Appendix G Stopbank geotechnical assessment

FILE NOTE

DATE 2 April 2025

AUTHOR Ella Boam – Senior Project Manager, Investigations

SUBJECT Waipoua River flood risk management - geotechnical report addendum

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Purpose

This file note acts as an addendum to the 'Stage 2 Report - Stopbanks Assessment, Waipoua River Stopbanks, Masterton' report that was prepared by ENGEO in October 2024. This note contextualises the conclusions presented in the report and highlights key points made in the Stage 1 Report – Preliminary Desktop Review, Waipoua River Stopbanks, Masterton, which was prepared by ENGEO in May 2024.

This note should be read in conjunction with both 'Stage 1 Report – Preliminary Desktop Review, Waipoua River Stopbanks, Masterton' (May 2024) and 'Stage 2 Report - Stopbanks Assessment, Waipoua River Stopbanks, Masterton' report (October 2024).

Background

ENGEO was engaged by Greater Wellington to undertake an assessment of the stopbanks along the urban reach of the Waipoua River through Masterton. The initial task was a review of available information and a site walkover (Stage 1). This was then followed by intrusive site investigations and geotechnical assessment (Stage 2).

Stage 1

The purpose of Stage 1 was to highlight concerns with the existing stopbank network. This was done using existing information and observations from a site walkover. Key points identified in the Stage 1 report are:

- The stopbank material was found to be largely strong/stiff and non-homogenous, consisting of a mixture of clay, silt, sand and gravel. It is likely that the stopbanks were built up multiple times with various materials. Tests indicate areas with a high content of cobbles and boulders have high permeability.
- There is a high likelihood of erosion along the river channel in flood flows. The section of stopbanks on the true right bank, from Bentley Street to near the footbridge in Queen Elizabeth Park, is considered the most susceptible to erosion during flood events.
- The cobble mortar facing appears to have been in place for a long time and there are several places where its functionality is compromised due to damage or missing cobbles.

- Several low-lying lengths of stopbank were identified which could create concentrated flows during flooding events.
- Multiple small failures, possibly due to surficial erosion, were observed on both sides of the stopbanks.

ENGEO concluded that the inspected stopbanks do not appear to be designed or constructed to an engineering standard and have been mostly placed out of convenience as a way to dispose of excess fill or rubbish. To inform Stage 2, ENGEO identified areas of the stopbank which could be improved to reduce the flood risk to Masterton, assuming that it was not feasible to replace the whole stopbank network. The areas identified were based on the height of the stopbanks, not structural integrity, seepage performance or ability to resist scour during a flood event.

Stage 2

The Stage 2 report presents the results of intrusive investigations which identified that the stopbank fill material is generally sandy gravels with varying amounts of silt and cobbles, as well as areas of silty sands with alternating silts. Occasional buried topsoil was also identified as well as manmade debris. It is concluded that the composition and competency of the stopbanks are generally consistent along the length of the stopbanks.

Based on the investigation results, remedial works to increase the height of low areas of the stopbank are proposed. A geological model is provided for the upgrades and seepage and stability analysis as well as other geotechnical considerations have been assessed based on this upgraded design. The conclusions presented suggest that the upgraded stopbanks will not fail due to seepage propagating through the stopbanks, internal erosion/piping or toe heaving in a 1% AEP flood event.

The report does not identify risks relating to the existing stopbank network (without being upgraded) with regard to structural integrity, seepage performance or ability to resist scour during a flood event.

Summary

The Stage 2 report suggests that the composition and competency of the stopbanks along the urban reach of the Waipoua River are generally consistent and the assessments presented do not highlight any significant risks of failure during a 1% AEP flood event. However, these conclusions are based on the following:

- The ground conditions are inferred between intrusive investigation locations. The actual conditions between test locations could vary from that assumed. The results of Stage 1 suggest that the stopbanks are likely to have been constructed out of a variety of materials and include zones of fine-grained materials and rubbish.

- The walkover undertaken in Stage 1 identified a number of zones along the stopbank network where existing failures had occurred. Visible deterioration of some sections of the stopbanks was observed.
- The assessment presented is based on the stopbanks being upgraded and is not necessarily reflective of the existing condition of the stopbanks. This includes both the composition and geometry. In Stage 1, it was concluded that the inspected stopbanks do not appear to be designed or constructed to an engineering standard.

It is therefore considered that while the geotechnical assessment identified that portions of the stopbanks are likely to be in adequate condition, there are also other zones of stopbank which have visibly deteriorated and are unlikely to meet current standards. There is uncertainty regarding the competence of the existing stopbanks and performance in a flood event (not just from overtopping failure). Therefore, it is recommended that the integrity of the full length of the stopbank network is evaluated against the assumptions used in this assessment as part of any detailed design works. At this time, it is also recommended that the assumptions relating to the following aspects are reviewed:

- Groundwater levels
- Variability of permeability throughout soil profile
- Site-specific calibration of seismic analysis
- Liquefaction potential for underlying soils
- Compaction requirements
- Traffic loads

ENGEO

GEOLOGY
GEOTECHNICAL
ENVIRONMENTAL
WATER RESOURCES

29 May 2024

Francie Morrow
Greater Wellington Regional Council
100 Cuba Street
Te Aro
Wellington 6011

Dear Francie

Stage 1 Report – Preliminary Desktop Review, Waipoua River Stopbank, Masterton

(Our Reference: 25306.000.001_01)

1 Introduction

ENGEO Ltd was requested by Greater Wellington Regional Council (GWRC) to undertake an initial assessment of the stopbanks along the Waipoua River through the Masterton urban reach. The purpose of this assessment is to highlight areas of the stopbank that provide the greatest risk of failure during a 1% Annual Exceedance Probability (AEP) flood event. This work has been carried out in accordance with our signed agreement dated 24 April 2024.

We have been provided with the following documents from GWRC for our desktop review:

- Concept Investigation Report - Masterton Flood Protection Works, NZ0115003 (Cardno, 2015)
- 2015 Masterton LiDAR: 1m DEM
- March 2022 Aerial: ortho (0.12 m GSD captured by Aeroplane)
- 2013 Stopbank survey
- 2016 and 2021 Cross-section survey
- Historical Cross-section survey
- Waipoua Benchmarks
- Stopbank footprints

2 Scope of Work – Stage 1

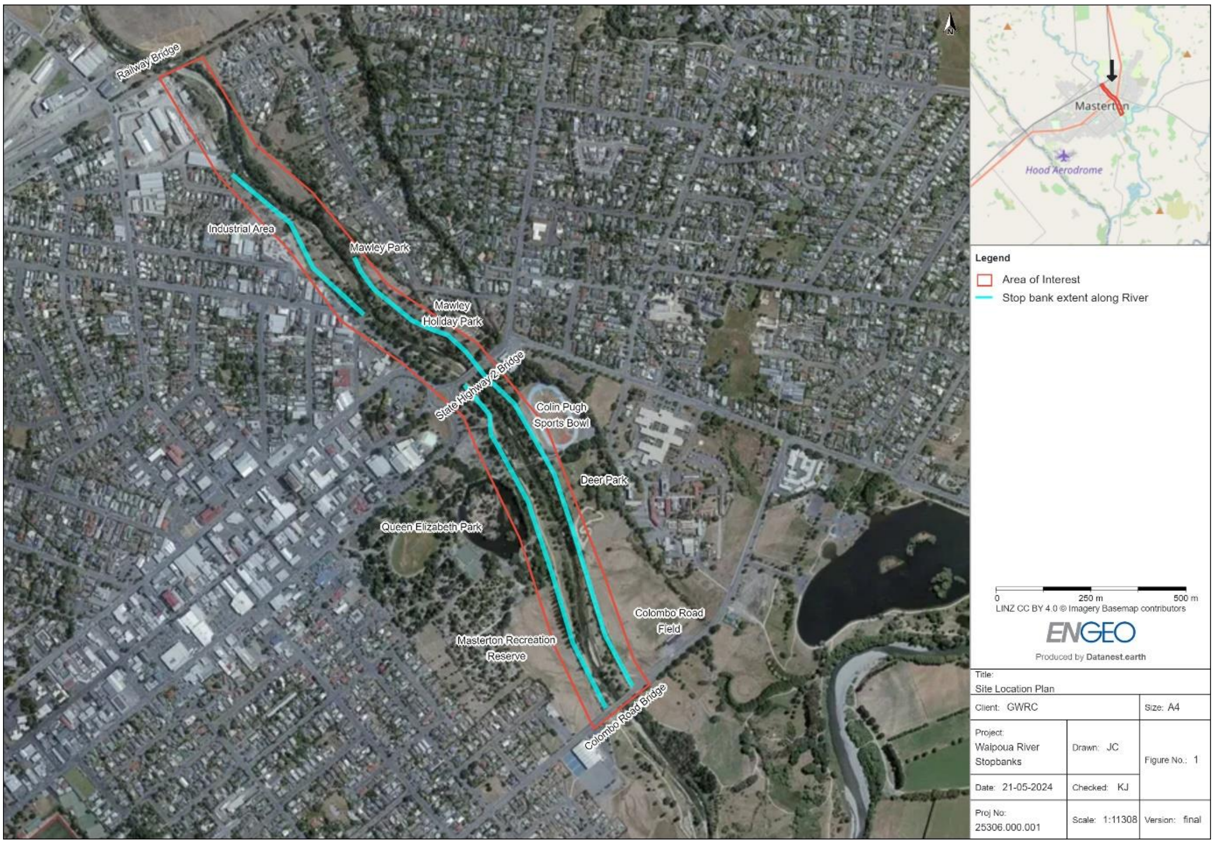
The following scope of work has been undertaken, as outlined in our Request for Proposal Response Form for the Geotechnical Investigations on the Waipoua River Stopbank (ENGEO, 2024).

- Undertake a desktop-based review of that data provided by GWRC including geophysical and flood hazard information.
- Undertake a site assessment paying particular attention to the condition and composition of the stopbank.
- Providing this summary report including recommendations for intrusive testing in Stage 2.

3 Site Description

The Waipoua River flows for 30 km from the Tararua Ranges and passes through the Masterton township. Stopbanks have been constructed to contain the river. Eventually, the Waipoua River joins the Ruamahanga River to the south of Masterton. The area of interest sits between the upstream railway bridge and the downstream Colombo Road bridge, with State Highway 2 bridge crossing in between the two end points. This equates to approximately 2.2 km-stretch of the Waipoua River. The site location plan is shown in Figure 1.

Figure 1: Site Location Plan



We understand that GWRC are proposing to improve the stopbanks to address the 1 in 100 AEP flood event, which is predicted to exceed the capacity of the current channel and stopbanks.

4 Previous Site Investigation

According to the concept investigation report (Cardno, 2015), geophysical and intrusive site investigations were carried out on the stopbanks to assess structural strength and likely failure modes. The investigations consisted of the following:

Geophysical Investigations

A series of Multi-channel Analysis of Surface Waves (MASW) and Ground Penetrating Radar (GPR) lines were surveyed along the Waipoua River stopbanks in February 2015. The geophysical investigation included 2.03 km of MASW survey line and 1.96 km of GPR lines. The survey locations are shown in Figure 2.

Intrusive Site Investigations

Cardno have carried out intrusive site investigations in March 2015 at four locations as shown in Figure 2, consisting of the following:

- Four hand augers / test pits to 0.5 m with accompanying dynamic cone penetrometer
- Four constant head permeability tests in the excavated pits.

Figure 2: Site Investigation Locations (Cardno, 2015)

4.1 Investigation Findings

In general, the stopbank material was found to be non-homogenous. It is likely that the stopbanks were built up multiple times with various materials including cobbles and boulders which are typically highly permeable. This is reflected in the GPR results that showed horizontal and sub-horizontal reflectors indicating changes in material. The non-homogenous layers may potentially cause concentrated zones with high conductivity within the stopbank where impounded water from Waipoua River will flow through the stopbank. Prolonged seepage through the high conductivity zones may cause piping erosion and undermine the stability of the stopbanks.

The GPR survey also showed anomalous areas at the western stopbank near the lake at Queen Elizabeth Park. Based on the hyperbolic diffractions, they are inferred to be either large, buried utilities or tunneling voids. The location of the anomalous area is shown in site investigation plan in Figure 2.

The MASW survey showed that the stopbank generally has high shear wave velocities in excess of 200 m/s with some localized areas with velocities of 150 m/s at Site 1 and Site 4. The shear wave velocities are generally considered to be high and indicates that the majority of the stopbank consists of a reasonably strong / stiff material. Based on the shear wave velocities, the stopbank material is inferred to consist of a mixture of either stiff clay / sand / gravels (Southern Geophysical, 2015).

Based on the investigation logs by Cardno, cobbles with diameter of up to 150 mm were encountered in the stopbank at Site 1, whereas gravelly material was encountered in the stopbank at Site 3 and Site 4. The stopbank at Site 2 consisted of clayey material overlying clayey gravels.

Groundwater and Permeability

Groundwater was not identified or encountered during the investigations, which is not surprising given the limited depth of the investigation. The permeability tests at Site 1 and Site 3 showed very high permeability of the stopbank due to the encountered cobble and gravels, whereas Site 2 and Site 4 showed much lower permeability due to the encountered clayey soil.

5 Flood Model

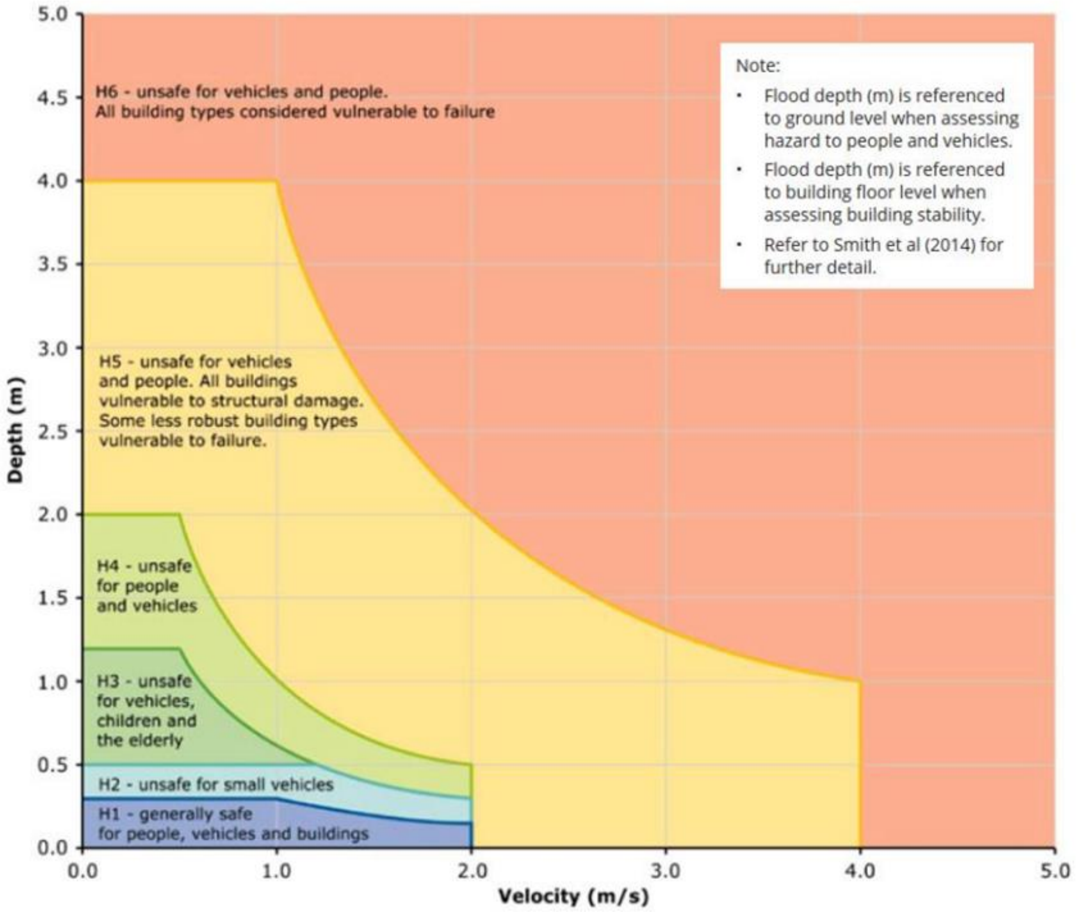
We have received a flood model containing the following information:

- 1% AEP with climate change 2D floodplain model with maximum hazard, inundation, velocity and Water Levels
- 1D channel model with river flood levels and flow velocities for 1% AEP with climate change, 1% AEP and 2% AEP

The models indicate where potential breaches of the stopbank occur and provide flood depths and flow velocities which could indicate where scour and / or eventual failure of the stopbanks could occur.

From the 2D floodplain model, we have determined the hazard level in accordance with the combined flood hazard curve (Smith, Davey, & Cox, 2014) reproduced in Figure 3.

Figure 3: Combined Flood Hazard Curves (Smith, Davey, & Cox, 2014)



A summary of the information from the 2D floodplain model is shown in Table 1. We have also summarized the information from the 1D channel model as shown in Table 2.

Figure 4 shows the location plan containing the flood model interpretations. Generally, the river channel flow velocities are on the high side and erosion of materials ranging from clays to gravels is very likely along the river channel.

Table 1: Summary Table of Information from 2D Floodplain Model

Location	Worst Flood Velocity (m/s)	Approximate Inundation Depths[1] (m)	Hazard Level[2]	Remarks
Mawley Park *Eastern bank, Section 9 – 10*	2.0	2.0 – 3.5	H6	Affected area is largely without permanent dwellings. Some residential dwellings along Oxford Street are affected.
Mawley Holiday Park & Motorhome area *Eastern bank, Section 7 – 9*	2.4	2.0 – 5.0	H6	Residential dwellings along Oxford Street are affected as well.
Colombo Road Field *Eastern bank, Section 3 – 4*	1.1	0.5 – 2.0	Between H3 and H5	Affected area is largely without permanent dwellings.
Masterton Recreation Reserve *Western bank, Section 3 – 4*	1.1	0.5 – 2.0	Between H3 and H5	Affected area is largely without permanent dwellings.
Along Villa Street *Western bank,* *Section 8 – 9*	0.9	< 1.0	Between H1 and H3	Affected area contains industrial and residential dwellings.
Industrial Area *Western bank,* *Section 9 – 10*	0.9	< 1.5	Between H1 and H3	Affected area contains industrial and residential dwellings.

1. Measured from ground level.
2. Hazard level according to Smith, Davey, & Cox, 2014.

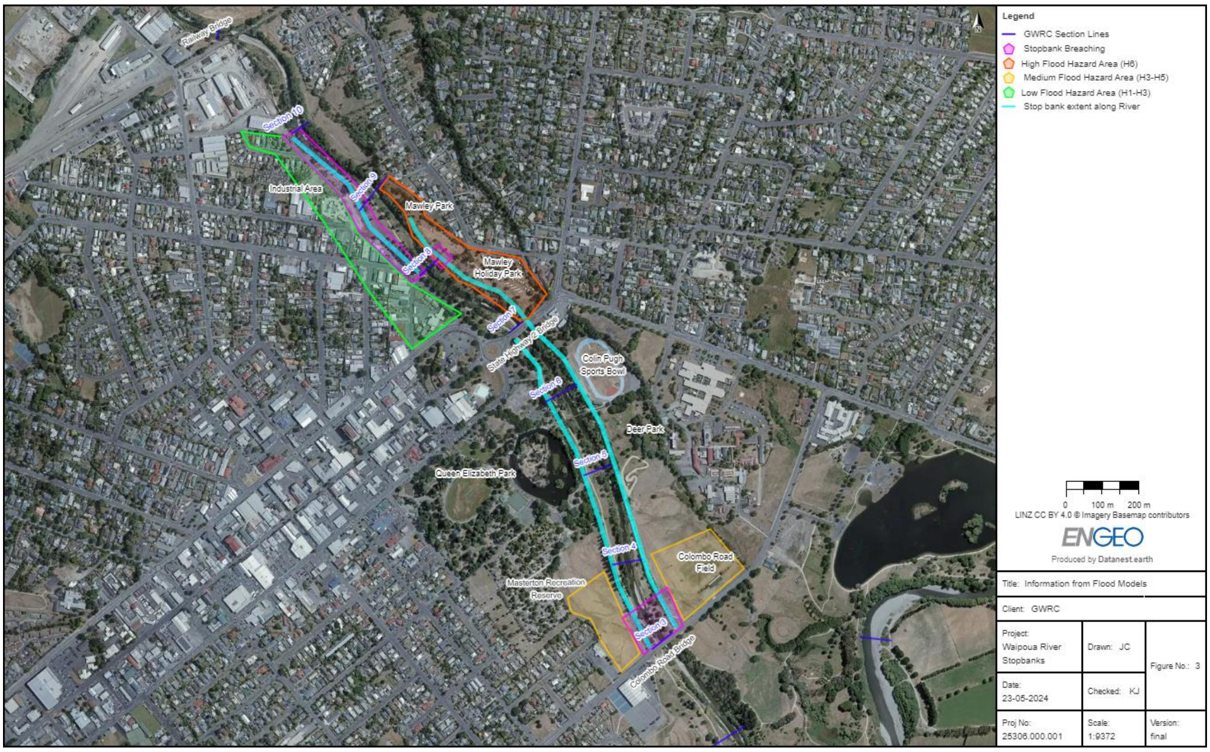
Table 2: Summary Table of Information from 1D Channel Model

Cross Section	Channel Velocity (m/s)[1]	Flood Water level (m)[1, 2]	Western Stopbank Crest Level (m)[3]	Eastern Stopbank Crest Level (m)[3]	Remarks
3 (Colombo Road Bridge)	3.0	113.94	113.61[a]	113.54 [a]	Will breach both western and eastern stopbanks
4	3.4	114.40	115.62[a]	115.24 [a]	
5	2.8	115.52	116.77 [a]	116.61 [a]	
6	3.2	116.60	117.87 [a]	118.26 [a]	
7 (SH2 Bridge)	3.2	118.25	119.30 [a]	118.66 [a]	
8	3.2	119.54	119.40 [a]	119.34 [a]	Will breach both western and eastern stopbanks
9	3.3	120.83	121.23[b]	-	Will breach the western stopbank
10	3.8	121.93	121.70[b]	-	Will breach the western stopbank

1. Flow velocities and water levels are from flood model with 1% AEP Storm considering water level rise due to climate change.
2. Water level in terms of GWRC Wairarapa vertical datum.
3. Stopbank crest level in terms of GWRC Wairarapa vertical datum.

a. Obtained from stopbank survey by Adamson Shaw Surveyors in April 2013. Stopbank crest levels may be updated if more recent survey data is available.
b. Obtained from stopbank survey from Railway Crescent to Bentley Street by Tomlinson & Carruthers Surveyors in 2021. Survey levels are converted from Wellington vertical datum to GWRC Wairarapa vertical datum.

Figure 4: Summary of Information from Flood Models



6 Site Visit on 10 May 2024

A joint site walkover with GWRC and ENGEO was conducted on 10 May 2024 to assess the conditions of the stopbanks. Our observations are summarized as follows:

- We have identified five different configurations of stopbanks which span along the area of interest, shown in Figure 5.
    - Type 1 – Simple vegetated berm without any hard facing. We consider this to be most susceptible to erosion during flood events but with the least difficulty for future improvement / replacement.
    - Type 2 – Embankment with hard cobble mortar facing away from the river.
    - Type 3 – Embankment with hard cobble mortar facing the river.
    - Type 4 – Embankment with footpath at the crest, retained by short cobble mortar (< 0.5 m high) on the side closest to the river.
    - Type 5 – Embankment retained by cobble mortar. We consider this to be the least susceptible to erosion during flood events but with highest difficulty for future improvement / replacement.
- The cobble mortar facing appears to have been in place for a long time and there are several places where its functionality was comprised due to damaged or was missing cobbles.

- Generally, the stopbanks appear to be made of non-homogeneous materials such as sandy silty gravel or some cobbles. In most instances, the stopbank is covered in vegetation and topsoil. Nevertheless, they appear to be in stable condition under normal (static) conditions.
- We have identified several low-lying lengths of stopbank which might create concentrated seepage flows during flooding events.
- Multiple small failures, possibly due to surficial erosion are observed on both sides of the stopbank inconsistently throughout the area of concern.
- There is a potential river pinch point where the river narrows at the point near the motorhome parking area. This may cause increased flow velocity and result in erosion of the riverbank at the pinch point. Discussions with GWRC indicate that these areas have scoured out in previous flood events.
- There is a break in the stopbank that is used as a footpath near the lake in Queen Elizabeth Park.
- Based on discussions with GWRC, we understand that the area beside the holiday park / motorhome area has the greatest risk (Stopbank Type 2). Based on our review of the provided 2D floodplain model, this area has the worst inundation (up to 3.5 m) and water velocities (up to 2.4 m/s).

Figure 5: Stopbank Types and Points of Interest Identified during Site Walkover

To view the photos, please use the provided login to access the ENGEO GIS portal.

7 Conclusions

The previous investigations (Cardno, 2015) showed that the stopbanks were constructed from non-homogenous materials. The stopbanks at Site 1 and Site 3 (Masterton Recreation Reserve and Mawley Park) have very high permeability whereas the stopbanks at Site 2 and Site 4 (Queen Elizabeth Park and Colombo Road Filed) have low permeability. The geophysical surveys (Southern Geophysical, 2015) showed anomalous areas with inferred buried utilities or tunneling voids. Nevertheless, the MASW survey results indicate that the majority of the stopbanks consist of reasonably strong / stiff material.

ENGEO has reviewed the provided 1D and 2D flood models, and identified several locations where the flood water level is very likely to breach the stopbanks at their current level. We have also determined the flood hazard levels based on the flood model inundation and velocities.

A joint site walkover attended by GWRC and ENGEO was conducted on 10 May 2024. ENGEO have identified five different configurations of stopbanks based on their erosion susceptibility and difficulty for future improvement and replacement. Generally, the stopbanks appear to be made of non-homogeneous materials and are in stable condition under normal (static) conditions. We have identified several points of interest including low-lying stopbanks, small failures / erosion areas, a river pinch point and breaks in the stopbank.

8 Discussion and Recommendations

The stopbanks inspected along the length of the Waipoua River do not appear to be designed or constructed to an engineering standard and have been mostly placed out of convenience as a way to dispose of excess fill or rubbish. We understand that removing and replacing the entire stopbank system associated with this project is not likely feasible due to budget constraints. Based on our review of the flood models and available information, we have identified isolated areas of the stopbank, where investment in their performance would achieve the greatest value in terms of flood performance and resilience to the community of Masterton. The areas are summarized in Figure 6 and Table 3.

In determining the areas to target, we have based our assessment on the height of the stopbanks rather than their structural integrity, seepage performance or ability to resist scour during a flood event.

Figure 6: Site Plan Showing Recommended Stage 2 Investigation Areas

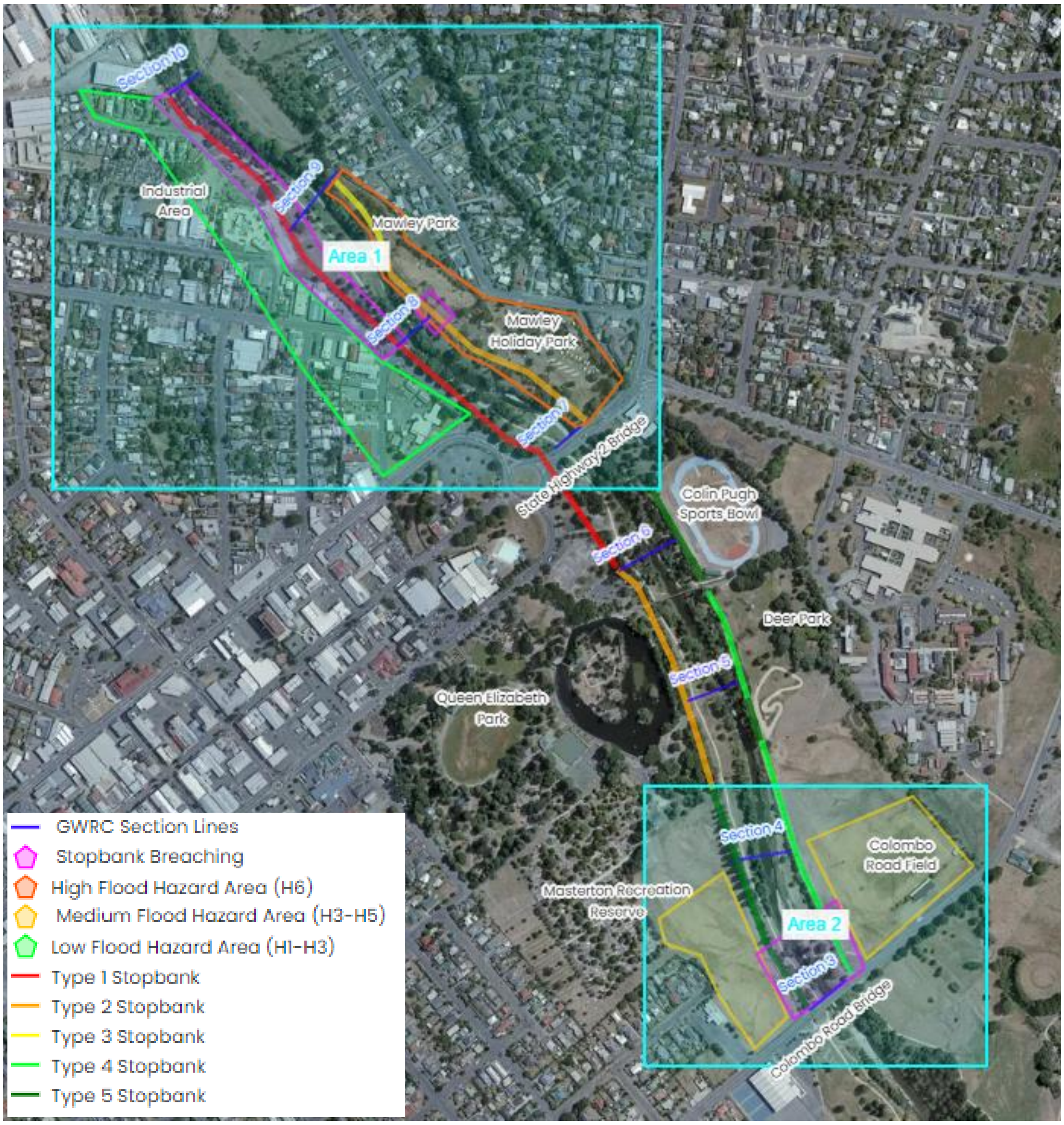


Table 3: Recommendations for Stage 2 Investigation Areas

Location	Affected Stopbank Types / Approximate Lengths	Remarks
Area 1 (North) – Higher Priority	Type 1 / 520 m Type 2 / 410 m Type 3 / 140 m	We recommend Area 1 as the higher priority area due to the flood water level potentially breaching the western stopbanks and flowing into the industrial area, causing public disruptions. There is also a high flood hazard (H6) at the eastern bank of Waipoua which is likely to cause building damage / failure if the stopbanks are breached. In our opinion, it is relatively simple to improve / replace the affected stopbank types.
Area 2 (South) – Lower Priority	Type 4 / 110 m Type 5 / 115 m	We recommend Area 2 as the lower priority area due to lower flood hazards (H1 to H3). In a flood event, we assume that there will be less impact to the community as there is no permanent dwellings in the affected areas. There might be some difficulty in improving / replacing the stopbank types due to the hard cobble mortar facings.

8.1 Investigation Options

Based on our findings, we have decided to revise the originally proposed investigation scope supplied in the RFP. We provide two options for GW to consider as outlined below.

Option 1:

Assuming the existing stopbank material can be reused for improvement, investigations are proposed to be carried out complete with laboratory testing. The investigations will determine the material properties (organic content, particle size distribution, etc.) and provide supporting evidence if the material is suitable to be re-used for improvements or built upon to raise the height of the stopbanks. A series of shallow investigations could consist of either the following:

- Shallow boreholes up to 2 m depth are completed along the stopbank in Area 1. This is to ensure that the stopbanks are kept mostly intact. At this stage, we recommend approximately 10 no. of machine boreholes spaced at 100 m centres along a combined length of approximately 1 km (both the true right and true left side) of the Area 1 stopbank (two days of investigation).

- We would also undertake shallow boreholes along both the true left and true right side of the Waipoua River Stopbanks along Area 2 for a combined approximate length of 230 m. At this stage, we recommend approximately 10 no. machine boreholes spaced at 50 m centres along approximately 230 m length of the true right and true left side of the Area 1 stopbanks (two days of investigation).

Or:

- Test pits along the Area 1 stopbanks. The larger test pit footprints will cause more damage to the stopbanks and more public disruption during the investigation works and require careful placement and re-compaction of the excavated material upon completion. The same extent of test pits will be undertaken as the shallow borehole scope along the true right and true left side of the Waipoua River for a combined length of 1 km (two days of investigation).
- We would also undertake test pits along both the true left and true right side of the Waipoua River Stopbanks along Area 2 for a combined length of 230 m. The same extent of testpits will be undertaken as the shallow borehole scope along the Waipoua River stopbanks (two days of investigation).

Soil samples will be collected from the boreholes or test pits to carry out laboratory tests for determining the material properties.

Option 2:

If the stopbanks in their current form are assumed to be constructed of poor-quality material and are susceptible to erosion / scour / piping in future flood events, then investigations are not required and instead the entire length of stopbank could be fully removed and replaced. No investigations are required to inform this option. Based on our inspections and review of the existing geotechnical investigation data, we think it likely that the stopbanks are constructed of poor-quality material and would fall short of industry recognised standards should they be retained for permanent use as stopbanks.

8.2 Future Work

If Option 1 is selected, ENGEO will provide an itemized fee estimate to undertake the Stage 2 Geotechnical Investigations. This will also include an assessment of the stability of the stopbanks and their performance under flood conditions (i.e. seepage analysis), as outlined in the RFP submission.

If Option 2 is selected, ENGEO will provide the required stopbank heights for Areas 1 and 2 to prevent overtopping to GWRC. ENGEO would then recommend that GWRC engage their hydraulic modelers to rerun the flood model to check if the proposed stopbank levels increase will reduce flooding extents. ENGEO would then recommend that GWRC engage their hydraulic modelers to rerun the flood model to check if the proposed stopbank height increase will reduce flooding extents. Further iteration of the stopbank heights may be required until the stopbanks achieve sufficient performance.

9 References

Cardno (NZ) Ltd. (2015). *Concept Investigation Report – Masterton Flood Protection Works.*

ENGEO. (2024). *Request for Proposal (RFP) for Geotechnical Investigations on the Waipoua River Stopbank – Part 2 – Response Form.*

NZSOLD. (2023). *New Zealand Dam Safety Guidelines.* ISBN: 978-0-473-69764-8: New Zealand Society of Large Dams.

Smith, G. P., Davey, E. K., & Cox, R. J. (2014). *Flood Hazard. WRL Technical Report 2014/07.*

Southern Geophysical Ltd. (2015). *Geophysical Investigation: Waipoua Stopbanks, Masterton – Final Report.*

10 Limitations

i. We have prepared this report in accordance with the brief as provided. This report has been prepared for the use of our client, Greater Wellington Regional Council and their professional advisers, in relation to the specified project brief described in this report. No liability is accepted for the use of any part of the report for any other purpose or by any other person or entity.

ii. The recommendations in this report are based on the ground conditions indicated from published sources, site assessments and subsurface investigations by others described in this report based on accepted normal methods of site investigations. ENGEO cannot guarantee the correctness of such 3rd party results. Only a limited amount of information has been collected to meet the specific financial and technical requirements of the Client's brief and this report does not purport to completely describe all the site characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgement and it should be appreciated that actual conditions could vary.

iii. This Limitation should be read in conjunction with the Engineering NZ / ACENZ Standard Terms of Engagement.

iv. This report is not to be reproduced either wholly or in part without our prior written permission.

We trust that this information meets your current requirements. Please do not hesitate to contact the undersigned on (04) 472 0820 if you require any further information.

Report prepared by

Josh Cheah
Geotechnical Engineer

Mathew Crighton

Engineering Geologist

Report reviewed by

Karen Jones, CEnvP, CMEngNZ (PEngGeol)
Principal Engineering Geologist

Mark Broughton, CMEngNZ (CPEng), RecEng DSAP, RecEng PIC
Associate Geotechnical Engineer

ENGEO Limited
Plimmer Towers, Level 18, 2-6 Gilmer Terrace, Wellington 6011
PO Box 25 047, Wellington 6140
T: +64 4 472 0820
www.engeo.co.nz

Project Number 25306.000.001

Stage 2 Report - Stopbanks Assessment

Waipoua River Stopbanks, Masterton

Submitted to:
Greater Wellington Regional Council
100 Cuba Street
Te Aro
Wellington 6011

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ENGEO Document Control:

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Executive Summary

ENGEO Ltd was requested by the Greater Wellington Regional Council (GWRC) to undertake geotechnical investigations and an assessment of the Waipoua river stopbanks. The following table provides a summary of the report findings.

Item	Finding	Section
Basis of Design	We have based the stopbank assessment criteria in accordance with the Fundamental Dam Safety Objective stated in the New Zealand Dam Safety Guidelines (NZSOLD, 2023). (MBIE, 2024).	3
Seismic Performance Criteria	We have considered the seismic performance criteria for the Waipoua Stopbank as defined in the New Zealand Dam Safety Guidelines (NZSOLD, 2023): • OBE – the dam and appurtenant structures remain functional and that the resulting damage is minor and easily repairable. • SEE – there is no uncontrolled release of the impounded contents when the dam is subjected to the seismic load imposed by the SEE. Damage to the structure may have occurred.	4.3.1
Site Investigation	Geotechnical investigations revealed that the existing stopbanks are relatively consistent in composition, consisting of sandy / silty gravels. The underlying natural alluvium material consists of medium dense to very dense sandy gravels. The existing stopbank fill material appears to be sourced from similar material as the underlying natural alluvium. We have checked our findings against the previous geophysical investigation (Cardno, 2015) and we are unable to identify and / or confirm the anomalous / low strength material encountered in the geophysical investigations. This implies that the composition and competency of the stopbanks are generally consistent along the site length.	5
Engineering Geological Model	We have presented a generalized geological profile and three geological cross sections, based on our investigation findings.	6
Proposed Stopbank Remedial Solution	In order to meet the design requirements of preventing overtopping and flooding during a 1% AEP (100-year Average Recurrence Interval) storm event, we propose to raise the existing stopbanks to a height of 1.0 m above the flood levels (i.e. achieve 1.0 m freeboard). This equates to raising the existing stopbanks by a maximum height of approximately 2.0 m. We have provided a nominal detail of the stopbank raising, which includes keying a new section of site won silty gravel into the existing stopbank. The solution above meets the design intent and does not compromise the existing performance of the stopbank. However, additional considerations should be made on the relocation of existing footpaths as well as the interaction of the raised stopbanks with the existing bridge approaches over the Waipoua River.	7

Item	Finding	Section
Seepage Analysis	For a 1% AEP+CC flood event, the water level retained behind the stopbanks does not occur for a sustained period such that seepage water can pass through the embankment and saturate the downstream (landward) toe. With no seepage flows able to propagate through the stopbanks, internal erosion/piping or toe heaving cannot occur.	8
Stability Analysis	Adequate factors of safety are achieved for all load cases with the exception of the seismic OBE and seismic SEE cases, where localized shallow instability is predicted in the stopbank downstream face. The amount of lateral displacement was assessed using Newmark displacement regression equations (Jibson, 2007) to be less than 70 mm in Section A-A, and less than 22 mm for the remaining sections. The shallow slope failures predicted and magnitude of expected displacement is considered to comply with the requirements of New Zealand Dam Safety Guidelines (NZSOLD, 2023) where minor deformations are acceptable provided there is no uncontrolled release of the water stored behind it.	9
Liquefaction and Lateral Spreading	The area surrounding Waipoua River has a low liquefaction potential (GWRC, 2019). The stopbanks and natural alluvium generally consists of dense gravels with the occasional thin layers of silt which are not considered likely to liquefy. With groundwater typically located approximately 4 m below the toe of the stopbank, there is ample crust thickness (i.e. non liquefiable soils) beneath the stopbank to mask the damaging effects of liquefaction should it occur in soils at depth. Liquefaction and lateral spreading of the stopbank is not likely to occur at the site.	10.1
Other Geotechnical Considerations	We estimate that less than 10 mm of static settlement could occur due to raising the existing stopbanks up to 2.0 m vertically. We consider that the existing stopbank material (silty gravel) has sufficient bearing strength to receive the additional stopbank fill. There is little to no risk of internal erosion occurring in the moderately to slightly dispersive stopbank materials identified due to our analysis showing no seepage passing through the downstream (landward) toe. Precautions can be used to limit this occurrence which can be investigated further during detailed design.	10.2 & 10.4
Recommendations for Raising Stopbanks	Site-won silty gravel materials can be used as backfill for the stopbank raising, however it shall meet the engineering properties stated in Table 15. We recommend that a topographical survey is carried out along the stopbanks to be raised to obtain the up-to-date stopbank crest levels. This is to confirm the required stopbank raising height and extents. As a preliminary estimate, a total length of up to 1,200 m of stopbank raising is required.	11

This table is not intended to exhaustively summarize our geotechnical assessment and findings. Accordingly, this report must be read and understood in full.

1 Introduction

ENGEO Ltd (ENGEO) was requested by Greater Wellington Regional Council (GWRC) to undertake geotechnical investigations and assessment of the Waipoua river stopbanks (Stage 2) between Lincoln Road and Colombo Road. This work has been carried out in accordance with our signed agreement dated 5 August 2024.

ENGEO have previously issued our Stage 1 Preliminary Desktop Review report (ENGEO, 2024). In the report, critical areas of the stopbank were identified where there is a high flood hazard, or where overtopping of the stopbanks is expected to occur during a 1% AEP flood. This report is to be read in conjunction with the Stage 1 report.

