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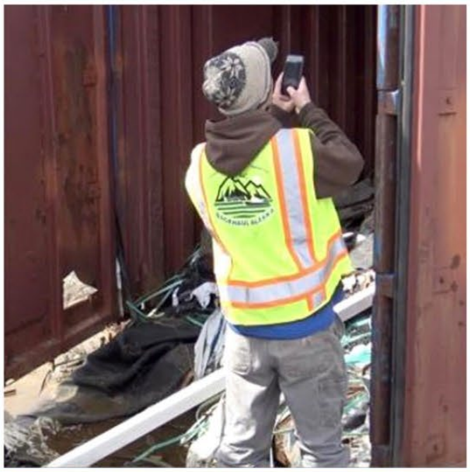

Office of Research and Development
Center for Environmental Measurement and Modeling
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Using Human-Centered Design to Create a Hazardous Waste Management App for use in Rural Alaska

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The list (above) excludes project participants who are also named authors of this report.

Acronyms and Definitions

ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
AIS	Automatic Identification System
AK	State of Alaska
ANTHC	Alaska Native Tribal Health Consortium
App	Digital application, especially a software application designed for a mobile device
ATV	All-Terrain Vehicle
Backhaul	Cargo carried on a return journey; to carry freight on a return journey
CIFAR	Canadian Institute for Advanced Research
CONEX	a type of shipping container: *Con*tainer *Ex*press (a large, steel-reinforced reusable container for shipping or storage).
CT	Control Tower
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ESRI	Environmental Systems Research Institute; suite of mapping tools by Esri Inc.
e-waste	Electronic waste
GIS	Geographic Information System
GPS	Global-Positioning System
GIF	a file in Graphics Interchange Format
HHW	Household Hazardous Waste
IARPC	Interagency Arctic Research Policy Committee
ID	Identification number
IRB	Institutional Review Board
LEO	Local Environmental Observer; LEO Network members share environmental data
MB	Megabyte
N/A	Not Applicable
OLEM	EPA Office of Land and Emergency Management
ORD	EPA Office of Research and Development
OS	Software operating system
PCB	Polychlorinated Biphenyl
PPE	Personal Protective Equipment
QAQCs	Quality Assurances and Quality Controls
R10	EPA Region 10
RC	Regional Coordinator
RCRA	The Resource Conservation and Recovery Act
RSTIP	EPA Regional State Tribal Innovation Project
SC	Statewide Coordinator
SWAT	Solid Waste Alaska Taskforce
USB	Universal Serial Bus, a standard for connecting digital devices to each other
VC	Village Coordinator
VHF	Very High Frequency Radio
WA	State of Washington
Wi-Fi	Wireless networking technology that uses radio waves to provide Internet access

Abstract

Roughly 200 rural Alaska communities, with mostly Alaska Native populations, operate Class III landfills that are not lined (due to environmental constraints). In such landfills household hazardous waste (HHW, e.g., batteries, electronics, and light bulbs) can leach chemicals into the environment which, through various pathways, impacts human health and subsistence resources that provide economic and nutritional value for many community members and are important culturally and for other reasons. Waste burning without emissions treatment or temperature control is also carried out at many of these landfills to reduce waste volume; presenting another potential point for toxins to enter the environment. Additionally, reactive and ignitable HHW materials can explode or catch fire under certain circumstances. To avoid potential toxin release, many communities employ "backhaul" as much as possible, which involves shipping out waste on barges and planes that might otherwise return south empty after bringing materials into communities. Communities receive discounted shipping rates; however, the practice is still expensive, coordination is challenging, and training is needed to ensure waste is packed properly and safely.

A program called Backhaul Alaska was created to address these challenges on a statewide scale. After developing successful approaches in several pilot locations, Backhaul Alaska identified a need to develop a digital application, or app, to support and improve backhaul training, waste inventory, tracking, and feedback. In response, this United States Environmental Protection Agency (EPA) Regional-State-Tribal Innovation Project (RSTIP) evaluates how an app can best support Backhaul Alaska and how different technology options might address these needs. We took a human-centered design approach that considers how the design of a technology goes beyond target users and looks at the full socio-political context in which a product is developed and deployed. We conducted 45 conversations, presentations, and/or workshops with 38 individuals internal and external to Backhaul Alaska and analyzed video footage of a pilot app being used by the program. Through qualitative analysis, our research identifies and describes critical themes and other program considerations that app development must address. We evaluate different users' app needs and how users relate to and work with digital technology. Critically important for app development, we also outline existing knowledge gaps about users' needs and how these unknowns should be taken into consideration when developing an app. We also evaluate the pros and cons of four app development options and how they suit Backhaul Alaska. While there is no perfect solution, our work provides a blueprint for developing one or more options to support Backhaul Alaska and provides important lessons learned for other programs operating in similar contexts that might wish to develop apps.

Executive Summary

There are roughly 200 communities in rural Alaska that operate Class III landfills. Class III landfills in Alaska are unlined (due to environmental constraints), which means that leachate cannot be collected and treated as it typically would in a lined landfill; and waste is often burned, without emissions control, to reduce volume. This is allowed under Alaska Administrative Code 18 AAC 60 (Alaska DEC 2022), because of a lack of infrastructure in rural Alaska. Leaching and burning of household hazardous wastes (e.g., lead acid batteries, electronics, and light bulbs) releases contaminants, creating human exposure risks. Contaminants also enter local food chains and are detrimental to cultural and subsistence hunting, fishing, and gathering activities that are important to residents, the majority of whom are Alaska Native. One option to deal with hazardous wastes is to "backhaul" them, a process where waste is shipped out on planes or barges that might otherwise return south empty after bringing materials into communities. Even at discounted backhaul rates, the practice is expensive, coordination is challenging, and training is needed to ensure waste is packed properly and safely.

To support solid and hazardous waste removal, a program called Backhaul Alaska was developed to coordinate statewide recycling logistics and provide training and assistance to community staff to ensure waste is safely and properly packed for transport (SWAT 2017, 2023, Backhaul Alaska 2017, 2023, https://backhaulalaska.org). As Backhaul Alaska expands past its successful pilot phase to eventually serve all rural communities statewide, program administrators identified a need to use digital applications (apps) to improve communication, data inventory, program management, and participant training.

In response, this United States Environmental Protection Agency (EPA) Regional-State-Tribal Innovation Project (RSTIP) aims to: (1) Understand the goals, practices, and preferences of Backhaul Alaska participants to ensure that app development meets their needs; (2) Identify areas where an app or similar technology can help build capacity for Backhaul Alaska and its constituency; and (3) Communicate the research process and outcomes to other programs operating in similar contexts. The project builds on a longstanding working relationship among EPA Region 10, EPA Office of Research and Development (ORD), and local partners working on backhaul and tribal solid waste management challenges in Alaska. This report is informative to Backhaul Alaska, its tribal participants, other groups with connections to Backhaul Alaska, and technology developers who might create future content for the program.

We took a human-centered design approach that considers how the design of a technology goes beyond target users and the immediate work environment where it will be used to understand how it will impact and be impacted by the larger social and environmental context in which it operates. Accordingly, we: (1) sought to learn from existing environmental or resource management apps being used in the region; (2) had conversations (interviews) with regional waste management experts (working external to Backhaul Alaska), technology experts, and Backhaul Alaska pilot participants and staff; and (3) analyzed video footage that was collected by pilot program participants and staff as they conducted backhaul activities and training, and used a pilot app in the field. Research activities were synthesized at several stages and communicated with Backhaul Alaska pilot participants and administrators to discuss project findings, explore outstanding questions, and co-interpret the work, resulting in 45 conversations, presentations, and/or workshops with 38 individuals.

Through qualitative analysis, our research details the working conditions in which people do backhaul work, as well as their views and attitudes about how they can be supported by an app. We identified and analyzed eight important themes: (1) working offline and in remote locations, (2) communication and coordination, (3) creating community profiles, (4) capacity building for people and programs doing the work, (5) inventorying and sharing information about equipment and materials, (6) opportunities for synergies, (7) addressing liability and safety concerns, and (8) addressing data sovereignty and culturally specific considerations for Alaska Native communities. We also evaluated how the program will grow over time, data management needs, and geospatial needs. Our analysis of these program dynamics provides a blueprint for developing a Backhaul Alaska app.

We also created user profiles detailing what different users will need from the app and how the app must account for their specific work environments and personal backgrounds. Critically important for app development, we also outline existing knowledge gaps about users' needs and how these unknowns should be taken into consideration when developing an app. Some things about users and their needs are unknown because of the limitations of this study. For example, we were unable to speak directly with all users. Unknowns and uncertainties in this category may warrant more specific user-based research. Other items remain unknown because Backhaul Alaska is continuing to evolve around how best to remove hazardous waste from rural Alaska communities, build local and regional capacities, support job creation, and improve human well-being. Therefore, app development must be able to adapt to program changes.

Finally, we assess the pros and cons of four app development options and how they suit Backhaul Alaska. These include custom app development, using third party apps (often chosen over custom development to reduce cost and long-term maintenance of the technology), web apps, and websites. We note tradeoffs in functionality and customizability vs. cost, which were key considerations for program administrators. Importantly, there is no one best solution. We also document Backhaul Alaska's experience trying two third party apps. This mini case study highlights the importance of financial costs when making decisions, and how previous investments in learning to work with a specific tool can be an obstacle to adapting something new. We also compare record collection with a digital app and paper-based documentation, verifying that digital technology was preferred.

Our work highlights important and transferable lessons. First, do not develop a tool based on an assumed problem. The initial scope of the project was to understand how to design a custom app. A fundamental principle of human-centered design, however, is to validate the problem statement through research. Once we understood the interests of most of the potential users, and learned from working with the pilot apps, we ended up shifting the focus from custom app development to more affordable alternatives. We chose not to develop or test specific user interfaces, which would take valuable researcher and participant time for something that may not have been needed. Rather, we continued to build foundational knowledge about the program's app development needs to inform app development options. We did, however, document important user interface improvements based on evaluation of one of the tested third-party apps.

Second, human-centered design can be a long road. Even after we formally closed the research phase of our project, EPA researchers and Backhaul Alaska administrators continued to work together to optimize Backhaul Alaska implementation, e.g., discuss third-party app options in order to assess product suitability for Backhaul Alaska, evaluate prices for different licensing options, and decide on a near-term app solution.

Building trusting and long-term working relationships is vitally important when designing from a human-centered perspective, perhaps even more so when the work depends on trust and relationships from community participation. We encourage other programs doing similar work to commit fully to developing these relationships, even if it means pushing back deadlines or engaging in extra tasks.

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Section 1. Introduction

1.1 Household Hazardous Waste in Rural Alaska and the Need for an App

During several cold spring days, working in the wind-swept Alaska tundra, local community members in a small, mostly Alaska Native fishing community, along with a state-wide nonprofit, gathered and safely packed 3,334 pounds of electronic waste, 12,558 pounds of lead acid batteries, and 283 pounds of UV lamps (Zender Group 2022). The material would later be transported south to Seattle, Washington where it could be safely disposed of or recycled in an appropriate facility. Had the waste not been shipped out, it would continue to accumulate indefinitely and leach into the environment over time, or worse, have been burned in an uncontrolled manner, releasing toxins and other contaminants.

The majority of communities in rural Alaska, roughly 190, have no road access to the State Highway System or to other communities (Barnes 2020), and are accessible only by boat or plane. Removal of waste and transporting it to an appropriate end-destination at a larger city recycling or disposal facility is both costly and difficult. Even for those communities that are connected to the road system, transport is challenging because of harsh weather or poor, often seasonal, roads. Due in part to their remoteness, communities in rural Alaska lack the infrastructure to safely dispose of hazardous waste locally. Because of complex geohydrological (land and water systems), economic, and logistical factors, most small communities in rural Alaska operate Class III landfills that, in compliance with Alaska Administrative Code 18 AAC 60 (Alaska DEC 2022), are exempt from several protective elements of the federal Resource Conservation and Recovery Act (RCRA) municipal landfill regulations, which outline minimum design and operation requirements. Class III landfills are unlined, which means that leachate cannot be collected and treated, as it would in a typical lined landfill. As part of the exemptions, burning of waste in steel tanks or cages lacking emissions treatment as well as any temperature and air controls may also occur because it is an inexpensive means of volume reduction and landfill litter control.

Toxic contaminants, via waste degradation and subsequent leaching or waste burning, are released into the surrounding soil, water, and air from Class III landfills. Of particular concern are electronic waste (e-waste) and lead acid batteries which contribute an estimated 95 percent by weight of toxic heavy metals in municipal waste streams (EPA 2021). Because community landfills in rural Alaska are often proximate to homes, human activities, water bodies used for drinking water, marine transportation, subsistence harvesting, and other purposes (Zender Group 2017, Kawerak 2021), there are many potential exposure pathways that can negatively impact human health and the environment (Samuelson 1998, Eisted and Christensen 2013, Keske et al. 2018).

One option to deal with these hazardous materials in rural Alaska communities is to ship them out by a series of plane and/or barge transportation legs to recycling processing facilities. This process is called "backhaul," which gets its name from the utilization of vessels, aircraft, and vehicles used in transportation that otherwise would have returned empty to hub locations from rural communities. There are no hazardous waste processors in Alaska, so materials must be transported to Vancouver or Seattle before being routed to its final destination. Arranging shipment is complicated and requires an iterative series of steps (Zender Group 2017, Kawerak 2021).

Intermittent backhauling by a handful of individual communities and organizations started in rural Alaska in the early 2000s. Many barge and plane transporters supported this effort and even provided free-of-charge or discounted shipping. By the 2010s, backhaul became more widespread throughout rural Alaska. Around this time, transporters began seeing not just increased volume, but poorly packaged materials, mislabeled hazardous waste, leaking batteries, and more (Figure 1.1). Shipping of hazardous waste falls under strict federal United States Department of Transportation (DOT) packaging regulations and requires safety training for all personnel that handle or transport the waste. At that point in time, recyclers were receiving materials that they had not agreed to take and for which communities did not pay. As a result, companies started to refuse any backhaul materials from rural Alaska, while others would not serve many of the smaller communities, and backhaul costs began to increase (Personal observations by authors LZ, RK, and SS who helped develop the Backhaul Alaska Program; Zender Group 2017, Kawerak 2021).

Photo credit: Backhaul Alaska

Figure 1.1. Backhaul Loading. Photo of an improperly packed load of waste (A, on left) and the same load repacked following the Backhaul Alaska training (B, on right).

In 2014, the Solid Waste Alaska Taskforce (SWAT) was formed as a multi-institution taskforce to collaboratively tackle rural Alaska solid/hazardous waste challenges (Zender Group 2017, SWAT 2023). SWAT is comprised of the Alaska Department of Environmental Conservation (ADEC), the Alaska Native Tribal Health Consortium (ANTHC), the non-profit corporation Kawerak, Inc., and the community-based non-profit Zender Environmental Health and Research Group (Zender Group 2017, Kawerak 2021). At that time, the activities and interests of several groups and initiatives came together through meetings and workshops as outlined in Zender Group (2017) and the Backhaul Alaska website [1] in order to develop a state-wide plan to address Alaska solid/hazardous waste challenges (SWAT, 2023). The groups and initiatives included work by the Alaska Senator's office, a statewide backhaul panel, meetings among Regional Tribal representatives and local communities, local, regional, statewide, Tribal, and federal governments and agencies, transporters, recyclers, and other groups with connecting interests. In 2017, after being vetted and refined, this plan resulted in the

[1] https://backhaulalaska.org/overview/

creation of the Backhaul Alaska Program, commonly called Backhaul Alaska and referred to as such throughout this document.

The goal of Backhaul Alaska is to coordinate the safe removal of hazardous and potentially harmful waste from rural communities, with a focus on bolstering local community capacity and creating local jobs. The program ensures that every participating community has trained staff that knows how to inventory, stage, and safely package waste for transport. Because it is economically and logistically infeasible for most communities to independently manage this process, Backhaul Alaska also helps to scale up these efforts by coordinating with vendors to ship waste material to recycling facilities (Zender Group 2017).

Starting in 2018, SWAT began to pilot Backhaul Alaska in order to develop, evaluate, and improve: (1) staff training, (2) waste and equipment inventory methods, and (3) transportation and shipping logistics (Kawerak 2021). It was essential for the program to consider how it would incorporate a range of unique needs throughout rural Alaska, which is culturally, environmentally, and geographically diverse (Figure 1.2). Alaska stretches from North of the Arctic circle, where the landscape is arctic tundra, 1,400 miles south to temperate rainforest along the south-central and southeast costs. Areas in between include boreal forest in the interior of the state and maritime tundra along the coast and islands (ADFG 2015). Rural Alaska includes roughly 200 small communities, typically with a few hundred residents, the majority of which are Alaska Natives living on ancestral lands (ADFG 2015). In total, there are 229 federally-recognized Alaska Native Tribes (ADFG 2015), using roughly 20 different languages; the number of speakers and levels of fluency vary among languages and communities.[2]

To establish a set of pilot communities, Backhaul Alaska, advertised the program and accepted applications from self-identifying communities, and also consulted with various regional and statewide peers to establish a pool of communities. These included communities with some backhaul experience, spanning Alaska's diverse geography, a range of population sizes, and airplane and barge access. Backhaul Alaska was able to include all 27 nominated communities within the phased three-year pilot (Personal observations by author LZ; Figure 1.2).

The Backhaul Alaska pilot paved the way for what is now a growing and successful hazardous waste removal and recycling system for small, remote communities (Kawerak 2021). At this stage, the pilot relied heavily on manual data entry, paper forms, email, and direct phone calling. SWAT identified a need to develop automated efficiencies in its coordination, communication, and verification processes as it scaled up over the next ten years to include approximately 160 to 200 communities[3] across rural Alaska (Kawerak 2021).

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[2] Alaska Native Language Preservation and Advisory Council. Accessed online (22 Febuary 2023) at https://www.commerce.alaska.gov/web/dcra/AKNativeLanguagePreservationAdvisoryCouncil/Languages.

[3] Kawerak (2021) uses an estimate of 160 communities for full program capacity which we continue to use here. The exact number of communities in the program may be more or less than this number depending on a variety of factors, and other backhaul planning and communication documents sometimes report a different target number.

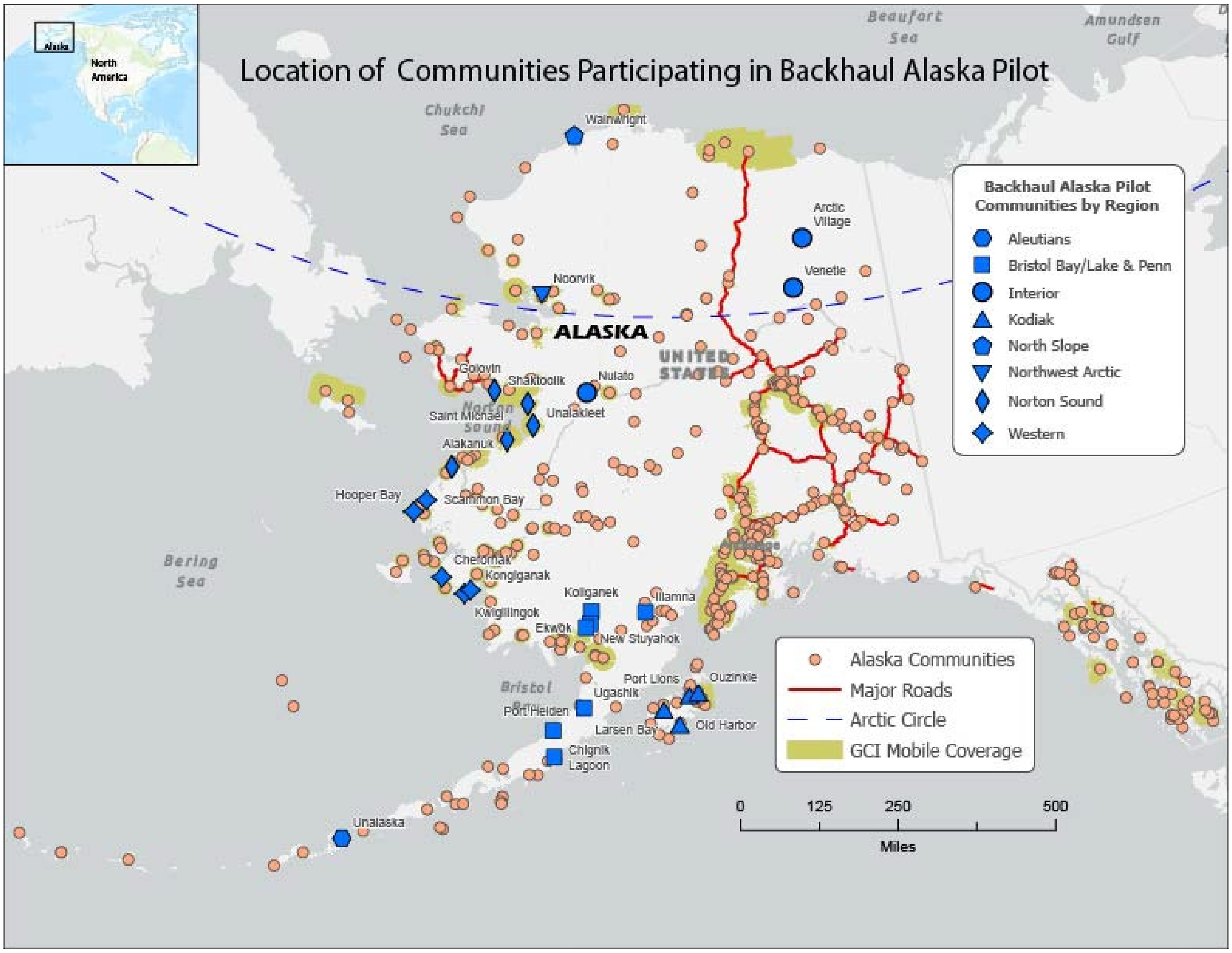


Figure 1.2. Location of communities participating in the Backhaul Alaska Pilot. Study area map showing the 27 rural Alaska communities that participated in the Backhaul Alaska pilot (blue symbols and gray names), with region indicated by the symbol shape. Other communities and roads are depicted for context. Most Backhaul Alaska pilot communities are not connected to the road network and are only accessible by boat or plane. Areas with mobile Wi-Fi access are shown in green shading. Data Sources: Pilot Communities https://backhaulalaska.org/pilot-program (Backhaul Alaska 2023) and Mobile coverage www.gci.com/.

As Backhaul Alaska expanded, SWAT and EPA Region 10 staff began to explore whether using a mobile app (i.e., digital application) for program participants could help address some of the logistical and coordination challenges and support additional program goals. Removal, recycling, source reduction, and cleanup activities associated with hazardous waste backhaul have potential for creating jobs, cost savings, improved health, and clean-up of culturally important areas. Day-to-day operational needs include methods to manage inventory, package, and track shipments, submit observations that impact operations, connect with peers, and receive program support. To help address these needs, EPA Region 10 and EPA Office of Research and Development (ORD) staff applied and received Regional-State-Tribal Innovation Project (RSTIP)[4] funds to develop criteria and evaluate options for the design of a mobile app, or similar technology solution, that would serve the user-base of Backhaul Alaska (including but not limited to regional and village backhaul

[4] The RSTIP program is an EPA ORD funding program to support EPA regions in pursuit of "innovative projects to address state and tribal science priorities".

coordinators and staff) and the wide-ranging data needs for operating the program. The project, which is the focus of this report, was a collaboration among EPA regional program staff, EPA research scientists, and the community-based non-profit, Zender Group, that is the lead for developing and administering the Backhaul Alaska Program on behalf of SWAT. Because of this partnership approach, the project drew from a variety of community-based research and human-centered design approaches as described below (Sections 1.6 and 1.7).

1.2 Statement of Authorship and Voice

As a collaboration among EPA regional program staff, EPA research scientists, and the community-based non-profit Zender Group, this report contains multiple voices. Zender Group and EPA Region 10 staff have been working for years on solid waste and related environmental issues in rural Alaska and are experts in this regard. Throughout the text, we have attempted to clarify who the active speaker is when warranted. This report presents a variety of research findings. Some findings are novel and illuminating to all team members. Other findings represent information well-known to the on-the-ground practitioners on the team and were analyzed or reinterpreted using specific methods and frames by the EPA research team for case specific or more generalizable objectives and audiences.

1.3 Project Objectives

Our guiding question was: *What are the best design options for a Backhaul Alaska Program data management application, or similar technology, that addresses different users' needs for supporting program operations and decision-making?*

The project aims to:

1) Understand the unique goals, practices, behaviors, and beliefs of Backhaul Alaska participants to ensure that app development meets their needs.
2) Identify areas where an app or similar technology can help build capacity for Backhaul Alaska and its constituency, including but not limited to training, program operations, and data management.
3) Communicate our process and outcomes so that other programs operating in similar contexts can learn from them.

The primary short-term outcome is to provide guidance for program administrators and participants that supports adaptive and responsive program operations, decision-making, and expansion. Long-term, the research presented in this report will help develop one or more information management tools that assist communities as they work to build their capacity to implement waste management best practices.

1.4 Report Audience

This report may be of interest to several audiences:

- **For Backhaul Alaska:** This report documents and analyzes important Backhaul Alaska operations, as well as data management and resource needs, among program participants. While this report is not an all-encompassing analysis of Backhaul Alaska, it does investigate important issues related to coordination and communication, information sharing and access, data collection, storage, and visualization, and overall program function in relation to developing an app, or similar technology, that can support Backhaul Alaska. It synthesizes and analyzes important insights from individuals involved in Backhaul Alaska, which can identify what is working and where opportunities exist for improvements.

- **For Programs of Similar Context:** This report outlines an approach to app development for a program meant to serve predominantly Alaska Native communities that are remote, with limited internet and technology infrastructure. The experiences and lessons learned that are presented in this report will be informative to similar programs and contexts (e.g., rural or island communities) throughout the United States and elsewhere.
- **For App Developers**: This report is designed to provide a foundation for developing an app, or similar technology solution, for Backhaul Alaska. It documents and analyzes the relevant program operations, users, and considerations such as costs and time investments that need to be included in an app by a technology developer. A single solution is not proposed; instead, the advantages and disadvantages of several development options are presented. Because choices about app user interfaces and features will be influenced by the specific app developed and its underlying software (Teacher et al. 2013, Jabangwe et al. 2018, Gerlitz et al. 2019), this report focuses on identifying users' needs and a holistic understanding of Backhaul Alaska that can assist with the selection of user interfaces and features, independent of the development approach. Where relevant, specific technology features and user interface recommendations are made.
- **For Communities in Rural Alaska:** This report documents important user needs and program logistics and analyzes them in a way that can be used to build tools to enhance local capacity to safely and effectively carry out backhaul activities. This report also supports activities intended to protect subsistence resources, create jobs, and remove toxins from the land; these values were considered when developing the mobile app technology for Backhaul Alaska.

1.5 Report Structure

This report consists of five sections, each concluding with a section summary. Additional and supplemental information are provided in seven appendices, labeled A through H.

Section one introduces Backhaul Alaska, and explains the context, research approach, methods, and sources of information used in this research project. A more detailed and technical methodology is provided in Appendix B.

Section two looks at how Backhaul Alaska operates and discusses what various characteristics of the program mean for app development. The chapter starts with an analysis of seasonal and interannual program activities and the opportunities for an app, or similar technology, to support various stages of the program. Section two outlines eight critical themes to consider when developing an app or similar technology. It also outlines the program's data management and geospatial data needs.

Section three focuses on likely app user groups within Backhaul Alaska, outlining their roles and responsibilities, working conditions, backgrounds, key challenges related to Backhaul Alaska, and what they are likely to do with a Backhaul Alaska app. Importantly, section three also outlines any unknowns and unanswered questions for different use types, and items that might warrant future research.

Section four explores the suitability of several different options for developing a Backhaul Alaska app, considering factors such as customizability, functionality, and cost. Section four also details a case study about Backhaul Alaska's trial use of two different apps during the 2020 - 2021 program pilot session. (Detailed user feedback is provided in Appendix A). The case study illustrates important decision points, historical dependencies, and long-term thinking that factor into Backhaul Alaska's app development choices and next steps. Finally, given the remote, offline environment, and harsh weather conditions of rural Alaska, which are challenges for many digital devices, section four discusses strengths and weaknesses of a digital vs. paper solution for Backhaul Alaska.

Section five provides a short summary of the report and discusses the findings. Section five also considers how anticipated environmental, technological, and economic changes might impact future design considerations for a Backhaul Alaska app and possible steps to consider in addressing such changes. Finally, section five provides a set of lessons learned that can be transferred to other programs interested in using human-centered design approaches for similar problems.

1.6 Research Context

Mobile apps are increasingly being used for environmental data collection, citizen monitoring, and gathering of public health information (Teacher et al. 2013, Andrachuk et al. 2019, Holeman and Kane 2019). Apps might be custom made, or developed using off-the-shelf software that allows selection of specific data fields, work flows, content, and possibly appearance and user interface elements (Andrachuk et al. 2019). Ideally, end users are consulted during development to ensure that apps meet program end goals and can be used effectively by target audiences (Teacher et al. 2013). All too often though, end users are not adequately involved in the development of digital applications. For example, in a review of 71 studies using apps for environmental conservation by Andrachuk et al. (2019), only 15% confirmed end user consultation during app development, 69% confirmed no user consultation, and 15% could not be determined. Similarly, out of

62 papers about environmental citizen science apps reviewed by Skarlatidou et al. (2019), only 29% involved direct user evaluation.

Consulting with end users to better understand the context in which an app will be used is particularly important in communities with extreme environmental conditions and a lack of digital infrastructure (Kouril et al. 2015, Kipp et al. 2019). Without a full understanding of local environmental, social, and technological characteristics of communities, developed apps may fail to meet program goals. As a research approach for product development or app design, community engagement can take several forms, ranging from consultation, where researchers discuss ideas with community members, to full co-development, in which researchers and community members co-develop questions, research methods, and work together on data analysis and interpretation (Reed et al. 2014, 2018). No single form of community engagement fits all situations, and the level of engagement should respect both researchers' and community participants' capacities, the scope of the research, and the research objectives (Jasney et al. 2021). Nonetheless, taking engagement seriously can help ensure that research will meet the needs of the communities involved (Kouril et al. 2015, Ford et al. 2016, IARPC 2018, Kipp et al. 2019).

When community-based work involves co-collecting data, or community members collecting data that is shared with research teams, data ownership and privacy are important issues (Kouril et al. 2015, Ford et al. 2016). Assumptions about data storage and sharing can lead to unintended consequences; for example, even well-meaning open-access data standards may serve to reinforce existing inequalities when those communities that wish to use and safeguard their own data lack the resources or expertise to do so (Lewis 2020). Understanding cultural and local socio-political contexts around technology and data are therefore vital to ensure that an app is developed successfully and mindfully.

