DOI: 10.14714/CP111.2015

PEER-REVIEWED ARTICLE

There is Always Another Version: Maintenance, Deprecation, and the Long-Term Life of Digital Maps

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This article is about the long-term life of digital maps. The deprecation of Adobe Flash and Esri Story Maps offers harsh lessons for digital cartographers. Namely, that our creations will not, and cannot, last forever. Combining literature review and research agenda, I argue that a long-term view of digital mapping is a lens into social, physical, and environmental processes. I begin with the relationship between digital maps, preservation, and ephemerality, pondering the end *of digital mapping projects, in specific contrast to print cartography. I then describe the challenges of sustaining and maintaining digital maps, drawing on the related field of digital humanities, and exploring how societal power structures devalue maintenance for novelty. Next, I introduce two technical frameworks, discussing how they each could support a more holistic long-term view of digital mapping. The first, free and open-source software (FOSS), puts technical control in the hands of map designers, but requires intentional commitment to the social dimensions of mapmaking to be effective. The second, minimal computing, positions* need *as the primary motivator of all decision-making throughout the mapping process—which is particularly relevant for local-scale projects. I end with a brief agenda for future directions for the research and practice of long-term digital mapping.*

KEYWORDS: Adobe Flash; long-term mapping; preservation; ephemerality; maintenance; sustainability; open-source; minimal computing

PART 1 — INTRODUCTION: FILE NOT FOUND

On January 12, 2021, Adobe Flash died.

In official terms, Flash was **deprecated**, software engineering terminology for the ending of project support. In addition to deprecating Flash, Adobe also fully blocked its use in browsers due to security concerns. Overnight, twenty-four years of online content became unusable.

The death of Flash was no surprise. When Apple CEO Steve Jobs (2010) announced that Flash would not be supported on the new iOS platform for mobile devices, it began to slowly fade from the web. Due to its steep bandwidth requirements, coupled with increasing security vulnerabilities, Flash had no place in the era of mobile computing (Roth et al. 2015). In the younger days of the internet, however, Flash was a staple—at one point installed on 98% of personal computing devices, its usage peaking in the mid-2000s (Jenny et al. 2008). A tremendous amount of multimedia content was created using Flash, including animations, games, and of course, maps.

Flash maps occupy a strange place in cartographic history. In the early days of web mapping, Flash offered consistency in an uneven browser landscape. As an Adobe product, it synchronized well with two of Adobe's other programs, Illustrator and Photoshop, already widely used by cartographers. Flash even allowed the incorporation of interactivity through its built-in scripting language (Roth et al. 2015). Indeed, Flash powered many standout web maps from the 2000s, including ones created by university labs (Roth and Harrower 2008) and major news organizations (Yau 2024). Flash was taught to, and used by, cartographers, and these cartographers produced countless maps—many of which are now lost, or buried on servers or old

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laptops, inaccessible and unusable without the assistance of emulators.

This article is about the long-term life of digital maps—or maps created for a digital medium, such as a personal computer or smartphone. I emphasize web maps, as these comprise the vast majority of digital maps today, but the ideas I explore, and the questions I raise, are applicable to the wider context of cartography. After all, cartography is always situated within technical flux (Monmonier 1985). How long should a digital map be designed to last? What factors should digital mapmakers consider to support the sustainability and maintenance of their projects? What technical and collaborative frameworks might be useful when taking a more active approach to long-term digital life? These questions center what happens to a digital map after its initial release, and offer a lens in which we can view many elements of cartography together. In the following sections, I argue that the long-term life of digital maps relates to larger social and physical infrastructures, mapping processes, design, the environment, and justice. I do not argue for universal preservation of all digital maps, but rather describe how long-term digital life is a multifaceted concept requiring careful, critical engagement. As such, this article is equal parts literature review and research agenda.

These questions are also urgent. While I write, Google Maps has just replaced "Lake Ontario" with "Lake America" (for US users), highlighting both the ephemeral nature of digital data, as well as the tangle between geospatial technology, capitalism, and the US empire. Climate change is embedded within these systems as well, and as global temperatures rise, it is becoming increasingly apparent that our current relationship to technology is unsustainable (Digital Humanities Climate Coalition 2025). Indeed, our daily interactions with technical systems are increasingly muddied by cloud computing, which situates technical processes as *elsewhere* (Chan and Sayers 2022). By exploring the long-term life of digital maps, I look to encourage what Thatcher and Dalton (2022) describe as "making present" the social processes that underlie technical systems.

And, what happened to Adobe Flash has happened again. In Q1 of 2026, Esri Story Maps was replaced fully by ArcGIS StoryMaps. In an article written prior to the change, Esri (2025) states: "After retirement, the classic Esri Story Maps templates will no longer be available, and the stories will not be viewable at their previous URLs." Did any of the people who created content with Esri Story Maps, many of whom lack formal cartographic training, consider what would happen to their stories in the long run? Do they have the resources to, as Esri (2025) suggests, "Use the Story Conversion Helper" to get them started in the move to ArcGIS StoryMaps? In many ways, this deprecation is more severe than that of Flash, as it is possible to resurrect Flash maps using emulators (though some functionality cannot be fully replicated). In the case of Story Maps, the original tool has simply been replaced, and many projects will vanish from the web. To engage with the long-term life of digital maps is to investigate the hows and whys of deprecation, and to imbue our design processes with an eye towards complete lifecycles.

The next part of this article describes the life stages of digital maps beyond initial release, specifically considering the end of a project, as well as a project's lifespan between initial release and deprecation. I discuss contrasts between digital preservation and ephemerality, arguing that cartographic processes could account more for the entire lifecycle of digital maps by foregrounding a project's end. I then explore how a digital map might be sustained and maintained to reach its end point, drawing on the related fields of digital humanities and media studies. Part 3 introduces two different technical frameworks, and the ways in which they could support a more holistic long-term view of digital mapping. The first framework, free and open-source software (FOSS), has potential to situate long-term control with the map designer, but is limited by perspectives that emphasize technical pragmatics over social relationships. To address these limitations, I explore three complementary guidelines to discuss how FOSS could be used to address mapping in the long-term: FAIR, TRUST, and CARE. The second framework, minimal computing, is a philosophical position about technology that positions *need* as the primary motivator of decision-making, one which has potential application to digital mapping broadly and community mapping in particular. I finish with a brief agenda for research directions to further explore the long-term life of digital mapping.

