KNOXVILLE UTILITIES BOARD

DESIGN GUIDE FOR CONSTRUCTION APPROVAL FOR WATER SYSTEMS

4th EDITION
September 2025

Introduction to Design Guide for Water Systems

The purpose of this document is to assist developers and design firms with successfully completing water designs for proposed developments. This guide offers a standard set of templates that are proposed for water system designs and outlines the minimum submittal information considered to be required by KUB for new systems such as subdivisions, extensions, upgrades, etc. The purpose of this guide is to improve the efficiency of reviews by reducing the number of re-submittals by the developer's design firm. Project submittals such as construction documents and associated calculations must be prepared according to this design guide.

As a general rule, each submittal should include one pdf copy of the design to KUB. Once reviewed, the design will be returned to the designer with comments for revisions. Once the plans are ready for approval, KUB will stamp the plans with a red approved for construction stamp and will return the plans with a letter, pending TDEC fees and utility agreements.

Hydraulic Hand Calculations and/or Hydraulic Computer Simulation Required Forms

This design guide packet contains several "fill in the blank" template forms that are either to be used directly or to be equally re-created as to the designer's preferences. Located in Section F of the design guide there are a few calculation forms that are intended to be used universally throughout the project for hand (manual) calculations using the Hazen-Williams equations. For an example of how the following forms can be used for different portions of a water project, see Sections H through J of this document. If there are two different water lines that are in a water project (Water Line A and Water Line B), the "Hydraulic Calculations Summary Form" can be filled out for Line A only and then filled out again for the Line B calculations. It is intended that each water line can have its own form for hydraulic calculations. Note that this form is required for all water system proposals that are designed by hydraulic hand calculations.

Hydraulic Hand Calculation Requirements Only

The "Hydraulic Calculations Summary Form" and "Critical Pressure Summary Form for Proposed Development" are summary hydraulic tables to assist the designer. The calculation forms (found in Section L), like the summary table forms previously mentioned, can be copied for multiple water line calculations for a project and can be used to ensure hydraulic sufficiency. Note that the "Hydraulic Calculations Summary Form" is the only required form for project submittals when a computer simulated hydraulic analysis is not used for design. Also provide a detailed narrative with the required "Hydraulic Calculations Summary Form" that indicates all the variables, assumptions, and information to analyze the project's hydraulic stability.

The "Initial Hydraulic Grade Line Elevation" form is intended to only be filled out once for the Fire Hydrant tested to create the Hydraulic Grade Line for the proposed water.

The "Friction Head Loss Between Two Points (X0 and X1)" form can be copied and filled out for each proposed water line hydraulic calculation. Note that X0 and X1 are arbitrary variables that indicate a beginning and ending point in hydraulic calculations for proposed water mains that have the same size, same direct flow path, and the same pipe roughness (C Factor).

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The "Final Hydraulic Grade Line Elevation" form can be copied and filled out for each proposed water line hydraulic calculation. Note that X0 and X1 are arbitrary variables that indicate a beginning and ending point in hydraulic calculations for proposed water mains.
The "Required Pressure Head Above the Ground Surface for the Top Level of a Building" form is intended to only be used once for a proposed building in the project that has the leading number of stories.

Note that the last four "By-Hand" hydraulic forms noted above are not required for project submittals, but can be a useful tool for water system design.

Hydraulic Computer Simulation Requirements Only

The "Water System Design by Computer Simulation (1 of 2)" form is based on the simulated data collected for the Nodes created throughout the project. Each Node should represent a significant point of interest in the proposed layout (bend, tee, cross, begin, end, etc.). Note that if the "Water System Design by Computer Simulation (1 of 2)" form does not have enough "blanks" to place all the proposed buildings information on, it is intended that the form be copied before any values have been placed on the document so the proposed information can be continued (i.e., the first copied form has Nodes 1-20, second copy has Nodes 20-40, etc.). Note that this form is required for water system proposals that are designed by hydraulic computer simulations only.

The "Water System Design by Computer Simulation (2 of 2)" form is based on the simulated data collected for the Links (Pipes) created throughout the project. Each Link should be shown in the summary table and clearly labeled in the proposed project. Note that if the "Water System Design by Computer Simulation (2 of 2)" form does not have enough "blanks" to place all the proposed buildings information on, it is intended that the form be copied before any values have been placed on the document so the proposed information can be continued (i.e., the first copied form has Links (Pipes) 1-20, second copy has Links (Pipes) 20-40, etc.). Note that this form is required for water system proposals that are designed by hydraulic computer simulations only.

Also provide a detailed narrative with the required "Water System Design by Computer Simulation" forms that indicates all the variables, assumptions, and information to analyze the project's hydraulic stability.

The "Hydraulic Calculations Summary Form" and "Critical Pressure Summary Form for Proposed Development" are summary hydraulic tables are to assist the designer and are not required for hydraulic analysis by computer simulation.

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Documents contained in the Sections

Several items located in this package can help assist designers in document submittal requirements when preparing proposed water plans and calculations. The sections are divided into several divisions that separate several subjects for clarity. The different sections include parts A through F focusing on required checklists that are used to approve project submittals, Section G focusing on a Proposed Water Drawing Example, and Sections H through K focusing on Water Project Example Calculations.

<u>Proposed Water Submittal Requirement Checklists (Sections A-E)</u>
Located in the Sections, there are sets of water checklists that are used to review the plans to improve the efficiency of the review process. It is important that the designer view the checklist items before project submittal to KUB. If an item on the checklist is not identified in the project submittals, the plans will not be approved and will have to be corrected.

<u>Proposed Water Hand Calculation Documents (Section F)</u>
Located in this section is a set of documents that can assist the designer with hydraulics through the Hazen-Williams equation.

<u>Proposed Water Computer Simulation Documents (Section G)</u>
Located in this section is a set of documents that can assist the designer with a format to submit the calculations resulting from hydraulic computer simulations. Proposed Water Drawing Examples (Section I) There is one drawing that provides an example of a satisfactory set of plans for a water proposal. The drawing is a general water site plan proposal that clearly identifies the design, location, and brief details of the water proposal.

<u>Water Project Example Calculations (Sections J-M)</u>
Depending upon the choice of calculations (Hand or Computer Simulation), an example of the preferred submittal format is illustrated. The calculation examples are all based on the same project layout, which is shown in Section I (the Proposed Water Drawing Examples).

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CHART A-1: Review Process -General Water

Comment Number	**First** Date:	**Second** Date:	**Review Criteria**
1			If submitted design plans are of a project with multiple phases, all prior phases and their respective easements and final subdivision plans must already be approved, accepted, and recorded if this phase will connect to an earlier phase.
2			Provided KUB logo is used.
3			Title Block at the bottom of each sheet must include:
4			-Project name as well as Public or Private
5			- Engineer's company, address and phone number
6			- Engineer's stamp (signed and dated)
7			- Developer's name, address, and phone number
8			- Sites platted address prior to subdivision
9			North Arrow on all sheets
10			Vicinity Map (Upper right-hand corner)
11			Location, Station Number, and elevation of nearest Fire Hydrant
12			Rights-of-way (ROW), Joint Permanent Utility Easements (JPUE), edges of pavement, driveways, and property lines are shown.
13			Clearly mark periodic station and line numbers throughout proposed project to match hydraulic calculations.
14			Show all vegetation, building footprints, and other proposed structures such as pool, garage, clubhouse, etc., on drawing plan that affect or complement the design (if applicable).
15			Provide a summarized table of property units for proposed public portion on front sheet only.
16			Check GIS for existing utilities in relation to project area.