1.7 Human-Centered Design in Research and Development

To ensure that this research provided a holistic understanding about how to develop an app, or similar technology, for Backhaul Alaska, we used *human-centered design*. Human-centered design is an approach to developing technology products that "puts people at the center … prioritizing [their] aspirations and ordinary experiences when imagining and implementing complex systems, services, or products" (Holeman and Kane 2019:488). Human-centered design is a dynamic field of practice, influenced by design, technology studies, human-computer interaction, anthropology, and public health (Bannon 2011, Holeman and Kane 2019). It shares some similarities with user-centered design, which emphasizes the experiences of target users (Harte et al. 2017). Human-centered design, however, is broader and less strict in scope, considering how the design of a technology goes beyond just target users, and looks at the full socio-political context in which a designed product is developed and deployed. Holeman and Kane (2019:496) further describe this idea:

> "... designers who build technologies or solve technical problems can hardly claim that their work is human-centered if they systematically ignore human rights or humanitarian concerns that are part of daily life for the people they purport to 'design with' or serve. … this … involves looking beyond the design of discrete technologies to reimagine services, the organization of health systems, and broader social arrangements that pattern who receives equitable care and who does not."

Human-centered design intentionally blurs the separation of design and implementation (Holeman and Kane 2019), which we interpret to also extend to research and implementation. It is an intentionally iterative process, through the phases of development, application, research, and reflection (Holeman and Kane 2019). While private sector development using human-centered design often targets short research and development cycles (Chen et al. 2020), tools for public health (an analog for Backhaul Alaska) might be developed and refined over several years (Holeman and Kane 2019).

Many of the human-centered design principles that are outlined above align tightly with community-based approaches that are essential when working with Indigenous communities (Ford et al. 2016, IARPC 2018). As reviewed by Chen et al. (2020), there are several differences worth noting. Human-centered design prioritizes empathy and creativity, focuses on understanding individual users at extreme ends of the user spectrum, often works under shorter time frames, and seeks to generate scalable solutions. In contrast, community-based research emphasizes relationship and trust building, often working with community members and other interested groups over long periods to develop local capacities and arrive at localized and context specific outcomes.

Because Backhaul Alaska focuses on serving Alaska Native communities, we integrate many of these community-based research principles with our human-centered design approach. Specifically, we pursue relationship and trust building with Backhaul Alaska participants and others with connections to Backhaul Alaska, as well as community capacity building and context specific solutions for rural Alaska waste management needs. Because Backhaul Alaska is statewide in scope and is expected to eventually encompass roughly 160 to 200 communities, we are also cognizant that the work done for this specific report cannot be fully community-based. Depth and breadth require a certain tradeoff, and our approach here might best be thought of as research and design that is locally informed and regionally focused.

1.8 Methods and Sources of Information

Figure 1.3 depicts the project timeline, which centered around three activities that built on one another through iterative rounds of research synthesis and participant engagement: (1) We held conversations with representatives from other programs in the region that had developed environmental or resource management apps in order to learn from their experiences. (2) We held conversations with regional waste management experts (working external to the Backhaul Alaska), technology experts, and Backhaul Alaska participants and staff (roles listed below). (3) We analyzed video footage, collected by Backhaul Alaska participants, of backhaul activities, training, and pilot app use in the field. The Backhaul Alaska staff and participants included the following: A Statewide Coordinator (SC) who oversees overall program implementation and day-to-day operations; a Control Tower (CT) that coordinates shipping and receiving of waste at final destinations; and Regional Coordinators (RCs) who work with, and coordinate among, individual Village Coordinators (VCs) and their assistants in each community of a given region (Kawerak 2021).

These research activities allowed us to develop both a foundational understanding of the users and variables affecting app design and use, and subsequent evaluative research to understand the strengths, limitations, and needed refinements of specific ideas or prototypes (Abras et al. 2004, Daae and Boks 2015, Chipchase 2017). All research was done remotely due to the Covid-19 pandemic when travel was restricted. Further details about methods are provided in Appendix B.

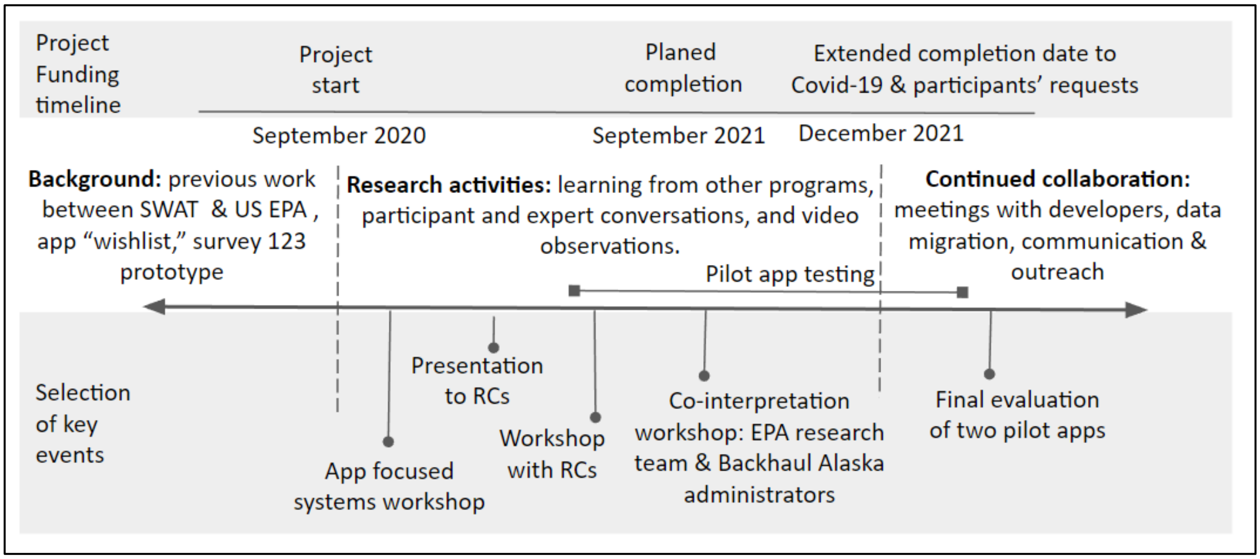


Figure 1.3. Overall project timeline. Timeline indicates project start and ends dates, background work that informed the project, and continued collaboration after the project. Several events are outlined in the lower part of the timeline for context. A more detailed timeline of specific research activities and intermediary synthesis documents is presented in Appendix B, Figure B.1.

Several important background research components and activities also informed the project. These included engagement with various experts related to Backhaul Alaska, consideration of prior work by EPA on the Backhaul Alaska system, on experiences of Zender Group in designing and beginning to implement the pilot program, and experience of ORD in development and use of other apps. Discussions during this background phase of work resulted in an itemized list of needed and desirable app features (known as the "app wish list"; Figure 1.3). An important learning opportunity for the project also involved observing and evaluating (through conversations and video documentation) a pilot app being used by Backhaul Alaska. This app, called Survey123, was an off-the-shelf, third-party app that EPA ORD researchers began to customize for Backhaul Alaska during the project planning stage. EPA had been working with Zender Group to identify multiple technology-based solutions to help with backhaul (e.g., shipping route optimization). Several EPA scientists (authors TB and PL) who were involved in the 'wish list' conversations recognized that Survey123 could be used for Backhaul Alaska's inventory needs, given their experiences using Survey123 for other projects (Section 4.0). This account illustrates how the current project was informed and supported by a long-term, ongoing relationship between EPA ORD, Region 10, and SWAT. The team's collaborations continued after the official end of the project (Figure 1.3), for which the implications on our own project and those looking to replicate similar efforts elsewhere are discussed in the conclusion (Section 5.0).

Participant engagement is a cornerstone of this project. Research activities were synthesized by the EPA research team at several stages (Appendix B, Figure B.1) to form the basis of three workshops and a presentation with Backhaul Alaska participants and administrators to discuss project findings, explore outstanding questions, and co-interpret the work (Figure 1.3, Table 1.1; details in Appendix B). One of these engagements was a presentation by the EPA research team to RCs (with the SC also in attendance) to explain the project, the planned research, and to discuss any questions and ideas from the RCs. RC insights were essential since RCs occupied a key role in the program, facilitating communication between villages in each region and statewide staff, allowing them to reflect on program operations at multiple levels. During the presentation, RCs requested that the project timeline be extended from September 2021 to late December 2021 to allow more time to learn from their upcoming summer backhaul experience and use of the Survey123 app. Extending the project end date also made sense due to research and administrative slowdowns caused by the ongoing Covid-19 pandemic (Figure 1.3). Thus, the project benefited from an adaptive and flexible approach that accounted for participants' needs and changing conditions.

Extending the project deadline also allowed everyone involved to learn from piloting a second app in addition to Survey123 (refer to Section 4.0). Piloting this second app led to a series of app development discussions and comparison work (details in Appendix B and Figure B.1) between Backhaul Alaska administrators and EPA scientists, and a deeper reflection on Backhaul Alaska's short vs. long-term app development needs (refer to Section 4.0).

In total, the conversations, workshops, presentations, and pilot app comparison work resulted in 45 engagements with individuals and programs, which were often represented by more than one individual (Table 1.2). In total, the project received participation and insights from 38 individuals (Table 1.2). While diverse in terms of geographic scope and subject matter, this participation may not be representative of all users and regions. In each subsequent chapter, we point out possible research limitations when documenting and analyzing how an app can support Backhaul Alaska (Section 2.0), its users' needs (Section 3.0), and development options (Section 4.0).

Table 1.1. The Number of Participant Engagements by Type.

Engagement Type	Count	Description
Conversations	33	Unstructured conversations with: • representatives of other programs using similar environmental monitoring or management apps, • technology and regional waste management experts (external to the Backhaul Program) • backhaul program participants and staff
Presentation and workshops • Organized by project team • Attended by project team*	 4 1	Presentations and discussions with RCs, CTs, and program administrators to get feedback about the project, discuss outstanding questions, and co-interpret results, and/or learn about technology considerations in the region.
Pilot app comparison work	7	A series of meetings among EPA ORD researchers, Backhaul Alaska administrators, and representatives from one or more app development companies to discuss, demo, and pilot two different apps for the program; and internal discussions between EPA ORD researchers and Backhaul Alaska administrators about different software options.
Total	**45**	
*****1 workshop was organized by Northern Connection and EPA ORD and Zender team members participated*		

Table 1.2. List of Participant Engagements by Participant Type. The number of engagements is listed as a total and with unique entities, i.e., programs or individuals, as we had repeated conversations and interactions with several individuals and/or programs. Several programs and companies were represented by more than one person; thus, the total number of unique programs or individuals (n = 27) is less than the total number of participants that we spoke with (n = 38). Total participants are not listed for each participant type to avoid double counting, since several participants occupied multiple roles (e.g., the same person may have participated as part of a group for a regional program using a similar app and individually as a regional expert).

Participant Type	**Total Engagements** (number)	**Unique Entities** (programs or individuals)	**Total Participants**
Representatives of SWAT	3	3	Individual breakdown not shown because several individuals occupied multiple roles
Control Tower (CT) and State Coordinator (SC) operators	3	3	
Regional Coordinators (RCs)	6	4*	
Village Coordinators (VCs) and their assistants	5	4	
Regional programs using similar apps	10	3	
Regional waste management experts (external to the program)	2	2	
Technology experts	10	6	
Workshops and presentations with RCs (SC also in attendance)	2	--	
Workshops and pilot app planning with program administrators	3	1	
Northern Connection Workshop	1	1	--
Total	**45**	**27**	**38**
**A fifth RC participated through the RC workshop*			

Section 2. The Backhaul Alaska System

This section provides a holistic understanding of the Backhaul Alaska Program. The section starts with an analysis of seasonal and interannual program activities (as they exist in the Backhaul Alaska pilot and initial implementation) and the opportunities for an app, or similar technology, to support current and future stages of the program (Section 2.1). The section then outlines eight critical themes to consider when developing an app (Section 2.2) and discusses Backhaul Alaska's data management (Section 2.3) and geospatial data needs (Section 2.4). It concludes with a bulleted summary (Section 2.5).

2.1 The Backhaul Alaska Program

To build each community's capacity to remove hazardous waste, Backhaul Alaska operates through a network of participants from the local to statewide level. These include a Statewide Coordinator (SC) who oversees overall program implementation and day-to-day operations; a Control Tower (CT) that coordinates shipping and receiving of waste at final destinations; and Regional Coordinators (RCs), who work with and coordinate among individual Village Coordinators (VCs) in each community of a given region (Kawerak 2021). These actors (SC, CT, RCs, and VCs) form the core of the Backhaul Alaska implementation team and are principal app users. During our research, however, we also discussed several other user groups for a Backhaul Alaska app. Greater detail about these potential app users will be addressed in other sections of this report (in particular, refer to Section 3: User Profiles). Backhaul Alaska is overseen by an Executive Committee that provides guidance and oversight (Figure 2.1., Kawerak 2021).

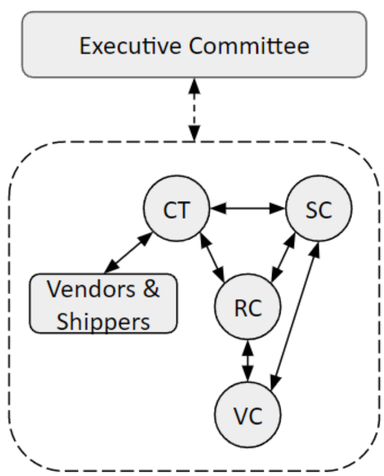


Figure 2.1. Illustration of core actors in the Backhaul Alaska Program. Each of the core actors that implement the Backhaul Alaska Program are shown: Control Tower (CT), Statewide Coordinator(s) (SC), Regional Coordinators (RC), and Village Coordinators (VC). Arrows show coordination between groups. Organization in this figure is based on the General Backhaul Process Flow diagram, prepared by Backhaul Alaska (Appendix E). Alternative graphics (e.g., in Kawerak 2021) depict a more hierarchical program structure.

At the community level, Backhaul Alaska revolves around a seasonal suite of activities that are designed to build local capacity and facilitate the removal of hazardous waste from rural communities (villages). The SC and RCs enroll new communities in Backhaul Alaska and train VCs and their staff on how to inventory and safely package waste. At the end of the summer backhaul season, the waste is shipped and then tracked by the CT (Figure 2.2). Each stage in program implementation has unique needs from an app, which could include deploying checklists and training information, multiple kinds of inventory surveys, visualizing information in dashboards, in-app communication, verification of different activities, and waste shipment tracking (Figure 2.2). Some features are more critical than others and inclusion of specific features to be incorporated in a Backhaul Alaska app may depend on how its production is implemented, e.g., whether the program uses existing apps versus custom builds (as explained in Section 4.0).

At the state level, and working within a multi-year timeline, Backhaul Alaska seeks to enhance regional and statewide coordination of waste removal, staff training, and financing to reduce costs and to build capacity across Alaska (refer to key themes in Sections 2.2.1 through 2.2.5). The program expects to grow in the next ten years from 27 pilot communities to a statewide program serving approximately 160 communities[5] (Figure 2.3a) (Kawerak 2021). Assuming three users per community, plus regional and administrative actors, an app for Backhaul Alaska must be able to support program growth and data storage needs for roughly 450 to 650 users (refer to Section 2.3 and Figure 2.3a).

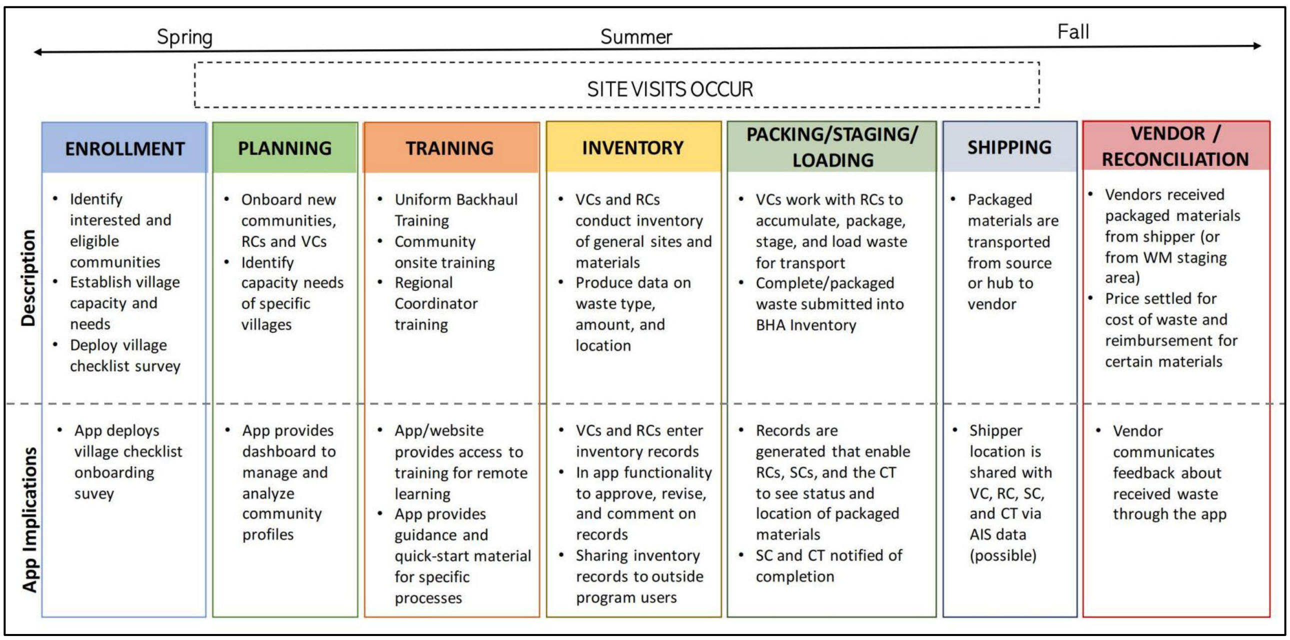


Figure 2.2. Annual Cycle of Backhaul Program Activities and how an app might support individual stages based on the research presented in this report.

[5] Kawerak (2021) uses an estimate of 160 communities for full program capacity for Backhaul Alaska, which we continue to use here. The exact number of communities in the program may be more or less than this number, depending on a variety of factors, and other Backhaul Alaska planning and communication documents sometimes report a different target number.

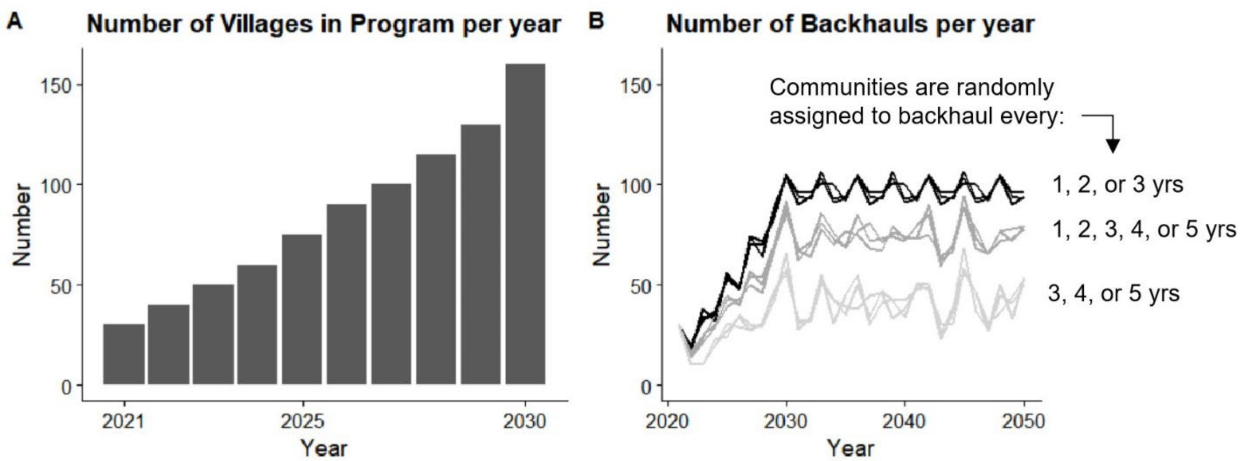


Figure 2.3. Backhaul implementation over time, showing (A) Program expansion (defined as number of villages) over time and (B) number of backhauls per year under different assumptions about how often villages do backhauls (every one to three years (upper black lines), one to five years (middle dark grey lines), and three to five years (lower light grey lines)). Because a specific frequency per village was randomly assigned, we run and plotted these scenarios three times to highlight possible variability, which is why there are replications for each set of grayscale lines in panel B. This variability does not change the overall picture since the three runs all follow a similar pattern. While a simplification of the program's dynamics (see details below), the number of backhauls occurring within a given year (B) are well below the total number of community programs enrolled in Backhaul Alaska. The Program expansion rate (A) was derived from Kawerak (2021, fig 1.2). Backhaul frequencies (B) are based on estimates provided by people during conversations for this research project (some people place their next backhaul at even longer time periods, such as five to ten years), and Zender Group (2017, table 5-4), which describes prioritizing backhaul in communities that have not had a backhaul within three years. The rate of actual backhauls may differ and there are likely regional variations. The figure does not incorporate a hub and spoke model that is being piloted in some regions, where waste from small communities is transported and consolidated to a larger, central location for backhaul. The numbers of backhauls (B) were calculated in the R computational language environment (R Core Team, 2022) using the "sample" function with replacements.

2.2 Critical Implementation Themes and Relevancy to App Development

2.2.1 Offline and Remote

"There are just obstacles here in Alaska that the rest of the country wouldn't understand or have to deal with. … Between the weather and the remoteness and the logistics, it's daunting."

- Backhaul Program administrative staff member

Backhaul Alaska operates in remote areas of Alaska, creating a set of unique challenges for app development. First and foremost, an app or technology solution must be able to work offline and where telecommunications services are limited, with unreliable service or low bandwidth. RCs and regional experts that participated in research activities for this project noted that community level staff prefer to use Zoom for video communication calls because it requires less bandwidth than many other video conferencing platforms; in some areas, many villages could not even use Zoom. As an extreme example, the community of Diomede gets internet service only about one week per month. Indeed, the SC and several RCs were unable to upload data in small communities when testing the Survey123 app. Consequently, waste inventories were stored on their phones for several days until they returned to larger communities with better telecommunications and could upload data. Even in communities with good internet connections, access may be limited to municipal or tribal government offices.

The type and availability of computer hardware and software also varies among communities. It was not uncommon for RCs, the SC, and regional experts to visit communities with limited, or outdated computer equipment and software. Most village level workers did have personal cell phones, according to RCs that participated in this project, which would allow use of a mobile app.

Backhaul Alaska participants also work in rugged conditions that challenge mobile app use. For example, and as seen in the video footage, participants inventorying waste in the rain and snow often had to take off a glove to use the Survey123 app. One village staff member described working in dusty, dirty conditions: "you … take out your phone," they said, "dust is built up on it." Dropping and breaking phones is always a risk when inventorying materials. Indeed, this village staff member crushed their phone, which was in their pants pocket, when lifting a heavy object to pack for backhaul. Ruggedized devices and/or protective cell phone cases could be appropriate hardware for Backhaul Alaska; adoption would depend on user preferences (see section 3.0) and funding.

2.2.2 Communication and Coordination

"Communication, communication; it is just so key with this program."

- Backhaul Alaska administrative staff member

Communication and coordination (henceforth treated as a subset of communication) are central to how an app can enhance Backhaul Alaska. Training staff to safely pack materials, sharing tricks of the trade from more experienced participants, and organizing sequential backhaul events among villages to reduce shipping costs, are all examples of communication and coordination needs. Table 2.1 describes five categories of communication within Backhaul Alaska and how they relate to app development.

Table 2.1: Backhaul Alaska Communication Types and their app development implications. All communications need to be resilient to availability of IT infrastructure and often may need to be performed in the absence of internet services and uploaded to relevant servers once internet connectivity is re-established.

Type of Communication	Description and Example	Implications for App Development
Training and education	Training is a cornerstone of Backhaul Alaska. The SC and RCs train village staff in the field at the start of the season (Figure 2.2) but may need to train new staff mid-season if there is staff turnover. Other education opportunities might include packing tutorials or cheat-sheets that all staff (VCs and RCs) could access in the field as refreshers.	Communication is primarily one-way (i.e., app users access static information). RCs expressed desires to have training checklists in the app. Training and education materials could be included as text, images, or videos in the app. Material for download must account for low bandwidths in villages.
Verification and confirmation	Certified packing requires several checks that materials are inventoried and packed correctly. Program participants require notification that corrections are needed. Backhaul Alaska also needs confirmation that materials are received by vendors.	Communications are primarily two-way (i.e., app users interact). Tasks assignments and confirmations (with feedback and notes) could facilitate packing and correction notifications. Surveys or task assignments could confirm receipt of materials.
Event dependent	Several communications might be triggered after an event or time period. For example, certain waste streams can only be held in storage for a year, communities are restricted to shipping a maximum of 16 pallets via barge, and VCs and RCs may want to know when a shipping vessel is within a given distance or transit time from a village. Event-dependent communications might also occur when prioritizing backhaul in communities that have not backhauled for several years, or if supplies, such as personal protective equipment (PPE), are low.	Communication is primarily one-way, where the app sends a message. An app might send notifications when waste storage is approaching a threshold, such as a time limit, or maximum number of pallets, when vessels are within specified distances or arrival windows, or which communities have not been served or need supplies.
Information sharing and coordination	Actors, both internal and external to Backhaul Alaska, regularly share information about program operations. This might include notifying colleagues about waste and equipment conditions or needs in villages that they visit and coordinating specific program activities.	Communication is primarily two-way (i.e., app users interact). Communications could occur through an in-app chat with a communication log (however, offline use of the app may complicate chat usage). Informal communications (email, phone, text) could be documented after the fact in dedicated space within the app. Features might also format and export communication records to share with other users (e.g., photos and description of needed equipment repair).
Advice seeking/ giving	VCs and RCs often seek or share advice on issues including best practices and how to address challenging issues. New staff want to learn from the experiences of seasoned practitioners and need insider advice about working in new locations.	Communications can be one- or two-way. Users might access static help forums (with regular updates). Message boards or question and answer forums could host more dynamic user exchange. Direct messaging and chat could also facilitate advice seeking and sharing.

Communication occurs among a network of individuals and entities involved with Backhaul Alaska (Figure 2.4). CT, SC, RCs, and VCs work within Backhaul Alaska and interact with external actors at the state and regional level. Shippers transport waste to southern locations, where the waste is received by recycling vendors. Backhaul Alaska also coordinates to receive materials from supply vendors. Participants share records, photos, and information about waste and equipment needs with external federal, state, and private sector partners who are involved with solid waste management. For example, during a site visit, the SC documented transformers filled with polychlorinated biphenyls (PCBs), which Backhaul Alaska is not equipped to deal with at this time. The transformers were documented, and the information sent to appropriate parties to be managed externally to Backhaul Alaska. Another time, the SC was able to send information about damaged equipment to repair personnel who were already working in the region on another project. In a third example, several regional experts discussed that school groups, governing councils, or other interested groups could help with backhaul inventorying and packing, after appropriate training (Section 3.0).

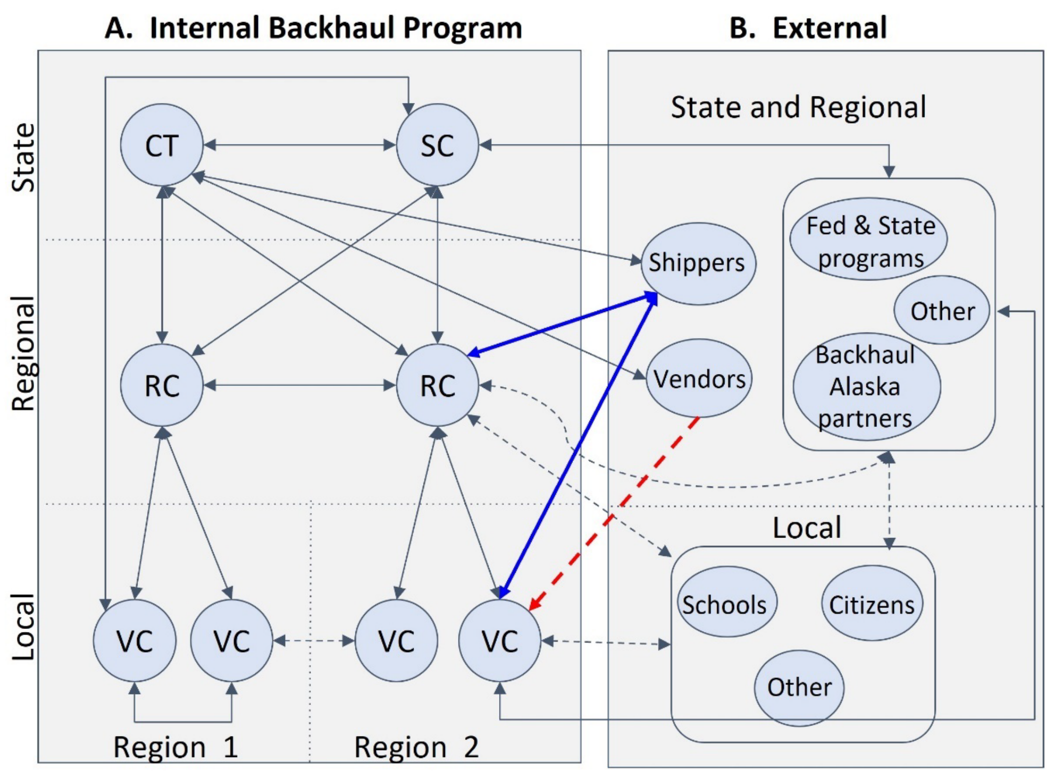


Figure 2.4. Communication pathways among actors in Backhaul Alaska. Internal actors are shown in panel A and external actors are in panel B. Solid black arrows indicate documented communication pathways and can account for multiple kinds of formal and informal communications. Dashed black arrows illustrate possible communication pathways, or those that might occur only in specific contexts, between various actors (circles) in Backhaul Alaska implementation. The heavy solid blue line from RC and VC to Shippers represents informal communication when identifying small local transport options, which are then communicated back to the CT through an RC. The red dashed line) from Vendors to VC represents a desired communication. While the goal is that VCs receive feedback from Vendors, communication could be through direct in-app communication, or conveyed through another pathway in the network, such as CT to RC to VC.

Some communication pathways within Backhaul Alaska are fixed. For example, the CT schedules and tracks shipping and communication between the CT and local communities, a process that is always mediated through RCs or the SC (Figs. 2.1 and 2.4). Other communications paths are less fixed. For example, the red dashed line in Figure 2.4 represents a request by VCs that vendors provide feedback about the quality of packing when they receive shipped materials. While the goal is that VCs receive feedback from vendors, communication could be through direct in-app messaging or conveyed through another pathway in the network, such as CT to RC to VC.

Formal communication paths, such as the CT coordinating with shippers, are often linked to informal communications. For example, many small communities cannot be accessed by large barges, or are too remote for access to be cost effective. In these cases, waste is transported by smaller local vessels, such as fuel barges or fishing boats. With their on-the-ground knowledge, VCs and RCs learn about local shipping options (heavy solid blue lines in Figure 2.4) and pass contact information to the CT, which organizes transport.

Backhaul Alaska participants and regional experts stressed the importance of informal communication among all parties. One regional expert noted that an informal conversation with local staff was useful for assessing the level of their knowledge or expertise, implying that a conversation was better than a formal checklist or training test, though it is important to note that checklists and training tests were frequently cited as app needs by several RCs. Personal contacts were considered key to facilitate communications and could even help in reaching out to other communities when RCs had trouble establishing local contacts. The SC was frequently cited as a critical connection for communications and operations.

