Fire Flow Assessment Report

Prepared for:

Lincoln New Hampshire

Prepared by:

Hoyle, Tanner & Associates, Inc.
www.hoyletanner.com

October 2018

Hoyle, Tanner Project No. 112514

TITLE SHEET

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The Town of Lincoln, NH

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Executive Summary

The Town of Lincoln retained Hoyle, Tanner & Associates Inc. (Hoyle, Tanner) to update and improve the calibration of the Town's water distribution system hydraulic model and assess the water system's fire flow level of service. Tasks performed included:

- Obtaining and reviewing recent water system production data;
- Obtaining information from Public Works on recent water main improvements to update pipe sizes in the model;
- Hydrant flow testing at eight locations;
- Obtaining field elevations and GPS coordinates at 51 locations;
- Updating and re-calibrating the water distribution system hydraulic model;
- Using the hydraulic model to perform the fire flow level of service analysis.

Available fire flow was estimated between <50 gallons per minute (gpm) (essentially little, to no fire flow) and >1,500 gpm. Most of the main pressure zone (served by the Forest Ridge tank) could provide >1,500 gpm; however, that flow rate dissipated to <500 gpm northward on Route 3. In the Loon Village pressure zone (served by the Loon Village tank) available fire flow was generally 500 to 750 gpm north of the East Branch of the Pemigewasset River and <500 gpm south of the River. In the Indian Head pressure zone (served by the Indian Head tank) available fire flow was estimated to be >1,500 gpm. In boosted pressure zones with no storage (I.e., a portion of South Peak, The Landing and a portion of Clearbrook) there was little, to no (<50 gpm) available fire flow from the distribution system. Although the water distribution system contains 1.6 million gallons among the three storage tanks, none of that storage is considered available to provide fire flow duration based on accepted minimum pressure criteria.

Besides the fire flow and available storage deficiencies noted in this assessment, both non-fire flow storage and water supply/treatment capacity has, or soon will, exceed the system's ability to keep up with development and meet normal demands.
The Town of Lincoln is at a crossroads; upgrading the water system is inevitable to serve and protect not only potential development, but the current residential and commercial buildings. This assessment was performed to properly define the existing deficiencies. The next step is the development of a comprehensive Capital Improvement Plan (CIP) with the following goals:

- Provide adequate available fire flow throughout the system,
- Provide adequate usable storage, and
- Maintain (or improve) distribution system water quality including, but not necessarily limited to, mitigating the formation of chlorinated Disinfection Byproducts while maintaining adequate chlorine residual.

The CIP development should lay out a long-term plan meeting these goals in the most cost-effective and affordable way.

1.0 Project Objectives

1.1 Project Tasks and Goals

The tasks and goals of the Lincoln Water System Fire Flow Assessment were:

1. Perform field testing, assisted by the Town, including hydrant flow testing and obtaining field elevation data;
2. Review distribution system piping and recent water main improvements with the Town;
3. Update and calibrate the existing hydraulic model including revising and redistributing current system water demands based on production data;
4. Using the updated hydraulic model, perform a fire flow availability assessment within the various pressure zones addressing both fire flow rate and duration;
5. Evaluate available water storage capacity in the distribution tanks and fire flow availability limitations based on system elevation criteria, and
6. Furnish the updated EPANET data file to the Town.

The project deliverables include this report, which describes the work performed and contains our analysis, data and conclusions, and the updated hydraulic model data file.

We note that the assessment identified areas of differing fire flow service levels for system planning purposes and not for design of site-specific fire suppression systems. Further, determination of system improvements to remedy insufficient available fire flow was beyond the scope of the assessment, although some general comments are offered.

1.2 Hydraulic Model Overview

Several hydraulic model programs are available on the open market that fundamentally work similarly. EPANET was used for the analysis and is the only fully-functioning freeware available; the other commonly-used programs are proprietary and generally include an initial cost and annual maintenance/update fees. The Lincoln hydraulic model data file was initially developed in the year 2000, was significantly updated in 2008, and then again for this fire flow assessment project.

For this project, the model was run under static hydraulic conditions – essentially a snap-shot in time – which is sufficient for the analysis performed. The EPANET program can perform dynamic (time-step) modeling which can simulate system response over a specified time period, however the input data requirements are much greater and beyond the scope of this assessment.

1.3 General Comments on Available Fire Flow

Available Fire Flow (AFF) in a water distribution system is comprised of two components: *flow rate*, generally expressed as gallons per minute (gpm), and *duration*, generally expressed in terms of minutes or hours. AFF at any given location varies depending on background demand conditions, tank levels and which system pumps are operating at the time. For that reason, AFF is estimated based on a set of reasonably assumed conditions for modeling purposes.

Determination of AFF at each location in the Lincoln system was beyond the scope of this project. Instead, areas of AFF ranges were determined to provide general guidance for Town planning purposes.

At any location in the water distribution system, the relationship between flow rate and pressure is inverse; the lower the pressure, the greater the flow rate (and visa-versa). The pressure reduction is limited by the generally accepted engineering criteria (also adopted by the New Hampshire Department of Environmental Services[1]) that the pressure at any customer location should not fall below 20 pounds per square inch (psi) under fire flow conditions. This suggested pressure limit could occur at the fire flow location or at another location in the pressure zone, often at a higher elevation point. For that reason, the residual pressure at the AFF flow rate is also generally noted. (System pressure under non-fire flow conditions is suggested to range between 35 and 90 psi.) The minimum pressure criterion of 20 psi was used to determine the AFF flow rate in each of the three major pressure zones (see discussion in Section 2).

System pumps and sources equipped with emergency, backup power were considered available for fire-fighting purposes. For that reason, the following sources and pumps were modeled as running for the determination of AFF flow rate: the water treatment plant, Cold Spring Well, Loon Village BPS (booster pumping station) and Boyce Brook BPS.

Fire flow duration in Lincoln is limited by two factors: the amount of distribution tank available storage and by source (and treatment) capacity. This assessment addressed the question of available storage. The issues of source of supply and treatment capacity were beyond the assessment scope and need to be addressed separately.

2.0 Model Description

The water distribution system hydraulic model includes a variety of system assets including sources of water (inputs), pipes, pumps, storage tanks and hydraulic control valves. Nodes (or junctions) are locations where two or more pipes connect. Nodes are also places where system demands (outputs) are included and where pressures are measured based on the node elevations. The following describes how these assets were treated in the Lincoln model. Note that the model does not include raw water sources or treatment systems – only finished water from the sources. A map of the water system produced by EPANET is attached in Appendix A and the field GIS elevation data is attached in Appendix D.

2.1 Sources of Supply

The Town of Lincoln water supply includes a surface-water water treatment plant (WTP) and a groundwater supply – the Cold Spring Well. The WTP receives raw water from the East Branch of the Pemigewasset River and a reservoir, Loon Pond. At the WTP, the filtered and chemically

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[1] The New Hampshire Code of Administrative Rules, Chapter Env-Dw400, Part Env-Dw404 *Design Standards for Large Public Water Systems* incorporates by reference the *Recommended Standards for Water Works*, 2003 Edition published by the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (commonly called the 10-state Standards) with certain exceptions.

treated water collects in a 250,000-gallon clearwell. High lift pumps convey the finished water into the distribution system (main pressure zone). The design points for the high lift pumps are 500 gpm at 202' TDH (total dynamic head). The clearwell provides both disinfection contact time (C-T) and backwash feedwater storage, so is not considered storage available for meeting distribution system requirements.

The hydraulic model includes the WTP clearwell, modeled as a reservoir (constant head node) with an estimated water level El. 1,044' connected to the system by the high lift pumps (with a single point / design point curve).

The Cold Spring Well can provide up to about 400,000 gpd (gallons per day) although generally provides under 200,000 gpd. The pump data design operating point is 131 gpm at 260' TDH. The pump is controlled by a variable frequency drive to maintain a set discharge pressure which may explain the variation in discharge flow rate. The Cold Spring Well is modeled as a reservoir at an estimated well-water pumping level at El. 820' connected to a pump with a standard extended curve.

2.2 Distribution Pressure Zones, Booster Pumps, Storage Tanks and Hydraulic Control Valves

The water distribution system contains at least six separate pressure zones. The majority of the system is contained within the main pressure zone which includes the water supply sources and the Forest Ridge Tank (also called the Pollard Tank). The Forest Ridge Tank is a pre-stressed concrete tank, 30 feet high with a diameter of 75 feet and a total storage capacity of 1,000,000 gallons. Based on the recent field testing, the overflow is at El. 1,088'. The tank is partially buried about 6 feet with an approximate floor elevation of El. 1,058'.

The northern/western portion of the system is boosted to serve the higher elevations. The Indian Head high pressure zone includes the Boyce Brook Booster Pump Station (BPS) and the Indian Head Tank. The 146,000-gallon Indian Head Tank is a cast-in-place, rectangular concrete structure with internal dimensions 65 feet long by 30 feet wide with a water depth varying between 10 and 10.5 feet (the floor is sloped to the drain). The overflow elevation is El. 1,266'. The Boyce Brook Booster Pump Station serves this zone at an elevation of El. 1,013'. The Boyce Brook pump is modeled as a multiple-point curve with a design point of 240 gpm at 210' TDH.

Loon Village, in the eastern portion of the system, is also served by a separate high-pressure zone. The zone includes a 500,000-gallon storage tank with a 65-foot diameter pre-stressed concrete tank with a water depth of 20 feet. The overflow elevation is El. 1,266'. Pumps located in the South Peak BPS feed the Village at Loon Mountain pressure zone from the main pressure zone. The pumps are modeled with a single design-point curve of 500 gpm at 202' TDH at El. 968'.

Two separate high-pressure zones are within the Loon Village pressure zone. South of the river, the 84-lot Landing at Loon Mountain development is served entirely by a booster pump station which also boosts pressure to 17 homes in the Beechwood II development. No tank is proposed; water for fire-fighting will be provided using cisterns. A four-pump Grundfos system is installed with a combined design point of 300 gpm at 213' TDH equipped with a VFD (variable frequency drive) at El. 1,156'.

North of the river, a higher-elevation portion of the Clearbrook development is served by a booster pump station. The lower elevation portion is in the Loon Village tank gradient. The Clearbrook water demand is in the model; the pumps are not because their effect on the fire flow assessment would be negligible.

The South Peak development contains an independent high-pressure zone served by a booster pump station which currently serves only Hemlock Drive. The original intent was to serve a larger area and to include a 300,000-gallon storage tank, but that has not occurred. The station contains two main pumps each rated at 150 gpm at 132’ TDH and a jockey pump capable of 40 gpm at 132’ TDH at El. 968’.

