PRESSURIZED IRRIGATION SYSTEM MASTER PLAN

(HAL Project No.: 314.18.100)

FINAL REPORT

JULY 2019

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GLOSSARY

Average Yearly Demand - The volume of water used during an entire year.

Build-out - When the development density reaches maximum allowed by planned development.

Demand - Required water flow or volume.

Distribution System - The network of pipes, valves and appurtenances contained within a water system.

Drinking Water - Water used for human consumption.

Dynamic Pressure - The pressure exerted by water within the pipelines and other water system appurtenances when water is flowing through the system.

Head - A measure of the pressure in a distribution system that is exerted by the water. Head indicates the height of the free water surface (or pressure reduction valve setting) above any point in the hydraulic system.

Headloss - The amount of pressure lost in a distribution system under dynamic conditions due to the wall roughness and other physical characteristics of pipes in the system.

Irrigated Acreage (Acres) - The area of land that is irrigated in acres.

Peak Day - The day(s) of the year in which a maximum amount of water is used in a 24-hour period.

Peak Day Demand - The average flow required to meet the needs imposed on a water system during the peak day(s) of the year.

Peak Instantaneous Demand - The flow required to meet the demands imposed on a water system during maximum flow on a peak day.

Pressure Reducing Valve (PRV) - A valve used to reduce excessive pressure in a water distribution system.

Pressure Zone - The area within a distribution system in which water pressure is maintained within specified limits.

Irrigation Water - Water used solely for outdoor watering. Not for human consumption.

Static Pressure - The pressure exerted by water within the pipelines and other water system appurtenances when water is not flowing through the system, i.e., during periods of little or no water use.

Transmission Pipeline - A pipeline that transfers water from a source to a reservoir or from a reservoir to a distribution system.

ABBREVIATIONS

ac-ft	acre-feet
blvd	boulevard
cfs	cubic feet per second (ft^3/s)
CUP	Central Utah Project or Central Utah Water Conservancy District
E	East
ft	foot or feet
GIS	Geographic Information System
gpm	gallons per minute
HAL	Hansen, Allen & Luce, Inc.
Hwy	highway
IA	irrigated acreage
ID #	identification number
in	inches
irr	irrigation
N	North
NW	Northwest
psi	pounds per square inch
RR	railroad
S	South
VFD	variable frequency drive
W	West
w/	with

CHAPTER 1

INTRODUCTION

BACKGROUND

Highland City (City) provides irrigation water to its residents through an existing pressurized irrigation system. This service is a great benefit to the residents as the service provides an adequate quantity and quality of water for outdoor use. The pressurized irrigation service has also reduced demand on the public drinking water system, allowing an efficient use of the higher quality drinking water for indoor use.

While the pressurized irrigation system continues to provide adequate service to most areas of the community, increased water demands due to growth are beginning to affect the reliability of the system in certain areas of the City. During times of high demand, water pressures in some areas of the City have decreased significantly. In other areas of the City, water pressures remain higher than the preferred maximums.

In order to accommodate the increased demand on the pressurized irrigation system, and in order to estimate the related infrastructure cost, the Highland City Council commissioned the development of a master plan. Highland City desired that the master plan evaluate the existing system and recommend necessary changes. Highland City also desired that the master plan predict infrastructure needs once the City density met a maximum under the current zoning.

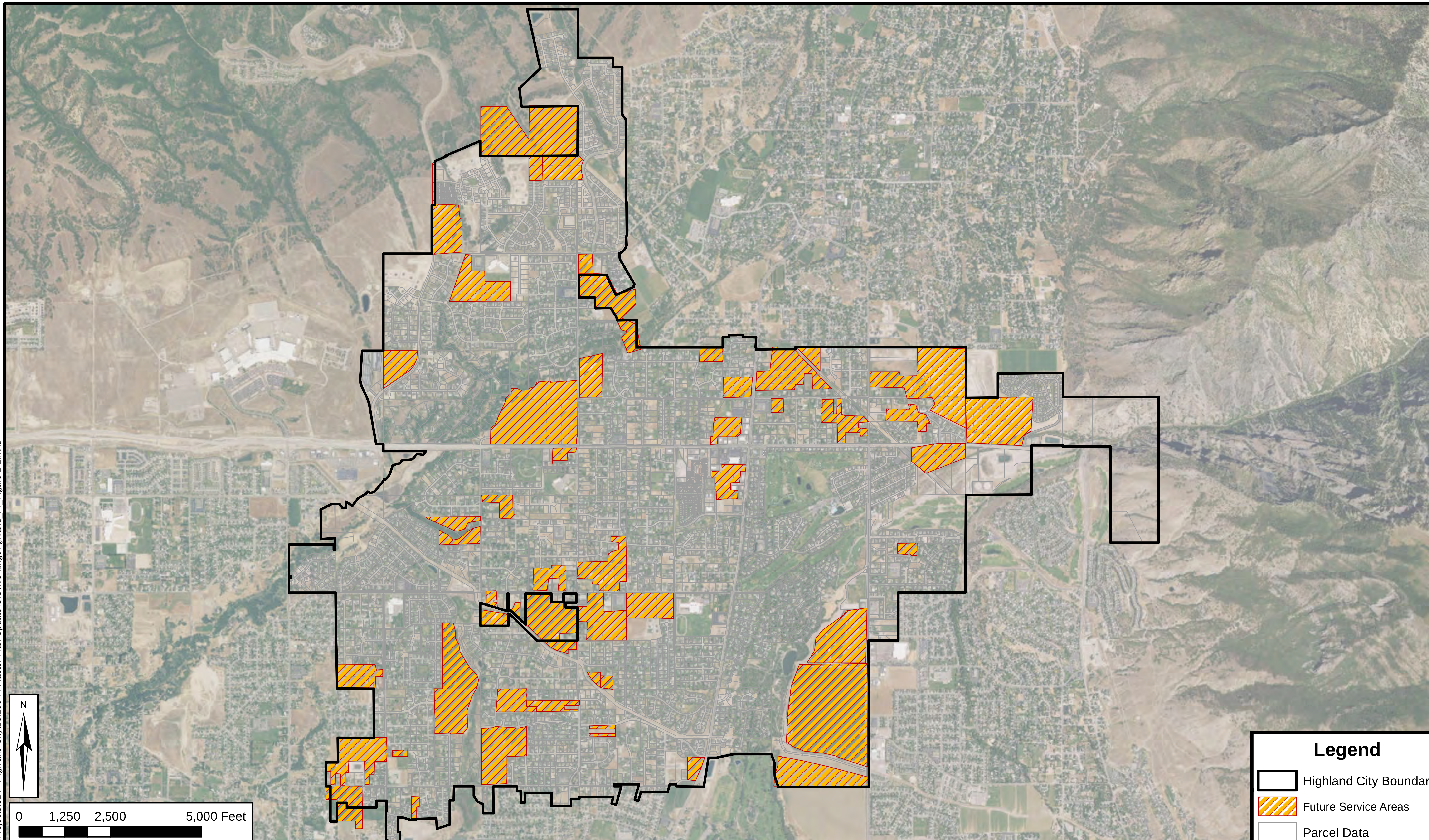
AUTHORIZATION

In December 2006, Highland City selected Hansen, Allen & Luce, Inc. (HAL) to assist in completing their first pressurized irrigation master plan. In January of 2018, the City requested HAL to update the master plan after a decade of development. Preparation of this master planning effort was completed under the direction of, and in cooperation with, Highland City staff.

WORK PLAN

The work plan for the pressurized irrigation system master plan included the following:

1. Coordination with Highland City.
2. Estimate existing demands on the system, estimate the needed existing water storage volume, predict future demands on the system, and predict the needed future water storage volume.
3. Update computerized hydraulic models of the existing and projected future water distribution systems. Identify potential problems along with solutions to those problems.
4. Prepare a capital improvements plan which includes cost estimates, population projections and implementation schedules.
5. Prepare a pressurized irrigation master plan document and make a presentation to Highland City.



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Highland City
Pressurized Irrigation System Master Plan

Existing and Future Service Areas

FIGURE 1-1

SERVICE AREA

A service area was established for the pressurized irrigation master plan. For the existing system, the service area was identified to be the corporate limit of Highland City with the exception of the Alpine Country Club and the Pheasant Hollow Subdivisions. These developments provide their own irrigation system and will not be connected to Highland City's pressure irrigation system. There are also several areas throughout Highland City that have not yet been developed that are not currently served by the pressure irrigation system. For the future system, the service area was expanded to include areas for which annexation into Highland City appeared likely and all areas within the current City boundaries that are expected to be developed. Areas that are expected to be annexed include unincorporated islands in the middle of the City and an area northwest of the City that is currently within the County and undeveloped. The areas to be served by the existing and future pressure irrigation systems are shown on Figure 1-1.

DESIGN CRITERIA

The evaluation of existing and future conditions of the pressurized irrigation system were based upon the design criteria provided in Table 1-1.

TABLE 1-1
DESIGN CRITERIA

CRITERIA	VALUE OR ASSUMPTION
Planning Period	Build-out
Land Use	Zoning - Provided by Highland City
Peak Day Demand	10 gpm / irrigated acre
Peak Instantaneous Demand	20 gpm / irrigated acre
Min. Storage	8,500 gallons / irrigated acre
Min. New Pipe Dia.	8-inch dia.
Min. New Pipe Pressure Rating	200 psi
Roughness Coefficient	Hazen-Williams C = 130
Maximum Water Pressure	Static or Dynamic Pressure at Point of Connection = 120 psi
Minimum Water Pressure	Static or Dynamic Pressure at Point of Connection = 50 psi
Maximum Pressure Change	Static or Dynamic Pressure at Point of Connection = 30 psi

CHAPTER 2

EXISTING PRESSURIZED IRRIGATION SYSTEM

EXISTING SYSTEM DESCRIPTION

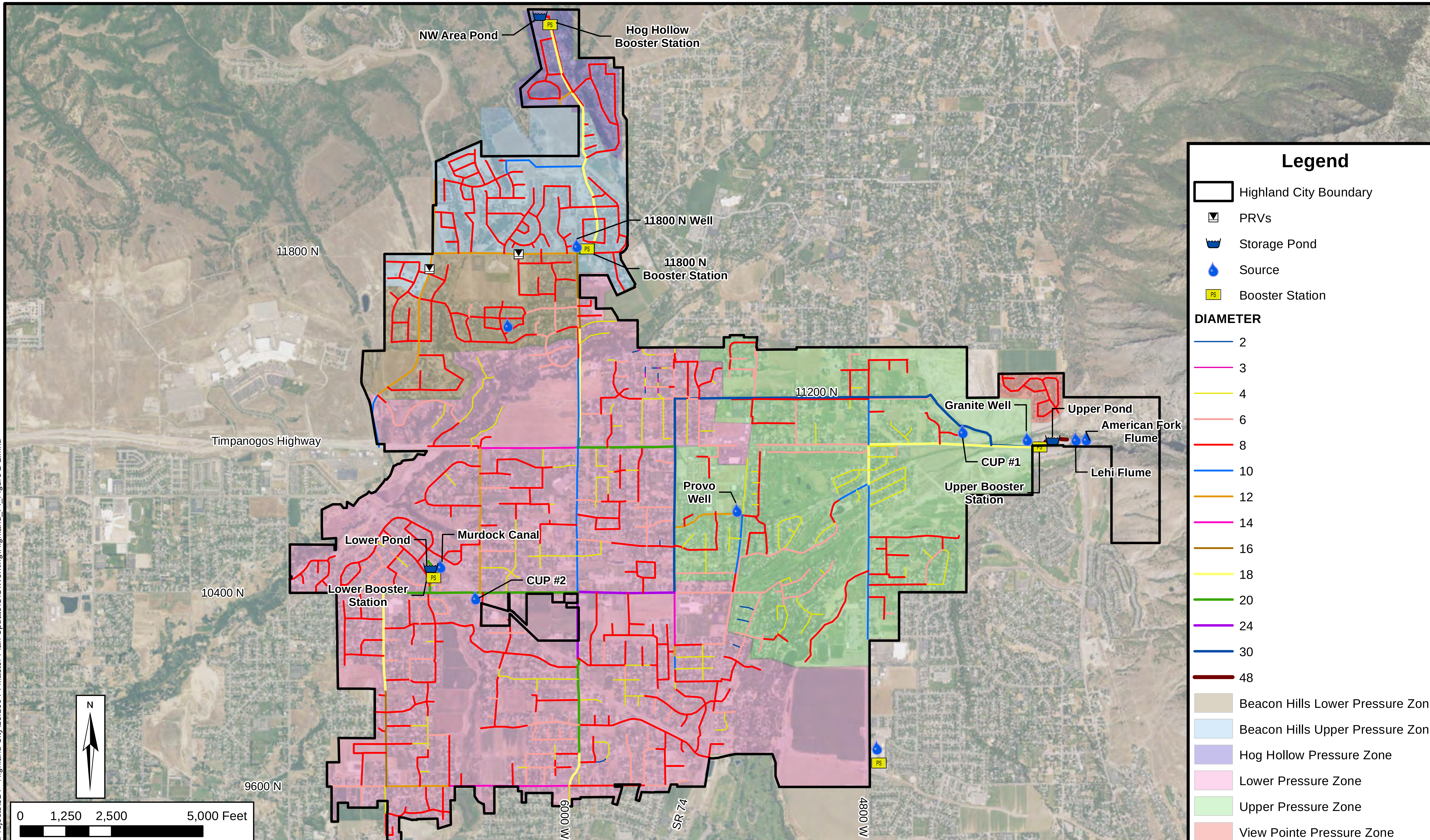
Construction on Highland City's pressurized irrigation system began in 1997 to provide secondary water for irrigation of landscaped areas and gardens. The system extends throughout the developed areas within the corporate boundaries of the City. The existing pressurized irrigation system is shown on Figure 2-1. A schematic representation of the system is shown on Figure 2-2. Sources of irrigation water include three surface water diversions, three underground water wells, and two connections to the Central Utah Project (CUP) wholesale system. There are currently three storage ponds and four booster stations. The distribution system is divided into six pressure zones and consists of approximately 86 miles of pipelines ranging in diameter from 2 inches to 30 inches.

SOURCES

Highland City currently receives secondary water from eight sources. Table 2-1 summarizes the approximate production capacity for each source during a normal year. Source background information is included in Appendix A.

