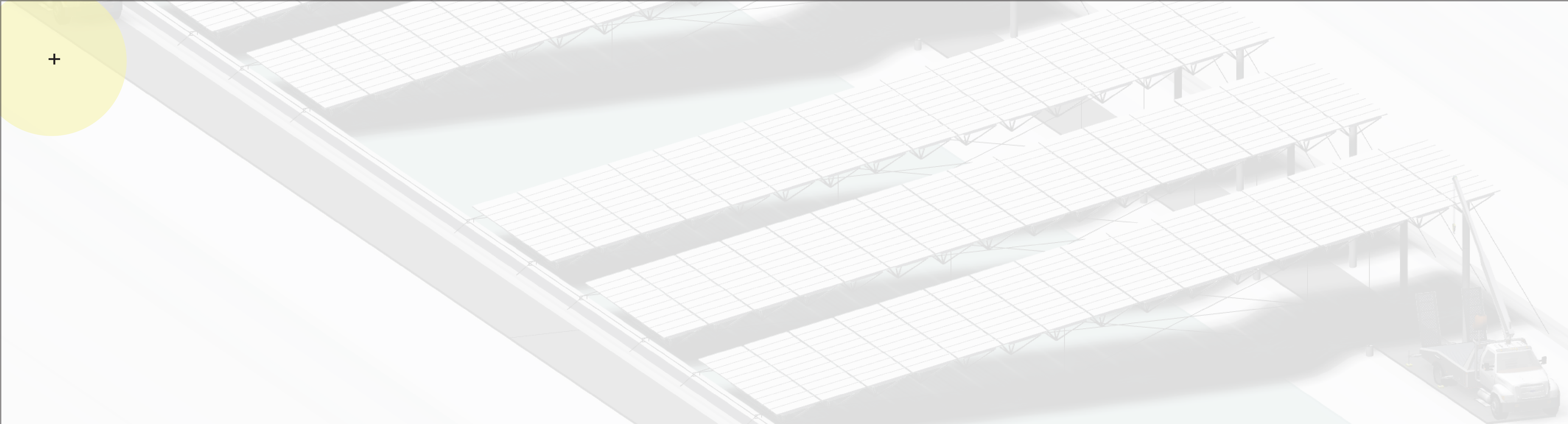


REWORKING EVAPORATION

NEW ENERGY CANALS FOR FARMS AND FISH IN KLAMATH FALLS OREGON

University of Oregon-Landscape Architecture
Master's Project 2023

McClean Gonzalez

P.V. Over Canal

Evaporation caused by sun, wind, and plant growth prevents significant amounts of the water flowing through irrigation canals from reaching the farms they serve. Research from U.C. Merced estimates that covering these canals with solar panels could reduce evaporation by up to 82% by blocking wind and shading the water of canals, saving water for farmers and fish[1]. This strategy, commonly referred to as P.V. or Photovoltaics Over Canal, would also provide farmers and nearby cities with a source of renewable electricity that does not block fish passage.

Global Context

Climate change is making these water savings increasingly urgent, as it reduces the snowpack and rainfall that ecosystems and people around the world depend on for fresh water. Unprecedented water shortages are forcing governments to make decisions, like those recently made in the Colorado River Basin, about who will have access to this decreasing and inconsistent supply of water.

1: McKuin, Brandi, Andrew Zumkehr, Jenny Ta, Roger Bales, Joshua H. Viers, Tapan Pathak, and J. Elliott Campbell. 2021. "Energy and Water Co-Benefits from Covering Canals with Solar Panels." Nature Sustainability 4 (7): 609–17. https://doi.org/10.1038/s41893-021-00693-8.

Global Water Crisis

Map From *A Quarter of Humanity Faces Looming Water Crisis*
By: Somini Sengupta and Weiyi Cai

https://www.nytimes.com/interactive/2019/08/06/climate/world-water-stress.html

U.S. states agree breakthrough deal to prevent Colorado River from drying up
By: Oliver Milman and Gabrielle Canon

https://www.theguardian.com/us-news/2023/may/22/colorado-river-states-california-arizona-nevada

Project Overview

This project seeks to further explore P.V. over canals specifically in urban contexts.

I will begin by giving a more detailed overview of climate, water, and energy within the Klamath Basin, focusing specifically on the A-Canal, my project site located in Klamath Falls, Oregon.

I will then provide a brief overview of the current state of P.V. over canal and discuss why I chose to focus specifically on this urban canal.

Then, I will switch to the process I took to develop objectives and identify the constraints to designing an urban P.V. over canal system in Klamath Falls.

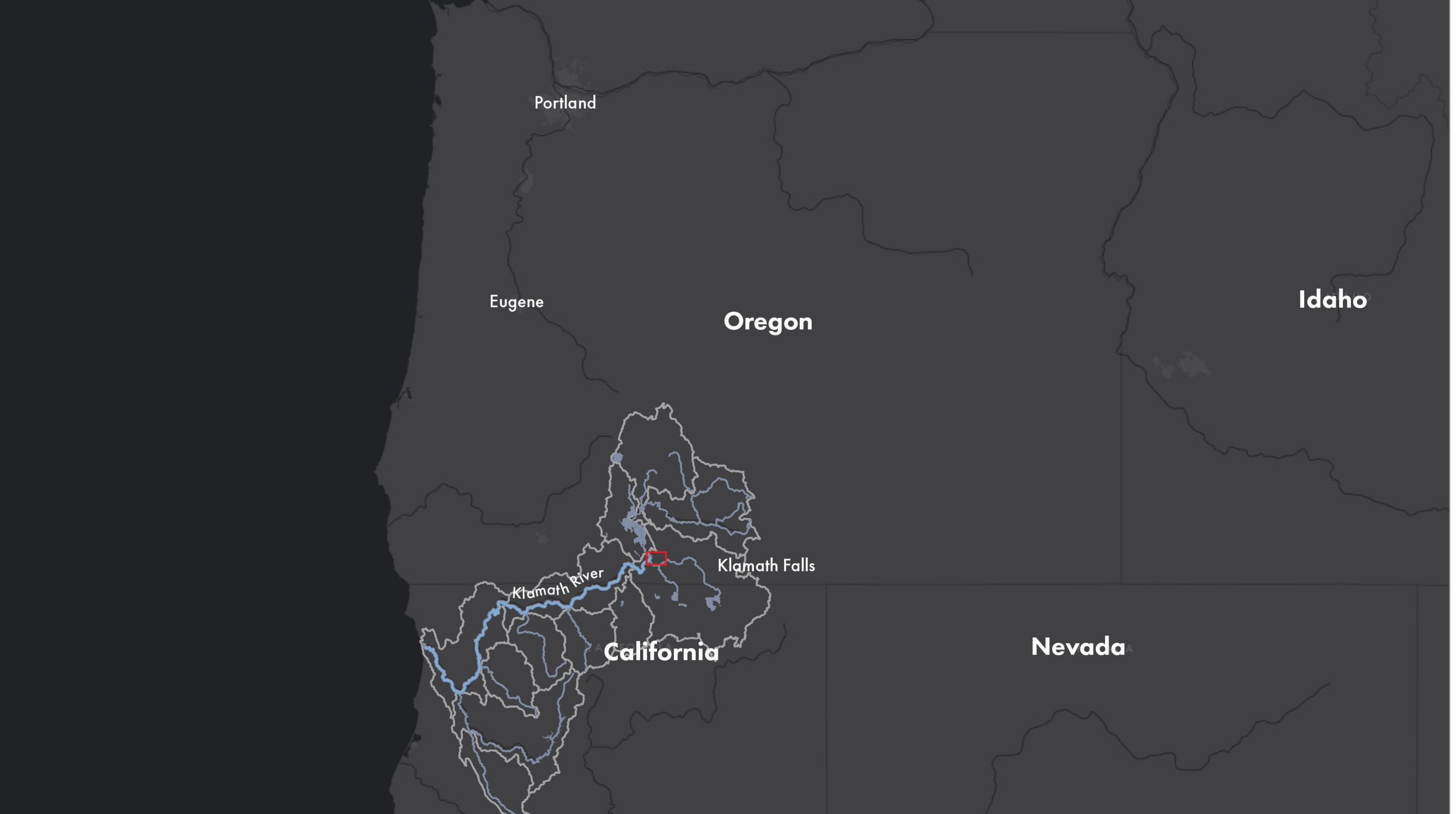
Then, I will walk through three design exercises where I explored the role that a landscape architect could play in a P.V. over canal project on the A-Canal or other urban canals.

At the end, I will provide an overview of what I learned from this process, including specific strategies that could be used to adapt P.V. over canal to more urban contexts.

Context

Climate, Water, & Energy in the Klamath Basin | P.V. Over Canal | Project Site A-Canal

+ Klamath River Basin



Klamath Basin

Conflicts over water are present here in the Pacific Northwest. The Klamath Basin, which extends from Southern Oregon to Northern California, is considered the most threatened and contentious river basin in the United States.

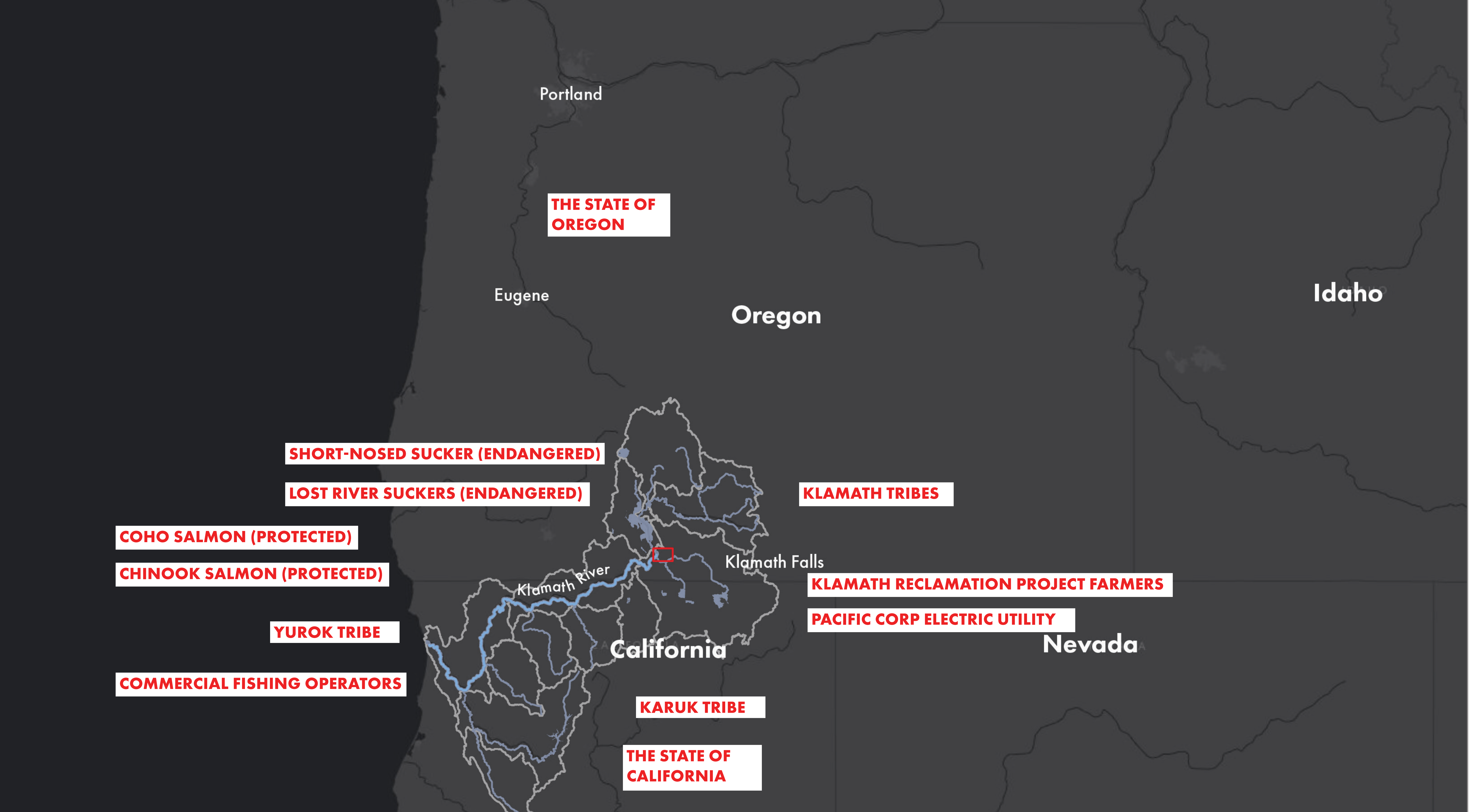
(on Left Page)

Map of Klamath Basin

Created By: McClean Gonzalez
Klamath Basin data from: Oregon Tech *Klamath Basin Sub-basins Map*

https://services1.arcgis.com/FB50u5E6wrw7l3d1/arcgis/rest/services/Klamath_Basin_Subbasins/FeatureServer

+ Groups with **Competing Interests in Klamath Basin Water**



Water Interests in Klamath Basin

Groups with competing interests have spent decades developing a Basin-wide agreement, the Klamath Agreement, which establishes a framework for the distribution of its decreasing supply of water and for restoring the ecological health of the Basin. These groups include the Yurok, Karuk, and Klamath Tribes, farmers, wildlife refuges, and fish protected by the Endangered Species Act[1].

1: "Summary of Klamath Basin Settlement Agreements." n.d. https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/docs/klamath_ferc2082/sttlemnt_smmry.pdf.

(on Left Page)

Map of Klamath Basin + Generalized Location of Groups Who Depend on the Water of the Klamath Basin

Created By: McClean Gonzalez

Klamath Basin Agreement

The Klamath Agreement process was created to address the concerns of all of these different groups in an organized way. The process that led to the agreement began in 2002 after federal water management decisions that prioritized irrigation diversions led to the death of more than 30,000 adult salmon[1].

1. Belchik, Michael, Dave Hillemeier, and Ronnie M. Pierce. 2004. "The Klamath River Fish Kill of 2002." Yurok Tribal Fisheries Program. https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/PCFFA&IGFR/part2/pcffa_155.pdf.

Groups involved

The Tribes

- KLAMATH TRIBES
- KARUK TRIBE
- YUROK TRIBE

States

- THE STATE OF OREGON
- THE STATE OF CALIFORNIA

Water Managers

- KLAMATH RECLAMATION PROJECT
- UPPER KLAMATH WATER USERS ASSOCIATION

Protected and Endangered Species

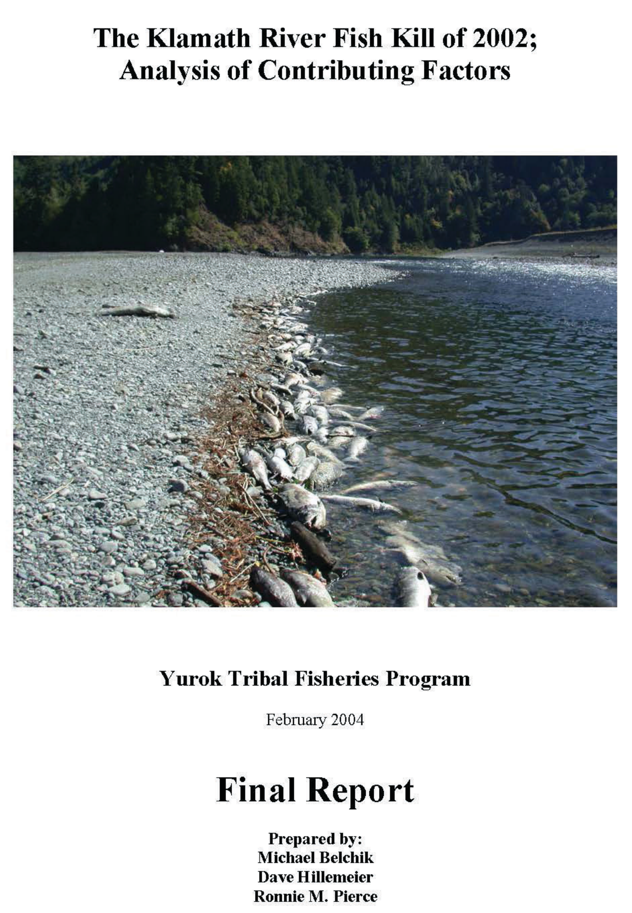
- SHORT-NOSED SUCKER (Endangered)
- LOST RIVER SUCKERS (Endangered)
- COHO SALMON (Protected)
- CHINOOK SALMON (Protected)

Other Organizations

- COMMERCIAL FISHING OPERATORS
- RECREATIONAL FISHING ADVOCATES

Goals

1. Restore and sustain natural production and provide for full participation in harvest opportunities of fish species throughout the Klamath Basin;
2. Establish reliable water and power supplies which sustain agricultural uses and communities and National Wildlife Refuges
3. Contribute to the public welfare and the sustainability of all Klamath Basin communities through these and other measures provided herein


The Klamath River Fish Kill of 2002;
Analysis of Contributing Factors

Yurok Tribal Fisheries Program

February 2004

Final Report

Prepared by:
Michael Belchik
Dave Hillemeier
Ronnie M. Pierce

Cover of Report: *The Klamath River Fish Kill of 2002; Analysis of Contributing Factors*
https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/PCFFA&IGFR/part2/pcffa_155.pdf

California Gov. Arnold Schwarzenegger, left, and United States Secretary of the Interior Ken Salazar
https://archive.nytimes.com/green.blogs.nytimes.com/2010/02/19/agreement-reached-on-klamath-river/

Thomas P. O'Rourke, Chairman Yurok Tribe, Kate Brown, Governor of Oregon, Sally Jewell, U.S. Secretary of the Interior, Edmund G. Brown Jr., Governor of California.
https://www.doi.gov/pressreleases/two-new-klamath-basin-agreements-carve-out-path-dam-removal-and-provide-key-benefits

Klamath Farmers

The group involved in this agreement that would receive the most direct impact from P.V. over canal on the A-Canal are the farmers and water managers of the Klamath Reclamation Project.

Klamath Reclamation Project

The Klamath Reclamation Project is a 20th-century Bureau of Reclamation project that converted lakes and wetlands into approximately 200,000 acres of irrigated cropland[1].

1. "Factual Data on the Klamath Project." n.d. Klamath Falls Oregon: Bureau of Reclamation Public Affairs Office. https://www.oregon.gov/owrd/programs/regulation/KlamathRegulation/2020%20KIDBOR/BOR%20Klamath%20Project%20Overview.pdf.

Groups involved

The Tribes

- KLAMATH TRIBES
- KARUK TRIBE
- YUROK TRIBE

States

- THE STATE OF OREGON
- THE STATE OF CALIFORNIA

Water Managers

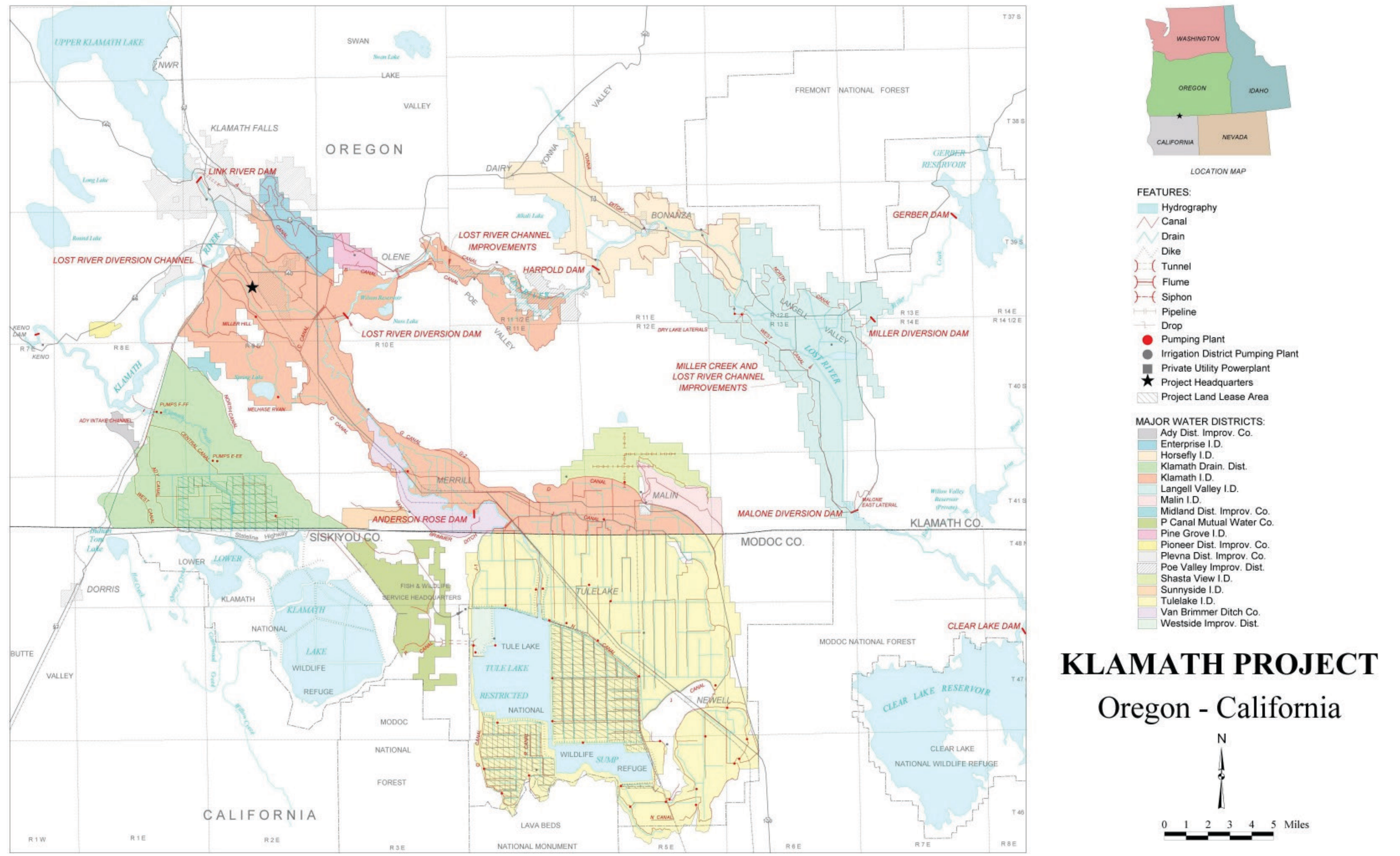
- **KLAMATH RECLAMATION PROJECT**
- UPPER KLAMATH WATER USERS ASSOCIATION

Protected and Endangered Species

- SHORT-NOSED SUCKER (Endangered)
- LOST RIVER SUCKERS (Endangered)
- COHO SALMON (Protected)
- CHINOOK SALMON (Protected)

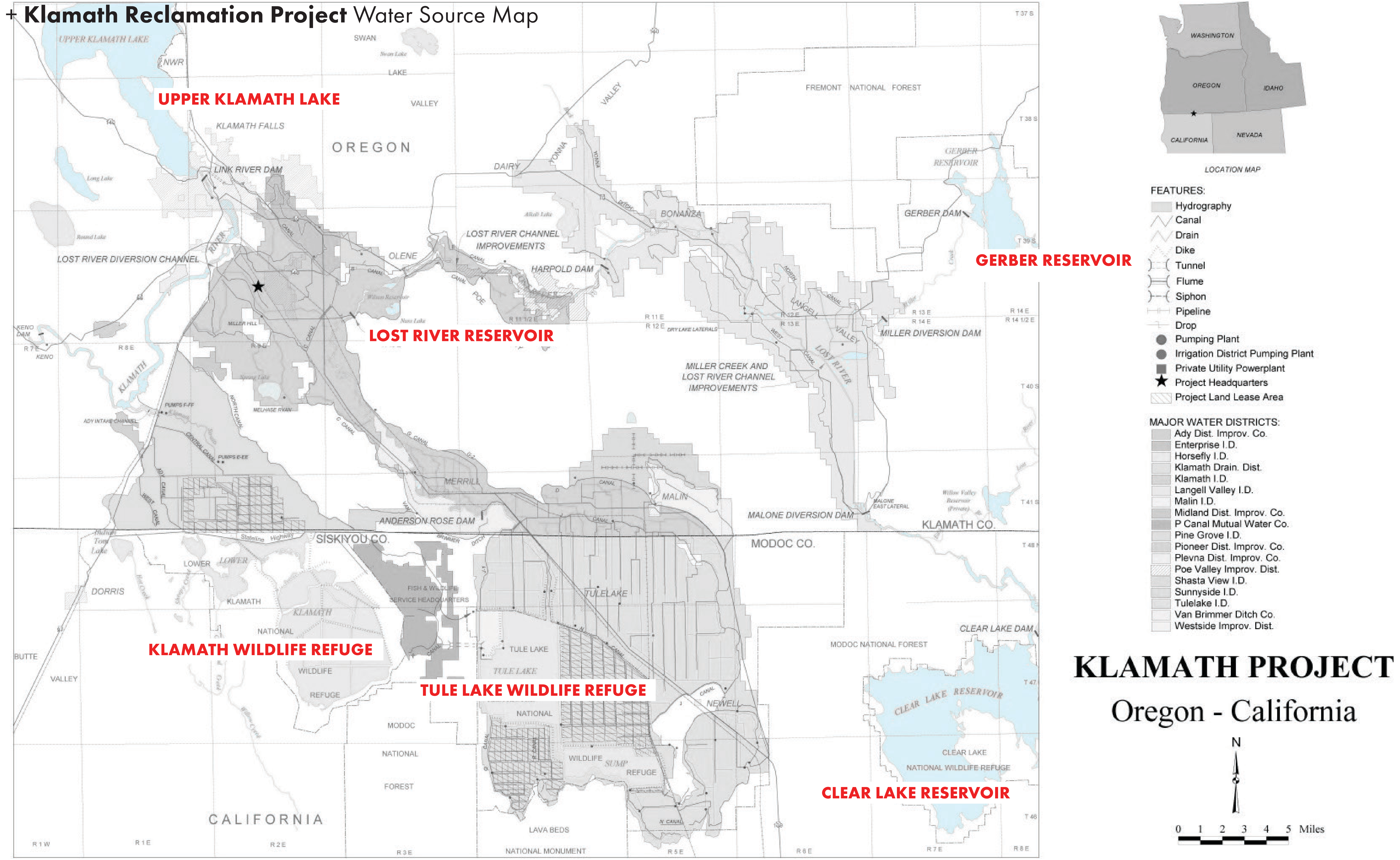
Other Organizations

- COMMERCIAL FISHING OPERATORS
- RECREATIONAL FISHING ADVOCATES



Map of Klamath Project
Created by: Bureau of Reclamation
https://www.usbr.gov/projects/index.php?id=470

+ **Klamath Reclamation Project** Water Source Map



Klamath Reclamation Project Water Distribution

865 miles of irrigation canals transport water to the farms from two main sources: the Upper Klamath Lake filled by the Klamath River, and the Clear Lake, Gerber, and Lost River Reservoirs[1].

1. "Factual Data on the Klamath Project." n.d. Klamath Falls Oregon: Bureau of Reclamation Public Affairs Office. https://www.oregon.gov/owrd/programs/regulation/KlamathRegulation/2020%20KIDBOR/BOR%20Klamath%20Project%20Overview.pdf.

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Modified Map of Klamath Reclamation Project Highlighting Water Sources

Modified By: McClean Gonzalez
Original Map Created by: Bureau of Reclamation
https://www.usbr.gov/projects/index.php?id=470

Water Reallocation

For some Klamath Project farmers, legal decisions in addition to climate change are affecting the amount of water they receive. These legal decisions are being made on behalf of endangered species that depend on the water in Upper Klamath Lake, wildlife refuges, and lower reaches of the Klamath River to support their habitats.

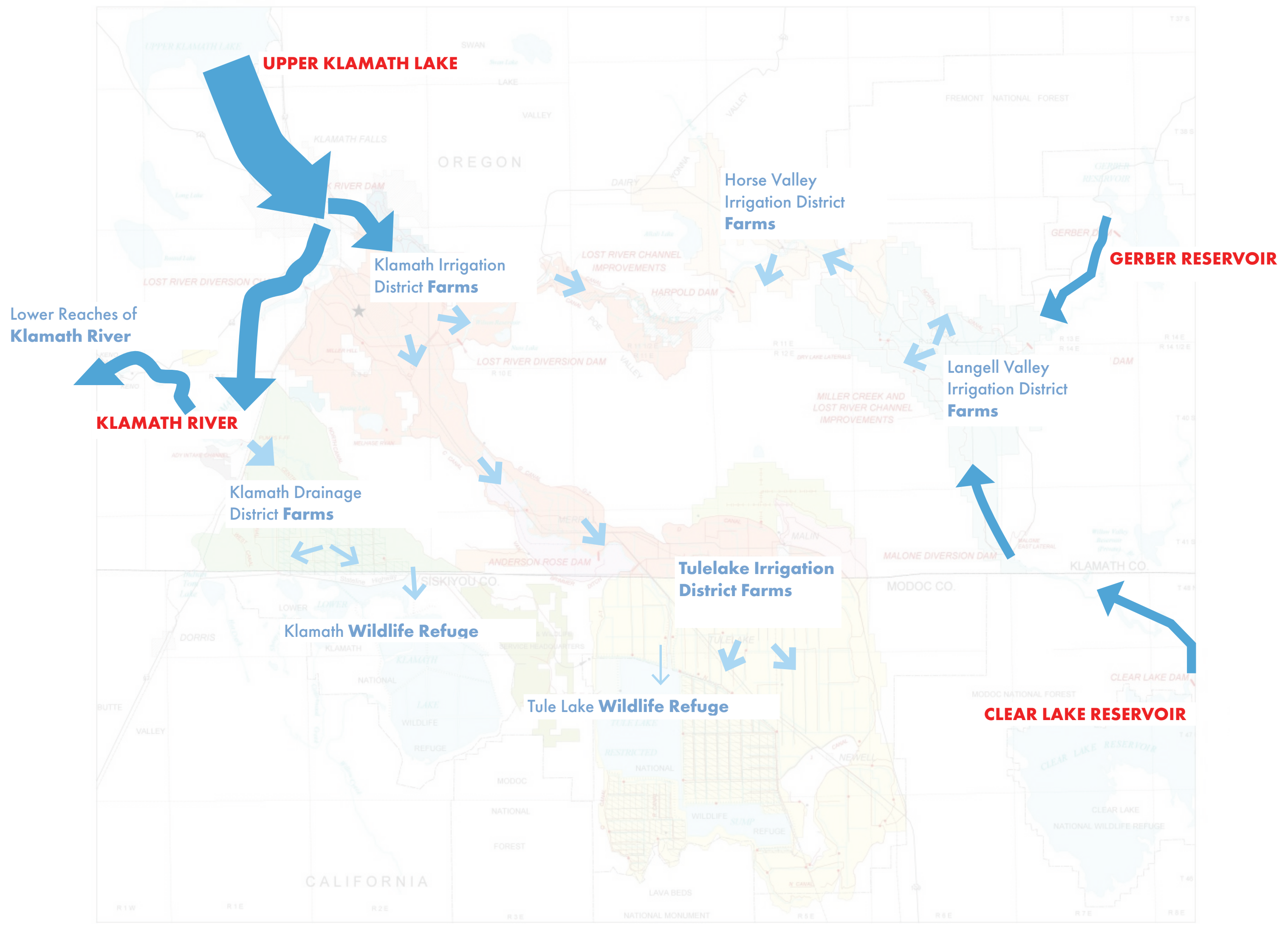
(on Right Page)

Diagram of Approximate Changes in Water Flow to Klamath Project

Created By: McClean Gonzalez
Base Map Created by: Bureau of Reclamation
https://www.usbr.gov/projects/index.php?id=470

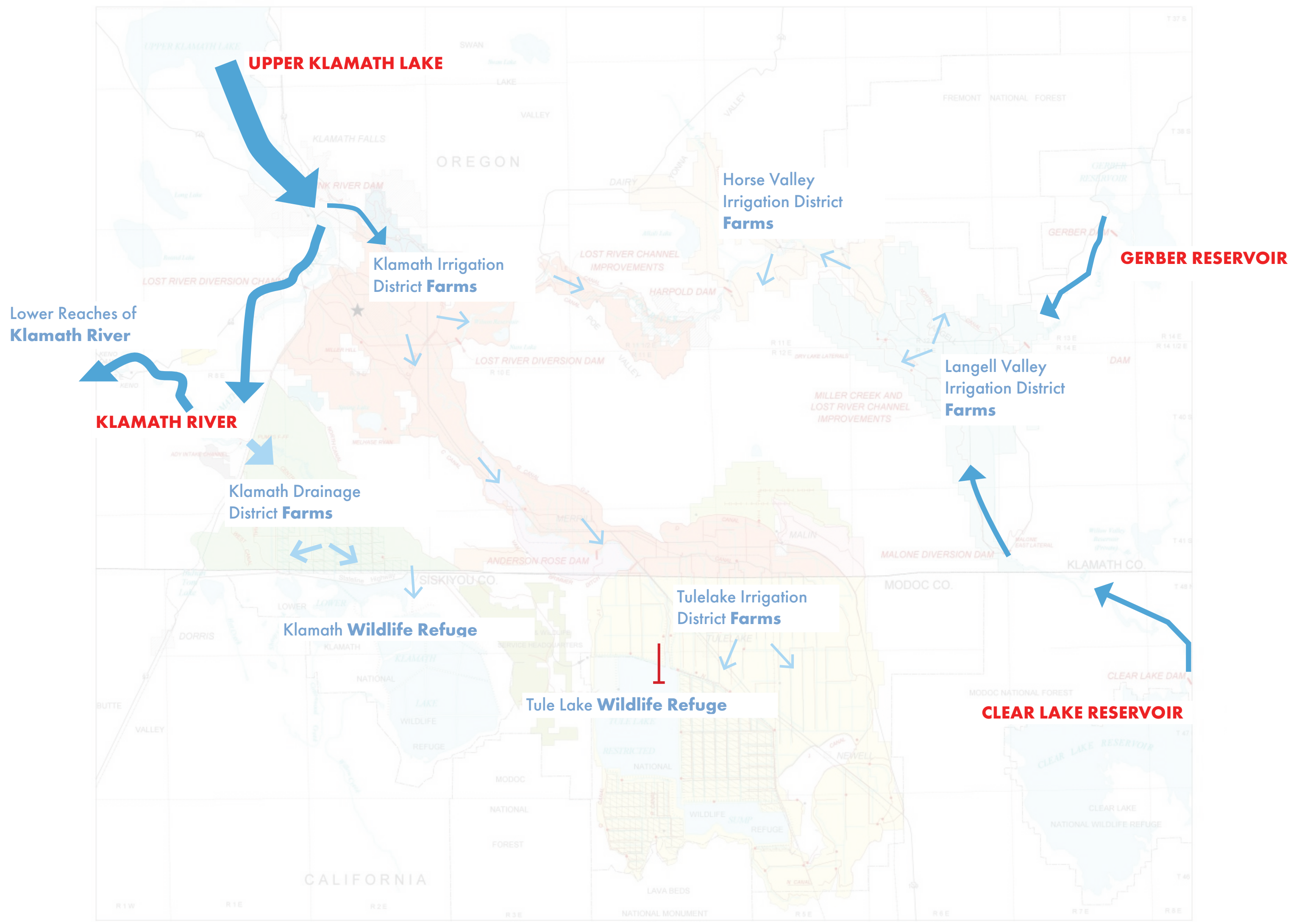
+ **Klamath Reclamation Project** Water Flows

Early Years



LARGER AND SMALLER WATER FLOW ARE APPROXIMATED
WATER SOURCE
Water Destination

Present (with climate change)



LARGER AND SMALLER WATER FLOW ARE APPROXIMATED
WATER SOURCE
Water Destination

Species-Based Water Reallocations

Within the Klamath Irrigation District where the A-Canal is located, the specific species involved are the endangered Coast River Sucker and the threatened Blunt-Nosed Sucker. Current estimates anticipate a loss of about 17-32% of the water that the District usually receives from Upper Klamath Lake. Additional water will likely also be withheld from the Irrigation District to ensure salmon have access to habitat and spawning grounds above and below Upper Klamath Lake.

