Project Number: 5-C4035.00

# Waiapu Cathedral of St. John the Evangelist, Napier

## Detailed Seismic Assessment

7 December 2021

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# Executive Summary

WSP has been engaged by Waiapu Cathedral of St John the Evangelist to carry out the seismic assessment of Cathedral building which is located at 38 Browning Street, Napier in accordance with the MBIE guidelines 'The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments, July 2017, Version 1.

## Cathedral Building

The Waiapu Cathedral Building is a multi-structure complex comprising of Chancel, Chapel, Nave, Vestry, Bell Tower and other single storey peripheral buildings constructed in three stages between 1956 and 1960.

The primary vertical and lateral load resisting system in both the longitudinal and transverse direction of the building is reinforced concrete walls and is supplemented by concrete moment frames in the Nave.

## Seismic Assessment Results

Table A below summarises the outcome of DSA for the governing cases in terms of %NBS rating.

*Table A: Summary of Detailed Seismic Assessment Results (for elements with <67% NBS only)*

| Building Component | %NBS Rating (IL3) | Critical Issues/Remarks |
|---|---|---|
| | ULS 1 in 1000 years RP | |
| Nave | 20 % | Rating is governed by capacity of concrete walls, spandrel beams and roof beams |
| Bell Tower | 20 % | Walls susceptible to undesirable non-ductile failure due to high axial loads and inefficient reinforcement and are considered a severe structural weakness (SSW) |
| Chancel | 30 % | Rating is governed by capacity of concrete walls. |
| Chapel | 40 % | Rating is governed by capacity of concrete walls. |
| Vestry | 25 % | Rating is governed by capacity of concrete walls. |

The Waiapu Cathedral building has a rating of less than <34% NBS (IL3), with the overall building rating limited by the Bell Tower and Nave to 20% NBS (IL3).

The Vestry and Chancel have slightly higher ratings but are still rated <34% NBS (IL3).

WSP have proposed concept structural strengthening to bring the structure rating up to greater than 34% NBS (IL3) and deal with the structural weaknesses. The illustrative sketches of proposed strengthening are presented in Appendix C.

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# Disclaimers and Limitations

This report ('**Report**') has been prepared by WSP exclusively for Waiapu Cathedral of St John the Evangelist ('**Client**') in relation to the detailed seismic assessment ('**Purpose**') of the structure. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

In preparing the Report, WSP has relied upon data, visual site inspections, analyses, designs, plans and other information ('**Client Data'**) provided by or on behalf of the Client. Except as otherwise stated in the Report, WSP has not verified the accuracy or completeness of the Client Data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in this Report are based in whole or part on the Client Data, those conclusions are contingent upon the accuracy and completeness of the Client Data. WSP will not be liable in relation to incorrect conclusions or findings in the Report should any Client Data be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP.

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# 1 Scope

WSP has been engaged by the Waiapu Cathedral of St John the Evangelist to carry out a seismic assessment of the Cathedral building located at 38 Browning Street, Napier, in accordance with the following seismic assessment guidelines (The Guidelines).

- The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments, July 2017, Version 1.

The Guidelines have been produced by New Zealand engineering technical societies in conjunction with the Ministry of Business, Innovation and Employment (MBIE) and the Earthquake Commission. The Guidelines came into force on 1 July 2017 and supersede the previous guidance published in 2006 by the New Zealand Society of Earthquake Engineering (NZSEE).

The scope of work for this Engineering Evaluation includes the following:

- Site inspection of the building.
- Quantitative structural assessment to determine the percentage of New Building Standard (%NBS) of the building based on Importance Level 3 (IL3).
- Concept strengthening scheme if the building is found to be less than 34% NBS (IL3).

# 2 Waiapu Cathedral

The Waiapu Cathedral Building is a multi-structure complex comprising of Chancel, Chapel, Nave, Vestry, Bell Tower and some single storey peripheral buildings constructed in three stages between 1956 and 1960. Figure 1 shows the structures with references within this report.

