

On Shaky Ground:
An Earthquake Discovery Center for the Pacific Northwest

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Abstract

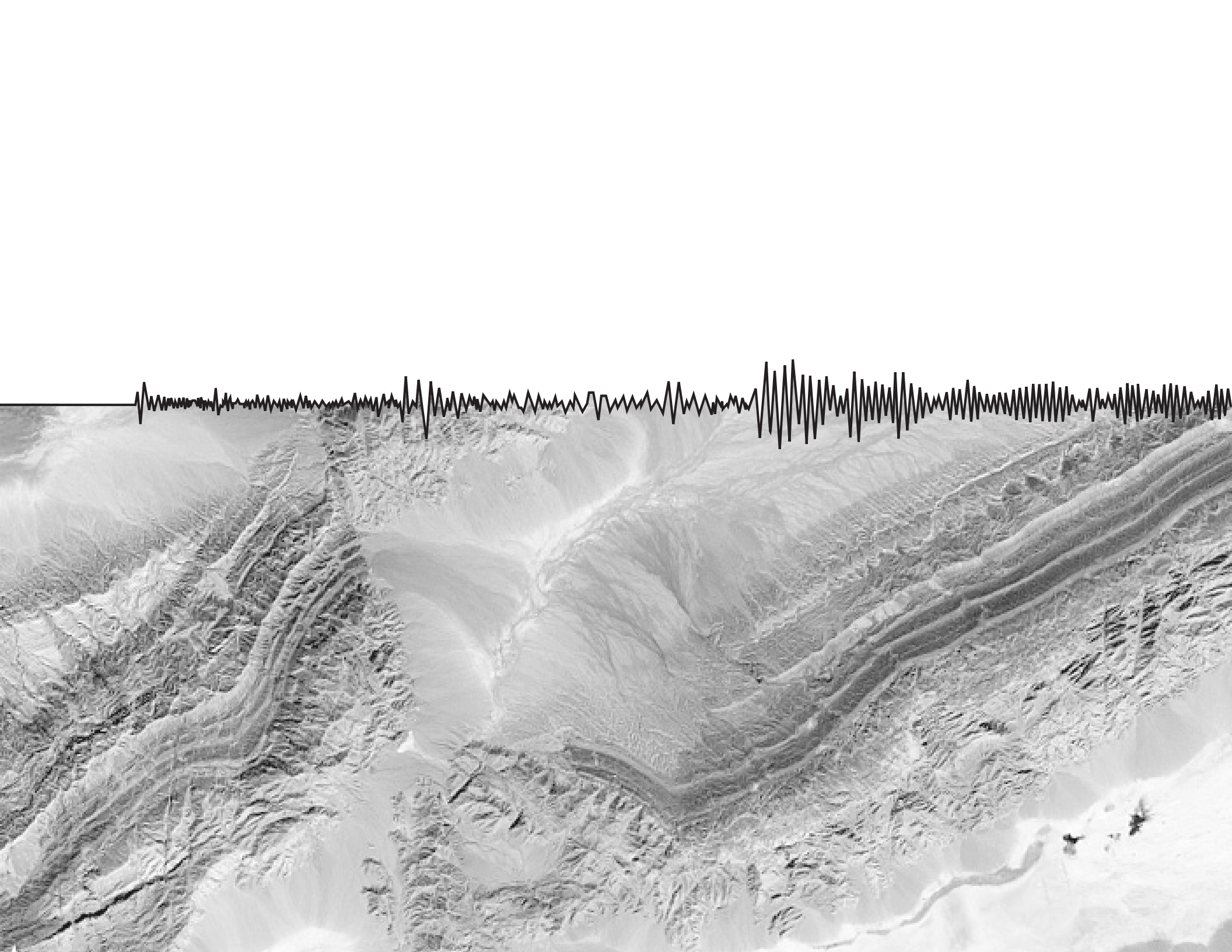
On Shaky Ground: An Earthquake Discovery Center for the Pacific Northwest

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Architecture

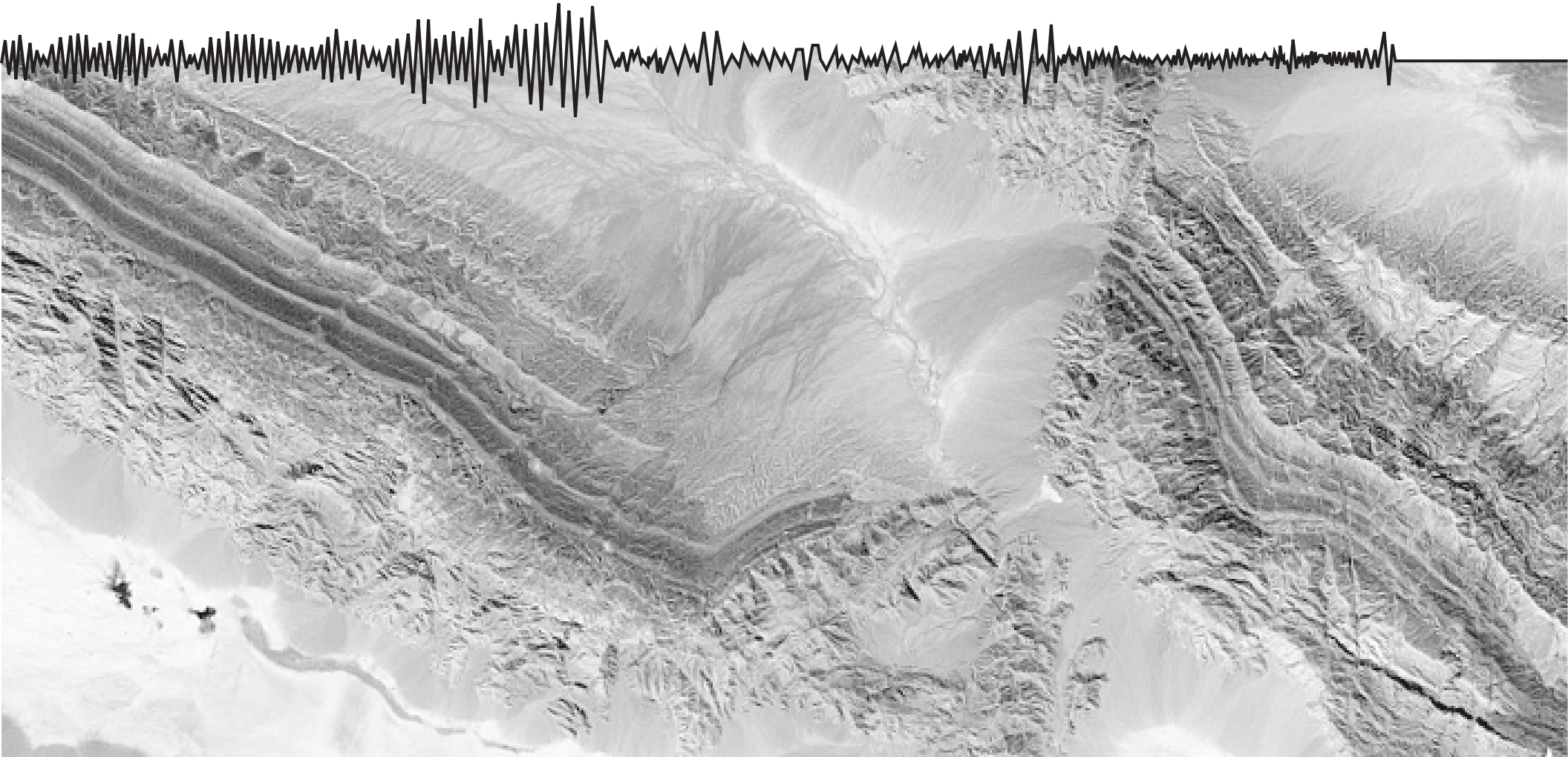
The Pacific Northwest is home to several fault lines which pose a significant threat to a largely unprepared area. The region must address the challenge of designing a resilient architecture in an earthquake prone environment. Buildings should respond to their context to better connect people to their environments and react to the changing seismic landscape in a sustainable way. This thesis will be investigated through a proposal for an earthquake discovery center, an interactive space where locals and tourists alike can come to learn about the unique seismic nature of the landscape in which they reside, as well the associated risks when a large earthquake inevitably strikes.

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ON SHAKY GROUND

An Earthquake Discovery Center for the Pacific Northwest

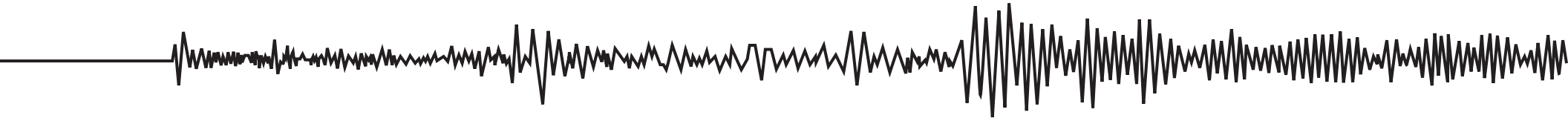


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CHAPTER 1

Introduction



Eathquakes and Nature

In today's urban society it is easy to forget about nature as an unpredictable, destructive force. Of all the natural disasters, our cities are most vulnerable to earthquakes which may be the most alarming of all. They come with no warning but can destroy lives and property. The devastating aftermath of earthquakes have not only physical, but psychological and social implications. Yet, the same tectonic plates which cause the tremors we call earthquakes are also responsible for some of the most spectacular natural features in the Pacific Northwest region. According to geologic theory, these same movements in tectonic plates that are responsible for earthquakes, produced volcanic landforms like Mount Rainier¹. While earthquakes pose a threat to cities across the United States, much of this seismic risk is concentrated on the West Coast.² The region of the Pacific Northwest is home to several fault lines which pose a significant threat to a largely unprepared region. Scientists and civic officials have predicted that the city of Seattle will experience a powerful earthquake in the near future.³

Buildings are typically regarded as shelter which protects its inhabitants. Yet, architecture can pose the largest threat to human life in the case of a seismic event. A common expression among seismologists is that "earthquakes don't kill people, buildings do."⁴ The same structures built by architects, engineers, and contractors can become weapons of devastation during an earthquake, so the responsibility lies with these professionals in the built environment to work to create solutions. When his Imperial Hotel in Tokyo survived a devastating earthquake in 1923, American architect Frank Lloyd Wright famously said, "why fight

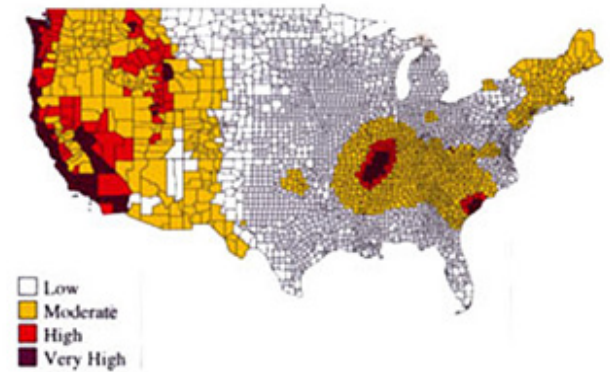


Figure 1 | Seismicity in the United States.

1 "Tectonic Plates, Earthquakes, and Volcanoes." PBS LearningMedia. KCTS9, 2017. Web. Apr. 2017.

2 "Earthquake Early Warning." ShakeAlert. USGS, 2016. Web. Apr. 2017. <<http://www.shakealert.org/>>.

3 City of Seattle. "Hazard Identification." SHIVA – The Seattle Hazard Identification & Vulnerability Analysis. 1. City of Seattle, Office of Emergency Management, 15 Apr. 2014. Web. Apr. 2017.

4 <http://mitigation.eeri.org/files/resources-for-success/00022.pdf>

the quake? Why not sympathize with it and outwit it?”⁵ As Andrew Charleson has argued, it is the architect’s moral responsibility to play a critical part in designing buildings that can “outwit” a quake to protect life safety. Architecture has a unique role to create buildings that not only ensure the safety of its occupants but also to educate and inspire them. Building for resilience against earthquakes acknowledges the imperative to protect the inhabitants from natural disasters but also to strive for a better connection to nature.

Earthquakes can be a difficult topic for the public to discuss, especially in areas like the Pacific Northwest region where they pose a serious threat. However, greater awareness and education can contribute to better preparedness and the potential of a better outcome in the event of a large earthquake. The architect has a unique role in orchestrating the design and engineering of a building to create more structurally stable and inspiring spaces. This kind of architecture can be both aesthetically pleasing and experientially interactive, creating a destination that will attract locals and visitors.

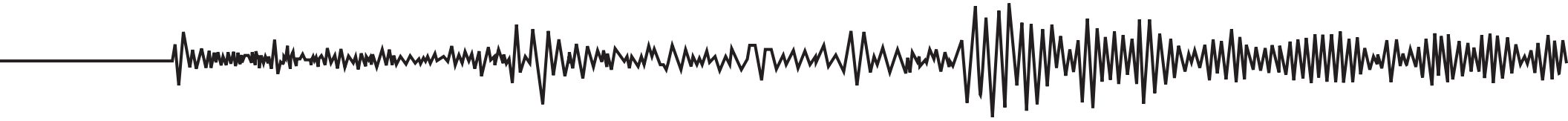
Claim

This thesis will address the challenge of how to design a building that can outwit the quake in an earthquake prone environment. With the recent population growth of the city of Seattle, and the projected future growth of the region, many people are moving to the area or visiting the city with limited knowledge of the associated seismic risks. While the aesthetic benefits of the Pacific Northwest’s natural context are well known in terms of health and leisure, it also brings the risks of natural disasters like earthquakes. Buildings must better respond to their context in order to connect people to their environments. This thesis aims to investigate how architecture can play a role in both educating and engaging the public about the impact of nature on the environment. Designing for resiliency will be studied in relation to how buildings can respond to the changing natural landscape in a sustainable way.

⁵ Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/Architectural, 2008. xiii. Print.

This thesis will be investigated through the proposal for a public earthquake education center, an interactive space where locals and tourists alike can come to learn about the particular seismic context and landscape of which they reside. The project will teach the public about these natural events as expressions of the unique topography, ecosystems, and biodiversity of the Pacific Northwest as well as make them aware of the associated risks when a large earthquake inevitably strikes.

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CHAPTER 2

Literature Review



The Nature of Earthquakes

The city of Seattle is located in a region that has a diversity of natural conditions. Nature in the Pacific Northwest is at the core of the region's identity, permeating the image of place, and supporting diverse recreational activities. However, nature is also a destructive force, capable of altering our built environments in a matter of seconds. During an earthquake, the shaking of the ground puts lateral stress on structures that can cause partial damage and/or collapse. But, in other situations this same movement of tectonic plates can produce positive results, as in the case of a compressive reverse fault in which produces the build-up of a mountain. This process shows how earthquakes are both a part of nature and at the same time have the ability to create nature. The threat of earthquakes is an unavoidable, and often a little discussed reality in the region. Designing for earthquake resilience is a necessity that can both protect against destruction and provide a better connection to place.

The Earthquake

To understand how to design for an earthquake prone region, it is first critical to understand what earthquakes are as a natural occurrence and as a potentially destructive event for human society. Knowledge of their causes, likelihood of occurrence, and impacts all help in better understanding the impact of an earthquake on the built environment.

Earthquakes are caused by the buildup of friction from two tectonic plates moving past one another resulting in a sudden freeing of mechanical energy, expressed in the form of tremors in the earth's crust.⁶ Natural volcanic activity and human-triggered explosions also have the capability to produce earthquakes, however this thesis will focus on ground shaking resulting from the natural movement of the earth's tectonic

⁶ García, Belén. Earthquake Architecture : New Construction Techniques for Earthquake Disaster Prevention. New York: LOFT and HBI : Distributed in U.S. and Canada by Watson-Guption Publications : Distributed throughout the Rest of the World by HarperCollins International, 2000. 8. Print.

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Figure 2 | Nature as an experiential amenity.



Figure 3 | Nature as a destructive force.