THE END?

Print vs. Digital

Let us begin at the end. How long should a digital map be designed to last? To explore this question, it is necessary to unpack the unique nature of digital artifacts.

Cartography has historically relied on print publication to produce and distribute maps Print is a relatively stable technology with a specific conception of finality. When a project is finished, it goes to print. When something is printed, its ability to be used over time is connected to its physical decay (Smithies et al. 2019). If a book goes out of print, copies preserved in libraries can ensure reusability (Brown et al. 2009). Today, public scholarship—even in fields leveraging digital publishing, such as the digital humanities—is still built upon a print paradigm (Dombrowski 2022). In other words, most scholarly projects are conceived with a clear end point (Smithies et al. 2019). Map production is no different. In Buckingham's (2019) *GIS&T Body of Knowledge* entry "Map Production and Management," most of the recommendations assume that print and digital mapmaking should follow the same procedures when they are "finished," involving a transfer of associated files to a client, as well as internal archiving.

However, print and digital maps should not, and do not, follow the same model of publication. Even something as seemingly simple as a file hand-off is complicated by the realities of digital publishing. Arrangements must be made for file storage and web hosting, responsibilities that might fall on either the client or the mapmaker—not to mention determining responsibility for updates. Digital archiving is not straightforward, either. As Brown et al. (2009, 6) write: "Even if no technological enhancements are desired, for an electronic text to remain usable, it has to be stored somewhere in a form that is accessible to evolving technologies." While all archives face entropy, digital environments, in particular, face multifaceted entropy, contingent not only on physical storage—which decays over time—but also on the rapid pace of technological change (Smithies et al. 2019). In other words, archiving alone does not guarantee a project's files will be usable in the future. Digital maps must evolve to survive.

The evolving nature of digital maps is an important element of the medium. Unlike print maps, for which updates and corrections can be expensive and resource-intensive, digital maps can be updated quickly, changing with their underlying data, or providing additional data as it becomes available (Majewicz et al. 2024). As such, digital mapping can be ongoing, challenging the traditional notion of maps being temporally limited (Wilson 2017), and even providing information in real-time as events unfold (Roth 2021). Digital mapping therefore requires different design paradigms. User-centered design (UCD), for example, presents a model of map production that aligns more with the realities of digital mapping. UCD situates map design as a continual process of iteration and feedback, emphasizing direct communication with a user base to ensure a project satisfies their requirements (Haklay et al. 2010). Importantly, UCD is a cycle, and the defined end point of one UCD cycle can be the beginning of another, and can in theory be practiced throughout the entire life of a digital mapping project (Roth 2019). A separate question is whether a project has the time, personnel, and funding resources to continually implement UCD, as is whether a project *should* be kept alive.

Ephemerality

All digital projects are ephemeral (Chun 2008). On one hand, technology evolves, putting older projects at risk of being deprecated. On the other, when a digital map is updated, it could become fundamentally different than its previous version. For geospatial archivists, the ephemeral nature of digital maps and geospatial data threatens a digital dark age, in which large quantities of information may be lost due to the limitations of the digital format (Majewicz et al. 2024). In comparison to print maps—which are usually either released once, or updated at regular intervals—large digital maps and datasets are continually updated, often overwriting previous records and rendering them inaccessible. These maps leave little information about particular moments in history. Over time, the lack of records may compound, leaving large gaps in historical geographic knowledge. For Majewicz et al. (2024), map library archives can serve a crucial role, creating systems for archiving data at established intervals. However, digital archiving itself must also confront its own ephemerality (Chun 2008). The archiving of web maps, a space of silence within map librarianship, is an additional challenge.

Different digital maps and mapping platforms can have greatly different ephemeralities. How a project or tool is created and funded, where, and by whom, as well as broader technological and social conditions, all affect how long it may last (Miller and Taylor-Poleskey 2020). A web map created by a student for a class project has a fundamentally different ephemerality than something created by a national government. Even within one particular arena of web mapping, ephemeralities can differ from one project to the next. For example, while both Flash and Esri Story Maps were the products of large tech corporations, the motivations for their deprecations diverge. By the time of its deprecation, Flash creations were increasingly insecure and targets for hackers, in addition to their lack of mobile compatibility (Smedberg 2017). In the case of Esri Story Maps, the new ArcGIS StoryMaps adds functionality missing from the original Esri Story Maps, and increases its compatibility with modern browsers. For Esri, it would not make sense to maintain multiple tools with largely the same function. One major difference, however, is that Esri Story Maps was usable through a free downloadable application, while ArcGIS StoryMaps is only usable through a subscription. In this case, the deprecation of Esri Story Maps aligns with an increased emphasis on subscription-based web services as revenue sources. Understanding the ephemerality of a mapping tool or a platform, or even a published map, involves recognizing a broad suite of actors—organizations, companies, institutions, individuals, or some combination thereof.

