Meander: Data Spatialization and the Mississippi River

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INTRODUCTION

Public art exists at the intersection of sculpture, architecture, and landscape, often integrating elements of all three, yet irreducible to any one discipline. The multifaceted nature of public art demands that it address multiple and sometimes competing imperatives, both conceptual and pragmatic, that continue to change over time. In recent years, these imperatives often include a populist dimension—public art is expected to engage a broad audience in accessible and legible ways (Knight 2008)—as well as the frequent mandate for "site specificity" and integration into the artwork's context (Kwon 2002). In addition to these conceptual aspects, public artists face a unique set of pragmatic and practical demands that can exceed those of a typical gallery or museum commission. Works of public art face much higher expectations for durability and longevity, and unlike architects, public artists can be directly responsible for both the design and construction of the work.

This paper explores these complex issues involved in the construction of compelling public art in the urban realm through a detailed case study of *Meander*, a public artwork completed in 2015 by the collaborative Futures North (fig. 1). *Meander* is a permanent piece commissioned for CHS Field, a new baseball stadium in the Lowertown neighborhood of downtown St. Paul, Minnesota. The artwork consists of fifteen sculptural pillars that creatively re-imagine over two hundred years of historical information about the Mississippi River, which runs several blocks from the site. The pillars are fabricated from custom cast glass fiber-reinforced concrete

Figure 1: View of Meander at dusk.

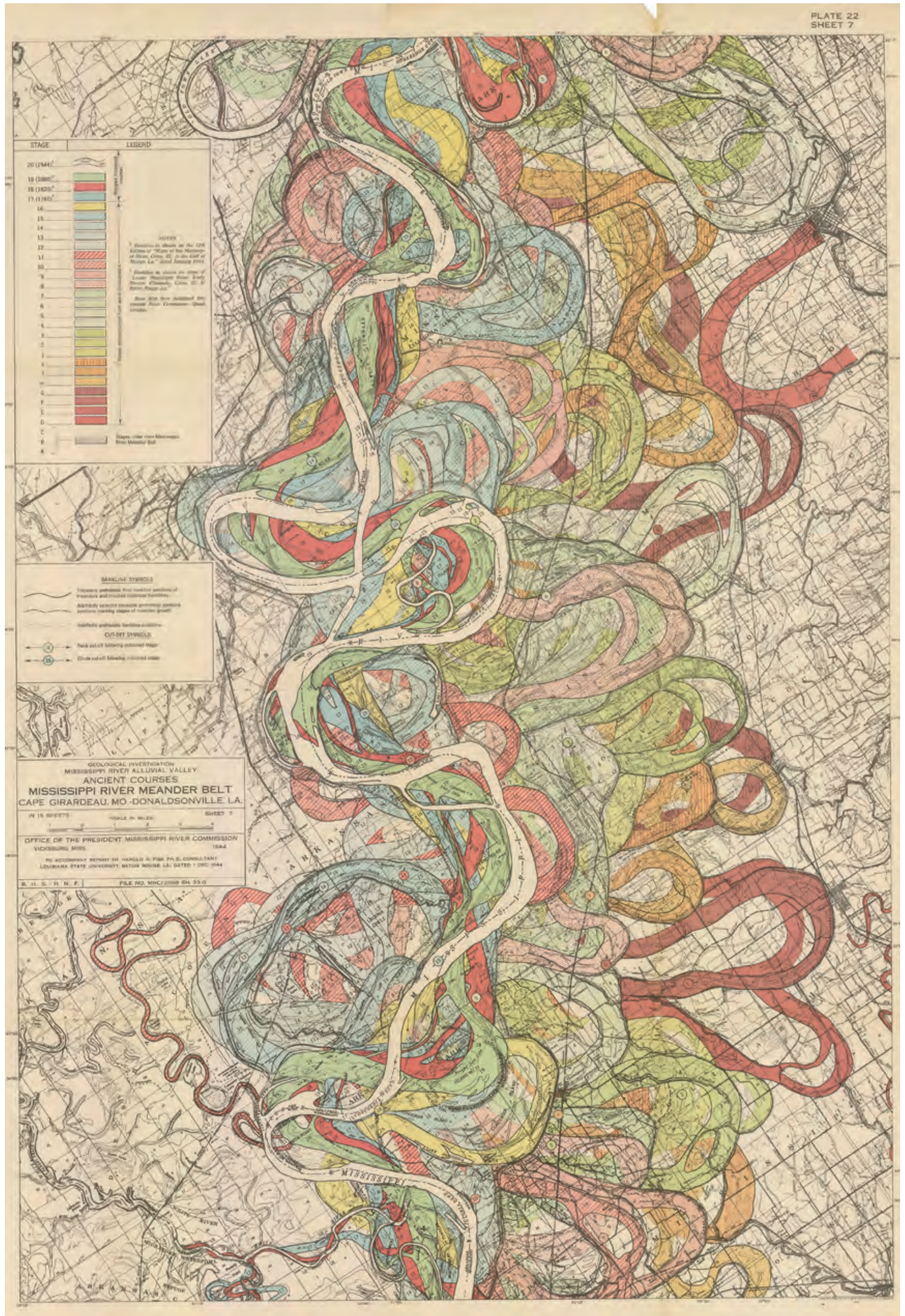


Figure 2: Harold Fisk, Mississippi River Meander Belt, Cape Girardeau, MO–Donaldsonville, LA, 1944.

