Brown AND Caldwell

Prepared for
Guam Waterworks Authority

GUAM WATERWORKS AUTHORITY

Water Resources Master Plan Update

# Volume 2: Water System

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

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# Table of Contents

List of Appendices ........ vi
List of Tables ........ viii
List of Abbreviations ........ x
1. Introduction ........ 1-1
2. Existing Water Distribution System ........ 2-1
2.1 Facilities ........ 2-1
2.1.1 Other Island Water Systems ........ 2-7
2.2 Pressure Zones ........ 2-7
2.2.1 Pressure Reducing Valves ........ 2-7
2.2.2 Choked Valves ........ 2-7
2.3 Distribution System Piping ........ 2-8
2.4 Storage Tanks ........ 2-8
2.5 Booster Pump Stations ........ 2-10
3. Existing Water Supply Description ........ 3-1
3.1 Wells ........ 3-1
3.2 Ugum Surface Water Treatment Plant ........ 3-3
3.3 Springs ........ 3-4
3.4 Navy Water ........ 3-6
3.4.1 Fena Water Treatment Plant ........ 3-7
3.5 Demand Summary ........ 3-7
4. Hydraulic Model Development ........ 4-1
4.1 Model Development ........ 4-1
4.2 Demands ........ 4-1
4.2.1 Water Billing Data ........ 4-1
4.2.2 Water Billing Versus Production ........ 4-2
4.2.3 Future Service Population ........ 4-3
4.2.4 Model Demand Allocation ........ 4-3
4.2.5 Diurnal Pattern ........ 4-3
4.2.6 Demand Scenarios ........ 4-5
4.3 Calibration ........ 4-5
5. Supply Evaluation ........ 5-1
5.1 Supply Capacity Evaluation ........ 5-1
5.1.1 Available Supply ........ 5-1
5.1.2 Supply Versus Demand ........ 5-3
5.1.3 Comparison with 2006 ........ 5-4
5.1.4 New Well Development ........ 5-4

5.2 Well Condition Assessment ..... 5-6
5.2.1 National Enforcement Investigations Center Well Facility Deficiencies ..... 5-6
5.2.2 Well Condition ..... 5-7
5.2.3 Well Pump Motor Failures ..... 5-13
5.2.4 Chlorides ..... 5-13
5.2.5 Well Production Variances ..... 5-14
5.2.6 Wells to Abandon ..... 5-16
5.3 Ugum Surface Water Treatment Plant Condition Assessment ..... 5-17
5.3.1 Capacity ..... 5-17
5.3.2 Developments Since 2006 Master Plan ..... 5-18
5.3.3 Physical Conditions ..... 5-19
5.3.4 Ugum SWTP Future Projects ..... 5-23
5.4 Well Recommendations ..... 5-23
5.4.1 Recommendations for New Wells ..... 5-23
5.4.2 Recommendations for Existing Wells ..... 5-24
5.4.3 Wellhead Protection and Well Abandonment ..... 5-25
5.4.4 Well Maintenance Rig ..... 5-26
5.4.5 General Production Wells ..... 5-26
5.5 Ugum Surface Water Treatment Plant Recommendations ..... 5-27
5.5.1 General Recommendations ..... 5-27
5.5.2 Future Recommendations ..... 5-27
5.5.3 Operational Improvements ..... 5-28
6. Storage Evaluation ..... 6-1
6.1 Storage Tank Capacity Evaluation ..... 6-1
6.1.1 Evaluation Criteria ..... 6-1
6.1.2 Analysis ..... 6-1
6.1.3 Future Storage ..... 6-4
6.2 Storage Tank Condition Assessment ..... 6-4
6.3 Recommendations ..... 6-5
7. Booster Pump Station Evaluation ..... 7-1
7.1 Capacity Evaluation ..... 7-1
7.1.1 Criteria ..... 7-1
7.1.2 Location Analysis ..... 7-1
7.1.3 Capacity Analysis ..... 7-2
7.2 Condition Assessment ..... 7-9
7.2.1 Condition Assessment Field Work ..... 7-9
7.2.2 Risk Calculations ..... 7-10
7.2.3 Summary ..... 7-11
7.3 Recommendations ..... 7-12
8. Distribution System Evaluation ..... 8-1

8.1 Capacity Evaluation ....8-1
8.1.1 Criteria ....8-1
8.1.2 Pressure Zone Realignment Analysis ....8-1
8.1.3 Piping Capacity Analysis ....8-3
8.1.4 Fire Flow Analysis ....8-3
8.1.5 Water Age Analysis ....8-4
8.2 Pressure Reducing Valves Condition Assessment ....8-9
8.3 Isolation Valves ....8-9
8.4 Piping Condition Assessment and Ranking ....8-10
8.4.1 Calculation of Total Renewal Needs per Year ....8-11
8.4.2 Risk Calculations ....8-15
8.4.3 Initial Ranking of Water Lines for Inspection or Renewal ....8-17
8.5 Pipeline Renewal Needs Analysis ....8-21
8.5.1 Candidate Project Areas ....8-21
8.5.2 Overall Renewal Recommendations ....8-25
8.5.3 Small Diameter and Asbestos Cement Pipe Replacement ....8-28
8.6 Recommendations ....8-29
8.6.1 Pressure Zone Realignment ....8-29
8.6.2 Piping Improvements ....8-29
8.6.3 Piping Condition Improvements ....8-32
8.6.4 Pressure Reducing Valves ....8-32
8.6.5 Valve Exercise and Maintenance ....8-32
9. Water Loss Control ....9-1
9.1 Water Loss Reduction and Prioritization ....9-1
9.1.1 2011–13 Leak Detection Program ....9-1
9.1.2 2013–15 Leak Detection Program ....9-4
9.1.3 Planned Leak Detection Program ....9-4
9.1.4 Repair Crews ....9-4
9.1.5 Line-Locating Program ....9-5
9.2 Water Meters ....9-5
9.2.1 Navy Source Meters ....9-5
9.2.2 GWA Master Meters ....9-6
9.2.3 GWA Water Production Meters ....9-6
9.2.4 GWA Residential/Commercial Meters ....9-6
9.3 Navy Water Purchases ....9-7
9.4 Non-Revenue Water ....9-7
9.4.1 Well H01 Production Versus Billing Data ....9-8
9.5 Recommendations ....9-9
9.5.1 Leak Detection and Repair ....9-9
9.5.2 Line Locating Crew ....9-9

9.5.3 Meter Calibration....9-9
9.5.4 Other Recommendations.... 9-10
10. Fire Hydrants.... 10-1
10.1 Condition Assessment.... 10-1
10.2 Repair and Replacement Program.... 10-2
10.2.1 Repair and Replacement Decision Making Process.... 10-3
10.3 Repair and Replacement Plan.... 10-4
10.4 Other Recommendations.... 10-5
10.4.1 Unique Identification.... 10-5
10.4.2 Color Coding.... 10-5
10.4.3 Other Notes.... 10-6
10.5 Recommendations.... 10-7
11. General System Recommendations.... 11-1
11.1 System-Wide Recommendations.... 11-1
11.1.1 OneGuam Analysis.... 11-1
11.1.2 2006 WRMP Recommended Projects.... 11-2
11.1.3 Property Ownership.... 11-2
11.1.4 Backflow Prevention and Cross Connection Control Program.... 11-2
11.2 Projects Summary.... 11-3
11.3 Project Rankings.... 11-6
12. Recommended Project Sheets.... 12-1
12.1 Pipeline Projects.... 12-2
12.2 Storage Tank Projects.... 12-20
12.3 Booster Pump Station Projects.... 12-44
12.4 Water Production Projects.... 12-48
12.5 Other Water Projects.... 12-60
13. References.... 13-1

# List of Appendices

Appendix A. Tank Photos....A-1
Appendix B. Booster Pump Station Photos.... B-1
Appendix C. Well Details....C-1
Appendix D. Model Development Notes.... D-1
Appendix E. Water Distribution System Evaluation/Design Criteria....E-1
Appendix F. Pipe Condition Assessment Data....F-1
Appendix G. Water Distribution System Recommendations.... G-1
Appendix H. Water Distribution System Recommendation Details.... H-1

Appendix I. Hydrant Condition Assessment Data ..... I-1
Appendix J. Wells to Abandon ..... J-1

## List of Figures

Figure 2-1. Water System Supply ..... 2-2
Figure 2-2. Water Distribution System (North) ..... 2-3
Figure 2-3. Water Distribution System (South and Central) ..... 2-4
Figure 2-4. Water Distribution System Hydraulic Schematic (North) ..... 2-5
Figure 2-5. Water Distribution System Hydraulic Schematic (South and Central) ..... 2-6
Figure 3-1. Typical Well Site ..... 3-2
Figure 3-2. Raw Water Pump Station ..... 3-4
Figure 3-3. Santa Rita Spring Tank and Booster Pump Building (left) and Pumps (right) ..... 3-5
Figure 3-4. Asan Spring Reservoir ..... 3-5
Figure 3-5. Total Daily Water Production for 2012 through 2016 ..... 3-8
Figure 3-6. Ugum SWTP Water Daily Production for 2012 through 2016 ..... 3-9
Figure 4-1. Diurnal Pattern ..... 4-4
Figure 5-1. Projected Demand Versus Available Supply ..... 5-4
Figure 5-2. Dam with Stop Logs in Place (left) and Intake Screen (right) ..... 5-20
Figure 5-3. Membrane Basin ..... 5-21
Figure 5-4. Extents of Reservoir on Ugum River with Dam at 45-foot Elevation ..... 5-22
Figure 5-5. Pump Station on the Talofofo River ..... 5-23
Figure 7-1. Profile of Piping from Yigo Tanks to Gayinero to Santa Rosa Tank ..... 7-3
Figure 7-2. Profile of Route 15 With and Without Proposed BPS ..... 7-4
Figure 7-3. Profile of Nimitz Hill Piping ..... 7-5
Figure 8-1. Fire Flow Analysis (North) ..... 8-5
Figure 8-2. Fire Flow Analysis (South and Central) ..... 8-6
Figure 8-3. Water Age Analysis (North) ..... 8-7
Figure 8-4. Water Age Analysis (South and Central) ..... 8-8
Figure 8-5. Diagram of the Approach to Ranking Water Piping ..... 8-10
Figure 8-6. Pipeline Renewal Needs by Year ..... 8-14
Figure 8-7. Likelihood and Consequence of Failure Results by Risk Category ..... 8-18
Figure 8-8. Risk Category Summary (North) ..... 8-19
Figure 8-9. Risk Category Summary (South and Central) ..... 8-20

Figure 8-10. Candidate Project Areas (North) ..... 8-23
Figure 8-11. Candidate Project Areas (South and Central) ..... 8-24
Figure 8-12. Proposed Water Distribution System (North) ..... 8-35
Figure 8-13. Proposed Water Distribution System (South and Central) ..... 8-36
Figure 8-14. Proposed Water Distribution System Hydraulic Schematic (North) ..... 8-37
Figure 8-15. Proposed Water Distribution System Hydraulic Schematic (South and Central) ..... 8-38
Figure 9-1. Location of Pinpointed Leaks (2011–2013) ..... 9-3
Figure 10-1. Fire Hydrant with Painted ID ..... 10-5
Figure 10-2. Fire Hydrant Color Coded by Fire Flow ..... 10-6

# List of Tables

Table 2-1. Distribution System Pipe Material Summary ..... 2-8
Table 2-2. Active Storage Tanks ..... 2-9
Table 2-3. Active Booster Pumps ..... 2-10
Table 3-1. Navy Connections to GWA ..... 3-6
Table 3-2. 2012 through 2016 Demand Summary ..... 3-8
Table 4-1. Number and Type of GWA Customers ..... 4-2
Table 4-2. Water Production Versus Billing Data ..... 4-2
Table 4-3. Model Demand Summary ..... 4-3
Table 4-4. Diurnal Pattern Peaking Factors ..... 4-4
Table 5-1. Available Supply ..... 5-2
Table 5-2. Available Versus Required Supply ..... 5-3
Table 5-3. New Production Well Requirements to 2035 ..... 5-5
Table 5-4. Well Recommended Improvements ..... 5-8
Table 5-5. Wells with High Chloride Levels ..... 5-14
Table 5-6. Wells with Large Difference Between Permitted and Actual Flows ..... 5-14
Table 5-7. Wells to Abandon or That Have been Abandoned ..... 5-16
Table 6-1. Storage Analysis ..... 6-2
Table 6-2. Storage Tank Summary with Recommendations ..... 6-5
Table 7-1. BPS Analysis ..... 7-7
Table 7-2. BPSs to be Renewed ..... 7-9
Table 7-3. Likelihood of Failure Factors ..... 7-10
Table 7-4. Consequence of Failure Factors ..... 7-10

Table 7-5. BPS Renewal Prioritization ........ 7-11
Table 7-6. BPS Recommendations ........ 7-12
Table 8-1. Fire Flow Analysis Summary ........ 8-4
Table 8-2. Length of Piping Installed by Decade ........ 8-11
Table 8-3. Pipe Service Life Values ........ 8-12
Table 8-4. Length of Piping to Renew by Decade ........ 8-13
Table 8-5. Likelihood of Failure Factors ........ 8-15
Table 8-6. Consequence of Failure Factors ........ 8-16
Table 8-7. Failure Summary ........ 8-17
Table 8-8. Risk Summary ........ 8-17
Table 8-9. Candidate Projects for Water Pipeline Rehabilitation and Replacement ........ 8-21
Table 8-10. Rehabilitation and Replacement Costs by Risk Category ........ 8-25
Table 8-11. Water Line Renewal Scenarios Cost and Timeframe Summary ........ 8-26
Table 8-12. Candidate Project Budgetary Cost Estimates for Pipeline Rehabilitation and Replacement ........ 8-27
Table 8-13. Total Remaining 2-Inch and AC Pipes ........ 8-28
Table 8-14. Candidate Project Areas with 2-Inch and AC Pipes ........ 8-28
Table 8-15. Recommended Piping Projects ........ 8-29
Table 9-1. Summary of Pinpointed Leaks (2011 – 2013) ........ 9-2
Table 9-2. Water System Audit Results (February 2015 – January 2016) (MG/year) ........ 9-7
Table 10-1. Village and Fire Hydrant Assessment Scores ........ 10-1
Table 10-2. FHRP Program Recommendations and Status ........ 10-3
Table 10-3. Color Scheme to Indicate Flow Capacity ........ 10-5
Table 11-1. Water System Improvements Projects with Estimated Costs ........ 11-3
Table 11-2. Water System Improvements Projects Ranking ........ 11-7

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# List of Abbreviations

| | |
|---|---|
| AC | asbestos cement |
| ADD | average day demand |
| AFB | Air Force Base |
| ARRA | American Reinvestment and Recovery Act |
| AWWA | American Water Works Association |
| BC | Brown and Caldwell |
| BPS | booster pump station |
| CCU | Consolidated Commission on Utilities |
| CIP | Capital Improvement Plan/Program |
| CMMS | computerized maintenance management system |
| DMA | district metered area |
| DoD | Department of Defense |
| DWSAP | Drinking Water Source Assessment and Protection |
| EPA | Environmental Protection Agency |
| EPS | extended period simulation |
| FHRP | Fire Hydrant Replacement and Repair Program |
| GAC | granular activated carbon |
| GAR | Guam Administrative Rules and Regulations |
| GFD | Guam Fire Department |
| GIAA | Guam International Airport Authority |
| GIS | geographic information system |
| GPA | Guam Power Authority |
| gpm | gallons per minute |
| GWA | Guam Waterworks Authority |
| HGL | hydraulic grade line |
| hp | horsepower |
| IFC | International Fire Code |
| kgal | thousands of gallons |
| LIDAR | Light Detection and Ranging |
| MCC | motor control center |
| MCL | maximum contaminant level |
| MDD | maximum day demand |
| MG | million gallons |
| mgd | million gallons per day |
| mg/L | milligrams per liter |
| NEIC | National Enforcement Investigations Center |
| NFPA | National Fire Protection Agency |
| NGLA | Northern Guam Lens Aquifer |
| NPDES | National Pollutant Discharge Elimination System |
| NRW | non-revenue water |
| NTU | Nephelometric Turbidity Units |
| O&M | operations and maintenance |
| PCE | perchloroethylene |
| PDT | Pressure Decay Test |
| PFOA | perfluorooctanoic acid |
| PFOS | perfluorooctyl sulfonate |
| PHD | peak hour demand |
| PRV | pressure reducing valve |
| psi | pounds per square inch |
| PVC | polyvinyl chloride |
| QAPP | Quality Assurance Project Plan |
| rpm | revolutions per minute |
| SCADA | supervisory control and data acquisition |
| SCC | System Control Center |
| SDWA | Safe Drinking Water Act |
| SOP | standard operating procedure |
| SRF | State Revolving Fund |
| SWTP | surface water treatment plant |
| TM | technical memorandum |
| USEPA | U.S. Environmental Protection Agency |
| UV | ultraviolet |
| VFD | variable frequency drive |
| WERI | Water and Environmental Research Institute of the Western Pacific at the University of Guam |
| WHPP | Wellhead Protection Plan |
| WRMP | Water Resources Master Plan |
| WRMPU | 2016 Water Resources Master Plan Update |
| WSA | water service area |
| WSS | Water System Standards (State of Hawaii) |
| WTP | water treatment plant |
| WWTP | wastewater treatment plant |

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## Section 1

# Introduction

This volume is the second of three volumes for the Guam Waterworks Authority (GWA) Water Resources Master Plan Update (WRMPU). This volume describes the island's water system facilities, an analysis of the water system, and outlines recommendations for improvements to the water system. This volume includes the following sections:

- **Section 2, Existing Water Distribution System:** describes existing water distribution system facilities.
- **Section 3, Existing Water Supply Description:** describes existing source water supplies.
- **Section 4, Hydraulic Model Development:** describes the computer model of the water distribution system.
- **Section 5, Supply Evaluation:** describes an evaluation of the capacity and condition of the water supply.
- **Section 6, Storage Evaluation:** describes an evaluation of the capacity and condition of the storage tanks.
- **Section 7, Booster Pump Station Evaluation:** describes an evaluation of the capacity and condition of the booster pump stations (BPSs).
- **Section 8, Distribution System Evaluation:** describes an evaluation of the capacity and condition of the distribution system piping and pressure zones.
- **Section 9, Water Loss Control:** discusses leak detection, line locating, metering, and non-revenue water.
- **Section 10, Fire Hydrants:** discusses an analysis of GWA's fire hydrants.
- **Section 11, General System Recommendations:** describes general recommendations for the water system.
- **Section 12, Recommended Project Sheets:** contains detailed sheets for each recommended improvement project.

Information detailing the history, occurrence, quality, and use of potable water resources by GWA can be found in Volume 1, Section 5 (Source Water). Issues influencing long-range planning, water policy, conservation strategy, and resource protection are also discussed in Volume 1, Section 5.

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## Section 2

# Existing Water Distribution System

This section describes GWA's existing water distribution system facilities.

## 2.1 Facilities

GWA provides potable water service to most of the island's civilian population of approximately 164,900 residents, with approximately 47,800 customer connections as of January 2016. GWA's water system facilities include the following:

- **Piping:** GWA's distribution system consists of approximately 586 miles of piping, ranging in diameter from 2 to 24 inches. The piping is primarily polyvinyl chloride (PVC) but includes several other pipe materials.
- **Valves:** the water system includes control valves used to separate service areas. The control valves include pressure reducing valves (PRVs) and choked (partially closed) isolation valves.
- **Storage tanks:** the water system has 26 active storage tanks with approximately 30.2 million gallons (MG) of total capacity.
- **Booster pump stations:** the water system includes 27 major BPSs.
- **Supply sources:** supply sources include 120 active groundwater wells, the Ugum Surface Water Treatment Plant (SWTP), and one active spring.

GWA's water system includes the following areas, as shown in Figure 2-1:

1. **North:** the North (brown) area is supplied by groundwater wells located in the North, where most of Guam's population lives.
2. **Central:** the Central (green) area is served from the Brigade BPS, which is usually supplied by groundwater from the north. The BPS can also be configured to pump Ugum SWTP water from the south. Some customers within the Central area are served by a spring and U.S. Department of the Navy (Navy) water.
3. **South:** the South (blue) area is usually served from the Ugum SWTP. If the Ugum SWTP is offline, this area can be served from the Brigade BPS with groundwater from the north.
4. **Nimitz:** the Nimitz (purple) areas are supplied by the Navy.

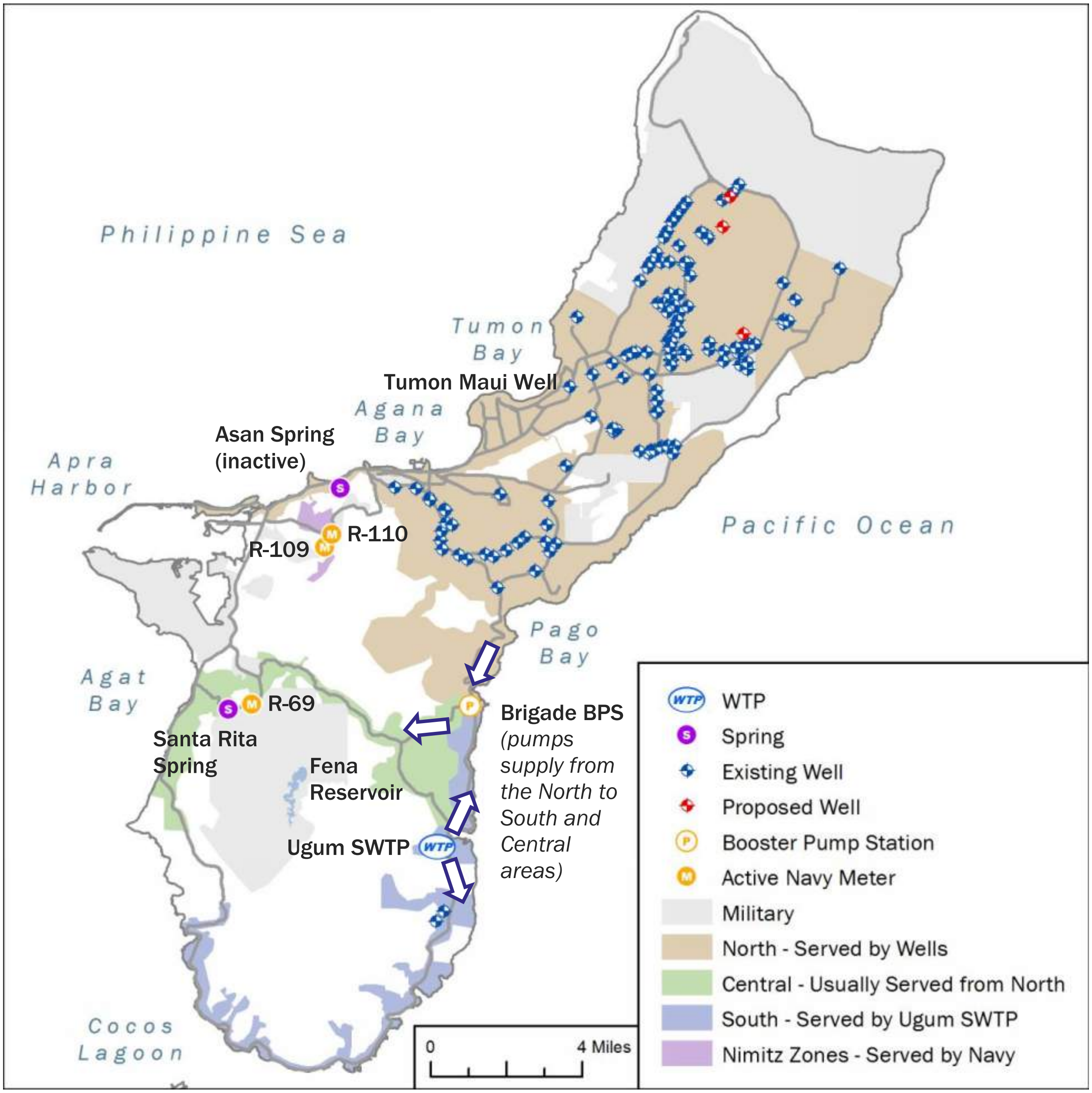


**Figure 2-1. Water System Supply**

The following figures show the GWA water system in more detail:

- **Figure 2-2 and Figure 2-3:** these figures show the location of GWA's water system facilities, including the facilities listed above.
- **Figure 2-4 and Figure 2-5:** these figures are hydraulic schematics of the water system that illustrate the relationship between supply, pumping, and storage facilities. Storage tanks and the areas they serve are illustrated relative to their actual elevations. Other facilities including BPSs, wells, valves, and piping are not shown at their actual elevations.

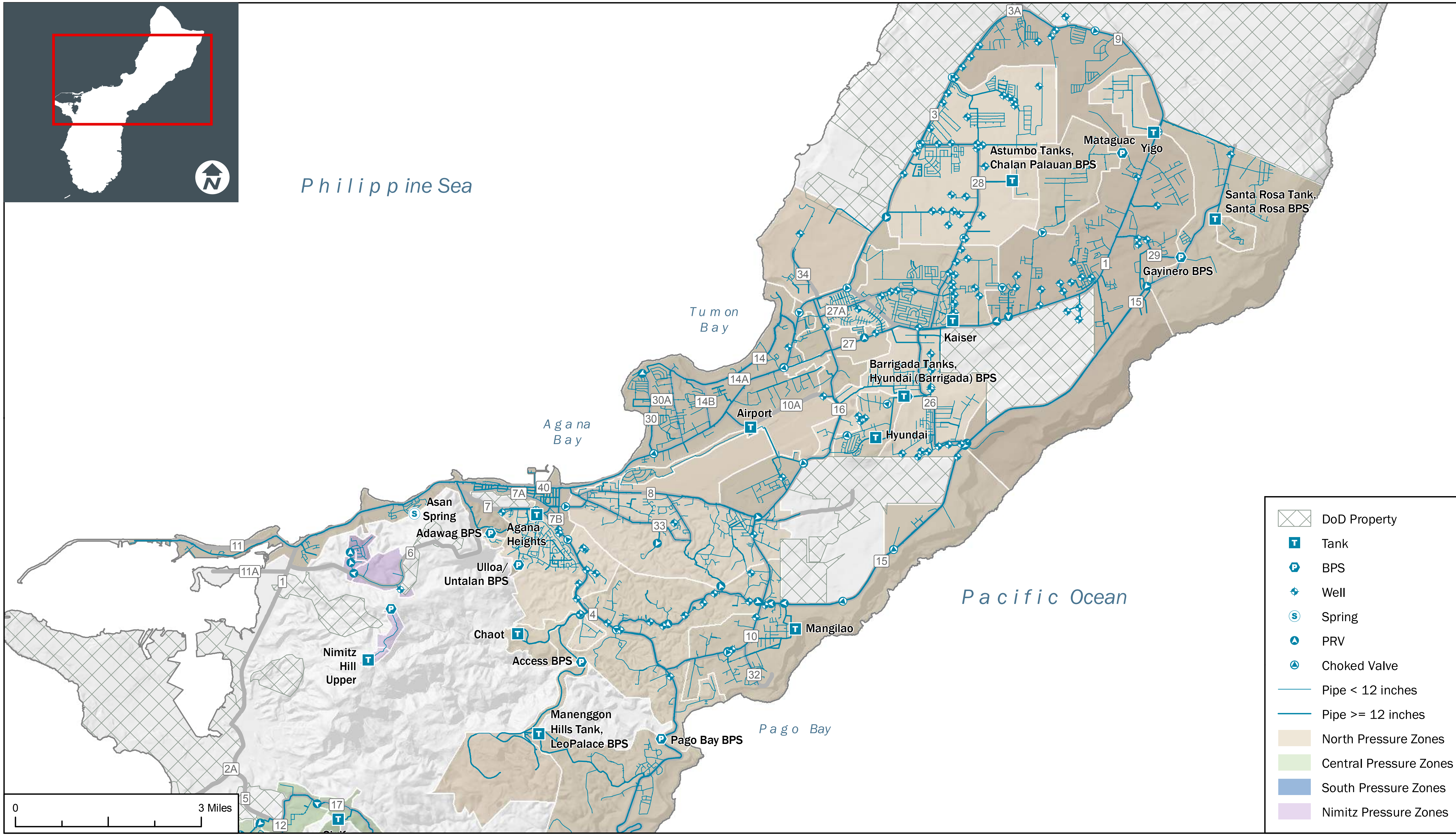


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**Figure 2-2. Water Distribution System (North)**

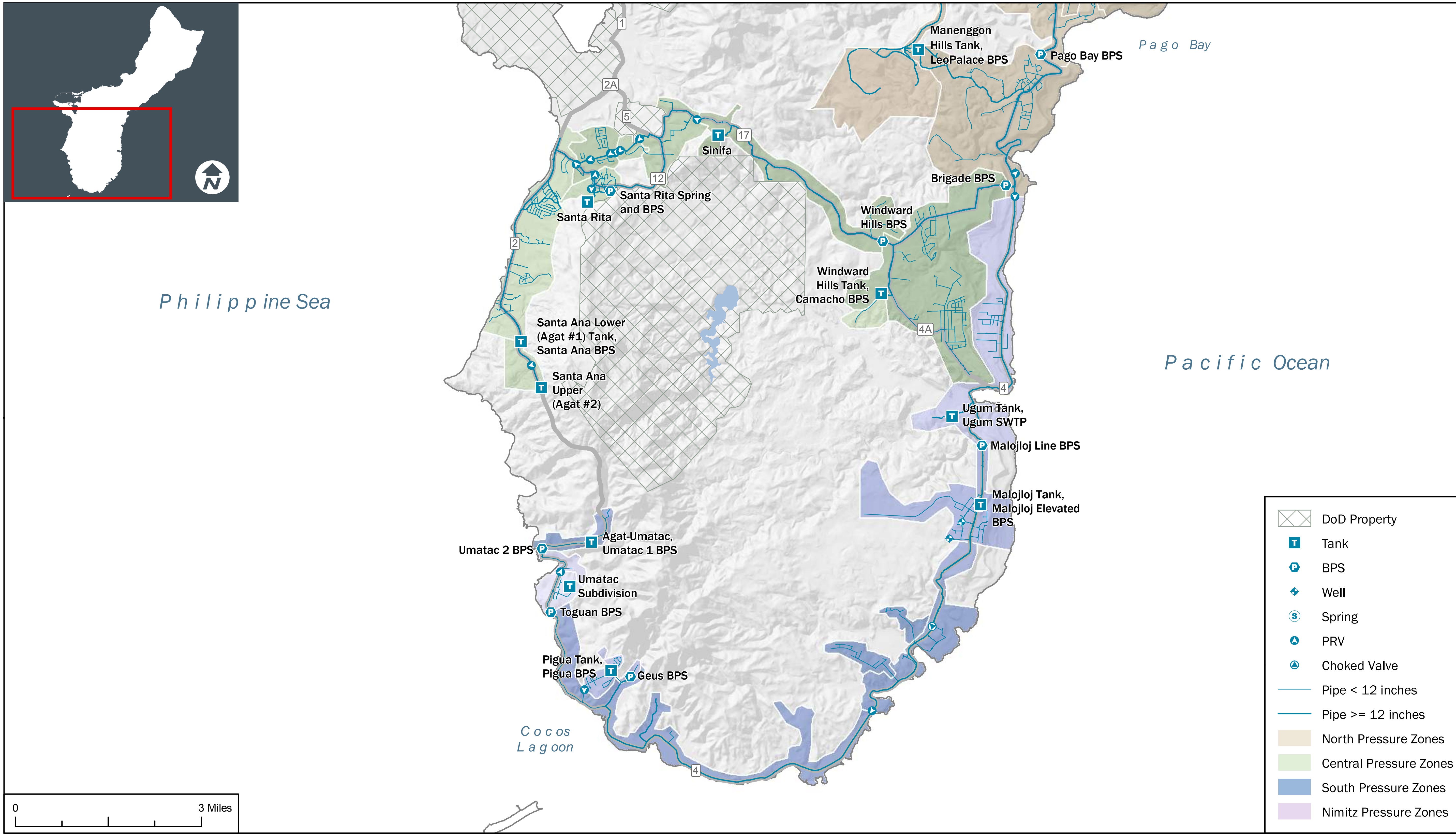


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Figure 2-3. Water Distribution System (South and Central)

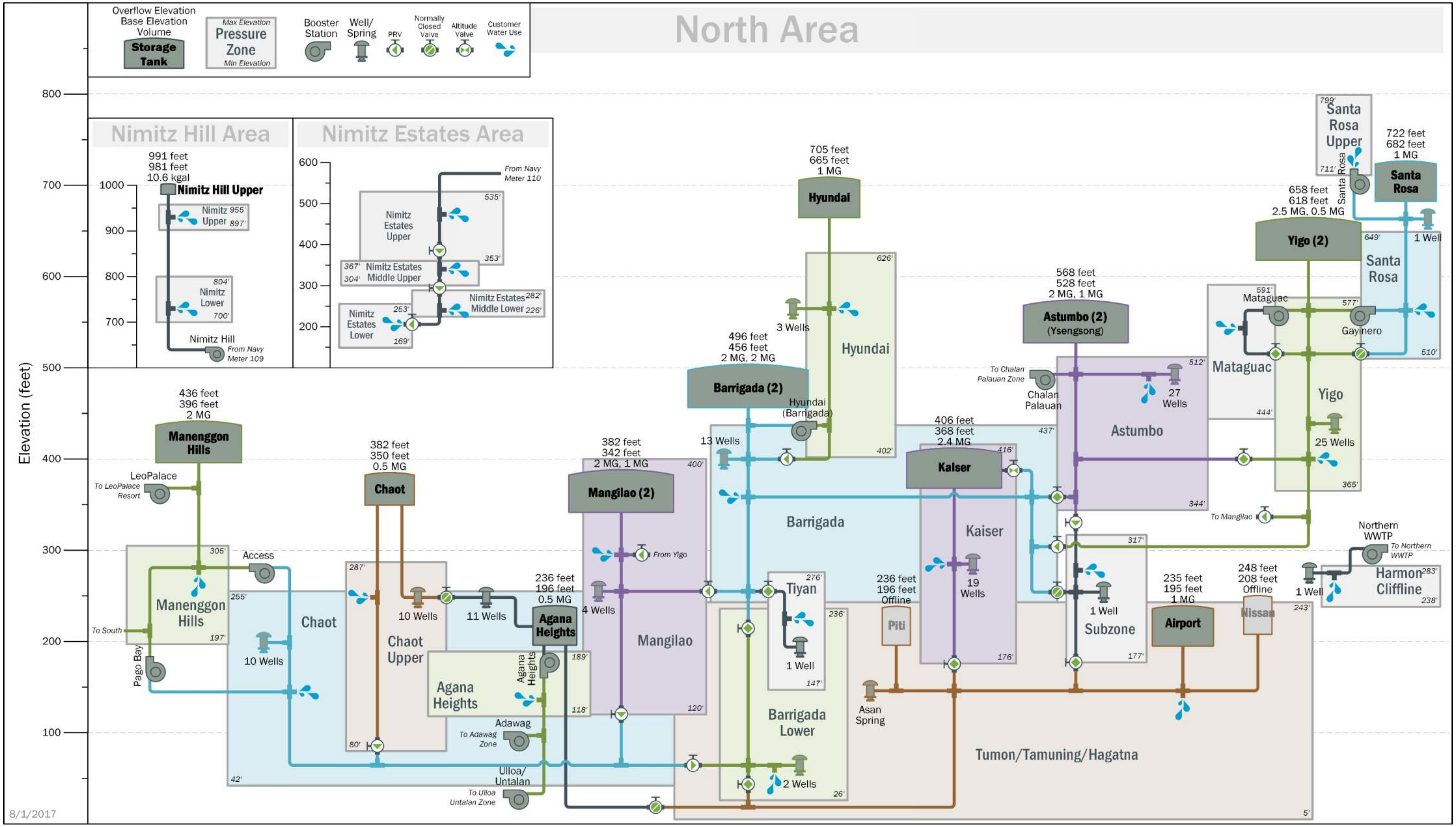


Figure 2-4. Water Distribution System Hydraulic Schematic (North)

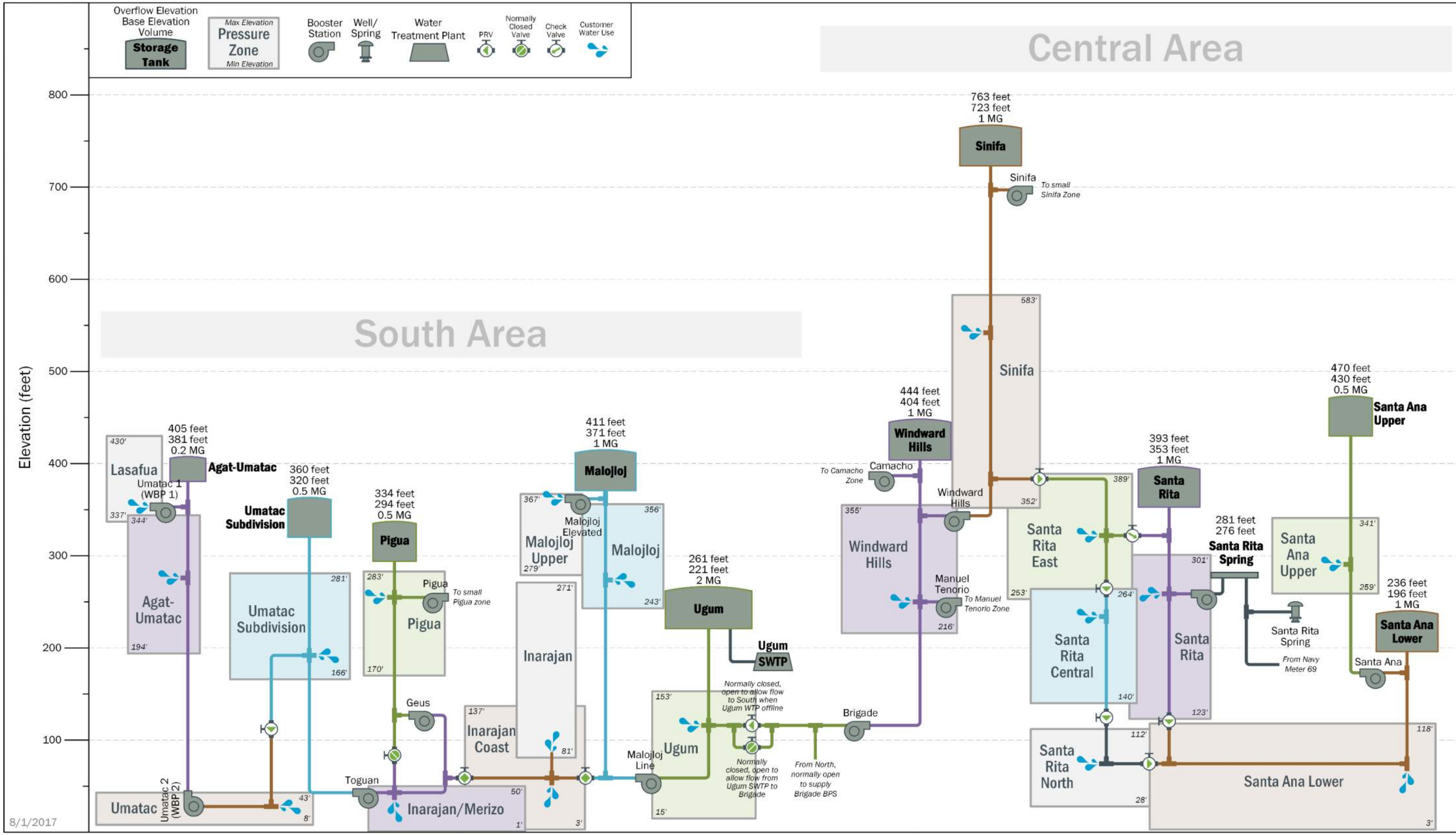


Figure 2-5. Water Distribution System Hydraulic Schematic (South and Central)

### 2.1.1 Other Island Water Systems

Other major water systems on the island include the following:

- **Andersen Air Force Base water system:** the Andersen Air Force Base (AFB) water system serves the main base and Northwest Field. This water system is supplied by wells in the main base, Northwest Field, and Andersen South.
- **Navy water system:** the Navy water system serves Naval Base Guam, several Navy annexes across the island, and some GWA customers, as discussed in Section 3.4. The water system is supplied by Navy wells in the north, water from the Fena Reservoir, and Navy springs in the south.
- **A.B. Won Pat International Airport water system:** the Guam International Airport Authority (GIAA) owns the water system serving the airport, which GWA operates under an agreement with GIAA. The airport is supplied by three wells located at the airport. The airport also has a 1.5-MG tank and BPS.