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CHART B-1: Review Process -General Water Main and Services

Comment Number	**First** Date:	**Second** Date:	**Review Criteria**
17			Existing and proposed water and/or wastewater lines shown appropriately.
18			Existing water mains and services (dashed lines)
19			Proposed water mains and services (solid continuous lines)
20			Proposed pipe materials and sizes clearly labeled on drawing. (i.e. 8" DIP, 2" PVC SDR 13.5, 2" Type-K Copper)
21			Bold all water utilities and gray out other utilities in order to clarify the project's items of interest.
22			All utilities shown where appropriate (i.e. water, sewer, gas, electric, storm, etc.)
23			Proposed water mains should be either in: A) Street right-of-way & out of paved areas at least 4 feet from edge of pavement or B) Easements.
24			Station 0+00 is located where proposed water is tapped from existing water main.
25			All the proposed locations of all services are shown with correct symbol: (M)
26			Each lot or structure contains a separate, individual water service line and lot number.
27			All typical residential services shall be constructed using a ¾ inch Type-K copper pipe or 1 inch PEX pipe if approved by KUB – No dissimilar materials along service. Any water services 2 inch or larger shall be DIP or Type-K copper.
28			Water service lines are installed in pairs near the common property corners of two adjacent lots that are adjoining the street right-of-way.
29			Typical Water Meter size is clearly indicated on the plans outside of paved areas.
30			Water meter has an appropriate size for the proposed service and the meter size is 5/8", 1", 2", 3", 4", 6", 8", and 10".
31			Specify if a fire-rated meter is necessary.
32			All private fire lines shall have a control valve located at either the edge of right-of-way or easement.
33			Clearly indicate concrete thrust blocks at all tees, bends, and dead ends.in the water main.

CHART C-1: Review Process – Materials

Comment Number	**First** Date:	**Second** Date:	**Review Criteria**
34			Location of all proposed fire hydrants and apparatuses shown.
35			Fire hydrants are spaced approximately 500 feet apart in city limits/TDEC. Verify specific requirements with appropriate fire agency.
36			Contact Hydrants@kub.org for all information regarding flow rate and pressure values for the existing fire hydrant used in the design of the proposed area in which the water system will be built. Data is valid for 6 months from testing date.
37			Provide residual pressure, static pressure, flow, and elevation for the existing fire hydrant tested on design and the date of the test.
38			Valve nest needs to be spaced out to extend to opposite side of road to ensure operational ability if intersection is flooded.
39			Valves are placed on each main branching from a tee or cross.
40			Valves are placed out of pavement, but within street right-of-ways or easements.
41			Valves shall not be spaced more than 1000 feet apart.
42			Clearly indicate the proposed location of each air release valve.
43			Air Release Valves are located at crest high points in the water main design.
44			Blow-Off assemblies are placed at the end of all water mains.
45			Public water mains that provide fire flow shall be no less than 8 inches in diameter.
46			All 2-inch water lines are required to be SDR 13.5 PVC or Type-K Copper
47			All water lines greater than 2 inches in diameter shall be Ductile Iron.
48			Indicate the dimensions used for thrust blocks at each tee, bend, and dead end.

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CHART D-1: Easements

Comment Number	**First** Date: _____	**Second** Date: _____	**Review Criteria**
49			All required easements and/or subdivision plats shall be submitted, approved, and recorded before the new water system will be accepted.
50			With project easements, a minimum 15-foot wide permanent utility easement exists (minimum 7.5 feet on either side) for all water and wastewater mains as installed plus an additional 10 foot utility construction and maintenance easement as required,
51			If joint permanent utility easement (JPUE) with utilities is used rather than public ROW, then JPUE must include with utilities to remove the requirement for the utility easement.
52			Signed and recorded utility easements and/or JPUE are required before the construction plans will be returned to the developer/consultant.
53			For existing easements, the deed instrument number shall be clearly indicated on the plans. If multiple instrument numbers exist for the development, then each instrument number shall be listed.

CHART E-1: Water Construction Notes

Comment Number	**First** Date: ______	**Second** Date: ______	**Review Criteria**
54			Road right-of-ways or utility easements shall be to finished grade and sloped to meet required specifications or as approved by KUB prior to staking and installing water mains.
55			The Developer's Authorized Representative shall stake the proposed water main layouts, property corners, and easement locations etc…prior to construction or approval of plans or both to allow ample time for KUB's inspectors to inspect the layouts prior to construction. KUB will determine if staking may be required prior to approval of plans.
56			Construction materials must meet KUB specifications. KUB representatives must approve material submittals prior to construction.
57			Water main installation must be inspected by KUB. Contact KUB field services at least three (3) days prior to construction at 558-2786. Trenches shall be left open and not backfilled until inspected by KUB.
58			Contractor will sterilize water mains when installation and testing are complete. Contractor shall provide taps as required for sterilizing mains. Water quality sampling and testing will be performed by KUB.
59			Contractor must have a valid State of Tennessee municipal utility license for construction of water mains on site at all times.
60			Air release valves shall be installed on high points on the mains in accordance with the plans and/or as requested by KUB's inspectors.
61			The Contractor must have water service lines installed across streets before any surface cover is finalized to include paving, concrete driveways, etc.

CHART E-2: General Water Notes

Comment Number	**First** Date: ______	**Second** Date: ______	**Review Criteria**
62			All water lines and appurtenances shall be installed in accordance with the Knoxville Utilities Board's Standard Water System Specifications and Details.
63			Requirements for proper trench and backfill operations must meet or exceed City of Knoxville, Knox County, and TDOT Standards.
64			Location of all existing utilities is approximate. Contractor shall field locate all existing utilities prior to excavation.
65			Water services shall be buried at a minimum depth of 24 inches to prevent freezing.
66			Minimum 36 inches depth of cover for water mains.
67			Utilities shall be installed after grading has been completed and approved before any surface cover is finalized to include paving, concrete driveways, etc…
68			After completing each section of the water, all debris and construction materials shall be removed from the work site. The disturbed ground surface shall be smoothly graded.
69			All water valves shall conform to KUB Standards and Specifications.
70			KUB personnel will test water service to the existing public ROW or easement from the existing system for the proposed water system.
71			Horizontal separation between water and sewer mains is a minimum of 10 feet.
72			Water mains are not installed in the same trench with other utilities unless approved through KUB Engineering in writing.
73			Any field changes to approved plans must be approved by the appropriate KUB representative before construction.
74			A copy of the latest approved set of utility plans designated by the KUB/TDEC RED stamp must be present during all times of construction of the appropriate utilities.

CHART F-1: Water Calculations By Hand

Comment Number	**First** Date: ______	**Second** Date: ______	**Review Criteria**
75			Clearly indicate location of each Nodes / Junctions used in calculations.
76			Clearly indicate location of each pipe used in calculations.
77			Indicate station critical points of pressure in the proposed system (i.e., High Elev. Points).
78			Clearly mark periodic station numbers throughout proposed project.
79			Clearly indicate location of existing fire hydrants and their surface elevation.
80			Clearly indicate all formulas used in hydraulic analysis of the proposed system.
81			Clearly define all the variables used in the calculations with their appropriate values.
82			Present appropriate units with all values used and obtained in every calculation.
83			Present calculations in an orderly, clear, and concise manner.
84			Clearly show station numbers and water line segments in the calculations [i.e., Label: Sta 9+40 (Line A) and Sta 0+00 (Line B)].
85			Present a calculation for the pressure at the top floor of the proposed building at the highest elevation in the system and for the furthest point in the system from the source tie-in.
86			Show that the pressure at all levels of all buildings with water service will be above 20 psi.
87			-(for each multiple story building: add 10 feet above the ground surface and add an additional 7 feet to the highest level for calculations)
88			-(for each single story building: add 7 feet from the ground surface)
89			Present specific building height calculations separately from the ground surface elevation calculations for hydraulic adequacy.
90			Write a brief narrative indicating all assumptions, data, and hydraulic results in the introduction of the proposed water system calculation sheets.
91			Provide a tabulated summary page identifying all important variables, calculations, and results. Please see example for required summary contents.
92			Suggest checking with fire marshal for additional flow requirements.

