Appendix C.6

Water Supply System Engineering Report

Water Supply System Engineering Report

Hilltop Village at Wappinger

Town of Wappinger, New York

September 30, 2011

Revised January 2, 2012

STATE OF NEW YORK
WILLIAM H. POVALL III
075020-1
LICENSED PROFESSIONAL ENGINEER

POVALL ENGINEERING, PLLC

25 Corporate Park Drive, Suite C

Hopewell Junction, New York 12533

Project No. 0552

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1 Introduction

The Applicant, Toll Brothers, Inc., is proposing to develop a 145.30 acres of a 149.35 acre parcel located at All Angels Hill Road (CR 94) in the Town of Wappinger, New York. "The "Hilltop Village at Wappinger" is a 225 unit age restricted residential development located in the Town of Wappinger. The residential development consists of 132 single family homes, 93 townhomes, and a club house with recreational facilities (e.g., swimming pool and tennis court). The site is identified on the Town of Wappinger Tax Map as Tax Number 6257-02-630770.

The Dutchess County Department of Health (DCDOH) in conjunction with the Town Engineer (Morris Associates) and CAMO Pollution Control, Inc. (water operator) will be responsible for the review and approval of the water distribution system, since the project is located Dutchess County and will connect to the Town of Wappinger sanitary water system.

The proposed water distribution system will conform to the requirements defined in 10 NYCRR Subpart 5-1 of the New York State Sanitary Code, which references the design standards in the *Great Lakes - Upper Mississippi River Board of State Public Health and Environmental Managers Recommended Standards for Water Works*, 2007 (also known as *Ten States Standards for Water*). The proposed water service will also conform to the requirements of the *DCDOH Water and Wastewater Systems Design and Construction Standards*, effective version and the National Fire Protection Association (NFPA) standards for fire protection and Town of Wappinger Water Department requirements.

2 Site Description

The parcel is located on All Angels Hill Road (CR 94) in the Town of Wappinger, Dutchess County, New York (see Figure 1). This parcel is bounded by All Angels Hill Road (CR 94) to the east, a commercial property to the north, and residential properties to the north, south, and west.

The site is currently undeveloped with the exception of a commercial paved driveway, which provides access to the adjacent Flavormatic business. The ground cover consists of a paved driveway, woods, and grass. The site varies in elevation from 256 feet, at the lowest elevation in the northwestern corner of the property, to 398 feet, at the highest elevation on a knoll in the middle of the site.

3 Projected Water Demands

3.1 Domestic Water Demand

The proposed residential development will require water service for both domestic and fire protection purposes. The Town of Wappinger has specific average daily flow rates for the single family homes and the townhomes, which will be used in lieu of the NYSDEC unit flow rates. The anticipated water demand for the club house will be determined by using the unit flow rates in the New York State Department of Environmental Conservation (NYSDEC) *Design Standards for Wastewater Treatment Works*, 1988. The anticipated water demand from each of the uses on the site is summarized in Table 1 below.

Table 1: Anticipated Domestic Water Demand

Use Type	Size	Unit	Flow Rate per Unit (gpd)	Wastewater Generation (gpd)
Single Family Homes	132	homes	320[(1)]	42,240
Townhomes	93	homes	200[(2)]	18,600
Club House	3,762	Sq. ft.	0.08[(3)]	301
Swimming Pool (1,071 sf)[(4)]	71	swimmers	10[(5)]	710
			Total	**61,851**

(1) The average daily use for a single family home with no more than four-bedrooms per residential unit in accordance with the Town of Wappinger's practices (Chapter 236-6 of the Town Code).
(2) The average daily use for a two-bedroom apartment/unit in accordance with the Town of Wappinger's practices (Chapter 236-6 of the Town Code).
(3) Water saving plumbing fixtures will be used and the NYSDEC *Design Standards for Wastewater Treatment Works* permits a 20 percent reduction in the hydraulic loading rate. The values shown have already been reduced by 20 percent.
(4) Number of swimmers/bathers is estimated on the basis of 15 sf of pool water surface area per patron as recommended in NYS Sanitary Code Subpart 6-1.
(5) NYSDEC *Design Standards for Wastewater Treatment Works* hydraulic loading rate without water saving plumbing fixture reduction.

3.2 Fire Suppression Needs

The residential development is in the Town of Wappinger New Hackensack Fire District. A network of fire hydrants will be provided within the development to provide fire suppression needs. The fire hydrants will also be used for water line flushing, when necessary.

The Insurance Services Office (ISO) formula will be used to determine the fire flow requirements for the proposed buildings. ISO uses the following formula to determine the Needed Fire Flow (NFFi):

$$NFF_i=(C_i)(O_i)(1.0+(X+P)_i)$$

Where:

NFF_i = needed fire flow (gpm)
C_i = construction factor, where $C=18(F)(A_i)^{0.5}$
F = construction class
A_i = effective area
O_i = occupancy factor
X_i = exposure factor
P_i = factor for communication between buildings

The needed fire flows used by ISO for one- and multi-family dwellings not exceeding two stories in height is summarized in Table 2 below.

Table 2: ISO Needed Fire Flow for Residential Dwellings

Distance Between Buildings	Needed Fire Flow (gpm)
More than 100’	500
31-100’	750
11-30’	1,000
10’ or less	1,500

Using Table 2 and the various separation distances between the buildings, needed fire flow ranges were determined for the single family homes and townhomes. The needed fire flow range for the single family homes is 750 to 1,000 gpm and for the townhomes is 750 to 1,500 gpm. For design purposes, the required fire flow is:

Single Family Homes = **1,000 gpm**.
Townhomes = **1,500 gpm**.

Using the needed fire flow formula, the needed fire flow for the club house was determined to be:

$$NFF_i = (18 \times 1.0 \times 3{,}762^{0.5})x(0.85)x(1.0+(0+0)) = 938 \text{ gpm}$$

Rounded to the nearest 250 gpm, the needed fire flow for the community center is **1,000 gpm**.

4 Proposed Water Source

The proposed project is located in the United Wappinger Water District (UWWD). The project will require water service for both domestic and fire protection purposes. The project is proposed to connect to the existing Town water system at two (2) locations to meet both requirements. The proposed water main will connect to the existing water line tee in the Shamrock Hills subdivision to the west and the existing water line located beneath Rich Drive to the east. The proposed water distribution system will be designed to serve all of the residential homes and community center. Water service from the main to each of the residential homes and community center building will be provided through individual service line connections.

The proposed project is in the New Hackensack Fire District. Based upon a discussion with Rick Anderson of this facility, New Hackensack Fire District owns the following pieces of Fire Apparatus:

- Three Class A Pumpers which all have 1,500 gallons per minute (gpm) pumps and 1,000 gallons water tanks.
- One Water Tankers with 2,000 gallons of water and 350 gpm pumps on each.
- One Heavy Duty Rescue Truck.
- Two Utility Trucks with a 150 gallon water tank and a 150 pounds per square inch (psi) pump.
- Three four-wheel drive trucks.

Based upon a discussion with Rick Anderson, the New Hackensack Fire District would have no difficulty providing fire protection to the proposed development. In addition, hydrants will also be provided throughout the development for fire protection.

5 Proposed Water Distribution System

5.1 Design and Layout

The proposed water distribution system will be designed to serve all of the residential homes and community center. The water main will be an 8-inch Class 52, cement-lined ductile iron pipe complying with the American Water Works Association (AWWA) Standards C151 and C104. The water main will generally be in or along roadways or parking areas. A ten foot horizontal separation distance and an 18-inch vertical separation distance will be provided between sanitary sewer and stormwater lines. All water distribution and service lines will be installed at a minimum of five feet below finished grade to provide for frost protection.

Water service from the main to each of the single family homes, townhomes, and club house building will be provided through individual service lines. The service lines for the single family homes and townhomes will be ¾ to 1 inch Type K copper or HDPE SDR-9 with a corporation stop at the main and a curb stop near the pavement line. The water service and fire suppression lines for the community center will be a 1-½ inch Type K copper or HDPE SDR-9 and 6-inch Class 52 cement-lined ductile iron pipe, respectively, with valves placed near the pavement line.

Isolation valves will be placed at not more than 800-foot intervals along the water mains. Hydrant spacing will be dependent on the final site design; however, hydrant spacing will be between 350 and 600-feet. Placement and spacing of the hydrants will be in accordance with ISO standards and *Ten States Standards for Water*.

5.2 Analysis

The hydrant pressures at Rich Drive and at the easement between Shamrock Hills Drive and Maxwell Place were provided by the Town Engineer and CAMO Pollution Control, Inc. The hydrant pressure at Rich Drive was 83 psi. The hydrant pressure at the easement between Shamrock Hills Drive and Maxwell Place is 46 psi (see Appendix A).

The proposed water distribution system "floats" off of the storage tank located off of Cider Mill Loop Road (see Figure 2) in the western portion of the Town of Wappinger. According to the "Engineer's Report Water Supply System Shamrock Hills Subdivision" prepared by Povall Engineering, PLLC last revised February 22, 2006 and approved by the DCDOH on August 16, 2006, the atmospheric tank is located at an isolated high point with an overflow elevation of approximately 470 and a normal minimum working elevation of 464 as reported by the Town Engineer and CAMO Pollution Control, Inc. (Town Water System Operator). The tank is located approximately 4,750 feet from the proposed Rich Drive connection and approximately 12,050 feet from the tee connection in the ROW off of Shamrock Hills Drive.

The static pressure for each of the units was analyzed when the water elevation within the storage tanks at the overflow level and at the normal minimum working level. Given the existing configuration of the water distribution system and the fact that the water distribution system will be looped within the proposed development, pressure losses due to friction (flow conditions) are assumed to be minimal and not significant. Therefore, the system pressures were analyzed for the static condition.

The highest static pressure will occur at the lowest proposed home elevation (S107) with the water elevation within the storage tanks at the overflow:

S107 FFE = 315.1
Atmospheric or 0 psi = water elevation at 470 at the tank overflow

$h_s = h_b - h_a = 470 - 315.1 = 155$ ft elevation change
$P_{static} = 155 \text{ ft} \times 62.4 \text{ lb/ft}^3 \times (1 \text{ sf}/144 \text{ in}^2) = \mathbf{67\ psi}$.

The normal lowest static pressure will occur at the proposed townhomes T51 and T52 with the water elevation within the storage tank at the normal minimum working level:

T51 and T52 FFE = 383.2
Atmospheric or 0 psi = water elevation at 464 at the tank overflow

$h_s = h_b - h_a = 464 - 383.2 = 81$ ft elevation change
$P_{static} = 81 \text{ ft} \times 62.4 \text{ lb/ft}^3 \times (1 \text{ sf}/144 \text{ in}^2) = \mathbf{35\ psi}$.

According to Section 8.2.1 "Pressure" of the *Ten States Standards for Water Works*, all water mains, including those not designed to provide fire protection, shall be sized after a hydraulic analysis based on flow demands and pressure requirements. The system shall be designed to maintain a minimum pressure of 20 psi at ground level at all points in the distribution system under all conditions of flow.

The normal working pressure ranges from 35 to 67 psi. The anticipated minimum static pressure within the proposed development complies with the minimum recommended working pressure. Although typical plumbing and appurtenances are capable of accommodating 100 psi pressures, individual pressure reduction valves will be specified for all homes where pressure at the meter will be in excess of 80 psi. The calculated static pressure for each of the units is provided in Appendix B.

6 Existing Well Abandonment

An existing well was located approximately 179 feet east of the existing sanitary sewer line running parallel to All Angels Hill Road during the Phase 1B Archeological Investigation (see Figure 3). The existing well shall be abandoned prior to the commencement of construction. A permit shall be obtained from the Dutchess County Department of Health prior to abandonment. If the well is very deep and narrow, it shall be sealed it with either bentonite or concrete. If the well is shallow and wide, it shall be backfilled. The well abandonment shall be certified in writing to the DCDOH by a NYS licensed professional engineer.

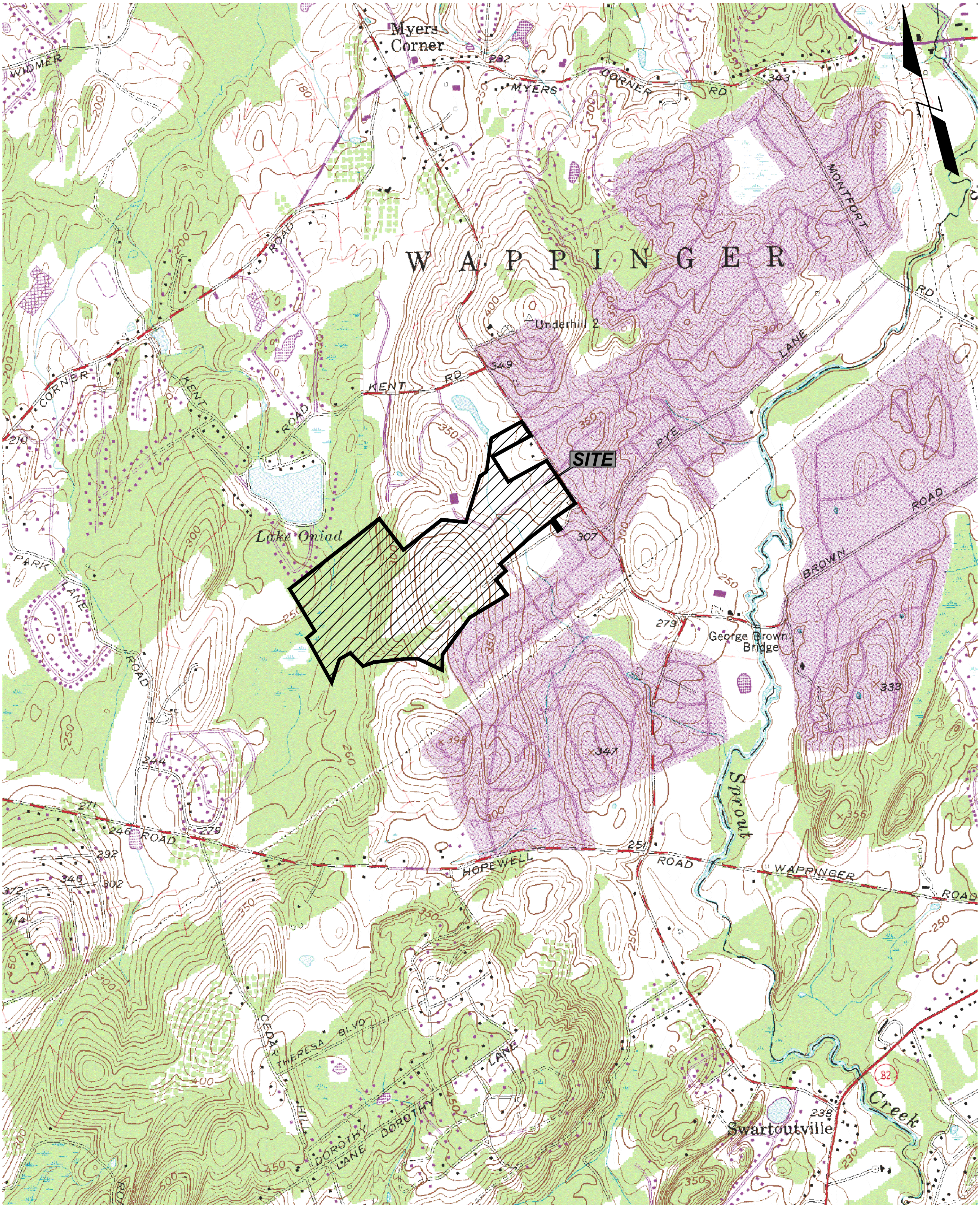
7 System Testing

The water mains shall be pressure tested in accordance with AWWA Standard C600 and disinfected with a chlorine solution in accordance with AWWA Standard C651 prior to being placed in service. The tablet method of disinfection shall not be used. The Engineer shall provide a certification letter to the DCDOH and Town once the testing has been completed. The testing and disinfection standards have been provided in Appendix C for reference purposes.

8 Conclusions

The existing water system has sufficient capacity to service the 225 unit age restricted residential development. The proposed water supply system has been designed in accordance with the *Ten States Standards for Water*, 2007; the DCDOH *Water and Wastewater Systems Design and Construction Standards*, effective version; and the National Fire Protection Association (NFPA) standards for fire protection and meets all Town of Wappinger requirements.

Figures



WAPPINGERS FALLS AND HOPEWELL JUNCTION QUADRANGLES

POVALL ENGINEERING, PLLC

WILLIAM H. POVALL III, P.E.
N.Y.S.P.E. LICENSE #075020

25 CORPORATE PARK DR., SUITE C
HOPEWELL JUNCTION, NY 12533

TEL.: (845) 897-8205
FAX: (845) 897-0042

HILLTOP VILLAGE AT WAPPINGER

USGS SITE LOCATION MAP

TOWN OF WAPPINGER — DUTCHESS COUNTY, NEW YORK

JOB #: 0552
DATE: 06/27/11
SCALE: 1"=2000'

FIGURE 1

File Path: R:\PE\DRAWINGS\0500\0552\dwg\0552_SWA 2011-09.dwg, Layout: FIG 1 USGS

REVISIONS	
DATE:	DESCRIPTION:

LEGEND

—W—W—W— *EXISTING WATER LINE*

▭ *EXISTING WATER STORAGE TANKS*

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N.Y.S.P.E. LICENSE #075020

25 CORPORATE PARK DR., SUITE C
HOPEWELL JUNCTION, NY 12533

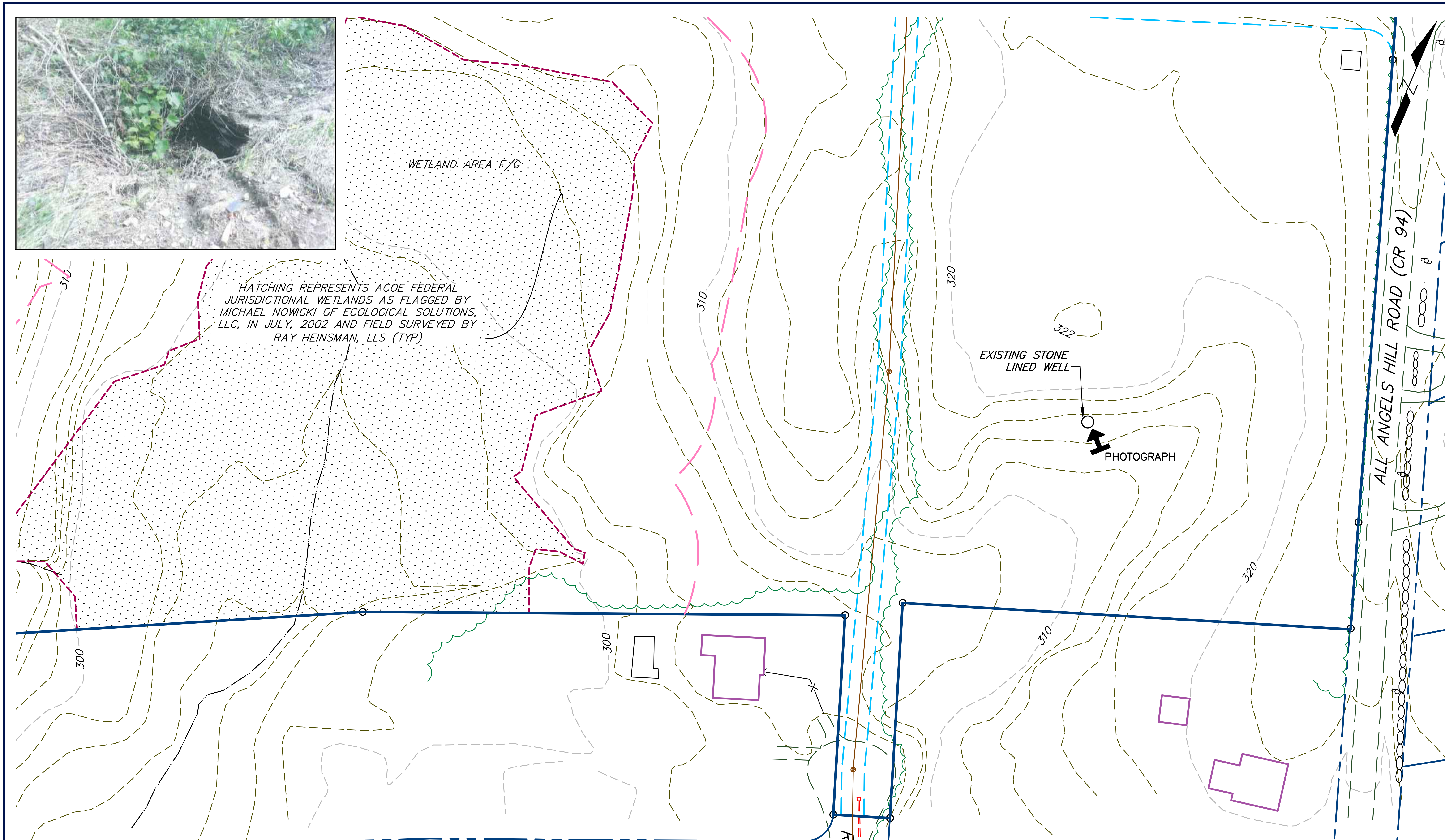
TEL.: (845) 897-8205
FAX: (845) 897-0042