Klamath Project Water Managers are looking for ways to make less water go further, attempting to find a balance between their own water needs and the greater needs of the basin.

(on Right Page)

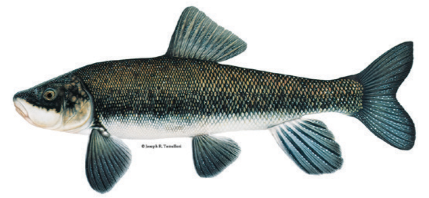
Diagram of Approximate Changes in Water Flow to Klamath Project + Annotation of Specific Causes of Changes

Created By: McClean Gonzalez
Base Map Created by: Bureau of Reclamation
https://www.usbr.gov/projects/index.php?id=470

Images of Fish from: https://www.fisheries.noaa.gov/find-species

+ Klamath Reclamation Project Water Flow Reduction and Reallocation

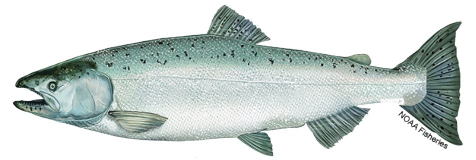
Present (with climate change)



Short-Nosed Sucker (Endangered)

Lost Coast Sucker (Endangered)

To Support



Chinook Salmon (Protected)

Coho Salmon (Protected)

To Support

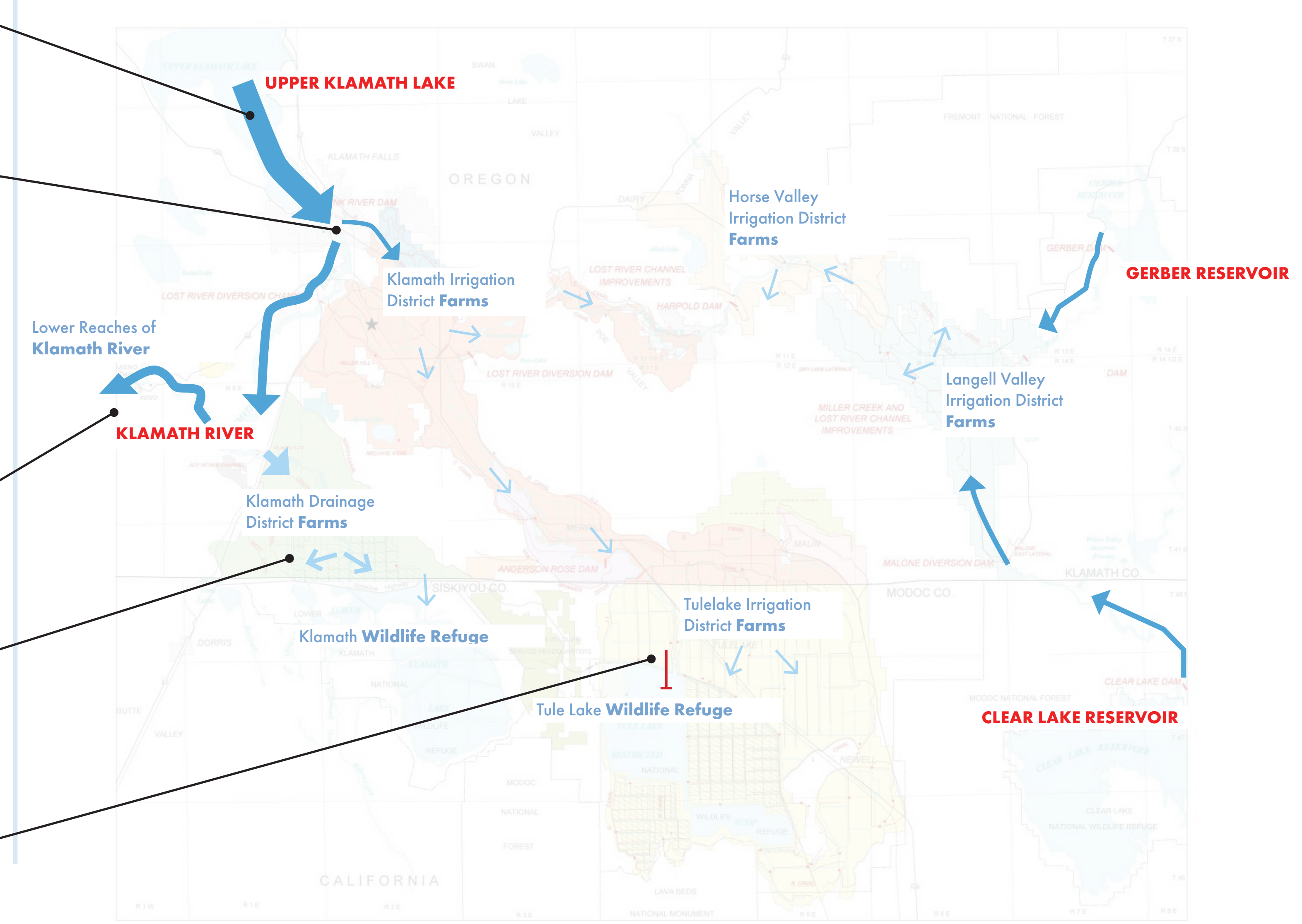
Climate change has **reduced total water in basin**

~17-32% Klamath Irrgation District's normal water allocation **will remain in Upper Klamath Lake**

Additional water **will flow to lower reaches of the Klamath River**

Klamath Drainage District has kept near normal water allocation based on pending legal decision

Reduced water entering Klamath Irrigation District (KID) will reduce or eliminate water sent from KID to Tule Lake Wildlife Refuge



LARGER **AND SMALLER** **WATER FLOW ARE APPROXIMATED**

WATER SOURCE

Water Destination

+ **P.V. Over Canal** for the Klamath Basin

Role of P.V. Over Canal For Basin

P.V. over canal could help ensure that more of the water that makes it to Klamath Project irrigation canals reaches the farmers they serve. The energy produced by these solar panels, the cooling effect of shading, and the potential to decrease organic growth in the canals will also help the Irrigation District to meet the water quality and energy goals established in the Klamath Agreement[1].

1: "Summary of Klamath Basin Settlement Agreements." n.d. https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/docs/klamath_ferc2082/sttlemnt_smmry.pdf.

(on Left Page)

Diagram of P.V. Over Canal

Created By: McClean Gonzalez
Original Image Source: "Conger Products." n.d. Conger Solar Systems (blog). Accessed April 2, 2023. https://www.conger.solar/products/.

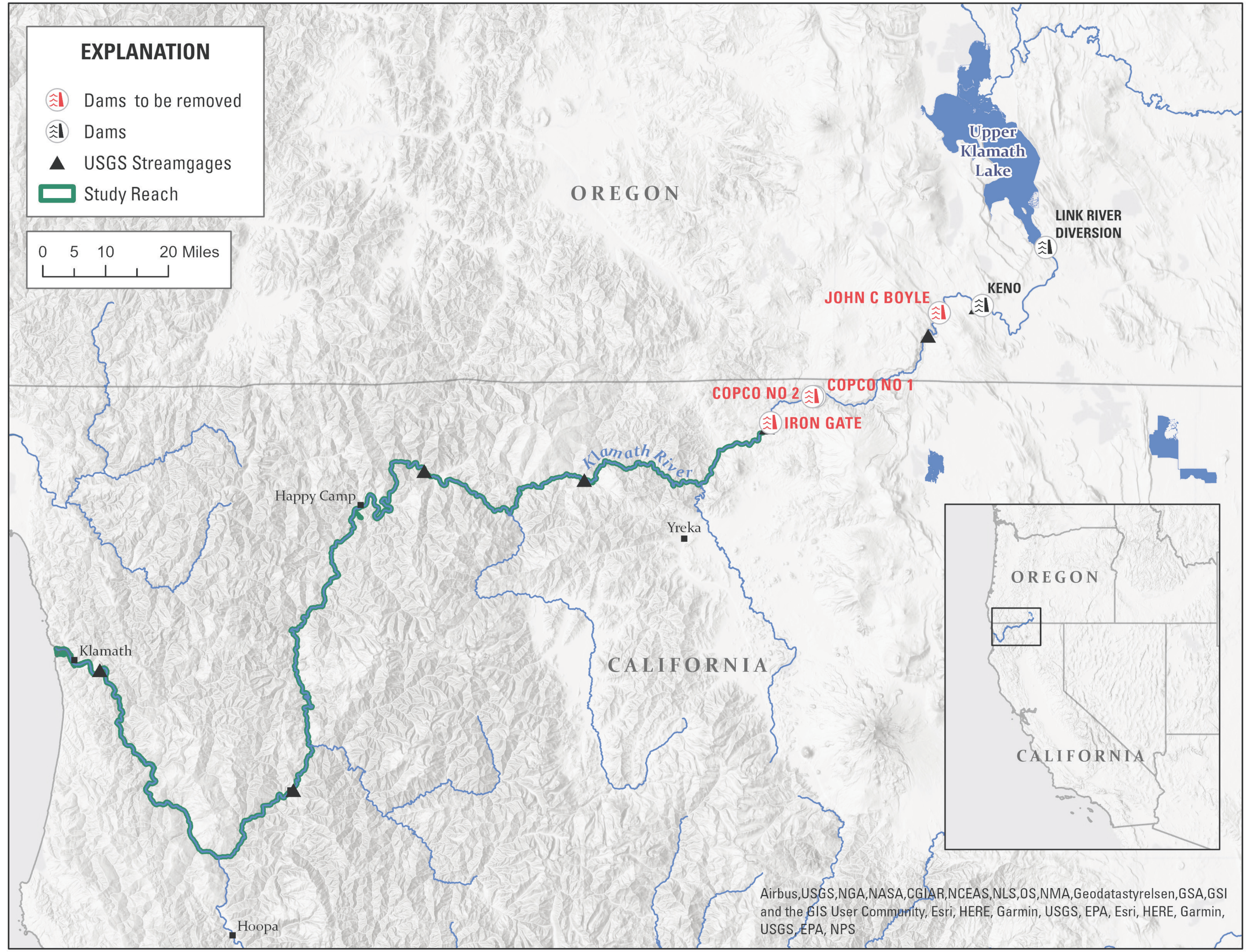
Energy in Klamath Basin

The Klamath Agreement also addresses energy production's impact on the health of the Klamath Basin, seeking to find a balance between ecosystem health and reliable electricity.

Dams as part of the Klamath Hydroelectric Project have provided electricity to farmers and to other users in the region since the first dam, Copco 1 became operational in 1918. Advocacy by the Yurok Tribe, the U.S. Fish and Wildlife Service, and legal protections for salmon in the Endangered Species Act have led to the decision to remove this dam and three others built in the Klamath Basin.

This dam removal project, the largest in U.S. history, was one of the key proposals of the Klamath Agreement, and in late 2022, federal regulators officially approved the project. The age of the dams and cost of these retrofits led the utility, Pacific Corp, to decide that removal was in the best interest of their customers.

+ **Dams** Slated for Removal



Map of Dams in Klamath River Dam Removal Sediment Study
Map Source:
https://www.usgs.gov/media/images/study-reach-klamath-river-dam-removal-sediment-study

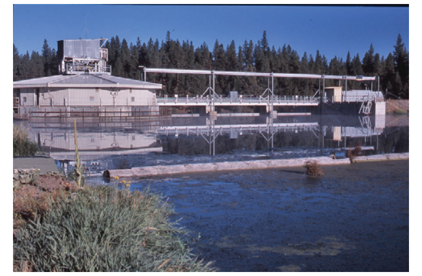
Remaining Dams

LINK RIVER DAM

* Principal source of water for the Klamath Project

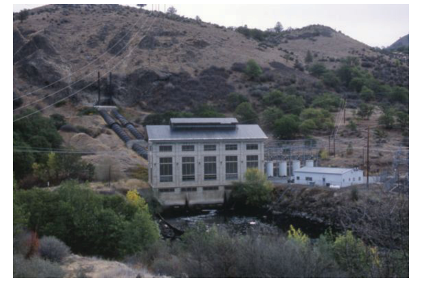
KENO DAM

To Be Removed



JC BOYLE DAM

COPCO NO. 1 DAM



COPCO NO.2 DAM

IRON GATE DAM

Images of Dams Remaining and Being Removed in Klamath Basin
Image Source: Klamath River Renewal Corporation
https://klamathrenewal.org/the-project/

+ **P.V. Over Canal** to Replace Electricity Capacity Lost by Dam Removals

20 Miles of P.V. Over Canal

=

Energy Lost by Four Dams

P.V. Panels Generate Electricity

Supporting farmers and nearby cities

P.V. Panels Shade Canal

Saving and cooling water & reducing organic growth

P.V. Over Canal's Potential to Replace Lost Energy

The 4 dams represented 2% of Pacific Corp's energy portfolio – approximately enough electricity to power 70,000 homes. Expansion of P.V. over canal in the region is one opportunity to replace the energy lost by removing these dams. Based on my estimates, 21 miles of a 70-foot wide, P.V. over canal system could produce 71,000 megawatt hours (MWh) of electricity per year, more electricity than the 4 dams produced each year at full capacity. A ground-mounted P.V. system would need about 176 acres to produce the same amount of electricity.

(on Left Page)

Diagram of P.V. Over Canal

Created By: McClean Gonzalez
Original Image Source: "Conger Products." n.d. Conger Solar Systems (blog). Accessed April 2, 2023. https://www.conger.solar/products/.

+

Context

Climate Water & Energy in the Klamath Basin | **P.V. Over Canal** | Project Site A-Canal

State of P.V. Over Canal

By saving water and producing clean electricity, P.V. over canal is becoming an increasingly important strategy to offset shortages of water and decarbonize energy production.

P.V. Over Canal Overview

P.V. over canal benefits from its location over already disturbed and centrally owned land, its ability to save water by shading the water of canals, and this configuration's improvement of solar panel efficiency.

(on Right Page)

Diagram of P.V. Over Canal

Created By: McClean Gonzalez
Original Image Source: "Conger Products." n.d. Conger Solar Systems (blog). Accessed April 2, 2023. https://www.conger.solar/products/.

+ P.V. Over Canal

P.V. Panels Generate Electricity

Supporting farmers and nearby cities

P.V. Over Canal Project by Conger Solar Systems
https://www.apsunsys.com/en/refperences/

P.V. Panels Shade Canal

Saving and cooling water & reducing organic growth

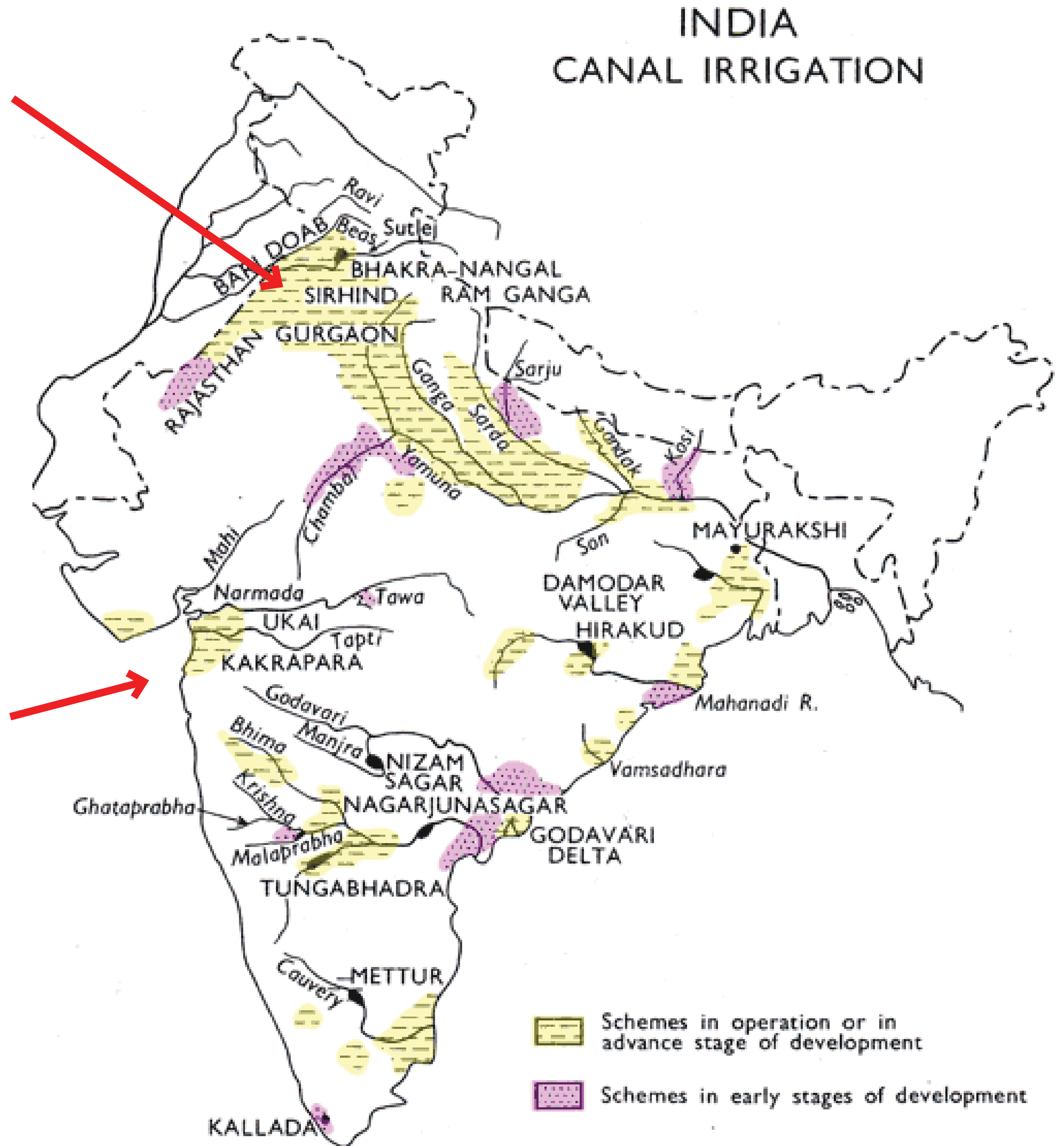
Located on Already Disturbed and Centrally Owned Land

Punjab

P.V. Over Canal Project in Punjab, India
https://www.conger.solar/products/

Gujarat

P.V. Over Canal Project in Gujarat, India
https://www.apsunsys.com/en/references/



Map of Canal Projects in India
https://www.civilsdaily.com/sources-and-methods-of-irrigation-tank-irrigation-wells-and-tubewells-canals-ultimate-irrigation-potential-net-irrigated-area-irrigation-intensity/?utm_source=mailchimp&utm_medium=cpc

P.V. Over Canal in India

P.V. over canal is in an early phase of research and development. Most built examples of P.V. over canal have been built in India. The Ministry of New and Renewable Energy partnered with state energy development agencies and technology providers to test the technology over the extensive canal systems in Punjab and Gujarat.

Conger Solar Systems in India

Conger Solar Systems–who designed and assisted in construction management on the projects in Punjab–has been chosen to design the first P.V. over canal system in California, which is breaking ground this year in 2023.

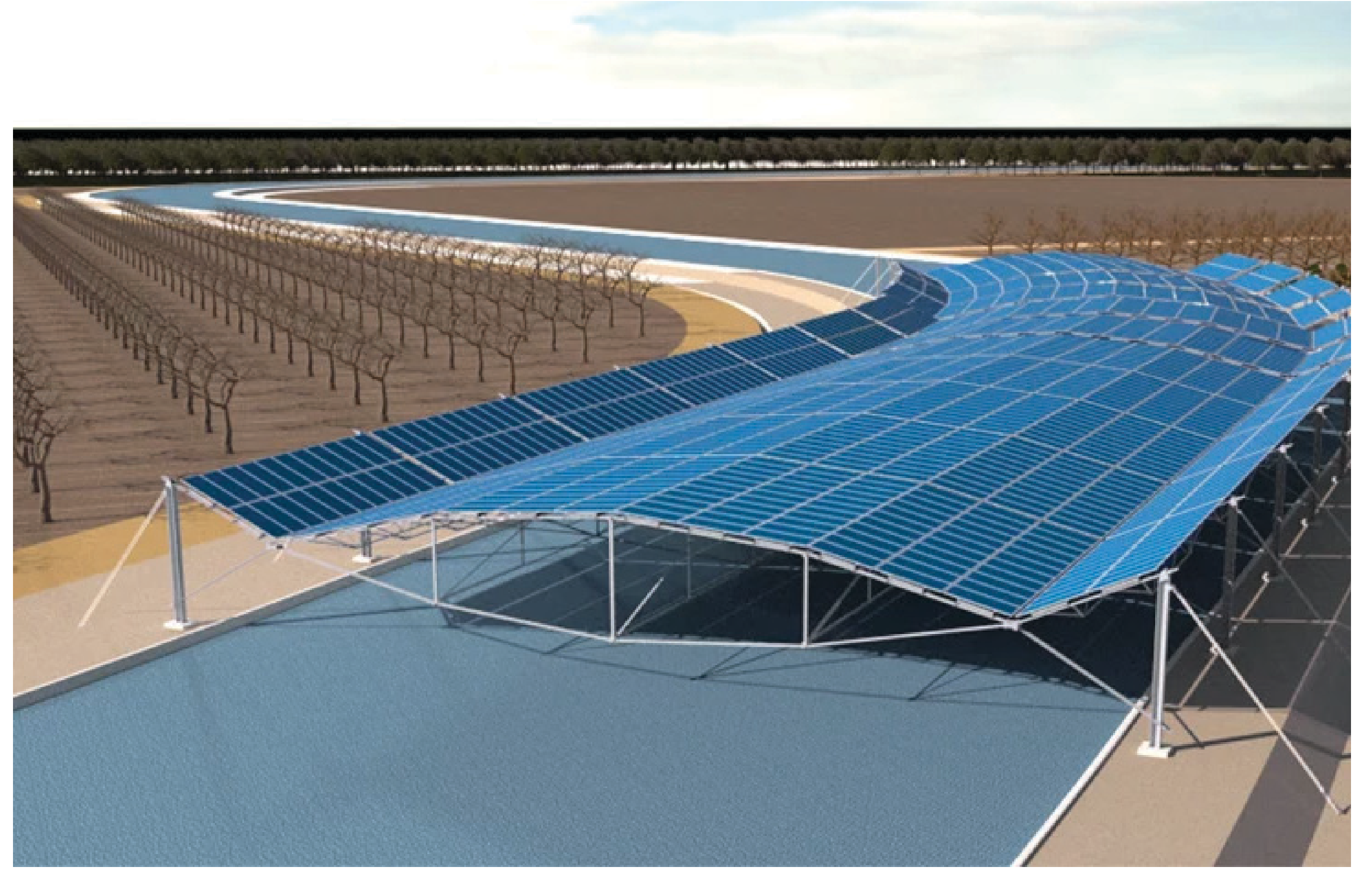
+ Built **P.V. Over Canal** by Conger Solar Systems

Images from Two Projects built by Conger Solar Systems in India
https://www.apsunsys.com/en/references/

Ground-Mounted

Utility Scale Ground-Mounted P.V. System
https://www.solarpowerworldonline.com/2016/11/big-three-avoid-utility-scale-ground-mounting-challenges/

P.V. Over Canal



Simulation of Conger's P.V. Over Canal System for Turlock Irrigation District in California
https://www.conger.solar/conger-solar-systems-selected-to-design-solar-canopies-for-project-nexus/

Ground-Mounted P.V. Vs. P.V. Over Canal

Research on P.V. over canal has focused on estimating its water savings ability and its economic feasibility. These tests of P.V. configurations against ground-mounted P.V. systems have considered water savings, increased solar panel efficiency, land cost savings, and cost savings from new cable support structural systems. This research shows that P.V. over canal systems are financially competitive to ground-mounted P.V. systems[1].

1: McKuin, Brandi, Andrew Zumkehr, Jenny Ta, Roger Bales, Joshua H. Viers, Tapan Pathak, and J. Elliott Campbell. 2021. "Energy and Water Co-Benefits from Covering Canals with Solar Panels." Nature Sustainability 4 (7): 609–17. https://doi.org/10.1038/s41893-021-00693-8.

Future Research for P.V. Over Canal

Operational and aesthetic concerns still exist, including adapting the technology to each canal system's bank material and structure, ensuring emergency and maintenance access to the canal, and avoiding conflicts with surrounding land uses. These site-specific challenges have become a primary focus of this project.

(on Right Page)

Diagram of Operational and Aesthetic Challenges of P.V. Over Canal

Created By: McClean Gonzalez
Original Image Source: "Conger Products." n.d. Conger Solar Systems (blog). Accessed April 2, 2023. https://www.conger.solar/products/.

Operation and Aesthetic Challenges

1. Adapting the technology to each canal system's bank material and structure.
2. Ensuring emergency and maintenance access to the canal.
3. Avoiding conflicts with surrounding land uses.

+

Context

Climate Water & Energy in the Klamath Basin | P.V. Over Canal | **Project Site A-Canal**

Project Site

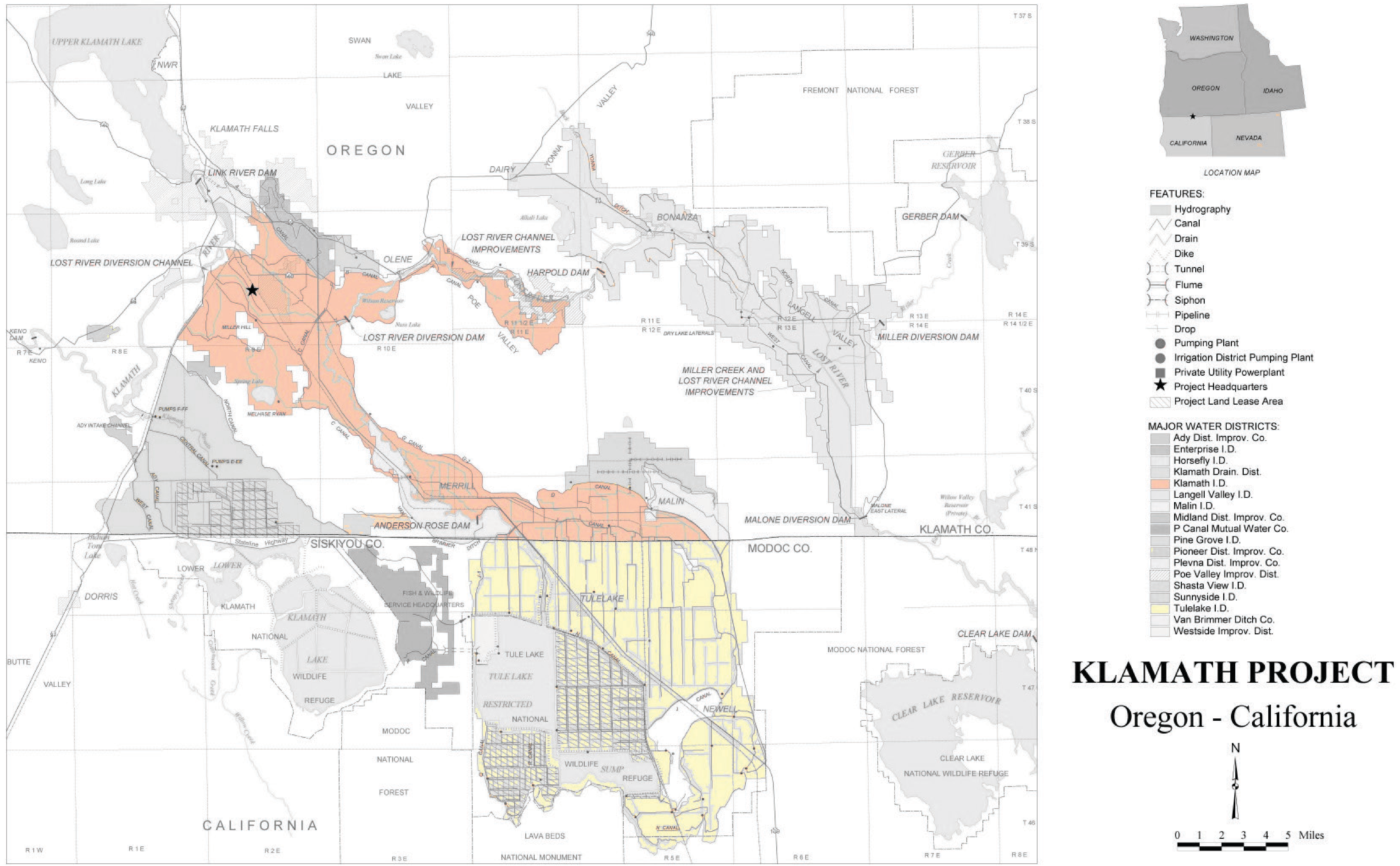
My project's site, the A-Canal, is the main feeder canal for the Klamath Irrigation District and the Tulelake Irrigation District, which are divided at the California border. These are 2 of the 18 Water districts of the Klamath Project.

