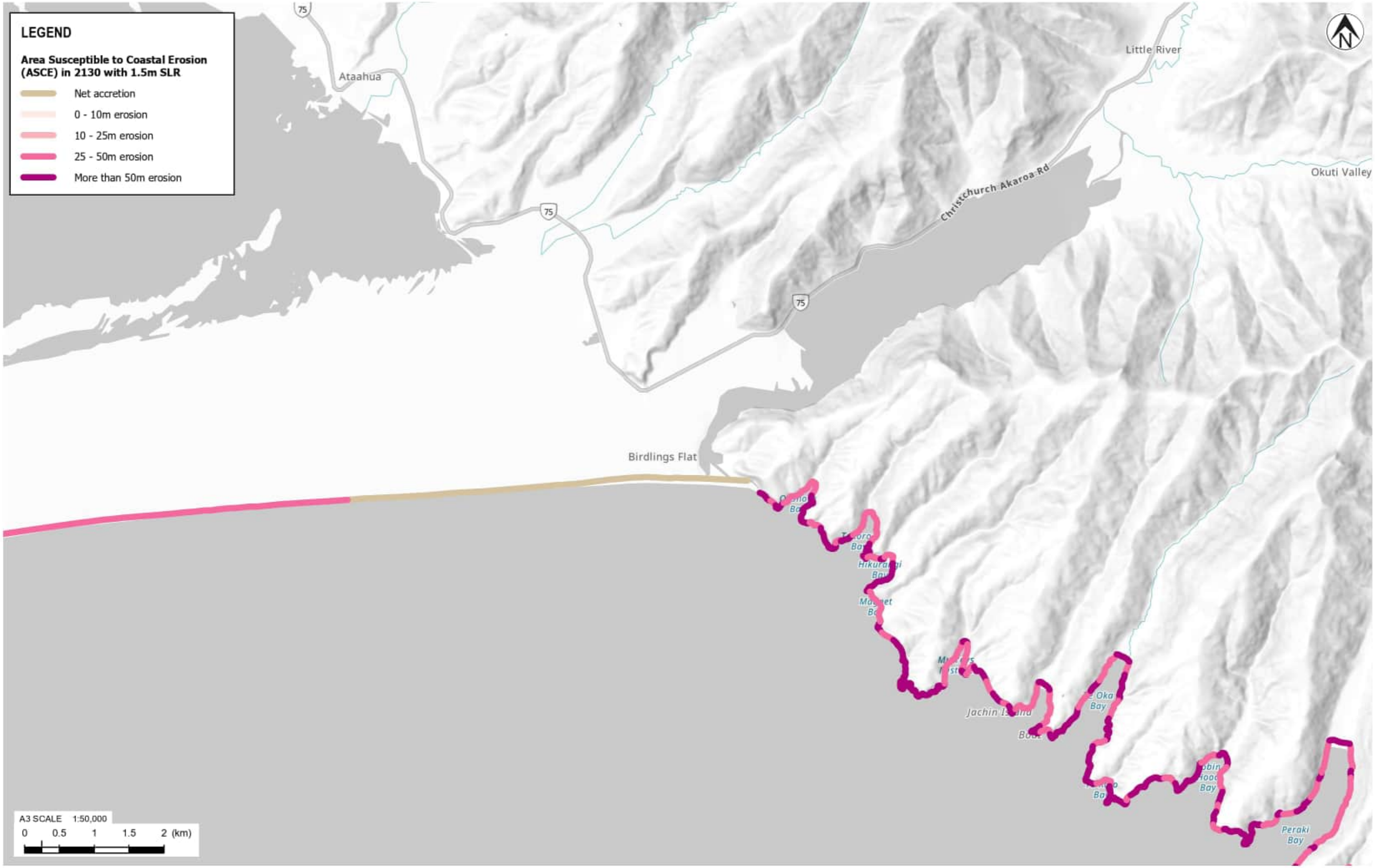

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PROJECT No.	1012976	
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CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 14B REV 1

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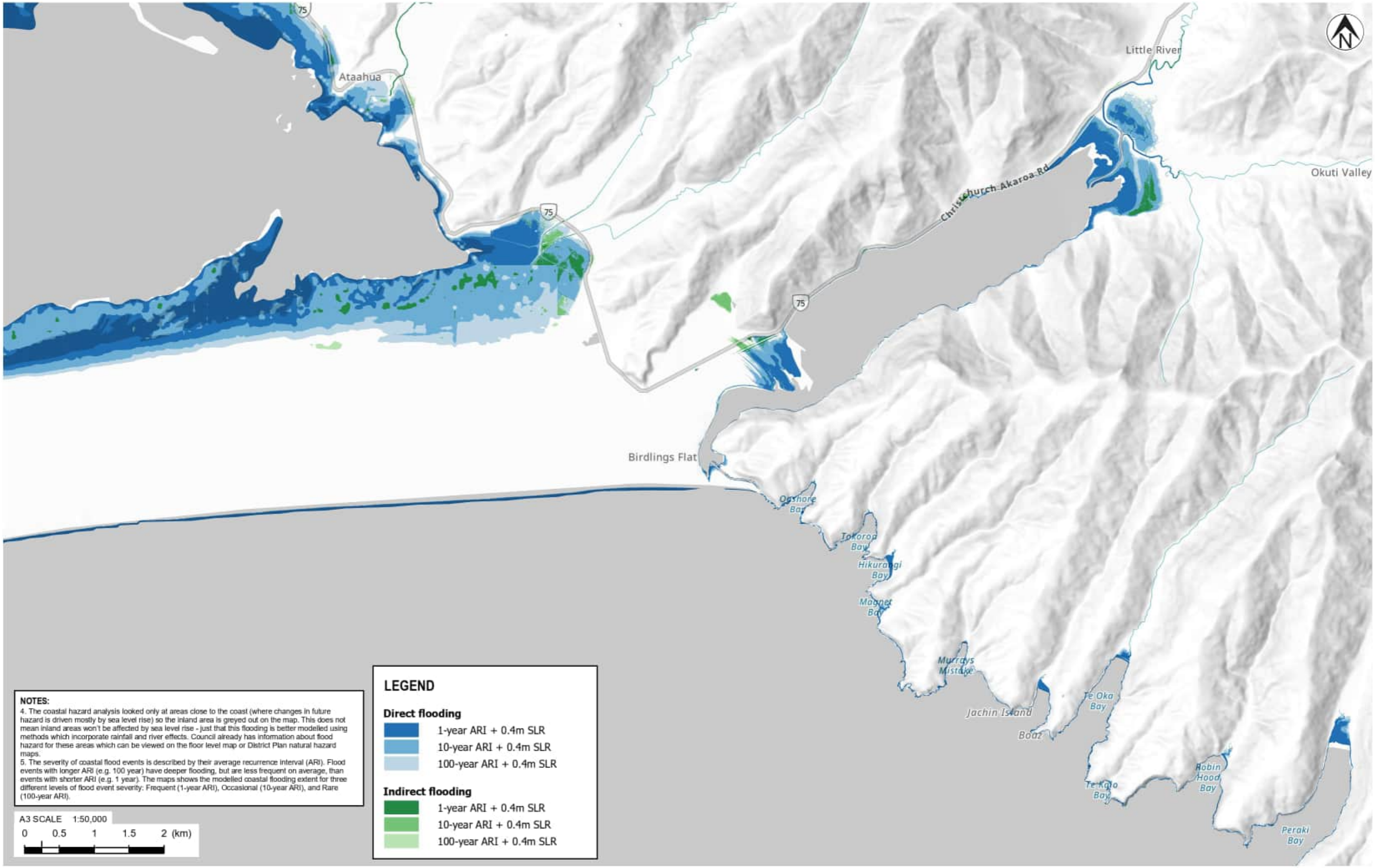