There are regional differences in communication patterns. Some VCs regularly reached out to RCs, while in other cases, the RCs were usually the ones to initiate conversations. Two RCs reported very little communication amongst villages in their regions, while other RCs noted more frequent communication. VCs and their staff working in the three villages that we spoke with also provided examples of sharing or receiving information and materials with other communities for backhaul and associated waste management activities.

There are pros and cons to having informal communication take place within a Backhaul Alaska app and caution should be taken not to stifle natural exchanges. For example, Section 3.2.4 outlines a case where the VC and VC Assistant often educate local citizens about waste management when citizens informally ask them about backhaul waste pickups and drop-offs. Institutionalizing pickup/drop-off in an app might take away this important opportunity to interact with the community. Several RCs said they envisioned informal coordination and planning conversations to take place outside of an app; however, they liked the idea of then documenting these conversations within the app. Program staff highlighted that it would be important to access and query such a conversation log by location, named individual, and date (i.e., most recent). Other suggested communication-related app content included checklists to document if communities need packing materials, if staff are up to date on packing certifications, and the names and contacts of local VCs, their assistants, and any other personnel. Several RCs indicated that a repository for "key contacts" in communities (e.g., transportation options, tribal and city administrators, landfill operator, environmental coordinator, etc.) and among vendors would make communications more efficient and effective. Should this content include any personal information, data safety should be a continuing topic of discussion with app developers.

While many communications that take place during Backhaul Alaska's implementation are informal, the packing and inventory stages are designed to follow a formal sequence of events with several checks and balances. Even these processes, however, are dynamic and fluid, with different actors stepping in for each other when there is limited capacity (Figure 2.5). As noted by one RC, "different communities have different needs and different levels of help." While some communities were easily able to complete and send inventory records, others lacked capacity and were unable to do so. In these cases, RCs worked with village staff to pack materials and complete inventory records. Overall, VCs and RCs often worked together on many tasks (Figure 2.5). Other observed modifications to standard protocols included the following: the CT requesting document verification before sending packing information to RCs and LCs, or when the CT requested rapid and direct email confirmation of packing corrections, which was considered "just easier, especially if you're in a time crunch" (Figure 2.5).

Several communication steps in Backhaul Alaska would benefit from formal task assignment, verification of completion, and rapid return of information. The request (outlined above) by the CT for rapid feedback is just one example. Several RCs also described communicating with local staff through emails and text messages to get confirmation that materials were packed properly. An app could streamline these notifications and verifications through tasks tagged to specific users (Figure 2.6a). Location and task filters could enhance the workflow and reduce possible errors, such as sending notices to the wrong party (Figure 2.6b).

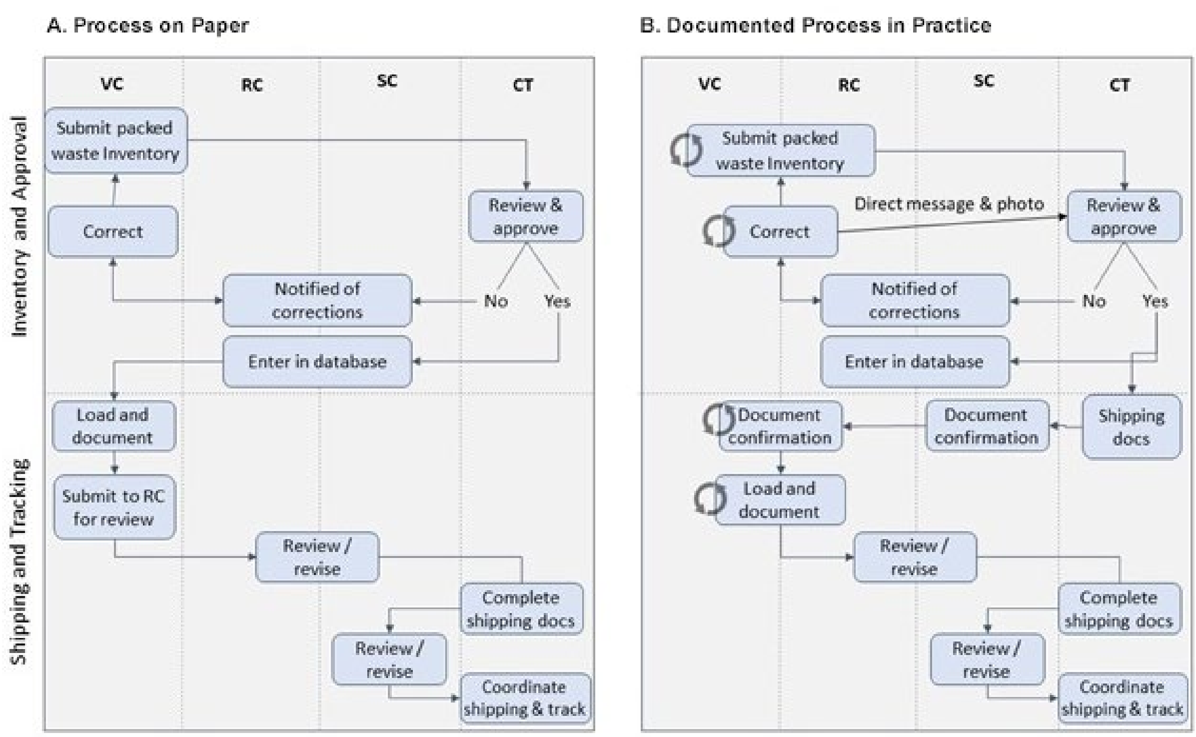


Figure 2.5. Process flow diagram for the loading and shipping phase of the backhaul process as documented on paper (panel A on left) and as observed in practice and documented during the research (panel B on right). Arrows indicate process and workflow between actions, which are captured in text boxes. Each column encompasses actions taken by responsible parties (VC, RC, SC, CT). Boxes spanning two columns indicate multiple parties. Circular arrows indicate an interactive workflow between two parties.

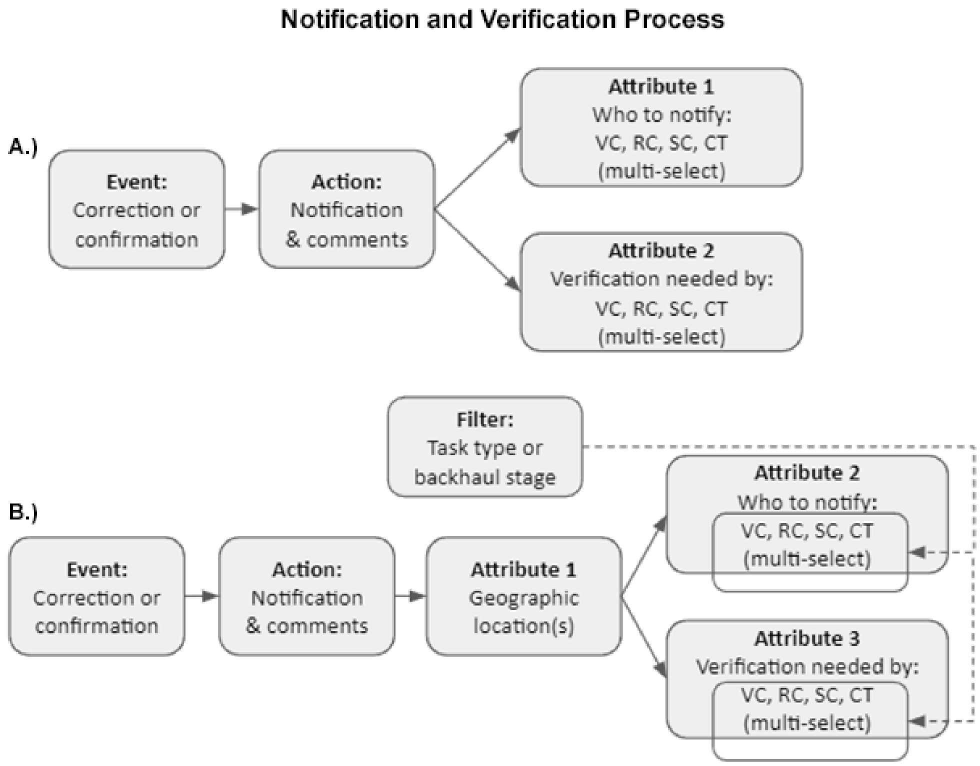


Figure 2.6. Proposed general process for formal notification and verification of tasks in Backhaul Alaska.
A) Notifications are provided with comments and specific recipients and verification needs are assigned.
B) More advanced notices might include specifying recipients by location. Recipient and verifying party options could be filtered by task or backhaul stage to reduce error of selecting the wrong actor.

2.2.3 Community Profiles

"[This community] is an old mining town. We've got all kinds of crazy stuff here. … We've had variations of military involvement. … We've just got a lot of stuff laying around here." *- Regional expert*

All RCs and regional experts stressed that it was important to know about a local community. "Don't go in blind," they said. Specifically, it was important to have (1) a historical, social, and environmental profile, as well as (2) an inventory of key people, places, and resources.

Historical context can provide insight about legacy wastes from old industry, military, or mining activities. Information about current population and demographics can help practitioners understand what waste types are currently being generated and their approximate volumes. Knowledge about local transportation infrastructure is vital (e.g., if there is a deep-water dock, or if materials must be beach-loaded onto a boat). It is also important to know what transport options exist (air, boat, or road), relevant shipping windows (e.g., subject to ice formation and break up, storm frequency, and shipping company schedules), and if there are any sensitive environmental features or cultural places. Such information could be hosted statically in an app, or perhaps made as a user generated and editable profile (akin to a wiki page).

RCs and regional experts also stressed that it was important to know about, and have a repository for, key people, places, and resources (e.g., "key contacts" such as transportation contacts, tribal and city administrators, landfill operator, environmental coordinator, etc.). An inventory of local supplies (e.g., PPE, packing and labeling materials, storage containers/locations) was similarly imperative. One regional expert also felt that having a sense of the age and background of local staff was helpful. The expert had observed cases where younger staff were not always comfortable speaking with various local contacts, while in other cases, an older experienced staff member was vital in communications and facilitation. While community dynamics are likely to be complicated and case-by-case, such background information could help RCs. As noted previously, before including any personal information in the app, Backhaul Alaska must work with app developers to decide what personal information, if any, should be stored and shared within the app.

RCs and regional experts also requested a list or database of shipping companies and schedules per region. One expert indicated that some shipping companies have specific stipulations. For example, they may only transport materials in the company's shipping containers, which must then be available for packing. Some companies may require that certain products are stripped of all rubber, plastic, oil, gas, and batteries before being loaded.

Finally, knowing local names, the distances between local places, and how hard it is to get materials between two locations could help RCs (refer to Section 2.4 for further discussion of mapping). The ability to search information by local names (e.g., "the pit" is what one communicant called their waste staging area), incorporate photographs of places, and view aerial photography were all seen as helpful features by RCs and regional experts.

2.2.4 Capacity of Staff and Personnel

"I did a double site visit in [one village] and then turned around the next day and did an overnight trip to [another village] because [the villages] just didn't have the human power to be able to package … and do the backhaul. … People just didn't have the capacity to do it. … And we lost the environmental coordinator [in that village] who was … the lead. [Now there is] a new person that is being trained." - Regional Coordinator

Some of the most frequently mentioned challenges for completing backhauls were staff turnover, a lack of qualified workers, and overtaxing existing staff. These concerns about staff and personnel capacity were more common at the village level, but we also observed staff turnover among RCs and the CT. Staff turnover can lead to the loss of institutional knowledge, delays in work, or decreases in efficiency while new staff get up to speed.

An app could play a role in documenting institutional knowledge and smooth transitions. Many of the features described under communication and community profiles (refer to Sections 3.2.2 and 3.2.3), such as communication logs, question and answer forums, contact lists, and community infrastructure maps, might help overall operational capacity. In-app training materials could also help RCs and Backhaul Alaska staff train new workers.

Backhaul Alaska administrators felt that peer-to-peer in-app communications, to allow village staff to openly discuss work and associated challenges, could help with staff retention. Features to rate and report job satisfaction were also considered as another way to improve retention. These ideas were rooted in direct observations during training programs that it was typical for job satisfaction related conversations to be initiated by participants. We were unable to further test or explore these ideas in the current project. These ideas and specific app features could be the subject of future work.

2.2.5 Equipment and Materials

"We're pretty fortunate to be tooled up and have had different opportunities to get tools ... That makes all the difference. You ain't got a Sawzall, you ain't got a pair of clippers, … makes it almost impossible. And a lot of villages don't." - Village Coordinator

Having the right equipment is essential for backhaul. PPE and packaging materials are critical. Storage space for waste is also important. Tools to disassemble waste into component parts, to weigh materials, and to load packed waste onto barges are similarly necessary. The types and quantities of tools and equipment that each community has, however, varies greatly. For marine backhaul shipments, it was common in some communities to transport backhaul materials to the beach/port in carts pulled by all-terrain vehicles (ATVs) and then to pack the materials into shipping container at that location, because these communities lacked loading equipment for large containers. Other communities had loaders that could lift and transport a filled shipping container from the site of packing to the water. Most communities lacked a scale to weigh pallets of waste, which RCs reported as problematic when working with the Survey123 pilot app, which required forced completion of the data entry field for weight (this should inform future app development; see Appendix A).

Several opportunities exist to address equipment and material needs through an app. While Backhaul Alaska provides participating communities with PPE and some packing materials, these need to be regularly inventoried, likely through a seasonal checklist that could be included as an app resource (refer to Figure 2.2). Equipment and infrastructure inventories (refer to Section 2.2.3) are also essential information. Several RCs suggested that an app could include information and locations for purchasing equipment and supplies. This may be helpful, especially for useful items not furnished by Backhaul Alaska.

Communication between communities (refer to Section 2.2.2) may also be an important part of the equipment puzzle. Local and regional staff frequently highlighted the importance of learning from other communities to develop creative solutions for equipment shortages. For example, one regional expert described the use of old DOT dust suppression bags (which many communities have lying around) to pack batteries, thus greatly reducing costs. Possibly because most live in remote communities without road access to commercial stores (except a small grocery store), village staff are resourceful and creative at finding workarounds to many problems. Whether shared through direct question and answer forums or as a standalone section in which to report success stories and workarounds, an app could document and facilitate knowledge exchange and idea sharing.

2.2.6 Opportunities for Synergies

"Many of these environmental staff, and just people with jobs … in the rural communities, wear multiple hats." - Regional Coordinator

For most Backhaul Alaska participants, especially RCs, VCs, and their assistants, backhaul activities dovetail with other activities. Among the village level participants that directly participated in this project, there was often little separation between backhaul-related work (targeting specific types of hazardous waste) and other waste management and recycling activities in which they were engaged. These participants often shared information or sought advice from other communities on wider recycling and solid waste management issues. Speaking to someone about non-Backhaul Alaska activities (e.g., other community waste issues) might be an opening to learn about more relevant, effective, or safer backhaul practices. Equipment and tools obtained from other programs and grants were often considered essential for doing backhaul work. While it is likely beyond the scope of a Backhaul Alaska app to serve all related environmental management efforts, certainly in the short-term, the communication features (outlined in Section 2.2.2) should seek to embody the holistic way that participants think about waste management and environmental programs in their communities, as opposed to thinking of backhaul as wholly separate. Backhaul Alaska participants, including Backhaul Alaska administrators with decades of experience working in rural waste management, live this holistic perspective of waste management and understand the end-health and community benefits of backhaul can only be assessed within the larger waste management circumstances of the community.

Beyond embodying this holistic perspective, there may be specific opportunities for a Backhaul Alaska app to support other activities and needs. Regional experts and Backhaul Alaska administrative staff frequently encountered materials or situations that they wanted to share with others in the wider waste management community. For example, the SC said:

"*A contractor … was coming in to fix equipment in a community. I was able to share info about where the equipment is, which saves the community money. [It's] a win-win for everyone*."

Similarly, an RC helped administer a program that repaired old computers to give them to community members. Any salvageable e-waste in Backhaul Alaska inventories could be repurposed along these lines. A Backhaul Alaska app might support such activities through general communication pathways (refer to Section 2.2.2) or more specific features designed for records export and sharing.

2.2.7 Liability and Safety Concerns

"We don't want to get involved with people getting themselves in trouble for trying to share something that they didn't really understand." *- Regional Expert*

Several liability and safety concerns came up during our conversations; though participants repeatedly noted that safety, especially related to packing and shipping, is a cornerstone of Backhaul Alaska. Concerns that were discussed by people during research activities for this project fell into two categories: (1) concerns related to Backhaul Alaska and how they might be addressed within the app and (2) specific app design issues.

In terms of concerns related to Backhaul Alaska, one RC suggested that some communities might worry about liability if they did something wrong; and this concern could, potentially, deter participation. The issue is not whether liability is a real risk (Backhaul Alaska has liability insurance and training/certifying individuals to properly pack waste is a cornerstone of the program). Rather, the fear of liability may be enough of a deterrent, irrespective of real liability rules and training certifications. Another RC commented that staying up to date on federal regulations was daunting and unrealistic as coordinating backhaul activities was not their full-time job. In both cases, providing easy-to-access information about rules and liability (ideally that clearly outlined immunity) in an app could go a long way to alleviating such concerns.

Several worst-case scenario stories also came up during research activities for this project, including that of finding old explosives at a backhaul event (Box 2.1), as well as a community having to pay when a shipper picked up the wrong pallet. Clear guidance and information about who to contact in the event of these types of scenarios (e.g., finding things that you are not equipped or authorized to handle, or what to do in the event of a spill or environmental contamination) could be content within a Backhaul Alaska app. Of course, app content should not replace existing emergency protocols, including but not limited to, an existing 24-hour emergency service that Backhaul Alaska utilizes.

Among the people that participated in research activities for this project, no one voiced concerns about health or safety while doing backhaul work, which may reflect the fact that Backhual Alaska focuses heavily on safety training and provides PPE to communities. As mentioned in previous sections, communicating safety protocols and ensuring that PPE inventories are appropriately stocked are important features of a Backhaul Alaska app.

In terms of app design issues, one regional expert was concerned that users might unintentionally disclose incriminating information, such as regulatory or safety violations. These violations might be seen in the background of a photo, for example. One solution would be an app feature to blur photo backgrounds; however, unintentionally documenting a violation or safety issues through photos could allow Backhaul Alaska to learn about and correct something important. Thus, app features that might protect the individual might also hinder the wider safety and compliance goals of Backhaul Alaska.

Box 2.1. A Nightmare Scenario

"Hey, we got a bunch of stuff up at our school, in the back room, that we just had over the years. Can I bring it in [to be backhauled]?" This well-intentioned request set in motion a day that waste managers would never forget. **(*Note, this was not a Backhaul Alaska event.*)**

Unaware that the school had once been used as an army holding facility, the waste management expert running the backhaul event invited the school down. "Everything they brought in was old military stuff, including dynamite," the waste management expert recalls. "My legs were shaking. I mean, literally!" he said. "The guy [brought it] in his truck, had this truck on the state ferries."

With swift thinking, our expert had the truck moved to an empty parking lot and isolated it. Later they brought in a specialist from Seattle that dealt with military waste. "We got it stored in a building, segregated the building off, put signs up: *Do not enter, danger*," our expert said. "You run across stuff like that [working in Alaska]," they concluded.

2.2.8 Data Sovereignty and Cultural Considerations

"We survive … it's hunting and gathering and that's where a lot of the main source of food comes from. It's expensive to get stuff here. … All that stuff [subsistence activities] is really important to us."

- Village Coordinator

The academic literature (Kouril et al. 2015, Ford et al. 2016, IARPC 2018, Kipp et al. 2019) and several experts that we spoke with emphasized the importance of understanding traditional knowledge and cultural activities when working with Native communities. During the RC workshop (Methods, Appendix B), participants noted that the app could provide opportunities to enhance language revival – a goal of many of the communities participating in Backhaul Alaska. While information in the app could be displayed in Native languages, it would be challenging to have information recorded that way since others involved with reviewing the data and inventories would also need to be familiar with the language. Several people (including VCs, RCs, and Backhaul Alaska administrators) with firsthand knowledge about communities repeatedly confirmed that almost everyone working in Backhaul Alaska was comfortable using English (Section 3.0). Capturing local terminology and units of measures (e.g., “a fish tote”) could be an important way to tailor the app for local users.

During the RC workshop, people also felt there were limited opportunities for a Backhaul Alaska app to engage with traditional knowledge, partly because hazardous waste packing is not about environmental observation or monitoring, and because waste management is subject to multiple state and federal regulations. Program staff suggested, however, that it might be important and helpful to provide space in the app for local staff to note if waste or waste storage was impacting species or areas of cultural significance. Reporting local weather conditions, as well as ice arrival and breakup, could also help with coordinating transportation. Planning for local site visits could similarly be enhanced by knowing more about important traditional harvesting activities, and when local staff might be unavailable because they are hunting or fishing.

Academic literature (Lewis 2020) and the technology experts that we spoke with also highlighted that data sovereignty and privacy were often important issues in primarily rural Alaska Native communities. In general, data sovereignty related to Backhaul Alaska did not raise many concerns among the VCs and RCs that we spoke with, though several RCs highlighted the importance of clear user agreements if using third party apps and data hosting sites. One regional expert noted that some tribal communities might have reservations about databases managed by the federal government, but this is not likely to be the case for Backhaul Alaska. Program administrators noted that community concerns over waivers or user agreements could arise on an individual basis and that in their experience, it was best to deal with any specific issues on a case-by-case basis.

During conversations for this project, at least one regional expert and VC brought up the idea of inventorying caches of legacy waste located outside of the village. Some of this waste might be associated with old mining camps or hunting and fishing activities and might include areas used for traditional hunting and gathering activities. Inventorying waste at subsistence sites could become sensitive since GPS coordinates are recorded during inventory, but hunters and fishers often want their harvesting spots to remain private. While Backhaul Alaska administrators did not foresee inventorying waste outside of the village in the immediate future, they are acutely aware of proprietary and cultural issues related to subsistence site location and purpose and recognized the potential sensitivity. An app would need to take such sensitivity into consideration.

2.3 Data Management Needs

“I wish I had a place where I could put all my correspondences. Sometimes I’m not sure if I put it under correspondence or … under a village.” *- Backhaul Alaska Program administrative staff member*

Backhaul Alaska collects text and numerical data about waste inventories, equipment, and community infrastructure. Photos and point locations (Global Positioning System (GPS) coordinates; Section 2.4) are also collected. Data must be stored on a server that can be accessed remotely through a relational database. Likely queries that RCs, SC, and CT discussed include but are not limited to, community name, waste type, date, packaging status (i.e., complete vs. incomplete), training and equipment needs, and names of individuals or companies when documenting correspondence (Appendix A: Survey123 user feedback, for more specific examples and discussion about data use and management). Program staff were pleased by the mapping and geospatial capabilities made possible with the use of the Survey123 app during the 2021 pilot (Section 2.4 and Appendix A). Geospatial data collection and visualization are likely needed for future app development, which might include community and public-facing dashboards (Section 3.0 and Section 4.0 outlining how different users might access information).

Data viewing will likely require some restrictions by user type and will depend on what information, if any, is sensitive or private for a given community. Several RCs noted that some communities may not want their waste inventories to be seen by other communities. According to one VC, waste inventories can certainly be sensitive, though the culture seems to be changing: "In the beginning years," said the VC, "people were embarrassed about the garbage. I don't think so much anymore. Now …. we are … showing that we're cleaning it up. We're proactive, … doing the right thing, rather than … ignoring it." RCs and program staff also noted that sharing village waste inventories was important for regional coordination. Training records and staff turnover were more likely to be seen as sensitive and more feasibly kept internal to community viewing, although they still need to be viewed by RCs and the SC. Finally, communication records among regional actors, including RCs, SC, CT, and possibly statewide partners (e.g., Federal and State; Figure 2.4), may also require restricted access that would likely be managed by the SC (Table 2.2).

Table 2.2. Possible scenario of generation and access for records among Backhaul Program actors.

Type of Record	Example	Creation by	Accesses by
Village level, non-sensitive	Waste inventories	All Villages RCs & SC Regional Partners	All Villages RCs, SC, & CT Regional Partners*
Village level, possibly sensitive	Training records and staff turnover	All Villages RCs & SC Regional Partners	Village (only its own) RCs, SC, & CT Regional Partners*
Regional Information	Regional coordination activities	RCs, SC, & CT Regional Partners	RCs, SC, & CT Regional Partners

** At the time of publishing, it was uncertain if regional partners needed to access these records.*

As previously discussed, the number of individuals who need to be app users within Backhaul Alaska is likely to be relatively small. Although Figure 2.3a shows a maximum capacity of 160 communities, we rounded this up to 200 communities to be conservative in case Backhaul Alaska expands even more. At 200 communities, the program would have about 600 to 650 app users. Each community will have on average between zero and three licensed users (zero for those communities lacking staff capacity, in which case the RC will assist; refer to sections 2.2.2 and 2.2.4). At the time of this project, Backhaul Alaska had seven RCs, though several more may be recruited. Finally, the SC and CT require user licenses, with the possibility of several more administrators in the future.

Backhaul Alaska is also unlikely to need large amounts of data storage. For the 2021 pilot program, consisting of 16 communities, Backhaul Alaska collected 50 - 100 megabytes (MB) of data using the Survey123 app. While the program is expected to grow rapidly over the next decade (Figure 2.3a), the generation of data records is unlikely to grow at the same pace because many communities only backhaul every few years (Figure 2.3b). Furthermore, even using an app with more advanced features and content than Survey123 (e.g., training materials, communication, and task assignments), storage needs are unlikely to be a limiting factor for the program. With terabytes of information able to be stored currently for just a few hundred dollars, data storage costs are low.

Finally, several data quality assurances and quality controls (QAQCs) may be needed for a Backhaul Alaska app. These QAQCs are specific to data management and differ from established safety, packing, and labeling "readiness checks" currently used by Backhaul Alaska for waste inventory and packing operations (e.g., training certified packers and photo verification of packed waste). Ensuring that data records are uploaded to the server is a key concern given remote offline working conditions (described in section 2.2.1). Two RCs experienced problems with data uploads using the Survey123 app (detailed in Appendix A, list 2, item 12). In both cases, the RCs assumed that the records had been uploaded upon reconnecting their phones with data or Wi-Fi services, only to learn later that not all of them had been. In one case, the RC only discovered the failed upload when they demonstrated use of the app for the EPA research team during the interview/conversation. Incorporating an easy-to-read upload status in the app and perhaps a reminder notification, could reduce upload errors from the field user's side. Notifying the SC and CT how many out of their total number of records had been received could also alleviate problems at the administrative end.

Another QAQC concern, while not observed and only hypothetical, is ensuring that duplicate records are not sent, and if they are sent, easily detecting them. Duplicate records could occur, for example, if state or federal partners (outlined in Section 2.1) and RCs working in a village at different times were unaware of each other's activities. While in-app communication records (Section 2.2.2) might reduce the potential for uncoordinated activities, they may not be reliable enough to prevent every possible case of duplicate records, which could have significant implications if duplicate inventory led to more expensive or unnecessary shipping arrangements.

Ensuring that mobile devices are up to date with any app build or content changes may also require QAQC measures. This is primarily a concern for village level staff, whose devices may be offline for long periods of time and not able to receive app updates immediately (Section 2.2.1). One solution may be to record app build versions and time stamps of most recent content updates among users. This information could then be used to trigger notices to both the VC and SC, who could monitor and assist if a device, or group of users (perhaps in a specific region) require updates.

2.4 Geospatial Needs

"A lot of times the waste is located offsite because [the local community] knows that it's potentially toxic, hazardous, … so they tend to place it somewhere hidden. [If] we can document it right then and there with the GPS location, then we have a better idea for when that time comes … to help them ship it out."

- Program Administrative Staff

Backhaul Alaska benefits greatly from a geospatial data collection and mapping. The 2021 piloting of the Survey123 app included features to geolocate waste and waste management infrastructure and to visualize these using a Geographic Information System (GIS). The RCs and program administrators were very enthusiastic about this feature as mapping helped them get a feel for local communities when they were unable to visit them and help new staff learn. Mapping also helped communicate and share information both within the program and to external partners (for example, the SC's account of sharing repair needs with external contractors, including location information, in Section 2.2.6).

Box 2.2. What is Geospatial Data?

In Geographic Information Systems (GIS), data can be recorded as points, lines, and polygons. Points document a single x-y position and are often used to record small features in the landscape (e.g., storm drains). Lines connect two or more points with a different start and end position; lines are often used to record features such as rivers or roads. Polygons connect three or more points to create a closed shape; polygons are often used to document building outlines or water bodies.

When using Survey123, Backhaul Alaska recorded all information as points, which is only one type of data that can be collected and mapped in a GIS (Box 2.2). When asked, several RCs said they saw little benefit to using polygons, an alternative geospatial data structure, which could be used to outline areas in detail, but require more effort to record than points (Box. 2.2). The RCs were open, however, to using polygons if there was a clear benefit. Several ways in which people thought polygons might be useful included recording the shape of landfills or buildings in the general sites survey, or documenting fences delineating landfills or other storage areas (a single length of fence would be a line, while a full enclosure would be a polygon). There was unanimous feedback that point locations were sufficient and desirable for locating pallets of materials for backhaul in the inventory survey.

Given the extra effort in the field to record polygons over points, app development should continue with using points. However, since mapping was described so favorably by program participants, it may be desirable to create more detailed community infrastructure maps for Backhaul Alaska using polygons for waste storage and staging areas. Data could be collected in the field when there is capacity, recorded from aerial images, or obtained from relevant administrative authorities to see if such GIS records already exist for some or all communities. Refer to Appendix A for details.

Note, while geospatial data collection and mapping are important for Backhaul Alaska, there is currently limited or no need for more advanced geospatial app functionality such as creating spatial buffers or searching for sites based on proximity to another site. However, Backhaul Alaska's needs and interest could change in the future.

2.5 Section Summary

- Backhaul Alaska operates through a seasonal cycle of activities, each with unique needs from an app.
- An app must work offline when telecommunications services are limited and there is unreliable service or low bandwidth. Devices may be offline for several days at a time.
- The app will be used where there is a risk of damage from water, dust, and crushing and should accommodate users wearing gloves in cold weather or to protect hands from injury and dermal exposure (e.g. lead) when packing.
- Several types of communication must take place within the app including training and education, verification and confirmation, information sharing, and coordination. Communication may be one- or two-way, informal or formal, and may depend on the occurrence of specific events.
- Documenting informal communications among people working at state and regional levels is important. At the village level, however, caution should be taken to ensure that app-based communication does not stifle opportunities for Backhaul Alaska participants to talk with and educate citizens, which occurs when citizens call for waste pickup/drop off or other information.
- An app should contain information about individual villages and people to contact.
- Staff turnover, a lack of qualified workers, and over-taxing existing staff were frequently cited challenges for completing backhaul work. Documenting communications, local information, and training materials may help alleviate these challenges.
- Backhaul requires specific tools and equipment. An app can host inventory lists, notifications when equipment needs restocking, and communication features to share equipment, backhaul best practices, and creative solutions to equipment shortages.
- Many Backhaul Alaska participants have other jobs and responsibilities that dovetail with Backhaul Alaska. Communication features should embody the holistic way that participants think about waste management and environmental programs in their communities, as opposed to thinking of backhaul activities as wholly separate.
- App features and content should consider, and ideally alleviate, any liability concerns that participating communities may have, even if the concerns are only hypothetical.
- Future app development should be cognizant of and evaluate any tradeoffs among individual user protections (such as blurred photo backgrounds) and opportunities to learn about and address unintentionally documented safety issues or regulatory violations.
- The concept of using the app to help support communities' language revival goals by displaying content in local languages was considered but because a primary Backhaul Alaska goal is uniform, efficient, and cost effective backhaul management, English is the recommended language for app content. Almost all current participants are comfortable with English and incorporating a variety of local languages into an app could slow down development and make it expensive. However, Backhaul Alaska could revisit this idea as the program evolves.