Tank data is summarized in Table 2.1.

Table 2.1: Existing Distribution Water Storage Tanks

Name	Overflow Elevation	Total Capacity (gal)	Pressure Zone
Forest Ridge (Pollard)	El. 1,088’	1,000,000	Main
Indian Head	El. 1,266’	146,000	Indian Head
Loon Village	El. 1,266’	500,000	Loon Village

Booster pump station data is summarized in Table 2.2.

Table 2.2: Booster Pumping Stations

Name	Elevation	Design Flow Point (gpm)	Design Total Dynamic Head (ft)
Boyce Brook BPS	El. 1,013’	240	210
Loon Village BPS	El. 968’	500	202
South Peak BPS main/jockey	El. 968’	150/40	132
The Landing BPS	El. 1,156’	300	213

Finally, two active pressure reducing valves (PRVs) serving lower-elevation areas are included in the model. One serves areas along Loon Brook Road from the Loon Village pressure zone with a setting of 67 psi. The other serves the lowest portion of the Landing including Wanigan Road with a setting of 65 psi. An inactive PRV in the Boyce Brook BPS is kept shut and is not included in the model.

2.3 Distribution Piping

The computer model contains approximately 31 miles of distribution piping ranging in size from 2” to 16”. The 16” piping serves the Forest Ridge tank. The piping diameters and lengths were derived from the Town’s GIS map of the water distribution system which is thought to be accurate but is subject to discrepancies. Table 2.3 contains an inventory of the piping network based on the Town’s GIS map.

Table 2.3: Distribution Pipe Inventory

Diameter	Total Length (ft)	Total Length (mi)
2.0 inch	3,470	0.7
4.0 inch	2,975	0.6
6.0 inch	18,955	3.6
8.0 inch	75,265	14.3
10.0 inch	3,431	0.65
12.0 inch	53,010	10.0
16.0 inch	5,470	1.0
Total	162,593	30.8

In addition to the distribution piping, the model contains 140 nodes (or junctions) where two or more pipes intersect and where system "demands" and "pressures" are included.

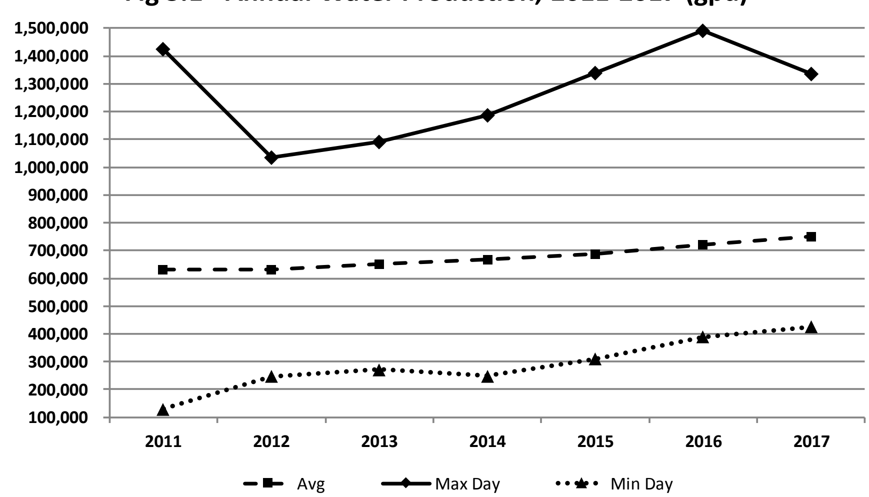
3.0 Water Demand Distribution for Modeling

Only water production (and not consumption) is metered by the Town. Because customer water usage is not metered, "water demand" and "water production" are used interchangeably in this report to denote water produced by the water treatment plant and the well.

3.1 Current Water Production

Annual average daily water production (ADP), maximum day production (MDP) and minimum day production over the past 7 years[2] are shown on Figure 3.1. For the 6-year period 2012 through 2017, ADP and MDP have increased annually an average of 3.6% and 5.6%, respectively. Of interest is how quickly the minimum day water production has grown at an average annual rate of over 12%.

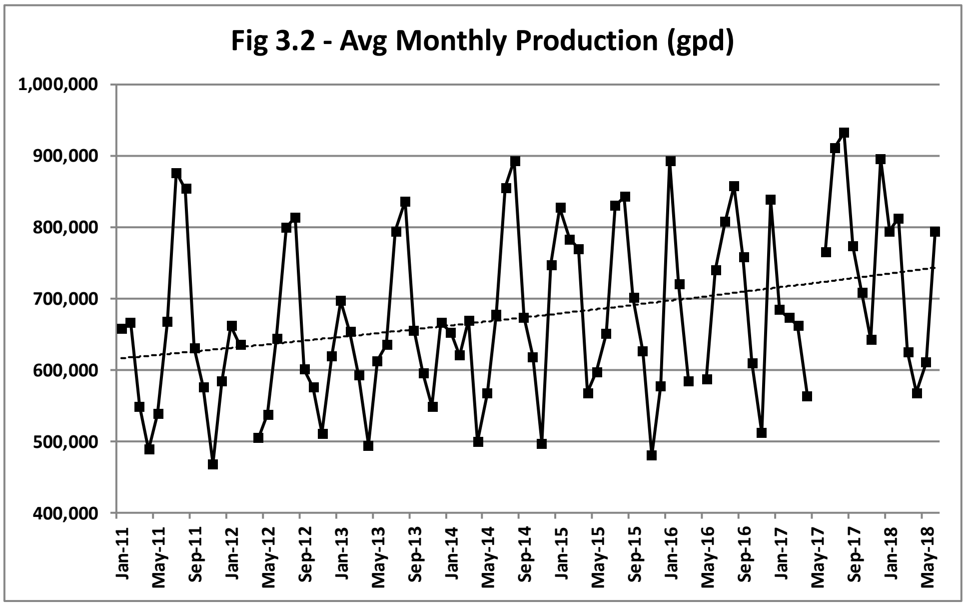
Fig 3.1 - Annual Water Production, 2011-2017 (gpd)

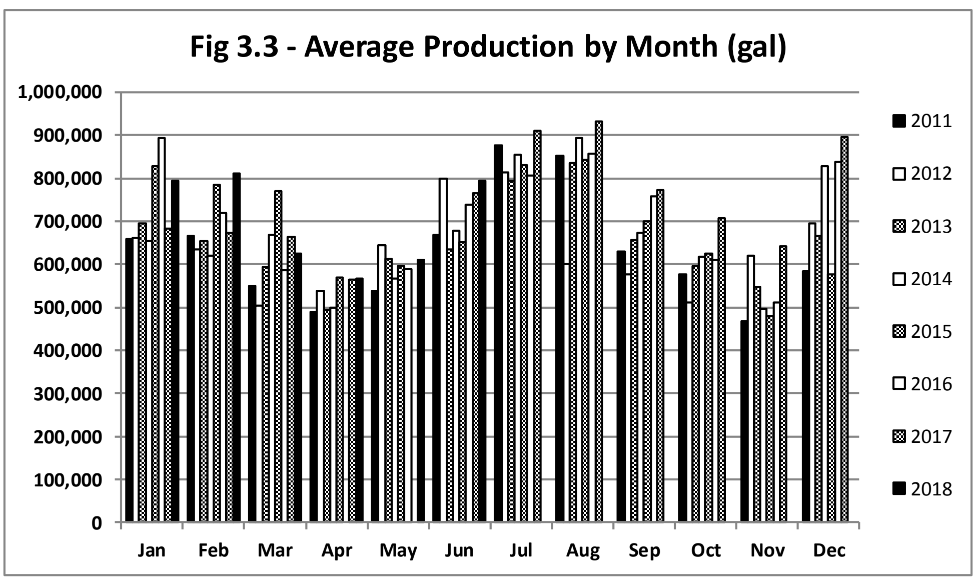


[2] Daily water production data from January 2011 through December 2017 was provided by the Lincoln Water Department except for the months of March 2012, March 2016 and May 2017 which was missing or not readable.

a. Average Water Production

The monthly trend in ADP through June 2018 is shown on Figures 3.2 and 3.3. Figure 3.2 indicates average production by month over the past 5 years. Figure 3.3 shows how production has varied monthly as well as yearly for each month.





As noted in our 2016 Water Assessment Report, water production tends to peak in summer, particularly July and August, like many systems nationwide. However, unlike many systems, Lincoln demonstrates a secondary peak in December, January and February during holiday periods and the winter ski season.

b. Maximum Day Water Production

Maximum Day Production (MDP) is an important parameter for evaluating system supply – general practice holds that the production and treatment capacity must at least equal MDP. The monthly trend in MDP is shown on Figures 3.4 and 3.5. Figure 3.4 indicates MDP by month over the past 7+ years. Figure 3.5 shows how production has varied monthly as well as yearly for each month. The average peaking factor (MDP divided by ADP) was 1.88 for the period 2011 through 2017.

