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Infrastructures of flow: streaming media as elemental media

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ABSTRACT
Streaming media are often placed in a lineage of electrical technologies that promise connectivity at a distance. We argue, however, that the material-discursive entanglement of streaming is a technological descendent of pre-electrical attempts to control essential resources through flow. Inspired by John Durham Peters's emphasis on elemental media, we examine streaming media practices that date to antiquity in order to assess infrastructures of flow today. By considering material technologies that capture and channel critical resources to be the "original" streaming media, we demonstrate how the idealized metaphor of streaming conceals the imbrication of human--technology--nature that underpins the capture and channel of flows. Consequently, we position streaming media as infrastructural, indebted to environments, and as part of a lineage that includes not only the telegraph, telephone, television, and film, but also rivers, canals, aqueducts, and pipelines.

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The term "streaming media" has come to refer to a wide array of platforms that enable content delivery, distribution, and interaction. Whether it's televisual and cinematic programming on Netflix, on-demand music from Spotify, or homemade audio-visual content on YouTube, numerous platforms and apps now make it clear: the age of "streaming" is fully upon us. Yet, today's digital streaming media also connect to an older hydrospheric lineage of electrical technologies of flow that includes not only the telegraph, telephone, radio, and television (Burroughs, 2019; Thibault, 2015; Uricchio, 2008), but also such pre-electrical technologies as canals, aqueducts, and pipelines. In this article, by conceptualizing streaming as an *infrastructure of flow*, we disclose a longer history of infrastructures as ensembles of natural elements and human craft that channel flows of essential resources. The "original" streaming media aren't just distributors of movies and music, but those technologies that capture and channel critical resources such as water and oil.

The lighthouse guiding this project is Peters's (2015) philosophy of elemental media. For Peters, media are "vessels and environments, containers of possibility that anchor our existence and make what we are doing possible." To recognize that media are "both natural and cultural" means reciprocally that "media are environments" and that

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"environments are also media" (Peters, 2015, pp. 2–3). Going further than Kittler's (1999) veritable catchphrase that "media determine our situation" (p. xxxix), and inspired by Innis's (1951) attention to infrastructures as mediums of power, Peters makes the case that media are elemental modes-of-being that, through their infrastructural arrangements, order civilization itself. It is with such an orientation that we approach the new media phenomenon of "streaming" in order to illustrate some historical entanglements of media, nature, and culture. To see rivers, canals, aqueducts, and pipelines as epistemologically kindred with the version of streaming associated with digital media environments, we argue, is to underscore how fundamentally media shape the many ways of being in the world. We do not mean to suggest that these hydro-historical antecedents have led in a linear or teleological way toward digital streaming as we know it today. (It would be hard to show how the technology enabling aqueducts to bring water through Rome was a causally necessary precursor to the technology enabling servers wirelessly to transmit data into a living room.) Yet, by taking seriously the entanglement of media and/as environments, we might begin to reveal the elemental and infrastructural "nature" of media as such.

In both vernacular and academic contexts, "media" has long been a term denoting those devices or systems that deliver signals and facilitate communication of symbolic meaning, whether through electrical technologies of mass media or more contemporary digital devices and platforms. Peters's expansion of media theory includes critical attention to environments and infrastructures challenges such conventional usage. As Liam Cole Young has observed of Peters's work, however, to expand "media" to include environments and infrastructures—indeed all "things in the middle"—risks attenuating the term until, if everything is media, then nothing is media (2020, p. 140). Favoring the more expansive notion of "mediation," Young's provocative work to understand salt as a medium circumvents such *si omnia nulla* problems by emphasizing Kittler's attention to processing, storage, and transfer as the constitutive elements of all media. Similarly, our attention to streaming as infrastructure of flow seeks to show the more elemental lineage of streaming media while acknowledging the cultural politics of their spread and function. We contend that accounts of infrastructures of flow are incomplete without attention to the pre-electrical media that channeled, stored, and diverted flows of natural resources. That is, a more expansive account of streaming infrastructures of flow must look beyond electrical media antecedents of the telegraph, telephone, radio, and television to some of the earliest attempts at shaping and making habitable the world by processing, storing, and transferring flows of resources like water and oil. Taking seriously the elemental media lineage of infrastructures of flow, then, demonstrates how contemporary streaming media can be viewed as ensembles of natural elements and human craft, often functioning toward the capture of flows for monetization and control.