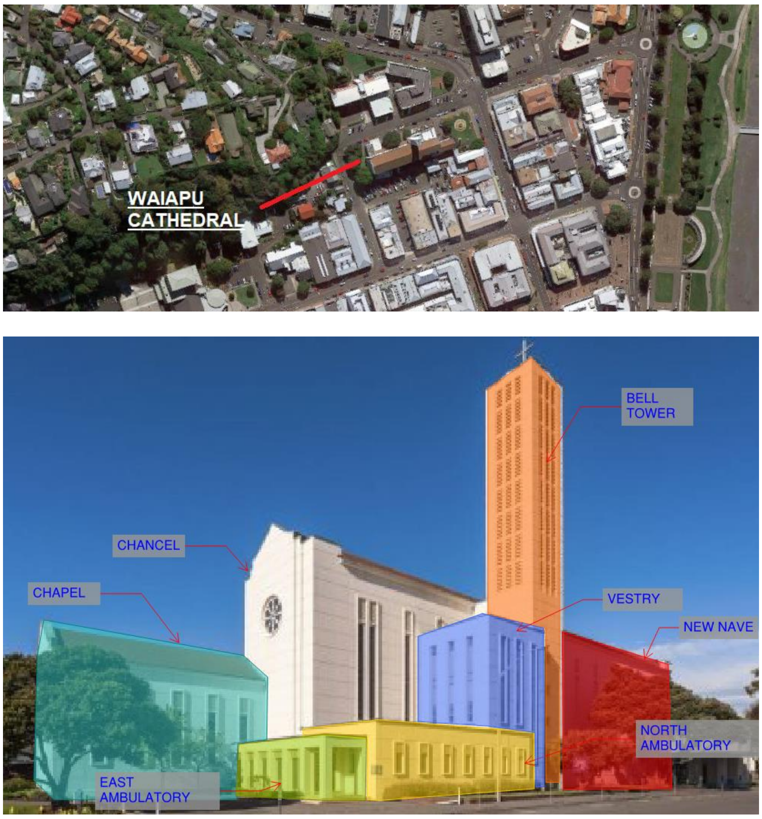


*Figure 1: Structures at Waiapu Cathedral*

## 2.1 Primary Lateral System

The primary vertical and lateral load resisting system in both the longitudinal and the transverse direction of the building is reinforced concrete walls and is supplemented by concrete moment frames in the Nave.

In the longitudinal direction, the lateral loads in the Nave, Vestry, Chapel and the Chancel are resisted by the concrete walls. In the transverse direction lateral loads are primarily resisted by the out of plane bending of walls in the Nave and the Chancel. The reinforced concrete portal frames over the Nave primarily carry gravity loads and partially resist the out of plane deformations of the wall piers.

The Bell Tower is constructed as a wall structure below the Nave roof level and as a moment resisting frame above the Nave roof.

The foundation consists of strip footings of various widths and are typically founded between 0.9m and 1.6m below existing ground level. The typical plan with structural elements are indicated in Figure 2.