## 2.2 Pressure Zones

The water distribution system is divided into pressure zones, which are separated by BPSs, pressure reducing valves (PRVs), closed valves, and choked valves. Figures 2-2 through 2-5 show these pressure zones as shaded areas. Each pressure zone is named after the storage tank(s) serving the zone or the name of the municipality or village the zone serves (e.g. the Yigo zone predominately serves the Yigo municipality and is served by the Yigo tanks, the Hyundai zone is served by the Hyundai tank, etc.).

### 2.2.1 Pressure Reducing Valves

The water distribution system includes approximately 38 PRV vaults (not including small PRVs to serve one or a few customers). Each vault includes one, two, or three PRVs. Some PRVs are operational, some are abandoned, some are bypassed, and the condition of others is unknown. Each PRV was surveyed in 2014; however, the operational status of some PRVs could not be determined at that time (for example, ports were not available at some PRVs to check pressures across the PRV). Figure 2-2 and Figure 2-3 show the locations of the PRVs.

### 2.2.2 Choked Valves

Choked valves are isolation valves that have been partially closed by operations staff. Valves are choked for the following reasons:

- **To reduce pressures in an area:** some valves are choked to perform a similar function as PRVs by reducing pressure. GWA would like to eventually eliminate choked valves and add PRVs to improve operations with improved and more consistent control of pressures. A plan for installing PRVs to define all pressure zone boundaries is explained in Section 8.6.
- **To prevent storage tanks from emptying:** some valves are choked to help keep storage tanks from draining.
- **To maintain pressure in an area:** some valves are choked to keep pressures from dropping too low in an area.
- **For unknown reasons:** some valves were choked in the past for various, currently unknown reasons. GWA periodically discovers and opens these choked valves, which has improved operation of the water system in those areas.

Operations staff maintain a list of choked valves that have been partially closed to maintain system pressures and tank levels. Figure 2-2 and Figure 2-3 show the locations of these choked valves.

## 2.3 Distribution System Piping

The distribution system includes approximately 586 miles of piping with diameters ranging from 2 to 24 inches. As a comparison, the total length of modeled piping in the 2006 Water Resources Master Plan (WRMP) was 462 miles. This increase in piping is primarily due to a more comprehensive database of pipes in the GWA geographic information system (GIS).

Most piping is PVC (about 62 percent), and the most common pipe in the system is 6-inch PVC (approximately 27 percent of total piping). Table 2-1 lists the length of piping by diameter and material. Figure 2-2 and Figure 2-3 show the locations of the piping listed in the table.

**Table 2-1. Distribution System Pipe Material Summary**

| Diameter (inches) | Length by Material (feet) | | | | | | | Total (feet) | Percent of Length |
|---|---|---|---|---|---|---|---|---|---|
| | Asbestos Cement | Cast Iron | Ductile Iron | Galvanized | PVC | Steel | Unknown | | |
| 2 | 11 | 7,158 | 200 | 1,176 | 33,239 | - | 36,876 | *78,661* | *3%* |
| 4 | 3,878 | 2,400 | 12,818 | - | 46,982 | - | 7,653 | *73,731* | *2%* |
| 6 | 76,059 | 31,146 | 19,067 | 598 | 843,568 | - | 188,465 | *1,158,904* | *37%* |
| 8 | 47,150 | 40,072 | 34,947 | - | 338,041 | 304 | 90,177 | *550,691* | *18%* |
| 10 | 4,566 | 7,798 | 11,132 | - | 20,536 | - | 11,071 | *55,103* | *2%* |
| 12 | 28,000 | 121,262 | 66,652 | - | 533,757 | - | 87,540 | *837,211* | *27%* |
| 14 | - | 18,712 | 13 | - | 10,954 | - | - | *29,679* | *1%* |
| 16 | 2,284 | 10,416 | 135,504 | - | 49,088 | - | 17,758 | *215,050* | *7%* |
| 18 | - | 419 | 2,986 | - | 8,829 | - | 26 | *12,261* | *0%* |
| 20 | - | - | 28,062 | - | 3,137 | - | 876 | *32,075* | *1%* |
| 24 | 119 | - | 25,596 | - | 15,689 | - | 10,504 | *51,907* | *2%* |
| **Total (feet)** | **162,068** | **239,384** | **336,978** | **1,774** | **1,903,819** | **304** | **450,947** | **3,095,273** | **100%** |
| **Total (miles)** | **30.7** | **45.3** | **63.8** | **0.3** | **360.6** | **0.1** | **85.4** | **586.2** | **100%** |
| **Percent of Length** | **5%** | **8%** | **11%** | **<1%** | **62%** | **<1%** | **15%** | **100%** | |

## 2.4 Storage Tanks

As of January 2017, GWA's water system had 26 active storage tanks with a total storage volume of 30.2 MG. GWA is currently rehabilitating and replacing existing storage tanks and designing new storage tanks. As of the 2006 WRMP, the system had 27 active tanks with a total storage of 30.4 MG. Since the 2006 WRMP, 14 of those tanks have been replaced or are planned for replacement with either new storage tanks or new pumping to replace the tanks. One of the tanks has been repaired and several other tanks that were out of service in 2006 have been repaired or replaced. There are also plans for several new tanks. Planned changes to storage tanks are discussed in Section 6.

The tanks provide storage to serve daily fluctuations in demand (equalization storage), fire flow storage, and emergency storage. Table 2-2 summarizes the storage facilities as of January 2017, not including tanks that have been abandoned. Appendix A contains a photograph of each storage tank.

**Table 2-2. Active Storage Tanks**

| Name | Volume | | Year Constructed (major repair) [b] | Material | Floor Elevation (feet) | Height (floor to overflow, feet) | Diameter (feet) | Source of Dimensions/ Elevations [c] |
|---|---|---|---|---|---|---|---|---|
| | Nominal (MG) | Actual (gallons) [a] | | | | | | |
| North | | | | | | | | |
| Agana Heights | 0.5 | 519,000 | 2016 | Concrete | 196 | 40 | 47 | Drawings |
| Airport | 1 | 1,024,000 | 1969 | Steel | 195 | 40 | 66 | GWA |
| Astumbo #1 | 1 | 1,024,000 | 1969 | Steel | 527.5 | 40 | 66 | Dimensions from GWA, elevation from drawings |
| Astumbo #2 | 2 | 2,011,000 | 1995 | Steel | 527.5 | 40 | 92.5 | Dimensions from GWA, elevation from drawings |
| Barrigada #1 | 2 | 2,011,000 | 2013 | Concrete | 456.43 | 40 | 92.5 | Drawings |
| Barrigada #2 | 2 | 2,011,000 | 2015 | Concrete | 456.43 | 40 | 92.5 | Drawings |
| Chaot #1 | 0.5 | 518,000 | 2016 | Concrete | 349.5 | 32 | 52.5 | Drawings |
| Hyundai | 1 | 1,024,000 | 1973 | Steel | 664.67 | 40 | 66 | Drawings for new neighboring tank |
| Kaiser | 2.5 | 2,364,000 | 1992 | Steel | 368 | 37.8 | 103.2 | GWA |
| Manenggon Hills | 2 | 2,011,000 | 1992 | Steel | 395.99 | 40 | 92.5 | Dimensions from GWA, elevation from drawings |
| Mangilao #1 | 1 | 1,024,000 | 2009 (2016) | Steel | 341.6 | 40 | 66 | GWA |
| Mangilao #2 | 2 | 2,011,000 | 1991 (2015) | Steel | 341.6 | 40 | 92.5 | GWA |
| Nimitz Hill Upper | 0.01 | 10,600 | 1981 | Steel | 981 | 10 | Varies | GWA |
| Santa Rosa | 1 | 1,024,000 | 1980 | Steel | 682.4 | 40 | 66 | Drawings for new neighboring tank |
| Yigo #1 | 0.5 | 541,000 | 1969 | Steel | 618 | 40 | 48 | Dimensions from GWA, elevation from drawings |
| Yigo #2 | 2.5 | 2,527,000 | 1995 | Steel | 618 | 40 | 103.7 | Dimensions from GWA, elevation from drawings |
| South | | | | | | | | |
| Agat-Umatac | 0.2 | 200,000 | Unknown | Steel | 380.75 | 24 | 37.7 | GWA |
| Malojloj | 1 | 1,000,000 | 1989 | Steel | 370.7 | 40 | 65.2 | GWA |
| Pigua | 0.5 | 500,000 | 1969 | Steel | 294 | 40 | 46.1 | GWA |
| Santa Ana Lower | 1 | 1,024,000 | 1997 | Steel | 196 | 40 | 66 | GWA |
| Santa Ana Upper | 0.5 | 500,000 | 1995 (2012) | Steel | 430 | 40 | 46.1 | GWA |

| Table 2-2. Active Storage Tanks | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Name | Volume | | Year Constructed (major repair) [b] | Material | Floor Elevation (feet) | Height (floor to overflow, feet) | Diameter (feet) | Source of Dimensions/ Elevations [c] |
| | Nominal (MG) | Actual (gallons) [a] | | | | | | |
| Santa Rita | 1 | 1,024,000 | 1981 | Steel | 352.79 | 40 | 66 | Drawings for new neighboring tank |
| Sinifa | 1 | 1,024,000 | 1983 | Steel | 723.08 | 40 | 66 | Drawings for new neighboring tank |
| Ugum | 2 | 2,011,000 | 1991 | Steel | 220.89 | 40 | 92.5 | Drawings for new neighboring tank |
| Umatac Subdivision | 0.5 | 500,000 | 1977 | Steel | 320 | 40 | 46.1 | GWA |
| Windward Hills #2 | 1 | 1,024,000 | 1974 | Steel | 404 | 40 | 66 | GWA |

*a. Actual volume was calculated from tank dimensions listed in this table.*

*b. The year that the tank had a major repair or rehabilitation is shown in parenthesis.*

*c. Data sources listed in the table include the following: Drawings = Drawings for the tank; Drawings for replacement tank = Drawings for a new tank that will be constructed nearby and the drawing showed this tank; GWA = Data provided by GWA in a spreadsheet; Dimensions from GWA, elevation from drawings = Dimensions provided by GWA in a spreadsheet, floor elevation obtained from drawings for a new tank that will be constructed nearby.*

## 2.5 Booster Pump Stations

Table 2-3 lists the pumps at each major BPS as of January 2017. Appendix B contains photographs of each BPS.

| Table 2-3. Active Booster Pumps | | | | | | | |
|---|---|---|---|---|---|---|---|
| BPS Name | Pump Number | Manufacturer | Model | Design Head (feet) | Design Flow (gpm) | Source of Information | Notes from Site Visits |
| Access | 1, 2 | Grundfos | CR120-3-2 | 256.9 | 634 | June 2016 site visit | Pump 3 not operational, GWA to remove pump completely |
| Agana Heights | 1, 2, 3 | Grundfos | CR120-3-2 | 116 | 567 | Drawings dated February 19, 2015 | |
| Brigade | 1, 2, 3 | Grundfos | CR120-3-2 | 256.9 | 634 | June 2016 site visit | |
| Gayinero | 1, 2 | Grundfos | CR64-2-1 | 176.5 | 339 | June 2016 site visit | |
| Geus | 1, 2 | Grundfos | CR45-3-1 | 264.4 | 238 | June 2016 site visit | |
| Hyundai (Barrigada) | 1, 2 | Grundfos | CR 90-3-2 | 251.6 | 476 | 2012 site visit | BPS only used for emergencies, to be renamed Barrigada BPS |
| Malojloj Elevated | 1 | Aurora | 382B DF | 80 | 250 | 2012 site visit | |
| | 2 | Aurora | No tag on pump | | | | |
| | 3 | Aurora | 382A BF | 80 | 250 | | |
| Malojloj Line | 1, 2 | Paco | 6019-7/8 KPV | 222 | 1600 | Pump transmittal dated June 4, 2015 | |
| | 3 | Paco | 3095-7/8 KPV | 230 | 500 | | |
| Mataguac | 2, 3 | Sulzer | 321098 | 216 | 300 | June 2016 site visit | Pump 1 not installed |

Brown AND Caldwell

**Table 2-3. Active Booster Pumps**

| BPS Name | Pump Number | Manufacturer | Model | Design Head (feet) | Design Flow (gpm) | Source of Information | Notes from Site Visits |
|---|---|---|---|---|---|---|---|
| Nimitz Hill | 1, 2 | Grundfos | CR5-18 | 440.3 | 30 | June 2016 site visit | |
| Pago Bay | 1, 2 | Paco | 6019-7/8 KP | 250 | 1800 | Pump transmittal dated June 4, 2015 | |
| | 3 | Paco | 4012-1/2 KP | 275 | 850 | | |
| Santa Ana | 1 | Grundfos | CR45-3-1 | 264.4 | 238 | June 2016 site visit | Pump 2 not operational, GWA plans to replace with same type as pump 1 |
| | 2 | Not operational, to be replaced | | | | | |
| Santa Rita Spring | 1 | Peerless | | 140 | 650 | June 2016 site visit | Pump 2 is a temporary submersible pump installed while fixing pump 2, which is same type as pump 1 |
| | 2 | Temporary submersible pump | | | | | |
| Santa Rosa | 1 | Grundfos | CR64-2-1 | 176.3 | 389 | 2012 field data | |
| | 2 | No tag on pump | | | | | |
| Toguan | 1 | Grundfos | CR32-4-2 | 256.6 | 159 | June 2016 site visit | |
| | 2 | Grundfos | CR45-3-1 | 264.4 | 238 | | |
| Umatac 1 (WBP 1) | 1 | Grundfos | NB32-160/137 | 98.1 | 122 | June 2016 site visit | |
| Umatac 2 (WBP 2) | 1 | Grundfos | CR45-3-1 | 264.4 | 238 | June 2016 site visit | Only 1 pump installed, GWA plans to add second pump similar to Pump 1 |
| Windward Hills | 1, 2 | Paco | 6019-7/8 KPV | 410 | 900 | Pump transmittal dated June 4, 2015 | |
| | 3 | Paco | 3095-7/8 KPV | 390 | 400 | | |

The following BPSs, not listed in Table 2-3, serve small areas:

- **Adawag:** serves approximately 30 homes in Asan
- **Camacho:** serves approximately 11 homes in Talofofo
- **Chalan Palauan:** serves approximately 20 homes in Dededo
- **LeoPalace:** owned by and serves LeoPalace Resort Guam
- **Manuel Tenorio:** serves approximately 20 homes in Talofofo
- **Northern District Wastewater Treatment Plant:** serves the Northern District Wastewater Treatment Plant (WWTP)
- **Pigua:** serves approximately 13 homes in Merizo
- **Sinifa:** serves several homes around the Sinifa Tank in Santa Rita
- **Ugum:** serves one home across the street from the Ugum SWTP
- **Ulloa/Untalan:** serves approximately four homes in Agana Heights

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# Section 3
# Existing Water Supply Description

Water sources on Guam include groundwater, surface water, and springs. Figure 2-1 provides a general overview of how the GWA water distribution system is served. The water system hydraulic schematics in Figure 2-4 and Figure 2-5 show the source of supply for each pressure zone in more detail.

Supply sources include the following:

- **Wells:** GWA maintains 120 wells including 118 in the North and 2 in the South. Except for wells in Agana, the wells pump directly into the distribution system. In the Agana area, several wells pump to a transmission main, then into the distribution system.
- **Ugum SWTP**: the Ugum SWTP treats water from the Ugum River and pumps the water into storage before serving the South system.
- **Springs:** the Santa Rita Spring pumps into the Central area. The Asan Spring, located in the North system, is currently offline.
- **Navy:** GWA purchases treated surface water from the Navy at the three locations shown in Figure 2-1. The Navy also serves several GWA customers directly throughout the island.

Each supply source is described in more detail below. Additional source water information including geology, policy, and resource protection is provided in Volume 1, Section 5.

## 3.1 Wells

GWA owns 120 wells, of which 108 were fully or partially active between 2012 and 2016. Figure 3-1 shows a typical well setup. Appendix C lists production and pump information for each well.

As of November 2016, 91 wells were operating, 3 were in standby mode, and 26 were inactive. Inactive wells are out of commission because of problems including screen failure, pump motor failure, casing failure, air entrainment, and water quality issues. GWA began operating the Navy's Tumon Maui well in 2016 (discussed in Volume 1, Section 5), which is not included in the 120 well total discussed above.

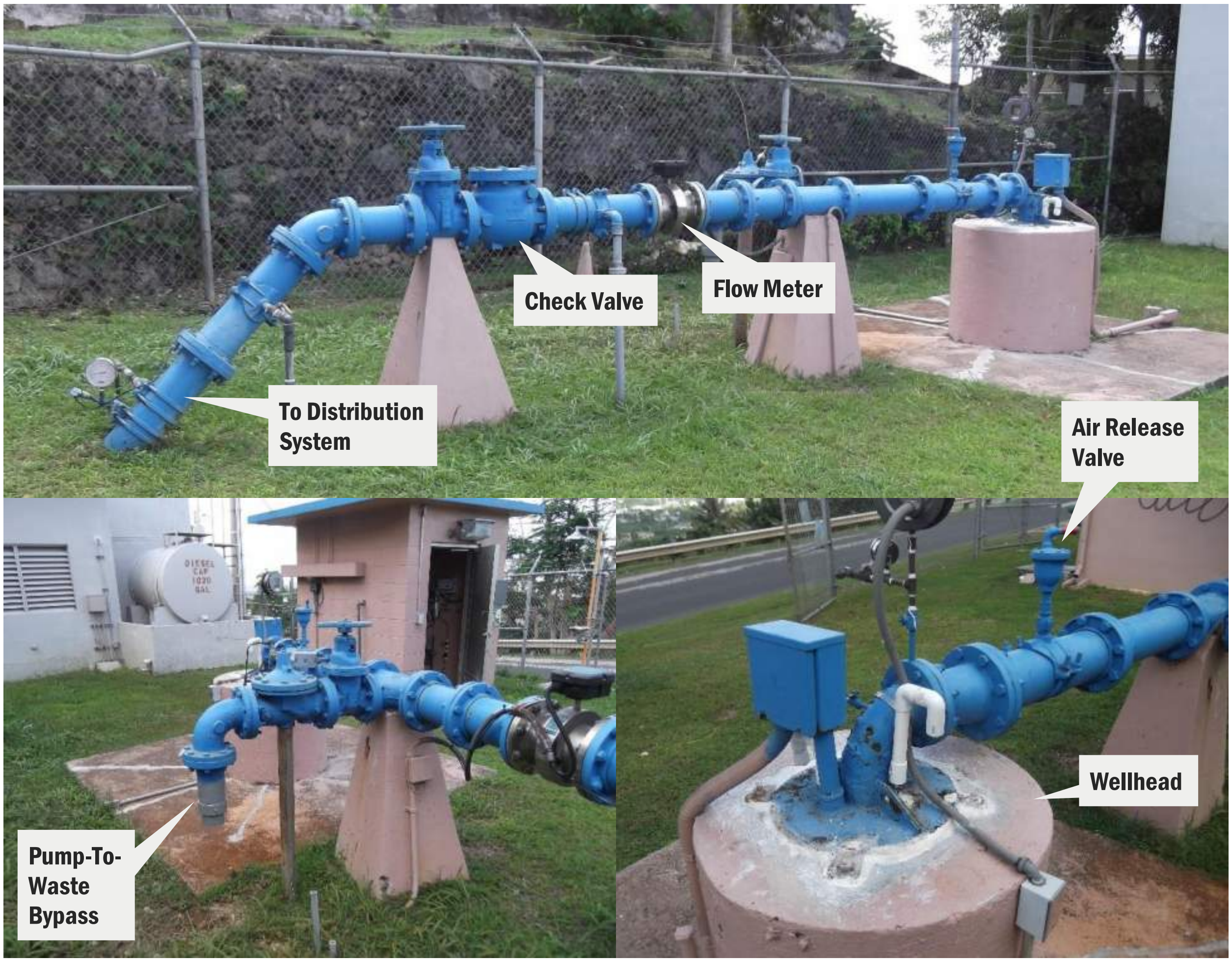


**Figure 3-1. Typical Well Site**

*(Well A-31, photos taken May 2012)*

Of the 120 wells, 113 are equipped with emergency generators to ensure continued supply if a power failure occurs. Wells D-03, D-17, D-18, HGC-2, MJ-5, HAS-1, and Y-14 are not currently equipped with generators.

Well water is chlorinated prior to distribution. Some wells are also equipped with granular activated carbon (GAC) systems to provide additional treatment for localized contamination issues. A few other wells may require GAC systems to treat contaminants. Wells equipped with or which may require GAC systems include:

- **F-8, NAS-1, Tumon Maui:** each well is equipped with a GAC system.
- **A-8:** this well is equipped with a GAC system, but the GAC system could be removed since the well no longer tests positive for contaminants.
- **A-23, A-25:** these wells are offline due to perfluorooctanoic acid (PFOA) and perfluorooctyl sulfonate (PFOS) contamination. GWA plans to place trailer-mounted GAC systems at these wells.
- **A-28, M-14:** these wells are offline due to contamination issues and require GAC systems before they can be brought online. A-28 is offline due to perchloroethylene (PCE) contamination and M-14 is offline due to chlordane contamination.

- **Airport wells:** the three wells in the airport water system, operated by GWA under an agreement with GIAA, are treated with a GAC system.

## 3.2 Ugum Surface Water Treatment Plant

The Ugum SWTP was originally constructed in 1991 as a rapid media (conventional filtration) plant, designed for a maximum production capacity of 4.0 million gallons per day (mgd). The plant operates 24 hours per day, 7 days per week, with a regular staff of 7 employees. The plant is in Talofofo, approximately one half-mile west of Highway 4, south of the village of Yona, and north of Inarajan. The plant is situated on a hill, with a finished water storage tank at an elevation that allows water to enter the local distribution system without pumping.

The original conventional filtration plant had difficulty producing the designed flowrate of 4.0 mgd while complying with the water quality requirements enforced by the U.S. Environmental Protection Agency (USEPA) and the Guam Environmental Protection Agency (EPA). To improve the plant's water quality and capacity, GWA used a Multi-Step Bid process for a rehabilitation/modification retrofit beginning in 2006—an upgrade required as a part of the Stipulated Order for Preliminary Relief, Civil Case No. 02-00035 (United States of America vs. Guam Waterworks Authority and the Government of Guam), filed in the District Court of Guam, June 6, 2003. The project converted the plant's treatment process to membrane treatment using the MEMCOR CS technology.

Construction of the retrofit began in March 2007. The MEMCOR CS system acceptance testing was completed on June 2, 2010, at which time the Ugum SWTP operated in a series configuration with membrane treatment followed by conventional filtration. The membranes passed Guam EPA-mandated bacteriological challenge testing in March 2011, and construction was considered substantially complete. Operation of the conventional sand filters ceased on March 28, 2011, and the Ugum SWTP has been operating solely on the MEMCOR CS system since that time.

The plant's treatment processes currently include:

- Pumping from the Raw Water Pump Station, which consists of three vertical turbine pumps (shown in Figure 3-2)
- Raw water screening
- Pre-disinfection with chlorine
- Coagulation, flocculation, settling, and clarifying
- Microfiltration using MEMCOR CS membranes
- Chlorination to provide disinfection and chlorine residual
- Storage in the 2.0-MG Ugum storage tank
- Pumping from a pump station adjacent to the tank for plant water demands
- Sludge management, including a thickening system and centrifuge
- Washwater treatment, including neutralization to adjust the pH of the membrane filter wash water before release into the Ugum River as a National Pollutant Discharge Elimination System (NPDES)-permitted discharge.

Figure 3-2. Raw Water Pump Station

The Ugum SWTP is also equipped with:

- Backup generators to provide power if the electric utility system fails
- Washwater recycling processes
- Chemical facilities
- Supervisory control and data acquisition (SCADA) to bring information to the operations staff and to collect and retain plant operating data

The stated capacity of the membrane plant is 4.0 mgd; however, there are some limitations in the treatment plant design and installed equipment that currently limits capacity to less than 4.0 mgd. These limitations include raw water pumping capacity and equipment redundancy issues, which are described in Section 5.3.

## 3.3 Springs

GWA has used water from several springs in the past, as discussed in Volume 1, Section 5. Most springs are no longer in use. GWA has plans for the following two springs.

- **Santa Rita Spring**: GWA currently uses water from the Santa Rita Spring, which produced an average of 0.10 mgd from 2012 through 2016. The spring's facilities include a multi-compartment storage tank and the Santa Rita BPS. Water from the spring flows into a 30-feet by 30-feet compartment in the tank. Water from Navy Meter 69 flows into another 30-feet by 30-feet compartment. The tank compartment sizes are estimates provided by GWA. Water from the spring compartment flows over a weir into the Navy side and into a wet well where it is pumped by the booster to the Santa Rita tank. Spring water is chlorinated prior to distribution. Table 2-3 provides booster pump information. Figure 3-3 shows photographs of the spring.
- **Asan Spring:** GWA is investigating rehabilitation of Asan Spring, which is not currently active. The spring produced approximately 0.14 to 0.8 mgd when it was active. Figure 3-4 shows photographs of the spring.

Figures 2-1 through 2-5 show the locations of these springs.

**Figure 3-3. Santa Rita Spring Tank and Booster Pump Building (left) and Pumps (right)**

*Photos taken June 2016*

**Figure 3-4. Asan Spring Reservoir**

*Photo taken in 2012*

## 3.4 Navy Water

GWA purchases water from the Navy at several locations in the water system. A 1982 Memorandum of Agreement allows GWA to purchase up to 4.39 mgd of water from the Navy and, though the Memorandum of Agreement has expired, both parties continue to operate cooperatively under its provisions. Water is purchased from the Navy for the following reasons:

- **To serve the main GWA system to supplement supply:** GWA has been working to reduce the need to use Navy water. GWA is currently using water from only one Navy meter within the main distribution system.
- **To serve small, separate systems:** the two small Nimitz distribution systems near Route 6 are not connected to the rest of the GWA system and are served only by Navy water. Customers in these areas are GWA customers and billed by GWA. GWA is currently investigating options for connecting these customers directly to the main GWA water system.
- **To serve individual, non-military customers not connected to the GWA water system:** as cited in Table 3-1, 33 Navy meters serve non-military GWA customers or groups of customers. These customers are billed by GWA but are not located near GWA piping. GWA has also been working to directly serve these customers where possible.

The Navy reads its water meters and bills GWA monthly for water used. Table 3-1 summarizes the Navy's supply connections to the GWA system and to non-military customers billed by GWA but served by the Navy.

**Table 3-1. Navy Connections to GWA**

| Navy Meter Number | Location | Average Annual Billed Water Use (gallons per day) | | | | | Notes |
|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2014 | 2015 | 2016 | |
| Serve Main GWA System | | | | | | | |
| R-69 | Flows from Navy's Fena WTP into the Santa Rita Spring tank | 1,352,742 | 1,309,348 | 1,257,192 | 936,206 | 1,167,871 | |
| R-106 | Enters GWA system at Piti Village | 296,523 | 236,033 | 218,499 | - | - | Not used since September 2014 |
| R-120 | Enters GWA system at intersection of Routes 6 and 7, just south of Route 1 | 27,399 | 8,914 | 9,791 | 2,745 | - | Not used since April 2015 |
| Serve Small, Separate Systems (served by Navy but billed by GWA) | | | | | | | |
| R-109 | Serves Nimitz Lower and Nimitz Upper pressure zones | 14,764 | 15,432 | 20,483 | 19,401 | 23,220 | Only source for this area |
| R-110 | Serves Nimitz Estates pressures zones | 185,636 | 181,616 | 200,000 | 181,489 | 198,244 | Only source for this area |
| Serve Individual Non-Military Customers (served by Navy but billed by GWA) | | | | | | | |
| Rest of Meters | Serves individual customers not connected to GWA system (number of active meters in parenthesis at right) | 820,863 (40 meters) | 752,159 (40 meters) | 667,022 (39 meters) | 680,318 (33 meters) | 569,431 (34 meters) | Only source for these customers |
| **Total** | | **2,697,927** | **2,503,502** | **2,372,987** | **1,820,159** | **1,958,768** | |

Use of Navy water is a concern for GWA. The utility has adopted the policy that all customers will have the same water rates, but Navy water currently costs more to purchase than GWA charges some of their customers. The Navy has sold water to GWA at the following rates per thousands of gallons (kgal) per fiscal year (October through September): 2012 = $4.48, 2013 = $4.57, 2014 = $5.41, 2015 = $7.59, 2016 = $8.64, and 2017 = $9.90.

GWA has been investigating options to reduce and eventually eliminate dependency on Navy water. As shown in Table 3-1, GWA has reduced its dependence on Navy water over the last several years and intends to continue to reduce the need for Navy water by fixing leaks, changing supply sources, and correcting flow and pressure problems within the GWA system. Another option that GWA has implemented has been removing power plants from Navy water supply lines and delivering water directly from the GWA system. One power plant was taken off Navy water in March 2016 and GWA plans to remove two additional plants from Navy supply in the near future.

Section 9.3 discusses options for reducing use of Navy water by reducing leaks.

### 3.4.1 Fena Water Treatment Plant

The Navy collects surface water in the Fena Reservoir. The reservoir water is treated at the Fena water treatment plant (WTP), which is owned by the Navy and operated by a private contractor. Fena WTP treatment processes include:

- Pre-chlorination
- Coagulation using alum, lime, and polymer
- Flocculation
- Sedimentation
- Dual-media filtration
- Ultraviolet (UV) disinfection
- Post-chlorination
- Fluoridation

The Fena WTP can treat up to 13.5 mgd, with recent production varying between 5.5 and 7 mgd. Production has steadily declined since 2010 because of reduced demand.

## 3.5 Demand Summary

Table 3-2 summarizes average day demand (ADD) and maximum day demand (MDD) for 2012 through 2016 for the areas shown in Figure 2-1.

| Table 3-2. 2012 through 2016 Demand Summary | | | | | | | |
|---|---|---|---|---|---|---|---|
| Demand | Area | Supply Source | Demand (mgd) | | | | |
| | | | 2012 | 2013 | 2014 | 2015 | 2016 |
| ADD | North | North Wells [a] | 34.71 | 32.53 | 33.92 | 33.83 | 33.97 |
| | | Navy Meters R-106, R-120 | 0.32 | 0.24 | 0.23 | - | - |
| | | **Subtotal** | **35.03** | **32.78** | **34.15** | **33.83** | **33.97** |
| | Central | North Wells [a] | 0.85 | 0.80 | 0.99 | 1.18 | 1.08 |
| | | Santa Rita Spring | 0.16 | 0.09 | 0.04 | 0.16 | 0.04 |
| | | Navy Meter R-69 (at Fena WTP) | 1.35 | 1.31 | 1.26 | 0.94 | 1.16 |
| | | **Subtotal** | **2.36** | **2.20** | **2.30** | **2.27** | **2.28** |
| | South | Ugum SWTP | 2.28 | 2.27 | 2.06 | 2.11 | 2.17 |
| | | Wells (MJ-1, MJ-5) | - | - | - | - | - |
| | | **Subtotal** | **2.28** | **2.27** | **2.06** | **2.11** | **2.17** |
| | Nimitz | Navy Meters R-109, R-110 | 0.20 | 0.20 | 0.22 | 0.20 | 0.22 |
| | **Total** | **All** | **39.87** | **37.45** | **38.72** | **38.42** | **38.65** |
| MDD | **Total** | **All** | **45.89** | **41.80** | **44.77** | **42.66** | **43.06** |

*a. Flow data is not available to split total well production between the North and Central areas. Well production was estimated by using the ratio of billed water use in the North versus Central areas.*

Figure 3-5 shows total daily production for all sources listed in Table 3-2 for 2012 through 2016.

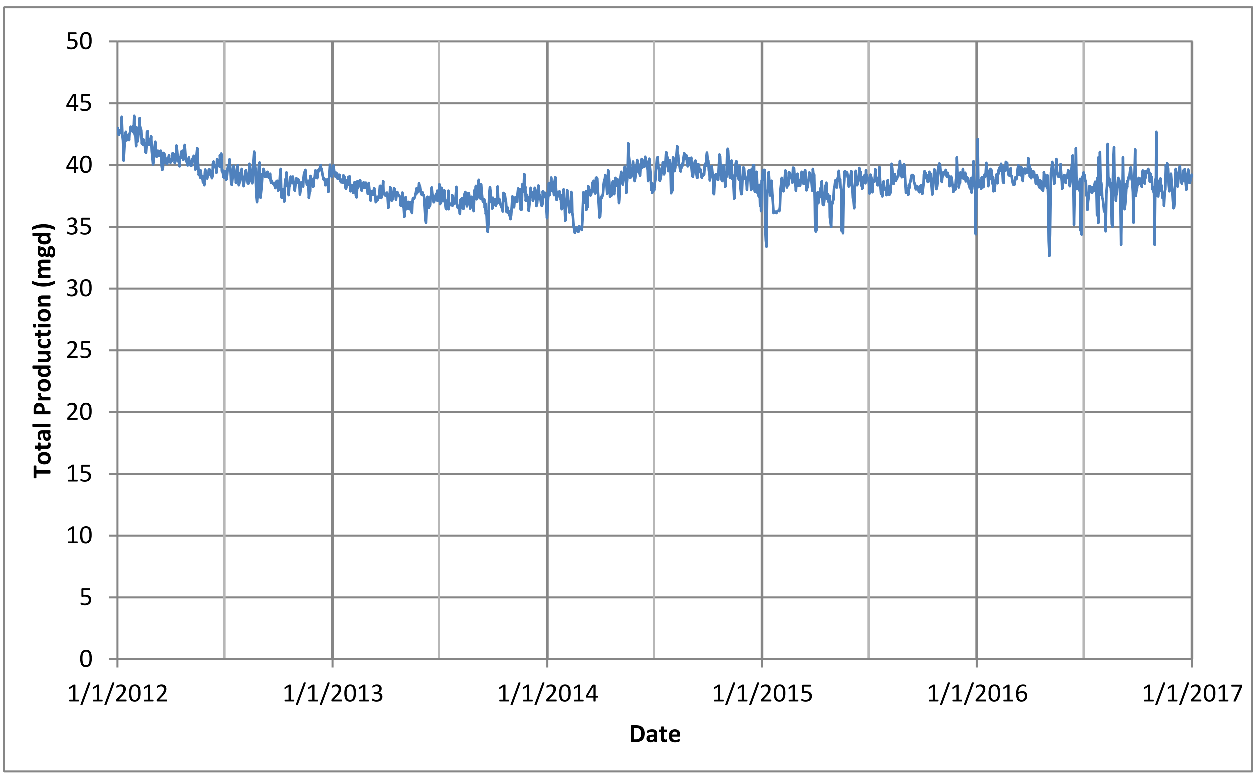


**Figure 3-5. Total Daily Water Production for 2012 through 2016**

Figure 3-6 shows daily water production for only the Ugum SWTP for the same years. Both figures show a stable to slightly declining production rate, even though Guam's overall population and the number of GWA customers increased over the period.

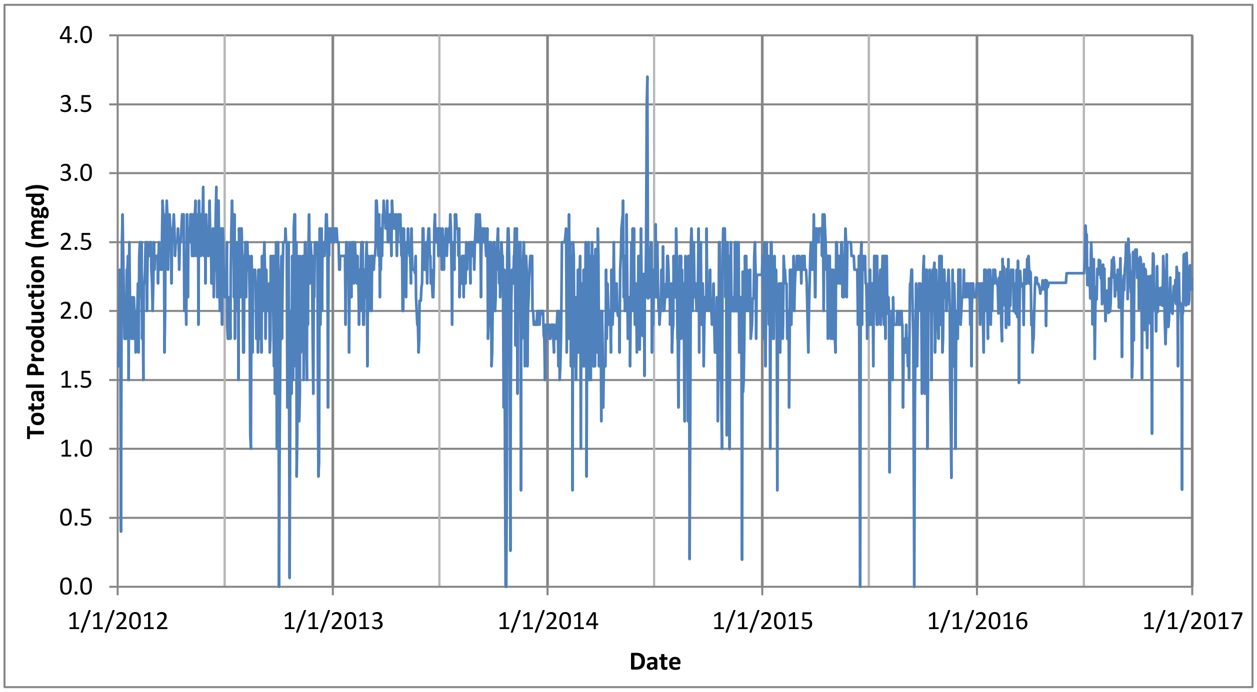


**Figure 3-6. Ugum SWTP Water Daily Production for 2012 through 2016**

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# Section 4
# Hydraulic Model Development

This section describes the development of the computer model used to evaluate distribution system capacity.

## 4.1 Model Development

A model was developed for the original 2006 WRMP in Innovyze's H2OMAP Water. The model was updated with more recent data and converted to Innovyze's InfoWater in 2012 and has been regularly updated since that time. Facilities in the model include:

- **Ground elevation:** elevations were assigned to model facilities (except for the facilities noted below) based on a 2007 island-wide Light Detection and Ranging (LIDAR) survey performed by the U.S. Army Corps of Engineers.
- **Piping:** piping was updated when the model was converted to InfoWater in 2012 and has been updated twice since that time. The piping was updated using GWA GIS data and based on information gathered during interviews with GWA staff and limited field reconnaissance.
- **Storage tanks:** storage tanks were added using the data listed in Table 2-2. The floor elevations listed in the table were used instead of elevations from the LIDAR data.
- **Booster pumps:** individual pumps at BPSs were added using the data listed in Table 2-3.
- **Wells:** Wells were added with a pump and fixed head reservoir representing the groundwater level. GWA supplied information for the well pumps. Pump curves were located for 89 of the 120 modeled well pumps, and the other 31 well pumps were modeled using a design head and flow. The groundwater level was back-calculated from average well discharge pressure and pump flow and head design points.
- **Control valves:** PRVs were added to the model based on settings reported by GWA operations staff. Choked valves were modeled as throttled control valves. Choked valve settings were adjusted during model calibration, as described below.
- **Junctions:** model junctions were created at the ends of all pipes. Model demands were applied to the junctions, as discussed later in this section.

## 4.2 Demands

The data and steps used to calculate and allocate model demands are described below. Existing model demands were calculated using water billing data and production data. Future model demands were calculated using projections for population growth and future development through 2035, as discussed in Volume 1, Section 4.

### 4.2.1 Water Billing Data

In February 2016, GWA provided a billing database of 47,845 customers. The average water use was calculated for each customer from March 2015 through February 2016. GWA has surveyed the location of 44,125 customer meters (92 percent). Several hundred of the remaining customers were located with assistance from GWA, until a total of 44,411 customer meters (93 percent) could be located. The located customers accounted for 98 percent of billed water use. Table 4-1 lists the number of customers by type of customer in the billing database.

| Table 4-1. Number and Type of GWA Customers | |
|---|---|
| **Customer Type** | **Number of Customers [a]** |
| Agriculture | 338 |
| Commercial 1 | 2,399 |
| Commercial 2 | 17 |
| Commercial 3 | 255 |
| Federal | 13 |
| Golf | 16 |
| Government | 391 |
| Hotel | 47 |
| Irrigation | 33 |
| Residential | 40,924 |
| Unknown | 2,839 |
| No Water Use | 573 |
| **Total** | **47,845** |

*a. This column lists the number of customers by type with at least some water use between March 2015 and February 2016. Customers with no water use during that period are listed separately.*

### 4.2.2 Water Billing Versus Production

Table 4-2 compares 2015 ADD water production (from Table 3-2) with average billed water use for March 2015 through February 2016 (due to a new billing system at the time, GWA was unable to provide data for the first two months of 2015, so the entire 2015 period could not be used to calculate average billing). The difference between water production and billed water use is called non-revenue water (NRW). NRW includes "unbilled authorized consumption (water for firefighting, flushing, etc.) plus apparent losses (customer meter inaccuracies, unauthorized consumption and systematic data handling errors) plus real losses (system leakage and storage tank overflows)" (American Water Works Association (AWWA), 2012c).

| Table 4-2. Water Production Versus Billing Data | | | | |
|---|---|---|---|---|
| **Area** | **2015 ADD (mgd) (from Table 3-2)** | **2015–2016 Average Billing Data (mgd)** | **NRW** | |
| | | | **mgd** | **Percent** |
| North | 33.91 | 14.46 | 19.46 | 57.4% |
| Central | 2.28 | 0.97 | 1.31 | 57.5% |
| South | 2.11 | 0.53 | 1.58 | 74.9% |
| Nimitz | 0.20 | 0.09 | 0.11 | 55.0% |
| **Total** | **38.51** | **16.05** | **22.46** | **58.3%** |

As shown in Table 4-2, NRW was estimated at approximately 58 percent using a direct correlation of ADD and average billing data. NRW was calculated by GWA to be approximately 49 percent using the

AWWA water audit methodology (see Table 9-2). Regardless of the method used, NRW is very high. NRW is discussed in more detail in Section 9.