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CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 14C REV 1

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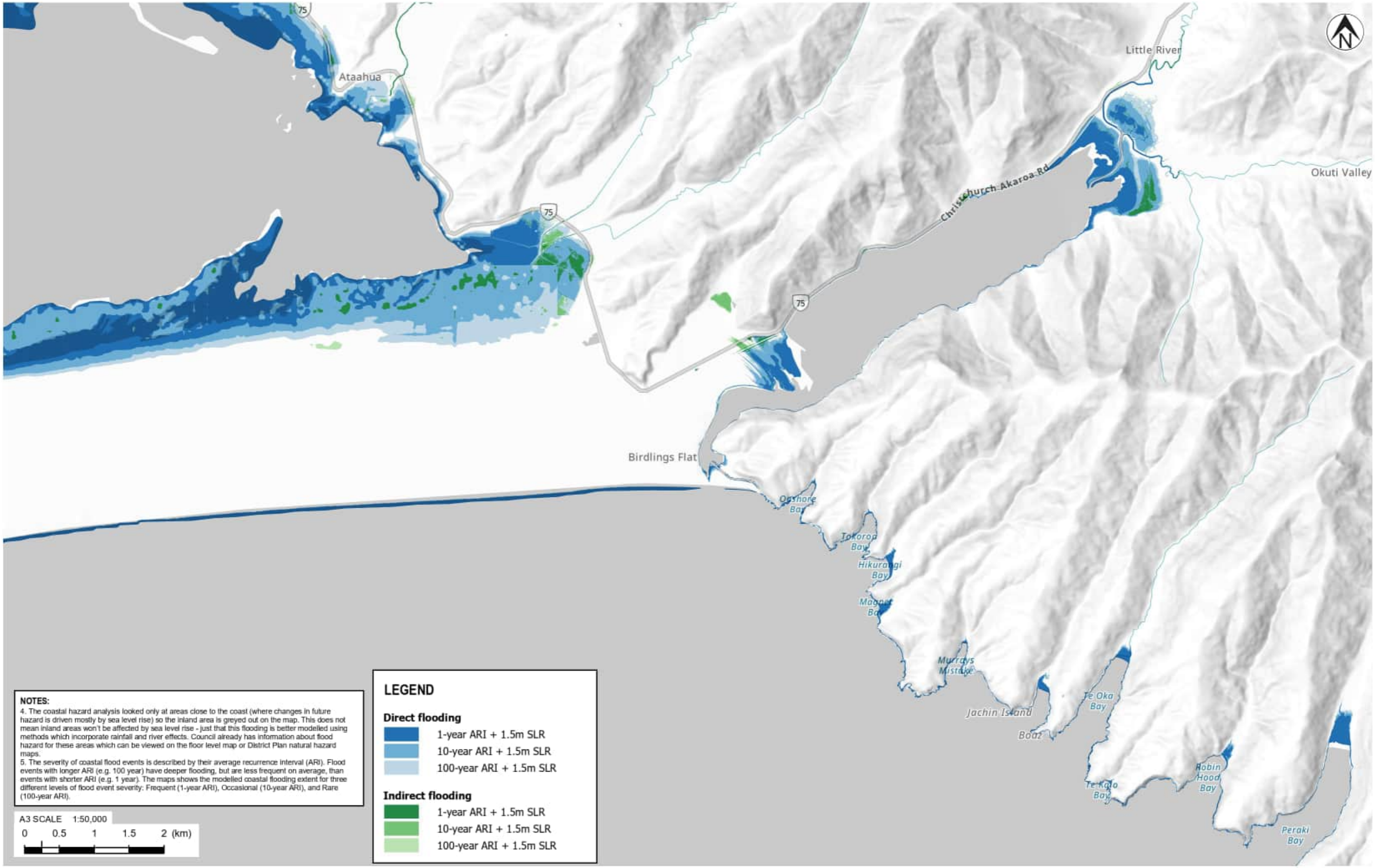

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A3 SCALE 1:50,000
0 0.5 1 1.5 2 (km)

LEGEND

Direct flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

Indirect flooding
- 1-year ARI + 1.5m SLR
- 10-year ARI + 1.5m SLR
- 100-year ARI + 1.5m SLR

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CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 14D REV 1

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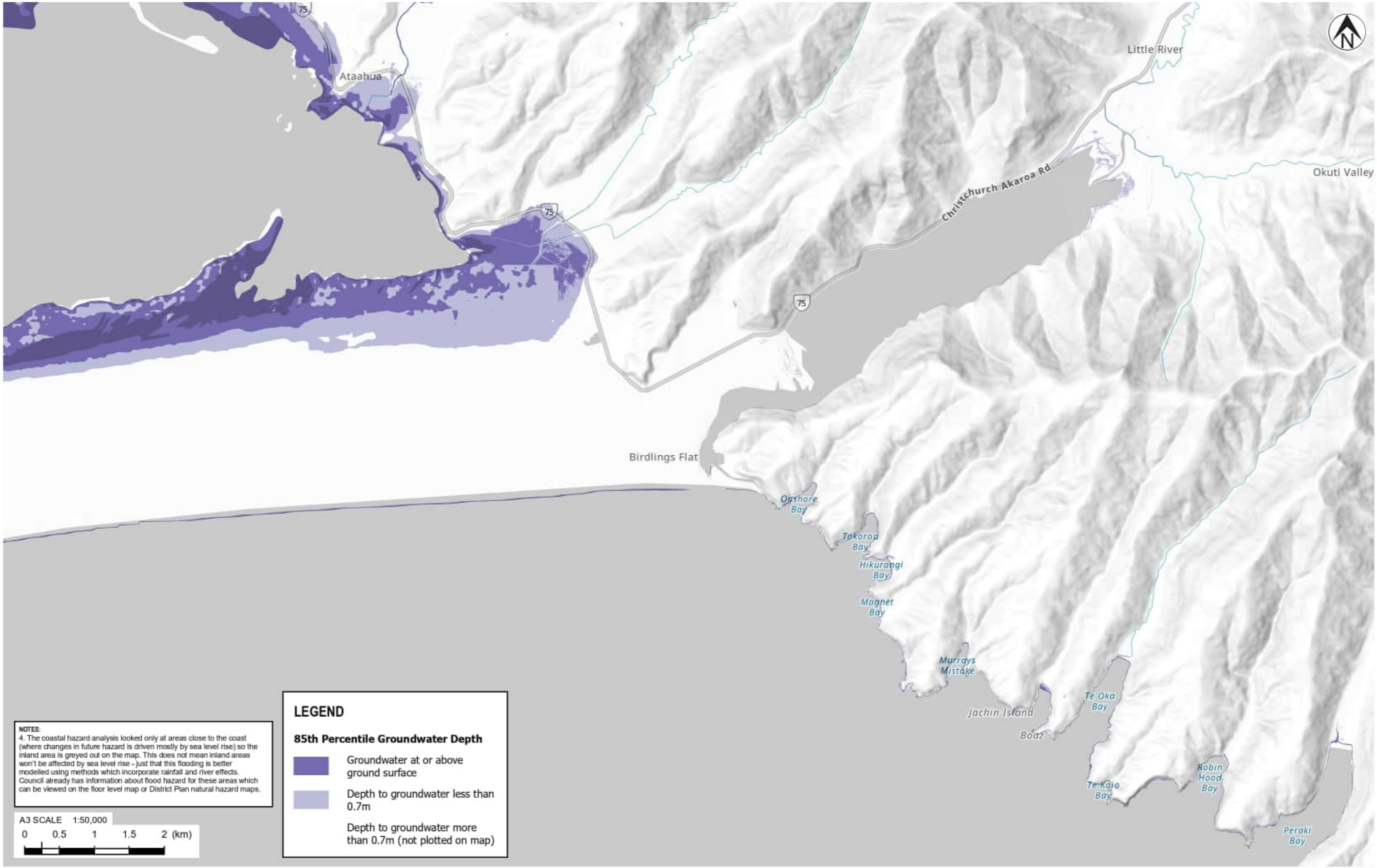