As frustrating as ephemerality can feel, sometimes we may want digital maps and data to be ephemeral, particularly when it comes to privacy. In 2022, Google Maps agreed to a $391.5 million settlement for misleading users regarding its privacy settings, recording user location history after users believed they had disabled it (Kang 2022). Indeed, digital footprints—used by companies like Google and Meta for advertising, and sometimes used as evidence for firings, arrests, or deportations—can be difficult, often impossible, to scrub from the web (Mayer-Schönberger 2009). While digital location data is simply one element of a larger assemblage of users, technology, and capital (Wilmott 2020), its persistence is an equally troubling counterexample to the ephemeral digital maps created with Flash. Less insidious is the idea, as Smithies et al. (2019) write, that some projects simply do not need to last:

> Not all projects should be maintained in perpetuity. Some are better conceived as short-term or even momentary interventions in the scholarly conversation, to be archived online for the historical record but not worth the intellectual, technical, and financial overhead of ongoing maintenance. (8)

Digital preservation also has an environmental cost. Web servers consume water and electricity, and large data centers consume tremendous amounts of both (Diaz Bejarano and Valdivia 2026). The decision to preserve a digital object is therefore one with ecological ramifications, which are increasingly obscured as storage is outsourced from local server infrastructures to larger cloud-storage providers, like Amazon Web Services (Chan and Sayers 2022; Digital Humanities Climate Coalition 2025).

To contend with the costs of digital publishing, perhaps digital mapping projects could embrace their ephemerality. Preservation itself is a reflection of a cultural emphasis on inscription—or the storage of knowledge through fixed objects (Louis 2004). In contrast, many Indigenous cultures include some combination of inscription and *incorporation*, in which the performance of information—such as through song, dance, or storytelling—is how knowledge, including geographic, is passed along (Louis 2004; Lucchesi 2018). When defining an Indigenous genre of cartography, Pearce (2014) emphasizes brevity, as only important geographic knowledge is remembered and passed down, shaped by the limitations of human memory. Not every place needs a name, nor to be remembered. Arola (2018) describes how digital media can reflect Indigenous relations to the land through form and content, and the creation of digital spaces meant to be interacted with at particular places, at particular times. Applied to digital mapping, a project could reflect a moment, or a relationship to place, then be taken offline. Alternatively, digital maps could be designed to last for a defined period, long enough for interested parties to print or record them (Gil 2015). Within the context of the digital humanities, Rockwell et al. (2014) recommend considering a digital project's end-of-life at its beginning, including when it should be taken offline, rather than responsibility ending when a project is handed off to a client. As such, addressing ephemerality requires careful consideration of what digital information is truly necessary to preserve, the costs of that preservation, and how much control one may have over that information in the long-term. I argue these considerations are necessary elements of all digital mapping processes.

THE MIDDLE: SUSTAIN AND MAINTAIN

Digital Sustainability

If the end-of-life of a digital project should be considered at its beginning, so should a plan for its entire life cycle. **Digital sustainability** refers to how a digital project is designed to meet its long-term goals, and is "achieved by producing, developing, maintaining and ensuring access to digital artifacts in a way that ensures their creation and facilitates their use" (Stuermer et al. 2017, 251). As such, digital sustainability must contend with multiple, conflicting temporalities—technological evolution, user understanding, and funding landscapes all shift at different rates, each providing their own challenges (Barats et al. 2020). These problems are not purely technical, either, and a project plan must be flexible enough to account for them all (Kräutli et al. 2022). Stuermer et al. (2017) suggest that shared governance and diversified funding are key to the sustainability of a scholarly digital project, while Edmond and Morselli (2020) suggest that sustainability is a function of both planning and documentation. Documentation, especially, is an often overlooked element of digital processes—typically relegated to a later stage in a project's development, despite its importance for communicating technical processes across levels of expertise (Reed 2014). Additionally, digital sustainability does not imply perpetual life, particularly when considering the broader environmental impacts involved in preserving digital works. Indeed, digital sustainability could be more fully aligned with environmental sustainability by better accounting for the environmental and human costs of digital objects (Digital Humanities Climate Coalition 2025). Decisions about what is worth preserving and sustaining, and in what way, are as ecological as they are technical, and should be carefully considered.

Within the world of digital mapping, there is one element of digital sustainability that requires deeper consideration: maintenance. In software development, maintenance is often a project's largest expense, comprising both more hours and resources than initial development (Ensmenger 2014; Mattern 2018). Maintenance of many digital projects (maps included) is rarely considered at a project's outset, often framed as a problem for the future—or dismissed from the conversation entirely to perpetuate a short-term contract model. Additionally, over time, revision becomes more difficult, as it needs to look both forward, understanding how changes will affect the project in the future, and backward, understanding how they will affect what has already been done (Reed 2014). Barats et al. (2020) report that many websites created for digital humanities projects wind up abandoned when they are deemed complete, as they lack funding for maintenance. Indeed, funding agencies, and even faculty tenure models, are more attracted to the development of new projects, rather than the maintenance of existing projects (Smithies et al. 2019).

The allure of novelty is on one hand a sensible one. Simply put, creating something new is fun. More than that, it can be easier, and less resource-intensive, to create a prototype rather than address an issue with an existing project. Real-world solutions often are more complicated and multifaceted than those conceived during initial design, potentially requiring more active negotiation with existing networks of project partners (Costanza-Chock 2020). On the other hand, an overemphasis on novelty is a symptom of broader power structures that actively devalue maintenance, reducing it to "a routine and low-status activity" (Ensmenger 2014, 8). As Costanza-Chock (2020, 162) writes: "under patriarchy, making something 'new' is valued more and is better rewarded than caretaking, maintaining, or supporting something 'old.'" In other words, maintenance is a feminized form of labor, devalued because it is antithetical to the forms of production driving the accumulation of capital. Mattern (2018) therefore situates technical maintenance within the larger history of care work, the largely uncompensated domestic work, often done by women, to care for children, households, and communities—or, more broadly, to maintain life.

