Facing the Flood

Amphibious Architecture for Flood Resilience in Peguis, Manitoba

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Floods are Canada's most common and costly natural hazard and flood risks are increasing due to climate change.[1] When floods affect housing, they not only inflict economic and property damage but also displace residents from their homes and affect people's sense of safety and community.

Conventionally, settlements built in flood-prone regions are protected by flood control infrastructure, like levees, dikes, dams, and diversion channels. This infrastructure cannot easily or quickly respond to changing flood conditions and sometimes transfers flood risk rather than mitigating it equitably.[2] We see this in Manitoba's Interlake Region, where First Nations communities bear a disproportionate burden from water diversion to protect large urban centers.[3,4]

Where conventional solutions have failed and new tools are urgently needed, amphibious construction can provide an option for mitigation (Fig. 0.1 - 0.2). Amphibious structures sit on dry land when water levels are normal, like an ordinary building. However, there is a buoyancy system, allowing the structure to float on the water in a flood. Vertical guidance, often posts, holds the building in place laterally while floating. When flood waters recede the building returns to its original position undamaged.

Inspired by community members who wish to stay on their land despite flood risks, this thesis proposes amphibious architecture for a site in the First Nations Community of Peguis, Manitoba. Relocated to flood-prone land after a fraudulent land transfer in 1907, the community experiences chronic flooding. They faced several floods in the last two decades and had their worst flood on record in 2022, emphasizing the urgency of providing solutions for residents.[5]

This thesis examines this history and a specific site in Peguis, identifying key considerations for implementing amphibious architecture there. Then, it assesses existing amphibious architecture precedents, looking at how these projects address common challenges. Drawing insights from this analysis, this thesis proposes a prototype design for the site in Peguis. Through documenting and discussing the design process, this work identifies options for implementing amphibious architecture and builds a guide that can inform future amphibious projects.

1 Katarzyna Alderman, Lyle R. Turner, and Shilu Tong, "Floods and Human Health: A Systematic Review," *Environment International* 47 (October 15, 2012): 37–47.

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3 Alderman, Turner, and Tong, "Floods and Human Health."

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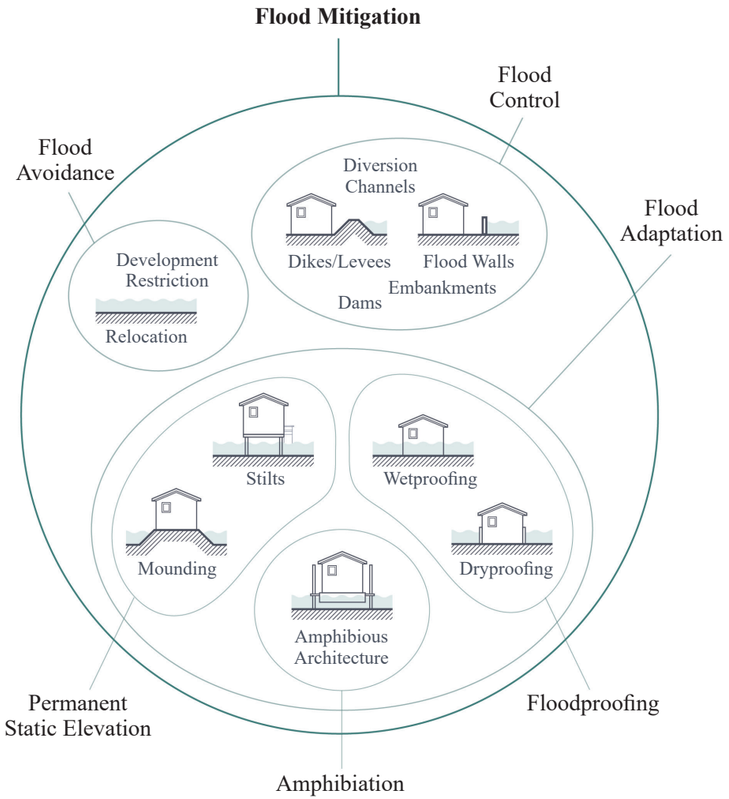


Fig. 0.1

Diagram of Flood Mitigation Strategies.

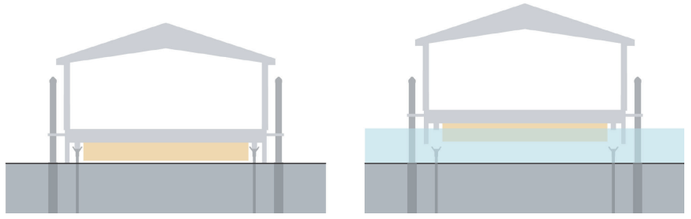


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Acknowledgments

To the land and the First Nations peoples who steward it -

I am deeply grateful to be on this land, with waters and landscapes I love and a history I am still learning. My work takes place on land granted in perpetuity to First Nations peoples. Those treaties were not kept - not in Manitoba, where Peguis First Nation was forced from their lands, and not in the Haldimand Tract, where 95% of the original land grant is no longer held by the Six Nations to whom it was promised, including the University of Waterloo campus. In this thesis, I strive to acknowledge the ongoing injustice of this history.

I am so thankful that I had the opportunity to visit Peguis, Manitoba, and speak with community members there who have faced flooding. Your powerful stories drive the work I have done, and I try to centre the perspectives you shared with me in this thesis. I hope what I have produced gives back in some small way. I appreciate you for generously sharing your time and experiences.

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List of Abbreviations

ASCE - American Society of Civil Engineers

CMHC - Canada Mortgage and Housing Corporation

CP - Certificate of Possession

EPS - Expanded Polystyrene

FEMA - Federal Emergency Management Agency (USA)

FN - First Nation

MIR - Make It Right Foundation

NBCC - National Building Code of Canada

ORL - Old River Landing

RTM - Ready-to-Move

Positionality Statement

Instead of proposing one right solution for the problems facing Peguis, my thesis strives to recognize the need for solutions and propose amphibious architecture as one potential option.

I approach this work with humility, mindful of the complex and often exploitative history of academic work involving Indigenous communities. I do not wish to impose a predetermined solution onto any community, especially given this history and the experimental nature of amphibious architecture. I do not have the authority to say what is or is not an appropriate solution for First Nations Communities.

However, I see a tremendous need for new solutions to flooding. I also see that First Nations communities face an unjust level of flood risk. So, when my involvement in amphibious architecture research brought me into contact with the First Nations community of Peguis, Manitoba, I was interested in contributing.

During my trip to Peguis, and through engagement with community members as a part of a broader research project, I had the opportunity to hear from people about their experiences with flooding (Fig. 0.3). The work I present in this thesis was shaped by these interactions, and responds to residents' visions for how amphibious architecture could help them and their community.

As a student of architecture, I strive to provide my research and design skills as an architect would to a client, responding to one of these community members and proposing solutions for their unique circumstances. I also hope that the analysis in this thesis provides insights that could go beyond this single site, informing future projects on other sites in Peguis and in similar communities.

This thesis is for those who shared their time and first-hand experiences with me. I am deeply grateful for your generosity and the opportunity to hear your stories.

...

It flooded less before they started diverting water (Portage Diversion)

...

I miss not only the people and community, but also the land

...

The water sat stagnant for weeks. Mould grew. Now they're up for replacement

...

It's been two years, and we've lived in seven different hotels

...

The house is mounded up, but now that's not enough without sandbagging too

...





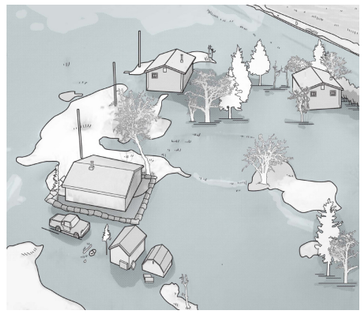


Fig. 0.3

Vignettes Based on Stories from Peguis Community Members.

Proposing Options for Adaptation

The Issue

About 200 kilometres north of the City of Winnipeg, Peguis Reserve 1B sits between Lake Manitoba and Lake Winnipeg (Fig. 0.4). The community of Peguis faced floods in 2004, 2006, 2009, 2011, 2014, 2017, and 2022, each requiring the evacuation of residents.[6] The frequency and severity of flooding leave the community in a constant cycle of evacuation and rebuilding, unable to recover and prepare proactively for the next flood.

Flooding is a natural process in this region but has worsened due to human manipulation. The flow of water in south-central Manitoba is highly engineered for drainage and flood mitigation purposes. Dikes, drainage culverts and diversion channels are used extensively to drain land and protect towns and cities from flooding, especially the City of Winnipeg. However, the province floods anyway and the flooding is worse for many on reserves and in rural areas because of efforts to divert water away from larger settlements.[7]

This paradigm is the result of an ongoing sequence of inequitable policy decisions. Peguis First Nation (FN) was violently relocated to its present site in the early 20th century as a part of a fraudulent land seizure by the federal and provincial governments. Then, they were left without appropriate flood mitigation.

Each flood damages more homes than the community can repair before the next flood, worsening the community housing shortage. Some Peguis residents displaced in 2011 were still living elsewhere as of 2024 despite a desire to return because their houses were damaged, repairs were not possible, and new housing was not available.[8] Despite all this, residents have grown attachments to the land and many would rather face the changing nature of flooding here than move their community again.[9,10] Driven by the tremendous need for new solutions in Peguis, and responding to a client who believes in the power of this solution for their community, this thesis investigates how amphibious architecture could be used for flood adaptation in Peguis, Manitoba, and similar communities.

6 See Appendix 1 for a table of flood and evacuation reports.

7 Ballard and Thompson, "Flooding Hope and Livelihoods."

8 Julia-Simone Rutgers, "Residents of Peguis First Nation Face an Impossible Choice as They Tackle yet Another Major Flood," *The Narwhal,* July 30, 2022.

9 Client in Peguis, in discussion with the author, December 10, 2023.

10 Rutgers, "Residents of Peguis First Nation Face an Impossible Choice as They Tackle yet Another Major Flood."

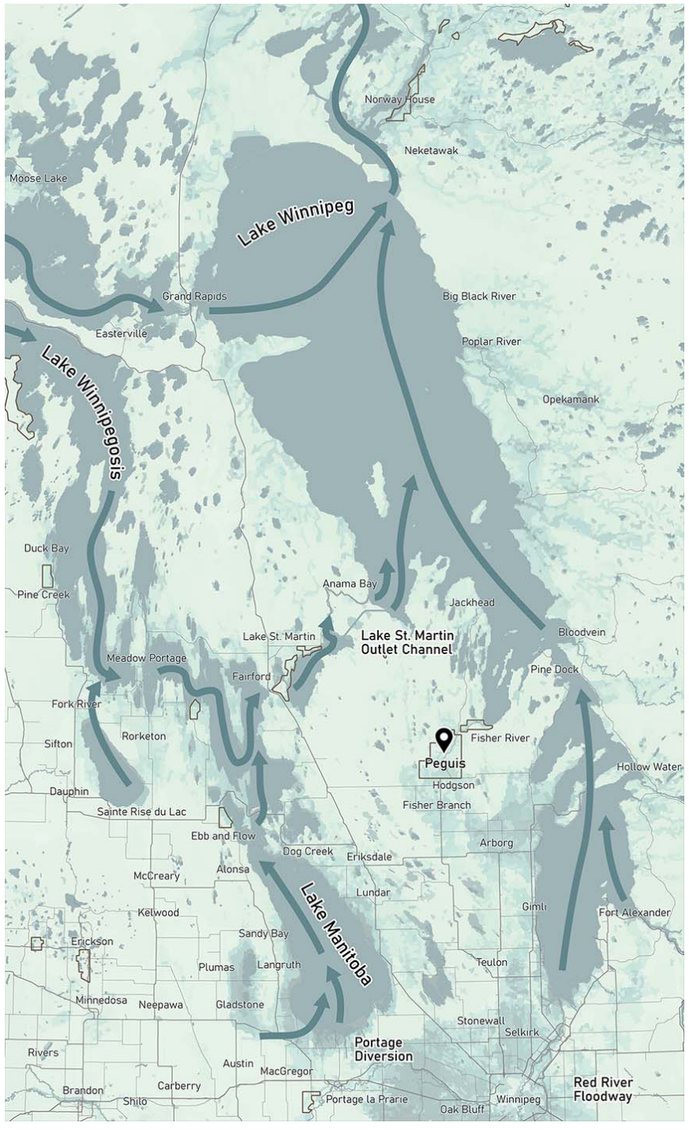


Fig. 0.4

Peguis and Surrounding Settlements, Water Bodies, and Hydrological Structures.

Objective

The goal of this work is to propose options, both broadly, discussing amphibious architecture as a flood mitigation option for Peguis, and specifically, discussing different options for addressing components of an amphibious retrofit design. This thesis also aims to contribute to the growing body of amphibious architecture knowledge by compiling resources on existing precedents and examining how they address challenges that arise during amphibious construction.

This culminates in an amphibious retrofit proposal for a specific site in Peguis. By documenting the design process and identifying key considerations for the implementation of amphibious architecture, this work hopes to provide a resource for future amphibious architecture projects in similar contexts.

Methodology and Scope

Chapter One discusses flooding in Peguis, including a historical summary and a description of the challenges facing the community today. This makes the case for why new and innovative solutions are needed here, and for First Nations communities in the Interlake Region more broadly.

Chapter Two focuses on a specific site in Peguis, discussing the implications of flood conditions on the design of an amphibious architecture prototype there. First-hand observation of the prototype site, photos and videos of the site during floods, and analysis of river flow and weather data were used to draw broad conclusions about flood characteristics. This analysis is also informed by conversations with Peguis residents, especially the property owner of the prototype site, who serves as the client for the final design proposal.

Chapters Three and Four are a literature review and precedent analysis, investigating precedent projects and existing research on amphibious architecture. This review documents the range of existing design solutions for key components of amphibious construction, such as the buoyancy system, the vertical guidance system, and the utility connections. Conceiving of each of these components as a design problem, and each precedent project as a bundle of potential solutions, this review will identify factors that affect when different solutions are suitable. It will

also discuss how precedent projects address common issues, including environmental hazards and economic constraints. This review seeks out scholarly sources where possible via systematic database searches, and supplements with information from other sources when no scholarly sources are available.

Chapter Five proposes an amphibious retrofit design for a client and site in Peguis. A prefabricated home is used as the base for this design, a typology that is common in Peguis and suitable for amphibious retrofit. Through the representation of a proposed design and discussion of design alternatives, this section explores different options for a hypothetical amphibious retrofit.

Together, this work makes the case for the feasibility of amphibious architecture in Peguis. Grounded in a specific site and context, this research takes a practical and community-focused approach to climate adaptation—one that proposes innovative strategies for flood-prone communities while recognizing the real-world constraints facing residents. The design proposal is informed by direct engagement with those affected by flooding and responds to the conditions of a specific site. As a result, it is a pragmatic proposal focussing on context-sensitive, realistic solutions. In this work, architectural design is a tool for problem-solving—responding to social, environmental, and technical challenges with care and creativity.

Flooding in Peguis

Manitoba is a 'wet prairie', receiving two to three times more rainfall than Saskatchewan or Alberta.[1] Flooding is a natural and cyclical event for this landscape. Situated between Lake Winnipeg and Lake Manitoba, the Interlake Region is no exception to this pattern. Multiple rivers create very high incoming flows during the spring, and because many rivers in this part of the province flow south to north, the headwaters often melt before the lower reaches of the river do, causing ice jams (Fig. 1.1). This type of flooding—"ice-jam generated overland flow"—is essential to health and productivity of floodplain ecosystems.[2]

However, floods here have worsened and shifted due to human manipulation of water and the landscape, both intentional and unintentional. In this chapter, I will discuss the forces that have led to frequent flooding here, and how colonial efforts have resulted in disproportionate flood impacts for First Nations communities like Peguis.

1.1 Migration and Relocation of Peguis First Nation

In the late 1790s, a group of Ojibwe[3] people left their traditional territory in the Sault Ste. Marie area. Led by Chief Peguis, they arrived in the south Interlake Area and settled near present-day Selkirk, Manitoba (Fig. 1.2). Historical accounts describe the relocation as voluntary, perhaps motivated by a search for better hunting grounds.[4] However, this migration is not how the group arrived at their present-day site.

Colonial settlement in Manitoba began in the 1810s when Lord Selkirk sponsored settlers to establish communities along the banks of the Red River. Although the relationship was not tension-free, both settler and First Nations' histories tell of an initially positive relationship between Peguis FN and the early settlers.[5,6] Chief Peguis and Lord Selkirk negotiated a treaty for the use of the lands along the Red River in 1817 (Fig. 1.3). When Manitoba joined the Canadian confederation in 1870, the federal government also sought a formal agreement with the FN people of the area. This treaty, the first formal treaty by the Government of Canada, set aside St. Peter's reserve and parish for Peguis FN in perpetuity (Fig. 1.4 to 1.5).

1 Shannon Stunden Bower, *Wet Prairie People, Land, and Water in Agricultural Manitoba,* Nature, History, and Society Series (Vancouver UBC Press, 2011).

2 D.L. Peters et al., "An Ecological Perspective on Floods in Canada," *Canadian Water Resources Journal* 41, no. 1–2 (April 2, 2016): 288–306.

3 Ojibwe people who moved west during the early colonial period are also referred to as Saulteaux, Red River Saulteaux, or Plains Ojibwe. For clarity, this specific group will be referred to as "Peguis FN"going forwards.

4 Albert Edward Thompson, *Chief Peguis and His Descendants* (Winnipeg : Peguis Publishers, 1973).

5 Ibid.

6 Donna G. Sutherland, *Peguis : A Noble Friend* (St. Andrews, Manitoba: Chief Peguis Heritage Park Inc., 2003).

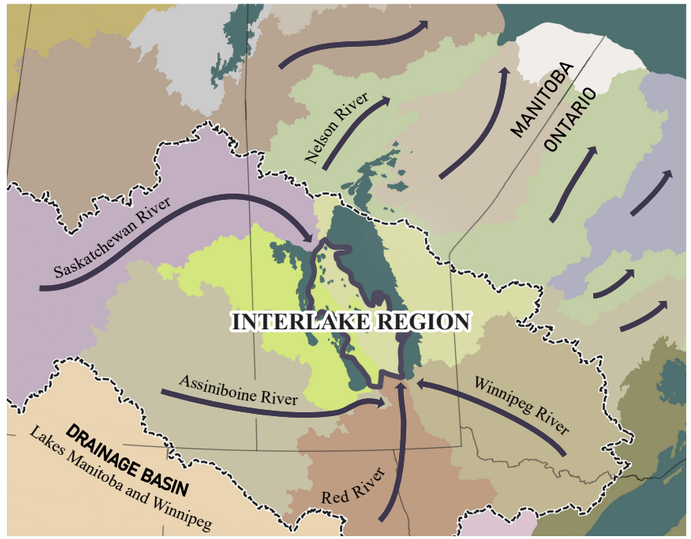


Fig. 1.1

The Interlake Region and Surrounding Watersheds.

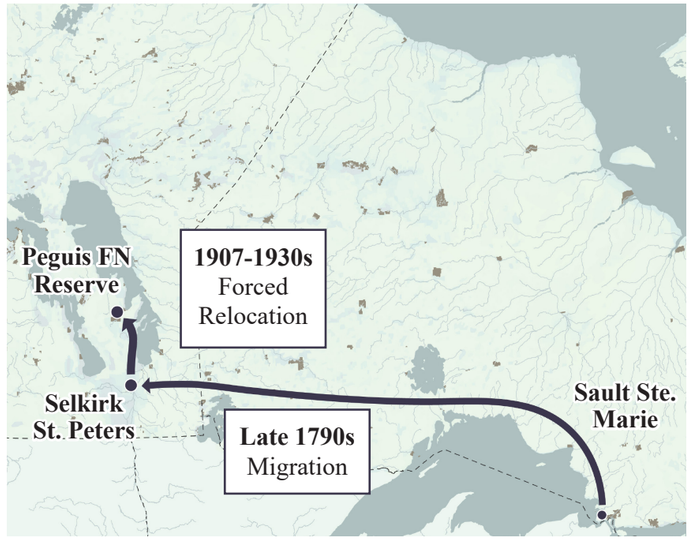


Fig. 1.2

Relocation and migration of Peguis First Nation.



Fig. 1.3

Peguis-Selkirk Treaty Map, 1817.



Fig. 1.4

Historic Location of St. Peter's Reserve and Parish.

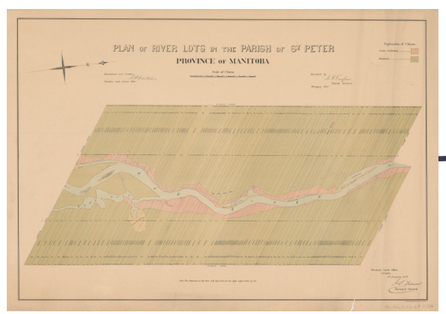


Fig. 1.5

Plan of the Parish of St. Peter, 1875.

However, as the colonial process continued, the settlers began to covet the prime agricultural land cultivated by those on St. Peter's Reserve.[7] Legal squabbles escalated until September of 1907, when the Department of Indian Affairs conducted a fraud referendum on the relocation of the reserve. Members of the community protested this vote, with serious grievances about the process and results. The vote was announced less than two days in advance, in violation of the First Nation administration's standard practice and the terms of Treaty One.[8] The terms of the surrender were not fully read out, and partial explanations were provided in English but not Cree or Ojibway.[9] First-hand reports state it appeared that the community voted in favour of staying in St. Peter's, with the majority of individuals voting against the referendum.[10] However, the colonial officials counted and declared the referendum had passed and the reserve would be relocated. All standard procedures and record-keeping practices were ignored, and as a result, there was no way to audit the vote, ensure only eligible individuals had voted, or verify the colonial officer's questionable vote count. The entire procedure was a farce, but the Department of Indian Affairs deemed that the community had agreed to a land surrender.

There was significant resistance to this injustice within the community and the relocation was violent and drawn out. Half the members of the community were still in the Selkirk area in 1919, and occupations and protests continued until 1930.[11] Many who were relocated attempted to return to their original reserve lands, and some were subsequently arrested for alleged "disobedience" to the land surrender agreement.[12]

1.2 Colonial Settlement and Water Control

This story of Indigenous displacement unfolds alongside the monumental government effort to drain and divert Manitoba's waters. Wetland prairies—like those once common in South-Central Manitoba—are a fluctuating but highly productive environment. First Nations Peoples and early European settlers in Manitoba recognized that this made them valuable, and would gather plants, dried grasses, and migratory game during periods of abundance, then move away during times of flood. Yields were variable since the amount and location of surface water were different every year. However, people adapted. Agricultural development, when it occurred, was based on suitable local conditions rather than top-down planning.[13]

7 Thompson, *Chief Peguis and His Descendants.*

8 Paul Burrows, "'As She Shall Deem Just' : Treaty 1 and the Ethnic Cleansing of the St. Peter's Reserve, 1871-1934" (University of Manitoba, 2009).

8 Ibid.

9 Ibid.

10 Sarah Carter, "They Would Not Give Up One Inch of It': The Rise and Demise of St Peter's Reserve, Manitoba," in *Indigenous Communities and Settler Colonialism,* ed. Zoë Laidlaw and Alan Lester, Cambridge Imperial and Post-Colonial Studies Series (London: Palgrave Macmillan UK, 2015).

11 Burrows, "As She Shall Deem Just."

12 Ibid.

13 Stunden Bower, *Wet Prairie People, Land, and Water in Agricultural Manitoba.*

In the 1870s, there was a reduction in this type of flexible land usage.[14] It is not a coincidence that this shift in land management occurred around the same time as relationships worsened between Peguis FN and the Selkirk Settlers. Both are partially explained by the enactment of the Manitoba Act in 1870 and the Dominion Lands Act in 1872. The Manitoba Act founded the province of Manitoba, then the Dominion Lands Act created a plan for dramatically expanded colonial settlement via a colonial grid and land allotment system (Fig. 1.6). A property grid necessitates permanent agricultural development within one's geometrically defined settlement plot every year. If the land is too wet to farm some years, or a flood destroys the year's crop, the settler-farmer loses their livelihood. Thus, to impose colonial ideas of structure onto land use practices and the landscape, the flow of water must be controlled.