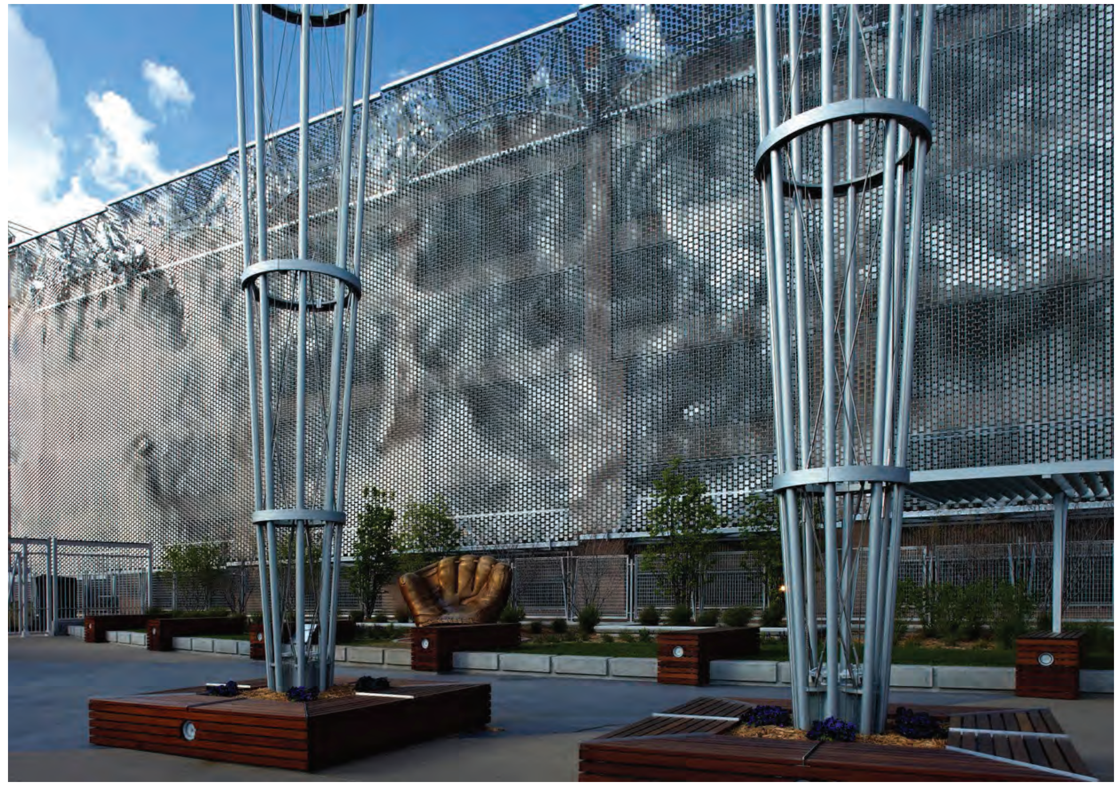


Figure 3: Ned Kahn, The Wave.

Figure 4: The Living, Amphibious Architecture.

Figure 5: Joseph Nicollet, Hydrographical Basin of the Upper Mississippi River, 1843.

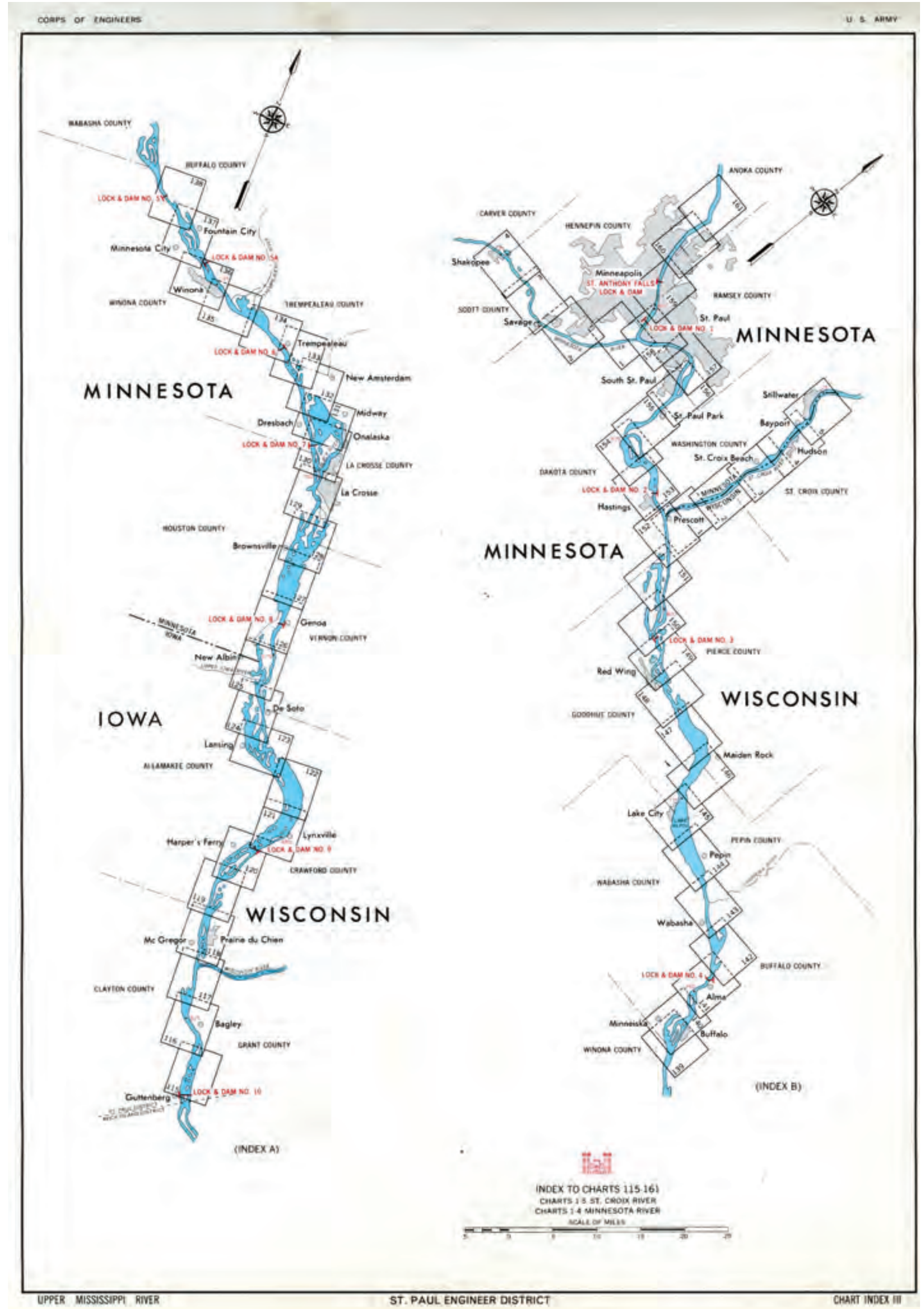


Figure 6: Army Corps of Engineers, Upper Mississippi River, 1963.

Figure 7: Google Maps, 2014.

(GFRC) and capped with custom cast glass lanterns containing programmable LED lights that broadcast information about the river.