CHART G-1: Water Calculations By Computer Simulation

Comment Number	**First** Date: _____	**Second** Date: _____	**Review Criteria**
93			Provide each Node's ID with simulated data results.
94			Node ID location identified in each drawing of proposed layout.
95			Each Node's elevation are shown on drawing and calculation results.
96			Provide each Node's flow / demand (gallons per minute).
97			Provide the Nodes contained between each section of pipe.
98			Provide each Pipe ID listed with a set of simulated data results.
99			Pipe ID location identified in each drawing of proposed layout.
100			Provide the length of each pipe in calculations.
101			Provide the diameter of each pipe in calculations.
102			Show each pipe's diameter and length of pipe on a drawing.
103			Provide each pipe's Roughness Coefficient (C) used in calculations.
104			Provide the pressure head and/or pressure calculated (psi or feet) for each node.
105			Provide the flow for each pipe calculated in gallons per minute.
106			Provide the friction head loss for each pipe calculated in feet.
107			Write a brief narrative indicating all assumptions, data, and hydraulic results in the introduction of the proposed water system calculation sheets.
108			Show that the pressure at all levels of the buildings will be above 20 psi.
109			-(for each multiple story building: add 10 feet above the ground surface and add an additional 7 feet to the highest level for calculations)
110			-(for each single story building: add 7 feet from the ground surface for hydraulic calculations)
111			Present specific building height calculations separately from the ground surface elevation calculations.
112			Provide a tabulated summary page identifying all important variables, calculations, and results.
113			Suggest checking with fire marshall for additional flow requirements.

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WATER HYDRAULICS HAND CALCULATIONS EXAMPLE

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HYDRAULIC CALCULATIONS SUMMARY FORM

PROPOSED WATER LINE (i.e., Line A, B, etc.): ______________________________________

PROPOSED WATER LINE LOCATION (i.e., Main Street): ______________________________________

FH_{ELEV} (ft):	
Q_R (gpm):	
Q_F (gpm):	
P_R (psi):	
P_S (psi):	

TOTAL NUMBER OF LOTS TO BE SERVED BY ENTIRE PROJECT:	
TOTAL NUMBER OF LOTS TO BE SERVED BY WATER LINE _____:	
NUMBER OF STORIES FOR PROPOSED BUILDINGS:	

HAZEN-WILLIAMS ROUGHNESS COEFFICIENT (C) :	
INNER NOMINAL PIPE DIAMETER (INCHES) :	

STATION NUMBER	SURFACE ELEVATION	WATER LINE ELEVATION	TOP BUILDING STORY ELEVATION	20 PSI ELEVATION LINE	REQUIRED TOP STORY PRESSURE	REQUIRED FLOW Q_{GPM}	CUMULATIVE FRICTION HEAD LOSS	HYDRAULIC ELEVATION GRADE LINE	TOP STORY AVAILABLE PRESSURE
(FEET)	(FEET)	(FEET)	(FEET)	(FEET)	(FEET)	(gpm)	(FEET)	(FEET)	(PSI)

WATER LINE ELEVATION: MINIMUM OF 3 FEET BELOW THE FINISHED GRADE ELEVATION

TOP BUILDING STORY ELEVATION: AN ADDITION OF 10 FEET ABOVE THE WATER LINE ELEVATION FOR EVERY STORY OF A BUILDING

20 PSI ELEVATION LINE: AN EQUIVALENT PRESSURE HEAD OF 20 PSI ABOVE THE WATER LINE ELEVATION

REQUIRED TOP STORY PRESSURE: 20 PSI EQUIVALENT PRESSURE HEAD AT HIGHEST LEVEL OF PROPOSED BUILDINGS

REQUIRED FLOW: AMOUNT OF FLOW PROPOSED FOR THE PROPOSED WATER LINE

CUMULATIVE FRICTION HEAD LOSS: CALCULATED WITH HAZEN-WILLIAMS EQUATION

HYDRAULIC ELEVATION GRADE LINE: INITIAL HYDRAULIC GRADE MINUS HEADLOSS

TOP STORY AVAILABLE PRESSURE: HYDRAULIC GRADE MINUS TOP BUILDING STORY ELEVATION CONVERTED TO PSI

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<u>HYDRAULIC GRADE LINE ELEVATION at TESTED FIRE HYDRANT</u>

$$X_{FH} = \left[P_S - \left(\frac{Q_R \; (P_S - P_R)^{0.54}}{Q_F} \right)^{(1.852)} \right] \times \left(\frac{2.31ft}{1psi} \right) + FH_{ELEV}$$

X_o = Initial Hydraulic Energy Grade Line Elevation at Tested Fire Hydrant (feet)

FH_{ELEV} = Fire Hydrant Surface Elevation where Fire Flow Test is conducted (feet)

Q_R = Required / Design Flow = Fire Flow + Residential Demand

Q_R = [500 gpm + (2 gpm/lot * number of proposed lots served)]

Q_F = Flow obtained by Pitot Gauge during Fire Flow testing (gpm)

P_R = Residual Pressure from Test Fire Hydrant (psi)

P_S = Static Pressure from Test Fire Hydrant (psi)

** NOTE: All Flows and Pressures must be obtained through KUB

$$X_{FH} = \left[\_\_\_\_\_ \; psi - \left(\frac{\_\_\_\_ \; gpm \; (\_\_\_\_ \; psi - \_\_\_\_ \; psi)^{0.54}}{\_\_\_\_\_ \; gpm} \right)^{(1.852)} \right] \times \left(\frac{2.31ft}{1psi} \right) + \_\_\_\_\_\_\_ \; ft$$

$$X_{FH} = \_\_\_\_\_\_ \; ft + \_\_\_\_\_\_\_ \; ft = \_\_\_\_\_\_\_\_\_\_\_ \; feet$$

TESTED KUB FH#____________

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FRICTION HEAD LOSS BETWEEN TESTED FH AND STA 0+00

Using the Hazen-Williams Equation:

$$h_L = 10.5\left(\frac{Q_{gpm}}{C}\right)^{1.85} \times \left(\frac{L_{ft}}{d_{in}^{\ 4.87}}\right)$$

h_L = Friction Head Loss from the distance between Tested FH and Sta 0+00 (feet)

Q_{gpm} = Expected / Required Flow that will be needed for the proposed pipe (gpm)

Q_{gpm} = (2 gpm/lot * number of lots) + 500 gpm needed if system supports fire flow

C = Roughness Coefficient for Hazen-Williams equation above (unit less)

C = usually 130 for new D.I. / PVC Pipe

L_{ft} = Length of pipe from X_{FH} to X_{0+00} (feet)

d_{in} = internal nominal diameter of proposed pipe in design (inches)

Therefore,

X_{FH} = __________ FEET

DISTANCE FROM TESTED FIRE HYDRANT TO STATION 0+00 OF THE PROPOSED WATER MAIN IS __________ FEET OF _____ INCH DIAMETER WATER PIPE

$$h_L = 10.5\left(\frac{\_\_\_\_\_\ gpm}{\_\_\_\_\_}\right)^{1.85} \times \left(\frac{\_\_\_\_\_\_\ ft}{\_\_\_\_\ inch^{4.87}}\right) = \_\_\_\_\_\_\_\_\_\_\ feet$$

X_0 IS LOCATED AT THE **TESTED FIRE HYDRANT** ALONG THE STREET NAME (i.e., Main Street) ________________________ AND BEGINS THE WATER MAIN THAT IS LABELED PROPOSED WATER LINE (i.e., Line A)______.