Rivers, streams, and flow

If the metaphor of streaming media invokes aqueous energy, power, movement, and transport, it may do so because streams are forces of nature—an integral agent in cycles of water distribution. Aqueous streams and rivers are, in principle, naturally occurring infrastructures of flow. (The word "stream" comes from Indogermanic roots that mean "to flow," as it does in Sanskrit, Greek, and other cognates.) Streams influence

human activities by providing drinking water, carrying waste, irrigating crops, powering cities, and offering recreational and commercial opportunities. Streams and rivers experience interruptions and vacillations in speed though seasonal cycles impacted by "terrain, climate, precipitation, glacier melt, water tables, and drainage bases" (Rafferty, 2011, pp. xi-xii). Attempts at human control of aqueous flows often result in interventions that interrupt, regulate, hasten, and reroute the core process of streaming. In a time of anthropogenic global warming, abundant examples show that human actions have massive consequences for flowing water—and devastating repercussions for the life that such water supports (American Rivers, 2019; Thompson, 2017). The invisibility of such human impacts on streams—direct or indirect—highlights the truism that infrastructure is often only noticed when expected functions are interrupted.

Fluid metaphors have been used to describe bodily, electrical, and subsequent forms of mass media for some time. In the late 1700s, the Mesmerist movement believed in a superfine fluid that both penetrated and surrounded all bodies, and that sickness resulted from obstacles impeding its animal magnetic flow through the body (Darnton, 1968). A century or so of fascination notwithstanding, the immaterial flows of Mesmerism are believed by few today, though the topoi of flow remain commonplace in understanding blood's movement through bodies. From a technological perspective, too, flow remains a salient metaphor even as older technologies have become obsolete. The analog television, for example, operated as a flow not just by "transmitting signals of various lengths through the wavelike electromagnetic spectrum" (Thibault, 2015, p. 115), but by delivering an experienced flow of content (Williams, 1974). Raymond Williams's influential work on televisual flows shows that while pre-televisual habits were shaped by the experience of discrete, isolated, and temporary events, the flowing experience of watching television as an unbroken broadcast (on account of its continuous programming and commercials) introduced new models of advertisement and monetization that became the real flow of events for the viewer (Williams, 1974).

Contemporary streaming media are often considered the next rung on the evolutionary ladder of the televisual; yet, such accounts are reductive, and recent scholarship has complicated the history of streams and flow to account for a cultural lineage that includes the telephonoscope, radio, and video conferencing (Burroughs, 2019). How to delimit and characterize exactly what constitutes contemporary streaming media is a massive challenge that involves not only the historical antecedents of streaming, but also the myriad contemporary social and mobile forms that streaming processes take. Oswald and Packer (2012) have suggested less attention to the representational content that keeps an audience's attention, and more to how digital screens guide populations, information, capital, and labor through space and time. Similarly, Lüders and Sundet (2021) contend that scholars today "should direct our attention toward how interfaces, algorithms, and menus work to create streaming flows, replacing the sequenced scheduling flow of linear television" (p. 4). After all, while the televisual flows that Williams described in the 1970s may be showing their age, flow remains conceptualized within the mass media landscape as related to unbroken experience, rhythm, and even jouissance—continuous "binge watching" being perhaps its quintessential fulfillment in streaming video platforms. What's clear is that flowing technologies like television, and their streamed variations today, are not only about the connectivity of seeing and

knowing through distances and time, but also about the mobility, monitoring, organization, and control of bodies, goods, money, information, and culture.

Whereas early electrical media like the telegraph and telephone, as well as mass media of radio, film, and television are technologies of transmission only, however, what we now think of as streaming media provide platforms for content delivery that also allow collection, accumulation, and processing of data as a material resource. In that sense, for scholars such as Thibault (2015) and Ernst (2011), digital "streaming" is a metaphorical disguise: streaming invokes a lineage of "true flows" by electrical and mass media while simultaneously obfuscating the material realities of streaming media and digital television that function by sending discrete packets of bits in non-continuous fashion. Similarly,Alexander (2017) explains that "The metaphor of streaming … might invoke a mental image of an eternal, sky-blue river peacefully moving through hills, mountains, and meadows," but in turn promotes the myth of seamless computational flow (p. 5). At the heart of Thibault and Alexander's critique, then, is the valid contention that idealized aqueous descriptions—at first appearing in public discourse and later adopted by theorists—function as discursive positionings of digital delivery that obfuscate both the materiality and increasing regimes of centralized control of digital infrastructures. Consequently, while it is possible to conceive of streaming media as an *infrastructure of digital flow*, there is a material-discursive friction that challenges not only the metaphorical conceptualizations of flow, but also the infrastructural antecedent technologies of unbroken electrical and radio delivery.