- There were few, if any, concerns over data sovereignty related to the information collected with a Backhaul Alaska app, though specific villages may have concerns that are not documented in this report.
- The app should provide opportunities for users to document any concerns about culturally significant areas, local weather conditions to help coordinate waste transport, and any staff unavailability due to subsistence hunting or fishing activities.
- Backhaul Alaska will require a relational database and there should be QAQC to ensure that records and content are synced properly considering poor internet connectivity. Any duplicate records should be easily flagged and corrected.
- Backhaul Alaska has modest data storage needs.
- Backhaul Alaska benefits greatly from geospatial capabilities.

Section 3. Users of the Backhaul Program App

3.1 Introduction

Human-centered design is fundamentally concerned with understanding who will use an app (or other technology), their concerns, and their activities (Teacher et al. 2013, Andrachuk et al. 2019, Siegler et al. 2021). While Section 2.0 fully embodies this perspective, it does so at a holistic programmatic level. In Section 3.0, focus is on specific types of users by outlining user profiles for different user groups. The profiles outline user's roles and responsibilities, working conditions, backgrounds, key challenges related to Backhaul Alaska, and what they are likely to do with a Backhaul Alaska app. Importantly, the profiles also outline any unknowns and unanswered questions for different use types and items that might warrant investigation for future rounds of human-centered design research.

The user profiles are based on information collected through the various research activities for this project and there are two data limitations worth noting. First, the village level participants that directly participated in research activities for this project likely fall towards one end of the capacity and technology-infrastructure spectrums (described in Section 2). For example, the VCs and village staff that participated in the conversations had time to participate and were, therefore, likely to be less overburdened than people in some other villages. They also had the digital resources to speak remotely, even if their internet bandwidth was not great (for example, the conversations were punctuated with transmission delays such that we had to turn off video at times to improve call quality). To account for this selective participation, we include information about village level users and their needs from the expert opinions of RCs, program administrators, and regional experts who have direct experience working with village level users in a variety of contexts. Such expert opinions help document the conditions and needs found in the diversity of villages that are served by Backhaul Alaska; however, there is always the potential that certain aspects about village level users may be missing since direct participation for this project by villages level participants is by necessity selective.

Second, the research activities for this project did not include direct participation from shippers and vendors (receiving and supply), a decision we made due to restraints of research time and logistics. Data about shippers and vendors are based on insights from RCs, program administrators, and regional experts who work with shippers and vendors during their backhaul work. While an important source of information, these past interactions where not directly focused on understanding shippers' and vendors' needs and interests in relation to a Backhaul Alaska app. Additional future work may be needed to better understand the needs and interests of shippers and vendors.

The following section, Section 3.2, provides a one-page profile for each user group: SC, CT, RCs, VCs, shippers, and vendors, followed by documentation of several ideas gathered about additional potential users. Section 3.3 summarizes user needs into four general categories and indicates how to address these needs in design and development of a Backhaul Alaska app.

3.2 User Profiles

Profiles start on next page.

3.2.1 The State Coordinator (SC)

Roles and Responsibilities

The SC oversees overall program implementation and day-to-day operations. They plan for each year's enrolment of new villages, train RCs, work with RCs to train VCs and village staff, and support village backhauls. The SC might be a single individual, or a lead and assistant. The SC works with the CT to review and approve waste packing and shipping. The SC was frequently cited as a key resource and information broker that both RCs and VCs would contact.

Working Conditions

Administrative work is done from an office using several software tools, including Microsoft SharePoint, Access, and EsriSurvey123; the SC commented that collecting, storing, and viewing all data within one software might be easier and more efficient. The SC and assistants also visit local villages to help train staff and assist with inventory and packing (Figure 3.1). While visiting villages, the SC and assistants might have limited access to the internet.

User Background

The SC's role requires a high level of computer literacy and ability to work with spreadsheets and relational databases. The two individuals occupying the SC/assistant roles both had extensive experience with backhaul and waste management in rural Alaska. Their institutional knowledge helped make them a key resource and central figures.

Key Challenges

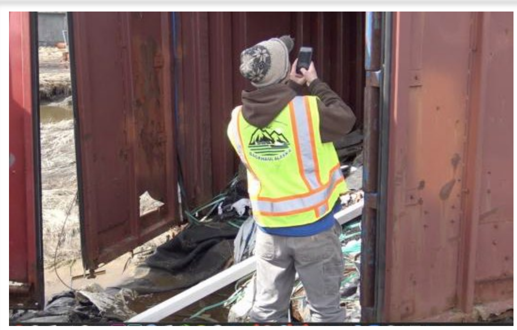
SC capacity may not scale linearly with the number of added communities as Backhaul Alaska expands. Program administrators added the SC assistant to help carry out the SC's role. As the program expands to serve more communities, the SC and assistant may not be able to maintain the same level of close community support without improved efficiency or additional assistants, which might add to communication and coordination challenges.

App Use

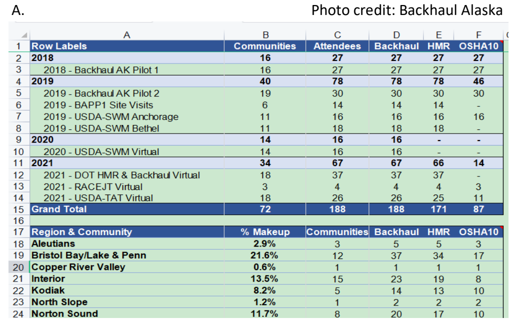
A SC would primarily use a Backhaul Alaska app for inventory, verification, communication, and coordination. They also view and manage data records and app user licensing. SCs may generate and update training and educational content for the app.

Unanswered Questions

As the program expands, Backhaul Alaska administrators envision reducing the amount of on-the-ground activities carried out by the SC and assistant(s) while transferring some of this work to the RCs. The SC and assistants will maintain some level of on-the-ground work to ensure program continuity, maintenance of their own field skills, and serving as RC backups. These changes may alter existing communication and coordination dynamics and app development should remain attuned to such changes.



A. Photo credit: Backhaul Alaska



	A	B	C	D	E	F
1	**Row Labels**	**Communities**	**Attendees**	**Backhaul**	**HMR**	**OSHA10**
2	**2018**	**16**	**27**	**27**	**27**	**27**
3	2018 - Backhaul AK Pilot 1	16	27	27	27	27
4	**2019**	**40**	**78**	**78**	**78**	**46**
5	2019 - Backhaul AK Pilot 2	19	30	30	30	30
6	2019 - BAPP1 Site Visits	6	14	14	14	-
7	2019 - USDA-SWM Anchorage	11	16	16	16	16
8	2019 - USDA-SWM Bethel	11	18	18	18	-
9	**2020**	**14**	**16**	**16**	**-**	**-**
10	2020 - USDA-SWM Virtual	14	16	16	-	-
11	**2021**	**34**	**67**	**67**	**66**	**14**
12	2021 - DOT HMR & Backhaul Virtual	18	37	37	37	-
13	2021 - RACEJT Virtual	3	4	4	4	3
14	2021 - USDA-TAT Virtual	18	26	26	25	11
15	**Grand Total**	**72**	**188**	**188**	**171**	**87**
16						
17	**Region & Community**	**% Makeup**	**Communities**	**Backhaul**	**HMR**	**OSHA10**
18	**Aleutians**	**2.9%**	3	5	5	3
19	**Bristol Bay/Lake & Penn**	**21.6%**	12	37	34	17
20	**Copper River Valley**	**0.6%**	1	1	1	1
21	**Interior**	**13.5%**	15	23	19	8
22	**Kodiak**	**8.2%**	5	14	13	10
23	**North Slope**	**1.2%**	1	2	2	2
24	**Norton Sound**	**11.7%**	8	20	17	10

B. Photo credit: Backhaul Alaska

Figure 3.1. SC assisting with local village backhaul (A) and tracking program training with a spreadsheet (B).

3.2.2 The Control Tower (CT)

Roles and Responsibilities

The CT coordinates shipping and receiving of waste at final destinations and may work with supply vendors to ensure that villages have certain equipment, such as CONEX shipping containers to load waste. The CT works closely with the SC and coordinates with the RCs for waste transport from villages. The CT also does a fair amount of logistical work with counterparts in Seattle, WA once materials are offloaded by the shipper. This includes arranging and overseeing storage of waste until various materials can be taken by recyclers.

Working Conditions

The CT works from an office and does substantial coordination by phone and email (phone calls are often followed up with email for documentation). They generate many records and communication logs that need to be entered into a relational database. The CT uses the same digital tools as the SC for waste tracking and verification.

The CT monitors and tracks shipping vessels; existing methods used include marine traffic automatic identification system (AIS) tracking apps and software.

User Background

The CT's role requires a relatively high level of computer literacy as they must work with spreadsheets and relational databases (e.g., Figure 3.2). The two people occupying the role of CT that participated in the unstructured conversations varied in their self-reported comfort with computers. One was quite comfortable with tools such as the Survey123 app, while the other felt less comfortable. In their own words: they "grew up when computers were big in college and not in elementary school." In part due to what they saw as a generational shift in the ease of use of digital tools.

Key Challenges

We observed staff turnover for the role of CT.

App Use

The CT would work with the data management and dashboard side of an app. They need to view and edit records, as well as send and receive communications to/from the SC, RCs, shippers, and vendors (shippers and vendors may not be app users; see below).

Unanswered Questions

Backhaul Alaska is still refining the role of the CT and who should fill it. There may be future changes to this position. Specific to a Backhaul Alaska app, it is unknown to what extent communications and records management with shippers and vendors would occur within versus outside the app.

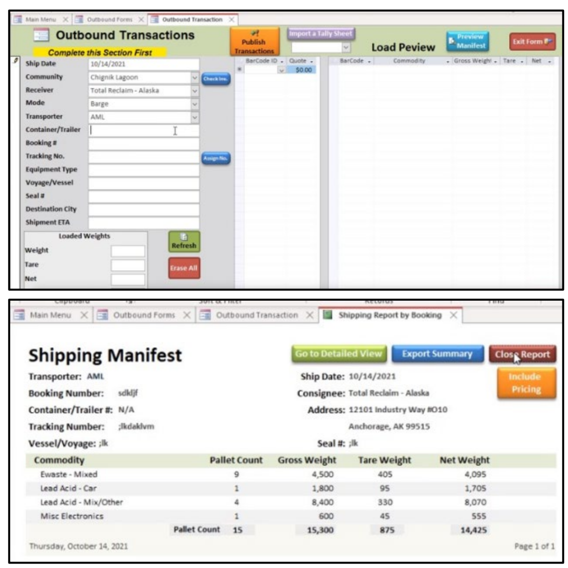


Photo credit: Backhaul Alaska

Figure 3.2. Database software (Microsoft Access) used by the CT for creating shipping manifests.

3.2.3 Regional Coordinators (RCs)

Roles and Responsibilities

RCs work with and coordinate among individual VCs. Primary tasks include training village staff (Figure 3.3), ensuring they have necessary safety and packing equipment, ensuring that village waste inventories are documented and received by the SC, and working with the CT to coordinate waste shipping. RC activities vary according to the level of support needed by each village. They work closely with VCs. An RC might do all waste inventory and packing for some villages.

Working Conditions

The RC is a part-time position, usually carried out by someone with a related job in the region, such as working for a tribal health or environmental organization. RCs wear multiple hats and make trips to villages for related activities (e.g., health and environmental monitoring), as well as backhaul. The RCs that participated in research activities for this project tended to use personal phones to collect information in villages, including photos, which were not just for backhaul activities. They preferred mobile phone cameras over dedicated cameras because phones were easier to use and produced higher quality photos. One RC wished for a separate work phone to separate work and personal content. Several others were comfortable using personal phones.

RCs may be in remote villages for several days with limited internet access. While assisting villages, they may work in extreme weather (wet and cold) and may be lifting heavy objects with the potential to damage a phone or tablet. Several RCs thought positively about being provided with ruggedized devices but questioned who would pay for them (e.g., personal expense, local tribes, Backhaul Alaska).

User Background

RCs are generally professionals with work experience in related fields of health and environmental management. Overall, the RCs were comfortable working with digital technology and a variety of software tools, though one person said they were uncomfortable with mobile apps and digital technology. Several RCs said they would like to have hard copy backups of the content in a Backhaul Alaska app due to personal preference or a lack of trust in technology. This was expressed by users at both high and low ends of the self-identified digital literacy spectrum. An app could allow easy selection and formatting of content to be printed.

Key Challenges

Because backhaul is only a small percentage of their work, staying up to date on best practices and regulations can be daunting. Not necessarily specific to their Backhaul Alaska work, RCs travel frequently in difficult work environments and find themselves having to work in villages about which they have limited, or no, prior knowledge. Burnout is a concern and there can be staff turnover. New RCs may have multiple steep learning curves for their duties with Backhaul Alaska, in addition to the other work their new position entails.

App Use

RCs would primarily use the app for inventory, verification, communication, and training. RCs need to view and manage data records. They may generate and update training and educational content.

Unanswered Questions

RCs may take on more autonomy as the program grows. It is unknown if this change would affect app use or needs.

Photo credit: **Kodiak Area Native Association 2021**

Figure 3.3. RC training village staff in an office.

3.2.4 Village Coordinators (VCs) and Supporting Staff

Roles and Responsibilities

VCs inventory and pack waste. They may employ one or more local staff for assistance. VCs and their staff may be community waste management leaders.

Working Conditions

Village conditions and resources vary (see section 2.0). In general, villages have poor internet services which may be limited to municipal/tribal buildings, while waste is stored and processed in shipping containers (e.g., CONEX) or other make-shift facilities that are sometimes far away.

"Our [waste] consolidation [area] turns to mud sometimes, … No electricity; no heat. It's not really that fun to be outside … in the winter … when it's pitch black and 20 below. … In the springtime, when it's [milder] we … get pallets ready."

"When they told us … the barge was [coming] … the [CONEX] that our e-waste was in was buried under like 12 feet of snow."

VCs and their staff often work in extreme weather (wet and cold, Figure 3.4), lifting heavy objects with the potential to damage a phone or tablet. One local laborer described crushing a phone while lifting items for backhaul. They liked the idea of a ruggedized device, though preferred a tablet over a phone for the larger screen size. A dedicated professional device would also prevent mixing personal and professional photos, which they were concerned about.

Many local communities have small, close-knit populations. In one community, according to one person, "everybody knows everybody." Community members will call to arrange battery pickup or drop-off and might reply to paper fliers or Facebook posts by the VC. The VC and staff use such engagements as opportunities to educate people about recycling and proper waste disposal.

User Background

Village participants are likely less comfortable with technology than RCs, but this is not a given. Notwithstanding possible rare exceptions, village staff are likely comfortable working in English. Many people participate in subsistence activities (e.g., hunting or fishing), and are absent for periods of time.

Key Challenges

Staff turnover and availability of qualified workers are major challenges. Village-level staff may leave for significant periods of time for subsistence activities. Backhaul inventory work is often interrupted; VCs and staff might not use an app for several months and can forget how to log in or use an inventory app. The seasonal pace of work also makes it hard to remember what waste materials, packing supplies, and safety equipment are on hand.

App Use

The VC and staff would primarily use the app for inventory, communication, and receiving training. They may want to view community and regional information on a dashboard.

Unanswered Questions

RCs and regional experts provided insights about community variability; however, this study likely does not capture the full spectrum of community app users because direct participation by village level staff in this research was limited by logistics. Thus, village level personal preferences (e.g., phones vs. tablets and specific user preferences) may not be fully characterized in this report.

Photo credit: Backhaul Alaska

Figure 3.4. Packing e-waste in 12 feet of snow.

3.2.5 Shippers (Small and Large)

Roles and Responsibilities

Shippers move packed waste from small communities to larger regional hubs, or from hubs to southern ports (generally Seattle). They may bring packaging, safety, and other equipment into communities.

Working Conditions

Shippers transport materials in variable, often extreme weather conditions. Shipping may be subject to seasonal weather windows and delayed due to weather or other extreme events. For example, the global Covid-19 pandemic delayed some shipping.

User Background

Shipping is done primarily by sea and air but can include overland transport for interior Alaska. Since the pilot communities were mostly coastal (Figure 1.2), this report primarily documents marine transport.

Large marine shipping companies serve the larger communities, which may serve as regional waste consolidation hubs, and transport materials to Seattle. Large companies have established protocols for shipping manifests, scheduling, and loading materials. The CT is familiar with these protocols and communicates with large shippers by email and phone. Large shippers generally do not visit smaller communities due to navigational or cost restrictions.

Smaller communities are served by small shippers, which might include local marine or river transport operators, fishing vessels, or fuel barges. Working with smaller shippers is often on a case-by-case basis and many opportunities to utilize small shippers are learned about by RCs and VCs through word of mouth.

Key Challenges

Working with smaller shippers can be challenging because transporting backhaul materials is often a supplement to their primary work and subject to an external schedule and set of objectives. Small shippers may not have proper permits, insurance, or training to carry certain materials, creating logistical obstacles. Communication with small carriers is primarily through cell phones; reception can be an issue. Many small shippers are also involved with subsistence activities and may be unavailable for long periods of time.

Credibility may also be a concern for some small shippers. One VC described stories of so-called “bad actors” who will take backhaul materials for a fee, and then dump them off the coast. Whether real or hypothetical, this concern highlights the value of delivery verification.

App Use

It is uncertain how shippers might use a Backhaul Alaska app. Some participants in this research project felt that shippers would not be interested in an app because they had their own well-established systems (e.g., for routing and lading). Others thought that local shippers would be interested in viewing transport opportunities so they could schedule pickups to make extra money, somewhat akin to a ride sharing app.

Unanswered Questions

There are many unknowns about shippers' needs and interests in an app. Shippers' interests in a Backhaul Alaska app remain speculative, and they may lack the required internet services to engage with more advanced app features such as communication, verification, and feedback. Very High Frequency radio (VHF) and satellite communications could play a role with small marine shippers, but this is unknown to us. Backhaul transportation can also encompass overland or air components for some communities. Materials management and safety issues would be similar; however, there would be differences in scale, seasonality, and timing from those locations that use marine transport. Each transportation industry also has unique regulatory, reporting, and communication standards.

3.2.6 Vendors (focusing on receiving and not supplying)

Roles and Responsibilities

Vendors include those receiving and supplying materials. Conversations and other research activities for this report tended to focus on vendors who receive materials after shipment south, which remain the focus here. While currently not a formal role of receiving vendors, several VCs and RCs requested verification that materials were received and feedback on the packing quality.

Working Conditions

Backhaul Alaska works with various recycling and waste management vendors in the Seattle, WA area. Different vendors receive different waste streams. Once materials are offloaded at destination (e.g., from shipping barges), they are staged in holding facilities in the Seattle area (e.g., Figure 3.5) until further transport of specific materials occurs. The CT oversees this process and coordinates with a colleague on the ground at holding facilities.

User Background

Very little was documented, during this research project, about this user group's background, other than that they include professional recycling and waste management companies.

Key Challenges

Timely transfer of materials to vendors is important. If materials reside too long in holding facilities, fees are charged to Backhaul Alaska.

App Use

Vendors would likely use an app to verify receipt of shipments and to provide feedback on packing.

Unanswered Questions

A lot remains unknown regarding app needs and uses for this user group, since we were unable to speak directly with these potential users during our research. Vendors likely have adequate internet and other infrastructure to use an app at the jobsite. User needs and interest in using a Backhaul Alaska app may largely depend on company and individual interest.

The administrators of Backhaul Alaska, in planning for program expansion, are also researching alternative or additional shipping destinations, including locations in the United States, Canada, and other international markets. Key considerations include cost, logistics, and ethical disposal practices. It is unknown how any possible shipping changes may impact app development.

Photo credit: Kawarak 2021

Figure 3.5. Properly packaged waste received in Seattle, WA (source: Kawarak 2021).

3.2.7 Other Users

Other Program Partners

This group includes federal, state, and nonprofit employees working on similar waste management issues in Alaska. This might include SWAT and members of the Backhaul Advisory Council. Several of the regional experts that participated in research activities for this project include such individuals; they were enthusiastic about using a Backhaul Alaska app in their work. These partners work with many local villages and are aware of waste management activities at local and statewide levels. Their needs are similar to those of the RC: they may need to inventory waste, communicate and coordinate with the SC and RCs, and view dashboards of Backhaul Alaska waste inventory and operations.

In general, these program partners are comfortable using apps and digital technology. They may live in rural hubs with more reliable internet, more up-to-date office equipment, and may have support staff. Program partners work in similar conditions to RCs and SCs and face similar internet and technology access limitations when in the field. Program partners may also want to use a dashboard associated with the app to generate and communicate Backhaul Alaska activities and accomplishments.

Local Community Groups and Members

One regional expert suggested that local school groups, council members, or individual community members might assist with Backhaul Alaska activities and thus, use the app. While Backhaul Alaska focuses on training and certifying community packers and does not generally work with volunteer or school groups, this person's vision still must be documented. Community members or school groups might engage in one time, or annual, events – possibly with an educational objective – and might only need a simplified version of an app limited to basic inventory and educational information.

Any safety or liability issues related to having community members, especially children, involved with backhaul inventory and packing, would need to be considered and addressed. Therefore, there are likely some important unknowns about citizen and community user groups that are not considered here.

There are also possible downsides to individual community members using an app to inventory waste at home, or to communicate about waste to VCs and staff. Shifting to virtual communication might erode the important informal communications that happen between the VC, their assistant, and community members as outlined in section 3.2.4. Alternatively, in-app communication could create opportunities. Many remote Native communities have increasingly used social media as an important resource. Thus, the implications of channeling community level waste management interactions into an app should not be assumed and warrant further study.

Resource Development Projects, Private Companies, and Social Investment Corporations

Several regional experts highlighted the important role of private sponsorship for some activities, which is echoed in Backhaul Alaska planing documents (e.g., Zender Group, 2017). For example, backhaul funding, barge availability, and supplies/materials are sometimes offered as potential development opportunities in the region. Private and corporate partners probably do not need to use a Backhaul Alaska app, and there could be potential conflicts of interest if some companies had access to information while others did not. Local villages may also have concerns about sharing information that can be accessed by private companies and developers. Nonetheless, future research should continue to track what, if any, app needs exist for these groups. Additionally, private sector businesses may participate, in the future, with Backhaul Alaska in lifecycle management of specific wastes in these rural communities.

3.3 Summary of Generalized App Needs by User Type

While the exact features and user interface of a Backhaul Alaska app and potential supporting dashboard will depend on the specific development path(s) chosen by the program (see section 4.0), the needs for both realized and potential user types can be simplified into four general categories, which are presented in Table 3.1.

Table 3.1. Generalized App needs for Backhaul Alaska user, by user type.

App needs	Users	Description
Full functionality	SC, CT, RCs, VCs, and other partners	App needs include communication and verification, inventory, accessing and/or updating training materials and tutorials, and other information relevant for program function.
Simple or limited functionality	Receiving vendors Supply vendors School and community groups	App needs are more basic, limited to documenting information. For receiving vendors, this might be as simple as sending a survey form confirming receipt of shipments and rating or commenting on packing quality. Less is known about supply vendors. For school or citizen groups, users may have some inventory needs and access to certain educational information, but they are unlikely to require more advanced features such as communication and task assignments
Dashboard or website (one-way information sharing)	Shippers SWAT and Backhaul Advisory Council	App needs are likely limited to viewing information. This could be accomplished through a web-hosted dashboard, or something supported on a mobile device (see section 4.0). Shippers may want to know what is available for shipping, its location, and contact information. Should in-app communication and verification be desired, shippers may need a more comprehensive app configuration. Entities such as SWAT, and the Backhaul Advisory Council, may wish to view information on a web-based dashboard or website for internal uses or to communicate Backhaul Alaska activities and accomplishments. This might also provide options to communicate to the general public who also may be interested to learn about Backhaul Alaska activities.
Unknown	Resource Development Projects, Private Companies, and Social Investment Corporations	It is unknown how these entities intersect with a Backhaul Alaska app. Interest may increase in the future if the capacity of Backhaul Alaska increases to include additional waste types or develops private-public collaborations for lifecycle waste management.

Section 4. App Development Options

4.1 Introduction

This section explores the suitability of several options for developing a Backhaul Alaska app. These include: (1) developing a custom, all-encompassing app, (2) using third-party "off-the-shelf" apps, (3) using a website-based system, and (4) combining a suite of apps ("off the shelf" or custom built) and a website. Section 4.2 outlines these four options, analyzes them using a customizability and functionality vs. cost framework, and considers how each option supports Backhaul Alaska's operations.

Section 4.3 details the testing of two different apps during the 2020 - 2021 pilot session. The pilot experiences and their outcomes help illustrate an important component of a human-centered design approach: time. Human-centered design, as embodied here, is often a long road, continually iterating through phases of development, application, research, and reflection (Holeman and Kane 2019). The pilot experiences illustrate important decision points, historical dependencies, and long-term thinking that affects Backhaul Alaska's app development choices.

Finally, given the remote, offline environment and harsh weather conditions of rural Alaska, which may not be kind to digital devices, we also consider whether a digital solution (e.g., an app or website) is even best for village level implementation tasks. Section 4.4 challenges the assumption that a digital solution is best and considers paper records as an alternative.

4.2 Development Options

While developing a customized app for Backhaul Alaska provided the original vision for this project, our early research showed that building a full custom app should be considered alongside several other development options. The technology experts and representatives from programs with similar experiences that we spoke with (see methods appendix), as well as the academic literature (Teacher et al. 2013, Andrachuk et al. 2019, Siegler et al. 2021), highlighted the high costs and challenges of developing a custom app. They encouraged us to consider third-party or "off-the-shelf" apps and websites, if appropriate for needs (Table 4.1).

These sentiments are in line with wider app development trends for community-based environmental monitoring (a likely analog for Backhaul Alaska). A recent review by Andrachuk et al. (2019) documents an increase in use of third-party apps, as opposed to developing new ones. This trend is likely driven by cost saving measures, lower technology barriers (compared to computer programming for custom app development), and management convenience (Andrachuk et al. 2019). Software updates are dealt with by the hosting company; server space and a website to view and share information collected by the app are often (but not always) provided, for a fee (Teacher et al. 2013, Andrachuk et al. 2019, Siegler et al. 2021). The availability of convenient cloud data storage via third-party apps is noteworthy since data sovereignty was not a major concern among Backhaul Alaska participants that participated in research activities for this project (section 2.2.8). Finally, most third-party apps work with multiple operating systems such as Apple and Android (Siegler et al. 2021). On the contrary, updates, server space, and dashboards for viewing data all add substantial and ongoing costs to custom app development, which is already very costly.

Table 4.1. Comparison of several different development options.

Single "All Inclusive" App	Third-Party, "Off-the-Shelf" App	Website (and Web Apps)	Suite of Apps/Website
Pros - Tailor made to meet program needs. - Possibly more control over data ownership.	**Pros** - Ready to use. - Data storage and viewing is likely provided. - User support.	**Pros** - Easy to update and maintain. - Inexpensive - Highly customizable within limitations	**Pros** - Individual apps / websites targeted for specific functions. - May offer cost savings over a single app build (depending on specific suite of apps).
Cons - Expensive to develop and maintain. - Harder/slower to update.	**Cons** - Ongoing subscription costs. - Third-party data storage. - Not custom built.	**Cons** - Online access - (Web apps) reduced user experience (compared to operating system specific apps (Box 4.1)) - Ongoing subscription costs.	**Cons** - Potentially complicated or cumbersome. - Multiple systems to update and maintain.

While academic research on app costs is sparse (Andrachuk et al. 2019), Siegler et al. (2021) estimate that developing a mobile health app with modest functionality costs $150,000 USD[6]; and Teacher et al. (2013) describe a modest app that was developed for £43,000 GBP (about $65,000 USD in 2013)[7]. Such pricing is in line with what the technology experts that we consulted with hypothesized a custom built Backhaul Alaska app might cost. Importantly, neither of these prices include maintenance over time, server space, or other services that may be required (Figure 4.1). Indeed, Andrachuk et al. (2019:439) conclude that "the costs of maintaining apps is highly underappreciated and underestimated (e.g., to refine functionality, address bugs, and update software to match operating system and hardware updates)."

Custom development also involves a lot of uncertainty. Siegler et al. (2021) outline several notes of caution, many of which were echoed by the technology experts with whom we spoke. Working with a trusted and reputable developer is important. Computer code can be written in a way that makes it hard for a new developer to work with should the client choose to change developers for future updates (perhaps because the original developer goes out of business or increases prices for example). Certain coding choices can lead to expensive bug fixes or other legacy effects that can be hard to change. Unplanned but desired app features can lead to substantial cost increases and development time delays. To address these concerns,

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[6] Siegler et al. (2021) focus on developing mobile health apps, which may not be a perfect comparison to environmental management. Mobile health app development can include additional costs to meet Federal privacy laws, which may not be the case for environmental management. However, app development costs depend on many factors and advanced features such as geospatial needs that may be central to environmental management may not be needed for health applications. Notwithstanding some uncertainty, Siegler et al.'s (2021) price estimate is likely comparable to Backhaul Alaska's needs.

[7] Development costs are likely to differ by countries as they reflect developer salary rates.

Siegler et al. (2021) advocate having an independent developer on the research or product management team that can monitor and oversee the contracted development. The added cost of the additional researchers is offset by reducing potential problems that would be costly to fix later.

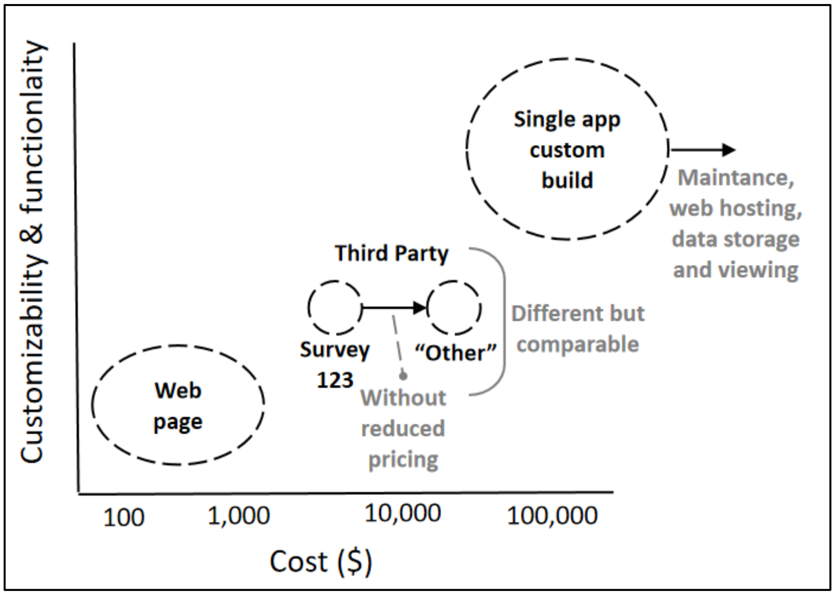

Figure 4.1. **Comparison of app development options considering customizability and functionality vs. costs.** The x-axis is a log scale, while the y-axis is unitless. Web page and single app custom build costs are estimates based on reports in the academic literature and expert opinions and do not represent any kind of market research. Third-party app costs (n = 2) represent actual price quotes and are presented in section 4.3. While web pages are highly customizable and offer substantial functionality (Andrachuk et al. 2019), we have placed web pages low on the y-axis because they cannot support Backhaul Alaska's offline needs.