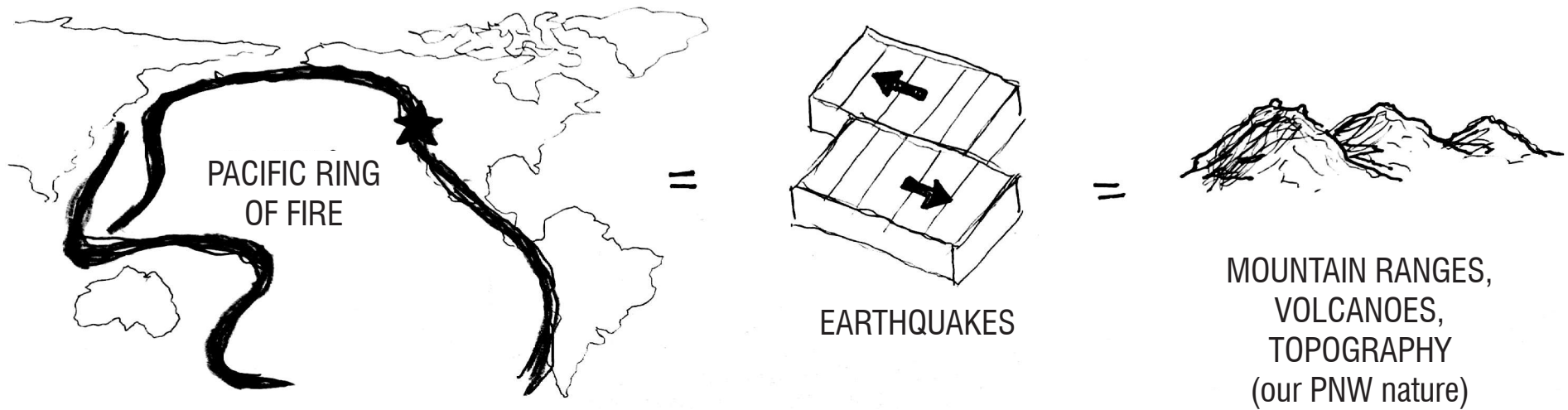


Figure 4 | Relationship between tectonic forces and nature.

plates. While it is almost impossible to predict when and where an earthquake will strike, scientists have identified the areas that have the highest potential to produce earthquakes and their relative range of magnitude. Government authorities define the term “hazard” as the susceptibility of a region to a disaster, whereas “risk” is the combination of hazard and the likelihood of damage and loss of life. In a 2014 vulnerability assessment, the City of Seattle’s Office of Emergency Management reported, “earthquakes are Seattle’s top hazard. No other [disaster] has the combination of likelihood and potential destructiveness.”⁷ The seismic risk of Seattle is high due to the location of fault lines beneath the earth’s surface and the extent of vulnerable building types in densely populated urban areas. The intensity and type of motion resulting from an earthquake, the preparedness of a region, and the time of day an earthquake occurs, all factor in to the outcome of a seismic event. While the timing and intensity of earthquakes cannot be controlled, the outcome can be influenced through the preparation and response of communities. The built environment plays a major role as well, in minimizing damage to physical structures and harm to people.

⁷ City of Seattle. “Hazard Identification.” SHIVA – The Seattle Hazard Identification & Vulnerability Analysis. 13. City of Seattle, Office of Emergency Management, 15 Apr. 2014. Web. Apr. 2017.

Earthquakes are typically measured by a seismograph network on the Moment and Magnitude Scale⁸.

The scale logarithmically measures the shaking of a seismic event and places it on a numerical scale ranging from 0-10 called the magnitude. Intensity is the measure of shaking and damage caused by an earthquake. The Mercalli intensity scale is a qualitative and quantitative method developed in 1931 to assess the severity of an earthquake based on shaking and damage. The numeric scale ranges from I-XII, measuring from not felt at all up to total destruction.⁹

INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
Shaking	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Damage	None	None	None	Very slight	Light	Moderate	Moderate/ heavy	Heavy	Very heavy
Peak Acc	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
Peak Vel	<0.1	0.1- 1.1	1.1- 3.4	3.4- 8.1	8.1- 16	16 - 31	31- 60	60-116	>116

Peak Acc = Peak ground acceleration (g), Peak Vel = Peak ground velocity (cm/s)

Figure 5 | The Mercalli intensity scale.

Types of Earthquakes

The shaking that occurs from an earthquake is dependent on the type of event and location of its epicenter. There are three types of earthquakes that occur in the Seattle area.¹⁰

1. Crustal / Shallow Quakes

Crustal or shallow earthquakes occur within 30 km of the crust's surface and result in intense shaking that diminishes quickly relative to distance. A shallow quake on the Seattle fault poses the greatest risk to the

⁸ Spence, William, Stuart A. Sipkin, and George L. Choy. "Measuring the Size of an Earthquake." U.S. Geological Survey. USGS. Web. Apr. 2017.

⁹ García, Belén. *Earthquake Architecture : New Construction Techniques for Earthquake Disaster Prevention*. New York: LOFT and HBI : Distributed in U.S. and Canada by Watson-Guption Publications : Distributed throughout the Rest of the World by HarperCollins International, 2000. 8-9. Print.

¹⁰ City of Seattle. "Hazard Identification." SHIVA – The Seattle Hazard Identification & Vulnerability Analysis. 1. City of Seattle, Office of Emergency Management, 15 Apr. 2014. Web. Apr. 2017.

urban Seattle region. These shallow quakes occur every 500 years or so on average and can cause tsunamis within Puget Sound. The City of Seattle reports that “a Seattle Fault quake could be as large as magnitude 7.5, but less than 7.0 is more probable.”¹¹

2. Intraplate / Deep Quakes

Intraplate or deep earthquakes are the most common in the Pacific Northwest and they are typically the least damaging because they occur 30-70 km deep in the oceanic crust. A magnitude 6.0 or greater deep earthquake event occurs about every 30 to 50 years in the region.

3. Subduction Zone / Megathrust Quakes

Subduction or megathrust earthquakes are the largest type of seismic event in the world. A subduction zone occurs at plate boundaries when one tectonic plate is forced under the other. These events occur every 200 to 1,100 years.¹² By better understanding these types of earthquakes as seismic events, the impact of the built environment can be better predicted. In this way, more resistant architecture can be designed by basing it on metrics that accurately reflect the region’s risk.

Earthquake Sources

Fault lines are a joint within the crust of the earth’s tectonic plates. Earthquakes primarily occur as a result from stress released along these faults where the plates are moving against one another in different directions or at different rates. Stress builds up as tectonic plates move past one another, and when the friction along the fault prevents the plates from smoothly moving past one another. The stress will eventually exceed the limit, causing a violent slip between the plates resulting in an earthquake. While there are different types of fault lines, all result in an earthquake.

¹¹ “Seattle Hazard Explorer.” Seattlecitygis.maps.arcgis.com. City of Seattle. Web. Apr. 2017.

¹² City of Seattle. “Hazard Identification.” SHIVA – The Seattle Hazard Identification & Vulnerability Analysis. 84. City of Seattle, Office of Emergency Management, 15 Apr. 2014. Web. Apr. 2017.

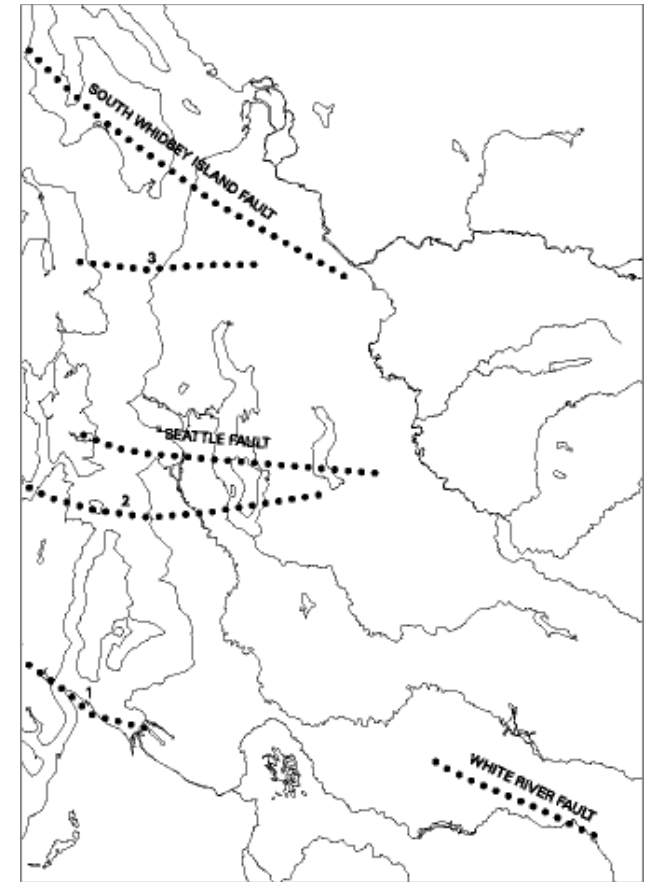


Figure 6 | Shallow faults mapped over the greater Seattle Area.

81% of the largest earthquakes have occurred along the perimeter of the Pacific Plate, commonly known as the “Ring of Fire,” on which the Pacific Northwest resides.¹³ Additionally, Seattle experiences seismic events due to three distinct ground conditions in the region¹⁴. These include:

1. The Cascadia Subduction Zone –

These subduction zone earthquakes result from the Juan de Fuca plate moving under the North American Plate.

2. Juan de Fuca plate –

Deep earthquakes resulting from friction relating to the Juan de Fuca plate.

3. Crustal Faults (such as the Seattle Fault, Tacoma, South Whidbey Island, and Olympia Faults) –

Shallow earthquakes resulting from friction in the crustal faults closer to the surface of the earth.

Process of an Earthquake

This knowledge of the process of an earthquake is relevant to architectural design in terms of its physical and social impact. The different types of shaking that occur are affected by ground conditions. The side to side shaking along with the up and down shaking at various frequencies damages a building in different ways. Understanding the additional forces that will be put on a structure is essential to understanding how it will respond to different forces. These conditions can be addressed in the architectural design through siting, form, and the integration of laterally resistant structure.

An earthquake is an event that unfolds in time and space, the process occurring in multiple stages.

The first vibration that is released is the fast-moving P-wave that originates from the quake’s epicenter. While typically not causing much damage, this first wave is what early warning systems use to identify when an

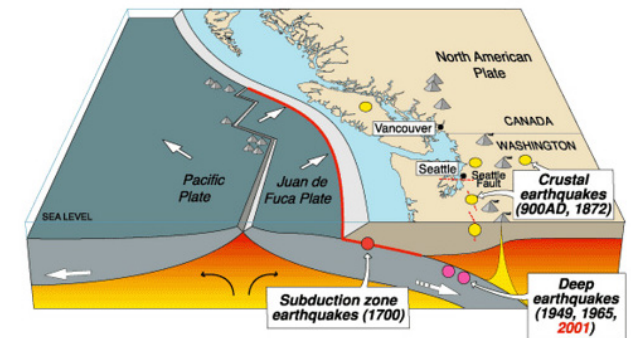
¹³ García, Belén. *Earthquake Architecture : New Construction Techniques for Earthquake Disaster Prevention*. New York: LOFT and HBI : Distributed in U.S. and Canada by Watson-Guption Publications : Distributed throughout the Rest of the World by HarperCollins International, 2000. 9. Print.

¹⁴ “Seattle Hazard Explorer.” Seattlecitygis.maps.arcgis.com. City of Seattle. Web. Apr. 2017.

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Cascadia earthquake sources



Source	Affected area	Max. Size	Recurrence
● Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
● Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
● Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?

Figure 7 | Types of faults found in the Pacific Northwest.

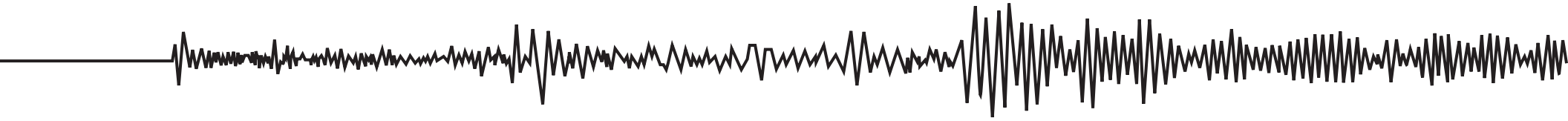


Figure 8 | Seattle’s seismic risk primarily comes from the Cascadia Subduction zone off of the West Coast (left), and the localized Seattle fault which crosses under downtown Seattle (right).

earthquake strikes. Afterwards slower shearing S-waves arrive, that move side to side and more slowly than the initial P-wave. Surface waves arrive last in the form of Rayleigh waves and Love waves. Rayleigh waves are the most architecturally damaging because, they slow down over time and increase in size while moving the ground up and down. Love waves are fast and move the ground from side to side. When earthquake waves hit softer ground, they also slow down and can increase in size by as much as 2 to 6 times compared to when they travel through bedrock.¹⁵

In learning about the process of an earthquake, there is an understanding that these tectonic movements are part of the everyday movement of the earth and nature. In the event of an earthquake, the earth's movement can become a destructive force. We must understand that it is a natural process and is a phenomenon we must become resilient to in our built environments and communities.

¹⁵ Lorant, Gabor. "Seismic Design Principles." WBDG Whole Building Design Guide. National Institute of Building Sciences, 11 Oct. 2016. Web. June 2017.



CHAPTER 3

Seismic Design in Architecture



Seismic Design in Architecture: Physical

The dynamic flowing forces of an earthquake can wreak much damage on the fixed forms of the built environment. Built at a time when there was much less knowledge of earthquakes, these structures are more likely to fail in a seismic event. These building types are vulnerable due to either their building materials or structural system. Therefore, it is particularly important to be aware of these structures especially when they are candidates for reuse and retrofit, (figure 10).

1. **Unreinforced masonry buildings**
2. **Soft story buildings**
3. **Pre-1976 concrete buildings**

Vulnerable Ground Conditions

In addition to these vulnerable types of structures, it is important to also identify the different ground conditions. For example, building on bedrock is desired for stability as opposed to sloppy sediment. A building must not only have resilient materials but be properly tied to its foundation to maintain its integrity.

The underlying geology of the ground contributes to risks such as liquefaction. This occurs when the structural property of the ground changes during the shaking of an earthquake. The water saturated ground of sand, silt, and gravel settlements becomes unstable, acting as a fluid rather than a solid and becomes unable to safely support the structures above it. This process of liquefaction of the “solid ground” makes it difficult to design stable structures. As seen in figure 9, the city of Seattle’s Emergency Management sector has mapped the zones in Seattle that are at risk to liquefaction.

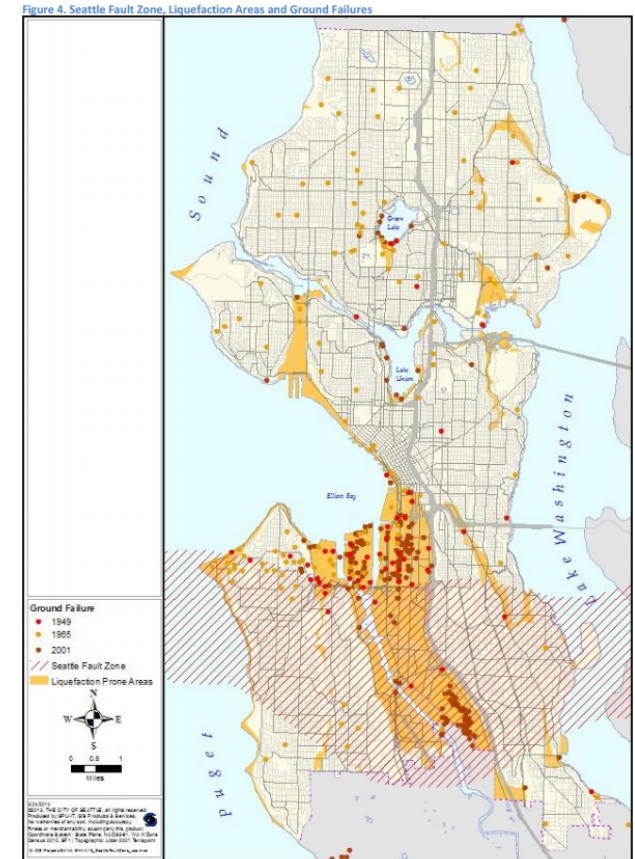


Figure 9 | Liquefaction hazard map of the city of Seattle.

Vulnerable Building Types



- 1. Unreinforced masonry buildings**
Over 1150 URMS in Seattle



- 2. Soft story buildings**
Vulnerable residential typology

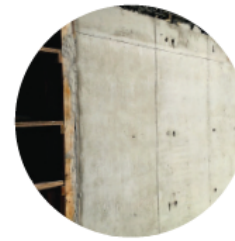


- 3. Pre-1976 concrete**
Non-ductile concrete

Structural Solutions



- 1. Diaphragms**



- 2. Braced Frame / Moment-Resistant Frames**



- 3. Shear Wall**

- 4. Reinforcement**

- 5. Base Isolation**



- 6. Energy-Dissipating Devices**

SOURCES:

- National Institute of Building Sciences, Seismic Design Principles

Figure 10 | Vulnerable building types with possible seismic solutions.