When placed in a longer history of infrastructural media, that is, the flow of resources essential to the maintenance of human societies becomes related to the comparatively short history of electrical and mass media, *and* to the material infrastructures of antiquity. Control of flow requires attention to infrastructures as chokepoints, leverages, brokers, and intermediaries—all aspects of Innis's (1951) massively influential work on infrastructure that, in part, inspires Peters's own account. While many Marxist-oriented contemporaries of Innis focused on power via the ideology of cultural content, Innis instead turned a scholarly gaze on power achieved via societal organization. For Innis, infrastructure allows a concentration of force over both people and nature; as such, who controls infrastructures matters. Not only does Innis provide insight as to the spatial and temporal bias of infrastructural arrangements, but his work also highlights infrastructures as media vessels of storage, transmission, or processing. Digital media —and its goals of data collection, storage, and processing, along with the management of subjects and its organization of time, space, and power—are more closely aligned with ancient media such as censuses, indexes, calendars, and catalogs than mass media such as radio, film, and television (Peters, 2015). Infrastructural media such as calendars and clocks give structure to the "flow" of time, and Peters himself examines how these media orient and store the experience of time as "sky media," often operating in conjunction with the Earth's cycles (Peters briefly examines diverse ancient water-powered clocks used in Egypt, Babylon, Greece, Rome, and China). Our point is that the range of experiential, temporal, metallurgical, and other treatments of flow only serve to complicate a concept that is often used in a metaphorical sense to describe electrical and mass media.

While "streaming" may not invoke the image of unbroken flows of digital content akin to pristine rivers for all people (it almost certainly does not for those living in the majority of the world, where internet connection remains messy and unreliable), the concept of

"streaming" predates electrical technologies and has now been firmly grafted on to intellectual conceptualizations of digital transmission. Digital streaming media operate in a materially different fashion than the electrical conduit of the telegraph and early telephone, and the wave-spectrum of radio and broadcast television, in that streaming data are broken into bits that can take different paths to the intended recipient, where the streamed content is reassembled. Similarly, of course, natural streams are also often broken, messy, and given to follow different paths. If one is willing to conceptualize streams infrastructurally, as complex compositions of the human, natural, and technological components that together co-create and remake worlds, then "streaming" can indeed serve as an appropriate descriptor—metaphorical or not—for digital forms of content delivery.

The value of an elemental media approach to studying infrastructures of flow is accordingly its ability to examine media as the material-discursive synthesis of natural and human technique alike. If media are truly vessels that anchor our existence, manage nature and culture, and order and maintain the world, then aqueous infrastructures are some of the most critical to human existence. In this regard, human interaction with flow is a story of infrastructural control. Consequently, concepts relating to the technological capture and replication of flows are equally applicable to the increasingly essential infrastructures of digital streaming media and to the delivery of water and other resources via canals, aqueducts, and pipelines.

The streaming infrastructures of canals, aqueducts, and pipelines

Canals

If streaming media are fundamentally about controlling and channeling flows, then perhaps the earliest example is the invention of the canal. Canals often function as systems of irrigation, a practice utilized since the beginning of sedentary civilization, dating to the early cultures of Mesopotamia (ca. 6,000 BCE) and Sumer (ca. 3,000 BCE) (Swamee & Chahar, 2015). Canals are either human-created channels that connect existing waterways, or naturally created channels dedicated to moving water for irrigation. Critical to many canals is the invention of the pound-lock, in which a two-gate system allows water-level to rise and fall, facilitating boat travel. While the first documented pound-lock in Europe came in 1373, the canal pound-lock was invented in China in 984 CE (Temple, 2007). Not only did the pound-lock make summit-level canals (connecting two rivers that rise and fall) possible, but pound-locks also saved precious water resources in particularly dry Chinese summers (Temple, 2007). Canals were similarly crucial to the functioning of ancient Egypt, allowing for irrigation and facilitating the shipment of quarried limestone used to build Egypt's great stone structures, including the massive architectural achievements of temples and pyramids (Romer, 2013). More contemporary forms of canals from the latter half of the nineteenth century onward added the functions of power generation and carrying ships by providing shortcuts or more desirable shipping routes (Swamee & Chahar, 2015). Whatever the purposes of a canal, however, the desire for uniform flow has always been crucial: canals have existed to achieve the benefits of natural water movement without the unreliability of accompanying fluctuations (Swamee &

Chahar, 2015). This is accomplished using dams or locks to control the speed of water flow.