Fig 3.4 - Maximum Day Production (gal)

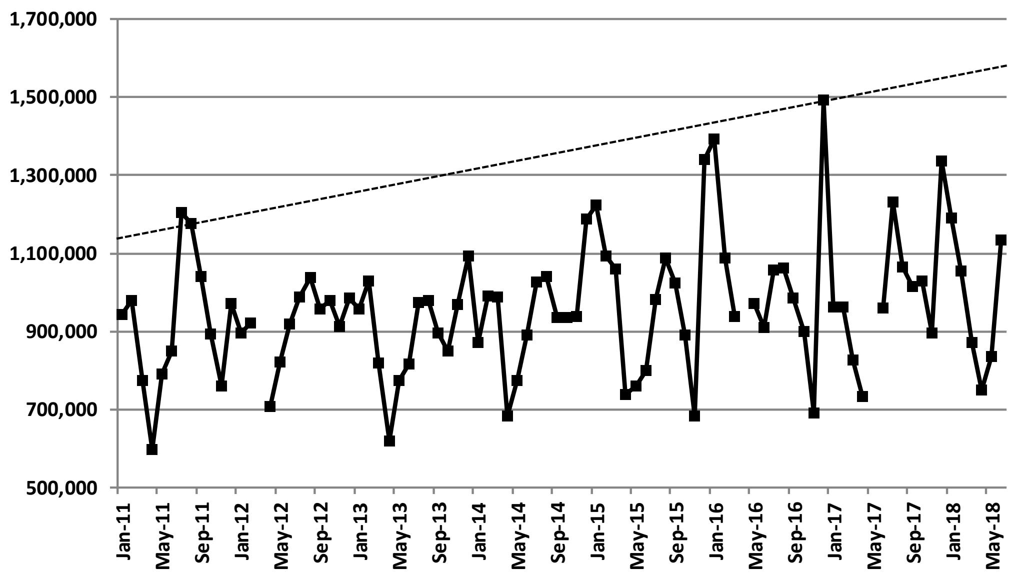
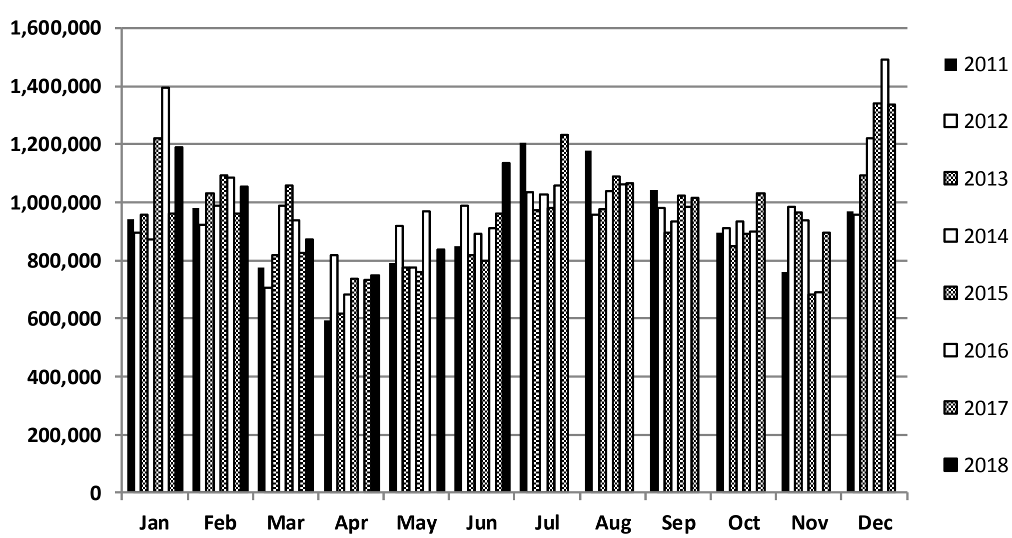


Fig 3.5 - Maximum Day Production by Month (gal)



3.2 Water Production Used in the Hydraulic Model

Based on the production trends presented, the base production (demand) used for modeling current conditions was 750,000 gpd which equates to 520 gpm over a 24-hour period. This system-wide production was then distributed to the three primary pressure zones – the Main, Loon Village and Indian Head pressure zones – based on usage over the most recent 18-month period shown on Figure 3.6. Based on the observed trends, the distribution of average demand (production) in the hydraulic model is shown on Table 3.1.

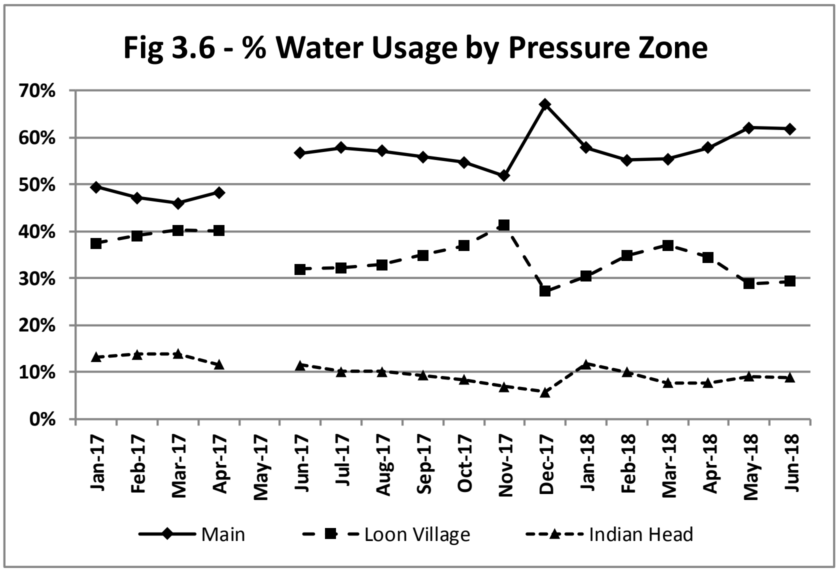


Table 3.1: Demand Distribution in Hydraulic Model				
Pressure Zone	**% of Demand**	**Avg Zone Demand (gpm)**	**Number of Junctions in Zone**	**Production Distribution per Junction (gpm)**
Main	58%	302	159	1.90
Loon Village	32%	166	53	3.13
Indian Head	10%	52	11	4.73

4.0 Model Calibration

A hydraulic distribution model must be calibrated to field data to determine how well it simulates the actual system operation. Calibration generally entails simulating hydrant flow tests in various parts of the system. If the differences between the field data and model results are large, then questions must be raised about the physical model data. Relatively small differences are generally reconciled by adjusting the pipe friction factors within acceptable and reasonable limits. Calibration of the Lincoln model was accomplished by simulating six hydrant flow tests performed in September 2007 by ISO (Insurance Services Office)[3]; two tests performed by Tri

[3] Although ISO conducted ten hydrant flow tests in 2007, four of the tests could not be interpreted sufficiently for calibration purposes possibly due to piping changes since then. Additionally, ISO did not record actual hydrant locations used for flow and pressure reading or the system conditions at the time of testing such as tank levels, background demand and which system pumps were operating.

State Fire Protection LLC on March 6, 2018; and eight tests conducted by Hoyle, Tanner and Town staff on August 9, 2018. Appendix B includes all the original field testing data used for calibration. **Error! Reference source not found.** shows the approximate locations of the hydrant tests used for calibration. The numbers at the locations correspond with Table 4.1.

Table 4.1: Field Hydrant Flow Test Results

No.	Test Date	Node	Flow (gpm)	Pressures (psi)		
				Static	Residual	Diff
1	9/5/07	50a	710	51	38	13
2	3/6/18	230/250	1,460	120	116	4
3	3/6/18	Maple St	1,525	105	100	5
4	9/5/07	262	1,210	117	107	10
5	9/5/07	340	1,540	92	84	8
6	9/5/07	LV04	690	50	45	5
7	9/5/07	LV29a	790	68	47	21
8	9/5/07	LV32	1,060	90	50	40
9	8/9/18	101-1	1,350	105	72	33
10	8/9/18	HYD113	1,000	65	46	19
11	8/9/18	118	1,260	122	75	47
12	8/9/18	220	1,455	106	95	11
13	8/9/18	138	650	73	33	40
14	8/9/18	146	1,190	70	40	30
15	8/9/18	203	1,190	128	60	68
16	8/9/18	222-1	1,590	124	120	4

Prior to calibration, the model piping was updated to reflect the most recent edition of the Town's available GIS data for the water distribution system. Various pipe sizes were updated, including several sections of 12" piping along Route 3. Additional edits were made to pipe sizes which were not reflected in the GIS based on Town staff comments during field testing including several sections of 8" pipe in the Indian Head pressure zone and several sections of 8" pipe along the Loon Village cross-country line. Corrections were also made around the South Peak BPS to better reflect the connections between the South Peak pressure zone, Loon Village pressure zone, and the Main pressure zone. Calibration then involved simulating the flow tests and comparing the differences between the static and residual pressures in both field tests and model runs.

The calibration results are shown in Table 4.2: Calibration Table and in Appendix C which adds information regarding system operation modeled for the flow test simulations – known for the August 2018 tests[4] and assumed for the others. Differences between the model and field static pressures can be attributed to different elevations, tank levels and which actual hydrants were used during the tests. The more important criteria for calibration is the differences in the system responses in pressure drop to the flow withdrawals.

[4] Operating data from the WTP for August 9, 2018 between 9:30 am and 3 pm indicated the following: Forest Ridge tank held at about 27'; Loon Village tank varied between 16' and 18'; Indian Head tank varied between 8' and 10'; and both the WTP and Loon Village BPS operated the entire time.

Of the 16 flow tests simulated, 11 were very close (the pressure drop differences were within 4% of the field static pressures), 3 were reasonably close (the pressure drop differences were within 6% to 8% of the field static pressures) and 2 were not close.

At tests #11 (Route 3 – White Mountain Motel) and #13 (Loon Brook Road), the field pressure drops were greater than the model simulations indicated they should have been. At the former location, the test flow rate of 1,350 gpm depressed the field pressure by 33 psi while the model simulation suggested a pressure drop of only 19 psi. The difference may indicate some additional head loss in the system possibly caused by a partially closed valve, pipe restriction or other hydrant loss.

At the latter test location, the Loon Brook Road area flow and pressure is regulated by a PRV connecting to the Loon Village pressure zone. The test flow rate of 650 gpm depressed the field pressure by 40 psi while the model simulation suggested a pressure drop of only 19 psi. Again, it is possible that some additional head loss is occurring at the PRV or the connecting piping. Future field testing by the Town is suggested in these two areas to further investigate these differences.

Once the results are reasonably close, "fine-tuning" is often accomplished by adjusting the pipe friction factors (Hazen-Williams "C-values") used in the model. The C-values used in the model were: 110 for 6" pipe; 115 to 130 for 8" pipe; 115 for 10" pipe; 120 to 130 for 12" pipe; and 130 for 16" pipe. However, further adjustments were not made to the pipe friction factors because no consistent systematic trend was observed. In other words, changes to the friction factors would not have universally improved the model calibration. For the current project, the model was considered adequately calibrated for the fire flow assessment and system planning purposes.

