



# Learning from Flint, leaning on engineers

This article explores the causes of the Flint, Michigan, drinking water crisis, based upon published accounts and a day-long visit there in December 2016. The root causes are not as simple as we think, nor are the solutions. Nevertheless, the public and government officials should learn from Flint and look towards the engineering community for both stability and creativity to ensure Americans have safe drinking water now and in the future.

## Chemistry (in brief)

For many years Flint purchased its drinking water from the Detroit Water & Sewer Department, with Lake Huron as the water source. Detroit treated the raw water with disinfection agents, pH (i.e., alkalinity/acidity), anti-corrosion chemicals, and other chemicals as needed. Flint Water Works Company (FWWC) received the treated Detroit water and pumped it through the distribution system in Flint. The phosphate anti-corrosion chemicals produced a coating on metal pipes, fittings and joining materials (i.e., iron, steel, copper, brass and lead), thereby minimizing corrosion and leaching of metals into the drinking water.

In 2013, the City of Flint decided to save money and switch to the Karegnondi Water Authority (KWA), which was building its own pipeline to Lake Huron. Flint declined to enter into an interim agreement with Detroit, and instead opted to draw Flint River water and restart the water treatment parts of the FWWC until KWA water became available. Both Michigan and FWWC officials advised against a quick restart of the treatment facility, due to low chemical supplies, lack of instrumentation, and untrained operators. But Flint proceeded anyway.

In May 2014, within weeks of the switch, residents complained to the Flint City Council, State of Michigan and the media that their tap water was orange or red, that it was foul-smelling, and that children were becoming sick. During the summer of 2014 several drinking water quality violations occurred, including high bacteria and high organic com-

pounds (e.g., trihalomethanes, potential carcinogens). Sampling at a residential tap also showed a high lead level. Eventually, engineering consultants, researchers from Virginia Tech, and responders from U.S. EPA and Michigan diagnosed the situation. A series of missteps at the FWWC and a directive from Flint officials to stop adding corrosion treatment chemicals (in order to save about \$100 per day) caused the metal parts of the distribution and indoor plumbing systems to corrode, and allowed very low disinfection levels which resulted in elevated levels of bacteria, including *Escherichia coli* (*E. coli*) and *Legionella* (*Legionnaires' disease*). The U.S. EPA took over the water system and switched the water source back to Detroit. U.S. Health and Human Services and the Michigan Health Department began addressing high blood lead levels in children. The State of Michigan began distributing bottled water and lead tap water filters to residents, and the Michigan Health Department began a series of programs for residents. (Ref. 1)

## Chemistry (details)

Corrosion control for drinking water systems has been known for decades, as summarized by U.S. EPA in 1985 (Ref. 2). Susan Masten (Ref. 3) of Michigan State University and her colleagues provide a thorough set of details on Flint's water chemistry. Unlike Lake Huron, the Flint River is a variable water source and has several challenges due to its acidity, relative high hardness and organic carbon, and fluctuations. FWWC operators did not have experience and did not understand how to adjust and control pH, disinfection, hardness, corrosivity and other parameters, and made matters worse by adding an iron compound to the system. The combination of no added phosphate, lower pH and additional iron caused the protective phosphate coating to be stripped from metal surfaces in the water distribution and domestic plumbing systems, resulting in iron, lead, copper and other metals leaching into the drinking water. Equally important, long residence time in the distribution system, inadequate

disinfection dosing, and reaction of iron with the chlorine allowed micro-organisms to grow, because of low or no measurable chlorine residual levels at taps around the city.

There are national drinking water standards, and federal authority is delegated to the states for implementation and licensing of drinking water purveyors. Routine testing should be conducted to ensure that the water quality meets the primary U.S. EPA standards (i.e., the Maximum Contaminant Levels and the Lead and Copper Rule), and any other state and local standards. The MCL for lead is 15 parts per billion. The highest lead reading for drinking water out of a household tap was 13,000 parts per billion, almost 900 times over the allowable limit. (Ref. 4) Kids really were poisoned by lead. Several fatal cases of *Legionnaires' Disease* in and around Flint were linked to Flint drinking water. (Ref. 5) Because Flint residents became reluctant to wash themselves with Flint drinking water, shigellosis, a gastrointestinal bacterial illness, also increased. (Ref. 6)

With oversight from U.S. EPA, the addition of appropriate levels of water treatment chemicals, and the formation of new phosphate coating on metal surfaces, the lead contaminants in Flint's drinking water dropped to about 12 parts per billion in early 2017, but residents still do not trust the public drinking water. (Ref. 7) Flint also decided to stay with Detroit water, rather than switch to Karegnondi during the spring of 2017.