The canal has a key place in the history of transport, traffic, and mobility. Maw (2013) argues that its role in the Industrial Revolution of England is often understated, as canals "combined a particular mix of engineering knowledge and capital concentration with a belief that natural resources could be improved for commercial advantage" (pp. 257–258). In England, canals assisted in transporting the industrial outputs of the 1790s onward, which included coal, corn, cotton, timber, and manufactured goods and textiles (Maw, 2013). Of course, the canals of England are part of a complex and evolving transportation history. The canals of the Industrial Revolution were the result of over one hundred years of river improvement and the desire to connect and control existing navigable rivers (Maw, 2013). Similarly, early French canals, such as military engineer Sébastien Le Prestre de Vauban's 1,699 river navigation project, offered the possibility of "rendering navigable those rivers that were not yet so, by means of canals 'to communicate the navigation of rivers one with another'" (Mattelart, 1996, p. 6). River navigation was vital not just on account of its economic benefits over land transportation; the added advantage of improved management of taxes added a political dimension to the efforts as well (Mattelart, 1996). Vauban's canal system created a network of interior navigation that was later mirrored by railways, and this concerted infrastructural configuration placed the capital city of Paris at the heart of transportation, communication, and commerce.

For Innis (1951), infrastructural media have an occupational history that requires attention to ratios of time, space, power, bottlenecks, and monopoly control. Such a power often comes with a high cost. In the United States, canals were largely built by the laboring poor in the north and slaves in the south (Dearinger, 2015). To entice workers for the northern canals, labor was articulated as honest work with a potential for upward mobility, but the reality involved dangerous labor, disease, and pollution (Dearinger, 2015). The harsh realities of canal building show how infrastructures organize modes of being, but not all individuals experience infrastructure the same way. That is, the brutal working conditions for canal builders were obscured by canals as a symbol of national growth, progress, and binding the union of states (Dearinger, 2015).

While canals were a heavily utilized form of transportation for some time, eventual advances in highways and railways led to disuse (Maw, 2013). The abandonment of canals for transportation in England is related to time: when time and distance could be more successfully compressed via land transportation, those new methods became the dominant mode of conveyance. But the argument for the superiority of railroad transportation to canals is a contentious one. Shell (2015) writes that while uneven geography and the subsequent expense that accompanied canal construction did contribute to the move from canals to railroads, the abandonment and neglect of canal creation in the United States, Canada, and England is also related to biases against canal workers, who were subject to racist and moralistic arguments as well as the perception of involvement in anti-imperial political movements, smuggling, crime, and generally dangerous revolutionary behavior toward the state. Canals also became symbolic of an older way of life—the image of the canal worker as a relic of the past contrasted the more dynamic image of the youthful railroad employee (Shell, 2015, p. 18). The perceived

decline in importance of the canal, then, demonstrates the complex natural, social, political, cultural, and economic dimensions of infrastructures.

Canals remain deceptively essential to contemporary global commerce and transportation through projects like the Suez and Panama Canals (Van Wagtendonk, 2014). Infrastructures are often invisible until the flow they enable breaks down—a fact that was laid bare in 2021 when the cargo ship "Ever Given" ran aground and blocked passage of the vital waterway for nearly a week. In addition to inspiring countless internet memes, the blockage held up an estimated $400 million per hour in trade (La Rocco, 2021). Furthermore, the Panama Canal's goal of controlling water flows has implications for the surrounding land and communities, with impacts for watershed management of nearby forested landscapes and agricultural zones (Carse, 2012). Though not on the same scale as the Panama Canal, recent canal restoration projects in British towns and cities (as elsewhere) have begun to reshape canal side areas by attracting new forms of recreational activities, as well as new inhabitants that include fish, otters, and waterfowl (Vidal, 2019). Regardless of their magnitude, canals reroute and control flow.