Design Guidelines

Understanding the impact of earthquakes on the built environment is essential to understanding how architecture can respond. Architecture professor and structural engineer Andrew Charleson states that the goals of seismic resistant design are architecture that protects human lives and limits building damage.¹⁶ He emphasizes that the integration and manipulation of structure within architectural design has the ability to create powerful spaces.

Structure is an indispensable architectural element imbued with the possibility of enhancing architectural functions and qualities. For example, appropriately designed structure can articulate entry into a building and celebrate interior circulation. It can create spaces and provide opportunities for aesthetic delight.¹⁷

Seismic design, therefore, must place an emphasis on the underlying structure of a building. This is done through the use of a primary horizontal structure and a primary vertical one. A secondary structure can be used for additional strength and to support non-structural elements. But as Charleson argues, the proper integration of the structure can result in more aesthetically pleasing spaces.

Though the architect is not primarily responsible for engineering the structure, it is important they have a basic understanding of how these elements work in order to incorporate them into the design. In The primary vertical structure must provide areas for continuous vertical elements that extend from the foundation to the roof. Options for a primary vertical structure include shear walls, braced frames, and moment frames.¹⁸ Each option has benefits and drawbacks which must be weighed against the intention for the architectural space.



Figure 11 | Structure demonstrating a more technical approach, implementing appropriate structural responses.

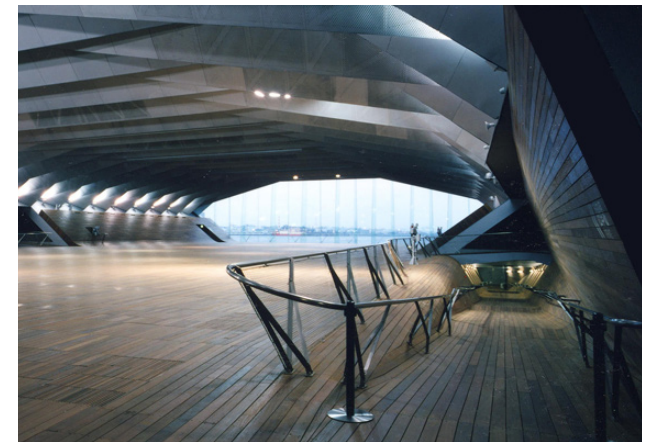


Figure 12 | Structure demonstrating a more conceptual, poetic approach of expression.

¹⁶ Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/ Architectural, 2008. 39. Print.

¹⁷ Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/ Architectural, 2008. xi. Print.

¹⁸ Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/ Architectural, 2008. 267. Print.

1. Shear Walls

A shear wall is a structural wall that is made to resist side to side shearing from horizontal forces.¹⁹ This solid type of wall is structurally the best choice for seismic resistance and should be the first consideration for a seismic design solution. Materials used in the construction of shear walls vary, but most commonly reinforced concrete or wood is used, though other options like steel plate walls are also possible. The effectiveness of the wall is dependent on its length so that the longer it is, the more stability it can provide, and is typically designed to be continuous through the entire height of the building. However, this wall is solid, so no major openings can be designed in areas which utilize a shear wall, meaning other structural options may be more appropriate for certain spaces.

2. Braced Frames

Braced frames are pin-jointed triangulated frames which utilize either tension or compression by using diagonal members to provide lateral stability.²⁰ These vertical frames are typically made from steel, though using wood or reinforced concrete is also possible. The architectural advantage of a braced frame is its transparency and ability to be placed in openings. The braced frame can prove to be a cost-effective option when compared to other structural methods because of the minimal material it uses in comparison to its strength ratio. A drawback for some designers is the diagonal aesthetic of a braced frame, though others embrace its triangulated appearance.

3. Moment Frames

Moment-resisting frames are a type of open structural frame which is rigidly connected at its corners.²¹

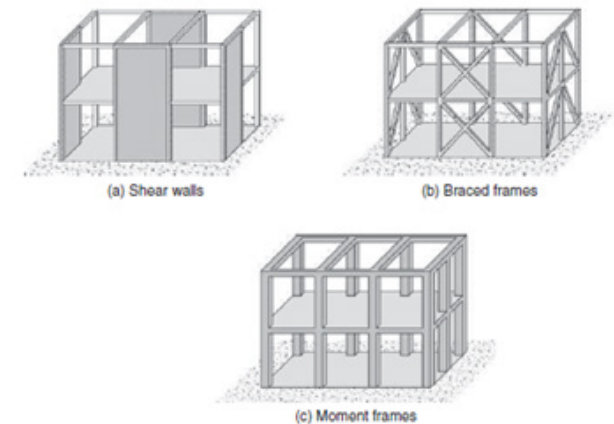
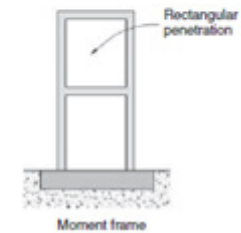
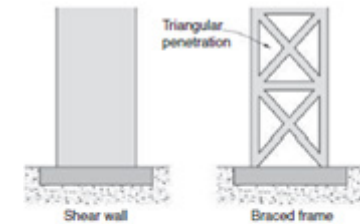


Figure 13 | The three basic seismic force resisting systems.

¹⁹ Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/ Architectural, 2008. 66-75. Print.

²⁰ Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/ Architectural, 2008. 76-80. Print.

²¹ Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/ Architectural, 2008. 81-89. Print.

These frames require deep columns to resist significant bending, beams and columns with similar depths, and rigid connections between the beams and columns to transfer forces. Like shear walls the frame's effectiveness is dependent on its length, based on the appropriate ratio for the member size to the length spanned. Like braced frames, moment frames are typically constructed from steel members. Moment frames visually take on the appearance of a thick frame, which can be completely hidden by interior finishes. They offer a minimal footprint with limited visible structural disruptions, making it a popular option for many designers. However, moment frames are an expensive option that are difficult to construct properly. The success of the frame relies on accurate detailing, and very high standards for the structural design and its construction.

In addition to a vertical seismic resisting system, a horizontal seismic resisting structure is also required. This horizontal system ties structural components together to create a seismic source path, or a path in which forces can be channeled downward through the building to the ground.²² The system also makes the building components move as one, so no differential movement between components can cause breakage. The primary horizontal structure is typically integrated into the floor and ceiling; so, it is not visually perceived in the same way as vertical seismic elements. When resisting lateral forces instead of just gravitational forces, the horizontal structure acts as a diaphragm or a beam that directs forces. A diaphragm is essentially a beam that acts horizontally and has a force path. The horizontal system must fully attach with the primary vertical system in order to work properly. Therefore, architectural openings and areas of floor penetration must be designed accordingly.

²² Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/ Architectural, 2008. 49-61. Print.

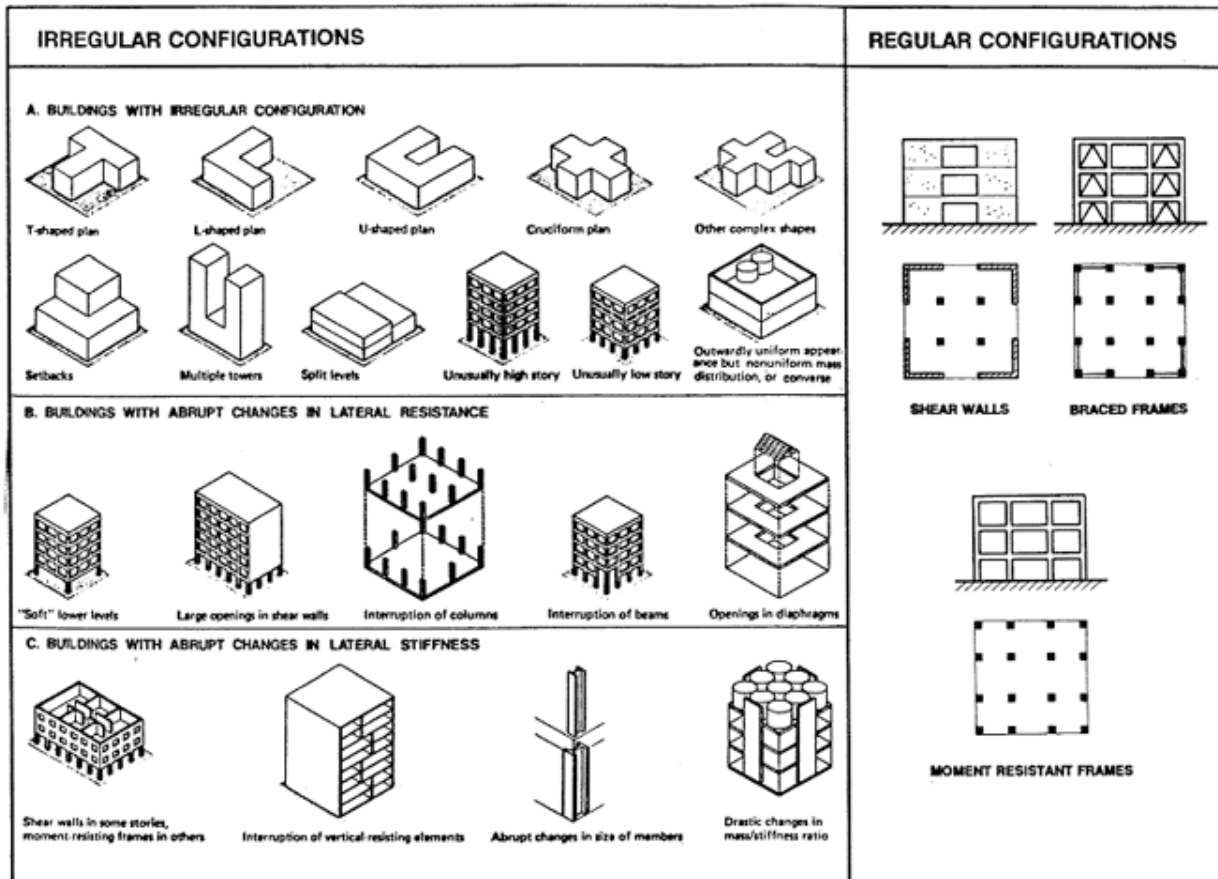


Figure 14 | Irregular and regular building configurations.

The configuration of the building also plays a major role in seismic performance.²³ Regular configurations perform best, but where irregular forms are used, seismic gaps can improve performance. Because the architect is typically responsible for a building's massing and layout, it is vital they understand that the configuration of a building can affect its seismic performance.

²³ Charleson, Andrew. *Seismic Design for Architects : Outwitting the Quake*. 1st ed. Amsterdam ; Boston ; London: Elsevier/ Architectural, 2008. 125-133. Print.

Seismic Design in Architecture: Social

Community

Earthquakes are not just a physical event but also a social one. Human perception of seismic risks plays a large role in how society prepares and responds to these events. Being aware of the ever-present hazards of earthquakes is one way to build for resilience in the built environment. More importantly, fostering a sense of community also builds for resilience by creating a social network in which people can aid one another in the event of a disaster. In this aim, Community Emergency Hubs is a program by the Emergency Management branch of the City of Seattle that is intended to “empower individuals through training, developing connection among neighbors and supporting community response efforts.”²⁴ In the proposed design of an education center, a community component must be included to fully integrate the building into its local neighborhood. As the public becomes more socially aware about earthquakes, communities can also choose to invest into seismic resistant infrastructures. By adding an outreach element such as a disaster preparedness kit distribution center, or earthquake simulation activities for schools, the building will be more successfully connected to the life of city residents.

Environment

The idea of resilience can also manifest itself in architecture by using passive sustainable systems that tap into the the flows of nature. Making use of existing environmental systems can increase the resilience of a building by enabling it to become less dependent on existing urban infrastructure. As stated in the LA Earthquake Source Book, “sustainability means that a locality can tolerate—and overcome—damage, diminished productivity, and reduced quality of life from an earthquake without significant outside assistance.”²⁵

²⁴ Seattle.gov. “Working Together Community Involvement.” Emergency Management. City of Seattle. Web. Apr. 2017.

²⁵ Koshalek, Richard, and Mariana Amatullo, comps. The L.A. Earthquake Sourcebook. 2008. 163. Art Center College of Design, 2008. Web. Apr. 2017.



Figure 15 | Community resilience.



Figure 16 | Responding to nature.

Other manifestations of resilient design would be to connect the building to outdoor spaces in order to emphasize its relationship (and by extension the community's relationship) with the landscape. Providing views to the outdoors is crucial to the education component of the building. The center is meant to instruct the community on how the landscape is both created and destroyed by the same forces of nature, meaning connections to the outside are essential. Creating a relationship between the exterior environment and the interior built environment promotes psychological well-being, fosters a sense of place, and generally creates a more pleasing space to inhabit.

Current seismic design often focuses just on structural issues rather than incorporating this into the architectural design. Architecture must demonstrate the opportunities within this integration. Resiliency does not have to be a kind of defensive response but can be an opportunity to work with earthquakes and natural forces.

Precedents

This thesis investigates three precedents of architectural projects that bring together the functions of education and engagement in buildings that push boundaries by integrating structural and aesthetic approaches to design.

Pierce County Environmental Services Building

The Pierce County Environmental Services Building is located on the waterfront in Pierce County, Washington and houses the county's public works employees.²⁶ The structure was completed in 2002 by the architecture firm Miller Hull. Consistent with the aims of this thesis, the Environmental Services building has a strong relationship to its site as well as including an education and outreach component in its program.

The project prioritizes views and daylight to turn a brownfield site project into a well-received community building where locals come to use the building as a wedding and event venue. The success of the



Figure 17 | The exterior of the Pierce County Environmental Services Building with view of Mount Rainier behind.

²⁶ Miller Hull Partnership. "Pierce County Environmental Services Building." Miller Hull. Web. Apr. 2017.

public reception of this building can be attributed to siting and massing, along with its integration of structural and environmental elements. The building is oriented in a north/south direction to maximize views out to the water on the west side and landscape views on the east. A deep overhang on the west side to reduce glare and direct afternoon sun on task surfaces while maintaining exterior views. On the east exterior, tightly planted poplar trees are arranged in a grid to shade and manage most early morning sunlight. The planted grid also enables sightlines to be kept out to the landscape. Additionally, daylight is prioritized in the interior. The width of the interior floor plate of the building is kept relatively thin to allow for daylight penetration and the use of translucent materials such as Kalwall helps fill the building with diffuse light. The building utilizes four concrete shear cores as the primary lateral structure of the building. Each core element has a skylight to one side, allowing the interior to be light washed from above.²⁷ This integration of natural daylight coupled with the lateral rigidity of the concrete walls transcends basic functions to create an expressive interior space. The architectural manipulation of the shear core elements allows the building to play with natural light enabling a spatial and aesthetic connection to the environment.

Sendai Mediatheque

Sendai Mediatheque is a library building in Sendai, Japan that survived the 9.0 Tohoku earthquake in 2011 with minimal damage. The building was designed by Toyo Ito in 1995 and opened in 2011. The primary structural strategy of the building lies in its thirteen twisted columns that extend from the basement to the roof. These steel structural tubes serve as both the primary seismic framework but also serve as an architectural expression in their twisted tubular form. These tubes serve both a practical and poetic function, used as a way to run services, ventilation and daylight through the structure. At the same time according to the architect, they are meant to represent seaweed swaying under the water. This structural feature unites the seven-story building



Figure 18 | The interior shear wall of the Pierce County Environmental Services Building with light washing.

²⁷ Meek, Christopher. "Sidelighting Design." Daylighting. University of Washington, Seattle. 25 Apr. 2017. Lecture.