The magnitude of ecological change in the south-central part of the province is staggering. One survey of townships in the Red River Valley found that less than 1% of the wetlands documented in 1870 still existed by the late 20th century.[15] Wetlands have a critical role in modulating the impacts of heavy rains and the spring melt. A flood model commissioned by the province showed that peak flows in the spring could be reduced up to 79% by restoring wetlands, and could more than double if wetland drainage continued.[16]

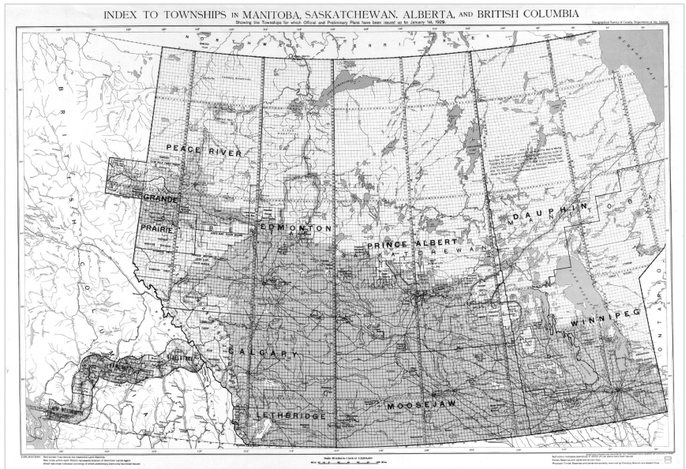


Fig. 1.6

A Dominion Lands Map of the Prairie Provinces, Showing the Colonial Grid.

14 Shannon Stunden Bower, "Natural and Unnatural Complexities: Flood Control along Manitoba's Assiniboine River," *Journal of Historical Geography* 36, no. 1 (January 1, 2010): 57–67.

15 Irene Hanuta, "A Reconstruction of Wetland Information in Pre-Settlement Southern Manitoba Using a Geographic Information System," *Canadian Water Resources Journal* 26, no. 2 (January 1, 2001): 183–94.

16 Manitoba Flood Review Task Force, *Report to the Minister of Infrastructure and Transportation* (Winnipeg, Manitoba: Manitoba Infrastructure and Transportation, 2013).

Today, the province acknowledges that wetland destruction and an unmoderated policy of drainage at all costs have contributed to several flood events, including the major flood in 2011.[17]

Province-scale flood mitigation efforts began following the 1950 Red River Flood, with the construction of the Red River Floodway in 1968 (Fig. 1.7). This exceptional project had a $72 million price tag at a time when the net provincial revenue was only $74 million. However, the government had a clear objective: to protect the city of Winnipeg at any cost. Since 1960, numerous other mitigation measures have been constructed with this same goal, including the Portage Diversion and the West/Brunkild Dike (Fig. 1.8).

To be clear, it is reasonable and essential to protect Winnipeg - about 55% of the population of the province lives there, and the city faced catastrophic flooding before the construction of these mitigation measures. Flood mitigation is needed, and the Red River Floodway and the wider Winnipeg flood mitigation network are marvels of engineering. However, it is important to look at what is and is not protected. Selkirk and the former St. Peter's Reserve are within the region where flooding is managed by the Red River Floodway and Portage Diversion. Many other small communities within the Red River Valley have received ring dikes, funded by the province.[18]

[17] Manitoba Flood Review Task Force, *Report to the Minister of Infrastructure and Transportation* (Winnipeg, Manitoba: Manitoba Infrastructure and Transportation, 2013).

[18] Bartley Kives, "No Ring Dike, but Why? Peguis First Nation Still Has No Permanent Flood Protection," CBC, May 11, 2022.



Fig. 1.7

The Red River Floodway.

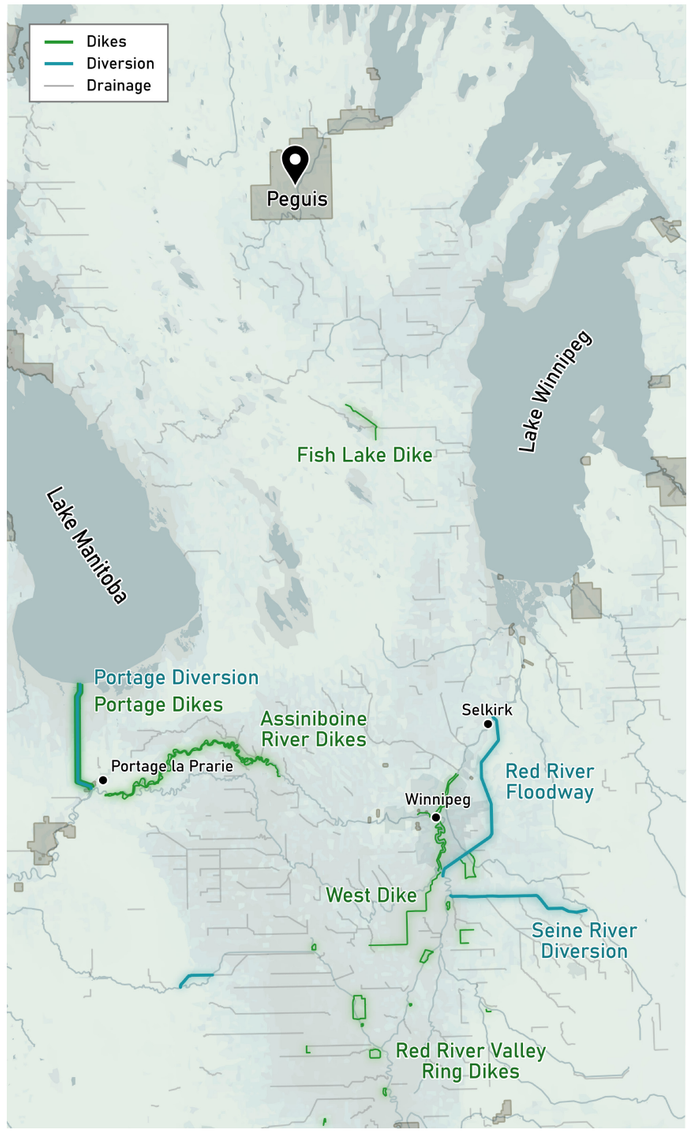


Fig. 1.8

Drainage and Flood Control in Central and South Manitoba.

The community was not only forced to live on flood-prone land, but also not given tools to protect themselves the way other communities in the province are protected. All of South-Central Manitoba is flood-prone, but massive human intervention means some places are less flood-prone than others. Peguis FN's former site faces a very different frequency of flooding than its present site. In the last 20 years, Peguis Reserve 1B has flooded six times. Selkirk and Winnipeg have flooded once.

1.3 Learning from Lake St. Martin

This situation facing Peguis is not unique. A 2013 report by the Auditor General reported that flood emergencies occur more often in First Nations communities than elsewhere in Canada.[19] A flood mapping study in Manitoba found that 83.3% of First Nations Communities in the Interlake Region have experienced flooding, or are at risk of flooding in the future.[20]

Lake St. Martin, a neighbouring FN community, has been directly displaced as a result of water management practices and flood diversions (Fig. 1.9).[21] During an unprecedented flood in 2011, the Provincial government diverted water into the Interlake Area to protect settlements and farmland in the south. The Portage Diversion, a floodwater diversion channel between the Assiniboine River and the Interlake watershed, was used at more than 140% of the capacity that it had been designed for, resulting in a rapid rise of water levels on Lake Manitoba and Lake St. Martin. Flood waters did not completely recede until late 2012, and thousands of people were displaced.[22]



Fig. 1.9

Houses in Lake St. Martin during the 2011 Flood.

19 Jason Thistlethwaite et al., "Indigenous Reserve Lands in Canada Face High Flood Risk" (Centre for International Governance Innovation, 2020).

20 Acosys Consulting, "Guidelines for Flood Mapping: Manitoba Indigenous Engagement Case Study," 2023.

21 Myrle Ballard and Shirley Thompson, "Flooding Hope and Livelihoods: Lake St. Martin First Nation," *Canadian Journal of Nonprofit and Social Economy Research* 4, no. 1 (Spring 2013): 43–65.

22 Gloria Galloway, "Flooded out to Save Winnipeg, Residents Now Feel Forgotten," *The Globe and Mail,* November 24, 2012.

During this flood event, cottages, farms, and urban areas were prioritized at the expense of First Nations communities. The overall amount of damage may have been reduced by these efforts, but the effects are profoundly unjust. In 2013, the province paid out a class action lawsuit to Lake St. Martin FN over the effects of this intentional water diversion.[23]

Lake St. Martin FN was moved to a defunct Cold War military base. Then, they were informed that the federal government had purchased a tract of land for a new reserve without the community's knowledge and against the guidance that had been provided during community consultation. This further delayed community members in their return to a site of their choosing.

A plan to cut diversion channels into and out of Lake St. Martin was proposed, but delayed by bureaucratic obstacles.[25] Nonetheless, some reconstruction of the community began in 2019, and a few residents returned to the shores of Lake St. Martin. However, more than a thousand people were still displaced as of 2023, twelve years after the flood. The Nation's Chief, Christopher Traverse, says living in temporary accommodations in Winnipeg for so long has had huge negative effects: 'A lot of people fall victim to violence here, to suicide, to drug overdoses'.[26] This aligns with the findings elsewhere, which document that protracted flood recovery has significant consequences for communities and residents. One study found that delays in returning to the community can have more impact on mental health outcomes than the flood event itself.[27]

This tragedy and its continuing effects are the result of human choices: the choice to put reserves on flood prone land, to protect some communities from flooding at the expense of others, and to disregard First Nations people when making decisions about land and water management.

1.4 The Present Situation in Peguis First Nation

Peguis has experienced seven major floods between 2004 and 2024. In 2022, the community experienced the most severe flood on record: a one-in-two-hundred year flood that washed out sections of roadway and affected more than 700 homes.[28] The severe flood in 2011 that displaced Lake St. Martin FN also affected Peguis, with more than 300 people being displaced from the community. Ninety-one of those 300 were still displaced as of 2020.[29]

23 Ian Froese, "Manitoba Government Deemed Partially Responsible for 2011 Flooding of Lake Manitoba," *CBC,* June 13, 2021.

24 "Lake Manitoba Flood Prevention Project Flawed, First Nations Study Suggests," *CBC News,* February 12, 2021.

26 Sarah Petz, "Lake St. Martin Flood Evacuee Would've Had Help in Community: Chief," *CBC,* February 19, 2024.

27 Kelly Dixon, Ian Shochet, and Jane Shakespeare-Finch, "Stress during the Rebuilding Phase Influenced Mental Health More than the Event Itself," in *Proceedings of the Australian and New Zealand Disaster and Emergency Management Conference* (2015), 21–33.

28 Bernhardt Darren, "100 Volunteers Recruited to Help Flood-Ravaged Peguis First Nation," *CBC,* May 4, 2022.

29 Erin Brohman, "Evacuees from Peguis First Nation Floods Left Scrambling as Federal Relief Ends," *CBC News,* April 28, 2022.

A flood mitigation study commissioned by the province looked at holding back water upstream, raising homes, building dikes and excavating a diversion channel; however, none of these were found to be feasible strategies to address the full scope of flooding in Peguis. The only "economically justifiable" option identified by the province was extensive diking and relocation of homes away from the river. The band council advocated for a diversion channel to avoid displacement of longtime residents from their family lands.[30] In the end, neither option was implemented, leaving Peguis with no plan to mitigate future flood impacts.

This has led to an untenable situation, where more homes are damaged in each flood than can be repaired before it floods again. Like many First Nations communities, Peguis faces a housing crisis. They do not have enough homes for all the members of their community who wish to live on their lands. The housing shortage also delays the return of displaced residents to the community, as there is nowhere for community members to return to if their home is condemned due to water damage or mould. This is significant; difficulty rebuilding and returning after a flood is a huge factor in the stress and disruption caused by flooding. Then, these issues compound when you consider the recurrent nature of the flooding here, with some residents being displaced multiple times by back-to-back floods. For many, the flood evacuations become quasi-permanent; they move into hotels, with friends and family, or into rental accommodations in nearby cities and remain there for years, with no timeline for return (Fig. 1.10 - 1.12).[30]

[29] Julia-Simone Rutgers, "Residents of Peguis First Nation Face an Impossible Choice as They Tackle yet Another Major Flood," *The Narwhal,* July 30, 2022

[30] Brohman, "Evacuees from 2011 and 2014 Peguis First Nation Floods Left Scrambling."



Fig. 1.10

Homes in Peguis during the 2022 flood.





Fig. 1.11 (left)

Peguis Housing Department Maps Flood-Damaged Homes in 2022.

Fig. 1.12 (right)

A Flood-Damaged House in Peguis.

Conventional flood mitigation has failed to protect Peguis FN and other FN communities in the Interlake Region. Additional relocations are not a satisfactory answer for those who have already faced historical forced displacement and who have a strong connection to their land.

Efforts to build resilience in place should not be an obstacle or alternative to more radical forms of justice. Efforts should be made to address the historical injustice of forced relocation wherever possible. However, many do not wish to leave the land where they live now, and for these individuals, options are urgently needed. With no plans in place to protect these areas, and a track record of government decision-making that has not served these communities adequately, residents who choose to remain need strategies to protect their homes and prevent flood damage.

Amphibious architecture is one approach that could help communities like Peguis build flood resilience. Residents could immediately reoccupy their undamaged amphibious homes after a flood, avoiding long-term disruption and the trauma of extended displacement. The following chapters will discuss the feasibility of this strategy for this community, ultimately proposing an amphibious architecture prototype for a specific site.

Assessing the Prototype Site

When in Peguis, I spoke with a contact who desires an amphibious house on his property (Fig. 2.1 - 2.2). He said there are others in Peguis in this situation, who are vocal about their desire to stay on their land regardless of worsening flooding.[1] Given the tremendous need for new solutions in Peguis, and informed by discussions with community members, this chapter will look at this property as a prospective site for an amphibious retrofit prototype.

The prototype property is within an area of dispersed settlement, typical for Peguis and the surrounding rural and Indigenous communities (Fig. 2.3). Homes are spread across a broad area, connected by mostly gravel roads. There is one existing house on the site, and a few neighbouring homes were visible from the property. To the north and east, there are treelines, which may provide some shelter from the wind for a house constructed here. Otherwise, the site is predominantly flat and open, with a few dispersed stands of trees (Fig. 2.4 - 2.5).

[1] Client in Peguis, in discussion with the author.

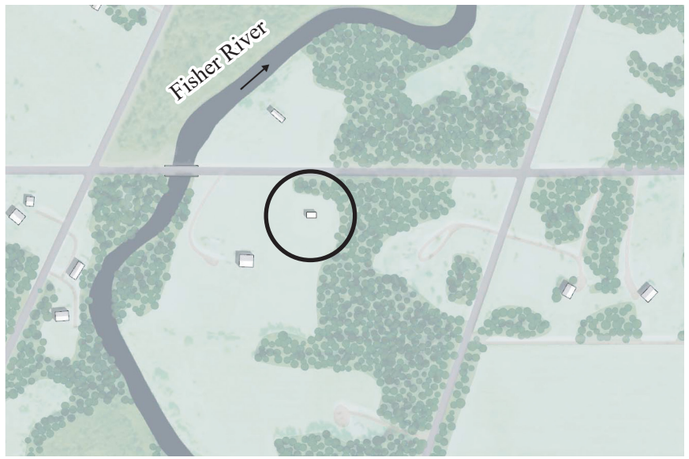
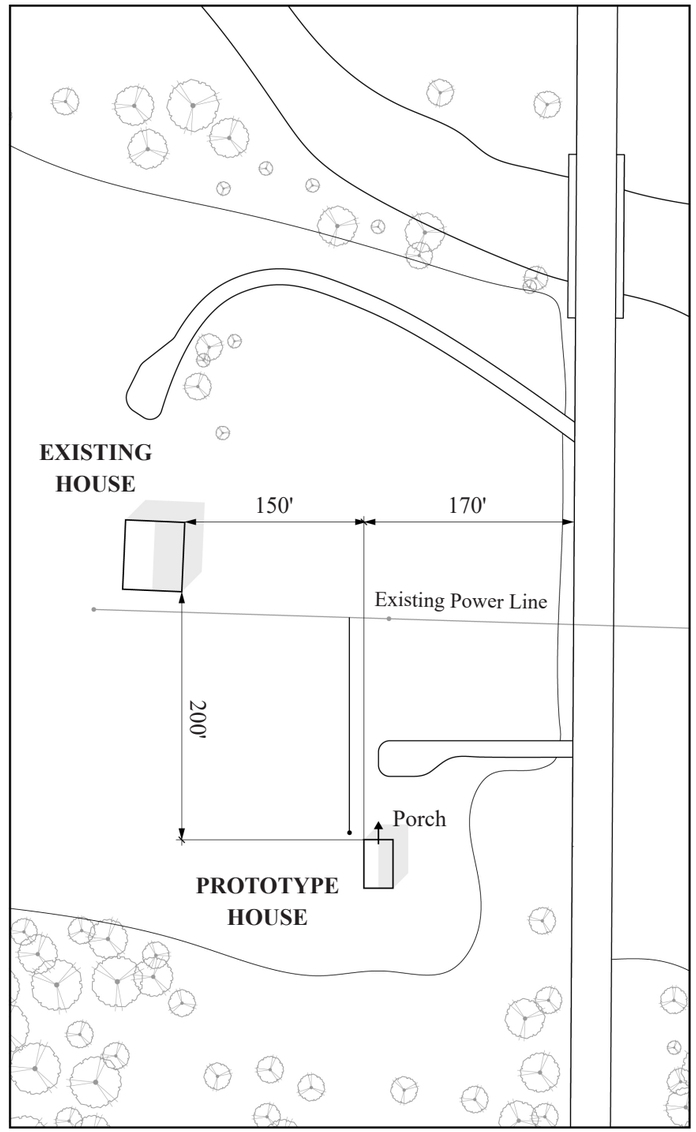


Fig. 2.1

Context Plan, with Amphibious Prototype Location Circled.





Key Plan

Fig. 2.2

Site Plan.

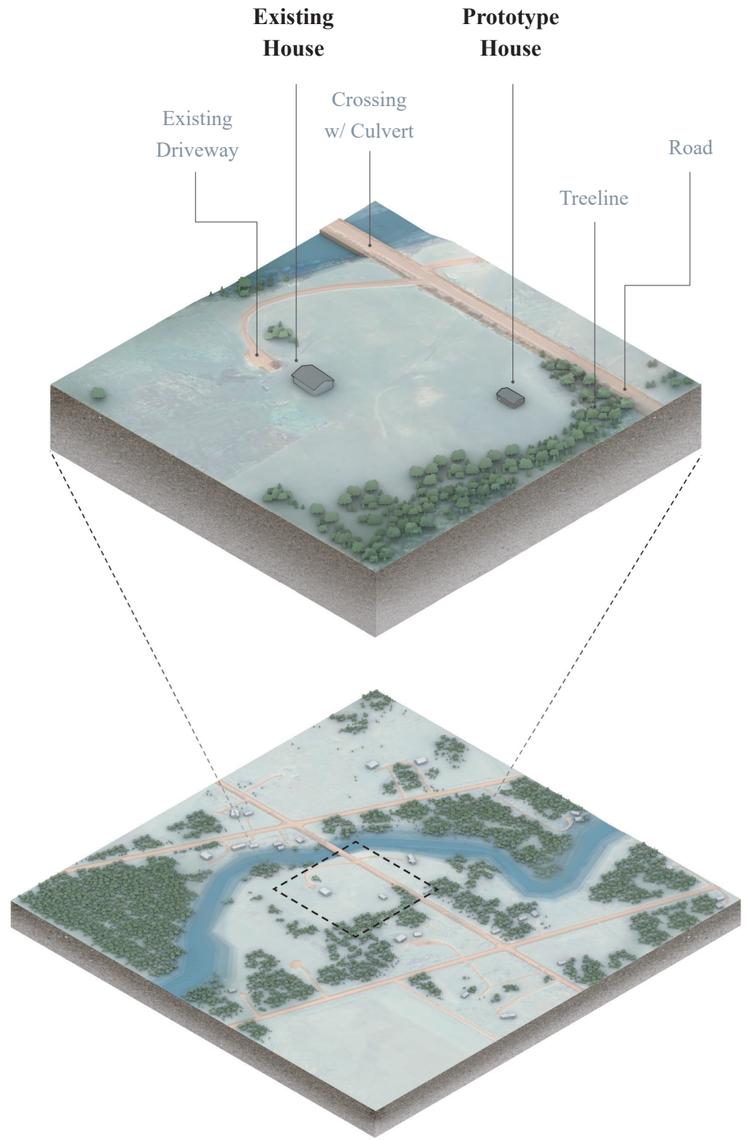


Fig. 2.3

Site and Surrounding Context





Fig. 2.4 (left)

View of the Property from the Prototype Site.

Fig. 2.5 (right)

View of Trees to the East near the Prototype Site.

Positioned on the inner side of a river meander, the site is less exposed to fast water flows than the outer side. The existing house has earth mounded around it to protect against flooding. However, water comes increasingly close to entering the house as flooding worsens (Fig. 2.6). The client plans to put a new prefabricated house in the north-east corner of the property, and do an amphibious retrofit to protect against future floods.



Fig. 2.6

The Property in Peguis During a Flood in 2024.

2.1 A Note on Property and Governance

There is a misconception, both in scholarly literature and the public imagination, that Indigenous peoples do not have institutions of private property.[2] However, this is a reductive simplification of the pre-colonial era, and is certainly not the case on FN reserves today. Some reserve land is collectively owned; for instance, common band lands. However, this is not the only way property on reserve lands is held and managed. There are multiple types of land tenure on most reserves, including Peguis 1B.

Customary rights are one type of on-reserve land ownership, where the use of the land by longtime occupants is recognized via an informal allotment by community leadership to the resident. In some cases, customary land allotments can be left as inheritance or subdivided amongst family members. However, these arrangements are not recognized by the federal government, and their existence is not accounted for in legislation. As a result, residents lack legal protection and the full privileges of land ownership—they cannot sell their land and must give up their customary land rights to obtain external financing, such as to fund the construction of a new home.[3]

Another type of ownership is the certificate of possession (CP), a type of land right recognition under the Indian Act. CP lands make up just 3% of all reserve territory, and this system is used in only 288 of Canada's 3,394 reserve communities.[4] Some of these communities have only a handful of CPs issued, while a few allocate most of their land this way. For instance, the Six Nations Reserve in Ontario has about 10,000 CPs, allocating almost the entire 46,500 acres of the reserve to individual residents and families.[5] Legal title remains with the Crown, as with all reserve lands, but property rights are otherwise held by the occupant. In addition to the right to leave land as inheritance or subdivide it, property can also be sold to other members of the First Nation. CP land disputes can be taken to a court of law, providing owners with legal protection of their property rights. CP holders are also technically able to obtain a mortgage, although practically many lenders are not willing to lend in this context due to the complexity of enforcing debt obligations on reserve lands.[6]

CP land ownership provides more individual property rights than other types of reserve land tenure. Critically for this project, the homeowner has the autonomy to make decisions about construction on their property, including the decision to install and retrofit a new home on the property.

2 Tom Flanagan, *First Nations? Second Thoughts, Second Edition* (McGill-Queen's Press - MQUP, 2008).

3 Tom Flanagan and Christopher Alcantara, "Individual Property Rights on Canadian Indian Reserves," *Public Policy Sources* 60 (July 2002).

4 Marena Brinkhurst and Anke Kessler, "Land Management on First Nations Reserves: Lawful Possession and Its Determinants," *Discussion Papers,* April 2013.

5 Flanagan and Alcantara, "Individual Property Rights on Canadian Indian Reserves."

6 Ibid.

2.2 Approximating Flood Conditions

Ideally, one would have flood modelling and site-specific flood data when beginning an amphibious architecture project. However, that data was not available for this site, and would likely not be accessible to most homeowners for their property. Instead, this section will attempt to approximate flood conditions using first-hand observation, publicly available quantitative data, and knowledge shared by community members.

There are river monitoring stations and weather stations somewhat near the prototype site, which give information on flow, flood level, climate and wind data (Fig. 2.7). This provides some of the information needed to design an amphibious retrofit, and this level of information would be available for most locations in Canada. However, because this data is collected away from the site, it will not be precise to the specific site conditions. Where possible, this data will be compared with resident reports and site observations to attempt to verify its approximate accuracy.