In the context of digital streaming, so does the packet-switching process it relies on. The example of Netflix is exemplary in this regard. As the company explains, when users decide to play streaming content, streaming infrastructure uses the most efficient path for packets of information, whereby the "shorter the route, the higher the video quality" (Netflix Help Center, n.d.). This narrative, however, is both idealized and potentially misleading, in that streaming traffic does not always follow the quickest route, but instead the least expensive. Starosielski puts it this way (2015a): "In some locations it is less expensive to buy a direct circuit to somewhere with 'cheap' Internet instead of buying Internet access out of one's own country, a scenario called 'pipe and port' in the industry" (p. 63). In the geographic terms of canal building, connecting and controlling waterways often creates both a shorter transportation distance and lowers conveyance costs. From a digital perspective, the potentially circuitous route for internet content can be an issue for a global platform like Netflix, with 150 million subscribers in over 190 countries accounting for an estimated 15% of total web traffic (Marvin, 2018).

Resultant attempts to alleviate bandwidth strain—such as Netflix's Open Connect Appliances[1]—are not merely a digital canal system. Yet, there are key similarities between the two infrastructures. Canals function to control flows, ease transportation, and reorient local and global pathways. Similarly, gateways, otherwise known as routers, are a critical aspect of internet infrastructure that route packets from one network to another and help organize the web (Dourish, 2015). When viewed from the perspective of these essential characteristics, human attempts both to mimic and control infrastructures of flow can be found just as readily in canals as processes of packet-switching.

Aqueducts

Aqueducts serve a similar function to canals, but are primarily concerned with the delivery of water itself. Like canals, aqueducts have a long history of human use, with evidence of complex irrigation networks in Armenia and Assyria from roughly 700 BCE onward (Hodge, 1992). The early history of aqueducts notwithstanding, these infrastructures are often synonymous with Rome due to the Empire's emphasis on innovation and grandeur.

Between 378 and 352 BCE, Rome became a walled city with a growing population (Aicher, 1995). Although the city had a sewer system to aid sanitation, these sewer flows operated at the behest of weather conditions. Refuse and filth could accumulate quickly in periods of drought (Aicher, 1995). The addition of aqueducts helped to alleviate this issue and added flowing water for household use. Nevertheless, Hodge (1992) notes that Rome already had cisterns and wells for individual water use, and that many cities, including London, never utilized aqueducts. Roman aqueducts, then, were a luxury and not a necessity—they were primarily built to supply bathhouses, along with water for gardens, aquatic shows, flour mills, and decorative fountains (Hodge, 1992). The lavishly appointed bathhouses served cultural and hygienic purposes, and were often open to the public at little to no charge (Aicher, 1995). In this manner, aqueducts, like televisual flows millennia later, helped to structure habits and cultural norms. Of course, much like the history of canals, the story of aqueducts is one of unseen labor and often nefarious practice. Roman aqueducts were built on the backs of slave labor, often by men hoping to earn their freedom (Winslow, 1963,). Moreover, the development of aqueducts occasionally entailed cheating, bribery, and fraud (Winslow, 1963, pp. 18–20).

The most prominent examples of aqueducts are ornate and intentionally above-ground aqueduct segments in Rome, Petra, India, and Sri Lanka (Hodge, 1992). Romans largely held so-called useless architectural displays such as the pyramids in contempt, but felt that the ornate and decorative nature of many above-ground aqueducts demonstrates a commitment to more practical displays of power, as well as the importance placed on streaming water (Winslow, 1963). However, most aqueducts were closed, underground pipelines of various materials (Hodge, 1992). Infrastructures are often hidden from sight not just because they are embedded in the quotidian, but because they are reliant on hidden labor and social systems of organization and knowledge (Bowker & Star, 2009). Once upon a time, electrical wires of the early telegraph were an extremely visible aspect of urban industrial modernity, and this intentional perceptibility was part of an ideology of "the electrical sublime"—the notion that electrical communication technologies could support humanity's enlightenment and progress, binding together national identities (Carey, 1989). By contrast, contemporary telephone wires are often buried, providing protection from the elements and the elimination of wires now considered an eyesore. For aqueducts, hiddenness is driven by the nature of underground springs, along with a desire to obscure the material messiness of everyday resource delivery. Even the beautiful aqueducts of Rome similarly obscured the maze of stone, lead, vitrified glass, wood, and cement pipes that gradually accumulated rust, algae, grime, and calcification over time.