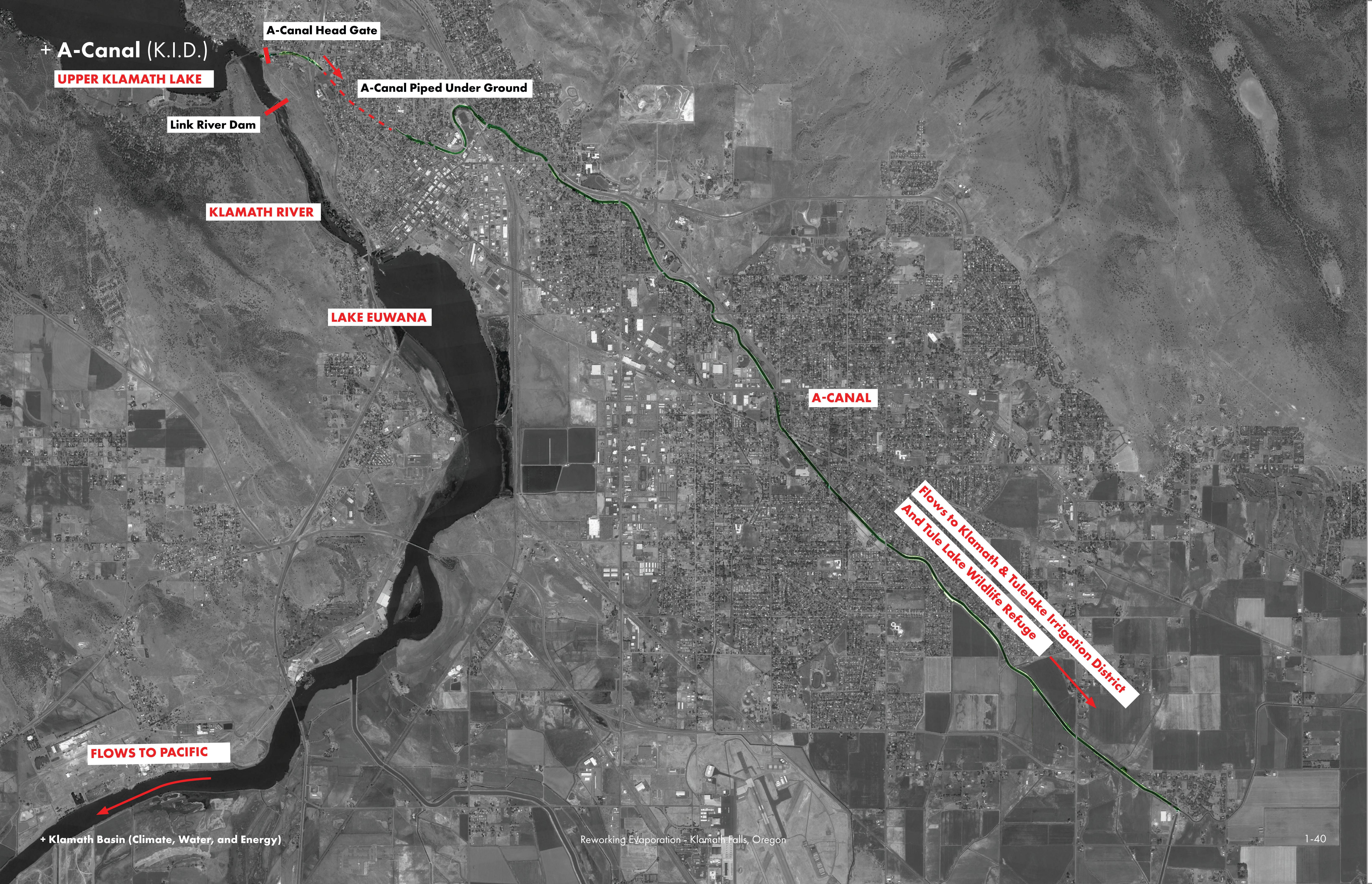
(on Right Page)

Modified Map of Klamath Reclamation Project Highlighting Klamath Irrigation District & Tulelake Irrigation District

Modified By: McClean Gonzalez
Original Map Created by: Bureau of Reclamation
https://www.usbr.gov/projects/index.php?id=470

+ Klamath Irrigation District and Tulelake Irrigation District





The A-Canal

The A-Canal runs through Klamath Falls, Oregon, Klamath County's largest city, making it an "urban canal." This project explores how P.V. over canal on the A-Canal could affect the health of the Basin overall, the people who live along its embankments, and the farmers who depend on the water that moves through it.

(on Left Page)

Annotated Aerial Image of the A-Canal in Klamath Falls Oregon

Created By: McClean Gonzalez
Aerial Image Source: Google Earth (Accessed May 2023)

Why the A-Canal & Urban Canals

Using the methods of landscape architecture, I explore the challenges of applying P.V. over canal systems to urban canals by investigating the site-specific challenges of the A-Canal.

I chose to focus on urban canals because of the need for additional research on P.V. over canal for the approximately 1,000 miles of urban canals in the United States.

I chose the A-Canal because of the need to address the extreme flood risk along one of its embankments and the water challenges that the Klamath Basin faces.

+ A-Canal / Urban Canals

To Address A-Canal's Needs
(water savings and reduction of flood risk)

Design a P.V. Over Canal System for A-Canal

To Explore P.V. Over Canal for Urban Canal

A-Canal
Image from Site Visit on Nov. 22, 2022

Grand Canal in Phoenix Arizona
https://www.phoenix.gov/streets/grandcanalscape

+

Design Process

Objectives | Site Analysis

+

Defining the Design Process

I started this exploration by determining what my place could be within a P.V. over canal project for Klamath Falls. I determined that the A-Canal could help me understand how the design and construction of a P.V. over canal system could change the experience of walking along the canal. From this understanding, I could then alter a possible P.V. over canal system to create both Basin-wide energy and water benefits and enhance the canal path, the central pedestrian corridor of Klamath Falls.

(on Right Page)

(Diagram on Left)
Annotated Image from Nov. 24th Site Visit to Klamath Falls A-Canal

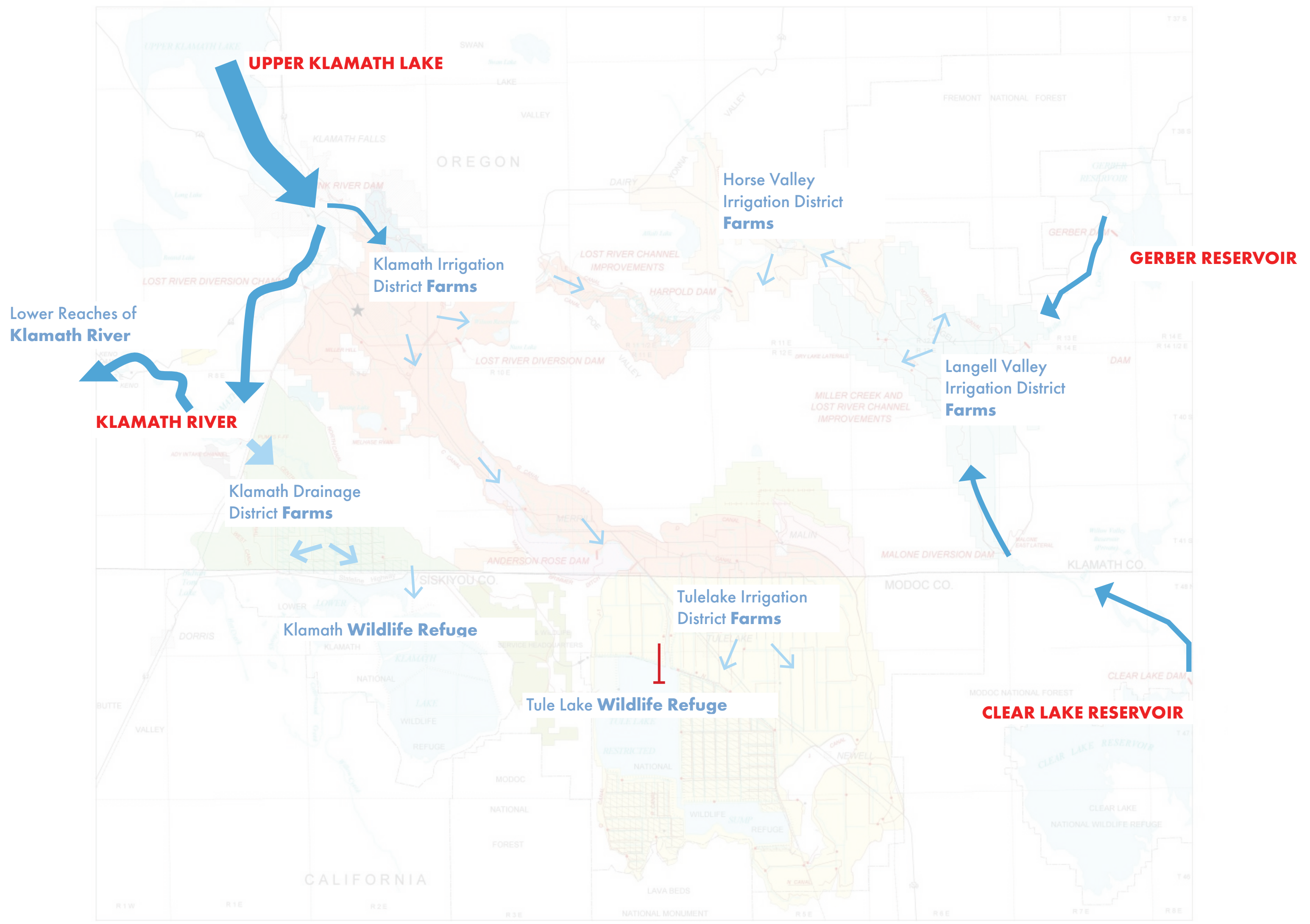
(Diagram on Right)
Diagram of Approximate Current Water Flow to Klamath Project

Created By: McClean Gonzalez
Base Map Created by: Bureau of Reclamation
https://www.usbr.gov/projects/index.php?id=470

+ Determining Project Priorities

Experience of Living and Walking Along the Path

Basin-Wide Energy and Water Benefits



LARGER AND SMALLER WATER FLOW ARE APPROXIMATED
WATER SOURCE
Water Destination

Technical Objectives

1. **Maximize** the **shading** of the **canal**.
2. **Maximize** the **energy efficiency** of **solar panels**.
3. Stick to **reasonable** or **proven** ways of **structurally supporting the solar panels**.
4. **Avoid disturbing** the **chalk rock** bottom of the canals.
5. **Avoid** extremely **expensive flood prevention structures**.

Experiential Objectives

1. **Mitigate light access impacts** on adjacent properties.
2. **Eliminate glare** impacts.
3. **Mitigate visual impacts** on adjacent properties and key viewpoints.
4. **Utilize** panel **structures** to **enhance** the **pedestrian trail** experience.
5. **Maintain views** of water if possible.

Creating Design Objectives

To guide me through this process, I created both technical objectives and experiential objectives. The technical objectives were informed by built P.V. over canal systems and research, and the experiential objectives, by the functional and aesthetic priorities of the field of landscape architecture.

Technical Objectives

1. **Maximize** the **shading** of the **canal**.
2. **Maximize** the **energy efficiency** of **solar panels**.
3. Stick to **reasonable** or **proven** ways of **structurally supporting the solar panels**.
4. **Avoid disturbing** the **chalk rock** bottom of the canals.
5. **Avoid** extremely **expensive flood prevention structures**.

Experiential Objectives

1. **Mitigate light access impacts** on adjacent properties.
2. **Eliminate glare** impacts.
3. **Mitigate visual impacts** on adjacent properties and key viewpoints.
4. **Utilize** panel **structures** to **enhance** the **pedestrian trail** experience.
5. **Maintain views** of water if possible.

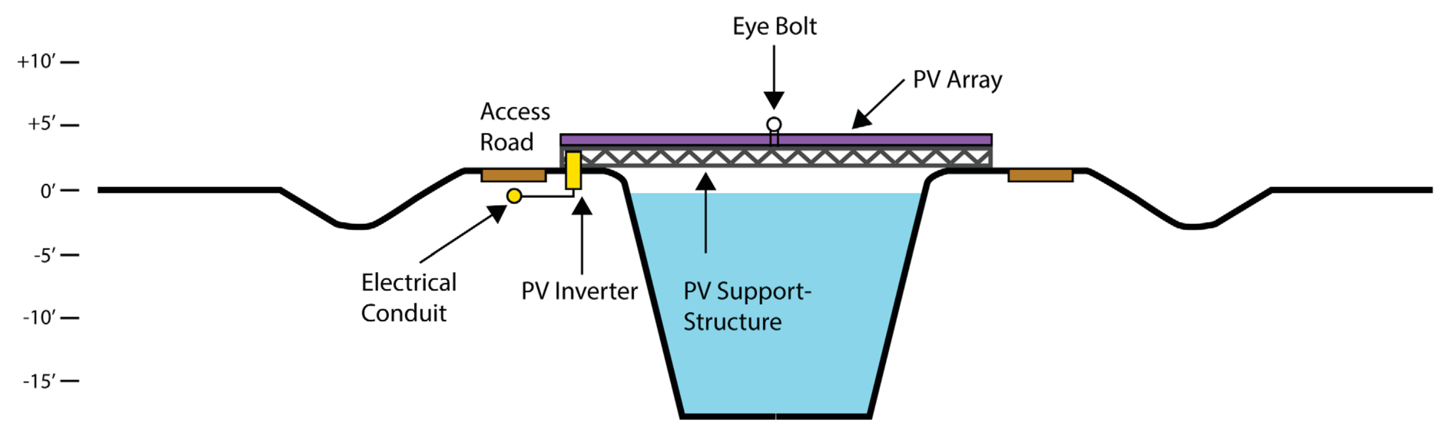
Technical Objectives

The technical objectives organize the core requirements that make a P.V. over canal system beneficial and feasible. I used them as a reference to ensure that my design exercises stayed grounded in reality.

Technical Objectives

1. **Maximize** the **shading** of the **canal**.
2. **Maximize** the **energy efficiency** of **solar panels**.
3. Stick to **reasonable** or **proven** ways of **structurally supporting the solar panels**.
4. **Avoid disturbing** the **chalk rock** bottom of the canals.
5. **Avoid** extremely **expensive flood prevention structures**.

Technically “Ideal” P.V. Over Canal System



Developed by Rob Ribe as a Part of PNNL Workshop:

Designing Place-Based Renewable Energy Infrastructure: Exploring Opportunities and Challenges for the Pacific Northwest Region

January 2023

Technically Ideal P.V. Over Canal System

From a technical perspective, the ideal P.V. over canal system orientation places the solar panels densely and continuously, as close as possible to the surface of the water, and at a south-facing angle corresponding to the site’s latitude. Solar panels closer to the water and perpendicular to the sun are more efficient.

Technical Objectives

1. **Maximize** the **shading** of the **canal**.
2. **Maximize** the **energy efficiency** of **solar panels**.
3. Stick to **reasonable** or **proven** ways of **structurally supporting the solar panels**.
4. **Avoid disturbing** the **chalk rock** bottom of the canals.
5. **Avoid** extremely **expensive flood prevention structures**.

Experiential Objectives

1. **Mitigate light access impacts** on adjacent properties.
2. **Eliminate glare** impacts.
3. **Mitigate visual impacts** on adjacent properties and key viewpoints.
4. **Utilize** panel **structures** to **enhance** the **pedestrian trail** experience.
5. **Maintain views** of water if possible.

Experiential Objectives

I then created experiential objectives to reference possible effects that a P.V. over canal system might have on people's experience of living and walking along the A-Canal.

Creating these also helped to clarify where conflicts existed between the technical and experiential objectives. Extra attention was needed, where conflicts existed, to deliberately deform the "technically ideal" P.V. over canal system to create enough additional amenity benefits to justify some loss in water savings and energy production.

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Design Process

Objectives | Site Analysis

Methods
Flood Risk
Embankment Dimensions
Flow Direction
Canal Path & Service Road

Site Analysis Overview

After defining these objectives, I returned my focus to the A-Canal to better understand the unique challenges it might present to a P.V. over canal system and to better understand the current configuration of the canal.

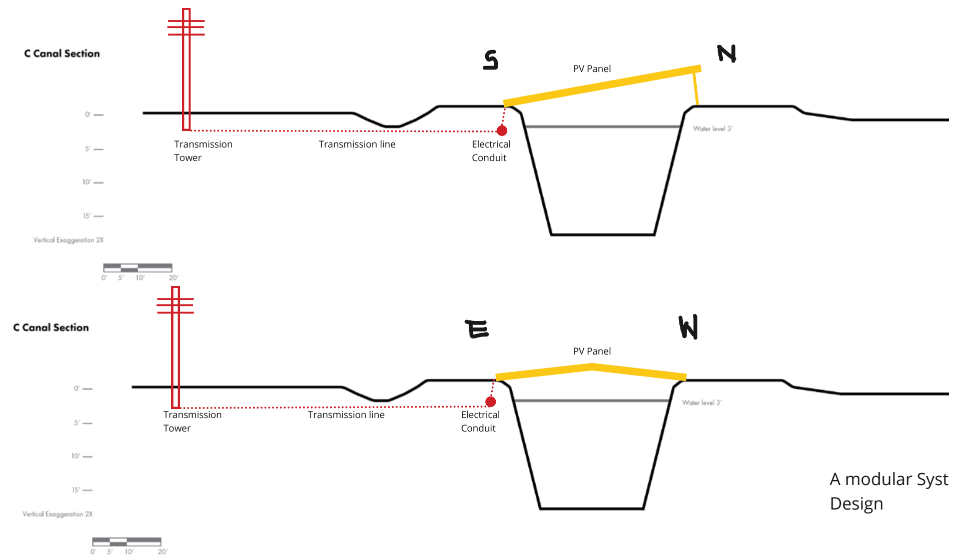
Meetings
& PNNL Workshop

Gene Souza
Klamath Irrigation District

Scott White
Klamath Drainage District

Jed Jorgensen
PNNL and Formerly Farmers Conservation Alliance

Keith Tourney
Farmers Conservation Alliance



Section Drawings Developed as a Part of PNNL Workshop:

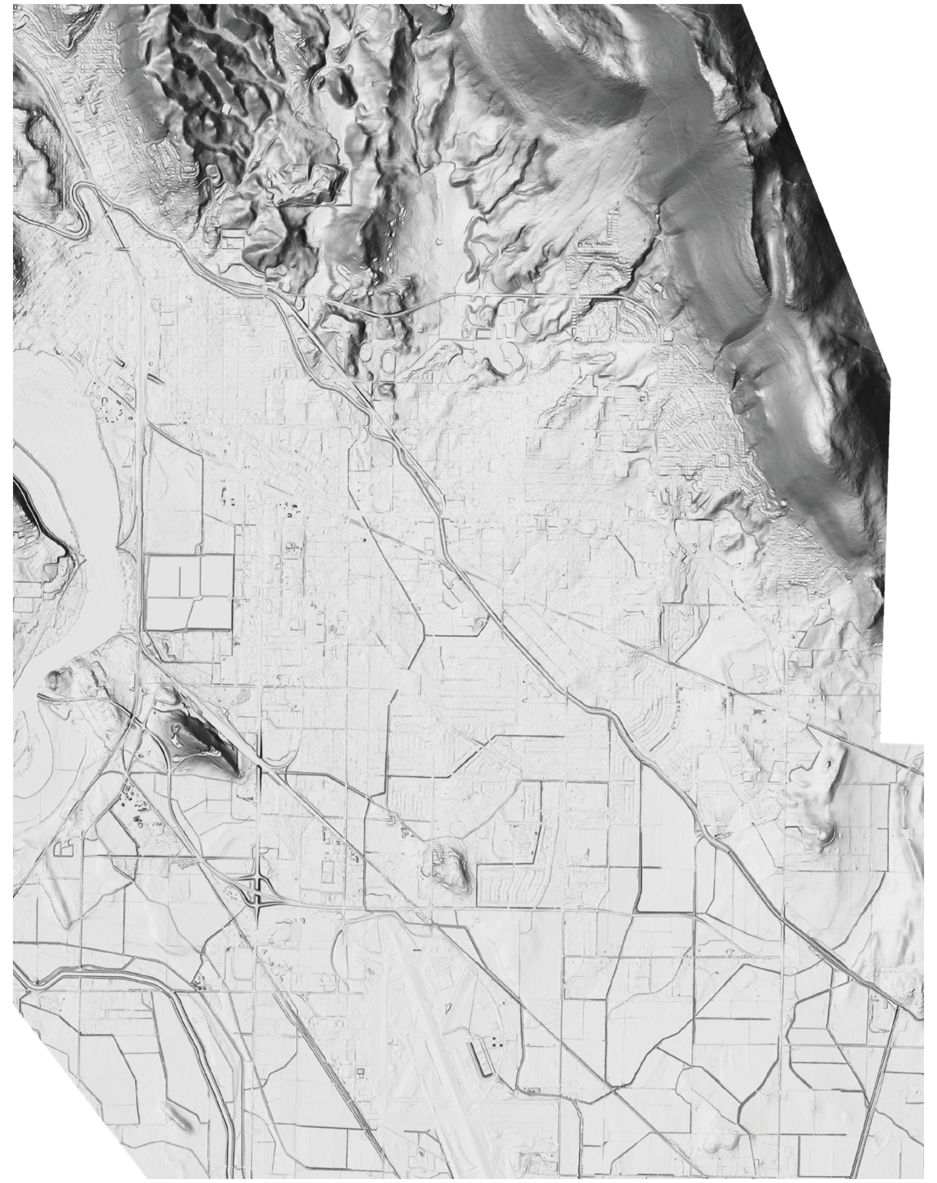
Designing Place-Based Renewable Energy Infrastructure: Exploring Opportunities and Challenges for the Pacific Northwest Region

January 2023

Site Visit
11.24.2022

Images from Nov. 24, 2023 Site Visit to A-Canal in Klamath Falls, Oregon

Detailed Elevation Data (LIDAR)
from DOGAMI



Hill-shade of A-Canal Klamath Falls Oregon

Elevation Data Source: DOGAMI
https://www.oregongeology.org/lidar/

Site Analysis Methods

To do this, Rob Ribe, my advisor, and I met with Gene Souza, the director of the Klamath Irrigation District, which operates the A-Canal.

I also analyzed detailed elevation data of the A-Canal and biked along the full canal path. From these sources, I identified characteristics that were representative of the A-Canal to inform my three design exercises.

Components of Flood Risk

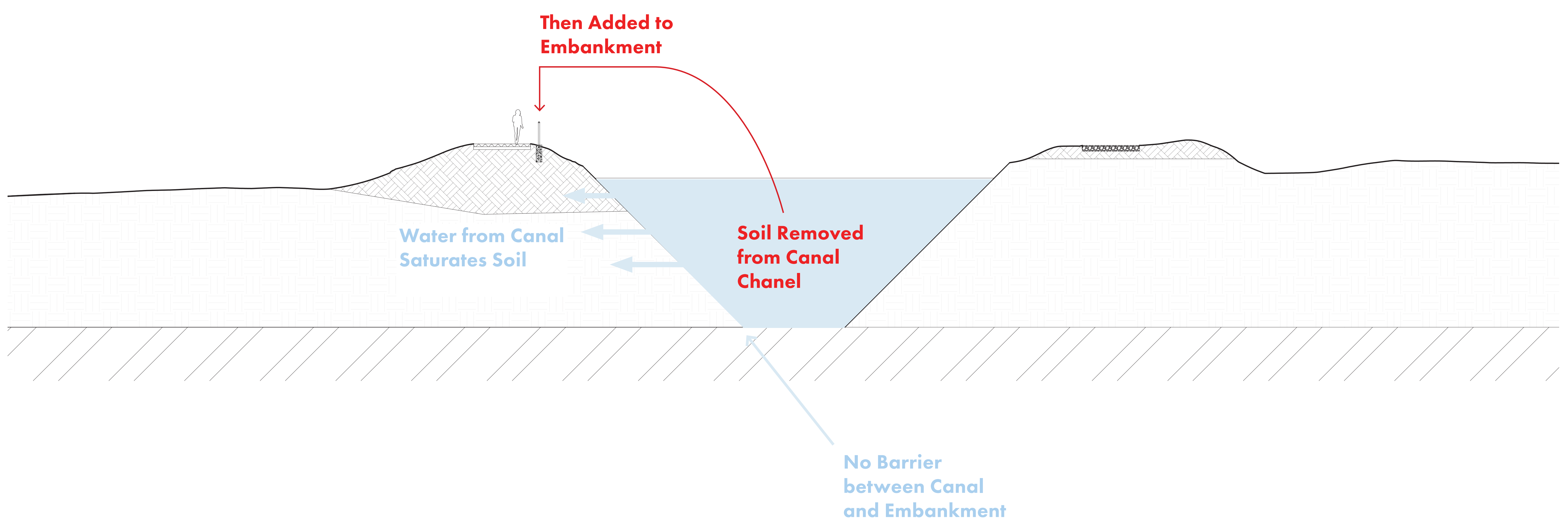
The high risk of embankment failure and flooding along the south embankment is one of the most urgent conditions found in this analysis. Gene Souza emphasized the need to maintain ready access to certain canal embankments in the event of their failure so that repairs could be made.

This risk of flooding is caused by the wrong fill material being used to build the canal in the early 1900s and the chalk rock bottom of the canal.

(on Right Page)

Diagram of Causes of Flood Risk for South Embankment of A-Canal
Created By: McClean Gonzalez

+ **Site Analysis** Flood Risk from Construction Methods



Chalk Rock

This impervious and slippery chalk rock bottom encourages the sliding of the embankment.

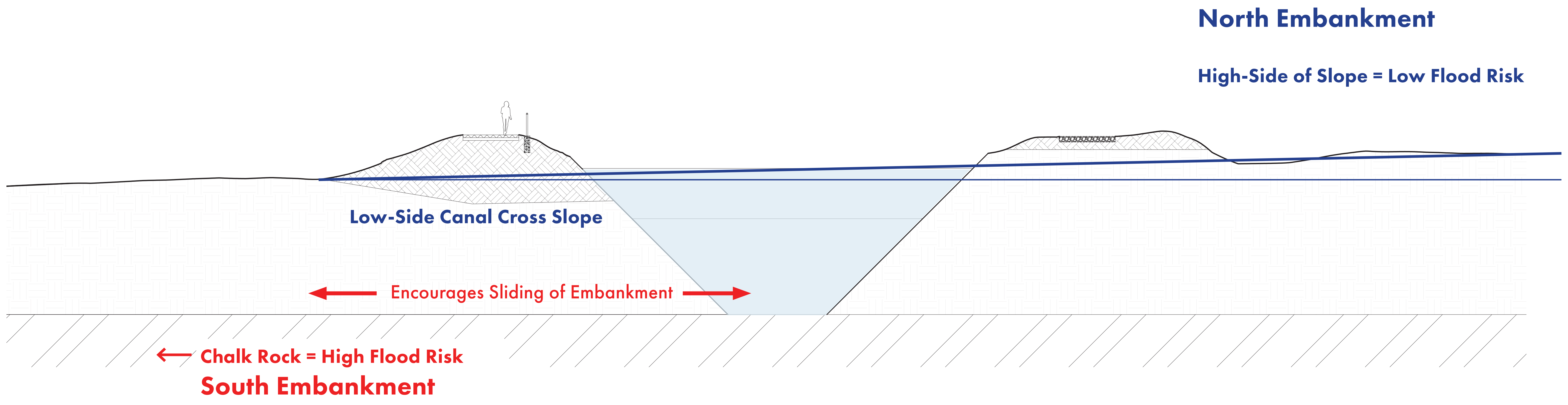
North Embankment Flood Risk

There is much less flood risk on the north embankment because it is on the upside of the canal's cross slope.

(on Right Page)

Diagram of Causes of Flood Risk for South Embankment of A-Canal
Created By: McClean Gonzalez

+ Site Analysis Flood Risk from Chalk Rock & Cross Slope



+ **Site Analysis** Flood Risk Map Components

Extent of Flooding
1944 Report

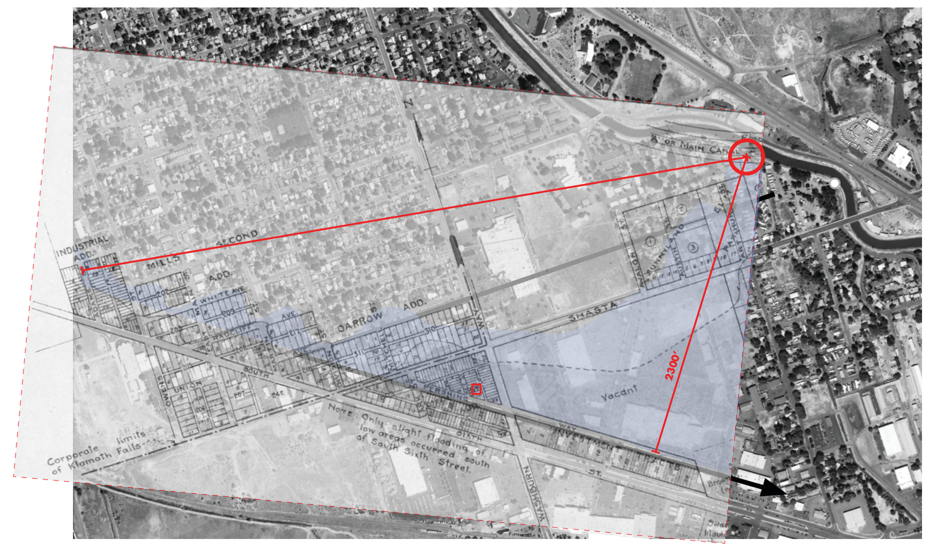


Diagram of Possible Flood Extent based on 1944 Flood
Report: *REPORT ON BREAK OF MAY 15, 1944*
IN MAIN CANAL OF KLAMATH PROJECT
OREGON - CALIFORNIA

Width and Height of Embankment
Analysis of Elevation Data

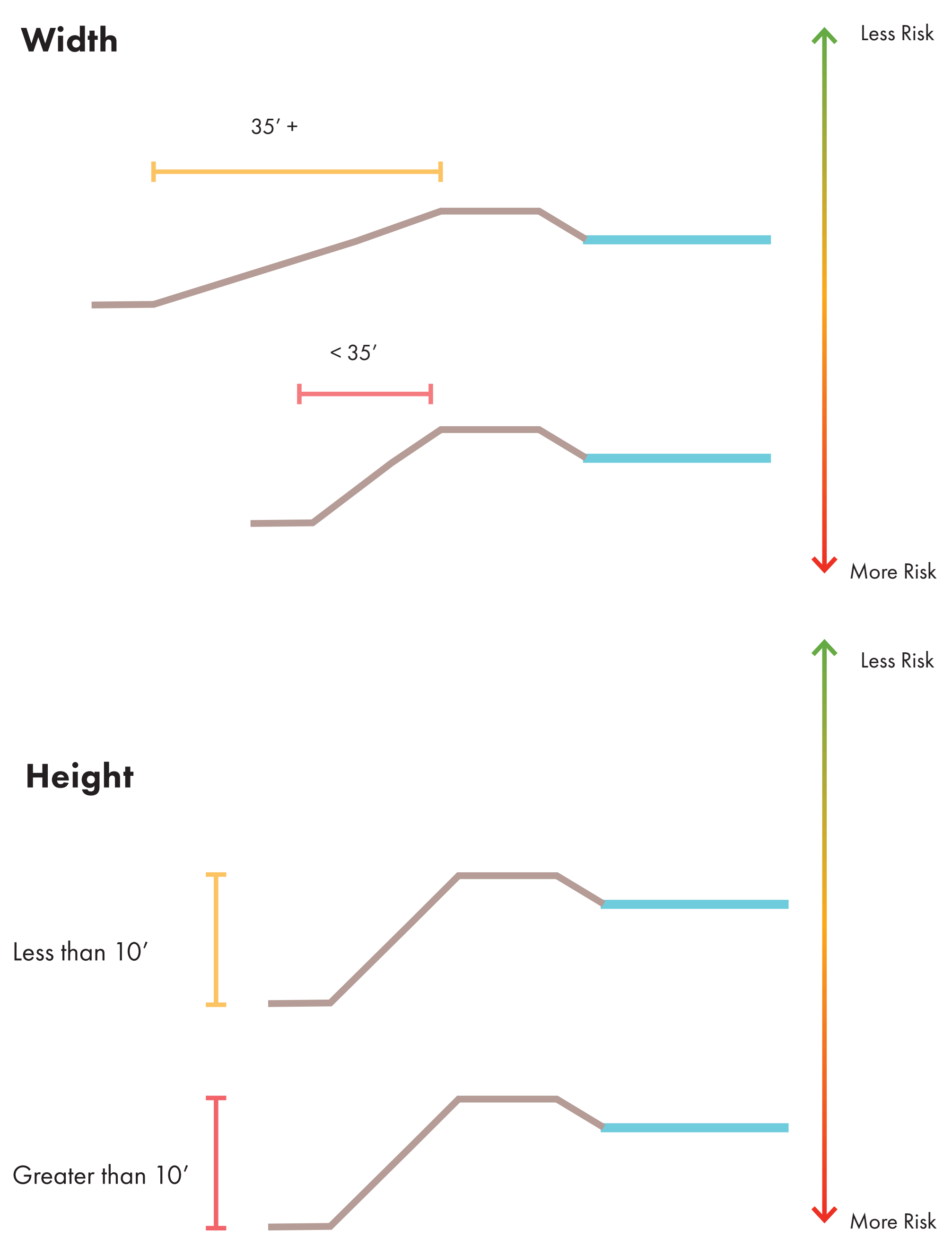


Diagram of Height and Width Flood Risk Factors
Created By: McClean Gonzalez

Land Use to South of Embankment
Analysis of Aerial Imagery and Zoning

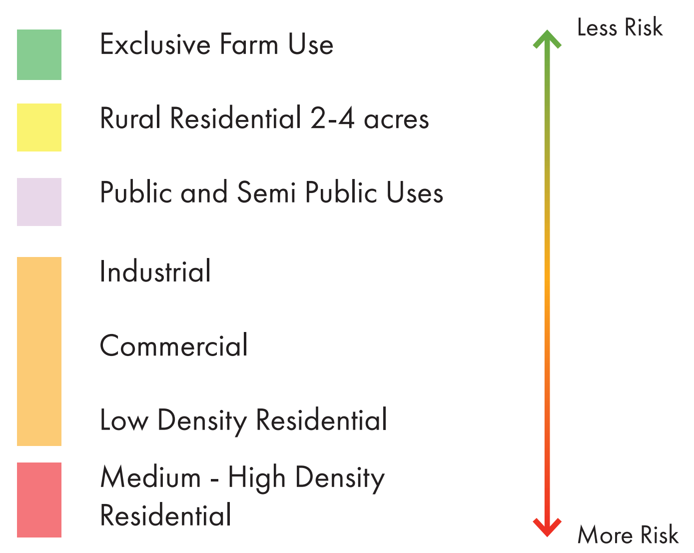


Diagram of Land Use Based Flood Risk Factors
Created By: McClean Gonzalez

Developing a Flood Risk Map

To determine how flood risk would affect the design of a P.V. over canal system for the A-Canal, I needed to better understand how this flood risk varied across its length. To do this, I created a composite map of flood risk informed by details of a 1944 report of one of these embankment failures, land use designations along the canal, and the width, height, and slope of the south embankment.

