The Municipality of the Village of Lions Bay

Water Storage Facility Replacement Water System Review and Analysis

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September, 2017

Project Number: 60546407

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Revision History

Revision #	Date	Revised By:	Revision Description
1	01/08/17	Semyon Chaymann	Draft #1
2	28/08/17	Graham Walker	Draft #2 – Separated from Pre-Design Technical Memorandum
3	30/08/17	Graham Walker	Draft #3 – For Infrastructure Committee Review
4	22/09/17	Semyon Chaymann	Final

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September 22, 2017

Naizam Jaffer
Public Works Manager
Village of Lions Bay
400 Centre Road
Lions Bay, BC V0N 2E0

Dear Mr. Jaffer:

Project No: 60546407

Regarding: Water Storage Facility Replacement Water System Review and Analysis

Please find attached our Water System Review and Analysis Technical Memorandum for the Village of Lions Bay Water Storage Facility Replacement project. If you have any questions please contact Graham Walker at 604.444.6436

Sincerely,
AECOM Canada Ltd.

Graham Walker

Quality Information

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1. Introduction

The Municipality of the Village of Lions Bay has retained AECOM Canada to evaluate configuration options and recommend a replacement strategy for the four water storage facilities – Harvey, Phase IV, Phase V, and Highway. This Pre-Design Technical Memorandum outlines the scope and impacts of the proposed water system configurations, site development and water storage construction.

Table 1: List of Key Terms and Abbreviations

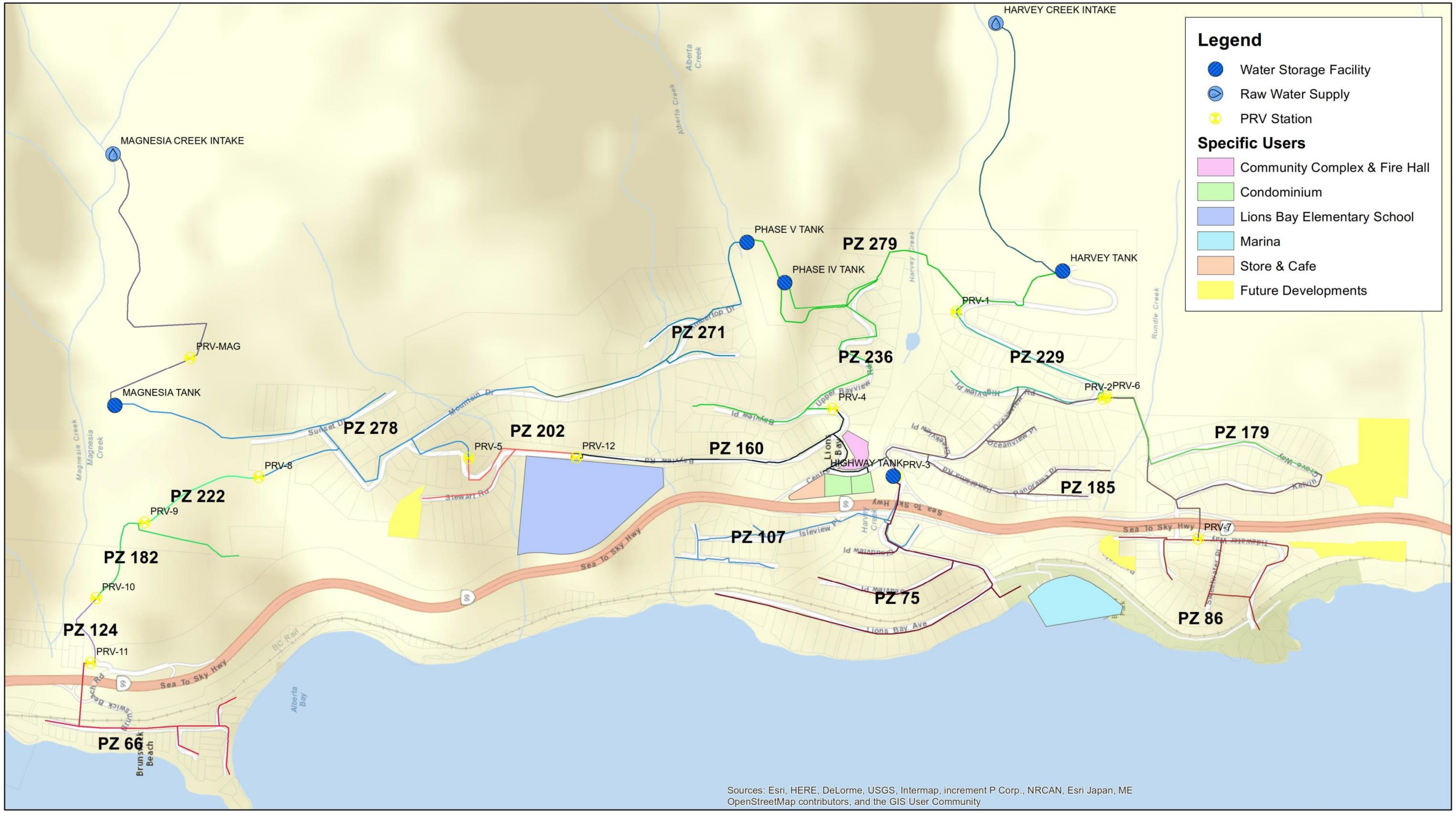
Key Term (and Abbreviation)	Definition
Average Daily Demand (ADD)	Annual water demand from all sources averaged to a single day (used, for example, to determine water licensing requirements).
Fire Underwriters Survey (FUS)	Standard criteria developed by the Insurance Industry to evaluate fire services, including minimum fire flow and fire storage requirements.
Headloss	The head, pressure or energy (they are the same) lost by water flowing through a pipe, bend/deflection, valve, etc. as a result of friction.
Hydraulic Grade Line (HGL)	The surface or profile of water flowing. The level water would rise to in a small vertical tube connected to the pipe. (HGL = elevation + pressure)
Leakage ("water loss")	Water lost from the system through cracks in water mains, unseated valves, loose end-caps, misaligned joints, reservoir cracks, overflows. (can occur on municipal water mains and on private services)
Million Litres (ML)	1 ML/day refers to 1 million litres of water per day
Maximum Day Demand (MDD)	Highest daily water usage over the entire year.
Peak Hour Demand (PHD)	Highest water usage for any given 1-hour period, over an entire year.
Pressure Reducing Valve (PRV)	A control valve that automatically reduces the inlet pressure in a water main to a set downstream pressure.
Pressure Zone (PZ)	A water service area (controlled by a reservoir, tank, or PRV) in which all the users have the same static HGL. Water cannot flow from one PZ to another without passing through a PRV or another control valve.
Water Age	Length of time that water is within the distribution system, measured from point where chlorination is introduced.
Unit Conversions	
Pressure **Psi to "m" or "kPa"**	1.0psi = 0.69m = 6.9kpa (so 100psi = 69m = 690 kPa)
Volume **Litres to gallons**	3.79 Litres = 1.0 US gallon and 4.54 Litres = 1.0 Imp. gallon
Flow Rate **L/s to gpm**	1.0 L/s = 15.9 USgpm = 13.2 Imp. gpm

1.1 Village of Lions Bay Water System Overview

The Village of Lions Bay is situated between Vancouver and Squamish, approximately 11km north of Horseshoe Bay along Howe Sound. The Village operates and maintains a water supply and distribution system that is responsible for providing water to their 1334 residents for potable (domestic), irrigation and fire protection usage. Water supply for the Village is drawn from two local creeks – Harvey Creek and Magnesia Creek. The water is treated and conveyed to the consumers through the following distribution system infrastructure:

- 17km of water main (various sizes and materials)
- 2 water treatment plants (Harvey Creek WTP, Magnesia Creek WTP)
- 8 water tanks (5 of which contain potable water and 3 of which contain non-potable water)
- 2 raw water intakes (Harvey Creek, Magnesia Creek)
- 529 property connections
- 13 pressure reducing valve arrangements
- 72 hydrants
- 250 valves

The system is separated into eighteen (18) pressure zones. The boundaries along the pressure zones consist of a series of closed valves and pipes, and pressure regulating valve (PRV) stations to decrease the pressure to an acceptable range for delivery of water to users.



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Client: The Village of Lions Bay
Date: July 2017
Created By: Semyon Chaymann
Reviewed By: Brett DeWynter (P.Eng)

The Municipality of the Village of Lions Bay

Water System Overview

Figure 1: The Village of Lions Bay Water System Overview

2. Water System Review and Analysis

2.1 Water Consumption

The Village of Lions Bay has two sources of water supply, Magnesia and Harvey Creeks. The Village currently operates two water treatment plants and has two water storage facilities at each creek (Magnesia and Harvey). Using the flow SCADA data from the PRVs at two sources, it is possible to construct a water consumption graph (Figure 2). The data gap in the month of June coincides with a SCADA failure and was confirmed by the Village's Public Works staff. To calculate the average water consumption for 2016, the annual average water consumption was calculated without any data gap in June. Based on the data the average water consumption for 2016 was calculated to be 10.75L/s or 0.93MLD.

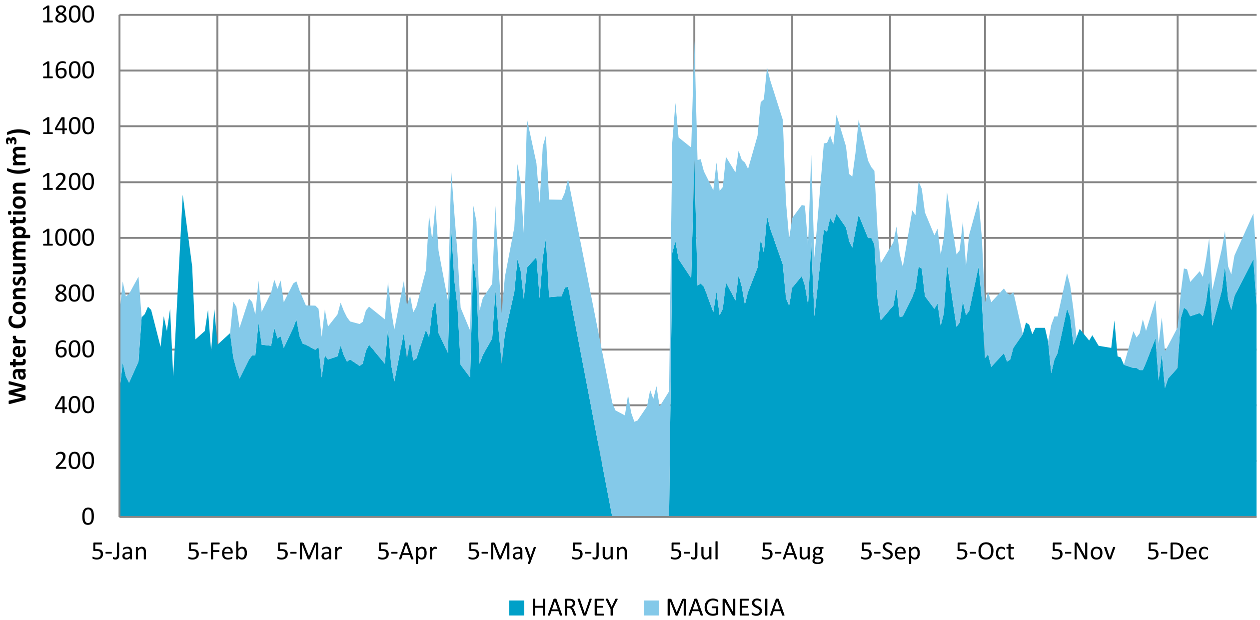

Figure 2: 2016 Water Consumption Stacked Graph for Village of Lions Bay

2.2 Projected Population Growth

Based upon the 2016 Canada Census Data, the Village's population rose by 16 individuals from the 2011 figure of 1318 to 1334.

Using the Census population and the SCADA flow data from the two water sources, it was calculated that the average per capita water consumption in the Village in 2016 was 698 litres per capita per day.

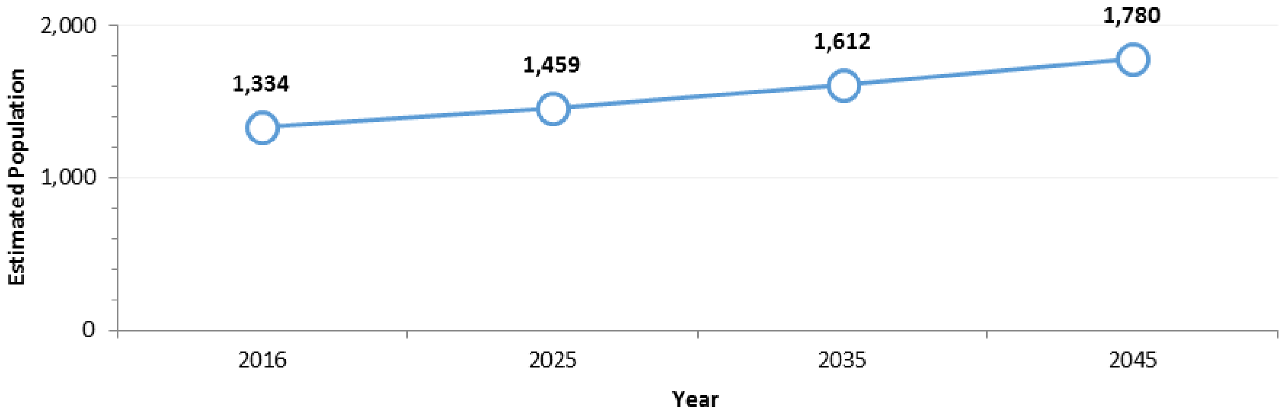

Figure 3: Estimated Population Growth at the Village of Lions Bay (2016-2045)

Based on the preliminary analysis by the Village staff, it is assumed that the future population growth will be approximately 1% per year. This means that by year 2045 the population of the Village of Lions Bay may reach 1780 persons. This value is consistent with the capacity of the potential developments, including condominiums, and sub-divisions of existing land lots, as foreseen by the Village administration.

2.3 Model Review and Update

In order to perform adequate fire flow and storage volume requirement analyses, the existing hydraulic model of the Village's water distribution system was reviewed and updated as follows:

- Water Demand Reallocated.
- Pressure Reducing Valve (PRV) settings and statuses confirmed.
- Isolation valves confirmed.
- Tank elevation and size confirmed.

The PRVs, isolation valves, tank sizes, and elevation data from GeoAdvice's April 2017 model were confirmed.

2.3.1 Demand Allocation Update

During the model review, it was determined that the model could be improved by reallocating the demand to better reflect the actual water demand distribution across the Village. For example, the previous iteration of the model allocated demand equally and indiscriminately across all demand nodes. However, from experience, we understand that a node representing a cluster of Industrial, Commercial, and Institutional (ICI) users will have higher demand than a node representing a cluster of single-family residential users. Additionally, using a series of draw down test results provided by the Village staff, it was estimated (and assumed in the updated model) that approximately 35% of the water supplied is attributed to Non-Revenue Water (leakage, flushing, etc.). The total demand can be split into three sub categories of demand – losses, residential demand, and ICI demand. The new demand split is reflected in the new demand dataset in the updated Village of Lions Bay hydraulic model. The updated water demands are presented in Table 2. Similarly, the 2045 ultimate buildout scenario demands were also updated using the same methodology. The updated 2045 water demands are presented in Table 3.

Table 2: Updated 2016 Village of Lions Bay Water Demand

Demand Scenario	Demand (L/s)	Per Capita Demand (L/capita/day)
Average Day Demand (ADD)	10.78	698
Maximum Day Demand (MDD) (ADD x 2)	21.56	1396
Peak Hour Demand (PHD) (ADD x 4)	43.12	2793

The projected water demands were updated for the 2045 Scenario based on the existing per capita water consumption rates. It is assumed that future consumption patterns for the Village will remain constant. This is a conservative assumption in relation to future water and it does not include any water conservation measures that the Village may promote or implement in the future.

Table 3: Updated 2045 Village of Lions Bay Water Demand Projection

Demand Scenario	Demand (L/s)
ADD	14.38
MDD (ADD x 2)	28.76
PHD (ADD x 4)	57.52

2.3.2 Design Criteria

The hydraulic design criteria for the Village of Lions Bay used in the analysis of the existing and future scenarios is based on the MMCD guidelines and previous discussions with the Village Operations staff.

Table 4: Hydraulic Design Criteria

Criteria	MMCD
Minimum Static Pressure	275 kPa (40psi)
Minimum pressure in the system during design Fire Flow and Maximum Day Demand (MDD+FF)	150 kPa (20psi)
Fire Flow Requirements for a typical land use or dwelling	Minimum Fire Flow
Single Family Residential	60 L/s
Institutional, Commercial, Industrial	150 L/s (unless calculated per FUS, 1999)

2.4 Existing System Performance

The existing system performance was reviewed in detail in the 2016 Village of Lions Bay Infrastructure Master Plan (IMP). The IMP recommended an upgrade of a total of 2,259 meters of water main, 1 storage tank upgrade (Magnesia Tank), and establishing PRV-12 as a permanent PRV to alleviate fire flow deficiencies in pressure zone PZ160. These recommendations were based on the hydraulic model calibration and validation using 2015 water consumption data and data collected for the purpose of the IMP. For this assignment, a similar exercise was performed to analyze the deficiencies under the 2016 water consumption conditions. For comparison purposes all scenarios were analysed for the existing water main diameters as well as proposed upgrades (referred to as “With Upgrades”).

Using the hydraulic design criteria and the Peak Hour Demand (PHD) modelling scenario, the system was analyzed for minimum static pressure requirement of 275kPa (40psi). The results of the analysis are presented in Figure 4 below. The results indicate that the majority of the system meets the hydraulic design criteria under the 2016 PHD Scenario.

2.4.1 Fire Flow Analysis for 2016 Scenario

The system was analysed for available fire flow under the Maximum Day Demand Scenario. The main criteria for analysis the water systems under the Maximum Day Demand and Fire Flow scenario is that all nodes within the modelled system should meet the fire flow requirements associated with the adjacent land use type or dwelling type described in Table 4. In the Storage Tank Sizing Analysis and PRV Sizing Analysis technical memorandums, prepared by GeoAdvice in April 2017, it is noted that, “the Village system is predicted to be incapable of providing fire flow to any of the newly identified sites requiring 150L/s”. However, a more precise fire flow requirement for each site can be calculated using the “Water Supply for Public Fire Protection”, Fire Underwriters Survey (1999). The available fire flow deficiencies are presented in Figure 5 below.

2.4.1.1 Fire Flow Requirements – 2016 Update

In the RFP, the Village has identified five (5) high water users, which fall into the land use categories of Industrial, Commercial, or Institutional (ICI). In previous technical memorandums, the fire flow demand was estimated at 150 L/s for each of these existing five ICI users. The 150 L/s is a generally accepted industry standard for the fire flow threshold and is used within the MMCD Design Guidelines. However, we undertook a review of the fire flow requirements for each site and calculate the fire flow requirements based on the “Water Supply for Public Fire Protections”, Fire Underwriters Survey (FUS) (1999). The intent of this analysis is to understand if there are cost-saving opportunities for the Village if the required fire flow is less than the previously estimated 150 L/s.

Table 5: Updated Fire Flow Requirements for Specific Water Users

Site	Address	Model Junction ID	Fire Flow Requirement per FUS (1999)
The Lions Bay Marina	60 Lions Bay Ave	JCT-GA-39	117 L/s
The Lions Bay Community School	250 Bayview Road	195	133 L/s
The Lions Bay General Store Complex	350 Centre Road	215	150 L/s
The Lions Bay Condominiums	402 and 422 Crosscreek Road	230	117 L/s
The Fire Hall/Ambulance Facility	410 Centre Road	220	83 L/s

From the fire flow requirement calculations, attached in Appendix C, it is evident that the required fire flow is generally less than 150 L/s (Table 5).

2.4.1.2 Fire Flow Analysis Results for the 2016 MDD + FF Scenario

All fire flow scenarios were modelled with all water storage facilities at full capacity. The available fire flow deficiencies are presented in Figure 5 below. The existing water system has fire flow deficiencies in the area supplied by the Highway Tank along Lions Bay Avenue and Isleview Place. Despite the lower than anticipated fire flow requirements for the five ICI users, the existing system continues to be unable to provide sufficient fire flow to these locations.

The upgrades recommended as part of the 2016 Village of Lions Bay IMP will alleviate the aforementioned deficiencies as evidenced by the 2016 MDD + FF Analysis with the recommended upgrades evidenced in Figure 6.