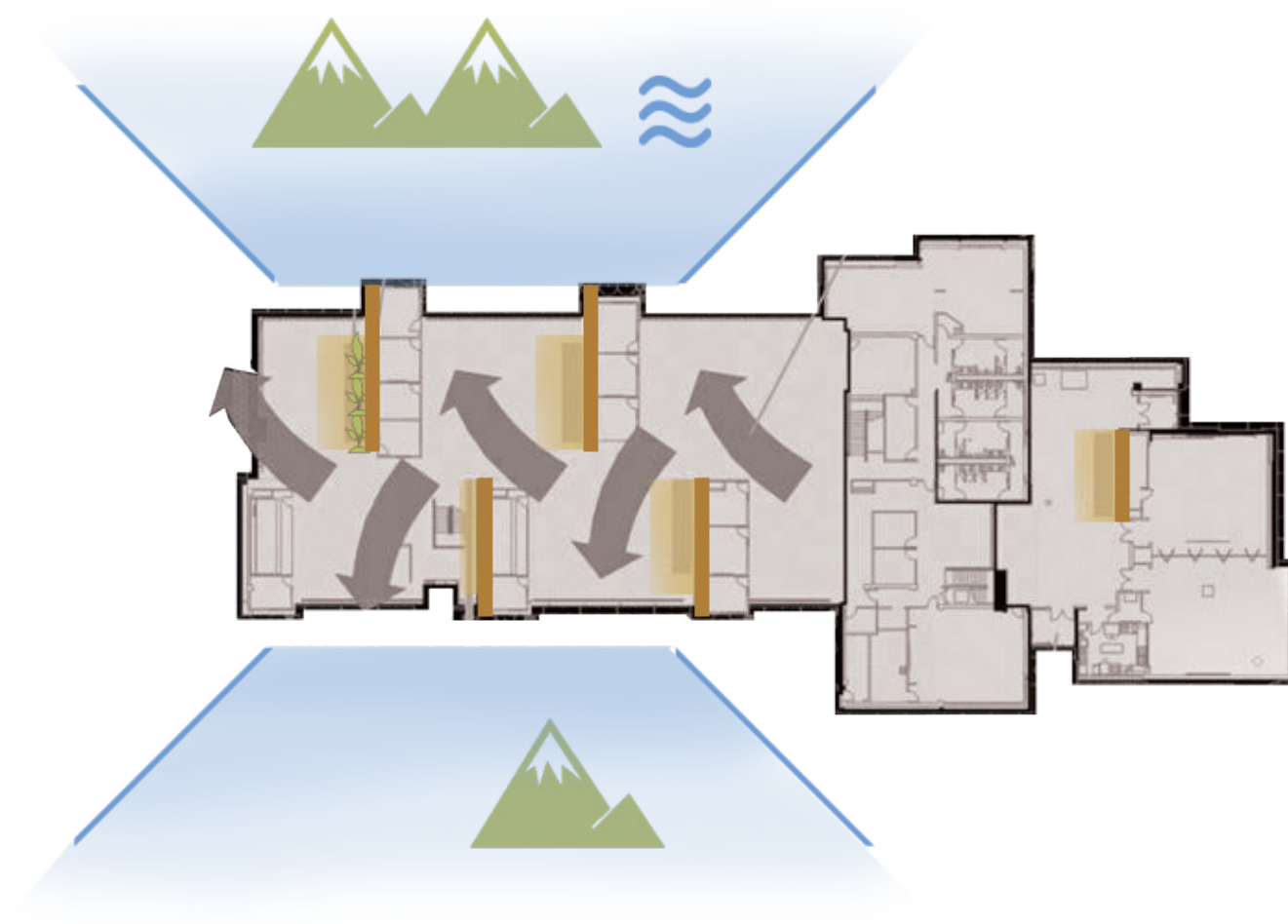


Figure 19 | The shear cores of the Pierce County Environmental Services Building are highlighted above along with key views.

as one mass. Vertical connections, like the elevators and stairways, are also located in these steel shafts which become both the utility and the artistry of the building.²⁸

The exterior of Sendai is predominately glazed to showcase the tubular structure within and to allow for daylight penetration. The steel honeycomb floor slabs are also visible on the exterior façade of the library. Each direction of the façade responds to the environmental demands of that side. For example, the south façade uses a double skin system to reduce summer heat gain, whereas the west side faces a neighboring lot and is rendered opaque to maintain privacy as a response to its context.

Blurring spatial boundaries, Sendai Mediatheque “features slabs and vertical tubes as its fundamental, and almost only, structural elements, creating spaces that . . . do not define the use of enclosed spaces, rather allowing its users to define [the building] organically.”²⁹ The lateral structure depends on a combination of rigid welded connections between the tubes and plates, as well as a damper mechanism in the first floor of the basement below. This mechanism transfers seismic energy to the ductile shafts, which minimizes lateral forces on the tubes above grade³⁰. Additionally, the foundation utilizes a flat slab below grade. The integration of spatial organization and seismic support allows Sendai Mediatheque to combine structural stability with conceptual vision.

Pocono Environmental Education Center

The Pocono Environmental Education Center is a visitor center in Dingmans Ferry, Pennsylvania which promotes environmental stewardship and education.³¹ The building was designed by the architecture firm Bohlin Cywinski Jackson and completed in 2005.

28 “Specifications.” Sendai Mediatheque | Architecture Specifications. Sendai Mediatheque, 2014. Web. Apr. 2017.

29 “Specifications.” Sendai Mediatheque | Architecture Specifications. Sendai Mediatheque, 2014. Web. Apr. 2017.

30 Wong, Jennifer, Lisa Teters, Regina Stamatiou, Georgina Davis, and Stephanie Fleming. Sendai Mediatheque. Crypt, 2011. Structural Analysis. Texas A&M University. Web. Apr. 2017.

31 “Pocono Environmental Education Center.” AIA Top Ten. The American Institute of Architects, 2005. Web. Apr. 2017.

ON SHAKY GROUND



Figure 20 | Exterior of Sendai Mediatheque.

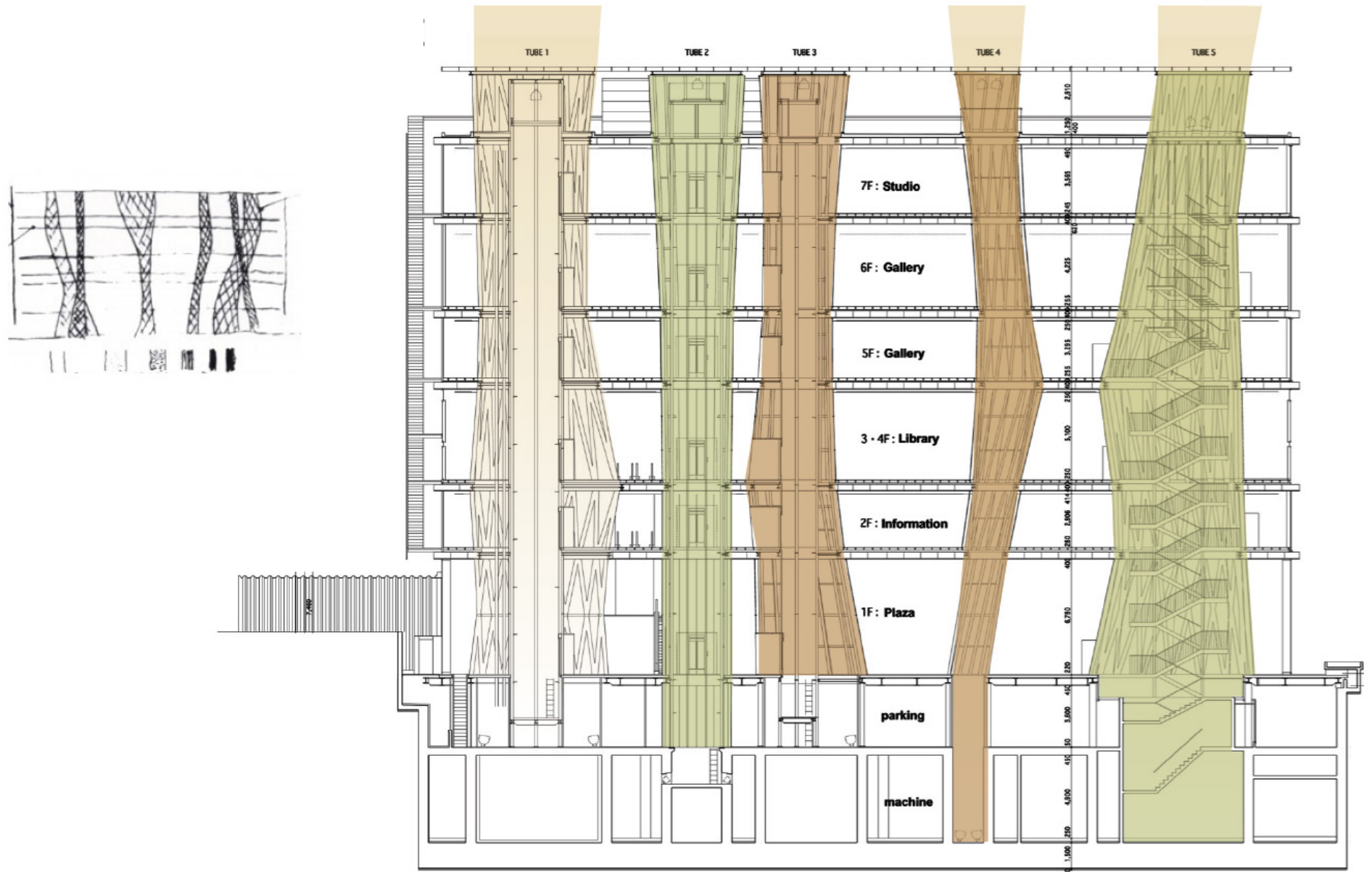


Figure 21 | Section of Sendai Mediatheque.

The Environmental Center resides along a hiking trail in a forested area on top of the Pocono Plateau. The building is meant to be used to educate its visitors. In order to “use the building as a teaching tool, manual devices rather than automated systems were selected to control natural ventilation and artificial lighting so that the users, mostly small children, would become part of the process of making energy choices and learn about green design.”³² Upon approach the north side of the building features a recycled tire wall, while the main activity area on the south façade opens into a tall glazed space with an expansive view onto the landscape. This activity area typically serves as the center’s dining hall and is predominately daylit. The deep overhang on the south side was designed to allow the low angle of the winter sun to passively heat the building, yet block most of the high angle summer sun. Passive solar heating and natural ventilation help regulate the building’s internal temperature by using sustainable methods. Passive ventilation strategies are employed in low operable windows to draw in fresh air and high windows on the south façade to exhaust warm summer air out of the building. Energy efficient insulation additionally assists the building regulate its temperature.³³

In addition to these environmental strategies the Pocono Environmental Center also integrates its structure with its form, the exposed wooden structure and frame become an integral part of the building’s architectural expression. Materials were chosen for the durability and longevity, as well as for their “...ability to serve as visible examples of environmental design, enhancing the building’s mission as a teaching tool for its users.”³⁴

32 “Pocono Environmental Education and Visitor Center.” Building Catalog: Case Studies of High Performance Buildings. U.S. Department of Energy. Web. May 2017. <<https://buildingdata.energy.gov/project/pocono-environmental-education-and-visitor-center>>.

33 “Facilities.” PEEC. Pocono Environmental Education Center, 2014. Web. May 2017. <<http://www.peec.org/about/facilities>>.

34 “Pocono Environmental Education Center.” AIA Top Ten. The American Institute of Architects, 2005. Web. Apr. 2017.

ON SHAKY GROUND



Figure 22 | Exterior of the Pocono Environmental Education Center.

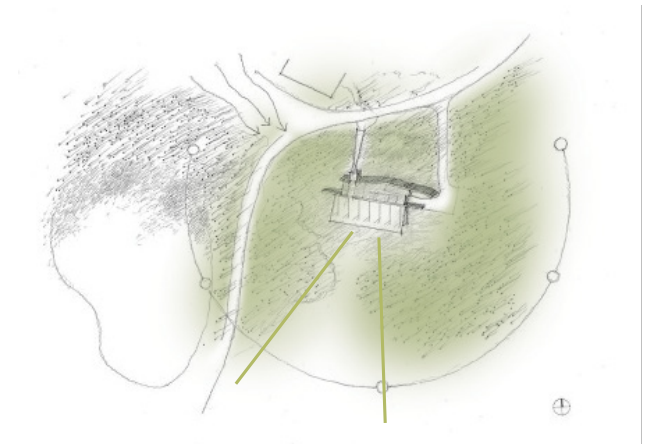
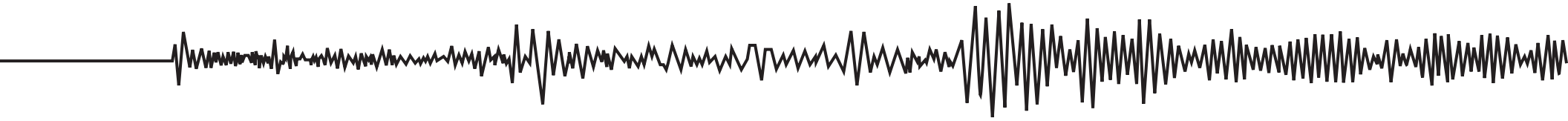


Figure 23 | Site plan responding to its landscape and surroundings in the way that the building is oriented and the specific views which it frames.

The Pierce County Environmental Services Building, the Sendai Mediatheque building, and the Ponoco Environmental Education Center all advance their architectural aims of engagement in the spaces while fulfilling needs of stability and practicality. This thesis similarly seeks to demonstrate how it is possible to produce buildings that educate and inspire the people who visit and inhabit them. This thesis will take lessons from the three types of responses in the case studies, and apply the structural and organizational strategies to the program.



Figure 24 | Interior experience of the Pocono Environmental Education Center.



CHAPTER 4

Methodology



Thesis Goals and Objectives

This thesis argues that architecture can play a role in educating the public about the phenomenon of earthquakes. The design for an Earthquake Discovery Center will serve as a teaching tool that emphasizes research and public awareness. The physical structure of the building will address issues of seismic design appropriate to the region in order to increase its resiliency. But at the same time the design will take its cues from the context to forge a more poetic connection with nature. Thus, this thesis proposes that architecture can provide an appropriate technical response to this natural phenomenon, and at the same time achieve a spatial integration with the environment. The proposed Earthquake Discovery Center will educate and engage visitors and local residents in the nature of earthquakes as threat and natural wonder. Following from the analysis of the precedents, the methodology now turns to the selection of site and development of program. The siting of the project and the development of program spaces must respond to the specific tectonic risks of Seattle and to the natural environment.

Site Selection and Analysis

The choice of a site for this thesis project must take into account proximity to areas of seismic risk and to natural landforms in the Seattle area. There are several geographic and demographic factors to consider in choosing a site. These factors include the location of tectonic landforms, (such as Mount Rainier, the Olympic Mountains, and the Cascade Range), the location of active fault lines such as the Seattle Fault, ground conditions such as liquefaction and landslide risk areas, the location of vulnerable buildings like unreinforced masonry structures, and finally population density.

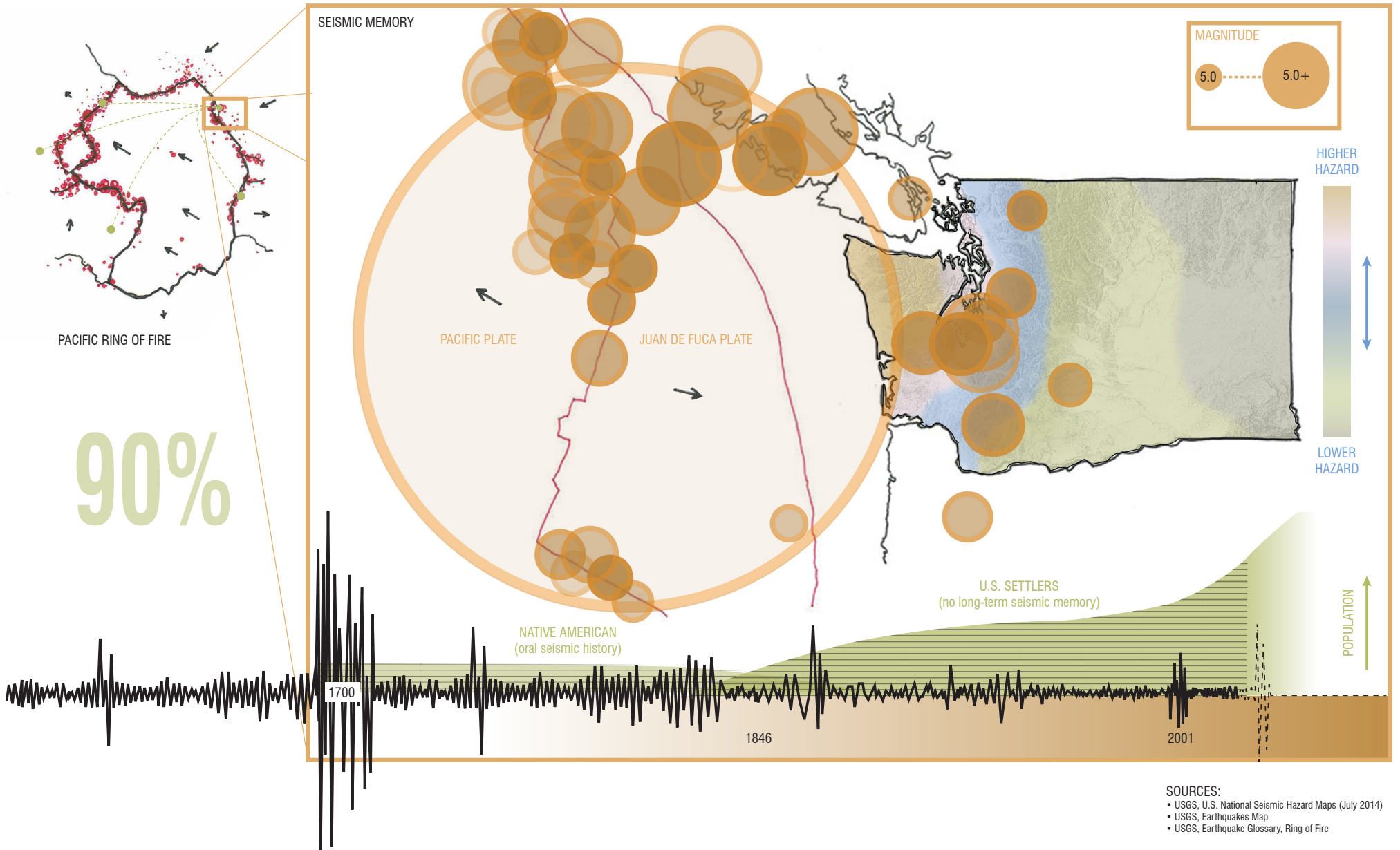


Figure 25 | The Pacific Northwest is located along the ring of fire. This zone surrounding the Pacific Ocean is responsible about 90% of the world's earthquakes, and also houses some of the largest seismic research centers. This diagram maps earthquakes over time as seismic memory. The larger the dot is, the larger magnitude of the earthquake was. And the lighter the dot, the further back in time the earthquake occurred. For example, the largest faint dot above represents the last major Cascadia Subduction zone earthquake from 1700, which was about a magnitude 9.0. On the lower graph, seismic activity is graphed over time alongside population. So previously when Washington was inhabited primarily by native tribes, there was a tradition of oral seismic history where the stories of these earthquakes were passed along, but once U.S. settlers came to the region, much of this seismic memory was lost and forgotten.