Findings from Stage 1 were presented by ENGEO to the Waipoua Project Team on 18 June 2024, where it was agreed to proceed with geotechnical investigations and laboratory testing to characterise the composition and engineering properties of the existing stopbanks and underlying geology. The intention of the investigations was to inform seepage and slope stability models which would be used to evaluate the competency of the existing stopbank and develop a solution to meet the required performance standards for a 1% AEP (100-year Average Recurrence Interval) storm event.

Our scope of works for Stage 2 included the following:

- Coordinate and engage Griffiths Drilling to undertake 10 boreholes at the critical areas of the stopbanks.
- Collect borehole samples and conduct laboratory tests.
- Review the borehole logs and laboratory test results to determine engineering properties of the stopbank material and underlying soils.
- Develop geological cross sections through the stopbanks and use these to undertake stability and seepage analysis at three representative locations through the stopbank.
- Determine the competency of existing stopbanks and develop solutions to raise the stopbanks to meet the required performance standards for a 1% AEP (100-year Average Recurrence Interval) storm event.

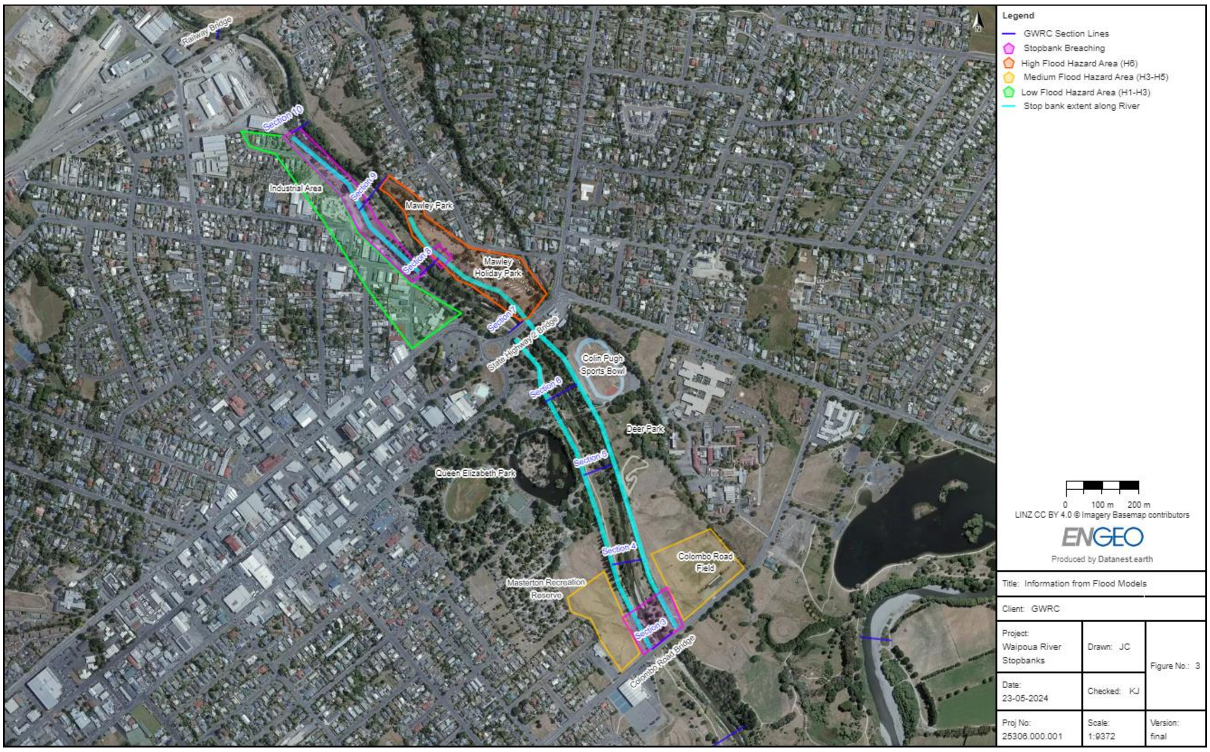
A draft version of this Stage 2 report was issued on 18 June 2024, where feedback was received from Tonkin + Taylor concerning the proposed stopbank raising height (to achieve 1.0 m of freeboard above the flood levels provided in the model) and preferred configuration of the stopbank raising (backfill with locally sourced silty gravel). In addition, we were advised that stopbank batter slopes of 1V:3.5H with a crest width of 4.0 m is preferred for maintenance access. These changes were incorporated into the modelling and adopted for this issue of the report.

2 Site Description

The Waipoua River flows for 30 km from the Tararua Ranges and passes through the Masterton township. Stopbanks have been constructed to contain the river. Eventually, the Waipoua River joins the Ruamahanga River to the south of Masterton. The area of interest sits between the upstream railway bridge and the downstream Colombo Road bridge, with the State Highway 2 bridge crossing in between the two end points.

ENGEO previously identified critical stopbank locations where potential breaches of the stopbank occur, and evaluated their hazard level in the preliminary desktop study (ENGEO, 2024). These areas are shown in the site location plan in Figure 1.

Figure 1: Critical Stopbank Areas (ENGEO, 2024)



3 Basis of Design

As the stopbanks behave similarly to dams, we have based the stopbank assessment criteria in accordance with the New Zealand Dam Safety Guidelines (NZSOLD, 2023). According to the guidelines, the Fundamental Dam Safety Objective is that people, property and the environment, present and future, should be protected from the harmful effects of a dam failure or an uncontrolled release of the reservoir contents. This report sets out the geotechnical performance criteria and analysis undertaken to inform the basis of design and comply with the above objective.

4 Desktop Study

4.1 Topography

Based on the provided LiDAR Digital Elevation Model produced by AAM in 2016, the area of interest consists of a relatively flat river plain sloping gently from North to South. The vertical elevation ranges from approximately 102 mRL at the southern side to 114 mRL to the northern side (Wellington Vertical Datum 1953).

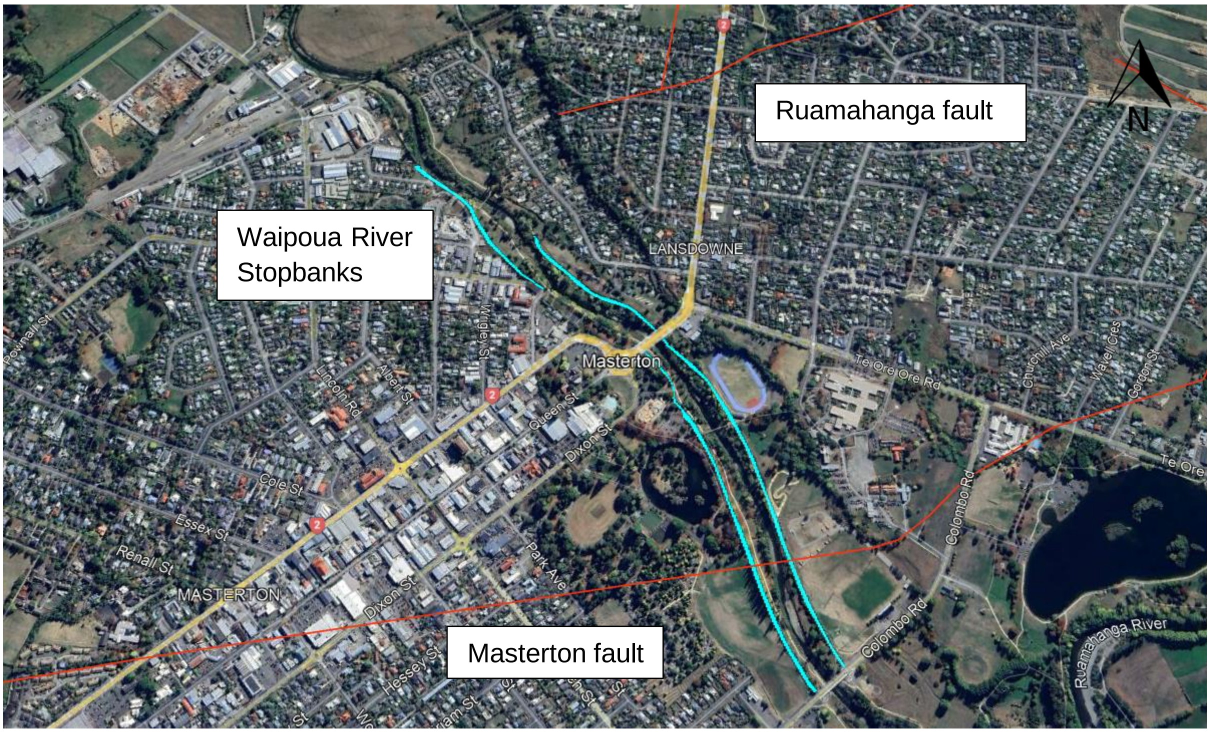
4.2 Geology and Geomorphology

We refer to the published Geological Map of New Zealand 1:250 000 (Heron, 2023) which indicates that the site is primarily underlain by Holocene River deposits described as loose gravel, sand, silt and clay in modern flood plains and low terraces.

4.3 Seismicity

The GNS Science New Zealand Active Faults Database website indicates that the Masterton fault crosses the Waipoua river at southern portion of the site. The Ruamahanga fault lies approximately 300 m northeast of the Waipoua river. The fault locations are shown in Figure 2.

Figure 2: Active Faults in Proximity to the Site



4.3.1 Seismic Performance Criteria

We have considered the seismic performance criteria for the Operating Basis Earthquake (OBE) and Safety Evaluation Earthquake (SEE) as defined in the New Zealand Dam Safety Guidelines (NZSOLD, 2023). The performance requirement as outlined in the guidelines are as follows:

- OBE – the dam and appurtenant structures remain functional and that the resulting damage is minor and easily repairable.
- SEE – there is no uncontrolled release of the impounded contents when the dam is subjected to the seismic load imposed by the SEE. Damage to the structure may have occurred.

Based on Table 1 in Module 3 of the New Zealand Dam Safety Guidelines (NZSOLD, 2023), the recommended performance criteria for earthquake hazard are summarized in Table 1.

Table 1: Recommended Performance Criteria (NZSOLD, 2023)

Hazard	Performance Criteria	Potential Impact Classification		
		Low	Medium	High
Earthquake	Operating Basis Earthquake (OBE)	1 in 150 Annual Exceedance Probability (AEP)		
	Safety Evaluation Earthquake (SEE)	At least 1 in 500 AEP[1]	Not more than 1 in 2,500 AEP[1]	Not more than 1 in 10,000 AEP[1]

1. Assuming SEE parameters developed by a probabilistic approach

We have adopted the following return periods for derivation of the peak ground acceleration used in our analysis:

- OBE – 1 in 150 AEP (150-year return period).
- SEE – 1 in 500 AEP (500-year return period).

4.3.2 Peak Ground Acceleration

We understand the stopbanks are Importance Level 2 (IL2) structures. Peak horizontal ground accelerations (a_{max}) for use in the analyses are provided in Table 2. a_{max} values have been taken from the recommended values from Table A1 for Masterton in the Module 1 guidance document (MBIE, 2021).

Table 2: Peak Horizontal Ground Acceleration

Design Earthquake	Return Period	a_{max}	Magnitude
OBE	150 years	0.34 g*	7.1*
SEE	500 years	0.68 g	7.7

*OBE a_{max} and Magnitude interpolated between 100-year and 250-year return period in Table A1 – Appendix A of MBIE/NZGS Module 1 (MBIE, 2021) for Masterton.

5 Site Investigation

5.1 Investigations Completed

ENGEO attended site between 5 August 2024 and 7 August 2024 to complete the following intrusive testing:

- Ten machine boreholes using sonic drilling techniques, named BH01 to BH10, to depths of up to 4.95 m.
- The boreholes were backfilled with bentonite and topped off with topsoil at the surface to preserve the stopbank vegetation.

The site investigation plan with the engineering borehole logs is shown in Appendix 1.

5.2 Laboratory Testing

We have selected representative borehole samples from both the stopbank fill and the underlying natural alluvium material for geotechnical laboratory testing. The laboratory tests are summarized as follows:

- Three (3) Particle Size Distribution and Hydrometer tests
- Two (2) Triaxial Constant Head Permeability tests
- Two (2) Pinhole Dispersion tests

The laboratory test results are summarized in Table 3 and are provided in Appendix 2.

Table 3: Laboratory Testing Results

Sample Location / Depth	Material Description	Particle Size Distribution				Constant Head Permeability		Pinhole Dispersion
		Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Permeability (m/s)	Final Dry Density (t/m^3)	
BH03 / 0.1 m – 0.4 m	Stopbank fill (Sandy SILT)	-	-	-	-	2.83E^{-09}	1.85	ND4
BH05 / 0.6 m – 1.4 m	Stopbank fill (Sandy GRAVEL with some silt)	43	34	17	6	-	-	-
BH10 / 0.1 m – 0.3 m	Stopbank fill (SILT with some sand and traces of clay)	-	-	-	-	-	-	ND3
BH09 and BH10 Bulk Sample	Stopbank fill (Sandy GRAVEL with minor silt)	70	20	7	3	-	-	-
BH04 / 2.1 m – 2.3 m	Natural alluvium (SILT with minor clay)	-	-	-	-	3.23E^{-10}	1.68	-
BH09 / 1.9 m – 4.5 m	Natural alluvium (Sandy GRAVEL with minor silt)	67	23	7	3	-	-	-

Notes

1. Test results obtained from Geotechnics report ref. 1096389.0000.0.0/Rep1 and 1096389.0000.02.0/Rep1
2. [-] denotes test not assigned
3. BH09 and BH10 bulk sample obtained by combining the stopbank fill borehole cores from BH09 (0.1 m to 2.0 m) and BH10 (0.1 m to 1.95 m)

5.3 Investigation Findings and Engineering Properties

5.3.1 Stopbank Fill Material

The stopbank fill material can be generally described as follows:

- Sandy gravels / gravelly sands with varying amounts of silt and cobbles (encountered in BH01, BH02, BH05, BH07, BH09 and BH10).
- Sandy gravels / silty sands with alternating silts, occasional buried topsoil (encountered in BH03, BH04, BH06 and BH08).

Generally, the fill material in the stopbank appears to be sourced from similar material as the underlying natural alluvium and a soil horizon was not readily observed during the investigations. We have inferred the stopbank fill depth based on the height of the stopbank, changes in SPT-N values and the presence of manmade debris in the borehole cores.

We have also compared our findings with the previous geophysical investigation (Cardno, 2015). In general, we were unable to identify and / or confirm the anomalous / low strength material encountered in the geophysical investigations. This implies that the composition and competency of the stopbanks are generally consistent along the site length.

Constant head permeability and pinhole dispersion tests have been carried out on the silt portion of the stopbank fill. The permeability of the silt portion of the silty gravel stopbank fill material is 2.8×10^{-09} m/s and the material are generally moderately to slightly dispersive (ND3 - ND4).

5.3.2 Natural Alluvium

The natural alluvium generally consists of medium dense to very dense sandy gravels.

Constant head tests have been carried out on the silt portion of the natural alluvium. The permeability of the silt portion is 3.2×10^{-10} m/s.

5.3.3 Groundwater

Groundwater was not encountered during our investigation. We have assumed the groundwater level as described in Section 6.1.

6 Engineering Geological Model

6.1 Groundwater

We have assumed the groundwater is the same as the normal river level based on the initial river level (time = 0) in the 1D flood hydrographs provided by GWRC.

6.2 Generalised Geological Profile

The engineering properties for each material were determined based on the SPT-N values and typical values based on particle size distribution.

The engineering geological model is summarized in Table 4.

Three geological cross sections across the critical stopbank areas, namely Section A-A through Section C-C were produced using the topography obtained from the Masterton LiDAR survey conducted in May 2015 (Wellington Vertical Datum 1958). The cross sections are shown in Appendix 3.

Table 4: Generalised Geological Profile

Unit	Description	Occurrence	Depth Range (m bgl)	Raw SPT N
Stopbank fill	Sandy GRAVELS / gravelly SANDS with varying amounts of silt and cobbles	BH01, BH02, BH05, BH07, BH09, BH10	0.9 – 1.9	N/A
Stopbank fill	Sandy gravels / silty sands with alternating silts, occasional buried topsoil	BH03, BH04, BH06, BH08	0.8 – 1.4	N/A
Natural Alluvium	Sandy GRAVELS, medium dense to very dense	All test locations	0.8 – 4.95+	30 – 50+

6.3 Assumptions and Uncertainties

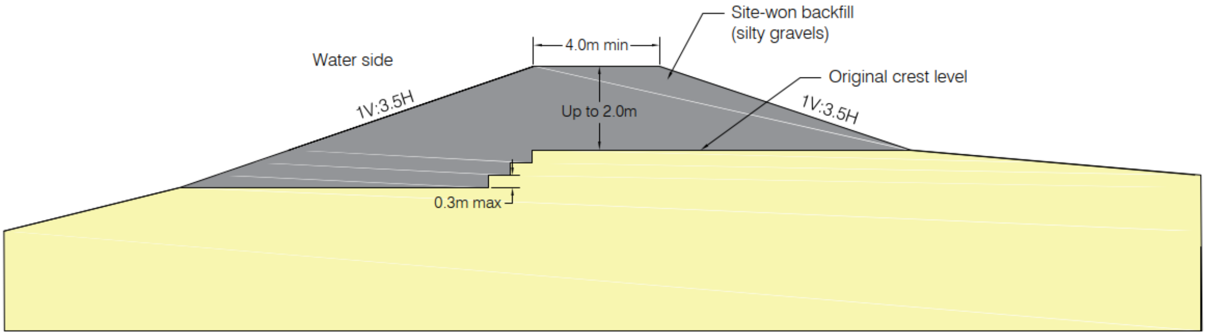
Assumptions made during the production of the engineering geological model are summarized as follows:

- The stopbank fill depth is inferred based on the height of the stopbank, changes in SPT-N values and the presence of manmade debris in the collected borehole cores
- Investigation points and understanding of the geomorphology of the site have been used to interpolate the contact between each unit presented in the ground model.

7 Proposed Stopbank Remedial Solution

The new stopbanks are proposed to be constructed to a height of 1.0 m above the flood levels provided (i.e. to achieve 1.0 m freeboard). As the existing stopbank crest levels vary, the raised height of the stopbank will also vary. A maximum height of approximately 2.0 m was considered. We have included a conceptual stopbank profile as shown in Figure 3, which is based upon the International Levee Handbook (CIRIA, 2013). This stopbank profile has been included in our analysis model for seepage and stability assessment with soil properties as shown in Table 5 and Table 7. The raised stopbank geometries are to be confirmed during detailed design.

Figure 3: Nominal Details for Stopbank Raising



8 Seepage Analysis

8.1 Methodology and Assumptions

To understand the effect of seepage on the embankment stability, seepage analysis was completed on the geological cross sections described in Section 6.2. Analysis was completed using Seep/W module (Geo-Slope International Ltd., 2021a). The material seepage properties adopted in the analysis are shown in Table 5.

Table 5: Soil Properties Adopted in Seepage Analysis

Unit	Material	Hydraulic Conductivity[1], k (m/s)	Coefficient of Compressibility[2], M_v (1/kPa)	Saturated Water Content[3] (m^3/m^3)	Residual Water Content[4] (m^3/m^3)
Existing stopbank fill	GRAVEL with some sand / Sandy GRAVEL	1.0×10^{-03}	1.0×10^{-05}	0.30	0.02
	Sandy GRAVEL / SILTS	1.0×10^{-04}	1.0×10^{-05}	0.35	0.02
Natural alluvium	SILT with minor clay	3.0×10^{-10}	1.0×10^{-04}	0.42	0.10
	Sandy GRAVEL	1.0×10^{-04}	1.0×10^{-05}	0.35	0.02
New stopbank fill[5]	Site won sandy / silty GRAVEL	1.0×10^{-03}	1.0×10^{-05}	0.30	0.02

1. Inferred from typical values based on published literature (Bowles, 1997), Table 2-3 Order of Magnitude for permeability k, based on description of soil and by the Unified Soil Classification System, m/s
2. M_v inferred from typical values based on published literature (Bowles, 1997)
3. Saturated water content taken from typical values from GeoStudio technical manual (Geo-Slope International Ltd, 2012), Figure 4-3 Sample Functions in GeoStudio.
4. Residual water content taken from typical values from GeoStudio technical manual (Geo-Slope International Ltd, 2012) Figure 4-2 Typical storage functions for 3 soil types for Clay, Silt and Sand.
5. We have assumed that the new stopbank fill is to comprise site-won sandy/silty gravel. Thus, we have adopted the same soil properties as the existing stopbank fill.

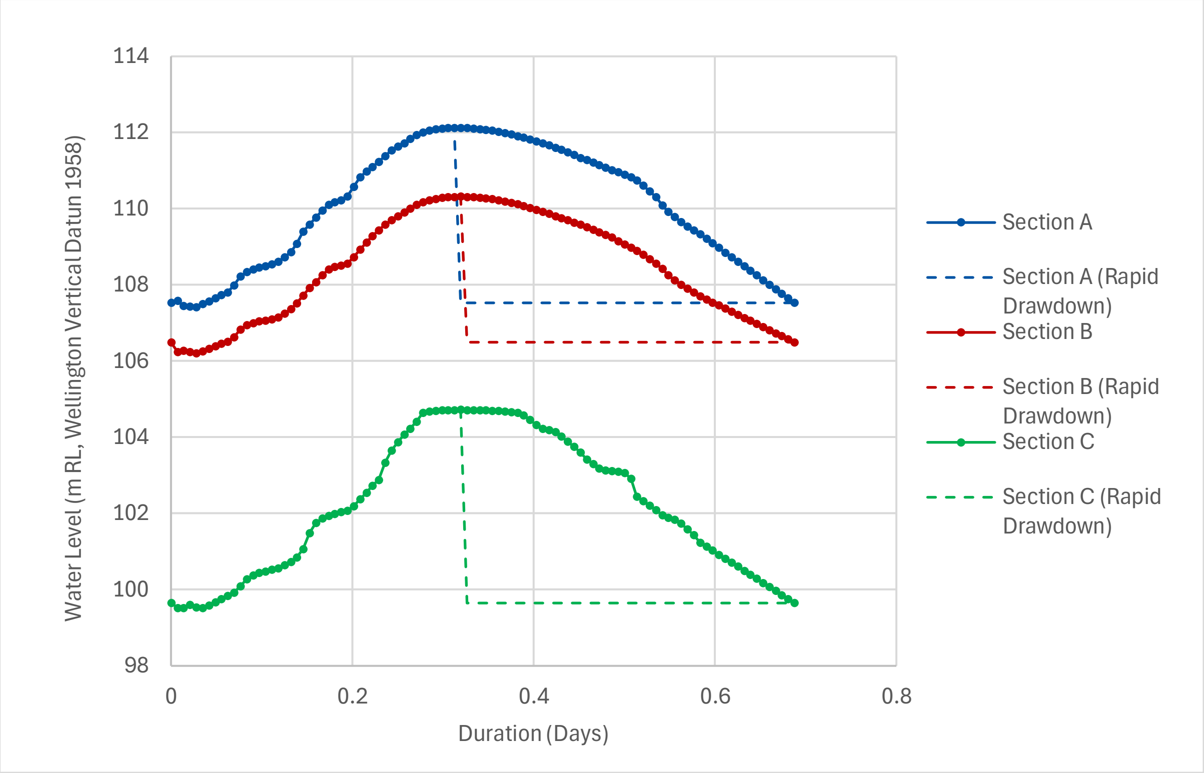
8.2 Flood Hydrograph

The flood hydrographs obtained from GWRC were developed using MIKE-11 one-dimensional hydrologic modelling software for a 1% Annual Exceedance Probability, 14-hour storm event with climate change considerations (1% AEP+CC). Figure 4 shows the flood hydrographs (including the modified hydrograph simulating rapid drawdown) at each cross section.

We have considered the following assumptions:

- The one-dimensional flood level is applicable beyond the Waipoua river channel.
- We have extrapolated beyond the 14-hour hydrograph until the flood level reaches the initial river level (t = 0).

Figure 4: Flood Hydrographs



8.3 Seepage Design Cases

Table 6 provides a description of the design cases considered in the seepage analysis.

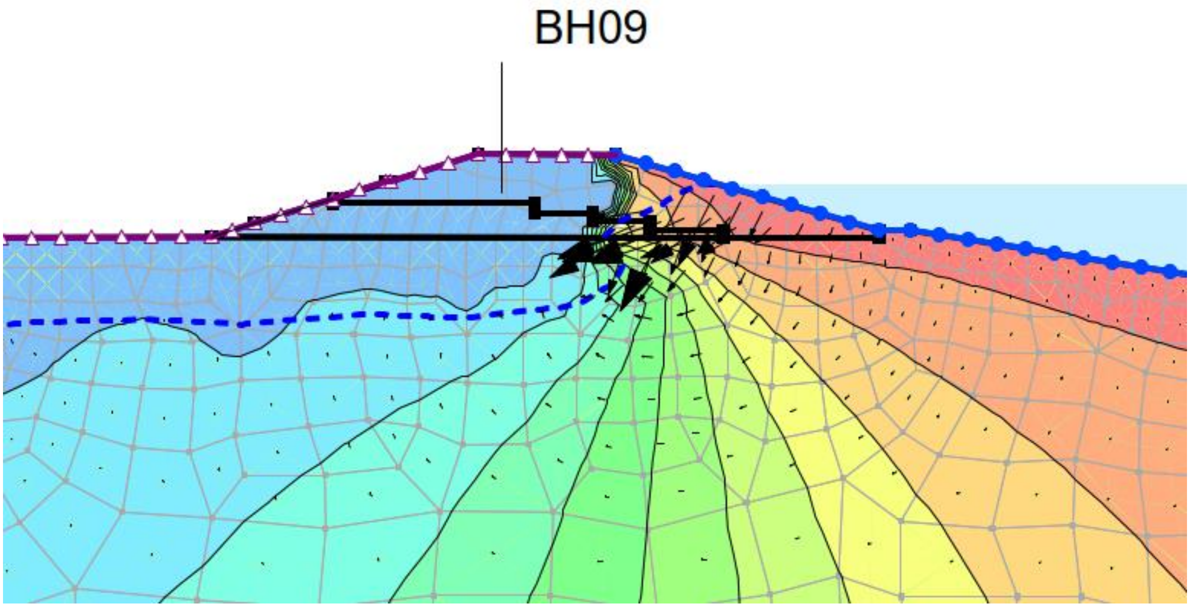
Table 6: Seepage Design Cases

Design Case	Description
1. Normal River Water Level (NWL)	Long term steady state with phreatic level at initial river level (t = 0) in the 1% AEP+CC 1D flood hydrograph.
2. Storm Event	Transient loading with water level increasing from NWL up to maximum level and eventually subsiding as determined by the 1% AEP+CC 1D flood hydrograph.
3. Storm Event with Rapid Drawdown	Transient loading with water level instantaneously dropping from the maximum level achieved during the storm event down to the NWL.

8.4 Analysis Results

Flow net models were developed with seepage evaluated through the raised stopbanks. In the transient loading cases, flow net models are developed for each time step in 0.5-hour increments. Seep/W (Geo-Slope International Ltd., 2021a) model outputs for each design case are included in Appendix 4. An extract from the seepage analysis output for Section C is shown in Figure 5.

Figure 5: Extract of Seepage Analysis Flow Net Model



The flow net model provides information on seepage water flow and hydraulic gradients through the embankment. Seepage flowing out of an embankment, especially at the downstream toe of the embankment meeting level ground may eventually cause internal erosion, piping failure or heaving of the embankment toe.

Based on the seepage analysis outputs for the 1% AEP+CC flood event, the water level retained behind the stopbanks does not occur for a sustained time period such that seepage water can pass through the embankment and saturate the downstream (landward) toe. With no seepage flows able to propagate through the stopbanks, internal erosion/piping or toe heaving cannot occur.

For completeness, we have also carried out a separate analysis case with the flood waters set at the maximum river level to understand the seepage behaviour through the stopbank. In general, the raised stopbank configuration is able to sustain a continuous flood event held at the maximum river level for a period of 24 hours before seepage through the downstream toe occurs.

9 Stability Analysis

9.1 Methodology and Assumptions

Porewater pressures determined in the Seep/W analysis documented in Section 8.4 were carried over into a Slope/W stability analysis. We assessed the same cross sections and seepage design cases described in Section 8.3. Analysis was carried out with Slope/W module (Geo-Slope International Ltd., 2021b) using the methodology developed by Morgenstern-Price.

The stability of the embankment was assessed assuming the following:

- Soil properties as given in Table 7.
- Peak Ground Acceleration as given in Table 2.
- A traffic live load of 5 kPa was applied (static case only) to the stopbank crest to allow for service vehicle access.
- We have not considered the effects of the raised stopbanks on existing footpaths or neighbouring structures such as bridges etc. These should be considered during the detailed design stage.

Table 7: Soil Engineering Properties for Design

Unit	Description	Unit Weight, γ (kN/m^3)	Friction Angle, ø' (degrees)	Drained Cohesion, c' (kPa)	Undrained Shear Strength, Su (kPa)
Existing stopbank Fill	GRAVEL with some sand / Sandy GRAVEL	18	32	0	-
Natural Alluvium	SILT with minor clay	18	28	2	50
	Sandy GRAVEL	18	34	0	-
New stopbank fill	Site won sandy / silty GRAVEL	18	32	0	-

9.2 Stability Design Cases

Porewater pressures generated from the associated seepage analysis model are used in the stability analysis model. Table 8 summarises the design cases considered in the stability assessment, with minimum factors of safety based on the New Zealand Dam Safety Guidelines (NZSOLD, 2023).

Table 8: Stability Design Cases

Design Case	Minimum Factor of Safety	Description	Embankment Face Considered
1. Static Normal River Water Level (NWL)	1.5	Static slope stability with phreatic surface from steady state seepage analysis with the river level at NWL.	Upstream and downstream
2. Static Normal River Water Level (NWL) with traffic surcharge	1.5	Static slope stability with phreatic surface from steady state seepage analysis with the river level at NWL with additional surcharge loads on the stopbank crest.	Upstream and downstream
3. Seismic OBE	1.0	Pseudo-static seismic analysis at the OBE with phreatic surface from steady state seepage analysis with the river level at NWL. Undrained soil parameters are used where applicable.	Upstream and downstream
4. Seismic SEE	1.0	Pseudo-static seismic analysis at the SEE with phreatic surface from steady state seepage analysis with the river level at NWL. Undrained soil parameters are used where applicable.	Upstream and downstream
5. Storm Event	1.2	Static slope stability with phreatic surface from transient loading with 1% AEP+CC storm hydrographs described in Section 8.2.	Upstream and downstream
6. Storm Event with Rapid Drawdown	1.2	Static slope stability with phreatic surface from transient loading with 1% AEP+CC storm hydrographs described in Section 8.2 and water level instantaneously dropping from the maximum level achieved during the storm event down to the NWL.	Upstream

9.3 Analysis Results

Tables 9 through 13 provide a summary of the stability analysis outcomes for each cross section, with detailed plots provided in Appendix 5. Failures towards the upstream and downstream face side of the stopbanks are shown.

The analysis results indicates that adequate factors of safety are achieved for all load cases with the exception of the seismic OBE and seismic SEE cases. During these load cases, localised shallow instability is predicted in the stopbank downstream face.

Under the New Zealand Dam Safety Guidelines (NZSOLD, 2023) a dam must be able to endure the Operating Basis Earthquake (OBE) and Safety Evaluation Earthquake (SEE) without uncontrolled release of the water stored behind it. Damage or lateral displacement of the stopbank is acceptable provided this does not occur.

The yield acceleration (a_{yield}) at which slope instability is predicted (i.e. Factor of Safety = 1.0 achieved) was determined for each seismic case. The lateral displacement was assessed using Newmark displacement regression equations (Jibson, 2007). In general, the predicted mean seismic displacement is less than 70 mm in Section A-A, and less than 22 mm for the remaining sections.

The magnitude of expected displacement is considered to comply with the requirements of New Zealand Dam Safety Guidelines (NZSOLD, 2023) where minor deformations are acceptable provided there is no uncontrolled release of the impounded contents.

We have also carried out a separate analysis case considering shallow local slope failures at both the stopbank face and the riverbank face. It was found that the critical local failures are predicted to occur at the riverbank face, away from the stopbanks which would not impact the ability of the stopbank to retain floodwaters.

Table 9: Stability Results Summary for Section A-A, Western Bank

Design Case	Required FoS	FoS Upstream Face	FoS Downstream Face	Comments
1. Static Normal River Water Level (NWL)	1.5	1.8	2.4	
2. Static Normal River Water Level (NWL) with traffic surcharge	1.5	1.7	2.3	
3. Seismic OBE	1.0	0.9	1.0	a_{yield} = 0.23 g, predicted mean seismic displacement = 5 mm
4. Seismic SEE	1.0	0.5	0.6	Shallow sloughing failure at the downstream face. a_{yield} = 0.23 g, predicted mean seismic displacement = 70 mm
5. Storm Event	1.2	1.5	2.4	
6. Storm Event with Rapid Drawdown	1.2	1.2	-	

Table 10: Stability Results Summary for Section B-B, Western Bank

Design Case	Required FoS	FoS Upstream Face	FoS Downstream Face	Comments
1. Static Normal River Water Level (NWL)	1.5	2.0	2.4	
2. Static Normal River Water Level (NWL) with traffic surcharge	1.5	2.0	2.3	
3. Seismic OBE	1.0	1.0	1.4	
4. Seismic SEE	1.0	0.6	0.6	Shallow sloughing failure at the downstream face. a_{yield} = 0.33 g, predicted mean seismic displacement = 22 mm
5. Storm Event	1.2	1.8	2.4	
6. Storm Event with Rapid Drawdown	1.2	1.8	-	

Table 11: Stability Results Summary for Section B-B, Eastern Bank

Design Case	Required FoS	FoS Upstream Face	FoS Downstream Face	Comments
1. Static Normal River Water Level (NWL)	1.5	2.6	2.5	
2. Static Normal River Water Level (NWL) with traffic surcharge	1.5	2.5	2.4	
3. Seismic OBE	1.0	1.0	1.0	
4. Seismic SEE	1.0	0.6	0.6	Shallow sloughing failure at the downstream face. a_{yield} = 0.37 g, predicted mean seismic displacement = 14 mm
5. Storm Event	1.2	2.3	2.5	
6. Storm Event with Rapid Drawdown	1.2	2.3	-	

Table 12: Stability Results Summary for Section C-C, Western Bank

Design Case	Required FoS	FoS Upstream Face	FoS Downstream Face	Comments
1. Static Normal River Water Level (NWL)	1.5	3.2	2.6	
2. Static Normal River Water Level (NWL) with traffic surcharge	1.5	3.2	2.4	
3. Seismic OBE	1.0	1.1	1.1	
4. Seismic SEE	1.0	0.6	0.7	Shallow sloughing failure at the downstream face. a_{yield} = 0.4 g, predicted mean seismic displacement = 10 mm
5. Storm Event	1.2	2.7	2.6	
6. Storm Event with Rapid Drawdown	1.2	2.2	-	

Table 13: Stability Results Summary for Section C-C, Eastern Bank

Design Case	Required FoS	FoS Upstream Face	FoS Downstream Face	Comments
1. Static Normal River Water Level (NWL)	1.5	2.6	2.3	
2. Static Normal River Water Level (NWL) with traffic surcharge	1.5	2.5	2.2	
3. Seismic OBE	1.0	1.1	1.0	
4. Seismic SEE	1.0	0.7	0.6	Shallow sloughing failure at the downstream face. a_{yield} = 0.37 g, predicted mean seismic displacement = 15 mm
5. Storm Event	1.2	2.1	2.3	
6. Storm Event with Rapid Drawdown	1.2	1.9	-	

10 Geotechnical Considerations

10.1 Liquefaction and Lateral Spreading

According to the Greater Wellington Regional Council Liquefaction Potential Map (GWRC, 2019), the area surrounding Waipoua River has a low liquefaction potential.

The geotechnical investigation showed that the stopbanks and natural alluvium generally consists of dense gravels with the occasional thin layers of silt. In general, dense gravels are not considered likely to liquefy.

Furthermore, with the groundwater typically located approximately 4 m below the toe of the stopbank, there is ample crust thickness (i.e. non liquefiable soils) beneath the stopbank to mask the damaging effects of liquefaction should it occur in soils at depth.

10.2 Static Settlement

We have proposed raising the stopbank heights to accommodate the river flood levels. As a preliminary estimate using the 2016 Masterton LiDAR survey and the provided one-dimensional 1% AEP+CC flood model, we expect that up to 2.0 m of stopbank raising is required. With this increase of stopbank height, we have assessed the total static settlement which may occur as a result.

We have estimated the static settlement using Settle3D Version 2.0 (Rocscience Inc., 2023) using the Westergaard method of stress distribution. The soil properties are derived using published literature (Bowles, 1997) and we have selected the worst-case ground model with the greatest thickness of silt material in our analysis. The settlement parameters adopted for analysis are presented in Table 14. The analysis outputs are presented in Appendix 6.

Table 14: Soil Properties for Static Settlement Analysis

Material	Unit Weight, γ (kN/m^3)	Poisson's Ratio, v (nu)	Constrained Modulus, E_s (kPa)[1]	Coefficient of Compressibility[2], M_v (1/kPa)
Existing stopbank fill: Sandy GRAVEL	18	0.35	135,000	n/a
Natural Alluvium: Sandy SILT	18	0.35	11,200	1.0×10^{-04}
Natural Alluvium: Medium Dense to Very Dense GRAVEL	18	0.35	95,000	n/a

1. E_s calculated from $1/M_v$ referring to published literature (Bowles, 1997)
2. M_v inferred from typical values based on published literature (Bowles, 1997)

Based on our settlement analysis, the expected total static settlement is predicted to be less than 10 mm. As such, we consider that the existing stopbank material has sufficient bearing strength to receive the additional stopbank fill.

10.3 Flooding

The stopbanks have been assessed to detain flood flows up to a 1% AEP event. The seepage analysis results indicated that no seepage is predicted to pass through the stopbanks, and stability analysis results showed that the target FoS is achieved during the storm event and rapid drawdown cases.

10.4 Dispersivity of Soil

The existing stopbank fill is classified as moderately to slightly dispersive (ND3 - ND4). As such, it may be susceptible to piping failure or seepage induced internal erosion along any conduits / culvert passing through the stopbank if high hydraulic gradients are present, for example during sustained floods.

Based on the results of our seepage analysis, we do not predict any toe seepages to occur within the stopbanks. Therefore, there is little to no risk of internal erosion occurring in the moderately to slightly dispersive stopbank materials identified.

During detailed design, a check on the filter compatibility between the existing stopbank material and the material proposed to be used to raise the stopbank should be undertaken.

As an added precaution, a sand filter could be included between the existing stopbank and the new raised section of stopbank to limit any migration of fine soil particles through the stopbank.

We also recommend careful detailing of sand filter diaphragms complete with suitable drains be adopted around any conduits passing through the embankment.

11 Stopbank Raising Recommendations

Site-won silty gravel materials can be used as backfill; however, it shall have engineering properties complying with those stated in Table 15. The raised stopbank should be keyed into the existing stopbank as per the nominal details shown in Figure 3. We recommend that a topographical survey is carried out along the stopbanks to be raised to obtain the up-to-date stopbank crest levels. This is to confirm the required stopbank raising height and extents.

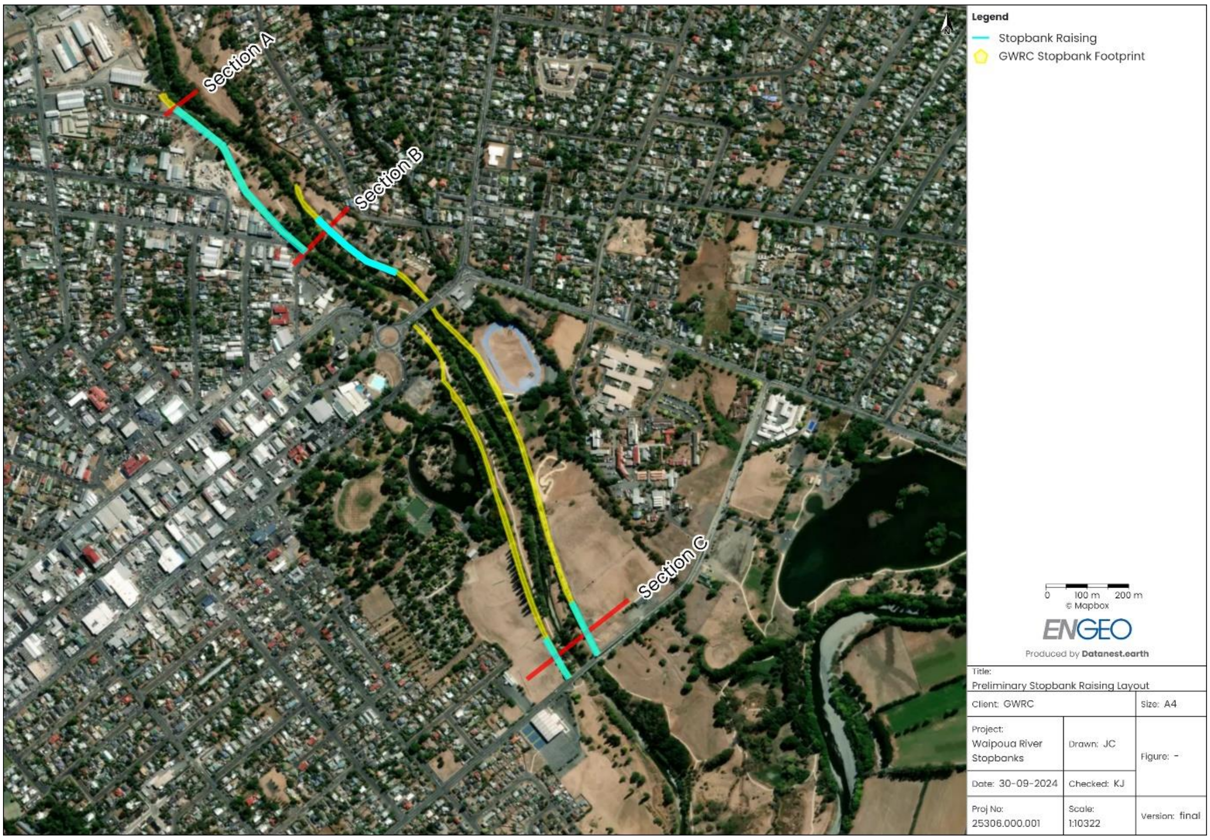
In addition, due to the additional footprint of the stopbanks, considerations should be made on the relocation of existing footpaths as well as the interaction of the raised stopbanks with the existing bridges over the Waipoua River.

