Positive Unintended Consequences
How Campbell Lake Gravity Sewer Pipeline Line Survived a Magnitude 7.1 Earthquake

David Persinger, P.E.,[1] Maury D. Gaston[2]

[1] M. AWWA. Past Chair and Current Director, Alaska Section; M.WEF; - Director, Operations and Maintenance, Anchorage Water and Wastewater Utility; 3000 Arctic Blvd.; Anchorage, Alaska 99503. David.Persinger@awwu.biz

[2]M. ASCE; M. WEF; M. AWWA; M. AWWA A21 Committee on Ductile Iron Products; Chair A21 Sub-Committee 1, Ductile Iron Pipe Design and Manufacture; Auburn University - Bachelor of Mechanical Engineering; Chairman, Alabama Iron and Steel Council; Director and past Chairman, State of Alabama Engineering Hall of Fame; Manager of Marketing Services, AMERICAN Cast Iron Pipe / Ductile Iron Pipe / SpiralWeld Pipe, P. O. Box 2727, Birmingham, Alabama 35202. mgaston@american-usa.com

ABSTRACT

Beta Construction of Seattle, Washington, began installation in November, 1989 of an 8,432 foot long 48-inch gravity sewer line that was installed across exclusive Campbell Lake in Anchorage, Alaska. In a unique and propitious series of events, the City of Anchorage and the Corps of Engineers collaborated on dam repairs and gravity sewer installation saving significant dollars for underwater construction and resulting almost 30 years later in unintended consequences. Unlike most unintended consequences, these were positive, even remarkably so.

On November 30, 2018, a magnitude 7.1 earthquake struck the Alaska-Aleutian Subduction Zone and liquefied the lakebed. While the 29-year old 48-inch diameter gravity sewer installation was dramatically disturbed, and while the disturbance went unnoticed for 104 days under ice, there was no sewage spill and repairs were able to be made with minimal complications. This paper will highlight the circumstances of the original construction and how material selection and construction methods resulted in a positive outcome years later before the advent of today's innovative and resilient seismic joints.

BACKGROUND

The co-author was West Coast District Manager for AMERICAN Ductile Iron Pipe, covering 11 states including Alaska. All of AMERICAN's manufacturing was done in Birmingham, Alabama, and other ductile iron manufacturers had 24-inch and smaller diameter production in the western United States with commensurate freight advantages, so it was a tough competitive environment in those diameters. Nevertheless, a 48-inch diameter ductile iron project in Anchorage was a reasonable competitive possibility, so AMERICAN chose to pursue it, and was the successful pipe manufacturer.

The dam at Campbell Lake had been constructed by a private developer in 1959. After original construction and remaining so ever since, the resultant 125-acre reservoir is a beautiful setting for exclusive homes with docks stretching into the water, a significant number of which have float planes tied to them. Many of Anchorage's and Alaska's most influential business, industry, and government leaders call Campbell Lake home. An aerial view of Campbell Lake and the surrounding neighborhood is shown in Figure 1.