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A3 SCALE 1:50,000
0 0.5 1 1.5 2 (km)

LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
- Depth to groundwater more than 0.7m (not plotted on map)

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NOTES:
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CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3): 1:50,000 FIG No. FIGURE 14E REV 1

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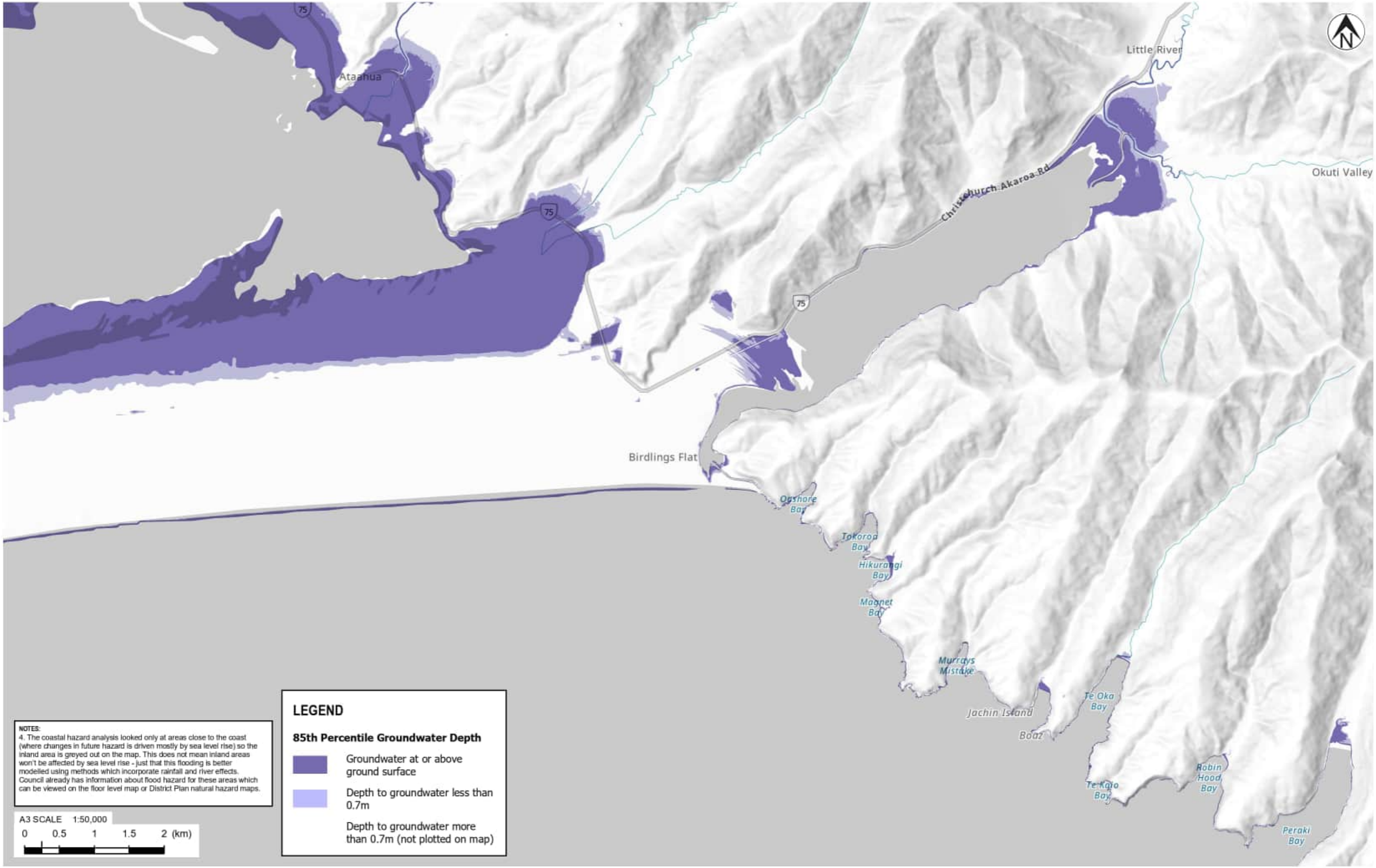

LEGEND

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A3 SCALE 1:50,000

0 0.5 1 1.5 2 (km)

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PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 14F REV 1

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NOTES:
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3. Basemap NZ Hillshade (Alpha): LINZ, Eagle Technology. NZ Topographic Map for use with relief - Grey: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.

REV	DESCRIPTION	GIS	CHK	DATE
1	Report issued	MEJ	RHAU	29/09/21

LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 15A REV 1

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LOCATION PLAN

PROJECT No.	1012976	
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CHECKED	RHAU	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL
PROJECT COASTAL HAZARD ASSESSMENT
TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE
SCALE (A3) 1:50,000   FIG No. FIGURE 15B   REV 1

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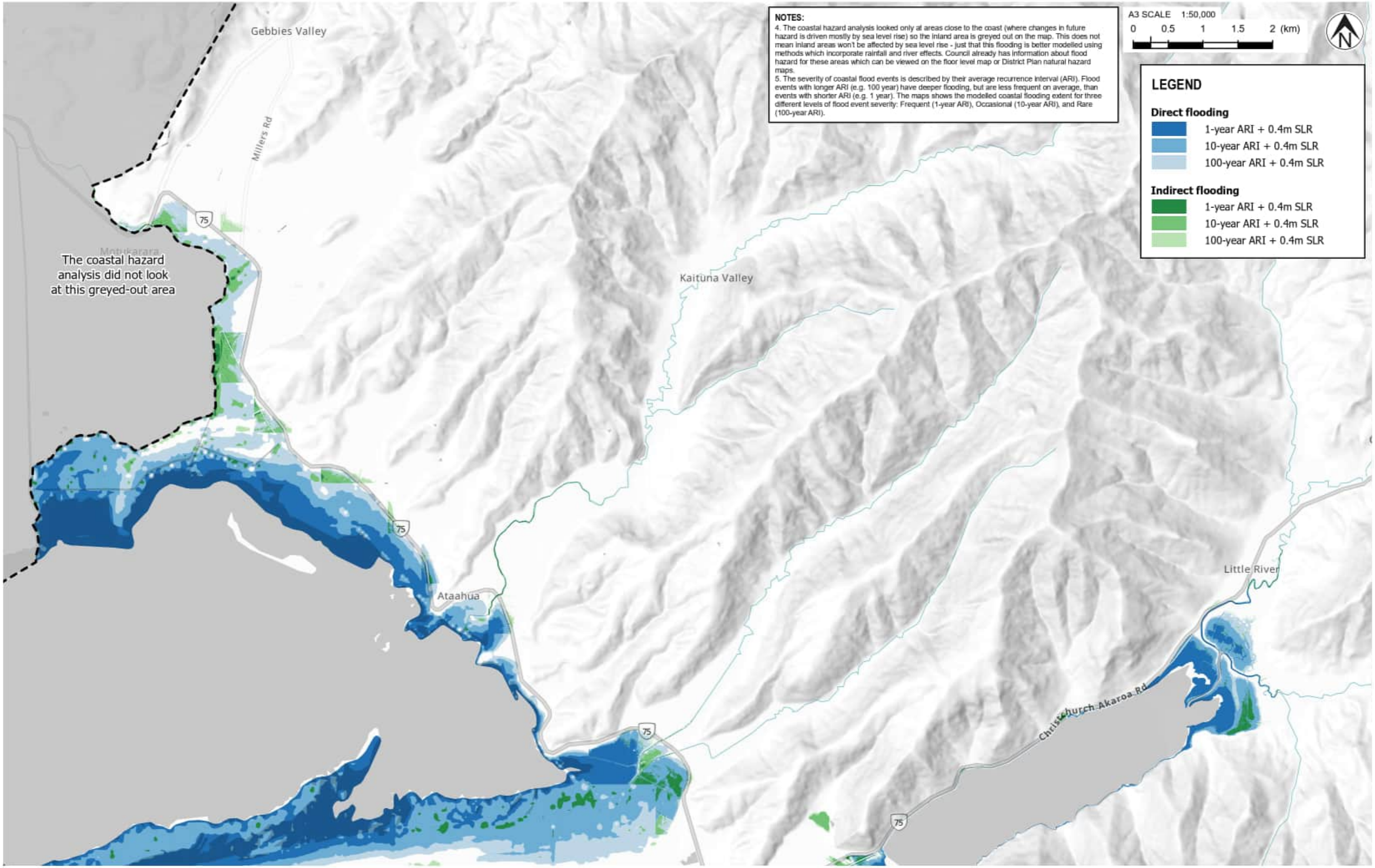

