Marking Risk and Response:
Design Interventions to Support Citizen Science Monitoring of the Trans Mountain Pipelines

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Abstract

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How can community-based monitoring create much needed visibility and oversight of buried tar sands pipelines that traverse human and non-human communities? The Trans Mountain Pipeline conveys up to 12.6 million gallons of diluted bitumen per day from the Athabasca tar sands of Alberta to ports in Vancouver (British Columbia) and Washington State, with construction underway on a second, paralleling pipeline that triples capacity. Meanwhile, the communities through which these pipelines invisibly pass possess little knowledge about how these pipelines are monitored or the results of that monitoring, despite an extensive history of spills. This thesis imagines a landscape architecture practice that contributes to citizen science monitoring through systems thinking, community engagement, and physical design. An adaptable design framework is proposed, where a network of citizen scientists insert site-responsive interventions into the landscape, which mark pipeline, social network, monitoring activity, and data. The result is greater legibility of physical interactions between pipeline, ecologies, and human communities. This mode of landscape architecture contributes to a growing community-based movement that challenges dominant paradigms of opaque infrastructure monitoring, whereby corporate data is shrouded within what Science and Technology Studies scholar Sara Ann Wylie calls "regimes of imperceptibility."[1]

1. Sara Ann Wylie, *Fractivism: Corporate Bodies and Chemical Bonds* (Durham: Duke University Press, 2018), 36.

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Thank you to my thesis committee, Catherine De Almeida and Jeff Hou, for your steady support and for pushing me to think expansively about place, ecologies, and design. Thank you to the people who generously shared stories about the lands traversed by the Trans Mountain pipelines, especially Chief T. Lee Spahan and Dr. Sean Kheraj. Thank you to classmates who helped me to see what this project might be. Thank you to family and friends for providing encouragement, wisdom, and levity throughout this process both in person and, during this COVID-19 pandemic, across laptop screens. I am indebted to you all.

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All photos by author, except where otherwise noted

1 Introduction

"Stand them in the stream, head them upstream, rejoice as they learn to love this green space they live in, its sticks and leaves and then the silent, beautiful blossoms.

Attention is the beginning of devotion."

-Mary Oliver, *Upstream*[1]

From a personal standpoint, this project started in Minneapolis. In 2013, while attending climate activism-related meetings and protests, I began to hear from Indigenous leaders and organizers about the Alberta tar sands. As a massive region of ancestral Indigenous lands was being rapidly scraped away and drilled to access oil, with massive consequences for surrounding rivers, it was becoming a central battleground for environmental and climate justice. On my bike ride to my job each day, I passed alongside and underneath oil tanker train cars that stretched in an ant line as far as I could see. I wondered what set of social and political solutions it might take to break our addiction to fossil fuels.

The political challenges of making any such shift away from fossil fuels took center stage during the 2016 Dakota Access Pipeline protests at Standing Rock, which provided a poignant window into the current state of resource politics. The world watched as a militarized government violently responded to community voices, demonstrating more concern for continued growth of resource economies than the communities affected by them. In Canada, where the Trans Mountain Pipeline

(TMP) runs underneath over 1,000 kilometers of Indigenous ancestral lands, there is a long history of violence and displacement underlying the politics that allow for crude oil pipelines to be built.

Oil companies wield their political power in the larger act of building pipelines and in ensuring maximum efficiency of that construction process, even when it may endanger communities. This has been relevant during the COVID-19 pandemic of 2020. In March 2020, the Canadian government deemed pipeline projects “essential,” including the Trans Mountain Expansion (TMX) pipeline, which is currently under construction and will parallel the existing TMP. Members of several pipeline-adjacent communities have raised concerns about the public health risks of large-scale pipeline construction.[2,3] The president of the Trans Mountain Corporation has assured community members that the company has “implemented all recommendations from Health Canada....to ensure that [they] can continue to do [their] work safely and responsibly,” despite photographs that suggests otherwise.[4]

Once built, pipelines persistently expose communities to risk because the fossil fuel companies that operate them avoid scrutiny through a combination of lax monitoring regulations and the physical invisibility of the pipeline itself. The TMP, which has been in operation since 1953, is but one of many underground pipelines where communities have a poor understanding of their physical presence, little access to information about spill risks, and no access to monitoring data. The Canadian government itself does not even have regular access to monitoring data; pipeline companies must merely submit an acceptable monitoring plan to the National Energy Board and undergo an audit every three years.[5] This status quo continues despite many pipeline spills in recent years, including a June 2020 spill at a Trans Mountain pump station that will potentially poison an aquifer from which the Sumas First Nation community gets its drinking water.[6] The risk of further spills will increase when the TMX pipeline begins its operations.

With that as a backdrop, this project responds to two main problems.

Problem Statements:

1. The physical realities and accompanying risks of pipelines—for both humans and non-humans—are invisible in the landscape.

2. Communities lack agency regarding the monitoring of pipelines, where regulation favors industry self-reporting and industry-set levels of acceptable risk.

Meanwhile, in recent decades, communities around the world have taken environmental monitoring into their own hands through practices of citizen science, which in many cases provide grounds to contest claims made by corporations and government about risks and impacts of industrial processes. In a world of increasing access to affordable technology and grassroots-initiated social networks, there is untapped potential for citizen science practices to play greater roles in landscape and community stewardship, including in the monitoring of critical infrastructures like pipelines.

Figure 1. The Trans Mountain Pipeline (TMP) and the Alberta tar sands

The potential for designers, including landscape architects, to contribute to citizen science efforts is underexplored. As participants in citizen science, landscape architects can be agents of change, where landscape-responsive design subverts dominant sociopolitical narratives and fosters more holistic intimacy between people and the environments they steward. In this practice, landscape architects can contribute their skills around multi-scalar analysis, community engagement, and physical design.

This thesis seeks to contribute ideas for how such a design practice might support visibility, agency, and public oversight of the Trans Mountain pipelines (the TMP and TMX), which carry Alberta tar sands oil across 1,150 kilometers between Edmonton and Burnaby, a part of Metro Vancouver (see Figure 1). As oriented around these pipelines and the diverse set of human and non-human communities they cross, this project responds to two primary research questions.

Research Questions:

1. How can landscape-based design amplify citizen science activities associated with pipeline landscapes, encouraging community-based oversight of these buried infrastructures?

2. How can designing for citizen science networks foster greater legibility of interactions between pipelines, human communities, and non-human communities?

In this project, I did not have the opportunity to deeply engage with the communities living along these pipelines but nevertheless strove to understand their views and concerns through primary and secondary sources. Based on the varied place-based risks that I found, in combination with design principles generated from a review of citizen science literature, the design portion of this thesis suggests an adaptable framework to support citizen science practices along the pipelines.

There are many ways that landscape architects might help increase the visibility of risk around pipelines and other critical infrastructures, where engagement with citizen science is but one. My hope is that this thesis contributes useful ideas about those possibilities.

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Map Data

Figure 1: Canadian Geographic, Wilderness Committee

2 Critical Stance

This chapter explains two sociopolitical and socioecological frames through which I approached this project. The first concerns the role of the landscape architect in citizen science, where landscape architecture focuses on community-based, activism-oriented practices. In the second, I explore an understanding of pipelines as integral ecological components of the landscapes in which most of us live. Together, these critical frames form the backdrop for the rest of the project: analysis of citizen science literature, analysis of the landscapes of the Trans Mountain pipelines, and subsequent design proposals.

Landscape Architecture as Activist, Political Practice

There are many versions of design activism that landscape architects can practice in collaboration with communities to affect political and social change. They can advocate for open public space through community planning and tactical placemaking. They can engage storytelling around specific social justice issues, like in "Coming Home," a Lava Mae project that shares narratives of homelessness.[1] They can work with informal communities in participatory design projects for a healthier built environment, such as in the work of nonprofits like Traction.[2] Lastly, they can work with citizen science groups to support community-based monitoring that challenges underregulated industrial pollution.

In landscape architecture private practice, offices infrequently spotlight citizen science as a featured program in public space design proposals. One exception is the office SCAPE, which has a particularly notable history of advocating for citizen science, including in prominent projects like Living Breakwaters and Public Sediment: Unlock Alameda Creek. While the insurgent politics that this citizen science might suggest are not necessarily called out, they are implied in the grassroots nature of the citizen science that is depicted; SCAPE principal Kate Orff has written at length about this type of bottom-up citizen science, including within Louisiana's "cancer alley."[3] Moving forward, it will hopefully become more common for design offices to articulate potential connections between landscape architecture and citizen science.

The idea of landscape architect as citizen science activist is, therefore, uncommon. This project explores notions of this label. In particular, if a citizen science that monitors corporate toxic pollution is inherently political in its challenge to unjust systems in the built environment, the landscape architecture practice that contributes to this citizen science is also political and confrontational. In this thesis, the landscape architect is a political activist and an ally to a grassroots, justice-oriented set of scientific practices.

Breaking down Binaries: Pipelines as Ecological + Colonial Infrastructures

In framing strategies and responses to risks of the Trans Mountain pipelines, my aim is to challenge culturally constructed binaries that have historically supported disembodiment of toxicity and perpetuation of environmental injustice: person versus environment, natural versus non-natural (or nature versus culture), and wild versus managed. These binaries inform the current invisibility of pipelines. They perpetuate conceptions of infrastructures as standing apart from nature, impenetrable, completely sealed from the environment, distant from our bodies, and embedded gently and safely in the landscape.

All three of these binaries are interrelated, and I draw on the ideas of writers who address each. The first of these binaries, person versus environment, is confronted by writers like social work scholar Susan Kemp, who argues that Western cultures, in contrast to many non-Western cultures, tend to assign place to the physical world, while self primarily exists within the consciousness.[4] This can reinforce a false sense of insulation from the larger environment, including the risks of exposure to toxicities. Kemp argues that in her field of social work, by viewing people as an integral part of the environment, professional practitioners can begin to cultivating more knowledge-based relationships with place, where people and practitioners work together to be place-makers.[5]

Sociologist Kath Weston has also studied the ways that humans experience breakdown of person/environment and nature/culture binaries. As she discusses in *Animate Planet*, "living versus nonliving,


WARNING
AVERTISSEMENT
TRANSMOUNTAIN
UNDERWATER PIPELINE CROSSING
OLÉODUC SOUS-MARIN
• NO DREDGING
• DRAGAGE INTERDIT
• NO ANCHORING
• ANCRAGE INTERDIT
• NO LOG DUMPING
• DÉCHARGE DE BILLES INTERDIT
IN CASE OF A PIPELINE EMERGENCY CALL 24 HOURS 1-888-876-6711
POUR TOUTE URGENCE CONNEXE À L'OLÉODUC, COMPOSEZ EN TOUT TEMPS LE 1-888-876-6711

biological versus technological, creature versus environment, cease to be hard-and-fast dichotomies. The world becomes a place in which human beings are and are not separate, a place in which people begin to perceive themselves as integral to ecologies that they acknowledge, however begrudgingly, they need."[6] She explores the ways these intimacies are manifested in our relationship with "non-natural" technological elements like cars, pipelines, and nuclear reactors, and argues that we understand our relationship with technology only when we have an embodied sense of that relationship.

In this thesis, I therefore suppose that community members can better understand their personal ties to pipelines and their risks, either potential or realized, when they more intimately engage with pipelines as part of their environments. This more integrated understanding of modern ecologies, including connections between human bodies and infrastructures, is something that has long been discussed, including by Donna Haraway, who wrote in her "Cyborg Manifesto" that, due to our frequent interactions with industrial chemicals, our bodies are both organic and technical systems.[7] These ideas have since been echoed by other scholars like sociology and health sciences scholar Sarah Ann Wylie, who expands that idea, writing that we have become "corporate bodes."[8]

Landscape architects have discussed at length the dismantling of the nature/culture binary as a means of encouraging productive landscapes where infrastructures are an integral part of landscape ecologies. This has included the conception of landscape as a "hybrid" or "cyborg" that lacks distinction of natural and non-natural, an idea that Elizabeth Meyer first introduced in *The Expanded Field of Landscape Architecture*.[9] Other landscape architecture scholars like Kees Lokman have since pushed this idea further, arguing that a "cyborg" landscape conception is key to climate resilience at site and landscape scales, with an emphasis on dynamic interrelationship of biotic and abiotic systems, and adaptive, multi-stakeholder-based co-management.[10]

By breaking down these binaries, we can begin to fundamentally recast and invert popular perceptions not just of infrastructure, but also of the corporate fossil fuel actors themselves: they are ecological and social actors first, economic actors second. This is important. In the words of Wylie, when we do the opposite—conceptualize their activities as being chiefly economic—we "relinquish the ability to evaluate their activities from the perspective of civil society, or to understand the vast industrial systems that employ people and shape environments worldwide."[11]

One more binary, "wild versus managed," is relevant to this project, given that the TMP (and pending TMX) passes through lands that are perceived by many, due to formal designation or informal perceptions, as "wilderness." These lands and all others along the pipelines' paths are located within ancestral Indigenous lands, including unceded Indigenous lands throughout the territory of British Columbia. If bringing visibility to the risks of pipelines entails breaking down nature versus non-nature binaries, then it also requires confronting social constructs built on displacement, including the idea of "wilderness," which environmental historian William Cronon described as a "mirror" reflecting colonizers' "unexamined longings and desires."[12] Moreover, the dispossession of Indigenous peoples from pipeline lands, both "wilderness" and otherwise, is actively maintained through colonial processes. As Indigenous Studies scholar Glen Coulthard describes, "the state's approach to reconciliation serves to neutralize the legitimacy of Indigenous justice claims by offering statements of regret and apology for harms narrowly conceived of as occurring in the past, thus off-loading Canada's responsibility to address structural injustices that continue to inform our settler-colonial present."[13] Understanding pipelines as part of the environment therefore requires us to see them as products of social and ecological histories, and to challenge some of the dominant narratives that allow them to remain invisible and under-monitored.

Endnotes

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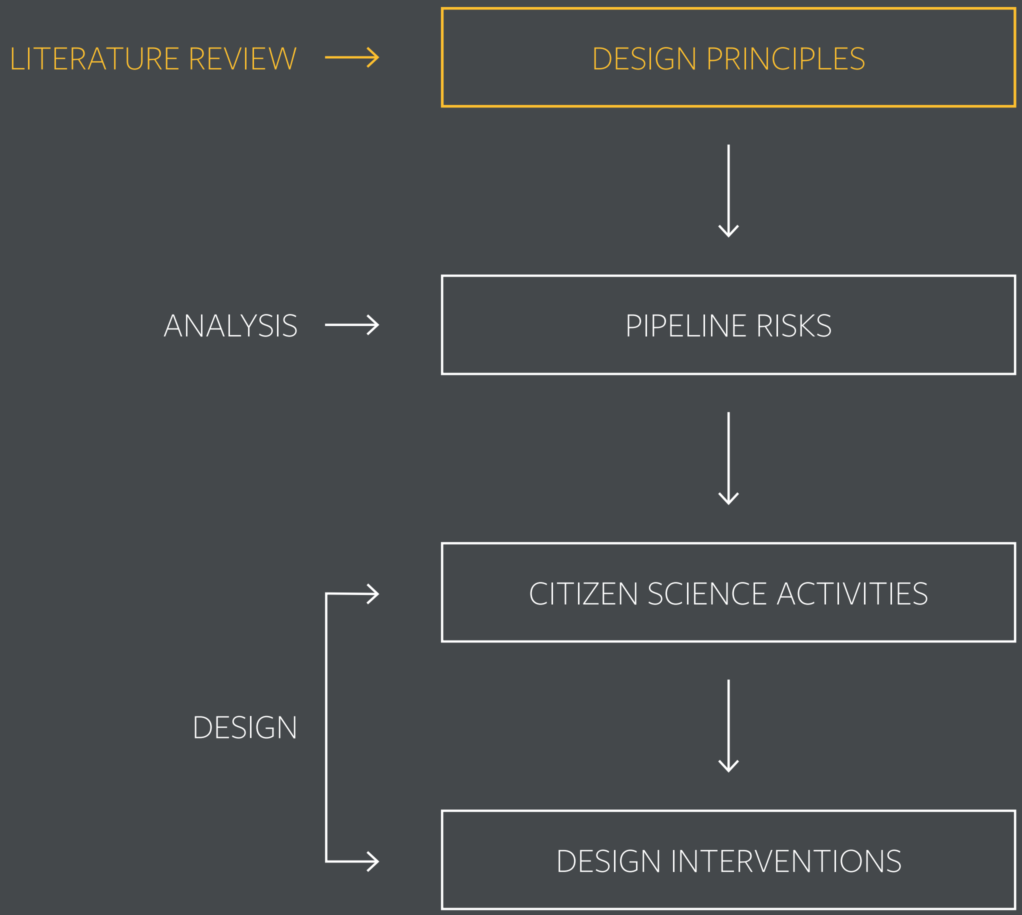
3 Citizen Science: Lessons + Potentials

In this chapter I determine design principles to frame landscape-based analyses and design responses along the Trans Mountain pipelines, based on understandings of citizen science practices. The relationship between design and citizen science has not been explored at length in academic scholarship, and so I chose to focus on lessons within the greater body of citizen science literature, with the intention of applying those lessons to design work that engages citizen science practices. As such, I review the history of citizen science, outcomes of various citizen science projects, and latent potentials in citizen science practices, with an emphasis on community-oriented, bottom-up practices. Four primary design principles emerge from these analyses, which fit into a process-based framework for the project (Figure 2). In this framework, these design principles provide the socioecological framing for determining risks (Chapters 4 and 5). Together, design principles and defined risks inform imagined citizen activities and design proposals (in Chapter 6).

Figure 2. Project framework

This chapter identifies design principles from a review of citizen science research.



An Introduction: The Emergence of Citizen Science in the U.S. as Top-Down and Bottom-Up Practices

Citizen science, as situated in this project, is an inherently political practice centered on pipelines, which are leaky infrastructures where industry heavily influences the regulatory bodies responsible for setting thresholds of "acceptable risk" associated with them. Furthermore, regulators do not solicit input from affected communities when defining those thresholds. This project imagines citizen scientists that respond to and challenge this milieu through monitoring and reporting of data. To understand where this type of citizen science—one of political action and community activism—fits within a broader field, it is therefore helpful to first examine the emergence of citizen science in North America, with a focus on the United States.

Citizen science is typically defined as any activities where members of the public voluntarily participate in the scientific process, with a typical focus on Western scientific methods.[1] To contextualize citizen science within this common notion of the term, I looked to the United States and the rise of community-based environmental health movements during the nineteenth century industrial revolution, which developed as a response to unhealthy conditions within urban built environments. In particular, social activists like Jane Addams and Alice Hamilton, who founded and lived at Chicago's Hull House, encouraged residents to record and disseminate experiences of health conditions among the greater public, including policy makers. Moving into the early twentieth century, community health centers began establishing block committees, which allowed community members to approach health professionals about issues arising in their neighborhoods. This was a critical step that set the stage for the 1965 establishment of Medicaid, Medicare, and associated community-based preventative health policies.[2]

In the 1960s, along with the publishing of Rachel Carson's *Silent Spring*, came skepticism about whether scientists were working in the public's best interests. As awareness of environmental disasters gained prominence, so did mistrust of scientists: many of these events became associated with incorrect professional assessments that had been valued over the intuition and experience of community members, mistakes that had left a trail of catastrophic health consequences. A notable example is that of sheep farmers in Cumbria, a county in northwestern England. There, in the years immediately following the Chernobyl nuclear disaster of 1986, farmers were told by scientists that the Chernobyl fallout was to blame for radioactive contamination of their grazing lands. In reality, the scientists had inadequately sampled the area's soils. As the farmers proved, the toxicity had in fact been caused by a nearby nuclear fuel reprocessing plant.[3] In cases like this, scientists who do not work closely with communities may engender mistrust, and communities may feel inspired to take matters into their own hands.

While the roots of citizen science extend back many decades, it was not until the 1990s that two academic scholars, Rick Bonney and Alan Irwin, separately coined the term "citizen science." The first, Rick Bonney, who studies public engagement in science research at the Cornell Lab of Ornithology, is most known for examining how professional scientists can successfully engage the public to participate in science research processes, which represents the top-down approach within the top-down (researcher-led) to bottom-up (participant-led) continuum of citizen science projects, as depicted in Figure 3. In top-down citizen science projects, participants often contribute data to research projects whose questions are best answered by crowdsourcing on a large scale. These top-down projects tend to primarily attract volunteers with preexisting interest in the topics being studied, though that varies based on recruitment; some studies, for example, recruit from K-12 classrooms.[4]

Most projects examined within this field of top-down citizen science have been oriented toward the academic field of conservation biology, and vary widely in their scopes, including monitoring of bird nest boxes, counting of monarch butterfly larvae, surveying and cataloging of invasive species, and precipitation monitoring.[5,6] In recent years, participation in these studies has greatly expanded with the creation of online platforms, including Merlin Bird ID (from the Cornell Lab of Ornithology), Zooniverse.org (created by researchers across several universities), and iNaturalist (a joint initiative by the California Academy of Sciences and the National Geographic Society). The research contributions across these projects are significant: a 2015 study evaluating the contributions of volunteers to Zooniverse.org projects measured $1.5 million worth of analysis in just 180 days across seven projects.[7] In the same year, another study estimated that, worldwide, 1.3 million volunteers contributed $2.5 billion worth of work to biodiversity-related studies.[8]

Bottom-up citizen science, in contrast, has its roots in questions of environmental justice, and how communities might equip themselves with research tools to address locally relevant environmental concerns, often with a direct link to human public health. This is the citizen science studied by Alan Irwin, the British science and technology policy scholar who also coined the term "citizen science." In his work, Irwin writes about the impact that citizens can have in democratizing research practices and influencing science research agendas.[9] This scholarship has spotlighted the impacts citizen scientists can make on community knowledge production and politics.

As this chapter explores, bottom-up citizen science is potentially impactful not just because it provides a means for communities to police existing environmental regulations, but also because it can go one step further: it allows citizens to make claims about how toxic exposure is defined in the first place. For example, in a mapping-based project called Air Watch: Bay Area, California Bay Area residents living near oil refineries expose issues with the way air pollution is defined and evaluated by regulators. Currently, laws account for average, chronic exposures, whereas residents experience toxic air pollution through transient, pronounced, sub-acute bursts of pollution. By validating and highlighting alignment of detected pollution and reports of embodied experience, citizens are doing what science and technology studies (STS) scholar Gwen Ottinger terms "undone science," where relevant

Figure 3. Types of citizen science projects

Community members can initiate and lead research projects (bottom-up), co-lead projects that are initiated by experts (intermediate), or contribute data to researcher-led projects (top-down).

Louisiana Bucket Brigade (LABB):
Initiated and led by community members

Alliance for Aquatic Resource Monitoring (ALLARM):
University program supporting local groups

Merlin Bird ID:
University and researcher led (Cornell University)

BOTTOM-UP (CITIZEN-LED)

TOP-DOWN (RESEARCHER-LED)

Public Lab:
Open source online community, professional scientists often take leadership roles

Hudson River Eels Project (EELS): Government agency-led, leadership roles for participants

Images (clockwise from top left): Marc Pagani, Holden Sparacino, Mike Fernandez, Teatown, Public Lab analytical frameworks have not previously been applied to existing data.[10] In contexts like this, bottom-up citizen science has the potential to fundamentally alter regulation and policy.

This project, and therefore this chapter, is focused on the bottom-up end of the citizen science continuum, with lessons relating to participant motivations, social networking, methods of citizen science practices, and potentials for making data more publicly legible. As diagrammed in Figure 3, within the bottom-up end of the spectrum, projects range from completely citizen-led and citizen-initiated projects that may consult with local scientists, to projects that partner more closely with outside institutions like universities or environmental nonprofits.

Bottom-Up Citizen Science: Local Expertise and Democratization of Monitoring

Over time, scholars have proposed a number of terms and frameworks for bottom-up citizen science. One of these, "Participatory Action Research" (PAR), refers to bottom-up citizen science as approached through a lens of community empowerment. In PAR, participants are involved in each step of the research process, with an emphasis on deliberate co-learning and collaboration. Proponents of PAR argue that this approach to citizen science contributes to resilient ecosystems and communities because it pays "explicit attention to power imbalances between scientists and non-scientists."[11] In doing so, it also focuses on issues of community identity, membership, roles of researchers, accountability, and sustaining the research, issues that persist across many projects.[12]

Since the emergence of PAR, various scholars have turned their attention to the ways science practices might intentionally disrupt dominant notions of class, gender, and politics, in the process democratizing access to scientific inquiry and knowledge production. These include Sara Ann Wylie and Max Liboiron, who both study at the intersection of anthropology and STS. Both approach citizen science through anti-colonial, feminist lenses by asking how citizen science can be a highly accessible process that documents physical realities and also challenges the larger hegemonic systems that make way for environmental degradation in the first place. They term this version of citizen science "civic science," which "empowers people to question the state of things rather than simply serving the state," bringing "the infrastructures responsible for sustaining collective human lives…into a state of public contemplation and accountability."[13] Much of their work confronts "slow" disaster zones where environmental harm to human and non-human communities is chronic, invisible, and slow-moving.[14] In the case of oil pipelines, while exposure to toxic chemicals may not be widespread or constant, the lead-up to spills is in some ways a "slow disaster" of its own: it is via a chronic lack of transparent monitoring processes that large spills

Right: Nature's Notebook is one of many researcher-led, conservation-based programs that allow community members to contribute to large biological survey data collection efforts. (Image: Sara N. Schaffer)

and slow leaks occur, as I discuss in Chapter 4.

Citizen scientist groups that have confronted these issues of toxic exposure have largely had grassroots origins and are typically sustained by community members. These groups have been varied in the issues they address (including exposure to lead paint, chemicals in fabrics, and others) but have predominantly studied impacts fossil fuel industries.[15] Notable cases include the groups of citizen scientists that have organized along Louisiana's petrochemical industry corridor that is known as "cancer alley." There, activists, including environmentalist Willie Fontenot and local academics like Florence Robinson of Southern University in Baton Rouge, have helped coordinated citizen science efforts since the 1980s, and have popularized tools of community activism like health maps.[16] The citizen scientists there have also fundamentally reshaped standard regulatory practices for assessing air quality through deployment of inexpensive but reliable vacuum canisters ("buckets") to sample ambient air. The leadership of these groups, including the Louisiana Bucket Brigade (LABB), has led to EPA enforcements and installation of air monitoring sensors along facility fencelines—and a resulting reduction in air pollution in some areas.[17] Today, citizen-led "bucket brigades" are found widely. Like the LABB, others have also successfully policed industrial air pollution, including a group in Tonawanda, New York, whose persistent work led to the closing down of a non-compliant coke plant.[18] Together, these groups serve as testament to the power of citizen science when motivated community participants are the leaders.