HILLTOP VILLAGE AT WAPPINGER

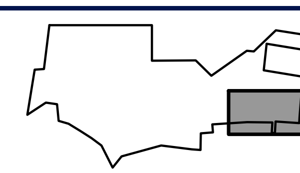
CIDER MILL LOOP ROAD EXISTING WATER STORAGE TANKS

TOWN OF WAPPINGER *DUTCHESS COUNTY, NEW YORK*

JOB #: 0552
DATE: 08/03/11
SCALE: 1"=600'
FIGURE 2



REVISIONS	
DATE:	DESCRIPTION:



POVALL ENGINEERING, PLLC

WILLIAM H. POVALL III, P.E.
N.Y.S.P.E. LICENSE #075020
25 CORPORATE PARK DR., SUITE C
HOPEWELL JUNCTION, NY 12533
TEL.: (845) 897-8205
FAX: (845) 897-0042

HILLTOP VILLAGE AT WAPPINGER

STONE LINED WELL

TOWN OF WAPPINGER DUTCHESS COUNTY, NEW YORK

JOB #: 0552
DATE: 08/03/11
SCALE: 1"=80'
FIGURE 3

Appendix A

Town Correspondence

HILLTOP VILLAGE – WATER

SmartZone Communications Center

bpovall@comcast.net

± Font size -

From : camocpinc@aol.com Wed Jun 15 2011 8:53:36 AM
Subject : <No Subject>
To : bpovall@comcast.net, RGray@MorrisEngineers.com

Bill, Bob:

The following information is a result of our discussions at the 6/14/2011 meeting regarding Hilltop Village:

1) CAMO checked the hydrant pressures on Rich Drive (83 lbs.) and Shamrock at the easement to Maxwell Place (46 lbs.).

2) We reviewed the location of the water mains at Rich Drive and Hilltop Drive. It would be best if both locations were looped through Hilltop Village.

3) CAMO will put blue marks on Rich Drive where the water main is located. The water main is believed to be 8 inch.

Mike Tremper
CAMO Pollution Control, Inc.

Appendix B

Design Calculations

POVALL ENGINEERING, PLLC
25 Corporate Park Drive, Suite C
Hopewell Junction, NY 12533
P: (845) 897-8205
F: (845) 897-0042

Job Name:	Hilltop Village at Wappinger	**Job No.:**	0552
Location:	All Angels Hill Road		
Municipality:	Town of Wappinger	**County:**	Dutchess
Prepared By:	CMZ	**Revised By:**	
Date:	9/21/11	**Rev. Date:**	
Reviewed By:	WHP	**Reviewed By:**	

STATIC PRESSURE CALCULATIONS

Water elevation within water storage tanks at:

Overflow = 470 ft

Normal minimum working level = 464 ft

Unit	Finshed Floor Elevation (ft)	Static Pressure @ Overflow (psi)	Static Pressure @ Normal (psi)	Pressure Reduction Valve Required
Club House	340.0	56.3	53.7	no
S1	360.7	47.4	44.8	no
S2	364.2	45.8	43.2	no
S3	367.7	44.3	41.7	no
S4	371.2	42.8	40.2	no
S5	374.7	41.3	38.7	no
S6	376.2	40.6	38.0	no
S7	373.9	41.6	39.0	no
S8	371.4	42.7	40.1	no
S9	368.3	44.1	41.5	no
S10	364.6	45.7	43.1	no
S11	360.7	47.4	44.8	no
S12	357.2	48.9	46.3	no
S13	355.6	49.6	47.0	no
S14	356.2	49.3	46.7	no
S15	357.9	48.6	46.0	no
S16	361.8	46.9	44.3	no
S17	365.3	45.4	42.8	no
S18	368.8	43.9	41.3	no
S19	371.4	42.7	40.1	no
S20	371.8	42.6	40.0	no
S21	371.0	42.9	40.3	no
S22	369.0	43.8	41.2	no
S23	366.3	44.9	42.3	no
S24	363.6	46.1	43.5	no
S25	360.8	47.3	44.7	no
S26	358.1	48.5	45.9	no
S27	355.3	49.7	47.1	no
S28	352.5	50.9	48.3	no
S29	350.1	52.0	49.4	no

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F: (845) 897-0042

Unit	Finshed Floor Elevation (ft)	Static Pressure @ Overflow (psi)	Static Pressure @ Normal (psi)	Pressure Reduction Valve Required
S30	371.8	42.6	40.0	no
S31	370.8	43.0	40.4	no
S32	369.1	43.7	41.1	no
S33	367.2	44.5	41.9	no
S34	365.3	45.4	42.8	no
S35	356.5	49.2	46.6	no
S36	355.7	49.5	46.9	no
S37	356.4	49.2	46.6	no
S38	357.7	48.7	46.1	no
S39	359.9	47.7	45.1	no
S40	362.0	46.8	44.2	no
S41	368.4	44.0	41.4	no
S42	370.5	43.1	40.5	no
S43	373.3	41.9	39.3	no
S44	375.5	41.0	38.4	no
S45	378.2	39.8	37.2	no
S46	379.9	39.0	36.4	no
S47	373.9	41.6	39.0	no
S48	371.3	42.8	40.2	no
S49	355.9	49.4	46.8	no
S50	357.5	48.8	46.2	no
S51	359.4	47.9	45.3	no
S52	361.3	47.1	44.5	no
S53	363.2	46.3	43.7	no
S54	365.2	45.4	42.8	no
S55	366.8	44.7	42.1	no
S56	366.5	44.9	42.3	no
S57	364.3	45.8	43.2	no
S58	365.2	45.4	42.8	no
S59	366.0	45.1	42.5	no
S60	368.0	44.2	41.6	no
S61	366.8	44.7	42.1	no
S62	366.3	44.9	42.3	no
S63	365.2	45.4	42.8	no
S64	363.5	46.2	43.6	no
S65	361.0	47.2	44.6	no
S66	359.1	48.1	45.5	no
S67	357.2	48.9	46.3	no
S68	355.6	49.6	47.0	no
S69	343.6	54.8	52.2	no
S70	339.2	56.7	54.1	no
S71	334.9	58.5	55.9	no

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F: (845) 897-0042

Unit	Finshed Floor Elevation (ft)	Static Pressure @ Overflow (psi)	Static Pressure @ Normal (psi)	Pressure Reduction Valve Required
S72	330.5	60.5	57.9	no
S73	326.6	62.1	59.5	no
S74	323.8	63.4	60.8	no
S75	320.5	64.8	62.2	no
S76	317.2	66.2	63.6	no
S77	315.2	67.1	64.5	no
S78	318.0	65.9	63.3	no
S79	318.0	65.9	63.3	no
S80	320.3	64.9	62.3	no
S81	323.6	63.4	60.8	no
S82	326.3	62.3	59.7	no
S83	329.0	61.1	58.5	no
S84	331.7	59.9	57.3	no
S85	335.2	58.4	55.8	no
S86	338.0	57.2	54.6	no
S87	340.8	56.0	53.4	no
S88	345.1	54.1	51.5	no
S89	357.3	48.8	46.2	no
S90	355.8	49.5	46.9	no
S91	353.7	50.4	47.8	no
S92	351.4	51.4	48.8	no
S93	349.1	52.4	49.8	no
S94	346.5	53.5	50.9	no
S95	344.2	54.5	51.9	no
S96	341.9	55.5	52.9	no
S97	339.7	56.5	53.9	no
S98	336.4	57.9	55.3	no
S99	333.7	59.1	56.5	no
S100	331.0	60.2	57.6	no
S101	328.3	61.4	58.8	no
S102	325.0	62.8	60.2	no
S103	322.3	64.0	61.4	no
S104	319.6	65.2	62.6	no
S105	317.3	66.2	63.6	no
S106	316.6	66.5	63.9	no
S107	315.1	67.1	64.5	no
S108	315.2	67.1	64.5	no
S109	316.2	66.6	64.0	no
S110	320.3	64.9	62.3	no
S111	322.8	63.8	61.2	no
S112	325.6	62.6	60.0	no
S113	328.2	61.4	58.8	no

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F: (845) 897-0042

Unit	Finshed Floor Elevation (ft)	Static Pressure @ Overflow (psi)	Static Pressure @ Normal (psi)	Pressure Reduction Valve Required
S114	330.8	60.3	57.7	no
S115	333.1	59.3	56.7	no
S116	335.5	58.3	55.7	no
S117	337.7	57.3	54.7	no
S118	340.4	56.2	53.6	no
S119	342.8	55.1	52.5	no
S120	345.2	54.1	51.5	no
S121	347.6	53.0	50.4	no
S122	350.9	51.6	49.0	no
S123	353.5	50.5	47.9	no
S124	356.2	49.3	46.7	no
S125	358.9	48.1	45.5	no
S126	361.9	46.8	44.2	no
S127	364.2	45.8	43.2	no
S128	363.0	46.4	43.8	no
S129	367.7	44.3	41.7	no
S130	365.2	45.4	42.8	no
S131	362.7	46.5	43.9	no
S132	360.3	47.5	44.9	no
T1	350.7	51.7	49.1	no
T2	352.5	50.9	48.3	no
T3	353.3	50.6	48.0	no
T4	356.1	49.4	46.8	no
T5	357.3	48.8	46.2	no
T6	360.4	47.5	44.9	no
T7	361.6	47.0	44.4	no
T8	364.0	45.9	43.3	no
T9	364.9	45.5	42.9	no
T10	366.8	44.7	42.1	no
T11	367.7	44.3	41.7	no
T12	369.4	43.6	41.0	no
T13	367.6	44.4	41.8	no
T14	361.5	47.0	44.4	no
T15	359.2	48.0	45.4	no
T16	358.0	48.5	45.9	no
T17	355.9	49.4	46.8	no
T18	354.4	50.1	47.5	no
T19	371.4	42.7	40.1	no
T20	369.7	43.5	40.9	no
T21	366.5	44.9	42.3	no
T22	365.9	45.1	42.5	no
T23	362.8	46.5	43.9	no

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Unit	Finshed Floor Elevation (ft)	Static Pressure @ Overflow (psi)	Static Pressure @ Normal (psi)	Pressure Reduction Valve Required
T24	365.1	45.5	42.9	no
T25	368.4	44.0	41.4	no
T26	368.9	43.8	41.2	no
T27	369.2	43.7	41.1	no
T28	368.2	44.1	41.5	no
T29	367.5	44.4	41.8	no
T30	366.3	44.9	42.3	no
T31	364.4	45.8	43.2	no
T32	364.2	45.8	43.2	no
T33	364.3	45.8	43.2	no
T34	364.8	45.6	43.0	no
T35	365.8	45.2	42.6	no
T36	365.7	45.2	42.6	no
T37	367.3	44.5	41.9	no
T38	367.0	44.6	42.0	no
T39	368.8	43.9	41.3	no
T40	369.4	43.6	41.0	no
T41	370.4	43.2	40.6	no
T42	371.3	42.8	40.2	no
T43	372.7	42.2	39.6	no
T44	379.2	39.3	36.7	no
T45	381.8	38.2	35.6	no
T46	382.2	38.0	35.4	no
T47	381.2	38.5	35.9	no
T48	379.1	39.4	36.8	no
T49	380.7	38.7	36.1	no
T50	382.5	37.9	35.3	no
T51	383.2	37.6	35.0	no
T52	383.2	37.6	35.0	no
T53	381.2	38.5	35.9	no
T54	321.2	64.5	61.9	no
T55	321.2	64.5	61.9	no
T56	322.2	64.0	61.4	no
T57	323.5	63.5	60.9	no
T58	324.9	62.9	60.3	no
T59	325.9	62.4	59.8	no
T60	326.4	62.2	59.6	no
T61	326.3	62.3	59.7	no
T62	326.1	62.4	59.8	no
T63	325.5	62.6	60.0	no
T64	324.8	62.9	60.3	no
T65	323.8	63.4	60.8	no

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25 Corporate Park Drive, Suite C
Hopewell Junction, NY 12533
P: (845) 897-8205
F: (845) 897-0042

Unit	Finshed Floor Elevation (ft)	Static Pressure @ Overflow (psi)	Static Pressure @ Normal (psi)	Pressure Reduction Valve Required
T66	322.2	64.0	61.4	no
T67	320.7	64.7	62.1	no
T68	319.2	65.3	62.7	no
T69	317.4	66.1	63.5	no
T70	316.8	66.4	63.8	no
T71	317.7	66.0	63.4	no
T72	319.5	65.2	62.6	no
T73	321.2	64.5	61.9	no
T74	322.1	64.1	61.5	no
T75	323.9	63.3	60.7	no
T76	321.7	64.3	61.7	no
T77	320.9	64.6	62.0	no
T78	320.3	64.9	62.3	no
T79	318.8	65.5	62.9	no
T80	317.9	65.9	63.3	no
T81	317.4	66.1	63.5	no
T82	317.3	66.2	63.6	no
T83	318.0	65.9	63.3	no
T84	319.5	65.2	62.6	no
T85	320.2	64.9	62.3	no
T86	320.9	64.6	62.0	no
T87	322.1	64.1	61.5	no
T88	323.8	63.4	60.8	no
T89	322.3	64.0	61.4	no
T90	321.6	64.3	61.7	no
T91	321.2	64.5	61.9	no
T92	320.1	65.0	62.4	no
T93	320.4	64.8	62.2	no

Notes:

(yellow)	= lowest static pressure
(orange)	=highest static pressure

Appendix C

Testing & Disinfection Standards

ANSI/AWWA C600-05
(Revision of ANSI/AWWA C600-99)

American Water Works
Association

The Authoritative Resource on Safe Water℠

AWWA Standard

Installation of Ductile-Iron Water Mains and Their Appurtenances

American National Standards Institute

Effective date: Dec. 1, 2005.
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6666 West Quincy Avenue
Denver, CO 80235-3098
T 800.926.7337
www.awwa.org

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Sections

AWWA Standard

This document is an American Water Works Association (AWWA) standard. It is not a specification. AWWA standards describe minimum requirements and do not contain all of the engineering and administrative information normally contained in specifications. The AWWA standards usually contain options that must be evaluated by the user of the standard. Until each optional feature is specified by the user, the product or service is not fully defined. AWWA publication of a standard does not constitute endorsement of any product or product type, nor does AWWA test, certify, or approve any product. The use of AWWA standards is entirely voluntary. AWWA standards are intended to represent a consensus of the water supply industry that the product described will provide satisfactory service. When AWWA revises or withdraws this standard, an official notice of action will be placed on the first page of the classified advertising section of *Journal AWWA*. The action becomes effective on the first day of the month following the month of *Journal AWWA* publication of the official notice.

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether that person has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review, and users are cautioned to obtain the latest editions. Producers of goods made in conformity with an American National Standard are encouraged to state on their own responsibility in advertising and promotional materials or on tags or labels that the goods are produced in conformity with particular American National Standards.

CAUTION NOTICE: The American National Standards Institute (ANSI) approval date on the front cover of this standard indicates completion of the ANSI approval process. This American National Standard may be revised or withdrawn at any time. ANSI procedures require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036; (212) 642-4900.

Science and Technology

AWWA unites the entire water community by developing and distributing authoritative scientific and technological knowledge. Through its members, AWWA develops industry standards for products and processes that advance public health and safety. AWWA also provides quality improvement programs for water and wastewater utilities.