TABLE 2-1
EXISTING PRESSURIZED IRRIGATION SOURCES

SOURCE	DESCRIPTION	APPROXIMATE CAPACITY (GPM)
American Fork Canyon - American Fork Flume	2-foot parshall flume diversion from American Fork River to the Upper Pond.	1,600 (August) to 6,300 (June) During drought could be as low as 1,350
American Fork Canyon - Lehi Flume	3-foot parshall flume on diversion from American Fork River to the Upper Pond.	1,600 (August) to 6,300 (June) During drought could be as lows as 900
Upper Pond / Granite Well	12-inch well (640 ft deep) pumping into 30-inch diameter transmission line from upper pond to lower pressure zone.	1,160
11800 North Well	24-inch well (1,000 ft deep) pumping into the lower pressure zone (in same building as the 11800 North booster pumps).	1,300
10700 North - Alpine Highway / Provo Well	16-inch well (500 ft deep) pumping into the lower pressure zone.	1,100
CUP Connection No. 1	PRV and meter station from high pressure CUP system to 30-inch transmission line to the lower pressure zone.	1,800 gpm (per Usage agreement) (Currently diverting 3,590 gpm in exchange for Murdock Canal diversion)
CUP Connection No. 2	PRV and meter station from high pressure CUP system to the lower pressure zone.	3,590 (per Usage agreement) Has been as high as 6,300 in the past
Murdock Canal	Diversion from Murdock Canal to the lower pond with a booster station directly into the lower pressure zone, with current orifice plate.	3,900 with current orifice plate. (PRWUA provided up to 6,800 with no plate.)
	TOTAL:	**16,050 (August) to 25,450 (June)**



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Highland City
Pressurized Irrigation System Master Plan

Existing Pressurized Irrigation System

FIGURE 2-1

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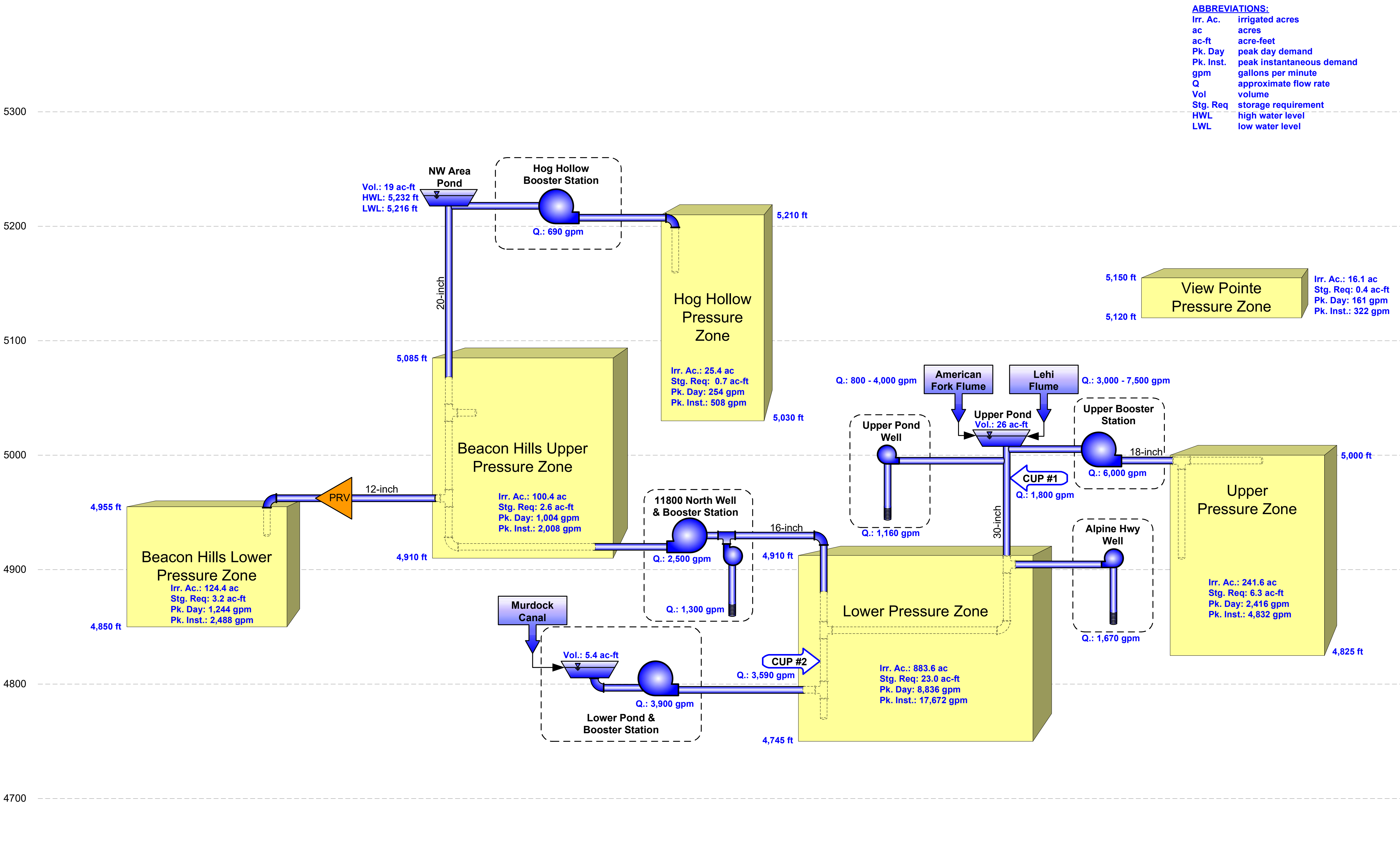

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HIGHLAND CITY
PRESSURE IRRIGATION SYSTEM MASTER PLAN

EXISTING SYSTEM SCHEMATIC DIAGRAM

FIGURE 2-2

STORAGE PONDS

Highland City currently operates three storage ponds for the pressure irrigation system. These storage reservoirs are described in Table 2-2.

TABLE 2-2
EXISTING STORAGE PONDS

STORAGE POND	DESCRIPTION	STORAGE CAPACITY (AC-FT)
Upper Pond (Mouth of American Fork Canyon)	Located at about 4000 West 11000 North. Serves the Lower Pressure Zone through a 30-inch transmission pipeline. Also serves the Upper Pressure Zone through the Upper Booster Station.	26
Lower Pond (Canterbury North)	Located at about 6600 West 10500 North. Serves the lower pressure zone through the Lower Booster Station.	5.4
Northwest (NW) Area Pond (Beacon Hills)	Located at about 6100 West 12700 North. Serves the Beacon Hills Upper and Lower Pressure Zones through a 20-inch transmission pipeline. Also serves the Hog Hollow Pressure Zone through the Hog Hollow Booster Station.	19
	TOTAL:	**50.4**

DISTRIBUTION SYSTEM

The existing distribution system is divided into six pressure zones with the goal to maintain system pressures within a range of 50 psi to 120 psi. The locations of these pressure zones are shown on Figure 2-1 and a description for each is included in Table 2-3.

TABLE 2-3
EXISTING PRESSURE ZONES

PRESSURE ZONE	DESCRIPTION	APPROXIMATE ELEVATION RANGE (FEET)
View Pointe Pressure Zone	Includes the View Pointe Subdivision located north of 11000 North and east of about 4400 West. This area is not served by the pressure irrigation system because there are no sources currently available at this location and elevation. Pressure irrigation in this area is provided by the Highland City drinking water system.	5,120 - 5,150
Upper Pressure Zone	Includes the area generally east of Alpine Hwy and north of about 10100 North. The single source for this zone is the Upper Booster Station.	4,825 - 5,000
Lower Pressure Zone	Includes the area generally west of Alpine Hwy and south of Dry Creek. This zone serves the largest area of the City. The majority of the sources are found in this zone.	4,745 - 4,910
Beacon Hills Lower Pressure Zone	Includes the area generally north of Dry Creek and south of 11800 North. This zone is served water through PRV’s.	4,850 - 4,955

Beacon Hills Upper Pressure Zone	Includes the area generally north of 11800 North and south of about 12200 North. This zone's source is the 11800 Booster.	4,910 - 5,085
Hog Hollow Pressure Zone	Includes the Hog Hollow area north of about 12200 North that cannot be served by gravity from the NW Area Pond. This zone source is the Hog Hollow Booster Station.	5,030 - 5,210

Due to the locations and elevations of the existing ponds and sources relative to the pressure zones, four booster stations have been constructed to set pressures in the distribution system. These booster stations are described in Table 2-4.

TABLE 2-4
EXISTING BOOSTER STATIONS

BOOSTER STATION	DESCRIPTION	STATION CAPACITY (GPM)*
Upper Booster Station (Mouth of Canyon – Upper Pressure Zone)	Pumps from the Upper Pond to the Upper Pressure Zone through an 18-inch pipeline. Pumps have a variable frequency drive (VFD) to pump on demand and regulate pressures in the Upper Pressure Zone.	6,000
Lower Booster Station (Canterbury North – Lower Pressure Zone)	Pumps from the Lower Pond directly into the Lower Pressure Zone. Pumps are manually operated in an on or off condition.	3,900
11800 North Booster Station (6000 W – Upper Beacon Hills Pressure Zone)	Pumps from a 16-inch diameter pipeline from the Lower Pressure Zone to the NW Area Pond through a 20-inch diameter pipeline.	2,000-2,500 depending on time of day
Hog Hollow Booster Station (Near NW Pond – Hog Hollow Pressure Zone)	Pumps from the NW Area Pond to the Hog Hollow Pressure Zone. Pumps have a VFD to pump on demand and regulate pressures in the Hog Hollow Pressure Zone.	690

*Values shown in Table 2-4 are total booster pumping capacity and have not been reduced to provide redundancy, except for the Hog Hollow Booster Station which has an additional 345 gpm pump. During maintenance, flow capacities will be reduced from the shown values.

CHAPTER 3

DEMAND CALCULATIONS

Pressure irrigation demands in Highland City were estimated based on a remote sensing approach. The dataset that was used for this approach was the National Agricultural Imagery Program (NAIP) which is available through the Utah Automated Geographic Reference Center (AGRC). This approach allows for the identification of areas of healthy vegetation growth. Areas that received their water from other sources were subtracted out of the dataset to only include areas irrigated by the City's PI water system. The City's irrigated acreage was then converted over to demands and storage requirements based on the level of service established by the City.

PLANNING PERIOD AND ZONING

Rather than selecting a planning period (20 years, 30 years, etc.), Highland City selected a build-out development condition for the master planning effort. This approach eliminates consideration of time. Build-out was defined by establishing a typical irrigated acreage from an established neighborhood and applying that factor to areas that are expected to be developed and use the City's PI system in the future.

An area near Freedom Elementary School was chosen as a typical Highland neighborhood to estimate the future IA. The total area (including streets) was compared to the Infrared data to establish what percentage of the total area is being irrigated. The calculated IA for this neighborhood was 40%. This is the value that will be assumed for the future developments with the exception of the gravel pit on the east side of town which will be assumed to be 20% irrigated. Figure 3-1 shows the area that was analyzed to establish the typical irrigated acreage for estimating future demands.

Figure 3-1. Typical Irrigated Acreage Example

The following is a summary of the analysis:

Total Selected Area = 242624.1 m^2
Irrigated Area in Selected Polygons = 97770 m^2
Percentage of Area that is irrigated = 97770/242624.1 = 0.4 or 40%

An analysis was also performed to establish the average percentage of a lot that is irrigated based on ranges of lot sizes. This information assists in planning purposes and when proposed developments come in for approval the City is able to estimate the irrigation demand based on proposed lot sizes. Table 3-1 provides the range of lot sizes and the average percentage of the lot that is typically irrigated based on the data for Highland City.

TABLE 3-2
HIGHLAND CITY AVERAGE PERCENT IRRIGATED PER LOT SIZE

Lot Size Range (acres)	Average Percent Irrigated
0.15 - 0.25	39
0.25 - 0.4	45
0.4 - 0.6	50
0.6 - 0.8	50
0.8 - 1.3	50
1.3 – 2.0	50

IRRIGATED ACREAGE

To estimate irrigated acreage for Highland City a remote-sensing approach was employed using National Agricultural Imagery Program (NAIP) data from the Utah Automated Geographic Reference Center (AGRC). The dataset is delivered in four bands (red, green, blue, and near infrared) at 1-meter resolution. A method known as the Normalized Difference Vegetation Index (NDVI) was used to detect vegetated areas. Healthy vegetation with more chlorophyll reflects higher levels of near-infrared and green light. The NDVI can distinguish between areas of thick, healthy plant life vs. unhealthy and/or sparse plant life.

To accomplish this goal, the NDVI utilizes the red light band (RED) from an image and the near-infrared light band (NIR) of the same image to isolate areas of vegetation. The typical formula for the NDVI is:

$$NDVI=((NIR-RED))/((NIR+RED))$$

This formula produces values between –1 and 1. For this study, a commonly applied scaling factor was selected as follows:

$$Scaled\ NDVI=(NDVI+1)*127.5$$

The scaling factor removes negative values and establishes higher pixel values with broader ranges that are easier to work with in a geographic information system (GIS).

To correlate vegetated area to irrigated area, an appropriate cutoff pixel value was selected based on aerial imagery. The pixel value threshold that represented irrigated area for Highland City was about 150. Pixel values below the selected cutoff point were excluded from any of the calculations for irrigated acreage. The NDVI pixel data for an area within Highland City is shown as Figure 3-2.

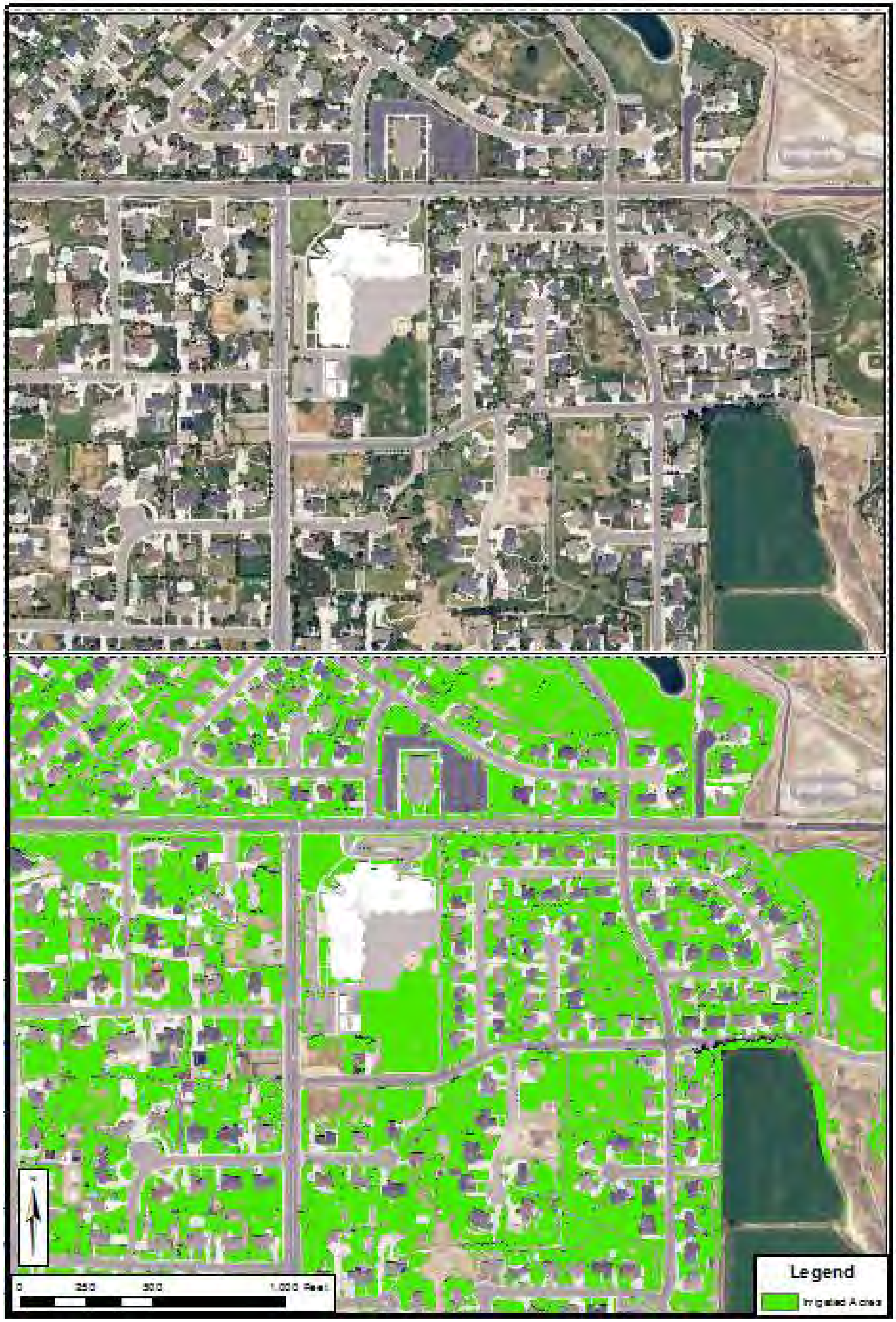

Figure 3-2. Example of NDVI pixels in Highland City

The final NDVI product is a raster dataset that includes pixels that are 1 meter square. GIS tools are capable of computing how many pixels there are in a given boundary. This allows for calculating irrigated acres based on a pixel count of the NDVI grid over a specified area.

Areas that were not watered by the City's PI system were screened out so that areas being irrigated by other sources were not included in the estimate of irrigated acres served by the City's system. The NAIP imagery that was used to produce the NDVI data was taken in the summer of 2016. Development that has occurred since then was included in the estimate of current irrigated acreage by using a typical percent irrigated and multiplying that by the area of the new developments. The typical percentage of irrigation over an area was established by drawing a boundary around a typical neighborhood and calculating how much of the total area is being irrigated.

Table 3-2 summarizes the total irrigated acreage for each pressure zone for the existing and future pressure irrigation system. This information has also been included on the existing and future system schematic diagrams (Figures 2-2 and 6-2, respectively).

TABLE 3-2
ESTIMATED IRRIGATED ACREAGE BY PRESSURE ZONE

PRESSURE ZONE	ESTIMATED IRRIGATED ACREAGE	
	EXISTING	FUTURE
View Pointe Pressure Zone	16.1	16.1
Upper Pressure Zone	280.5	330.8
Lower Pressure Zone	844.7	1,190.6
Beacon Hills Lower Pressure Zone	124.4	141.2
Beacon Hills Upper Pressure Zone	100.4	160.8
Hog Hollow Pressure Zone	25.4	25.4
TOTALS:	**1,391.5**	**1,864.8**

UNIT DEMANDS

Highland City has established a level of service that it will provide to each resident who is connected to the City's PI system. The level of service establishes how much source and storage each resident is allotted to use as well as how much of the cost of the system each connection should bear. The SCADA records of the City were analyzed to develop a reasonable level of service based on actual water use and plans for water conservation efforts. Table 3-3 details the established level of service for the City's PI system.