In contrast to purely citizen-led, bottom-up models, there are many projects that fall closer to the middle of the citizen science spectrum, where community members may partner with larger nonprofits, universities, or foundations that provide scientific expertise or funding. One such project that has endured is the Alliance for Aquatic Resource Monitoring (ALLARM), a Dickinson College-based initiative that has provided technical assistance for watershed health monitoring throughout Pennsylvania since 1986. One of the successes of ALLARM has been its responsiveness to community concerns, whereby communities are viewed as the "experts" on local issues and have full ownership over how data is used and shared. As a result, ALLARM has shifted in the type of technical expertise it provides: while it began with an orientation toward acid rain issues, it now also supports monitoring the effects of shale gas fracking.[19] The continued success of the ALLARM program therefore may be a product of its "co-expertise" approach, whereby participants retain agency to define relevant issues.[20]

As the cases discussed here illustrate, the most sustained community-based citizen science projects center on highly local interests and concerns of community members. This is unsurprising, and it is also substantiated by survey results, such as those documented by Phillips et al. Among participants within

Left: Public Lab provides open-source resources for balloon mapping, which allow citizen scientists to capture high resolution aerial images in areas of potential environmental concern, including within no-fly zones. (Image: Public Lab)

Different strengths accompany different organizational structures:

Top Left: Local groups seek technical assistance in stream monitoring from the Dickinson College-based ALLARM program. (Image: ALLARM)

Top Right: "Bucket" air quality sampling has its roots in community activism, including communities like Citizen Science Community Resources in Tonawanda, NY. (Image: Citizen Science Community Resources)

Bottom Left: Annual Public Lab "Barnraisings" mirror its online community in their democratic conference approach. Participants set agendas together each day. (Image: Public Lab) "co-created" projects like LABB and ALLARM, this study found that "environmental concerns" and "community concerns" are the two most often cited reasons for continued involvement. Participants furthermore often described using project data for their own personal ends.[21] As it relates to the potential for design work within citizen science, these cases and accompanying survey responses affirm the importance of supporting adaptable solutions that can respond to each community's most pronounced concerns.

Therefore,

Design Principle 1: Design for adaptability and decentralization.

The Importance of Social Networking and Issues of Diversity, Equity, and Inclusion

Many scholars studying citizen science have long assumed that what motivates participants to begin and continue to volunteer is the desire to gain new knowledge and skills, and to contribute to science for science's sake. However, in most projects, and especially those related to environmental justice issues, participants cite social factors more often than knowledge-seeking as primary motivations for their involvement. This includes a desire to be part of a community of like-minded individuals. In the aforementioned Phillips et al. study, two thirds of participants across a variety of citizen science projects described "the importance of using social interactions to share knowledge and enhance their engagement in the project." In that same study, 90% of interviewees described using mutual resources for sharing knowledge, with many citing the importance of having developed a sense of community with other volunteers.[22]

While resource sharing has been observed extensively within citizen science, designing citizen science projects around effective social networking is relatively underexplored. The potential for internet-based social networks to encourage collective action within the context of citizen science is something that Triezenberg et al. explored by examining theories of internet social networks as applied to citizen science. In their writings, the group highlighted the potentials of internet-based social networks, but warned against "homophily," defined as a social interaction pattern, "where individuals have higher rates of contact with people who have similar characteristics than with people who have dissimilar characteristics." This certainly applies to citizen science, where social networks can enhance face-to-face relationships, but the authors warned that "coordinators should be careful not to reinforce homophilous networks in a way that creates a divide between those who engage in citizen science and those who do not."[23] It is worth noting that social interaction is already baked into the design of many internet-based science projects, but these tend to connect participants transiently, as opposed to being designed with the explicit goal of building online social communities.

The issue of how to invite a diverse and representative cohort of participants and avoid homophily is one worth exploring, because many projects are notably lacking in these regards. This poses a fundamental challenge around the democratization of science: if citizen science is only perceived as being accessible by few, predominantly college-educated community members, the designs of citizen science studies are unlikely to adequately reflect the concerns of those most vulnerable to chronic toxic exposure. Most projects tend to attract participants with preexisting interest in and, often, experience with the topic being studied.[24] In situations in which concerned community members initiate study, this can mean better participation by affected community members, such as in groups that research local pollution exposure. These include LABB and the Williamsburg Around the Bridge Block Association, in which Brooklyn residents in the 1990s successfully challenged lead paint exposure assessments.[25] In contrast, when universities initiate studies, even if the research is directed at environmental justice issues, they often attract a less diverse cohort of participants. For example, a recent project by Carnegie Mellon's CREATE Lab tested an app-based system for reporting industrial pollution odors in Pittsburgh. Despite reaching out to local advocacy groups, this study reported that the participant cohort was not representative of the greater population; all but one participant had attained Bachelor's or graduate-level degrees.[26] In the case of ALLARM, which was discussed earlier in this chapter, participants have also primarily been of retirement age or are predominantly college educated, and may already be involved with local watershed groups.[27] Yet, the scope of a project like ALLARM nevertheless highlights potential for addressing environmental concerns: according to ALLARM's website in spring 2020, they have trained over 2,000 volunteers in Pennsylvania, New York, and West Virginia to detect potential signs of fracking-related pollution.[28] While the issues of representation within citizen projects is difficult to solve, these cases highlight the importance of long-term trust-building between communities and the institutions that may provide technical and financial support, like universities.

The importance of building a diverse, equitable, and inclusive social network is of paramount importance in conceiving of a pipeline-based citizen science monitoring network. Beyond the immediate benefits of social cohesion, a strong social network creates more favorable conditions for resource sharing and consensus-building, crucial qualities for linking citizen science efforts across the many communities who live along a pipeline. Secondly, it creates more favorable conditions for community response to a spill event. As University of Washington landscape architecture scholar Jeff Hou notes in his work studying disaster resilience, it is the communities who are most cohesive and well organized prior to disaster events that are most likely to respond with creative, spontaneous, and self-organized design solutions.[29]

Therefore,

Design Principle 2: Design for equitable network building and shared agency.

Right: In the 1990s, the Louisiana Bucket Brigade introduced the "bucket" ambient air sampler, which is now widespread as a tool for contesting industry claims about air quality. (Image: LABB)


LOUISIANA
BUCKET
BRIGADE

Who Does Science? Exploring Accessibility in Materials and Methods

Beyond the question of what most motivates participants to get involved, a persistent issue for citizen science projects is the cost and accessibility of data collection and analysis. While in some cases there are not direct replacements for complex and expensive chemical or biological analyses, many have worked in recent years to develop accessible and low-cost citizen science tools that are reliable and scientifically valid.

Max Liboiron, whose disruptive, feminist, anti-colonial approach to citizen science I discussed earlier in this chapter, is one scholar who pushes ideas about what it means for science practices to be truly accessible. Liboiron's academic marine pollution research group, Civic Laboratory for Environmental Action Research (CLEAR), which is based in Memorial University in Newfoundland, challenges hierarchical structures within academic research, including in the development of low-cost, open-source data collection tools. Most notably, this includes a surface trawl for capturing marine microplastics called "BabyLegs," a $12 device made from baby tights and plastic bottles. BabyLegs was created with a primary goal of accessibility, including ease of use and widespread availability of cheap materials.[30] BabyLegs is now used by citizen scientists around North America, providing a prime example of a scientifically valid, replicable, and low-cost means of collecting data.

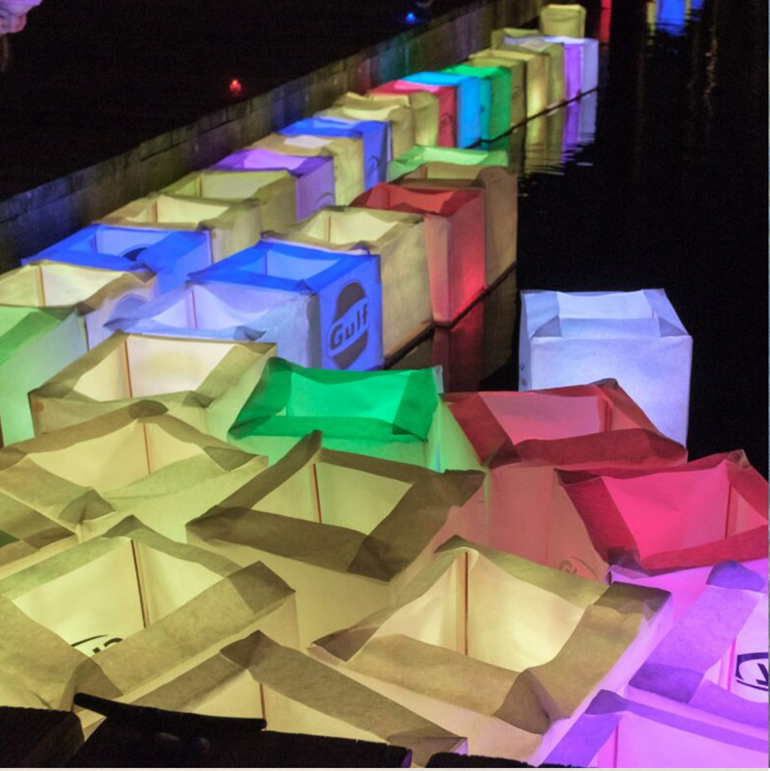
Other organizations and projects have likewise aimed to provide open-source tools specific to citizen science research questions. Most notably, Public Lab, a (mostly) web-based open-source research and development community, provides tools, methods, and databases for addressing a number of environmental topics, with the expressed goal of changing how people conceptualize of citizen science not just in environmental terms, but also in social and political terms.[31] The group was founded in response to the 2010 BP Deepwater Horizon oil spill when a no-fly order inspired citizen balloon mapping of damaged coastline. The Public Lab community has since expanded greatly and now engages citizen scientists across the U.S. who study an array of environmental issues.[31]

As of spring 2020, members of the Public Lab community are actively working to develop affordable, open-source techniques for detecting oil contamination in water and soil. This includes a spectroscopy kit for identifying presence of different crude oils, made from cardboard and a $3 blue/violet laser pen.[32] Further development of affordable techniques like this are critical to oil pollution monitoring, as most citizen science projects cannot financially afford regular testing via mainstream lab- or field-based techniques, which can cost upwards of several hundred dollars per sample.[33]

Accessibility is an issue not just for data collection but also for data analysis, as Ottinger highlighted in a 2017 paper that discussed how participants may disengage when they find traditional methods of analysis confusing or uninteresting.[34] One case that Ottinger highlights is a Carnegie Mellon CREATE Lab project called Shenango Channel, a collaboration with Allegheny County Clean Air Act Now (ACCAN), a grassroots citizen group founded as a response to a

Top: BabyLegs is a low-cost trawl that provides communities with a technically valid means of quantifying marine microplastics pollution. (Image: Meopar)

Left: BabyLegs inventor Dr. Max Liboiron demonstrates sample processing at a workshop in New York City. (Image: Cooper Hewitt)



Data and citizen science activity can become more legible through "witnessing" and "performing":

Top Left: By marking illegal industrial releases with "data lanterns" in Chelsea Creek (Boston), community members generated dialogue about industrial pollution issues. (Image: David Mussina)

Top Right: Participants in the Shenango Channel study engaged with coal processing-related air pollution by creating and exchanging GIFs. (Image: shenangochannel.org)

Bottom Left: "Hoosic Expeditions," by David Buckley Borden, explores use of landscape-based installations to increase awareness about changing river ecologies. (Image: David Buckley Borden) now shuttered coal processing plant in the Pittsburgh area. In this project, researchers found that community members who had been tasked with identifying instances of fugitive emissions only became enthusiastic after being provided the opportunity to make sense of data through production of animated GIFs, which could then be shared with other participants and friends.[35,36] This case, in tandem with the examples of Public Lab, "BabyLegs," and bucket air sampling, illustrate the potential to increase accessibility and resulting impacts of citizen science monitoring through low-cost, novel methods.

Therefore,

Design Principle 3: Design for accessible and low-cost materials and methods.

Performing and Witnessing Data

While unconventional methods of data analysis have been explored within internet-based citizen science projects, physical interventions have rarely been the focus for reporting data and generating greater accountability around pollution. This is therefore an underexplored topic, and one designers might more actively engage. When data is communicated through physical interventions in unexpected ways, it can be impactful because, according to Wylie, it can then be more "performative" and "descriptive of exposure evidence."[37] Wylie's research group at Northeastern University has explored this in several ways, ranging from use of sensors and dyes to create visibility of thermal plumes in the Charles River to floating of cheaply-produced colored lanterns in Chelsea Creek (in Boston) to create more awareness about instances of pollution discharges that exceed EPA limits. In the latter case, the nighttime "data lanterns" performance stimulated discussion amongst community members, including how the community might increase oversight of the responsible industrial actors.[38] It is therefore important to consider performance as a potentially impactful lens through which to tell stories of data, in the process energizing citizen science participants and engaging other community members. In this work, landscape architects might contribute their skills in place-making and systems-based thinking to design novel data "performances."

The idea of physically and socially engaging visualizations of environmental data is one that artists and landscape architects have previously explored outside the realm of citizen science research. One such artist is David Buckley Borden, whose installations and speculative drawings explore environmental awareness and action, often employing humor as a means of engagement. For example, in the speculative project "Hoosic Expeditions," Buckley Borden imagines art installations along the Hoosic River in North Adams, Massachusetts, that use play and color to express narratives of a changing river ecology and to generate discussion about modern flood control methods. Some of Buckley Borden's other projects draw attention to the importance of valuing non-human species, like the "Hemlock Hospice Trail," a sculpture-based project in the Harvard Forest that used bright colors and iconographic motifs to generate awareness of the effects of the hemlock woody adelgid on Eastern Hemlock trees.[39]

The cases discussed in this section highlight the potential for landscape architects to work as activists who encourage performance and witnessing of citizen science data. The landscape-based interventions that work toward these ends might draw inspiration from tactical urbanism, with an emphasis on ephemerality. They might also be more permanent in nature, allowing for place-making through continual building of data narratives.

Therefore,

Design Principle 4: Design for "witnessing" and "performance" of citizen science activities and data.

The four design principles from this chapter are summarized in Figure 4. These principles suggest that landscape architects practicing citizen science might contribute their skills around systems thinking to understand connections within the citizen science network. They also suggest that landscape architects might contribute physical and spatial designs that speak to local concerns, in the process increasing access to and legibility of citizen science practices and data.

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Figure 4. Design principles

Four primary design principles emerged from a review of citizen science literature. Together, these frame subsequent analysis and design approaches.

ADAPTABILITY / DECENTRALIZATION

SHARED AGENCY / NETWORK BUILDING

ACCESSIBLE / LOW COST

PERFORMING / WITNESSING

Images (top to bottom): Marc Pagani, Public Lab, Max Liboiron, David Mussina

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Right: On Stó:lō ancestral lands in Hope, B.C., the TMP crosses the Coquihalla River just upstream of its confluence with the Fraser River.

4 Framing the Trans Mountain Pipelines: Canadian Extraction Politics, Toxic Legacies, and Toxic Risks

The Trans Mountain Pipeline (TMP) does not exist in isolation. It is part of a larger spatial network of pipelines and a larger history of oil extraction and transport in Canada. In this chapter, to understand the context-specific risks I discuss in the following chapter (Chapter 5), I first explore the contextual frames for colonial resource politics and pipeline oil spill risk that have put the Trans Mountain pipeline system front and center in the Canadian consciousness. In the first section of the chapter, I place the Trans Mountain pipelines within the larger context of the Alberta tar sands. In the second, I introduce readers to the Trans Mountain Expansion (TMX) pipeline project, which will twin the existing TMP. I then summarize controversies and perspectives regarding Indigenous consultation in pipeline projects, including the TMX pipeline. I devote the last two sections to understanding spill risks, existing monitoring activities, and toxicities associated with spills. Together, these sections establish fundamental arguments for community-based citizen science monitoring of the Trans Mountain pipelines.

Extracting Albertan Earth: Economic Resource First, Land Resource Second

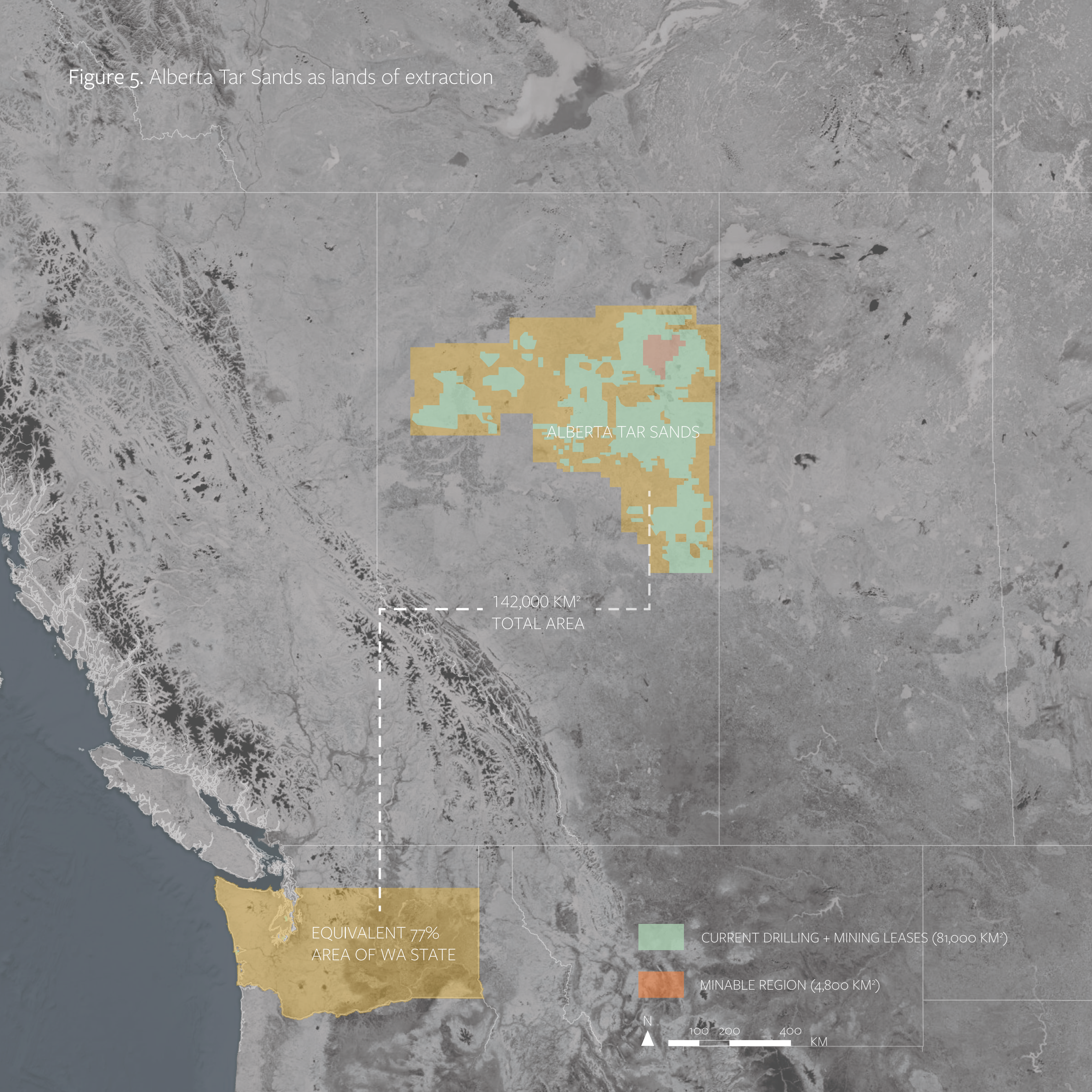
The TMP does not carry just any oil product. It carries northern Albertan bitumen, a thick, gummy oil—so thick, in fact, that it needs to be diluted with lighter oil products to be pumped through a pipeline. These properties of bitumen explain the first half of the colloquial term "tar sands," whereby "sands" refer to the matrix of sand, clays, and water from which the oil has to be separated via a series of chemical and physical processes.[1,2] This mixture of oil and surrounding inorganic materials is extracted from the lands of the Athabasca region of Alberta by either by scraping away the entire forest floor to mine it (when it is found at less than 75 meters depth) or by injecting massive amounts of steam deep into the ground to force the bitumen up to the surface. The energy footprint of these extractive processes is huge, and it leaves behind toxic tailing ponds at massive scales.[3,4] The leakiness of these extraction activities, including its byproducts, has had profound effects on surrounding waterways, ecosystems, and the health of downstream human communities.[5,6]

From time immemorial, the region of the tar sands, including its boreal forests, muskeg (peat bogs), and rivers, has been home to the Dene, Cree and Métis Indigenous peoples. Along this region's river banks, these peoples have long used the bitumen that seeped from its soils as a waterproofing substance. It was only in the 18th and 19th centuries, upon the arrival of colonizing fur trappers, that the bitumen was redefined for its potential value as an energy commodity. It is at this point that colonists accelerated their use of writing and mapping to erase Indigenous human communities and their claims to land: in 1899, British nationalist fur trader Charles Mair stated that the region was "a *terra incognita*—rude and dangerous."[7]

Today, the Athabasca region continues to be viewed by the Canadian government and fossil fuel industry as a place of resource (oil) and overburden (any barrier to the oil), not a place of dynamic lands and human communities. While extraction of bitumen was for many years considered too inefficient to support a large scale of operations, that outlook has shifted in the last two decades, on account of economic factors and technological advances.[8] As mapped in Figure 5, the current scale of oil exploration and extraction is difficult to fathom, with 142,000 square kilometers of land area designated as oil reserve—the equivalent of roughly 77% of Washington State's land area. This corresponds to at least 173 billion barrels of extractable oil waiting to be pulled out of the ground, with current drilling and mining leases existing for an area of 81,000 square kilometers (approximately the area of the state of Maine). Of this, 4,800 square kilometers (approximately the area of the state of Delaware) has bituminous sands that lie at depths shallow enough to make massive scales of open pit mining possible.[9]

Right: Open pit mining for bitumen requires destruction of large areas of boreal forest and muskeg (peat bog) in the Alberta tar sands region. (Image: Alex Maclean)

Figure 5. Alberta Tar Sands as lands of extraction



Projected levels of extraction in the tar sands have dire implications for Canada's emissions commitments under the UN Paris Climate Accord. A study by Hughes in 2016 demonstrated that, based on conservative estimates, the entire Canadian economy outside of oil and gas will have to contract its emissions by 52% from 2014 levels by 2030 for the country to meet its goals, an unattainable figure.[10] In the longer term, if all known oil reserves in the tar sands are extracted and burned, this alone will contribute an additional 0.4 degrees Celsius to global temperature increases.[11] With a goal of keeping total overall global warming to a maximum of 1.5 degrees Celsius (above pre-industrial averages), that scale is staggering.

Such a rapid increase in tar sands oil production has, not surprisingly, created a bottleneck for transporting oil from the site of extraction. The result in the last decade has been the development of plans for numerous new pipelines, as shown in Figure 6, including the TMX pipeline that is the focus of this project, as well as the long controversial Keystone XL pipeline. Regarding these new pipeline projects, the aforementioned 2016 study by Hughes shows that, as illustrated in Figure 7, if Canada stands a chance to meet its Paris Accord goals, assuming a cap on tar sands-associated carbon dioxide emissions at 100 megatons per year, the region cannot increase its current pipeline capacity.[12] Despite this, the Canadian government's stance has been to double down on the perceived economic potential of building new pipelines. At a 2017 energy conference in Texas, Canada's Prime Minister Justin Trudeau boldly proclaimed, "No country would find 173 billion barrels of oil in the ground and just leave

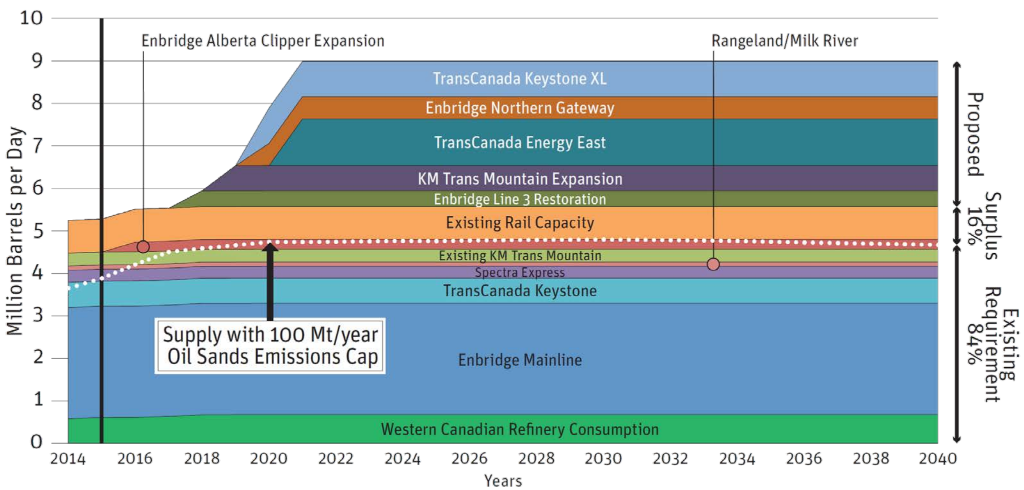


Figure 7. Under a 100 Mt/year emissions cap for the Alberta tar sands, no new pipelines, including the future TMX pipeline, can be in operation. From Hughes (2016).

them there."[13] Then, in spring 2018, Canada's federal government purchased the TMX pipeline project, a rare foray into crude oil pipeline ownership by a Canadian or United States government. Trudeau, who also oversaw Canada's signing of the Paris Accord, has claimed that the country can offset pipeline-associated emissions by directing profits toward the country's transition to renewable energy, a fanciful claim lacking evidence to support its feasibility.

Trudeau's characterization of the tar sands as a cornerstone of Canadian economic growth represents an entrenched view by a colonial government and fossil fuel industry who see land firstly as economic store, disembodying non-human communities and dehumanizing Indigenous peoples. These attitudes are inherited from a long history of colonial resource politics, and form the backdrop against which petrochemical companies also disembody pipelines, projecting sterilized images of sustainable practices, safe transport, and ample monitoring.[14]

Two Pipelines, Two Routes, Sensitive Diversions

The TMX is a second pipeline, a twinning of the existing, 1,150 kilometer TMP, which since 1953 has transported oil products between Edmonton and a marine terminal in Burnaby, a part of Metro Vancouver within the ancestral lands of the Tsleil-Waututh peoples. While construction has just begun on the TMX in recent months (early 2020), the project has been hotly debated since its initial proposal in 2013 due to issues related to Indigenous consultation, tar sands expansion, climate change, and increased risks of spills.

If completed, the Trans Mountain Expansion line will increase climate change and spill risks just based on the increase in volume of oil transported. It will nearly triple the current maximum capacity of the overall pipeline system from 300,000 barrels per day to 890,000 barrels per day.[15] From an emissions standpoint, this increase represents the equivalent of adding at least 30 million new vehicles to the road.[16] As discussed in the previous section, this also represents a tipping point regarding Canada's Paris Climate Accord goals.

While the climate change implications of the TMX project are great, the primary controversies of the pipeline have revolved around its potential leakiness and the negotiation of its route, especially as it concerns the many Indigenous communities whose lands the pipeline traverses; this particular issue is discussed in depth in the next section of this chapter. As is illustrated in Figure 8, 73% of the proposed pipeline will be trenched and buried next to the existing pipeline. Of the remaining 27%, 16% will expand upon existing linear rights-of-way, like telecommunications lines, while the remaining 11% will require clearing of new rights-of-way.[17] Throughout, the pipeline passes through a highly diverse set of human and non-human communities.

