MAPPING THE PAST, SECURING THE FUTURE:

Developing a 3D Scanning and Virtual Reality Based Workflow for the Conservation of At-Risk Heritage Sites in Auckland, New Zealand.

Image of Nigel Hanlon Memorial Hut Modified by Author, Courtesy of Stefan Marks.

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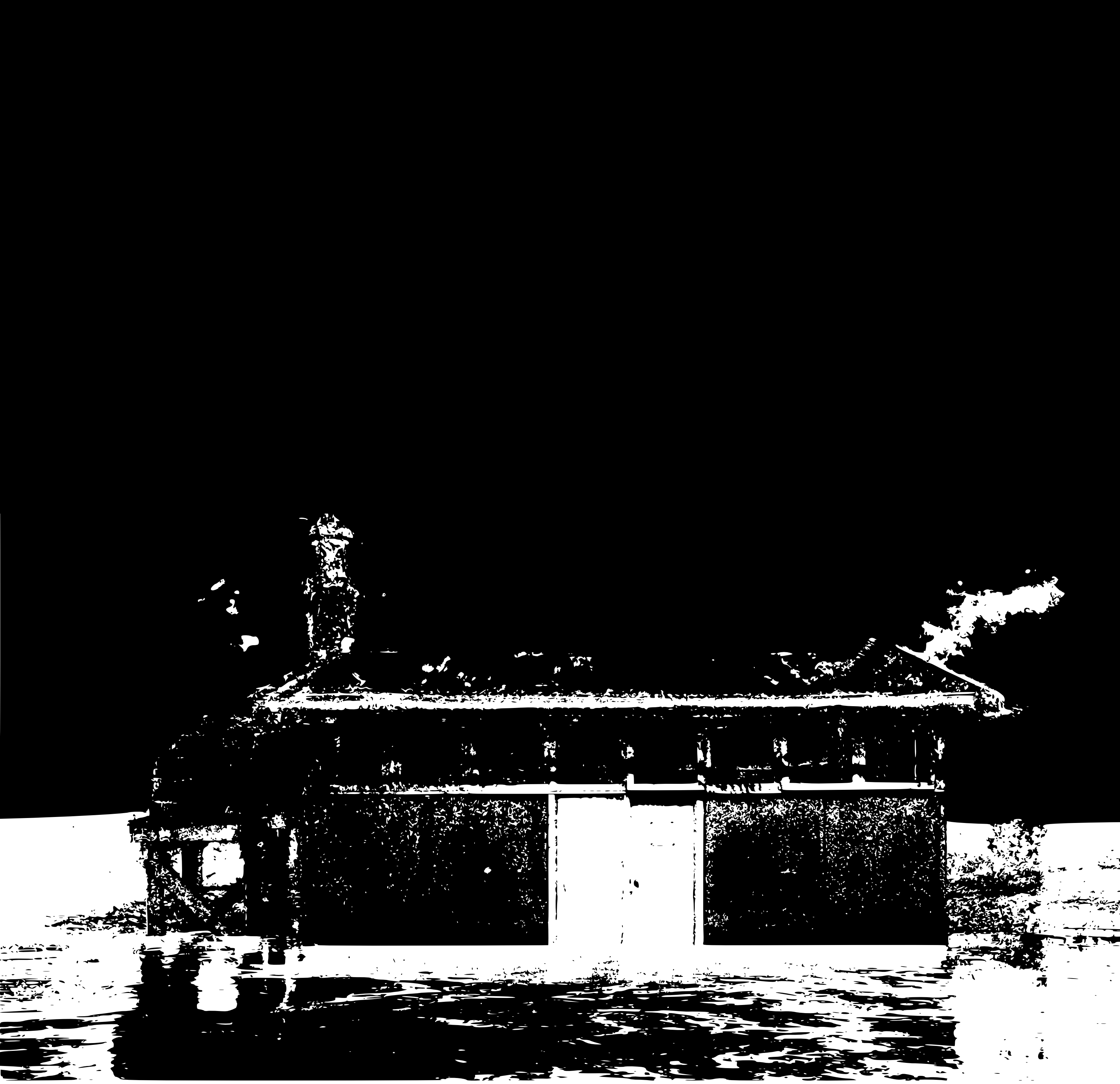

Image Of Nigel Hanlon Memorial Hut, Point Clouds Rendered on Twinmotion, Modified by Author.

No amount of money ever bought a second of time.

- Iron Man (Avengers: Endgame, 2019)

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Figure 1. Image of Nigel Hanlon Memorial Hut Modified by Author, Courtesy of Stefan Marks

ABSTRACT

In the face of rapid urban development and environmental challenges, historic buildings and sites in Auckland New Zealand, stand as reminders of the city's rich architectural heritage. Many of these buildings and sites are now threatened by a combination of factors, including demolition, climate change induced flooding, and vandalism. This thesis explores the opportunities offered by 3D digital data archiving and virtual reality (VR) applications to support conservation processes for at risk cultural heritage sites, specifically focusing on the Nigel Hanlon Memorial Hut in Piha, West Auckland. The research investigates how a VR-based workflow can enhance existing conservation methodologies by providing an immersive, interactive platform for analysis and design, addressing the research question: How can the integration of a virtual reality-based workflow contribute to the conservation and contemporary intervention for at-risk cultural heritage sites in New Zealand?

The study proposes a digital workflow for documenting and designing contemporary interventions for heritages sites, leveraging technologies like Agisoft Metashape for photogrammetry and Shapelab VR for producing and visualising contemporary design responses. While many existing heritage documentation guidelines focus on application to World Heritage Sites, this thesis specifically explores the application of these guidelines to local heritage, demonstrating how international standards can be adapted to smaller scale yet locally significant sites in New Zealand. By doing so, it showcases Auckland's architectural heritage under threat while emphasising the value of cultural memory as an integral part of conservation.

This thesis focuses on creating an immersive architectural experience of memories at the Nigel Hanlon Memorial Hut and its surrounding landscape in Piha, West Auckland. Architectural responses to the site includes immersive visual experiences like canoeing and campfires to evoke a sense of connection with the site's cultural and historical significance. The outcome of this thesis is a set of design guidelines tested through the development of architectural follies that draw on the tangible and intangible heritage of the site's history, demonstrating the application of virtual reality in conserving these aspects of heritage. By doing so, the project highlights the potential of VR to bridge the gap between the tangible and intangible, past and present. This thesis seeks to empower communities to engage with their heritage through virtual reality, fostering appreciation for Auckland's cultural legacy and mobilising action to secure the future of these endangered sites.

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor used artificial intelligence tools or generative artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Devarsh M. Patel

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Thank you all for being part of this journey with me.

GLOSSARY

Heritage Conservation Terms:

3D Scanning: A technology that captures the shape and surface details of an object or site to create accurate 3D digital models (Rocha et al., 2020).

At-Risk Heritage Sites: Heritage sites vulnerable to threats such as environmental factors, human activity, neglect, or natural disasters (Machat & Ziesemer, 2016).

Authenticity: The credibility or truthfulness of the surviving evidence and knowledge of the cultural heritage value of a place (ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010).

Conservation: All the processes of understanding and caring for a place to safeguard its cultural heritage value (ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010).

Cultural Heritage: Traditions or living expressions inherited from our ancestors and passed on to our descendants, such as, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts (What Is Intangible Cultural Heritage? Culture Sector - UNESCO, 2011).

Digital Documentation: The process of capturing and conserving detailed information about heritage sites using digital technologies such as photogrammetry, laser scanning, and 3D modelling (Letellier et al., 2007).

Documentation: Collecting, recording, keeping, and managing information about a place and its cultural heritage value, including information about its history, fabric, and meaning; information about decisions taken; and information about physical changes and interventions made to the place (ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010).

Folly Architecture: Ornamental and often symbolic architectural structures, historically used in landscape design, reimagined in this thesis as creative interventions for heritage storytelling and engagement (Florence Griswold Museum, 2021).

Heritage Conservation: The process of conserving, protecting, and maintaining cultural heritage sites, structures, and objects to ensure their longevity and historical significance (de la Torre, 2013).

Resilient Design: An approach to architectural and site design that ensures structures can withstand and adapt to environmental challenges such as flooding, erosion, and climate change (UNESCO et al., 2023).

Tangible Heritage: Physical, material objects and structures that can be seen, touched, and measured, such as buildings, artifacts, and landscapes (What Is Intangible Cultural Heritage? Culture Sector - UNESCO, 2011).

Intangible Heritage: Non-physical elements such as traditions, oral histories, knowledge, and cultural practices that are passed down through generations (What Is Intangible Cultural Heritage? Culture Sector - UNESCO, 2011).

Designing & Technological Terms:

Augmented Reality (AR): An interactive technology that overlays digital information onto the real world, enhancing the physical environment with virtual elements (Lin, 2017).

Fully Immersive: An experience where the user is completely enveloped within a created digital environment, losing awareness of the real world (Hamann, 2025).

Immersive: An experience that gives the user a sense of being present within a created environment, even though they are aware it is not real (Hamman, 2025).

Rendering: The process of generating a photorealistic or non-photorealistic image from a 3D model using computer software (Pixcap, 2024).

Texture Mapping: The process of applying images or patterns to the surface of a 3D model to create realistic visual details (Antartic Heritage Trust, 2025a).

Virtual Reality (VR): An immersive technology that creates a simulated environment, allowing users to interact with and explore digital representations of real-world objects and spaces (Lin, 2017).

Agisoft Metashape: Photogrammetry software used to process images into 3D point clouds, meshes, and textured models for digital documentation (Agisoft, 2025).

Autodesk ReCap: Software used to convert point cloud data into formats compatible with other design software like Revit, aiding in the creation of HBIM models (Autodesk, 2025a).

Computer-Aided Design and Drafting (CAD): Software for creating precise technical drawings, integrating data from various sources for sharing and printing (Letellier et al., 2007).

Heritage Building Information Modelling (HBIM): A digital representation of a heritage building that includes its geometry, spatial relationships, and associated data, used for documentation, analysis, and conservation (Rocha et al., 2020).

LiDAR (Light Detection and Ranging): A remote sensing technology that uses laser pulses to measure distances to the Earth's surface, generating precise, three-dimensional information about its shape and characteristics (NOAA, 2024).

Lumion: Rendering software used to create realistic visualisations of architectural designs, including heritage conservation projects (Lumion, 2025).

Photogrammetry: A technique that uses photographs to create precise 3D models of objects, structures, and sites by measuring distances between points in images (Letellier et al., 2007).

Point Cloud: A collection of data points in 3D space representing the surface of an object or site, typically generated from photogrammetry or laser scanning (Letellier et al., 2007).

Autodesk Revit: Building information modelling (BIM) software used for creating detailed architectural designs and HBIM models, including for heritage structures (Autodesk, 2025b).

Shapelab VR: A virtual reality software tool used for 3D modelling, editing, and visualising digital designs in an immersive environment (Shapelab, 2025).

Organisations:

International Committee of Architectural Photogrammetry (CIPA): Establishes principles for documenting heritage sites through digital and manual techniques (CIPA, 2025).

Heritage New Zealand Pouhere Taonga: Responsible for identifying, protecting, and promoting New Zealand's unique historical and cultural heritage (Fast-track, 2025).

International Council on Monuments and Sites (ICOMOS): A global organisation that promotes the conservation of cultural heritage sites (UNESCO, 2025).

The United Nations Educational, Scientific and Cultural Organisation (UNESCO): Promotes the protection of cultural heritage through global initiatives and frameworks (UNESCO Institute for Statistics, 2025).

Local Terms:

Piha: A coastal settlement in Auckland, New Zealand, known for its cultural, historical, and environmental significance, and the site of the Nigel Hanlon Memorial Hut (Coney, 2025).

Nigel Hanlon Memorial Hut: A heritage Hut in Piha used as a case study in this thesis (Reynolds Associates, 2010).

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

1.1.1 GLOBAL RISKS TO CULTURAL HERITAGE

Cultural heritage sites worldwide are increasingly threatened by climate change, urbanisation, and environmental degradation (Sesana et al., 2021). Rising sea levels, extreme weather events, and pollution accelerate the deterioration of these irreplaceable sites, with estimates suggesting that one in six cultural heritage sites globally is at risk due to climate change (UNESCO et al., 2023). For instance, the giant statues of Easter Island, known as *moai*, are deteriorating due to exposure to wind, saltwater, rain, and sun, with rising sea levels and increasingly violent storms further endangering these cultural treasures (Meyerfeld Bruno & Nui Rapa, 2024). Furthermore, rapid urbanisation often contributes to environmental pollution and physical damage from construction activities, further jeopardising the structural integrity and cultural significance of heritage assets (Fu et al., 2023). As *"Good Practices for Disaster Risk Management of Cultural Heritage Practices of ITC Participants"* highlights, urban expansion frequently disturbs heritage sites, leading to increased exposure to environmental risks and necessitating proactive conservation strategies (Jigyasu et al., 2024).

The International Council on Monuments and Sites (ICOMOS), a global organisation dedicated to heritage conservation, addresses these challenges through reports such as *"Future of Our Pasts"*, which advocates for adaptive strategies, including vulnerability assessments, resilient design principles, and multi-stakeholder collaboration (Climate Change and Heritage Working Group, 2019). *"UNESCO's Enhancing Our Heritage Toolkit 2.0"* also emphasises the importance of comprehensive risk assessments, particularly for hazards like flooding, to inform effective conservation plans. *"Good Practices for Disaster Risk Management of Cultural Heritage Practices of ITC Participants"* further emphasises that prioritising risk assessments enables heritage managers to allocate resources effectively, developing targeted disaster management plans that strengthen resilience against environmental threats (Jigyasu et al., 2024). By systematically evaluating potential threats, heritage managers can prioritise interventions, ensuring that resources are allocated to address the most pressing risks first. This prioritisation is crucial, as it enables the development of targeted disaster risk management plans that enhance the resilience of cultural heritage sites against environmental threats (UNESCO et al., 2023).

1.1.2 RESEARCH MOTIVATIONS: LOCAL RISKS FACED HERE IN NEW ZEALAND

New Zealand’s cultural heritage faces a variety of natural hazards, including earthquakes, volcanic eruptions, and cyclones, due to its unique geographic and environmental context (Fattaruso, 2023). Coastal and riverine sites are particularly vulnerable to flooding, erosion, and ground instability (Hicks et al., 2021). Additionally, urban expansion and vandalism pose persistent threats to the integrity of historically significant structures such as the incident in Symonds Street Auckland Cemetery where vandalism to the tombstones took place in recent years (Auckland Council, 2019).

In February 2023, Cyclone Gabrielle struck New Zealand, causing widespread devastation across the North Island. The cyclone led to significant damage to homes, infrastructure, and cultural heritage sites, particularly in regions such as Hawke's Bay and Tairāwhiti. Flooding and landslides severely impacted Māori communities, with marae and other cultural sites suffering extensive damage. In response, Heritage New Zealand Pouhere Taonga provided rapid assistance to affected marae (communal meeting grounds central to Māori social and cultural life) and hapori Māori (Māori communities), emphasising the importance of conserving cultural heritage in the aftermath of natural disasters. (Cyclone Gabrielle Māori Communities Response Fund, 2024). The cyclone also highlighted the vulnerability of New Zealand's cultural heritage to environmental hazards. In the wake of Cyclone Gabrielle, Heritage New Zealand underscored the importance of cultural monitoring and resilience planning to protect Māori archaeological sites and other heritage places from the impacts of climate change and natural disasters (David Watt, 2024). This event underscores the necessity for proactive risk management and the integration of disaster preparedness into heritage conservation strategies to safeguard New Zealand's cultural legacy against future environmental threats. The Guide to the Management of Historic Heritage in Regional Plans emphasises integrating conservation with sustainable development, highlighting the necessity of community engagement, and proactive risk management plans (Heritage New Zealand & Pouhere Taonga, 2022). Recent studies also call for improved disaster preparedness, particularly against natural hazards such as flooding and wildfires, to protect at-risk heritage sites (Ministry for the Environment, 2020). These localised risks demand tailored conservation strategies that address both the environmental and cultural dimensions of heritage management.

1.1.3 RESPONSE TO THE CHALLENGES

This thesis investigates and develops a set of design guidelines that address the global and local challenges faced by at-risk heritage sites, with a focus on digital documentation workflows and key principles. These guidelines advocate for a structured conservation workflow encompassing precise data acquisition, processing, visualisation, and producing design solutions. Advanced technologies, including photogrammetry, 3D scanning, and VR, play a central role in enabling accurate and interactive representations of heritage sites while providing tailored design solutions. This workflow demonstrates how virtual integration can complement traditional conservation methods to create innovative design solutions. While the stakeholders were not directly involved in the design process, future applications could integrate community engagement to explore digital models and actively participate in the design and conservation process (UNESCO et al., 2023).

The Nigel Hanlon Memorial Hut in Piha, West Auckland, serves as the focal site for applying these guidelines. This research aims to address the site's contextual characteristics and risks such as flooding and vandalism through a comprehensive and innovative conservation approach. By leveraging VR and digital workflows, this thesis demonstrates how technology can bridge the gap between heritage documentation and public engagement, ensuring that cultural assets are both conserved and appreciated by future generations.

1.2 Research Motivations

The increasing frequency of extreme weather events and rising sea levels, amplifies the risks to heritage sites. These environmental threats endanger not only the physical structure of sites but also the cultural identity they represent. Recognising the potential for using emerging technologies to document and conserve the site, the Nigel Hanlon Memorial Hut was selected as the focal point for this thesis. The aim of this thesis is to explore strategies that leverage digital documentation workflows and virtual reality applications to conserve at-risk heritage sites and opportunities to engage communities in the process.

1.3 Research Question

The integration of Virtual Reality (VR) in heritage conservation presents new possibilities for documenting, designing, and conserving at-risk sites. This thesis explores how a VR-based workflow can enhance existing conservation methodologies by providing an immersive, interactive platform for analysis and design.

The following research question guides the investigation:

Question: How can the use of a virtual reality-based conservation workflow contribute to the conservation and contemporary intervention for at-risk cultural heritage sites in New Zealand?

1.4 AIMS & OBJECTIVES

1.4.1 Aims

This thesis focuses on developing an efficient and immersive digital workflow for documenting and designing solutions for heritage sites at risk, with a specific focus on the Nigel Hanlon Memorial Hut in Piha, West Auckland. By integrating photogrammetry and Heritage Building Information Modelling (HBIM) a digital representation of heritage buildings that includes their geometry, spatial relationships, and associated metadata and virtual reality (VR) technologies, the research aims to demonstrate the applicability of a VR-based workflow and design guideline, investigated through the development of architectural follies for the site.

The research seeks to contribute to the integration of digital technologies into conservation practices, fostering future community engagement and ongoing appreciation of cultural heritage by developing Virtual Reality (VR) experiences that allow the local community to virtually explore and interact with the Nigel Hanlon Memorial Hut. This immersive approach enables community members to contribute oral histories, personal narratives, and local knowledge, ensuring that digital documentation reflects diverse cultural perspectives. Such engagement not only aids in conserving the site's cultural significance but also strengthens the community's connection to its heritage (Murphy, 2022; UNESCO, 2024).

Although not designated as a national or World Heritage site, the Nigel Hanlon Memorial Hut holds significant value to the local community and ongoing traditions of outdoor education for children. This research acknowledges the importance of applying established conservation principles to locally significant sites to ensure their conservation and continued relevance.

This research aims to enhance the accuracy and efficiency of digital documentation processes by utilising Virtual Reality, which allows users to interact with 3D models generated through photogrammetry and HBIM. This approach facilitates precise analysis, comprehensive site assessments, and the development of design solutions while maintaining an understanding of both intricate details and the broader site context (Buragohain et al., 2024; Tini et al., 2024).

1.5 SCOPE AND LIMITATIONS

1.5.1 Scope

This thesis examines and refines conservation workflows by integrating digital technologies such as photogrammetry, HBIM, and VR to document and conserve at-risk heritage sites. While the study provides a detailed analysis of these workflows, it does not address long-term maintenance or funding challenges associated with implementing digital conservation strategies.

The research explores the potential of VR for heritage analysis and visualisation, particularly in enhancing site documentation and design processes. However, it does not investigate advanced VR functionalities, such as real-time collaboration or large-scale applications, due to hardware limitations and time constraints.

The proposed workflow is tested on the Nigel Hanlon Memorial Hut, offering insights into broader heritage applications and demonstrating how digital tools can support conservation efforts. However, as this research is based on a single case study, its findings may not fully represent the challenges faced by larger or more complex heritage sites. The small scale and remote location of the Hut created unique challenges in data collection and documentation, differing from larger, more accessible heritage sites. Additionally, the Hut's environmental vulnerability, situated in a flood-prone zone, highlights the need for tailored conservation approaches to address threats such as flooding and coastal erosion. Beyond its physical challenges, the Hut holds cultural significance for the local community, particularly due to its historical role in outdoor education and youth development, emphasising the importance of community engagement in conservation efforts.

1.5.2 Limitations:

This thesis acknowledges several challenges associated with digital documentation and conservation workflows. Technological constraints arose due to the reliance on accessible photogrammetry equipment, as access to advanced tools such as LiDAR and high-resolution VR setups was limited. While these devices provided a cost-effective and accessible solution, they lacked the precision required for capturing fine surface details, potentially affecting the accuracy of the documentation process (Farhadi, 2024), as further discussed in Chapter 4.2.

Site specific challenges also impacted data collection, particularly due to the flood prone location of the Nigel Hanlon Memorial Hut. Adverse weather conditions restricted access to elevated structures such as roofs as discussed in Chapter 4.1.

The application of established guidelines remains another consideration, as each heritage site has unique conservation requirements. As outlined in "UNESCO's Operational Guidelines for the Implementation of the heritage site has unique conservation requirements. As outlined in *"UNESCO's Operational Guidelines for the Implementation of the World Heritage Convention"* (Heritage Centre, 2011). Heritage sites require tailored approaches beyond standardised workflows, which may necessitate modifications for future applications. The digital documentation framework proposed in this thesis follows established heritage conservation principles but must be adaptable to site specific needs and environmental factors particularly when compliance with local building codes and heritage regulations influence data collection methods.

Community engagement was not conducted in this project; however, VR technology has the potential to facilitate broader participation in heritage conservation in future applications. The high cost of VR hardware currently limits accessibility for many stakeholders, restricting opportunities for immersive digital interactions. As VR technology advances and becomes more affordable, it could enable wider engagement in conservation planning and decision making, as noted on Reflection & Future Works.

This thesis acknowledges these challenges and aims to provide a robust framework practiced on the Nigel Hanlon Memorial Hut site which can be used as an example to practice onto different contexts. By leveraging VR's capabilities and integrating advanced documentation techniques, this research seeks to push the boundaries of existing conservation practices.

1.6 Chapter Structure

This thesis presents a structured framework integrating photogrammetry, Heritage Building Information Modelling (HBIM), and Virtual Reality (VR) to address the challenges of conserving at-risk heritage sites. Traditionally, conservation practices have involved converting point cloud data into HBIM models using software like Revit or Blender. As discussed in Chapter 4, this process involves importing laser-scanned point clouds to create detailed 3D representations of structures, supporting heritage conservation. Building on these established methods, this research explores the integration of HBIM with VR, allowing users to interact with digital heritage sites in an immersive environment. As noted in Chapter 4, combining HBIM with VR enhances visualisation and enables real-time exploration of design modifications. This approach provides a more intuitive and interactive platform for conservation efforts, potentially improving collaborative decision making and stakeholder engagement (Lin, 2017).

1.6.1 Chapter 2: Literature Review

This Chapter establishes the theoretical framework for the research, focusing on the role of digital technologies in heritage conservation. It examines the challenges of documenting at-risk heritage sites and explores the benefits of photogrammetry, HBIM, and Virtual Reality (VR) in conservation. The review highlights global and local studies demonstrating how these technologies enhance accuracy, accessibility, and potentially help create creative design outputs in heritage conservation. It also discusses the challenges of implementing digital documentation, such as cost and maintaining authenticity. The methodologies outlined in this Chapter provide a foundation for the digital workflow proposed in Chapter 4. Additionally, this chapter supports the development of key design principles tested in later chapters, including Conservation of Authenticity, Creative Engagement through VR, Community Engagement and Accessibility and Iterative and Collaborative Design.

1.6.2 Chapter 3: Case Study Analysis

This Chapter analyses three case studies, Sir Edmund Hillary's Antarctic Hut, the Bamiyan Buddhas, and the Notre Dame Cathedral fire restoration to illustrate the role of digital documentation and VR in conservation. The Antarctic Hut project demonstrates how VR enhances accessibility to remote heritage sites. The Bamiyan Buddhas case highlights the use of photogrammetry in reconstructing heritage destroyed by conflict. The Notre Dame Cathedral restoration underscores the value of pre-emptive digital documentation in facilitating accurate rebuilding. Lessons from these case studies inform the workflow developed in Chapter 4, particularly in leveraging photogrammetry, HBIM, and VR for conservation.