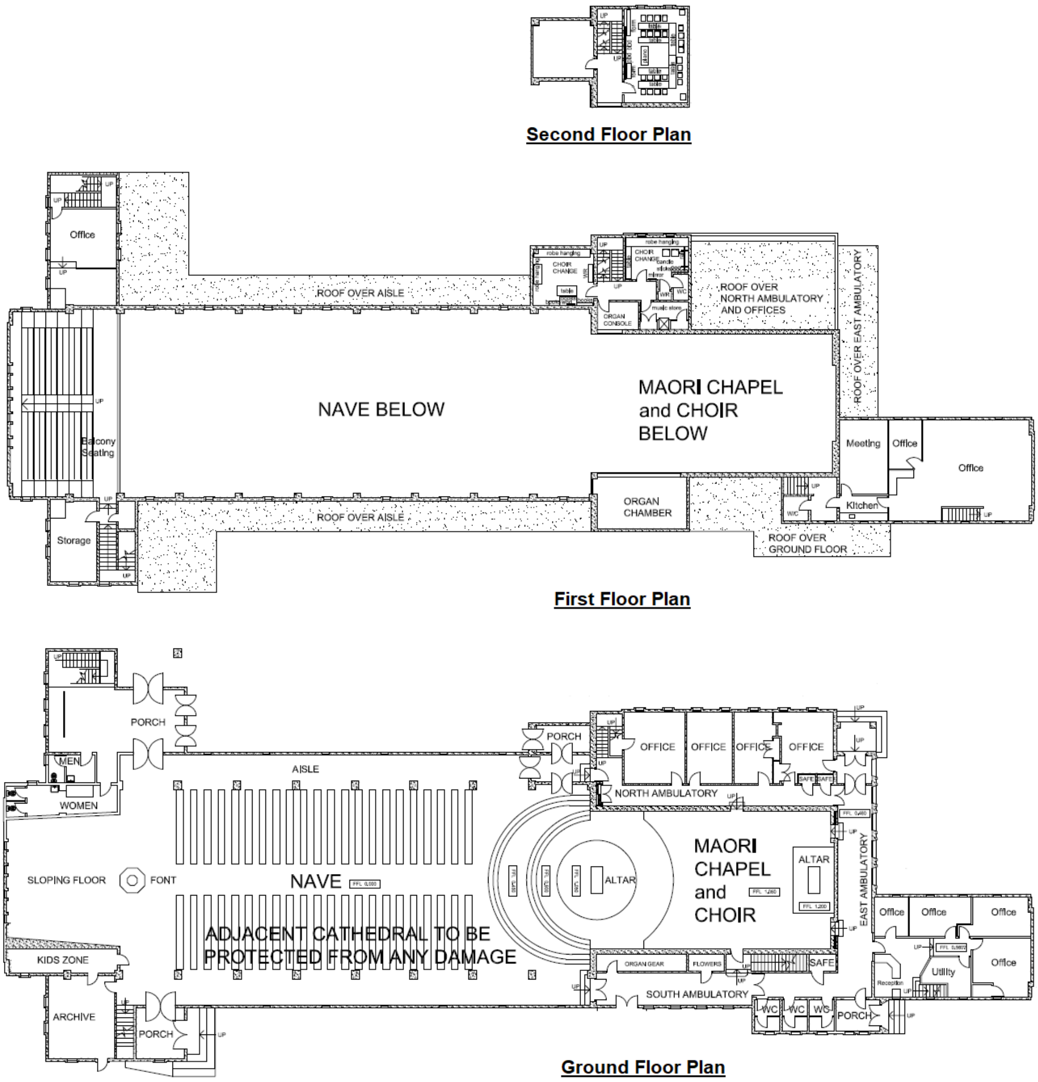


*Figure 2: General Plan of Cathedral*

# 3 Source of Building Data

The following documents were referred for the assessment of the Cathedral.

## 3.1 Drawings

- New Chancel for St. John's Cathedral, Napier – Malcolm and Sweet – 1955
- New Nave for St. John's Cathedral, Napier – Malcolm and Sweet – 1958
- Tower for St. John's Cathedral, Napier – Malcolm and Sweet – 1958
- Stage Three Waiapu Cathedral, Napier – Malcolm and Sweet – 1960

## 3.2 Site Geotechnical Information

The WSP geotechnical engineers conducted the desktop study and have classified the site subsoil as 'Class C' (shallow soil) in accordance with NZS 1170.5 for this DSA. The site dominant period is determined as 0.6 seconds. In the absence of any site-specific geotechnical site investigations, soil parameters for this study have been taken from the following sources:

- Opus letter report 2-S2551.00/14/01 Issue 1 dated December 2014 Geotechnical Investigation, Liquefaction Analysis and Site Subsoil Class Assessment of St John's Cathedral, 28 Browning Street, Napier.
- WSP Geotechnical assessment report 2-S5458.02/03/20 dated April 2020 of the adjacent site of Anglican Diocese of Waiapu, 21 Hastings Street, Napier.

## 3.3 Site Visit

A site visit was conducted by WSP structural engineer in March 2020 to visually determine general conformity to the occupancy and geometry of structure from the available drawings. The inspected areas were found to generally conform to the available drawings. During the inspection a few minor hairline cracks were observed in the walls but no deterioration that would significantly affect the building's structural performance was noted. Cracks were mainly around ground floor window openings of Nave and vertical cracks at the cold joint between Nave and Bell Tower.