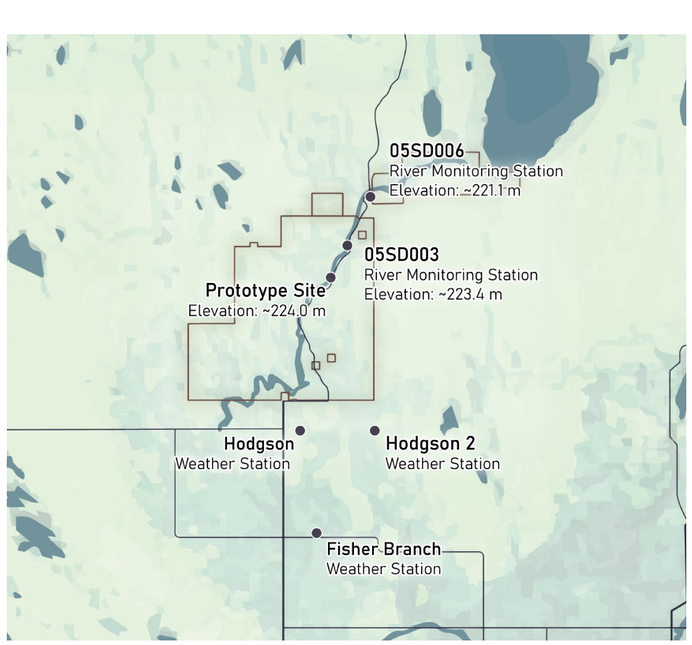


Fig. 2.7

Map of Closest Weather and Hydrometric Monitoring Stations.

2.2.1 Flood Depths

The information from the hydrometric monitoring stations provides very accurate information about a specific point on the river. However, that does not tell us what the correlating flood depth will be for our specific site. Monitoring station 05SD003 is much closer to the site at a similar elevation but was decommissioned in 2017. Monitoring station 05SD006 is further downstream and has data for 2018 to the present.

The prototype site is fairly flat, at an elevation of about 224 metres above sea level. This aligns with the available data; years in which the peak water level was less than 224 metres have no reported flooding, and years in which the peak water level was above 224 metres did have reported flooding. This also aligns with the resident reports of flood depths, saying the floods in 2022 were about "up to the waist" and floods in 2014 were about "to the top of the boots" (Fig. 2.8).

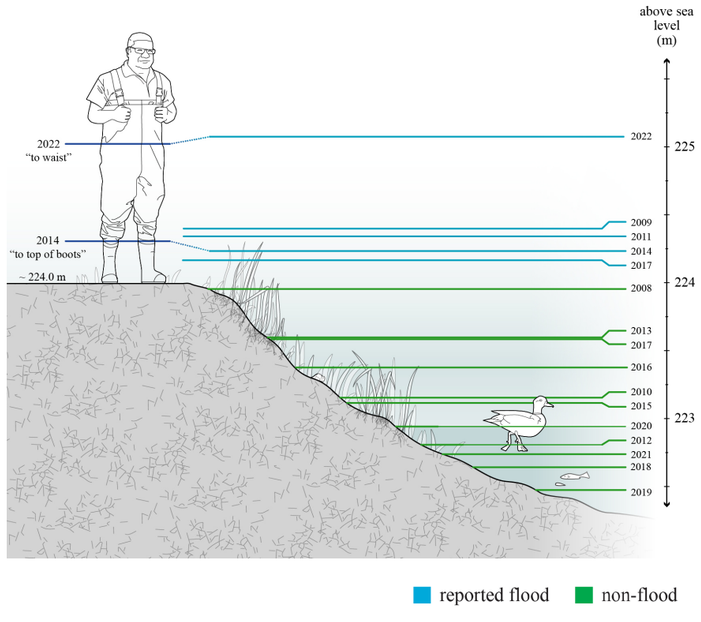


Fig. 2.8

Peak Water Levels in Spring, Comparing Resident Reports and Hydrological Monitoring Data.

Of course, this is an imprecise way of assessing flood depths. Nonetheless, it is helpful to know that the approximate flood depths are accurate. The deepest flood recorded on this site is therefore about 1.1 to 1.3 metres. Therefore, the guidance posts should be designed to account for more than that amount of water, with a generous margin to account for the imprecision of the data and anticipated worsening flooding.

2.2.2 Corresponding Weather Conditions

The precedent review establishes a lack of amphibious architecture projects constructed in very cold climates. Pegius, Manitoba, has deep winters, often reaching -30 ºC, with a low-temperature record of -44 ºC.[7] However, when designing an amphibious architecture prototype, the relevant weather conditions are the weather conditions that co-occur with flood events. To obtain an accurate understanding of the combinations of weather and flooding that are typical for this region, I used data from river monitoring stations, news reports of evacuation orders, and weather station records from the nearby town of Fisher (Table 2.1). A table of additional weather data for the flood season is available in Appendix 2.

[7] "Historical Climate Data," Environment Canada, accessed May 13, 2024, https://climate.weather.gc.ca/index_e.html.

Looking at data from recent floods, there are some notable patterns. Although this is not nearly a large enough dataset to accurately assess the full range of possible conditions, it gives a rough idea of what is typical for the region. Floods typically occur in March, April, and May. There are sometimes high winds, which must be considered when designing an amphibious prototype, but not severe wind storms. Water levels remain high for a few days to a few weeks, giving a sense of how long an amphibious homeowner may be displaced during a flood year (a non-amphibious homeowner would be displaced for that period plus the time required to make repairs). There are sometimes trace amounts of snow on the ground, but not deep snow, which makes sense given the season and the fact that the floods are caused by the snow melt. After the flood begins, there are occasionally subzero temperatures, but not prolonged periods that risk the floodwaters freezing solid.

This aligns with the information shared by community members and knowledge keepers. They spoke about the floods coming during the spring, often during the spring melt, sometimes being worsened by ice jams along rivers as the winter ice broke up.

Table 2.1

Recent Floods and Corresponding Weather Conditions. *Data from Environment Canada, Historical Climate Data and Hydrometric Data. Collated by Author.*

Year	Max. Water Level	Max. Level Date	Level >1m Above Average	Evac. Order	Gust Max.* (km/h)	Snow Depth* (cm)	Mean Temp.* (°C)	Temp. Range* (°C)
2004	224.267 m	Apr 8	Apr 6 - Apr 9	no data	no data	0	0	-8 to 14
2006	223.694 m	Apr 10	Apr 10 - Apr 16	no data	no data	0	10	0 to 25
2009	224.389 m	Apr 17	Apr 15 - Apr 21	no data	48 km/h	0	5	-2 to 18
2011	224.342 m	Apr 14	Apr 11 - Apr 21	Apr 19	63 km/h	5	2	-9 to 14
2014	224.175 m	Apr 26	Apr 24 - Apr 29	Apr 25	59 km/h	3	5	-2 to 14
2017	224.165 m	Apr 2	Mar 30 - Apr 3	Apr 1	41 km/h	<1	5	0 to 11
2022	225.110 m†	May 5	Apr 24 - May 14	May 2	73 km/h	0	6	-11 to 20

* During high water dates listed.

† Data from 2022 is taken from a different monitoring station, at a lower elevation. 2.3m has been added to approximately adjust the data for the prototype site.

2.2.3 Flood Predictability

Peguis has not historically experienced flash flooding, where flood waters rise in under 6 hours. The nature of the region's snow-melt flooding means that there is some predictability of when a flood will occur after the weather starts to warm. Although the peak water levels occur at different dates each season, the interval between when water levels start to rise and when they peak is consistently four to five days (Fig. 2.9).

This aligns with resident reports. The client stated that there are typically signs when a flood is imminent a few days in advance, allowing people to make preparations such as sandbagging their homes.[8] However, multiple community members expressed that provincial forecasts, issued weeks in advance, were not particularly helpful or considered to be a reliable way to make decisions about flood preparation.[9] The client also mentioned that in 2017, flood waters rose overnight and took them by surprise.[10]

With this in mind, it would be optimal to select amphibious architecture strategies that do not require much resident intervention to prepare the house to float, as floods are often only predictable a few days in advance. For instance, utility lines which must be manually disconnected are less suitable here than in ORL, where flooding can be reliably predicted further in advance. However, unlike a site with flash flooding, there is some possibility for residents to make preparations and safely evacuate.

[8] Client in Peguis, in discussion with the author.

[9] Ibid.

[10] Ibid.

Based on the evacuation orders, flood reports, and weather data, flooding consistently occurs within 5 days of the spring melt. It seems reasonable to expect an engaged amphibious homeowner would keep an eye on forecasts and river monitoring for that week in order to remain informed and prepare if flooding appears imminent.

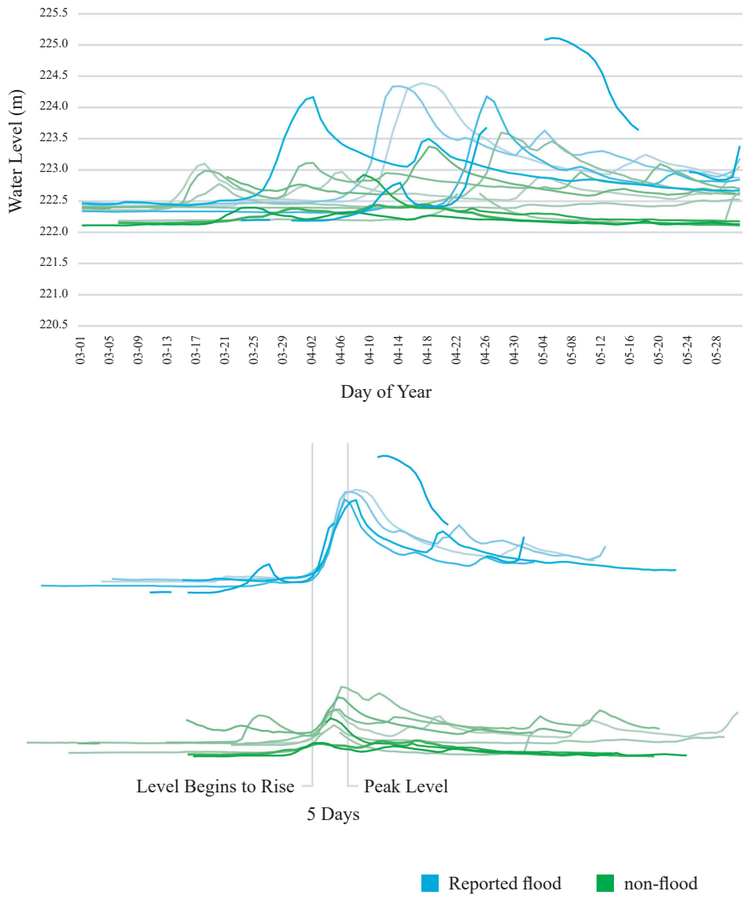


Fig. 2.9

Flood Predictability and Regularity. *Data from Environment Canada, Historical Climate Data and Hydrometric Data.*

2.3 The Prototype House

The client in Peguis has selected a ready-to-move (RTM) home, sourced from a local vendor. RTM houses are prefabricated off-site, then transported and installed on-site as a single unit, usually moved by truck and then lifted into place by a crane (Fig. 2.10). During my site visit to Peguis, I observed some existing RTM homes in the community of a similar type (Fig. 2.11). I also received information about the RTM house selected by the client from the manufacturer, which will be used as a base for the retrofit design (Fig. 2.12 - 2.13). This house is not yet installed on the property, but within this thesis, it will be treated as though it is exists on-site.

RTM homes are only one type of housing found in Peguis. Before my visit to Peguis, I did feasibility assessments looking at implementing amphibious architecture retrofit for various other sites and houses in the community. These drawings are available in Appendix 3.



Fig. 2.10

A Ready-to-Move Home being Lifted into Place.











Fig. 2.11

Three Examples of Prefabricated Homes in Peguis.

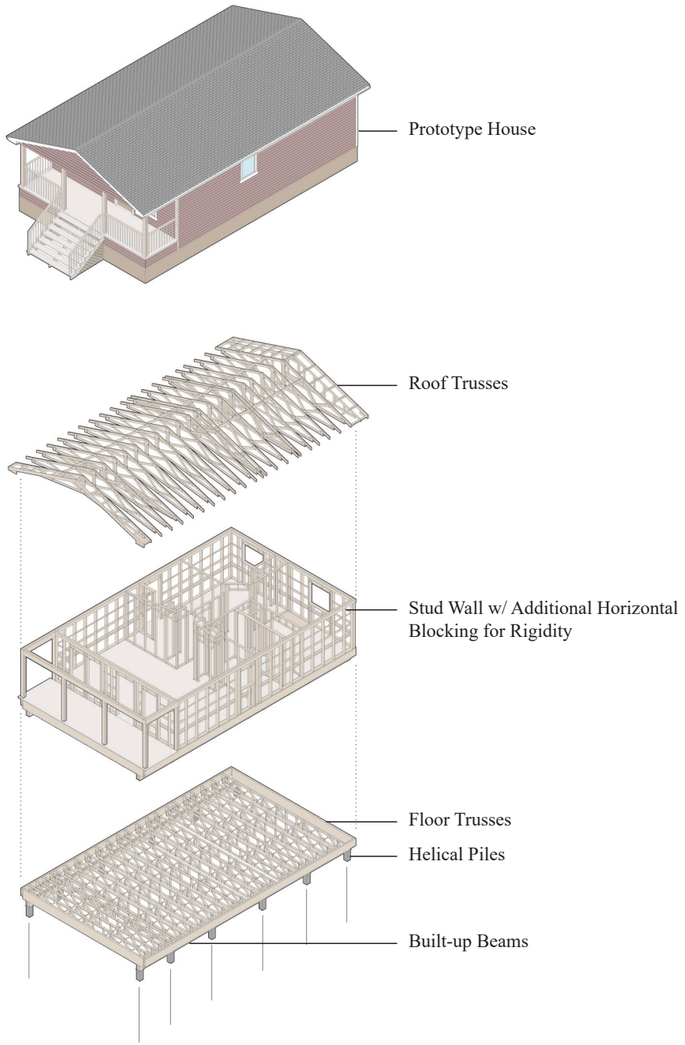


Fig. 2.12

Axonometric Showing Structure of the Ready-to-Move Prototype House.

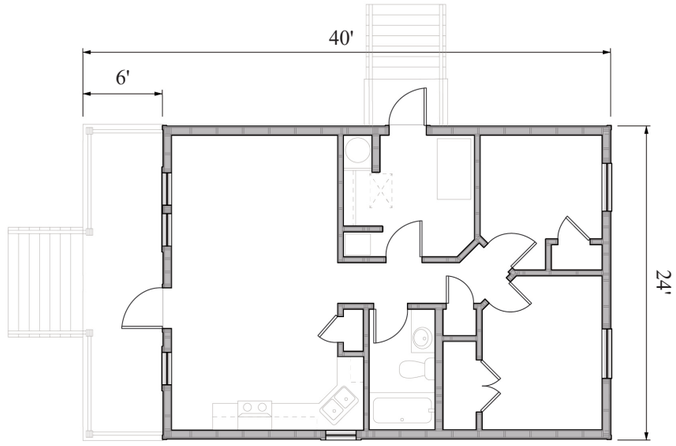


Fig. 2.13

RTM house floor plan.

2.4 Summary and Limitations

Several types of information are beyond my expertise as an architecture researcher to assess, and for which there are no comprehensive public datasets, such as soil conditions and flood water speeds. These influence the engineering of the prototype, but have less influence on the architectural design and thus will not be considered within this thesis. Of course, many sites in FN communities will have access to this low level of data or less. If this technology is to be implemented more broadly, it will be important to develop a standard method to assess flood conditions. Ideally, this could be done using widely accessible information, minimizing the amount of specialized data collection.

The available information suggests that flooding on site is of moderate depth, with relatively predictable and seasonal onset. The client's interest in RTM homes provides a specific housing typology to consider when proposing an amphibious retrofit, and the prevalence of prefabricated housing in Peguis makes this a useful typology to focus on. The following section will explore these factors further, drawing on literature and precedent projects to inform the design approach.

An Amphibious Precedent Review

There are many components in an amphibious building that are quite different from a conventional structure. Buoyancy must be added to allow the building to float in a flood and posts must be provided to guide it back down into the correct place. Because the building will be floating, the utilities must be connected in a way that allows for significant amounts of movement. The structure also must be designed to account for these dynamic forces. There are no conventional solutions to these design challenges because these conditions and components do not exist in a typical building. Existing amphibious buildings address these design components with a range of strategies and by looking at a comprehensive range of precedents, this chapter indexes the range of possible solutions.

Many amphibious buildings have limited documentation, which makes it difficult for designers to use existing precedents to inform new designs. Although some work has been done to compile this information, there is a need for an updated collection of existing amphibious architecture projects, research on amphibious architecture, and information on how existing projects have approached these novel design challenges. This will make it much easier for new amphibious projects to build upon the limited but diverse pool of amphibious precedents, as well as make it easier to identify places where innovation is required.

It is also important to consider that amphibious architecture projects exist across a range of different contexts. An amphibious house in rural Vietnam has a very different set of design requirements compared to an amphibious Dutch vacation villa (Fig. 3.1 - 3.2). These two different homes are constructed with different conceptions of acceptable risk and different engineering and construction practices. This context influences the selection of amphibious architecture strategies. Where possible, this review will document these factors and discuss the implications for a design in Peguis.





Fig. 3.1 (left)

An Amphibious House in Maasbommel.

Fig. 3.2 (right)

An Amphibious House in the Mekong Delta, Vietnam.

3.1 The Term "Amphibious Architecture"

The term "amphibious architecture" has been used since at least the 1980s, although originally it was used generically to describe a variety of waterside construction techniques including floating homes and houses on stilts.[1,2] The first record of using the term to describe houses that can both exist on land and float was in the Netherlands in 2004, by the creators of the Amfihuis Project, who described their design as "amfibische" (amphibious in Dutch).[3] This portable modular house was not intended for flood mitigation, but rather designed to be used as either a conventional home or a houseboat to increase options for construction. In the mid to late 2000s, the term was popularized to mean 'capable of floating or existing on land', primarily by Dutch Architects including Koen Olthius.[4,5]

By constructing amphibious houses in flood zones so that homes could float during floods, amphibious architecture can serve as a resilience-in-place flood mitigation strategy. Unlike dikes, levees and water diversion channels, amphibious architecture applies flood mitigation at the level of a single building and does not obstruct or change the flow of water. For communities like Peguis First Nation, this has the potential to provide autonomy over flood mitigation without disrupting the river and landscape.

1 Giles H. R. Tillotson, "The Rajput Palaces," *The Development of an Architectural Style,* 1987, 1450–1750.

2 Sumet Jumsai, "Case Study 4—Thailand House on Stilts," *Architecture and Identity,* 1983, 55–61.

3 ArchitectenWeb, "Amfihuis supersterke woning voor starters," November 11, 2004.

4 Elizabeth English, "Amphibious Foundations and the Buoyant Foundation Project." (Paris, France: UNESCO-IHP and COST Action C22, 2009).

5 Jill Ferenbacher, "Waterstudio's Flood-Resistant Architecture," *Inhabitat* (blog), August 28, 2006.

[6] Elizabeth English, Natasha Klink, and Scott Turner, "Thriving with Water: Developments in Amphibious Architecture in North America," *E3S Web of Conferences* 7 (2016): 13009.

Amphibious architecture also provides an occupant-friendly and affordable alternative to static elevation.[6] In Manitoba, where static elevation is not typically used, it provides a way to protect homes without significantly altering their appearance. It does not substantially increase the number of steps required to access the house, important in a community like Peguis where many homes have ramps to accommodate the elderly and people with disabilities. If flood conditions are expected to change, the height of the guidance posts can be adjusted to accommodate the new water depths. For Peguis, where flooding is worsening due to climate change and manipulation of water flow, amphibious architecture can adapt.

3.2 Methodology for a Comprehensive Precedent Review

There are no known precedents for amphibious construction in Canada, let alone in a Canadian First Nations Community. However, there are still lessons to be learnt from the existing body of precedents. This review will catalogue design solutions from existing amphibious architecture projects, and future chapters will use this information to inform a design for the site in Peguis.

A search of the Omni and Scopus databases for "amphibious architecture," "amphibious housing," "can float building," "amphibious structure," "amphibious construction", and "amphibious building" yields forty-seven results that discuss amphibious architecture as defined in this thesis. Papers about exclusively floating buildings were excluded from this count. The most common result was hypothetical proposals, discussing the feasibility of amphibious architecture for various sites. There were also many case studies of built amphibious projects; the most discussed project being the Maasbommel amphibious houses in the Netherlands.

Some amphibious architecture projects go unmentioned within these scholarly databases. Therefore, to assess the full scope of existing amphibious architecture projects, this precedent review will also consult non-scholarly sources as required, particularly news articles and design magazines, as they often contain additional information about projects not documented in the scholarly literature.

This review collected information about nineteen projects, eleven of which will be discussed in depth in this chapter.

3.3 Precedent Projects

Project	Date	Designer	Location	Buoyancy/Lift	Guidance	Utilities
Maasbommel	2006	Factor Architecten	River Maas, Netherlands	Open Concrete Caisson	Steel Posts	Flexible Water Supply and Sewage
Ohe en Laak	2012	Factor Architecten	Maasplassen, Netherlands	Open Concrete Caisson	Steel Posts	Flexible Water Supply and Sewage
Old River Landing	1970s to Present	Community Designed	Raccourci Old River, Louisiana, USA	PS Blocks, Barrels, Dock Floats	Steel Posts	Various Solutions
Lakeview House	2007	Bill Spatz *(Developer)*	New Orleans, Louisiana, USA	Steel Pontoon(s)	Timber Posts	Manual Disconnect Sewage
FLOAT House	2009	Morphosis and UCLA students	New Orleans, Louisiana, USA	EPS w/ Fibreglass Reinforced Concrete Shell	Steel Posts within Walls	Unclear
House on the Thames	2016	BACA Architects	Marlow, UK	Open Concrete Caisson	Steel Posts	Flexible Water Supply and Sewage
Warsaw River Pavilion	2017	RS Architektura Krajobrazu and Artchitecture	Warsaw, Poland	Steel Pontoons	Steel Posts	Flexible Water Supply and Sewage
Kaiapoi House	2018	Buck Architects and Ashby Consulting	Kaiapoi, New Zealand	Polystyrene Blocks	Timber Posts	Presumably Flexible or Self-sealing
Lifetable Greenhouse	2015	BAT Studio	Middlesex, UK	Hydraulic Lift	N/A	Contained in stationary service core
LIFT House	2010	Prithula Prosun	Dhaka, Bangladesh	Open Ferrocement Caisson, Recycled Plastic Bottles	Steel Vertical Guidance Tracks	Flexible Water Supply and Sewage
Vietnam Retrofits	2018	Buoyant Foundation Project	Mekong Delta, Vietnam	Recycled Plastic Jugs and Barrels	Steel Posts	No Plumbing

3.3.1 Maasbommel

The amphibious houses in Maasbommel, the Netherlands, are the most widely documented example of amphibious architecture (Fig. 3.3 - 3.4). After a series of floods in the 1990s, the Dutch government began looking for new flood mitigation solutions. This led to the development of the Netherlands' Room for the River program, which involved relocating dikes and lowering floodplains.[7] As a result, large swathes of land were made more susceptible to flood, and therefore no longer suitable for conventional construction. However, there was still demand for new housing. The Dutch government permitted experimental construction on 15 riverside sites.[8] Housing development company Dura Vermeer and architecture firm Factor Architecten proposed a novel solution for one site in Maasbommel: amphibious architecture. This project was the result. Construction of the thirty-two amphibious houses and fourteen exclusively floating houses finished in 2006.

The homes in Maasbommel are sometimes called the first amphibious buildings. For instance, in Mattijs Loor's article, he refers to them as the "first amphibious houses".[9] However, this is inaccurate. A more reasonable superlative would be the first 'fully engineered' amphibious buildings. Although amphibious architecture existed previously, this is the first known instance where an amphibious project was designed in adherence with building codes, by a team of licensed engineers and architects.[10]



Fig. 3.3

Amphibious Houses in Maasbommel.

7 Stefan Verweij, Tim Busscher, and Margo van den Brink, "Effective Policy Instrument Mixes for Implementing Integrated Flood Risk Management," *Environmental Science & Policy* 116 (February 1, 2021): 204–12

8 Anne Loes Nillesen and Jeroen Singelenberg, *Amphibious Housing in the Netherlands*: (Rotterdam: nai010 publishers, 2011).

9 Mattijs Loor, "Amphibious Housing in Maasbommel, the Netherlands," *Climate-ADAPT,* June 7, 2016.

10 Ibid.



Fig. 3.4

Floating and Amphibious Houses in Maasbommel.