NOTES:

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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
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APPROVED	P. COCHRANE	29/09/21

CLIENT: **CHRISTCHURCH CITY COUNCIL**
PROJECT: **COASTAL HAZARD ASSESSMENT**
TITLE: COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3): 1:50,000   FIG No.: FIGURE 15C   REV: 1

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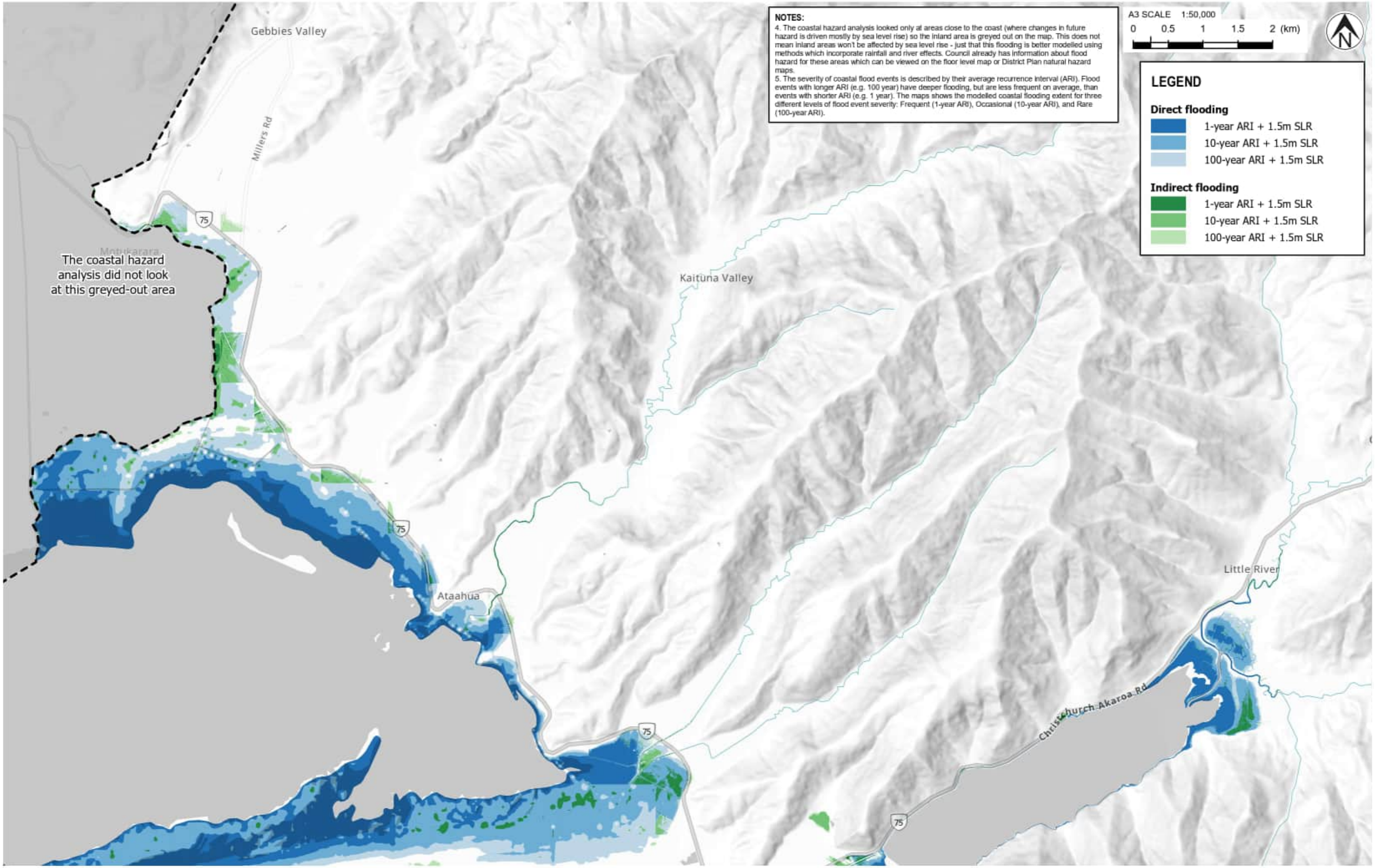

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CHECKED	PPK	SEP.21
APPROVED	P. COCHRANE	29/09/21

CLIENT: CHRISTCHURCH CITY COUNCIL
PROJECT: COASTAL HAZARD ASSESSMENT
TITLE: COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE
SCALE (A3): 1:50,000   FIG No. FIGURE 15D   REV 1

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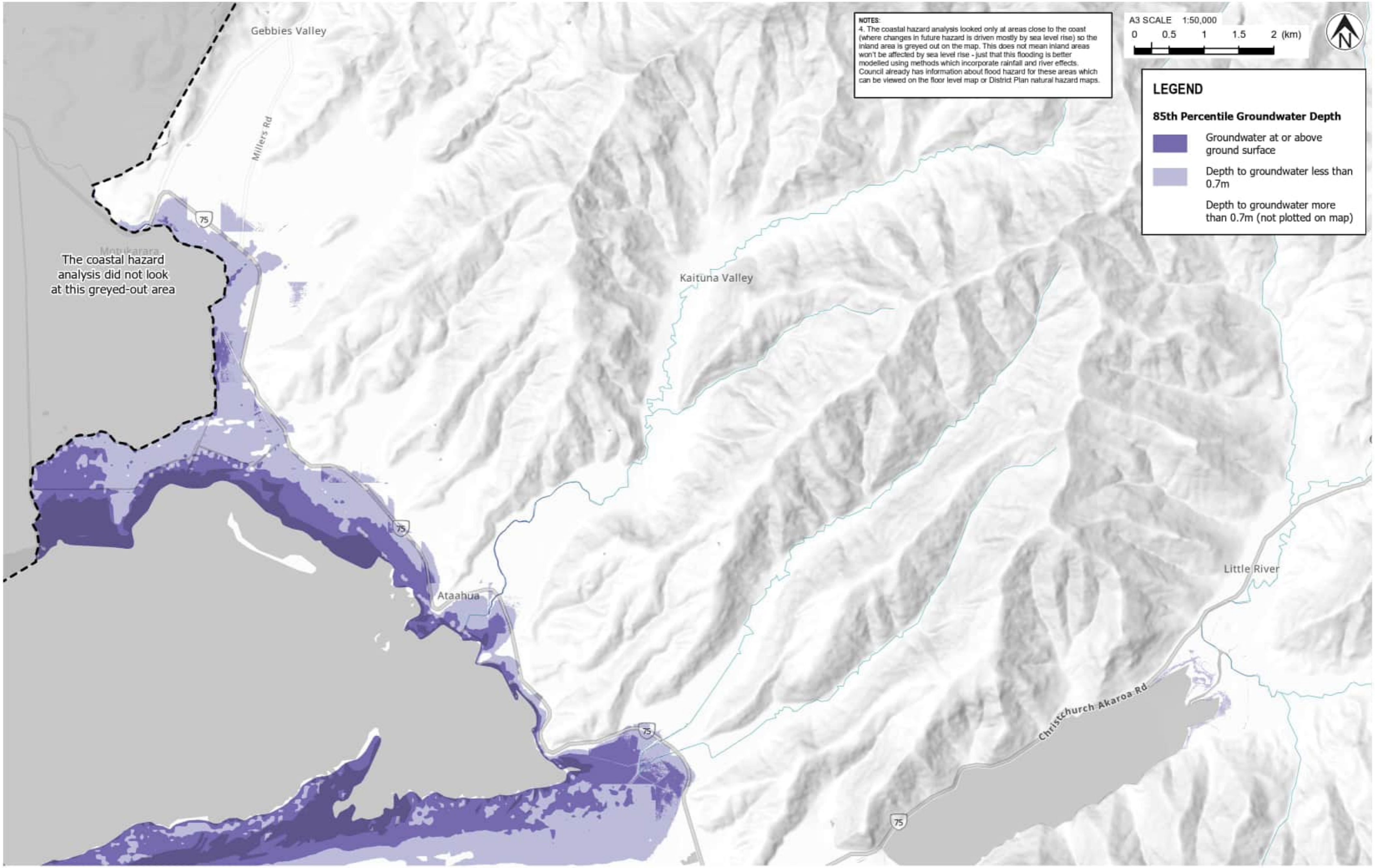