The thesis will now map the layers of earthquake risk in the Seattle area to understand the comprehensive tectonic situation of the city. First the major geological forms surrounding the Seattle area are mapped, as seen in figure 26, to understand the dominance of the natural context in the area. The Olympic Mountains, the Cascade Range, and Mount Rainier are the three primary major landforms in the area that are all a product of tectonic movement. Next, to evaluate seismic risk, active fault line locations, existing vulnerable buildings, ground conditions, and population density are considered.

As seen in figure 27, the Seattle fault line runs directly under parts of downtown and West Seattle. The strong shaking that occurs in these fractures in the earth's surface would affect the entire city from the shallow ground shaking produced from this crustal fault. The USGS has stated that the potential of large earthquakes on the Seattle fault has only recently been acknowledged and that “because crustal earthquakes are shallow—at depths of 5 to 20 km—and may occur directly beneath urban areas, they have the potential to do great damage.”³⁵ The presence of this fault line must be directly acknowledged in the aim of earthquake education and awareness in the region.

Next the built layers visible above the surface must be considered in selecting a site for the project, in particular those building types most vulnerable to earthquakes are most important to raise awareness of. Currently there are over 1150 unreinforced masonry buildings in Seattle that pose a seismic risk as highly susceptible to damage.³⁶ Over 700 of these URMs have still not been upgraded, nor do they have permits in with plans to upgrade. Many of these buildings are clustered around Pioneer Square, though they can be found throughout the entire city. Another concern in terms of potential damage are buildings located near landslide risk areas, where lateral shaking has the potential to trigger a landslide. Liquefaction risk areas additionally pose a hazardous unstable ground condition during an earthquake for buildings.



Figure 26 | Looking at the Washington state region, Seattle is nestled between grand landscape forms which resulted from tectonic movement, with the Olympic Mountains to the west and the Cascades to the east along with Mount Rainier, an active volcano. The major Cascadia subduction zone sits off the west coast while the localized Seattle fault looms below Puget Sound and the city of Seattle.

³⁵ Frank, Dave. “Earthquake Hazards.” Pacific Northwest Geologic Mapping and Urban Hazards. USGS, 13 Dec. 2016. Web. June 2017.

³⁶ Seattle Department of Construction & Inspections. List of URMs Identified by Seattle DCI – April 2016 (2016): The City of Seattle, Apr. 2016. Web. <https://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2422247.pdf>.

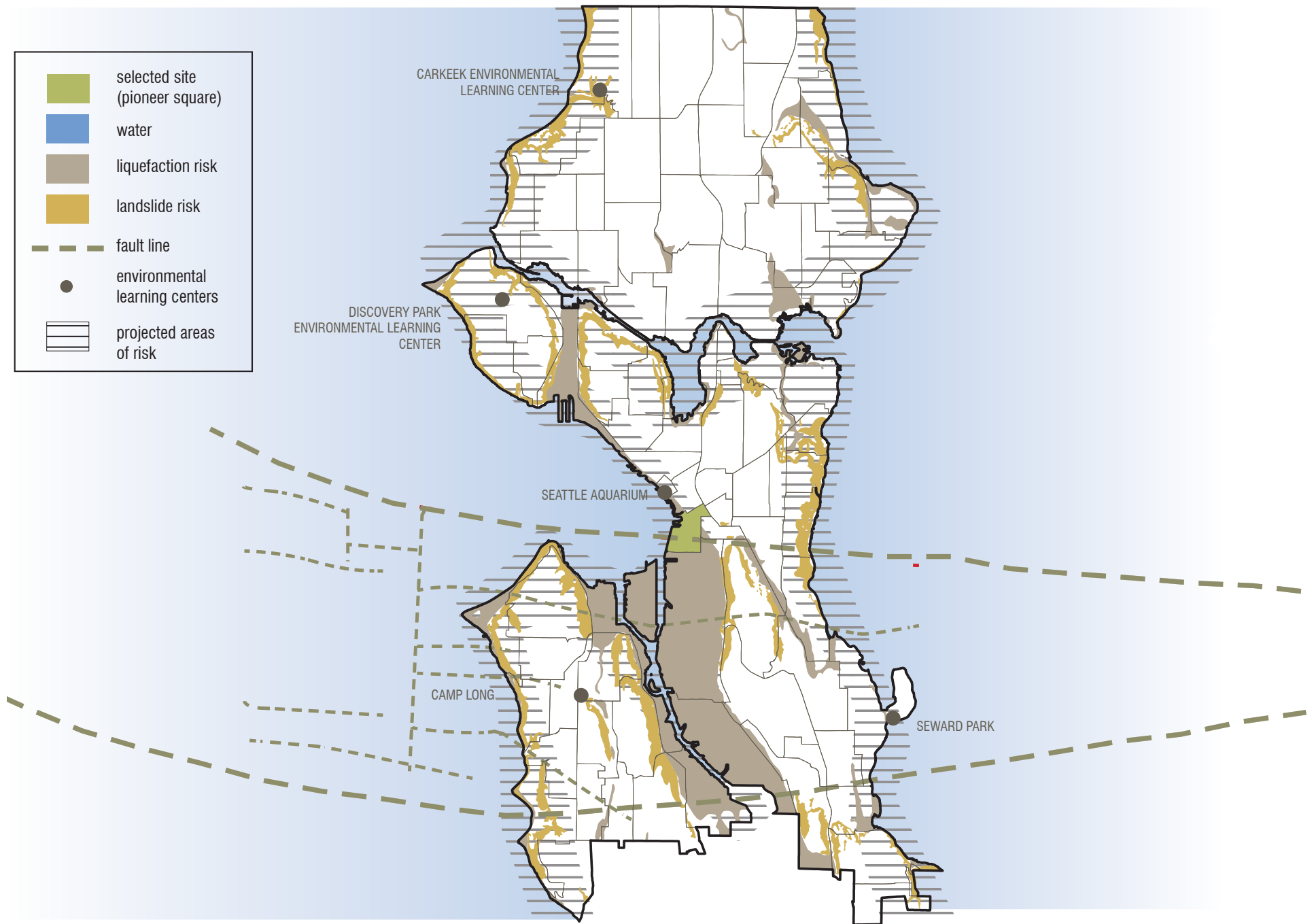


Figure 27 | Overlay of seismic risk factors and surrounding natural context.

The criteria for an appropriate site for the Earthquake Discovery Center include its proximity to the fault line so conditions of seismic risk are highlighted. In addition, it must be located to have a good visual connection to the natural landscape in order to connect the dangers and the wonders of our regional ecologies in peoples minds. Proximity to existing vulnerable buildings in the neighborhood would assist the project in serving as teaching tool and promote outreach. Pioneer Square was chosen as the site for its connection to nature, the high presence of URM structures, and for its central placement within the city of Seattle. As seen in figure 30, the selected site of Pioneer Square exemplifies some of the greatest risk and need for awareness of seismic issues because it is located at a crossroads of these risks with the Seattle fault running directly below it.

The Site

Pioneer Square is a historic neighborhood located in downtown Seattle on the west coastline of the city. While located within the city boundaries, it provides a strong visual connection to nature in its placement along the waterfront, and back to the urban environment of the city. On a clear day, the neighborhood offers exceptional views of the Olympic Mountains to the west across the sound.

The plot of land chosen in Pioneer Square is located at the intersection of Alaskan Way, Yesler Way, and Western Avenue. The current state of the site in 2017 can be seen in figure 28 and 29. The site currently functions as an underutilized parking lot at the heart of neighborhood. The property has the added challenge of being located in a liquefaction-prone area, which is where “sites with loose, saturated soil lose the strength needed to support a building during earthquakes”.³⁷ To address this challenging ground condition the design proposal will utilize a deep pier foundation system to gain sufficient strength on the poor soil condition. The property has been owned by Washington State since 2012 and is to be used in the deconstruction of the Viaduct.³⁸ This thesis is proposing a design after the removal of the viaduct, and implementation of the new waterfront design.

³⁷ Seattle Department of Construction & Inspections. “Environmentally Critical Areas (ECA) Code.” Codes, Seattle.gov, 2017, www.seattle.gov/dpd/codesrules/codes/environmentallycriticalareas/default.htm.

³⁸ Seattle Department of Construction & Inspections. “Seattle Parcel Data.” Seattle Parcel Data, Seattle.gov, 2017, web6.seattle.gov/dpd/parceldata/parcel.aspx?pin=7666202575.

ON SHAKY GROUND

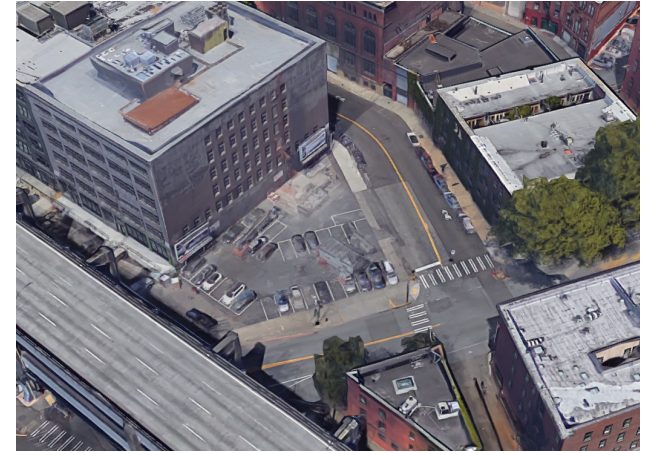


Figure 28 | Current state of the site.



Figure 29 | On site, looking north at the south facade of the neighboring structure.

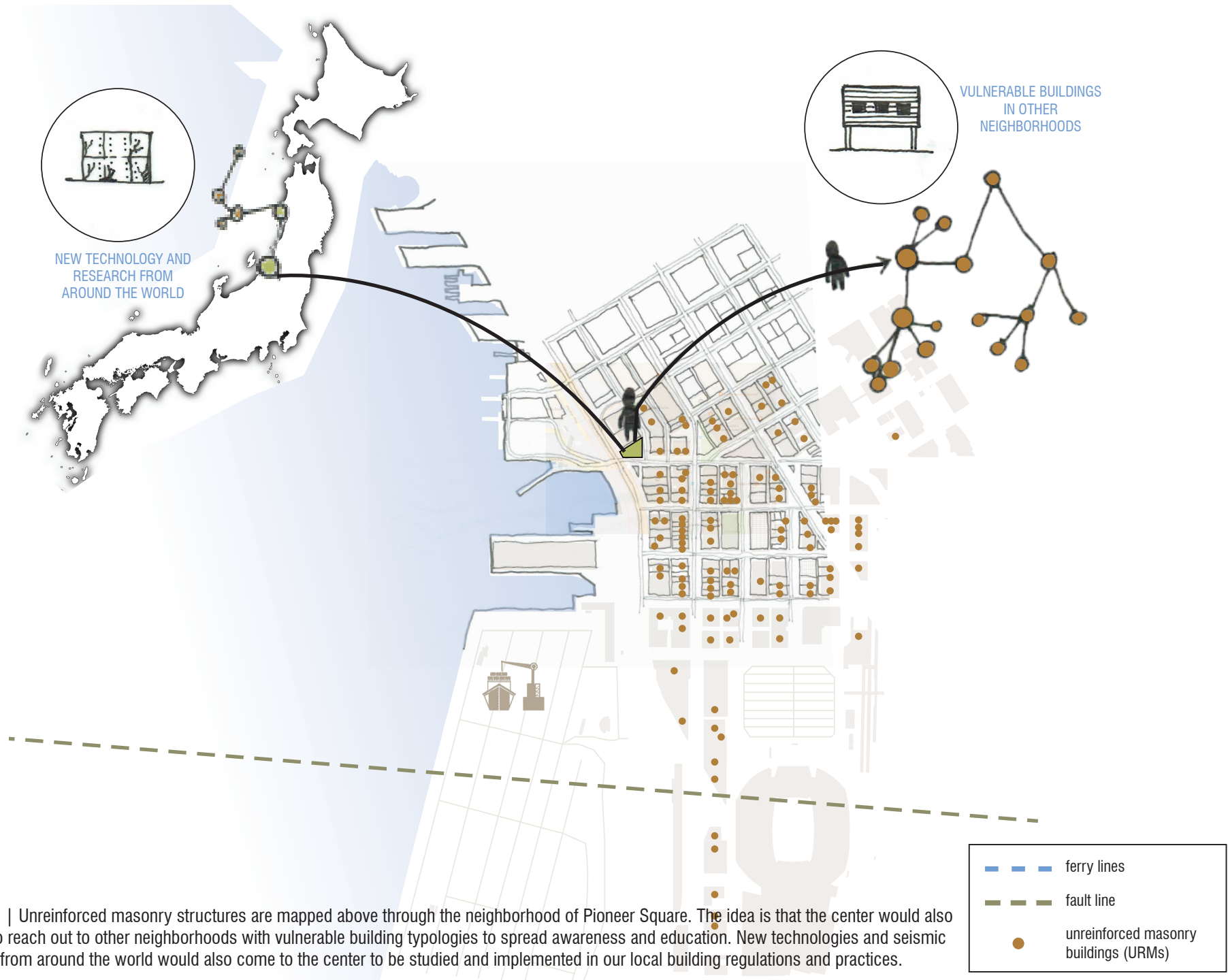


Figure 30 | Unreinforced masonry structures are mapped above through the neighborhood of Pioneer Square. The idea is that the center would also be able to reach out to other neighborhoods with vulnerable building typologies to spread awareness and education. New technologies and seismic research from around the world would also come to the center to be studied and implemented in our local building regulations and practices.

Two unreinforced masonry structures are located directly across the site. The existing URMs in the neighborhood will be used as a design resource for the public to learn from. The center will additionally aid in upgrading the adjacent buildings as part of its outreach and education efforts. The design proposal will also respect the existing six story building to the north of the site by stepping back and allowing daylight in for the series of window openings which exist on the building's south façade facing the proposed lot.