An examination of the diversions of the proposed TMX route from the TMP illuminates several of the major risks that accompany the traversing of a highly complex socioecological landscape. In some cases, the proposed TMX route avoids high landslide and rockslide risk areas of the existing line, like in the Coquihalla

Figure 6. Proposed and existing pipelines carrying Alberta tar sands oil

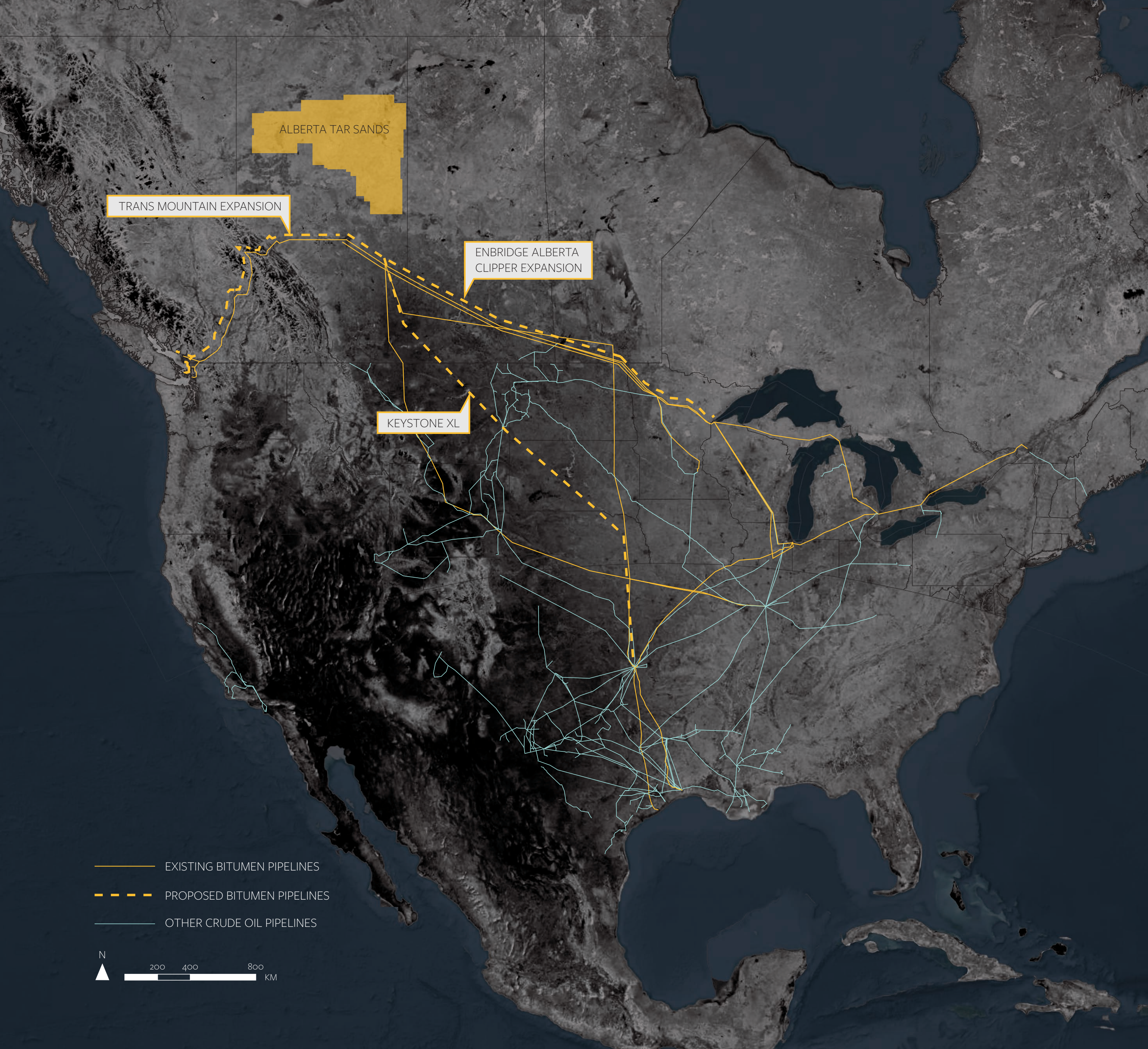
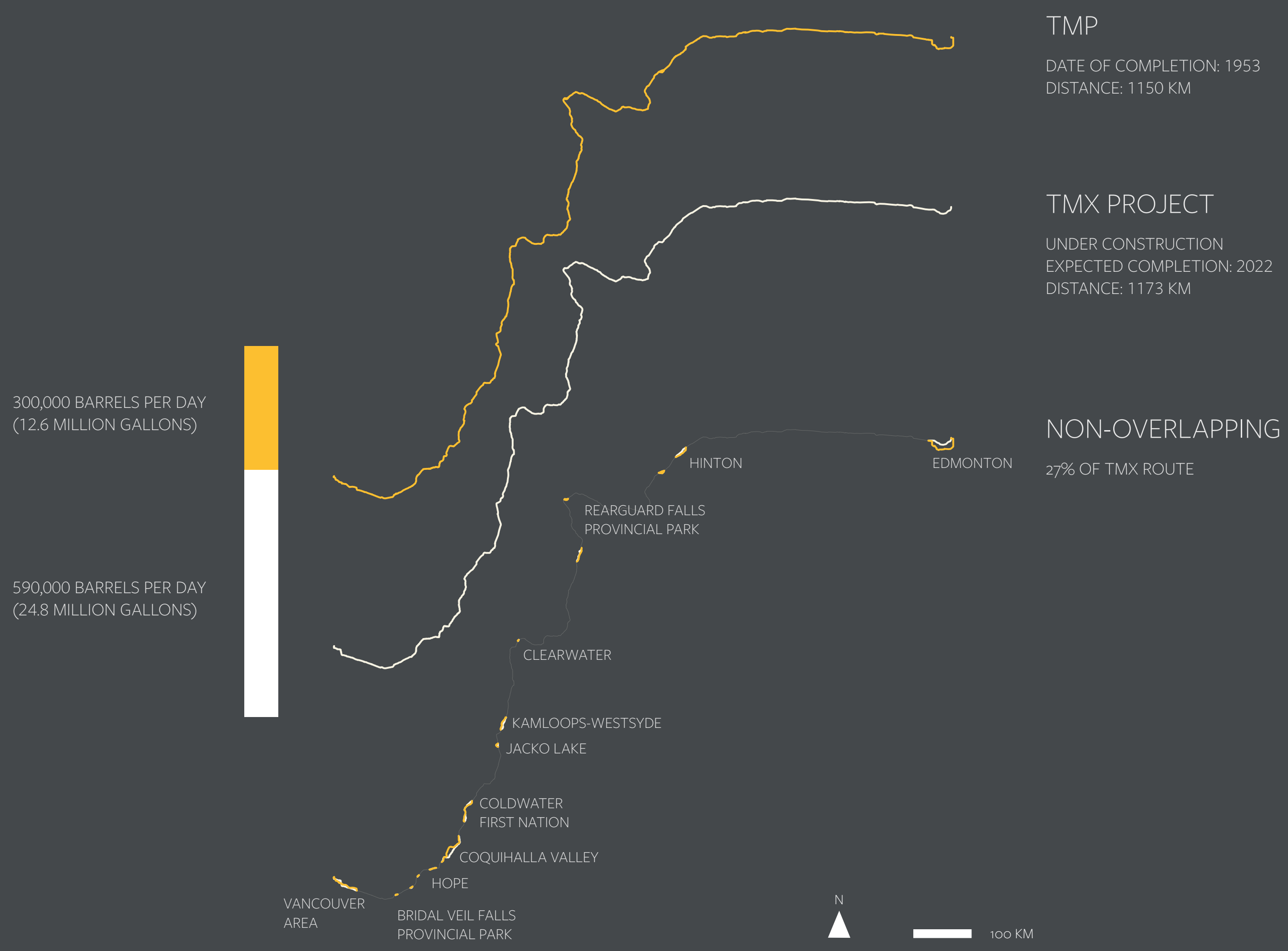


Figure 8. Trans Mountain pipelines, route diversions, and capacities



Construction is underway on the Trans Mountain Expansion Pipeline. (Image: Trans Mountain Corporation)

River valley, where it follows the less exposed (but still rockslide-prone) Coquihalla highway.[18,19] In other places, it avoids provincial parks and other government protected conservation lands. Finally, the TMP also passes through First Nations Reserve lands, such that TMX diversions sometimes skirt just beyond the legal borders of these communities.[20]

Along the TMX pipeline's path, community members are not always unanimous in their opinions about different routing options. One such example is the city of Kamloops. There, the proposed TMX route avoids the Westsyde neighborhood, where the TMP runs under residences, schools, and parks. Instead, the TMX line is slated to be buried within the neighboring Lac Du Bois Grasslands Protected area, a BC Parks conservation area that hosts many of the region's at-risk species, within one of North America's most endangered ecosystem types. Debates around the two routing options have understandably drawn critics on both sides, where opponents of both options fear the impact of construction-related disturbance and the potential impact of future spills.[21,22,23] Similarly, in Metro Vancouver, as the pipeline traverses the municipalities of Surrey, New Westminster, Coquitlam, and Burnaby, the Expansion route once again avoids the primarily residential areas of the existing line. A controversial consequence is that the TMX will instead pass through or near several well-stewarded conservation areas.[24,25]

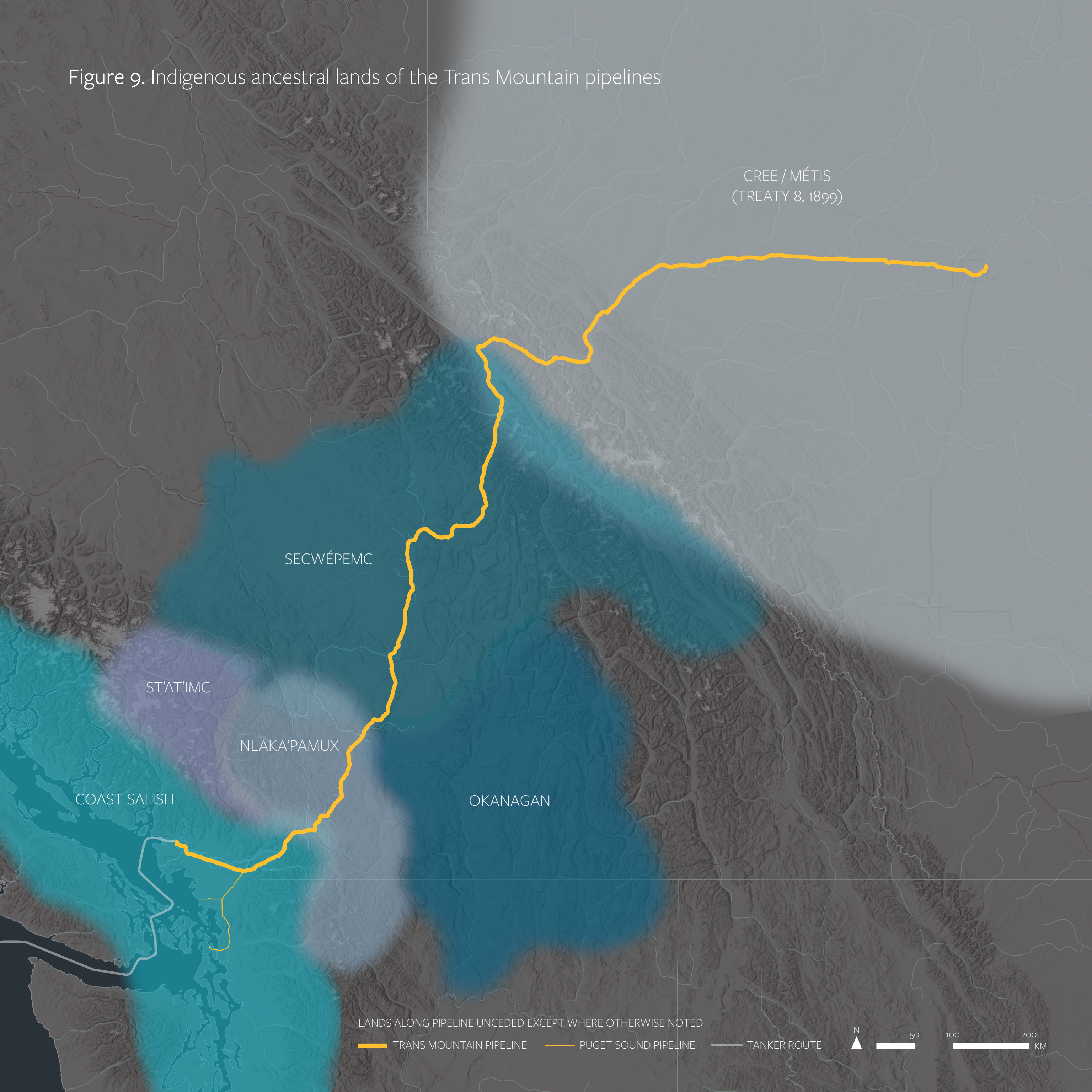
As it concerns the building of a citizen science network along these pipelines, these cases begin to show the highly varied residential and conservation-focused contexts of the pipelines, and demonstrate that concerned stakeholders steward lands across them. As such, citizen science-oriented design work should be adaptable, accommodating these different social and ecological conditions. This calls back to the first design principle from Chapter 3, "design for adaptability and decentralization."

Duplicitous Governance: Issues of Colonial Resource Politics, Indigenous Sovereignty, and Indigenous Consultation

In addition to the locations discussed in the previous section, another place where the two pipeline routes diverge is at the Coldwater Indian Band reserve, several kilometers south of Merritt, B.C. The primary reason for this diversion is the community's concern for the aquifer that has long supplied its drinking water, which is already crossed by the TMP. The TMP alone has had impact enough: there are ongoing issues of leaks, layered upon a failure of the Trans Mountain Corporation to comply with court orders that required a renegotiation of the contract for the pipeline right-of-way; an initial sum of $1,836 in the 1950s is to date the only payment the Coldwater Band has received for the pipeline's operation through their land.[26,27] Meanwhile, the Band is also suing the Trans Mountain Corporation over the proposed TMX route, which skirts just uphill

Right: Chief T. Lee Spahan of the Coldwater Indian Band points down the TMP right-of-way to a pump house that supplies drinking water for the Coldwater community.

Figure 9. Indigenous ancestral lands of the Trans Mountain pipelines



of the reserve boundaries, potentially affecting the aquifer (just as the TMP currently does). Based on Trans Mountain's initial application, the National Energy Board required a full hydrogeological study of the aquifer as a necessary condition for the Expansion project to move forward. When Trans Mountain neglected to conduct that study, the Coldwater Band sued, joining several other First Nations groups that either allege insufficient consultation or contest Trans Mountain's impact assessments.[28,29]

In June 2019, the Canadian government approved the TMX project despite Trans Mountain's failure to meet all of the National Energy Board's stated conditions, and in February 2020, Canada's Federal Court of Appeals struck down lawsuits brought against Trans Mountain by several First Nation groups, including the Coldwater Band. In their ruling, the court determined that Trans Mountain's consultation efforts had been sufficient, including its intentions to conduct necessary impact studies. This ruling allows the TMX project to move forward, potentially even with some of the National Energy Board's conditions left unfulfilled. Trans Mountain still plans to complete its hydrogeological study, and time will tell whether Trans Mountain follows through—but the Coldwater people are now relying on the good faith of Trans Mountain and the National Energy Board's willingness to play enforcer, having failed to impel the courts to more strongly bind Trans Mountain to their commitments.[30] In my own conversations with Chief Lee Spahan in January, he had lost faith in Trans Mountain's willingness to engage the Coldwater community in good faith.[31]

The Federal Court of Appeals ruling reinforces an unfortunate status quo around Indigenous sovereignty, where sufficiency of consultation is achieved based on the Canadian government's standards, with little feedback from Indigenous communities about what constitutes true engagement or, most importantly, consent. This is crucial regarding the future of Indigenous communities and their ancestral lands, especially following several notable uprisings of Indigenous activists calling for greater Indigenous rights. Most notable is "Idle No More," a women-led, feminist Indigenous movement that came to prominence in 2012 when its founders led a series of demonstrations responding to proposed national legislation that would have curtailed Indigenous rights relating to sovereignty and land management. Idle No More sought to reject dominant notions of Indigenous land as resource and to declare Indigenous sovereignty as necessary, where Indigenous communities should not need to sign contracts with resource extraction corporations to survive.[32,33] This movement forced the Canada's government to acknowledge a need to redefine Indigenous consultation. At the 2015 Assembly of First Nations, Prime Minister Justin Trudeau proclaimed that relations between the Canadian government and First Nations would need to be characterized not as "an inconvenience, but rather a sacred obligation…one that respects inherent rights, treaties and jurisdictions."[34]

The problem is that the Canadian government and Indigenous groups do not agree on the meaning of "inherent rights" when treaties have not been signed, which raises important questions about sovereignty. This is especially relevant to the Trans Mountain pipelines. Within British Columbia, Indigenous groups have never signed treaties with the Canadian government, and therefore never ceded their ancestral lands, as mapped in Figure 9 (Note: this style of mapping may not effectively communicate Indigenous conceptions of territory). Some Indigenous activists, like the "Tiny House Warriors," who have set up a blockade of tiny houses along the proposed TMX route within Secwépemc ancestral lands, claim that they have a right to determine colonial government use of their unceded ancestral lands.[35] From their perspective, without consent, it is a violation of Indigenous rights to build a pipeline across that land. The Canadian government and oil industry share a very different perspective, whereby consent is unnecessary; "good faith" consultation, as defined by the Canadian government, is the bar of sufficiency. This paradigm is a symptom of colonial dominance and industry-government coziness, such that there is an active maintenance of low barriers to new pipeline construction.

If the roughly 130 Indigenous groups living along the path of the TMX looked to the Federal Court of Appeals February 2020 ruling as indicative of any shift—or perhaps a lack thereof—in standards around Indigenous consultation, the reality is not encouraging. As of December 2019, 50 of these groups have signed mutual benefit agreements with Trans Mountain, and 10 groups had presented legal challenges. This leaves more than half having not signed any agreement.[36] Contrary to Trudeau's stated goals, it therefore appears that consultation is still but a box to check for Trans Mountain. The type of contact preferred by Trans Mountain in consultation processes supports that notion: according to research by journalists Jillian Kestler-D'Amours and Megan O'Toole, of the 25,000 consultations reported by Trans Mountain between 2015 and 2018, only three percent were conducted in person.

Many of the Indigenous groups most insulted by this process, and especially Vancouver's First Nations groups, have been the visible leaders of pipeline opposition, including in the context of protests.[37] As a result, the most visible issue articulated at protests is the disruption of livelihoods and connection to lands. This challenges notions of pipeline lands as economic corridors, an important foundational context for developing citizen science monitoring of the pipeline. If the pipeline is broadly understood as an integral part of ecosystems and human communities, it stands to reason that it requires active watching.

It is important to note that there is diversity in views among Indigenous groups and the general populations living along the proposed TMX route. While this thesis will not include a review of those many views and the underlying reasons for them, this reinforces the notion that design interventions supporting citizen science need to be adaptable to different contexts and the accompanying sociopolitical circumstances of those places.

Right: Following discovery of a potential TMP leak, test wells have been installed within the Coldwater Indian Band reserve.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Lastly, it is also crucial in any discussion about interactions between the Canadian government and communities living along the Trans Mountain pipelines to discuss the fact that the Canadian government is the current owner of the TMP and TMX projects. This highly unusual instance of public ownership of a large crude oil pipeline system is closely related to issues of Indigenous consultation: the government's spring 2018 purchase of the pipeline system for $4.5 billion from long-time operator Kinder Morgan (a Texas-based multinational corporation) occurred amidst a storm of lawsuits brought forward by Indigenous groups, which at the time had stalled progress of the project.[38] As of spring 2020, despite persistent concerns about Indigenous consultation and rising financial costs (that taxpayers must now bear), construction is currently moving forward, straight through disputed, unceded Indigenous territory.

Against this backdrop of contested landscapes and colonial negligence, it is especially crucial that design for citizen science along the Trans Mountain pipelines might allow for expressions of agency over land, which in some cases may contest the Canadian government's legal definitions of land ownership within pipeline rights-of-way.

Buried Data, Sneaky Leaks, and Managing Public Perceptions

If many of the human communities living along the TMP and TMX understand them as risky ecological infrastructures, it is important to investigate why, what risks are involved, and how that interacts with the pipeline's various socioecological contexts. While the scope of those investigations could be quite broad and far-reaching, including for example, analyses of risks related to habitat disruption, I chose to focus specifically on risks that relate directly to spills. The story of spills in this thesis begins with a discussion of the pipeline's spill history, its leak detection systems, and public engagement programs around spill monitoring. I argue that more oversight is needed regarding both proactive and reacting monitoring.

When it was completed in 1953, the TMP was an engineering feat. Construction crews built the 1,150 kilometer pipeline across a wide array of ecological conditions between Edmonton and Burnaby, crossing both the Rockies and Cascades, navigating steep valleys like that of the Coquihalla River, and passing through Indigenous reserves and other populations centers, as mapped in Figure 10, based on present day population totals (see also Appendix A1, "Predominant Ecosystems of the Trans Mountain pipelines," for a map of the relative distribution of coniferous forest and grasslands along the pipeline). While impressive, the pipeline was not infallible, and it began spilling early on—in fact, on the first day of slated operations. As historian Sean Kheraj documents, the 84 significant reported spills that followed have occurred with an unpredictable frequency and for varied reasons, ranging from human error to natural causes, the latter of which include acute events like landslides and slower causes like corrosion. Human-induced incidents have also varied in their exact causes, including a 2007 spill in which an urban residential neighborhood of Burnaby was

Figure 10. Population centers of the Trans Mountain pipelines

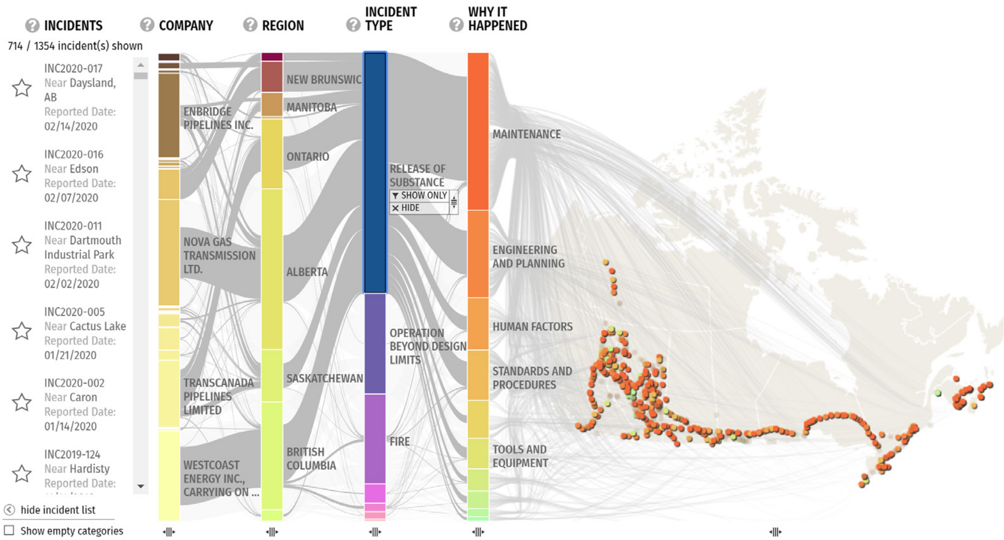


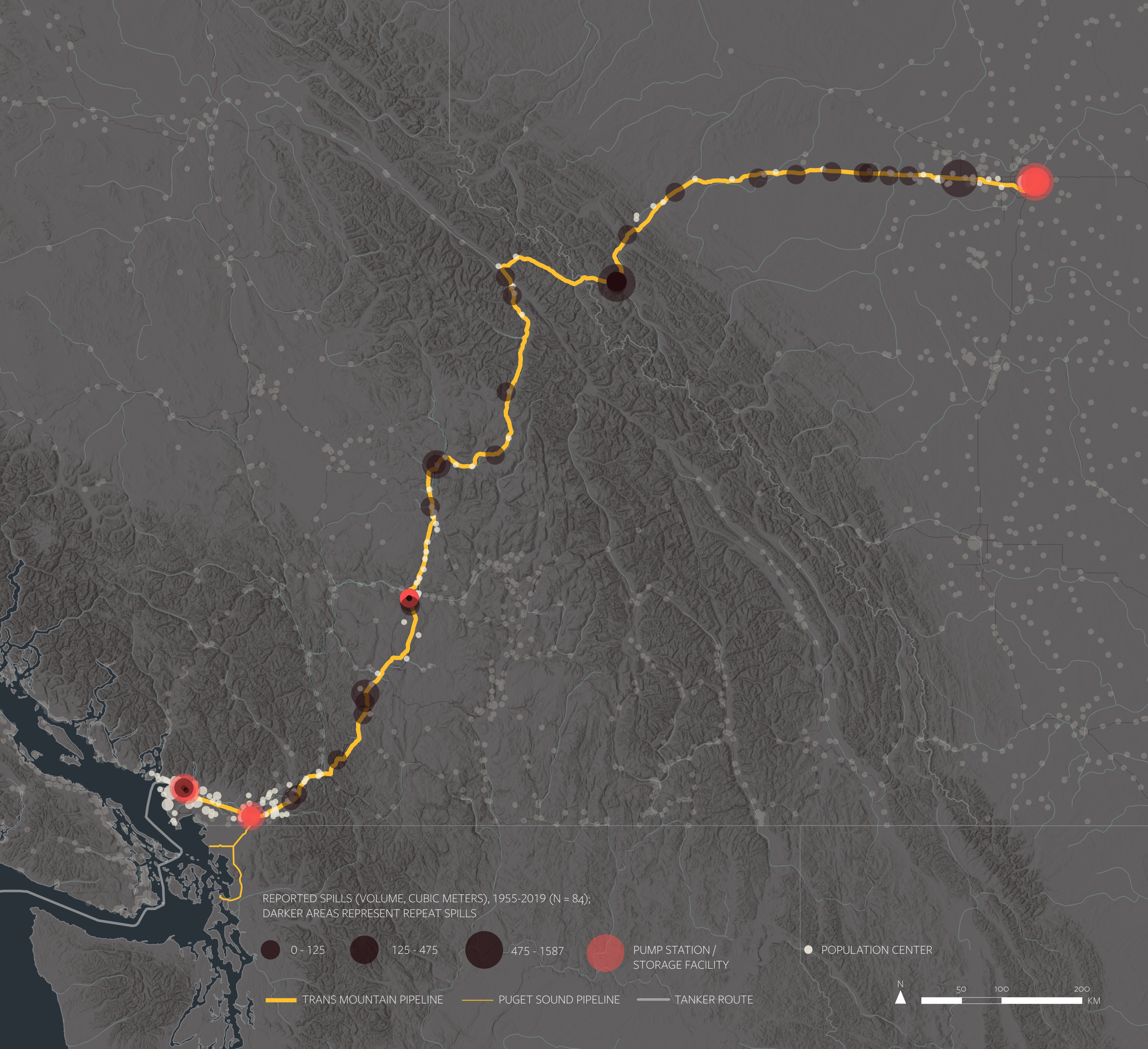
Figure 12. From 2008 to early 2020, the causes of pipeline incidents continued to vary widely across Canada. Data visualization from Canada Energy Regulator.

coated in diluted bitumen after a contractor mistakenly ruptured the TMP while excavating for a new sewer line. As soils shift in the span of 50 years, so does the location of the pipeline, and the maps on which the contractor had relied were no longer accurate.[39] All 84 spills are mapped in Figure 11, including their proximity to population centers and whether they occurred at storage and pump facilities (Note: there are some overlaps in locations where there have been multiple spills). Variation in causes of spills has continued in recent years, both for the TMP and across Canada's entire system of crude oil pipelines, the latter of which is mapped in Figure 12. As of the last decade, operators are required to provide more detailed incident reports, including causes.

