Brown AND Caldwell

Prepared for
Guam Waterworks Authority

GUAM WATERWORKS AUTHORITY

Water Resources Master Plan Update

Volume 2: Water System Appendices

Final | August 2018

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Water Resources Master Plan Update

Volume 2

Water System

Final | August 2018

Prepared for

Guam Waterworks Authority, Mangilao, Guam

August 2018

Brown and Caldwell

414 W. Soledad Avenue, Suite 602

Hagåtña, Guam 96910

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Appendix C

Well Details

Table C-1 summarizes annual well production for 2012 through 2015 and other well information. The data comes from the following sources:

- Guam EPA-Permitted Flow Rate – This flow rate was supplied by GWA.
- Average Annual Flow – The flow rates were calculated from monthly well reports supplied by GWA.
- Casing Diameter – The diameters came from the 2013 well assessment report (BC, April 2013c).
- Pump Horsepower, Well Depth – These values were supplied by GWA in a spreadsheet in April 2016.
- Critical Well – GWA identified wells as critical during the 2013 well assessment (BC, April 2013c). The critical wells are described in Section 5.

Table C-1. 2012-2015 Well Summary

Well	Guam EPA-Permitted Flow Rate (gpm)	Average Annual Flow (gpm)					Casing Diameter (inches)	Pump Horse-power	Well Depth (feet)	Critical Well
		2012	2013	2014	2015	Average 2012-2015				
A-1	216	174	79	172	297	181	8	50	224	No
A-2	241	92	0	0	0	23	8	40	174	No
A-3	180	229	114	242	198	196	6	40	383	No
A-4	244	291	298	306	310	301	6	50	301	No
A-5	269	246	234	228	219	232	6	50	323	Yes
A-6	241	282	296	295	276	287	8	50	307	Yes
A-7	113	0	0	0	0	0	Unknown	50	187	No
A-8	206	267	217	207	207	224	10	50	300	No
A-9	230	249	234	233	229	236	6	50	211	No
A-10	233	147	213	233	170	191	8	40	219	No
A-12	176	16	15	0	9	10	Unknown	50	337	No
A-13	237	263	132	159	133	172	Unknown	30	290	Yes
A-14	147	171	168	159	166	166	8	40	255	Yes
A-15	231	296	196	278	295	266	8	50	246	Yes
A-17	180	218	193	180	169	190	6	50	235	No
A-18	229	164	162	165	232	181	6	40	240	No
A-19	138	195	177	175	180	182	8	40	178	Yes
A-21	213	287	283	222	243	259	6	50	235	No

Table C-1. 2012-2015 Well Summary										
Well	Guam EPA-Permitted Flow Rate (gpm)	Average Annual Flow (gpm)					Casing Diameter (inches)	Pump Horse-power	Well Depth (feet)	Critical Well
		2012	2013	2014	2015	Average 2012-2015				
A-23	317	326	302	309	283	305	Unknown	60	85	Yes
A-25	245	330	332	332	330	331	Unknown	50	69	Yes
A-26	50	16	0	0	0	4	Unknown	15	184	No
A-28	223	0	0	0	0	0	Unknown	50	246	No
A-29	403	0	27	4	0	8	Unknown	50	105	No
A-30	755	635	666	612	723	659	Unknown	100	74	Yes
A-31	293	279	293	290	262	281	Unknown	50	245	Yes
A-32	173	229	241	234	236	235	6	40	198	Yes
AG-1	250	17	135	149	62	91	10	50	496	No
AG-2A	500	446	449	463	487	461	12	150	577	Yes
D-1	257	250	244	291	288	268	6	50	418	No
D-2	187	223	234	227	231	229	8	60	416	No
D-3	189	0	0	0	0	0	Unknown	40	409	No
D-4	172	238	244	247	248	244	8	50	411	No
D-5	166	166	86	0	0	63	Unknown	50	412	No
D-6	189	263	267	271	225	256	8	50	449	No
D-7	198	194	180	192	205	193	8	50	453	No
D-8	185	136	151	156	142	146	6	50	447	No
D-9	196	208	210	219	155	198	6	50	419	No
D-10	351	249	295	198	0	186	6	50	416	No
D-11	226	143	224	146	154	167	8	50	430	No
D-12	188	186	146	173	183	172	8	50	469	No
D-13	172	0	0	0	0	0	6	50	460	No
D-14	200	201	197	198	164	190	Unknown	50	374	No
D-15	202	166	185	178	77	152	8	60	423	No
D-16	161	210	75	171	190	161	6	50	384	No
D-17	199	0	0	0	0	0	Unknown	50	350	No
D-18	180	0	0	0	0	0	Unknown	50	360	No
D-19	227	182	189	185	215	192	6	60	441	No
D-20	207	200	215	219	190	206	8	50	421	No
D-21	157	187	85	126	135	133	6	50	425	No
D-22	200	0	0	0	0	0	Unknown	40	435	No
D-24	180	185	192	200	202	195	12	50	502	No
D-25	400	288	344	346	332	327	12	100	445	No

Table C-1. 2012-2015 Well Summary										
Well	Guam EPA-Permitted Flow Rate (gpm)	Average Annual Flow (gpm)					Casing Diameter (inches)	Pump Horse-power	Well Depth (feet)	Critical Well
		2012	2013	2014	2015	Average 2012-2015				
D-26	250	195	140	238	269	210	12	50/60	411	No
D-27	400	376	381	384	486	407	12	100	478	No
D-28	200	179	201	224	224	207	12	50	435	No
EX-5	254	378	377	309	325	347	6	60	420	No
EX-11	210	230	7	161	226	156	10	50	448	No
F-1	140	122	117	111	128	119	6	50	460	No
F-2	121	151	144	106	81	121	Unknown	40	490	No
F-3	142	76	0	52	74	50	6	50	480	No
F-4	137	153	115	122	150	135	6	50	505	No
F-5	145	171	164	160	203	174	8	50	427	No
F-6	151	203	215	142	151	178	6	40	375	No
F-7	170	157	183	174	160	169	6	60	407	No
F-8	149	177	167	156	167	167	6	50	468	No
F-9	140	74	90	138	156	115	8	40	427	No
F-10	142	144	129	149	141	141	6	50	481	No
F-11	148	172	144	148	90	139	Unknown	50	485	No
F-12	148	201	192	190	191	193	8	50	495	No
F-13	380	291	268	221	220	250	12	75	496	No
F-15	440	224	223	236	230	228	12	75	485	Yes
F-16	230	268	239	227	202	234	12	75	520	Yes
F-17	240	179	172	221	228	200	12	60	539	Yes
F-18	240	322	331	306	263	305	12	60	528	Yes
F-19	200	208	146	193	206	188	12	60	415	No
F-20	200	57	0	148	213	104	12	60	422	No
G-501	183	216	151	150	183	175	6	60	465	No
H-1	288	295	294	277	262	282	8	50	445	Yes
HGC-2	444	557	429	474	555	504	12	150	575	Yes
M-1	109	132	130	82	0	86	6	60	467	No
M-2	184	189	185	180	154	177	10	50	458	No
M-3	177	253	203	183	173	203	6	60	478	No
M-4	138	270	265	256	256	262	8	50	472	No
M-5	176	206	190	200	157	188	6	50	405	No
M-6	168	148	157	155	21	120	8	50	406	No
M-7	175	208	206	207	212	208	6	50	340	No

Table C-1. 2012-2015 Well Summary										
Well	Guam EPA-Permitted Flow Rate (gpm)	Average Annual Flow (gpm)					Casing Diameter (inches)	Pump Horse-power	Well Depth (feet)	Critical Well
		2012	2013	2014	2015	Average 2012-2015				
M-8	158	199	194	185	182	190	8	50	495	No
M-9	162	164	144	141	142	148	6	50	509	Yes
M-12	104	0	0	0	0	0	6	50	380	No
M-14	239	0	0	0	0	0	Unknown	50	315	No
M-15	172	240	233	243	246	241	6	50	347	No
M-17A	202	0	0	0	0	0	Unknown	75	476	No
M-17B	354	241	228	249	236	238	10	75	521	Yes
M-18	325	252	268	293	283	274	12	50	244	No
M-20A	400	230	192	277	303	251	12	100	528	Yes
M-21	200	195	196	258	236	221	12	75	395	Yes
M-23	225	221	221	247	252	235	12	60	451	No
MJ-1	56	0	0	0	0	0	Unknown	7.5	367	No
MJ-5	58	0	0	0	0	0	Unknown	40	Unknown	No
NAS-1	200	195	183	232	199	202	10	50	340	No
Y-1	141	210	208	193	174	196	6	50	460	No
Y-2	161	185	94	180	95	139	Unknown	60	484	No
Y-3	138	58	154	149	70	107	6	50	470	No
Y-4	180	202	202	121	171	174	8	50	432	No
Y-5	148	220	177	193	230	205	6	60	482	No
Y-6	136	209	147	128	93	144	6	60	481	No
Y-7	514	312	314	348	492	366	12	125	460	Yes
Y-9	472	392	468	467	472	450	12	150	456	Yes
Y-10	250	220	218	222	235	224	12	50	447	No
Y-12	235	323	126	367	352	292	12	75	378	No
Y-14	400	381	275	417	430	376	12	100	462	No
Y-15	600	524	440	456	687	527	12	150	445	Yes
Y-16	200	304	312	300	298	303	12	75	445	No
Y-17	300	315	222	237	238	253	12	50/60	323	No
Y-18	250	295	295	283	261	284	12	75	446	Yes
Y-19	500	655	632	600	624	628	12	150	424	Yes
Y-20	500	321	586	546	663	529	12	150	425	Yes
Y-21A	350	144	290	315	294	261	12	75	425	No
Y-22	300	282	265	256	261	266	12	75	469	Yes
Y-23	300	283	284	274	284	281	12	40	296	No

Table C-1. 2012-2015 Well Summary										
Well	Guam EPA-Permitted Flow Rate (gpm)	Average Annual Flow (gpm)					Casing Diameter (inches)	Pump Horse-power	Well Depth (feet)	Critical Well
		2012	2013	2014	2015	Average 2012-2015				
Tumon Maui	800	0	0	0	0	0	Unknown	Unknown	Unknown	No
Total (gpm)	28,671	24,693	23,148	24,245	24,311	24,099				
Total (mgd)	41.29	35.56	33.33	34.91	35.01	34.70				

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Appendix D

Model Development Notes

This appendix contains additional details regarding the development of the water model described in Section 4.

Diurnal Pattern

To calculate the diurnal patterns, it was assumed that the supply sources were running at a constant flow during an entire day. GWA records daily well flow rates and run times, but well flows were not available at more frequent intervals. It was assumed that the flow rate was constant for wells that ran for an entire day. The actual flow rate will vary as distribution system pressures change throughout the day, but there will not typically be a big change in flow rates at a well during a single day. Therefore, this assumption should not have had a big effect on the diurnal calculations.

Most of the wells that were running during the 2012 and 2014 periods ran for the entire periods. Only 19 wells were turned on or off during the entire 50-day period that was analyzed. For those wells that were turned on or off and therefore only ran part of a day, it was assumed that the wells ran the entire day because data was not available to figure out at what time the wells were turned on or off. This assumption should also have little effect due to the small number of wells that were turned on or off.

Model Demands

As discussed in Section 4, model demands were calculated from billing data, production records, and projected growth. Table 4-3 summarizes existing and future demands.

Scaling Factors

The demand calculations included scaling billed water use for each GWA customer until the total billing data matched actual water production. The scaling was done to allocate the NRW, or the difference between the billing and production. The curve shown in Figure D-1 was used to calculate the scaling factor for each customer. The points in the graph compare the 2015-16 average billed water use for each customer with the calculated scaling factor.

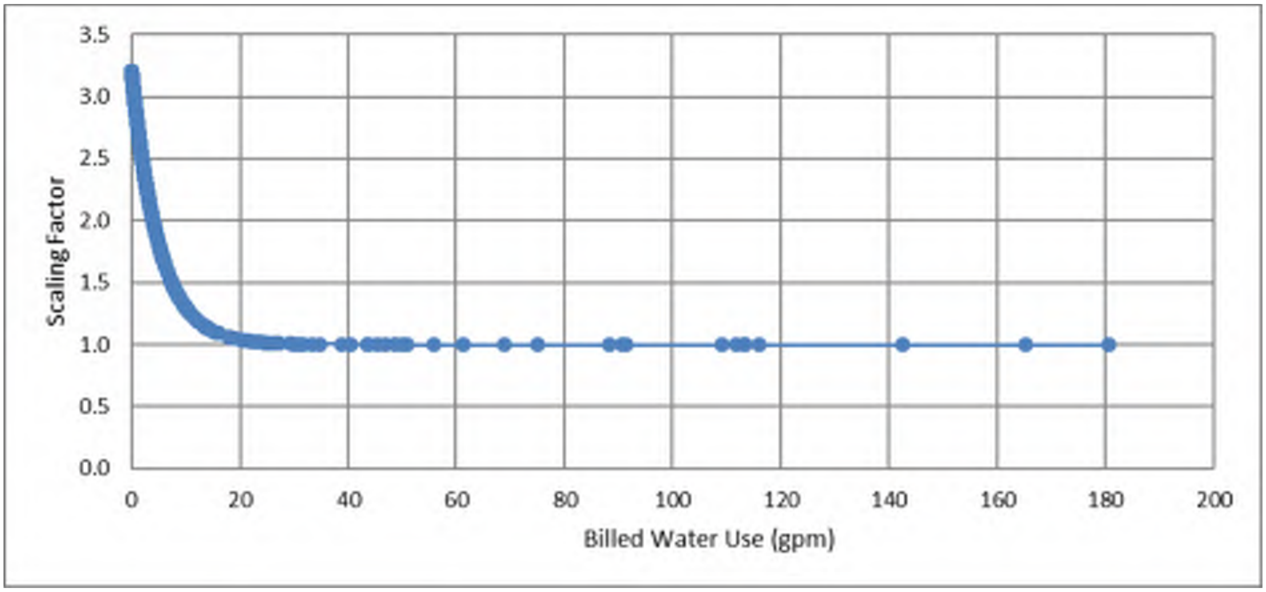

Figure D-1. Billed Water Use Scaling Factors

An exponential decay curve was used so the largest users would not receive a disproportionate amount of the NRW. For example, if a single scaling factor was used for all customers in the North, the scaling factor would be 2.4 (North ADD of 36.2 mgd divided by North billing total of 15.4 mgd in Table 4-3). Using a single scaling factor, a user with a billed water use of 20 gpm would be scaled to 48 gpm and a smaller user with a billed water use of 2 gpm would be scaled to 4.8 gpm. This would place a large amount of NRW at the location of the customer with the larger billed water use. Using the curve in Figure D-1, the 20 gpm user would scale to 20.8 gpm and the 2 gpm user would scale to 5 gpm. This process was done to avoid applying too much NRW at a single location and so most of the NRW would be spread out at the more numerous small users throughout the rest of the system.

Demand Calculation Steps

The following steps describe the entire process of calculating demands and allocating them to the model. As an example and to aid in understanding the calculations, the steps list the actual values used in the calculations for the Tamuning municipality. Figure D-2 shows the existing and future customers in the Tamuning municipality. Note that for simplicity, most values in the example are rounded to the nearest 0.1 mgd.

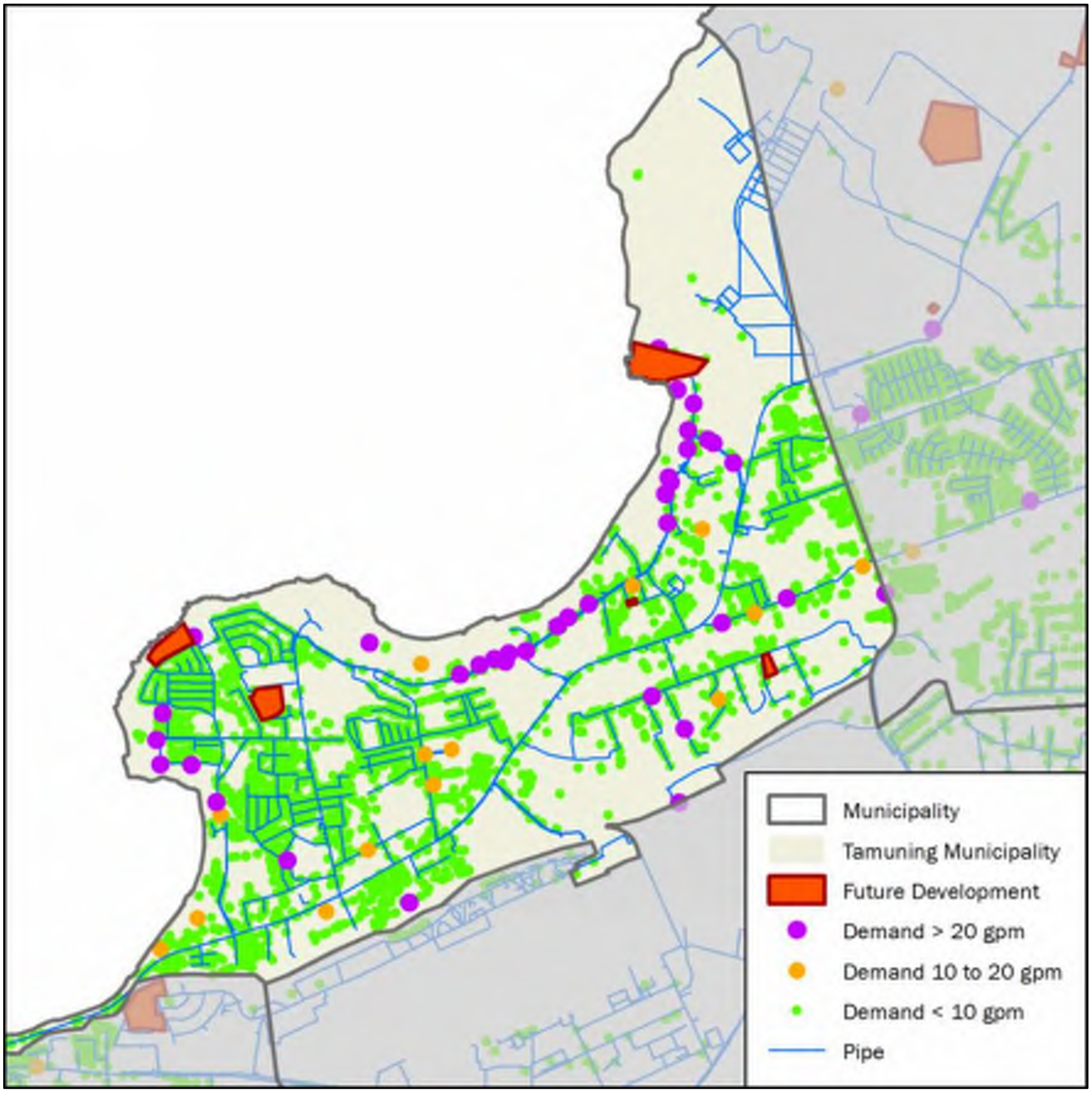

Figure D-2. Billed Water Customers and Future Development in the Tamuning Municipality

Calculate Scaling Factors from Billing Data to Existing ADD

1. Calculate a scaling factor for each customer using the scaling factors in the graph above.
2. Calculate the demand for each customer by multiplying the billed water use by the scaling factor. Sum the scaled demands for each area (North, South, and Nimitz). The total demand for each area now equals the total production for that area.

Calculate Tamuning Existing ADD

The Tamuning ADD cannot be calculated directly from water production data because piping is intertied between each municipality. Therefore, estimate the ADD by summing the scaled customer demands for customers within Tamuning.

3. Calculate Tamuning ADD by summing all scaled customer demands within Tamuning.
   - ADD = 8.8 mgd

Scale Existing ADD to Future ADD for Tamuning

Calculate the overall increase due to future growth for each municipality using projected growth rates. That increased demand is assigned to the model in 2 ways: 1) demands for known, planned developments, 2) the rest of the increased demand is then spread out over the existing users.

4. Calculate increase in existing ADD to future ADD for Tamuning with the projected growth rate of 17.6 percent (2015 to 2035 non-military growth of 29,399 on top of existing population of 164,882 as described in Section 4).
   - Increase in ADD from Existing to Future = 8.8 mgd (step 3) x 0.176 = 1.5 mgd
5. Obtain demands for future development from developers. Scale those demands by 10 percent to account for NRW that will likely eventually occur at the new developments. Historical NRW has been closer to 50 percent in Guam, but 10 percent is reasonable for new developments (assuming good construction of the water infrastructure).
   a. Future development demand = 0.75 mgd (the sum of the demands for the projected future developments shown in Figure D-2 and listed in Volume 1, Section 4)
   b. Scaled demand for each future development = 0.75 mgd x 1.1 = 0.83 mgd
6. Calculate the remaining increase in demand.
   - Remaining increase in ADD = 1.5 mgd (step 4) - 0.83 mgd (step 5b) = 0.72 mgd
7. Calculate scaling factor for existing users. Assume they will all grow by same percent to spread out remaining demand due to growth.
   - Existing user future scaling factor = (8.8 mgd (step 3) + 0.72 mgd (step 5b)) / 8.8 mgd (step 3) = 1.08
8. Finish calculations for increased future demands. Scale all existing customers from existing to future ADD. Add in future development demands.
   a. Existing users = Scale each existing user by 1.08 (step 7)
   b. Future development = Use scaled demands for future developments (step 5b)

Assign ADD Demands to the Model

9. Assign existing and future ADD demands to model junctions.
   a. The closest distribution system pipe to each customer was identified using the modeling software. The software only checked for customers within 1,000 feet of a pipe. Customers more than 1,000 feet from a pipe with demands greater than 1 gpm were assigned by hand. The remaining small customers, which account for only 0.6 percent of the total demand, were not assigned.
   b. The existing and future ADD customer demands were assigned to the closest junction on that pipe.
   c. The total demand for each model junction was calculated as the sum of the water use for all customers assigned to that junction for existing ADD and then for future ADD.

Calculate MDD Demands

10. Calculate scaling factors from ADD to MDD for each area (North, South, Nimitz pressure zones). The following scaling factors were applied to Tamuning.
    a. Existing ADD to MDD north scaling factor = 39.7 mgd (Existing North MDD from Table 4-3) / 36.2 mgd (Existing North ADD from Table 4-3) = 1.10
    b. Use same existing ADD to MDD scaling factor of 1.10 for future demands

11. Calculate the existing and future MDD demands for each model junction by multiplying the existing and future ADD demands at each junction by the MDD scaling factors from the previous step.

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Appendix E

Water Distribution System Evaluation/Design Criteria

This appendix outlines criteria to be used for the evaluation and design of the water distribution system. The evaluation criteria will be used in identifying deficiencies during the analysis of the distribution and collection systems. The design criteria will be used in developing recommendations to address the identified deficiencies.

GWA adopted the State of Hawaii, Water System Standards (WSS) in October 2015. GWA will modify the WSS standards during 2017 to create a new set of GWA Water Standards. Because the GWA Water Standards were not yet available when this memorandum was written, the WSS standards were used as the primary source for the water system criteria. Other sources that are cited in this appendix include:

- GWA Rules
- Guam Building Code
- GWA Engineering
- AWWA M32 Computer Modeling of Water Distribution Systems

Storage Criteria

The storage criteria presented in this appendix are from standards listed in AWWA M32 and were used for the *Water System Hydraulic Analysis Report* (BC, May 2013). The report documented an analysis which calculated existing and future storage needs for GWA. AWWA M32 splits storage into three components, which are then added together for the total required storage (AWWA, 2012b):

1. Equalization storage
1. Fire storage
2. Emergency storage

Even though GWA recently adopted the Hawaii WSS for their standard, it is recommended that the AWWA criteria continue to be used. The AWWA storage criteria give GWA more flexibility in sizing storage to meet GWA's needs than the Hawaii WSS storage criteria. A primary difference between the criteria is the method of calculating emergency storage, which is a major component of required storage volume. The Hawaii WSS criteria include requirements for emergency storage to handle one day of maximum day demand. The AWWA criteria will allow GWA to size emergency storage based on their needs. Each storage component is described below.

Equalization Storage

Equalization storage is the storage volume required to "meet the demands in excess of the production and delivery capabilities." For GWA, equalization storage is the storage required to keep up with peak hour demands when the demands are greater than the available well and water treatment plant production. Equalization storage is typically 15 to 20 percent of the MDD (AWWA, 2012b).

Equalization storage can be calculated using a diurnal pattern, which is a set of peaking factors that define how water system demands change over 24 hours. Diurnal patterns were calculated using several weeks of tank level and well production data from 2012 and 2014. Figure E-1 shows a diurnal pattern from September 2012. The pattern in the figure is divided into the blue area below the average MDD and the green area above the average MDD. Equalization storage is calculated by summing the demand in the green area, or the demand above the MDD.

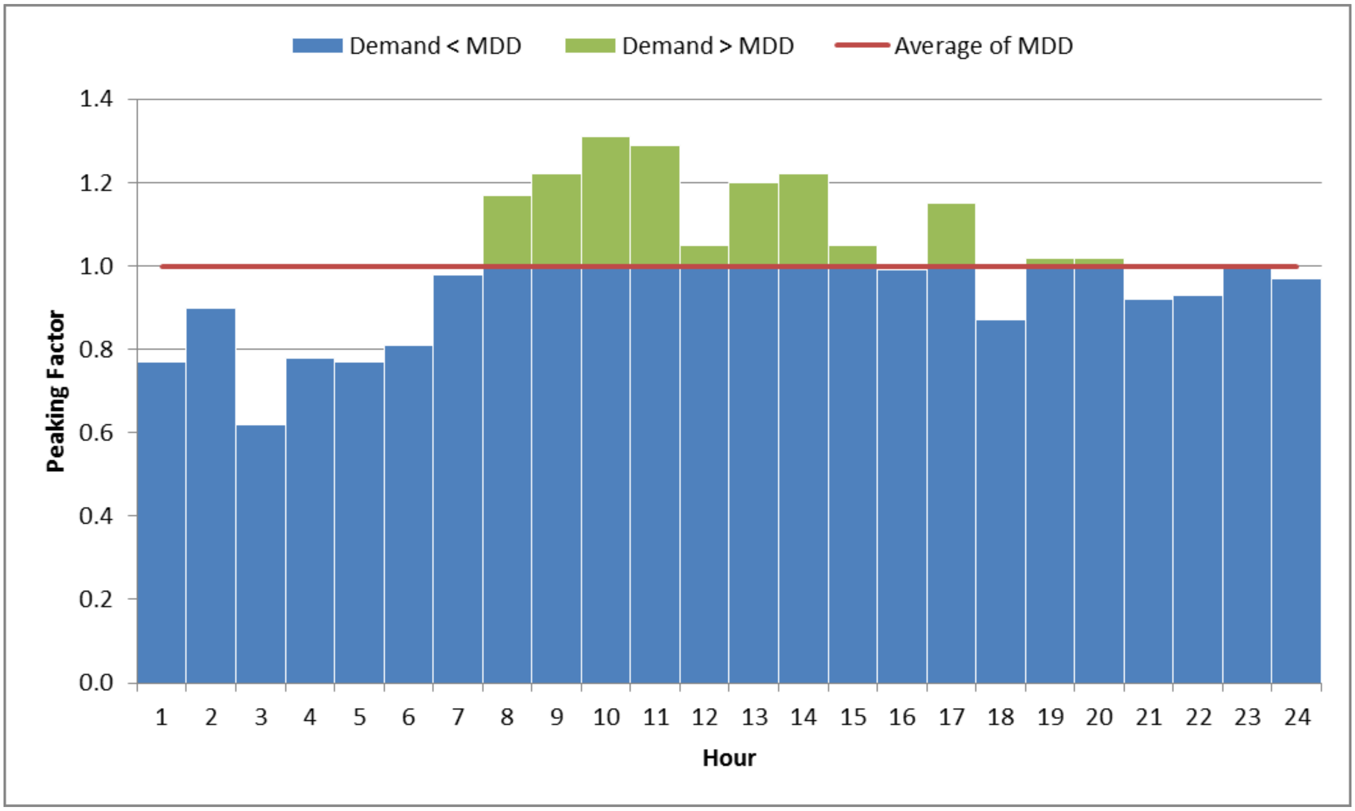


Figure E-1. Diurnal pattern used to calculate equalization storage

The equalization storage calculated from the diurnal pattern in Figure E-1 is 7 percent of the MDD. This was the highest equalization storage calculated from the diurnal patterns from 2012 and 2014. Because the available data to calculate diurnal patterns only covered a few weeks from each year, the more conservative AWWA amount of 15 percent of the MDD will be used.

Note that equalization storage is calculated assuming that there is sufficient supply to meet the average of MDD. Emergency storage, described below, can be sized to compensate for short-term supply deficiencies.

Fire Storage

Fire flow requirements were assigned to each customer listed in the GWA customer billing database based on the customer rate schedule classification used in the GWA billing database. The classification indicates the type of customer, such as residential, commercial, hotel, etc. After assigning a fire flow to each customer, the fire flow for the customers in each pressure zone were compared and the highest fire flow in the zone was used to calculate the required fire storage for the zone.

The appropriate level of fire protection was determined from discussions with GFD and from the Hawaii WSS. According to a discussion that GWA Engineering had with the GFD in April 2016, the GFD uses the 2009 International Fire Code (IFC) but is transitioning to the 2015 IFC (International Code Council 2015). The 2015 IFC does not have any changes from the 2009 IFC regarding fire flow requirements. The IFC gives a clear fire flow requirement for one and two-family residential dwellings. However, fire flow requirements in the IFC are calculated for non-residential buildings based on the building construction and square footage. Building construction and square footage were not available for buildings throughout Guam. Therefore, fire flow requirements from the Hawaii WSS were used for non-residential buildings (Hawaii WSS, Section 111.05). Each non-residential rate schedule was assigned the fire flow from the closest corresponding land use in the Hawaii WSS. Fire flow requirements in the WSS vary for some classifications depending on which Hawaiian island is listed. Fire flow requirements for Maui were used after discussions with GWA. The non-residential fire flow requirements were sent to the GFD for approval, but they did not respond to the request for approval. The rate schedule classifications and the corresponding fire flow requirements are listed in Table E-1.

Table E-1. Storage Fire Flow Requirements

Customer Billing Rate Schedule	Description	Fire Flow (gpm)	Duration of Fire Flow (hours)	Notes
W-AGRIR	Agriculture	500	2	
W-COM1	Commercial 1	2,000	2	Rate schedule includes bars without dining facilities, car wash, department and retail stores, hospital and convalescent, laundromat, professional offices, repair shops and service stations, schools and colleges, soft water service, markets without garbage disposal.
W-COM2	Commercial 2	2,000	2	Rate schedule includes hotels, commercial and industrial laundry.
W-COM3	Commercial 3	2,000	2	Rate schedule includes auto steam cleaning, bakery and wholesale, markets with garbage disposal.
W-FGOV, W-GVGUAM	Federal Government, GovGuam	2,000	2	Assumed to be commercial land use type.
W-GOLF	Golf	2,000	2	Assumed the clubhouse is a commercial land use type.
W-HOTEL	Hotel	2,500	2	
W-RES	Residential	1,000	1	Source is 2015 IFC, which specifies 1,000 gpm for one and two-family dwellings with a fire-flow calculation area <= 3,600 square feet. For larger, multi-family buildings, the fire flow is higher. However, the billing data does not specify the number of families, so it was assumed that W-RES billing locations are one to two-family dwellings.
W-IRRI	Irrigation	Not applicable		No fire flow required for irrigated land.

The required fire storage volume for a storage tank is the largest fire flow in the area served by the tank multiplied by the fire flow duration. It is assumed that there will only be a single fire at a time, so the fire storage can be shared between zones.

Emergency Storage

Emergency storage is the volume required to provide water during events like power outages, equipment failures, natural disasters, etc. AWWA does not specify the amount needed for emergency storage because the amount will depend on the type of emergencies a community will likely encounter. The required emergency storage should consider the frequency, intensity, duration, and consequence of the emergency condition, as well as the available supply. The emergency storage should at least “provide adequate volume to supply the system’s average daily demand for the estimated duration of a possible emergency” (Linsley 1979, 281). A concern to consider in setting emergency storage is that too much emergency storage could lead to water quality problems. Emergency storage can be calculated in two ways:

1. Assume that the emergency is localized, so emergency storage can be shared between zones. For example, if an emergency occurred in the Yigo pressure zone, the emergency storage available in the Santa Rosa tank could be counted for the Yigo pressure zone. The Santa Rosa tank could flow down into the Yigo pressure zone by opening a normally closed valve.
2. Assume that the emergency is island-wide, so emergency storage is required to be available for all zones at the same time. This option would allow excess emergency storage in a higher elevation zone to be used in a lower elevation zone when the excess storage can flow to the lower zone by gravity. For example, extra storage in the Santa Rosa tank available after subtracting the Santa Rosa pressure zone emergency storage requirements could be available to the Yigo pressure zone.

Based on the types of outages seen by GWA, GWA Engineering established a criterion of one day of ADD for emergency storage and that emergency storage should be sufficient for each zone separately (option 2 above).

Storage Summary

It can be overly conservative to assume that an emergency and fire will occur at the same time. GWA Engineering decided that GWA will use the greater of the emergency and fire storage for each pressure zone. The required storage for each pressure zone will be calculated as:

Equalization Storage + Greater of Fire (largest fire demand in zone) or Emergency Storage (1 day ADD)

Distribution Piping Criteria

The criteria in Table E-2 will be used for water distribution piping and dedicated transmission piping.

Table E-2. Distribution Piping Criteria

Item	Description	Value	Source / Notes
Pressure	Minimum	20 psi	Hawaii WSS 111.06. Per GWA Rules §2103, customers at elevations that cannot be properly served may need to install a tank or pump.
	Desired minimum	35 psi	GWA Engineering. GWA's goal is to maintain a minimum of 35 psi.
	Maximum	90 psi	GWA Rules §2103
Pipe Size	Minimum	6 inch	GWA Engineering
Velocity	Maximum (evaluating system)	10 feet/second	GWA Engineering
	Maximum (designing new piping)	6 feet/second	Hawaii WSS 111.06
Fire Flow	GWA currently does not size pipelines to supply fire flow to all customers in the distribution system		GWA Engineering

Booster Pump Station Criteria

The criteria in Table E-3 will be used for BPSs.

Table E-3. BPS Criteria

Item	Value	Source / Notes
Redundancy / reliability	Each BPS should have a minimum of 2 supply pumps	Hawaii WSS 111.08
Minimum capacity (with largest pump on standby)	Pumps are sized to meet MDD over 24 hours	Hawaii WSS 111.08 (for Kauai and Hawaii). The WSS lists additional requirements for pumping fire flow, but these are not included here.
	For BPSs pumping into an area without a storage tank, the BPS must be able to pump the peak hour demand	GWA Engineering

Supply Criteria

The criteria in Table E-4 will be used for supply.

Table E-4. Supply Criteria		
Item	**Value**	**Source / Notes**
Capacity	Supply must be sufficient to deliver the greater of: • MDD • 1.2 x ADD For 2012 through 2015, MDD ranged from 1.11 to 1.15 times ADD. Because 1.2 times ADD was higher than MDD, 1.2 times ADD will be used as the minimum required supply.	Hawaii WSS 111.04 Potable Water Production Enhancement Plan (GWA, 2010), see Volume 1, Section 5.5 for additional information

Appendix F

Pipe Condition Assessment Data

This appendix contains background data used in the condition assessment of the water facilities.

Data Used in Water System Analysis

To support the condition assessment of the water system pipe network, the following information was gathered:

- GWA GIS data included the following datasets:
  - Water main pipe data
  - Pressure zones
  - Municipal/Village boundaries
  - Customer meter accounts and critical customers
  - Digital orthophotography of the service area
- Federal data included the following datasets:
  - TIGER roads
  - Census population
  - Place locations (hospitals, schools, churches)
- NOAA included the following datasets:
  - LIDAR elevation data
  - Landcover data
- Google Earth included the following datasets:
  - Hotel locations
  - Locations of potential critical customers

The following gaps in the available data were identified during the analysis:

- Unknown Installation Dates – Approximately 13 percent of the water mains do not have an installation date noted in the GIS database. The date of installation of a water pipe is an important piece of information for determining a pipe's remaining service life. During the analysis performed and documented in this report an assumption was made to apply the median age of the system, identified as 1990, to pipes with an unknown installation date within the GWA GIS database.

Likelihood of Failure Factors

Table F-1 lists the scoring breakdown for the likelihood of failure factors.

Table F-1. Likelihood of Failure Factors	
Input Value	Score
P2, Soils	
Agfayan-Akina association, Agfayan-Akina-Rock outcrop association, Agfayan-Rock outcrop complex, Akina-Agfayan association, Akina-Atate association, Akina-Badland association, Akina-Badland complex, Akina-Urban land complex, Guam-Saipan complex, Guam-Urban land complex, Guam-Yigo complex, Pulantat-Urban land complex, Ritidian-Rock outcrop complex, Rock outcrop-Ritidian complex, Togcha-Ylig complex, Troposaprists, Urban land-Ustorthents complex	1
Akina silty clay, Akina-Atate silty clays, Guam cobbly clay loam, Inarajan sandy clay loam, Shioya loamy sand, Togcha-Akina silty clays, Water	3
Agfayan clay, Chacha clay, Chacha variant clay, Inarajan clay, Inarajan variant mucky clay, Pulantat clay, Pulantat-Chacha clays, Pulantat-Kagman clays, Sasalaguan clay, Ylig clay	5
P3, Past Breaks/Leaks	
No recorded issues	1
1 recorded issue	3
> 1 recorded issues	5
P4, Pipe Installation or Lining Year	
>= 2010	1
1995 through 2009	2
1980 through 1994	3
1965 through 1979	4
< 1965	5
P5, Material	
Other, Unknown	1
Copper, Ductile Iron, PVC	2
Galvanized Iron, Steel	3
Cast Iron	4
Asbestos Cement	5
P9, Operating Pressure	
Pressure < 20 psi	1
Pressure 20 to 40 psi	2
Pressure 40 to 60 psi	3
Pressure 60 to 80 psi	4
Pressure > 80 psi	5
P11, Depth and Road Crossings	
All others	1
Depth = 0 to 1 feet, does not cross road	2
Depth = 3 feet, crosses road	3
Depth = 1 to 2 feet, crosses road	4
Depth = 0 feet, crosses road	5

Consequence of Failure Factors

Table F-2 lists the scoring breakdown for the consequence of failure factors.

Table F-2. Consequence of Failure Factors

Input Value	Score
C1, Damage or Disruption to Sensitive Locations	
Distance > 500 feet from sensitive location	1
Distance = 301 to 500 feet from sensitive location	2
Distance = 201 to 300 feet from sensitive location	3
Distance = 101 to 200 feet from sensitive location	4
Distance = 0 to 100 feet from sensitive location	5
C2, Damage or Disruption to Roadways	
Pipes not near a roadway	1
<= 50 feet from minor roadway	3
<= 50 feet from major roadway	5
C4, Service Outage - Customer Demand	
0 to 5,000 gallons per month	1
5,001 to 10,000 gallons per month	2
10,001 to 40,000 gallons per month	3
40,001 to 1,000,000 gallons per month	4
Greater than 1,000,001 gallons per month	5
C7, Flooding Potential - Flow	
Average flow = 0 to 5 gpm	1
Average flow = 5 to 50 gpm	2
Average flow = 50 to 100 gpm	3
Average flow = 100 to 500 gpm	4
Average flow = > 500 gpm	5
C8, General Disruption - Landcover	
Pipe within other type of area	1
Pipe within developed open space	3
Pipe within impervious surface	5
C10, Pipe Redundancy	
Does not have redundant pipes	5
Has redundant pipes	1
C11 Population Density	
Population density <= 250 persons per square mile	1
Population density = 251 – 500 persons per square mile	2
Population density = 501 – 750 persons per square mile	3

Table F-2. Consequence of Failure Factors	
Input Value	Score
Population density = 751 – 1,500 persons per square mile	4
Population density > 1,500 persons per square mile	5

Appendix G

Water Distribution System Recommendations

This appendix contains figures showing detailed instructions on how the existing pressure zones can be realigned. The figures are ordered from north to south as shown in Figure G-1. The details referenced in the figures are shown in Appendix H. Note that choked valves are not shown in the figures but this plan assumes that all choked valves will be opened in a new pressure zone.

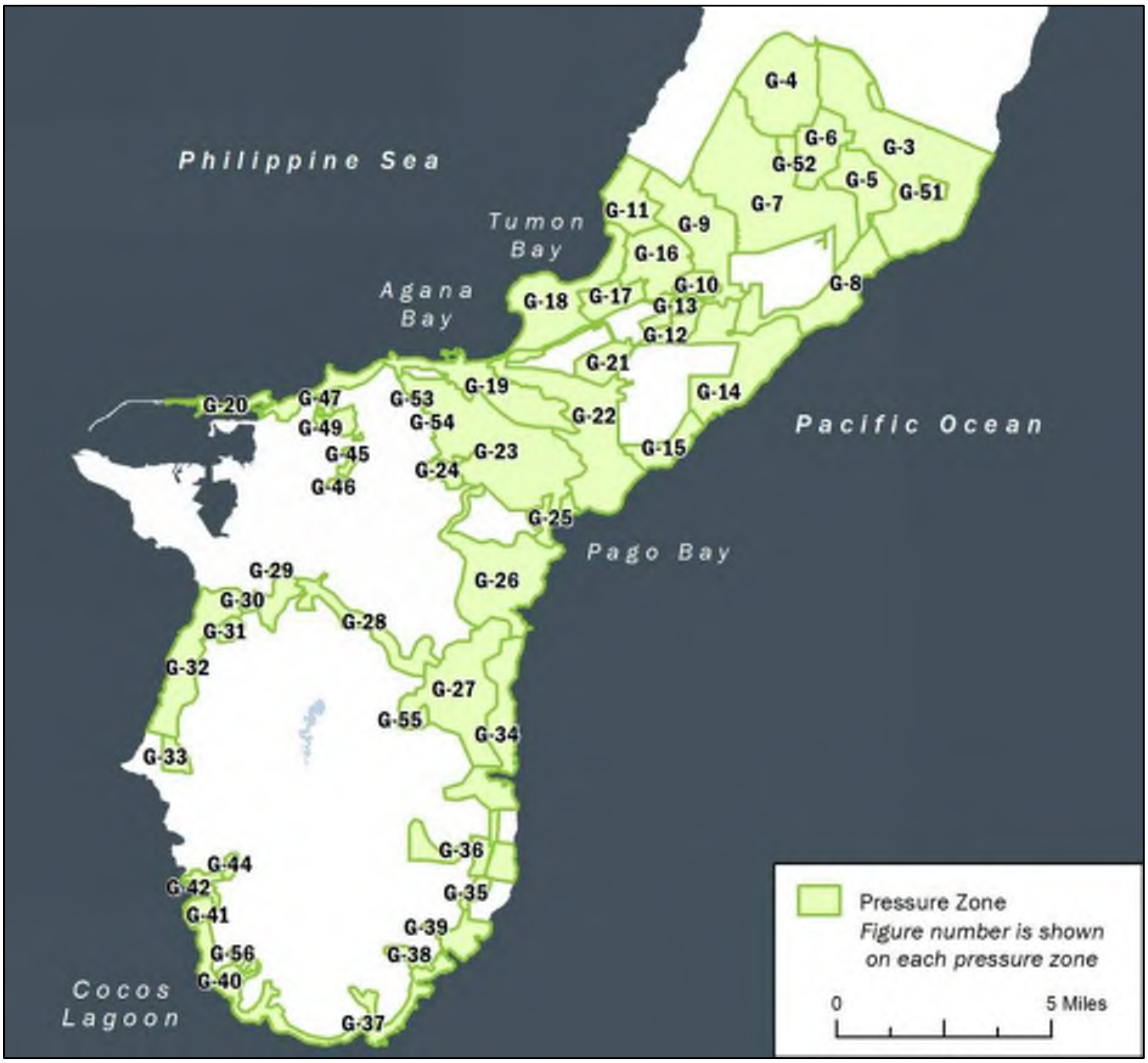


Figure G-1. Key Map for Pressure Zone Detail Figures

Figure G-2 shows an example of how the rest of the figures in this appendix are formatted. The example Figure G-2 shows the area served by the Santa Ana Lower tank. Figure G-2 and the following text help explain how to interpret the figures in the rest of this appendix.

Naming

For zones served by a tank, the zones were given the name of the tank serving the zone. For zones served by PRVs, the zones were named after the village(s) served by the zone. Each pressure zone was also assigned a HGL. The HGL is the elevation above sea level of the water in a tank when the tank is full. For areas served by PRVs, the HGL is the elevation of the PRV above sea level plus the pressure head.

In Figure G-2, the new pressure zone is labeled “Santa Ana Lower (236).” The zone was named after the tank serving the zone (Santa Ana Lower tank). The HGL is the elevation when the Santa Ana Lower tank is full (236 feet).

Elevations

The following shading is shown in Figure G-2 to represent ranges of elevations:

- Dark Gray – Customers in the dark gray shaded areas can be served by the Santa Ana Lower tank at pressures between 35 and 90 psi.
- Light Gray – Customers in the light gray shaded areas would have pressures above 90 psi if they are served directly by the Santa Ana Lower tank.
- White – Customers in the white, unshaded areas would have pressures below 35 psi if they are served directly by the Santa Ana Lower tank.

The actual pressures for each customer will vary depending on the water level in the Santa Ana Lower tank and headloss through the piping from the tank to the customers.

Pressures

Figure G-2 shows the locations of the customer meters. The customer meters are shaded according to their predicted pressures. The pressures were calculated by the model for a 24-hour model run with the revised pressure zone boundaries. Pressure zone boundaries could not always be set to only serve customers within the correct elevation range as explained in the following description of the shading:

- Solid circle – Customers with pressures between 35 and 90 psi throughout a maximum day.
- Hollow circle – Customers with pressures below 35 psi at some time during a maximum day. These typically include customers that are at a higher elevation as compared to the majority of the customers in a pressure zone, such as just below a storage tank. These customers may need to be served by small booster pumps.
- Hollow square – Customers with pressure above 90 psi at some time during a maximum day. These include customers that are typically at a lower elevation as compared to the majority of the customers in a pressure zone. For example, for the Santa Ana Lower tank service area, customers on the west side of the pressure zone along the coast are in an elevation area that is too low to be served directly by the tank without seeing pressures above 90 psi. Because of the current piping configuration, it would be difficult to separate this area into two separate pressure zones. Therefore, most of this pressure zone was left as it is currently configured. Customers with higher pressures may currently have or may need PRVs on their service lines.

Boundary Notes

In Figure G-2, the dashed line shows the current WSA boundary and the purple line shows the new proposed boundary. The boundaries remain the same in some areas. In other areas, the boundary was moved to combine areas of similar elevation into a single pressure zone. For example, Figure G-2 shows an area along Sumay Memorial Street that is not currently served by the Santa Ana Lower tank. However, the area is at the correct elevation to be served by the tank, so the pressure zone boundary was adjusted to include the area.

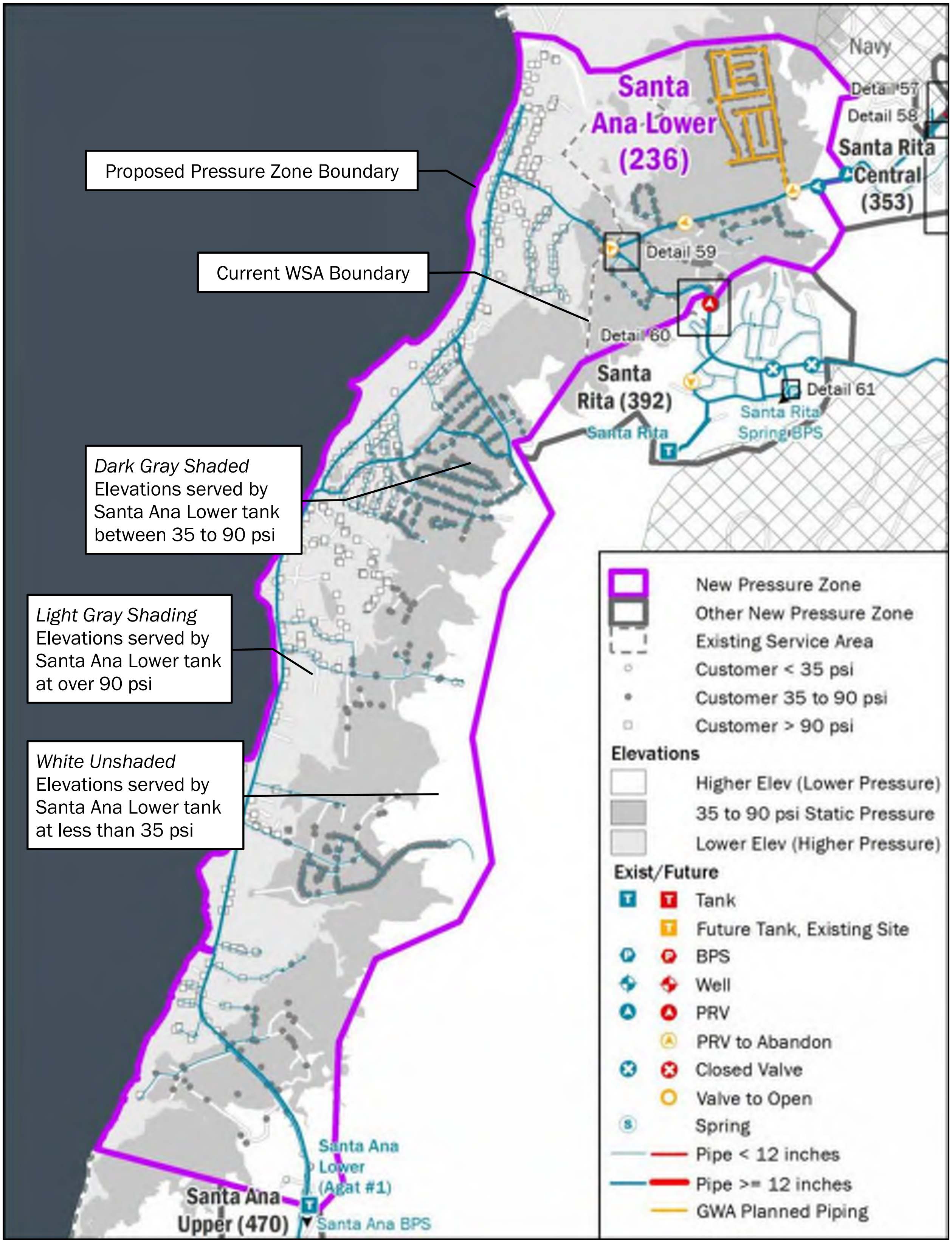
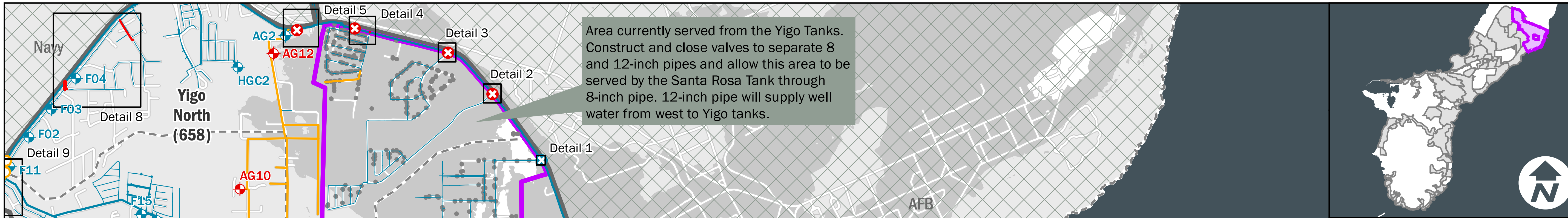


Figure G-2. Santa Ana Lower Tank Service Area



Pressure (psi)	Num Customers
0-20	26 (2%)
20-35	47 (3%)
35-90	1,593 (95%)
90-100	-
100-120	4 (0%)
> 120	-
Total	1,670

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

Elevations

Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

Exist/Future

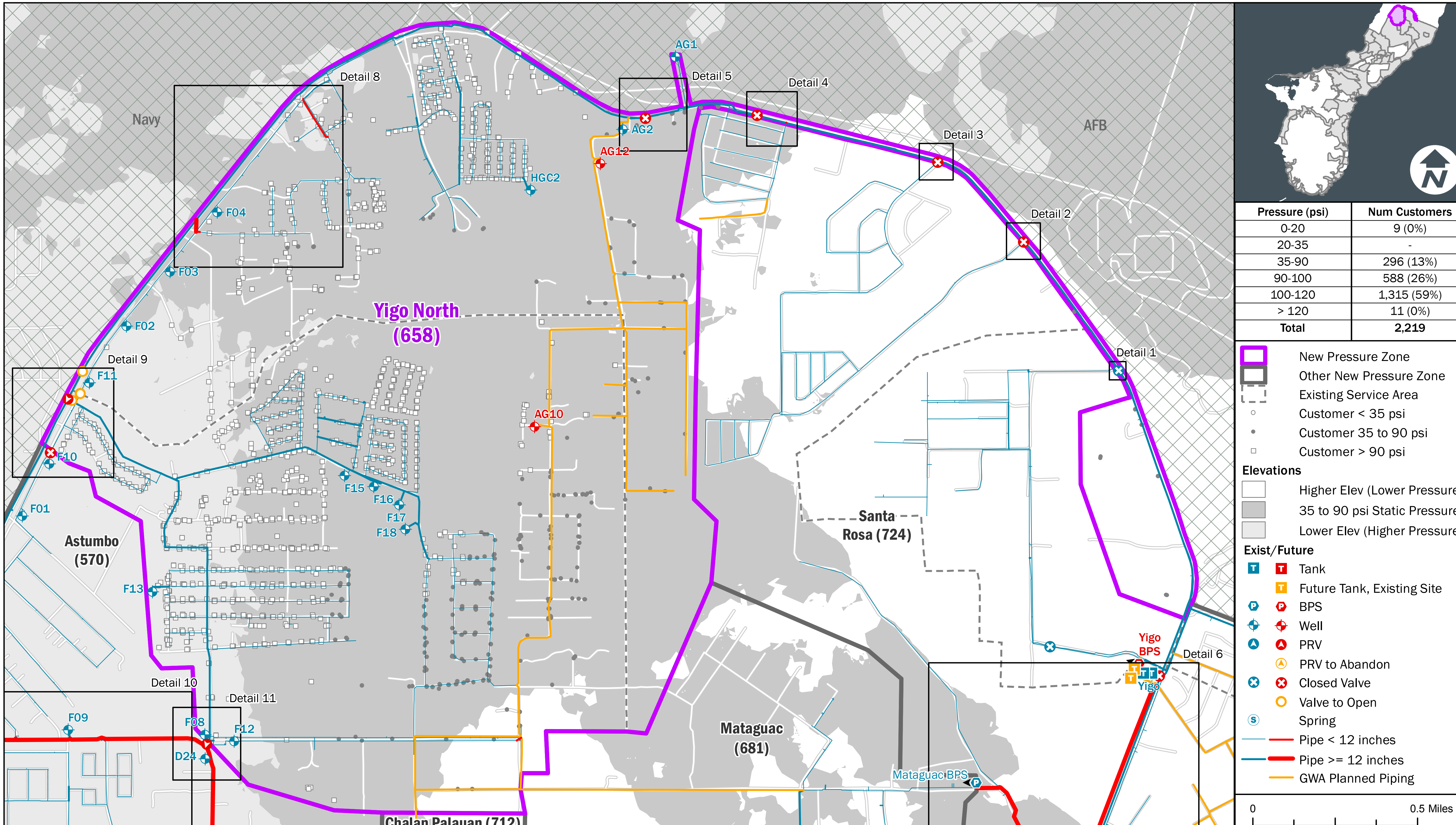
Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 — 1 Miles

8/10/2017

Figure G-3. Santa Rosa (724) Pressure Zone

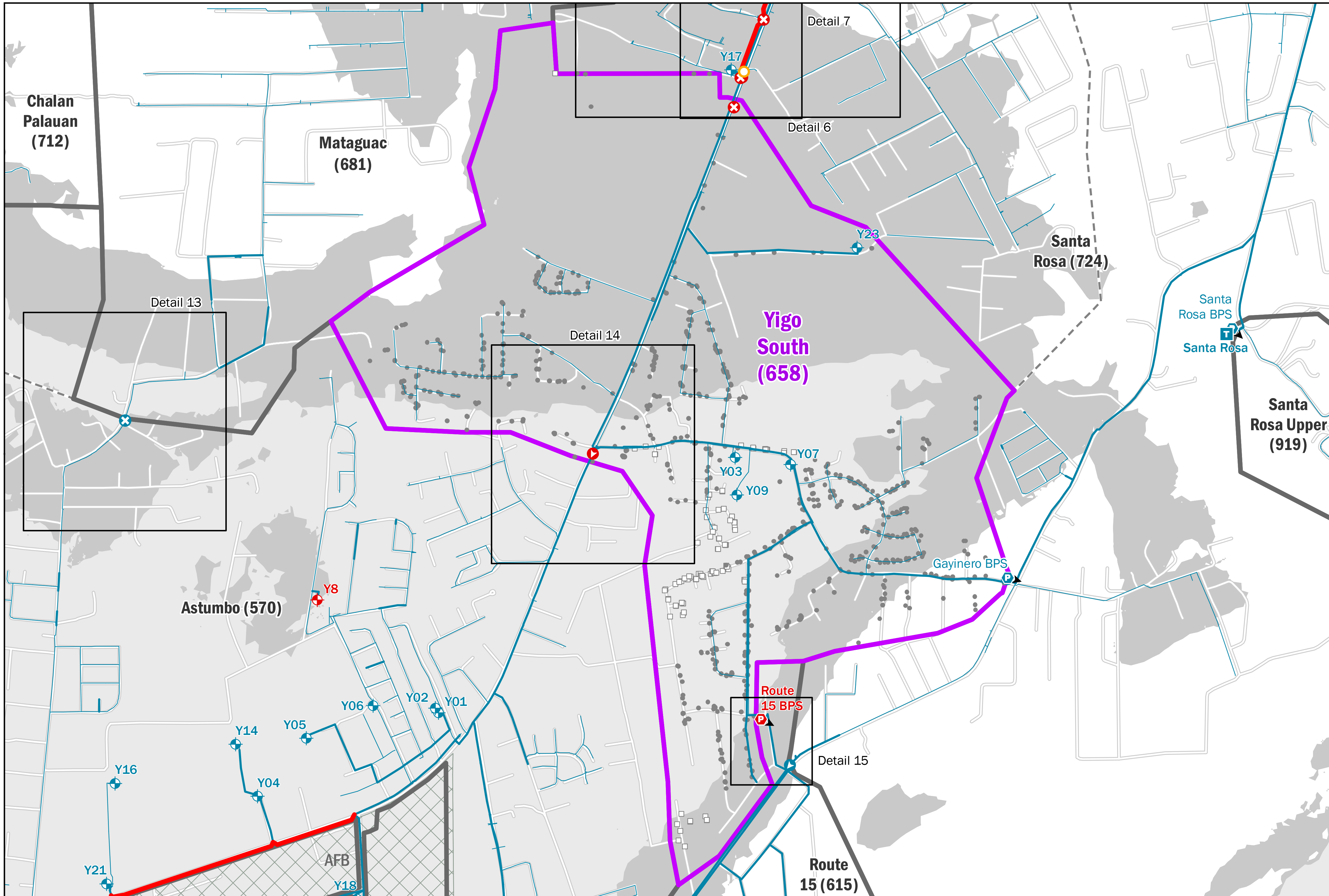
Brown AND Caldwell

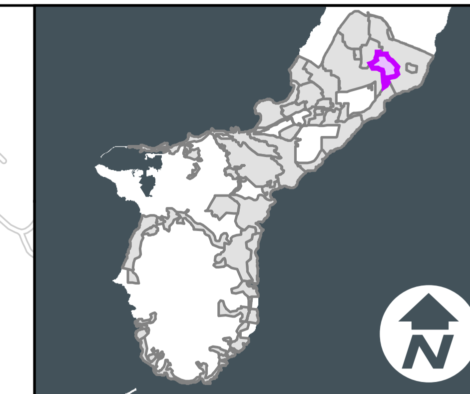


Pressure (psi)	Num Customers
0-20	9 (0%)
20-35	-
35-90	296 (13%)
90-100	588 (26%)
100-120	1,315 (59%)
> 120	11 (0%)
Total	**2,219**

8/10/2017

Figure G-4. Yigo North (658) Pressure Zone





Pressure (psi)	Num Customers
0-20	69 (6%)
20-35	-
35-90	850 (78%)
90-100	152 (14%)
100-120	5 (0%)
> 120	11 (1%)
Total	1,087

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

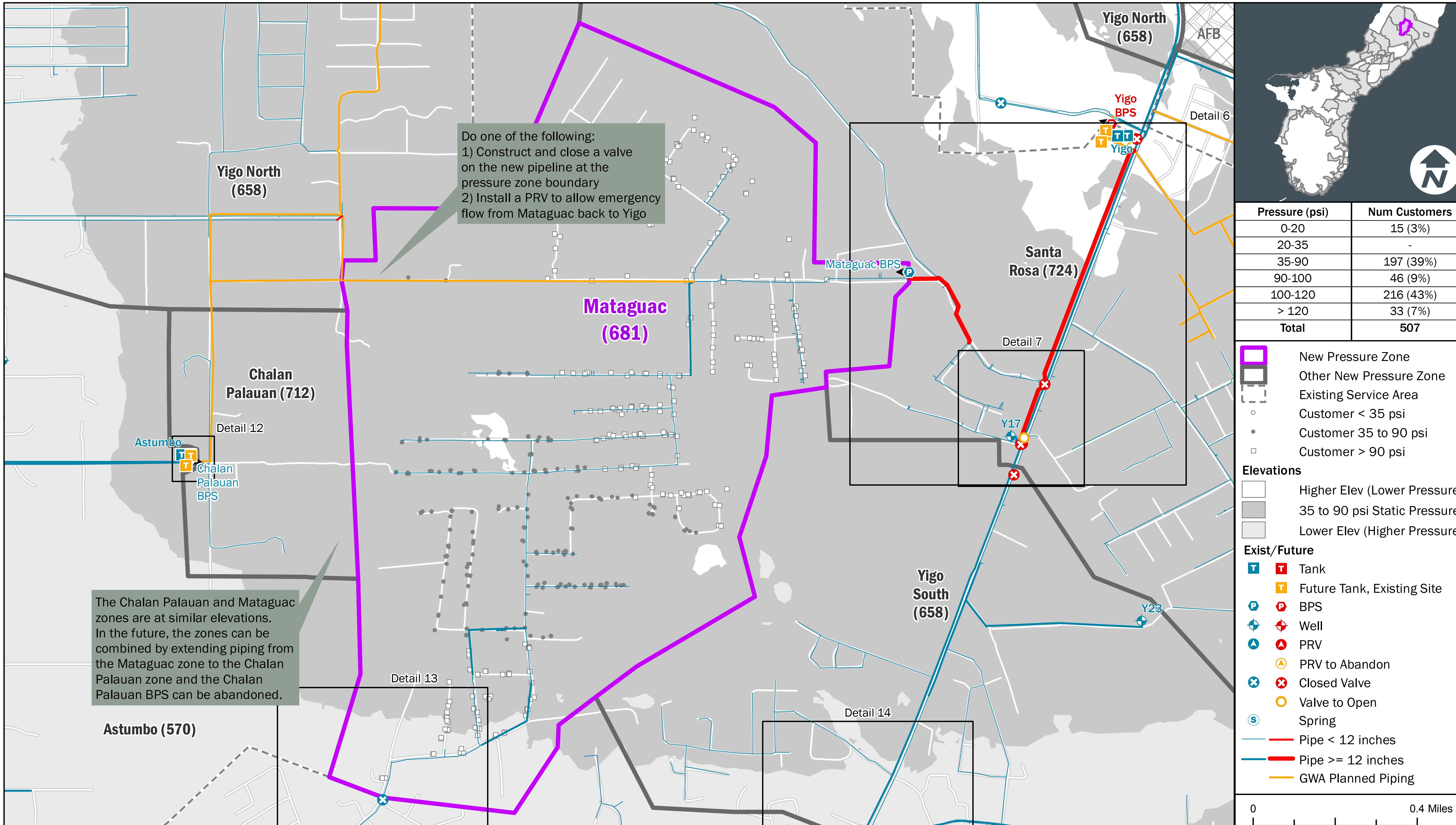
Elevations
Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