Through a detailed account of the design and construction of *Meander,* this paper argues that techniques of computational design and digital fabrication can be leveraged to address both the conceptual and pragmatic demands of realizing innovative works of public art. In particular, we discuss how the project is an exploration of what we refer to as *data spatialization:* a technique for mining existing data sets to inspire and design new formal and spatial constructions. Both the artwork's form and its dynamic lighting were designed with parametric modeling software and advanced computational processes that reinterpret the Mississippi River's geometry and environmental behaviors. The

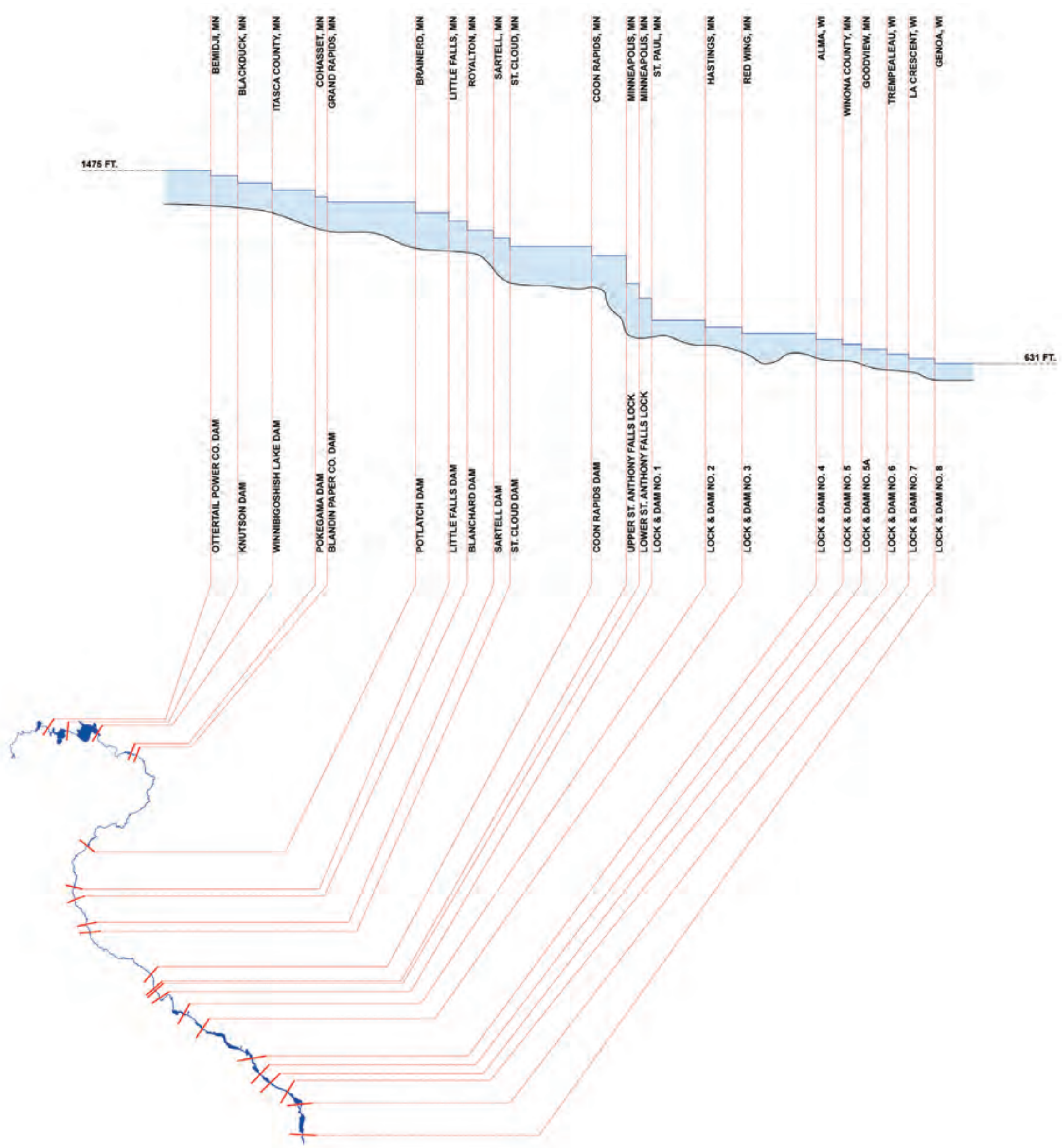


Figure 8: Section diagram of the Upper Mississippi, showing changes in the river's elevation and depth.

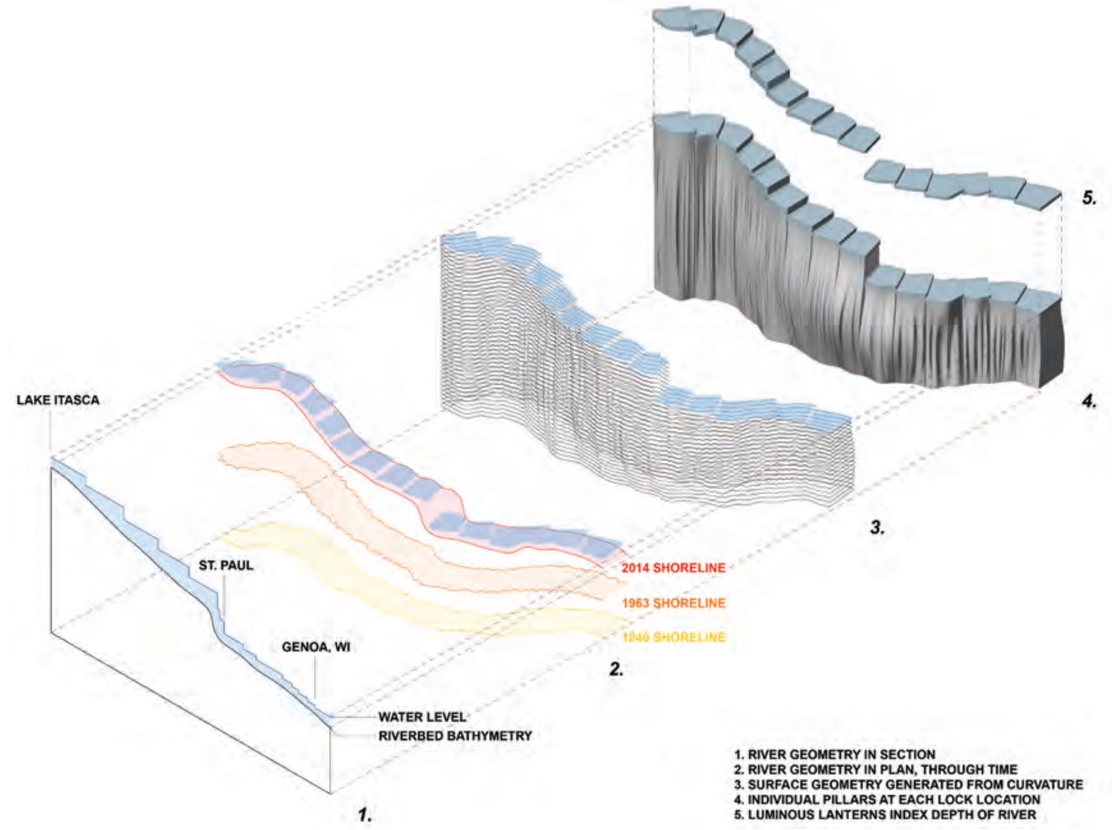


Figure 9: Diagram of design process, showing the translation of river data to sculptural form.

technique of data spatialization embraces a representational capacity while also grounding the project in its local context, thereby rendering the project both accessible and site-specific. And yet, the project's data-driven process paradoxically yields a degree of abstraction that ultimately precludes the artwork's immediate legibility as either a direct re-creation of the Mississippi river, or a fully integrated feature of the ballpark's architecture. In other words, *Meander* is simultaneously referential (it clearly represents the Mississippi and is recognizable as such) and abstract (the piece is not a perfectly accurate representation, because it uses abstracted data as the basis for its design).