X_1 IS LOCATED AT **STA# 0+00** ALONG THE STREET NAME (i.e., Main Street) ________________________ AND BEGINS THE WATER MAIN THAT IS LABELED PROPOSED WATER LINE (i.e., Line A)______.

$$X_{0+00} = X_{FH} - h_L$$

X_{FH} = Hydraulic Grade Line Elevation at the Tested Fire Hydrant (feet)

h_L = Friction Head Loss from the distance between the Tested Fire Hydrant and Sta 0+00

X_{0+00} = ____________ *ft* – _____________ *ft* = ______________ *feet*

X_{0+00} IS LOCATED ALONG THE STREET NAME (i.e., Main Street) _______________________

AND BEGINS THE WATER MAIN THAT IS LABELED PROPOSED WATER LINE (i.e., Line A)

____________.

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ENTIRE HYDRAULIC GRADE LINE ELEVATION CALCULATIONS

Using the Hazen-Williams Equation:

$$h_L = 10.5\left(\frac{Q_{gpm}}{C}\right)^{1.85} \times \left(\frac{L_{ft}}{d_{in}^{\;4.87}}\right)$$

h_L = Friction Head Loss from the distance between X_{0+00} to X_1 (feet)

Q_{gpm} = Expected / Required Flow that will be needed for the proposed pipe (gpm)

Q_{gpm} = (2 gpm/lot * number of lots) + 500 gpm needed if system supports fire flow

C = Roughness Coefficient for Hazen-Williams equation above (unit less)

C = usually 130 for new D.I. / PVC Pipe

L_{ft} = Length of pipe from X_{0+00} to X_1 (feet)

d_{in} = internal nominal diameter of proposed pipe in design (inches)

DISTANCE FROM STATION 0+00 TO STATION __________ OF THE PROPOSED WATER MAIN IS __________ FEET.

$$h_L = 10.5\left(\frac{\_\_\_\_\_\_\ gpm}{\_\_\_\_\_\_}\right)^{1.85} \times \left(\frac{\_\_\_\_\_\_\_\_\ ft}{\_\_\_\_\ inch^{4.87}}\right) = \_\_\_\_\_\_\_\_\_\_\_\ feet$$

X_{0+00} IS LOCATED AT **STA# 0+00** ALONG THE STREET NAME (i.e., Main Street)

________________________ AND BEGINS THE WATER MAIN THAT IS LABELED

PROPOSED WATER LINE (i.e., Line A)______.

X_1 IS LOCATED AT **STA#** __________ ALONG THE STREET NAME (i.e., Main Street)

________________________ AND BEGINS THE WATER MAIN THAT IS LABELED

PROPOSED WATER LINE (i.e., Line A)______.

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$$X_1 = X_{0+00} - h_L$$

X_1 = Hydraulic Grade Line Elevation at the Final Station (feet)

h_L = Friction Head Loss from the distance between X_o to X_1 (feet)

X_1 = ____________ ft – _____________ ft = ______________ feet

X_{0+00} IS LOCATED AT **STA# 0+00** ALONG THE STREET NAME (i.e., Main Street)

________________________ AND BEGINS THE WATER MAIN THAT IS LABELED

PROPOSED WATER LINE (i.e., Line A)______.

X_1 IS LOCATED AT **STA#** __________ ALONG THE STREET NAME (i.e., Main Street)

________________________ AND BEGINS THE WATER MAIN THAT IS LABELED

PROPOSED WATER LINE (i.e., Line A)______.

FRICTION HEAD LOSS BETWEEN TWO POINTS (X_O AND X_1)

Using the Hazen-Williams Equation:

$$h_L = 10.5\left(\frac{Q_{gpm}}{C}\right)^{1.85} \times \left(\frac{L_{ft}}{d_{in}^{\;4.87}}\right)$$

h_L = Friction Head Loss from the distance between X_o to X_1 (feet)

Q_{gpm} = Expected / Required Flow that will be needed for the proposed pipe (gpm)

Q_{gpm} = (2 gpm/lot * number of lots) + 500 gpm needed if system supports fire flow

C = Roughness Coefficient for Hazen-Williams equation above (unit less)

C = usually 130 for new D.I. / PVC Pipe

L_{ft} = Length of pipe from X_o to X_1 (feet)

d_{in} = internal nominal diameter of proposed pipe in design (inches)

DISTANCE FROM STATION __________ TO STATION __________ OF THE PROPOSED WATER MAIN IS __________ FEET.

$$h_L = 10.5\left(\frac{\_\_\_\_\_\_\ gpm}{\_\_\_\_\_\_}\right)^{1.85} \times \left(\frac{\_\_\_\_\_\_\_\_\ ft}{\_\_\_\_\ inch^{4.87}}\right) = \_\_\_\_\_\_\_\_\_\_\ feet$$

X_0 IS LOCATED AT **STA#** __________ ALONG THE STREET NAME (i.e., Main Street)

________________________ AND BEGINS THE WATER MAIN THAT IS LABELED

PROPOSED WATER LINE (i.e., Line A)______.

X_1 IS LOCATED AT **STA#** __________ ALONG THE STREET NAME (i.e., Main Street)

________________________ AND BEGINS THE WATER MAIN THAT IS LABELED

PROPOSED WATER LINE (i.e., Line A)______.

$$X_1 = X_o - h_L$$

X_1 = Hydraulic Grade Line Elevation at the Final Station (feet)

h_L = Friction Head Loss from the distance between X_o to X_1 (feet)

X_1 = ___________ *ft* – ____________ *ft* = _____________*feet*

X_0 IS LOCATED AT **STA#** __________ ALONG THE STREET NAME (i.e., Main Street) ________________________ AND BEGINS THE WATER MAIN THAT IS LABELED PROPOSED WATER LINE (i.e., Line A)______.

X_1 IS LOCATED AT **STA#** __________ ALONG THE STREET NAME (i.e., Main Street) ________________________ AND BEGINS THE WATER MAIN THAT IS LABELED PROPOSED WATER LINE (i.e., Line A)______.

WATER HYDRAULICS COMPUTER SIMULATION EXAMPLE

WATER SYSTEM DESIGN BY COMPUTER SIMULATION (1 of 2)

Network Table - Nodes (Junctions in the Proposed Water System)

PROPOSED WATER LINE (i.e., Line A, B, etc.): ______________________________________

PROPOSED WATER LINE LOCATION (i.e., Main Street): ______________________________________

NUMBER OF STORIES FOR PROPOSED BUILDINGS: __________________

Node ID Number	Station Number	Water Line ID	Elevation (feet)	Demand (gpm)	Head (feet)	Pressure (psi)

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WATER SYSTEM DESIGN BY COMPUTER SIMULATION (2 of 2)

Network Table - Links (Pipes)

PROPOSED WATER LINE (i.e., Line A, B, etc.): ______________________________

PROPOSED WATER LINE LOCATION (i.e., Main Street): ______________________________

NUMBER OF STORIES FOR PROPOSED BUILDINGS: _______________

Link ID	Length (feet)	Diameter (inches)	Roughness (unit less)	Flow (gpm)	Velocity (ft/sec)	Unit Headloss (ft / K ft)

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CHART I-1: Hydraulic Calculations Summary Form (LINE A)