### 4.2.3 Future Service Population

Future demands were calculated for 2035 using the population projections discussed in Volume 1, Section 4. The total population for 2015 and 2035 to be served by GWA were calculated as the following values:

- 2015 population = 164,882
- 2015 to 2035 non-military growth = 29,399
- 2015 to 2035 military growth (on-base troops and dependents) = 6,300
- 2035 total population = 164,882 (2015) + 6,300 (military growth) + 29,399 (non-military growth) = 200,581

Projected growth will not occur evenly throughout each municipality. Much of the non-military growth will occur in new developments. Planned new developments and military growth that GWA is tracking are shown in Volume 1, Table 4-18 and Figure 4-16.

### 4.2.4 Model Demand Allocation

Existing model demands were calculated by scaling billed water use to match production within each area. The process of scaling and assigning demands is discussed in more detail in Appendix D. Scaling billed water use accounted for NRW. Future (2035) demands were calculated by scaling existing demands and adding demands for projected future developments. Scaled water use was then assigned to nearby model junctions. Table 4-3 lists the total demands used in the model for existing and future conditions.

**Table 4-3. Model Demand Summary**

| Area | 2015–2016 Average Billing Data (mgd) | Existing (2015) (mgd) | | Future (2035) (mgd) | |
|---|---|---|---|---|---|
| | | ADD | MDD | ADD | MDD |
| North | 14.46 | 33.92 | 37.19 | 39.89 | 44.26 |
| Central | 0.97 | 2.28 | 2.50 | 2.68 | 2.94 |
| South | 0.53 | 2.11 | 2.70 | 2.48 | 3.18 |
| Nimitz pressure zones | 0.09 | 0.20 | 0.27 | 0.24 | 0.32 |
| Finegayan Buildup | 0 | 0 | 0 | 0.90 | 1.38 |
| **Total** | **16.05** | **38.51** | **42.66** | **46.18** | **52.07** |

### 4.2.5 Diurnal Pattern

A diurnal pattern is a set of peaking factors that represents fluctuation in demand over a day. A diurnal pattern consisting of hourly peaking factors was created for the water system to model variation in demand for a 24-hour period. Diurnal patterns are calculated by subtracting inflows into the system (supply and tanks draining into the system) from flows out of the system (flow into tanks as they fill) throughout a day. The difference is the system demand.

Pressure loggers were placed at storage tanks for several weeks in 2012 and 2014 to gather tank level data (for a total of 50 days). Using tank level and production data, diurnal patterns were calculated for those weeks. A typical or representative diurnal pattern was selected from that data from August 2, 2014. The selected diurnal pattern, shown in Figure 4-1, was applied to all model demands. See Appendix D for additional details on the calculation of diurnal patterns.

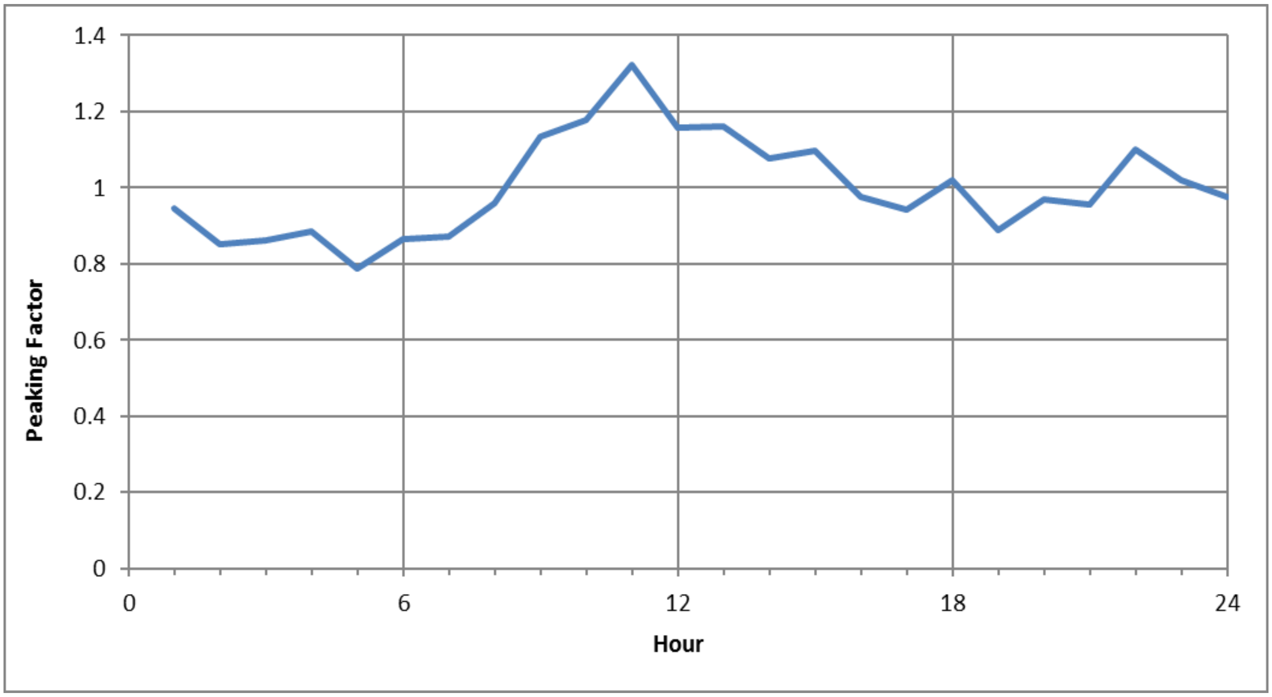


**Figure 4-1. Diurnal Pattern**

The diurnal pattern peaking factors from Figure 4-1 are listed in Table 4-4.

**Table 4-4. Diurnal Pattern Peaking Factors**

| Hour | Peaking Factor | Hour | Peaking Factor |
|---|---|---|---|
| 1 | 0.95 | 13 | 1.16 |
| 2 | 0.85 | 14 | 1.08 |
| 3 | 0.86 | 15 | 1.10 |
| 4 | 0.89 | 16 | 0.98 |
| 5 | 0.79 | 17 | 0.94 |
| 6 | 0.87 | 18 | 1.02 |
| 7 | 0.87 | 19 | 0.89 |
| 8 | 0.96 | 20 | 0.97 |
| 9 | 1.13 | 21 | 0.96 |
| 10 | 1.18 | 22 | 1.10 |
| 11 | 1.32 | 23 | 1.02 |
| 12 | 1.16 | 24 | 0.98 |

### 4.2.6 Demand Scenarios

Extended period simulation (EPS) scenarios were set up within the model. An EPS scenario runs for 24 hours or more, simulating changing demands and operation of pumps and tanks. Four scenarios were created in the model for existing and future conditions. The scenarios included:

- **Existing ADD:** includes demands scaled to the 2015 ADD.
- **Existing MDD:** includes demands scaled to the 2015 MDD.
- **2035 ADD:** includes future development and scaling of existing demands so total demands equal the 2035 ADD.
- **2035 MDD:** includes future development and scaling of existing demands so total demands equal the 2035 MDD.

## 4.3 Calibration

The model has been adjusted and refined during several rounds of calibration since it was converted to InfoWater in 2012. The following data was collected from 2012 to 2016 to aid in model calibration:

- **Pressure loggers:** pressure loggers have been placed throughout the water system to record pressures for several weeks at a time. GWA currently owns and places the pressure loggers.
- **Tank levels:** pressure loggers were placed at the storage tanks for two periods in 2012 and 2014 to record tank level data.
- **PRV site visits:** each PRV vault was visited in 2014 to assess if the PRVs were operational and to record pressure settings.
- **Well discharge pressures:** GWA records well discharge pressures as each well is visited daily. In 2014, the pressure gauges at each well were verified using calibrated pressure gauges. A list of inaccurate gauges was reported to GWA.
- **Flow metering:** flow meters have been placed at some PRVs for several weeks at a time to record flows through the PRVs.
- **Pump flows/pressures:** each BPS was visited in 2012 and again in 2016 to record booster pump flows and pressures.
- **Site visits:** choked valves and hydrants throughout the system have been visited to record pressures.
- **Interviews:** operations staff have been interviewed several times between 2012 and 2016 to discuss the operations of facilities, PRV and choked valve locations and settings, piping that was incorrect in the GIS, and other system operation data.

Using collected field data, the model has been calibrated by adjusting the following model facilities:

- **Valves:** PRV and choked valve settings have been adjusted to match field pressures.
- **Pump settings:** well and booster pumps are turned on and off manually by operations staff based on tank levels. Pump operations have been automated in the model to match typical field operations.
- **Pipe connectivity:** pipe connectivity (how pipes are connected) has been adjusted based on interviews with operations staff.

Some areas of the model are not fully calibrated, primarily because of unknown choked valves in some areas, difficulty in accurately modeling choked valves, and unknown or incorrect piping. As more information is learned about the system, the model will continue to be calibrated. For example, the model predicted that a valve in Santa Rita was probably choked because flow was restricted between the Sinifa and Santa Rita tanks. An unknown choked valve was discovered in Santa Rita and then fully opened. The system now operates more closely to the operations predicted by the model. The model will continue to be improved as more information is discovered about the system.

The latest calibrated model was used for this master plan update. No additional calibration was performed for this master plan update.

# Section 5
# Supply Evaluation

This section describes the capacity and condition evaluation of GWA water supply facilities. Additional detail regarding source water availability, development, risks, and policy can be found in Volume 1, Section 5.

## 5.1 Supply Capacity Evaluation

The capacity of GWA's water supply facilities was analyzed and compared to existing and future demand using the following criterion:

- Supply must be sufficient to deliver at least 1.2 times the ADD. Appendix E discusses the source of this criterion.

Model results were reviewed to identify existing and future supply deficiencies. Capacity was analyzed for the three main areas shown in Figure 2-1:

1. **North:** the North (brown) area in Figure 2-1 served by the North wells.
2. **Central:** the Central (green) area in Figure 2-1 served from the Brigade BPS. This area is typically served by the North wells but can also be served by the Ugum SWTP.
3. **South:** the South (blue) area in Figure 2-1 served by the Ugum SWTP.

### 5.1.1 Available Supply

Table 5-1 summarizes total supply available in the North, Central, and South areas. In the table, the Central area only lists the Santa Rita Spring as a source because the Central supply is supplemented by supply from the North or South. The analysis did not consider Navy supplies as a current GWA source.

| Table 5-1. Available Supply | | |
|---|---|---|
| **Source** | **Available Supply (mgd)** | **Notes** |
| North | | |
| Existing Wells | 39.14 | Sum of permitted flow rates for GWA's northern 118 wells except for the wells discussed below this table |
| Tumon Maui | 1.15 | Permitted flow rate of 800 gpm |
| Future Wells | 1.87 | Permitted flow rates for future wells AG-10 (500 gpm), AG-12 (500 gpm), and Y-8 (300 gpm) |
| Asan Spring | 0.47 | Average of reported flow of 0.14 to 0.8 mgd when operating = 0.47 mgd |
| **Subtotal** | **42.63** | |
| Central | | |
| Santa Rita Spring | 0.10 | Average flow of 69 gpm (0.10 mgd) from 2012 through 2016 |
| South | | |
| Existing Wells | 0.16 | Permitted flow rates for MJ-1 (56 gpm) and MJ-5 (58 gpm). Operation of these very low capacity wells is not economical compared to other sources. They can provide a local water source if there is a major system outage such as a shutdown at the Ugum SWTP. |
| Ugum SWTP | 2.00 | Volume 1, Section 5.3.1 discusses that during the dry season, the plant can only take approximately 2 mgd out of the Ugum River and still maintain a minimum flow in the river. |
| **Subtotal** | **2.16** | |
| **Total** | **44.89** | |

The "Existing Wells" totals for the North and South areas in Table 5-1 were calculated by summing the Guam EPA-permitted flow rate for most of the existing wells. Some wells included in the existing wells totals were offline at the time of this report. However, GWA would like to rehabilitate and operate most of the wells that are currently offline. GWA will probably not rehabilitate or use the following wells, which were not included in the available supply for this analysis:

- **A-29**: Well A-29 and Well A-30 cannot run at the same time because there is too much drawdown with both wells running. For this capacity analysis, it was assumed that A-29 would remain offline because it has a lower Guam EPA-permitted flow rate (403 gallons per minute (gpm)) compared to A-30 (755 gpm).
- **D-13**: this well has historically high chloride levels and should be removed from service when practical. The well is currently offline.

During the dry season months of April, May, and June, there are years when withdrawal from the Ugum River should be limited by the need to maintain minimum required river flows (see Volume 1, Section 5.3.1 on Source Water). A stream monitoring program at the Ugum River intake is needed to determine an accurate and reasonable value for the minimum stream flow required to maintain aquatic life (typically referred to as "7Q10"). The supply analysis assumed a maximum reliable capacity of 2.0 mgd from the Ugum SWTP year-round. Additional sources, a reservoir, or reliance on Navy water as a back-up will be required for the South. To calculate this deficit, this analysis was done with the assumption that GWA would not purchase any Navy water.

### 5.1.2 Supply Versus Demand

Table 5-2 compares available supply (from Table 5-1) to existing (2015) and future (2035) MDD (from Table 4-3) for the three areas.

**Table 5-2. Available Versus Required Supply**

| Period | Available Supply (mgd) | | | | Required Supply, 1.2xADD (mgd) | Extra / Deficient Supply (mgd) |
|---|---|---|---|---|---|---|
| | From North | From South | From Central | Total | | |
| North, Nimitz, Finegayan Buildup | | | | | | |
| 2015 (from wells/springs) | 42.63 | - | - | **42.63** | 40.84 | **1.79** |
| 2035 (from wells/springs) | 42.63 | - | - | **42.63** | 49.11 | **-6.48** |
| South | | | | | | |
| 2015 (from wells/SWTP) | - | 2.16 | - | **2.16** | 2.53 | **-0.37** |
| 2035 (from wells/SWTP) | - | 2.16 | - | **2.16** | 2.98 | **-0.82** |
| Central | | | | | | |
| 2015 (springs and excess from North) | 1.79 | - | 0.10 | **1.89** | 2.73 | **-0.84** |
| 2035 (springs and excess from North) | 0 | - | 0.10 | **0.10** | 3.21 | **-3.11** |
| Entire System | | | | | | |
| 2015 [a] | 42.63 | 2.16 | 0.10 | **44.89** | 46.10 | **-1.21** |
| 2035 | 42.63 | 2.16 | 0.10 | **44.89** | 55.30 | **-10.41** |

*a. Note that excess supply from the North included in the 2015 Central Available Supply is not added to the entire system total.*

Table 5-2 shows the following:

- **North:** the North will face a supply shortfall in the future. The Nimitz pressure zone and the Finegayan buildup demands listed in Table 4-3 were added to the North demands. GWA would like to supply the Nimitz areas, which are currently supplied by the Navy, to reduce reliance on Navy supply.
- **South:** the South will need additional supply when the Ugum SWTP can only supply 2 mgd during the dry season (see Table 5-1).
- **Central:** GWA has a goal for the Ugum SWTP (along with the Santa Rita Spring) to supply all water to the South and Central areas. As shown in the table, the Ugum SWTP does not have sufficient capacity to supply the South and Central areas during dry seasons. Additional supply will be required for the Central area in the future.

Figure 5-1 shows projected ADD, MDD, and 1.2 x ADD versus available supply until 2035 for the entire system. The table and figure show that with current supply, barely enough supply is available for existing MDD and not enough supply is available for 1.2 x ADD. GWA currently purchases water from the Navy to close this deficit. In 2035, there is projected to be a supply deficiency of 10.4 mgd for 1.2 x ADD and 6.7 mgd for MDD. Options for additional supply are discussed later in this section.

Figure 5-1 also shows the effects of reductions in NRW of 10 percent and 20 percent by 2035. NRW was gradually reduced from 2015 to 2035 for the 1.2 x ADD curve. As shown in the figure, the 1.2 x ADD curve with the 20 percent reduction is almost flat, which means that the reduction in NRW would almost equal the increased demand due to growth. As rehabilitation and replacement work is done on the piping (as described in Section 8.5), especially with the replacement of 2-inch and asbestos cement (AC) pipes, NRW should be reduced. As GWA begins to see results in the reduction of NRW, this analysis should be updated to account for reduced demands, such as during the next WRMP update. Note that the change in slope of the projected demands in Figure 5-1 in 2020 is based on the projected population growth shown in Figure 4-13 and Figure 4-14 in Volume 1.

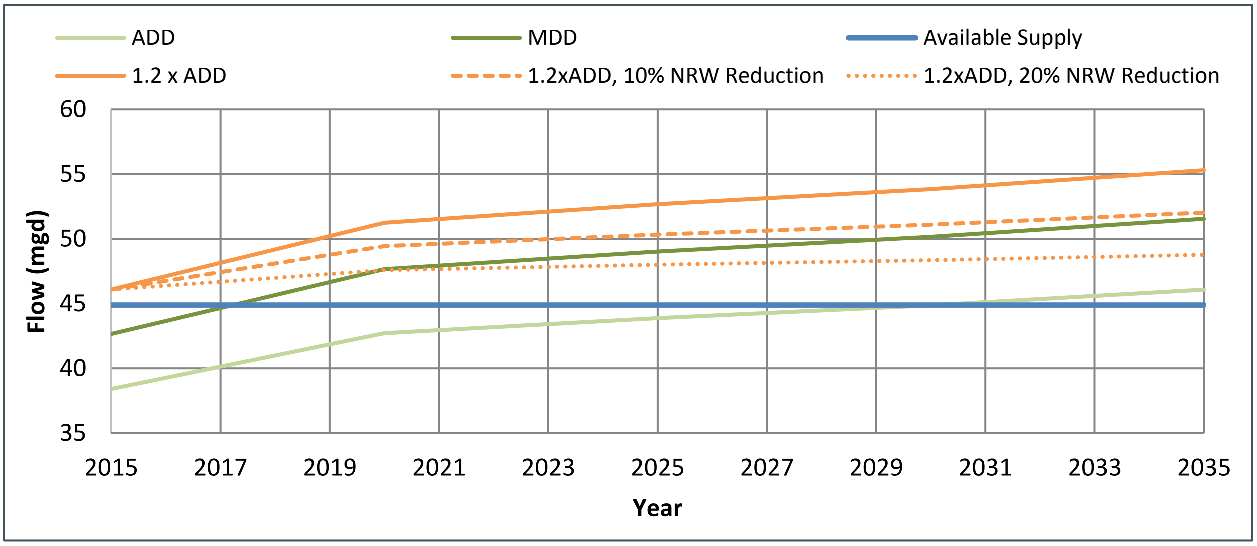


**Figure 5-1. Projected Demand Versus Available Supply**

### 5.1.3 Comparison with 2006

GWA had 120 operational wells in 2006, as listed in the Master Plan. In 2017, GWA has the same number of wells included in the inventory list plus the addition of the Tumon Maui well. The number of wells in operation varies from time to time due to items such as equipment failures and local temporary water quality issues. GWA has not added any new capacity into the system over the past 10 years, except for the Tumon Maui Well.

### 5.1.4 New Well Development

GWA has two State Revolving Fund (SRF) projects scheduled to rehabilitate up to 10 wells that have been out of operation (SRF projects 7A/B and 13). Two of the wells (M-9 and F-3) were repaired and operating as of July 2017 will not add capacity to the overall system. The remaining eight wells include wells A-2, A-7, A-12, D-3, D-5, D-17, D-18, and D-22. The total design capacity of these wells is 2.2 mgd. GWA is also in the process of drilling three new wells: AG-10, AG-12, and Y-8 with a total design capacity of over 1.7 mgd. It is estimated that six of the 11 wells being developed or rehabilitated will add to system capacity, and five of the wells will offset other wells that need to be shut down due to high chlorides, contaminants, or other operational issues. These wells would be maintained in standby mode for emergency use or to assist during system outages.

Based on the data from Table 5-2, there will be an estimated supply deficit of approximately 10.4 mgd by 2035 (1.2 x ADD minus existing supply). This deficit can be made up by constructing new production wells or by reducing NRW in the distribution system as discussed above. Using the estimated production deficit and evaluating reductions in NRW of 10 percent and 20 percent, the number of required new production wells was determined as shown in Table 5-3. The number of new production wells is based on an expected average flow rate of 300 gpm (0.43 mgd) per well. The table includes the added capacity from well development and rehabilitation projects in progress. The table also assumes two standby wells. It was assumed that the production deficit will primarily be made up by additional production wells because most of Guam's projected development is expected to be in the North and there are production limitations at Ugum SWTP.

**Table 5-3. New Production Well Requirements to 2035**

| Scenario | Estimated Supply Deficit (mgd) (at 1.2 x ADD) | Capacity Added from Current Well Projects (mgd) | Capacity Required from New Wells (mgd) | Number of New Production Wells | Number of Standby Wells | Total Number of Wells Required |
|---|---|---|---|---|---|---|
| No Reduction In NRW | 10.4 | 2.6 | 7.8 | 18 | 2 | 20 |
| 10% Reduction in NRW | 7.1 | 2.6 | 4.5 | 11 | 2 | 13 |
| 20% Reduction in NRW | 3.9 | 2.6 | 1.3 | 3 | 2 | 5 |

As shown in Table 5-3, a reduction in NRW may greatly reduce the needed number of new wells. For planning purposes in the master plan, it was assumed that a 10 percent reduction in NRW will be achieved by 2035. The number of required new production wells will be directly related to the effectiveness of GWA's leak detection and NRW reduction plans. GWA should review the rates of NRW reduction in the future and adjust the number of new wells required accordingly.

The current projects underway by GWA as described above will add the required capacity to the system in the near term. These projects are expected to be complete by 2020, so the projects for new wells should be planned to start in 2020.

Most of GWA's wells were constructed in the 1960s and 1970s, before the structure of the Northern Guam Lens Aquifer (NGLA) had been well defined. Since then, the Water and Environmental Research Institute of the Western Pacific at the University of Guam (WERI) has studied the aquifer extensively, which allows for more informed decisions to be made for future well locations. The goal is to develop more productive wells that are less susceptible to chloride contamination in the future.

It is recommended that GWA undertake a well exploration and development project to plan the location of the future wells. Future well sites can be provided for increased capacity as well as to provide alternate locations for wells that it may be desirable to relocate due to specific well issues which may include elevated chloride levels, contamination, susceptibility to contamination, poor operations access or other property issues. GWA can select optimal sites for future wells using the NGLA base maps developed by WERI to select areas that have high expected capacity and low contamination probability. Then GWA, with assistance from Land Management, the Chamorro Land trust, and others, can refine the proposed well list based on current land ownership and development status. The water system hydraulic model can then be used to prioritize the construction sequencing of the new wells to supply the areas with more immediate capacity needs first in the development sequence.

A well development project would include the following:

- Complete a desktop study using input from WERI, NGLA studies, current land use and land use plans, and the GWA water system hydraulic model to select optimal locations for future production wells.
- Develop a contract to drill pilot holes and complete capacity tests for the potential well locations.
- Purchase/acquire land at each successful well site, and consider actions to protect the land near the well sites for aquifer protection.
- Develop design and construction contracts for well development as increases in production are required.

For the purposes of this water system master plan, it is assumed that four well exploration projects would be conducted over the 20-year period, with each project locating approximately 4 to 5 wells for development. The quantity of wells and frequency of development will be evaluated as system requirements and pilot well capacity are determined.

It is also assumed that five well design and construction projects would be initiated over the planning period. Each project would design and construct two to three new production wells. The quantity of wells and frequency of development will be reevaluated as system capacity requirements, NRW reduction progress, and actual well capacities are updated.

## 5.2 Well Condition Assessment

GWA currently has 120 production wells that are or are intended to be operational. Of these wells, more than 35 will be over 50 years old by 2020. The system also includes more than 65, 8-inch diameter wells. This combination of increasing well age and small well diameters indicates that GWA will need to significantly prioritize well improvements over the next 20 years.

Two detailed condition assessments have been completed in the past few years. The first was summarized in a technical memorandum (TM) titled *Water Well Rehabilitation Program Plan* (Brown and Caldwell (BC), April 2013c). This TM was based on a detailed site visit to nearly every well in GWA's system. The recommendations from the 2013 TM were updated in a second TM titled *Water Well Rehabilitation Program Plan*, dated October 22, 2014 (BC, 2014). During the site visits, GWA identified wells that they classified as critical for operation of the system. These critical wells are identified in Appendix C. Much of the following section is taken from these reports.

### 5.2.1 National Enforcement Investigations Center Well Facility Deficiencies

From January 19 through March 1, 2013, Brown and Caldwell (BC) visited 120 GWA well sites. The primary purpose of the site visits was to document well site repairs performed in response to deficiencies identified by the USEPA National Enforcement Investigations Center (NEIC) during an inspection performed from April 23 to May 4, 2012. The USEPA delivered a report to GWA in November 2012 that summarized deficiencies found during their inspection (USU, 2012). Each well site was also reviewed to identify deficiencies that GWA can correct and improvements that GWA can make to help prevent future USEPA inspection directives.

The USEPA NEIC report identified the following well facility deficiencies (USEPA, 2012):

- Open sounding tubes
- Cracks in well pads
- Improperly sealed well casings and sanitary seals
- Lack of well pads at some locations
- Missing screens on well casing vents
- Missing air-gaps on pump-to-waste bypass lines

The BC site visits showed that corrective repairs were completed. Well pad cracks were filled with expansion cement and pump heads were sealed with a latex-based caulking material. Sounding tubes were capped, and 22 new well pads were constructed. New casing vents were constructed with PVC pipe to help withstand the island's harsh environment. The PVC pipes were installed vertically, then inverted and capped, and small holes were drilled into the caps to allow air to enter and exit the well casing. Air gaps were provided on all pump-to-waste bypass lines.

### 5.2.2 Well Condition

As of November 2016, 26 wells were inactive due to problems including screen failure, pump motor failure, casing failure, air production, and water quality issues. Several of the wells have the potential to be placed back into service after rehabilitation and/or reconstruction.

Many of the wells' above-ground equipment, such as the pump pedestal, valves, meters, safety devices, fencing, and electrical equipment, is nearing the end of its useful life due to age, corrosion, and inadequate maintenance. This equipment should be refurbished or replaced. In addition, the condition of well casings and screens is unknown, which presents a significant risk because casing and/or screen failure can result in complete well loss.

Table 5-4 lists each well and the improvements recommended at each well site. Critical wells are shaded in pink. The nine improvements summarized in the table are described in more detail on the following pages. The well conditions are constantly changing as GWA completes some projects and new issues develop. Visual inspection of the wells is recommended to assess their condition when a repair/rehabilitation project is being planned and a specific work plan should be developed for each well.

**Table 5-4. Well Recommended Improvements**

| Well | 1. Well and Well Pump Upgrades | 2. House-keeping | 3. Safety Equipment Upgrade | 4. Pump Pedestal | 5. Discharge Piping | 6. Paint | 7. Chlorine Equipment | 8. Electrical Improve-ments | 9. Site Work |
|---|---|---|---|---|---|---|---|---|---|
| Agana Wells | | | | | | | | | |
| A-1 | X | X | X | X | X | X | X | X | X |
| A-2 | Design for improvements in progress | | | | | | | | |
| A-3 | X | X | X | X | X | X | X | X | X |
| A-4 | X | X | X | X | X | X | X | | X |
| A-5 | X | X | X | X | X | X | X | X | X |
| A-6 | X | X | X | X | X | X | X | X | X |
| A-7 | Design for improvements in progress | | | | | | | | |
| A-8 | X | | X | | | X | X | | X |
| A-9 | X | X | X | X | X | X | X | | X |
| A-10 | X | X | X | X | X | X | X | X | X |
| A-12 | Design for improvements in progress | | | | | | | | |
| A-13 | X | X | X | X | X | X | X | | X |
| A-14 | X | X | X | X | X | X | X | X | X |
| A-15 | X | X | X | X | X | X | X | X | X |
| A-17 | X | X | X | X | X | X | X | | X |
| A-18 | X | X | X | X | X | X | X | | X |
| A-19 | X | X | X | X | X | X | X | | X |
| A-21 | X | X | X | X | X | X | X | | X |
| A-23 | X | X | X | X | X | X | X | | X |
| A-25 | X | X | X | X | X | X | X | | X |
| A-26 | X | X | X | X | | X | X | | X |
| A-28 | X | X | X | X | X | X | X | X | X |
| A-29 | X | X | X | | | X | X | X | X |
| A-30 | X | | X | X | X | X | X | X | X |
| A-31 | X | | X | | X | X | X | X | X |
| A-32 | X | | X | | | | X | X | X |
| Dededo Wells | | | | | | | | | |
| D-1 | X | X | X | X | X | X | X | | X |
| D-2 | X | X | X | X | X | X | X | | X |
| D-3 | Well improvements under construction | | | | | | | | |
| D-4 | X | X | X | | | X | X | X | X |
| D-5 | Design for improvements in progress | | | | | | | | |
| D-6 | X | X | X | X | X | X | X | | X |
| D-7 | X | X | X | | | X | X | X | X |

| Table 5-4. Well Recommended Improvements | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Well | 1. Well and Well Pump Upgrades | 2. House-keeping | 3. Safety Equipment Upgrade | 4. Pump Pedestal | 5. Discharge Piping | 6. Paint | 7. Chlorine Equipment | 8. Electrical Improve-ments | 9. Site Work |
| D-8 | X | X | X | X | X | X | X | | X |
| D-9 | X | X | X | X | X | X | X | | X |
| D-10 | X | X | X | X | X | X | X | | X |
| D-11 | X | X | X | X | X | X | X | | X |
| D-12 | X | X | X | X | X | X | X | | X |
| D-13 | X | X | X | X | X | X | X | X | X |
| D-14 | X | X | X | X | X | X | X | | X |
| D-15 | X | X | X | X | X | X | X | | X |
| D-16 | X | X | X | X | X | X | X | X | X |
| D-17 | Well improvements under construction | | | | | | | | |
| D-18 | Well improvements under construction | | | | | | | | |
| D-19 | X | X | X | X | X | X | X | X | X |
| D-20 | X | X | X | X | X | X | X | | X |
| D-21 | X | X | X | X | X | X | X | X | X |
| D-22 | Well improvements under construction | | | | | | | | |
| D-24 | X | X | X | | | X | X | | X |
| D-25 | X | X | X | | | X | X | | X |
| D-26 | X | X | X | | | X | X | | X |
| D-27 | X | X | X | | | X | X | X | X |
| D-28 | X | X | X | | | X | X | | X |
| Finegayan Wells | | | | | | | | | |
| F-1 | X | X | X | | | X | X | | X |
| F-2 | X | X | X | X | X | X | X | X | X |
| F-3 | Design for improvements in progress | | | | | | | | |
| F-4 | X | X | X | | | | X | | X |
| F-5 | X | X | X | X | X | X | X | | X |
| F-6 | X | X | X | X | X | X | X | | X |
| F-7 | X | X | X | | | X | X | | X |
| F-8 | X | X | X | | | X | X | | X |
| F-9 | X | X | X | X | X | X | X | | X |
| F-10 | X | X | X | X | X | X | X | X | X |
| F-11 | X | X | X | X | X | X | X | X | X |
| F-12 | X | X | X | X | X | X | X | | X |
| F-13 | X | X | X | | | X | X | X | X |
| F-15 | X | X | X | | | X | X | | X |

| Table 5-4. Well Recommended Improvements | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Well | 1. Well and Well Pump Upgrades | 2. House-keeping | 3. Safety Equipment Upgrade | 4. Pump Pedestal | 5. Discharge Piping | 6. Paint | 7. Chlorine Equipment | 8. Electrical Improve-ments | 9. Site Work |
| F-16 | X | X | X | | | X | X | | X |
| F-17 | X | X | X | | | X | X | | X |
| F-18 | X | X | X | X | X | X | X | | X |
| F-19 | X | X | X | | | X | X | | X |
| F-20 | X | X | X | | X | X | X | X | X |
| Barrigada Wells | | | | | | | | | |
| M-1 | X | X | X | X | X | X | X | X | X |
| M-2 | X | X | X | X | X | X | X | X | X |
| M-3 | X | X | X | X | X | X | X | X | X |
| M-4 | X | X | X | X | X | X | X | | X |
| M-5 | X | X | X | X | X | X | X | | X |
| M-6 | X | X | X | X | X | X | X | | X |
| M-7 | X | X | X | X | X | X | X | | X |
| M-8 | X | X | X | | | X | X | | X |
| M-9 | Well improvements under construction | | | | | | | | |
| M-12 | X | X | X | | | | X | | X |
| M-14 | X | X | X | X | X | X | X | X | X |
| M-15 | X | X | X | | | X | X | | X |
| M-17A | X | X | X | X | X | X | X | X | X |
| M-17B | X | X | X | | | X | X | | X |
| M-18 | X | | X | | | X | X | | X |
| M-20A | X | X | X | X | X | X | X | | X |
| M-21 | X | X | X | | | X | X | | X |
| M-23 | X | X | X | | | X | X | | X |
| Yigo Wells | | | | | | | | | |
| Y-1 | X | X | X | X | X | X | X | | X |
| Y-2 | X | X | X | X | X | X | X | | X |
| Y-3 | X | X | X | X | X | X | X | X | X |
| Y-4 | X | X | X | | X | X | X | | X |
| Y-5 | X | X | X | X | X | X | X | | X |
| Y-6 | X | X | X | X | X | X | X | | X |
| Y-7 | X | X | X | X | X | X | X | | X |
| Y-9 | X | X | X | X | X | X | X | X | X |
| Y-10 | X | X | X | | | X | X | | X |
| Y-12 | X | X | X | | | X | X | | X |

| Table 5-4. Well Recommended Improvements | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Well | 1. Well and Well Pump Upgrades | 2. House-keeping | 3. Safety Equipment Upgrade | 4. Pump Pedestal | 5. Discharge Piping | 6. Paint | 7. Chlorine Equipment | 8. Electrical Improve-ments | 9. Site Work |
| Y-14 | X | X | X | | X | X | X | | X |
| Y-15 | X | X | X | | | X | X | X | X |
| Y-16 | X | X | X | | | X | X | | X |
| Y-17 | X | X | X | | | X | X | | X |
| Y-18 | X | X | X | | | X | X | | X |
| Y-19 | X | X | X | | | X | X | | X |
| Y-20 | X | X | X | | | X | X | | X |
| Y-21A | X | X | X | | | X | X | | X |
| Y-22 | X | | X | | | X | X | | X |
| Y-23 | X | X | X | | | X | X | | X |
| Miscellaneous Wells | | | | | | | | | |
| AG-1 | X | X | X | X | X | X | X | X | X |
| AG-2A | X | X | X | | | X | X | | X |
| EX-5 | X | X | X | | | X | X | | X |
| EX-11 | X | X | X | | | X | X | X | X |
| G-501 | X | X | X | X | X | X | X | | X |
| H-1 | X | X | X | | | X | X | | X |
| HGC-2 | X | X | X | | | X | X | | X |
| MJ-1 | X | X | X | X | X | X | X | X | X |
| MJ-5 | X | X | X | | | X | X | X | X |
| NAS-1 | X | X | X | X | | | X | | X |
| Total | 110 | 109 | 110 | 66 | 69 | 108 | 110 | 110 | 110 |

The nine improvement factors summarized in Table 5-4 are outlined in more detail below.

1. **Well and well pump upgrades**
    a. Remove pump and conduct a video inspection survey of the well.
    b. Rehabilitate well, if necessary.
    c. Add cooling and temperature-sensing equipment to motor and reinstall the pump with appropriately-sized motor, drop pipe, check valves, and an access tube for measuring water level.
    d. Replace or refurbish the pump discharge heads.

    *Notes:*

    - *Well rehabilitation procedures will differ for each well. Procedures will depend upon the amount and type of well screen plugging or casing damage. Typical rehabilitation activities include scratching the well screen, chemical treatment, air-lift swabbing, and disinfection.*
    - *Many of the existing pump discharge heads are in extremely poor condition due to corrosion. The discharge heads bear most of the overall pump weight and corrective actions should be performed as soon as possible.*

- *The estimated task cost varies and depends on the rehabilitation requirement and current equipment status. For example, Well Y-20 has been equipped with a motor shroud, but should also be equipped with a temperature-sensing device.*

2. **Housekeeping**
   a. Remove old SCADA equipment and other unused equipment and conduits.
   b. Pressure wash concrete and metal surfaces.
   c. Demolish and remove old concrete slabs.
   d. Fill holes in concrete and non-concrete surfaces.
3. **Safety equipment upgrade**
   a. Ensure that all safety equipment is up-to-date and functioning properly.
   b. Replace missing equipment.
   c. Install new eyewash plumbing and refresh fire extinguishers.
   d. Add outside lighting and improve building ventilation.
4. **Pump pedestal**
   a. Construct a new concrete pedestal with a minimum height of 18 inches.
   b. Add a casing vent with a minimum screen height of 36 inches.
   c. Add a permanent sounding pipe, install an electrical splice box, elevate the well casing above the pedestal, and provide a flange for pump head connection.

   *Notes:*
   - *Minimum pedestal and casing vent heights cited are per California code requirements. USEPA is likely to enforce these in the future.*
   - *Elevating the pump head base flange off the pedestal as suggested will eliminate the need for a well head seal.*
5. **Discharge piping**
   a. Install new reconfigured discharge piping and pipe supports and construct new pump pedestal where required.
   b. Provide a flow meter and pressure gage to accommodate future replacement with a SCADA-capable pressure transmitter.
   c. Install a check valve, gate valve for well isolation, and air release and vacuum valve.
   d. Install a flange isolation kit at the pump head discharge flange to prevent stray currents from reaching the pump.
   e. Construct manually operated pump-to-waste piping.

   *Notes:*
   - *New calibrated flow meters and pressure gages will enable GWA to closely monitor pump performance to maintain optimal electrical efficiency.*
   - *Most sites are currently equipped with undersized air release valves. In addition to providing air relief, the valves should provide vacuum relief to prevent vacuum conditions in the pump drop pipe.*
6. **Paint**
   a. Paint pump heads and discharge piping.
   b. Paint building walls.

7. **Chlorine equipment**
   a. Rewire chlorine exhaust fans to be triggered by door opening.
   b. Replace flow switches and other older equipment.
   c. Add chlorine residual analyzers.
   d. Replace existing 1 horsepower (hp)-booster pumps with 2 hp-higher flow and pressure pumps.
   e. Plug chlorine building holes.
8. **Electrical improvements**
   a. Add submersible motor temperature monitoring in the motor control panel.
   b. Add sub-monitor motor protection.
   c. Replace old motor control panel components, conduit, and wiring.
9. **Site work**
   a. Construct concrete well pads.
   b. Fix/upgrade fences and gates and install new warning signs.
   c. Improve site drainage for rain and pump-to-waste water.
   d. Construct all-weather access for vehicles.

### 5.2.3 Well Pump Motor Failures

GWA has experienced an abnormally high rate of well pump motor failures. GWA has attempted to determine the cause of the high failure rate, but has not been able to define a specific root cause of the failures. Based on observations and available evidence, inadequate submersible motor cooling is currently considered the primary reason for the high proportion and frequency of well pump and motor failures.

The problem is expected to persist because GWA currently uses 6-inch diameter submersible motors in most wells. When a 6-inch diameter motor is set below or within well screen intervals in 6- and 8-inch cased wells, the motor cannot be cooled per the manufacturer's requirements. Where possible, a flow inducer cooling sleeve (shroud) should be used to force water past the motor. Where a shroud is not possible, a flow tube could be provided to improve motor cooling.

GWA has started to address this problem in some wells and needs to address the problem with other wells, as recommended later in this section.