## Acute root causes of Flint crisis

In retrospect, operators were not trained and were not qualified to restart the treatment section of the FWWC. The Flint City Council (and the former mayor and the state appointed emergency manager) would not accept input from the operators at the water works regarding treatment chemicals. And some officials from the State of Michigan turned a blind eye to calls for help. Bundled together, these are the acute root causes, often characterized as social or environmental injustice. The State

## GUEST COLUMN

of Michigan Flint Water Advisory Task Force Report (Ref. 8) is a comprehensive listing (nine pages) of roles, responsibilities, and culpabilities at the local, state and federal level. Local and state officials continue to be charged in connection with the Flint water crisis, including two state cabinet-level officials. (Refs. 9, 10) Yet the report, charges and criticism stem only from the instant crisis.

### Chronic root causes of Flint

Victoria Morckel, PhD – urban planning faculty at the University of Michigan – concludes that the Flint water crisis was decades in the making due to depopulation of its urban area. (Ref. 11) GM and Chevrolet were born in Flint. The FWWC and distribution system had been constructed to service 300,000 people plus the industrial plants. At its height in the 1960s, Flint had a population of 200,000, with 80,000 people employed by the auto industry. The largest auto plant closed in the 1980s, and today the Flint population hovers around 100,000, although the population of Genesee County (with Flint at its center) has remained nearly the same for the past 50 years or so.

As depopulation was occurring, Flint did not reach out to Genesee County to provide or to share services. Nor did Genesee County reach out to Flint for water or to share services with Flint (such as fire and police) as suburban sprawl accelerated. Instead, Flint attempted to maintain its infrastructure (including the FWWC and its distribution system) and services by itself, despite a diminished tax base and a more dispersed population, which in turn lead to less cost efficient services. As a result, Flint has the highest water rates in the United States, has minimal police and fire coverage, high unemployment and low property values.

### Outlook

The acute root causes resulted in a public health crisis that will last at least a generation. U.S. EPA will likely have a presence in Flint through the end of 2017, now that Flint is moving back to Detroit water. The U.S. Department of Health and Human Services will track the children in Flint for the next 20 years, until they youngest of the affected with lead turn 21. Flint and Michigan officials will continue to be charged. However, the chronic root cause began a long time ago, and Flint's inward focus was a major part of the problem.

Indeed, Flint is not the only city in America experiencing depopulation. Our government officials and citizens need to acknowledge depopulation and work together locally and regionally to mitigate its adverse effects. Be aware of your local and county situation, and speak up and get involved if you see something adverse. It is more than simple chemistry.



*Digging a trench on a side street in Flint to replace the lead service line, December 2016. Photo credit: Alan Olson.*

The State of Michigan recently settled a Flint citizens' suit for \$80 million, some for replacing lead service lines which connect drinking water mains to the house. The current practice for replacing lead service lines in Flint is to dig a trench at the curb to locate the service line, then use a horizontal boring machine to run drill pipe from the curb to the basement of a house, guided by a GPS transmitter at the drill bit. A new copper line is threaded inside the drill pipe. The drill pipe is removed, and the copper line is connected via trench to the water main, buried below the middle of the street. The old service line is abandoned. On a good day, two crews of four can replace five or six service lines. At the end of 2016, Flint had replaced fewer than 1,000 of its 29,000 lead service lines. Posters inside Flint City Hall recruit additional crews to replace the lead service lines to supplement those on the streets.



*Old lead service line at bottom of trench, Flint, December 2016. Trench is 4' deep. Photo credit: Alan Olson.*



*New copper service line at bottom of trench, Flint, December 2016. Photo credit: Alan Olson.*

### Final thoughts

Nationally, about seven percent of our drinking water service lines are lead, or about six million lines in total, and concentrated in the Midwest. (Ref. 12) Despite good water treatment technology, many people advocate replacing all lead service lines. But is the current approach employed in Flint the best we can do? Consider this: In addition to the traditional "egg drop" and bridge-building contests for National Engineers Week, maybe we ought to think about a "replace lead service lines" contest. This is a big problem nationwide, and I'd like some creative ideas from our kids. I'd like to hear your thoughts too.



*Old lead service line. Scale in inches. December 2016. Photo credit: Alan Olson.*

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See "Learning from Flint," page 12

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**From "Learning from Flint," page 7**

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