1944 Flood Report

Details of recent failures are classified because of possible risks of vandalism, but Souza was able to provide a public report of a 1944 flood that occurred near the intersection of Shasta Way and the A-Canal. It provides a view into the extent of the damage that could occur along most of the extent of the A-Canal.

(on Right Page)

Images from 1944 Flood Report, Red Circles Highlight People
Image Source: *REPORT ON BREAK OF MAY 15, 1944 IN MAIN CANAL OF KLAMATH PROJECT OREGON - CALIFORNIA*

+ Site Analysis Flood Risk 1944 Flood

16

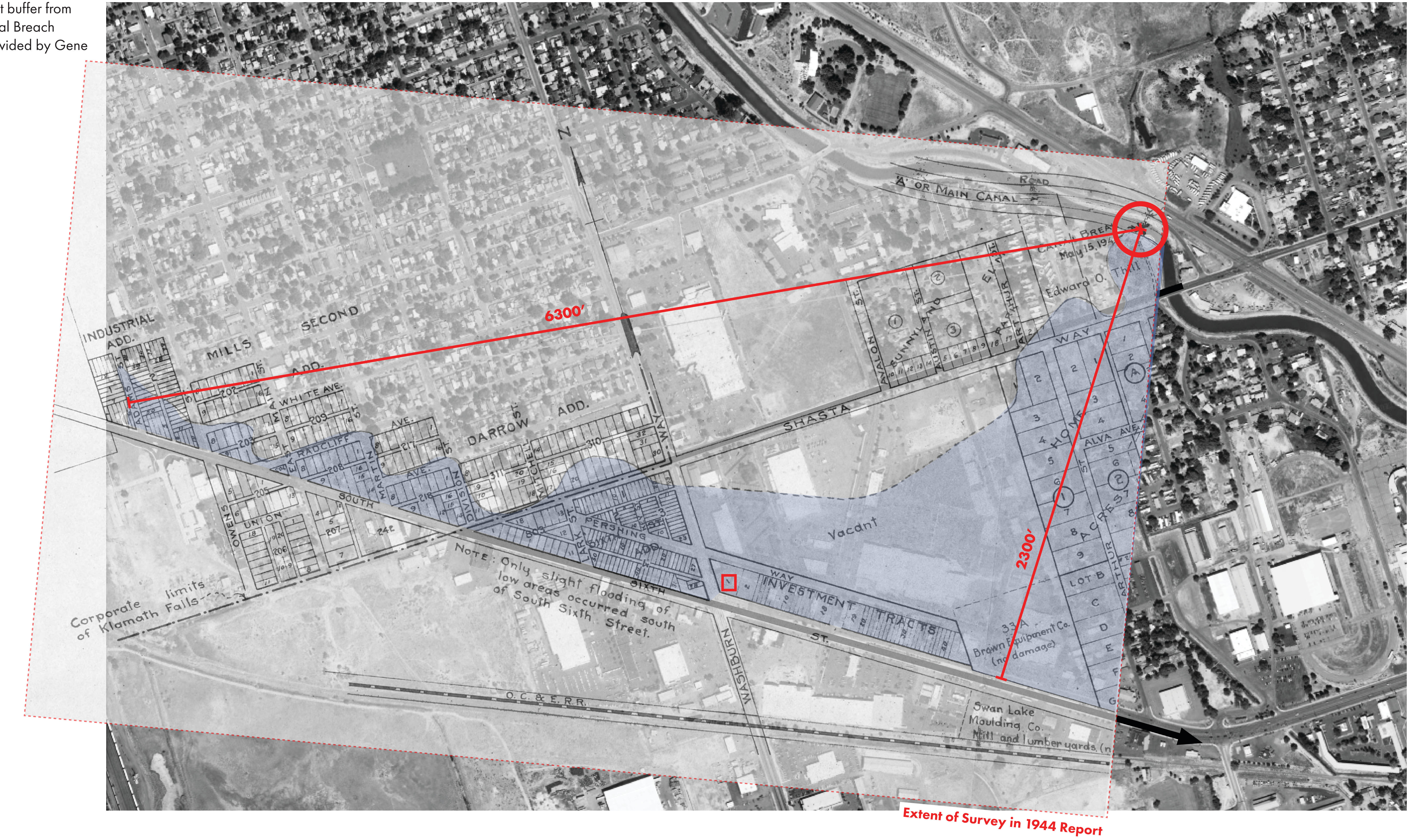
(4) Flood waters around the Tower Theatre on Lot 1 of Investment Tracts. View taken from corner of Washburn Way and South Sixth St. looking northeasterly. (See item #167 of Appraisal of Damages.)

13

(1) Canal waters running out of break in Klamath "A" or Main Canal. View from property of Edward O. Thill (see item #1 of Appraisal of Damages), looking in a northeasterly direction. Dark area in center of photograph shows portion of gunite lining which held.

+ **Site Analysis** Flood Risk 1944 Flood Extent

6,300-foot buffer from 1944 Canal Breach Report Provided by Gene Souza



Components of Flood Risk - Flood Extent

The approximately 6,300-foot distance that flood waters extended from the canal in this 1944 flood informed the distance from the canal that I estimated flood risk to extend in my flood risk map.

(on Left Page)

Base Aerial Image: Google Earth (Accessed April 2023)
Survey Image Source: *REPORT ON BREAK OF MAY 15, 1944 IN MAIN CANAL OF KLAMATH PROJECT OREGON - CALIFORNIA*

Components of Flood Risk - Land Use

The urban land uses to the south downhill side of the A-Canal contribute to high levels of potential damage from embankment failure.

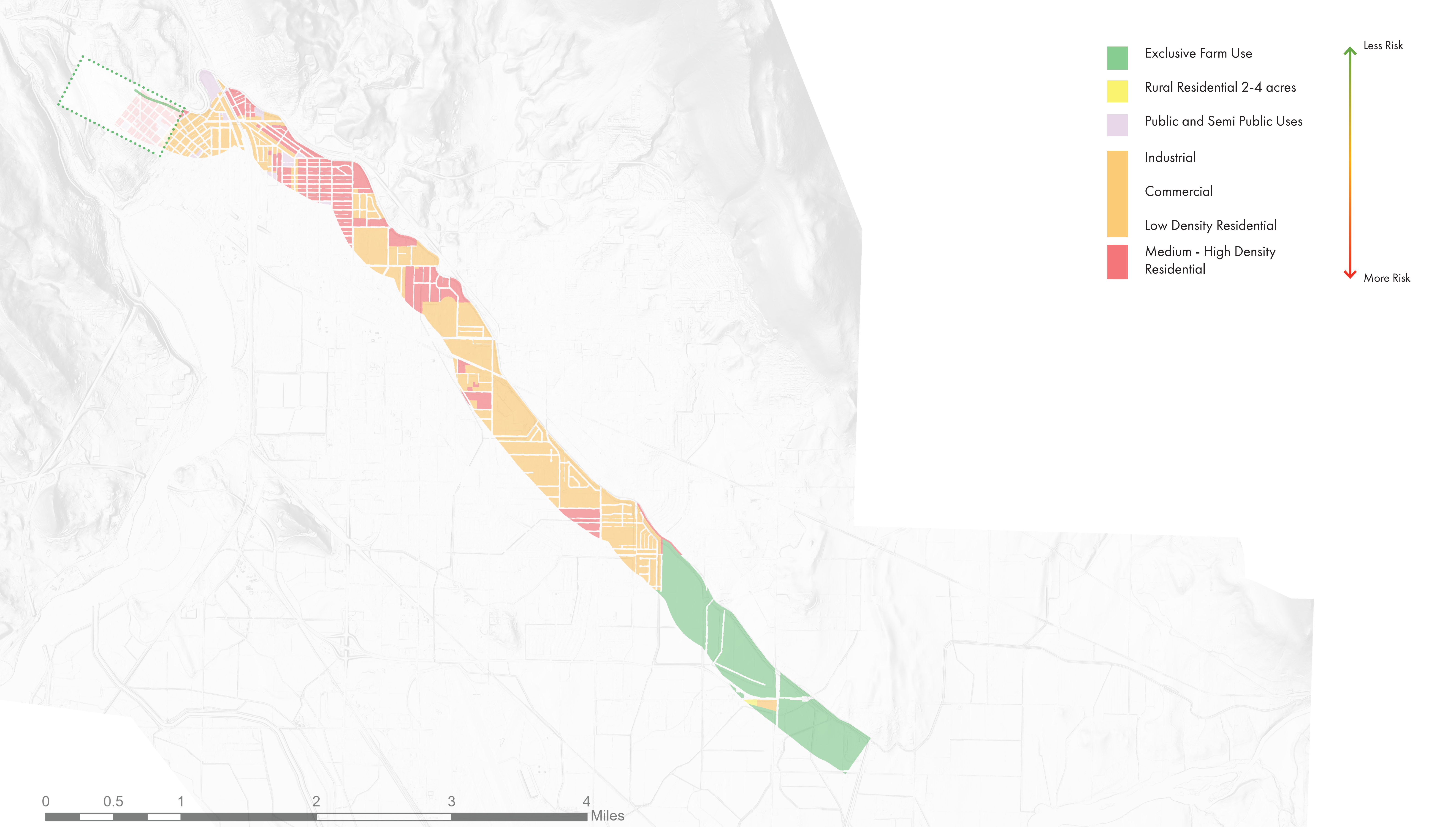
Most of the canal is surrounded by middle to low-density residential housing, shown in red and orange.

(on Right Page)

Land Use Flood Risk Map with Lower Risk Northern Extent Highlighted

Elevation Data: *DOGAMI* https://www.oregongeology.org/lidar/
Zoning Data: *Oregon Department of Land Conservation and Development https://www.oregon.gov/lcd/about/pages/maps-data-tools.aspx*

+ **Site Analysis** Surrounding Land-Use Damage Risk



Components of Flood Risk - Land Use

The housing is dense around the northern extent of the canal, but **there is no flood risk for the northernmost 1.1 miles.** This is because on this portion of the A-Canal there is no embankment.

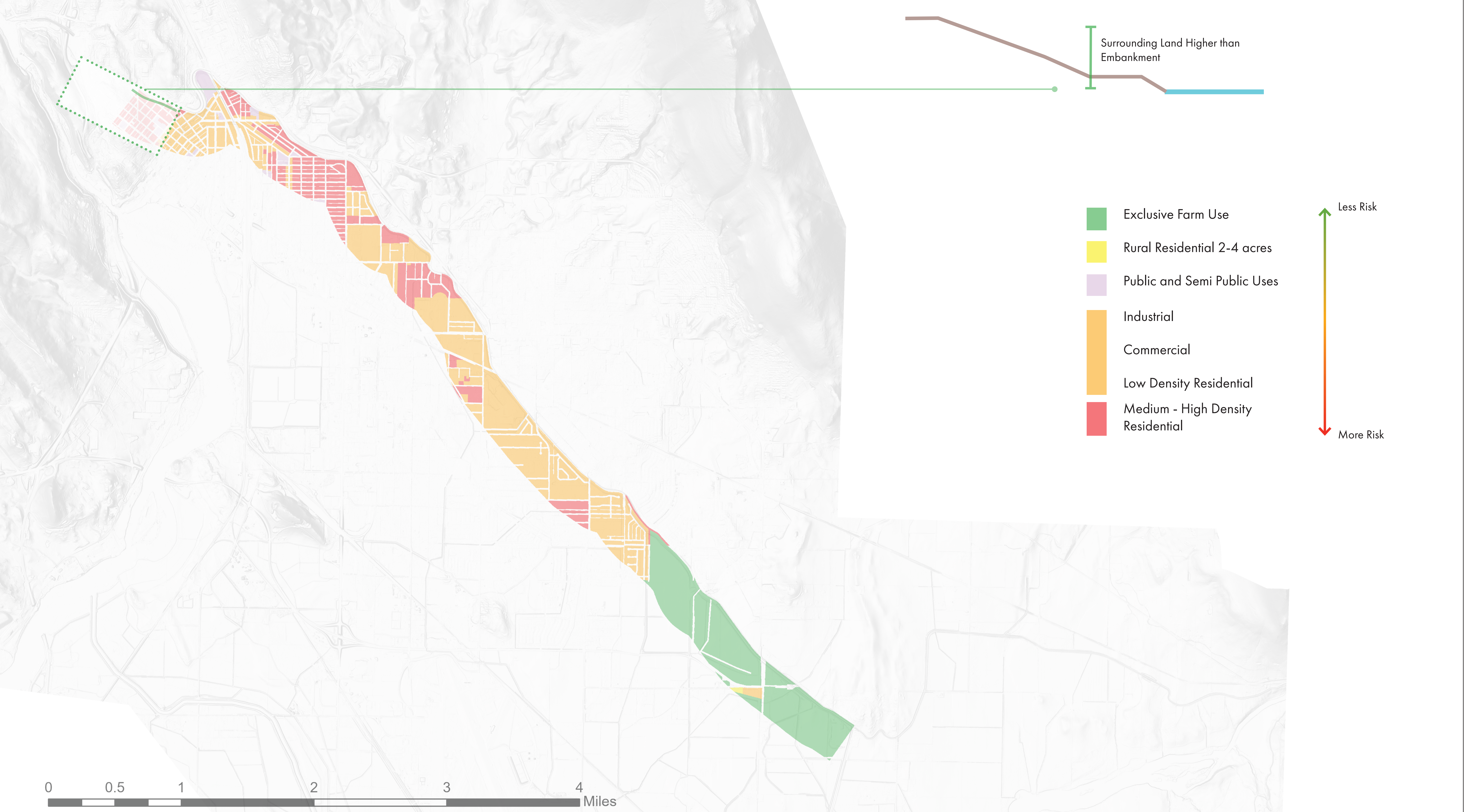
For the remainder of the A-Canal, I define the land-use-based flood risk by assigning each land use category a level of risk based on the potential property damage that would occur if the embankment was breached.

(on Right Page)

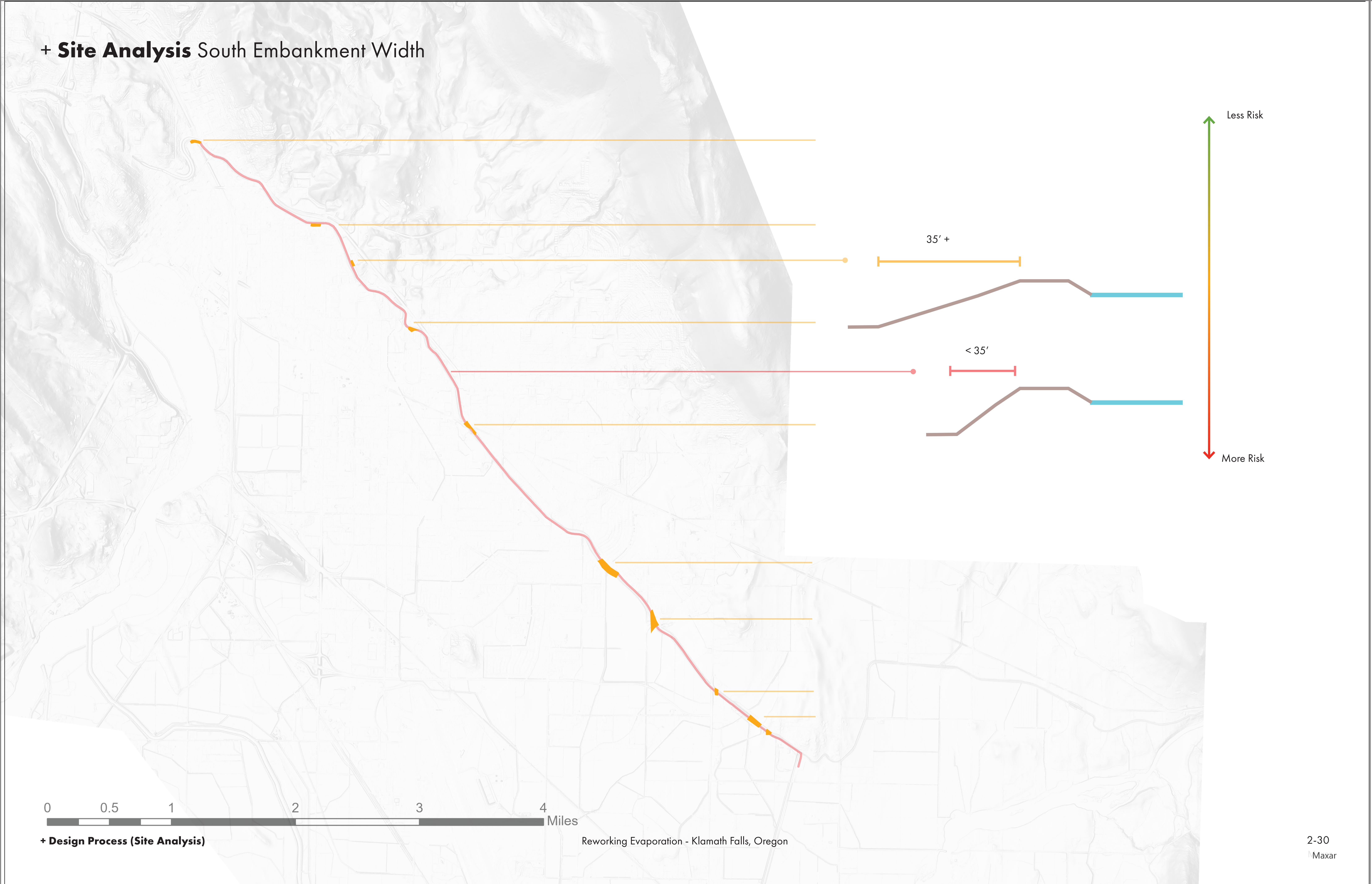
Land Use Flood Risk Map with Lower Risk Northern Extent Highlighted

Elevation Data: *DOGAMI* https://www.oregongeology.org/lidar/
Zoning Data: *Oregon Department of Land Conservation and Development https://www.oregon.gov/lcd/about/pages/maps-data-tools.aspx*

+ **Site Analysis** Surrounding Land-Use Northern 1.1 Miles



+ **Site Analysis** South Embankment Width



Maxar

Components of Flood Risk - Width & Height

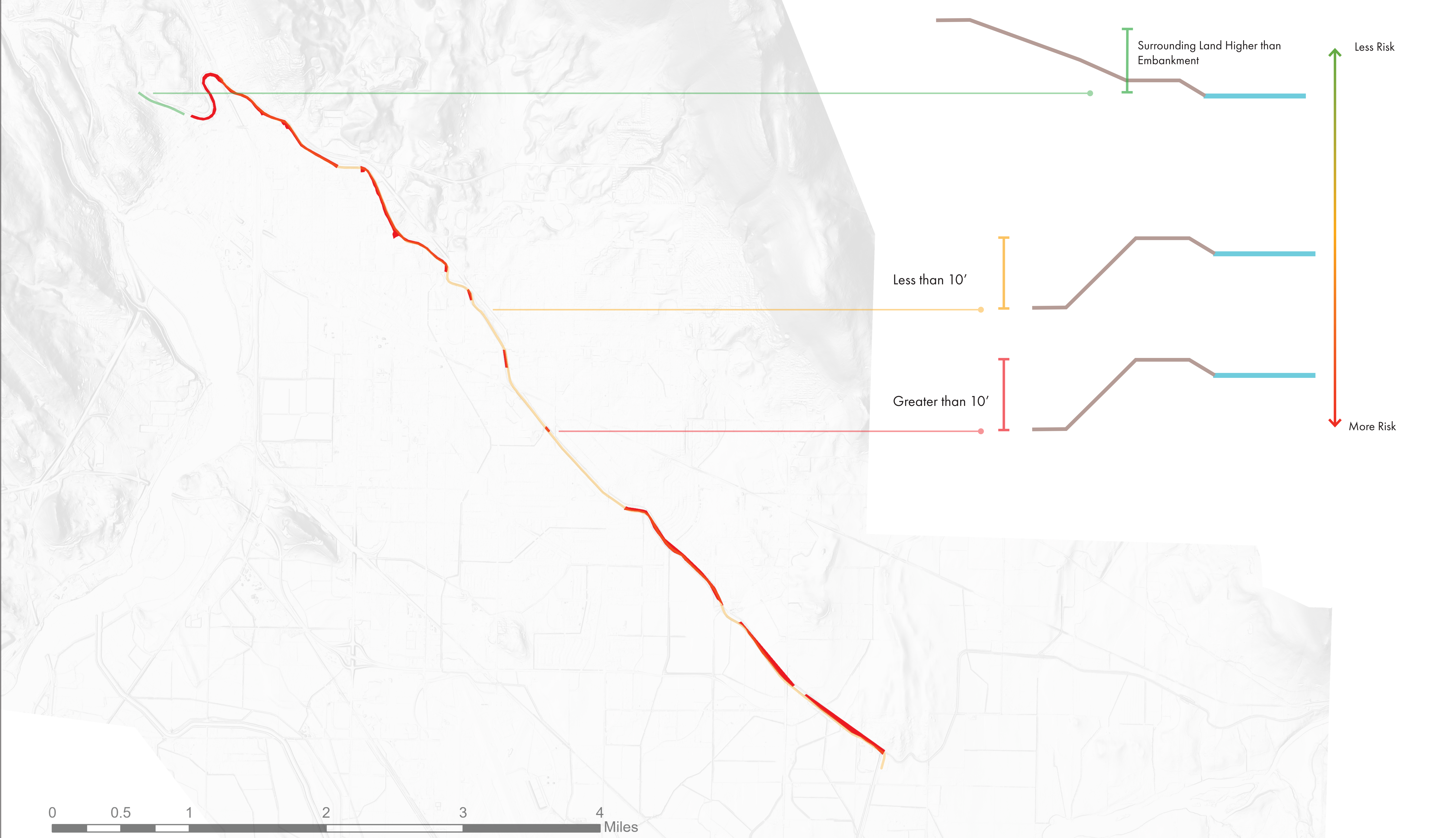
Flood risk is primarily reduced based on the width and height of the embankment where roads cross the canal. Places where the south embankment is wider and lower may pose less flood risk by being more structurally significant.

(on Left Page)

Flood Risk Map Based on Width of South Embankment

Elevation Data: *DOGAMI*
https://www.oregongeology.org/lidar/

+ **Site Analysis** South Embankment Height



Components of Flood Risk - Width & Height

Most of the canal fits into the red high flood-risk category based on its width and height.

(on Left Page)

Flood Risk Map Based on Height of South Embankment

Elevation Data: *DOGAMI*
https://www.oregongeology.org/lidar/

Composite Flood Risk Map

I then overlaid these flood risk factors to create a composite flood risk map that could inform the selection of the sites for my design exercises.

A limited extent of the A-Canal's south embankment was wide enough or low enough to reduce the flood risk, so for most of the canal, **land use is the primary variable of flood risk**.

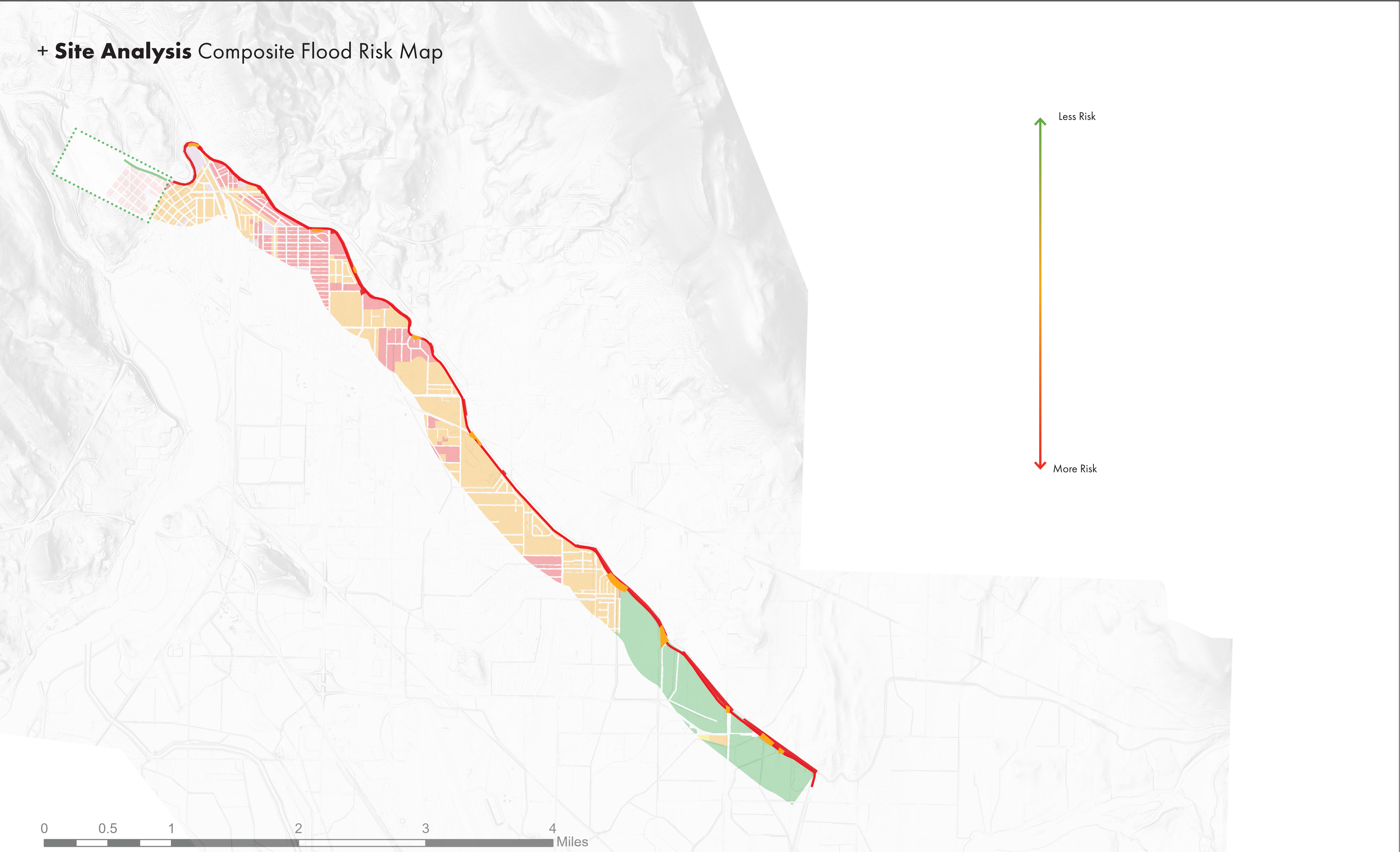
This mapping showed me that no large portions of the A-Canal have significantly reduced flood risk, outside of the northern 1.1 miles and the southern 2 miles where there are farms along the south embankment.

(on Right Page)

Composite Flood Risk Map

Elevation Data: *DOGAMI* https://www.oregongeology.org/lidar/
Zoning Data: *Oregon Department of Land Conservation and Development https://www.oregon.gov/lcd/about/pages/maps-data-tools.aspx*

+ Site Analysis Composite Flood Risk Map



Maxar

Flood Risk for Design Exercises

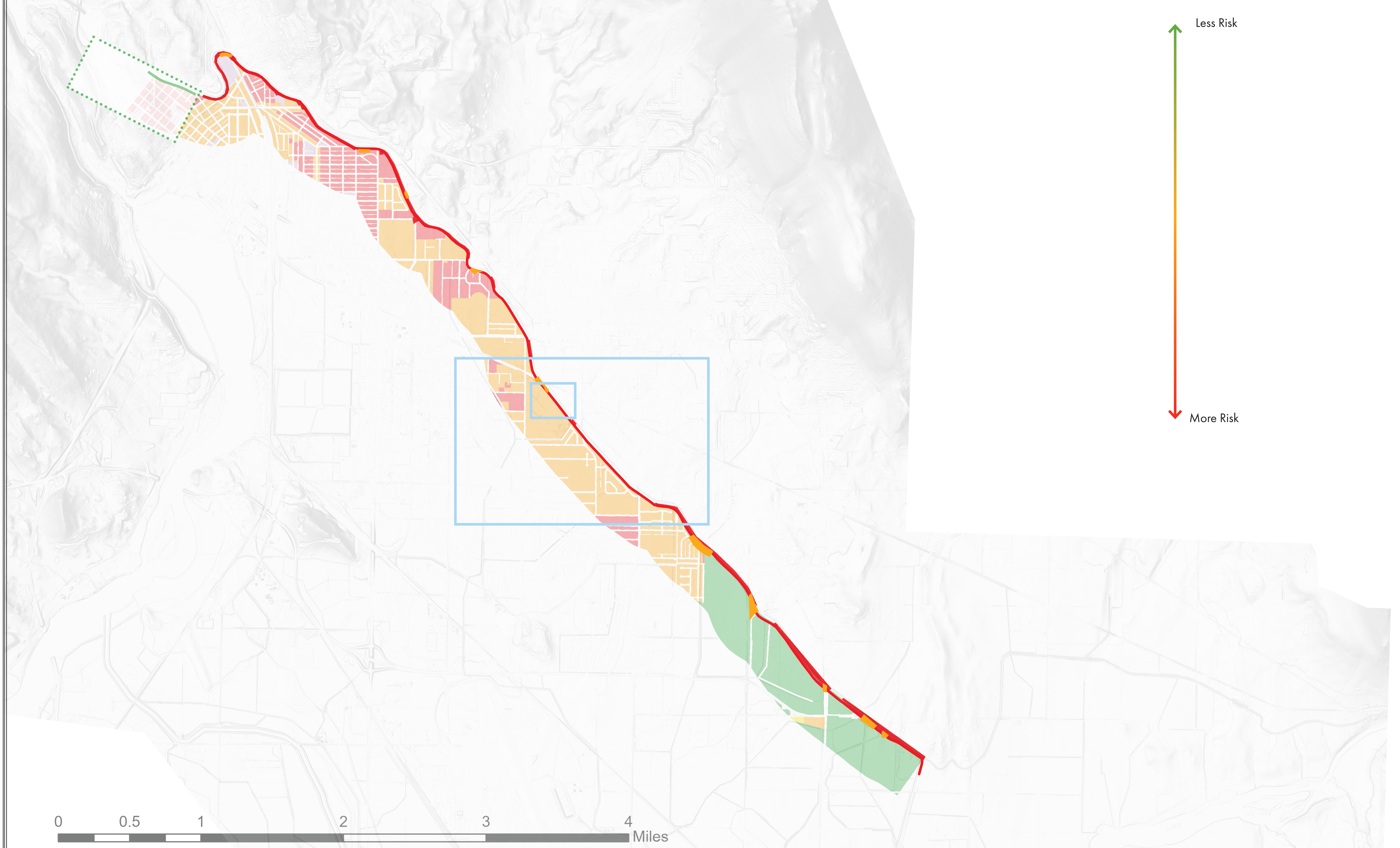
By having a better understanding of flood risk variation along the A-canal, I was able to choose the two sites in blue that contained the components of flood risk which a full modular P.V. over canal system would need to adapt to.