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TABLE 3-3
HIGHLAND CITY PI SYSTEM LEVEL OF SERVICE

DEMAND CATEGORY	HIGHLAND CITY REQUIREMENT
Annual Average Demand (ac-ft / irrigated acre)	5.17
Peak Day Demand (gpm / irrigated acre)	10
Peak Instantaneous Demand (gpm / irrigated acre)	20
Storage Volume (gallons / irrigated acre)	8,500

CHAPTER 4
SOURCE REQUIREMENTS

PEAK DAY DEMANDS

The source requirement for the pressurized irrigation system is equal to the peak day demand on the system. The existing and future peak day demands for each pressure zone were calculated based on the irrigated acreage and peak day requirement per irrigated acre included in Tables 3-2 and 3-3. Table 4-1 compares the peak day demand (source requirement) for each pressure zone in the existing and future system to the existing source supply.

TABLE 4-1
ESTIMATED PEAK DAY DEMAND BY PRESSURE ZONE

PRESSURE ZONE	PEAK DAY DEMAND (GPM)		SOURCE SUPPLY (GPM)
	EXISTING	FUTURE	
View Pointe Pressure Zone	161	264	(Provided by Drinking Water System)
Upper Pressure Zone	2,805	3,308	**16,050 gpm (August) to 25,450 gpm (June)**
Lower Pressure Zone	8,447	11,906	
Beacon Hills Lower Pressure Zone	1,244	1,412	
Beacon Hills Upper Pressure Zone	1,004	1,608	
Hog Hollow Pressure Zone	254	254	
TOTALS:	**13,915**	**18,751**	**16,050 - 25,450**

SOURCE EVALUATION AND RECOMMENDATIONS

Existing pressurized irrigation sources for Highland City have been summarized in Table 2-1 and are shown on Figures 2-1 and 2-2. Comparison of the total source capacity in the system with the total peak day demand reveals that Highland City has sufficient total source capacity for existing conditions however lacks capacity for future during the late irrigation month when the AF River sources decrease. However, all of these sources initially enter the system in the Lower Pressure Zone. Therefore, source requirements for all of the other pressure zones must be satisfied by booster stations. The source capacity for the Northwest Area is near the existing peak day demand and could not sustain buildout within the upper zones. The existing source capacity does not provide for redundancy. An evaluation of existing booster stations is included in the distribution system analysis in Chapter 6.

The View Pointe pressure zone is located north of the Upper Pond and is significantly higher in elevation. This pressure zone is disconnected from the pressure irrigation system and does not have a source of irrigation water. The irrigation demands are currently served by the City's drinking water system. One option for providing irrigation water to the View Pointe subdivision is to install a booster station and pipeline from the Upper Pond to the subdivision. However, because of the small size of the subdivision, Highland City decided that the expense of a booster station and pipeline was too great for the benefit it would provide. Therefore, outdoor watering needs of the View Pointe subdivision will continue to be served by the drinking water system.

CHAPTER 5
STORAGE REQUIREMENTS

STORAGE DEMANDS

The existing and future storage demands for each pressure zone were calculated based on the irrigated acreage and the storage requirement per irrigated acre included in Tables 3-2 and 3-3. Table 5-1 compares the storage demand for each pressure zone in the existing and future system to the existing storage capacity. As is illustrated in Figure 2-2, the Upper Pond provides storage for both the Upper and the Lower pressure zones. Similarly, the NW Area Pond provides storage for the Beacon Hills Upper and Lower Pressure Zones, the Hog Hollow Pressure Zone, and the future NW Area Upper and Lower Pressure Zones. The Lower Pond provides storage for the Lower Pressure Zone only.

TABLE 5-1
STORAGE DEMAND BY PRESSURE ZONE

	STORAGE DEMAND (AC-FT)		
PRESSURE ZONE	**EXISTING**	**FUTURE**	**STORAGE CAPACITY (AC-FT)**
View Pointe Pressure Zone	0.4	0.4	Within Drinking Water System
Upper Pressure Zone	7.3	8.6	0.4 – Drinking Water System 26.0 - Upper Pond 5.4 - Lower Pond
Lower Pressure Zone	22.0	31.1	
Zone Total:	**29.7**	**40.1**	**31.8**
Beacon Hills Lower Pressure Zone	3.3	3.7	
Beacon Hills Upper Pressure Zone	2.6	4.2	
Hog Hollow Pressure Zone	0.7	0.7	19.0 - NW Area Pond
Zone Total:	**6.6**	**8.5**	**19.0**

STORAGE EVALUATION AND RECOMMENDATIONS

Existing storage ponds in the pressurized irrigation system are summarized in Table 2-2. Comparison of the existing storage capacity to the future storage demands reveals that Highland City will be deficient at buildout in the Lower Pressure Zones.

The View Pointe subdivision is not connected to the pressure irrigation system. Storage for irrigation demands is provided by the 250,000 gallon tank connected to the drinking water system. As discussed in Chapter 4, this subdivision will continue to be served by the drinking water system. It should be noted, however, that the storage tank supporting this development is smaller than would be typically provided for this size of subdivision, when considering both indoor and outdoor service. The estimated storage needed is 285,000 gallons. It is recommended that Highland City closely monitor water use, tank performance and irrigated area developed for the View Point Subdivision to determine whether and when additional storage capacity is needed.

CHAPTER 6

DISTRIBUTION SYSTEM REQUIREMENTS

The pressurized irrigation distribution system was evaluated by its ability to convey water under peak instantaneous demands. Highland City desires to maintain system pressures between 50 psi and 120 psi. Evaluation of the distribution system required development of a hydraulic model of the existing and future pressure irrigation systems. This chapter documents the development of the model. Solutions to the identified deficiencies in the existing and future distribution systems are also provided.

PEAK INSTANTANEOUS DEMANDS

The existing and future peak instantaneous demands for each pressure zone were calculated from the irrigated acreage and the peak instantaneous requirement per irrigated acre included in Tables 3-2 and 3-3. Table 6-1 identifies the peak instantaneous demands for each pressure zone.

TABLE 6-1
ESTIMATED PEAK INSTANTANEOUS DEMAND BY PRESSURE ZONE

PRESSURE ZONE	ESTIMATED PEAK INSTANTANEOUS DEMAND (GPM)	
	EXISTING	FUTURE
View Pointe Pressure Zone	322*	322*
Upper Pressure Zone	5,610	6,615
Lower Pressure Zone	16,894	23,811
Beacon Hills Lower Pressure Zone	2,488	2,825
Beacon Hills Upper Pressure Zone	2,008	3,215
Hog Hollow Pressure Zone	508	508
ROUNDED TOTALS:	**27,830**	**37,297**

* View Pointe peak instantaneous demands are not included in the total because this pressure zone is served by the drinking water system.

DISTRIBUTION SYSTEM MODELING

The hydraulic model of the distribution system was initially developed by HAL using EPANET software. The primary elements of the model are pipes and nodes. The pipe elements store physical attributes of the actual pipeline such as length, diameter, and roughness. Variables such as flow, velocity, and headloss are calculated on these elements. Node elements serve as point locations where two pipe elements are joined and store point information such as elevation and demand. The system head or pressure is computed at each node in the model. Other model elements used in the computer model include reservoirs, pumps, and valves which simulate the effect of these features upon the network of pipes and nodes.

The model was updated to include pipelines constructed over the past 10 years. Additional information was provided by system operators during master plan meetings. Node elevations were estimated based on the City's 2-foot interval surface contours. The remote sensing approach discussed in Chapter 3 was used to allocate irrigated acreage demands to the model nodes. Demands and irrigated acreage were assigned based on the nearest nodes within the model network.

EXTENDED PERIOD SIMULATION

The previous master plan modeling effort utilized a steady state model that was used to evaluate "worst case" or peak instantaneous demands on the system. The modeling effort for this master plan update included a conversion of the model to an extended period model. An extended-period model represents system behavior over a period of time: ponds filling and draining, pumps turning on or off, pressures fluctuating, and flows shifting in response to demands. A peak day extended period model can be used to identify zone to zone water transfers, analyze system controls, and the general system performance over time.

SYSTEM CURVE

A key element to extended period simulations is a representative system curve that defines the demand pattern experienced by the system. The system curve for the Highland system was developed based on SCADA data from the Hog Hollow pump station. The curve was modified slightly to achieve a reasonable peaking factor of 2.0. The system curve is shown in Figure 6-1 with time zero representing midnight.

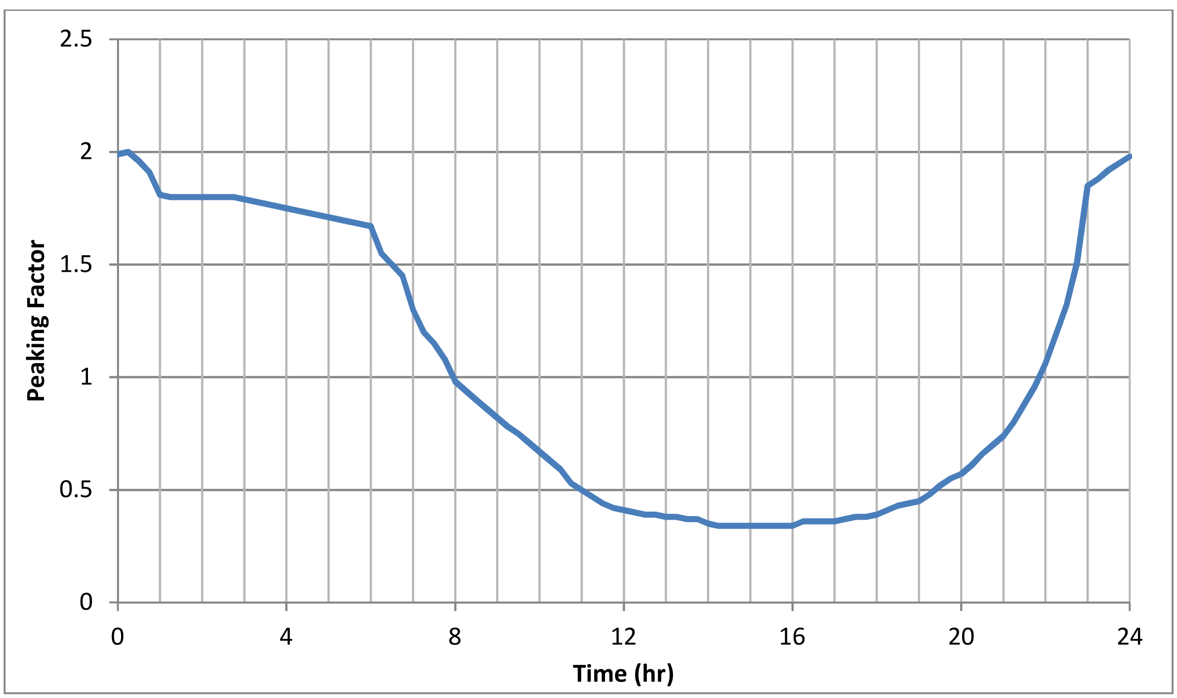


Figure 6-1. Highland City Demand Pattern for Pressurized Irrigation Use

DISTRIBUTION SYSTEM CALIBRATION

The calibration scenario was developed to determine the validity of the assumptions made during development of the computer model. SCADA data was utilized to compare actual system pressures at the pump stations with model pressures and general trends in pond elevations. These comparisons throughout the system showed the model reproduced the actual conditions in the system with reasonable accuracy. Therefore, the system curve and demand allocations used in the model were found to be a reasonable representation of the demands experienced by the system during peak day conditions.

EXISTING DISTRIBUTION SYSTEM EVALUATION

The existing system scenario was developed to evaluate the existing distribution system for deficiencies. This scenario was developed by imposing the existing peak instantaneous demands from Table 6-1 on the model with the existing system sources operating as they would during the peak demands in the summer time. An area of the distribution system was considered to be deficient if the system pressure was less than about 40 psi or greater than about 120 psi.

Figure C1, which provides predicted pressure contours has been prepared. The predicted contours are based upon the system peak demand results and provide a guide of existing system pressures. While the contours are expected to be generally correct, there may be isolated areas within the existing distribution system which vary from the pressures shown. Figure C1 is provided in Appendix C.

Performance of booster stations was also evaluated in the distribution system analysis for pressure zones that are completely dependent upon booster stations for their source of water. This included the Upper Pressure Zone, the Hog Hollow Pressure Zone, the Beacon Hills Upper and Lower Pressure Zones. Each booster station was evaluated based on peak instantaneous demand unless it pumped into a storage pond in which case it was evaluated based on peak day demands. Table 6-2 summarizes the capacities of booster stations relative to the existing and future peak instantaneous or peak day demands. This comparison reveals that the existing booster stations have sufficient capacity for existing conditions.

TABLE 6-2
BOOSTER STATION EVALUATION

BOOSTER STATION	PRESSURE ZONES SERVED	CAPACITY (GPM)	CRITICAL DEMAND (GPM)	
			EXISTING	FUTURE
Upper Booster Station	Upper Pressure Zone	6,000	Peak Instantaneous	
			5,610	6,615
11800 North Booster Station	Beacon Hills Upper, Beacon Hills Lower, and Hog Hollow	2500	Peak Day	
			2,502	3,274
Hog Hollow Booster Station	Hog Hollow Pressure Zone	690	Peak Instantaneous	
			508	527

BOOSTER STATION & SOURCE REDUNDANCY

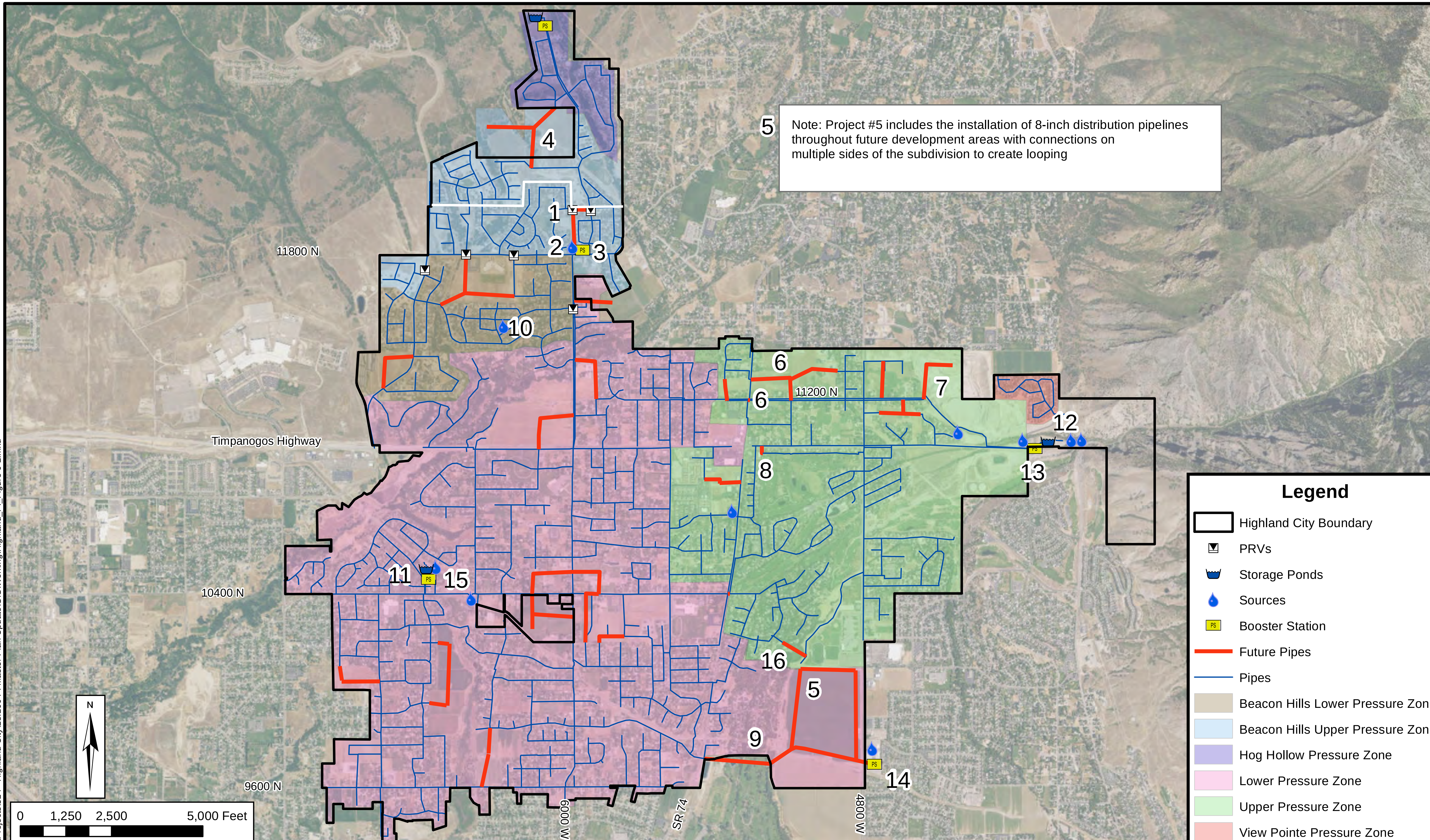
Highland City has evaluated the need, level and types of booster station redundancy desired in the pressurized irrigation system. The level of redundancy refers to a booster station's ability to continue providing service during conditionals of mechanical failure or unanticipated demand. With no redundancy, a pump station will be unable to meet full demand during a mechanical failure. The City would like to utilize the following redundancy: multiple pump stations with excess capacity serving the same area, an additional pump within a pump station that can be activate during a failure, or stocking key components which can be installed within a short time period after a failure.