*Previous visit on January 2014:*

A visual and limited intrusive inspection was conducted by Opus structural engineer to investigate the detailing of the reinforcing dowel connection between the Chancel and the Bell Tower in 2014. A total of two horizontal bar laps were exposed at the vertical joint between the construction. One bar was lap welded, while the other had a small amount of weld length similar to tack weld.

Findings from the above site visits are summarized in the site visit report in Appendix B.

# 4 Detailed Seismic Assessment

## 4.1 Assessment Criteria

### *4.1.1 General*

The purpose of this assessment is to determine the %NBS rating of the Cathedral Building and assess life safety of the occupants during a major seismic event.

### *4.1.2 Design Life*

The seismic demands have been based on an assumed future lifespan of the facility of 50 years.

### *4.1.3 Importance Level, IL*

The seismic loading specified in the code for building structures is a function of Importance Level (IL) of the structure in accordance with AS/NZS 1170.0:2004.

The Cathedral Building is a public assembly building with an area greater than 1000m2 and therefore is categorised and assessed as an Importance Level 3 (IL3) structure in accordance with Table 3.2 of AS/NZS 1170.0:2004.

### *4.1.4 Material Properties*

The following material properties and parameters were taken for seismic assessment of the structure. In the absence of site-specific data, necessary assumptions were made.

| | |
|---|---|
| • Probable Concrete Strength, $f_c'$ | 20 MPa (as per drawings) x 1.5 = 30MPa |
| • Probable Reinforcement Strength, $f_y$ | 227MPa (based on age of building as per the Guidelines) x 1.08 x 1.15 = 282MPa |
| • Structural Steel, $f_y$ | 232MPa (based on the age of the building as per the Guidelines) |

### *4.1.1 Seismic Loading Spectrum*

The seismic loading spectrum was determined using the parameters below in accordance with NZS 1170.5.

| Parameter | Value | Remarks |
|---|---|---|
| • Site sub-soil class | C | Based on local conditions at site |
| • Site Hazard Factor 'Z' | 0.38 | Minimum hazard factor for Napier |
| • $R_u$ (ULS) | 1.3 | Importance Level 3 |
| • N (T,D) | 1.0 | Near fault factor |

## 4.2 Assessment Methodology

A force-based analysis approach was adopted using Modal Response Spectrum analysis method, in accordance with Sections C2 and C5 in the Guidelines.

The global response parameters were assessed in terms of the total displacement demands, base shear and the global stability.

The local parameters were assessed in terms of the member flexure and shear demands and the out-of-plane bending. The structures were also assessed for any severe structural weaknesses.

## 4.3 Analytical Modelling

The 3D model of the Cathedral was created using ETABS v18. The wall piers and slabs were modelled as area elements, whereas columns, beams and spandrels were modelled using line elements. The foundation is modelled as rigid elastic for the main cathedral. Equivalent static and response spectrum cases were defined for analysis.

A separate analysis of the Bell Tower was conducted for two scenarios; one with the Tower and the Nave as integral elements, and another with the Tower as a standalone structure after losing the connection to the Chancel walls.

The tower foundations were modelled as area elements with compression-only *Winkler's* springs. The non-linear static analysis cases were defined for this analysis to incorporate the soil springs.

## 4.4 Limitations and Assumptions

The following are the limitations and assumptions made during the assessment.

a. Our assessment is based on the structure being in 'as new' condition, without taking in to account any damage or deterioration to the elements.

b. The opinions in this document are based on the conditions and information available at the time the document was published and assume that the structure was built as per the materials, reinforcement sizes, etc. shown on the drawings available to us.

c. The assessment does not cover any non-structural components and fit-out within the building.

d. The proposed strengthening is conceptual and limited to the structural elements with less than 33%NBS (IL3) rating.

e. The deterioration and existing damage to the structural members, if any, is not taken in to account in the DSA and strengthening. Repair of damaged structural members, if any, would need to be considered as part of the detailed strengthening design.

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## 4.5 Detailed Seismic Assessment Results

Table 1 below summarizes the findings of the DSA and the ratings of the critical members in the Cathedral Building in terms of Percentage New Building Standards (%NBS). The table also gives summary of the limiting factor governing the rating.