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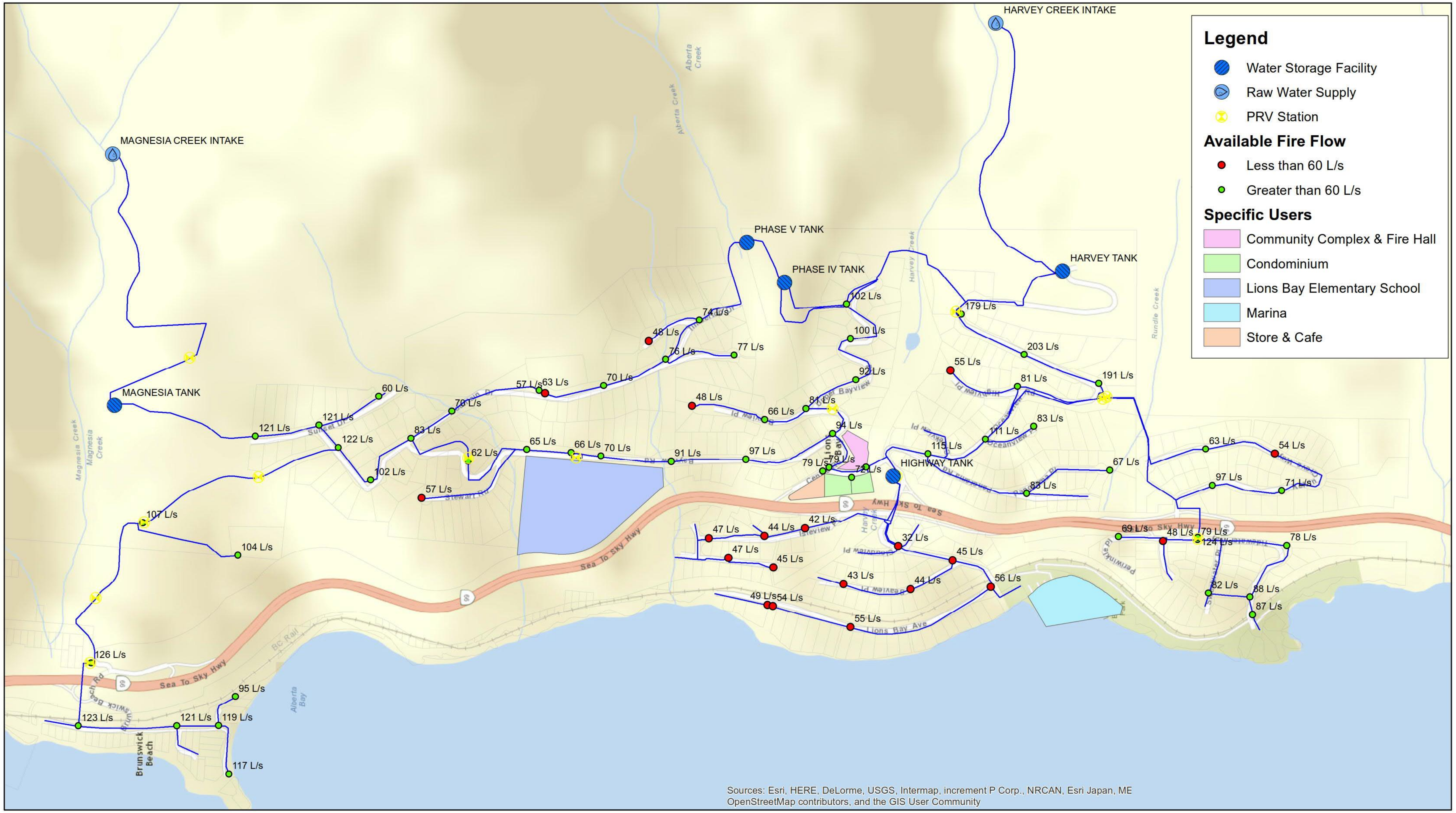
2016 Peak Hour Demand Scenario Analysis Results

Minimum Pressure

Figure 4: 2016 PHD Scenario Results - Minimum Pressure



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Meters

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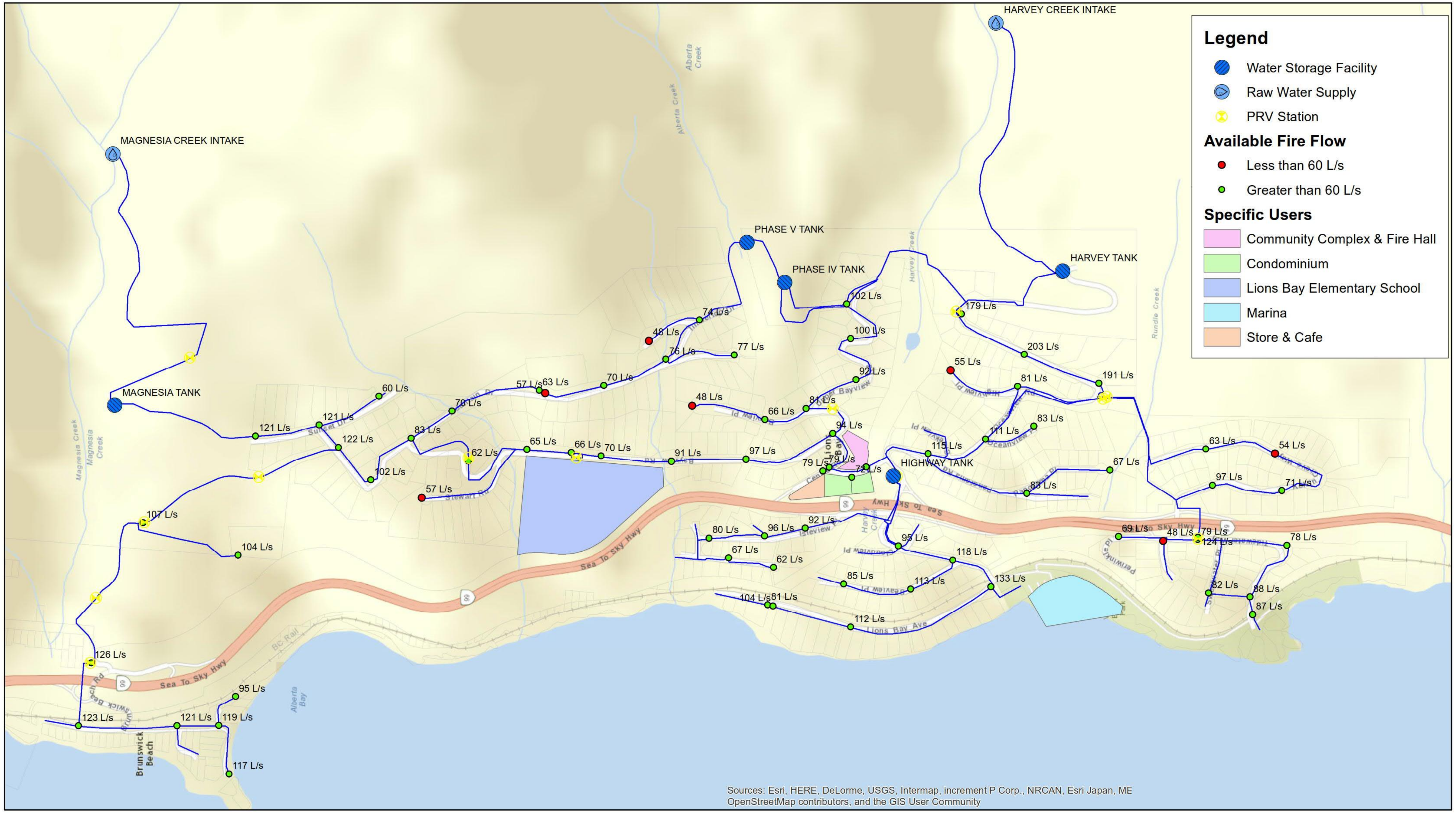
2016 MDD+FF Scenario Analysis Results
No Upgrades

Available Fire Flow

Figure 5: 2016 MDD+FF Scenario Results



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2016 MDD+FF Scenario Analysis Results With IMP Recommended Upgrades

Available Fire Flow

Figure 6: 2016 MDD+FF Scenario Analysis Results with IMP Recommended Upgrades

2.5 Future System Performance

The Village of Lions Bay water system was analyzed under future demand conditions. The year 2045 was used as a marker to build the ultimate future scenario. This ultimate future scenario was then used to review the impacts of potential development on the Village and its impact on the water supply system over the next 30 years. The 2045 Scenario was analyzed using the same hydraulic design criteria as the existing 2016 Scenario. The model demands were updated and are presented in Table 3. The population growth figure is consistent with the information provided by the Village of Lions Bay, the 2016 IMP, and Appendix B of RFP.17.01 Water Storage Facility Replacement (attached for reference as Appendix D). The main criterion for this analysis remains the minimum pressure under the Peak Hour Demand scenario. The results of the hydraulic analysis are presented in Figure 7. The results show that majority of the water system is able to sustain minimum of 40 psi. One block of residential area in PZ86 has minimum pressure of 38 psi downstream of PRV-7 on Tidewater Way and 40 psi at the cul-de-sac on Periwinkle Place. This deficiency may be rectified by adjusting the PRV-7 outlet pressure from 40psi to 42psi.

2.5.1 Fire Flow Analysis for 2045 Scenario

The fire flow requirements for the 2045 Scenario are calculated per the "Water Supply for Public Fire Protections", Fire Underwriters Survey (1999) for the five existing ICI users (Table 5) and the potential future development sites listed in Table 6. It is important to note that the fire flow requirements for the potential developments are assumed values based on MMCD requirements since the size and the construction materials of these developments cannot be confirmed at the time of writing this technical memorandum.

2.5.1.1 Fire Flow Requirements – 2045 Update

Table 6: Fire Flow Requirement for Potential Developments at the Village of Lions Bay

Site	Type	Address	Model Junction ID	Fire Flow Requirement per MMCD
Potential Development	Single Family Residential	251 Steward Road	185	60L/s
Potential Development Site	Condominiums	5 Tidewater Way	460	150L/s
Potential Development Site	10-15 Unit Condominium	89 Tidewater Way	800	150L/s
Potential Development Site	29-40 Unit Condominium	175-185 Kelvin Grove Way	780 and 785	150L/s

2.5.1.2 Fire Flow Analysis Results for the 2045 MDD + FF Scenario

All fire flow scenarios were modelled with all water storage facilities full. The results of the fire flow analysis for the updated 2045 MDD+FF Scenario in Figure 8 show that the available fire flow is insufficient in the area downstream of the Highway Tank (PZ107 and PZ75).

The upgrades recommended as part of the 2016 Village of Lions Bay Infrastructure Master Plan will alleviate the aforementioned deficiencies as evidenced by the 2045 MDD + FF analysis with the recommended upgrades demonstrated in Figure 9.

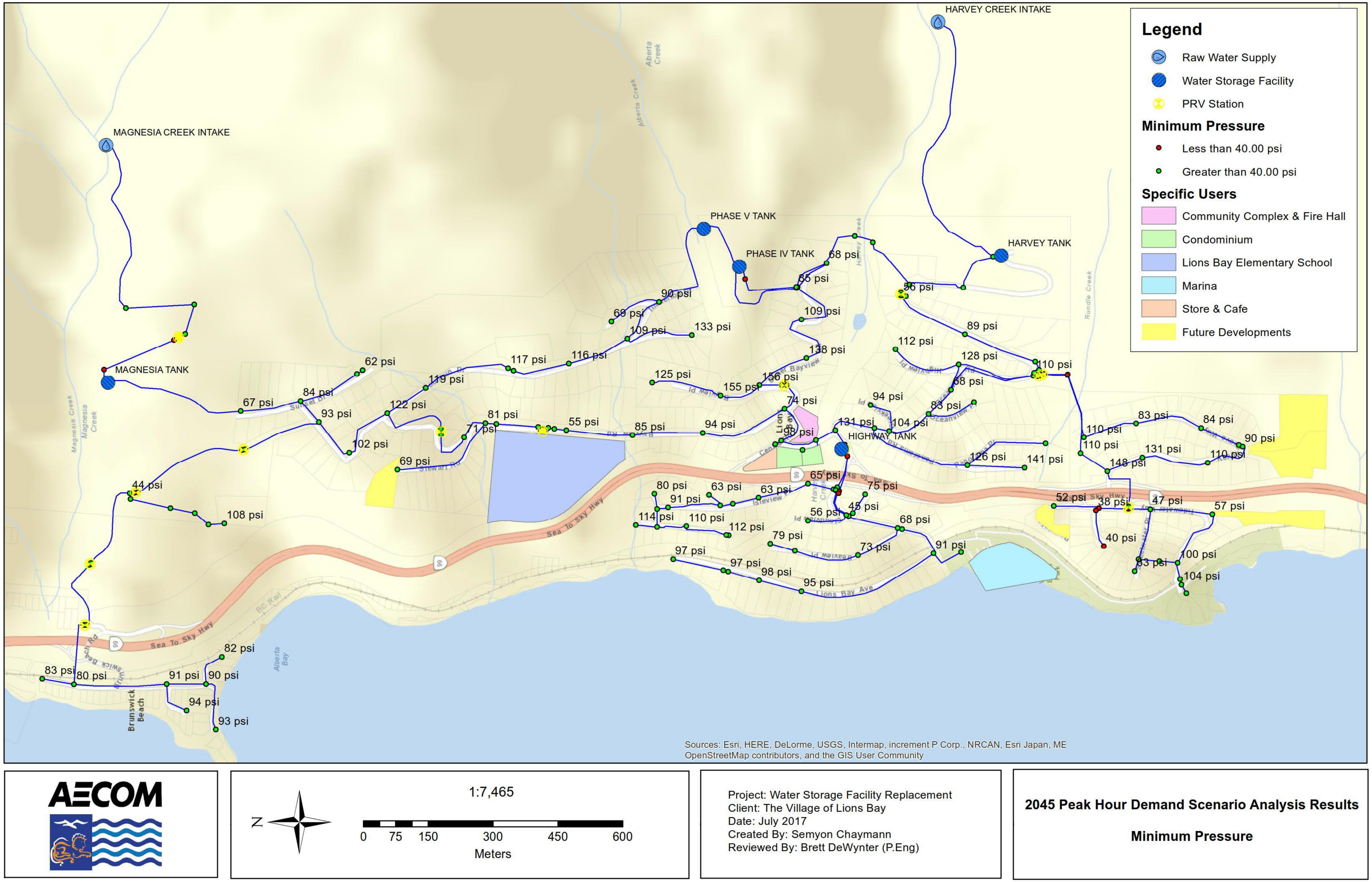
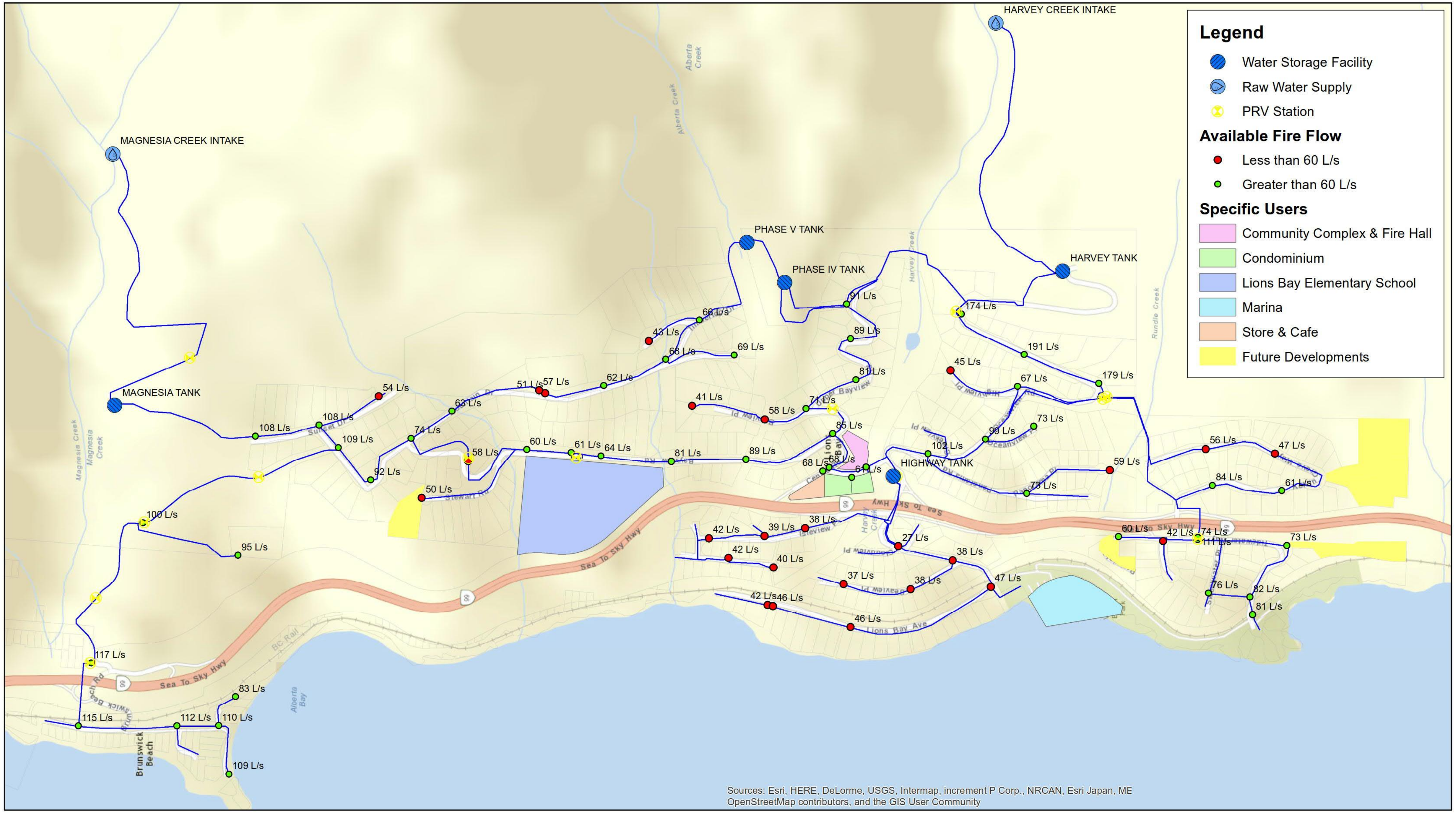


Figure 7: 2045 Peak Hour Demand Scenario - Minimum Pressure



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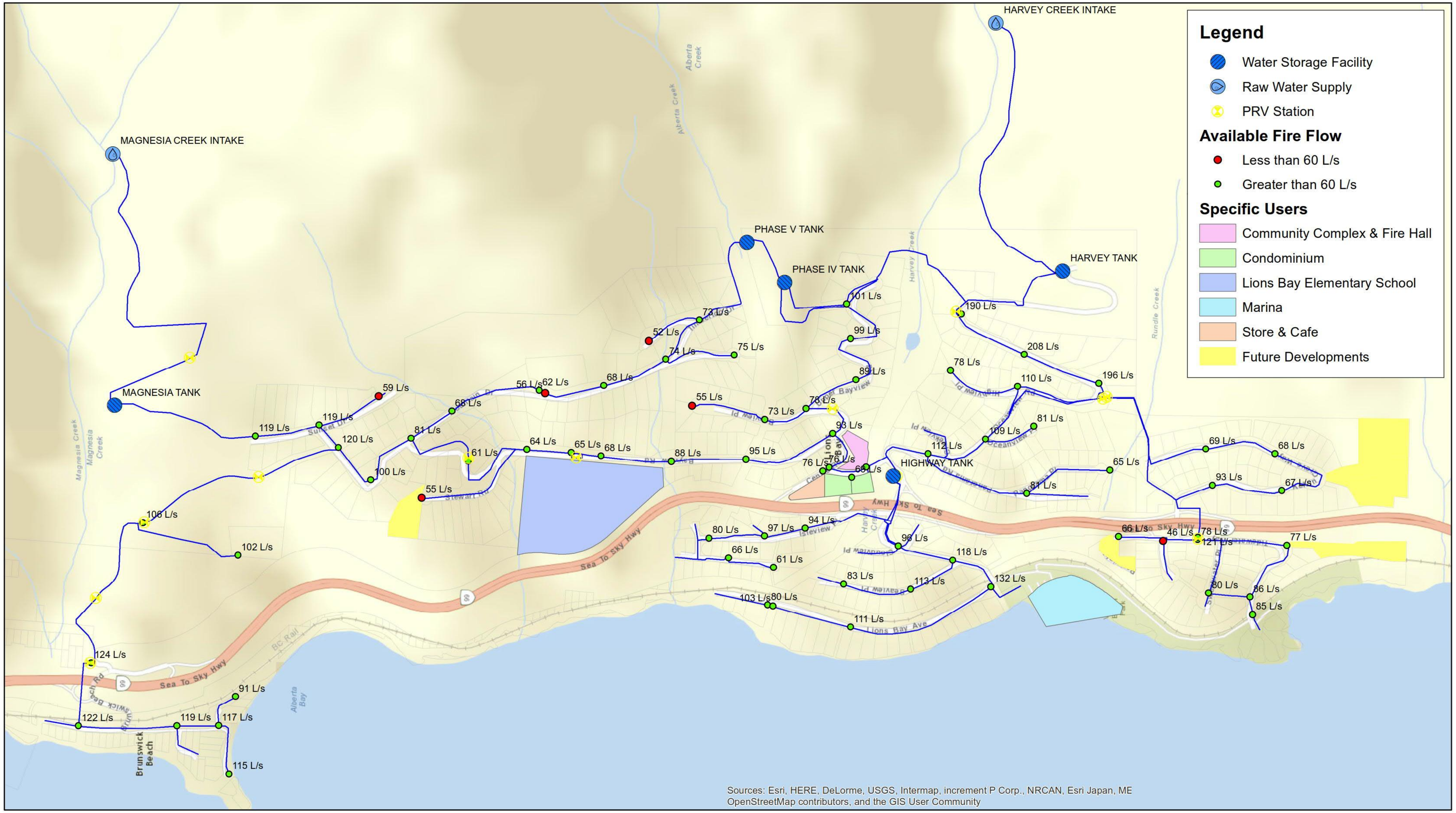
2045 MDD+FF Scenario Analysis Results

Available Fire Flow

Figure 8: 2045 MDD+FF Results



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2045 MDD+FF Scenario Analysis Results With IMP Upgrades

Available Fire Flow

Figure 9: 2045 MDD+FF Scenario Results – With IMP Upgrade Recommendations

2.6 Water Quality

To analyze water quality, three parameters were investigated – raw water quality, residual chlorine, and water age as outlined in the following section. The raw water turbidity readings are used to understand if there is a major difference in the source water in the two creeks (Magnesia and Harvey). In addition to turbidity levels, the analysis compared raw water pH, hardness, and total suspended solids in two sources.