1.6.3 Chapter 4: Developing a Digital Documentation and Design Workflow for VR Heritage Conservation

This Chapter details the methodology for capturing, processing, and applying digital documentation techniques for heritage conservation. It compares available technologies such as LiDAR, photogrammetry, and HBIM, evaluating their suitability for the Nigel Hanlon Memorial Hut case study. Due to cost and accessibility constraints, photogrammetry was chosen as the primary documentation method, as discussed in Chapter 4. The workflow integrates Agisoft Metashape for point cloud generation and Revit for HBIM modelling, followed by VR applications like Shapelab VR for immersive visualisation. The workflow is tested through architectural follies, which translate cultural memory into design interventions, as further explored in Chapter 6.

1.6.4 Chapter 5: Site Selection & Analysis – Nigel Hanlon Memorial Hut, Piha

This Chapter outlines the process for selecting the Nigel Hanlon Memorial Hut as the research site, considering factors such as historical significance, environmental vulnerability, and accessibility for digital documentation. The Hut was identified as an ideal case study due to its risk of flooding, coastal erosion and vandalism, reinforcing the urgency of digital conservation.

The site's scale made it feasible for photogrammetry using accessible equipment, as discussed in Chapter 4. Additionally, the Hut's cultural significance for outdoor education and community engagement highlights the potential for VR applications in conservation, aligning with themes explored in Chapter 6.

1.6.5 Chapter 6: VR Workflow Proof of Concept - Folly Architecture

This Chapter applies the digital workflow developed in Chapter 4 to the design of architectural follies, small scale structures that act as interactive heritage interventions. These follies serve various functions, from storytelling and artistic expression to memory conservation, and are designed using photogrammetry, HBIM, and VR. The Graffiti Wall Folly, for example, provides a space for community driven artistic contributions, while the Campfire Folly fosters storytelling traditions. VR enhances the iterative design process, allowing real-time exploration and modification of the structures. This Chapter demonstrates how digital tools can conserve both tangible and intangible heritage, ensuring engagement with cultural narratives for future generations.

CHAPTER 2 LITERATURE REVIEW

The field of heritage conservation is increasingly shaped by the integration of advanced digital technologies, which offer new ways to document, conserve, and analyse at-risk cultural sites (But, 2024). This thesis centres on the development and application of a Virtual Reality (VR) Workflow described in the methodology in Chapter 4. In developing this workflow including methods of heritage documentation, it is very important to understand site requirements and community needs. In the context of heritage conservation, authenticity means the "*credibility or truthfulness of the surviving evidence and knowledge of the cultural heritage value of a place*" (ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010). The *"ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value (2010)"* highlights that conserving authenticity is essential to maintaining the historical and cultural integrity of heritage sites (ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010). The following sections of this literature review will examine these ideas through three key themes: (i) 2.1 The Need for Heritage Documentation for Cultural Heritage at Risk, (ii) 2.2 Designing for cultural heritage using Virtual Reality (VR), and (iii) 2.3 Proposed Digital Documentation and Design Principles.

2.1 The Need for Heritage Documentation for Cultural Heritage at Risk

Cultural heritage sites face increasing risks from climate change, human activities, and natural disasters, making effective documentation essential. The proceedings of the International Co sponsored Meetings of the Intergovernmental Panel on Climate Change (IPCC) - International Council For Monument and Sites (ICOMOS) - International Union for Conservation of Nature (IUCN) - on Impacts, Vulnerability, and Understanding Risks from Climate Change to Culture and Heritage that took place virtually from 6 - 10 December 2021 highlights the need to understand the vulnerability of cultural heritage sites and to adopt adaptive documentation practices, which involve flexible and evolving methods tailored to different typologies of structures from small scale vernacular buildings to large scale monuments, by employing appropriate technologies such as photogrammetry to protect cultural assets (Nicholas P. Simpson et al., 2022). Digital technologies provide precise and efficient methods for recording at-risk sites, supporting conservation and disaster management efforts (Laohaviraphap & Waroonkun, 2024). These tools enhance resilience and These tools enhance resilience and ensure the conservation of cultural heritage for future generations.

The documentation and conservation of cultural heritage sites are increasingly reliant on digital technologies, which provide precise, efficient, and sustainable methods for addressing challenges posed by environmental, human-induced, and natural threats (Laohaviraphap & Waroonkun, 2024). Heritage Building Information Modelling (HBIM) supports interdisciplinary collaboration by allowing architects, conservationists, and engineers to work within a unified digital platform. This approach ensures that conservation strategies are informed by a comprehensive understanding of a site's condition and historical context (Stylianidis & Remondino, 2016).

2.1.1 Global Context of Heritage Documentation

ICOMOS addresses challenges and threats to cultural heritage as a result of climate change through its *"Future of Our Pasts report"*, which emphasises the need for international collaboration, public awareness, and adaptive design strategies in heritage conservation. The report provides a framework for systematically assessing climate related risks, such as sea level rise and coastal flooding, which directly threaten sites like the Nigel Hanlon Memorial Hut in Piha as discussed in Chapter 5 (The Future of Our Pasts - Engaging Cultural Heritage in Climate Action ICOMOS, 2019). The *"ICOMOS Principles for the recording of monuments, groups of buildings and sites (1996)"* highlight the importance of precise and accessible documentation for understanding and conserving cultural heritage outline that documentation serves to capture the physical configuration, condition, and use of heritage sites at specific points in time, thereby supporting informed conservation decisions (ICOMOS, 1996). The responsibility for accurate and comprehensive recording lies with those managing or owning the heritage site.

The *"UNESCO Enhancing Our Heritage Toolkit 2.0"* offers a structured framework for addressing the unique challenges of conserving at-risk heritage sites (UNESCO et al., 2023). It is divided into three phases - preparing, gathering information, and implementation. The toolkit provides tools such as the Identification of Site Values and Assessment of Vulnerability, which align closely with this thesis's focus on digital documentation for conserving the Nigel Hanlon Memorial Hut. These values highlight the need for comprehensive digital documentation, conserving both tangible and intangible heritage for future generations. The toolkit's emphasis on stakeholder engagement and adaptive management highlights the potential of integrating digital tools into heritage conservation strategies. For the Hut, incorporating these international frameworks and principles ensures that digital documentation efforts are thorough, standardised, and conducive to effective conservation and creative design outputs.

The *"UNESCO Dive into Heritage"* project exemplifies the global effort to digitise cultural heritage for accessibility and conservation. Similar to the 3D Past platform, it enables public access to World Heritage sites through high-resolution digital archives, ensuring the transmission of heritage knowledge to future generations. By facilitating detailed digital documentation, projects like these support both conservation and educational outreach, reinforcing the role of VR and HBIM in heritage engagement (Stylianidis, 2019).
CIPA's evolving heritage documentation standards ensure that digital conservation practices remain technologically advanced and responsive to emerging challenges (Stylianidis, 2019). By aligning with these frameworks, this thesis establishes a technologically strong approach to digital heritage conservation with the available technologies.

Effective data management is essential for ensuring the longevity and accessibility of digital heritage records. Applying FAIR (Findable, Accessible, Interoperable, Reusable) principles enhances data usability, while CARE (Collective Benefit, Authority to Control, Responsibility, Ethics) ensures ethical handling, particularly for Indigenous knowledge (Carroll et al., 2021).

By integrating methodologies from the "*Enhancing Our Heritage Toolkit 2.0*" and adhering to ICOMOS and CIPA guidelines, this project ensures the Nigel Hanlon Memorial Hut is both conserved and reimagined through innovative architectural interventions. While the Toolkit focuses on assessing vulnerabilities and implementing conservation strategies, ICOMOS and CIPA establish global standards for accurate and accessible heritage documentation (ICOMOS, 1996; UNESCO et al., 2023). Additionally, "*UNESCO's Dive into Heritage project*" shows how projects can be presented to a wider audience to bring exposure to heritage sites. Together these frameworks support the use of photogrammetry, HBIM, and VR, ensuring both precision and adaptability in conservation efforts.

2.1.2 Local Applications of Digital Documentation

The scope of digital documentation for cultural heritage at risk is growing in Aotearoa New Zealand (Harkness, 2022) and is becoming central to heritage conservation efforts. While Institutions such as the National Library of New Zealand focus on digital archiving of historical documents, recent initiatives have expanded to include rapid digitally collect, conserve, and provide access to the nation's digital heritage. Projects utilising photogrammetry, 3D scanning, and HBIM aim to capture detailed records of heritage structures before they deteriorate or are lost. These efforts emphasise a national commitment to safeguarding cultural assets through advanced digital recording techniques (Khan et al., 2024; Vallis et al., 2018).

The International Council on Monuments and Sites *"ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value"* provides guiding principles for conservation practices within the national context (ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010). The Charter while states *"The documentation of the conservation work as it proceeds; and where appropriate, the deposit of all records in an archival repository"* Clause 15 Line 9-10 it does not explicitly address the methodologies for digital documentation. This suggests a potential gap in the guidance, highlighting the need for updated protocols that incorporate modern digital techniques to enhance the accuracy and accessibility of heritage records within the New Zealand context (ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010).

Local architectural projects exemplify the practical application of these technologies. For example, the Christchurch Cathedral that was severely damaged during the Canterbury earthquake sequence (2010-2011), is a prominent example. Due to the Cathedral's structural instability, the building was at risk of demolition necessitating innovative approaches for assessment and conservation planning. In 2021, a collaborative effort involving architectural firm Warren and Mahoney and technology company Aware Group introduced "Spot," a robotic dog equipped with laser scanning technologies (Aware Group, 2025). Spot navigated the risky terrain within the interior of the cathedral, capturing high resolution 3D data that showed insights to the condition. This data helped understand the development of precise reconstruction strategies, ensuring that restoration efforts aligned cathedral's historical significance while including modern safety standards. This project shows a local context to the use of digital technologies incorporated within the workflow to conserve heritage site (Aware Group, 2025). Another example is the work undertaken at the site of the Colonial

Ammunition Company Shot Tower in Auckland. Constructed around 1916, the Tower was the last remaining shot tower in New Zealand, a tall structure historically used for manufacturing lead shot by dropping molten lead from a height to form spherical pellets (Engineering New Zealand te ao rangahau, 2025). It was recognised for its unique steel framed structure. In February 2023, concerns about structural instability were raised with the understanding of the upcoming Cyclone Gabrielle, this led to the decision to demolish the tower to ensure public safety. Prior to demolition, a team from Massey University's School of the Built Environment and Unitec's School of Architecture conducted an urgent drone based 3D scan of the structure. This initiative aimed to create a comprehensive digital record of the tower, conserving its historical and architectural significance for future research and public access. The digital models now serve as permanent archives, enabling virtual engagement with the site and supporting educational endeavours in heritage conservation (Drone Footage Used to Make Digital Record of New Zealand's Last Standing Shot Tower - Massey University, 2023; Potangaroa et al., 2023).

This study builds on insights from local initiatives, guiding the integration of digital technologies to address the research questions.

2.2 Designing for cultural heritage using Virtual Reality (VR)

The application of Virtual Reality (VR) in the design and conservation of heritage sites has revolutionised preceding methodologies, offering immersive and interactive experiences that enhance conservation processes and public engagement. This section explores the global and local contexts of VR integration in heritage conservation, showcasing significant examples and expert viewpoints.

2.2.1 Global Perspectives on VR in Heritage Conservation

Globally, VR has proven to be a powerful tool in cultural heritage conservation. According to a review by "*A Survey of Augmented, Virtual, and Mixed Reality for Cultural Heritage*", VR technologies are now advanced enough for practical use, enabling virtual tours and immersive experiences that help conserve both physical structures and intangible cultural elements like traditions and narratives (Bekele et al., 2018). A significant global initiative is the "*3DPAST - Living & Virtual Visiting European World Heritage*" project, supported by International Council on Monuments and Sites (Escola, 2025). This project uses photogrammetry to document and virtually present Nigel Hanlon Memorial Hut making local heritage site accessible to a wider audience. This approach promotes awareness, education, and conservation by allowing global audiences to experience heritage sites they might never visit in person (Escola, 2025).
The website for the "*3D Past*" project highlights its success, reporting over 17,000 page views, 97,000 3D model views, and engagement from users across 94 countries. These metrics demonstrate the project's effectiveness in increasing global accessibility to heritage sites. This success underscores the potential for applying similar digital strategies to the Nigel Hanlon Memorial Hut, expanding its reach and engagement through virtual heritage platforms (Escola, 2025).

2.2.2 Challenges and Considerations for VR applications in Heritage Conservation

While VR holds great potential for heritage conservation, the current challenges must be addressed to fully realise its benefits. According to (Bekele et al., 2018), despite advancements in VR technology, high development costs, the need for interdisciplinary collaboration, and user experience design issues remain significant obstacles. Creating high-quality VR experiences requires substantial investment in hardware, software, and skilled personnel, making it costly, particularly for smaller projects. Additionally, effective VR-based heritage projects rely on collaboration among experts from diverse fields, which can be challenging due to differing methods and goals (Wang et al., 2024). Furthermore, sustaining digital conservation efforts over the long term requires ongoing resources and careful data management to prevent technological obsolescence and ensure accessibility for future generations (Buragohain et al., 2024; Digital Preservation Handbook, 2025). Addressing these challenges through adequate funding, interdisciplinary teamwork, user focused design, and sustainable practices will enhance the effectiveness of VR in cultural heritage conservation. These considerations are essential while the thesis researches for a suitable workflow for the chosen site. With these in mind, this research has tailored solutions for the selected site as discussed in Chapter 4.2 to overcome these factors.

2.3 Proposed Digital Documentation and Design Principles

2.3.1 Digital Documentation Workflow

A comprehensive workflow often begins with photogrammetry, a method that utilises photographic images to generate detailed point clouds and textured 3D models of heritage sites (Mostafavi et al., 2019). These models are processed using specialised software such as Agisoft Metashape, which constructs high-resolution 3D representations from the captured images. This process has also been replicated in the chosen site as explained in Chapter 4.2. Photogrammetry, combined with Building Information Modelling (BIM) using software like Revit, has become a standard approach in heritage conservation. This method involves capturing detailed images to create accurate 3D models, which are then used in Heritage Building Information Modelling (HBIM) for effective management and conservation of cultural heritage sites.

2.3.2 Design Principles

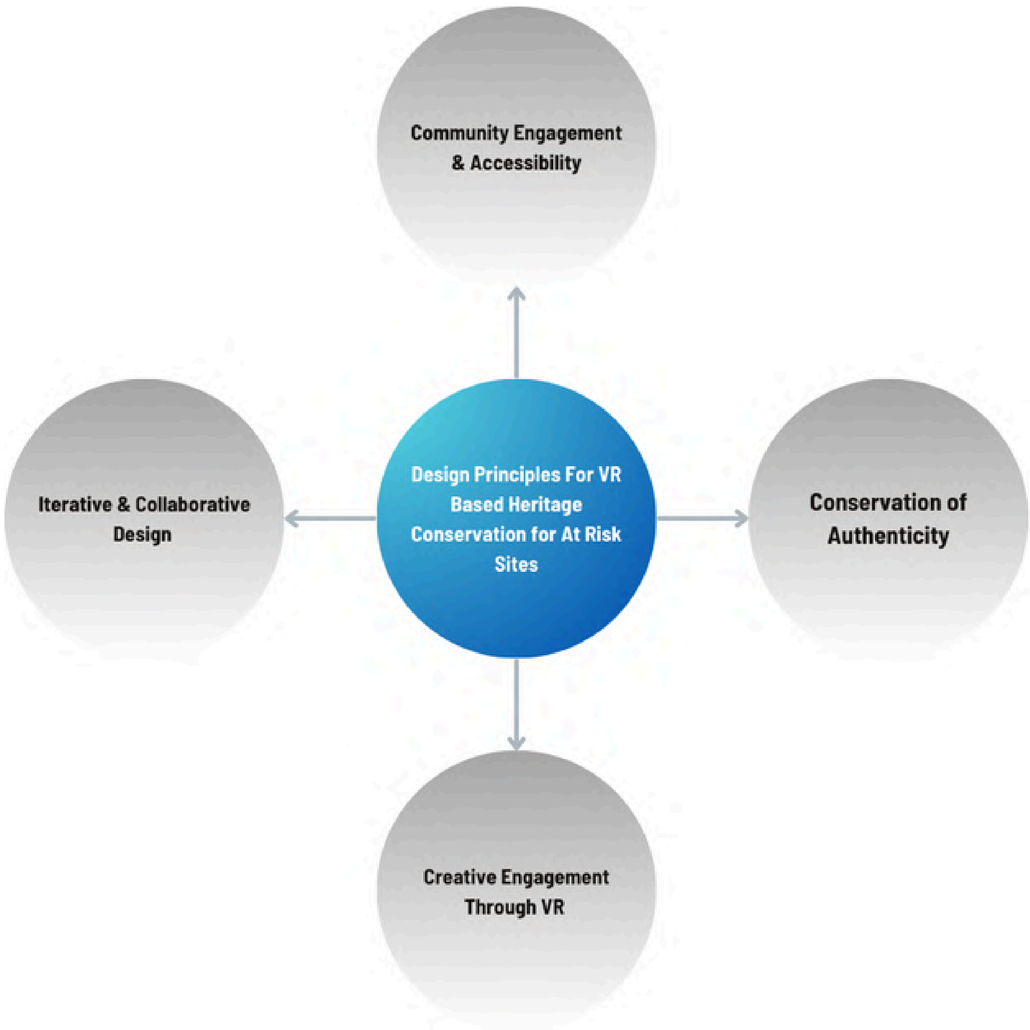

Figure 2. Design Principles for VR Based Heritage Conservation for At Risk Sites, by Author

The following principles as shown in Figure 2 have been established using the conservation literature and guidelines, including the "*ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value (2010)*", the "*UNESCO Operational Guidelines for the Implementation of the World Heritage Convention (2024)*", and the "*ICOMOS Principles for the Recording of Monuments, Groups of Buildings, and Sites (1996)*". These frameworks provide the foundation for ensuring authenticity, sustainability, and best practices in heritage conservation in mind, ensuring the effective application of Virtual Reality (VR) while aligning with conservation priorities. These principles will be applied to inform the development of architectural follies for the Nigel Hanlon Memorial Hut in Chapter 6, demonstrating their role in guiding design and documentation within the VR-based workflow. The first principle, Conservation of Authenticity, emphasises conserving a site's cultural values through accurate documentation of its form, design, materials, and function. By using photogrammetry and Heritage Building Information Modelling (HBIM), the framework ensures that any interventions maintain the site's historical integrity rather than compromise it, safeguarding its authenticity for future generations (ICOMOS, 1996; Letellier et al., 2007; UNESCO World Heritage Centre, 2020).

Creative Engagement through VR allows users to explore heritage sites immersive and interactive, enhancing public understanding and appreciation. VR also provides a platform for stakeholders to participate in the design and decision-making process, ensuring diverse perspectives are included in conservation efforts (Arts Management & Technology Laboratory, 2022; Bekele & Champion, 2019; Escola, 2025).

Community Engagement and Accessibility are achieved by using VR to make heritage sites more accessible to a broader audience, including those unable to visit in person (UNESCO World Heritage Centre, 2020). Although the Nigel Hanlon Memorial Hut is not a World Heritage site, it holds cultural significance for the Piha community as mentioned in Chapter 5.3 and in the "*Nigel Hanlon Memorial Hut*" Report (Reynolds Associates, 2010). VR enables virtual access and fosters community involvement by translating local memories into tangible architectural forms, promoting shared responsibility and stewardship (Murphy, 2022).

Finally, iterative and collaborative design is supported by VR's capability for continuous testing, visualisation, and refinement of conservation interventions before implementation. This iterative process allows stakeholders to collaboratively assess changes and make informed decisions, aligning with CIPA's principles of continuous improvement in heritage documentation (ICOMOS, 1996).

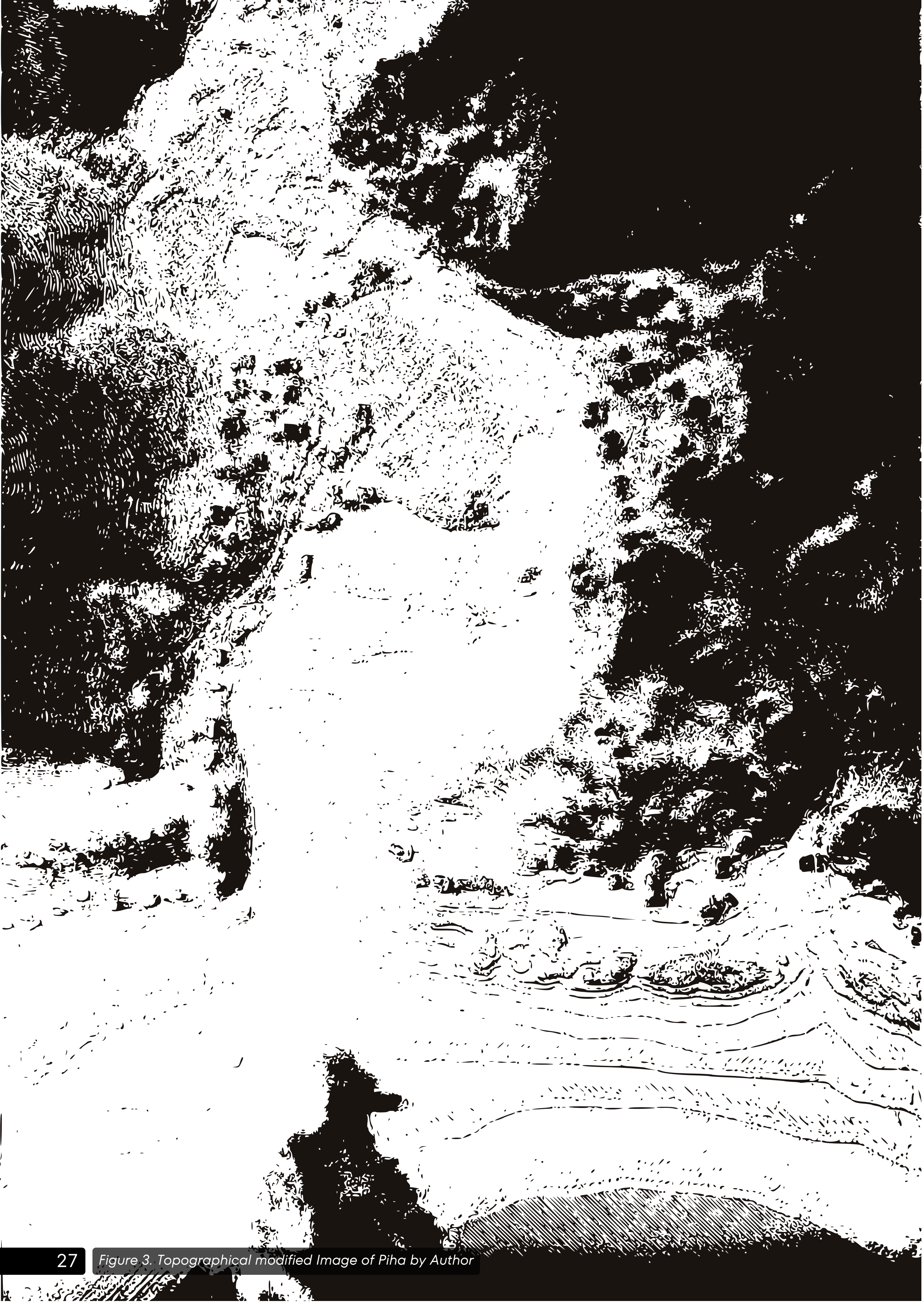

Figure 3. Topographical modified Image of Piha by Author

CHAPTER 3 CASE STUDY ANALYSIS

This Chapter examines three significant case studies that highlight the diversity of architectural heritage, geographical contexts, and conservation challenges. Sir Edmund Hillary's Antarctic Hut, built in 1957 as part of the Commonwealth Trans Antarctic Expedition, is an example of 20th century expedition architecture, represents a remote and extreme environment where access to limitations necessitate digital solutions such as virtual reality (VR) to ensure global accessibility. The Bamiyan Buddhas in Afghanistan, carved in the 6th century, were monumental rock cut sculptures that stood as significant cultural and religious icons. They were destroyed in 2001 by the Taliban as part of a campaign against non-Islamic imagery, leading to an international effort to conserve their memory through digital reconstruction and photogrammetry. The Notre Dame Cathedral in Paris, an exemplar of Gothic architecture, was constructed between 1163 and 1345. Its 2019 fire highlighted the importance of pre-emptive digital documentation, as prior laser scanning and HBIM models played a crucial role in guiding its restoration efforts. Together, these case studies illustrate how advanced technologies like VR, photogrammetry, and BIM contribute to the conservation of different architectural heritage typologies across various scales, locations, and historical contexts.