Several technology experts that we spoke with also highlighted the benefits of using websites and web-apps (Box 4.1). Websites are inexpensive and easy to update. Unless a highly customized site is desired, a website can easily be built and maintained using any number of third-party subscription services. Websites and web apps must be accessed online, which is a major limitation of their use for Backhaul Alaska (section 2.2.1). Mobile apps do exist, however, that allow single web pages, or an entire website (a collection of pages under a unique URL) to be downloaded and stored on a mobile device. Using such apps could allow Backhaul Alaska to host and easily update content such as training materials, checklists, and community profiles on a website that users could download to their mobile devices. We did not, however, test or investigate such options in detail. Therefore, the suitability of downloading websites for offline use requires further investigation.

While there are many pros and cons to each development approach, the technology options are not mutually exclusive. Several third-party apps, or apps and websites could be combined for a "suite of apps/website" approach (Table 4.1). The suite could also involve developing a small app, with limited functionality, which can be cheaper than producing an all-encompassing custom app (Teacher et al. 2013), though likely still subject to ongoing maintenance, data storage, and server costs. A suite of apps, however, may become cumbersome to manage and the total costs for several expensive third-party apps might quickly add up in price to what an all-encompassing custom build might cost.

Box 4.1. What is an App?

An app is a software program, designed to work within a specific operating environment (e.g., Android or Apple iOS), that often interact with specific hardware (e.g., phone GPS sensors and cameras), other apps, and external services such as remote data storage and websites (Jabangwe et al. 2018, Gerlitz et al. 2019, Lai and Flensburg 2020). While an app may look like a stand-alone tool, it cannot be divorced from its larger context. An app is built to work with, and is dependent on, a complex assemblage of supporting hardware, software, inter-app communication choices made by its developers, as well as compliance with the requirements of its underlying operating system (OS) and distribution environments. App development and configuration also have important economic, socio-political, and data-security implications (Gerlitz et al. 2019, Lai and Flensburg 2020) – apps cannot be separated from the larger context in which they are developed and used.

Jabangwe et al. (2018) categorize three categories of apps: OS-specific apps, also called "native apps" are designed to "live" on a mobile device with builds that are specific to a given operating system (e.g., Android or Apple iOS). OS-specific, or "native apps" maximize the benefits of a particular OS and generally can work offline. Web-apps, alternatively, are developed to be accessed by internet browsers (requiring online access), and are therefore, more independent of specific operating systems. Hybrid apps combine the two but are closer in function to web-apps (Jabangwe et al. 2018).

4.3 Pilot App Case Studies

During the 2020 - 2021 Backhaul Alaska pilot, the program used the Esri software tool, Survey123, to inventory waste and community infrastructure. Survey123 was adopted by Backhaul Alaska prior to the start of this research project, to provide a digital inventory tool during one of the program's pilot efforts. EPA had been working with Zender Group to identify technology-based solutions to help with backhaul (e.g., shipping route optimization). Several EPA scientists (authors TB and PL) who were involved in those conversations had been working with Survey123 for other projects and suggested that it could be used for Backhaul Alaska's inventory needs. Backhaul Alaska administrators decided to try Survey123 and were provided access to Esri online ArcGIS Survey123 through EPA's administrative license for research and piloting purposes (see Appendix A for more details).

Survey123 was adopted to address an immediate applied need and was not necessarily intended to be a long-term solution for the program. Yet as we learned more about the upfront and long-term costs and administrative challenges of custom app development (section 4.2), third-party app solutions began to look more promising, at least in the near term.

Survey123 was not the only third-party option tested. Over the course of our research, we identified and evaluated other app-based data collection options. Subsequently, several conversations were held to learn from a company that had experience working in remote Alaska communities and that was making digital tools with great potential to meet many of Backhaul Alaska's app needs. In November and December 2021, Backhaul Alaska administrators decided to pilot this company's app in several Alaska communities, with very promising results.

Deciding which app would ultimately serve Backhaul Alaska's near-term needs, specifically, between Survey123 or the "other" app, was not an easy choice. While both options met Backhaul Alaska's waste inventory needs, the "other" option had several features that program administrators favored. The user interface was streamlined and easy to use and the app was able to support communication and coordination needs though in-app group chat that also could forward to personal email accounts. Program administrators valued the opportunity to work with a company that understood the challenges of working in rural Alaska. They also identified the long-term potential to integrate waste management services with other infrastructure services (an all-in-one community tool), one of which this company was providing already to many rural Alaska communities.

Backhaul Alaska, however, already had trained RCs and VCs to use Survey123 (summer 2021) and the next backhaul season (summer 2022) was fast approaching with Survey123 ready to be used. Using a tried and tested tool reduced uncertainty as the program started its first formal (post-pilot) implementation year, bringing many new communities on board (see Figure 2.2). If Backhaul Alaska purchased its own Esri administrative license, data migration from EPA's administrative license would be simple, and program administrators valued the fact that EPA colleagues could help with this transition. Finally, the geospatial capabilities and visualizations that came with Survey123 had become invaluable to the program and they saw exciting options in Esri's wider suite of tools, such as Story Maps, an Esri product that would allow communities participating in Backhaul Alaska, as well as program administrators themselves, to make interactive, online map-based stories to communicate their experiences to wider audiences. Such story mapping would fall under Backhaul Alaska's goals for local capacity building and help build wider financial support for the program.

Cost was a big factor as well. The "other" option would cost around $20,000 per year to support the program at full capacity. Licensing costs for Survey123 would only cost the program about $6,000 per year, a price that reflected discounted pricing for non-profit organizations. Entities working with government (e.g., local, state, or tribal) and university partners may also be able to benefit from licensing discounts. The commercial licensing rate for Survey123, however, is on par with the cost for the "other" app option (Figure 4.1).

Survey123 was selected for the near-term because of the existing investment to train RCs and VCs to use Survey 123, the app's geospatial capabilities and visualizations, and the financial savings, While Survery123 was chosen for near-term use, working with a company that understands rural Alaska remains important to Backhaul Alaska and developing an integrated utility app that includes waste management is exciting to Backhaul Alaska administrators. The "other" option is something that may be reconsidered in the future.

Backhaul Alaska's experience with these two pilot apps highlights several important considerations for app development. First, path dependency – the idea that current options are constrained by past choices – can be a significant factor. Backhaul Alaska had already trained RCs and VCs to use Survey123 and felt that it was best to stay the course and work with an existing solution that Backhaul Alaska participants were happy with. Using Survey123 was somewhat serendipitous; it was a practical solution to an immediate and applied need for the Backhaul Alaska pilot. Other projects engaged in human-centered design, however, might seek to delay adopting a specific technology solution until more research can be done about the range of options. Testing several options from the outset might place each on more equal footing and reduce the potential for path dependency. We recognize, however, adherence to this recommendation in the real world might be difficult, just as it was in the case of Backhaul Alaska.

Second, Backhaul Alaska's experiences with these two apps reveals an evolving story, which is in line with human-centered design: it is a process, continually iterating through phases of development, application, research, and reflection (Holeman and Kane 2019). Research, development, and application are intentionally blurred (Holeman and Kane 2019). Backhaul Alaska administrators emphasized that the program might benefit from a different app solution in the future. While Survey123 provided an immediate solution, it can also be a tool for continued learning. Indeed, part of Survey123's appeal was that it was a low-cost option (both financially and in human capacity), with promising room for growth (e.g., combining with other Esri apps) that the program could use while finding its stride. As the program grows over the next ten years (adding 10-20 communities per year) it will continue to make app development choices that meet evolving user needs in a dynamic technology landscape.

4.4 Future Development Options for Backhaul Alaska

While Backhaul Alaska is using Esri apps for its near-term needs (see section 4.3), there are many options that the program might consider. As the name implies, Survey123 is first and foremost a survey to collect information, which can include text, numerical, and geospatial data as well as photos. It is not designed to support many of the communication and coordination needs outlined in section 2.0.

Backhaul Alaska could, however, work creatively with Survey123 to address many needs. For example, user guidance and other documentation can be included as collapsible notes and images within the Survey123 form. Only static images are supported in the Survey123 mobile app (offline), while the online web app also supports animated graphics (e.g., files in Graphics Interchange Format (GIF)). Supplemental information, such as quick reference guides (i.e., cheat sheets) outlining shipping options and contact information, or what to do with broken or damaged materials (e.g., broken batteries) can also be embedded in the form. Static community profiles could be integrated in a similar way. Organizing such content with skip logic (a feature that changes what question or page a respondent sees next based on how they answer the current question) or conditional questions can help keep the forms streamlined, avoiding information overload. Survey123 forms could be used to make checklists for documenting things such as PPE, training activities, or packing materials inventories (see appendix A for more detail). A form could also be developed for recycling vendors to provide feedback about the packing of received shipments (as requested in section 2.2). This form might be very simple, documenting a photo, star rating, and comments. Lastly, several Esri apps support task assignments and confirmation, which could address certain two-way communication needs outlined in section 2.2.

Other options might include shifting to a different third party "off the shelf" app at a future date, one that provides desired features unavailable with Esri products. For example, at the time of writing, Esri apps did not support text messaging or chat (personal communication with Esri staff), a feature considered highly desirable by program administrators. Additional third-party apps could replace Survey123 or be used alongside it, embodying the "suite of apps" approach (Table 4.1), which also might include websites or small custom app development. Developing an all-encompassing Backhaul Alaska app also remains an option, should the program decide such an app is needed. The data and analysis in this report provide an important foundation to base any such app development on the needs and experiences of its users.

4.5 What About Paper?

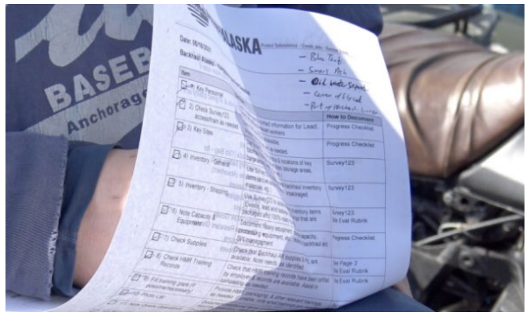

Photo credit: Backhaul Alaska

Figure 4.2. The challenge of trying to do Backhaul inventory using paper, which is being blown around.

Given the harsh working conditions and offline environment of backhaul activities, it is tempting to question if a digital solution is really better. What about good old-fashioned paper? Backhaul Alaska participants and regional experts quickly quelled this concern, but also highlighted the important role that paper should play as a vital information backup.

Even in some of the most remote communities with the worst digital infrastructure, cloud-based digital records were often favored over paper because paper records could easily be lost, especially during staff turnover. Though as noted in Section 3.0; this report may not document the full spectrum of local villages, and there may be different opinions on the merits of paper records.

Additionally, printer cartridges are hard to dispose of properly in rural Alaska communities and are often thrown in the trash or mailed back for recycling, which incurs additional costs. These factors can make printing undesirable for some people. For example, one local expert said that when they ask a community if they want a paper copy of a permit or other document, the response is usually that they want a digital one.

Paper is also hard to work with during backhaul inventory. According to one VC support staff: "[before Survey123], we relied on good old clipboard and paper … and it gets dusty down there and we're wearing gloves … and that paper would get dirty or stepped on, or dropped, and rained on." Indeed, the EPA research team saw firsthand in the video analysis, how hard it was to record information on paper while it was flapping in the wind (Figure 4.2).

The switch to a digital app over paper may also promote behavior changes conducive to better records management. For example, one VC's assistant described what would happen when they needed to verify information that had been recorded on paper:

> "[the recycling] center, it's like three or four miles away [from the office, where there is an internet connection]. … If … somebody has a question about [a] pallet [that was packed at the recycling center] then we're going to sit here like, *'oh, man, where is our darn paper here?'* … But now with the [Survey123] app, it's easier because now we have the entry of what we have ready … [We] just open the app and simply look up what we got going on."

This account is interesting. First, it demonstrates that a digital app is favored over paper. However, the digital device still needs to be brought back to the office to be synced over Wi-Fi or entered manually into a computer (which the assistant had been doing because they were unaware that they could upload the Survey123 form over Wi-Fi). It is still possible, however, to leave the phone or tablet at the recycling center, putting the assistant back in the position of, *where is our darn record*? Presumably, however, using the app forces them to take the record back to the office since the record cannot be completed until synced. The technology may be creating a behavioral change to take the record with them. The records can also be accessed from multiple locations, by phone or computer.

If paper is undesirable for inventory, what role might it play? Several RCs said they would want hard copy backups of the community profile and training records content in a Backhaul Alaska app either because of personal preference or a lack of trust in technology. Preferences for hard copy backups were expressed by users at both high and low ends of the self-identified digital literacy spectrum. Hard copies or printouts were also highlighted as an important way to provide training or educational information to communities that might lack technology infrastructure or resources to use the app.

Paper resources were often stored in an iconic work binder used by many RCs and local staff. The exact content of a binder might vary by community because it would contain local contacts, shipping routes and logistics, and other context or lexicon specific issues. Other information might be more universal, such as DOT packing regulations. One RC explained that it might be nice to have a binder template, with standard materials included, plus placeholders to enter customized information. An app could help create these hard copy backups by allowing easy selection and formatting of binder content and then a feature to send material to print. (Note, functions to export material for printing must account for the often-poor digital resources outlined in Section 2.2.1. Providing several export options such as USB in addition to Bluetooth, Wi-Fi, and sharing to email, would be important as some communities may lack advanced technology like Bluetooth or Wi-Fi connections.)

4.6 Section Summary

- There are several options for app development including: custom developed, third-party apps, websites and web-apps, or working with a suite of multiple apps.
- Each development option has pros and cons and there is a general cost trade-off with customizability and functionality.
- In general, third-party apps can address many user needs and there is a trend among community based environmental monitoring programs to choose third-party apps over custom app development.
- Custom app development is expensive, with long-term and uncertain costs for maintenance, data storage, and data access.
- Website and web apps can provide many features at low costs but cannot work offline, which is a problem for Backhaul Alaska.
- Backhaul Alaska had positive experience piloting two third party apps, both with offline capabilities. While neither app addressed all desired features that the program wanted, they will continue using one of these apps in the near-term. The app addresses their most pressing inventory and data management needs for a reasonable price.
- Backhaul Alaska had used one pilot app longer than the other and had trained staff in its use, which was an incentive to continue using this app and not have to retrain staff.
- Cost was another important consideration when comparing the two apps that were piloted.
- Backhaul Alaska administrators emphasized that the program might benefit from a different app solution in the future, since the chosen pilot app does not fulfill every functionality need.
- Among users that we spoke with, the pilot app chosen was vastly favored over a paper-based inventory system.
- Several users, however, said they would want hard copy backups of the community profile and training records content in a Backhaul Alaska app, either because of personal preference or a lack of trust in technology. An app could help create hard copy backups by allowing easy selection and formatting of content to print. Multiple export options for digital files are needed (e.g., via Wi-Fi, Bluetooth links, email, or USB connections) as computer resources and technology vary among communities.

Section 5. Conclusion and Recommendations

5.1 Report Summary

In this research project, we set out to understand: ***What are the best design options for a Backhaul Alaska data management application (or similar technology) that addresses different users' needs for supporting program operations and decision-making?*** We used human-centered design, combined with several tenets of community-based research, to explore the needs, interests, and options of people involved in Backhaul Alaska. We learned from multiple sources of information including unstructured conversation and workshops with Backhaul Alaska participants and external experts, direct (albeit remote for the EPA research team) observations of backhaul activities and pilot app use, and co-interpretation of data among program administrators and the EPA research team. The data were analyzed qualitatively using several thematic coding approaches. Results are meant to (1) support and improve Backhaul Alaska by helping the program make decisions about app selection and development, (2) help build capacity in the communities participating in Backhaul Alaska, (3) provide a foundation for app developers to understand the program and potential app users, and (4) provide a case study that other programs and projects can learn from.

Section two detailed **Backhaul Alaska operations** in relation to app development. It outlined the experiences of the people doing backhaul that an app must support. The section identified and analyzed eight important themes and several other critical components relative to app development (i.e., how the program will grow over time, data management needs, and geospatial needs). Section two is a blueprint for developing a Backhaul Alaska app.

Several themes in section two touched upon app features or content with user safety implications. These included: key contact lists and other information within community profiles (sections 2.2.2 and 2.2.3), documenting institutional knowledge (section 2.2.4), information about liability and non-compliance issues (section 2.2.7), data sovereignty and, though unlikely at this time, potentially documenting culturally sensitive areas such as resource harvesting areas (section 2.2.8), and tiered data access as part of data management protocols (section 2.3). Several people (but not all), that participated in research activities for this project, also noted preferences for dedicated mobile work devices to avoid mixing-up personal and work photos or contact information. In designing an app, safety for app users and Backhaul Alaska should be a top concern.

Section three focused on **specific app users**, chronicling what they need from an app and how they will use it. User profiles were developed for key users (SC, CT, RCs, VCs and staff, shippers, and vendors) and other potential users were discussed. Critically important for app development, section three also outlines existing knowledge gaps about users' needs and how these unknowns should be taken into consideration when developing an app. Some things about users and their needs are unknown because of the limitations of this study. For example, (1) the EPA research team was unable to speak directly with shippers and (2) the report is not based on a statewide representative sample of local village staff. Unknowns and uncertainties related to user groups may warrant more specific user-based research. Other items remain unknown because Backhaul Alaska is continuing to evolve and learning how best to remove hazardous household waste from rural Alaska communities, build local and regional capacities, support job creation, and improve human well-being. Examples include possible changes to the role of the CT and planned changes for more autonomous RCs. Therefore, app development must stay attuned and adapt to future program changes.

Section four focused on the pros and cons of four **app development options** and how they suit Backhaul Alaska. There are tradeoffs in functionality and customizability vs. cost, which program administrators need to consider. Importantly, there is no one best solution. This project also documented Backhaul Alaska's experience piloting two third party apps. This mini case study highlighted the importance of financial costs when making decisions and how previous investments in learning to work with a specific tool can be an obstacle to adapting something new. Finally, section four compared record collection with a digital app and paper, verifying that digital technology was preferred. This observation contrasts with observations in the Canadian Arctic, where paper has been preferred over digital apps for environmental monitoring due to the remote, offline, and harsh environmental working conditions (Kipp et al. 2019).

5.2 Looking to the Future

Backhaul Alaska is a long-term program by design. It has a ten-year rollout from a pilot in 27 villages to a statewide program covering all rural Alaska; and it will continue to operate thereafter. Rural Alaska is likely to experience important environmental, social, and technological changes during this time (AEC 2021, Ford et al. 2012, 2015, Kipp et al. 2019) that may intersect with app development needs.

Backhaul Alaska is investigating how to improve integration with a circular economy[8] that might involve private sector partners (e.g., manufacturers of performance clothing looking to make jackets from recycled plastics). The program is also hoping to develop product stewardship relationships with manufacturers that might ultimately help pay for a component of the local programs (Kawerak 2021, Zender Group 2017). These private sector partners may want or require certain information on packing and inventory practices. Future app development should stay aware of any needed changes and apps should be developed in way so that they can accommodate circular economy and product stewardship needs.

Local environmental changes that are driven by human induced climate change (e.g., (Ford et al. 2015, Debortoli et al. 2019)) may impact Backhaul Alaska operations with important implications about how an app is used. Sections two and three document how seasonal weather and local conditions have profound impacts on Backhaul Alaska activities. These impacts include, but are not limited to, shipping windows when materials can be picked up for transport, the time(s) of year when local village staff are able to work outside to inventory and backhaul materials, and working conditions including snowfall, rain, and groundcover. Climate changes are also likely to impact when and where important subsistence resources can be hunted, fished, and gathered (Green et al. 2021), which may alter the availability of local staff engaged in subsistence activities. Finally, alterations to permafrost will impact local infrastructure such as roads, runways, ports, riverbanks, landfills, and backhaul facilities (Hinzman et al. 2005, Reimchen et al. 2009, UAF et al. 2019).

[8] Circular economy is defined as an economy that reduces material use, redesigns materials, products, and services to be less resource intensive, and recaptures "waste" as a resource to manufacture new materials and products (https://www.epa.gov/recyclingstrategy/what-circular-economy).

The most immediate implication of these potential environmental changes for a Backhaul Alaska app is a heightened role for documenting local and traditional knowledge for the benefit of participating communities. Several participants in the various research activities carried out for this project noted some limited opportunities for a Backhaul Alaska app to include features where local environmental observations and subsistence hunting, fishing, and gathering schedules could be documented (section 2.2.8). Given the potential for environmental changes to significantly impact several key dynamics that affect the timing of backhaul activities and local village capacities, such observations should be given more attention in a backhaul app. The ability to document observations under specific headings such as shipping, local infrastructure, or working conditions could be one path forward. There might also be benefits or opportunities to integrate a Backhaul Alaska app with other apps being used in the region for environmental monitoring, such as the Local Environmental Observer (LEO) Network app (https://www.leonetwork.org/en/mobile) to avoid replicated efforts.

As the climate changes, backhaul activities may also be impacted by changing Arctic shipping conditions (Hildebrand et al. 2018), which might include changes in access to international shipping routes as well as local shipping season and access changes. As outlined in section three, the research documented in this report did not evaluate what role, if any, international shipping may play for Backhaul Alaska in the future. Changes in seasonality and shipping routes, however, will likely impact the financial costs and logistics of getting materials in and out of communities. While many of these considerations likely fall outside of the design of specific app features and user experiences, they would directly affect the system in which the app is used and warrant consideration.

A final important factor to consider is the changing technology landscape. Section two outlines the need for an app solution that works offline, which constrains the suitability of options presented in section four. While rural Alaska currently has extremely poor internet infrastructure, several groups are working to improve internet access among northern communities (e.g., AEC 2021). The possibilities exist for a very different technology future in rural Alaska that would enable vastly different app solutions for Backhaul Alaska.

One way for Backhaul Alaska to consider and make sense of the aforementioned large-scale environmental, socio-political, and technological changes would be through scenario planning. Scenario planning is a visioning and modeling activity that considers several plausible futures under several intersecting dynamics of change (Carpenter et al. 2006). Scenarios are not designed to be predictions; instead, they depict a range of plausible futures that can be used to help prepare for the unknown and unexpected. Scenario planning could help Backhaul Alaska consider which app development choices hold up against the largest range of possible futures. Scenario planning might also contribute to long-term economic and other planning for Backhaul Alaska and its participating communities.

5.3 Transferable Lessons Learned

There are several important lessons learned that are transferable to other programs with similar contexts and needs.

First, when developing an app or any tool for a geographically dispersed, community-based environmental management program such as Backhaul Alaska, **start by focusing on what people need in the broadest sense**. We (the entire project team) started our research using an open and unstructured data gathering approach to listen and learn from program participants and external experts. This helped to develop a holistic understanding of needs for and interests in an app. Not everything we discussed was entirely relevant to developing an app, but it allowed the EPA research team to gain a full understanding of the context in which an app would be used and for the on-the-ground practitioners to gain new perspectives about how their work translated into app development needs.

Second, **tradeoffs between cost and functionality** must be considered. The initial motivation for this research project was to develop a custom, standalone app that met the unique needs of Backhaul Alaska participants. Part of our research involved investigating the upfront and long-term maintenance costs of custom app development. As large costs became apparent, custom development became less attractive. Custom development is not necessarily off the table indefinitely, nor are any number of combinations of app solutions. By assessing the cost vs. functionality tradeoffs, Backhaul Alaska avoided overextending itself at a critical and early moment in its development, when it was not ready to take on the initial and ongoing costs of custom app development. Rather, Backhaul Alaska needed to focus on developing a fast and reliable solution for its most critical app needs.

Third, **do not develop a tool based on an assumed problem**. The initial idea for the project was to design a custom app to meet the needs of Backhaul Alaska. A fundamental principle of human-centered design, however, is to validate the problem statement through research. You may not end up where you thought you would. As all members of the project continued to better understand the interests and priorities of different users, and Backhaul Alaska's short- and long-term needs, we ended up downplaying the focus of custom app development, instead prioritizing more affordable alternatives that met these needs. We chose not to develop and test specific user interfaces, which would use valuable researcher and participant time for something that might not be needed if Backhaul Alaska never builds a custom app. Rather, we continued to build foundational knowledge about Backhaul Alaska's app development needs to inform any app development options, from custom development to a suite of third party off the shelf apps. We did, however, document important user interface improvements based on our evaluation of Survey123 (see appendix A).

Fourth, **it is possible to do a lot of work remotely**. Because of the global Covid-19 pandemic, the EPA research team was unable to travel to Alaska to do direct observations or user testing. The EPA research team was able to speak with app users through video conferencing and at times have them demo an app (Survey123), which provided important learning opportunities. As a collective project, we also asked Backhaul Alaska participants to film short videos with their phones while doing backhaul activities and using Survey123. These videos provided important learning opportunities, providing insights that may not have been discovered otherwise. Because we did not want to overburden participants, and because the video approach was experimental, we only asked for a handful of videos. Since these videos turned out to be very useful, we recommend that researchers who are unable to perform site visits and user testing (due to travel or costs restrictions) collect ample video footage of work being done in the field.

Fifth, **researchers should commit fully to ensuring the best outcomes** even if it is not part of the formal research process. Human-centered design, or at least the approach adopted here (i.e., Bannon 2011, Holeman and Kane 2019), takes time and commitment. EPA and Zender Group continued to work together to optimize Backhaul Alaska implementation well after the research phase of the project was formally closed. For example, the EPA research team helped support Backhaul Alaska administrators in discussions with third party app companies, evaluate prices for different licensing options, and deliberate on a near term app solution. As researchers familiar with the technology, the EPA research team was able to help translate what concepts such as data management and feature options meant for Backhaul Alaska. There is overlap here with sentiments voiced by researchers involved with translational science (Littell et al. 2017): some of the most important parts of working within a collaborative transdisciplinary project can be in opposition to what research scientists are evaluated on, i.e., tangible research outputs. Building a trusting and long-term working relationship among everyone involved, project partners and research participants, is vitally important when designing from a human-centered perspective. Our project team encourages other programs doing similar work to commit fully to developing these relationships, even if it means pushing back deadlines, or engaging in extra tasks.

In conclusion, our project was enhanced by focusing first on what Backhaul Alaska and the people involved needed from an app in the fullest sense, both in the near and long-term. Our understanding was informed by repeated engagements with a variety of Backhaul Alaska participants and other people and programs with connections to Backhaul Alaska, as well as by having regular internal team discussions that included co-interpretation of data. Multiple engagements with key participants, such as the presentations and workshops that we held, also likely helped build trusting relationships. Our successful teamwork, combined with the fact that the chosen pilot app (section 4.0) is adequately and favorably supporting Backhaul Alaska illustrates successful near-term outcomes of the project. We hope that: (1) this report can further support Backhaul Alaska under any future app development paths; and (2) the report serves as a proof of concept that provides insights for other programs interested in developing similar apps in remote and/or tribal contexts.

Section 6. Literature Cited

Abras, C., Maloney-Krichmar, D. & Preece, J. 2004. *User-Centered Design.* Bainbridge, W., Ed., Encyclopedia of Human-Computer Interaction, Sage Publications, Thousand Oaks, CA, 445-456.

Alaska Department of Fish and Game (ADFG). 2015. *Alaska Wildlife Action Plan*. ADFG. Juneau, Alaska. 236pp. https://www.adfg.alaska.gov/static/species/wildlife_action_plan/2015_alaska_wildlife_action_plan.pdf.

Alaska Department of Environmental Conservation (ADEC).2022. A*DEC Regulations 18 AAC 60, Solid Waste*. State of Alaska. 122pp. https://dec.alaska.gov/media/1042/18-aac-60.pdf.

Andrachuk, M., M. Marschke, C. Hings, and D. Armitage. 2019. Smartphone technologies supporting community-based environmental monitoring and implementation: a systematic scoping review. *Biological Conservation* 237:430–442. doi.org/10.1016/j.biocon.2019.07.026.

Arctic Economic Council (AEC) 2021. Arctic Connectivity Working Group 2021. https://arcticeconomiccouncil.com/wp-content/uploads/2021/05/aec-cwg-report-050721-6.pdf.

Backhaul Alaska. 2017. *Backhaul Alaska overview brochure*. http://www.zendergroup.org/docs/trifold.pdf.

Backhaul Alaska 2023. Backhaul Alaska Pilot Program. https://backhaulalaska.org/pilot-program/

Bannon, L. 2011. Reimagining HCI: Toward a More Human-Centered Perspective. *Interactions* 4(18):50–57. doi.org/10.1145/1978822.1978833.

Bernard, R. H. 2006. *Research methods in anthropology: qualitative and quantitative approaches*. 4th Ed. AltaMira Press. 824pp.

Barnes, D. L., Connor, B., Trost, B., McTigue, E., Krauss, K., and Bluehorse, B. 2020. Managing Alaska's Road-Dust Problem: A Model for Road Dust–Impacted Regions. *J Transp Eng A Syst*. 2020 Apr; 146(4): 10.1061/JTEPBS.0000314. doi.org/10.1061/JTEPBS.0000314.

Carpenter, S. R., Bennett, E. M., & Peterson, G. D. (2006). Scenarios for ecosystem services: an overview. *Ecology and Society*, 11(1), 29. doi.org/10.5751/ES-01610-110129.

Chen, E., C. Leos, S. D. Kowitt, and K. E. Moracco. 2020. Enhancing Community-Based Participatory Research Through Human-Centered Design Strategies. *Health Promotion Practice* 21(1):37–48. doi.org/10.1177/1524839919850557.

Chipchase, J. 2017 *The Field Study Handbook.* Field Institute. ISBN: 978-1939727091. 505pp.

Daae, J. & Boks, C. 2015. A classification of user research methods for design for sustainable behavior. *J Clean Prod* 106, 680–689. doi.org/10.1016/j.jclepro.2014.04.056.

Debortoli, N. S., D. G. Clark, J. D. Ford, J. S. Sayles, and E. P. Diaconescu. 2019. An integrative climate change vulnerability index for Arctic aviation and marine transportation. *Nature Communications* 10(1):2596. doi.org/10.1038/s41467-019-10347-1.

EPA. 2021. *Kawerak earns federal grant for hazardous waste 'backhaul' efforts in rural Alaska*. EPA Region 10 News, June 16, 2021. https://www.epa.gov/newsreleases/kawerak-earns-federal-grant-hazardous-waste-backhaul-efforts-rural-alaska.