The booster station capacities provided in Table 6-2 are for total pumping capacity (except for the Hog Hollow Booster Station which has an additional 345 gpm pump beyond the value shown). No redundancy has been included in the table. After the drought conditions of 2018 the City determined to provide additional sources of water that would utilize 'storage shares' from the Murdock Canal. The City in the past was able to utilize excess capacity through the CUP aqueducts to access shares typically conveyed in the Murdock Canal. However, after discussion with CUWCD the excess capacity will likely not be available through the summer during dry years. New development and their demands will require additional capacity at the Murdock Canal along with new well capacity for the northwest upper zones to access municipal ground water rights.

Table 6-3 includes a description of the identified deficiencies in the existing distribution system. Solutions to the deficiencies are also included in this table and are also shown on Figure 6-2 by identification number.

TABLE 6-3
EXISTING SYSTEM PROJECT

ID #	LOCATION	PROBLEM DESCRIPTION	RECOMMENDED SOLUTION
1	North of 11800 – System Piping	Current boundary between the Beacon Hills Upper and Lower Pressure Zones results in pressures exceeding 120 psi in this area of the Beacon Hills Upper Pressure Zone.	Adjust pressure zone boundary by doing the following: · Install a 16-inch I.D. transmission line from the 11800 N Booster Station north along the utility corridor to Chamberry Way and replace a section of existing 8-inch pipe at the intersection of Beacon Hill Blvd and Century Heights Dr. · Install new dual PRV vault on the existing 18-inch dia. pipeline just south of Century Heights Dr on Beacon Hill Blvd. & smaller PRV on Chamberry Way. · Open/close zone valves.



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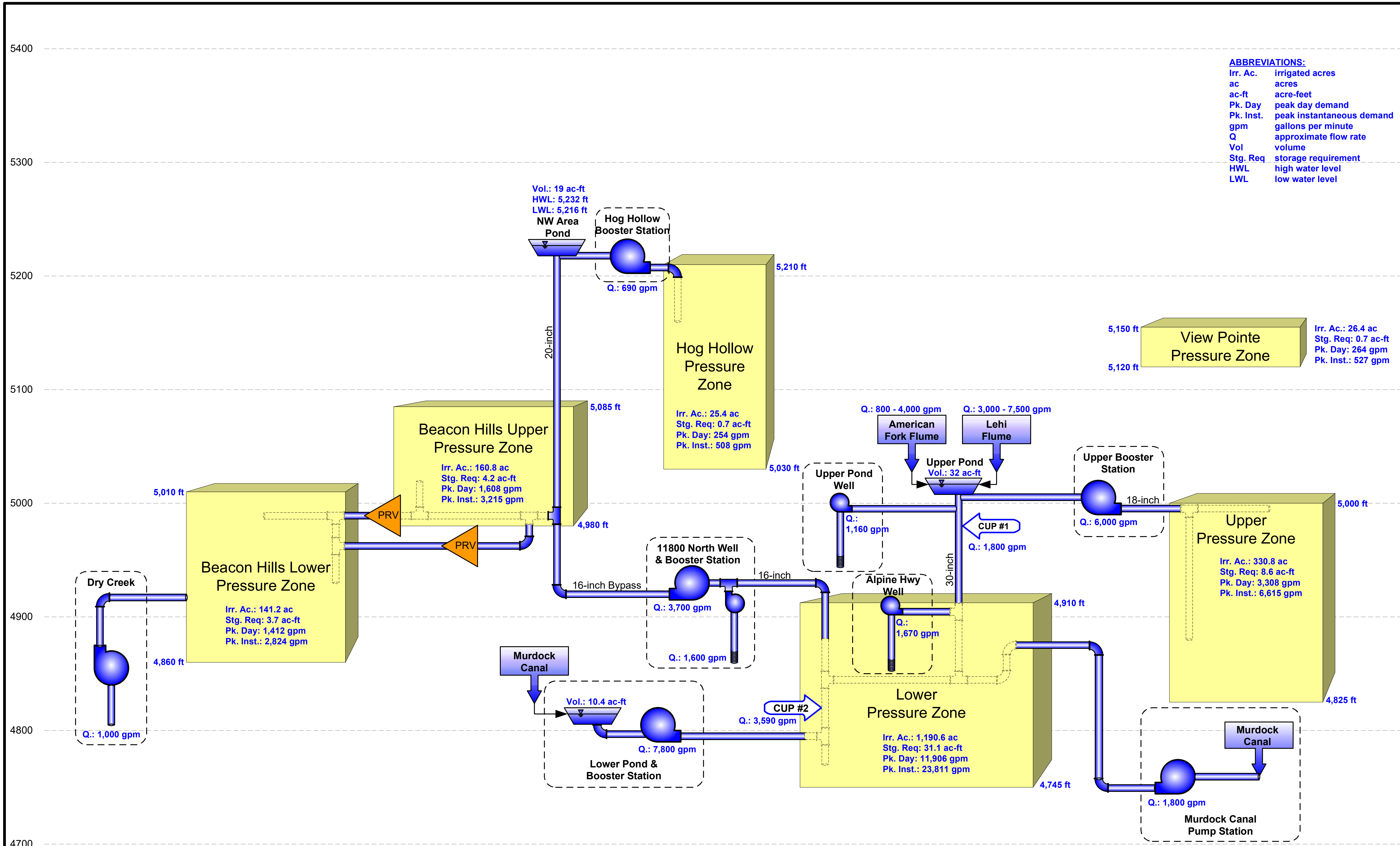
HANSEN ALLEN & LUCE INC ENGINEERS

Highland City
Pressurized Irrigation System Master Plan

Future Pressurized Irrigation System and Capital Improvements

FIGURE 6-2



HANSEN ALLEN & LUCE inc ENGINEERS

HIGHLAND CITY
PRESSURE IRRIGATION SYSTEM MASTER PLAN

FUTURE SYSTEM SCHEMATIC DIAGRAM

FIGURE 6-3

BUILDOUT SYSTEM EVALUATION

The buildout system scenario was developed to evaluate the performance of the existing distribution system with future peak instantaneous demands from Table 6-1 imposed on the system. The peak instantaneous demand for each undeveloped area within the proposed future service area was applied to a new node at the highest elevation within the undeveloped area. No attempt was made to identify actual final pipeline locations through these undeveloped areas in the computer model. Instead, conceptual pipelines were placed in the model from nodes on the larger existing pipelines adjacent to each undeveloped area to the new node for that area. Undeveloped areas along with their new nodes and conceptual pipelines are shown on Figure 6-2.

Figure C2, which provides predicted future pressure contours, has been prepared. The predicted contours are based upon the system peak instantaneous model results and provide a guide of future system pressures. While the contours are expected to be generally correct, there may be isolated areas within the future distribution system which vary from the pressures shown. Figure C2 is provided in Appendix C.

The future system scenario model was used to identify deficiencies in the system under future peak instantaneous conditions. Table 6-4 includes a description of the identified deficiencies in the future system along with proposed solutions for each deficiency. Proposed solutions are also identified on Figure 6-2 by the identification number included in Table 6-4. Figure 6-3 is a schematic representation of the future pressurized irrigation system after implementation of the proposed solutions in Tables 6-3 and 6-4.

TABLE 6-4
FUTURE SYSTEM PROJECTS

ID #	LOCATION & TYPE	PROBLEM DESCRIPTION	RECOMMENDED SOLUTION
2	11800 Well – Source	Increase capacity of well through additional development	· Increase source capacity for new development in the Northwest.
3	Beacon Hills Zones - Source	Future peak day demand in these pressure zones is greater than the capacity of the 11800 North Booster Station.	· Expand the 11800 North Booster Station to a future capacity of at least 3,700 gpm.
4	Beacon Hills Upper Pressure Zone – System Piping	No connection to existing 12 inch line coming off main 20 inch transmission line at the north end of pressure zone.	· When this area develops, continue 12 inch line through development to connect into existing 10 inch line. Also extend an additional line to the west to serve undeveloped area. By Developer.
5	Undeveloped Areas throughout the City – System Piping	No distribution pipelines exist in undeveloped areas.	· Install 8-inch distribution pipelines throughout areas as they develop. Connect to existing pipelines on multiple sides of the subdivision to

			create looping throughout each area to be developed.
6	11000 N to 11400 N & 5200 W to 5400 W – System Piping	Friction losses through non-looped pipelines to this area results in pressures below 50 psi during future peak instantaneous conditions.	· Connect 8-inch diameter pipelines across Alpine Hwy along 11200 N. · When the area north of 11200 N between 4900 W and Alpine Hwy develops, require looping throughout subdivision with 8-inch pipelines.
7	11000 N to 11400 N & 4400 W to 4800 W – System Piping	Limited distribution capacity to this area results in pressures below 50 psi during future peak instantaneous conditions.	· Provide looping throughout new development in this area with 8-inch pipelines.
8	5250 W from 10700 N to 11000 N – System Piping	Limited distribution capacity through 6-inch distribution line along 11000 N results in excessive pressure losses in this area.	· Connect the 6-inch pipeline that runs along the back of homes on the south side of 11000 N to the existing pipeline at 10970 N 5250 W.
9	Developmental Center Property – Source & System Piping	Transmission lines in the Lower Pressure Zone to the west of this area do not have sufficient capacity to serve this area when developed.	· Install 12-inch pipeline from Alpine Hwy to Murdock Canal with the Canal Blvd project. The project is requirement for the new development.
10	Near Dry Creek Bench Park - Source	Additional source needed in Beacon Hills Lower Pressure Zone	· Drill a new well to provide additional source in the upper pressure zones. It is anticipated this new well will provide between 1,000 - 1,500 gpm. · The well will require a VFD · During low demands a newly constructed pressure relief valve will allow water to enter into the Lower Zone.
11	Lower Pond Expansion – Storage	Increase capacity of Lower Pond for Future Development	· Expand Existing Pond by 5.0 Ac-ft
12	Upper Pond Expansion – Storage	Increase capacity of Upper Pond for Future Development	· Expand Existing Pond by 3.7 Ac-ft
13	Upper Pump Station - Source	Future peak demand in the pressure zone is greater than the capacity of the Booster Station.	Increase the Upper Booster Station to a future capacity of at least 6,600 gpm.
14	Murdock Canal PS @ State Property – Source & Piping	Additional source and transmission line at the southeast corner of the City. The pump station will boost water from the Murdock Canal into the lower zone. The 12-inch	Construct a new pump station near the existing turnout for the property (4 cfs capacity). PRWUA has an existing turnout vault. · Provide 12-inch transmission line

		transmission line will provide source into and out of the area.	
15	Lower Pump Station Upgrade - Source	The existing source capacity of 8 cfs is not sufficient for buildout or when CUWCD no longer has capacity to convey Provo Water shares. PRWUA has reviewed turnout capacity and believes they can provide up to 16 cfs at the location.	Construct a new pump station above grade that has capacity for 16 cfs. PRWUA has an existing turnout vault.
16	Highland Glen Transmission Line - Distribution	Limited distribution capacity in this area results in large pressure swings. An 8-inch transmission line from Knight Avenue to the Highland Glen system will assist with the pressure swings.	Construct an 8-inch line from the Knight Avenue line to the Highland Glen PI Main.

ADDITIONAL RECOMMENDATIONS

In addition to the recommended improvements otherwise provided, we recommend that the City consider the following:

- Smart Irrigation Controllers: These devices monitor weather conditions continuously and adjust irrigation sprinkling based upon need. The smart controllers may receive data from an on-site weather station, or may receive weather data from data providers via the phone or internet. Many water providers have established incentive programs to assist water users with start-up costs. Smart Irrigation Controllers may help reduce water consumption through conservations.

- Water Meters: Currently, Highland City does not meter irrigation water use. Water users do not have a financial incentive to limit water use to their needs. The use of water meters has been shown to increase water conservation.

APPENDIX A

WATER SOURCE INFORMATION & MEMORANDUM

MEMORANDUM

DATE:	July 10, 2019
TO:	Highland City Engineering 5400 West Civic Center Dr., Suite 1, Highland, Utah 84003
FROM:	Tavis B. Timothy, P.E. Hansen, Allen & Luce, Inc. (HAL) 1045 South 500 East, Suite 110 American Fork, Utah 84003
SUBJECT:	Water Rights & Shares
PROJECT NO.:	314.05.117

INTRODUCTION

At the request of Highland City, Hansen, Allen, & Luce, Inc. (HAL) has performed an analysis of the City's water rights and shares for both Drinking Water and Secondary Water. The intent of the memo is to provide background information to allow for informative City policies related to water sources and their use.

WATER SYSTEM'S BACKGROUND

Drinking Water System

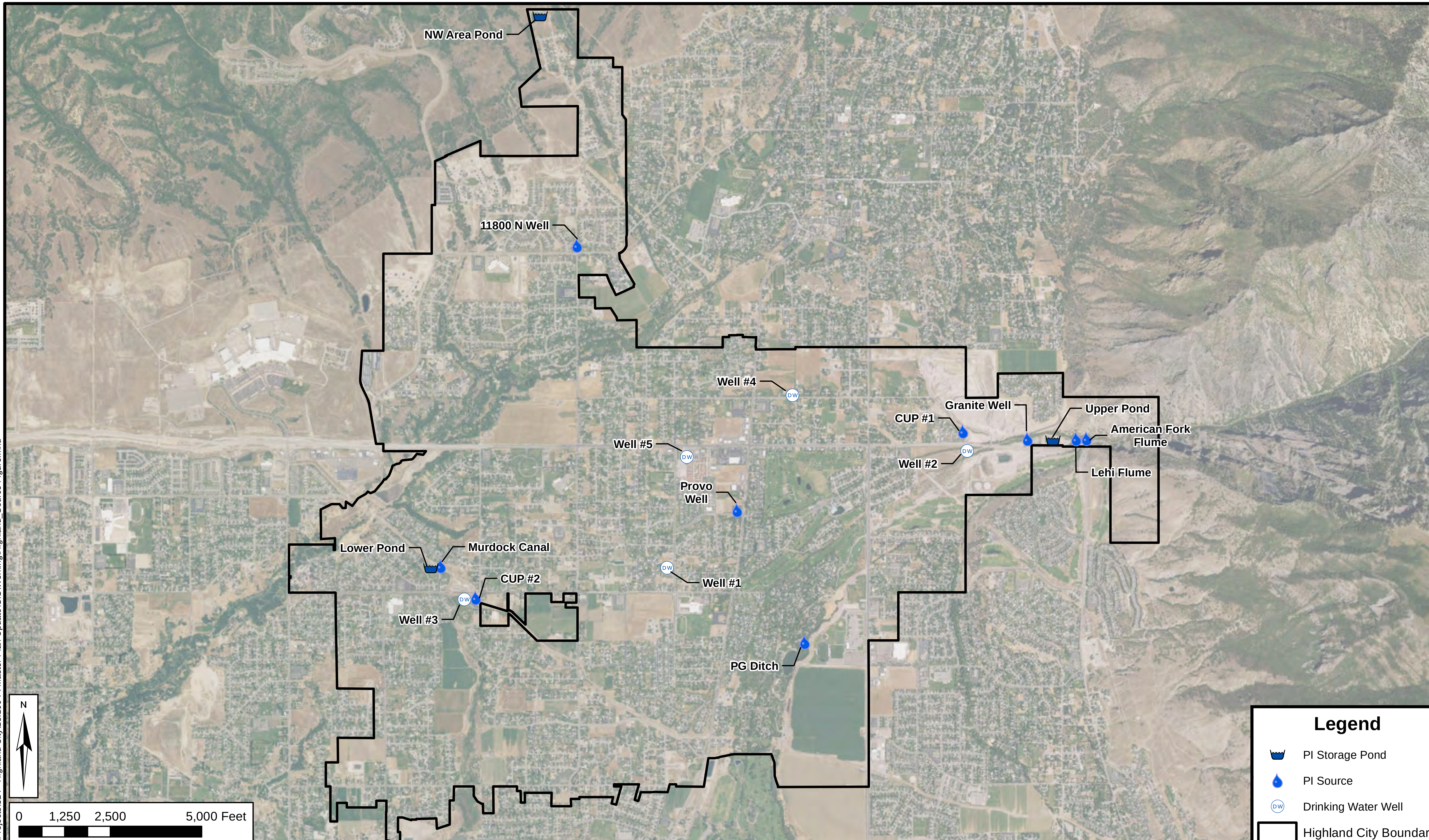
Construction of the drinking water (DW) system began in 1958 to provide drinking water. The Highland Water Company was established to acquire water rights, and own and operate the system. During the Fall of 2004 the membership of the Water Company voted to dissolve the Company and transfer all assets and obligations to Highland City. Since 2005, the City has operated and maintained the drinking water system. The system is comprised of five wells, four tanks, two booster pump stations and miles of water lines.