While spill reports in Canada now require documentation of cause, it is difficult to find cause-related data pre-2008. This is indicative of a longer history of lax regulation of oil pipelines, whereby Canadian regulatory agencies have required little disclosure of monitoring activity, monitoring data, or spill information.

There are many reasons for this legacy of corporate data sequestration. Among them is the past work of pipeline companies to cultivate a public perception of control and safety through marketing materials. As Kheraj documents, Trans Mountain did not always depict their pipeline as impenetrable, with early company annual reports openly describing and visualizing issues with spills. This changed in the 1950s and 1960s, as spill issues began to accrue, and Trans Mountain subsequently shifted toward depicting harmonious relationships between pipeline and landowners, as well as between pipeline and environment.[40] See Appendix A2, "Trans Mountain Annual Report Images," for several examples.

Figure 11. Reported TMP spills, 1961 - 2019, with population centers



The 2010 Kalamazoo oil spill from an Enbridge pipeline could have been stopped earlier had control room operators not mistakenly interpreted sensor alarms as being caused by benign air bubbles.

Top: The ruptured section of pipe from which approximately one million gallons of diluted bitumen spilled. (Image: National Transportation Safety Board)

Left: Persistence of submerged bitumen, which is adhered to sediments, has impeded cleanup efforts. (Image: Michigan Department of Environmental Quality)

Based on political influence and a carefully managed public image, fossil fuel companies in Canada have been able to ensure that a permissive regulatory atmosphere around pipeline monitoring persists. Canadian regulatory agencies perform audits of leak monitoring programs only once every three years, and reporting requirements are minimal. In fact, to date, there are no requirements for pipeline companies to regularly submit leak monitoring data to regulators, much less the public; pipeline companies need to merely submit their monitoring plans for review.[41,42]

This poses potential issues when the real-time leak monitoring systems of TMP (and other crude oil pipelines) are not particularly good at detecting leaks. These systems, which rely on computer models that respond to fluctuations in pressure, temperature and product density, only detect fairly large changes in these readings. Specifically, Trans Mountain has acknowledged that these sensors have a detection limit at 2-5% change in flow rate. Even at the low end, 2%, this still corresponds to roughly one Olympic-sized swimming pool of spilled oil per month of non-detection (assuming maximum flow rate), a massive volume in terms of ecosystem impacts.[43,44]

These limitations have real consequences for detecting issues. The data bear this out: recent studies by government regulators in both Canada and the US found that control rooms successfully detect leaks only 15-17% of the time, whereby air patrols and ground monitoring crews are more likely to find leaks.[45,46] The causes of these leaks is varied, with internal corrosion being the leading cause among pipeline leaks in Alberta, according to the Alberta Energy Regulator.[47]

In the interest of addressing these issues, pipeline companies are beginning to explore the potential of high-tech optic fiber leak detection systems, but the feasibility of these systems, both with respect to performance and cost, has not been demonstrated on a large scale. As it concerns the TMX project, Trans Mountain has only referred to an intention to investigate whether such a system might be implemented, with no guarantees.[48]

Meanwhile, the only reliable method for detecting structural abnormalities like dents, cracks, and corrosion is the periodic use of in-line inspection tools, nicknamed "smart pigs," which use a series of highly sensitive sensors.[49] These instruments are sent through sections of the pipeline by Trans Mountain, but the scheduling of these activities and the results of their readings are undisclosed.

This is indicative of a larger pattern in North America, whereby pipeline companies sequester and compartmentalize their monitoring data, rendering it nearly impossible for the public to access. This benefits fossil fuel companies, not necessarily because of the results themselves, but because this maintenance of opacity allows for public disengagement from risk, the engendering of an air of safety, and a continued exclusion of affected communities from conversations about determining thresholds of "acceptable risk." As Wylie describes it, "information sequestration makes it hard for private individuals to move between the scales of local, state, national, and international regulatory and policy arenas in ways that are available to industry," which sustains "regimes of imperceptibility," whereby "the very tools intended to investigate a problem actually work to render the problem less visible."[50]

Together, these issues draw into relief the need for more transparency around Trans Mountain's monitoring programs. This is an issue that citizen science monitors might address, and that designers are especially poised to highlight in the built environment. If this project presumes that greater visibility of this issue may generate more accountability, citizen scientists and the design interventions that support them might focus some of their efforts on issues of corporate sequestration of pipeline monitoring data.

Does it Float? A Trail of Escaped Bitumen

Addressing current inadequacies of leak monitoring in pipelines is a more urgent matter when the substance pumped through the pipeline is diluted bitumen, as in the case of the TMP and pending TMX lines. This section briefly discusses what makes diluted bitumen unique among crude oil products, and how these properties further reinforce the need for citizen science monitoring of the Trans Mountain pipelines.

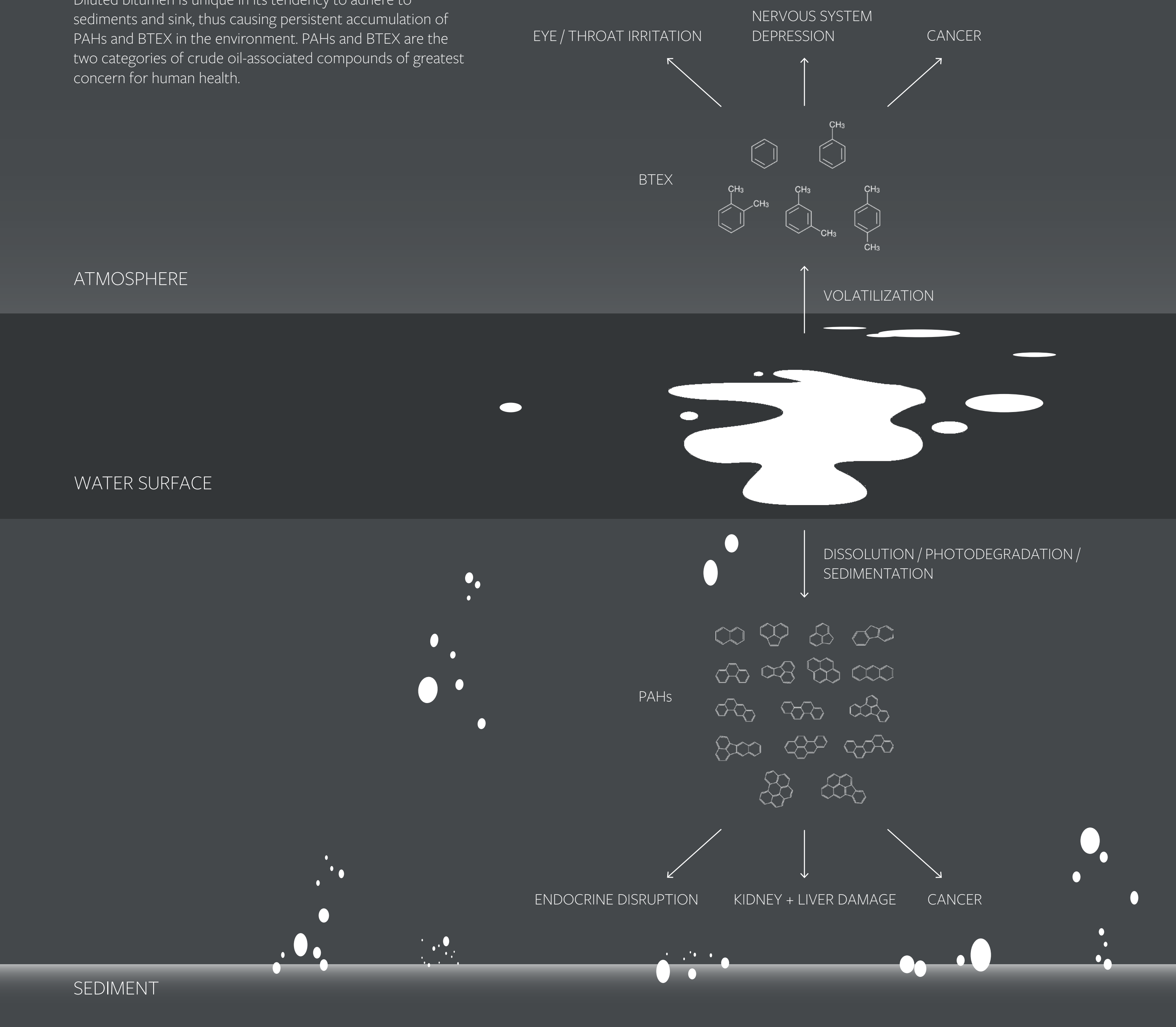
One of the common behaviors of diluted bitumen in a pipeline is that it can produces air bubbles. This physical reality illuminates one issues that can arise with current leak monitoring systems: the low sensitivity of sensors can mean that real alarms are mistaken for more benign situations. This is exactly what happened in Kalamazoo, Michigan in 2010, when an Enbridge pipeline spilled nearly one million gallons of diluted bitumen into the Kalamazoo River. In this case, oil spilled for 17 hours while control operators mistakenly interpreted an alarm as being caused by air bubbles.[51]

Beyond illuminating issues around leak detection systems, the Kalamazoo spill provided a rare window into the behavior of diluted bitumen in freshwater environments. When diluted bitumen spills, a cascade of physical and chemical processes follows, highlighted by its unique behavior that begins several hours following its release, at which point the oil begins to weather. As this weathering proceeds, the diluents separate from the bitumen, and volatile compounds, including toxic benzene, toluene, ethylbenzene, and xylenes (BTEX), evaporate. In Kalamazoo, as a result, area residents complained of headaches, nausea, and respiratory symptoms the day of the spill.[52]

More critically, the Kalamazoo spill provided anecdotal data on long-debated questions about whether bitumen sinks once it has separated from its diluents, which has critical implications for methods and costs of cleanup. The studies on this topic have yielded mixed results, but those that claim that it will float do not account for the behavior of bitumen when it begins interacting with suspended sediments, at which point it can form aggregates that settle onto the stream or river bed. This is what happened in Kalamazoo. Based on this observation and results from other studies demonstrating the same effect, a comprehensive review by the National Academies of Science, Engineering, and Medicine concluded that diluted bitumen's heavy

Figure 13. Fates and human health impacts of spilled diluted bitumen

Diluted bitumen is unique in its tendency to adhere to sediments and sink, thus causing persistent accumulation of PAHs and BTEX in the environment. PAHs and BTEX are the two categories of crude oil-associated compounds of greatest concern for human health.



constituents are likely to sink. This means that many common practices of oil spill cleanup, like in situ burning and use of dispersants, are effective only in the first 6-12 hours following a spill.[53] For the Kalamazoo site, the consequence has been a cleanup whose costs have approached $1 billion, with devastation to habitats and ongoing plans to perform large-scale dredging of contaminated sediments.[54]

Bitumen sedimentation is toxic not only because it physically coats the bed of the waterway, but also because it introduces a variety of toxic chemicals whose impacts on biota are far-reaching, yet severely understudied, as noted in the aforementioned National Academies review. The few studies investigating effects of diluted bitumen on fish species have found a number of developmental effects, presence of polycyclic aromatic hydrocarbons (PAHs) in tissue, and cardiac failure at sufficient concentrations. Toxicities for humans are similarly high. Many compounds known to be present in diluted bitumen products, including PAHs, are known carcinogens, and likely cause endocrine disruption and other negative effects at lower concentrations.[55] These processes of diluted bitumen weathering and associated downstream impacts are summarized in Figure 13.

The sinking of diluted bitumen in the environment, and especially in inland freshwater rivers and streams, means that rapid detection is key, and also that it can be difficult to determine spill cleanup endpoints, because a sunken oil adhered to sediments is more persistent in an ecosystem. This once again points to the importance of an engaged and informed public whose citizen scientists can quickly evaluate presence and quantities of spilled oil and associated toxins, potentially contesting industry claims about remediation status and challenging regulatory limits of acceptable toxicity.

Based on these suggestions, design interventions should support awareness of spill risks and response procedures (e.g., who to contact). With a longer view of remediation processes, there are also potentials for design interventions to support citizen science activities that evaluate remediation processes, including continual marking of toxicity-related data.

This chapter therefore summarizes political and ecological risks associated with pipeline building and pipeline spills. In the next chapter, I will focus on more context-specific risks that begin to explain the diversity and complexity of socioecological landscapes along the TMP. These more specific risks will be located within defined landscape typologies, which will serve as sites for testing risk-responsive citizen science design interventions.

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Map Data:

Figure 5: Canadian Geographic, Wilderness Committee

Figure 6: U.S. Energy Information Administration, Canadian Association of Petroleum Producers

Figure 8: Wilderness Committee

Figure 9: BC Ministry of Education, Data BC, native-land.ca, Wilderness Committee

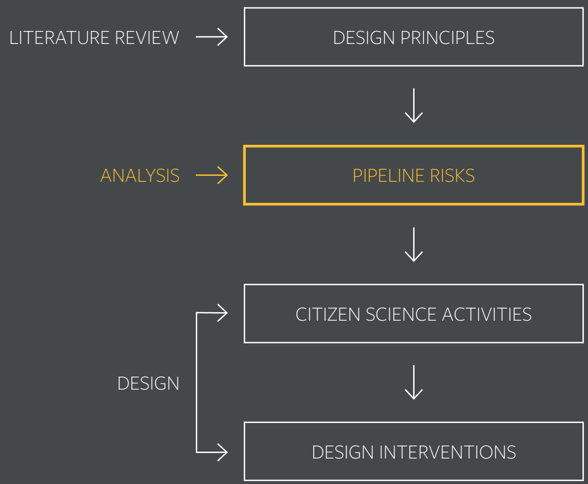
Figure 10: Data BC, Open Data Canada, Wilderness Committee

Figure 11: Data BC, Open Data Canada, Trans Mountain Corporation, Wilderness Committee

The TMP is buried beneath a schoolyard in the Westsyde neighborhood of Kamloops, on Secwépemc ancestral lands.

5 Defining Key Risks

There are many types of perceived spill risks along the path of the Trans Mountain pipelines. Some are based on past incidents, while others are based on probabilities determined by consulting experts. In some cases, the two overlap. In this chapter, I identify and describe three focal risks, and spatially locate those risks within the complex socioecological landscapes of the Trans Mountain pipelines that Chapter 4 introduced. First, based on spatial analyses of social and ecological data along the Trans Mountain pipelines, I define a series of landscape typologies. Second, based on my analyses of perceived pipeline risks, I introduce and discuss three focal risks for this project, whereby each corresponds to different landscape typologies. These risks subsequently provide a foundation for testing design proposals in the next chapter (Chapter 6). See below for a reiteration of this larger project framework.



Defining Landscape Typologies

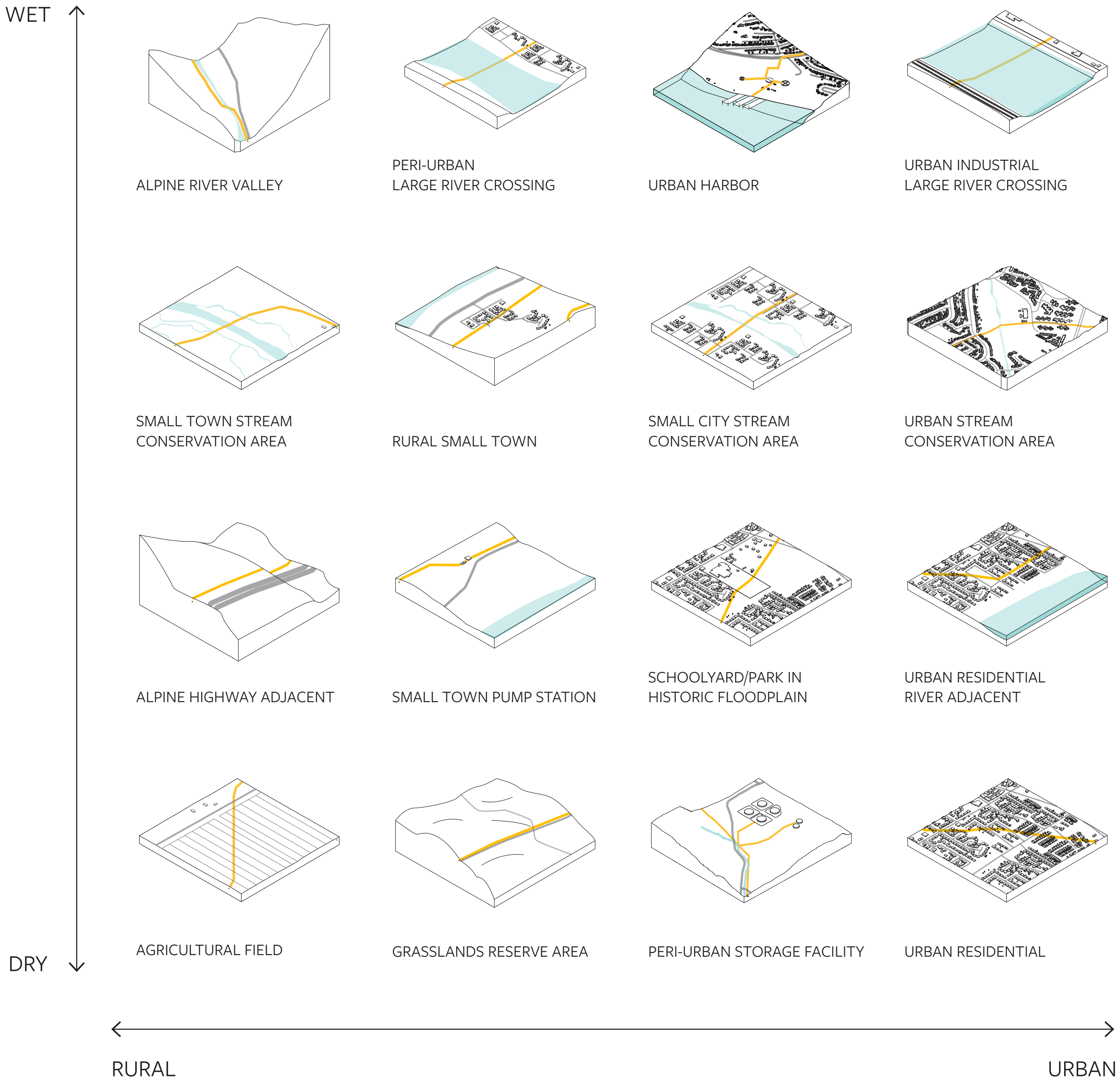
Citizen science monitoring takes different forms across various social and ecological contexts. Along the paths of the TMP and TMX, these contexts vary greatly, and therefore so do the specific pipeline risks and set of stakeholders who might document those risks. It is therefore critical to identify key site-scale socioecological contexts, or landscape typologies, of the Trans Mountain pipelines. By defining these dynamic typologies, I could begin to understand how risks, ecologies, and communities intersect.

I determined the landscape typologies of the Trans Mountain pipelines based on a qualitative approach, whereby I synthesized analyses from site visits, press coverage, pipeline incident history, regulatory documentation (including the TMX project applications), and GIS data related to socioecological factors (including presence of human populations, current and historic land uses, hydrology, topography, and ecosystem types). This process generated the qualitative socioecological matrix in Figure 14, which abstracts landscapes into 16 typologies along two axes: one for average "wetness" (dry to wet) and one for presence of human populations (rural to urban). Each typology suggests a highly unique physical, social, and ecological landscape, and therefore suggests varied opportunities and constraints for citizen science activities associated with the pipeline.

Through these analyses, I also identified three key landscape-based spill risks that could frame this project's design explorations: stream and river proximity, landslide and rockslide risk, and presence of pump stations and storage facilities. These risks are described in depth in the following pages and are the basis of design explorations in Chapter 6.

It should be noted that these three risks are not the only risks worth tracking along the pipelines. Rather, they serve as an entry point into potential citizen science activities in different contexts, and how participants can work in network across these varied landscapes. Based on review of corporate documentation and press around the pipeline, other issues of concern that this project does not explore at length include potential groundwater contamination, seismic activity, and wildfire.

Figure 14: Landscape typologies of the Trans Mountain pipelines. Synthesis of pipeline risks and GIS-based analysis of socioecological factors generated a series of typologies differentiated by proximity to human populations and wetness.


WET
DRY
ALPINE RIVER VALLEY
PERI-URBAN
LARGE RIVER CROSSING
URBAN HARBOR
URBAN INDUSTRIAL
LARGE RIVER CROSSING
SMALL TOWN STREAM
CONSERVATION AREA
RURAL SMALL TOWN
SMALL CITY STREAM
CONSERVATION AREA
URBAN STREAM
CONSERVATION AREA
ALPINE HIGHWAY ADJACENT
SMALL TOWN PUMP STATION
SCHOOLYARD/PARK IN
HISTORIC FLOODPLAIN
URBAN RESIDENTIAL
RIVER ADJACENT
AGRICULTURAL FIELD
GRASSLANDS RESERVE AREA
PERI-URBAN STORAGE FACILITY
URBAN RESIDENTIAL
RURAL
URBAN

Risk 1: Stream + River Proximity

Much of the path of the existing TMP follows the lower portions of valleys. Along the way, in addition to being buried in parallel to rivers and streams, it crosses many of them. These watercourses range in order from small streams to larger, high-order rivers. The number of watercourse crossings by the proposed TMX line differs depending on the criteria used, with estimates ranging from 1,063 by the National Energy Board to over 1,300 by some activist groups.[1,2] As it regards the current TMP line, Trans Mountain currently claims to actively monitor 550 crossing, which likely equates to roughly half of all crossings, assuming a similar number to the TMX line. It is difficult to find publicly available data on the details of that monitoring activity.[3] The map here (Figure 15) marks 124 of these crossings, based on GIS analysis of intersections of the TMP pipelines and salmon-bearing streams and rivers.

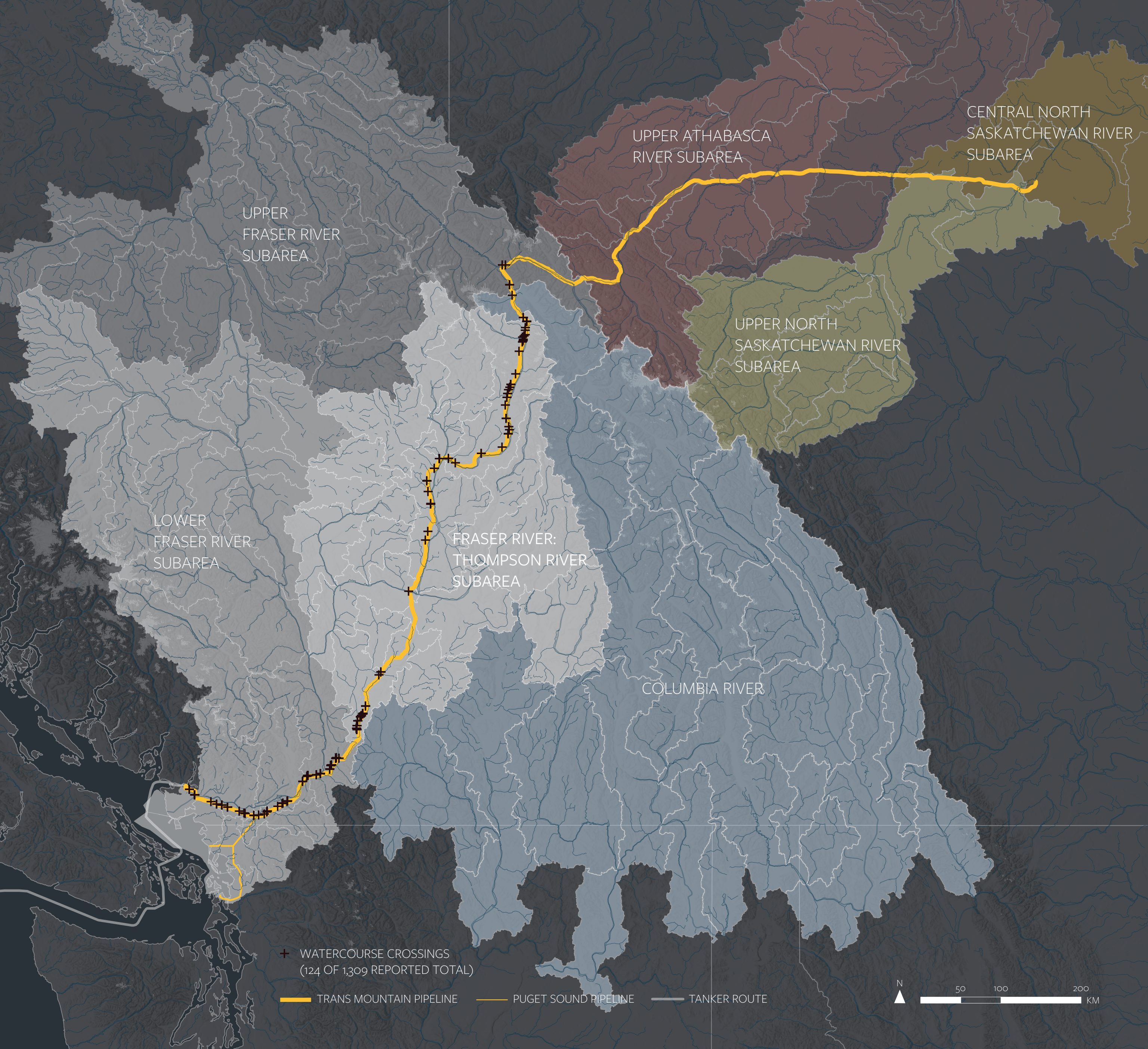
The surrounding socioecological contexts of these crossings vary widely, and therefore correspond to a number of the proposed landscape typologies. Across these typologies, organized, community-based stewardship of streams and rivers varies widely. At some crossings, restoration efforts are ongoing, often led by regional watershed protection nonprofits like the Fraser Valley Watersheds Coalition. These groups may or may not already pursue citizen science efforts like water quality monitoring and macroinvertebrate surveys, the latter being a common method to assess overall stream health and potential impacts of petrochemical-related pollution. However, communities do not actively monitor most watercourse crossings due to sheer number; yellow pipeline stakes are often the only obvious visible signs of human intervention in the landscape.

Within these landscapes, there are many potential culprits of spills and leaks, including corrosion, bank erosion, and channel scour, the latter of which has exposed the pipeline within watercourses at many points in the TMP's history, with the potential that some channel scour-related exposures of the pipeline have gone undetected and undocumented.[4,5] Of the 434 identified geohazards along the TMX pipeline route (which mostly mirrors the TMP route), most fall under the umbrella category of "hydrotechnical" risks: flooding, bank erosion, or channel scour.[6] Once exposed, the pipeline is highly susceptible to rupture via chronic wear or more acute impact of moving rocks.[7]

As part of citizen science monitoring at pipeline watercourse crossings (and at reference sites), participants must also consider disturbance associated with construction. In order to bury the pipeline underneath watercourses, Trans Mountain typically uses one of two construction techniques: trenching, in which case the waterway is temporarily dammed to bury the pipeline, or trenchless techniques like horizontal directional drilling, which cause less surface disturbance but are accompanied by other risks that are outside the scope of this discussion.[8,9]

Design interventions at watercourse crossings might focus on monitoring activities specific to the type of stream or river (including stream order), the habitats it supports, and existing stakeholders.

Figure 15. Watersheds and watercourse crossings of the TMP



The TMP and the proposed TMX line cross the Peach Creek wetlands in Chilliwack, B.C., on ancestral lands of the Stó:lō peoples. Local groups, including the Fraser Valley Watersheds Coalition, have helped restore habitat here for salmon and other critical species.