(on Right Page)

Composite Flood Risk Map With Design Exercise Sites Highlighted in Blue

Elevation Data: *DOGAMI* https://www.oregongeology.org/lidar/
Zoning Data: *Oregon Department of Land Conservation and Development https://www.oregon.gov/lcd/about/pages/maps-data-tools.aspx*

+ Site Analysis Composite Flood Risk Map With Design Exercise Sites



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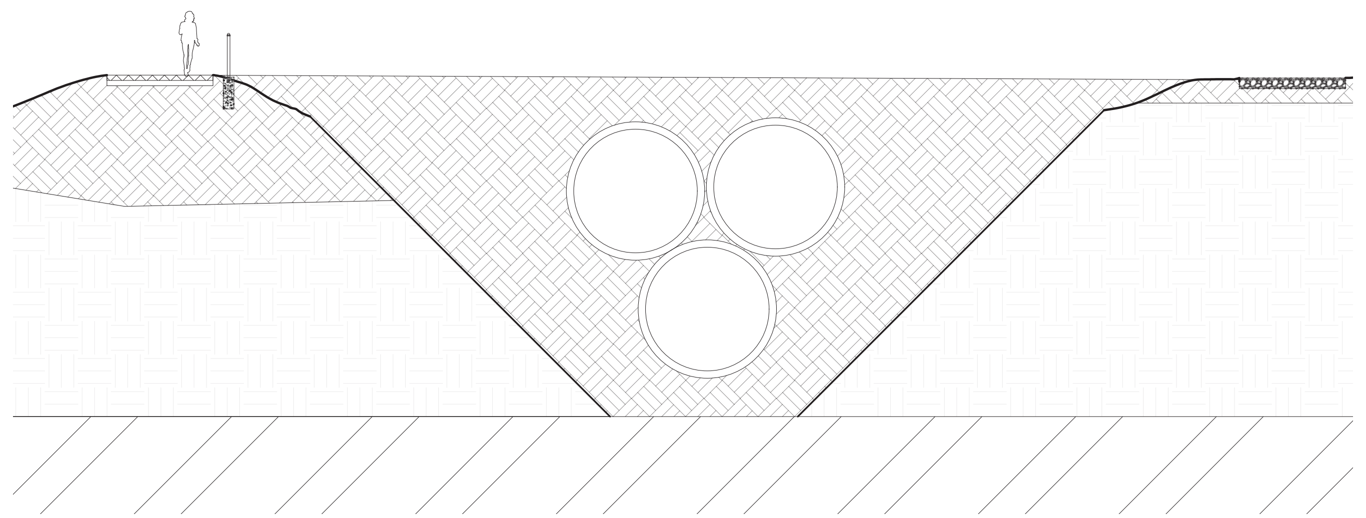
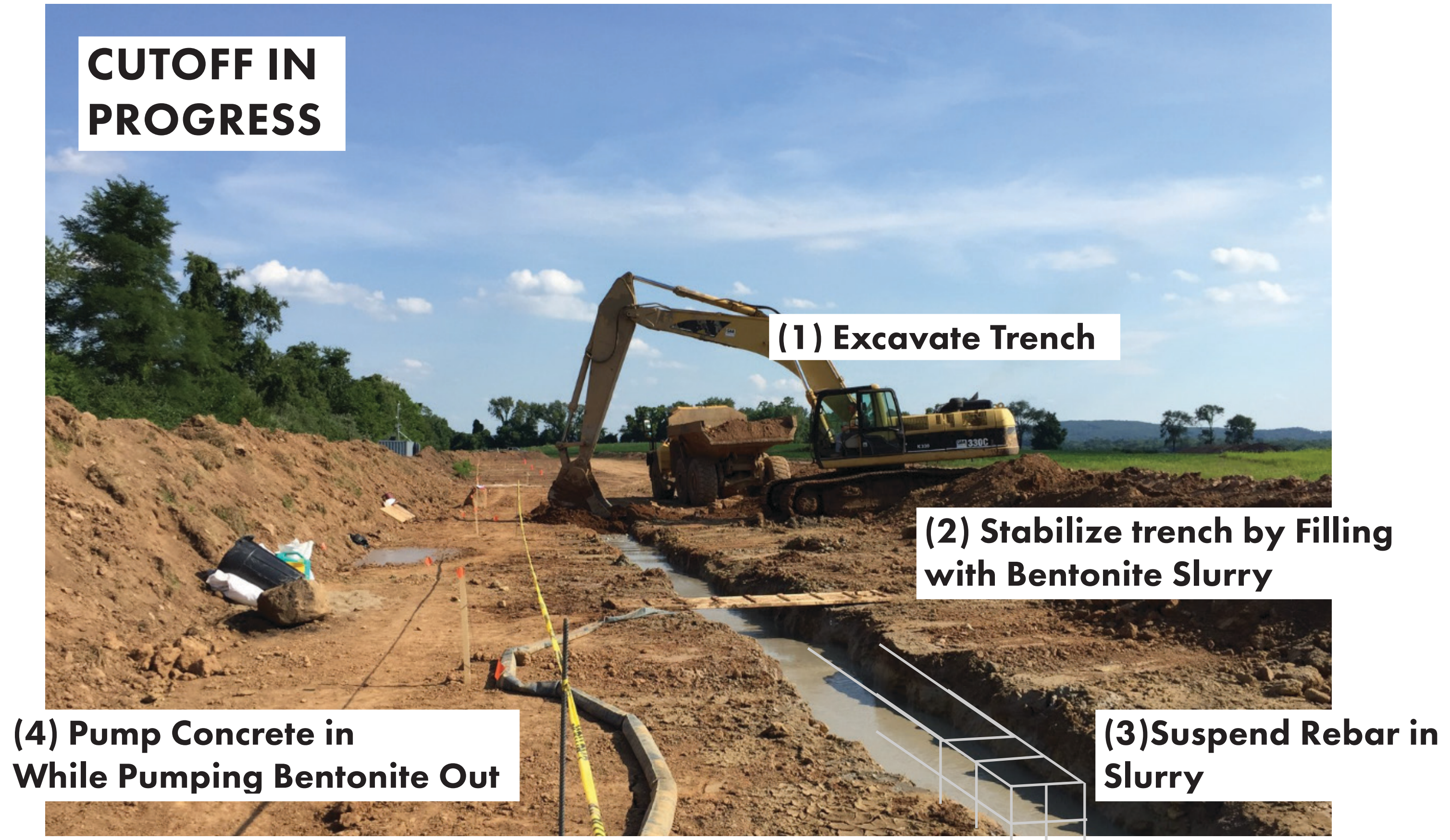
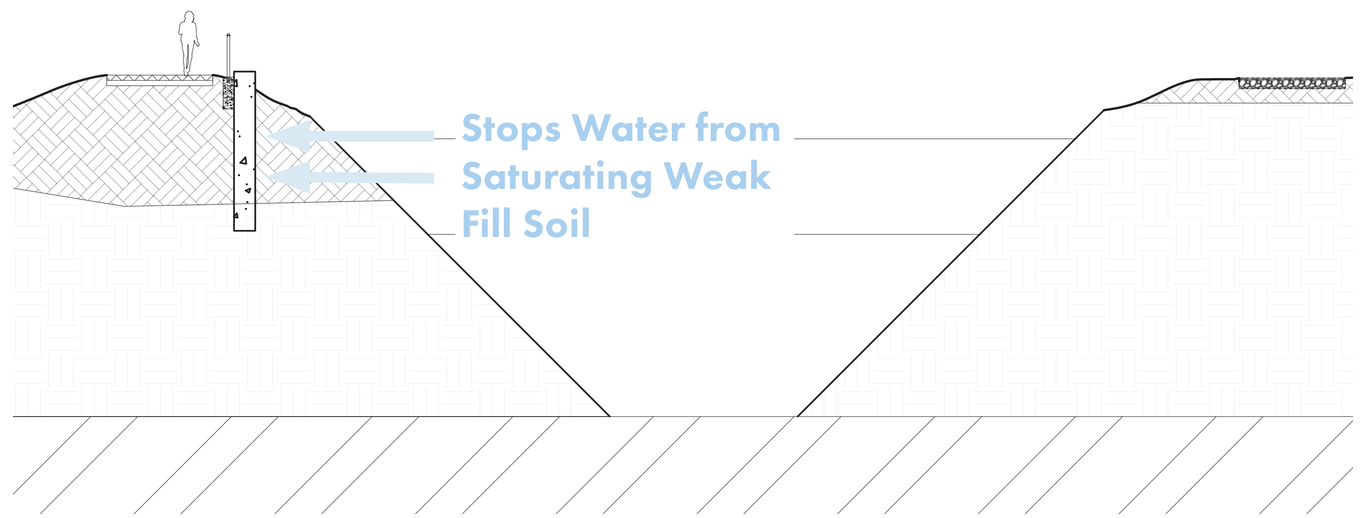
Underground Pipe



Cutoff Wall





Options for Reducing Flood Risk

Addressing this extreme level of flood risk is a major concern of the Irrigation District. They have considered multiple solutions, including piping and covering large portions of the A-Canal and reinforcing the south embankment with a cutoff wall.

(on Left Page)

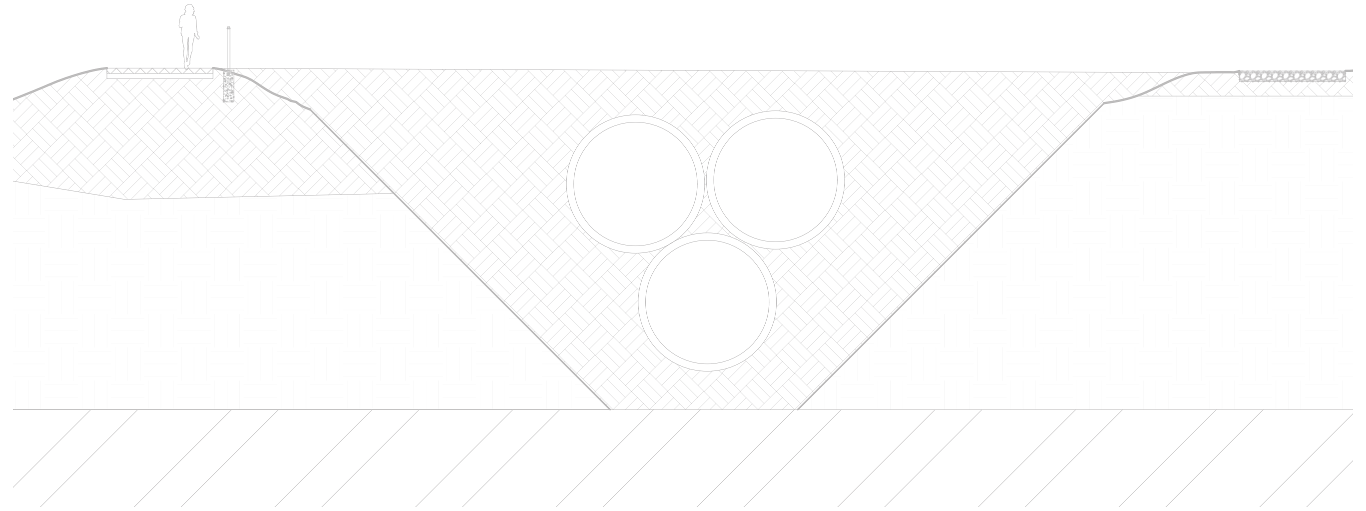
Diagram of Flood Risk Mitigation Options
Created by: McClean Gonzalez

Pipeline Base Image (left): *https://www.deschutesriver.org/blog/things-are-changing-for-the-river-and-for-canals-heres-why/*

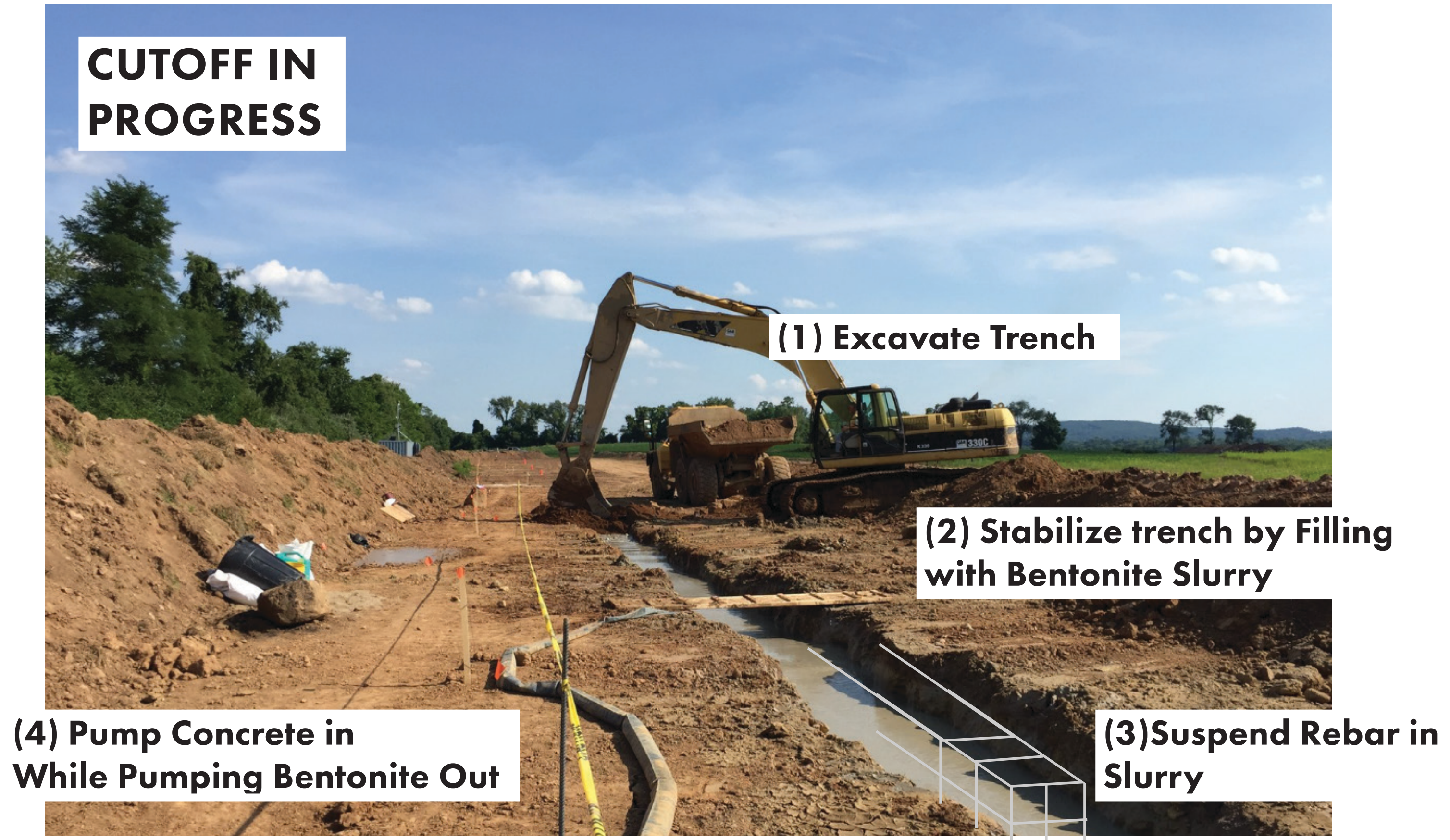
Cutoff Wall Base Image (right): *https://digitalcommons.bucknell.edu/nSF-SB-Cutoff-Wall-visuals/18/*

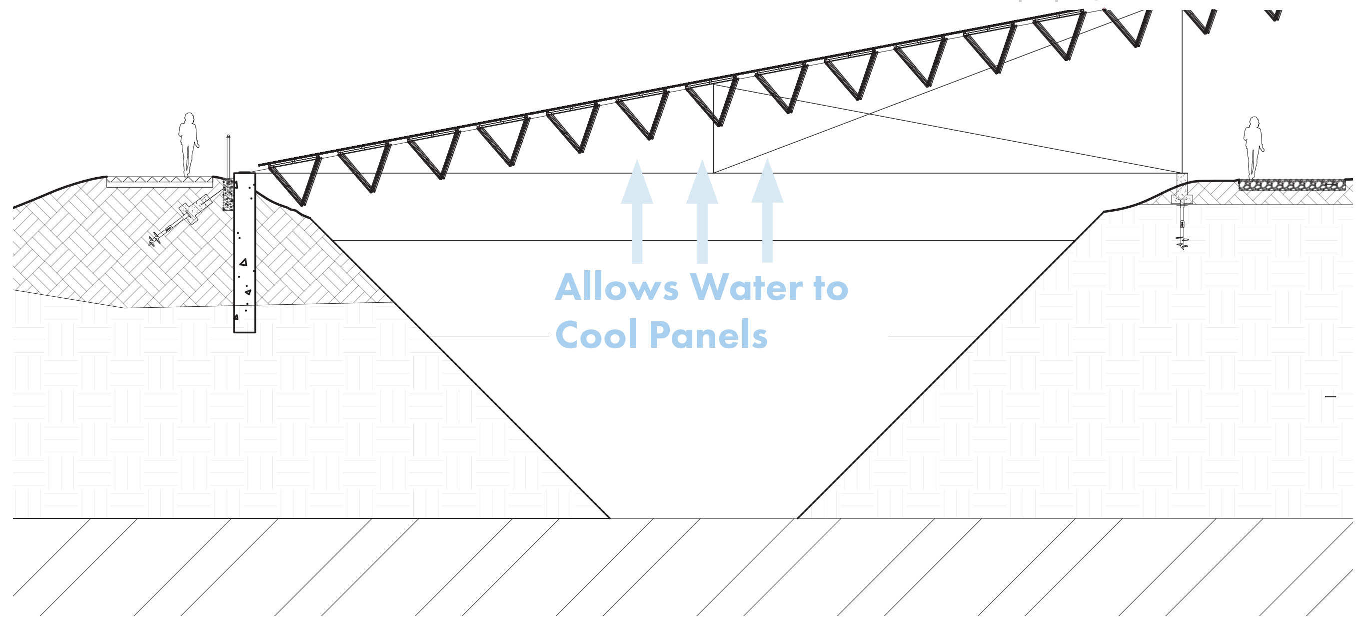
+ **Site Analysis** Flood Risk Preventions Strategies

Underground Pipe



Cutoff Wall





Cutoff Wall to Reduce Flood Risk

While both options address the flood risk challenge, I used a cutoff wall in this project. I chose this method because it maintains the gains in panel efficiency created when they are placed close to water. It also maintains views of the canal, something that may be valuable to the people who live and walk along it.

A cutoff wall when constructed with P.V. over canal could create co-benefits. Revenues from the P.V. could help offset cutoff wall costs, and the cutoff wall could both act as the anchoring system for the P.V. system on the south embankment and reduce the flood risk “from extreme to moderate” (email from Gene Souza).

(on Left Page)

Diagram of Flood Risk Mitigation Options
Created by: McClean Gonzalez

Pipeline Base Image (left): *https://www.deschutesriver.org/blog/things-are-changing-for-the-river-and-for-canals-heres-why/*

Cutoff Wall Base Image (right): *https://digitalcommons.bucknell.edu/nSF-SB-Cutoff-Wall-visuals/18/*

Canal Dimensions

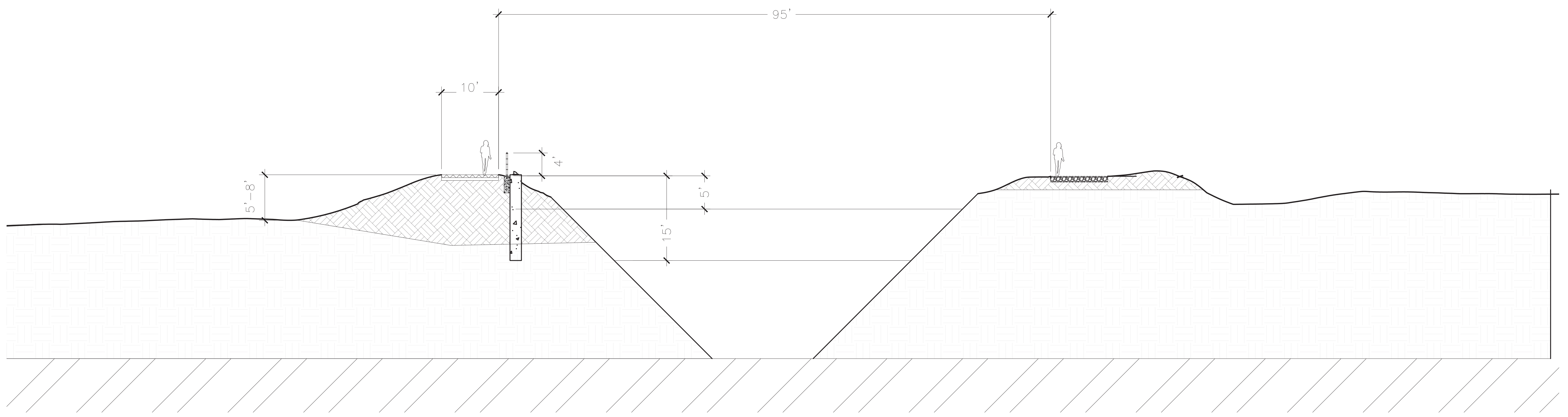
After analyzing flood risk, I used the elevation data and descriptions from Gene Souza to develop a representative cross-section of the A-Canal, which I found was relatively uniform in its embankment dimensions and flow direction.

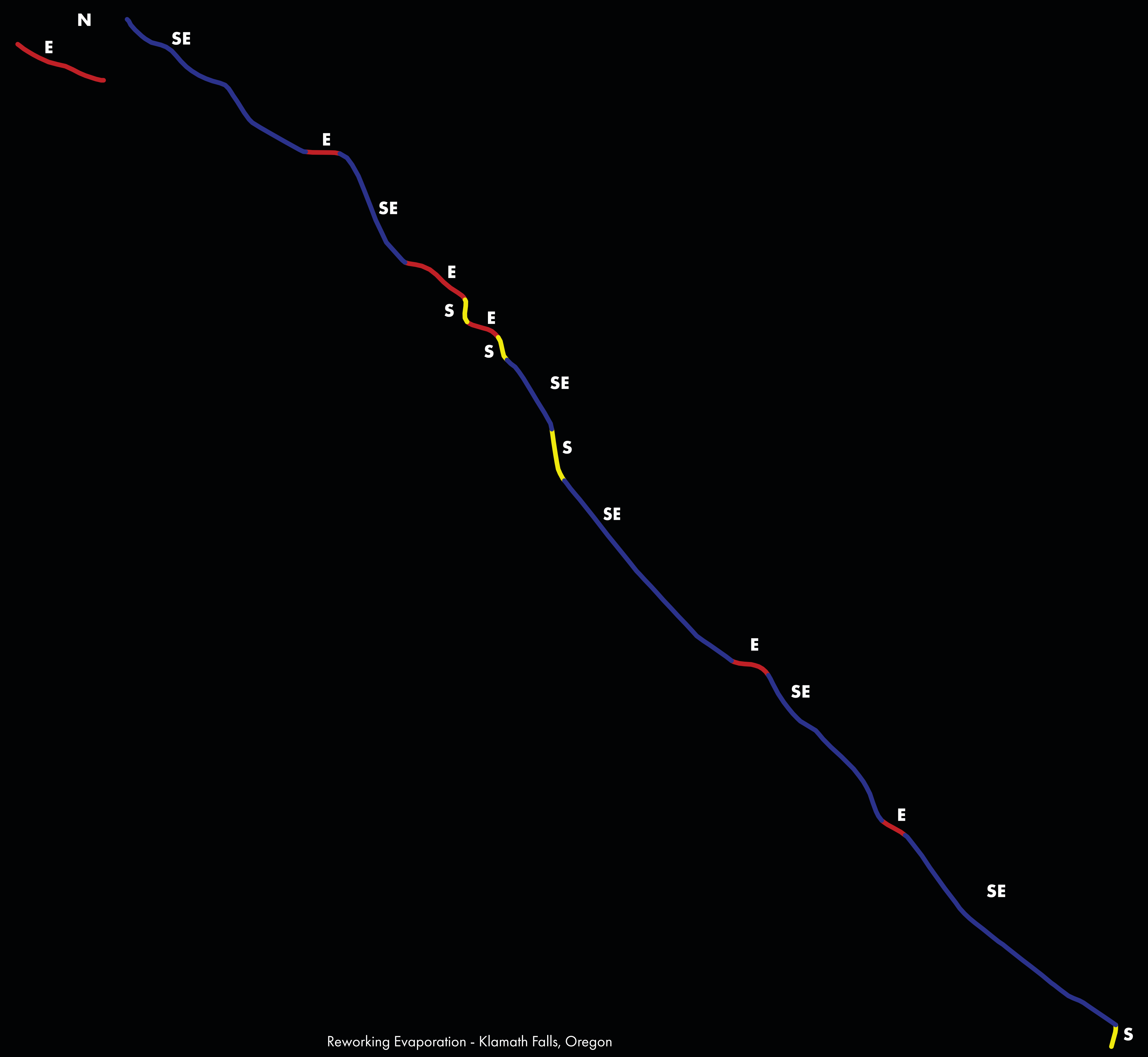
(on Right Page)

Section Drawing of A-Canal Annotated with Dimensions
Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/

+ **Site Analysis** Canal Dimensions





Solar Orientation of A-Canal

The solar orientation will affect the angle of the panel structures in relation to the canal. The Canal primarily flows to the south-east (blue). A few small sections are oriented towards to the south (yellow) or toward the east (red).

(on Left Page)

Diagram of A-Canal Solar Orientation
Created by: McCleon Gonzalez

Canal Path and Service Road

Both embankments have a path or service road for a majority of the length of the canal.

On the south embankment, a paved path begins at the intersection of the A-Canal and Esplanade Avenue in downtown Klamath and runs 4 miles, ending at the A-Canal's intersection with Homedale Road. A gravel service road extends from Homedale Road to the end of the A-Canal.

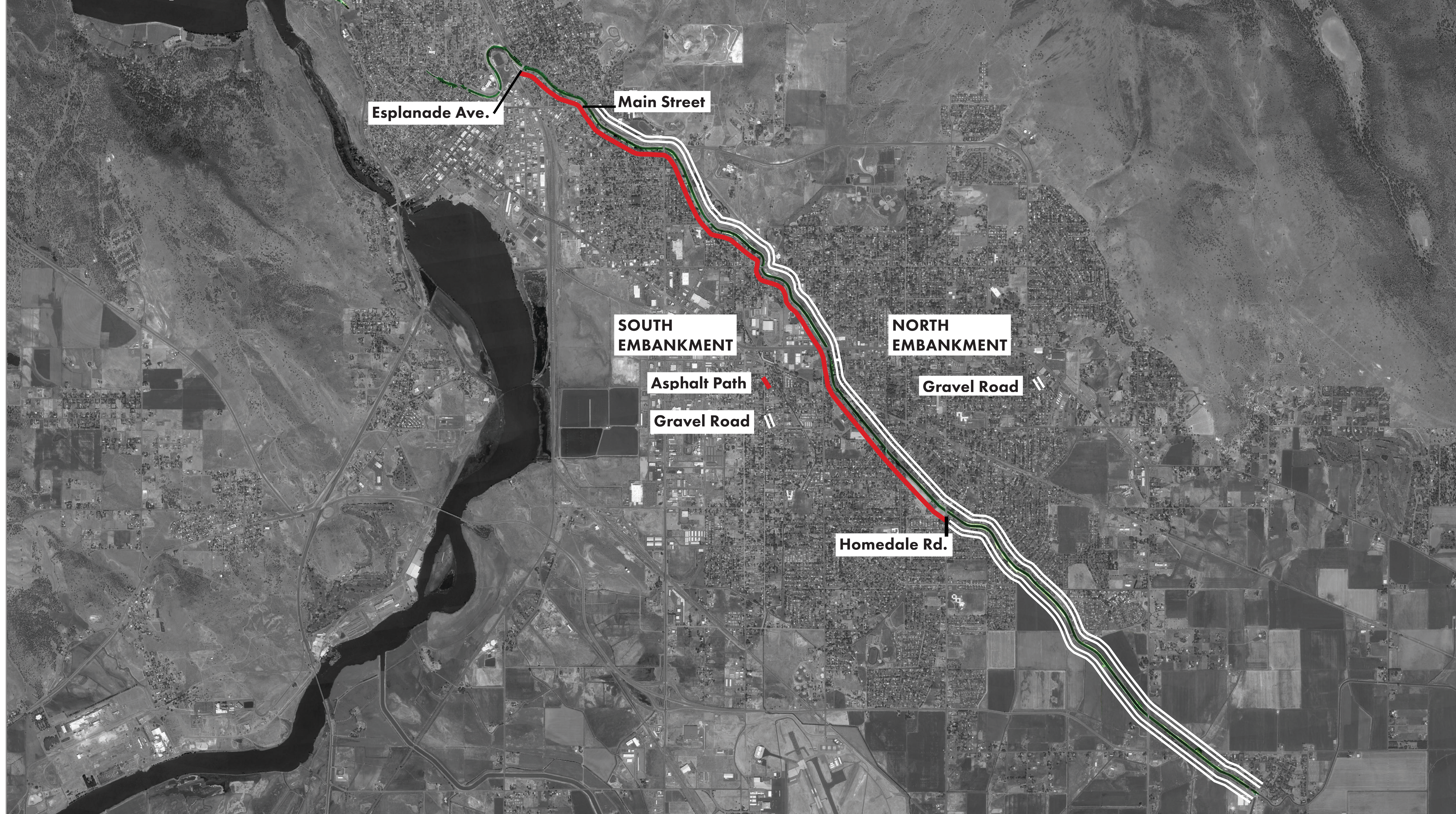
On the north embankment, a gravel service road begins at Main Street and extends to the end of the A-Canal.

(on Right Page)

Annotated Aerial Image of the A-Canal Paths in Klamath Falls Oregon

Created By: McClean Gonzalez
Aerial Image Source: Google Earth (Accessed May 2023)

+ Site Analysis South Embankment Path & North Embankment Service Road



Design Exercises

With an understanding of the A-canal, the complex Basin-wide water challenges, and the state of P.V. over canal, I began a series of three design exercises.

+

Design Exercises

Modular | Neighborhood | Gateway

Three Design Exercises

The goal of these was to explore the role landscape architects could take across several scales of projects of this kind.

The three exercises were:

First, the development of a modular structural system for P.V. over canal on the A-Canal.

Second, a master plan scale layout of these structures along a 1-mile test site (the Mazama High School Neighborhood).

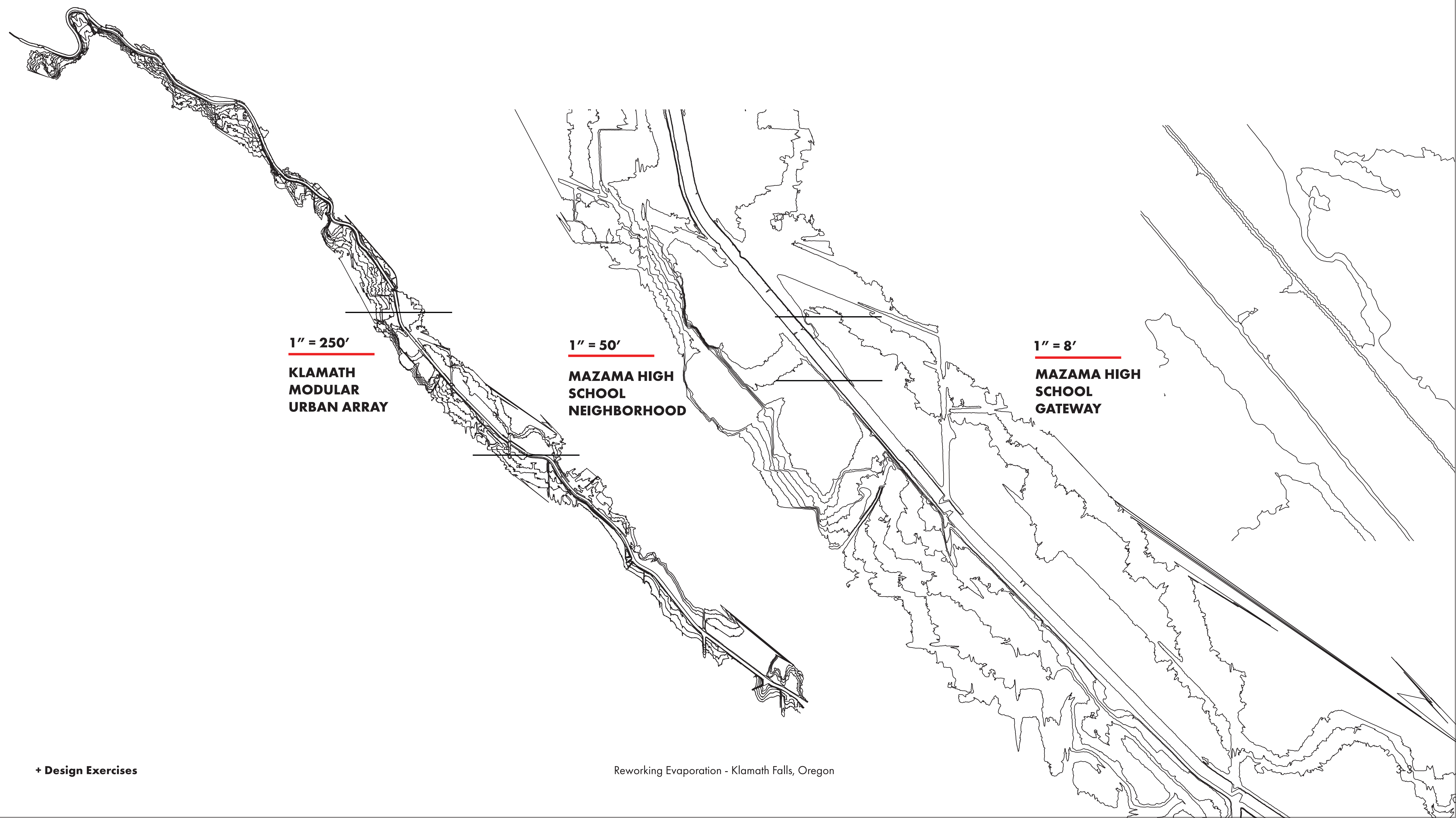
Third, the site design of one entrance to the trail within this neighborhood, the Mazama High School Gateway.

(on Right Page)

Contours of Three Design Exercises Scales
Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/

+ Design Exercises Three Scales



A Modular System

To give a project of this scale a chance at being financially feasible, I needed to develop a structural system that favored established building components and techniques and that could adapt readily to much of the canal.

(on Right Page)

Contours of Three Design Exercises Scales
Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/

+

Design Exercises

Modular | Neighborhood | Gateway

Flood Risk Reduction (Cutoff Wall)
North Embankment Sub-Structure
Cable Spanning System

Klamath Array Overview

I began the process by separating a potential modular P.V. over canal system into its parts: the cutoff wall for flood risk reduction and to anchor the structure on the south embankment, the substructure for the north embankment, and the cable spanning system that suspends the solar panels over the canal.