2.6.1 Raw Water Quality

Raw water turbidity levels are recorded by the Village of Lions Bay on a daily basis. A review of this 2016 raw water quality data for Magnesia and Harvey Creeks was conducted to investigate potential differences between the two water supplies. Based on the reported turbidity values (Table 7) it was inferred that the water quality in both creeks is similar. This is important when proposing mixing of the two sources of water within the distribution system for resiliency of supply and increasing available fire flow.

Table 7: 2016 Average Monthly Raw Water Turbidity Readings

	Harvey Creek			Magnesia Creek		
Month	Ave (NTU)	Max (NTU)	Min (NTU)	Ave (NTU)	Max (NTU)	Min (NTU)
January[1]	0.92	3.42	0.11	0.36	0.58	0.23
February	0.51	0.95	0.25	0.46	0.75	0.23
March	0.64	1.23	0.14	0.82	4.39	0.21
April	0.41	1.20	0.17	0.34	0.77	0.20
May	0.40	0.88	0.15	0.36	1.55	0.19
June	0.36	0.82	0.18	0.37	0.91	0.16
July	0.65	1.45	0.24	0.46	1.23	0.16
August	0.73	1.44	0.25	0.25	0.37	0.15
September	0.68	1.55	0.22	0.24	0.49	0.15
October	0.86	3.23	0.31	1.42	8.69	0.18
November	0.71	2.03	0.29	0.74	1.86	0.28
December	0.36	0.57	0.23	0.34	0.55	0.19
Annual Values	**0.57[1]**	**3.42**	**0.11**	**0.53[1]**	**8.69**	**0.15**

From the water quality lab analysis results, as published in the 2016 Village of Lions Bay Water Quality Report, we can note that pH levels at Harvey (pH 6.65 in April and pH 6.94 in September) Magnesia (pH 6.77 in March and 6.90 in September) raw water supplies is comparable while the hardness levels are greater in Magnesia Creek (7.44mg/L in March and 14.1 mg/L in September) than in Harvey Creek (3.36 mg/L in March and 5.72 mg/L in September).

[1] Values for the months of January were not calculated in the annual average because Magnesia plant was off-line for a portion of the month

2.6.2 Residual Chlorine

The Village of Lions Bay reports the levels of residual chlorine throughout the distribution system for both Magnesia and Harvey supplied networks consistently on a daily basis. Table 8 summarises the lowest residual chlorine values at each sampling location for 2016. Canadian Drinking Water Quality Guidelines desire a minimum of 0.2 mg/L of free chlorine at all locations in the system and these values indicate the Village of Lions Bay is in compliance. Free chlorine residual is the chlorine concentration that remains in water after the initial dose of chlorine has decayed by reacting with organics within the water and along the pipe walls. Chlorine residual is variable on an hourly (and daily) basis as it fluctuates based on flow, reservoir turn-over, temperature, turbidity and the level of organics.

Table 8: Minimum Sampled Residual Chlorine Values for 2016

HARVEY					MAGNESIA		
400 HAR. TANK	**PRV-3**	**STORE/CAFÉ**	**LIONS BAY AVE.**	**KELVIN GROVE**	**100 MAG. TANK**	**PRV-5**	**BRUNSWICK B.**
Min CL2 Res. (ppm)	Min CL2 Res. (ppm)	Min CL2 Res. (ppm)	Min CL2 Res. (ppm)	Min CL2 Res. (ppm)	Min CL2 Res. (ppm)	Min CL2 Res. (ppm)	Min CL2 Res. (ppm)
0.49	0.43	0.2	0.2	0.2	0.55	0.28	0.2

2.6.3 Water Age Analysis using Hydraulic Model

The residual chlorine levels were used to analyse the water quality within the treated water for both Harvey and Magnesia fed systems. The hydraulic model was used to run the water age analysis simulation in order to determine where old, stale water exists, leading to water quality issues and potential health concerns.

In order to properly simulate the water age analysis, the overall demand in the system needs to be representative of the low water use months. For British Columbia, much like the rest of Canada, the water use is typically lowest during the winter period (December, January, and February). For the water age analysis, the Village's average water consumption for the period from December 2015 to February 2016, inclusive, was used to allocate demand in the model. The ADD for this period was calculated to be 9.17 L/s. This value is also 85% of the annual average ADD calculated using the 2016 water consumption data. This percentage is consistent with our previous experience in calculating Minimum Day Demand for other municipalities across Canada and their design guidelines.

Water-age is defined as the time spent by a particle of water in the water system (including residence time in reservoirs and tanks). As a general best practice, water age within the system should be minimized which becomes a challenge at the extremities of the system where demands are low but pipe diameters are still large enough to convey fire flows.

The results of the hydraulic model analysis show that the residual times within the system range from 52 to 86 hours (Figure 11) primarily due to the turnover rate in the Harvey Tank. The turnover rate in the tank is simulated based on the control parameters provided by Public Works which indicated that the tank water level fluctuates between 8.51m (i.e. 96% full) and full which results in a 0.47 metre change in water level per fill cycle. The Harvey tank water age stabilizes at 50 hours (see Figure 10) which results in the rest of the system having water age which is greater than 50 hours.

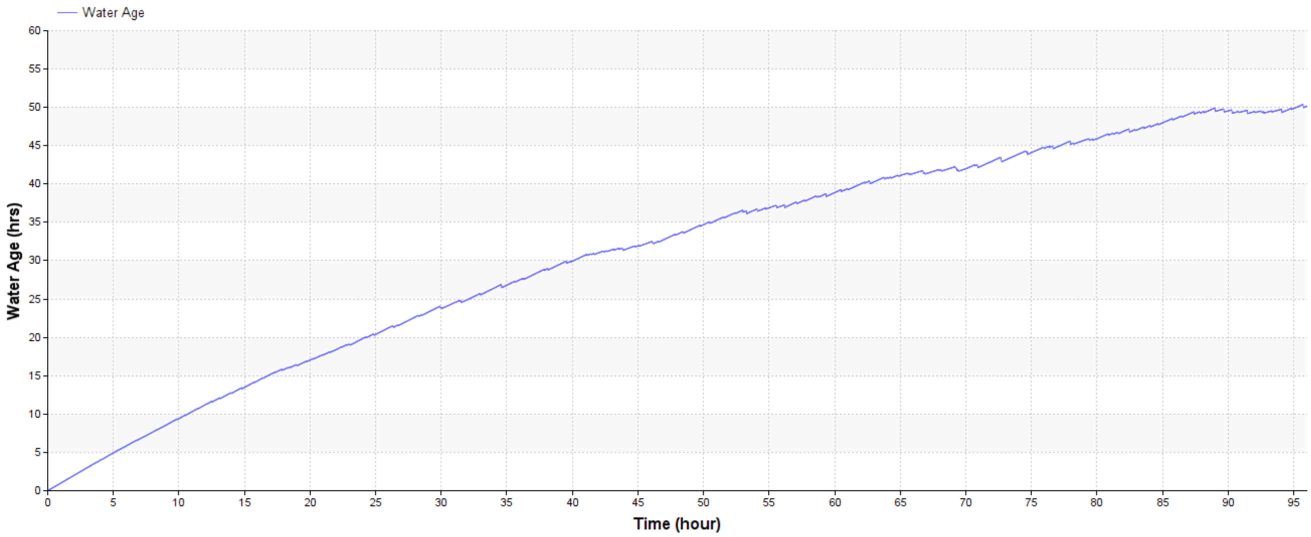

Figure 10: Water Age Analysis Result Graph - Harvey Tank

The water system does not have reported issues with residual chlorine according to the Village's water quality reports. The Village is maintaining adequate residual chlorine levels at the water distribution system extremities through operational procedures which include irregular flushing at three dead end areas – Lions Bay Avenue, Brunswick Beach, and Kelvin Grove. According to Village public works staff, the dead ends are flushed three to four times a year when the residual chlorine levels drop below 0.2 ppm. Currently, the dead end flushing is conducted by the Public Works Operations staff and the Village is investigating options to systematise the process with investment in automatic flushing stations.

2.6.4 Water Quality Recommendations

The water distribution system has been able to meet Canadian Drinking Water Quality Guidelines and Public Works Operations standards for residual chlorines levels at the water system extremities as indicated by the water quality reports. However, as a result of analysing water quality data for the Village of Lions Bay, it can be summarized that the system generally has high water age due to low demand and short tank fill time. The tank fill time is unable to be significantly improved due to the requirement for sufficient fire flow storage to be available when required.

The following conclusions and recommendations can be made to maintain and improve water quality within the system:

- The raw water quality in Magnesia and Harvey Creeks does not provide cause for concern in case the two sources of water are mixed within the water distribution system, especially after each source is treated at the water treatment plant using same technology.

- The Village's water source is unfiltered which will lead to the accumulation of particles within the water mains and which need to be removed by flushing. The importance of the water main flushing program is highlighted though this analysis as accumulation of particles combined with high water age can quickly lead to chlorine decay within the system.

- Replacement tank designs should incorporate mixing technology to mitigate stratification of water layers and stagnation of water which will likely be achieved through inlet nozzle design and outlet pipe placement.

- Development of automated controls to alternate between the Magnesia and Harvey Creek supplies would allow for sharing of tank storage capacity for fire flow requirements and therefore allowing for deeper circulation of the tanks to reduce tank water age. The installation of a valve chamber or above grade kiosk with an automated valve would be able to facilitate this work while also eliminating the stagnation in the pipelines due to the dead end mains currently formed by the closed valve on Mountain Drive. Lastly, this control would also allow the Village to change which reservoir is supplying water to the entire system without requiring field crews to mobilize to open valves.

- In the Infrastructure Master Plan (AECOM, 2016) it was recommended to install a permanent PRV station to replace the temporary PRV12 which is located on Bayview Road by the school. An automated control valve within this PRV station would allow the pressure zone to be supplied water from either water source while also reducing water age by flushing the dead ends currently formed by the close valves.

- An alternative to mixing water sources is the use of a two cell tank system which could be automated to alternate the filling and drawn down of each cell and thereby decreasing water age. The system also provides redundancy and maintenance improvements as one cell can stay in operation while the other is undergoing maintenance.

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Water Age Analysis Results

Figure 11: Water Age Analysis Results

2.7 Water Supply Resiliency

In order to analyse the system resiliency, the system performance was evaluated based on the hydraulic design criteria under two scenarios – Harvey Creek intake out of service and Magnesia Creek intake out of service. The analysis looks at minimum pressure deficiencies under the Average Day Demand conditions and outlines areas where the system is at greater risk for loss of service in the event of an emergency or scheduled shutdown. It is assumed that in the event of an emergency at the source, the fire flow may already be compromised and the effort is made to sustain minimum requirement for adequate level of service. For this analysis the adequate level of service is defined as minimum pressure of 275kPa (40psi) under the Average Day Demand conditions.

<u>Resiliency of Supply Scenario 1: Magnesia Creek Intake Out of Service</u>

The Magnesia Creek Intake out of service scenario is simulated by inactivating the Magnesia Creek Intake within the model, leaving only the Magnesia Tank connected to the system. The further analysis is made with assumption that the Magnesia Tank is full prior to Magnesia Water Supply Intake being out of service.

With Magnesia Tank full and the intake out of service, the system is still able to provide adequate level of service for 39 hours, after which the tank will be fully drained (Figure 12). However, with operational mitigation measures the system can be adjusted to provide adequate level of service for a longer duration.

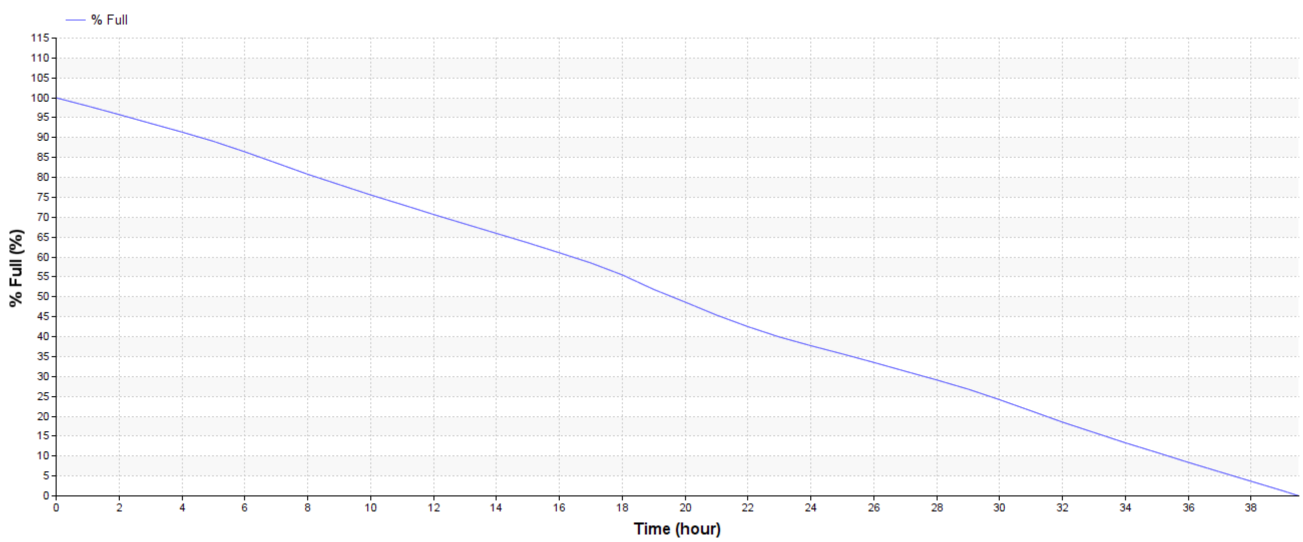


Figure 12: Magnesia Tank Level with Creek Supply Shutdown

In order to mitigate negative performance effects of the Magnesia Intake being out of service, the Village can open the closed connection at approximately 295 Mountain Drive. This connection is normally closed and separates the PZ278 (Magnesia Supply) and PZ271 (Harvey Supply). With this connection open, the Magnesia Tank still drains within 39 hours but the Harvey system is able to supply water to the Magnesia system and establish adequate level of service for the entire water distribution system (Figure 13).

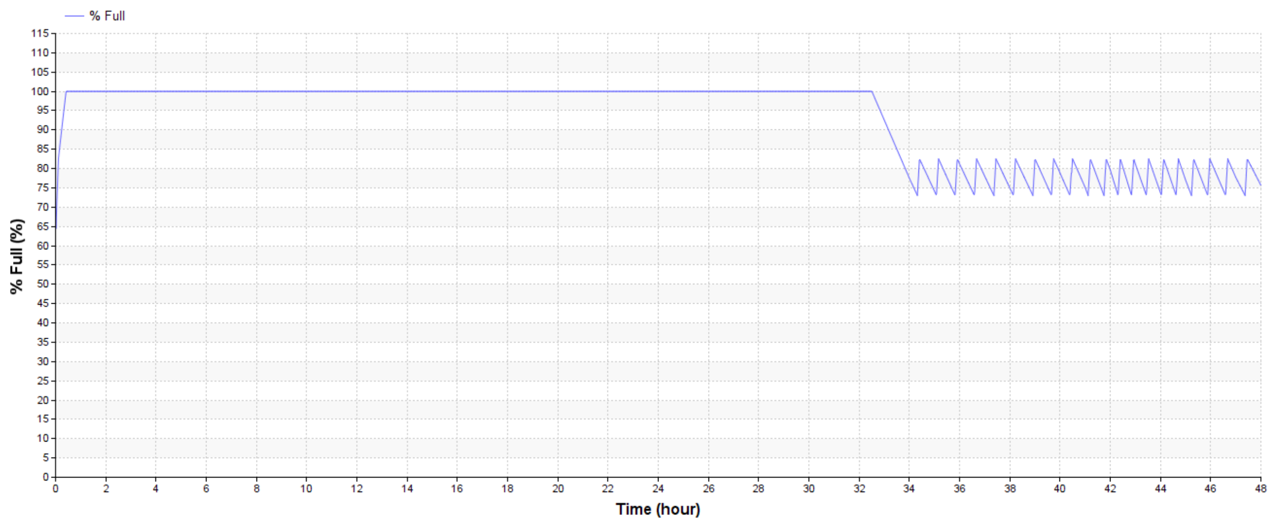


Figure 13: Phase V Tank Level under Strategy for Magnesia Creek Supply Shutdown

Resiliency of Supply Scenario 2: Harvey Creek Intake Out of Service

The Harvey Creek Intake out of service scenario is simulated by inactivating the Harvey Creek Intake within the hydraulic model, leaving only the Harvey Tank connected to the system. The further analysis is made with assumption that the Harvey Tank is full prior to Harvey Creek Intake being out of service.

With Harvey Creek Intake out of service, the system is able to provide adequate level of service for 67 hours (Figure 14). While 67 hours is an acceptable measure by current best practices (48 hours @ ADD), operational mitigations could be done to continue to supply adequate level of service to the entire Village after the Harvey Tank drains. These mitigation measures require isolating Phase V and Phase IV Tanks and commissioning the existing by-pass valves, which allow for water from the Magnesia Intake to supply the water system downstream of the Harvey Tank.

The 2016 IMP recommendation to establish PRV-12 as a permanent PRV was made based on the insufficient fire flow supply for PZ160. However, the resiliency of supply analysis shows that additional benefit of commissioning a permanent PRV near the Lions Bay Community School is the supply of water to the PZ160 under emergency condition in which the Harvey Creek Intake is compromised.