Eisted R., and T.H. Christensen. 2013. Environmental assessment of waste management in Greenland: current practice and potential future developments. *Waste Manage Res* 31:502–509. doi.org/10.1177/0734242x13482175.

Ford, J. D., K. Bolton, J. Shirley, T. Pearce, M. Tremblay, and M. Westlake. 2012. Mapping human dimensions of climate change research in the Canadian Arctic. *Ambio* 41(8):808--22. doi.org/10.1007/s13280-012-0336-8.

Ford, J. D., G. McDowell, and T. Pearce. 2015. The adaptation challenge in the Arctic. *Nature Climate Change* 5(12):1046--1053.

Ford, J. D., E. Stephenson, A. C. Willox, V. Edge, K. Farahbakhsh, C. Furgal, S. Harper, S. Chatwood, I. Mauro, T. Pearce, S. Austin, A. Bunce, A. Bussalleu, J. Diaz, K. Finner, A. Gordon, C. Huet, K. Kitching, M. Lardeau, G. McDowell, E. McDonald, L. Nakoneczny, and M. Sherman. 2016. Community-based adaptation research in the Canadian Arctic. *Wiley Interdisciplinary Reviews: Climate Change* 7(2):175–191. doi.org/10.1002/wcc.376

Gerlitz, C., A. Helmond, D. B. Nieborg, and F. N. van der Vlist. 2019. Apps and Infrastructures – a Research Agenda. *Computational Culture* (7). http://computationalculture.net/apps-and-infrastructures-a-research-agenda/.

Green, K., Beaudreau, A., Lukin, M., & Crowder, L. (2021). Climate change stressors and social-ecological factors mediating access to subsistence resources in Arctic Alaska. *Ecology and Society*, 26(4): 15. doi.org/10.5751/ES-12783-260415.

Harte, R., L. Glynn, A. Rodríguez-Molinero, P. M. Baker, T. Scharf, L. R. Quinlan, and G. ÓLaighin. 2017. A Human-Centered Design Methodology to Enhance the Usability, Human Factors, and User Experience of Connected Health Systems: A Three-Phase Methodology. *JMIR Human Factors* 4(1):e8. doi.org/10.2196/humanfactors.5443.

Hildebrand, L. P., L. W. Brigham, and T. M. Johansson, editors. 2018. *Sustainable Shipping in a Changing Arctic*. Springer. 486pp. doi.org/10.1007/978-3-319-78425-0.

Hinzman, L. D, N.D. Bettez, et al. 2005. Evidence and Implications of Recent Climate Change in Northern Alaska and Other Arctic Regions. *Climatic Change* 72, 251–298. doi.org/10.1007/s10584-005-5352-2.

Holeman, I., and D. Kane. 2019. Human-centered design for global health equity. *Information Technology for Development* 26(3):1–29. doi.org/10.1080/02681102.2019.1667289.

IARPC. 2018. *Principles for Conducting Research in the Arctic* U.S. Interagency Arctic Research Policy Committee (IARPC). 4pp. https://www.iarpccollaborations.org/uploads/cms/documents/principles_for_conducting_research_in_the_arctic_final_2018.pdf

Jabangwe, R., H. Edison, and A. N. Duc. 2018. Software engineering process models for mobile app development: A systematic literature review. *Journal of Systems and Software* 145:98–111. doi.org/10.1016/j.jss.2018.08.028.

Jasny, L., J.S. Sayles, M. Hamilton, L. Roldan Gomez, D. Jacobs, C. Prell, P. Matous, E. Schiffer, A. Guererro Gonzalez, M. Barnes. 2021. Participant engagement in environmentally focused social network research. *Social Networks*, 66: 125-138. doi.org/10.1016/j.socnet.2021.01.005

Kawerak. 2021. *Proposal for the Rural Alaska Household Hazardous Waste Backhaul Service Program Funding Opportunity*. Kawerak, Inc., Internal document. 36pp.

Keske C.M.H., M. Mills, T. Godfrey, L. Tanguay, and J. Dicker. 2018. Waste management in remote rural communities across the Canadian north: challenges and opportunities. *Detritus* 2:63. doi.org/10.31025/2611-4135/2018.13641.

Kipp, A., A. Cunsolo, D. Gillis, A. Sawatzky, and S. L. Harper. 2019. The need for community-led, integrated and innovative monitoring programmes when responding to the health impacts of climate change. *International Journal of Circumpolar Health* 78(2):1517581. doi.org/10.1080/22423982.2018.1517581.

Kouril, D., C. Furgal, and T. Whillans. 2015. Trends and key elements in community-based monitoring: a systematic review of the literature with an emphasis on Arctic and Subarctic regions. *Environmental Reviews* 13(November 2015):1--13. doi.org/10.1139/er-2015-0041.

Lai, S. S., and S. Flensburg. 2020. A proxy for privacy uncovering the surveillance ecology of mobile apps. *Big Data & Society* 7(2):2053951720942543. doi.org/10.1177/2053951720942543.

Lewis, J. E., editor. 2020. December 1. Indigenous Protocol and Artificial Intelligence Position Paper. Honolulu, Hawai'i: The Initiative for Indigenous Futures and the Canadian Institute for Advanced Research (CIFAR). 205pp. doi.org/10.11573/spectrum.library.concordia.ca.00986506.online at https://spectrum.library.concordia.ca/id/eprint/986506/7/Indigenous_Protocol_and_AI_2020.pdf

Littell, J. S., A. J. Terando, and T. L. Morelli. 2017. Balancing research and service to decision makers. *Frontiers in Ecology and the Environment* 15(10):598--598. doi.org/10.1002/fee.1739.

R Core Team, 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org.

Reed, M. S., L. C. Stringer, I. Fazey, A. C. Evely, and J. H. J. Kruijsen. 2014. Five principles for the practice of knowledge exchange in environmental management. *Journal of Environmental Management* 146:337--345. doi.org/10.1016/j.jenvman.2014.07.021.

Reed, M. S., S. Vella, E. Challies, J. de Vente, L. Frewer, D. Hohenwallner-Ries, T. Huber, R. K. Neumann, E. A. Oughton, J. S. del Ceno, and H. van Delden. 2018. A theory of participation: what makes stakeholder and public engagement in environmental management work? *Restoration Ecology* 26:S7–S17. https://doi.org/10.1111/rec.12541.

Reimchen, D., G. Doré, D. Fortier, B. Stanley, and R. Walsh, 2009: Cost and constructability of permafrost test sections along the Alaska Highway, Yukon. *Proceedings, Transportation Association of Canada Annual Conference,* 20 pp.

Saldaña, J. 2013. *The Coding Manual for Qualitative Researchers, Second Edition*. Thousand Oaks, CA: Sage Publishing. 329pp. online at https://emotrab.ufba.br/wp-content/uploads/2020/09/Saldana-2013-TheCodingManualforQualitativeResearchers.pdf

Samuelson G.M. 1998. Water and waste management issues in the Canadian arctic: Iqaluit, Baffin Island. *Can Water Resour J (4)* 23:327–338. doi.org/10.4296/cwrj2304327.

Siegler, A. J., J. Knox, J. A. Bauermeister, J. Golinkoff, L. Hightow-Weidman, and H. Scott. 2021. Mobile app development in health research: pitfalls and solutions. *mHealth* 7(0):32–32. doi.org/10.21037/mhealth-19-263.

Skarlatidou, A., A. Hamilton, M. Vitos, and M. Haklay. 2019. What do volunteers want from citizen science technologies? A systematic literature review and best practice guidelines. *Journal of Science Communication* 18(01): A02. doi.org/10.22323/2.18010202.

Solid Waste Alaska Taskforce (SWAT) 2017. *Solid Waste Alaska Taskforce Guide to Solid Waste Management in Alaska.* 72pp. https://anthc.org/wp-content/uploads/2015/12/Solid-Waste-Guide-_Feb2017.pdf.

Solid Waste Alaska Taskforce (SWAT) 2023. *About Solid Waste Alaska Taskforce* (website). https://907swat.org/about/. accessed February 2023.

Teacher, A. G. F., D. J. Griffiths, D. J. Hodgson, and R. Inger. 2013. Smartphones in ecology and evolution: a guide for the apprehensive. *Ecology and Evolution* 3(16):5268–5278. doi.org/10.1002/ece3.888.

University of Alaska Fairbanks Institute of Northern Engineering (UAF), U.S. Army Corps of Engineers Alaska District, and U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory. 2019. *Statewide threat assessment: identification of threats from erosion, flooding, and thawing permafrost in remote Alaska communities*. Report prepared for the Denali Commission, report #INE 19.03 Denali Commission. 199pp. https://www.denali.gov/wp-content/uploads/2019/11/Statewide-Threat-Assessment-Final-Report-20-November-2019.pdf

Zender Group. 2017. *Sustainable Statewide Backhaul Program Draft Plan*. SWAT, 106pp. http://zendergroup.org/docs/sustainable_statewide_backhaul_draft.pdf

Zender Group. 2022. *Backhaul Alaska Pilot Program Status Report, March 2022.* Internal document. Backhaul Alaska,13pp.

Appendix A. Survey123 User Feedback

A.1 Objective

This appendix outlines user feedback about Esri's Survey123 app for Backhaul Alaska. Survey123 is an off-the-shelf web and mobile app that enables customized survey forms to collect information, including photos and geospatial information. References to "Survey123" in this appendix include the user generated form and the application's user interface, database, and workflow. Where relevant, the Survey123 form (i.e., the survey designed to collect information for Backhaul Alaska) is distinguished from the Esri software/app.

User feedback about Survey123 and its use in Backhaul Alaska was solicited as part of larger discussions about the program's app development needs (see methods section A.3.0, below). While feedback about Survey123 is not mutually exclusive from broader app needs (discussed in the main report), this appendix attempts to distinguish items specific to using Survey123 from the larger conversation of app development. For example, during research for this project, Backhaul Alaska participants requested that vendors send feedback about the quality of packing when the vendors received shipments. While this feedback can easily be supported by Survey123 (e.g., by developing a rapid, standalone Survey123 form for vendor feedback, which could include a picture, star rating, and comments field), the desire for vendor feedback is not specific to Survey123. It is a broader app development issue that might be addressed in different ways for different app development approaches. Other desired app features are beyond the scope of Survey123, for example hosting video tutorials or detailed training manuals, as Survey123 is not designed to communicate such content. Therefore, such issues are not covered in this appendix. Rather, this appendix focuses on issues specific to Survey123.

While specific to Survey123, many of the documented favorable features and desired improvements are informative across platforms. For example, observing that the "save" and "send" buttons in Survey123 confuse some users (see below), which might benefit from more descriptive names, can help improve Survey123 and is relevant for other apps. While this appendix documents feedback specific to Survey123, the information is relevant beyond Survey123.

This appendix might be used to:

- Improve Survey123 (and/or other Esri products) for continued use by Backhaul Alaska.
- Inform Backhaul Alaska app development regardless of chosen platform or software.

This appendix is organized as follows:

- Section A.2.0 provides background about Backhaul Alaska's use of Survey123.
- Section A.3.0. briefly outlines methods and data sources for collecting user feedback.
- Section A.4.0 details positive and negative user feedback for Survey123.
- Section A.5.0. outlines possible expansions to Survey123 that advance Backhaul program.

A.2 Background

Prior to the September 2020 start of human-centered design project that is the focus of this report, EPA had been working with Zender Group to identify a number of technology-based solutions to help with backhaul (e.g., shipping route optimization). Several EPA scientists involved in those conversations had been using Survey123 for other projects and suggested that it could be customized and used for Backhaul Alaska's inventory needs. Survey123 forms were developed for the program quickly thereafter, through conversations between EPA scientists and Zender Group. Survey123 was adopted to address an immediate applied need and was not explicitly intended as a prototype test for a human-centered design study about Backhaul Alaska app needs. Survey123, however, provided an important opportunity to learn about the use of a digital app to inventory waste in Backhaul Alaska.

A.3 Data and Methods

To understand the strengths and weaknesses of Survey123, the EPA research team sought user feedback during unstructured conversations with Backhaul Alaska participants (four local coordinators (LCs), two regional coordinators (RCs), and three staff fulfilling state coordinator (SC) and control tower (CT) roles), a three day workshop-style discussion with staff from Zender Group, during which preliminary project findings were discussed, and two meetings with Esri program management and Zender staff to discuss the use of Esri products beyond the backhaul pilot (see materials and methods in Appendix B).

Participants provided feedback about Survey123, including their likes and dislikes. Because conversations were unstructured and covered additional topics beyond Survey123, participants were able to discuss Survey123 in response to broader discussion topics and prompts (e.g., digital tools they used for their job, or when describing their workflow). RCs and the SC were also asked to take short videos of themselves and others using Survey123 in the field in order to directly observe and learn about its use. During these trips to local communities, RCs and the SC were also training some village level staff how to use Survey123 therefore providing an opportunity for the EPA research team to observe some short periods of training (Figure A.1 and Figure A.2). All conversations and videos were qualitatively coded as outlined in Appendix B.

The discussions around Survey123 prioritized understanding what needed to be improved and thus, tended to document needed improvements rather than strengths of the tool. This uneven feedback is not a quantitative measure of pros vs. cons and simply reflects the nature of the conversations.

This appendix is written from the perspective and voice of the EPA research team, which analyzed the data.

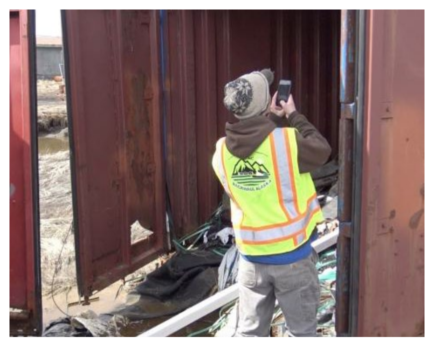

Photo credit: Backhaul Alaska

Figure A.1. Backhaul Alaska staff using Survey123 in the field to inventory waste located in a shipping container.

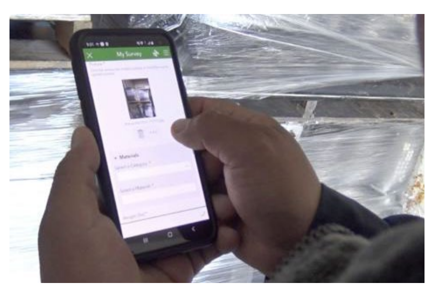

Photo credit: Backhaul Alaska

Figure A.2. Local village staff completing a survey on the app.

A.4 Participant Feedback

A.4.1 Survey123, Positive Sentiments

Backhaul Alaska Program participants were generally positive about using Survey123. Several participants said that Survey123 was preferable to the old method of using paper inventory forms, which were entered into a spreadsheet or photographed and shared as an image over email. Notwithstanding some confusion about how to install and login to Survey123 (see below), most users felt that the app was easy to use. One person described Survey123 as "pretty straightforward." Another said, "Survey123 [is] very easy … everything is in order [and] comes in steps. [The backhaul program] makes sure that steps are completed. And if there's something missing, … someone looks it over and says, we need [it] like this. So, I like how [it's] made." This comment not only illustrates a positive experience using Survey123, but also an appreciation for the quality controls and feedback that Backhaul Alaska used.

In addition to the survey form itself, program participants appreciated Survey123's geospatial capabilities. RCs and Backhaul Alaska administrators praised the ability to view data on a map. Mapping helped them get a feel for local communities when they were unable to visit them, was seen as a useful way to communicate or share information and was considered an essential tool to help new staff get up and running when working in the field. Statements such as the following were common:

> "[A new] coordinator comes in and they're like, 'we don't know anything about this waste.' … A lot of times the waste is located offsite because [the local community] knows that it's potentially toxic, hazardous, … so they tend to place it somewhere hidden. [With Survey123] we can document it right then and there with the GPS location. … We're ready to help."
>
> – Program Administrative Staff

> "An infrastructure map is a good way to put it, even for folks that are not part of our program. For example, I knew a contractor that was coming in to fix equipment in a community. I was able to share info about where equipment is, which saves the community money. So, it is a win-win for everyone. – Program Administrative Staff

Additional favored or praised features that participants mentioned included the following:

- Improvement over paper (as discussed above)
- GPS and mapping capabilities (as discussed above)
- Copy and paste feature to help repetitive inventory (such as multiple boxes of light bulbs).
- Saving a favorite profile to auto populate records for a common waste type.
- Satellite base map when taking GPS points.
- On the database side, benefits of filtering and searching items by community.
- In the videos, we observed that the auto-population feature and dropdown menus seem to be adopted by users and helped minimize the time required to complete a survey.

A.4.2 Survey123 Improvements

While people were generally positive about Survey123, they also reported a number of possible improvements, which are outlined below. The order of items does not indicate importance. In the following reporting, a description of the type of user is provided to help illustrate user needs, the data source is given (conversations or videos), and often the context in which users experienced problems or undesirable issues is also provided. Several items in the discussion of potential improvements (Lists A.1, A.2 and A.3) are preceded by italic text that presents *Analyst's notes* that document suggestions or qualifications for app development solutions for the given issues.

List A.1. Training Materials, Software Access, and Related Issues

- **Video tutorial and training, in a small file size**: According to a RC, local staff were not using the Survey123 training materials. The RC recommended creating a video on how to use the tool for those people that cannot attend in person training, or when there is staff turnover in the middle of a season. The RC recommended use of multiple kinds of training materials to accommodate different learning styles. The RC also noted that video content should respect local bandwidth issues; e.g., downloading large files in communities could be a limitation. Similarly, several Village Coordinators (VCs) and/or VC assistants commented that they did not always remember how to access or use the app, since they only used the app intermittently, often going weeks or months without using it. This episodic use pattern highlighted the need for improved training and refresher content.
- **Promote use of phone app over desktop app:** According to a RC, local staff were using the Survey123 desktop version, which does not work as well as the phone version. The RC felt that local staff were used to working on the computer and did not realize that a phone app was available. The RC observed that using the phone app allowed people to take photos as they completed the survey, however, when they took photos with their phone and went back to the office to complete Survey123 on the computer, they could not always remember which photos were from a particular location in the community since some communities had multiple storage locations. While one person working at the village level said they preferred using Survey123 on the computer because of the larger screen space and the ability to use a computer mouse, the participant noted that they liked the idea of using Survey123 on a tablet because it would be more comfortable to use than a phone. Furthermore, the tablet would allow them to enter all their data while at the waste storage location and later syncing it over the office Wi-Fi (the participant did not have Wi-Fi or data access when outside of the office).
- **Assign dedicated usernames and passwords:** Several village level and regional participants had trouble logging in to Survey123 or could not remember their usernames and passwords. Backhaul Alaska had assigned generic usernames and passwords to participants, which they found hard to remember. In some cases, VCs and their assistants were sharing usernames and passwords, which they found problematic. *Analyst's note: Individual usernames, perhaps the user's name, and self-chosen passwords, would likely facilitate access, as would dedicated assistance for login issues.*

List A.2. Form and User Interface Improvements

- **Tooltips:** Several people expressed a desire for some type of tool tip feature to provide in-app instructions. *Analyst's note: Recent builds of Survey123 Connect allow for short pop-up style tools tips that are limited to a few lines of text. Other workarounds include putting tool tips or guidance as collapsible notes or images within the form. (Only static images are supported in the Survey123 field app (offline), while the online web app also supports animated GIFs.)*
- **Multiple favorite profiles:** One person wished for the ability to save multiple favorite profiles, e.g., one for e-waste, batteries, lamps, etc., in order to auto-populate fields and then take individual pictures of the waste.
- **Allow for multiple photos:** Several people (both at the village and regional level) said they would like to be able to add multiple photos in a survey. Multiple photos seemed to be more important for the general sites survey. Several regional staff said a single photo of the pallet was sufficient for packaged materials. The videos showed regional staff taking multiple photos when doing general inventory, often one close-up photo and one from afar, corroborating the aforementioned expressed desires.
- **Annotating photos:** One person wished to annotate photos, for example, commenting or labelling to indicate that some pallets in the photo had been finished and others needed to be completed later. *Analyst's note: While photo annotation may not be possible in Survey123, it may be possible to include a comments field.*
- **Copy and paste photos between surveys:** One person wished to be able to copy photos from a general site survey to a shipping survey so that new photos did not need to be taken. *Analyst's note: Copying photos may save time but it may be a good idea to force new photos for shipping to ensure the photo is as up to date as possible.*
- **Separate "General Materials Survey" into two surveys:** Several people suggested creating separate surveys for 1) sites where materials were stored (e.g., the landfill), and 2) the actual materials to be inventoried. User observations confirm the benefit of separating these surveys: In one video, a local staff member expressed confusion about answering waste inventory questions in a survey that was meant to document waste management facilities.
- **Improve default map location when opening survey:** The video analysis showed that a local staff member had trouble determining their location on the survey map as the map appeared to open in Los Angeles. A RC confirmed this could be a stumbling block during conversations. *Analyst's note: Auto locating the user seems desirable, though for cases where the user lacks internet access, it may be sufficient to have the map default to Alaska.*
- **Improve how surveys upload, possibly with notification:** Two people expressed concern with how surveys were uploaded. In demonstrating the use of Survey123 during a conversation, one person was surprised to find several surveys in their outbox that had not been sent. This person thought they would automatically upload when they got back onto a Wi-Fi connection, and if this was an issue of user settings, the participant was unclear about the settings. Another person explained a problem they had where they thought they had uploaded all their surveys, only to learn from the

SC that not all had been uploaded. They speculated that an internet interruption caused this error and wished for an easy to see notification that surveys were sent. *Analyst's note: The ability to change how surveys upload may be limited in Survey123, but can we think creatively about some way to incorporate notifications or feedback?*

- **Easy viewing of unique IDs:** One person described how there was insufficient time to write down information that was briefly displayed. They explained that a unique identification number (ID) is generated when creating a new record in Survey123, and this number must be written on the pallet of waste. The unique ID only appears on the screen for a short period of time, which is not long enough to write down. The IDs can be viewed by going into the outbox, but a way to improve unique ID retrieval would be desirable.
- **Remove forced completion of weights field:** Two people commented that the survey form required them to fill in weights, but they did not know the weights and could only estimate them. Similar confusion and dissatisfaction among users was also documented in the video analysis. *Analyst's note: There may be several workarounds depending on the chosen field type for the survey question. If using a numeric field, a tool tip could prompt participants to enter "-999." Switching to a text field could allow for "unknown." The simplest solution may be to allow non-responses.*
- **Allow for responses of "not relevant":** A RC said that some entries in Survey123 do not apply to all loads, and they told local staff to just "click yes" for everything. Certain fields in the survey would likely benefit from an option to enter 'Not Applicable (N/A)" or "Does not apply.".
- **Address photo quality and storage issues:** An RC noted that photos taken with the in-app camera on Survey123 were of lower quality than those taken with their own camera app. The RC also had trouble with photo storage. They were unable to find where photos taken using the camera function within the Survey123 app were stored on the phone, or if they were stored at all. This confusion created problems later when the RC wished to access photos for further evaluation of the packed waste. *Analyst's note: If these issues cannot be addressed by changing Survey123 settings or performance, these issues may be cataloged under List A.1 as training issues and guidance on photo capture and storage can be provided.*
- **Allow surveys to be edited:** A program administrative staff member noted that surveys could not be edited, and they would like to be able to edit them. *Analyst's note: I believe the participant was referring to saving a survey and then reopening it to edit, but I am not sure. When improving Survey123, the developer should verify if this is the case.*
- **Address "check-mark error" when completing surveys:** The video analysis showed that users make a common error of accidentally pressing a "check mark" that appears at the top of the keyboard or number pad when completing an individual field within a survey. Pressing the check mark prompts the dialog box that contains options for completing the survey. This check box was repeatedly pressed as a means to complete the specific field, rather than being used only to indicate readiness to complete the survey. *Analyst's note: I am unsure if this checkbox can be edited in Survey123 but if so, this ambiguity could be removed by replacing the check with a more specific icon/button.*

- **Address ambiguity over survey completion actions:** The video analysis showed that some users were confused about the survey completion buttons, and a RC also expressed a similar concern during conversations. When users are ready to complete the survey in Survey123, they are given three options related to saving, sending, and continuing the survey. In the video, local staff were confused by the difference between saving and sending and received instructions that if they did not have internet service, they should save the survey, rather than send it. *Analyst's note: The ability to edit these buttons in Survey123 may be limited but, if possible, more descriptive names should be used. Otherwise, this issue might be addressed through tool tips, explanatory text, or educational materials. If development occurs outside of Survey123 and custom button names are allowed, descriptive names should be used.*

List A.3.: Database and Data Management Improvements

- **Allow program administrative staff to flag and ask for resubmission of form:** A program administrative staff member wished for a straightforward way to flag when something needed to be corrected in a submitted inventory and a simple way to get verification of the correction. *Analyst's note: Such workflow may be possible using Esri Workforce; Section A.5.0. outlining possible expansions*.
- **Improve reactivity between Survey123 and SharePoint:** The current workflow uses Power Automate to automatically update records in SharePoint once a Survey123 form is uploaded. However, if Backhaul Alaska administrative staff edit the survey record in Survey123, the update is not made in SharePoint and they have to manually edit SharePoint as well. *Analyst's note: The solution likely has to do with adjusting the Power Automate web-hook function.*
- **Improve control for program administrators:** Backhaul Alaska administrators commented that they had little control over many backend aspects of Survey123 because they were using EPA licenses. They did not have full control over developer view and did not have permission to change certain things. The staff also noted that in dashboard mode, they could only edit records that they had created and would like to see what was possible if they had full administrative rights.
- **Desktop version runs slowly:** Backhaul Alaska administrators noted that the desktop version of Survey123 ran slowly and that the phone app version was much faster. They hoped the desktop version could be made to run smoother.
- **Batch download all of a community's photos:** One Backhaul Alaska administrators noted that on the 'analyze' pages, they could filter by community and see all pictures for that community. Pictures, however, could only be downloaded individually, which was undesirable. They would like to download all the photos at once.
- **Edit an entire map in map view:** One Backhaul Alaska administrators said that when working in map view, they could edit data in "individual map view," but they could not edit data when the entire map was up, which would be nice to be able to do.
- **Enable surveys to sync across a user's devices:** One Backhaul Alaska administrators said that they use both their phone and tablet to complete surveys and would like their completed surveys to sync across both devices.

A.5 Possible Expansions

While this appendix is primarily meant to document user feedback about Survey123, it is worth outlining several possible expansions of Survey123 that may address Backhaul Alaska app needs. This section is brief and focuses on additional capabilities of Survey123 and other Esri products (since all Esri apps and products can be combined, to a certain degree), to avoid redundancy with the discussion of broader app development outlined in the main report. (Note: this is not a promotion of Esri products; refer to disclaimer on first page of report).

Points vs. Polygons for Mapping: Survey123, as part of the Esri suite of apps and tools, is built around geospatial data and mapping. In geographic information systems (GIS), data can be recorded as points, lines, and polygons. Points document a single x-y position and are often used to record small features in the landscape (e.g., storm drains). Lines connect two or more points with a different start and end position and are often used to record features such as rivers or roads. Polygons connect three or more points to create a closed shape; polygons are often used to document contiguous land cover types, building outlines, or waterbodies. The Backhaul Alaska pilot Survey123 app currently records all features using points. The EPA research team discussed possible benefits of recording information using polygons with several RCs and Backhaul Alaska program staff.

These individuals saw little benefit to using polygons but were open to it if there was a clear advantage. Several people commented that they could see some benefit to recording the shape of landfills or buildings in the general sites survey as polygons. One person also commented that documenting fences around landfills or other storage areas might be useful (a single length of fence would be a line, while a fill enclosure would be a polygon). There was unanimous feedback that point locations were sufficient and desirable for locating pallets in the inventory survey.

Given the extra effort needed in the field to record polygons over points, Backhaul Alaska should probably continue using points in the Survey123 forms. However, since mapping was described so favorably (Section A.4.1.), Backhaul Alaska might, as a secondary task, seek to create polygons of waste storage and staging to generate more detailed infrastructure maps of communities. GPS points could be collected in the field for a given village if staff had time and capacity. Polygons could also be created by tracing features on satellite images (a process called "digitizing') in a GIS program like Esri's ArcGIS online (there are also free open-source alternatives that could be used). ***Of course, before undertaking this work, Backhaul Alaska staff should consult with relevant administrative authorities (Alaska state, federal, or Indian Environmental General Assistance Program) to see if such GIS records already exist for some or all communities.*** If GIS records exist (or have been created by Backhaul Alaska), they can be easily integrated into Esri dashboards and apps.

Creatively adding content and other solutions to Survey123: Creative uses of existing Survey123 capabilities could help address some of the desired app features and functions that Backhaul Alaska participants described. There is limited capacity to include pop-up style tool tips in Survey123 (analyst's note under "tool tips" in list A.2 within Section A.4.2). Tool tips and other guidance documentation can also be included as collapsible notes or images within the form. (Only static images are supported in the Survey123 field app (offline), while the online web app also supports animated GIFs.)

Supplemental information embedded in the form could also include items such as cheat sheets outlining shipping options and contact information, or what to do with broken or damaged materials (e.g., broken batteries). Skip logic or conditional questions can keep the forms streamlined, avoiding information overload. For example, the form might include a question: “Do you need additional information about packing, dealing with damaged goods, or shipping options?” Replying “no” would simply move to the next part of the inventory form, while a “yes” might open a multiple-choice question to display the needed guidance (e.g., broken batteries, shipping information). To avoid burdening administrative staff with having to update information, content could be limited to relatively static information (e.g., packing broken batteries) or information that is updated at regular intervals (e.g., DOT transport guidelines). Content and access should be user tested to ensure it helps users and does not complicate their workflow.

Survey123 forms could be used to host a variety of checklists for documenting things such as PPE, training activities, and packing materials inventories. All of these items and app features were requested by various Backhaul Alaska participants during conversations (in main report). Developing such content in Survey123 could be a low-cost, low-tech way to integrate and document checklists within the currently used technology.

Finally, small surveys could be built to address other Backhaul Alaska user needs. For example, while not specific to Survey123, several people requested that vendors send feedback about the quality of packing upon receiving materials. This feedback could be recorded in a small standalone Survey123 form that includes a picture, star rating, and comments field that the vendor could install on their phone to send feedback.

Using Other Compatible Esri Products: The data recorded by Survey123 can readily be used with other Esri tools that may address some additional needs or desires of Backhaul Alaska. The people spoken to for this project liked ArcGIS Online’s mapping capabilities (Section A.4.1). Other options might include using Esri Story Maps to present information. ***Backhaul Alaska could even invest in training community members to use tools such as ArcGIS Online and Story Maps, enabling communities to use their data and tell their own stories. Such activities align with the program's goal of local capacity building and job creation***.

Another expansion might be to integrate Survey123 with other Esri apps, such as Field Maps or Workforce. These apps include features that allow administrative staff to assign tasks and for field workers to confirm completion, and provide feedback that can include notes, photos, videos, and audio. There is a lot of potential for these apps to fulfill some of the communication and confirmation needs that Backhaul Alaska staff and participants requested. If these kinds of features are attractive to Backhaul Alaska, there are a few ways to access them. Survey123, Workforce, and Field Maps can exist as side-by-side applications that use the same underlying data. Access to Survey123 forms can also be embedded in Workforce and prompted by a Workforce task assignment. Backhaul Alaska may also consider transitioning to Field Maps, which integrates many task assignment and tracking features with data collection forms. Since these apps are all part of the Esri tool suite, anyone familiar with Survey123 should be able to transition to one of the other apps.