Components of Flood Risk

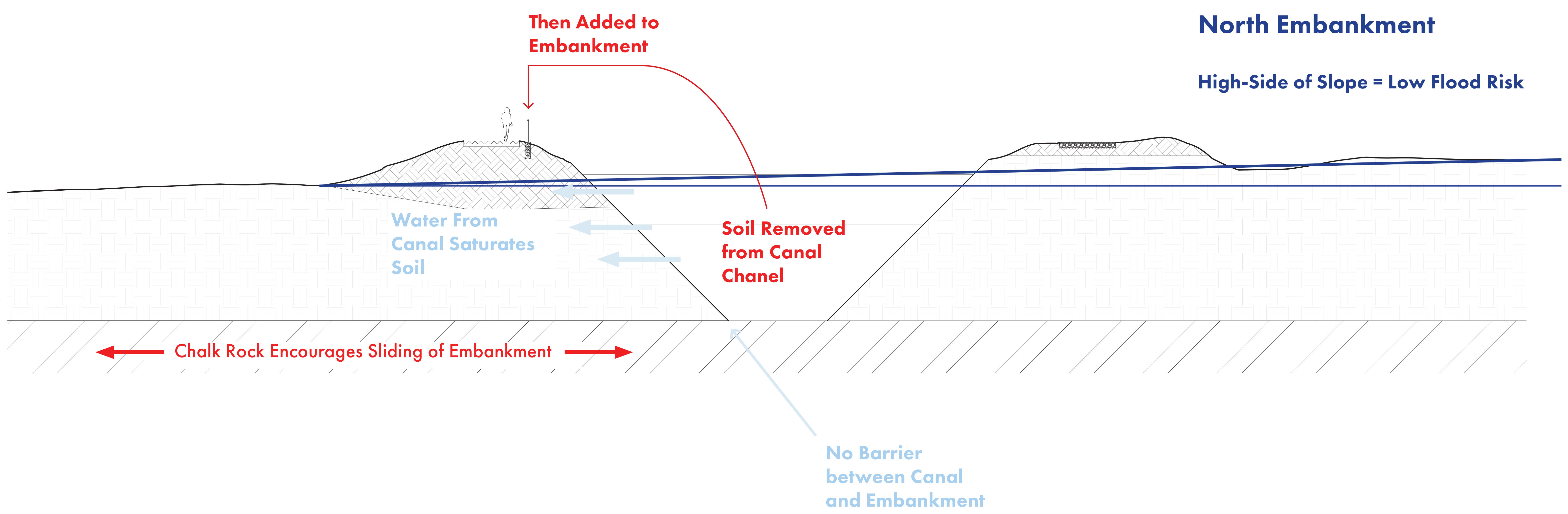
For the flood risk reduction system, the primary concern was to eliminate flood risk along the south embankment. One key way to reduce this flood risk is to prevent the Canal's water from saturating the south embankment.

(on Right Page)

Section Drawing of A-Canal Annotated with Flood Risk
Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/

+ **Modular System** Components of Flood Risk



Cutoff Wall to Reduce Flood Risk

The cutoff wall achieves this reduction in flood risk by adding an impermeable layer of concrete along the north side of the south embankment. It also acts as the foundation substructure for mounting the P.V. over the canal system.

In places where the wall is acting only as a barrier to water, bentonite or other lower-strength but low-permeable fill materials might be sufficient and could reduce the overall cost of the structure.

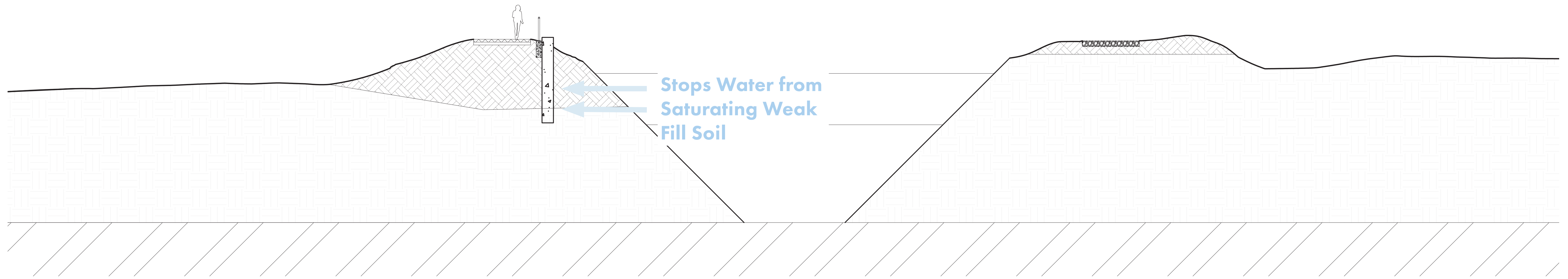
A steel adjoining plate would be embedded into the top of the wall to connect the spanning structure securely to the cutoff wall.

(on Right Page)

Section Drawing of A-Canal with Detail of Cutoff Wall to Reduce Flood Risk
Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/

+ **Modular System** Flood Risk Reduction (Cutoff Wall)



Helical Piers Support Structure on North Embankment

Since the substructure for the north embankment will not need to prevent flooding, a continuous wall was not required. Instead, helical piers would be embedded into the embankment north of the service road with embedded anchors to support a steel column.

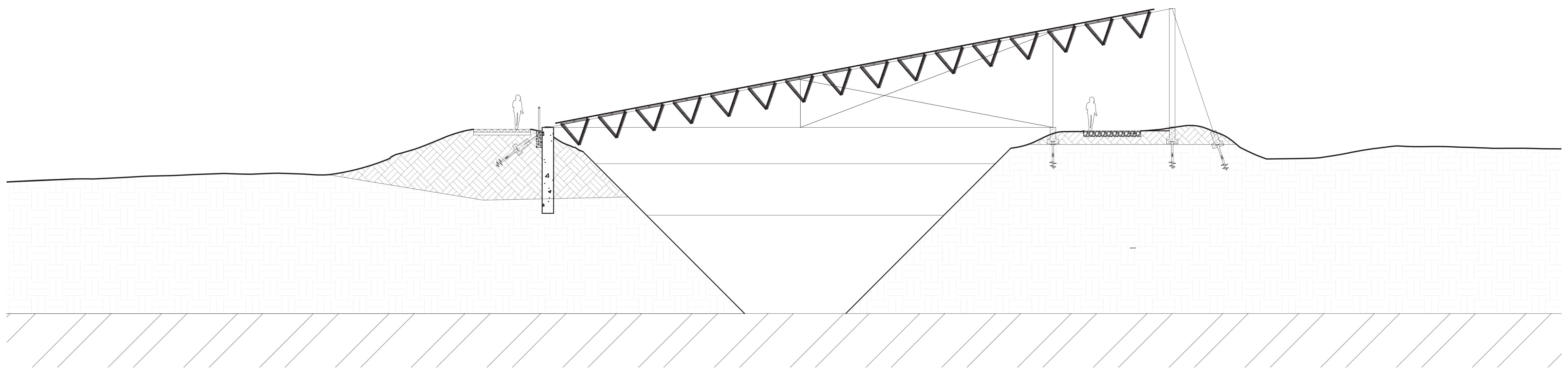
(on Right Page)

Section Drawing of A-Canal With North Embankment Anchor System and Cable Spanning Structure

Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/

+ **Modular System** North Embankment Anchor System



Requirement of Spanning System

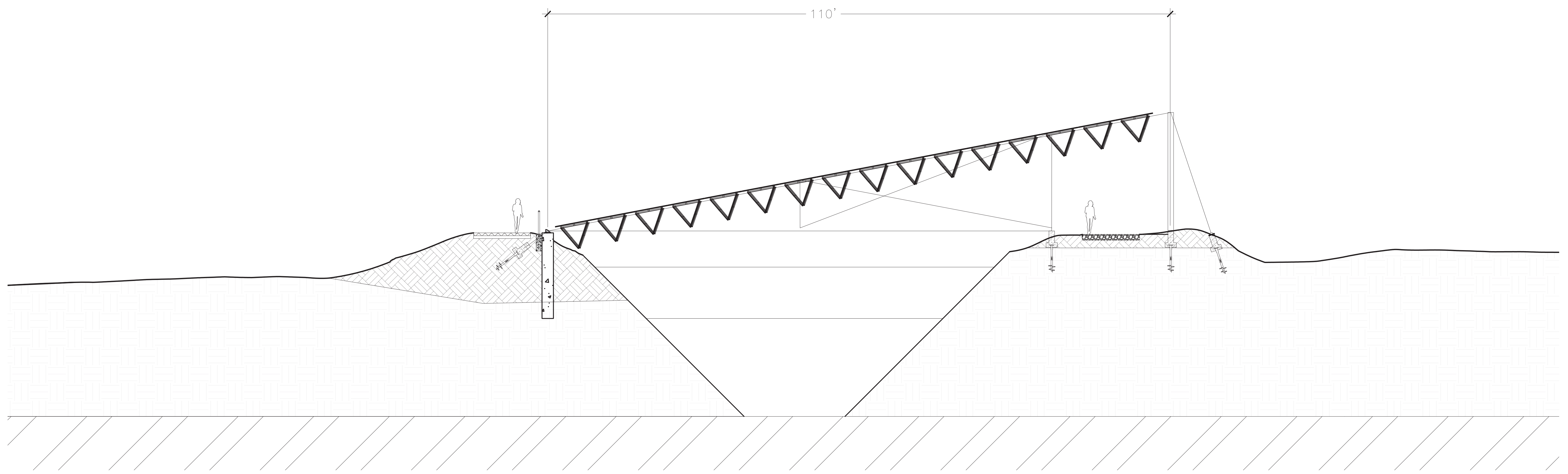
The structure that spans the canals must reach about 110 feet. This distance includes the approximately 70-foot canal and approximately 40 feet of embankment. The structure also needed to be repeatable, recognizable, and practical.

(on Right Page)

Section Drawing of A-Canal Annotated With Distance of Span Structure
Created by: McClean Gonzalez

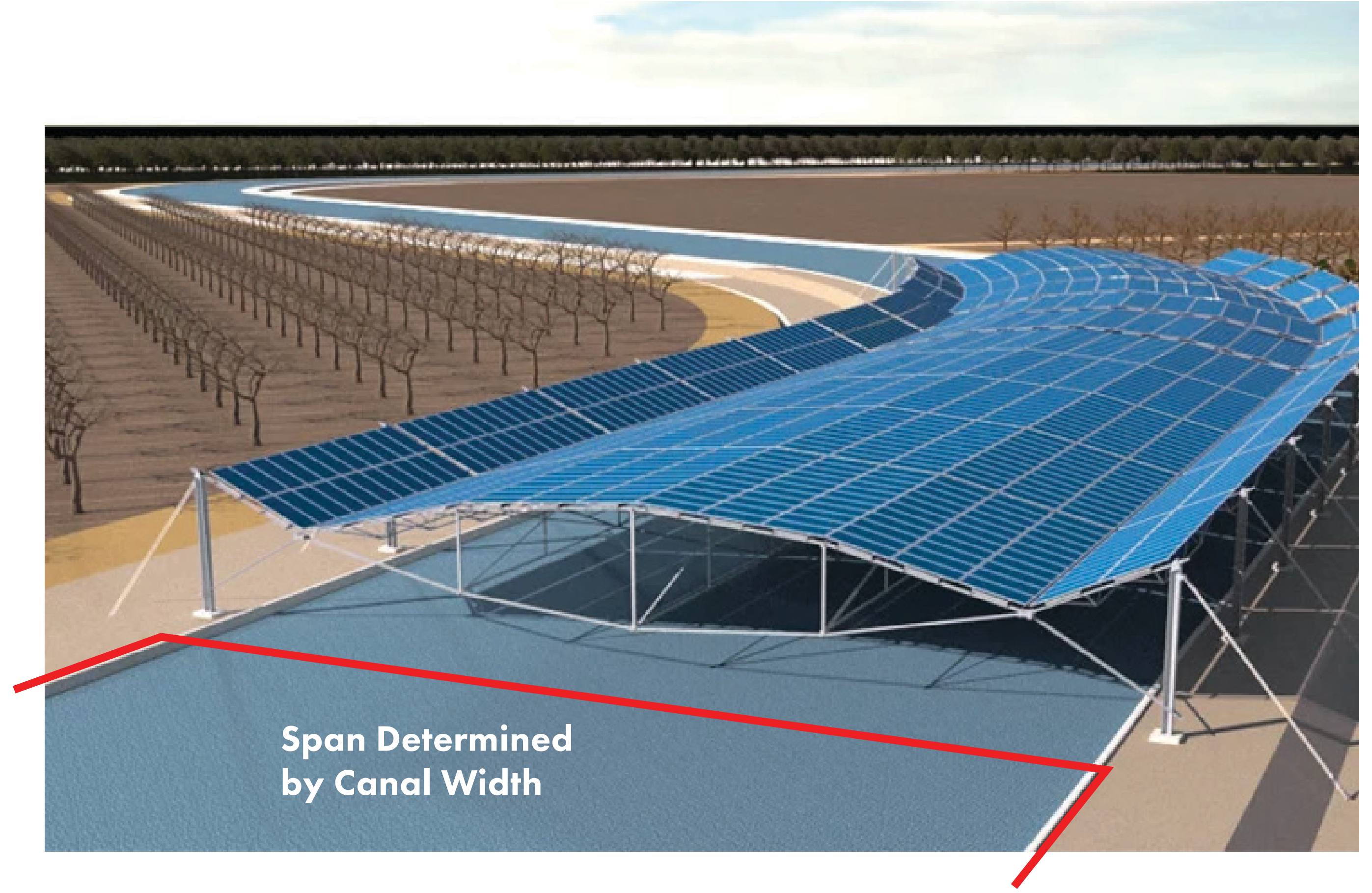
Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/

+ Modular System Span Distance



Ground-Mounted

P.V. Over Canal



Why Steel Cables?

Steel cable structural systems for supporting P.V. have been identified as an essential technological advancement that makes such spans possible and financially competitive[1].

1: McKuin, Brandi, Andrew Zumkehr, Jenny Ta, Roger Bales, Joshua H. Viers, Tapan Pathak, and J. Elliott Campbell. 2021. "Energy and Water Co-Benefits from Covering Canals with Solar Panels." Nature Sustainability 4 (7): 609–17. https://doi.org/10.1038/s41893-021-00693-8.

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Annotations
Created by: McClean Gonzalez

Ground-Mounted P.V. Image (left): https://www.solarpowerworldonline.com/2016/11/big-three-avoid-utility-scale-ground-mounting-challenges/

P.V. Over Canal Image (right): https://www.conger.solar/conger-solar-systems-selected-to-design-solar-canopies-for-project-nexus/

Choosing Steel Cable Structural System

To develop my theoretical structural system, I analyzed the work of A+ Sun Systems (on the left) and Conger Solar Systems (on the right), who have developed cable support systems specifically for P.V. over canal projects.

(on Left Page)

A+ Sun Systems Image (left): https://www.apsunsys.com/en/references/
Conger Solar Systems Image (right): https://www.conger.solar/

A+ Sun Systems

https://www.apsunsys.com/en/references/

Conger Solar Systems

https://www.conger.solar/

Conger Solar Systems’ Steel Cable Structural System

Conger’s system’s ability to densely cover wide canals best meets the needs of the A-Canal.

(on Left Page)

A+ Sun Systems Image (left): https://www.apsunsys.com/en/references/
Conger Solar Systems Image (right): https://www.conger.solar/

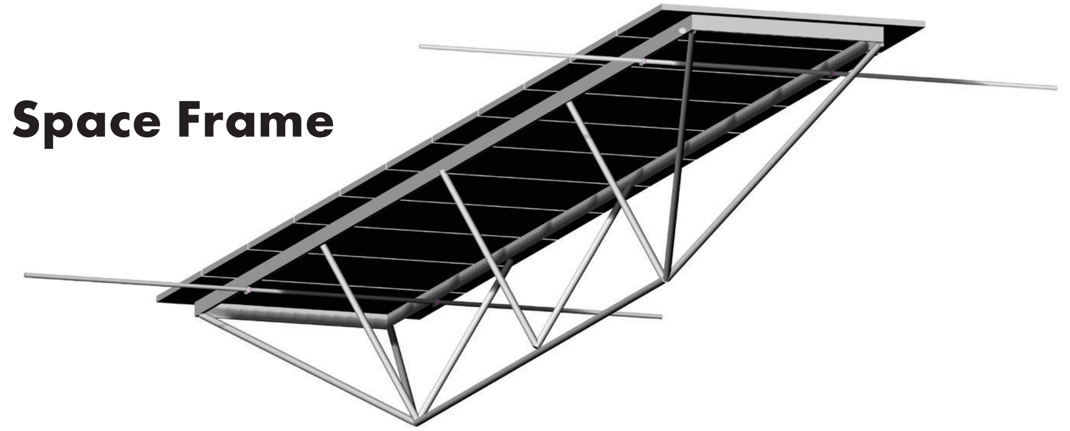
A+ Sun Systems

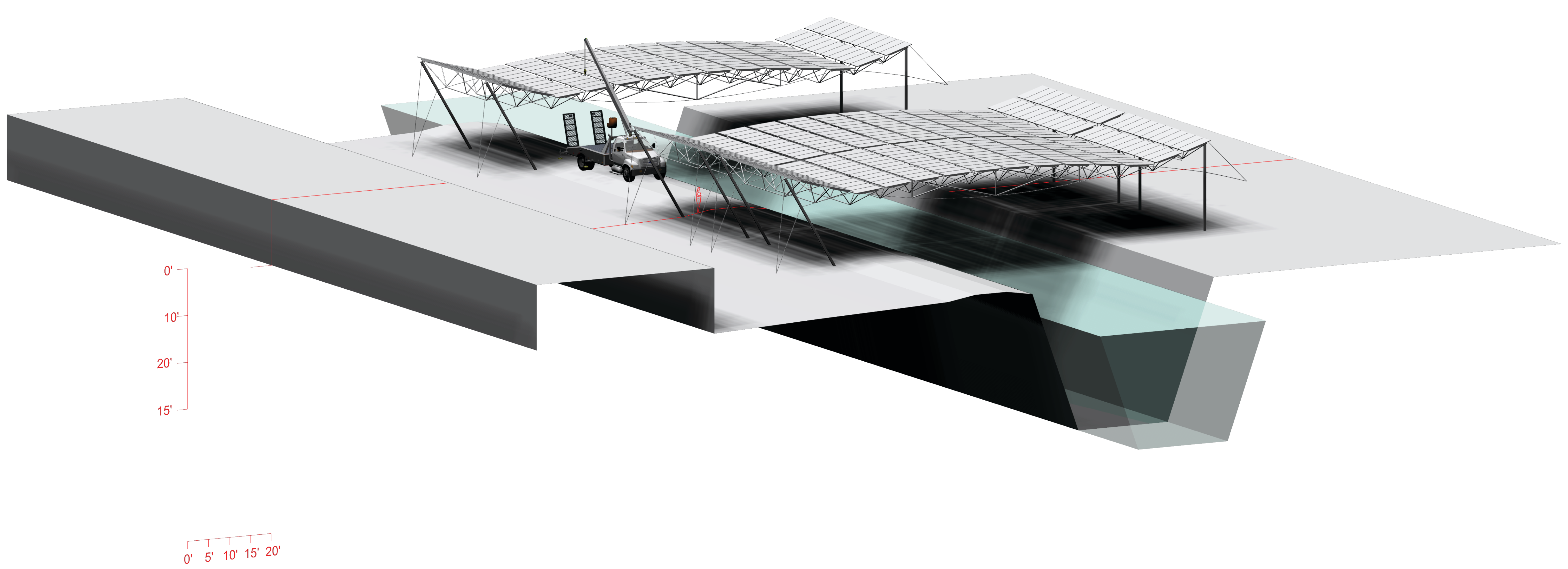
https://www.apsunsys.com/en/references/

Conger Solar Systems

+ **Modular System** Conger System

Conger Space Frame





Conger Solar Systems Technology

The system uses tensioned cables to span the canals and a "space frame" with 11 commercial P.V. panels connected to the structure. These "space-frames" connect to the steel cables using a bolting system the company developed.

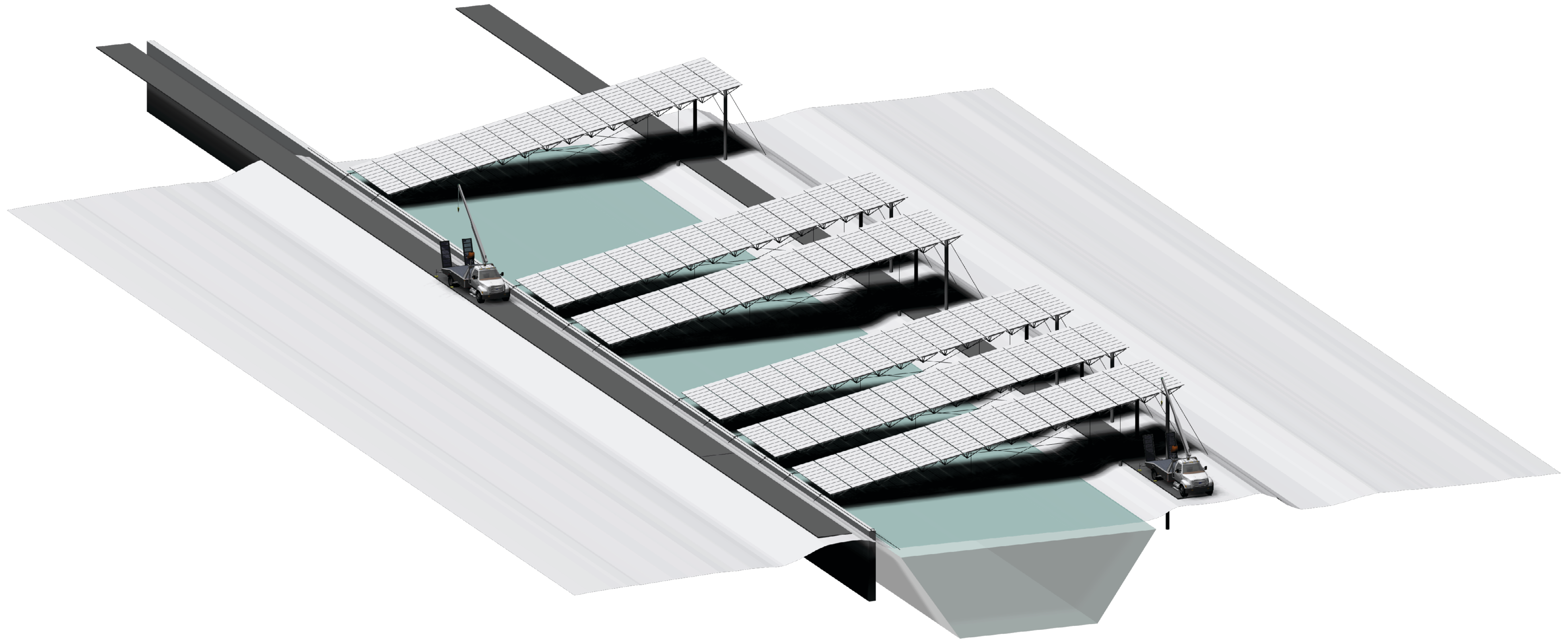
(on Left Page)

Image of 3D Model of A-Canal With 3D Model Based of Conger Solar Systems' P.V. Over Canal System

3D Models Created By: McClean Gonzalez

Models Based on Drawings and Images from: https://www.conger.solar/

+ **Modular System** Conger System Adapted to Urban A-Canal



Conger System Adapted to A-Canal

I adjusted the steel cable structural system, which Conger adapts for each project, to meet the urban context of the A-Canal.

I focused these adjustments on creating opportunities for people along the Canal to see the water, optimizing the angle of the panels, and ensuring that service vehicles could travel along both sides of the Canal.

I determined the slope of the structure by assessing the optimal angle for P.V. panels at 42 degrees latitude and by determining what angle allowed for views of the Canal under the panel structure and left space for maintenance vehicles to drive under the P.V. system along the north service road.

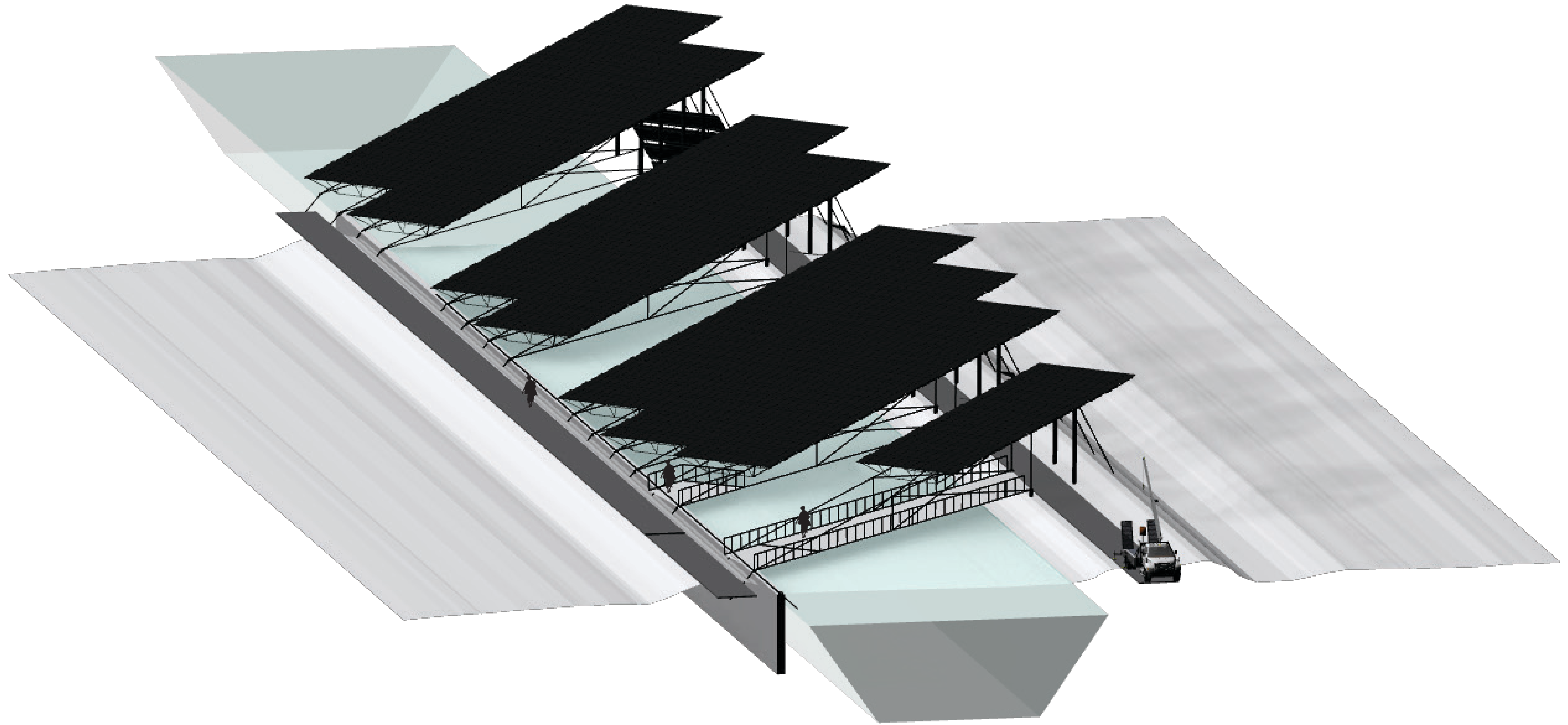
(on Left Page)

Image of 3D Model of A-Canal With 3D Model of Conger System adapted to the A-Canal

3D Model Created By: McClean Gonzalez

Models Based on Drawings and Images from: https://www.conger.solar/

+ **Modular System** Klamath Array Pedestrian Bridge



Conger System Adapted to A-Canal

This angled system also allows for pedestrian platforms and bridges to be built using the cable structure at various intervals along the Canal.

These pedestrian spaces bring people out over the Canal to enjoy views of the water in the shade and out of the rain. They also create pedestrian access across the Canal, expanding on the one pedestrian bridge which currently crosses the Canal.

(on Left Page)

Image of 3D Model of A-Canal With 3D Model of Conger System adapted to the A-Canal

3D Model Created By: McClean Gonzalez

Models Based on Drawings and Images from: https://www.conger.solar/

Conger Solar Systems' Steel Cable Structural System

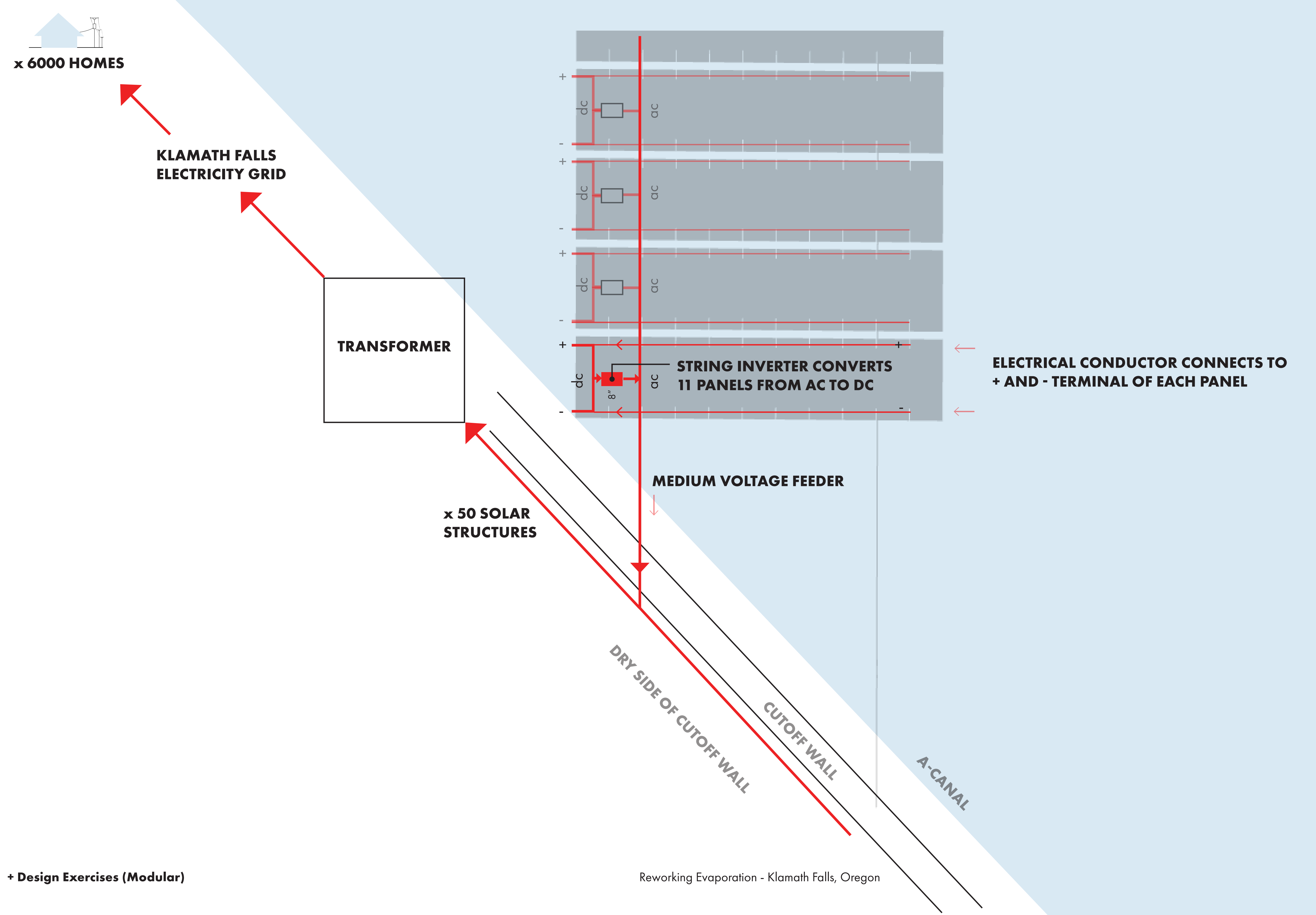
Electrical conductors run between each panel along the structure of the "space frame" to a string inverter. Then, a medium voltage feeder runs along the cable-spanning structure to the south embankment where a conduit is buried along the dry side of the cutoff wall to ensure maintenance access.

For every sequence of 50 spanning solar structures, a transformer and switchgear will be needed before connecting to the electricity grid. A 50-structure system will generate enough electricity for more than 6,000 homes.

(on Right Page)

Diagram of Energy transmission on Proposed Modular System
Created by: McClean Gonzalez

+ **Modular System** Klamath Array Electricity Flow



Two Site-Scale Design Exercises

After developing the modular system, I moved to the Neighborhood and Gateway scales to explore decisions about the placement of the modular structure along the Canal and to further develop the details that would shape the pedestrian experience along the P.V. over canal system.