KUB **HYDRAULIC CALCULATIONS SUMMARY FORM - LINE A**

LINE A: HILLSIDE DRIVE

LINE B: CUB COVE

FH_{ELEV} (ft):	1033.55	TOTAL NUMBER OF LOTS TO BE SERVED BY PROJECT:	20
Q_R (gpm):	540	TOTAL NUMBER OF LOTS TO BE SERVED BY LINE A:	20
Q_F (gpm):	1509	TOTAL NUMBER OF LOTS TO BE SERVED BY LINE B:	3
P_R (psi):	80		
P_S (psi):	105		

LINE A

HAZEN-WILLIAMS ROUGHNESS COEFFICIENT (C) : 130

INNER NOMINAL PIPE DIAMETER (INCHES) : 8.0

STATION NUMBER	SURFACE ELEVATION	WATER LINE ELEVATION	SECOND* STORY ELEVATION	20 PSI ELEVATION LINE	REQUIRED SECOND* STORY PRESSURE	REQUIRED Q_{GPM}	CUMULATIVE FRICTION HEAD LOSS	HYDRAULIC ELEVATION GRADE LINE	SECOND* STORY AVAILABLE PRESSURE
(FEET)	(FEET)	(FEET)	(FEET)	(FEET)	(FEET)	(gpm)	(FEET)	(FEET)	(PSI)
0	1033.55	1030.55	1050.55	1076.75	1096.75	540	0.00	1267.49	93.91
150	1036.00	1033.00	1053.00	1079.20	1099.20	540	0.88	1266.61	92.47
300	1038.00	1035.00	1055.00	1081.20	1101.20	540	1.76	1265.73	91.23
450	1032.00	1029.00	1049.00	1075.20	1095.20	540	2.63	1264.86	93.44
600	1032.00	1029.00	1049.00	1075.20	1095.20	540	3.51	1263.98	93.06
750	1036.00	1033.00	1053.00	1079.20	1099.20	540	4.39	1263.10	90.95
900	1042.00	1039.00	1059.00	1085.20	1105.20	540	5.27	1262.22	87.97
1050	1050.00	1047.00	1067.00	1093.20	1113.20	540	6.14	1261.34	84.13
1200	1056.00	1053.00	1073.00	1099.20	1119.20	540	7.02	1260.47	81.15
1390	1064.00	1061.00	1081.00	1107.20	1127.20	540	8.13	1259.35	77.21

*Note: Top Story = Second Story for Proposed Buildings in this Project

CHART I-2: Hydraulic Calculations Summary Form (LINE B)

KUB **HYDRAULIC CALCULATIONS SUMMARY FORM - LINE B**

LINE A: HILLSIDE DRIVE

LINE B: CUB COVE

FH_{ELEV} (ft):	1033.55	TOTAL NUMBER OF LOTS TO BE SERVED BY PROJECT:	20
Q_R (gpm):	540	TOTAL NUMBER OF LOTS TO BE SERVED BY LINE A:	20
Q_F (gpm):	1509	TOTAL NUMBER OF LOTS TO BE SERVED BY LINE B:	3
P_R (psi):	80		
P_S (psi):	105		

LINE B

HAZEN-WILLIAMS ROUGHNESS COEFFICIENT (C) : 130

INNER NOMINAL PIPE DIAMETER (INCHES) : 2.0

STATION NUMBER	SURFACE ELEVATION	WATER LINE ELEVATION	SECOND* STORY ELEVATION	20 PSI ELEVATION LINE	REQUIRED SECOND* STORY PRESSURE	REQUIRED Q_{GPM}	CUMULATIVE FRICTION HEAD LOSS	HYDRAULIC ELEVATION GRADE LINE	SECOND* STORY AVAILABLE PRESSURE
(FEET)	(FEET)	(FEET)	(FEET)	(FEET)	(FEET)	(gpm)	(FEET)	(FEET)	(PSI)
0	1044.00	1041.00	1061.00	1087.20	1107.20	6	0.00	1261.99	87.01
50	1044.00	1041.00	1061.00	1087.20	1107.20	6	0.06	1261.93	86.98
100	1045.00	1042.00	1062.00	1088.20	1108.20	6	0.12	1261.87	86.52
150	1046.00	1043.00	1063.00	1089.20	1109.20	6	0.18	1261.81	86.06
240	1044.00	1041.00	1061.00	1087.20	1107.20	6	0.29	1261.70	86.88

*Note: Top Story = Second Story for Proposed Buildings in this Project

CHART I-3: Critical Pressure Summary for Individual Second Story Buildings

Lot Number (---)	Line A Water Station Number (feet)	Line B Water Station Number (feet)	Finish Floor Elevation (feet)	Highest Water Supply Elevation (feet)	Required Second* Story Pressure (feet)	Hydraulic Grade Line Elevation (feet)	Available Second* Story Pressure (feet)	Available Second* Story Pressure (psi)
1	350	---	1037	1054	1100.2	1265.4	211.4	91.5
2	475	---	1034	1051	1097.2	1264.7	213.7	92.5
3	575	---	1030	1047	1093.2	1264.1	217.1	94.0
4	620	---	1030	1047	1093.2	1263.9	216.9	93.9
5	700	---	1040	1057	1103.2	1263.4	206.4	89.3
6	800	---	1042	1059	1105.2	1262.8	203.8	88.2
7	---	225	1042	1059	1105.2	1261.7	202.7	87.8
8	---	190	1046	1063	1109.2	1261.8	198.8	86.0
9	---	75	1047	1064	1110.2	1261.9	197.9	85.7
10	1100	---	1051	1068	1114.2	1261.0	193.0	83.6
11	1200	---	1055	1072	1118.2	1260.4	188.4	81.6
12	1300	---	1058	1075	1121.2	1259.9	184.9	80.0
13	1340	---	1062	1079	1125.2	1259.6	180.6	78.2
14	1225	---	1057	1074	1120.2	1260.3	186.3	80.7
15	1125	---	1051	1068	1114.2	1260.9	192.9	83.5
16	1025	---	1047	1064	1110.2	1261.5	197.5	85.5
17	915	---	1044	1061	1107.2	1262.1	201.1	87.1
18	815	---	1040	1057	1103.2	1262.7	205.7	89.1
19	690	---	1034	1051	1097.2	1263.4	212.4	92.0
20	340	---	1034	1051	1097.2	1265.5	214.5	92.9

** Assumes Second Story Buildings (20 FT above water main or 17 FT above FFE)

* Note: Top Story = Second Story for Proposed Buildings in this Project

FFE = Approximate Centroidal Elevation of each Proposed Lot

HWSE = 17 FT + FFE

Required Second Story Pressure = [(20 psi) * (2.31 FT/psi)] + HWSE

Available Second Story Pressure = Hydraulic Grade Line - Second Story Elevation

SECTION J: Hydraulic Hand Equations (Manual)

The following are basic equations that are commonly used in hydraulic design of a water system. This equation sheet is presented to provide the reader with an acceptable example to follow when presenting calculations in a hydraulic analysis document. It is required that the design presents the calculations in a clear, and understandable manner that can be understood by another. It is preferred that these equations listed be used in the form shown in the following page. However, if other equations are used, identify all the components of the calculations so the review process is more efficient.