Table 4.2: Calibration Table

No.	Test Date	Node	Flow	Field Pressures (psi)			Modeled Pressures (psi)			Difference (Field-Model) psi	Location
				Static	Residual	Diff	Static	Residual	Diff		
1	9/5/07	50a	710	51	38	13	54	39	15	**-2**	Route 3 & Woodwards Lane @ Pump House
2	3/6/18	230/250	1,460	120	116	4	124	115	9	**-5**	Labreque & Main (flow); Connector Rd & Main (monitor)
3	3/6/18	Maple St	1,525	105	100	5	109	104	5	**0**	Maple St near Main
4	9/5/07	262	1,210	117	107	10	117	112	5	**5**	Papermill Drive
5	9/5/07	340	1,540	92	84	8	94	86	8	**0**	Lodge Road near Main Street
6	9/5/07	LV04	690	50	45	5	49	45	4	**1**	Big Rock Road. - near Beech Road
7	9/5/07	LV29a	790	68	47	21	70	53	17	**4**	Granite Road and Easterly Road
8	9/5/07	LV32	1,060	90	50	40	91	48	43	**-3**	Black Mountain Road w/o Sunset Ave.
9	8/9/18	101-1	1,350	105	72	33	107	88	19	**14**	White Mountain Motel, Route 3
10	8/9/18	HYD113	1,000	65	46	19	75	51	24	**-5**	Rodeway Inn, Route 3
11	8/9/18	118	1,260	122	75	47	128	72	56	**-9**	Route 3 - On Indian Head High Pressure
12	8/9/18	220	1,455	106	95	11	104	96	8	**3**	Riverside Terrace Condos, South Peak
13	8/9/18	138	650	73	33	40	73	54	19	**21**	Loon Brook Rd.
14	8/9/18	146	1,190	70	40	30	72	45	27	**3**	Rams Horn Condos
15	8/9/18	203	1,190	128	60	68	134	71	63	**5**	Pollard Brook Rd.
16	8/9/18	222-1	1,590	124	120	4	129	121	8	**-4**	12" River Crossing @ Gene's Playhouse

5.0 Fire Flow Availability Assessment

Available fire flow and duration were assessed in the three primary pressure zones: the main pressure zone, the Loon Village pressure zone and the Indian Head pressure zone.

5.1 Fire Flow Rate

Fire flow analysis was performed to determine the system's behavior in the event of a fire flow demand by analyzing system pressures and flows. Because the current project focused on identifying areas of potentially insufficient fire flow availability, the following ranges were used for the assessment:

- > 1,500 gpm
- 1,000 to 1,500 gpm
- 750 to 1,000 gpm
- 500 to 750 gpm
- < 500 gpm
- < 50 gpm (essentially no availability)

The results are shown in Figure 5.1: Fire Flow Availability Map based on analyzing flows at 36 selected nodes (26% of the 140 total). The flow rate ranges shown on the map are the instantaneous available flows based on system hydraulics applying the previously mentioned criteria of a 20-psi minimum customer pressure. Flow duration is addressed separately in the next section. The system conditions under which the simulations were performed included:

- A background demand of 520 gpm (0.75 mgd)
- All system pumps on including the WTP, Cold Spring Well, Loon Village BPS, Boyce Brook BPS, The Landing BPS and the South Peak jockey pump
- Tank levels: Forest Ridge at 27', Loon Village at 17' and Indian Head at 7'

In summary, the main pressure zone east of I-93 exhibited a fire flow availability of >1,500 gpm. However, that flow rate dissipated heading north of Route 3 to <500 gpm. The fire flow availability in the Loon Village pressure zone was in the 500 to 750 gpm range north of the Pemigewasset River and <500 gpm south of the river. In the Indian Head pressure zone, fire flow availability was >1,500 gpm including the high-pressure pipe running south of the Boyce Brook BPS. And, as previously mentioned, the boosted pressure zones without storage or fire pumps (a portion of South Peak, The Landing and a portion of Clearbrook) are essentially without available fire flow from the water distribution system.

5.2 Fire Flow Duration

Distribution system water storage serves two principal purposes: fire reserve and meeting hourly peak demand fluctuations. A third purpose – emergency reserve – is sometimes included where supply may be unreliable.

Water in non-pressurized, gravity-fed storage tanks (such as Lincoln's) is considered "available" provided the minimum pressure criteria presented in Section 2 are met – namely maintaining 20 psi and 35 psi at user locations under fire- and non-fire flow conditions, respectively, focusing for this analysis on fire-flow conditions.

5.2.1 Main Pressure Zone

The main pressure zone contains some of the largest buildings and the main commercial district in Lincoln. The maximum flow rate used by the ISO (Insurance Services Office) for determining a community's classification is 3,500 gpm. Because both the WTP and the Cold Spring Well are available for fire-fighting, approximately 2,600 gpm should come from the Forest Ridge Tank. For the main pressure zone analysis, the storage volume for fire protection is a 3-hour[5] flow at 2,600 gpm which equals 468,000 gallons.

Over the past 18 months, main pressure zone daily water usage has averaged 407,000 gpd. The suggested storage reserve for hourly usage fluctuations is 25% of the maximum day water usage which for the main pressure zone would be 193,000 gallons (using the 1.9 maximum day factor). The total suggested usable storage requirement in the main pressure zone is summarized in Table 5.1.

Table 5.1: Minimum Suggested Main Pressure Zone Storage Requirement

Item	Calculation	Volume (gal)
Fire Flow Reserve	[3,500 gpm – 900 gpm] x 3 hrs	468,000
Peak hourly demand fluctuations	407,000 gpd x 25% x 1.9	193,000
Total minimum storage requirement		661,000

Usable (or available) storage in the Forest Ridge Tank was determined by simulating a 3,500 gpm fire flow in the town center at the intersection of Connector Road and East Spur Road. With that flow rate withdrawal, there is virtually no usable storage in the Forest Ridge Tank. The limiting locations, which fall to 20 psi, are generally along Crooked Mountain Road, south of the river, at elevations around El. 1,000'. If Crooked Mountain Road were served by the South Peak pump station, as originally intended, the Forest Ridge Tank would likely meet the minimum suggested storage requirement noted above.

5.2.2 Loon Village Pressure Zone

The Loon Village pressure zone contains many multiple-unit condo buildings and single- family homes. In 2007, ISO (Insurance Services Office) suggested a needed fire flow of 3,000 gpm at the condos (at Big Rock Road near Beech Road). Because the Loon Village BPS is available for fire-fighting, approximately 2,500 gpm should come from the Loon Village tank.

[5] The American Water Works Association in Manual M31, Distribution System Requirements for Fire Protection, Third Edition, 1998 indicates required fire flow durations of 3 hours for fire flows of 3,000 to 3,500 gpm and 2 hours for fire flows of 2,500 gpm or less.

Over the past 18 months, Loon Village pressure zone daily water usage has averaged 250,000 gpd. The minimum suggested usable storage requirement in the Loon Village pressure zone is summarized in Table 5.2.

Table 5.2: Minimum Suggested Loon Village Pressure Zone Storage Requirement

Item	Calculation	Volume (gal)
Fire Flow Reserve	[3,000 gpm – 500 gpm] x 3 hrs	450,000
Peak hourly demand fluctuations	250,000 gpd x 25% x 1.9	119,000
Total minimum storage requirement		569,000

The suggested minimum storage requirement exceeds the total tank capacity.

Under the current conditions and the minimum pressure criteria applied, the Loon Village tank has no usable storage and is especially limited by the high elevations in the Rams Horn condos. For comparison, when the Rams Horn condo limitation was removed from the simulation, a fire flow of about 2,500 gpm at the Loon Village condos resulted in about 325,000 gallons of usable storage in the Loon Village tank primarily limited by the suction pressure at The Landing booster pump station and the high elevations at Birch Road and Clearbrook Road.

5.2.3 Boyce Brook Pressure Zone

The Indian Head pressure zone contains many hotels, commercial buildings and homes. In 2007, ISO (Insurance Services Office) suggested a needed fire flow of 2,500 gpm at the Indian Head Resort. Because the Boyce Brook BPS is available for fire-fighting, approximately 2,200 gpm should come from the Indian Head tank.

Over the past 18 months, Indian Head pressure zone daily water usage has averaged 72,000 gpd. The minimum suggested usable storage requirement in the Indian Head pressure zone is summarized in Table 5.3.

Table 5.3: Minimum Suggested Indian Head Pressure Zone Storage Requirement

Item	Calculation	Volume (gal)
Fire Flow Reserve	(2,500 gpm – 300 gpm) x 2 hrs	264,000
Peak hourly demand fluctuations	72,000 gpd x 25% x 1.9	34,000
Total minimum storage requirement		298,000

The suggested minimum storage requirement is twice the total tank capacity of 146,000 gallons. Under the current conditions, the Indian Head tank has little to no usable storage based on the criteria described above.

5.3 Areas of Very Limited Fire Flow Availability

Several areas serviced by booster pump stations have very limited to no fire flow availability. Available water in these areas is less than 50 gallons per minute with no available distribution storage. These areas are privately owned developments including The Landing and portions of the Clearbrook condos and South Peak.

6.0 General Conclusions and Comments

The Lincoln water system fire flow level of service assessment included:

1. Fire flow tests conducted at eight hydrant locations and field elevations determined at 51 locations,
2. Distribution system piping review using Town GIS,
3. The existing hydraulic model update and calibration including revising and redistributing current system water demands based on adding recent production data,
4. A fire flow availability assessment within the various pressure zones addressing both fire flow rate and duration using the hydraulic model, and
5. Assessment of available water storage capacity in the distribution tanks and fire flow availability limitations based on system elevation criteria using the hydraulic model.

Figure 5.1 shows the current ranges of estimated, available fire flow under the conditions modeled. Although the Lincoln water distribution system contains 1.6 million gallons among the three storage tanks, none of that is considered available for fire flow based on minimum system pressure criteria. And, with no available fire flow storage, there is no available fire flow duration.

This assessment focused on Available Fire Flow (AFF) and usable storage. The Needed Fire flow (NFF) in any given location is typically determined by local fire officials, insurance rating agencies and, in the case of individual building fire suppression systems, fire protection engineers. Having said that, generally-accepted published guidelines indicate that AFF less than 500 gpm is insufficient for fire-fighting in residential, and certainly commercial, areas. Those areas are shown on Figure 5.1.

The Lincoln water system has expanded over the years in the absence of comprehensive planning and suffers from serious deficiencies as a result. Beside the fire flow and available storage deficiencies noted in this assessment, both non-fire flow storage and water supply/treatment capacity has, or soon will, exceed its ability to keep up with development and meet system demands. Hoyle, Tanner's 2016 assessment focused primarily on issues of system ownership and an inability to manage customer demands because of no metered water use records.