Figure 6 shows a preliminary layout of the proposed stopbank raising. As a preliminary estimate using the 2016 Masterton LiDAR survey and the provided one-dimensional 1% AEP+CC flood model, a total length of up to 1,200 m of stopbank raising is required.

Table 15: Soil Engineering Properties for Raised Stopbank Backfill

Material	Hydraulic Conductivity[1], k (m/s)	Coefficient of Compressibility[2], Mv (1/kPa)	Unit Weight, ᵞ (kN/m^3)	Friction Angle, ø' (degrees)	Drained Cohesion, c' (kPa)
Site won sandy / silty GRAVEL	1.0×10^{-03}	1.0×10^{-05}	18	32	0

Figure 6: Preliminary Stopbank Raising Layout



12 Conclusions and Recommendations

ENGEO has been engaged by Greater Wellington Regional Council (GWRC) to undertake geotechnical investigations and an assessment the Waipoua river stopbanks (Stage 2) between Lincoln Road and Colombo Road. The investigations and laboratory tests were used to inform seepage and slope stability models which have been used to evaluate the competency of the existing stopbank and develop a solution to meet the required performance standards for a 1% AEP (100-year Average Recurrence Interval) storm event.

Our findings are summarised as follows:

- Geotechnical investigations revealed that the existing stopbanks are relatively consistent in composition, consisting of sandy / silty gravels. The existing stopbank fill material appears to be sourced from similar material as the underlying natural alluvium. We have referenced our findings with the previous geophysical investigation (Cardno, 2015) and we are unable to identify and / or confirm the anomalous / low strength material encountered in the geophysical investigations. This implies that the composition and competency of the stopbanks are generally consistent along the site length.

- Natural alluvium underlying the stopbank consists of medium dense to very dense sandy gravels.

- Laboratory testing comprising Particle Size Distribution and Hydrometer tests, Triaxial Constant Head Permeability tests, and Pinhole Dispersion tests were undertaken to inform the engineering properties of the stopbank and underlying geology used in our seepage and stability analyses.

- We have obtained from GWRC and included in our analysis flood hydrographs for a 1% Annual Exceedance Probability, 14-hour storm event with climate change considerations for each geological cross section.

- Stopbank performance was assessed against the same criteria used for Dams in accordance with the New Zealand Dam Safety Guidelines (NZSOLD, 2023).

- In order to meet the design water level as indicated by the provided hydraulic models, ENGEO propose an option to raise the height of the stopbanks in critical areas as identified in Figure 1, which includes backfilling with site-won materials with the permeability of at least 1.0×10^{-03} m/s.

- Seepage analysis was undertaken using Seep/W (Geo-Slope International Ltd., 2021a). Based on the seepage analysis outputs for the 1% AEP+CC flood event, the water level retained behind the stopbanks does not occur for a sustained time period such that seepage water can pass through the embankment and saturate the downstream (landward) toe. With no seepage flows able to propagate through the stopbanks, internal erosion / piping or toe heaving cannot occur.

- We carried out a separate analysis case with the flood waters set at the maximum river level to understand the seepage behaviour through the stopbank. In general, the raised stopbank configuration is able to sustain a continuous flood event held at the maximum river level for a period of 24 hours before seepage through the downstream toe occurs.

- Slope stability assessment was undertaken using Slope/W module (Geo-Slope International Ltd., 2021b) using the methodology developed by Morgenstern-Price. Based on the stability analysis outputs, adequate factors of safety are achieved for all load cases with the exception of the seismic OBE and seismic SEE cases. During these load cases, localised shallow instability is predicted in the stopbank downstream face.

- Slope failures predicted during the OBE and SEE seismic load cases were typically characterised by shallow local slope failures at both the stopbank face and the riverbank face. In addition, the amount of lateral displacement was assessed using Newmark displacement regression equations (Jibson, 2007) to be less than 70 mm in Section A-A, and less than 22 mm for the remaining sections. The shallow slope failures predicted and magnitude of expected displacement is considered to comply with the requirements of New Zealand Dam Safety

Guidelines (NZSOLD, 2023) where minor deformations are acceptable provided there is no uncontrolled release of the water stored behind it.

- The area surrounding Waipoua River has a low liquefaction potential (GWRC, 2019). This is further backed up by the results of the geotechnical investigations which indicated that the stopbanks and natural alluvium generally consists of dense gravels with the occasional thin layers of silt which are not considered likely to liquefy. With groundwater typically located approximately 4 m below the toe of the stopbank, there is ample crust thickness (i.e. non liquefiable soils) beneath the stopbank to mask the damaging effects of liquefaction should it occur in soils at depth. Liquefaction and lateral spreading of the stopbank is not likely to occur at the site.

- We have estimated the linear static settlement of the raised stopbanks (estimated to be up to 2.0 m) to be less than 10 mm. As such, we consider that the existing stopbank material has sufficient bearing strength to receive the additional stopbank fill.

- The existing stopbank fill is classified as moderately to slightly dispersive (ND3 - ND4). As such, it may be susceptible to piping failure or seepage induced internal erosion along any conduits / culvert passing through the stopbank if high hydraulic gradients are present, for example during sustained floods. Based on the results of our seepage analysis, we do not predict any toe seepages to occur within the stopbanks. Therefore, there is little to no risk of internal erosion occurring in the moderately to slightly dispersive stopbank materials identified. Precautions can be used to limit this occurrence which can be investigated further during detailed design.

- In order to meet the design requirements of preventing overtopping and flooding during a 1% AEP (100-year Average Recurrence Interval) storm event, we propose to raise the existing stopbanks to a height of 1.0 m above the flood levels (i.e. 1.0 m freeboard). This equates to raising the existing stopbanks by a maximum height of approximately 2.0 m. We have provided a nominal stopbank raising section which includes keying a new section of site won silty gravel into the existing stopbank.

- The solution above meets the design intent and do not compromise the existing performance of the stopbank. However, additional considerations should be made on the relocation of existing footpaths as well as the interaction of the raised stopbanks with the existing bridges over the Waipoua River.

13 Future Work

We anticipate that the following is required during the detailed design stage:

- Filter compatibility check between new / old fill materials proposed at the stopbanks.

- Iterations of the hydraulic flood model with the new stopbank heights.

- Check on the interaction of the stopbank widening with the existing footpaths and walkways along the Waipoua River, including interaction with bridge approaches.

- Detailed design drawings and stopbank specifications package.

14 Limitations

i. We have prepared this report in accordance with the brief as provided. This report has been prepared for the use of our client, Greater Wellington Regional Council, their professional advisers and the relevant Territorial Authorities in relation to the specified project brief described in this report. No liability is accepted for the use of any part of the report for any other purpose or by any other person or entity.

ii. The recommendations in this report are based on the ground conditions indicated from published sources, site assessments and subsurface investigations described in this report based on accepted normal methods of site investigations. Only a limited amount of information has been collected to meet the specific technical requirements of the client's brief and this report does not purport to completely describe all the site characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgement and it should be appreciated that actual conditions could vary from the assumed model.

iii. Subsurface conditions relevant to construction works should be assessed by contractors who can make their own interpretation of the factual data provided. They should perform any additional tests as necessary for their own purposes.

iv. This Limitation should be read in conjunction with the Engineering NZ/ACENZ Standard Terms of Engagement.

v. This report is not to be reproduced either wholly or in part without our prior written permission.

We trust that this information meets your current requirements. Please do not hesitate to contact the undersigned on (04) 472 0820 if you require any further information.

Report prepared by

Josh Cheah

Geotechnical Engineer

Report reviewed by

Mark Broughton, CMEngNZ (CPEng), RecEng DSAP, RecEng PIC

Associate Geotechnical Engineer

Karen Jones, CEnvP, CMEngNZ (PEngGeol)

Principal Engineering Geologist

15 References

Bowles, J. E. (1997). *Foundation Analysis and Design, Fifth Edition.* Singapore: McGraw-Hill Companies, Inc.

Cardno. (2015). *Concept Investigation Report - Masterton Flood Protection Works.* Lower Hutt: Cardno NZ Ltd.

CIRIA. (2013). *The International Levee Handbook.*

ENGEO. (2024). *Stage 1 Report - Prelminary Desktop Review, Waipoua River Stopbank, Masterton.*

Geo-Slope International Ltd. (2012). *Seepage modelling with Seep/W.*

Geo-Slope International Ltd. (2021a). *Seep/W Geostudio 2021.4.* version 11.3.1.23726.

Geo-Slope International Ltd. (2021b). *Slope/W Geostudio 2021.4.* version 11.3.1.23726.

GWRC. (2019, June 13). *Wellington Region Liquefaction Potential.* Retrieved from https://data-gwrc.opendata.arcgis.com/datasets/GWRC::wellington-region-liquefaction-potential/explore

Heron, D. (2023). *Geological Map of New Zealand 1:250 000 (4th ed.) [digital data].* Lower Hutt (NZ): GNS Science.

Jibson, R. W. (2007). Regression models for estimating coseismic landslide displacement. *Engineering Geology 91*, 209-218.

MBIE. (2021). *Building Performance, Earthquake Geotechnical Engineering Practice, Module 1.* Ministry of Business, Innovation and Employment.

MBIE. (2024). *Guide to complying with the Dam Safety Regulations.* Ministry of Business, Innovation and Employment.

NZSOLD. (2023). *New Zealand Dam Safety Guidelines.* ISBN: 978-0-473-69764-8, Wellington: The New Zealand Society of Large Dams.

Rocscience Inc. (2023). *Settle 3D.* version 5.022.

APPENDIX 1:

Site Investigation Plan and Borehole Logs

Legend

⊕ Machine Boreholes

⬠ GWRC Stopbank Footprint

0 100 m 200 m

© Nearmap

ENGEO

Produced by **Datanest.earth**

Title: Site Investigation Plan		
Client: GWRC		Size: A4
Project: Waipoua River Stopbanks	Drawn: JC	Appendix No.: 1
Date: 01-10-2024	Checked: KJ	
Proj No: 25306.000.001	Scale: 1:8676	Version: final

LOG OF BORING BH01

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client	: GWRC	**Core Diameter**	: 83 mm
Date	: 05-08-2024	**Energy Transfer Ratio**	: 84.3 %
Hole Depth	: 3.3 m	**Logged By/Reviewed By**	: CW / CM
Drilling Method	: Rotosonic	**Latitude**	: -40.9413978
Drilling Contractor	: Griffiths Drilling Ltd	**Longitude**	: 175.6609687

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	FILL		GW	[FILL] Fine to coarse GRAVEL with some sand, minor cobbles, minor silt and trace rootlets and organics; brownish grey. Well graded; subangular to rounded, moderately strong to very strong, slightly weathered to unweathered Greywacke; sand is fine to coarse; cobbles are subrounded, strong, unweathered Greywacke. Organics are rootlets and amorphous material.									
0.5 1.0	FILL?	NR	-	0.35 m to 1.5 m - No Recovery (cobble lodged in barrel). Assumed same material as above based on height of stopbank.	NR				N/A				
1.5	ALLUVIUM?		GW	Sandy fine to coarse GRAVEL with minor silt, trace rootlets and trace organics; brownish grey. Well graded; subangular to rounded, moderately strong to very strong, slightly weathered to unweathered Greywacke; sand is fine to coarse. Organics are amorphous.					Medium Dense	1/3//2/3/2/3 N=10			
2.0 2.5 3.0	ALLUVIUM		GW	Sandy fine to coarse GRAVEL with minor silt and minor cobbles; light brownish grey. Well graded; gravel and cobbles are subangular to rounded, moderately strong to strong, slightly weathered to unweathered Greywacke; sand is fine to coarse.					Very Dense	11/11//15/25/10 N=50+ for 50 mm			

End of Hole Depth: 3.3 m
Termination: Target depth

Borehole met target depth of 3.3 m

Standing groundwater was not encountered.

LOG OF BORING BH02

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 05-08-2024
Hole Depth : 4.95 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd

Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9429495
Longitude : 175.662891

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
0.5	FILL		GW	[FILL] Sandy fine to coarse GRAVEL with minor silt, trace cobbles and trace rootlets; greyish brown. Well graded; subangular to rounded, moderately strong to very strong, slightly weathered to unweathered Greywacke; sand is fine to coarse; cobbles are subrounded, slightly weathered Greywacke. 0.4 m - With some cobbles; becomes brownish grey.					N/A				
1.0	FILL?		-	0.95 m to 1.5 m - No Recovery.	NR								
1.5	ALLUVIUM		GW	Fine to coarse GRAVEL with some cobbles and minor sand; grey. Well graded; gravel and cobbles are subangular to subrounded, moderately strong to strong, slightly weathered to unweathered, Greywacke; sand is fine to coarse.					Medium Dense	10/9//8/6/4/2 N=20			
2.0			GW	Sandy fine to coarse GRAVEL with minor silt; brownish grey. Well graded; angular to subrounded, moderately strong to strong, slightly weathered to unweathered Greywacke; sand is fine to coarse.									
			SM	Silty fine to coarse SAND with some gravel; brown. Well graded; gravel is fine to coarse, subangular to subrounded, moderately strong to strong, slightly weathered Greywacke.					N/A				
2.5			GW	Sandy fine to coarse GRAVEL with some silt and trace cobbles; grey. Well graded; subangular to rounded, strong, slightly weathered to unweathered Greywacke; sand is fine to coarse.									
			SW	Gravelly fine to coarse SAND with minor silt and trace cobbles; dark grey. Well graded; gravel is fine to coarse, subangular to subrounded, strong, slightly weathered Greywacke.									
3.0 3.5			GW	Sandy fine to coarse GRAVEL with minor cobbles and minor silt; grey. Well graded; angular to subrounded, moderately strong to strong, slightly weathered to unweathered Greywacke; sand is fine to coarse; cobbles are subrounded, strong, slightly weathered Greywacke.					Medium Dense	5/5//5/3/3/3 N=14			
4.0					NR								

Borehole met target depth of 4.95 m.

Standing groundwater was not encountered.

LOG OF BORING BH02

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client	: GWRC	**Core Diameter**	: 83 mm
Date	: 05-08-2024	**Energy Transfer Ratio**	: 84.3 %
Hole Depth	: 4.95 m	**Logged By/Reviewed By**	: CW / CM
Drilling Method	: Rotosonic	**Latitude**	: -40.9429495
Drilling Contractor	: Griffiths Drilling Ltd	**Longitude**	: 175.662891

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	ALLUVIUM			3.95 m to 4.5 m - No recovery at end of run.	NR				N/A N/A				
4.5			GW	Sandy fine to coarse GRAVEL; brownish orange. Well graded; angular to subrounded, weak to moderately strong, moderately weathered Greywacke; sand is fine to coarse.					Dense	8/11//8/8/12/14 N=42			

End of Hole Depth: 4.95 m
Termination: Target depth

Borehole met target depth of 4.95 m.

Standing groundwater was not encountered.

ENGEO

LOG OF BORING BH03

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 07-08-2024
Hole Depth : 3.45 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd

Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9424819
Longitude : 175.664138

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	T		ML	[TOPSOIL] SILT with some sand and minor rootlets; brown. Low plasticity; sand is fine to medium.					N/A				
	FILL?		SP	[FILL?] Fine to medium SAND with minor silt and trace rootlets and organics; dark grey. Poorly graded. Organics are fibrous.									
0.5			ML	[FILL?] SILT with some sand and minor rootlets; grey mottled orange-brown. Low plasticity; sand is fine to medium.									
1.0	ALLUVIUM		SW	Fine to coarse SAND with some gravel, some silt and trace cobbles; grey. Well graded; gravel is subangular to subrounded, weak to strong, slightly weathered Greywacke; cobbles are subrounded, strong, slightly weathered Greywacke.									
		NR		1.1 m to 1.5 m - No recovery.	NR								
1.5			GW	Sandy fine to coarse GRAVEL with minor cobbles and trace silt; dark grey. Well graded; angular to rounded, strong, slightly weathered Greywacke; sand is fine to coarse; cobbles are subangular to subrounded, strong to very strong, slightly weathered to unweathered Greywacke.					Very Dense	13/17//15/15/20 N=50+ OTL			
2.0													
2.5				2.5 m - With minor silt.									
3.0										12/11//10/11/15/14 N=50+			

End of Hole Depth: 3.45 m
Termination: Target depth

Borehole met target depth of 3.45 m.
Standing groundwater was not encountered.
T = TOPSOIL

OTL = on the line.

ENGEO

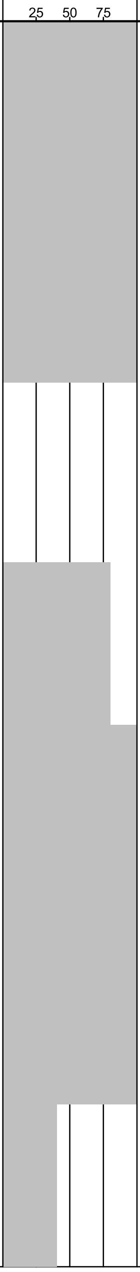
LOG OF BORING BH04

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 05-08-2024
Hole Depth : 3.45 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd

Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9443909
Longitude : 175.6646469

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%)	Notes
	FILL		GW	[FILL] Silty fine to coarse GRAVEL with some sand and trace asphalt; greyish brown mottled black. Well graded; angular to subrounded, moderately strong, slightly weathered Greywacke; sand is fine to coarse. Strong petrol odour.					N/A				
			ML	[FILL] Sandy SILT with some gravel; greyish brown mottled orange-brown and black. Low plasticity; sand is fine to coarse; gravel is fine to coarse, subangular to subrounded, strong, slightly weathered Greywacke. Strong petrol odour.									
0.5			GW	[FILL] Sandy fine to coarse GRAVEL with minor silt; dark brownish black. Well graded; subangular to subrounded, strong, slightly weathered Greywacke; sand is fine to coarse. Strong petrol odour.									
			ML	[FILL] SILT with some sand, minor gravel and trace cobbles; light greyish brown mottled black. Low plasticity; sand is fine to coarse; gravel and cobbles are subrounded, strong, slightly weathered Greywacke. Strong petrol odour. 0.9 m - Becomes sandy; with black staining.									
1.0	FILL?	NR	-	1.0 m to 1.5 m - No Recovery.	NR								
1.5			GM	[FILL?] Sandy, silty fine to coarse GRAVEL; dark grey mottled black. Well graded; angular to subrounded, strong, slightly weathered Greywacke.					Loose	2/2//2/1/1/2 N=6			
2.0	ALLUVIUM		SM	Silty fine to medium SAND with trace rootlets; light greyish brown. Poorly graded.									
2.5 3.0			GW	Sandy fine to coarse GRAVEL with trace silt; light brownish grey. Well graded; subangular to rounded, moderately strong to strong, slightly weathered Greywacke; sand is fine to coarse.					Dense	8/13//8/8/8/14 N=38			



End of Hole Depth: 3.45 m
Termination: Target depth

Borehole met target depth

Standing groundwater was not encountered.

LOG OF BORING BH05

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 07-08-2024
Hole Depth : 3.45 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd
Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9441566
Longitude : 175.6656313

Depth (m BGL)	Material	USCS Symbol	DESCRIPTION	Consistency/ Density Index	SPT N-Value
	T	ML	[TOPSOIL] SILT with some sand; dark brown. Low plasticity. Contains some rootlets.	N/A	
0.5	FILL	GW	[FILL] Sandy fine to coarse GRAVEL with minor cobbles and trace rootlets; greyish brown. Well graded; gravels and cobbles are subangular to rounded, moderately strong to strong, slightly weathered, Greywacke; sand is fine to coarse.		
1.0		SW	[FILL?] Gravelly, silty fine to coarse SAND with minor cobbles; greyish brown. Well graded; gravel is fine to coarse, subangular to subrounded, moderately strong to strong, slightly weathered Greywacke; cobbles are subrounded, strong, slightly weathered Greywacke.		
1.5 2.0 2.5	ALLUVIUM	GW	Sandy fine to coarse GRAVEL with minor cobbles and trace silt; dark grey. Well graded; angular to subrounded, strong, slightly weathered Greywacke; cobbles are subangular to subrounded, strong, slightly weathered to unweathered Greywacke.	Dense	8/4//6/10/14/10 N=40
3.0				Very Dense	3/17//13/17/10/10 N=50+

End of Hole Depth: 3.45 m
Termination: Target depth

Borehole met target depth

T = TOPSOIL

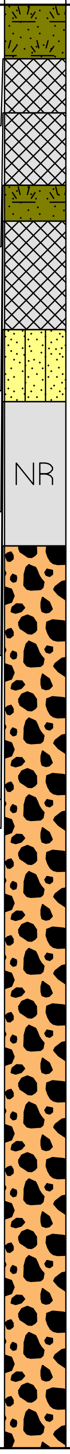
Standing groundwater was not encountered.

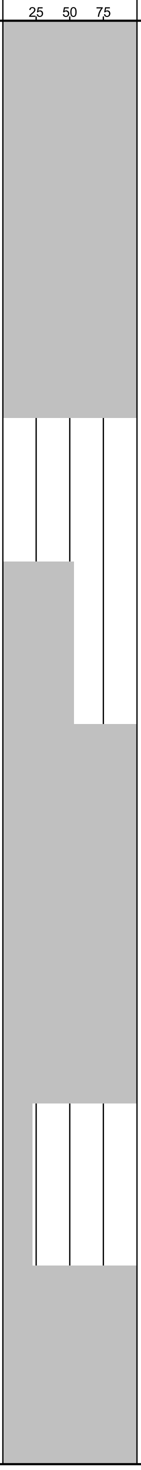
LOG OF BORING BH06

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 07-08-2024
Hole Depth : 4.95 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd
Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.945335
Longitude : 175.667952

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	T		SM	[TOPSOIL] Silty fine to coarse SAND with trace gravel and minor rootlets; dark brown. Well graded; gravel is fine to medium, angular to subangular, strong, slightly weathered, Greywacke.									
	FILL		SM	[FILL] Silty fine to coarse SAND with some gravel and trace rootlets; brown. Well graded; gravel is fine to coarse, subangular to subrounded, strong, slightly weathered Greywacke.									
	FILL?		GW	[FILL] Sandy fine to coarse GRAVEL with minor cobbles; brownish grey. Well graded; subangular to rounded, strong, slightly weathered Greywacke; sand is fine to coarse; cobbles are subrounded, strong, slightly weathered Greywacke.									
0.5	BT		SM	[BURIED TOPSOIL] Silty fine to coarse SAND with minor gravel and minor rootlets; brown. Well graded; gravel is fine to coarse, subangular to rounded, strong, slightly weathered Greywacke.									
	FILL?		GW	[FILL?] Sandy fine to coarse GRAVEL with trace cobbles; brownish grey. Well graded; subangular to subrounded, strong, slightly weathered Greywacke; sand is fine to coarse; cobbles are subrounded, strong, slightly weathered Greywacke.					N/A				
1.0	ALLUVIUM?		SM	Silty fine to coarse SAND with trace gravel and trace organics; brownish grey. Well graded; gravel is fine to coarse, subrounded, strong, slightly weathered Greywacke. Organics are fibrous. 1.0 m - With minor gravel.									
		NR	-	1.1 m to 1.5 m - No recovery.	NR								
1.5	ALLUVIUM		GW	Sandy fine to coarse GRAVEL with minor cobbles and trace silt; grey. Well graded; angular to subrounded, strong, slightly weathered to unweathered Greywacke; sand is fine to coarse; cobbles are subrounded, strong, slightly weathered, Greywacke.					Dense	4/11//12/8/10/7 N=37 9/14//10/10/10/10 N=40			
2.0													
2.5													
3.0													
3.5													
4.0													





Borehole met target depth of 4.95 m.

Standing groundwater was not encountered.

T = TOPSOIL, BT = BURIED TOPSOIL

LOG OF BORING BH06

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 07-08-2024
Hole Depth : 4.95 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd

Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.945335
Longitude : 175.667952

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
4.5	ALLUVIUM		SM	Gravelly, silty fine to coarse SAND; orange-brown. Well graded; gravel is fine to coarse, subangular to rounded, moderately strong to strong, slightly weathered, Greywacke and basalt.					Dense	3/2//6/7/9/8 N=30			

End of Hole Depth: 4.95 m
Termination: Target depth

Borehole met target depth of 4.95 m.

T = TOPSOIL, BT = BURIED TOPSOIL

Standing groundwater was not encountered.

LOG OF BORING BH07

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 06-08-2024
Hole Depth : 3.22 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd

Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9478852
Longitude : 175.66935

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	FILL		SW	[FILL] Gravelly fine to coarse SAND with trace shell fragments; light whitish brown. Well graded; gravel is fine to coarse, angular to subrounded, moderately strong, moderately to slightly weathered, limestone and Greywacke.					N/A				
0.5			GW	[FILL] Sandy fine to coarse GRAVEL; brownish dark grey. Well graded; angular to subrounded, strong, slightly weathered Greywacke; sand is fine to coarse. Contains trace bitumen-bound aggregate, tar odour.									
			SM	[FILL] Silty fine to coarse SAND with some gravel and minor cobbles; light brown. Well graded; gravel is fine to coarse; gravel and cobbles are subangular to subrounded, moderately strong to strong, slightly weathered, Greywacke. 0.9 m - Becomes gravelly.									
1.0		NR	-	1.0 m to 1.5 m - No Recovery.	NR								
1.5			GW	[FILL] Gravelly fine to coarse SAND; grey. Well graded; gravel is subangular to subrounded, strong, slightly weathered Greywacke.					Loose	2/2//2/2/2/2 N=8			
2.0 2.5	ALLUVIUM?		SW	Fine to coarse SAND with some silt, some gravel, minor cobbles and trace rootlets; brown. Well graded; gravel is fine to coarse; gravel and cobbles are subangular to subrounded, strong, slightly weathered, Greywacke.					N/A				
	ALLUVIUM		SW	Gravelly fine to coarse SAND; grey. Well graded; gravel is subangular to rounded, strong, slightly weathered, Greywacke.									
3.0			GW	Sandy fine to coarse GRAVEL; grey. Well graded;subangular to rounded, strong, slightly weathered, Greywacke; sand is fine to coarse.					Very Dense	3/12//19/19/14 N=50+ for 70 mm			

End of Hole Depth: 3.22 m
Termination: Target depth

Borehole met target depth

Standing groundwater was not encountered.

LOG OF BORING BH08

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 06-08-2024
Hole Depth : 4.93 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd
Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9506296
Longitude : 175.6706369

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	FILL		SW	[FILL] Fine to coarse SAND with some silt, trace gravel and minor rootlets; brown. Well graded; gravel is fine, subangular.					N/A				
0.5 1.0			SM	[FILL] Silty, gravelly fine to coarse SAND with trace cobbles and trace rootlets; greyish brown. Well graded; gravel is fine to coarse, subangular to rounded, moderately strong to very strong, slightly weathered to unweathered Greywacke; cobbles are subrounded, strong to very strong, slightly weathered Greywacke.									
			SM	[FILL] Silty fine to coarse SAND with minor gravel and trace charcoal; greyish brown speckled orange-brown. Well graded; gravel is fine to coarse, subrounded, strong, slightly weathered Greywacke.					Dense	19/20//16/9/9/13 N=47			
1.5	ALLUVIUM?		SW	Fine to coarse SAND with some gravel, some silt, minor cobbles and trace charcoal; greyish brown speckled orange-brown. Well graded; gravel is fine to coarse, gravel and cobbles are subrounded, strong, slightly weathered Greywacke.									
2.0	ALLUVIUM		GW	Sandy fine to coarse GRAVEL with minor silt and minor cobbles; grey. Well graded; angular to subrounded, strong, slightly weathered Greywacke; sand is fine to coarse; cobbles are subrounded, strong, slightly weathered to unweathered Greywacke.					N/A				
2.5 3.0 3.5 4.0			SW	Fine to coarse SAND with some silt, some gravel and minor cobbles; greyish brown speckled orange-brown. Well graded; gravel is fine to coarse; gravel and cobbles are subangular to rounded, strong, slightly weathered Greywacke. SPT 5.6.6.7.7.8 n=28 r=150 As above. 3.8 m - Becomes friable; with trace rootlets.					Medium Dense	5/6//6/7/7/8 N=28			

Borehole met target depth of 4.93 m.

Standing groundwater was not encountered.

LOG OF BORING BH08

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 06-08-2024
Hole Depth : 4.93 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd
Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9506296
Longitude : 175.6706369

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	ALLUVIUM		SW	Fine to coarse SAND with some silt, some gravel and minor cobbles; greyish brown speckled orange-brown. Well graded; gravel is fine to coarse; gravel and cobbles are subangular to rounded, strong, slightly weathered Greywacke.					Medium Dense				
			-	4.15 m to 4.5 m - No Recovery.	NR				N/A				
4.5			GW	Sandy fine to coarse GRAVEL with minor silt; grey. Well graded; angular to subrounded, strong, slightly weathered Greywacke; sand is fine to coarse.					Very Dense	4/3//5/17/20/8 N=50+ for 25 mm			

End of Hole Depth: 4.93 m
Termination: Target depth

Borehole met target depth of 4.93 m.

Standing groundwater was not encountered.

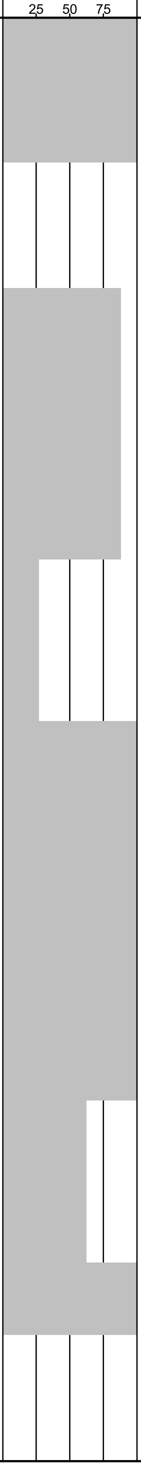
ENGEO

LOG OF BORING BH09

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 06-08-2024
Hole Depth : 4.65 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd

Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9529273
Longitude : 175.6717306

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
0.5	FILL		SW -	[FILL] Gravelly fine to coarse SAND with some silt and minor cobbles; brown. Well graded; gravel is fine to coarse, subangular to rounded, strong to very strong, slightly weathered Greywacke; cobbles are subrounded, strong, slightly weathered Greywacke. Contains trace rootlets. 0.4 m - 0.75 m - No Recovery. Assumed to be the same as above.	NR								
1.0 1.5			SW	[FILL] Gravelly fine to coarse SAND with some silt and minor cobbles; brown. Well graded; gravel is fine to coarse, angular to subangular, strong to very strong, slightly weathered Greywacke; cobbles are subrounded, strong, slightly weathered Greywacke. 1.35 m - 1.5 m - No Recovery.					N/A Medium Dense	2/3//5/5/4/5 N=19			
2.0 2.5 3.0 3.5	ALLUVIUM		GW	Sandy fine to coarse GRAVEL with minor cobbles, trace silt, trace rootlets and trace organics; brownish grey. Well graded; angular to subrounded, strong, slightly weathered Greywacke; sand is fine to coarse; cobbles are subrounded, strong, slightly weathered Greywacke 2.5 m - Rootlets and organics cease.					Medium Dense	4/4//5/6/9/27 N=47			
4.0				3.65 m to 4.1 m - No recovery.					N/A				

Borehole met target depth of 4.65 m.

Standing groundwater was not encountered.

LOG OF BORING BH09

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 06-08-2024
Hole Depth : 4.65 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd
Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9529273
Longitude : 175.6717306

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	ALLUVIUM			3.65 m to 4.1 m - No recovery.									
			GW	Sandy fine to coarse GRAVEL with minor cobbles; brownish grey. Well graded; gravel and cobbles are subangular to subrounded, strong, slightly weathered Greywacke; sand is fine to coarse.					N/A				
4.5			SW	Gravelly fine to coarse SAND with minor cobbles; brownish grey. Well graded; gravel is fine to coarse; gravel and cobbles are subangular to subrounded, strong, slightly weathered Greywacke.									
			GW	Sandy fine to coarse GRAVEL with minor cobbles; brownish grey. Well graded; gravel and cobbles are subangular to subrounded, strong, slightly weathered Greywacke; sand is fine to coarse.					Very Dense	31/19 N=50+ for 70 mm			

End of Hole Depth: 4.65 m
Termination: Target depth

Borehole met target depth of 4.65 m.

Standing groundwater was not encountered.

ENGEO

LOG OF BORING BH10

Waipoua River Stopbanks
Waipoua River
Masterton, New Zealand
25306.000.001
N/A

Client : GWRC
Date : 07-08-2024
Hole Depth : 3.45 m
Drilling Method : Rotosonic
Drilling Contractor : Griffiths Drilling Ltd

Core Diameter : 83 mm
Energy Transfer Ratio : 84.3 %
Logged By/Reviewed By : CW / CM
Latitude : -40.9530168
Longitude : 175.6730292

Depth (m BGL)	Material	Sample Type	USCS Symbol	DESCRIPTION	Log Symbol	Elevation (mRL)	Water Level	Moisture	Consistency/ Density Index	SPT N-Value	Torvane Shear (kPa)	Total Core Recovery (%) 25 50 75	Notes
	FILL		SW	[FILL] Gravelly fine to coarse SAND with trace silt and trace shell fragments; light whitish brown. Well graded; gravel is fine to coarse, angular to subrounded, weak to strong, moderately weathered to slightly weathered, limestone and Greywacke.					N/A				
0.5			ML	[FILL] SILT with some gravel and some sand; brown. Low plasticity; gravel is fine to coarse, subangular to rounded, strong, slightly weathered Greywacke; sand is fine to coarse.									
1.0			GW	[FILL] Sandy fine to coarse GRAVEL with some silt and minor cobbles; greyish brown. Well graded; angular to rounded, strong, slightly weathered Greywacke and basalt; sand is fine to coarse; cobbles are subrounded, strong, slightly weathered Greywacke.									
			-	0.85 m to 1.5 m - No recovery. Assumed same as above.	NR								
1.5	FILL?		GW	[FILL?] Sandy fine to coarse GRAVEL with some silt and minor cobbles; greyish brown. Well graded; angular to rounded, strong, slightly weathered Greywacke and basalt; sand is fine to coarse; cobbles are subrounded, strong, slightly weathered Greywacke.					Medium Dense	4/3//4/3/4/3 N=14			
2.0 2.5	ALLUVIUM		GW	Sandy fine to coarse GRAVEL with minor cobbles and minor silt; light brownish grey. Well graded; subangular to rounded, strong, slightly weathered, Greywacke; sand is fine to coarse; cobbles are subrounded, strong, Greywacke.					N/A				
			SW	Fine to coarse SAND with minor gravel; dark grey. Well graded; gravel is fine to medium, angular to subrounded, strong, Greywacke.									
3.0			GW	Sandy fine to coarse GRAVEL with minor cobbles; dark grey. Well graded; angular to rounded, strong, slightly weathered Greywacke; sand is fine to coarse; cobbles are subangular to subrounded, strong, slightly weathered Greywacke.					Dense	8/8//8/6/12/12 N=38			

End of Hole Depth: 3.45 m
Termination: Target depth

Borehole met target depth

Standing groundwater was not encountered.

APPENDIX 2:

Geotechnical Laboratory Test Results

GEOTECHNICS

2 September 2024
Our Ref: 1096389.0000.0.0/Rep1
Customer Ref: 25306.000.001

Engeo Limited
PO Box 25-047
Wellington 6146

Attention: Josh Cheah

Dear Josh

Waipoua River, Masterton

Laboratory Test Report

Samples from the above-mentioned site have been tested as received according to your instructions and the results are included in this report. Results apply only to the sample(s) tested.

This report has been prepared for the benefit of Engeo Limited, with respect to the particular brief given to us and it cannot be relied upon in other contexts or for any other purpose without our prior review and agreement.

This report may be reproduced only in full.

Samples not destroyed during testing will be retained for one month from the date of this report before being discarded. If we can be of any further assistance, feel free to get in touch. Contact details are provided at the bottom of this page.

Geotechnics Ltd
1 Hill Street, Onehunga, Auckland, 1061 | PO Box 13171, Onehunga, Auckland, 1643
+64-9-356 3510 | enquiry@geotechnics.co.nz | www.geotechnics.co.nz

GEOTECHNICS LTD

Report approved by:

…………………………………………………
Kelsey Sanderson
Laboratory Technician
Key Technical Person

Authorised for Geotechnics by:

Steven Anderson
…………………………………………………
Steven Anderson
Project Director

2-Sep-24
T:\GeotechnicsGroup\Projects\1096389\IssuedDocuments – Report 1

Geotechnics Project ID	1096389.0000.1.0
Customer Project ID	25306.000.001

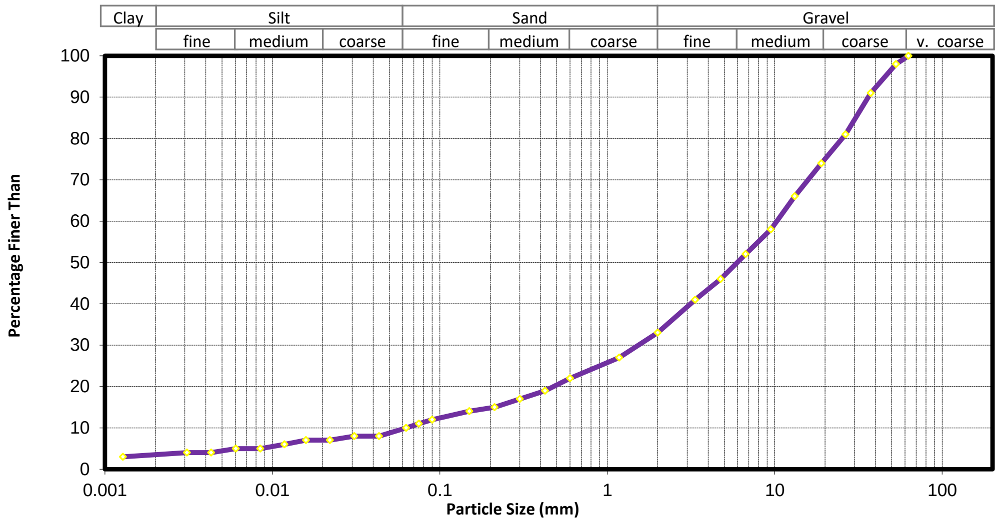
Determination of the Particle Size Distribution - NZS 4402:1986 Test 2.8.1 (Wet Sieve Method)
Determination of the Particle Size Distribution - NZS 4402:1986 Test 2.8.4 (Hydrometer Method)

TEST DETAILS

LOCATION	**ID**	BH09		
	Description	Waipoua River, Masterton		
	Data	N/A		
SAMPLE	**Geotechnics ID**	AKL975.1		
	Reference	Natural Alluvium	**Depth**	1.9-4.5 m
	Description	Sandy GRAVEL, with minor silt, and trace of clay; dark brown. Wet		
SPECIMEN	**Reference**	-	**Depth**	-
	Description	-		

TEST RESULTS

PARTICLE SIZE ANALYSIS



Sieve Size (mm)	Percentage Passing (%)	Sieve Size (mm)	Percentage Passing (%)	Sieve Size (mm)	Percentage Passing (%)
150.0	-	16.0	-	0.600	22
100.0	-	13.2	66	0.425	19
75.0	-	9.50	58	0.300	17
63.0	100	6.70	52	0.212	15
53.0	98	4.75	46	0.150	14
37.5	91	3.35	41	0.090	12
26.5	81	2.00	33	0.075	11
19.0	74	1.18	27	0.063	10

Equivalent Particle Diameter D (mm)	Percentage of Particles Finer than D (%)	Equivalent Particle Diameter D (mm)	Percentage of Particles Finer than D (%)
0.0363	8	0.0031	4
0.0269	8	0.0014	3
0.0201	7		
0.0148	7		
0.0112	6		
0.0082	5		
0.0060	5		
0.0044	4		

TEST REMARKS

• The material used for testing was natural, whole soil. • The percentage passing the <0.063 mm was obtained by difference. • An assumed solid density value of 2.65 t/m³ was used. We do not take responsibility for misrepresentation or misinterpretation arising from the use of this assumed value.

Two representative sub samples were split from the original sample for wet sieve and hydrometer analysis. The wet sieve sample was washed over 0.063 mm test sieve, until the individual particles were clean. The material retained on 0.063 mm test sieve was oven dried and dry sieved. The hydrometer sample was oven dried at the end of the test to determine the mass passing 0.063 mm for hydrometer calculations. The sieve data was combined with the hydrometer analysis to give a continuous curve.
Suspension pH 8.0
The classification of gravel-sand-silt-clay components are described on the basis of particle size analysis.

Date tested: 28/08/2024

This test result is not IANZ accredited due to insufficient sample mass.