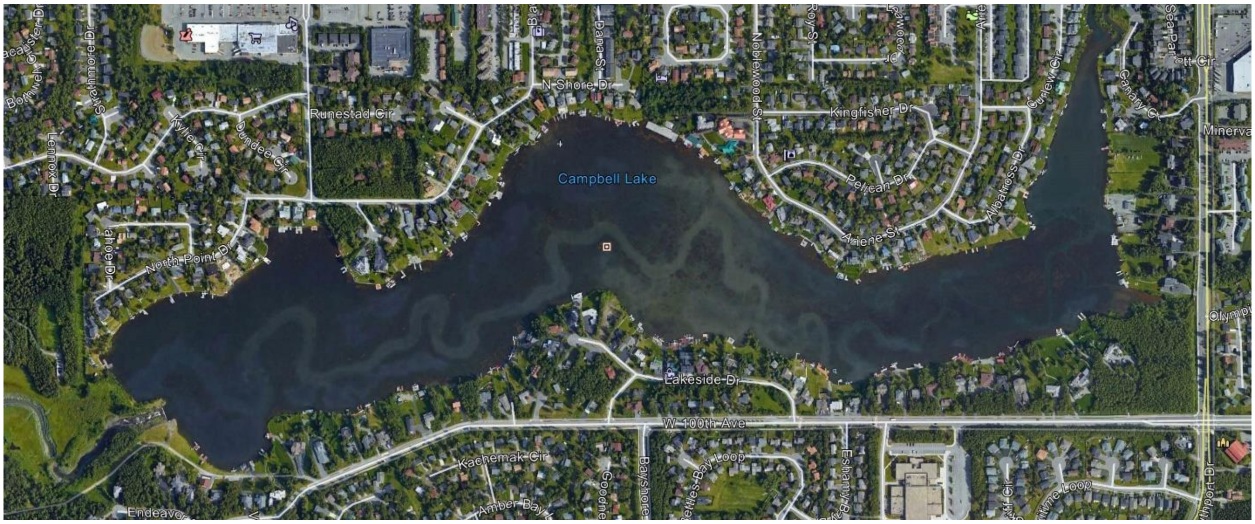

Figure 1. Aerial view of Campbell Lake and surrounding neighborhood. (www.alaskalandmine.com n.d.)

Campbell Lake and its dam have had their challenges. The dam was destroyed by a 1964 earthquake and rebuilt, and then damaged by a 100-year flood event on August 25, 1989 (Cherie Northon 2007). That flood resulted in repairs being made under the direction of the Corps of Engineers. At the same time, Anchorage Water and Wastewater Utility (AWWU) was planning to construct a trunk sewer to serve the larger area, and the trunk line needed to cross beneath Campbell Lake. One option was to construct a force main using ball and socket joint piping along the contour of the lakebed. While exceptionally robust and adaptable with a 15-degree omni-rotational joint, ball and socket piping is commensurately expensive and requires unique construction equipment and installation practices, further adding to cost and schedule. By coordinating with dam repairs and the Corps of Engineers, a faster and more economical plan was developed by Anchorage Water and Wastewater Utility.

PROJECT PLAN

Given the simultaneous needs to repair the dam and construct a trunk sewer, AWWU and the Corp of Engineers worked together to devise the following plan:

- Following a 100-year flood cresting on August 25,1989, and resultant damage to the Campbell Lake dam, Campbell Lake would be lowered to allow dam repairs to be made before ground conditions became frozen.
- This same lowering of Campbell Lake would expose and allow access to significant areas of the lakebed for installation of the trunk line.
- The exposed areas of lakebed would freeze soon thereafter.
- While that area was frozen, the route of the trunk line would be trenched to a gravity-flow grade. The bottom of the trench would extend to a depth as great as 22 feet below

the lake bed. (Corwin and Associates and Anchorage Water and Wastewater Utility 1989)

- The bottom of the trench would be backfilled with an aggregate base.
- Unrestrained 48-inch diameter push-on joint ductile iron piping wrapped with polyethylene encasement would be installed to grade for the gravity-flow trunk line.
- The 48-inch diameter unrestrained push-on joint ductile iron piping would be outfitted with concrete collars to hold the pipe in place against buoyant forces.
- The unrestrained 48-inch diameter push-on joint ductile iron piping would be backfilled with aggregate to provide further stability and support in the lakebed soil conditions.
- Campbell Lake would fill from the spring melt before the summer recreational season.

Beta Construction was awarded the contract at $3,716,276. The Engineer's estimate was $4,900,875, and the high bid was $5,434,039 (Gaston 1989).

This unique cooperation between Anchorage Water and Wastewater and the Corps of Engineers saved both time and money by allowing a gravity-flow trunk line using push-on joint ductile iron piping instead of a pressure force main requiring pump stations and ball and socket joint pipe.