Committee Personnel

The AWWA A21 Subcommittee on the Installation of Ductile-Iron Pipe, which developed and reviewed this standard, had the following personnel at the time:

Charles W. McCauley Jr., *Chair*

General Interest Members

K.W. Henderson, Malcolm Pirnie Inc., White Plains, N.Y.	(AWWA)
P.I. McGrath Jr., Birmingham, Ala.	(AWWA)
J.R. Plattsmier, MWH Americas Inc., Denver, Colo.	(AWWA)
W.H. Smith, Flora, Ill.	(AWWA)
J.M. Vellano, Vellano Brothers Inc., Latham, N.Y.	(AWWA)

Producer Members

L.R. Dunn, U.S. Pipe & Foundry Company, Birmingham, Ala.	(DIPRA)
Harold Kennedy Jr., Harold Kennedy & Associates, Cary, N.C.	(AWWA)
Michael Lundstrom, Eastland, Texas	(AWWA)
C.W. McCauley Jr., Griffin Pipe Products Company, Lynchburg, Va.	(DIPRA)
P.A. Selig, American Cast Iron Pipe Company, Birmingham, Ala.	(DIPRA)
E.J. Shields Jr., Waterworks Supply Corporation, Malden, Mass.	(AWWA)
T.F. Stroud, Ductile Iron Pipe Research Association, Birmingham, Ala.	(DIPRA)

User Members

D.T. Bradley, Oak Lodge Water District, Milwaukie, Ore.	(AWWA)
A.J. DeBoy, American Water—Central Region, St. Louis, Mo.	(AWWA)
J.L. Doane, Tualatin Valley Water District, Beaverton, Ore.	(AWWA)
R.R. Goold, Kansas City Water Services Department, Kansas City, Mo.	(AWWA)
D.S. Mathon, City of Columbia Water & Light, Columbia, Mo.	(AWWA)
R.Y. Matsui, Honolulu, Hawaii	(AWWA)
D.D. Montgomery, Independence Water Department, Independence, Mo.	(AWWA)
C.J. Patla, Connecticut Water Service Inc., Clinton, Conn.	(AWWA)
C.R. Schwenker, Fairfax Water, Fairfax, Va.	(AWWA)
R.L. Worden, Guadalupe–Blanco River Authority, Seguin, Texas	(AWWA)
R.D. Zwygart, Tampa Water Department, Tampa, Fla.	(AWWA)

The AWWA Standards Committee, Ductile-Iron Pipe and Fittings, which reviewed and approved this standard, had the following personnel at the time of approval:

John R. Plattsmier, *Chair*

Charles W. McCauley Jr., *Vice-Chair*

General Interest Members

K.W. Henderson, Malcolm Pirnie Inc., White Plains, N.Y.	(AWWA)
H.E. Holcomb, Jordan Jones & Goulding Inc., Norcross, Ga.	(AWWA)
M.B. Horsley, Black & Veatch, Kansas City, Mo.	(AWWA)
D.H. Kroon, Corrpro Companies Inc., Houston, Texas	(AWWA)
G.E. Laverick, Underwriters Laboratories, Northbrook, Ill.	(AWWA)
T.J. McCandless,[*] Standards Engineer Liaison, AWWA, Denver, Colo.	(AWWA)
P.I. McGrath Jr., Birmingham, Ala.	(AWWA)
J.R. Plattsmier, MWH Americas Inc., Denver, Colo.	(AWWA)
W.H. Smith, Flora, Ill.	(AWWA)
L.C. Yates, McGoodwin Williams & Yates, Fayetteville, Ark.	(AWWA)
M.C. Young,[*] Bucher Willis & Ratliff Corporation, Kansas City, Mo.	(AWWA)
Ken Zastrow,[†] Underwriters Laboratories Inc., Northbrook, Ill.	(AWWA)

Producer Members

John Critchlow, Pacific States Cast Iron Pipe Company, Provo, Utah	(AWWA)
L.R. Dunn, U.S. Pipe & Foundry Company, Birmingham, Ala.	(DIPRA)
Harold Kennedy Jr., Harold Kennedy & Associates, Cary, N.C.	(AWWA)
Michael Lundstrom, Eastland, Texas	(AWWA)
C.W. McCauley Jr., Griffin Pipe Products Company, Lynchburg, Va.	(DIPRA)
T.J. Muntz, Fab Pipe Inc., Rogers, Minn.	(AWWA)
Gene Oliver,[†] American Cast Iron Pipe Company, Birmingham, Ala.	(DIPRA)
P.A. Selig, American Cast Iron Pipe Company, Birmingham, Ala.	(DIPRA)
J.E. Shea,[†] McWane Cast Iron Pipe Company, Birmingham, Ala.	(AWWA)
E.J. Shields Jr., Waterworks Supply Corporation, Malden, Mass.	(AWWA)

*Liaison, nonvoting

†Alternate

T.F. Stroud, Ductile Iron Pipe Research Association, Birmingham, Ala.	(DIPRA)
T.B. Wright,* National Association of Pipe Fabricators, Edmond, Okla.	(DIPRA)

User Members

D.T. Bradley, Oak Lodge Water District, Milwaukie, Ore.	(AWWA)
T.E. Coughran, City of Santa Ana, Santa Ana, Calif.	(AWWA)
A.J. DeBoy, American Water—Central Region, St. Louis, Mo.	(AWWA)
R.R. Goold, Kansas City Water Services Department, Kansas City, Mo.	(AWWA)
G.L. Meyer, City of Sioux Falls, Sioux Falls, S.D.	(AWWA)
D.D. Montgomery, Independence Water Department, Independence, Mo.	(AWWA)
T.C. Moreno, Bexar Metro Water District, San Antonio, Texas	(AWWA)
C.J. Patla, Connecticut Water Service Inc., Clinton, Conn.	(AWWA)
C.R. Schwenker, Fairfax Water, Fairfax, Va.	(AWWA)
R.L. Worden, Guadalupe–Blanco River Authority, Seguin, Texas	(AWWA)
R.D. Zwygart, Tampa Water Department, Tampa, Fla.	(AWWA)

*Alternate

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Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

Foreword

This Foreword is for information only and is not a part of ANSI/AWWA C600.

I. Introduction.

I.A. *Background.* The provisions of this standard are intended to act as a guide for installing extensions to existing distribution systems and in preparing contract documents for the construction of new systems or extensions. The standard is to be used as a guide for installing bell-and-spigot cast-iron pipe and does not cover the provision and delivery of material, any other type of pipe, or any other type of joint. The standard includes a model addendum that was to be used with project contract documents and is designed to be used as a part of the contract documents.

I.B. *History.* The first edition of this AWWA standard, titled "Standard Specifications for Laying Cast-Iron Pipe" (7D.1-1938), was adopted in April 1938. The standard was published in the February 1938 edition of *Journal AWWA*. The standard was revised in 1949, including a change of title to "Standard Specifications for Installation of Cast-Iron Water Mains" (7D.1-T-1949 and C600-49T). The standard was expanded by adding numerous tables and installation guidelines. The model addendum was also expanded. The revised standard was published in the December 1949 edition of *Journal AWWA*. Section 9b, Joining of Mechanical-Joint Pipe, was added in May 1954. Section 9c, Joining of Push-On Joint Pipe, was added in 1964.

In 1975, the AWWA Standards Council formed the present C600 committee to revise ANSI/AWWA C600 to reflect current practices and to add ductile iron as a pipe material. To do this, the committee decided to completely change the character of the standard, removing the model addendum and making the standard consistent with the style of other AWWA standards.

In 1980, an addendum to the standard was approved that revised parts of Sec. 3.4 regarding mechanical-joint assembly.

The revisions made in the 1982 edition included the elimination of references to gray cast-iron pipe as a material for new pipeline installation, because it was no longer manufactured for water utility service. Also, metric conversions were included in the 1982 revision; these were direct conversions of customary US inch–pound units, rather than those shown in International Organization for Standardization (ISO) standards.

The revisions made in 1987 included new references, a caveat against prolonged exposure of polyethylene film to sunlight, revised sections on thrust restraint and hydrostatic testing, and a discussion on making service taps on polyethylene-encased iron mains. Subsequent revisions to ANSI/AWWA C600 were approved by the AWWA Board of Directors in 1993 and 1999. This tenth edition of C600 was approved by the AWWA Board of Directors on June 12, 2005.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.[*] Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.

2. Specific policies of the state or local agency.

3. Two standards developed under the direction of NSF, NSF[†]/ANSI[‡] 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.

4. Other references, including AWWA standards, *Food Chemicals Codex, Water Chemicals Codex,*[§] and other standards considered appropriate by the state or local agency.

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*Persons outside the United States should contact the appropriate authority having jurisdiction.

†American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

‡NSF International, 789 N. Dixboro Road, Ann Arbor, MI 4810.

§Both publications available from National Academy of Sciences, 500 Fifth Street, N.W., Washington, DC 20001.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C600 does not address additives requirements. Users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues. ANSI/AWWA C600, Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances, can be used as a reference when making extensions to existing distribution or transmission systems or when constructing new distribution or transmission systems using ductile-iron mains with either mechanical or push-on joints. It is not intended for this standard to be used as a contract document, but it may be used as a reference in contract documents. It is based on a consensus of the committee on the minimum practice consistent with sound, economical service under normal conditions, and its applicability under any circumstances must be reviewed by a responsible engineer. The standard is not intended to preclude the manufacture, marketing, purchase, or the use of any product, process, or procedure.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following items should be provided by the purchaser:

1. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required, in addition to the requirements of the Safe Drinking Water Act.

2. Details and requirements of state, local, and provincial requirements (Sec. 4.2).

III.B. *Modification to Standard.* Any modification of the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. Major Revisions. Major revisions to this edition of the standard include the following:

1. The format has been changed to AWWA style.
2. Editorial changes throughout the standard for clarification of various installation issues.
3. Highway and railroad crossing restrictions for filling the void space between carrier and casing pipe are addressed (Sec. 4.5.3).
4. Trenchless application methods are discussed (Sec. 4.6).
5. Modification of the hydrostatic testing allowance formulas to reflect more conservative testing values (Sec. 5.2).

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer and Technical Support Group at 303.794.7711, FAX 303.795.7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail at standards@awwa.org.

ANSI/AWWA C600-05
(Revision of ANSI/AWWA C600-99)

American Water Works
Association

AWWA Standard

Installation of Ductile-Iron Water Mains and Their Appurtenances

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes installation procedures for ductile-iron mains and their appurtenances for water service.

1.1.1 *Conditions not discussed.* Installations that require special attention, techniques, and materials are not discussed. Each of these installations requires special considerations based on many influencing factors that cannot be discussed adequately in a single standard. These installations may require design by a competent engineer and consultation with representatives of the material manufacturing industry. Some of these installations include the following:

1. Piping through rigid walls.
2. Piping on supports above or below ground.
3. Piping requiring insulation.
4. Treatment plant or pump-station piping.
5. Flanged joint piping.
6. Ball and socket piping.
7. Grooved and shouldered piping.
8. Restrained joint piping.

9. Industrial piping.
10. Piping through geologically hazardous areas.
11. Piping in high-density, stray-current environments.
12. Piping through corrosive soil.
13. Piping through unstable soil.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for the installation of ductile-iron water mains and their appurtenances, including materials, dimensions, tolerances, and testing procedures.

Sec. 1.3 Application

This standard can be referenced in specifications for installing ductile-iron water mains and their appurtenances. The stipulations of this standard apply when this document has been referenced and then only to the installation of ductile-iron water mains and their appurtenances.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within this standard. In any case of conflict, the requirements of this standard shall prevail.

AASHTO* T99, The Moisture-Density Relations of Soils Using a 2.5 kg (5.5 lb) Rammon and a 305 mm (12 in.) Drop.

ANSI†/AWWA C105/A21.5—American National Standard for Polyethylene Encasement for Ductile-Iron Pipe Systems.

ANSI/AWWA C111/A21.11—American National Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.

ANSI/AWWA C150/A21.50—American National Standard for the Thickness Design of Ductile-Iron Pipe.

ANSI/AWWA C500—Metal-Seated Gate Valves for Water Supply Service.

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*American Association of State Highway and Transportation Officials, 444 N. Capitol St. N.W., Ste. 429, Washington, DC 20001.

†American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

ANSI/AWWA C509—Resilient-Seated Gate Valves for Water Supply Service.

ANSI/AWWA C651—Disinfecting Water Mains.

AWWA Manual M17, *Installation, Field Testing, and Maintenance of Fire Hydrants.*

AWWA Manual M27, *External Corrosion: Introduction to Chemistry and Control.*

The reader of ANSI/AWWA C600 is referred to the following standards for additional information on the use or limitations of specific products.

ANSI/AWWA C151/A21.51—American National Standard for Ductile-Iron Pipe, Centrifugally Cast, for Water or Other Liquids.

ANSI/AWWA C515—Reduced-Wall, Resilient-Seated Gate Valves for Water Supply Service.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Contract documents:* The package consisting of the plans, specifications, and the contract under which the products are being purchased and installed.

2. *Ductile iron:* Cast ferrous material in which a major part of the carbon content occurs as free graphite in a substantially nodular or spheroidal form.

3. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

4. *Mechanical joint:* The gasketed and bolted joint as detailed in ANSI/AWWA C111/A21.11.

5. *Plans:* Drawings normally prepared by an engineer employed or retained by the ultimate system-operating company showing the location and details of the construction of the pipeline and appurtenances.

6. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

7. *Push-on joint:* The single rubber-gasket joint as described in ANSI/AWWA C111/A21.11.

8. *Restrained joint:* A pipe joint designed to resist forces that act to separate a joint, such as thrust caused by internal pressure, external pulling forces, etc.

9. *Surge pressure:* The transient internal hydrostatic pressure that the pipeline is subjected to because of pressure waves created by the conveying fluid's velocity change.

10. *Test pressure:* The internal hydrostatic pressure specified in the contract documents to which the pipeline shall be subjected during the hydrostatic pressure test and the testing allowance test.

11. *Working pressure:* The internal hydrostatic pressure that the pipeline is subjected to, not including surge pressure.

SECTION 4: REQUIREMENTS

Sec. 4.1 Permeation

The selection of materials is critical for water service and distribution piping in locations where there is likelihood the pipe will be exposed to significant concentrations of pollutants composed of low molecular weight petroleum products or organic solvents or their vapors. Research has documented that pipe materials, such as polyethylene, polybutylene, polyvinyl chloride, and asbestos–cement, and elastomers, such as used in jointing gaskets and packing glands, are subject to permeation by lower molecular weight organic solvents or petroleum products. If a water pipe must pass through a contaminated area or an area subject to contamination, consult with the manufacturer regarding permeation of pipe walls, jointing materials, etc., *before* selecting materials for use in that area.

Sec. 4.2 Materials

Materials shall comply with the requirements of the Safe Drinking Water Act and other federal requirements.

Sec. 4.3 Installing Ductile-Iron Mains

4.3.1 *Alignment and grade.* The water mains shall be laid and maintained on lines and grades established by the contract documents for the project. Fittings, valves, tapped or bossed outlets, and hydrants shall be installed at the required locations unless field conditions warrant otherwise, and these changes are approved in accordance with the contract documents. Valve-operating stems shall be oriented to allow proper operation. Hydrants shall be installed plumb.

4.3.1.1 Prior investigation. Prior to excavation, an investigation shall be conducted to determine the location of existing underground structures and conflicts. During excavation, damage to existing structures should be avoided. Special precautions shall be taken when the water main being installed crosses or is adjacent to a facility that is cathodically protected.

4.3.1.2 Unforeseen obstructions. When obstructions not indicated on the contract documents interfere with the progress of work, alteration of the contract documents is required. These alterations or deviations in line and grade, or the removal, relocation, or reconstruction of the obstructions shall be performed in accordance with the contract documents.

4.3.1.3 Clearance. When crossing existing pipelines or other structures, alignment and grade shall be adjusted as necessary, in accordance with the contract documents, to provide clearance as required by federal, state, or provincial, and local regulations or as deemed necessary to prevent future damage or contamination of either structure.

4.3.2 *Trench construction.* The trench shall be excavated to the required alignment, depth, and width specified or shown in the contract documents and shall conform with all federal, state or provincial, and local regulations for the protection of the workers.

4.3.2.1 Trench preparation. Trench preparation shall proceed in advance of pipe installation as stated in the contract documents.

4.3.2.1.1 Discharges from trench dewatering pumps shall be directed away from the trench to prevent trench instability and shall be in accordance with federal, state or provincial, and local point-discharge requirements.

4.3.2.1.2 Excavated material shall be placed in a manner that will not obstruct the work nor endanger workers or the public nor obstruct sidewalks, driveways, roadways, or other structures. Excavated material shall be placed in compliance with federal, state or provincial, and local regulations.

4.3.2.2 Pavement removal. Pavement and road surfaces shall be removed as part of the trench excavation. The amount removed shall depend on the width of trench required for the installation of the pipe and the dimensions of the area into which valves, hydrants, specials, manholes, or other structures will be installed. The dimensions of pavement removed shall not exceed the dimensions of the opening required for installation of pipe, valves, hydrants, specials, manholes, and other structures by more than 6 in. (150 mm) in any direction, unless otherwise stipulated in the contract documents. Sawing, drilling, or chipping shall be used to ensure the breakage of pavement along straight lines.

4.3.2.3 Width. The width of the trench at the top of the pipe shall equal the single-pass capabilities of normally available excavating equipment. The width shall permit the pipe to be laid and joined properly and to allow the backfill to be placed in accordance with the contract documents. Trench widths shown in Table 1 may be used as a guide. When required, trenches shall be wider to permit the placement of timber supports, sheeting, bracing, and appurtenances as required by the safety requirements of the agency having jurisdiction.

4.3.2.4 Bell holes. Holes for the bells shall be provided at each joint, and they shall be no larger than necessary to allow joint assembly and to ensure that the pipe barrel will lie flat on the trench bottom. The dimensions of bell-hole depressions for push-on type joints should be large enough to ensure that the pipe is not resting on the bells and is supported by the full length of the pipe barrel.

4.3.2.4.1 Other than noted previously, the trench bottom shall be true and even to provide support for the full length of the pipe barrel. A slight depression may be provided to allow withdrawal of pipe slings or other lifting tackle without damaging coating or polyethylene encasement.

Table 1 Suggested trench widths at the top of the pipe

Nominal Pipe Size		Trench Width	
in.	*(mm)*	*in.*	*(m)*
3 and 4	(76 and 102)	28	(0.71)
6	(152)	30	(0.76)
8	(203)	32	(0.81)
10	(254)	34	(0.86)
12	(305)	36	(0.91)
14	(356)	38	(0.97)
16	(406)	40	(1.02)
18	(457)	42	(1.07)
20	(508)	44	(1.12)
24	(610)	48	(1.22)
30	(762)	54	(1.37)
36	(914)	60	(1.52)
42	(1,067)	66	(1.68)
48	(1,219)	72	(1.83)
54	(1,400)	78	(1.98)
60	(1,500)	84	(2.13)
64	(1,600)	88	(2.24)

4.3.2.5 Rock conditions. When excavation of rock is necessary, all rock shall be removed to provide a clearance below and on each side of all pipe, valves, and fittings of at least 6 in. (150 mm) for nominal pipe sizes 24 in. (610 mm) or smaller and 9 in. (230 mm) for nominal pipe sizes 30 in. (762 mm) and larger. When excavation is completed, a layer of appropriate backfill material (see Sec. 4.2.5) shall be placed on the bottom of the trench to the appropriate depths, then leveled and tamped.

4.3.2.5.1 These clearances and bedding procedures shall also be observed for pieces of concrete or masonry and other debris or subterranean structures, such as masonry walls, piers, or foundations that may be encountered during excavation.

4.3.2.5.2 This installation procedure shall be followed when gravel formations containing loose cobbles or boulders greater than approximately 8 in. (200 mm) in diameter are encountered.

4.3.2.5.3 In all cases, the specified clearances shall be maintained between the bottom of all pipe and appurtenances and any part, projection, or point of rock, boulder, or stone of sufficient size and placement that could cause a fulcrum point or pointload.

4.3.2.6 Previous excavations. If the trench passes over a previous excavation, such as a sewer, the trench bottom shall be sufficiently compacted to provide support equal to that of the native soil or conform to other regulatory requirements in a manner that will prevent damage to the existing installation.

4.3.2.7 Blasting. Blasting for excavation shall be permitted only after securing approval(s) and establishing the hours of blasting as required by the contract documents. The blasting procedure, including protection of persons and property, shall be in strict accordance with federal, state or provincial, and local regulations.

4.3.2.8 Protecting property. Trees, shrubs, fences, and all other property and surface structures shall be protected during construction, unless their removal is shown in the contract documents.

4.3.2.8.1 Any cutting of tree roots or branches shall be performed in accordance with the contract documents.

4.3.2.8.2 Temporary support, adequate protection, and maintenance of all underground and surface structures, drains, sewers, and other obstructions encountered during the work shall be provided in accordance with contract documents or applicable regulations.

4.3.2.8.3 All properties that have been disturbed shall be restored as completely as practical to their original condition.

