Gilson Middle School

CPVC Plastic Piping Failure Analysis

Richard Armstrong 3/2/21

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Executive Summary

In the 6+ years since completion of the school (August 2014), there were a number of failures in piping, some of which were involved in the hydronic heating system (2) which used copper pipe, and one of which was a leak that appeared in the copper run-out piping to a domestic hot water faucet, which was not the subject of this analysis. Leaks involved exclusively in the CPVC pipe or fittings carrying domestic hot or cold water were in the kitchen (1), in the boiler room (3), and in the gym storage room (2), for a total of six reported CPVC domestic water leaks since school opening.

The kitchen leak was above the ceiling in the food storage area. That leak occurred in a transition fitting that was used to join the CPVC plastic pipe with copper pipe, and was not a leak in the pipe itself, but a transition fitting leak. The transition fitting leak is suspected to have been caused by a contaminated fitting or solvent which caused the solvent to fail to properly adhere to the fitting and pipe, as evidenced by the pipe being able to rotate and leak in the female adaptor. It was exacerbated by the lack of a proper support, which put the pipe under stress as noted in the body of the report.

It is the writer's opinion that the other six failures were all caused by a failure to accommodate for expansion and contraction of the cold water, hot water, and recirculated hot water piping. These failures were basically in only two locations, one being at the wall between the gym storage room and the boiler room (two pipes that had four failures), and the other being at the top of a riser pipe that served cold water (CW) to one of the two hot water generators. It is noted that during the original few years of operation, the hot water recirculation system which is used to assure that hot water will be available as soon as practicable after the hot water is turned on, was cycled on and off daily through a timer to save energy when the school was not occupied. The cycling allowed the hot water piping to contract as it cooled off each night and then expand again when the hot water recirculation pump started again, causing expansion. CPVC pipe, along with all plastic pipe systems, has a relatively large thermal expansion property, so expansion loops and other devices must be installed to compensate for this trait. In these failures, the expansion loop was not professionally installed as discussed in the report.

CPVC piping is reportedly immune to corrosion and degradation from Chlorine based disinfectants and aggressive water which makes it ideal for the Valdez situation. CPVC piping does have varying degrees of incompatibility with certain chemicals which can weaken the pipe and cause eventual failures. CPVC is an amorphous polymer that derives its strength from the fact that it is made up of long chain-like molecules all tangled together according to the manufacturer, Charlotte Pipe and Foundry Company. As described in the manufacturer's white paper titled "Understanding Chemical Incompatibility", some incompatible chemicals can weaken the pipe and cause environmental stress cracking, especially if combined with other stresses such as expansion/contraction forces or lack of proper pipe support. The pipe manufacturer has a program titled the "FBC system compatible program" which goes into more detail regarding incompatible materials. There was no evidence of this type of failure or the presence of incompatible materials touching the pipe. We note that most of the failed components had been disposed of after the repairs were made so further analysis of the failure mode is not possible.

It is concluded that the two locations where all 5 failures occurred were due to thermal expansion and contraction. We recommend that new expansion loops be installed, or pipe clamps be adjusted at these two locations to allow necessary pipe expansion and contraction without damage to the pipe. It is further recommended that the entire installation be inspected, and pipe hangars and clamps be adjusted to allow for thermal expansion, as required in the plans and specifications. There were also two cases of inadequate pipe support which should be addressed, as described in more detail within this report.

Background

The Gilson Middle School (GMS) facility was designed in 2013 and was constructed during 2014 adjacent to the Valdez High School at the same site as the old school. The Valdez School District has had numerous past problems with facilities using copper domestic water piping, so they directed the designers to specify chlorinated polyvinyl chloride (CPVC) piping since CPVC is impervious to most chemicals found in many water supplies. This material has outstanding corrosion resistance, which makes it a superior product over copper due to the water make up at Valdez. At the time of design and construction, Polypropylene piping was not an available option.

After occupancy, some leaks were observed in both the domestic and the hydronic piping systems. In the case of the hydronic system, the leaks were typically seals at control valves or pumps with small leaks, but not actual pipe leaks in the copper piping. One pinhole leak was observed at a kitchen faucet supply, with the cause unknown.

The CPVC plastic piping developed leaks typically at elbows where the highest expansion/contraction stresses typically develop. The City is concerned that the failures may continue and cause damage to the building and disruption to classes, so they have been considering a wholesale replacement of all the CPVC piping in the building, which is estimated to cost over $2.3 million. This study was chartered to try to determine the cause of the failures and determine if the pipe manufacturer is as fault, or if there is a better approach to the issue rather than complete pipe replacement.