### 5.2.4 Chlorides

Current chloride levels in the wells were reviewed to identify wells with chloride levels exceeding 250 milligrams per liter (mg/L), which is the maximum contaminant level (MCL) for potable water quality based upon the Secondary Drinking Water Regulations. Table 5-5 lists the wells with chloride levels exceeding 250 mg/L over at least one quarter in the last half of 2016 and the first half of 2017. Values highlighted in red exceed the 250 mg/L MCL.

| Table 5-5. Wells with High Chloride Levels | | | | |
|---|---|---|---|---|
| Well | Chloride Levels (mg/L) by Quarter | | | |
| | 2016 Quarter 3 | 2016 Quarter 4 | 2017 Quarter 1 | 2017 Quarter 2 |
| A-9 | 237.4 | 237.4 | 242.9 | 272.4 |
| A-10 | 383.8 | 358.4 | 354.4 | 370.4 |
| A-13 | 443.8 | 438.8 | 511.8 | 486.3 |
| A-14 | 237.4 | 231.9 | 268.9 | 238.9 |
| A-17 | 238.9 | 200.4 | 220.4 | 124.5 |
| A-18 | 309.9 | 316.4 | 319.9 | 321.4 |
| A-19 | 470.8 | 451.8 | 484.3 | 474.8 |
| A-21 | 377.8 | 281.4 | 322.9 | 318.4 |
| M-9 | 233.4 | 237.4 | 189.9 | 78.0 |
| D-8 | 215.9 | 214.4 | 185.9 | 229.9 |
| F-6 | 207.9 | 200.9 | No Data | No Data |
| F-19 | 219.4 | 208.4 | 180.9 | 180.9 |

Of the wells listed in Table 5-5, all but A-9, M-9, F-6, and F-19 also had high chloride levels in 2006. As new or rehabilitated wells are brought online, the high chloride wells should be taken out of service or the pumping rates should be reduced until chloride levels are consistently below 250 mg/L. Some wells with historically high chloride levels, such as A-13 and A-19, may need to be shut down permanently.

### 5.2.5 Well Production Variances

Several wells are currently equipped with pumping equipment that is producing more or less than the Guam EPA-permitted flow rate. Table 5-6 lists wells with a difference of greater than 20 percent between the average 2015 flowrate when the pumps were operating and Guam EPA-permitted flows. The table does not include wells that were offline in 2015.

| Table 5-6. Wells with Large Difference Between Permitted and Actual Flows | | | | |
|---|---|---|---|---|
| Well | Average 2015 Flow When Well Operated (gpm) | Guam EPA-Permitted Flow Rate (gpm) | Difference (gpm) | Percent Difference |
| Wells Pumping Below Permitted Flow Rate | | | | |
| F-15 | 241 | 440 | -199 | 45% |
| F-13 | 223 | 380 | -157 | 41% |
| A-13 | 158 | 237 | -79 | 33% |
| D-11 | 157 | 226 | -69 | 31% |
| AG-1 | 176 | 250 | -74 | 29% |
| M-17B | 257 | 354 | -97 | 27% |
| M-20A | 303 | 400 | -97 | 24% |
| M-6 | 129 | 168 | -39 | 23% |

| Table 5-6. Wells with Large Difference Between Permitted and Actual Flows | | | | |
|---|---|---|---|---|
| Well | Average 2015 Flow When Well Operated (gpm) | Guam EPA-Permitted Flow Rate (gpm) | Difference (gpm) | Percent Difference |
| Wells Pumping Above Permitted Flow Rate | | | | |
| M-4 | 259 | 138 | 121 | 88% |
| Y-5 | 241 | 148 | 93 | 63% |
| Y-12 | 379 | 235 | 144 | 61% |
| Y-16 | 314 | 200 | 114 | 57% |
| D-4 | 252 | 172 | 80 | 47% |
| Y-1 | 204 | 141 | 63 | 45% |
| F-5 | 208 | 145 | 63 | 44% |
| M-15 | 247 | 172 | 75 | 44% |
| A-1 | 303 | 216 | 87 | 40% |
| A-25 | 338 | 245 | 93 | 38% |
| F-12 | 203 | 148 | 55 | 37% |
| Y-20 | 687 | 500 | 187 | 37% |
| A-32 | 236 | 173 | 63 | 36% |
| D-6 | 258 | 189 | 69 | 36% |
| A-4 | 328 | 244 | 84 | 35% |
| A-19 | 185 | 138 | 47 | 34% |
| F-8 | 200 | 149 | 51 | 34% |
| HGC-2 | 589 | 444 | 145 | 33% |
| EX-5 | 336 | 254 | 82 | 32% |
| Y-19 | 644 | 500 | 144 | 29% |
| D-2 | 240 | 187 | 53 | 28% |
| A-15 | 296 | 231 | 65 | 28% |
| Y-2 | 199 | 161 | 38 | 24% |
| D-16 | 198 | 161 | 37 | 23% |
| D-9 | 241 | 196 | 45 | 23% |
| D-27 | 490 | 400 | 90 | 22% |
| M-7 | 212 | 175 | 37 | 21% |
| M-8 | 189 | 158 | 31 | 20% |
| D-24 | 216 | 180 | 36 | 20% |

GWA also currently has a project underway to field-verify production meter performance and plans to replace under-performing and failed production flow meters at all GWA groundwater well sites. Any flow meters that are determined to be reporting inaccurately also need to be considered in adjusting well pumping capacity or permitted well flow rates.

GWA should maintain an inventory of pumps of various sizes so that well pumps that fail can be replaced quickly with an appropriately sized pump. This will reduce instances of over or under pumping.

### 5.2.6 Wells to Abandon

Several wells are no longer in use by GWA and need to be properly capped and abandoned per Guam EPA requirements. Table 5-7 lists wells that have been identified as needing to be properly abandoned. Appendix J provides additional detail for each well including mapping, photographs, and the Guam EPA abandonment procedure.

**Table 5-7. Wells to Abandon or That Have been Abandoned**

| Well | Location | Notes from GWA |
|---|---|---|
| A-11 | Chalan Pago | The well has been abandoned per GWA documentation. The well was initially secured due to a collapsed well screen. The well was unsuccessfully redrilled three times, but was then abandoned due to high turbidity (whiteish water) of flow test water in the two additional well borings accomplished 100 feet from the original collapsed well. According to the Guam EPA FY09 Annual Well Inspection Report, the discharge and suction sections have both been capped with metal plates. |
| A-22 | Radio Barrigada | The well had not been in operation for over three years as of 2009 when GWA visited the well. The well is believed to have been abandoned prior to 1989. The wellhead is still in place with a 90-degree elbow (without lift shackles), pump, motor, and column. The lifting eye is broken. GWA staff knows little about this well. |
| A-27 | Mongmong Toto Maite | The well was cut and capped with steel in 2006. The well was permitted for 60 gpm, but went completely dry soon after development. |
| AL-1 | Inarajan | According to the Guam EPA FY09 Annual Well Inspection Report, the well pipe assembly has been removed and the discharge and suction sections have both been capped with metal plates. |
| AL-2 | Inarajan | According to the GUAM EPA FY 09 Annual Well Inspection Report, the discharge and suction sections have both been capped with metal plates. |
| D-23 | Dededo | The well had not been in operation for over three years as of 2009 when GWA visited the well. It is suspected that only a pocket of groundwater exists. In 1997, crews changed the pump from the designed 50 hp to 30 hp and then to 15 hp, and the well still went dry. The well flow would go from 100 gpm to no flow in less than 10 minutes.<br>According to the Guam EPA FY 09 Annual Well Inspection Report, the discharge and suction sections have both been capped with metal plates. |
| M-13 | Dededo | The exact location of this well is unknown. It is believed to be in the flea market parking lot. The location has a monitoring well and piping (filled with concrete). The well has possibly been abandoned. |
| T-1 | Talofofo | According to operations staff, the well site is inaccessible. |
| Y-4 | Yigo | This well has been capped with steel. |
| YL-4 | Yona | The well is not in operation due to high turbidity. The well was located, but is difficult to access due to overgrown vegetation. The vegetation would need to be cleared to access the site for inspection and abandonment. |
| YL-5 | Yona | The well is not in operation due to high turbidity. The well was located, but is difficult to access due to overgrown vegetation. The vegetation would need to be cleared to access the site for inspection and abandonment. |

## 5.3 Ugum Surface Water Treatment Plant Condition Assessment

The following section describes the condition of the Ugum SWTP.

### 5.3.1 Capacity

Ugum SWTP production data from January 2012 through December 2016 is shown in Figure 3-6. The following provides information about the average and peak plant capacity over that period:

- The plant has been in operation and producing more than 1 mgd 98.5 percent of the time since the conversion to the membrane process in 2012.
- The average production rate was 2.17 mgd with the typical range between 1.7 and 2.7 mgd.
- There were less than 20 days when the production exceeded 2.7 mgd.
- There were 6 days when no production was recorded and 28 days when production was 1.0 mgd or less.
- The maximum production rate recorded was 3.7 mgd, but this occurred during a capacity test and it is unlikely that the flow represents a sustainable production capacity for the Ugum SWTP.
- The worst period of the plant's operation was between September 19, 2013 and September 22, 2013 when the plant was shut down for more than two days. Four of the reported 28 low-production days occurred during this period.

The following conclusions can be drawn from the production data:

- The plant has been a reliable water treatment facility with few complete outages over the 5-year period.
- The current plant configuration has shown that it is capable of reliably producing at least 2.5 mgd on a continuous basis in its current condition and configuration.
- The plant has never produced the design capacity of 4.0 mgd since the upgrade to the membrane process.
- Plant production fluctuates significantly during the wet season, typically due to elevated turbidity levels in the river.

Several factors at the plant contribute to the production limitations, including the following:

- **Raw water quality (turbidity):** the plant cannot treat water when the surface water is highly turbid, which happens during significant rainfall events. When turbidity in the raw water stream is over 100 Nephelometric Turbidity Units (NTU), the plant flow rate is reduced to the capacity of a single pump. Plant flow is further reduced when the raw water is turbid due to screen washes, which occur every 5 minutes instead of the normal operation of every 25 minutes.
- **Raw Water Pump Station capacity and operation:** the currently installed pumps are not able to achieve 4 mgd. During a capacity check in 2014, two raw water pumps (out of three total pumps) operating at synchronous speed were only able to achieve 3.3 mgd. This flow rate is the potential capacity of the raw water pumps and not the actual plant production rate, which is further limited by the backwash water flows required for the intake filters and membranes.
- **Process redundancy:** the plant's process redundancy is limited such that when maintenance is required or when equipment fails, a component of the process is not available for an extended period. Significant process items that do not have backups include the contact tanks, membrane tanks, and sludge and neutralization tanks. The treatment plant production is therefore limited by the specific equipment that is out of service.
- **Membrane condition:** the microfiltration membranes are near the end of their useful service life and there are issues with the membrane racks and other items that need to be repaired.

The Ugum SWTP is functioning well and reliably in the 2–2.5 mgd production range because there is essentially a standby treatment train in service. Under this condition, if a unit needs to be taken offline for any reason, there is adequate capacity in the remaining process units so the plant production rate is not significantly impacted. This will not be the case if GWA decides to significantly increase the plant's production rate. At higher flow rates, if a unit is taken offline, the plant production rate will need to be reduced relative to the capacity of the out-of-service unit. This could be acceptable for short-term outages, but longer outages would require the production to be supplemented by other sources.

A detailed plant bottleneck study should be completed if the plant's production is increased significantly beyond the current production rates.

### 5.3.2 Developments Since 2006 Master Plan

In 2006, the Ugum SWTP was a rapid media (conventional sand filter) plant that had significant physical and operational limitations. The plant was routinely unable to meet drinking water standards. The 2006 Master Plan noted several design limitations at the plant that needed to be addressed. The Master Plan recommended the following major improvements:

1. Replace dual media filters with membrane filters
2. Construct a new 2.0 MG finished water tank
3. Provide chemical feed equipment redundancy
4. Modify the raw water intake to minimize siltation
5. Repair the existing Ugum SWTP finished water tank

The 2006 Master Plan also suggested that a raw water reservoir could be constructed for the Ugum SWTP but it was not included in the capital improvement program because of the high cost. The conceptual raw water reservoir would provide approximately 150 MG of storage to enable the plant to continuously produce 4.0 mgd year-round and ensure drought protection.

Since 2006, significant modifications have been completed at the Ugum SWTP to improve the treatment performance and plant reliability. Items 1 and 3 from the 2006 Master Plan list have been completed, including the conversion to membrane treatment and upgrade of the chemical feed system. Since these upgrades were complete, Ugum SWTP has consistently met drinking water standards and there have been no violations since the membrane treatment process was put into service.

A project has been planned to modify the raw water intake (item 4), but the project has not proceeded to the implementation stage. The project remains a priority for future Ugum SWTP projects. A capital improvement project has also been planned to clear silt from around the cage and improve the intake. However, this project has been in procurement for a significant amount of time. Improvements to the river screen and removal of sediment buildup around the intake are currently planned in GWA's capital improvement plan (CIP). Permits were previously obtained and drawings were prepared to undertake the intake area silt clearing projects. Upgrades to the Ugum SWTP river intake structure are included in the recommendations later in this section.

Items 2 and 5 are discussed with other storage tank improvements in Section 6.

### 5.3.3 Physical Conditions

At least four condition assessments have been completed for the Ugum SWTP and intake since the plant was constructed. Two condition assessments were completed since the conversion to the membrane treatment process to analyze operational issues the plant has experienced and to recommend improvements. The most recent assessment concluded that the plant was in relatively poor operating condition. Older components are starting to require excessive maintenance and some components require replacement. The two assessments completed since the conversion to the Membrane Treatment Process were summarized in the following reports:

- Operational Assessment of the Ugum Raw Water Intake and Water Treatment Plant, Brown and Caldwell, April 2013 (BC, April 2013b).
- Final Draft Technical Memorandum, Ugum Water Treatment Plant Assessment, Brown and Caldwell, December 2015 (BC, December 2015a).

A review of the reports indicated that maintaining continuous, reliable operation of the Ugum SWTP has been challenging due to a variety of issues. Some of the major issues that have been difficult to resolve include:

- The dam and intake continue to be operational issues from performance and safety perspectives. Siltation at the plant intake structure needs to be addressed. As noted in the 2015 report, an intake cleaning project has been planned, but for various reasons has not been implemented.
- The overall plant design capacity is currently not achievable. There are several limitations to the reliable production capacity as noted above.
- The life expectancy of the membranes is an issue. The membranes are projected to have an operational life of seven years under normal operating condition. The membranes have not been able to achieve this as GWA is currently in the process of replacing the membrane modules. Improvements to the plant and plant operations should be enacted to improve the membrane life and protect GWA’s investment in the technology.
- The one finished water tank needs repair, but cannot be taken offline. A new tank is planned for construction to provide additional storage capacity as well as redundancy to allow the existing tank to be taken offline.

Since the 2015 report, significant progress has been made in addressing some of the noted deficiencies as reported from site visits in 2016 and 2017. However, there are remaining items that need to be corrected. Some of the significant items from the 2015 report that still need to be addressed include the following:

#### Dam

- During high river flow rates, the stop logs are pushed into an open position due to the river flow velocity. The stop logs then must be manually moved (reset) which requires employees to walk out onto the slippery dam to push the stop logs back into place. This creates a safety issue in which an employee could slip and fall over the dam. Figure 5-2 shows the stop logs in position.

#### Intake Facilities

- It is difficult and dangerous for the employees to get to the intake screen structure to clear debris. To clean the intake screen structure, the employees are required to wade out to the intake screen or place a ladder from the edge of the river to the top of the cage. This is an unsafe situation as the employees are working in or above the river depending on how they access the screen. A new screen with proper access should be provided. Figure 5-2 also shows the intake screen.

- The high sediment load in the water causes sediment buildup at the intake, requiring extra maintenance to keep the intake clear.

**Figure 5-2. Dam with Stop Logs in Place (left) and Intake Screen (right)**

### Raw Water Pumps

- The emergency generator can only support one pump, although it is intended to run two.
- There is no ability to monitor or operate the pumps from the control center at the Ugum SWTP.

### Coagulation

- The sludge collection system in Contact Basin No. 2 is out of service and requires replacement.

### Membranes

- The membranes have typically had unacceptable and variable pressure decay test (PDT) readings due to design and operation issues and are near the end of their useful service. In April 2016, the Consolidated Commission on Utilities (CCU) approved procurement and replacement of the microfiltration membrane cells. The membrane units have been delivered, but not yet installed.
- There are leaks in the system which must be repaired.
- Pinning of the racks has not been completed on the required schedule. In addition, some of the racks are bent so GWA staff are concerned about breaking them.
- There are issues with the end caps of the manifolds. Six of the 12 racks on cell 2 require weld repairs, and at least two more were identified as needing repair.
- There are safety issues with respect to fall protection, access to the membrane racks, overhead crane use, and other issues.

The membranes are shown in Figure 5-3.

**Figure 5-3. Membrane Basin**

**Other Components**

- The control system is becoming obsolete and there is no installed backup to maintain operation if there is a fault. A new/upgraded control system with redundant backup system should be considered.
- Other minor issues with ancillary systems were described in the 2013 and 2015 assessment reports including issues with the sludge management system, SCADA system, and others. Refer to the Condition Assessment reports for additional details.

Since the completion of the assessment reports, GWA has installed the third raw water pump, repaired the raw water screens, repaired the centrifuge dewatering system, and completed other minor improvements.

#### 5.3.3.1 Ugum SWTP Raw Water Supply

As described in Volume 1, Section 5 (Source Water), a supplemental raw water source or raw water reservoir is necessary for the Ugum SWTP to produce water at the plant capacity of 4.0 mgd year-round. A detailed study of the river, pump station, pipeline, plant capacity, and alternate sources is recommended to establish the long-term requirements for Ugum. This study would be a component of a proposed South Guam Water Study. The study should evaluate factors relative to the Ugum SWTP such as:

- The required size and cost of a raw water reservoir on the Ugum river to provide 4.0 mgd capacity year-round. In the 2006 master plan, the required volume was estimated to be 150 million gallons.
- The size, location, pipeline requirements, and costs for a supplemental raw water pump station on the Talofofo river.

- Comparison to other water supply options such as improved supply from the northern wells, continued reliance on Navy water, and establishing new sources or re-establishing historic sources in South Guam.
- Evaluation of improvements required at Ugum SWTP to reliably produce 4 mgd of treated water year-round.
- Determination of the ideal capacity for the Ugum SWTP (which could be more than 4 mgd) in conjunction with the reservoir size and alternate source supply.

A raw water reservoir or access to an alternate raw water supply should also improve the water quality (mainly turbidity) of the raw water entering the SWTP, resulting in an overall improvement of plant performance. This would be accomplished by selecting the water source with the lowest turbidity level for plant supply. The raw water supply to the plant could be altered based on river flow, river turbidity, power costs, and plant operations. Figure 5-4 shows a possible location and the extents of a raw water reservoir on the Ugum river and Figure 5-5 shows one option for a pump station at the Talofofo river.

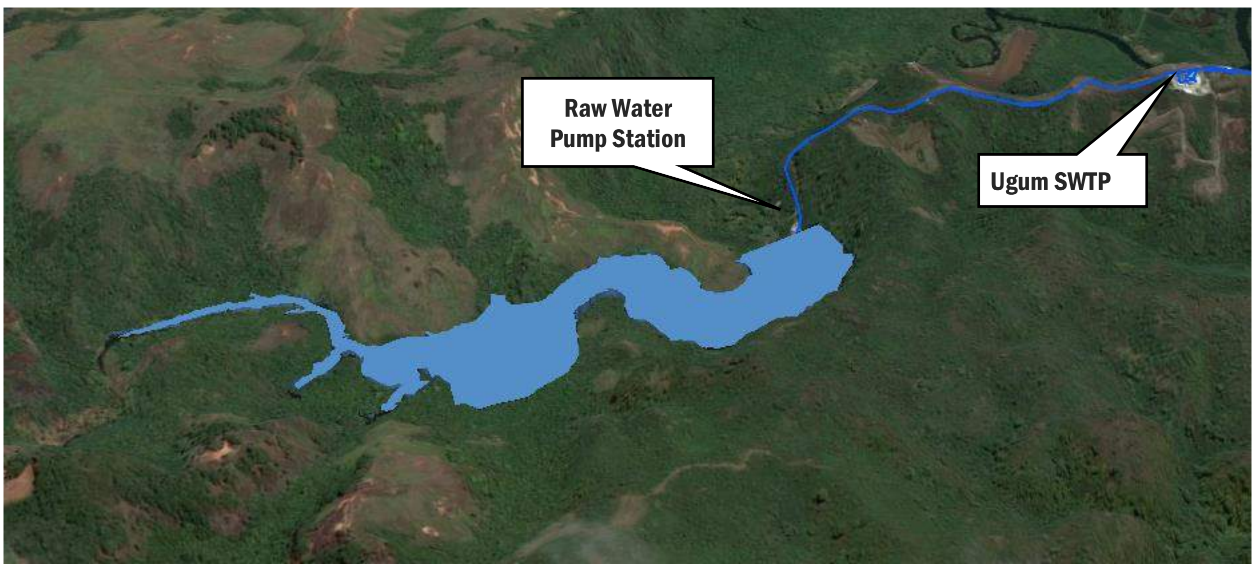


**Figure 5-4. Extents of Reservoir on Ugum River with Dam at 45-foot Elevation**

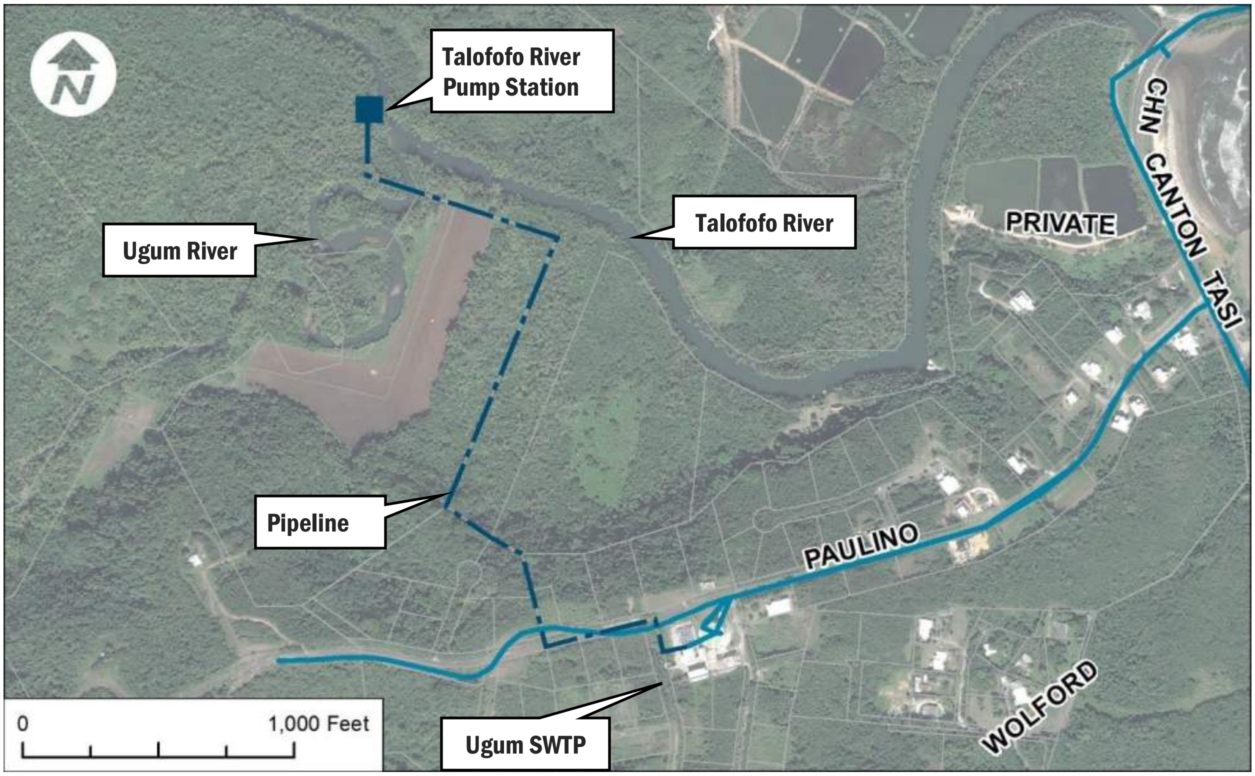


Figure 5-5. Pump Station on the Talofofo River

### 5.3.4 Ugum SWTP Future Projects

Recommendations for improvements at the Ugum SWTP are summarized in Section 5.5. The projects address water sources and current and future rehabilitation of the Ugum SWTP.

## 5.4 Well Recommendations

Several projects are recommended for GWA to improve the capacity, reliability, and safety of the water system with respect to existing or proposed production wells. These recommendations are summarized below.

### 5.4.1 Recommendations for New Wells

GWA should plan for approximately 13 new wells between 2020 and 2035, as discussed in Section 5.1.4. The quantity of wells required is based on the population projections and a 10 percent reduction in NRW. It is recommended that GWA undertake a well exploration and development project to plan the location of the future wells. A well development project would include the following:

- Complete a desktop study using input from WERI, NGLA studies, current land use and land use plans, and the GWA water system hydraulic model to select optimal locations of future production wells.
- Develop a contract to drill pilot holes and complete capacity tests for potential well locations.
- Purchase/acquire the land at each successful well site and consider actions to protect the land and aquifer near the well sites.
- Develop design and construction contracts for well development as increases in production are required.

### 5.4.2 Recommendations for Existing Wells

This section summarizes recommendations needed to keep the existing wells in service and return currently inactive wells to service.

#### 5.4.2.1 Requirements for Condition Assessment

Section 5.2 discusses a condition assessment of GWA's production wells. As the assessment indicates, there are areas that need improvement at nearly every production well. Some improvements are minor and some are more extensive.

Each of the 120 system wells can be expected to require a significant rehabilitation project every 15 to 20 years. The sequence of well rehabilitation will be selected based on repair needs and the well's criticality. Critical wells that must remain operational will need to be addressed first, bringing new wells into service or re-establishing operation of existing wells to supplement supply while the critical well is repaired.

#### 5.4.2.2 Requirements for Water Quality

As mentioned in Section 3.1, wells offline due to contamination issues include A-28 (PCE) and M-14 (chlordane). Each well requires a GAC system before it can be brought online. The rehabilitation work listed in Table 5-4 should also be completed before the wells are returned to service.

Wells A-23 and A-24 are also offline due to the recent detection of PFOS/PFOA contamination. The extent of contamination and treatment alternatives are being developed for these wells.

Wells showing high chloride levels should be evaluated to determine if a reduced pumping rate will lower chloride levels.

Wells pumping higher than Guam EPA-permitted levels, but with consistent chloride levels below the MCL, should be discussed with Guam EPA to have their permitted pumping rates increased to a higher allowable level.

#### 5.4.2.3 Requirements for Motor Cooling

As noted in Section 5.2.3, GWA has started addressing problems with well pump motor failure due to inadequate motor cooling. It is recommended that GWA continue to address this problem as described in the *Water Well Rehabilitation Program Plan* (BC, 2014).

#### 5.4.2.4 Well Meters

Accurate flow meters are essential to effectively assess production costs and determine NRW. In 2016 as part of a preventive maintenance program, 16 of the system's 120 flow meters at wells were replaced with magnetic flow meters. GWA has also initiated a project to review all production well flow meters and prepare plans and specifications for a repair and replacement project. See Section 9.2.3 for additional details on the well meters.

#### 5.4.2.5 Planned Projects for Existing Wells

Two types of projects are recommended for the existing wells:

- Annual projects to address relatively minor issues that can affect one or all system wells, such as flow meter replacement, modifications for improved motor cooling, minor improvements from the condition assessments, etc. This project would include the addition of generators at wells that currently do not have them.
- Extensive well overhaul projects to address significant issues and equipment replacement, new borehole development, and similar major rehabilitation requirements. There should be two different project types, one to cover normal aging of mechanical and electrical equipment and a second to cover major well overhauls which would include new boreholes.

The scope of each project would include any or all items listed in Table 5-4, such as well and well pump upgrades, safety issues, discharge piping, chlorination equipment, electrical improvements, and other improvements.

### 5.4.3 Wellhead Protection and Well Abandonment

A Drinking Water Source Assessment and Protection (DWSAP) Program and Wellhead Protection Plan (WHPP) was completed in 2015. The DWSAP program was prepared in accordance with the 1996 reauthorization of the federal Safe Drinking Water Act (SDWA), which requires states and territories to develop comprehensive programs to assess sources of drinking water to determine system susceptibility to identified sources of contamination and ensure that related information is publicly available. The DWSAP and WHPP lay the foundation for protection of GWA-supplied water quality from contamination in northern Guam. The OneGuam Framework for the Department of Defense (DoD) and GWA system integration includes budgeted funding for wellhead protection.

Several wells in GWA's system need to be properly abandoned. These wells are potential contamination sources as they provide a direct path from the surface to the aquifer below and need to be properly closed. A listing is provided in Section 5.2.6 and Appendix J. A project is included to plan for the well abandonment work in conjunction with implementing the WHPP. In addition to properly securing and decommissioning exploratory boreholes and abandoned wells, other aspects of the project include:

- Land purchase to control land use within the wellhead protection areas.
- Development and implementation of a contingency plan for water supply.
- Extending collection systems to facilitate the elimination of septic/cesspool properties currently located within wellhead protection zones.
- Point source management, and financial support for spill prevention and response programs within wellhead protection zones.
- Public education and outreach, postings, and signage identifying wellhead protection areas
- Increased involvement by GWA personnel to advocate for the implementation of existing water resources protection codes and regulations and enforcement of existing zoning requirements that restrict location of new high-risk PCAs, such as onsite sewage disposal systems or ponding basins within designated distances from a water supply.
- Increased involvement by GWA personnel in the Territorial land use planning, and permit review process to ensure that concerns involving the protection of the drinking water source are addressed prior to permitting of new land uses within wellhead protection zones.
- Increased involvement by GWA personnel with developers at the planning stage to ensure that easements exist, land for infrastructure is assigned, and the wellhead protection plan is adhered to.

Additional detail regarding the WHPP can be found in Volume 1, Section 5.2.

### 5.4.4 Well Maintenance Rig

GWA currently needs to hire outside crane or well drilling rig services when down hole work is required at a well, such as for pump removal. This service is costly and scheduling of the services can delay the response to an emergency condition at any well. It is recommended that GWA purchase a pump hoist rig with a minimal rating of 12 tons to perform pump removal and installation activities such as bailing, swabbing, scratching, air-lifting, and jetting. This will enable GWA to resolve down-hole well issues efficiently.

### 5.4.5 General Production Wells

The following are general recommendations for GWA to improve the operation and reliability of production wells. These recommendations are mainly operational in nature.

- Establish and maintain an inventory of pump and piping components such as check valves, power cable, motors, pumps, flow meters, and other instrumentation so that a well can be placed back into service without delay.
- Consolidate available well and pump data in a central location and scan the data for easy computer access. All well-related equipment and operational records should be compiled and scanned, such as published pump curves, pump/motor brands and model numbers, standby generator make and usage, motor control type and size, water quality results, water level history, well production data, and all available maintenance and repair records. Having this information readily available will make day-to-day operations and maintenance (O&M), long-term planning, and cost tracking more efficient for administrative, engineering, and operations staff.
- Develop a monitoring program to check well performance, measured versus predicted, and track trends. Operating parameters to monitor include flow rate, pressure, voltage and amperage by phase, and motor temperature. Data should be compared to published pump performance curves and historical well operating parameters and changes in parameters should trigger remedial actions, when necessary.
- Assign responsibility for each well to a specific GWA employee to provide continuous site monitoring, housecleaning, recordkeeping, and general oversight. Daily inspection reports should be developed to monitor water levels, production rate, discharge pressure, site security, overall site condition, safety devices, chlorine equipment, etc.
- Review potential for using 1,800 revolutions per minute (rpm) pumps and motors at wells where practical. If possible, a trial installation could be used in one of the 12-inch diameter wells. The slower speed pump and motor should have a much longer life due to a reduced rate of mechanical wear.
- Include capability to control pumps based on system pressure in new well designs and refurbishments. This could be done by starting and stopping pumps or controlling pump speed if a variable frequency drive (VFD) is installed. The well pumps are not controlled on an automatic basis by high and low pressure and are continuously run until failure.

## 5.5 Ugum Surface Water Treatment Plant Recommendations

Capital improvements, as well as improvements to maintenance and operations, are necessary to provide continued reliable operation of the Ugum SWTP. Recommended improvements are summarized below.

### 5.5.1 General Recommendations

Additional training is necessary to provide operations staff with the skills required to manage plant operations, as noted in the 2013 and 2015 condition assessment reports discussed in Section 5.3. Operational issues are discussed in detail in the reports.

Maintenance is also important for membrane treatment systems to maintain performance and extend the operational life of membrane units. Membrane life is significantly reduced when membranes are operated outside their design conditions. Considering the cost of the membranes, it is typically less costly in the long term to operate membranes within their design parameters rather than incur the cost of early replacement of membrane modules.

One of the major deficiencies in the design and operation of Ugum SWTP is the ability to produce and distribute the design capacity of 4.0 mgd. If Ugum SWTP can reliably produce 4.0 mgd, and the supply could be transported through the distribution system to the required areas, the plant could meet South Guam's projected water demands. However, several factors currently limit Ugum SWTP's capacity, including:

- Adequate, year-round raw water supply from the Ugum river
- Variability in the raw quality (turbidity) of the Ugum river
- Bottlenecks within the treatment plant
- Ability to distribute water into the GWA distribution system

Future development of Ugum SWTP is only one part of the broader issue of providing a reliable water supply to South Guam. A comprehensive review of the requirements for water supply to South Guam should be completed before any improvements are considered to increase capacity at Ugum SWTP. This study is included in a planned improvement project.

### 5.5.2 Future Recommendations

The following capital improvement projects and water system evaluations are recommended for the continued long-term operation of Ugum SWTP. Some of these projects were described in the 2006 Master Plan and are still relevant.

#### 5.5.2.1 Intake Cleaning

The existing intake requires frequent maintenance because there is a high accumulation of sediment near and upstream of the Ugum SWTP intake. Silt carried into the Raw Water Pump Station causes a variety of operating issues including excessive pump wear and high raw water screen clogging/backwash rates. An intake area cleaning project would remove sediment accumulation in the river at and just upstream of the intake. This cleaning project will improve operations by reducing the amount of maintenance required at the intake and the amount of sediment carried into the Raw Water Pump Station.

#### 5.5.2.2 Raw Water Intake Upgrade

An upgrade to the intake (originally planned as existing CIP project PW 09-01) will allow GWA to efficiently extract Ugum water even during high turbidity periods and operate at low river conditions. To minimize silt carryover into the pump station and provide more reliable raw water supply during low river flow conditions, this project is expected to include a new intake structure and modifications to the existing Raw Water Pump Station. The effort includes an alternative analysis and design concept report to refine the extent and cost of improvements, and master planning for future treatment capacity and projects that increase plant capacity and other items.

#### 5.5.2.3 Reliability Improvements

This project will refurbish and upgrade existing equipment and systems at Ugum SWTP that need repair, replacement, or modification to improve plant capacity and maintain plant operability. The project will generally include the following:

- Complete pump and generator improvements at the Raw Water Pump Station
- Enclose the Raw Water Pump Station motor control center (MCC) and VFDs in an air-conditioned room
- Repair the SCADA communications line from the raw water intake facilities to the control center.
- Repair the No. 2 coagulation basin sludge collection system
- Complete replacement of the membrane modules
- Replace the No. 1 air compressor
- Replace the No. 2 backwash clarifier collection system
- Complete other plant operational improvements
- Install an Ugum river stream gauge at or near the diversion structure

#### 5.5.2.4 Routine Equipment Overhaul Program

Based on the typical operational life and major maintenance requirements of process equipment, routine plant overhauls should be planned during the 20-year planning period for the master plan. The expected operational life of treatment membranes average approximately 7 years before they are due for the next expected replacement. The major equipment overhaul program would include the next scheduled replacement of the treatment membranes and removal and overhaul of major plant equipment such as raw water pumps, blowers, compressors, finished water pumps, centrifuge, and other components.

### 5.5.3 Operational Improvements

The following are general recommendations for GWA to improve operation and reliability of the Ugum SWTP. These recommendations are operational improvements which should be completed as part of overall Ugum O&M plans. The following improvements, defined in the 2015 assessment and discussed in Section 5, are still necessary and should be implemented as soon as practical.

**Safety Improvements**

- Install fall protection around the membrane cells.
- Enclose the chlorine system in a structure and install a scrubber system so that leaks can be contained and neutralized if they occur.
- Develop formal emergency response plans for chlorine and other chemical emergencies.
- Perform emergency response drills regularly to train staff on how to respond to emergencies.

### Operational Procedure Improvements

- Provide additional operator training for Ugum SWTP operators in the areas of preventive maintenance, utility performance, and technical treatment processes. GWA's comprehensive Training Master Plan provides guidance for this training.
- Improve the preventive maintenance program for plant equipment. Develop a comprehensive maintenance program for the plant to help prevent unexpected outages and maintain equipment operations.
- Develop a plant competency test to be completed by operators annually.
- Develop a document to track all purchase and project requests to provide an easy way to follow up on the status of requests.
- Perform visual tests during the membrane PDT cycle to help prioritize which racks to pin and complete pinning activities to improve water quality. Use the existing pinning Excel spreadsheet to track which membranes have been pinned.
- Develop a specific O&M procedure for completing membrane wash activities and using the neutralization tank.
- Develop an annual schedule for membrane washes and use the off-shift swing and graveyard shifts to complete the work. The washes need to be manually initiated but are controlled by the SCADA system.
- Track membrane washes via SCADA or written documentation.
- Use the existing plant inspection sheet weekly to document new or existing problems in the plant.

### Maintenance Management Improvements

- Develop an annual master maintenance schedule in monthly increments.
- Develop preventive maintenance tasks for each maintenance activity.
- Develop a valve exercise program, especially for valves that are not operated often yet are needed to isolate critical functions.
- Purchase tools required to complete plant maintenance.
- Develop a spare parts and equipment list for the plant based on equipment/process criticality and lead time.
- Develop an annual maintenance contract with Siemens for on-call support for the plant control system.

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# Section 6
# Storage Evaluation

This section describes the capacity and condition evaluation of the storage tanks.

## 6.1 Storage Tank Capacity Evaluation

Storage was evaluated under MDD conditions for existing and future scenarios. Model results were reviewed to identify existing and future deficiencies.

### 6.1.1 Evaluation Criteria

Storage components include:

- **Equalization storage:** storage required to keep up with peak hour demands (PHD) when demands are greater than available well and WTP production. Equalization storage was calculated as 15 percent of MDD for the storage tank service area.
- **Fire storage:** the largest fire flow in the storage tank service area multiplied by the duration the fire flow is required.
- **Emergency storage:** the volume required to provide water during events like power outages, equipment failures, natural disasters, etc. Emergency storage was calculated as 100 percent of ADD for the storage tank service area.

See Appendix E for additional details on the storage components. Storage was analyzed by summing the components using the following formula:

- Storage = equalization storage + fire storage or emergency storage (whichever is greater)

Each pressure zone was evaluated to determine if sufficient existing or planned storage capacity is available to meet storage requirements for existing and 2035 demands. GWA currently has plans for new storage throughout the water system based on previous studies done by GWA and others. As part of those plans, new tanks have been recently constructed, new tanks are under design, and GWA has plans to add additional storage tanks in the system.

### 6.1.2 Analysis

A storage analysis was performed on the realigned pressure zones and is summarized in Table 6-1. The storage analysis compared available versus required storage. Available storage calculated for this analysis includes currently operating storage, plus planned storage, minus storage that will be taken offline. GWA was in the planning and design phases for new storage tanks when this analysis was performed. Therefore, the number and size of storage tanks planned by GWA were adjusted during discussions with GWA in conjunction with this analysis to minimize existing and future storage deficiencies. Table 6-1 summarizes the following:

- **Storage tanks:** tank(s) that serve a set of pressure zones.
- **Pressure zones served:** pressure zones served by the set of storage tanks.
- **Available storage:** total storage for the group of tanks equals existing storage plus storage currently planned by GWA. Currently planned storage is summarized in Table 6-2 later in this section.