Meander also demonstrates how computational fluency in the fabrication stage can enable a streamlined translation from design to construction, mitigating some of the pragmatic challenges of building interactive and complex works of public art. We utilized file-to-fabrication workflows and digital fabrication technologies to achieve complex curvature in both the concrete and glass elements, and we developed custom software to forge a link between the river's environmental data and the lighting controller. Digital processes are combined with the age-old materials of concrete, glass, and light to yield a hybridized materiality that is at once contemporary and rooted in traditional craft. The project leverages advanced technologies to shape raw, earthen materials of concrete and silica into a data-rich artwork that evokes the site's layered geographical and environmental histories.

PRECEDENTS

An initial inspiration for *Meander* was the remarkable set of cartographic drawings produced by Dr. Harold Fisk in the 1940s. These famous "meander maps" of the Mississippi River (fig. 2) were the product of an exhaustive mapping project that Fisk conducted on behalf of the Army Corps of Engineers, which sought to better understand the geological origins and evolution of the alluvial valley of the Lower Mississippi River (Fisk 1944). Fisk painstakingly documented the river's historical geometries through time, using color to code the significant variation of its course throughout its history. His drawings are entirely empiri-

Figure 10: View of Meander along CHS Field entry plaza.

Figure 11: Diagram of the water quality, wind speed, and water temperature datasets used to drive the artwork's light animation.

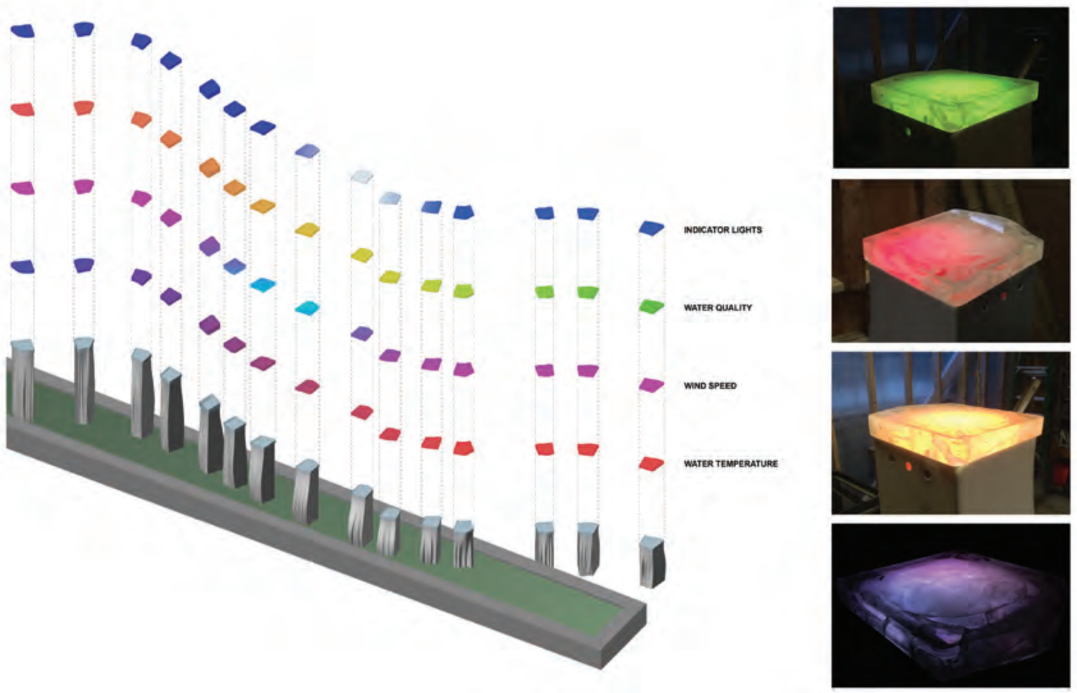
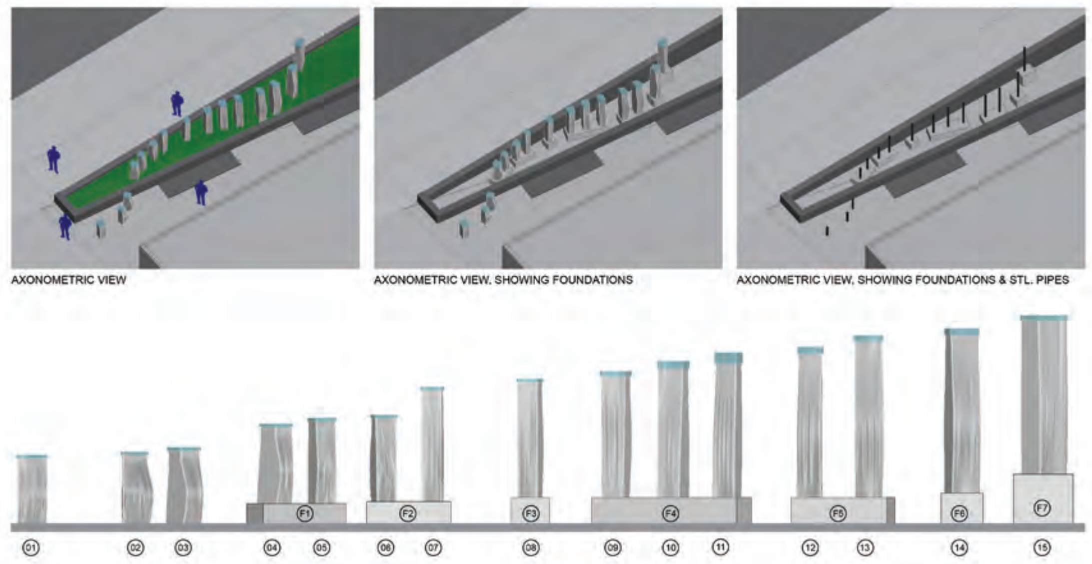


Figure 12: Views of Meander throughout the data animation cycle.

Figure 13: Views of integrated digital model.