Approved by KTP GEGO **Date** **2/09/2024**

Geotechnics Project ID 1096389.0000.1.0

Customer Project ID 25306.000.001

Determination of the Particle Size Distribution - NZS 4402:1986 Test 2.8.1 (Wet Sieve Method)

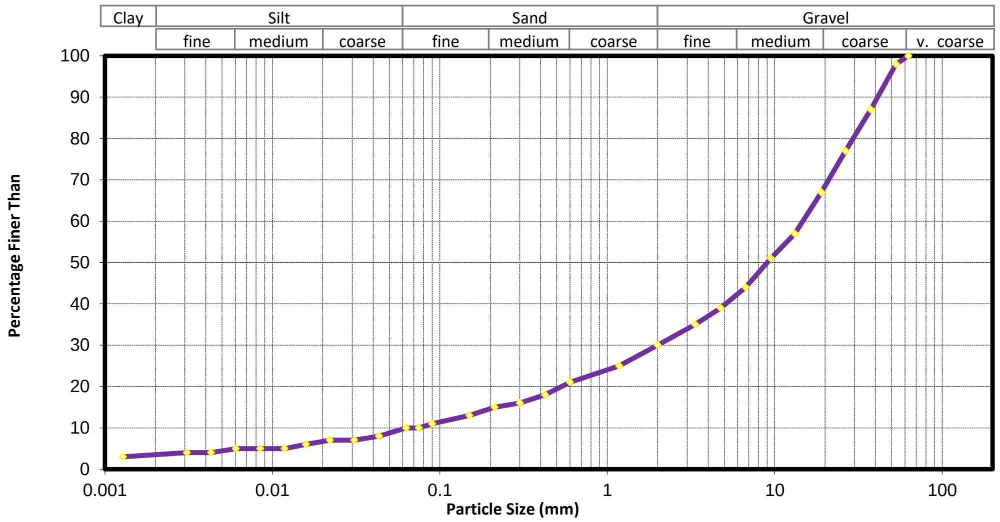
Determination of the Particle Size Distribution - NZS 4402:1986 Test 2.8.4 (Hydrometer Method)

TEST DETAILS

LOCATION	**ID**	BH09/BH10		
	Description	Waipoua River, Masterton		
	Data	N/A		
SAMPLE	**Geotechnics ID**	AKL975.2		
	Reference	Stopbank Fill	**Depth**	0 m
	Description	Sandy GRAVEL, with minor silt; dark brown. Dry to moist		
SPECIMEN	**Reference**	-	**Depth**	-
	Description	-		

TEST RESULTS

PARTICLE SIZE ANALYSIS



Sieve Size (mm)	Percentage Passing (%)	Sieve Size (mm)	Percentage Passing (%)	Sieve Size (mm)	Percentage Passing (%)
150.0	-	16.0	-	0.600	21
100.0	-	13.2	57	0.425	18
75.0	-	9.50	51	0.300	16
63.0	100	6.70	44	0.212	15
53.0	98	4.75	39	0.150	13
37.5	87	3.35	35	0.090	11
26.5	77	2.00	30	0.075	10
19.0	67	1.18	25	0.063	10

Equivalent Particle Diameter D (mm)	Percentage of Particles Finer than D (%)	Equivalent Particle Diameter D (mm)	Percentage of Particles Finer than D (%)
0.0363	8	0.0032	4
0.0275	7	0.0014	3
0.0201	7		
0.0151	6		
0.0115	5		
0.0084	5		
0.0061	5		
0.0044	4		

TEST REMARKS

• The material used for testing was natural, whole soil. • The percentage passing the <0.063 mm was obtained by difference. • An assumed solid density value of 2.65 t/m³ was used. We do not take responsibility for misrepresentation or misinterpretation arising from the use of this assumed value.

Two representative sub samples were split from the original sample for wet sieve and hydrometer analysis. The wet sieve sample was washed over 0.063 mm test sieve, until the individual particles were clean. The material retained on 0.063 mm test sieve was oven dried and dry sieved. The hydrometer sample was oven dried at the end of the test to determine the mass passing 0.063 mm for hydrometer calculations. The sieve data was combined with the hydrometer analysis to give a continuous curve.
Suspension pH 8.0
The classification of gravel-sand-silt-clay components are described on the basis of particle size analysis.

Date tested: 28/08/2024

This test result is not IANZ accredited due to insufficient sample mass.

Approved by KTP **GEGO** **Date** **2/09/2024**

Determination of the Particle Size Distribution - NZS 4402:1986 Test 2.8.1 (Wet Sieve Method)

Determination of the Particle Size Distribution - NZS 4402:1986 Test 2.8.4 (Hydrometer Method)

TEST DETAILS

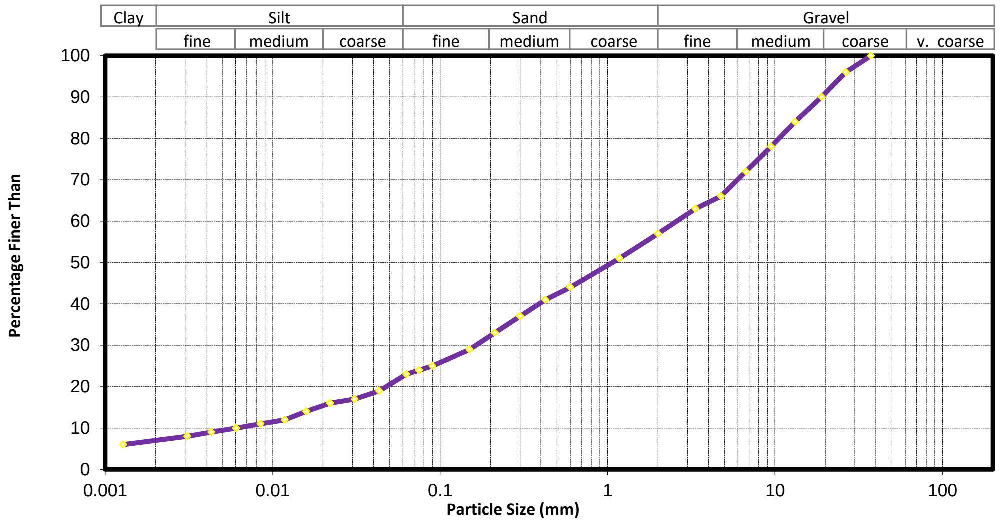
LOCATION
ID BH05
Description Waipoua River, Masterton
Data N/A

SAMPLE
Geotechnics ID AKL975.3
Reference Stopbank Fill **Depth** 0.6-1.4 m
Description Sandy GRAVEL, with some silt, and minor clay; dark brown. Wet

SPECIMEN
Reference - **Depth** -
Description -

TEST RESULTS

PARTICLE SIZE ANALYSIS



Sieve Size (mm)	Percentage Passing (%)	Sieve Size (mm)	Percentage Passing (%)	Sieve Size (mm)	Percentage Passing (%)
150.0	-	16.0	-	0.600	44
100.0	-	13.2	84	0.425	41
75.0	-	9.50	78	0.300	37
63.0	-	6.70	72	0.212	33
53.0	-	4.75	66	0.150	29
37.5	100	3.35	63	0.090	25
26.5	96	2.00	57	0.075	24
19.0	90	1.18	51	0.063	23

Equivalent Particle Diameter D (mm)	Percentage of Particles Finer than D (%)	Equivalent Particle Diameter D (mm)	Percentage of Particles Finer than D (%)
0.0359	19	0.0032	8
0.0269	17	0.0014	6
0.0199	16		
0.0149	14		
0.0115	12		
0.0084	11		
0.0061	10		
0.0044	9		

TEST REMARKS

• The material used for testing was natural, whole soil. • The percentage passing the <0.063 mm was obtained by difference. • An assumed solid density value of 2.65 t/m³ was used. We do not take responsibility for misrepresentation or misinterpretation arising from the use of this assumed value.

Two representative sub samples were split from the original sample for wet sieve and hydrometer analysis. The wet sieve sample was washed over 0.063 mm test sieve, until the individual particles were clean. The material retained on 0.063 mm test sieve was oven dried and dry sieved. The hydrometer sample was oven dried at the end of the test to determine the mass passing 0.063 mm for hydrometer calculations. The sieve data was combined with the hydrometer analysis to give a continuous curve.
Suspension pH 8.0
The classification of gravel-sand-silt-clay components are described on the basis of particle size analysis.

Date tested: 28/08/2024

This test result is not IANZ accredited due to insufficient sample mass.

Approved by KTP **GEGO** **Date** **2/09/2024**

GEOTECHNICS

19 September 2024
Our Ref: 1096389.0000.02.0/Rep1
Customer Ref: 25306.000.001

Engeo Limited
PO Box 25-047
Wellington 6146

Attention: Josh Cheah

Dear Josh

Waipoua River, Masterton

Laboratory Test Report

Customer's Instructions

Detailed test instructions are provided via emails from Mr Josh Cheah from 21st to 26th August 2024 along with a schedule.

Sampling Procedure

Samples have been tested as received from the customer.

Sample Location Plan

Not applicable.

Samples

We received three small bag samples labelled with location ID and sample depth. The fourth sample scheduled for Permeability was missing.

Date of Sample Receipt

21 August 2024

Test Method(s)

ISO 17892:2019 Part 11 - Permeability Tests

ASTM D4647-13 (2020) - Pinhole

NZS 4402: 1986 Test 2.1 - Water Content

Material Description

Descriptions are provided in the attached presentation pages.

Test Results

Table 1: Summary of Single-Point Compaction results

Location ID	Sample Depth (m)	Water Content (%)	Bulk Density (t/m^3)	Dry Density (t/m^3)
BH04	2.1 – 2.3	25.5	2.00	1.59

Remaining test results are attached on page 3 to 6.

Test Remarks

We performed a single-point NZ standard compaction test on sample BH04, 2.1 to 2.3 (m) to produce a specimen for a triaxial permeability test, and to obtain a target dry density for remoulding each scheduled pinhole and permeability test specimen at as received water content. Unfortunately, all samples were too wet to be remoulded properly at natural water content. As a result, we dried samples to the water contents which were handleable in sample preparation.

In addition, the target dry density was too low for remoulding the samples at modified water content, and therefore we remoulded each specimen to the lowest consistent dry density achievable in the lab.

All other test remarks are detailed on the presentation page.

General Remarks

Samples not destroyed during testing, will be retained for one month from the date of this report before being discarded.

Descriptions are enclosed for your information but are not covered under the IANZ endorsement of this report.

This report has been prepared for the benefit of Engeo Limited, with respect to the particular brief given to us and it cannot be relied upon in other contexts or for any other purpose without our prior review and agreement.

Please reproduce this report in full when transmitting to others or including in internal reports.

If we can be of any further assistance, feel free to get in touch. Contact details are provided at the bottom of the letterhead page.

GEOTECHNICS LTD

Report approved by:	Authorised for Geotechnics by:
Helen Wang	
....	....
Helen Wang Triaxial Laboratory Manager Key Technical Person	Vic O'Connor Project Director

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

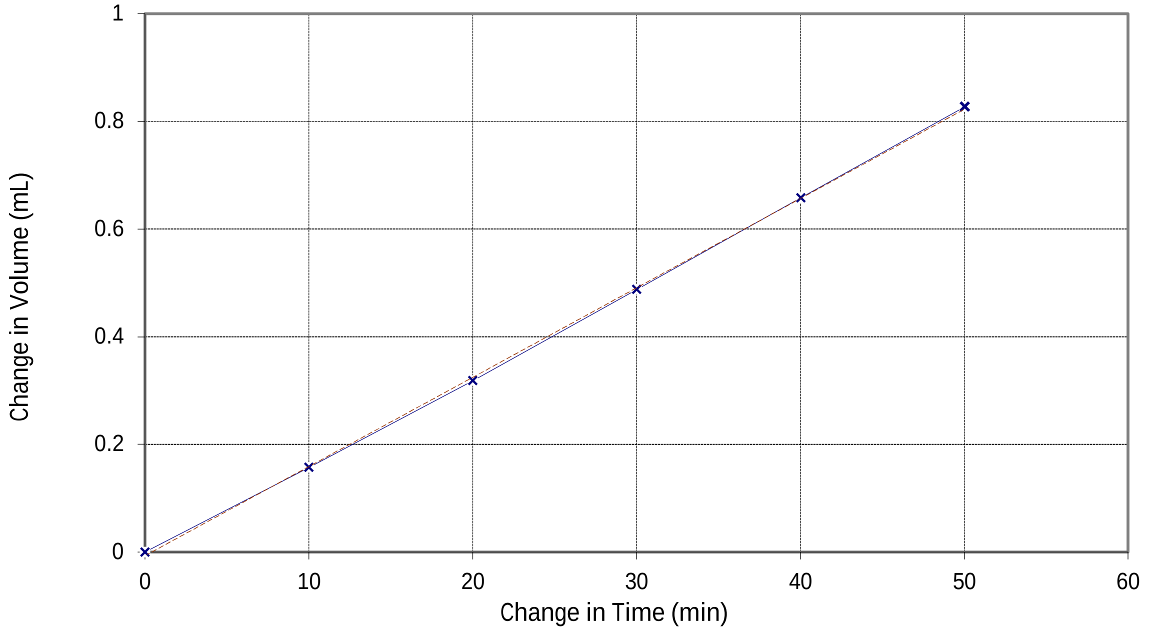
19-Sep-24
t:\geotechnicsgroup\projects\1096389\02 triaxial\issueddocuments\20240919.waipoua river, masterton.pihe.rep1.docx

GEOTECHNICS
1 Hill Street
Onehunga
Auckland
New Zealand
p. +64 9 356 3510

Geotechnics Project ID: 1096389.0.2.0
Customer Project ID: 25306.000.001

Site/Location:	Waipoua River, Masterton	Location ID:	BH03
Sample Ref.:	-	Depth (m):	0.1 - 0.4
Test Method Used:	ISO 17892-11:2019 Part 11 Permeability Tests		
	NZS 4402:1986 Test 2.1 Determination of Water Content		

CHANGE IN VOLUME VS CHANGE IN TIME



Coefficient of Permeability at 19.5 °C = 2.83E-09 (m/s)

Initial sample height	59	(mm)	Initial bulk density	2.22	(t/m³)
Initial sample diameter	60	(mm)	Initial dry density	1.97	(t/m³)
Saturation at test (B)	96	(%)	Initial water content	12.6	(%)
Back pressure level	560	(kPa)	Final water content	15.4	(%)
Consolidation stress level	30	(kPa)	Final dry density	1.85	(t/m³)
Head difference	20	(kPa)	Hydraulic gradient	34	

SAMPLE DESCRIPTION

Sandy SILT with a trace of clay, moist, dark greyish brown, highly dilatant.

SAMPLE HISTORY

The natural water content 20.1 % was too high for us to get the sample remoulded properly. We dried the soil to the water content 16.6 % and remoulded it to the lowest consistent dry density achievable in the lab.

TEST REMARKS

Constant-head permeability test in a triaxial cell. De-aired tap water was used in the test.
The sample was saturated by increments of cell pressure and back pressure.

Tested by: BESH Date: 11/09/2024 Approved by: Date: 18/09/2024

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Auckland
New Zealand
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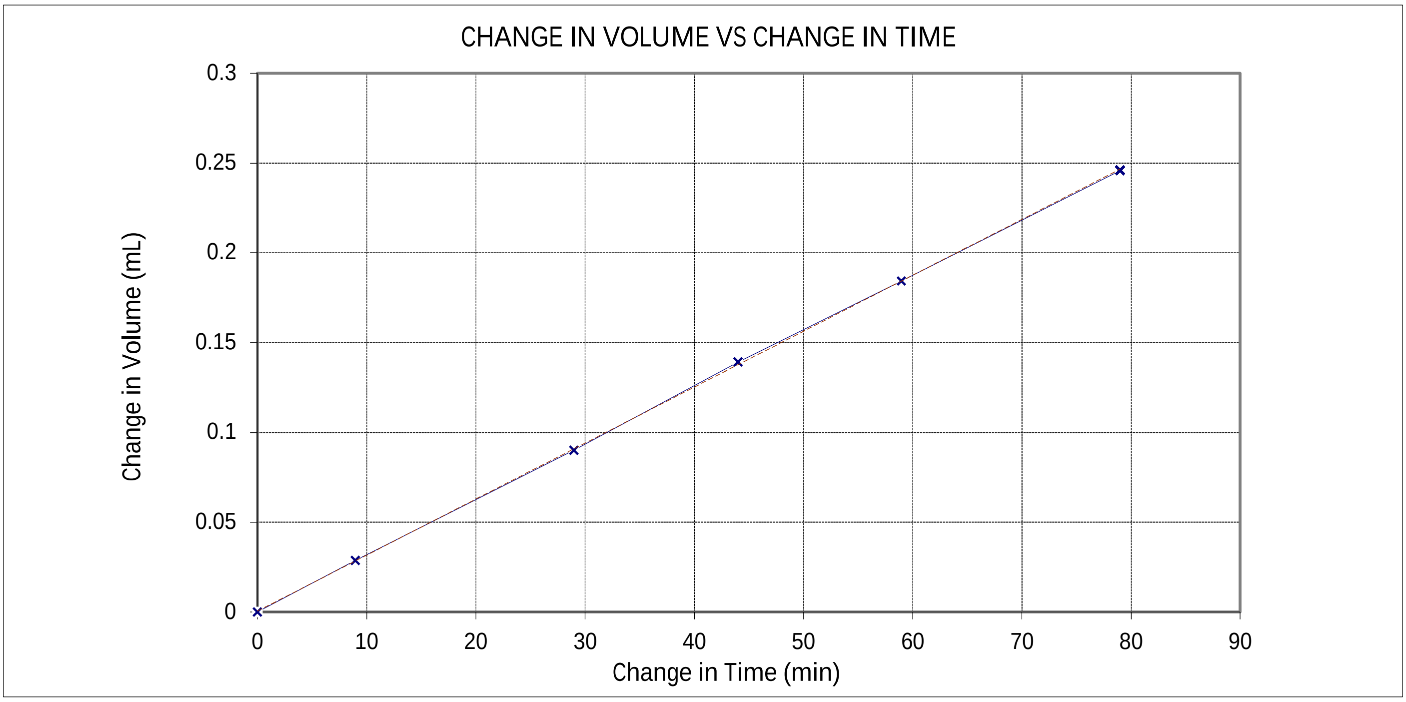
Geotechnics Project ID: 1096389.0.2.0
Customer Project ID: 25306.000.001

Site/Location:	Waipoua River, Masterton	Location ID:	BH04
Sample Ref.:	-	Depth (m):	2.1-2.3
Test Method Used:	ISO 17892-11:2019 Part 11 Permeability Tests NZS 4402:1986 Test 2.1 Determination of Water Content		



Coefficient of Permeability at 19.5 °C = 3.23E-10 (m/s)

Initial sample height	54	(mm)	Initial bulk density	1.96	(t/m³)
Initial sample diameter	60	(mm)	Initial dry density	1.60	(t/m³)
Saturation at test (B)	90	(%)	Initial water content	22.7	(%)
Back pressure level	465	(kPa)	Final water content	21.0	(%)
Consolidation stress level	45	(kPa)	Final dry density	1.68	(t/m³)
Head difference	30	(kPa)	Hydraulic gradient	57	

SAMPLE DESCRIPTION

SILT with minor clay and traces of sand, highly dilatant, dark grey

SAMPLE HISTORY

We compacted the sample at the natural water content 25.5 % with NZ standard compaction effort. Unfortunately, the sample was deformed when it's extruded from the proctor mould due to a high moisture content. We then dried the sample to 22.7 % water content and remould it to the target dry density 1.59 t/m3, which was obtained from a single-point NZ standard compaction test.

The test was performed on whole soil.

TEST REMARKS

Constant-head permeability test in a triaxial cell. De-aired tap water was used in the test.
The sample was saturated by increments of cell pressure and back pressure.

There was insufficient material to remould the sample to a 1:1 dimension. The sample was remoulded to the closest height achievable.

Tested by:	BESH	Date:	11/09/2024	Approved by:		Date:	18/09/2024

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1 Hill Street
Onehunga
Auckland
New Zealand
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Geotechnics Project ID: 1096389.0.2.0
Customer Project ID: 25306.000.001

Site/Location:	Waipoua River, Masterton	Location ID:	BH03
Sample Ref.:	-	Depth:	0.1-0.4 (m)

Test Method Used: ASTM D4647-13 (2020) Pinhole Test (Method A)
NZS 4402:1986 Test 2.1 Determination of Water Content

Initial Water Content	16.0	(%)	Initial Bulk Density	2.29	(t/m³)
Final Water Content	14.9	(%)	Initial Dry Density	1.97	(t/m³)

Hydraulic head H (mm)	Duration of flow (min)	Rate of flow q (mL/sec)	Cloudiness of flow	
			From side	From top
50	5	0.67	Barely visible	Barely visible
		0.68	Barely visible	Barely visible
		0.79	Barely visible	Barely visible
50	5	0.80	Barely visible	Barely visible
		0.82	Slightly dark	Slightly dark
		0.80	Slightly dark	Slightly dark
180	--			
380	--			
1020	--			

Hole diameter after test: 1.2 (mm) Dispersion Category: ND4

Sample Description: Sandy SILT with a trace of clay, moist, dark greyish brown, highly dilatant.

Sample History: The natural water content 19.6 % was too high for a proper sample remoulding. We dried the soil to the water content 16.6 % and remoulded the sample to the lowest consistent dry density achievable in the lab.

The test was performed on the fraction passing 2 mm sieve.

Test Remarks:

1. The pinhole was formed with 1.1 mm diameter pin.
2. Distilled water was used in the test.
3. Classification:
   D1, D2 -- Dispersive;
   ND4, ND3 -- Moderately to slightly dispersive;
   ND2, ND1 -- Non-dispersive.
4. The soil classified as non-dispersive still can erode in some circumstances.

Large organics were removed during the remoulding process.

Tested by: BESH Date: 9/09/2024 Approved by KTP: Date: 18/09/2024

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1 Hill Street
Onehunga
Auckland
New Zealand
p. +64 9 356 3510

Geotechnics Project ID: 1096389.0.2.0
Customer Project ID: 25306.000.001

Site/Location: Waipoua River, Masterton
Location ID: BH10
Sample Ref.: -
Depth: 0.1-0.3 (m)
Test Method Used: ASTM D4647-13 (2020) Pinhole Test (Method A)
NZS 4402:1986 Test 2.1 Determination of Water Content

Initial Water Content	17.2	(%)	Initial Bulk Density	2.10	(t/m³)
Final Water Content	21.5	(%)	Initial Dry Density	1.79	(t/m³)

Hydraulic head H (mm)	Duration of flow (min)	Rate of flow q (mL/sec)	Cloudiness of flow	
			From side	From top
50	5	0.26	Perfectly clear	Perfectly clear
		0.26	Perfectly clear	Perfectly clear
		0.27	Perfectly clear	Perfectly clear
50	5	0.27	Perfectly clear	Perfectly clear
		0.27	Perfectly clear	Perfectly clear
		0.27	Perfectly clear	Perfectly clear
180	5	1.02	Perfectly clear	Perfectly clear
		1.09	Perfectly clear	Perfectly clear
		1.10	Barely visible	Perfectly clear
380	5	1.96	Perfectly clear	Perfectly clear
		1.96	Perfectly clear	Perfectly clear
		2.04	Perfectly clear	Perfectly clear
1020	--			

Hole diameter after test: 1.6 (mm) Dispersion Category: ND3

Sample Description: SILT with some fine to coarse sand and traces of clay, dark greyey brown, dilatant, moist

Sample History: The target dry density 1.59 t/m3 was too low to be achieved. As a result, we remoulded the sample at the natural water content to the lowest consistent dry density achievable in the lab.

The test was performed on the fraction passing 2 mm sieve.

Test Remarks:

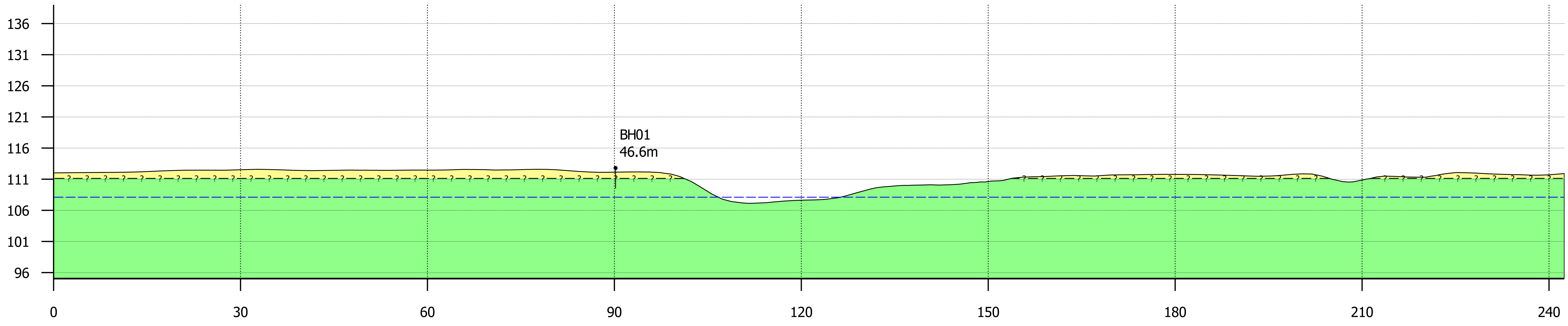
1. The pinhole was formed with 1.1 mm diameter pin.
2. Distilled water was used in test.
3. Classification:
   D1, D2 -- Dispersive;
   ND4, ND3 -- Moderately to slightly dispersive;
   ND2, ND1 -- Non-dispersive.
4. The soil classified as non-dispersive still can erode in some circumstances.

Tested by: ALWI/BE Date: 6/09/2024 Approved by KTP: Date: 18/09/2024

APPENDIX 3:

Geological Cross Sections

Cross Section A



Scale: 1:650

Vertical exaggeration: 1x

0m 50m

Legend

Geological Units

🟩 Holocene Alluvium

🟨 Stopbank Fill

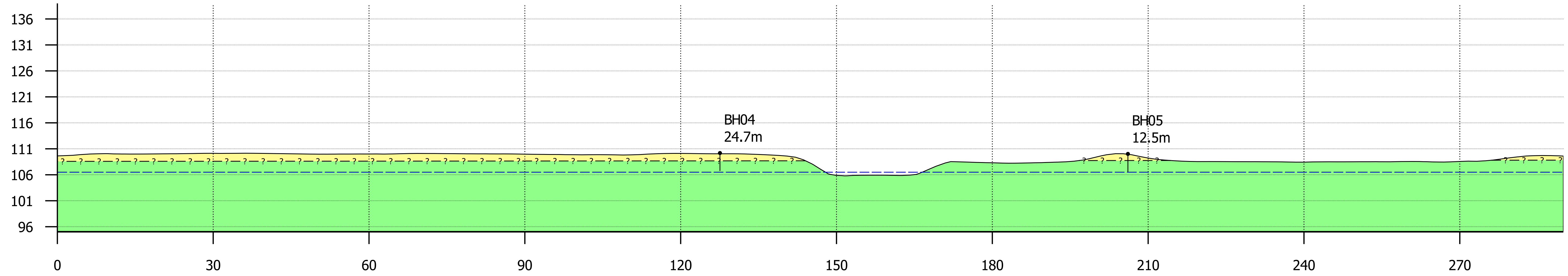
Geological Surfaces

—?—?- Inferred Geological Contact

– – – – Groundwater level

Responsible dept.	Wellington
Technical reference	26234.000.001
Creator	JC
Approved by	MB / KJ
Legal owner	
Document type	Geological Section
Document status	Final
Title	Waipoua River Stopbanks ssessment - Cross Section A
Identification number	Appendix 3
Rev.	A
Date of issue	10/10/2024
Sheet	1

Cross Section B



Scale: 1:780

Vertical exaggeration: 1x

0m 50m

Legend

Geological Units

🟩 Holocene Alluvium

🟨 Stopbank Fill

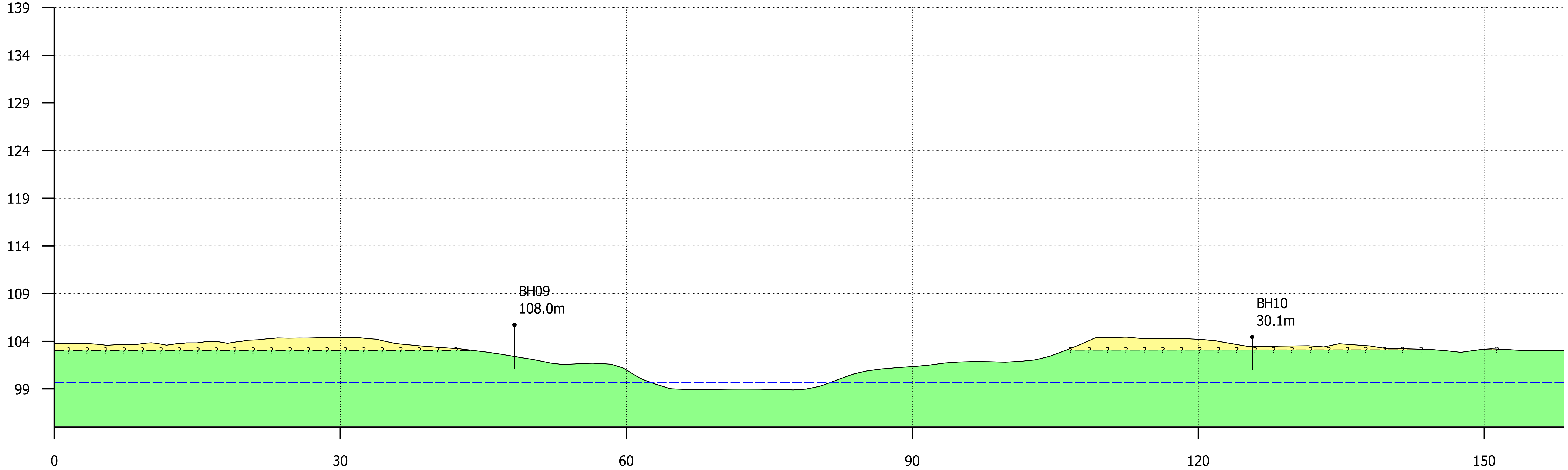
Geological Surfaces

–?–?- Inferred Geological Contact

– – – – Groundwater level

Responsible dept. Wellington	Technical reference 26234.000.001	Creator JC	Approved by MB / KJ
Legal owner ENGEO		Document type Geological Section	Document status Final
		Title Waipoua River Stopbanks ssessment - Cross Section B	Identification number Appendix 3
			Rev. A
			Date of issue 10/10/2024
			Sheet 2

Cross Section C



Scale: 1:430

Vertical exaggeration: 1x

0m 50m

Legend

Geological Units

- 🟩 Holocene Alluvium
- 🟨 Stopbank Fill

Geological Surfaces

- —?—?- Inferred Geological Contact

- - - - Groundwater level

Responsible dept. Wellington	Technical reference 26234.000.001	Creator JC	Approved by MB / KJ
Legal owner ENGEO		Document type Geological Section	Document status Final
		Title Waipoua River Stopbanks ssessment - Cross Section C	Identification number Appendix 3
			Rev. A Date of issue 10/10/2024 Sheet 3

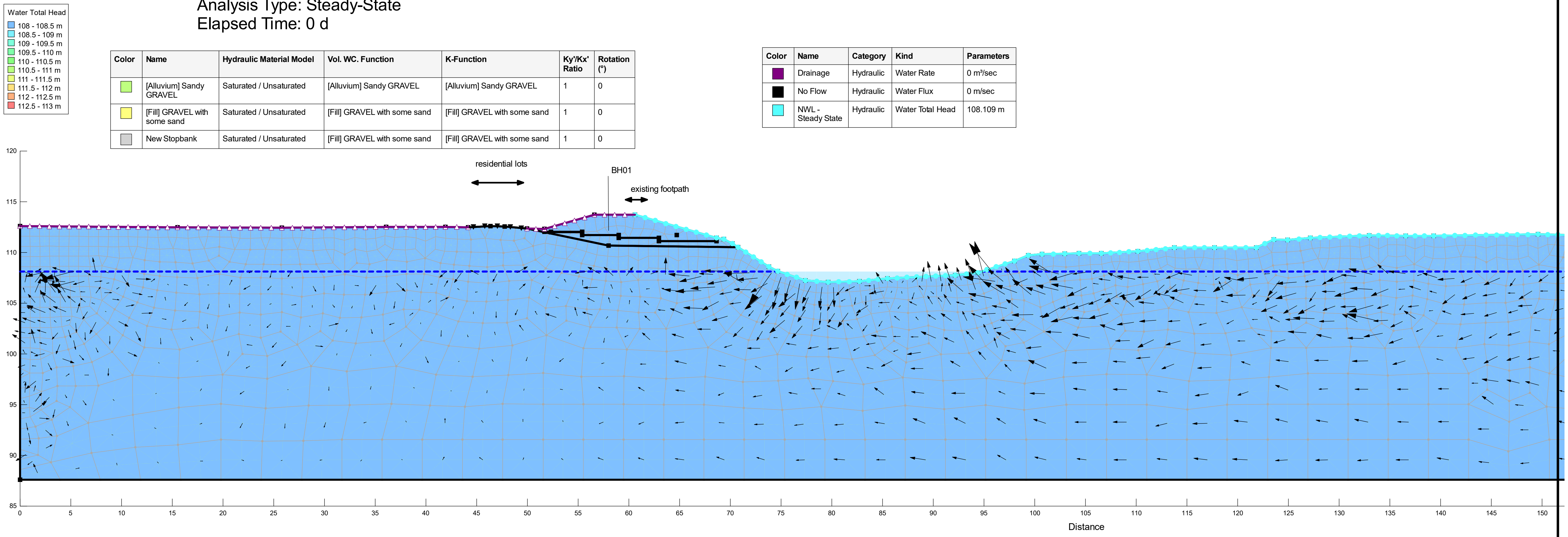
APPENDIX 4:

Seepage Analysis Outputs

Kind: SEEP/W
Analysis Type: Steady-State
Elapsed Time: 0 d

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟨	[Fill] GRAVEL with some sand	Saturated / Unsaturated	[Fill] GRAVEL with some sand	[Fill] GRAVEL with some sand	1	0
⬜	New Stopbank	Saturated / Unsaturated	[Fill] GRAVEL with some sand	[Fill] GRAVEL with some sand	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
⬛	No Flow	Hydraulic	Water Flux	0 m/sec
🟦	NWL - Steady State	Hydraulic	Water Total Head	108.109 m



NWL - Steady State

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

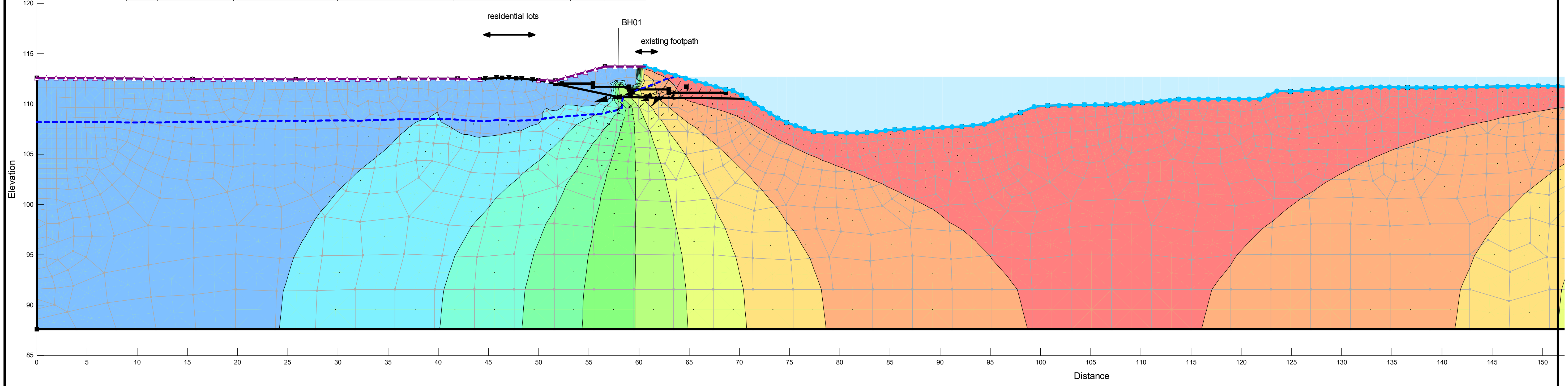
Kind: SEEP/W
Analysis Type: Transient
Elapsed Time: 0.326377 d

Water Total Head

- 🟦 108 - 108.5 m
- 🟦 108.5 - 109 m
- 🟩 109 - 109.5 m
- 🟩 109.5 - 110 m
- 🟩 110 - 110.5 m
- 🟩 110.5 - 111 m
- 🟨 111 - 111.5 m
- 🟨 111.5 - 112 m
- 🟧 112 - 112.5 m
- 🟥 112.5 - 113 m

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟨	[Fill] GRAVEL with some sand	Saturated / Unsaturated	[Fill] GRAVEL with some sand	[Fill] GRAVEL with some sand	1	0
⬜	New Stopbank	Saturated / Unsaturated	[Fill] GRAVEL with some sand	[Fill] GRAVEL with some sand	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
⬛	No Flow	Hydraulic	Water Flux	0 m/sec
🟦	Storm Hydrograph	Hydraulic	Water Total Head	1%+CC Storm Hydrograph



1%+CC - Hydrograph

Waipoua Stopbank Assessment - Section A_western bank.gsz

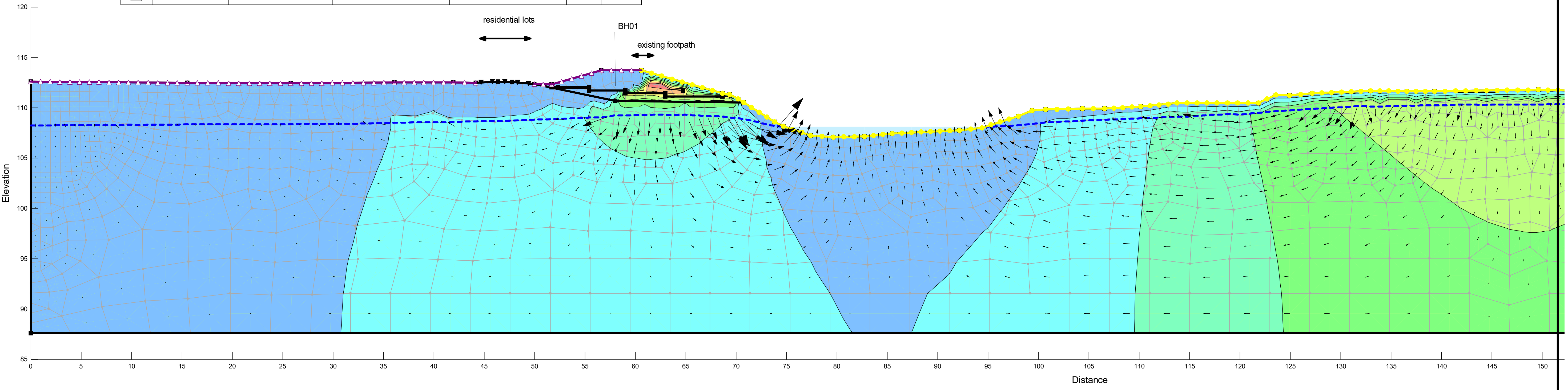
21/10/2024 1:400

Kind: SEEP/W
Analysis Type: Transient
Elapsed Time: 0.6875 d

Water Total Head	
🟦	108 - 108.5 m
🟦	108.5 - 109 m
🟩	109 - 109.5 m
🟩	109.5 - 110 m
🟩	110 - 110.5 m
🟩	110.5 - 111 m
🟨	111 - 111.5 m
🟨	111.5 - 112 m
🟧	112 - 112.5 m
🟥	112.5 - 113 m

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟨	[Fill] GRAVEL with some sand	Saturated / Unsaturated	[Fill] GRAVEL with some sand	[Fill] GRAVEL with some sand	1	0
⬜	New Stopbank	Saturated / Unsaturated	[Fill] GRAVEL with some sand	[Fill] GRAVEL with some sand	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
⬛	No Flow	Hydraulic	Water Flux	0 m/sec
🟨	Rapid Drawdown Hydrograph	Hydraulic	Water Total Head	Rapid Drawdown Hydrograph



RDD - Hydrograph

Waipoua Stopbank Assessment - Section A_western bank.gsz

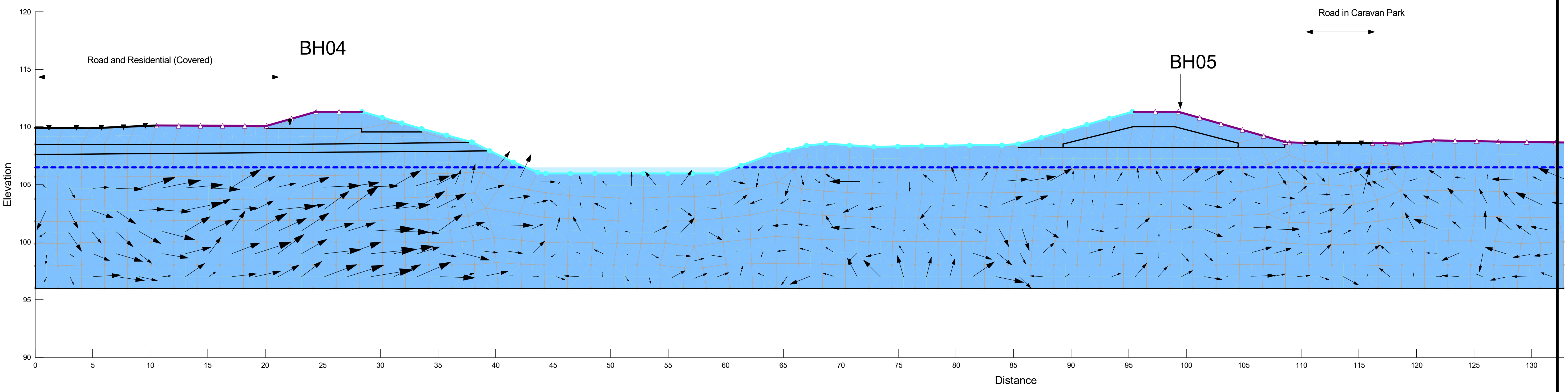
21/10/2024 1:400

Kind: SEEP/W
Analysis Type: Steady-State
Elapsed Time: 0 d

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟩	[Alluvium] SILT	Saturated / Unsaturated	[Alluvium] SILT	[Alluvium] SILT	1	0
🟨	[Fill] Sandy GRAVEL	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0
⬜	New Stopbank	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
⬛	No Flow	Hydraulic	Water Flux	0 m/sec
🟦	NWL - Steady State	Hydraulic	Water Total Head	106.495 m