Pressurized Irrigation System

Construction of the pressurized irrigation (PI) system began in 1997 to provide outdoor water for residents of the City. The system is comprised of three wells, three reservoirs, four booster pump stations and miles of water lines.

EXISTING WATER SOURCES

The City utilizes numerous water sources for their PI System and uses wells exclusively for their DW System (see Figure 1). Table 1 lists the groundwater rights associated with the well sources and Table 2 summarizes the City's surface water shares. The volumes provided in the tables are a full allocation. During drought conditions the actual allocation will be less. Table 6 and the ensuing write up (at the end of the memo) provides a brief summary for each of the water sources, their relevant share allocation, capacity and location.



HANSEN ALLEN & LUCE INC ENGINEERS

Highland City
Water Source Analysis

Existing Water Source Locations

FIGURE 1

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TABLE 1
HIGHLAND CITY WATER RIGHTS SUMMARY (5-1-18)

Water Right Number	Approved points of Diversion	Status	Beneficial Use	Flow cfs	Volume ac-ft	Irrigation Company Shares	Comments
55-751 (a31084)	8 City Wells	Approved	Municipal	10	2000		Proof submitted in Oct. 2017
55-908 (a31084)	8 City Wells	Approved	Municipal	4.2	1200		
55-1018 (a5260)	Provo Well	Certificated	Irrigation	3.75	685		Sole supply for right has not been quantified. Jm Riley indicated largest volume pumped historically from well is 685 ac-ft
55-1424, 55-3829, 55-4184, 55-4678, 55-7741 all included under a28710	Westfield Road Well	Approved Non-Use	Municipal		117.564		
55-1636 (a22423)	Provo Well	Approved	Municipal	0.304	40		
55-2081 (a22423)	Provo Well	Approved	Municipal	0.011	3.84		
55-6054 (a31084)	8 City Wells	Approved	Municipal	2	192		Proof submitted in Oct. 2017
55-9341 (a28180)	11 wells, including Granite and Westfield Road	Approved	Municipal		121	East Jordan 25 shares	
55-9453 (a26314)	Granite Well	Approved	Municipal		290.4	East Jordan 60 shares	
55-9656 (a26306)	Granite Well	Approved	Municipal		39.35	Field-Little Dry Creek WUA 5 shares	

Water Right Number	Approved points of Diversion	Status	Beneficial Use	Flow cfs	Volume ac-ft	Irrigation Company Shares	Comments
55-9707 (a31083)	8 City Wells	Approved	Municipal		288.99	South Jordan 58.5 shares	
55-9708 (a27167)	Granite Well, Beacon Hill Area	Approved	Municipal		694.07	South Jordan 140.5 shares	
55-11898 (a27836)	Granite Well	Approved	Municipal		41.14	East Jordan 8.5 shares	
55-12283 (a33000)	Unnamed Spring & 8 City Wells	Approved	Municipal		52		
55-9284 (a21958)	9 City Wells	Approved	Municipal		96.8	East Jordan 20 shares	Alpine Valley provided shares for Highland Hills, WR need segregated and placed in City name
55-11962 (a28534)	11800 Well	Lapsed	Municipal		275.94	Utah Lake Dist. 54 shares	Evan Johnson provided shares in 2004, WR has lapsed due to not filing extension and WR not placed in City's name.
TOTAL					6,138.094		
TOTAL APPROVED FOR MUNICIPAL USE					5,862.154		

TABLE 2
Surface Water Shares Summary - (5-1-2018)

Irrigation Company	# of Shares	Estimated Volume ac-ft/share	Estimated Volume ac-ft	# Shares in Ground Water Rights	Volume Tied to Water Rights	Remaining Volume	Assessment Cost Per Share	Assessment Cost Per ac-ft	Delivery Cost Wheeled	Delivery Cost Pumped	Total Surface Water Cost/Ac-ft	Background/Description
Alpine Irrigation Company	2	4	8			8	1.5	0.4			$0.38	Alpine Irrig. Is not able to enter the system due to location or turnout.
American Fork Irrigation Company	1229.03	2	2458.06			2458.06	22	11			$11	American Fork River source at mouth of Canyon.
East Jordan Irrigation Company	113.5	4.84	549.34	113.5	549.34	0						Utah Lake Irrigation Company, surface rights were changed to groundwater rights.
Fort Field Little Creek Water Users	5	7.87	39.35	5	39.35	0						Surface water was converted to groundwater rights
Highland Conservation							49	49	37	25	$86 - $74	
A Shares	31.575	1	31.575			31.575						Provo river system water delivered thruogh the Murdock Canal and a turnout at the lower pond.
B Shares	2010.675	1	2010.675			2010.675						CUP will deliver water through pressurized aqueduct with a wheeling fee.
D Shares	76.175	0.9	68.5575			68.5575						
Total Shares as reported by HC (3-28-18)	2118.425											
Lehi Irrigation Company	963.15	2	1926.3			1926.3	40	20			$20	American Fork River source at mouth of Canyon.
Pleasant Grove Irrigation Company	333.863	1.7	567.5671			567.5671	50	29			$30	American Fork River source at mouth of Canyon.
Provo Reservoir Water Users Association												
												Provo river system water delivered thruogh the Murdock Canal and a turnout at the lower pond.
Full Shares	238.633	4	954.532			954.532	50	12.5	37	25	$50 - $38	CUP will deliver water through pressurized aqueduct with a wheeling fee.
C Shares	106.97	0.4	42.788			42.788						
Late Shares	227.183	2.5	567.9575			567.9575	50	20	37	25	$57 - $45	
C Shares	194.35	0.25	48.5875			48.5875						
South Jordan Canal company	199	4.94	983.06	199	983.06	0	46	9				Utah Lake Irrigation Company, surface rights were changed to groundwater rights.
Utah Lake Distribution *	54	5.11	275.94	54	275.94	0	20	4				Utah Lake Irrigation Company, surface rights were changed to groundwater rights.
Winn Ditch Irrigation Company	463.5	0.06	27.81			27.81						
Pheasant Hollow	60				$							Shares were transferred by Pheasant Hollow Irrigation Company.
CUP	415	1	415			415	176	176			$176	City's share of CUP water available each year.
ESTIMATED TOTAL	8842.029		10975.0996		1847.69	9127.4096						
TOTAL (Excluding Utah Lake Distribution)						8851.4696						

Approximately 630 Acre*Feet of Water is Leased by City in 2018 (Assuming Full Allocation)

The City Purchased approximately 620 Acre*Feet of Water since 1997

*Ground water right change application associated with these shares lapsed. City coordinating on approvals with DWR.

Water Source Annual Use

Water source use for the PI System changes each year and depends on availability of the different sources which are directly impacted by snow pack. However, the sources for the DW System are fairly similar year after year. Figure 2 provides the amount of water sources utilized each year for the PI System and Figure 3 provides volumes for the DW System.

Cost of Each Water Source

The water sources vary in their costs. The more expensive water sources require pumping into the system and have more expensive yearly assessments. Table 3 provides the cost range for each of the water sources. Specific costs are provided in Table 4 for surface water shares.

Table 3
Approximate Source Costs per Acre-Feet

Source	Cost per AF
American Fork River	$11-$30
Provo River via Murdock Canal (Pumped by City)	$38-74
Provo River via CUWCD Aqueduct	$50-$86
CUP Water	$176
Provo & Granite Wells	$65-$75
11800 Well	$120-$150
DW Wells	$90

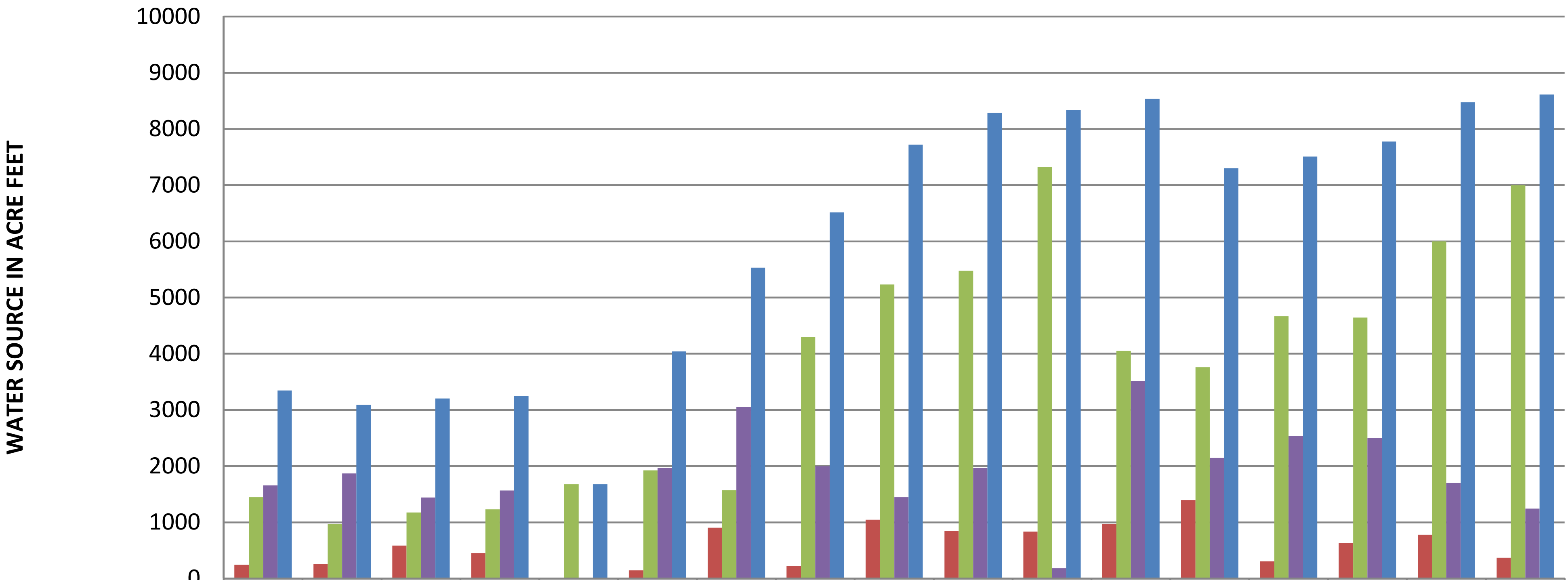
Water Share Rentals

To supplement the City's water resources, each year, the City has rented water shares from residents. The City pays for the share assessment and $10 per share. Table 4 provides the number of shares rented in 2018 and the cost per acre*feet (AF) of the rented water from the various surface water sources.

Table 4
2018 Rented Water & Costs

Shares	Shares Rented	Total AF Rented	Cost per AF
American Fork Irrigation	23.44	46.88	$16
Lehi Irrigation	202	404	$26.25
Highland Conservation	106.85	106.85	$59
Provo Res - Full	24.83	99.32	$24
Provo Res - Late	27.5	68.75	$15.25

Figure 2 - Highland City Annual PI Sources



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Well Total	245	256	586	454	0	146	906	222	1,048	842	834	968	1,394	307	634	777	370
Total AF/LEHI Irr	1,446	970	1,177	1,230	1,674	1,924	1,568	4,296	5,231	5,477	7,321	4,048	3,762	4,665	4,643	6,000	7,002
CUP/DEER CREEK	1,656	1,868	1,441	1,568	0	1,969	3,057	1,999	1,445	1,971	180	3,519	2,145	2,537	2,502	1,700	1,243
TOTAL	3,347	3,094	3,204	3,252	1,674	4,039	5,531	6,517	7,724	8,290	8,335	8,535	7,301	7,509	7,779	8,477	8,615

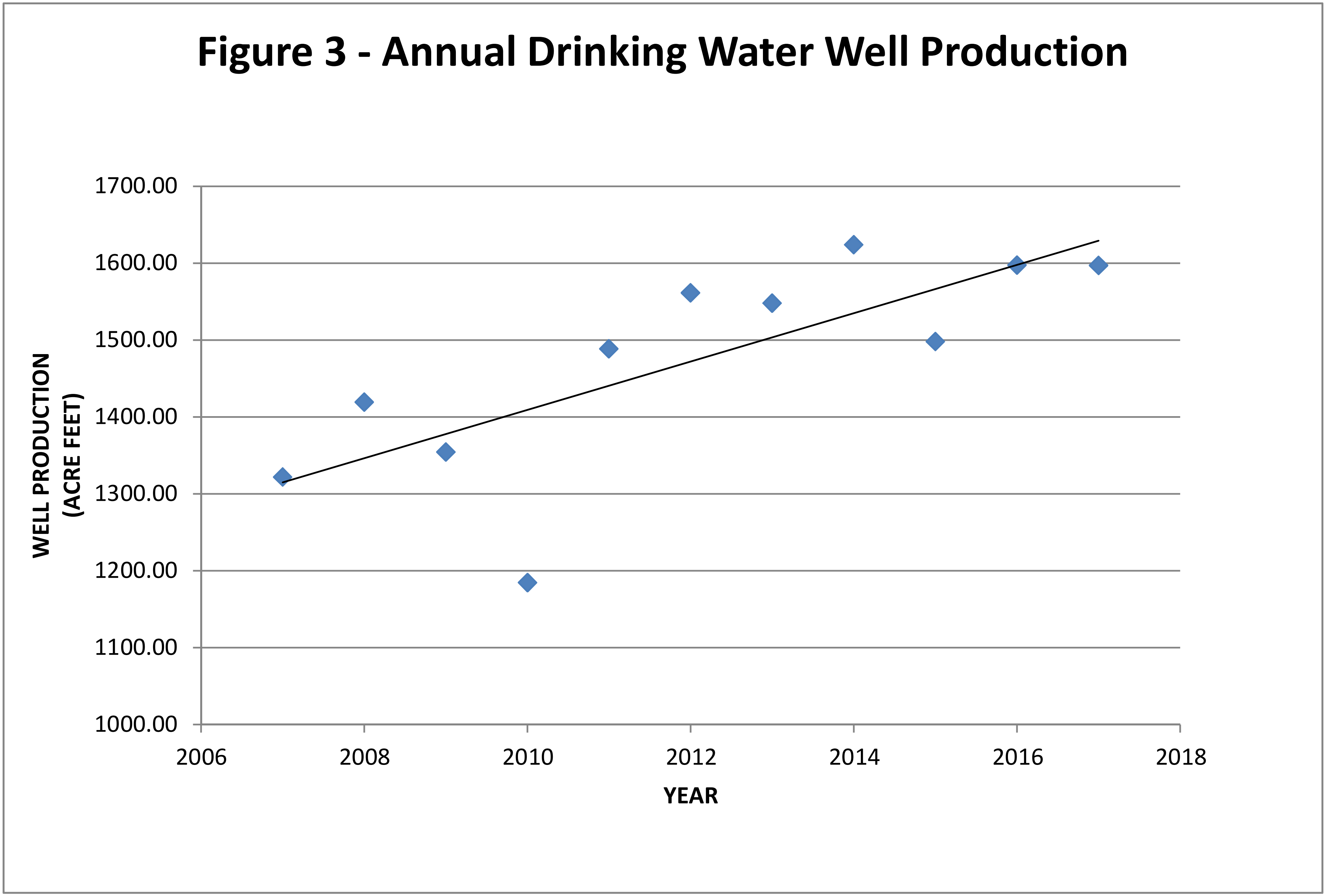


Figure 3 - Annual Drinking Water Well Production
WELL PRODUCTION
(ACRE FEET)
1700.00
1600.00
1500.00
1400.00
1300.00
1200.00
1100.00
1000.00
2006
2008
2010
2012
2014
2016
2018
YEAR

FUTURE WATER SOURCES & DEVELOPMENT

Development of raw ground requires that the property owner convey water shares or rights to the City. The requirement is 3 AF per acre of ground being developed and 1 AF per acre of ground if the area was not in Highland Water Company's service area.