To function, streaming media rely critically on cloud infrastructure; and, like most aqueducts, cloud infrastructure is often hidden. As Holt and Vonderau (2015) have highlighted, Google, Apple, Facebook, and Microsoft have all attempted to showcase "transparency" regarding their own infrastructures via "slick, artful images of buildings, wires, pipes, servers, and dedicated workers who populate the centers" (p. 71). These data centers are often rendered tidy, veiled, and natural on the exterior, but the reality is messy, dirty, and involves massive unseen energy consumption (Holt & Vonderau, 2015). In a related sense, the topological distribution of cloud data centers is heavily indebted to the environment. The immense energy consumption of data centers requires a substantial investment in cooling, which means that these infrastructural hubs are often

located in cooler climates (Holt & Vonderau, 2015). Even still, data centers require immense amounts of water for the purposes of cooling the masses of servers housed inside, and companies like Google have gone to great lengths, including legal battles, to avoid disclosing the company's water consumption (Sattiraju, 2020). The ancient aqueducts that structured cities were far less environmentally destructive than the cloud storage facilities, but were similarly beholden to nature via the requirement of a natural water source and incline. In this way, both aqueducts and cloud data centers are intertwined with the environment. While cloud architecture is not merely a digital aqueduct, attention to these historical infrastructures of flow can highlight meaningful continuities in the distribution, storage, and construction of spaces through broken and unbroken flows.

Unlike wells and cisterns, which store water, aqueducts do not draw water from a standing reservoir; instead, they draw from streams that feed water into an infrastructure that seeks to continue channeling their natural flow, albeit in more directed ways (Hodge, 1992). Aqueduct pipes utilize gravity and slope to create this flow, which requires complex engineering and calculation. Aqueduct pipes in Rome mostly fed into a castellum, a distribution tank that diverted water into other parts of the city (Hodge, 1992). Similarly, the pre-Incan technologies called *amunas*, built between 600 and 1,000 CE, function not only to channel water flows to allow access to potable water, but also to divert flows into water holes that can help last the long dry season (Nagabhatla et al., 2018). Now centuries later, as Lima, Peru experiences a water crisis driven by the rising temperatures of climate change, there are efforts to refurbish these ancient irrigation systems to solve contemporary problems of water flow (Tomaselli, 2020). While these examples make clear that aqueducts can take many forms, there is an essential component of storage underlying these infrastructures of flow.

Cloud infrastructure is similar to these aqueous infrastructures in that it's fundamentally about the storage and channeling of resources. For example, not only is cloud infrastructure hidden from the everyday experience of those using cloud-based technologies; it's also increasingly critical to web activities generally and to streaming media specifically. Most simply, cloud infrastructure facilitates the process of outsourcing data storage to a web-connected server. The use of cloud storage is also critical to streaming media, as major platforms including Netflix, Hulu, and Amazon Prime Instant Video rely on cloud infrastructure provided by Amazon Web Services in order to more effectively (and cheaply) store and transmit streaming content to users. Regardless of the provider, the cloud is critical to streaming, in that cloud infrastructure handles essentially everything before users hit play, "including all of the logic of the application interface, the content discovery and selection experience, recommendation algorithms, transcoding, etc." (Florance, 2016).

While the image of "the cloud" invokes a rhetoric of ephemerality that frames information capture as light and free, it obscures issues of differential access, surveillance and data collection, enforced limitations, resource control, and loss of ownership (Andrejevic, 2007). Certainly, streaming media vis-à-vis cloud technology functions as an obfuscation of digital materiality and the imposition of protocological rules to channel packets in the correct, just-in-time order. From the perspective of aqueous infrastructure in everyday life, at least in developed countries, "on-demand" flows of water are enabled by indoor plumbing, another mundane and quotidian infrastructure foregrounded by

aqueducts. However, a critical difference between plumbing and aqueducts is that aqueducts supplied water that was predominately untapped, as its unstopped flows essentially acted as streams diverted into personal or public residences (Hodge, 1992). Even so, cisterns and tanks capable of temporarily storing water have always been logistically critical to carrying off the conceit of an aqueduct's untapped flow. Much like the quotidian conceptualizations of the cloud, in short, understanding aqueducts as channeling unbroken flows obfuscates the essential aspect of the material storage of important resources.