(on Left Page)

Contours of Three Design Exercises Scales
Created by: McClean Gonzalez

Elevation Data: *DOGAMI*
https://www.oregongeology.org/lidar/

+

Design Exercises

Modular | **Neighborhood** | Gateway

+ **Mazama High School Neighborhood** Site Selection

Choosing the Neighborhood Scale

To select the Mazama High School Neighborhood site I identified a 1-mile site that contained characteristics representative of the A-Canal and which had the characteristics that make a P.V. over canal system most feasible: consistent flow direction, straightness, and needs for flood prevention.

The site is primarily made up of high levels of flood risk and flows in the predominant southeast flow direction.

(on Left Page)

Aerial Image Annotated with Neighborhood Site Selection Criteria
Created by: McClean Gonzalez

Aerial Image: Google Earth Accessed May 2023

+ **Mazama High School Neighborhood** Site Selection

Choosing the Neighborhood Scale

The Mazama High School Neighborhood site is defined by the OC&E State Trail at the north and Homedale Road's intersection with the A-Canal at the south. The site includes a mix of land uses including a baseball field, a high school, and single-family housing.

(on Left Page)

Aerial Image Annotated with Neighborhood Site Selection Criteria
Created by: McCleon Gonzalez

Aerial Image: Google Earth Accessed May 2023

Crossing the A-Canal in the Mazama High School Neighborhood

The site includes two vehicular bridges and the only pedestrian bridge that crosses the A-Canal. These provide opportunities to test how the modular structure interacts with structures currently spanning the canal.

(on Right Page)

Aerial Image Annotated with Neighborhood Site Crossings
Created by: McClean Gonzalez

Aerial Image: Google Earth Accessed May 2023
Images of Crossings: Google Street View Accessed May 2023

+ **Neighborhood** Crossings

Accessing the A-Canal Path

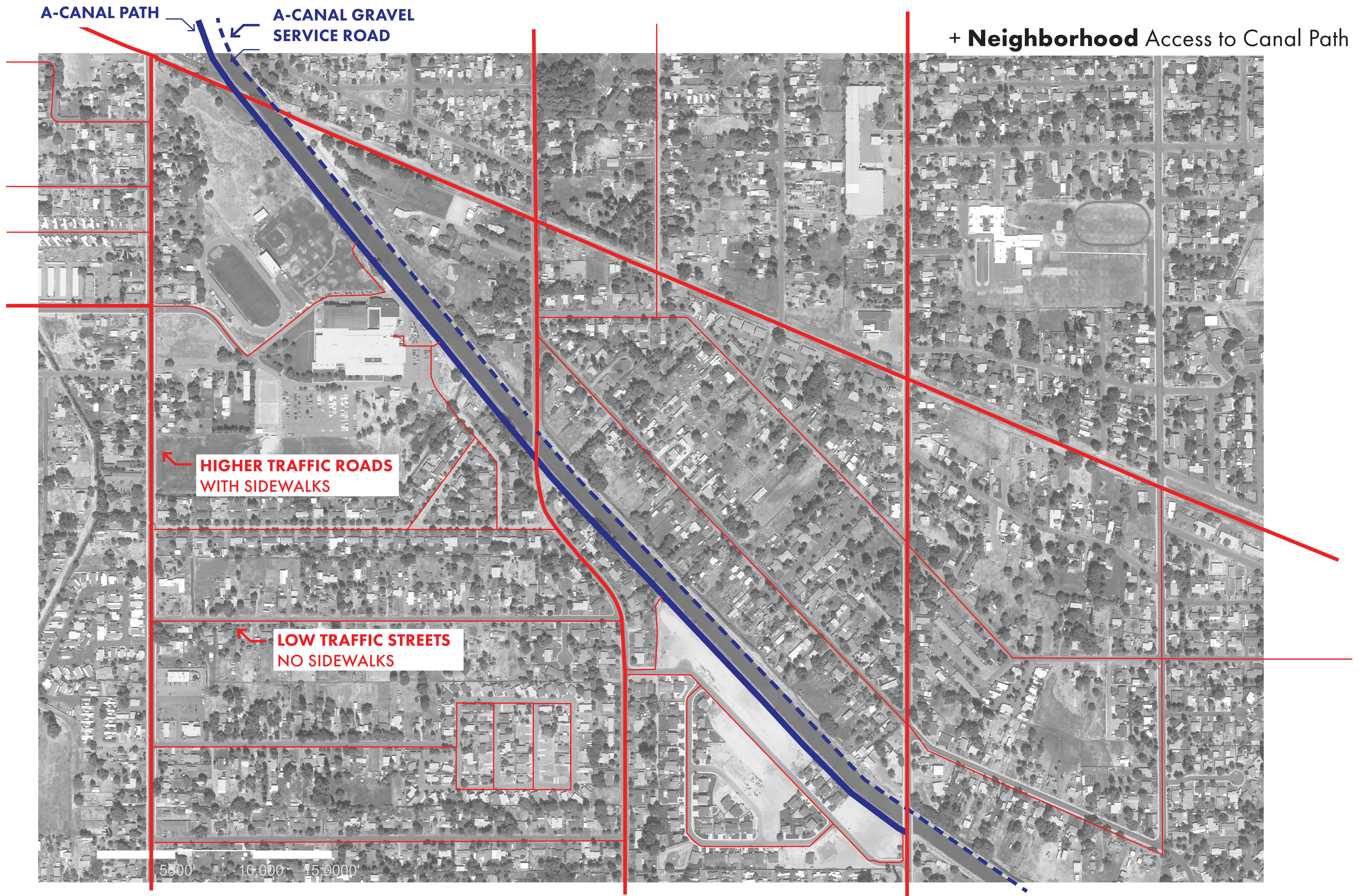
Pedestrian access to the canal is primarily by low-traffic neighborhood streets without sidewalks.

(on Right Page)

Aerial Image Annotated with Circulation in Mazama High School Neighborhood
Created by: McClean Gonzalez

Aerial Image: Google Earth Accessed May 2023

+ **Neighborhood** Access to Canal Path



Main Access Points to A-Canal Path

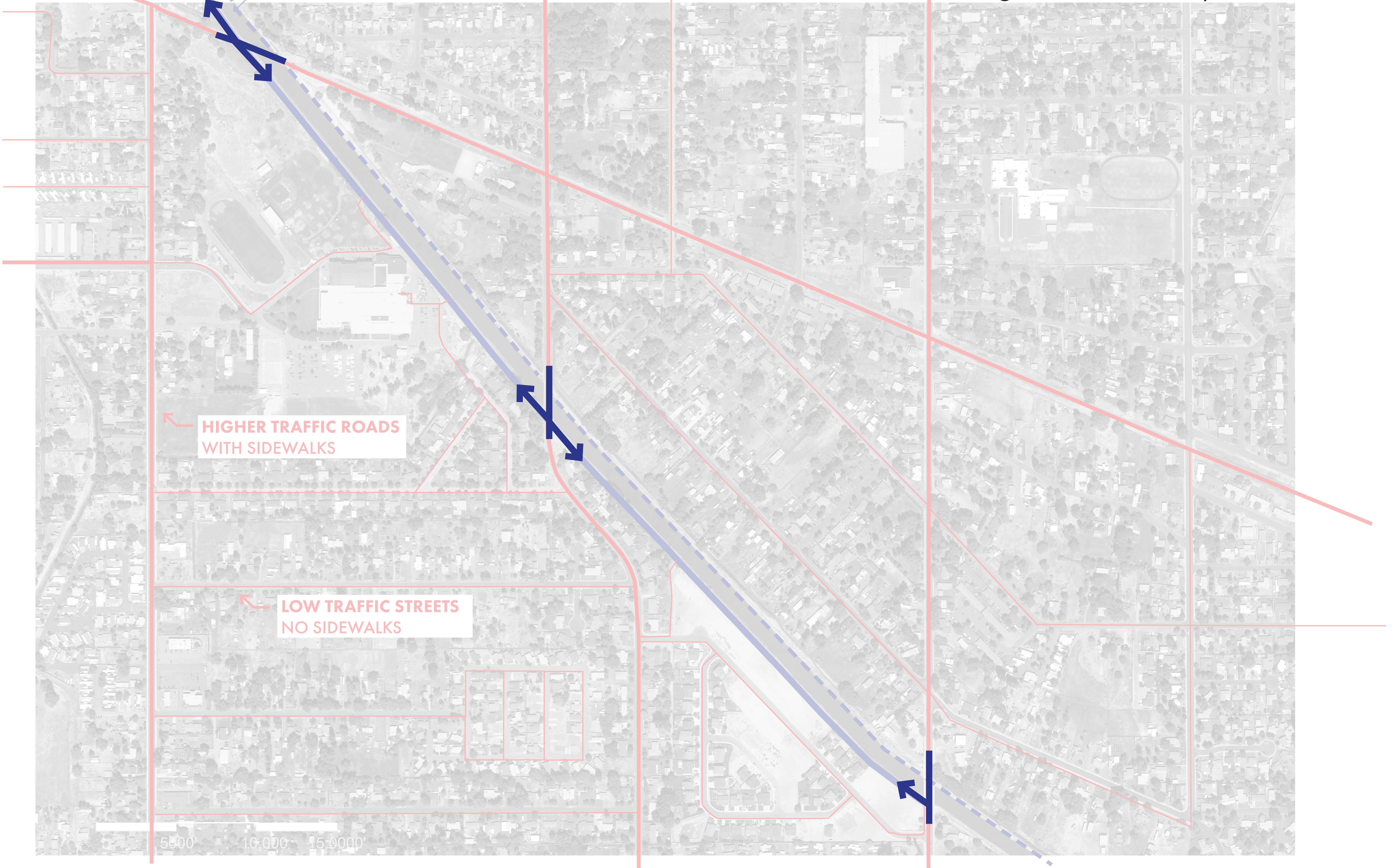
The entrances to the Canal are limited due to private property along the Canal. The main access points to the Canal are at the OC&E pedestrian bridge, the vehicle bridges, and the grounds of Mazama High School.

(on Right Page)

Aerial Image annotated with Main Access Points
Mazama High School Neighborhood
Created by: McClean Gonzalez

Aerial Image: Google Earth Accessed May 2023

+ **Neighborhood** Primary Entrances to Path



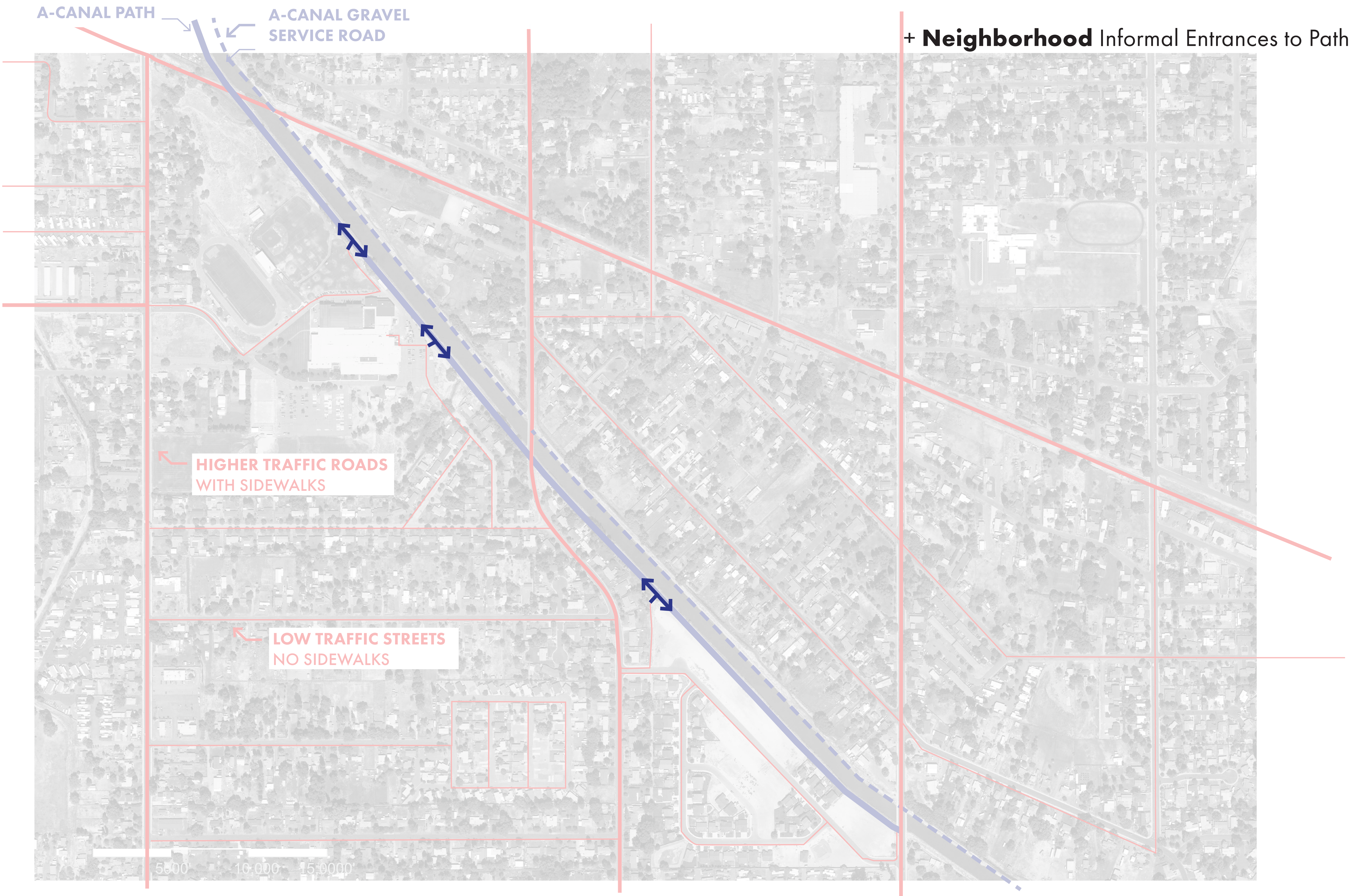
Informal Access Points to A-Canal Path

Informal access points are also present but do not provide accessible entrances and could be shut down at the will of the private landowners.

(on Right Page)

Aerial Image annotated with Informal Access Points
Mazama High School Neighborhood
Created by: McClean Gonzalez

Aerial Image: Google Earth Accessed May 2023



Access Points to A-Canal Path from the North

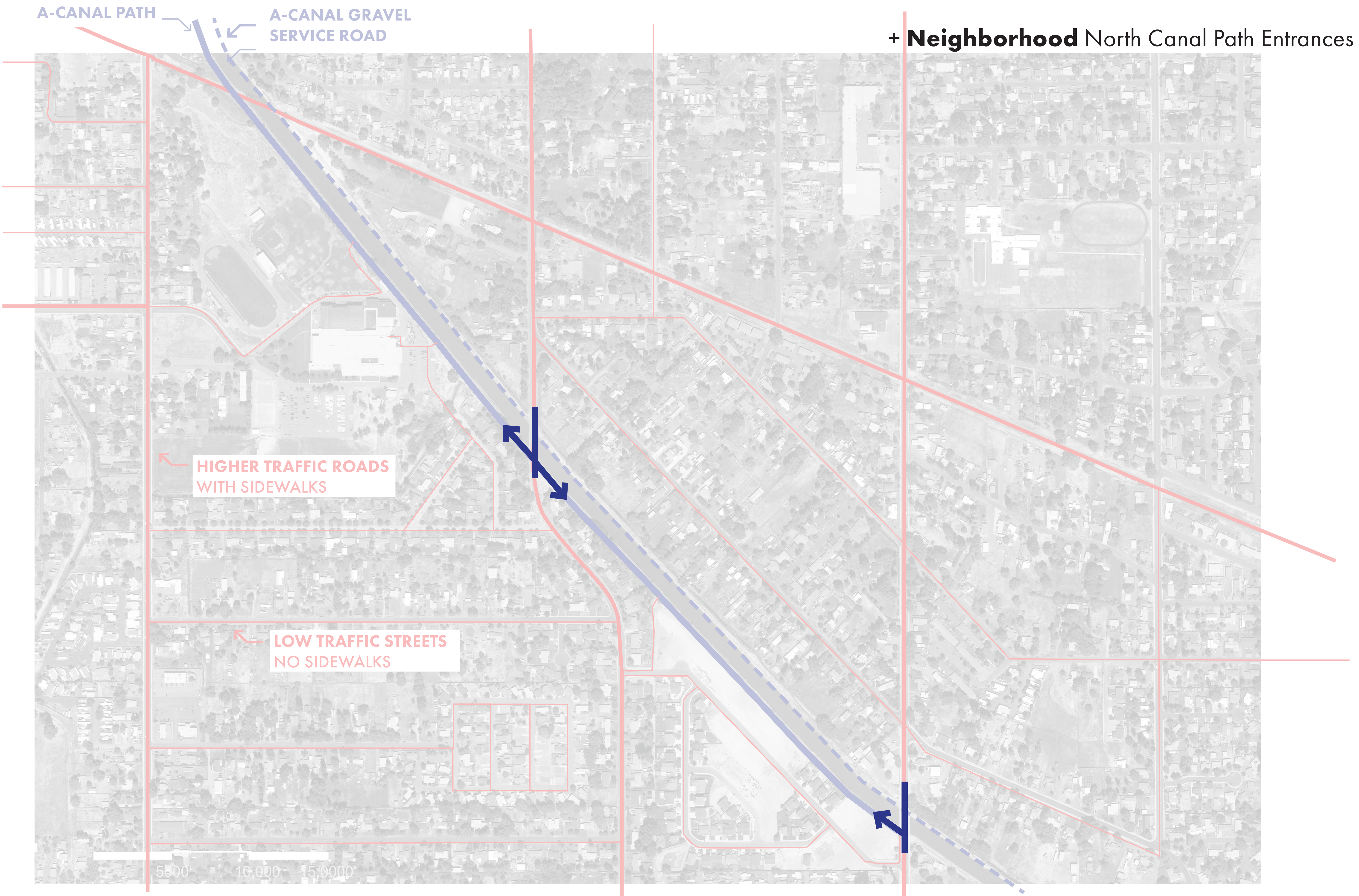
The two vehicle bridges are the primary access points from most housing north of the Canal. These bridges with fast-moving traffic and narrow sidewalks limit inclusive and safe access to the A-Canal trail.

(on Right Page)

Aerial Image annotated with Access Points From North of A-Canal
Mazama High School Neighborhood
Created by: McClean Gonzalez

Aerial Image: Google Earth Accessed May 2023

+ **Neighborhood** North Canal Path Entrances



+ **Neighborhood** Concept Plan

1. Layout of the structures along the 1-mile stretch to create a **pattern that emphasizes proposed and existing entrances** to the Canal.
2. The distribution of new over-water access points to allow **regular access between embankments** and to create regular opportunities to experience the water of the Canal.
3. The **paving of the north service road** to improve maintenance and pedestrian access to the north portion of the Canal.
4. A new **Canal planting strategy** to fit within the new conditions created by the P.V. over canal system.

The Klamath Array in the Mazama High School Neighborhood

From this analysis, I developed four neighborhood-scale adjustments to the modular system.

First, modify the layout of the structures along the 1-mile stretch to create a pattern that emphasizes proposed and existing entrances to the Canal.

Second, define the distribution of new over-water access points to allow regular access between embankments and to create regular opportunities to experience the water of the Canal.

Third, pave the north service road to improve maintenance and pedestrian access to the north portion of the Canal.

Fourth, develop a new Canal planting strategy to fit within the new conditions created by the P.V. over canal system.

(on Left Page)

Aerial Image Annotated with Proposed Adjustments
Created by: McClean Gonzalez

Aerial Image: Google Earth Accessed May 2023

+

Design Exercises

Modular | Neighborhood | Gateway

(on this Page)

Contours of Three Design Exercises Scales
Created by: McClean Gonzalez

Elevation Data: *DOGAMI*
https://www.oregongeology.org/lidar/

Selecting the Mazama High School Gateway

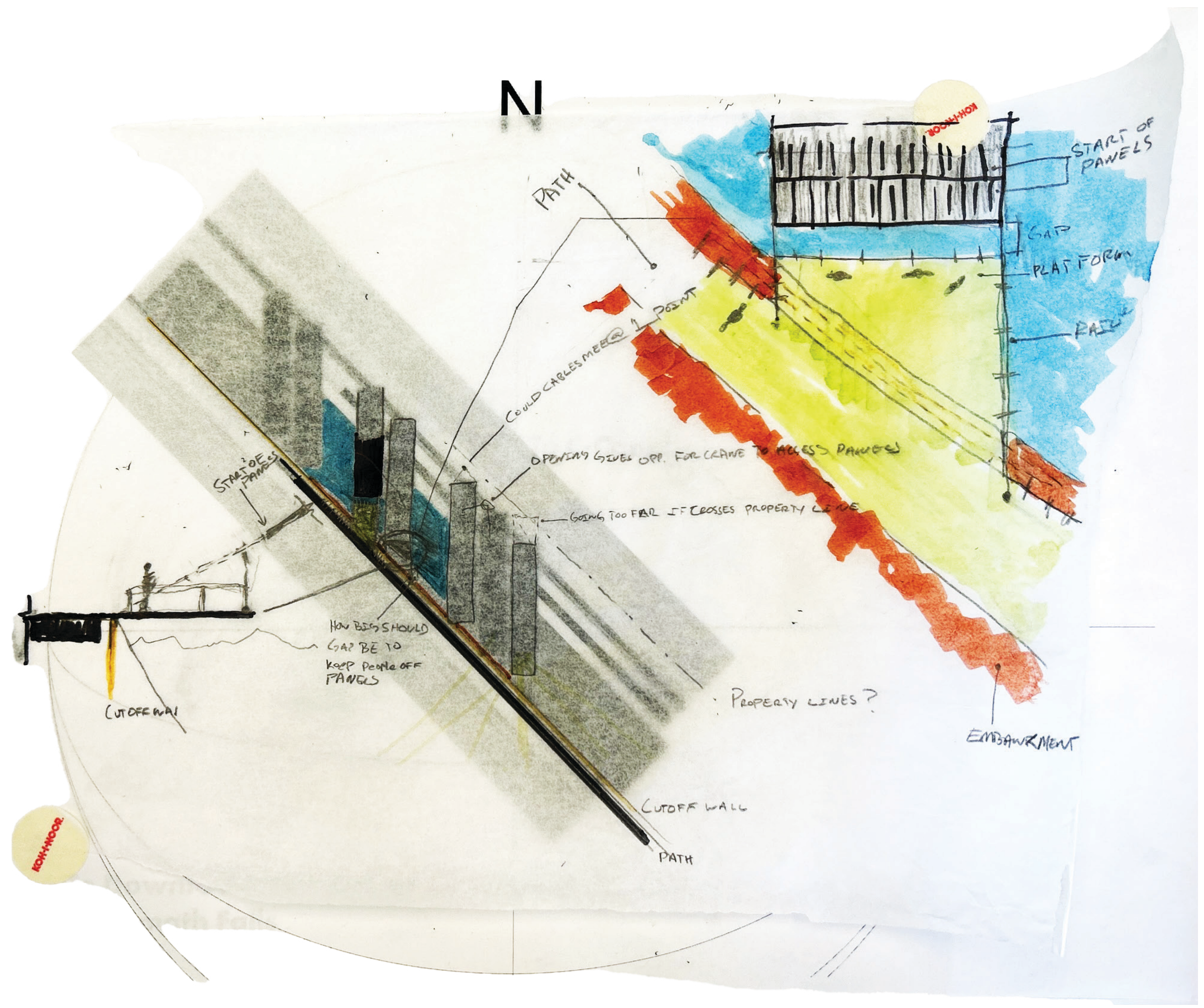
At the gateway scale, pedestrian access adjustments were explored in more detail.

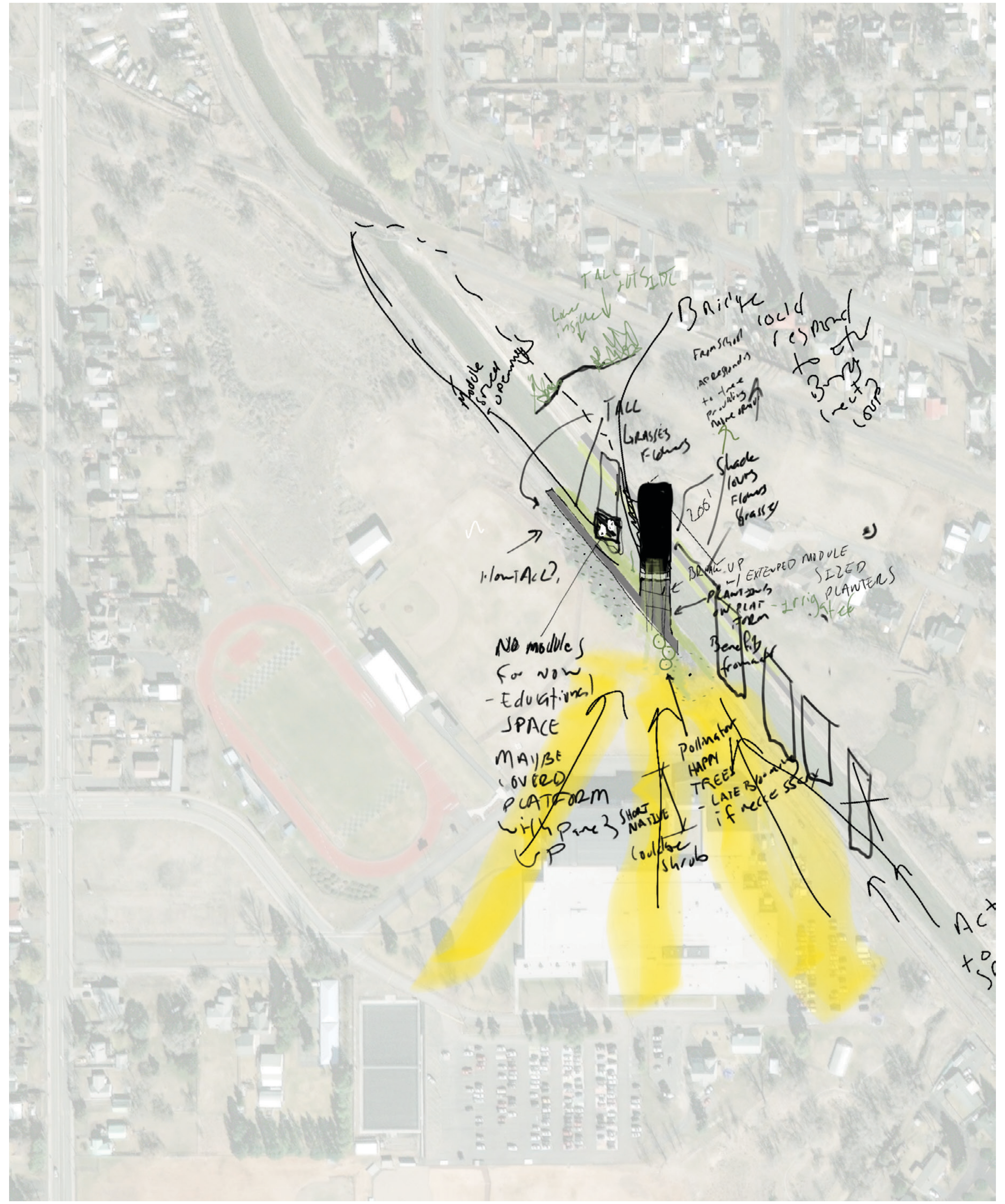
The Mazama High School Gateway site is the entrance point to the south embankment canal path between the Mazama High School baseball field and the school itself.

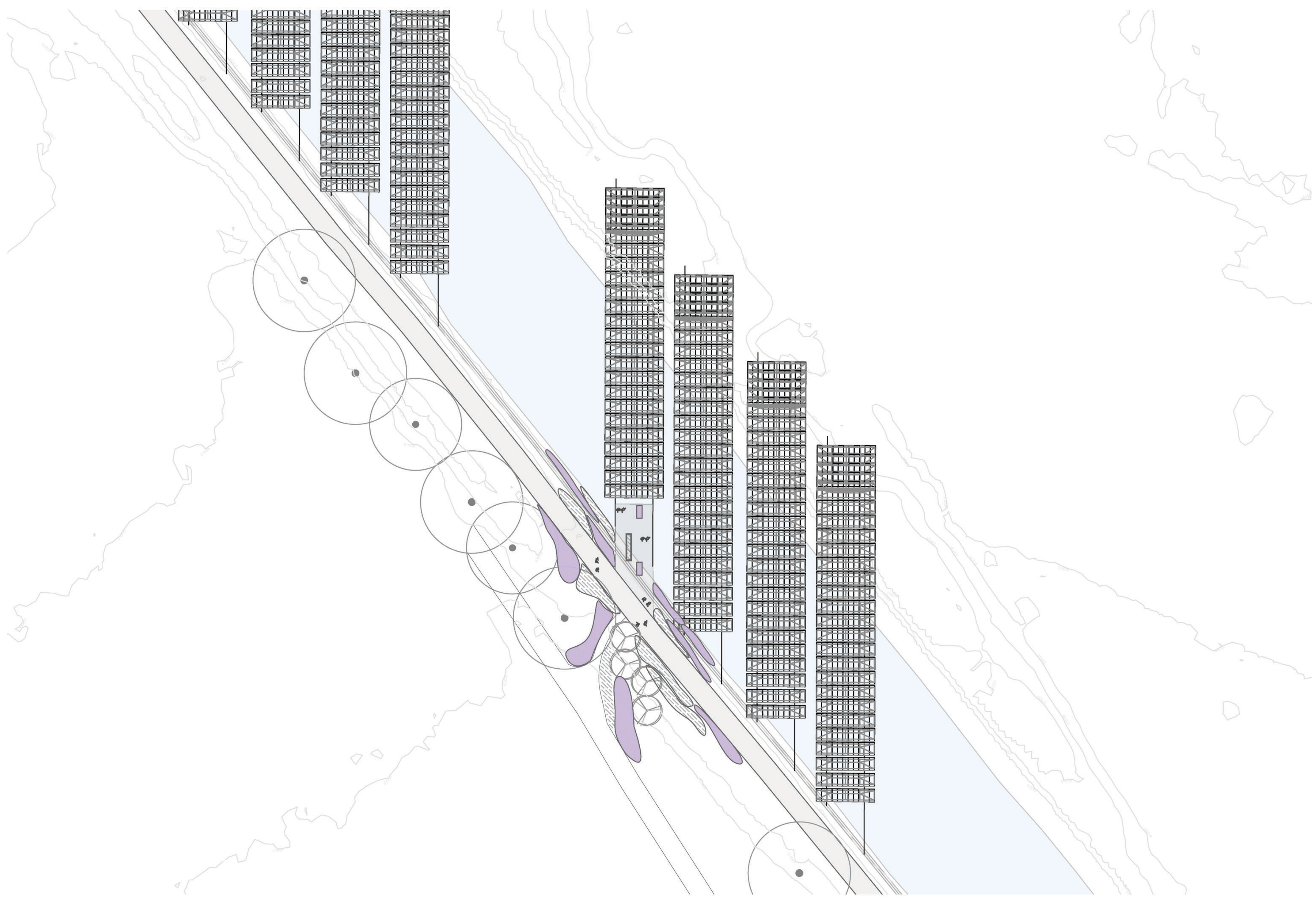
(on Right Page)

Aerial Image annotated with Gateway Scale Proposals
Created by: McClean Gonzalez

Aerial Image: Apple Maps Accessed May 2023







Aligning Structures to Enhance Existing Entrances at the Gateway Scale

At this scale, specific dimensions were established for the spacing between the modular structures at the Canal entrances, responding to the specific entrance site, defining the visual landmark to the entrances, and exploring the necessary spacing to expand the views to the water.

(on Left Page)

Concept Plan for Mazama High School Gateway
Created by: McClean Gonzalez

Elevation Data: *DOGAMI*
https://www.oregongeology.org/lidar/

Developing Pedestrian Bridge Detail

The details of the pedestrian bridge itself were created at the gateway scale.