Exist/Future
Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 0.4 Miles

8/10/2017

Figure G-5. Yigo South (658) Pressure Zone

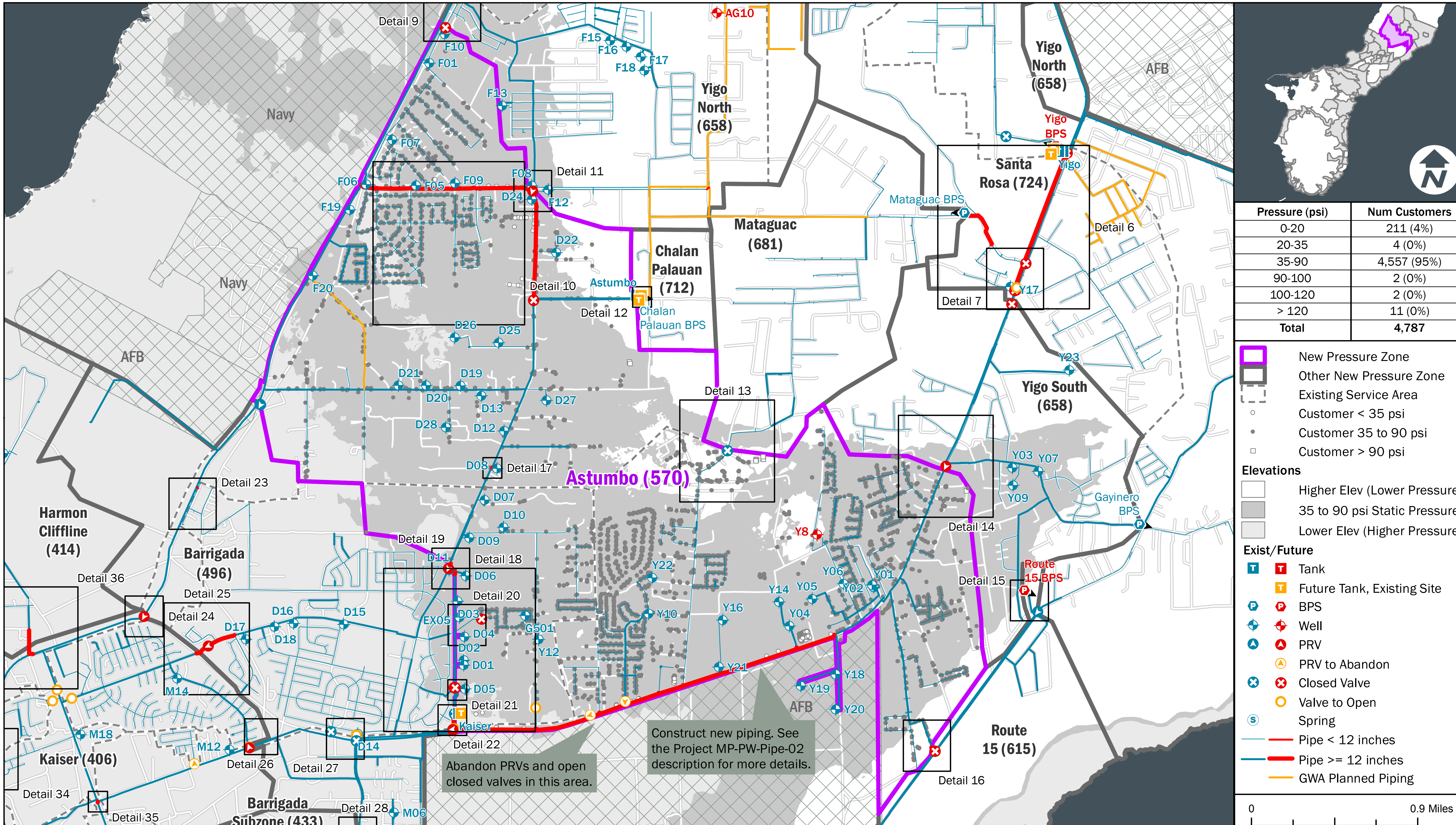


Pressure (psi)	Num Customers
0-20	15 (3%)
20-35	-
35-90	197 (39%)
90-100	46 (9%)
100-120	216 (43%)
> 120	33 (7%)
Total	507

8/10/2017

Figure G-6. Mataguac (681) Pressure Zone

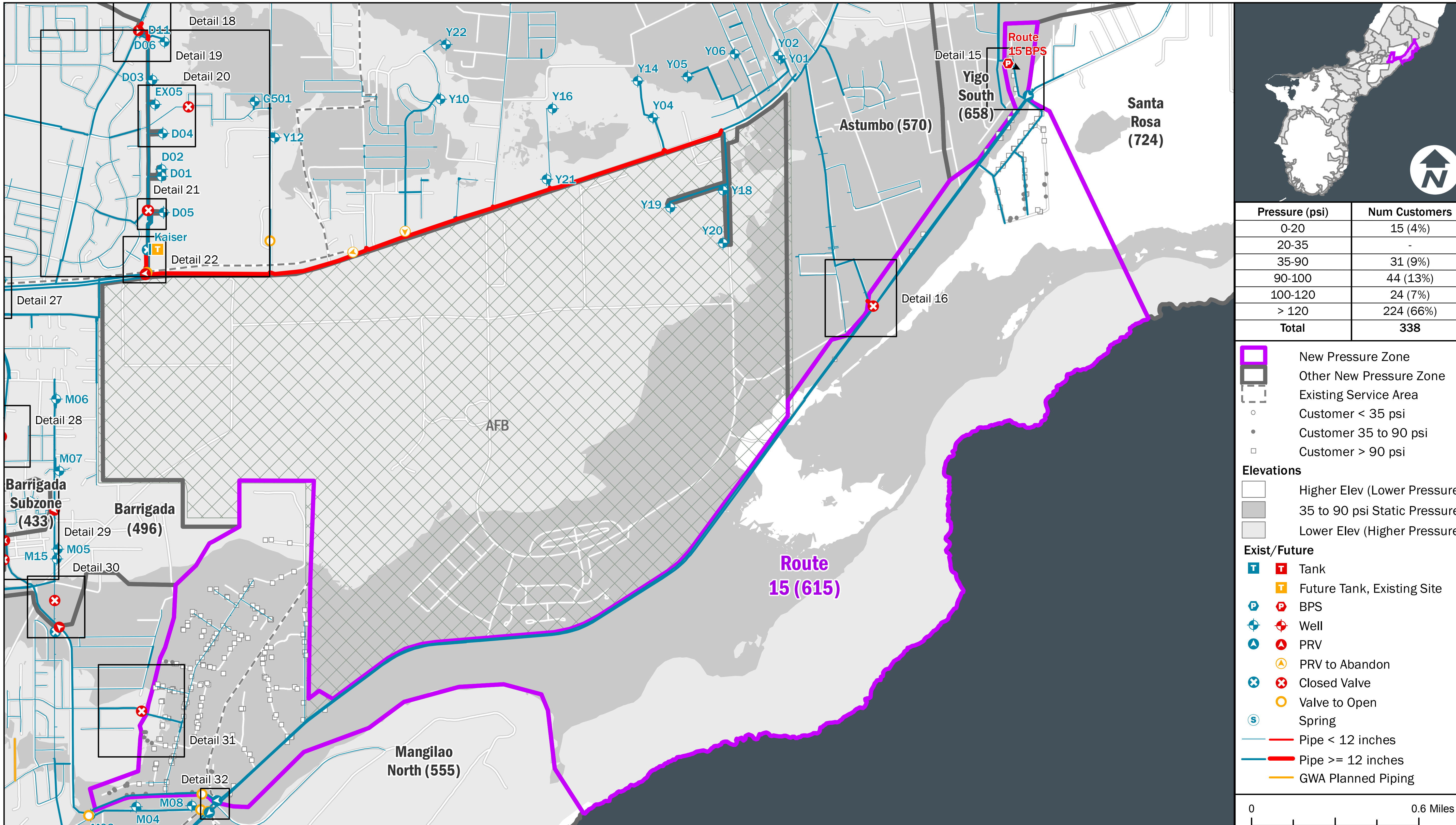
Brown AND Caldwell



Pressure (psi)	Num Customers
0-20	211 (4%)
20-35	4 (0%)
35-90	4,557 (95%)
90-100	2 (0%)
100-120	2 (0%)
> 120	11 (0%)
Total	**4,787**

8/10/2017

Figure G-7. Astumbo (570) Pressure Zone



Pressure (psi)	Num Customers
0-20	15 (4%)
20-35	-
35-90	31 (9%)
90-100	44 (13%)
100-120	24 (7%)
> 120	224 (66%)
Total	**338**

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

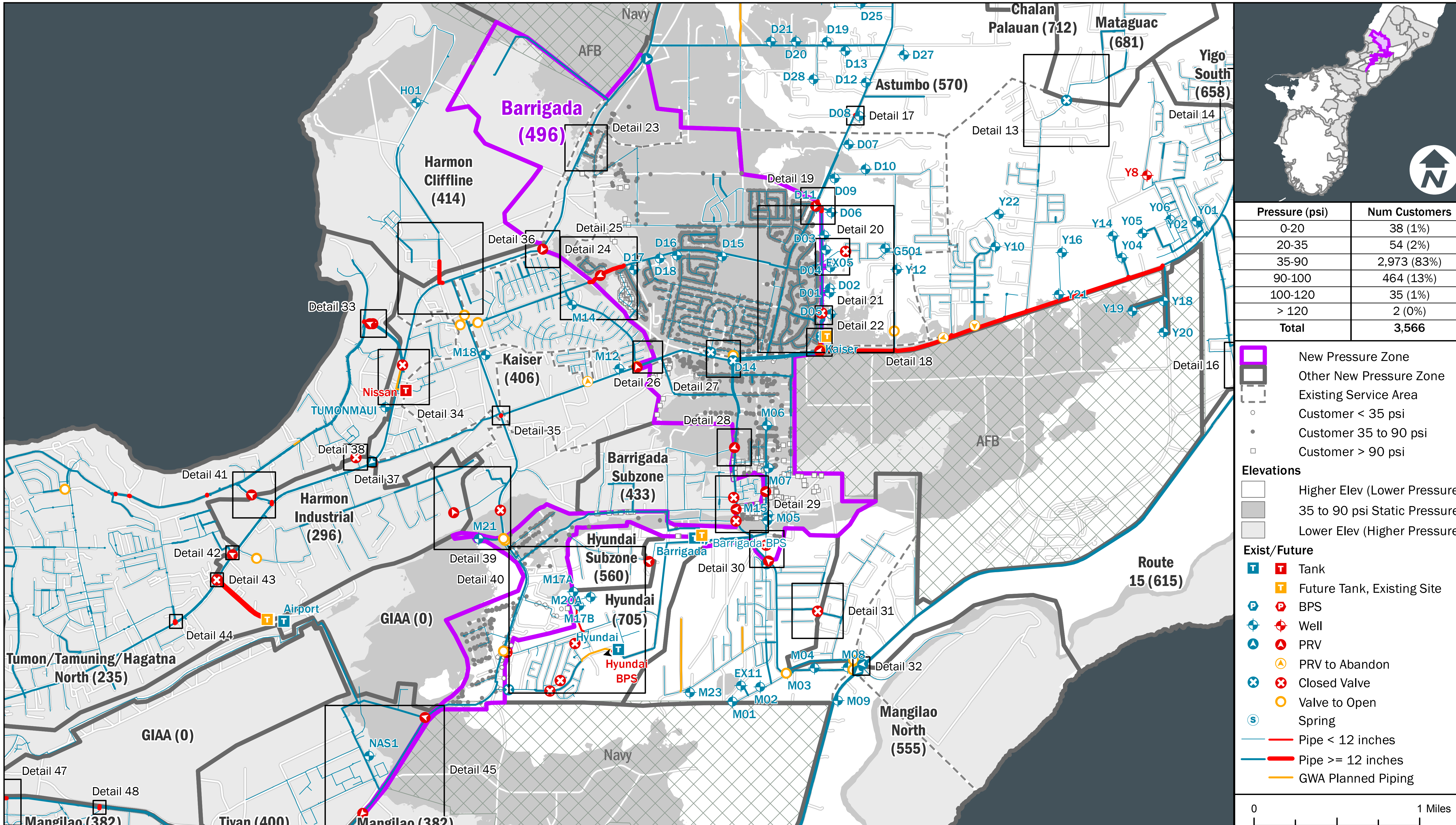
Elevations
Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

Exist/Future
Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 0.6 Miles

8/10/2017

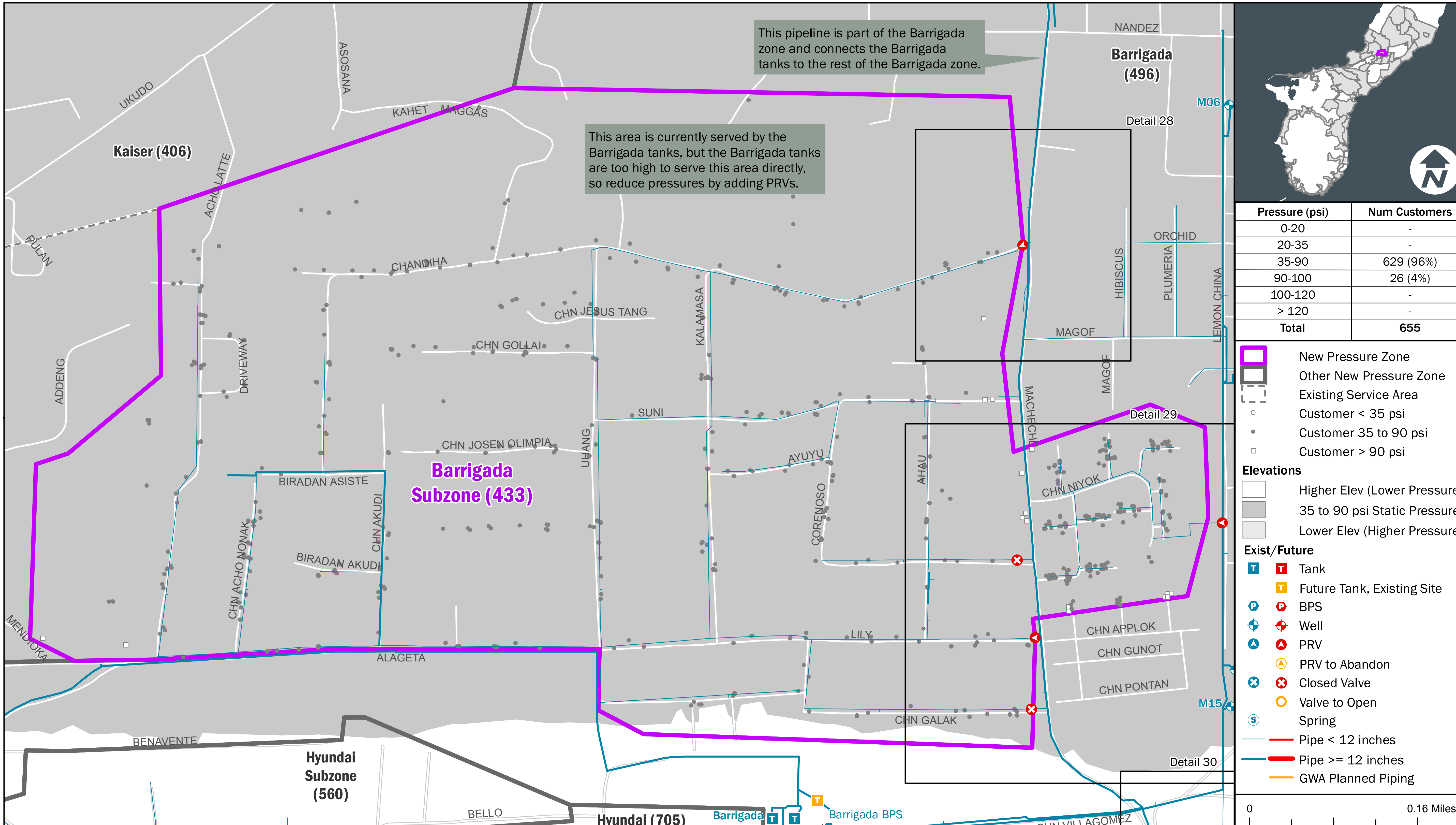
Figure G-8. Route 15 (615) Pressure Zone



Pressure (psi)	Num Customers
0-20	38 (1%)
20-35	54 (2%)
35-90	2,973 (83%)
90-100	464 (13%)
100-120	35 (1%)
> 120	2 (0%)
Total	3,566

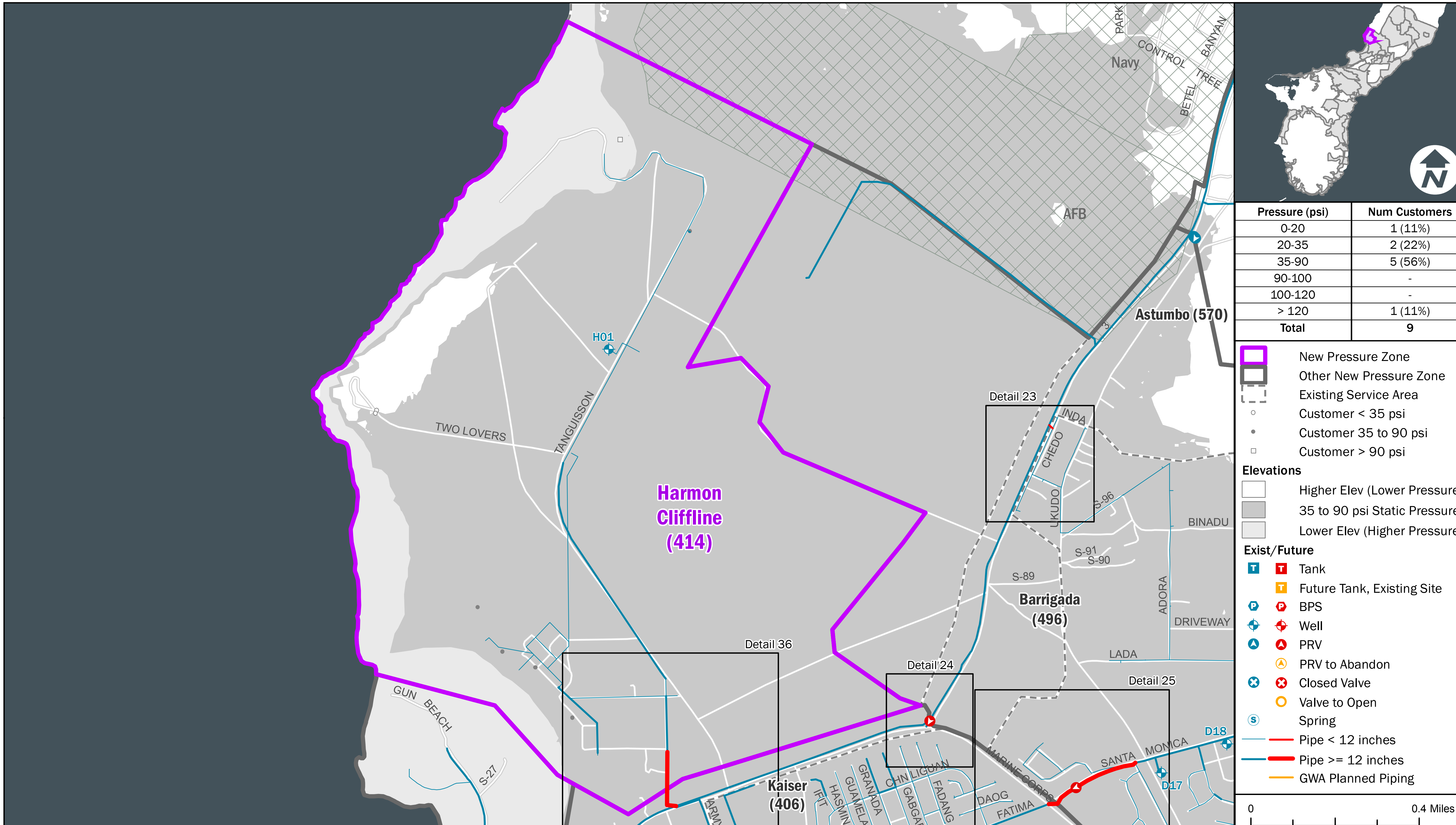
8/10/2017

Figure G-9. Barrigada (496) Pressure Zone



8/10/2017

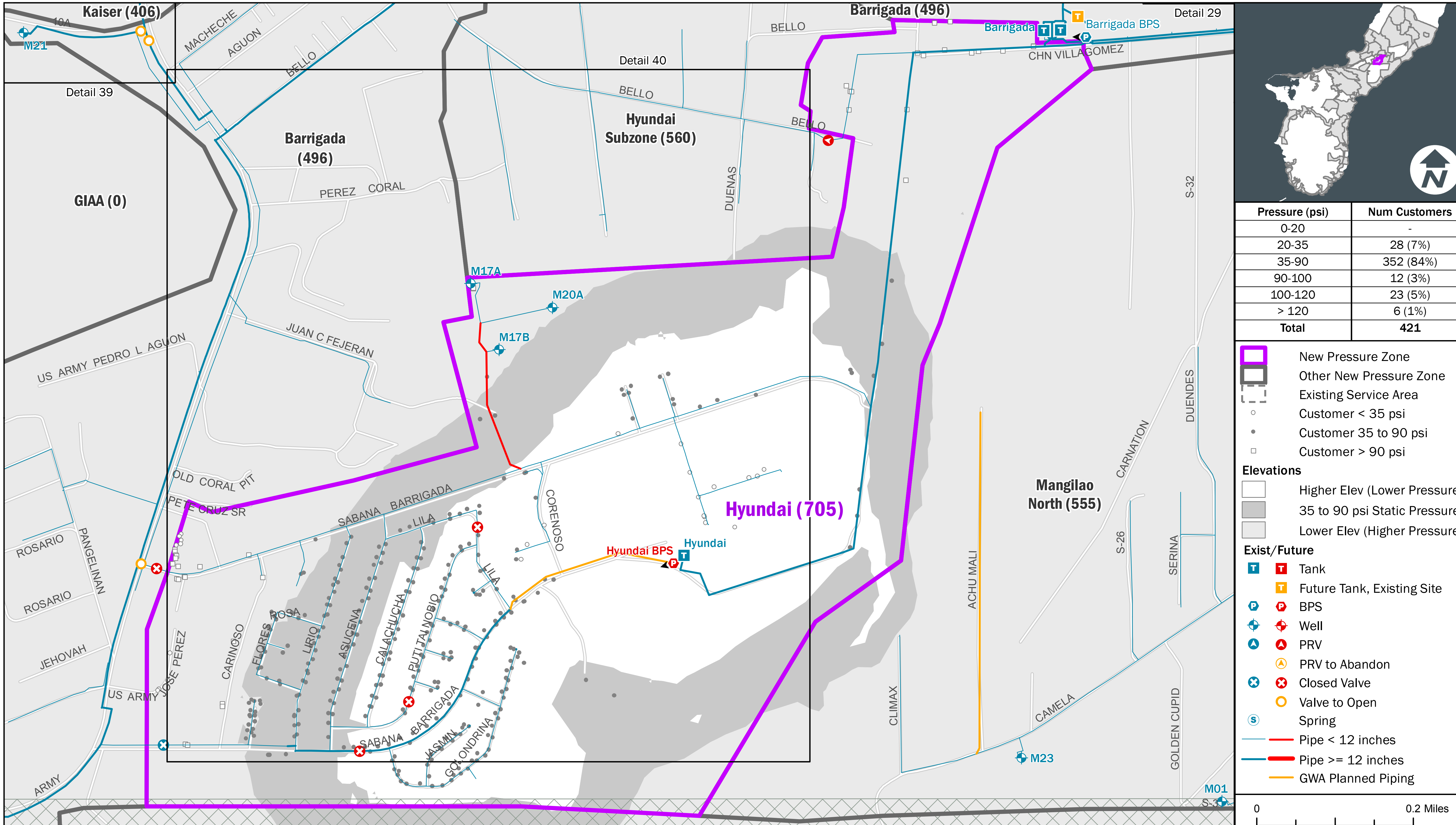
Figure G-10. Barrigada Subzone (433) Pressure Zone



Pressure (psi)	Num Customers
0-20	1 (11%)
20-35	2 (22%)
35-90	5 (56%)
90-100	-
100-120	-
> 120	1 (11%)
Total	9

8/10/2017

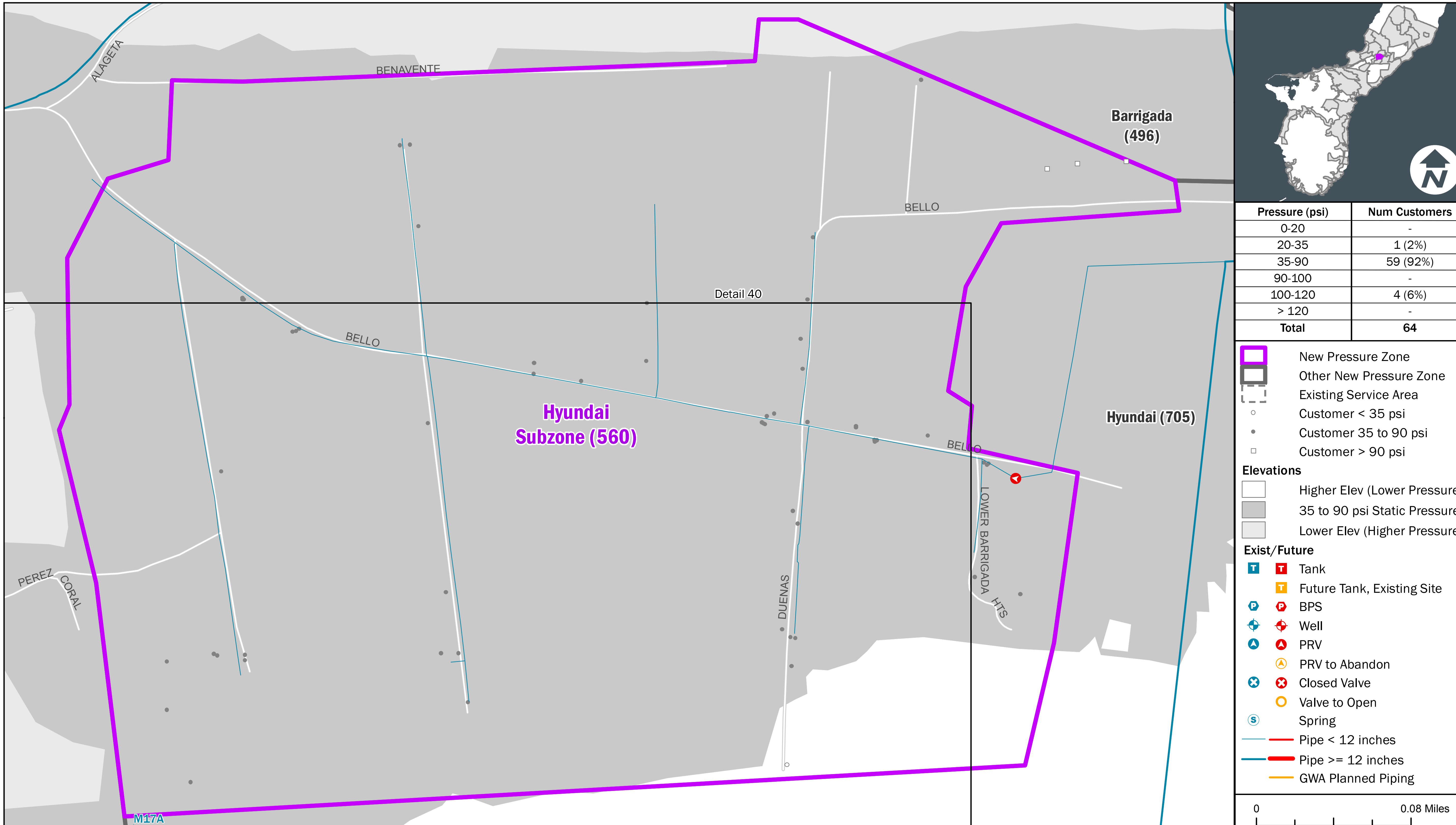
Figure G-11. Harmon Cliffline (414) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	28 (7%)
35-90	352 (84%)
90-100	12 (3%)
100-120	23 (5%)
> 120	6 (1%)
Total	421

8/10/2017

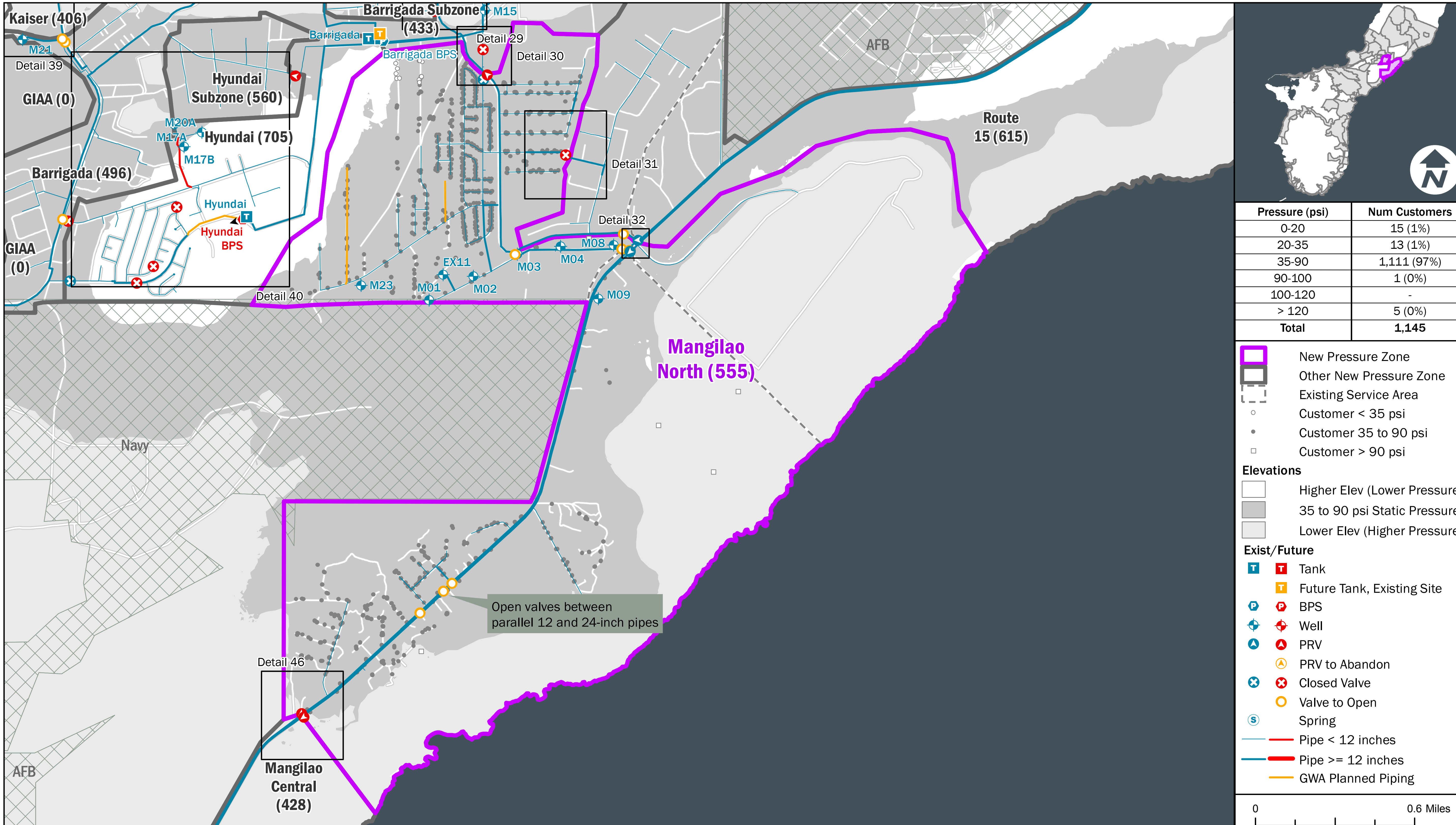
Figure G-12. Hyundai (705) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	1 (2%)
35-90	59 (92%)
90-100	-
100-120	4 (6%)
> 120	-
Total	**64**

8/10/2017

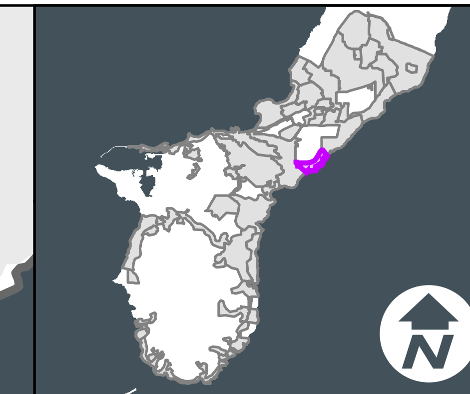
Figure G-13. Hyundai Subzone (560) Pressure Zone



Pressure (psi)	Num Customers
0-20	15 (1%)
20-35	13 (1%)
35-90	1,111 (97%)
90-100	1 (0%)
100-120	-
> 120	5 (0%)
Total	1,145

8/10/2017

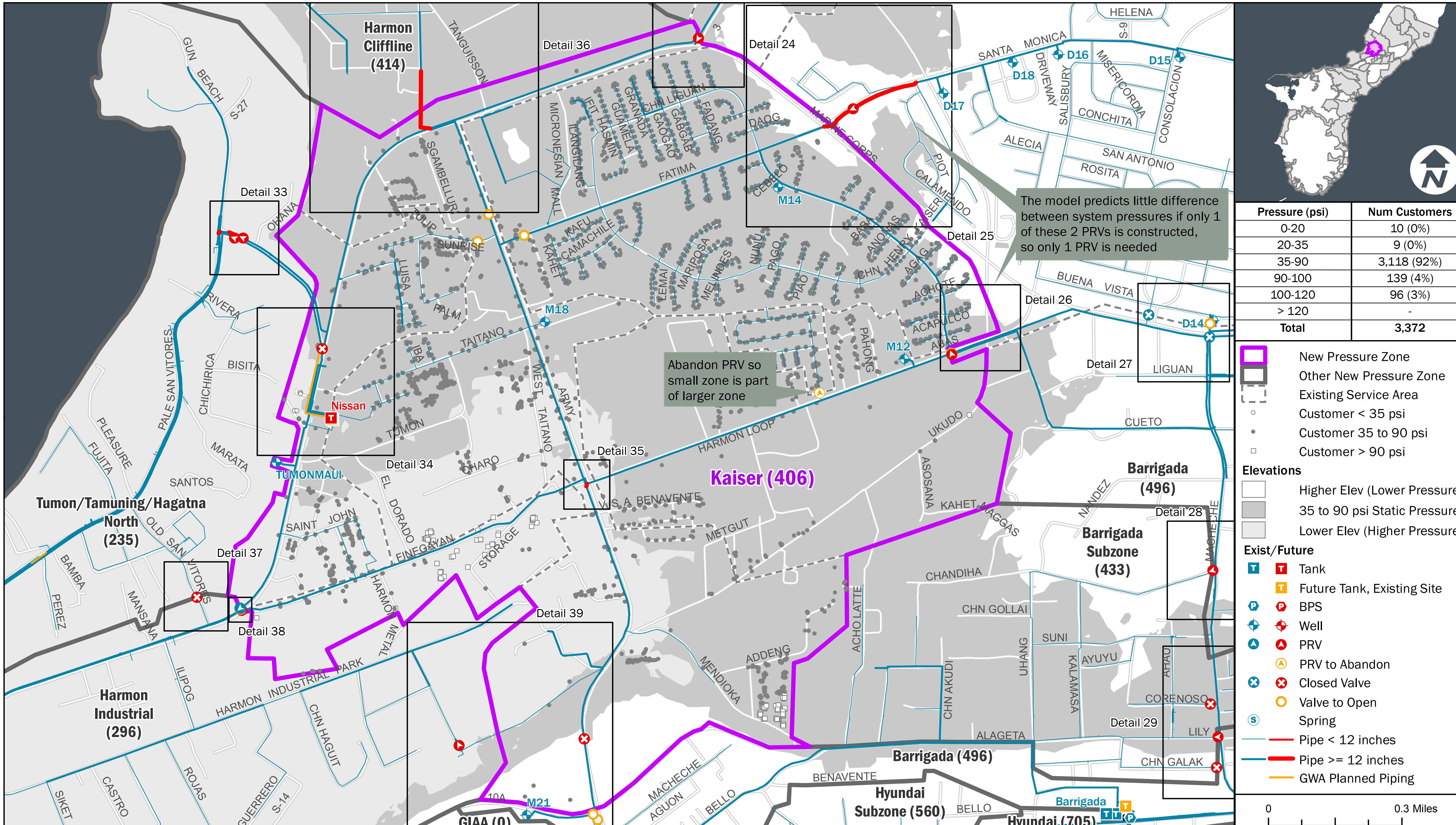
Figure G-14. Mangilao North (555) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	56 (98%)
90-100	-
100-120	-
> 120	1 (2%)
Total	**57**

8/10/2017

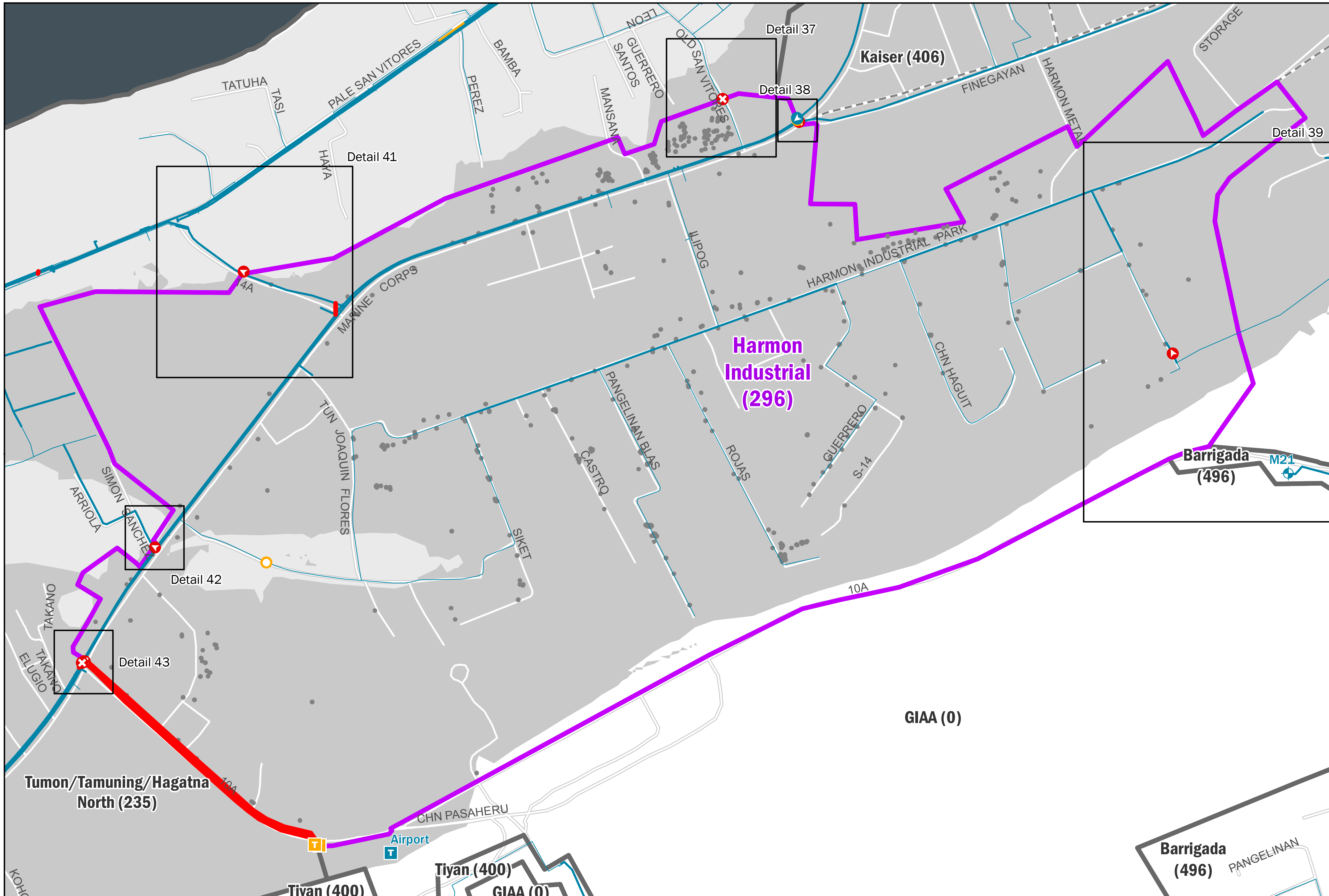
Figure G-15. Mangilao Central (428) Pressure Zone



Pressure (psi)	Num Customers
0-20	10 (0%)
20-35	9 (0%)
35-90	3,118 (92%)
90-100	139 (4%)
100-120	96 (3%)
> 120	-
Total	3,372

8/10/2017

Figure G-16. Kaiser (406) Pressure Zone

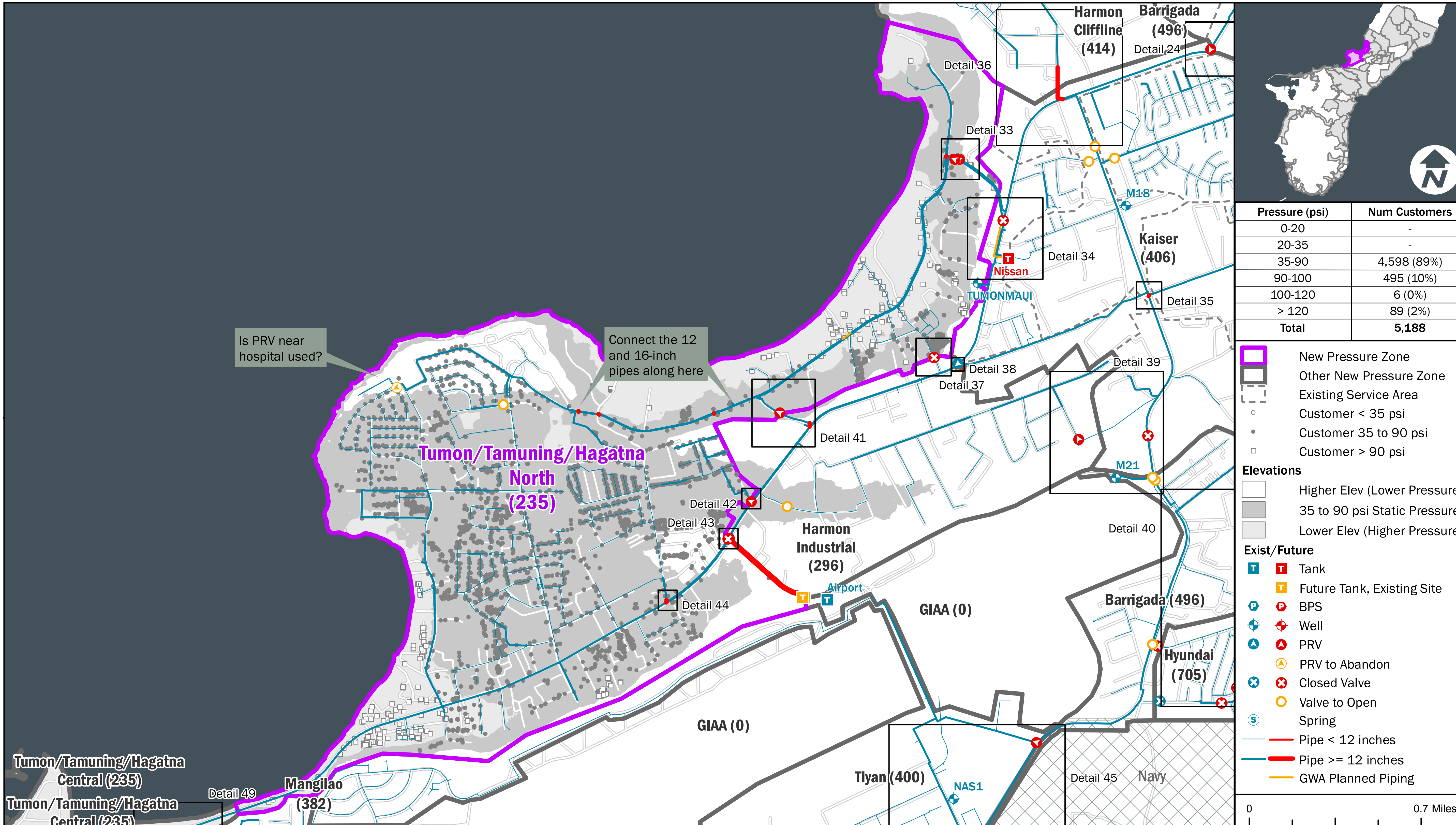


Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	673 (100%)
90-100	-
100-120	-
> 120	-
Total	673

8/10/2017

Figure G-17. Harmon Industrial (296) Pressure Zone

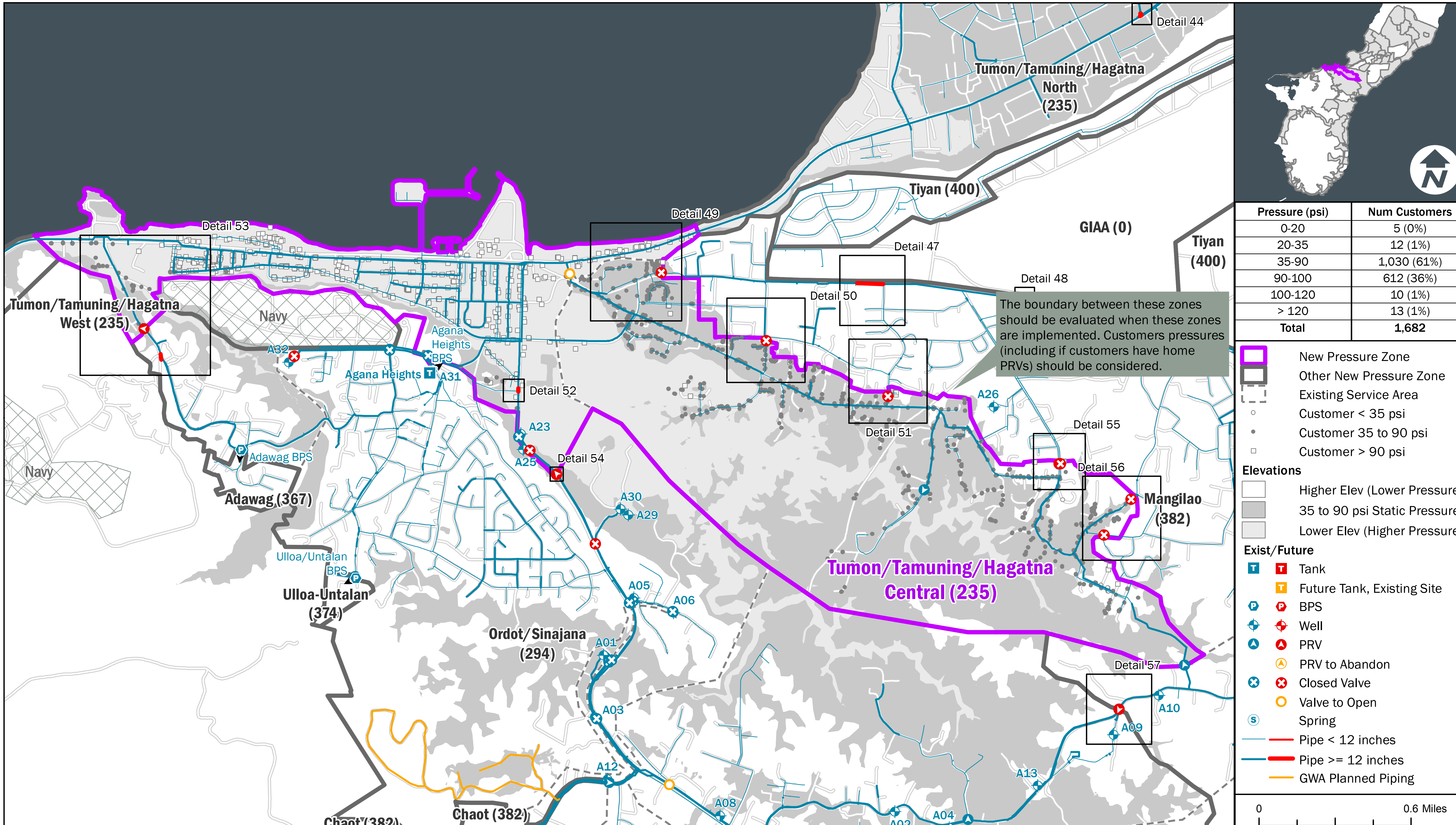
Brown AND Caldwell



Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	4,598 (89%)
90-100	495 (10%)
100-120	6 (0%)
> 120	89 (2%)
Total	**5,188**

8/10/2017

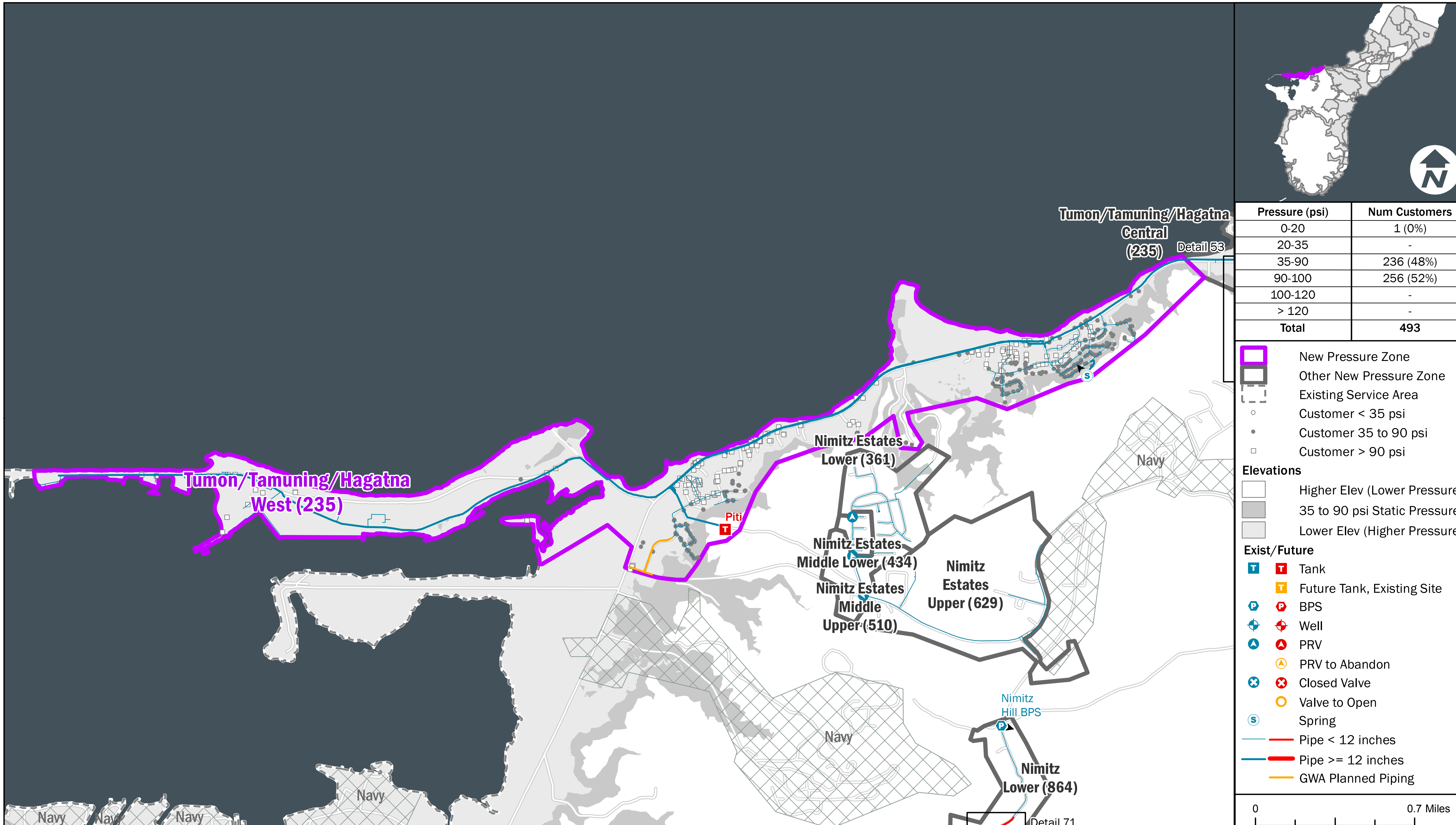
Figure G-18. Tumon/Tamuning/Hagatna North (235) Pressure Zone



Pressure (psi)	Num Customers
0-20	5 (0%)
20-35	12 (1%)
35-90	1,030 (61%)
90-100	612 (36%)
100-120	10 (1%)
> 120	13 (1%)
Total	**1,682**

8/10/2017

Figure G-19. Tumon/Tamuning/Hagatna Central (235) Pressure Zone

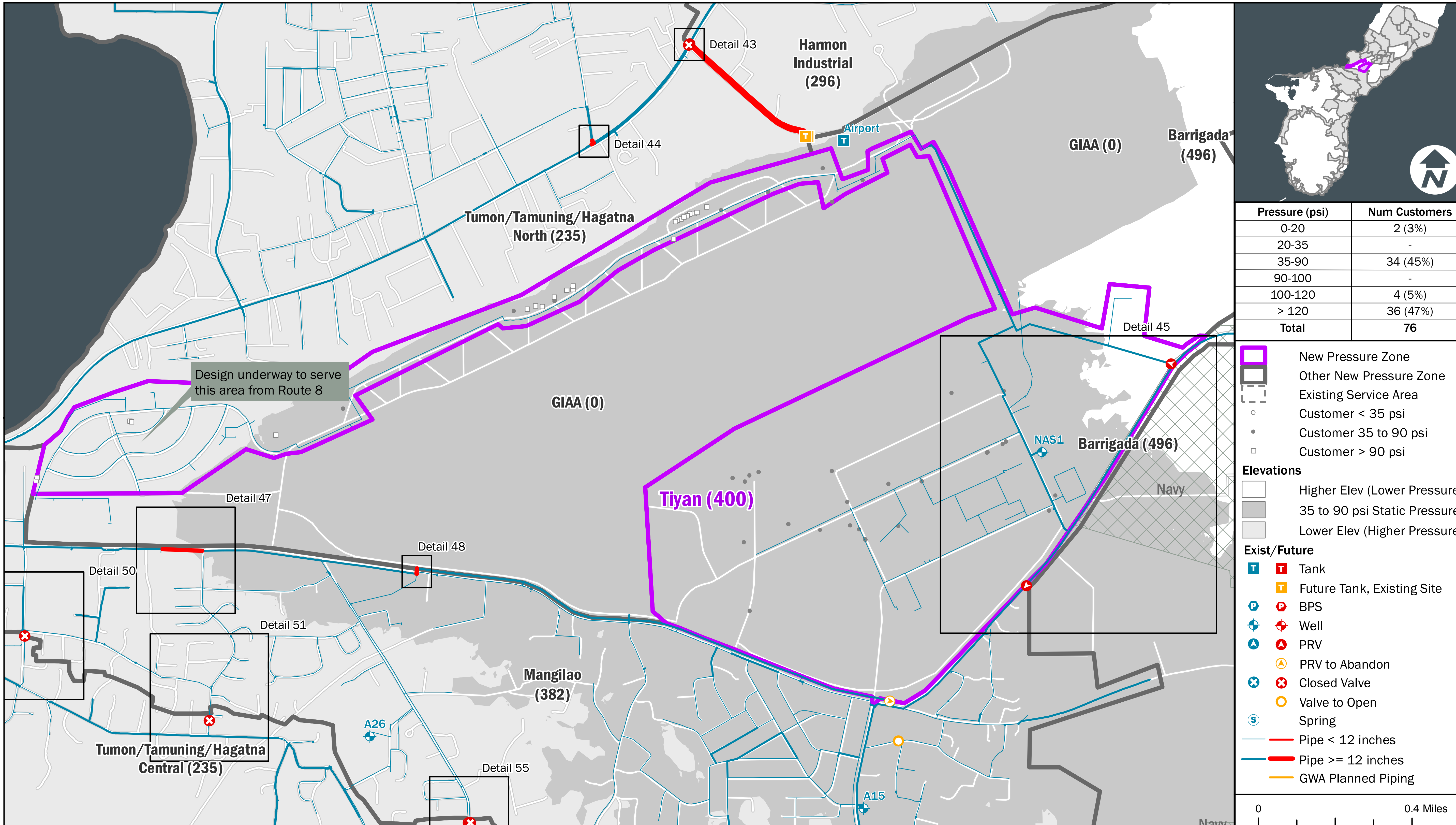


Pressure (psi)	Num Customers
0-20	1 (0%)
20-35	-
35-90	236 (48%)
90-100	256 (52%)
100-120	-
> 120	-
Total	493

8/10/2017

Figure G-20. Tumon/Tamuning/Hagatna West (235) Pressure Zone

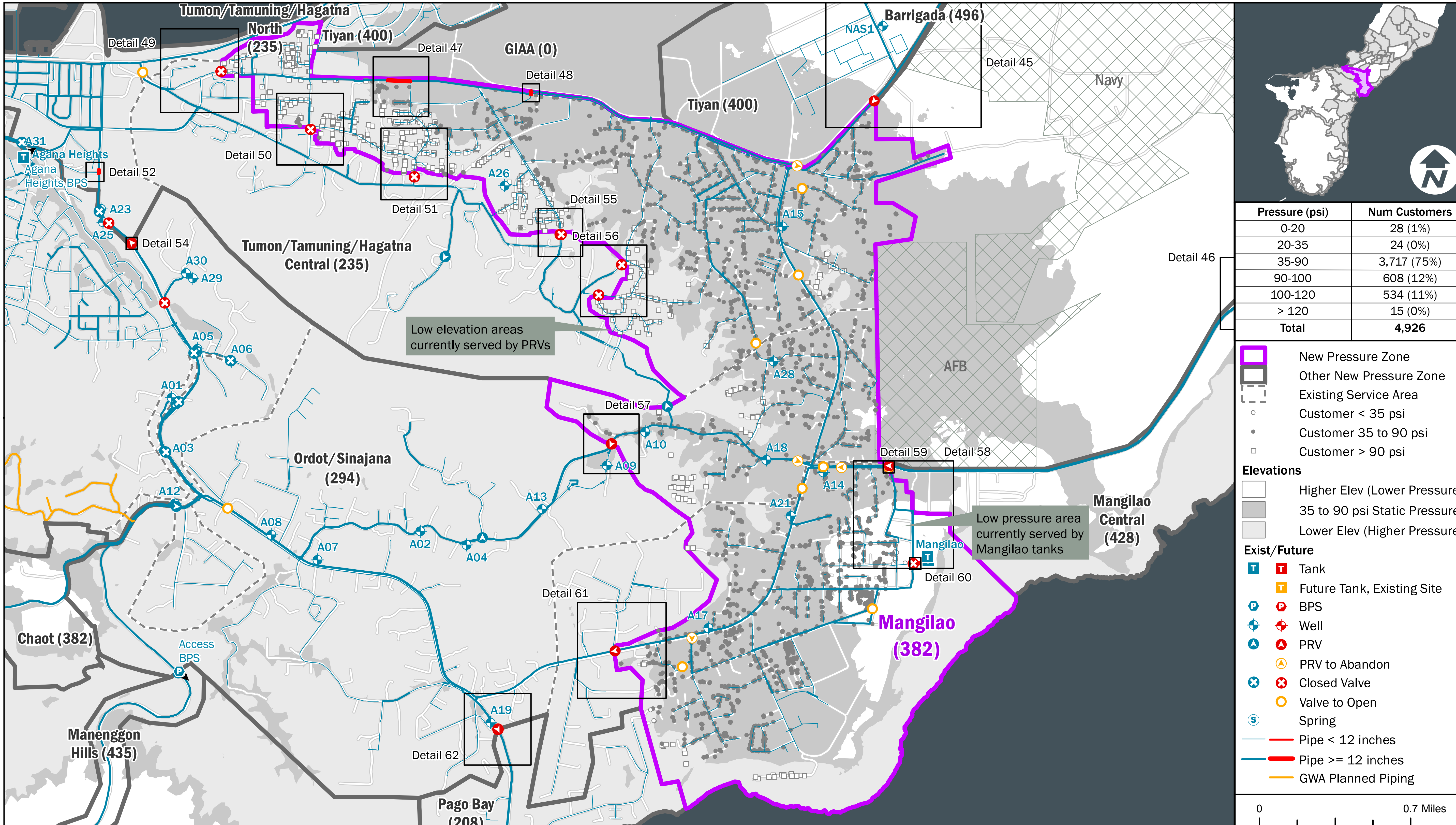
Brown AND Caldwell



Pressure (psi)	Num Customers
0-20	2 (3%)
20-35	-
35-90	34 (45%)
90-100	-
100-120	4 (5%)
> 120	36 (47%)
Total	76