3.1 Sir Edmund Hillary's Antarctic Hut

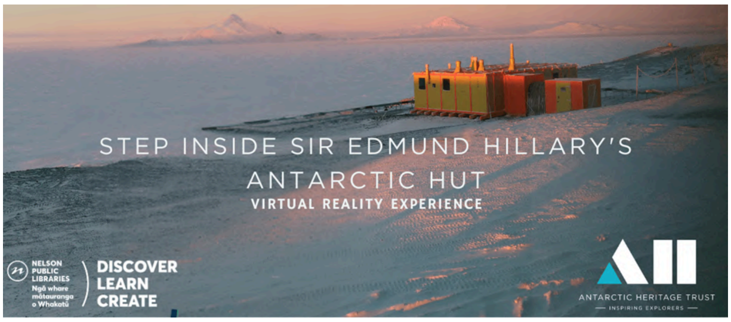

Figure 4. Hillary's Antarctic Hut VR Experience ©AHT/Tim McPhee, (Hillary's Antarctic Hut VR Experience, 2024)

Established in 1957 during the Commonwealth Trans-Antarctic Expedition, Sir Edmund Hillary's Antarctic Hut (Figure 4) at New Zealand's Scott Base bears historical significance. Due to its remote location, the Antarctic Heritage Trust, in collaboration with Auckland University of Technology (AUT), developed a virtual reality (VR) experience to digitally conserve and share the Hut with a global audience. This initiative aimed to conserve its physical attributes, including its original structure, interior layout, furniture, and scientific equipment, while making the site accessible through mobile devices and VR headsets (Antartic Heritage Trust, 2025). To create an immersive VR model, AUT's research team together with Staples VR used photogrammetry, capturing high resolution images to construct detailed 3D models of the Sir Edmund Hillary's Antarctic Hut's five rooms. These models were integrated into an interactive VR environment using Unreal Engine, allowing users to explore the Hut and understand the living conditions of its original occupants

(Gregory Bennett, 2021). This project demonstrates how VR technology can overcome geographic barriers, making remote heritage sites accessible while enhancing public engagement. By offering virtual tours, it fosters appreciation for New Zealand's Antarctic heritage and ensures the legacy of Sir Edmund Hillary is conserved for future generations (Antartic Heritage Trust, 2020). The methodology used in this project closely aligns with the digital workflow proposed in this thesis. Photogrammetry ensured historical accuracy, while VR integration enabled interactive engagement, mirroring this thesis's approach to the Nigel Hanlon Memorial Hut. The case study highlights the importance of high-quality data capture and immersive storytelling, reinforcing the role of VR in both conservation and community engagement. By using precise pre-emptive imagery and historical records, the project maintains authenticity, ensuring the digital reconstruction accurately reflects the original site without speculation. This demonstrates how digital tools can conserve heritage while upholding historical integrity.

3.2 The Bamiyan Buddhas, Afghanistan

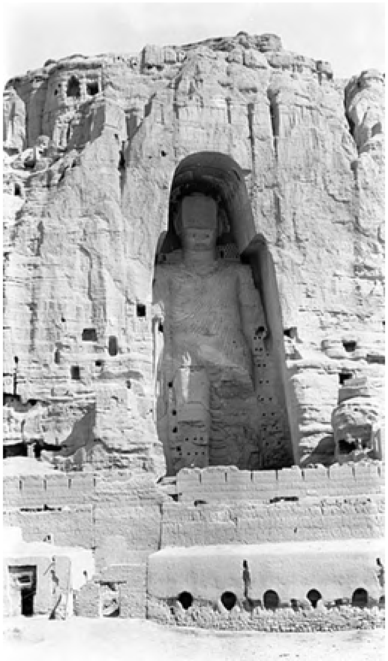

Figure 5. Bamiyan Buddha After Demolition, (Clapp, 1936)

The Bamiyan Buddhas, two monumental statues carved into Afghanistan's Bamiyan Valley in the 6th century, stood as cultural and religious icons for centuries. Their destruction in 2001 by the Taliban was a major loss to global heritage as seen in Figure 5. In response, researchers from ETH Zürich used photogrammetry and 3D modelling to digitally reconstruct the larger Buddha using before destruction photographs. This process combined automatic and manual triangulation with texture mapping, resulting in a high-resolution digital model that conserves the statue's memory and could support potential physical reconstruction (Grün et al., 2004).

This project demonstrates the importance of digital documentation in conserving heritage lost to conflict or disasters. Photogrammetry ensured that, despite the physical loss, the Buddhas' cultural significance could be digitally conserved, aligning with this thesis's approach to documenting heritage at risk. The digital reconstructions uphold authenticity by relying on accurate before the destruction imagery, historical documentation, and 3D scanning, rather than speculative or imaginative rebuilding. The project also highlights the value of community engagement in digital conservation. By making these digital reconstructions publicly accessible, it fosters global awareness and appreciation of Afghan cultural heritage. Similarly, the proposed VR framework for the Nigel Hanlon Memorial Hut aims to engage the local community, ensuring the site's historical and cultural significance is both conserved and experienced by future generations. This case study reinforces the role of digital tools in both conservation and public education.

3.3 Notre Dame Cathedral, Paris, France

Figure 6. Notre-Dame Cathedral: 2019 fire (Britannica, 2019)

The Notre Dame Cathedral in Paris, a landmark of Gothic architecture, suffered severe damage in a 2019 fire as seen in Figure 6, leading to the collapse of its spire and structural instability (Vannucci et al., 2019). This incident highlighted the importance of precise digital documentation for restoration efforts. Fortunately, prior to the fire, Professor Andrew Tallon, an architectural historian at Vassar College (Cook '10, 2023), had conducted detailed laser scans, creating comprehensive digital records that became essential for reconstructing damaged elements accurately. Building Information Modelling (BIM) further facilitated collaboration among architects, engineers, and conservators, ensuring that the restoration conserved the Cathedral's original design while incorporating modern safety standards (Dollard, 2019; Khalil, 2024).

This project underscores the value of pre-emptive digital documentation in heritage conservation, which refers to the proactive recording of a heritage site's condition before damage occurs, enabling accurate reconstruction when needed (1993 ICOMOS New Zealand). The use of laser scanning provided highly accurate spatial data, ensuring the authenticity of the reconstruction by maintaining the cathedral's original proportions, materiality, and architectural details. As previously stated, authenticity in heritage conservation refers to the credibility and truthfulness of surviving evidence (ICOMOS New Zealand Charter for the Conservation of Places of Cultural Heritage Value, 2010), and in this case, the Notre Dame restoration relied on precise digital documentation to uphold this principle. Similarly, this thesis advocates for photogrammetry and HBIM to create detailed digital models, ensuring at-risk heritage sites are recorded for future conservation. The Notre Dame case also highlights the importance of interdisciplinary collaboration, where experts from various fields worked together to balance historical authenticity with contemporary needs (Historic Preservation: How Laser Scanning Can Save Historic Sites - Curbed, 2019).

Lessons from these case studies directly inform the digital workflow proposed in this thesis. The Antarctic Hut project was completed over several years, with researchers using on-site photogrammetry to create a VR model for public access via mobile devices and headsets. The Bamiyan Buddhas reconstruction has been ongoing since 2001, with digital scans based on archival photos due to restricted site access. The Notre Dame restoration, initiated in 2019, benefited from pre-existing laser scans and remains a multi-year effort. While the Antarctic Hut data is publicly available through the Antarctic Heritage Trust, access to Notre Dame and Bamiyan Buddhas data is primarily restricted to conservation teams and researchers. These examples provide a strong foundation for integrating photogrammetry, HBIM, and VR in conserving at-risk heritage sites, ensuring both tangible and intangible heritage are conserved for future generations.

CHAPTER 4 DEVELOPING A DIGITAL DOCUMENTATION AND DESIGN WORKFLOW FOR VR HERITAGE CONSERVATION

This Chapter explores various digital documentation technologies used to capture form, comparing their effectiveness for heritage conservation. It examines how these methods, including photogrammetry, LiDAR, and HBIM, can be integrated with virtual Reality (VR) to develop new approaches for documenting and conserving at-risk heritage sites while innovating creative outputs.

4.1 Comparing Market Technologies

Table 1 below presents a comparative analysis of various digital documentation methods considered for this thesis, highlighting their advantages and disadvantages for both documentation and design applications. The methods evaluated include photogrammetry, 3D laser scanning (LiDAR), manual measurement and sketching, and photographic documentation. Each method was assessed, based on its accuracy, cost effectiveness, accessibility, and suitability for creating detailed 3D models. This analysis played a critical role in determining the most appropriate technique for documenting the Nigel Hanlon Memorial Hut, considering the project's resource constraints, site conditions, and design objectives.

Table 1. Digital Documentation Methods

Digital Documentation Methods		
Photogrammetry Uses overlapping photographs taken from multiple angles to create detailed 3D models of buildings.	**Advantages for Documentation**	**Advantages for Design Application**
	• Provides detailed and textured 3D models. • Cost effective and accessible with modern smartphones and cameras. • Can be done remotely, reducing the need for onsite visits.	• High resolution textures enhance visual realism. • Useful for creating accurate visualisations and context aware designs.
	Disadvantages for Documentation	**Disadvantages to Design Application**
	• Requires careful planning and consistent image overlap. • Sensitive to lighting conditions and image quality. • Post processing can be time consuming and complex.	• Textures may not always perfectly align with geometry. • Less effective in capturing detailed structural data without additional methods.

3D Laser Scanning (LiDAR) Uses laser pulses to measure distances and create highly accurate 3D point clouds of structures.	**Advantages for Documentation**	**Advantages for Design Application**
	• Captures highly accurate geometric data. • Effective in various lighting conditions and can scan large areas quickly. • Provides detailed point clouds that capture intricate details.	• Provides precise measurements and detailed geometric data, aiding in accurate design. • Useful for creating detailed and accurate 3D models that can be directly used in design software.
	Disadvantages for Documentation	**Disadvantages for Design Application**
	• Equipment is expensive and requires significant expertise to operate. • Data files are large, requiring substantial storage and processing capacity. • Limited texture information compared to other methods.	• High costs associated with equipment and software. • Data processing can be complex and time consuming. • Mobility and accessibility limitations in complex or confined spaces.

Manual Measurement and Sketching Involves taking physical measurements and creating hand drawn sketches or digital drawings.	**Advantages for Documentation**	**Advantages for Design Application**
	• Provides detailed and direct measurements of specific features. • Allows for personal observations and notes.	• Useful for preliminary design and conceptualisation. • Allows for direct interaction and observation of the site.
	Disadvantages for Documentation	**Disadvantages for Design Application**
	• Time consuming and prone to human error. • Limited in capturing complex geometries or large-scale features.	• Lack of precision compared to digital methods. • Limited in creating detailed or accurate digital models. • Challenges with capturing complex geometries and fine surface details.

Photographic Documentation Involves capturing high resolution photographs of the building's features.	**Advantages for Documentation**	**Advantages for Design Application**
	Provides visual records of building conditions and features. Easy to capture and integrate with other methods.	• Useful for reference and creating visual context in design. • Can be combined with other methods for a comprehensive understanding.
	Disadvantages for Documentation	**Disadvantages for Design Application**
	• Limited to visual information without detailed spatial data. • Requires careful planning for consistent coverage and context.	• Cannot provide detailed geometric data or accurate measurements. • Dependent on the quality of the photographs and camera equipment.

A key factor influencing the choice of photogrammetry for this thesis was the unavailability of LiDAR equipment at Auckland University of Technology (AUT). While LiDAR offers highly accurate geometric data and detailed point clouds, its inaccessibility due to equipment constraints made it impractical for this project. The high costs and specialised expertise required for LiDAR further contributed to the decision to pursue a more accessible method. The use of drones to capture the roof and surrounding area of the Nigel Hanlon Memorial Hut was considered, particularly for the roof structure. However, the site's location within a regional park posed significant challenges, as drone flights are prohibited without prior permission from Auckland Council. Given the constraints of the project timeline, obtaining the necessary permissions was not feasible. Fortunately, the simplicity of the Hut's roof design allowed for an accurate estimation of its shape without aerial data. These limitations and considerations led to the selection of photogrammetry using an Android phone, offering a practical, cost-effective solution that met the documentation needs of the project while working within the available resources and time frame.

4.2 Tailoring Workflow Solutions

Based on the discussions in Chapter 2 and Case Studies in Chapter 3 as well as Table 1, photogrammetry was chosen as the most appropriate approach for this project due to its cost-effectiveness, accessibility, and ability to produce high resolution 3D models. Given the scale of the Nigel Hanlon Memorial Hut and the available resources, photogrammetry provided a practical solution that balanced accuracy and feasibility. Figure 7 shows the Virtual Reality integrated workflow.

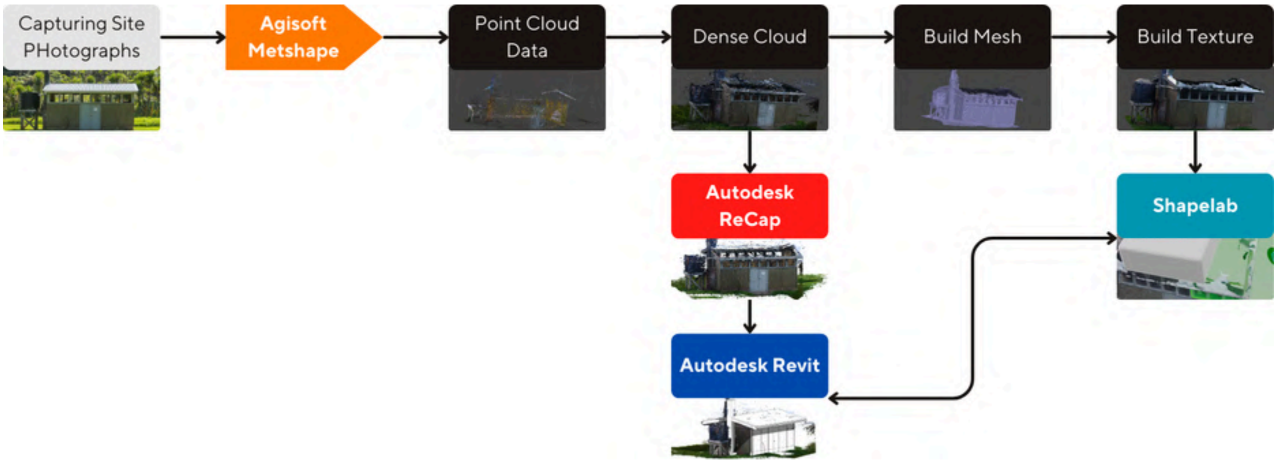

Figure 7. Explaining Workflow of research, by Author

4.2.1 Phase 1 – Data Capture

The initial phase established a theoretical foundation through a comprehensive literature review, drawing from key resources such as *"UNESCO's Enhancing Our Heritage Toolkit 2.0"* (UNESCO et al., 2023) and International Council on Monuments and Sites "*ICOMOS's The Future of Our Pasts Report*" (Climate Change and Heritage Working Group, 2019). These frameworks provided insights into global conservation strategies, including adaptive management practices and the integration of digital technologies.

Studies like the *"CIPA 3x3' RULES"* (Waldhäusl & Cliff Ogleby, 2013) informed the selection of photogrammetry as a primary data capture method. Photogrammetry is recognised for its cost effectiveness and accuracy, particularly for small scale heritage sites (Fondazione et al., 2009). Fieldwork focused on capturing high resolution images of the Nigel Hanlon Memorial Hut using accessible equipment, aligning with UNESCO's emphasis on resource conscious approaches in heritage documentation (UNESCO et al., 2023).

This phase also contextualised the site's vulnerabilities, including flood risks and vandalism, by referencing localised flood risk assessments (Tonkin & Taylor Ltd, 2019). Such risks underscored the importance of adopting resilient conservation methods informed by digital documentation.

4.2.2 Phase 2 – Data Processing

As outlined in Chapter 4.2, Agisoft Metashape was used for point cloud generation, which was later refined and integrated into HBIM & VR models to enhance the accuracy of digital documentation. This aligns with the principles outlined in *"UNESCO's World Heritage Resource Manual: Managing Disaster Risks for World Heritage"* (UNESCO et al., 2010), which advocates for leveraging digital tools to document and conserve site vulnerabilities. The generated data was refined using Autodesk ReCap, enabling the conversion of raw photogrammetric outputs into .rcs (spatially indexed point cloud data) files. These files were then integrated into Revit to create HBIM models, incorporating material properties, spatial data, and annotations. This process aligns with International Council on Monuments and Sites ICOMOS's Principles for the Recording of Monuments, Groups of Buildings, and Sites (1996) (ICOMOS, 1996), which emphasises detailed documentation as a foundation for conservation planning.

4.2.3 Phase 3 – Workflow Application

Phase 3.1 Standard Practice

The initial application of traditional conservation workflows established a baseline for evaluating the benefits of integrating VR. Standard practices were informed by International Council on Monuments and Sites ICOMOS guidelines, particularly those outlined in the *"Charter on the Built Vernacular Heritage (1999)"* (ICOMOS, 1999), which prioritises the safeguarding of intangible and tangible heritage elements.

Phase 3.2 Virtual Reality Workflow

As discussed in Chapter 2.2, VR has been integrated into conservation workflows to provide immersive engagement and enable virtual exploration of heritage sites. HBIM models were transferred into immersive VR environments using Shapelab VR. These tools facilitated real time interaction and analysis of conservation scenarios, supporting the integration of VR as recommended by (UNESCO et al., 2023) for enhancing stakeholder engagement in heritage management.

This phase enabled simulations of site-specific challenges, including flooding and structural decay, within an interactive VR platform. The ability to visualise these scenarios aligns with the International Council on Monuments and Sites ICOMOS & Article 12 of the Records of the General Conference, 32nd session, Paris of UNESCO, which highlights VR's role in improving stakeholder collaboration and conservation decision-making.

4.2.4 Phase 4 – Evaluation

As previously discussed in Chapter 3, digital accessibility and design ideation is critical for conservation efforts. This phase assessed how the workflow could be adapted to different heritage contexts involved evaluating the effectiveness of the proposed workflow against traditional methods. Metrics such as precision, adaptability, and stakeholder engagement were used, consistent with the evaluation criteria outlined in *"UNESCO's Periodic Reporting System for World Heritage Sites"*. Iterative testing and stakeholder feedback informed refinements to the workflow, ensuring its scalability and adaptability to diverse heritage contexts. The results validated VR's potential to transform heritage conservation practices by enhancing documentation, analysis, and design processes (Climate Change and Heritage Working Group, 2019a).

4.3 Photogrammetry

During my bachelor's degree at Unitec, I enrolled in an elective course titled Digitalisation of Heritage, led by Renata Jadresin Milic, Thomas Reutlinger, and Sian Singh.

Figure 8. Point cloud image of the main façade of Building One, Generated by the Digital Heritage Research Centre at Unitec (Milic, 2024).

During this course we understood the use of LiDAR cameras to produce photogrammetry models as shown in Figure 8, which were then provided to us to convert into 3D models using these models as references in Heritage Building Information Model (HBIM) replicating the original structure of Unitec's Building One (Andrew, 2020; Milic, 2024). This Building was under the threat of demolition at the time and the idea of conserving it before it was forever demolished, to conserve the memories of people that had attachments to this site, sparked an interest in me. Building on the digital methods explored in this project and the insights from Chapters 2 and 3, the following workflow has been tailored for the Nigel Hanlon Memorial Hut. Unlike the Building One project, which used LiDAR scanners to generate point cloud data, this study relied on photogrammetry due to limited access to LiDAR technology. The photogrammetry based workflow is explained in detail in the following section.

4.3.1 Capturing Site Photographs

Figure 9. Example of two photos of the target object, taken with a minimum overlap of 40%, by Author

Capturing photographs accurately is a crucial aspect of the photogrammetry process, directly impacting the precision and quality of the resulting 3D models. In accordance with the CIPA guidelines, thorough photographic coverage was ensured, with consistent lighting, appropriate overlap, and correct exposure throughout the process (Waldhäusl & Cliff Ogleby, 2013). An Android phone was used to capture multiple images from different angles, ensuring sufficient overlap between each shot. Figure 9 is an example of two photos of the target object, taken with a minimum overlap of 40%. This approach is essential for generating an accurate photogrammetry model in the subsequent steps. An example of multiple images from different angles can also be viewed in Figure 13.

4.3.2 Agisoft Metashape

Agisoft Metashape was integral in processing digital documentation of the Nigel Hanlon Memorial Hut. The following images illustrate the step-by-step process undertaken to create a detailed 3D model of the site.

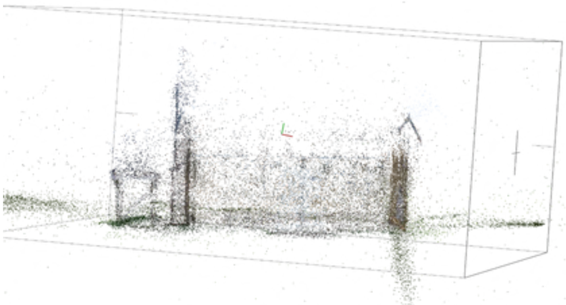

Figure 10. Point Cloud Model in Agisoft Metashape, by Author

After importing the photographs into Agisoft Metashape, the software aligned the images to generate a sparse point cloud as seen in Figure 10. This initial 3D representation is done to make sure the camera alignment is correct at the beginning of the model creation.

The dense cloud seen in Figure 11, derived from the point cloud, offers a higher level of detail. It shows the complex geometry of the heritage site, allowing for a more refined and comprehensive digital model.

Figure 11. Dense Cloud Model in Agisoft Metashape, by Author

The textured model as seen in Figure 12 incorporates photographic data to provide a realistic visual representation of the site. This model enhances the visualisation of the heritage site, making it easier to understand its current condition and potential areas requiring conservation.

Figure 12. Textured Model in Agisoft Metashape, by Author

Figure 13 illustrates the camera angles, and the alignment of photographs used to create the 3D model of the Nigel Hanlon Memorial Hut. This visual representation is critical for understanding how the photographs were positioned and their contribution to the overall model.

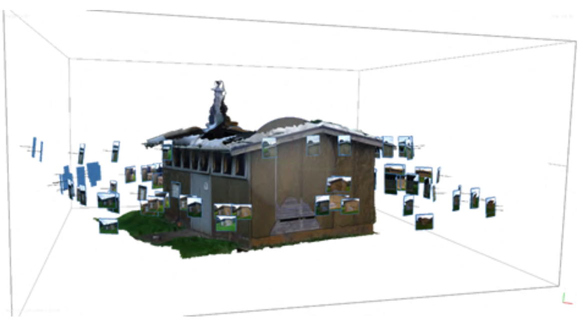

Figure 13. Camera and Image Alignment Model in Agisoft Metashape, by Author

The integration of digital documentation workflows improves the accuracy of heritage recording, facilitates collaborative conservation efforts, and ensures sustainable digital archives. The combination of photogrammetry and HBIM streamlines data collection, modelling, and conservation planning, allowing for more precise documentation and restoration. Additionally, HBIM provides a structured approach to managing historical data and material specifications, supporting long-term heritage management and public engagement (Giuliani et al., 2024; Letellier et al., 2007).

4.3.3 Importing Landscape File from GeoMaps

Figure 14. Contours selected on GeoMaps (Auckland Council GeoMaps, 2025)

The Data was first exported from the GeoMaps website (Auckland Council GeoMaps, 2025) using the .dwg format. Figure 14 shows a screenshot of the GeoMaps website to show the area selected to export.

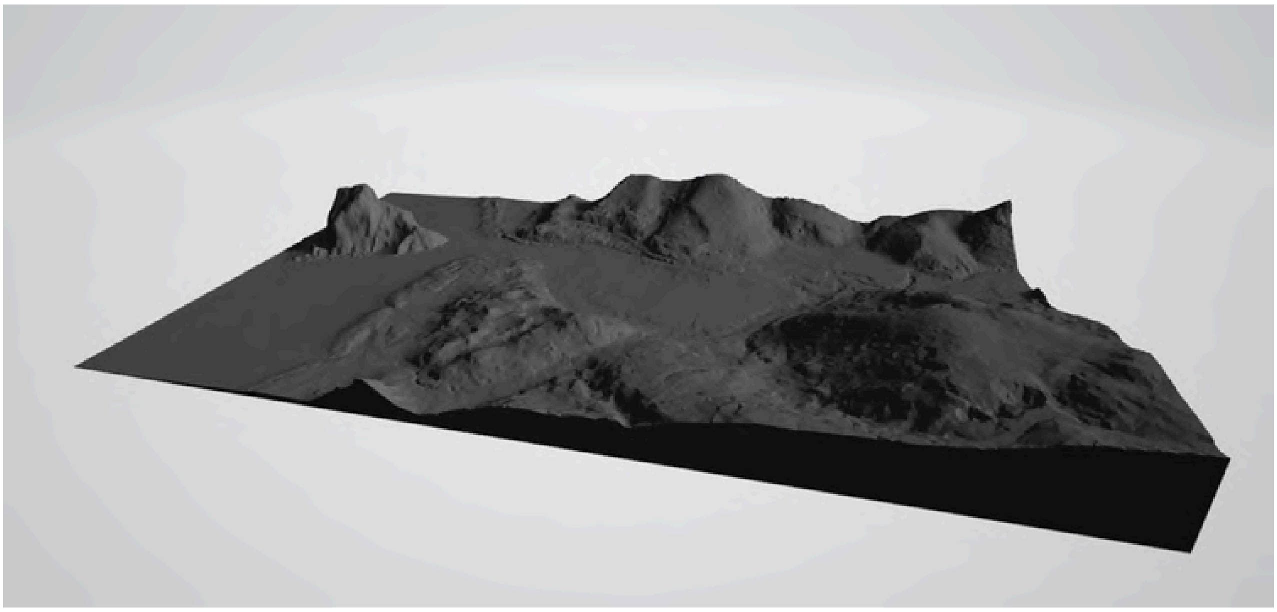

Figure 15. Contours translated to 3D model on Revit by Author.