*Table 1: %NBS Rating for Assessed Structural Elements*

| Structural Element | %NBS Rating (IL3)<br>ULS (1 in 1000 years RP) | Critical Issues/Remarks |
|---|---|---|
| **Nave 20% NBS (IL3)** | | |
| Perimeter Concrete Walls | 20 %<br>(C.S.W) | Rating is governed by;<br>- In plane capacity of end piers = 20%<br>- Out of plane capacity of internal piers = 25% |
| Concrete Spandrel Beams | 20 % | The rating is governed by bending of spandrel beams at roof level |
| Roof Diaphragm | 40 % | Governed by inadequate diaphragm stiffness |
| Concrete Columns | 80 % | Adequate to carry the imposed demands |
| Aisle Roof as Transfer Diaphragm | 100 % | Adequate to transfer loads from first floor Nave internal walls to the ground floor walls. |
| **Chancel 30% NBS (IL3)** | | |
| Perimeter Concrete Walls | 30 % | Rating is governed by;<br>- Inplane capacity of end piers = 45%<br>- Out of plane capacity of internal piers = 30% |
| Concrete Spandrel Beams at Roof Level | 60 % | The rating is governed by bending of spandrel beams at roof level |
| **Bell Tower 20% NBS (IL3)** | | |
| Concrete Walls | 20 %<br>(S.S.W) | Due to large openings at the Tower base, the walls are subjected to high axial load ratio and lack sufficient confinement reinforcement increasing the likelihood of non-ductile axial-shear failure and loss of gravity load carrying capacity. |
| Connection to Chancel | 20 % | Insufficient capacity of dowel connections provided between Chancel and the bell tower |

C.S.W = Critical Structural Weakness | S.S.W = Severe Structural Weakness

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*Table 1 Continued: %NBS Ratings for Assessed Structural Elements*

| Structural Element | %NBS Rating (IL3) ULS (1 in 1000 years RP) | Critical Issues/Remarks |
|---|---|---|
| **Chapel 40% NBS (IL3)** | | |
| Perimeter Concrete Walls | 40 % | Rating is governed by;<br>- In plane capacity of end piers = 64%<br>- Out of plane capacity of internal piers = 40% |
| Concrete Spandrel Beams | 65 % | The rating is governed by minor axis bending of spandrel beams at roof |
| **Vestry 25% NBS (IL3)** | | |
| Perimeter Concrete Walls | 25 % | Rating is governed by out of plane capacity of internal piers |

## 4.6 Structural Weaknesses Identified

The severe structural weakness SSW's identified through the DSA is;

- Bell Tower walls at ground floor are susceptible to axial-shear failure. Due to large openings at the base of the Tower these slender lightly reinforced walls are subjected to high axial loads at the base. The walls lack sufficient confinement reinforcement to prevent non-ductile failure which may result in potential loss of gravity load carrying capacity.

Other critical structural weaknesses CSW's identified includes;

- Inadequate connection between the Bell Tower and the Chancel walls at the cold joint. The provided dowel connection lacks sufficient anchorage and the shear capacity to withstand demands from the Tower overturning.
- Soft storey mechanism in the Bell Tower due to large openings at the bottom storey
- Lack of robust roof diaphragm in the transverse direction over the Nave and the Chancel roof. This results in out of plane bending of slender wall piers and large demands on spandrel beams.
- Insufficient shear capacity of the Nave concrete walls to resist seismic shear forces in the longitudinal direction.