8/10/2017

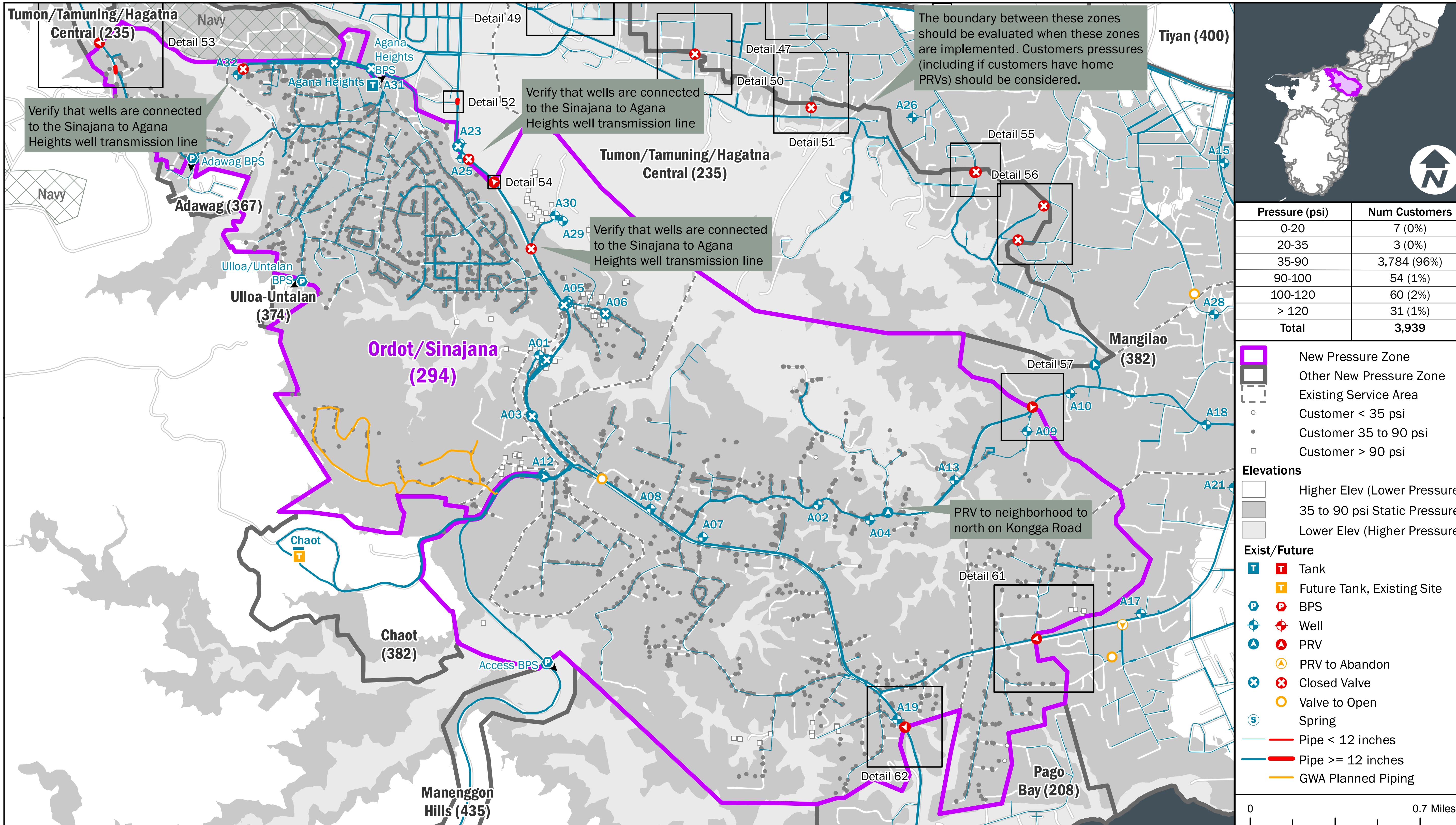
Figure G-21. Tiyan (400) Pressure Zone



Pressure (psi)	Num Customers
0-20	28 (1%)
20-35	24 (0%)
35-90	3,717 (75%)
90-100	608 (12%)
100-120	534 (11%)
> 120	15 (0%)
Total	**4,926**

8/10/2017

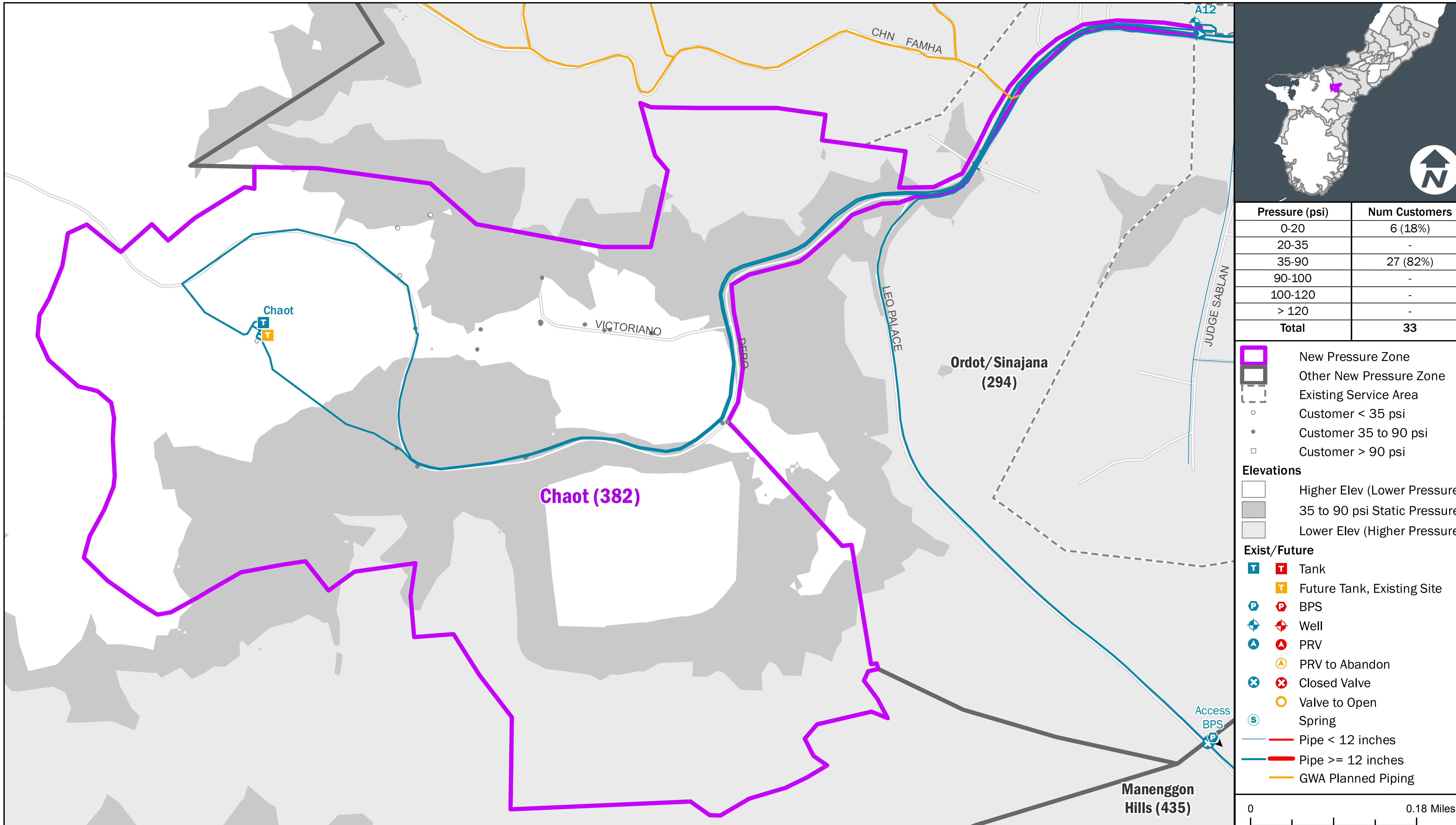
Figure G-22. Mangilao (382) Pressure Zone



Pressure (psi)	Num Customers
0-20	7 (0%)
20-35	3 (0%)
35-90	3,784 (96%)
90-100	54 (1%)
100-120	60 (2%)
> 120	31 (1%)
Total	3,939

8/10/2017

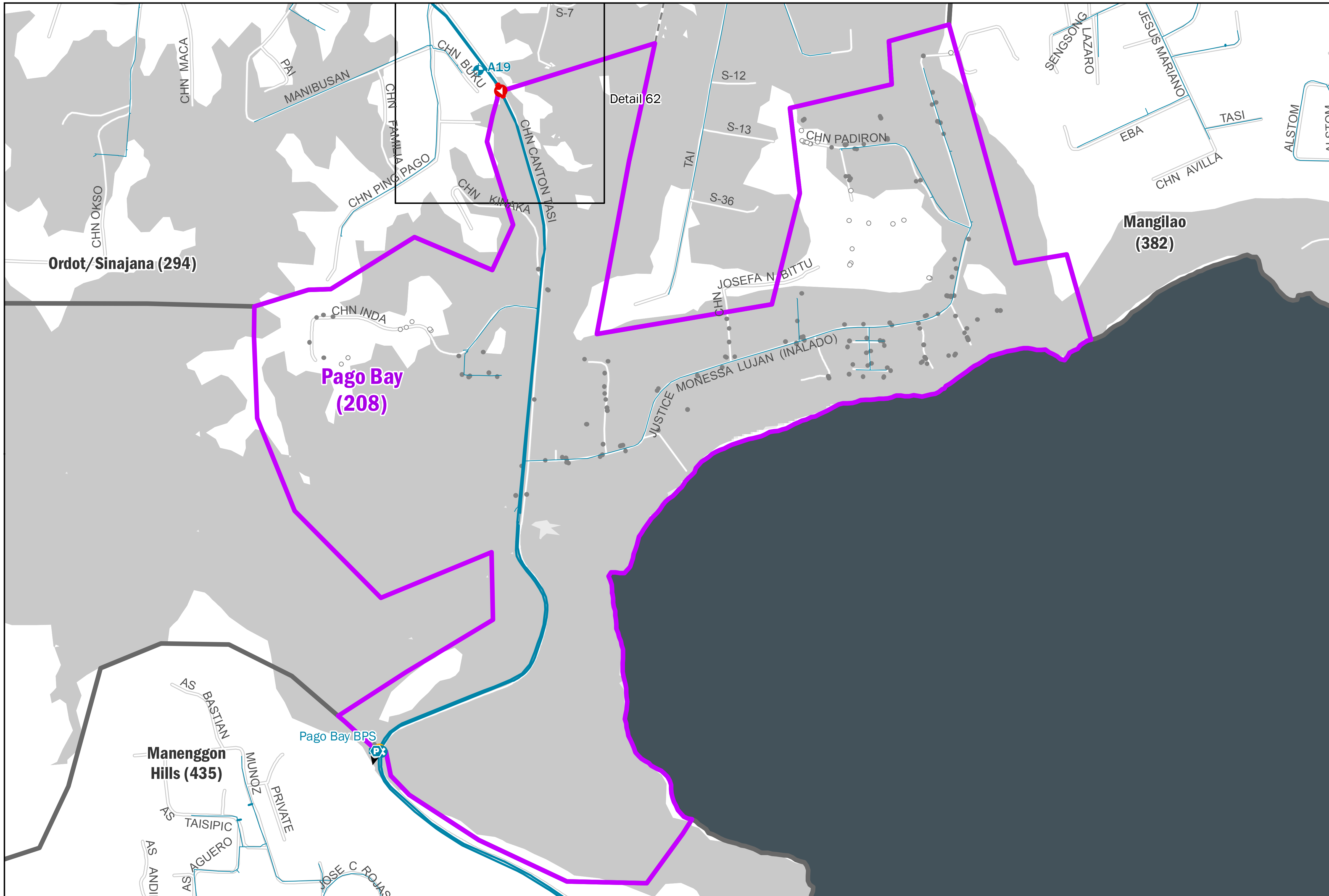
Figure G-23. Ordot/Sinajana (294) Pressure Zone

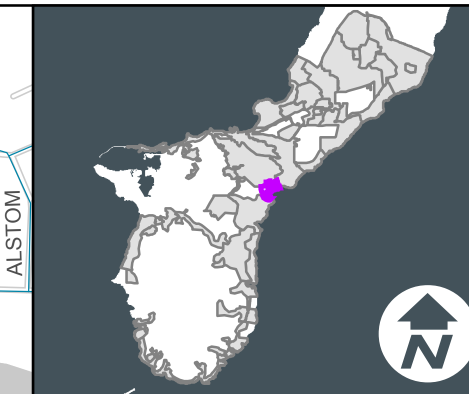


Pressure (psi)	Num Customers
0-20	6 (18%)
20-35	-
35-90	27 (82%)
90-100	-
100-120	-
> 120	-
Total	**33**

8/10/2017

Figure G-24. Chaot (382) Pressure Zone

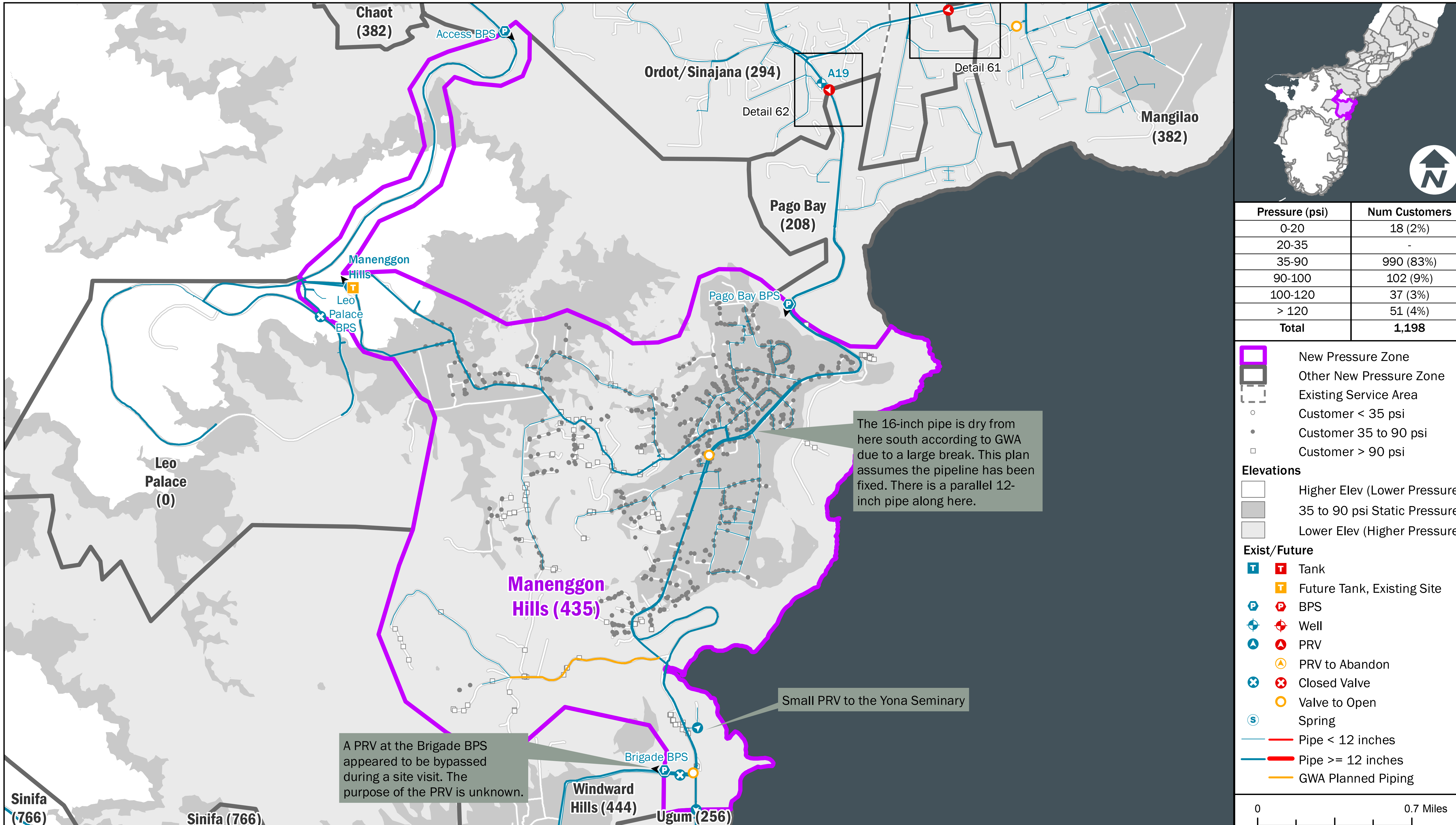




Pressure (psi)	Num Customers
0-20	2 (1%)
20-35	27 (14%)
35-90	163 (85%)
90-100	-
100-120	-
> 120	-
Total	192

8/10/2017

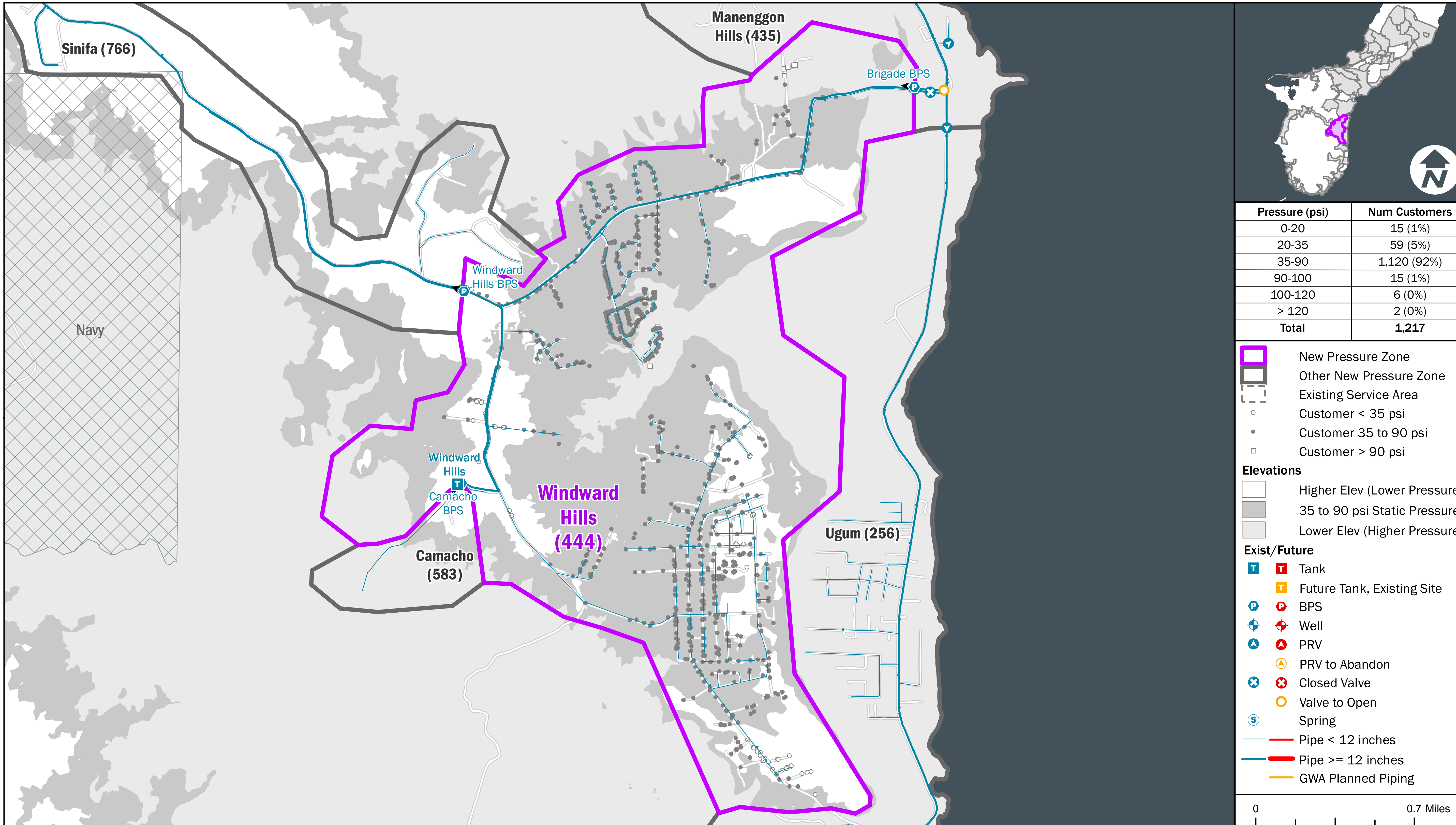
Figure G-25. Pago Bay (208) Pressure Zone



Pressure (psi)	Num Customers
0-20	18 (2%)
20-35	-
35-90	990 (83%)
90-100	102 (9%)
100-120	37 (3%)
> 120	51 (4%)
Total	**1,198**

8/10/2017

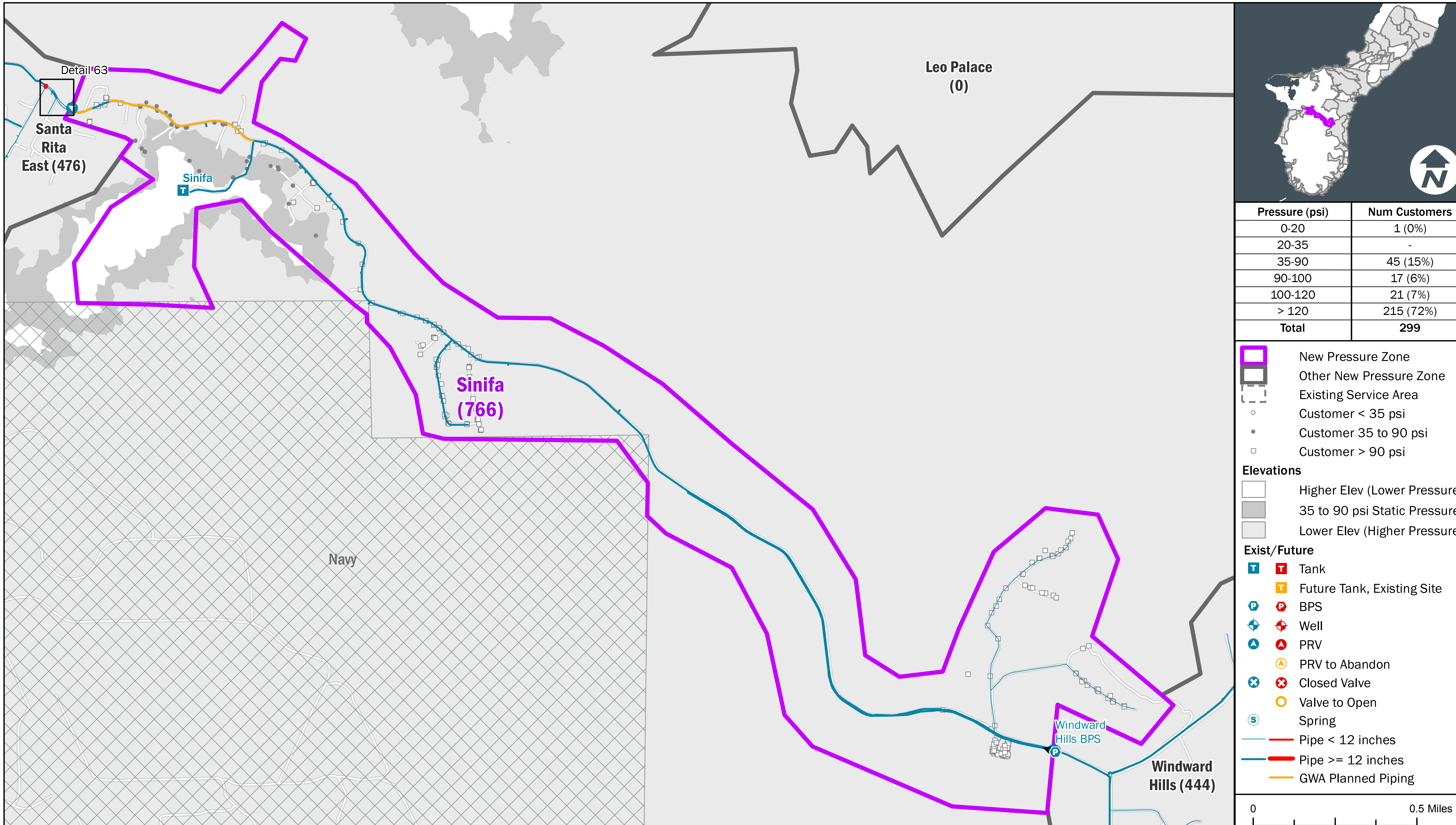
Figure G-26. Manenggon Hills (435) Pressure Zone



Pressure (psi)	Num Customers
0-20	15 (1%)
20-35	59 (5%)
35-90	1,120 (92%)
90-100	15 (1%)
100-120	6 (0%)
> 120	2 (0%)
Total	1,217

8/10/2017

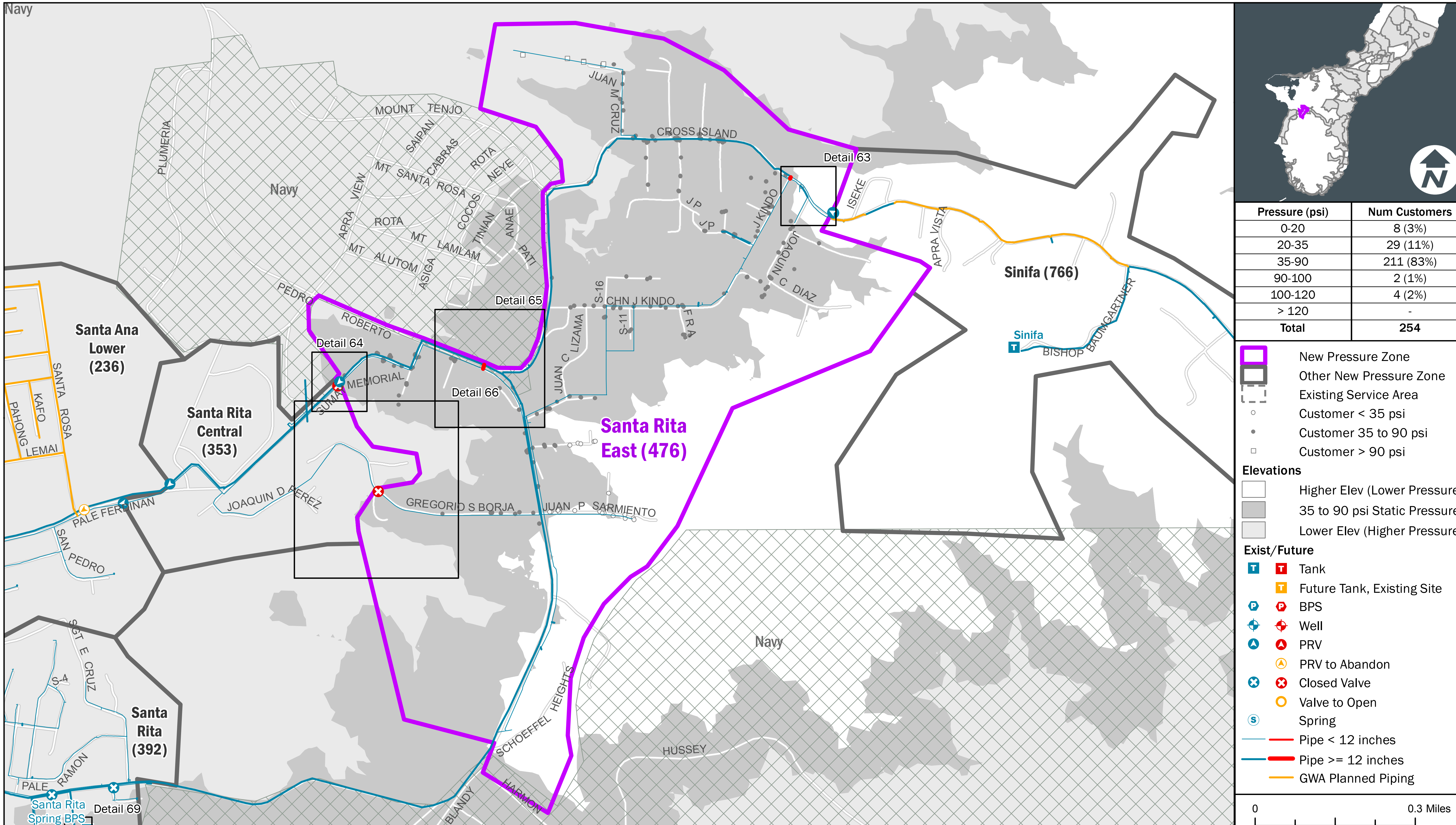
Figure G-27. Windward Hills (444) Pressure Zone



Pressure (psi)	Num Customers
0-20	1 (0%)
20-35	-
35-90	45 (15%)
90-100	17 (6%)
100-120	21 (7%)
> 120	215 (72%)
Total	**299**

8/10/2017

Figure G-28. Sinifa (766) Pressure Zone



Pressure (psi)	Num Customers
0-20	8 (3%)
20-35	29 (11%)
35-90	211 (83%)
90-100	2 (1%)
100-120	4 (2%)
> 120	-
Total	254

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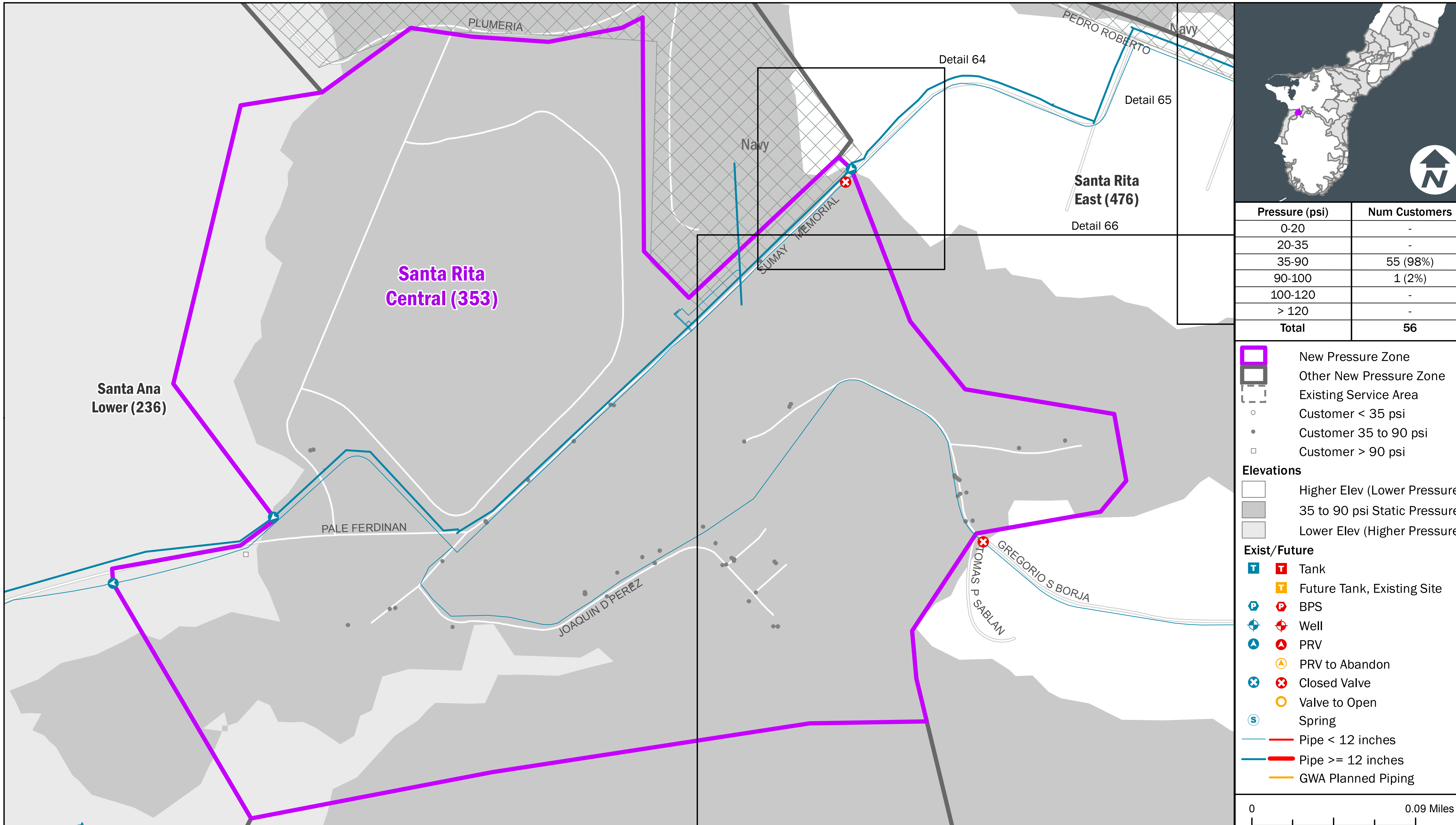
Figure G-29. Santa Rita East (476) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	55 (98%)
90-100	1 (2%)
100-120	-
> 120	-
Total	56

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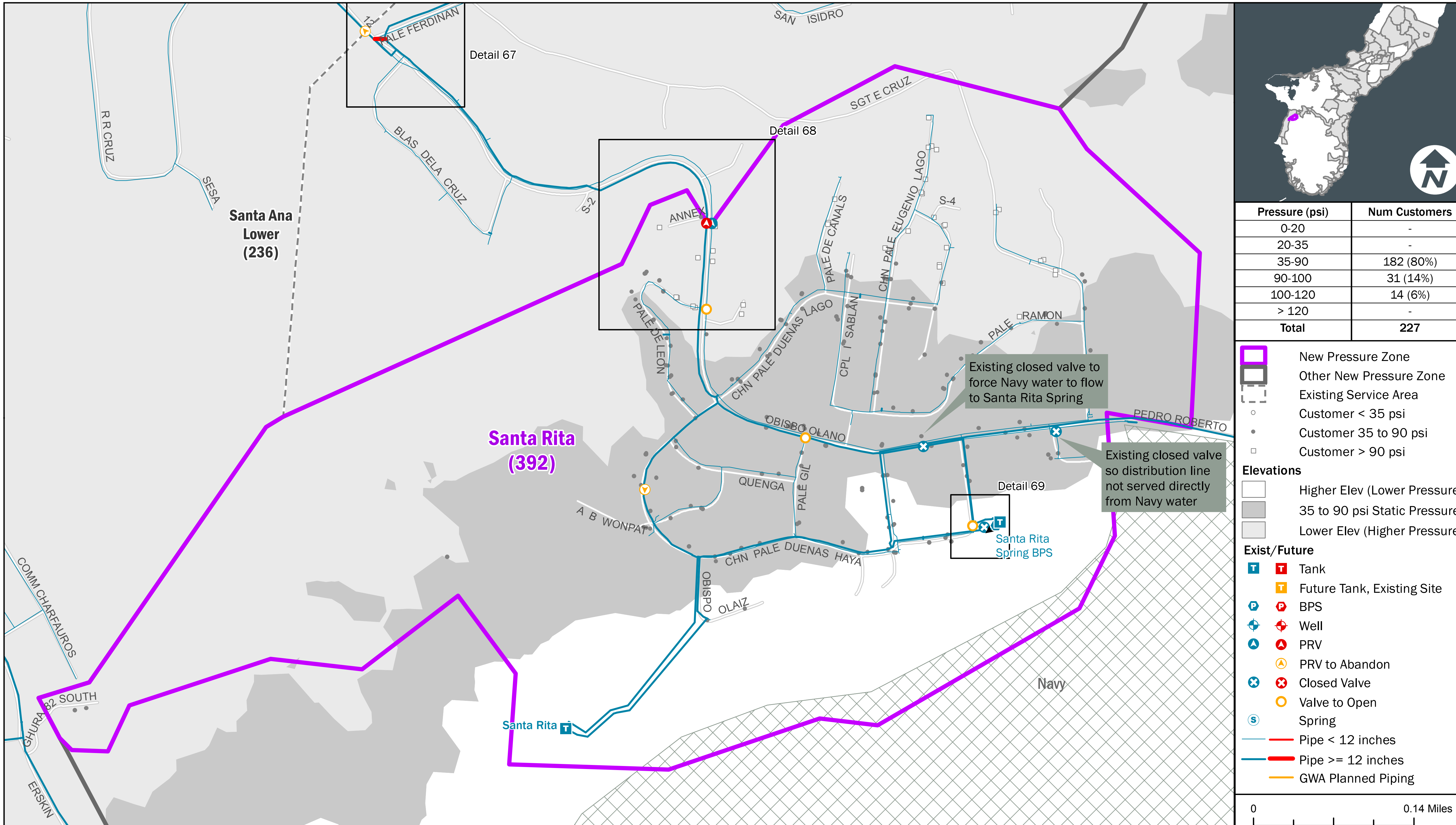
Figure G-30. Santa Rita Central (353) Pressure Zone

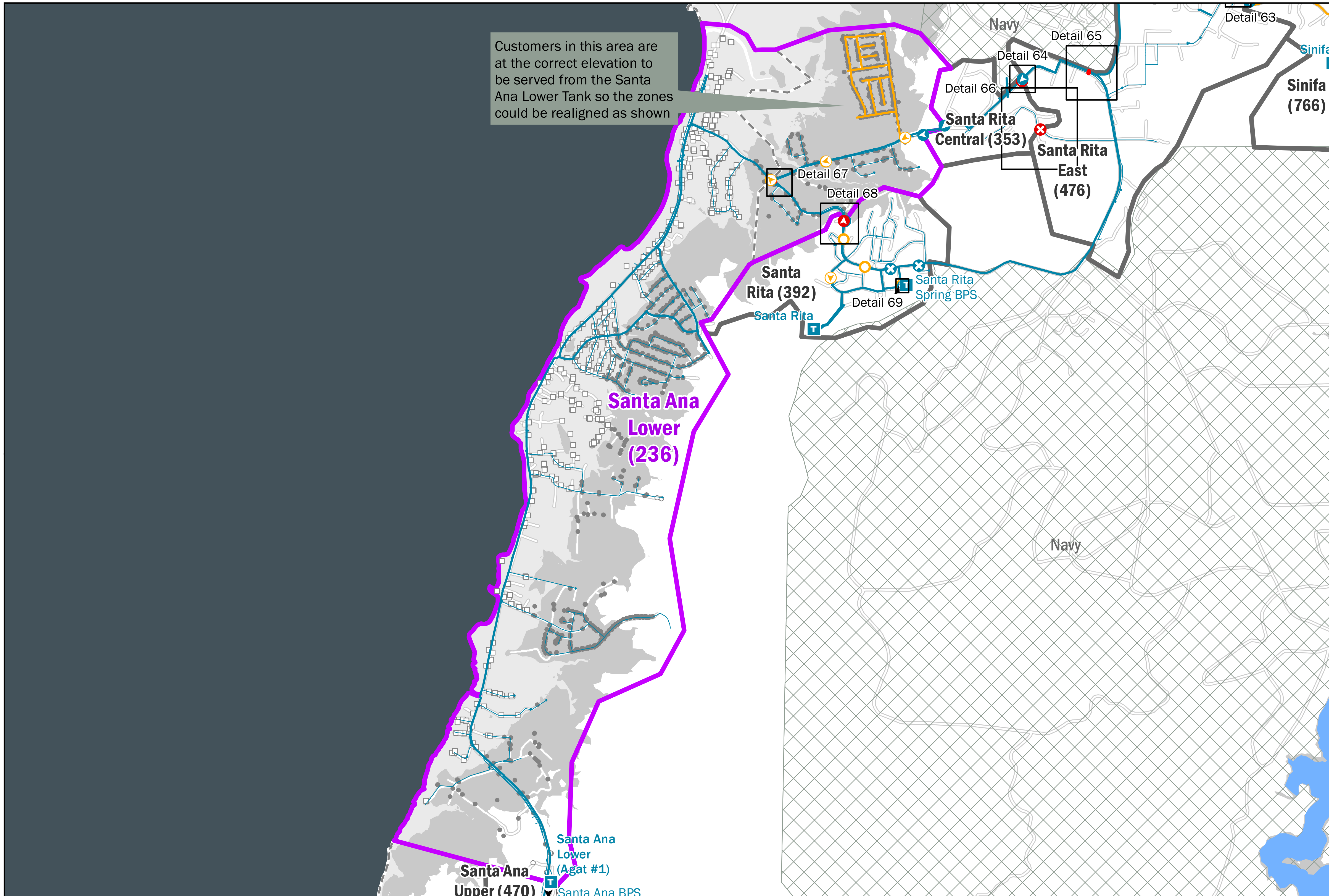


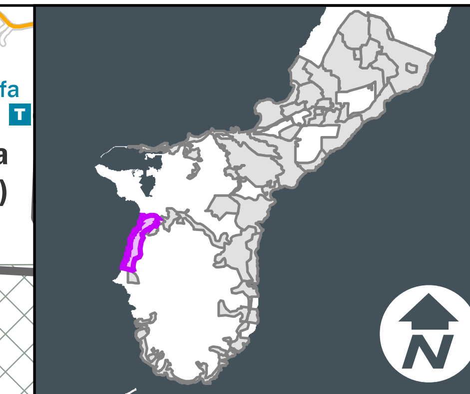
Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	182 (80%)
90-100	31 (14%)
100-120	14 (6%)
> 120	-
Total	**227**

8/10/2017

Figure G-31. Santa Rita (392) Pressure Zone

Brown AND Caldwell





Pressure (psi)	Num Customers
0-20	-
20-35	7 (0%)
35-90	968 (58%)
90-100	706 (42%)
100-120	-
> 120	-
Total	**1,681**

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

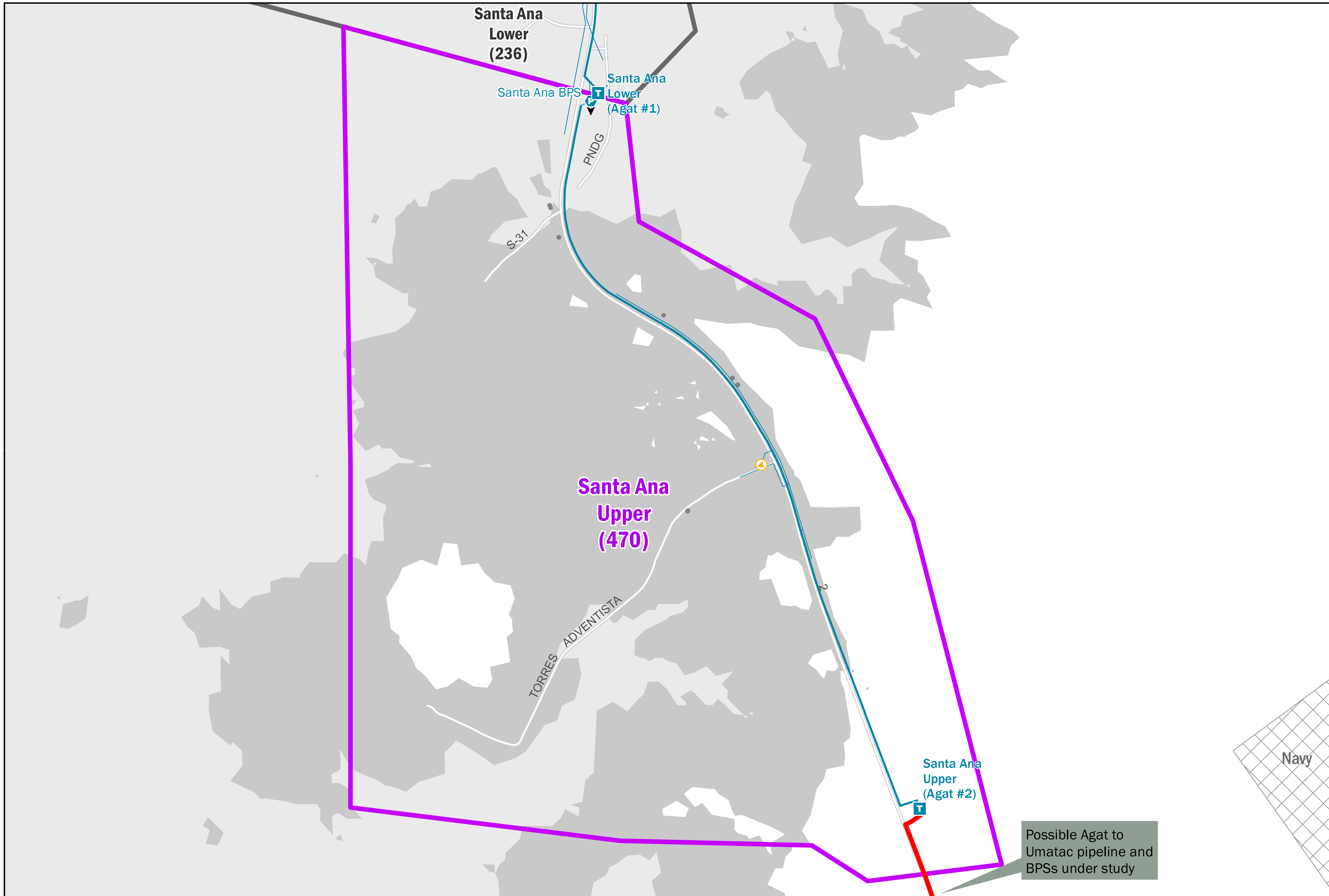
Elevations
Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

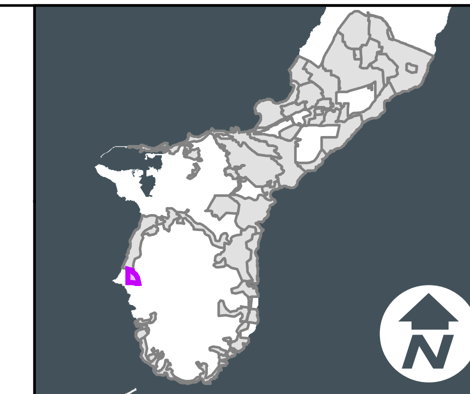
Exist/Future
Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 0.7 Miles

8/10/2017

Figure G-32. Santa Ana Lower (236) Pressure Zone





Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	8 (100%)
90-100	-
100-120	-
> 120	-
Total	**8**

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

Elevations

Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

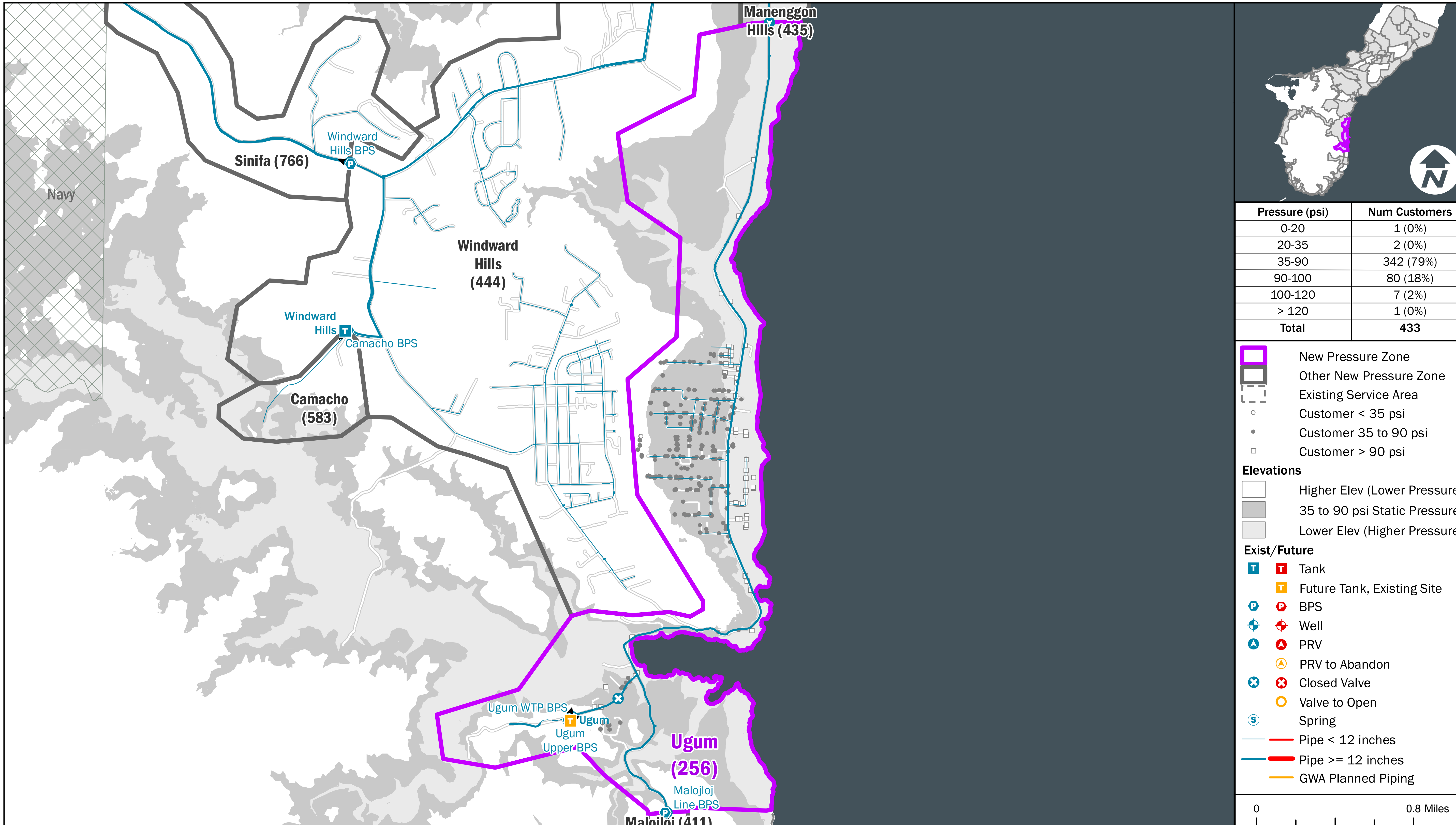
Exist/Future

Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 0.19 Miles

8/10/2017

Figure G-33. Santa Ana Upper (470) Pressure Zone



Pressure (psi)	Num Customers
0-20	1 (0%)
20-35	2 (0%)
35-90	342 (79%)
90-100	80 (18%)
100-120	7 (2%)
> 120	1 (0%)
Total	**433**

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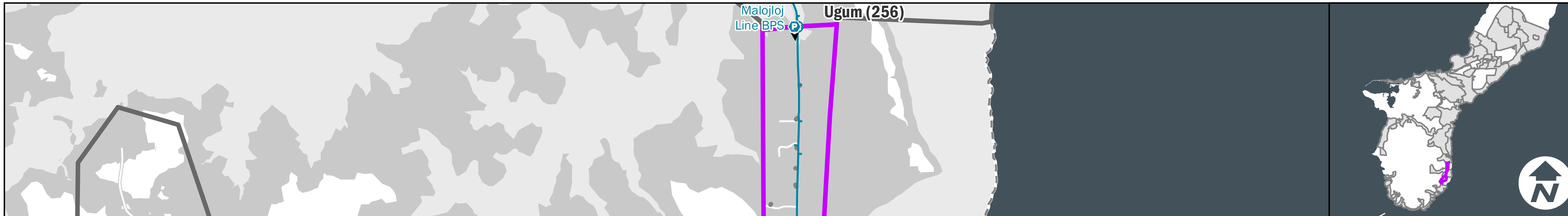
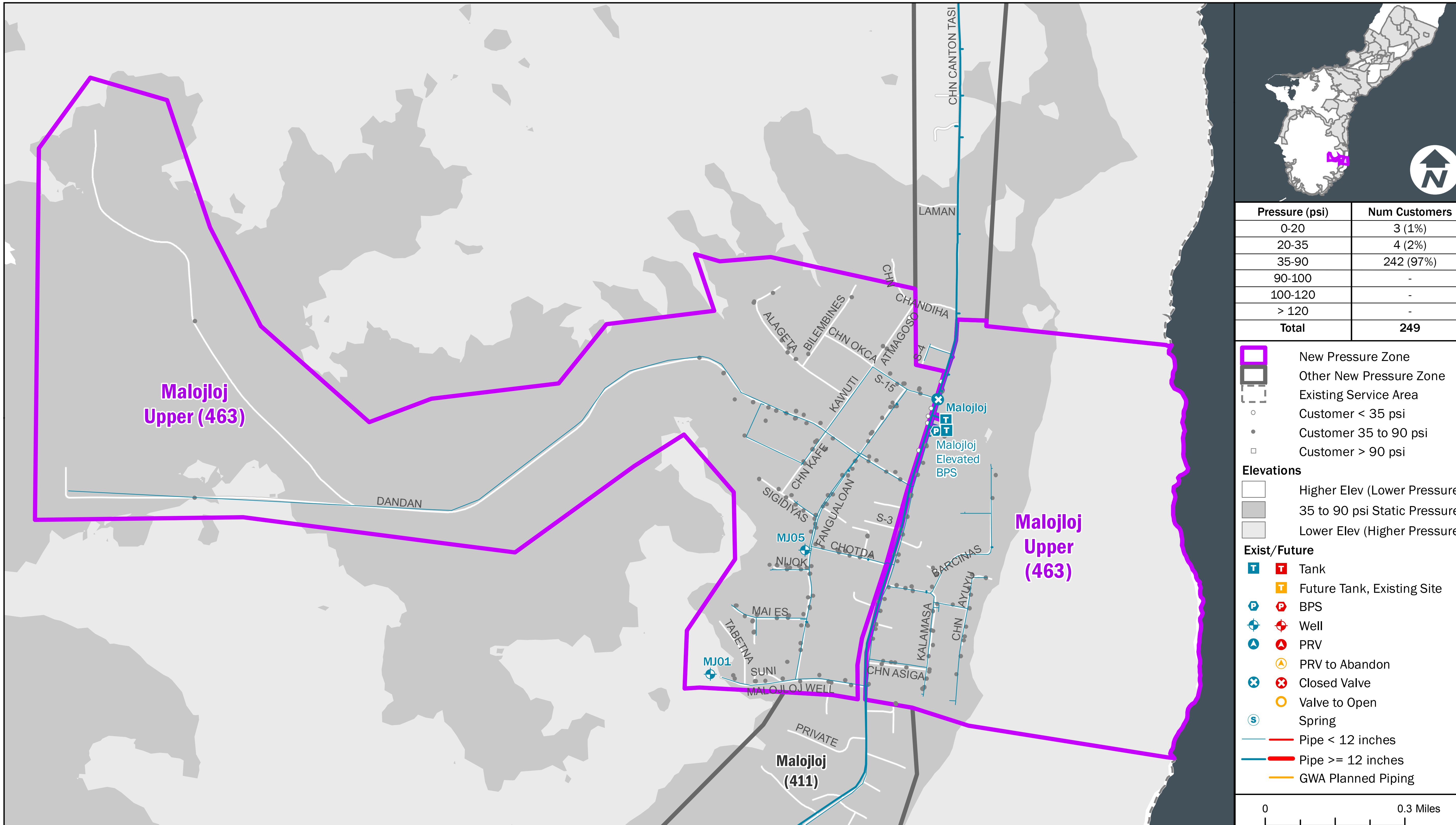
Figure G-34. Ugum (256) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	16 (18%)
35-90	74 (82%)
90-100	-
100-120	-
> 120	-
Total	90

8/10/2017

Figure G-35. Malojloj (411) Pressure Zone



Pressure (psi)	Num Customers
0-20	3 (1%)
20-35	4 (2%)
35-90	242 (97%)
90-100	-
100-120	-
> 120	-
Total	249

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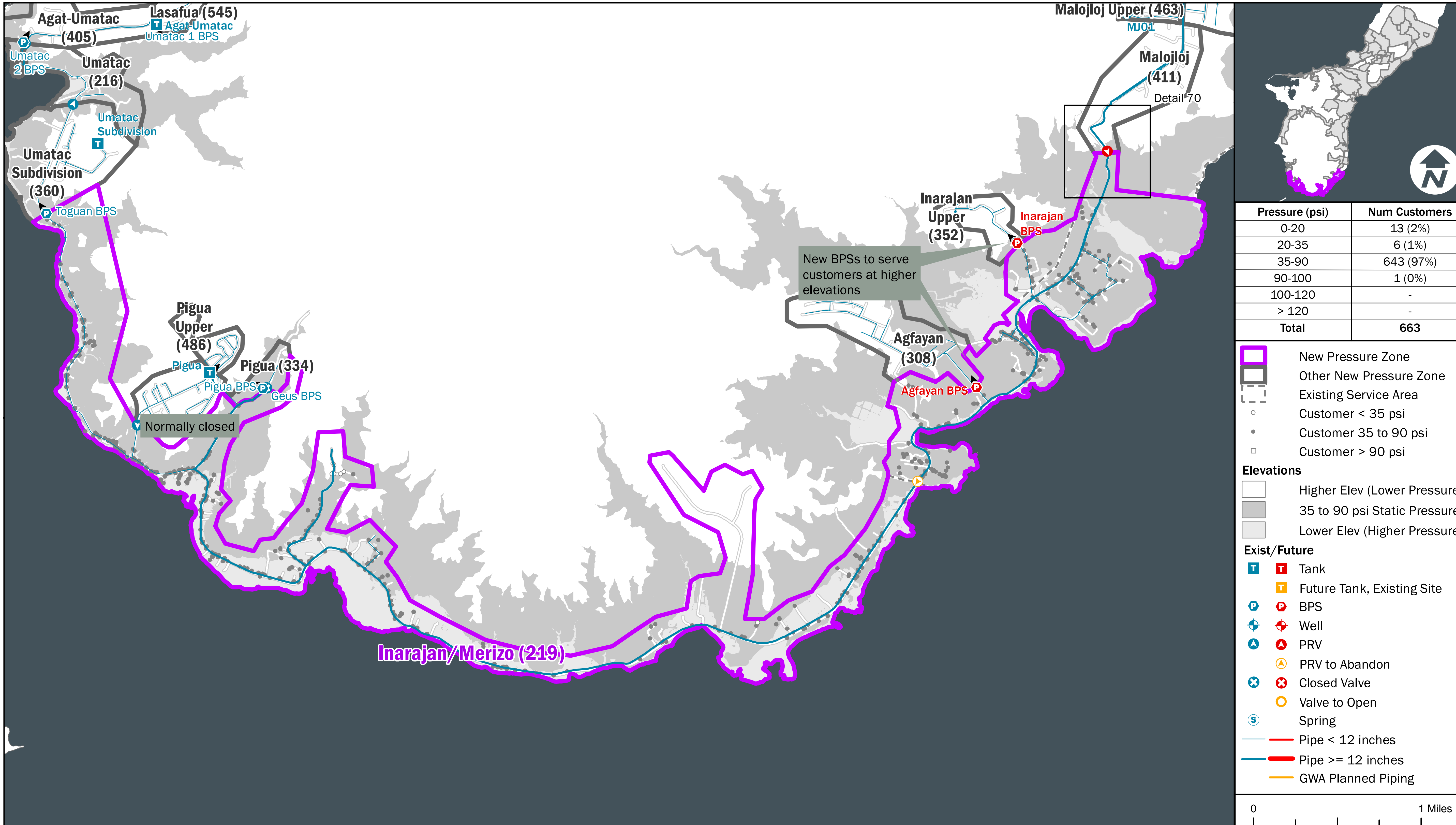
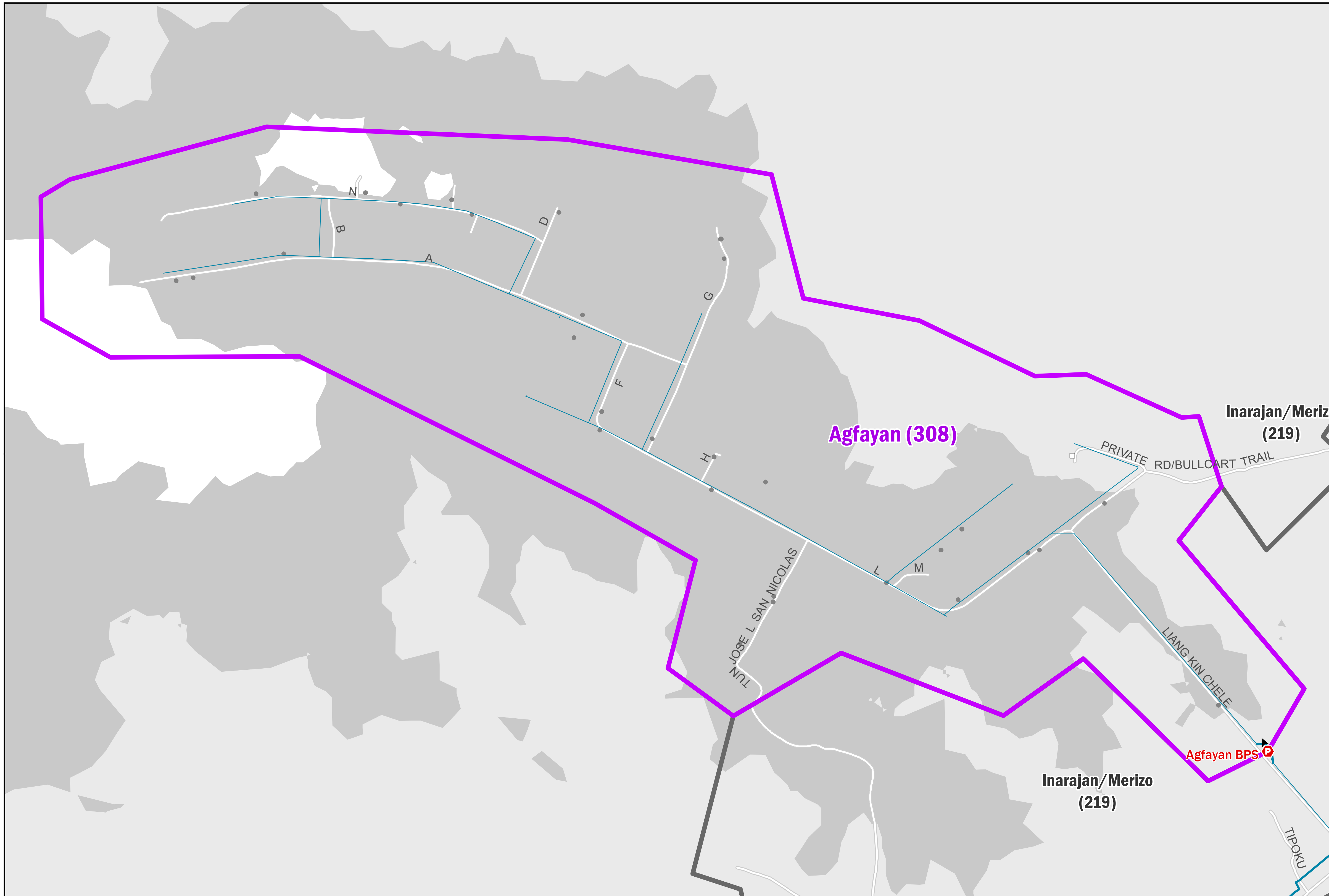
Figure G-36. Malojloj Upper (463) Pressure Zone