The Town of Lincoln is at a crossroads; upgrading the water system is inevitable to serve and protect the current residential and commercial buildings and to support potential future development. This assessment was performed to properly define the existing fire flow deficiencies. The next step is the development of a comprehensive Capital Improvement Plan (CIP) with the following goals:

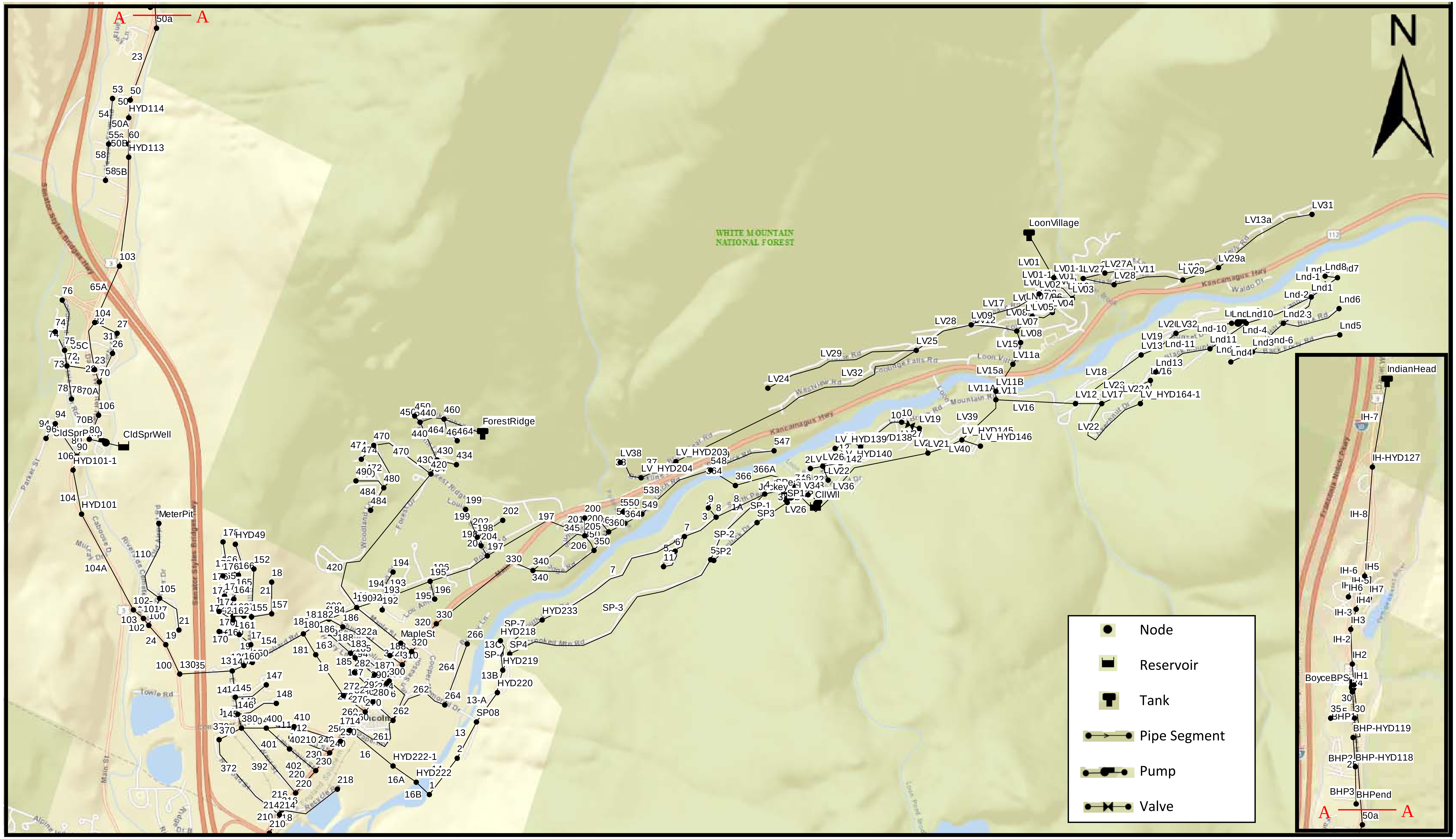
- Provide adequate available fire flow throughout the system,
- Provide adequate usable storage,
- Maintain (or improve) distribution system water quality including, but not necessarily limited to, mitigating the formation of chlorinated Disinfection Byproducts and maintaining an adequate chlorine residual.

The CIP development should lay out a long-term plan meeting these goals in the most cost-effective and affordable way.

Appendix A

Water System Map

Water System Map
Town of Lincoln, NH



Hoyle, Tanner & Associates, Inc.

Appendix B

Field Data Sheets – Fire Hydrant Flow Tests

HYDRANT FLOW TEST FORM

Fire Flow Assessment Project

Date and time 8/9/18 9:55 Test # 1

Location Rt 3

Residual Hydrant A # 101-1 Flowing Hydrant B # 101

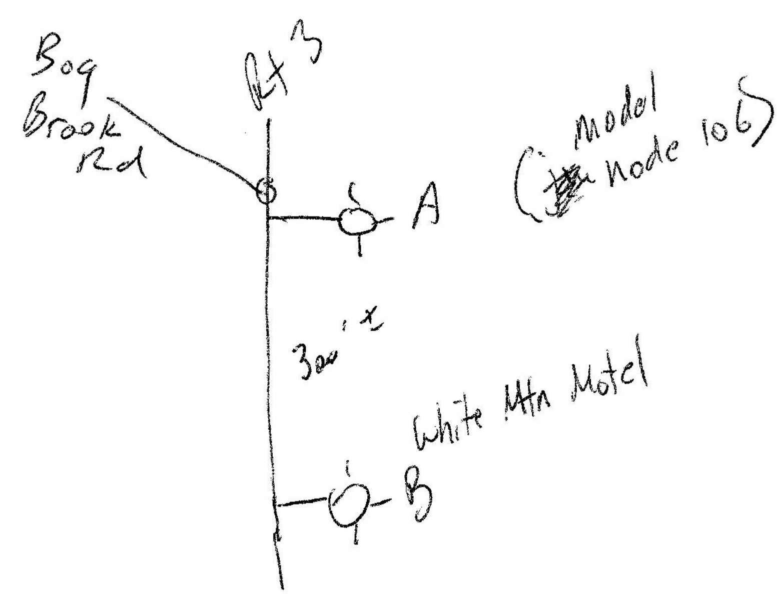
Notes (tank levels, pump operation, etc.):

Residual Hydrant (A) 101-1	
Static Pressure (psi)	105
Flowing Pressure (psi)	72

Curved

101 Flowing Hydrant (B) @ White Mtn Motel			
Orifice/Nozzle Size (in)	Coefficient	Pitot Reading (psi)	Flow Rate (gpm)
2.5"	1	–	1350
4"			

SKETCH OF HYDRANT LOCATIONS AND CONNECTING PIPING



Town of Lincoln, NH **HYDRANT FLOW TEST FORM** Fire Flow Assessment Project

Date and time 8/9/2018 9:18 Test # 2

Location Rt 3

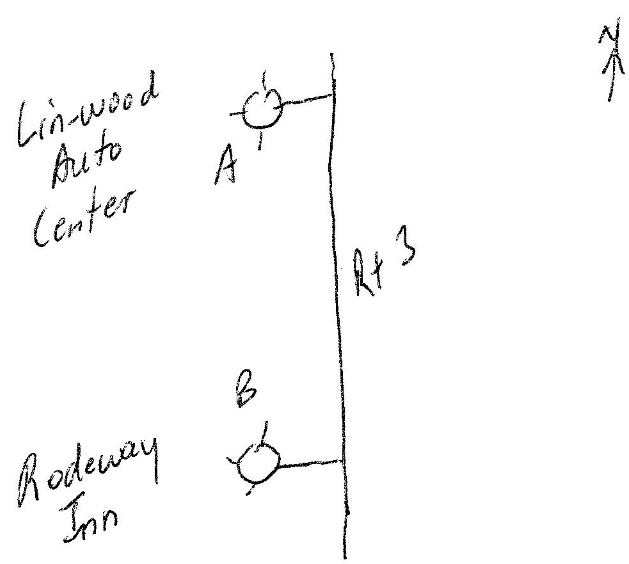
Residual Hydrant A # 114 Flowing Hydrant B # 113

Notes (tank levels, pump operation, etc.):

Residual Hydrant (A)	
Static Pressure (psi)	65
Flowing Pressure (psi)	46/47

Flowing Hydrant (B)			
Orifice/Nozzle Size (in)	**Coefficient**	**Pitot Reading (psi)**	**Flow Rate (gpm)**
2.5"	1	—	1,000
4"			

SKETCH OF HYDRANT LOCATIONS AND CONNECTING PIPING



Town of Lincoln, NH **HYDRANT FLOW TEST FORM** Fire Flow Assessment Project

Date and time 8/9/18 9:33 Test # 3

Location Rt 3

Residual Hydrant A # 128 Flowing Hydrant B # 119

Notes (tank levels, pump operation, etc.):

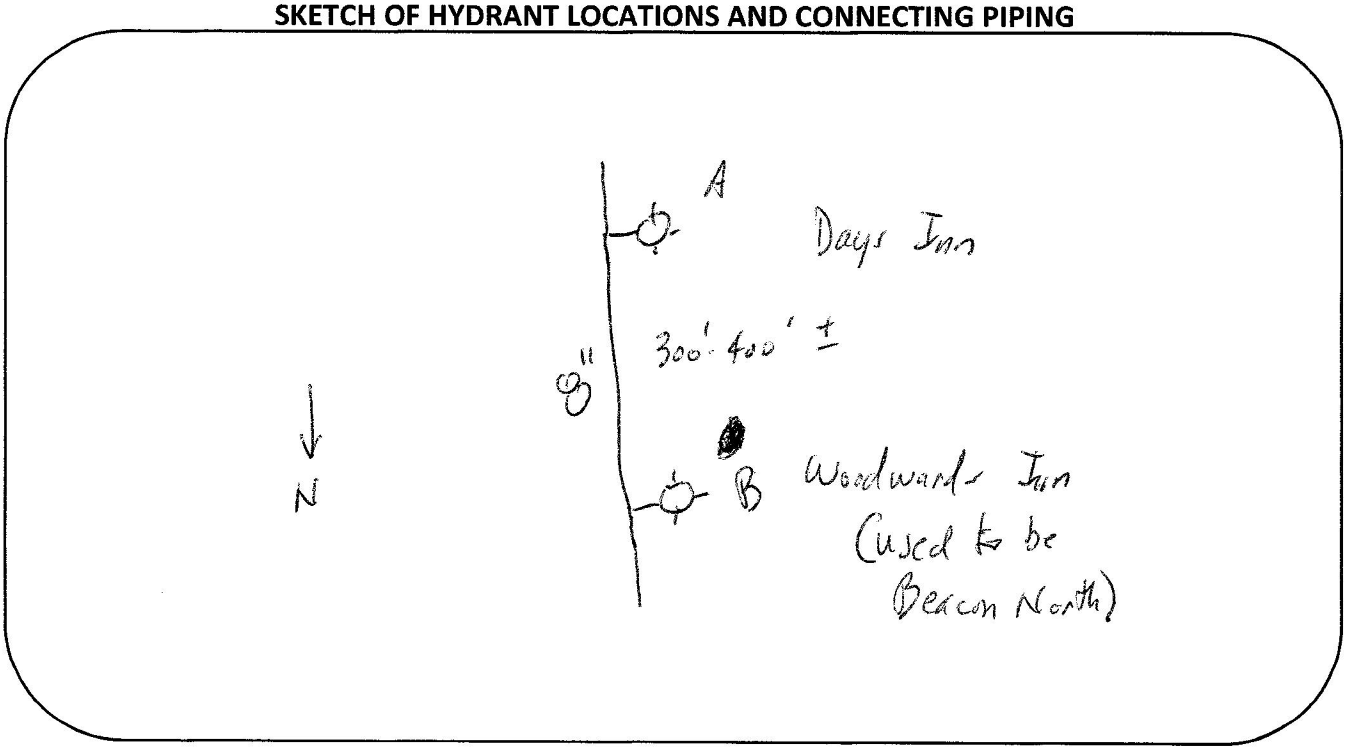
On Indian Head high Pressure - 8" line runs South of Boyce BPS