Figure 15 shows an image of the 3D model created in Revit using the .dwg file to convert into a topographically accurate 3D model using the "Massing & Site" then "Create from Import" and then finally "Create from CAD" which is then ready to be exported in the desired format.

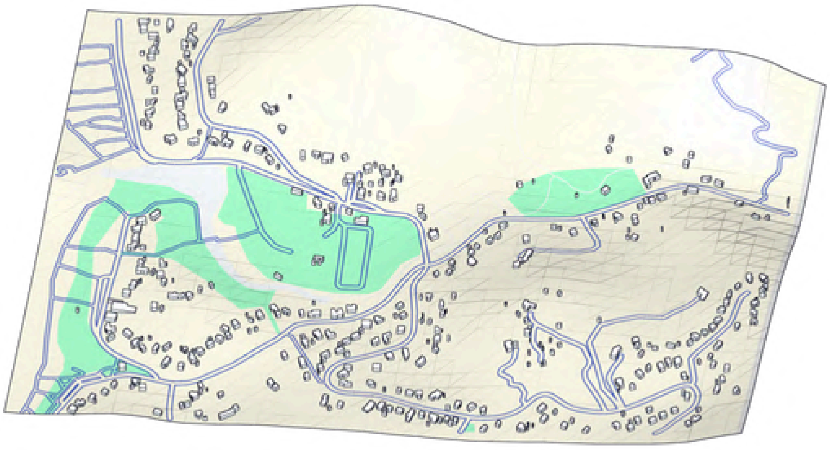

Figure 16. CADMAPPER Topography & Site Context

Figure 16 shows the file exported from "CADMAPPER" including the context models to give a better idea of the site as a whole when imported in Virtual Reality (VR) in the next steps.

4.4 Standard Practice

4.4.1 Point cloud to HBIM for Revit

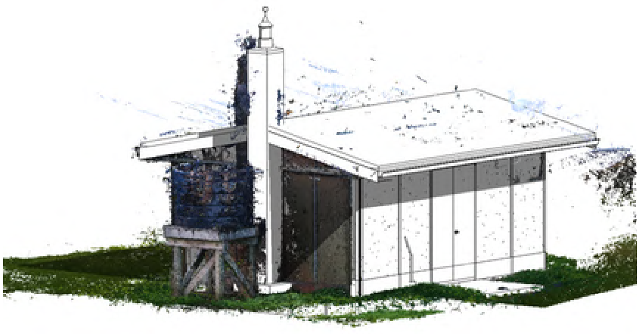

Figure 17. Point Cloud Image of the Nigel Hanlon Memorial Hut, created by the Author in Revit using Recap point cloud data.

Similar to the Building One Project. The Nigel Hanlon Memorial Hut was recreated on Revit using modelling tools to create an HBIM model as seen in Figure 17 which could be used to create realistic and authentic renders of the structure.

Figure 18. Rendered model for Nigel Hanlon Memorial Hut Piha using Lumion, by Author.

As discussed in Chapter 2.3.1, photogrammetry and HBIM are widely used for digital heritage documentation, enabling accurate 3D reconstruction of historical sites. The 3D model created in Agisoft Metashape and Revit was imported into Lumion as seen in Figure 18, a rendering software used to generate photorealistic visualisations of architectural models. Lumion was used to render the Piha Hut model, which was developed through a workflow as shown in Figure 19. Traditionally, architectural visualisation relied on manual sketching, physical models, or CAD-based renderings to represent designs and site conditions. In contrast, standard workflows, as mentioned in Chapter 2.3.1, integrate digital tools such as photogrammetry and HBIM to create highly detailed representations. Lumion was used to enhance the accuracy of the model by incorporating environmental context extracted from GeoMaps & Cadmapper as mentioned in Chapter 4.2.3 and integrating a background that closely matches the actual Piha location.

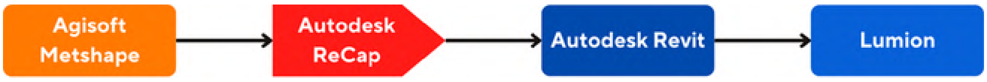

Figure 19. Workflow for Lumion, by Author

However, the geometrical complexity of the model, with its numerous detailed elements, strained the computer's processing power and graphics capabilities. This limitation is particularly relevant for future projects involving larger sites, where greater accuracy would demand more computational resources. Additionally, a notable restriction was Lumion's inability to export files into formats compatible with Virtual Reality (VR) applications, limiting flexibility for further immersive interactions. While Lumion supports the creation of 360 degree panoramas and images suitable for VR viewing, it lacks direct integration with VR platforms, necessitating additional steps and software to achieve a fully immersive VR experience (Ravi, 2021). Despite these challenges, the decision to use Lumion was influenced by familiarity and proficiency with the software. Lumion's user friendly interface and library of materials and objects facilitated the creation of a realistic visualisation of the Piha Hut within its natural surroundings (Lumion, 2025).

Figure 20. Rain rendered visualisation of the Nigel Hanlon Memorial Hut in Piha, created by the Author in Lumion

4.5 Virtual Reality Integration

4.5.1 Shapelab VR Lite

Shapelab VR, introduced in 2023 after several years in early access, is a versatile tool designed for manipulating and editing 3D models within a virtual reality environment. Its intuitive interface and user-friendly design make it relatively easy to learn and operate, especially when compared to more complex software like Blender. This ease of use allowed me to quickly master the application and achieve desired outcomes efficiently.

Figure 21. Smoothing of surfaces of the Nigel Hanlon Memorial Hut, Piha in Shapelab VR application, created by the Author.

Figure 21 displays the process of smoothing the texture of the Piha Hut wall using Shapelab VR. In reality, the wall is a smooth, flat board, but the initial photogrammetry model rendered it with rough with inaccurate textures. By using Shapelab VR, I was able to correct this discrepancy, enhancing the visual accuracy of the model. The software's texture smoothing tool allowed me to achieve a more realistic representation of the wall surface.

Figure 22. Painting over surfaces of the Nigel Hanlon Memorial Hut, Piha in Shapelab VR application, created by the Author.

Figure 22 illustrates the use of Shapelab VR's painting tools to restore the Piha Hut model by addressing vandalism. The software allows for adjusting resolution levels and provides flexibility in painting directly onto the model's texture. This feature enabled me to cover graffiti and other damage, restoring the model to its original state. The eyedropper tool was used to accurately match and apply colours, ensuring precise colour correction and a more authentic representation of the heritage site

Figure 23. Adding model details to the Nigel Hanlon Memorial Hut, Piha in Shapelab VR application, created by the Author.

Figure 23 shows the process of adding elements to the 3D model using Shapelab VR. While the software offers useful tools for modifying and enhancing models, it has limitations in accurately creating complex architectural features, such as the roof. In this case, the simplicity of the roof design meant that detailed modelling was unnecessary for conservation efforts, and alternative methods could be used to approximate its form. Although Shapelab VR provides a user-friendly interface for refining 3D models, its capabilities are more suited for surface adjustments and design ideation rather than intricate structural modifications. Compared to more advanced modelling software, it offers a more accessible but less precise solution for conservation workflows.

4.6 3D Printing

The use of 3D printing in this thesis provided a physical representation of the Nigel Hanlon Memorial Hut, allowing for direct comparison with the digital model. While VR offers an immersive experience, a physical model enables detailed examination of scale, proportions, and spatial relationships, which may not always be fully perceived in a virtual environment. Additionally, 3D printing helped validate the accuracy of the photogrammetry model, ensuring that the dimensions and geometry were correctly translated from digital data to a physical form. The Quality of these models can also be seen in Figures 24 to 28.

Although stakeholder engagement was not part of this study, 3D printing could serve as a useful tool for presenting conservation work to stakeholders who may not have access to VR or other digital technologies. A physical model allows for better visualisation of the site, particularly in cases where technological limitations prevent access to digital formats. This could be beneficial for heritage professionals, policymakers, and community members, making conservation planning more inclusive.

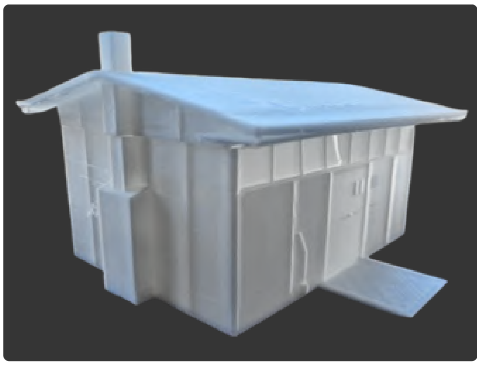
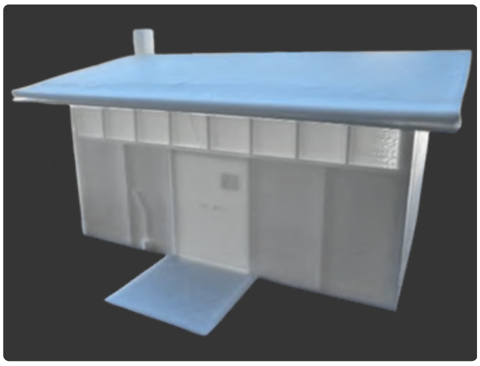

Figure 24 & Figure 25. 3D print of the Nigel Hanlon Memorial Hut HBIM model, created by the Author in Revit.

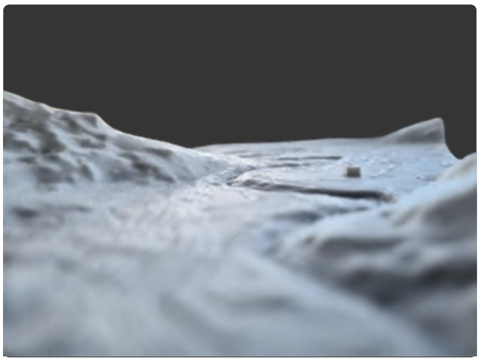
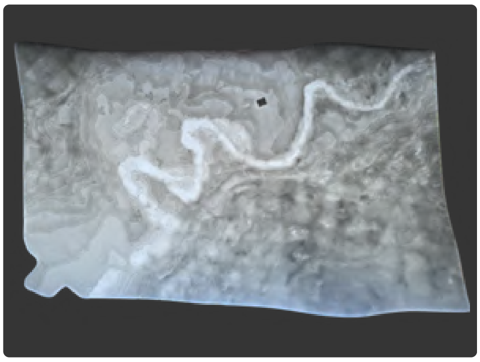

Figure 26 & Figure 27. 3D printed model of the Nigel Hanlon Memorial Hut site, created by the Author.

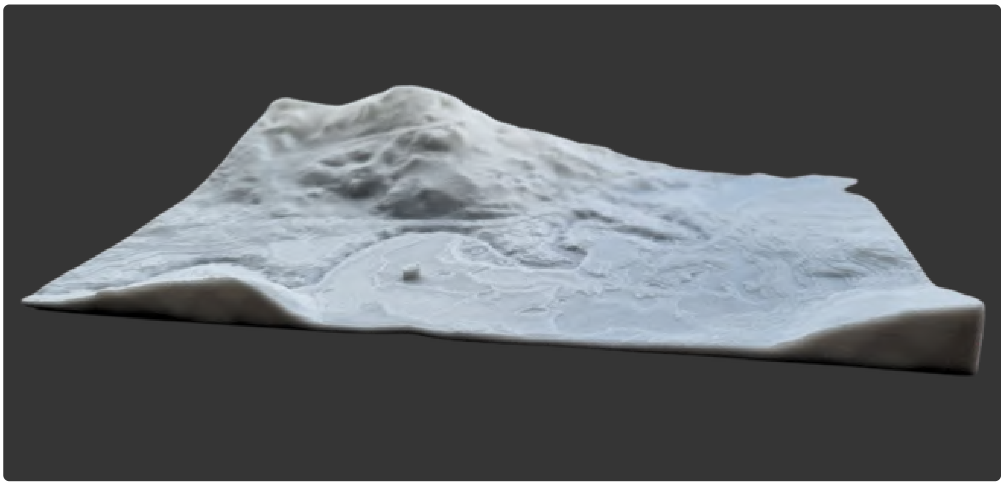

Figure 28. 3D printed model of the Nigel Hanlon Memorial Hut site, created by the Author.

Note: Figures 26 & 27 shows the Piha Topography in a 3D Printed format using data taken from GeoMaps as well as using the data made by the Author on Revit. This model also serves as a visual and tangible representation of what the user would be able to see in VR.

CHAPTER 5 SITE SELECTION & ANALYSIS – NIGEL HANLON MEMORIAL HUT PIHA

5.1 Site Identification

Specific selection criteria was established to ensure the selection of a research site that aligned with the objectives of this thesis. The selection criteria focused on identifying a site that was at risk, whether due to natural factors such as environmental degradation and climate related threats, or human induced risks such as neglect, vandalism, or potential redevelopment. In addition to being at risk, the site needed to be accessible for thorough documentation, allowing for the practical application of digital tools and technologies. Another important consideration was selecting a lesser-known heritage site to provide an opportunity to raise awareness about its historical and cultural significance through the research.

These criteria played a crucial role in shaping the site selection process and guided the search for a suitable location. The initial phase of this process involved an extensive exploration of potential sites that met these parameters. Heritage documentation from various sources was reviewed to assess the historical importance, current condition, and conservation needs of each site. Additionally, the suitability of each location was evaluated based on its potential for digital documentation, considering factors such as accessibility for fieldwork and the feasibility of applying photogrammetry and virtual reality-based workflows.

Scoping activities included The Falls Bistro, where contact was attempted through social media and existing connections; as well as consideration of Old Choral Hall, Strand Arcade, and Civic Theatre before being introduced to the Nigel Hanlon Memorial Hut by Graeme Johansen through architecture work experience.
The Hut's historical significance and current site challenges formed urgent drivers that align with the objectives of this thesis.

The outcome of this phase was a comparative analysis of multiple heritage sites, as seen in Table 2, each analysed for its basic architectural characteristics, specific risks to the cultural heritage, level of accessibility, and public use. This evaluation ensured that the selected site would not only align with the thesis objectives but also serve as a valuable case study for demonstrating the integration of digital tools in heritage conservation. The table below summarises the key findings from this site selection process, providing a detailed comparison of the various locations considered and highlighting the rationale behind the final choice.

Table 2.Selecting the Research Site

Site	Historic Building Typology	Scale	Risk Type	Degree of accessibility for research	Current public use status
REMOVED FOR COPYRIGHT REASONS *Figure 29. St James Theatre (Powell, 2022).*	Historical theatre in need of conservation	Large	Outdated fire safety measures; renovation concerns	Central city location	Restricted
REMOVED FOR COPYRIGHT REASONS *Figure 30. Civic Theatre (Hisgett, 2016).*	Recently renovated historic theatre	Large	No Current Risks	Central city location	Restricted
REMOVED FOR COPYRIGHT REASONS *Figure 31. Strand Arcade (My guide Auckland, 2025).*	Historic arcade with potential renovation	Medium to Large	No Current Risks	Accessible but challenging for data collection due to constant public use	Open to Public
REMOVED FOR COPYRIGHT REASONS *Figure 32. Old Choral Hall (Schwede66, 2016).*	Heritage hall with historical significance	Medium	Lack of modern reinforcement; future retrofitting	Central city location	Restricted
REMOVED FOR COPYRIGHT REASONS *Figure 33. The Falls Bistro (Localist, 2025).*	Restaurant with heritage elements	Small	Risk of going Out of Business	Less central location	Restricted

REMOVED FOR COPYRIGHT REASONS *Figure 34. Nigel Hanlon Memorial Hut (Reynolds Associates, 2010).*	Memorial Hut with historical significance	Small	Flood-prone zone, vandalism, coastal erosion	Located outside central city	Open to Public

5.2 G. J Architect

After completing my studies, I joined Graeme Johansen Architect, where I was given the opportunity to work on residential projects. During this time, I learned about the firm's connection with the Boys' Brigade Northern Regional Trust and their long-standing relationship with the Nigel Hanlon Memorial Hut in Piha. Through these conversations, I discovered the site's deep significance to both the Boys' Brigade and the wider community as a venue for camps and outdoor education.

Constructed in 1954 by carpenter and Boys' Brigade Captain Ian McIntosh and later named after Nigel Hanlon Memorial Hut in the 1990s, the Hut has been a vital location for community gatherings and outdoor education (Hut Bagger, 2025). However, it now faces significant threats, including flooding (Later seen in Figure 40), coastal erosion, and vandalism. The *"Nigel Hanlon Memorial Hut (2010)"* risk assessment report highlights the environmental hazards to the site and stresses the urgency of conservation efforts (Reynolds Associates, 2010).

5.3 Overview of Site History: Nigel Hanlon Memorial Hut

5.3.1 Historical Context of Piha

As discussed in Table 2 Nigel Hanlon Memorial Hut Piha was chosen as the site for application of this workflow due to its alignment with the thesis such as the time frame, public use status and heritage building typology.

The Hut's location in Piha adds another layer of historical and cultural depth. Piha is a site of historical significance, originally established by the Te Kawerau ā Maki iwi. The name "Piha" derives from "Te Piha," symbolising the divided ripple at the bow of a canoe, referencing the waves breaking around Lion Rock (Figures 35 & 36). This connection to Māori heritage emphasises Piha's cultural richness and its importance as a place of indigenous significance (Coney, 2025). The arrival of European settlers in the 19th century brought significant change to Piha, including the establishment of timber milling operations driven by the area's abundance of Kauri trees. By the early 20th century, Piha transitioned into a popular holiday destination, known for its black sand beaches, volcanic landscapes, and coastal forest. The region continues to attract both permanent residents and seasonal visitors, highlighting its dual role as a cultural and environmental heritage site (Caballar, 2021).

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Figure 35. Aerial view of Piha Beach in 1930 (Piha History, 2025b)

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Figure 36. Aerial view of Piha Village in 1940 (Piha History, 2022).

Figure 37. Map showing Piha in context to Auckland, retrieved from GeoMaps (Auckland Council GeoMaps, 2025.)

Figure 38. Aerial map showing the context of Piha Village, retrieved from GeoMaps (Auckland Council GeoMaps, 2025)

Figure 39. Aerial map showing the context of Piha Village, retrieved from GeoMaps (Auckland Council GeoMaps, 2025)

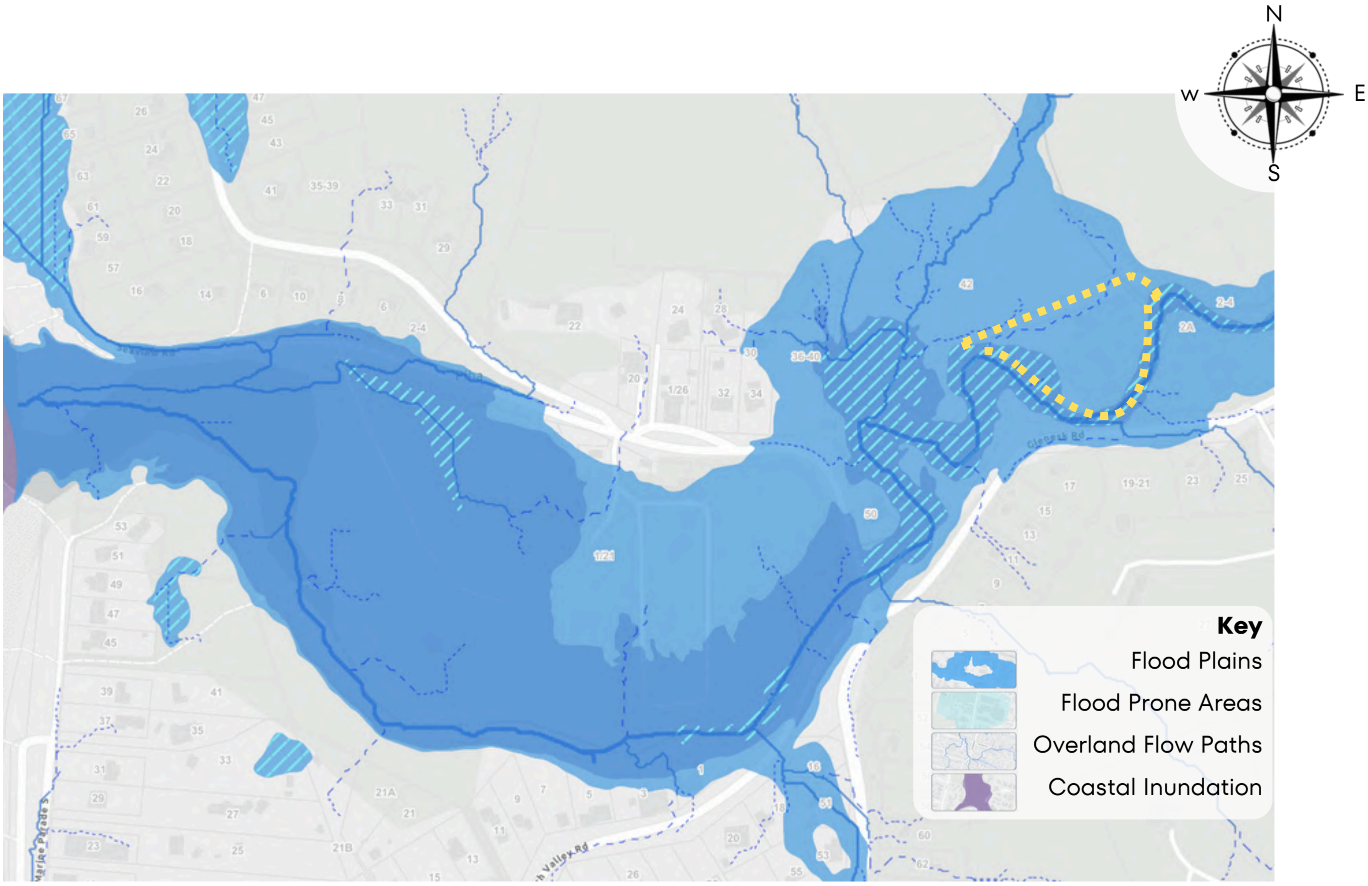

Figure 40. Flood prone zone at Piha (Auckland Council, 2025)

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Figure 41. Mrs J C Macky and friends with their tents at Piha (Hibbs, 1890-1919)

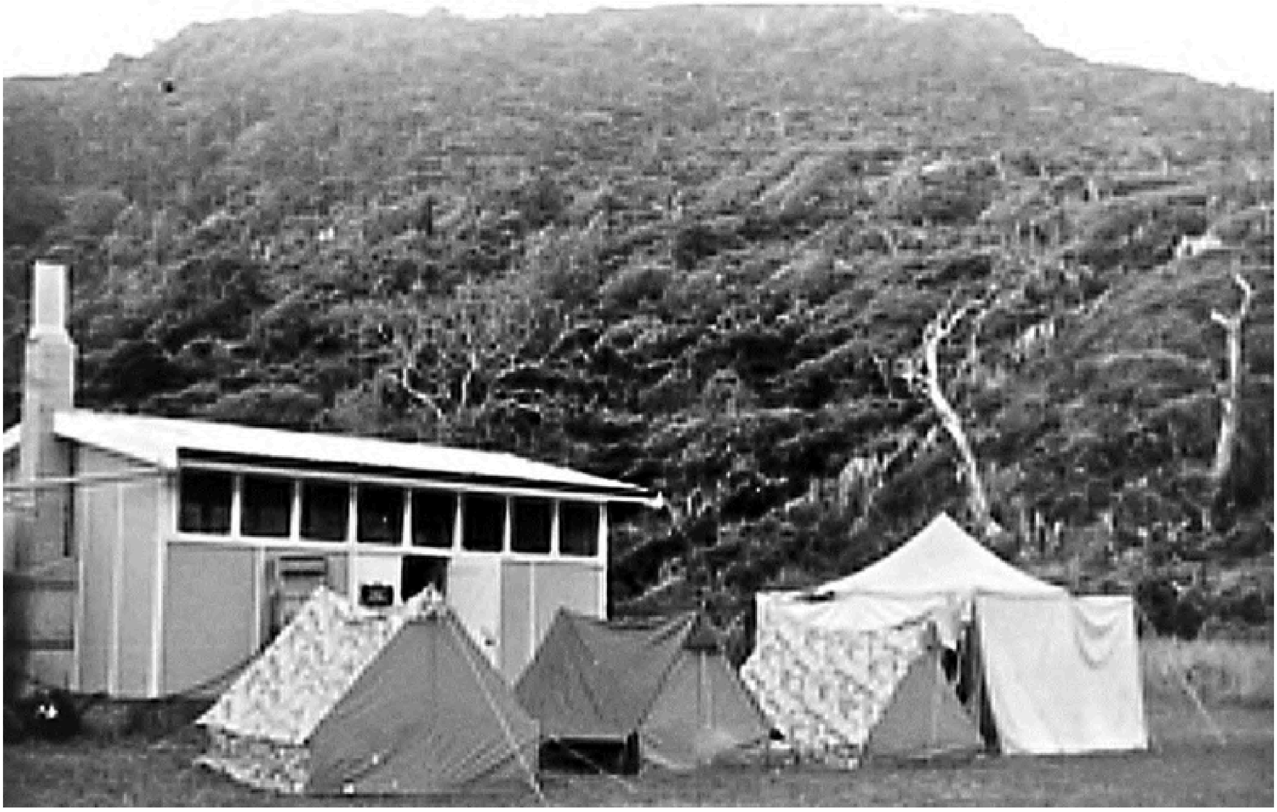

Figure 42. 52nd Auckland Company Camp at the Nigel Hanlon Memorial Hut, Piha, mid 1970s (Courtesy of Graeme Johansen, Boys' Brigade Group).