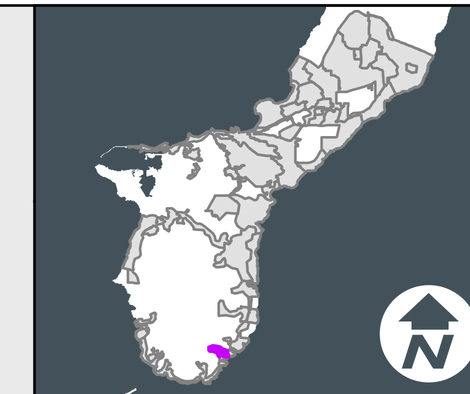


Pressure (psi)	Num Customers
0-20	13 (2%)
20-35	6 (1%)
35-90	643 (97%)
90-100	1 (0%)
100-120	-
> 120	-
Total	663

8/10/2017

Figure G-37. Inarajan/Merizo (219) Pressure Zone



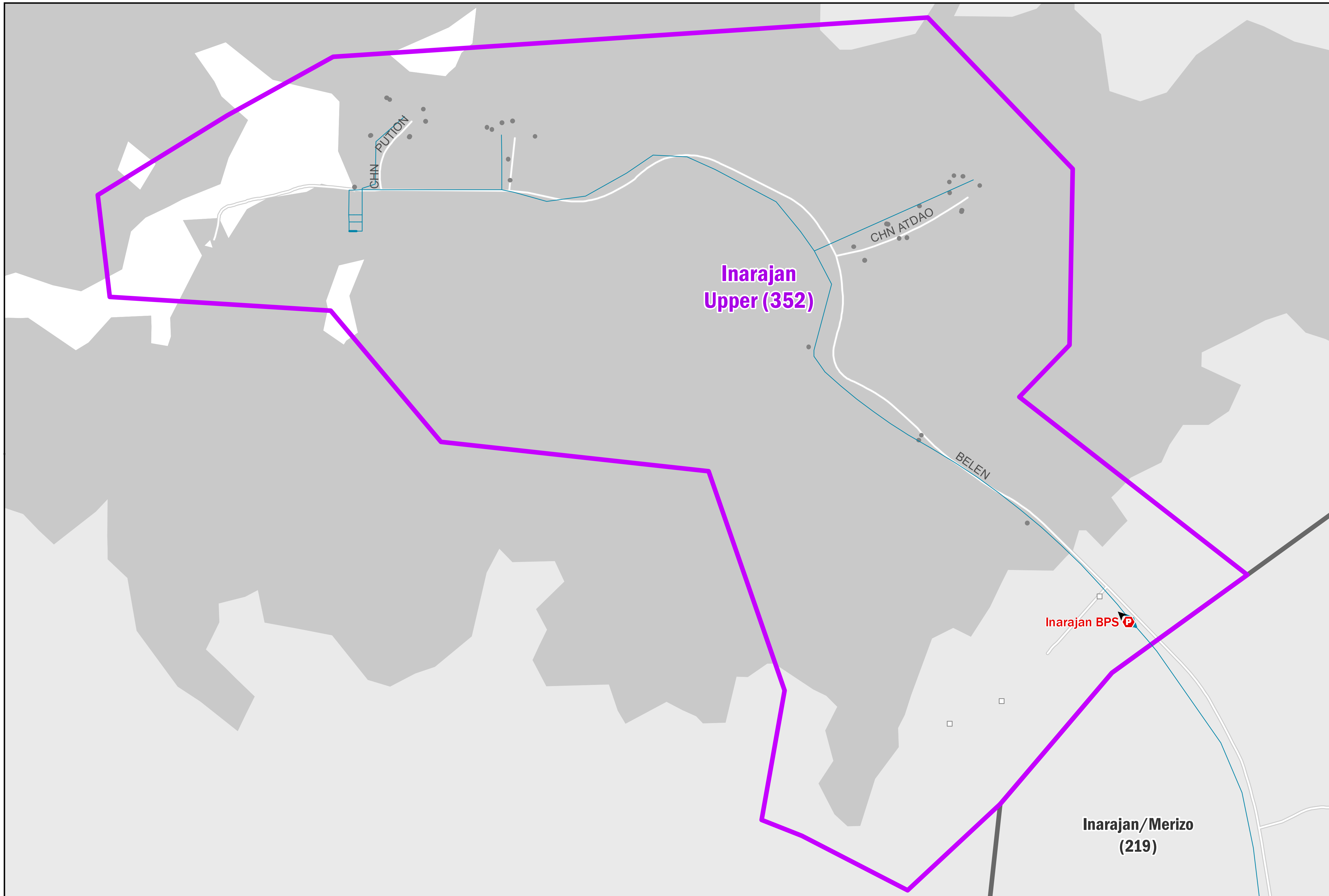


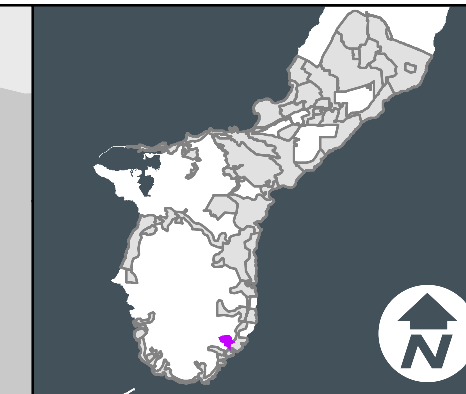
Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	31 (94%)
90-100	2 (6%)
100-120	-
> 120	-
Total	**33**

8/10/2017

Figure G-38. Agfayan (308) Pressure Zone

Brown AND Caldwell

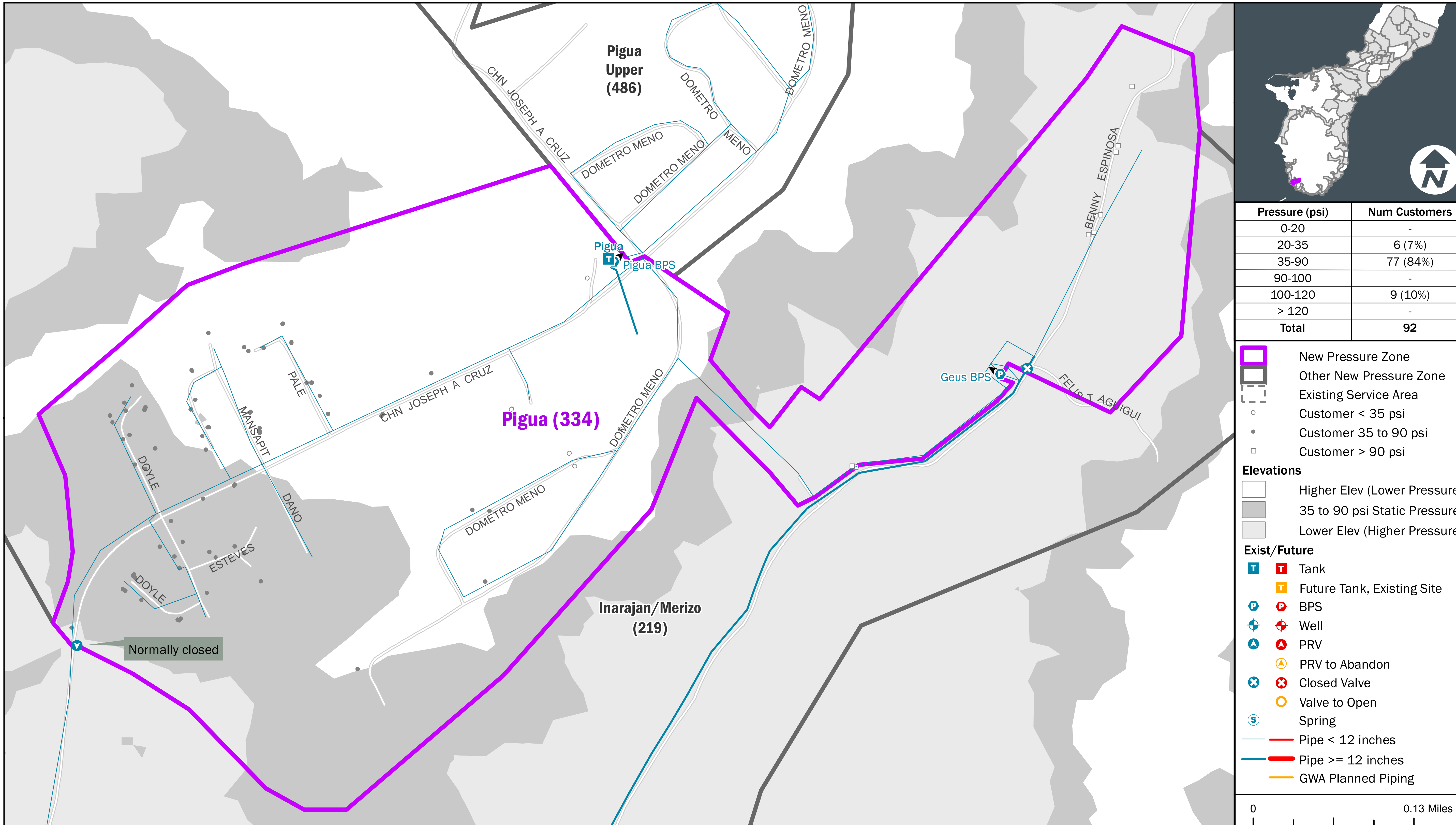




Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	43 (93%)
90-100	3 (7%)
100-120	-
> 120	-
Total	**46**

8/10/2017

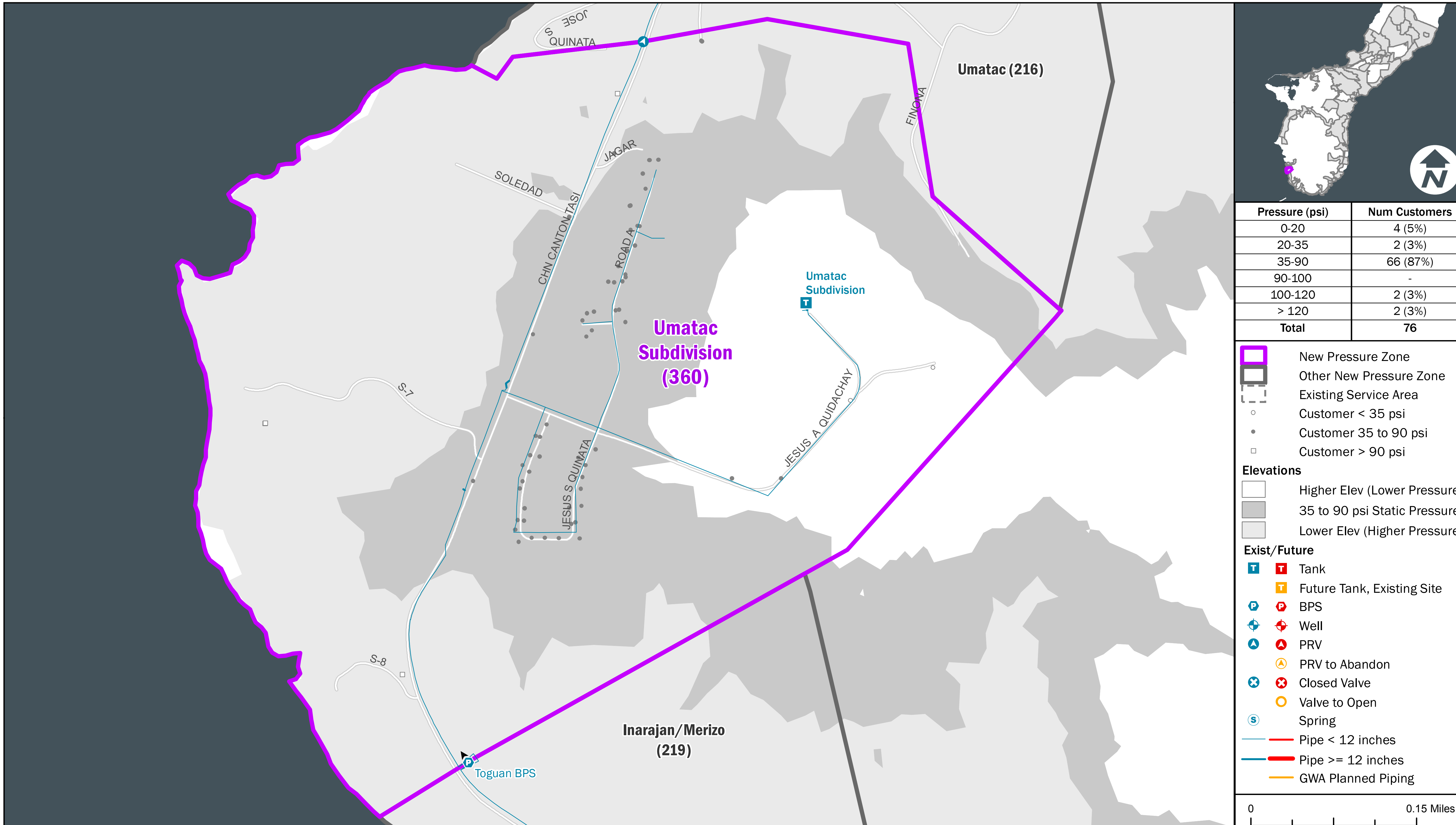
Figure G-39. Inarajan Upper (352) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	6 (7%)
35-90	77 (84%)
90-100	-
100-120	9 (10%)
> 120	-
Total	92

8/10/2017

Figure G-40. Pigua (334) Pressure Zone



Pressure (psi)	Num Customers
0-20	4 (5%)
20-35	2 (3%)
35-90	66 (87%)
90-100	-
100-120	2 (3%)
> 120	2 (3%)
Total	**76**

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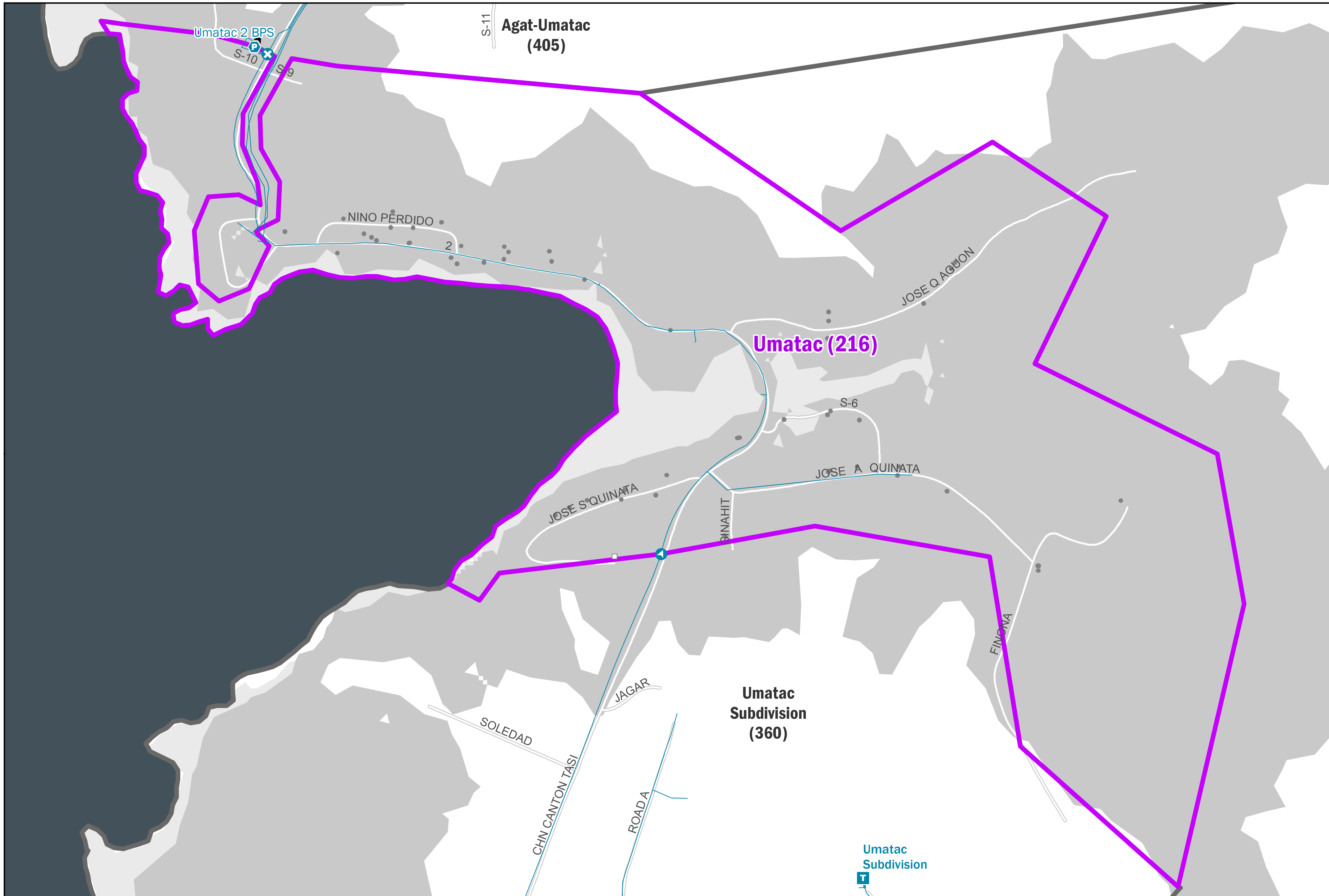
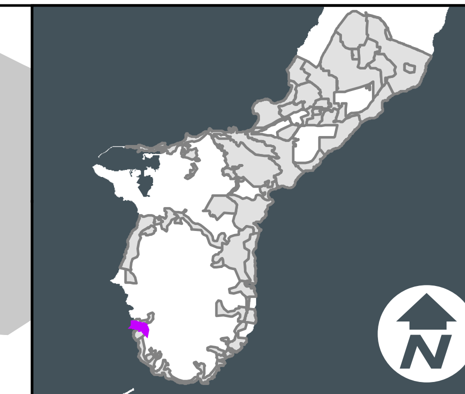
Figure G-41. Umatac Subdivision (360) Pressure Zone





Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	56 (98%)
90-100	-
100-120	-
> 120	1 (2%)
Total	**57**

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

Elevations

Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

Exist/Future

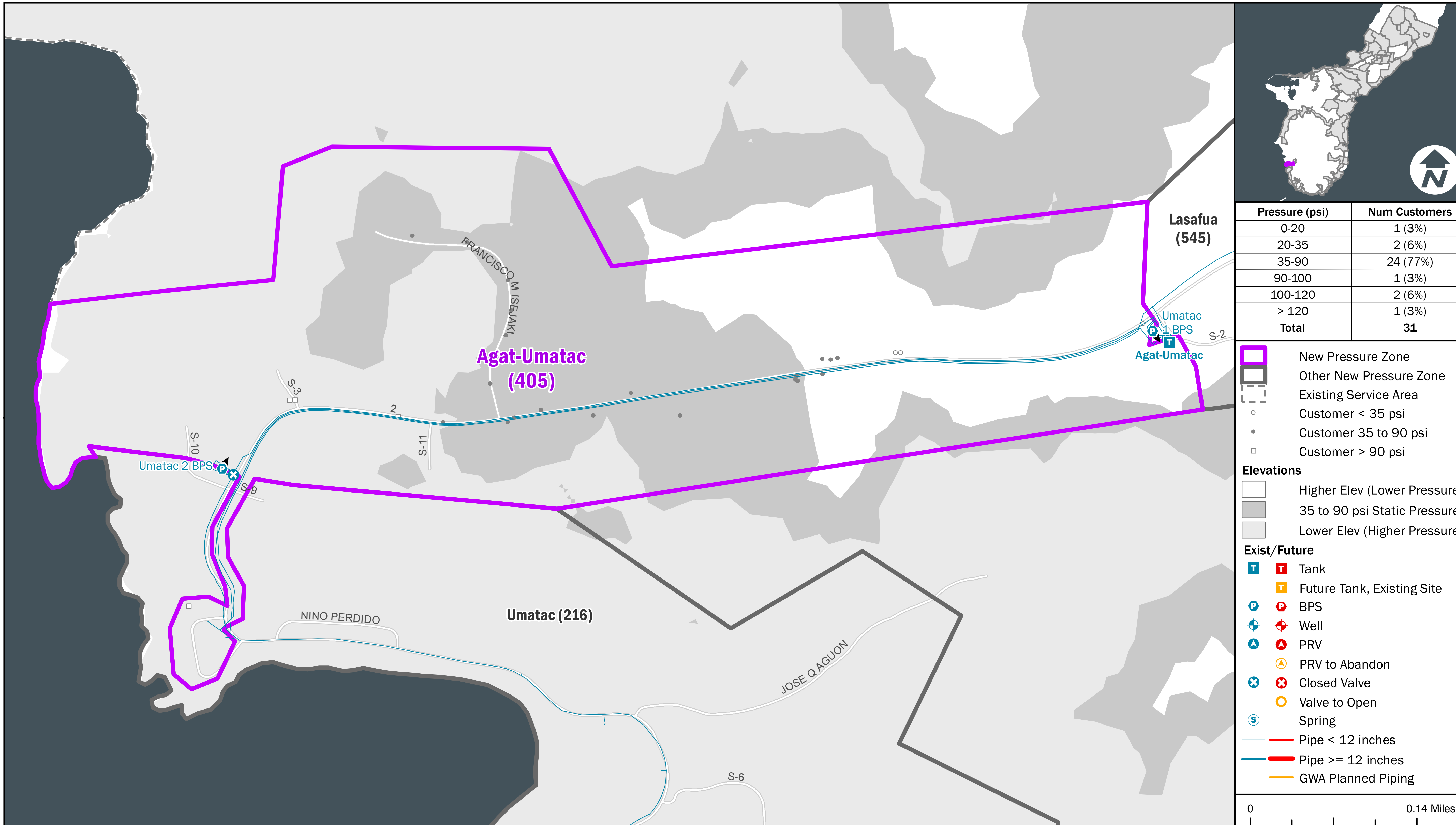
Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 0.13 Miles

8/10/2017

Figure G-42. Umatac (216) Pressure Zone

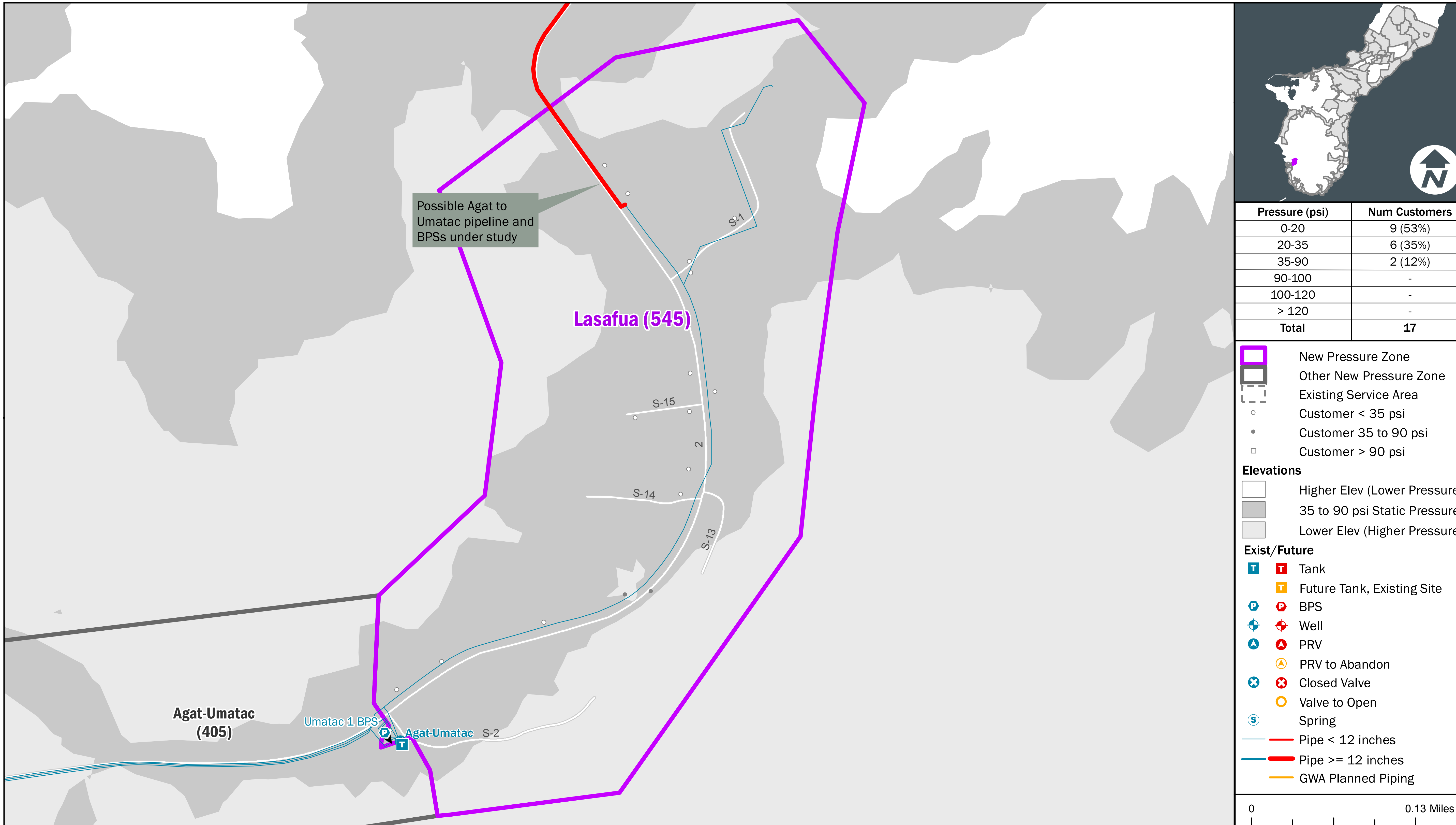
Brown AND Caldwell



Pressure (psi)	Num Customers
0-20	1 (3%)
20-35	2 (6%)
35-90	24 (77%)
90-100	1 (3%)
100-120	2 (6%)
> 120	1 (3%)
Total	31

8/10/2017

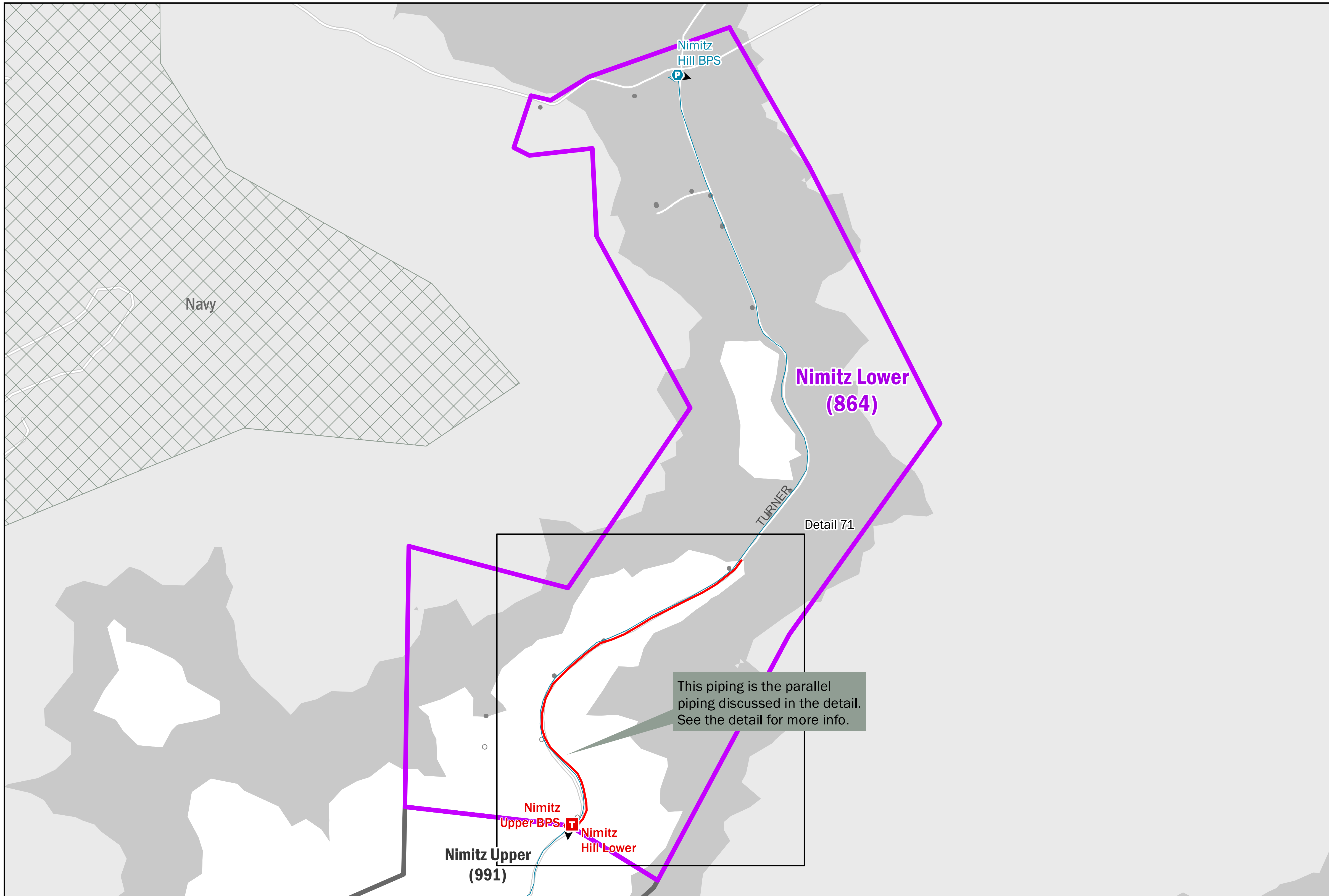
Figure G-43. Agat-Umatac (405) Pressure Zone

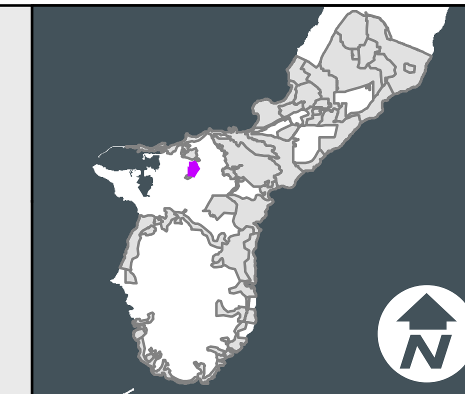


Pressure (psi)	Num Customers
0-20	9 (53%)
20-35	6 (35%)
35-90	2 (12%)
90-100	-
100-120	-
> 120	-
Total	17

8/10/2017

Figure G-44. Lasafua (545) Pressure Zone





Pressure (psi)	Num Customers
0-20	2 (9%)
20-35	3 (13%)
35-90	18 (78%)
90-100	-
100-120	-
> 120	-
Total	**23**

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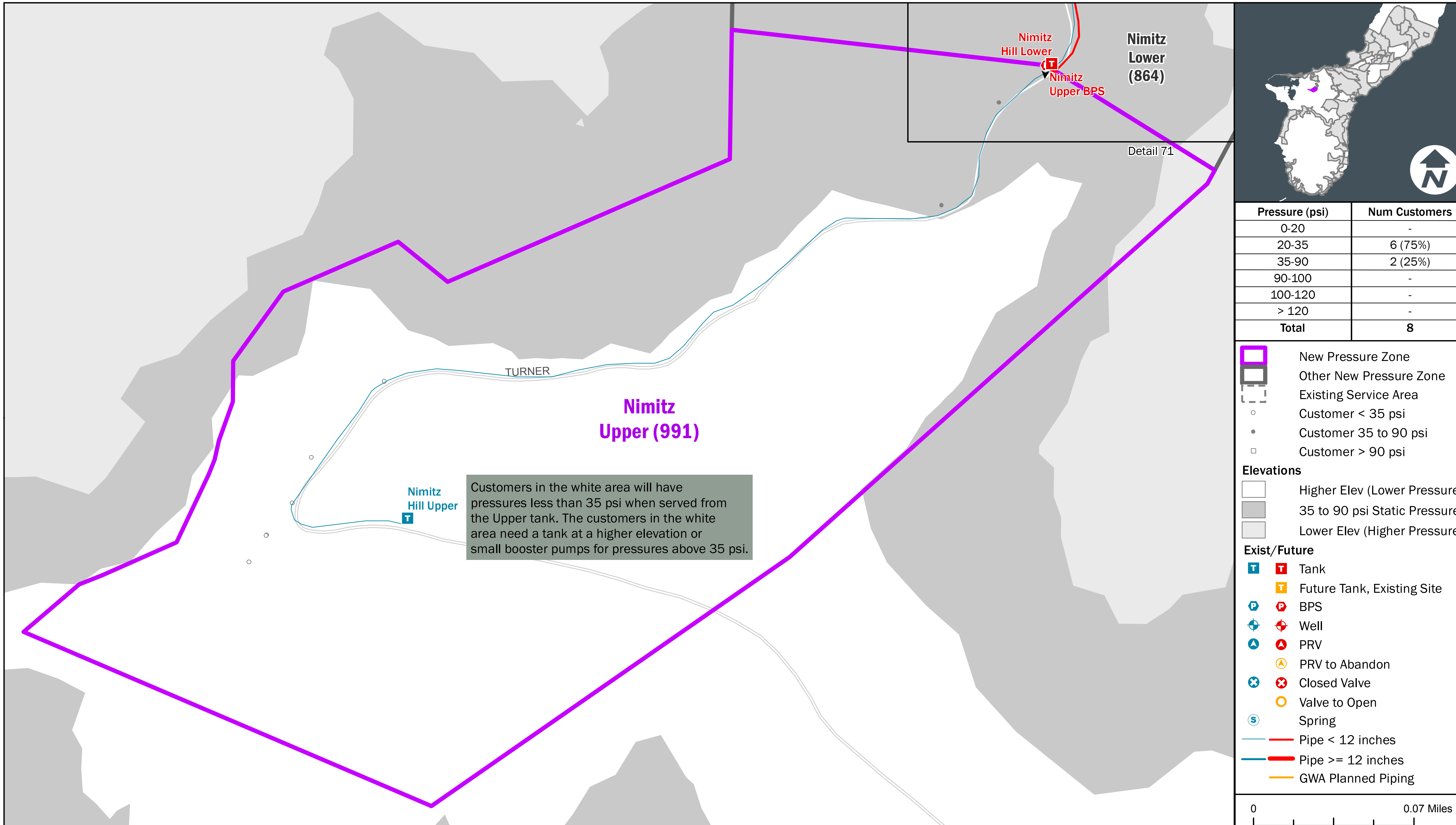
Figure G-45. Nimitz Lower (864) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	6 (75%)
35-90	2 (25%)
90-100	-
100-120	-
> 120	-
Total	**8**

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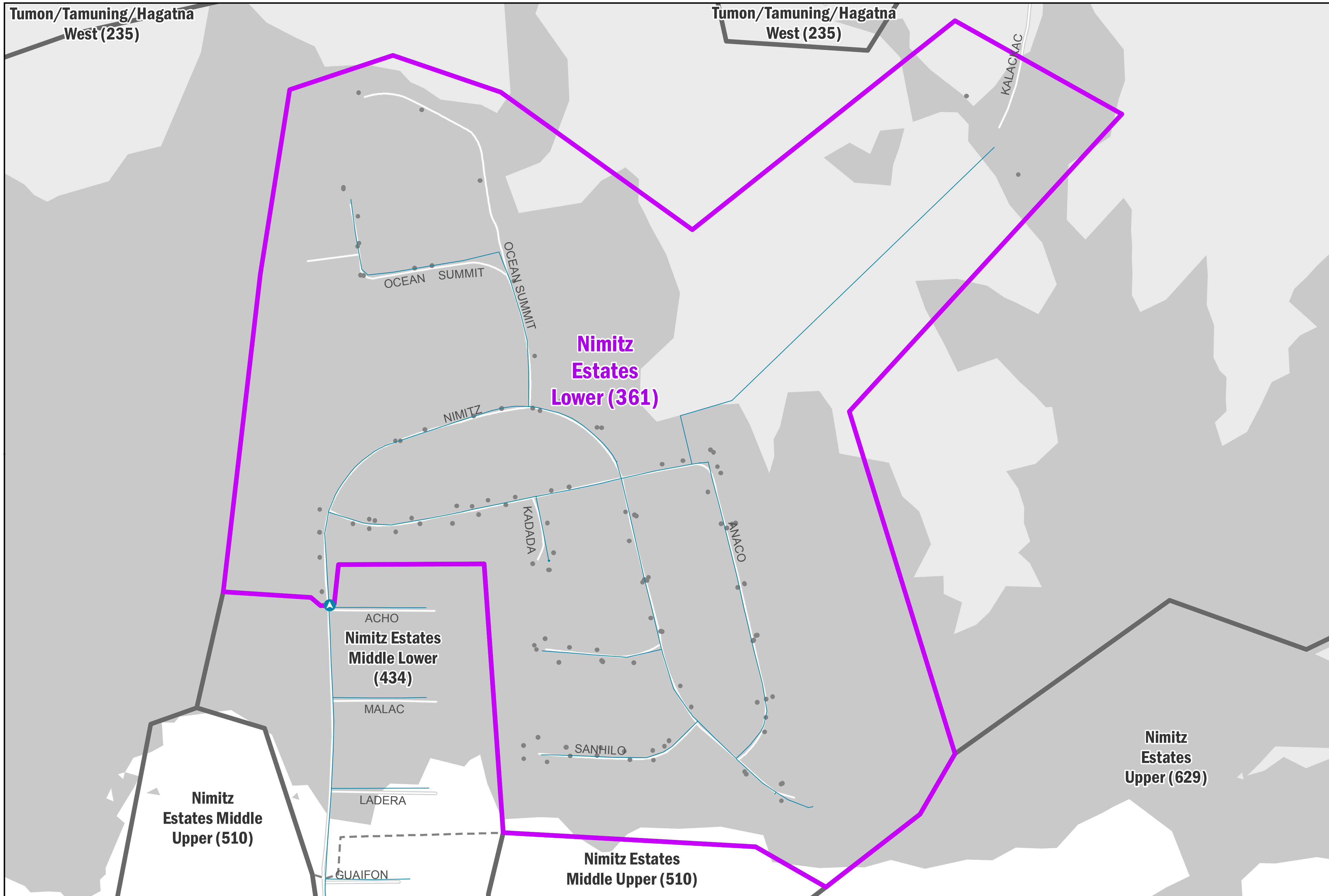
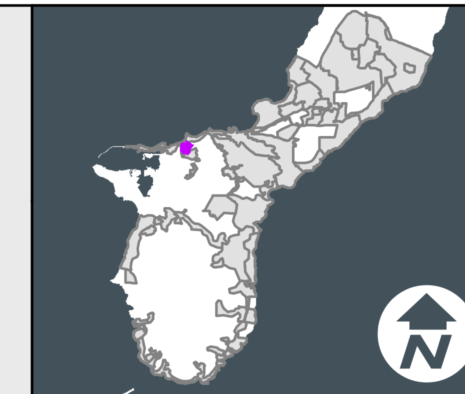
Figure G-46. Nimitz Upper (991) Pressure Zone





Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	125 (100%)
90-100	-
100-120	-
> 120	-
Total	**125**

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

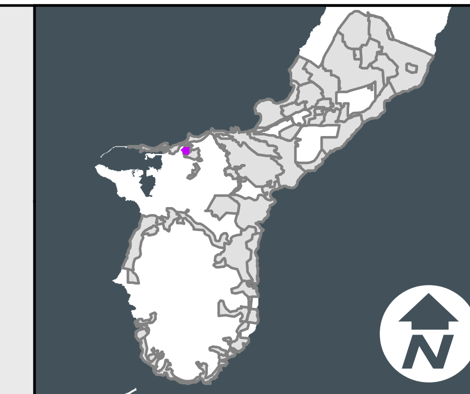
Elevations
Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

Exist/Future
Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

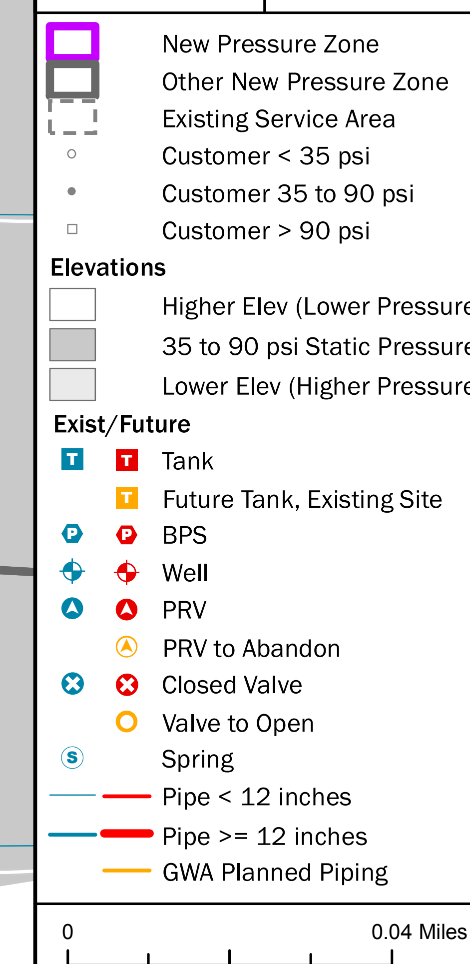
0 0.09 Miles

8/10/2017

Figure G-47. Nimitz Estates Lower (361) Pressure Zone

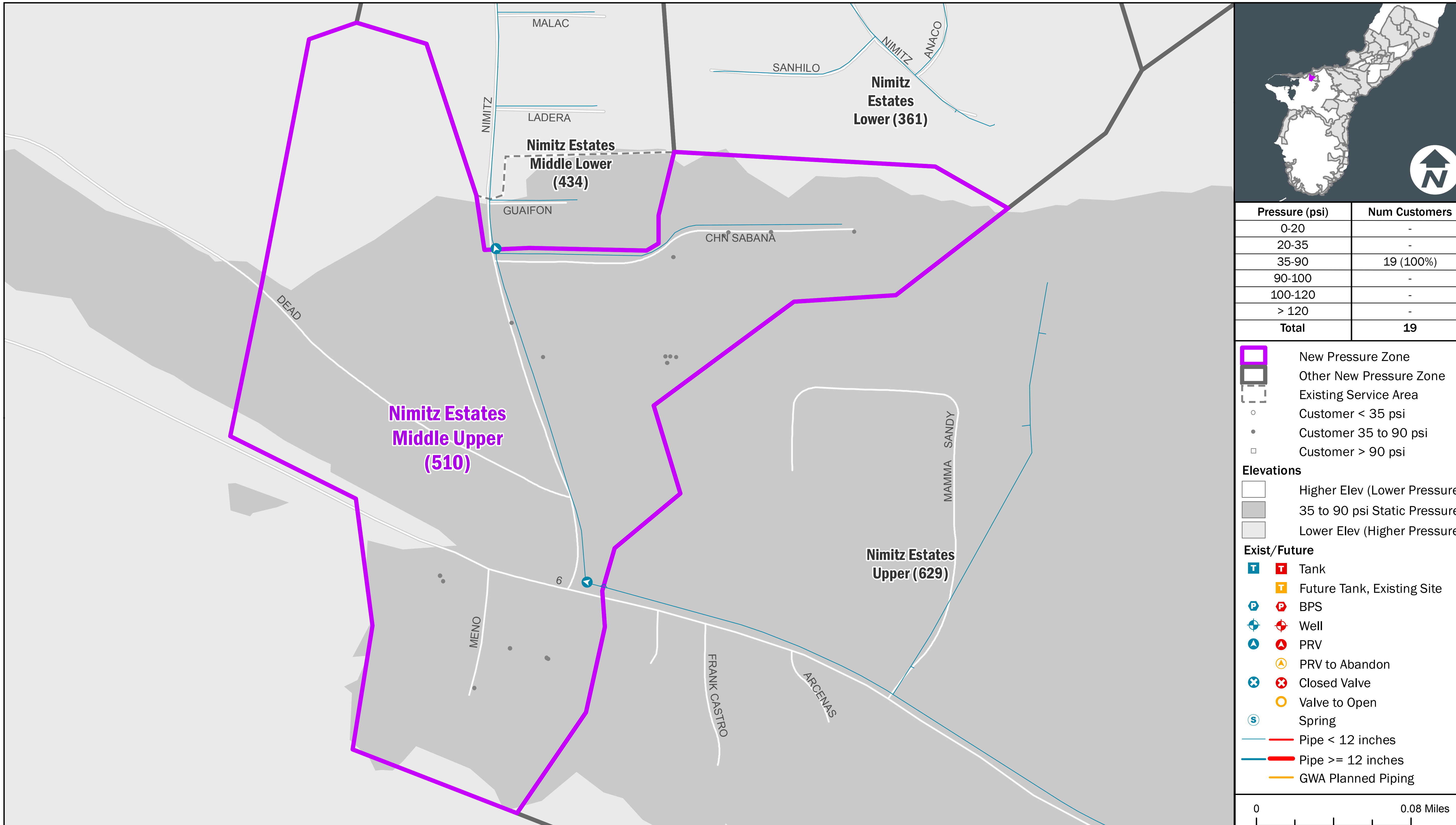


Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	33 (72%)
90-100	13 (28%)
100-120	-
> 120	-
Total	**46**



8/10/2017

Figure G-48. Nimitz Estates Middle Lower (434) Pressure Zone

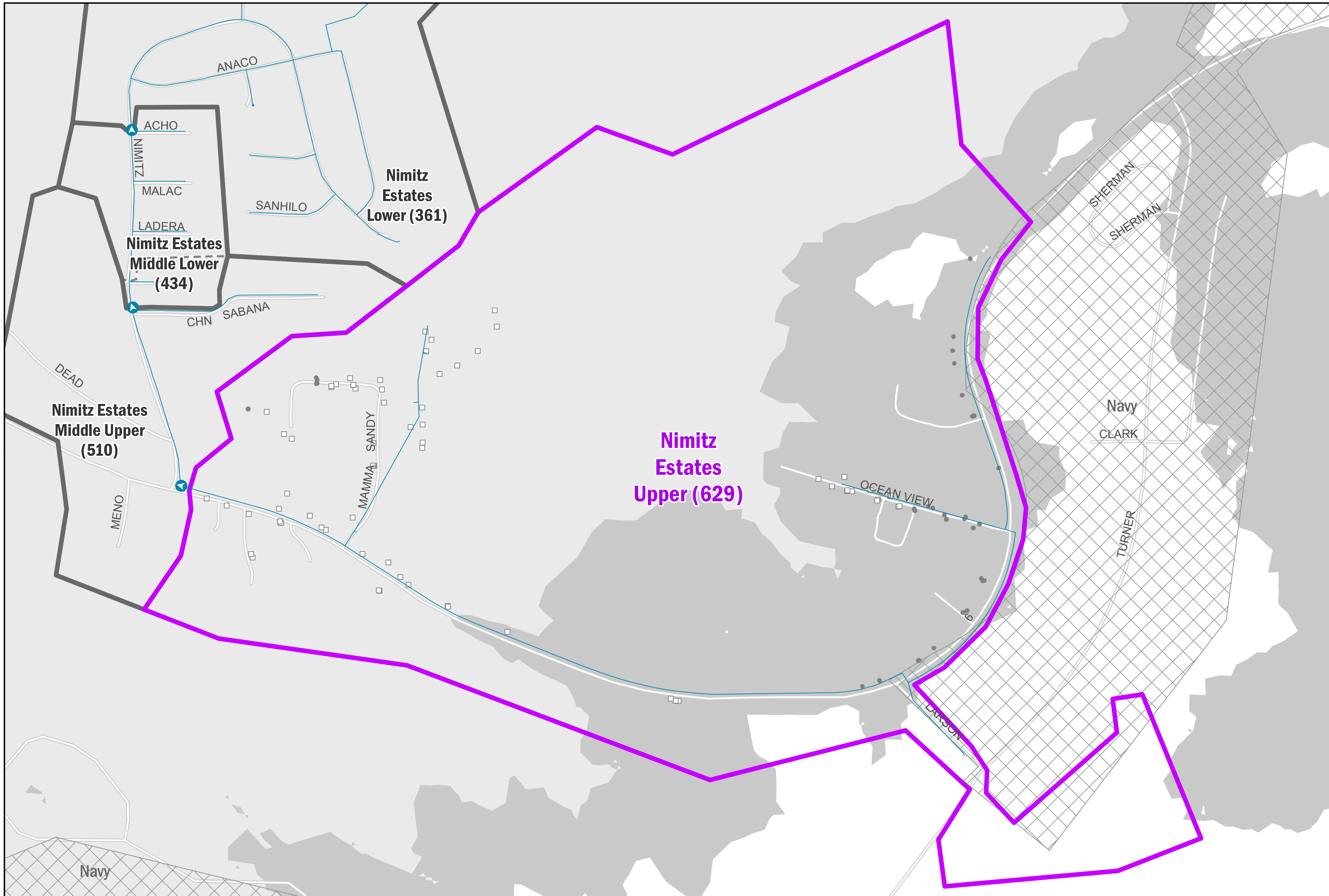


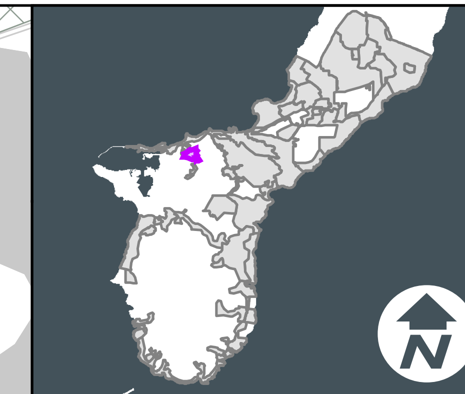
Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	19 (100%)
90-100	-
100-120	-
> 120	-
Total	**19**

8/10/2017

Figure G-49. Nimitz Estates Middle Upper (510) Pressure Zone

Brown AND Caldwell





Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	45 (37%)
90-100	11 (9%)
100-120	10 (8%)
> 120	57 (46%)
Total	**123**

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

Elevations
Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

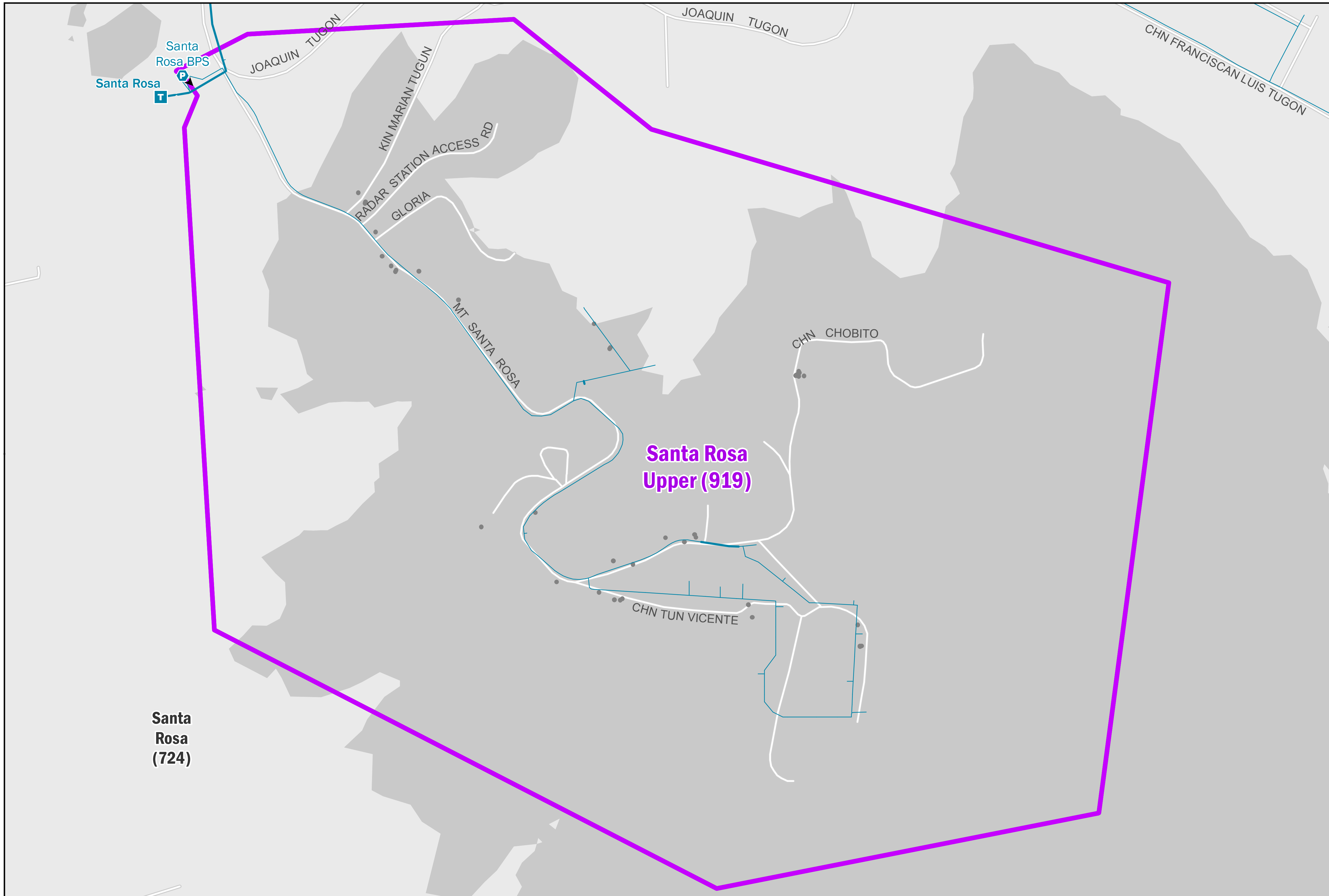
Exist/Future
Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 0.17 Miles

8/10/2017

Figure G-50. Nimitz Estates Upper (629) Pressure Zone

Brown AND Caldwell



Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	42 (100%)
90-100	-
100-120	-
> 120	-
Total	42

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

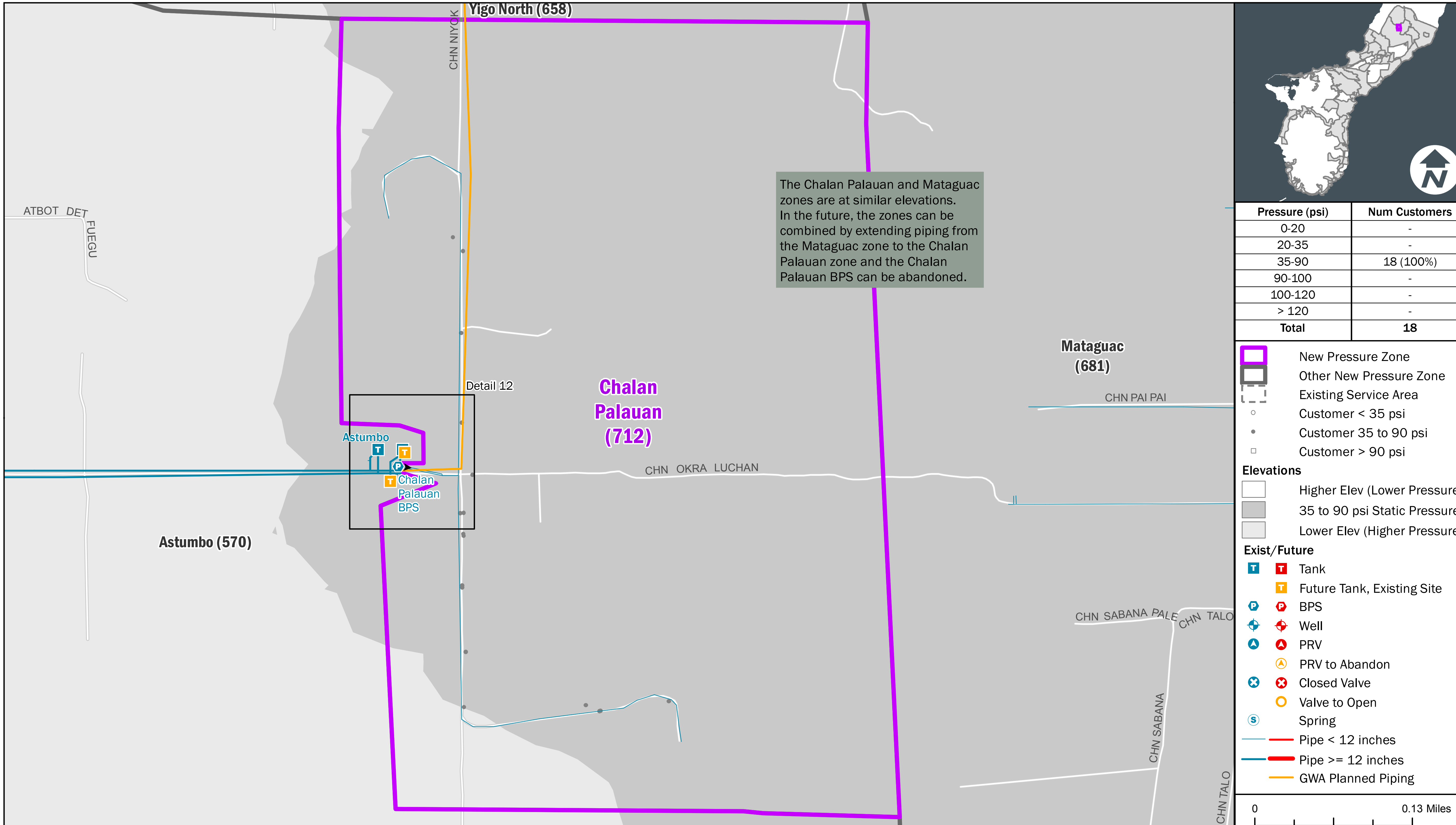
Elevations
Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

Exist/Future
Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 0.12 Miles

8/10/2017

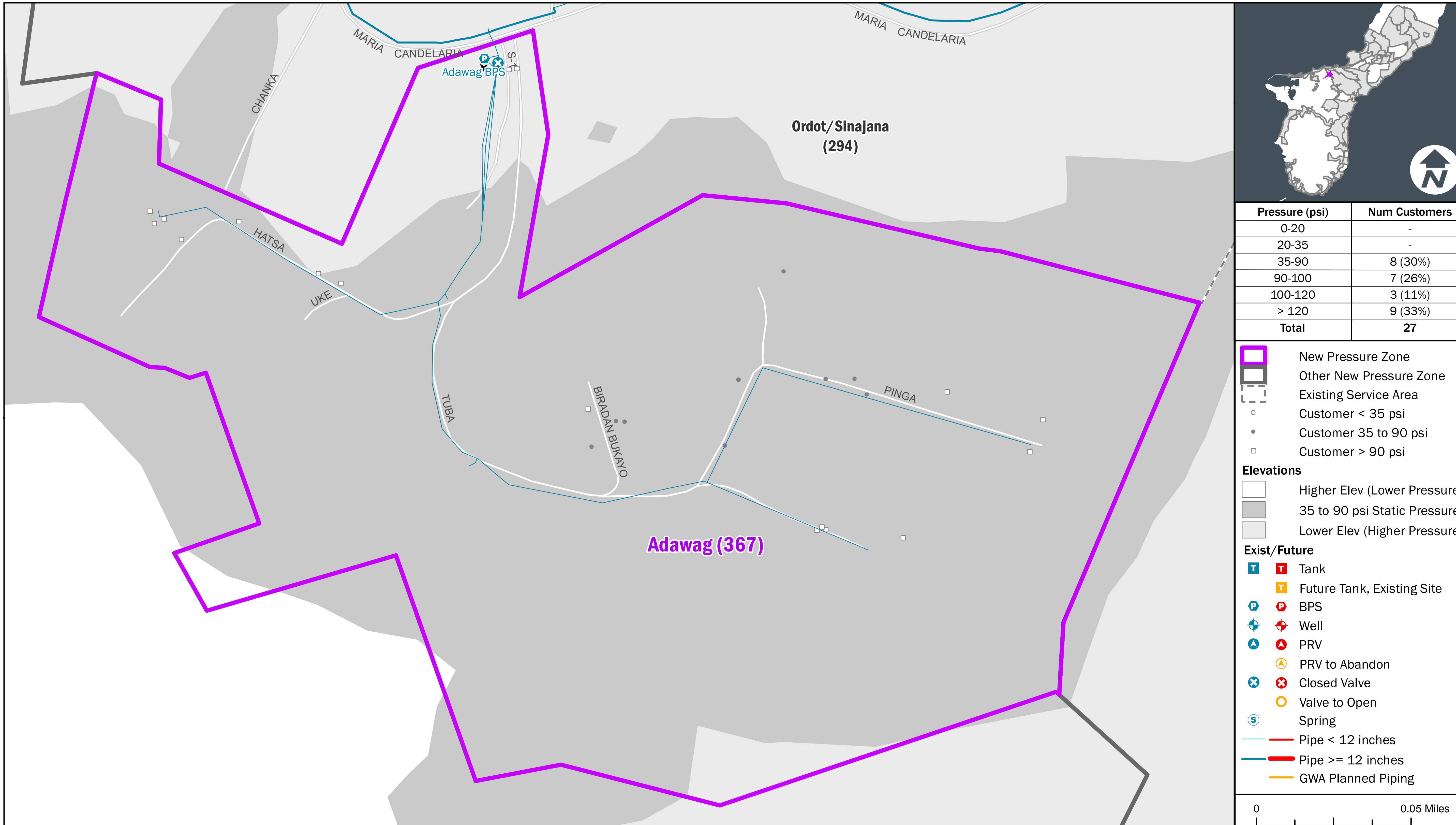
Figure G-51. Santa Rosa Upper (919) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	18 (100%)
90-100	-
100-120	-
> 120	-
Total	**18**

8/10/2017

Figure G-52. Chalan Palauan (712) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	8 (30%)
90-100	7 (26%)
100-120	3 (11%)
> 120	9 (33%)
Total	**27**