The Maasbommel project used an open concrete caisson to provide buoyancy to the building, which provides buoyancy much like a ship's hull (Fig. 3.5). These concrete boxes were constructed on site and then placed into a concrete foundation niche in the riverbank. The house is constructed on top using light wood framing. The homes are paired to provide additional stability, each connected to one neighbour using steel trusses. Between the two homes, two 5.5-metre-tall steel posts prevent lateral movement while floating (Fig. 3.6). Utilities are provided using flexible connections, including a flexible sewage connection (Fig. 3.7). Solid waste passes through a macerator to allow it to move smoothly through the long, flexible sewage hoses. The project received international attention, and residents report being very satisfied with their homes.[11]

11 Ibid.



Fig. 3.5

Concrete Caisson Hoisted into Place with a Crane During the Construction of Amphibious Homes in Maasbommel.



Fig. 3.6 (left)

Vertical Guidance Post Between Two Houses in Maasbommel.

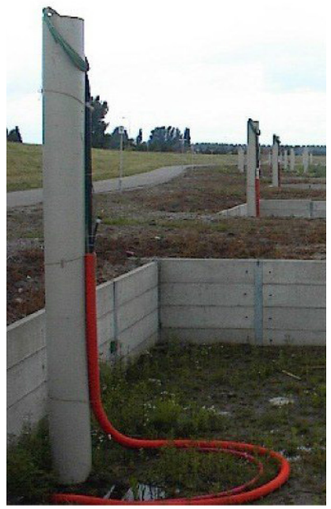


Fig. 3.7 (right)

Flexible Utility Lines During the Construction of Amphibious Homes in Maasbommel.

3.3.2 Maasvillas in Ohe en Laak

Following the success of the Maasbommel project, Dura Vermeer and Factor Architecten continued their collaboration on a second amphibious project. Completed in 2012, the Maasvillas are constructed similarly to the houses in Maasbommel, with a wooden frame and a concrete caisson. The original concept images show wooden guidance posts, but photos of the constructed building appear to show that they were made using steel (Fig. 3.8 - 3.9). Utilities are presumably connected via flexible connections, based on the fact that the houses remain operational while floating.

Originally, they planned to construct four piers, each with four floating homes and four amphibious homes. However, only six homes were ever constructed - four floating and two amphibious. Much like Maasbommel, these are designated as vacation properties.[12]

[12] Annette Weerts, "Maasvilla's Ohé en Laak," *Factor Architecten* (blog), accessed March 12, 2024, https://www.factorarchitecten.nl



Fig. 3.8

Homes at Ohe en Laak. Yellow Home is Amphibious, whereas the Others are Exclusively Floating.



Fig. 3.9

An Amphibious Home During High Water at Ohe en Laak.

3.3.3 Old River Landing

In Raccourci Old River Landing (ORL), there are dozens of amphibious building retrofits designed and constructed by residents (Fig. 3.10). This community has roughly 40 amphibious buildings, mostly fishing camps.[13] This community is not protected by Louisiana's levee system, so buildings are frequently inundated by the annual fluctuations of the Mississippi River. Flooding has worsened in recent years, which has led to more homeowners adopting amphibious architecture.

The buildings in ORL are typical typologies for the region, often trailers or prefabricated homes. There is some variation in how the retrofits are constructed, but many use the same basic materials and amphibious construction strategies. Many homes use EPS blocks for buoyancy (Fig. 3.11). These are fastened underneath the existing frame of the building. Some other buildings use plastic barrels or manufactured dock floats. Steel sleeves slide up and down vertical steel posts; steel components are sometimes sourced from friends of community members who work in the oil industry.[14] To centre the building onto its foundations after the flood water recedes, these retrofits use fins welded onto the vertical guidance posts (Fig. 3.12). For some houses, water supply and sewage must be manually disconnected before the house begins to float, and reconnected after the flood event (Fig. 3.13). The resident of the home that uses the pictured connection said that the disconnection can be completed in "a few minutes".[15] Other homes use flexible connections for the water supply.



Fig. 3.10

Amphibious Fishing Camp in ORL.

[13] Elizabeth English in discussion with the author, January 17, 2025.

[14] Stephanie Wakefield, "Forum 3: Amphibious Architecture beyond the Levee," *Mobilities* 14, no. 3 (May 4, 2019): 388–94.

[15] Louisiana Fishermen Pioneer Floating Architecture, 2017, https://www.youtube.com/watch?v=D8prRSK2rmM.



Fig. 3.11

Foam Blocks Underneath a House in ORL.



Fig. 3.12 (left)

A Steel Post and Post Sleeve in ORL.



Fig. 3.13 (right)

Utility Connections for an Amphibious Retrofit in ORL.

The amphibious buildings in ORL adapt existing structures, make use of available materials, and use do-it-yourself labour, all strategies that reduce cost and make amphibious architecture feasible in a wider range of contexts. The retrofits in ORL highlight that individuals, with basic materials and knowledge, can implement amphibious architecture. However, while this approach is functional, widespread adoption necessitates standardization and a more systematized approach to ensuring safety. Regardless, the affordability and resourcefulness shown in ORL make this project an important precedent for a prospective project in a First Nations community in Canada.

3.3.4 Lakeview House

The Lakeview House (the Noah's Ark Project) was constructed in 2007 by a commercial speculator in New Orleans (Fig. 3.14). Buoyancy was provided by a hollow steel barge (Fig. 3.15). The entry stair, which provides access to the porch, is not attached and does not move upwards when the house rises. The three-foot tall barge was custom-made for this project, welded together from plate steel and containing trusses to carry the load of the house.[16] The space within the barge functions as a crawlspace and is completely outside the thermal envelope of the house.[17]



Fig. 3.14
The Lakeview House.

Four driven wood piles act as guidance posts. The developer Bill Spatz noted that this was a difficult detail of the project, requiring perfectly straight piles and precision when driving them into the ground to ensure they were perfectly vertical.[18] Each pile is attached via a set of steel brackets welded to the steel buoyancy barge. These brackets are larger than the diameter of the posts, providing room for the house to move freely up and down (Fig. 3.16).

[16] Clayton DeKorne, "Floating Out the Storm: A Concept Home Designed to Resist Flood and Wind Rises out of the Wreckage of New Orleans" (Coastal Contractor, 2008).

[17] Ibid.

[18] DeKorne, "Floating Out the Storm."





Fig. 3.15 (left)
Steel Pontoon Sitting on Concrete Slab at Lakeview House.

Fig. 3.16 (right)
Vertical Guidance Post and Welded Steel Brackets at Lakeview House.

Like ORL, this amphibious house is in Louisiana. However, as a new building in an urban area, it was subjected to scrutiny and regulation that the houses in ORL are not. A manual disconnect was chosen for the sewage, primarily due to the cost of a breakaway connection. However, this sewage connection caused difficulty in obtaining an occupancy permit.[19] They considered changing it to a breakaway connection but making these changes after the fact was costly, and other issues soon arose.

The project faced continued opposition from the Federal Emergency Management Agency (FEMA), and the contractor ultimately chose to deconstruct the amphibious foundation to get a certificate of occupancy, ensure eligibility for flood insurance, and sell the home.[20]

3.3.5 FLOAT House

Designed by Thom Mayne and Morphosis Architects, the FLOAT house was a part of the 'Make it Right' (MIR) Foundation's project to construct 150 homes in the Lower Ninth Ward of New Orleans (Fig. 3.17).[21] Headed by actor Brad Pitt, MIR collected several high-profile architects including Frank Gehry, Shigeru Ban, and David Adjaye. Each designer proposed sustainable and hurricane-resistant designs for residents, attempting to revitalize this community that was struggling to rebuild after Hurricane Katrina.

[19] English, "Amphibious Foundations and the Buoyant Foundation Project."

[20] English, Klink, and Turner, "Thriving with Water."

[21] Jonathan Alarcón, "The FLOAT House - Make It Right / Morphosis Architects," *ArchDaily,* August 2, 2012



Fig. 3.17

The Morphosis FLOAT House.

Quirky and brightly coloured, the FLOAT house initially received very positive attention in the media.[22] The design was inspired by the Louisiana shotgun house and used amphibious architecture to avoid permanent elevation while improving flood resilience, preserving the relationship between the porch and the street.[23] To allow the building to float, the raised base is made to function as a sort of 'chassis'. This prefabricated unit is made of EPS foam, and coated in fibreglass reinforced concrete (Fig. 3.18). At each end, a vertical steel guidance post runs through the chassis, preventing lateral movement while the house is floating. The walls and roof of the house are constructed from a panelized and prefabricated kit-of-parts. The house had a list price of $150,000 USD in 2009, but this was subsidized by MIR.[24] The actual price was never disclosed.



Fig. 3.18

The EPS Foam Chassis for the FLOAT House.

22 Doug MacCash, "Brad Pitt's Architect Thom Mayne Designs Floating House in New Orleans," *The Times-Picayune,* October 7, 2009

23 "FLOAT House," Morphopedia, 2009, https://www.morphosis.com/architecture/126/.

24 Fenuta, "Amphibious Architectures."

In addition to incorporating amphibious design strategies, the original design for the house also incorporated photovoltaic panels and rainwater collection, obtaining a LEED platinum certification. These sustainable strategies meant that the FLOAT house was capable of functioning off of the city's utility infrastructure. Exactly how these systems would adapt when the building is floating is not completely clear.

The goal was to produce at least 14 copies of each MIR home design, including the FLOAT House, but residents shied away from the radical design and only one FLOAT House was ever built (Fig. 3.19). Quickly, this house, and the broader 'Make it Right' project, began to face controversy. It became apparent that the homes were poorly constructed, with "flashings nailed to timber upstands, waterspouts discharging onto enclosed staircases, minimal threshold and cills [sic], and high maintenance exteriors".[25] In 2018, residents filed a class action lawsuit against MIR; the foundation countersued its own head architect and its former director. Before shutting down its operations, an undisclosed number of MIR homeowners were made to sign non-disclosure agreements.[26] Many of the houses, including the FLOAT House, were left abandoned and in disrepair.[27]



Fig. 3.19

The FLOAT House next to another 'Make it Right' House.

25 Rhys Gwilym, "Brad Pitt's Pet Project Fails to Deliver," *The Architectural Review,* January 30, 2012.

26 Martin C. Pedersen, "Lessons from Brad Pitt's Failed Architectural Experiment in New Orleans," *Architectural Record,* 2022.

27 Gwilym, "Brad Pitt's Pet Project Fails to Deliver."

The project was remarkably successful at attracting positive media attention, raising awareness for the potential of amphibious architecture. However, the technical details of the amphibious retrofit should be viewed with skepticism. The detailing of many Make It Right houses was shoddy, and the ability of the FLOAT House to float during a flood has never been tested.

In her work, Elizabeth English states that the guidance post sleeve details are "constructed with insufficient tolerance (space between the post and the sleeve) to allow sliding and prevent binding", and argues that the development of standards for amphibious construction would help to avoid errors like this in the future.[28,29]

3.3.6 House on the Thames

Baca Architects in London constructed their Amphibious House on the Thames, sometimes also called ‘Formosa’, on a riverside location in Buckinghamshire (Fig. 3.20 - 3.21). On the small island where the house is located, it is typical to elevate homes one metre to protect against regular flood levels.[30]

However, an additional 1.5 metres of elevation would be needed to protect against worsening flooding expected for the site. Because zoning regulations imposed a maximum height limit, elevating the home by 2.5 metres would have significantly reduced its usable size, making the option undesirable for the homeowners. So, they decided to pursue an alternative flood mitigation strategy.[31]



Fig. 3.20 (left)

The Thames House from the River.



Fig. 3.21 (right)

The Thames House During a Flood.

28 English, Klink, and Turner, “Thriving with Water.”

29 Łukasz Piątek and Elizabeth C. English, “Amphibious Structures for Smart Flood Risk Reduction and Climate Change Adaptation,” in *The Routledge Companion to Smart Design Thinking,* ed. Mitra Kanaani (London: Routledge, 2024)

30 “Case Study: Amphibious House,” Baca Architects, accessed April 8, 2024, https://www.baca.uk.com/case-study-amphibious-house.html.

31 Jessica Mairs, “Baca Architects Completes Buoyant House on the River Thames,” *Dezeen,* January 20, 2016.

The house was the first of its kind in the UK and received multiple awards for design and innovation. For the homeowner, preserving the home's connection to the river was important, which this design accomplishes.[32] It also shows how amphibious architecture can provide new options in areas with restrictive zoning and flood protection requirements.

The House on the Thames draws heavily on Dutch amphibious architecture precedents, using a concrete caisson for buoyancy. The steel guidance posts are integrated into recesses in the walls, making them less visually prominent (Fig. 3.22). The house can rise three metres during a flood. Utilities are provided via flexible connections.[33]



Fig. 3.22

The House on the Thames. Note the guidance posts recessed into the side of the building.

3.3.7 Warsaw River Pavilion

The Warsaw River Pavilion is the only selected precedent with a non-residential program (Fig. 3.23). Constructed as a part of a waterfront revitalization project in Warsaw, the amphibious pavilion was part of a larger series of flood-resilient constructions on the bank of the Vistula River. A permanently floating structure and a statically elevated structure were also constructed as part of this revitalization.

32 Ibid.

33 Ibid.



Fig. 3.23

The River Pavilion.

The amphibious pavilion is modular, with 2.5-metre by 7-metre modules, each built on top of a 0.7-metre deep steel pontoon (Fig. 3.24). Steel posts hold the pavilion in place while it is floating. The entire structure rests on the ground, so visitors must go up a ramp or a few steps to climb onto the pontoon and enter the building.[34]

There has not been a flood since the pavilion was installed, and so the amphibious systems have not yet been tested. In their paper, Piątek and Wojnowska-Heciak note that many have concerns over the pavilion's capacity for flotation, but do not elaborate on what these potential issues are.[35]



Fig. 3.24

The River Pavilion Under Construction.

[34] Łukasz Piątek and Magdalena Wojnowska-Heciak, "Multicase Study Comparison of Different Types of Flood-Resilient Buildings," *Sustainability* 12, no. 22 (November 21, 2020): 9725.

[35] Ibid.

3.3.8 Kaiapoi House

Built on a flood and quake-prone site, the Kaiapoi house was given a specialized foundation meant to survive both types of hazardous events (Fig. 3.25 - 3.26). By adding buoyancy elements to the foundation, the house can not only float on flood waters but also remain on the surface of liquified soil - a phenomenon where the ground suddenly loses bearing capacity as a result of earthquake shaking.[36] Three wooden piles act as vertical guidance posts - one at the midpoint and two at either end on the opposite side. The guideposts pass through the framing of the front and back decks, which is how they are attached to the home's structure. It is unclear how utilities are connected to the house.

The house is made using light wood framing and sits on top of a catamaran pontoon made of EPS. The EPS blocks are wrapped in a black waterproof membrane (Fig. 3.27). Unlike other examples that use EPS blocks, this house bears directly onto the block framing, which sits upon a slab on grade. This design for the buoyancy elements dramatically increased the cost of the project - the pontoons and specialized subfloor framing cost $100,000 NZD.[37]



Fig. 3.25

The Kaiapoi Amphibious House.

[36] Colin Williscroft, "Pitched as a Solution for Sea Level Rise, Questions Remain over Floating Houses' Affordability," *Stuff*, September 17, 2018.

[37] Ibid.





Fig. 3.26 (left)

The Kaiapoi House from the Street.

Fig. 3.27 (right)

EPS pontoons for the Kaiapoi House, wrapped in a waterproof membrane and framed in wood.

3.3.9 Lifetable Greenhouse

After their garage was destroyed by a series of floods, a couple in Middlesex, UK wanted to build a flood-resilient storage shed and greenhouse on their property. The result is the Lifetable Greenhouse - a mechanically-elevated amphibious structure capable of 'growing' 0.8-metre legs (Fig. 3.28). Unlike the other precedents, which use buoyancy elements to passively lift the house when flood waters rise, the Lifetable Greenhouse uses a hydraulic jack (Fig. 3.29). This is connected to the greenhouse's steel and glulam frame and allows the entire structure to be lifted off the ground. The system can be controlled remotely but does require occupant intervention to initiate the lifting process.[38]

Other amphibious architecture prototypes have also been constructed using hydraulic lifts to move the structure, including the FloodJack prototypes in the UK, and the High Tide Home in New Jersey.[39,40] Although this is not an approach being considered for the prototype in Peguis, it shows the diverse possibilities of amphibious architecture.

[38] "Greenhouse That Grows Legs," Batt Architects, https://www.batstudio.co.uk/art-and-research/greenhousethatgrowslegs.

[39] Dan Bowens, "NJ Home Can Be Raised and Lowered to Avoid Flooding," *FOX 5 NY,* July 20, 2022.

[40] Rick Kazmer, "Expert Develops Incredible Technology for Homes in Flood-Prone Areas" *The Cool Down* (blog), January 24, 2024





Fig. 3.28 (left)

The Lifetable Greenhouse.

Fig. 3.29 (right)

The Hydraulic System inside the Greenhouse, which lifts the structure.

3.3.10 LIFT House

The LIFT House was created in 2011 by Prithula Prosun as part of her Master's thesis (Fig, 3.30). The project experiments with unique amphibious architecture strategies, most notably the vertical guidance system. Unlike the other projects discussed, which use posts, this project uses vertical rails, hidden between the amphibious modules and the non-amphibious "spine" in the centre, made of brick. The service spine also contains all the services for the building, including a rainwater cistern, the washroom, and the kitchen.[41]

[41] Prosun, "The LIFT House."



Fig. 3.30

The LIFT House.

The two modules have different buoyancy systems, with one using an open ferrocement caisson, and the other using resealed and bundled plastic water bottles (Fig. 3.31 - 3.32). The plastic water bottles are reclaimed, far less expensive than other buoyancy types, and require no specialized labour or heavy machinery to construct, making them an appealing and sustainable choice if they can provide sufficient buoyancy.[42]

[42] Ibid.



Fig. 3.31 (left)

The LIFT House Concrete Caisson Under Construction.



Fig. 3.32 (right)

Water bottles, Bundled and Resealed for Buoyancy.

3.3.11 Vietnam Buoyant Foundation Retrofits

In 2018, the Buoyant Foundation Project, in collaboration with local partners, retrofitted four homes in Vietnam's An Giang and Long An Provinces (Fig. 3.33). This project aimed to show that amphibious retrofit could act as a passive flood adaptation strategy for communities in the Mekong Delta, reducing displacement and allowing for rapid recovery.[43] The homes used steel posts embedded in concrete and recycled materials such as plastic barrels and jugs for buoyancy.

[43] E. C. English et al., "Development of Amphibious Homes for Marginalized and Vulnerable Populations in Vietnam," Final Report – Executive Summary (University of Waterloo, July 2020)



Fig. 3.33

One of the Retrofitted Homes in Vietnam, with Buoyancy Jugs Visible.

The guidance posts are steel, with sleeves made of wood and rope (Fig. 3.34). Like the retrofits in Old River Landing, these buildings use centring devices to ensure the house settles into the correct place (Fig. 3.35 - 3.36). There are no utilities, and therefore no utility connections.

In 2018, the project team returned to monitor the houses during the flood season. One house was modified in 2019 to add more buoyancy, increasing the freeboard when floating, but all houses performed successfully, returning to their original positions intact. This project is noteworthy for its emphasis on engaging local experts and sharing the knowledge and resources needed to continue developing amphibious housing. The way this project responded to community needs and leveraged local skills provides a model for future community-focused, collaborative amphibious architecture design projects.[44]

[44] Elizabeth English et al., "An Innovative Strategy to Increase the Resilience of Flood-Vulnerable Communities While Reducing Risk of Population Displacement and Psychological Trauma" (8th International Conference on Building Resilience, 2018).



Fig. 3.34

One Type of Guidance Post Sleeve used for the Vietnam Retrofit Homes.





Fig. 3.35 - 3.36

Different Centring devices used on the Amphibious Houses in Vietnam.

3.3.12 Other Precedents

Various other precedents for amphibious construction exist around the world, showcasing the diverse possibilities of amphibious architecture (Fig. 3.37 - 3.48). The table below summarizes the other precedents identified during the literature review.

Project	Date	Designer	Location	Buoyancy/Lift	Guidance	Utilities
Thailand Prototype	2013	Chutayaves Sinthuphan	Bangkok, Thailand	Steel Pontoons filled w/ Styrofoam	Perimeter Retaining Wall	Unknown
LSU Prototype	2007	Buoyant Foundation Project	Baton Rouge, Louisiana, USA	Foam Blocks	Steel Posts	None
NRC Pavilion	2019	Buoyant Foundation Project	Waterloo, Ontario, Canada	Plastic Barrels	Anchors and Chains	None
Amphinest	2021	Nanma Gireesh	Kozha, Kerala, India	Concrete Pontoon	Steel Posts	None
FloodJack	2022	Andrew Parker	Yorkshire, UK	Mechanical Lift	N/A	Unknown
Dunbogan Amphibious Caravan	2024	JDA Co	New South Wales, Australia	Steel Pontoon	Steel Posts	Unknown
Arcadia Education Centre	2016	Saif Ul Haque	South Kanarchor, Bangladesh	Recycled Steel Drums	Bamboo Posts	Self Contained
High Tide House	2022	Phil DeStafano	Verona, New Jersey, USA	Mechanical Lift	N/A	Unknown
Oolderhuuske Amphibious Buildings	2010 to 2022	Multiple Designers	Limburg, Netherlands	Aluminium Pontoons	Steel Posts	Unknown



Fig. 3.37

The Thailand Amphibious Architecture Prototype.



Fig. 3.38 (left)

The LSU Prototype Floating in a Test Tank.



Fig. 3.39 (right)

The NRC Amphibious Research Pavilion.



Fig. 3.40 (left)

The Amphinest Prototype.



Fig. 3.41 (right)

The FloodJack house, with the Mechanical Lifts Visible.



Fig. 3.42

The Dunbogan Amphibious Caravan.



Fig. 3.43 (upper left)

Steel Drums Used for Buoyancy in the Arcadia Education Centre project.



Fig. 3.44 (lower left)

The Arcadia Education Centre.



Fig. 3.45 (right)

Bamboo Posts used for Vertical Guidance at the Arcadia Education Centre.



Fig. 3.46

The High Tide Home.



Fig. 3.47 (left)

An Amphibious Caravan in Oolderhuuske.



Fig. 3.48 (right)

The Caravan Home Being Lifted into Place.

3.4 Precedent Strategy Summary

Drawing from this pool of precedents, there are many possible strategies for amphibious construction. The tables below will summarize different methods for achieving lift, guidance, and utility connections. Additional components include centring devices and debris screens, although these were not used for all projects or required in all contexts. The following chapters will identify which approaches are appropriate for this retrofit project.

Buoyancy/Lift Strategies used by Precedents

Foam Blocks 	**Pros:** Available widely Lightweight Can be installed by hand	**Cons:** Vulnerable to impact Sheds small particles that can contaminate the environment	**Examples:** Some ORL retrofits Kaiapoi House
Steel Barges, Pontoons 	**Pros:** Robust Many sizes Purpose-built	**Cons:** Likely custom, costly Needs heavy equipment Transport limits size	**Examples:** Warsaw Pavilion Lakeview House
Concrete Caisson 	**Pros:** Robust Many sizes Purpose-built	**Cons:** Custom, costly Needs heavy equipment	**Examples:** Ohe en Laak Maasbommel Thames House
Hydraulic Lift 	**Pros:** Robust Controlled lifting	**Cons:** Non-passive system	**Examples:** Lifetable Greenhouse FloodJack High Tide Home
Recycled Items 	**Pros:** Light Can be installed by hand Inexpensive	**Cons:** Variable quality and availability	**Examples:** Some ORL Retrofits LIFT House Vietnam Retrofits

Key Considerations:

Cost and Availability of Materials

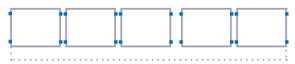
Debris Protection

Passive versus Active Systems

Vertical Guidance Post Materials

Steel Posts 		**Examples:**		
	Many precedents High load capacity	Old River Landing Warsaw Pavilion	Thames House Maasbommel	Ohe en Laak + Others
Wooden Posts 	**Traits:** Sustainable Material	**Examples:** Kaiapoi House Lakeview House		
Bamboo Posts 	**Traits:** Sustainable Material Regional Availability	**Examples:** Arcadia Education Centre *(posts failed, building floated away)*		

Vertical Guidance System Configurations used by Precedents

 ORL Example 1	 ORL Example 2	 Kaiapoi House	 Ohe en Laak
 LIFT House	 Arcadia Education Centre		 FLOAT House
 Lakeview House	 House on the Thames	 Maasbommel	 Warsaw Pavilion

*approximately relative scale

Vertical Guidance System Attachments used by Precedents

External Posts 	**Pros:** Many precedents Easy to Retrofit	**Cons:** Visible Posts	**Examples:** Some ORL Retrofits Warsaw Pavilion Lakeview House Ohe en Laak
Posts through Platform 	**Pros:** Many precedents Easy to Retrofit Platform can Widen Buoyancy System	**Cons:** Visible Posts	**Examples:** Some ORL Retrofits Maasbommel Kaiapoi House
Posts in Walls 	**Pros:** No visible posts	**Cons:** Difficult to use in a Retrofit	**Examples:** FLOAT House
Vertical Channels 	**Pros:** No visible posts	**Cons:** Difficult to use in a Retrofit	**Examples:** LIFT House

Key Considerations:

Lateral Loads

Visual Appearance

Access to and Requirement for Heavy Machinery

Building Size, Shape, and Aspect Ratio

Utility Connection Strategies used by Precedents

Electrical Service is provided for all precedents by a coil of excess wire or slack in an overhead supply, which can easily account for building movement. However, water supply and sewage connections may be more complex.