Residual Hydrant (A)	
Static Pressure (psi)	122
Flowing Pressure (psi)	75

7.77' Indian Head Tank

Flowing Hydrant (B)			
Orifice/Nozzle Size (in)	**Coefficient**	**Pitot Reading (psi)**	**Flow Rate (gpm)**
2.5"	1	–	1,260
4"			

SKETCH OF HYDRANT LOCATIONS AND CONNECTING PIPING



HYDRANT FLOW TEST FORM

Date and time 8/9/18 10:43 Test # 4

Location South Peak

Residual Hydrant A # 218 Flowing Hydrant B # 219

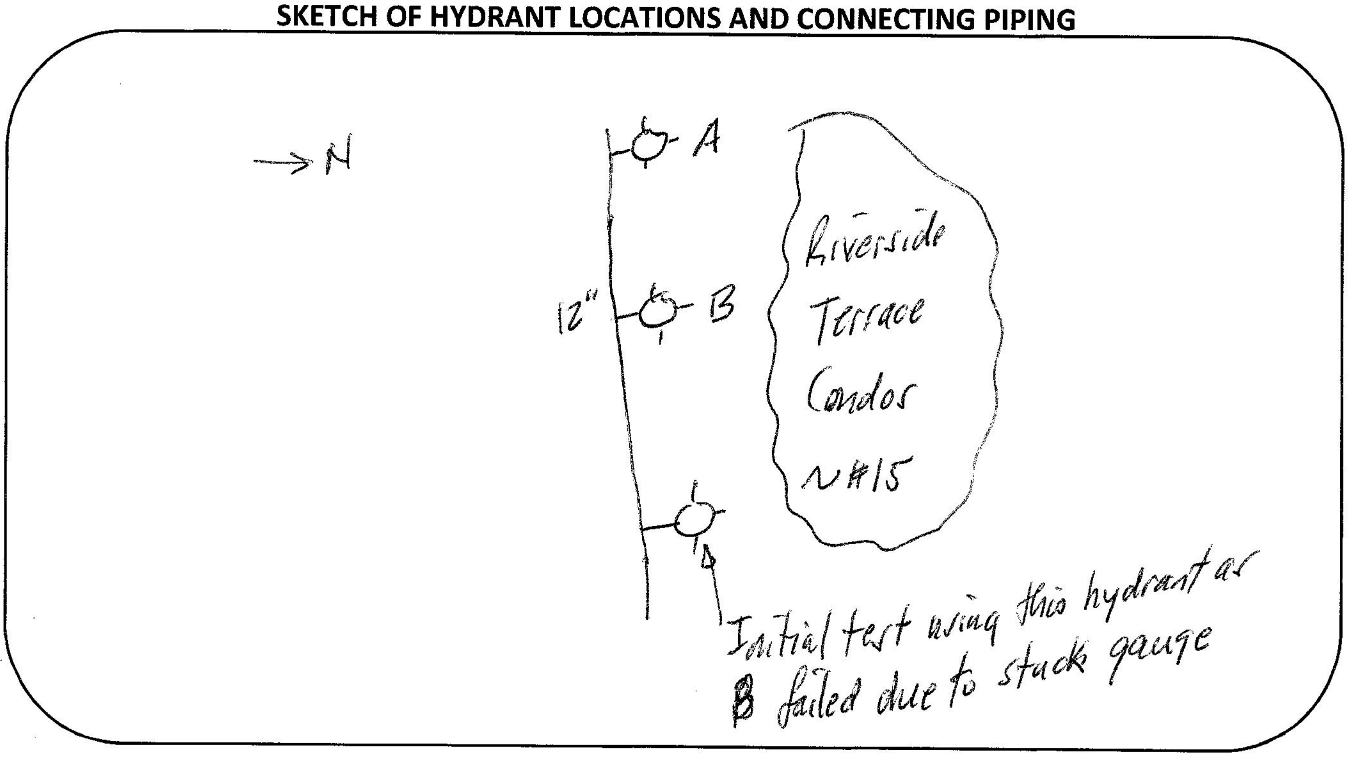
Notes (tank levels, pump operation, etc.):

Static pressure was measured at hydrant B = 101 psi

Residual Hydrant (A)	
Static Pressure (psi)	106
Flowing Pressure (psi)	95

Flowing Hydrant (B)			
Orifice/Nozzle Size (in)	Coefficient	Pitot Reading (psi)	Flow Rate (gpm)
2.5”	1	–	1,455
~~4”~~			

SKETCH OF HYDRANT LOCATIONS AND CONNECTING PIPING



HYDRANT FLOW TEST FORM

Date and time 8/9/18 11:30 Test # 5

Location Loon Brook Rd

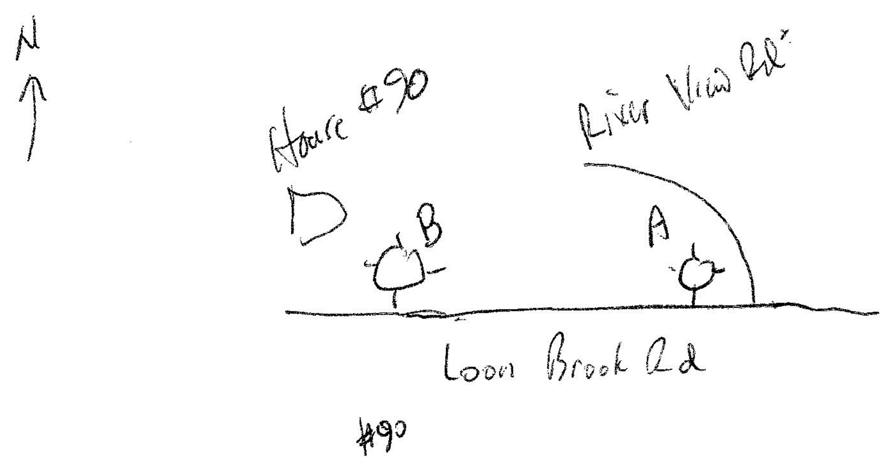
Residual Hydrant A # 138 Flowing Hydrant B # No tag

Notes (tank levels, pump operation, etc.):

Residual Hydrant (A)	
Static Pressure (psi)	73
Flowing Pressure (psi)	33/34

Flowing Hydrant (B)			
Orifice/Nozzle Size (in)	Coefficient	Pitot Reading (psi)	Flow Rate (gpm)
2.5"	1		650
4"			

SKETCH OF HYDRANT LOCATIONS AND CONNECTING PIPING



Town of Lincoln, NH **HYDRANT FLOW TEST FORM** Fire Flow Assessment Project

Date and time 8/9/18 1:22 Test # 6

Location Rams Horn Condos

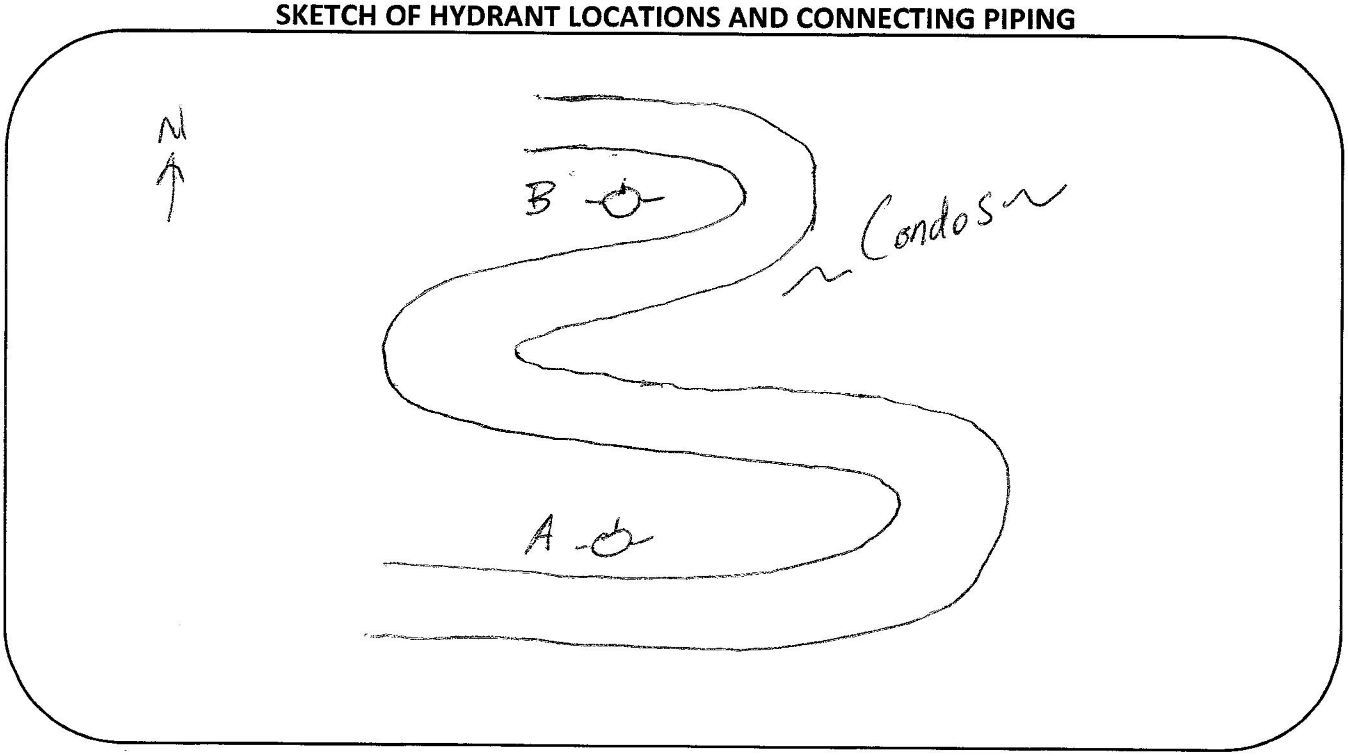
Residual Hydrant A # 146 Flowing Hydrant B # 145