THE SEISMIC EVENT

The trunk line served three decades as constructed and intended, and then on November 30, 2018, a magnitude 7.1 earthquake struck the Alaska-Aleutian Subduction Zone and liquefied the lakebed of Campbell Lake. Because the gravity-flow trunk line was not full, significant buoyant forces were present. When the collars holding the buoyant forces in check were disturbed by the quake and liquefaction, the line floated. What is remarkable and the point of this paper, is that the unrestrained, 48-inch diameter push-on joint ductile iron pipes did not separate even though they experienced deflection well beyond both their intended performance and rated joint deflection.

The crown of the line was 14 feet below the surface of the lake, and when the quake occurred, the lake had an ice surface 16-inches thick. A section of the line 180 feet in length deflected and rose to the surface without separating, at which point the 16-inch thick ice held it in place. Figure 2 shows the profile of this post-quake deflection (Willie B. O'Malley 2019).

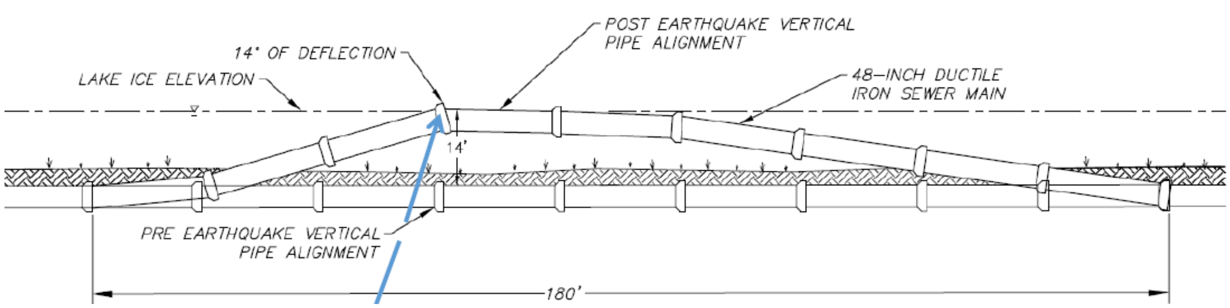

Figure 2. Post-quake profile of the deflected pipe joints held in place by the 16-inch thick ice surface 14-feet above the crown of the pipe (Willie B. O'Malley 2019).

The maximum buoyant force of an empty 48-inch class 52 ductile iron pipe fully submerged is 507 pounds per foot, or 10,140 pounds per joint length (American Ductile Iron Pipe 2016). The experiential, actual, buoyant forces in this case varied due to whatever volume of flow was in the line and shared stability from connecting joints. The capacity of the 16-inch thick ice surface to hold down buoyancy of the disturbed piping is not certain, but resources estimate a wide range from as little as 8,500 pounds, the weight of a medium truck, to as much as 25 tons (The Editors 2017). Quality and age are important contributors to the strength of ice and are some of the factors in that great variation of estimated strength.

The point here is that 16 inches of ice on the surface at the time of the temblor was sufficient to prevent the still-connected push-on joint ductile iron pipe from further deflection and increased potential of joint separation. If joint separation had occurred under the ice, the pump station downstream would have received a tremendous inflow of lake water, and the trunk line would have to be taken out of service. The likelihood of a sewage spill would also be highly probable.

Calculated joint deflections of the profile vary to a maximum of 14-degrees for the joint at Sta 68+00, the joint pressing under the ice.

On March 14, 2019, 104 days after the event, the ice had melted enough that buoyant forces exposed the dislocated ductile iron piping. A photograph of the highest-elevated joints rising through the ice resembling a surfacing submarine is shown in Figure 3.

Figure 3. The highest-elevated joints rising through the ice
on March 14, 2019, 104 days after the event.

IMMEDIATE RESPONSE

A stabilizing assembly was quickly designed and constructed, driven into the lakebed, and assembled over the trunk line to prevent it from further flotation, likely joint separation, and sewage spill. (Lauren Maxwell 2019) This structure is shown in Figure 4.

Figure 4. A stabilizing assembly driven into the lakebed
to hold the ductile iron piping in place after the ice had melted.