4.3.2.9 Unsuitable material. When the material is found to include ashes, cinders, refuse, organic material, or other unsuitable material, this material shall be removed to a minimum of at least 6 in. (150 mm) below the bottom of the pipe or to the depth required by the contract documents. The removed material shall be replaced with clean, stable backfill material. When these potentially corrosive materials are encountered, polyethylene encasement should be used to protect the pipe (see Sec. 4.3.3.8). The bedding shall be consolidated and leveled so that the pipe may be installed in accordance with Sec. 4.3.2.4.

4.3.2.10 Unstable material. When the bottom of the trench consists of material that is unstable to such a degree that its removal is impractical, a foundation for the pipe or appurtenance shall be constructed using piling, treated timber, concrete, or other materials, in accordance with the contract documents.

4.3.2.11 Traffic control. Appropriate traffic-control devices shall be provided in accordance with federal, state or provincial, and local regulations to regulate, warn, and guide traffic at the work site.

4.3.3 *Installing pipe.* The proper implements, tools, and facilities shall be provided and used for the safe and convenient performance of the work. All pipe, fittings, valves, and hydrants shall be lowered carefully into the trench using a backhoe, a crane, ropes, or other suitable tools or equipment, in such a manner as to prevent damage to water main materials and protective coatings and linings. Under no circumstances shall water main materials be dropped or dumped into the trench. Where practical, the trench should be dewatered prior to installation of the pipe.

4.3.3.1 Examining material. All pipe, fittings, valves, hydrants, and other appurtenances shall be examined carefully for damage and other defects immediately before installation. Defective materials shall be marked and held for final disposition as required by the contract documents.

4.3.3.2 Pipe ends. All lumps, blisters, and excess coating shall be removed from the socket and plain ends of each pipe, and the outside of the plain end and the inside of the bell shall be wiped clean and dry and be free of dirt, sand, grit, or any foreign materials before the pipe is laid.

4.3.3.3 Pipe cleanliness. Foreign material shall be prevented from entering the pipe while it is being placed in the trench. No debris, tools, clothing, or other materials shall be placed in the pipe at any time.

4.3.3.4 Pipe placement. As each length of pipe is placed in the trench, the joint shall be assembled and the pipe brought to correct line and grade. The pipe shall be secured in place with approved backfill material.

4.3.3.5 Direction of bells. It is common practice to lay pipe with the bells facing the direction in which work is progressing; however, it is not mandatory. For example, when the main is being laid on a slope, the pipe is frequently laid with the bells facing uphill for ease of installation. The direction of the bells is not functionally related to the direction of flow within the main.

4.3.3.6 Pipe plugs. When pipe-laying is not in progress, the open ends of pipe shall be closed by a watertight plug or other means as specified. The plug shall be fitted with a means for venting. When practical, the plug shall remain in place until the trench is pumped completely dry. Care must be taken to prevent pipe flotation if the trench fills with water.

4.3.3.6.1 Prior to removal of the plug for extending the line or for any other reason, air and water pressure in the line shall be released.

4.3.3.7 Ductile-iron laying conditions. The laying conditions for ductile-iron pipe shall be completed in accordance with ANSI/AWWA C150/A21.50 as illustrated in Figure 1 of this standard and as required by the contract documents.

4.3.3.7.1 Loosely placed backfill above the pipe may allow settlement that could be detrimental to improvements subsequently placed over the trench.

4.3.3.8 Polyethylene encasement. For any installation requiring polyethylene encasement for corrosion protection of ductile-iron pipe, the encasement shall be installed in accordance with ANSI/AWWA C105/A21.5 and as required by the contract documents.

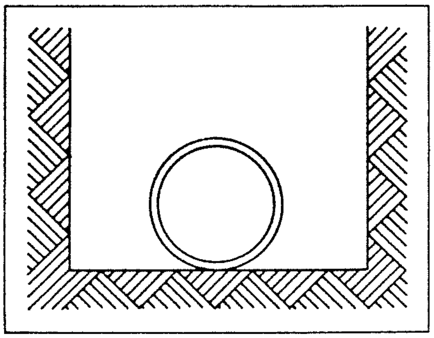
4.3.3.9 Other forms of corrosion protection. For installations requiring other forms of corrosion protection, refer to AWWA Manual M27, *External Corrosion: Introduction to Chemisty and Control.*

4.3.3.10 Specials. Special transition couplings or gaskets are required for joining different types of pipe, such as steel pipe, asbestos–cement pipe, and plastic pipe. These transition devices are available. When ordering, the actual outside diameter of the pipe should be provided.

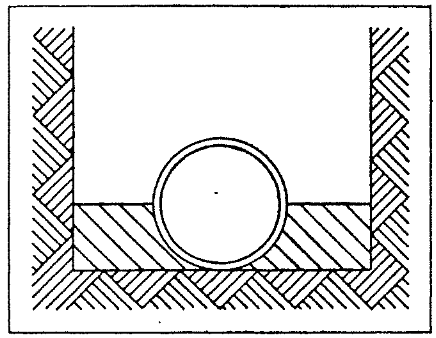
4.3.4 *Joint assembly.*

4.3.4.1 Push-on joints. Push-on joints shall be assembled as described and illustrated in Figure 2.

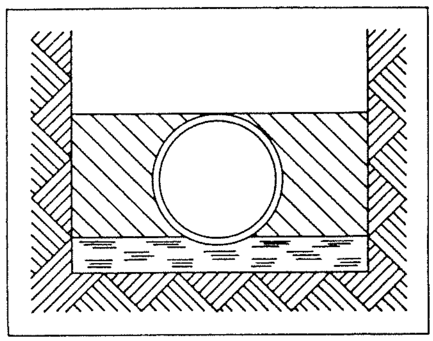
4.3.4.2 Mechanical joints. Mechanical joints shall be assembled as described and illustrated in Figure 3 and Table 2.



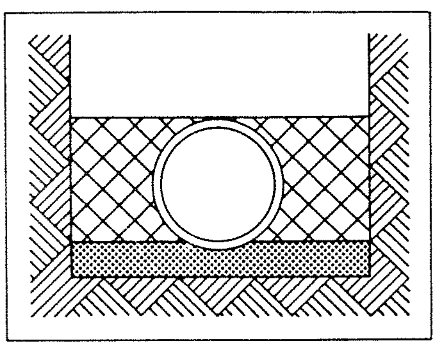
Type 1*
Flat-bottom trench.† Loose backfill.



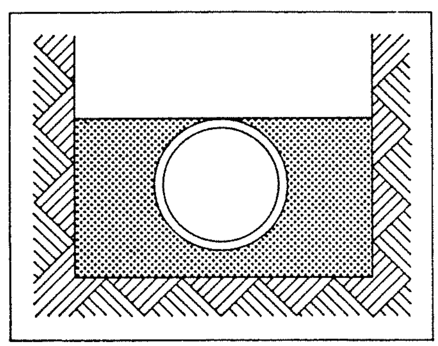
Type 2
Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.



Type 3
Pipe bedded in 4 in. (100 mm) minimum of loose soil.‡ Backfill lightly consolidated to top of pipe.



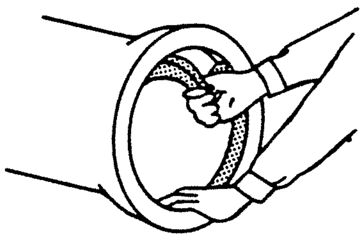
Type 4
Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4 in. (100 mm) minimum. Backfill compacted to top of pipe. (Approximately 80 percent Standard Proctor, AASHTO T-99.)



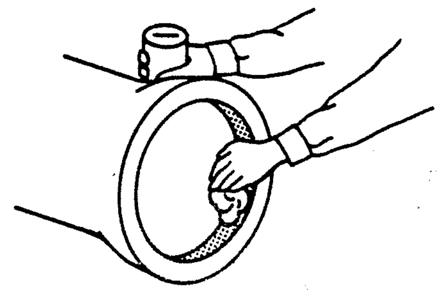
Type 5
Pipe bedded in compacted granular material to centerline of pipe. Compacted granular or select material‡ to top of pipe. (Approximately 90 percent Standard Proctor, AASHTO T-99).

*For 14-in. (355-mm) and larger pipe, consideration should be given to the use of laying conditions other than Type 1.
†"Flat-bottom" is defined as undisturbed earth.
‡"Loose soil" or "selected material" is defined as native soil excavated from the trench, free of rocks, foreign materials, and frozen earth.

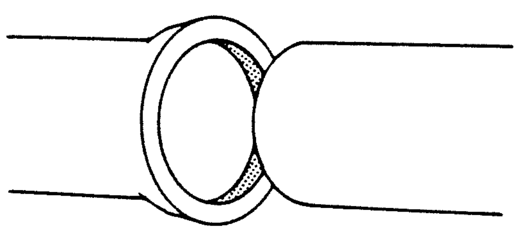
Figure 1 Laying conditions for ductile-iron pipe



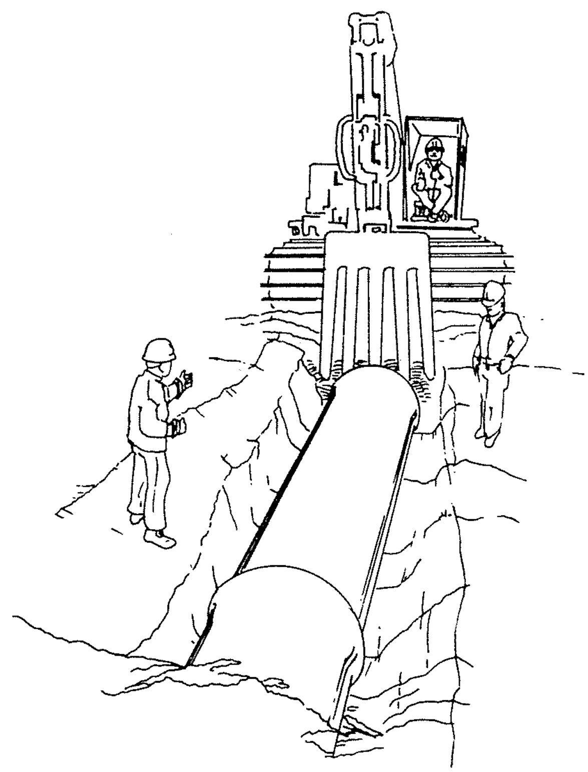
1. Thoroughly clean the groove and the bell socket of the pipe or fitting; also clean the plain end of the mating pipe. Using a gasket of the proper design for the joint to be assembled, make a small loop in the gasket and insert it in the socket. For pipe sizes larger than 20 in., it may be necessary to make 2 loops in the gasket (6 and 12 o'clock). Assure that the gasket faces the correct direction and that it is properly seated. NOTE: In cold weather, it is preferable to warm the gasket to facilitate assembly of the joint.



2. Apply lubricant to the exposed surface of the gasket and plain end of the pipe in accordance with the pipe manufacturer's recommendations. Do not apply lubricant to the bell socket or the surface of the gasket in contact with the bell socket. Lubricant is furnished in sterile containers, and every effort should be made to protect against contamination of the container's contents.

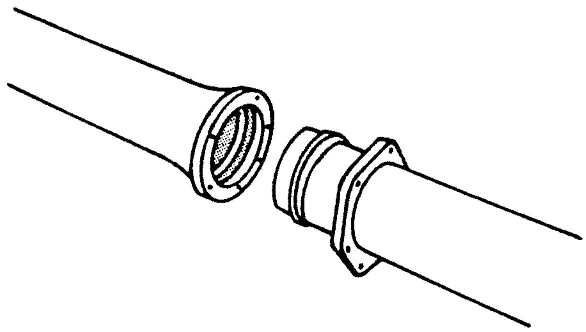


3. Be sure that the plain end is beveled per the manufacturer's recommendations; square or sharp edges may damage or dislodge the gasket and cause a leak. When pipe is cut in the field, bevel the plain end with a heavy file or grinder to remove all sharp edges. Push the plain end into the bell of the pipe. Keep the joint straight while pushing. Make deflection after the joint is assembled.

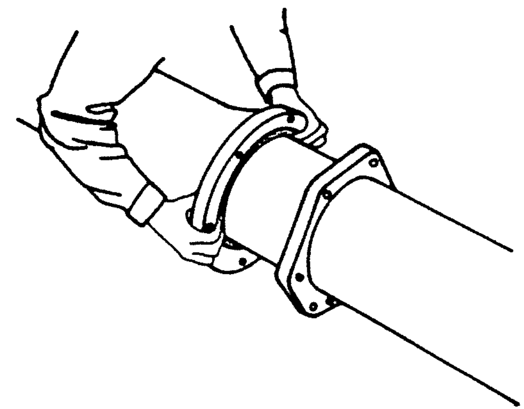


4. Small pipe can be pushed into the bell socket with a long bar. Large pipe requires additional power, such as a jack, lever puller, or backhoe. The supplier may provide a jack or lever puller on a rental basis. A timber header should be used between the pipe and jack or backhoe bucket to avoid damage to the pipe.

Figure 2 Push-on-joint assembly

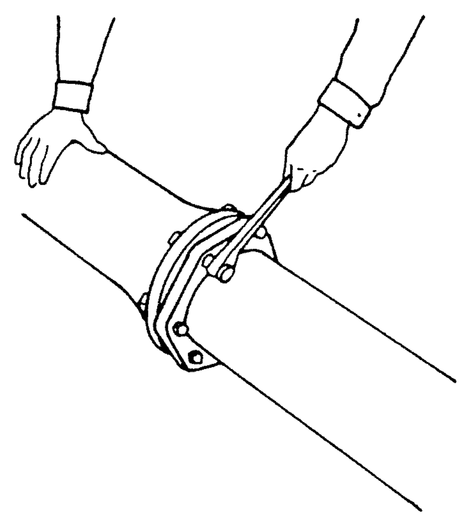


1. Clean the socket and the plain end. Lubrication and additional cleaning should be provided by brushing both the gasket and plain end with soapy water or an approved pipe lubricant meeting the requirements of ANSI/AWWA C111/A21.11 just prior to slipping the gasket onto the plain end for joint assembly. Place the gland on the plain end with the lip extension toward the plain end, followed by the gasket with the narrow edge of the gasket toward the plain end. NOTE: In cold weather it is preferable to warm the gasket to facilitate assembly of the joint.



2. Insert the pipe into the socket and press the gasket firmly and evenly into the gasket recess. Keep the joint straight during assembly.

3. Push the gland toward the socket and center it around the pipe with the gland lip against the gasket. Insert bolts and hand-tighten nuts. Make deflection after joint assembly but before tightening bolts.



4. Tighten the bolts to the normal range of bolt torque as indicated in Table 2 while at all times maintaining approximately the same distance between the gland and the face of the flange at all points around the socket. This can be accomplished by partially tightening the bottom bolt first, then the top bolt, next the bolts at either side, finally the remaining bolts. Repeat the process until all bolts are within the appropriate range of torque. In large sizes (30–48 in. [762–1,219 mm]), five or more repetitions may be required. The use of a torque-indicating wrench will facilitate this procedure.

Figure 3 Mechanical-joint assembly

Table 2 Mechanical-joint bolt torque

Joint Size		Bolt Size		Range of Torque		Length of Wrench*	
in.	*(mm)*	*in.*	*mm*	*ft•lb*	*(N•m)*	*in.*	*(mm)*
3	(76)	5/8	(16)	45–60	(61–81)	8	203
4–24	(102–610)	3/4	(19)	75–90	(102–122)	10	254
30–36	(762–914)	1	(25)	100–120	(136–163)	14	356
42–48	(1,067–1,219)	1¼	(32)	120–150	(163–203)	16	406

*The torque loads may be applied with torque-measuring or torque-indicating wrenches, which may also be used to check the application of approximate torque loads applied by a worker trained to give an average pull on a definite length of regular socket wrench. If effective sealing is not attained at the maximum torque indicated, the joint should be disassembled, thoroughly cleaned, and reassembled. Overstressing bolts to compensate for poor installation practice is not acceptable.

4.3.4.3 Restrained joints. Restrained joints shall be installed where required by the contract documents, in accordance with applicable sections of this standard and the manufacturer's guidelines and requirements.

4.3.4.4 Joint deflection. When it is necessary to deflect pipe from a straight line in either the horizontal or vertical plane, the amount of joint deflection shall not exceed that shown in Tables 3 and 4. The deflections listed are maximum deflections and should not be exceeded. For design purposes, deflection should be limited to 80 percent of the values shown. Figure 4 illustrates the maximum offset *S* and approximate radius curve *R*, which are listed in Tables 3 and 4.

4.3.4.5 Pipe cutting. Cutting pipe for insertion of valves, fittings, or closure pieces shall conform to all safety recommendations of the manufacturer of the cutting equipment. Cutting shall be done in a safe, professional manner to prevent damage to the pipe or cement–mortar lining.

4.3.4.5.1 Existing gray-iron pipe may be cut using a hydraulic squeeze cutter, abrasive pipe saw, rotary wheelcutter, guillotine pipe saw, or milling wheel saw.

4.3.4.5.2 Ductile-iron pipe may be cut using an abrasive pipe saw, rotary wheelcutter, guillotine pipe saw, milling wheel saw, or oxyacetylene torch if recommended by the pipe manufacturer.

4.3.4.5.3 Cut ends and rough edges shall be ground smooth, and, for push-on joint connections, the cut end shall be beveled by methods recommended by the manufacturer.

4.3.4.5.4 ANSI/AWWA C151/A21.51 requires factory gauging of the spigot end to ensure that the outside diameter of each spigot end falls within the tolerances stipulated in that standard. Accordingly, pipes selected for cutting should

Table 3 Maximum joint deflection* full-length pipe—push-on-type joint pipe

Nominal Pipe Size		Deflection Angle—θ	Maximum Offset—S† in. (m)				Approx. Radius of Curve—R† Produced by Succession of Joints ft (m)			
			L†=18 ft (5.5 m)		L†=20 ft (6 m)		L†=18 ft (5.5 m)		L†=20 ft (5 m)	
in.	*(mm)*	*degree*								
3	(76)	5	19	(0.48)	21	(0.53)	205	(62)	230	(70)
4	(102)	5	19	(0.48)	21	(0.53)	205	(62)	230	(70)
6	(152)	5	19	(0.48)	21	(0.53)	205	(62)	230	(70)
8	(203)	5	19	(0.48)	21	(0.53)	205	(62)	230	(70)
10	(254)	5	19	(0.48)	21	(0.53)	205	(62)	230	(70)
12	(305)	5	19	(0.48)	21	(0.53)	205	(62)	230	(70)
14	(356)	3*	11	(0.28)	12	(0.30)	340	(104)	380	(116)
16	(406)	3*	11	(0.28)	12	(0.30)	340	(104)	380	(116)
18	(457)	3*	11	(0.28)	12	(0.30)	340	(104)	380	(116)
20	(508)	3*	11	(0.28)	12	(0.30)	340	(104)	380	(116)
24	(610)	3*	11	(0.28)	12	(0.30)	340	(104)	380	(116)
30	(762)	3*	11	(0.28)	12	(0.30)	340	(104)	380	(116)
36	(914)	3*	11	(0.28)	12	(0.30)	340	(104)	380	(116)
42	(1,067)	3*	11	(0.28)	12	(0.30)	340	(104)	380	(116)
48	(1,219)	3*			12	(0.30)			380	(116)
54	(1,400)	3*			12	(0.30)			380	(116)
60	(1,500)	3*			12	(0.30)			380	(116)
64	(1,600)	3*			12	(0.30)			380	(116)

*For 14-in. and larger push-on joints, maximum deflection angle may be larger than shown above. Consult the manufacturer.