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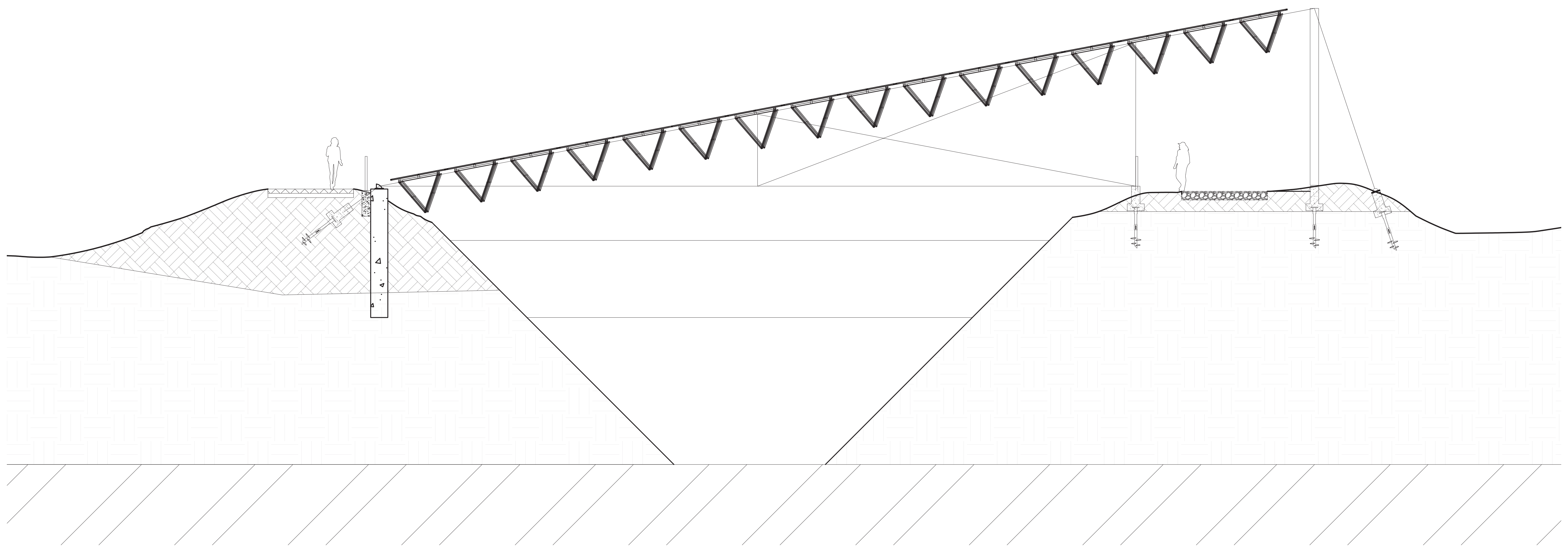
Section Drawing of A-Canal With Span Structure
Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/



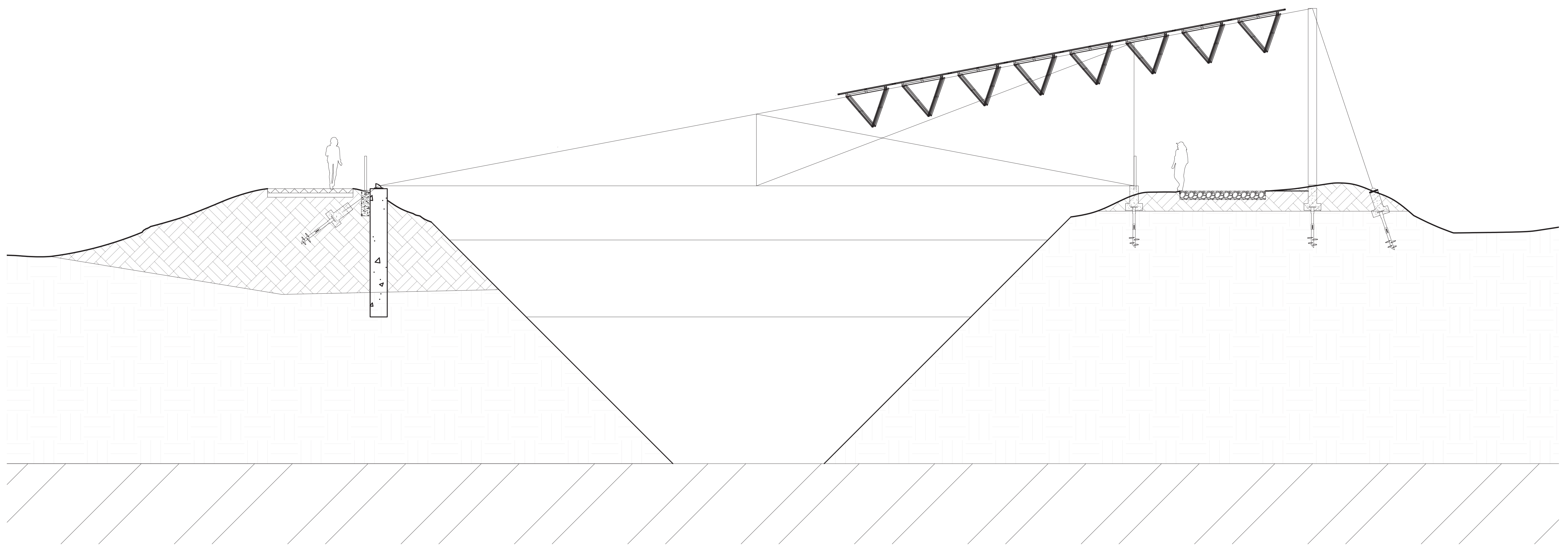
Developing Pedestrian Bridge Detail - Peel Back 8 “Space Frames”

Peeling back of the first eight “space frames” creates eight feet of headroom.

(on Right Page)

Section Drawing of A-Canal With Span Structure and Pedestrian Bridge Details
Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/



Developing Pedestrian Bridge Detail - Walking Surface

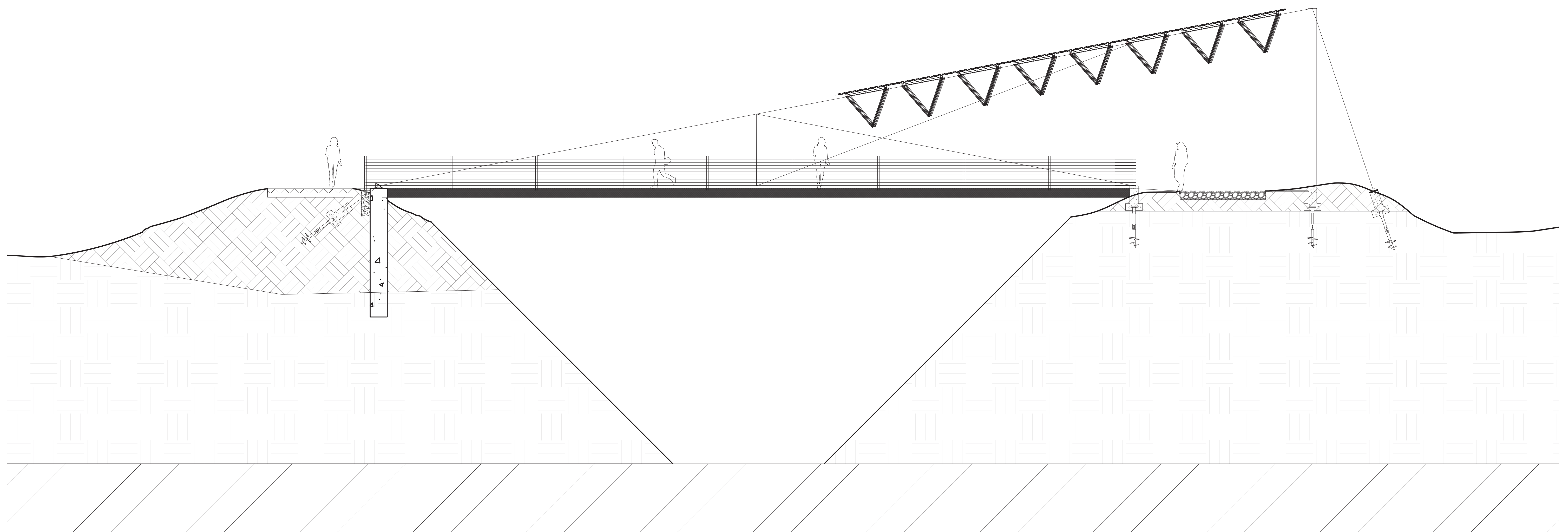
A walking surface with cable railings is added between the bottom cables of the spanning structure.

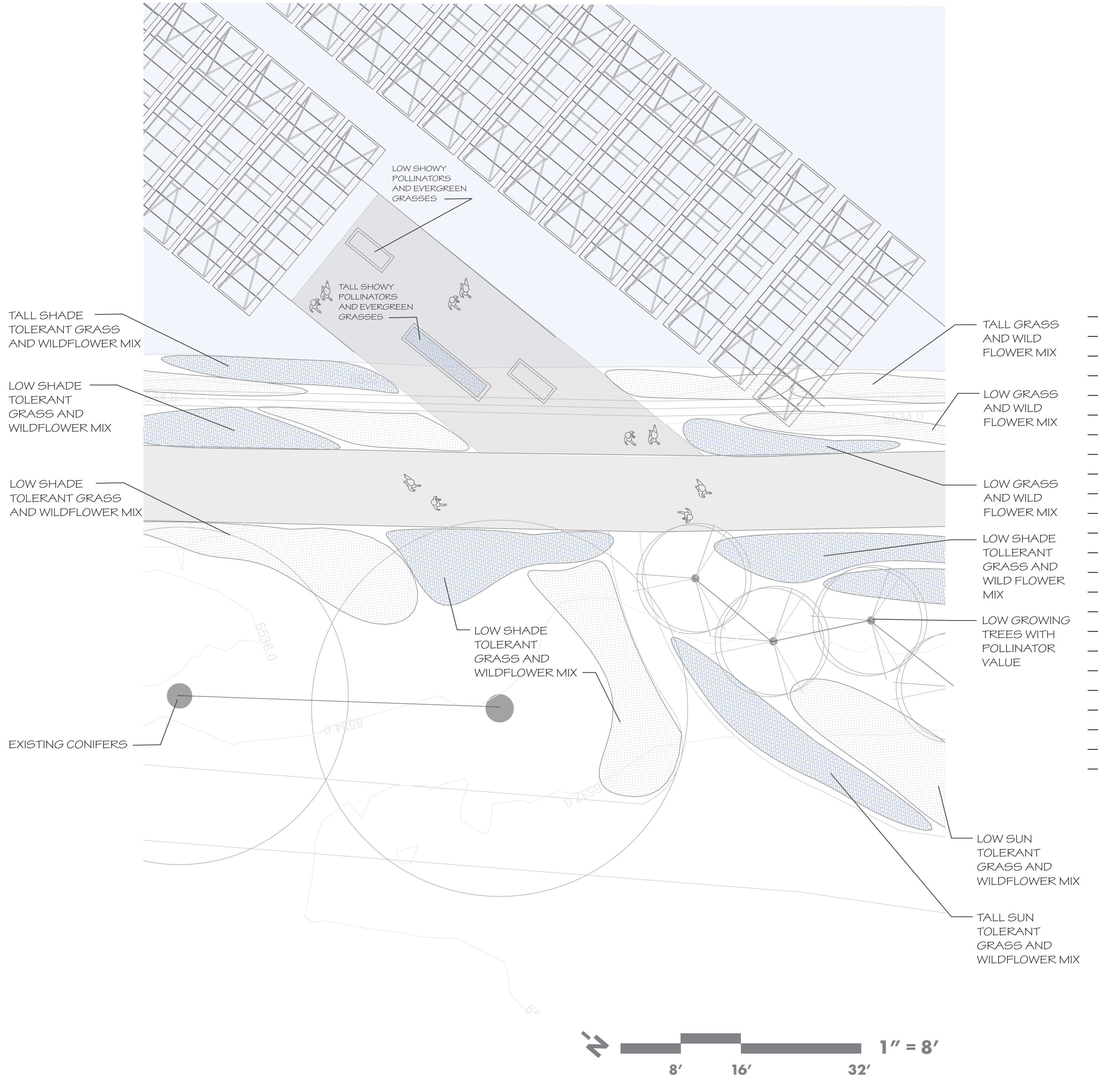
Concepts for programmed spaces were also explored for along the pedestrian bridge, including planting beds, tables, and benches to create new opportunities for people in the neighborhood to spend time over the Canal.

(on Right Page)

Section Drawing of A-Canal With Span Structure and Pedestrian Bridge Details
Created by: McClean Gonzalez

Elevation Data: DOGAMI
https://www.oregongeology.org/lidar/





Plant Palette

Soil Type: Fill

Klamath Falls
A-Canal Canal Covered Solar

Plant	Width and Height	Soil Moisture	Sun / Shade	Evergreen Structure	Winter Interest	Early Fall	Late Fall	Early Spring	Late Spring	Summer	Habitat / Native	Notes: design terms form role / function Root Depth
Wildflowers												
* Achillea millefolium[1] (Yarrow)	1′-1.5′ x 3′	Dry- moist	○ ◑							○	X	attracts both bees and butterflies. common and easily recognized wildflowers, has a long history of medicinal use
* Camassia quamash[1] (Camus)	1′-2′ x 1′ - 3′	Moist Soil	○								X	Considered among the easiest of and showiest of native bulbs. **Drought Tolerant**
* Euthamia occidentalis[1] (Goldenrod)	15′-50′ x 2.5′	Moist Well Drained	○								X	Habitat: Edges of marshes and ditches at low elevations. Common around Klamath Falls.
* Lupinus polyphyllus[1] (Lupine)	2′-3′ x 3′- 4′	Moist soils	○ ◑								X	Leaves are palmately compound with 5-17 finger-like leaflets up to 6 in. long. Pea-like flowers are white to blue or violet on large racemes up to 16 in. long.
Hydrophyllum capitatum[1]	1′ x 1′	moist	○◑●								X	Leaves are lanceolate to ovate in outline, 4-6 in. long, and deeply divided into 5-7 main divisions poisonous to cattle
* Lithophragma bulbifera[1]	0.5′ x 2.5′	Dry	○					○	○	○	X	
Bidens cernua[1]	1′-2′ x 3.5′	Moist	◑								X	Wetlands and canals at low elevations. Common around Klamath Falls.
Lomatium vaginatum[1]	1′-2′ x 2.5′	Dry	○								X	
Lomatium triternatum[1]	1′-2′ x 2.5′	Dry	○								X	
Grasses												
Koeleria macrantha[2]	1-3′ x 9-18″	tolerates drought/ dry / Sandy / rocky soils	○								X	Prevents Soil Erosion, nesting material for native bees
Elymus glaucas	2′-4′ x 4′	Moist to dry well drained soil	◑								X	Good for erosion control
Bouteloua curtipendula	1′-3′ x 4′	dry moist	○ ◑								X	
Carex lasiocarpa	2′-3′ x 4′	Moist to wet	○◑●								X	
Dichanthelium acuminatum	1.5′ x 2.5′	Moist to drier soils	◑								X	Good low traffic ground cover **Native Habitat:** Rocky or sandy river banks; moist rock crevices; below 4500 ft.
Juncus torreyi	2′ x 3′	Moist to wet	○								X	**Native Habitat:** Wet Meadow/Prairie/Field,Swamp/Marsh Flower head is a globular spike of capsules like a starburst, 1 cm across.
Calamagrostis canadensis	2′-3′ x 5′-6′	Moist to wet	○◑●								X	This species is the most frequent grass associate of sedges and is a valuable wetlands restoration species.
Poa pratensis	0.5′-1′ x 3′	Dry to Moist	○								X	
Sporobolus airoides	2′-3′ x 5′	Moist	◑								X	**Soil Description:** Moist to dry, alkaline, fine-textured soils. Sandy, Sandy Loam, Medium Loam Clay Loam, Clay, Caliche type, Saline tolerant
Setaria parviflora	2′-3′ x 4′	Moist	◑								X	Bottle Brush top
Danthonia unispicata[1]	1′ x 1′	dry - moist	○								X	
Elymus elymoides[1]	1′-2′ x 2′	Dry	○								X	Flowers June-Aug. Used for restoration after disturbances because it competes well with cheatgrass.

[1] Found in *Common Plants of the Upper Klamath Basin*
* Late Season Blooms

Possible Additions

Monch Frikart's Aster Aster x frikartii)
California Poppy (Eschscholzia californica)
Globe gilia (Gilia capitata)
Douglas aster (Symphyotrichum subspicatum)

Developing a Planting Strategy at the Gateway Scale

For the planting, at this scale, I explored the specific climatic conditions to further refine the potential planting plan for the system.

These planting typologies respond to the specific climatic conditions of the P.V. over canal system. These conditions include: the space under the proposed pedestrian bridge, both sides of the north and south embankments, and where there is existing vegetation such as established conifers near the embankments.

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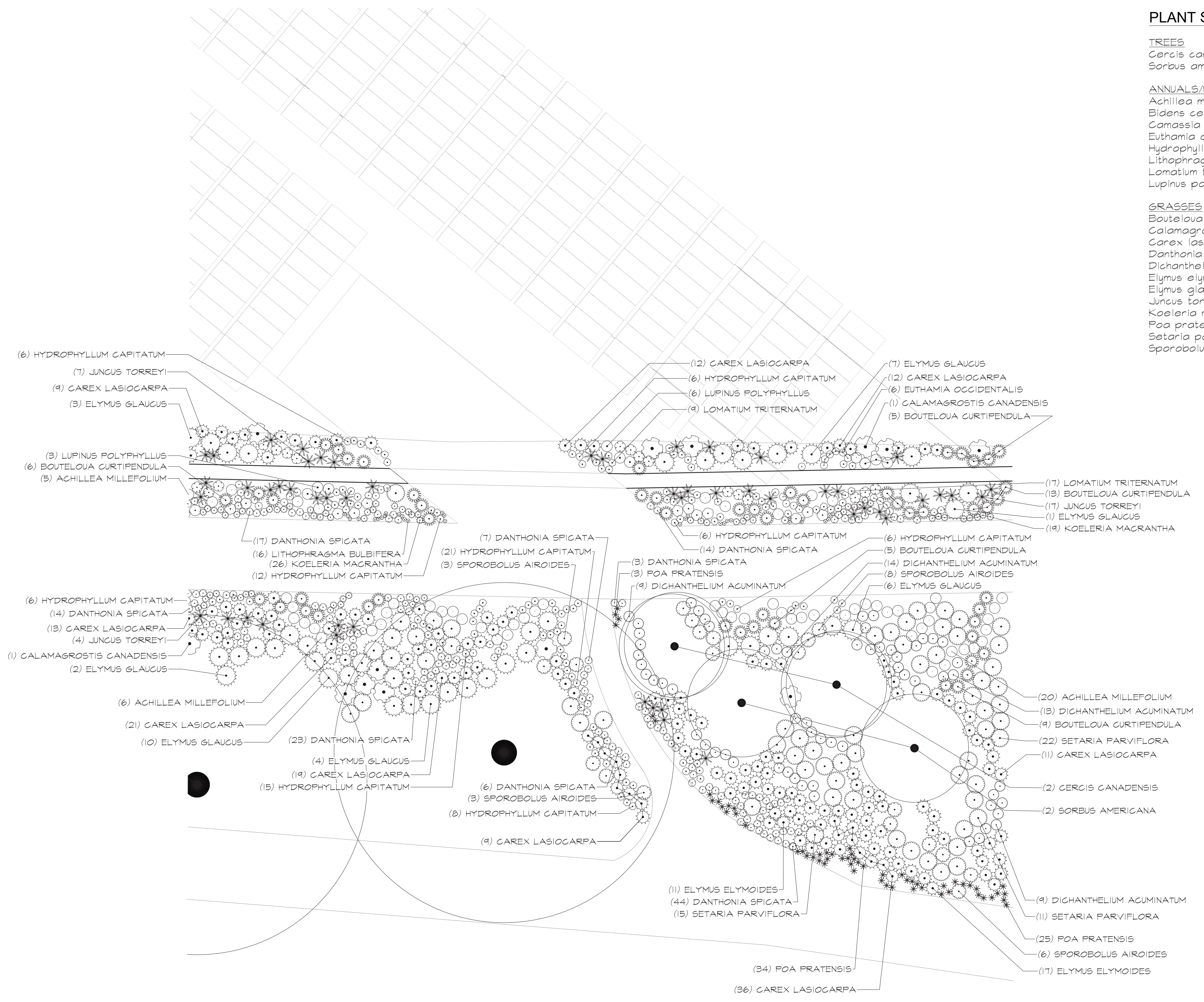
Concept Planting Plan and Planting Palette for Mazama High School Gateway Site
Created by: McClean Gonzalez

Elevation Data: *DOGAMI*
https://www.oregongeology.org/lidar/

+ **Design Exercises** Test of Seed Mixes Gateway Site



PLANT SCHEDULE KAZAMA TEST SITE

TREES	CONT	QTY
Cercis canadensis / Eastern Redbud Multi-trunk	5 Gal	2
Sorbus americana / Mountain Ash	5 Gal	2
ANNUALS/PERENNIALS	**CONT**	**QTY**
Achillea millefolium / Common Yarrow	1 gal	62
Bidens cernua / Nodding Beggartick	1 gal	17
Camassia quamash / Small Camas	1 gal	13
Euthamia occidentalis / Western Goldentop	1 gal	28
Hydrophyllum capitatum / Ballhead Waterleaf	1 gal	95
Lithophragma bulbifera / Smallflower Woodland Star	1 gal	31
Lomatium triternatum / Nine-leaf Lomatium	1 gal	26
Lupinus polyphyllus / Large-leaved Lupine	1 gal	9
GRASSES	**CONT**	**QTY**
Bouteloua curtipendula / Side Oats Grama	1 gal	53
Calamagrostis canadensis / Bluejoint Grass	1 gal	12
Carex lasiocarpa / Woollyfruit Sedge	1 gal	135
Danthonia spicata / Poverty Oatgrass	1 gal	146
Dichanthelium acuminatum / Tapered Rosette Grass	1 gal	61
Elymus elymoides / Squirreltail Grass	1 gal	32
Elymus glaucus / Blue Wildrye	1 gal	46
Juncus torreyi / Torrey's Rush	1 gal	52
Koeleria macrantha / Prairie Junegrass	1 gal	65
Poa pratensis / Kentucky Bluegrass	1 gal	59
Setaria parviflora / Marsh Bristlegrass	1 gal	61
Sporobolus airoides / Alkali Sacaton	1 gal	20

Developing a Planting Strategy at the Gateway Scale

These new planting typologies are also informed by their height in relation to the path and pedestrian bridges and platforms.

These typologies help to inform a series of initial plant mixes made up of native grasses and flowers which respond to these conditions and could eventually establish a pollinator corridor along the Canal.

A preliminary planting plan was developed to test these seed mixes. A site like this Gateway Site could be used to test a potential planting strategy for the full extent of the A-Canal.

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Detailed Planting Plan and Planting List for Mazama High School Gateway Site
Created by: McClean Gonzalez

Elevation Data: *DOGAMI*
https://www.oregongeology.org/lidar/

+

Conclusion

Regional Context | Modular | Neighborhood | Gateway

Research Questions

1. What specific challenges exist when designing P.V. over canal?
2. What could the role of a Landscape Architect be in the process of adapting one to a specific site?

To Address A-Canal's Needs
(water savings and reduction of flood risk)

Design a P.V. Over Canal System for A-Canal

To Explore P.V. Over Canal for Urban Canal

A-Canal
Image from Site Visit on Nov. 22, 2022

Grand Canal in Phoenix Arizona
https://www.phoenix.gov/streets/grandcanalscape

Returning to Research Questions

I then returned to my guiding questions to develop takeaways both for the A-Canal and similar projects. These questions are:

1. What specific challenges exist when designing P.V. over canal? and
2. What could the role of a Landscape Architect be in the process of adapting one to a specific site?

Findings from Design Exercises

From this process, I developed a theoretical design and a set of objectives and recommendations that could inform a P.V. over canal project on the A-Canal. Many of these findings could also inform other urban P.V. over canal projects.

The first is spacing P.V. over canal structures to make entrances to canal paths clear and maintain or improve views of the water in the canal.

The second is choosing structural systems that also function as platforms or bridges to improve access between embankments and create new opportunities for pedestrians to experience the canals.

And the third is developing planting strategies that respond to the new microclimates created by the P.V. over canal system, improve the aesthetic experience of walking along the canal paths, and improve the ecological function and embankment stability.

+ Conclusion **Summary of Recommendations and Potential Details**

Modular

1. Cutoff Wall + Anchor
2. Helical Pier + Anchor
3. Adapted Conger Structural System
4. Preliminary Electricity Distribution system

Neighborhood

1. Lay out modular structures to **create a pattern that emphasizes proposed and existing entrances**
2. **Distribute over-water access points** to allow regular access between embankments and to create regular opportunities to experience the water of the canal.
3. **Pave north service road**
4. Develop **new planting strategy** to fit new conditions created by the P.V. over canal system

Gateway

1. **Adjusted pattern** to respond to Gateway entrance
2. Details of structure adjustment to add **pedestrian bridge**
3. **Planting typologies** and **preliminary plant mixes**

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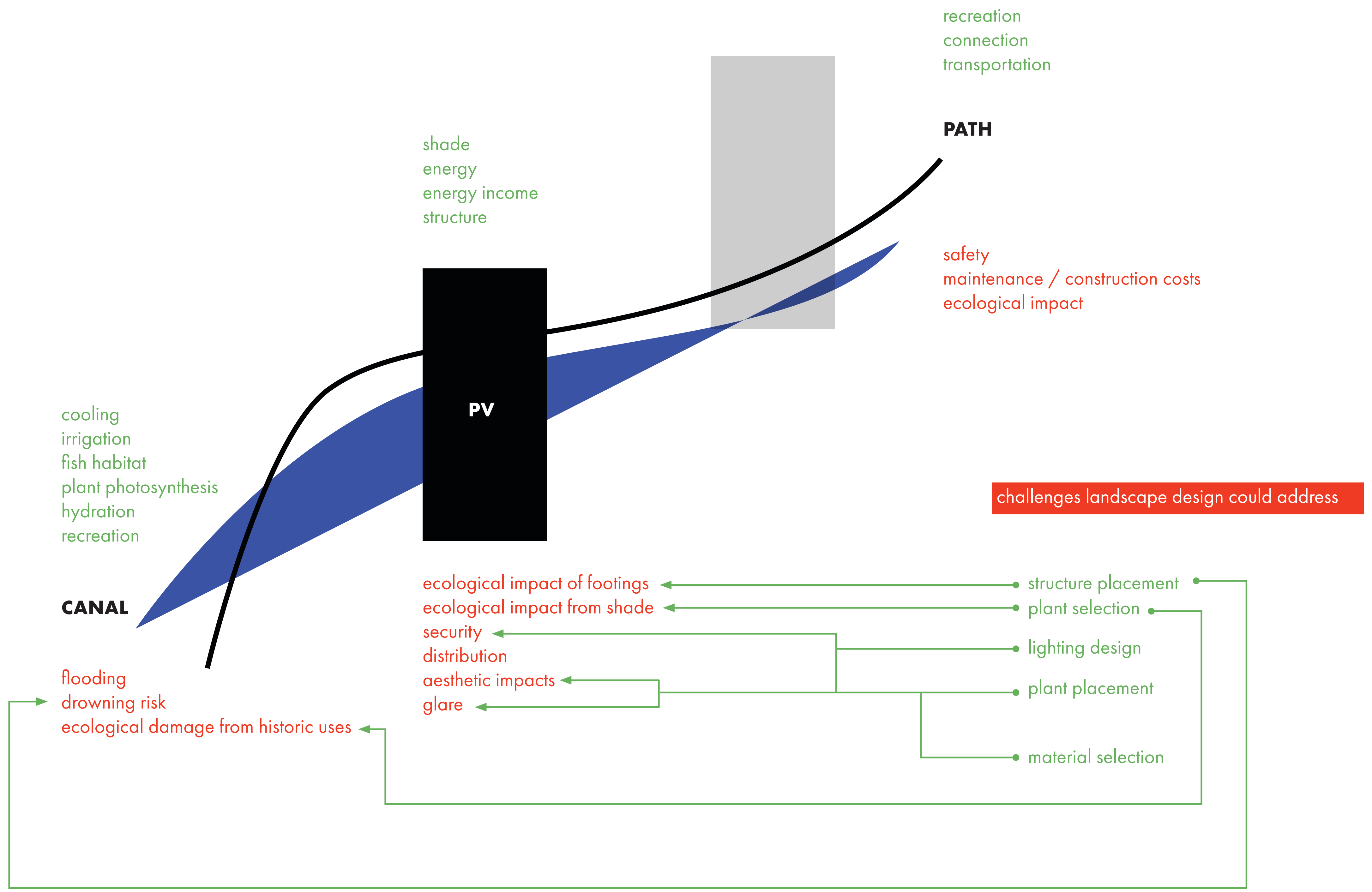
Contours of Three Design Exercises Scales
Created by: McClean Gonzalez

Elevation Data: *DOGAMI*
https://www.oregongeology.org/lidar/

+ Conclusion **Landscape Architecture for P.V. Over Canal**



Role of Landscape Architecture in Renewable Energy Projects

The process also allowed me to explore the role that a landscape architect might take in renewable energy projects: advocating for functional, aesthetic, and ecological objectives alongside the technical objectives of efficiently generating low-carbon energy.

By designing and representing the human-scale details of these projects and asking questions about walking along or living near these important pieces of infrastructure, landscape architecture can shape these projects to not only create the global benefit of reducing the release of carbon into the atmosphere, but also add local value to the places these projects are located.

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Diagram of Potential Role of Landscape Architects in P.V. Over Canal Projects
Created by: McClean Gonzalez

A Possible Future for P.V. Over Canal in the Klamath Basin

As farmers and residents of Klamath Falls determine their role in the future of the Klamath Basin, a project like P.V. over canal could add to their role by providing clean electricity and saving water for farms and the rest of the Basin.

The way that the project gets built could make the P.V. over canal system feel like something that gets imposed upon residents, or it could feel like a way they could further contribute to the regions.

Details that we could be involved in as landscape designers, and allowing residents to shape those details, could go a long way in getting residents and farmers to feel like an important part of the project.

We as landscape designers are in a position to serve residents as clients. I wasn't able to involve community members directly in this project, but I believe it's an important part of moving a project like this forward.

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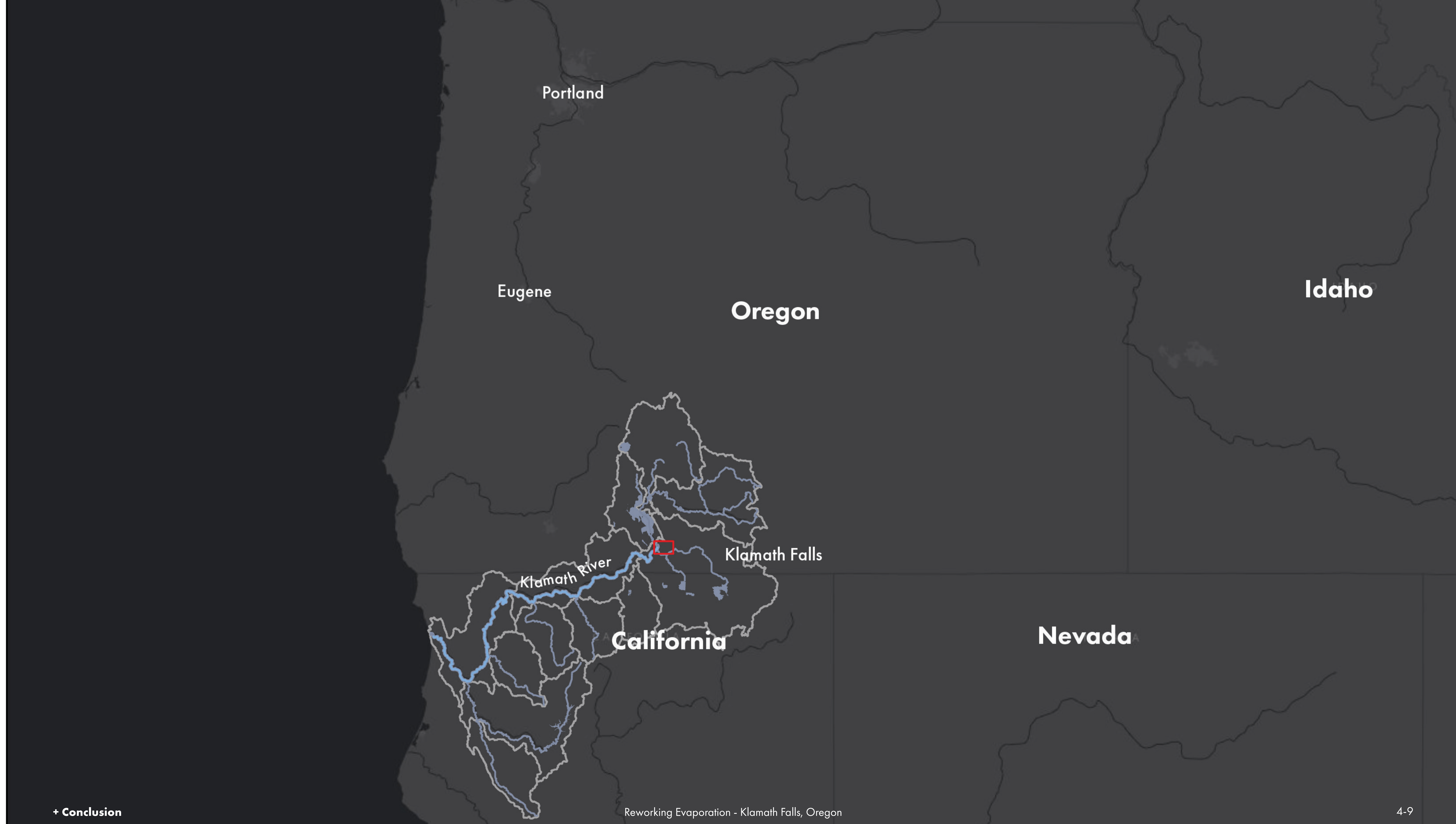
Map of Klamath Basin

Created By: McClean Gonzalez
Klamath Basin Data from: Oregon Tech *Klamath Basin Sub-basins Map*
https://services1.arcgis.com/FB50u5E6wrw7l3d1/arcgis/rest/services/Klamath_Basin_Subbasins/FeatureServer



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