The most severely deflected joint in the post-quake assembly was at Sta 68+00, the joint against the ice shown in Figure 2. It was calculated to be deflected to 14-degrees, well beyond its rated special deflection of 4-degrees. This joint is shown as a photograph in Figure 5 in full exposure following complete ice melt. Notice the significant length of spigot that has spent 30 years inside the bell protected with traditional polyethylene encasement. The resilience of this joint to perform in such a manner is remarkable and will be discussed later in this paper.

Figure 5. A Fastite push-on joint ductile iron pipe deflected at a
calculated angle of 14-degrees and maintaining joint performance.

OVERVIEW OF THE DUCTILE IRON PUSH-ON JOINT

Now, let's examine in more detail the push-on joint used for this project. In 1989, two brands of push-on joints were available for ductile iron pipe, Tyton and Fastite. Fastite was developed by

AMERICAN Cast Iron Pipe, the manufacturer of the pipe used in this AWWU project, and United States Patent Number 2,991,092 was issued for it to AMERICAN's J. W. McKay on July 4, 1961. (Michael J. McGuire n.d.)

The 48-inch diameter Fastite joint has a published standard deflection value of 3-degrees. This provides 12 inches of vertical offset over a 20-foot pipe length. Joint deflections compound, so a full circle can be made in a radius of 380 feet by using standard 3-degree deflections.

The standard Fastite gasket is SBR rubber of dual durometer. The higher-durometer section has a square cross section to hold the gasket securely in place against spigot insertion forces. The softer durometer section is fatter and provides a bottle-tight seal against the fully-homed spigot.

For joint assembly, the cast-in-place gasket groove within the bell is cleaned, the dual-durometer gasket is seated in the cast-in-place gasket recess, the gasket is lubricated with vegetable-grade lubricant, the exterior of the joining spigot is cleaned and lubricated, and the spigot is inserted in straight alignment into the bell until the spigot stripe is within the bell indicating the joint is fully assembled. The same backhoe that constructed the trench and lowered the pipe is typically used to push the spigot into the bell. After assembly, the joint may be deflected to its rated value.

An image of the standard Fastite joint and gasket in straight alignment is shown in Figure 6.

Figure 6. Standard Fastite joint and SBR gasket in straight alignment (American Ductile Iron Pipe 2016).

The Campbell Lake sub-aqueous trunk sewer utilized "Special Deflection Bells," bells which had been machined to allow greater-than-standard deflection. This was desirable to maximize constructability in such a remote area within limited timeframes. The special deflection bells allow rated joint deflection of 4-degrees, providing 17 inches of vertical offset, and construction of a full circle with a radius of only 285 feet. A section view of 4-degree special deflection 48-inch diameter Fastite joint with dimensions is shown in straight alignment in Figure 7.

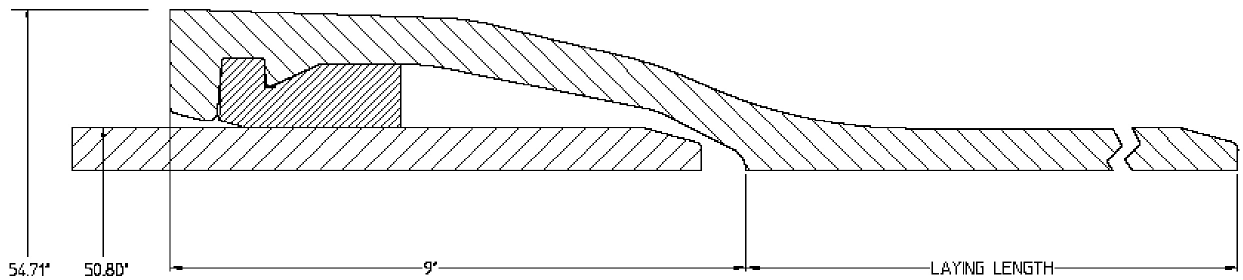

Figure 7. A 4-degree special deflection 48-inch diameter Fastite joint
In straight alignment with dimensions (American Ductile Iron Pipe 2019).