Dimensions of Maintenance

Within a digital context, maintenance is not simply about the preservation of technical objects. Instead, a digital object could be reframed as a "human and community asset in need of maintenance and support" (Smithies et al. 2019, 6), as opposed to simply a technical asset in need of management. The maintenance of any technology—be it a bridge, a utility line, or a web map—attends as much to social infrastructure as it does to technical infrastructure (Mattern 2018). Digital projects are the fruits of social collaboration (Maron and Pickle 2014; Miller and Taylor-Poleskey 2020), and these relationships must be maintained alongside technology. Maintenance can even encourage the formation of new, generative relationships. Schlotterback et al. (2022) describe an internal audit on

a digital database they manage. The audit uncovered resource gaps within their materials, which prompted them to intentionally contact new communities as a method of filling these gaps, strengthening both relationships and database coverage. Denieul-Pinsky (2025) describes the ongoing challenges and negotiations of a digital land defense project centered on Kanehsatà:ke, an Indigenous community in southern Quebec, asking: "what if researchers spent less time making maps, and more time investing in the relationships that shape them?" (44).

How digital maps and their surrounding relationships are maintained, and who does the maintaining, are embedded within larger socio-technical infrastructures, of which the digital map is only one element. The matrix of domination is a Black feminist model describing how unequal power relations structure life across society, including through interpersonal relationships, media, policy, and the enforcement of laws. Through the matrix of domination, discrimination proliferates based upon race, gender, sexual orientation, disability, citizenship, and other characteristics of identity, privileging a dominant group—in US society, this is white, straight, cisgendered, able-bodied men (Collins 1991; D'Ignazio and Klein 2020). Maps and their makers are always situated within the matrix of domination, and mapping processes often mask the mechanisms of power within which they are created. Kelly and Bosse (2022) invite mapmakers to pause throughout the design process to reflexively consider their relationship to the power structures within which they are embedded. Engaging with the matrix of domination, and investigating broader structures of power, is necessary for understanding how a digital object might be maintained.

For digital projects with limited time or funding resources, it can often be easier to pay for maintenance from a service provider rather than arrange an in-house technology stack (Dohe 2019). For example, ArcGIS StoryMaps is a purely subscription-based platform, also known as **software-as-a-service**—a cloud computing platform on which the provider manages all software and storage in exchange for subscription fees (Chan and Sayers 2022). Software-as-a-service platforms transfer the sustainability and maintenance from the creator to the software provider. However, by offsetting sustainability and maintenance, long-term control of a project's availability is ceded to the provider. How long something will be maintained, can be maintained, or how much it will cost to maintain is essentially unknown. Perhaps twenty years, perhaps five.

How Maintenance Manifests

For an example of how the maintenance of digital maps relates to broader physical and social infrastructures, I turn to my own cartographic past. In 2018, I was the lead designer of a web atlas published by Oregon State University Libraries and Press: ***The Atlas of the Pacific Northwest***. While I led front-end development, hosting and back-end development were arranged by the library's IT department, and the project is currently hosted from a library server. While this arrangement sounds simple, when considering maintenance it becomes increasingly tangled. At the most straightforward level, I am no longer employed by Oregon State University Libraries and Press, and much of the knowledge of the site's front-end remains with me. My documentation of the project was . . . spotty . . . at best, and it would be difficult for someone unfamiliar with the project to update it, requiring (at minimum) a knowledge of multiple coding frameworks. The level of education required to know these technical frameworks, as well as to be hired by the Libraries and Press in the first place, limits who a potential replacement might be. Additionally, I do not know if the current IT staff at the library is the same, but I do know that the project's managers have moved on to other projects. Technically and relationally, the project is dormant. Yet, it remains online, for now. The library's back-end servers require technical maintenance from IT, but these servers will inevitably degrade over time, leading to necessary replacement. These replacement servers are contingent on funding, and their very creation is contingent upon a global network of natural resources and labor exploitation, unequally distributed across the matrix of domination. Even thinking locally, servers require electricity, which is itself contingent upon materials and maintenance (see Touya et al. 2025 for a more detailed discussion of how digital maps are embedded within larger technical infrastructures). Considering the environmental and human cost of technology, some things should not be maintained, or repaired if they are broken (Mattern 2018). It does not matter how sophisticated technology is or becomes, questions of sustainability and maintenance will endure (Smithies et al. 2019). Insights from this example are summarized in **Table 1**.

Element	Function	Software Maintenance	Physical Maintenance
Project Management	Determines web mapping project goals and a reasonable timeline for completion. Acquires and/or manages project funds. Collaborates with clients and/or community members.	Communications between clients, users, community members, and/or developers. Funds for software maintenance. Relevant Group(s): *project managers; funding providers; clients; users; community members.*	Funds are needed to maintain and/or replace physical infrastructure, such as personal computers or servers. Relevant Group(s): *project managers; funding providers.*
Map and Interface	The front-end web map display, what a user will see and interact with.	Updates to website files through HTML/JS/CSS or a content management system (CMS). Relevant Group(s): *web mapping developer/designer; users/community members.*	See *Hosting*.
Database	Back-end data displayed on the web map, other website data.	Regular updates to the data, database provider (e.g., *MySQL*, *PostGIS*), web security. Relevant Group(s): *IT expert; web mapping developer/designer; cloud storage provider; data collector; community data providers.*	See *Hosting*.
Hosting	Web hosting provider, facilitates storage of front-end and back-end files, as well as client display.	Regular updates to hosting server (e.g., *Apache*, *Tomcat*), web security. Relevant Group(s): *IT expert; cloud storage provider.*	Servers require replacement, either at a home institution, a local IT service, or the server farm of a cloud storage provider. Relevant Group(s): *IT expert; cloud storage provider; server and server parts manufacturers; raw material producers.*
Internet Service Provider (ISP)	Provider of internet connectivity.	Updates to file transfer and security protocols. Relevant Group(s): *ISP.*	Cables, routers, and modems require replacement—sometimes to increase internet speeds. Relevant Group(s): *ISP; internet user; cable, router, and modem manufacturers; raw material producers.*
Electricity Network	Provider of electricity.	Updates to software used for provisioning electric service and responding to outages. Relevant Group(s): *electricity network provider.*	Physical power plants, substations, and transmission lines require continual maintenance and occasional replacement. Server farms, in particular, require large quantities of electricity. Relevant Group(s): *environment; electricity network provider; raw material producers; energy product manufacturers; electric customers.*

Table 1. General summary of infrastructure required for an in-house web mapping project, including requirements for the maintenance of both software and physical hardware, as well as relevant groups involved with each element.