- **Required storage:** storage required for each group of tanks and pressure zones. Required storage was calculated using the criteria listed at the beginning of this section, including equalization, fire, and emergency storage.
- **Excess/deficit storage:** calculated as the available minus the required storage. A positive value indicates excess storage and a negative value indicates deficient storage.
- **Excess/deficit storage after using upstream excess:** excess storage in upper/higher pressure zones was applied to downstream/lower pressure zones (if excess water could flow to the lower zones by gravity). A positive value indicates excess storage and a negative value indicates deficient storage. The following should be noted for this analysis:
  - The analysis assumed that excess storage shared with lower zones should only be used to handle emergency storage. Each area should have enough storage to handle operational and fire demands before using excess storage from other areas.
  - As an example of how the excess storage was applied, excess storage from the Yigo tanks was applied to Astumbo, the next downstream zone that can be served by gravity from Yigo. Remaining excess storage was then applied to Barrigada, the next downstream zone. This process continued until the excess storage was used up or there was no additional need in the lower zones.
- Excess/deficit storage values are shaded pink for deficient (negative) values, light green for excess (positive) values between 0.5 and 1.0 MG, medium green for excess (positive) values between 1.0 and 2.0 MG, and dark green for excess (positive) values greater than 2.0 MG.

**Table 6-1. Storage Analysis**

| Storage Tanks | Pressure Zones Served | Available Storage (MG) [a] | Required Storage (MG) | | Excess/Deficit Storage (MG) | | Excess/Deficit After Using Upstream Excess (MG) | |
|---|---|---|---|---|---|---|---|---|
| | | | 2017 | 2035 | 2017 | 2035 | 2017 | 2035 |
| North | | | | | | | | |
| Santa Rosa | Santa Rosa Upper, Santa Rosa | 2.05 | 1.58 | 1.79 | 0.47 | 0.26 | 0.47 | 0.26 |
| Yigo | Yigo, Mataguac, Mangilao North, Mangilao Central | 6.55 | 4.15 | 4.99 | 2.40 | 1.56 | - | - |
| Astumbo | Astumbo, Chalan Palauan | 6.03 | 3.86 | 4.64 | 2.17 | 1.39 | 2.16 | - |
| Hyundai | Hyundai, Hyundai Subzone | 1.02 | 0.28 | 0.32 | 0.74 | 0.71 | 0.74 | - |
| Barrigada | Barrigada, Barrigada Subzone, Tiyan | 6.03 | 4.09 | 5.07 | 1.94 | 0.97 | 1.94 | - |
| Kaiser | Kaiser, Harmon Industrial | 5.35 | 4.13 | 4.85 | 1.22 | 0.50 | 1.22 | - |
| Mangilao | Mangilao | 3.04 | 3.86 | 4.53 | -0.83 | -1.50 | - | - |
| Chaot, Agana Heights | Chaot, Ordot/Sinajana, Adawag, Ulloa-Untalan | 1.56 | 2.94 | 3.57 | -1.39 | -2.01 | -0.05 | -0.07 |
| Airport, Tumon (Nissan), Piti | Tumon/Tamuning/Hagåtña | 10.06 | 9.35 | 11.62 | 0.71 | -1.56 | 0.71 | - |
| Manenggon Hills | Manenggon Hills, Pago Bay | 4.02 | 1.30 | 1.63 | 2.73 | 2.40 | 2.73 | 2.40 |
| Nimitz Lower, Nimitz Upper | Nimitz Lower, Nimitz Upper | 0.07 | 0.06 | 0.07 | - | - | - | - |
| None | Nimitz Estates | - | 0.28 | 0.28 | -0.28 | -0.28 | -0.28 | -0.28 |

| Table 6-1. Storage Analysis | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Storage Tanks | Pressure Zones Served | Available Storage (MG) [a] | Required Storage (MG) | | Excess/Deficit Storage (MG) | | Excess/Deficit After Using Upstream Excess (MG) | |
| | | | 2017 | 2035 | 2017 | 2035 | 2017 | 2035 |
| None | Harmon Cliffline | - | 0.24 | 0.24 | -0.24 | -0.24 | - | -0.13 |
| Served through Brigade BPS | | | | | | | | |
| Windward Hills | Windward Hills, Camacho | 1.02 | 0.89 | 1.02 | 0.14 | - | 0.14 | - |
| Sinifa | Sinifa, Santa Rita Central, Santa Rita East | 1.02 | 0.43 | 0.53 | 0.60 | 0.50 | 0.60 | 0.50 |
| Santa Rita, Santa Ana Lower | Santa Rita, Santa Ana Lower | 2.05 | 1.59 | 1.87 | 0.46 | 0.18 | 0.46 | 0.18 |
| Santa Ana Upper | Santa Ana Upper | 0.50 | 0.24 | 0.24 | 0.26 | 0.26 | 0.26 | 0.26 |
| South | | | | | | | | |
| Ugum | Ugum | 4.02 | 0.47 | 0.57 | 3.55 | 3.45 | 2.91 | 2.52 |
| Malojloj | Malojloj Upper, Malojloj, Inarajan/Merizo, Inarajan Upper, Agfayan | 1.00 | 1.64 | 1.93 | -0.64 | -0.93 | - | - |
| Pigua | Pigua, Pigua Upper | 0.50 | 0.26 | 0.27 | 0.24 | 0.23 | 0.24 | 0.23 |
| Umatac Subdivision | Umatac Subdivision, Umatac | 0.50 | 0.27 | 0.27 | 0.23 | 0.23 | 0.23 | 0.23 |
| Agat-Umatac | Agat-Umatac, Lasafua | 0.20 | 0.07 | 0.08 | 0.13 | 0.12 | 0.13 | 0.12 |

*a. Note that the available storage includes currently planned storage as discussed in the bullets above the table.*

### Deficient Areas

The following groups of tanks do not have sufficient storage after applying excess storage.

- **Nimitz Upper and Lower:** these zones do not have enough storage to handle the required fire demand of 60,000 gallons. Currently a 10,575-gallon storage tank serves these areas and there are plans to reinstall an old 5,000-gallon storage tank. This does not provide enough storage to handle a fire. Additional storage is recommended to serve the area, as listed in Table 6-2.
- **Nimitz Estates and Harmon Cliffline:** these areas are not connected to the main distribution system; therefore, they currently do not have any access to storage. A piping project, described in Section 12, is recommended to connect the Harmon Cliffline zone to the Tumon/Tamuning/Hagåtña zone. At the time of this report, GWA was investigating adding storage to serve the Nimitz Estates area, which would replace the Piti tank.
- **Chaot, Agana Heights:** this area is projected to have a very small deficit. No recommendations will be made in this master plan to address this. However, this storage deficit should be reanalyzed in the future as growth projections are updated.

As part of OneGuam (see Section 11.1), water from the two DoD tanks could be used by GWA to help with storage deficiencies. Storage from these tanks was not accounted for in the storage analysis. The two tanks include:

- The Air Force's 2.0-MG buried Santa Rosa tank, on Mount Santa Rosa next to GWA's 1-MG Santa Rosa tank. The Air Force tank elevation ranges from 683 to 698 feet and the GWA tank ranges from 682 to 722 feet. Therefore, the Air Force tank would only be able to supplement storage when the GWA tank is below 16 feet. The DoD and GWA, as part of OneGuam, have discussed sharing storage at this location.
- The Navy's 3.1-MG buried Adelup tank is just off Route 6, about 0.6 miles south of Route 1 and the Governor's complex. This tank could connect to and serve the future GWA Tumon/Tamuning/Hagåtña zone with the addition of about 0.25 miles of piping. The Adelup tank elevation ranges from 206.5 to 224.4 feet, compared to tanks serving the Tumon/Tamuning/Hagåtña zone which range from 195 to 235 feet. Because the floor elevation for the Adelup tank is about 10 feet above the floor of the GWA tanks and the top of the Adelup tank is about 10 feet below the GWA tanks, the Adelup tank could only serve GWA when the GWA tanks are not full. The GWA tanks could also serve back to the Navy zone.

### 6.1.3 Future Storage

The end of this section lists recommendations for future storage to meet storage needs.

## 6.2 Storage Tank Condition Assessment

GWA is currently assessing the structural integrity and safety of all storage tanks, as required to fulfill portions of a Court Order filed by the USEPA on November 10, 2011. The Court Order stated that GWA was required "to complete the assessment and necessary repair, rehabilitation, replacement, and relocation of all of its 29 storage tanks" (USEPA, 2011).

The tanks can be grouped as follows:

- **Tanks already abandoned:** some tanks were already abandoned/demolished due to poor condition prior to the Court Order.
- **Tanks to be inspected:** some of these tanks cannot be taken offline, so inspection will occur after new storage is constructed.
- **Tanks already inspected:** GWA first inspected the exterior of the tanks. Tanks classified as being in poor condition after the exterior inspection were planned for abandonment. GWA then took the remainder of the tanks offline and inspected the interior of the tanks. Based on the interior and exterior inspections, the tanks were grouped as follows:
  - **Inspected and returned to service:** tanks deemed to be in good shape during the inspection were returned to service.
  - **Inspected and repaired:** a few tanks were repaired after they were inspected.
  - **Inspected and abandoned:** several tanks were abandoned/demolished due to the inspections.
  - **Inspected and planned for abandonment:** GWA plans on abandoning several other tanks after new storage is constructed.

Table 6-2 later in this section lists the status of each storage tank.

## 6.3 Recommendations

Table 6-2 lists the existing and recommended storage tanks based on the analysis in this section. GWA will inspect some of the existing storage tanks in the next few years. Plans for new storage may change depending on the results of those tank inspections. For example, some storage tanks may be in poor condition and may need to be replaced. Figure 8-12 and Figure 8-13 in Section 8 show the location of the tanks.

**Table 6-2. Storage Tank Summary with Recommendations**

| Tank Name | Tank Number | Status [a] | Volume (MG) | | WRMP Project Number | Notes |
|---|---|---|---|---|---|---|
| | | | Existing | Planned | | |
| North | | | | | | |
| Agana Heights | 1 | New (2016) | 0.5 | | - | |
| Airport | 1 | To abandon (2019) | 1.0 | - | MP-PW-Tank-02 | GWA is working on property for additional tanks and will probably demolish the existing tank and construct two new tanks. |
| | 1 | Future (2019) | - | 3.0 | | |
| | 2 | Future (2029) | - | 3.0 | | |
| Astumbo | 1 | To abandon (2017) | 1.0 | - | MP-PW-Tank-03 | GWA plans to demolish existing tank No. 1 and is building a new tank on the same footprint. After the new tank No. 1 is completed, existing tank No. 2 will undergo major repairs or will be replaced with a new tank of the same size. GWA plans on acquiring property to build tank No. 3. |
| | 1 | Under construction (2017) | - | 2.0 | - | |
| | 2 | To inspect (2018) | 2.0 | | MP-PW-Tank-03 | |
| | 3 | Future (2029) | - | 2.0 | MP-PW-Tank-03 | |
| Barrigada | 1 | New (2013) | 2.0 | | - | |
| | 2 | New (2015) | 2.0 | | - | |
| | 3 | Future (2030 or later) | - | 2.0 | MP-PW-Tank-04 | |
| Chaot | 1 | New (2016) | 0.5 | | - | |
| | 2 | Under design (2018) | - | 0.5 | MP-PW-Tank-05 | |
| Hyundai | 1 | To abandon (2018) | 1.0 | - | MP-PW-Tank-06 | GWA plans to demolish this tank and build a new tank on the same footprint. |
| | 1 | Under design (2018) | - | 1.0 | | |
| Kaiser | 1 | To inspect (2018) | 2.4 | | MP-PW-Tank-07 | Existing tank needs to be inspected. GWA expects the tank will require major repairs. Storage analysis recommends another tank at this location. |
| | 2 | Future (2030 or later) | - | 3.0 | MP-PW-Tank-07 | |
| Manenggon Hills | 1 | To inspect (2019) | 2.0 | | MP-PW-Tank-09 | Existing tank needs to be inspected. GWA expects the tank will require repairs. GWA working on purchasing property near tank No. 1 to build 2 new tanks. The first new tank will replace the old Pulantat tank and a second new tank (not listed to left) could be built in the future, if needed for future growth. |
| | 2 | Future (2018) | - | 2.0 | | |
| Mangilao | 1 | Repaired (2016) | 1.0 | 1.0 | - | |

| Table 6-2. Storage Tank Summary with Recommendations | | | | | | |
|---|---|---|---|---|---|---|
| Tank Name | Tank Number | Status [a] | Volume (MG) | | WRMP Project Number | Notes |
| | | | Existing | Planned | | |
| | 2 | Repaired (2015) | 2.0 | 2.0 | | |
| Nimitz Hill Lower | 1 | Future (2019) | - | 35,000 gallons | MP-PW-Tank-10 | GWA may put the lower storage back into service or may supply the upper and lower zones from the Nimitz Hill Upper tank. 65,000 gallons is needed to supply fire, emergency, and equalization. 27,000 gallons is needed for emergency and equalization. Total demand could be divided, with all fire storage at the top tank and a smaller lower tank—or demand could be split equally between the tanks or in some other proportion, but a BPS at the lower tank would need to be sized to pump some of the fire flow to the upper zone. |
| Nimitz Hill Upper | 1 | To inspect (2019) | 10,000 gallons | 35,000 gallons | MP-PW-Tank-10 | |
| Tumon (Nissan) | 1 | Future (2018) | - | 1.0 | MP-PW-Tank-11 | GWA plans to replace the abandoned tank with new tank on the same footprint. Land is available for a second tank. |
| | 2 | Future (2029) | - | 2.0 | | |
| Piti | 1 | Future (2020) | - | 1.0 | MP-PW-Tank-13 | GWA is working to obtain land to build a new tank to replace the old abandoned tank. |
| Santa Rosa | 1 | To abandon (2019) | 1.0 | - | - | GWA plans to replace the existing tank with a new tank of the same size. The existing tank will probably be demolished and another tank could be constructed on the old tank's footprint. |
| | 1 | Under design (2018) | - | 1.0 | MP-PW-Tank-16 | |
| | 2 | Future (2029) | - | 1.0 | | |
| Yigo | 1 | To abandon (2018) | 0.5 | - | MP-PW-Tank-21 | Existing tank No. 1 will be demolished and tank No. 2 will be inspected (and will probably require repairs) after construction of the new tank No. 1. |
| | 1 | Under construction (2017) | - | 2.0 | | |
| | 2 | To inspect (2018) | 2.5 | | | |
| | 3 | Under construction (2017) | - | 2.0 | | |
| South | | | | | | |
| Agat-Umatac | 1 | To inspect (2018) | 0.2 | | MP-PW-Tank-01 | GWA plans to inspect this tank, and the tank is expected to remain in service after repairs. |
| Malojloj | 1 | To inspect (2018) | 1.0 | | MP-PW-Tank-08 | GWA plans to inspect this tank, and the tank is expected to remain in service after repairs. |
| Pigua | 1 | To inspect (2019) | 0.5 | | MP-PW-Tank-12 | GWA plans to inspect and repair this tank. |
| Santa Ana Lower | 1 | To inspect (2019) | 1.0 | | MP-PW-Tank-14 | GWA plans to inspect and repair this tank. |
| Santa Ana Upper | 1 | Repaired (2012) | 0.5 | | - | |
| Santa Rita | 1 | To abandon (2018) | 1.0 | - | MP-PW-Tank-15 | GWA plans to replace the existing tank with a new tank of the same size. |
| | 1 | Under design (2018) | - | 1.0 | | |
| Sinifa | 1 | To abandon (2019) | 1.0 | - | MP-PW-Tank-17 | GWA will construct a new tank and inspect the existing tank. GWA expects that the existing tank will require abandonment. |
| | 2 | Under design (2018) | - | 1.0 | | |
| Ugum | 1 | To inspect (2020) | 2.0 | | | |

**Table 6-2. Storage Tank Summary with Recommendations**

| Tank Name | Tank Number | Status [a] | Volume (MG) | | WRMP Project Number | Notes |
|---|---|---|---|---|---|---|
| | | | Existing | Planned | | |
| | 2 | Under design (2019) | - | 2.0 | MP-PW-Tank-18 | GWA has planned to build a new tank across the street from Ugum SWTP. However, a new location may need to be found due to land issues with the proposed site. GWA will then inspect the existing tank, which is expected to require repairs, and return the tank to service. |
| Umatac Subdivision | 1 | To inspect (2019) | 0.5 | | MP-PW-Tank-19 | GWA plans to inspect the tank and decide to whether to proceed with repair or replacement. |
| Windward Hills | 2 | To inspect (2018) | 1.0 | | MP-PW-Tank-20 | GWA plans to inspect the tank, which is expected to require repairs, and return the tank to service. |
| Total | | | 30.1 | 56.2 | | |

*a. Actual or estimated years for the actions are given in parenthesis.*

Recommendations for potable water storage tanks include the following:

- All storage tanks should be inspected every five years. Based on the condition of the tanks, some tanks may need more frequent inspections, such as the existing steel tanks. Deficiencies should be noted and fixed, such as required cleaning and painting of the tanks, valves, and piping at each tank site.
- Storage tank projects should plan on costs for purchasing property if GWA does not own property where the tanks will be constructed.

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# Section 7

# Booster Pump Station Evaluation

This section describes the capacity and condition evaluation of the BPSs.

## 7.1 Capacity Evaluation

The BPSs were evaluated under MDD conditions for existing and future scenarios. The hydraulic model results were reviewed to identify existing and future deficiencies.

### 7.1.1 Criteria

The BPSs were analyzed using the following criteria (see Appendix E for additional details on the criteria):

- Redundancy/reliability
  - Each BPS should have a minimum of two supply pumps.
- Minimum capacity (with largest pump on standby)
  - BPS must be able to pump MDD flows for 24 hours.
  - For BPSs pumping into an area without a storage tank, the BPS must be able to pump the peak hour demand.

### 7.1.2 Location Analysis

Using system pressures calculated by the model, locations were identified with low pressures that could be solved by moving or adding new BPSs. The analysis of each location is described below. Potential locations for new BPSs are also listed below, but the final locations will depend on the availability of land.

#### Gayinero Booster Pump Station

The Gayinero BPS currently has very low suction pressures. The BPS is supplied from the Yigo tanks and pumps up to the Santa Rosa tank. The BPS cannot supply the Santa Rosa zone with sufficient flow if well Y-15 is offline. Figure 7-1 shows an elevation profile of the piping from the Yigo tanks, to the Gayinero BPS, and then to the Santa Rosa tank. As shown in Figure 7-1, the low suction pressures are caused by the elevation of the BPS compared to the Yigo tanks. When the Yigo tanks are empty, the maximum pressure that can be achieved at the Gayinero BPS is 17 pounds per square inch (psi).

To keep pressures in system piping above 35 psi (the minimum desired system pressure, as listed in Appendix E), the Gayinero BPS should be moved west on Gayinero Drive to a lower elevation. Ideally, the BPS (currently located at 580 feet) should be located between an elevation of 516 and 537 feet. If the BPS is located above 537 feet, the BPS will have a suction pressure below 35 psi when the levels in the Yigo tanks are low. If the BPS is located below 516 feet, the BPS will have a discharge pressure above 90 psi when the Santa Rosa tank is full. The bottom right of Figure 7-1 shows the area between 516 and 537 feet.

**Route 15 Booster Pump Station**

The Yigo tanks currently serve piping that runs south along Route 15. However, pressures at the top of a hill on Route 15 are very low due to the hill's elevation compared to the Yigo tanks. Figure 7-2 shows an elevation profile of the piping from the Yigo tanks to the hill (point F in the figure) and then further south. The green hydraulic grade line (HGL) in the graph at the top right of the figure shows the HGL from the Yigo tanks to the hill, based on model results for a peak demand period. The intersection of the HGL with the ground indicates that pressures may approach zero at the top of the hill during peak demand periods.

Options to increase pressures along Route 15 include using existing facilities to boost pressures or constructing a new BPS to boost pressures. The option to use existing facilities would include connecting the Route 15 piping to the higher-pressure Santa Rosa zone. This option is not ideal because neither the Gayinero BPS nor the piping within the Santa Rosa zone are sized for the amount of flow conveyed down Route 15. Therefore, the best option would be to construct a new BPS to boost flows somewhere between the Yigo tank and Route 15. The BPS should be located between points B and C in Figure 7-2. The bottom right of the figure shows a potential location for the new BPS that gave good pressure results in the model.

**Nimitz Hill Upper Booster Pump Station**

The current Nimitz Hill BPS pumps to the Nimitz Hill Upper tank. However, pressures at the discharge side of the BPS exceed 90 psi due to the tank's high elevation compared to the BPS. The Nimitz Hill pressure zone should be divided into two zones to keep pressures below 90 psi. This would include constructing a new upper BPS and a new lower tank at the same location. The existing lower BPS would pump to the new lower tank. The new upper BPS would then pump to the existing upper tank.

Figure 7-3 shows the location and profile of the piping. The new BPS and tank should ideally be placed between points A and B labeled in the figure. If the facilities are located above point A, the new lower tank would be too high to keep pressures below 90 psi at the bottom of the lower zone. If the facilities are located below point B, customers served from the existing upper tank would still have pressures above 90 psi. Note that the pressures referenced here are static pressures that occur during low demand periods. Due to the small size of the existing 2-inch piping, there may be considerable headloss when pumps are active, which would raise pressures at the discharge side of pumps and could cause pressures to exceed 90 psi. An optimal location that considers pipe sizes and available land should be studied.

### 7.1.3 Capacity Analysis

The capacity of the BPSs and spring pumps were evaluated for existing and projected future requirements using the criteria listed at the beginning of this section. Table 7-1 summarizes this analysis. Very small BPSs serving a single location or up to approximately 30 homes (see Section 2.5) were not analyzed. Capacity of the BPSs to convey fire flow demands was not analyzed. Shaded green cells indicate that the BPS's capacity or condition is sufficient. Shaded pink cells indicate a deficiency.

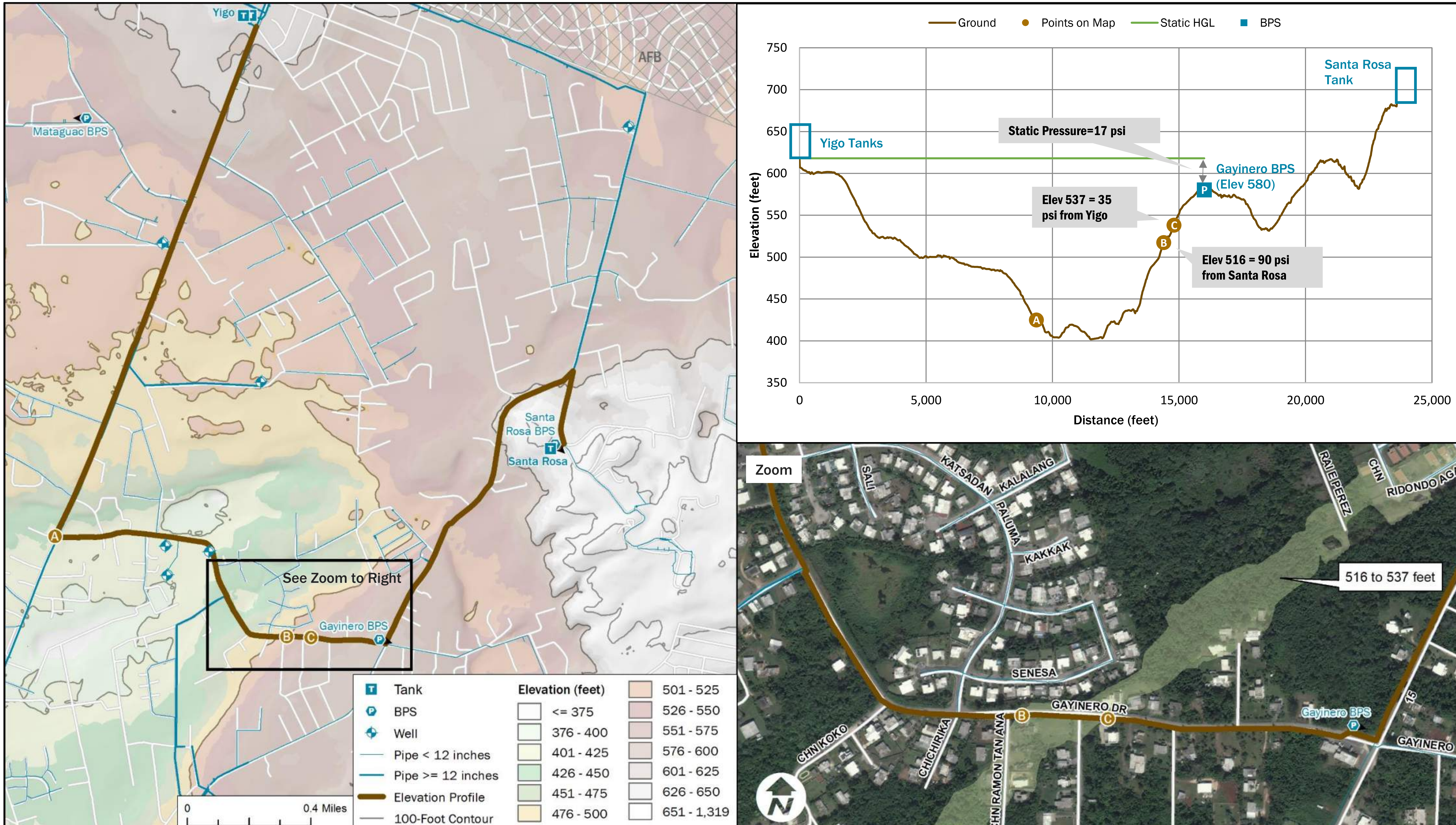


Figure 7-1. Profile of Piping from Yigo Tanks to Gayinero to Santa Rosa Tank

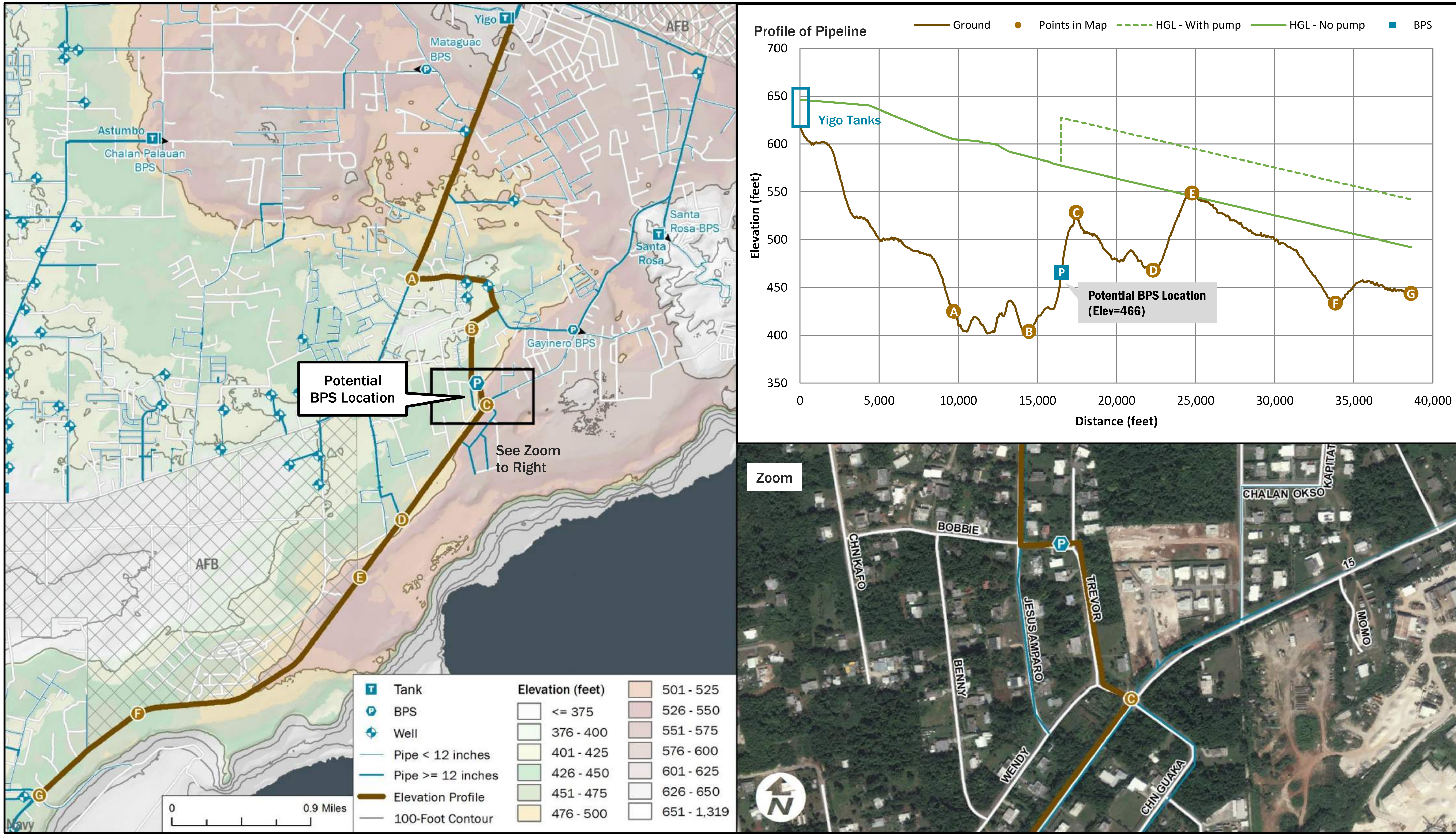


Figure 7-2. Profile of Route 15 With and Without Proposed BPS

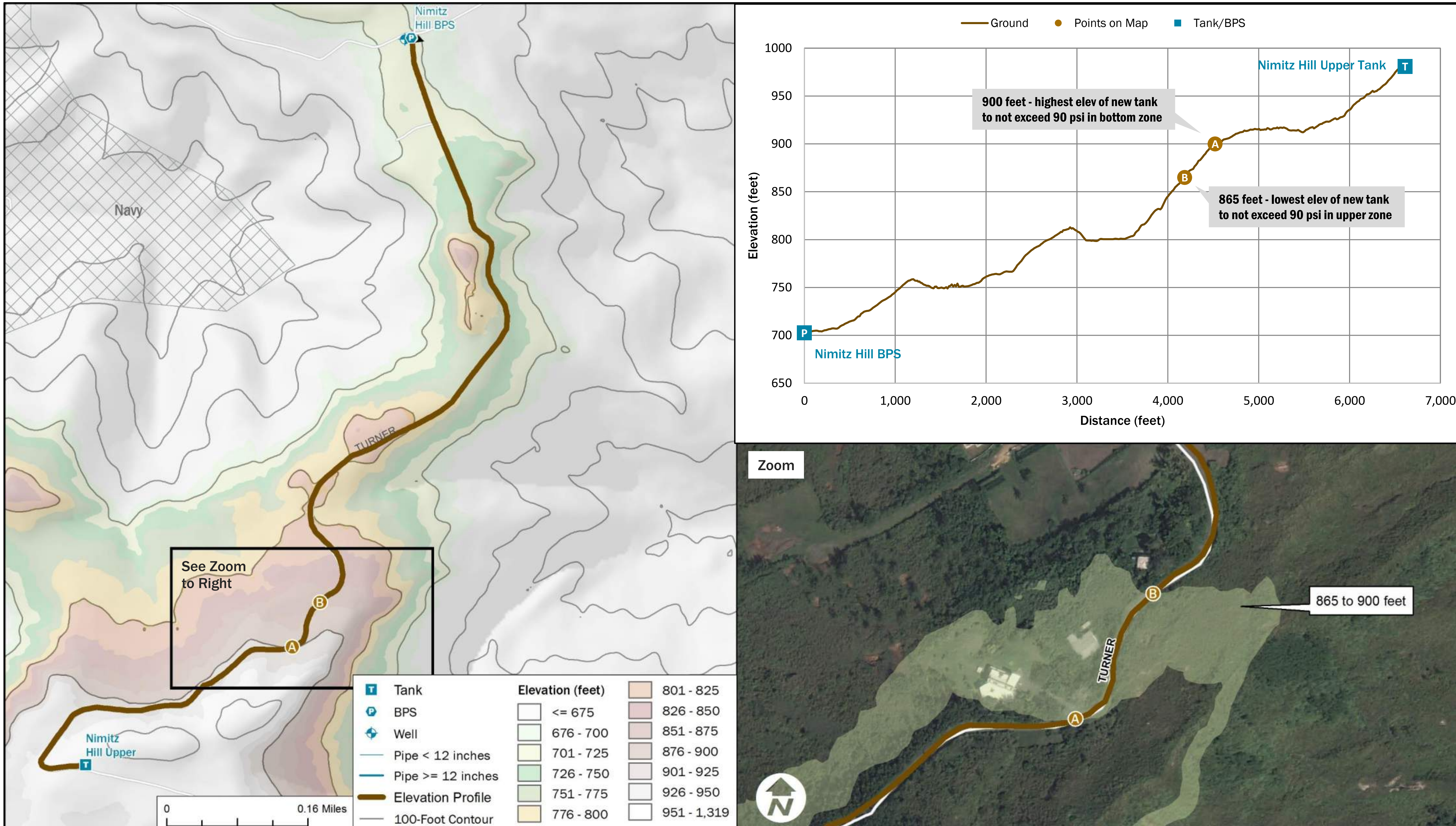


Figure 7-3. Profile of Nimitz Hill Piping

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**Table 7-1. BPS Analysis**

| BPS Name | Pressure Zones Served | Required Demand, Existing / Future (gpm)[a] | Capacity (gpm) | | BPS Status as of July 2016 | Capacity Analysis Results [d] | Condition |
|---|---|---|---|---|---|---|---|
| | | | Each Pump [b] | Total BPS Firm [c] | | | |
| Recently Constructed or Rehabilitated BPS | | | | | | | |
| Agana Heights | Adawag, Ordot/ Sinajana, Ulloa-Untalan | See notes to right | 567 (3) | 1,134 | New. Recently constructed, in service in 2016. | Sufficient. The BPS and Chaot tanks serve these areas together. Therefore, there is not a defined MDD for this area. | New |
| Malojloj Line | Agat-Umatac, Agfayan, Inarajan/Merizo, Inarajan Upper, Lasafua, Malojloj, Malojloj Upper, Pigua, Pigua Upper, Umatac, Umatac Subdivision | MDD = 1,398 / 1,644 | 500 (1) 1,600 (2) | 2,100 | New. Recently reconstructed, in service in 2015. | Sufficient | New |
| Pago Bay | Brigade BPS, Leo Palace, Manenggon Hills | MDD = 2,989 / 3,341 | 1,800 (2) 850 (1) | 2,650 | New. Recently reconstructed, in service in 2015. | Sufficient. The BPS can serve Brigade BPS and all but 340 (existing) of 692 (future) gpm of Leo Palace, Manenggon Hills demand. The remaining demand will be served by the Access BPS. | New |
| Windward Hills | Santa Ana Lower, Santa Ana Upper, Santa Rita, Santa Rita Central, Santa Rita East, Sinifa | MDD = 1,502 / 1,755 | 400 (1)<br>900 (2) | 1,300 | New. Recently reconstructed, in service in 2015. | Model indicates insufficient capacity if the Santa Rita Spring and Navy are offline under existing demands. | New |
| Planned New BPS | | | | | | | |
| Agfayan | Agfayan (no storage in zone) | PHD = 41 / 48 | Under design | Under design | Planned, design just started. BPS planned to serve small area in Inarajan. | Sufficient | To be constructed |
| Hyundai | Hyundai Upper (no storage in zone) | PHD = 96 / 112 | Under design | Under design | Planned, design is at 90%. A new BPS named the Hyundai BPS will be constructed as part of the Hyundai tank project to serve customers near the Hyundai tank that are at too high of an elevation to be served by the Hyundai tank. | Sufficient | To be constructed |
| Inarajan | Inarajan Upper (no storage in zone) | PHD = 83 / 98 | 165 (3) 1,573 (1) (design) | 495 (design) | Planned, design is at 60%. New BPS planned to serve small area in Inarajan. | Sufficient | To be constructed |
| Yigo | Santa Rosa (areas north of Yigo tanks) | MDD = 277 / 324 | 500 (3) (design) | 1,000 (design) | Planned, design is underway. New BPS planned to serve area north of the Yigo tanks. | Sufficient | To be constructed |
| Existing BPS, Planned for Rehabilitation | | | | | | | |
| Access | Leo Palace, Manenggon Hills | MDD = 839 / 839 | Under design | Under design | Existing, to be replaced, design is at 30%. Under design for Manenggon Hills tank project. | Sufficient, assuming the new Access BPS will have capacity so that Access plus Pago Bay can handle demand (see notes for Pago Bay). | To be upgraded |
| Barrigada (Old Hyundai) | Hyundai, Hyundai Subzone, Hyundai Upper | MDD = 273 / 321 | Under design | Under design | Existing, to be replaced, design is at 90%. The existing Hyundai BPS located next to the Barrigada tanks will be replaced as part of the Hyundai tank project and will be renamed the Barrigada BPS as a backup BPS for the Hyundai wells. | Sufficient | To be upgraded |
| Brigade | Camacho, Santa Ana Lower, Santa Ana Upper, Santa Rita, Santa Rita Central, Santa Rita East, Sinifa, Windward Hills | MDD = 2,150 / 2,502 | 634 (3) | 1,268 | Existing. GWA has plans to upgrade this BPS, but the timing is currently undecided. | Does not appear to have capacity if the Santa Rita Spring and Navy are offline. This should be considered in an upgrade to the BPS. | To be upgraded |
| Malojloj | Malojloj Upper (no storage in zone) | PHD = 438 / 516 | 280 (3) (design) | 560 (design) | Existing, to be replaced, design is underway. The existing Malojloj Elevated BPS will be reconstructed. | Sufficient | To be upgraded |
| Santa Rosa | Santa Rosa Upper (no storage in zone) | PHD = 31 / 36 | 366 (2) (design) | 366 (design) | Existing, to be replaced, design is underway. | Sufficient | To be upgraded |
| Existing BPS, No Current Rehabilitation Plans | | | | | | | |
| Gayinero | Santa Rosa (areas not served by new Yigo BPS), Santa Rosa Upper | MDD = 825 / 965 | 339 (2) | 339 | Existing | Does not have capacity. Should be moved as discussed in Section 7.1.2. | See Section 7.2 |
| Geus | Pigua, Pigua Upper | MDD = 97 / 114 | 238 (2) | 238 | Existing | Sufficient | See Section 7.2 |
| Mataguac | Mataguac (no storage in zone) | PHD = 527 / 602 | 300 (2) | 300 | Existing. Only two pumps currently installed in three available locations. Would have capacity with third pump. | Needs third pump | See Section 7.2 |
| Nimitz Hill | Nimitz Lower, Nimitz Upper | MDD = 14 / 16 | 30 (2) | 30 | Existing | Capacity is sufficient, but a second BPS is needed to keep pressures below 90 psi, as detailed in Section 7.1.2 | See Section 7.2 |

**Table 7-1. BPS Analysis**

| BPS Name | Pressure Zones Served | Required Demand, Existing / Future (gpm)[a] | Capacity (gpm) | | BPS Status as of July 2016 | Capacity Analysis Results [d] | Condition |
|---|---|---|---|---|---|---|---|
| | | | Each Pump [b] | Total BPS Firm [c] | | | |
| Santa Ana | Santa Ana Upper | MDD = 6 / 7 | 238 (1) | 0 | Existing. Only one pump currently installed in two available locations. With second pump, would have capacity (capacity of existing pump is 238 gpm). | Needs second pump | See Section 7.2 |
| Santa Rita Spring | Serves Santa Rita Spring, Navy Meter R-69 | MDD = 847 / 847 | 650 (2) | 650 | Existing | Does not have capacity | See Section 7.2 |
| Toguan | Agat-Umatac, Lasafua, Umatac, Umatac Subdivision | MDD = 170 / 200 | 159 (1)<br>238 (1) | 159 | Existing | According to operations staff, a larger pump is required to fill the Umatac Sub tank. Insufficient capacity if larger pump is offline. | See Section 7.2 |
| Umatac 1 (WBP 1) | Lasafua (no storage in zone) | PHD = 36 / 42 | 122 (1) | 0 | Existing. Only one pump currently installed. | Needs second pump | See Section 7.2 |
| Umatac 2 (WBP 2) | Agat-Umatac, Lasafua | MDD = 46 / 54 | 238 (1) | 0 | Existing. One pump currently installed in two available locations. With second pump, would have capacity (capacity of existing pump is 238 gpm). | Needs second pump | See Section 7.2 |

*a. The existing required demand is listed first and the future (2035) required demand is listed second. The demand is the total demand served by the BPS. If the BPS serves a pressure zone that does not have a storage tank, the BPS must be able to handle PHD. If there is storage in the zone(s), the BPS needs to handle MDD (the storage will handle the daily PHD). PHD was calculated as MDD x 1.5. The 1.5 factor is slightly more conservative than the highest diurnal peaking factor listed in Section 3.*

*b. Capacity of each pump at the BPS. The number of pumps with that capacity is given in parenthesis.*

*c. Firm capacity is the capacity of all pumps with the largest pump offline.*

*d. For BPSs currently under design but the design flow is not yet known, the capacity analysis assumed that the design capacity will be sufficient for the required demands.*

## 7.2 Condition Assessment

A risk-based approach was used to prioritize BPSs, similar to the water system piping. This section describes risk calculations and recommendations for BPS renewal. Table 7-1 grouped the BPSs into the following categories:

- Recently constructed or rehabilitated BPS
- Planned new BPS
- Existing BPS, planned for rehabilitation
- Existing BPS, no current rehabilitation plans

The first three groups of BPSs were not analyzed for their condition because they were recently constructed or rehabilitated or were planned for rehabilitation at the time of this report. Only the final set of BPSs were analyzed. BPSs serving small areas, as noted in Section 2.5, were not included in this analysis.