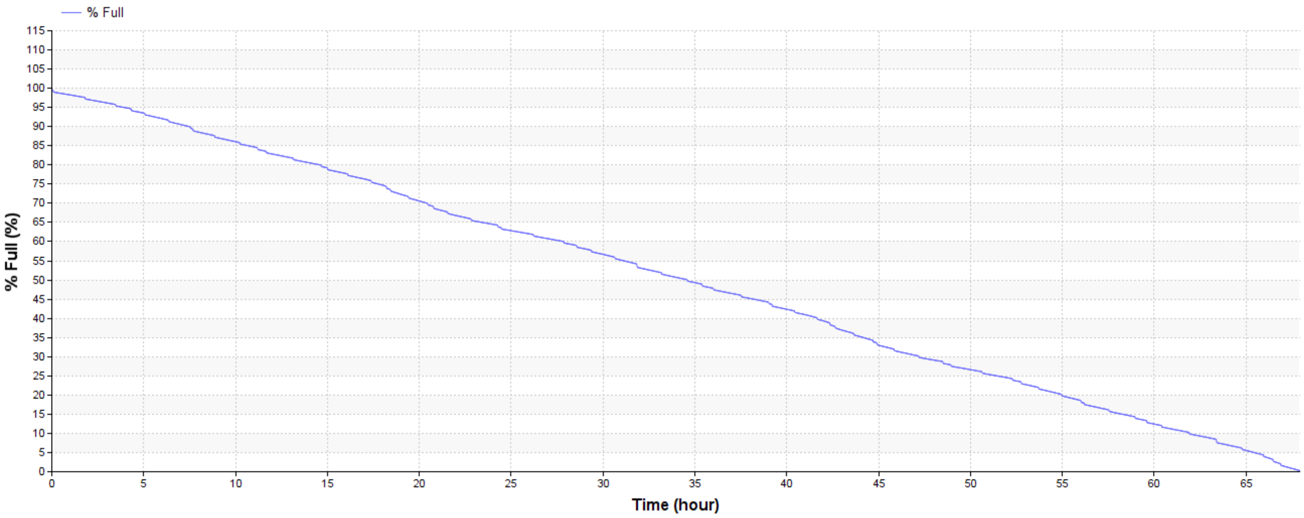


Figure 14: Harvey Tank Level with Creek Supply Shutdown

Emergency Fire Fighting Supply During Tank Outages

AECOM conducted an interview with Andrew Oliver, Fire Chief for the Village of Lions Bay, as part of the water system resiliency review to discuss the impacts on firefighting based on operational issues.

According to the fire chief, all the active reservoirs/tanks maintain water levels and storage sufficient for firefighting. Generally the fire department has no issue with tank isolation as long as a minimum available flow of 600GPM (37.8 L/s) can be drawn at each hydrant in the system.

The fire department does not have any issues when the Harvey Tank is isolated and bypassed due to outage/scheduled maintenance especially if notified in advance. During previous Harvey Tank outage/bypass events, the fire department has not experienced issues with fire flow availability at the Village. It was noted that when previous tank isolation/outages occurred an email is sent to the Village residents advising them to reduce water use, which would become particularly important during the summer when creek flows are at lower rates.

3. Field Investigation

On August 22, 2017 AECOM conducted field hydrant flow testing to determine the general accuracy of the InfoWater hydraulic model of the Village's water distribution system. The primary objective of the hydrant flow tests was to quantify the impact of the existing PRVs on the pressure surges in the system.

The testing included four hydrant flow tests all of which were completed in the western pressure zones (PZ66, 75, 86, and 107) of the Village systems which are at the lowest elevations and furthest from the Magnesia and Harvey water reservoirs. Each hydrant flow test report shows the field static pressure (normal operational conditions) and residual pressure (pressure with high water demand at an assigned hydrant) (Appendix B).

AECOM staff utilized a pitot tube to calculate the flow from the operating test hydrant while automated electronic hydrant pressure loggers were used to measure pressure at residual hydrants. The reading frequency of the pressure loggers was at 1/second during the flow tests which provides information on the transient forces which occur within the distribution system when a large demand such as a fire flow is generated. Transient forces are changes in pressure caused by the momentum of water the non-compressible fluid and are often referred to as "water hammer".

3.1 Fire Flow Testing Results

Flow and pressure data collected in the field was used to calculate estimated flow at 20psi, which is equivalent to available fire flow simulated in the hydraulic model. The field static and pressure readings and estimated fire flow calculation results were compared to the results of the hydraulic model.

While investigating the PRV cavitation we have identified an issue that should be noted to the Village. The comparison analysis shows that the model simulated available fire flow is less than what was calculated using the field data (Figure 15).

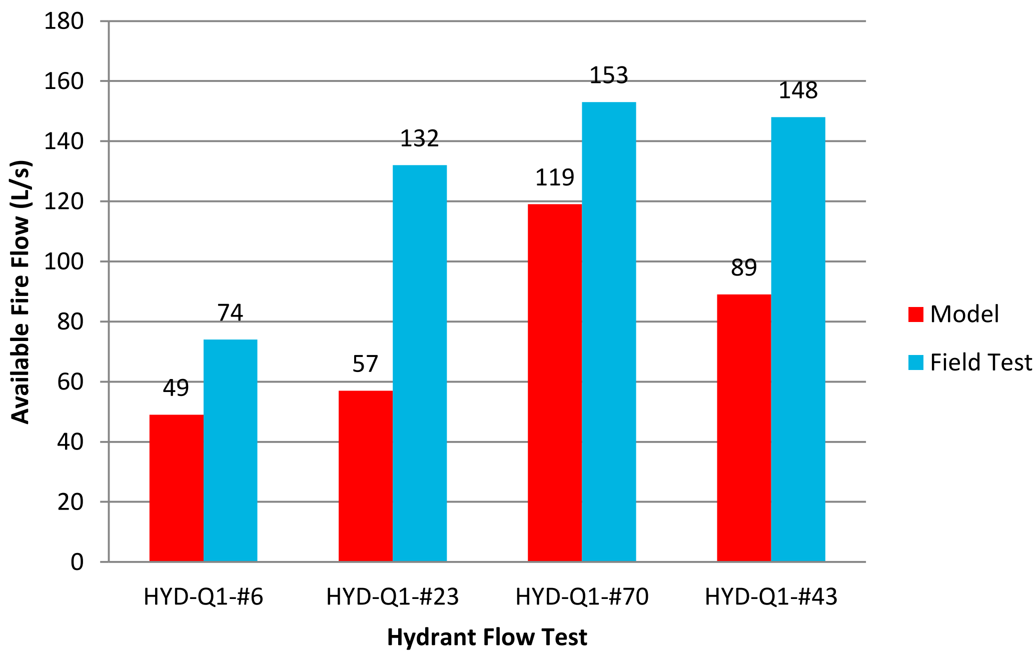


Figure 15: Comparison of Available Fire Flow Results

The hydraulic model calibrated using static pressure readings as part of the Infrastructure Master Plan (AECOM 2016). The discrepancy between the field test results and the model outputs are significant and beyond the range acceptable for planning purposes. Therefore, we recommend that the Village undertakes a more detailed model calibration exercise to confirm the model accuracy using the residual pressure readings prior to implementing any water main upgrades driven by fire flow deficiencies.

The point of caution is that water infrastructure upgrades have been previously recommended based on a poorly calibrated model. Our field test data shows that the model accuracy can be further refined and improved. Therefore, a more detailed calibration exercise would return confidence in the model results and water infrastructure upgrade recommendations based on the modelling analysis. Calibration of the model was outside of the scope of this analysis and therefore further work on these improvements has not been completed at this time.

3.2 Transient Pressure Testing Results

The field tests were conducted with one residual pressure logger within the same zone as the flow hydrant and with a second residual pressure logger in the upstream pressure zone. By establishing the tests in this way, the results can be used to determine the interaction between the two pressure zones; particularly the differences between zones separated by a PRV or those with an altitude valve in combination with an equalization tank. The graphs of the test results along with maps displaying showing the flow hydrants and the residual hydrants are included in Appendix B.

The field testing provided sufficient information to state the following findings:

- An instantaneous draw down of pressure in the pressure was observed at the residual hydrant closest to the flow hydrant in Tests No.1 (PZ107) and No. 3 (PZ66). None of the pressure drops observed put the system below 20 psi below which point there would be a risk of negative pressures which can result in pipe collapse. However, the residual pressure readings were not taken at the highest elevation within the pressure zone and therefore would not be the lowest pressure felt within the system.

- The surges of pressure observed were generally found to be at or below the static pressure level within the zone. The observed spikes in pressure observed in Test No.1 (PZ107) are attributed to a rapid opening or closure of the hydrant which in turn generated pressure surges above 25 psi.

- Cyclical variations in pressure were observed in the upstream pressure zone for all three instances where a PRV was used to separate the zones opposed to an equalization tank. The changes in pressure were most prominent in Test No. 4 (PZ86) where the change was approximately 30 psi with each wave. The findings are likely caused due to the rapid opening and closing of the upstream PRV which in this case was PRV-7.

- There was no significant variance in the pressure in the upstream pressure zone during Test No.2 (PZ178) which indicates that the Highway Tank was able to sufficiently buffer and absorb the pressure surges induced by the hydrant flow.

4. Hydraulic Analysis

From the RFP.17.01 Water Storage Facility Replacement, it was clear that the Village is looking to replace four of the five storage tanks – Harvey, Phase IV, Phase V, and Highway. The following discussion provides options related to replacement of the four water storage facilities outlined in the original RFP.

The three water storage facility replacement options are proposed:

Option 1: Full Replacement

- Replace the existing Harvey, Highway, Phase IV, and Phase V Tanks.

Option 2: Partial Replacement

- Replace the Harvey and Highway Tanks;
- Remove the Phase V Tank and redefine the PZ 271 Zone;

- Remove the Phase IV Tank and replace with a permanent PRV station.

Option 3: Harvey Only Replacement

- Replace the Harvey Tank;
- Remove the Phase V Tank and redefine the PZ 271 Zone;
- Remove the Phase IV Tank and replace with a permanent PRV station;
- Remove the Highway Tank and replace with a permanent PRV station.

The next section of this technical memorandum presents the results of the hydraulic analysis for each proposed system improvement option.

4.1 Option 1 – Full Replacement

The first option for water storage facility replacement is upgrade of the Harvey Tank and direct one-to-one replacement of Highway, Phase IV and Phase V Tanks.

The Harvey Tank needs to be upgraded to 1.98ML to accommodate the increased fire storage in the 2045 Scenario. The Highway, Phase IV, and Phase V Tanks are to be replaced with storage tanks of the same volume as the analysis shows that they are sized sufficiently to provide the equalization storage capacity for the ultimate 2045 Scenario. Table 9 shows the upgraded tank storage requirements and the approximate dimensions of the storage tanks. The maximum level specified in the table is the height required to meet the volume requirements and the actual dimensions of the tank may be higher.

Table 9: Option 1 - Tank Dimensions and Storage Volume

Storage Tank	Bottom Tank Elevation (m)	Maximum Level (m)	Diameter (m)	Storage Volume (ML)
TNK-HARVEY	270	10.2	15.78	1.98
TNK-HIGHWAY	76.65	3.35	5.48	0.10
TNK-PHASE_IV	233.70	2.44	6.34	0.10
TNK-PHASE_V	266.40	3.15	6.38	0.10
			Total Storage Volume Available	2.28

The suggested tank configuration would provide sufficient fire storage capacity for the Harvey Creek supplied areas, as indicated by the 2045 Scenario results. The total volume of storage in the system is 2.28ML. With the current Average Day Demand at 0.93ML, the upgraded storage capacity will be able to provide over two days' worth of emergency storage.

Although Option1 for the replacement of the storage facilities is able to meet the fire storage requirements, the distribution system is still not able to provide sufficient available fire flow for the existing ICI users and potential future developments. The fire flow availability was analyzed for the 2016 and 2045 MDD+FF Scenarios with 2016 IMP water main upgrade recommendations. The results of the analyses are presented in Figure 16 and Figure 17. The available fire flow deficiency was also identified during the analysis of the existing water distribution system; therefore the implementation of Option1 does not negatively impact the existing water distribution system.

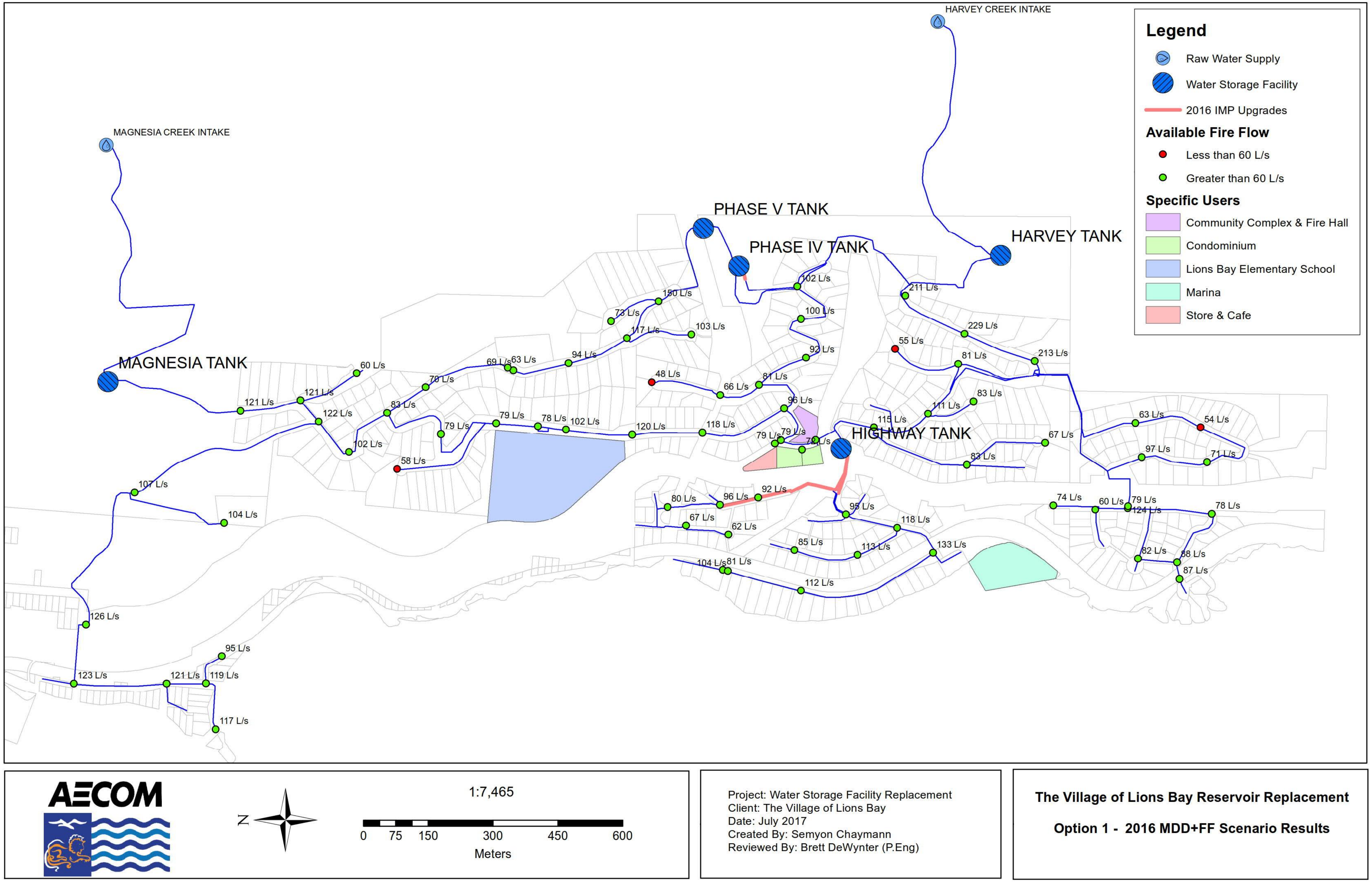
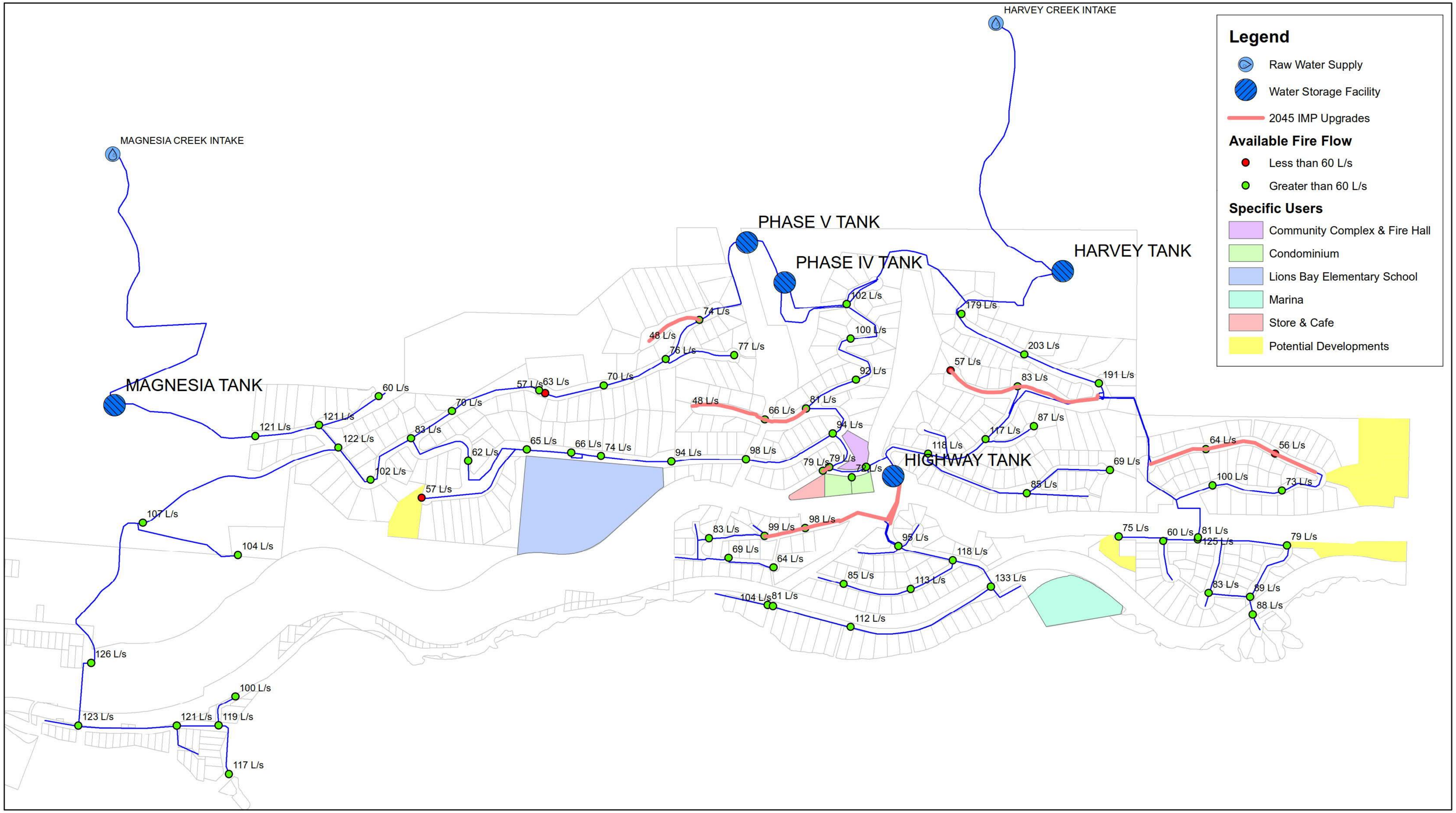


Figure 16: Water Storage Facility Replacement Option # 1 - Available Fire Flow Analysis 2016 Results



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Option 1 - 2045 MDD+FF Scenario Analysis Results

Figure 17: Water Storage Facility Replacement Option # 1 - Available Fire Flow Analysis 2045 Results

4.2 Option 2 – Partial Replacement

The second option for water storage facility replacement is to decommission Phase IV and Phase V Tanks and install a PRV in place of Phase IV. To increase access and reduce maintenance costs it is advised to install the PRV at Upper Bayview Road. To mitigate the reduction in total storage capacity Harvey and Highway Tanks need to be upgraded to provide sufficient equalization and fire storage for the ultimate 2045 scenario.

The Harvey Tank needs to be upgrade to 2.16ML to accommodate the increased fire storage and incorporate the equalization storage from the previous Phase IV and Phase V Tanks. The Highway Tank is to be replaced with a storage tank of the same volume; the analysis shows that it is sufficiently sized to provide the equalization storage capacity for the ultimate 2045 Scenario. Table 10 shows upgraded tank storage requirements including the approximate dimensions. The maximum level specified in the table is the height required to meet the volume requirements and the actual dimensions of the tank may be higher.

Table 10: Option 2 Tank Dimensions and Storage Volume

Storage Tank	Bottom Tank Elevation (m)	Maximum Level (m)	Diameter (m)	Storage Volume (ML)
TNK-HARVEY	270	10.75	16	2.16*
+ **TNK-PHASE_IV Equalization Storage**	-	-	-	0.10
+ **TNK-PHASE_V Equalization Storage**	-	-	-	0.10
TNK-HIGHWAY	76.65	3.35	5.48	0.10

*Note: * Harvey Storage Volume includes equalization storage requirements for Phase IV and Phase V Tanks in the ultimate 2045 scenario.*

The new proposed Phase IV PRV site location and system configuration is presented in Figure 18. The Phase IV PRV should have a setting to sustain a minimum 40psi downstream pressure. The new configuration would require:

1. Decommission the existing Phase IV and Phase V Tanks near Alberta Creek;
2. Commission PRV to replace Phase IV Tank on Upper Bayview Road;
3. Upgrade the existing Harvey per dimension established in Table 10:
    - The upgraded Harvey Tank would require having capacity to meet the fire storage requirement to meet anticipated 150 L/s fire flow requirement in the 2045 Future Scenario and provide equalization storage capacity that incorporates the equalization storage for decommissioned Phase IV and Phase V water storage tanks;
4. System Optimization Option - Install 400m of new 200mm diameter ductile iron water main across Alberta Creek from Upper Bayview Road to Timbertop Road.