ANALYSIS

Water Use

Recent metering analysis has determined that the City utilizes approximately 12 gpm per irrigated acre during the summer months. This average is twice the amount of metered systems. The capacity of the sources and the transmission lines are not sufficient to provide this amount water during buildout. A minimum reduction of 20% to 10 gpm per irrigated acre would assist the systems operations.

Average Water Year

During an average water year when the American Fork System provides adequate water throughout the summer it is beneficial to utilize first the water from the Canyon. In 2017 the City utilized AF River water as 81% of its total PI water use. The Provo System contributed 14% with wells the remaining 5% of the PI systems total water use. Utilizing the AF River provides the lowest cost for the City as it allows for less pumping and conveyance costs.

Drought Conditions

During drought conditions the current plan for the City is to utilize as much surface water as possible and supplement through groundwater. A surface water reduction will require more use from the costly PI wells. During the low water years of 2012 & 2013 the City's AF River source was only 50% of PI water use, compared to 2017's 81%. The Provo System contributed 35% with groundwater the remaining 15% for these less than average years.

Reservoir Stored Water

Water shares originating from the Provo System can be saved and 'carried over' in subsequent years assisting with drought conditions lasting a single year. Droughts consisting of multiple years will not receive the benefit of previous saved shares.

Ground Water Rights

The City currently has 5,765 af of groundwater rights for indoor and outdoor use. These rights are typically not affected by below average yearly precipitation. The total City water use for 2017 was 10,212 af. During a normal year the City uses roughly 2,000 af of groundwater while in 2012 (highest recent well extraction) the City utilized 2,950 af of groundwater. The City's master plan and 40 year water rights plan provides that there is sufficient groundwater through buildout. Extraction of the water through wells is more costly than other sources.

AF Canyon water vs Stored Water (Provo System)

The City currently has 4,987 af of AF Canyon water versus 4,014 af of Provo stored water. Of the Provo stored water 415 af is from CUP and must be taken each year and may not be saved. The remaining Provo water can be saved and stored for a future year if conditions allow. The condition that allows is if Deer Creek Reservoir does not reach maximum level and does not spill.

AF Canyon water has relatively minor storage at Tibble Fork and Silver Lake. These small reservoirs do not provide a great deal of storage through the end of June in a drought year. AF Canyon water is abundant during the spring and early summer and then lessens during late summer. During low snowfall years the decrease is substantial and often inconsequential during the late summer months. See Figure 4 that provides the recent flow data for the AF River. As shown in the graph 2017 provide at least 40 cfs through August 15 while 2012 provided 40 cfs only to July 17 and then provided only minor flows through the rest of the year. An inflow from the river of at least 10 cfs is beneficial for the City. Less than 10 cfs requires the stored water shares to be used.

Cost of Existing Water Sources:

When selecting water sources during the season it may be important to understand associated costs. The following list provides the least costly sources to the highest costly sources for delivery into system (power & wheeling) of existing City shares:

- American Fork Irrigation, Lehi Irrigation, Pleasant Grove Irrigation & Winn Ditch @ $0 af
- CUP @ $0 af
- Highland Conservation & Provo Reservoir pumped @ $25
- Highland Conservation & Provo Reservoir wheeled @ $37
- Provo & Granite Wells @ $65-$75
- Drinking Water Wells @ $90
- 11800 Well @ $120

Annual Share Assessments

Not all of the water accepted by the City has the same assessment per af of water, the following provides the assessment cost per af of water. This information should be used in developing water acceptance policies for new development.

American Fork Irrigation @ $11
Provo Reservoir Full @ 12.50
Provo Reservoir Late @ $20
Lehi Irrigation @ $20
Pleasant Grove Irrigation @ $29
Highland Conservation @ $49

Drought Sources

A 40-year water rights plan was provided to the State of Utah Division of Water Rights. The plan was mandated by the State to provide an analysis that the City would need all of its water rights at buildout. Table 5 was provided in the analysis as a total water summary and has been

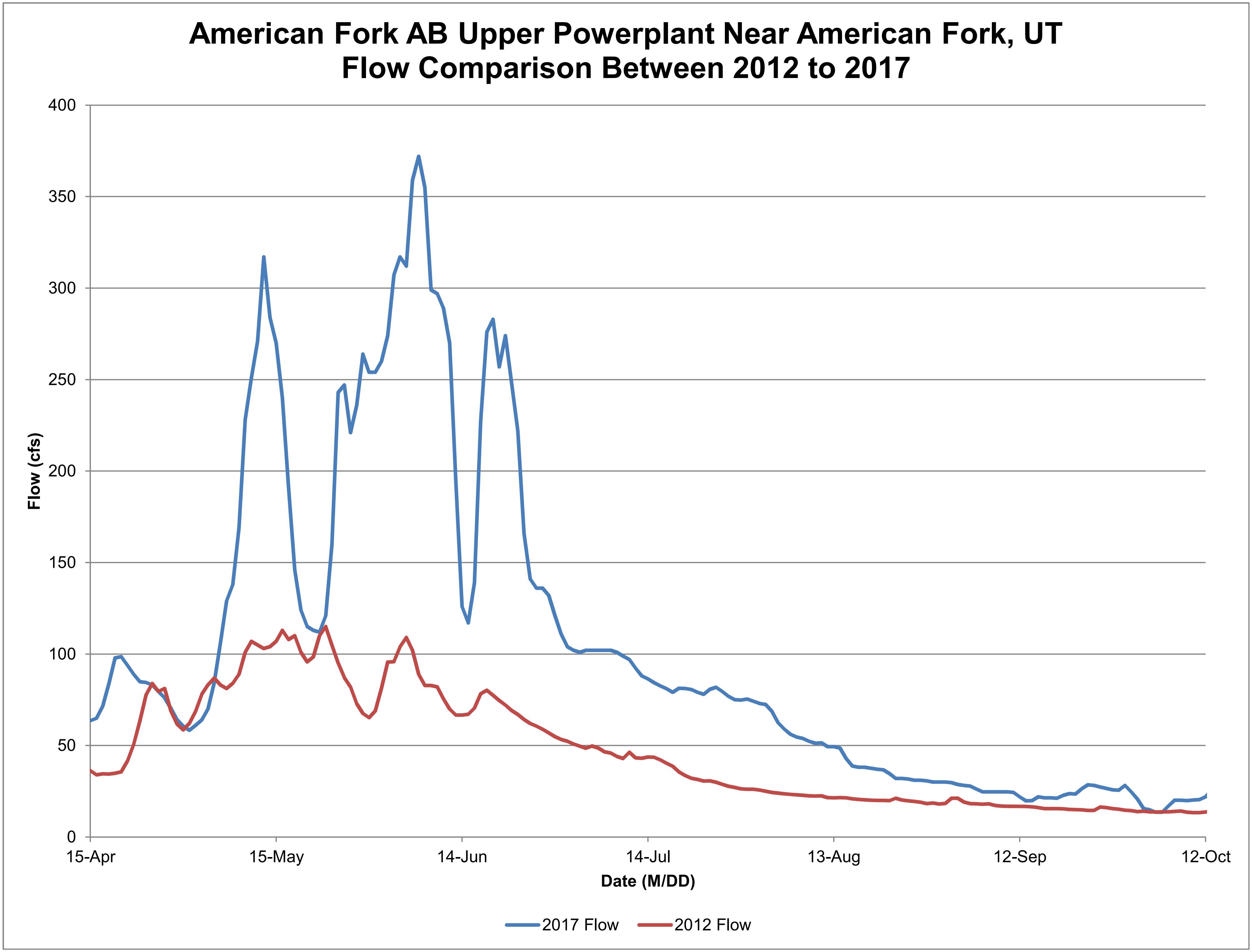

American Fork AB Upper Powerplant Near American Fork, UT
Flow Comparison Between 2012 to 2017
Flow (cfs)
400
350
300
250
200
150
100
50
0
15-Apr
15-May
14-Jun
14-Jul
13-Aug
12-Sep
12-Oct
Date (M/DD)
2017 Flow
2012 Flow

TABLE 5
HIGHLAND CITY WATER RIGHTS & SHARES SUMMARY
1-Mar-18

2017 Pressurized Irrigation Use:	8,615	A.F.
2017 Drinking Water Use:	1,597	A.F.
TOTAL 2017 Use:	10,212	A.F.
Groundwater (Municipal Water Rights):	5,177	A.F.
Groundwater (PI Water Rights):	685	A.F.
TOTAL GROUNDWATER RIGHTS:	5,862	A.F.
Central Utah Project Water:	415	A.F.
American Fork River Irrigation Shares:	4,988	A.F.
Provo System Irrigation Shares:	3,725	A.F.
*Utah Lake Irrigation Shares:	276	A.F.
TOTAL SURFACE WATER SHARES:	9,404	A.F.
TOTAL (EXCLUDING UTAH LAKE):	9,128	A.F.
TOTAL USEABLE RIGHTS & SHARES:	14,990	A.F.
Anticipated water during a Drought that decreases surface water by 50%	10,426	A.F.
<u>Current Well Capacity</u>		
3 - Pressurized Irrigation Wells:	3,400	GPM
5 - Drinking Water Wells:	4,150	GPM
TOTAL WELL CAPACITY:	7,550	GPM
Current volume if all wells were pumped straight for 4 months	3,993	A.F.

*Utah Lake Shares are currently not able to be used as their water rights have issues. The City is currently trying to remedy.

updated to current water shares. The Table provides information on water sources needed when there has been a drought reducing the surface water by 50%. The use data was for 2017 and does not include any conservation. The table provides that the City has sufficient water rights and shares to provide water during a 50% year.

CONCLUSIONS AND RECOMMENDATIONS

- Highland Conservation is a lot more expensive than American Fork River water.
- City to segregate water rights attributed to 20 shares of East Jordan canal company for WR 55-9284 (a21958).
- City to request leniency in the lapse of water right 55-11962 (a28534) which utilizes 54 shares from the Utah Lake Distributing Canal Company. If the state will not approve the request the City should look to trade water rights to another municipality that can utilize.
- Utilize the least expensive water first within the system.
- Utilize groundwater within the secondary system throughout the year only as needed.
- Enclosed Water Shares for the next 18 years carry the highest cost per af, approximately $500 per af. Once the principal with interest has been paid off the cost will be the same as the non-enclosed shares of the same water source.
- City should develop a policy on water share renting dependent on source and cost.
- Due to the amount of existing City groundwater rights, surface water only should be allowed for the PI System.
- The City should review the amount of water required from stored/Provo sources with the recommendation of modifying to receive the same amount of AF River sources to Provo River sources.
- The City's current mixture of surface and ground water provides for relief from drought conditions through ground water wells, which is a higher cost water source.
- During high runoff years AF Canyon water shares are the best as they are low cost. However during low runoff years the Provo River water shares are the best as they are available later in the year through storage in Deer Creek.
- Review PG Irrigation shares and amount required at Highland Glen Park. Should there be excess shares during a certain year workout a trade to receive shares at upper pond.
- The City should review policy and procedure for allowing more expensive shares into the system due to their High assessment fees.

Table 6 - Surface Water Sources

Source	Water Shares	Location/Description
AF Irrigation Flume	American Fork Irrigation Company	The Flume is located downstream of the AF River Weir. A turnout on the main AF Ditch is connected directly to the flume. The flume provides source directly to the Upper PI Pond. Flows are influenced by snow melt and springs in AF Canyon. It is typical for the stream flow to reduce significantly during the end of summer months.
Dry Creek in Alpine	Alpine Irrigation Company	The City is not able to utilize these shares at this time.
Murdock Canal	Highland Conservation Provo Reservoir Water Users Association (Full & Late Shares)	The City has one turnout from the Murdock Canal that it can introduce water into the PI system. Provo River Water Users Association (PRWUA) operates and maintains the turnout. The turnout is directly connected to Lower Pond. Water originates at the Provo River below Deer Creek Reservoir. The water conveyed through the canal is termed 'stored water'. The water is held in the reservoir until requested by the City. Pumping is required from the Lower Pond into the system. The turnout is limited in capacity due to the Citys pump station's existing capacity of 3,900 gpm. However, in discussion with PRWUA the full capacity of the turnout s near 6,800 if an orifice plate were to be removed. The City recently has been reviewing the opportunity of a new turnout near North County Blvd. PRWUA has an existing turnout and could supply the City 4 CFS for a future pump station to provide source to the new State Development.
Lehi Irrigation Flume	Lehi Irrigation Company	The Flume is located downstream of the AF River Weir. A turnout on the main Lehi Ditch is connected directly to the flume. The flume provides source directly to the Upper PI Pond. Flows are influenced by snow melt and springs in AF Canyon. It is typical for the stream flow to reduce significantly during the end of summer months.
Pleasant Grove Ditch	Pleasant Grove Irrigation Company	The turnout for the Citys share of the PG Irrigation Company is located to the east of the Highland Glen Park. The shares provide for water to the pond exclusively. The City is not able to utilize these shares in their PI System at this time. The Irrigation Company's water rights originate with the AF River.
Winn Ditch	Winn Ditch Irrigation Company	The City is able to utilize its water shares through the Lehi Flume. The City is the sole owner of the shares in the Irrigation Company. The Winn ditch is allowed 4.5/11 of any surplus over 75 cfs passing over the weir from March 1 through July 1.

CUP #1	Central Utah Project (CUP) Water	The turnout is located at the end of CUWCD Aqueduct and is connected directly into the Upper Pond. The aqueduct is pressurized and is operated and maintained by CUWCD. The aqueduct was intended to convey CUP water. However, CUWCD has allowed non project water to be conveyed with a 'wheeling' charge. The City can have Highland Conservation and Provo Reservoir Water (both non project water) conveyed under pressure to the City, saving on pumping costs. The waters origins is the Provo River System. The City has an agreement for 4 CFS of CUP Water at this source, however the City has taken 9 CFS. CUWCD plans to provide Alpine water at the turnout. This will decrease the City's access to 4 CFS at some point in the near future.
	Highland Conservation	
	Provo Reservoir Water Users Association (Full & Late Shares)	
CUP #2	Central Utah Project (CUP) Water	The turnout is located off of Aqueduct XX and is connected directly into the system near 10400 North and 6400 West. The aqueduct is pressurized and is operated and maintained by CUWCD. The aqueduct was intended to convey CUP water. However, CUWCD has allowed non project water to be conveyed with a 'wheeling' charge. The City can have Highland Conservation and Provo Reservoir Water (both non project water) conveyed under pressure to the City, saving on pumping costs. The waters origins are the Provo River System.
	Highland Conservation	
	Provo Reservoir Water Users Association (Full & Late Shares	

Ground Water Sources

Source	Capacity	Location/Description
DW Well #1	550 gpm	Located at 5600 W and 10500 N. Drilled in 1968.
DW Well #2	900 gpm	Located near SR-92 5600 W and 4400 W. Drilled in 1958.
DW Well #3	900 gpm	Located at 10400 N and 6450 W. Drilled in 1977.
DW Well #4	800 gpm	Located at 11200 N and 5100 W. Drilled in 1986.
DW Well #5	1,000 gpm	Located at 11000 N and 5550 W. Drilled in 1987. Can be utilized in secondary system.
PI Well #6	1,200 gpm	Located at 6000 W and 11800 N. Drilled in 2004. Well was drilled to drinking water standards but currently utilized in secondary water system.
PI Provo Well	1,100 gpm	Located at Alpine Hwy and 10700 N. Drilled in 1968.
PI Granite Well	1,100 gpm	Located within Public Works Facility. Deepened in 2000.