For decades, the Nigel Hanlon Memorial Hut has been a focal point for small camps, youth events, and community gatherings (Figure 42). Its connection to the Auckland Centennial Memorial Park, now part of the Waitākere Ranges Regional Park managed by Auckland Council, further embeds it within the social and environmental fabric of the region (OurAuckland, 2020). The Hut's history represents a microcosm of New Zealand's heritage, reflecting the intersection of community driven initiatives, youth development, and the conservation of natural and cultural landmarks.

5.3.2 Relevance to Virtual Reality Applications

Figure 43. Nigel Hanlon Memorial Hut, Piha, North Elevation (Courtesy of Stefan Marks, 2024).

The Nigel Hanlon Memorial Hut (Figure 43) represents an ideal case study for exploring the applicability of Virtual Reality (VR) in heritage conservation. The Hut's modest scale, historical significance, and accessible location make it a prime candidate for VR based digital documentation. By employing photogrammetry and 3D scanning technologies, a detailed digital model of the Hut can be created, conserving its architectural and cultural details with precision (Fondazione et al., 2009).

5.3.3 Potential Benefits of VR for the Nigel Hanlon Memorial Hut

Digital documentation can ensure that the Nigel Hanlon Memorial Hut's structural and historical attributes are recorded and conserved, protecting against threats such as physical deterioration, environmental damage, and vandalism (Climate Change and Heritage Working Group, 2019). This aligns with "*ICOMOS's New Zealand Charter for the Conservation of Places of Cultural Heritage Value*", which emphasise the importance of digital documentation in safeguarding heritage sites from natural and human-induced risks as mentioned in Chapter 2.1. Virtual reality (VR) tours can enhance public awareness and appreciation of the Hut's history and significance by providing an interactive way to experience the site. This is particularly valuable in engaging younger generations and fostering a deeper connection to New Zealand's cultural heritage as mentioned in Chapter 2 (UNESCO World Heritage Centre, 2020). Additionally, VR can overcome the geographical challenges of Piha's remote location, allowing individuals who may not be able to visit in person to explore the site virtually. This approach supports "*Enhancing our heritage toolkit 2.0*" goals of promoting inclusive and accessible heritage conservation strategies (UNESCO et al., 2023). Beyond remote access, these technologies also serve as educational tools, providing historical and cultural insights into the Hut, the Boys' Brigade movement, and the broader context of Piha's heritage. Schools, museums, and community outreach programs could integrate VR simulations to enrich public engagement and learning (Letellier et al., 2007).

5.3.4 Challenges to the site using VR

The application of Virtual Reality (VR) in heritage conservation presents several potential challenges that must be addressed to ensure its effectiveness, particularly when applied to the Nigel Hanlon Memorial Hut. One primary challenge is ensuring data accuracy and completeness, as VR models are dependent on high poly photogrammetry scans. Limited access to certain areas of the site, such as the roof, may result in gaps or inaccuracies within the digital model, impacting its reliability for detailed analysis and design. As discussed in Chapter 2.3.1, photogrammetry is widely used in digital documentation to create accurate 3D models, but site constraints can impact data capture and model precision. Another challenge is the resource-intensive nature of VR development. High-resolution 3D models require significant processing power, and specialised hardware and software can be costly and difficult to access. The processing of large datasets for VR applications takes time and can slow down workflows, especially when working with detailed heritage models. As outlined in Chapter 2, VR technology enhances visualisation and stakeholder engagement, but accessibility remains a limiting factor.

The technological learning curve associated with VR platforms and digital documentation methods also presents a challenge, requiring adequate training and technical proficiency, which may impact project timelines. Environmental constraints, such as the prohibition of drone usage in the regional park where the Nigel Hanlon Memorial Hut is located, further limit the ability to capture aerial data needed for VR modelling, as discussed in Chapter 4.1. However, despite these challenges, VR presents significant opportunities for enhancing engagement, design experimentation, and immersive storytelling in heritage conservation. As explored in Chapter 6, the development of the architectural follies demonstrates how VR can be used not only as a documentation tool but also as a creative medium for interpreting cultural narratives and fostering community interaction. Through immersive design exploration, these follies translate historical memories into interactive spaces, showcasing the transformative potential of VR beyond conservation into active cultural engagement.

CHAPTER 6 VR WORKFLOW PROOF OF CONCEPT - DESIGN DEVELOPMENT OF ARCHITECTURAL FOLLIES

6.1 Introduction

Architectural follies have been a part of landscape design since the 18th century, originally serving as decorative structures in European gardens. Inspired by historical and imaginative themes, they acted as focal points, encouraging storytelling, reflection, and artistic expression (Florence Griswold Museum, 2021). This study employs architectural follies as a strategy to engage with cultural memory by blending architecture and narrative. They create interactive spaces that allow communities to connect with historical and environmental contexts. This Chapter applies architectural follies as design interventions within the Piha landscape where Nigel Hanlon Memorial Hut is located, using digital workflows and Virtual Reality (VR) technologies to develop structures that reflect Piha's cultural and environmental heritage.

VR enhances design and development of follies by allowing real-time adjustments to textures, materials, and spatial layouts. Unlike traditional design methods, this interactive approach supports iterative experimentation with forms and materials. In this thesis, VR serves as a design tool and an immersive experience, ensuring that the follies connect with Piha's landscape and history (Hou, 2022; O'Connell, 2021), as further explored in Chapter 6.

The proposed follies celebrate Piha's cultural heritage while serving functions such as storytelling, artistic expression, and environmental engagement. By incorporating VR into the design process, these structures accurately reflect the textures, materials, and atmosphere of Piha, creating an immersive link between past and present as discussed in Chapter 5.3 on community engagement through digital conservation. The following sections will delve into each folly design in detail, demonstrating how VR technologies were used to develop and refine these structures, in response to the landscape of the Nigel Hanlon Memorial Hut.

6.2 Conceptual Framework for Follies

The folly architecture in this thesis is guided by three key principles that shape their design, development, and implementation at the Nigel Hanlon Memorial Hut. These principles ensure the follies are not just structures but also contribute to heritage conservation, community engagement, and technological innovation.

6.2.1 Conservation of Memory

Each folly represents Piha's cultural and environmental heritage, drawing from its history of outdoor recreation, community gatherings, and artistic expression. These structures serve as physical representations of local identity, conserving cultural narratives through architectural

6.2.2 Engagement through Design

The follies provide interactive and immersive experiences, encouraging community participation while raising awareness of Piha’s historical and environmental significance. As outlined in the “*Enhancing Our Heritage Toolkit 2.0*” (UNESCO et al., 2023), public engagement is essential in contemporary heritage conservation, ensuring that heritage remains relevant and accessible. By inviting visitors to interact with these structures, the follies transform conservation into a shared community effort as well as potentially reduce the risk of neglect and vandalism as explored in Chapter 5 on community involvement in heritage conservation.

6.2.3 Innovation via VR

Virtual Reality (VR) enhances the design process, allowing real-time adjustments to surfaces, textures, and spatial elements. Beyond its design applications, VR also serves as an engagement tool, offering immersive experiences that merge traditional conservation with modern technology. The digital recreation of Sir Edmund Hillary’s Antarctic Hut by the Antarctic Heritage Trust demonstrates VR’s potential to make heritage sites more accessible to global audiences, a principle adopted in this thesis as discussed in Chapter 4 on VR’s role in heritage documentation.

6.2.4 Integrated Conservation Strategy

The follies in this thesis, inspired by Piha’s cultural narratives, are developed using VR technologies that support iterative design and immersive experiences. By integrating memory conservation, community engagement, and technological innovation, the architectural follies serve as a contemporary approach to conservation, ensuring that Piha’s heritage is both conserved and reinterpreted for future generations.

6.3 Individual Folly Designs

The architectural follies designed with the help of the framework discussed before in 6.2, this study serve as experimental interventions that bridge the tangible and intangible aspects of heritage conservation. These designs are inspired by the cultural and environmental context of the Nigel Hanlon Memorial Hut site, aiming to evoke historical narratives while offering unique interactive experiences. Each folly is conceived as a small-scale structure that resonates with the site's memory, fostering engagement through storytelling, artistic expression, and communal participation.

Virtual Reality (VR) plays a critical role in the iterative design process of these follies, allowing the user to test spatial arrangements, modelling applications, and environmental responses through designs before physical implementation. The integration of VR ensures that the proposed interventions align with the historical and ecological integrity of the site, providing a dynamic platform for visualisation and design refinement.

The design of these follies can be further refined for potential construction, but during the design phase, they can be explored through Virtual Reality (VR). Additionally, VR provides an accessible means of interaction when site access is restricted due to safety concerns or environmental risks, ensuring that the public can still engage with the architectural concept remotely.

Figure 44. Existing Site Plan, by Author

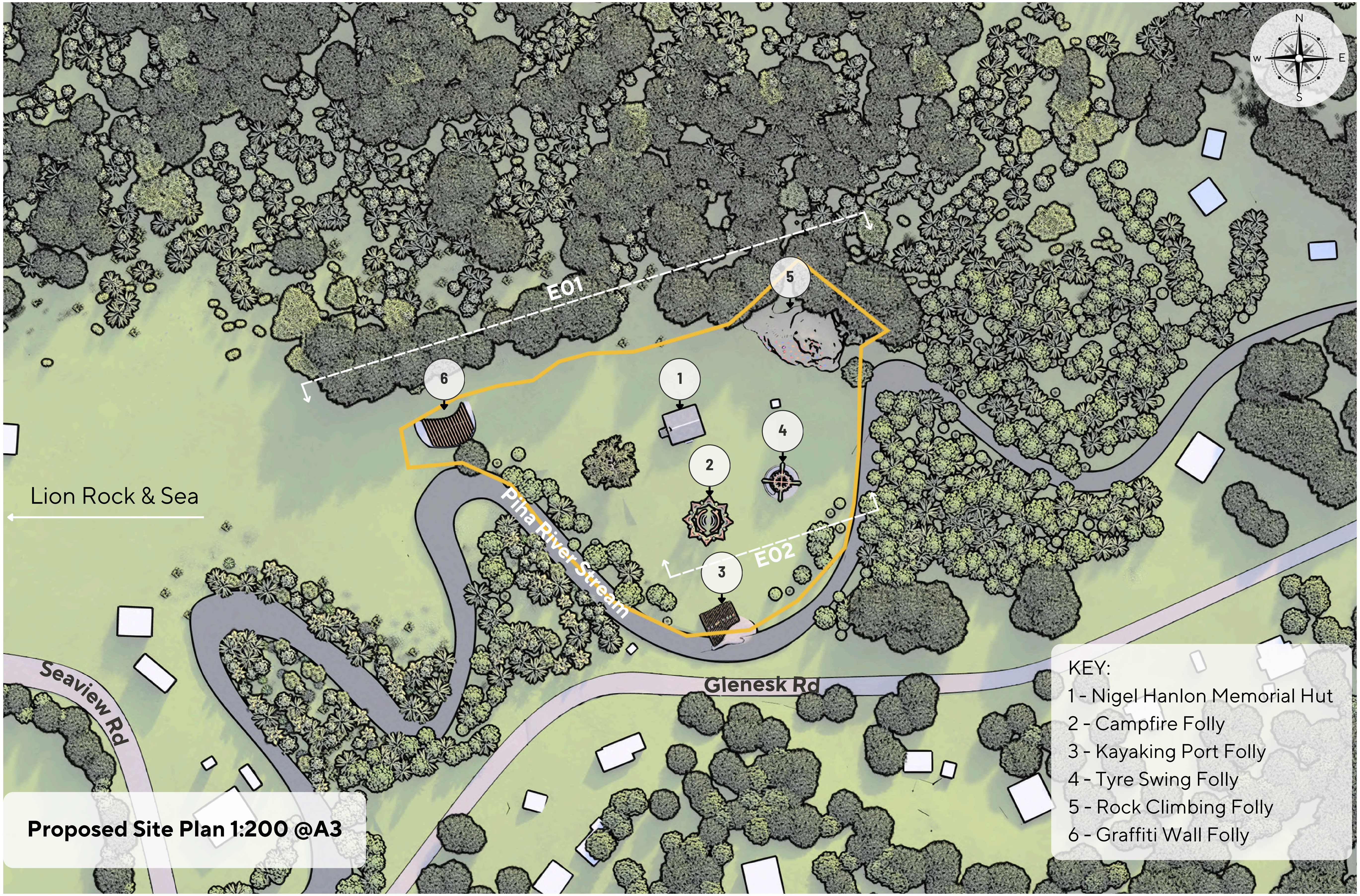

Figure 45. Proposed Site Plan, by Author

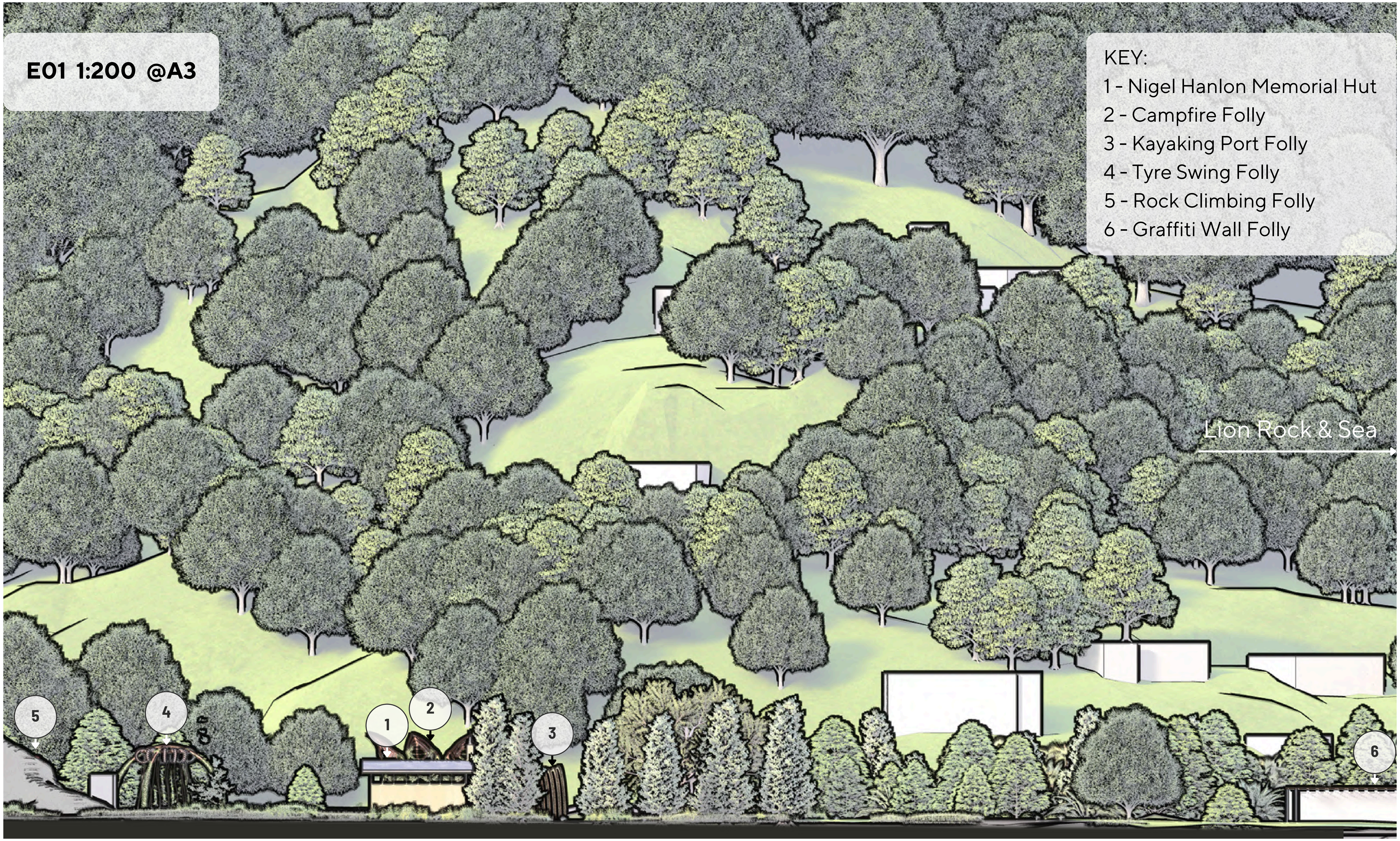

Figure 48. Proposed Elevation 01 of Site, by Author

Figure 49. Proposed Elevation 02 of Site, by Author

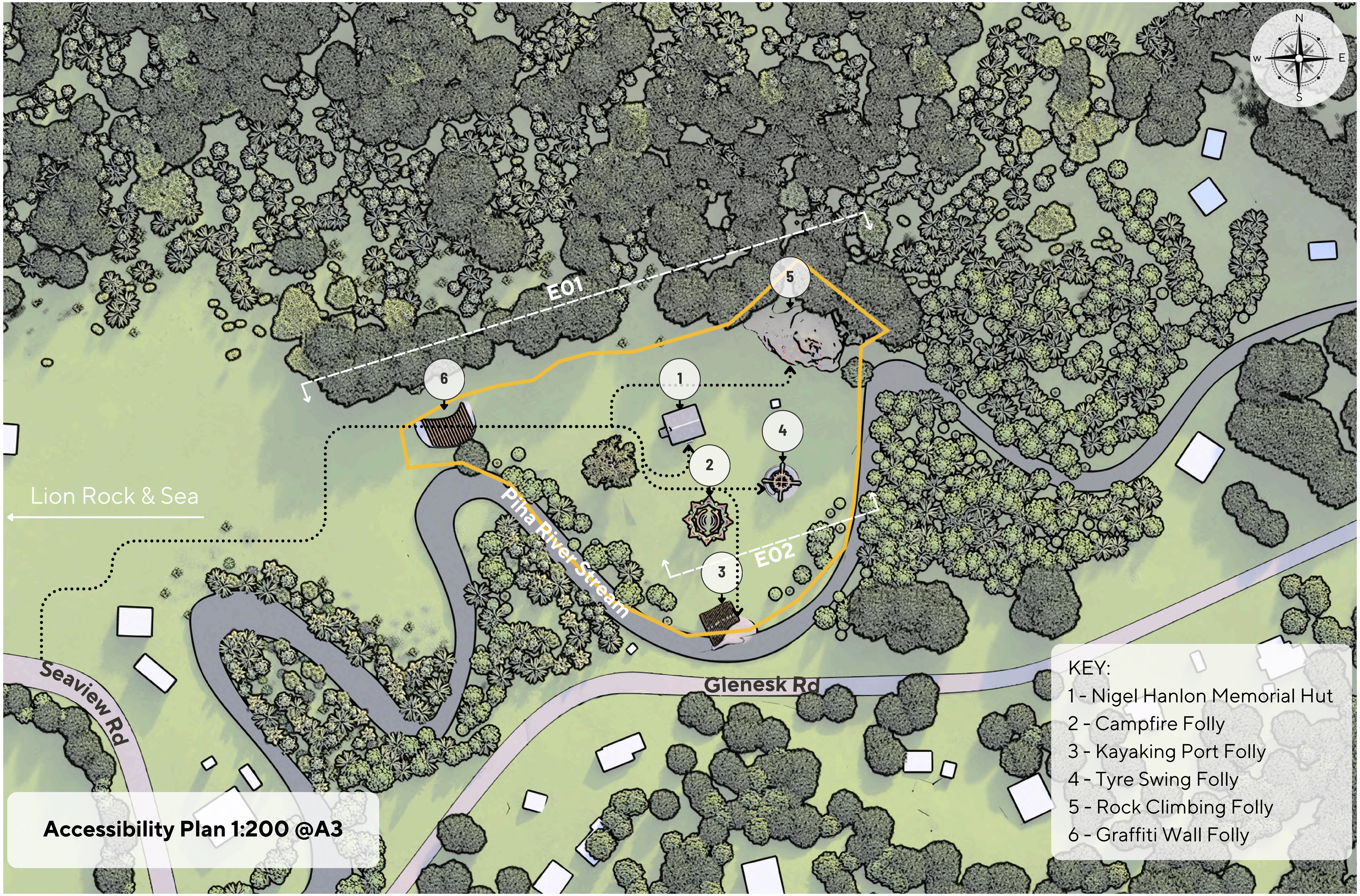

Figure 46. Proposed Accessibility Site Plan, by Author

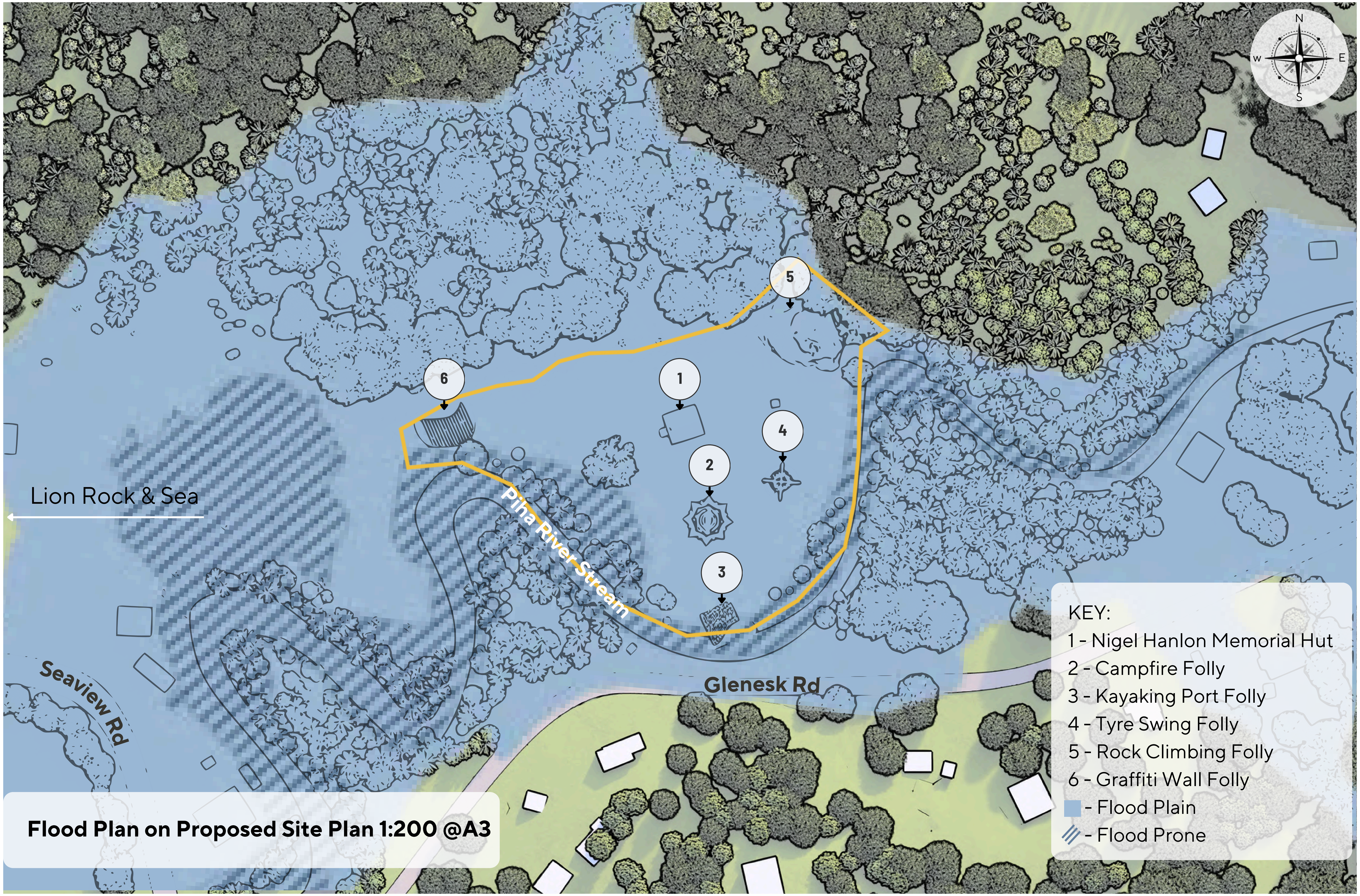

Figure 47. Flood Plan on Proposed Site Plan, by Author

Figure 50. Campfire Folly in Context, by Author

Figure 51. Campfire Folly exterior, rendered in Lumion by Author

Figure 52. Campfire Folly Interior, rendered in Lumion by Author

6.3.1 Campfire Folly

The Campfire Folly is inspired by Piha's tradition of oral storytelling and communal gatherings, where stories, histories, and cultural narratives have long been passed down. The design aims to recreate the intimacy and inclusivity of a traditional campfire, reinforcing Piha's cultural memory through an interactive, built environment. Developed using Shapelab VR, the folly was initially conceptualised with fluid, flame-like forms, capturing the dynamic nature of fire as seem in Figure 54 to 56. The design was further refined in Revit to ensure structural integrity, while Lumion allowed for light and material testing, ensuring that the space provided a warm and inviting atmosphere as discussed in the VR workflow methodology in Chapter 4.