Pipelines

The evolution of canals, aqueducts, and pipelines demonstrates that water is not the only essential resource in the industrialized world. While aqueducts carried the essential resource of water, contemporary pipelines such as the Trans-Alaska Pipeline, Black Mesa Coal Pipeline, Baku-Tbilisi Ceyhan Pipeline, and West–East Gas Pipeline Project are all immense infrastructures that transport oil and natural gas across great distances (PBS, n.d.). Such pipelines, of course, are also controversial, not just because of their association with petrocapital, but because their economic benefits are constantly weighed against potential environmental impacts and dangers of spills, breaks, and bursts (Phillips, 2017). Pipelines have uneven effects. The controversial Dakota Access Pipeline's proposed route crosses over sacred lands of the Standing Rock Sioux Tribe. Yet again, streaming infrastructures are not merely neutral media of transport. Instead, streaming, like other infrastructures, has impacts on politics, identity, the economy, the environment, etc. A history of streaming is, and continues to be, part of a history of being. As such, pipelines are made conspicuous due to the fraught political, economic, and ecological dimensions of the infrastructure.

As digital streaming media go, their reliance on packet-switching, cloud infrastructures, and transmission protocols is made possible through fiber optic cables that aren't so unlike pipelines. Our increasingly wireless and mobile connections to the internet obscure the need for physical infastructure to support it, often via undersea and underground fiber optic cables (Starosielski, 2015a). These fiber optic cables are, in essence, a pipeline for the internet and, by extension, streaming media. Not only are cables optically similar to pipelines, but the two infrastructures share historical overlap as well. For example, a secret Allied forces World War II project called Operation PLUTO used a modified ship and technologies made for laying undersea communications cable in order to create 17 wartime oil pipelines (Wells, 2020). Moreover, many fiber optic cables mirror the historical routes of telegraph cable infrastructures of the early twentieth century. Starosielski (2015b) notes that contemporary fiber optic cable routes are critically shaped by historical territorial politics, political ties, and colonial geographies. In this regard, attention to cables as media infrastructures considers how "flows of audiovisual content and technical, social, and natural systems are always constituted in relation to each other" (Starosielski, 2015a, p. 55). Attention to the geographic, environmental, and historical dimensions of fiber optic cables reveals the complex lineage of infrastructural flows that facilitate streaming media.

To smooth the operation of flow, both pipelines and undersea cables utilize compression. In his examination of the importance of compression to communication infrastructures, Sterne (2015) defines compression as "the mode of representation adequate to

its infrastructures. But compression also renders infrastructures adequate to representation" (p. 35). The value of compression to infrastructures, then, is in allowing infrastructures to hold materials they previously could not. Compressor stations are crucial to transporting natural gas through pipelines, as scrubbers and filters act to extract liquids and solids from a gas stream (Messersmith, 2015). Typically located every 40–70 miles of a pipeline, compressor stations allow natural gas to maintain pressure and avoid pipeline buildup. Moreover, the surrounding environment matters to pipeline compression, as fluctuations in temperature or elevation can affect the state of natural gas.

Bandwidth issues are important to internet undersea cables as well, and web content also undergoes compression. When it comes to streaming video content, it was Move Network's 2007 introduction of HTTP-based adaptive streaming that facilitated the widespread use of digital streaming in minimizing buffering and connectivity issues (Zambelli, 2013). Other improvements included techniques like adaptive bitrate streaming and new file formats that reduced video size, allowing for significant improvements to streaming video delivery (Sandvig, 2015). We want to emphasize that while the discursive terminology of "compression" applies to oil pipelines and digital media alike, there are differences between what exactly compression entails. For natural gas, compressor stations filter excess matter and use temperature to regulate pressure, and, by extension, movement. When it comes to digital data, compression encodes information with fewer bits that can be either lossless, where no image information is affected, or lossy, where some image composition is lost (Li et al., 2014). Yet again, we do not wish to make the claim that compression functions in *literally* the same fashion for pipelines and digital media. What *is* important is that pipelines demonstrate many of the same fundamental aspects of compression as digital infrastructures of flow.