Risk 2: Landslide + Rockslide Risk

As it traverses a number of alpine zones, the Trans Mountain pipelines are exposed to many steep slopes, some of which are highly prone to landslides or rockslides under conducive conditions. A review of Trans Mountain's survey of geotechnical risks along the TMX route revealed 64 instances of soil or rock movement that might endanger the pipeline. The map here (Figure 16) highlights areas with high concentrations of those risks, taking into account whether the hazard potential was categorized as low, medium, or high, and based on terrain stability ratings, which were categorized on a five-point scale.[10]

In Kheraj's *Historical Background Report* of the TMP, he documents several past incidents related to landslides or rockslides. The circumstances of each has been unique, highlighting the potential for catastrophic failure of either pipeline (the TMP or TMX) in the future, given sufficient geology-related forces. Areas of high landslide or rockslide risk are concentrated in higher elevation landscapes, where the pipeline typically runs alongside or uphill of high energy alpine rivers. Past incidents also demonstrate that the pipeline can break in different manners, be it via rockfall puncturing the pipeline or due to movement of soil that bends the pipeline to a point of failure.[11] As climate change accelerates, causing large rainfall events and dramatic temperature fluctuations to become more frequent, this may also be associated with an increased frequency of these geological events.

The highlighted areas of high landslide or rockslide risk in Figure 16 are mostly located in rural areas where there are few stakeholders living nearby. That does not always mean that they are devoid of human traffic. For example, in the case of the Coquihalla River valley, which is visualized in the Appendix ("A3. Slope Analysis of the Coquihalla Valley") there are two sources of human activity. First, the planned TMX route follows an existing utility right-of-way that parallels the busy Coquihalla Highway through an adjacent valley. This valley, while less exposed to risk compared to the Coquihalla River valley, nevertheless crosses underneath the paths of many steep slopes with high potential for rockslides.[12] Second, the existing TMP follows the Coquihalla River, which has carved an extremely steep valley in many places; this topography made it the most technically challenging section of the TMP to construct.[13] In this section of the route, a dirt pipeline service road that follows an old railway grade is designated as part of the Kettle Valley Rail Trail, as well part of the Trans Canada Trail. This road is therefore traveled by many cyclists during warm summer months.

Design interventions in these high landslide and rockslide risk areas should support citizen science activities that draw on the ways that preexisting stakeholders, including touring cyclists, engage with these largely rural landscapes. Interventions may therefore play on qualities of recreation, procession, and view.

Figure 16. High landslide and rockslide risk areas of the Trans Mountain pipelines

As the TMP comes into the lower Fraser River valley, it emerges from a mountainous landscape where landslides and rockslides have left a legacy of spills and near-spills.

Risk 3: Pump Stations and Storage Facilities

Of the 84 reported spills documented along the TMP (from 1961 through 2019), over half, 53, have occurred at pump stations or oil storage facilities. Twenty-five of these have occurred at the Edmonton terminal that is the beginning of the pipeline and host to 20 feeder lines.[14] Of the other 28, almost all have occurred at storage facilities that also serve as transfer stations for the pipeline's products. Many of these have occurred in recent years, including a June 2020 spill of more than 150,000 liters of crude oil at the Sumas Pump station in Abbotsford, B.C., where there have been four spills in the last 15 years.[15] Past spills across these sites have varied in the location of the spill with respect to the facility itself (whether they occur inside or just outside the facility), their causes, and their volumes.

Pump station and storage facility-associated spills are marked in red on the map in Figure 17, where repeat spills at a given location are visually disaggregated outward from that location.

As is the case with the rest of the Trans Mountain pipeline system, these facilities coexist within complex hydrogeological and socioecological contexts, corresponding to several of the landscape typologies defined in Figure 14. In almost all cases, these facilities are located nearby population centers, with the density of population varying greatly between rural, peri-urban, and urban facilities. Typically, the immediate vicinity of these facilities is dominated by private land uses, and accompanying pipeline rights-of-way leading into these facilities are owned by these private entities, though municipalities in some cases own small portions.[16] Citizen scientists monitoring these facility vicinities might reach agreements with the city or private landowners to conduct monitoring activities like soil testing. These activities might track both changes in levels of toxicity over time and how these toxicities migrate within soils and waterways. Furthermore, citizen scientists may detect new, small leaks whose presence might not be as immediately obvious as in the case of larger spills.

Figure 17. Reported TMP spills, 1961 - 2019, with locations of repeat spills disaggregated

There have been at least four reported spill events and a number of smaller scale incidents at the Westridge Marine Terminal on Tsleil-Waututh ancestral lands in Burnaby, B.C. There, diluted bitumen and other oil products are transferred to tanker ships that navigate Vancouver's narrow Burrard Inlet en route to other ports, primarily in California.

Endnotes

1. Brent Patterson, "Trans Mountain Pipeline Would Cross 1,309 Watercourses," *The Council of Canadians*, 2017, https://canadians.org/analysis/trans-mountain-pipeline-would-cross-1309-watercourses.

2. "Trans Mountain Pipeline: The Truth About Construction," *Stand.earth*, (Vancouver, British Columbia: Stand.earth, 2019).

3. "More Than 550 Watercourse Crossings Get Close Attention Along Trans Mountain Pipeline Route," *Trans Mountain*, November 12, 2015, https://www.transmountain.com/news/2015/more-than-550-watercourse-crossings-get-close-attention-along-trans-mountain-pipeline-route.

4. Kheraj, "Historical Background Report: Trans Mountain Pipeline, 1947-2013."

5. "Trans Mountain Pipeline ULC Application for the Trans Mountain Expansion Project."

6. "Trans Mountain Expansion Project: An Application Pursuant to Section 52 of the National Energy Board Act: Project Design & Execution - Engineering," in *Trans Mountain ULC* (Kinder Morgan Canada, 2013).

7. "Trans Mountain Pipeline ULC Application for the Trans Mountain Expansion Project."

8. Ibid.

9. "Trenchless Construction," *Trans Mountain*, 2020, https://www.transmountain.com/trenchless-construction.

10. "Trans Mountain Expansion Project: An Application Pursuant to Section 52 of the National Energy Board Act: Project Design & Execution - Engineering."

11. "Historical Background Report: Trans Mountain Pipeline, 1947-2013."

12. "Trans Mountain Expansion Project: An Application Pursuant to Section 52 of the National Energy Board Act: Project Design & Execution - Engineering."

13. "Historical Background Report: Trans Mountain Pipeline, 1947-2013."

14. "Pipeline System," *Trans Mountain*, 2020, https://www.transmountain.com/pipeline-system.

15. Amy Judd, "Sumas First Nation Chief Says Spill at B.C. Trans Mountain Facility 4th 'in the Last 15 Years'," *Global News*, June 15, 2020, https://globalnews.ca/news/7068655/spill-trans-mountain-facility-abbotsford-bc-update/.

16. "Detailed Route," *Trans Mountain*, 2020, https://www.transmountain.com/detailed-route.

Map Data:

Figure 15: Data BC, Open Data Canada, Wilderness Committee

Figure 16: Data BC, Open Data Canada, Sean Kheraj, Trans Mountain Corporation, Wilderness Committee

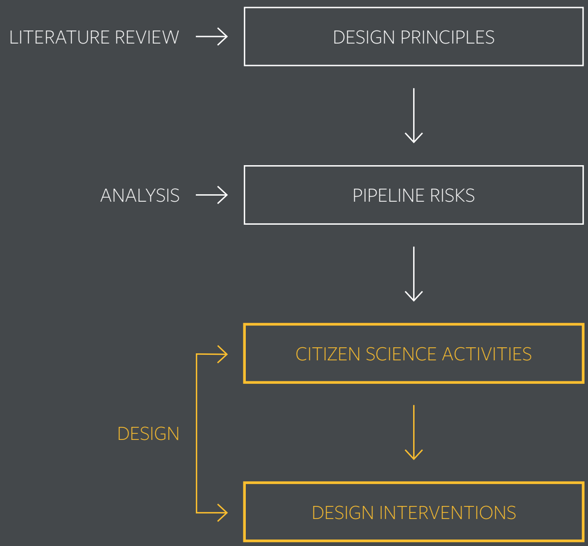
Figure 17: Data BC, Open Data Canada, Trans Mountain Corporation, Wilderness Committee

Right: A TMP road crossing on the outskirts of Merritt, B.C., on Nlaka'pamux ancestral lands.


WARNING
HIGH
PRESSURE
PETROLEUM
PIPELINE

6 Marking Risk + Response

In the design portion of this project, I first explore the development of a citizen science network. I then introduce an adaptable design language for landscape-based interventions that amplify this network and its citizen science activities. Finally, I test this approach within three landscape typologies, corresponding to the three focal risks identified in Chapter 5. Design interventions mark pipeline, citizen science activities, and data, and connect citizen scientists and greater public to the spatial, social, and programmatic qualities of the greater citizen science network.



Citizen Science Monitoring of Pipelines as Networked Activity

The strength of social connections and resource sharing within a larger citizen science network of the Trans Mountain pipelines would ultimately be the primary determinant of the collective impact of monitoring efforts. In this network, citizen science practices would differ across varied contexts but members of the public would share common general concerns about spill risks. It is by collecting and sharing best practices and data across this network that these community members might generate the necessary information—and therefore leverage—to effectively contest industry practices and claims. As such, these community members might together enforce existing regulations and also suggest needed changes in regulations (such as increasing public reporting requirements for pipeline monitoring data). This network might also support protest of the pipelines, especially following spill events. Together, these collective activities would generate greater accountability, and might positively affect communities' senses of agency over land.

In this section of the chapter, I briefly explore the basic form and function of this hypothetical citizen science network that spans the pipeline's different socioecological contexts. This provides a foundation for approaching the development of a common physical design language suited to citizen science in these contexts.

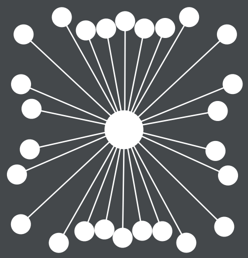
There are many types of social networks that this citizen science network may resemble. These range on a spectrum from centralized to decentralized to distributed, as explained in Figure 18. These forms of network might furthermore differ across a number of factors. These factors might include the type of citizen science (context-based factors). For example, participants analyzing photodocumentation of landscape change might distribute tasks in a more decentralized manner than in a network of participants interested in testing soil. Networks might also change in form at different stages of development (temporal factors). Each part of the network may become more decentralized over time as the network builds consensus regarding best practices.

Figure 19 begins to explore these temporal, developmental dynamics of the pipeline monitoring network. It suggests basic forms of the network at two stages: 1) early development and 2) mature network. In early stages, as the network develops its initial identity, its overall form is decentralized but may lean heavily on a central hub of dialogue, which is manifested through online (virtual) and physical meetings, the latter of which might include annual conferences and celebrations. Technical advisory boards may also play an important role in helping develop best practices at these early stages.

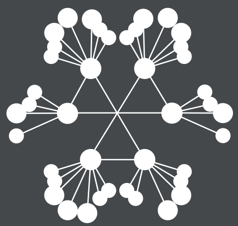
Over time (in the "mature network"), the network becomes increasingly decentralized, and various communities work within regional hubs to tailor solutions to their needs, while also interfacing with an expanded central hub. There, communities based around specific citizen science topic areas discuss best practices, observations, and response-based actions.

Figure 18. Types of social networks

In a centralized network, primary decisions lie in a central owner or leadership structure. In decentralized networks, leadership or decision-making lies within multiple hubs. Distributed networks eliminated centralization entirely, allocating power and ownership throughout the network.



CENTRALIZED



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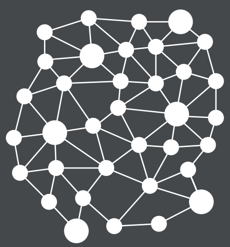
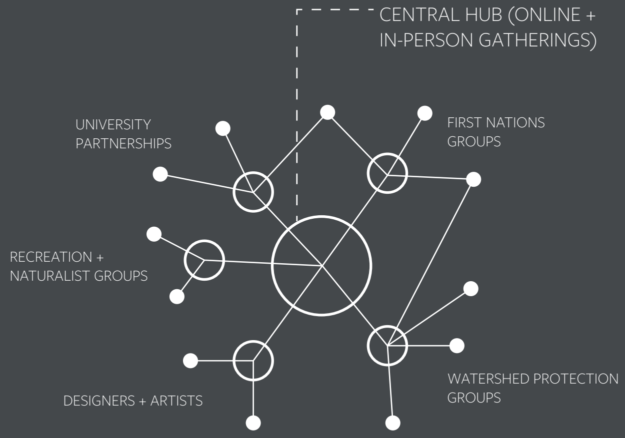


DISTRIBUTED

Figure 19. Phasing a citizen science network

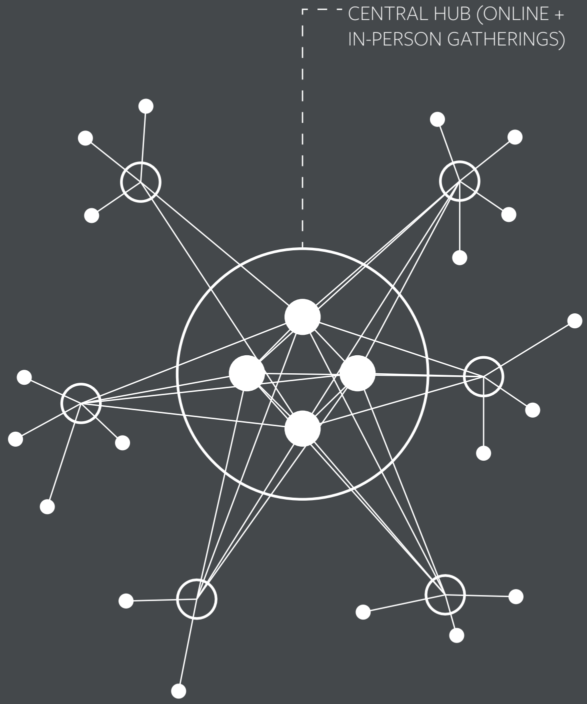


Early Development

Preexisting, engaged stakeholders coalesce to begin creating unifying frameworks for a citizen science network. Stakeholders may identify with multiple groups. In these fledgling stages, the network may be characterized by a relatively centralized form while it defines larger network mission and goals. It also must build in adaptability to accommodate the unique concerns of each group and the accompanying citizen science practices that address those concerns.

PARTICIPANT GROUP

STAKEHOLDER GROUP



A Mature Network

As the network develops, it becomes more decentralized, with a thriving open-source online community that amplifies community stories and draws from technical experts engaged across universities and many other communities. Online and in-person (annual) gatherings connect the full network, but also allow for context-specific communal work. Designers play critical roles finding and expressing connection between groups who track different risks, such as those related to stream protection or photodocumentation of landscape changes.

PARTICIPANT GROUP

REGIONAL HUB

CITIZEN SCIENCE TOPIC GROUPS (SOIL, STREAMS, GROUNDWATER, PHOTOGRAPHY, DESIGN INTERVENTION, ETC.)

Conversation between these citizen science topic groups would also be critical. In these inter-group communications, landscape architects might participate to help identify connections and to facilitate co-creation of a legible and adaptable design language that could be applied across various citizen science activities and landscapes.

This design language would therefore encourage relationship between the different citizen science groups and their specialties, which in some cases might be critical in proving pipeline pollution-related effects. For example, to capture relationship between pipeline leaks, stream sediment toxicity, and the health of that stream's biotic communities, several types of data are required. Different citizen science groups would be needed to track the relationship between these different processes. Close relationship between related groups in the network would therefore be critical to the network's functioning.

Building close inter-group relationships within the network would also be critical to pipeline spill response. As noted in Chapter 3, social cohesion within communities leads to more robust and creative response. The development of a physical design language might further encourage this sense of social connection, thereby affecting better response to leaks and spills.

Further explorations of these network dynamics would be worthwhile, and might draw from scholarship within fields of sociology, psychology, STS, and others. This section's brief investigation of a pipeline citizen science network nevertheless grounds the design work of this chapter at a pipeline-scale, both politically and spatially. This is critical for conceiving of physical interventions, including a common design language for the overall citizen science network.

Introducing a Framework: Design Interventions in Support of Citizen Science

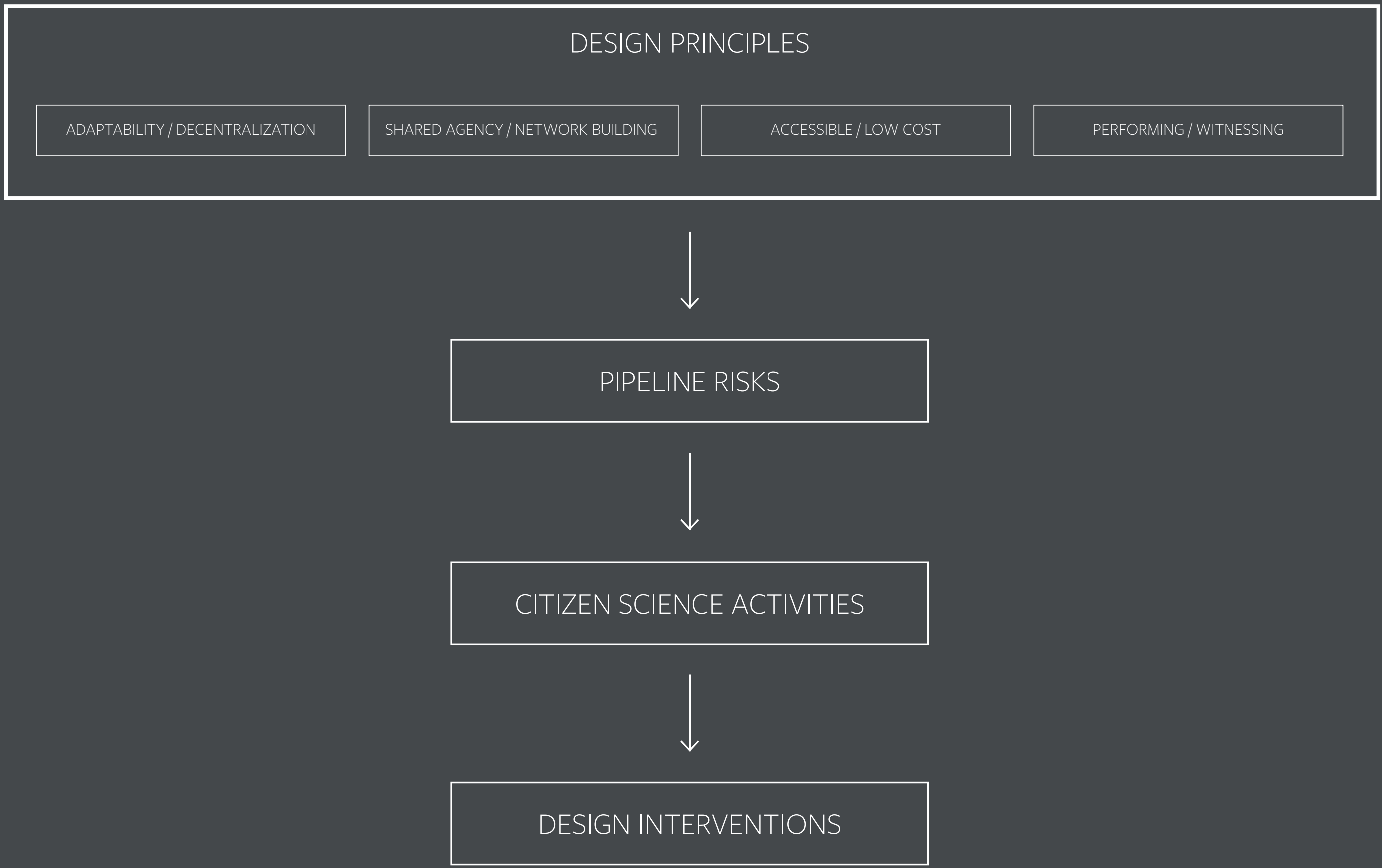
Based on the diversity of contexts that might be monitored by citizen scientists across the Trans Mountain pipelines, the main goal of the design portion of this project was to test activism-oriented physical interventions that are in conversation with citizen science activities and corresponding landscape-pipeline relationships. The different design ideas I explore were based on research summarized in the preceding chapters: definition of citizen science-based design principles (Chapter 3) and identification of key spill-related risks of the Trans Mountain pipelines (Chapters 4 and 5). Across these design interventions, my aim is to encourage members of the public to record changes in the landscape and the relationships of those changes with community and pipeline—in other words, to claim agency through monitoring.

Based on the stated design principles of this project (as situated within the project framework in Figure 20), it was important to propose designs that emphasize accessibility through common, low-cost materials. It was also important to establish a common design language that would articulate network and relationships between pipeline, communities, and ecologies. The following proposals therefore take a loose kit-of-parts approach, not in the sense that there is a common set of interventions that are bundled together, but rather in the sense that common materials and common elements are translated across the citizen science network's various contexts.

Both the design framework and the more specific design ideas that follow provide one approach, and while there are suggestions of physical forms, the design here should not be viewed as prescriptive. Instead, they serve as an example of how adaptable design might be approached by citizen science communities, whereby each might work with locally-based (or non-locally-based) designers to develop locally relevant and locally expressive interventions that use the same basic design language that found across the network..

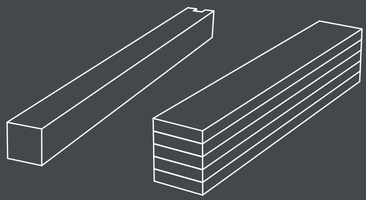
By amplifying citizen science activities and data, these interventions also aim to encourage intimacy and physical engagement with land and its processes, and to disrupt notions of pipelines as sterile, isolated infrastructures. They call attention to local, place-based risks, perhaps in ways that might nudge citizen scientists and other members of the public to more regularly reflect on pipelines as ecological infrastructures embedded within historically complex landscapes.

Figure 20. Design principles as situated within the project framework



Determining Common Materials

In the interest of establishing low barriers to implementation, design interventions use four primary, low-cost, widely available materials: common-sized lumber, straps made from webbing or vinyl, paint, and plantings. These form the foundation of this project's loose kit-of-parts approach.



WOOD

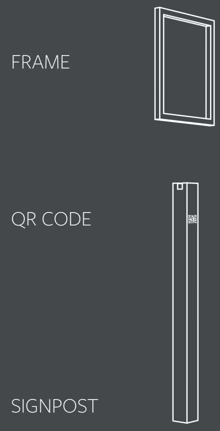
WEBBING OR VINYL STRAP

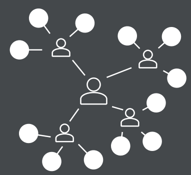
PAINT

PLANTINGS

Locating and Connecting within a Network

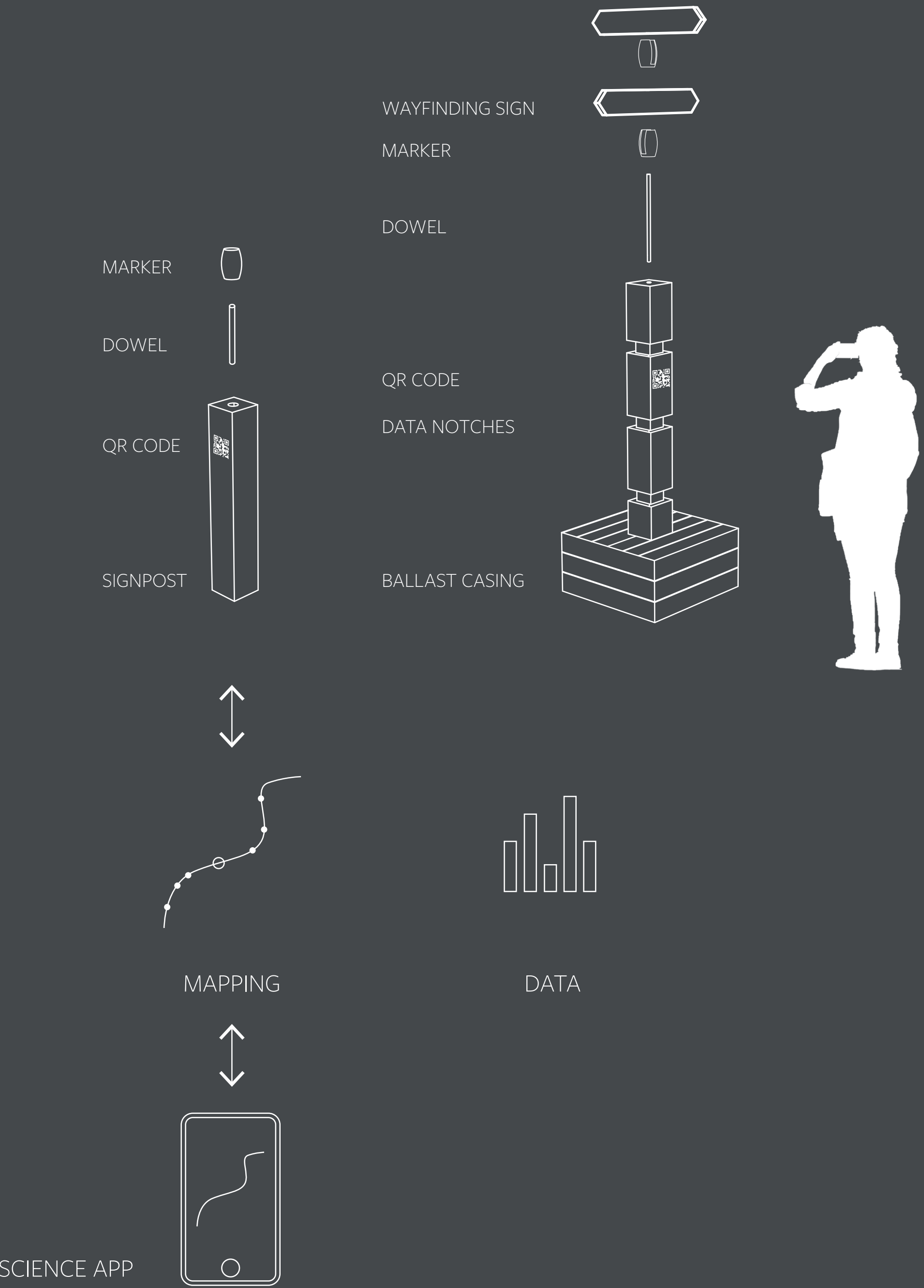
There were several key, larger goals that guided the form of the design interventions. The first was to help the public locate themselves in relation to pipeline and data collection points. This drove the development of wayfinding elements that allow for connection to greater network, to mapping, and to citizen science data. Different wayfinding elements respond to site contexts, including the degree to which the site is accessible for installation, maintenance, and use of the intervention. These interventions also provide connection to a citizen science app that serves as a central virtual meeting place, resource hub, and data repository. It is worth noting that many app-based platforms already exist, and this project does not explore at length whether this citizen science network would use one of these existing platforms (such as GLOBE Observer, developed by NASA) or develop a pipeline-specific platform. While the latter would allow for an interface more tailored to the citizen science activities of the pipeline, this would also require sustained engagement from a group of community members who would develop and maintain that platform.