The fire flow availability was analyzed for the 2016 and 2045 MDD+FF Scenarios with 2016 IMP water main upgrade recommendations. The results of the analyses are presented in Figure 19 and Figure 20. The available fire flow deficiency was also identified during the analysis of the existing water distribution system; therefore the implementation of Option 2 does not negatively impact the existing water distribution system.

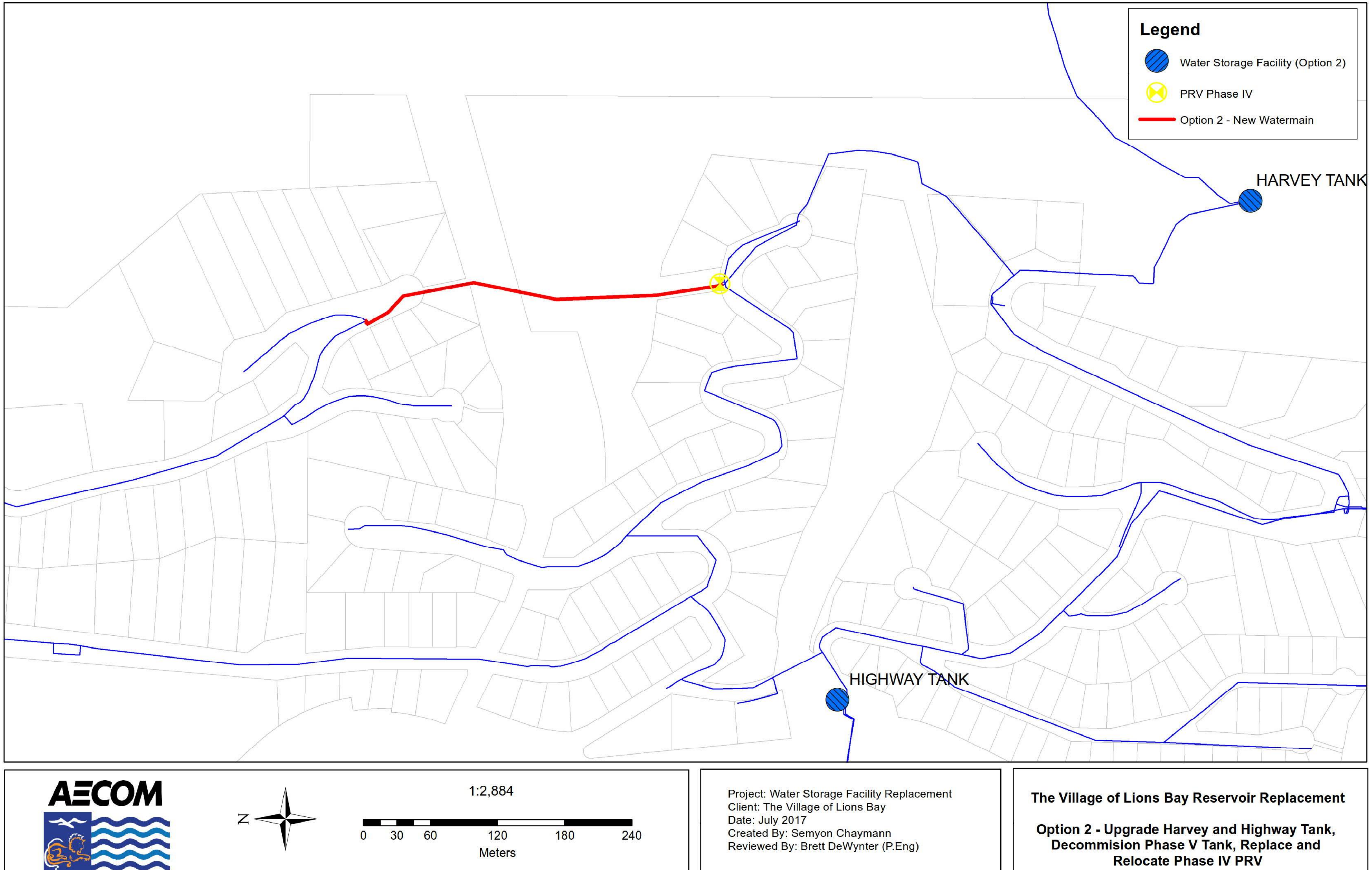
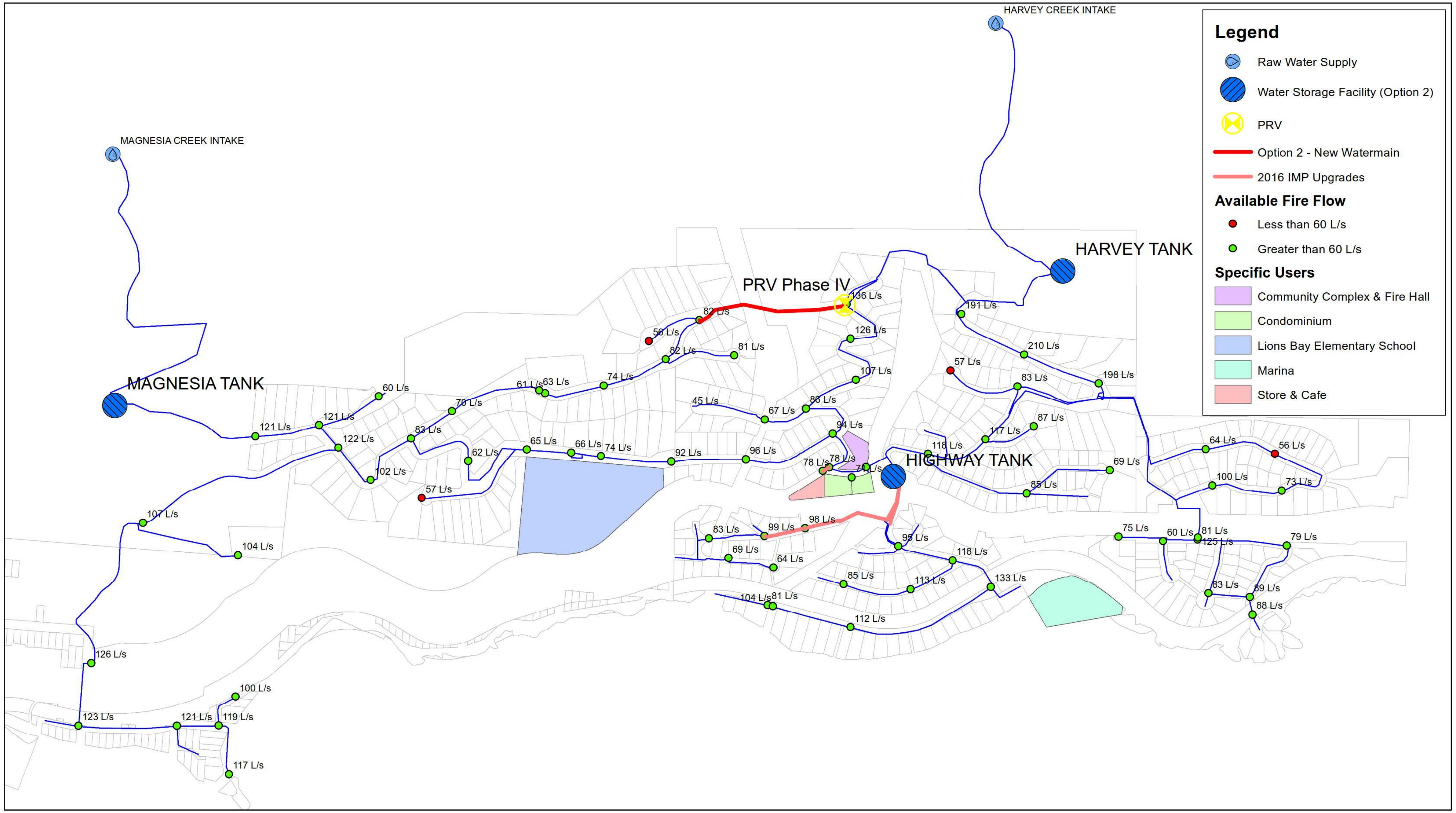


Figure 18: Water Storage Facility Replacement Option #2 – Overview Map



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Option 2 - 2016 MDD+FF Scenario Analysis Results

Figure 19: Water Storage Facility Replacement Option # 2 – 2016 MDD+FF Scenario

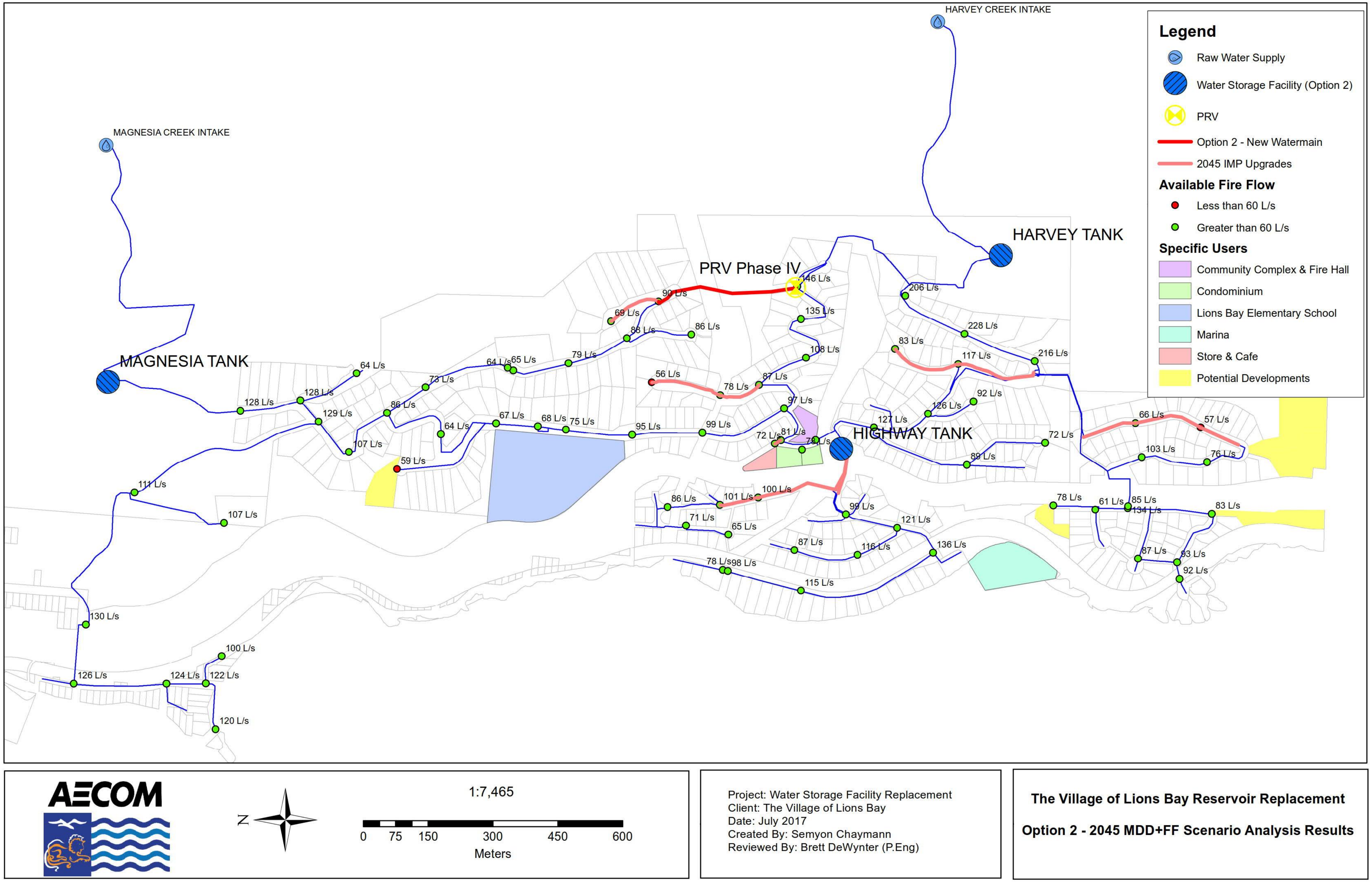


Figure 20: Water Storage Facility Replacement Option # 2 – 2045 MDD+FF Scenario

4.3 Option 3 – Harvey Only Replacement

The third option for water storage facility replacement is to upgrade the existing Harvey Tank, Replace Phase IV and Highway Tanks with permanent PRVs and decommission Phase V Tank completely (Figure 21).

The Harvey Tank, with current capacity at 1.72ML needs to be upgrade to 2.28ML to accommodate the increased fire storage in the 2045 Scenario and the equalization storage from the Highway, Phase IV, and Phase V Tanks. Table 11 shows upgraded tank storage requirements and approximate dimensions of the Harvey storage tank that would provide the required volume. The maximum level specified in the table is the height required to meet the volume requirements and the actual dimensions of the tank may be higher.

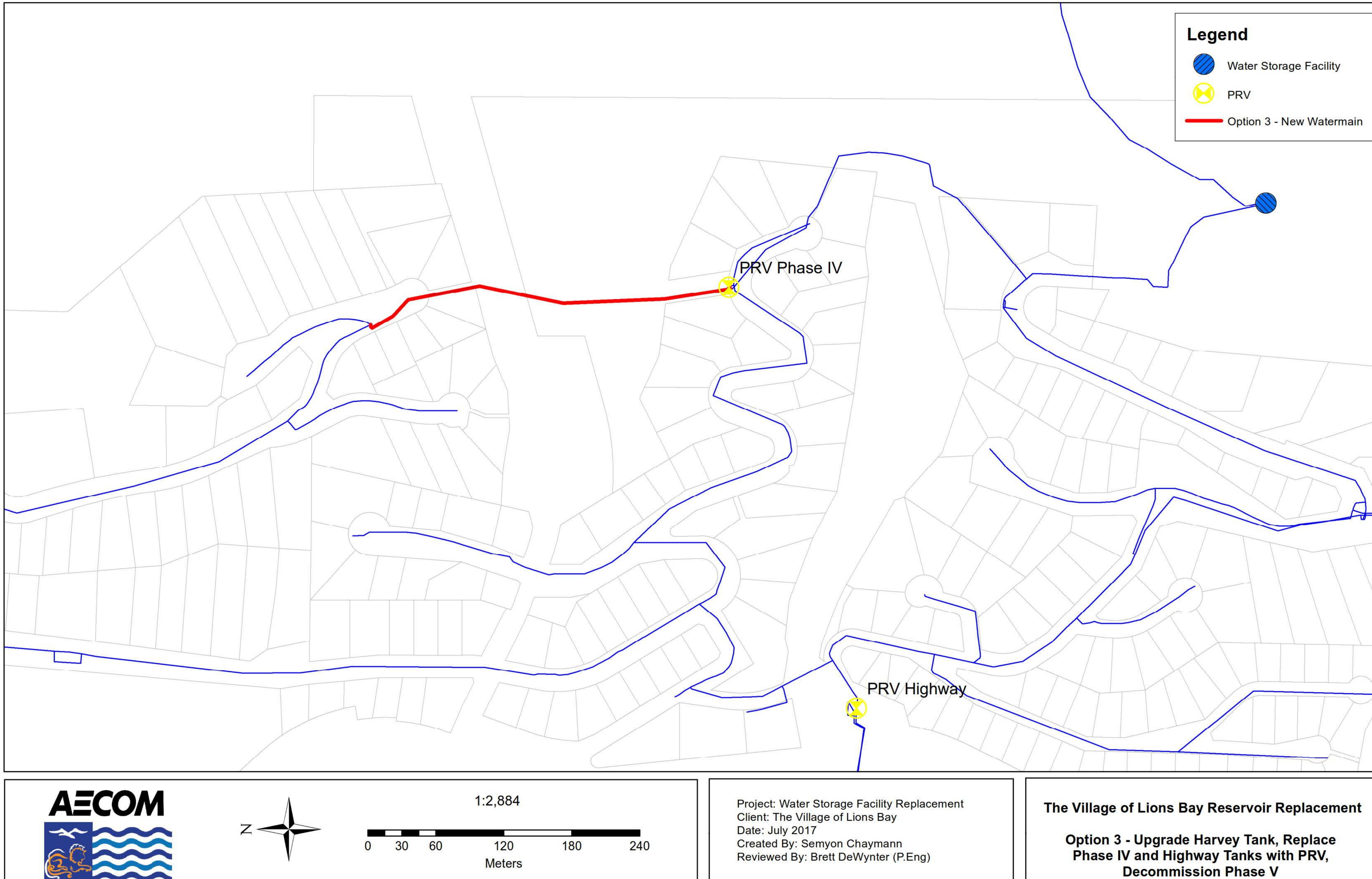
Removal of equalization tanks from the water distribution system goes against recommended best practices, as the equalization tanks provide protection against pressure and flow surges. The Highway water storage facility is designed to act as an equalization tank for part of system. Equalization storage is important in reducing the negative impact of multiple PRVs cascading flow to the extremities of the system. Further analysis is required to understand if the existing system is experiencing impacts on the system, such as PRV chatter, that cause instability. Hydrant pressure monitoring equipment can be installed at the lowest pressure zones to record pressure fluctuations associated multiple PRVs reducing water pressure from the Harvey and Magnesia water storage facilities.

Table 11: Option 3 Water Storage Facility Replacement - Tank Dimensions and Storage Volume

Storage Tank	Bottom Tank Elevation (m)	Maximum Level (m)	Diameter (m)	Storage Volume (ML)
TNK-HARVEY	270	11.5	15.78	2.28*
+ **Highway Tank Equalization Storage**	-	-	-	0.10
+ **Phase IV Tank Equalization Storage**	-	-	-	0.10
+ **Phase V Tank Equalization Storage**	-	-	-	0.10
			Total Storage Volume Available	2.28

*Note: * Harvey Storage Volume includes equalization storage requirements for Highway Tank in the 2045 demand scenario.*

The available fire flow was analyzed using the 2016 and 2045 MDD+FF Scenarios (Figure 22 and Figure 23). The water main upgrades that were recommended as part of the 2016 Village of Lions Bay IMP allow for greater supply of flow in the event of fire. However, operational changes to the settings in the existing PRV-3 (change setting to 45psi downstream) and future PRV-Highway (current model setting 4.76psi) may help provide more available fire flow. Despite the upgrades to the water storage based on the updated fire storage requirements, the system is still unable to provide sufficient fire flow to existing ICI users and potential future multi-residential developments. However, implementation of Option 3 does not decrease the amount of available fire flow in the system and at critical nodes. Similarly to Option 2, it is recommended that a new 200mm diameter ductile iron water main is commissioned across Alberta Creek for system optimization.