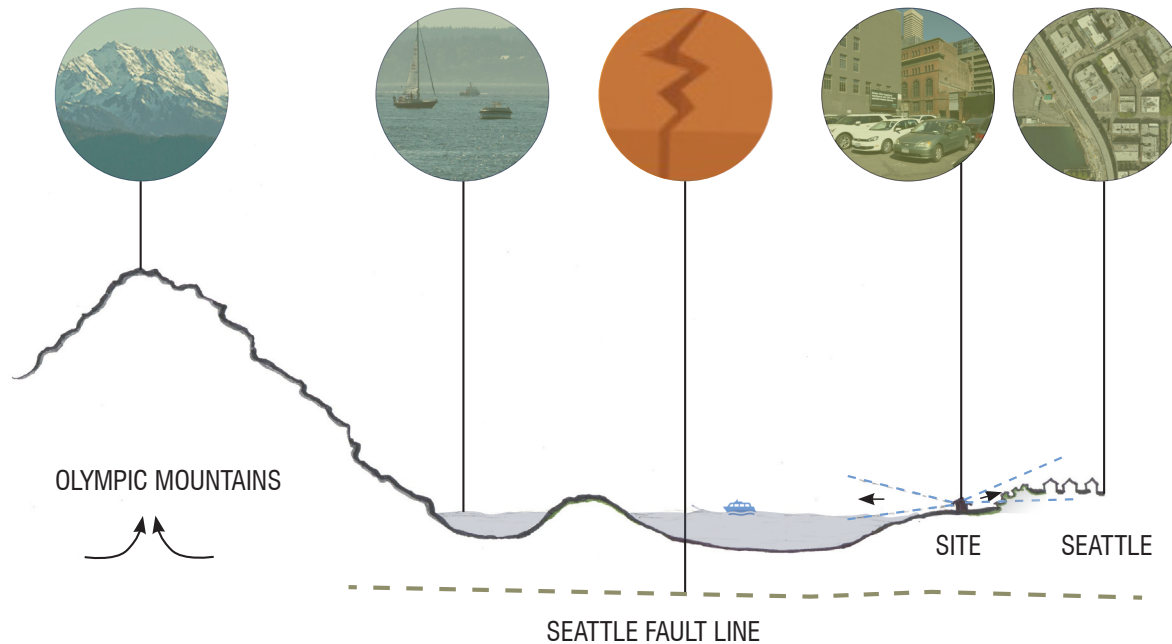


Figure 31 | Conceptual section cut showing the relationship between some of the elements on site, and emphasizing the great sightline to the Olympic Mountains across the sound, as well as back to the city.

Program of Spaces

Narrative of Spaces

The program of the proposed Earthquake Discovery Center seeks to reflect the thesis goals of education and engagement. The building will make visitors aware of the geological timeline of the Pacific Northwest in connection to the flow of experience within the building. This narrative relates the function of spaces in the project to the larger aims of the thesis to educate and provide a connection to the landscape.

ON SHAKY GROUND

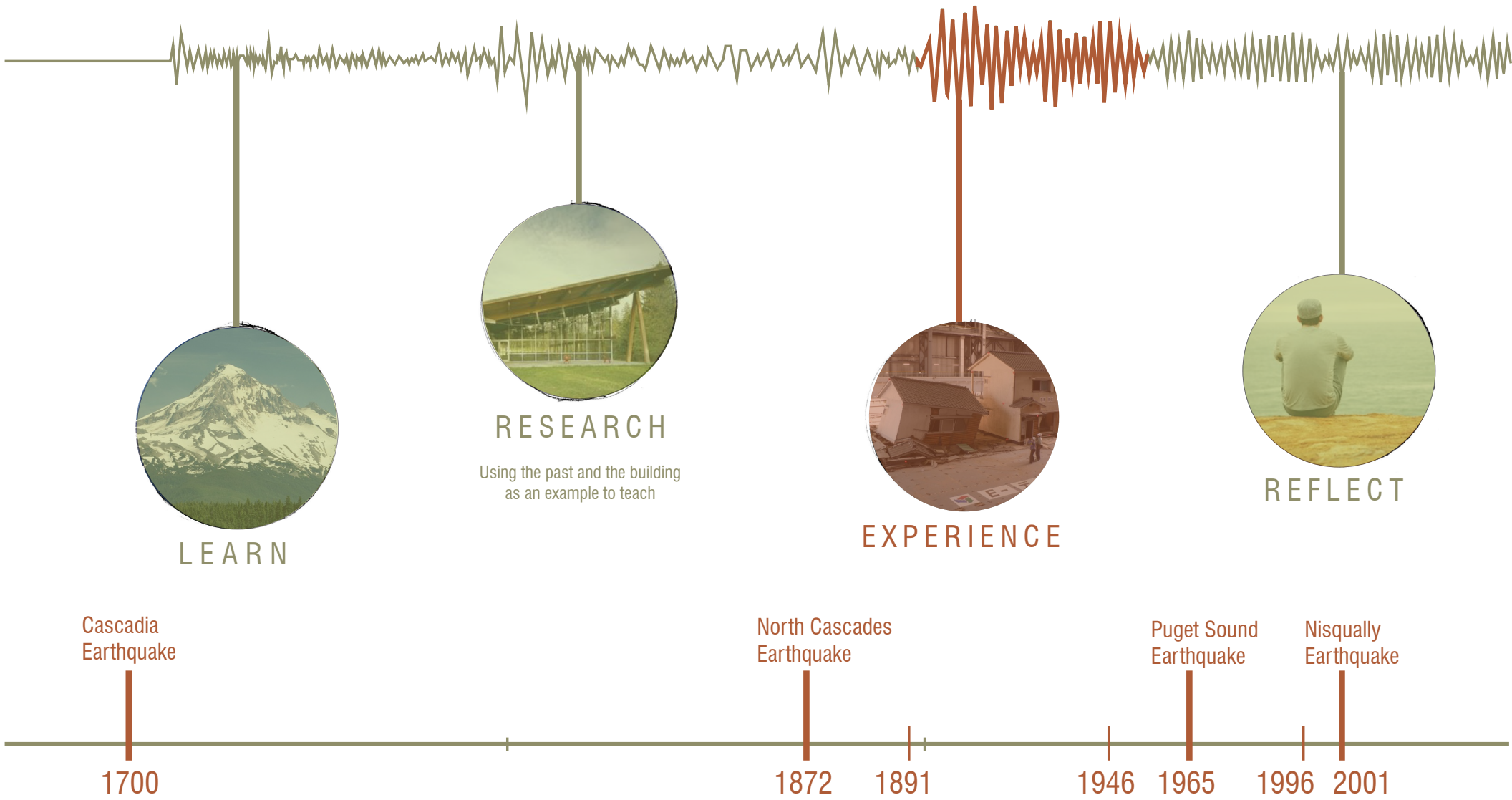


Figure 32 | Geologic timescale of Washington related to the function of spaces.

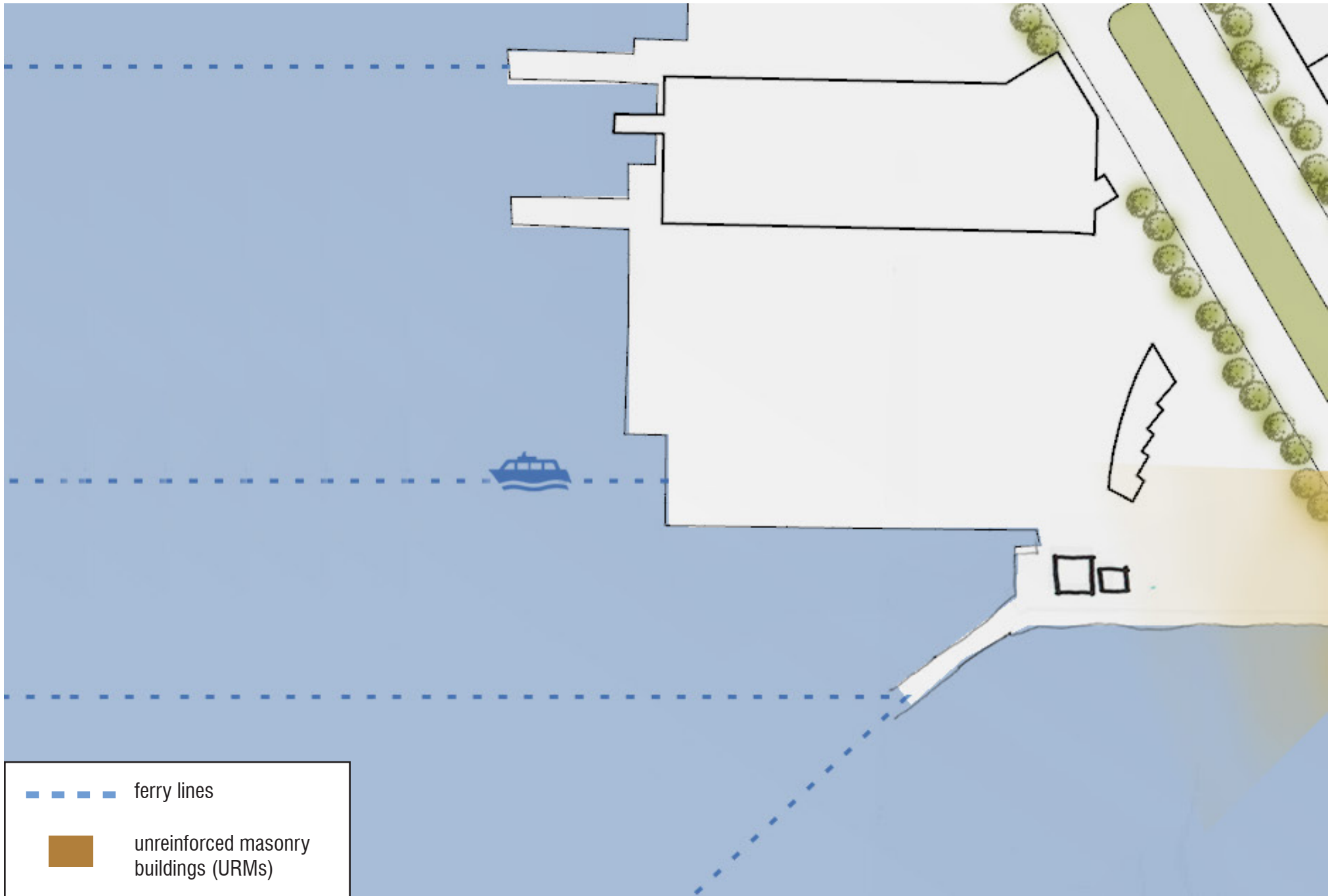


Figure 33 | Site Plan.

ON SHAKY GROUND



Programmatic Strategy

The project will serve as a place for earthquake education and research. The building will be an active center for studying seismic technology as well as for seismic education and public outreach. The building area will be divided between a research area, interactive exhibit spaces, a community outreach space, a space for reflection, and spaces for disaster preparation. The project brings the program functions together in one building to make earthquake research and public awareness of the dangers of earthquakes in Seattle an open conversation for the greater Seattle area.

In its architectural design the building seeks to integrate architecture with seismic resistance. The siting is deliberate based on the presence of seismic risks and views out to the Olympics. The building will connect to its surroundings through massing, materiality, and views to the landscape. This thesis takes the stance that as an entire community we must become more educated about earthquakes as a natural phenomenon since they are an integral part of the Pacific Northwest context. Though earthquakes can be devastating catastrophes, the beauty of the Pacific Northwest landscape would not exist without seismic activity in the region.

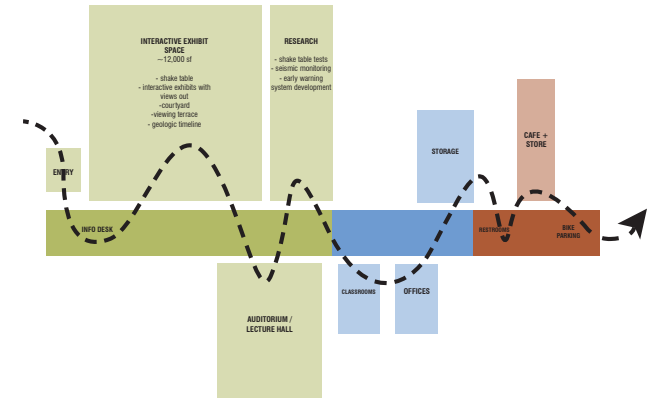


Figure 34 | A representation of flow and relative size of program spaces.

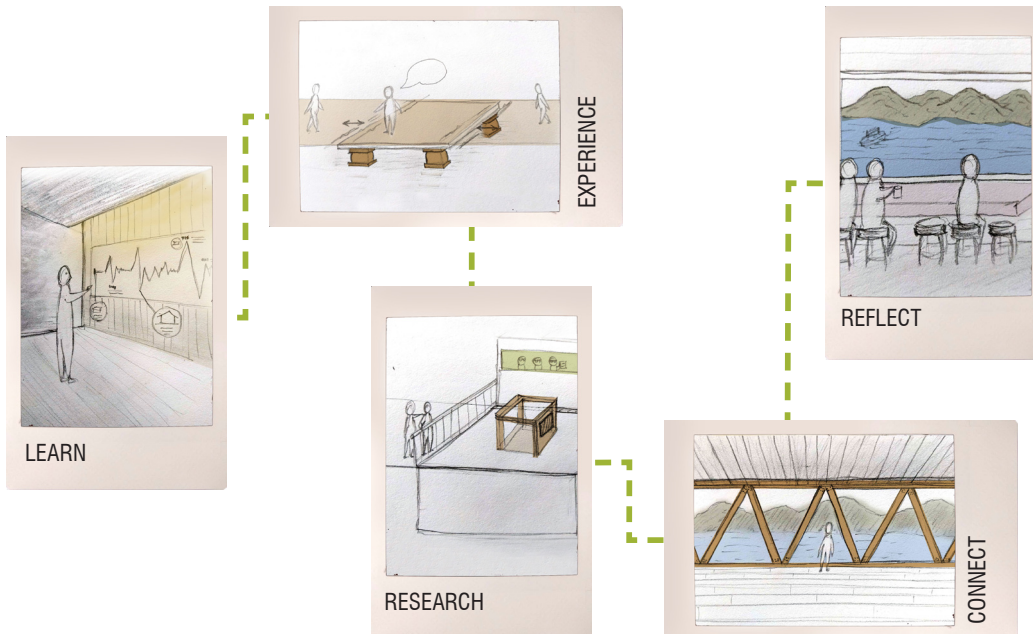


Figure 35 | Some of the moments meant to happen within the Earthquake Discovery Center.