Water Total Head
- 🟦 106.495 - 106.995 m
- 🟥 106.995 - 107.495 m



NWL - Steady State

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

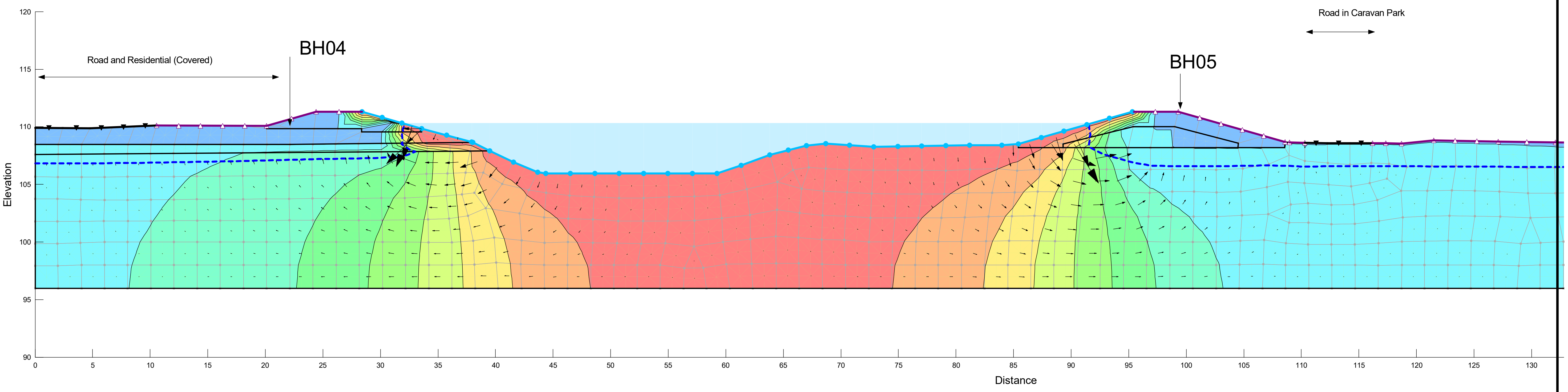
21/10/2024 1:350

Kind: SEEP/W
Analysis Type: Transient
Elapsed Time: 0.319444 d

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟩	[Alluvium] SILT	Saturated / Unsaturated	[Alluvium] SILT	[Alluvium] SILT	1	0
🟨	[Fill] Sandy GRAVEL	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0
⬜	New Stopbank	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
⬛	No Flow	Hydraulic	Water Flux	0 m/sec
🟦	Storm Hydrograph	Hydraulic	Water Total Head	1%+CC Storm Hydrograph

Water Total Head
- 🟦 106 - 106.5 m
- 🟦 106.5 - 107 m
- 🟩 107 - 107.5 m
- 🟩 107.5 - 108 m
- 🟩 108 - 108.5 m
- 🟨 108.5 - 109 m
- 🟨 109 - 109.5 m
- 🟧 109.5 - 110 m
- 🟥 110 - 110.5 m



1%+CC - Hydrograph

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

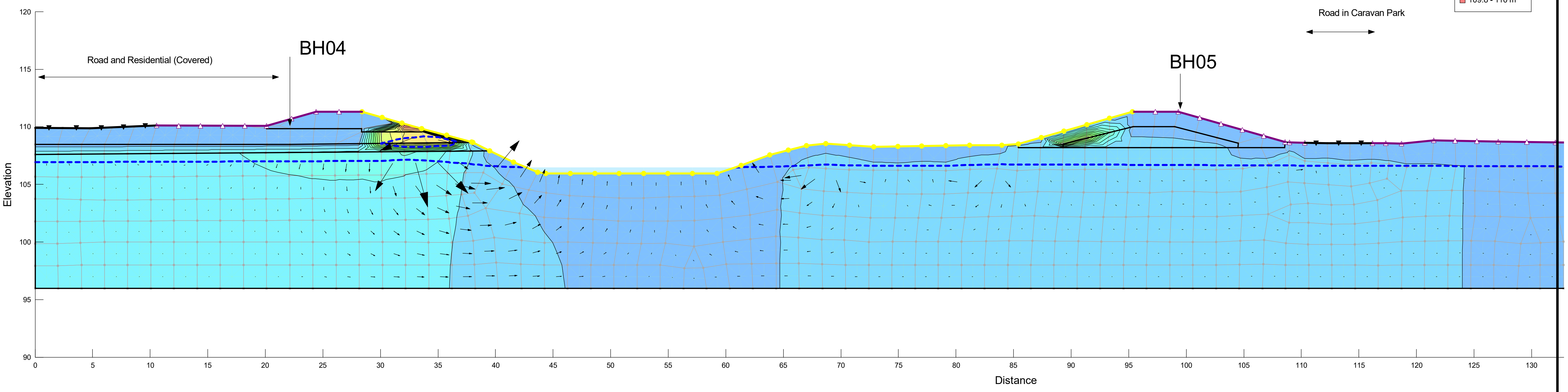
21/10/2024 1:350

Kind: SEEP/W
Analysis Type: Transient
Elapsed Time: 0.6875 d

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟩	[Alluvium] SILT	Saturated / Unsaturated	[Alluvium] SILT	[Alluvium] SILT	1	0
🟨	[Fill] Sandy GRAVEL	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0
▨	New Stopbank	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
⬛	No Flow	Hydraulic	Water Flux	0 m/sec
🟨	Rapid Drawdown Hydrograph	Hydraulic	Water Total Head	Rapid Drawdown Hydrograph

Water Total Head
- 🟦 106.4 - 106.6 m
- 🟦 106.6 - 106.8 m
- 🟦 106.8 - 107 m
- 🟦 107 - 107.2 m
- 🟩 107.2 - 107.4 m
- 🟩 107.4 - 107.6 m
- 🟩 107.6 - 107.8 m
- 🟩 107.8 - 108 m
- 🟩 108 - 108.2 m
- 🟩 108.2 - 108.4 m
- 🟩 108.4 - 108.6 m
- 🟨 108.6 - 108.8 m
- 🟨 108.8 - 109 m
- 🟨 109 - 109.2 m
- 🟧 109.2 - 109.4 m
- 🟧 109.4 - 109.6 m
- 🟥 109.6 - 109.8 m
- 🟥 109.8 - 110 m



RDD - Hydrograph

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

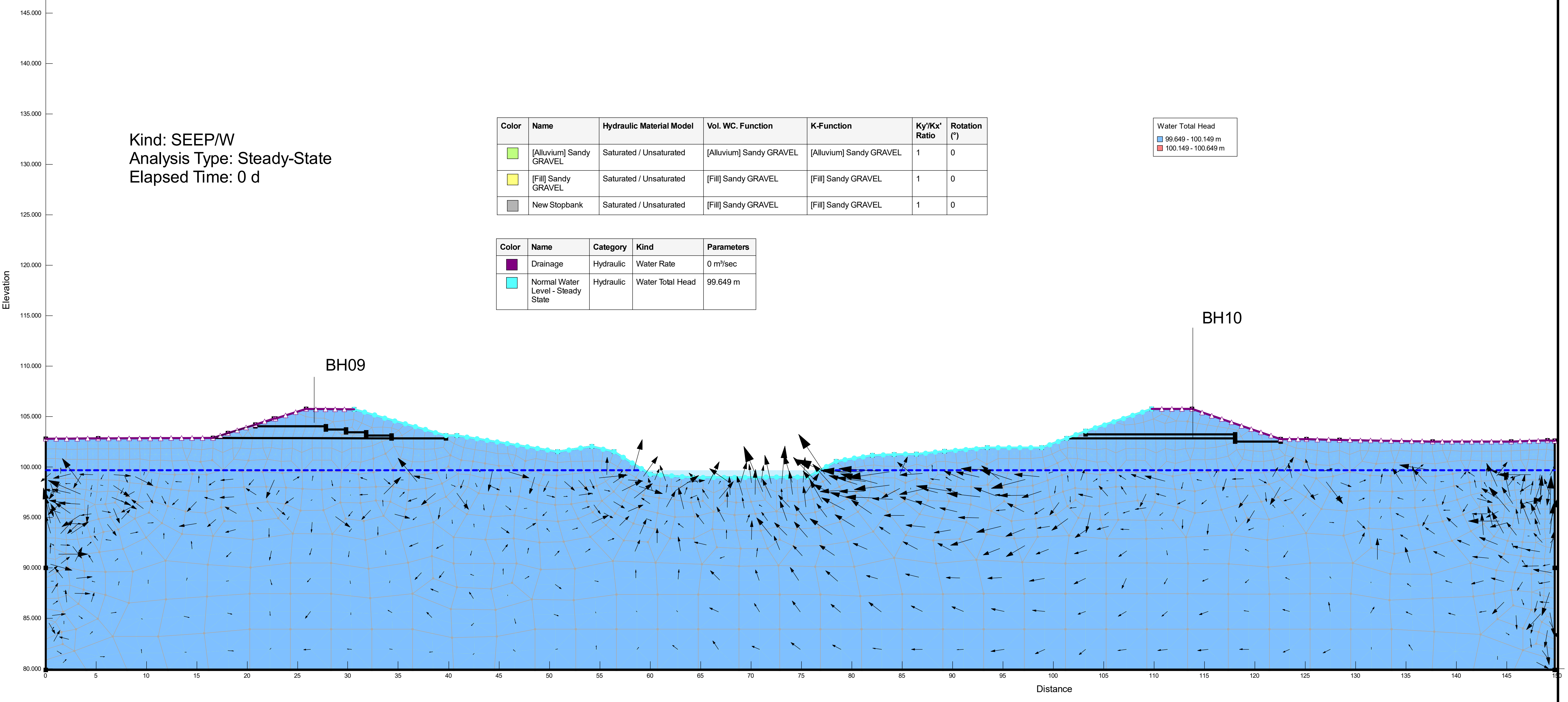
21/10/2024 1:350

Kind: SEEP/W
Analysis Type: Steady-State
Elapsed Time: 0 d

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟨	[Fill] Sandy GRAVEL	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0
⬜	New Stopbank	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
🟦	Normal Water Level - Steady State	Hydraulic	Water Total Head	99.649 m

Water Total Head
- 🟦 99.649 - 100.149 m
- 🟥 100.149 - 100.649 m



NWL - Steady State

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

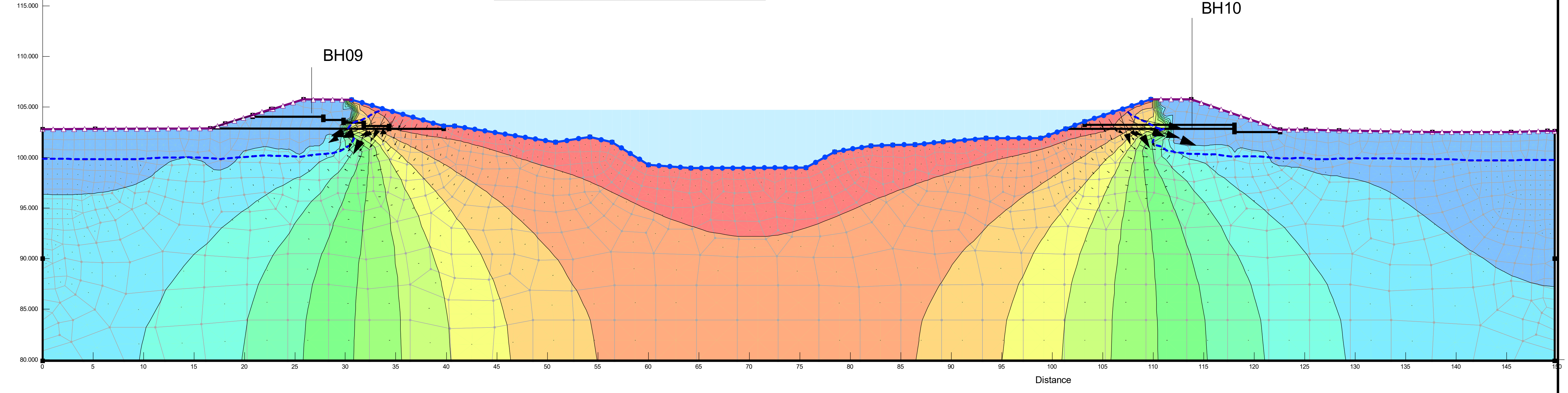
18/10/2024 1:400

Kind: SEEP/W
Analysis Type: Transient
Elapsed Time: 0.319444 d

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟨	[Fill] Sandy GRAVEL	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0
▨	New Stopbank	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
🟦	Flood hydrograph - Section C	Hydraulic	Water Total Head	Section C Storm Hydrograph

Water Total Head
- 99.5 - 100 m
- 100 - 100.5 m
- 100.5 - 101 m
- 101 - 101.5 m
- 101.5 - 102 m
- 102 - 102.5 m
- 102.5 - 103 m
- 103 - 103.5 m
- 103.5 - 104 m
- 104 - 104.5 m
- 104.5 - 105 m



1%+CC Hydrograph

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

18/10/2024 1:400

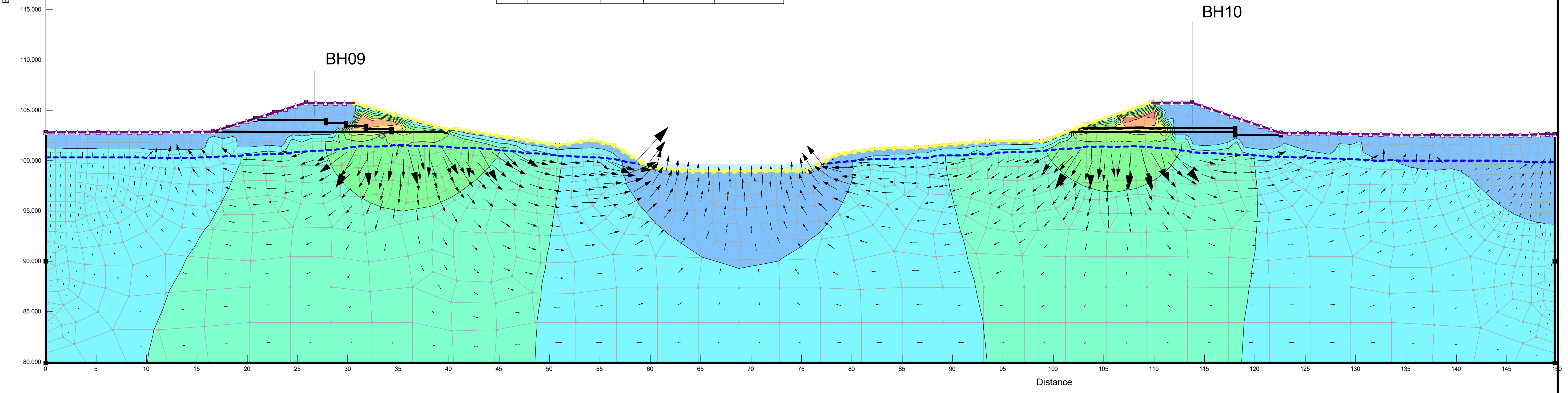
Kind: SEEP/W
Analysis Type: Transient
Elapsed Time: 0.6875 d

Color	Name	Hydraulic Material Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Rotation (°)
🟩	[Alluvium] Sandy GRAVEL	Saturated / Unsaturated	[Alluvium] Sandy GRAVEL	[Alluvium] Sandy GRAVEL	1	0
🟨	[Fill] Sandy GRAVEL	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0
⬜	New Stopbank	Saturated / Unsaturated	[Fill] Sandy GRAVEL	[Fill] Sandy GRAVEL	1	0

Color	Name	Category	Kind	Parameters
🟪	Drainage	Hydraulic	Water Rate	0 m³/sec
🟨	Rapid Drawdown hydrograph - Section C	Hydraulic	Water Total Head	Section C Rapid Drawdown Hydrograph

Water Total Head

🟦	99.5 - 100 m
🟦	100 - 100.5 m
🟩	100.5 - 101 m
🟩	101 - 101.5 m
🟩	101.5 - 102 m
🟨	102 - 102.5 m
🟨	102.5 - 103 m
🟧	103 - 103.5 m
🟥	103.5 - 104 m



RDD Hydrograph

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

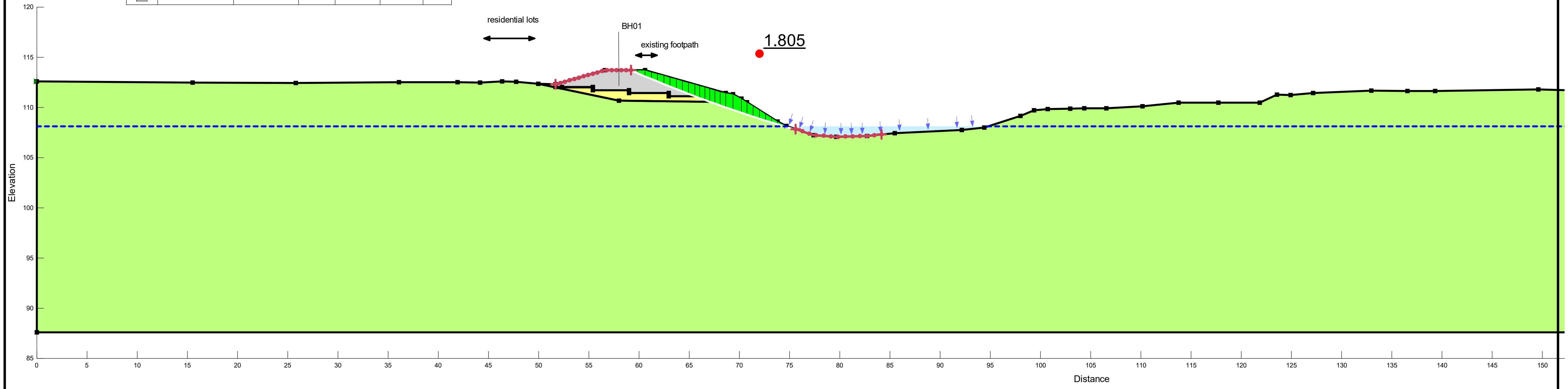
18/10/2024 1:400

APPENDIX 5:

Stability Analysis Outputs

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



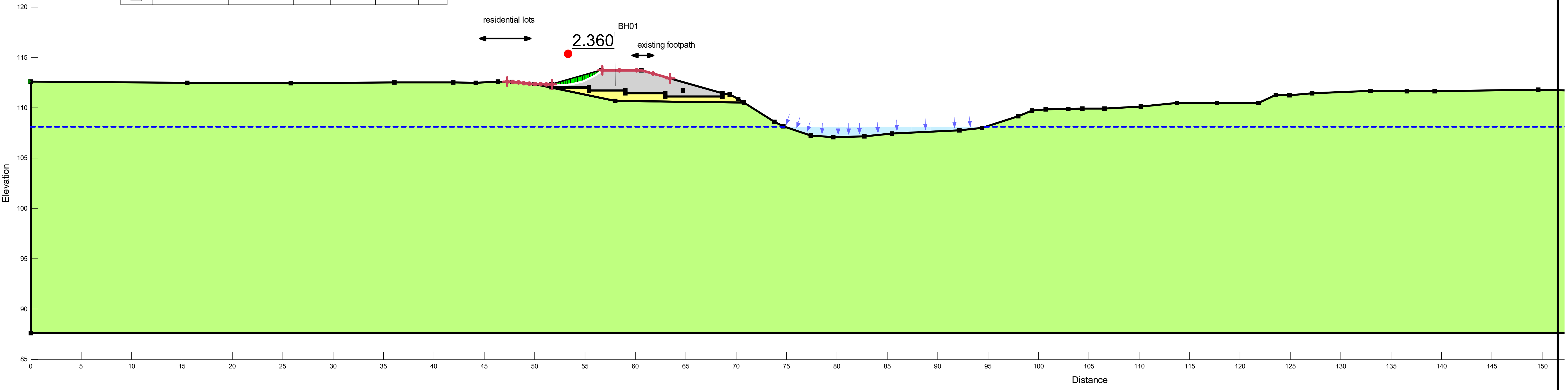
NWL Static Upstream

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



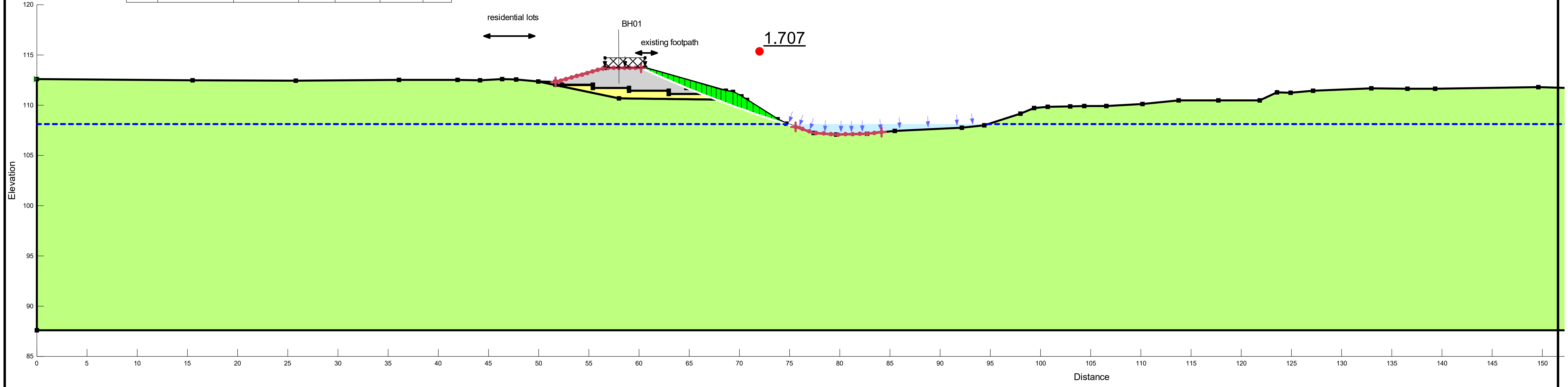
NWL Static Downstream

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



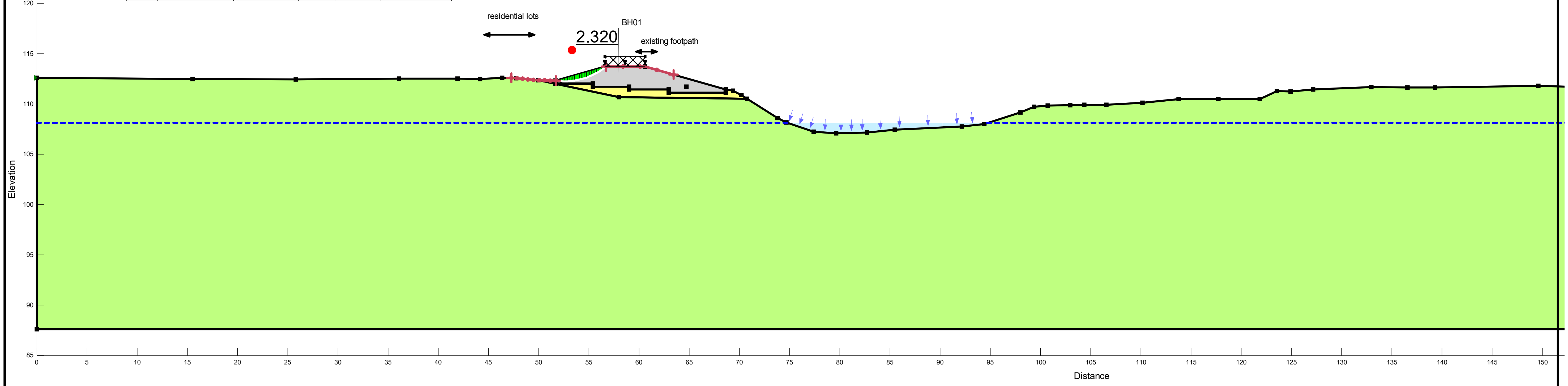
NWL Static Upstream with Surcharge

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



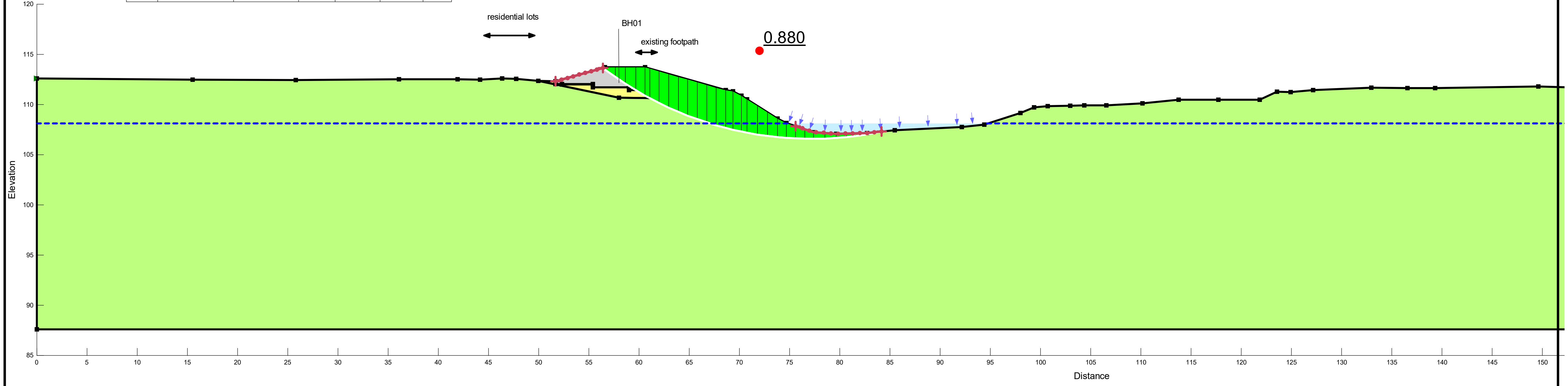
NWL Static Downstream with Surcharge

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

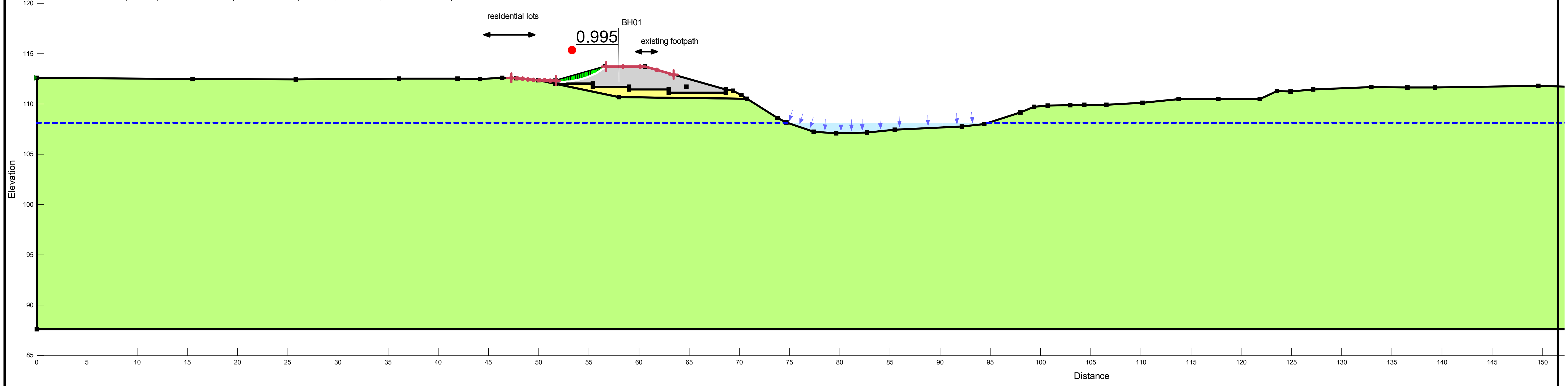
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



NWL Seismic OBE Upstream
Waipoua Stopbank Assessment - Section A_western bank.gsz
21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



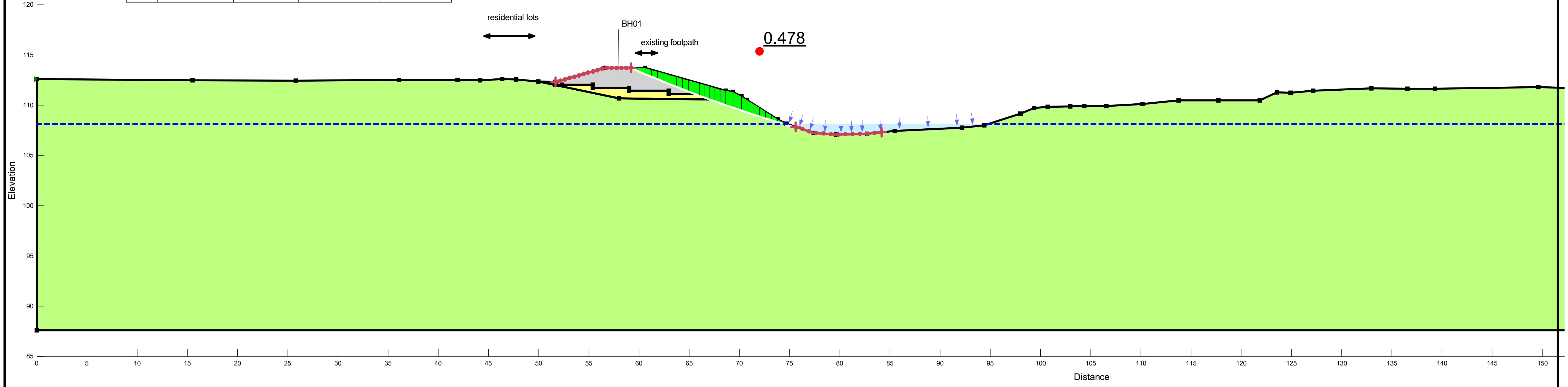
NWL Seismic OBE Downstream

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

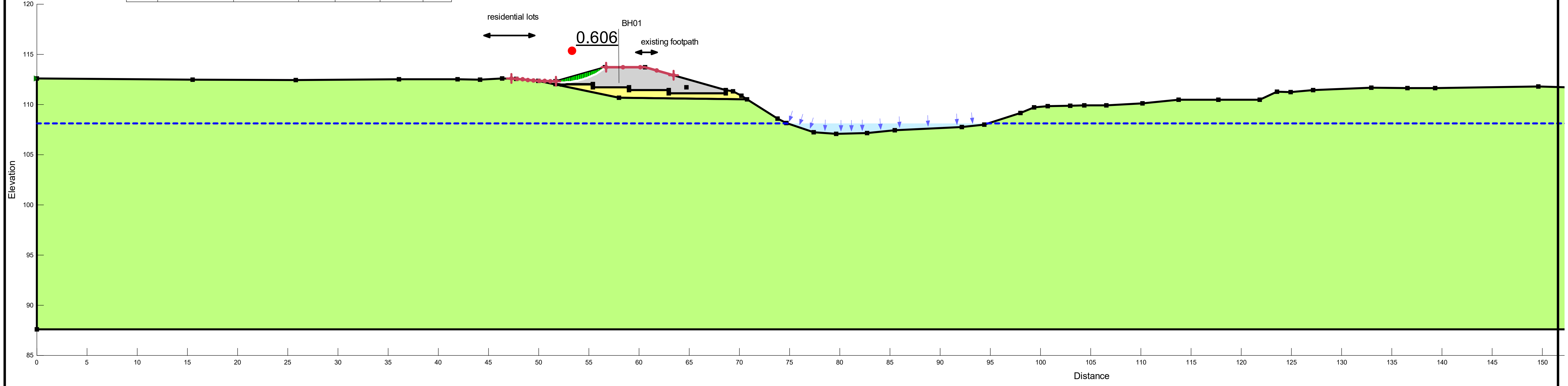
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



NWL Seismic SEE Upstream	
Waipoua Stopbank Assessment - Section A_western bank.gsz	
21/10/2024	1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



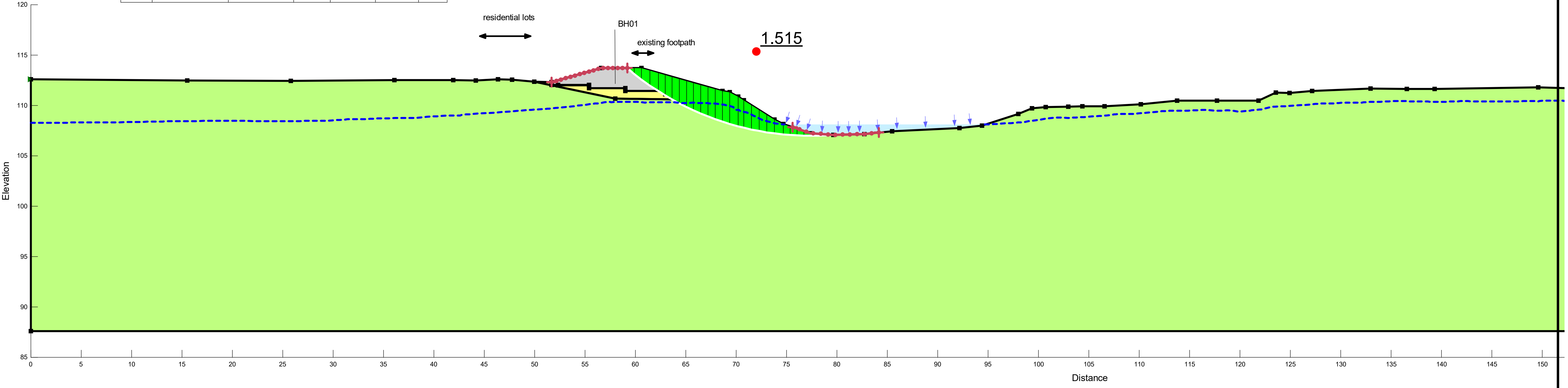
NWL Seismic SEE Downstream

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



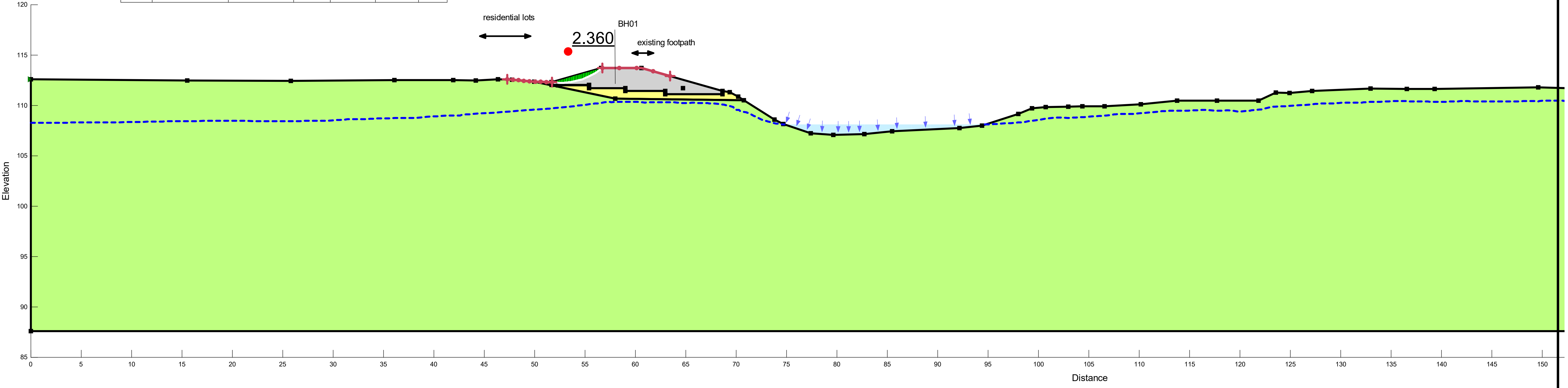
Storm Static Upstream

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



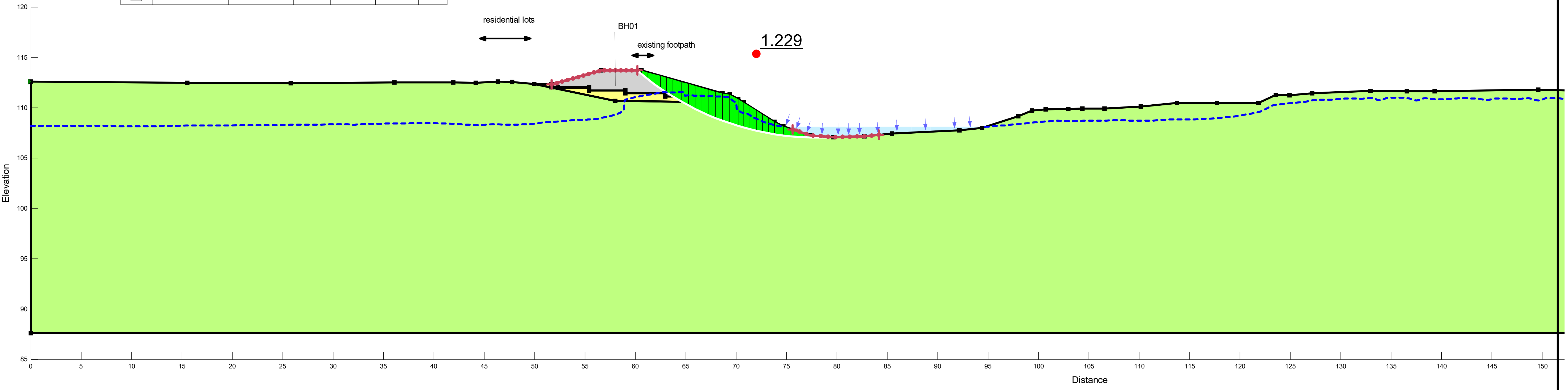
Storm Static Downstream

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] GRAVEL with some sand	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



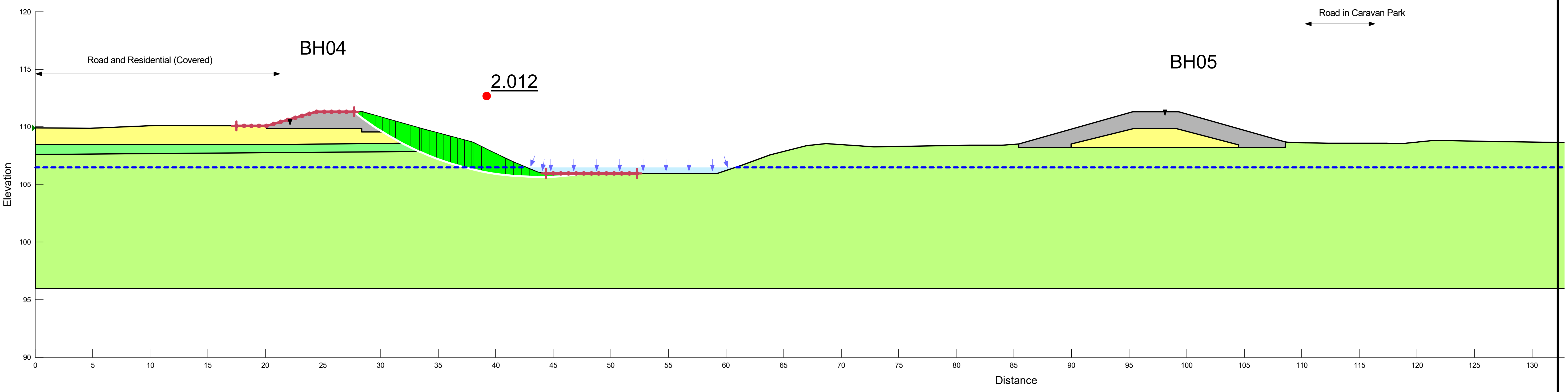
RDD Static Upstream

Waipoua Stopbank Assessment - Section A_western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



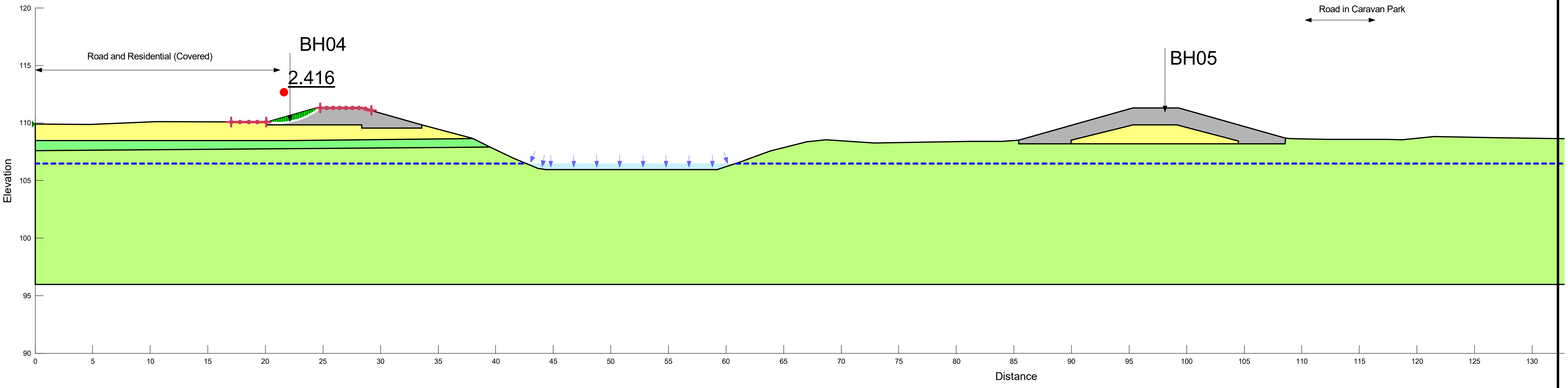
NWL - Static Upstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