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Appendix B. Details of Materials and Methods

B.1 Research Approach and Materials

This research project sought to answer the question: *What are the best design options for a Backhaul Alaska program data management application, or similar technology, that addresses different users' needs for supporting program operations and decision making?* The research was centered around three activities that built on one another through iterative rounds of research synthesis and participant engagement (Figure B.1). These research activities provided complementary strains of inquiry that were appropriate for establishing a) foundational research, which provides a full understanding of the users and variables affecting app design and use, and b) evaluative research, which builds from the foundational work to understand the strengths, limitations, and needed refinements of specific ideas or prototypes (Chipchase 2017). All research was done remotely due to the Covid-19 pandemic, which restricted travel.

Our research was also informed by a pre-planning phase leading up to the project proposal during which time EPA scientists and Zender Group (who are the administrators of Backhaul Alaska on behalf of the Solid Waste Alaska Taskforce (SWAT) walked through expected implementation tasks and brainstormed potential steps that might be expedited through the use of an app (see appendix G). Following this pre-planning phase, the three research activities that we undertook included the following:

First, we sought to learn from existing environmental or resource management apps that are being used in Alaska, and in similar remote areas, in order to understand the local context and best practices for app development. We held a series of conversations (N = 8, Table B.1) with product teams representing these apps in order to understand how they were developed for, and received by, their target audiences. Conversations were held by videoconference software and were mostly unstructured, although an agenda was shared with participants ahead of time. Conversations were documented using written notes that were used to create a synthesis of technology factors and locally relevant norms and practices that should be considered for app development with rural Alaska communities. To the extent feasible, we also sought to learn about the environmental and community contexts within which the app will be operated.

Second, the EPA research team held conversations (n = 16, Table B.1) with key Backhaul Alaska participants and staff, including CTs, SCs, RCs, and VCs. Following the guidelines of the Interagency Arctic Research Policy Committee's (IARPC) "Principles for Conducting Research in the Arctic" (IARPC 2018), all RCs and representatives of SWAT were invited to have a series of conversation about Backhaul Alaska and its app development activities (Table B.1). The EPA research team also worked with Backhaul Alaska administrators to invite additional participation by VCs and their assistants from several pilot communities (Table B.1). Several RCs, VCs, and assistants participated in more than one conversation, which allowed the team to learn about program operations over time and follow up on questions that arose during initial rounds of analysis. The EPA research team also held conversations with a purposely selected sample of regional and technology experts (N = 9, Table B.1) to learn about regional waste management, technology, and app development considerations. Further details about conversation structure, agendas, and analysis are provided in section B.3.0 and Appendix C.

Third, the EPA research team asked RCs and SCs to collect and share video footage (details in section B.4.0) of backhaul activities in the field, including training and use of Survey123. These materials provided direct but limited observations of backhaul and inventory app use, which were important for understanding the setting and context in which an app would be used. They also helped to observe and document development needs that the users might not be directly aware of and were an important complement to the conversations (Abras et al. 2004, Daae and Boks 2015).

Each of the above research activities (regional app investigation, conversations, and user observations) informed the others and were integrated and synthesized at multiple time periods during the project (Figure B.1). These intermediary syntheses were then used as the basis for several workshops with RCs, SCs, and program administrators to discuss project findings, explore outstanding questions, and co-interpret the work with the EPA research team.

Table B.1. List of Conversations by Participant Type. The middle column lists the total number of conversations and includes repeated conversations with several individuals and/or programs, while the right-hand column lists the number of unique programs or individuals that participated.

Participant Type	Total conversations*	Unique entities (individuals or programs)
Technology experts	7	6
Regional waste management experts (external to Backhaul Alaska)	2	2
Regional programs using environmental or resource management apps	8	3
Representatives of SWAT	3	3
Control Tower (CT) and State Coordinator (SC) operators	2	2
Regional Coordinators (RCs)	6	4**
Village Coordinators (VCs) and their assistants	5	4
Total:	**33**	**24**

Notes:
*Several programs and companies were represented by more than one person; thus, the total number of unique programs or individuals (N = 24) is less than the total number of participants that we spoke with.
**A fifth RC participated through the RC workshop.

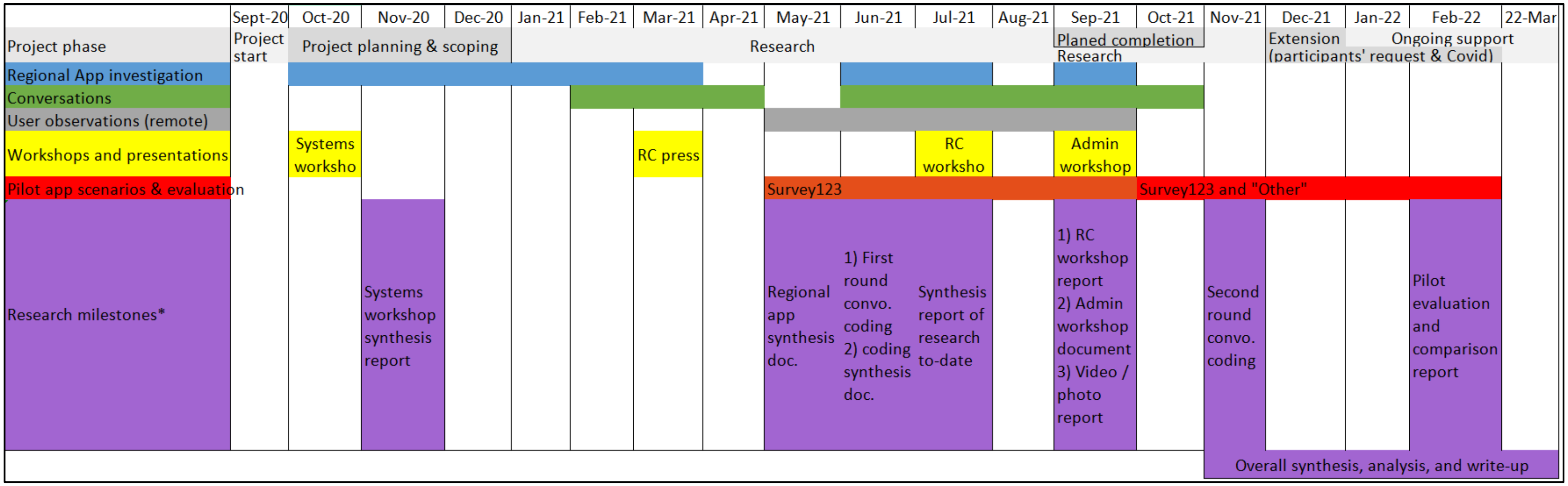

Figure B.1. Activity Timeline of the RSTIP. From project start date (September 2020) to extended completion date (December 2021) and ongoing support. The timeline does not cover activities between EPA ORD, Region 10, and tribal groups prior to the start date (pre-planning phase Jan-Aug, 2020). Such pre-project buildup is outlined in Figure 1.3 in the main text. Note that in the milestones (*), "reports" are internal documents that are shared with the entire RSTIP team and beyond as needed. "Documents" are internal write-ups for use within a smaller EPA research team that completed human subjects training and are listed on the Institutional Review Board (IRB). (This project was deemed exempt from IRB approval of human subjects research, see Appendix H)

B.2 Project Timeline

At the start of the project, the EPA research team held a systems diagram workshop (October 2020) with Backhaul Alaska program administrators (Zender Group) to understand the process and stages of backhaul and how they might relate to a supporting app. Results from the workshop (presented in Appendix E) were used to develop conversation agendas for use in eliciting input from all participants (Tables B.2 and B.3). Additionally, the project and its objectives were presented to RCs (March 2021) prior to staring conversations with the RCs to familiarize them with the project and receive feedback and questions. At this point, RCs requested that the project timeline be extended from September 2021 to late December 2021. The extension would allow everyone involved in the work to learn from the upcoming summer backhaul and the use of the Survey123 app, for which planning was underway. Extending the project end date also made sense due to research and administrative slowdowns caused by the ongoing Covid-19 pandemic.

Initial conversations with RCs were held from late March through April 2021. Thematically coded results of these conversations, along with findings from other research activities to date (Figure B.1), were compiled into a report and discussed with RCs in a 60-minute workshop (July 2021). The workshop consisted of three short presentations of the research findings and discussion questions. Following each set of questions, participants were directed to virtual and collaborative workspaces, using Google Jam Boards, where they could post responses to the questions (lasting 5 to 7 minutes) followed by short (3 to 5 minute) periods of open discussion.

Following the workshop, the EPA research team held conversations with representatives of SWAT, VCs, and their assistants (July through early September 2021). Conversation topics varied according to the expertise of the participant, but Survey123 use was a major focus during conversations with VCs and their assistants, who had by now had experience using the app. This stage of the research culminated in three day workshop between the EPA research team and Zender Group. The EPA research team shared all research syntheses to date, as well as a list of discussion points and questions that emerged during analysis. These items were discussed by the group to arrive at conclusions and establish future lines of inquiry.

The EPA research team then held a final round of conversations (October 2021) with several RCs, CTs, SCs, and one VC's assistant. Survey123 use was a major point of discussion. These conversations also provided opportunities to discuss observations from the video footage with RCs (Figure B.1).

Throughout the above outlined activities, the EPA research team also held conversations with several people with expertise about regional waste management and technology considerations. Several conversations with technology experts transitioned into a series of feasibility scoping and pricing activities with Esri and another app development company (as discussed in the main text, Section 4.3). Additionally, Backhaul Alaska conducted a pilot of the app from this other development company during December 2021. Because we had reached the extended research project deadline, we were unable to document and analyze use of the local app through videos and conversations. Instead, the EPA research team and Backhaul Alaska administrators (Zender Group) held several discussions to reflect on the experiences working with the apps. These conversations culminated in a formal written comparison that was shared with developers to document Backhaul Alaska's app choice in moving forward. The evaluation criteria included the following (the order of items does not imply importance): (1) the readiness of the apps for immediate use in the upcoming backhaul season, 3) ease of transition, (2) costs, (3) desired features, (4) available technical support, (5) the background of the app company, especially its familiarity with work in rural Alaska, and (6) short term vs. long-term needs of Backhaul Alaska.

B.3 Details of Conversations, Participant Recruitment, and Coding

All participants were selected for app development project participation based on their involvement in Backhaul Alaska and as individuals with expertise in regional waste management or app development in similar contexts. Zender Group, the administrator of Backhaul Alaska on behalf of SWAT, assisted in identifying Backhaul Alaska participants and regional experts. Technology experts were identified through a review of published or gray literature (materials and research produced by organizations outside of the traditional commercial or academic publishing and distribution channels).

While the research project was deemed not to constitute human subjects research by the University of North Carolina at Chapel Hill, which assists with administration of human subject research for EPA (Appendix H), all participants were provided a written summary of the project outlining their participation and use/storage of all data collected following standard protocols for the involvement of human subjects as outlined by the University of North Carolina at Chapel Hill. All of the EPA team members who participated in the conversations and/or worked with data prior to its being de-identified and aggregated had completed human subject research training.

Conversations with representatives of SWAT, SCs, CTs, RCs, VCs, and assistants (N = 16, Table B.1) lasted from 60 to 90 minutes, followed a meeting agenda (Table B.2), and were largely unstructured, allowing participants to skip questions and introduce new lines of inquiry during the discussions. Conversations were audio recorded, transcribed, and thematically coded using a deductive approach, in which a set of codes are established beforehand and then applied to the text (Bernard 2006, Saldana 2015).

After completing the first round of RC conversations (N = 4), two researchers read through all four transcripts, plus an additional fifth transcript from a conversation with a regional waste expert, to generate a set of thematic codes. The RC transcripts where then coded by a single researcher and reviewed by the second, in order to allow discussion of how well the codes were capturing the desired themes and if anything was missing. Several codes were added and removed over multiple rounds of coding and discussion, until a final code book was generated (Appendix C); this code book was then re-applied to the original RC conversations and subsequent conversations with representatives of SWAT, SCs, CTs, RCs, VCs, and assistants (N = 16).

Conversations with regional and technology experts (N = 9, Table B.1) were also unstructured and guided by a meeting agenda (Table B.3). These conversations were audio recorded and were not transcribed; rather, these audio files were played back to document a detailed set of meeting notes, which were integrated into intermediary research synthesis reports and documents (Figure B.1).

Table B.2. Example conversation agenda used with representatives of SWAT, RCs, VCs, and their assistants during the early stages of the project.

Meeting objectives:
1. Learn about logistical, administrative, and budgetary requirements for the Backhaul Alaska program, the community contexts in which the program operates, and its participants' needs. 2. Discuss future meetings, including those to get feedback on prototypes of the app and incorporate this into the app's design.
Agenda:
1. EPA ORD describes the project's background and goals
2. Learn about Backhaul Alaska program a) Participants' role in the Backhaul Alaska Program. b) Time and resource constraints c) Management and logistical specifics d) Existing tools being used
3. Learn about app use a) Helpful and unhelpful app features
4. Learn about challenges and opportunities when doing backhaul
5. Next steps a) Scheduling future meetings b) Additional contacts
6. Wrap up and sharing any final thoughts

Table B.3. Example conversation agenda used with technology experts during early stages of the project.

Meeting objectives:
1. Learn from past experiences working on technology and app development. 2. Develop a background level of understanding about app development needs and choices to support a Backhaul Alaska app and to help contextualize what is feasible and under what conditions.
Agenda
1. EPA ORD describes the background and goals of the project
2. Participants describe past work on apps and technology
3. General app development process, tips, and advice
4. Backhaul Alaska app development a) Development choices i. Potential tradeoffs in functionality ii. Path dependency or lock-ins? iii. Programming languages/environments b) App maintenance, integration, longevity, and ownership? c) Thoughts on development costs and time d) Advice on development needs based on what you heard about our project
5. Next steps a) Future feedback? b) Recommendation for additional contacts
6. Wrap up and sharing any final thoughts

B.4 Details of Photo and Video Interpretation

The EPA research team provided RCs and SCs with guidelines about the kinds of video footage content that they thought would be useful for foundational and evaluative research (Chipchase 2017). Training and use of Survey123 were important topics that the project wished to record. Participants were also provided instruction to document general day-to-day backhaul activities (see Appendix D). To avoid burdening RCs and SCs while they conducted important backhaul work and training, the EPA research team's requests, in terms of number of videos and length, were minimal. The EPA research team also asked for photos and while they were important for observing the overall context in which backhaul took place, the photos were less informative about potential app user activities. Therefore, analysis was restricted to the videos.

One RC was able to provide ten short cellphone videos, ranging from 30 to 90 seconds, from three different village visits. A professional videographer, who was contracted by Backhaul Alaska to accompany visits to several other villages for developing promotional videos, also provided content. The professional videographer provided 445 video files, ranging from several seconds to approximately nine minutes.

A single researcher reviewed all footage from the professional videographer. Forty-four video files (9.8%) that included backhaul activities (e.g., people doing backhaul work, using or being trained on the survey123 app, or depicted storage or staging of backhaul materials) were determined relevant to the analysis. The remaining files were largely landscape shots or other supplementary footage (i.e., "b-roll") that might be used as by the professional videographer for their work. The selected 44 files, along with the ten others from the RC, were reviewed a second time by the same researcher for coding and analysis. Each video was tagged with a binary yes/no to indicate if it included content for each of the codes in Table B.4 and a set of key insights learned was then written up for each video. This data was further synthesized into a report outlining the use of Survey123 in the field and associated trainings, local working conditions (in field and office), considerations about technology hardware, waste packing and storage, the use of paper in the field, and any new questions that arose to be addressed in future rounds of research.

Table B.4. Thematic codes for binary tagging of video content.
Codes are listed in alphabetical order and presented in two columns to reduce table length.

Thematic Codes	*shown In alphabetical order*
Communications	Packing
Culturally specific issues	Paper use in the field (or other analog tools)
Hardware and OS (tablet use/device use)	Storage
How would community coordination work/look like?	Synergistic opportunities/challenges and problems
Liability and safety concerns	Training
Loading and Shipping	Waste inventory and ID
Local Office Conditions (distinct from field work)	What might be sensitive information among communities?
Non-local waste location/storage (e.g., at a camp or hunting site)	

Appendix C. Thematic Code Book

The table below lists the code book used for coding conversations with representatives of SWAT, SCs, CTs, RCs, VC, and their assistants. The coder was instructed to code entire ideas (most likely one or more sentences), as opposed to single words or snippets, in order understand the context and meaning of any coded statement even after extracting the coded section from the main transcript.

Table C.1. Thematic code book used to analyze content of conversations related to Backhaul Alaska

Thematic Codes in Groups (bold)	Explanation and Examples (where needed)
Backhaul Alaska system and process	A thematic set of codes to document stages and key items in the backhaul. This group was largely based on the systems diagram activity, with some modifications.
1. Communications	
2. Training	
3. Initial planning and equipment inventory	
4. Waste inventory and ID	
5. Site visits	
6. Packing	
7. Storage	
8. Loading and shipping	
9. Tracking and receiving	
10. Other Backhaul Alaska Program systems and processes	
App Functions and Features	Record sentiments and statements about …
11. Desired functions and features (general apps)	… favorable technology features (directly stated or indirectly implied)
12. Undesired functions and features (general apps)	… unfavorable technology features (directly stated or indirectly implied)
13. Wishlist for an app	… desired features specifically about the app (directly stated or indirectly implied)
14. App alternatives and concerns (Sub theme: Use of paper in the field)*	… technology concerns or alternatives (directly stated or indirectly implied), e.g., technophobia, paper-based options, etc.
15. Hardware and Operating System	… hardware and OS that are being used, desired or undesired, and other related issues and challenges
16. Survey123 (specific to app)**	… the use of and/or training on Survey123. Coded material should include, but not be limited to, strengths and weaknesses of Survey123, desired improvements (specifically expressed or implied), and general discussions about the app.
Table continues next page	

Thematic Codes in Groups (bold)	Explanation and Examples (where needed)
Governance and Infrastructure	Record sentiments and statements about …
17. Community level	… any issues occurring within a community that affect the BHA process. This includes community infrastructure and cultural or political issues (which we might sub-code later on). This is NOT the place to record information about collecting a community profile or history, however.
18. Regional level	… any issues occurring among communities or about regional planning and logistics that affect the backhaul process.
19. Larger governmental	… any issues involving higher levels of government/ governance, such as state or interstate.
20. People and organizations	... people and organizations that participants discuss in relation to the Backhaul Alaska Program.
21. Places	… place names or other locations that participants discuss.
Backhaul Program Items	
22. Regional coordinator site reconnaissance	… information, activities, and resources that RCs want, collect, or use to understand a community and its context ahead of time (directly stated or indirectly implied)
23. Regional coordinator community of practice (Informal sharing, peer-to-peer learning, etc.)	… information, activities, and resources that RCs share/coordinate among themselves and/or other regional actors (directly stated or indirectly implied)
24. Culturally specific issues/ indigenous technology and data sovereignty	… cultural issues, opportunities, or concerns as they relate to the app or Backhaul Alaska Program. This includes, but is not limited to, issues related to technology use and data storage / access
25. Synergistic opportunities	… opportunities and ideas for the Backhaul Alaska Program to complement, tie in, or otherwise support other community and regional goals (e.g., jobs, conservation, etc). One example that a RC brought up was a computer recycling program that they are working on.
26. Challenges and problems	… key challenges and problems that people talk about. E.g., staff turnover is a recurring example. Note: while solving staff turnover might have synergistic effects with other programs, as staff turnover effects many related jobs in these communities, we did not code it as synergistic opportunities unless someone specifically framed it that way. We did make this link later in the analysis, however.
27. Liability and safety concerns	… actual safety situations and hypothetical issues or concerns that an actor might have. E.g., a community concerned that they could be liable/responsible if they do not do something correctly. Independent of their actual liability, they still have the concern, so it is an issue that needs to be addressed.
28. Covid related	… issues related to the ongoing Covid-19 pandemic.
Table continues on next page	

Thematic Codes in Groups (bold)	Explanation and Examples (where needed)
Data Management and Next Steps	
29. Scheduling and follow-ups	Document any key scheduling information or follow-up items that people mention
30. Additional contacts	Document any people or organizations that are recommend as possible participants or people/organizations that we should follow up with
31. Resources	Document things such as websites, documents, etc. Not every mention of such things needs to get coded if, for example, it is clearly not relevant. However, we should document such content and keep in mind that something may not at first seem relevant but turn out to be relevant later as we learn more, so it is better to code than not to code.
32. Key Quotes	Highlight any statements that just stand out and seem like they might be used to illustrate a point or used in a presentation as an example about why we are proposing something.
Notes: *During the first round of coding, paper, and the use of binders came up as app alternatives, which led to a more focused coding of the sub-theme "Use of paper in the field" during the second round of coding. ** The Survey123 theme was predominantly used during the second round of conversation coding.	

Appendix D. Storyboard Provided to Professional Videographer and RCs for Collecting Video Footage of Backhaul Activities

D.1 Storyboard Provided to Professional Videographer:

Objectives and instructions for collecting video clips and photos of Backhaul Alaska Program activities
Overview: The "user centered design" approach for app development puts the user's needs and experience at the center of the development process. Directly observing people doing tasks in the field or at their place of work provides valuable information about how to customize an app to meet their needs. Because of distance, cost, logistics, and the Covid-19 pandemic, we are unable to travel and observe backhaul activities in person. Therefore, we want to use photos and videos to learn about what people are doing. Watching how people conduct their work for the backhaul events during site visits—and seeing other activities during the site visit—can provide important learning opportunities.

While this information will help us, **your needs and your work come first! We do not want this exercise to disrupt anyone's work or responsibilities during site visits and we do not want the presence of a camera or camera-phone to influence the way someone is doing their work.** We want to be "flies on the wall." Ultimately, we hope to gain a better understanding about backhaul operations on the ground.

Questions we hope to answer from this content are:

1. Who is involved in the backhaul operations? What are their tasks and objectives?
2. What are the specific stages/processes of backhaul operations? What are the activities occurring within each stage?
3. Where are backhaul operations taking place (e.g., indoors vs. outdoors) and what does the place look like? What is around them?
4. What types of devices or tools are used during backhaul operations (e.g., phone, tablet, computer, fax, etc.)?
5. Is anything restricting or complicating data collection activities (such as PPE, winter or field clothing, holding other devices/tools, inclement weather, etc.)?

Instructions for Collecting Videos and Photos (ideally for each village/site visit)

Please collect brief videos and photos of a few different activities/scenarios as you are able.

Table D.1 offers guidelines on what to film and photograph. For each scenario, we think **2 to 3 videos of 30 to 60 seconds and 3 photos** will be sufficient; however, the table is just a guide; you are free to adjust what you film or photograph based on the opportunities presented to you in the field.

Table D.1 Guidelines for Professional Videographer on What to Film and Photograph

Media	What to Record and Photograph	What We Hope to Learn
Videos (4-6), 30-60 sec Photos (10)	**Processes/Operations:** How do local backhaul staff perform their backhaul duties?	Who is involved in the process? What are the jobs to be done? How are these tasks completed?
Videos (2-3), 30-60 sec Photos (3)	**Tools/Devices:** What tools/devices are being used by the backhaul staff to perform backhaul duties?	What tools/devices are used for data collection/entry? How are these tools/devices used?
Videos (2-3), 30-60 sec Photos (3)	**Materials, documentation, training, paperwork:** How is data managed in the field?	How is data managed/recorded? How is training administered?
Videos and/or photos, as you see fit	The different workspaces where the app will be used.	What are the different places and settings where the BHA operations occur?
Videos and/or photos, as you see fit	Other photos and videos you think we might find interesting.	See something that sticks out to you about using the app? **Document it and let us know!**

D.2 Storyboard Provided to RCs:

Objectives and instruction for collecting video clips and photos of Backhaul Alaska Program activities

Overview: The "user centered design" approach for app development puts the user's needs and experience at the center of the development process. Directly observing people in the field or at their place of work, provides valuable information about how to customize an app to meet their needs. Because of distance, cost, logistics, and the Covid-19 pandemic, we are unable to travel and see BAP activities in person. Therefore, we want to use photos and videos to learn about what people are doing. Watching how people use the Survey123 app during site visit--and seeing other activities during the site visit--can provide important learning opportunities.

While this information will help us, **your needs and your work come first! We do not want this exercise to disrupt anyone's work or use of Survey123, and we do not want the presence of a camera or camera-phone to influence the way someone is doing their work.** We want to be "flies on the wall." Ultimately, we hope to gain a better understanding about how the app will be used in the field.

Questions we hope to answer from this exercise are:

1. What type of device(s) is the app being used on (e.g., phone, tablet, Android, Apple, etc.)?
2. Where is the person using the app working (e.g., indoors vs. outdoors) and what does the place look like? What is around them?
3. Is anything restricting or complicating their use of the app (such as PPE, winter or field clothing, holding other devices/tools, etc.)?
4. Is the person using the app doing other activities at the same time?

Instructions for Collecting Videos and Photos (<u>ideally for each village/site visit)</u>
Please use your cell phone to collect videos and photos of a few different activities/scenarios.

Table D.2 offers guidelines on what to film and photograph. For each scenario, we think **2 to 3 videos of 30 to 60 seconds and 3 photos** will be sufficient; however, the table is just a guide; you are free to adjust what you film or photograph based on the opportunities presented to you in the field. You are on the ground; you are the expert!

Table D.2 Guidelines for RCs on What to Film and Photograph

Media	What to Record and Photograph	What We Hope to Learn
Videos (2-3), 30-60 sec Photos (3)	**Wide-shot, or landscape** (app user and surroundings), of people using the app as they would for a future backhaul event.	What is happening around the individual that may affect the app's use.
Videos (2-3), 30-60 sec Photos (3)	**Close-up (approx. 6 feet away)** of someone while they are using the app in the course of their work.	What the individual is doing, wearing, and holding while they are using the app.
Videos (2-3), 30-60 sec Photos (3)	People using the app during app training.	How training is done.
Videos and/or photos, as you see fit	The different workspace(s) where the app will be used.	The different places and settings where the app will be used.
Videos and/or photos, as you see fit	Other photos and videos you think we might find interesting.	See something that sticks out to you about using the app? **Document it and let us know!**

Appendix E. App Requirements Document Used for Communicating with Developers During the Project

An app requirements document is a short document intended to communicate a client's wishes and needs to an app developer. The document helps the developer understand the scope of work and evaluate if their services can meet the client's needs. The following app requirements document was prepared to communicate with several developers during the project. The document was updated several times over the course of our research to reflect the research teams' most current understanding of Backhaul Alaska's app development needs. It was last updated in December 2021. The content of this requirements document was sufficient for its intended use of communicating with developers during the project, but it is far less comprehensive than the information documented in the main text of this report. This document is not a deliverable of the EPA funded project (i.e., RSTIP); rather, it was a research and communication tool used during the project.

At the end of this document are three appendices (Figures E.1, E.2, and E.3) prepared by Backhaul Alaska administrators outlining various planned workflows. These planned workflows have been compared, in the main text or body of the report, to the workflows in practice that were documented through conversations during the research project.

E.1 Backhaul Alaska Software Application Functional Specification Document

E.1.0 Background

There are roughly 200 rural Alaska villages that are not connected to the road system, many operating Class III permitted landfills that may lack containment or treatment. Few options exist to properly dispose of household hazardous wastes, which often end up being burned if disposed of in local landfills. Improper disposal releases contaminants to the surrounding environment, creating human exposure risks and interfering with important cultural and subsistence hunting, fishing, and gathering. One option to deal with these hazardous wastes is to ship them out by plane or barge. It is economically and logistically infeasible, however, for each village to independently ship out their waste. A region-wide program is needed.

Backhaul Alaska (https://backhaulalaska.org) addresses this issue by organizing statewide recycling logistics for rural community hazardous wastes and for bolstering local programs through needed training and infrastructure assistance. The program has been successful at pilot scale and as it begins its expansion to serve all villages statewide, seeks to develop a more robust and tailored digital infrastructure that will best accommodate its reverse supply chain data needs and align with the unique cultural and operating conditions of its clientele and users.

E.1.1 Objectives & Outcomes

The objectives of this document are to outline the software application needs for the Backhaul Alaska program. Data organization and digital processing efficiencies are needed to reduce local village human resource needs and move waste materials so that village programs operate safely, storage sites do not overflow, and village foods and water are not contaminated.

E.1.2 Product Context

The Backhaul Alaska Program has multiple broad functions:

- Program management (i.e., planning, scheduling, village enrollment, etc.)
- Logistics management (i.e., shipping, barge tracking, transporter/vendor selection, packaging/ materials approval, coordination)
- Operations (i.e., site-visits, authorization, loading, collection/packaging, inventory management)
- Job training (i.e., hazmat training, curriculum development)

Each of these broad Backhaul Alaska functions requires multiple program staff to engage in processes with different data management needs and there are different implications for functional requirements. A software application would need to address components of each of these functions with a primary focus on **logistics management** and **operations**. Section E.2 presents app requirements and concepts developed through this research. Table E.1 describes what an app must and should be able to do in order to meet Backhaul Alaska's needs. Three figures following the text outline additional information including: (1) a conceptual model of the Backhaul Alaska process (and components of this system that need software application functionality) (Figure E.1), (2) a process flow diagram for the shipment sub-process (Figure E.2), and (3) an inventory management data flow outline (Figure E.3).

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E.2. Requirements

E.2.1 Functionality Table

Table E.1 Functionality Table Listing functional needs desired for proposed Backhaul Alaska App

#	Function	Description	Priority
1	Inventory and records management	Must enable Village Coordinators (and sometimes Regional Coordinators and other workers associated with Backhaul Alaska) to upload data (numeric, geospatial (GPS points), and media) and metadata identifying, organizing, prioritizing, and the status of packing waste materials. These records must be stored and accessible to Backhaul Alaska staff. This functionality is currently being addressed by Survey123 and an Access database in SharePoint.	Must
2	Verification and approval	Regional Coordinators and Statewide Coordinators must be able to see the status of, verify, and approve* multiple steps of the packing and shipping process. *Note: An ideal workflow improvement would be to have functionality that permits records to be returned to the record creator if something is incorrect/incomplete, and to allow for commenting on completed records so that the record creator can receive feedback.	Must
3	Survey creation and administration	Backhaul Alaska staff must be able to create and deploy surveys (or simple checklists) for data collection and feedback purposes. Currently this function is being addressed through Survey123.	Must
4	Shipment planning, tracking, and routing	Must enable staff to manage shipping logistics (including scheduling, booking, tracking, and record keeping). Barge/plane location and status should be reported and visualized (both en route to communities/hubs and en route to recyclers).	Must
5	Communication	Likely needs to enable both two-way (peer to peer, peer to expert, and peer to management) communication and one way communication (notifications, announcements, status updates, etc.).	Should
6	Resource access	Must provide access to document library that contains training materials (videos, documents, manuals, FAQs, communications information, etc.).	Must
7	Community information	Likely needs to provide community information and data in both geospatial and tabular/text formats that summarizes a community's profile and onsite capacity: storage facilities, barge access points, inventory, and relevant historic information, along with community contact information.	Should
8	Analytics/ Dashboard	Must enable program staff (State and Regional Coordinators) to track and view data for each community and for each backhaul event along with easy export formats for data and possible report generation. Should be able to transform data into shipping logs/bills of lading (BOL) to minimize manual data migration/form completion.	Must

E.2.2 Usability Requirements

The inventory and records management functions of the app must be usable by rural Alaskans and must cover a range of digital literacy and digital access. The user interface must be straightforward and utilitarian, with intuitive navigation, data entry, and communication. Native language options (or translation capabilities, especially Yup'ik) would be an enhancement but not a requirement, since virtually all potential users are comfortable with English. Inventory and records management functions (especially the process of data collection and uploading by Village Coordinators) must be easy to perform in a rural Alaska context, which often includes field environments with poor weather conditions and where other program operations are occurring concurrently. Data entry and upload must take advantage of experience with using cellphones to take photos and videos and must allow for this to happen while wearing personal protective equipment (PPE) or winter clothing (gloves).