Site Visit Findings

A site visit was made to the GMS on February 23-24, 2021. Those in attendance were:

Richard S. Armstrong	Richard S. Armstrong, PE, LLC
Scott Benda	Sr. Project Manager, Inspector, City of Valdez
Rod Morrison	Principal, GMS School
Craig Chafer	Facility Manager, GMS
Bihn Nguyea	Maintenance Tech, GMS School

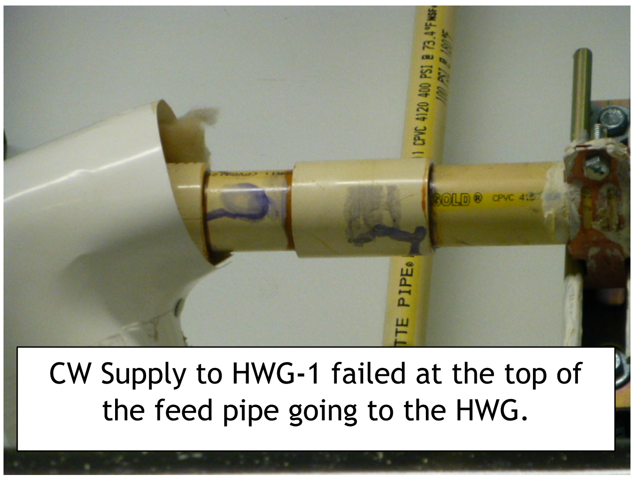
The group walked the school and pointed out areas of old piping leaks, as well as other concerns regarding the piping system. Only two samples of pipe/fitting failures were available, and they were given to the writer for further examination. After the tour, the writer began an independent review of each of the areas of concern, and took readings related to the domestic water system to assist with the failure analysis. Some of the data collected is listed below:

- Hot water generator (HWG) temperature/pressure relief valve (TPRV) setting (typical of both): 150 PSI, 210 deg F. Found HWG-1 was weeping at TPRV discharge line. (probably debris on the valve seat of the TPRV).
- Water service pressure ahead of the pressure regulating valve (PRV), on sprinkler header pipe, with a peak historical reading = 100 PSIG.
- Water service pressure at 3" check valve downstream from water meter = 70 PSIG.
- Water pressure downstream of the service PRV = varies 55-65 PSIG.
- Water pressure at HWG expansion tank overnight high reading = 60 PSIG.
- Water pressure at kitchen hot water (HW) = 60 PSIG.
- Water pressure at kitchen cold water (CW) = 60 PSIG.
- Air pressure on HWG expansion tank bladder = 60 PSIG.
- City water PH read with Litmus paper = 7.0. See water analysis at Exhibit B.
- Hot water temperature at 120F HWG line= 120F.
- Hot water temperature at 140F HWG = 140F.
- Sleeves at fire walls – Outside of pipe insulation.
- Fire stop material – Red in color, between wall and sleeve, no contact with pipe.
- CPVC Pipe ID: Flowguard Gold 11 CPVC 4120, manufacture date 5/29/13. No sign of fading from UV, sunlight.
- Fitting solvent: yellow.
- Hot water recirc pumps: UPS 15-55 SFC (typ of 2), ¾" pipe, 120F water, 140F water. Always on, balance valves set to wide open (Note: recirc had been on a timer but was changed to continuous to reduce daily expansion/contraction in the HW system).
- Voltage potential between copper pipe at kitchen and grounded MC cable jacket: 0 volts AC.
- Paint, grease, wire, Polyurethane foam, fire caulk or other materials on CPVC pipe: none observed.
- Pipe insulation used: Yellow fiberglass pre-formed.
- Shock arrestors observed installed per plans.