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Reviewed By: Brett DeWynter (P.Eng)

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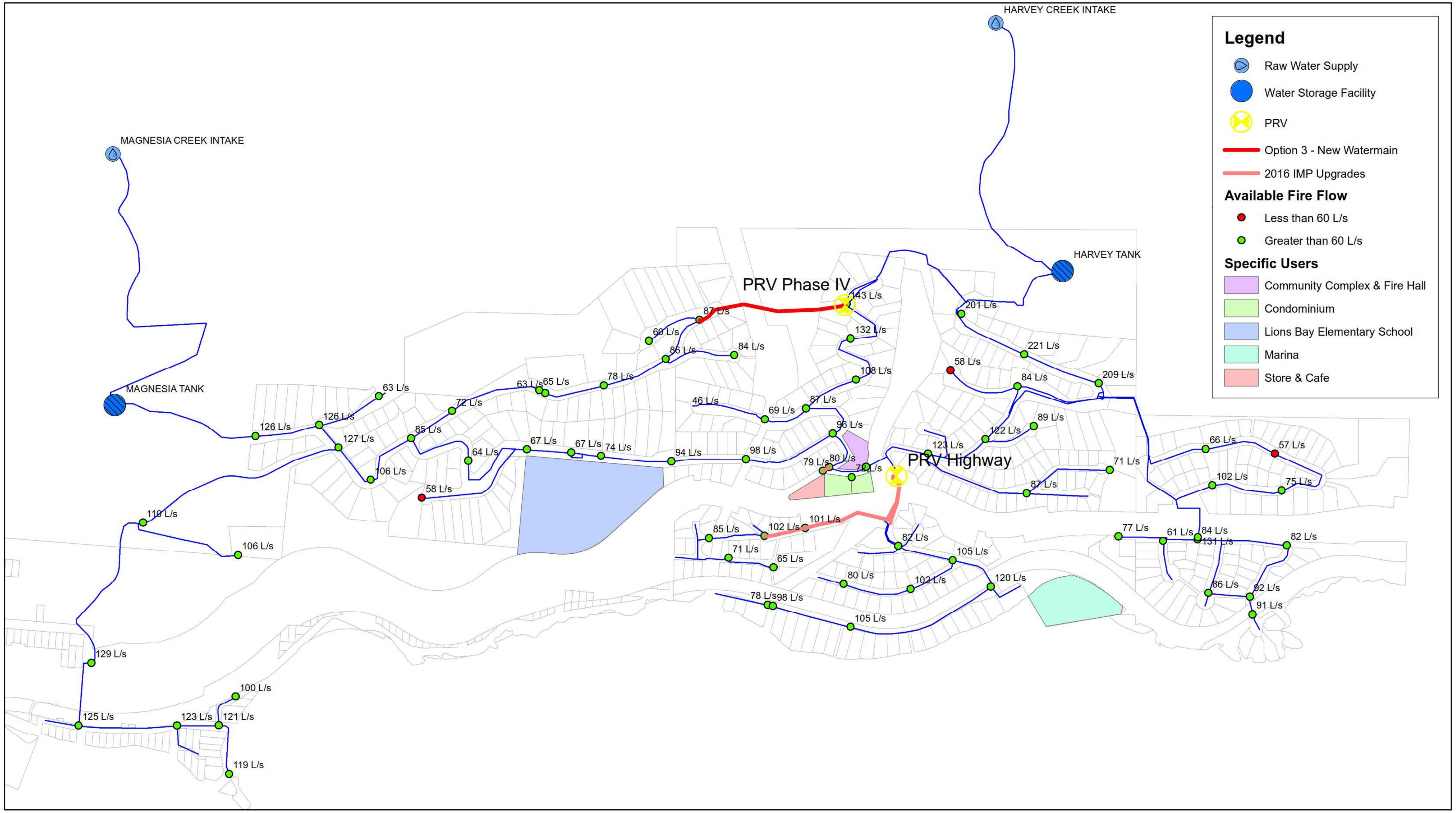
Option 3 - Upgrade Harvey Tank, Replace Phase IV and Highway Tanks with PRV, Decommission Phase V

Figure 21: Water Storage Facility Replacement Option # 3 – Overview Map



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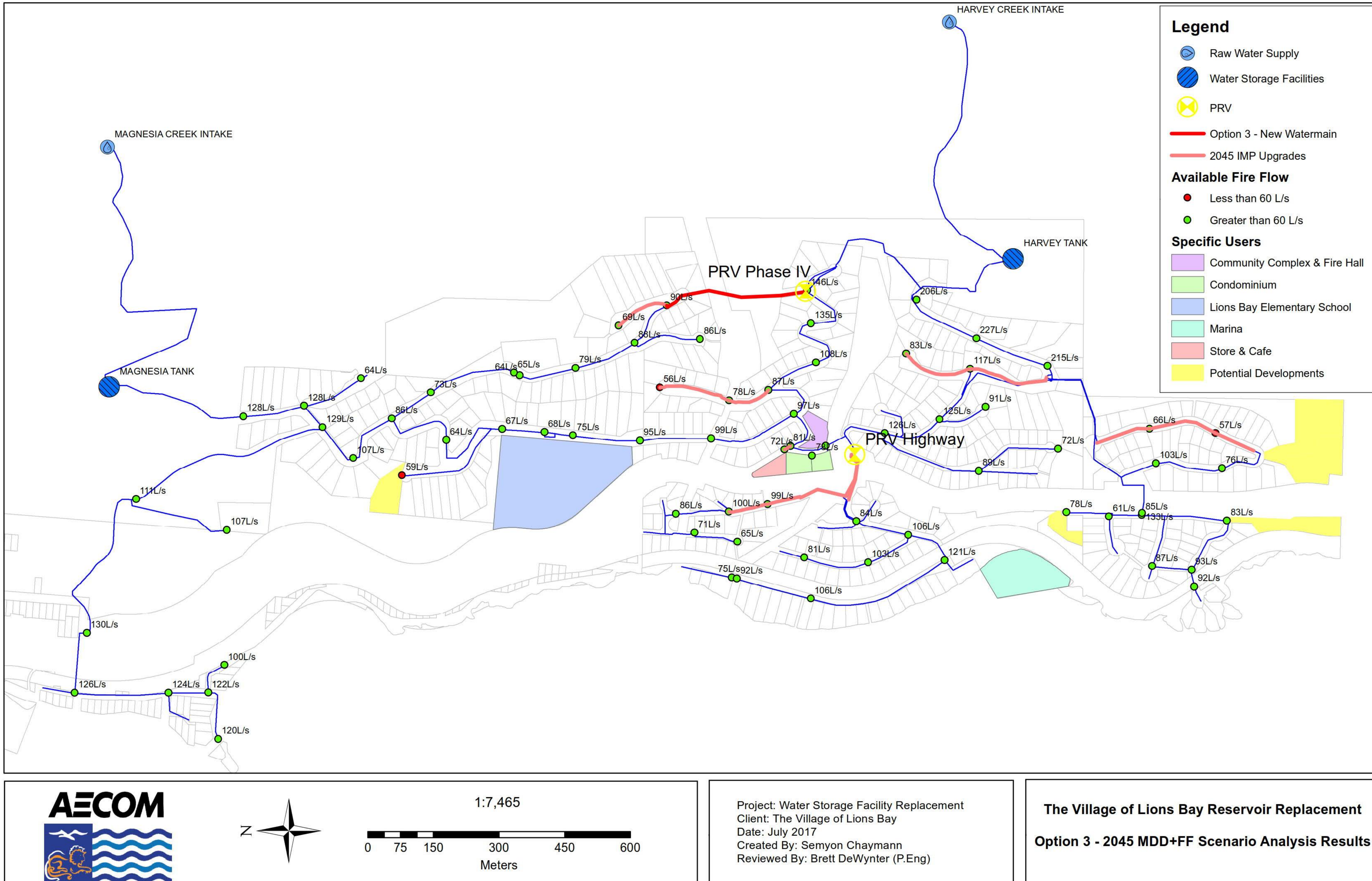
Option 3 - 2016 MDD+FF Scenario Analysis Results

Figure 22: Water Storage Facility Replacement Option # 3 – 2016 MDD+FF Scenario



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Option 3 - 2045 MDD+FF Scenario Analysis Results

Figure 23: Water Storage Facility Replacement Option # 3 – 2045 MDD+FF Scenario

Based on the results of the above mentioned analyses, Option 2 is recommended for implementation. This option will reduce the O&M requirements for servicing existing hard to reach storage facilities while providing adequate level of service to the Village. The Harvey Tank can be upgraded to meet all storage sizing requirements; however, water main improvements are required within the village distributions system to provide adequate fire flow for existing and future ICI and multi-family residential users. The analysis also shows that the water main and valve improvement recommendations from the 2016 Village of Lions Bay Infrastructure Master Plan increase overall water distribution system performance. While the recommended upgrades do not fully alleviate the available fire flow deficiencies, this technical memorandum reiterates those recommendations. To meet the minimum available fire flow requirements at the existing ICI users and potential future developments it is recommended that the Village explore possibility of upgrading water mains highlighted in Figure 24.

5. Conclusions and Recommendations

Based on the analysis of the Village of Lions Bay existing water storage facilities using the updated 2016 water consumption data and updated fire flow requirements based on detailed FUS guidelines, the recommendations for future water system upgrades are summarized as following:

- All three of the proposed options for reconfiguration of the system is capable of meeting the water demands of the Village with the provision of adequate storage in the new infrastructure and also the upgrades of linear infrastructure to meet fire flow requirements.

- Phase IV, Phase V, and Highway water storage facilities are acting as equalization tanks and do not provide sufficient fire flow storage for the area they supply. It is possible to replace the equalization tanks with properly sized PRVs with appropriate settings thus eliminating the need to service and access these tanks, and still providing acceptable level of service to the Village.

- However, it should be noted that removal of the equalization tanks is against best practices, as their main purpose is to protect the water system from sudden surges in flow and pressure. It is important to conduct pressure testing in the system to better understand the pressure fluctuations with PRV operation and confirm that removal of equalization tanks is not a concern for the Lions Bay water system.

- Harvey Tank is sized to provide sufficient fire flow for the entire Harvey Creek fed system based on the previous fire flow requirements. With the updated fire flow requirements, as calculated per the FUS guidelines, the Harvey Tank needs to be upgraded to 1.98ML storage capacity to meet the future fire storage requirements. In the event that the Phase IV, Phase V and Highway Tanks are removed from the system then the Harvey Tank should be sized for 2.28ML.

- The storage sizing analysis identified that the Magnesia Tank is not sized appropriately to provide sufficient fire flow protection for the downstream pressure zones. With updated fire flow requirements at the Village of Lions Bay Community School, the existing Magnesia Tank is deficient by 1.06ML of storage capacity.

- The Magnesia Tank replacement analysis was not included as part of the scope of work in the RFP 17.01, however, if Magnesia Tank is not sized appropriately to include required fire storage for the school, then Harvey Tank needs to be upgraded to include the additional fire flow storage capacity and the water system needs to be configured for Harvey Creek to be able to feed the entire Village of Lions Bay. Without upgrades to Magnesia Tank, Harvey Tank would need to be upgraded to 1.94ML tank to meet the 2016 fire storage requirements and upgraded to 2.13ML to meet the 2045 fire storage requirements.

- The model assessment of water quality indicated that the water is remaining in the system beyond the recommended residence time. However, the chlorine residual testing completed by the Village indicated that they are not significant water quality issues. The importance of the water main flushing program is highlighted though this analysis as accumulation of particles from the Village's unfiltered water source combined with high water age can quickly lead to chlorine decay within the system.

- Field hydrant testing found that the model results do not closely correlate with field results. Further model calibration is required to provide confidence in the fire flow results of the hydraulic mode.

- Development of automated controls to alternate between the Magnesia and Harvey Creek supplies would allow for sharing of tank storage capacity for fire flow requirements and therefore allowing for deeper circulation of the tanks to reduce tank water age. The installation of an automated control valve on Mountain Drive facilitate this while also allowing the Village to change which reservoir is supplying the entire system without mobilizing field crews.

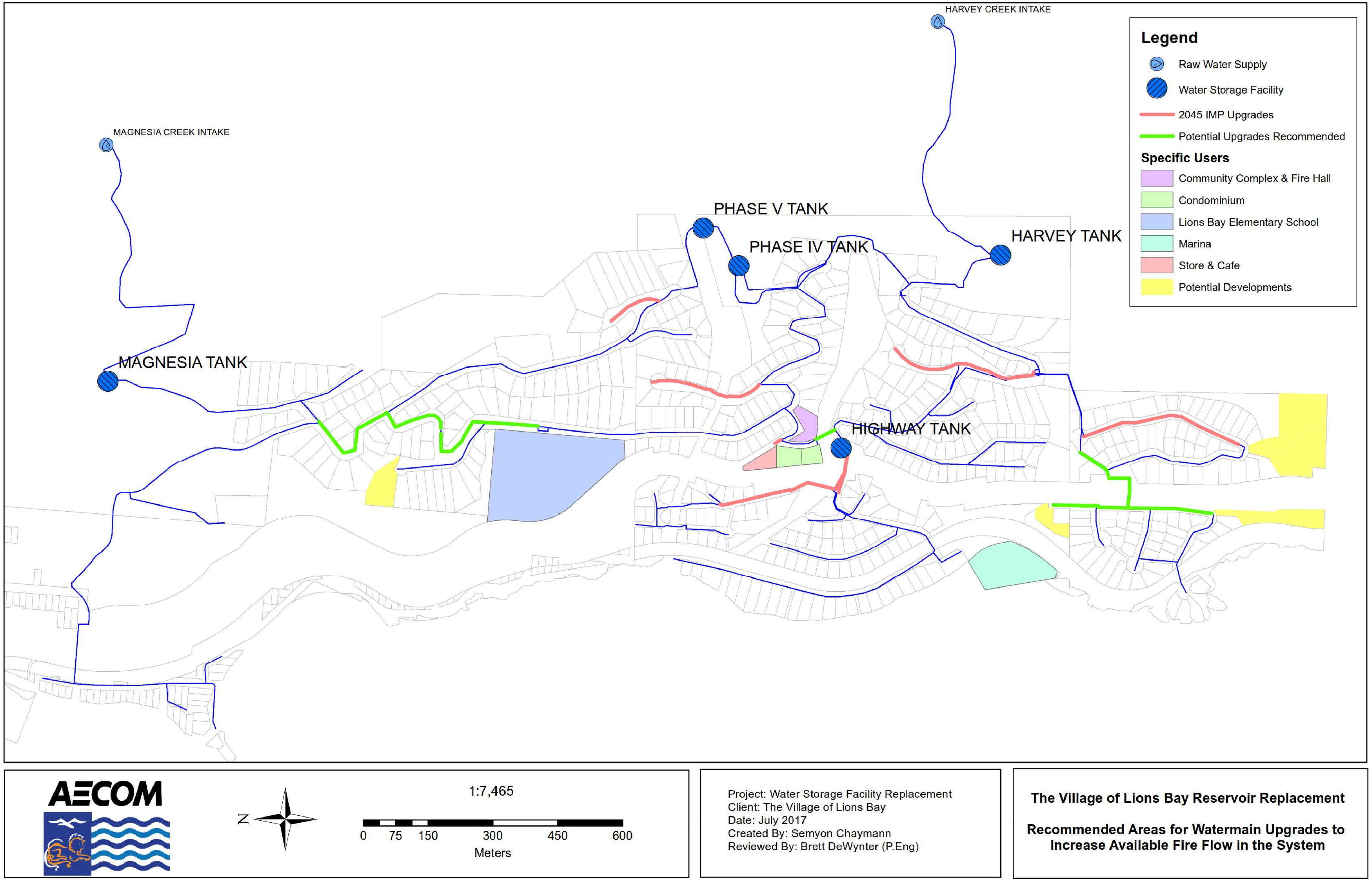

Figure 24: Recommended Water Main Upgrades to Increase Fire Flow Protection

Appendix A

Calculations Spreadsheet

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Intentional Omitted from Printed Sets

Appendix B

Fire Flow Testing & Model-Field Comparison Graphs

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Hydrant Flow Test #1 of 4

Project: Village of Lions Bay - Water Storage Facility Replacement

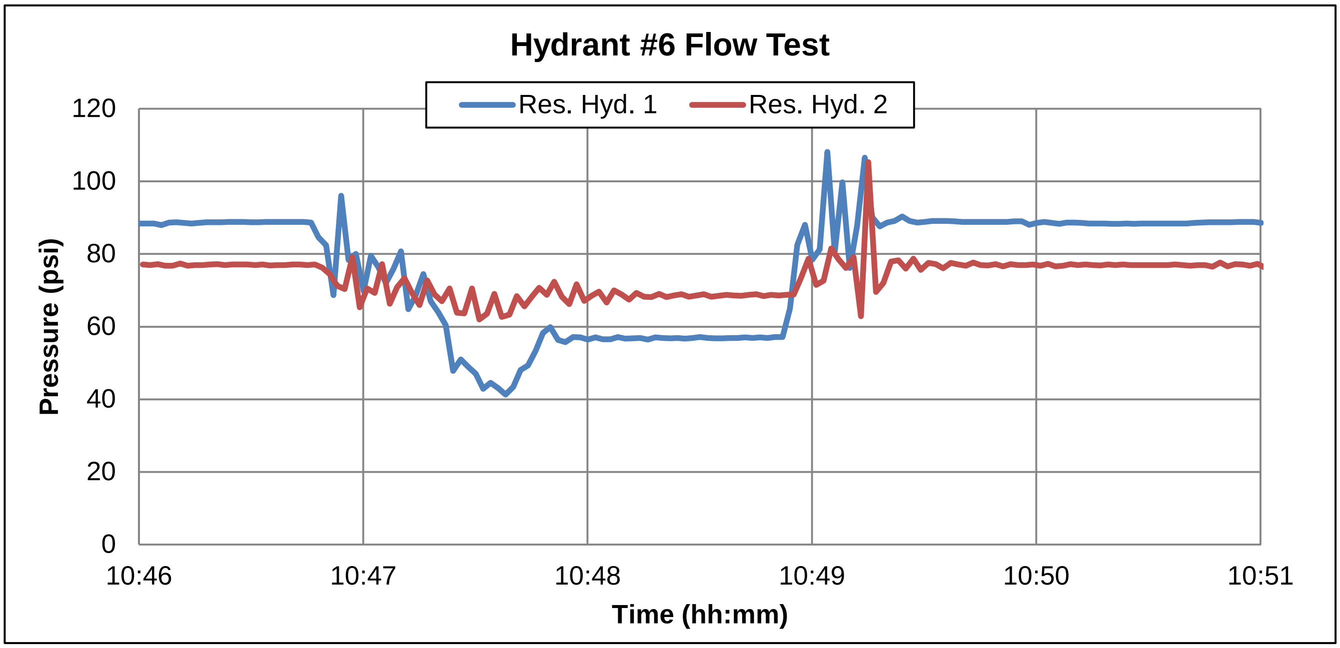
Project #: 60273537 **Preformed By:** Ian Rennie, EIT

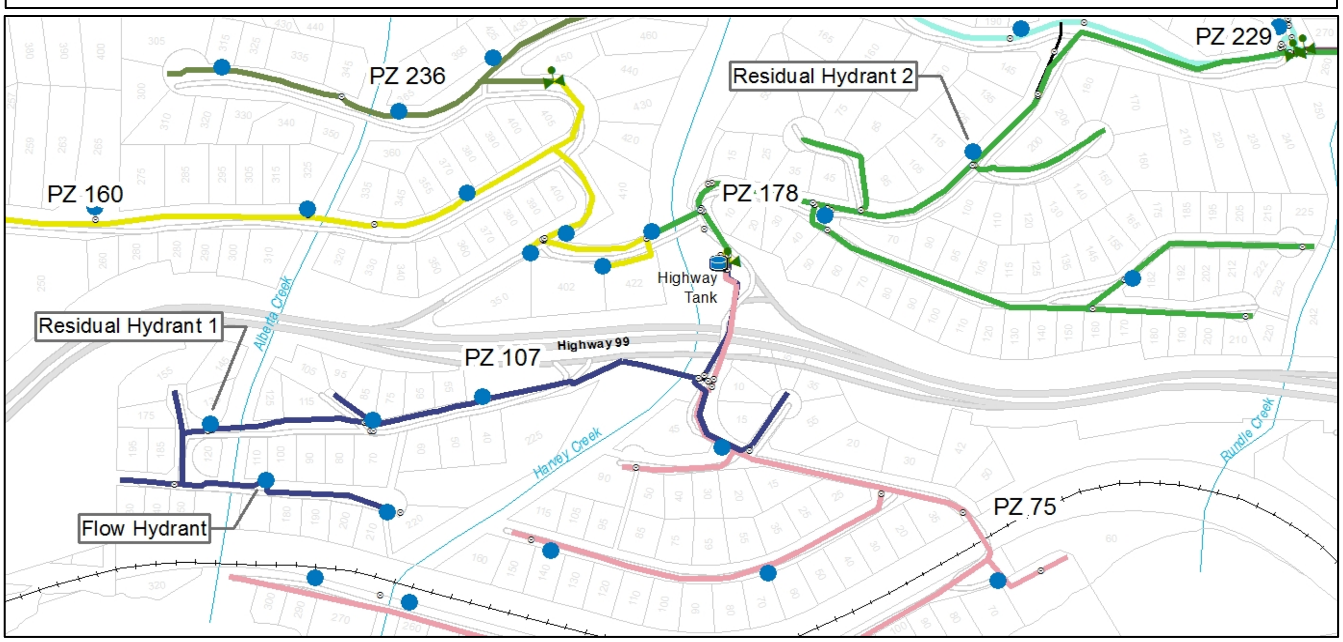
Date: Aug 22, 2017 **Time:** 10:48 **Location:** Isleview Place (Hyd #6)