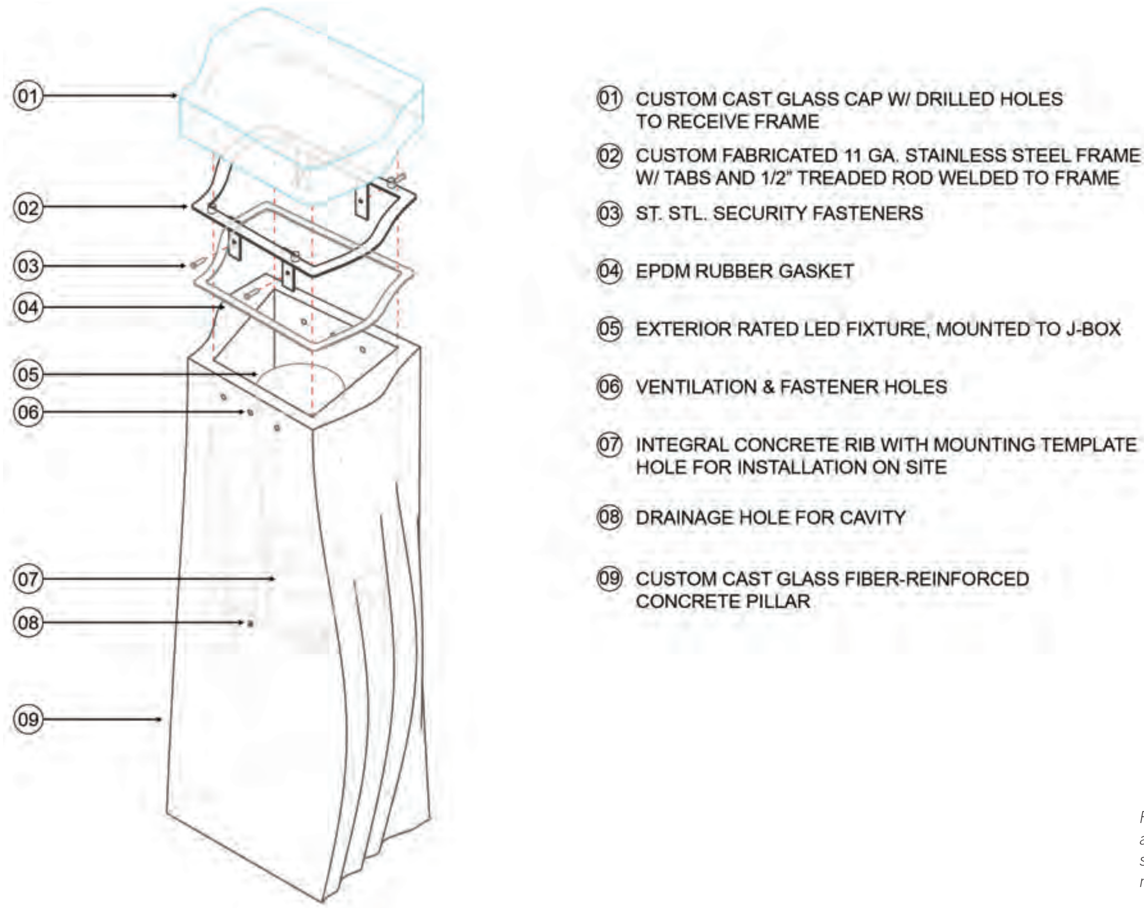
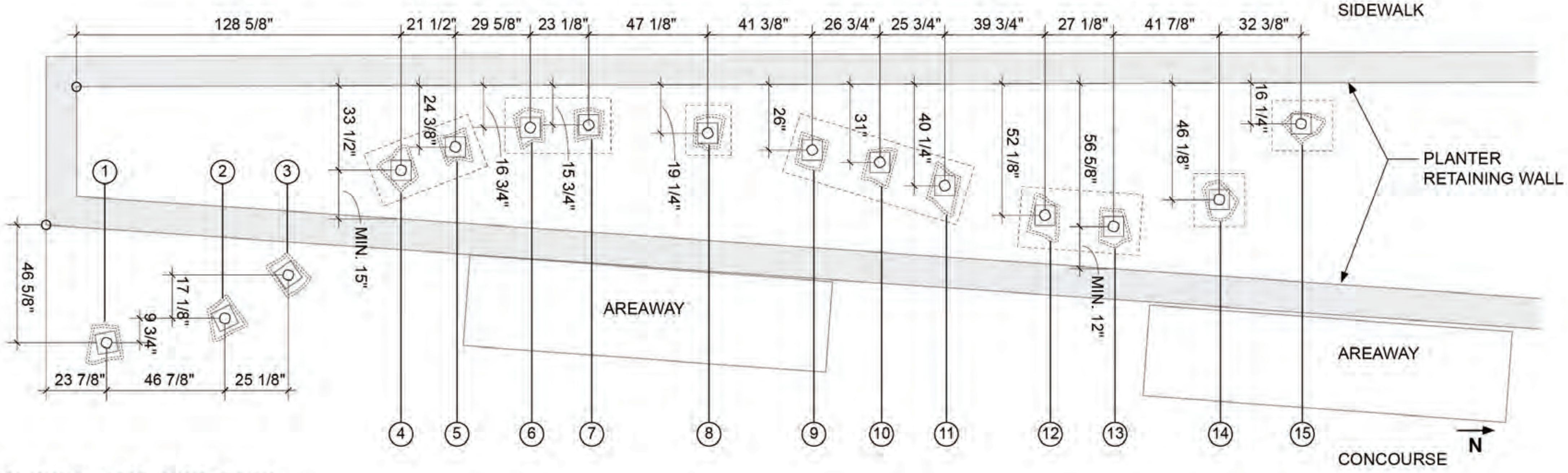


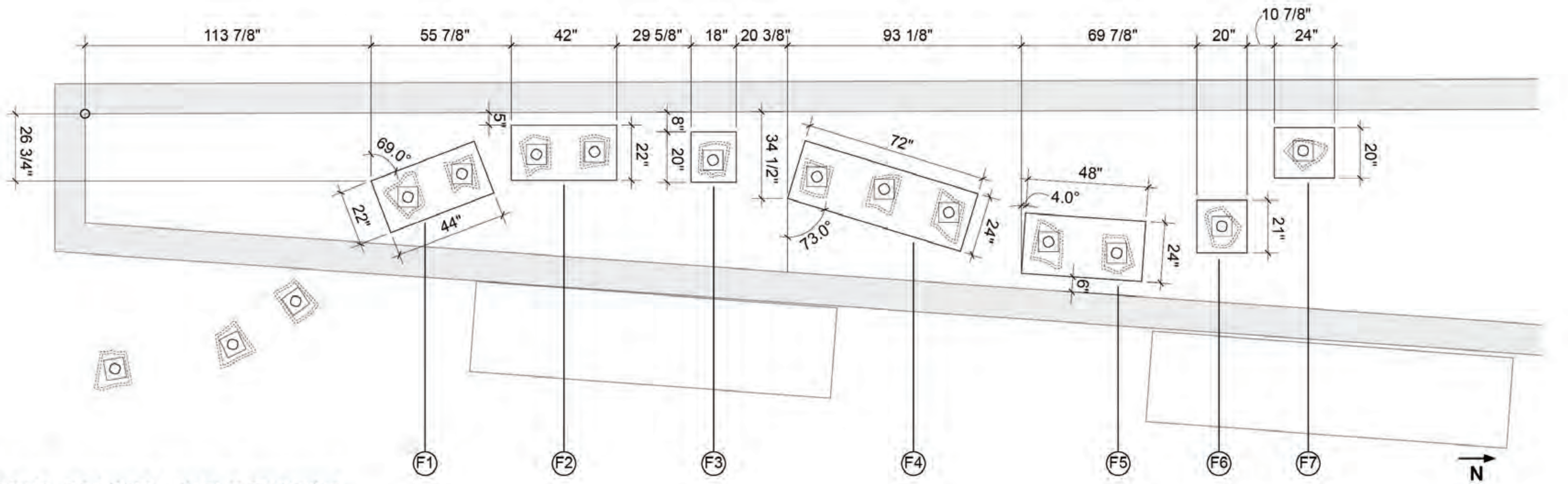
Figure 14: Exploded axonometric diagram, showing the components of each pillar.