One critical difference between streaming and these aqueous infrastructures, however, is the aspect of data collection. Streaming platforms record significant aspects of user data, which includes the what, when, where, how long, with what device, etc. of user streaming activity (Leonard, 2013). It is in data collection that the so-called old and new functions of media meet. Data collection, storage, and processing occur simultaneously with the transmission of audio-visual content, but forms of data collection and monitoring are key to canals, aqueducts, and pipeline infrastructures as well. Vauban's canal project, for instance, was tied by design to a regime of meticulous record keeping. But more recently, advances in oil pipeline monitoring and leakage detection include acoustic sensing, fiber optic sensing, infrared thermography, and drone detection (Adegboye et al., 2019). Perhaps even more directly analogous are water and electricity meters. Electricity meters measure kilowatt hours of energy use, and new smart meters provide two-way communication between the home and utility company for real-time monitoring. Designed to monitor domestic water use, water meters measure the velocity of water flows entering the home. While traditional water meters are affected by flow-distortions and degradation, newer water meters promise more accurate readings, leak detection, and water conservation once they learn the rhythm of the home through an "internet of things" (Arregui et al., 2005; Ricker, 2019). Though these processes function differently (and perhaps less efficiently than the pervasive data capture of streaming infrastructures), monitoring is important for these aqueous infrastructures of flow. Data collection, storage, and processing allow

for optimization of flows through these infrastructures, which, in turn, allows for more efficient monetization. Or, as Starosielski elucidates (2015a), "cable companies see the circulations of users, of cloud computing companies, and of various other industries as resources, a set of unruly flows that can be channeled and made profitable, much like a river or an oil reserve" (p. 60). Viewed from this perspective, the data generated by streaming user activity is part of a long lineage of the capture and control of flows toward monetization.

Conclusion

This article has made a case for attention to the lineage of streaming media as related to pre-electrical infrastructures that include rivers, canals, aqueducts, and pipelines. Metaphors of streaming can invoke not only the idealized topoi of streams, but also the flow of electrical media such as the telegraph, telephone, and television. Following Peters's (2015) elemental media approach, we have treated "media" as ensembles of natural elements and human techniques, giving attention to the infrastructural and ontological dimensions of mediation. As an increasingly utilized process, the mediation facilitated by streaming technologies simultaneously involves infrastructures of data collection, storage, processing, and transmission. One implication of this is that streaming media of all sorts are inexorably bound with questions of power, politics, logics of monetization, industry shifts, and everyday routines. Insofar as Peters's work is inspired, in part, by Innis's focus on infrastructure's role in capture and control, ours is also sympathetic with Innis's concern about monopolization through infrastructural control. We live in a time when the line between digital platforms and essential infrastructure has blurred, when a consolidated and powerful consortium of tech companies battle for industry dominance and new sites of data collection, storage, and processing (Plantin & Punathambekar, 2019). Power, control, monetization—these aspects of infrastructures matter. But the ability to turn a critical eye on them will falter without the insight that infrastructures are ensembles of human craft and natural elements. From water pipes to social media platforms, infrastructures are at the heart of various social, cultural, political, and environmental crises (Hallinan & Gilmore, 2021). Digital infrastructures may be framed as immaterial, but in fact have very real-environmental impacts and consequences.

Recently, scientists have proposed covering 4,000 miles of the California Aqueduct with solar panels to generate renewable energy, meet decarbonization goals, and reduce water evaporation (McKuin et al., 2021). Such an idea is not only a reminder of the environmental precarity and ongoing challenges of the Anthropocene, but also of how infrastructures from the past continue to matter to the present. Streaming media are often given a comparatively short history in scholarly accounts. Conceptualizing streaming as an infrastructure of flow, however, reveals their far longer aqueous lineage. Doing so in turn enables a more critical attention to the infrastructures that, often without second thought, continue to organize and shape different modes of being on this planet. While the various layers of today's streaming media are not merely digital versions of canals, aqueducts, and pipelines, an elemental media lineage of streaming does show some older analogs to today's communication protocols, computing devices, servers, cloud infrastructures, and undersea cables. Recognizing the co-

constitutive relation of humans and the planet to infrastructures of flow in turn underscores that infrastructures are at once invisible and seen, ancient and new, powerful and fragile, human and not.

Note

1. Netflix's Open Connect Appliances circumvent undersea cables by copying files from its US-based transcoding repository to storage facilities within other countries.

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