### 7.2.1 Condition Assessment Field Work

BC and GWA staff performed condition assessments in January 2013. Assessment results were documented in a TM titled *Booster Pump Station Rehabilitation Program Plan* (BC, March 2013a). GWA operations staff also performed condition assessments on several BPSs in December 2016. Condition assessments were documented in forms completed in the field. This analysis uses the newest available data for each BPS, as listed in Table 7-2.

**Table 7-2. BPSs to be Renewed**

| BPS | Source of Condition Information | Notes |
|---|---|---|
| Gayinero | 2013 BPS Rehabilitation Plan | |
| Geus | 2013 BPS Rehabilitation Plan | |
| Mataguac | Dec. 2016 GWA Inspection | |
| Nimitz Hill | 2013 BPS Rehabilitation Plan | |
| Santa Ana | 2013 BPS Rehabilitation Plan | |
| Santa Rita Spring | Dec. 2016 GWA Inspection | GWA has reported the following issues for this BPS:<br>• Repairs were made to the BPS for an existing CIP project (PW-05-03) in 2006 and 2007, and there are still funds remaining in the project for further rehabilitation.<br>• The tank's metal roof was replaced as part of the CIP project, but the screws securing the roof are severely corroded. The long-term solution is to replace the metal roof with a concrete roof.<br>• The CIP project replaced the MCC, but it may need to be upgraded.<br>• GWA has discussed a project with WERI to investigate altering the intake to capture more water. A future project should include this work.<br>• A PRV on the Navy line allows only enough water into the tank to keep it full. The PRV does not have sufficient pressure to operate and should be replumbed. |
| Toguan | Dec. 2016 GWA Inspection | |

| Table 7-2. BPSs to be Renewed | | |
|---|---|---|
| BPS | Source of Condition Information | Notes |
| Umatac 1 (WBP 1) | Dec. 2016 GWA Inspection | |
| Umatac 2 (WBP 2) | Dec. 2016 GWA Inspection | |

### 7.2.2 Risk Calculations

Table 7-3 lists the likelihood of failure factors and Table 7-4 lists the consequence of failure factors. Each factor was given a score (with being 1 a good score and 5 a poor score) and a weight (which allowed some factors to be given more importance than others).

| Table 7-3. Likelihood of Failure Factors | | | | |
|---|---|---|---|---|
| ID | Criteria | Factor Description | Score | Weight |
| L1 | Capacity Issue | BPS does not have enough capacity now or will not have enough capacity in the future | 1 = Sufficient Capacity<br>3 = Needs another pump to meet capacity requirements<br>4 = Insufficient capacity<br>5 = Severely insufficient capacity | 0.33 |
| L2 | Condition | Overall condition of the BPS | For 2016 inspections, several key components from the inspection sheets were scored 1 to 5, and then a weighted average was calculated to give a final score of 1 to 5<br>For the 2013 inspections, scoring was taken from the 2013 report with scores converted to 1, 3, and 5 | 0.33 |
| L3 | Location | Location of each BPS was analyzed using the model | 1 = BPS location ok<br>5 = BPS needs to be relocated | 0.33 |

| Table 7-4. Consequence of Failure Factors | | | | |
|---|---|---|---|---|
| ID | Criteria | Factor Description | Score | Weight |
| C1 | Flow | BPSs were ranked by importance according to their future MDD listed in Table 7-1 | 1 = <100 gpm<br>2 = 100-300 gpm<br>3 = 300-500 gpm<br>4 = 500-800 gpm<br>5 = >800 gpm | 1 |

Scores were calculated for each BPS using the following steps:

1. Assign a score of 1 to 5 for each likelihood of failure factor to each BPS.
2. Calculate a total likelihood of failure factor for each BPS by summing the scores: $L1_{score} \times L1_{weight} + L2_{score} \times L2_{weight} + \ldots Ln_{score} \times Ln_{weight}$
3. Normalize all likelihood of failure scores so the scores range from 1 to 5. A higher score indicates a higher likelihood of failure.
4. Repeat steps 1 to 3 for consequence of failure.

5. Calculate the total risk for each BPS: likelihood of failure score (1 to 5) x consequence of failure score (1 to 5).
6. Normalize all risk scores so the highest score is 100.

Table 7-5 lists priorities for BPS renewal based on the risk calculations.

Table 7-5. BPS Renewal Prioritization

| BPS | Failure Score (1 to 5) | | Risk (1 to 100) |
|---|---|---|---|
| | Likelihood | Consequence | |
| Gayinero | 5 | 5 | 100 |
| Geus | 2.3 | 2 | 18 |
| Mataguac | 1.8 | 4 | 29 |
| Nimitz Hill | 1.7 | 1 | 7 |
| Santa Ana | 2.3 | 1 | 9 |
| Santa Rita Spring | 2.3 | 5 | 46 |
| Toguan | 2.5 | 2 | 20 |
| Umatac 1 (WBP 1) | 3 | 1 | 12 |
| Umatac 2 (WBP 2) | 2 | 1 | 8 |

### 7.2.3 Summary

The 2013 BPS Rehabilitation Plan stated, “The pump stations have in general reached the end of their useful service life and require extensive rehabilitation or replacement” (BC, 2013). All BPSs listed in Table 7-5 (not currently planned for renewal) are recommended for rehabilitation or replacement. GWA operations staff have rehabilitated some BPSs, but full rehabilitation is recommended to address all outstanding issues. The timing of rehabilitation of the BPSs should take into account the order determined by the risk analysis presented in Table 7-5.

## 7.3 Recommendations

Table 7-6 lists recommended BPS improvements based on the location, capacity, and condition analyses presented in this section.

**Table 7-6. BPS Recommendations**

| BPS Name | Status | WRMP Project Number | Recommendation |
|---|---|---|---|
| Brigade | Existing, planned for rehabilitation | Existing project | Review design. Design firm capacity does not appear to have capacity if the Santa Rita Spring and Navy are offline. |
| Windward Hills | Recently constructed | No project | Model shows that the BPS does not have capacity for existing demands if the Santa Rita Spring and Navy are offline. No project is recommended, but this should be taken into consideration when planning for alternate sources of supply to Santa Rita and Santa Ana. |
| Gayinero | Existing | MP-PW-BPS-01 | Replace BPS for condition and capacity in a new location at a lower elevation. A new BPS will allow the BPS to supply the Santa Rosa zone with good suction pressures and will supply redundancy to the Santa Rosa zone if well Y-15 is offline. |
| Geus | Existing | | Rehabilitate BPS due to poor condition. |
| Mataguac | Existing | | Rehabilitate BPS due to poor condition. Install a third pump or increase capacity of existing pumps to meet capacity requirements. |
| Nimitz Hill Lower | Existing | | Rehabilitate BPS due to poor condition. |
| Santa Ana | Existing | | Rehabilitate BPS due to poor condition. Install a second pump to meet capacity requirements. |
| Santa Rita Spring | Existing | | Rehabilitate BPS and tank due to poor condition and increase capacity. |
| Toguan | Existing | | Rehabilitate BPS due to poor condition and increase capacity. |
| Umatac 1 (WBP 1) | Existing | | Rehabilitate BPS due to poor condition. Install a second pump to meet capacity requirements. |
| Umatac 2 (WBP 2) | Existing | | Rehabilitate BPS due to poor condition. Install a second pump to meet capacity requirements. |
| Nimitz Hill Upper | Proposed | MP-PW-BPS-02 | Construct a new BPS to divide the Nimitz Hill pressure zone into two separate zones. |
| Route 15 | Proposed | MP-PW-BPS-03 | Construct a new BPS to booster pressures from the Yigo tanks along Route 15. |

The following BPSs are not listed in Table 7-6 but are already planned for construction (as listed in Table 7-1):

- Agfayan (under design)
- Hyundai (under design)
- Inarajan (under design)
- Yigo (under design)

The following BPSs and springs are not listed in Table 7-6 but are already planned for rehabilitation:

- Access (under design)
- Asan Spring (under design, CIP Project PW 05-15)
- Barrigada (Old Hyundai) (under design)
- Malojloj (under design)
- Santa Rosa (under design)

Additional recommendations for BPSs include the following:

- GWA has seen surge issues at startup or shutdown of pumps, especially at BPSs with high suction pressures. GWA should develop a project to determine where soft starters or VFDs should be installed to reduce surge issues.

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# Section 8
# Distribution System Evaluation

This section describes the capacity and condition of the distribution system piping, valves, and pressure zones, and outlines recommendations for distribution system improvements.

## 8.1 Capacity Evaluation

Distribution piping was evaluated under MDD conditions for existing and future scenarios. Model results were reviewed to identify existing and future deficiencies.

### 8.1.1 Criteria

The distribution system was analyzed using the following criteria (see Appendix E for additional details on the evaluation criteria):

- Minimum pressure: 20 psi
- Desired minimum pressure: 35 psi
- Maximum pressure: 90 psi
- Maximum velocity: 10 feet/second
- Fire flow: GWA currently does not size pipelines to supply fire flow to all customers in the distribution system. However, GWA would like to consider sizing pipelines to handle fire flow in the future, possibly for the next WRMP update.

### 8.1.2 Pressure Zone Realignment Analysis

GWA's water system computer model was used to develop new pressure zone boundaries throughout the water system. This analysis built on the pressure zone realignment plan presented in the TM titled *Pressure Zone Realignment and Pressure Improvement* (BC, December 2015b). GWA has implemented some pressure zone realignment recommendations from the 2015 TM. Most recommendations, which have not yet been implemented, have been further developed in this WRMP update to correlate with new recommended improvements to piping, storage, and pumping.

Development of the new pressure zones included switching from using water service areas (WSAs) to using pressure zones. WSAs and pressure zones are defined as follows:

- **WSA:** a WSA is a service area divided by closed valves, PRVs, BPSs, and choked (partially closed) distribution valves. GWA has created the WSAs over time as GWA has added and abandoned PRVs and choked valves to obtain desired pressures for customers in specific areas.
- **Pressure zone:** a pressure zone is a service area also divided by closed valves, PRVs, and BPSs. However, choked valves are not typically used in dividing pressure zones. Pressure zones are planned to serve specific areas of similar elevations based on achieving a desired range of pressures.

Pressure zones were defined by drawing boundaries that include the range of elevations that can be served by a tank. The boundaries were established so that a tank can provide a minimum static pressure of 35 psi when the tank is empty and a maximum static pressure of 90 psi when the tank is full. Elevation ranges were created for the entire GWA service area so areas could be served by tanks at pressures between 35 and 90 psi. For zones served by PRVs but not served directly by a tank, elevation ranges were delineated to allow PRVs to maintain pressures of 35 to 90 psi.

Pressure zone boundaries were delineated by using existing WSA boundaries in some areas and by modifying WSA boundaries in other areas. The model was used to analyze existing and proposed facilities to aid in setting the boundaries. This included adding new PRVs, abandoning some PRVs, closing and opening isolation valves, opening all choked valves, and adding new piping and storage.

The following issues should be considered as GWA implements the pressure zone realignment:

- In general, implementation of the pressure zone realignment should proceed from the north pressure zones to south pressure zones because the north zones will feed the south zones. However, actual timing of the implementation of the realignment projects will need to be decided based on engineering judgement. For example, if a new storage tank is constructed in a location, it may be best to construct a nearby, proposed PRV needed for the realignment at the same time.
- GWA should develop an implementation plan to cover contingencies as pressure zones are created. The plan should cover potential issues (such as a line break due to higher pressures in a new zone) and how those issues will be handled.
- As WSAs are realigned into pressure zones, areas that historically experience low pressures should see improved pressures. In some cases, areas may see significantly higher pressures, which could cause additional line breaks and leaks. Conversely, some areas that see high operating pressures may see lower pressures in the future. Therefore, any realignment of WSAs must consider impacts to the distribution system and should be performed cautiously over an extended period. Wherever possible, GWA should implement changes to one or two pressure zones at a time and monitor the results of each change. In the long term, realigning the WSAs should make the system simpler and easier to operate. The realignment should also reduce or eliminate the need for choked valves.
- As explained in Section 8.2, PRVs were visited in 2014 to verify if they were operational. The PRVs were only visually inspected. As pressure zones are set up for the pressure zone realignment, the PRVs should be inspected to ensure they are fully operational and repaired if necessary. As the PRVs are inspected, piping condition for piping in the PRV vaults should also be noted to assist in gathering data for condition assessment of the system piping.
- A maintenance plan should be developed to maintain new and existing PRVs as pressure zones are created.

- Water levels in the storage tanks are often kept at very low levels. These levels should be maintained at much higher levels for the following reasons:
  - Pressures may fall below desired pressures in the realigned pressure zones if levels in the tanks are allowed to fall to low levels.
  - The storage analysis described in Section 6 calculated minimum equalization, emergency, and fire storage. If the currently planned storage is constructed, equalization and fire storage would take up approximately 83 percent of total storage, which means that to continuously maintain full fire and emergency storage, tank levels should not be allowed to cycle below 83 percent full. This is an average value that will vary for each zone according to the emergency and fire storage required in each zone. Note that keeping storage tanks this full may not be desirable in every zone, as tanks may not cycle enough to keep fresh water in the tanks and maintain a good chlorine residual.
- Choked valves are not shown in the figures of the improvements, but all choked valves in a zone should be opened as a pressure zone is realigned.

### 8.1.3 Piping Capacity Analysis

Distribution system and transmission piping was evaluated using the criteria listed at the beginning of this section. The model was used to evaluate the piping under 24-hour MDD conditions for 2015 and 2035, and with realigning the pressure zones as discussed above. Because realigning the pressure zones changes flow through some system piping, it was logical to evaluate piping while also evaluating realigned pressure zones. The model was used to identify deficiencies and develop recommended improvements, which are detailed at the end of this section.

Note that for the military buildup, it was assumed that new supply will be developed to serve the proposed Finegayan Cantonment. Because the location of new supply is currently unknown, no new piping was added to supply this area.

### 8.1.4 Fire Flow Analysis

As mentioned above, GWA does not currently size pipelines to supply fire flow to all customers in the distribution system. To gain an idea of the current ability of the water system to supply fire flow, the model was used to analyze fire flows throughout the water system. A fire flow demand was calculated for each customer based on the customer type and the corresponding fire flow demand in Table E-1 in Appendix E. Hydrants were not added to the model (to avoid splitting model pipes at each hydrant), so the fire flow demands were assigned from the customers to the nearest model node. Because several customers could be close to a junction, the largest fire flow demand from surrounding customers was analyzed at each junction. The analysis was run under 2015 MDD conditions, but after the implementation of the pressure zone realignment plan and piping improvements recommended in this section.

Table 8-1 summarizes the number of model junctions that could get their required fire flow and maintain a 20-psi residual pressure. The table lists the number of junctions that pass (the system can supply the fire flow demand) or fail (system cannot supply the fire flow demand). Within the fail category, the table lists the percent of fire flow the system could supply to the junctions. Figure 8-1 and Figure 8-2 show the same percentages at each model junction.

| Table 8-1. Fire Flow Analysis Summary | | | | |
|---|---|---|---|---|
| Fire Flow Demand (gpm) | Pass (100% of Fire Flow Available) | Fail | | |
| | | 75-99% of Fire Flow Available | 50-75% of Fire Flow Available | <50% of Fire Flow Available |
| 500 | 28 | 2 | 4 | 6 |
| 1,000 | 5,900 | 595 | 483 | 684 |
| 2,000 | 1,051 | 109 | 110 | 138 |
| 2,500 | 36 | 2 | 6 | 2 |
| **Total** | **7,015** | **708** | **603** | **830** |
| **Percent** | **77%** | **8%** | **7%** | **9%** |

If GWA decides to work towards sizing the water distribution system to supply fire flow to customers, GWA should set up a plan to prioritize which areas and customers to upgrade first. The computer model should be used to identify areas and customers where the water system cannot supply the required fire flow. Those areas and customers should then be prioritized using factors such as critical facilities (e.g. hospitals, schools) and the amount of infrastructure needed to supply the areas.

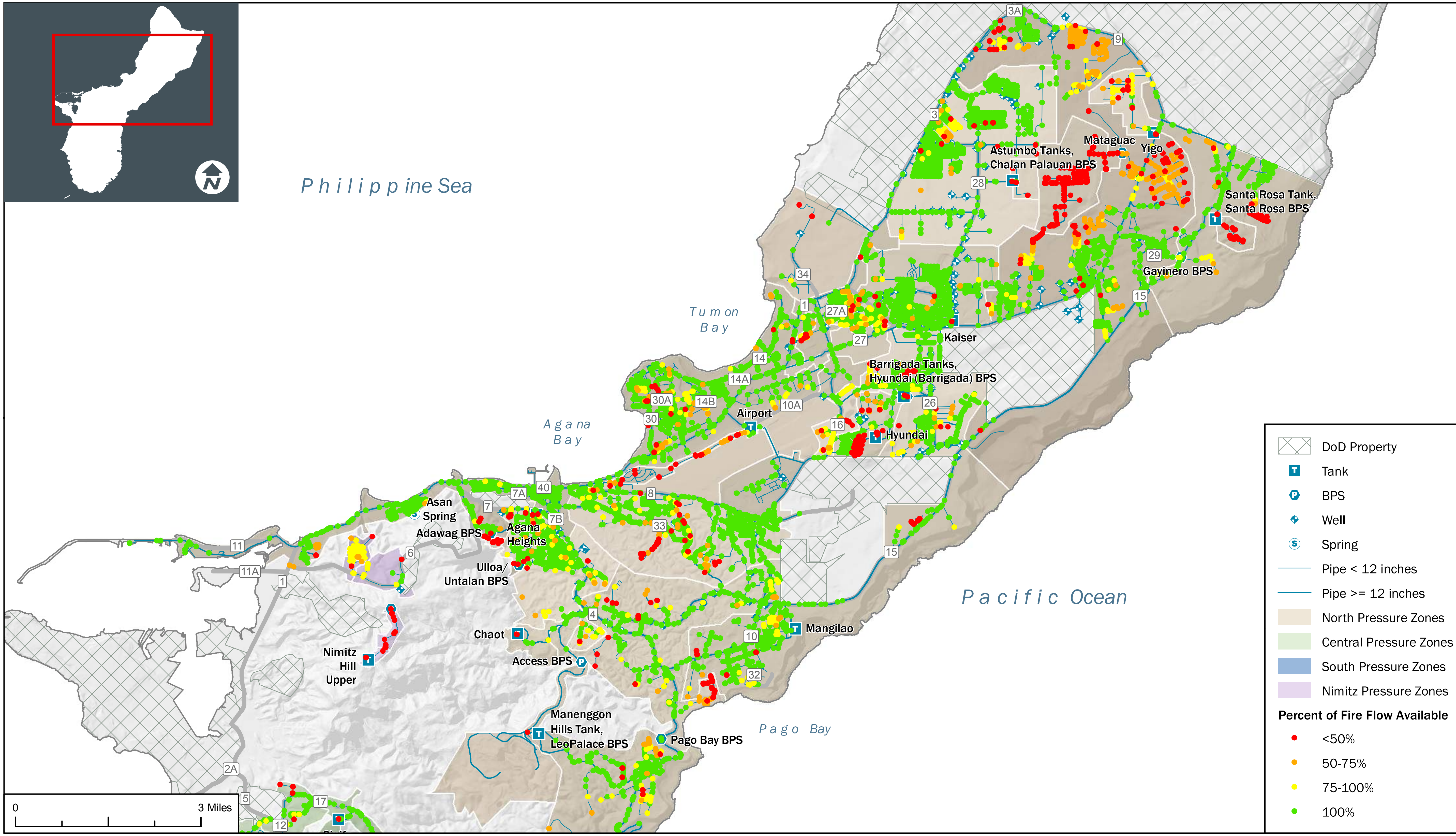
Another item to consider is that as new buildings are constructed, dedicated fire tanks and pumps are required if the system cannot supply the required fire flow. In the long term, it may be more efficient and cost effective to work towards supplying fire flow demands through the distribution system.

### 8.1.5 Water Age Analysis

A model water age analysis is often used to identify areas of high water age. A high water age is often due to poor circulation through an area, which may indicate potentially low chlorine residual. Water age is often used to analyze chlorine residual because it is difficult to accurately model chlorine residual. There are no set standards for acceptable water age because water quality issues due to high water age vary from system to system depending on initial chlorine residual, water temperature, the amount of biofilm on piping, etc. However, a water age analysis will identify areas with high water age relative to the rest of the system. The chlorine residual in areas of high water age can be tested and compared to minimum recommended levels.

A water age analysis was run for 28 days for 2015 MDD conditions, but after the implementation of the pressure zone realignment plan and piping improvements recommended in this section. Water age was calculated in the storage tanks and piping.

Figure 8-3 and Figure 8-4 shows the maximum water age in the system pipes. The figure does not show high water age at the many short dead-end pipes with zero demand. The areas shown with relatively high water age (greater than 15 days) should be analyzed to were highlighted as potential water age issues. As seen in the figures, the overall water age is good after implementation of the pressure zone realignment. There are some areas of poor water age, but those are primarily areas of low flow and low demand.




11/20/2017

Figure 8-1. Fire Flow Analysis (North)

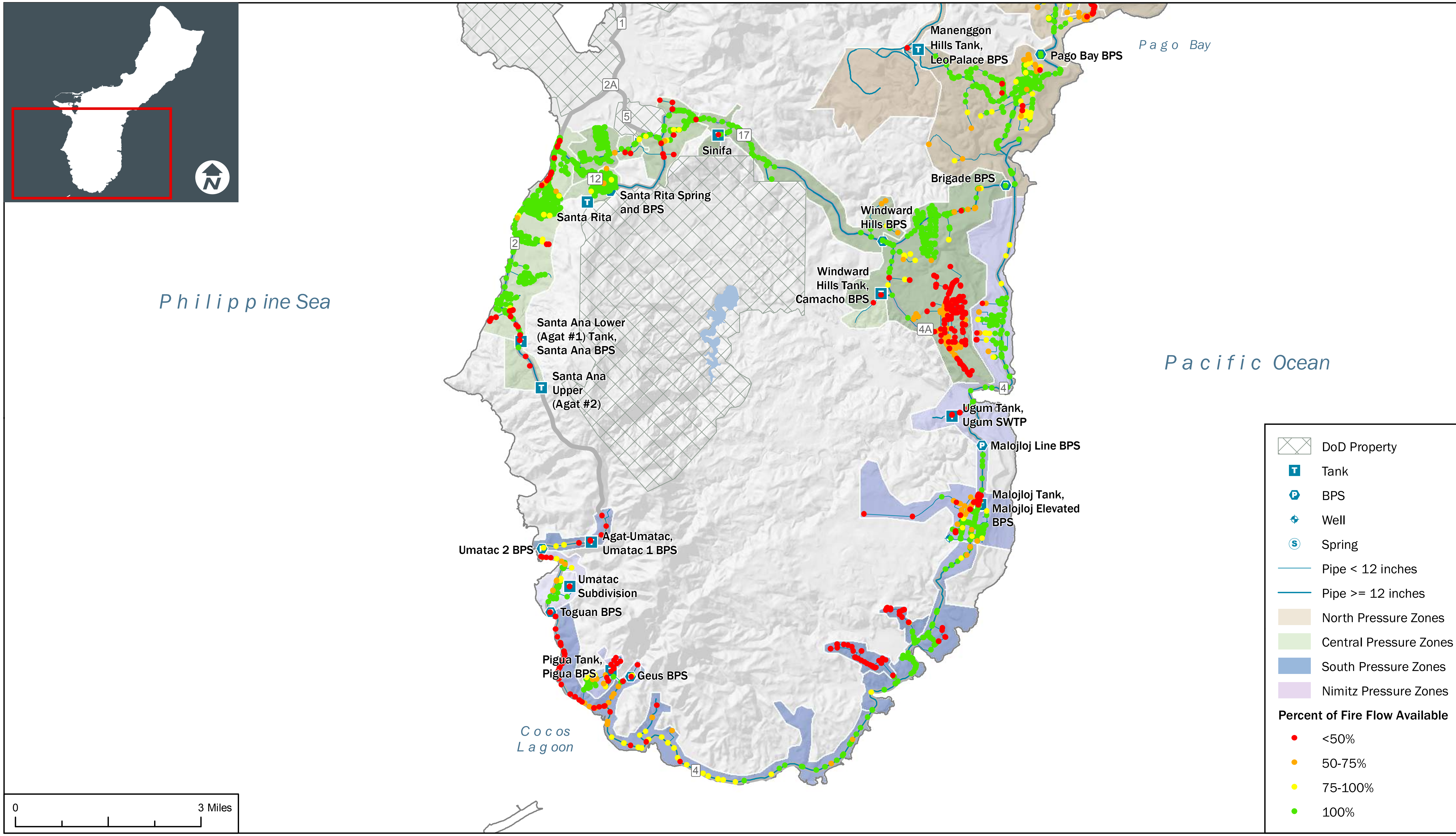



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Figure 8-2. Fire Flow Analysis (South and Central)

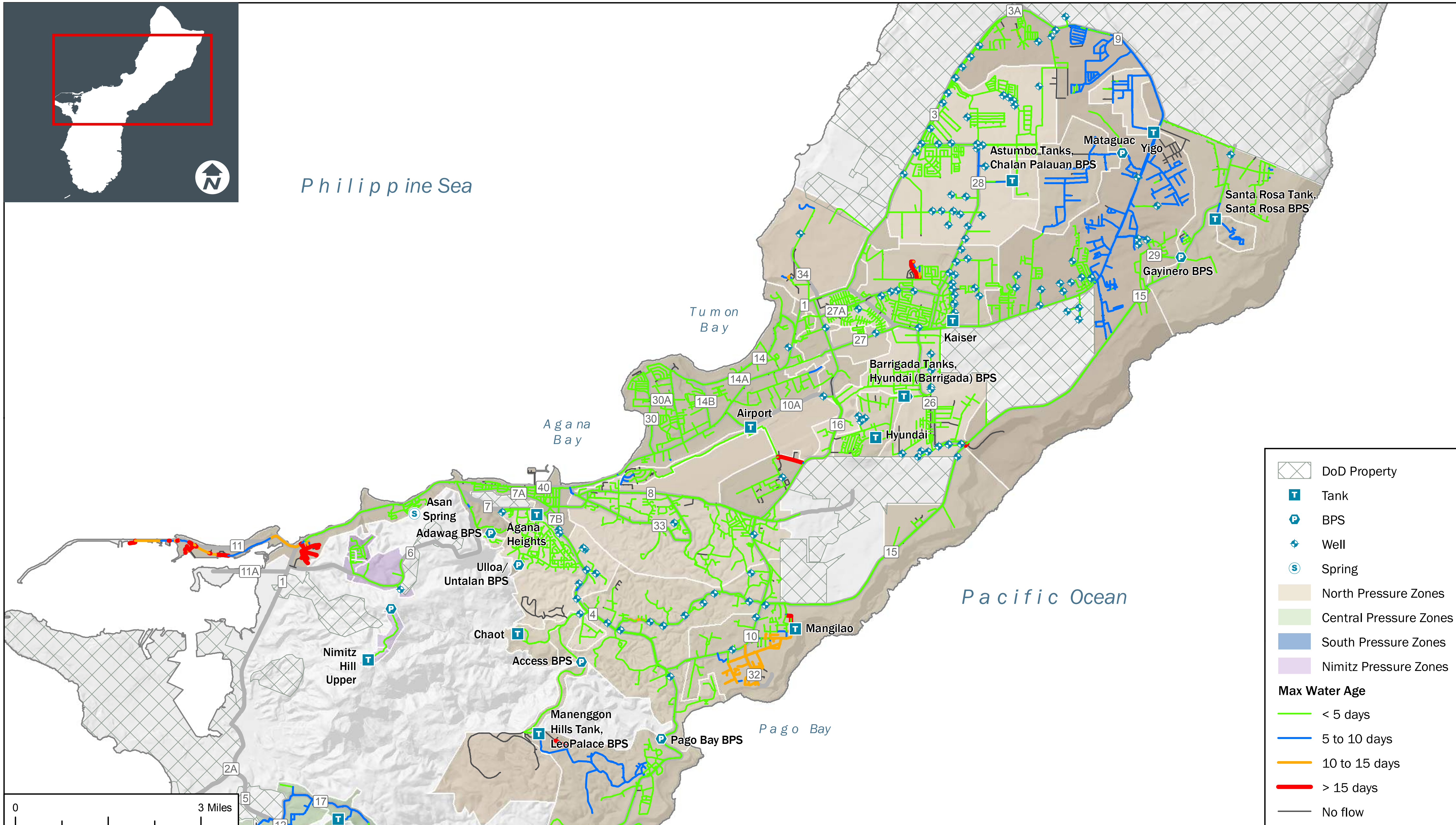


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Figure 8-3. Water Age Analysis (North)

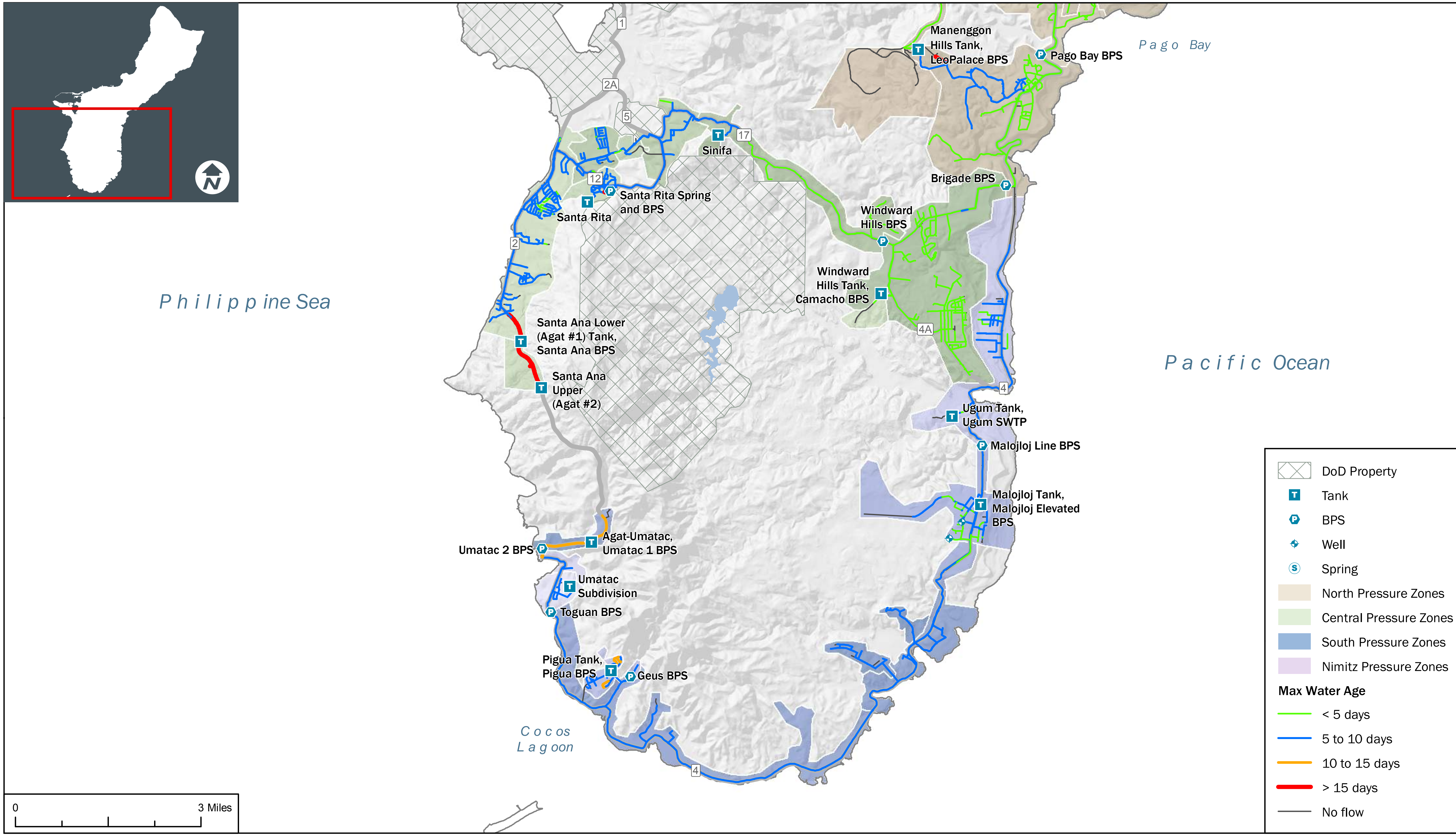


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Figure 8-4. Water Age Analysis (South and Central)

## 8.2 Pressure Reducing Valves Condition Assessment

Field visits were made to all known PRVs in April and May 2014 by BC; EA Engineering, Science, and Technology, Inc.; and GWA field staff. A TM dated September 16, 2014 was delivered to GWA to document issues found with the PRVs during the field visits. Issues included PRVs that were not operational and pressure taps were not available on several PRVs to verify if they were operational. Most existing PRVs were considered important hydraulic features in the distribution system and should stay in service. Therefore, PRVs identified as requiring maintenance are identified in the 2014 TM and will need to be repaired as pressure zones are realigned.

## 8.3 Isolation Valves

GWA should implement an isolation valve exercise, maintenance, and replacement program to locate and fix broken, closed, and choked valves. In the past, GWA has closed and choked isolation valves to set pressures throughout the water system. This process will be unnecessary with the implementation of the pressure zone realignment. It will be important to locate and open closed and choked valves to properly implement the pressure zone realignment. In addition, operations staff have not had funding to fix broken valves; therefore, operators have avoided operating these valves, which has led to difficulties in operating valves when needed. The following steps are recommended for a valve exercise and maintenance program:

- GWA should implement a valve exercise program with a crew of two operators. The program should be managed with the computerized maintenance management system (CMMS) system. The program should be developed based on practices identified in the AWWA manual *M44 Distribution Valves: Selection, Installation, Field Testing, and Maintenance* (AWWA, 2015).
- GWA should purchase a valve exercise machine, with hands-on training to ensure proper operation, to allow operators to operate valves that are difficult or require high numbers of turns to open or close.
- Broken valves should be documented as they are located. After a number of broken (do not turn, do not isolate or fully open) valves are identified, the valves should be grouped into a project and put out to bid to be fixed by a qualified contractor.
- A report titled *Development Plan for Long-Term Comprehensive Water Distribution System Program* presents additional information on setting up a program (BC, April 2013a).

## 8.4 Piping Condition Assessment and Ranking

This section describes a risk-based approach to prioritizing the renewal (rehabilitation or replacement) of GWA's water distribution pipelines. This risk-based approach will help to advance beyond the current water pipe replacement scheduling process, and is based on analyses that leverage GWA's existing GIS data, work order management systems, and other databases. The analyses provide guidance to answer the following questions:

- How much water line renewal is enough each year to sustainably and economically renew the system over short- and long-term horizons?
- What is the best way to accurately predict the condition of buried water pipe assets based on previous water main failures and the location of system assets, as well as other environmental characteristics?
- Which water main assets pose the largest consequence of failure risk to system performance, human health and welfare, and damage to infrastructure due to their potential failure?
- How can GWA develop a long-term approach to replacing or inspecting pipeline assets that balances risks of failure with other needs such as hydraulics and firefighting?

Figure 8-5 illustrates components of the analysis and flow of information between these components. The process begins in the upper left quadrant of Figure 8-5 with existing information about water line assets, and flows clockwise through several analytical steps to ultimately arrive at an updated capital plan for GWA's water line assets. This approach is continuous, providing GWA with a methodology to reuse over time. Results can be linked to the existing GWA water piping GIS database and updated as future changes are made to the assets or more data is collected. Data used in the analysis is summarized in Appendix F.

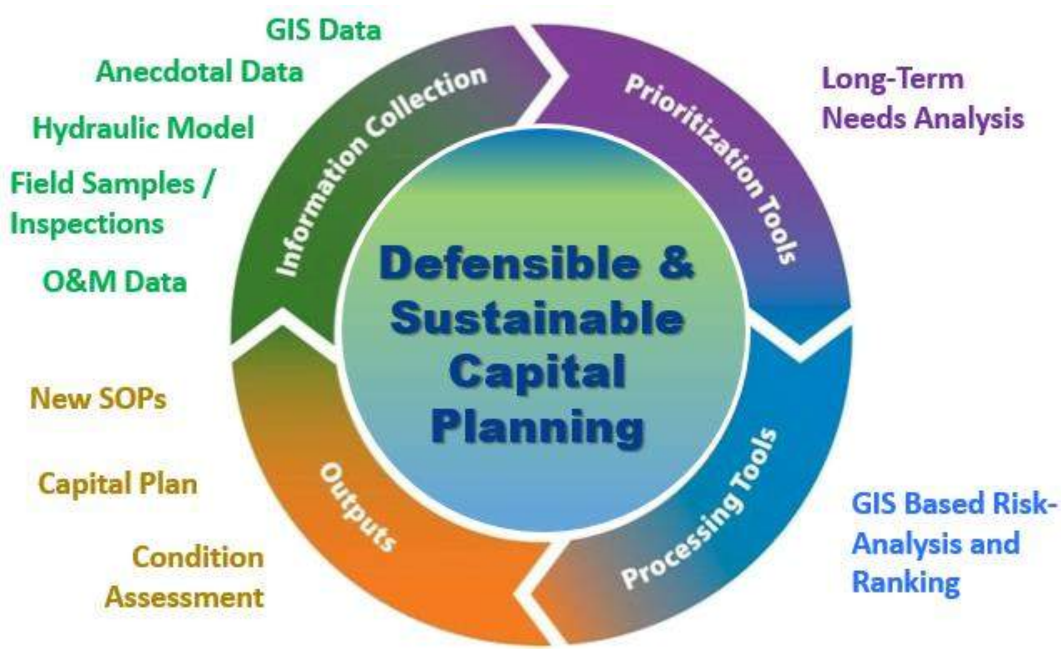



Figure 8-5. Diagram of the Approach to Ranking Water Piping

Analysis of pipeline renewal needs included the following two steps, which are described in more detail below:

1. Calculate total renewal needs per year.
2. Calculate which pipes need to be renewed per year using a risk-based approach.

A 20-year planning horizon was used to calculate pipeline renewal needs. As part of the analysis, a renewal needs model was run for 65 years. A renewal needs model is typically run for a long period to observe how the model reacts in later years. The renewal needs model results were then put into the context of the 20-year planning horizon.

### 8.4.1 Calculation of Total Renewal Needs per Year

The first step in prioritizing the renewal of distribution piping was to calculate total renewal needs per year using a long-term outlook. This step is described below.

#### 8.4.1.1 Installed Pipeline Inventory

Existing pipeline data from GWA's GIS was used as an input to the renewal analysis because age and material of existing piping significantly impacts future replacement needs. Table 8-2 lists the length of piping by material and decade installed. As a comparison, Table 2-1 lists the length of piping by material and diameter.

**Table 8-2. Length of Piping Installed by Decade**

| Years | Length of Piping (miles) | | | | | | | | Percent of Length |
|---|---|---|---|---|---|---|---|---|---|
| | Asbestos Cement | Cast Iron | Ductile Iron | Galvanized | PVC | Steel | Unknown | Total | |
| 1960–1969 | 1.1 | 16.4 | 1.3 | - | 6.1 | - | 0.3 | **25.2** | **4%** |
| 1970–1979 | 11.0 | 13.8 | 3.1 | - | 25.3 | - | 1.8 | **55.0** | **9%** |
| 1980–1989 | 1.7 | 9.9 | 19.3 | - | 52.7 | - | 9.6 | **93.3** | **16%** |
| 1990–1999 | 0.8 | 0.4 | 20.7 | - | 106.5 | - | 4.1 | **132.6** | **23%** |
| 2000–2009 | 0.4 | 0.0 | 4.1 | - | 15.2 | - | 0.1 | **19.8** | **3%** |
| 2010–2011 | - | - | - | - | 0.5 | - | - | **0.5** | **0%** |
| Unknown | 15.7 | 4.9 | 15.2 | 0.3 | 154.2 | 0.1 | 69.5 | **259.8** | **44%** |
| **Total** | **30.7** | **45.3** | **63.8** | **0.3** | **360.6** | **0.1** | **85.4** | **586.2** | **100%** |
| **Percent of Length** | **5%** | **8%** | **11%** | **0%** | **62%** | **0%** | **15%** | **100%** | |

Most piping in the GIS that did not have an installation date is expected to be PVC. Because the average installation date for most PVC in the system (for piping with known installation dates) is approximately 1990, and because a large amount of piping was installed in 1990 due to the island's high growth period, piping missing an installation date was assumed to be installed in 1990.