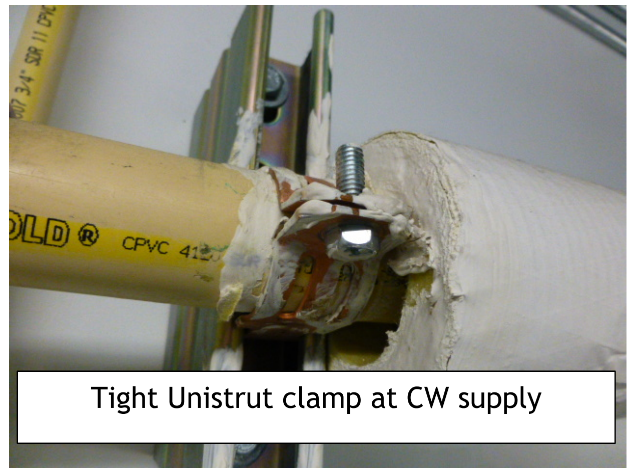
Pipe Failure Observations

1. **Failure #1**: CW feed to HWG-1 at top of pipe: This failure occurred in a 1.5" CW supply pipe that feeds the hot water generator. The CW pipe runs horizontally along the back wall of the boiler room, which feeds both HWG-1 and HWG-2. The pipe or fitting breakage occurred at or close to the downturn elbow at the left (south) end of the horizontal run. (see photo below). There is a Unistrut and clamp within a few inches to the right of the downturn elbow that appears to be cemented to the strut (see photo below), which is made up very tight to the pipe. The vertical pipe that feeds down to the HWG-1 appears to have movement available, but the horizontal run

did not have any movement available up or down or left to right. As cold water flows through the pipe to feed the HWG-1, it can cool from room temperature (Est at 70F) to an estimated 36-degree service temperature for a temperature difference of 34F. The vertical pipe is about 10' long. Charlotte Pipe has published the coefficient of expansion for CPVC pipe to be 0.408 inches/10 deg F/100 LF. The vertical pipe would therefore expand approximately 0.1387" when it went from 70 deg F to 36 deg F. It is recommended that the clamp on the horizontal pipe be loosened to allow vertical and horizonal movement for this expansion and contraction.

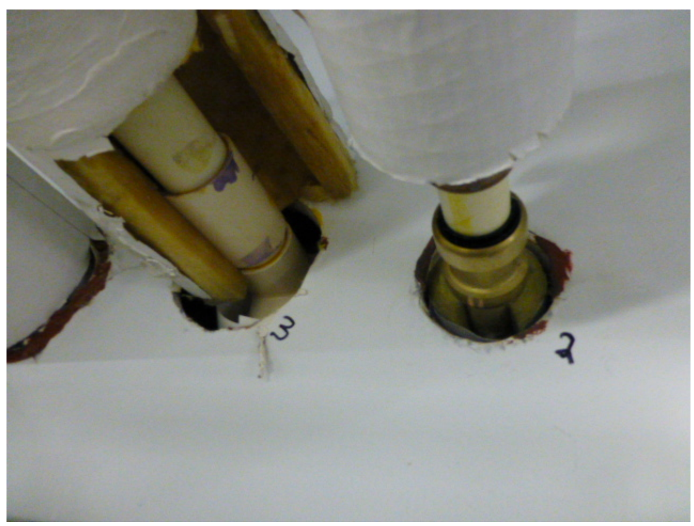


CW Supply to HWG-1 failed at the top of the feed pipe going to the HWG.