Murdock Enclosure Water Shares

The City currently owns shares from two irrigation companies that were impacted by the enclosure of the Murdock Canal. To fund the project Provo River Water Users Association (PRWUA) offered 10% additional capacity in the pipeline to account for losses. This new water was first offered to existing share holders through the respective irrigation companies that had conveyed water through the canal. The City elected to purchase these 'saved' water shares through their existing Highland Conservation District and Provo Reservoir Water. Each year the City pays an assessment fee that includes principal and interest for a 25 yr loan. The following is information on how each of the companies elected to distribute the 'saved' water shares:

Highland Conservation District Summary

A Shares (1 Full Share): Canal Enclosure paid in full by Owner of Shares. These Shares do not require the enclosure assessment only the O&M yearly assessment. These are the best shares for the City.

B Shares (1 Full Share): These shares are encumbered by the enclosure assessment. Shareholders agreed to pay for the additional 1/10th through financing/loans. These shares are required to pay 'enclosed' assessments yearly along with the O&M. These shares should also require additional payment of the enclosed shares outstanding, or the City will be paying interest on the remainder of the loan.

D Shares (0.9 Full Share): The original owners of these shares did not elect to purchase the 'saved' water through the enclosure of the canal. These shares are required to only pay for the yearly O&M yearly assessment. However these shares are only worth 9/10 in value of the A & B shares. These shares should be accepted as 9/10th of a share?

S Shares (0.1 Full Share): These shares are for the 0.1 'saved' portion that the above-mentioned D shareholders did not elect to pay for. The majority of these shares were purchased by AF or JVWCD. Yearly O&M and Enclosure assessments are necessary if the original share was financed. The City does not own any of these shares.

Provo Reservoir Enclosed Shares Summary

The Irrigation Company issued a new class of shares for the 'contained shares' equal to 1/10 of an original share. These contained shares are differentiated from full shares by a 'C' with the certificate number. Principal can be paid off early with no penalty.

Deer Creek Stored Water Shares

The City currently owns shares from two irrigation companies (Highland Conservation and Provo Reservoir) that provide 'stored' water shares in Deer Creek Reservoir. Stored water may be saved over from previous years if high runoff hasn't displaced the carry over water in the reservoir by spilling over the dam. Highland Conservation only provides for stored water in Deer Creek whereas Provo Reservoir has other sources of available water throughout the year.

Provo Reservoir Water Sources

Provo Reservoir shares provide natural flow water, secondary storage water and Deer Creek storage water. The following is a description of each type:

Natural Flows

Natural flows are 'use it or lose it'. Natural flow water begins high in the spring and then declines over the course of the summer. Before July 1st the City has a 2% share in natural flows, but after the 1st the City's share increases to 5.7%.

Blue Cliff Water Right – Depending on the amount of water this source may not have a fee associated. Recently, with the reconstruction of the Olmsted Power Plant the water has been available without a fee. Once the Olmsted Power Plant is operational, depending on source amounts the City may have to reimburse for the power generation lost at the plant due to taking water.

Secondary Blue Cliff Right - If the water right is sufficient to run the power plant, surplus water is divided between the shareholders.

Shingle Creek – Flows from Shingle Creek from 0-50 cfs are allocated to shareholders throughout the year.

Secondary Stored Water

These secondary water rights provide stored water from other locations away from Deer Creek. The amount of water is determined yearly and is dependent on flows/snow pack.

Upper Lake Water Right – This water source originates in the Uintahs and provides water from reservoirs and lakes in the upper system. This water is allocated yearly and can be held in Deer Creek for only a year. In 2017 Highland was allocated a full 241 af from this source.

Echo Storage – In the past Provo Reservoir Company purchased water from the Weber drainage. This water must be used yearly. The allotment is calculated yearly. In 2017 Highland was provided 155 af.

Deer Creek Stored Water

Through Provo Reservoir Company the City is allocated water stored in Deer Creek. The water may be held over year after year, however will be lost if in a year the water is displaced by new water coming into the reservoir through high runoff. In 2017 all stored water was replaced by new water. The City was allocated 836 af in Deer Creek in 2017 and did not use any of the water, thus being able to carry it over into 2018.

APPENDIX B

NEW WELL DRILLING LOCATION MEMO

Memorandum

DATE: June 12, 2018
TO: Highland City

FROM: J. Lance Nielsen, P.E.
PROJECT: Pressurized Irrigation Master Plan Update
PROJECT NO.: 314.18.100
RE: Evaluation of Alternative Well Drilling Locations

PROFESSIONAL ENGINEER 6/12/2018 No. 354085-2202 J LANCE NIELSEN STATE OF UTAH

PURPOSE/BACKGROUND

Highland City will soon need additional sources for its secondary water system in order to meet peak summer demands. Highland has identified two possible well sites: (1) in the area of the City secondary water pond at the end of Angels Gate Way, and (2) Dry Creek Park. Highland City retained Hansen, Allen & Luce, Inc. (HAL) to evaluate these well sites. This memorandum summarizes key findings of this evaluation.

HYDROGEOLOGY

Hydrogeologic data used for this evaluation included the following data sources:

1. Biek, Robert F. 2003. *Interim Geologic Map of the Jordan Narrows Quadrangle, Salt Lake and Utah Counties, Utah*. Open-File Report 415. Utah Geological Survey.
2. Biek, Robert F. 2005. *Geologic Map of the Lehi Quadrangle and Part of the Timpanogos Cave Quadrangle, Salt Lake and Utah Counties, Utah*. Map 210. Utah Geological Survey.
3. Cederberg, Jay R., Philip M. Gardner, and Susan A. Thiros. 2009. *Hydrology of Northern Utah Valley, Utah County, Utah, 1975-2005*. Scientific Investigations Report 2008-5197. U.S. Geological Survey.
4. Gardner, Philip M. 2009. *Three-Dimensional Numerical Model of Ground-Water Flow in Northern Utah Valley, Utah County, Utah*. Scientific Investigations Report 2008-5049. U.S. Geological Survey.
5. Utah Division of Water Rights website (waterrights.utah.gov). 2018. Well driller's reports for existing wells.

Based on Cederberg, et al. (2009), the aquifer system in the northern Utah Valley consists of a basin fill aquifer in the valley areas surrounded by mountains. A large portion of the recharge to the aquifer is from infiltration of precipitation into the mountain bedrock aquifers, which then flows into the basin fill aquifers in the valley. Precipitation over the basin fill deposits along the margins of the valley also contributes to recharge along with infiltration from streams and irrigation.

Gardner (2009) used the information developed by Cederberg, et al. (2009) to complete a 3-dimensional groundwater model of northern Utah Valley. The aquifers simulated in the model include the following:

1. Shallow Unconfined aquifer,
2. Shallow Pleistocene aquifer (confined),
3. Deep Pleistocene aquifer (confined),
4. Quaternary / Tertiary aquifer (confined),
5. Western unconsolidated aquifer,
6. Bedrock aquifer, and
7. Pre-Lake Bonneville unconfined aquifer.

Basin Fill Aquifers

Within the area of Highland City, the Shallow Pleistocene (SP), Deep Pleistocene (DP), and Quaternary / Tertiary (QT) aquifers constitute the principle basin fill aquifers and consist of unconsolidated deposits of gravels and sands. These aquifers are separated by laterally continuous clay layers that extend throughout the middle of the valley, but thin and disappear near the mountains. In the vicinity of Highland, the confining clay layers extend approximately to the Timpanogos Highway. The basin fill aquifer north of this highway is unconfined (Pre-Lake Bonneville unconfined aquifer) and extends to a fault that acts as the boundary between the basin fill aquifer and the bedrock aquifer of the Traverse Mountains. Based on Cederberg, et al. (2009), the primary source of recharge to the basin fill aquifer near Highland is from precipitation within the Dry Creek and American Fork River drainages.

Secondary Pond Site

Based on Cederberg et al. (2009), the confined aquifers of northern Utah Valley do not extend to the Secondary Pond site. The main source of groundwater at this location is the bedrock aquifer of the Traverse Mountains.

The bedrock aquifer of the Traverse Mountains consists of limestone and dolomite formations of the Oquirrh Group overlain by Tertiary volcanics and alluvial fan deposits. Based on Biek (2005), there are several faults through this bedrock aquifer which have likely resulted in significant fracturing. Recharge from the Traverse Mountains is limited due to the small volume of precipitation that falls within these mountains compared to the higher elevations and larger collection areas of the Dry Creek and American Fork River drainages.

A well owned by Lehi City completed into the Oquirrh Formation produced 536 gpm when tested. This well is located along a fault and the yield is primarily due to secondary permeability provided by fractures and fissures due to faulting and folding of the limestone formation. In fractured limestone formations, there is a potential for a high yielding well, but if the well misses a fracture system by even just a few feet, the well could yield very little or no water at all. In this way, drilling in a bedrock formation can be very risky. Locating wells near faults increases the likelihood of hitting a fracture system.

Several faults are present immediately north of the secondary pond, as shown in Figure 1. If Highland City desires to drill a well in this area, we recommend drilling above the pond in order to target areas of faulting. It is estimated that a well north of the pond could have a capacity of 200 – 1,000 gpm, depending on the extent of fracturing. Due to the limited recharge from the Traverse Mountains, large annual withdrawals may not be sustainable at this location, even if a favorable fractured limestone formation is encountered. This may not be an issue if the well is only used for peak summer demands limiting the annual withdrawal rate.

Dry Creek Park Site

Well logs from several wells near Dry Creek Park were analyzed for production potential. A well approximately 1000 feet to the south (Hammond Well) is located near Dry Creek. The driller for this well reported gravels with good hydraulic conductivity at a depth of about 300 feet. With an open bottom and an 8" casing, it produced 30 gpm when it was tested. Using the Cooper-Jacob aquifer solution, this corresponds to a hydraulic conductivity of approximately 100 ft/day. This is an indication that alluvial deposits from the Dry Creek drainage with good hydraulic conductivity are present in the area.

Highland City Well #6 is located approximately 3,000 feet to the northeast. It produces about 1,300 gpm. Hydraulic conductivity is much lower, at approximately 5 ft/day. This is likely an indication that Well #6 is outside of the more productive Dry Creek deposits.

Gardner (2009) reports hydraulic conductivities in the vicinity of Dry Creek Park ranging from over 100 ft/day in the SP aquifer to around 10 ft/day in the QT aquifer. The DP aquifer is not present at this location. The thickness of the SP aquifer may be limited compared to the thickness of the QT aquifer.

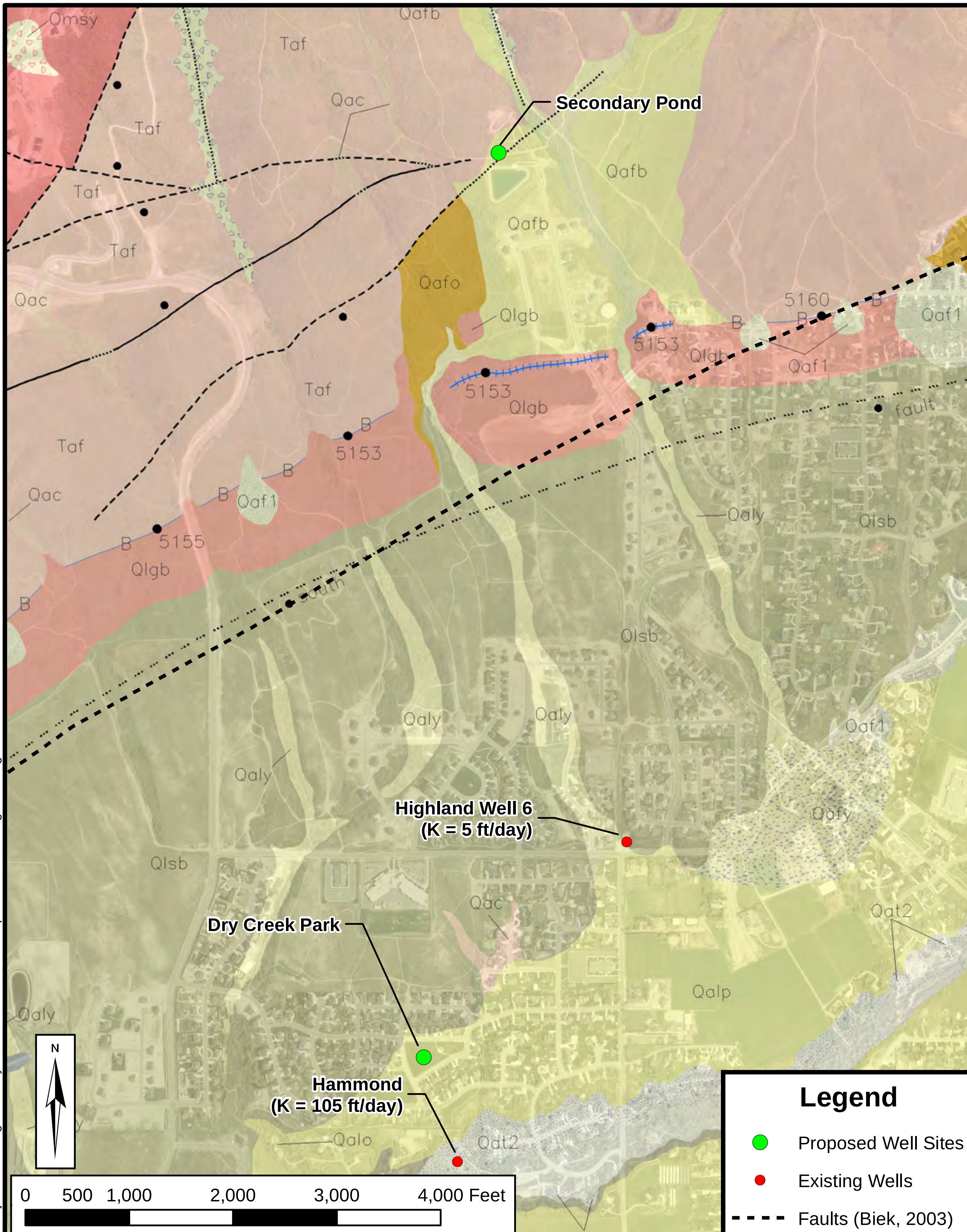
Based on this data, deposits originating from the Dry Creek drainage have a higher potential for a successful well than those upslope, which more likely originate from the Traverse Mountain range. This is because Dry Creek drainage experiences significantly more recharge than Traverse Mountain and there is greater historical potential for larger gravel and sand deposits. Based on data from Biek (2005), Dry Creek Park appears to be on the fringes of alluvial deposits from Dry Creek. Figure 1 shows geologic mapping of the area.

If a well at this site intercepts deposits originating from the Traverse Mountains, the capacity of a well at this location may be similar to that of Well #6. If it intercepts more productive alluvial deposits from Dry Creek, the capacity might be greater. It is estimated that a well at Dry Creek Park likely has the potential to produce from 1,000 – 2,000 gpm.

CONCLUSIONS

Based on the above evaluation, we make the following conclusions:

- The Dry Creek Park site (estimated 1,000 – 2,000 gpm) has a greater potential to produce larger quantities of water than the Secondary Pond site (estimated 200 – 1,000 gpm).
- Drilling a successful well at the Secondary Pond site is contingent upon encountering fractured limestone deposits and whether fracture zones are well connected to the recharge source. For this reason, drilling at this site is risky. If a well is drilled at this location, we recommend locating it above the pond where several faults are present and the potential to penetrate fracture zones is higher.