Figure 15: Coordinated drawings used for locating the concrete footings and steel posts.



ALL DIMENSIONS TO CENTERLINE OF STL. POST, UNLESS OTHERWISE NOTED.

1. STL. POST LAYOUT DRAWING
Scale 1/4" = 1'-0"



FOOTING SCHEDULE

FOOTING #	DIMS	HEIGHT
F1	22"x44"	14"
F2	22"x42"	14"
F3	20"x18"	15"
F4	24"x72"	14"
F5	24"x48"	14"
F6	21"x20"	16"
F7	20"x24"	24"

2. CONC. FOOTING LAYOUT DRAWING
Scale 1/4" = 1'-0"

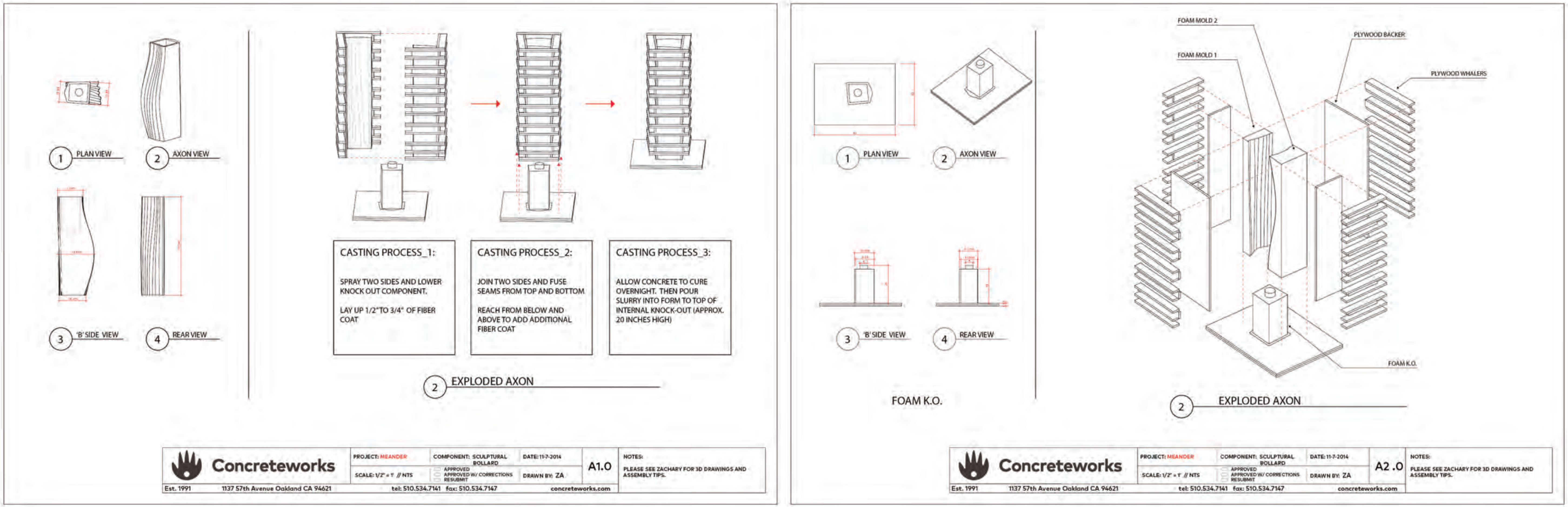


Figure 16: Shop drawings of typical mold for cast concrete pillar.

cal—grounded in historical, geological data—and yet the accumulation of the quantitative information yields a highly abstract and evocative result. This oscillation between the representational and the abstract was an inspiration for *Meander's* design.

In addition to its cartographic roots, *Meander* draws inspiration from the broader context and tradition of environmental art—in particular, artworks that aestheticize the quantification of nature through digital processes. This includes precedents such as Maya Lin's *Systematic Landscapes*, a series of large-scale installations that re-present landscape geometry with elegant simplicity, in an abstract yet highly legible way (Lin 2006). Natural and environmental phenomena are also central to the work of Ned Kahn, but in a more immediate and dynamic sense. Kahn's monumental, wall-mounted installation, *The Wave* (fig. 3), consists of thousands of small, kinetic elements that together produce a real-time illustration of the wind's movement across the surface of the structure (Kahn 2010). This sensibility is also present in *Amphibious Architecture* (fig. 4), a work by The Living that utilizes electronic sensors, microcontrollers, and LED lights to visualize water quality in New York's East River in real-time (Geiger 2010, 60-65). With *Meander*, Futures North sought to merge the technological sophistication of this type of work with the capacity of Lin's sculptures to speak to more timeless and ineffable qualities of the natural landscape.

DATA SPATIALIZATION: FORM

> *The Mississippi is well worth reading about. It is not a commonplace river, but on the contrary is in all ways remarkable... It is the longest river in the world— four thousand three hundred miles. It seems safe to say that it is also the crookedest river in the world, since in one part of its journey it uses up one thousand three hundred miles to cover the same ground that the crow would fly over in six hundred and seventy-five.*
>
> *–Mark Twain, Life on the Mississippi (Twain 1883)*

Futures North began the design process by researching the Mississippi River, the defining feature of the project's environmental context and, in many ways, the reason for St. Paul's existence as a city. During this research phase, we uncovered a number of historical maps of the upper Mississippi River, from contemporary satellite maps to the less accurate but no less significant maps of early European explorers and settlers of the eighteenth century. We used this information to construct a new, updated "meander map" of the upper Mississippi. In particular, we selected three maps to encompass the full range of the river's cartographic history: the map drawn by French geographer Joseph Nicollet in the 1840s, a survey by the Army Corps of Engineers from 1963, and a satellite map accessed from Google in 2014 (figs. 5–7).