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2. For Banks Peninsula, map assumes that 85th percentile groundwater level is approximately equal to MHWS high tide level.
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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 15E REV 1

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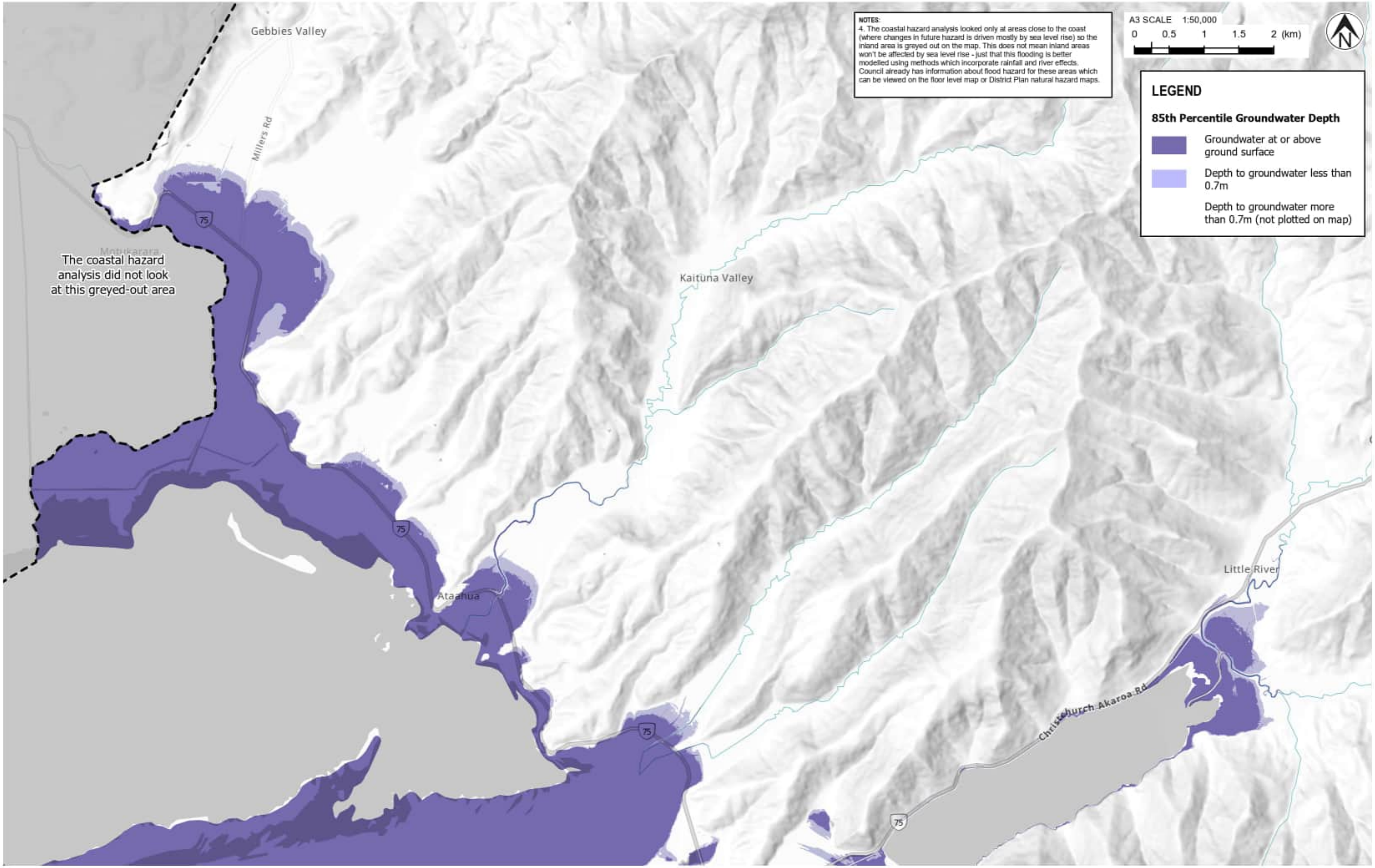

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LEGEND

85th Percentile Groundwater Depth

- Groundwater at or above ground surface
- Depth to groundwater less than 0.7m
- Depth to groundwater more than 0.7m (not plotted on map)

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CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 15F REV 1