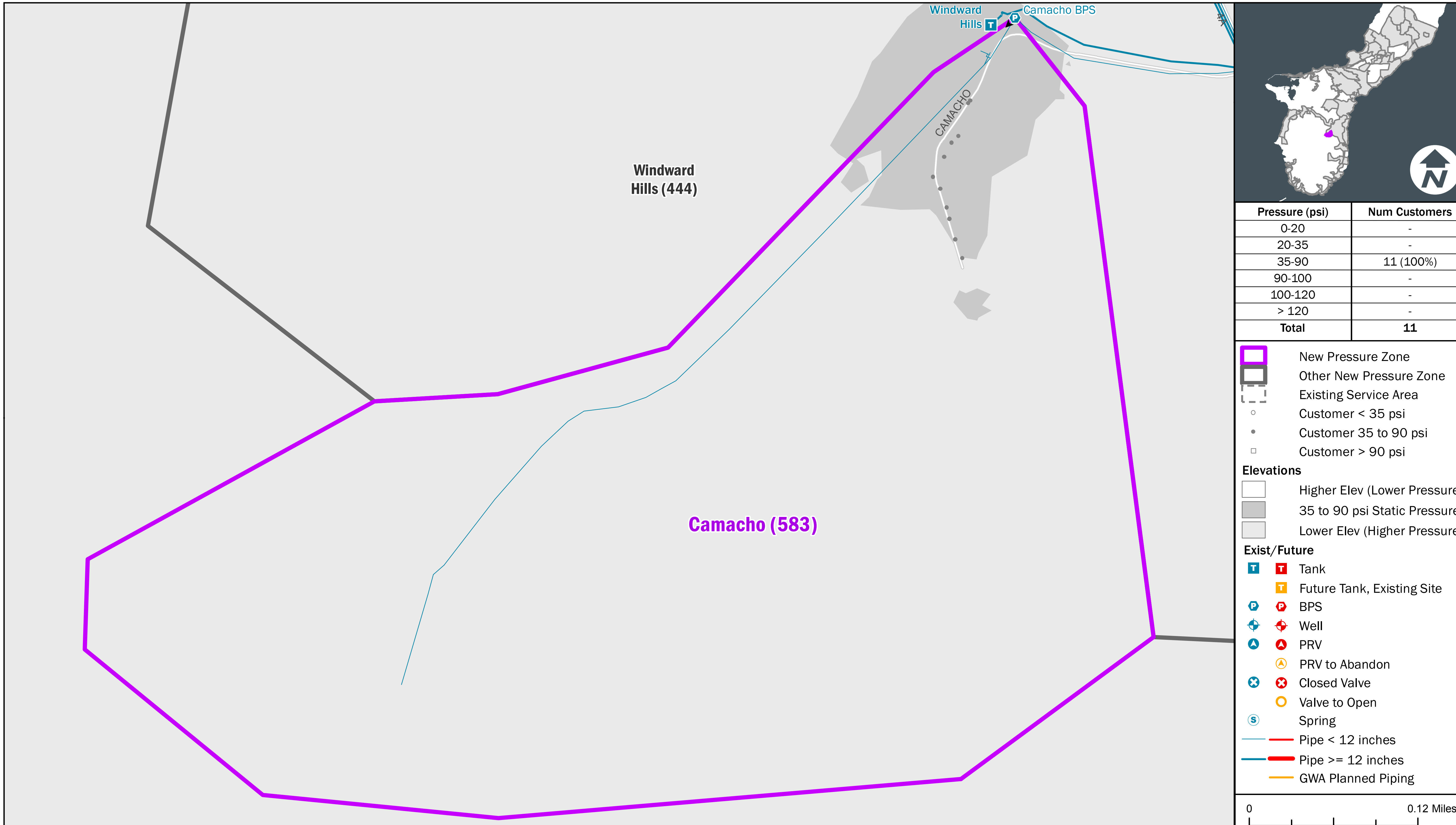
8/10/2017

Figure G-53. Adawag (367) Pressure Zone

Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	20 (100%)
90-100	-
100-120	-
> 120	-
Total	**20**

8/10/2017

Figure G-54. Ulloa-Untalan (374) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	-
35-90	11 (100%)
90-100	-
100-120	-
> 120	-
Total	**11**

New Pressure Zone
Other New Pressure Zone
Existing Service Area
Customer < 35 psi
Customer 35 to 90 psi
Customer > 90 psi

Elevations

Higher Elev (Lower Pressure)
35 to 90 psi Static Pressure
Lower Elev (Higher Pressure)

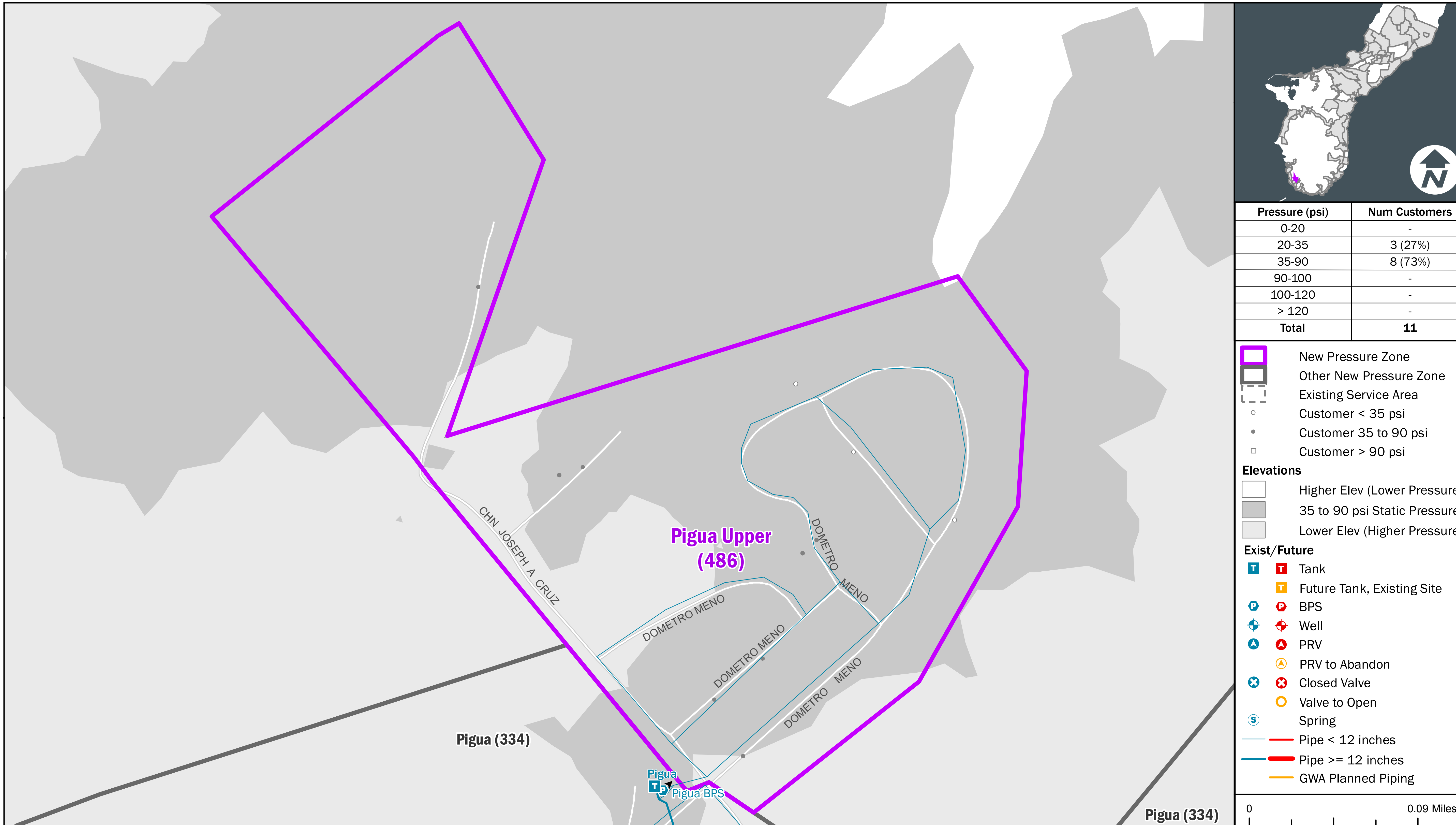
Exist/Future

Tank
Future Tank, Existing Site
BPS
Well
PRV
PRV to Abandon
Closed Valve
Valve to Open
Spring
Pipe < 12 inches
Pipe >= 12 inches
GWA Planned Piping

0 0.12 Miles

8/10/2017

Figure G-55. Camacho (583) Pressure Zone



Pressure (psi)	Num Customers
0-20	-
20-35	3 (27%)
35-90	8 (73%)
90-100	-
100-120	-
> 120	-
Total	**11**

8/10/2017

Figure G-56. Pigua Upper (486) Pressure Zone

Appendix H

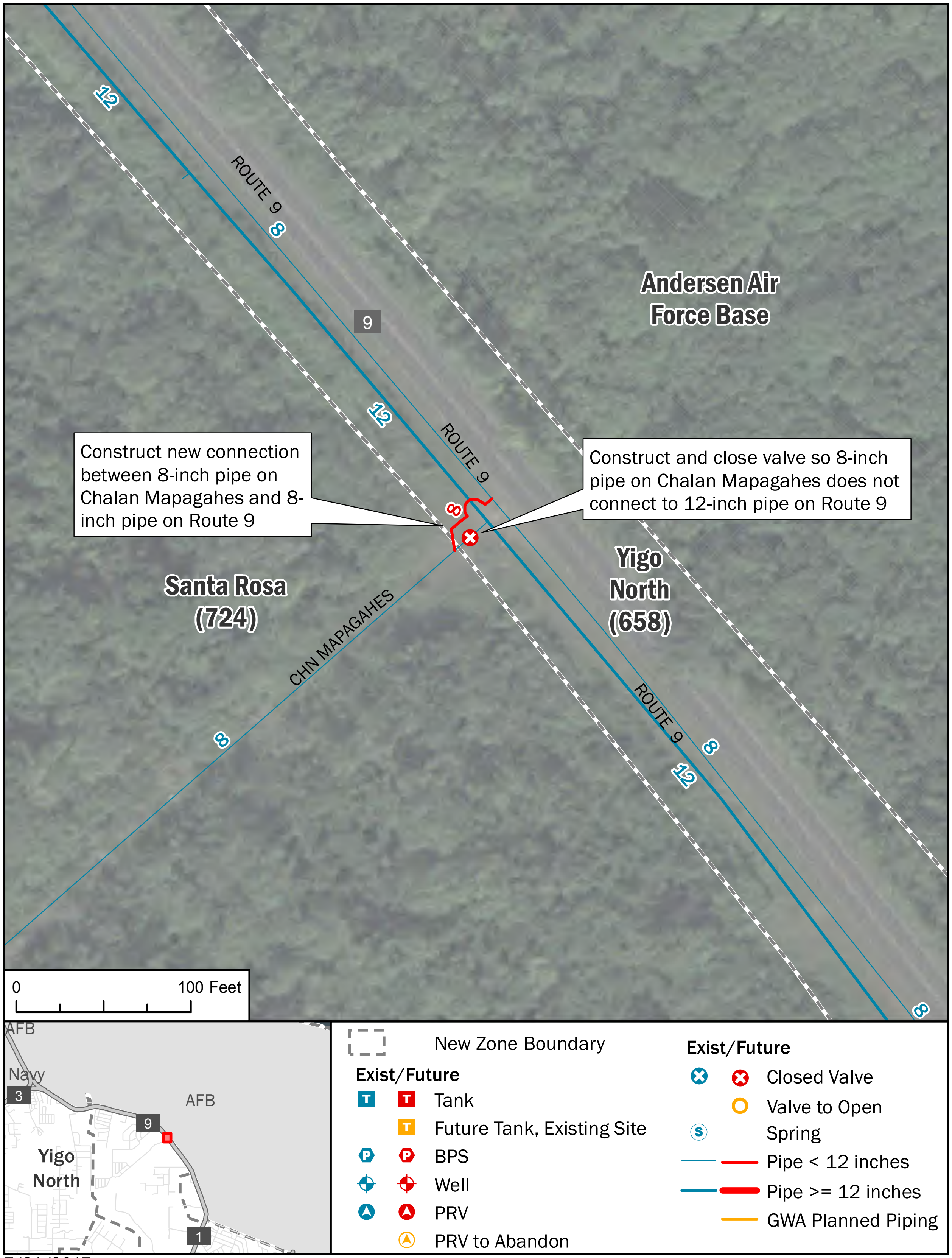
Water Distribution System Recommendation Details

This appendix contains the detail maps referenced in the figures in Appendix G. Here are a few notes about the figures:

- Several figures mention closing an isolation valve at a zone boundary. The comments typically say to “Construct and close valve.” There may be an isolation valve at that location already, but it may not be fully functional and may need to be replaced.

7/31/2017

Detail 1

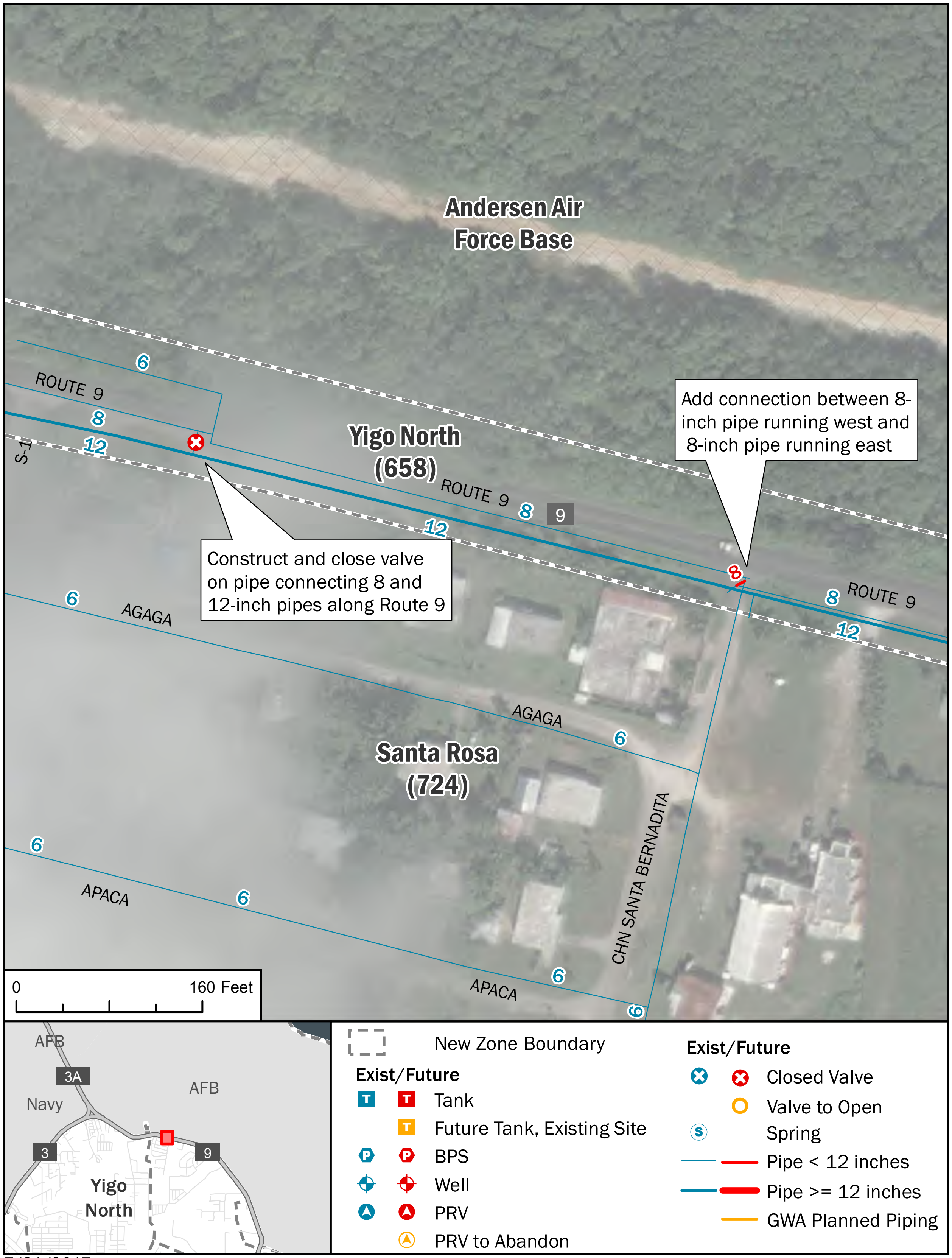


7/31/2017

Detail 2

7/31/2017

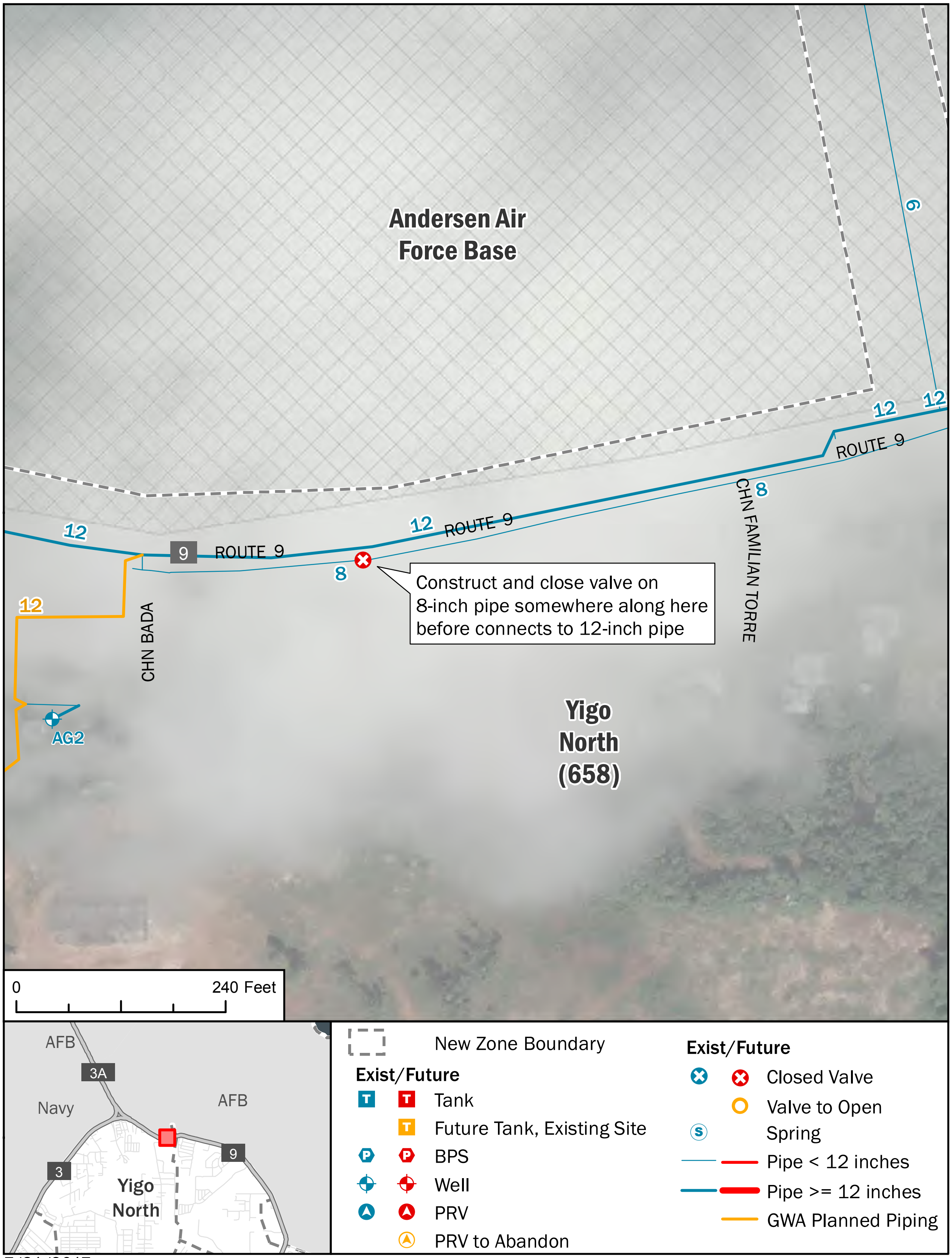
Detail 3



7/31/2017

Detail 4

Brown AND Caldwell



7/31/2017

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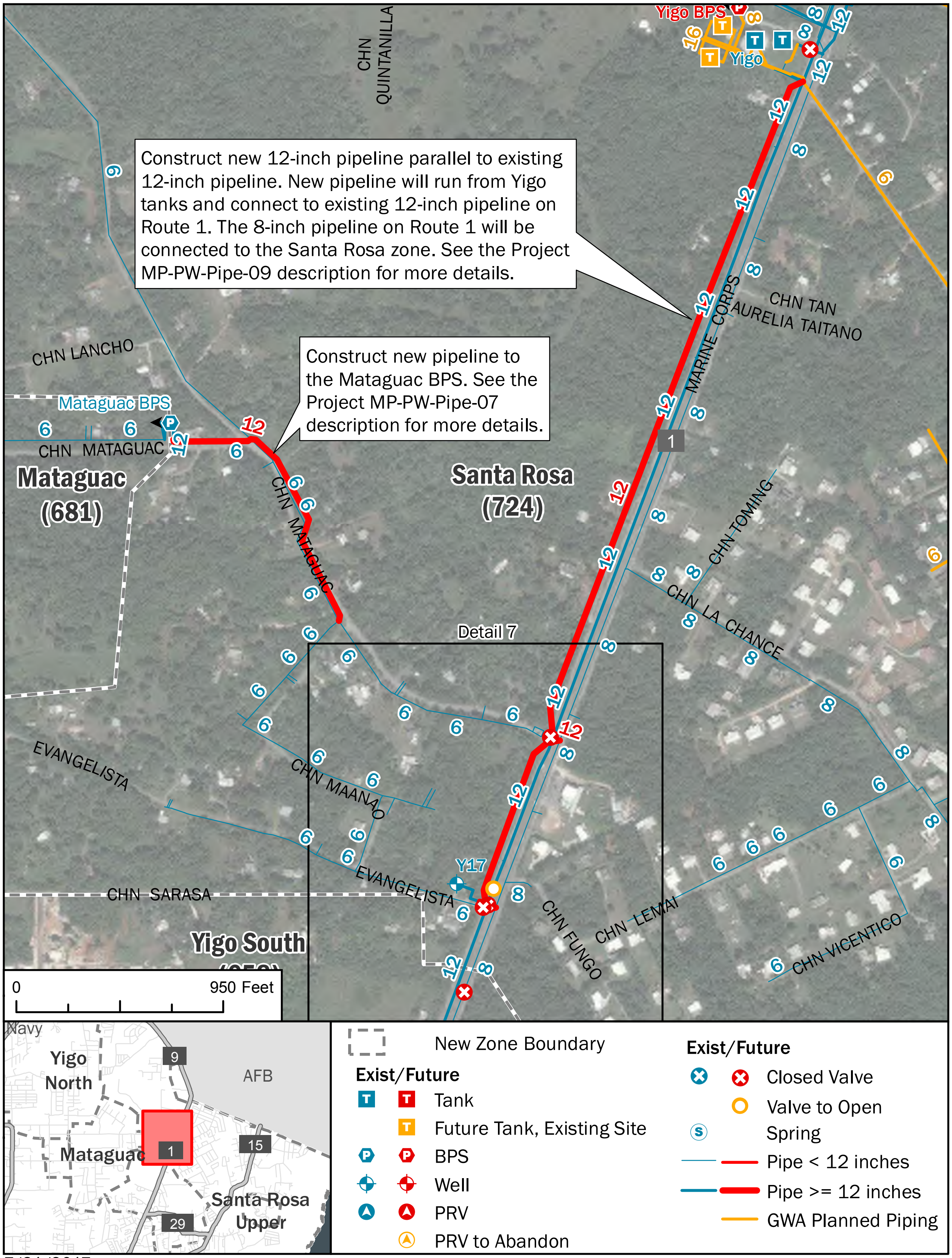

7/31/2017

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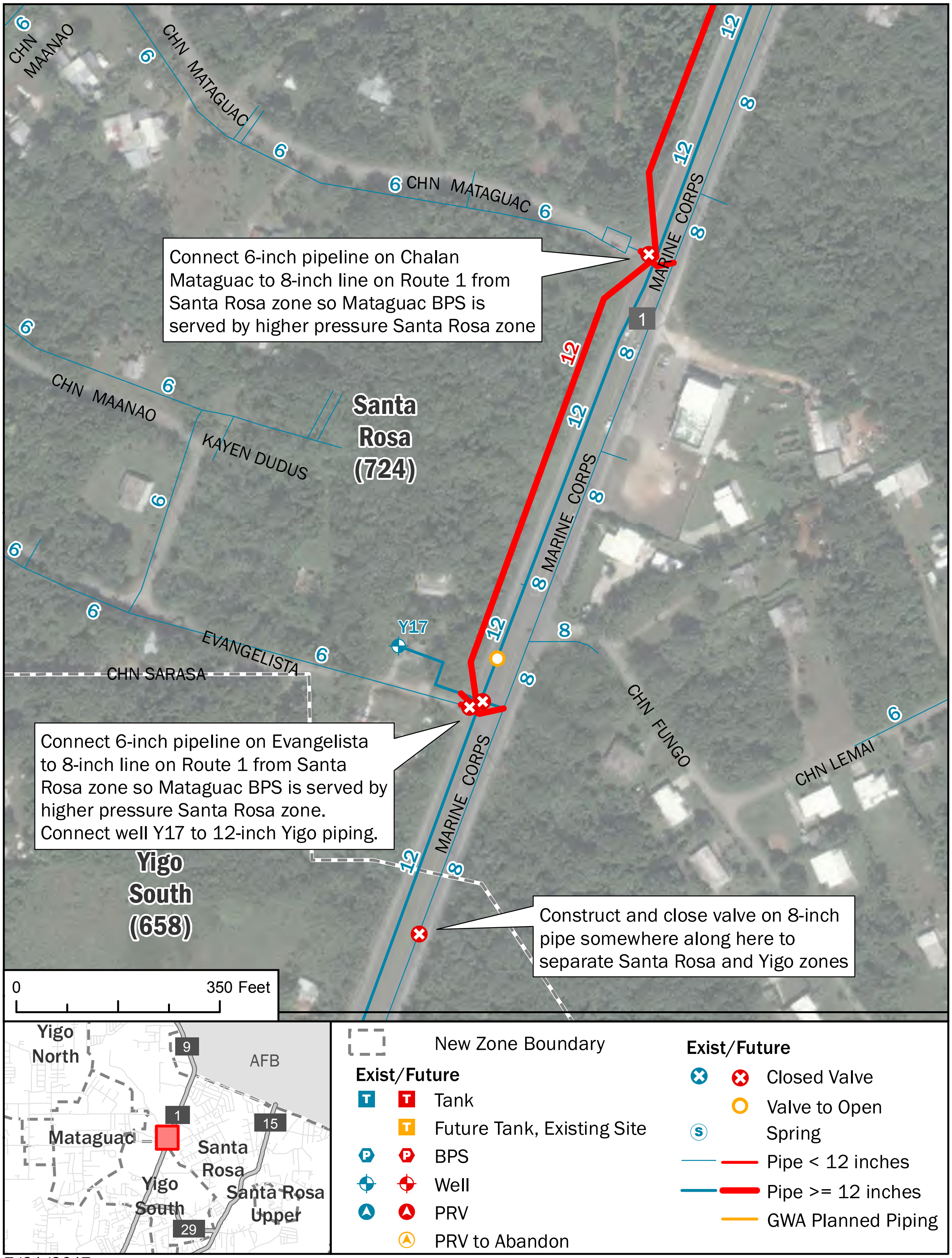

7/31/2017

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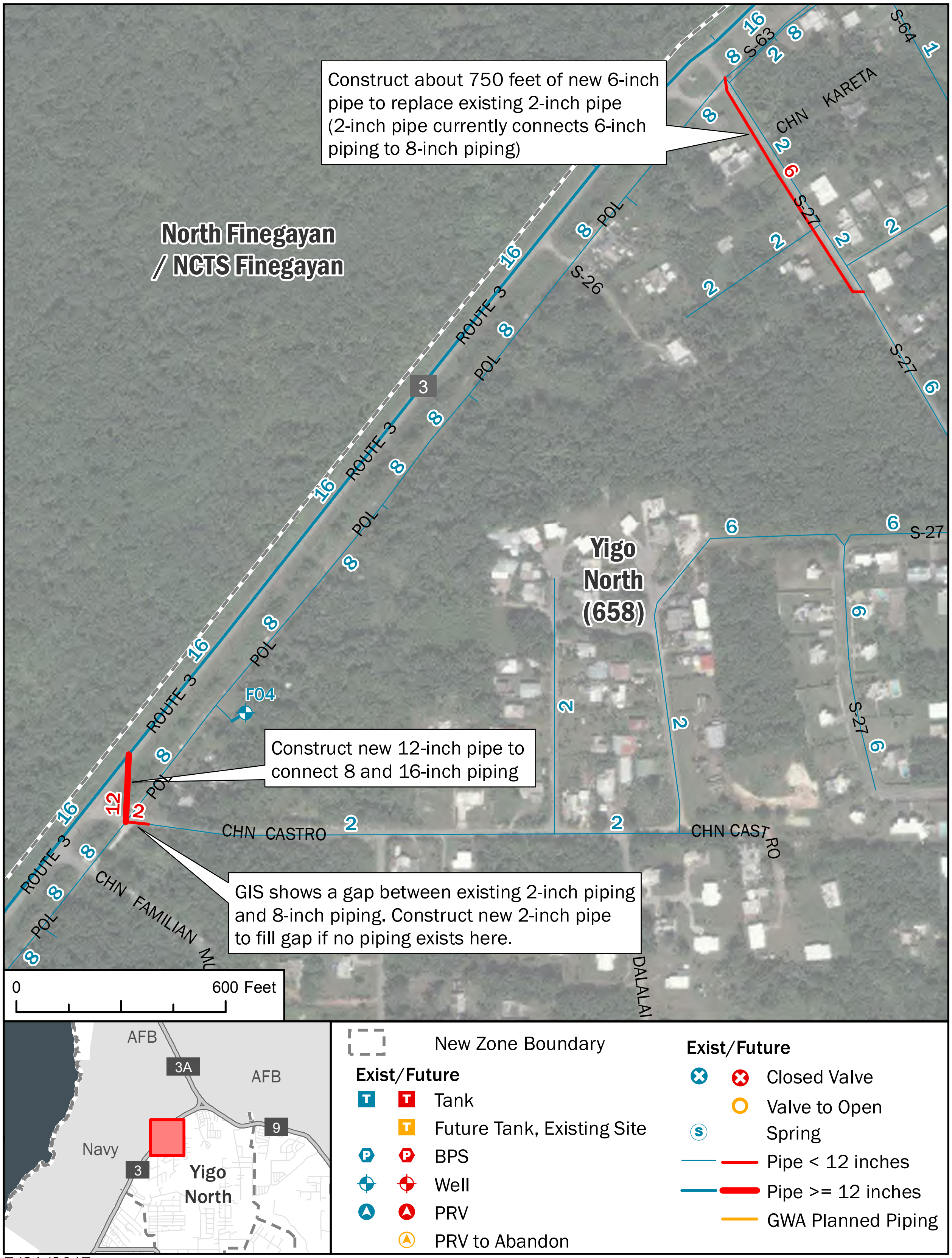


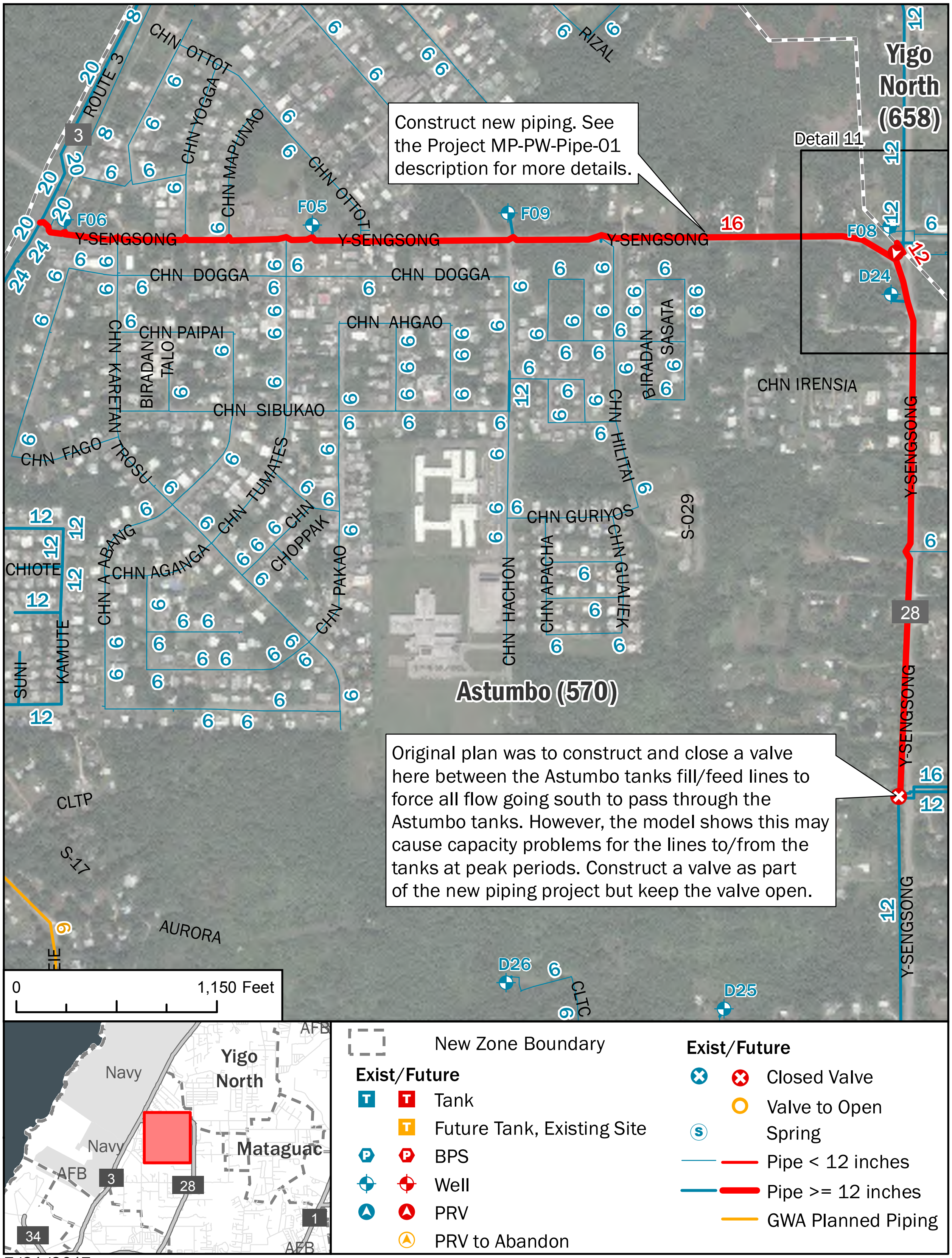
7/31/2017

Detail 8

7/31/2017

Detail 9

Brown AND Caldwell



7/31/2017

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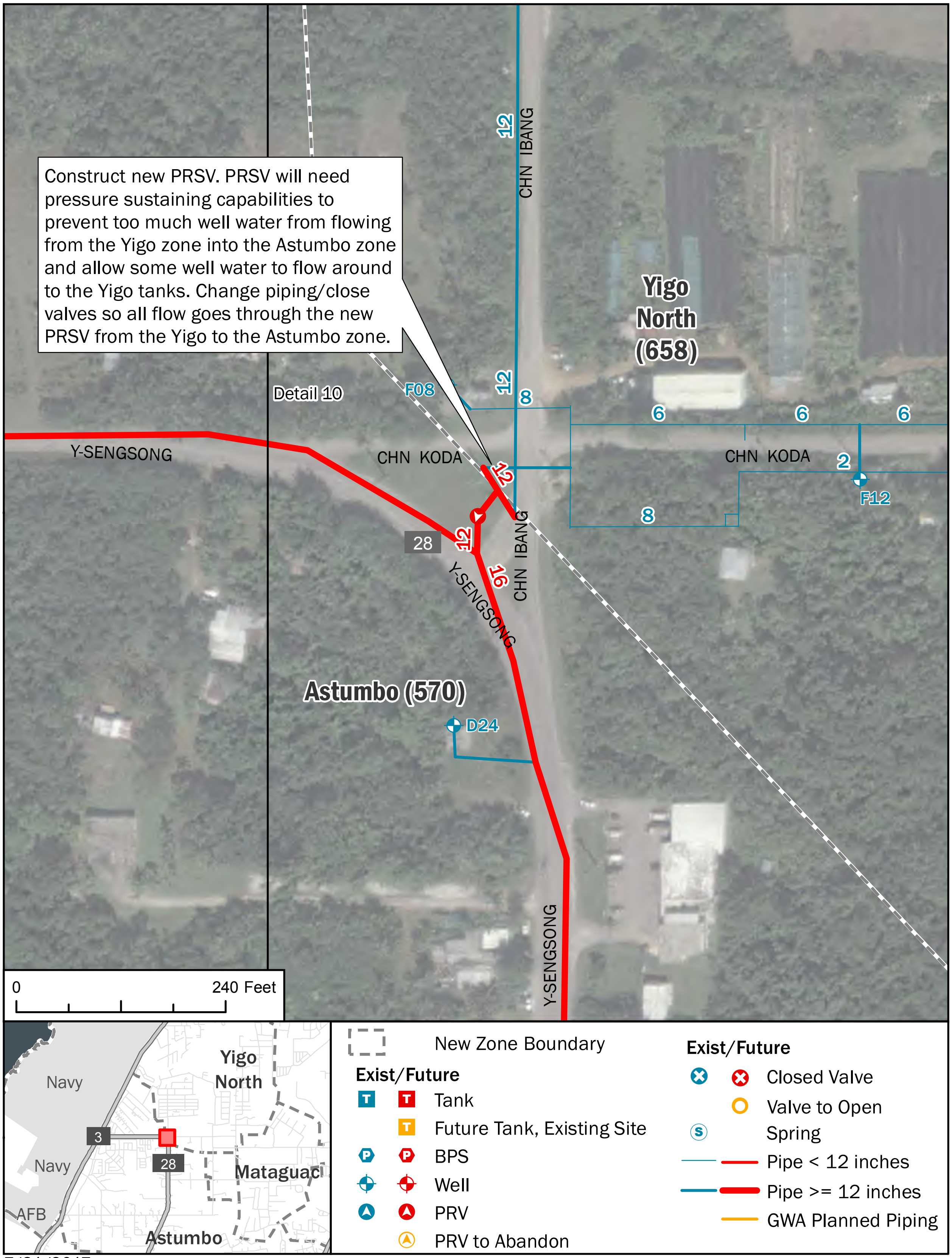

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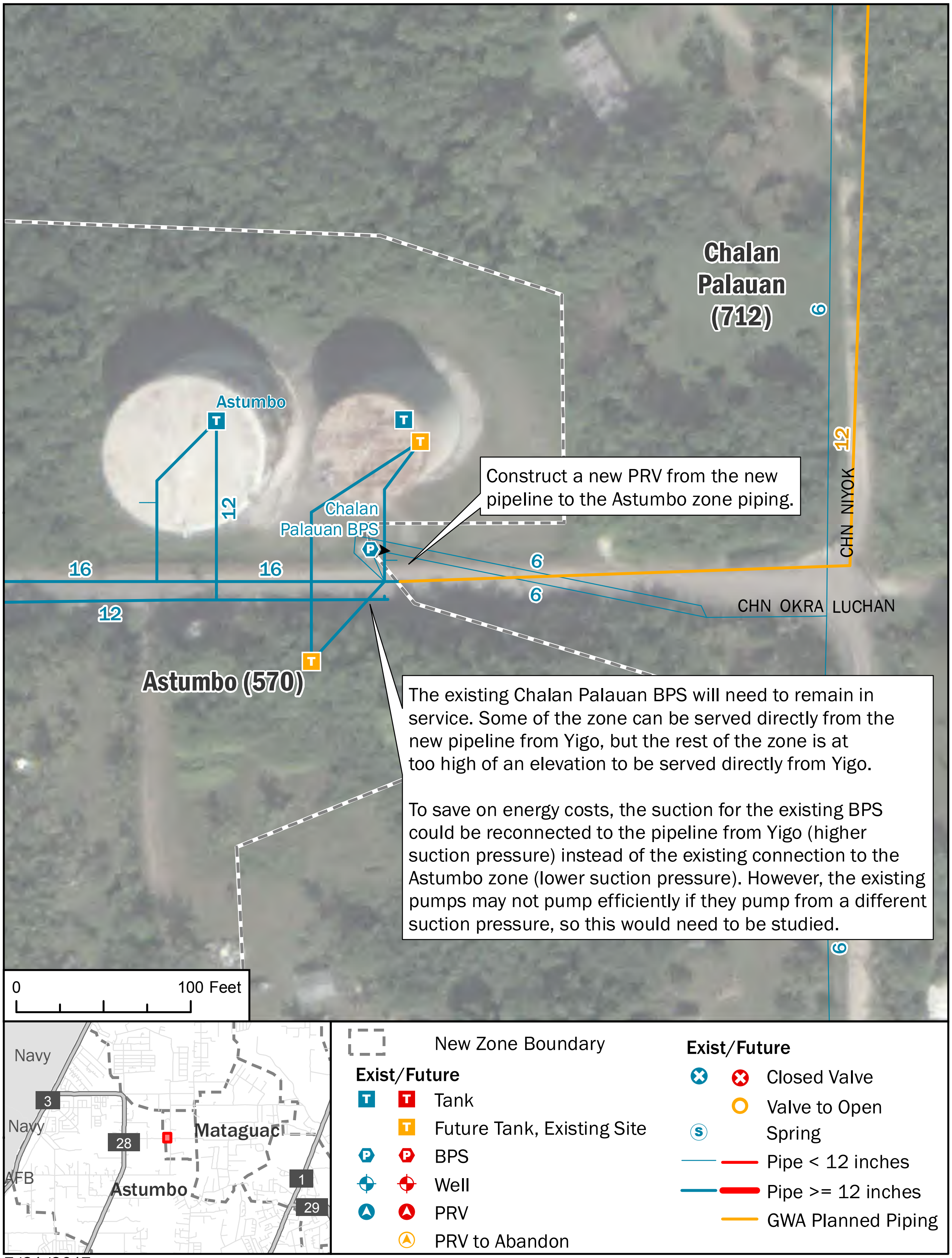

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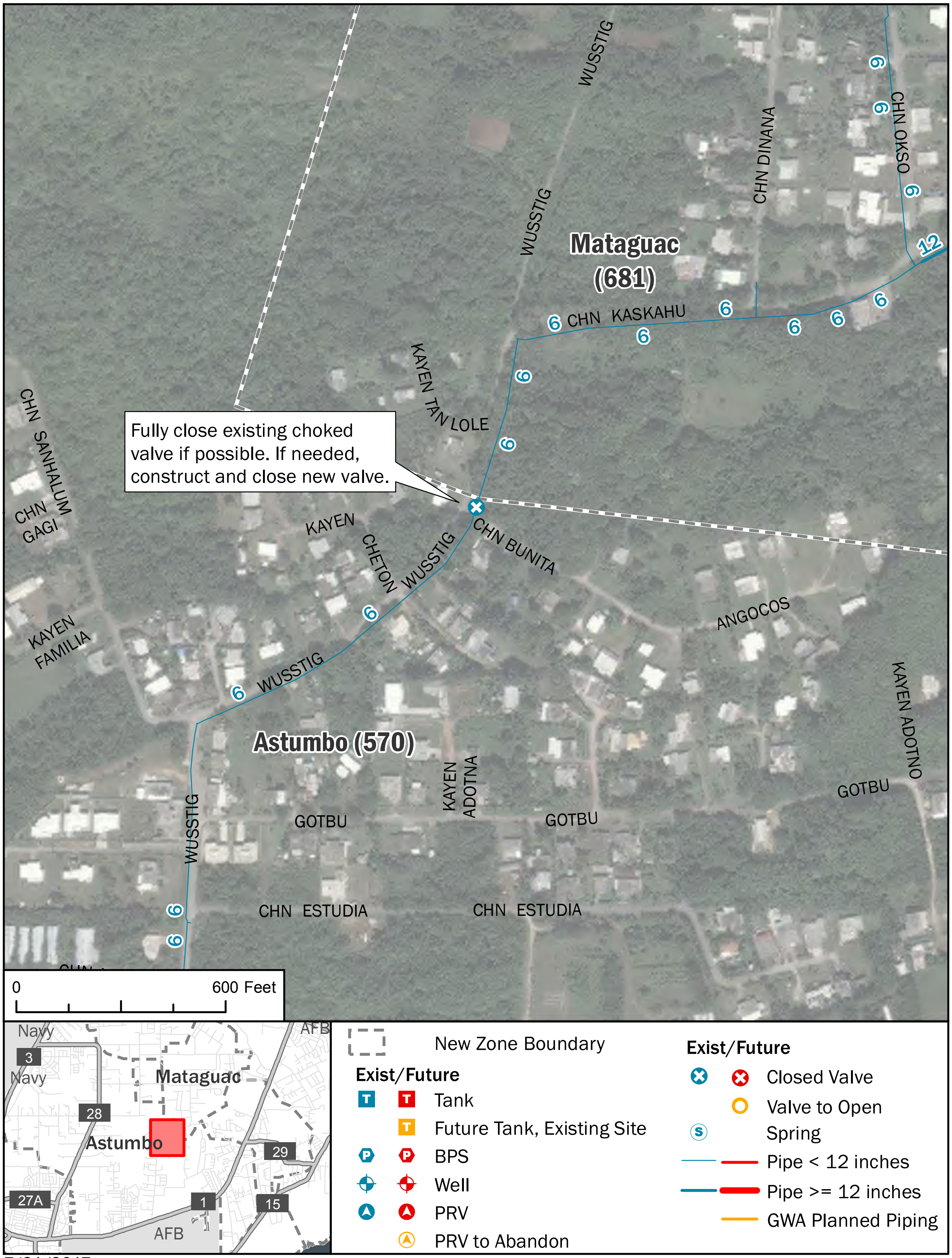

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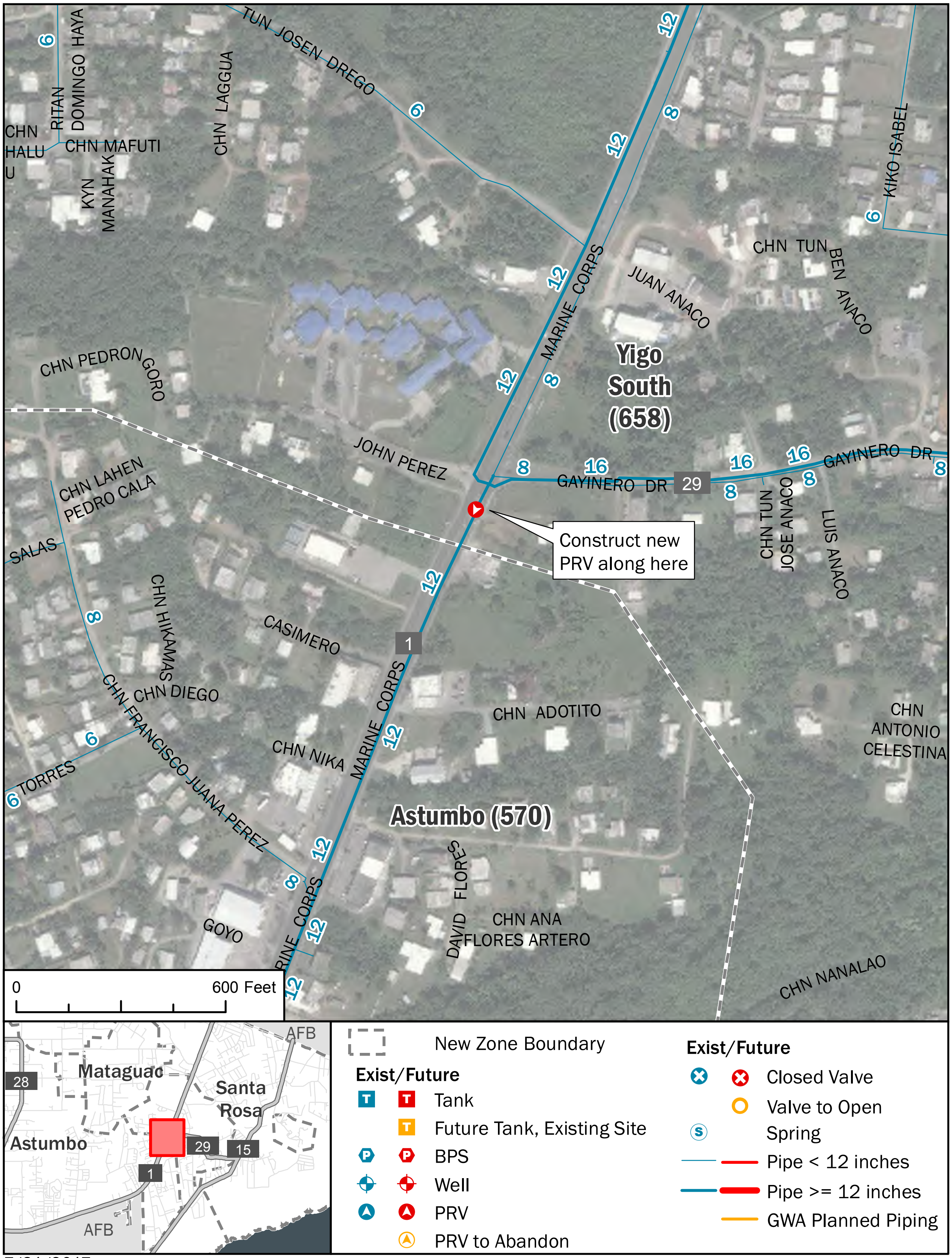

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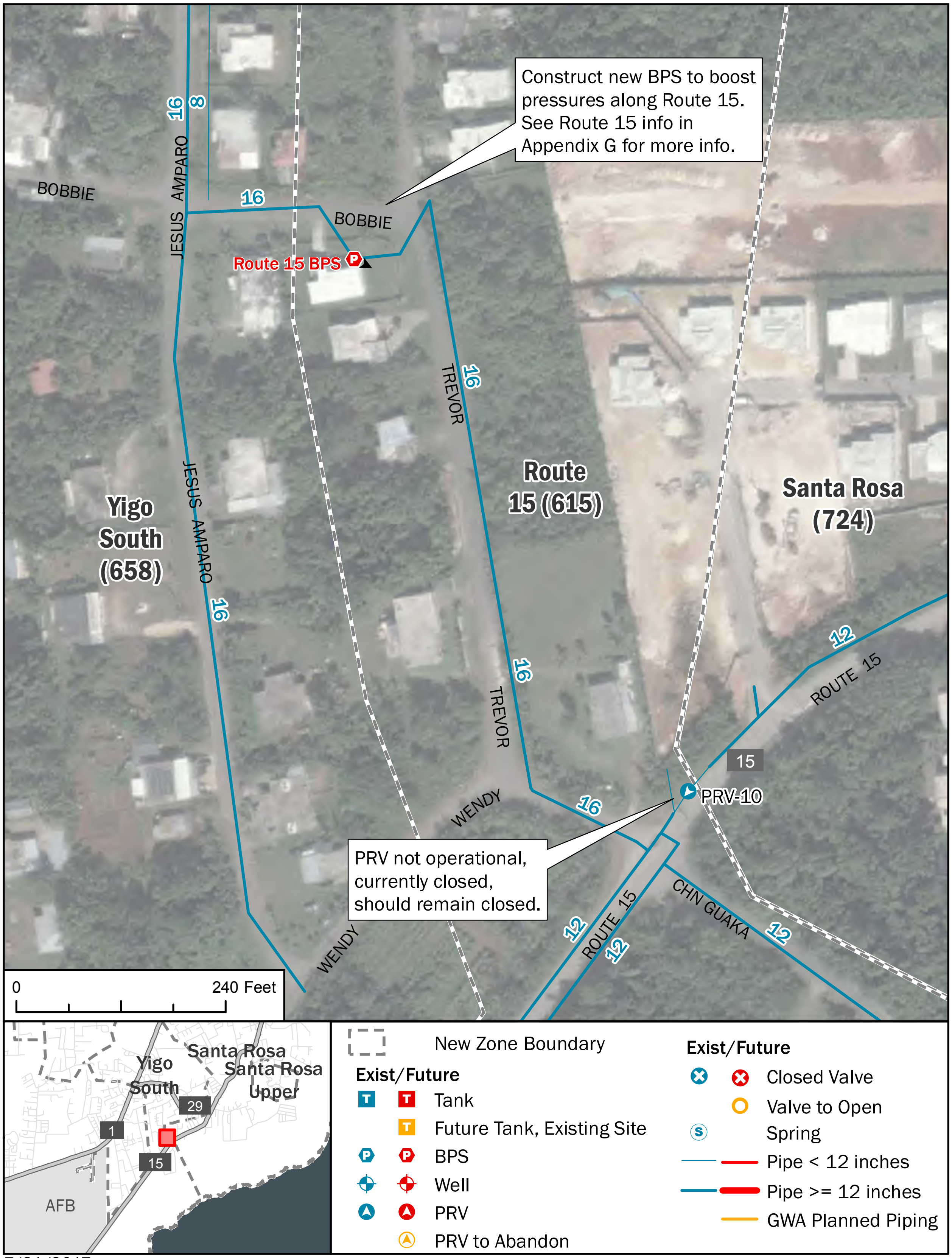

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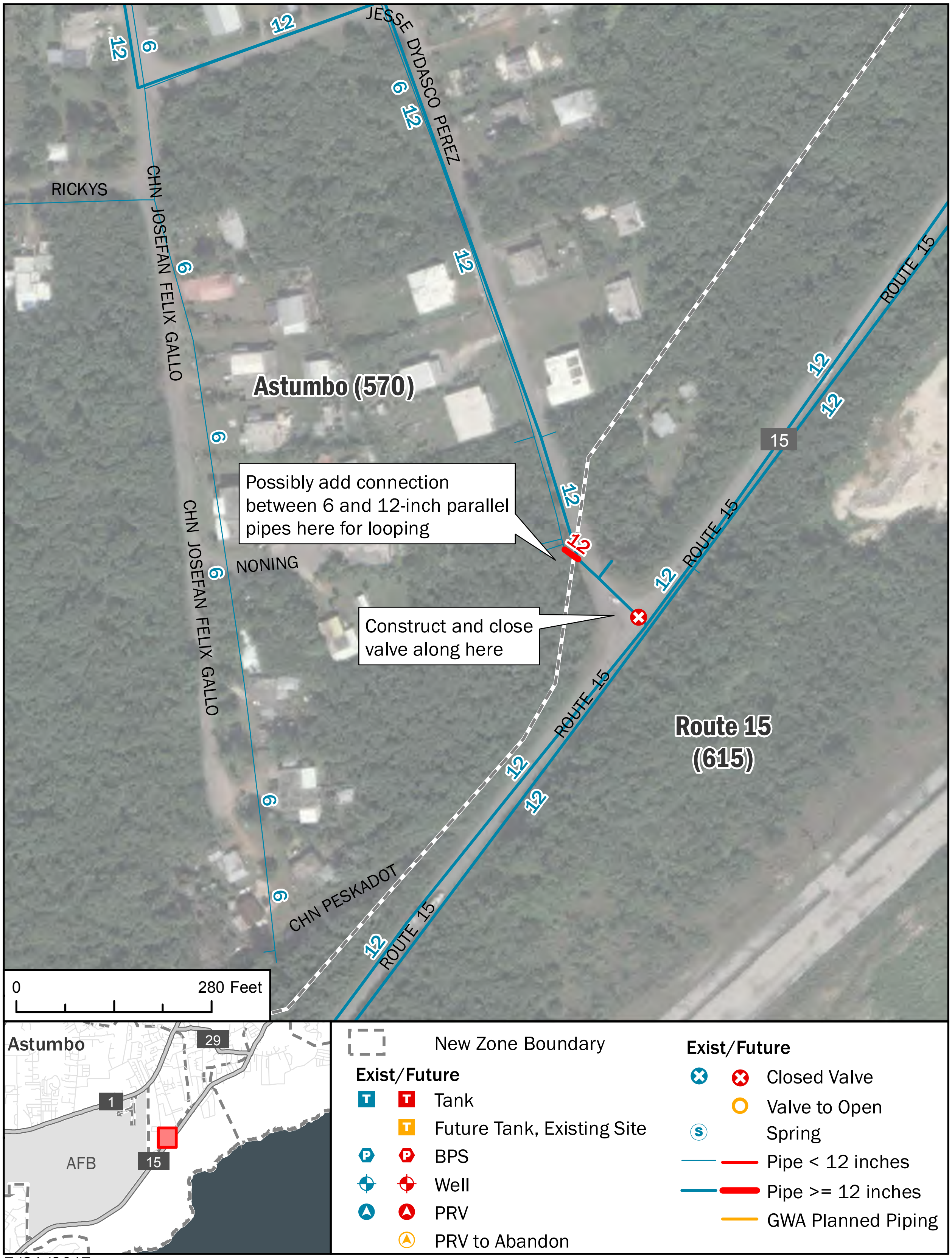

7/31/2017

Detail 16

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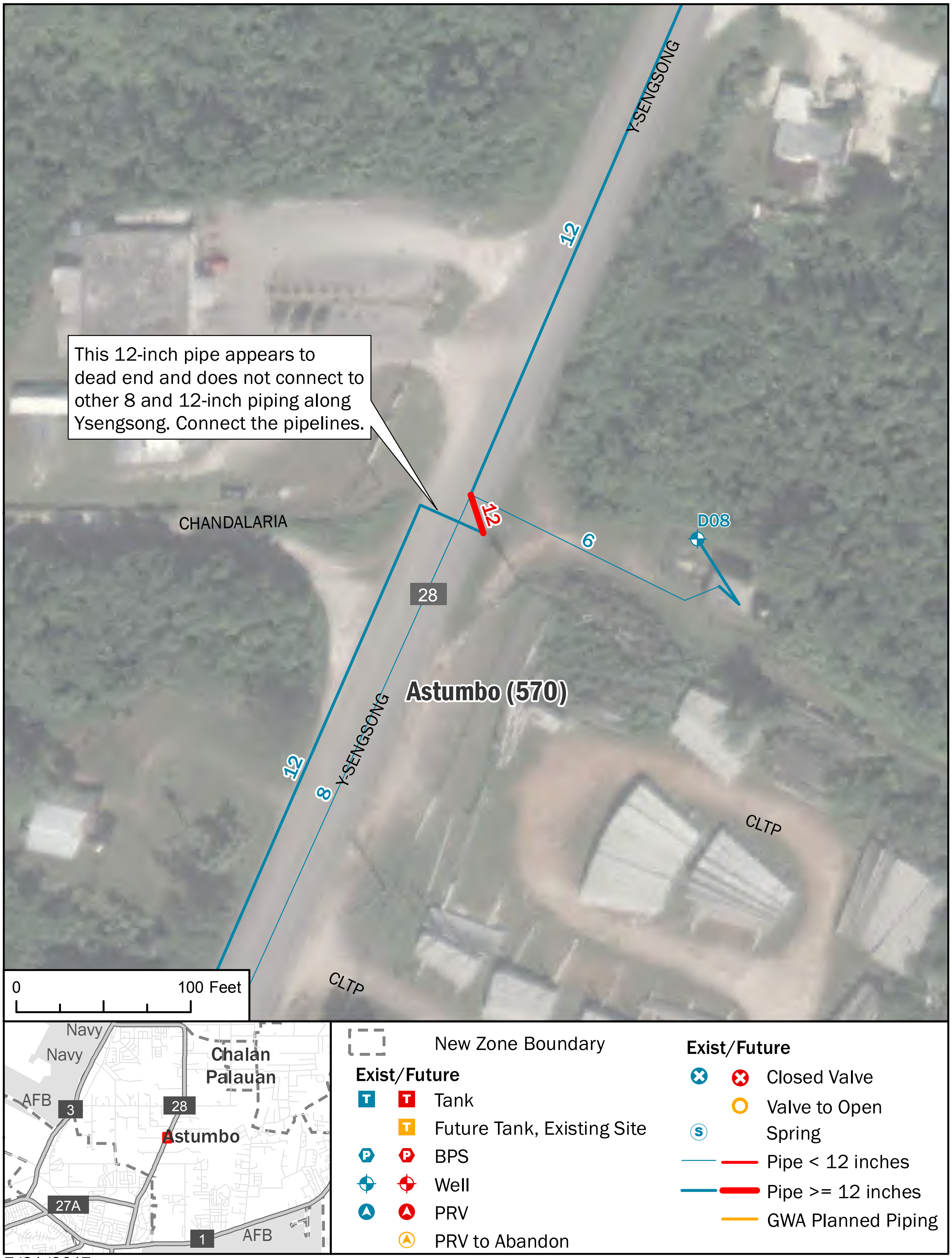