NETWORK + RESOURCES

CITIZEN


WAYFINDING SIGN
MARKER
DOWEL
QR CODE
DATA NOTCHES
BALLAST CASING
MARKER
DOWEL
QR CODE
SIGNPOST
MAPPING
DATA
SCIENCE APP

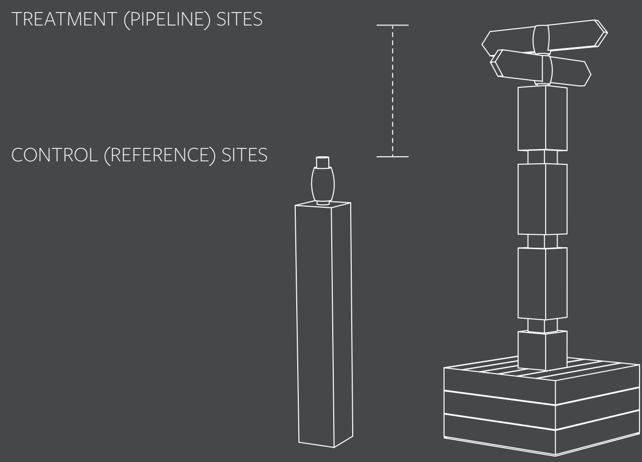
Indicating Activities and Conditions

It was also critical to develop a design language for indicating site-specific citizen science activities and their interaction with site conditions.

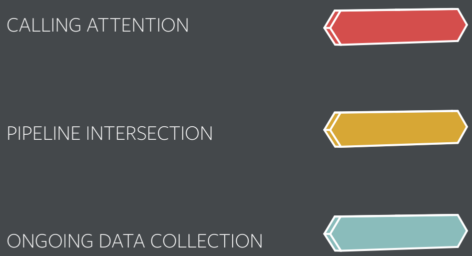
Left: Heights of wayfinding elements differentiate types of data collection sites, where shorter interventions indicate data collection at reference sites and taller interventions indicate data collection at pipeline intersections.

Middle: Color differentiates different activities or conditions. Yellow indicates presence of pipeline, according to typical conventions for color coding oil and gas pipelines. Blue marks citizen science activity (e.g., data collection). Red signals alert, such as presence of a leak that is not fully resolved, biotic data that may indicate potential pipeline integrity issues such as presence of a leak, or long periods of time elapsing between announcements of in-line integrity testing results.

Right: To bring attention to the often unclear extents of the pipeline's right-of-way (the "prescriptive zone"), plantings delineate and foster discussion about land use within these zones. At present, the National Energy Board of Canada requires landowners and other members of the public to gain permission from pipeline operators for activities that cause ground disturbance anywhere within the "prescribed zone," which extends 30 meters on either side of the pipeline centerline. These laws exist in the interest of safety but have important implications for public agency over the lands through which the pipeline passes.



DIFFERENTIATING DATA COLLECTION SITES

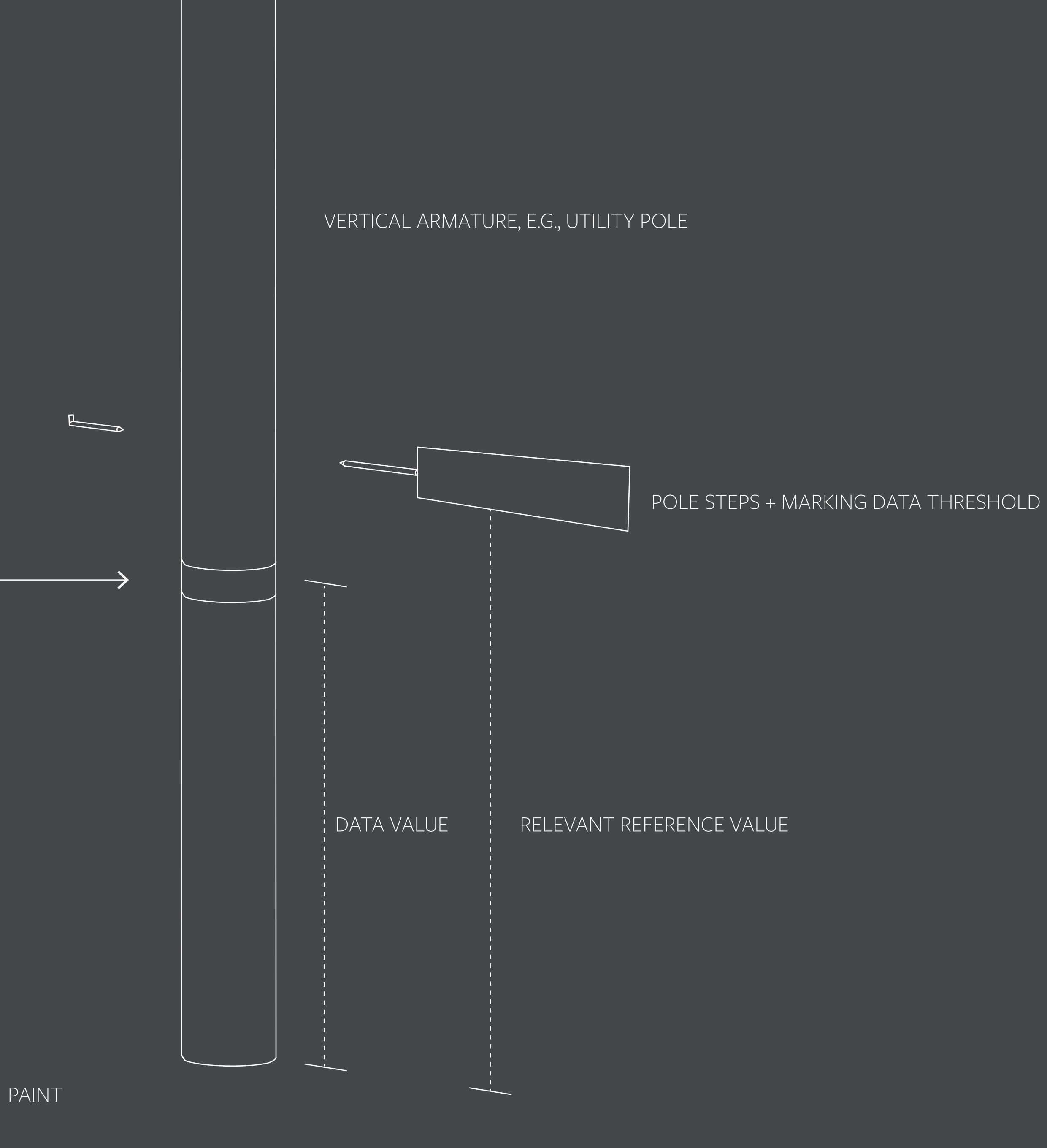


DIFFERENTIATING ACTIVITIES/CONDITIONS

DELINEATING RIGHTS-OF-WAY

Marking Data

There are many possibilities for marking citizen science data in simple, accessible ways, some of which may fall within a category of “tactical” design. These design interventions explore an approach for marking data that applies meaning to everyday objects, such as vertical armatures, like fences or utility poles. For example, straps may be added to indicate data values, with additional objects, like specialized utility pole steps, indicating critical reference values for that data. Depending on the structure on which the data is being marked, other accessible materials, like paint, may be a better option. Regardless, the location of these interventions within private or public lands may suggest cooperation with landowners or a more spontaneous, guerrilla approach.


VERTICAL ARMATURE, E.G., UTILITY POLE
POLE STEPS + MARKING DATA THRESHOLD
DATA VALUE
RELEVANT REFERENCE VALUE
PAINT

RISK

Choosing Sites

Three landscape typologies correspond to the three key risks identified in Chapter 5. These are the grounds for exploring and testing manifestations of this project's design principles, where landscape-based interventions support citizen science at intersections of pipeline, human communities, and ecological processes.

For risks associated with stream and river proximity, I explore a small town stream and accompanying trail system where there are high levels of community engagement and day-to-day activity. For risks associated with landslides and rockslides, I zoom in on an alpine river valley with a pipeline service road. This is a dynamic, fast-changing context with low levels of human activity. For risks related to a history of spills at pump storage facilities, I examine facilities located in a peri-urban context, where local citizen scientists engage with a complex mosaic of private land use.

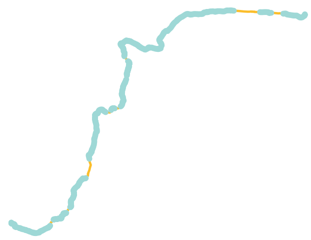
These explorations depict a citizen science network that engages changing landscapes throughout the seasons. In the following pages, in correspondence with the design language described earlier in this chapter, blue represents citizen science data collection, yellow represents pipeline intersection, and red represents an alert needing attention.

DIAGRAM KEY (THIS + FOLLOWING PAGES):

= RELATING TO PIPELINE

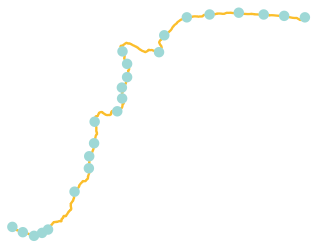
= CITIZEN SCIENCE ACTIVITY

= ALERT



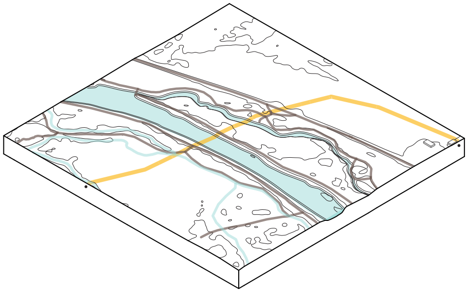
1. STREAM + RIVER PROXIMITY

2. LANDSLIDES + ROCKSLIDES

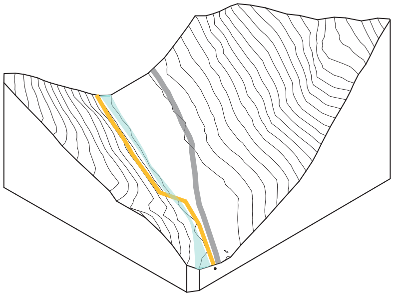


3. PUMP STATIONS + STORAGE FACILITIES

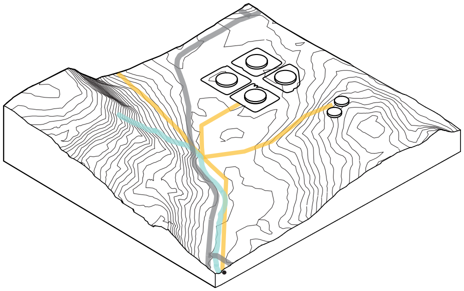
SITE



1. SMALL TOWN STREAM



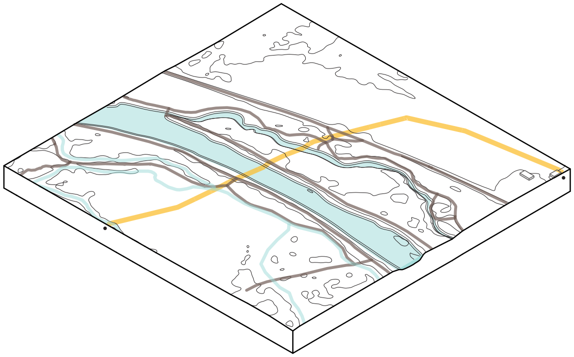
2. ALPINE RIVER VALLEY

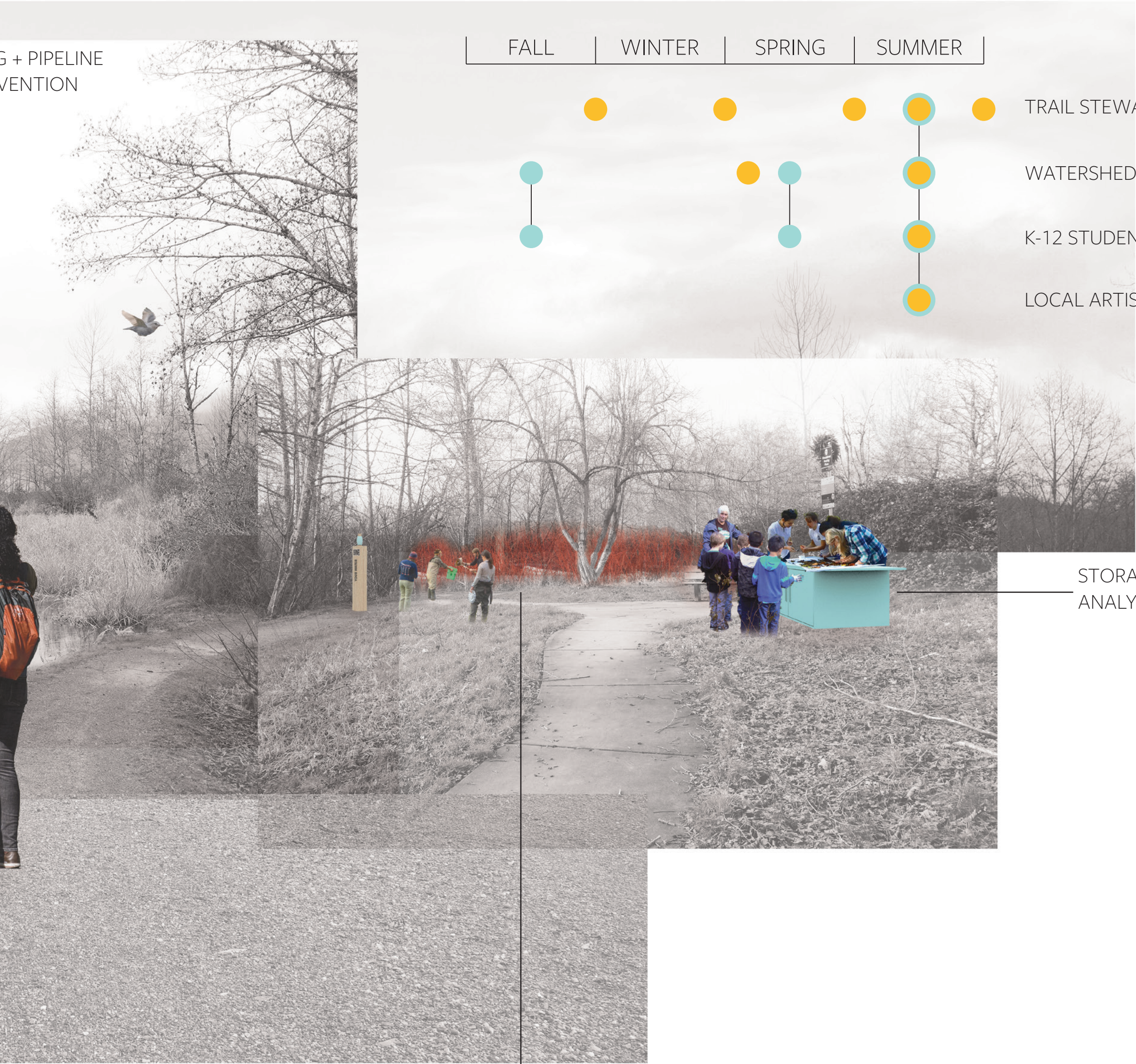


3. PERI-URBAN STORAGE FACILITY

Site 1: Marking Stewardship and Accountability at a Salmon-Bearing Stream

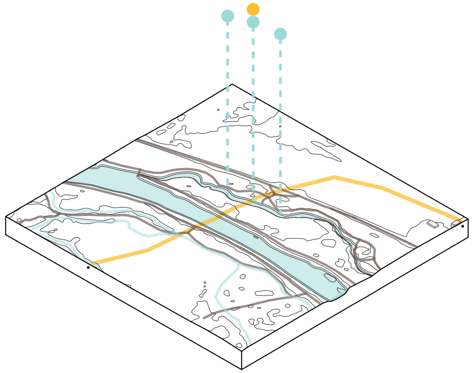
In many of the communities living along the pipeline, a variety of stakeholders access streams and their paralleling trails. There are therefore multiple types of engagement around which design interventions might be oriented. Many community members steward these salmon-bearing waterways and associated riparian habitats through involvement with local or regional watershed protection groups. Trail stewards, K-12 students, and local artists can all be involved at different points in the year in this stream stewardship work. The design interventions here engage these and other members of the public in the citizen science of stream monitoring at intersection with the pipeline.

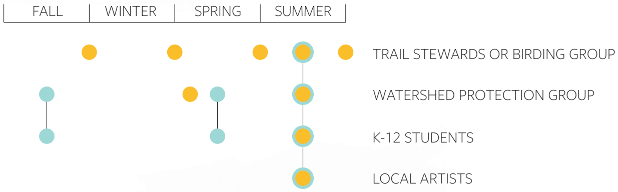



G + PIPELINE
VENTION
FALL
WINTER
SPRING
SUMMER
TRAIL STEWARDS OR BIRDING GROUP
WATERSHED PROTECTION GROUP
K-12 STUDENTS
LOCAL ARTISTS
STORAGE LOCKER /
ANALYSIS TABLE
RIGHT-OF-WAY BORDER
PLANTINGS

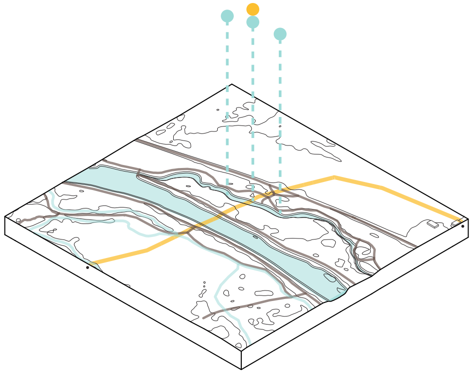
Finding Pipeline + Network

The central design intervention at this site is a wayfinding point that orients members of the public with respect to place, pipeline, and citizen science activities. The yellow signage indicates pipeline intersection and provides distances to nearest "upstream" and "downstream" pump stations, while blue signage indicates locations of data collection transects along the stream. The intervention also encourages app users to engage with the citizen science network via QR code. App users can connect with citizen science volunteers at the site and can view stream health data collected over time.

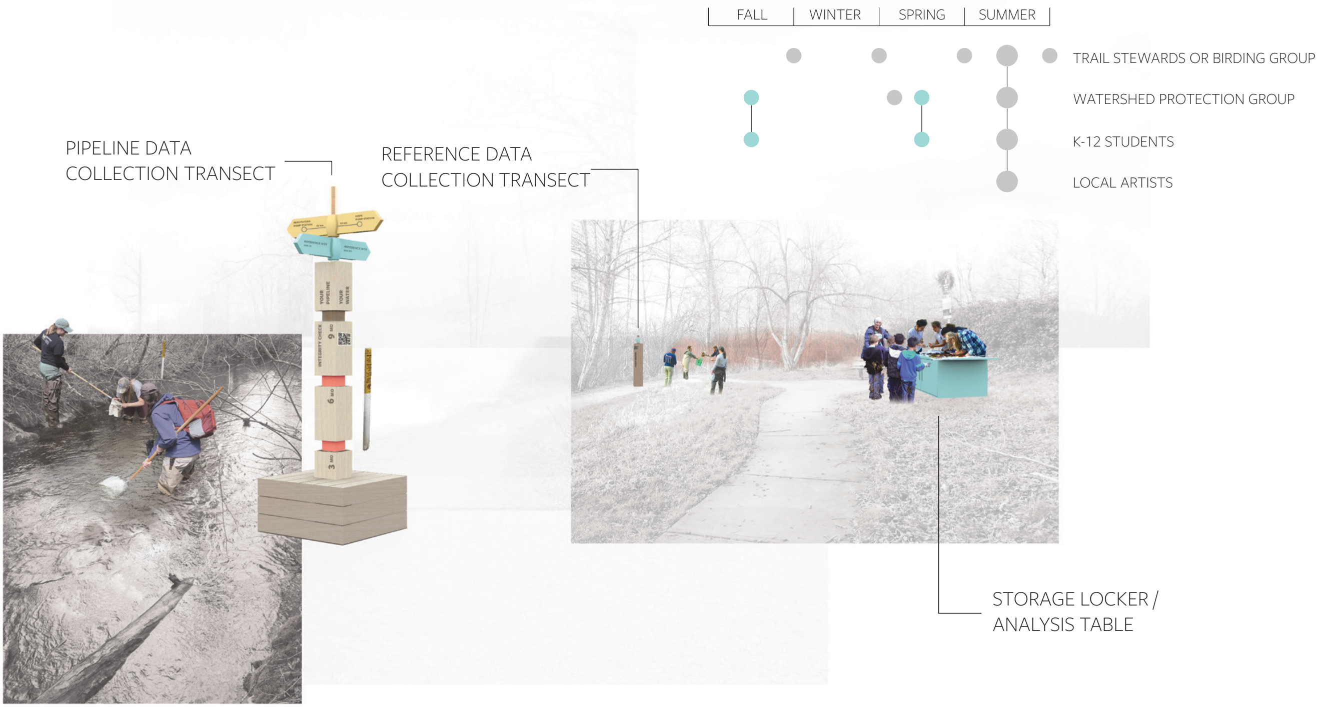




Marking Stream Monitoring

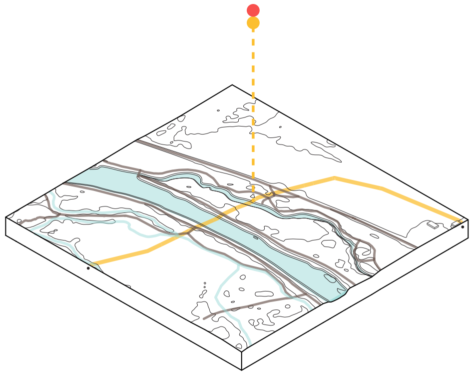


The wayfinding interventions also help citizen scientists to orient themselves (blue markers). Reference data collection transects are marked with shorter wayfinding interventions that indicate presence of citizen science activity and provide location-specific data via QR code. Participants measure stream health via macroinvertebrate surveys and other measures of water and sediment quality. Participants conduct macroinvertebrate surveys in spring and fall, and teach K-12 students about pollution-sensitive and pollution-tolerant taxa at a storage locker that doubles as an analysis table.



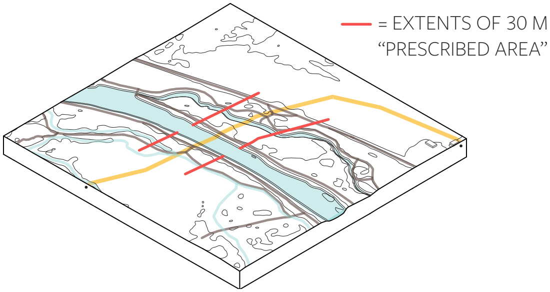
Marking In-line Pipeline Integrity Data

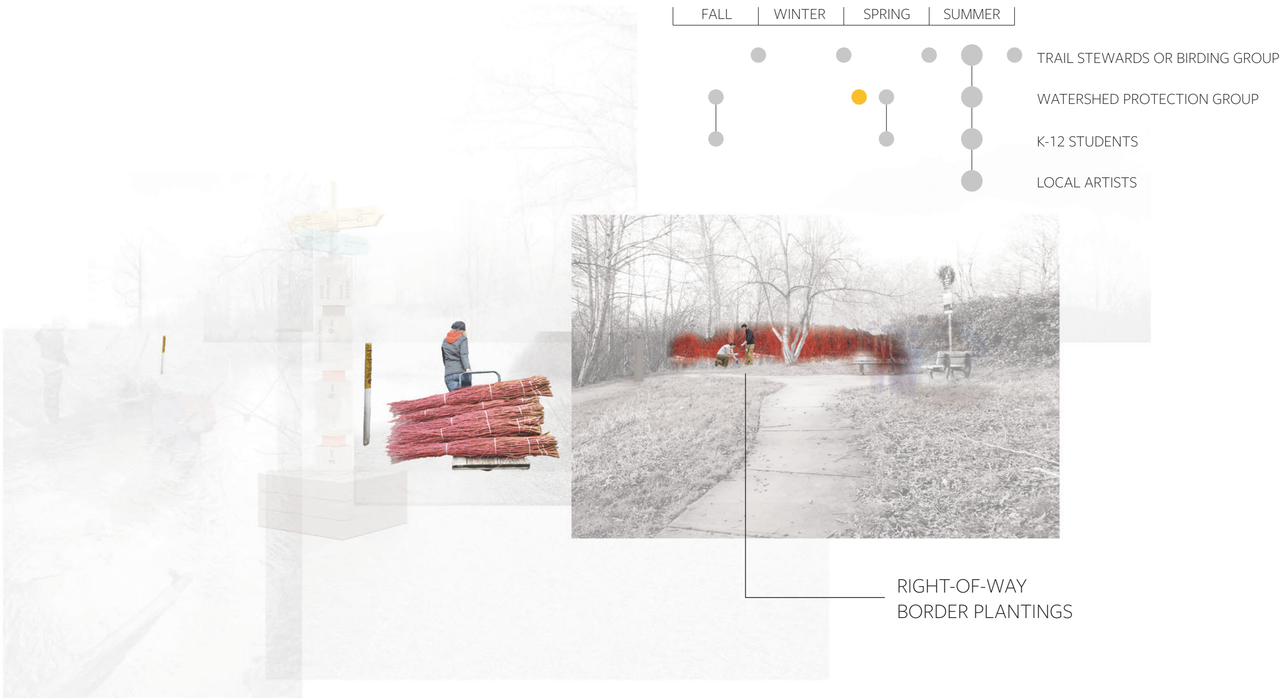
Given the many public stakeholders circulating through this site, the wayfinding point also provides an opportunity to bring awareness to transparency of corporate monitoring data, including that relating to integrity of the pipeline itself. Local trail stewards add red straps to indicate how much time has elapsed since integrity testing results were last made publicly available, a type of data that at present is never shared by the Trans Mountain Corporation. This creates more awareness of corporate data sequestration, and encourages accountability of pipeline company to the



Marking Rights-of-Way

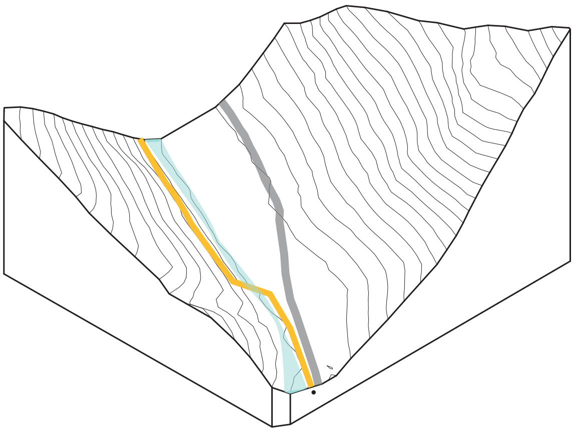
In this riparian zone, red osier dogwood marks the extents of the right-of-way. Plants become a dynamic marker delineating freely alterable public space from that which is de facto controlled by Trans Mountain. These plantings are educational tools that encourage dialogue around the politics of fossil fuel pipelines as colonial infrastructures.