† See Figure 4.

be field-gauged. A mechanical-joint gland inserted over the barrel might serve as a convenient indicator for this purpose. When glands are not available, pipe can be selected by measuring with a tape in accordance with the manufacturer's recommendation.

4.3.5 *Backfilling* Backfill shall be accomplished in accordance with the specified laying conditions as described in Sec. 4.3.3.

4.3.5.1 Backfill material. All backfill material shall be free from cinders, ashes, refuse, vegetable or organic material, boulders, rocks or stones, frozen soil, or other unsuitable material.

4.3.5.1.1 From 1 ft (300 mm) above the top of the pipe to grade or to the subgrade of the pavement, material containing stones up to 8 in. (200 mm) in their greatest dimension may be used, unless otherwise specified.

Table 4 Maximum joint deflection full-length pipe—mechanical-joint pipe

Nominal Pipe Size		Deflection Angle—θ	Maximum Offset—S* in. (m)				Approx. Radius of Curve—R* Produced by Succession of Joints ft (m)			
			L*=18 ft (5.5 m)		L*=20 ft (6 m)		L*=18 ft (5.5 m)		L*=20 ft (6 m)	
in.	*(mm)*	*degree*								
3	(76)	8–18	31	(0.79)	35	(0.89)	125	(38)	140	(43)
4	(102)	8–18	31	(0.79)	35	(0.89)	125	(38)	140	(43)
6	(152)	7–07	27	(0.69)	30	(0.76)	145	(44)	160	(49)
8	(203)	5–21	20	(0.51)	22	(0.56)	195	(59)	220	(67)
10	(254)	5–21	20	(0.51)	22	(0.56)	195	(59)	220	(67)
12	(305)	5–21	20	(0.51)	22	(0.56)	195	(59)	220	(67)
14	(356)	3–35	13.5	(0.34)	15	(0.38)	285	(87)	320	(98)
16	(406)	3–35	13.5	(0.34)	15	(0.38)	285	(87)	320	(98)
18	(457)	3–00	11	(0.28)	12	(0.30)	340	(104)	380	(116)
20	(508)	3–00	11	(0.28)	12	(0.30)	340	(104)	380	(116)
24	(610)	2–23	9	(0.23)	10	(0.25)	450	(137)	500	(152)

* See Figure 4.

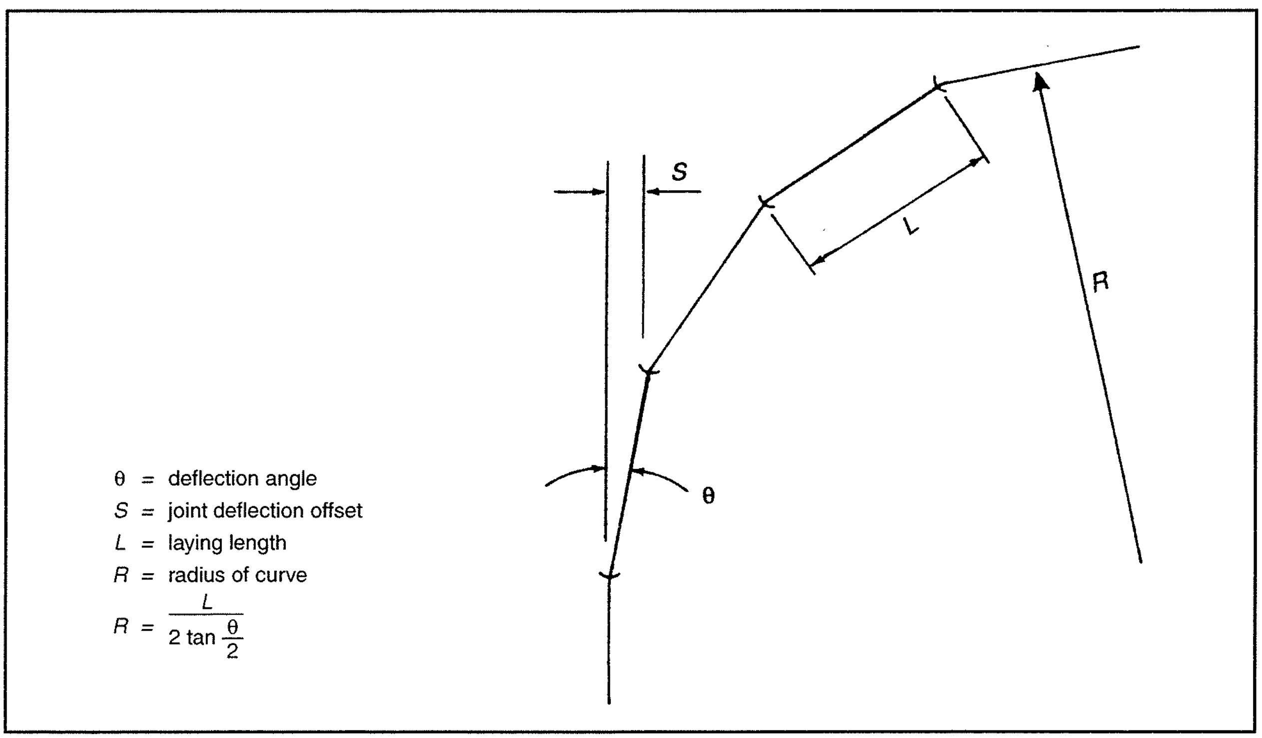


Figure 4 Pipeline curve geometry

4.3.5.1.2 When the type of backfill material is not indicated in the contract documents or is not specified, the excavated material may be used, provided that this material consists of loam, clay, sand, gravel, or other suitable materials.

4.3.5.1.3 If excavated material is indicated in the contract documents or specified for backfill, and there is a deficiency because a part of that material has been rejected, the required amount of sand, gravel, or other approved material shall be provided.

4.3.5.1.4 For purposes of definition: (a) *sand* is material graded from fine to coarse, containing less than 10 percent by weight of loam and clay that passes a 3/4-in. (19-mm) sieve with no more than 5 percent by weight remaining on a US No. 4 sieve; (b) *gravel* is a reasonably uniform combination, containing no boulders or stones larger than 2 in. (50 mm) and not containing excessive amounts of clay and loam; (c) *crushed stone* is limestone or dolomite ledge-rock material that all passes a ½-in. (13-mm) sieve with no more than 25 percent passing a US No. 100 sieve.

4.3.5.2 Compaction. When special backfill compaction procedures are required, they shall be performed in accordance with the contract documents or applicable federal, state or provincial, and local regulations.

4.3.5.3 Partial backfilling during testing. Newly installed pipelines are normally tested after backfilling. When unusual conditions require that pressure and leakage testing be performed before completion of backfilling or with pipe joints accessible for examination, sufficient backfill material shall be placed over the pipe barrel between the joints to prevent movement, with consideration given to restraining thrust forces during the testing. In particular, restrained-joint systems, which derive their stability from the interaction of the pipe and soil, should be backfilled prior to testing.

4.3.5.4 Repairs. If polyethylene encasement is used, any damage that occurs to the wrap shall be repaired in accordance with ANSI/AWWA C105/A21.5.

4.3.6 *Valve and fitting installation.*

4.3.6.1 Examining material. Prior to installation, valves shall be inspected for direction of opening, number of turns to open, freedom of operation, tightness of pressure-containing bolting and test plugs, cleanliness of valve ports, and especially seating surfaces, handling damage, and cracks. Defective valves shall be marked and held for final disposition as required by the contract documents. All bolts and nuts, with the exception of seat-adjusting bolts or screws in butterfly valves, shall be checked for proper tightness. Seat-adjusting bolts in butterfly valves shall only be adjusted on the recommendation from the manufacturer.

4.3.6.2 Placement. Valves, fittings, plugs, and caps shall be set and joined to the pipe according to Sec. 4.3.3 for cleaning and laying, and to Sec. 4.3.4 for joining pipe. Valves, 12 in. (305 mm) and larger, should be provided with special support, such as treated timbers, crushed stone, concrete pads, or a sufficiently tamped trench bottom, so that the pipe will not be required to support the weight of the valve. Valves installed aboveground or in plant piping systems shall be supported to prevent bending of the valve end connections as a result of pipe loading. Valves shall be installed in the closed position.

4.3.6.3 Valve location. Valves in water mains shall, where practical, be located within or immediately adjacent to the street property lines unless shown otherwise on the contract documents.

4.3.6.3.1 Mains shall be drained through drainage branches or blowoffs. Drainage branches, blowoffs, and appurtenances shall be provided with control valves and shall be located and installed as shown in the contract documents. Drainage branches or blowoffs shall not be directly connected to any storm or sanitary sewer, submerged in any stream, or installed in any other manner that will permit backsiphonage into the distribution system.

4.3.6.3.2 Air-release or vacuum vents shall be provided at high points in the line and in areas of potential negative pressure. The air release or vacuum vents shall not be connected to any storm or sanitary sewer, and they shall be protected from freezing in cold locations.

4.3.6.4 Valve protection. A valve box or a vault shall be provided for every valve.

4.3.6.4.1 A valve box shall be provided for every valve that has no gearing or operating mechanism or in which the gearing or operating mechanism is fully protected with a gear case. The valve box shall not transmit shock or stress to the valve. The valve box shall be centered over the operating nut of the valve, with the box cover flush with the surface of the finished area or another level as specified.

4.3.6.4.2 A valve vault designed to prevent settling on the pipe shall be provided for every valve that has exposed gearing or operating mechanisms. The operating nut shall be readily accessible for operation through the opening in the valve vault. The opening shall be set flush with the surface of the finished pavement or another level as specified. Vaults shall be constructed to permit minor valve repairs and to protect the valve and pipe from impact where they pass through the vault walls.

4.3.6.4.3 In no case shall valves be used to bring misaligned pipe into alignment during installation. Pipe shall be supported to prevent stress on the valve.

4.3.6.4.4 Thrust resulting from closure of valves shall be carefully considered in the design of the piping system and vaults.

4.3.6.5 Plugs and caps. All dead ends on new mains shall be closed with plugs or caps that are suitably restrained to prevent blowing off under test pressure. If a blowoff valve precedes the plug or cap, it too shall be restrained against blowing off. All dead ends shall be equipped with suitable blowoff or venting devices.

4.3.6.6 Additional information. Additional information regarding installation of gate valves can be found in the appendixes of ANSI/AWWA C500, ANSI/AWWA C509, and ANSI/AWWA C515.

4.3.7 *Installing hydrants.*

4.3.7.1 Examining materials. Prior to installation, all hydrants shall be inspected for direction of opening, nozzle threading, operating-nut and cap-nut dimensions, tightness of pressure-containing bolting, cleanliness of inlet elbow, handling damage, and cracks. Defective hydrants shall be marked and held for final disposition required by the contract documents.

4.3.7.2 Placing hydrants. All hydrants shall stand plumb and shall have their nozzles parallel with or at right angles to the curb, with the pumper nozzle facing the curb. Hydrants having two-hose nozzles 90° apart shall be set with each nozzle facing the curb at an angle of 45°.

4.3.7.2.1 Hydrants shall be set to the established grade, with the lowest nozzle at least 12 in. (300 mm) above the ground or as required by the contract documents. The lowest nozzle shall be installed away from the curb line at a sufficient distance to avoid damage from or to vehicles. Traffic-model hydrants (hydrants that are intended to fail at the ground line on vehicle impact) shall be installed so that the breakaway flange is not less than 2 in. (50 mm), nor more than 6 in. (150 mm), above the established grade.

4.3.7.2.2 Each hydrant shall be connected to the main with a 6-in. (152-mm) or larger-diameter branch controlled by an independent valve, unless otherwise specified. The valve shall be restrained to allow shutoff when the hydrant is to be removed.

4.3.7.2.3 When a dry-barrel hydrant is set in soil that is impervious, drainage shall be provided at the base of the hydrant by placing coarse gravel or crushed stone mixed with coarse sand from the bottom of the trench to at least 6 in. (150 mm) above the drain-port opening in the hydrant and to a distance of 1 ft (300 mm) around the elbow. Where groundwater rises above the drain port or when the hydrant is located within 8 ft (2.4 m) (or the distance required by the applicable regulatory agency) of a sanitary sewer main, or where drainage is not permitted by the applicable regulatory agency, the drain port shall be plugged and water pumped from the hydrant when freezing may occur.

4.3.7.2.4 When a dry-barrel hydrant with an open drain port is set in clay or other impervious soil, a drainage pit 2 ft × 2 ft × 2 ft (0.6 m × 0.6 m × 0.6 m) shall be excavated below each hydrant. The drainage pit shall be filled with coarse gravel or crushed stone mixed with coarse sand under and around the elbow of the hydrant to a level of 6 in. (150 mm) above the drain port. To prevent possible contamination of the water supply, do not connect hydrant drains to a sanitary sewer or storm sewer.

4.3.7.3 Location. Hydrants shall be located as shown in the contract documents or as specified.

4.3.7.4 Protection. In the case of traffic hydrants, adequate soil resistance must be provided to avoid transmitting shock moment to the lower barrel and inlet connection. In loose or poor load-bearing soil, this may be accomplished by pouring a concrete collar approximately 6 in. (150 mm) thick to a diameter of 2 ft (0.6 m) at or near the ground line around the hydrant barrel.

4.3.7.5 Additional information. Additional information regarding installation of hydrants can be found in AWWA Manual M17, *Installation, Field Testing, and Maintenance of Fire Hydrants*.

4.3.8 *Thrust restraint.*

4.3.8.1 Hydrants. The bowl of each hydrant shall be well braced against a sufficient area of unexcavated earth at the end of the trench with thrust blocks of concrete or other specified blocking materials, or it shall be tied to the pipe with suitable metal tie rods, clamps, or restrained joints as shown in the contract documents or as specified.

4.3.8.2 Fittings. All plugs, caps, tees, reducers, and bends, unless otherwise specified, shall be provided with thrust blocks or suitably restrained joints as shown in the contract documents or as specified.

4.3.8.3 Design. The thrust restraint design pressure is the maximum pressure to which the pipeline will be subjected, with consideration given to the vulnerability of the pipe–soil system when the pressure is applied. In most cases, this will be the test pressure of the pipe, applied shortly after installation, when the pipe–soil system is normally most vulnerable.

For buried pipelines, thrust restraint is achieved by transferring the thrust force to the soil structure outside the pipe. The objective of the design is to distribute the thrust forces to the soil structure, preventing joint separation in unrestrained joints.

4.3.8.4 Concrete thrust blocks. Vertical and horizontal thrust blocks shall be made of concrete having a compressive strength of not less than 2,000 psi (13.8 MPa) after 28 days. The blocks shall be placed between solid ground and the fitting(s) to be anchored. The mass of the block or the area of bearing on the pipe and on the ground in each instance shall be that shown in the contract documents or as specified. The blocking shall, unless otherwise shown or specified, be located so as to contain the resultant thrust force in such a way that the pipe and fitting joints will be accessible for repair.

4.3.8.5 Restrained joints. If indicated in the contract documents, restraining mechanisms for push-on or mechanical joints may be used instead of concrete thrust blocking. Tie rods, clamps, or other components shall be made of corrosion-resistant material or suitably protected against corrosion.

4.3.9 *Flushing.* Foreign material left in the pipelines during installation often results in valve- or hydrant-seat leakage during pressure tests. The pipelines shall be kept clean during installation. Thorough flushing is recommended prior to a pressure test. Flushing should be accomplished by partially opening and closing valves and hydrants several times under expected line pressure, with flow velocities adequate to flush foreign material out of the valves and hydrants.

Sec. 4.4 Disinfection

A newly installed main shall be disinfected in accordance with ANSI/AWWA C651. Following chlorination, the main should be flushed as soon as possible (within 24 hr), because prolonged exposure to high concentrations of chlorine might damage the asphaltic seal coating.

NOTE: Provisions should be made to avoid contamination of existing mains by cross-connection during testing/disinfection/flushing of newly installed mains.

Sec. 4.5 Highway and Railroad Crossings

4.5.1 *Casing pipe.* When protective steel casing pipe is specified for highways or railroad crossings, the project shall be completed in accordance with applicable federal, state or provincial, and local regulations. In the case of railroad crossings, the project should also comply with regulations established by the railroad company. Crossings are normally made by boring, jacking, or tunneling.

4.5.2 *Carrier pipe (ductile-iron pipe).* The casing pipe should be 6–8 in. (150–200 mm) larger than the outside diameter of the ductile-iron pipe bells. Carrier pipe may be pushed or pulled through the completed casing pipe. Insulating chocks, skids, or spacers should be placed on or under the carrier pipe to ensure approximate centering within the casing pipe and to prevent damage during installation. Metal-to-metal contact must be avoided. End caps or other methods of sealing the casing pipe shall be provided as specified.

4.5.3 *Restrictions.* At very long crossings, it is often necessary to partially fill the space between the ductile-iron carrier pipe and the casing pipe (e.g., with sand) to prevent movement. In order to avoid the transfer of earth and live loads to the carrier pipe, the space between the carrier pipe and the casing pipe should not be filled completely. Pressure grouting of the entire annular space between the pipeline and casing pipe is not recommended unless grouting pressure is controlled to pressures below that which could cause buckling failure of the pipeline.

Sec. 4.6 Trenchless Applications

4.6.1 *Methods.* There are several methods of installing ductile-iron pipe in trenchless applications, including directional drilling and microtunneling. Ductile-iron pipe, manufactured in accordance with ANSI/AWWA C151/A21.51, can be installed using various pipe pushing/pulling methods and directional drilling. The methods involve forming a hole slightly larger than the outside diameter of the pipe joint, after which the ductile-iron pipe is pushed or pulled through the hole. When pipe is pulled into position, restrained joints are utilized. Also, specially designed and manufactured microtunneling pipe is currently available.

Sec. 4.7 Subaqueous Crossings

4.7.1 *Subaqueous installations.* When it is necessary to cross a body of water requiring only a small deflection in the joints, and joint restraint is not a consideration, standard mechanical-joint or push-on joint pipe can be used. If the water is deep and the angle of deflection in the joint necessary to follow the contour of the riverbed is great, or if changing bottom conditions are anticipated, ball-and-socket pipe or fittings, which will deflect up to 15°, should be used. A combination of restrained and river-crossing joints may be used, depending on bottom conditions and service requirements.

4.7.1.1 Strongback. There are several methods of installing subaqueous ductile-iron pipe. Ductile-iron pipe can be assembled in sections of three or four lengths, either on shore or on the deck of a barge, attached to a "strongback." The assembly is then lowered to the streambed where the sections are connected by divers. Ball-and-socket pipes use joints with positive locking devices. This type of pipe can also be assembled on a chute affixed to the barge and lowered into position as the assembly progresses.

4.7.1.2 Drag or float. Another method of installation is to assemble the pipeline on shore and either drag it into position along the bottom or float it into position using barrels or floats attached to the pipe. The barrels or floats are punctured or released in a controlled fashion when the pipe reaches the desired position. Regardless of the method used, joints should not be allowed to become overly deflected or subjected to excessive beam load during the installation process.