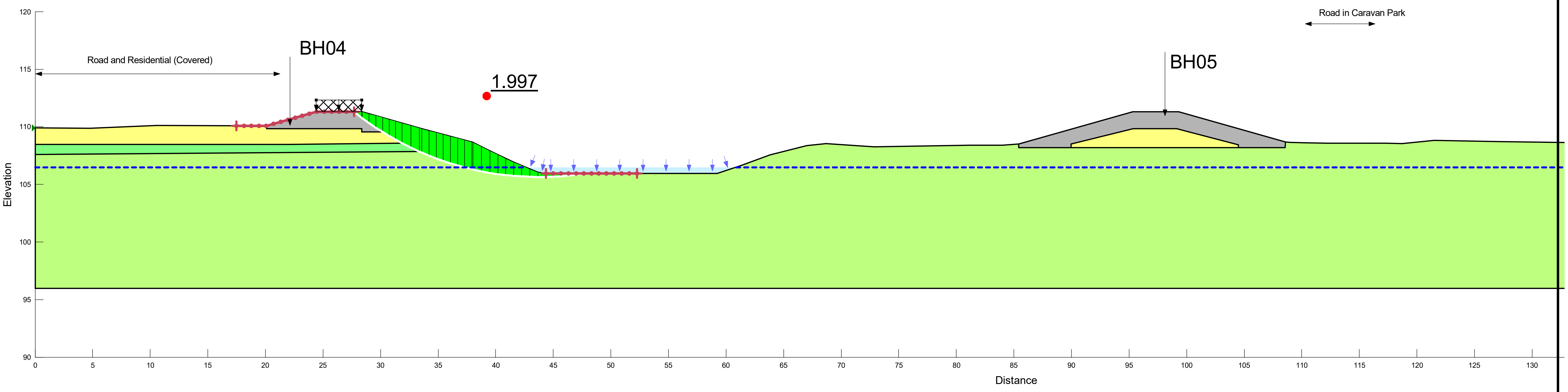
NWL - Static Downstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



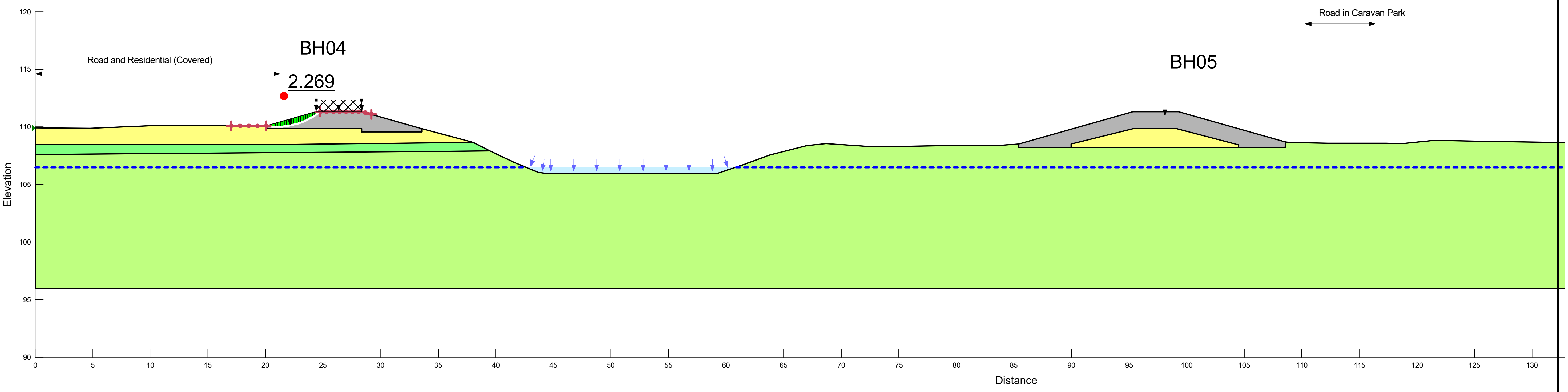
NWL - Static Upstream with surcharge

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



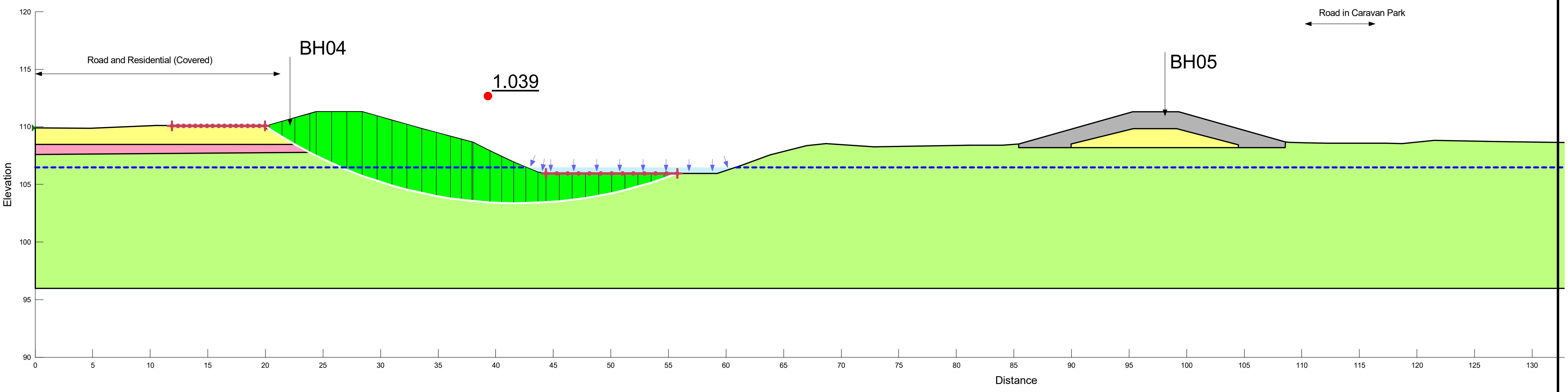
NWL - Static Downstream with surcharge

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

Color	Name	Slope Stability Material Model	Unit Weight (kN/m^3)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19		0	34	0
🟥	[Alluvium] SILT_undr	Undrained (Phi=0)	18	50			
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18		0	32	0
▨	New Stopbank	Mohr-Coulomb	18		0	32	0



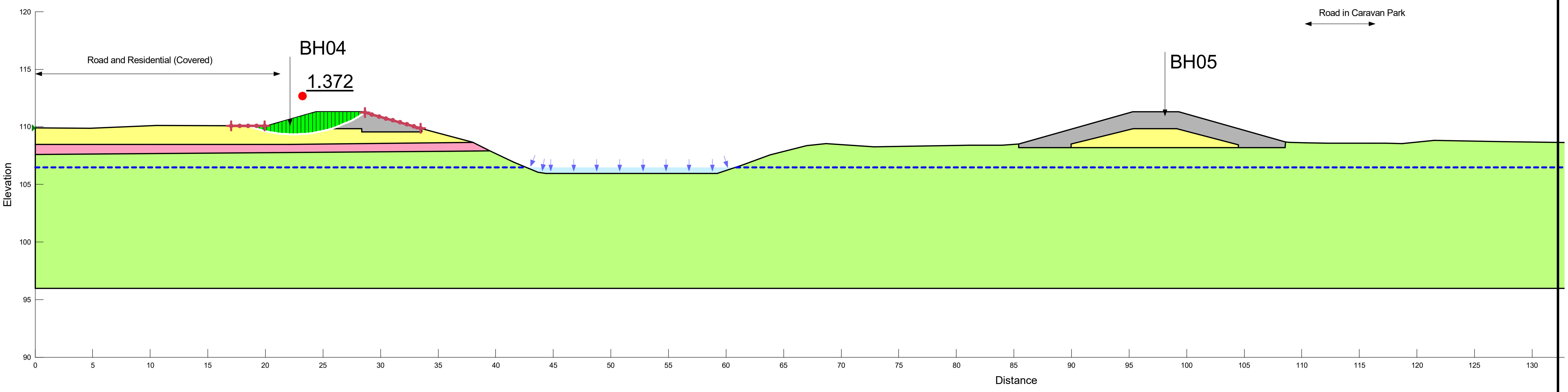
NWL - OBE Seismic Upstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19		0	34	0
🟥	[Alluvium] SILT_undr	Undrained (Phi=0)	18	50			
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18		0	32	0
⬛	New Stopbank	Mohr-Coulomb	18		0	32	0



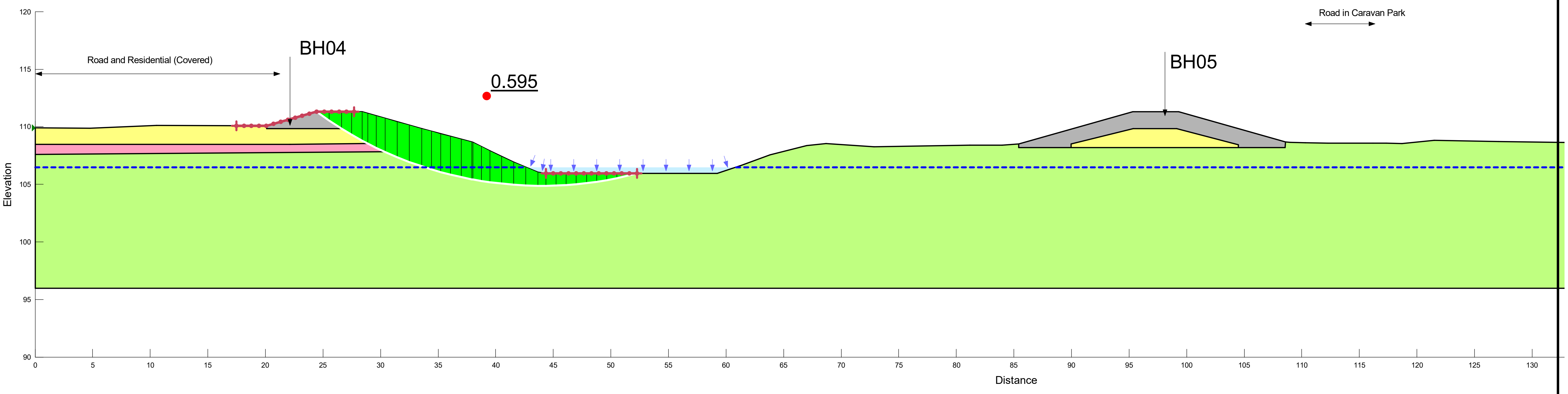
NWL - OBE Seismic Downstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19		0	34	0
🟥	[Alluvium] SILT_undr	Undrained (Phi=0)	18	50			
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18		0	32	0
▨	New Stopbank	Mohr-Coulomb	18		0	32	0



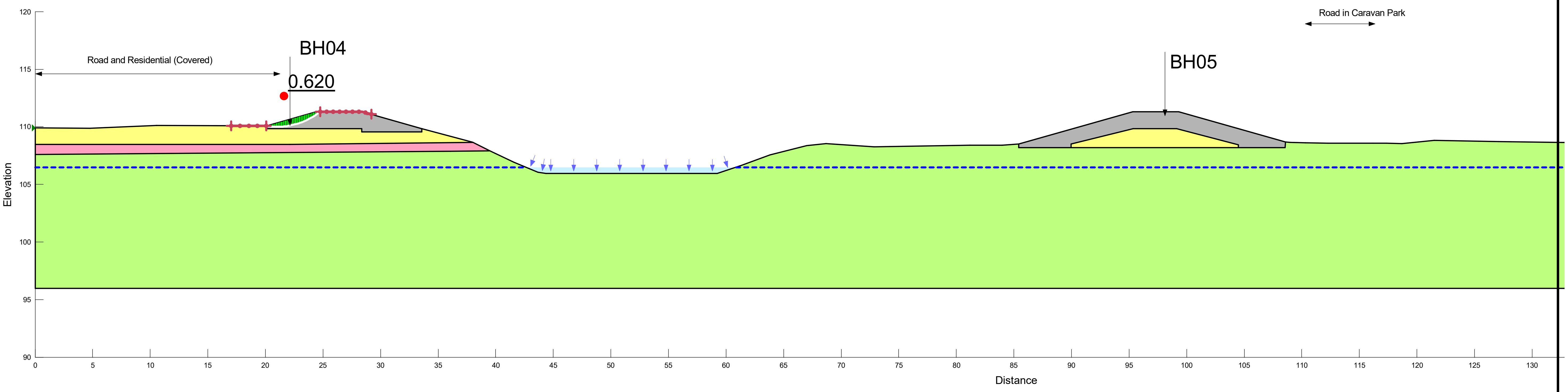
NWL - SEE Seismic Upstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19		0	34	0
🟥	[Alluvium] SILT_undr	Undrained (Phi=0)	18	50			
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18		0	32	0
⬜	New Stopbank	Mohr-Coulomb	18		0	32	0



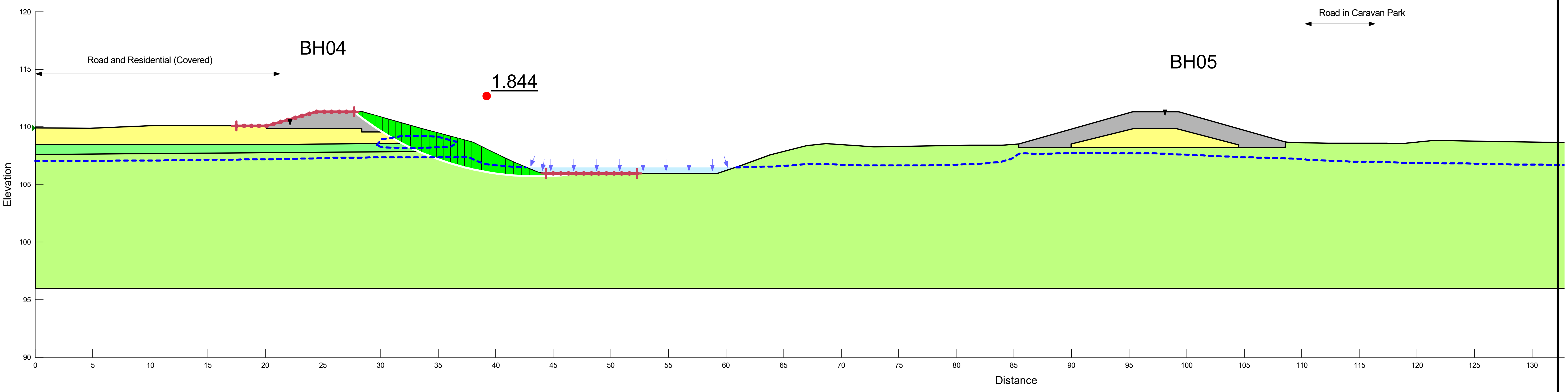
NWL - SEE Seismic Downstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



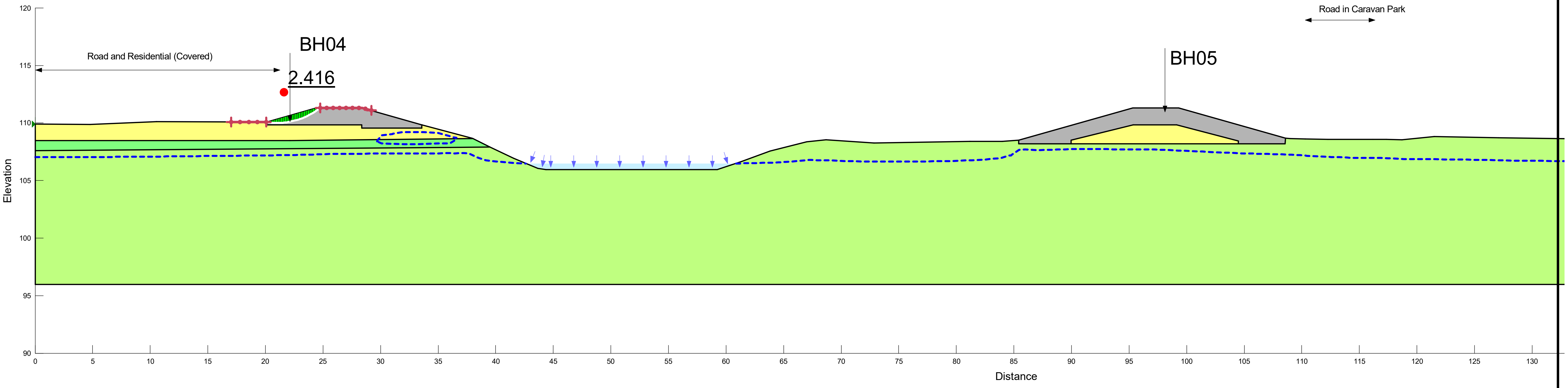
Storm - Upstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



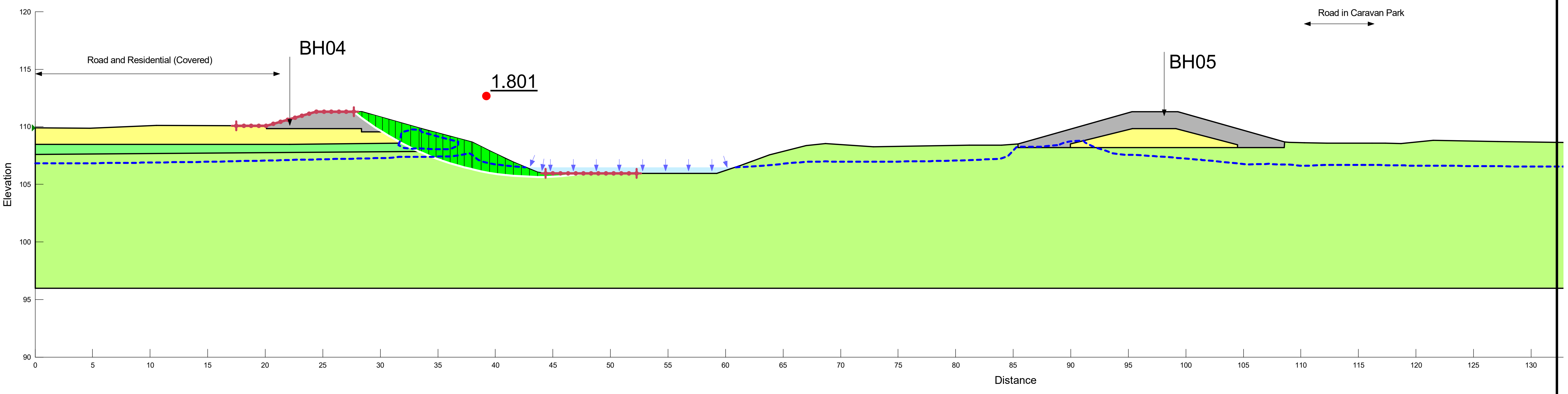
Storm - Downstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



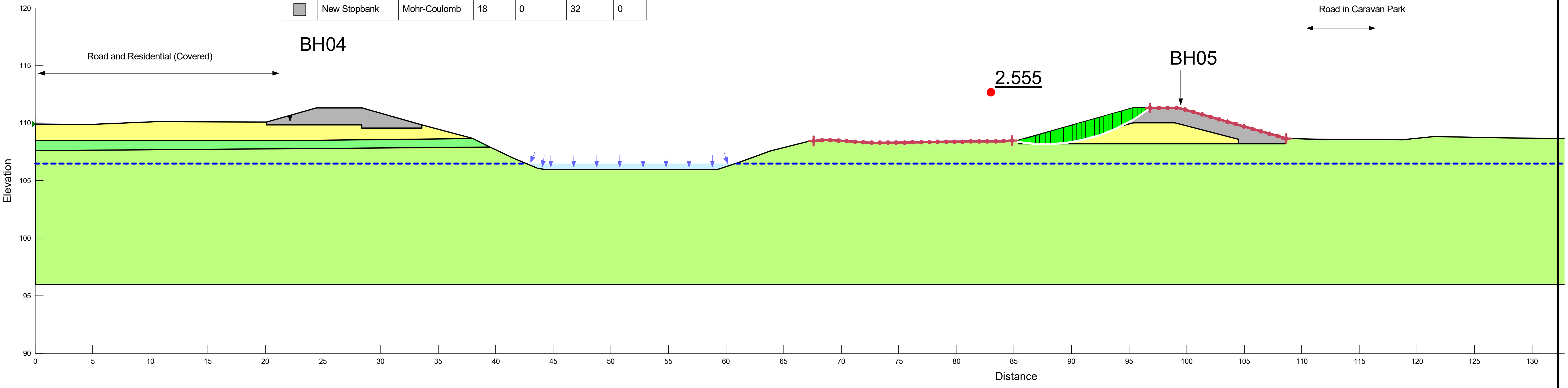
RDD - Upstream

Waipoua Stopbank Assessment - Section B_western bank.gsz

22/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



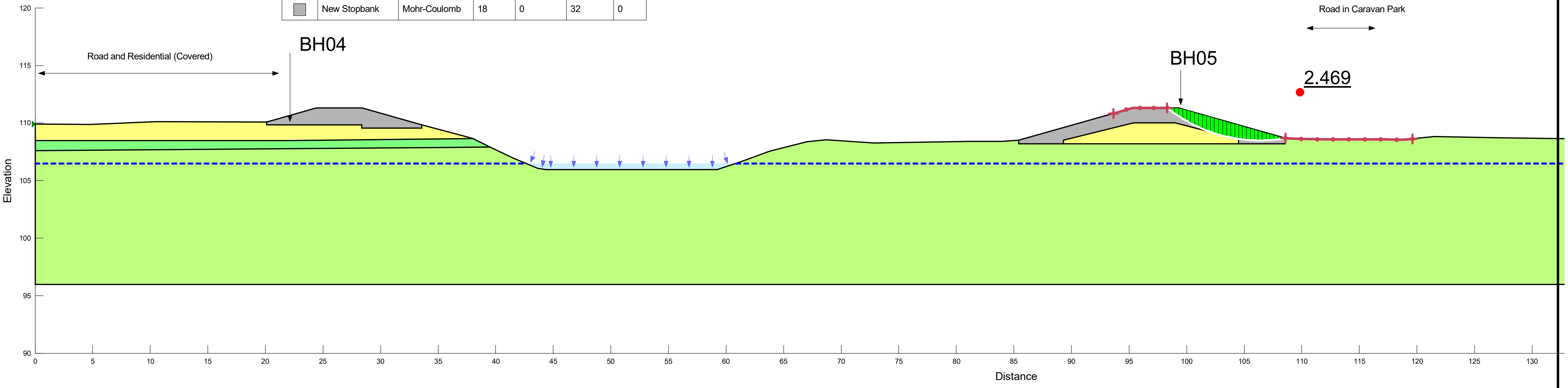
NWL - Static Upstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
◼	New Stopbank	Mohr-Coulomb	18	0	32	0



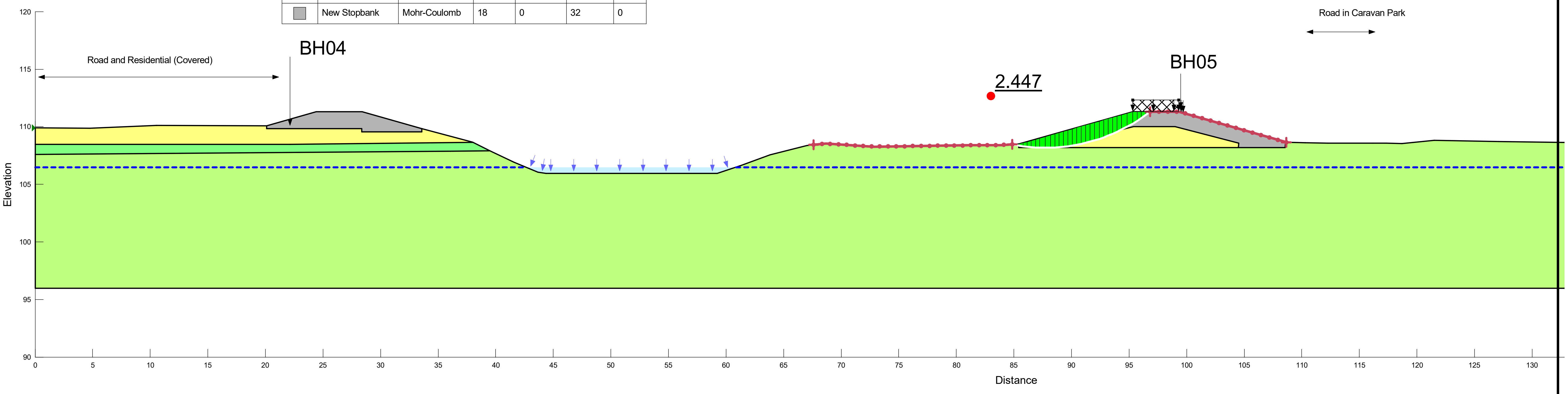
NWL - Static Downstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



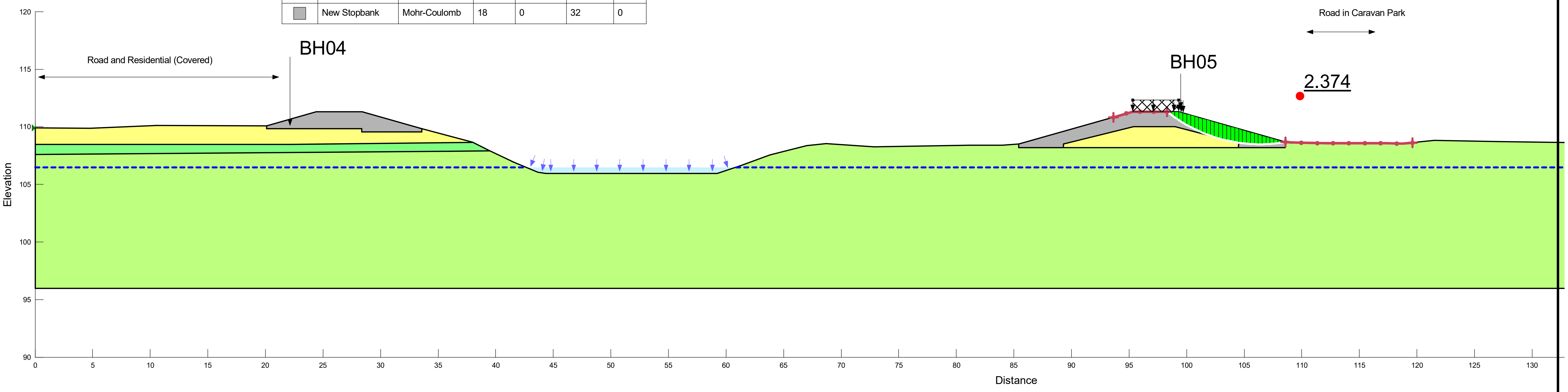
NWL - Static Upstream with surcharge

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬛	New Stopbank	Mohr-Coulomb	18	0	32	0



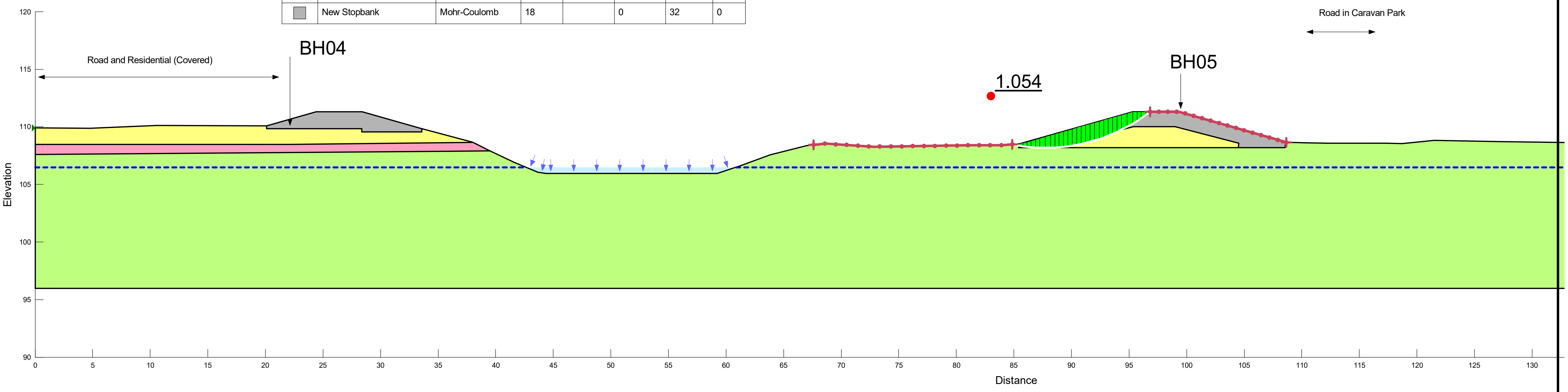
NWL - Static Downstream with surcharge

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19		0	34	0
🟥	[Alluvium] SILT_undr	Undrained (Phi=0)	18	50			
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18		0	32	0
⬜	New Stopbank	Mohr-Coulomb	18		0	32	0



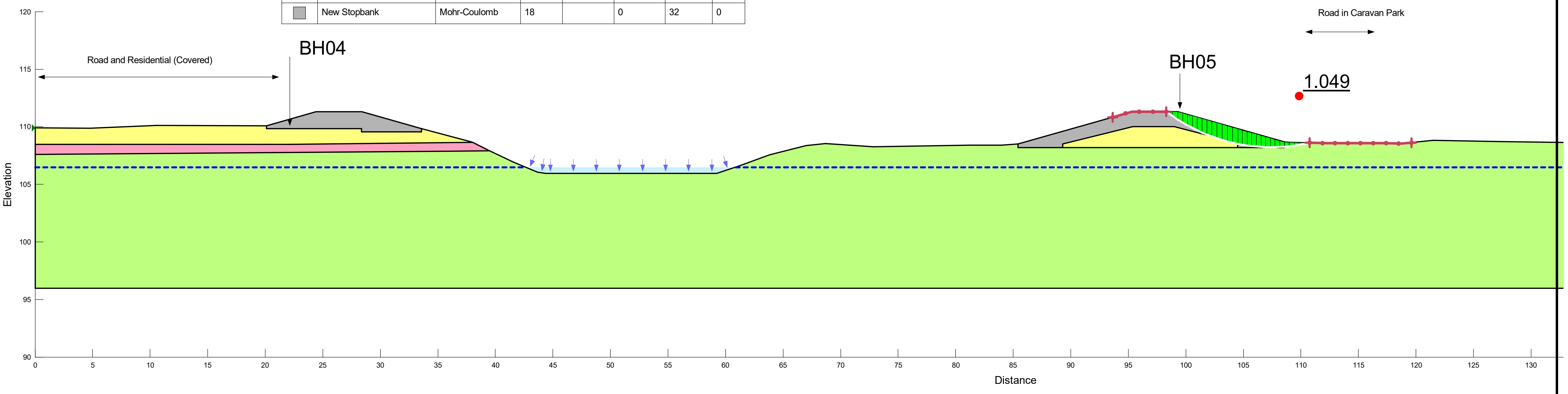
NWL - OBE Seismic Upstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19		0	34	0
🟥	[Alluvium] SILT_undr	Undrained (Phi=0)	18	50			
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18		0	32	0
▨	New Stopbank	Mohr-Coulomb	18		0	32	0



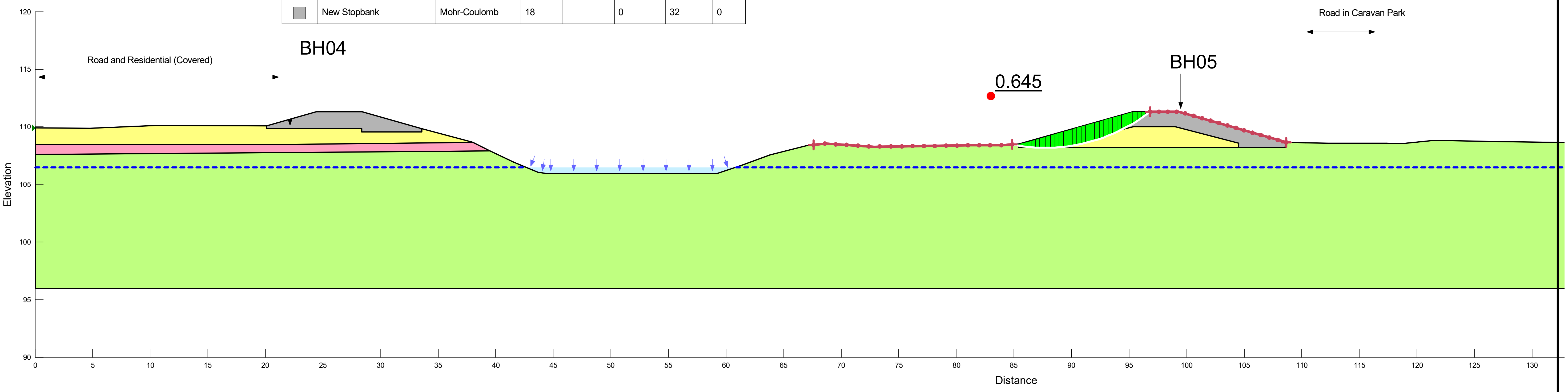
NWL - OBE Seismic Downstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19		0	34	0
🟥	[Alluvium] SILT_undr	Undrained (Phi=0)	18	50			
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18		0	32	0
▨	New Stopbank	Mohr-Coulomb	18		0	32	0



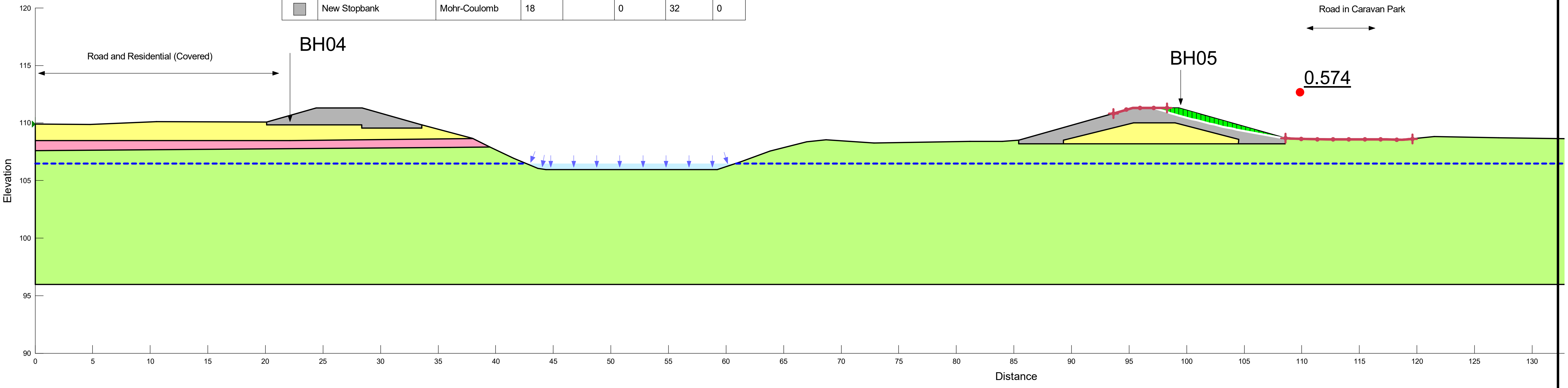
NWL - SEE Seismic Upstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19		0	34	0
🟥	[Alluvium] SILT_undr	Undrained (Phi=0)	18	50			
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18		0	32	0
⬜	New Stopbank	Mohr-Coulomb	18		0	32	0



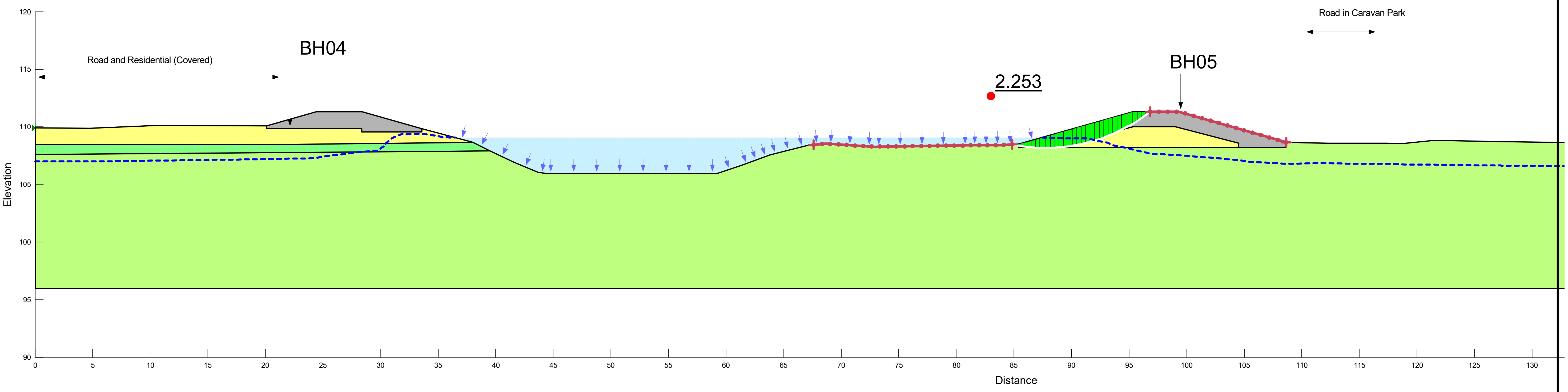
NWL - SEE Seismic Downstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



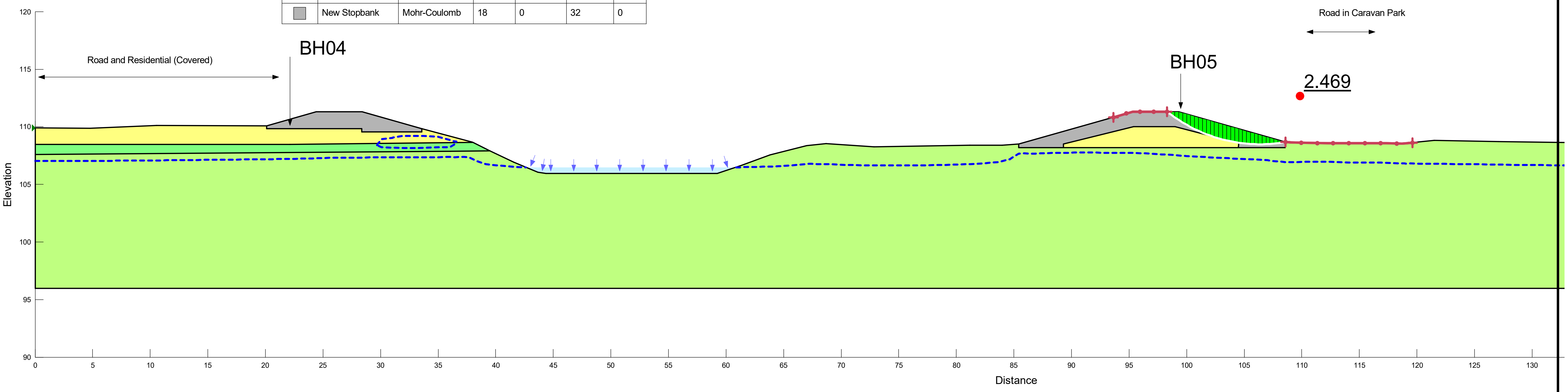
Storm - Upstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



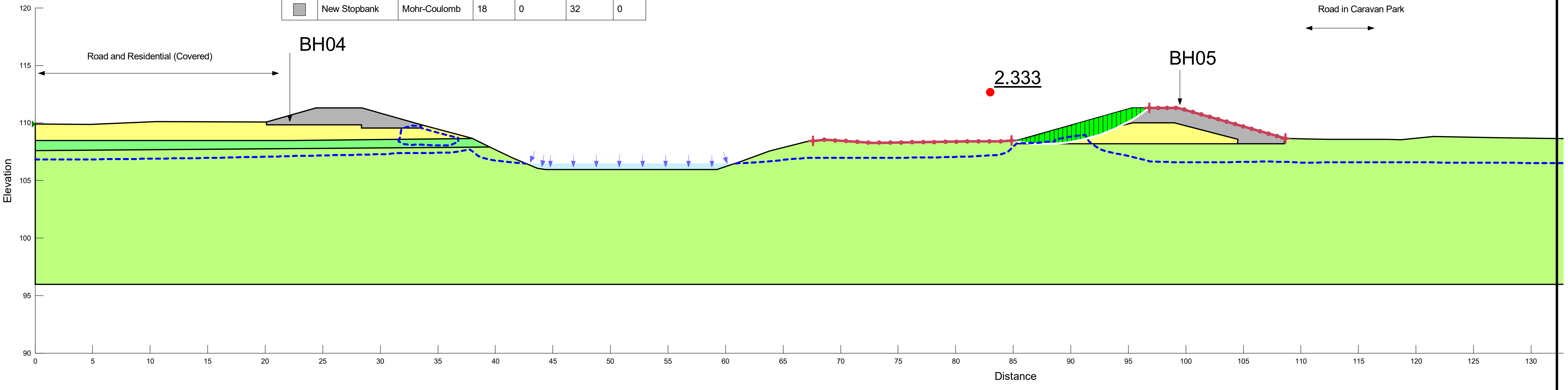
Storm - Downstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0