### 8.4.1.2 Service Life Curve Development

The renewal modeling calculations used estimated pipe service life values to develop service life curves, indicating how pipe assets will “survive” over time. The curves are similar to a human life expectancy curve with the majority of people surviving to middle age, some infant mortality, and the rest living to an old age. The curves were developed using a three-point method with the following three points:

1. The first point is the year at which 100 percent of the pipes within that group are expected to remain in service before they completely fail.
2. The second point is the year at which 50 percent of the pipes in that pipe category are expected to remain in service and the other 50 percent fail.
3. The third point is the year at which only 10 percent of the pipes remain in service.

A Hertz distribution function was used to randomly select pipe segments of each material type to model the failure of the complete set of pipes of each material type based on the length of time they have been in the ground. Through this process, the real-world random distribution of water line failure was estimated.

To develop the service life values for GWA, information was used from other utilities and the latest AWWA guidance regarding water pipe service life (AWWA, 2012a). Table 8-3 lists the pipe service life values used in the analysis.

**Table 8-3. Pipe Service Life Values**

| Material Description | Pipe Age at % of Service Life Remaining | | | AWWA Service Life (years) | Notes |
|---|---|---|---|---|---|
| | 90% | 50% | 10% | | |
| Asbestos Cement | 40 | 60 | 80 | 80 | |
| Cast Iron | 40 | 75 | 120 | 120 | |
| Ductile Iron | 40 | 70 | 110 | 110 | |
| PVC | 40 | 65 | 90 | 100 | PVC water line manufacturers have stated that PVC pipe generally has a 100-year life span, but many systems are experiencing issues with PVC piping earlier than 100 years. |
| Unknown/Other | 40 | 60 | 80 | | |

### 8.4.1.3 Long-Term Renewal Needs

The renewal needs model generated a year-by-year quantity of piping by material type that should be targeted for replacement between 2015 and 2080. Table 8-4 summarizes the length of piping to renew by decade. Figure 8-6 shows a graph of the same information.

**Table 8-4. Length of Piping to Renew by Decade**

| Years | Length of Piping (miles) | | | | | | | Percent of Total System to Replace per Year |
|---|---|---|---|---|---|---|---|---|
| | Asbestos Cement | Cast Iron | Ductile Iron | PVC | Other/ Unknown | Total | Miles to Replace per Year | |
| 2015–2019 | 1.1 | 1.4 | 0.2 | 3.5 | 0.4 | 6.5 | 1.3 | 0.2% |
| 2020–2029 | 4.2 | 5.0 | 1.9 | 22.0 | 3.7 | 36.9 | 3.7 | 0.6% |
| 2030–2039 | 6.7 | 6.5 | 5.6 | 54.7 | 11.2 | 84.6 | 8.5 | 1.3% |
| 2040–2049 | 7.4 | 7.2 | 7.6 | 71.1 | 19.0 | 112.3 | 11.2 | 1.8% |
| 2050–2059 | 6.1 | 7.4 | 8.8 | 73.2 | 21.6 | 117.0 | 11.7 | 1.9% |
| 2060–2069 | 3.8 | 6.9 | 9.0 | 61.5 | 15.5 | 96.6 | 9.7 | 1.5% |
| 2070–2080 | 1.8 | 6.4 | 8.8 | 46.8 | 8.1 | 72.0 | 6.5 | 1.0% |
| **Total to Renew (2015 through 2080)** | **31.1** | **40.7** | **41.8** | **332.9** | **79.4** | **526.0** | **8.0 (average per year)** | **1.3% (average per year)** |
| **Total in System (from Table 8-2) [a]** | **30.7** | **45.3** | **63.8** | **360.6** | **85** | **586.2** | **-** | **-** |
| **Percent to Renew (Total to Renew/ Total in System)** | **100%** | **90%** | **66%** | **92%** | **93%** | **90%** | **-** | **-** |

*a. The length of asbestos cement pipe to renew is longer than the total length of asbestos cement pipe because a slightly different GIS dataset was used for the long-term renewal needs analysis.*

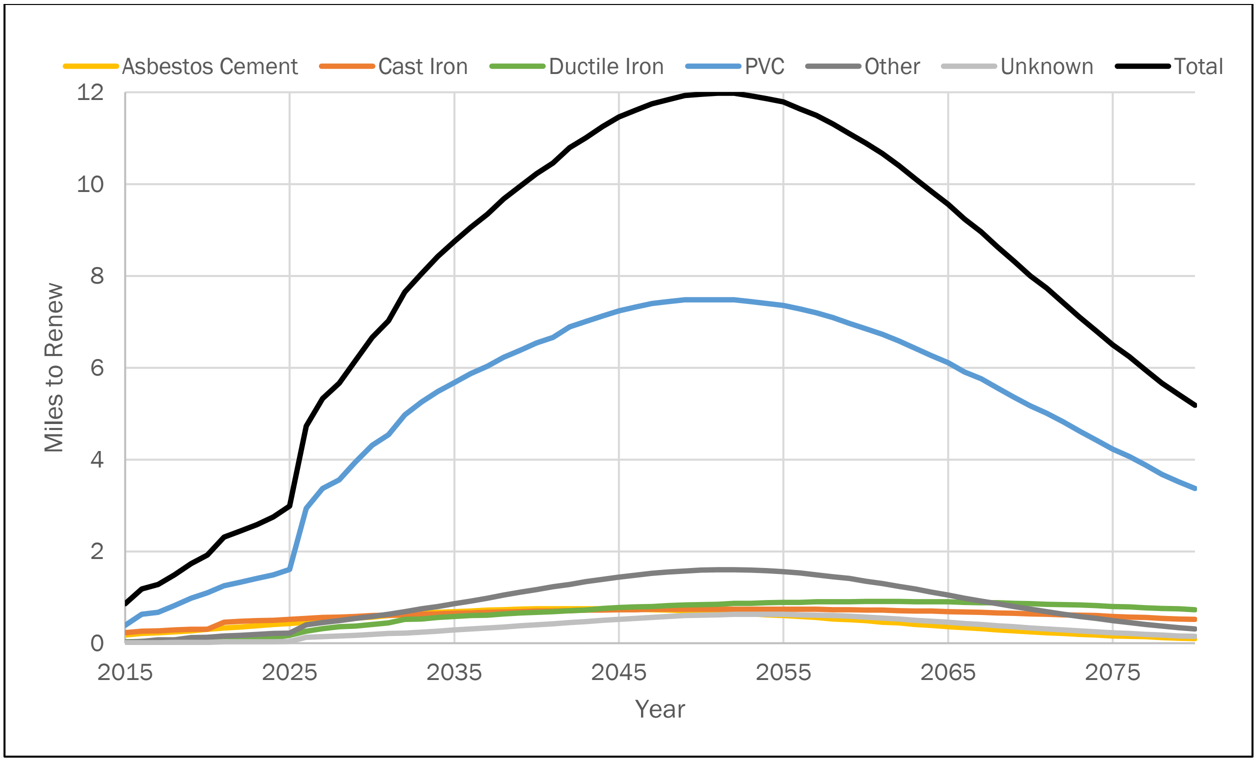



**Figure 8-6. Pipeline Renewal Needs by Year**

Table 8-3 shows that the projected renewal need over the next 65 years is an average of 8.0 miles per year, or about 1.3 percent of the total existing piping. This is slightly higher than the general rule of thumb within the industry of renewing a minimum of 1 percent per year. Renewal needs will vary by year, ranging from approximately 1.3 miles per year to 11.7 miles per year. The greater required number of miles to replace per year is due to the large amount of piping constructed in the 1980s and 1990s. The assumed year of construction of 1990, mentioned above, also impacts the calculations.

In GWA's current, 5-year CIP program (2016–2020), the capital plan for water lines is included as CIP PW 09-03, Water Distribution System Pipe Replacement. This project has a 4-year schedule and a budget of $20,893,000, which includes planning, design, inspection, and other supporting costs. The project is expected to replace approximately 0.8 miles per year, or 3 miles of water pipelines over the 4-year period. Because the current CIP will replace fewer miles of pipeline than the recommended replacement schedule shown in Table 8-4, GWA should continue to increase water line renewal in the next CIP update.

The goal of this analysis is to estimate the overall amount of piping that needs to be renewed to reach a steady state of pipe installation and retirement over time. In other words, this analysis estimated the amount of pipe that needs to be renewed on average every year. The analysis does not identify specific pipeline segments that may experience early failures and may need to be replaced before the end of their useful life.

### 8.4.2 Risk Calculations

The next step in calculating renewal needs was to estimate and prioritize which pipes require replacement each year using a risk-based methodology. Risk was calculated from the likelihood of failure and consequence of failure of each pipe. Each pipe was ranked to prioritize rehabilitation or replacement of the pipe compared to the piping in the rest of the system. The goal of this analysis was to identify areas of the system with the greatest potential impact in the event of a failure and focus asset management resources on the most critical assets to minimize risks of failure. The factors used to calculate likelihood and consequence of failure are discussed below.

**Likelihood of Failure Risk Factors**

Calculating likelihood of failure involves obtaining information about the pipeline's original design, material, installation, and operating parameters in conjunction with an assessment or estimate of its potential condition. While condition assessment techniques are evolving rapidly, GWA acknowledges that it is not currently feasible to inspect large portions of water lines. Therefore, desktop techniques were used to rank potential condition using available data.

Table 8-5 lists the likelihood of failure factors and Appendix F lists the scoring breakdown for each factor. Each factor was given a score ranging from 1 (good) to 5 (poor) and a weight (which allowed some factors to be given more importance than others).

**Table 8-5. Likelihood of Failure Factors**

| ID | Criteria | Factor Description | Process | Weight |
|---|---|---|---|---|
| P2 | Soils | Ranked pipes for potential failure based on soil type or corrosivity of soil. Clay soils trap water, which can increase rate of corrosion. Pipelines within a clay based soil were ranked worst, within a loam or silty soil type were ranked medium, and within an urban area soil type were ranked best. | • Intersected pipes with soil data from the NRCS. | 0.20 |
| P3 | Past breaks/ leaks | Ranked pipes based on past breaks/leaks. Pipes that have experienced past issues are more likely to experience future issues at an increasing frequency. Frequent repairs can become costlier than a full replacement. | • Break/leak info available from GWA snapped to the nearest pipe.<br>• Summed number of breaks on each pipe. | 0.25 |
| P4 | Pipe installation or lining year | Ranked pipes based on installation or lining year. This factor is purely based on age with the assumption that older pipes are more likely to fail. | • Grouped pipes by GIS install year field.<br>• Set pipes with unknown install year field to 1990 as discussed above. | 0.20 |
| P5 | Material | Ranked pipes for potential failure based on material. Different materials have different thicknesses and thus different expectations at which they will fail. | • Used pipe GIS material field. | 0.10 |
| P9 | Operating pressure | Pipes operating at higher pressures are more likely to fail. | • Grouped pipes by pressures from the hydraulic model. | 0.15 |
| P11 | Depth and road crossings | Ranked pipes based on depth and crossing roads. Shallow pipes are more likely to fail due to vehicles passing over the pipe. | • GIS depth field used to determine pipe depth.<br>• Pipes classified based on depth field and intersection with streets. | 0.10 |

### Consequence of Failure Risk Factors

Determining the consequence of failure involves assessing potential consequences if a pipe fails. Table 8-6 lists the consequence of failure factors and Appendix F lists the scoring breakdown for each factor. As with the likelihood of failure, each factor was given a score and weight.

**Table 8-6. Consequence of Failure Factors**

| ID | Criteria | Factor Description | Process | Weight |
|---|---|---|---|---|
| C1 | Damage or disruption to sensitive locations | Pipes that could flood or disrupt priority facilities in the event of failure were given a higher consequence of failure. Priority facilities include hospitals, schools, police stations, fire stations, government buildings, and hotels. | • Data merged from multiple sources (including U.S. Geological Survey Place Names and Google Earth hotel locations) to develop sensitive locations list: Schools, Hospitals, Mayor's Office, Churches, and Hotels.<br>• Distance calculated from sensitive locations to pipes. | 0.20 |
| C2 | Damage or disruption to roadways | Pipes that will damage or flood important roads or highways in the event of failure were given a higher consequence of failure. | • Distance determined from pipes to major and minor streets. | 0.15 |
| C4 | Service outage – customer demand | Pipes that affect larger demands in the event of failure were given a higher consequence of failure. | • Customer meter points assigned to closest pipe and summed for each pipe.<br>• GIS valves used to simulate pipes that would not deliver water during a repair due to closing the valves.<br>• Calculated affected demand based on average billed water use between March 2015 to January 2016. | 0.15 |
| C7 | Flooding potential - flow | Quantified potential for economic damage and negative publicity in the event of pipe failure. This factor was used to estimate volume of water during a break. | • Used average flow from the hydraulic model for each pipe. | 0.15 |
| C8 | General disruption - landcover | Ranked pipes based on potential economic damage and negative publicity in the event of pipe failure. Pipelines within impervious areas were scored highest due to their potential to disrupt citizens and damage infrastructure. | • Classified data into impervious, developed open space, and other using NOAA Landcover Classification (2011) data. | 0.10 |
| C10 | Pipe redundancy | Pipes without redundancy (such as looping) were given a higher consequence of failure. | • Ran a looping algorithm to calculate if a pipe is looped or single feed. | 0.10 |
| C11 | Population density | Pipes serving areas with higher population densities will experience greater disruption in the event of failure and were given a higher consequence of failure. | • Calculated population density as persons per square mile using Guam Population by Municipality derived from U.S. Census Tracts 2010. | 0.15 |

**Risk Calculation**

Scores were calculated for each pipe segment using the following steps:

1. Assign a score of 1 to 5 for each likelihood of failure factor to each pipe segment.
2. Calculate a total likelihood of failure factor for each pipe segment by summing the scores: $L1_{score} \times L1_{weight} + L2_{score} \times L2_{weight} + \ldots Ln_{score} \times Ln_{weight}$
3. Normalize all likelihood of failure scores so the scores range from 1 to 5. A higher score indicates a higher likelihood of failure.
4. Repeat steps 1 to 3 for consequence of failure.
5. Calculate total risk for each pipe segment: likelihood of failure score (1 to 5) x consequence of failure score (1 to 5).

### 8.4.3 Initial Ranking of Water Lines for Inspection or Renewal

This section describes the overall results of the system-wide risk analysis. Table 8-7 summarizes the likelihood and consequence of failure score ranges. Likelihood of failure scores ranged from 1.2 to 4.35 and consequence of failure scores ranged from 0.95 to 4.75. Higher scores indicate a higher likelihood or consequence of failure.

**Table 8-7. Failure Summary**

| Score Range | Likelihood of Failure | | Consequence of Failure | |
|---|---|---|---|---|
| | Miles | Percent of Total System | Miles | Percent of Total System |
| 0–1 | 0.0 | 0.0% | 0.4 | 0.1% |
| 1–2 | 86.6 | 14.8% | 21.3 | 3.6% |
| 2–3 | 395.2 | 67.4% | 328.6 | 56.0% |
| 3–4 | 93.2 | 15.9% | 214.4 | 36.6% |
| 4–5 | 2.3 | 0.4% | 12.8 | 2.2% |
| Insufficient Data | 8.8 | 1.5% | 8.8 | 1.5% |
| **Total** | **586.2** | **100%** | **586.2** | **100%** |

Likelihood of failure and consequence of failure scores were broken into four categories: high priority, high likelihood, highly critical, and lower priority. These categories were established using a threshold score of 3 for likelihood and consequence of failure. Table 8-8 and Figure 8-7 summarize the results by risk category.

**Table 8-8. Risk Summary**

| Risk Category | Score Range | Miles | Percent of Total System |
|---|---|---|---|
| High Priority | Likelihood and consequence of failure are greater than or equal to 3 | 41.1 | 7.0% |
| High Likelihood | Likelihood of failure is greater than or equal to 3 and consequence of failure is less than 3 | 54.5 | 9.3% |
| Highly Critical | Likelihood of failure is less than 3 and consequence of failure is greater than or equal to 3 | 186.1 | 31.8% |
| Lower Priority | Likelihood and consequence of failure are less than 3 | 295.7 | 50.4% |
| Insufficient Data | Insufficient data to perform the analysis for these pipes | 8.8 | 1.5% |
| **Total** | | **586.2** | **100.0%** |

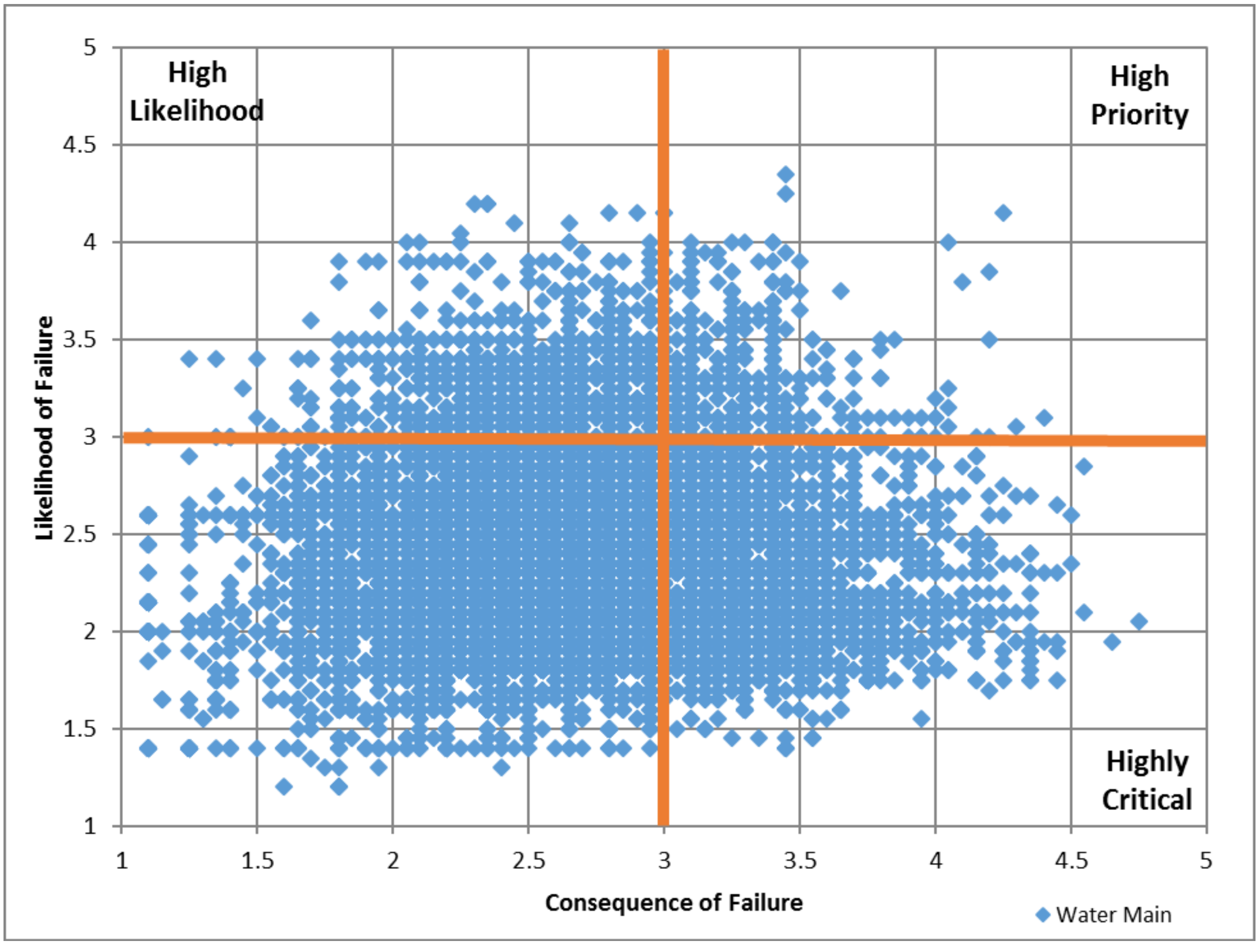
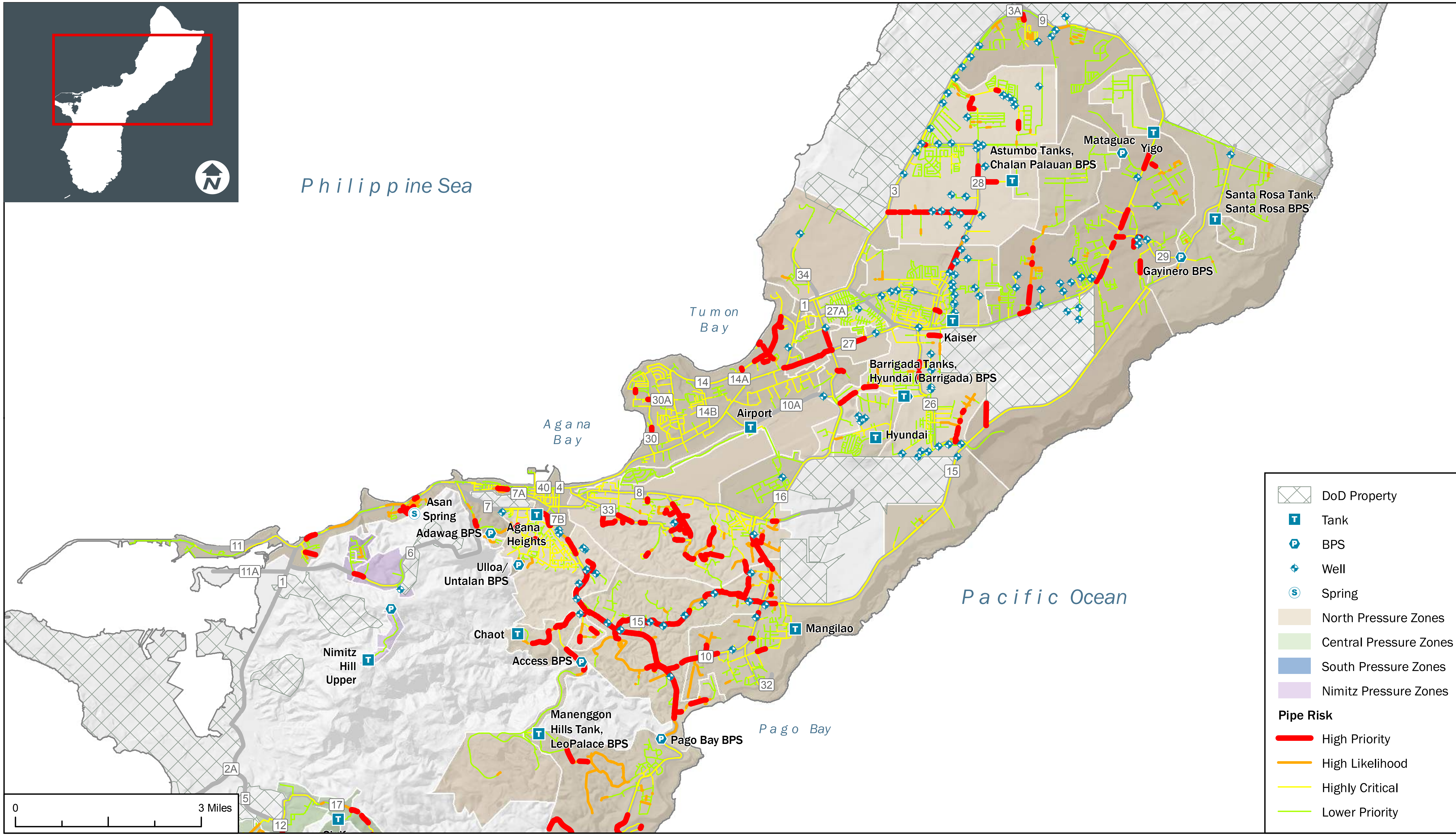



**Figure 8-7. Likelihood and Consequence of Failure Results by Risk Category**

Piping was grouped into the four categories to allow decisions to be made for renewal actions. Note that the least amount of piping falls into the high priority and high likelihood categories, which aligns with the overall renewal needs explained earlier. Because high priority water lines comprise approximately 7 percent of the total system, that piping could be renewed within seven years at a 1 percent annual renewal rate. Figure 8-8 and Figure 8-9 provide system-wide maps showing the water lines color coded by the risk categories.




11/17/2017

**Figure 8-8. Risk Category Summary (North)**

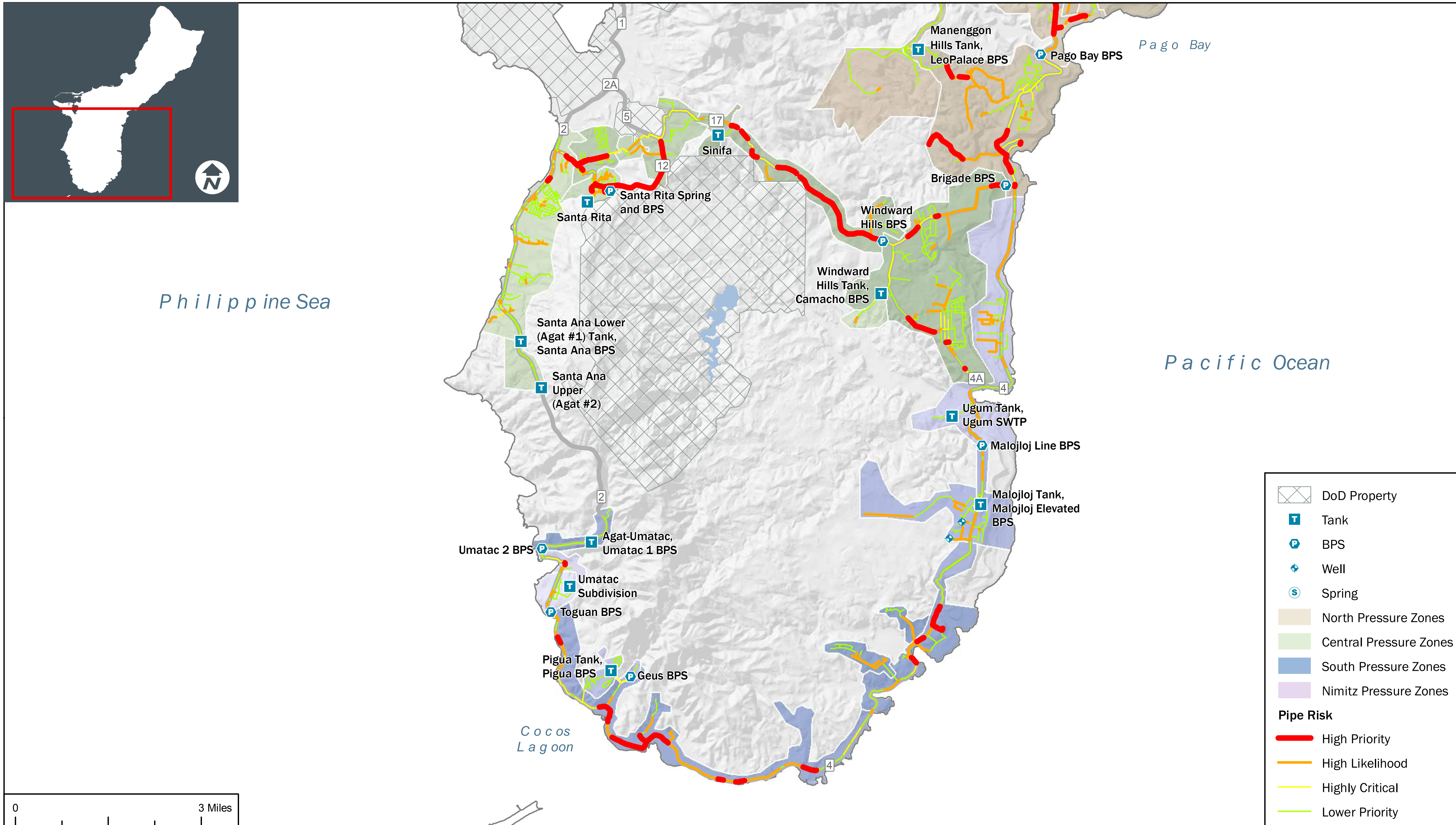



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Figure 8-9. Risk Category Summary (South and Central)

## 8.5 Pipeline Renewal Needs Analysis

The following section describes the rehabilitation or replacement needs of GWA's water distribution pipelines. The rehabilitation and replacement needs were developed using the following approaches:

1. **Full replacement:** full replacement assumes that all piping within a project area will be replaced.
2. **Targeted rehabilitation and replacement:** targeted rehabilitation and replacement assumes that condition assessments will be performed on all pipes in a project. For a project, 20 percent of pipelines inspected by condition assessment will require rehabilitation (14 percent) or replacement (6 percent). These percentages are based on values observed by BC in similar projects.

The following assumptions were used to develop the cost estimates in this section:

- Costs for condition assessment work were based upon values observed by BC for similar projects on the mainland. An escalation factor was established by comparing costs for new pipeline replacement on the mainland to new pipeline costs on Guam used for this project (which are listed in Volume 1, Appendix D). This factor was applied to escalate condition assessment costs to expected costs on Guam.
- The cost estimates are for budgeting purposes only and may not represent the actual cost of conducting condition assessment, rehabilitation, and replacement activities in these areas. Unit costs for condition assessment, rehabilitation, replacement, and engineering costs are listed in Volume 1, Appendix D.
- All costs are in 2017 dollars.

### 8.5.1 Candidate Project Areas

Using the likelihood and consequence of failure results and risk categories, pipes were grouped into candidate project areas for condition assessment, rehabilitation, and replacement activities. Pipes from the high priority and high likelihood categories were grouped based on proximity to each other. Pipes from the lower ranking categories were included if located between higher priority pipes. Because there were scattered, individual pipes in the higher-ranking categories that were not close to other high priority pipes, these individual pipes were not included in projects at this time. These individual pipes should be considered for rehabilitation or replacement after the identified projects are completed.

Table 8-9 lists candidate project areas and water pipes included within each area. Figure 8-10 and Figure 8-11 illustrate the location of each proposed project area. Note that if targeted rehabilitation and replacement is used, all pipes within a project will have condition assessment performed, but only those that are found to be in poor condition will be rehabilitated or replaced.

**Table 8-9. Candidate Projects for Water Pipeline Rehabilitation and Replacement**

| Condition Project ID | Average Score Weighted by Length of Each Pipe | | Percent of Project Length by Risk Category | | | | Length of Pipe (miles) |
|---|---|---|---|---|---|---|---|
| | Likelihood | Consequence | High Priority | High Likelihood | Highly Critical | Lower Priority | |
| 01 | 3.6 | 3.8 | 100% | - | - | - | 1.96 |
| 02 | 3.5 | 3.4 | 100% | - | - | - | 1.81 |
| 03 | 3.6 | 3.2 | 77% | 22% | 1% | - | 1.32 |

| Table 8-9. Candidate Projects for Water Pipeline Rehabilitation and Replacement | | | | | | | |
|---|---|---|---|---|---|---|---|
| Condition Project ID | Average Score Weighted by Length of Each Pipe | | Percent of Project Length by Risk Category | | | | Length of Pipe (miles) |
| | Likelihood | Consequence | High Priority | High Likelihood | Highly Critical | Lower Priority | |
| 04 | 3.5 | 3.1 | 88% | 11% | 1% | - | 1.12 |
| 05 | 3.4 | 3.4 | 93% | 6% | 1% | - | 2.70 |
| 06 | 3.3 | 3.1 | 75% | 14% | 7% | 4% | 0.71 |
| 07 | 3.3 | 3.4 | 84% | 13% | 3% | - | 1.95 |
| 08 | 3.3 | 3.3 | 78% | 9% | 10% | 3% | 2.84 |
| 09 | 3.3 | 3.6 | 100% | - | - | - | 0.65 |
| 10 | 3.3 | 3.8 | 85% | 11% | 4% | 0% | 1.67 |
| 11 | 3.3 | 3.2 | 77% | - | 23% | - | 1.42 |
| 12 | 3.2 | 3.5 | 100% | - | - | - | 1.69 |
| 13 | 3.1 | 3.3 | 77% | 20% | 1% | 3% | 2.22 |
| 14 | 3.1 | 4.3 | 100% | - | - | - | 0.16 |
| 15 | 3.0 | 3.0 | 81% | 11% | - | 8% | 0.61 |
| 16 | 2.9 | 4.1 | 90% | - | 10% | - | 1.22 |
| 17 | 3.8 | 2.9 | 59% | 41% | - | - | 0.43 |
| 18 | 3.5 | 2.7 | 27% | 66% | - | 8% | 1.68 |
| 19 | 3.6 | 2.8 | 25% | 69% | - | 5% | 2.30 |
| 20 | 3.3 | 2.9 | 64% | 29% | 6% | 1% | 1.43 |
| 21 | 3.2 | 2.9 | 39% | 55% | 5% | 1% | 2.06 |
| 22 | 3.2 | 2.9 | 33% | 44% | 2% | 21% | 1.03 |
| 23 | 3.2 | 2.8 | 52% | 48% | - | - | 1.54 |
| 24 | 3.2 | 2.7 | 49% | 49% | 3% | 0% | 4.43 |
| 25 | 3.0 | 3.0 | 74% | 26% | - | - | 0.61 |
| 26 | 3.5 | 2.9 | 3% | 95% | - | 3% | 1.80 |
| 27 | 3.4 | 2.6 | 18% | 78% | - | 4% | 1.85 |
| 28 | 3.5 | 2.5 | - | 100% | - | 0% | 1.54 |
| 29 | 3.4 | 2.7 | 9% | 90% | - | 1% | 3.10 |
| 30 | 3.3 | 2.6 | - | 98% | - | 2% | 0.97 |
| 31 | 3.3 | 2.9 | - | 100% | - | - | 0.79 |
| 32 | 3.2 | 2.7 | - | 93% | - | 7% | 1.66 |
| 33 | 3.1 | 2.8 | 23% | 70% | - | 7% | 2.05 |
| 34 | 3.1 | 2.8 | 12% | 88% | - | 0% | 1.36 |
| **Total** | | | | | | | **54.68** |

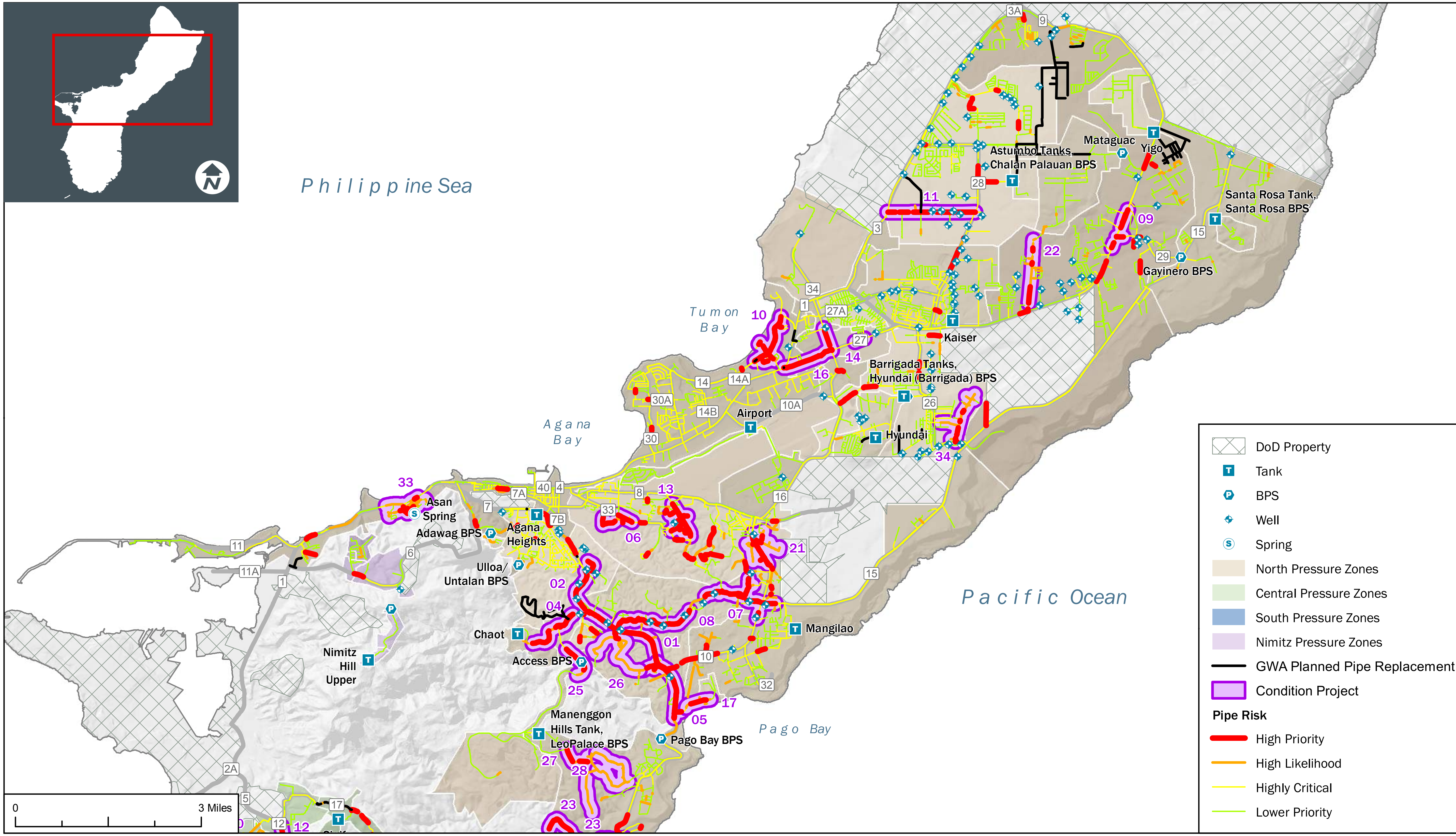


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**Figure 8-10. Candidate Project Areas (North)**

Brown AND Caldwell

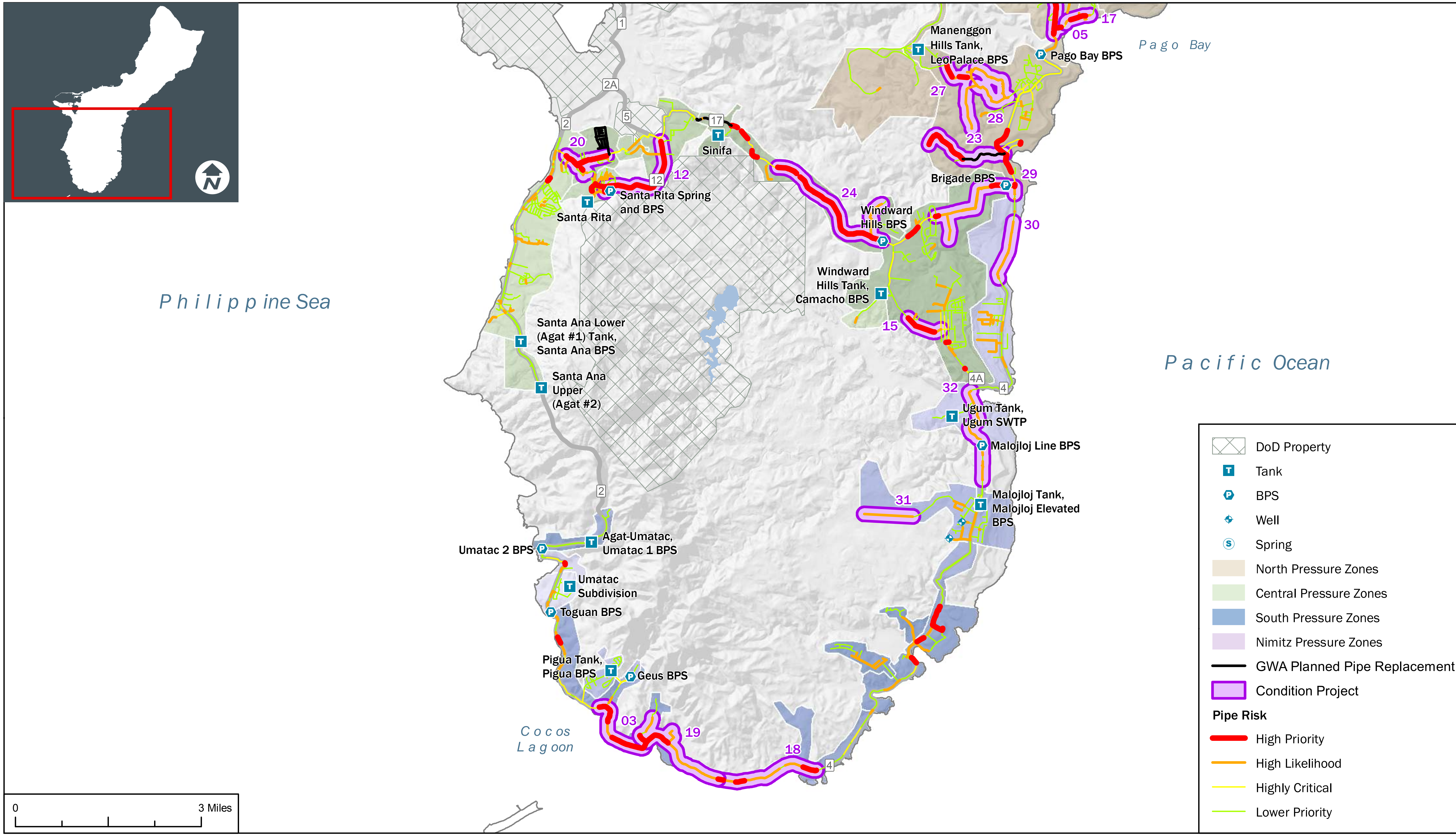


Figure 8-11. Candidate Project Areas (South and Central)

### 8.5.2 Overall Renewal Recommendations

The following steps were used to develop renewal recommendations:

1. Calculate water line rehabilitation and replacement costs.
2. Identify scenarios for the planning timeframe using different amounts of water line replacement work based on long-term analysis results.
3. Develop proposed project.