4.7.1.3 Skids. A similar method is to assemble the pipe on shore, attach floats, and pull the pipe down skids into the water as each length is connected. The line extends farther into the water as each successive length is laid, and the finished line is submerged appropriately.

4.7.1.4 Covered. Subaqueous lines laid in navigable streams must be placed in trenches and covered to protect them from damage or displacement by ship or boat traffic. Where applicable, procedures should conform to appropriate governmental regulations.

Sec. 4.8 Service Taps

4.8.1 *Tapping.* Corporation stops may be installed either before or after pipe installation. Generally, they are located at ten o'clock or two o'clock on the circumference of the pipe* and may be screwed directly into the tapped and threaded

*In cold climates with deep frost penetration, freezing of service lines can be a problem. In these localities, installing corporation stops horizontally at the three o'clock or nine o'clock position on the pipe circumference will conserve available cover over the service line or reduce the necessary depth that the main pipeline should be buried.

main without any additional appurtenances. When more than one tap is necessary to deliver the required flow in an existing gray-iron pipe, the taps should be staggered around the circumference at least 12 in. (300 mm) apart (not in a straight line). These restrictions do not apply to ductile-iron pipe. Furthermore, ductile-iron pipe in all classes, including standard pressure-class pipe, may be directly tapped with standard corporation stops; however, the torque requirement for the installation may be effectively reduced by the application of two layers of 3-mil (0.1-mm) pipe-thread sealant tape to the male threads of the corporation stop.

4.8.1.1 Polyethylene. Service taps on gray-iron and ductile-iron mains encased in polyethylene may be accomplished by making an X-shaped cut in the polyethylene and temporarily folding back the film. After the tap has been completed, cuts in the polyethylene and any other areas of damage to the film shall be repaired with tape as described in ANSI/AWWA C105/A21.5. Direct service taps may also be made through the polyethylene, with any resulting damaged areas being repaired as described previously. The preferred method of making direct service taps consists of applying two or three wraps of polyethylene adhesive tape completely around the pipe to cover the area where the tapping machine and chain will be mounted. This method minimizes possible damage to the polyethylene during the direct tapping procedure. After the tapping machine is mounted, the corporation stop is installed directly through the tape and polyethylene, as shown in Figure 5.

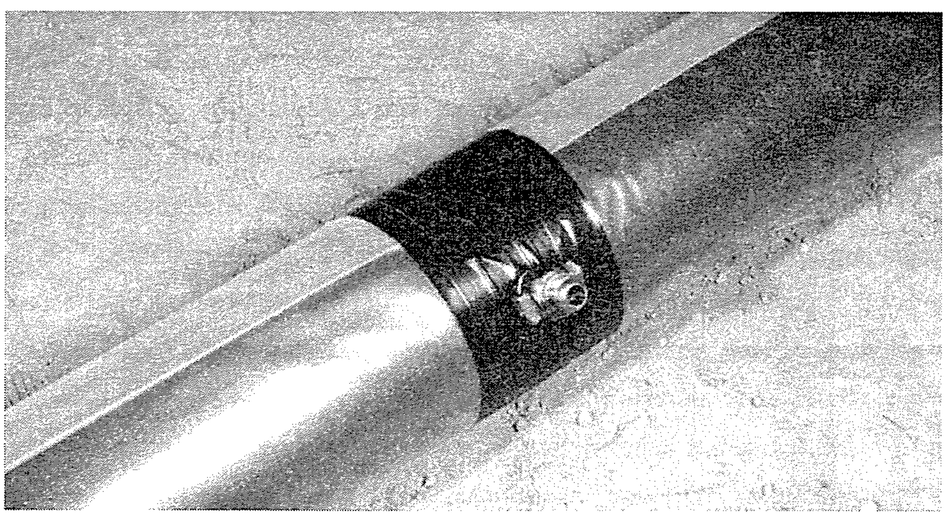


Figure 5 Preferred method for making direct service taps on polyethylene-encased iron pipe

This method is very effective in eliminating damage to the polyethylene encasement by the tapping machine and chain during the tapping operation. After the direct tap is completed, the entire circumferential area should be closely inspected for damage and repaired if needed. Service lines of dissimilar metals also shall be wrapped with polyethylene or a suitable dielectric tape for a minimum clear distance of 3 ft (0.9 m) away from the gray-iron or ductile-iron main.

SECTION 5: VERIFICATION

Sec. 5.1 Inspection

If stipulated by the purchaser, all materials are subject to inspection and approval at the manufacturer's plant.

5.1.1 *Inspection on delivery.* All pipe and appurtenances are subject to inspection on delivery. Neither inspection nor failure to provide inspection shall relieve the manufacturer of the responsibility to provide materials meeting the requirements of the contract documents. Materials not conforming to the requirements of this standard shall be made satisfactory or replaced. Tests may be performed as specified in the applicable AWWA standard to ensure conformance with the standard. Pipe or appurtenances that fail to comply with specified tests shall be made satisfactory or replaced.

5.1.2 *Workmanship.* All pipe and appurtenances shall be installed and joined in conformance with this standard and tested under pressure for defects and leaks in accordance with Sec. 5.2 of this standard.

Sec. 5.2 Hydrostatic Testing

WARNING: The testing methods described in this section are specific for water-pressure testing only. These procedures should not be applied for air-pressure testing because of the serious safety hazards involved with compressed air. Also, pipelines intended for buried service should generally be tested with the backfill in place.

5.2.1 *Hydrostatic pressure test.*

5.2.1.1 Test restrictions.

5.2.1.1.1 The test pressure shall not be less than 1.25 times the stated working pressure of the pipeline measured at the highest elevation along the test section and not less than 1.5 times the stated working pressure at the lowest elevation of the test section.

5.2.1.1.2 The test pressure shall not exceed the thrust restraint design pressures or 1.5 times the pressure rating of the pipe or joint, whichever is less (as specified by the manufacturer).

5.2.1.1.3 Valves shall not be operated in either direction at a differential pressure exceeding the rated valve working pressure. A test pressure greater than the rated valve working pressure can result in trapped test pressure between the gates of a double-disc gate valve. For tests exceeding the rated valve working pressure, the test setup should include a provision, independent of the valve, to reduce the line pressure to the rated valve working pressure on completion of the test. The valve can then be opened enough to equalize the trapped pressure with the line pressure, or the valve can be fully opened if desired.

5.2.1.1.4 The test pressure shall not exceed the rated working pressure of the valves when the pressure boundary of the test section includes closed, resilient-seated gate valves or butterfly valves.

5.2.1.2 Test setup and pressurization. Following the installation of any new pipeline, all newly laid pipe or any valved section thereof shall be subjected to a hydrostatic pressure test. Each valved section of pipeline shall be slowly filled with water. When venting air from pipelines, it is important to limit the pipeline fill rate to avoid excessive surge pressures when the water reaches the air venting opening(s). The specified test pressure shall be applied using a suitable pump connected to the pipeline. (NOTE: The specified test pressure shall be based on the elevation of the lowest point of the pipeline or section under test and corrected to the elevation of the test gauge—see test restrictions.) Before applying the specified test pressure, air shall be expelled completely from the pipeline section under test. If permanent air vents are not located at all high points, corporation cocks shall be installed at these points to expel any air as the line is filled with water. Use of corporation cocks above rated pressure must be at the risk of the user and authorized specifically by the maufacturer. Following removal of any air, the corporation cocks shall be closed and the test pressure applied (at the conclusion of the pressure test, the corporation cocks shall be removed and the pipe plugged, or left in place as required by the contract documents). The pipeline shall be allowed to stabilize at the test pressure before conducting the hydrostatic test. This may require several cycles of pressurizing and bleeding trapped air prior to beginning the test. The hydrostatic test shall be of at least a 2-hr duration. The test pressure shall not vary by more than ±5 psi (34.5 kPa) for the duration of the test. Test pressure shall be maintained within this tolerance by adding makeup water through the pressure test pump into the pipeline. The amount of makeup water added shall be accurately measured (in gallons or liters per hour) by suitable methods and shall not exceed the applicable testing allowance as specified in Tables 5A or 5B (see Sec. 5.2.1.4).

5.2.1.3 Examination. Any exposed pipe, fittings, valves, hydrants, and joints shall be examined carefully during the pressure test. Any damaged or defective pipe, fittings, valves, hydrants, or joints that are discovered during or following the pressure test shall be repaired or replaced with reliable material, and the test shall be repeated until satisfactory results are obtained.

5.2.1.4 Testing allowance. Testing allowance shall be defined as the maximum quantity of makeup water that is added into a pipeline undergoing hydrostatic pressure testing, or any valved section thereof, in order to maintain pressure within ±5 psi (34.5 kPa) of the specified test pressure (after the pipeline has been filled with water and the air has been expelled*). No pipe installation will be accepted if the quantity of makeup water is greater than that determined by the following formula:

In inch–pound units,

$$L = \frac{SD\sqrt{P}}{148{,}000} \qquad \text{(Eq 1)}$$

Where:

L = testing allowance (makeup water), in gallons per hour

S = length of pipe tested, in feet

D = nominal diameter of the pipe, in inches

P = average test pressure during the hydrostatic test, in pounds per square inch (gauge)

In metric units,

$$L_m = \frac{SD\sqrt{P}}{794{,}797} \qquad \text{(Eq 2)}$$

Where:

L_m = testing allowance (makeup water), in liters per hour

S = length of pipe tested, in meters

*The testing allowance may not be reasonable if the pressure boundary of the test section includes appurtenances subjected to pressures above their rated working pressures because of possible leakage by those appurtenances.

Table 5A Hydrostatic testing allowance per 1,000 ft of pipeline*—*gph*†

Avg. Test Pressure	Nominal Pipe Diameter—*in.*																	
psi	3	4	6	8	10	12	14	16	18	20	24	30	36	42	48	54	60	64
450	0.43	0.57	0.86	1.15	1.43	1.72	2.01	2.29	2.58	2.87	3.44	4.30	5.16	6.02	6.88	7.74	8.60	9.17
400	0.41	0.54	0.81	1.08	1.35	1.62	1.89	2.16	2.43	2.70	3.24	4.05	4.86	5.68	6.49	7.30	8.11	8.65
350	0.38	0.51	0.76	1.01	1.26	1.52	1.77	2.02	2.28	2.53	3.03	3.79	4.55	5.31	6.07	6.83	7.58	8,09
300	0.35	0.47	0.70	0.94	1.17	1.40	1.64	1.87	2.11	2.34	2.81	3.51	4.21	4.92	5.62	6.32	7.02	7.49
275	0.34	0.45	0.67	0.90	1.12	1.34	1.57	1.79	2.02	2.24	2.69	3.36	4.03	4.71	5.38	6.05	6.72	7.17
250	0.32	0.43	0.64	0.85	1.07	1.28	1.50	1.71	1.92	2.14	2.56	3.21	3.85	4.49	5.13	5.77	6.41	6.84
225	0.30	0.41	0.61	0.81	1.01	1.22	1.42	1.62	1.82	2.03	2.43	3.04	3.65	4.26	4.86	5.47	6.08	6.49
200	0.29	0.38	0.57	0.76	0.96	1.15	1.34	1.53	1.72	1.91	2.29	2.87	3.44	4.01	4.59	5.16	5.73	6.12
175	0.27	0.36	0.54	0.72	0.89	1.07	1.25	1.43	1.61	1.79	2.15	2.68	3.22	3.75	4.29	4.83	5.36	5.72
150	0.25	0.33	0.50	0.66	0.83	0.99	1.16	1.32	1.49	1.66	1.99	2.48	2.98	3.48	3.97	4.47	4.97	5.30
125	0.23	0.30	0.45	0.60	0.76	0.91	1.06	1.21	1.36	1.51	1.81	2.27	2.72	3.17	3.63	4.08	4.53	4.83
100	0.20	0.27	0.41	0.54	0.68	0.81	0.95	1.08	1.22	1.35	1.62	2.03	2.43	2.84	3.24	3.65	4.05	4.32

* If the pipeline under test contains sections of various diameters, the testing allowance will be the sum of the testing allowance for each size.

† Calculated on the basis of Eq 1.

Table 5B Hydrostatic testing allowance per 300 m of pipeline* —*L/h*†

Avg. Test Pressure *KPa*	Nominal Pipe Diameter—*mm*																	
	76	102	152	203	254	305	356	406	457	508	610	762	914	1,067	1,219	1,400	1,500	1,600
3,000	1.57	2.11	3.14	4.20	5.25	6.31	7.36	8.39	9.45	10.50	12.61	15.75	18.90	22.06	25.20	28.94	31.01	33.06
2,800	1.52	2.04	3.04	4.05	5.07	6.09	7.11	8.11	9.13	10.15	12.18	15.22	18.26	21.31	24.35	27.96	29.96	31.96
2,600	1.46	1.96	2.93	3.91	4.89	5.87	6.85	7.81	8.80	9.78	11.74	14.67	17.59	20.54	23.46	26.95	28.87	30.79
2,400	1.41	1.89	2.81	3.75	4.70	5.64	6.58	7.51	8.45	9.39	11.28	14.09	16.90	19.73	22.54	25.89	27.74	29.59
2,200	1.35	1.81	2.69	3.59	4.50	5.40	6.30	7.19	8.09	8.99	10.80	13.49	16.18	18.89	21.58	24.79	26.56	28.33
2,000	1.28	1.72	2.57	3.43	4.29	5.15	6.01	6.85	7.71	6.58	10.30	12.86	15.43	18.01	20.58	23.63	25.32	27.01
1,800	1.22	1.63	2.43	3.25	4.07	4.88	5.70	6.50	7.32	8.14	9.77	12.20	14.64	17.09	19.52	22.42	24.02	25.62
1,600	1.15	1.54	2.29	3.06	3.83	4.60	5.37	6.13	6.90	7.67	9.21	11.50	13.80	16.11	18.40	21.14	22.65	24.16
1,400	1.07	1.44	2.15	2.87	3.59	4.31	5.03	5.73	6.45	7.17	8.62	10.76	12.91	15.07	17.22	19.77	21.18	22.60
1,200	0.99	1.33	1.99	2.65	3.32	3.99	4.65	5.31	5.98	6.64	7.98	9.96	11.95	13.95	15.94	18.31	19.61	20.92
1,000	0.91	1.22	1.81	2.42	3.03	3.64	4.25	4.85	5.45	6.06	7.28	9.10	10.91	12.74	14.55	16.71	17.90	19.10
800	0.81	1.09	1.62	2.17	2.71	3.26	3.80	4.33	4.88	5.42	6.51	8.14	9.76	11.39	13.01	14.95	16.01	17.08
600	0.70	0.94	1.41	1.88	2.35	2.82	3.29	3.75	4.23	4.70	5.64	7.05	8.45	9.87	11.27	12.94	13.87	14.79

* If the pipeline under test contains sections of various diameters, the testing allowance will be the sum of the testing allowance for each size.

† Calculated on the basis of Eq 2.

D = nominal diameter of the pipe, in millimeters

P = average test pressure during the hydrostatic test, in kilopascals

5.2.1.4.1 These formulas are based on a testing allowance of 10.49 gpd/mi/in. (1.079 0.971 L/d/km/mm) of nominal diameter at a pressure of 150 psi (1,034 kPa). Values of testing allowance at various pressures are shown in Tables 5A and 5B. When testing against closed metal-seated valves, an additional testing allowance per closed valve of 0.0078 gal/hr/in. (1.2 mL/hr/mm) of nominal valve size shall be allowed. When hydrants are in the test section, the test shall be made against the main valve in the hydrant.

5.2.1.5 Acceptance of installation. Acceptance shall be determined on the basis of testing allowance only. If any test of a new pipeline discloses a testing allowance greater than that specified in Sec. 5.2.1.4, repairs or replacements shall be accomplished in accordance with the contract documents. All visible leaks are to be repaired regardless of the allowance used for testing.

SECTION 6: DELIVERY

Sec. 6.1 Unloading, Handling, and Storage

6.1.1 *Handling.* All pipe, fittings, valves, hydrants, and accessories shall be loaded and unloaded by lifting with lift hoists or skidding in order to avoid shock or damage. Under no circumstances shall this material be dropped. Pipe handled on skidways shall not be rolled or skidded against other pipe.

6.1.2 *Unloading pipe.* Trucks shall be parked on level ground for unloading. Rail sidings are generally level enough for unloading purposes.

6.1.2.1 Strapping. Before releasing the chains, cables, and strapping around the pipe, the loads shall be checked to ensure that all chock blocks are securely in place on both ends of all support timbers. If not, chocks or other suitable wedges shall be nailed into position to prevent the pipe from rolling when the other restraints are removed. Under no circumstances shall the chocks be removed while there is any possibility of pipe rolling out of control and causing damage or injury. Only after all chocks are in place shall the chains or other binders securing the load to the truck or railcar be released. Personnel shall never remain on, in front of, or alongside the load of pipe after the restraints are removed.

6.1.2.2 Off-loading. Unloading shall be done by lifting with a fork truck, a crane, or other suitable lifting device. Pipe shall never be rolled off the truck or railcar. When pipe is being unloaded one at a time, or in single layers, the restraining bands or straps shall be removed only from the layer being unloaded. Steel bands shall be cut with a long-handled bolt cutter or similar tool. Do not cut the bands with an ax, chisel, or other tool likely to cause product damage or personal injury. Personnel not directly involved in the unloading operation shall stand clear. Never stand under a lifted load. Inspect, repair, and replace lifting devices on a timely basis.

6.1.3 *Padding.* Slings, hooks, or pipe tongs shall be padded, and the padding shall be used to prevent damage to the exterior surface or internal lining of the pipe, fitting, or related product.

6.1.4 *Storage.* If stored, materials shall be kept safe from damage. The interior of all pipe, fittings, and other appurtenances shall be kept free from dirt or foreign matter at all times. Valves and hydrants shall be drained and stored in a manner that will protect them from damage by freezing.

6.1.4.1 Stacking. Pipe shall not be stacked higher than the limits shown in Table 6. The bottom tier shall be kept off the ground on timbers, rails, or other suitable supports. Pipe in tiers shall be alternated as follows: bell, plain end; bell, plain end. At least two rows of timbers shall be placed between tiers, and chocks shall be affixed to each timber in order to prevent movement. The timbers shall be large enough to prevent contact between the pipe in adjacent tiers.

6.1.4.2 Gaskets. Gaskets shall be stored in a cool location, out of direct sunlight. Gaskets shall not come in contact with petroleum products. Gaskets shall be used on a first-in, first-out basis.

6.1.4.3 Mechanical joints. Mechanical-joint bolts shall be stored in a dry location and handled in a manner that will ensure proper use with respect to types and sizes.

6.1.4.4 Sunlight. Prolonged exposure to sunlight will eventually deteriorate polyethylene film. Therefore, exposure to sunlight prior to backfilling the wrapped pipe should be kept to a minimum.

Table 6 Maximum stacking heights—ductile-iron pipe*

Nominal Pipe Size		
in.	*(mm)*	Number of Tiers
3	(76)	18
4	(102)	16
6	(152)	13
8	(203)	11
10	(254)	10
12	(305)	9
14	(356)	8
16	(406)	7
18	(457)	6
20	(508)	6
24	(610)	5
30	(762)	4
36	(914)	4
42	(1,067)	3
48	(1,219)	3
54	(1,400)	3
60	(1,500)	3
64	(1,600)	3

*For 18- or 20-ft (5.5- or 6.1-m) lengths.