FREE AND OPEN-SOURCE (FOSS)

Geospatial FOSS in the Long-Term

Free and open-source software (FOSS) is an approach to digital creation with an orientation towards open access, contrasting with the software-as-a-service model, and supporting long-term control of digital objects. FOSS includes programs, data, and coding libraries that are made available to share and modify at no cost. Adopting FOSS makes it necessary to arrange maintenance at an organizational or individual level, but also situates control of sustainability and maintenance directly with project creators. Geospatial FOSS (or FOSS4G) has its origins with tools like the Map Overlay Statistical System in 1977 and GRASS GIS in the 1980s, before more widespread popularization in the 2000s with crowdsourcing, map hacks, and map mashups—allowing mapmakers from various backgrounds and with varying levels of expertise to create and recombine maps and data (Moreno-Sanchez and Maria Antonia 2023). FOSS4G represented an alternative to "the closed-world of cartographic officialdom, with its unaccountable state authorship, its emphasis upon owned and protected products as capital assets, and its claims to provide an exclusive topographic text" (Dodge et al. 2009, 226).

More recently, a variety of FOSS tools have been developed for the creation of web maps, often plugins for web-programming languages. FOSS web mapping plugins are interoperable—guided by common technical formats that work across platforms and operating systems (Doctorow 2023). Interoperability supports long-term life by situating digital artifacts outside proprietary control. Several widely used FOSS4G plugins include *Leaflet*, *OpenLayers*, and *MapLibre*, each of which is provided through open-source licensing—specifically a BSD (Berkeley Software Distribution) license, which **provides guidelines** for the reuse and redistribution of code. However, not all FOSS tools are created equal. While some FOSS tools are created by volunteers or not-for-profit organizations, others are provided by corporate sponsors and are just as vulnerable to overnight changes in access as software-as-a-service. For example, until 2020, Mapbox GL JS—an open-source web mapping plugin—was provisioned through a BSD license. In 2020, Mapbox switched the plugin to a proprietary license, and began requiring an API key. While previous versions of the plugin would remain covered by the BSD license, all versions since have been proprietary (Gooding 2020). The deprecation of Esri Story Maps similarly illustrates the vulnerability of corporate-provided FOSS. In addition to the uncertainties of licensing, the development of FOSS tools and data is generally limited to people and places with adequate financial resources and time. It is estimated that only two percent of FOSS developers are women (Costanza-Chock 2020), and FOSS technologies are often developed in Western countries, with limited applicability to the Global South (Carroll et al. 2020). How FOSS solutions are implemented or governed therefore creates significant implications for their long-term equity and availability.

FOSS Frameworks: FAIR, TRUST, and CARE

To address the various long-term challenges of FOSS, and to move towards a more equitable web (Dodge et al. 2009), several frameworks have been developed to address its uncertainties and disparities. Three frameworks—**FAIR** (Wilkinson et al. 2016), **TRUST** (Lin et al. 2020), and **CARE** (Carroll et al. 2020)—offer a suite of suggestions for open-source data work that can be extended to web mapping.

- FAIR (*Findable, Accessible, Interoperable, Reusable*) standards were created for the broader open scientific data movement and encourage responsible data stewardship (Wilkinson et al. 2016). Degbelo (2022) describes the application of FAIR principles to cartography and geovisualization.

- TRUST (*Transparency, Responsibility, User Focus, Sustainability, Technology*) principles were developed for the design of open-source data repositories, and framed as a necessary complement to FAIR principles to cultivate user-centered practices (Lin et al. 2020).

- The CARE (*Collective Benefit, Authority to Control, Responsibility, Ethics*) framework addresses extractive relationships between the FOSS movement and Indigenous communities, emphasizing both relationships and sovereignty—as well as disparities between open-source development and use. While CARE is specifically oriented towards work with Indigenous people, the guidelines can be applied to other community-based mapping work (Carroll et al. 2020).

Table 2 describes each element of the three frameworks and their potential application to digital maps and the long-term sustainability of those maps.

While each framework provides useful recommendations on its own, we can see resonances and tensions related to digital sustainability when they are viewed together. Carroll et al. (2020) describe FAIR principles as primarily *data-oriented*, while CARE principles complement them by being primarily *purpose-* and *people-oriented*. FAIR principles emphasize how data are structured, or how maps are created—focusing on sites of technology. By extension, FAIR principles do not address the social context of data or maps, which can change rapidly. TRUST principles are primarily *purpose-oriented*, extending FAIR by encouraging the creation of infrastructure allowing continual open access to data and maps. In the case of TRUST, sustainability relates directly to long-term map access, accounting for potential changes in funding and governance (Lin et al. 2020). Spatial data infrastructures (SDI)—institutional efforts, typically administered by governments or inter-governmental agencies and designed to make spatial data publicly accessible (de Man 2006; Grus et al. 2010)—often implement elements of both TRUST and FAIR. For example, the European Data Portal (EDP) of the European Union emphasizes interoperability with an emphasis on metadata standards and responding to technical change. The EDP creates a hub for member-country data that is oriented towards long-term maintenance. By situating control of FOSS spatial data beyond both corporations and individual governments, the shared governance model of the EDP is designed to withstand short-term instabilities. Obviously, the EU has tremendous resources that a small-scale digital project lacks, but creating systems of shared governance that foreground how a project might withstand change, and how the possibility of change might inform technical choices, are important lessons for any FOSS deployment.