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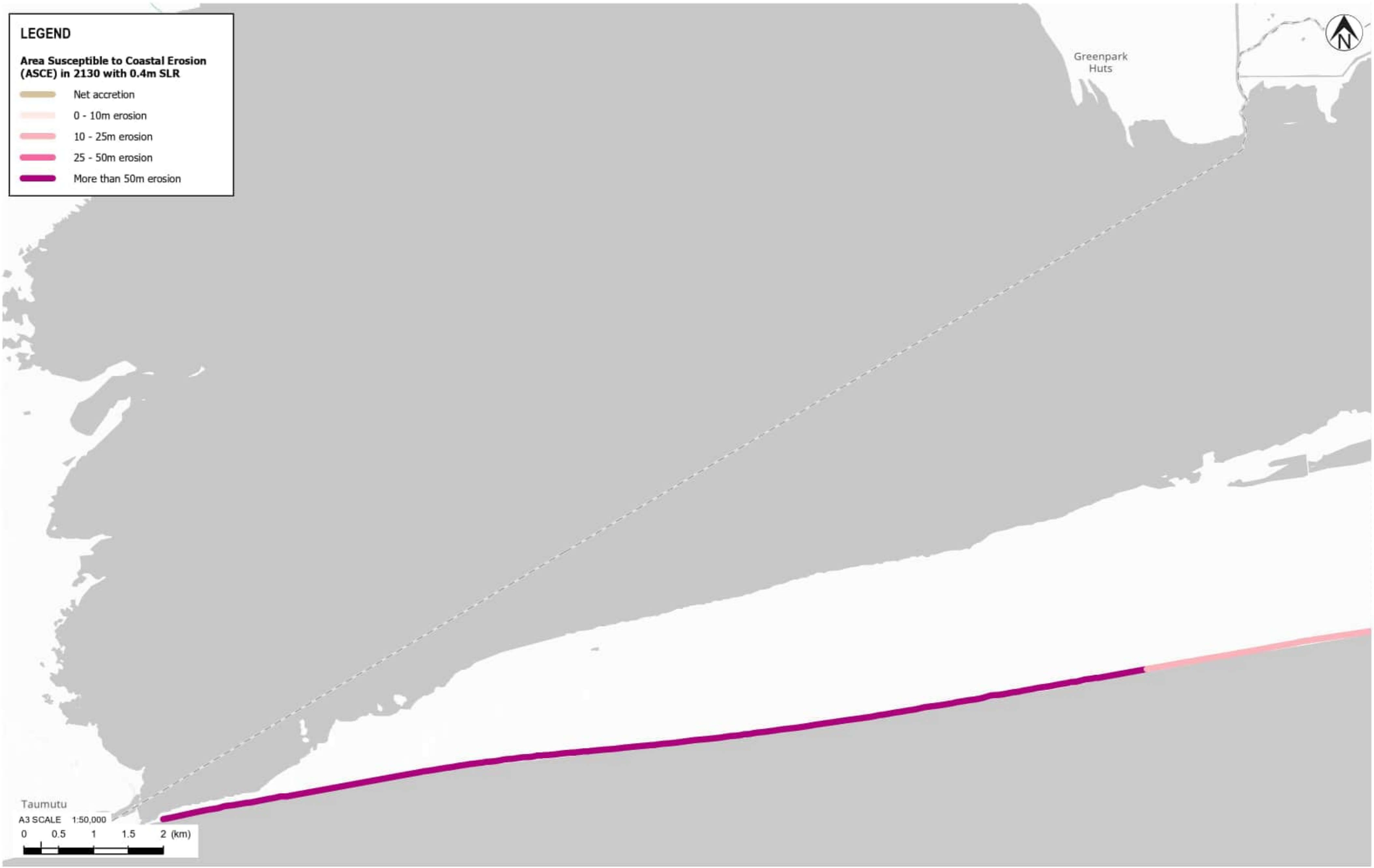

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CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 0.4M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 16A REV 1

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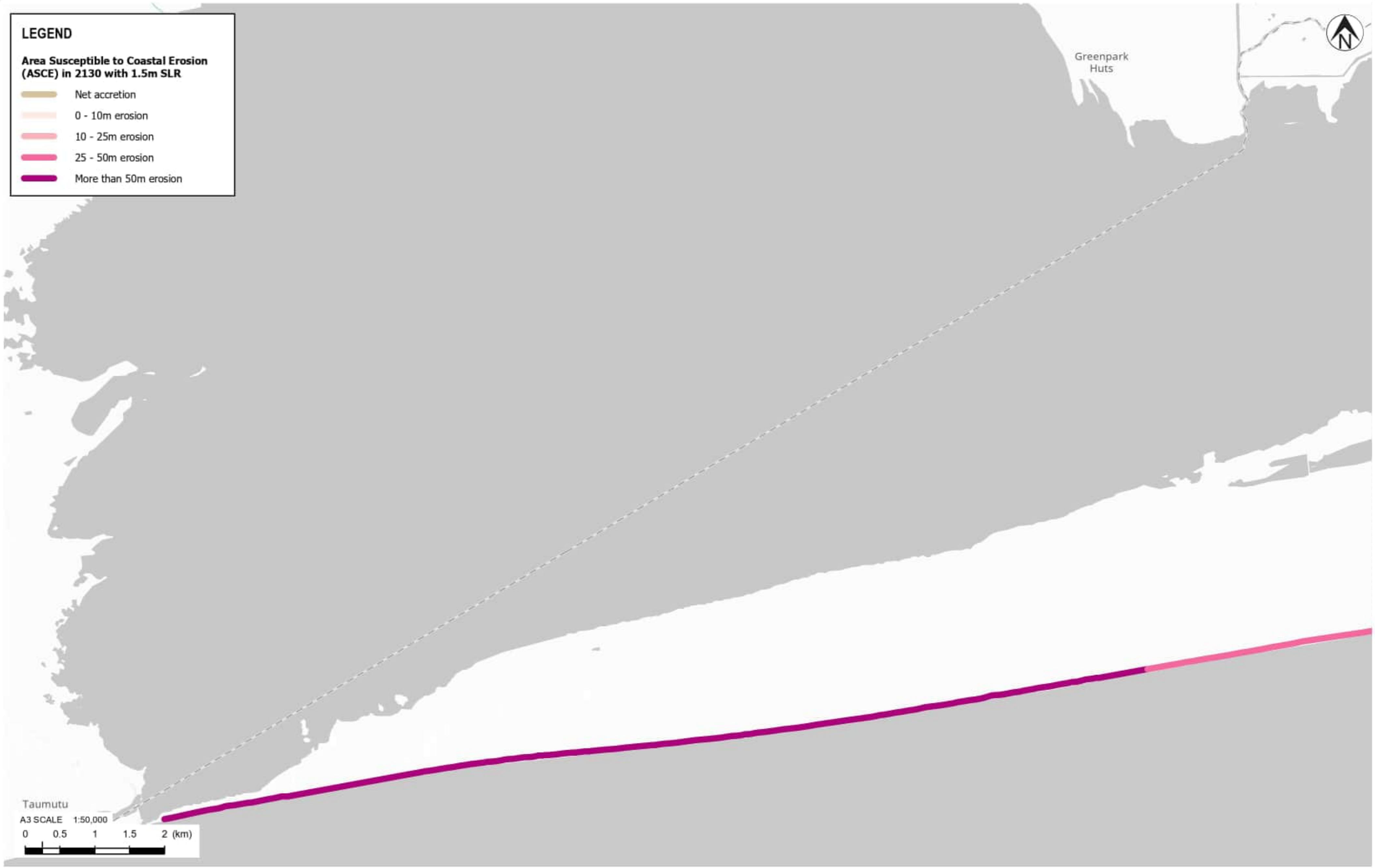

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APPROVED	P. COCHRANE	29/09/21

CLIENT CHRISTCHURCH CITY COUNCIL

PROJECT COASTAL HAZARD ASSESSMENT

TITLE COASTAL EROSION ANALYSIS
SCENARIO: YEAR 2130 WITH 1.5M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 16B REV 1