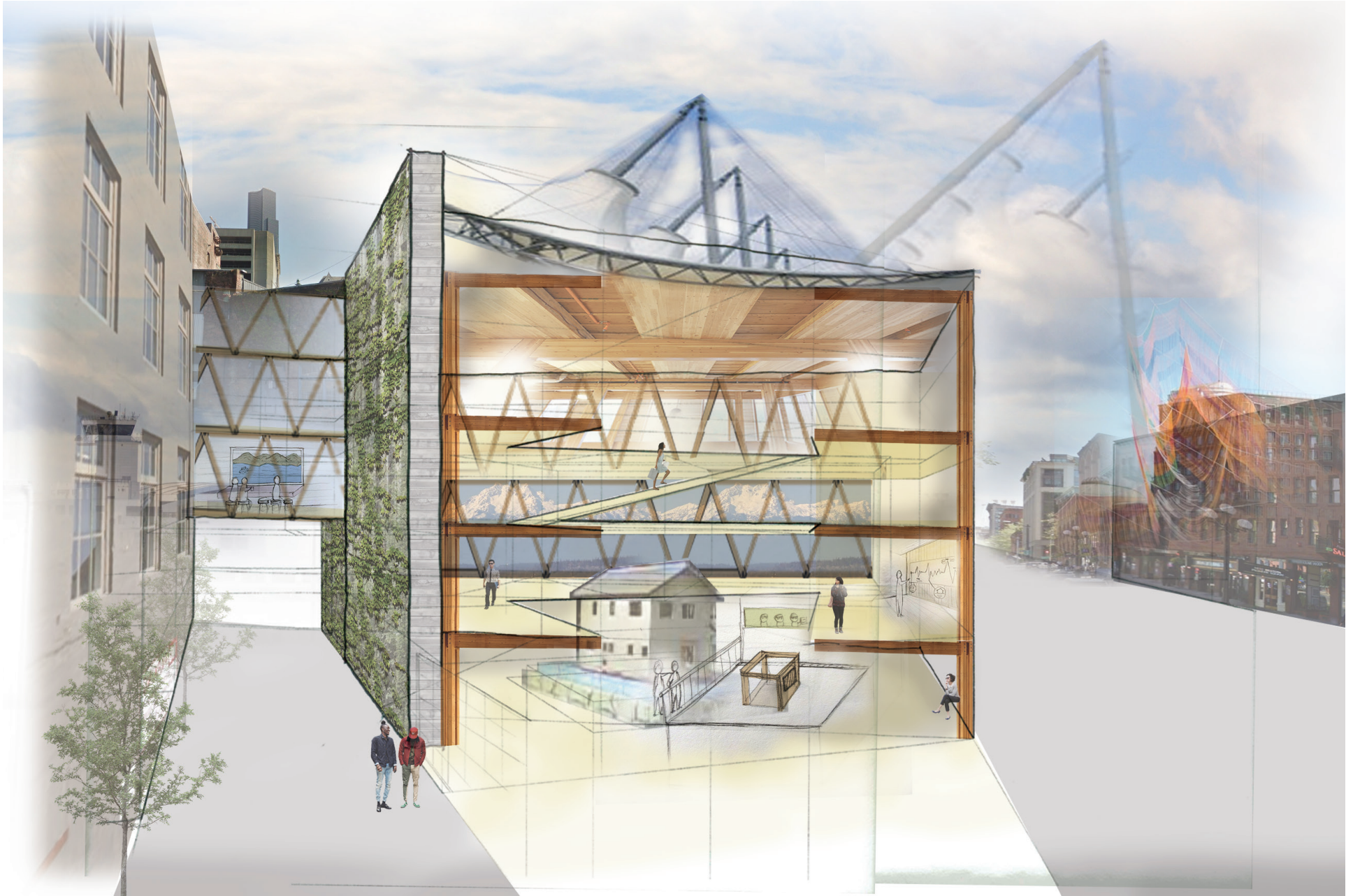
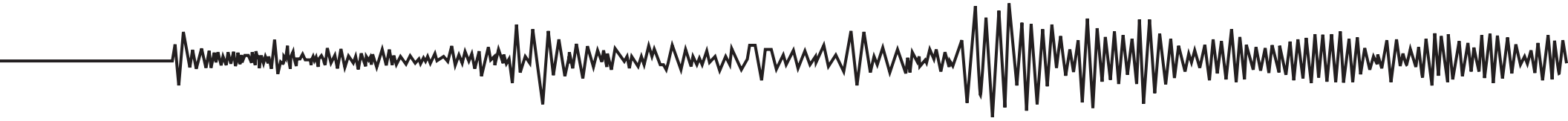
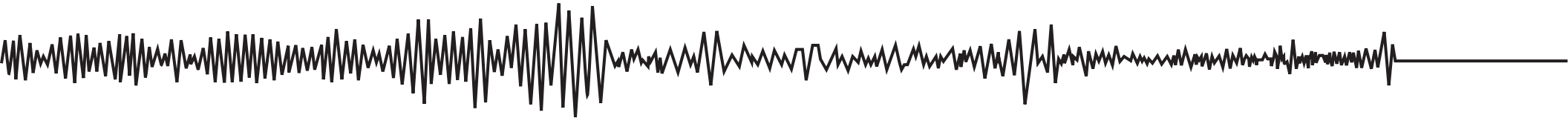


Figure 36 | An early conceptual image of a center which responds to the seismic risk of the Pacific Northwest through architecture. To serve as an example, to inspire and teach, to foster a connection to nature and place, and to express seismic and architectural solutions.



CHAPTER 5

Design Proposal



Concept

The concept of a shear drives the architecture of the Earthquake Discovery Center in acting as a disruption and union of two structural systems in the building. These structures showcase distinct strategies that modern buildings can use in a seismically active region. One half of the building responds as flexible, with the use of steel structure, by demonstrating a dramatic cantilever in its massing and an open floor plan. The other half responds as strong, with the use of mass timber structure, acting as a monolithic structure in contrast to the visually delicate steel portion. The middle shear division acts similarly to a fault line in its concept. At this point of discontinuity, a change in structure, massing, and material occurs.

This conceptual shear, as seen in figure 37, acts as both the division and connection within the architecture. Similarly to a fault line, a disruption occurs at this divide. The shear represents a change of program and a joining of spaces, and houses the experiential circulation stair as an open space suspended between two halves of the structure. Visitors feel a moment of uneasiness on the weaving staircases within the shear that challenges them to think about structure. This space is where one can best experience the two structures at once. Feelings of unease turn to stability upon entering the expressive steel and wood structures.

The exposed structural systems of the building showcase two distinct strategies that buildings can use in a seismically active region. The variety of structural solutions used are to be utilized as teaching tools so that visitors can learn directly from the architecture of the building and the integration of its structure.

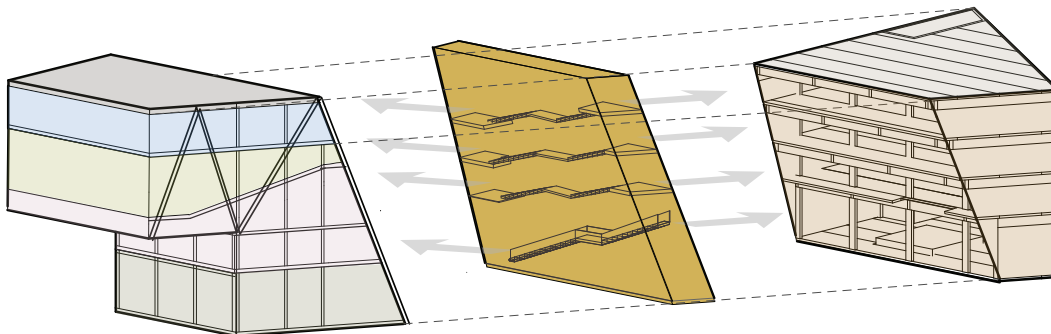


Figure 37 | The shear separating and uniting the two masses of structure.

Program

The center houses a series of interactive exhibit spaces as the main attraction. Additional programs include multiple floors of research for seismic related studies, a store to support the exhibition area and to stock emergency supplies, a community auditorium and classroom space, as well as a café. An outdoor garden is additionally located on the roof of the exhibition structure, while energy generating photovoltaic panels cover the roof above the café.

The proposed massing of the building on the irregular site is broken into two masses which divide program as well as structure. On the community focused half is the store on ground-level, research spaces above, a community lecture hall, and a café at the top. The interactive exhibition spaces fill the other half with circulation space diving the structures.

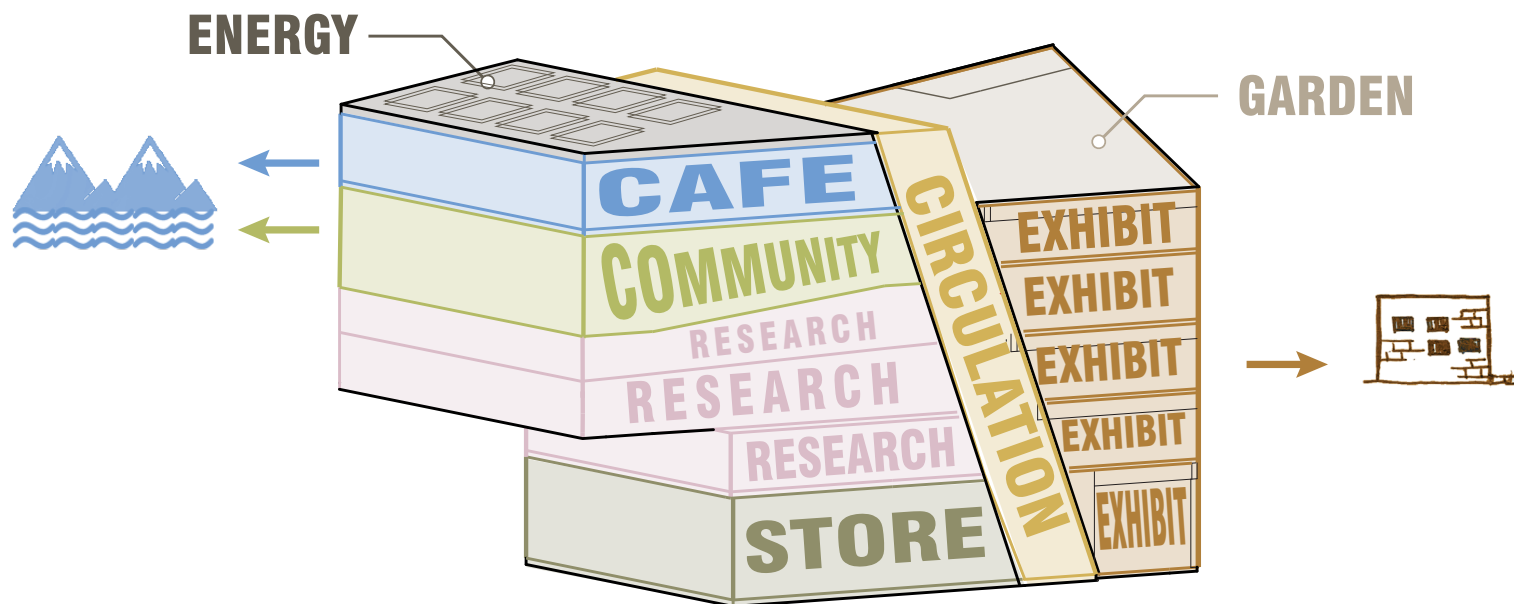


Figure 38 | Program and massing diagram.

The programmatic section below shows how the spaces are divided within the center. To the east is the exhibition space (as seen in orange), with the research shake table located at the ground floor. Views out to the adjacent unreinforced masonry structures are also seen from the exhibition space through punched openings. While along the waterfront, the research spaces, the café, and community space is located on the west side of the shear, looking out to the Olympics.

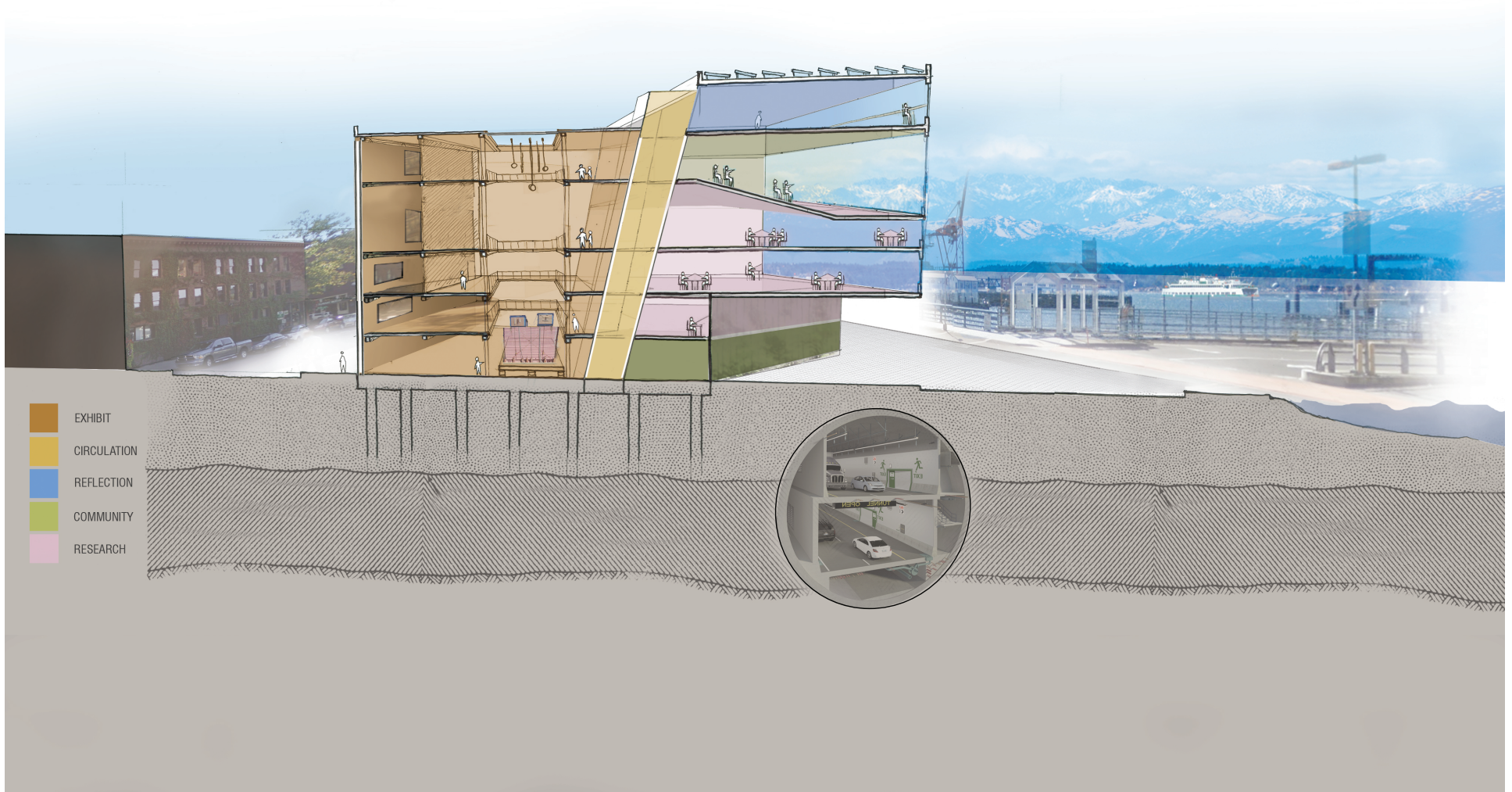


Figure 39 | Programmatic section looking south.

ON SHAKY GROUND



Figure 40 | Here is the earthquake discovery center within the context of Pioneer Square. The split is seen between the two structures within the building and their relationship to the neighborhood building context. The more transparent half faces outward towards Puget Sound and the natural tectonic landforms, while the exhibition space focuses inward to the city and built environment.



Figure 41 | Standing along the new waterfront on Alaskan and Yesler Way, the translucent upper mass cantilevers out towards the water. The activity of events, researchers, and exhibition goers, can be seen inside.

ON SHAKY GROUND



Figure 42 | A passageway is created from the center's setback to the neighboring structure. This alley acts as an extension of the discovery center, as well as an urban pass thru.

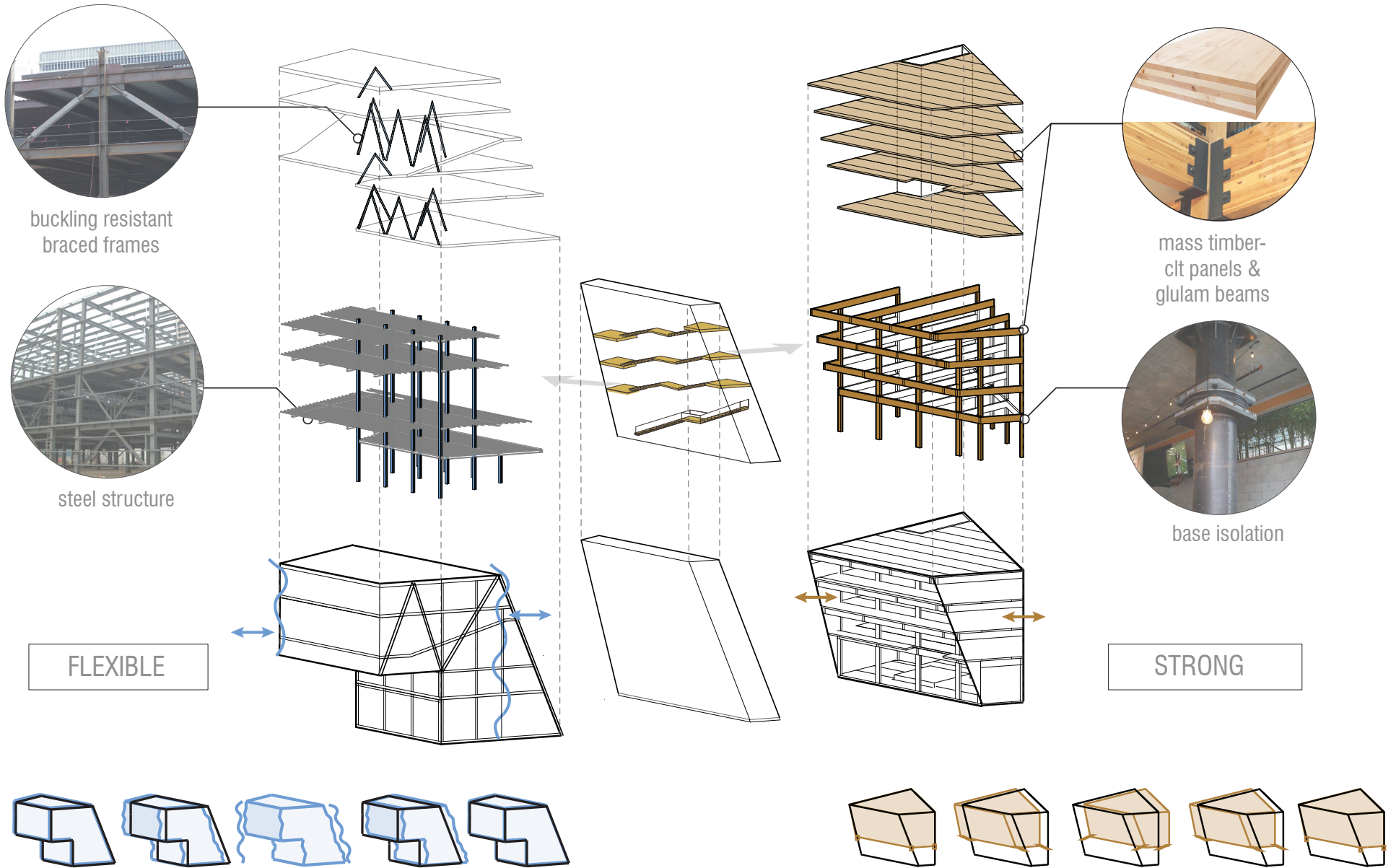


Figure 43 | On the interior, the center is broken up into two structural systems to showcase the two structural responses a building can have to an earthquake. By dividing the irregular building in two, each half becomes laterally stronger. One half acts as flexible, while the other is strong.