For both TRUST and FAIR frameworks, open-source exists in specific contrast to closed-source. Closed-source represents everything that FOSS does not, preventing the dissemination of knowledge and technology (Wilkinson et al. 2016), and potentially signifying nefariousness or

FAIR From Wilkinson et al. 2016 & Degbelo 2022.	**Findability** Data and maps must contain appropriate metadata and descriptions so they can be easily found. Maps and data should be hosted at a persistent URL.	**Accessibility** Digital maps should be delivered through common protocols (such as HTTP) that are platform and device independent.	**Interoperability** Development of digital maps should be understandable in different contexts and for different use cases.	**Reusability** Map source code should be made available through the adoption of open licensing such as Creative Commons, to facilitate code sharing.	
TRUST From Lin et al. 2020.	**Transparency** A digital map should include a description of what services are being provided, as well as established digital preservation standards.	**Responsibility** Maps should follow metadata and curation standards used in digital mapping. The intellectual property rights connected with data displayed on digital maps must be respected.	**User Focus** The digital map should be created in conversation with the user-base and provide methods of facilitating user feedback.	**Sustainability** The map's access and usability should be sustained in the long run through funding and governance.	**Technology** Mapping infrastructure should be responsive to changing software and digital security standards.
CARE From Carroll et al. 2020.	**Collective Benefit** The digital map should provide benefit to Indigenous communities and reflect their values. Communities should be included throughout the mapping process.	**Authority to Control** Maps and data should conform to the principles of data governance established by the Indigenous communities they are produced with/by.	**Responsibility** Respectful and reciprocal relationships with the Indigenous communities where data and maps originate must be cultivated.	**Ethics** Indigenous rights, wellbeing, and relationships should be centered throughout the digital mapping process.	

Table 2. A breakdown of the FAIR, TRUST, CARE frameworks as applied to the long-term life of digital maps.

bad faith acting (Mayer-Schönberger 2009). While these concerns are well founded, there are many situations when communities or individuals may not want data or maps to be open or public. Indigenous communities, in particular, have been vulnerable to data exploitation and the extraction of cultural knowledge without their consent, an outcome of the ongoing processes of colonialism (Kukutai and Taylor 2016). For example, findability may threaten communities by publicizing protected data. This concern is compounded by the rise of generative artificial intelligence (AI), which has been critiqued for ignoring the intellectual property rights of the organizations and individuals used to generate training data (Shen 2024). These both have significant implications for digital sustainability, as they transfer control of information away from its creators and intended beneficiaries.

Instead, CARE principles foreground human relationships and adherence to established data governance structures (Carroll et al. 2020). When the frameworks are combined, FAIR and CARE can address sites of both technical and social intervention, both necessary aspects of digital maintenance (Mattern 2018). Indigenous data governance principles can be applied to each FAIR principle, creating guidelines for how data and maps should be created and distributed in ways appropriate to the context of their creation. The meaning of findability shifts from making all maps and data open for everyone towards making them open and accessible for the communities in which they are situated—and only opened to the broader public if it aligns with a community's stated desire. When CARE is extended to TRUST, sustainability broadens to the creation of long-term infrastructure in alignment with community values and with respect to sovereignty.

While Wilkinson et al. (2016) situate FAIR principles as a framework for securing the long-term care of open data, the lack of discussion of relationships is an inherent limitation (Carroll et al. 2020). Applications of CARE principles can also be limited by time and funding constraints. Strathman (2019) analyzed the state of several digital Indigenous heritage projects developed in the 2000s—primarily created using FOSS—and found that most faced difficulty with continued maintenance, losing university collaborators to graduation or other institutions, or lacking funding to maintain technical systems. Denieul-Pinsky (2025) and Lucchesi (2018) describe maintaining digital mapping projects as an exercise of care, reminding that relationships can persist even in times of uncertain funding, shifting employment, and variable deadlines—but they must be actively maintained. For example, Denieul-Pinsky (2025) situates the role of the mapmaker (or mapmakers) as a *fire keeper*, someone (or a group of people) responsible for the work of sustaining Indigenous digital mapping projects. TRUST principles can extend discussion of maps, data, and relationships to broader questions of funding, infrastructure, and personnel. Again, when viewed together, FAIR, TRUST, and CARE can address data, purpose, and people, all of which are required for the maintenance of a FOSS digital mapping project.

Table 3 summarizes some FOSS interventions I identified as important for long-term maintenance and sustainability, and how they could be applied through FAIR, TRUST, and CARE. While the FAIR, TRUST, and CARE frameworks can address limitations to FOSS development, and provide useful recommendations for how to maintain FOSS projects, especially when viewed together, they leave out questions of labor and need.

MINIMAL COMPUTING

CENTERING CONSTRAINT

While FOSS can facilitate greater long-term control of digital artifacts, particularly when combined with *people-*, *purpose-*, and *data-oriented* frameworks, a broader shift in our relationship with technology is necessary to facilitate more holistic long-term planning and maintenance. In other words, FOSS is missing an orientation towards need. **Minimal computing** is an approach to digital work that centers constraints, be they technical, financial, or social, and uses these constraints to meet established project needs (Digital Humanities Climate Coalition 2025). The minimal computing movement began in the digital humanities as a method to disrupt access barriers between scholars in the Global North and the Global South. Within academia, the use of technology, and emphasis on innovation, reflects a broader relationship between technology, capitalism, and colonialism—perpetuating a global hierarchy wherein knowledge production in the Global North is overrepresented (Risam and Gil 2022). As the