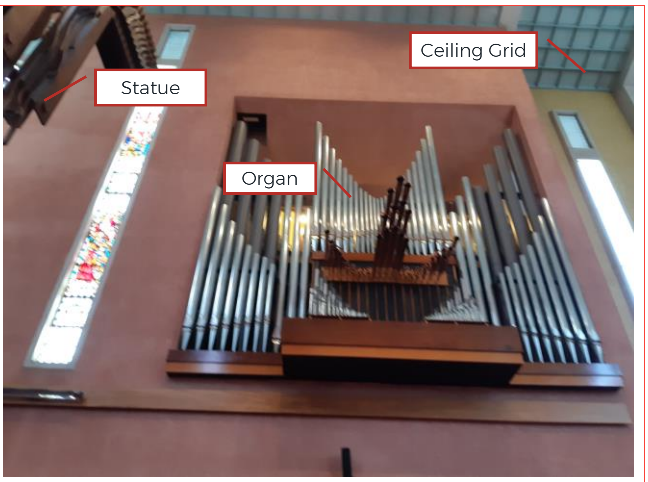
## 4.7 Secondary Risks Identified

The safety of the occupants may be affected if heavy items are not adequately secured and properly restrained. We have not assessed these non-structural items in our DSA, however, we do suggest providing proper restraint to the elements we have identified below and the likes of those.

### *4.7.1 Roofing Tiles*

The roof above the Nave and Chancel is provided with clay tiles that are supported on timber framing. The average height of these tiles is approximately 17m above the Nave floor level. If not properly connected to the roofing grid and the structure framing these heavy clay tiles may displace and could results in life safety issue.

(a) Clay roofing tiles




(b) Miscellaneous non-structural elements

*Figure 3: Non-structural elements*

#### *4.7.2 Ceiling*

Ceiling grids are suspended below the sloped roofs beams in the Chancel and Chapel. Ceiling grids are suspended between the sloped beams in the Nave. The ceiling grid is constructed of timber framing and lacks seismic restraint to the structural roof beams.

#### *4.7.3 Organs and Statues*

There are several elements including organs and statues around the cathedral building placed at heights and the restraints of these elements would require proper assessment.

#### *4.7.4 Cross*

There is limited information available on the details of the connection between the base of the cross and the tower roof slab.

# 5 Conclusion

The Waiapu Cathedral building has a rating of less than <34% NBS (IL3), with the overall building rating limited by the Structural weaknesses of the Bell Tower and Nave to 20% NBS (IL3).

A building with an earthquake rating less than 34%NBS fulfils one of the requirements for the Territorial Authority to consider it to be an Earthquake-Prone Building (EPB) in terms of the Building Act 2004, and a building rating less than 67 %NBS is considered as an Earthquake Risk Building (ERB) by the New Zealand Society for Earthquake Engineering.

The strength and stiffness of reinforced concrete buildings generally do not degrade as rapidly as Un-Reinforced Masonry (URM) buildings do with an increasing number of cycles and prolonged duration of ground shaking. Unrestrained elements in reinforced concrete structures are unlikely to degrade, lose strength and topple like unrestrained elements in URM structures. For these reasons it is expected that a reinforced concrete building will generally pose a lesser life safety risk than an URM building of the same rating.

WSP encourages the client to liaise with the Napier City Council after the results of the DSA report have been discussed, to comply with the regulatory expectations and time frames.

Concept strengthening scheme to bring the structure to a minimum of 34% NBS (IL3) is discussed in section 6 of this report.

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# 6 Concept Strengthening

As requested WSP have proposed concept structural strengthening to mitigate the structural weaknesses identified by the report and bring the structure rating up to a rating of greater than 34% NBS (IL3). The objective of strengthening is to improve the seismic performance of structures and elements that are rated less than 34% NBS (IL3) with priority given to addressing the severe (SSW), and structural weaknesses (SW).

## 6.1 Bell Tower

Given the height of Bell Tower, priority should be given to eliminate the severe structural weakness (SSW) and enable the Tower to remain stable after the connection with Chancel walls have deteriorate. The proposed strengthening involves:

(a) closing the large openings in the Bell Tower at the ground floor with new reinforced concrete walls to improve shear strength in the transverse direction and eliminate the soft storey mechanism.
(b) jacketing of the existing walls to minimize the likelihood of axial-shear failure by providing adequate reinforcement content and axial load carrying capacity.
(c) strengthening to the Tower columns above the Nave roof through concrete jacketing or FRP wrapping. This will ensure proper ductile response at the column plastic hinge zones.

## 6.2 Nave, Chancel and Vestry

Improvement in the overall response of the structure and to tackle the structural weaknesses (SW) is the focus of suggested strengthening as follows:

(a) provide steel roof bracing and perimeter struts between the existing concrete beams to improve the roof diaphragm behaviour of Nave.
(b) haunching of the roof beam-ends to improve out-of-plane behaviour of walls.
(c) jacketing of the existing end walls from internal side to improve the shear capacity.