Self-Sealing Breakaway 	**Pros:** Water goes off, encouraging evacuation Passive disconnection	**Cons:** Needs to be reconnected Can be costly	**Uses:** For water supply For sewage
Flexible 	**Pros:** Remains operational while floating No reconnection	**Cons:** Costly for sewage, requires macerator	**Uses:** For water supply For sewage, with macerator
Manual Disconnect 	**Pros:** Inexpensive Simple to construct	**Cons:** Requires homeowner engagement Requires forewarning to prepare	**Uses:** Used in ORL for water supply and sewage, not recommended for application alsewhere

Key Considerations:

Cost

Flood Forewarning

Requirement for Reconnection

Programmatic Utility Requirements

Operational During Floods or Non-Operational Encouraging Evacuation

Resident Involvement and Engagement

Challenges and Insights for Peguis

The limited number of amphibious buildings makes it difficult to draw broad conclusions about how to approach future amphibious architecture projects. However, the literature documents several issues that are relevant to consider when amphibious architecture is implemented in the Canadian context. Regulatory obstacles, financing and cost issues, and varying attitudes towards amphibious construction were encountered by several precedent projects. This section will elaborate on the issues these projects faced, and comment on how these precedents can inform a new amphibious architecture design for Peguis.

4.1 Building Regulations and Governance

Interacting with regulatory frameworks and building codes is a significant challenge for amphibious projects. There are no specific guidelines for amphibious architecture in any country, and so there is no clear path for the implementation of new amphibious projects. As the first engineered amphibious architecture project, there were no clear standards for dealing with the homes at Maasbommel. Multiple levels of government had to interpret existing regulations to accommodate this new type of building, a process which was neither clear nor consistent.[1] In New Zealand, we see that a lack of regulatory clarity can also increase the cost of the project. To obtain permits to construct the buoyant home, the design team for the Kaiapoi house was required to "jump through hoops and pay a fortune".[2]

Another potential obstacle comes from river and water conservation authorities, who often have say about construction close to rivers. In the Netherlands, the Rijkswaterstaat - the Ministry of Environment office tasked with managing public waterways - must approve any construction in a flood zone. The Ohe en Laak and Maasbommel projects both received special exceptions as a part of a broader government program of experimental construction.[3] We also see this in the UK; the architect's website for the Thames House states they had to negotiate with river conservation authorities.[4]

1 Mattijs Loor, "Amphibious Housing in Maasbommel, the Netherlands," *Climate-ADAPT,* June 7, 2016.

2 Colin Williscroft, "Pitched as a Solution for Sea Level Rise, Questions Remain over Floating Houses' Affordability," *Stuff,* September 17, 2018.

3 Loor, "Amphibious Housing in Maasbommel, the Netherlands."

4 "Case Study: Amphibious House," Baca Architects, accessed April 8, 2024, https://www.baca.uk.com/case-study-amphibious-house.html.

In Louisiana, precedents show how regulatory hurdles can completely prevent the occupation of an amphibious building. Because the Lakeview House could not obtain an occupancy permit as an amphibious structure, the building had to be completely unamphibiated. The FLOAT House, on the other hand, was successfully constructed because it had support from regulators. The project was the only amphibious new build to ever achieve permits for building and occupancy in the United States, thanks in part to the New Orleans Building Department which was supporting the project.

In ORL, building permits are not obtained before constructing amphibious retrofits. This works for ORL, because they are rural, do the retrofits themselves without involving outside parties, and are outside the protection of the levee system where they are not likely to face opposition from inspectors and outside authorities. Because FEMA objects to amphibious construction in the USA, retrofits in ORL are not eligible for the National Flood Insurance Program.[5] The amphibious homes are no longer damaged by floods regularly, so this is a tradeoff homeowners in ORL are willing to make. However, it is illogical that amphibious homes cannot be insured while flood-vulnerable homes, which are exposed to much higher flood risk, are insurable. Reducing the risk of flood damage should not require forfeiting insurance coverage, and recognizing amphibious architecture in building codes would help to remove this bureaucratic challenge.[6]

The project in Peguis would not encounter many of the potential bureaucratic obstacles to the implementation of amphibious architecture, because it will be built on CP reserve lands and with private financing. The Canada Mortgage and Housing Corporation (CMHC) often issues loans to fund home construction on reserves. The CMHC requires that projects they fund abide by the National Building Code, which prevents the use of innovative new techniques like amphibious architecture. However, no funding is being obtained from the CMHC for this project so this is not an obstacle. Similarly, Indigenous Services Canada has no jurisdiction and is not involved financially. Broader implementation in other contexts would likely require engagement with these organizations, but the landowner in this case has the ability for self-determination.

First Nations Reserves, including Peguis, can create or adopt a community building code that differs from Federal and Provincial standards.[7] If a community decided that amphibious architecture was a suitable solution for them, they would have the ability to allow it. Of course, it is critical

5 Elizabeth English, Natasha Klink, and Scott Turner, "Thriving with Water: Developments in Amphibious Architecture in North America," *E3S Web of Conferences* 7 (2016): 13009.

6 Ibid.

7 Shelagh McCartney, Jeffrey Herskovits, and Lara Hintelmann, "Failure by Design the On-Reserve First Nations' Housing Crisis and Its Roots," *The Canadian Journal of Native Studies* 38 (December 1, 2018): 101–24.

to ensure proposed designs provide an acceptable level of safety. There is a long history of substandard construction on reserves, in part due to the lack of requirements for building code compliance.[8] The need for appropriate and safe housing must be upheld when implementing a novel technology like amphibious architecture.

To develop a set of standards for amphibious architecture, one could begin by looking at these codes from adjacent domains. In their 2020 paper, Piątek and Karczewski summarize the existing standards for stability of floating buildings and houseboats (Fig. 4.1 and Table 4.1).[9] The existing codes provide different acceptable maximum heel angles, ranging from 4 to 15 degrees; acceptable levels of freeboard in these codes also vary, from 0 to 0.5 metres.[10] Further analysis is needed to determine whether these requirements are suitable for an amphibious building as well.

8 Ibid.

9 Łukasz Piątek and Artur Karczewski, "The Influence of the Cuboid Float's Parameters on the Stability of a Floating Building.," *Polish Maritime Research* 27 (2020): 16–21.

10 Ibid.

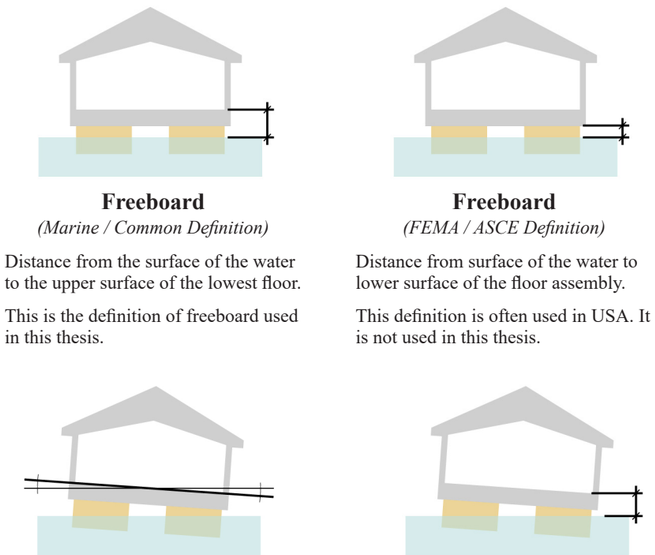


Fig. 4.1

Freeboard and Related Term Definitions.

Title	Region	Min Freeboard (Fb)	Max. Heel Angle	Min. Residual Freeboard
Building Code for Float Homes	Alaska, USA	0.36 m (14")	4°	1/2 Fb
Regulation of the Construction and Maintenance of Floating Homes	California, USA	0.38 m (15")	4°	1/3 Fb
British Columbia Float Home Standard	British Columbia, Canada	0.4 m	5°	1/2 Fb
Technical Regulation on the Stability, Buoyancy, etc. of Houseboats and Floating Structures	Denmark	0.5 m	4°	1/3 Fb
Queensland Development Code. MP 3.1 Floating Buildings	Queensland, Australia	0.4 m	-	0.25 m
NTA 8111 Drijvende Bouwwerken	Netherlands	0.0 m / 0.3 m	4°	0.05 m
AS 3962-2001 The Australian Standard: Guidelines for the Design of Marinas	Australia	-	15°	0.05 m
PN-EN 14504: 2010 Inland Navigation Vessels - Floating landing stages and floating bridges	Europe	0.03 m	10°	-
Guidelines for Floating Platforms for Yacht Marinas	Poland	0.05 m	6°	-

Table 4.1

Freeboard and Heel Angle Requirements in different guidelines. *Table by Piątek and Karczewski, from* "The Influence of the Cuboid Float's Parameters on the Stability of a Floating Building."

4.2 Financing and Cost

Obtaining mortgages or financing for amphibious homes can be challenging or impossible. This is due to a combination of factors, such as the perceived risk of amphibious construction, a lack of experience with amphibious construction, regulatory obstacles discussed above, and disagreement about whether amphibious houses are vessels or buildings.

In the Netherlands, banks that finance amphibious homes often do so at very high rates intended to finance the purchase of houseboats.[11] The amphibious homes at Maasbommel are also expensive when compared to typical houses in the Netherlands, partially due to the custom components

11 Loor, "Amphibious Housing in Maasbommel, the Netherlands."

that were fabricated specifically for the project. The houses in Maasbommel were originally sold for $310,000 USD in 2006, expensive for that time in that area of the Netherlands.[12] The area on the water side of the dike in Maasbommel is zoned for recreational use, meaning the amphibious homes there are designated as vacation properties and are not intended for year-round habitation. This further limits the range of people who can own amphibious homes.

Because the Lakeview house was constructed by commercial speculators, rather than by an individual, it avoided the difficulties of obtaining financing for a mortgage. The house was also costly compared to conventional houses of a similar size, at an asking price of $525,000 USD in 2008.[13] The designers describe that they considered cost in selecting their amphibious design strategies, such as when they chose a manual sewage disconnection over a self-sealing breakaway connection, but this only partially mitigated the expense and costs were still high.[14] FEMA later objected to the manually disconnecting sewer attachment for the Lakeview House. The change was ultimately not made, but making these changes would have increased project costs—highlighting how ambiguous standards contribute to higher expenses in amphibious construction.

Costs in ORL are much lower. Homeowners do the retrofits themselves which significantly lowers costs, and use salvaged and repurposed materials. The least expensive retrofits in ORL cost around $5000 USD when they were constructed 15 to 30 years ago.[15] Unlike the other figures, which take into account the entire house, this only includes the cost of the buoyant retrofit. Nonetheless, it demonstrates that the retrofits in ORL are substantially less costly than the other projects discussed.

Part of this may be because the retrofits in ORL do not necessitate any substantial changes to the structure of the building. The Kaiapoi house also uses EPS blocks but the buoyancy pontoons cost around $100,000 NZD to construct.[16] Although there are multiple differences between the two designs, the fact that the Kaiapoi House pontoons bear the weight of the house seems to increase complexity and substantially increase costs.

Keeping the prototype design affordable is a consideration for this project. To show that amphibious architecture is a viable solution for communities like Peguis, this design must use strategies that can be reasonably implemented with a much smaller budget than the Maasbommel project or the Kaiapoi House.

[12] Loor, "Amphibious Housing in Maasbommel, the Netherlands."

[13] Clayton DeKorne, "Floating Out the Storm: A Concept Home Designed to Resist Flood and Wind Rises out of the Wreckage of New Orleans" (Coastal Contractor, 2008).

[14] Ibid.

[15] Elizabeth English in discussion with the author, February 2025.

[16] Williscroft, "Pitched as a Solution for Sea Level Rise, Questions Remain over Floating Houses' Affordability."

The occupant is financing construction, so no approval from outside financiers would be needed to realize this project. However, if amphibious architecture is eventually implemented in more First Nations communities, there may be a need to interact with organizations such as Indigenous Services Canada and the Canada Mortgage and Housing Corporation to finance construction. This is not directly relevant to this project but is important to keep in mind and may represent a challenge to the implementation of amphibious architecture for Indigenous communities in Canada more broadly.

4.3 Public Perception and Attitudes

Although residents of amphibious homes in the Dutch context appreciate the flood resilience that the homes provide, some residents also indicate that they view amphibious architecture as an "adventurous" choice.[17] This sentiment is likely different from the feelings of someone retrofitting their primary residence. The prototype project in Peguis intends to increase flood resilience, not create amphibious architecture as a novelty.

On the other hand, autonomy and staying in place are important to those at ORL. One analysis of the community wrote that "the 'good life' at Old River Landing is more worthwhile than surviving on someone else's terms", despite the challenges.[18] Although the cultural context is different from Peguis, those in ORL have a strong attachment to their location and use amphibious architecture as a tool to build resilience and remain there.

We also see that challenges emerge when residents and regulators have conflicting expectations. Some residents use the homes in Maasbommel as primary residences, even though they are legally vacation properties. This has caused conflict with the municipality which deems permanent occupation of the amphibious homes unlawful.[19]

Occupant expectations must be in alignment with official policies on amphibious construction. For instance, evacuation can be mandated when the house is floating, but rules do not guarantee that occupants will leave. It is possible to allow residents to stay in an amphibious house while it is floating, like in the Dutch projects discussed. However, the design solutions are appropriately engineered to ensure both life safety and occupant comfort in the house while floating. This results in a higher cost,

[17] Loor, "Amphibious Housing in Maasbommel, the Netherlands."

[18] Stephanie Wakefield, "Forum 3: Amphibious Architecture beyond the Levee," Mobilities 14, no. 3 (May 4, 2019): 388–94.

[19] Loor, "Amphibious Housing in Maasbommel, the Netherlands."

but it is essential to ensure a high degree of safety when occupants stay in the house while floating. If the intention is for residents to be elsewhere during the duration of the flood, like most of the houses in ORL, that changes the risk profile and may broaden the scope of acceptable solutions.

It is important that the proposed design and accompanying precautions provide acceptable levels of safety, and that all parties involved are in agreement, especially in regards to safety policies. Any effort to implement amphibious architecture in a First Nations community ought to involve a collaborative discussion about acceptable risk. The prototype in Peguis is designed with the expectation that residents will evacuate during a flood. This aligns with the client's goals to protect the home from flood damage allowing for immediate return when waters recede.

4.4 Environmental Hazards

Discussion of wind is common in the literature, as the design of the vertical guidance system requires consideration of wind forces. Documentation of the Lakeview house includes information about how the house will resist high wind speeds, as that project is in a hurricane-prone region.[20] English et al. note that damage from strong winds is reduced by keeping buildings close to the ground by amphibiating them rather than elevating them permanently.[21]

There was very little discussion of water speeds and the implications of fast-moving water on amphibious construction. One paper attempted to quantify and address the issues with implementing amphibious architecture in a coastal location that experiences storm surges and ocean waves.[22] However, there is a lack of credible work on this topic. In her work, English states that amphibious architecture is not recommended in places with fast-moving water.[23]

Peguis does not experience the hurricane-force winds that Louisiana faces, so this is not a critical consideration for the implementation of amphibious architecture there. The site analysis could not find information about flood water speeds in Peguis, but the water from snow-melt riverine flooding is not likely to present the same challenges as storm surge or ocean waves.

20 DeKorne, "Floating Out the Storm: A Concept Home Designed to Resist Flood and Wind Rises out of the Wreckage of New Orleans."

21 Elizabeth English, Fatemeh Orooji, and Carol Friedland, "Mitigating Wind and Flood: The Increased Wind Vulnerability of Static Elevation vs. Amphibious Retrofit," In *Proceedings of BBAA VIII,* 2016.

22 Russell Archer et al., "Adaptive Coastal Construction: Designing Amphibious Homes to Resist Hurricane Winds and Storm Surges," *Journal of Ocean Engineering and Marine Energy* 9, no. 2 (May 1, 2023): 273–90.

23 English, Elizabeth. "Amphibious Foundations and the Buoyant Foundation Project: Innovative Strategies for Flood Resiliant Housing." *UNESCO-IHP and COST Action C22,* 2009.

4.5 Amphibious Retrofit of Prefabricated Housing

Multiple precedent projects show amphibious architecture being used for mobile homes or prefabricated houses. The Dunbogan Floating Caravan and the retrofits in Old River Landing both show amphibious construction being used for this housing type. It appears in photos that some of the amphibious buildings in Oolderhuuske are also prefabricated units.

Previous amphibious architecture research has noted that prefabricated homes can withstand additional movement and environmental hardship when compared to conventional construction, which has advantages for amphibious architecture retrofit.[24] Prefabricated homes need to be constructed durably to ensure they are not damaged during the transport process, so manufacturers add glue when installing drywall and sheathing, add additional reinforcement for rigidity, and strengthen connections by using screws and metal strips. These adaptations allow the structure to tolerate being lifted and moved during the installation process, a process that applies dynamic loads different from those a building encounters when stationary. Dynamic loads would also be applied when the building is floating after an amphibious retrofit, so these adaptations will increase the resistance of the house to movement while floating.

Many prefabricated houses are transported in two or more pieces, then are joined on site. The seam where two modules join creates a potential weak point, which would need to be considered and potentially reinforced before installing an amphibious retrofit. RTM houses do not face this issue, as they are constructed and transported in a single piece. For instance, the prototype house has floor trusses which span the full width of the house, and built-up beams which span the full length. Like other prefabricated houses in Peguis, the prototype house has a fairly symmetrical, rectangular plan, with a gabled roof. This simple, continuous structure is already designed to be lifted during the installation process, which should make it easier to account for the new forces experienced when the house is lifted by buoyancy elements during a flood (Fig. 4.2).

In their paper, Tramontini and English note that prefabricated homes often cluster bathrooms and kitchens on the same side of the house and that buoyancy systems may need to be designed to account for these concentrated loads.[25] This is the case in the prototype house, with the bathroom and kitchen both along one wall. Further investigation is required to assess whether this will affect the stability of the house while floating.

24 Lia Tramontini and Elizabeth English, "Amphibiating Prefabricated Housing," in *Proceedings of International Conference on Amphibious Architecture, Design, and Engineering,* 2015.

25 Ibid.

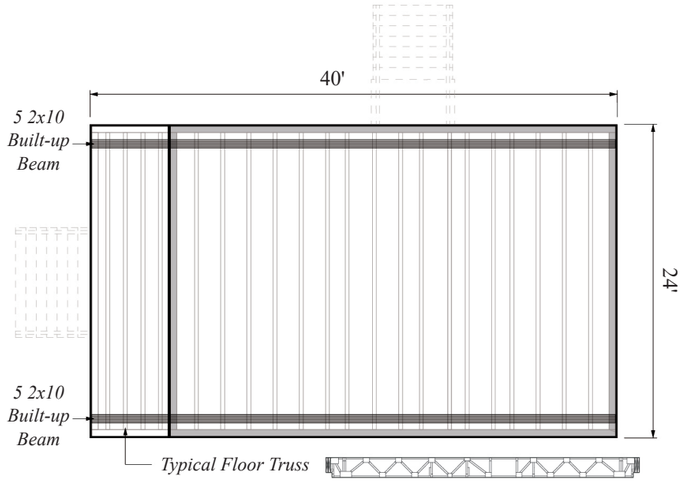


Fig. 4.2

RTM House Floor Structure Plan.

4.6 Takeaways for a Design in Peguis

Although designers can draw upon regulations for houseboats or floating buildings, as discussed above, these structures are operational and occupied while they float. This is not necessarily the case for a buoyant foundation that mitigates the risk of flooding. Information for these types of buildings can be helpful to address technical questions. However, there are more philosophical questions which must be answered, such as what the occupant expects from their amphibious home and what an acceptable level of risk is for an amphibious building in this context.

The conflicts over full time occupancy in Maasbommel show that policies and designer intentions do not align with resident expectations, and that this can lead to issues once the building is constructed and occupied. Any effort to implement amphibious architecture in a FN community ought to involve a collaborative discussion about acceptable risk, including the necessity of safe evacuation during a flood event.

There are many unique aspects to the Peguis prototype project. This technology has not been implemented in Canada, and no precedent has been constructed in a context with weather as cold as Manitoba. Many of

the projects constructed in the developed world do not seem to be overly concerned with cost, using expensive solutions for vertical guidance, buoyancy elements, and utility connections. However, there are options for lower-cost amphibious construction, as demonstrated by the retrofits in Old River Landing.

Approval from external bodies, such as banks determining mortgage eligibility and building inspectors issuing occupancy permits, represents a significant challenge for implementing amphibious architecture. Although this prototype is not dependent on this sort of approval, it is an important consideration for future projects. The literature also underscored that environmental threats like high wind or moving water must be considered, and may make the amphibious architecture non-feasible for certain sites.

Overall, this analysis shows that the site and house in Peguis has many characteristics that make it promising for the implementation of amphibious architecture. The housing is suitable for amphibious retrofit, with existing precedents for amphibious construction. The site does not experience flash flooding, storm surge, or hurricane-force winds. This is a manageable context for testing this technology. By demonstrating the suitability of amphibious architecture here, a prototype in Peguis could help prove the feasibility of the strategy for the Interlake Region and First Nations communities.

An Amphibious Retrofit Proposal

This chapter proposes an amphibious retrofit for the prefabricated home and site in Peguis. Key aspects covered include the selection and integration of buoyancy elements, vertical guidance mechanisms, centring devices, utility connections, and modifications to the building envelope (Fig. 5.1). Each section discusses the design decision process and presents drawings of chosen solutions.

This is an exploration of possibility, not a construction drawing set. However, this chapter considers material realities using detail drawings to describe specific components and imagine potential methods of assembly.

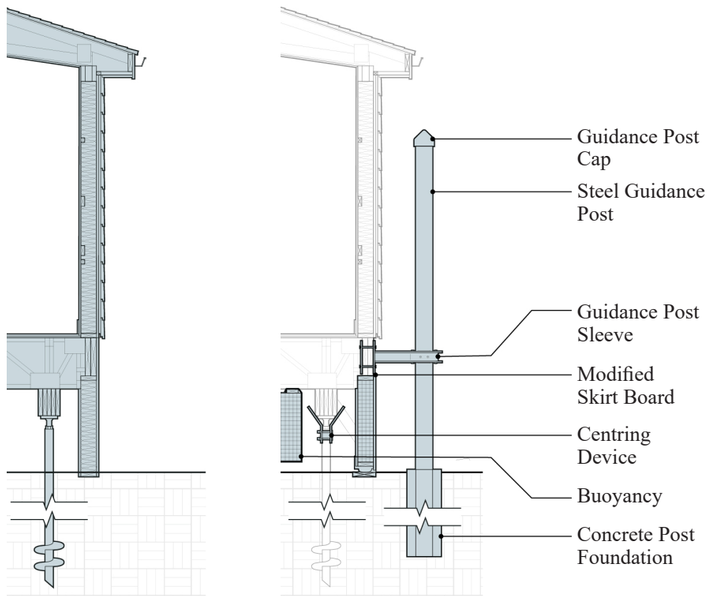


Fig. 5.1

Prototype House Before and After Retrofit.

5.1 Buoyancy

The RTM home weighs 35 lbs/ft^2, and can be installed with an up to 30 inch crawlspace. This weight and height are set variables which govern the design of a buoyancy system for the house. However, several other, less definite factors need to be considered, such as other loads, load factors, and the desired level of freeboard.