INITIAL HYDRAULIC GRADE LINE ELEVATION EQUATION

$$X_O = X_{0+00} = \left[P_S - \left(\frac{Q_R \, (P_S - P_R)^{0.54}}{Q_F} \right)^{(1.852)} \right] \times \left(\frac{2.31 ft}{1 psi} \right) + FH_{ELEV}$$

X_o = Initial Hydraulic Energy Grade Line Elevation (feet)

FH_{ELEV} = Fire Hydrant Surface Elevation where Fire Flow Test is conducted (feet)

Q_R = Required / Design Flow = Fire Flow + Residential Demand

Q_R = [500 gpm + (2 gpm/lot * number of proposed lots served)]

Q_F = Flow obtained by Pitot Gauge during Fire Flow testing (gpm)

P_R = Residual Pressure from Test Fire Hydrant (psi)

P_S = Static Pressure from Test Fire Hydrant (psi)

** NOTE: All Flows and Pressures must be obtained through KUB

FINAL HYDRAULIC GRADE LINE ELEVATION EQUATION

$$X_1 = X_o - h_L$$

X_1 = Hydraulic Grade Line Elevation at the Final Station (feet)

h_L = Friction Head Loss from the distance between X_o to X_1 (feet)

FRICTION HEAD LOSS BETWEEN TWO POINTS (X_O AND X_1)

Using the Hazen-Williams Equation:

$$h_L = 10.5\left(\frac{Q_{gpm}}{C}\right)^{1.85} \times \left(\frac{L_{ft}}{d_{in}^{\ 4.87}}\right) \quad \textbf{OR...}$$

$$h_L = (0.002083) \times L_{ft} \times \left(\frac{100}{C}\right)^{1.85} \times \left(\frac{Q_{gpm}^{\ 1.85}}{d_{in}^{\ 4.8655}}\right)$$

h_L = Friction Head Loss from the distance between X_o to X_1 (feet)

Q_{gpm} = Expected / Required Flow that will be needed for the proposed pipe (gpm)

Q_{gpm} = (2 gpm/lot * number of lots) + 500 gpm needed if system supports fire flow

C = Roughness Coefficient for Hazen-Williams equation above (unit less)

C = usually 130 for new D.I. / PVC Pipe

L_{ft} = Length of pipe from X_o to X_1 (feet)

D_{in} = internal nominal diameter of proposed pipe in design (inches)

CALCULATION EXAMPLE TO INSURE THAT A SECOND STORY BUILDING AT THE HIGHEST SURFACE ELEVATION WILL HAVE ADEQUATE PRESSURE

In order to calculate the pressure at the top floor of a second story building, 10 feet for every story above a single story building must be added to the surface elevation of the point of interest. In addition to adding 10 feet for every story that is above the single story of a proposed building, it is necessary to add 7 feet once to the highest story elevation to account for overhead plumbing used in the utmost portion of the structure. Therefore, it is assumed that the KUB Subdivision will have 2nd-Story buildings build on all 20 proposed lots and the Required Pressure (P_{REQ}) above the surface elevation is:

P_{REQ} = [10 ft * (No. of Building Stories – 1) + 7 ft + (20 psi * 2.31 ft / psi)]

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SECTION K: Hydraulic Hand Calculations Example (Manual)

CALCULATION OF FRICTION HEAD LOSS
BETWEEN X_O AND X_1 FOR LINE A

Using the Hazen-Williams Equation:

$$h_L = 10.5\left(\frac{Q_{gpm}}{C}\right)^{1.85} \times \left(\frac{L_{ft}}{d_{in}^{\;4.87}}\right)$$

h_L = Friction Head Loss between Stations 0+00 to 13+90 (On Hillside Drive – Line A)

Q_{gpm} = (2 gpm/lot * 20 Lots) + 500 gpm = 540 gpm

C = 130 for new D.I. / PVC Pipe

L_{ft} = 1390 feet

d_{in} = 8 inches

$$h_L = 10.5\left(\frac{540\ gpm}{130}\right)^{1.85} \times \left(\frac{1390\,ft}{8\ inch^{4.87}}\right) = \underline{\underline{8.13\,ft}}$$

CALCULATION OF THE FINAL HYDRAULIC
GRADE LINE ELEVATION FOR LINE A

$$X_1 = X_o - h_L$$

$X_O = X_{0+00}$ =1267.49 feet

$X_1 = X_{13+90}$

h_L = 8.13 feet

$X_{13+90} = X_{0+00} - h_L$

X_{13+90} = *1267.49 ft – 8.13 ft* = *1259.36 feet*

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CALCULATION EXAMPLE OF INITIAL HYDRAULIC GRADE LINE ELEVATION

FOR 2" WATER LINE FROM STATION 0+00 – 2+10 (LINE B – Cub Cove)

$X_o = X_{9+40}$ (LINE A) = X_{0+00} (LINE B) =[X_{0+00} (LINE A) – h_L @ Station 9+40 (LINE A)]

X_{0+00} (LINE B) = X_{9+40} (LINE A) = Initial Hydraulic Grade Line Elevation for LINE B (found on Cub Cove) (feet)

X_{0+00} (LINE A) = X_0 (LINE A) = Hydraulic Energy Elevation at the beginning of the proposed project (feet)

h_L @ Station 9+40= Head loss produced from station 0+00 to 9+40 on LINE A (feet)

X_{0+00} (LINE A) = 1267.49 feet

FH_{ELEV} = 1033.55 feet

$$h_L = 10.5\left(\frac{Q_{gpm}}{C}\right)^{1.85} \times \left(\frac{L_{ft}}{d_{in}^{\ 4.87}}\right)$$

$$h_L = 10.5\left(\frac{540\ \ gpm}{130}\right)^{1.85} \times \left(\frac{940\,ft}{8\ \ inch^{4.87}}\right) = \underline{\underline{5.50\,ft}}$$

X_{0+00} (LINE B) =[X_{0+00} (LINE A) – h_L @ Station 9+40 (LINE A)]

X_{0+00} (LINE B) = 1267.49 ft – 5.50 ft = $\underline{\underline{\text{1261.99 feet}}}$

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CALCULATION OF THE FRICTION HEAD LOSS BETWEEN X_O AND X_1 FOR LINE B

Using the Hazen-Williams Equation:

$$h_L = 10.5\left(\frac{Q_{gpm}}{C}\right)^{1.85} \times \left(\frac{L_{ft}}{d_{in}^{\ 4.87}}\right)$$

h_L = Friction Head Loss between Stations 0+00 to 2+40 (LINE B on Cub Cove)

Q_{gpm} = (2 gpm/lot * 3 Lots) + 0 gpm = 6.0 gpm

C = 130 for new D.I. / PVC Pipe

L_{ft} = 240 feet

d_{in} = 2 inches

$$h_L = 10.5\left(\frac{6.0\ \ gpm}{130}\right)^{1.85} \times \left(\frac{240\,ft}{2\ \ inch^{4.87}}\right) = \underline{\underline{0.29\,ft}}$$

CALCULATION OF THE FINAL HYDRAULIC GRADE LINE ELEVATION FOR LINE B

$$X_1 = X_o - h_L$$

$X_O = X_{0+00}$ =1261.99 feet

$X_1 = X_{2+40}$ = ??

h_L = 0.29 feet

$X_{2+40} = X_{9+40} - h_L$

X_{2+40} = 1261.99 ft – 0.29 ft = <u>1261.70 feet</u>

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CALCULATION EXAMPLE TO INSURE THAT A SECOND STORY BUILDING AT THE HIGHEST SURFACE ELEVATION WILL HAVE ADEQUATE PRESSURE

In order to calculate the pressure at the top floor of a second story building, 10 feet for every story above a single story building must be added to the surface elevation of the point of interest. In addition to adding 10 feet for every story that is above the single story of a proposed building, it is necessary to add 7 feet once to the highest story elevation to account for overhead plumbing used in the utmost portion of the structure. Therefore, it is assumed that the KUB Subdivision will have 2nd-Story buildings build on all 20 proposed lots and the Required Pressure (P_{REQ}) above the surface elevation is:

P_{REQ} = [10 ft * (No. of Building Stories – 1) + 7 ft + (20 psi * 2.31 ft / psi)]

Therefore, for KUB Subdivision:
Number of Stories in a Building = 2 Stories

P_{REQ} = [10 FT/STORY * (2 STORIES – 1 STORY) + 7 FT + (20 PSI * 2.31 FT / PSI)]

P_{REQ} = [10 FT + 7 FT + 46.2 FT]

P_{REQ} = 63.2 FT above the surface elevation

At STATION 13+90 on Line A, the highest surface elevation is found which is 1064.00 FT above sea level.