The 48-inch diameter special deflection Fastite joint has a socket depth of 9 inches. In its fully-deflected position of 4-degrees, there is a 3.3 inch joint separation between the end of the spigot and the shoulder inside the bell. A 4-degree special deflection 48-inch diameter Fastite joint is shown in the deflected position in Figure 8.

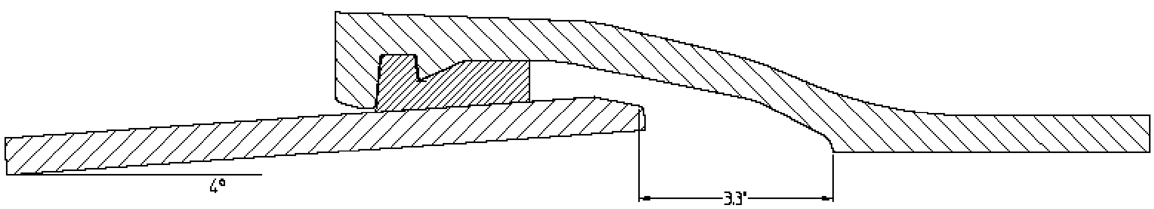

Figure 8. A 4-degree special deflection 48-inch diameter Fastite joint
in the deflected position (American Ductile Iron Pipe 2019).

The 4-degree, 48-inch diameter Class 52 special deflection Fastite joint is rated for 300 psi internal pressure to match the pressure rating of the 0.65-inch thick wall. Being a gravity trunk line, this is moot, but it's pertinent to the design, manufacture, and performance of the joint. Push-on joints for ductile iron pipe are under the American Water Works Association Standard C111/C21.11, " Rubber Gasket Joints for Ductile Iron Pressure Pipe and Fittings" (American Water Works Association 2017). For this special deflection joint, the manufacturer asssembled two pipes, capped the ends, and restrained the assembly in a test press. The assembly was hydrostatically tested to twice the rated pressure in both straight and fully deflected alignment. (Drake 2020).

TRANSPORTATION

It's 3,337 miles from Birmingham, Alabama, to Anchorage, Alaska. Shipping 421 pieces of 48-inch diameter ductile iron pipe, each one being 20-feet in length and 6,584 pounds in weight, is no small task. The manufacturer has an extensive history of shipping product around the world, and this was similar to an export order in that it involved multiple transit modes including rail, barge, and truck.

Groups of four pipe were loaded onto piggyback trailers. These are tractor-trailer flatbeds designed to be loaded onto rail cars and later hauled by a conventional cab tractor to their final destination. Two pallets of two pipe each comprised each flatbed load, each pallet utilizing a rack to raise one pipe just high enough to fit both pipe within the width requirements of the piggyback flatbed. These loaded flatbeds, in turn, were transferred onto rail cars and pulled by the Burlington Northern railroad from Birmingham to Vancouver, Washington. There, the piggyback trailers were transloaded to barges and shipped 2,192 miles through the inland passage from Vancouver to Anchorage. Two-thirds of the trip from Birmingham to Anchorage was by barge through the inland passage. After off-loading the 106 trailers in Anchorage, they were driven as conventional truck loads to the Campbell Lake jobsite and unloaded. The transit time from Birmingham to the jobsite varied with each shipment but was generally about three weeks. The first shipment was December 14, 1989. Freight costs were $185 per ton, $609 per pipe length, $30.45 per foot. The pipe sale price, delivered, was $110.00 per foot. (AMERICAN Cast Iron Pipe 1989).

RESILIENCE

Another presentation at this conference is entitled, “What is Pipeline Resilience?” In preparing that topic, the co-author asked the question to a number of industry subject matter experts.

Dr. Graham Bell, formerly of HDR Engineering and now Structural Technologies, commented that resilience is survivability in off-normal design events such as seismic, flood, storm surge, hurricane, tsunami, etc. Dr. Bell added that for pipe, it comes down to joint strength and flexibility (Graham E. C. Bell 2018). With joint performance at 14 degrees deflection, 350% beyond the rated 4-degrees, this pipeline demonstrated “off-normal design” resilience in spades.