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Figure 53. Camping by American army near Piha, (Piha History, 2025a)

Figure 54. Camp fire installation proposed at Piha, by Author

Early iterations as seen in Figures 54 to 56 were not practical and were early experimental modelling to explore the Shapelab VR software opportunities, requiring further refinement of surface curvature and user accessibility. Adjustments in VR modelling allowed for improved seating arrangements and public flow optimisation, ensuring that the structure remained both aesthetically striking and functionally effective. The final design as shown in Figures 50 to 52 successfully integrates cultural conservation and community engagement, providing a space where visitors can actively participate in storytelling, reinforcing the significance of Piha's intangible heritage (UNESCO et al., 2023). The VR integration allowed for precise placement and real-time experimental analysis, ensuring that the folly contributes effectively to the conservation and reinterpretation of Piha's social history.

Figure 55. Piha Site with the Folly architecture, by Author.

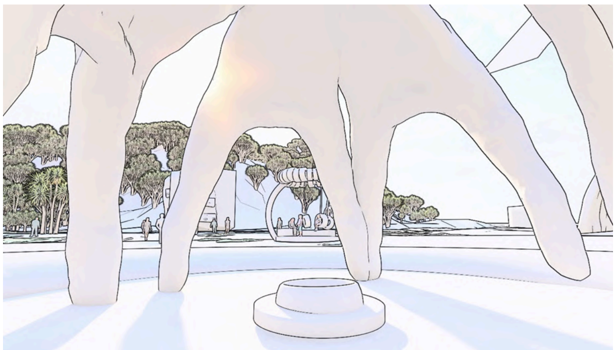


Figure 56. View inside the Camp fire installation created in VR, by Author

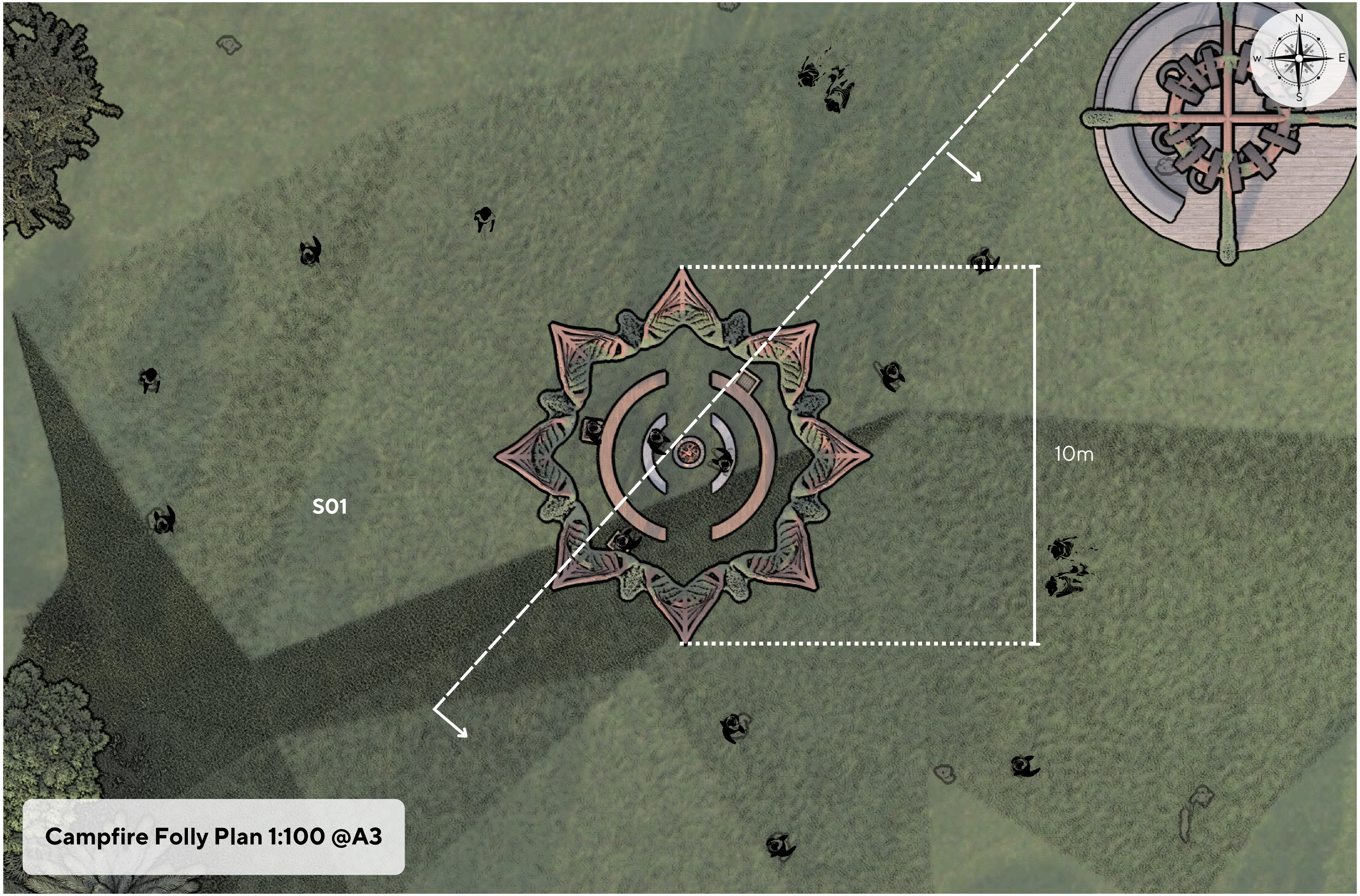
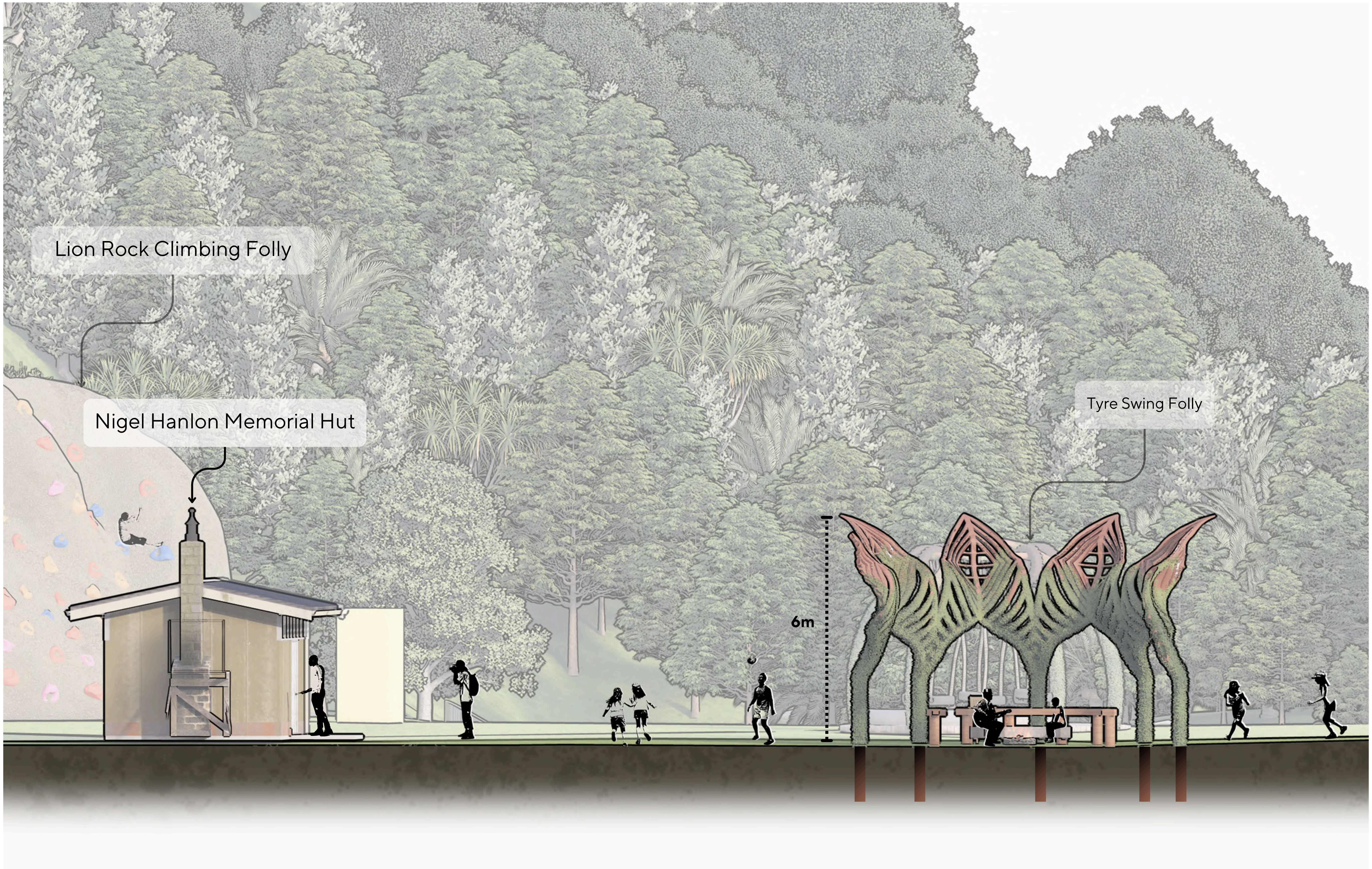


Figure 57. Campfire Folly Plan, by Author



Campfire Folly - S01 1:100 @A3

Figure 58. Campfire Folly Section, by Author

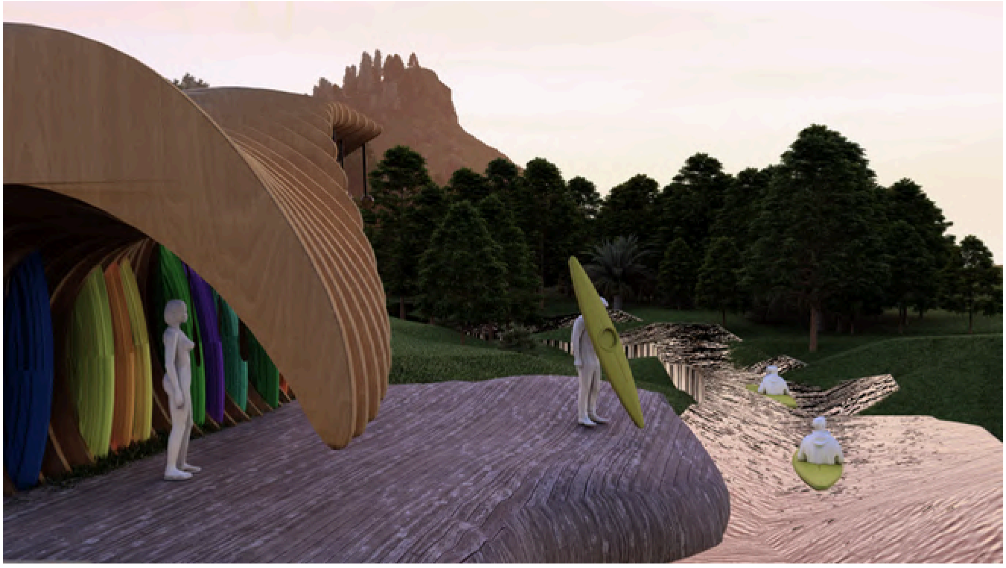


Figure 59. Kayak Folly 01 rendered in Lumion by Author.

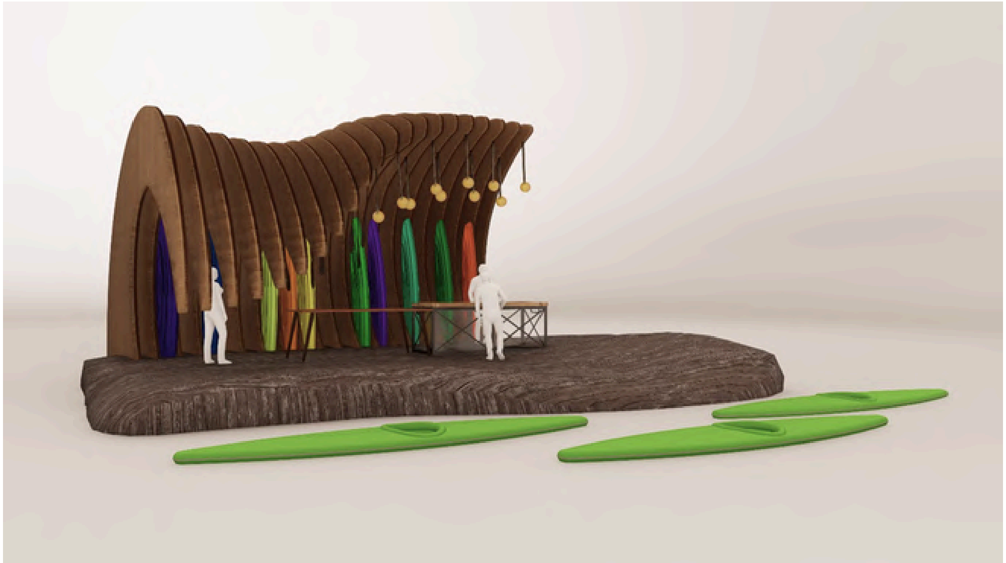


Figure 60. Kayak Folly 02 rendered in Lumion by Author.

Figure 61. Kayak Folly 03 rendered in Lumion by Author.

6.3.2 Kayaking Port

Piha's strong association with water-based recreation, particularly kayaking and surfing, served as the inspiration for this folly. The structure functions both as a functional docking point for kayakers and as an architectural representation of ocean waves. The initial design as seen in Figure 62 was modelled in Shapelab VR, where organic, undulating forms were sculpted to reflect the fluidity and rhythm of waves. This workflow, as established in Chapter 4, enabled real-time scale adjustments and spatial testing, ensuring the structure seamlessly integrated with the adjacent stream. Early iterations struggled with site integration, particularly in aligning the base structure with the streambed contours. Using VR modelling, I was able to design organic and smooth models, refine terrains, and test iterative placements and modification to the design in real time to ensure a smooth, functional transition between land and water. This can be seen in Figures 59 to 61. The ability to visualise these scenarios and placements allowed for adjustments in elevation and curvature, ensuring the structure interacted naturally with its surroundings. The final structure enhances public accessibility to Piha's waterways while reinforcing its outdoor adventure culture. The use of VR for site testing and interaction mapping, ensured that the folly balanced functionality with conservation goals, reinforcing the sustainable engagement with Piha's natural landscape.

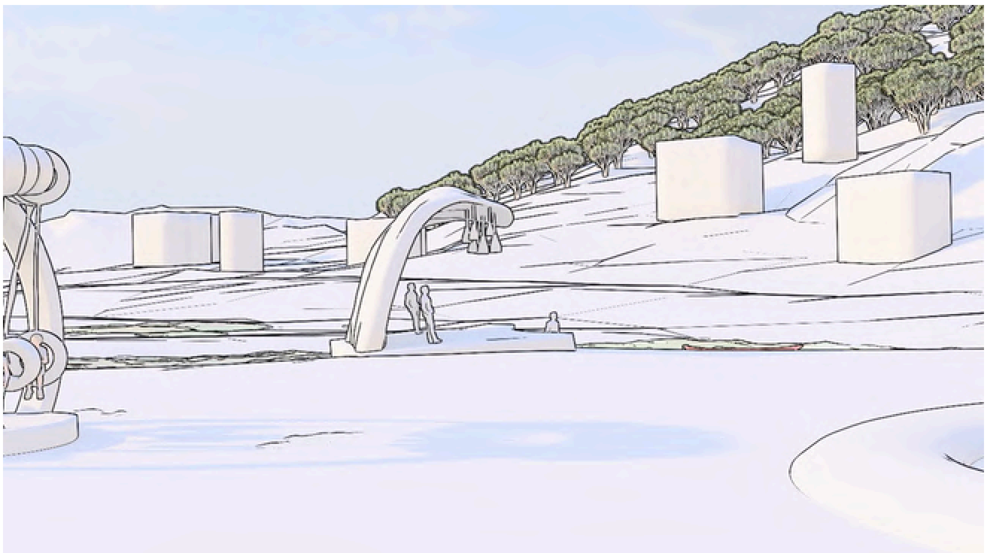


Figure 62. Early design of Kayaking Port Folly by Author.

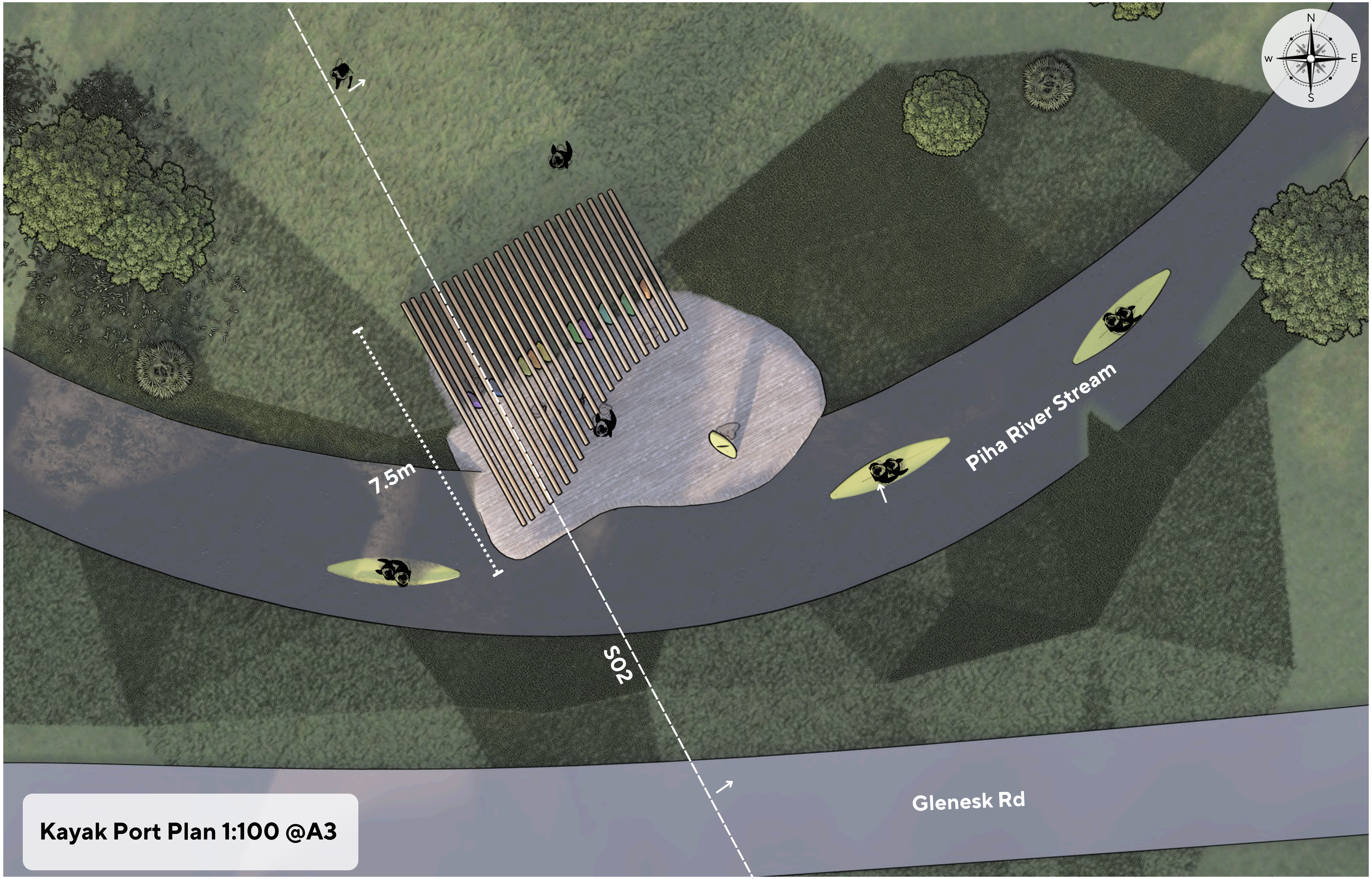
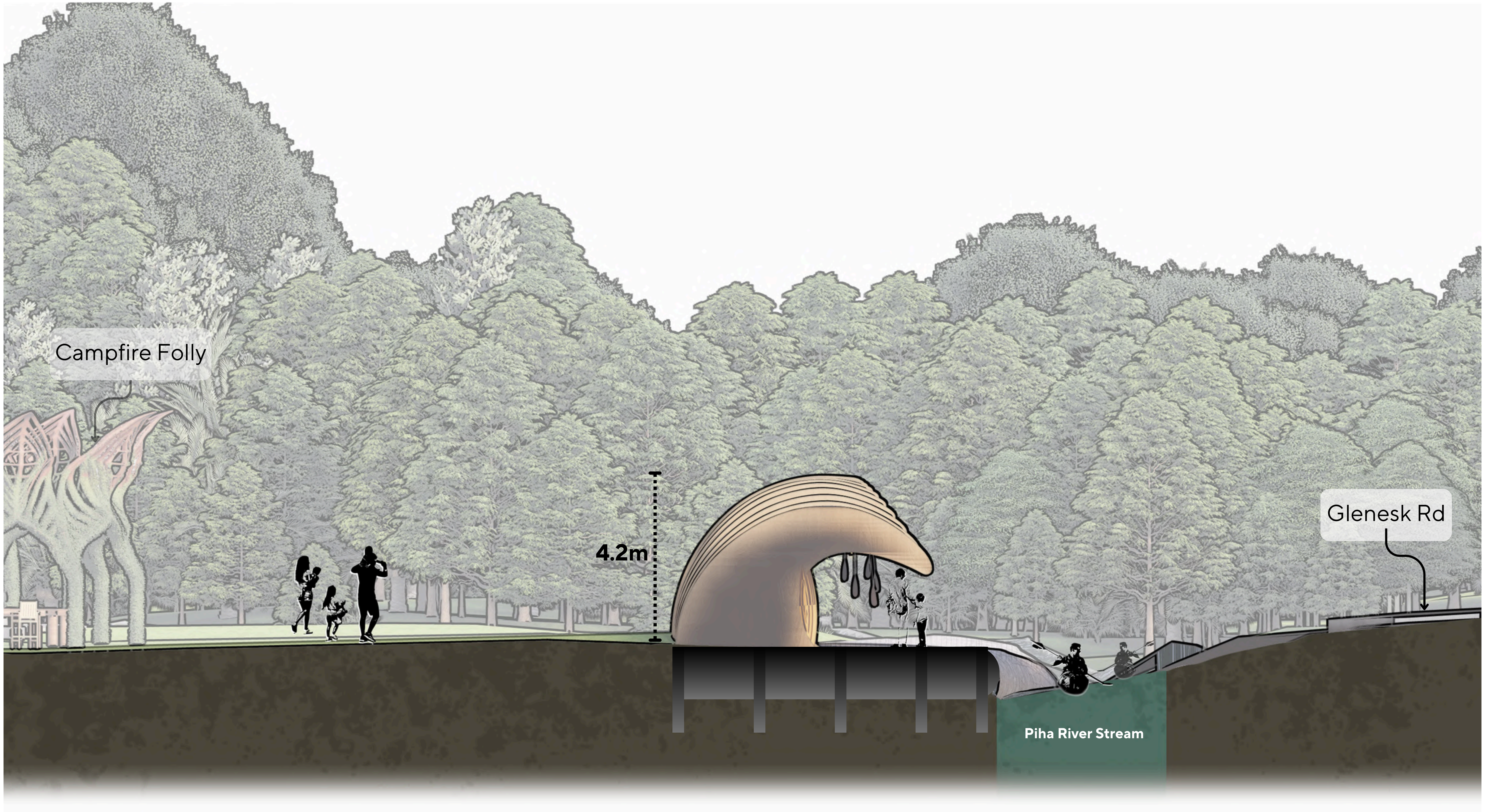


Figure 63. Kayak Port Folly Plan, by Author



Kayak Port Folly - S02 1:100 @A3

Figure 64. Kayak Port Folly Section, by Author

Figure 65. Graffiti Space Folly rendered in Lumion, by Author

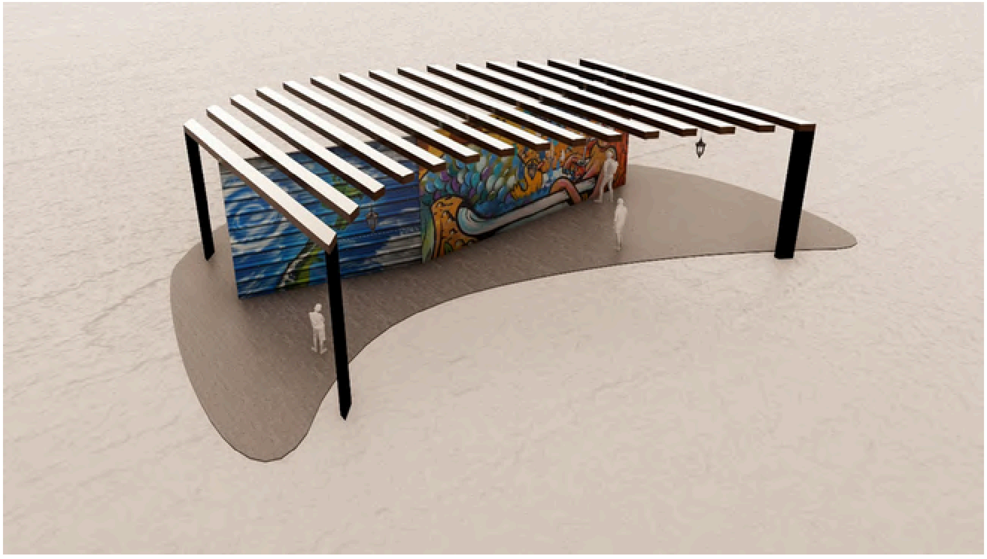


Figure 66. Graffiti Space Folly 01 rendered in Lumion, by Author.