The Required Head (X_{REQ}) for STATION 13+90 (LINE A):

X_{REQ} = P_{REQ} + SURFACE ELEVATION

X_{REQ} = 63.2 FT + 1064.0 FT

X_{REQ} = 1127.2 FT

For the designed water system to be acceptable, the Actual Head at the Point of Interest ($X_{STATION}$) must be greater than the Required Head at the same Point of Interest (X_{REQ}) at a value of 20psi or more. Therefore, for STATION 13+90:

X_{0+00} (LINE A) = 1267.49 FT (Calculated by using the Hydraulic Grade Line Equations previously mentioned in the beginning of this document)

X_{13+90} (LINE A) = X_{0+00} – hL (from STATION 0+00 TO STATION 13+90)

X_{13+90} (LINE A) = 1267.49 FT – 8.13 FT = 1259.35 FT

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Available pressure at the top level, in a two-story building, is:

P = (Hydraulic Grade Line – Surface Elevation – 17 ft) / 2.31 ft/psi

P = (1259.35 FT – 1064.00 FT – 17 FT) / (2.31 FT/psi)
P = 77.21 psi

Since 77.21 psi ≥ 20 psi, the pressure in the second story of a two-story building will be acceptable.

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SECTION L: Hydraulic Computer Simulation (Model)

The following is an acceptable example set of hydraulic analysis through computer simulation modeling through EPANET 2.0 software. When performing computer simulations for project submittals, the following format is what is to be expected.