Element	Maintenance Intervention	FAIR Principle(s)	TRUST Principle(s)	CARE Principle(s)
Project Management	**Shared Governance** (Stuermer et al. 2017; Carroll et al. 2020)		**Sustainability** Multiple stakeholders and funding sources can distribute responsibility for maintenance.	**Collective Benefit** Demonstrate benefit to the community the web map centers. **Authority to Control** Follow existing community governance practices. **Responsibility** Establish a collaborative access plan for both the interface and database of a web map.
Map and Interface	**Documentation** (Reed 2014; Edmond and Morselli 2020)	**Interoperability** Include clear documentation so new developers/maintainers can easily understand technical elements, or the web map could be repurposed for a different context.	**Transparency** Include web preservation plan in documentation.	**Authority to Control** Documentation should align with and be responsive to community governance practices. **Ethics** A web map's values should be included in the documentation. Some documentation should only be visible to members of community involved in its creation.
Database	**Controlled Access** (Kukutai and Taylor 2016)	**Findability/Accessibility** The web map should be findable and accessible for a defined audience or community, which may or may not include the broader public.	**Responsibility** Mapmakers should ensure that they respect the intellectual property of the creators and subjects of the data that they show.	**Authority to Control** Who has access to maps and data is determined by the community depicted through maps and data. **Responsibility** Web mapping data created with communities should be the result of reciprocal relationships, which should extend beyond the creation of data. **Ethics** Maps and data should follow community standards and requests.
Hosting	**Persistent URL** (Degbelo 2022)	**Findability** The web map should utilize a persistent URL so it can be accessed easily by its target audience or community.	**User Focus** Web map users should be able to locate and share the map easily. **Sustainability** Funding should be obtained to purchase a URL for the desired length of the project.	

Table 3. FOSS maintenance interventions and how the FAIR, TRUST, and CARE frameworks can apply to them.

digital humanities proliferated in the 2010s, computationally intensive applications created by scholars in the North were often unusable by scholars in the South due to disparities in internet access, bandwidth, and cost (Viglianti et al. 2022). Even journal articles, distributed largely through dynamic web applications (and often locked behind paywalls), can represent an inaccessible combination of computational complexity and cost (Chan and Sayers 2022). Minimal computing therefore suggests interoperability across digital contexts, not simply between software environments, creating digital materials designed to work with slow connections and facilitate a truly accessible global digital scholarship (Risam and Gil 2022). As such, minimal computing "gestures towards a decision-making process driven by the local contexts in which scholarship is being created" (Risam and Gil 2022, 1), an explicit call for a reconnection between digital scholars and the technology they use (Gil 2015).

Minimal Computing in Practice

Minimal computing is a process, not a prescriptive set of guidelines. At its core, a minimal computing approach begins with the question: *what do we need?* (Gil 2015). The emphasis on need resists a trend towards using more computationally intensive technologies—referred to here as maximal computing—encompassing a wide variety of technologies, including generative AI, blockchains, and big data (Digital Humanities Climate Coalition 2025). Maximal computing scholarship often prioritizes innovation over need, utilizing technologies for the sole sake of their availability without considering the practicality of implementation and sustainability in a real-world context. Maximal computing projects and rhetoric overemphasize the role of new technology as opposed to investing in improving existing solutions, effectively devaluing maintenance (Costanza-Chock 2020).

Considering need also improves conditions for the actual completion of a project, as it creates a framework for accountability, and helps resist scope creep, the tendency of digital projects to continually add features in the planning stage (Reed 2014). While need should guide minimal computing decisions, a series of secondary factors provide useful context for implementation: existing technology, priorities, and potential sacrifices (Risam and Gil 2022). At the beginning of a project, inventorying existing technologies and project team knowledge can help appropriately scope a project's constraints. Additionally, not all priorities can be treated equally, even within minimal computing. For example, while a FOSS-created digital map might provide flexibility, if no one on a project team has sufficient programming experience to easily implement FOSS, it would make sense to prioritize an out-of-the-box solution—perhaps even using software-as-a-service (Dombrowski 2022).

Minimal computing also prompts increased attention to the physical infrastructure and associated environmental costs of adopting technology (Chan and Sayers 2022). Maximal computing methods, particularly AI, have been critiqued for their extreme energy usage, negatively contributing to carbon emissions and climate change (Digital Humanities Climate Coalition 2025). Digital mapping, I argue, is often situated within maximal computing, especially navigation applications. Wu et al. (2024) estimate the total carbon footprint of Google Maps usage in 2021 to be equivalent to the total electricity usage of over 250,000 people. In response, Wu et al. (2024) recommend considering a digital map's carbon footprint in its design, selecting colors, generalization, and typefaces that minimize battery-usage. While this approach is laudable, it is also limited to the site of map design. The true environmental cost of digital mapping is much higher, considering the overall cost of energy, materials and infrastructure that enable the internet in the first place (Touya et al. 2025). Map-based software-as-a-service platforms (like ArcGIS Online) conceal the specifics of technology's social and material relations (Chan and Sayers 2022). Not only is this unsustainable from an ecological perspective, but it leaves projects more vulnerable to long-term decay. As mentioned earlier, technical maintenance—indeed all elements of digital sustainability—is offset.

Instead, Chan and Sayers (2022) recommend imbuing minimal computing with a focus on labor. Labor is a pathway to both reducing the opacity of technical processes and encouraging a more thorough engagement with the material conditions of knowledge production. Technical labor is often hidden, despite digital artifacts being the products of many hands. This is particularly true for mapping and data visualization, where lack of sufficient information about authorship can reinforce an understanding that knowledge simply exists—as opposed to being a product of specific sociopolitical and cultural forces (D'Ignazio and Klein 2020; Kelly and Bosse 2022). Digital projects bring together people with a variety of backgrounds and expertise. However, these differences in expertise can

also put digital projects at risk when personnel shift, especially when certain technical knowledge exists within a single member of a project team. For programmers, how coding is practiced can actively contribute to the alienation of non-programmers. One potential solution to this tension is pseudocode, or the plain-language "informal description of how a computer program operates" (Chan and Sayers 2022, 5). Pseudocode allows non-programmers to understand how a program works, and reinforces a practice of description that is agnostic to changes in technology. However, minimal computing itself, and many of the proposed solutions offered by its advocates, imply a high degree of technical competence, often the ability to code.