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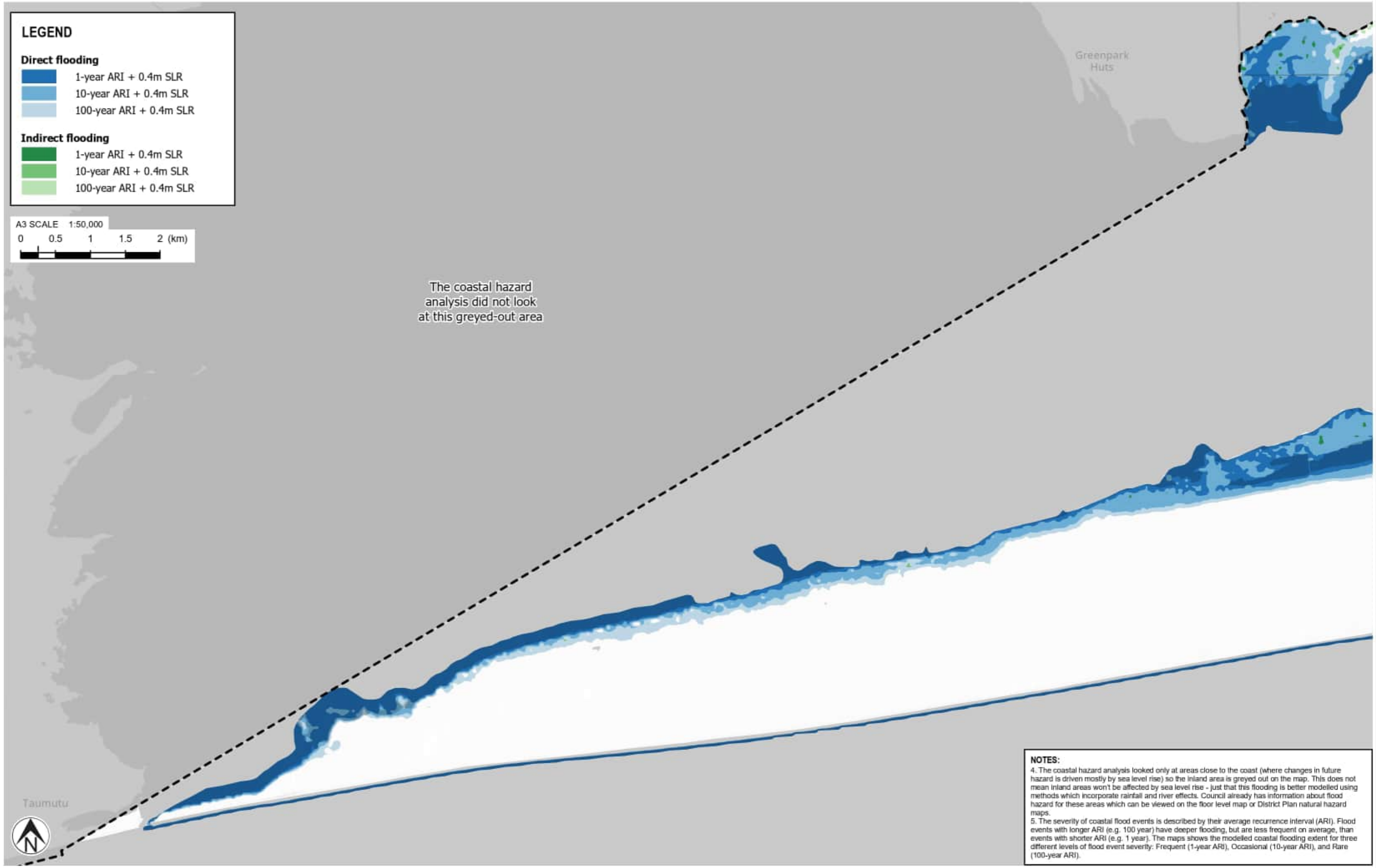

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REV	DESCRIPTION	GIS	CHK	DATE
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LOCATION PLAN

PROJECT No.	1012976	
DESIGNED	MEJ	SEP.21
DRAWN	MEJ	SEP.21
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APPROVED	P. COCHRANE	29/09/21

CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 0.4M SEA LEVEL RISE

SCALE (A3) 1:50,000   FIG No. FIGURE 16C   REV 1

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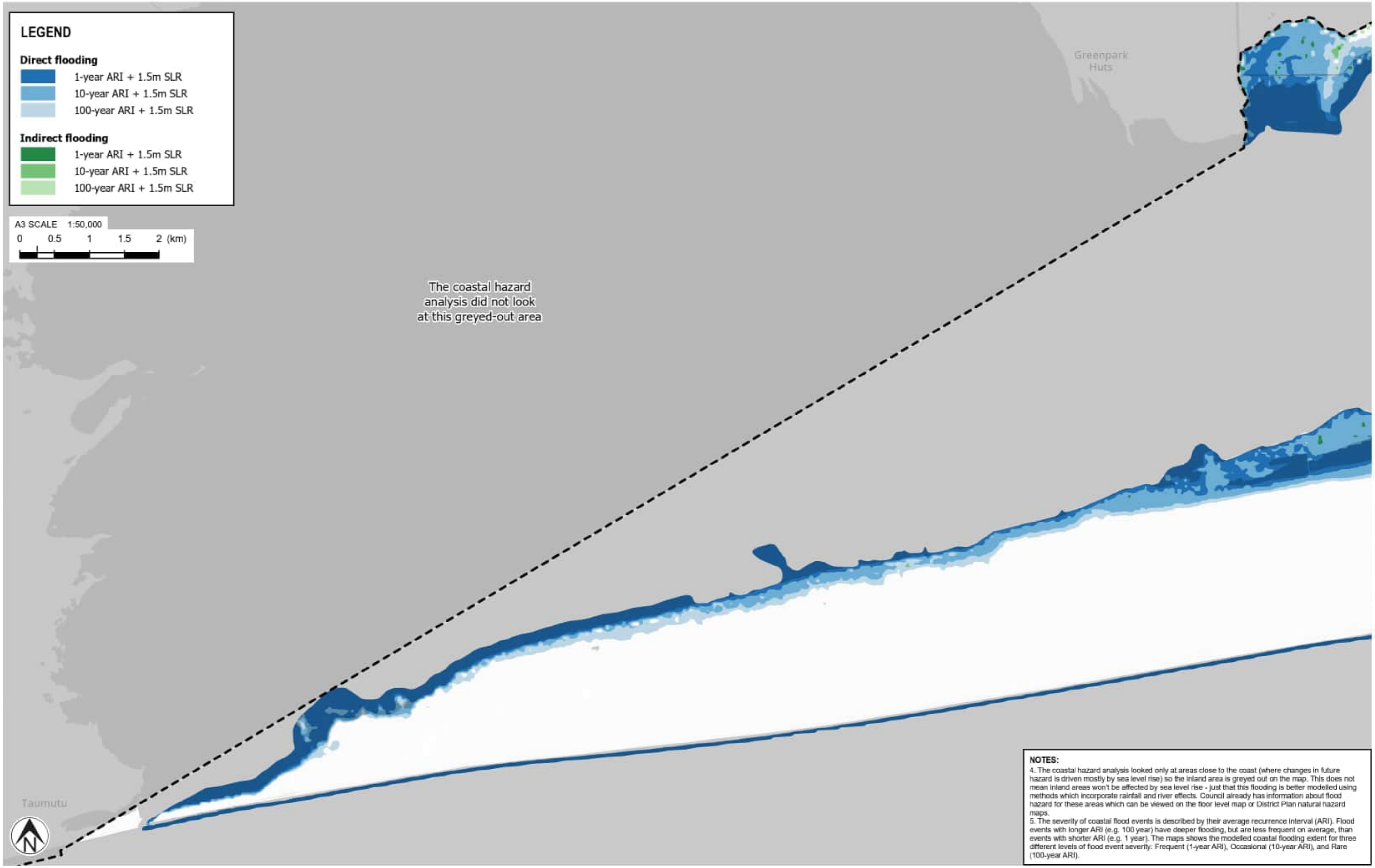

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LOCATION PLAN

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CLIENT **CHRISTCHURCH CITY COUNCIL**