Figure 67. Graffiti Space Folly 02 rendered in Lumion, by Author.

6.3.3 Graffiti Space Wall

The Graffiti Space Folly reinterprets graffiti as a participatory and community-driven artistic expression, rather than an issue of vandalism. As highlighted in the literature review Chapter 2, urban art plays a significant role in documenting cultural narratives, and this folly provides a dedicated space for community-driven storytelling through visual art. The structure was initially designed using Shapelab VR as shown in Figures 68 and 69, where surface proportions were adjusted to ensure accessibility and scalability for large-scale artwork. Further refinements in Revit allowed for the optimisation of modular walls, ensuring that the space could be reconfigured and repainted over time, reinforcing its dynamic and evolving nature.

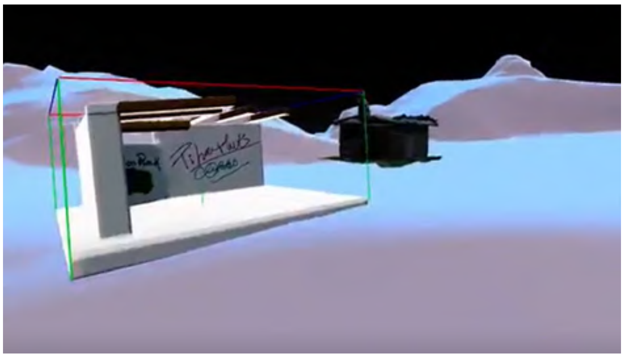


Figure 68. Early design for Graffiti wall 01 in relation to the Hut created in VR, by Author

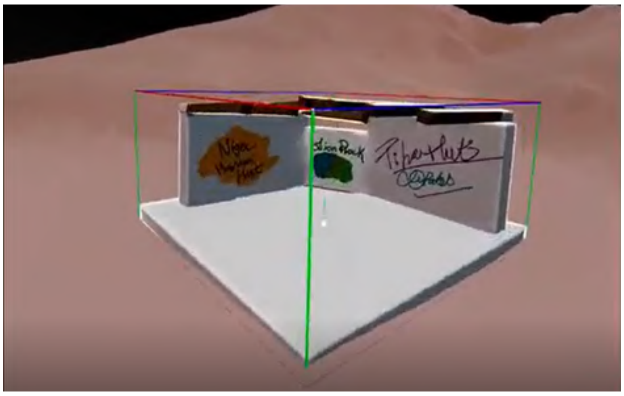


Figure 69. Early design for Graffiti wall 02 in relation to the Hut created in VR, by Author

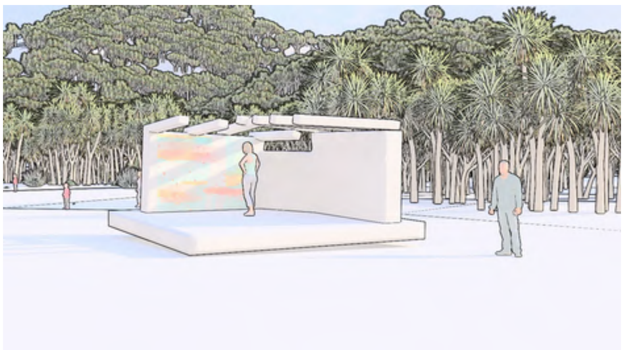


Figure 70. Early design for Graffiti Space folly architecture, by Author.

Initial iterations of the folly lacked sufficient surface area as well as made the structure closed off, which limited artistic potential and recognition. VR modelling enabled scaling adjustments and positioning refinements, ensuring an optimal balance between public accessibility as well as a large canvas to work on. The final design seen in Figures 65 to 67 encourages community interaction and self-expression, fostering a stronger connection between Piha's artistic and cultural identity. By integrating VR into the design process, real-time placement testing ensured that the folly enhances site accessibility and encourages creative engagement. Unlike traditional modelling software such as Revit, which primarily offers static, screen-based visualisation, VR allows for full-scale, immersive interaction with the design in a spatially accurate environment. This enabled real-time adjustments to scale, position, and user pathways, ensuring the folly integrates naturally with its surroundings. Additionally, VR provided a first-person perspective, allowing for an intuitive understanding of accessibility, and interactive potential elements that are harder to assess in conventional 3D modelling software.

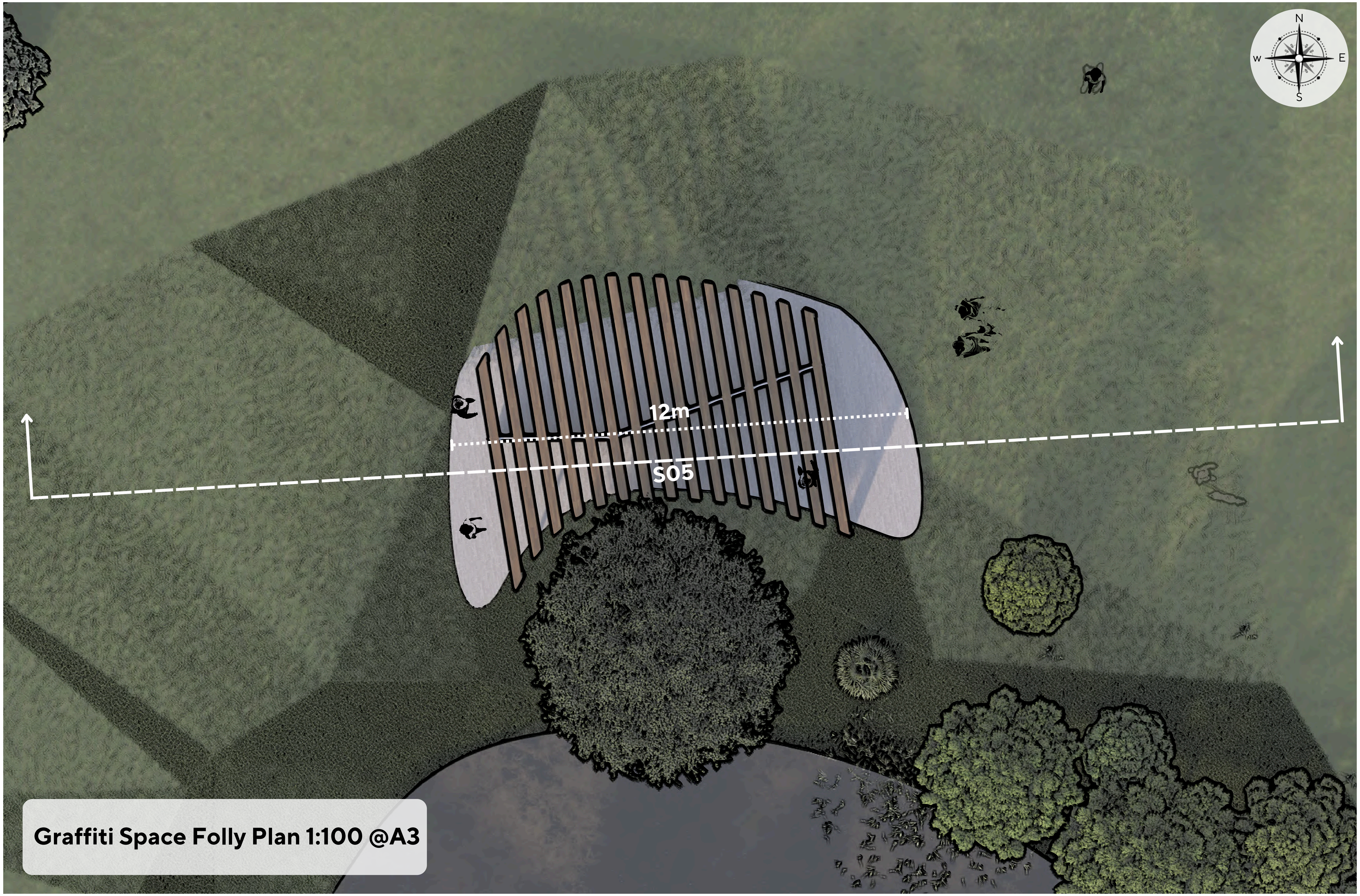
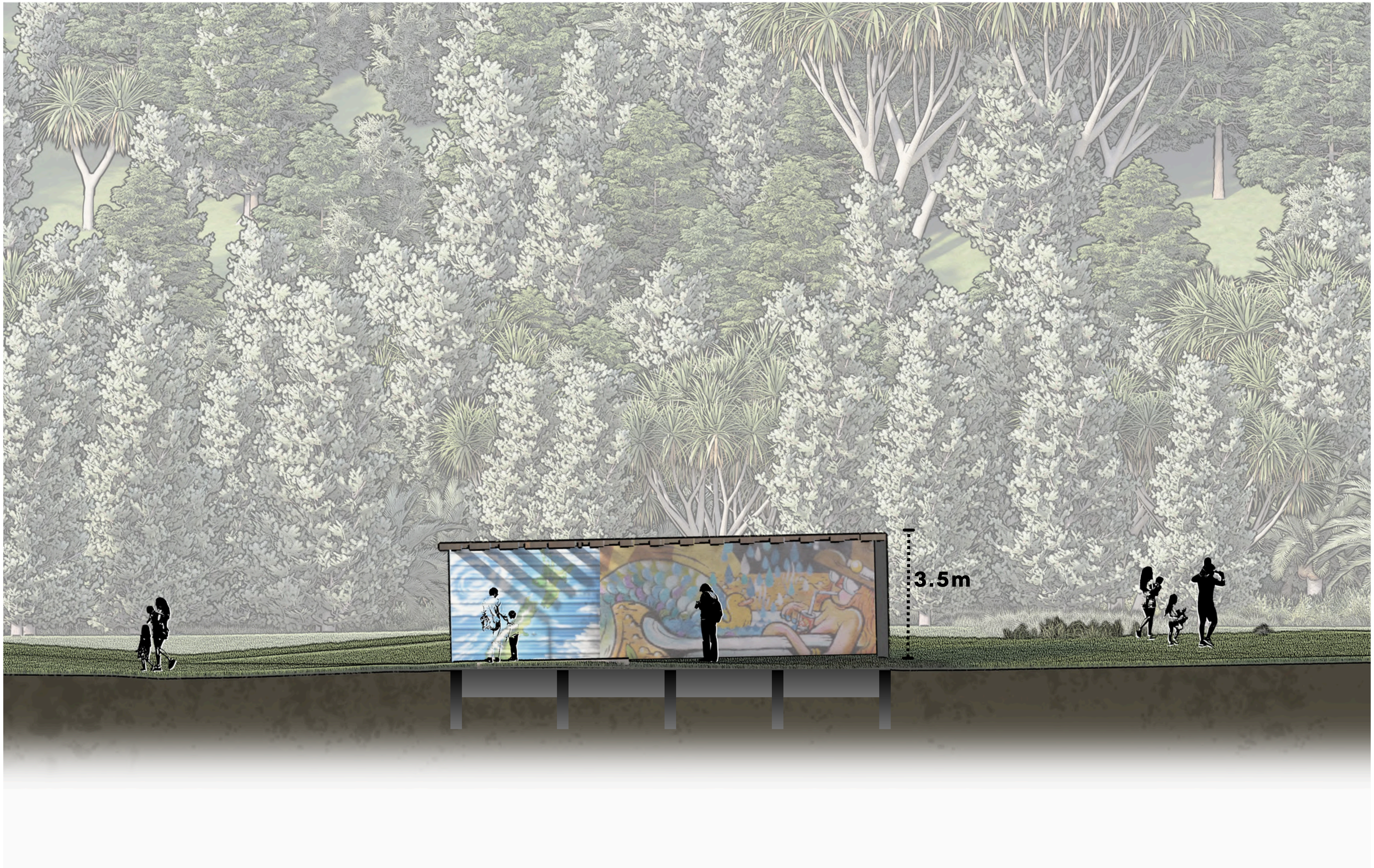


Figure 71. Graffiti Space Folly Plan, by Author



Graffiti Space Folly - S05 1:100 @A3

Figure 72. Graffiti Space Folly Section, by Author

Figure 73. Lion Rock Climbing Folly 01 rendered in Lumion, by Author.

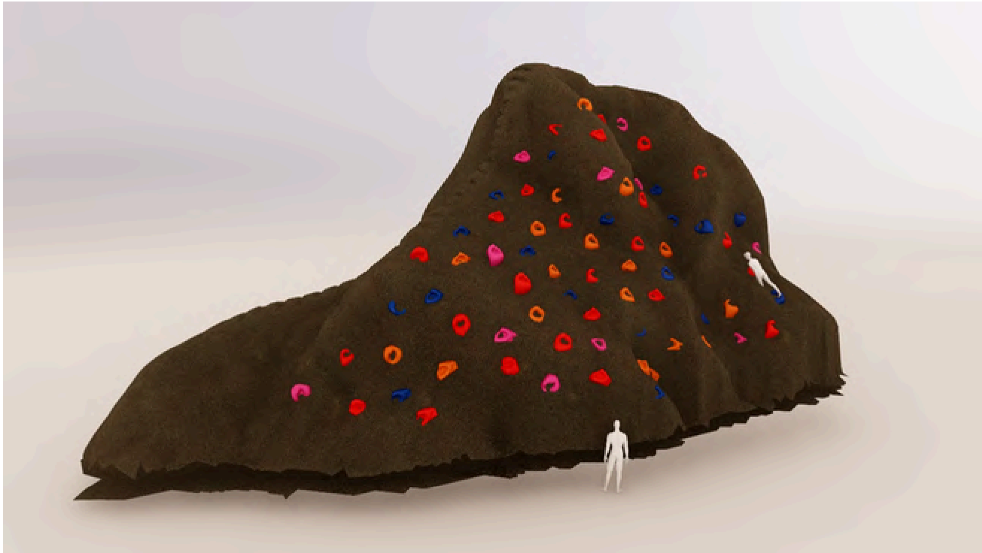


Figure 74. Lion Rock Climbing Folly 02 rendered in Lumion, by Author.

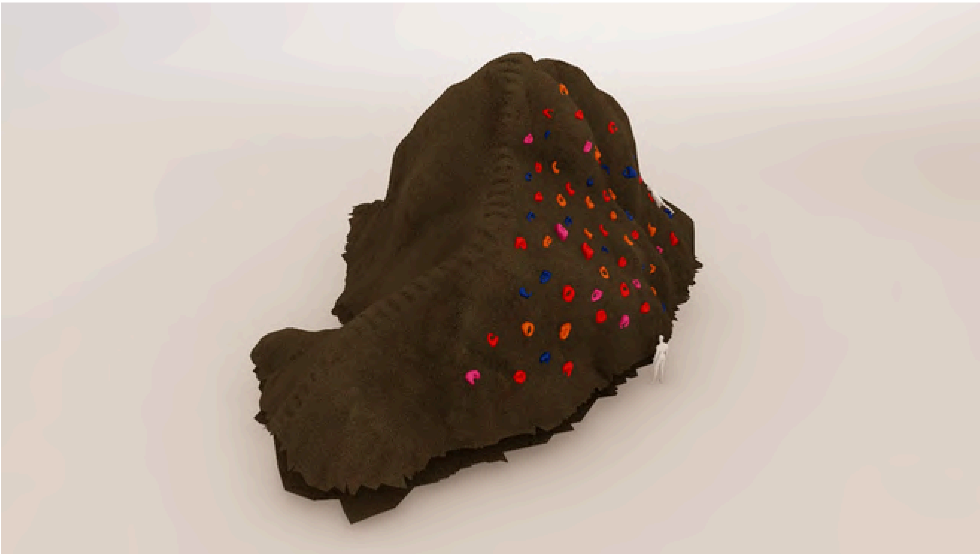


Figure 75. Lion Rock Climbing Folly 03 rendered in Lumion, by Author.

6.3.4 Lion Rock Climbing Folly

Piha's Lion Rock is a landmark for climbing and outdoor adventure, yet safety concerns in recent years have raised challenges for accessibility. This folly reinterprets the spirit of climbing in a controlled, accessible format, allowing visitors to engage with Piha's adventurous culture in a safe and structured manner. The initial design was modelled in Shapelab VR as seen in Figure 77, where topographical data of Lion Rock was imported and refined. Using VR, the handholds and climbing elements were scaled and positioned ergonomically, ensuring they aligned with real-world accessibility considerations.

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Figure 76. People walking by the rock at Piha (Piha History, 2025a)

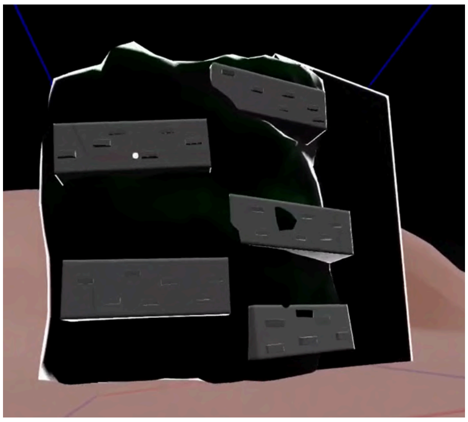


Figure 77. Early design work for Lion Rock climbing installation created in VR, by Author

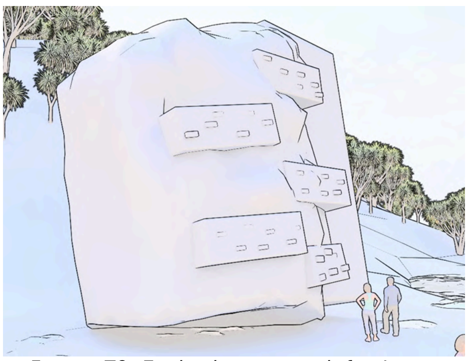


Figure 78. Early design work for Lion Rock climbing installation created in Lumion, by Author

Challenges arose in textural inconsistencies and structural feasibility, particularly in maintaining an authentic rock-like appearance while ensuring climbing safety. VR modelling allowed for adjustments in scaling and indentation refinements, ensuring that the structure was ergonomic.

Beyond its immediate application, VR also serves as a long-term accessibility tool, enabling future generations to experience and interact with Lion Rock even if physical access becomes increasingly restricted due to environmental factors or conservation policies. In a 50-100-year timeframe, rising sea levels, erosion, or conservation efforts may limit direct engagement with the site. Through VR, the essence of Lion Rock can be conserved digitally, ensuring that its adventurous spirit and cultural significance remain accessible, regardless of physical limitations.

The final design captures the essence of Lion Rock as shown in Figures 73 to 75, providing an interactive climbing experience that aligns with Piha's outdoor heritage while addressing both current safety concerns and future accessibility challenges.

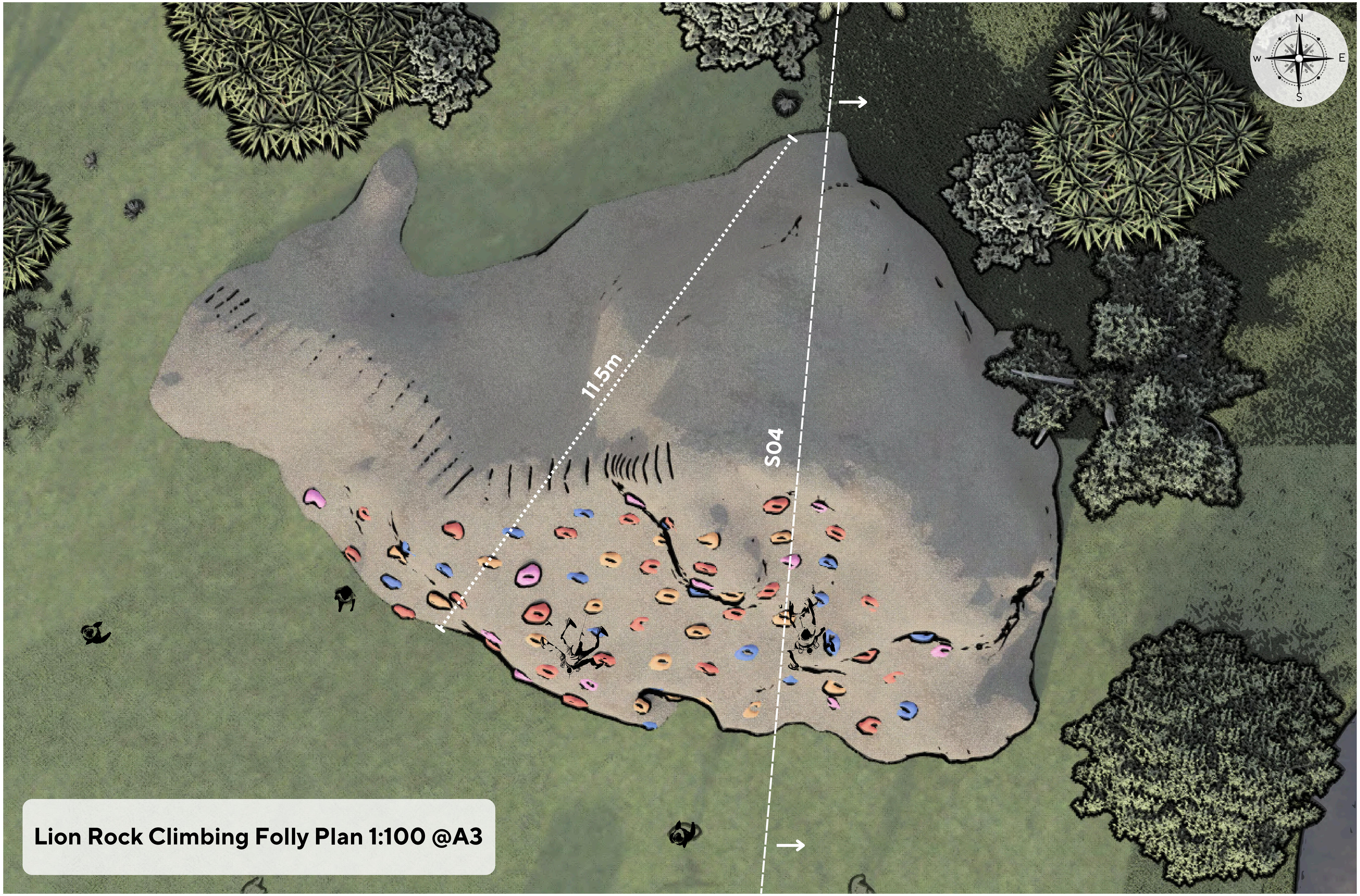
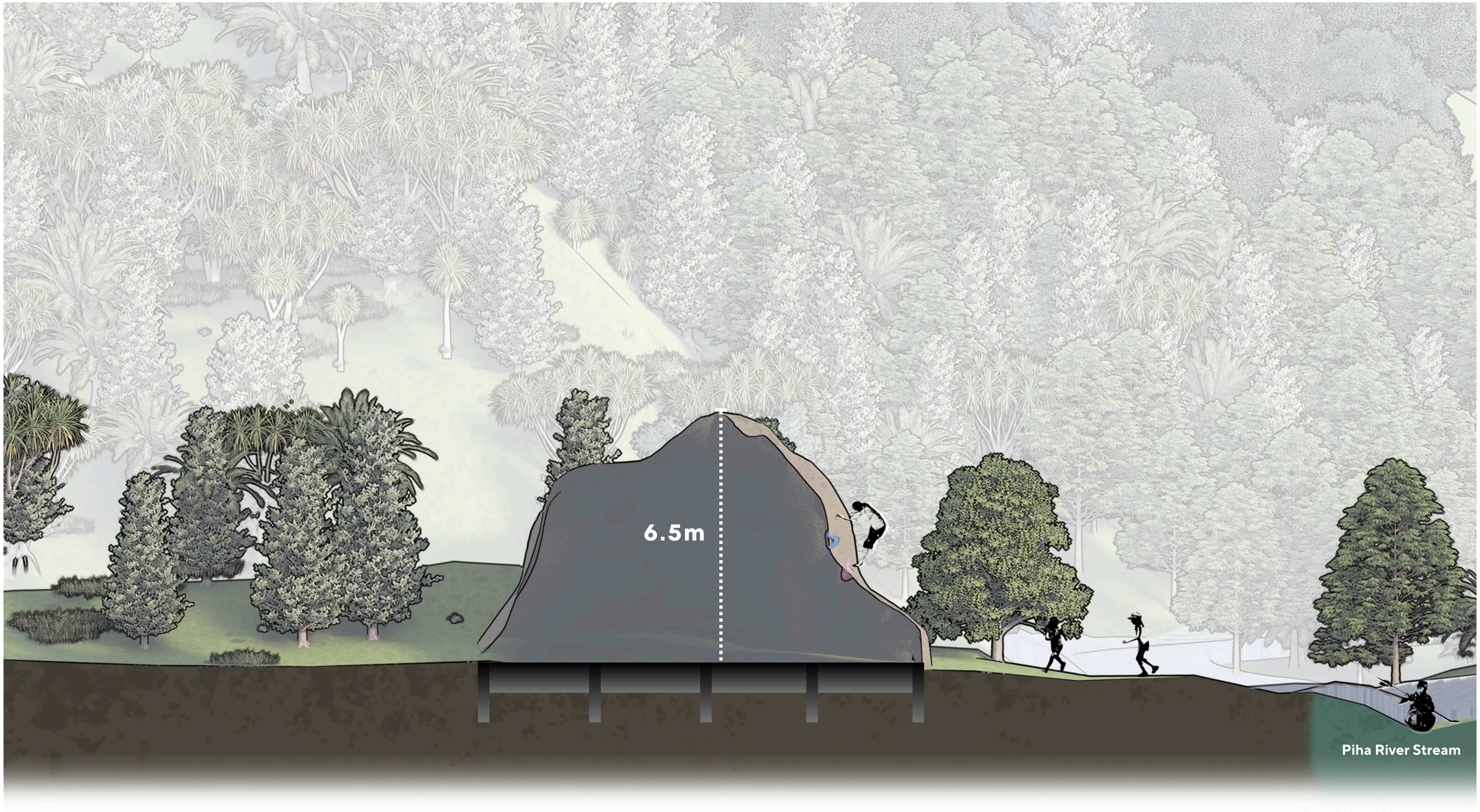


Figure 79. Lion Rock Climbing Folly Plan, by Author



Lion Rock Climbing Folly - S04 1:100 @A3

Figure 80. Lion Rock Climbing Folly Section, by Author

Figure 81. Tyre Swing Folly 01 rendered in Lumion, by Author.