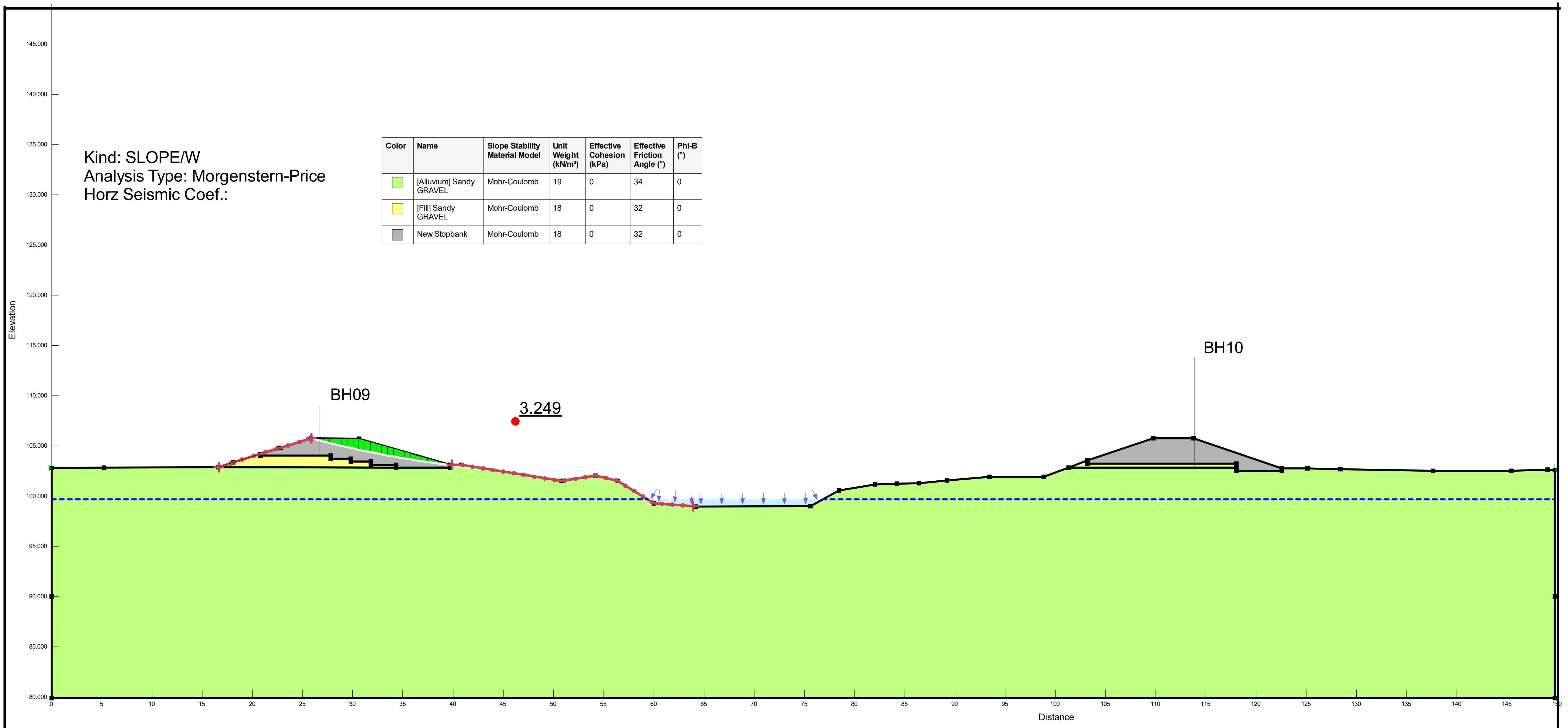
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟩	[Alluvium] SILT	Mohr-Coulomb	18	0	30	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



RDD - Upstream

Waipoua Stopbank Assessment - Section B_eastern bank.gsz

21/10/2024 1:350



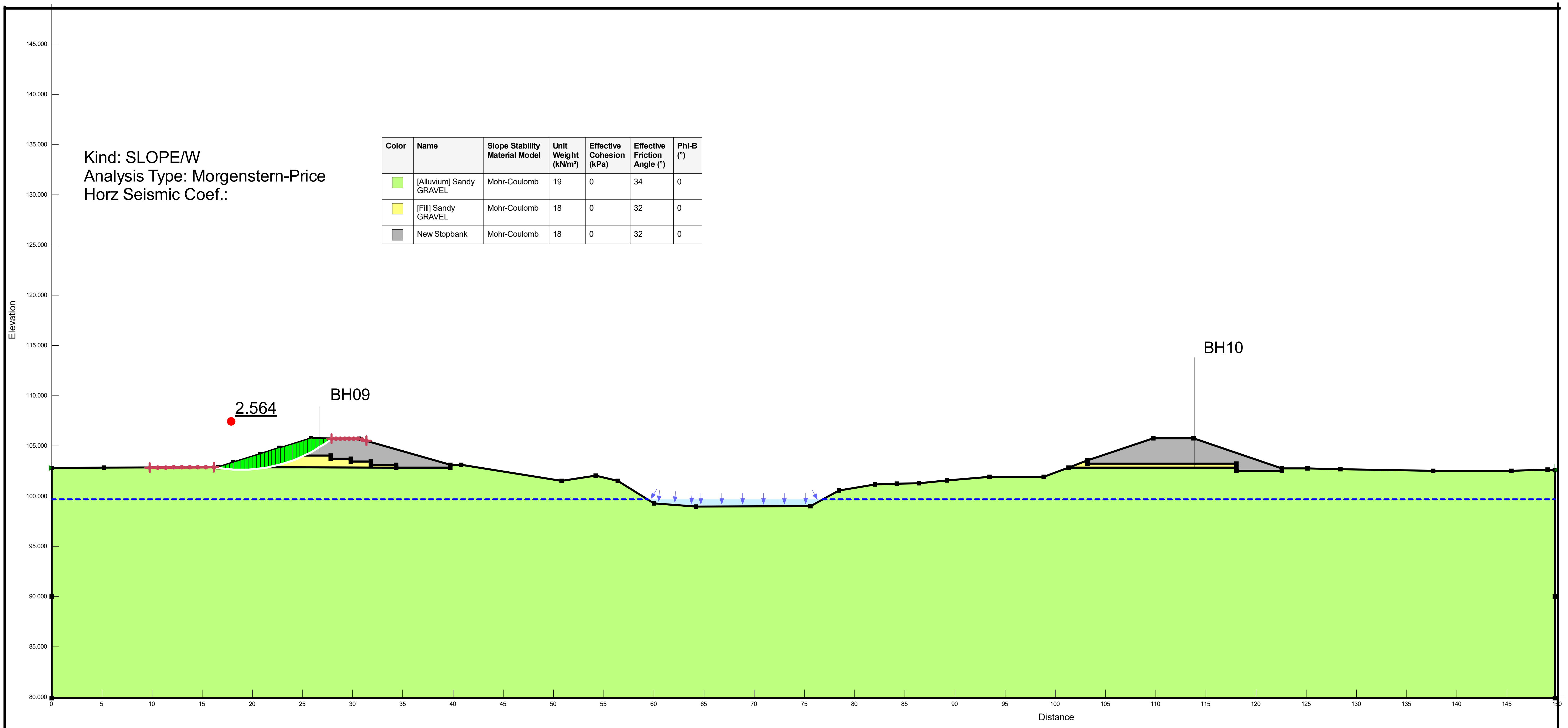
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0

NWL - Stability Upstream

Waipoua Stopbank Assessment - Section C western bank.gsz

21/10/2024 1:400



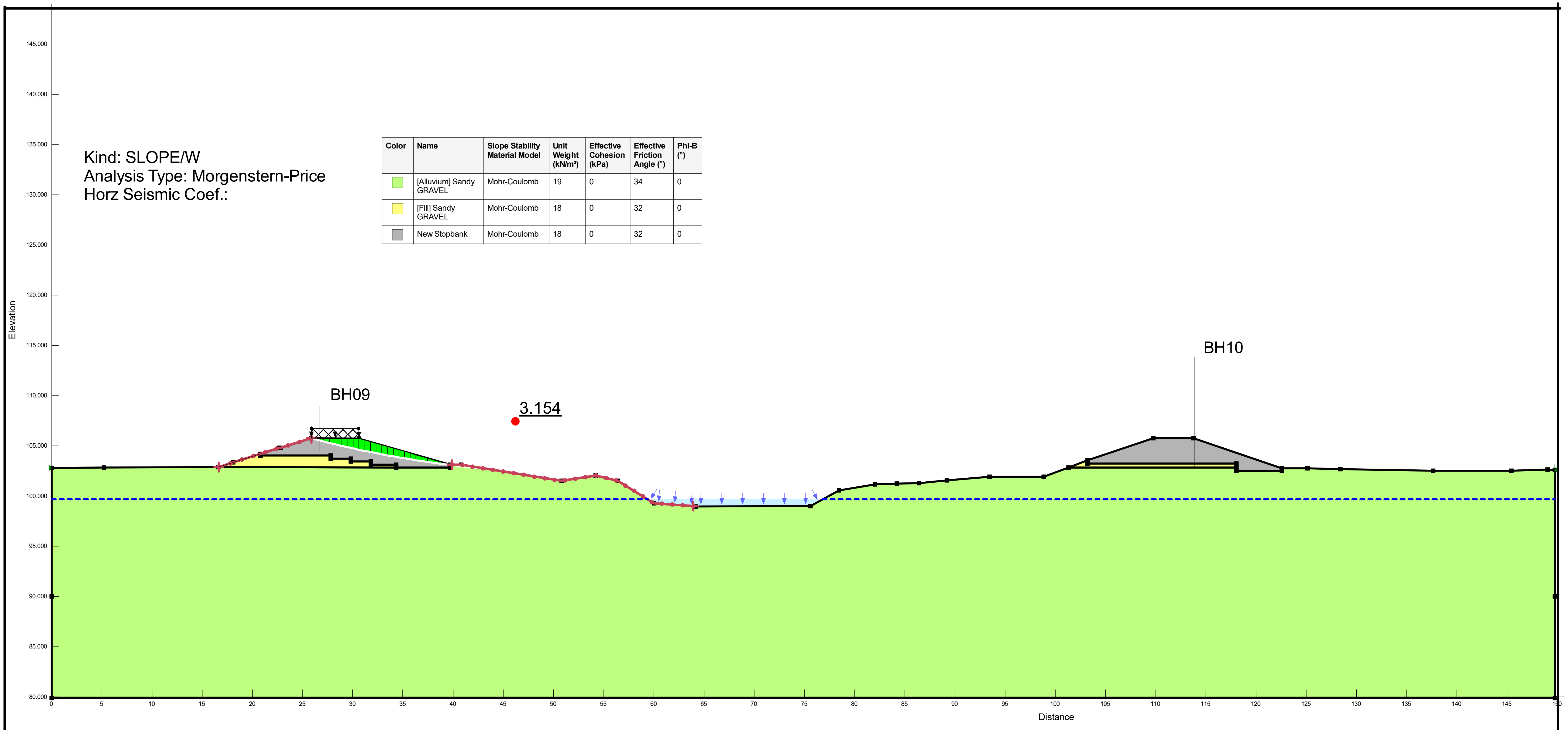
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0

NWL - Stability Downstream

Waipoua Stopbank Assessment - Section C western bank.gsz

18/10/2024 1:400



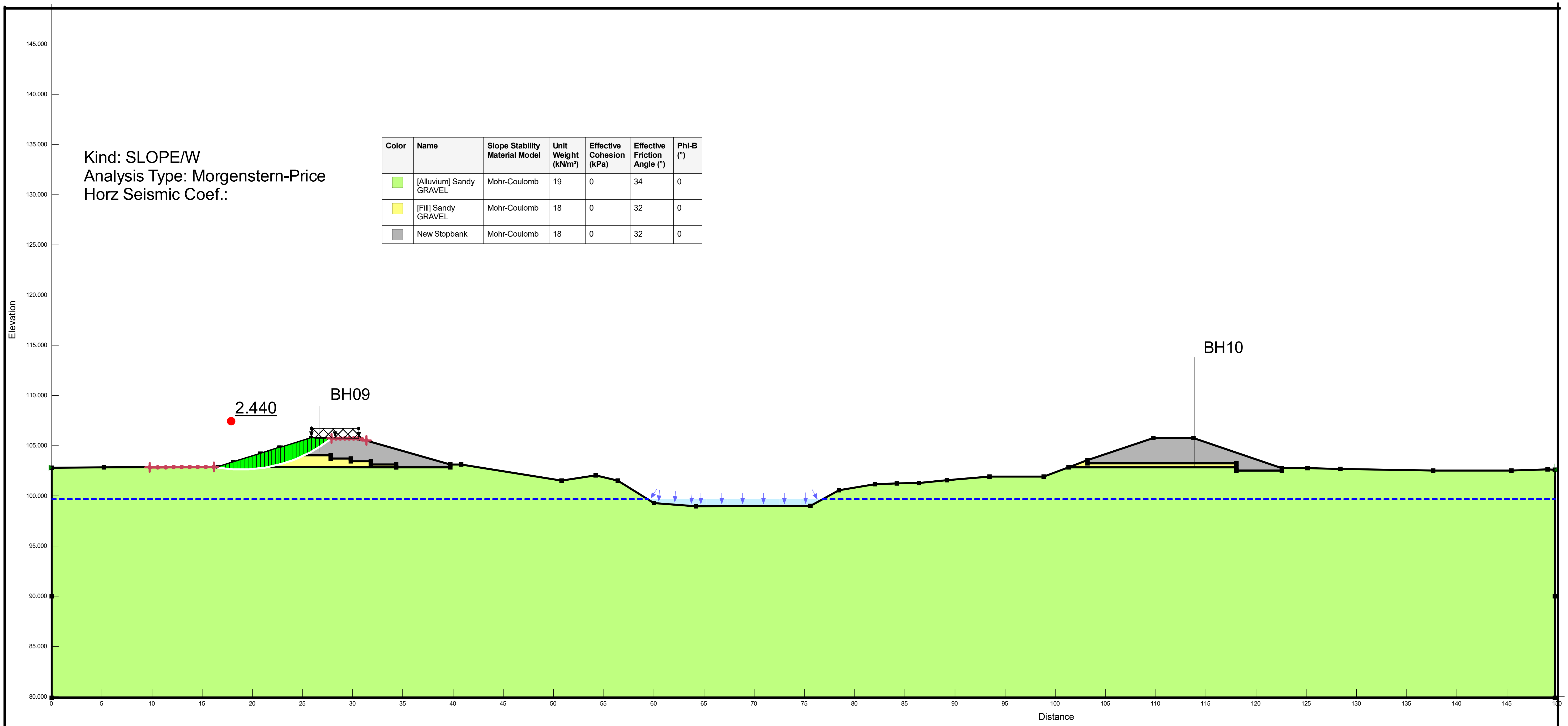
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0

NWL - Stability Upstream with surcharge

Waipoua Stopbank Assessment - Section C western bank.gsz

21/10/2024 1:400



Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0

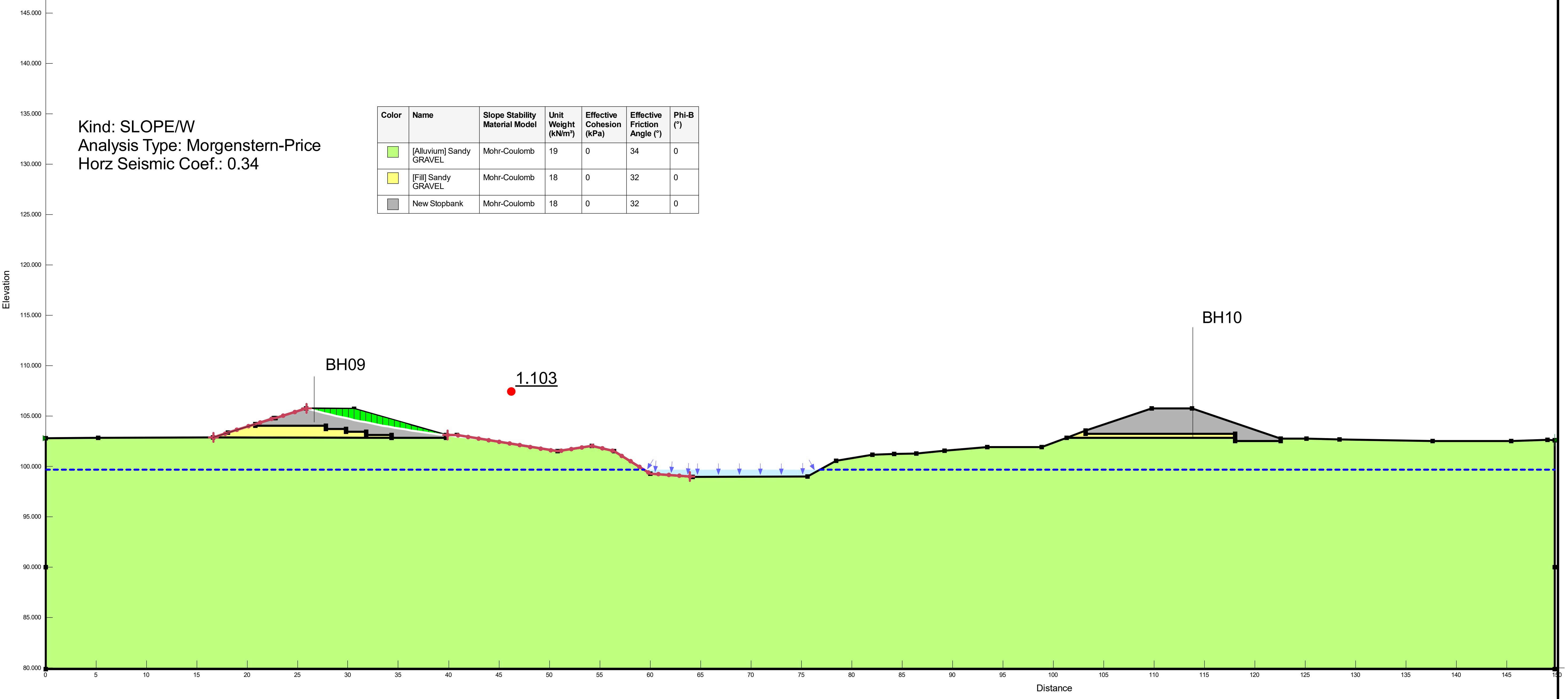
NWL - Stability Downstream with surcharge

Waipoua Stopbank Assessment - Section C western bank.gsz

18/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

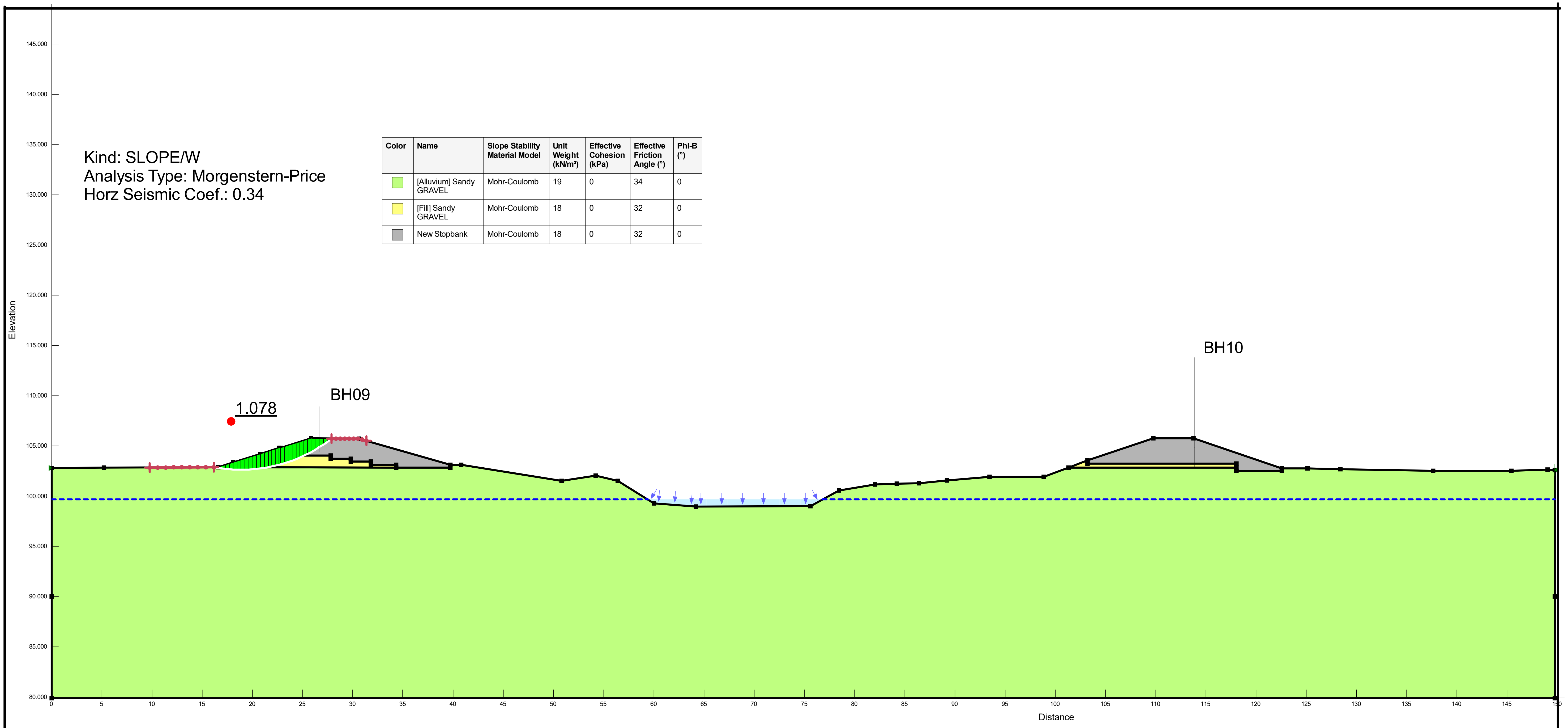
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



NWL - OBE Seis. Stability Upstream

Waipoua Stopbank Assessment - Section C western bank.gsz

21/10/2024 1:400



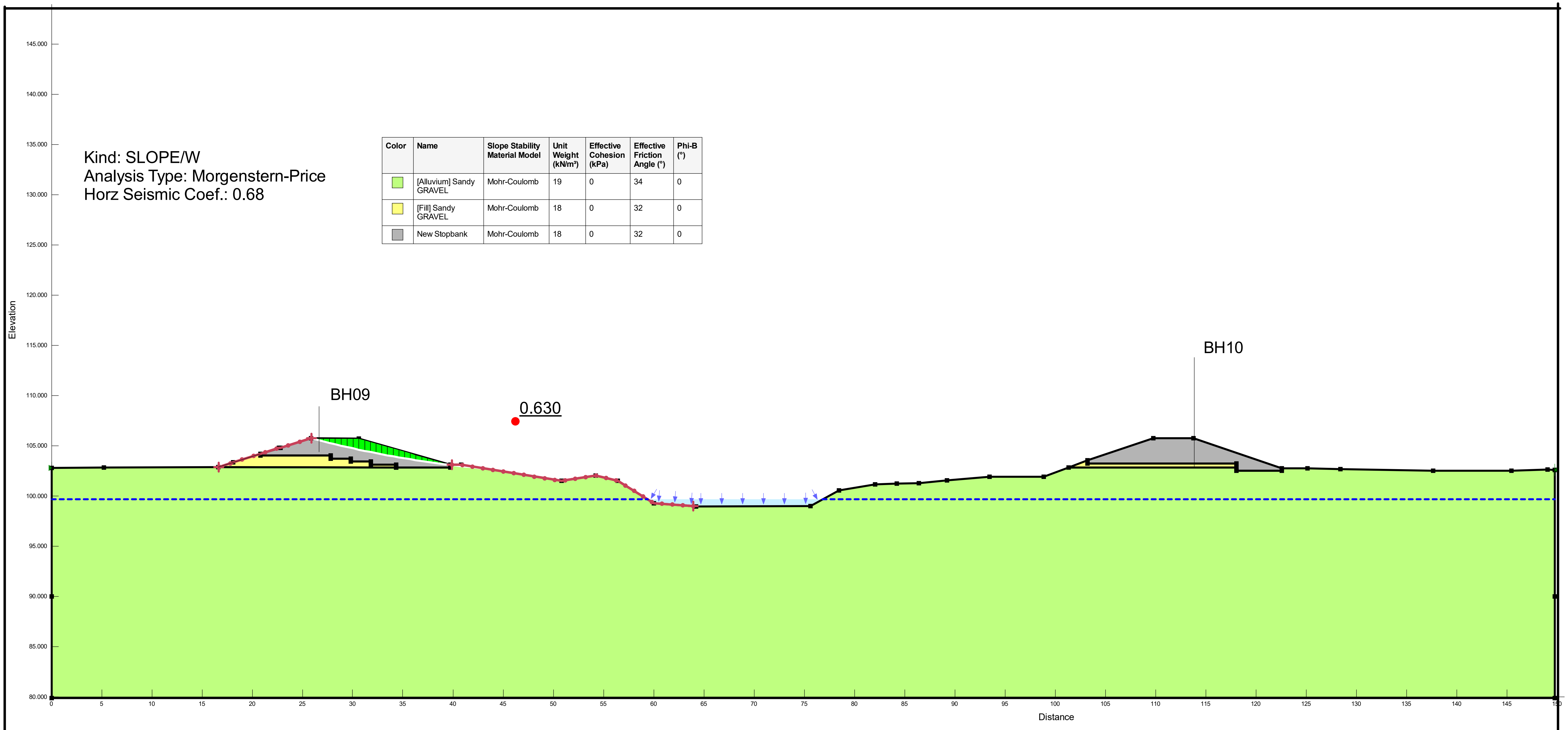
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0

NWL - OBE Seis. Stability Downstream

Waipoua Stopbank Assessment - Section C western bank.gsz

18/10/2024 1:400



Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0

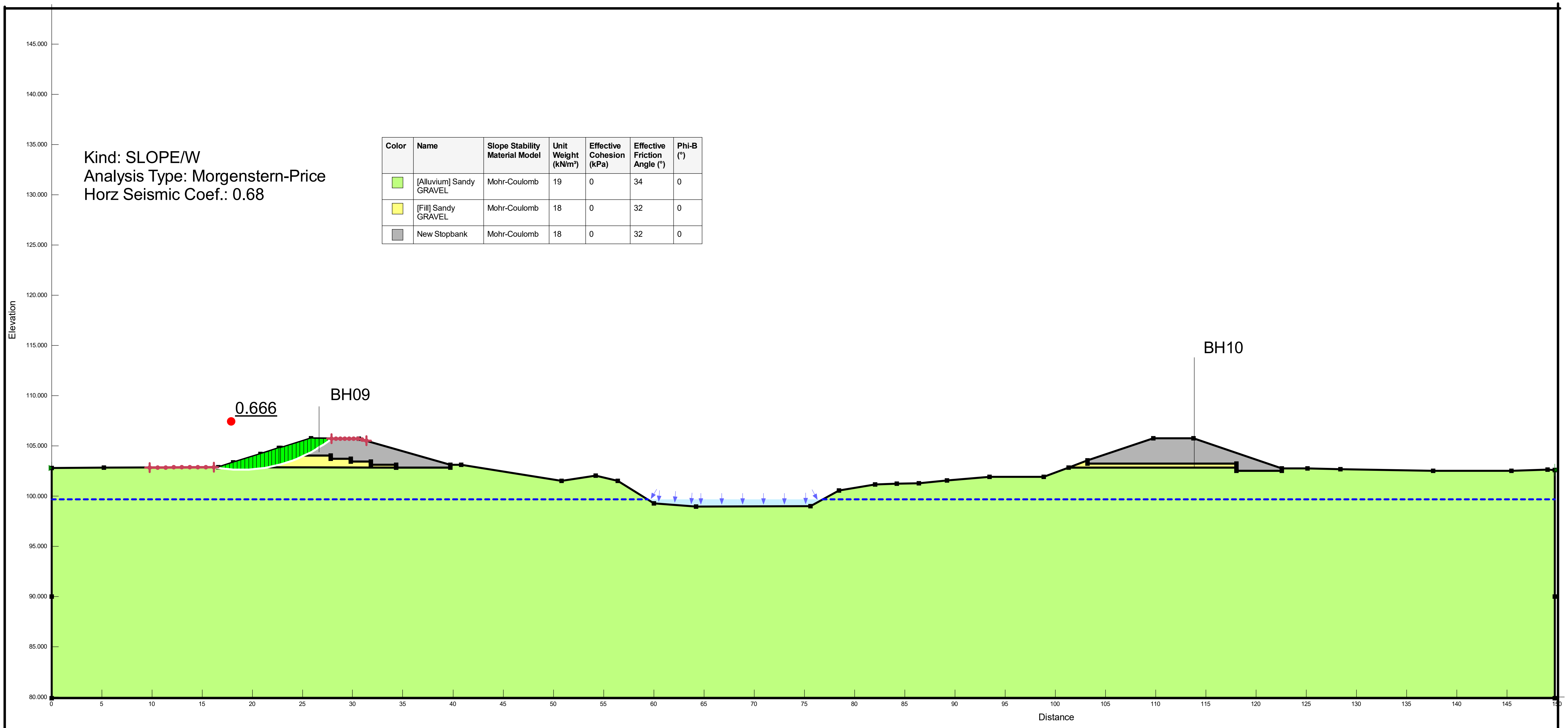
NWL - SEE Seis. Stability Upstream

Waipoua Stopbank Assessment - Section C western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

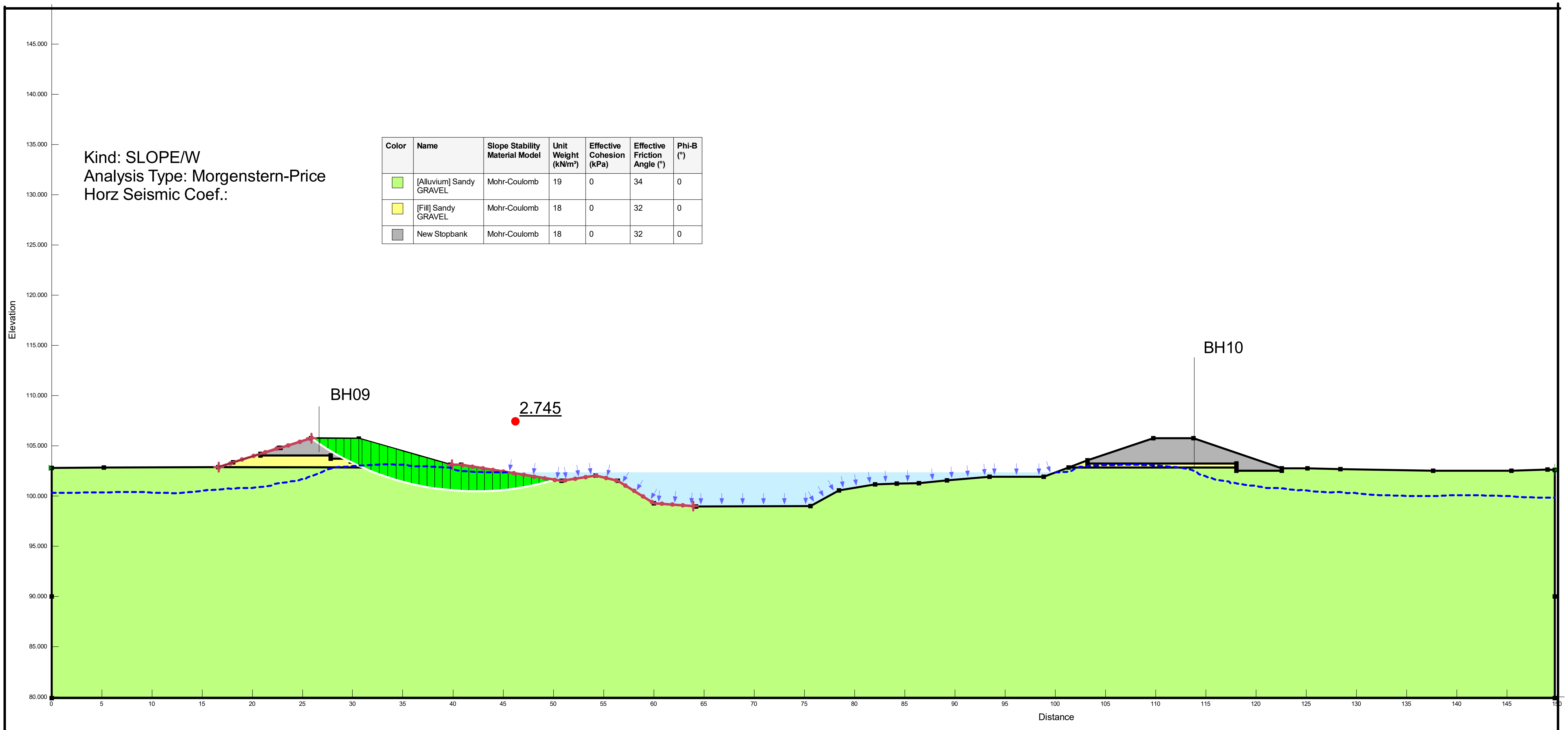
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



NWL - SEE Seis. Stability Downstream

Waipoua Stopbank Assessment - Section C western bank.gsz

18/10/2024 1:400



Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▒	New Stopbank	Mohr-Coulomb	18	0	32	0

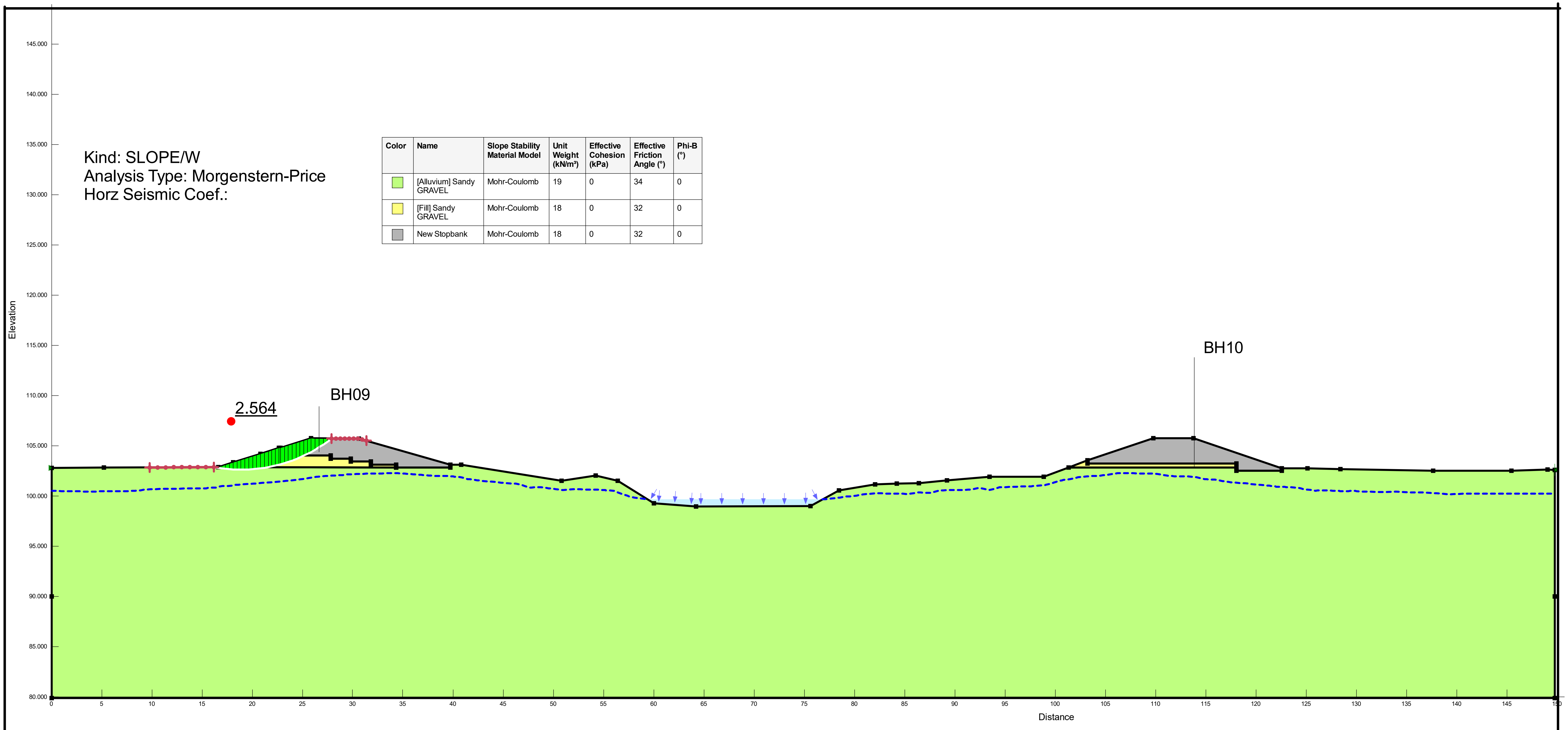
Storm - Stability Upstream

Waipoua Stopbank Assessment - Section C western bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



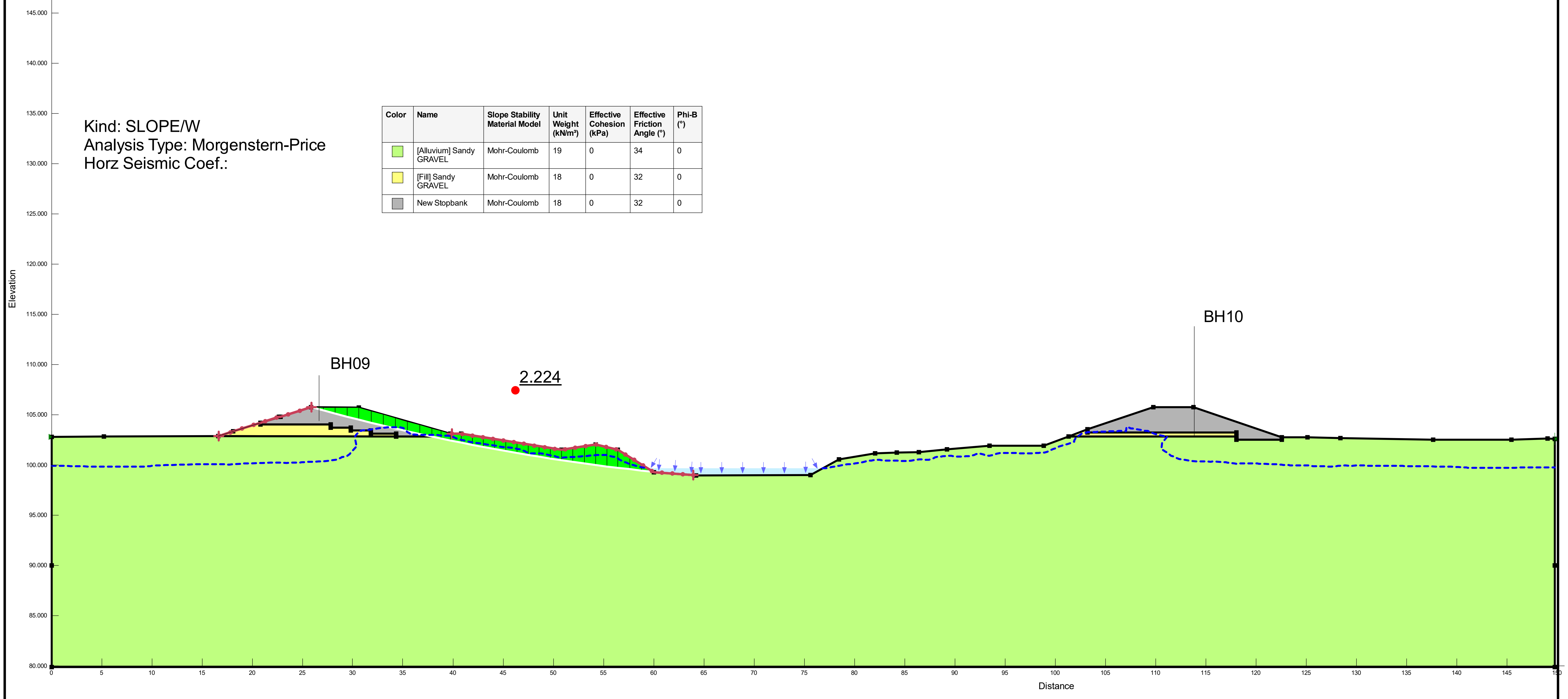
Storm - Stability Downstream

Waipoua Stopbank Assessment - Section C western bank.gsz

18/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

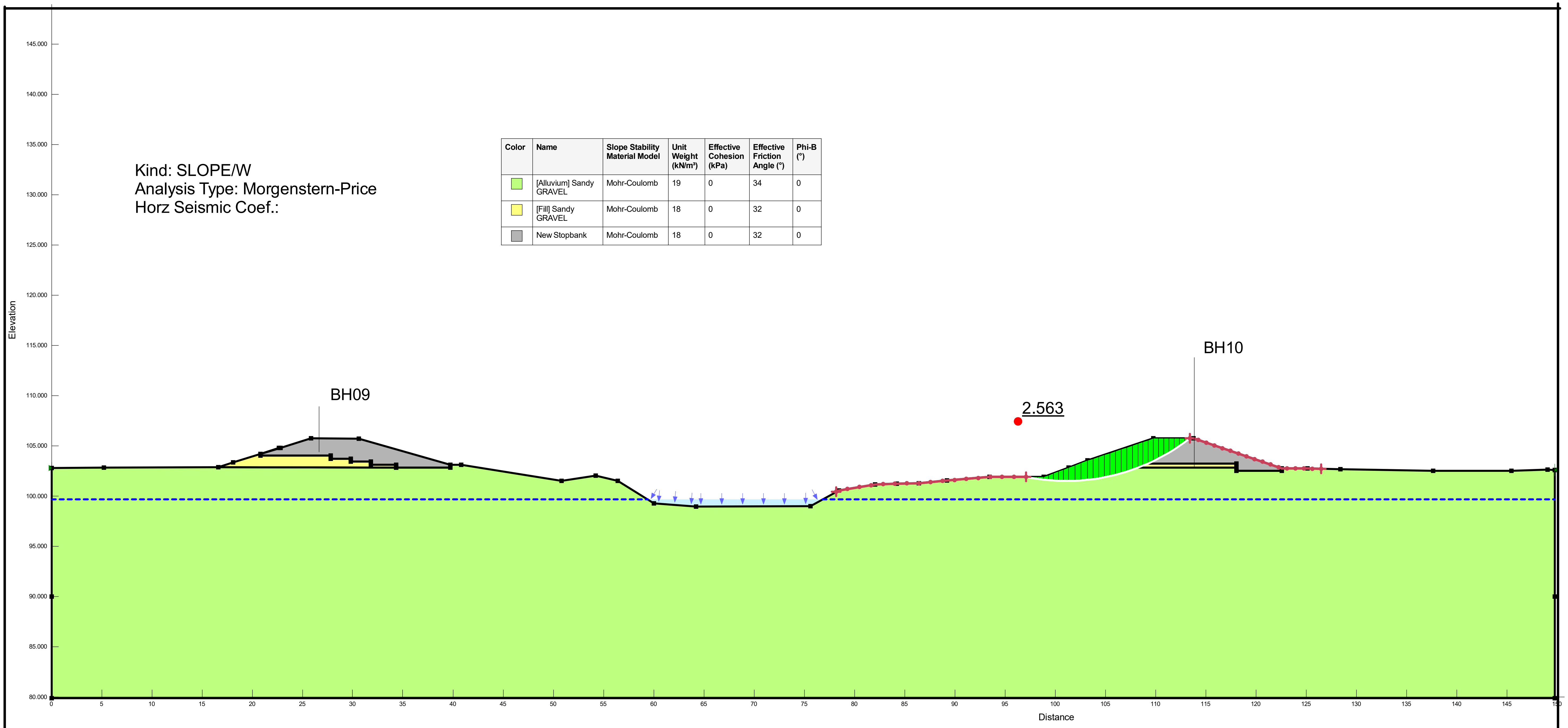
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