Notes (tank levels, pump operation, etc.):

Residual Hydrant (A)	
Static Pressure (psi)	70
Flowing Pressure (psi)	40

Flowing Hydrant (B)			
Orifice/Nozzle Size (in)	**Coefficient**	**Pitot Reading (psi)**	**Flow Rate (gpm)**
2.5"	1	–	1,190
4"			

SKETCH OF HYDRANT LOCATIONS AND CONNECTING PIPING



HYDRANT FLOW TEST FORM

Date and time 8/9/18 1:45 Test # 7

Location Pollard Brook Rd

Residual Hydrant A # 204 Flowing Hydrant B # 203

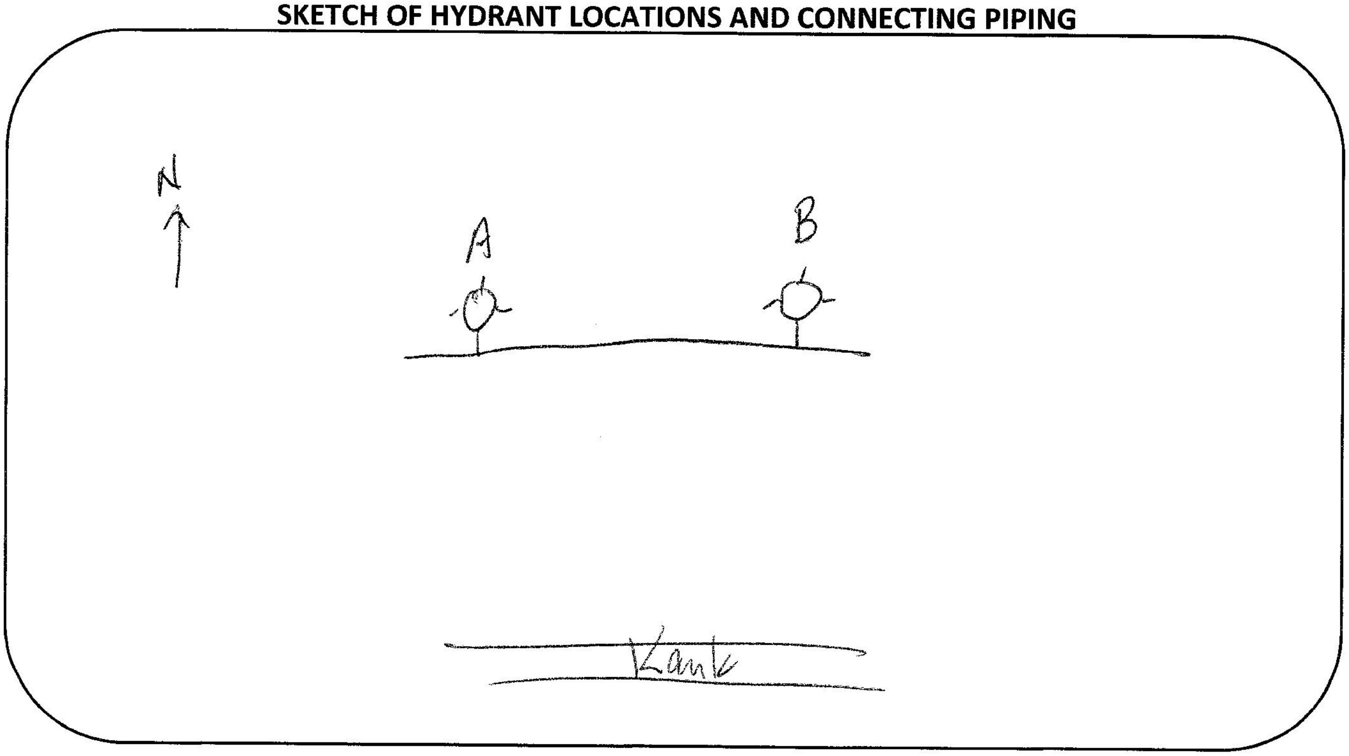
Notes (tank levels, pump operation, etc.):

17.33' Tank

Residual Hydrant (A)	
Static Pressure (psi)	128
Flowing Pressure (psi)	60

Flowing Hydrant (B)			
Orifice/Nozzle Size (in)	Coefficient	Pitot Reading (psi)	Flow Rate (gpm)
2.5"	1	-	1,190
4"			

SKETCH OF HYDRANT LOCATIONS AND CONNECTING PIPING



Town of Lincoln, NH **HYDRANT FLOW TEST FORM** Fire Flow Assessment Project

Date and time 8/9/18 2:15 Test # 8

Location 12" River Crossing near Jean's Playhouse

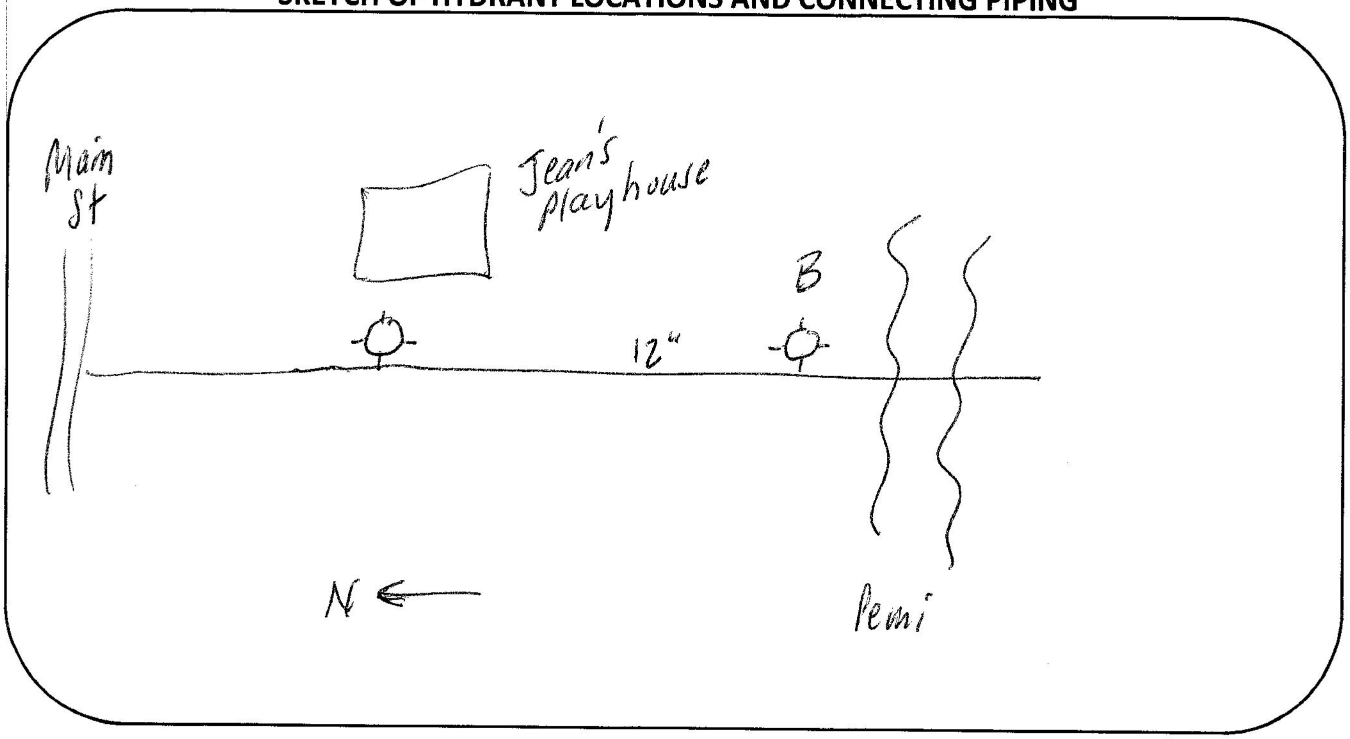
Residual Hydrant A # 222-1 Flowing Hydrant B # 222

Notes (tank levels, pump operation, etc.):

Residual Hydrant (A)	
Static Pressure (psi)	124
Flowing Pressure (psi)	120

Flowing Hydrant (B)			
Orifice/Nozzle Size (in)	Coefficient	Pitot Reading (psi)	Flow Rate (gpm)
2.5"	1	–	1,590
4"			

SKETCH OF HYDRANT LOCATIONS AND CONNECTING PIPING



Gilford, Lancaster, Nashua, Hudson & Newington, NH
Telephone: (603) 293-7531
Fax: (603) 589-2051
www.getfireprotection.com

TRI STATE FIRE PROTECTION, LLC

Remit to:
26 Hampshire Drive
Hudson, NH 03051

SPRINKLER SYSTEM SERVICE
Comm. of Mass. Sprinkler Contractor SC-210059

WORK ORDER #: 14271781	DATE: 03/06/2018 08:00am EST	CUSTOMER ID:

BILL TO: LAHOUTS APARTMENTS
26 UNION STREET
LINCOLN NH 03561

Phone:
Email:

SHIP TO: LAHOUTS SHOPPES LINCOLN
165 MAIN STREET
LINCOLN NH 03251

Contact:
Phone: (603) 728-8161

SERVICE REPORT

P.O. :	F.A. PANEL MFG.:	
MODEL #:	SPRINKLER SYS. MFG.:	TYPE: wet
SYSTEM LEFT IN SERVICE: ☑ YES ☐ NO	FIRE DEPT. CONTACTED: ☑ YES ☐ NO	

SERVICES PERFORMED:

performed flow test on city hydrants outside lahouts shops for new design flow data, also performed flow test on main street for new hampton inn hotel for new design flow data.