PROJECT **COASTAL HAZARD ASSESSMENT**

TITLE COASTAL FLOODING ANALYSIS
SCENARIO: 1.5M SEA LEVEL RISE

SCALE (A3) 1:50,000 FIG No. FIGURE 16D REV 1

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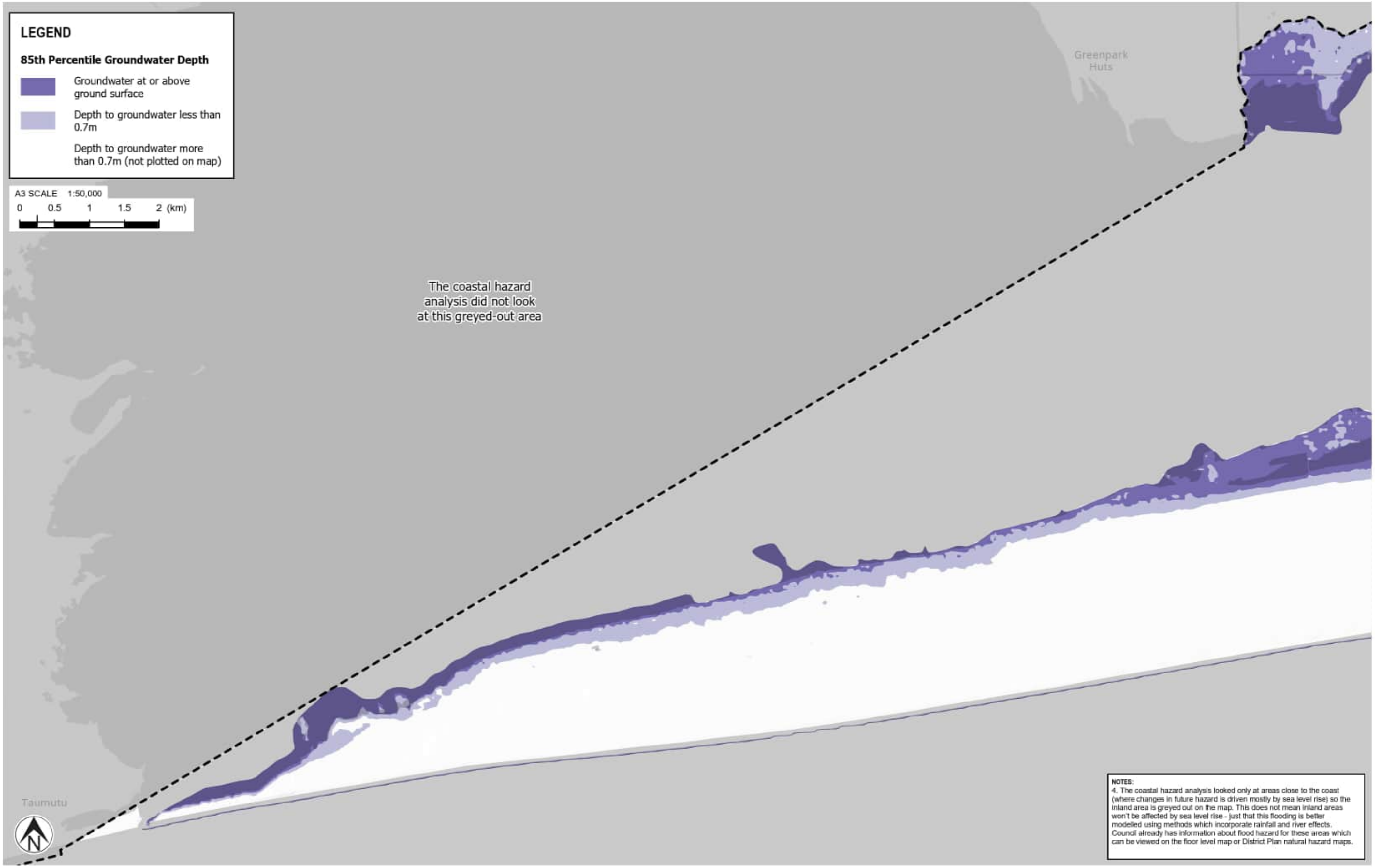

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CLIENT	**CHRISTCHURCH CITY COUNCIL**
PROJECT	**COASTAL HAZARD ASSESSMENT**
TITLE	COASTAL GROUNDWATER ANALYSIS SCENARIO: 0.4M SEA LEVEL RISE
SCALE (A3)	1:50,000
FIG No.	FIGURE 16E
REV	1

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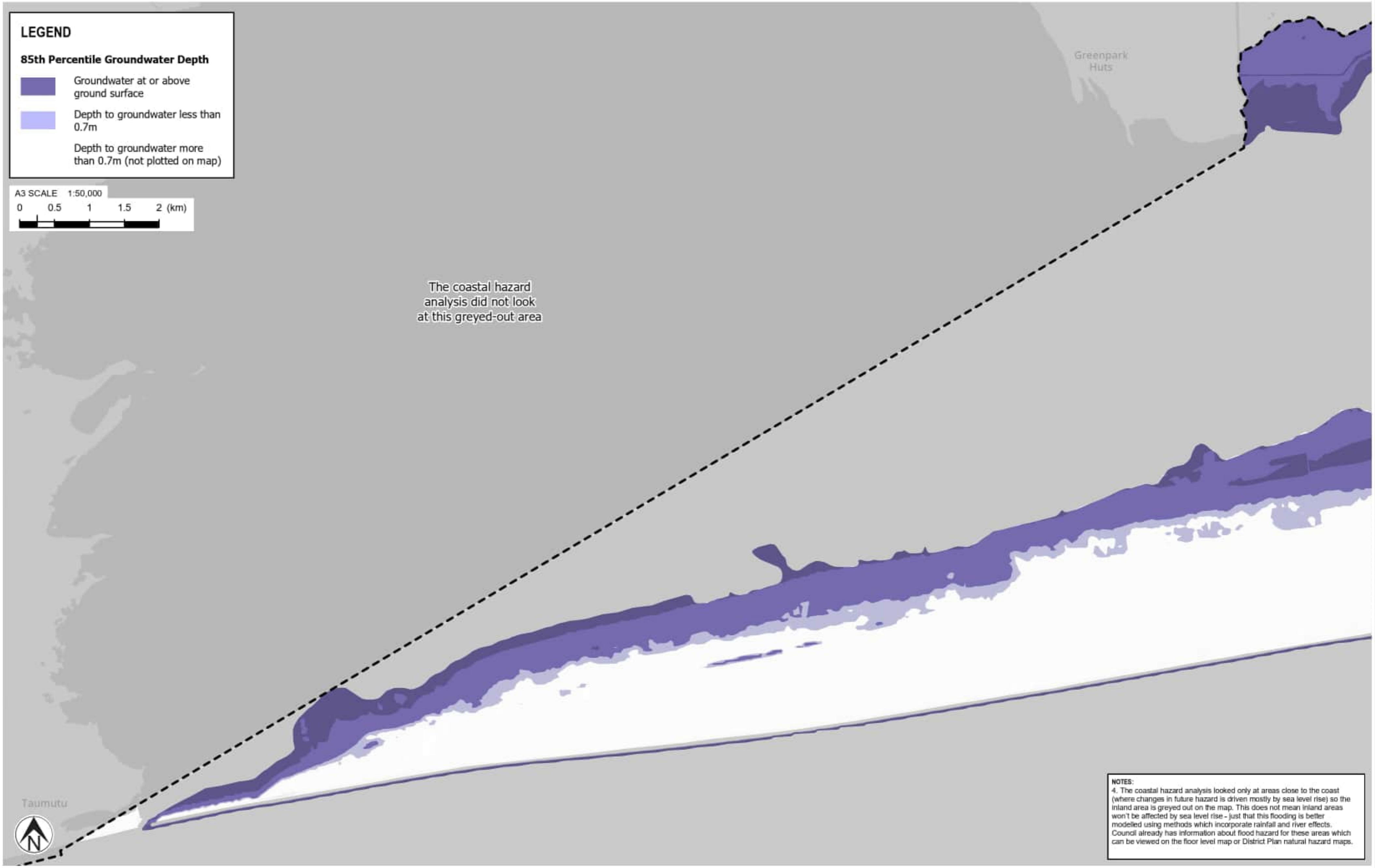

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P. COCHRANE		29/09/21
APPROVED		DATE

CLIENT **CHRISTCHURCH CITY COUNCIL**
PROJECT **COASTAL HAZARD ASSESSMENT**
TITLE COASTAL GROUNDWATER ANALYSIS
SCENARIO: 1.9M SEA LEVEL RISE
SCALE (A3) 1:50,000 FIG No. FIGURE 16F REV 1

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