In another interview, Charles F. Anderson, Senior Management Consultant with CDM Smith in Ft. Worth, Texas, and a past president of the American Water Works Association, replied concerning pipeline resilience,

> Joining pipeline sections with properly designed joints to minimize leakage and provide good horizontal restraint and also vertical and lateral flexibility suitable to resist embedment movement forces (Anderson 2018).

During and after the magnitude 7.1 earthquake, these ductile iron push-on joints prevented any leakage and provided sufficient flexibility. Here, too, resilience was demonstrated.

John R. Plattsmier is recently retired as Senior Vice President of HDR, Inc., and has been Chief of Pipeline and Pump Station units in previous roles at other firms. Mr. Plattsmier is also Chair of the American Water Works Association A21 Committee, the standards committee governing all ductile iron products – pipe, fittings, joints, linings, coatings, installation and more, including Manual of Practice M41. In these roles, he sees many pipeline applications.

Mr. Plattsmier offered the following uniquely qualified observations:

> There are several terms that are used frequently in our industry, and I wonder if folks really think about what they mean – resilience, sustainable, and robust, come to mind. I believe they mean different things to different organizations and under different circumstances. Pipeline resilience seems to focus on the ability to recover, and I agree that is obviously a component. My complete view, however, is there are also components of strength and toughness that I think are important in pipeline design and performance.
>
> Whether transmission or distribution, pipeline resilience is a synthesis of strength, toughness, flexibility, and durability in the sense of long-term performance, and the ability to recover from extra-normal conditions.
>
> Strength and toughness speak to the ability to survive an event without interruption of service. This could be seismic, a land slide, external loading, transient pressures, or any number of other things that can stress the piping system. We can design in different ways to provide strength and toughness. One obvious way is simply the material itself since each material has different strength and toughness characteristics.
>
> Joints are critical. They need to resist forces that act upon them and continue performing. ***A joint's ability to deflect and accommodate movement is a tremendous dimension of pipeline resilience***.
>
> The ability to recover from extra-normal conditions is affected by the system design with respect to the ability to drain and fill, access to the pipeline, availability of repair materials, repairability and field adaptability of the material which includes the operations and maintenance crews' familiarity with the material and construction.
>
> I would suggest that when engineers and owners scope a job for design, construction, and operation, there needs to be a discussion about the intended level of resiliency. This should include tolerance for risk, definition of failure, and level of redundancy. This will drive material specification and method of construction. Expectations should be different based on the purpose of the line. For example, a primary transmission line or a sole supply line to a hospital will have different expectations than a distribution line that feeds five homes (John R. Plattsmier 2018).

These comments by Mr. Plattsmier concerning resilience are the result of many years of experience with many clients and circumstances, and he notes a number of dimensions of resilience that proved themselves following the Campbell Lake seismic event including strength, toughness, durability, the ability to recover from extra-normal conditions, a joint's ability to deflect and accommodate movement, and more. The material selection of ductile iron pipe and its robust push-on joint 29 years earlier proved propitious and made possible a recovery which will be the topic of a separate presentation at this conference.

CORROSION RESILIENCE

Another item of resilience to note is the condition of the pipe after 29 years in the sediment lakebed of Campbell Lake. The ductile iron pipe had a standard factory applied asphaltic top coat covering its annealing scale; and because of the arduous and critical installation, the pipe was wrapped in a double layer of traditional polyethylene encasement. This is the same encasement that was originally used in Lafourche Parish, Louisiana in 1958 (Cox June 2012) which is also the topic of another presentation at this conference. The wrap is governed by AWWA C105, "Polyethylene Encasement for Ductile-Iron Pipe Systems" and is made of virgin polyethylene material conforming to the requirements of ANSI/ASTM Standard Specification D1248 (American Water Works Association 2011). Figure 9 shows the condition of the wrap, the condition of the peen pattern on the surface of the pipe, and the previously noted excessive deflection of the joint while still performing.

Figure 9. The exposed most-severely deflected joint showing condition of the traditional polyethylene encasement and the peen pattern of the pipe surface after 29 years beneath the lakebed.