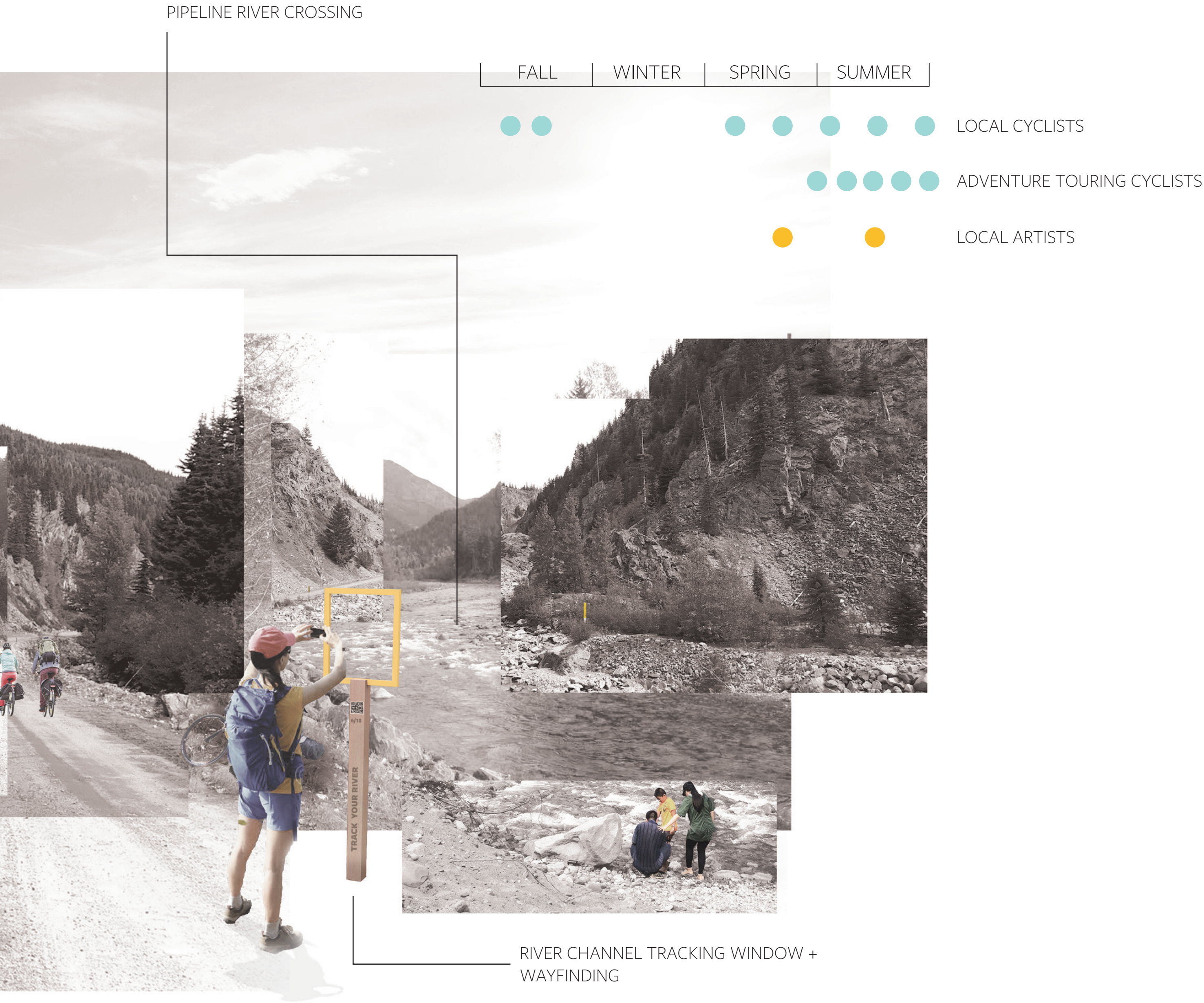


2. Tracking River Channel and Pipeline in an Alpine River Valley

Several critical sections of the Trans Mountain pipelines follow remote, sparsely populated alpine river valleys susceptible to dynamic landscape changes. Within these landscapes, cycles of temperature change, snowmelt, and accompanying geological and hydrological shifts cause landslides, rockslides, and flooding. These processes can expose and physically impact pipelines, increasing risk of pipeline spills. The set of interventions here test design for citizen science in this context, responding to the presence of existing stakeholders, including cyclists who access the valley's dirt pipeline maintenance road as part of designated cycling routes. In the event of a spill, other stakeholders from area communities may come to monitor spill response and remediation in this highly rural landscape.

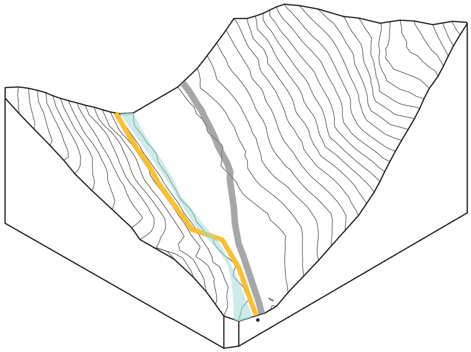


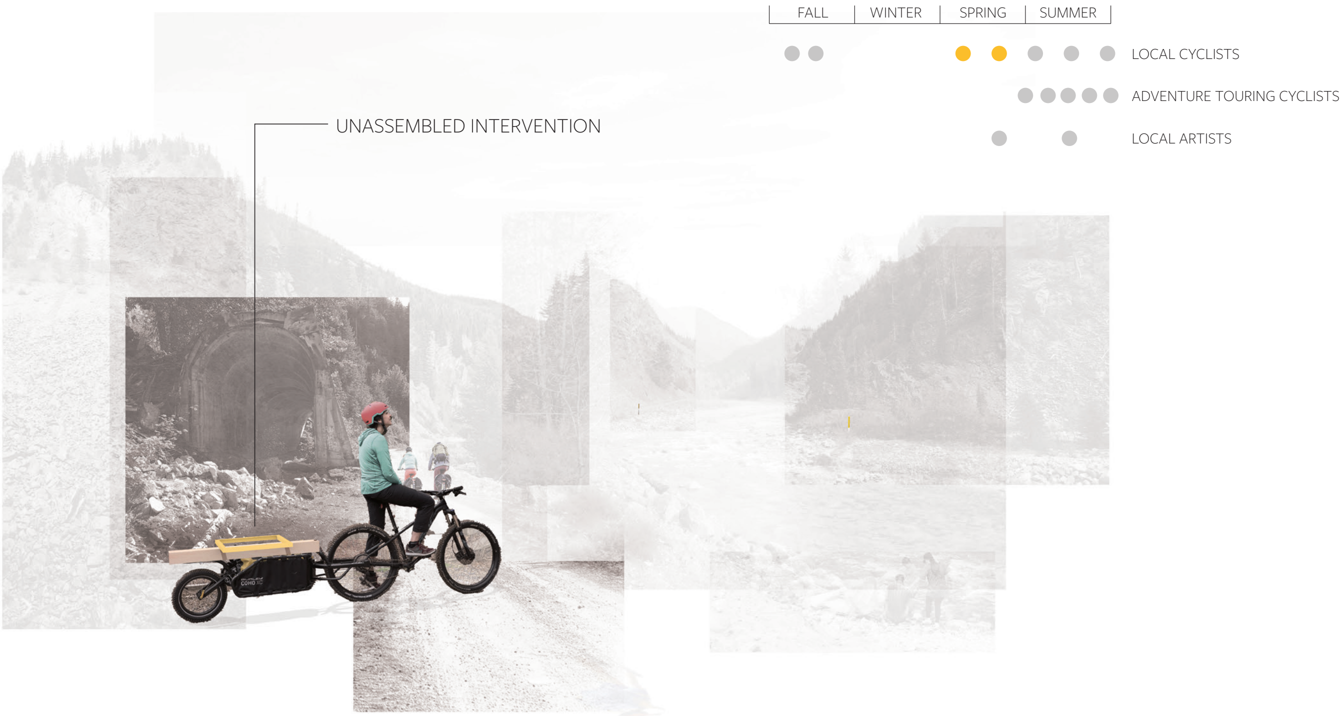
WAYFINDING
ON FORMER TRAIN TUNNEL


PIPELINE RIVER CROSSING
FALL
WINTER
SPRING
SUMMER
LOCAL CYCLISTS
ADVENTURE TOURING CYCLISTS
LOCAL ARTISTS
TRACK YOUR RIVER
RIVER CHANNEL TRACKING WINDOW + WAYFINDING

Installation of Lightweight Interventions

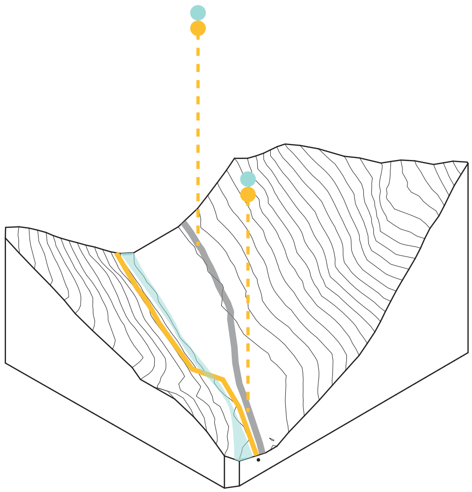
At the outset of establishing monitoring along the valley, local cyclists, designers, stream stewardship volunteers from nearby municipalities, and local ecologists work together to develop lightweight wayfinding and data collection interventions. Cyclists transport these interventions to the site by bicycle trailer in the spring.

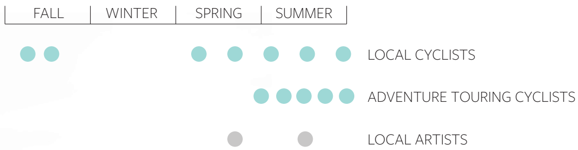


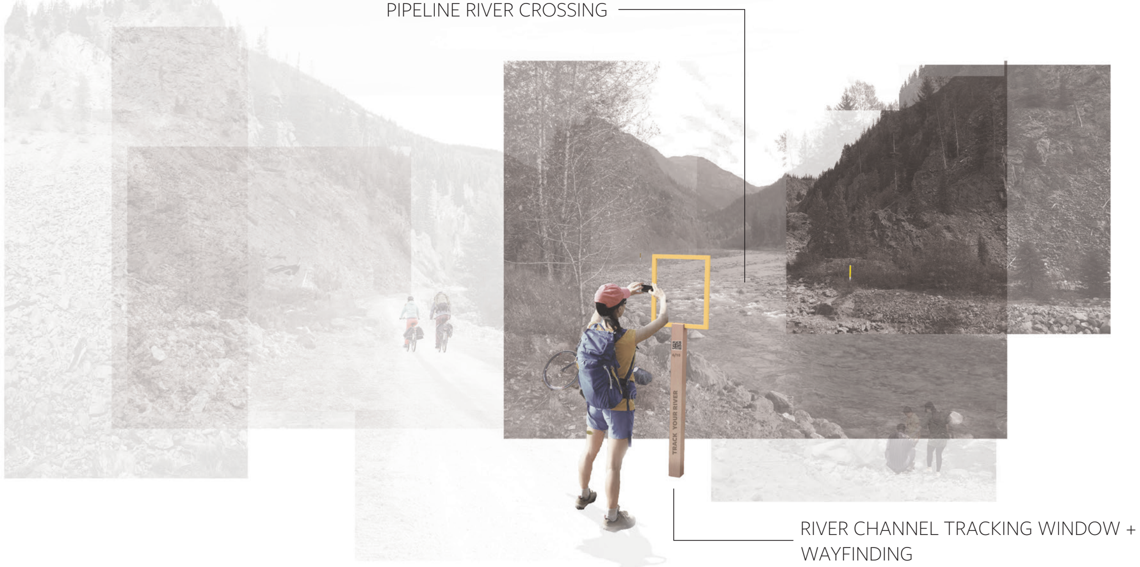


Crowdsourcing Documentation of River Channel Migration

One of these interventions is a “picture frame” wayfinding device that encourages passing cyclists to contribute photographs that track changes in the river channel, including those caused by flooding and rockfall. Volunteers place these interventions at strategic points along the maintenance road, corresponding to areas at highest risk for landslides, rockslides, or flooding-related changes. Citizen analysts alert the network if significant changes warrant further investigation as it concerns the pipeline’s integrity. The resulting on-the-ground assessments may challenge corporate accounts that are based on aerial survey.

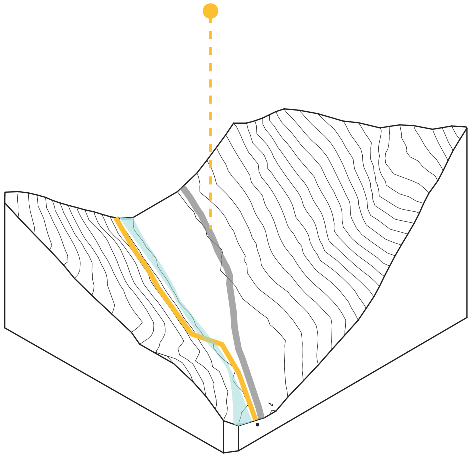


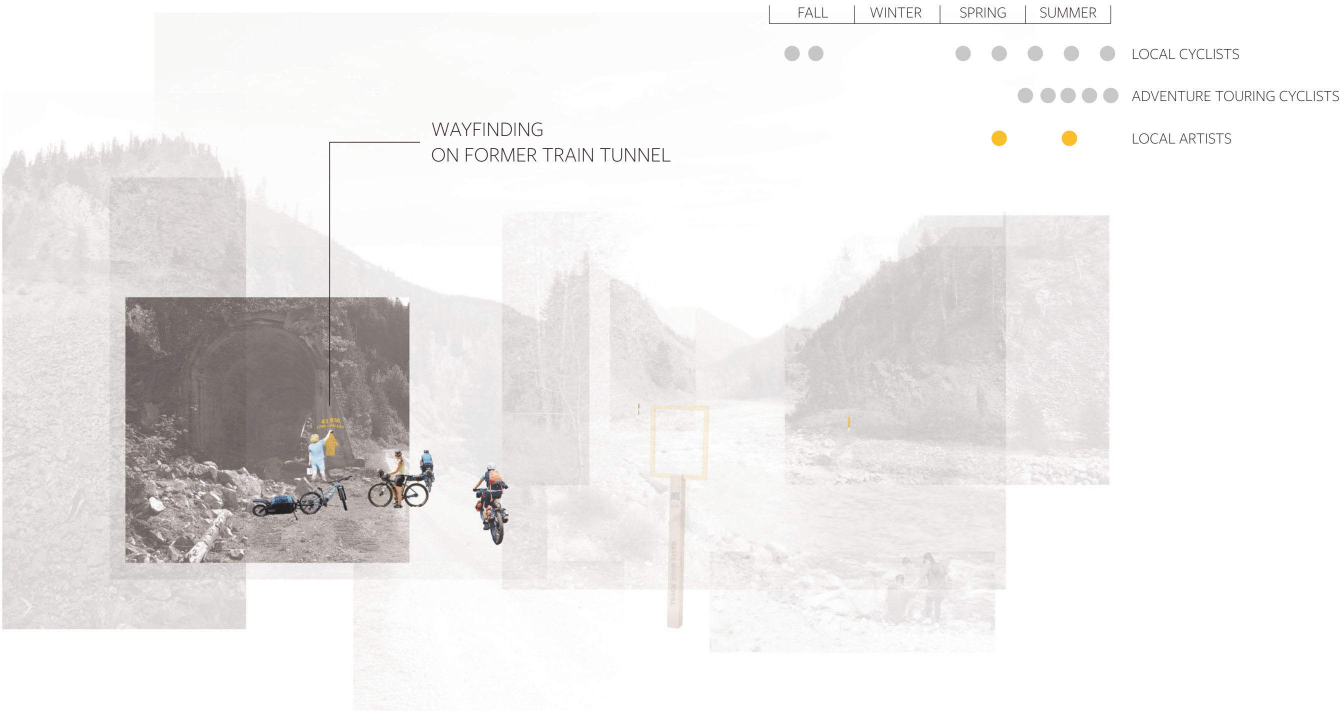




Historical Remnant as Wayfinding Point

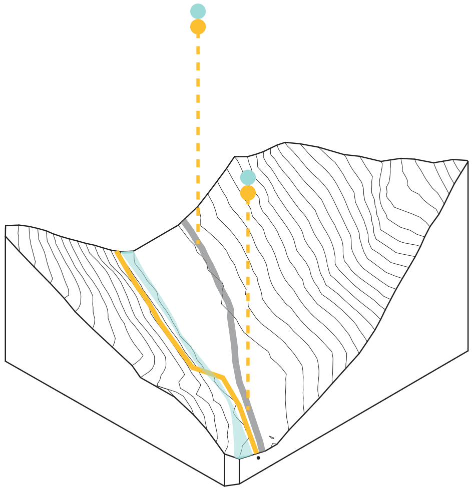
In addition to marking specific locations of data collection, citizen scientists and local artists may use existing structures along the service road to communicate further wayfinding information. For example, artists may paint remnants of a former railroad, such as abandoned tunnels. These interventions can communicate presence of the pipeline, its extents, or locations of past pipeline incidents.

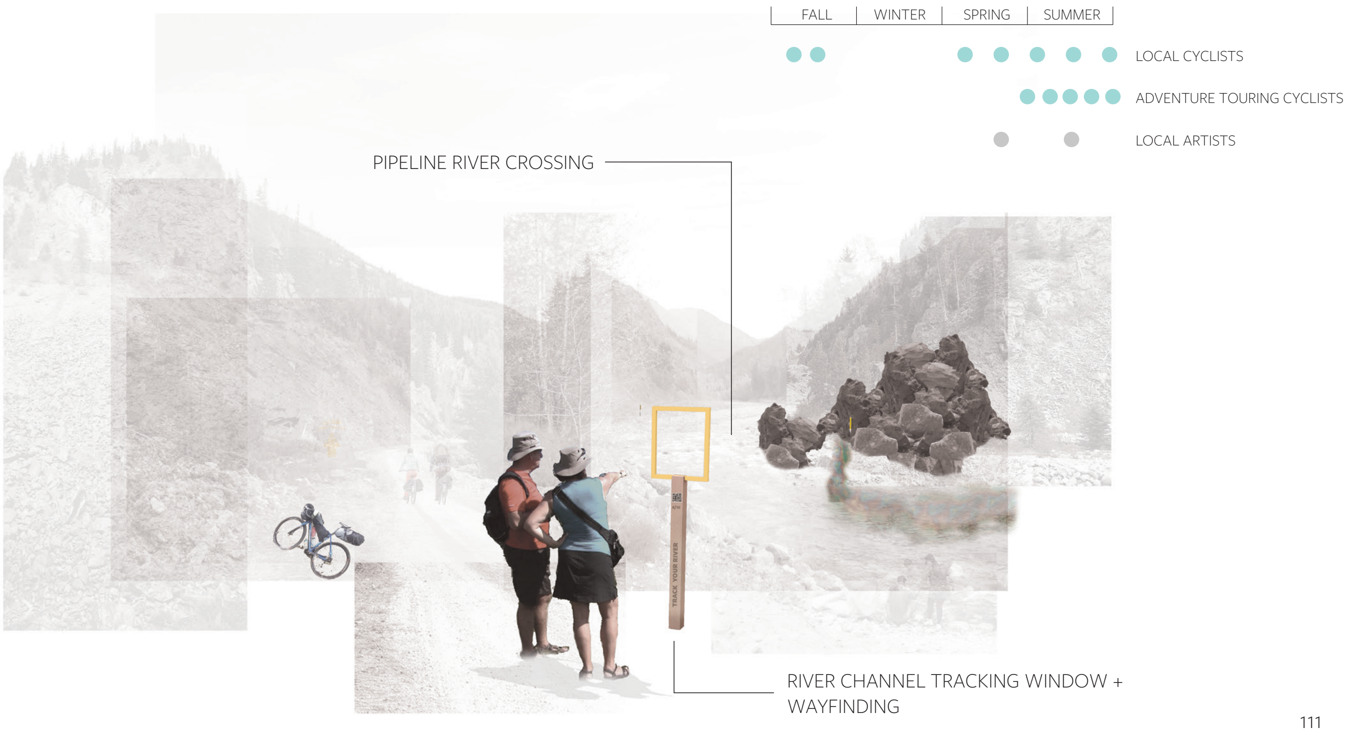




Detecting Release

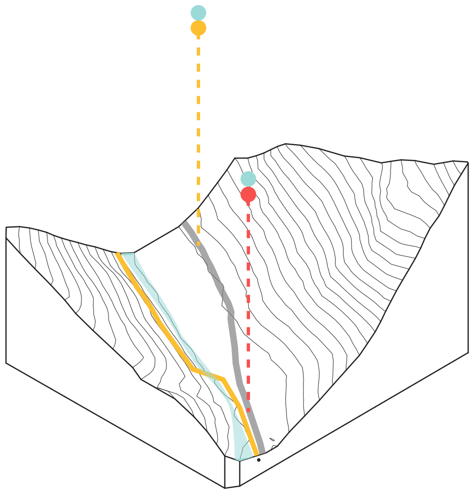
In the event that rockslide activity or channel migration is detected, passersby are encouraged to pay heightened attention at these locations of interest. In the event of a spill, they may notice evidence in visual (appearance of oil slick on the water's surface), olfactory (smell of oil), or auditory (hissing sounds) forms. Upon suspecting a spill, community members alert the citizen science network.

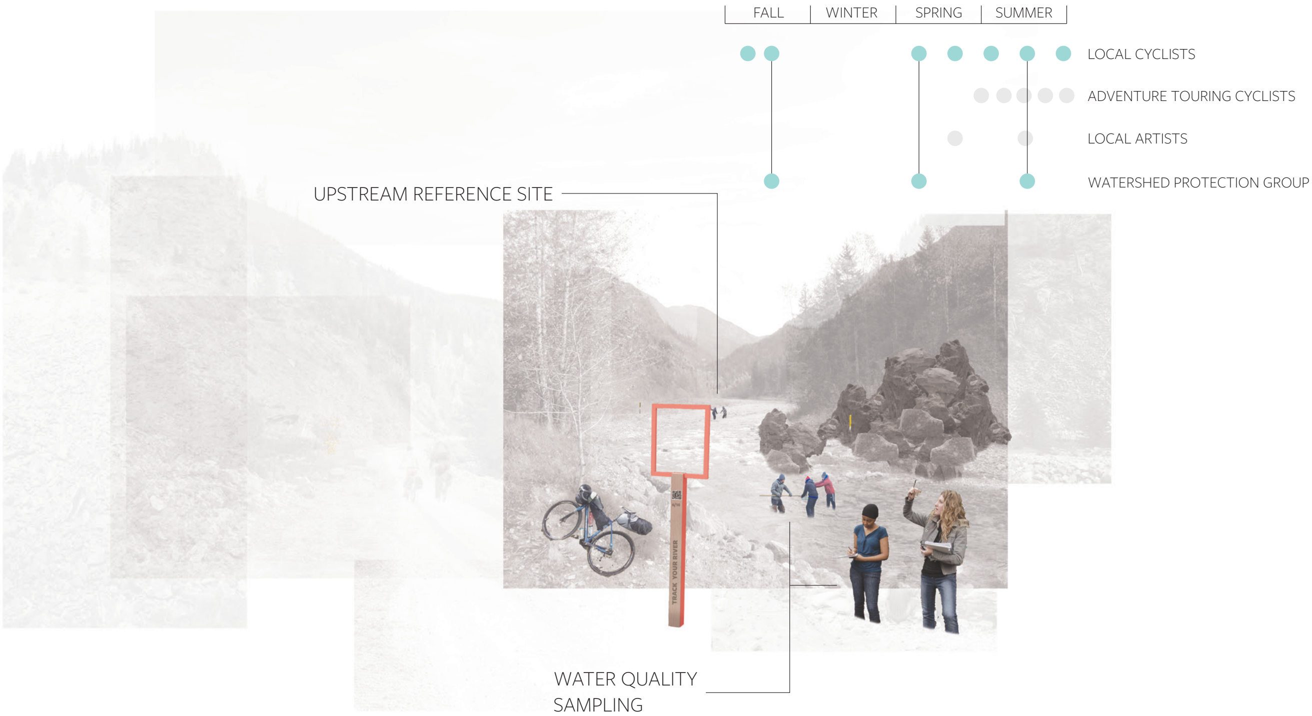




Marking Spill Response

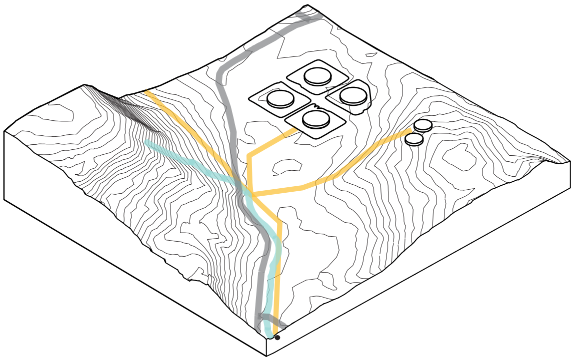
During spill response and remediation phases, wayfinding elements, including “picture frame” interventions, are re-painted red to signal alert, and marked accordingly within the mobile app. Residents living in the nearest municipalities, and especially those actively engaged in stream and river stewardship efforts, may organize trips several times per year to these remote locations to monitor the river for toxicity. These monitoring activities may include water quality testing, sediment testing, and, when cleanup is declared “complete,” monitoring the return of macroinvertebrate communities.

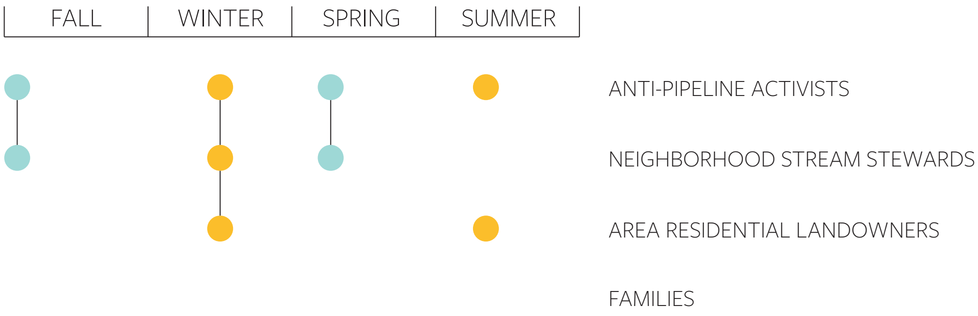




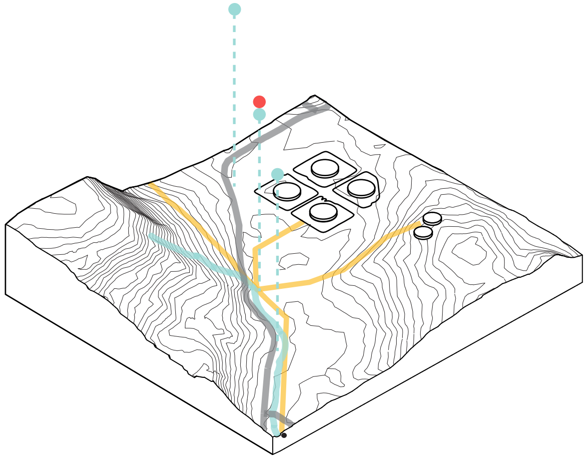
3. Monitoring Toxic Legacies at a Peri-urban Storage Facility

Storage facilities and pump stations are critical in the story of pipeline risk. At these locations, there are potentials for citizen scientists to bring greater oversight to remediation of past spill areas and detection of new areas of contamination.. Access to the lands adjacent to these facilities poses a central challenge, whereby private landowners may or may not be sympathetic to citizen scientists and their desired monitoring activities. As a result, these citizen scientists may find it necessary and constructive to practice a more guerrilla-style citizen science near roadways. This may take shape in the form of a tactical approach that makes use of public-facing infrastructure, such as utility poles. In this example, utility poles are the armature for data visualization regarding the persistence and migration of toxicities within soil, critical watercourses, and groundwater.