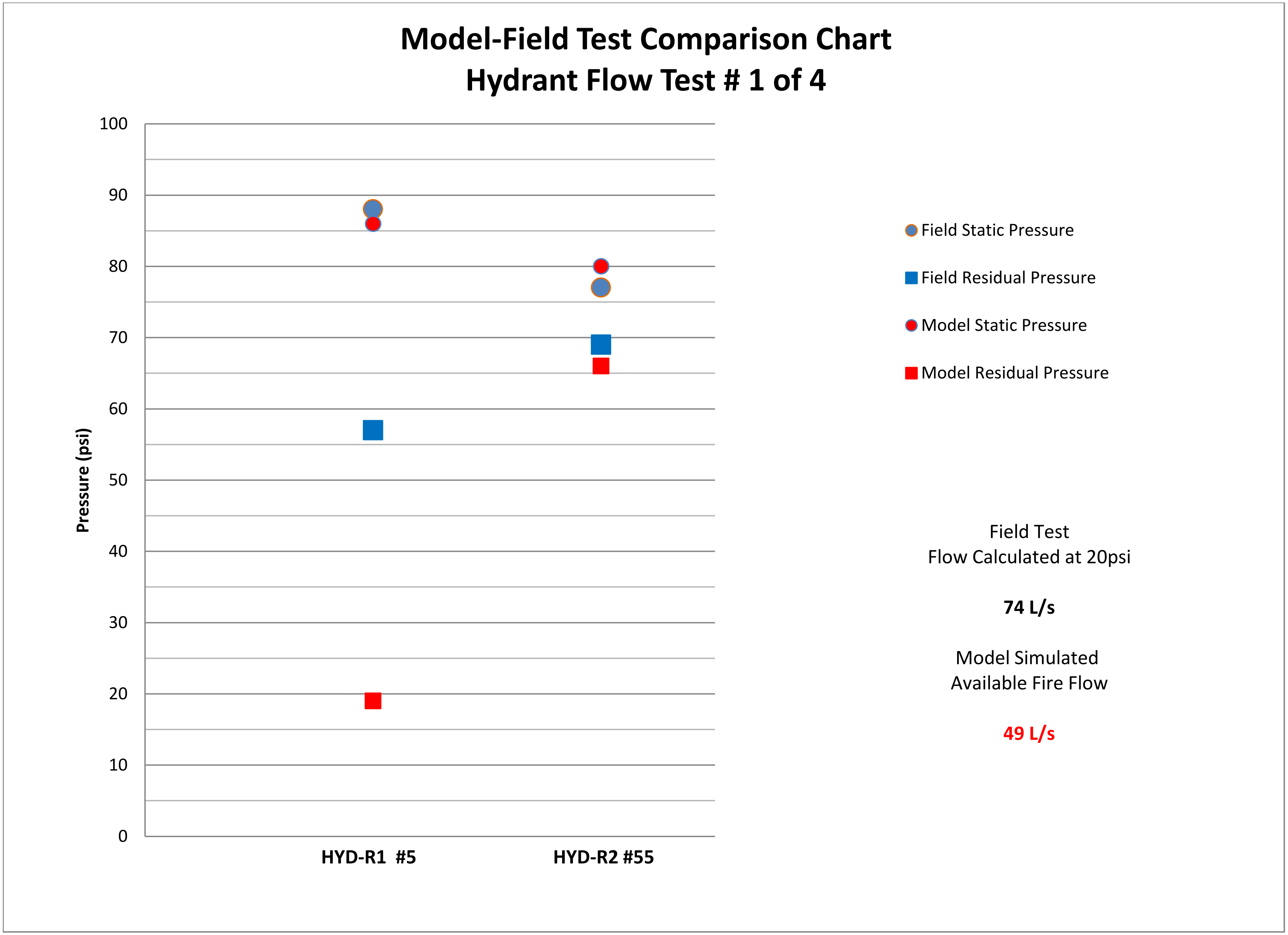
Flow Hydrant	Residual Hydrant 1 (#5)		Residual Hydrant 2 (#55)		Flow Calculated at 20 psi
(L/s)	Static (psi)	Residual (psi)	Static (psi)	Residual (psi)	(L/s)
49	88	57	77	69	74

[1]Flow measured using Pollard Piezo Diffuser connected to one 2.5" port

[2]Formula for fire flow at desired 20 psi $Q_r = Q_f \times h_r^{0.54} / h_f^{0.54}$ where Q_r is flow at desired rate, Q_f is flow during test, h_r is pressure drop to desired rate, h_f pressure drop during test






Model-Field Test Comparison Chart
Hydrant Flow Test # 1 of 4
100
90
80
70
60
50
40
30
20
10
0
Pressure (psi)
HYD-R1 #5
HYD-R2 #55
Field Static Pressure
Field Residual Pressure
Model Static Pressure
Model Residual Pressure
Field Test
Flow Calculated at 20psi
74 L/s
Model Simulated
Available Fire Flow
49 L/s

3232 Production Way, Suite 330
Burnaby BC, Canada V5A 4R4
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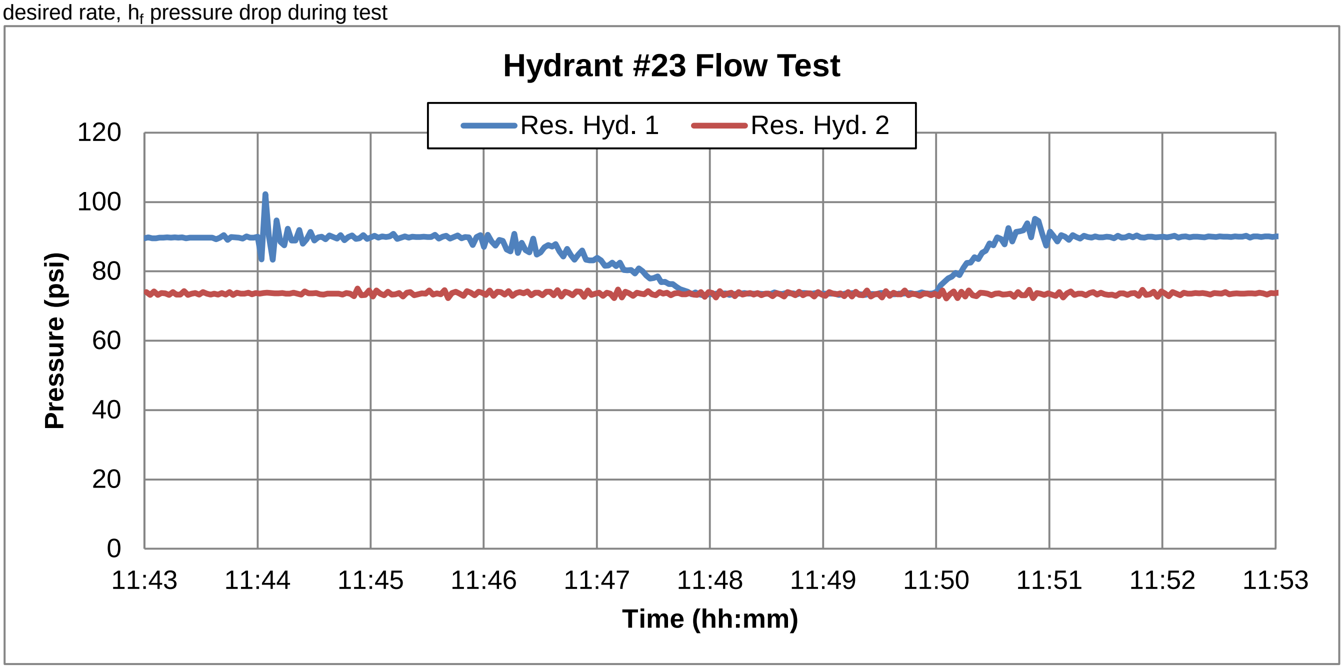
Hydrant Flow Test #2 of 4

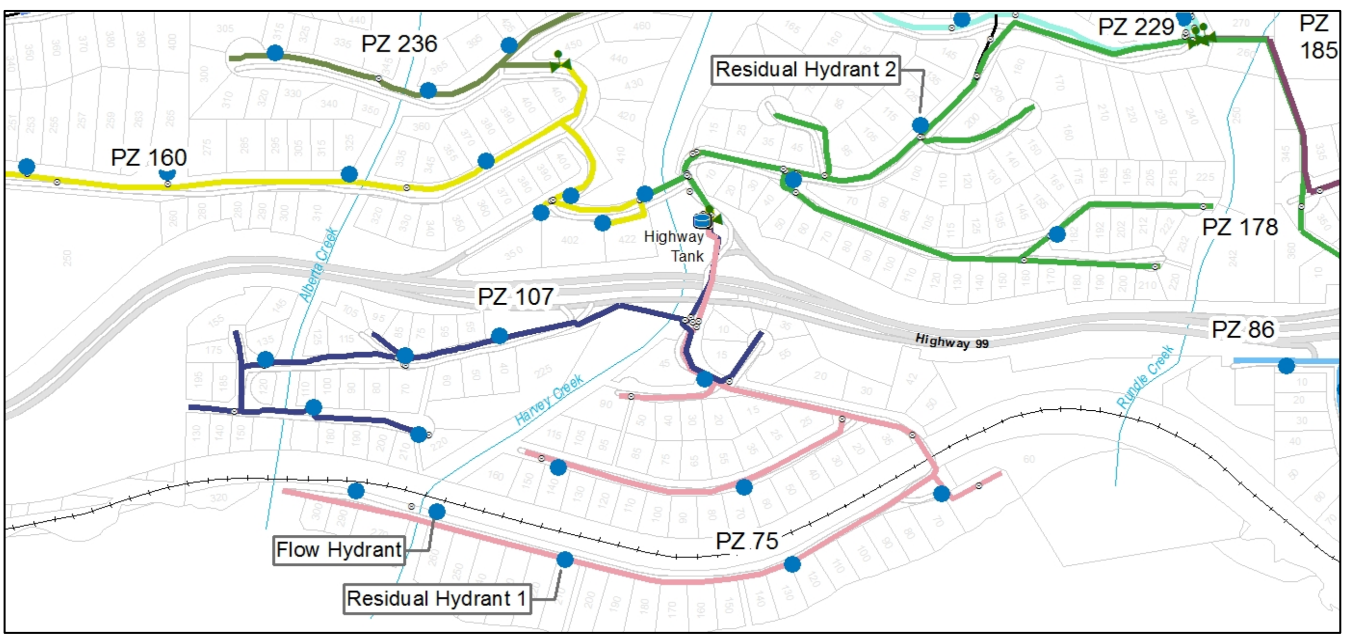
Project: Village of Lions Bay - Water Storage Facility Replacement
Project #: 60273537 **Preformed By:** Ian Rennie, EIT
Date: Aug 22, 2017 **Time:** 11:49 **Location:** Lions Bay Avenue (Hyd #23)

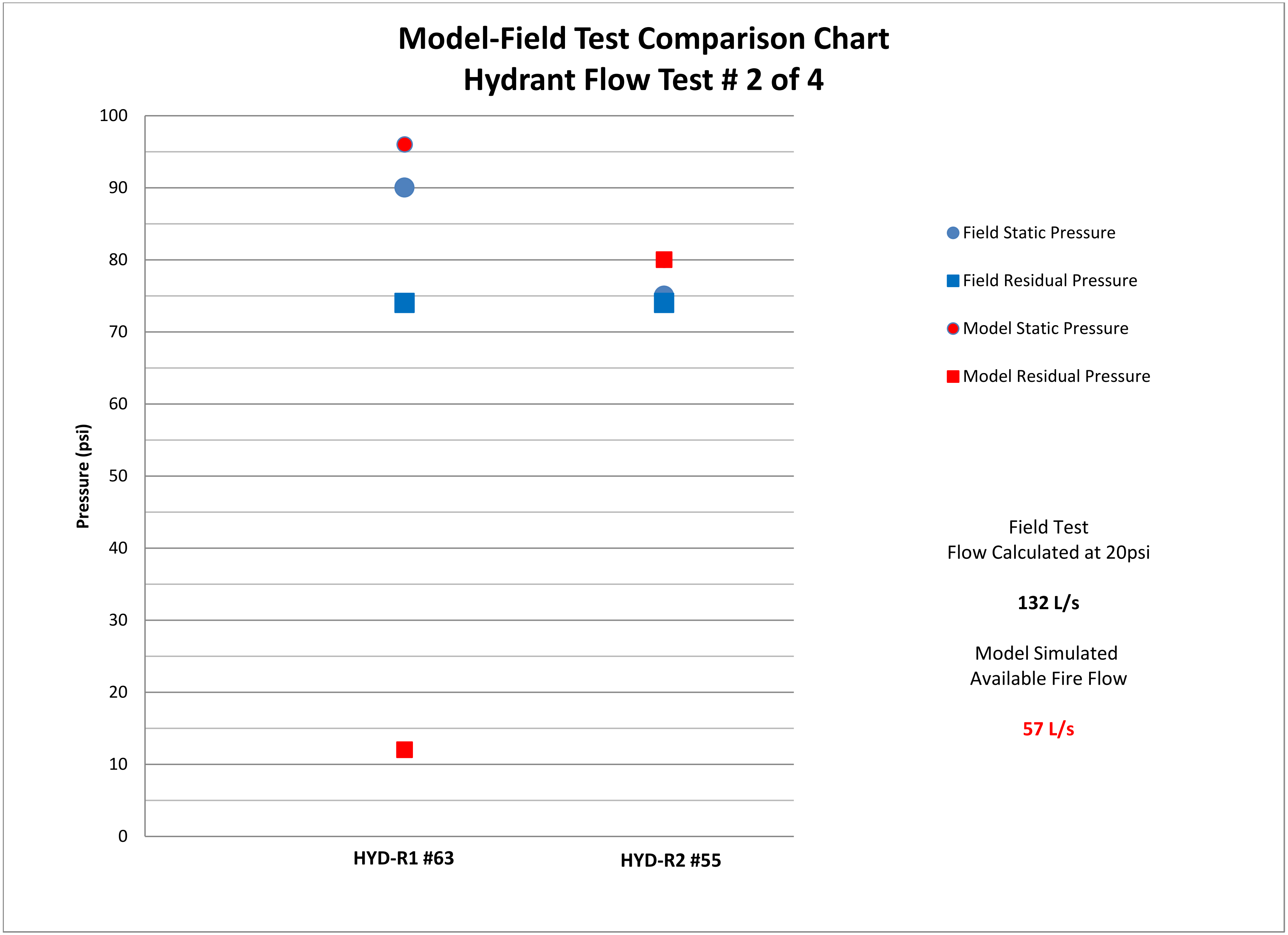
Flow Hydrant	Residual Hydrant 1 (#63)		Residual Hydrant 2 (#55)		Flow Calculated at 20 psi
(L/s)	Static (psi)	Residual (psi)	Static (psi)	Residual (psi)	(L/s)
60	90	74	75	74	132

[1]Flow measured using Pollard Piezo Diffuser connected to one 2.5" port

[2]Formula for fire flow at desired 20 psi $Q_r = Q_f \times h_r^{0.54} / h_f^{0.54}$ where Q_r is flow at desired rate, Q_f is flow during test, h_r is pressure drop to desired rate, h_f pressure drop during test







Model-Field Test Comparison Chart
Hydrant Flow Test # 2 of 4
Pressure (psi)
100
90
80
70
60
50
40
30
20
10
0
HYD-R1 #63
HYD-R2 #55
Field Static Pressure
Field Residual Pressure
Model Static Pressure
Model Residual Pressure
Field Test
Flow Calculated at 20psi
132 L/s
Model Simulated
Available Fire Flow
57 L/s

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Hydrant Flow Test #3 of 4

Project: Village of Lions Bay - Water Storage Facility Replacement

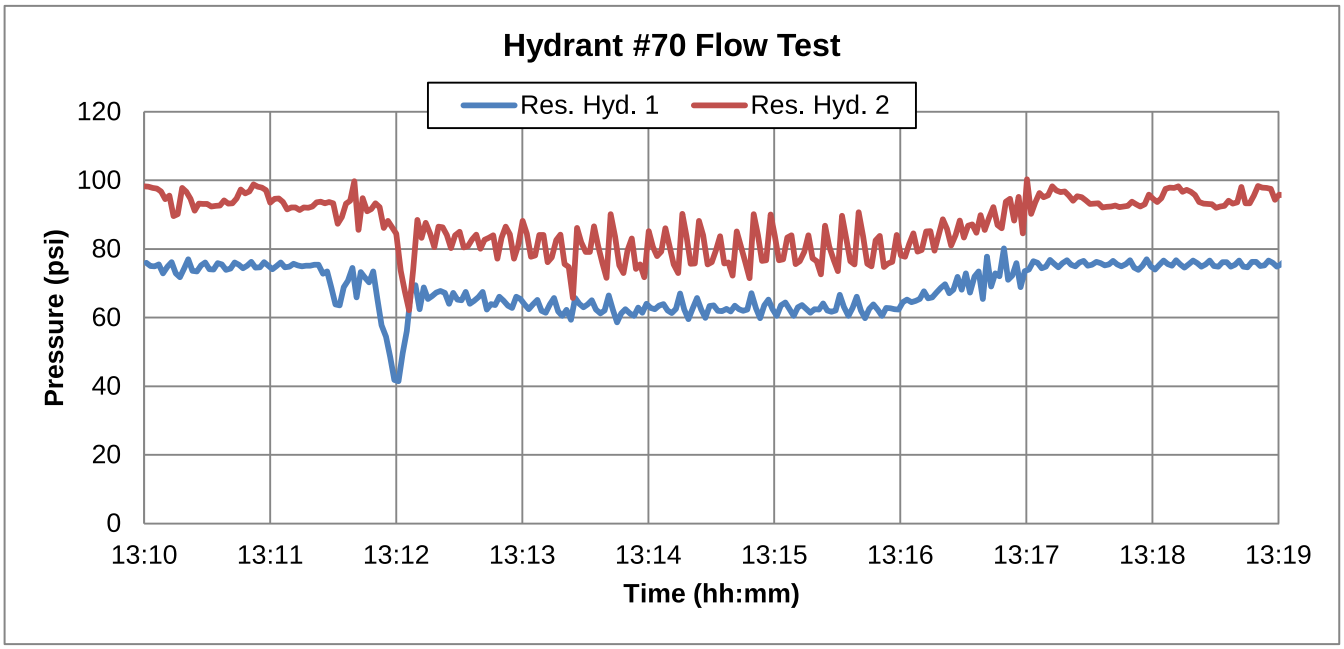
Project #: 60273537 **Preformed By:** Ian Rennie, EIT

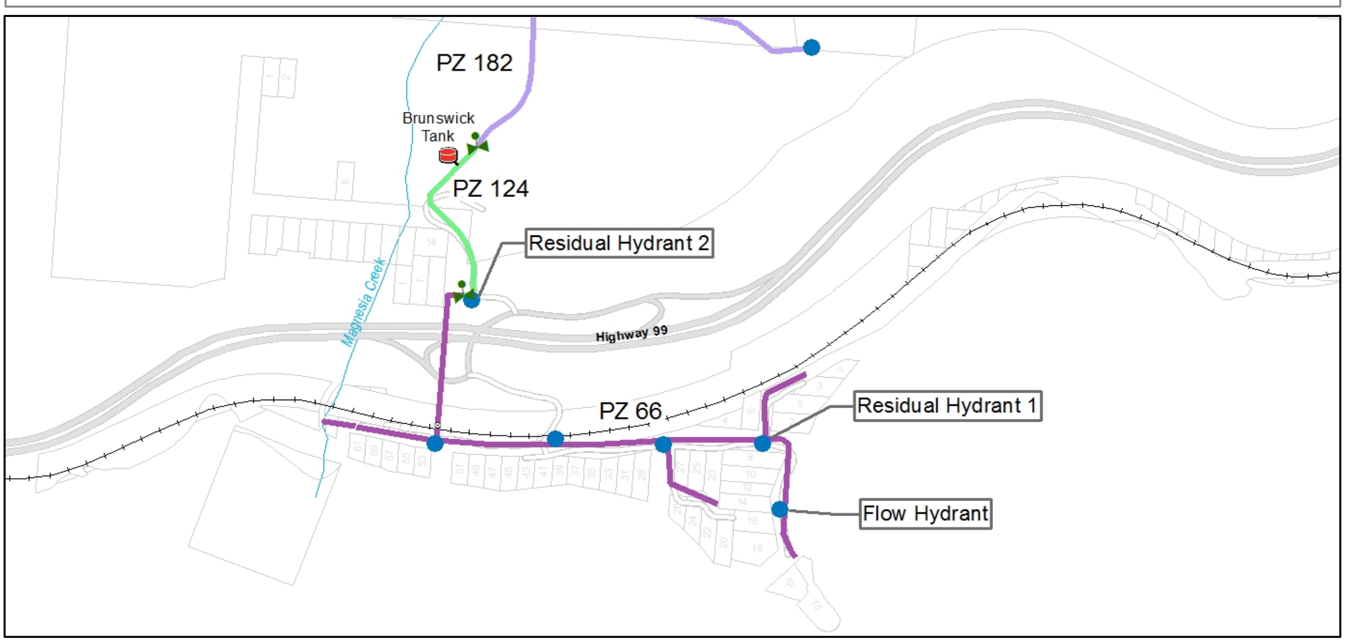
Date: Aug 22, 2017 **Time:** 13:14 **Location:** Brunswick Beach Rd (Hyd #70)