Each of the *Meander* pillars consists of a curvilinear cast concrete base topped with a cast glass lantern. We developed a formal logic for the project through the creation of a digital, parametric model that provided a means to precisely adjust the geometry and iterate through numerous design studies. In the digital, three-dimensional environment, the outlines of the river in each of the three maps were positioned vertically in space to create a volumetric form. With the Nicollet map at the base, the Army Corps map in the center, and the Google satellite map at the top, the resulting volume constitutes a three-dimensional representation of the river's changing geometry over time. This curvilinear form was then divided in fifteen places, which correspond to the locations of locks and dams along the upper Mississippi (fig. 8). At each of these locations, there is a significant change in the elevation of the river's surface, and this sectional variation was used to inform the height of each of the fifteen volumetric segments. Finally, the thickness of the glass lanterns corresponds to the changing depth of the Mississippi river between each lock location (fig. 9). This generative process demonstrates how simple planar and sectional operations can be used to translate geological and hydrological geometries into sculptural form with both abstract and representational capacities.

Figure 17: Images of concrete fabrication process.

Figure 18: Images of glass mold-making process.

The fifteen resulting volumes are offset in plan to create a meandering line of pillars that weave in and out of a planted berm that defines the edge of the ballpark's entrance plaza. The artwork's orientation matches that of the river, with the northernmost pillar representing the Mississippi River's headwaters in Minnesota at Lake Itasca. We worked closely with the ballpark's landscape architect Bob Close to carefully coordinate the pillars with the design and grading of the planted area. As the pillars decrease in height, they echo the slope of the berm and adjacent sidewalk; pedestrians walking downhill from the north follow the stepped lanterns down to the southernmost pillars, which are sited in the plaza itself and invite visitors to touch them (fig. 10).

DATA SPATIALIZATION: LIGHT

Futures North not only leveraged computational processes in the development of the artwork's form, but also in the design of its dynamic lighting. Each lantern contains

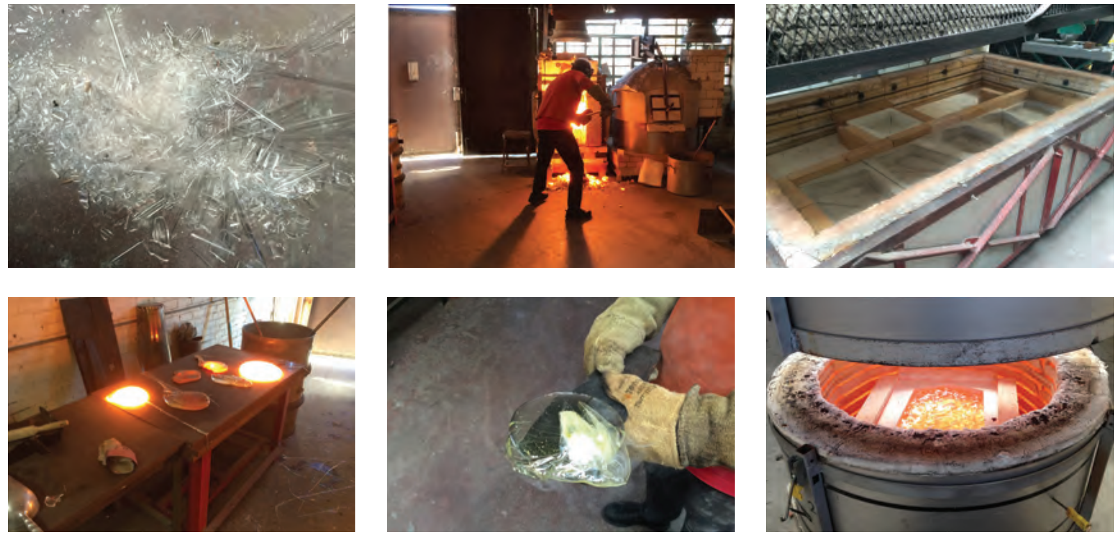


Figure 19: Images of glass casting process.

Figure 20: Images of steel attachment frame fabrication process.

Figure 21: Images of installation process on site.

a programmable LED fixture, and the color, pattern, and intensity of these lights are driven by recorded environmental data about the Mississippi River. In the research phase of the project, the artists screened and analyzed data collected by the Army Corps of Engineers and the University of Minnesota's St. Anthony Falls Research Laboratory to identify information about the Upper Mississippi River that would be most compelling and relevant for a public audience. This process yielded three datasets: the changing water quality (or level of nitrates) over time, the changing wind speed along the river's length over time, and the changing temperature of the water over time.

We used several software platforms to translate the raw data into a light and color animation accessible to a public audience. These included the Grasshopper parametric modeling engine, as well as the TouchDesigner programming interface that ports the quantitative data to RGB instructions for each individual LED fixture. Each dataset is assigned a unique gradient that corresponds to its respective range of quantitative information (fig. 11). For example, the water quality dataset is represented through a green-white-orange gradient that communicates the amount of nitrogen in the water compared to one year previous; green indicates less nitrogen (improved water quality), orange indicates more nitrogen (lower water quality), and white indicates no change.

The three datasets are stitched together to form a single 30-minute program of data-driven light that cycles continuously from dusk to dawn (fig. 12). At any given moment, the color and dynamic behavior is correlated to quantitative data from that section of the river. Although the animation is driven entirely by environmental data, a viewer's experience is not contingent upon understanding the connection to the data; by leveraging quantitative operations for maximal qualitative effect, the artwork's dynamic presence provides an engaging addition to the urban streetscape.

INTEGRATION OF ART + ARCHITECTURE

The project's integration with the ballpark's architecture necessitated a high degree of coordination between Futures North and the building's design/construction team. We maintained an integrated digital model throughout the design process, which interfaced with the ballpark's master BIM model used by the architect and contractor. This digital workflow eliminated the often-complicated back-and-forth of shop and coordination drawings that is common for public artworks built within a large construction project. The digital model that we used accurately communicated the location and orientation of each of the concrete pillars, along with the associated structural steel and electrical infrastructure (fig. 13).