5.1.1 Calculating Buoyancy and Considering Risk

Risk is often conceived of as a matrix, considering both the probability and severity of a given event. The risk of encountering challenges with experimental technology is higher than with conventional construction. However, the probability of additional extreme conditions occurring during a flood event is lower than the probability of those extreme conditions occurring in general. For instance, the probable amount of snow accumulation in Peguis during a flood is lower than the probable amount of snow accumulation generally, because floods occur after the weather begins to warm.

Additionally, the severity of failure is lower if amphibious buildings are expected to be unoccupied for the duration of the flood, an important difference when it comes to considering risk. There may be some low risks to property from amphibious construction, but if an unamphibiated house in the same context would certainly be damaged by flooding, then those risks may be acceptable to residents. Of course, an evacuation order does not necessarily mean that residents will actually leave the house as instructed. The possibility of non-compliance must be taken into account to some degree when assessing the risks and probable conditions during a flood event.

When calculating loads for conventional buildings, designers can refer to building codes for load factors and design load combinations that take a probabilistic risk assessment into account. However, amphibious architecture presents a unique circumstance not accounted for in these regulations. The buoyancy provided by the buoyancy system is only in use during flood events, meaning the relevant combination of loads is not the expected maximum overall, but rather the expected maximum during a flood.

The overall dead load for this particular structure is known. The RTM house is lifted by a crane during the installation process, meaning the home manufacturer has an accurate idea of how much the house weighs. For projects that retrofit other types of houses, these loads might be more of an estimate. Ensuring the buoyancy system can lift the weight of the amphibious building is critical and Dr. Elizabeth English generally proposes an additional factor on dead loads when designing buoyancy systems for this reason. However, for this project, it is probably not required. Reductions in the dead load factor might be appropriate because of how reliable the information about the house's weight is compared to a site-built house.

In Chapter 2, a preliminary analysis of weather data for the site during flood events determined that significant snow loads are not a concern. Floods here are caused by the spring snow melt when there is no snow or only trace amounts. The full snow load for this site—40 psf, or two feet of snow depth—is not reasonably likely during the flood season. Snow loads are likely to be very small or zero, and as a result were not considered in the design load conditions.

The live load for residential floors in the National Building Code of Canada is 40 lbs/ft^2. Usually, this is multiplied by a 1.5 load factor. However, when dealing with large tributary areas, there are formulas provided to calculate factors to reduce the live load.[1] This is based on an assessment of the probability of different extreme loading conditions—one room of a house might be filled shoulder-to-shoulder with people during a party, but every room would not be fully occupied at the same time even under extreme conditions.

We can extend this logic to reasonably say that design live loads would be lower during a flood event where residents are meant to be evacuated. Furniture would still be in place, and there is a possibility that residents would not comply with the order to evacuate, but that would still be a smaller load than the crowded conditions accounted for under typical circumstances.

It is important to note that this would not be the case for all amphibious architecture projects; an amphibious house that is not intended to be evacuated may become a place of refuge during a flood, in which case it is necessary to use larger factors for the live load that account for crowded conditions.

[1] National Building Code of Canada 2020, NR24-28/2020E, 4.1.5.8

For the dead load, a factor of 1.2 is taken from the NBCC. A factor of 1.05 is proposed as a potentially more appropriate factor, reflecting the accurate dead loads available for RTM homes like the one in Peguis. A more conservative factor of the 1.2 NBCC factor multiplied by 1.15 is also proposed as being potentially appropriate, as discussed by English. This higher factor accounts for the importance of the buoyancy system, as inadequate buoyancy during a flood event could cause serious, immediate damage to the building.

The NBCC prescribes a live load factor of 1.5. However, a reduced factor of 1.0 is proposed to take into account the fact that evacuation is expected. In this scenario, the live load would consist primarily of furniture and fixtures and, at most, a few individuals do not comply with evacuation protocols.

These factors are then combined and a range of possible design loads are calculated for this project. Snow loads and other environmental loads were not taken into account.

To calculate an actual anticipated load, the unfactored dead load is combined with a significantly reduced live load. This actual anticipated load is compared to the design loads by calculating the percent of the buoyancy that would be above water under actual anticipated loads—in other words, the amount of the buoyancy that would still be unsubmerged under service loads. This provides a basis for estimating freeboard once the depth and configuration of buoyancy elements is determined.

This approach needs refinement. However, the key issues raised here are important and merit further investigation and discussion. A balance needs to be struck between a reasonable margin of safety, and designing to actual expected loads. Providing excessive buoyancy is not only costly but also affects the stability of the floating structure. The following calculations take this into account, proposing a range of potential live and dead design load factors (Table 5.1).

Design Load Factors:

Possible Dead Load Factors:

1.2 (NBCC)
1.05 (because load is well known)
1.2*1.15 (additional load factor)

Possible Live Load Factors:

1.5 (NBCC)
1.0 (reduced)

Design Loads:
Unfactored Live Load (L): 40 lbs/ft^2
Unfactored Dead Load (D): 35 lbs/ft^2

Anticipated Actual Load:
Given dead load plus greatly reduced live load
D + 0.5 L = 55 lbs/ft^2

1 - (Anticipated Actual Load / Design Load) =
% of Block Exposed Under Actual Anticipated Load

#	Design Load	lbs/ft^2	lbs load	% of Block Exposed Under Anticipated Actual Load
1	1.05 D + 1 L	77	73 920	28.5%
2	1.2 D + 1 L	82	78 720	32.9%
3	1.2 (1.15 D) + 1 L	88	84 480	38%
4	1.05 D + 1.5 L	97	93 120	43%
5	1.2 D + 1.5 L	102	97 920	46%
6	1.2 (1.15 D) + 1.5 L	108.3	103 968	49%

Table 5.1
Considering the design load.

5.1.2 Buoyancy Materials

Concrete caissons or steel pontoons were used for several of the precedent amphibious projects discussed in the previous chapter, including the Lakeview House, Warsaw Pavilion, Maasbommel, and the house on the Thames. However, all of these buoyancy systems are made up of large and heavy pieces, either constructed in place or requiring a crane to be installed.

These pieces would either need to be in place before the delivery of the house, necessitating additional coordination with the prefabricated home manufacturer, or the house would need to be lifted again to install the buoyancy elements, adding cost and complexity. Concrete caissons could be constructed onsite, but this would require specialized onsite labour not readily available inland, let alone in a rural FN community. On the other hand, shipping the products from elsewhere to the site would add costs and logistical complexity. As such, these approaches were not appropriate for this design.

Using recycled or repurposed materials for buoyancy elements is a strategy that has been used for some of the houses in ORL and multiple projects in developing regions, such as the LIFT House in Bangladesh and the Buoyant Foundation Project retrofits in the Mekong Delta, Vietnam.

Using recycled materials has appealing sustainability and affordability benefits, and merits further investigation to determine whether it would be suitable for projects in Canada. Plastic barrels are often used in Canada for dock construction, and sometimes used for do-it-yourself houseboats, making them a potential option for use in an amphibious building (Fig. 5.2 - 5.3).

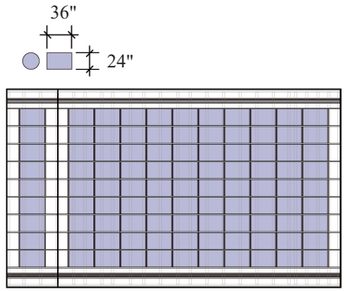




Fig. 5.2 (left)
A Dock Under Construction made with Plastic Barrels.

Fig. 5.3 (right)
A House Boat with Plastic Barrels for Buoyancy.

Unfortunately, standard-sized barrels do not fit in the crawl space vertically, and do not fit horizontally with enough efficiency to provide sufficient buoyancy (Fig. 5.4).



Volume per barrel = 9.42 ft^3
Barrels = 99

Total Volume of barrels
= 932 ft^3

Pounds of Water Displaced
= 58150 lbs

This is not a sufficient amount of buoyancy (Table 5.1).

Fig. 5.4
Layout for Barrels as a Potential Buoyancy Material.

Another possibility is to use larger repurposed containers, like intermediate bulk containers (Fig. 5.5). It is worth noting that, unlike plastic barrels, bulk containers are not typically used as buoyancy elements for floating docks, and perhaps have traits that make them unsuitable for use as flotation elements. Anecdotally, I could find one case in which someone attempted to use reclaimed bulk totes for a dock, and the totes did not remain airtight, ultimately resulting in the dock sinking shortly after being put into the water.[2] At a standard height of 46 inches, they are too large for this crawl space, but their rectangular shape and large size are promising traits for use in a buoyancy system if the air tightness issues are resolvable.

Manufactured, EPS-filled, polyethylene dock floats were also considered, as they are purpose-built and durable (Fig 5.6). These floats are widely available commercially. However, at $120 to $600+ per unit, the quantity of buoyancy required to lift a house would be so costly that it is non-viable for this project (Table 5.2).

Ultimately, this project selected EPS foam blocks like those used in Old River Landing. They are widely available, as EPS foam has numerous

[2] IBC Tote Dock Build, 2022, https://www.youtube.com/watch?v=6G-zqnNIAiM.





Fig. 5.5 (left)
Intermediate Bulk Totes.

Fig. 5.6 (right)
Foam-filled Polyethylene Dock Floats.

Buoyancy Type	Cost per lb of Buoyancy	Approximate Cost for Buoyancy	Pros	Cons
Steel Pontoons	varies	Unknown High Cost	Durable and Purpose Built	Specialized, Requires Equipment, Hard to use for Retrofit
Concrete Caissons	varies	Unknown High Cost	Durable and Purpose Built	Specialized, Requires Equipment, Hard to use for Retrofit
Polyethylene Dock Floats	$0.65 - $0.75	$70 000 +	Durable and Purpose Built	Non-viable Cost
Recycled / Reclaimed Materials	$0 - $0.05	$0 - $5600	Affordable, Sustainable	Not Always Available, Inconsistent Quality
EPS Foam Billets	$0.03 - $0.06	$3200 - $6400	Widely Available, Versatile	Environmental Impact

Table 5.2
Cost of Possible Buoyancy Materials.

uses in the building industry. They were found to be more affordable than obtaining a manufactured buoyancy product and were available in a range of sizes that fit within the height constraint of the crawlspace. EPS is also very light, at only about one pound per cubic foot, making it an efficient choice for buoyancy. EPS is resistant to humidity, has a low water absorption rate, and does not host mould or pests. Unlike repurposed plastic containers, which achieve buoyancy through airtightness, there is less risk of sudden failure. Expanded polystyrene foam also has disadvantages. Although it has a smaller carbon footprint than alternative foams, like extruded polystyrene, it still has a relatively high environmental impact. It is not degradable and rarely recycled.

To attach the EPS blocks, an additional layer of wood strapping would be added underneath the floor trusses, then two lengths of webbing would loop under the foam block and clip it into place (Fig. 5.7). Using clips would also allow the blocks to be easily removed if needed (Fig. 5.8).

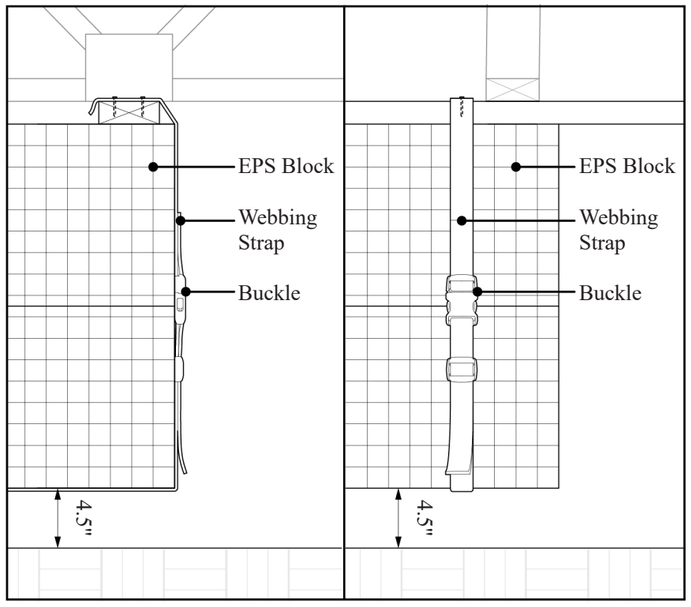


Fig. 5.7
Buoyancy Attachment.

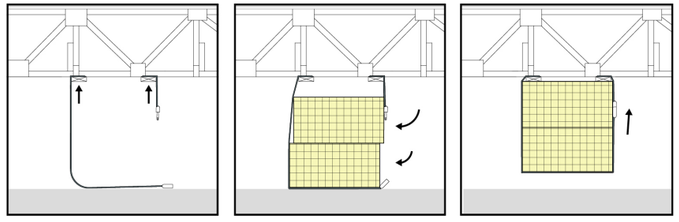
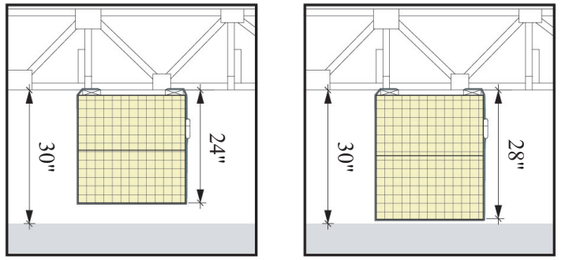


Fig. 5.8
Installation Process for Buoyancy Blocks.

5.1.3 Buoyancy Layouts

Using foam blocks for buoyancy, there are a number of ways to arrange them within the crawl space while still maintaining access to plumbing connections. Some configurations also allow for an access aisle in the crawl space. It is possible to accommodate every load equation from Section 5.1.1 using the space between the two sill beams, and blocks up to 28" deep (Fig. 5.9). These layouts attempt to balance maximum buoyancy with access and the use of mostly standard 4-foot by 8-foot foam blocks. However, the more conservative combinations make access to the crawlspace difficult and require irregular 14" deep foam blocks, which would be inconvenient and increase costs.

This thesis will proceed with Buoyancy Design C at 24" depth (Fig. 5.10 - 5.11) (Table 5.3). This layout prioritizes the use of standard 12" deep foam blocks, but does present some challenges for access and maintenance in the crawlspace.

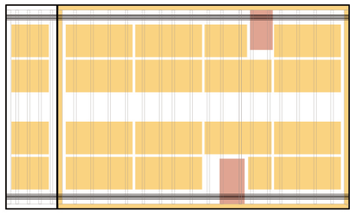


Convenient depth with standard pieces of foam (2 x 12").

Maximum feasible depth.

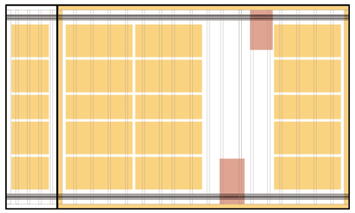
Fig. 5.9
Options for Buoyancy Depth.

Buoyancy Layout A



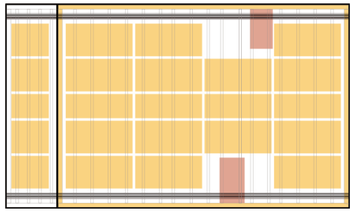
Block Depth	ft^3 Buoyancy
at 24”	1200 ft^3
at 28”	1400 ft^3

Buoyancy Layout B



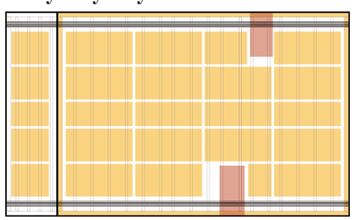
at 24”	1215 ft^3
at 28”	1420 ft^3

Buoyancy Layout C



at 24”	1390 ft^3
at 28”	1690 ft^3

Buoyancy Layout D



at 24”	1455 ft^3
at 28”	1695 ft^3

Obstacles

EPS Buoyancy Blocks

Fig. 5.10

Possible Buoyancy Configurations.

Given:
Density of Water:
62.4 lbs/ft^3

Estimated Density EPS Foam:
1 lbs/ft^3

Net Buoyancy:
61.4 lbs/ft^3

Design Load and Buoyancy Layout Options:

#	lbs load	ft^3 EPS Foam	Compatible Layouts (at specified depth)			
			A	B	C	D
1	73 920	1200	24"	24"	24"	24"
2	78 720	1280	28”	28”	24"	24"
3	84 480	1375	28”	28”	24"	24"
4	93 120	1520	-	-	28”	28”
5	97 920	1595	-	-	28”	28”
6	103 968	1695	-	-	-	28”

Table 5.3

Load Combinations and Buoyancy Layouts

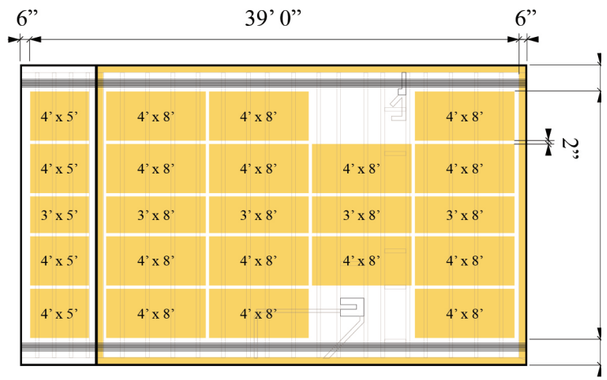


Fig. 5.11

Selected Buoyancy Configuration.

5.2 Heel Angle and Stability

Another important consideration is the buoyant stability of the amphibious structure when it is floating. This thesis will not analyze the buoyant stability of the prototype house—other research work is ongoing to do these calculations and develop a model for how they can be done going forward. However, it will discuss how these stability calculations impact the design of an amphibious architecture project.

Wind and moving water will apply forces to the house while floating. Even if speeds are moderate, as they are on the prototype site, these forces will cause the house to tilt (refer back to Fig. 4.1). If rotation reaches a critical threshold, the house could capsize, resulting in catastrophic failure. However, smaller heel angles could also cause issues. Rotation that results in the submersion of water-sensitive materials like drywall is not acceptable. If an amphibious building is designed to remain occupied, occupant comfort would also limit how much rotation is allowable. Several floating house codes limit the heel angle to a four- or five-degree rotation, suggesting this may be an appropriate serviceability limit for comfort in an occupied context (refer back to Table 4.1).

Regardless of which considerations govern the design, it is important to ensure that the maximum calculated heel angle under expected loads and forces does not compromise the house or its occupants. For this prototype, occupant comfort is not a primary concern as the prototype is expected to be evacuated. Although the floor trusses are not intended for extended contact with water, it was decided that it is acceptable for them to briefly touch the water when the house tilts. However, it is critical to prevent the corner of the finish floor from submerging, as this would cause damage to the water sensitive interior finishes of the house. This would occur at a seven-degree rotation. Coincidentally, seven degrees is also the angle that would cause the skirt boards to hit the foundation piles. Therefore, the heel angle for this project needs to be limited to six degrees or less (Fig. 5.12).

Preliminary calculations for the prototype house found that it tilts about five degrees under design loading conditions, within the acceptable range. These calculations are not yet complete, but this design will proceed with this five-degree number as an estimate.

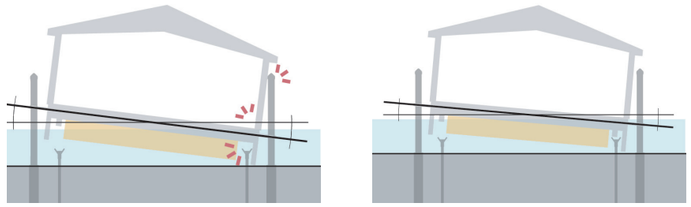


Fig. 5.12
Unacceptable and Acceptable Heel Angles.

If the calculated heel angle is higher than the acceptable heel angle, additional design modifications can be made to increase the buoyant stability of the house. A wider buoyancy base and lower centre of gravity will increase the stability of an amphibious house (Fig. 5.13). The centre of gravity of a retrofit house cannot be easily modified. However, the buoyancy base can be widened for additional stability, potentially into a catamaran configuration. If needed, the buoyancy base can even be extended beyond the original footprint of the house via the use of a wrap around deck.

Freeboard also affects stability and the acceptable heel angle. More freeboard will raise the centre of gravity, worsening buoyant stability, but it can also make higher degrees of tilt acceptable by increasing the distance between the surface of the water and water-sensitive components.

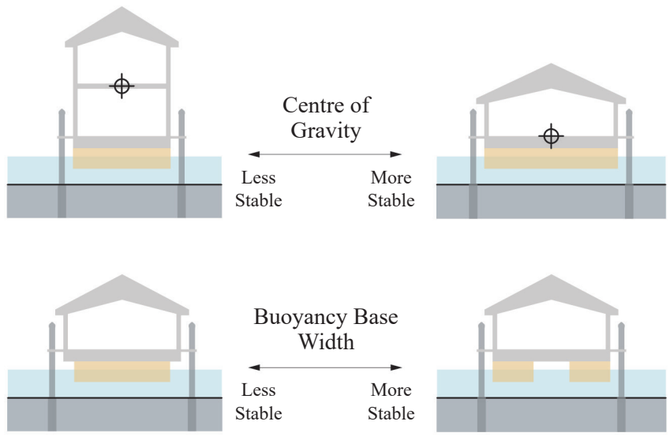


Fig. 5.13
Factors Impacting Buoyant Stability.

5.3 Vertical Guidance

Projects like the FLOAT House and LIFT House have integrated guidance systems concealed within the building walls. However, as this is a retrofit, the most practical solution is to use external guidance posts.

This project considered both steel and wood posts. The client had access to some discarded telephone poles, so repurposing those as wooden posts was considered. However, there were also concerns about the inconsistent shape and size of the wooden posts, with knots in the wood and a tapering shape which would need to be accounted for when designing the guidance post sleeves. Steel posts were ultimately selected due to their dimensional uniformity.

Maasbommel and the Kaiapoi house have guidance posts that go through a deck that surrounds the house. However, the prototype house has an integrated porch, so adding on a deck isn't desired or necessary. Instead, it will use a vertical guidance system more like some camps at ORL or the amphibious houses at Ohe en Laak, with external guidance posts.

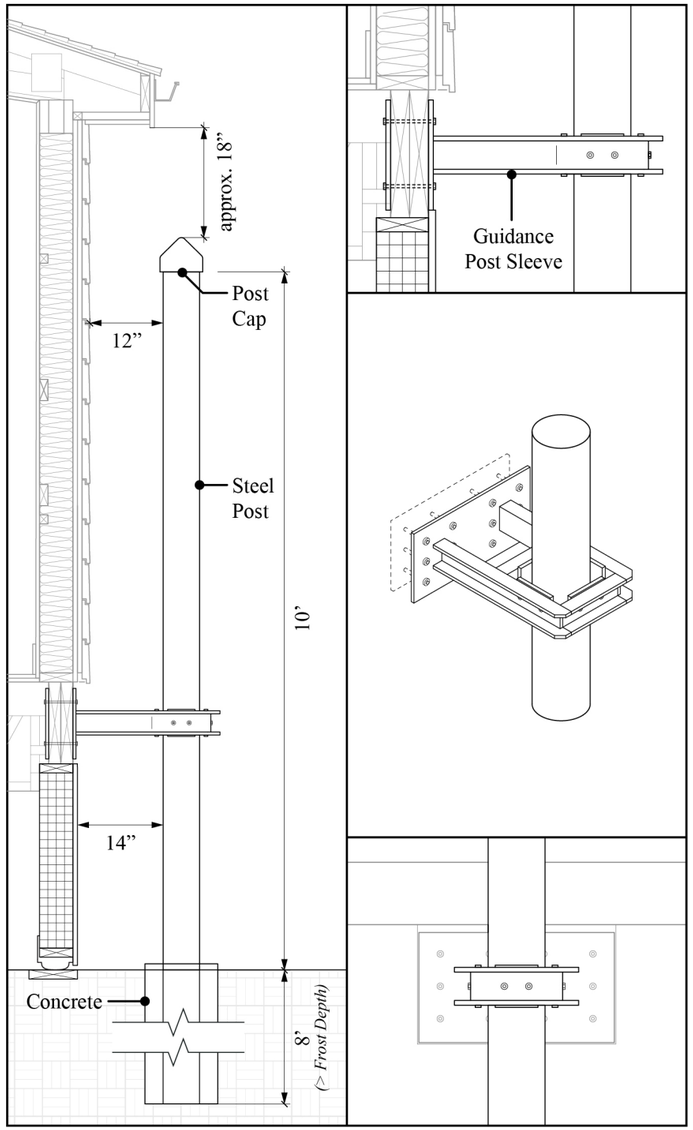
Telescoping poles were not used in any of the prototype projects, and ultimately not selected, but are a promising strategy for potential future projects where the visual impact of guidance posts is a concern.[2]

The design for the guidance post sleeve draws on the design of pile brackets for docks (Fig. 5.14). These come in many styles, some with rollers or polyethylene blocks to avoid metal-on-metal contact. This provides smoother movement, reduced noise, and increased durability. Rollers have moving components, which introduces additional potential points of failure. However, something similar to the blocks was deemed suitable for implementation here.