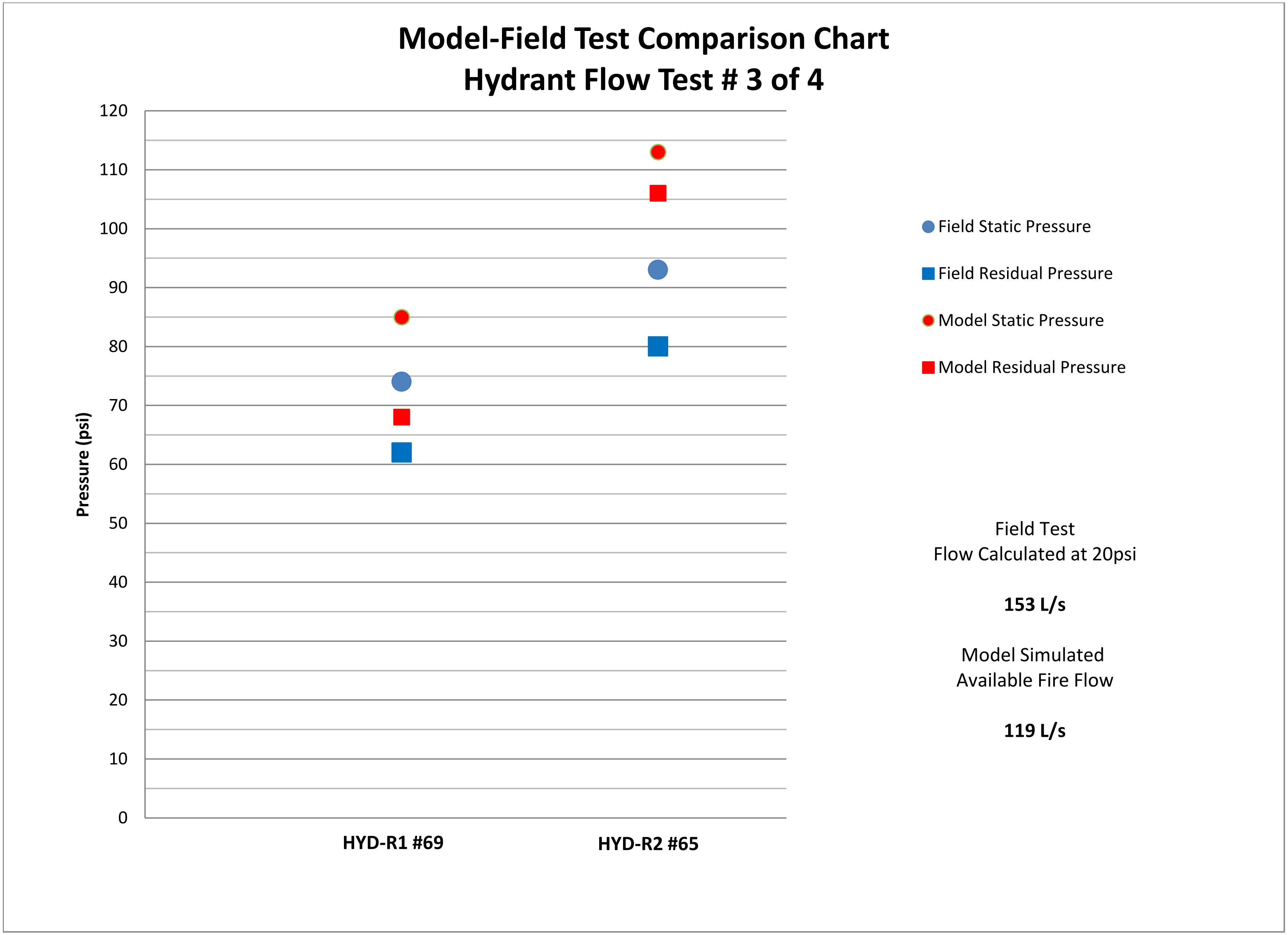
Flow Hydrant	Residual Hydrant 1 (#69)		Residual Hydrant 2 (#65)		Flow Calculated at 20 psi
(L/s)	Static (psi)	Residual (psi)	Static (psi)	Residual (psi)	(L/s)
67	74	62	93	80	153

[1]Flow measured using Pollard Piezo Diffuser connected to one 2.5" port

[2]Formula for fire flow at desired 20 psi $Q_r = Q_f \times h_r^{0.54} / h_f^{0.54}$ where Q_r is flow at desired rate, Q_f is flow during test, h_r is pressure drop to desired rate, h_f pressure drop during test






Model-Field Test Comparison Chart
Hydrant Flow Test # 3 of 4
Pressure (psi)
120
110
100
90
80
70
60
50
40
30
20
10
0
HYD-R1 #69
HYD-R2 #65
Field Static Pressure
Field Residual Pressure
Model Static Pressure
Model Residual Pressure
Field Test
Flow Calculated at 20psi
153 L/s
Model Simulated
Available Fire Flow
119 L/s

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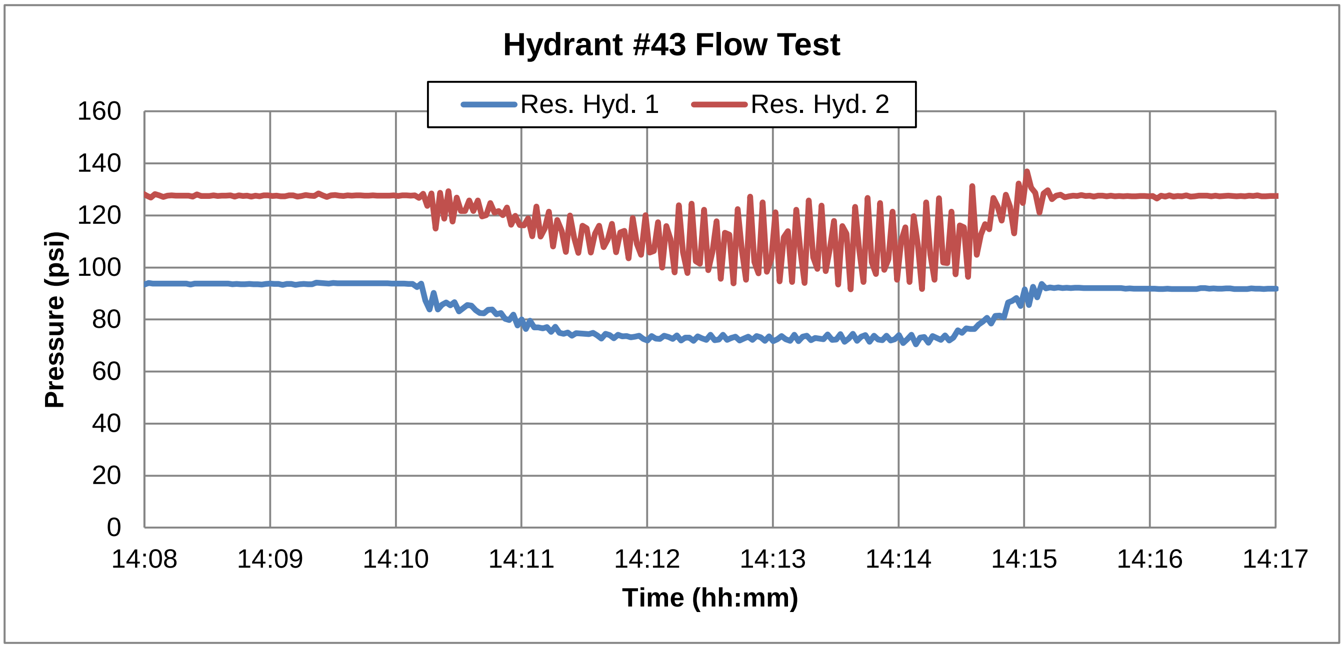
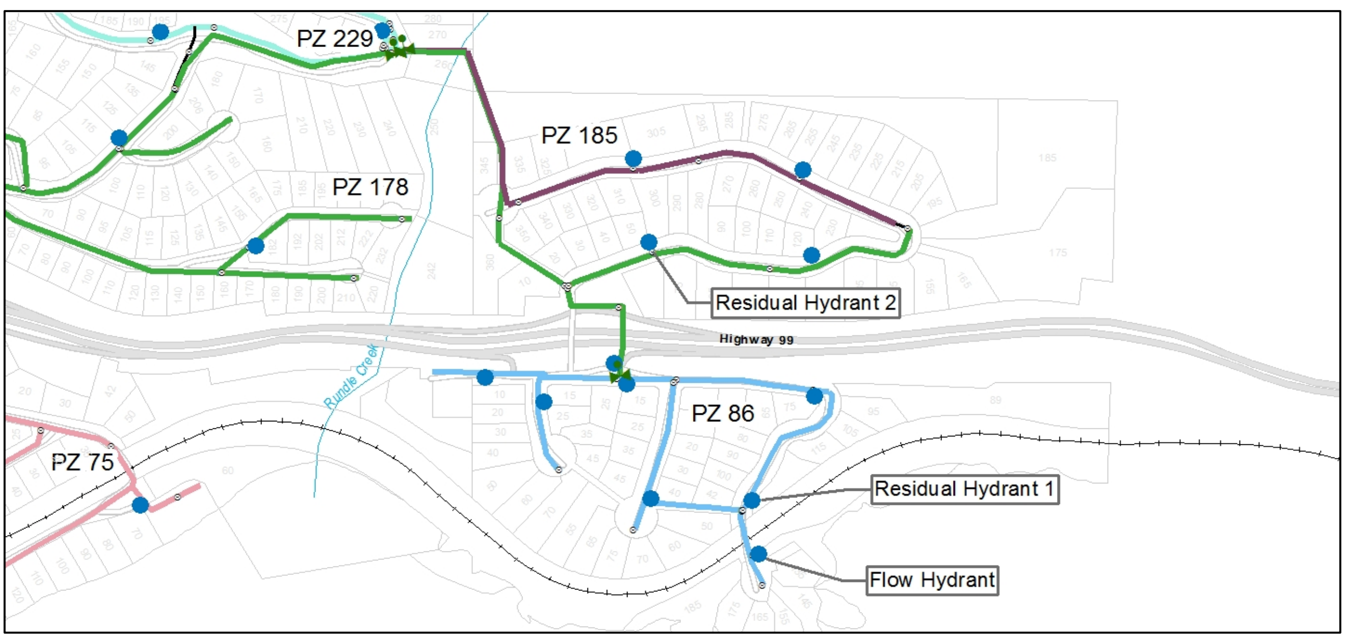
Hydrant Flow Test #4 of 4

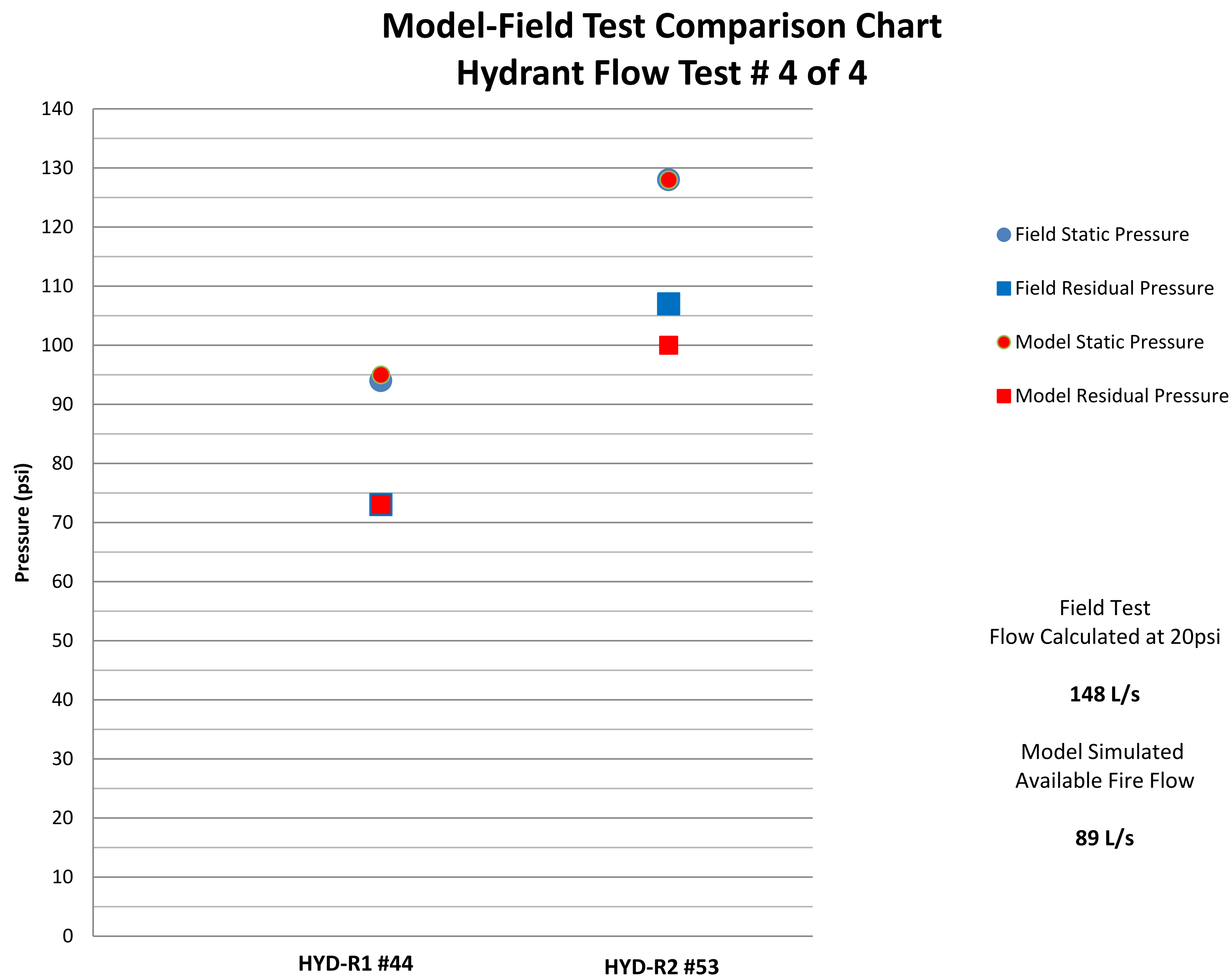
Project: Village of Lions Bay - Water Storage Facility Replacement
Project #: 60273537 **Preformed By:** Ian Rennie, EIT
Date: Aug 22, 2017 **Time:** 14:13 **Location:** Tidewater Way (Hyd #43)

Flow Hydrant	Residual Hydrant 1 (#44)		Residual Hydrant 2 (#53)		Flow Calculated at 20 psi
(L/s)	Static (psi)	Residual (psi)	Static (psi)	Residual (psi)	(L/s)
75	94	73	128	107	148

[1]Flow measured using Pollard Piezo Diffuser connected to one 2.5" port
[2]Formula for fire flow at desired 20 psi $Q_r = Q_f \times h_r^{0.54} / h_f^{0.54}$ where Q_r is flow at desired rate, Q_f is flow during test, h_r is pressure drop to desired rate, h_f pressure drop during test







Field Test
Flow Calculated at 20psi

148 L/s

Model Simulated
Available Fire Flow

89 L/s

Appendix C

Fire Flow Requirement Calculations Spreadsheets

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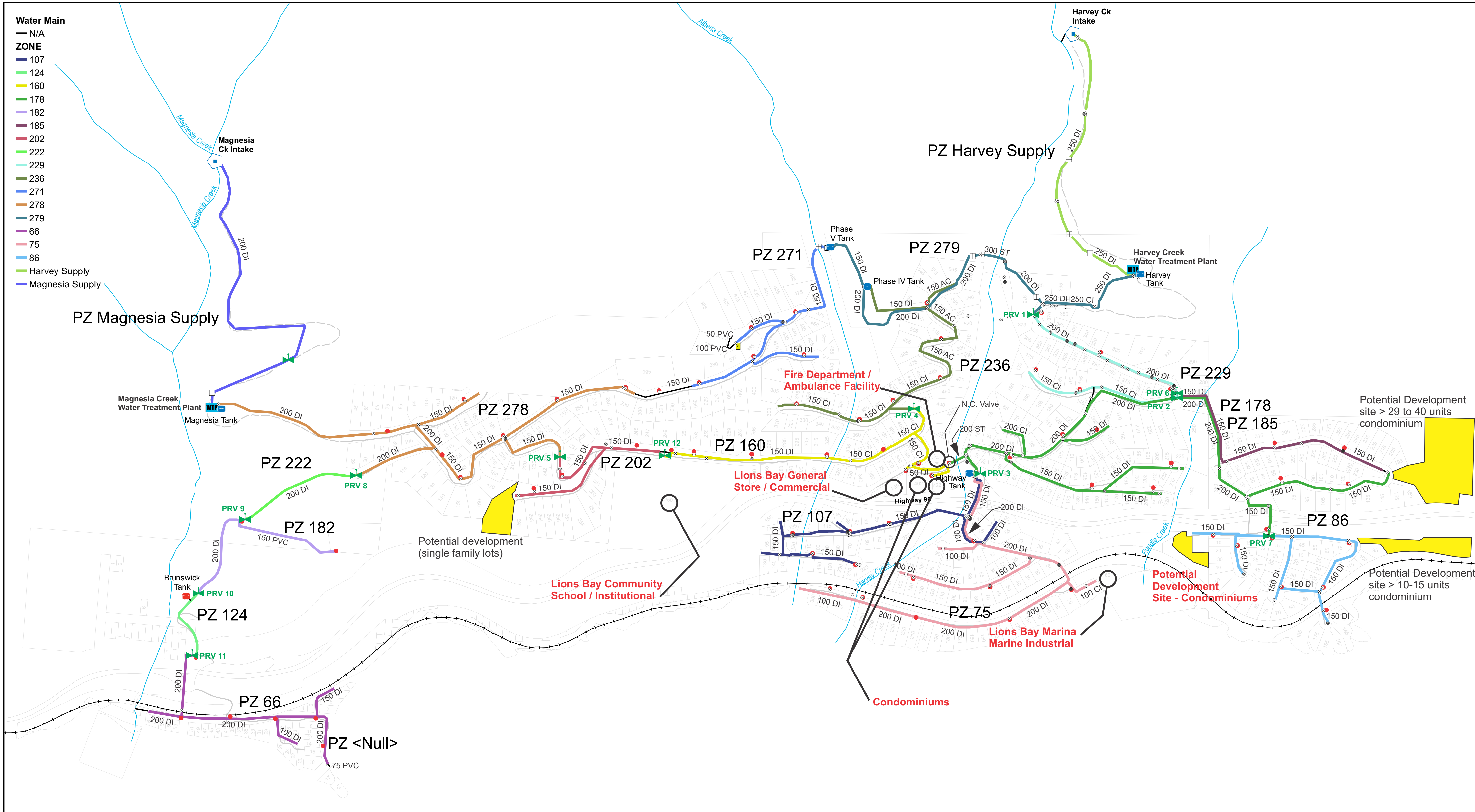
Intentional Omitted from Printed Sets

Appendix D

Potential Future Developments



VILLAGE OF LIONS BAY
Infrastructure Master Plan
Figure 2-2 Pressure Zones

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Legend

Property Parcels

Village Roads
- Sealed
- Unsealed

MOTI Roads
- On-Ramp
- Highway

- Treatment Plant
- Intake

Tanks (by Water Type)
- Not In Service
- Raw Water
- Treated Water

Valves (by Type)
- Air Valve
- Check Valve
- Gate Valve
- PRV

- Hydrant
- Pump Station

0 50 100 200
Metres

Village of Lions Bay

About AECOM

AECOM (NYSE: ACM) is built to deliver a better world. We design, build, finance and operate infrastructure assets for governments, businesses and organizations in more than 150 countries.

As a fully integrated firm, we connect knowledge and experience across our global network of experts to help clients solve their most complex challenges.

From high-performance buildings and infrastructure, to resilient communities and environments, to stable and secure nations, our work is transformative, differentiated and vital. A Fortune 500 firm, AECOM companies had revenue of approximately US$19 billion during the 12 months ended June 30, 2015.

See how we deliver what others can only imagine at aecom.com and @AECOM.

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