DETAIL & DESIGNED ASSEMBLY

Although *Meander* is a relatively small public art project, its integration of multiple materials and construction trades (steel, concrete, glass, electrical, rigging, landscaping) resulted in a high degree of complexity throughout its fabrication and installation. Futures North anticipated these complexities by front-loading the design process with concerns of tolerance, sequencing, and clear communication between team members. Scott Marble has referred to this approach as "designed assembly":

> *Through CNC technologies, architects can reposition design strategically within fabrication and construction processes, such that design information extends beyond the representational to include highly precise sets of instructions used to drive manufacturing processes. Moreover, these instructions can embed the logic of building assemblies into the manufacturing processes, linking design to a new definition of detail that re-establishes the role of craft in the design process (Marble 2012).*

Several aspects of *Meander* reflect this kind of process. The concrete pillars and glass lanterns were fabricated off-site using CNC-routed formwork, in controlled conditions that allowed for a high degree of precision and craft necessary for realizing the unique and complex forms of each part. The pillars were craned in and grouted on site to galvanized steel posts that anchor them to the building structure and incorporate the electrical conduit for each light; each pillar was fabricated with an integral mounting template in its hollow interior that precisely established its position during installation. Each unique lantern is mechanically fastened to its respective pillar via a custom waterjet-cut eleven-gauge stainless steel frame, with an integrated synthetic rubber gasket (EPDM) to provide a tight weather seal. The frame includes a concealed security fastener, so the lantern can be removed for maintenance of the LED fixture (fig. 14).

The integrated digital model was crucial in managing these aspects of the project, as it allowed for greater flexibility, clarity, and live feedback throughout the design process. The model's parametric functionality—the live connection between the artwork's overall geometry and the fabrication drawings for its constituent parts—allowed the artists to evolve the geometry throughout the design process with immediate feedback on how changes would affect pragmatic concerns of material takeoffs, cost, and installation. For example, with each update of the river mapping data that drives the overall geometry of the *Meander* pillars, the resulting change in form would ripple through the digital model such that the concrete molds and two-dimensional templates for the lantern attachment plates would automatically adjust.

We also used the model to output coordinated two-dimensional drawings for the pouring of the concrete footings and installation of the steel support posts, which, due to construction sequencing of the stadium,

Figure 22: Views of Meander.

were completed six months before the pillars arrived on site (fig. 15). This drawing was coordinated precisely with a hole cast into a concealed, integrated rib in the center of each pillar, providing a means for the riggers to locate precisely each pillar during installation. This ensured the precise position and orientation of each pillar, which is essential for the artwork to be properly experienced. In this regard, the integrated model provided a means to bridge the work of two separate trades—metalworkers and riggers—performed six months apart, while maintaining high precision and preserving the design intent of the artwork.

PROTOTYPING & FABRICATION

Futures North completed a number of full-scale prototypes in order to test and refine the fabrication processes for the concrete pillars and the glass lanterns. This involved close collaboration with fabricators to ensure maximum precision and craft in the final product. File-to-fabrication workflow enabled a streamlined interface with the concrete and glass fabricators, which allowed for a high degree of control and precision with the project's complex geometry.

The pillars were fabricated by Concreteworks, a concrete fabrication shop in Oakland, California that specializes in casting glass fiber-reinforced concrete (GFRC) into complex geometries. The Concreteworks team used a robotic CNC router to fabricate expanded polystyrene (EPS) foam molds for each concrete pillar. Each mold consisted of three parts: two halves that produced the pillar's exterior geometry, and a central "knockout" insert that established the proper depth of the internal cavity for the LED fixture and also located the hole for installation over the steel posts (fig. 16). A custom GFRC mix was applied to the molds via a standard spray applicator until 3/4" of thickness was achieved (fig. 17).

The glass lanterns, fabricated by glass artist David Ruth, were produced using a similar process. We milled EPS foam positives for each of the fifteen unique lanterns using a 3-axis CNC router. Each positive incorporated the unique shape and drainage slope for its respective lantern. David Ruth's studio then cast plaster negative molds around the foam positives (fig. 18). The glass casting process consisted of two stages. The first involved producing large pieces of solid borosilicate glass (commonly known as Pyrex, and notable for its very low coefficient of expansion). The glass casting team crushed unused laboratory equipment from the 1950s (Pyrex beakers and tubes) and placed the fragments in a high-heat furnace to melt them into solid pieces of glass. In the second stage, these parts were arranged in the plaster molds and fired in a kiln. This process melts the Pyrex again and fuses the individual pieces into a single yet highly differentiated glass cast (fig. 19).

We fabricated the stainless steel attachment frames using a CNC waterjet, to ensure that they would match the curved geometry of both the pillars and the lanterns. The Concreteworks team fit each frame to its respective concrete pillar in order to precisely locate the four attachment tabs and coordinate them with the fastener holes cast into the concrete prior to welding them on. Concreteworks also welded 1/2" long stainless steel threaded rods to the top of each frame, to mate with holes drilled in each of the glass lanterns, which were then attached using a high-strength adhesive (fig. 20).

INSTALLATION

Upon completion of fabrication, the concrete pillars and glass lanterns were crated individually and shipped to St. Paul. Upon delivery to the site, the ballpark rigging and concrete subcontractors installed the fifteen pillars over a ten-day period. Each pillar was craned into place, positioned precisely using the integral rib as a template, and grouted in place. The electrical subcontractor then installed and terminated the LED fixtures within the pillar cavities, and the glass lanterns were mounted to the pillars using secure fasteners (fig. 21). The project was completed in advance of the May 2015 Opening Day celebrations for the ballpark.

CONCLUSION

Through its logics of both design and fabrication, *Meander* illustrates how computation and digital fabrication can be leveraged to produce compelling works of public art (fig. 22). Employing these technologies both in the design and fabrication phases enhanced both the conceptual and pragmatic aspects of the project. The use of computational techniques of data spatialization to inform the artwork's sculptural geometry and dynamic lighting behaviors demonstrates how such tools can open up new forms of interactive engagement with public audiences. Employing an integrated parametric model and streamlined file-to-fabrication workflows enabled the artists to execute the project with precision and a level of resolution that otherwise would not have been possible. These aspects of the project demonstrate how emerging technologies can help facilitate the design and construction of long-lasting, conceptually accessible works of public art.

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IMAGE CREDITS

Figure 1, 10, and 22: Stefanie Motta

Figure 2: U.S. Army Corps of Engineers

Figure 3: Ned Kahn

Figure 4: The Living

Figure 5: Obtained from the John R. Borchert Map Library at the University of Minnesota.

Figure 6: U.S. Army Corps of Engineers

Figure 7: Google Maps and its data providers.

Figure 8, 9, 11–15, and 17–21: Futures North

Figure 16: Concreteworks

ACKNOWLEDGEMENTS

Futures North: Daniel Dean; John Kim; Adam Marcus; Molly Reichert

Client: Ryan Companies; City of Saint Paul

Concrete Fabrication: Concreteworks

Glass Fabrication: David Ruth

LED Visualization and Programming: Max McDougall

Mississippi River Data Research: Jacques Finlay, The Saint Anthony Falls Laboratory, University of Minnesota