Additionally, most minimal computing solutions, which are lightweight and designed for operation in low-bandwidth environments, require some amount of labor to both create and maintain. Dombrowski (2022) advocates for increasing the capacity of minimal computing technology, including guides to assist decision-making, writing thorough and highly detailed documentation, and building GUIs where possible to allow for non-expert use. **Table 4** summarizes minimal computing interventions in relation to the maintenance and sustainability of digital maps. I retrospectively apply these recommendations as a series of generative questions to the *Atlas of the Pacific Northwest* project, described earlier.

Element(s)	Recommendation	*Atlas of the Pacific Northwest* Application
Project Management, Interface, Database, Hosting	**Needs Assessment** Determining the needs of a community or target audience, including technical access and local context of use. Sometimes, a digital map may not be the best solution, and alternatives should be considered. (Gil 2015; Digital Humanities Climate Coalition 2025)	**Needs Assessment** Who will be specifically using the *Atlas* and what are their technical abilities? Where and when might the *Atlas* be used, and what is the level of connectivity in those places/times?
Project Management, Interface, Database, Hosting	**Expertise/Resource Evaluation** Determining what technical expertise exists on a project team, as well as existing technical infrastructure, and how it could be applied to the creation of a digital map. (Dombrowski 2022; Digital Humanities Climate Coalition 2025)	**Expertise/Resource Evaluation** Who will be on the *Atlas* project team for the long run? What are their technical skills and abilities? Who might be updating the map in the future? What server infrastructure exists at the library and how long is it designed to last?
Interface, Database	**Pseudocode** When coding, including detailed pseudocode and commenting to communicate the purpose of code to a non-expert audience. (Chan and Sayers 2022)	**Pseudocode** How could the pseudocode of the maps themselves be expanded to communicate to the wider development team?
Interface, Database, Hosting	**Bandwidth Testing** Consistently test storage and network file transfer sizes, attempting to minimize the amount of data being sent/received to a user, or to match the requirements of a target audience. (Risam and Gil 2022; Wu et al. 2024; Touya et al. 2025)	**Bandwidth Testing** What is the overall file size transferred over the network to users? How can file size be minimized for the least-connected user? Should the *Atlas* be downloadable and used in places without internet?

Table 4. Minimal computing recommendations for digital maps.

PART 4 — CONCLUSION: WAYS FORWARD

The long-term life of digital maps is a lens in which we can view digital mapping within larger technical, social, and environmental processes. The deprecation of digital mapping tools like Flash and Esri Story Maps can cause mapping projects to be lost—perhaps forever. Deprecation may always loom, but if we take a proactive approach to long-term life, we can ensure deprecation is not unexpected. Additionally, it is not possible to preserve every digital map indefinitely. Indeed, there are environmental costs to digital preservation, and to maintain digital objects involves a web of collaborators and materials. While I raise questions, and explore potential solutions, more work is certainly needed. On one hand, I seek increased awareness of the critical issue of digital sustainability and maintenance. On the other, I encourage further work that analyzes mapping processes over time, accounting for the unique and ephemeral lifespans of digital maps. As such, there are many remaining questions related to the long-term life of digital maps, several of which are as follows:

How can the unique qualities of digital maps, particularly in relation to their long-term life, be reflected in mapping processes?

There has been an increased emphasis on mapping as a process as opposed to maps as a product. Processual cartography emphasizes how map meaning is continuously re-inscribed as maps are designed and used. In other words, maps are never finished—every person who encounters a map, as creator or user, brings it into their own personal milieu, defined by their own experiences and knowledge, and heavily dependent on the circumstances of the encounter (Kitchin and Dodge 2007). Process enables analysis across sites of production and use, as well as the study of mapmaking processes themselves, and the conditions under which maps are produced. Process research could be fruitful for exploring how digital maps might be—or have been—maintained and sustained, reflecting existing practices and building new models for digital mapping work. In particular, I wonder how the application of Mattern's (2018) understanding of maintenance as care could be applied to mapmaking. Recent work by Denieul-Pinsky (2025) serves as an excellent example.

What practices can be adopted in digital mapping to center both technical and social elements, and how do these practices manifest in the long-term?

Digital mapping is a collaborative socio-technical activity. Maintenance attends to both technology and relationships, and for digital projects to persist, planning needs to account for both (Mattern 2018). FOSS frameworks like TRUST (Lin et al. 2020) and CARE (Carroll et al. 2020), along with minimal computing (Gil 2015), seek to unite people with technology, emphasizing holistic, community-based decision making. How has digital mapping adopted these frameworks, and how have these adoptions affected their relationships to long-term planning, maintenance, and sustainability? More broadly, how can digital mapping—and its associated technology—be reframed through collaboration? Choice of technology has social implications. Examples of existing projects, and accounts of how new projects adopt unique, collaborative approaches, could provide a guide for future mapping work.

How can long-term digital mapping practices better address social justice and the climate crisis?

While Wu et al. (2024) provide a useful framework for addressing energy use through map design, digital maps are integrated into a much larger socio-technical assemblage that contributes directly to the climate crisis. Beyond simply materials and energy, digital maps enable resource extraction and war, major contributors to environmental destruction and emissions. Emphasizing maintenance can prompt an increased awareness of both physical infrastructure and the labor involved in digital mapping work, as well as its real-world consequences, ideally recentering local contexts. What are the environmental costs of digital map preservation, and how can these be balanced against the importance of a map's creation? What work is worth saving, and for how long? More broadly, how can digital mapping practices be reframed to account for their relationship to ecological destruction—and, potentially, restoration and community-based research?

How could minimal computing be applied to web mapping?

Through its processual recommendations, minimal computing has much to contribute to the design of digital maps. The process of determining need aligns closely with community-driven design processes, which center relationships and an assessment of overall community capacity (Costanza-Chock 2020). A minimal computing framework could guide choices of technology that digital mapping teams are capable of actually maintaining, while also

encouraging increased awareness of larger infrastructures and their social and ecological effects.

FINANCIAL DISCLOSURE

I, as the author, have no financial interests in the subject(s) discussed.

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