LAHOUTS SHOPPS-
static: 105psi
residual: 100psi
PSI: 83
GPM: 1525

HOTEL MAIN ST.-
static: 120psi
residual: 116psi
PSI: 76
GPM: 1460

☐ Work described above has passed re-inspection

LABOR		HOURS			MATERIALS & BILLING		
DATE	NAME	ST	OT	DT	QUANTITY	DESCRIPTION	PO# FO# STOCK
3/6/2018	BM	4HR					
3/6/2018	DS	4HR					

TRAVEL: 2HR
ARRIVAL TIME:
DEPARTURE TIME:

THIS IS NOT AN INVOICE

3/6/2018
CUSTOMER'S SIGNATURE - DATE

☐ BILLING ADDRESS CONFIRMED

3/6/2018
TECHNICIAN'S SIGNATURE - DATE

CUSTOMER'S PRINTED NAME

INSURANCE SERVICES OFFICE, INC.

HYDRANT FLOW DATA SUMMARY

City Lincoln

unty Grafton State New Hampshire Witnessed by Insurance Services Office, Inc. Date September 9, 2007

EST NO.	TYPE DIST.*	TEST LOCATION	SERVICE	FLOW - GPM $Q=(29.83(C(d^2)p^{0.5}))$ INDIVIDUAL HYDRANTS			TOTAL	PRESSURE PSI STATIC	PRESSURE PSI RESID.	FLOW -AT 20 PSI NEEDED **	FLOW -AT 20 PSI AVAIL.	REMARKS***
1	Comm	Rte. 3 & Woodwards Ln.	Town of Lincoln, Main Service	710	0	0	710	51	38	3000	1100	
2	Comm	Rte. 3 & Drummer Ln.	Town of Lincoln, Main Service	2120	0	0	2120	82	32	3000	2400	
3	Comm	Connector Rd. & Bern Dibner Rd.	Town of Lincoln, Main Service	2020	0	0	2020	122	80	5000	3300	(A)-(3840 gpm)(D)-(4707 gpm)
3a	Comm	Connector Rd. & Bern Dibner Rd.	Town of Lincoln, Main Service	2020	0	0	2020	122	80	1250	3300	
4	Comm	Main St. & School St.	Town of Lincoln, Main Service	2470	0	0	2470	115	70	5000	3700	(A)-(2500 gpm)(D)-(4707 gpm)
4a	Comm	Main St. & School St.	Town of Lincoln, Main Service	2470	0	0	2470	115	70	2000	3700	
5	Comm	Papermill Dr. near South Mountain Dr.	Town of Lincoln, Main Service	1210	0	0	1210	117	107	3500	4100	
6	Comm	Lodge Rd. near Main St.	Town of Lincoln, Main Service	1540	0	0	1540	92	84	7000	5000	(A)-(4010 gpm)(D)-(4707 gpm)
5a	Comm	Lodge Rd. near Main St.	Town of Lincoln, Main Service	1540	0	0	1540	92	84	3500	5000	(A)-(2590 gpm)
7	Comm	Big Rock Rd. near Beech Rd.	Town of Lincoln, Loon system	690	0	0	690	50	45	3000	1800	(A)-(2250 gpm)(C)-(2410 gpm)
3	Comm	Granite Rd. & Easterly Rd.	Town of Lincoln, Loon system	790	0	0	790	68	47	1250	1200	
)	Comm	Black Mountain Rd. w/o Sunset Ave.	Town of Lincoln, Loon system	1060	0	0	1060	90	50	1500	1400	
0	Comm	Rte. 30 at Indian Head Resort	Town of Lincoln, High system	1350	0	0	1350	83	20	2500	1400	(A)-(1920 gpm)(B)-(1149 gpm)

ABOVE LISTED NEEDED FIRE FLOWS ARE FOR PROPERTY INSURANCE PREMIUM CALCULATIONS ONLY AND ARE *NOT* INTENDED TO PREDICT THE MAXIMUM AMOUNT OF WATER REQUIRED FOR A LARGE SCALE FIRE)ITION.

AVAILABLE FLOWS ONLY INDICATE THE CONDITIONS THAT EXISTED AT THE TIME AND AT THE LOCATION WHERE TESTS WERE WITNESSED.

nm = Commercial; Res = Residential.

eded is the rate of flow for a specific duration for a full credit condition. Needed Fire Flows greater than 3,500 gpm are not considered in determining the classification of the city when using the Fire)ression Rating Schedule.

\)-Limited by available hydrants to gpm shown. Available facilities limit flow to gpm shown plus consumption for the needed duration of (B)-2 hours, (C)-3 hours or (D)-4 hours.

Appendix C

Field Calibration Sheet

Field Calibration Sheet

CALIBRATION TABLE												System Conditions						
No.	Test Date	Node	Flow	FIELD DATA			MODEL DATA			FIELD-MODEL	Location	WTP	Cold Spring Well	Loon BPS	Boyce BPS	Forest Ridge Tank	Loon Village Tank	Indian Head Tank
				Static	Residual	Diff	Static	Residual	Diff									
1	9/5/07	50a	710	51	38	13	54	39	15	**-2**	Route 3 & Woodwards Lane @ Pump House	off	off	off	off	27	17	8
2	3/6/18	230/250	1,460	120	116	4	124	115	9	**-5**	Labreque & Main (flow); Connector Rd & Main (monitor)	off	off	off	off	27	17	8
3	3/6/18	Maple St	1,525	105	100	5	109	104	5	**0**	Maple St near Main	off	off	off	off	27	17	8
4	9/5/07	262	1,210	117	107	10	117	112	5	**5**	Papermill Drive	off	off	off	off	27	17	8
5	9/5/07	340	1,540	92	84	8	94	86	8	**0**	Lodge Road near Main Street	off	off	off	off	27	17	8
6	9/5/07	LV04	690	50	45	5	49	45	4	**1**	Big Rock Road. - near Beech Road	off	off	off	off	27	17	8
7	9/5/07	LV29a	790	68	47	21	70	53	17	**4**	Granite Road and Easterly Road	off	off	off	off	27	17	8
8	9/5/07	LV32	1,060	90	50	40	91	48	43	**-3**	Black Mountain Road w/o Sunset Ave.	on	off	on	off	27	17	8
9	8/9/18	101-1	1,350	105	72	33	107	88	19	**14**	White Mountain Motel, Route 3	on	off	on	off	27	17	8
10	8/9/18	HYD113	1,000	65	46	19	75	51	24	**-5**	Rodeway Inn, Route 3	on	off	on	off	27	17	8
11	8/9/18	118	1,260	122	75	47	128	72	56	**-9**	Route 3 - On Indian Head High Pressure	on	off	on	on	27	17	8
12	8/9/18	220	1,455	106	95	11	104	96	8	**3**	Riverside Terrace Condos, South Peak	on	off	on	off	27	16	8
13	8/9/18	138	650	73	33	40	73	54	19	**21**	Loon Brook Rd.	on	off	on	off	27	16	8
14	8/9/18	146	1,190	70	40	30	72	45	27	**3**	Rams Horn Condos	on	off	on	off	27	17	8
15	8/9/18	203	1,190	128	60	68	134	71	63	**5**	Pollard Brook Rd.	on	off	on	off	27	17	8
16	8/9/18	222-1	1,590	124	120	4	129	121	8	**-4**	12" River Crossing @ Gene's Playhouse	on	off	on	off	27	17	8

Note: Added Loss Coefficient of 500 to pipe SP-3 to account for 6" pipe segment in manhole

Appendix D

GIS Field Elevations

GIS Field Elevations

Featype	Descrip	ID_asset	X-Coordinate	Y-Coordinate	Elevation
Meter Pit	meter pit		979665.72	565278.77	828.38
Gate Valve	gv		994149.41	568036.18	1031.15
Gate Valve	gv		994166.95	568086.15	1033.73
Gate Valve	gv		994152.58	568105.51	1033.99
Hydrant	hyd		994160.98	568117.88	1035.61
Gate Valve	gv		994416.34	568221.44	1084.07
Gate Valve	gv		994223.64	568393.22	1071.38
Gate Valve	gv		994757.67	569285.39	1147.19
Hydrant	hyd		994757.08	569302.51	1145.90
Gate Valve	gv		994758.36	569297.67	1147.74
Gate Valve	gv		994737.71	569452.90	1179.81
Gate Valve	gv		994747.07	569435.87	1203.42
Gate Valve	gv		993829.57	567399.17	979.38
Gate Valve	gv		993792.29	567492.83	963.76
Gate Valve	gv		990793.98	565691.08	1049.59
Gate Valve	gv		990799.19	565674.54	1085.87
Manhole	smh		990775.55	565673.38	1063.12
Manhole	mh		990867.67	565716.23	1048.46
Water Meter	wmeter		990880.25	565723.92	1048.39
Hydrant		101-1	978252.57	566087.74	837.88
Hydrant		101	978409.92	565457.04	832.51
Hydrant		114	979164.07	572150.50	924.39
Hydrant		113	979163.67	571491.26	910.74
Hydrant		128	979516.99	574628.47	973.48
Hydrant		119	979481.70	575132.49	989.03
Other	indian head tank pit hatch		980032.94	581138.11	1271.88
Other	indian head tank entry hatch		980026.67	581112.75	1271.96
Hydrant		127	979805.33	579699.04	1181.15
Hydrant		212	985525.69	563128.69	849.59
Hydrant		219	985506.11	562886.54	856.10
Hydrant		220	985373.50	562411.53	845.21
Gate Valve	gate valves for s peak rd and pump station		990393.52	565906.37	966.03
Other	s peak booster front door		990400.61	565820.07	966.80
Hydrant		138	991496.67	566561.53	949.09
Hydrant		140	991172.48	566285.46	971.12
PRV	prv on 8"" to loon brook		992306.05	566972.07	962.14
Hydrant		146	993453.81	566617.16	1108.14
Hydrant		145	993220.78	566820.11	1042.66
Hydrant		203	988388.19	566319.02	956.10
Hydrant		204	987810.30	566040.64	954.76
Hydrant		222	983997.36	560910.18	779.75
Hydrant		222-1	983681.66	561272.50	786.61
Other	loon vill tank base		994371.86	570149.82	1254.00
Other	oceola cir high point before loon tank		994807.58	569443.18	1163.60
Other	birch rd high point		995623.77	569503.05	1165.45
Other	beechnut st highpoint		996169.21	567366.36	1218.61

Hydrant		164-1	996171.46	567387.88	1218.84
Other	forest rudge fill pipe		985123.56	566822.07	1054.75
Other	forest ridge tank base elev		985138.03	566826.83	1063.63
Other	sports club high point		983129.14	566300.52	912.64
Other	6 spruce dr high point		984477.59	567039.91	975.69
Hydrant		49	980952.02	564919.70	930.85