RDD - Stability Upstream

Waipoua Stopbank Assessment - Section C western bank.gsz

21/10/2024 1:400



Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0

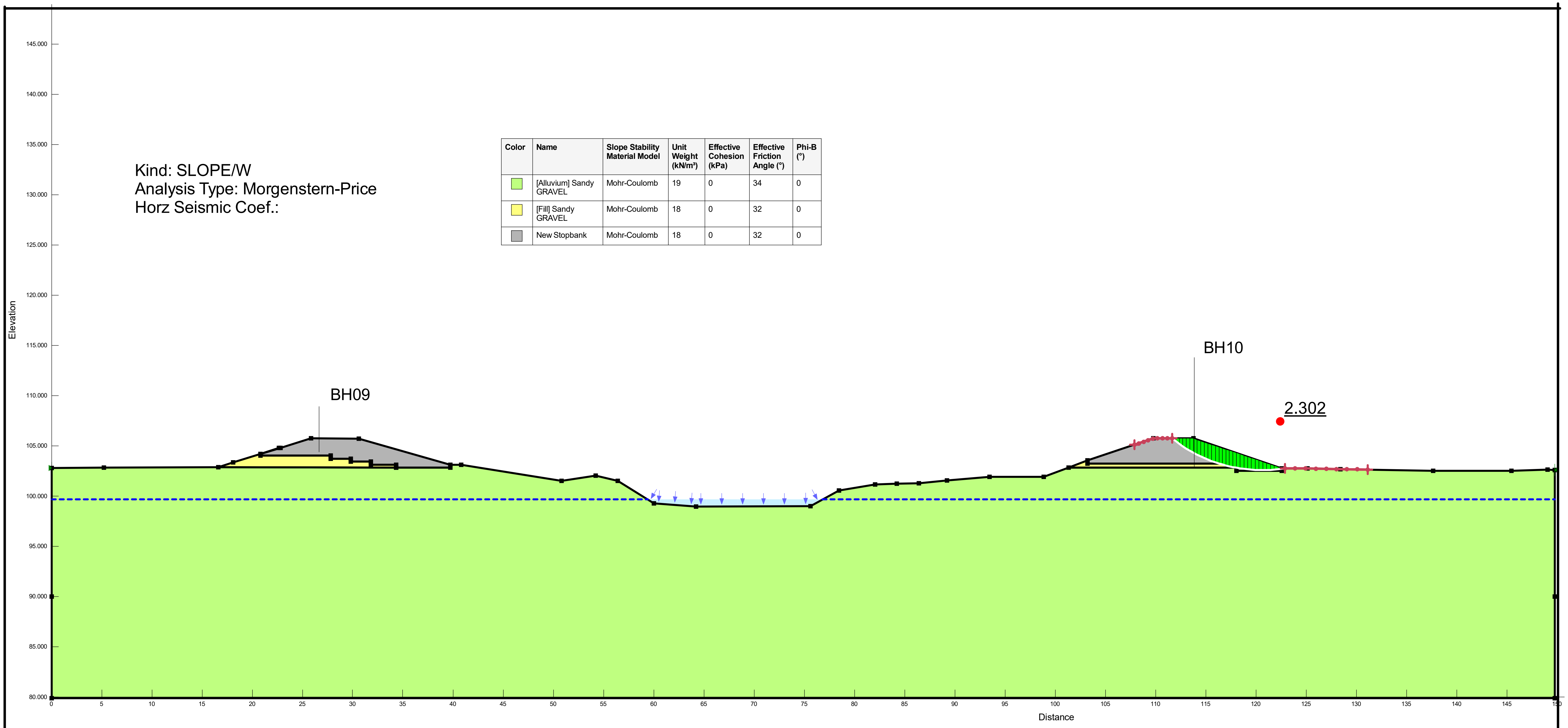
NWL - Stability Upstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



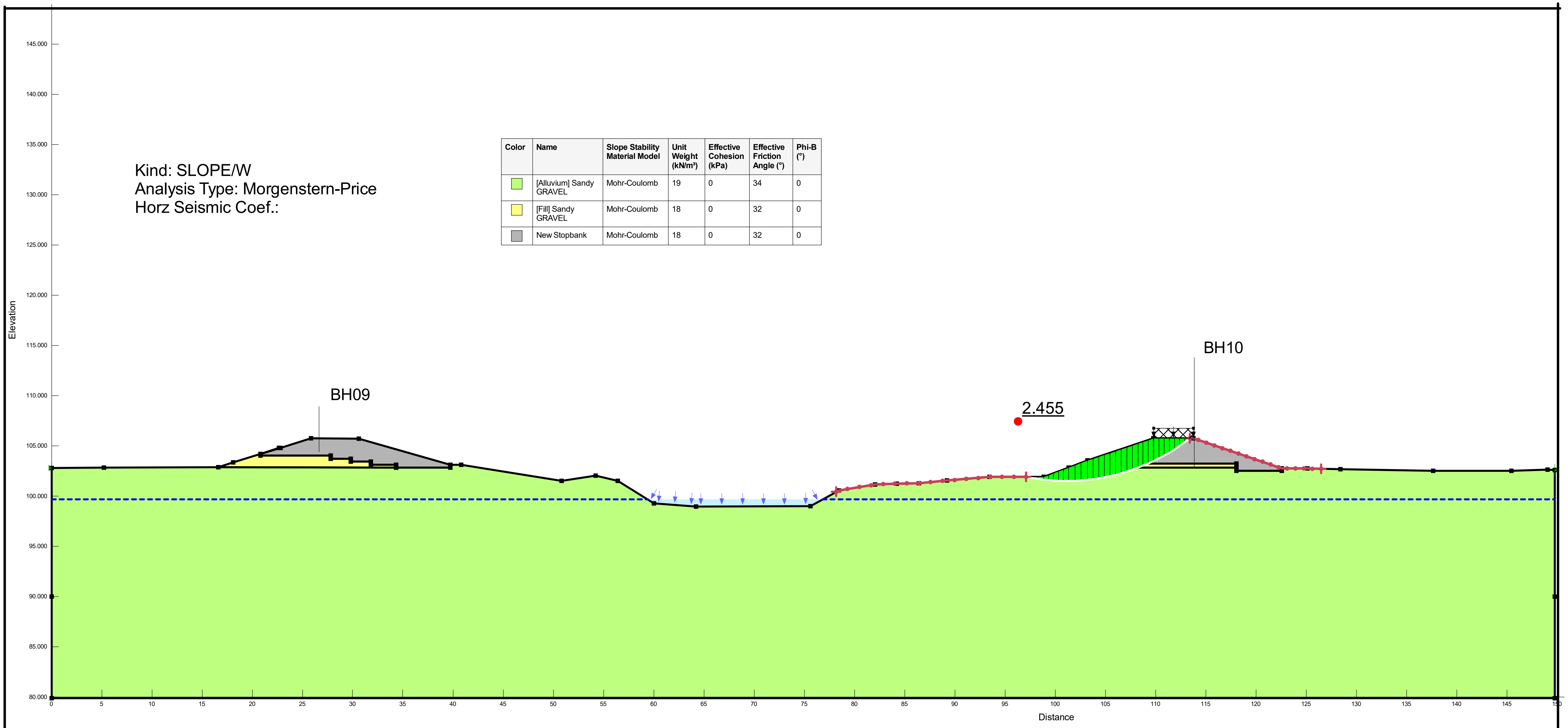
NWL - Stability Downstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

18/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



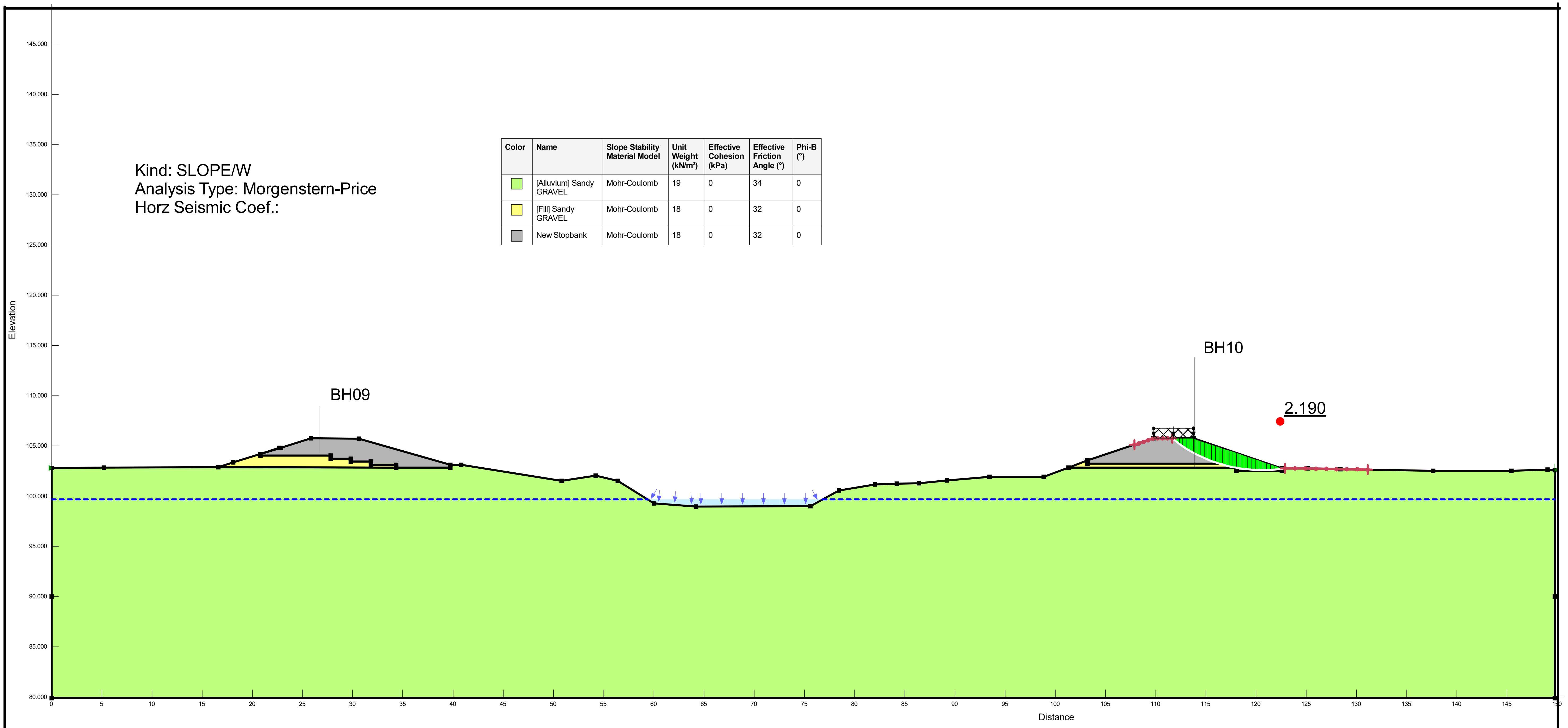
NWL - Stability Upstream with surcharge

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

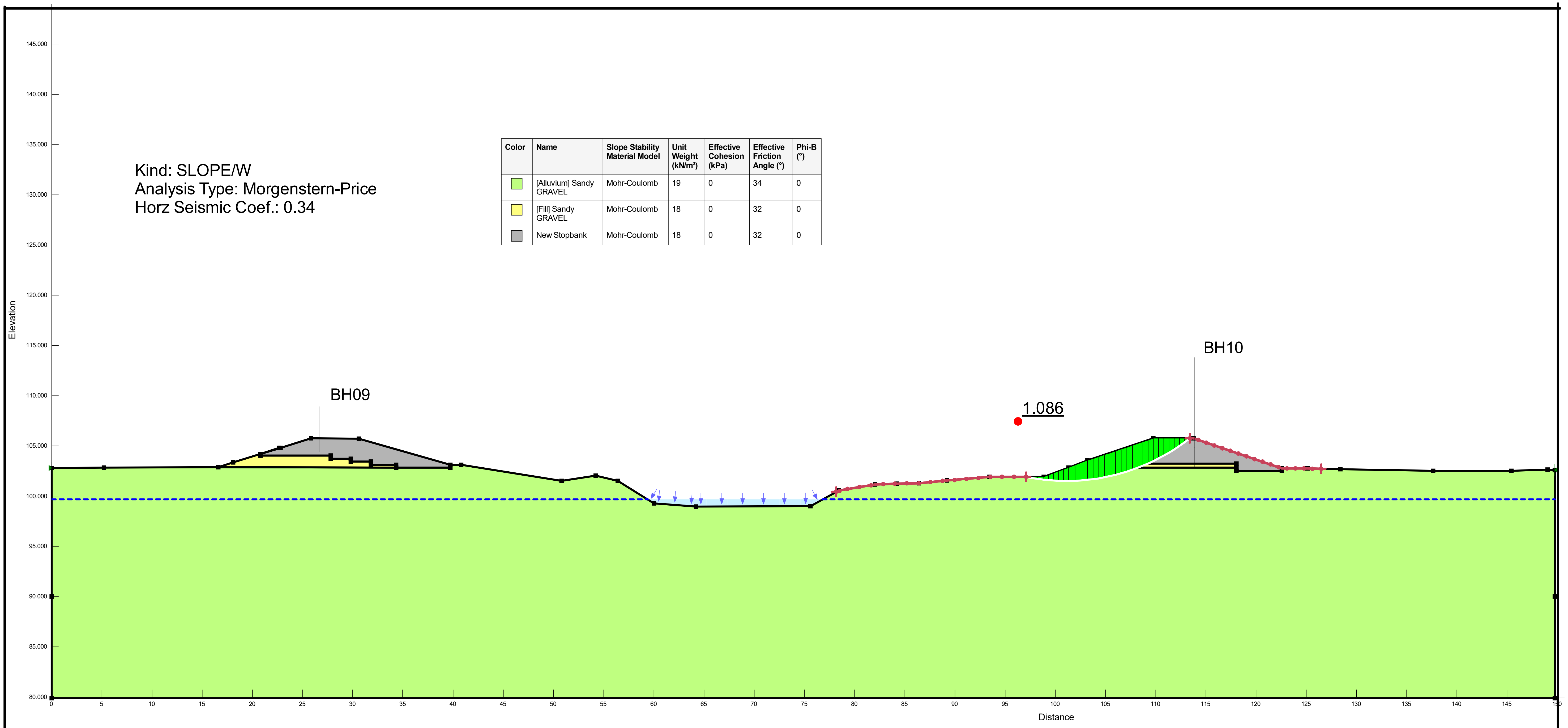
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



NWL - Stability Downstream with surcharge

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

18/10/2024 1:400



Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0

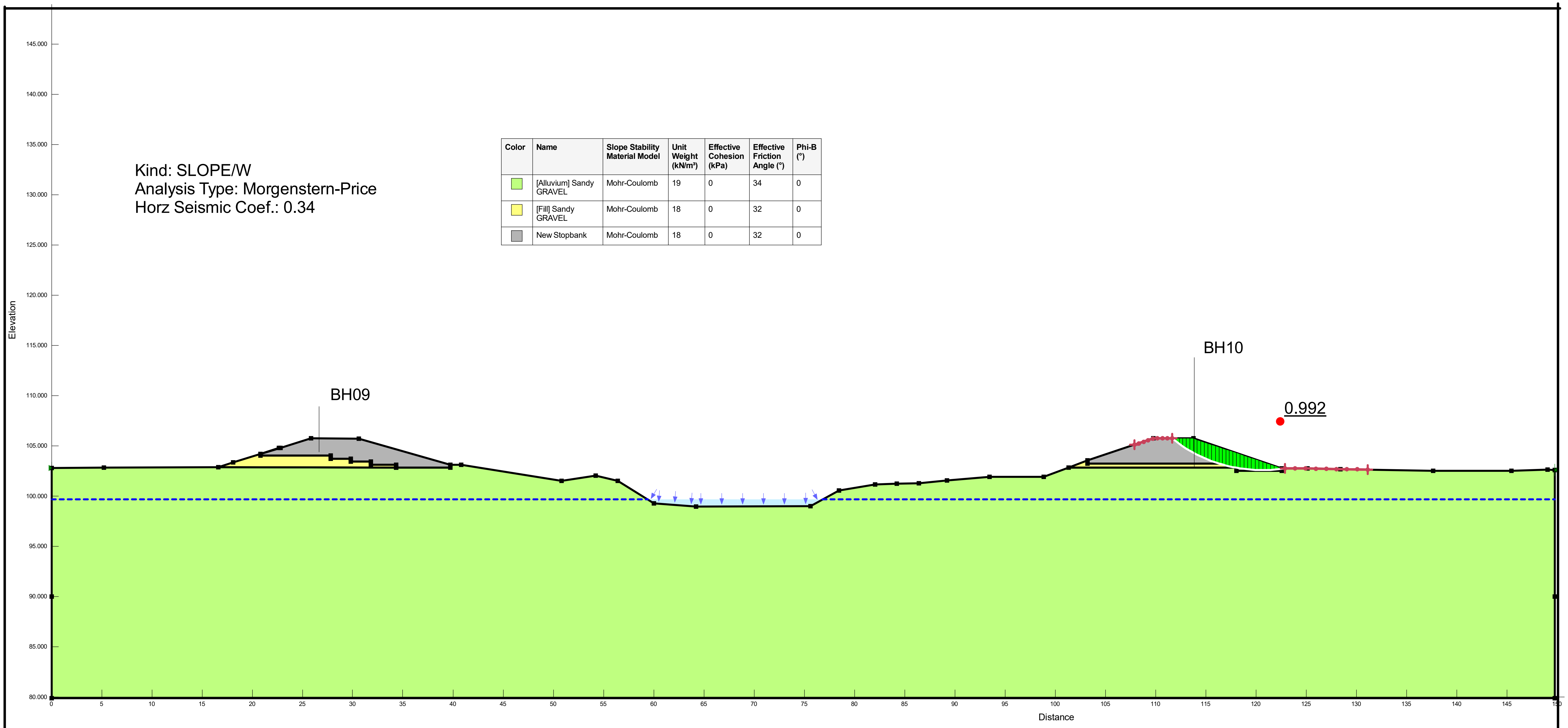
NWL - OBE Seis. Stability Upstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

21/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.34

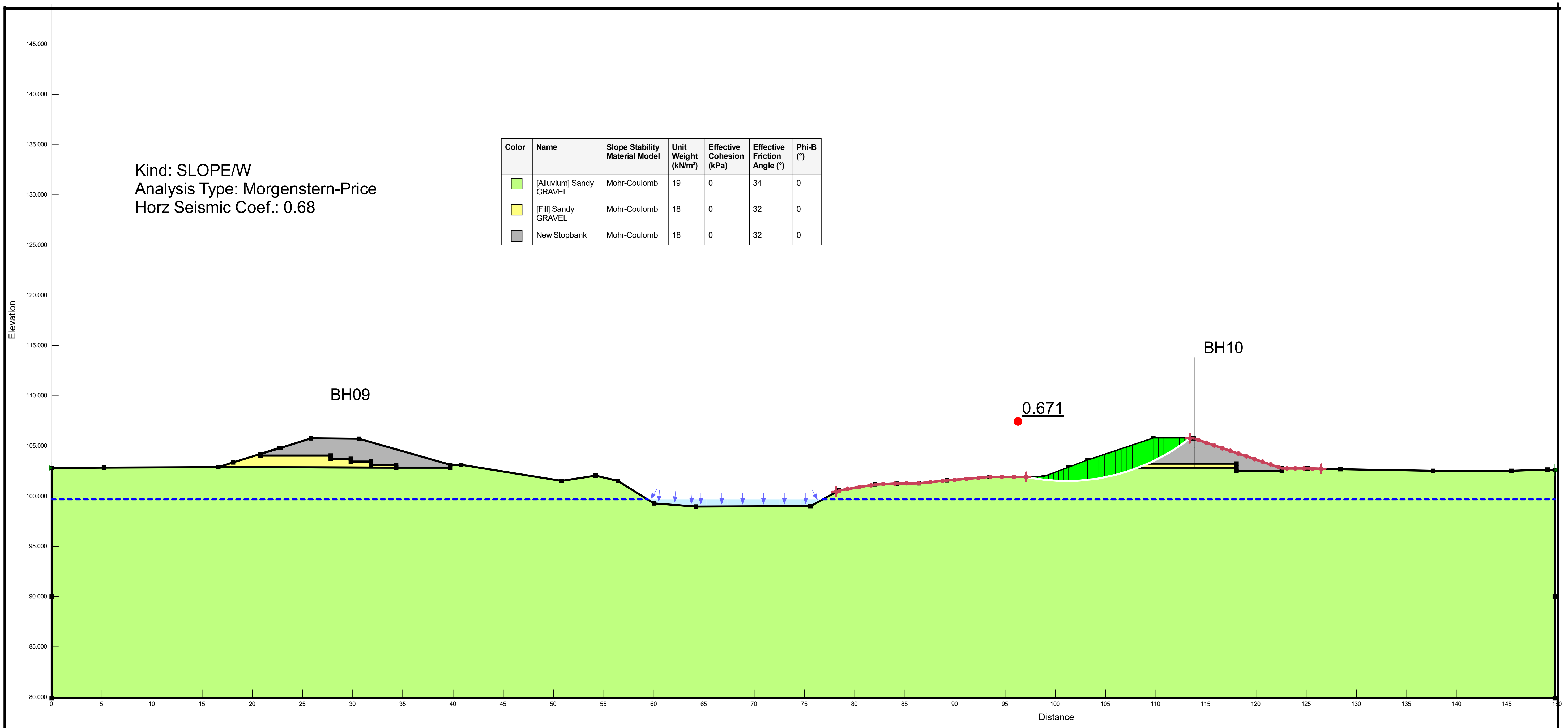
Color	Name	Slope Stability Material Model	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



NWL - OBE Seis. Stability Downstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

18/10/2024 1:400



Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

Color	Name	Slope Stability Material Model	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0

NWL - SEE Seis. Stability Upstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

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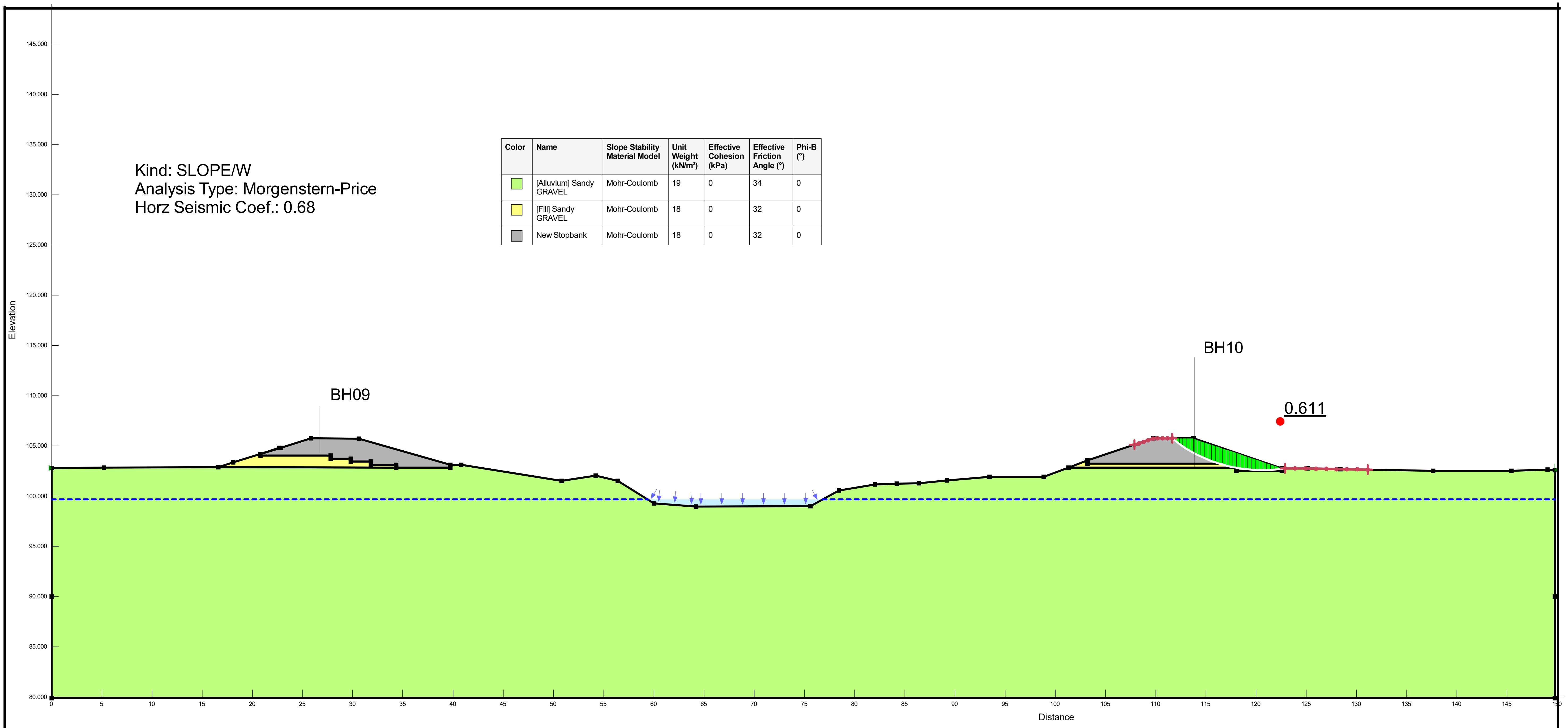
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.: 0.68

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0



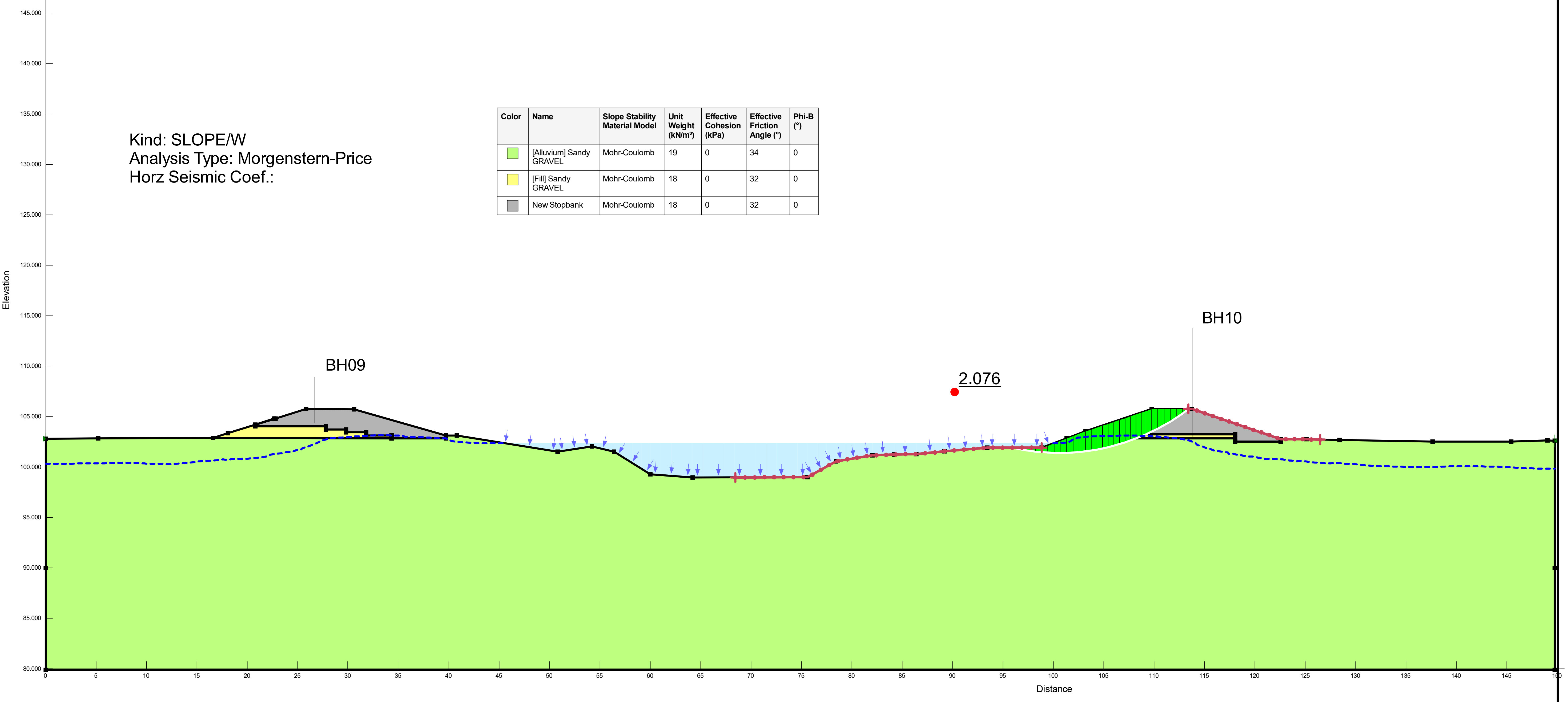
NWL - SEE Seis. Stability Downstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

18/10/2024 1:400

Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

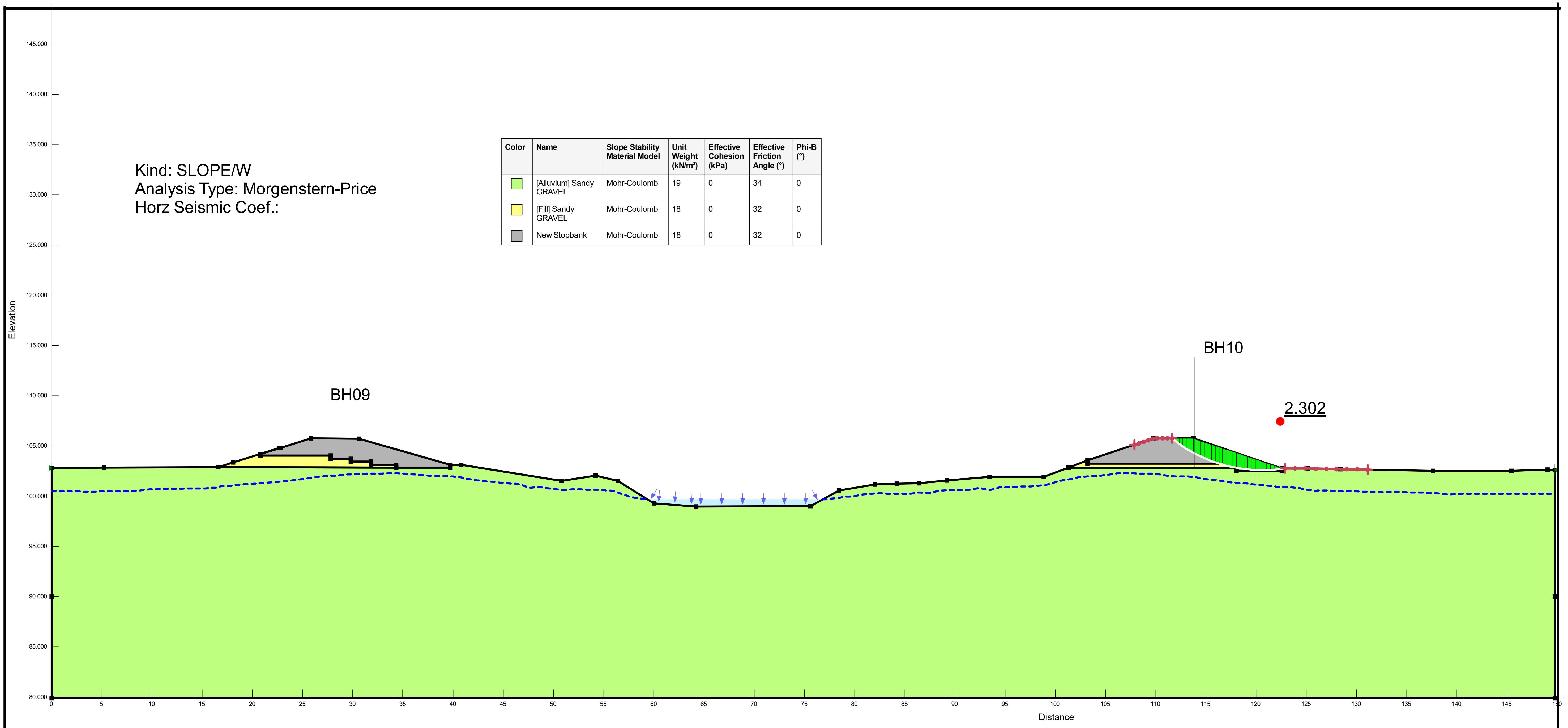
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0



Storm - Stability Upstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

21/10/2024 1:400



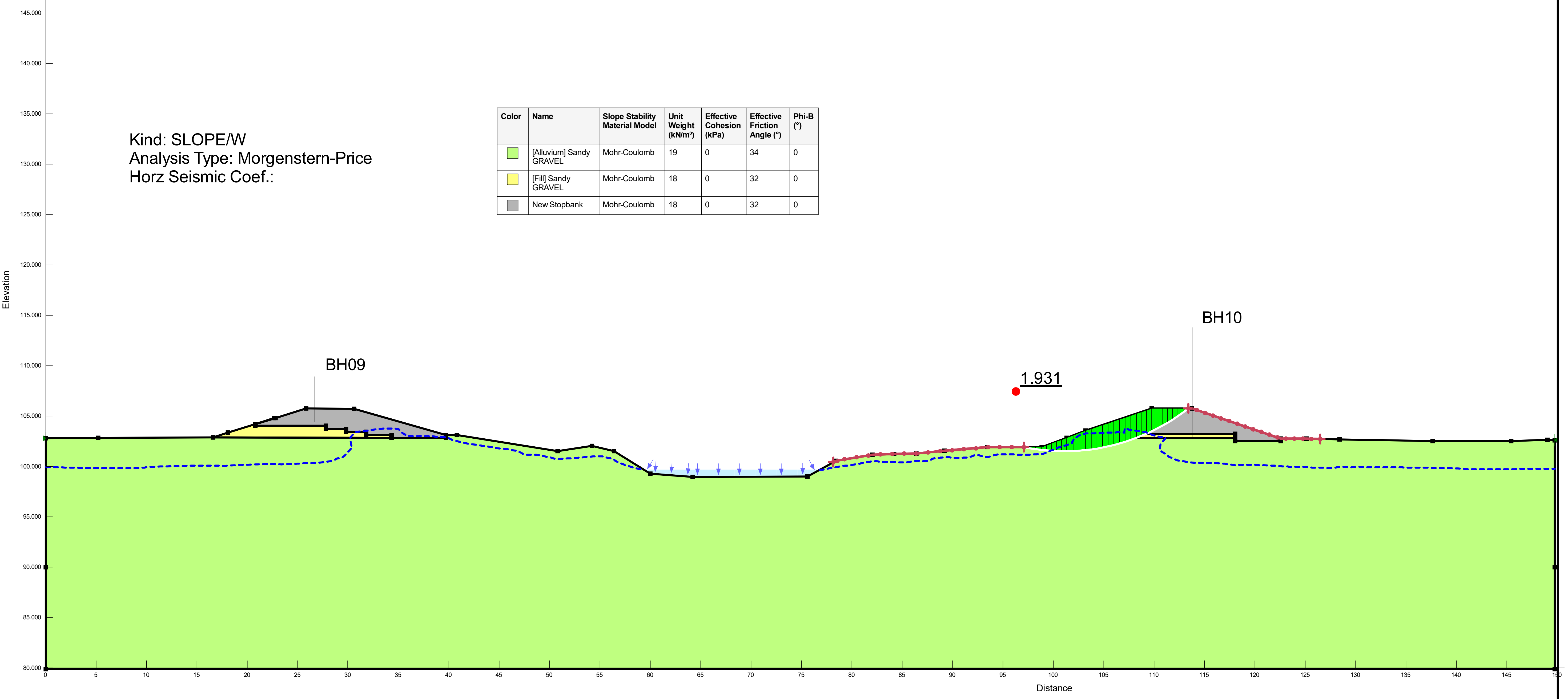
Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
⬜	New Stopbank	Mohr-Coulomb	18	0	32	0

Storm - Stability Downstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

18/10/2024 1:400



Kind: SLOPE/W
Analysis Type: Morgenstern-Price
Horz Seismic Coef.:

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
🟩	[Alluvium] Sandy GRAVEL	Mohr-Coulomb	19	0	34	0
🟨	[Fill] Sandy GRAVEL	Mohr-Coulomb	18	0	32	0
▨	New Stopbank	Mohr-Coulomb	18	0	32	0

RDD - Stability Upstream

Waipoua Stopbank Assessment - Section C_eastern bank.gsz

21/10/2024 1:400

APPENDIX 6:

Static Settlement Analysis Output

Project Settings

Document Name	2024.10.22 Stopbank Raising Settlement Analysis MB.s3z
Date Created	21/10/2024, 1:36:00 pm
Last saved with Settle3 version	5.017
Stress Computation Method	Westergaard
Stress Units	Metric, stress as kPa
Settlement Units	millimeters

Advanced Settings

Start of secondary consolidation (% of primary)	95
Min. stress for secondary consolidation (% of initial)	1
Reset time when load changes for secondary consolidation	No
Use settlement cutoff	
Load/Insitu vertical stress ratio	0.1
Minimum settlement ratio for subgrade modulus	0.9
Use average poisson's ratio to calculate layered stresses	
Update Cv in each time step (improves consolidation accuracy)	
Ignore negative effective stresses in settlement calculations	
Add field points to load edges	

Soil Profile

Layer Option	Horizontal Soil Layers
Vertical Axis	Elevation
Ground Elevation (m)	0

Results

Time taken to compute: 0 seconds

Stage: Stage 1

Data Type	Minimum	Maximum
Total Settlement [mm]	0	8.03344
Total Consolidation Settlement [mm]	0	2.96339
Virgin Consolidation Settlement [mm]	0	2.96339
Recompression Consolidation Settlement [mm]	0	0
Immediate Settlement [mm]	0	5.07006
Loading Stress ZZ [kPa]	0	36.9496
Loading Stress XX [kPa]	-0.499449	19.3845
Loading Stress YY [kPa]	-0.499449	19.3845
Effective Stress ZZ [kPa]	0	210.578
Effective Stress XX [kPa]	-0.139449	97.5824
Effective Stress YY [kPa]	-0.139449	97.5824
Total Stress ZZ [kPa]	0	367.538
Total Stress XX [kPa]	-0.139449	254.542
Total Stress YY [kPa]	-0.139449	254.542
Modulus of Subgrade Reaction (Total) [kPa/m]	0	0
Modulus of Subgrade Reaction (Immediate) [kPa/m]	0	0
Modulus of Subgrade Reaction (Consolidation) [kPa/m]	0	0
Total Strain	0	0.00667642
Pore Water Pressure [kPa]	0	156.96
Degree of Consolidation [%]	0	100
Pre-consolidation Stress [kPa]	0.18	210.516
Over-consolidation Ratio	1	1
Void Ratio	0	0
Hydroconsolidation Settlement [mm]	0	0
Undrained Shear Strength	0	0.927418

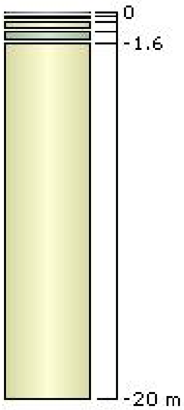
Embankments

1. Embankment: "Stopbank Raising"

Label				Stopbank Raising			
Center Line				(0, -18.6411) to (0, 14.4289)			
Near End Angle				90 degrees			
Far End Angle				90 degrees			
Number of Layers				1			
Base Width				18			
Layer	**Stage**	**Left Bench Width (m)**	**Left Angle (deg)**	**Height (m)**	**Unit Weight (kN/m3)**	**Right Angle (deg)**	**Right Bench Width (m)**
1	Stage 1	0	15.9	2	18	15.9	0

Soil Layers

Layer #	Type	Thickness [m]	Elevation [m]
1	Stopbank Fill: sandy GRAVEL	0.2	0
2	sandy SILT	0.3	-0.2
3	MD-VD Sandy Gravel	0.5	-0.5
4	sandy SILT	0.6	-1
5	MD-VD Sandy Gravel	18.4	-1.6



Soil Properties

Property	MD-VD Sandy Gravel	sandy SILT	Stopbank Fill: sandy GRAVEL
Color	🟨	🟩	⬛
Unit Weight [kN/m3]	18	18	18
Saturated Unit Weight [kN/m3]	18	18	18
K0	0.47	1	1
Immediate Settlement	Enabled	Enabled	Enabled
Es [kPa]	95000	11200	135000
Esur [kPa]	95000	11200	135000
Primary Consolidation	Disabled	Enabled	Disabled
Material Type		Linear	
mv [m2/kN]	-	0.0001	-
mvur [m2/kN]	-	0.0001	-
Undrained Su A [kN/m2]	0	0	0
Undrained Su S	0.2	0.2	0.2
Undrained Su m	0.8	0.8	0.8
Piezo Line ID	1	1	1

Groundwater

Groundwater method	Piezometric Lines
Water Unit Weight	9.81 kN/m3

Piezometric Line Entities

ID	Elevation (m)
1	-4 m