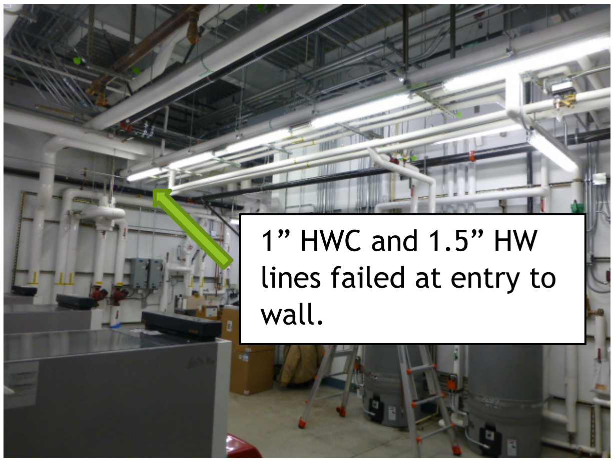


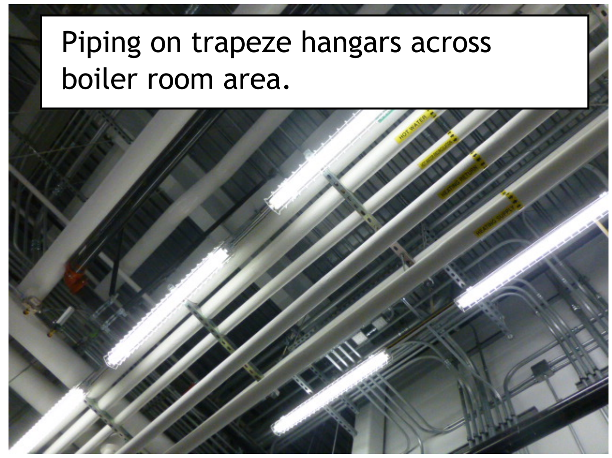
Tight Unistrut clamp at CW supply

2. Failure #2, #3: These two failures occurred high at the plan south wall of the boiler room. The failure shown as #2 was in a 1" CPVC 120-degree hot water recirculation (HWC) line where it went into the wall. We were advised that the leak occurred at the coupling, but we could not verify this since the repair was already completed. A 1" shark bite coupling was used to make the repair. There is a downturn 90-degree elbow just inside the wall that would have restrained thermal expansion and contraction, and which failed at the opposite side of the wall as well at another time. The 1.5" HW pipe just to the left of failure #2 is identified as #3. It also has a 90-degree elbow just inside the wall and is at the end of a run of piping that is supported with trapeze hangars and Unistrut clamps. It appears that expansion could not occur due to the 90-degree downturn elbows at each pipe, and the wall behind trapping those fittings. As noted below, both pipes on the opposite side of the wall also failed at or near the lower 90-degree



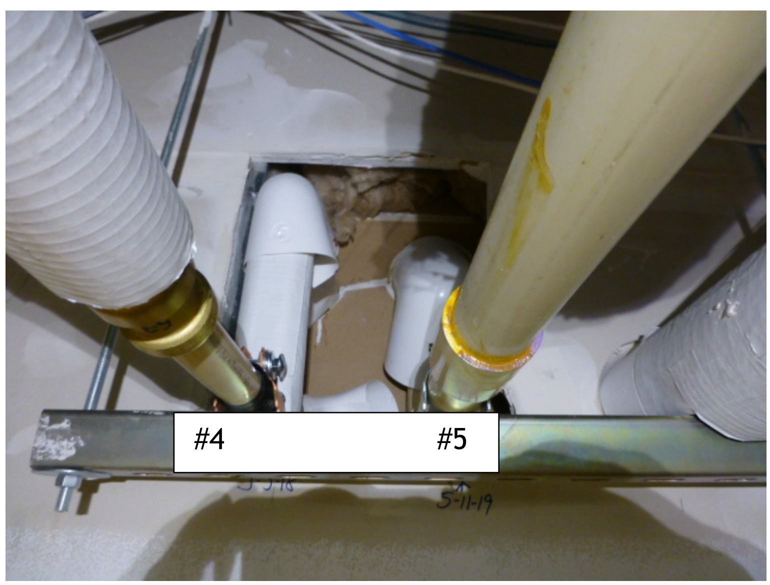
elbow that continued the pipeline service to the south above the lay-in ceiling at the gym storage room.





The length of the straight run of piping on the trapeze hangars was measured to be about 25', and there were no expansion loops or offsets in that run. It was not determined if the Unistrut clamps were loose or tight along the trapeze hangers. Project specifications Section 22 05 29, 2.1 C 5, and 3.3 I do permit use of trapeze hangers, especially where piping is installed parallel and at the same elevation. Section 3.3 M also does require that the hangers be designed for pipe movement without disengagement of supported pipe.

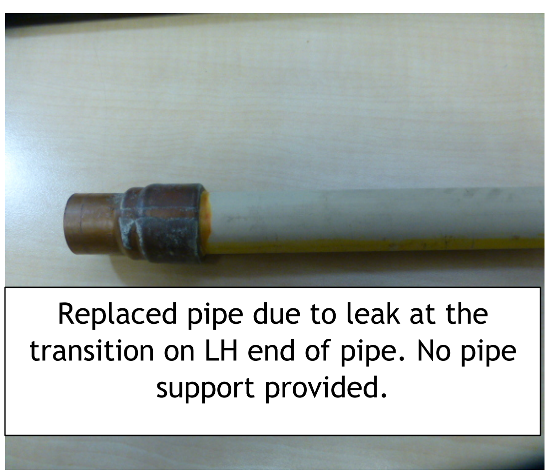
3. **Failure #4, #5:** These two failures occurred on the opposite side (south side) of the boiler room wall above the lay-in ceiling in the gym storage room, on the same two pipes described in failure 2,3 above. Both the 1.5" HW line and the 1" HWC lines failed at or near the lower 90-degree elbow facing the plan north, as the piping continued to the boy's locker room ceiling cavity on the opposite side of the corridor outside of the gym storage wall. As noted on the wall, the 1.5" HW line failed on 5/11/19, and the 1" HWC line failed on 5/3/18. We do not know if the trapeze clamps were tight or loose, but either