To ensure the wall does not collide with the guidance posts as it floats, the posts were placed 12 inches away from the exterior face of the wall. This distance was calculated based on the necessary clearance to prevent contact at a five- or six-degree rotation angle.

For amphibious projects where the guidance posts are taller than the building story height, posts would need to be placed further away to avoid contact with the eaves. Larger expected heel angles caused by high wind or water speeds would also affect the placement and design of the guidance system. Neither of these challenges is present at Peguis, allowing the posts to be tucked beneath the eaves, relatively close to the building.

[2] Elizabeth English, "Amphibious Foundations and the Buoyant Foundation Project." (Paris, France: UNESCO-IHP and COST Action C22, 2009).



1:25 (left)
1:15 (right)

Fig. 5.14
Vertical Guidance System.

5.4 Centring Devices

The vertical guidance posts prevent large lateral movements, but a centring device can allow for more precise control over the final location of the building when flood waters recede. Whether a centring system is required largely depends on the tolerance of the gravity-bearing foundation to slight variations in the building's final resting position. Centring is not a concern for some amphibious structures, like the houses in Maasbommel or the Warsaw pavilion, which rest on continuous concrete slabs. If the house is meant to rest on piers, piles, or a continuous foundation wall, its final location must be controlled to ensure proper alignment with the foundation.

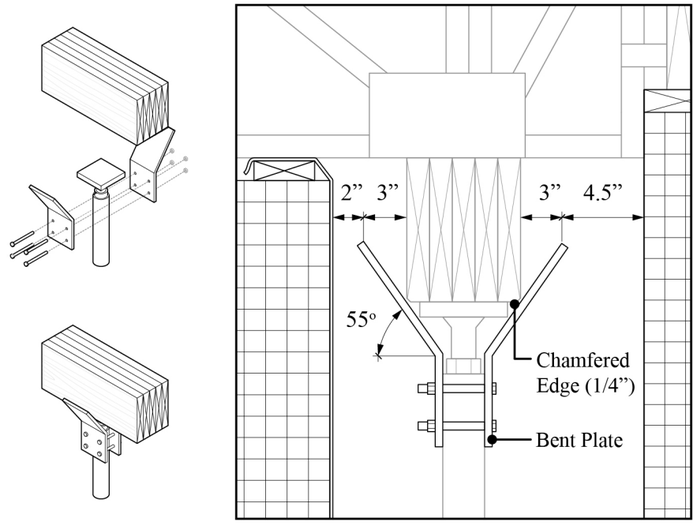
This house is supported by sill beams resting on helical piles. When settling back into place after a flood, these beams must land on the bearing plates attached to the vertical piles. Thus, some centring system is required.

In Old River Landing, some houses have triangular fins on the guidance posts, which centre the house as it returns to the ground. However, this solution introduces new challenges. Over time, the posts and fins can move out of their precise position. This can cause the guidance post sleeves to bear weight down onto the fins, transferring gravity loads to the vertical guidance posts, for which they were not designed. Alternatively, it can mean the guidance post sleeves and fins no longer make contact and cannot adequately centre the house.

Given the issues seen in ORL with the triangular fin strategy, this thesis proposes a centring system made with bent steel plates. Different details would be needed to centre the building both left-to-right and front-to-back; these could be installed at different locations where the sill beam bears on the pile foundation (Fig. 5.15 - 5.16).

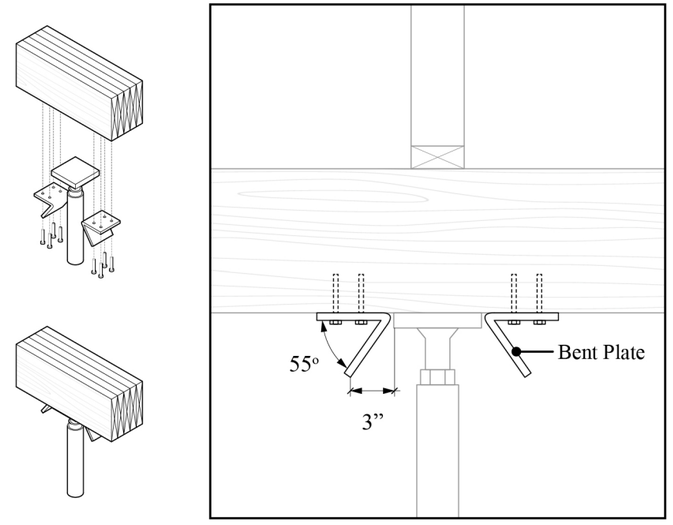
5.5 Skirt Boards

The RTM home manufacturer installs their houses with thermally insulated skirt boards to improve the energy performance of the house, keep pests out of the home's crawlspace, and prevent water lines from freezing during the winter. This is a common practice for prefabricated homes in this climate zone (Fig. 5.17). However, it is not something that was addressed in any of the amphibious architecture precedents.



1:10

Fig. 5.15
Centring Device #1



1:10

Fig. 5.16
Centring Device #2

These skirt boards will need to be modified during the amphibious retrofit process. First, any water-sensitive materials would need to be replaced with alternatives that are resistant to water exposure. For instance, batt insulation should be replaced with EPS. Additional bracing may be required, to resist water pressure, movement, and impact from floating debris.

Looking at houses made by the same manufacturer, the bottom edge of the skirt board is typically buried after installation (Fig. 5.18). The connection at the bottom of the skirt board would have to be changed to just a connection at the top, allowing the skirt boards to lift with the house. This proposal addresses these issues by modifying and bracing the skirt boards (Fig. 5.19).

Another important consideration is crawlspace access for inspecting buoyancy elements and reconnecting water and sewage lines. Access to buoyancy elements in the building's crawl space is ideal, especially for hollow buoyancy elements like containers or barrels. Regular visual inspection of this type of buoyancy system is important, as hollow buoyancy can crack and leak. In contrast, foam blocks have less potential for failure, lowering inspection and maintenance requirements. It is also important that some access is provided to the utility connections, especially if they require manual reconnection or disconnection.

The type and configuration of buoyancy affect how access can be accommodated. This project is selecting a conservative approach to calculating the required volume of buoyancy, so a central access aisle in the crawlspace is not possible. Instead, hinged sections of skirt boards or access hatches could provide access to utility connections and buoyancy elements. These would be used to place buoyancy elements into the crawl space during installation and to remove them if necessary.



Fig. 5.17 (left)
Skirt Board Framing.



Fig. 5.18 (right)
A RTM Home with Skirt Boards from the Same Manufacturer.

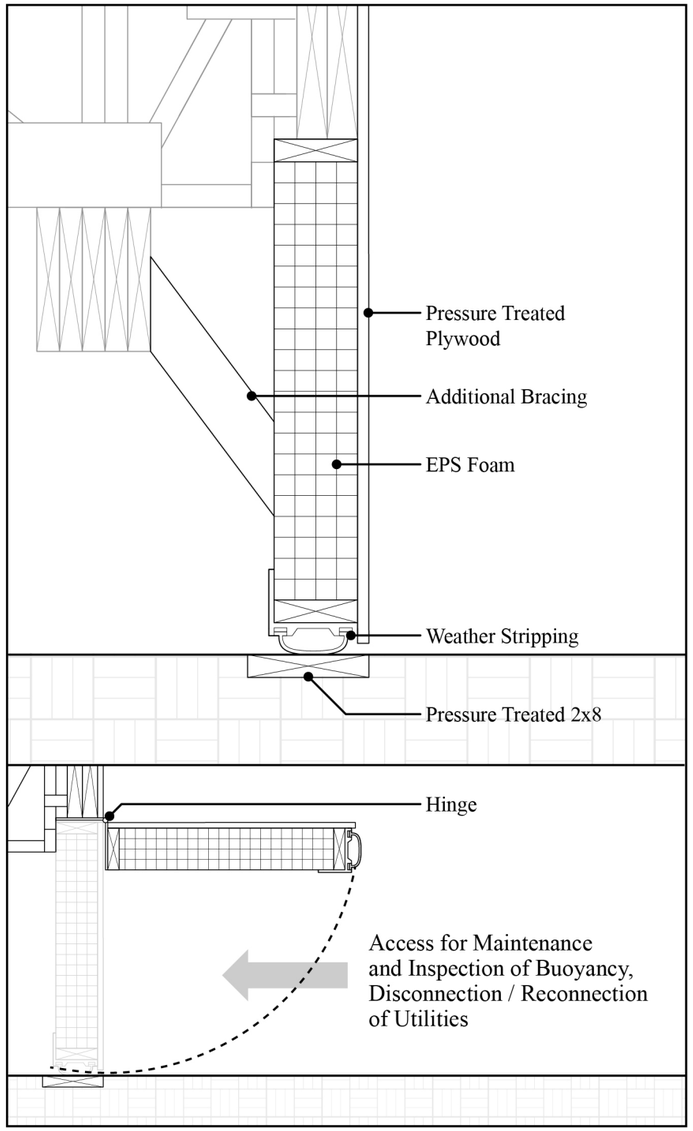


Fig. 5.19
Skirt Board Modifications.

5.6 Utility connections

This house receives its water from a well, is connected to the Manitoba electrical grid, and manages wastewater with a septic system. The connection to each of these services must be considered and potentially modified to allow for the house to float during flood conditions.

Like much of Canada, electrical service in this region is delivered through an overhead wire. This connection should require little to no modification to support the amphibious retrofit (Fig. 5.20).

The water supply connection can also be easily modified by providing coils of flexible piping in the crawlspace (Fig. 5.21).

The sewage line connection is slightly more complicated, but precedent projects provide a few different potential approaches. In ORL, sewage lines are modified with rubber couplings so that they can be manually disconnected before a flood event. These components are widely available and affordable, but the non-passive disconnection requires predictable flooding and an engaged homeowner who is willing and able to take time to prepare the home. This strategy works in ORL, where residents are knowledgeable in amphibious construction. However, the risk of the disconnection being missed or forgotten makes this solution not recommended for other contexts.

These sewage lines could also be made flexible, allowing sewage to remain connected when the house is floating. However, before waste water is pumped through the flexible line, it needs to be put through a macerator. This specialized machinery increases costs. However, flexible lines do not require reconnection after a flood, making them the easiest option for residents. They also remain operational during flood events, which is important for projects where evacuation is not expected.

This project proposes a self-sealing breakaway or 'pull-apart' connection to handle sewage. The sewage line would disconnect as the house lifts, a valve would seal the septic side pipe, and the two parts could be reattached once the residents return (Fig. 5.22). Although these types of connections require manual reconnection, they have the benefit of disconnecting passively, meaning no resident intervention is required to prepare the house to float. It is important that residents know they cannot use the wastewater system when the house is floating. For projects like this, where evacuation is expected, it is an appropriate solution.

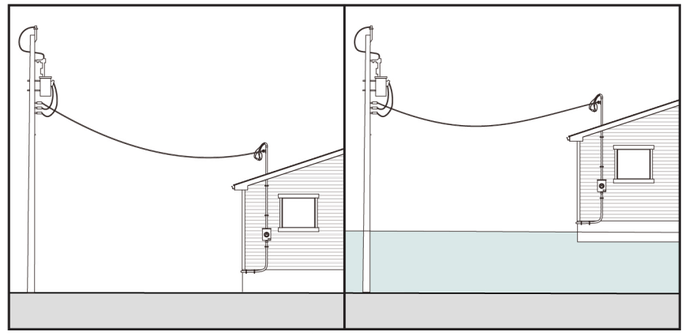


Fig. 5.20

Electrical Connection Before and During a Flood.

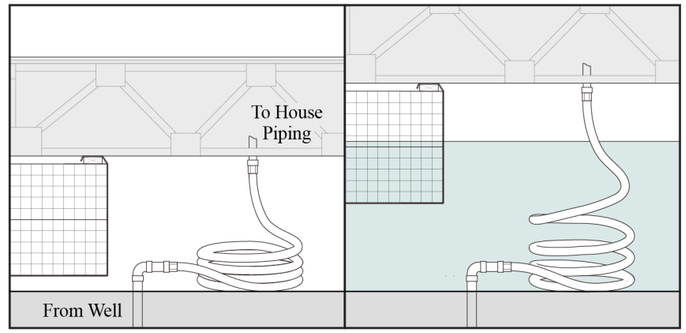


Fig. 5.21

Water Supply Connection Before and During a Flood.

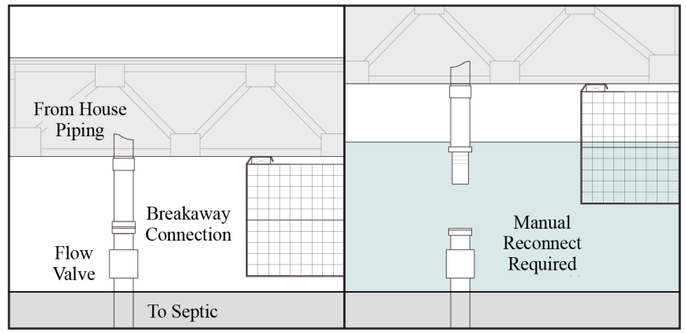


Fig. 5.22

Sewage Connection Before and During a Flood.

5.7 Decision-Making Considerations

This design provides an investigation of options for the Peguis site, but further research and prototyping is necessary to refine these ideas and test their real-world performance. However, the considerations discussed here form a framework of considerations that would also apply to amphibious construction elsewhere, especially in similar contexts. The following questions summarize some of these key factors.

Site and Context

Is there high wind or fast-moving water during floods?

Is there snow accumulated on roofs during flood events?

How deep is flooding? Is flooding expected to worsen?

How reliable and site specific is this data?

Retrofit

Can the existing structure tolerate dynamic loads? Does it need to be reinforced?

Do any of the envelope details require modification, like skirt boards?

Is the existing house installed with a sufficiently tall crawlspace to install buoyancy elements?

Risk

Is evacuation expected? Are residents in alignment with this policy?

Do flood waters rise so quickly that residents might become unintentionally trapped in the house during a flood?

What level of risk is acceptable to residents and designers?

Governance

How friendly are local authorities to amphibious construction?

Are there any local codes for houseboats or other similar types of construction to borrow from?

Is insurance, financing, or other forms of outside approval an obstacle to using amphibious architecture here?

Buoyancy

What loads does the buoyancy system need to accomodate?

Is machinery available to install heavy elements, like pontoons?

Consider cost. Some buoyancy materials can be costly.

Are maintenance and inspection needed? How likely are buoyancy elements to degrade or fail?

Guidance

What lateral loads and rotation angles does the guidance system need to be designed for?

How can the vertical guidance system be implemented with minimal visual impact, if this is a concern?

How is the guidance system attached to the main structure of the building?

Utilities

What utilities are present? How do connections need to be modified to accommodate movement during a flood?

Do utilities need to be operational during a flood event?

Are residents engaged and willing to use non-passive disconnections?

Do residents have sufficient warning of imminent flooding to disconnect their utilities?

Are they willing to have utilities require reconnection after a flood?

Consider cost. Some connection types are much more costly.

Centring

How much variation in final position does the guidance system allow?

How precisely must the building be aligned with its foundation?

How much variation in final position do utility connections allow for?

Debris

Is floating debris a common hazard?

Are buoyancy elements vulnerable to impact?

Beyond the Prototype

This thesis explores amphibious architecture as a flood mitigation option for Peguis First Nation. It looks at Peguis' history and the characteristics of flooding there, demonstrating that new solutions are needed. It shows that amphibious architecture is suitable for the specific type of flooding and some types of housing present in the community. Then, it reviews existing amphibious architecture projects and literature, documenting challenges and design options for this novel building type. Finally, informed by this analysis, this thesis proposes an amphibious retrofit design.

This work is only one step towards making amphibious architecture a reality for communities like Peguis. A desire to remain grounded in site-specific conditions and respond to the needs of real community members facing floods means that this work has a focus on one site and typology of housing. However, the challenges, decision-making process, and key considerations hold some insights that are more broadly applicable. Through compiling literature on existing projects and discussing alternative solutions for future projects, this work aims to produce resources that are helpful to the implementation of amphibious architecture more broadly as well.

Further work is needed to ensure the safety and reliability of amphibious construction, refine design approaches, and scale these ideas for broader implementation. This thesis exists within a broader research effort where some of this work is already being done. However, significant gaps remain. Amphibious architecture is a novel technology with a unique risk profile—especially when used as proposed here, to protect evacuated homes during flood events. If the objective is to implement amphibious architecture more widely, then there must be consistent standards for amphibious construction that take into account the difference between amphibious architecture as a novelty, and amphibious architecture retrofit as an affordable and accessible flood resilience solution.

For those who face floods, need community-led solutions, and wish to maintain a connection to land and community, amphibious architecture offers a vision for adaptation (Fig. 6.1).

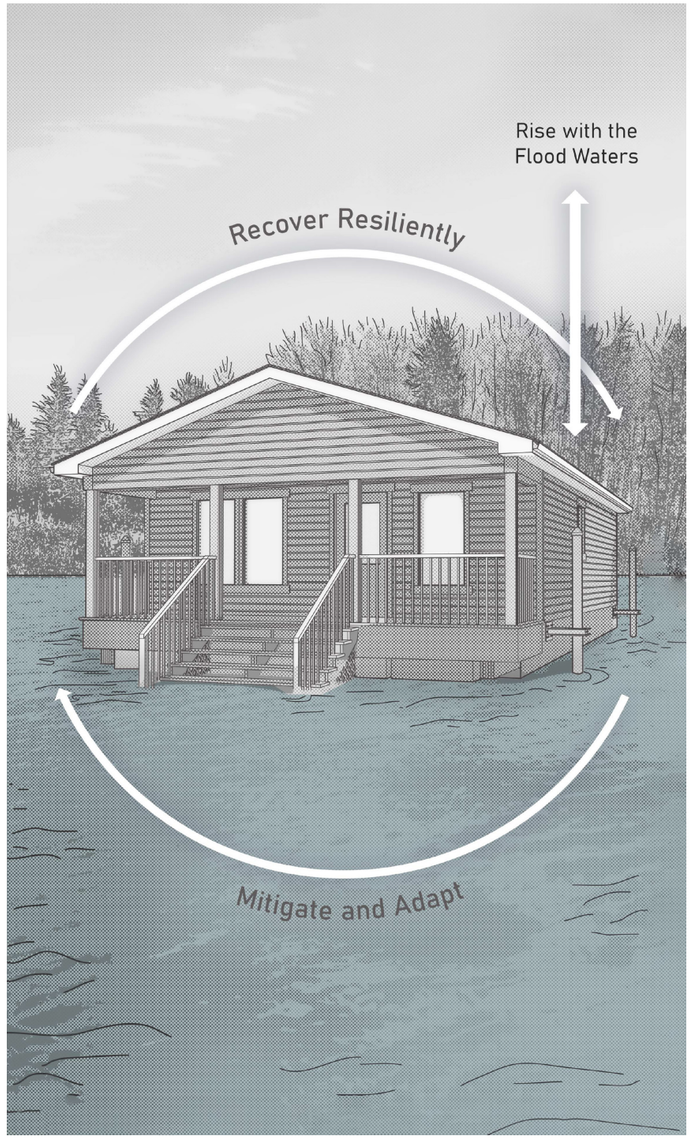


Fig. 6.1

Amphibious Architecture for Flood Resilience.

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Appendix 1:

Flood and Evacuation reports for Peguis, Manitoba.

2004 Flood

Source Date	# of Evacuees	Report Type	Source
Apr 2004	650	Initial Evacuation	"Residents hoping for sunny skies; Weekend deluge floods farmland, basements in R.M. of Fisher." *Winnipeg Free Press,* May 31, 2006, A7. *Gale OneFile: News.*

2006 Flood

Source Date	# of Evacuees	Report Type	Source
Nov 2007	180 homes	Discussion of Initial Evacuation On May 2006	"Disaster aid coming for Fisher River flooding." *Winnipeg Free Press,* November 29, 2006. *Gale OneFile: News.*

2009 Flood

Source Date	# of Evacuees	Report Type	Source
Apr 2009	740	Initial Evacuation	*CTV News.* "Manitoba First Nations Bear Brunt of Flooding." April 19, 2009.

2011 Flood

Source Date	# of Evacuees	Report Type	Source
Apr 2011	300	Initial Evacuation Report	"Prairie flooding forces hundreds to flee; Worst of record-setting spring deluge may still be weeks away." *Guelph Mercury* [Guelph, Ontario], April 14, 2011, A9. *Gale OneFile: News.*
Nov 2012	102	still displaced after 7 months	"Fighting for their promised land." *Globe & Mail* [Toronto, Canada], November 24, 2012, F1. *Gale OneFile: News.*
Apr 2022	91	still displaced after 10 years as of May 2021	Brohman, Erin. "Evacuees from 2011 and 2014 Peguis First Nation Floods Left Scrambling as Federal Relief Ends." *CBC News,* April 28, 2022.

2014 Flood

Source Date	# of Evacuees	Report Type	Source
Apr 2014	136	Initial Evacuation Report	"FLOOD BULLETIN #22." *Canadian Government News,* 30 Apr. 2014. *Gale OneFile: News.*
Apr 2022	121	still displaced after 8 years	Brohman, Erin. "Evacuees from 2011 and 2014 Peguis First Nation Floods Left Scrambling as Federal Relief Ends." CBC News, April 28, 2022.

2017 Flood

Source Date	# of Evacuees	Report Type	Source
Apr 2017	84	Initial Evacuation Report	Grabish, Austin. "Floodwaters Force 84 People out of Peguis First Nation." *CBC News*, April 2, 2017.

2022 Flood

Source Date	# of Evacuees	Report Type	Source
May 2022	1900	Initial Evacuation Report	Cameron, MacLean. "Chiefs Call for Permanent Protection for Peguis First Nation after Historic Flood." *CBC*, May 20, 2022.
Feb 2023	900	still displaced after 9 months	Greenslade, Brittany. "'I Don't Have a Home to Go to': Peguis First Nation Evacuees Left in Limbo 9 Months after Flooding." *CBC News,* February 6, 2023.
May 2023	610	still displaced after 1 year	Blunt, Marney. "'I Pray That We Can All Go Home': 610 Peguis Flood Evacuees Still Unable to Return." CBC News, February 6, 2023.
Apr 2024	540	still displaced after almost 2 years	Karpa, Alex. "Some 540 Peguis First Nation Residents Still Displaced after 2022 Flooding." CityNews, April 30, 2024.

Appendix 2:

Additional Weather Data During the Peguis Flood Season.

Spring Weather Chart for HISTORIC HODGSON WEATHER STATION 2 and 05SD003
For the months of March, April, and May

Data from Environment Canada, Historical Climate Data and Hydrometric Data. Chart by Author.