E.2.3 Technical Constraints

The app must be able to provide offline capability to Village Coordinators and other program staff for entering data with limited/no cellular access. The app must also support the use of this interface and the storage/submission of records from limited bandwidth facilities.

E.2.4 Device Specifications

The system must be supported on both mobile devices and tablets and should provide access to certain information (e.g., the dashboard or analytics) through a desktop accessed website. We currently do not know if there are preferred operating systems but acknowledge that program staff will be accessing mobile applications on personal devices and both iOS and Android are currently used.

E.2.5 Data Requirements

Data sovereignty and ownership are key considerations for the communities that we worked with. The usage agreement must be flexible and permit different communities to specify different parameters for who has access to their data and how it is used.

E.2.6 Access Requirements

Different components of the app will require different levels of permissions and access. Statewide Coordinators should have access to all data generated by program participants and staff. Regional Coordinators should be able to view the data generated by the communities they coordinate. Village Coordinators should have access to records they generate, including historical records so that continuity of information can be retained through staff turnover.

E.2.7 Security Requirements

Some of the information captured may be sensitive in nature. Examples might include community dynamics like staff turnover or locations that people may not wish everyone to know about. Photos may capture content (e.g., activities in the background) that could be sensitive. Functionality should permit record generation to specify sensitivity concerns or flag a record as being potentially sensitive.

Figure E.1 Backhaul Process Flow Diagram

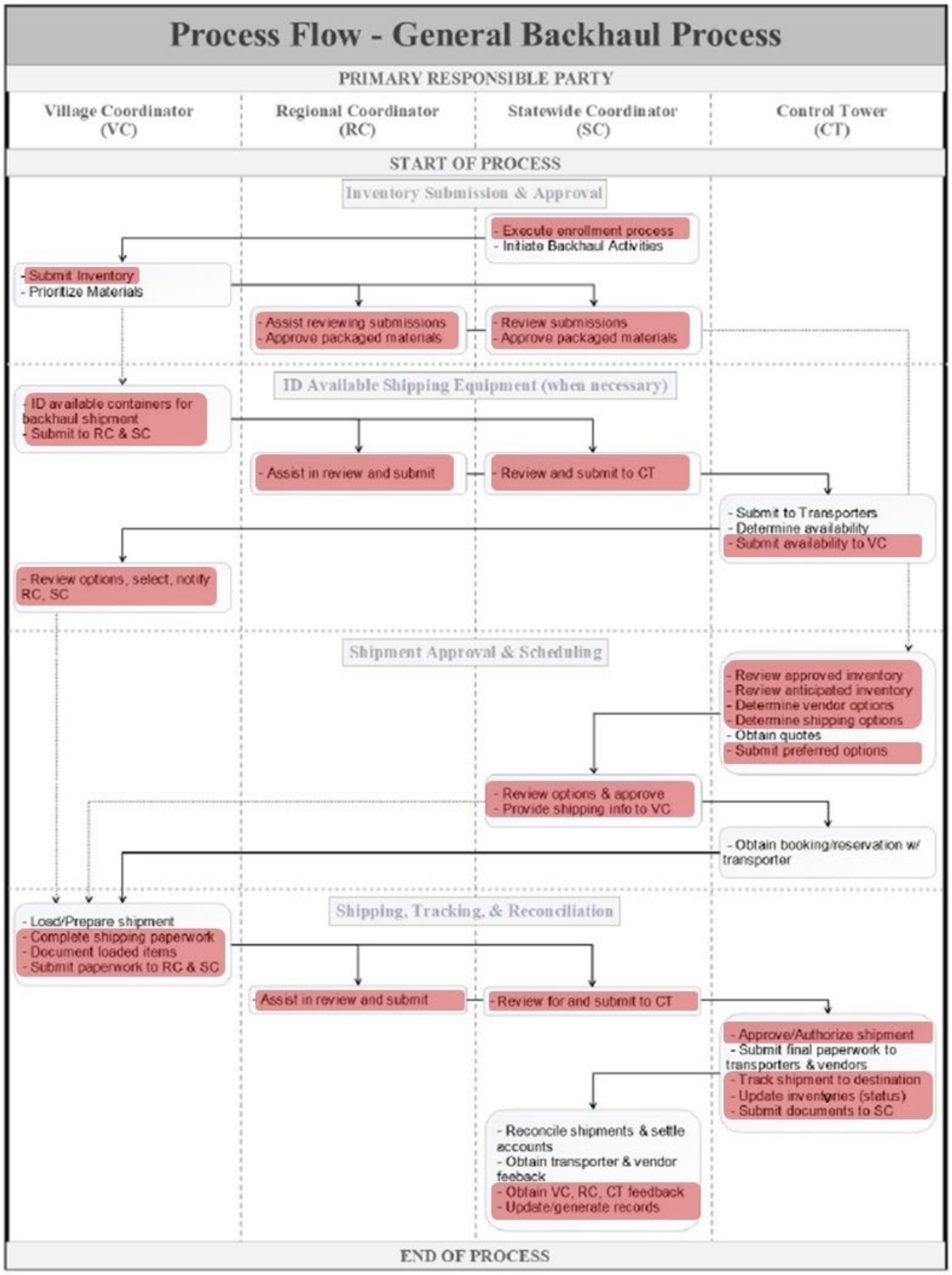

Figure E.1 Backhaul Process Flow Diagram. Flow diagram indicates processes and actions taken by Backhaul Alaska staff (VC. RC, SC, and CT) during general implementation of Backhaul Alaska. Details are shown for steps in the process of (1) Inventory submission and approval, (2) Identifying shipping equipment, (3) Shipment approval and scheduling, and (4) Shipping, tracking, and reconciliation. Pink shading indicates actions appropriate for a app.

Figure E.2 Shipment Sub-Process Flow Diagram

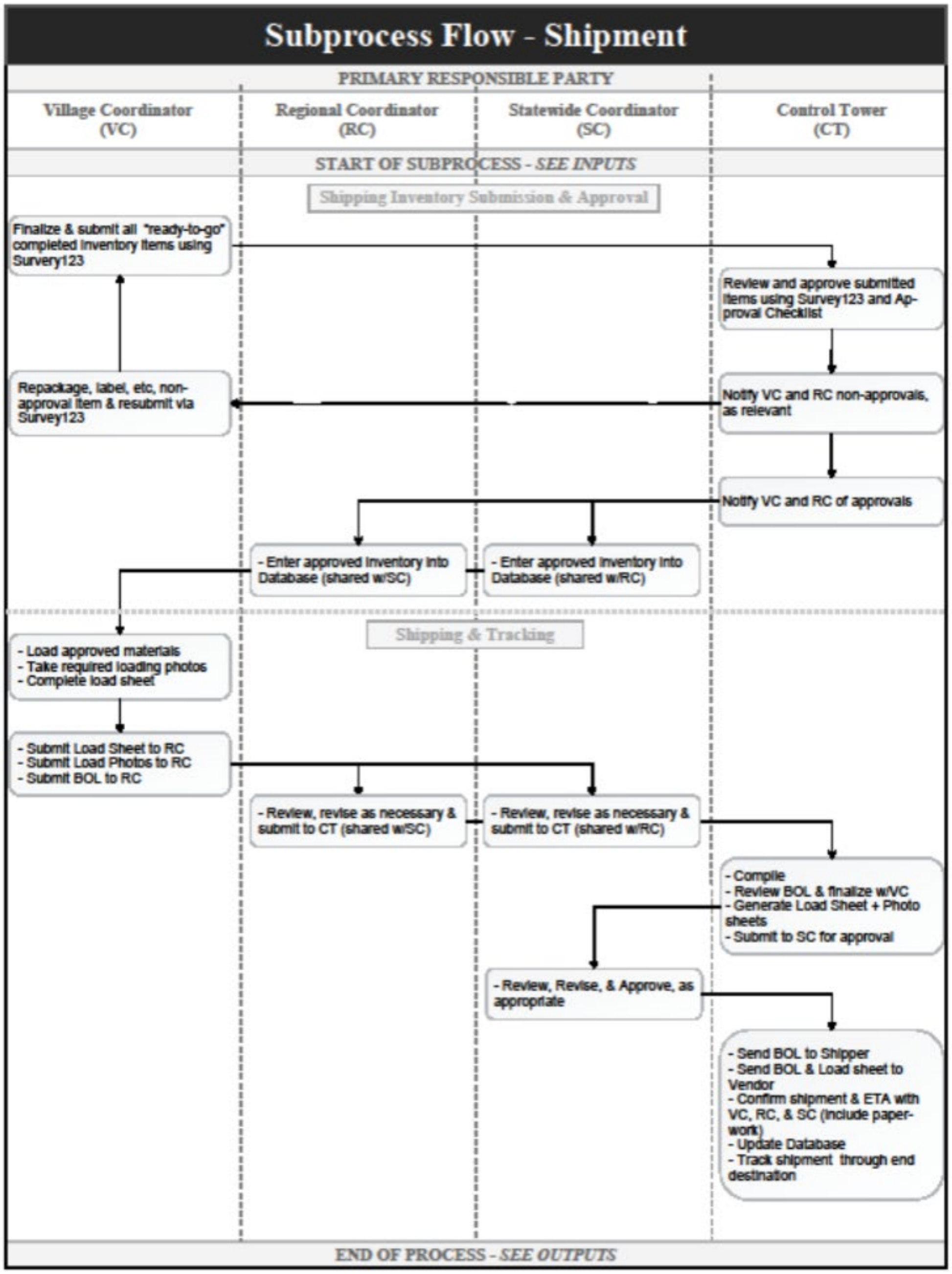

Figure E.2 Shipment Sub-Process Flow Diagram. Flow diagram indicates processes and actions taken by Backhaul Alaska staff (VC. RC, SC, and CT) during the shipment sub-process of Backhaul Alaska implementation. Details are shown for steps in the process of (1) shipping inventory submission and approval, and (2) shipping and tracking.

Figure E.3 Inventory Management Data Flow Outline

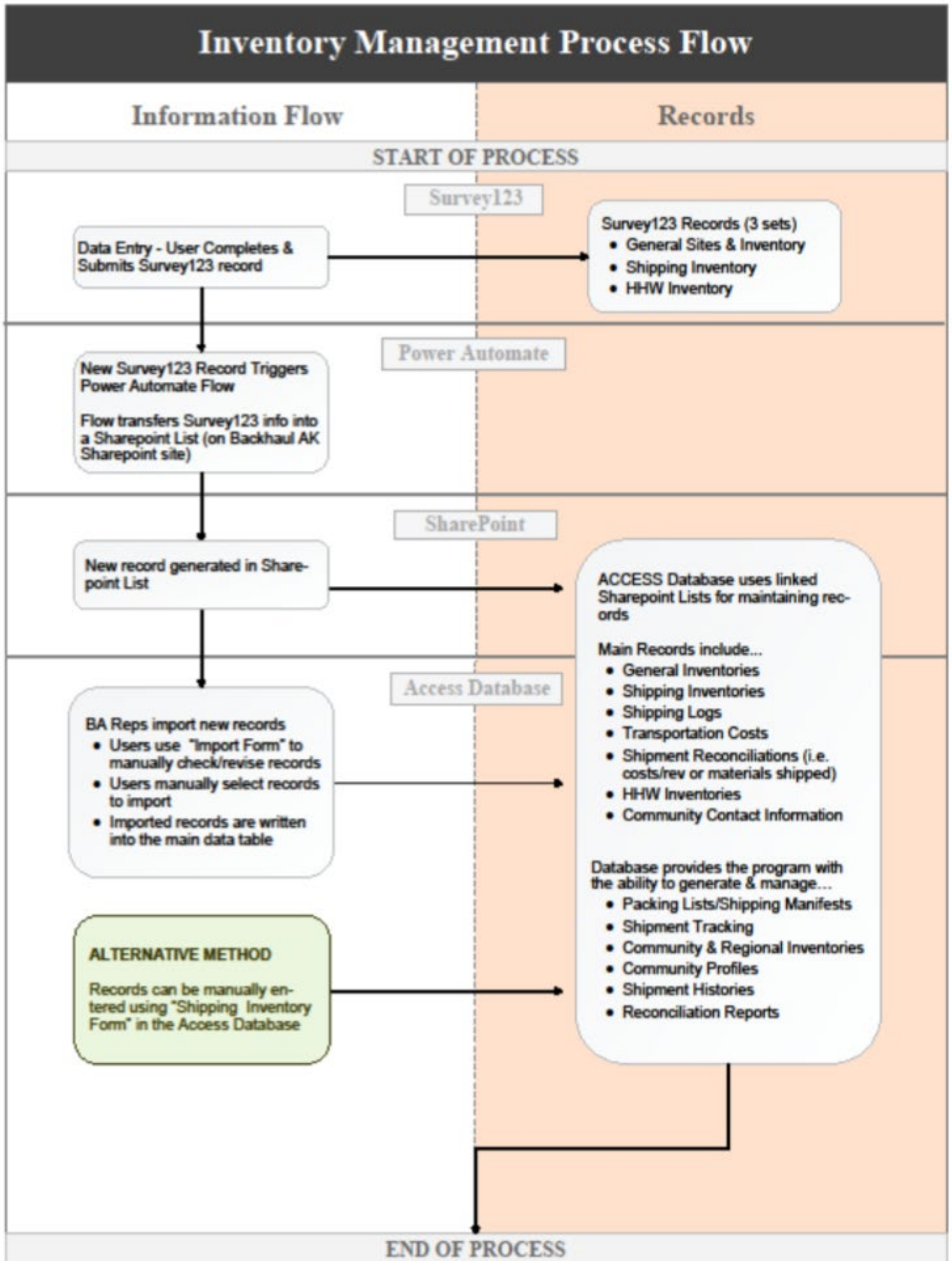

Figure E.3 Inventory Management Process Flow Diagram. Flow diagram depicts the inventory processes (left panel) and records generated (right panel) when using the Survey123 app during Backhaul Alaska implementation. Data entry into Survey 123 by the user triggers automated population of fields in a Backhaul Alaska Sharepoint list, followed by transfer to a linked Access database, where records are maintained. The alternative method requires manual entry of data directly into the database. Details are shown for steps in these processes and the records that are created.

Appendix F. Select Results from the App Specific Systems Workshop

The following diagram (Figure F.1) and table (Table F.1) are the finalized output of the app specific systems workshop held in October 2020 with Backhaul Alaska administrators (Zender Group). The objective of the workshop was to develop an overall picture of Backhaul Alaska operations and how they might relate to an app. Major objective of the workshop were to outline (1) potential app users and (2) the processes for which they might use an app were. The diagram and table below do not represent a final understanding of Backhaul Alaska's users, operations, or app needs, which are discussed in the main report. Rather, this figure and table document an early research stage of the project (October 2020) that informed subsequent stages of the work.

(The rest of this page is intentionally left blank to allow for landscape orientation of the following pages).

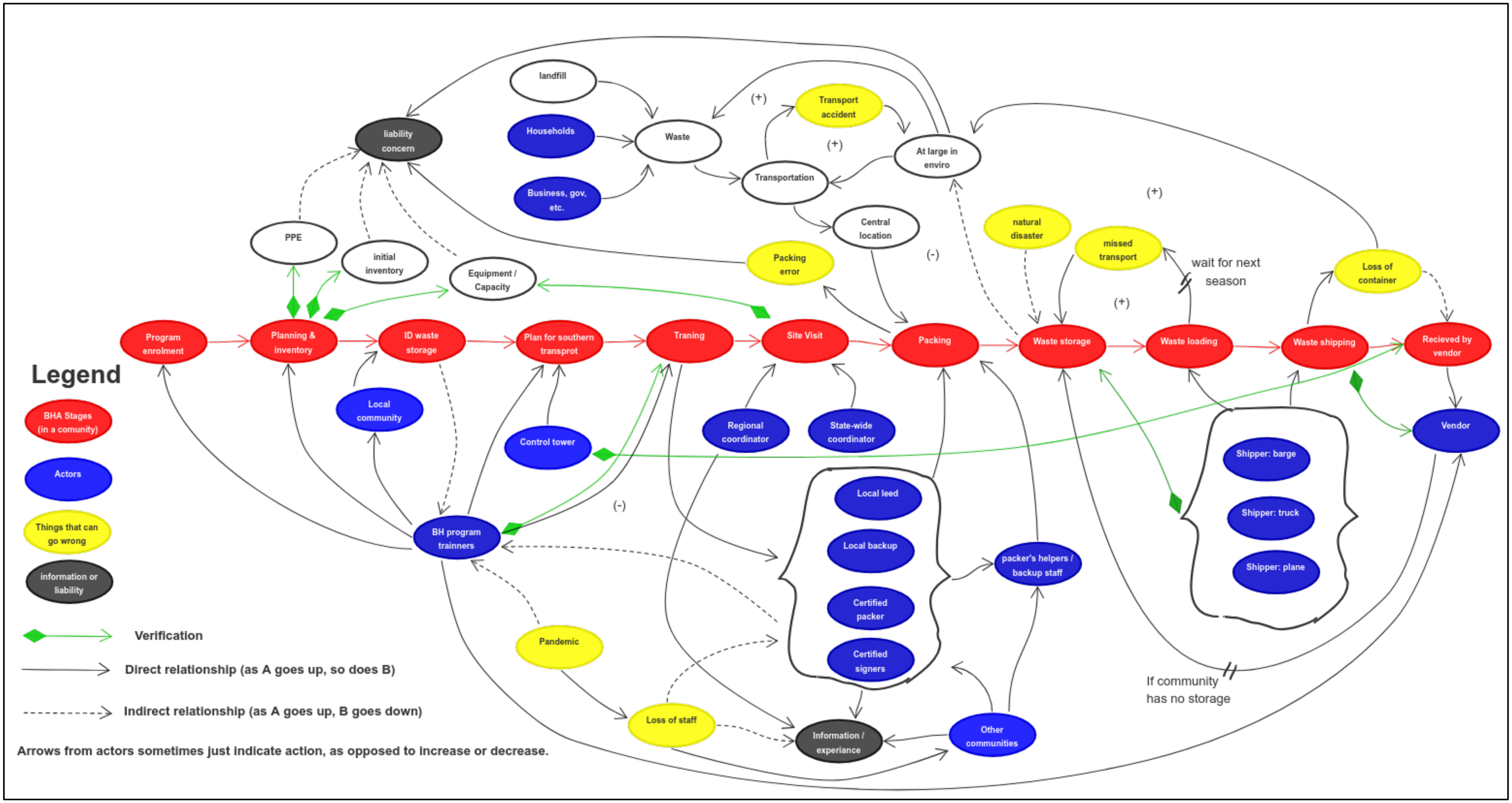

Figure F.1. System diagram of Backhaul Alaska operations pertinent to use of an app.
Final diagram generated during the October 2020 systems workshop with Backhaul Program Administrators.

Table F.1. Table showing lists of many of the key actors and system dynamics components that were generated during the Systems Workshop discussion. Note that columns are independent lists of items, and the content should not be read or linked across rows. *(Page 1 of 2)*

Actors	Program Levels	Local Disturbances	Regional Disturbances	Information Exchange	Legal/Liability	Regional Dynamics	Local-Regional Interaction	Verification
Local lead	Local backhaul	Loss of staff	Loss of staff	Planning and inventory; need to know what kind of storage capacity community has.	Spills, fires, on the job injuries	Work with control tower to plan shipping for all communities	Work with control tower to plan shipping for all communities	Planning and inventory: storage capacity
Local backup	Control Tower	Flood	natural disaster	Planning: if community does not have storage container, contact vendor to supply one for south-bound shipping.	Accident when transporting waste to central location (e.g., person dumps ATV).	Site visits done by regional or statewide coordinator	Site visits done by Regional or Statewide Coordinator	Planning and inventory: initial itinerary
control tower	Regional coordination	Missing transport	pandemic	Work with control tower to plan south bound transport for each community.	Natural disasters: where does waste go. What is in it?	Natural disasters: where does waste go? What is in it?	Villages have many needs that vary	Planning and inventory: PPE
Shippers: barge	State coordination	Pandemic		Site visit: assess readiness and capacity (storage equipment and facilities, do they own or need to rent, what are the barge facilities (or airport) like). Would be nice to know what supplies are on hand in a community, and how much material. In a mature program, we hope site visits would only occur for new staff situations. For pilot we visit every site.	Shipping wrong or improperly packed materials	Would be nice to have waste go to central hub to cut down on costs.	Backup staffing often comes from other villages	Verify that training is still good (good for 3 years)
Shippers: truck	Interstate transport			After site visit, periodically check to make sure all is ok.	Loss of shipping container at sea	Virtual site visits could help program efficiency	Would be nice to have waste go to central hub to cut down on costs.	Site visit: verify equipment and capacity
Shippers: plane				Communities currently fill out form to outline collection methods for households, businesses, etc.			Distance learning could help to ensure that villages have certified person; do not want them to have to wait 6 - 12 months	Control tower verifies that waste is received by vendor
BHA trainers				Would be great if barge companies could communicate with community via an app; now they call them or use VHF.			Virtual site visits could help program efficiency	Shippers want to know that waste is correctly packed
Certified signer				Vendors want to know that the goods are on the way.			Regional Coordinators tend to work with communities in other capacities, so they know communities	Vendors want to know that waste is en route

Actors	Program Levels	Local Disturbances	Regional Disturbances	Information Exchange	Legal/Liability	Regional Dynamics	Local-Regional Interaction	Verification
Certified packer				Loss of trained person is a "gut punch" to program.			Smaller communities might not ship every year; this might affect staffing	
Packer's helpers				Trained people need to be reachable with two-way communication.				
Regional coordinator				Waste that is spread out is a problem. Need it central and need an inventory.				
Backup staff (for local packing)				Need a Plan B if a community misses a shipment. Where will the waste be stored; what is in the waste?				
Statewide coordinator				If there was an accident, need an inventory of the waste.				
Vendor				Record keeping so that when a person leaves, the community is not left starting over from scratch				
*Local community member (i.e., waste producer)								
*Local organizations (i.e., waste producers)								

Note: *Likely not an actor or user from the perspective of the app and its development.

Appendix G. App Wish List Developed Before Commencement of RSTIP

Table G.1 is a wish list of items for a custom developed Backhaul Alaska app that was generated by Zender Group, EPA Region 10, and ORD prior to the start of research (i.e., the RSTIP funded project). This list was used to help customize the Survey123 pilot app. This is a partial representation of the work during those meetings. Listed items were also ranked based on priority, however priorities are omitted here, as those priorities and the list itself represent an early understanding of Backhaul Alaska's app needs. The main body of the report, and Appendix A, discuss a more up-to-date understanding of app development needs.

Table G.1. Pre-project "Wish List" of items for a custom developed Backhaul Alaska app. *(Page 1 of 2)*

Category *(Note that order does not indicate priority)*	**Function**
Inventory management (backhaul items & supplies)	Backhaul inventory management
Inventory management (backhaul items & supplies)	Generate and scan QR codes for inventory management.
Community & regional information	Contact Info (village, regional, statewide, BHA administrators, vendors, etc.)
Communication	Contact list management – Village Coordinators, Regional Coordinators, vendors (transporters and end destinations)
Backhaul activities/operations	Material inventory data entry by Village/Regional Coordinators with capabilities to attach photos and files
Transportation activities/operations	Transporter options/contacts, route options, etc. per village
Transportation activities/operations	Shipment tracking & status updates
Other	Varying levels of permission
Other	Dashboard where, if there is tiered access, you can get an idea what's happening at a regional or statewide level
Other	The general ability to take photos and upload to certain folders/records--for inventory and ready to ship, maybe ability to upload a photo of the loaded Conex (open door) or the final palletized e-wastes, etc.
Other	A method for uploaded photos to be tagged/sorted automatically depending on where in the app they are uploaded
Other	Recordkeeping – being able to pull up past shipping docs, inventory records, training certs, checklists, etc.
Other	General ability to use the app while offline/out of cell coverage, and sync data when back online/in data coverage range
Community & regional information	Community profiles & onsite capacity; being able to capture a summary of a community's collection and storage program
Transportation Activities/Operations	Port (or hub?) infrastructure quality status tracker--ability to allow villages to confirm that barge docking area is adequate; document with photos?

Category *(Note that order does not indicate priority)*	**Function**
Backhaul activities/operations	Training credential tracking (maybe this is only for Statewide Coordinator?)
Backhaul activities/operations	Notification of expiring training certs
Backhaul activities/operations	Tracking when the barge is coming, airplane is coming (notifying village, vendors)
Backhaul activities/operations	Ability to access, complete, and submit checklists (as needed/developed) & upload
Backhaul activities/operations	Regional Coordinator site visit review documentation and acknowledgement that village is "ready to ship"
Backhaul activities/operations	Readiness checklist completion by Regional Coordinator
Transportation activities/operations	Booking & scheduling shipments (through the Control Tower)
Communication	A trouble-shooting file/record maybe for each category--ex: if folks are having questions on a certain battery type, identifying a material, or a question on whether their storage area was organized well, along with the ability to load that into a checklist record
Community & regional information	Community maps (that folks can tap on the screen or otherwise to designate locations of storage or what not)
Inventory management (backhaul items & supplies)	Supply inventory management (packing/PPE supplies, equipment inventory tracking)
Communication	Peer-to-peer & peer-to-expert contact for troubleshooting (Facetime/Skype/Zoom, direct messaging options)
Communication	Messaging system – chat box? Message center? For communication between villages, regions, and statewide
Communication	Feedback/evaluation form submittal by Village and Regional Coordinators
Communication	Program announcements
Transportation activities/operations	Completing/submitting shipping paperwork (BOLs, manifests, airway bills, etc.)
Community & regional information	Access to community Integrated Waste Management Plans, Landfill Operations Plans, and any community specific procedures they have initiated (if available)
Backhaul activities/operations	Training videos, informational documents, manuals, etc.
Outreach & education media	Community education resources--sharing items or being able to download posters or materials
Outreach & education media	Templates for PSAs, flyers, event planning, etc.
Transportation activities/operations	Carrier board to manage third party bidding for rural shipments--compatibility with external app?

Appendix H. Statement of Human Subject Exemption

Letter from the Institutional Review Board (IRB) of the University of North Carolina, Chapel Hill, NC, which assists EPA ORD in administering its Human Subjects Research program. *(Page 1 of 2)*

3/16/2021 Mail - Sayles, Jesse - Outlook

IRB Notice - 21-0019

IRB <no_reply@unc.edu>

Mon 3/1/2021 8:23 AM

To: TenBrink, Marilyn <Tenbrink.Marilyn@epa.gov>
Cc: Carvalho, Gabriela <Carvalho.gabriela@epa.gov>; Sayles, Jesse <sayles.jesse@epa.gov>

To: Marilyn TenBrink
Aux Services Affiliates: EPA

From: Office of Human Research Ethics

Date: 3/01/2021
RE: Determination that Research or Research-Like Activity does not require IRB Approval
Study #: 21-0019

Study Title: Human-centered Design to Improve Management of Household Hazardous Waste Programs in Alaskan Tribal Communities
This submission, Reference ID 320510, was reviewed by the Office of Human Research Ethics, which has determined that this submission does not constitute human subjects research as defined under federal regulations [45 CFR 46.102 (e or l) and 21 CFR 56.102(c)(e)(l)] and does not require IRB approval as it is not systematic investigation for generalizable knowledge.

Study Description:

Purpose:

From https://www.epa.gov/innovation/region-10-human-centered-design-improve-management-household-hazardous-waste-programs

"Because of their remote location, Alaska's rural tribal communities have limited options for disposal of hazardous waste - which often means disposal in an unlined landfill or burning without any emissions control. Backhaul Alaska is an EPA-funded pilot program that coordinates the hauling of hazardous waste out of rural Alaskan communities using empty cargo space in barges and planes on return trips. Beginning in 2021, a 10-year plan will expand the Backhaul Alaska program to serve 160 communities across Alaska."

"This project will employ a human-centered design approach (i.e., a methodology that focuses on the needs of end-users) to create a mobile application for backhaul service operations. A data management app will be created that supports different user needs including tribal and municipal government staff, citizens, program administrators, and others. The app will help individuals in rural Alaska villages manage inventory, track shipments, and submit observations that impact waste management operations. The app will also support program implementation such as optimizing transportation logistics. Anticipated project results include cost-effective program operations, reduced health and environmental risks, and support for each tribe's capacity to manage their local backhaul program. "

Participants:

https://outlook.office365.com/mail/search/id/AAQkADdlMjdiMTM2LWMxNzUtNDlkOC04ODhhLWYxMzA4ZjAyMGQ0YgAQACg7NmZ1kI5luX48fNgHix... 1/2

Regional and local community backhaul program coordinators that are working for and/or participating in the Backhual Alaska pilot program, as well as relevant knowledge experts and app developers.

Procedures (methods):

Participants will be purposefully selected because of their work and/or participation in the backhaul pilot program, or because we have identified them as a knowledge expert doing work relevant to our app development goals. We may also ask participants to refer other people that we should speak with.

We will hold one or more unstructured conversations with participants to learn from their experiences. In the case of backhaul program participants, we will also aim to understand their needs, as described above, and how the app can best be designed to serve their needs.

After conducting an initial set of conversations, we will begin to develop prototypes of the app. These will be initially be in the form of Microsoft PowerPoint sketches and will later be mocked up in Adobe Xd (Experience Design) in order to enable more realistic representation and introduce visual designs, (such as the shape or color of specific elements), content (such as instructions and other "copy"), and basic interactivity (such as the transition from a button to its associated page within the application).

We will solicit user feedback primarily through unstructured conversations, but may also use other activities such as card sorting, ranking or choosing among different options if we feel these activities will enhance our interactions with participants. Are methods are solely intended to facilitate conversation and gather information about how to customize the app for its intended users. Our methods are NOT intended to test hypotheses or create generalizable knowledge.

Please be aware that approval may still be required from other relevant authorities or "gatekeepers" (e.g., school principals, facility directors, custodians of records), even though IRB approval is not required.

If your study protocol changes in such a way that this determination will no longer apply, you should contact the above IRB before making the changes.

CC:
Gabriela Carvalho, Aux Services Affiliates: EPA
Jesse Sayles, Aux Services Affiliates: EPAIRB Informational Message - please do not use email REPLY to this address

United States
Environmental Protection
Agency

PRESORTED STANDARD
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Office of Research and Development (8101R)
Washington, DC 20460