FIGURE L-1: Defined Layout of Simulated Water System

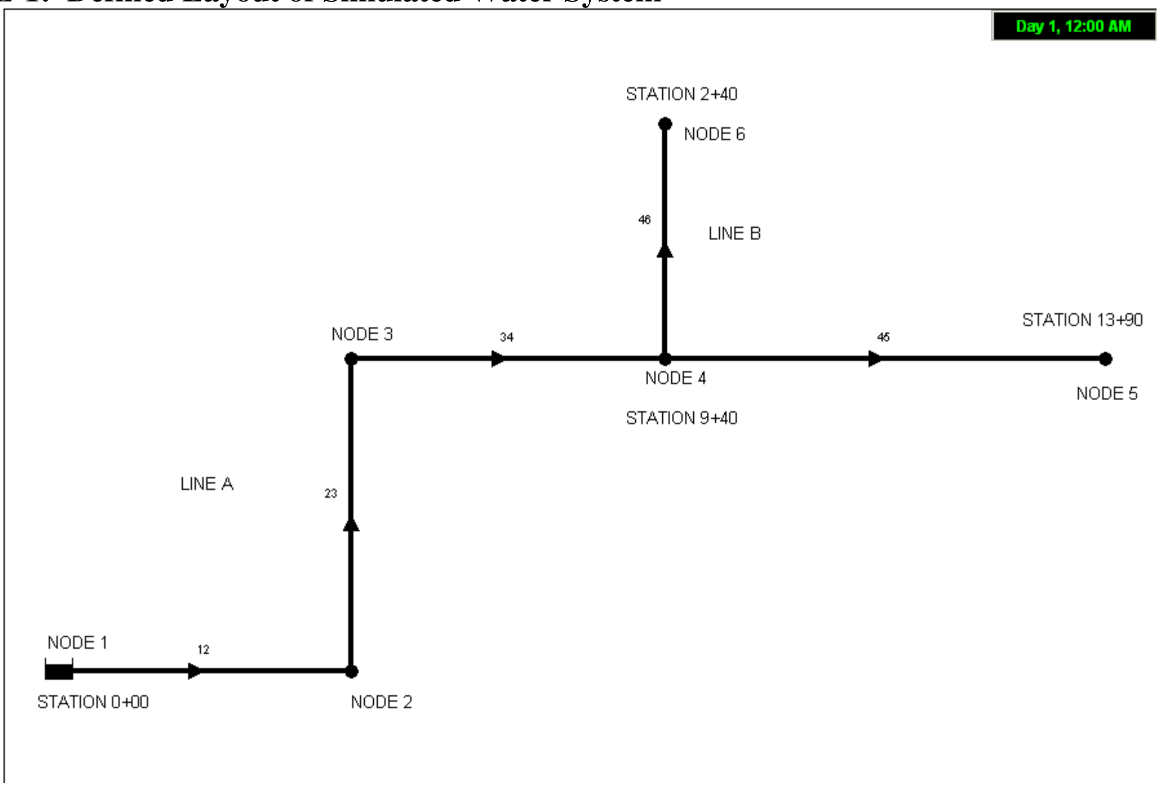

FIGURE L-2: Graphical Pressure Variation in Simulated Water System

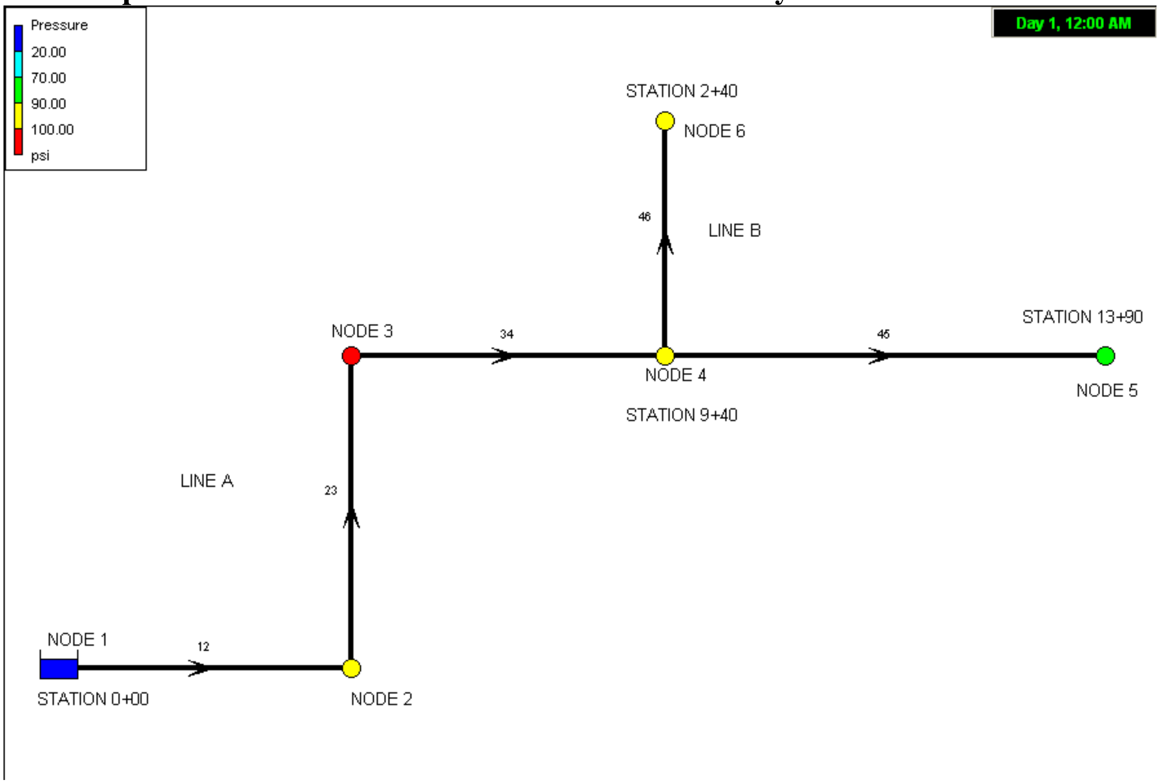

FIGURE L-3: Graphical Pressure Head Variation in Simulated Water System

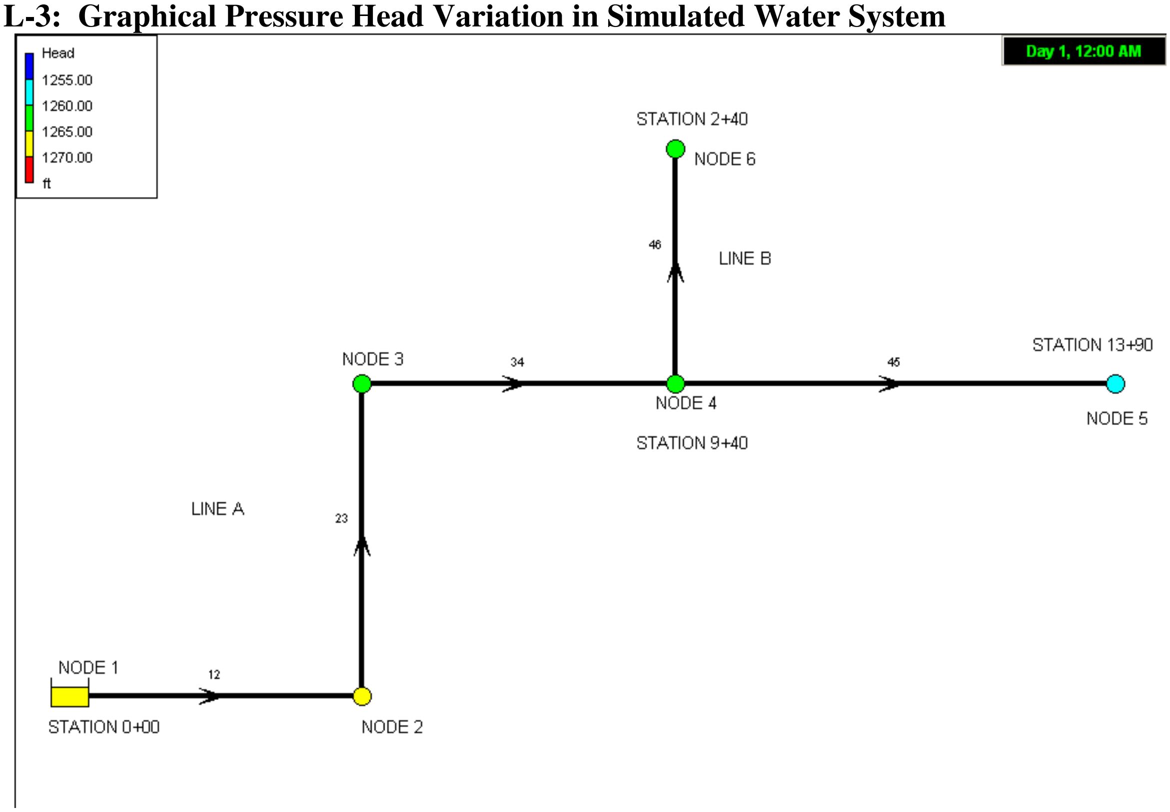

FIGURE L-4: Graphical Distribution of Flow in Simulated Water System

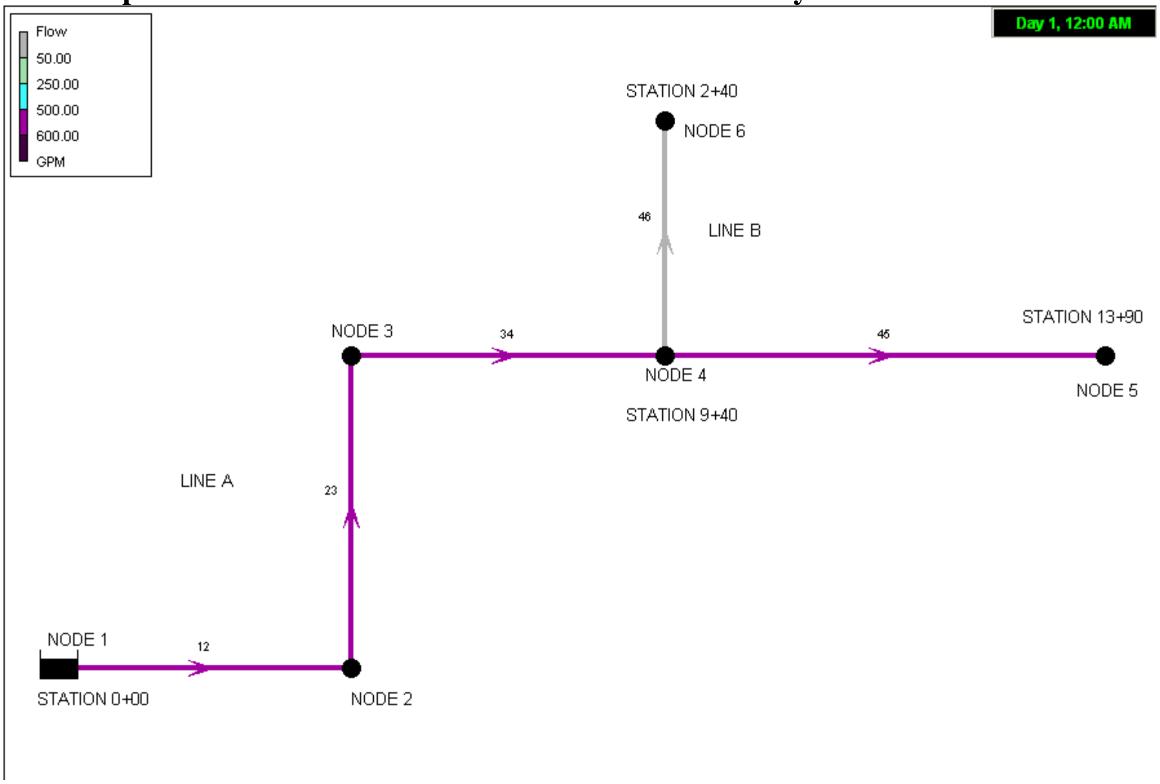

CHART L-1: Computer Simulation Data Tables for Proposed System

EPANET WATER SYSTEM DESIGN EXAMPLE

Network Table - Nodes

Node ID	Elevation (feet)	Demand (gpm)	Head (feet)	Pressure (psi)
Junc 2	1038.0	0	1265.75	98.68
Junc 3	1032.0	0	1263.88	100.47
Junc 4	1044.0	0	1262.02	94.47
Junc 5	1064.0	534	1259.44	84.69
Junc 6	1044.0	6	1261.73	94.34
Resvr 1	1267.5	-540	1267.50	0.00

EPANET WATER SYSTEM DESIGN EXAMPLE

Network Table - Links

Link ID	Length (feet)	Diameter (inches)	Roughness (unit less)	Flow (gpm)	Velocity (ft/sec)	Unit Headloss (ft / K ft)
Pipe 12	300	8	130	540	3.45	5.83
Pipe 23	320	8	130	540	3.45	5.83
Pipe 34	320	8	130	540	3.45	5.83
Pipe 45	450	8	130	534	3.41	5.72
Pipe 46	240	2	130	6	0.61	1.20