American Water Works Association

ANSI/AWWA C651-99
(Revision of ANSI/AWWA C651-92)

AWWA STANDARD FOR

DISINFECTING WATER MAINS

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard presents essential procedures for the disinfection of new and repaired potable water mains. All new water mains shall be disinfected before they are placed in service. All water mains taken out of service for inspection, repair, or other activities that might lead to contamination of water shall be disinfected before they are returned to service.

Sec. 1.2 Purpose

The purpose of this standard is to define the minimum requirements for the disinfection of water mains, including the preparation of water mains, application of chlorine, and sampling and testing for the presence of coliform bacteria.

Sec. 1.3 Application

This standard can be referenced in specifications for the disinfection of water mains and can be used as a guide for the preparation of water mains, application of chlorine, and sampling and testing for the presence of coliform bacteria. The stipulations of this standard apply when this document has been referenced and then only to the disinfection of water mains.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ANSI*/AWWA B300—Standard for Hypochlorites.

*American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

ANSI/AWWA B301—Standard for Liquid Chlorine.

Simplified Procedures for Water Examination. AWWA Manual M12. AWWA, Denver (1997).

Standard Methods for the Examination of Water and Wastewater. APHA,* AWWA, and WEF.† Washington, D.C. (20th ed., 1998).

Additional materials relating to activity under this standard include the following:

Chlorine Manual—Chlorine Institute Inc.‡

Introduction to Water Treatment. WSO Series, Vol. 2. AWWA, Denver (1984).

Material Safety Data Sheets for forms of chlorine used (provided by suppliers).

Safety Practice for Water Utilities. AWWA Manual M3. AWWA, Denver (1990).

Water Chlorination Principles and Practices. AWWA Manual M20. AWWA, Denver (1973).

Water Quality and Treatment. AWWA, Denver (4th ed., 1990).

SECTION 3: DEFINITIONS

This standard has no applicable information for this section.

SECTION 4: REQUIREMENTS

Sec. 4.1 Forms of Chlorine for Disinfection

The forms of chlorine that may be used in the disinfection operations are liquid chlorine, sodium hypochlorite solution, and calcium hypochlorite granules or tablets.

4.1.1 *Liquid chlorine.* Liquid chlorine conforming to ANSI/AWWA B301 contains 100% available chlorine and is packaged in steel containers usually of 100-lb, 150-lb, or 1-ton (45.4-kg, 68.0-kg, or 907.2-kg) net chlorine weight. Liquid chlorine shall be used only (1) in combination with appropriate gas-flow chlorinators and ejectors to provide a controlled high-concentration solution feed to the water to be chlorinated; (2) under the direct supervision of someone familiar with the physiological, chemical, and physical properties of liquid chlorine who is trained and equipped to handle any emergency that may arise; and (3) when appropriate safety practices are observed to protect working personnel and the public.

4.1.2 *Sodium hypochlorite.* Sodium hypochlorite conforming to ANSI/AWWA B300 is available in liquid form in glass, rubber-lined, or plastic containers typically ranging in size from 1 qt (0.95 L) to 5 gal (18.92 L). Containers of 30 gal (113.6 L) or larger may be available in some areas. Sodium hypochlorite contains approximately 5% to 15% available chlorine, and the storage conditions and time must be controlled to minimize its deterioration. (Available chlorine is expressed as a percent of weight

* American Public Health Association, 1015 15th St. N.W., Washington, DC 20005.

† Water Environment Federation, 601 Wythe St., Alexandria, VA 22314.

‡ Chlorine Institute, 2001 L St. N.W., Washington, DC 20036.

when the concentration is 5% or less, and usually as a percent of volume for higher concentrations. Percent × 10 = grams of available chlorine per litre of hypochlorite.)

4.1.3 *Calcium hypochlorite.* Calcium hypochlorite conforming to ANSI/AWWA B300 is available in granular form or in 5-g tablets, and must contain approximately 65% available chlorine by weight. The material should be stored in a cool, dry, and dark environment to minimize its deterioration.

CAUTION: Tablets dissolve in approximately 7 hours and must be given adequate *CT*. Also, do not use calcium hypochlorite intended for swimming pool disinfection, as this material has been sequestered and is extremely difficult to eliminate from the pipe after the desired *CT* has been achieved.

Sec. 4.2 Basic Disinfection Procedure

The basic disinfection procedure consists of:

1. Inspecting all materials to be used to ensure the integrity of the materials.
2. Preventing contaminating materials from entering the water main during storage, construction, or repair and noting potential contamination at the construction site.
3. Removing, by flushing or other means, those materials that may have entered the water main.
4. Chlorinating any residual contamination that may remain, and flushing the chlorinated water from the main.
5. Protecting the existing distribution system from backflow caused by hydrostatic pressure test and disinfection procedures.
6. Documenting that an adequate level of chlorine contacted each pipe to provide disinfection.
7. Determining the bacteriological quality by laboratory test after disinfection.
8. Final connection of the approved new water main to the active distribution system.

Sec. 4.3 Preventive and Corrective Measures During Construction

4.3.1 *General.* Heavy particulates generally contain bacteria and prevent even very high chlorine concentrations from contacting and killing these organisms. Therefore, the procedures of this section must be observed to assure that a water main and its appurtenances have been thoroughly cleaned for the final disinfection by chlorination. Also, any connection of a new water main to the active distribution system prior to the receipt of satisfactory bacteriological samples may constitute a cross-connection. Therefore, the new main must be isolated until bacteriological tests described in Sec. 5 of this standard are satisfactorily completed.

4.3.2 *Keeping pipe clean and dry.* The interiors of pipes, fittings, and valves shall be protected from contamination. Pipe delivered for construction shall be strung to minimize the entrance of foreign material. All openings in the pipeline shall be closed with watertight plugs when pipe laying is stopped at the close of the day's work or for other reasons, such as rest breaks or meal periods. Rodent-proof plugs may be used when watertight plugs are not practicable and when thorough cleaning will be performed by flushing or other means.

4.3.2.1 Delay in placement of delivered pipe invites contamination. The more closely the rate of delivery is correlated to the rate of pipe laying, the lower the risk of contamination.

4.3.3 *Joints.* Joints of all pipe in the trench shall be completed before work is stopped. If water accumulates in the trench, the plugs shall remain in place until the trench is dry.

4.3.4 *Packing materials.* Yarning or packing material shall consist of molded or tubular rubber rings, rope of treated paper, or other approved materials. Materials such as jute or hemp shall not be used. Packing material shall be handled in a manner that avoids contamination. If asbestos rope is used, asbestos shall be prevented from entering into the water-carrying portion of the pipe.

4.3.5 *Sealing materials.* No contaminated material or any material capable of supporting prolific growth of microorganisms shall be used for sealing joints. Sealing material or gaskets shall be handled in a manner that avoids contamination. The lubricant used in the installation of sealing gaskets shall be suitable for use in potable water and shall not contribute odors. It shall be delivered to the job in closed containers and shall be kept clean and applied with dedicated, clean applicator brushes.

4.3.6 *Cleaning and swabbing.* If dirt enters the pipe, it shall be removed and the interior pipe surface swabbed with a 1 to 5% hypochlorite disinfecting solution. If, in the opinion of the purchaser, the dirt remaining in the pipe will not be removed using the flushing operation, then the interior of the pipe shall be cleaned using mechanical means, such as a hydraulically propelled foam pig (or other suitable device acceptable to the purchaser) in conjunction with the application of a 1% hypochlorite disinfecting solution. The cleaning method used shall not force mud or debris into the interior pipe-joint spaces and shall be acceptable to the purchaser.

4.3.7 *Wet-trench construction.* If it is not possible to keep the pipe and fittings dry during installation, the water that may enter the pipe-joint spaces shall contain an available chlorine concentration of approximately 25 mg/L. This may be accomplished by adding calcium hypochlorite granules or tablets to each length of pipe before it is lowered into a wet trench or by treating the trench water with hypochlorite tablets.

4.3.8 *Flooding by storm or accident during construction.* If the main is flooded during construction, it shall be cleared of the floodwater by draining and flushing with potable water until the main is clean. The section exposed to the floodwater shall then be filled with a chlorinated potable water that, at the end of a 24-h holding period, will have a free chlorine residual of not less than 25 mg/L. The chlorinated water may then be drained or flushed from the main. After construction is completed, the main shall be disinfected using the continuous-feed or slug method.

4.3.9 *Backflow protection (optional).** As an optional procedure (if specified by the purchaser), the new water main shall be kept isolated from the active distribution system using a physical separation (see Fig. 1) until satisfactory bacteriological testing has been completed and the disinfectant water flushed out. Water required to fill the new main for hydrostatic pressure testing, disinfection, and flushing shall be supplied through a temporary connection between the distribution system and the new main. The temporary connection shall include an appropriate cross-connection control device consistent with the degree of hazard (a double check valve assembly or a reduced pressure zone assembly) and shall be disconnected (physically separated) from the new main during the hydrostatic pressure test. It will

*Optional Sec. 4.3.9 is not included as part of the standard unless specifically identified in the purchaser's specifications.

be necessary to reestablish the temporary connection after completion of the hydrostatic pressure test to flush out the disinfectant water prior to final connection of the new main to the distribution system. NOTE: Exposure to high levels of chlorine or high pH can cause severe irritation to customers. Also, the chlorinated water can be high in disinfection by-products.

Sec. 4.4 Methods of Chlorination

4.4.1 *General.* Three methods of chlorination are explained in this section: tablet, continuous feed, and slug. Information in the foreword is helpful in determining the appropriate method. The tablet method gives an average chlorine dose of approximately 25 mg/L; the continuous-feed method gives a 24-h chlorine residual of not less than 10 mg/L; and the slug method gives a 3-h exposure of not less than 50-mg/L free chlorine.

4.4.1.1 Preflushing of source water. The source water used for disinfection and pressure testing shall be flushed prior to its use to ensure that contaminants or debris are not introduced into the new pipe. Adequate drainage must be provided during flushing. Drainage should take place away from the construction area. During the contact period, it is recommended that the valve isolating the new main from this system (if applicable) be tagged to prevent unintentional release of the elevated chlorine residual water into the system.

4.4.2 *Tablet method.* The tablet method consists of placing calcium hypochlorite granules or tablets in the water main as it is being installed and then filling the main with potable water when installation is completed.

This method may be used only if the pipes and appurtenances are kept clean and dry during construction.

4.4.2.1 Placing of calcium hypochlorite granules. During construction, calcium hypochlorite granules shall be placed at the upstream end of the first section of pipe, at the upstream end of each branch main, and at 500-ft intervals. The quantity of granules shall be as shown in Table 1.

WARNING: This procedure must not be used on solvent-welded plastic or on screwed-joint steel pipe because of the danger of fire or explosion from the reaction of the joint compounds with the calcium hypochlorite.

4.4.2.2 Placing of calcium hypochlorite tablets. During construction, 5-g calcium hypochlorite tablets shall be placed in each section of pipe. Also, one tablet shall be placed in each hydrant, hydrant branch, and other appurtenance. The number of 5-g tablets required for each pipe section shall be 0.0012 d^2L rounded to the next higher integer, where d is the inside pipe diameter, in inches, and L is the length of

Table 1 Ounces of calcium hypochlorite granules to be placed at beginning of main and at each 500-ft interval

Pipe Diameter		Calcium Hypochlorite Granules	
in.	*(mm)*	*oz*	*(g)*
4	(100)	0.5	(14)
6	(150)	1.0	(28)
8	(200)	2.0	(57)
12	(250)	4.0	(113)
16 and larger	(400 and larger)	8.0	(227)

Table 2 Number of 5-g calcium hypochlorite tablets required for dose of 25 mg/L*

Pipe Diameter		Length of Pipe Section, *ft (m)*				
		13 (4.0) or less	18 (5.5)	20 (6.1)	30 (9.1)	40 (12.2)
in.	*(mm)*	Number of 5-g Calcium Hypochlorite Tablets				
4	(100)	1	1	1	1	1
6	(150)	1	1	1	2	2
8	(200)	1	2	2	3	4
10	(250)	2	3	3	4	5
12	(300)	3	4	4	6	7
16	(400)	4	6	7	10	13

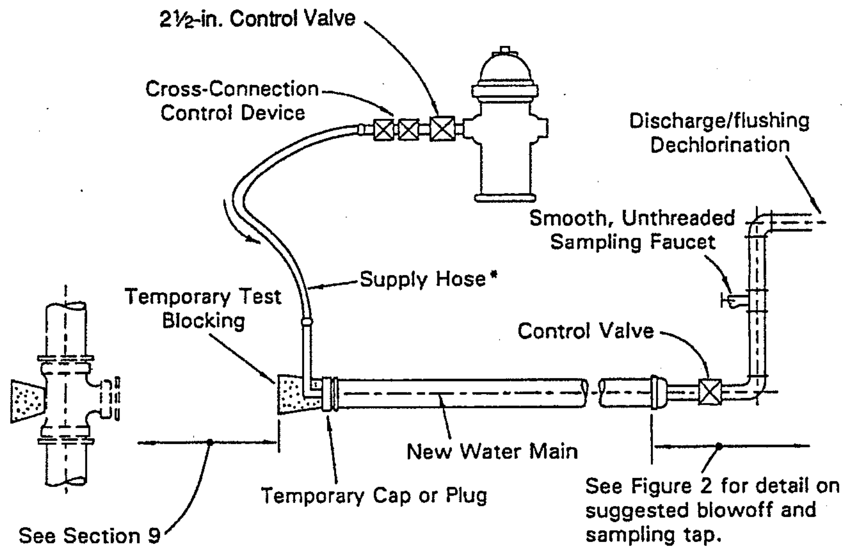
*Based on 3.25-g available chlorine per tablet; any portion of tablet rounded to the next higher integer.

the pipe section, in feet. Table 2 shows the number of tablets required for commonly used sizes of pipe. The tablets shall be attached by a food-grade adhesive.* There shall be adhesive only on the broadside of the tablet attached to the surface of the pipe. Attach all the tablets inside and at the top of the main, with approximately equal numbers of tablets at each end of a given pipe length. If the tablets are attached before the pipe section is placed in the trench, their position shall be marked on the section to indicate that the pipe has been installed with the tablets at the top.

4.4.2.3 Filling and contact. When installation has been completed, the main shall be filled with water at a rate to ensure that the water within the main will flow at a velocity no greater than 1 ft/s (0.3 m/s). Precautions shall be taken to ensure that air pockets are eliminated. This water shall remain in the pipe for at least 24 h. If the water temperature is less than 41°F (5°C), the water shall remain in the pipe for at least 48 h. As an optional procedure (if specified by the purchaser), water used to fill the new main shall be supplied through a temporary connection that shall include an appropriate cross-connection control device, consistent with the degree of hazard, for backflow protection of the active distribution system (see Figure 1). A detectable chlorine residual should be found at each sampling point after the 24-h period. The results must be reported.

4.4.3 *Continuous-feed method.* The continuous-feed method consists of placing calcium hypochlorite granules in the main during construction (optional), completely filling the main to remove all air pockets, flushing the completed main to remove particulates, and filling the main with potable water. The potable water shall be chlorinated so that after a 24-h holding period in the main there will be a free chlorine residual of not less than 10 mg/L.

*Examples of food-grade adhesives are Permatex Form-A-Gasket No. 2 and Permatex Clear RTV Silicone Adhesive Sealant, which are manufactured by Loctite Corporation, Kansas City, KS 66115. These products have been approved by the US Drug Administration (USDA) for uses that may involve contact with edible products. Neither product has been approved in accordance with NSF 61. Other company products, such as Permatex Form-A-Gasket No. 1, have not received FDA approval.



*Clean potable-water hose only. Size and number of taps per Table 3. This hose must be removed during the hydrostatic pressure test.

NOTE: Figure 1 applies to pipes with diameters 4 in. (100 mm) through 12 in. (300 mm). All larger sizes must be handled on a case-by-case basis.

Figure 1 Suggested temporary flushing/testing connection

4.4.3.1 Placing of calcium hypochlorite granules. At the option of the purchaser, calcium hypochlorite granules shall be placed in pipe sections as specified in Sec. 4.4.2.1. The purpose of this procedure is to provide a strong chlorine concentration in the first flow of flushing water that flows down the main. In particular, this procedure is recommended when the type of pipe is such that this first flow of water will flow into annular spaces at pipe joints.

4.4.3.2 Preliminary flushing. Before the main is chlorinated, it shall be filled to eliminate air pockets and flushed to remove particulates. The flushing velocity in the main shall not be less than 2.5 ft/s (0.76 m/s) unless the purchaser determines that conditions do not permit the required flow to be discharged to waste. Table 3 shows the rates of flow required to produce a velocity of 2.5 ft/s (0.76 m/s) in commonly used sizes of pipe. Note that flushing is no substitute for preventive measures during construction. Certain contaminants, such as caked deposits, resist flushing at any feasible velocity.

For 24-in. (600-mm) or larger diameter mains, an acceptable alternative to flushing is to broom-sweep the main, carefully removing all sweepings prior to chlorinating the main.

4.4.3.3 Procedure for chlorinating the main.

1. Water supplied from a temporary, backflow-protected connection to the existing distribution system or other approved supply source shall flow at a constant,

Table 3 Required flow and openings to flush pipelines (40 psi [276 kPa] residual pressure in water main)*

Pipe Diameter		Flow Required to Produce 2.5 *ft/s* (approx.) Velocity in Main		Size of Tap, *in.* (*mm*) 1 (25)	1½ (38)	2 (51 *mm*)	Number of 2½-*in.* (64-*mm*) Hydrant Outlets
in.	(*mm*)	*gpm*	(*L/s*)	Number of Taps on Pipe†			
4	(100)	100	(6.3)	1	—	—	1
6	(150)	200	(12.6)	—	1	—	1
8	(200)	400	(25.2)	—	2	1	1
10	(250)	600	(37.9)	—	3	2	1
12	(300)	900	(56.8)	—	—	2	2
16	(400)	1,600	(100.9)	—	—	4	2

*With a 40-psi (276-kPa) pressure in the main with the hydrant flowing to atmosphere, a 2½-in. (64-mm) hydrant outlet will discharge approximately 1,000 gpm (63.1 L/s); and a 4½-in. (114-mm) hydrant outlet will discharge approximately 2,500 gpm (160 L/s).

†Number of taps on pipe based on discharge through 5 ft (1.5 m) of galvanized iron (GI) pipe with one 90° elbow.

measured rate into the newly installed water main. In the absence of a meter, the rate may be approximated using a Pitot gauge in the discharge, measuring the time to fill a container of known volume, or measuring the trajectory of the discharge and using the formula shown in Figure 2.

2. At a point not more than 10 ft (3 m) downstream from the beginning of the new main, water entering the new main shall receive a dose of chlorine fed at a constant rate such that the water will have not less than 25 mg/L free chlorine. To ensure that this concentration is provided, measure the chlorine concentration at regular intervals in accordance with the procedures described in the current edition of *Standard Methods for the Examination of Water and Wastewater* or AWWA Manual M12, or using appropriate chlorine test kits (see appendix A).

Table 4 gives the amount of chlorine required for each 100 ft (30.5 m) of pipe of various diameters. Solutions of 1% chlorine may be prepared with sodium hypochlorite or calcium hypochlorite. The latter solution requires 1 lb (454 g) of calcium hypochlorite in 8 gal (30.3 L) of water.