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Detail 17

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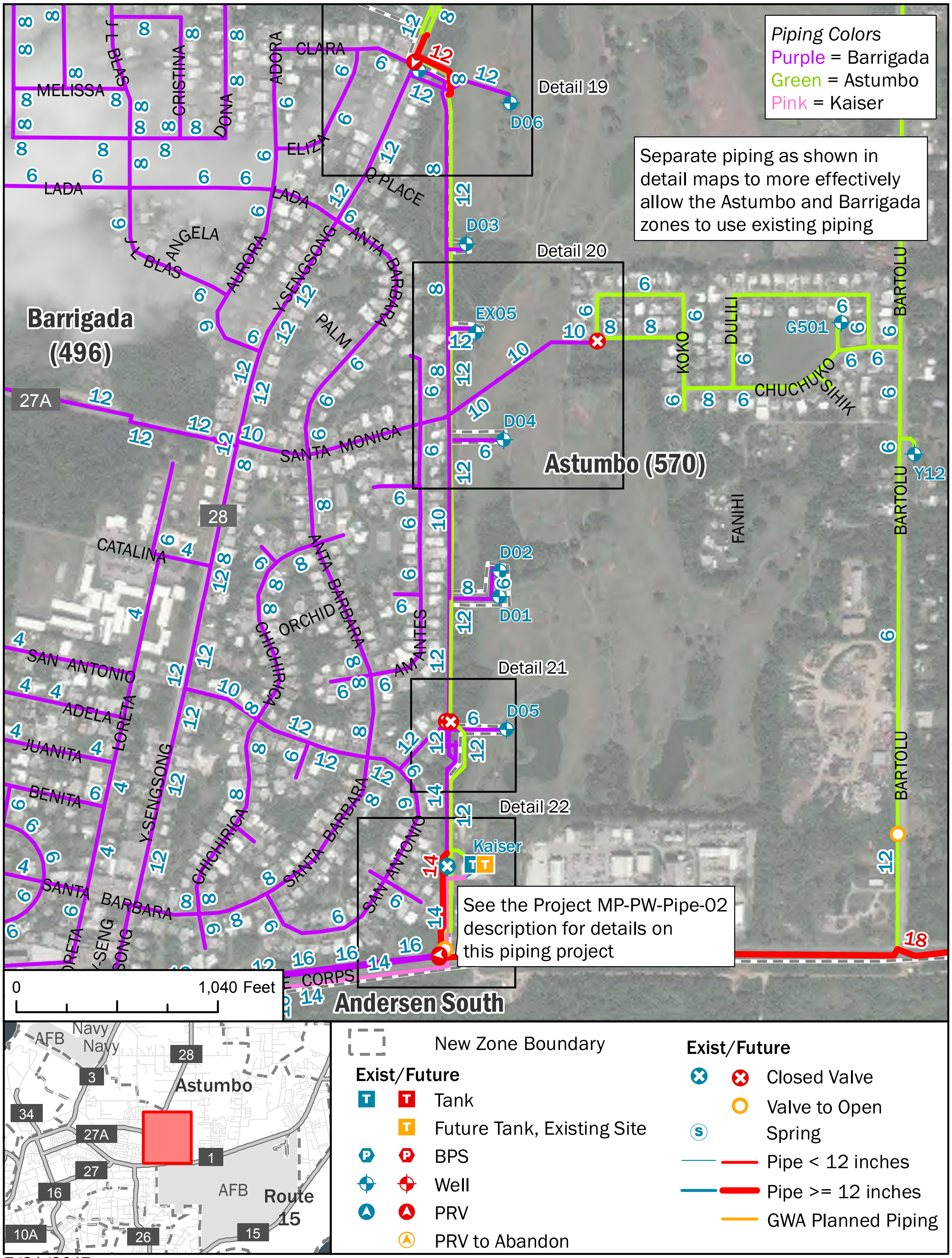
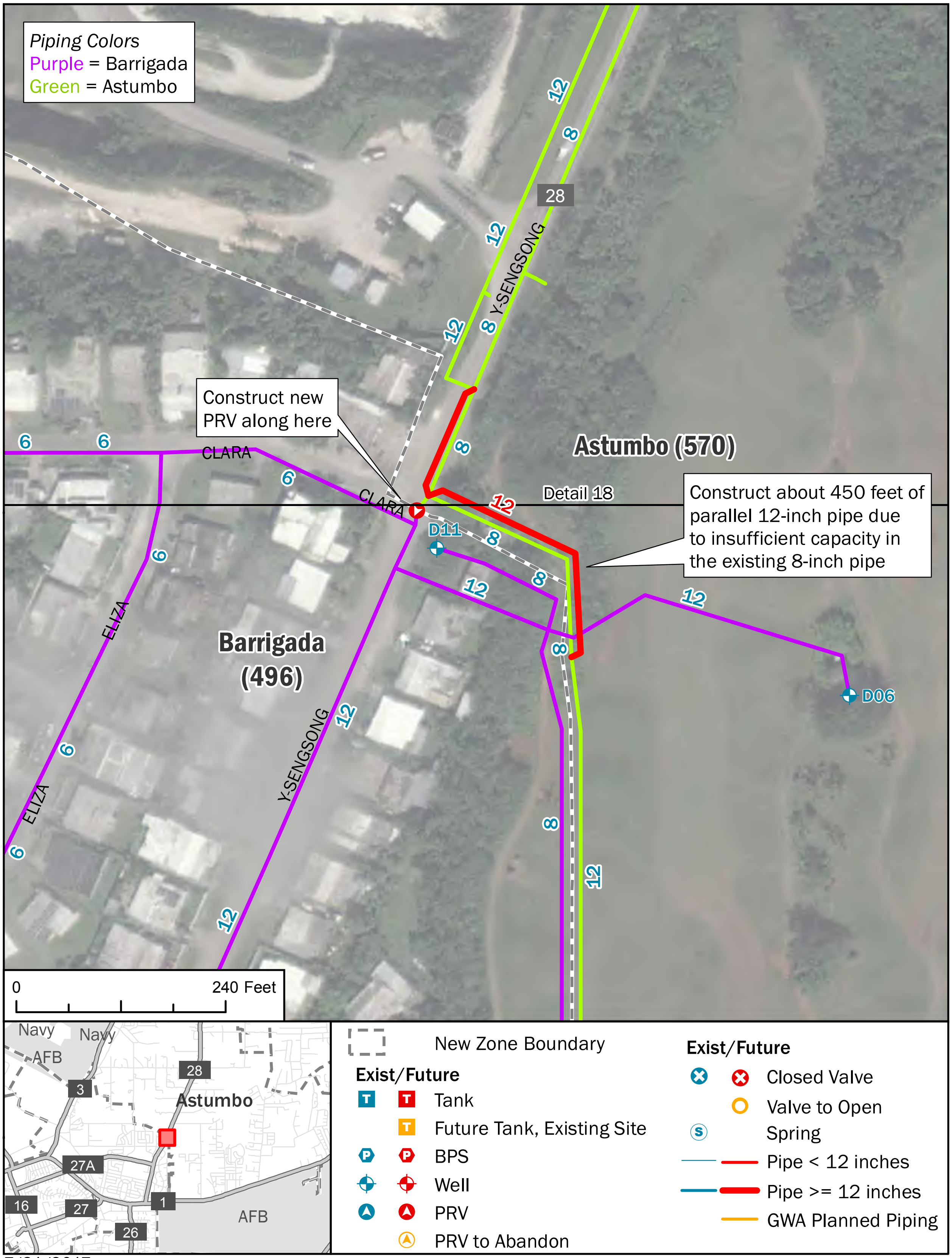


7/31/2017

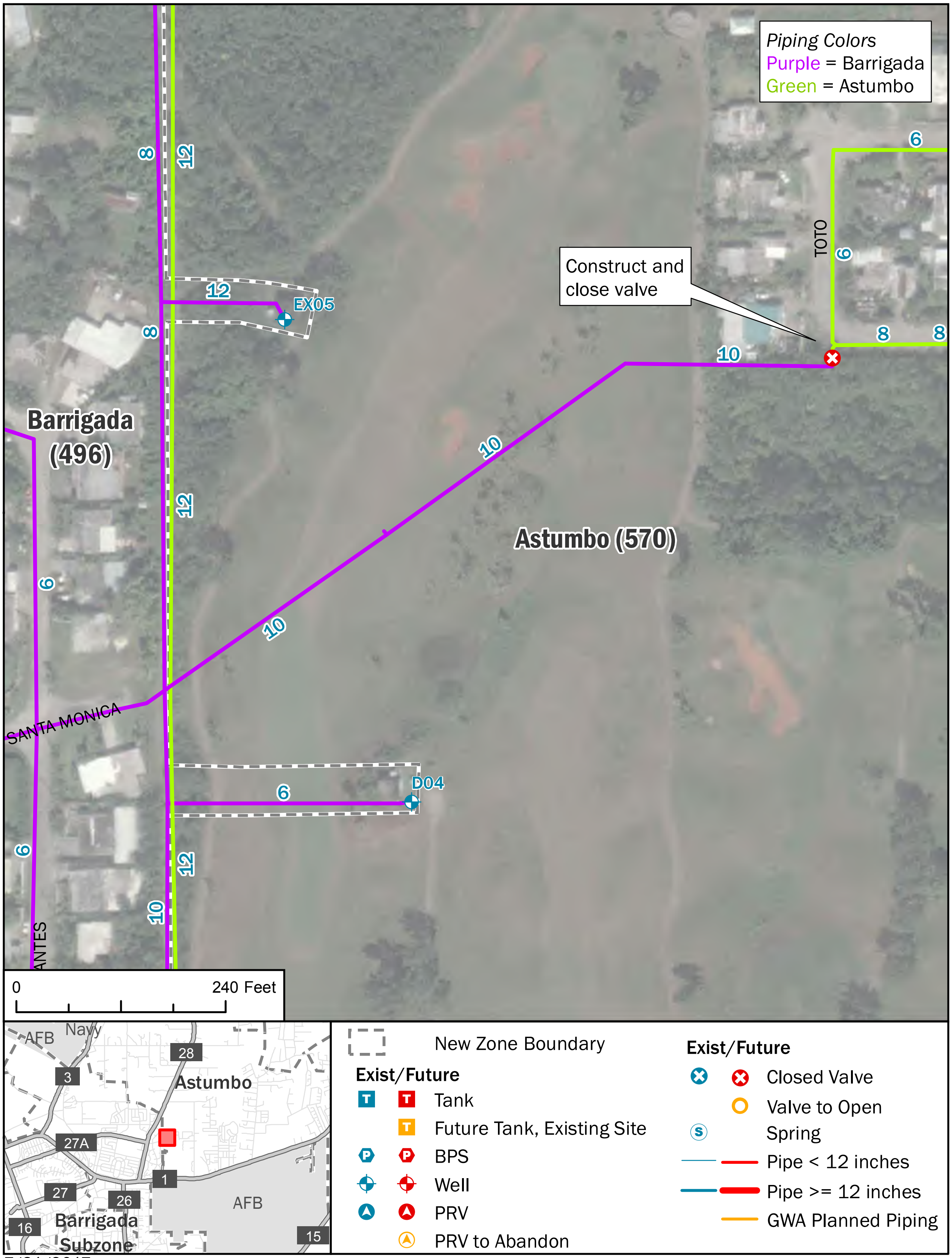
Detail 18

Brown AND Caldwell



7/31/2017

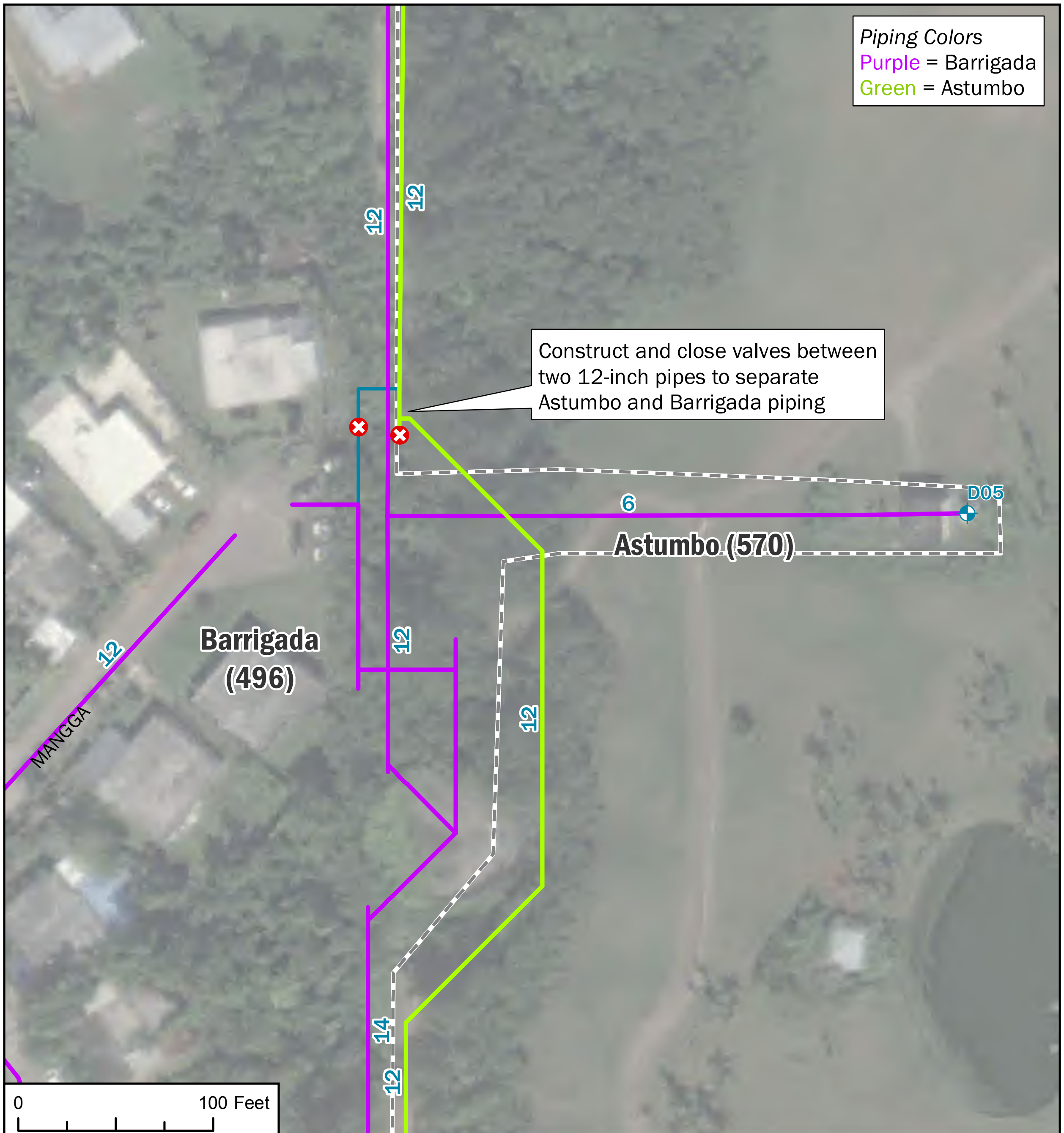
Detail 19

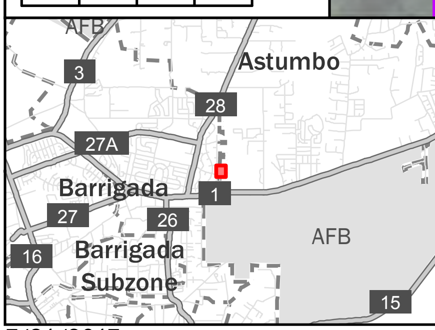


7/31/2017

Detail 20

Brown AND Caldwell





New Zone Boundary

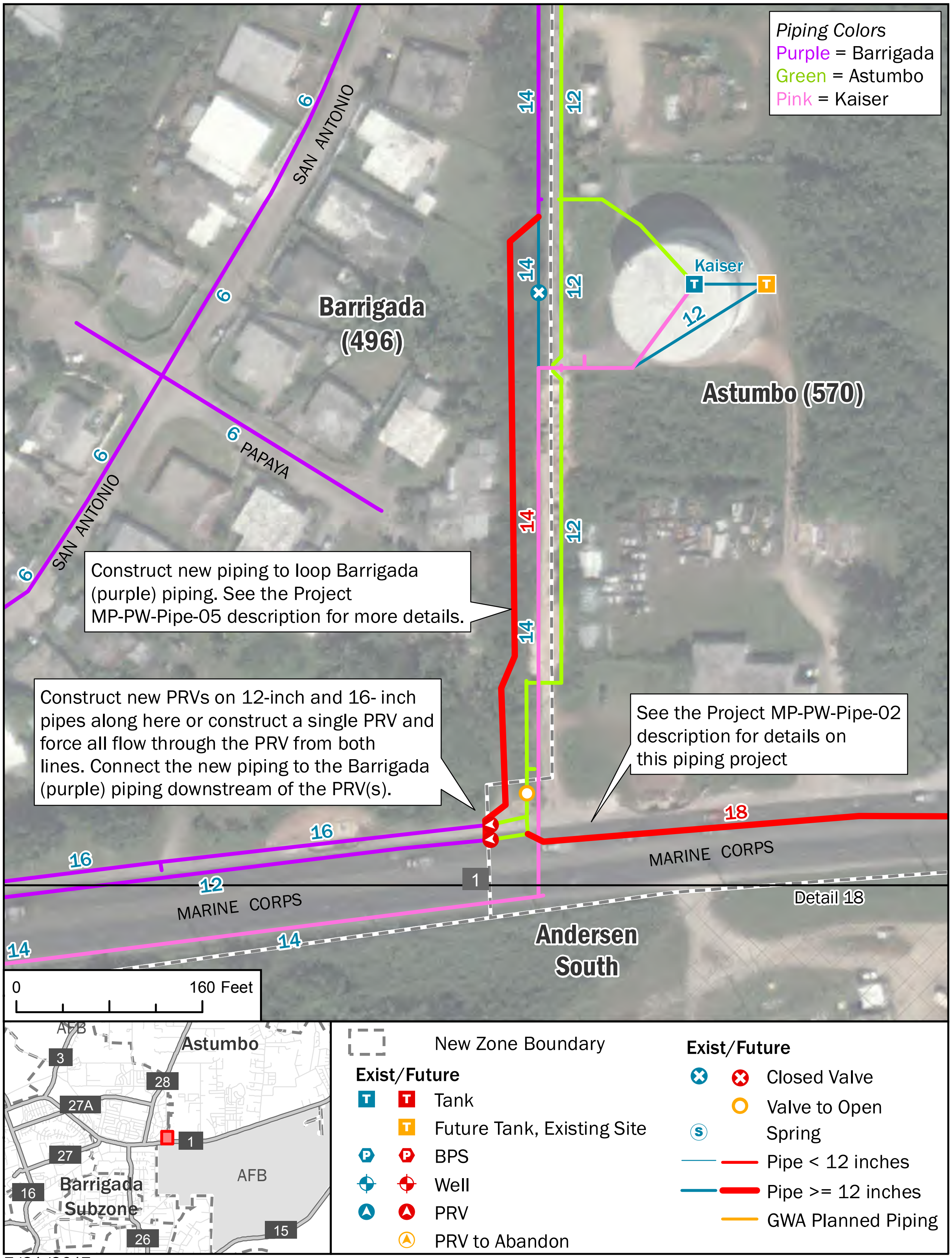
Exist/Future
- Tank
- Future Tank, Existing Site
- BPS
- Well
- PRV
- PRV to Abandon

Exist/Future
- Closed Valve
- Valve to Open
- Spring
- Pipe < 12 inches
- Pipe >= 12 inches
- GWA Planned Piping

7/31/2017

Detail 21

Brown AND Caldwell

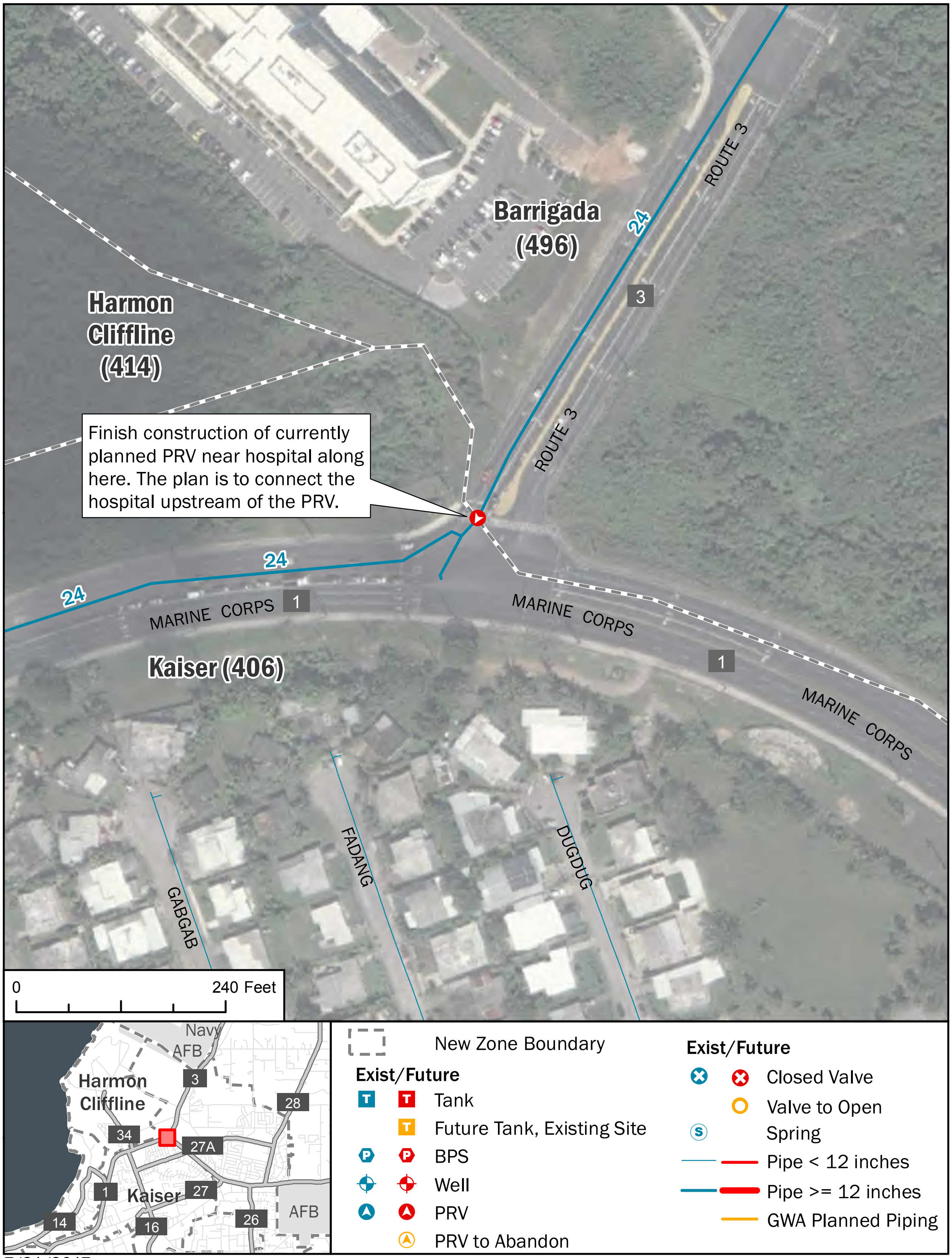


7/31/2017

Detail 22

7/31/2017

Detail 23



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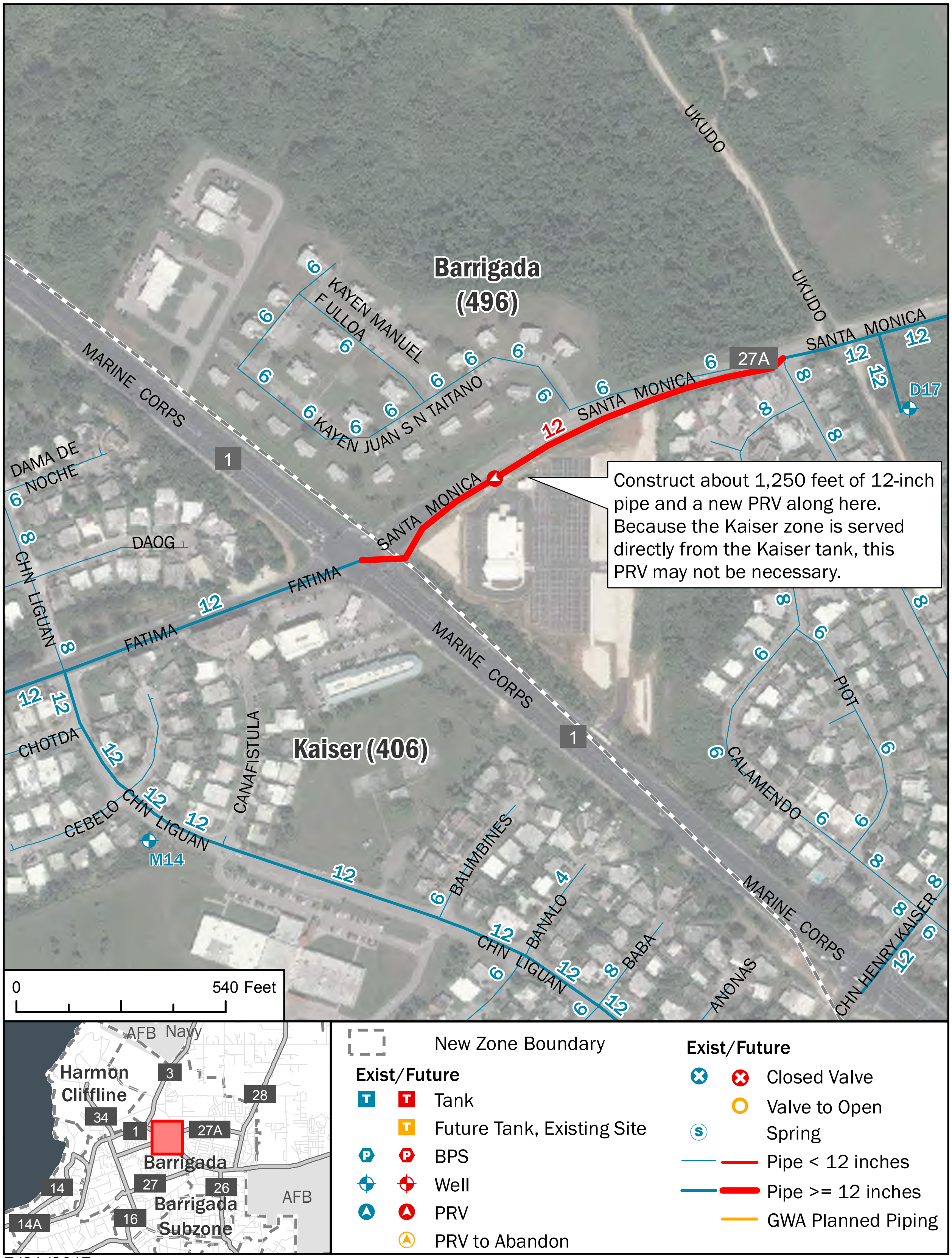
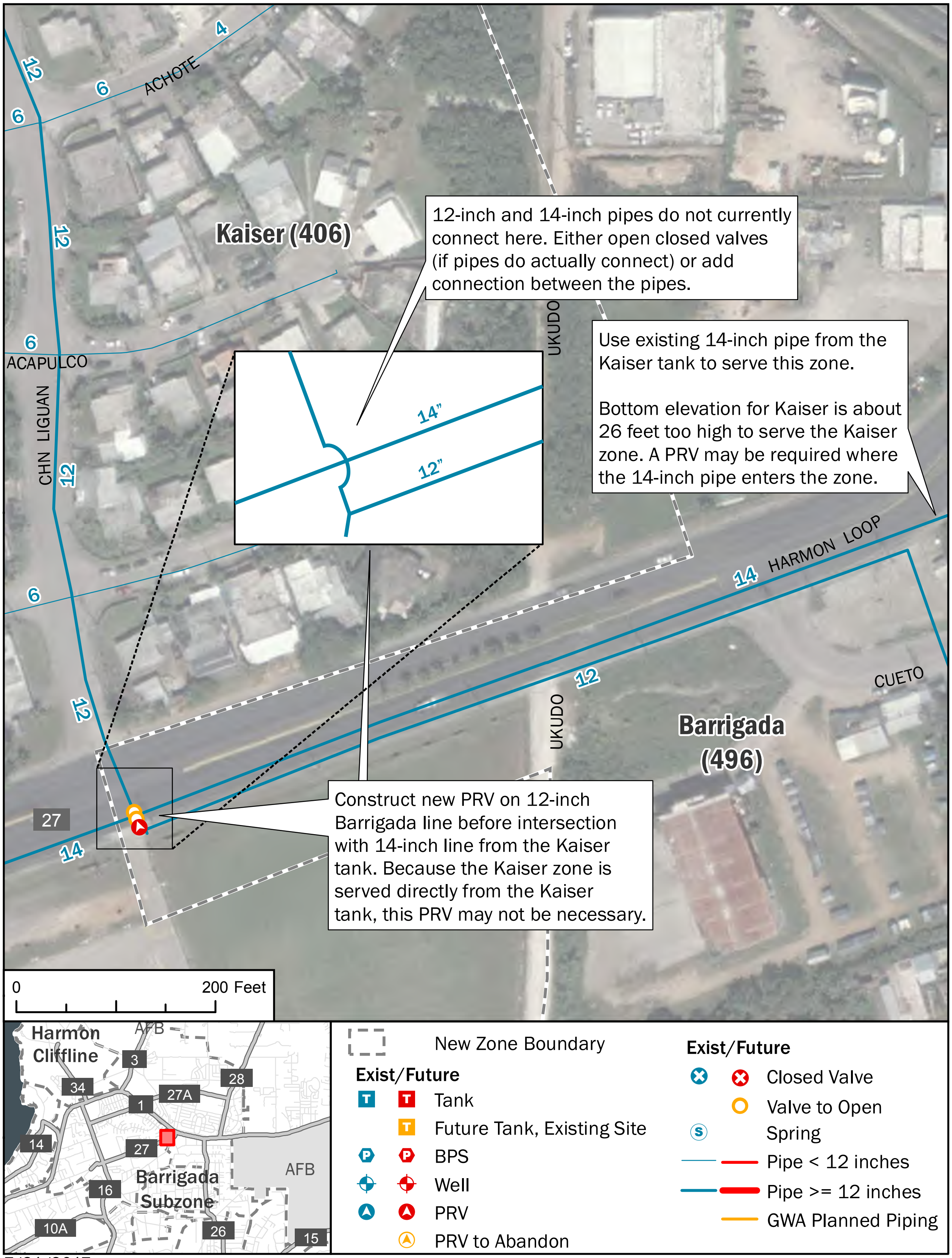


7/31/2017

Detail 25

Brown AND Caldwell



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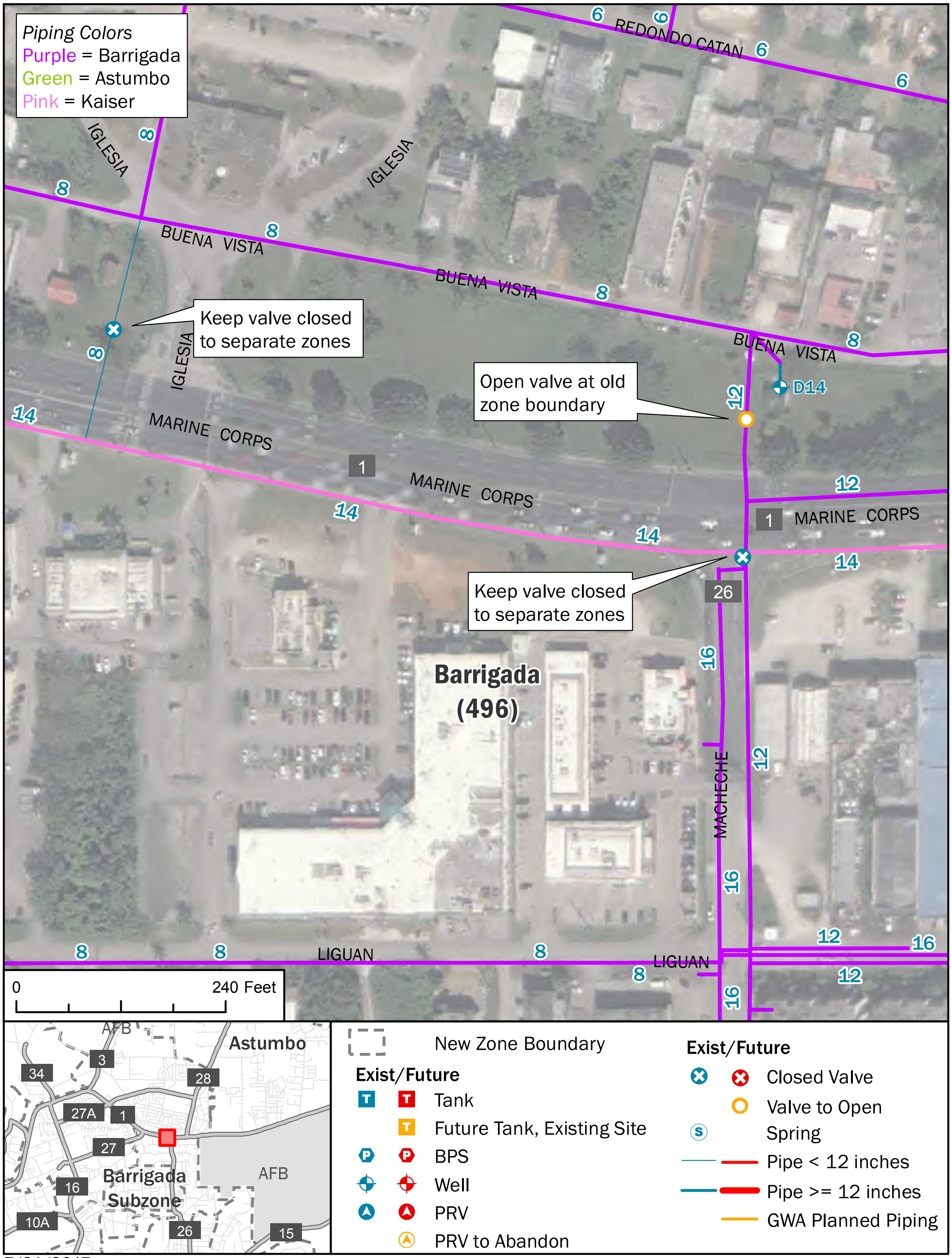
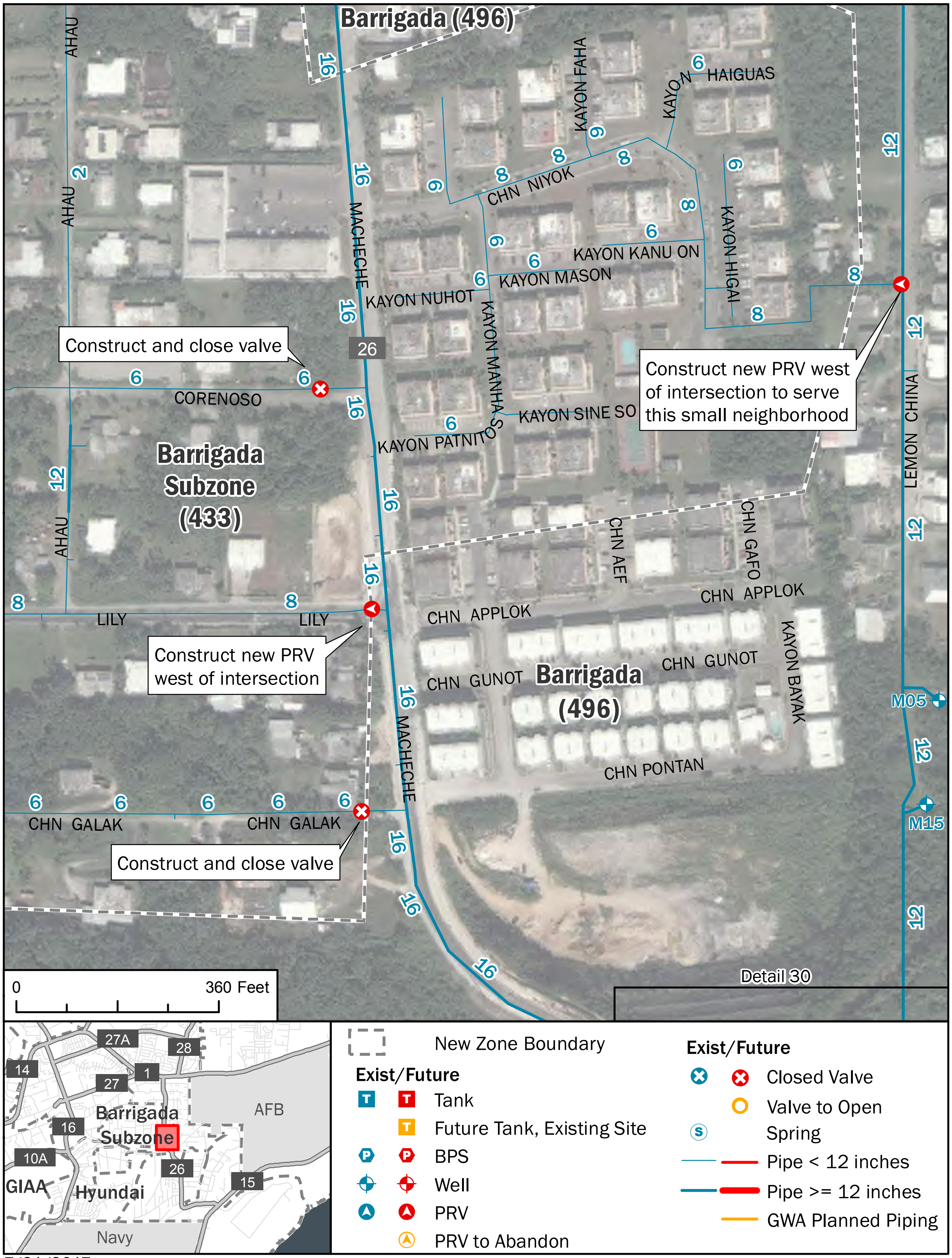


7/31/2017

Detail 27

7/31/2017

Detail 28



7/31/2017

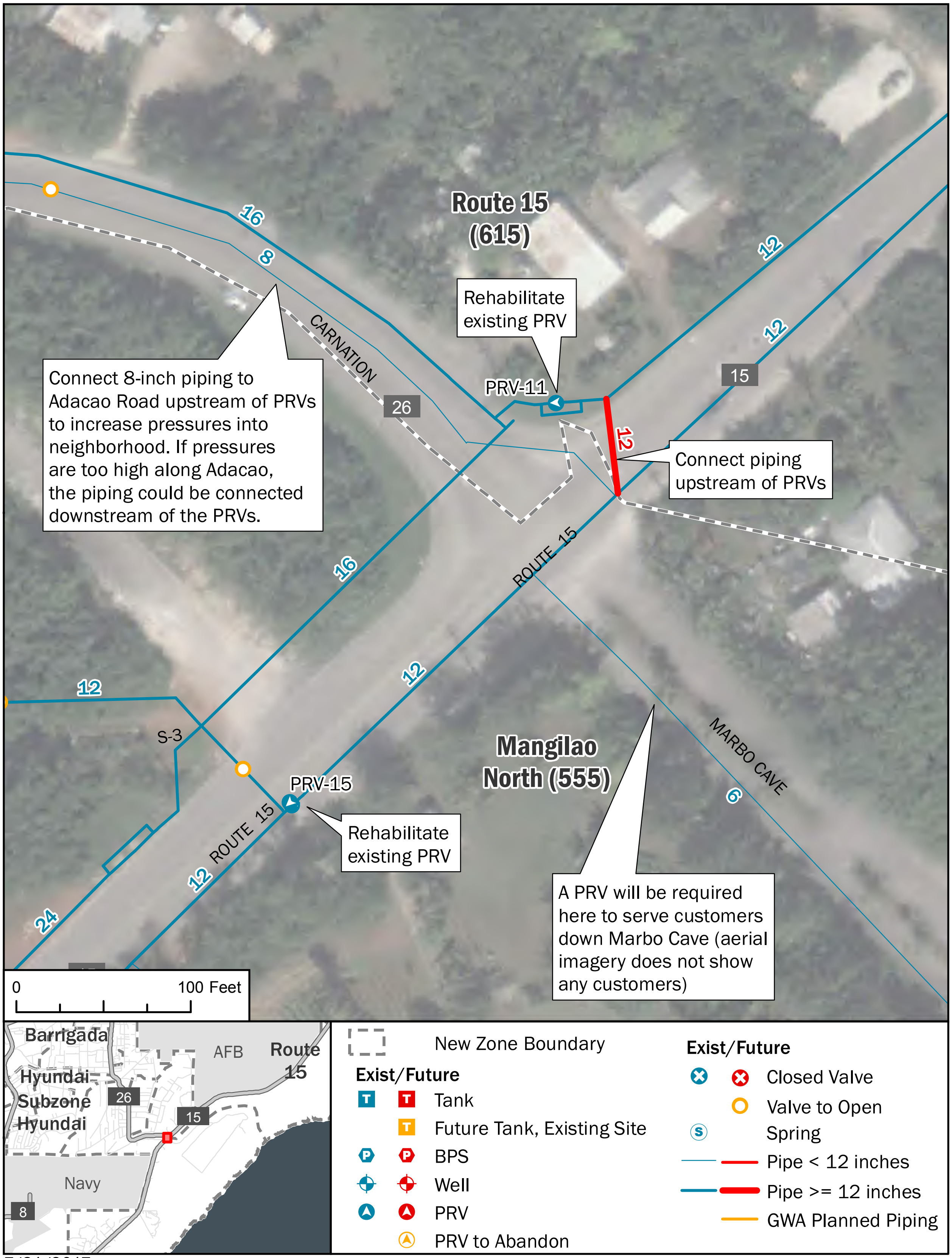
Detail 29

7/31/2017

Detail 30

7/31/2017

Detail 31



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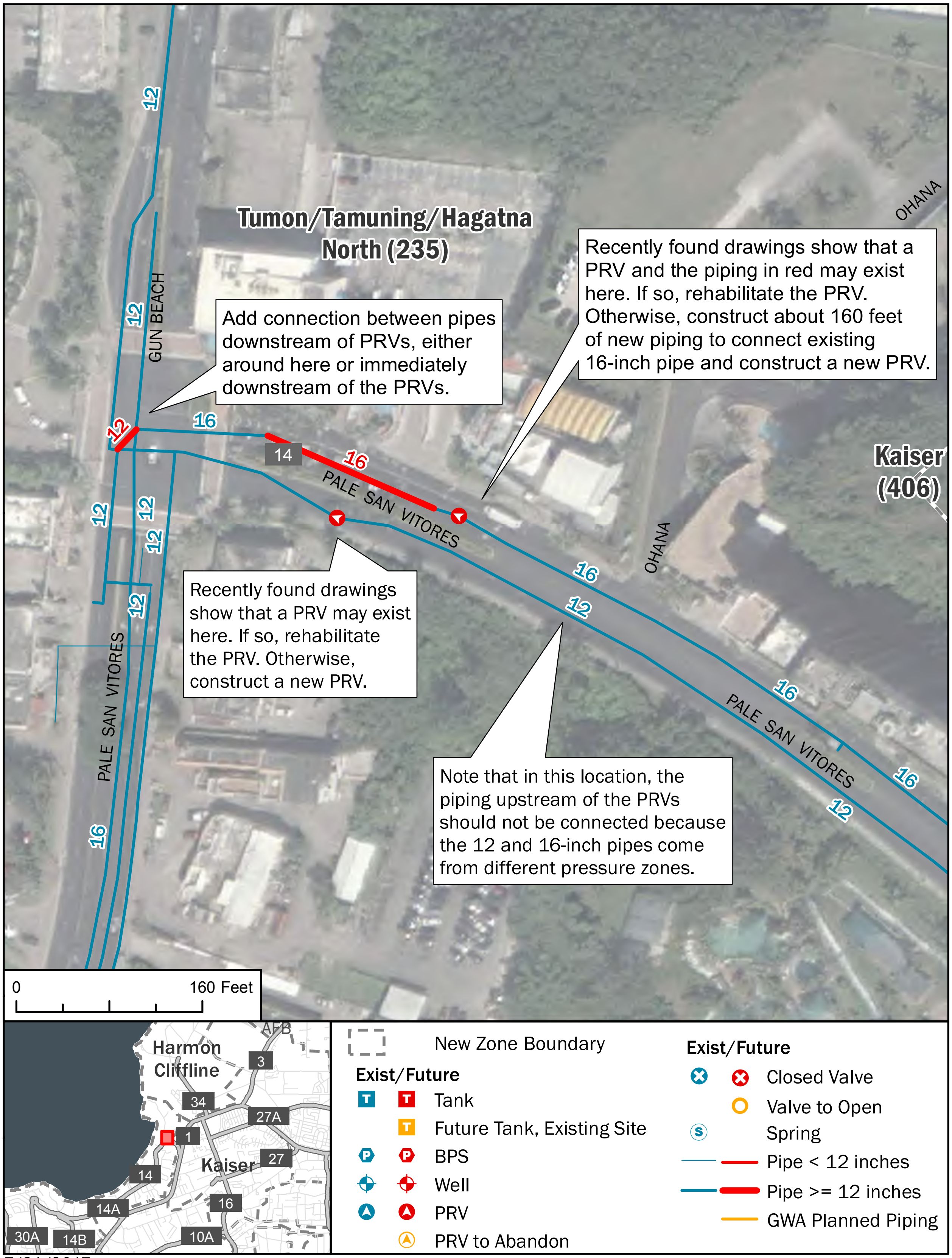

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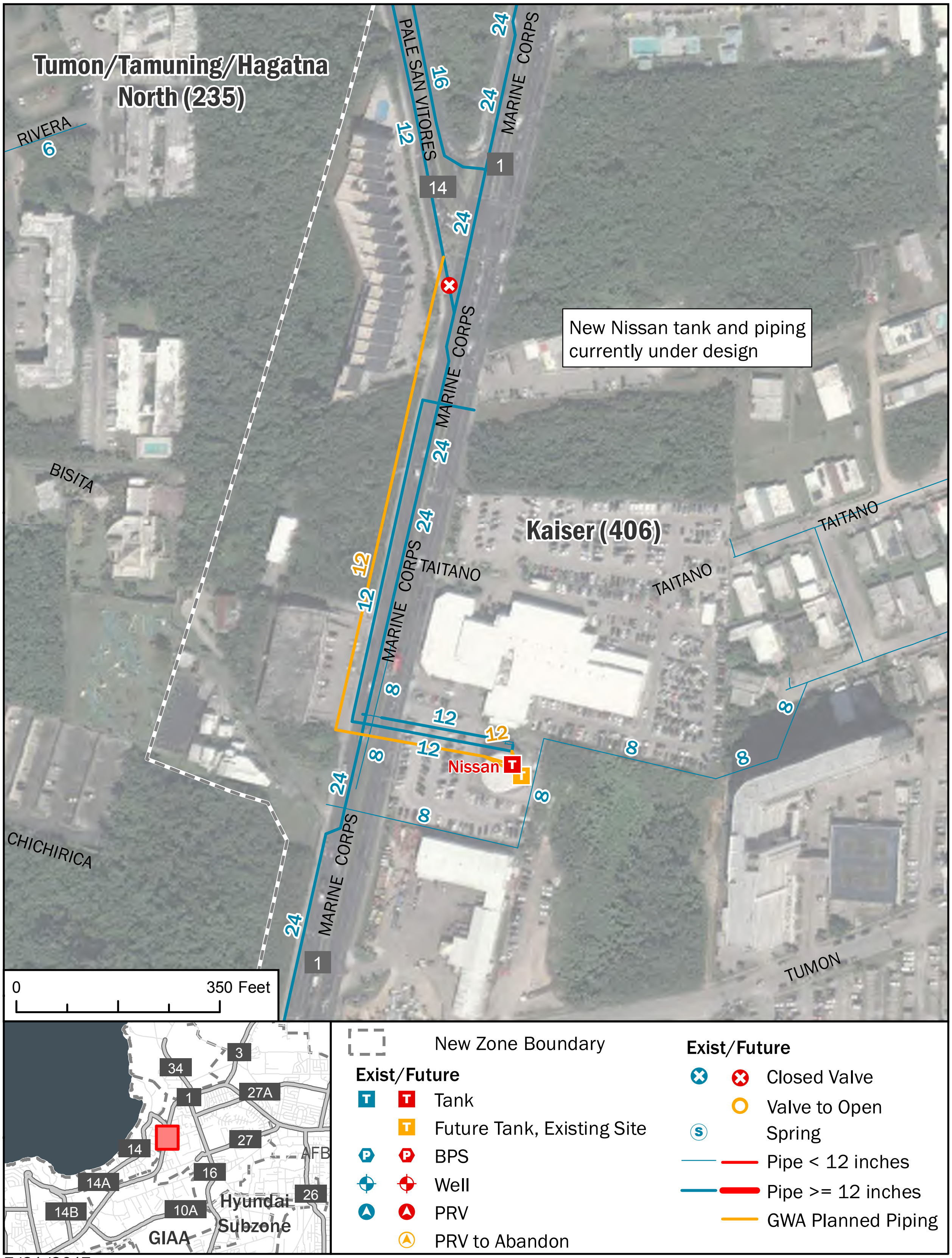

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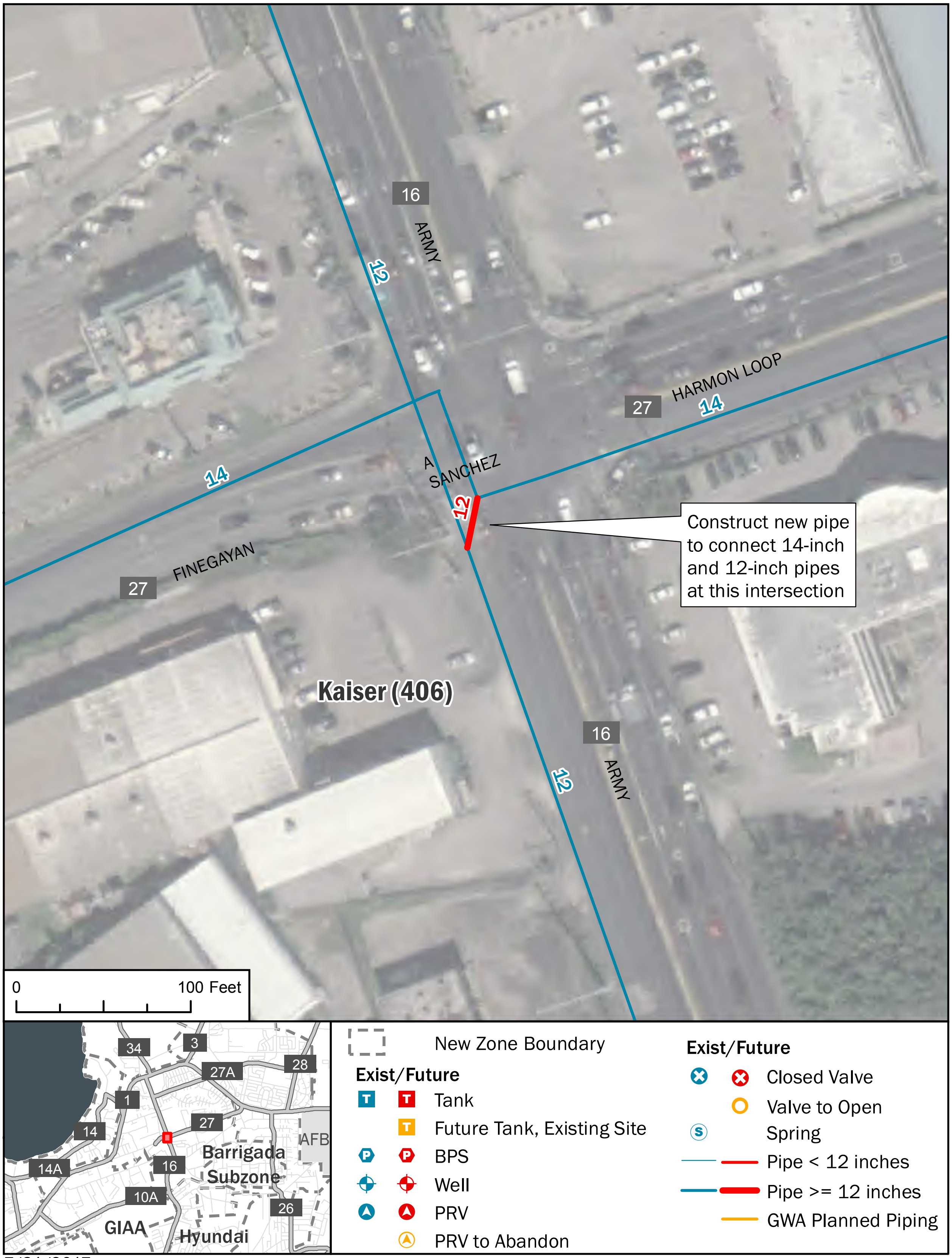

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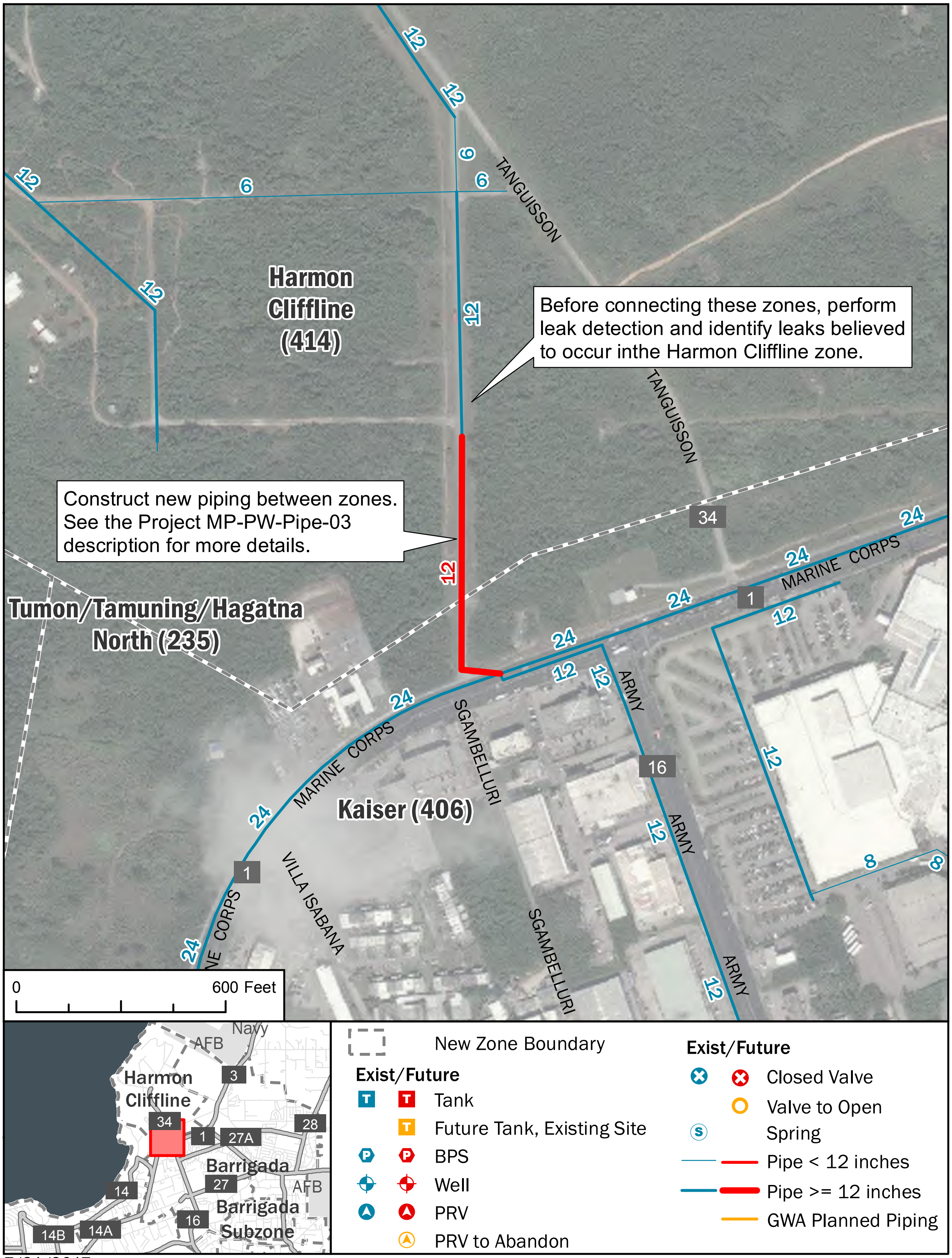
Detail 35

Brown AND Caldwell



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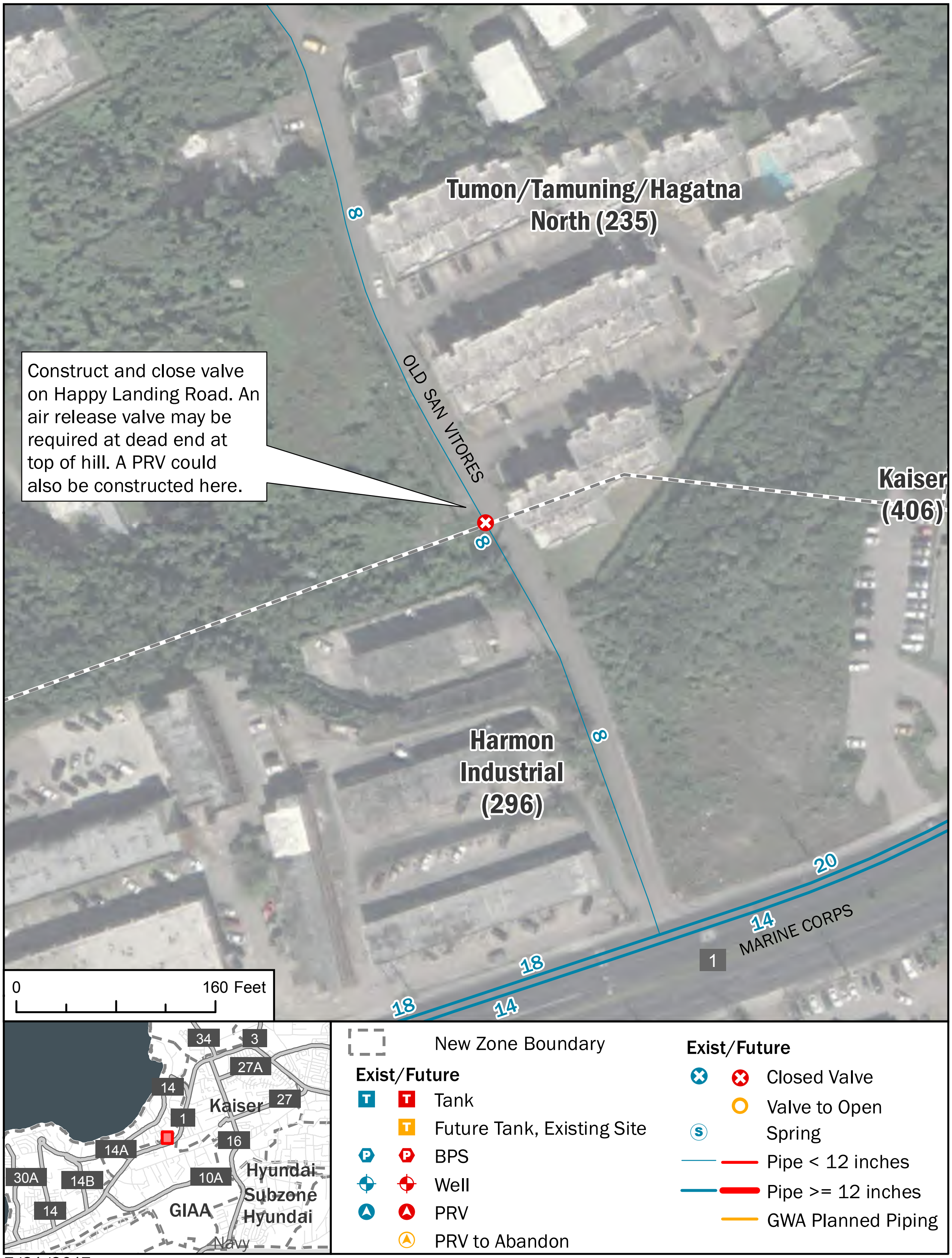

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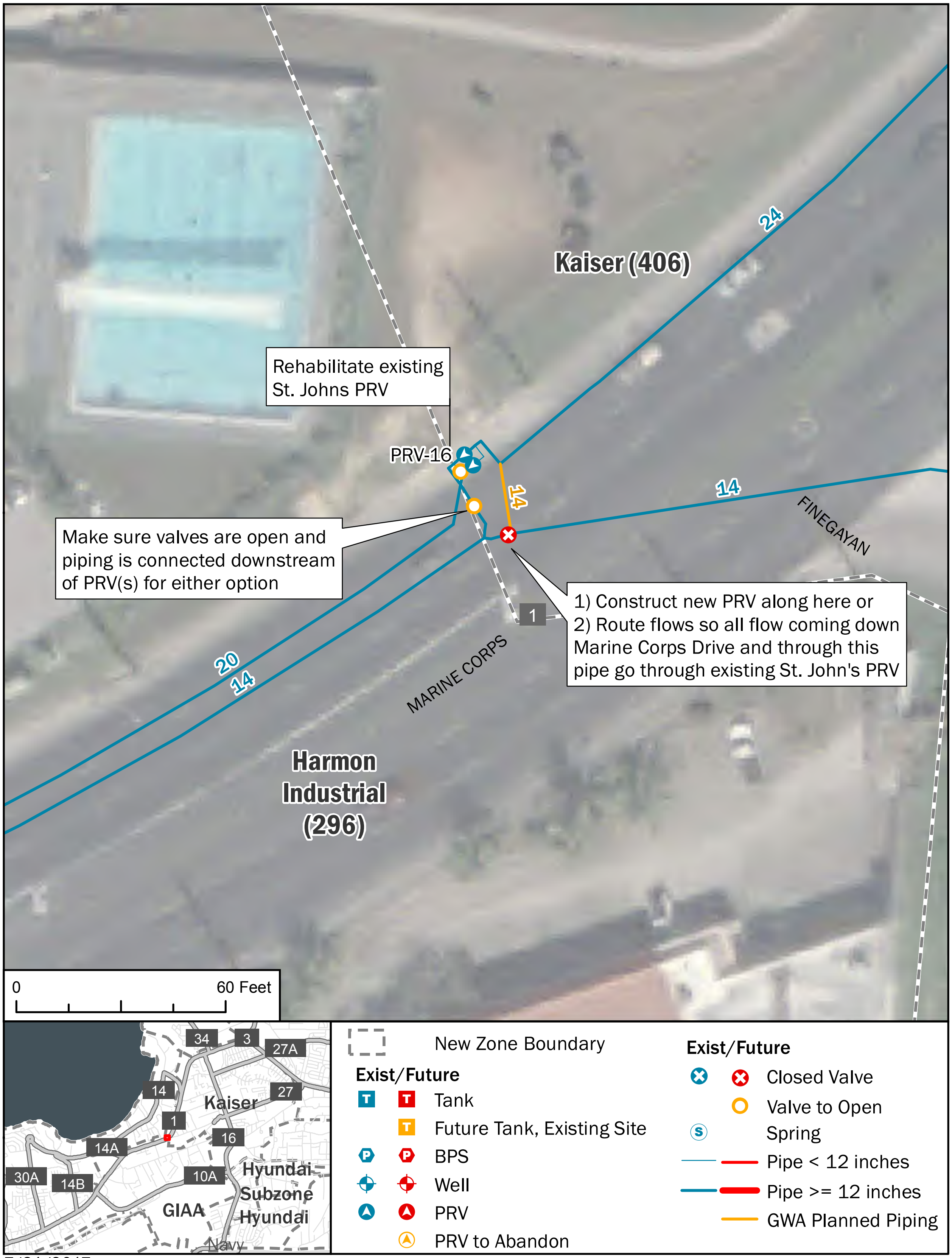