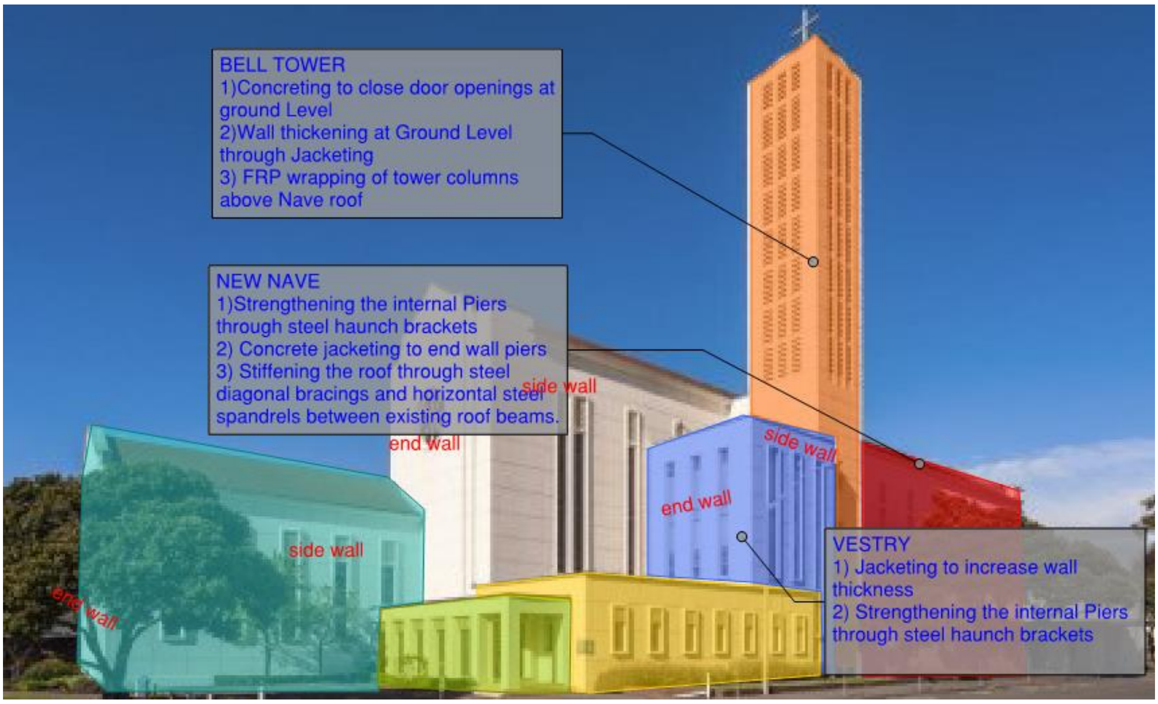


*Figure 4: Summary of proposed strengthening scheme*

# 7 Proposed Alterations

Waiapu Cathedral of St John the Evangelist has indicated they wish to create a new door opening on the north side of the mezzanine balcony, in the Nave. The new opening is to be similar size to the staircase door opening on the south side of the mezzanine balcony.

The rating of the Nave walls is governed by the south side walls. Creating an opening on the north side will result in rating of the north side diminishing to the same rating as the south walls. Therefore, creating the new opening will not diminish the overall rating of the Nave area.

# 8 Next Steps

The proposed strengthening scheme is conceptual only and would require detailed feasibility and analysis prior to commencement of works as follows:

- Architectural design with careful consideration to heritage aspects
- Comprehensive audit and design of restraint for non-structural elements
- Detailed analysis and design of strengthening and documentation for building consent application to the local territorial authority
- Detailed investigation of existing damage and design of repair strategy

WSP will be glad to discuss above steps and assist the client in planning the road map to carry out proposed strengthening works.

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# Appendix A

## Technical Summary Tables

# Appendix B
# Site Visit

## Summary Report

# Appendix C
# Concept Strengthening Scheme

## Illustrative Sketches