3. As an optional procedure (if specified by the purchaser), water used to fill the new main during the application of chlorine shall be supplied through a temporary connection. This temporary connection shall be installed with an appropriate cross-connection control device, consistent with the degree of hazard for backflow protection of the active distribution system (see Figure 1). Chlorine application shall not cease until the entire main is filled with heavily chlorinated water. The chlorinated water shall be retained in the main for at least 24 h, during which time all valves and hydrants in the treated section shall be operated to ensure disinfection of the appurtenances. At the end of this 24-h period, the treated water in all portions of the main shall have a residual of not less than 10 mg/L of free chlorine.

4. Direct-feed chlorinators, which operate solely from gas pressure in the chlorine cylinder, shall not be used for the application of liquid chlorine. (The danger of using direct-feed chlorinators is that water pressure in the main can exceed gas pressure in the chlorine cylinder. This allows a backflow of water into the cylinder,

resulting in severe cylinder corrosion and escape of chlorine gas.) The preferred equipment for applying liquid chlorine is a solution-feed, vacuum-operated chlorinator and a booster pump. The vacuum-operated chlorinator mixes the chlorine gas in solution water; the booster pump injects the chlorine-gas solution into the main to be disinfected. Hypochlorite solutions may be applied to the water main with a gasoline or electrically powered chemical-feed pump designed for feeding chlorine solutions. Feed lines shall be made of material capable of withstanding the corrosion caused by the concentrated chlorine solutions and the maximum pressures that may be created by the pumps. All connections shall be checked for tightness before the solution is applied to the main.

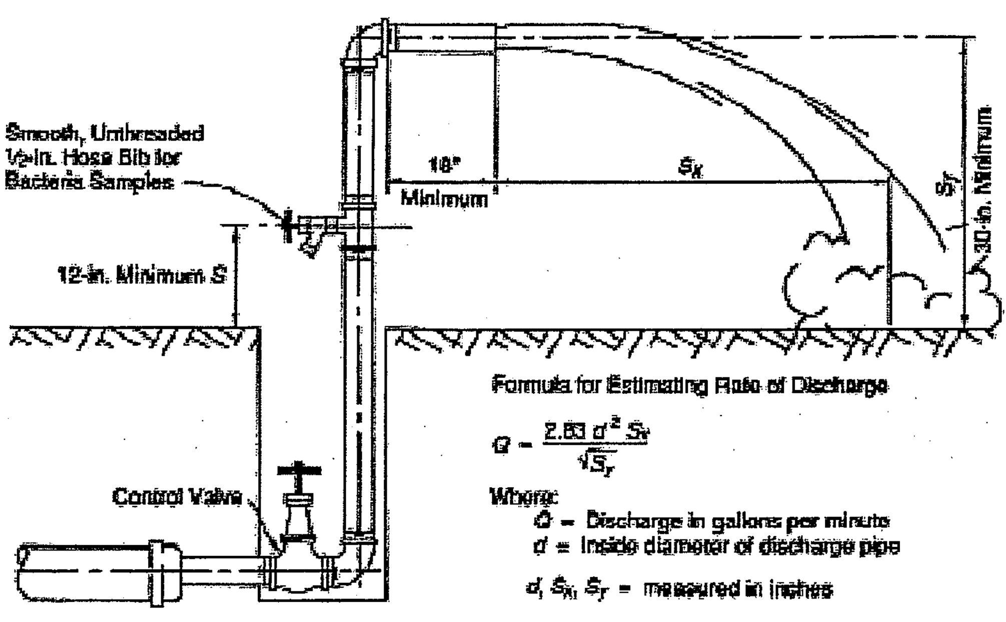
4.4.4 *Slug method.* The slug method consists of placing calcium hypochlorite granules in the main during construction; completely filling the main to eliminate all air pockets; flushing the main to remove particulates; and slowly flowing through the main a slug of water dosed with chlorine to a concentration of 100 mg/L. The slow rate of flow ensures that all parts of the main and its appurtenances will be exposed to the highly chlorinated water for a period of not less than 3 h.

4.4.4.1 Placing calcium hypochlorite granules. Same as Sec. 4.4.3.1.

4.4.4.2 Preliminary flushing. Same as Sec. 4.4.3.2.

4.4.4.3 Chlorinating the main.

1. Same as Sec. 4.4.3.3(1).
2. At a point not more than 10 ft (3 m) downstream from the beginning of the new main, water entering the new main shall receive a dose of chlorine fed at a constant rate such that the water will have not less than 100 mg/L free chlorine. To ensure that this concentration is achieved, the chlorine concentration should be



NOTE: This figure applies to pipes up to and including 8-in. (200 mm) diameter.

Figure 2 Suggested combination blowoff and sampling tap

Table 4 Chlorine required to produce 25-mg/L concentration in 100 ft (30.5 m) of pipe by diameter

Pipe Diameter		100% Chlorine		1% Chlorine Solution	
in.	*(mm)*	*lb*	*(g)*	*gal*	*(L)*
4	(100)	.013	(5.9)	.16	(0.6)
6	(150)	.030	(13.6)	.36	(1.4)
8	(200)	.054	(24.5)	.65	(2.5)
10	(250)	.085	(38.6)	1.02	(3.9)
12	(300)	.120	(54.4)	1.44	(5.4)
16	(400)	.217	(98.4)	2.60	(9.8)

measured at regular intervals. The chlorine shall be applied continuously and for a sufficient period to develop a solid column, or "slug," of chlorinated water that will, as it moves through the main, expose all interior surfaces to a concentration of approximately 100 mg/L for at least 3 h.

3. The free chlorine residual shall be measured in the slug as it moves through the main. If at any time it drops below 50 mg/L, the flow shall be stopped; chlorination equipment shall be relocated at the head of the slug; and, as flow resumes, chlorine shall be applied to restore the free chlorine in the slug to not less than 100 mg/L.

4. As the chlorinated water flows past fittings and valves, related valves and hydrants shall be operated so as to disinfect appurtenances and pipe branches.

Sec. 4.5 Final Flushing

4.5.1 *Clearing the main of heavily chlorinated water.* After the applicable retention period, heavily chlorinated water should not remain in prolonged contact with pipe. In order to prevent damage to the pipe lining or to prevent corrosion damage to the pipe itself, the heavily chlorinated water shall be flushed from the main fittings, valves, and branches until chlorine measurements show that the concentration in the water leaving the main is no higher than that generally prevailing in the distribution system or that is acceptable for domestic use.

4.5.2 *Disposing of heavily chlorinated water.* The environment to which the chlorinated water is to be discharged shall be inspected. If there is any possibility that the chlorinated discharge will cause damage to the environment, then a neutralizing chemical shall be applied to the water to be wasted to neutralize thoroughly the residual chlorine. (See appendix B for neutralizing chemicals.) Where necessary, federal, state, provincial, and local regulatory agencies should be contacted to determine special provisions for the disposal of heavily chlorinated water.

Sec. 4.6 Final Connections to Existing Mains (Optional)*

As an optional procedure (if specified by the purchaser), water mains and appurtenances must be completely installed, flushed, disinfected, and satisfactory bacteriological sample results received prior to permanent connections being made to

*Optional Sec. 4.6 is not included as part of the standard unless specifically identified in the purchaser's specifications.

the active distribution system. Sanitary construction practices must be followed during installation of the final connection, so that there is no contamination of the new or existing water main with foreign material or groundwater.

4.6.1 *Connections equal to or less than one pipe length (≤18 ft [5.5 m]).* As an optional procedure (if specified by the purchaser), the new pipe, fittings, and valve(s) required for the connection may be spray-disinfected or swabbed with a minimum 1–5% solution of chlorine just prior to being installed, if the total length of the connection from the end of a new main to the existing main is equal to or less than 18 ft (5.5 m).

4.6.2 *Connections greater than one pipe length (>18 ft [5.5 m]).* As an optional procedure (if specified by the purchaser), the pipe required for the connection must be set up aboveground, disinfected, and bacteriological samples taken, as described in Sec. 5, if the total length of the connection from the end of a new main to the existing main is greater than 18 ft (5.5 m). After satisfactory bacteriological sample results have been received for the "predisinfected" pipe, the pipe can be used in connecting the new main to the active distribution system. Between the time the satisfactory bacteriological sample results are received and the time that the connection piping is installed, the ends of the piping must be sealed with plastic wraps, watertight plugs, or caps.

Sec. 4.7 Disinfection Procedures When Cutting Into or Repairing Existing Mains

The following procedures apply primarily when existing mains are wholly or partially dewatered. After the appropriate procedures have been completed, the existing main may be returned to service prior to the completion of bacteriological testing in order to minimize the time customers are without water. Leaks or breaks that are repaired with clamping devices while the mains remain full of pressurized water may present little danger of contamination and therefore may not require disinfection.

4.7.1 *Trench treatment.* When an existing main is opened, either by accident or by design, the excavation will likely be wet and may be badly contaminated from nearby sewers. Liberal quantities of hypochlorite applied to open trench areas will lessen the danger from this pollution. Tablets have the advantage in this situation, because they dissolve slowly and continue to release hypochlorite as water is pumped from the excavation.

4.7.2 *Swabbing with hypochlorite solution.* The interior of all pipe and fittings (particularly couplings and sleeves) used in making the repair shall be swabbed or sprayed with a 1% hypochlorite solution before they are installed.

4.7.3 *Flushing.* Thorough flushing is the most practical means of removing contamination introduced during repairs. If valve and hydrant locations permit, flushing toward the work location from both directions is recommended. Flushing shall be started as soon as the repairs are completed and shall be continued until discolored water is eliminated.

4.7.4 *Slug chlorination.* Where practical, in addition to the procedures previously described, the section of the main in which the break is located shall be isolated, all service connections shut off, and the section flushed and chlorinated as described in Sec. 4.4.4. The dose may be increased to as much as 300 mg/L and the *CT* reduced to as little as 15 min. After chlorination, flushing shall be resumed and continued until discolored water is eliminated and the chlorine concentration in the water exiting the main is no higher than the prevailing water in the distribution system or that which is acceptable for domestic use.

4.7.5 *Bacteriological samples.* Bacteriological samples shall be taken after repairs are completed to provide a record for determining the procedure's effectiveness. If the direction of flow is unknown, then samples shall be taken on each side of the main break. If positive bacteriological samples are recorded, then the situation shall be evaluated by the purchaser who can determine corrective action. Daily sampling shall be continued until two consecutive negative samples are recorded.

Sec. 4.8 Special Procedure for Caulked Tapping Sleeves

Before a tapping sleeve is installed, the exterior of the main to be tapped shall be thoroughly cleaned, and the interior surface of the sleeve shall be lightly dusted with calcium hypochlorite powder.

Tapping sleeves are used to avoid shutting down the main. After the tap is made, it is impossible to disinfect the annulus without shutting down the main and removing the sleeve. The space between the tapping sleeve and the tapped pipe is approximately ½ in. (13 mm), so that as little as 100 mg/ft^2 of calcium hypochlorite powder will provide a chlorine concentration of more than 50 mg/L.

SECTION 5: VERIFICATION

Sec. 5.1 Bacteriological Tests

5.1.1 *Standard conditions.* After final flushing and before the new water main is connected to the distribution system, two consecutive sets of acceptable samples, taken at least 24 h apart, shall be collected from the new main. (NOTE: The pipe, the water loaded into the pipe, and any debris all exert a chlorine demand that can interfere with disinfection.) At least one set of samples shall be collected from every 1,200 ft (366 m) of the new water main, plus one set from the end of the line and at least one set from each branch. All samples shall be tested for bacteriological (chemical and physical) quality in accordance with *Standard Methods for the Examination of Water and Wastewater*; and shall show the absence of coliform organisms; and, if required, the presence of a chlorine residual. Turbidity, pH, and a standard heterotrophic plate count or test may be required at the option of the purchaser, because new material does not typically contain coliforms but does typically contain HPC bacteria.

5.1.2 *Special conditions.* If trench water has entered the new main during construction or if, in the opinion of the purchaser, excessive quantities of dirt or debris have entered the new main, bacteriological samples shall be taken at intervals of approximately 200 ft (61 m), and the location shall be identified. Samples shall be taken of water that has stood in the new main for at least 16 h after final flushing has been completed.

5.1.3 *Sampling procedure.* Samples for bacteriological analysis shall be collected in sterile bottles treated with sodium thiosulfate as required by *Standard Methods for the Examination of Water and Wastewater.* No hose or fire hydrant shall be used in the collection of samples. (NOTE: For pipe repairs, if no other sampling port is available, well-flushed fire hydrants may be used with the understanding that they do not represent optimum sampling conditions.) A suggested combination blowoff and sampling tap used for mains up to and including 8-in. (200-mm) diameter is shown in Figure 2. There should be no water in the trench up to the connection for sampling. The sampling pipe must be dedicated and clean, and disinfected and flushed prior to sampling. A corporation cock may be installed in the main with a copper-tube gooseneck assembly. After samples have been collected, the gooseneck assembly may be removed and retained for future use.

5.1.4 *Record of compliance*. The record of compliance shall be the bacteriological test results certifying that the water sampled from the new water main is free of coliform bacteria contamination and is equal to or better than the bacteriologic water quality in the distribution system.

Sec. 5.2 Redisinfection

If the initial disinfection fails to produce satisfactory bacteriological results or if other water quality is affected, the new main may be reflushed and shall be resampled. If check samples also fail to produce acceptable results, the main shall be rechlorinated by the continuous-feed or slug method until satisfactory results are obtained.

NOTE: High velocities in the existing system, resulting from flushing the new main, may disturb sediment that has accumulated in the existing mains. When check samples are taken, it is advisable to sample water entering the new main to determine the source of turbidity.

SECTION 6: DELIVERY

This standard has no applicable information for this section.

APPENDIX A

Chlorine Residual Testing

This appendix is for information only and is not a part of AWWA C651.

SECTION A.1: DPD DROP DILUTION METHOD (FOR FIELD TEST)

The N, N-diethyl-p-phenylenediamine (DPD) drop dilution method of approximating total residual chlorine is suitable for concentrations above 10 mg/L, such as those applied in the disinfection of water mains or tanks.

Sec. A.1.1 Apparatus

1. A graduated cylinder for measuring distilled water.
2. An automatic or safety pipette.
3. Two dropping pipettes that deliver a 1-mL sample in 20 drops. One pipette is for dispensing the water sample, and the other is for dispensing the DPD and buffer solutions. The pipettes should not be interchanged.
4. A comparator kit containing a suitable range of standards.

Sec. A.1.2 Reagents

1. DPD indicator solution. Prepare as prescribed in *Standard Methods for the Examination of Water and Wastewater* (20th ed.), Section 4500-Cl, p. F.2*b*.

Sec. A.1.3 Procedure

1. Add 10 drops of DPD solution and 10 drops of buffer solution (or 20 drops of combined DPD–buffer solution) to a comparator cell.
2. Fill the comparator cell to the 10-mL mark with distilled water.
3. With a dropping pipette, add the water sample one drop at a time, mix until a red color is formed that matches one of the color standards.
4. Record the total number of drops used and the final chlorine reading obtained (that is, the chlorine reading of the matched standard).
5. Calculate the milligrams per litre of free residual chlorine as follows:

$$\text{mg/L chlorine} = \frac{\text{reading} \times 200}{\text{drops of sample}}$$

SECTION A.2: HIGH-RANGE CHLORINE TEST KITS

Several manufacturers produce high-range chlorine test kits that are inexpensive, easy to use, and satisfactory for the precision required.

APPENDIX B

Chlorine Dosages

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Table B.1 Amounts of chemicals required to produce various chlorine concentrations in 100,000 gal (378.5 m^3) of water*

Desired Chlorine Concentration in Water	Liquid Chlorine Required		Sodium Hypochlorite Required: 5% Available Chlorine		Sodium Hypochlorite Required: 10% Available Chlorine		Sodium Hypochlorite Required: 15% Available Chlorine		Calcium Hypochloride Required: 65% Available Chlorine	
mg/L	*lb*	*(kg)*	*gal*	*(L)*	*gal*	*(L)*	*gal*	*(L)*	*lb*	*(kg)*
2	1.7	(.77)	3.9	(14.7)	2.0	(7.6)	1.3	(4.9)	2.6	(1.18)
10	8.3	(3.76)	19.4	(73.4)	9.9	(37.5)	6.7	(25.4)	12.8	(5.81)
50	42.0	(19.05)	97.0	(367.2)	49.6	(187.8)	33.4	(126.4)	64.0	(29.03)

*Amounts of sodium hypochlorite are based on concentrations of available chlorine by volume. For either sodium hypochlorite or calcium hypochlorite, extended or improper storage of chemicals may have caused a loss of available chlorine.

Table B.2 Amounts of chemicals required to produce chlorine concentration of 200 mg/L in various volumes of water*

Volume of Water		Liquid Chlorine Required		Sodium Hypochlorite Required: 5% Available Chlorine		Sodium Hypochlorite Required: 10% Available Chlorine		Sodium Hypochlorite Required: 15% Available Chlorine		Calcium Hypochloride Required: 65% Available Chlorine	
gal	*(L)*	*lb*	*(g)*	*gal*	*(L)*	*gal*	*(L)*	*gal*	*(L)*	*lb*	*(g)*
10	(37.9)	0.02	(9.1)	0.04	(.15)	0.02	(.08)	0.02	(.08)	0.03	(13.6)
50	(189.3)	0.1	(45.4)	0.2	(.76)	0.1	(.38)	0.07	(.26)	0.15	(68.0)
100	(378.5)	0.2	(90.7)	0.4	(1.51)	0.2	(.76)	0.15	(.57)	0.3	(136.1)
200	(757.1)	0.4	(181.4)	0.8	(3.03)	0.4	(1.51)	0.3	(1.14)	0.6	(272.2)

*Amounts of sodium hypochlorite are based on concentrations of available chlorine by volume. For either sodium hypochlorite or calcium hypochlorite, extended or improper storage of chemicals may have caused a loss of available chlorine.

APPENDIX C

Disposal of Heavily Chlorinated Water

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1. Check with the local sewer department for the conditions of disposal to the sanitary sewer.
2. Chlorine residual of water being disposed will be neutralized by treating with one of the chemicals listed in Table C.1.

Table C.1 Amounts of chemicals required to neutralize various residual chlorine concentrations in 100,000 gal (378.5 m^3) of water*

Residual Chlorine Concentration	Sulfur Dioxide (SO_2)		Sodium Bisulfite ($NaHSO_3$)		Sodium Sulfite (Na_2SO_3)		Sodium Thiosulfate ($Na_2S_2O_3 \bullet 5H_2O$)	
mg/L	*lb*	*(kg)*	*lb*	*(kg)*	*lb*	*(kg)*	*lb*	*kg*
1	0.8	(.36)	1.2	(.54)	1.4	(.64)	1.2	(.54)
2	1.7	(.77)	2.5	(1.13)	2.9	(1.32)	2.4	(1.09)
10	8.3	(3.76)	12.5	(5.67)	14.6	(6.62)	12.0	(5.44)
50	41.7	(18.91)	62.6	(28.39)	73.0	(33.11)	60.0	(27.22)

*Except for residual chlorine concentration, all amounts are in pounds (kilograms).