A steel structure which also supports the cantilever is used on the flexible side, with buckling resistant braced frames used for the lateral system.

Deep glulam beams and columns, along with cross-laminated timber (CLT), is used on the strong portion. Shear walls and base isolation are used for the lateral system here. Each half demonstrates a varied response to earthquake forces.

Organization

The floor plans are organized in two halves. One half houses the research and community focused programs, while the other half contains the exhibition spaces. The occupant walks up a weaving central stair from floor to floor between the exhibit and adjacent research and community spaces until reaching the top floor café and garden space.

The discovery center acts as a hub for seismic issues due to the blending of programs it houses. Research spaces draw in specialists from seismic related fields ranging from seismologists, to structural engineers, and architects. The shake table housed in the exhibition space is utilized by both researchers as well as visitors who can experience simulated earthquake forces as an immersive activity. The earthquake discovery center integrates two distinct structures in its architectural expression to become a physical and contextual demonstration of seismic response in the Pioneer Square neighborhood of Seattle. The two types of structures used in the building are divided by the circulation shear in the middle of the earthquake discovery center which also acts as the seismic gap between the two distinct structures.

Façade

The exterior elevations of the building, as seen in figure 45, are clad in response to the shear and change in structure. The steel portion is clad in flexibly suspended glazing to promote views and transparency. While the timber portion is clad in modern terracotta which responds to the historic masonry structures of the neighborhood.

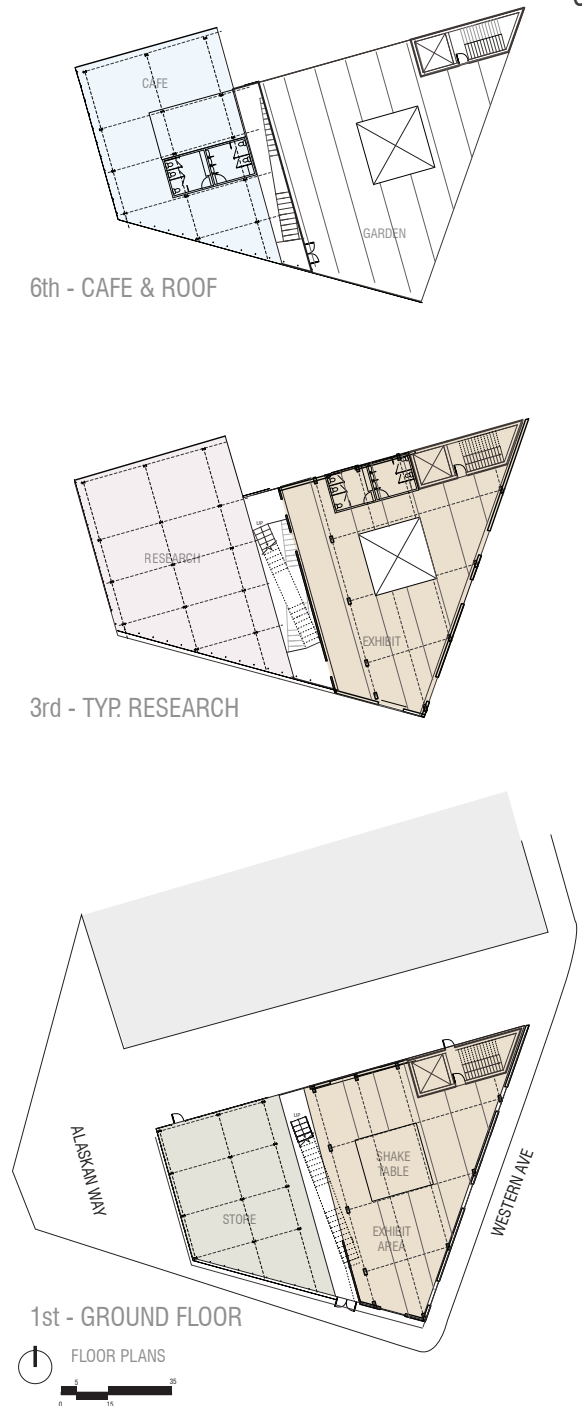
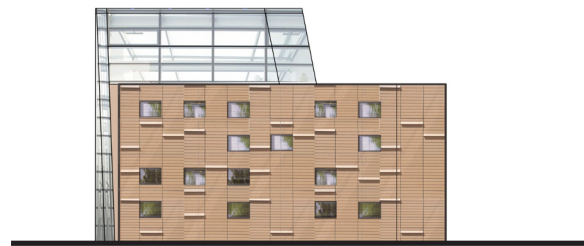


Figure 44 | Typical floor plans.



ALASKAN WAY



WESTERN AVE



PASSAGEWAY

Figure 45 | Elevations



Figure 46 | Perspective representing how it would feel to be in the shear between the two structures, looking up and out. It is in this space that a visitor would begin their journey up and through the building. The circulation fills the void between the two structures, as staircases interlink program spaces across the shear. This space also provides vertical relief and a connection to the sky within the central space.

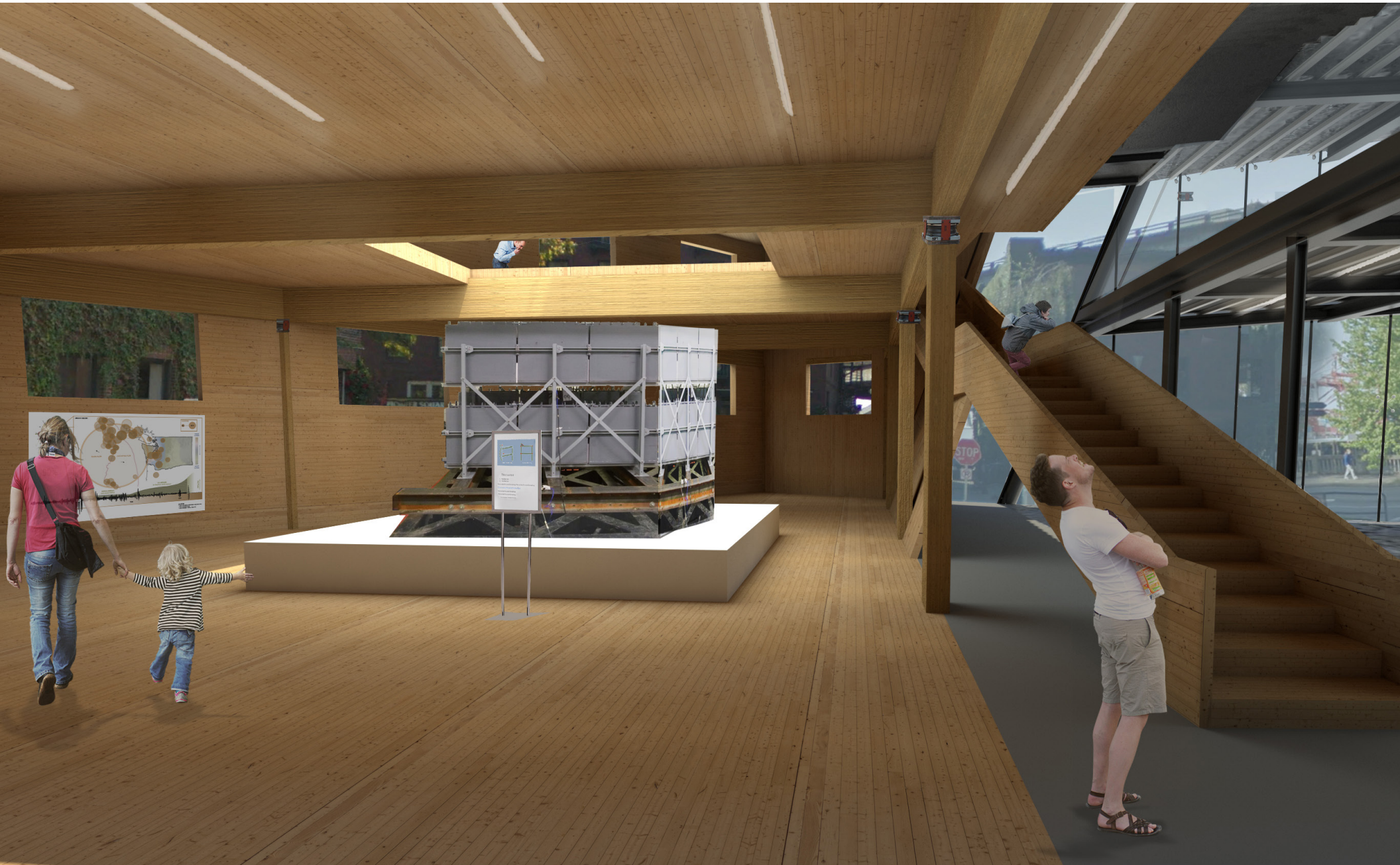


Figure 47 | Once a visitor enters the exhibit space, on the first floor they will find a shake table used for research and earthquake simulations, while framed openings at the exterior walls will highlight key views out to the city.

ON SHAKY GROUND



Figure 48 | Within the building, views between opposing program spaces are highlighted. Here visitors in the exhibition space can view the researchers working in the lab across the shear through a framed opening in the CLT.

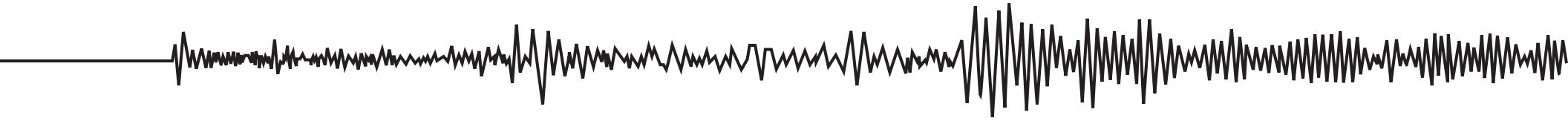


Figure 49 | Upon arriving at the cafe on the top floor, visitors are wowed by the extensive view of Puget Sound. The space can be used as a contemplative area for visitors, as a lunch spot for workers in the area, or as an alternative work space for the researchers.

ON SHAKY GROUND



Figure 50 | The view from the top café floor, looking back at the city from above the passageway. The upper floor provides a moment to reflect back at our built environment and urban Seattle. Situated between nature and city. A space to reflect within and observe from.



CHAPTER 6

Conclusion



Conclusion

As new knowledge and research emerges about the seismic condition of the Pacific Northwest, a renewed sense of awareness must be spread about the resilience needed in our built environments. It cannot be the role of engineering alone to solve issues of seismic resilience in our urban communities, but rather is a design problem at its core. Seismic resilience cannot solely come from a technological fix, it must be contextual, which is where the role of architecture comes into play. Architecture and design have power beyond making a building stand up to the forces of nature. Architecture can facilitate the sharing of knowledge, creation of communities, and inspire others to do better.

This thesis offers the idea of an earthquake discovery center that not only draws in curious minds, community leaders, and researchers, but also acts as the physical embodiment for seismic advocacy. Though emergency management groups in the region exist to spread awareness about preparing for the event of a natural disaster, no physical space currently exists for this sharing of knowledge. There is a need for a physical place where professionals and residents can come to exchange information and resources about living in a seismically active region. The building has the unique ability to act as both a learning space and community center.

A higher level of advocacy is needed in earthquake prone regions like Seattle for seismically responsive architecture. Buildings should respond to their context to better connect people to their environments and react to the changing seismic landscape in a sustainable way. There is a design richness to be explored in resilient architecture that is not yet being explored in buildings. The holistic integration of design, structure, and landscape results in safer and more inspiring structures that better connect inhabitants to their environment.

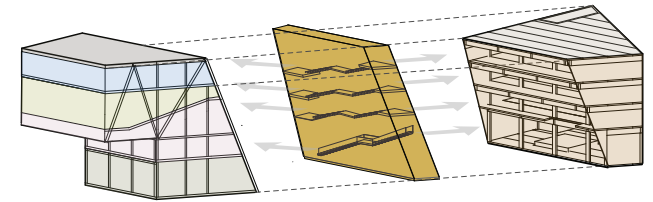


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26. Looking at the Washington state region, Seattle is nestled between grand landscape forms which resulted from tectonic movement, with the Olympic Mountains to the west and the Cascades to the east along with Mount Rainier, an active volcano. The major Cascadia subduction zone sits off the west coast while the localized seattle fault looms below Puget Sound and the city of Seattle.

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41. Standing along the new waterfront on Alaskan and Yesler Way, the translucent upper mass cantilevers out towards the water. The activity of events, researchers, and exhibition goers, can be seen inside.
42. A passageway is created from the center's setback to the neighboring structure. This alley acts as an extension of the discovery center, as well as an urban pass thru.
43. On the interior, the center is broken up into two structural systems to showcase the two structural responses a building can have to an earthquake. By dividing the irregular building in two, each half becomes laterally stronger. One half acts as flexible, while the other is strong.
A steel structure which also supports the cantilever is used on the flexible side, with buckling resistant braced frames used for the lateral system.
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50. The view from the top café floor, looking back at the city from above the passageway. The upper floor provides a moment to reflect back at our built environment and urban Seattle. Situated between nature and city. A space to reflect within and observe from.

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APPENDIX

Types of Faults

There are three types of faults that can result in an earthquake:

1. Strike and slip fault
2. Normal fault (also called a dip-slip)
3. Reverse fault (also called a thrust)

The rupture is where the fault line has moved. Faults most often occur along plate boundaries, but can be found at other points as well. During a seismic event the fault ‘unzips,’ meaning it does not all move at once, but ruptures at a starting point and then moves along the fault.

The Cascadia Subduction Zone

The Cascadia subduction zone is the area off the coast of Washington where the Juan de Fuca plate is subducting under the North American plate into the mantle. This type of geologic condition has the potential to produce a megaquake over a 9.0 similar to the 2011 Tohoku earthquake in Japan. Geological history suggests that a large seismic event occurred along this zone in 1700, and today scientist estimate that in the next fifty years “the Pacific Northwest has a 10 percent chance of a magnitude 8 to 9 megathrust earthquake on the Cascadia subduction zone.”³⁹

Historical Earthquake Precedents

Past significant earthquakes serve as a precedent of what future seismic events could look like in the region. The 2001 Nisqually earthquake was the most recent significant quake in the Pacific Northwest, while the 2011 Tohoku quake serves as an example of what a large subduction fault earthquake could produce.

1. 2001 Nisqually (magnitude 6.8)

The Nisqually earthquake was a significant quake to the region being the most recent earthquake to effect Seattle. Though the earthquake was rated a VIII on the Mercalli intensity scale, which indicates a severe earthquake, the event resulted from a deep quake from subduction in the Juan de Fuca plate and therefore caused a less catastrophic outcome than a shallow earthquake of the same intensity on the Seattle fault may have. Several unreinforced masonry buildings in Seattle lost bricks during the Nisqually quake. Fortunately, no deaths resulted directed from the earthquake, though the event served as a warning of the potential events from future shaking.

2. 2011 Tohoku earthquake (magnitude 9.0)

The 2011 earthquake in Japan resulted from the same type of earthquake as a megaquake on the Cascadia subduction zone would produce, making it a relevant study for the Pacific Northwest region.

³⁹ “Earthquake Early Warning.” ShakeAlert. USGS, 2016. Web. Apr. 2017. <<http://www.shakealert.org/>>.

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MODEL PHOTOGRAPHS