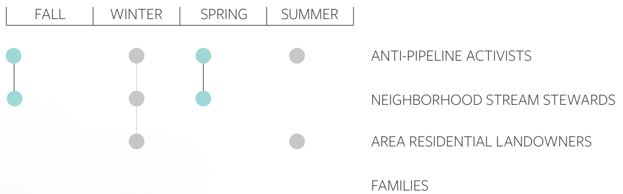


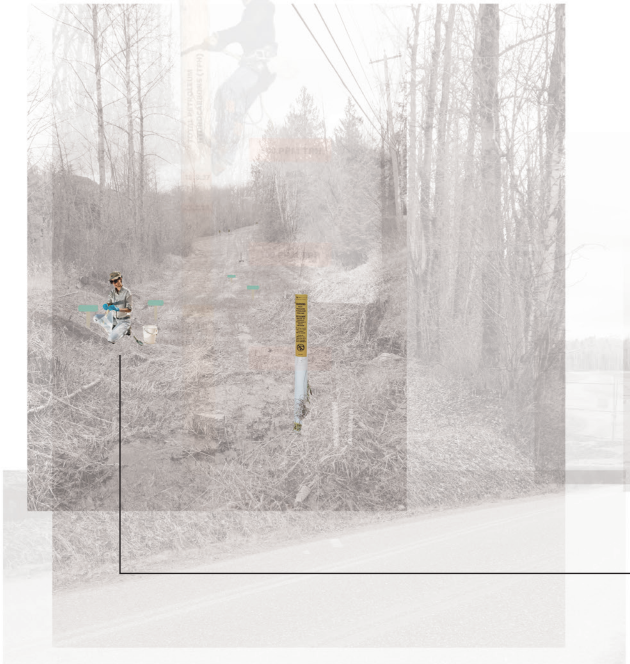
MARKING SOIL SAMPLING

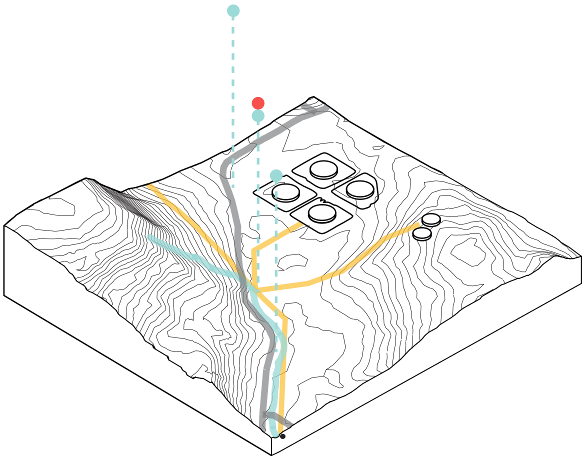


Tracking Toxic Migration

The primary citizen science activity for this site is soil testing. Biannually (or more frequently), local residents and other area activists sample transects at past spill locations, as well as at reference transects uphill and downhill of these locations. This activity may confirm or refute corporate claims about persistence and migration of toxicity within soil and surrounding streams. Sampling may be marked with simple stakes whose color signals citizen science data collection. Depending on available budget, participants can evaluate samples for presence of crude oil with home tools (like Public Lab's near-violet laser spectroscopy kit) or send samples to testing labs for more comprehensive analytical panels.

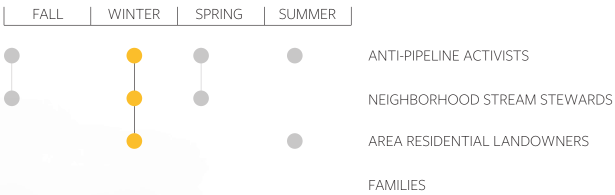


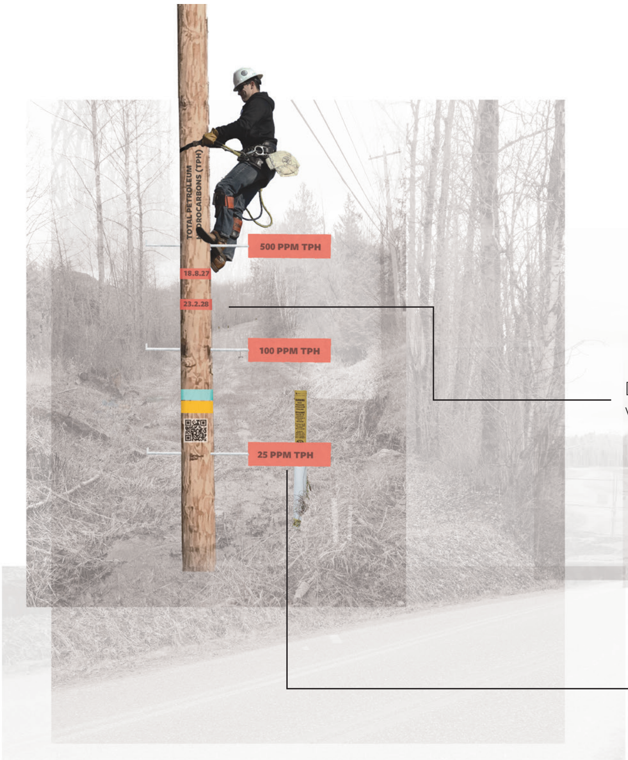


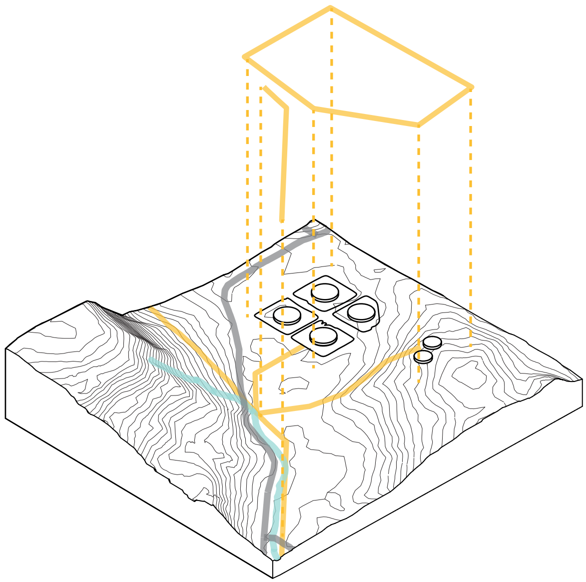


Marking Persistent Toxicities

As soil monitoring data accumulates, citizen scientists seek to make them more visible from the public realm through application of colored bands to previously unadorned utility poles, either in guerrilla action or in cooperation with utility pole owners and right-of-way landowners. Bands mark presence of pipeline (yellow) and data collection (blue), and red bands indicate data readings. Specialized pole steps mark well-established critical thresholds of toxicity along a vertical data "axis." Reporting of persistent high levels may trigger legally mandated remediation processes and bring more public awareness to ongoing issues.

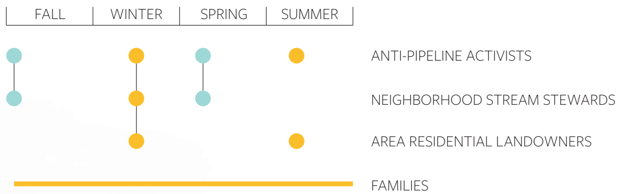






Monitoring Decommissioned Pipeline Landscapes

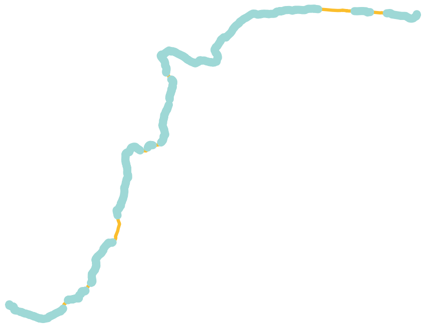
After decommissioning the Trans Mountain pipelines, the pipes will likely remain buried and invisible, but the fates of storage facilities is more uncertain. Municipalities may purchase these facilities, creating new public parks that are also repositories of pipeline history and sites where communities work with municipal entities to track remediation processes. In facility vicinities, former pipeline rights-of-way can be converted into walking trails that link park to neighborhood. These sites therefore become democratic spaces for spotlighting community-led stewardship of industrial and post-industrial sites, including the role of citizen science in those processes.



Conclusions: Designing for Site and Network

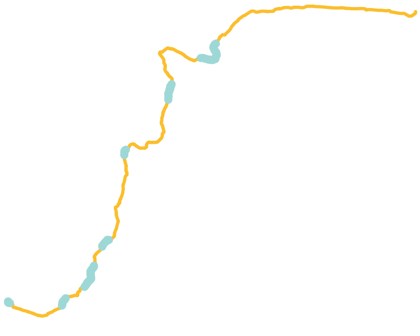
In this chapter, I described the role of landscape-based design interventions in amplifying citizen science practices within a pipeline-wide network. To do this, I chose to test how these interventions might help citizen scientists and general public connect to a larger citizen science network and to document intersections of the pipeline, human communities, and ecologies. Across these locations and scenarios, landscape architecture brings visibility to pipelines and to the potential for community agency over pipeline landscapes. This agency may be expressed by marking human activity, marking data, and through more general stewardship of place.

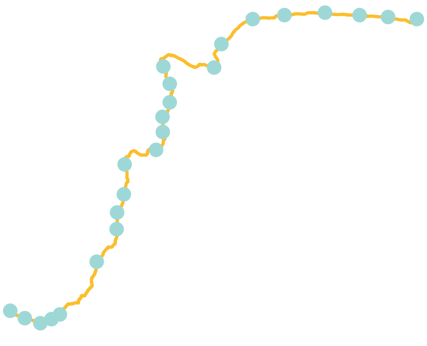
Applying this approach across the pipeline's many other risks and landscape typologies would require that I continually shift between network and site scales. In this design work, ideas about design for larger network interactions would inform site-based design, and vice versa. This feedback process suggests what might happen were this network to actually be established: locally-based designers might engage with their local communities and with a network-wide community of designers. Together, designers would work on adaptable interventions that amplify various citizen science practices. Design might therefore be considered an integral citizen science practice in its own right, as essential to success of citizen science goals as data collection itself.




TRACK YOUR RIVER


TOTAL PETROLEUM
DROCARBONS (TPH)
500 PPM TPH
18.8.27
23.2.28
100 PPM TPH
25 PPM TPH





7 Reflections

"The journey to a different future must begin by defining the problem differently than we have done until now. ... The task is not to find substitutes for chemicals that disrupt hormones, attack the ozone layer, or cause still undiscovered problems, though it may be necessary to use replacements as a temporary measure. The task that confronts us over the next half century is one of redesign."

-Dianne Dumanoski, John Peterson Myers, and Theo Colborn, *Our Stolen Future*[1]

There are many ways that landscape architects and other designers might engage with the risks of a pipeline. In this project, I suggest that one potential entry point is a citizen science network where members of the public track landscape change on and around the path of a pipeline through collection of data that may potentially contest corporate claims about toxic impacts of the pipeline. Within this citizen science practice, landscape architects participate through the design and implementation of site-responsive interventions that provide methods for marking place, data, and network. To interrogate this idea, I tested a design framework through a series of interventions at three sites, corresponding to three key risks.

Through this framework, I sought to contribute to a body of work that challenges traditional assumptions about landscape architecture design and practice. Specifically, this project proposes

landscape architecture embedded within politically aware, activism-based community work in the form of citizen science. As such, the landscape architect is not in service to a client, but rather is a co-creator of change—in this case, within efforts to democratize infrastructure monitoring. This type of design activism practice engages with landscape in ways that challenge status quo colonial politics, which prioritize fossil fuel industry interests over community well-being.

While I explored design for three key risks associated with the Trans Mountain pipelines, there are many other potential risks I could have explored in this project. These include contamination of aquifers, wildfire risk, seismic risk, and disturbance of habitat corridors. Each of these risks corresponds to different landscape typologies and citizen science practices. By testing design in these other contexts, a richer design language for the overall network might be synthesized and proposed.

As a broader exploration, the framework of this thesis might be applied to the landscapes of other types of potentially toxic infrastructures. In these other contexts, the primary goals of design for citizen science would remain the same, but the work would likely produce an entirely different design language. For example, a citizen science network that tracks air pollution associated with oil refineries introduces a completely different set of contextual factors, where more frequent sub-acute bursts of pollution dissipate over many miles. Compared to pipeline monitoring, there is therefore an entirely different set of design challenges relating to spatial, temporal, social, and toxicological factors. The resulting citizen science network and accompanying design work would look very different and is worth exploring.

Another potential direction for this project is the engagement of more confrontational political action that would draw on citizen scientists' deep knowledge of data and place. In particular, it is important to consider protest as a potential type of "data performance" (as discussed in Chapter 3) that might broadly and impactfully communicate toxicity-related data. This exploration might test design interventions for protest that make effective use of citizen science data, in the process engaging politicians and the general public with issues of environmental justice.

The idea of citizen scientists as activist protesters is not without precedent, as many citizen science groups, including members of the Louisiana Bucket Brigade, have in the past protested as a means of generating attention around issues of concern. My proposal for potentially exploring protest as data performance is also inspired, however, by the current racial justice protest movement, which in many instances has used data to make more effective arguments for change.

In light of these current movements pushing for more racially just systems and built environments, it is important that I describe how I see this project relating to those efforts. I pursued this thesis topic out of an interest in climate justice and environmental justice issues related to toxic pipelines, downstream infrastructures, and surrounding communities. Historically, these and other infrastructures associated with petrochemical industries have disproportionately affected Black communities, Indigenous communities, and other communities of color (BIPOC). As it concerns the Trans Mountain pipelines, I discuss in Chapter 4 the issue of direct impacts (potential and realized) on 130 Indigenous groups and the unceded ancestral lands of many Indigenous peoples. These pipelines represent a forced colonial imposition of dangerous infrastructures on these communities, and therefore a continuation of several hundred years of colonial violence against Indigenous peoples in Canada. The failure of Trans Mountain to regard consent by Indigenous groups as necessary in the TMX application process therefore ties this project to broader movements of racial justice.

As a white-identifying settler male, these are not my stories. In my research from afar in Seattle, I primarily turned to secondary sources to better understand how the pipeline and its risks are perceived by some members of these communities. What I learned in my research influenced my understanding of key issues and the resulting framing of design approaches, but I would have liked to have more deeply and meaningfully engaged members of Indigenous communities and other BIPOC communities affected by the Trans Mountain pipelines. The resulting design work might have more directly and explicitly spoken to the potentials of citizen science activism within these affected communities, which deserve a spotlight and substantive, unconditional support from all designers. Moreover, ideas within this project might be picked up and reenvisioned by members of various communities affected by these pipelines.

Regardless, I brought my own identities and worldviews into this project, and that included the ways I defined citizen science, whereby I privileged a Western science approach that is steeped in histories of colonialism. A deeper engagement with Indigenous communities might have provided an opportunity to broaden my definitions of data, and to allow Indigenous voices to speak to different forms of knowledge that Western systems, including many institutions of Western science, have historically devalued. That said, it is also worth noting that many Indigenous citizen scientists participate in Western science-based practices as part of stewarding the places for which they care, practices that are not necessarily in conflict with non-Western forms of Indigenous knowledge.

This project is a response to a physical infrastructure whose routing, operation, and lackluster monitoring are all symptoms of the colonial, racist system that I discuss in this thesis, especially in Chapter 4. Through a framework-based approach to design, I aimed to explore a landscape architecture practice that directly responds to the power dynamics of that system, and to insert design as a practice that encourages community agency and supports healthier human and non-human communities. In its exploratory nature, this project of design for citizen science is therefore just a beginning and an entry point into a larger puzzle.

Endnotes

1. Dianne Dumanoski, John Peterson Myers, and Theo Colborn, *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival?* (New York: Penguin Group, 1997), 248.

Appendix


TRANSMOUNTAIN
Trans Mountain Pipeline
WARNING
HIGH
PRESSURE
PETROLEUM
PIPELINE
AVERTISSEMENT
PIPELINE DE
PRODUITS
PÉTROLIERS À
HAUTE
PRESSION
CALL BEFORE YOU DIG
1-800-474-6886
TELEPHONEZ
AVANT DE CREUSER
IN CASE OF
EMERGENCY CALL
1-888-876-6711
EN CAS D'URGENCE,
VEUILLEZ COMPOSER LE
CALL BEFORE YOU DIG

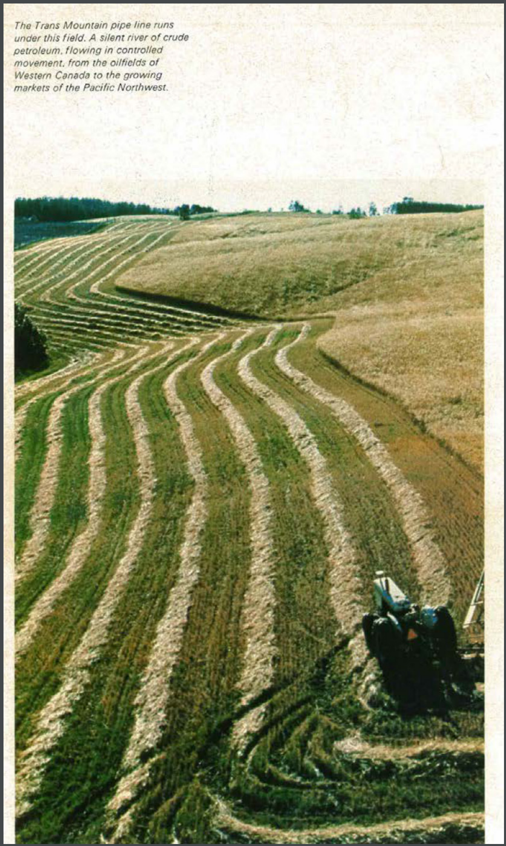
Appendix A1. Predominant Ecosystems of the Trans Mountain pipelines

The TMP and proposed TMX pipelines traverse many ecosystem types but primarily various types of coniferous forest. They also pass through grasslands ecosystems that are home to a large percentage of B.C.'s at-risk species. These areas include the Lac Du Bois Grasslands Protected Area in Kamloops, which is discussed in Chapter 4.

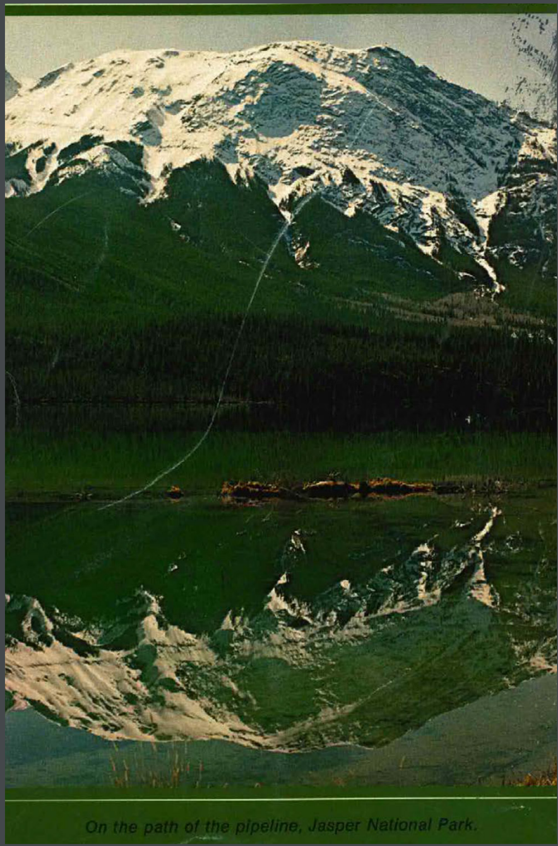

TRANS MOUNTAIN PIPELINE
PUGET SOUND PIPELINE
TANKER ROUTE
POPULATION CENTER/
FIRST NATION RESERVE
CONIFEROUS
FOREST (B.C.)
GRASSLANDS
(B.C.)
PROVINCIAL +
NATIONAL PARKS
N
50
100
200
KM

Appendix A2. Trans Mountain Annual Report Images

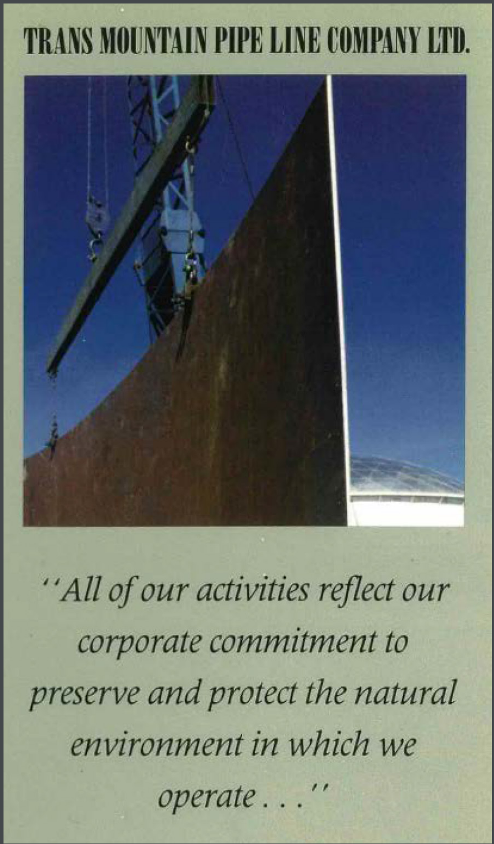
The following Trans Mountain marketing images, all of which were part of the company's annual reports, depict a pipeline that is in harmony with communities and environment.



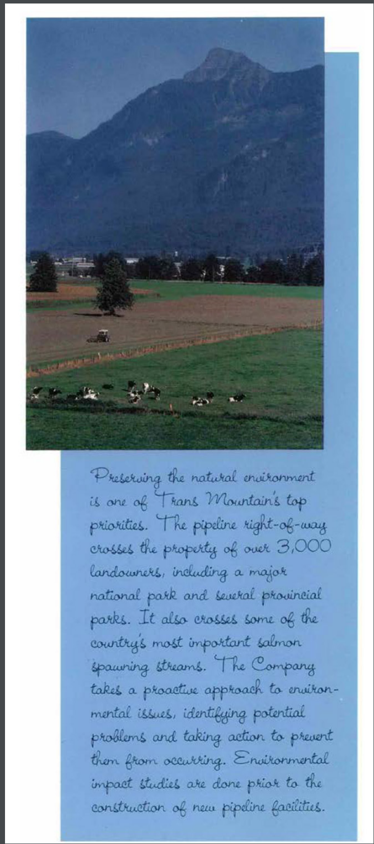
1970



1973



1989

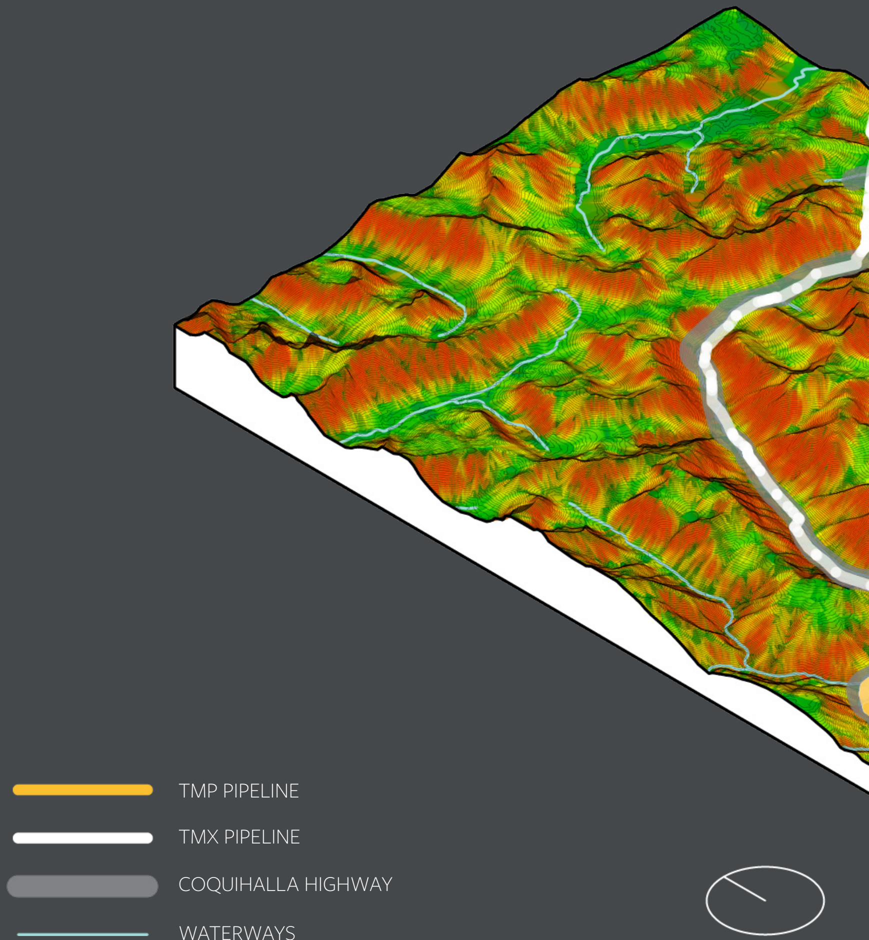


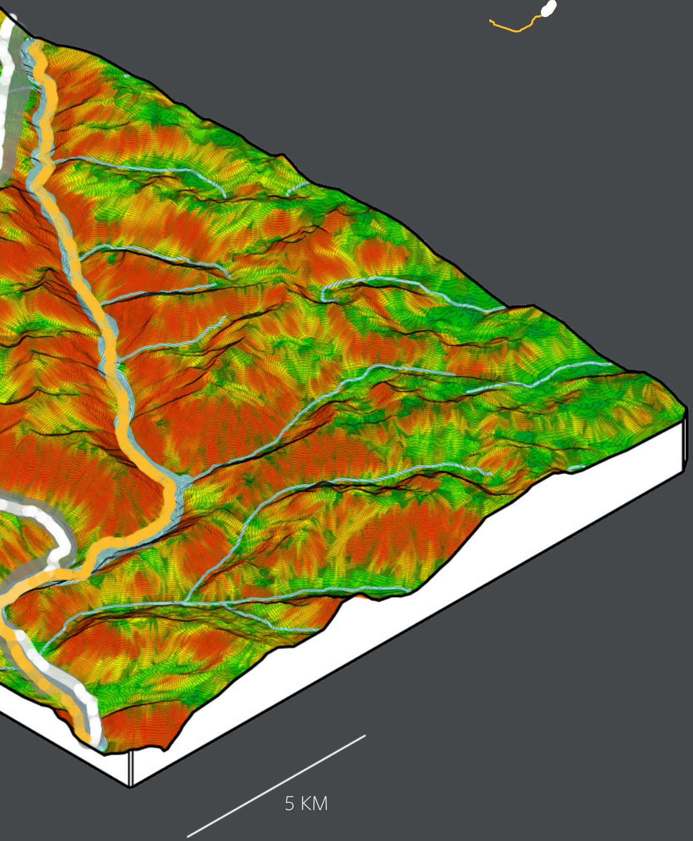
1990

All images from Trans Mountain Pipe Line Company *Annual Report* publications (Trans Mountain Corporation). Reproduced from Kheraj, "Historical Background Report: Trans Mountain Pipeline, 1947-2013," (City of Vancouver, 2015).

Appendix A3. Slope Analysis of the Coquihalla Valley

Steep slopes frame the paths of the TMP and proposed TMX pipelines, which follow the Coquihalla River and Coquihalla Highway, respectively.





A terrain model was generated using qGIS and Lands Design. Slope analyses were generated using the Grasshopper plugin Bison.

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Bibliography (Style: Chicago 16th Footnote)

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