WHAT IF DESIGNED TODAY

In spite of this excellent performance and demonstration of exceptional resilience, product innovations have occurred since the installation of this trunk line 29 years earlier which would add additional value today. These include boltless and flexible restrained joints, metallized arc-sprayed zinc coatings, and V-Bio enhanced polyethylene encasement. Each of these has been presented at previous ASCE UESI Pipelines conferences.

RESTORATION

After the deflected joints were stabilized, a plan was developed to restore the trunk line alignment and profile. This is a topic for another presentation at the conference this week by members of the Anchorage Water and Wastewater team, but it's worth mentioning here the gaskets continued to perform until it was decided to disassemble the pipe, install new gaskets, and use the same pipe again in a restored alignment and profile, this time with additional anchors for stability in the event of another seismic shock.

CONCLUSIONS

The use of ductile iron pipe with its push-on joints and rubber gaskets allowing liberal deflection and its encasement in protective polyethylene 29 years before a potentially catastrophic seismic event made possible survivability and restoration of a critical infrastructure in an environmentally and economically sensitive area.

References

n.d. *www.alaskalandmine.com.* Accessed November 11, 2019. https://alaskalandmine.com/landmines/the-bizarre-story-of-campbell-lake-the-private-lake-that-isnt/.

AMERICAN Cast Iron Pipe. 1989. "Shipping List and Invoice 82687." Birmingham: American Cast Iron Pipe, December 14.

American Ductile Iron Pipe. 2019. "48-Inch Extra-Deflection Joint Detail." Birmingham: Not Published, December 2.

—. 2016. *American Pipe Manual - Twentieth Edition.* Birmingham: American Cast Iron Pipe Company.

American Water Works Association. 2017. "ANSI/AWWA C111/A21.11-17." *Rubber Gasket Joints for Ductile Iron Pressure Pipe and Fittings.* Denver: American Water Works Association, June.

—. 2011. *M41 - The Manual of Practice for Ductile Iron Pipe and Fittings.* Denver: American water Works Association.

Anderson, Charles F., interview by Maury D. Gaston. 2018. *Senior Management Consultant - CDM Smith* (November 7).

Cherie Northon, Ph.D. 2007. "A Cultural and Historical Geography of Campbell Creek, Anchorage, Alaska." *Alaska Humanities Forum.*

Corwin and Associates and Anchorage Water and Wastewater Utility. 1989. " Invitation to Bid No. 89-C61." *Campbell Creek C-5 Trunk Sewer - Phase 1 - Replacement.* Anchorage: Municipality of Anchorage, September 15.

Cox, Allen. June 2012. "Fifty Year History of External Corrosion Control for Iron Pipelines with Polyethlene Encasement." *Materials Performance* Volume 51, Number 6, page 46.

Drake, David M., interview by Maury D. Gaston. 2020. *Technical Director, AMERICAN Cast Iron Pipe* (January 2).

Gaston, Maury D. 1989. "Personal Notes." Anchorage: Not Published, November 1.

Graham E. C. Bell, PhD., interview by Maury D. Gaston. 2018. *Business Class Director - Condition Assesment and Rehabilitation - HDR Engineering, Inc.* (November 6).

John R. Plattsmier, P. E., interview by Maury D. Gaston. 2018. *Senior Vice President* (November 7).

Lauren Maxwell. 2019. *11 KTVA.* May 3. Accessed November 11, 2019. https://www.ktva.com/story/40410502/crews-draining-campbell-lake-for-work-on-sewer-pipe.

Michael J. McGuire, P.E. n.d. *This Day in Water History.* Accessed November 11, 2019. https://thisdayinwaterhistory.wordpress.com/2019/07/04.

The Editors. 2017. "Ice Thickness Safety Chart." *The Old Farmer's Almanac.* November 10. Accessed November 11, 2019. https://www.almanac.com/content/ice-thickness-safety-chart.

Willie B. O'Malley, P.E., interview by Maury D. Gaston. 2019. *Project Manager, Anchorage Water and Wastewater Utility* (November 26).