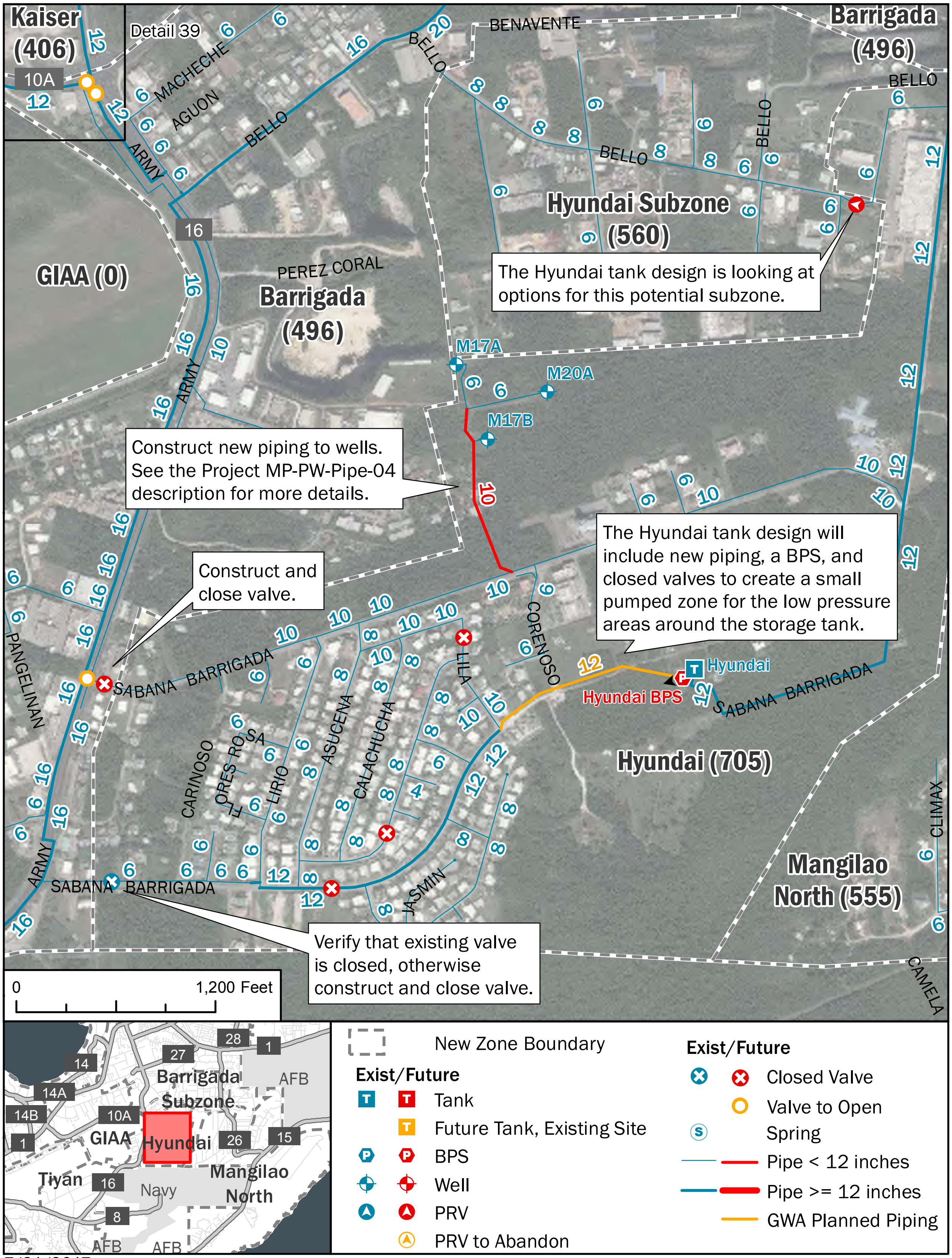
7/31/2017

Detail 38

7/31/2017

Detail 39

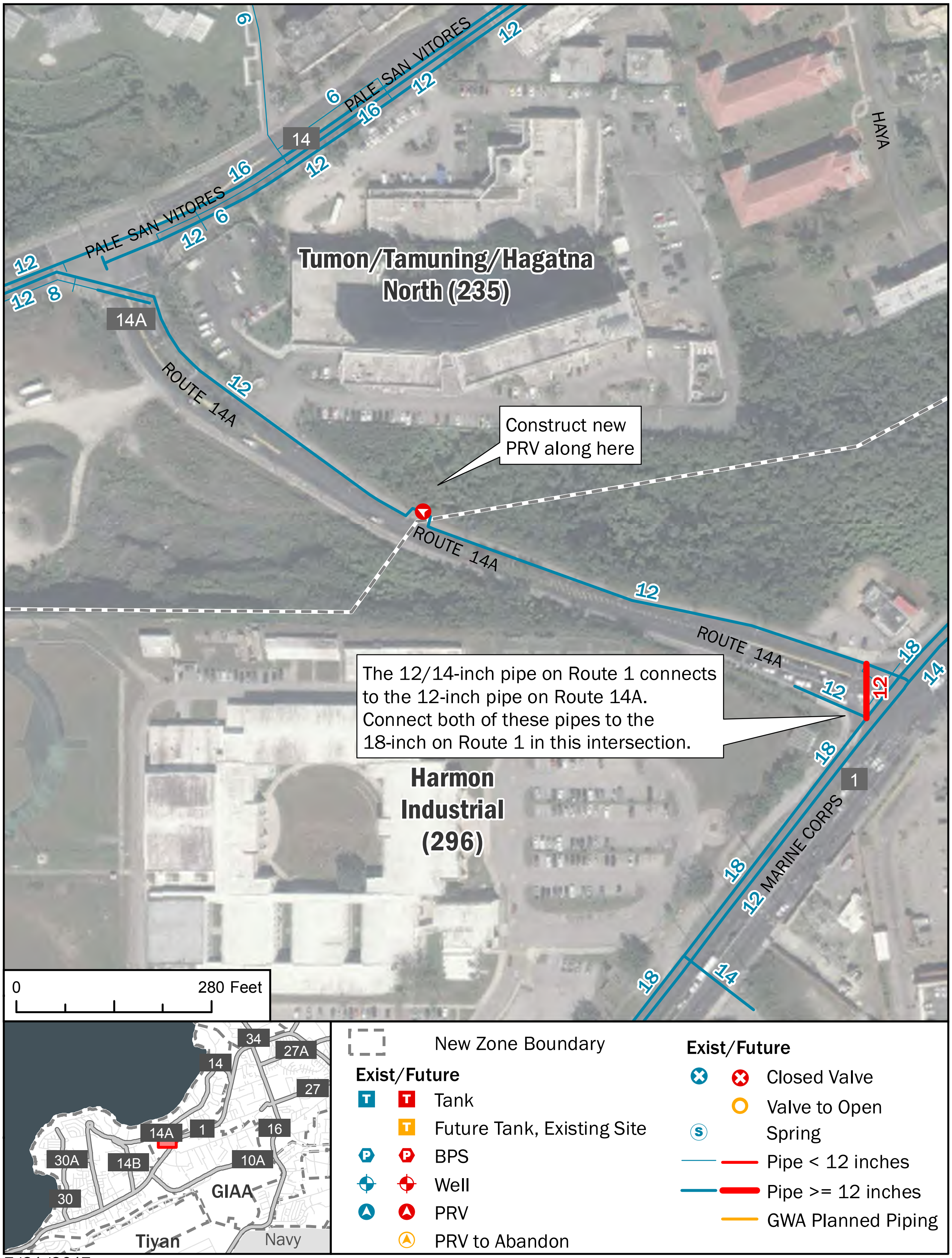
Brown AND Caldwell



7/31/2017

Detail 40

Brown AND Caldwell



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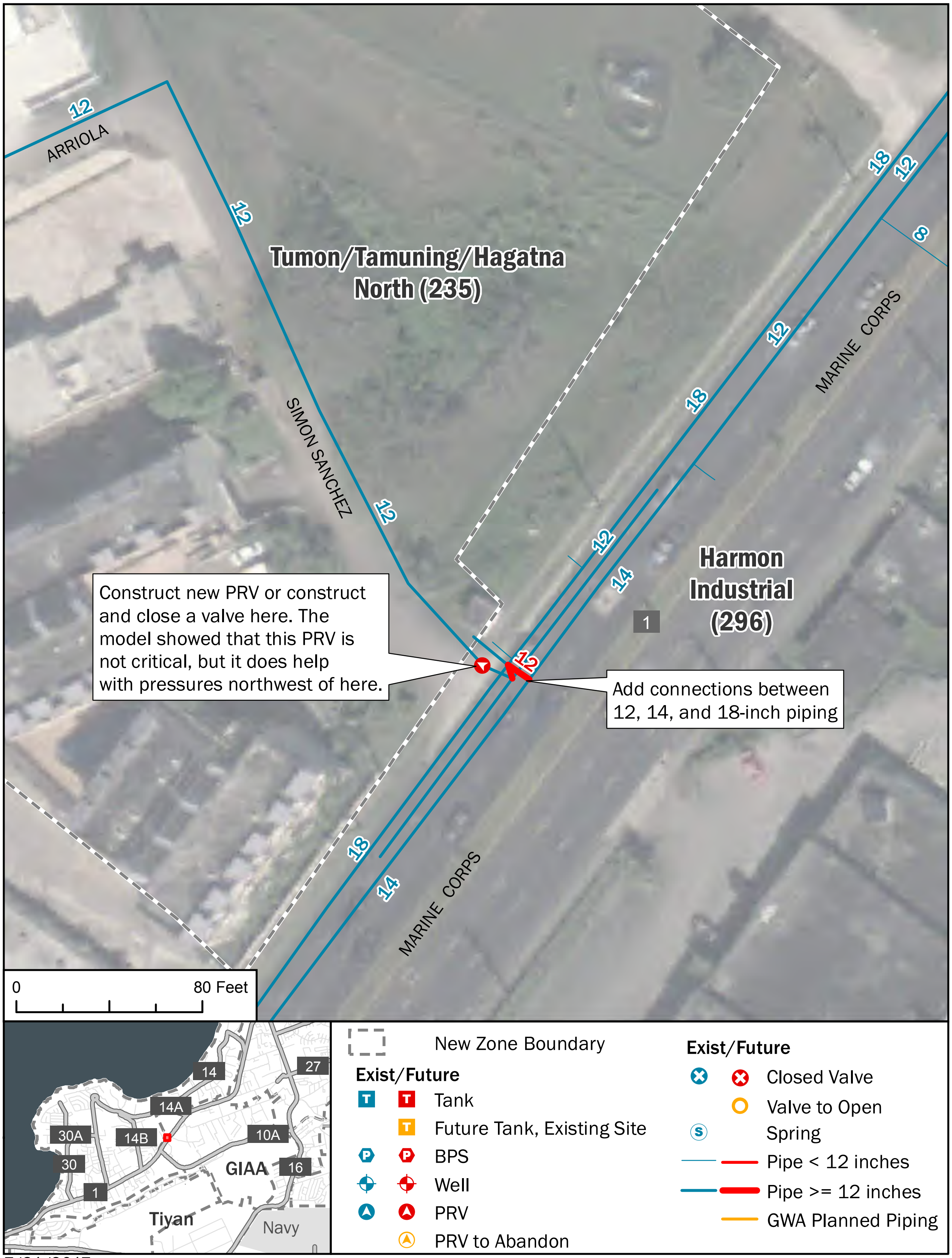
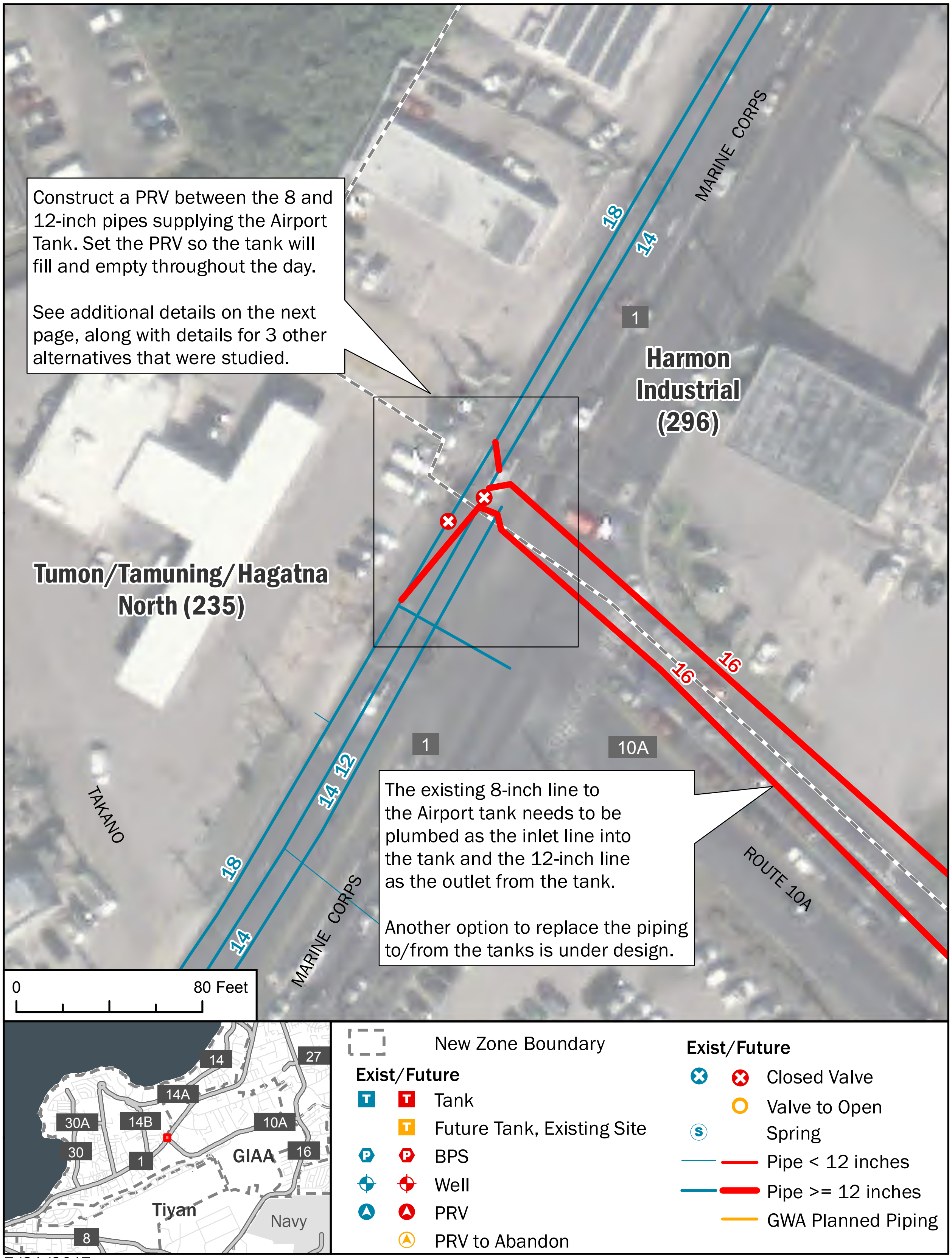


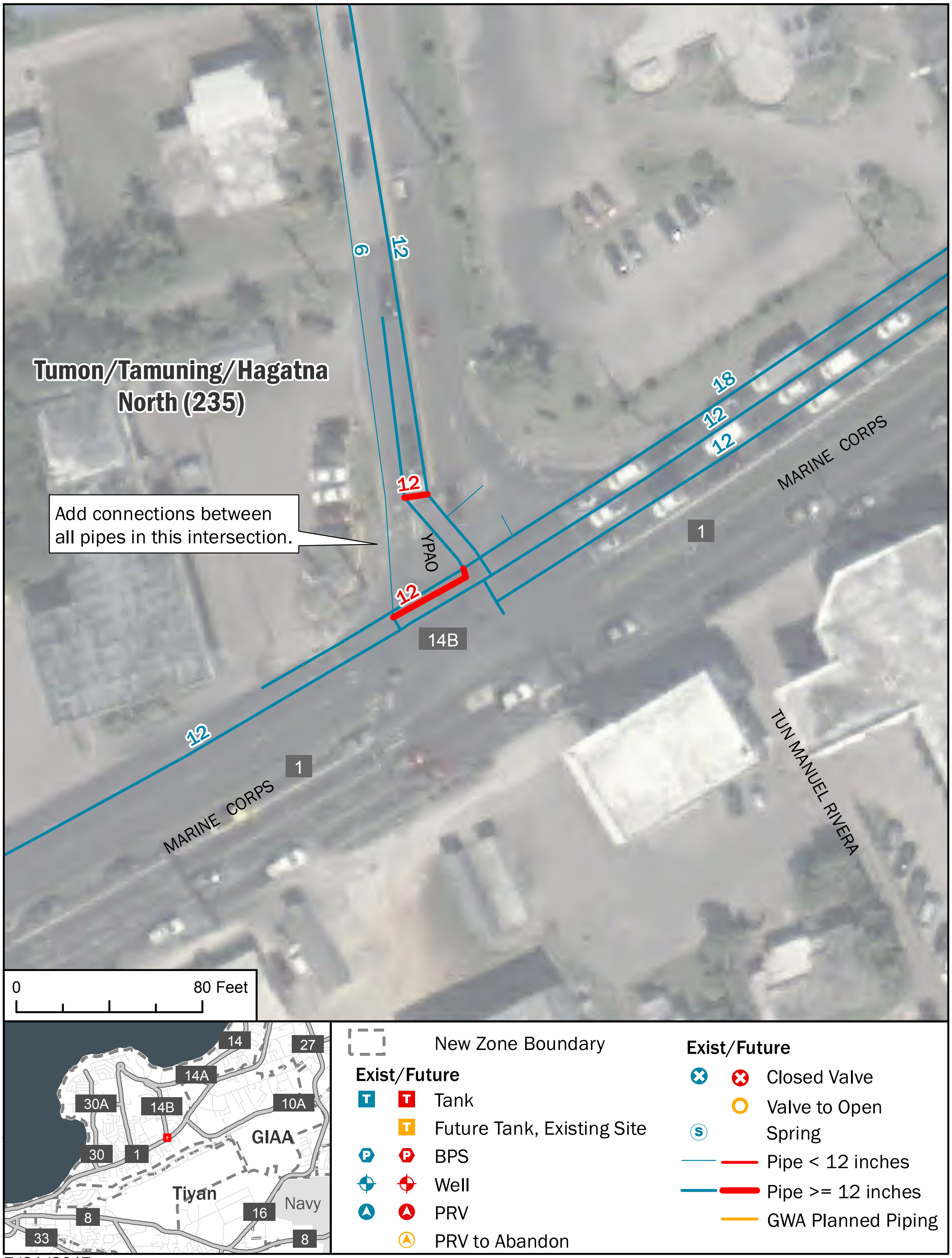
7/31/2017

Detail 42



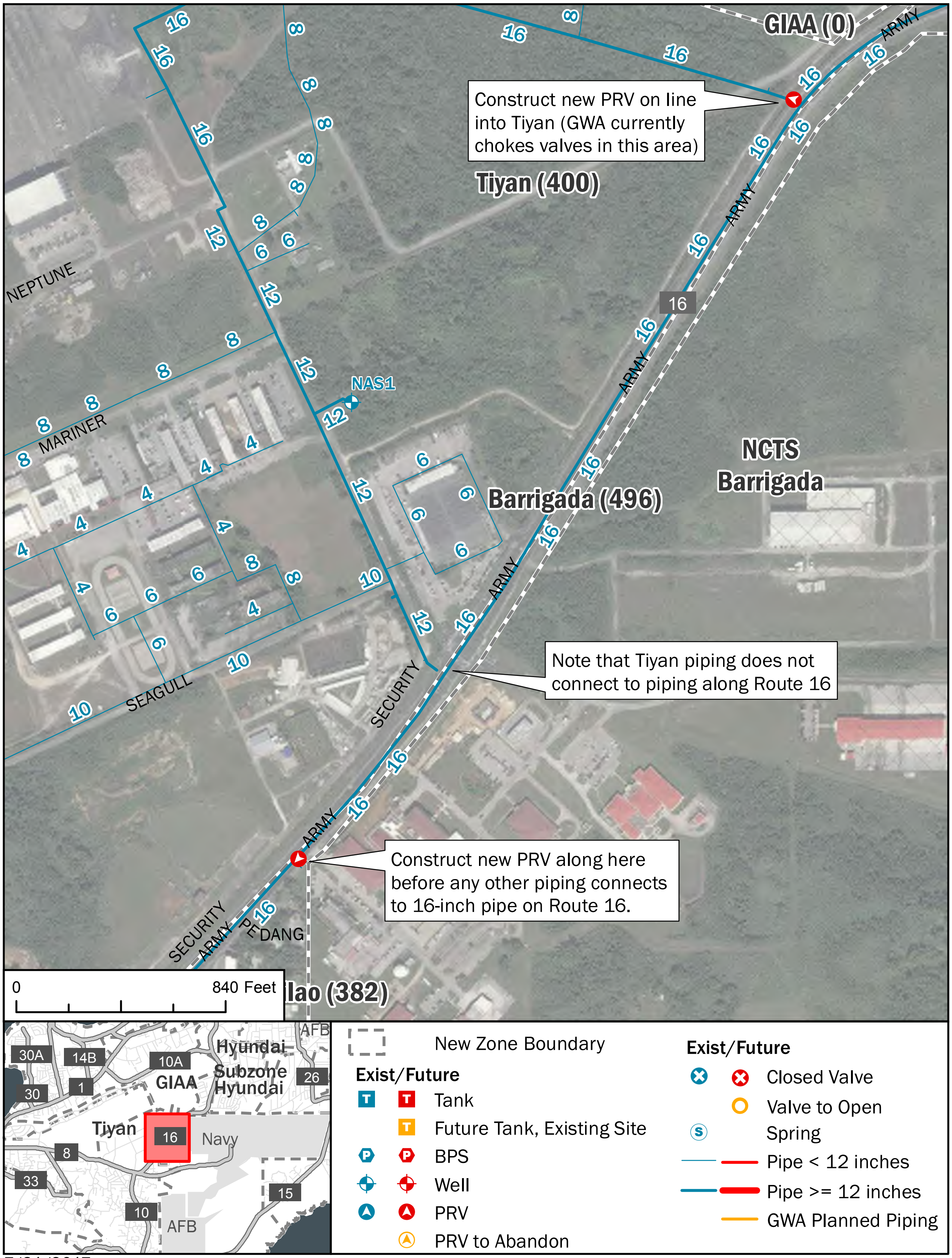
7/31/2017

Detail 43



7/31/2017

Detail 44



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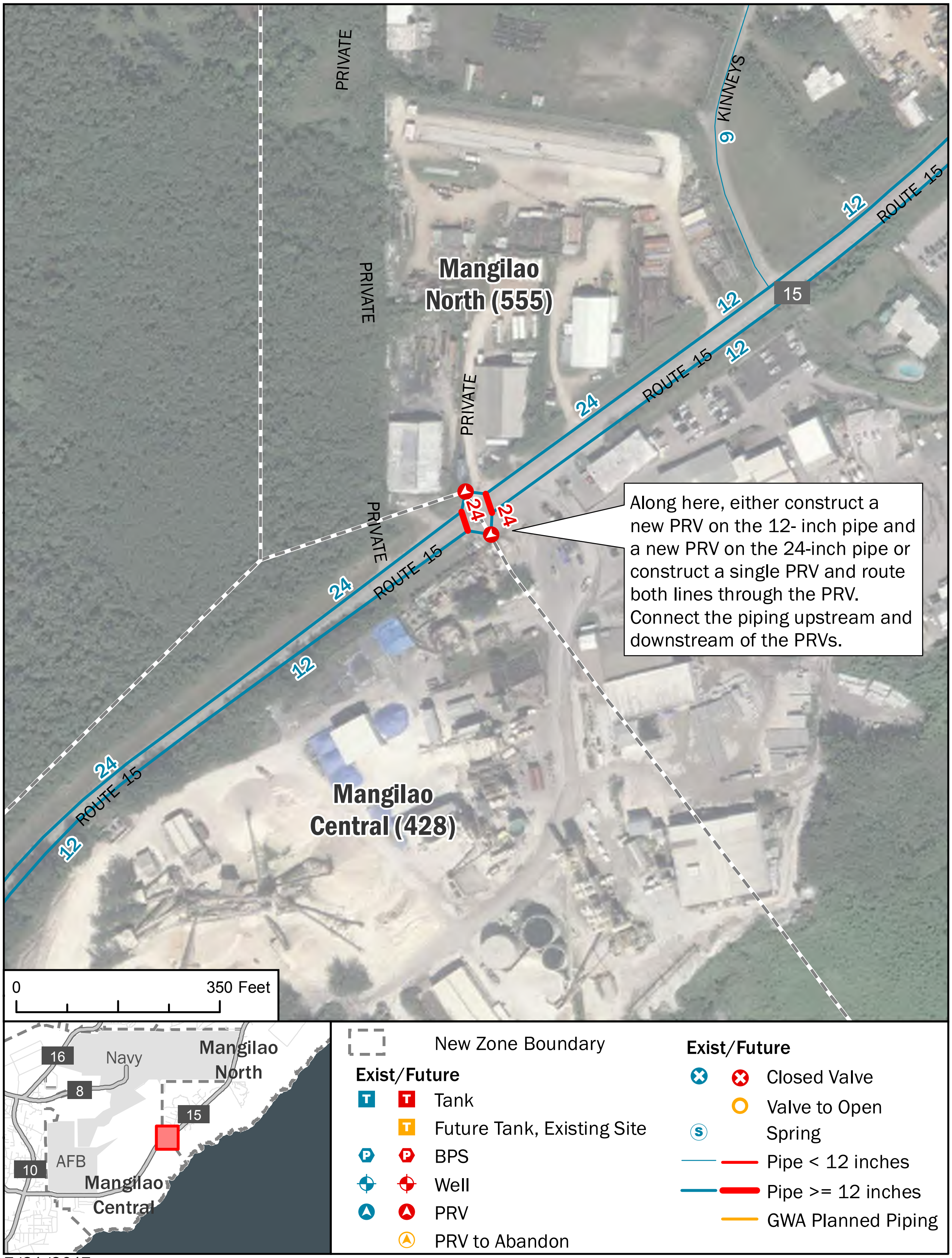
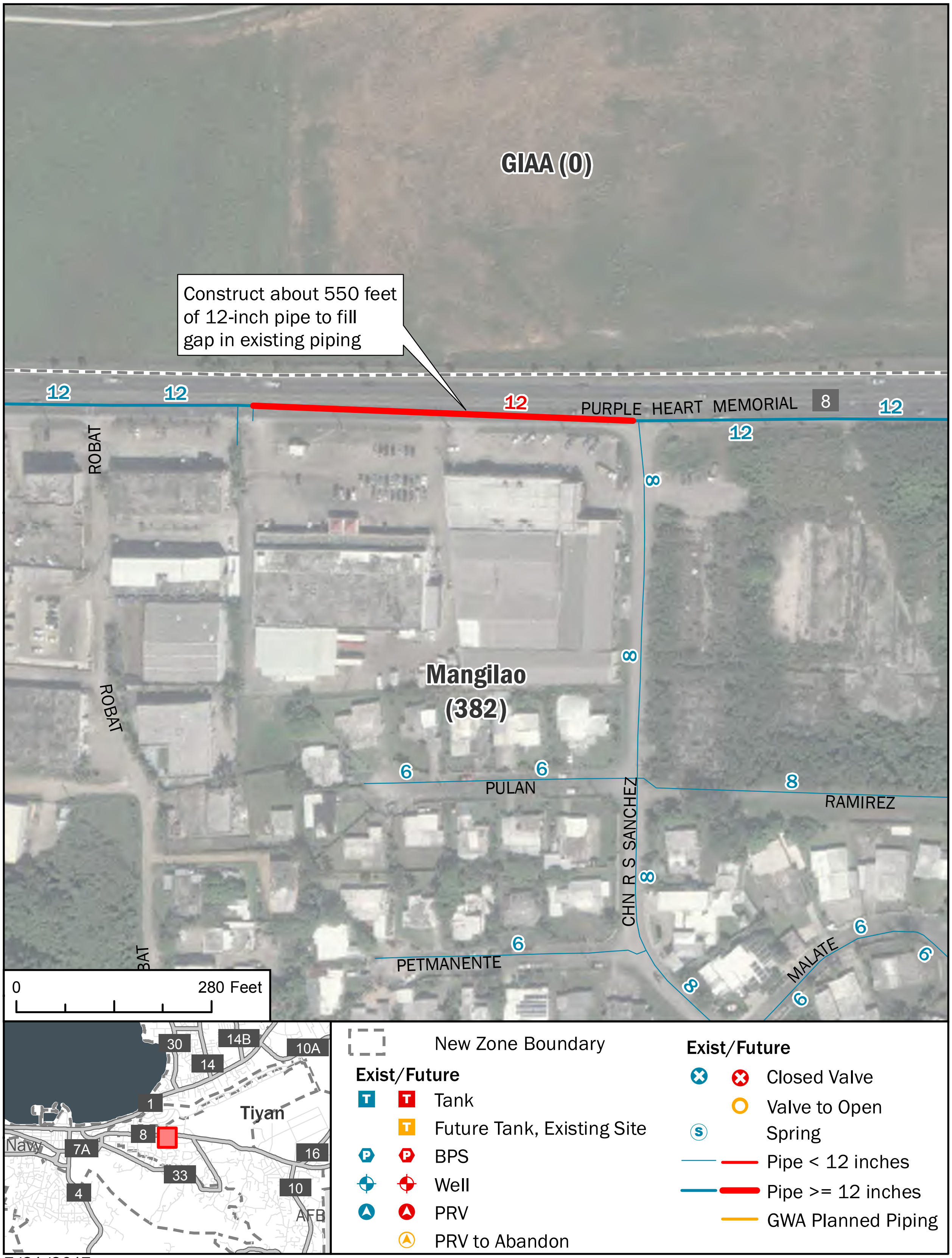
Detail 45