way there was no room for thermal expansion. The pipes continue to run to the south to a space above the boy's locker room. Plans 1/M222 and 2/M222 show a 28" offset expansion loop in the piping above the boy's locker room (which has a hard ceiling with no access), but it is not known if the trapeze hanger clamps from failure point 4A and 3A above were loose or tight to adsorb or restrain movement. It is recommended that a horizontal design expansion loop be installed at the south boiler room wall where these four failures occurred, with one horizontal leg for each pipe in the south side of the boiler room and the other horizontal leg for each pipe in the space above the storage room, with a restraint at the loop center. See Exhibit A for sizing details.

CW, HW, HWC piping above drop ceiling in corridor outside entry to boys' locker room. Piping with offset expansion loop is above hard ceiling and is concealed.

4. Failure #6: This was a ¾" CPVC pipe above the kitchen food storage lay-in ceiling. The failure occurred in a copper to CPVC transition coupling. The solvent weld at the transition leaked, and the pipe was able to be twisted at the female transition. It is suspected that the fitting was dirty or inadequate solvent was applied, since there was no fillet of solvent evident at the fitting. The pipe was not adequately supported, that may have stressed the fitting as well. The pipe itself did not leak, only the fitting connection.



Replaced pipe due to leak at the transition on LH end of pipe. No pipe support provided.

5. Potential Failure #1: There is a hot and cold water ¾" CPVC feed to a clothes washer in the receiving room. See detail 5/M801 and 1/M212, upper RH corner of plan leading to washer box P-9. The two pipes each have a water hammer arrestor, but when water is drawn from the piping on the south end of that room, the HW and CW pipes vibrate and move around enough to eventually cause a failure in the piping. Recommend seismic pipe support at the piping, and adjustment of the clevis hangar levels or offset 90s to provide level piping to the wall.

Level ¾" HW and CW and provide additional support to stop vibration and pipe movement.

Exhibit A: Charlotte Pipe Technical Manual

Expansion and Contraction of CTS CPVC

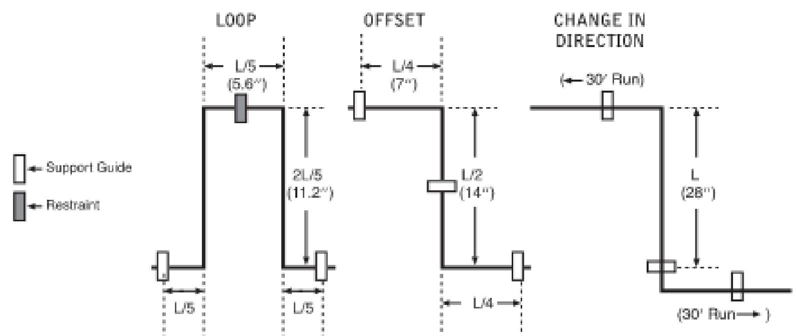
Basic expansion loop requirements for FlowGuard Gold® and ReUze® CTS CPVC are described below. One or more expansion loops, properly sized, may be required in a single straight run. The following charts can be used to determine expansion loop and offset lengths.

Expansion Loop Length (L), inches
for
100°F Temperature Change

Length of Run in Feet

Nominal Dia., In.	20′	40′	60′	80′	100′
½	16	23	28	32	36
¾	19	29	33	38	43
1	22	31	38	44	49
1¼	24	34	42	48	54
1½	26	37	45	52	59
2	30	42	52	60	67

Example: Tubing Size = 1/2″ Length of run = 60′ L = 28″ (from table)



NOTICE

Failure to compensate for expansion and contraction caused by temperature change may result in system failure and property damage.
- Do not restrict expansion or contraction. Restraining movement in piping systems is not recommended and may result in joint or fitting failure.
- Use straps or clamps that allow for piping system movement.
- Align all piping system components properly without strain. Do not bend or pull pipe into position after being solvent welded.
- Do not terminate a pipe run against a stationary object (example: wall or floor joist).
- Do not install fittings under stress.

WHERE DOES MY WATER COME FROM?

The City of Valdez maintains three water systems within the city limits. In 2019 all systems collectively produced over 628 million gallons of water for Valdez consumers. A sanitary survey was conducted in 2019 on all three water systems. A sanitary survey is required every three years.