Data Year	Max. Discharge Date	Total Days After < ºC	Temp. Range Mar ºC*	Consec. Days Consist. < ºC Mar	Temp. Range Apr ºC*	Consec. Days Consist. < ºC Apr	Temp. Range May ºC*	Consec. Days Consist. < ºC May
1967	Apr 16	3	-31 to 6	17	-27 to 14	2	-11 to 26	1
1968	Apr 9	0	-29 to 12	6	-12 to 22	3	-9 to 25	0
1969	Apr 13	0	-29 to 7	13	-22 to 20	2	-6 to 29	0
1970	Apr 20	0	-38 to 6	16	-20 to 14	3	-7 to 30	0
1971	Apr 12	1	-29 to 6	7	-26 to 21	3	-6 to 28	0
1972	Apr 19	0	-36 to 9	11	-26 to 24	5	-8 to 33	0
1973	Mar 26	4	-18 to 16	3	-14 to 20	1	-8 to 27	0
1974	Apr 22	0	-35 to 5	15	-24 to 23	2	-6 to 21	0
1975	Apr 19	0	-32 to 6	13	-30 to 17	4	-3 to 26	0
1976	Apr 9	1	-35 to 9	17	-12 to 20	1	-8 to 30	0
1977	May 20	0	-28 to 16	2	-14 to 29	2	-6 to 33	0
1978	Apr 18	0	-31 to 6	8	-14 to 21	1	-4 to 31	0
1979	Apr 23	1	-32 to 4	15	-32 to 11	8	-6 to 27	1
1980	Apr 11	0	-40 to 8	14	-10 to 34	0	-7 to 38	0
1991	May 14	0	-23 to 11	3	-15 to 21	1	-10 to 29	0
1982	Apr 28	0	-37 to 3	11	-30 to 24	6	-3 to 29	0
1983	Apr 8	4	-25 to 6	7	-13 to 23	4	-9 to 24	0
1984	Apr 2	2	-37 to 8	14	-7 to 24	2	-9 to 33	0
1985	Apr 3	2	-26 to 8	8	-10 to 27	1	-5 to 28	0
1986	Apr 4	3	-35 to 10	9	-13 to 20	3	-6 to 34	0
1987	Apr 8	0	-31 to 13	6	-20 to 27	1	-9 to 33	0
1988	Apr 5	1	-28 to 11	11	-14 to 26	1	-8 to 34	0
1989	Apr 23	0	-38 to 6	12	-14 to 24	0	-13 to 30	0
1990	Apr 2	7	-26 to 9	8	-13 to 27	2	-7 to 28	0
1991	May 12	0	-31 to 12	8	-11 to 23	1	-5 to 29	1
1992	Apr 28	0	-25 to 8	8	-14 to 20	2	-5 to 35	0

Spring Weather Chart for FISHER BRANCH WEATHER STATION and 05SD003
For the months of March, April, and May

Data from Environment Canada, Historical Climate Data and Hydrometric Data. Chart by Author.

Data Year	Max. Discharge Date	Days After Max. < ºC	Temp. Range Mar ºC*	Consec. Days Consist. < ºC Mar	Temp. Range Apr ºC*	Consec. Days Consist. < ºC Apr	Temp. Range May ºC*	Consec. Days Consist. < ºC May
1993	Mar 30	0	-25 to 5	6	-11 to 12	0	-2 to 21	0
1994	Apr 12	0	-23 to 6	4	-15 to 19	0	-7 to 17	0
1995	Mar 27	3	-36 to 6	9	-20 to 14	3	-7 to 33	0
1996	Apr 20	2	-36 to 3	15	-26 to 12	4	-6 to 25	0
1997	Apr 22	0	-28 to 9	17	-24 to 14	6	-7 to 29	0
1998	Apr 4	0	-28 to 11	18	-5 to 27	0	-2 to 24	0
1999	Apr 9	1	-24 to 11	10	-5 to 25	1	-3 to 28	0
2000	Mar 8	12	-19 to 16	9	-12 to 24	1	-4 to 24	0
2001	Apr 13	2	-24 to 6	10	-10 to 27	1	-2 to 27	0
2002	Apr 14	0	-33 to 5	25	-16 to 18	7	-8 to 28	0
2003	Mar 29	5	-37 to 12	14	-13 to 23	5	-7 to 27	0
2004	Apr 8	3	-29 to 10	6	-9 to 19	3	-9 to 26	0
2005	Apr 6	1	-29 to 8	11	-7 to 22	0	-8 to 27	1
2006	Apr 10	0	-28 to 7	8	-9 to 25	0	-5 to 29	0
2007	Mar 31	6	-30 to 11	7	-16 to 24	6	-2 to 30	0
2008	Apr 17	0	-32 to 5	9	-18 to 20	2	-7 to 24	0
2009	Apr 17	0	-32 to 7	8	-11 to 18	1	-7 to 22	0
2010	Apr 6	0	-19 to 19	3	-6 to 23	0	-4 to 28	0
2011	Apr 14	0	-35 to 3	10	-13 to 20	0	-7 to 27	0
2012	Mar 30	1	-24 to 24	9	-13 to 20	1	-3 to 28	0
2013	Apr 28	1	-30 to 4	25	-18 to 17	2	-10 to 27	1
2014	Apr 26	0	6 to -36	9	-24 to 14	3	-5 to 32	0
2015	Apr 1	2	-28 to 12	5	-16 to 26	2	-5 to 29	0
2016	Apr 18	0	-31 to 13	5	-17 to 20	4	-6 to 35	0
2017	Apr 2	0	-27 to 11	9	-10 to 20	0	-5 to 24	0
2018	no data	-	-23 to 5	5	-26 to 24	8	-6 to 31	0
2019	no data	-	-30 to 10	11	-10 to 20	1	-6 to 27	0
2020	Apr 9	3	-24 to 12	10	-20 to 24	3	-10 to 28	0
2021	Mar 24	5	-30 to 14	3	-9 to 20	2	-8 to 31	0
2022	May 5	0	-27 to 8	14	-16 to 12	3	-2 to 23	0

Appendix 3:

Amphibious Feasibility Studies for Houses in Peguis

Before the selection of a specific prototype house in Peguis, I studied some houses in the vicinity that represented common typologies for Peguis. Simple rectangular structures with crawlspaces were common in the community, traits that are compatible with the style of buoyant retrofit shown in Chapter 5. Although these studies are not directly relevant to the prototype proposed in this thesis, they do show the broader applicability of amphibious architecture for this community, and capture some of the variation found in housing within the community of Peguis.

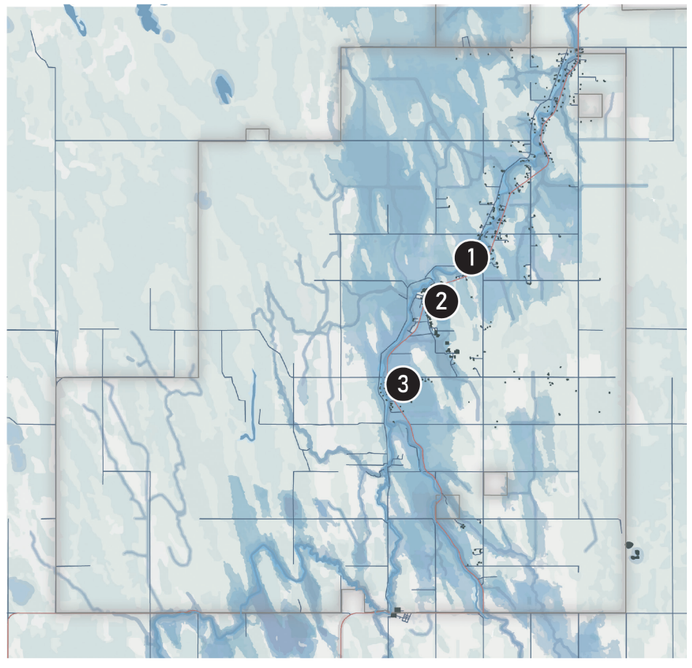


Fig. 6.1

Example House Location Map.

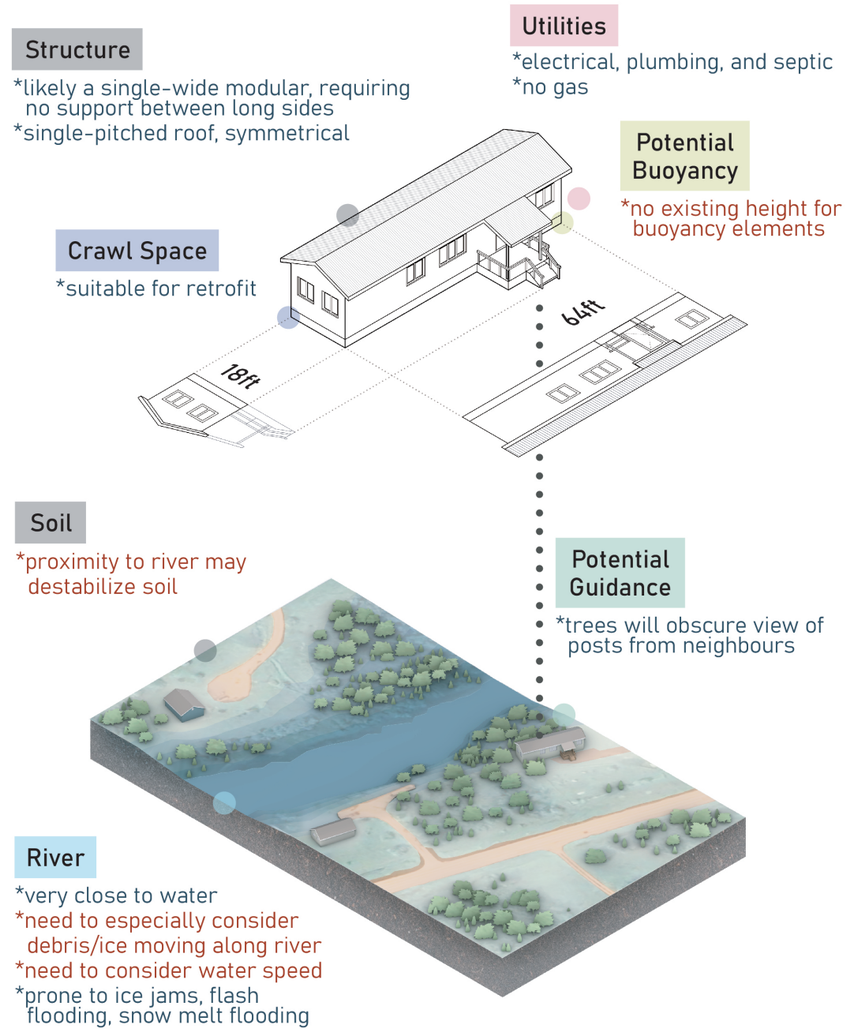


Fig. 6.2

Feasibility Study 1.

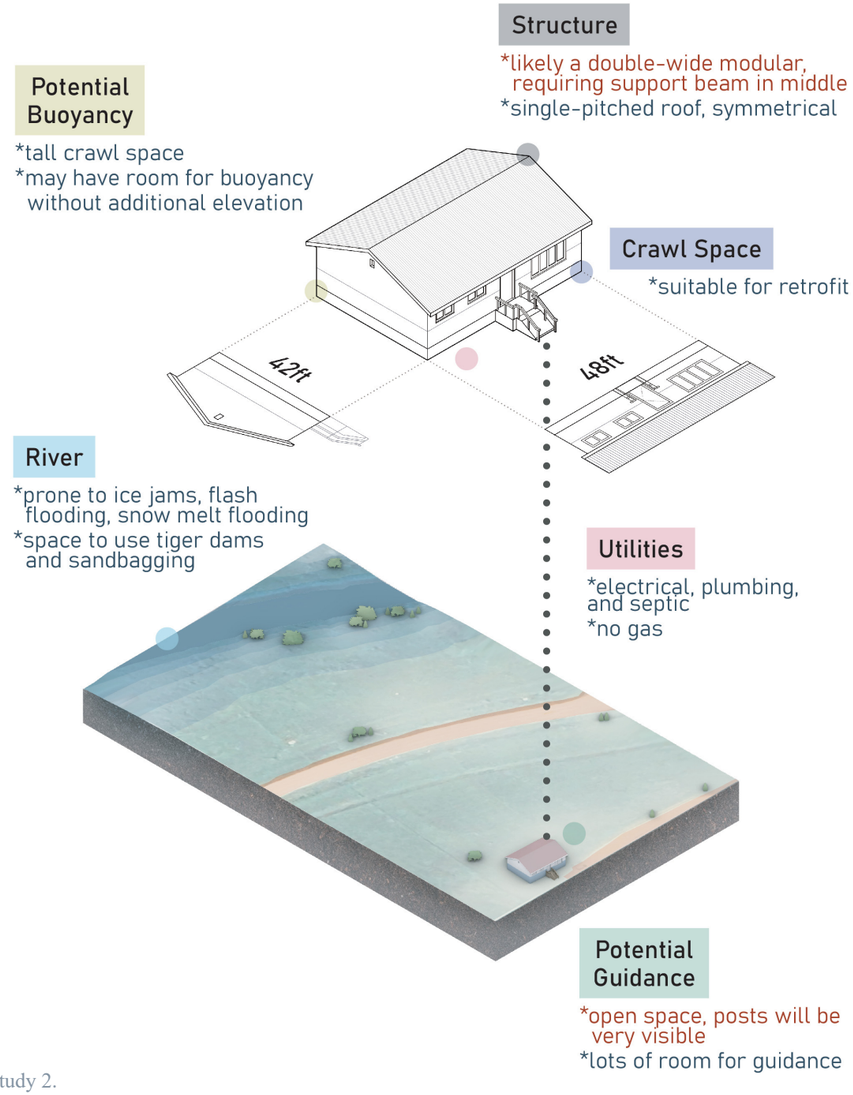


Fig. 6.3

Feasibility Study 2.

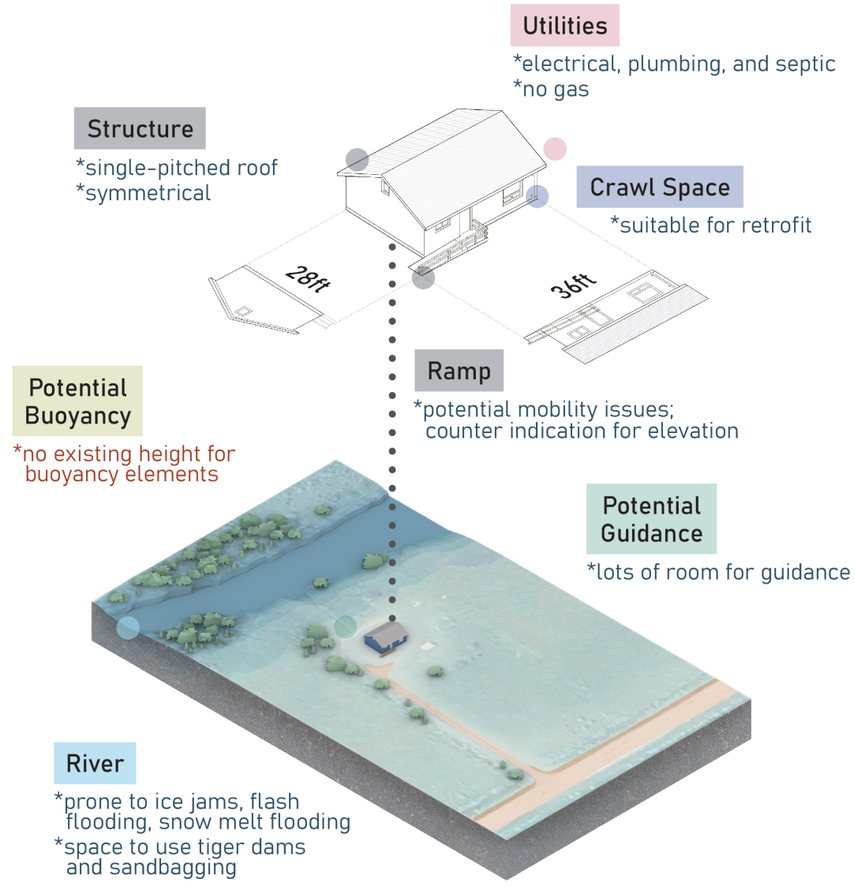
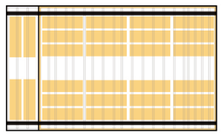


Fig. 6.4

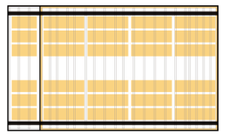
Feasibility Study 3.

Appendix 4:

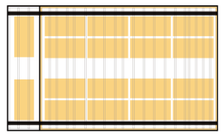
Early buoyancy configurations prioritized small, maneuverable block sizes and a central access aisle. Adding more buoyancy required larger blocks without an aisle. Then, buoyancy was shaped around the plumbing and utility connections.



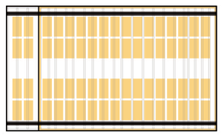
24” Depth: 1270 ft^3
28” Depth: 1460 ft^3
Access Aisle: 52”
2x8 ft blocks (0 irregular)



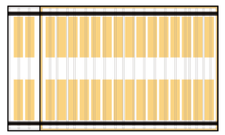
24” Depth: 1260 ft^3
28” Depth: 1450 ft^3
Access Aisle: 52”
2x8 ft blocks (6 irregular)



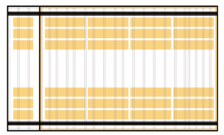
24” Depth: 1305 ft^3
28” Depth: 1500 ft^3
Access Aisle: 44”
4x8 ft blocks (0 irregular)



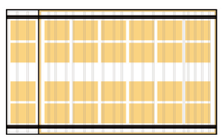
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28” Depth: 1425 ft^3
Access Aisle: 44”
2x4 ft blocks (0 irregular)



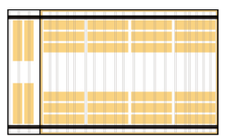
24” Depth: 1240 ft^3
28” Depth: 1425 ft^3
Access Aisle: 48”
2x8 ft blocks (0 irregular)



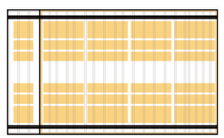
24” Depth: 1010 ft^3
28” Depth: 1160 ft^3
Access Aisle: 87”
2x8 ft blocks (6 irregular)



24” Depth: 1270 ft^3
28” Depth: 1460 ft^3
Access Aisle: 40”
4x6 ft blocks (0 irregular)



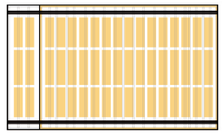
24” Depth: 1045 ft^3
28” Depth: 1200 ft^3
Access Aisle: 87”
2x8 ft blocks (0 irregular)



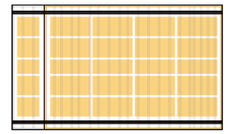
24” Depth: 1230 ft^3
28” Depth: 1415 ft^3
Access Aisle: 48”
2x8 ft blocks (14 irregular)

Fig. 6.5

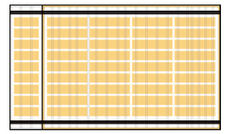
Buoyancy Configurations with an Aisle.



24” Depth: 1405 ft^3
28” Depth: 1615 ft^3
2x6 and 2x8 ft blocks



24” Depth: 1480 ft^3
28” Depth: 1705 ft^3
4x8 ft blocks (9 irregular)



24” Depth: 1460 ft^3
28” Depth: 1675 ft^3
2x8 ft blocks (9 irregular)

Fig. 6.6

Buoyancy Configurations without an Aisle.

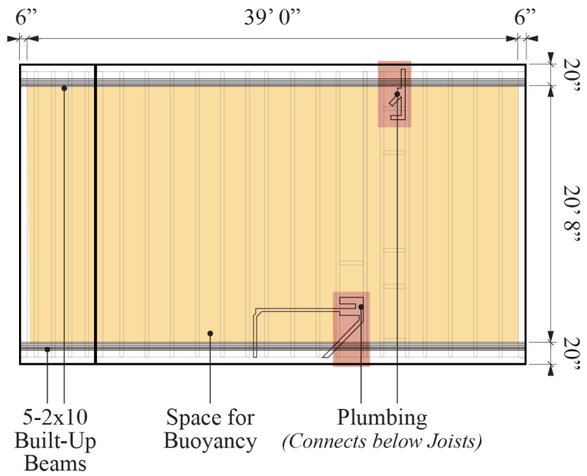
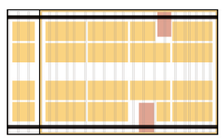
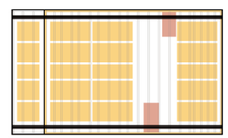


Fig. 6.7

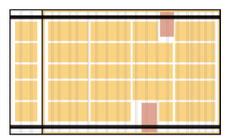
Space available for Buoyancy.



24” Depth: 1200 ft^3
28” Depth: 1400 ft^3
4x8 ft blocks (6 irregular)



24” Depth: 1215 ft^3
28” Depth: 1420 ft^3
4x8 ft blocks (8 irregular)



224” Depth: 1455 ft^3
28” Depth: 1695 ft^3
4x8 ft blocks (11 irregular)

Fig. 6.8

Final Buoyancy Configurations.

An Amphibious Architecture Lexicon

1-in-100-Year Flood

A flood event with a 1% probability of occurring in any given year, based on historical data and statistical modeling.

Amphibiate

A verb to describe installing an amphibious retrofit onto an existing building.

Also: Unamphibiate

The opposite of amphibiate. A verb to describe removing the amphibious elements of a building.

See: Amphibious Retrofit

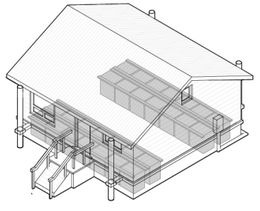
Amphibious Architecture

An innovative construction technique that enables a building, which typically rests on solid ground, to float temporarily during flood or high-water conditions. The structure returns to its original position when the water recedes.

Alternative Terms: Amphibious Building, Amphibious House, Amphibious Structure, Amphibious Construction

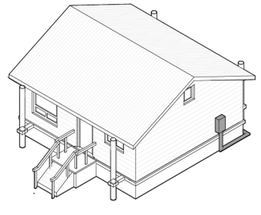
Amphibious Retrofit

Making an existing conventional building into an amphibious building by adding buoyancy elements, guidance posts, and other modifications.



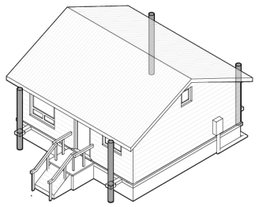
Buoyancy Elements

The buoyant items placed underneath the amphibious building that give it the ability to float: e.g. EPS blocks.



Utility Connections

The manner in which electricity, gas, water and septic/sewer services are provided to an amphibious building.



Vertical Guidance

System that guides the building while floating and prevents excess lateral (side-to-side) movement.

Structural Modification

The floor structure must be supplemented to accommodate the new forces while the building is floating.

Other Components

A barrier to block floating debris or additional guides to centre the house on its foundations may also be required.

Buoyancy Elements

The buoyant items placed underneath the amphibious building that give it the ability to float.

Buoyant Foundation

An amphibious retrofit technique in which buoyancy elements made of foam or another material are installed underneath the building's floor structure. Guidance posts are added and other modifications to the building's foundation and structure may be needed depending on the design of the house being retrofitted. This specific style of amphibious architecture was pioneered by Elizabeth English and the Buoyant Foundation Project.

Flood Mitigation

Strategies and actions designed to reduce or prevent the damage caused by flooding.

Grey Infrastructure

Human-made infrastructure, typically constructed from concrete, steel, and other durable materials, designed to manage environmental challenges. In the context of flooding, this term refers to engineered structures, such as levees, flood walls, and drainage systems, designed to control or manage floodwaters.

Guidance Posts

Structural elements used to guide an amphibious building while it floats during flood or high-water conditions. These posts are typically anchored into the ground and are designed to prevent lateral (side-to-side) movement.

Also: Guidance Post Sleeves

The connection between the amphibious structure and guidance posts. This component transfers lateral forces from the structure to the guidance posts while still allowing for vertical movement.

Mechanically-Elevated Amphibious Building

A type of amphibious architecture where a mechanical system, such as a hydraulic jack, lifts the building. Unlike passive buoyancy-based systems, elevation must be triggered actively by the homeowner or by a sensor that detects rising waters.

Prefabricated Housing

A construction method where houses are built in a factory setting, then transported to the final site for installation and assembly. This reduces on-site labour, speeds construction, and allows for standardized quality, which can make it a cost-effective and efficient type of housing construction.

Also: Ready-to-Move Home

A pre-built house that's fully constructed and finished in a factory, and then transported to its final location in a single piece. This is a subtype of prefabricated housing.

Also: Modular Home

A pre-built house where individual pieces (modules) are constructed in a factory, then transported and assembled on site. This is a subtype of prefabricated housing.

Resilience-in-place

An umbrella term for flood mitigation strategies that reduce flood damage and build capacity for faster recovery after flood events without relocating the flood vulnerable population.

Relocation

Also known as managed retreat. A flood mitigation approach where homes and communities are moved to higher ground or less flood prone areas to avoid flood risk.

Static Elevation

Also called permanent static elevation. Raising a structure to a fixed height above expected flood levels to protect it from flooding.

Utility Connections

The manner in which electricity, gas, water and septic/sewer services are provided to an amphibious building.

Also: Coiled/Flexible Utility Lines

A utility connection made with longer than typical wires or hoses, which remain connected and are long enough to accommodate the movement of the house while floating

Also: Self-Sealing Breakaway Connections

A utility connection with a component that disconnects and seals the disconnected ends when the two sides are pulled apart by the movement of the building.

Also: Manually Disconnected Utilities

A utility connection which can be quickly disconnected by residents e.g. the sewage connections to houses in Old River Landing.