7/31/2017

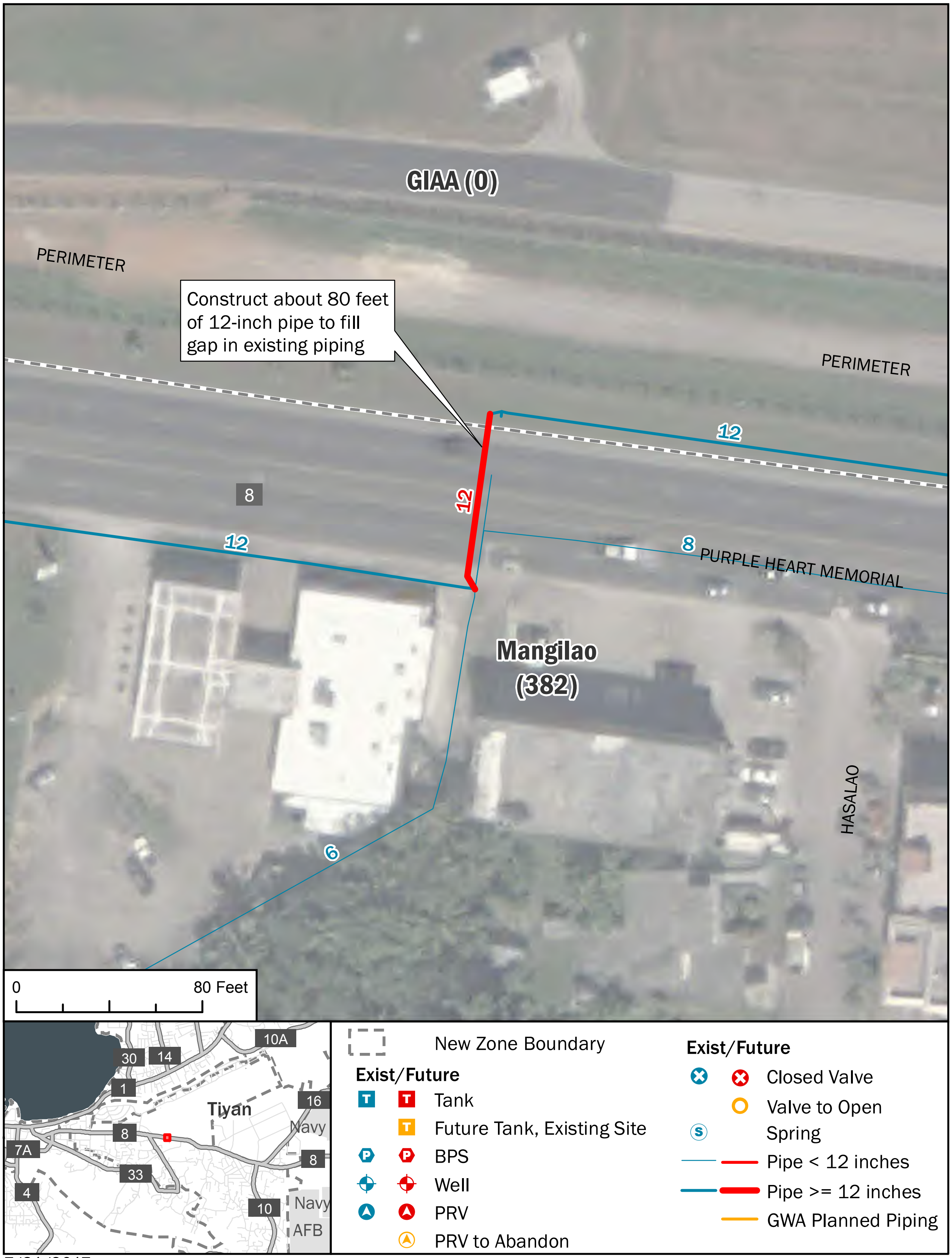
Detail 46

Brown AND Caldwell



7/31/2017

Detail 47



7/31/2017

Detail 48

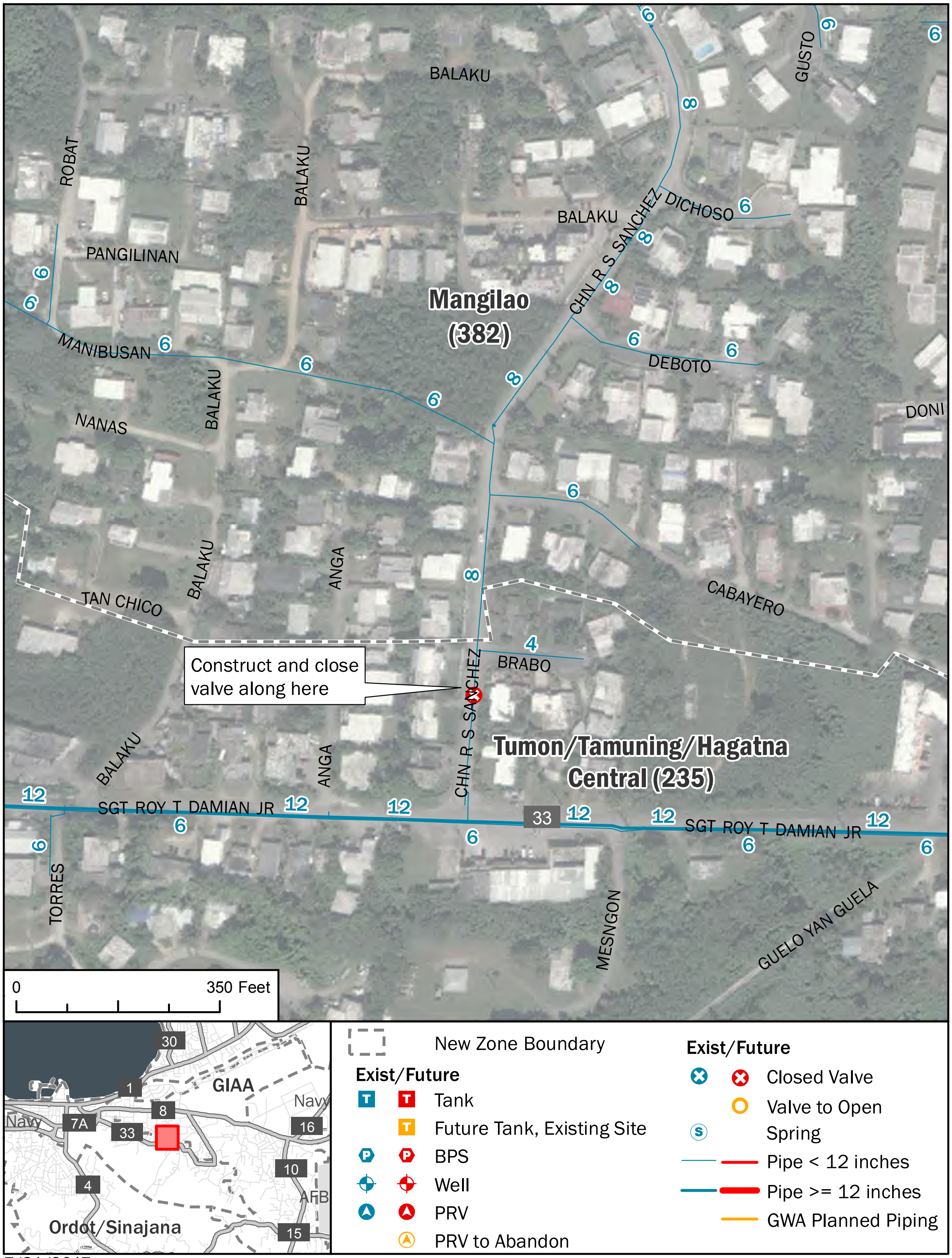
7/31/2017

Detail 49

7/31/2017

Detail 50

Brown AND Caldwell

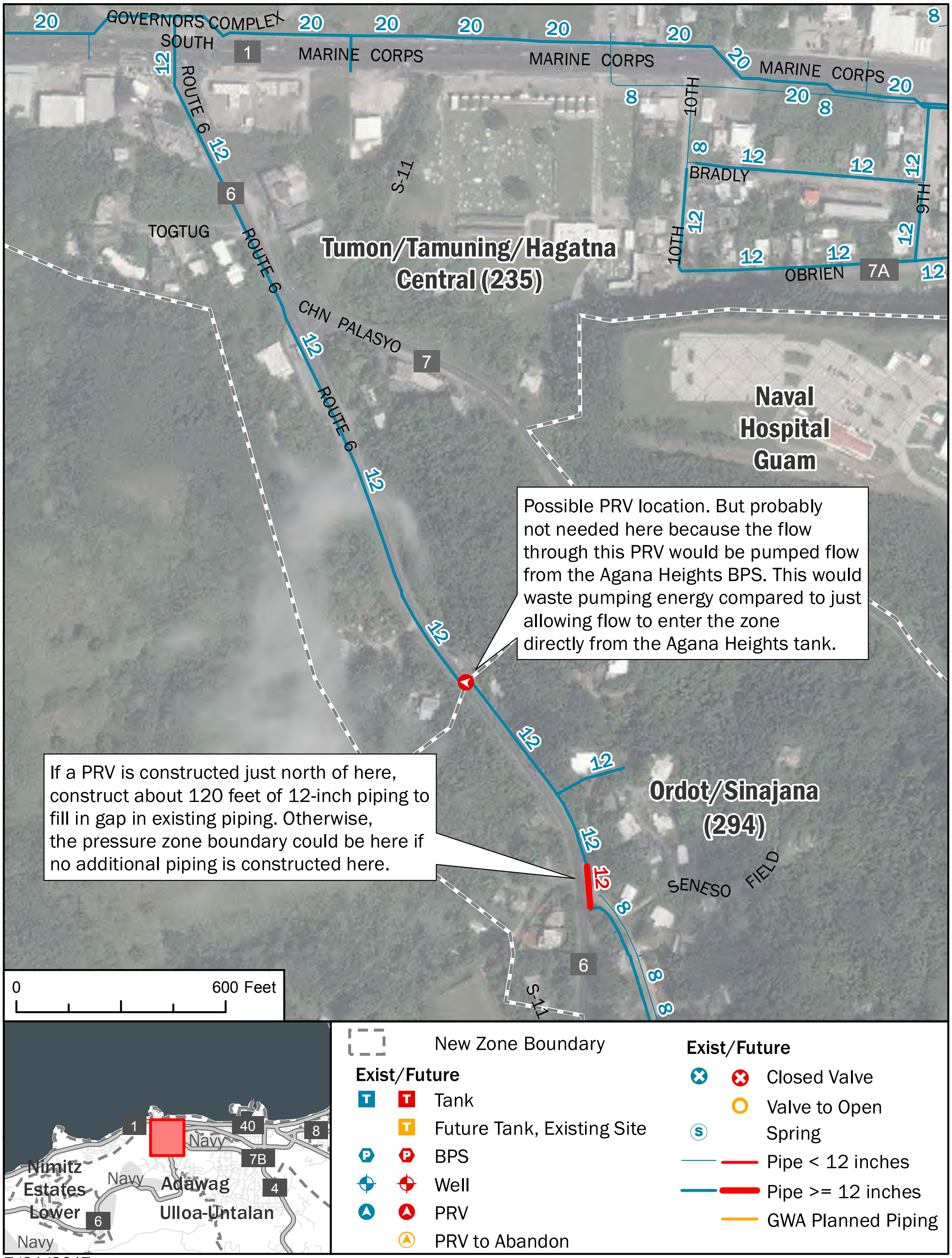


7/31/2017

Detail 51

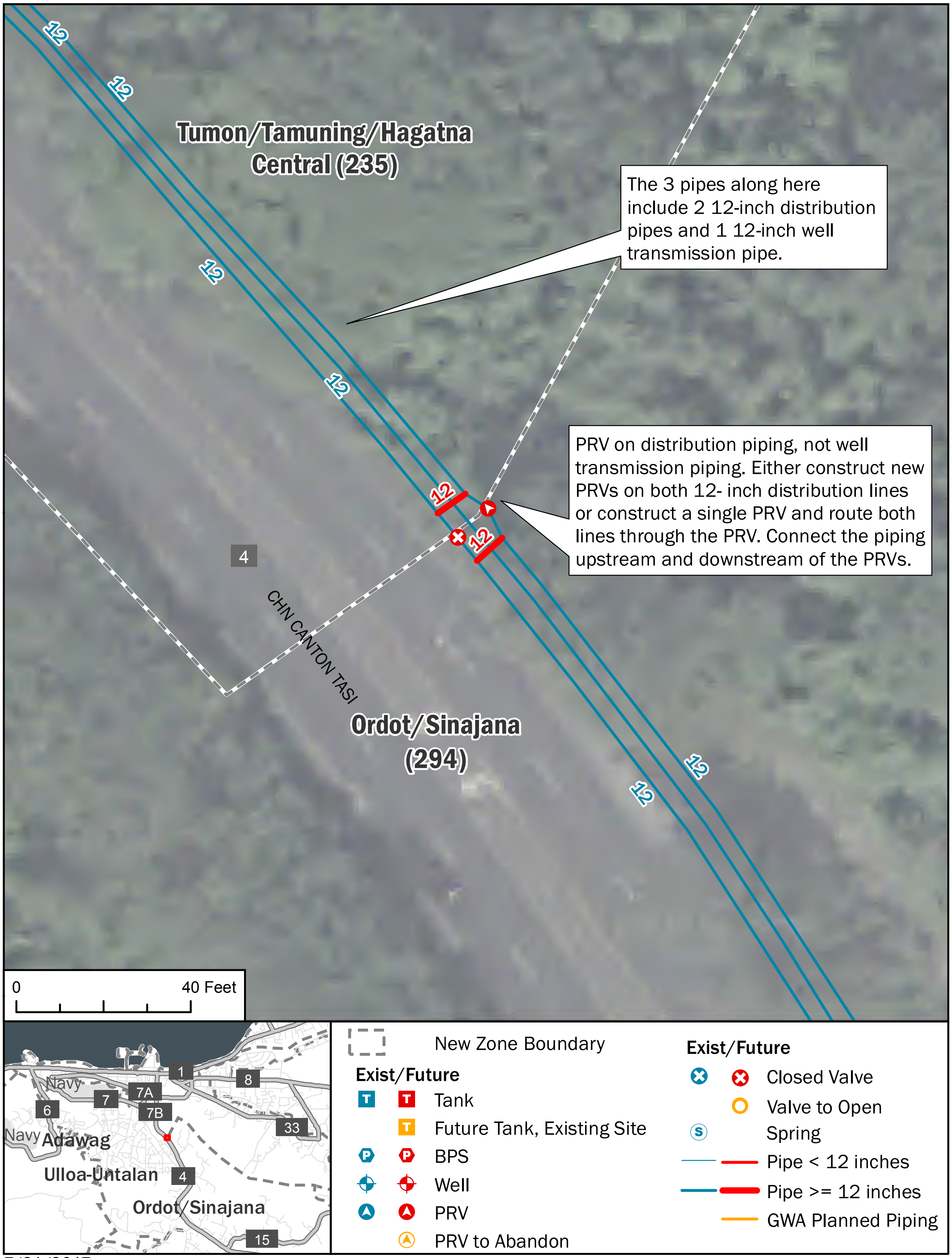
7/31/2017

Detail 52



7/31/2017

Detail 53

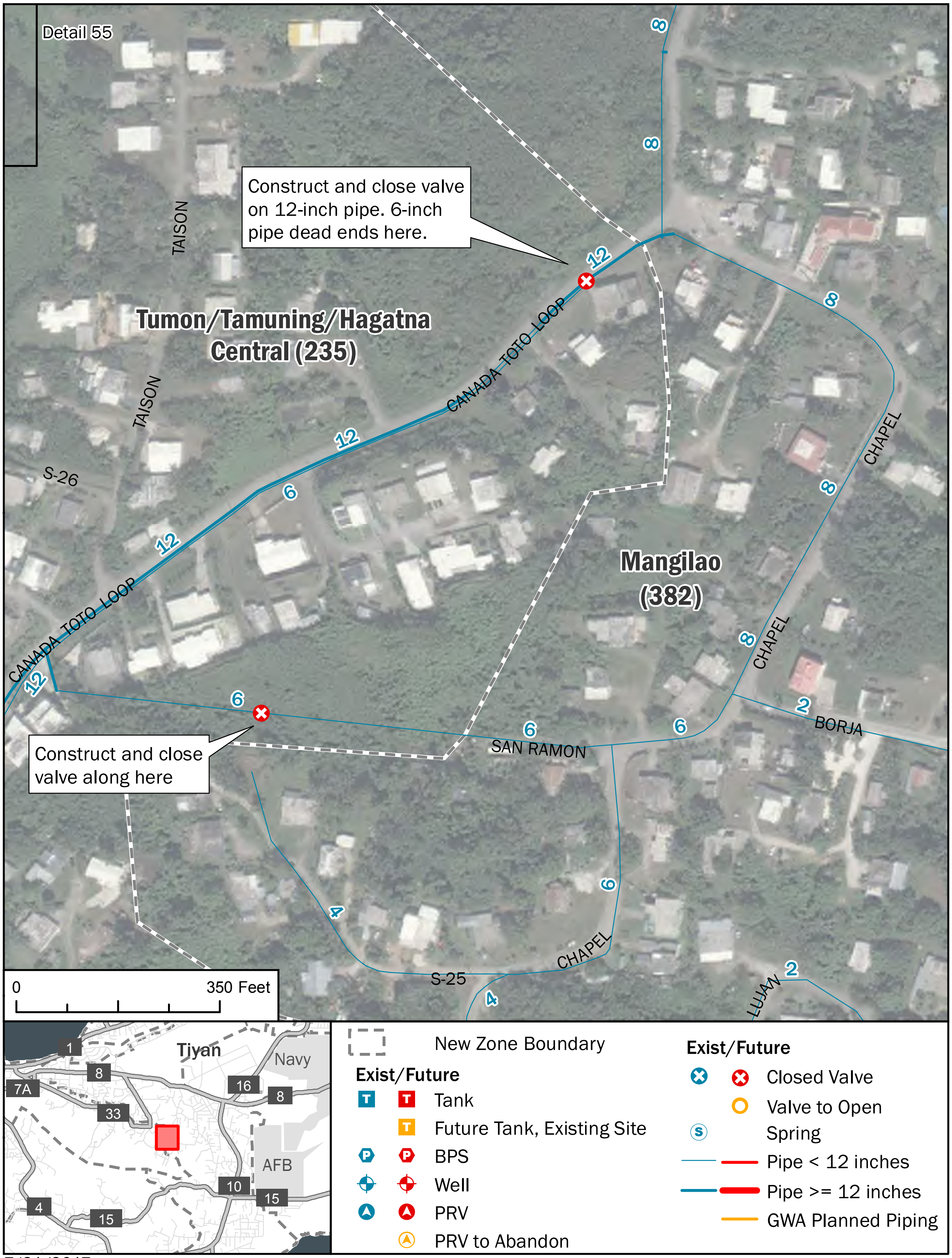


7/31/2017

Detail 54

7/31/2017

Detail 55

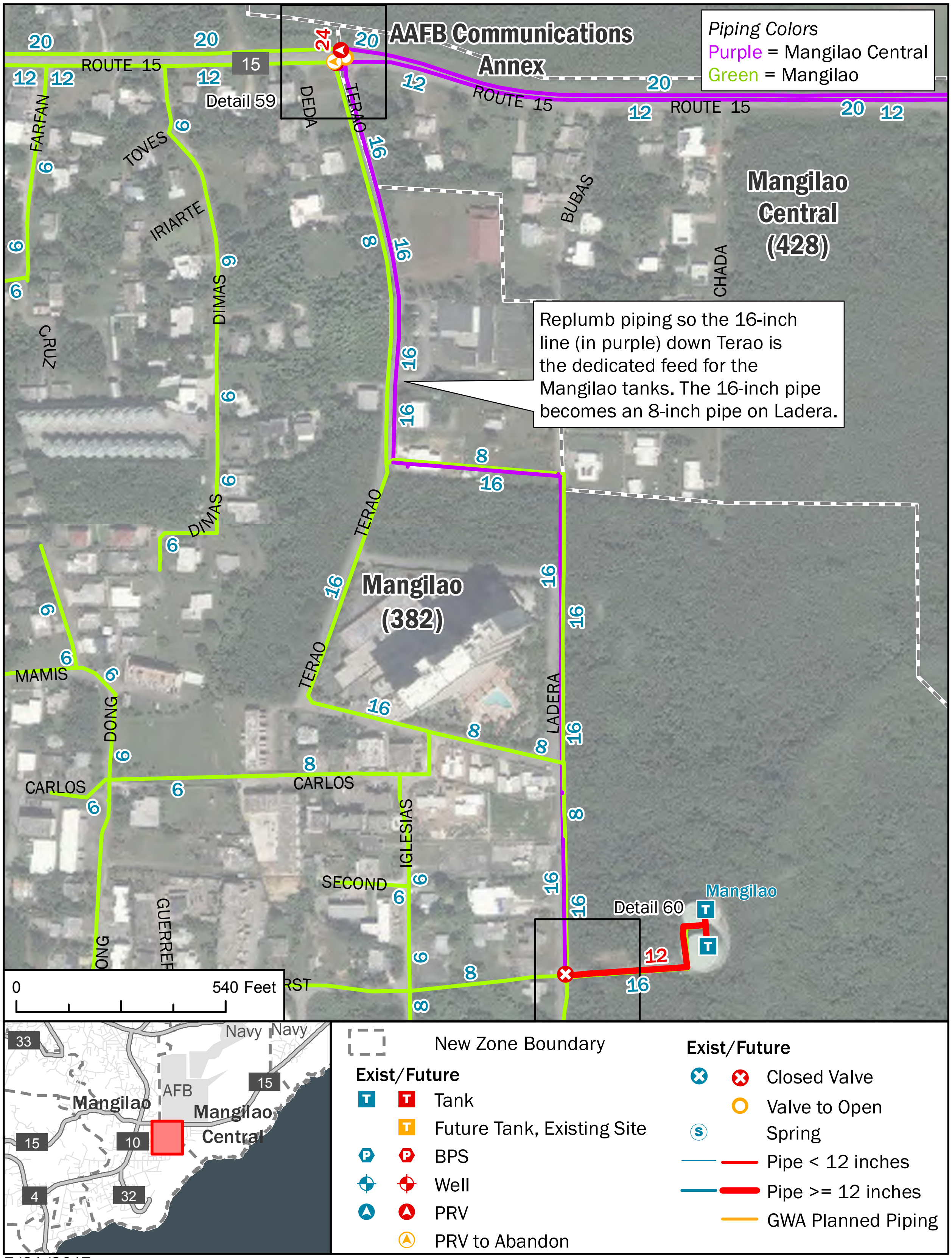


7/31/2017

Detail 56

7/31/2017

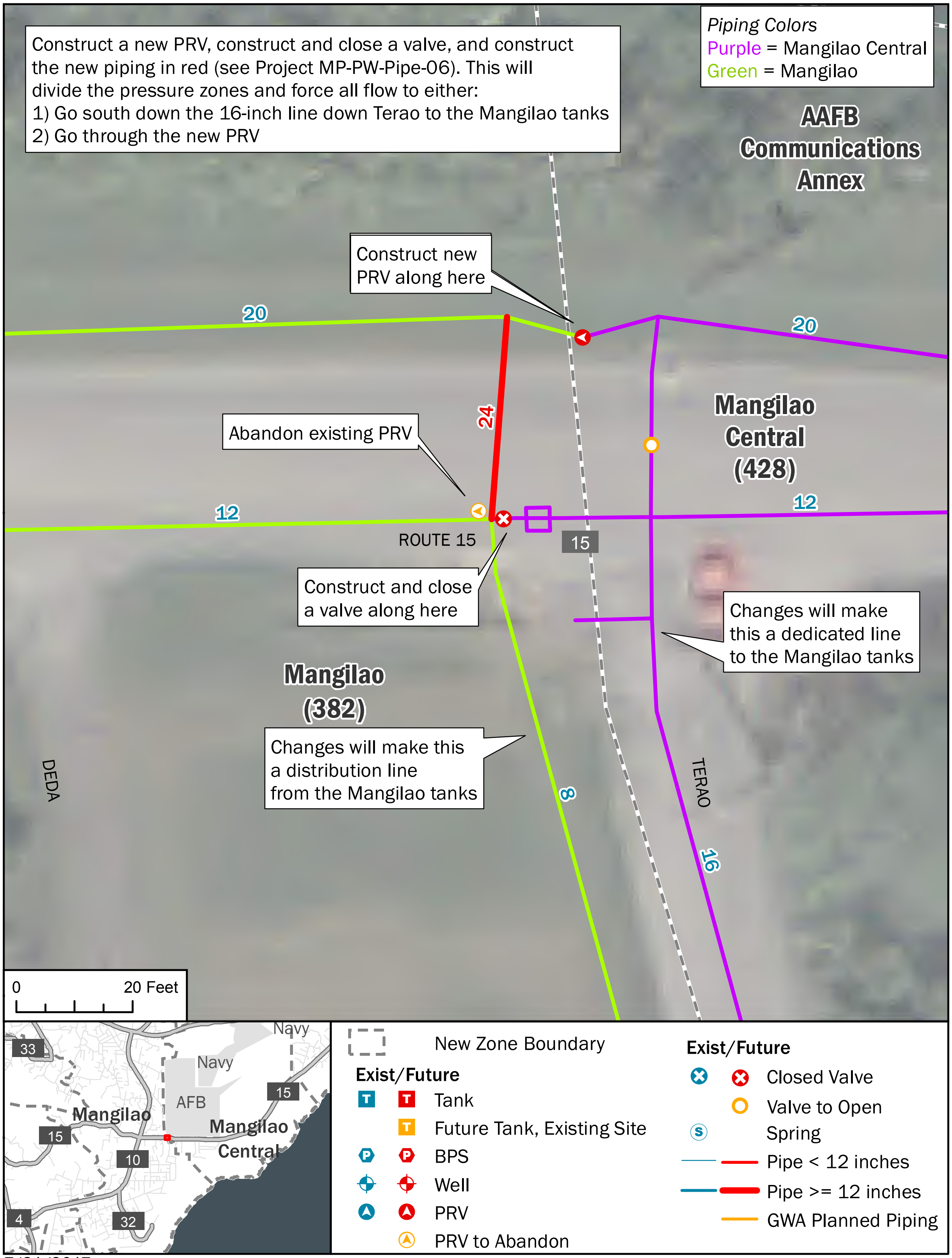
Detail 57



7/31/2017

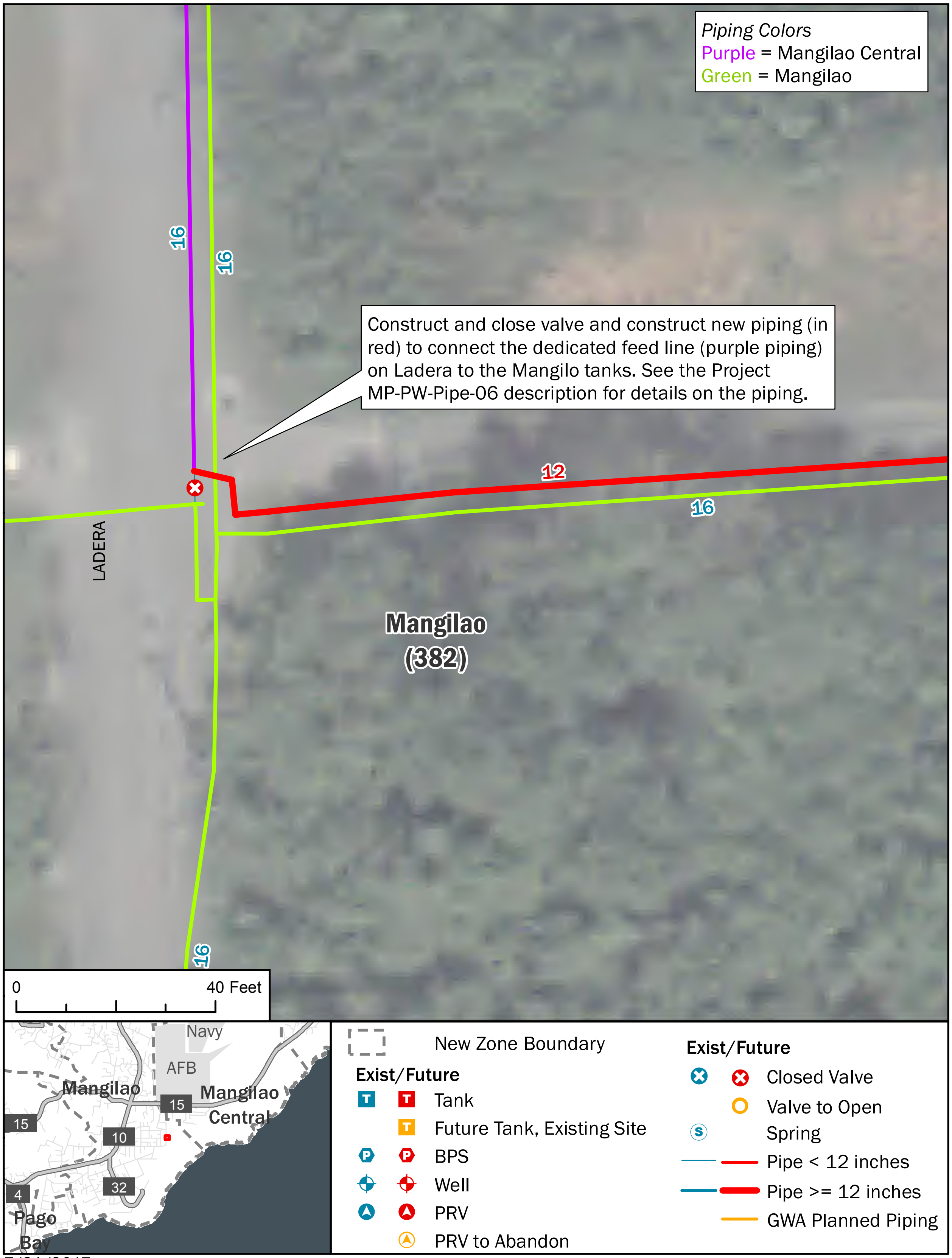
Detail 58

Brown AND Caldwell



7/31/2017

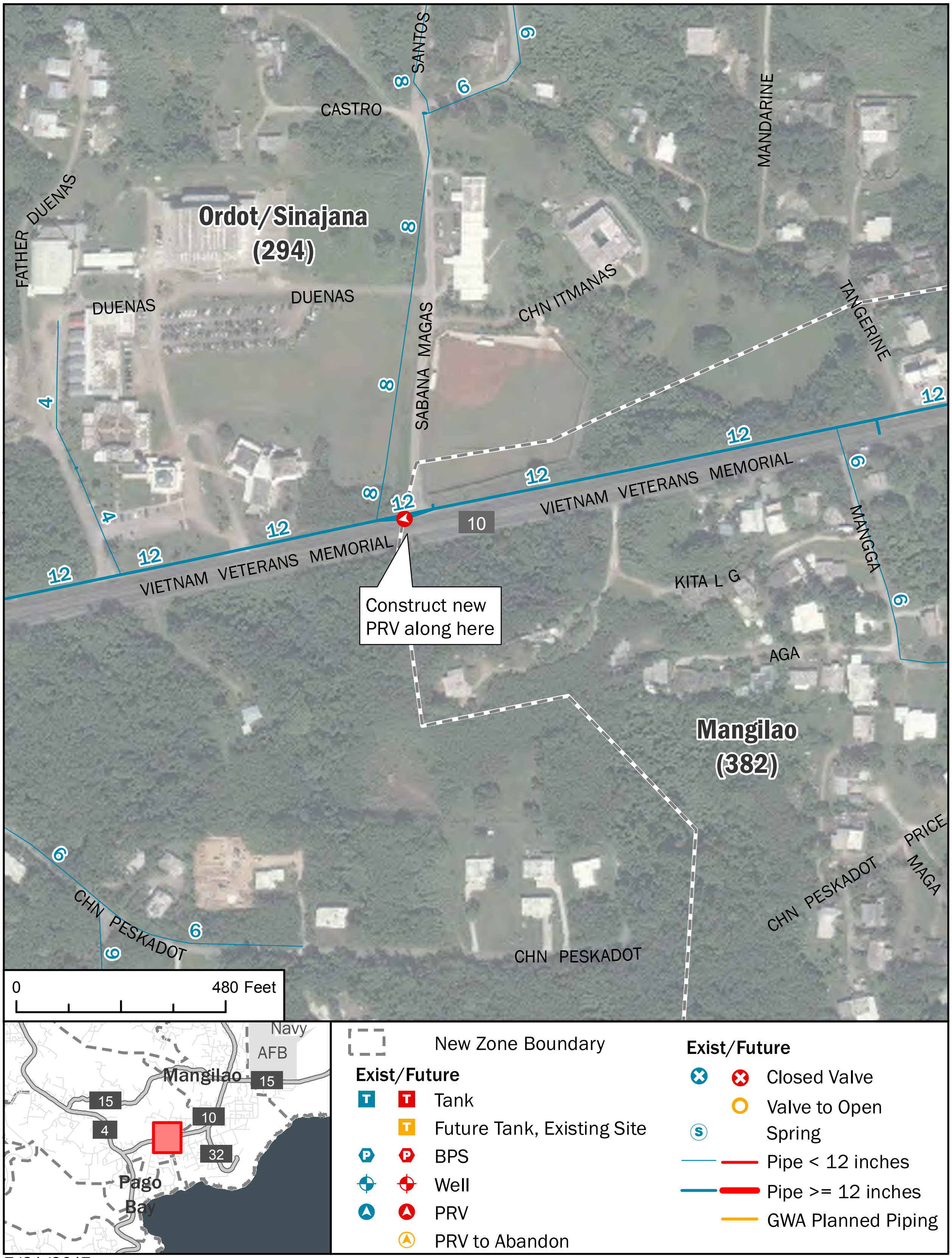
Detail 59



7/31/2017

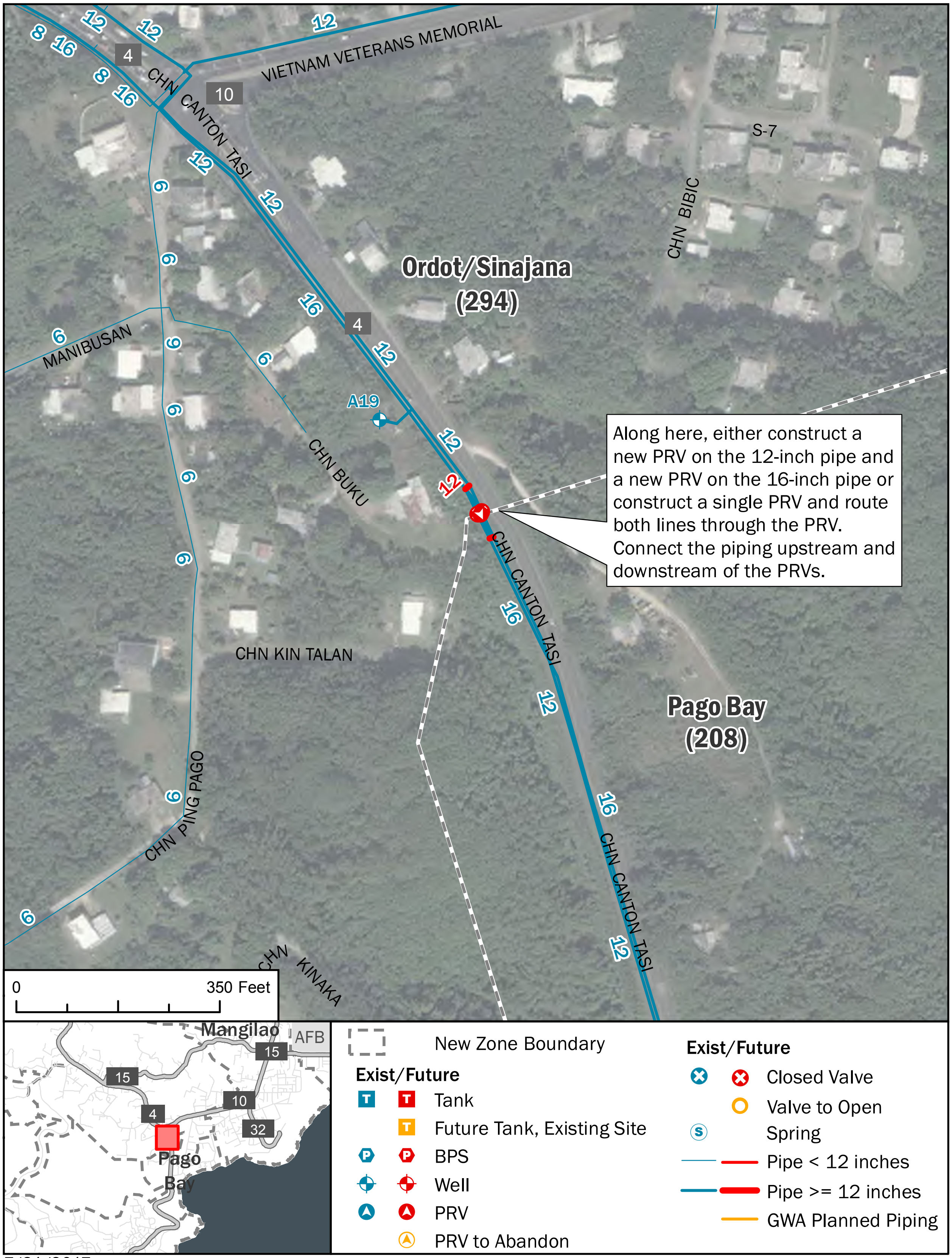
Detail 60

Brown AND Caldwell



7/31/2017

Detail 61



7/31/2017

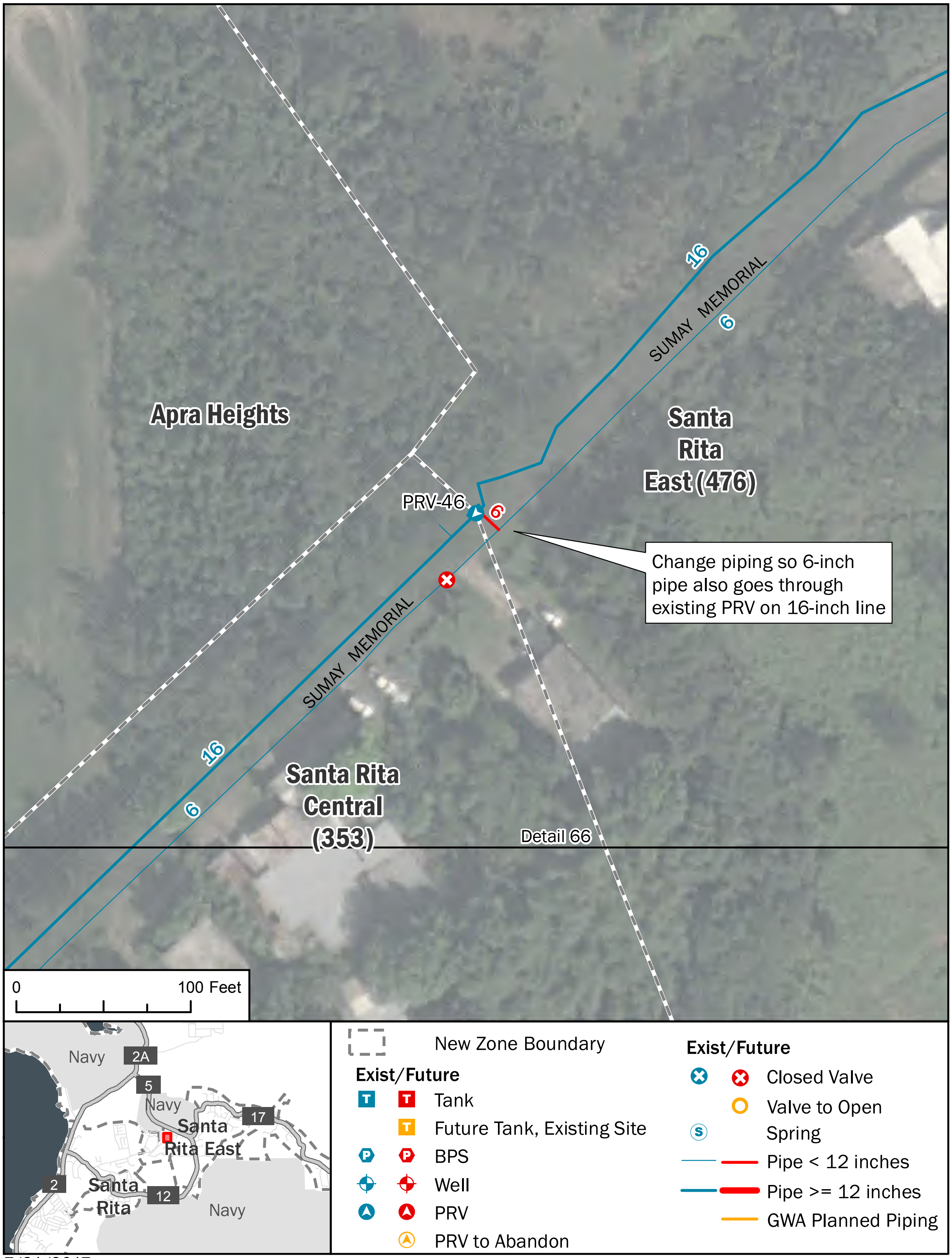
Detail 62

Brown AND Caldwell

7/31/2017

Detail 63

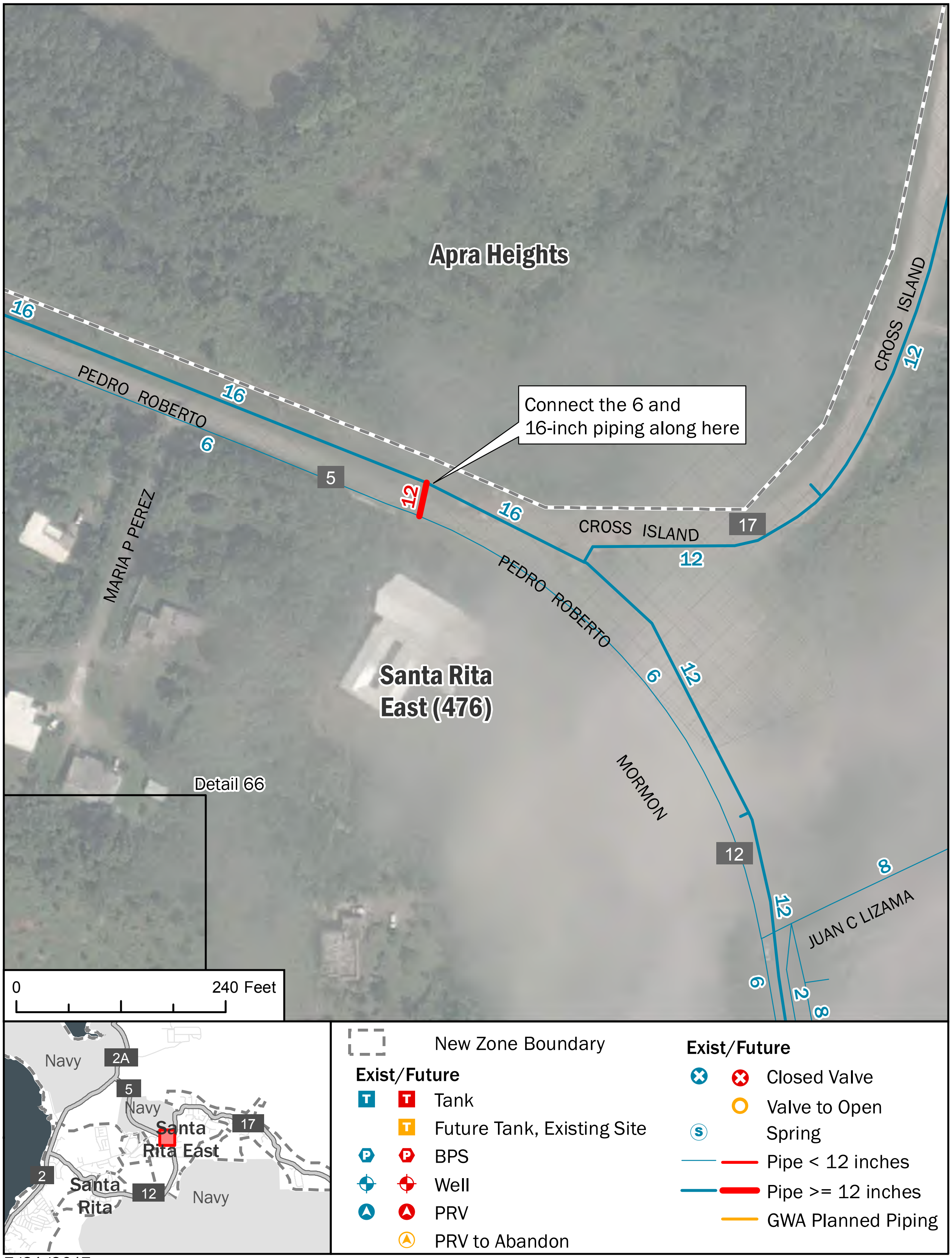
Brown AND Caldwell



7/31/2017

Detail 64

Brown AND Caldwell

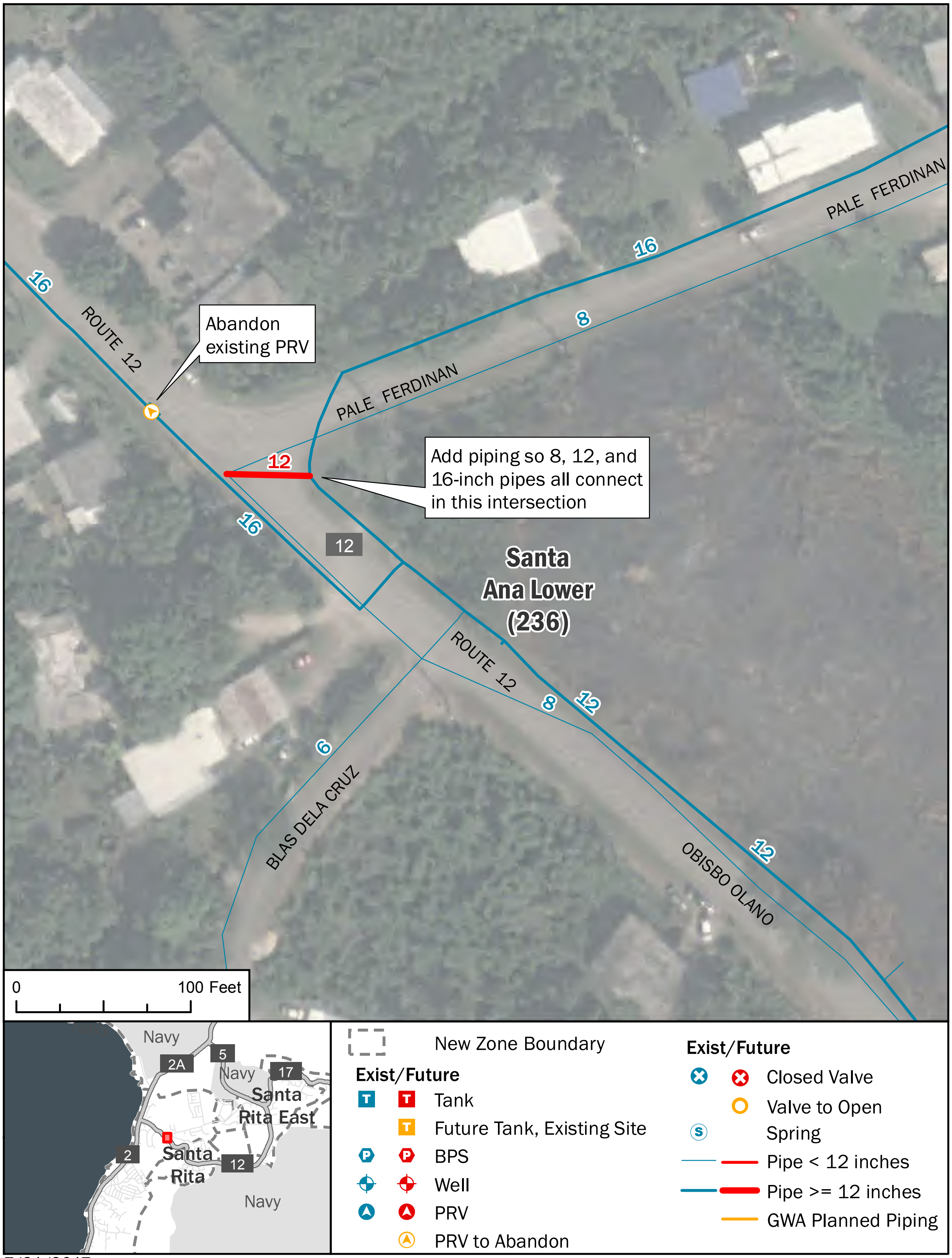


7/31/2017

Detail 65

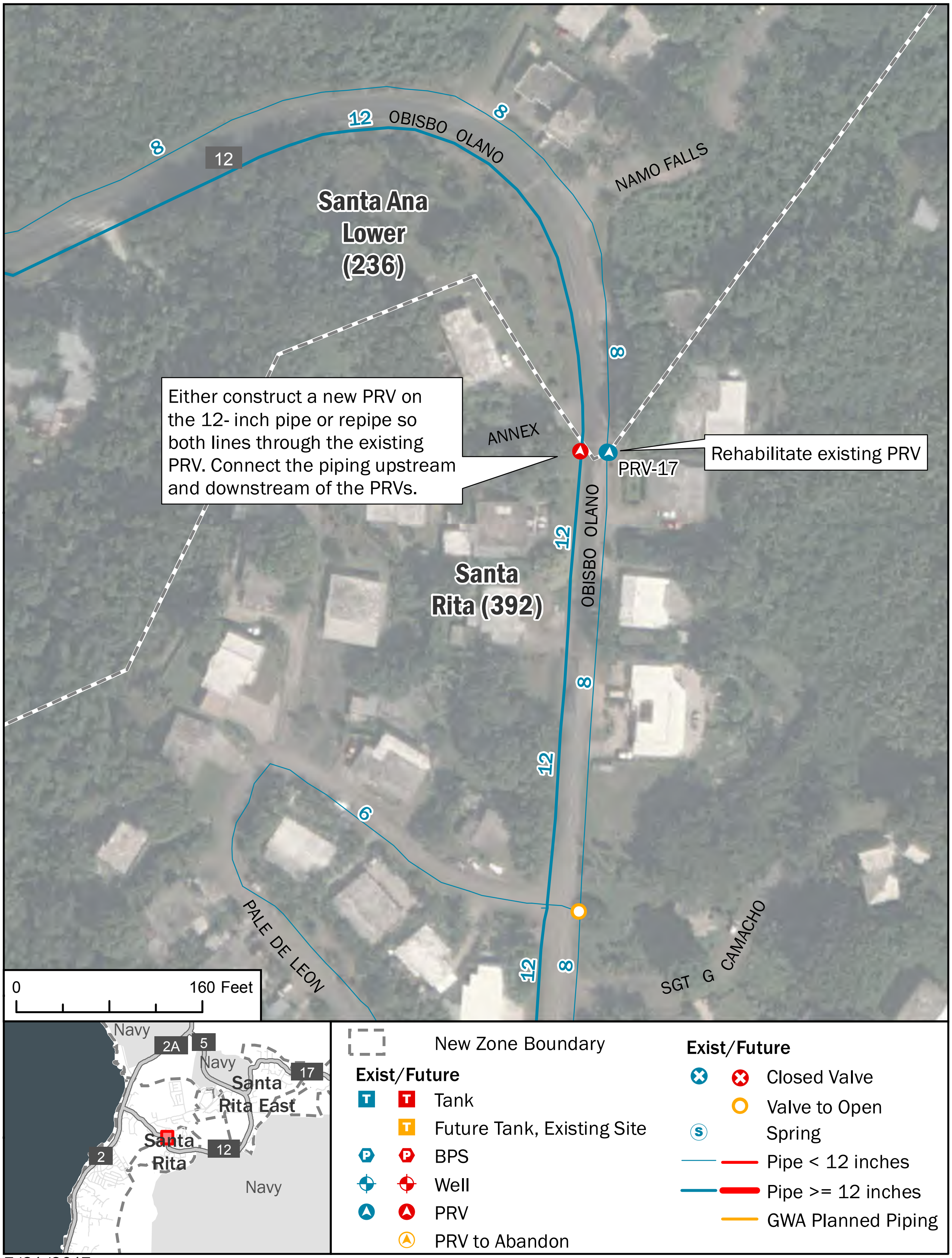
7/31/2017

Detail 66



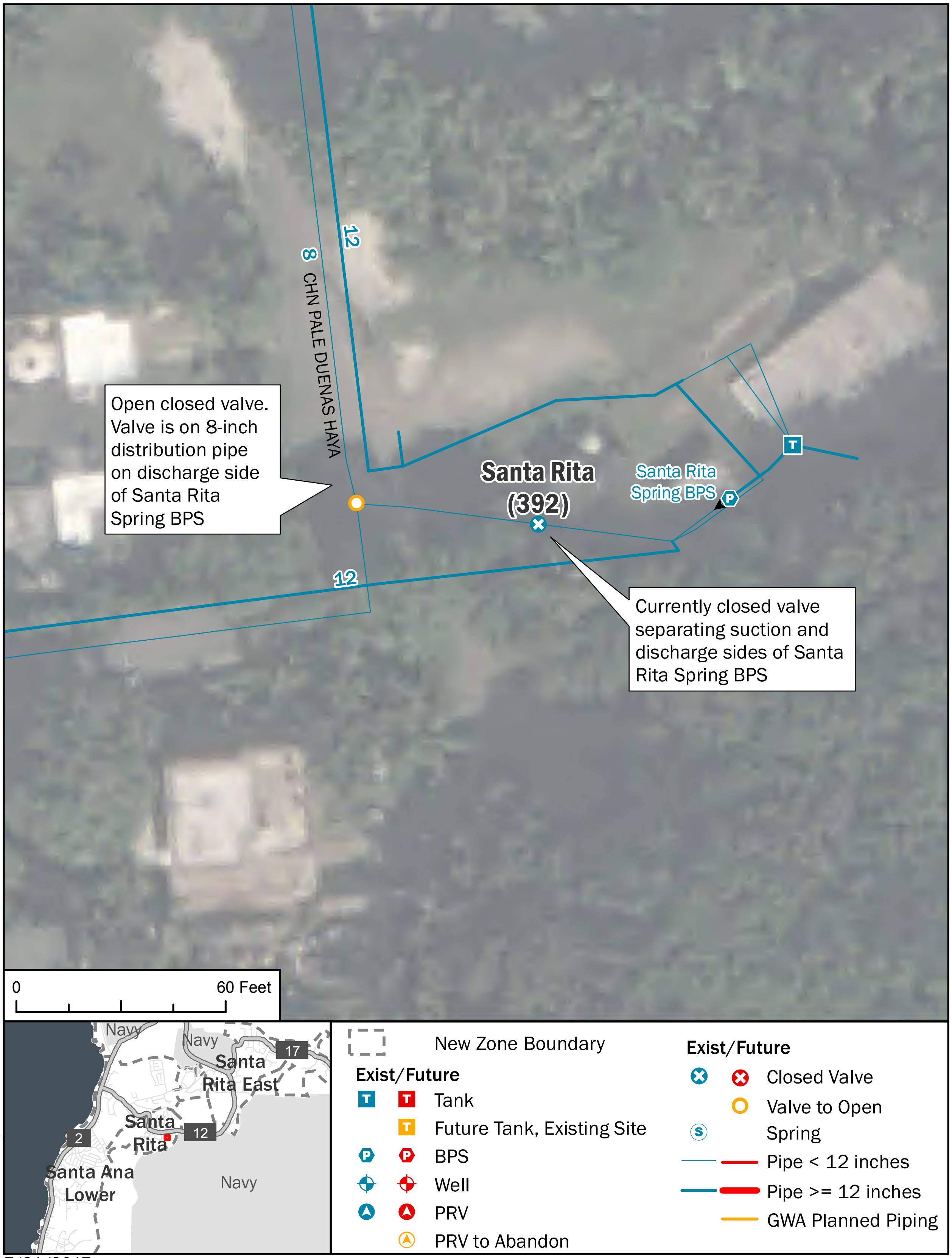
7/31/2017

Detail 67



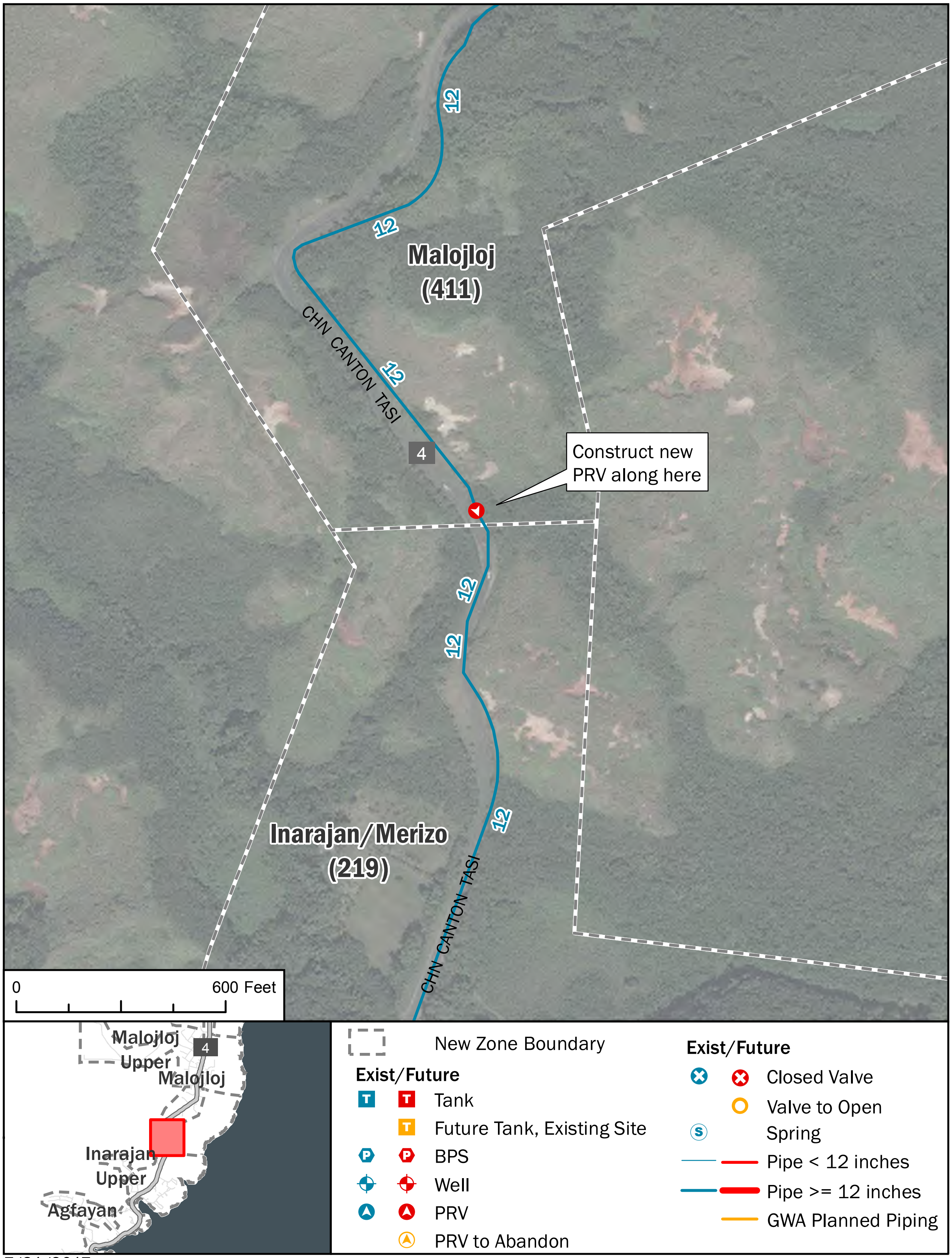
7/31/2017

Detail 68



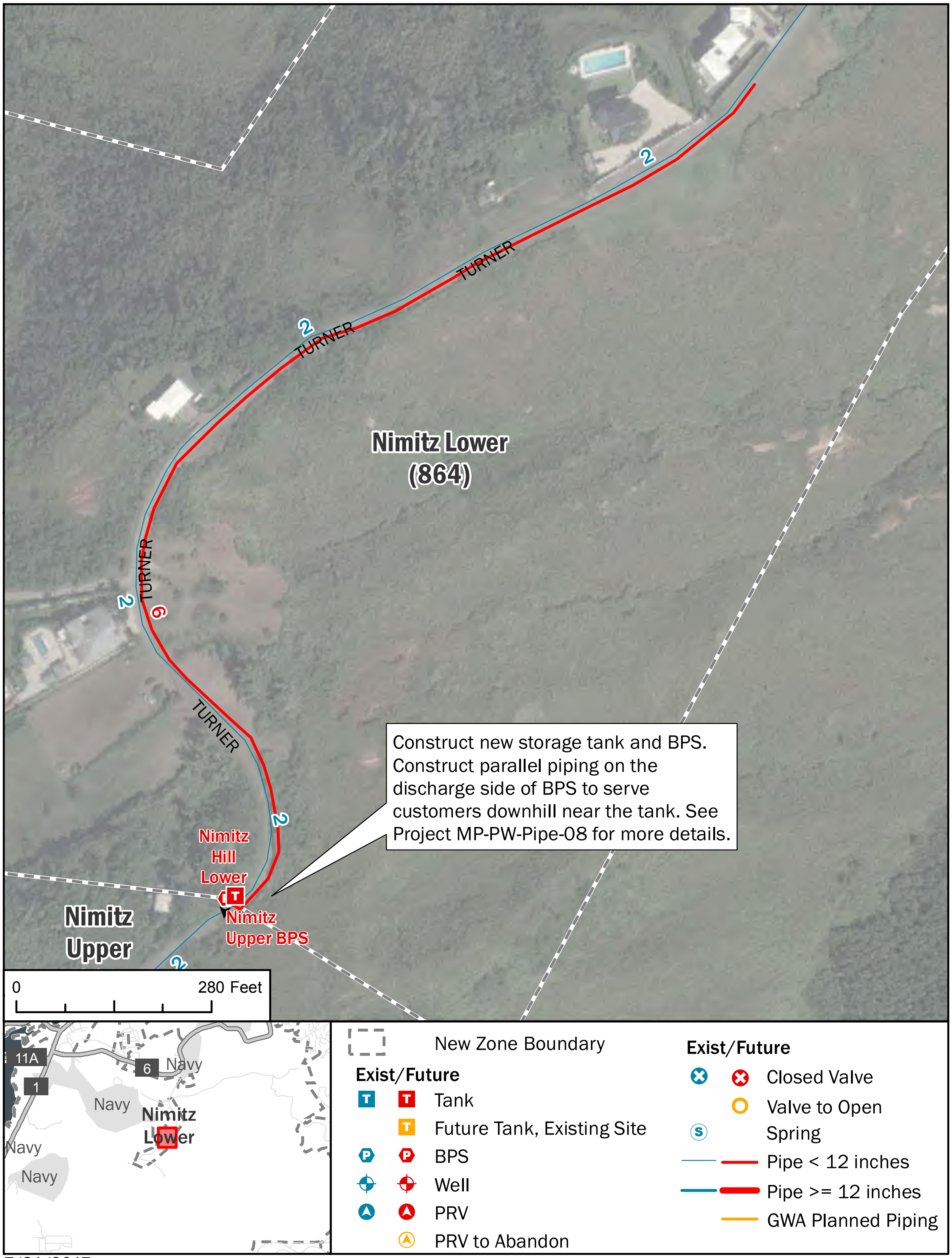
7/31/2017

Detail 69



7/31/2017

Detail 70



7/31/2017

Detail 71

Appendix I

Hydrant Condition Assessment Data

This appendix contains background data used in the condition assessment of the water facilities.

Rating Definitions for Direct Visual Assessment of Hydrants

1. Excellent Overall Condition

No noticeable defects. Some aging or wear may be visible. The Asset is fully functional.

1. Looks similar to when it was first installed and accepted. May be still under warranty.
2. Pipe is properly sized and specified for the proper and required fire-flow through the hydrant.
3. Gages and other ancillary equipment are new and working properly.
4. Pipe hangers and supports are aligned, spaced properly and tight against the pipe.
    a. Pipe is being supported not sagging.
5. There is proper clearance between hydrant and wall or other obstruction.
6. Hydrant joint restrainers are properly constructed, secure and tight.
7. Thrust blocking is tight, secure and designed correctly for the intended purpose.
8. Hydrant is secure and tight with no leaks.
9. The types of pipe joints that will generally be encountered on the plant are:
    a. Mechanical joint - No missing “T” bolts or nuts, rubber gasket is seated properly, not protruding or pinched
    b. Flange joint - There are no bolts or nuts missing, gasket is secure and not protruding.
    c. Thread or (Screw) joint is properly constructed, excess pipe joint compound is cleaned up.
    d. Bell and spigot joint no lead joint is acceptable, rubber ring is seated properly and not protruding. Use a feeler gage if necessary to check ring seat.
    e. Soldered joints are clean and secure without excess solder drip.
    f. Brazed joints are clean and secure without excess solder drip.
    g. Welded pipe is secured, no cracking welds and no signs of undercut or buried slag. Weld looks solid and complete with good penetration all around.
10. The types of pipe that will be encountered are:
    a. Ductile iron - No signs of corrosion.
    b. Cast iron - No signs of corrosion.
    c. Steel
        i. High and low Carbon - No signs of corrosion.
        ii. Sch-80 Sch-40 - No signs of corrosion.
        iii. Galvanized Pipe is coated with sacrificial zinc which may have corroded slightly to protect the iron pipe under the zinc.

   d. Copper tubing
      i. Type K - Some patina may develop to protect the copper under.
      ii. Type L - Some patina may develop to protect the copper under.
   e. Stainless steel tubing - No signs of corrosion.
   f. Plastic
      i. SDR-35 cracking or signs of UV degradation.
11. Valves are of proper size, class, rating and configuration for the application.
12. Coating on hydrant is in excellent condition
13. Hydrant is plumb and at the correct height.
14. Hydrant opens and closes properly without any leaks.

2. Good Overall Condition

Only minor deterioration or defects are evident. Noticeable wear or aging is visible. The Asset is fully functional.

1. This asset may have minor signs that maintenance has been provided, but in no case should the asset look like it has been damaged.
   a. No Hammering, chipping gouging, heating or cutting.
2. Pipe is properly sized and specified for the intended purpose.
3. Gages and other ancillary equipment are working properly.
4. Hydrant hangers and supports are aligned, spaced properly and tight against the pipe.
   a. Pipe is being supported not sagging.
5. There is proper clearance between pipe and wall or other obstruction.
6. Hydrant joint restrainers are properly constructed, secure and tight.
7. Thrust blocking is tight, secure and designed correctly for the intended purpose.
8. Hydrant is secure and tight with no leaks.
9. Valves are of proper size, class, rating and configuration for the application.
10. Coating on hydrant is in good condition
11. Hydrant is plumb and at the correct height.
12. Hydrant opens and closes properly without any leaks.

3. Fair Overall Condition

Some deterioration or defects are evident. Significant aging or wear is visible. Function is not significantly affected.

1. There are visible signs of wear, but no signs of damage.
   a. Hammering, heating, chipping, or scoring cutting.
   b. Brush away loose paint to reveal the surface and assure that there is no cracking.
2. Pipe is properly sized and specified for the intended purpose.
3. Gages and other ancillary equipment are working properly.
4. Hydrant hangers and supports are aligned, spaced properly and tight against the pipe.
   a. Pipe is being supported not sagging.
5. There is proper clearance between pipe and wall or other obstruction.
6. Hydrant restrainers are properly constructed, secure and tight.

7. Thrust blocking is tight, secure and designed correctly for the intended purpose.
8. Hydrant is secure and tight with no leaks.
9. Valves are of proper size, class, rating and configuration for the application.
10. Coating on hydrant is in fair condition
11. Hydrant is plumb and at the correct height.
12. Hydrant opens and closes properly without any leaks.

4. Poor Overall Condition

Serious deterioration or defects in at least some portion of the asset. Extensive aging or wear is visible. Note: No equipment can be restored back to its original excellent condition standard and therefore cannot receive a grade of one. Function is significantly affected.

Note: The piping system should be considered in poor shape if two or more of the following conditions exist:

1. This asset must receive signification maintenance, rebuilt or a subcomponent replaced to restore its condition to a higher level.
2. There are heavy visible signs of wear or maintenance, showing signs of abuse.
   a. Hammering, heating, chipping, or scoring cutting.
   b. Brush away loose paint to reveal the surface and assure that there is no cracking.
3. Pipe is improperly sized and specified for the intended purpose.
4. Gages and other ancillary equipment are not working properly.
5. Pipe hangers and supports are not aligned and tight against the pipe.
   a. Pipe is sagging.
6. There is no clearance between pipe and wall or other obstruction.
7. Hydrant is not properly constructed, secure and tight there is some dripping or leaking.
8. Thrust blocking is tight, secure and designed correctly for the intended purpose.
9. Hydrant joints may be leaking.
10. Valves are not properly sized, or the class is wrong, or the rating and configuration are wrong for the application.
11. Coating on hydrant has is cracked, chipped or failing
12. Hydrant is not plumb and not at the correct height.
13. Hydrant open and close but not easily and has leaks.

5. Extremely Poor Overall Condition

Extensive deterioration or defects in the asset. Age or wear is beyond repair. The Asset is barely functional.

Note: The piping system should be considered as inoperable if four or more of the following conditions exist:

1. This asset needs extensive maintenance, including entire rebuild to make it reliable and will need to be replaced as soon as possible.
2. There are heavy visible signs of wear or showing signs of abuse.
   a. Hammering, heating, chipping, or scoring cutting.
   b. Brush away loose paint to reveal the surface there are signs of cracking.

3. Pipe is improperly sized and specified for the intended purpose.
4. Gages and other ancillary equipment are not working.
5. Hydrant hangers and supports are not aligned and tight against the pipe.
   a. Pipe is sagging.
6. There is no clearance between pipe and wall or other obstruction.
7. Hydrant joint restrainers are not properly constructed, secure and tight there is some dripping or leaking.
8. Thrust blocking is tight, secure and designed correctly for the intended purpose.
9. Hydrant joints may be leaking.
10. Valves are not properly sized, or the class is wrong, or the rating and configuration are wrong for the application.
11. Coating on hydrant has failed
12. Hydrant is not plumb and not at the correct height
13. Hydrant does not open and closes properly and leaks.

ANY DEFECT THAT WOULD CREATE ANY POSSIBILITY THAT SAFETY OF PERSONNEL OR PROPERTY IS IN JEOPARDY MUST BE REPORTED IMMEDIATELY!

Hydrants by Manufacturer

Table I-1 summarizes the number of hydrants by manufacturer as found during the 2013 and 2014 condition assessment.

Table I-1. Fire Hydrant Manufacturers and Quantities

Manufacturer	Quantity
Unknown (Hydrant missing or name is missing)	425
AMERICAN	10
AMERICAN VALLEY VALVE	4
AMERICAN WATER WORKS INT'L.	1
AMERICAN-DARLING VALVE	3
ANNISTON	24
ANNISTON, DRESSER	2
AVK	17
BSP	1
CLOW	929
CLOW/EDDY	1
CLOW/LONG BEACH	97
DRESSER	106
EDDY	13
GREENBERG	179
IOWA	3
JONES	527

Table I-1. Fire Hydrant Manufacturers and Quantities	
Manufacturer	**Quantity**
KENNEDY	474
LONGBEACH	475
METRO	6
MH929	8
MUELLER	196
NH	1
OHIO	1
PACFIC STATES	10
PHILLIPINE	13
PSCIP	44
RICH	83
RICHMOND	2
USP	6
WATEROUS	152

Hydrants with Scores of 4 and 5

Table I-2 lists the hydrants with scores of 4 and 5 by village. These values were used in the repair and replacement cost calculations in Section 10.

Table I-2. Hydrants with Scores of 4 by Village

Village	Score of 4				Score of 5			
	Dry Barrel	Wet Barrel	Unknown Barrel Type	Total	Dry Barrel	Wet Barrel	Unknown Barrel Type	Total
Agat	17	18	2	*37*	5	8	-	*13*
Asan	7	3	-	*10*	1	2	-	*3*
Barrigada	29	48	39	*116*	18	20	8	*46*
Chalan Pago Ordot	6	15	29	*50*	10	6	14	*30*
Dededo	191	286	24	*501*	53	41	7	*101*
Hagåtña	5	9	1	*15*	-	1	-	*1*
Agana Heights	12	11	-	*23*	-	1	-	*1*
Inarajan	17	4	-	*21*	1	2	-	*3*
Mangilao	40	34	13	*87*	16	8	4	*28*
Merizo	9	8	-	*17*	5	-	-	*5*
Mongmong/Toto/Maite	13	19	7	*39*	13	4	2	*19*
Piti	7	6	7	*20*	-	4	6	*10*
Santa Rita	15	13	-	*28*	2	1		*3*

Table I-2. Hydrants with Scores of 4 by Village

Village	Score of 4				Score of 5			
	Dry Barrel	Wet Barrel	Unknown Barrel Type	Total	Dry Barrel	Wet Barrel	Unknown Barrel Type	Total
Sinajana	3	10	-	*13*	-	-	-	-
Talofofo	25	26	-	*51*	17	8		*25*
Tamuning	41	77	20	*138*	27	15	18	*60*
Umatac	1	4	-	*5*	-	-	-	-
Yigo	40	238	1	*279*	12	23	3	*38*
Yona	47	47	4	*98*	18	14	-	*32*
Total	*525*	*876*	*147*	*1,548*	*198*	*158*	*62*	*418*

Appendix J

Wells to Abandon

This appendix contains additional information on the wells to abandon. The photographs shown in Figure J-1 to J-9 were all taken in October or November 2009. The pages following the figures show the Guam EPA procedures for abandoning wells as obtained from GWA. GWA should check with Guam EPA to see if there is a newer well abandonment procedure at the time that a well is abandoned.

Figure J-1. Photographs and Map of Well A-11

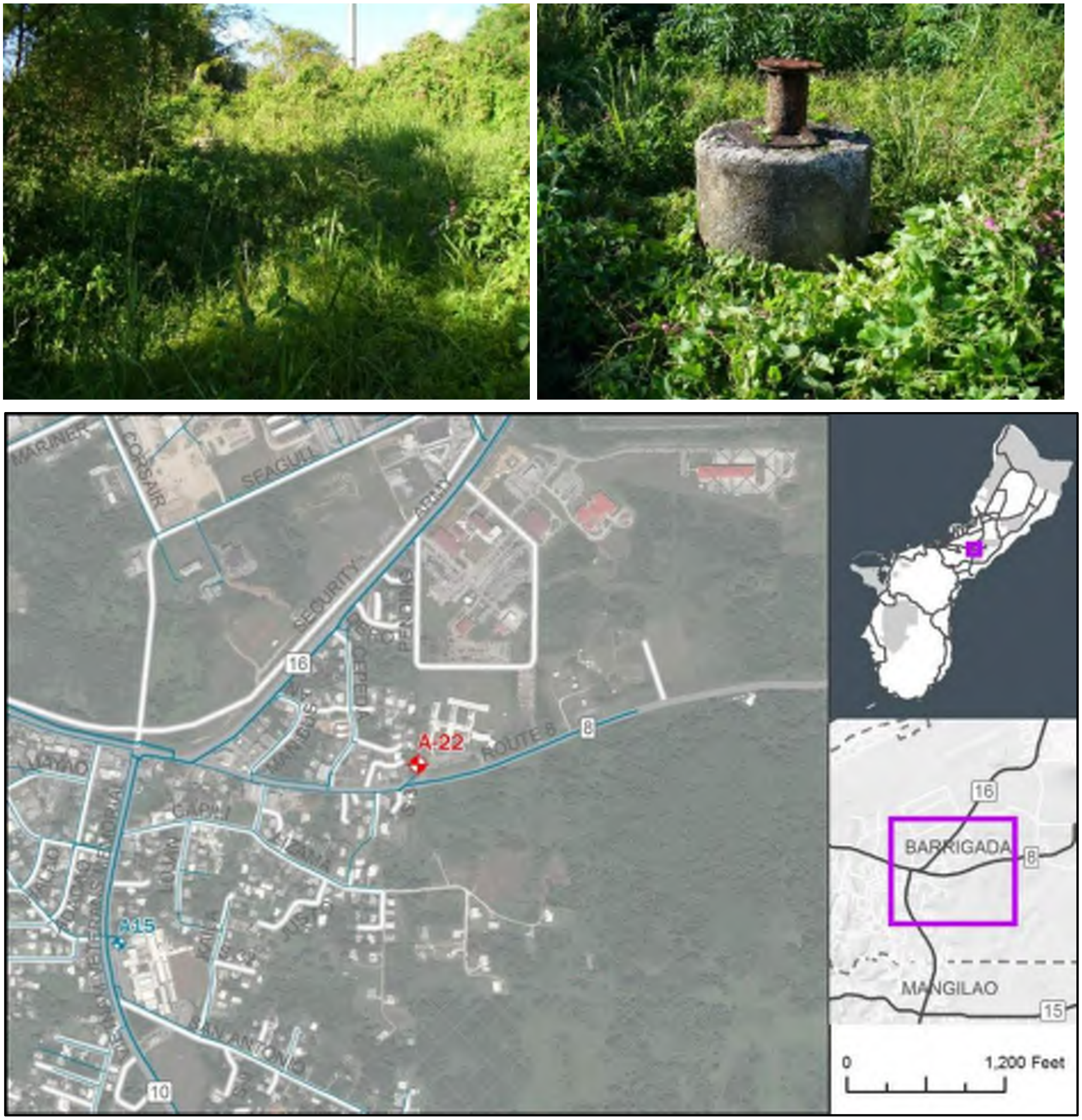


Figure J-2. Photographs and Map of Well A-22

Figure J-3. Photographs and Map of Well A-27

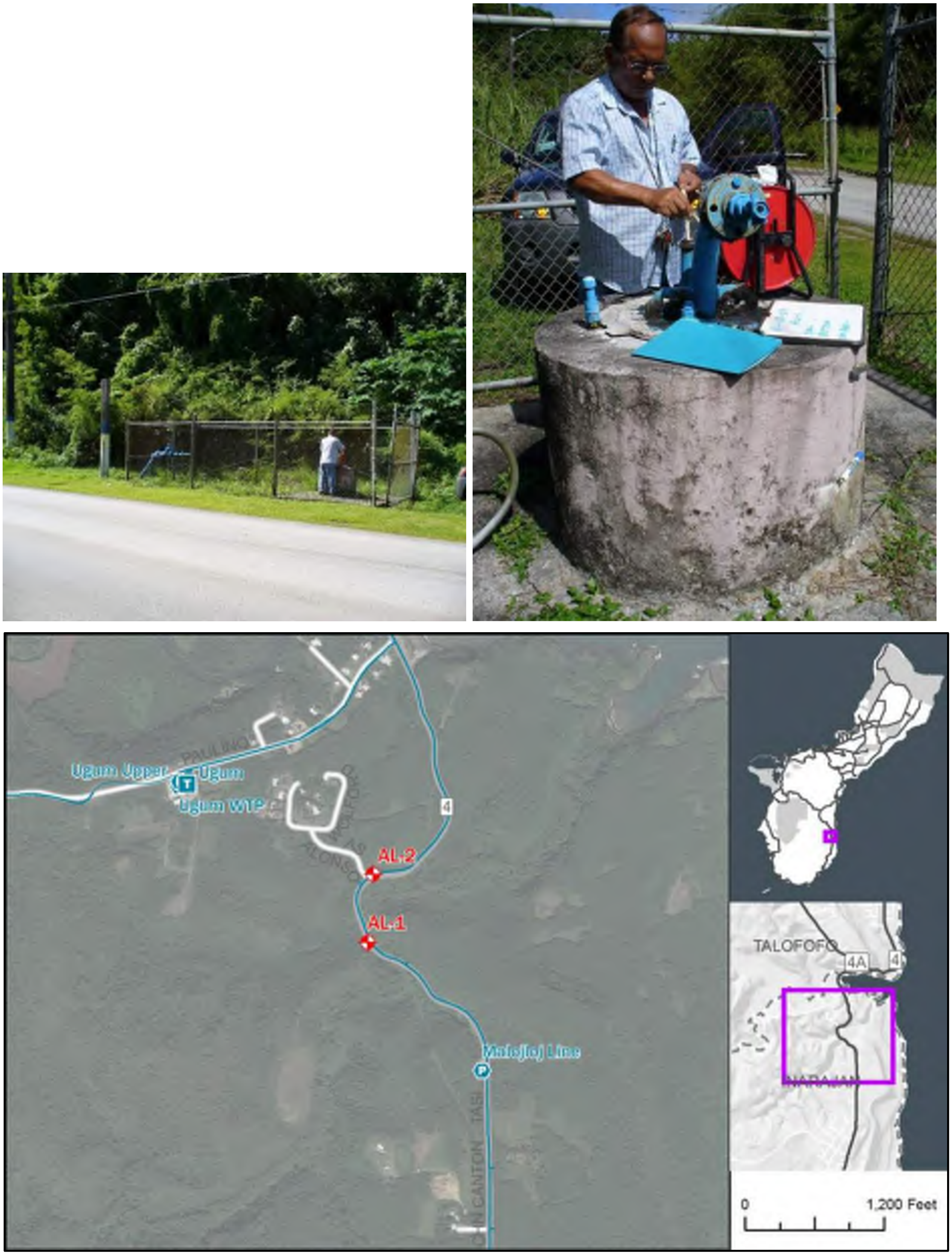


Figure J-4. Photographs and Map of Well AL-1

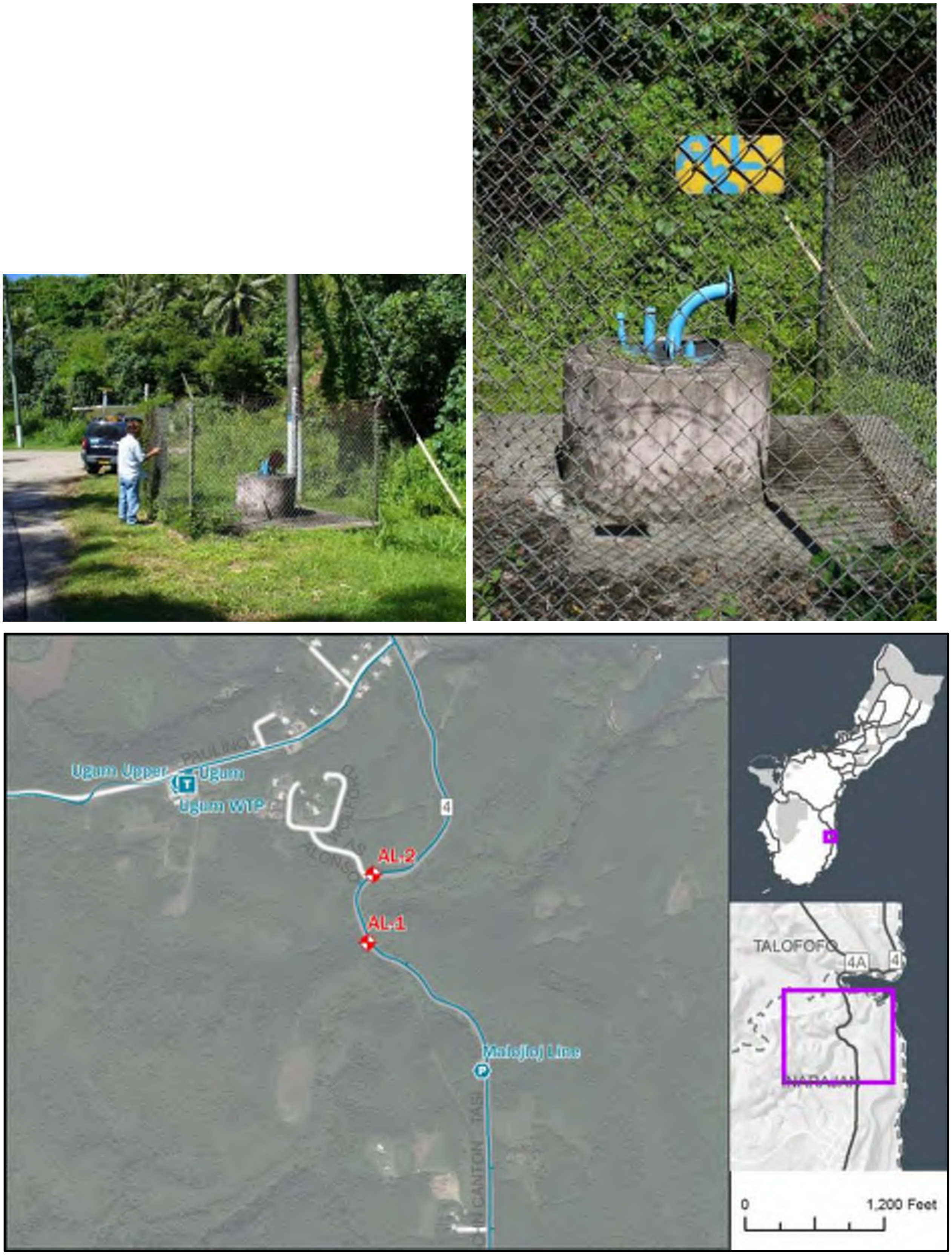


Figure J-5. Photographs and Map of Well AL-2

Figure J-6. Photographs and Map of Well D-23

Figure J-7. Photographs and Map of Estimated Location of Well M-13

Figure J-8. Photographs and Map of Well Y-4

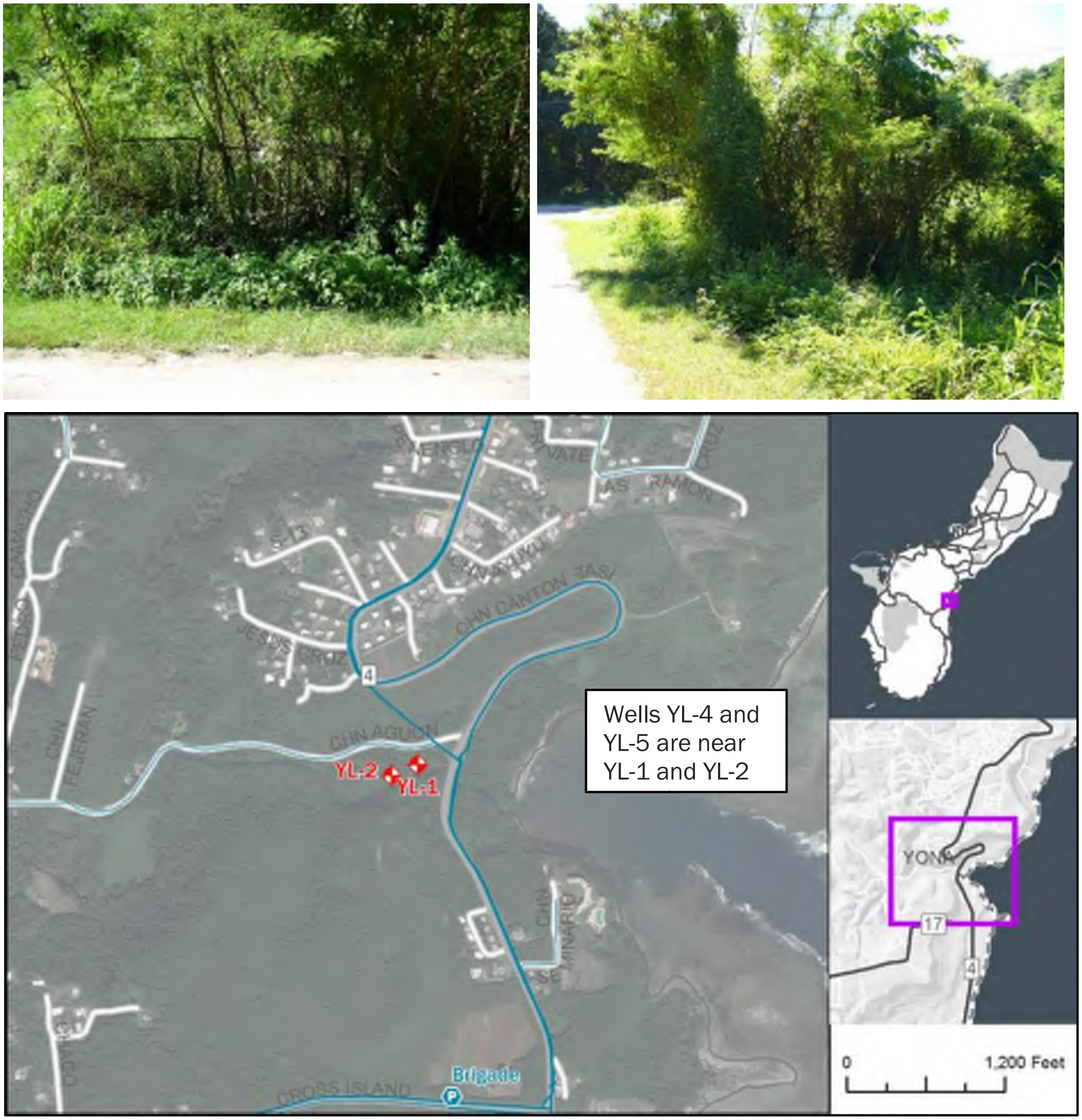


Figure J-9. Photographs and Map of Wells YL-4 and YL-5

Well Abandonment Procedure

Guam Environmental Protection Agency

Water Resources Management Program

GENERAL NOTES:

A. The driller shall submit a well abandonment plan following the procedure below to Guam EPA for review/approval. The plan shall include a cross-section drawing of the well, showing the water table, locations of the different types of fill, known dimensions, etc.

B. The driller shall notify Guam EPA administrator 48 hours prior to starting date of the abandonment.

C. All above-ground materials shall be removed from the well site and disposed in a manner that conforms to the appropriate Guam EPA regulation.

D. If a well is in an area that is covered with asphalt or concrete that is not to be removed (such as a parking lot or a driveway/street), the native soil fill may be replaced with neat cement and then covered with new asphalt or concrete.

I. Abandonment Procedure for a Cased Well that ***Will Not*** Have its Casing Removed

1. Remove the well pedestal and concrete pad if applicable.
2. Excavate down to six feet (6') and cut/remove the casing.
3. If the well is completely within the vadose zone and does not penetrate the water table, proceed to item "I.5."
4. If the well extends into the water table, measure the depth to the water table (DWT) and fill the well with 3/8 to ¾ inch clean washed aggregate to three feet (3') above the water table. Prior to proceeding to "I-5", measure the DWT again to ascertain that the temporary rise of the water table within the casing has subsided below the elevation of the washed aggregate.
5. Provide a two-foot (2') bentonite plug by placing ¾ inch bentonite chips in six-inch (6") lifts and hydrate each lift with potable water.
6. Fill the casing with neat cement up to six feet (6') below the ground surface to form a mushroom cap over the casing.
7. Fill the final six feet (6') with the soil native to the site.

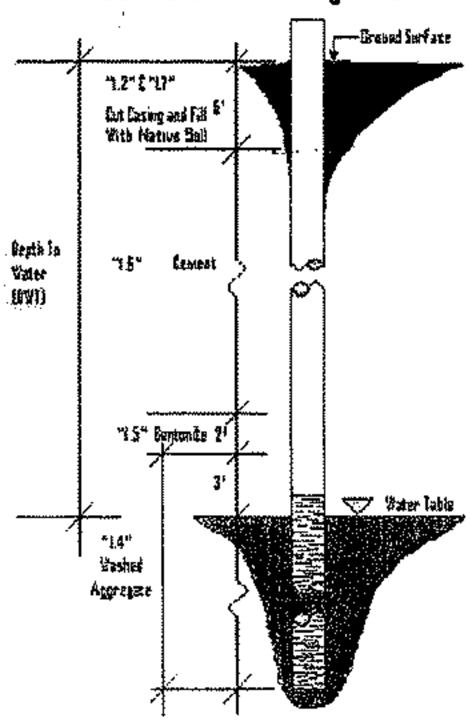
NOTES:

A. For wells with a DWT greater than ten feet (10'), the total depth of fill for item "I.6" will be equal to DWT less ten feet (10').

B. For shallow wells with a DWT greater than eight feet (8'), but less than ten feet (10') above the water table, item "I.6" will not be included.

C. For shallow wells with a DWT greater than three feet (3'), but less than eight feet (8'), items "I.5" and "I.6" will not be included.

Well Abandonment with Casing in Place



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II. Abandonment procedure for open borehole or a well that *will* have its casing removed

1. Remove the well pedestal and concrete pad if applicable.
2. If this is not an open borehole, remove the casing.
3. If the well extends into the water table, measure the depth to the water table (DWT) and fill the well with 3/8 to 3/4 inch clean washed aggregate to three feet (3') above the measured water table. Prior to proceeding to "I-5", measure the DWT again to ascertain that the temporary rise of the water table within the casing has subsided below the elevation of the washed aggregate. If the well is completely within the vadose zone, proceed to item "II.4."
4. Provide a two-foot (2') bentonite plug by placing 3/4 inch bentonite chips in six-inch (6") lifts and hydrate each lift with potable water.
5. Fill the remaining portion with bentonite and cement slurry (30% of bentonite mix by volume) in 10-foot (10') lifts up to twenty-six feet (26') below the ground surface.
   a. After each 10-foot (10') lift, the hole shall be sounded to determine if ten feet (10) of the hole is actually filled with the bentonite/cement slurry by at least eight feet (8'). If the depth of the fill is greater than eight feet (8'), continue with the next ten-foot (10') lift of bentonite/cement slurry. If the depth of the fill is less than eight feet (8') (an indication that there is a cavity), go to "II.5.b." Otherwise, continue with item "II.5.a." When the bentonite/cement fill reaches a height of twenty-six feet (26') below the ground surface, go to item "II.6."
   b. Fill the next ten feet (10') with 3/8 to ¾ inch clean washed aggregate. Sound the hole to ensure that at least nine feet (9') has been filled with clean aggregate. If less than nine feet (9') is filled, repeat another ten-foot (10') lift of the washed aggregate until the sounding of the well/borehole reveals a rise of nine feet (9') or greater. Go to item "II.5.c."
   c. Provide a two-foot (2) bentonite plug above the clean aggregate by placing ¾ inch bentonite chips in six-inch (6") lifts and hydrate with potable water. Go to item "II.5.a."
6. Fill the next twenty feet (20') above the bentonite/cement fill with neat cement.
7. The remaining six feet (6') shall be filled with soil native to the site.

NOTES:

A. For wells with a DWT greater than thirty-one feet (31'), the total depth of bentonite/cement slurry fill for item "II.5" will be equal to DWT less thirty-one feet (31').

B. For shallow wells with a DWT greater than eleven feet (11'), but less than thirty-one feet (31') above the water table, item "II.5" will not be included.

C. For shallow wells with a DWT greater than nine feet (9'), but less than eleven feet (11') above the water table, items "II.5" and "II.6" will not be included.

D. For shallow wells with a DWT greater than three feet (3'), but less than nine feet (9'), items "II.4", "II.5" and "II.6" will not be included.

Abandonment with Casing Removed or of Bore Hole