The Main In-town system provides water to the residences and businesses in the immediate town area. Three wells on Hanagita Street draw water from a groundwater aquifer located approximately 60 feet below the surface, providing water to Reservoir #1 on 'water tower hill'. A second well located on Egan Drive also draws water from an aquifer 60 feet below the surface and stores the water in Reservoir #2, located on the hill behind this station. It is suspected that the water from these two reservoirs is not completely blended in the system, therefore water is monitored from each reservoir to ensure the water tested is representative of the entire system.

The South Central system is now connected with the Loop Road and Airport water systems forming a looped system. Located next to the Senior League field, this station has two wells that draw water from an aquifer located approximately 60 feet below the surface, storing it in the onsite reservoir. Water is supplied to the residences and businesses along Salcha Way, Airport Road, Atigun Street, Sawmill Drive and around Loop Road to the Richardson Highway.

The Robe River water system also draws water from an aquifer located roughly 60 feet below the surface and stored in the onsite reservoir. This system provides water to all the service connections in the Robe River subdivision.

SOURCE WATER ASSESSMENTS have been completed by the ADEC as a first step towards voluntary local source water protection efforts. Vulnerability ratings are assigned based on the susceptibility of the drinking water source, recent sampling results and the presence of potential contaminant sources – they do not necessarily indicate these contaminants will reach your source water.

The Main In-town water system has received a vulnerability rating of 'Very High' for nitrates and nitrites, volatile organic chemicals, heavy metals, cyanide and other inorganic chemicals, and other organic chemicals and a vulnerability rating of 'High' for bacteria and viruses and synthetic organic chemicals.

The South Central water system has received a vulnerability rating of 'High' for bacteria and viruses, nitrates and nitrites, volatile organic chemicals, heavy metals, cyanide and other inorganic chemicals, and other organic chemicals and a vulnerability rating of 'Medium' for synthetic organic chemicals.

The Robe River water system has received a vulnerability rating of 'High for bacteria and viruses, nitrates and nitrites, and volatile organic chemicals and a vulnerability rating of 'Medium' for heavy metals, cyanide and other inorganic chemicals, synthetic organic chemicals and other organic chemicals.

The Planning and Zoning Commission has been designated as the Source Water Protection Planning Team. For more information on scheduled meetings contact Community Development at 834-3404.

Water Quality Testing

Because of the numerous potential source and varieties of contaminants, state and federal law mandates the routine testing of all contaminants known to pose a risk to public health. Some contaminants can affect water sources very quickly and others are not expected to vary significantly from year to year. Therefore testing frequency varies from weekly to once every nine years, depending on risk and contaminant. Your water is tested for all applicable hazardous contaminants, however only those detected are listed in the adjacent table.

CONTAMINANT	MCL	MCLG	Units	Main In-Town Reservoir #1 PWSID 298103	Main In-Town Reservoir #2 PWSID 298103	South Central PWSID 291229	Robe River PWSID 291211	Year Tested	Possible Source of Contamination
NITRATE (as Nitrogen)	10	10	mg/l	0.952	0.681	0.255	0.491	2019	Leaching from septic tanks; erosion of natural deposits.
COPPER	1.3 (AL)	1.3	mg/l	0.235*	0.235*	0.054	0.128	2017	Corrosion of household plumbing systems.
LEAD	15(AL)	0	ug/l	3.16*	3.16*	2.94	2.41	2017	Corrosion of household plumbing systems.
Radium (combined 226/228)	5	0	pCi/L	0.30	0.60	0.11	0.55	2016	Erosion of natural deposits
Alpha emitters	15	0	pCi/L	0.45	-0.17	-0.720	1.50	2016	Erosion of natural deposits
Barium	<2000	0	ug/l	3.87	ND	ND	27.5	2019	Erosion of natural deposits

Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. MCL's are set as close to the MCLG's as feasible using the best available technology.
Maximum Contaminant Level Goal (MCLG); The level of a contaminant in drinking water below which there is no known or expected health risk. MCLG's allow for a margin of safety.
Action Level (AL): The concentration of a contaminant, which if exceeded triggers treatment or other requirements which a water system must follow.
Milligrams per liter (mg/l): One part per million parts.
Micrograms per liter (ug/l): One part per billion parts.
Picocuries per liter (pCi/L): A unit of Radioactivity.
ND: None detected.
* Collected in 2018

***** Tampering with a water facility is a FEDERAL OFFENSE. Please report all suspicious activity to 835-4560. *****

Exhibit B: City of Valdez Water Analysis