HIGHLAND CITY
PROPOSED WELL SITES AND EXISTING WELLS

FIGURE
1

HANSEN ALLEN & LUCE INC ENGINEERS

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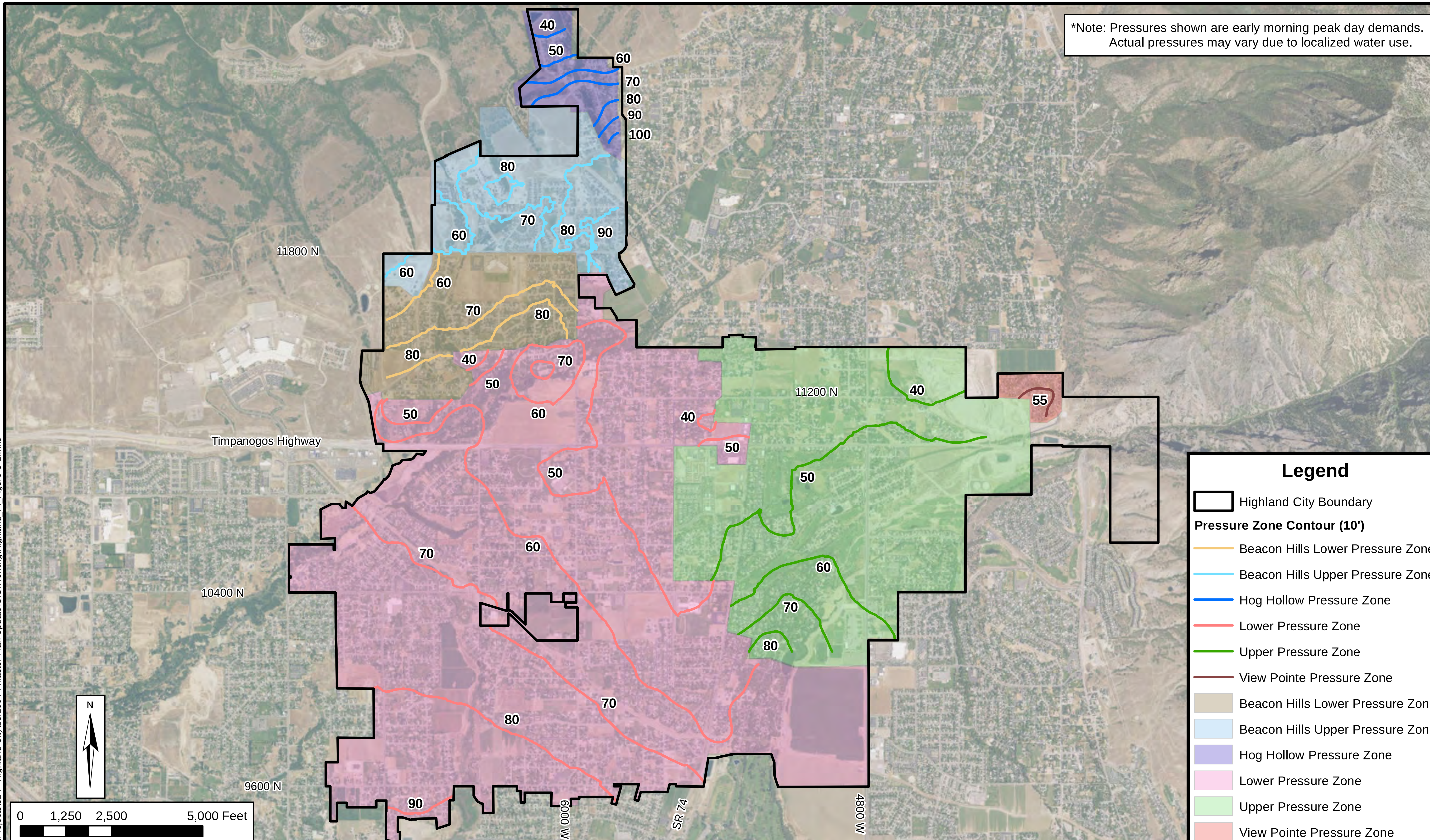
APPENDIX C

PRESSURE CONTOUR MAPPING



HANSEN ALLEN & LUCE INC ENGINEERS

Highland City
Pressurized Irrigation System Master Plan

Future Pressure Zone Contours

FIGURE C-2

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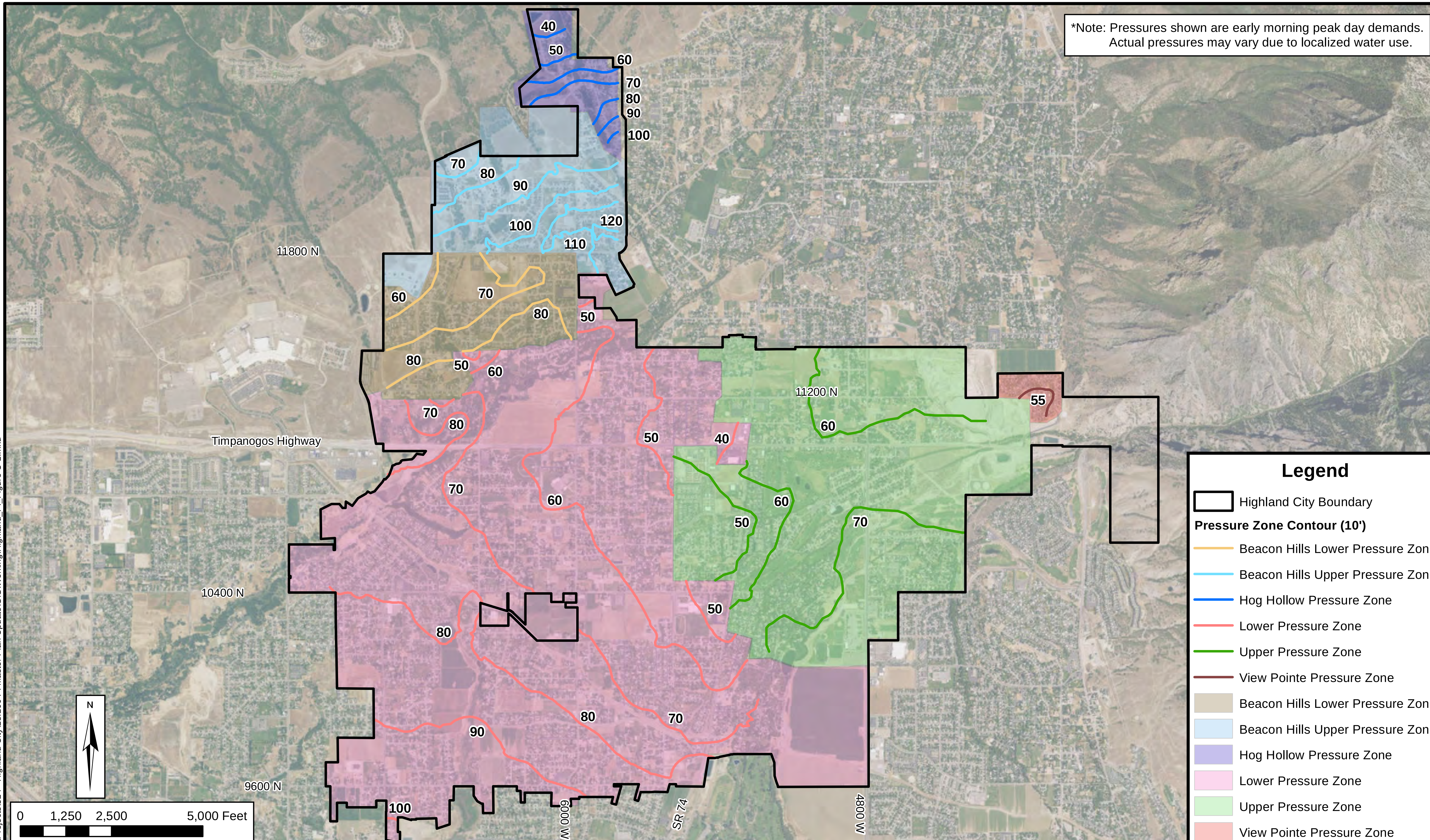

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HANSEN ALLEN & LUCE INC ENGINEERS

Highland City
Pressurized Irrigation System Master Plan

Existing Pressure Zone Contours

FIGURE C-1

APPENDIX D

COST DATA

HIGHLAND CITY PI MASTER PLAN
PRELIMINARY ENGINEERING ESTIMATE OF COSTS - 2018 DOLLARS

	Item	Unit	Unit Price	Quantity	Total Price
1	***North of 11800***				
	New 16" DIP transmission pipe	LF	$ 140	120	$ 16,800
	New 20" HDPE transmission pipe	LF	$ 160	1030	$ 164,800
	Connection inside Booster Station	LS	$ 20,000	1	$ 20,000
	New Dual 10" PRV Station on existing 18" line	LS	$ 75,000	1	$ 75,000
	New 6" PRV on 8" Chamberry Lane	LS	$ 25,000	1	$ 25,000
	Open/Close zone valves to separate zones			Valve operation by city staff	
	Mobilization (10%)	LS	$ 30,160	1	$ 30,160
	Testing (5%)	LS	$ 15,080	1	$ 15,080
				Engineering & Admin. (15%)	$ 52,026
				Contingency (20%)	$ 69,368
				Total for North of 11800	**$ 468,000**
2	***11800 Well***				
	Remove and Replace Existing Pump & Column	LS	$ 30,000	1	$ 30,000
	Chemical Treatment	LS	$ 20,000	1	$ 20,000
	Dual Swab Treatment	HRS	$ 350	360	$ 126,000
	Test Pumping	LS	$ 55,000	1	$ 55,000
	Mobilization (10%)	LS	$ 23,100	1	$ 30,000
				Engineering & Admin. (15%)	$ 39,150
				Contingency (20%)	$ 52,200
				Total for 11800 Well	**$ 352,000**
3	***Beacon Hill Booster Capacity Improvements***				
	Expand 11800 N Booster Station Capacity to 3700 gpm	LS	$ 100,000	1	$ 100,000
	Mobilization (10%)	LS	$ 10,000	1	$ 10,000
				Engineering & Admin. (15%)	$ 16,500
				Contingency (20%)	$ 22,000
				Total for Beacon Hill Booster Capacity Improvements	**$ 149,000**
4	***Beacon Hills Upper Pressure Zone***				
	New 12" pipe through Beacon Hills Upper Pressure Zone	LF	$ 90	3200	$ 288,000
	Mobilization (10%)	LS	$ 28,800	1	$ 28,800
	Testing (5%)	LS	$ 14,400	1	$ 14,400
				Engineering & Admin. (15%)	$ 49,680
				Contingency (20%)	$ 66,240
				Total for Beacon Hills Upper Pressure Zone	**$ 447,000**
5	***Distribution Piping Throughout Future Developments***				
	Install 8" Distribution Piping as areas develop	LF	$ 65	8000	$ 520,000
	Mobilization (10%)	LS	$ 52,000	1	$ 52,000
	Testing (5%)	LS	$ 26,000	1	$ 26,000
				Engineering & Admin. (15%)	$ 89,700
				Contingency (20%)	$ 119,600
				Total for Distribution Piping Throughout Future Developments	**$ 807,000**
6	***11000 N. to 11400 N. & 5200 W. to 5400 W.***				
	New 8" pipe HDD crossing Alpine Hwy at 11200 N	LF	$ 450	110	$ 49,500
	New 8" pipes through development	LF	$ 65	3700	$ 240,500
	Mobilization (10%)	LS	$ 29,000	1	$ 29,000
	Testing (5%)	LS	$ 14,500	1	$ 14,500
				Engineering & Admin. (15%)	$ 50,025
				Contingency (20%)	$ 66,700
				Total for 11000 N. to 11400 N. & 5200 W. to 5400 W.	**$ 450,000**
7	***11000 N. to 11400 N. & 4400 W. to 4800 W.***				
	New 10" pipes through development	LF	$ 75	4300	$ 322,500
	Mobilization (10%)	LS	$ 32,250	1	$ 32,250
	Testing (5%)	LS	$ 16,125	1	$ 16,125
				Engineering & Admin. (15%)	$ 55,631
				Contingency (20%)	$ 74,175
				Total for 11000 N. to 11400 N. & 4400 W. to 4800 W.	**$ 501,000**

HIGHLAND CITY PI MASTER PLAN
PRELIMINARY ENGINEERING ESTIMATE OF COSTS - 2018 DOLLARS

	Item	Unit		Unit Price	Quantity		Total Price
8	***5250 W. from 10700 N. to 11000 N.***						
	New 6" pipe (HDD bore) at about 10970 N 5250 W	LF	$	250	140	$	35,000
	Mobilization (10%)	LS	$	3,500	1	$	3,500
	Testing (5%)	LS	$	1,750	1	$	1,750
					Engineering & Admin. (15%)	$	6,038
					Contingency (20%)	$	8,050
					Total for 5250 W. from 10700 N. to 11000 N.	**$**	**54,000**
9	***Developmental Center PI Line***						
	New 12" Pipeline (From Alpine Hwy to Nth Side of Canal)	LF	$	90	2700	$	243,000
	Canal Crossing w HDD	LF	$	350	100	$	35,000
	Replace Existing 8" with 12" PVC	LF	$	95	380	$	36,100
	Mobilization (10%)	LS	$	31,410	1	$	31,410
	Testing (5%)	LS	$	15,705	1	$	15,705
					Engineering & Admin. (15%)	$	54,182
					Contingency (20%)	$	72,243
					Total for Developmental Center PI Line	**$**	**488,000**
10	***New Well Near Dry Creek Bench Park - 1,000 gpm***						
	Drill New Well (500' Deep) - 16" Casing	LS	$	1,000	500	$	500,000
	New Well House & Piping Connections	LS	$	700,000	1	$	700,000
	Mobilization (10%)	LS	$	120,000	1	$	120,000
					Engineering & Admin. (10%)	$	132,000
					Contingency (10%)	$	132,000
					Total for New Well Near Dry Creek Bench Park - 1,000 gpm	**$**	**1,584,000**
11	***Lower Pond Expansion - Expand Existing Pond by 5.0 AC-FT***						
	Concrete Demolition	SY	$	100	1100	$	110,000
	Excavate & Embankment for Pond Expansion	CY	$	25	7000	$	175,000
	5"-Thick Concrete Liner	SY	$	100	3830	$	383,000
	Extend the Overflow Line	LF	$	100	400	$	40,000
	Revise Landscaping	LS	$	20,000	1	$	20,000
	Mobilization (10%)	LS	$	72,800	1	$	72,800
	Testing (5%)	LS	$	36,400	1	$	36,400
					Engineering & Admin. (15%)	$	125,580
					Contingency (20%)	$	167,440
					Total for Lower Pond Expansion - Expand Existing Pond by 5.0 AC-FT	**$**	**1,130,000**
12	***Upper Pond Expansion - Expand Existing Pond by 6.0 AC-FT***						
	Concrete Demolition	SY	$	100	2000	$	200,000
	Excavate for Pond Expansion	CY	$	15	20000	$	300,000
	5"-Thick Concrete Liner	SY	$	100	4600	$	460,000
	Extend the Overflow Line	LF	$	100	400	$	40,000
	Revise Entrance and Parking Lot	LS	$	20,000	1	$	20,000
	Mobilization (10%)	LS	$	102,000	1	$	102,000
	Testing (5%)	LS	$	51,000	1	$	51,000
					Engineering & Admin. (15%)	$	175,950
					Contingency (20%)	$	234,600
					Total for Upper Pond Expansion - Expand Existing Pond by 6.0 AC-FT	**$**	**1,584,000**
13	***Upper Pump Station***						
	Expand the Upper Pump Station Capacity to 6600 gpm	LS	$	100,000	1	$	100,000
					Engineering & Admin. (15%)	$	15,000
					Contingency (20%)	$	20,000
					Total for Upper Pump Station	**$**	**135,000**
14	***Murdock Canal PS @ State Property (4 CFS)***						
	Pump Station	LS	$	600,000	1	$	600,000
	Property Acquisition	LS	$	75,000	1	$	75,000
	Mobilization (10%)	LS	$	60,000	1	$	60,000
	Testing (5%)	LS	$	30,000	1	$	30,000
					Engineering & Admin. (15%)	$	114,750
					Contingency (20%)	$	153,000
					Total for Murdock Canal PS @ State Property (4 CFS)	**$**	**1,033,000**

HIGHLAND CITY PI MASTER PLAN
PRELIMINARY ENGINEERING ESTIMATE OF COSTS - 2018 DOLLARS

Item	Unit	Unit Price	Quantity	Total Price
15 Lower Booster Improvements @ Lower Pond (16 CFS)				
Pump Station	LS	$ 1,200,000	1	$ 1,200,000
Property Acquisition	LS	$ -	1	$ -
Mobilization (10%)	LS	$ 120,000	1	$ 120,000
Testing (5%)	LS	$ 60,000	1	$ 60,000
			Engineering & Admin. (15%)	$ 207,000
			Contingency (20%)	$ 276,000
			Total for Lower Booster Improvements @ Lower Pond (16 CFS)	**$ 1,863,000**
16 Highland Glen Connection				
New 8" pipe from Knight Ave to Highland Glen	LF	$ 1,000	100	$ 100,000
Mobilization (10%)	LS	$ 10,000	1	$ 10,000
Testing (5%)	LS	$ 5,000	1	$ 5,000
			Engineering & Admin. (15%)	$ 17,250
			Contingency (20%)	$ 23,000
			Total for Highland Glen Connection	**$ 155,000**