Figure 82. Tyre Swing Folly 02 rendered in Lumion, by Author.

Figure 83. Tyre Swing Folly 02 rendered in Lumion, by Author.

6.3.5 Tyre Swing Folly

This folly promotes sustainable architecture by repurposing discarded tyres, transforming waste into an interactive play structure. The design was modelled in Shapelab VR, where swing heights and spatial configurations were tested in real-time.

Early iterations lacked stability due to insufficient support for the halo, which was evident through visualisations as seen in Figures 84 and 85. To resolve this, the design was modified to incorporate four support poles, enhancing structural integrity. The poles were initially designed in Revit for precise dimensions and load distribution, then further developed in VR to ensure accurate positioning and integration with the surrounding environment. The final design enhances community engagement with sustainability, offering an interactive play space that educates visitors on upcycling and environmental consciousness.

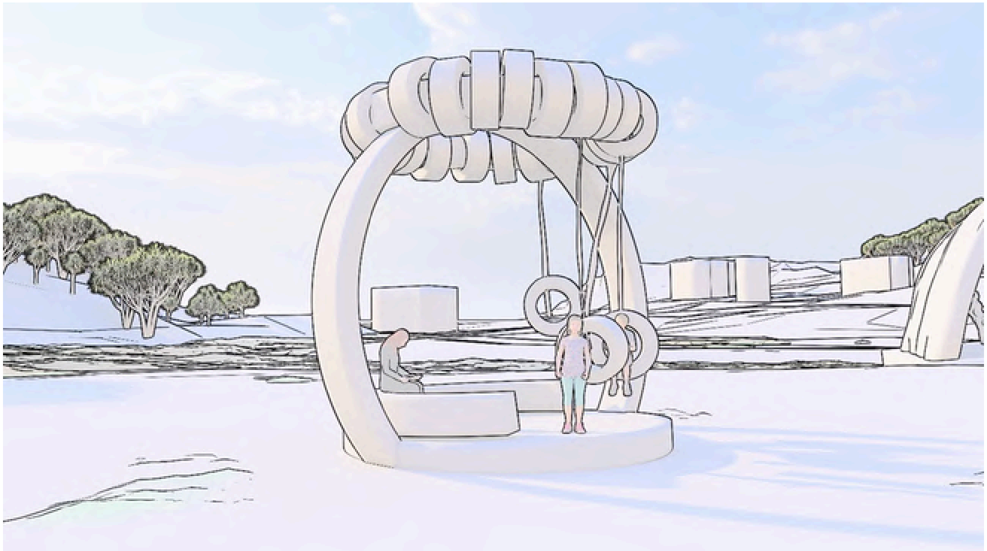


Figure 84. Early design work for Tyre Swing Folly 01, by Author.

Figure 85. Early design work for Tyre Swing Folly 02, by Author.

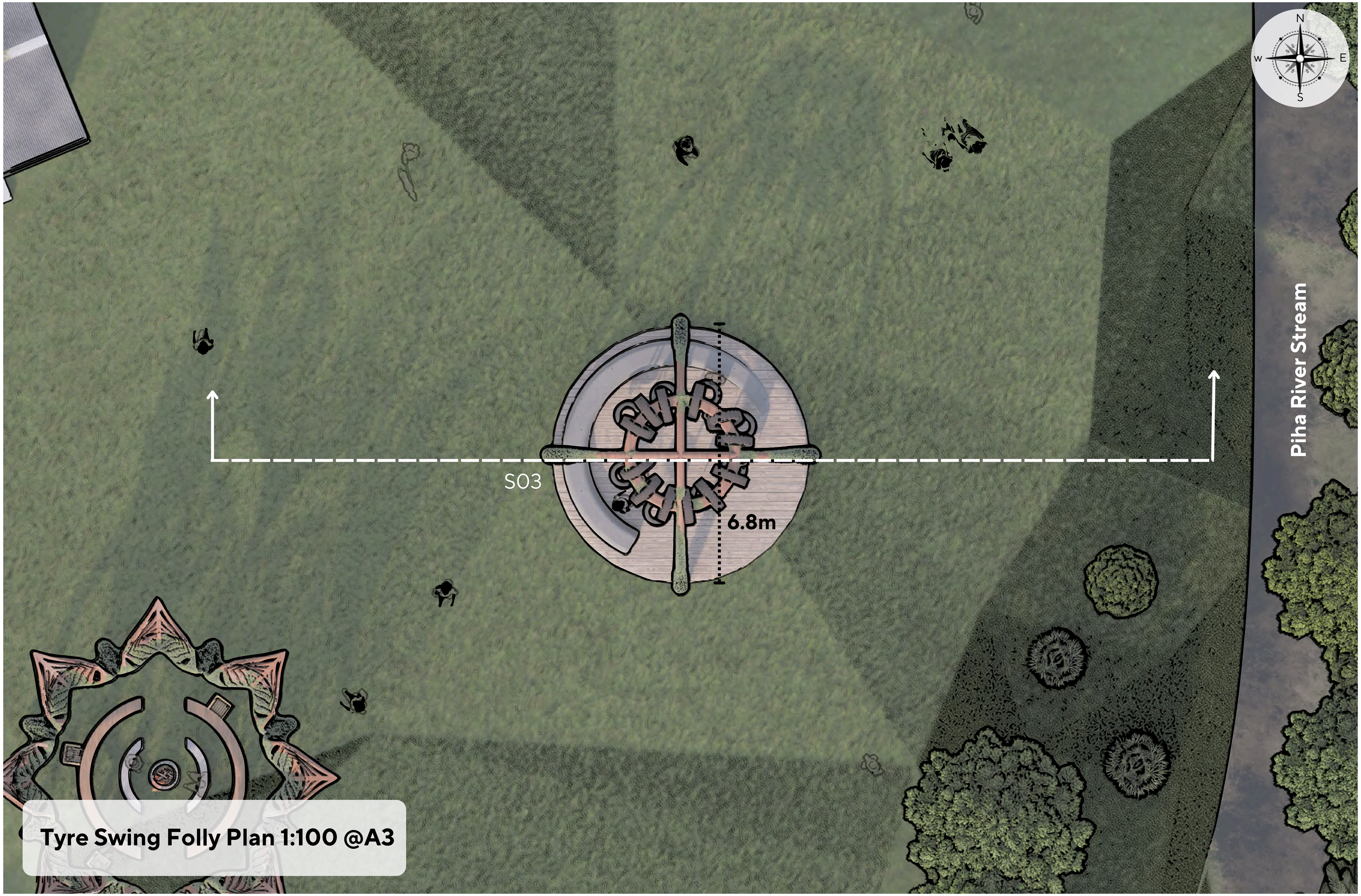
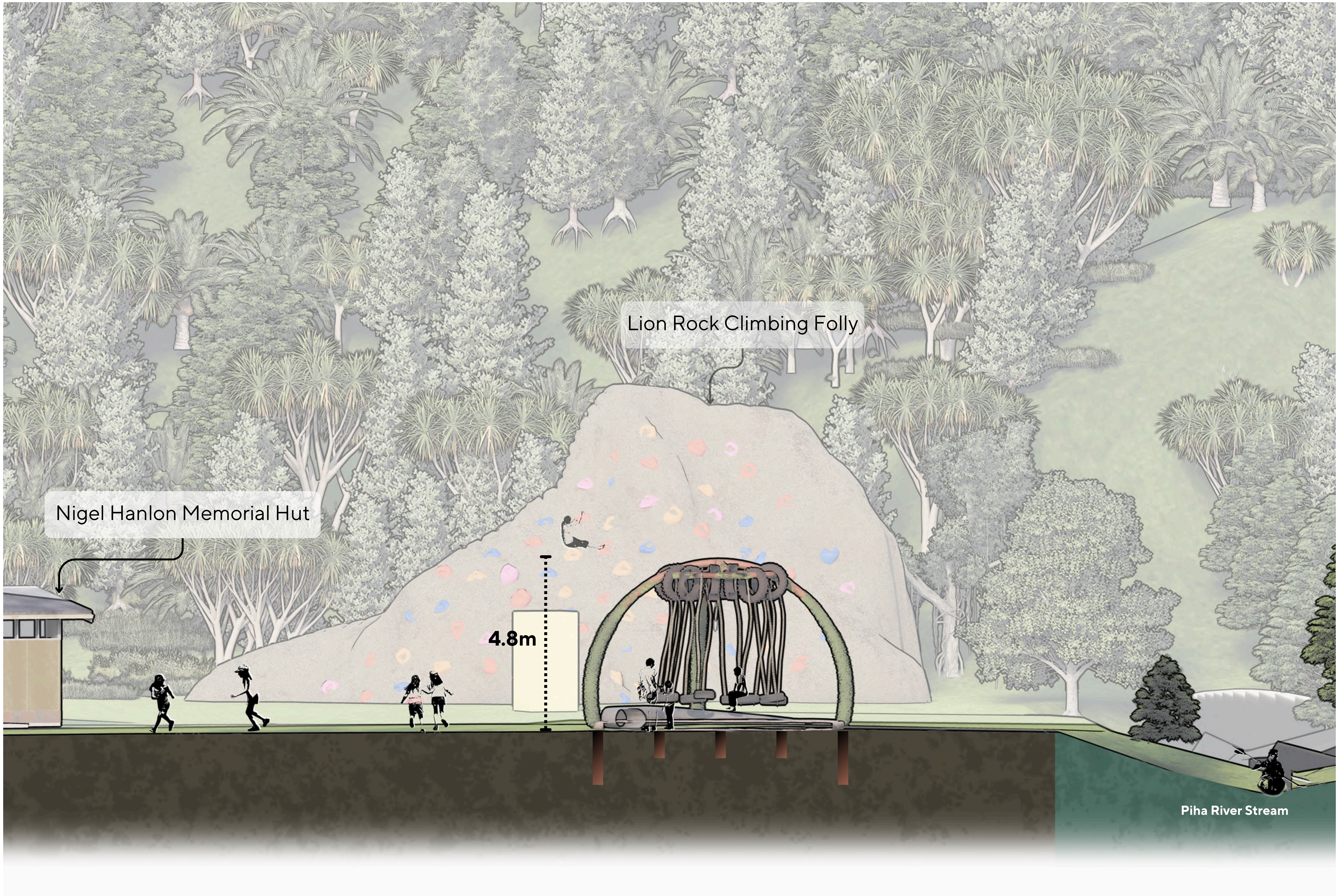


Figure 86. Tyre Swing Folly Plan, by Author



Tyre Swing Folly - S03 1:100 @A3

Figure 87. Tyre Swing Folly Section, by Author

6.4 Reflections

The application of these conceptual principles Conservation of Memory, Engagement through Design, and Innovation via VR as discussed in 6.2 has played a fundamental role in shaping the design and development of the follies within this project. By grounding the follies in historical narratives and community traditions, they function not only as architectural interventions but also as storytelling devices that bridge past and present experiences

The integration of Virtual Reality (VR) as an innovative tool enabled rapid iteration and real-time engagement with the design process, which is uncommon in traditional conservation workflows. However, challenges arose in ensuring that VR-based designs translated effectively particularly while accurate scaling, maintaining practical feasibility and avoiding design decisions that might become overly abstract in the immersive experience. While VR enhanced the conceptualisation and visualisation stages, further exploration is required to streamline the transition from digital models to tangible, conservation focused architectural interventions.

These reflections demonstrate the evolving nature of heritage conservation, particularly in the context of small-scale heritage sites like the Nigel Hanlon Memorial Hut. The follies serve as an experimental case study, highlighting the potential of immersive virtual reality in conservation strategies for heritage at risk. By integration of memory, engagement, and technology ensures that the site's cultural significance is not only documented but also reinterpreted for future generations, marking a shift from static heritage documentation toward a more interactive and participatory conservation approach.

CHAPTER 7 CONCLUSION

Key Findings

Key findings of this study are the applications of VR workflows for heritage conservation, demonstrating how digital documentation and immersive technologies can enhance heritage conservation workflows from site analysis, documentation, ideation for contemporary design intervention, and user experience. This thesis set out to address the research question: How can the use of a virtual reality-based workflow contribute to the conservation and contemporary intervention for at-risk cultural heritage sites in New Zealand? Through the case study of the Nigel Hanlon Memorial Hut, this research has demonstrated that Virtual Reality (VR), when integrated with photogrammetry and Heritage Building Information Modelling (HBIM), offers a viable and effective workflow for digital documentation, conservation planning, and immersive site engagement due to the small scale of the Nigel Hanlon Memorial Hut's, site accessibility, and cost-effective photogrammetry & VR tools available to the general public such as a smartphone and VR Headset.

Heritage Building Information Modelling (HBIM) typically follows a structured process that includes data acquisition, modelling, and integration into shared databases for heritage management and conservation as explored in Chapter 2. While this research aligns with HBIM principles in its use of photogrammetry for data capture and 3D modelling in Revit, it diverges from traditional HBIM workflows by prioritising immersive engagement through Virtual Reality (VR). Unlike conventional HBIM models, which are primarily used for archival documentation and restoration planning, this project explores VR's potential in user interaction and experiential storytelling. While this thesis primarily involved an person using VR to explore ideas, more participation can be possible in the future. Additionally, while HBIM data is often stored in centralised repositories for heritage professionals, the digital models in this project are not yet fully integrated into such open-access platforms but could be adapted for broader accessibility in future developments.

The design principles outlined in earlier chapters played a crucial role in shaping the development of the folly interventions. The Heritage conservation principles including authenticity guided material choices and spatial organisation to ensure that the interventions maintained a strong dialogue with the existing site conditions. Similarly, the emphasis on community engagement informed design decisions that encouraged interaction, storytelling, and memory conservation within the folly spaces. However, challenges arose in balancing contemporary design interventions with heritage conservation ethics. While VR provided a powerful tool for iterative design exploration, translating digital models into practical and viable construction drawings would require further advancements in the technology. Furthermore, site-specific challenges, such as flood risk amongst other risks mentioned in Chapter 5.3 required site-specific modifications as well as the flexibility to work across different platforms with the help of exporting models, demonstrates the importance of flexible workflow in heritage based design. The application of the conservation principles Conservation of Memory, Engagement through Design, and Innovation via VR were fundamental to the design and development of the follies in this project. Each folly expressed a unique narrative linked to community traditions and outdoor activities. The workflow supported quick drafting and modelling, helping bring these stories to life and reinforcing cultural memory. Iterative design in VR enabled responsive spatial planning and control over the broader site, enhancing engagement through design. Innovation via VR was made possible through the integration of accessible digital tools, allowing the final outcome to align with these principles and support the conservation of the at-risk Nigel Hanlon Memorial Hut in Piha.

Reflection on the advantages of a VR-based workflow in heritage conservation

By implementing a VR-based workflow, this study has addressed key challenges in heritage conservation. Photogrammetry provided a cost-effective and accessible method for generating high-accuracy 3D models, compensating for the inaccessibility of LiDAR technology. The integration of VR platforms like Shapelab VR enabled a more interactive approach to conservation and design, allowing for the exploration of architectural interventions within an immersive digital environment. These findings align with global conservation frameworks, including "*UNESCO's Enhancing Our Heritage Toolkit 2.0*" and ICOMOS principles, underscoring the role of digital tools in heritage management.

Beyond its technical applications, this thesis has explored VR's potential in exploring digital tools and strategies to enhance future community engagement with heritage sites at risk. VR enables a deeper interaction with cultural memory by allowing users to virtually explore and experience historical spaces. This approach highlights how digital conservation is not just about conserving physical structures but also about maintaining the narratives and cultural significance embedded within them.

Reflection on the challenges of a VR-based workflow in heritage conservation

However, while this study has demonstrated the potential of VR in heritage conservation, it also acknowledges current limitations. The application of VR is not yet entirely viable in some areas where software capabilities are still developing. Existing VR tools lack advanced collaborative editing features and architectural precision, limiting their direct integration into professional conservation workflows. However, as VR software continues to evolve, with future updates aimed at enhancing multi-user collaboration and improving architectural modelling tools, its applications in heritage conservation will become increasingly refined. Greater community engagement and interdisciplinary collaboration will also play a role in shaping these digital tools to better meet conservation needs.

Despite challenges such as hardware accessibility and computational constraints, this study provides a framework that can be adapted for future conservation efforts. As VR technology becomes more advanced and accessible, its integration into heritage workflows will likely expand, offering new possibilities for documentation, design, and public engagement. By demonstrating that VR can enhance both the conservation and reinterpretation of cultural heritage, this research contributes to the evolving discourse on digital conservation.

This thesis demonstrates that VR-based workflows can play a significant role in the conservation of at-risk heritage sites by improving documentation accuracy, enabling contemporary design interventions, and creating immersive experiences that engage both experts and the public. While VR applications are not yet fully developed in certain areas, ongoing software improvements and increased user collaboration will further enhance its effectiveness. By merging technological innovation with conservation ethics, VR provides a powerful tool to safeguard and reimagine heritage, ensuring its accessibility and appreciation for future generations.

Future Work

Further exploration is needed to expand the applicability, accessibility, and effectiveness of these methods. Future research can enhance community engagement, integrating interactive gaming elements, exploring emerging virtual technologies, and incorporating new software innovations in heritage conservation. These considerations are discussed in the following sections below.

Enhancing Accuracy in Heritage Conservation with Upcoming Software

With continuous advancements in 3D scanning, HBIM, and VR modelling software, heritage conservation workflows must adapt to incorporate new tools and methodologies. Future research should evaluate emerging platforms that enhance automation in photogrammetry processing, improve point cloud accuracy, and facilitate real-time collaboration between conservation experts. The development of AI-assisted heritage documentation tools could streamline the classification, reconstruction, and material analysis of historic structures, making digital conservation more efficient and scalable. Integrating cloud-based platforms for collaborative heritage projects could also improve data sharing and interdisciplinary research efforts.

Gamification for Heritage Interpretation

The incorporation of game design principles in heritage conservation offers an innovative way to enhance visitor engagement and education. Gamification elements, such as interactive site exploration, puzzles, and historical reconstructions, could be integrated into VR models, making digital heritage more engaging for broader audiences. Case studies from cultural heritage projects that employ serious games demonstrate that gamified VR applications can improve historical learning (Champion, 2020), visitor retention, and conservation awareness. Future research should investigate how virtual reality game mechanics can be applied to heritage sites to create interactive learning environments that complement traditional documentation efforts.

Exploration of Emerging Virtual Technologies such as Augmented Reality (AR) & Mixed Reality (MR)

The rapid evolution of VR, Augmented Reality (AR), and Mixed Reality (MR) presents new opportunities for more immersive and dynamic heritage experiences. Future work should explore how AR can overlay historical reconstructions onto physical sites, allowing visitors to experience heritage spaces as they existed in different time periods. Additionally, the use of haptic feedback, AI-driven interactive storytelling, and digital twin technology could enhance the realism and interactivity of virtual heritage applications. Advancements in cloud-based VR streaming could also improve accessibility, enabling remote users to experience heritage sites without requiring high end hardware (Pasupuleti, 2025).

Community Engagement

Future work should prioritise increasing public participation in heritage conservation through interactive VR experiences and digital storytelling. Developing community focused VR applications could encourage wider engagement, allowing stakeholders, including local iwi, heritage professionals, and the general public, to interact with heritage sites in new ways .

Beyond enhancing user engagement, these digital tools also create opportunities for more inclusive participation in the design process itself. VR enables stakeholders to interactively explore, test, and refine conservation strategies in real time, providing valuable input before physical implementation. With further advancements collaborative VR experiences could allow communities to contribute oral histories, personal narratives, and local knowledge while also influencing design decisions, ensuring that digital documentation and conservation efforts reflect diverse cultural perspectives.

Data Management for Integrated Workflows

Future priorities should focus on standardised metadata frameworks, secure long-term storage, and interoperable platforms to integrate photogrammetry, HBIM, and VR efficiently. As technology evolves, decentralised storage and blockchain-based verification could enhance data conservation and accountability in digital conservation.

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Appendix 1: Letter of Support Graeme Johansen, Boys Brigade Trust Representative

GRAEME JOHANSEN
BOYS BRIGADE TRUST
ARCHITECT

16th April 2024

DOCUMENTATION ON NIGEL HANLON HUT, PIHA

I, Graeme Johansen , as a duly authorized representative of Boys Brigade Trust, hereby grant permission for documentation activities to be conducted at Piha Nigel Hanlon Hut. This authorization is granted to Devarsh Patel, a student at AUT University, for the purpose of his thesis project.

Devarsh Patel is permitted to carry out documentation activities, including but not limited to, image and video capture at Piha Nigel Hanlon Hut. Additionally, he is granted permission to utilize a drone for the purpose of documentation as outlined in his thesis project.

I acknowledge and understand that Devarsh Patel will be conducting these activities under the guidelines and regulations set forth by AUT University and any applicable local laws or regulations. Boys Brigade Trust holds no liability for any incidents or accidents that may occur during the documentation process.
Please extend all necessary cooperation and assistance to Devarsh Patel to facilitate his documentation activities at Piha Nigel Hanlon Hut.

Graeme Johansen

Appendix 2: Letter of Support from Ian Bogue, Boys Brigade Trust Chairman

IAN BOGUE

BOYS BRIGADE TRUST (BBNZNRT)

CHAIRMAN

10th May 2024

DOCUMENTATION ON NIGEL HANLON HUT, PIHA

I, Ian Bogue , as a duly authorized representative of Boys Brigade Trust, hereby grant permission for documentation activities to be conducted at Piha Nigel Hanlon Hut. This authorization is granted to Devarsh Patel, a student at AUT University, for the purpose of his Masters of Architecture thesis project.

Devarsh Patel is permitted to carry out documentation activities, including but not limited to, image and video capture at Piha Nigel Hanlon Hut. Additionally, he is granted permission to utilize a drone for the purpose of documentation as outlined in his thesis project.

I acknowledge and understand that Devarsh Patel will be conducting these activities under the guidelines and regulations set forth by AUT University and any applicable local laws or regulations. Boys Brigade Trust holds no liability for any incidents or accidents that may occur during the documentation process.

Please extend all necessary cooperation and assistance to Devarsh Patel to facilitate his documentation activities at Piha Nigel Hanlon Hut.

Ian Bogue