The following sections describe each step.

**Step 1. Pipeline Rehabilitation and Replacement Costs**

Table 8-10 lists total costs for pipeline rehabilitation and replacement by risk category. The table includes costs for full replacement and targeted rehabilitation and replacement. As discussed above, targeted replacement includes performing condition assessment on all pipes in a project and assumes that 20 percent of the pipes will require rehabilitation or replacement. Table 8-10 does not include 2-inch or asbestos cement piping, which is treated separately later in this section.

**Table 8-10. Rehabilitation and Replacement Costs by Risk Category**

| Risk Category | Miles | Percent of Total System | Full Replacement (millions of dollars) | Targeted Rehabilitation and Replacement (millions of dollars) |
|---|---|---|---|---|
| High Priority | 37.6 | 6.4% | $104.2 | $20.1 |
| High Likelihood | 46.2 | 7.9% | $118.6 | $23.6 |
| Highly Critical | 176.4 | 30.1% | $496.3 | $96.4 |
| Lower Priority | 273.6 | 46.7% | $690.7 | $138.9 |
| Insufficient Data | 6.9 | 1.2% | $19.4 | $3.7 |
| **Total** | 540.6 | 92.2% | $1,429.1 | $282.7 |

**Step 2. Water Line Capital Needs Scenarios**

Table 8-11 lists four scenarios that were developed which consider either full replacement or targeted rehabilitation and replacement.

The scenarios also vary based on assumed available funding per year. In GWA's current, 5-year CIP plan (2016–2020), the capital plan for water lines is included as CIP PW 09-03, Water Distribution System Pipe Replacement. The funding level for this project is $20,893,000 over four years, which equates to approximately $5 million per year. As noted above, this analysis does not include 2-inch or asbestos cement piping, which is treated separately later in this section.

| Table 8-11. Water Line Renewal Scenarios Cost and Timeframe Summary | | | | |
|---|---|---|---|---|
| Number | Scenario | System Renewal Timeframe (years) | Average Miles per Year | Average Annual Cost (millions of dollars) |
| 1 | Full replacement using average yearly renewal rate of 8 miles per year, as identified by the long-term analysis in Table 8-4 (540.6 miles total length/8 miles per year) | 68 (full replacement of entire system) | 8.0 (full replacement) | $21.2 |
| 2 | Targeted rehabilitation and replacement using average yearly renewal rate of 8 miles per year, as identified by the long-term analysis in Table 8-4 (540.6 miles total length/8 miles per year). Assuming condition assessment finds that 20 percent of system needs rehabilitation or replacement, 40 miles would need to be inspected. | 14 (targeted renewal for entire system) | 8.0 (rehab or replacement)<br>40.0 (targeted replacement) | $21.0 |
| 3 | Full replacement using current funding of $5 million per year ($1.43B from Table 8-10 for $5M per year) | 286 (full replacement of entire system) | 1.9 (full replacement) | $5.0 |
| 4 | Targeted rehabilitation and replacement using current funding of $5 million per year ($283M from Table 8-10 for $5M per year). Assuming condition assessment finds that 20 percent of system needs rehabilitation or replacement, 2.1 miles would be rehabilitated or replaced. | 57 (targeted renewal for entire system) | 1.9 (rehab or replacement)<br>9.6 (targeted replacement) | $5.0 |

The first scenario more than triples GWA's current annual funding level by assuming that all pipes will be fully replaced. The second scenario uses targeted replacement and has an annual cost higher than the current funding level. The third scenario results in an unacceptable system renewal timeframe of 286 years. Finally, the fourth scenario is based on maintaining current funding levels and using a targeted rehabilitation and replacement approach. Based on a review of the four scenarios, the fourth scenario is recommended and was used for development of the proposed improvement project. Although scenario 2 meets the long-term recommendation of replacing 4.5 miles per year, scenario 4 is recommended if GWA can maintain the current funding of $5.0 million per year.

As a comparison, a 2013 study, *Water Distribution Pipeline Prioritization Model Review,* recommended a replacement of $7.5M per year to reduce system leaks (BC, March 2013b). The study used a risk-based approach to calculate the amount of piping needed per year to reduce system leaks. Note that the pipe replacement costs used for the 2013 study are lower than the costs used for this study. The 2013 study also only considered full pipe replacement and not condition assessment and rehabilitation of pipelines.

**Step 3. Proposed Improvement Project**

Table 8-12 lists planning level costs developed using unit cost assumptions for each candidate project area. The plan shown in the table was developed by applying the Scenario 4 assumptions of targeted rehabilitation and replacement (perform condition assessment on all pipes in a project and assume that 20 percent of the pipes will require rehabilitation or replacement) and annual funding of $5 million to the list of candidate projects presented in the previous sections. This plan optimizes use of GWA's resources by prioritizing the highest risk pipelines for renewal. The candidate projects are proposed projects for the first six years of rehabilitation and replacement. Following completion of the proposed projects, GWA should reassess the risk profile of the water system based on the condition assessment findings and rehabilitation and replacement performed.

**Table 8-12. Candidate Project Budgetary Cost Estimates for Pipeline Rehabilitation and Replacement**

| Condition Project ID | Length of Pipe (miles) | Cost | | | | Annual Cost | Year |
|---|---|---|---|---|---|---|---|
| | | Condition Assessment | Targeted Rehabilitation (Lining) | Targeted Replacement | Total | | |
| 01 | 1.96 | $410,100 | $352,900 | $350,000 | $1,113,000 | $5,235,500 | 1 |
| 02 | 1.81 | $378,700 | $279,200 | $305,300 | $963,200 | | |
| 03 | 1.32 | $276,900 | $205,600 | $226,000 | $708,500 | | |
| 04 | 1.12 | $233,800 | $174,600 | $192,600 | $601,000 | | |
| 05 | 2.70 | $565,200 | $462,900 | $464,700 | $1,492,800 | | |
| 06 | 0.71 | $149,200 | $101,900 | $105,900 | $357,000 | | |
| 07 | 1.95 | $408,500 | $305,500 | $309,100 | $1,023,100 | $4,594,500 | 2 |
| 08 | 2.84 | $594,200 | $516,600 | $485,600 | $1,596,400 | | |
| 09 | 0.65 | $136,500 | $98,400 | $105,900 | $340,800 | | |
| 10 | 1.67 | $349,500 | $252,800 | $270,000 | $872,300 | | |
| 11 | 1.42 | $296,400 | $221,300 | $244,200 | $761,900 | | |
| 12 | 1.69 | $353,000 | $263,600 | $290,900 | $907,500 | $5,420,000 | 3 |
| 13 | 2.22 | $464,900 | $311,300 | $318,700 | $1,094,900 | | |
| 14 | 0.16 | $33,600 | $29,500 | $27,800 | $90,900 | | |
| 15 | 0.61 | $128,300 | $88,600 | $92,400 | $309,300 | | |
| 16 | 1.22 | $254,700 | $213,100 | $210,600 | $678,400 | | |
| 17 | 0.43 | $90,400 | $59,900 | $61,000 | $211,300 | | |
| 18 | 1.68 | $351,500 | $262,500 | $289,700 | $903,700 | | |
| 19 | 2.30 | $481,500 | $354,600 | $387,900 | $1,224,000 | | |
| 20 | 1.43 | $299,000 | $236,000 | $234,500 | $769,500 | $5,760,100 | 4 |
| 21 | 2.06 | $431,700 | $299,800 | $314,900 | $1,046,400 | | |
| 22 | 1.03 | $214,500 | $147,100 | $152,900 | $514,500 | | |
| 23 | 1.54 | $321,300 | $212,900 | $216,600 | $750,800 | | |
| 24 | 4.43 | $926,000 | $680,100 | $742,900 | $2,349,000 | | |
| 25 | 0.61 | $128,300 | $95,800 | $105,800 | $329,900 | | |
| 26 | 1.80 | $376,400 | $249,400 | $253,700 | $879,500 | $5,208,000 | 5 |
| 27 | 1.85 | $387,800 | $269,100 | $283,000 | $939,900 | | |
| 28 | 1.54 | $322,600 | $226,000 | $239,200 | $787,800 | | |
| 29 | 3.10 | $647,400 | $531,400 | $516,600 | $1,695,400 | | |
| 30 | 0.97 | $202,200 | $151,000 | $166,600 | $519,800 | | |
| 31 | 0.79 | $165,000 | $109,400 | $111,200 | $385,600 | | |
| 32 | 1.66 | $348,200 | $260,000 | $286,900 | $895,100 | $2,644,000 | 6 |
| 33 | 2.05 | $428,500 | $311,600 | $312,900 | $1,053,000 | | |
| 34 | 1.36 | $284,800 | $199,900 | $211,200 | $695,900 | | |
| **Total** | **54.71** | **$11,440,600** | **$8,534,300** | **$8,887,200** | **$28,862,100** | | |

### 8.5.3 Small Diameter and Asbestos Cement Pipe Replacement

The 2006 WMRP documented the need to remove smaller diameter (less than 6 inches) water lines and AC-pipe water lines. GWA would like to continue to make progress towards this goal by replacing 2-inch and AC piping. Table 8-13 summarizes the length of 2-inch and AC pipe and associated replacement costs by risk category. The table lists full replacement costs because it is assumed that condition assessment will not be performed on 2-inch and AC piping and all piping will be replaced. The costs for 2-inch pipe replacement assume that the 2-inch piping will be replaced with 6-inch PVC piping. The costs for AC pipe replacement assume that AC pipes will be replaced with similar sized PVC piping and that all piping with be at least 6-inch diameter PVC piping.

**Table 8-13. Total Remaining 2-Inch and AC Pipes**

| Risk Category | Overall Miles | 2-Inch Pipe | | | AC Pipe | | |
|---|---|---|---|---|---|---|---|
| | | Miles | Percent of Total System | Full Replacement Cost ($M) | Miles | Percent of Total System | Full Replacement Cost ($M) |
| High Priority | 41.1 | 0.2 | 0.0% | $0.48 | 3.3 | 0.6% | $8.53 |
| High Likelihood | 54.5 | 1.7 | 0.3% | $3.94 | 6.7 | 1.1% | $16.98 |
| Highly Critical | 186.1 | 0.5 | 0.1% | $1.21 | 9.2 | 1.6% | $23.22 |
| Lower Priority | 295.7 | 11.0 | 1.9% | $25.78 | 11.2 | 1.9% | $27.31 |
| Insufficient Data | 8.8 | 1.5 | 0.3% | $3.58 | 0.4 | 0.1% | $0.89 |
| **Total** | **586.2** | **14.9** | **2.5%** | **$34.99** | **30.7** | **5.2%** | **$76.94** |
| **Average Cost per Year (Over 20-Year Planning Period** | | | | **$1.75** | | | **$3.85** |

Additional CIP beyond the condition projects developed in this section are included to replace existing 2-inch and AC piping throughout the system. Table 8-13 includes annual costs to replace 2-inch and AC piping over a 20-year period.

The condition project areas contain some limited quantities of AC piping and small diameter piping, as listed in Table 8-14. Some overlap exists between piping listed in Tables 8-13 and 8-14; however, the overlap is only a small portion of the system's overall 2-inch and AC piping so no adjustment to the projects has been made to account for the limited overlap.

**Table 8-14. Candidate Project Areas with 2-Inch and AC Pipes**

| Condition Project ID | Total Length of Pipe (miles) | 2-Inch Length of Pipe (miles) | AC Pipe Length of Pipe (miles) |
|---|---|---|---|
| 03 | 1.32 | - | 0.24 |
| 05 | 2.70 | - | 0.32 |
| 07 | 1.95 | - | 0.69 |
| 08 | 2.84 | 0.02 | 0.08 |
| 10 | 1.67 | - | 0.04 |
| 18 | 1.68 | - | 0.97 |
| 19 | 2.30 | - | 0.73 |

| Table 8-14. Candidate Project Areas with 2-Inch and AC Pipes | | | |
|---|---|---|---|
| Condition Project ID | Total Length of Pipe (miles) | 2-Inch Length of Pipe (miles) | AC Pipe Length of Pipe (miles) |
| 21 | 2.06 | - | 0.44 |
| 26 | 1.80 | - | 0.65 |
| **Total** | **18.32** | **0.02** | **4.16** |

A report titled *Development Plan for Long-Term Comprehensive Water Distribution System Program* presents information on setting up a small diameter pipe program (BC, April 2013a).

## 8.6 Recommendations

This section summarizes recommendations for piping, PRV, and isolation valve improvements to address capacity and condition issues and realign existing WSAs into pressure zones. Recommended improvements are shown in the following figures and appendices:

- **Figure 8-12 and Figure 8-13:** these figures show overall maps of the recommended improvements. These figures are the same as Figure 2-2 and Figure 2-3 with the addition of recommended improvements.
- **Figure 8-14 and Figure 8-15:** these figures show hydraulic schematics of the recommended future system. These figures are the same as Figure 2-4 and Figure 2-5 with the addition of recommended improvements.
- **Appendix G:** this appendix contains figures for each pressure zone with improvements shown in more detail.
- **Appendix H:** this appendix contains details referenced in the maps in Appendix G. The detail maps show zoomed views of the improvements including locations of new piping to construct, PRVs to abandon, PRVs to construct, and isolation valves to open or close.

### 8.6.1 Pressure Zone Realignment

The figures in Appendix G and Appendix H show recommended improvements to realign the pressure zones. The improvements are summarized below for piping and valves.

### 8.6.2 Piping Improvements

Table 8-15 summarizes recommended piping projects to address identified capacity issues and for pressure zone realignment.

| Table 8-15. Recommended Piping Projects | | | | | | |
|---|---|---|---|---|---|---|
| Project Name | Project Number | Description | Reasons for Piping | Length of Piping | | Drawing |
| | | | | Diameter (inches) | Length (feet) | |
| Astumbo Zone Piping | MP-PW-Pipe-01 | Replace the existing 12-inch pipeline with a 16-inch pipeline along Ysengsong from Route 3 to the Astumbo tanks. | The existing piping is undersized to convey flows from the wells and to/from the Astumbo tanks. | 12<br>16 | 150<br>8,200 | Appendix H, Detail 10 |
| Route 1 Astumbo Zone Piping | MP-PW-Pipe-02 | Replace the existing 12-inch pipeline along Route 1. | The existing piping is undersized to convey the full permitted flow rates from the existing wells that pump into | 18 | 11,550 | Appendix G, Figure G-6 |

**Table 8-15. Recommended Piping Projects**

| Project Name | Project Number | Description | Reasons for Piping | Length of Piping | | Drawing |
|---|---|---|---|---|---|---|
| | | | | Diameter (inches) | Length (feet) | |
| | | | distribution piping that flows into this line. | | | |
| Harmon Cliffline Piping to Route 1 | MP-PW-Pipe-03 | Construct new piping to connect the Harmon Cliffline zone to the rest of the distribution system on Route 1. | Well H01 has more capacity than needed in the Harmon Cliffline zone. Connecting the Harmon Cliffline zone to the rest of the system will allow well H01 to pump extra flow into the rest of the system. A connection will also provide storage from the main system back to the Harmon Cliffline zone. | 12 | 780 | Appendix H, Detail 36 |
| Hyundai Well Piping | MP-PW-Pipe-04 | Replace the existing 6-inch piping from wells M17A, 17B, and 20A. | The existing 6-inch piping does not have sufficient capacity to allow the 3 wells to pump their full permitted flow rates. | 10 | 1,080 | Appendix H, Detail 40 |
| Kaiser Zone Looping | MP-PW-Pipe-05 | Construct new piping from north of the Kaiser tank to Route 1. | The piping will provide looping to improve flow around the Kaiser tank for the newly realigned Barrigada zone. | 12<br>14 | 20<br>550 | Appendix H, Detail 22 |
| Mangilao Pressure Zone Realignment | MP-PW-Pipe-06 | Construct new 24-inch piping to connect two lines in Route 15.<br>Construct a new 12-inch pipeline from Ladera to the Mangilao tanks to serve as an inlet line. The existing 16-inch inlet/outlet line will become an outlet line. | The piping will implement the pressure zone realignment for the new Mangilao pressure zone. | 12<br>24 | 590<br>40 | Appendix H, Details 58, 59, 60 |
| Mataguac BPS Suction Piping | MP-PW-Pipe-07 | Replace existing 6-inch piping on the suction side of the Mataguac BPS. | The existing piping is undersized to handle peak flows, which causes low suction pressures at the Mataguac BPS. | 12 | 1,350 | Appendix H, Detail 6 |
| Nimitz Lower BPS Piping | MP-PW-Pipe-08 | Construct parallel piping on the discharge side of the proposed Nimitz Hill Upper BPS. The size of the new piping will depend on whether the piping will serve fire flow demands. | This piping is needed when the Nimitz Hill pressure zone is divided into two pressures zones. Customers just downhill of the proposed lower tank would have low pressures if connected to the tank. The piping would server customers below the tank by extending the upper zone downhill. | 6 | 1,790 | Appendix H, Detail 71 |
| Yigo, Santa Rosa Zone Realignment | MP-PW-Pipe-09 | Construct a new 12-inch pipeline parallel to the existing 12-inch pipeline. The new pipeline will run from the Yigo tanks and connect to the existing 12-inch pipeline on Route 1. The 8-inch pipeline on Route 1 will be connected to the Santa Rosa zone. | This piping is needed for the realignment of the Yigo and Santa Rosa pressure zones. The new piping will help connect the Yigo tanks to the Yigo zone south on Route 1. | 12 | 4,310 | Appendix H, Detail 6 |

| Table 8-15. Recommended Piping Projects | | | | | | |
|---|---|---|---|---|---|---|
| Project Name | Project Number | Description | Reasons for Piping | Length of Piping | | Drawing |
| | | | | Diameter (inches) | Length (feet) | |
| Miscellaneous Piping Projects | MP-PW-Pipe-10 | Small pipe projects should be done for the pressure zones listed below as they are realigned. | These projects are primarily to connect piping within new pressure zone boundaries and to loop piping. | - | - | - |
| | | Astumbo | - | 12 | 450 | Appendix H, Detail 19 |
| | | Barrigada, Kaiser | - | 12 | 1,250 | Appendix H, Detail 25 |
| | | Mangilao | - | 12 | 550 | Appendix H, Detail 47 |
| | | Mangilao | - | 12 | 80 | Appendix H, Detail 48 |
| | | Ordot/Sinajana | - | 12 | 120 | Appendix H, Detail 53 |
| | | Tumon/Tamuning/Hagåtña | - | 16 | 160 | Appendix H, Detail 33 |
| | | Yigo North | - | 6 | 750 | Appendix H, Detail 8 |
| Miscellaneous Piping Connections | MP-PW-Pipe-11 | Construct connections between piping throughout the system, as identified in the figures in Appendices G and H. | Connections are needed for piping at intersections or to connect parallel piping. | Varies | Varies | Appendix G, Appendix H |
| Cross Island Highway Piping | MP-PW-Pipe-17 | Replace the existing 8-inch pipeline with a 12-inch pipeline along Cross Island Road between the Sinifa tank and the Sinifa PRV. | Existing piping is undersized to convey flows along Cross Island Road from Windward Hills to Agat and Santa Rita. | 12 | 3,060 | Appendix G, Figure G-28 |

The following pipeline projects were not included in Table 8-15 because they are already under study or design by GWA:

- **Agat Umatac Pipeline:** a proposed pipeline from Agat to Umatac is being studied as a possible alternate and redundant supply line from the North to the South. The pipeline would include BPSs to pump up the hill and PRVs on the other side to reduce pressures. The project could include additional storage tanks along the route. Figure 8-13 shows the location of the proposed pipeline.
- **Airport Tank Piping:** as part of the preliminary design of the new Airport tanks, alternatives are being studied for supplying the tanks. The existing 8 and 12-inch pipelines between the existing Airport tank and Route 1 are undersized for peak flows. One option being studied is to replace the existing pipelines with larger pipelines. Appendix G, Figure G-17 shows the location of the proposed pipelines.

### 8.6.3 Piping Condition Improvements

Table 8-9 lists candidate projects for pipeline rehabilitation and replacement. Table 8-13 summarizes the 2-inch and AC piping that should be replaced. Annual projects are proposed to continue the work with these pipe replacements.

### 8.6.4 Pressure Reducing Valves

For the pressure zone realignment, existing PRVs need to be rehabilitated and new PRVs need to be constructed. New master meters should be added to each new or rehabilitated PRV, if possible. The following list includes the number of PRVs anticipated to serve each pressure zone. Locations and numbers of the PRVs may change depending on site conditions such as the location of existing piping within a road and utility conflicts. The location of the PRVs are shown in the figures in Appendix G and Appendix H.

- Astumbo (new=3)
- Barrigada (rehabilitation=1, new=4)
- Barrigada Subzone (new=3)
- Harmon Industrial (rehabilitation=2, new=1)
- Hyundai Subzone (new=1)
- Inarajan/Merizo (new=1)
- Kaiser (new=3)
- Manenggon Hills (rehabilitation=1)
- Mangilao (new=2)
- Mangilao Central (new=2)
- Mangilao North (rehabilitation=3)
- Nimitz Estates Lower (rehabilitation=1)
- Nimitz Estates Middle Lower (rehabilitation=1)
- Nimitz Estates Middle Upper (rehabilitation=1)
- Ordot/Sinajana (rehabilitation=1, new=2)
- Pago Bay (new=1)
- Santa Ana Lower (rehabilitation=3, new=1)
- Santa Rita Central (rehabilitation=1)
- Santa Rita East (rehabilitation=1)
- Tiyan (new=1)
- Tumon/Tamuning/Hagåtña (rehabilitation=1, new=5)
- Umatac (rehabilitation=1)

### 8.6.5 Valve Exercise and Maintenance

As detailed above, GWA should implement an isolation valve exercise and maintenance program with the following steps:

- GWA should implement a valve exercise program with a crew of two operators. The program should be managed with the CMMS system.
- GWA should purchase a valve exercise machine, with hands-on training to ensure proper operation, to allow operators to operate valves that are difficult or require high numbers of turns to open or close.

- Broken valves should be documented as they are located. After a number of broken (do not turn, do not isolate or fully open) valves are identified, the valves should be grouped into a project and put out to bid to be fixed by a qualified contractor.

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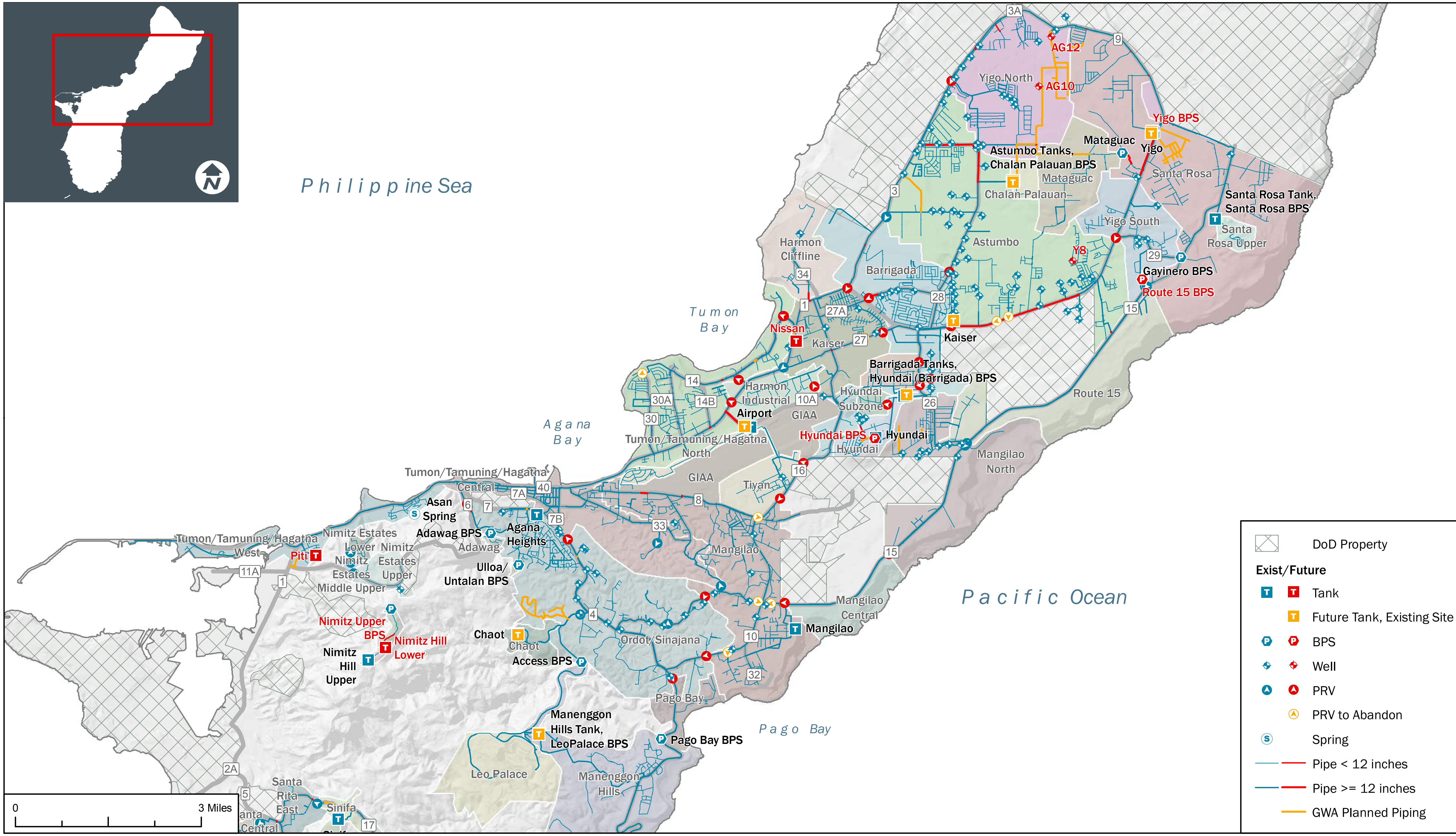


11/17/2017

**Figure 8-12. Proposed Water Distribution System (North)**

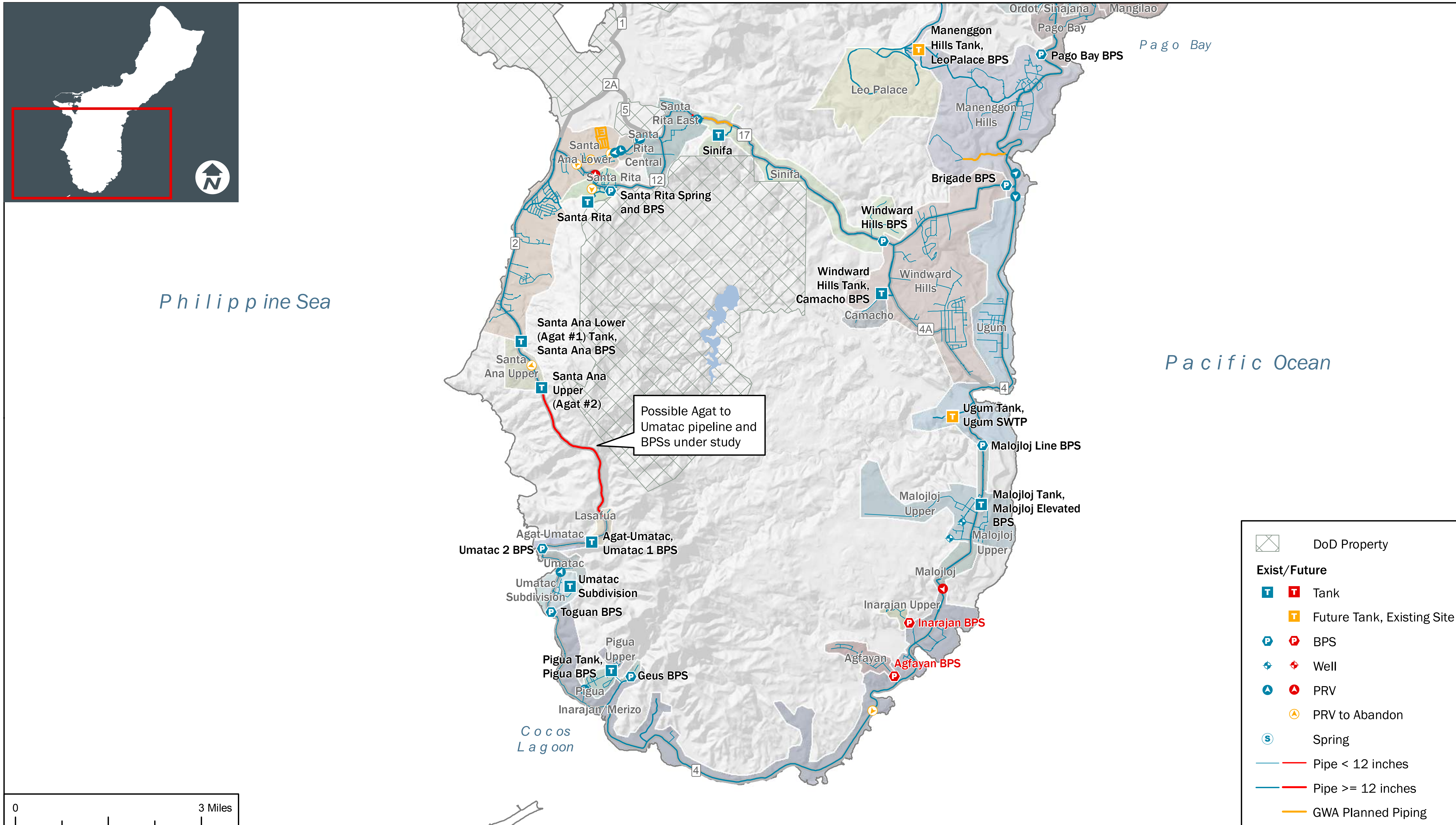


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Figure 8-13. Proposed Water Distribution System (South and Central)

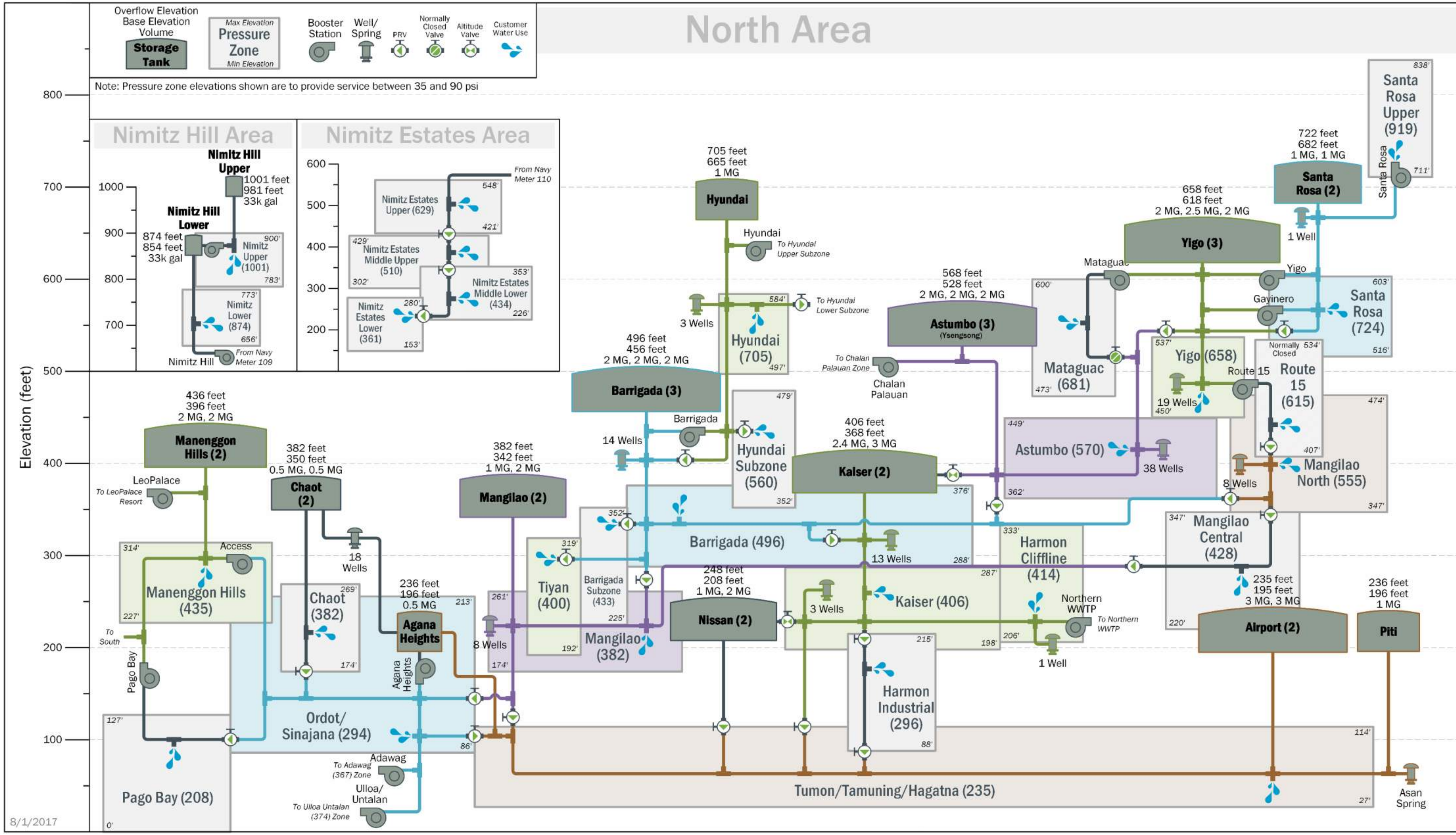


Figure 8-14. Proposed Water Distribution System Hydraulic Schematic (North)

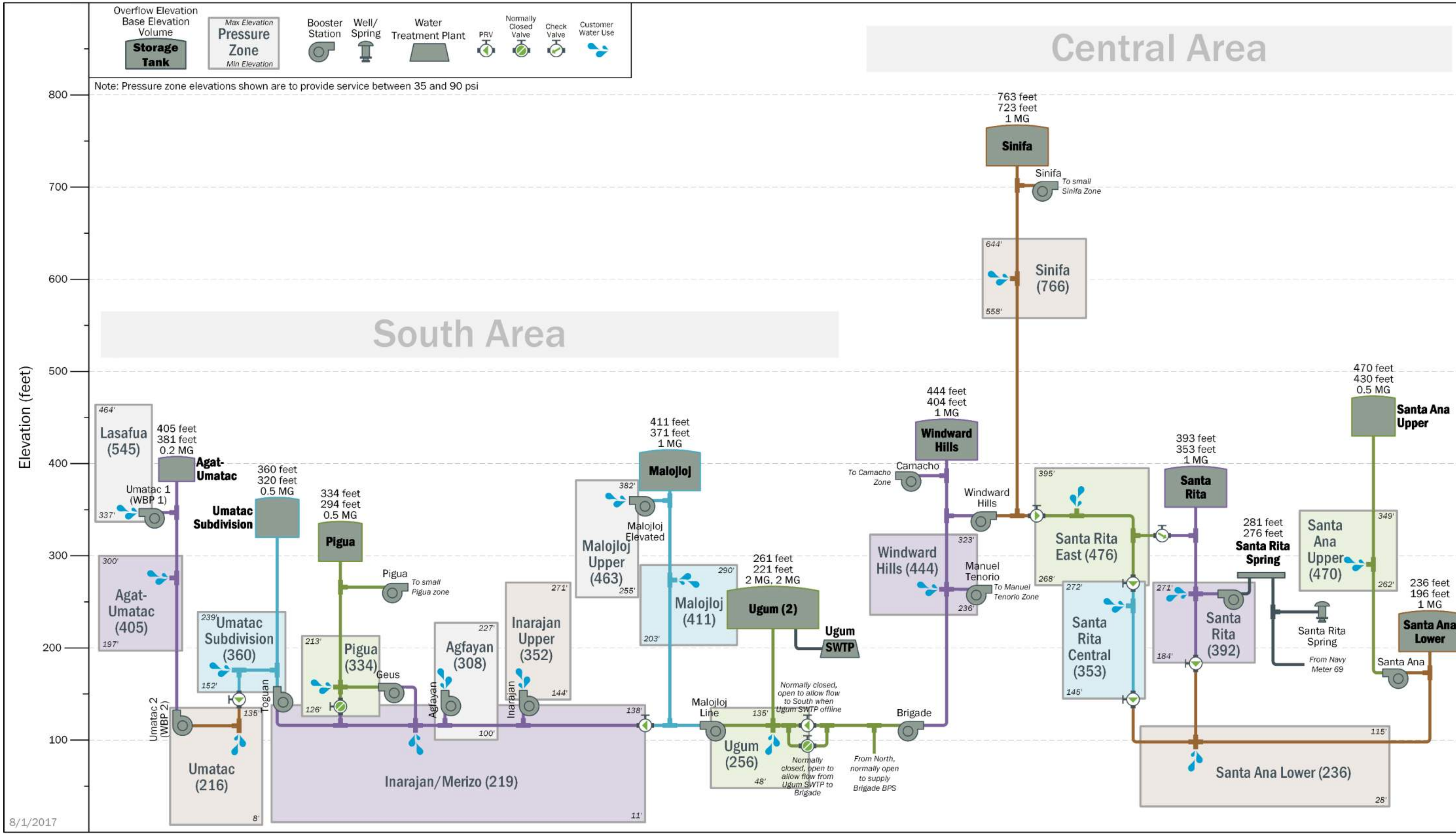


Figure 8-15. Proposed Water Distribution System Hydraulic Schematic (South and Central)

# Section 9

# Water Loss Control

Volume 2, Chapter 4 of the 2006 WRMP described a leak detection program with initial results and listed the following recommendations:

- Implement an aggressive, high-priority water loss control program.
- Make the Central System the top priority because this area relies on water purchased from the Navy.
- Coordinate leak repair and line replacement with other needs, such as 2-inch line replacement and improvements to meet fire flow and pressure standards.
- Target a 20 percent loss control program in the first five years.

The following summarizes GWA's progress to date and outlines additional recommendations that should be implemented to further reduce water losses.

## 9.1 Water Loss Reduction and Prioritization

This following section describes the 2006 WRMP recommendations for water loss reduction and measures taken by GWA through the ongoing leak detection program.

### 9.1.1 2011–13 Leak Detection Program

The 2006 WRMP recommended forming a dedicated 12-person team to locate and map leaks throughout the water system. The 2006 WRMP also indicated that, due to the complexities of leak detection, training from outside consultants would be needed.

In October 2011, with funding through the American Reinvestment and Recovery Act (ARRA) and approval from USEPA Region 9, GWA initiated a Leak Detection and Control Program aimed at identifying water distribution system infrastructure; locating, mapping, and repairing leaks; and determining pressures throughout the system to assess background water losses and monitor pressures within each pressure zone. GWA contracted with subcontractor GRH Technologies Construction Co. Ltd. to perform the work and train GWA staff. The leak detection program consisted of the following tasks:

- **Water line locating and mapping:** this task was designed to improve the accuracy of existing known water lines and water system assets and identify previously unmapped assets including water mains, valves, and hydrants using a handheld GPS device.
- **Leak detection and leak survey:** this task was intended to identify potential leaks, confirm the presence of leaks, and map locations of confirmed leaks with GPS.
- **Leak statistics and analysis:** this task was designed to transmit leak detection data to GWA operations staff so that leaks could be repaired in a timely manner, and additional critical asset information could be collected and incorporated into the GIS for use in future asset management activities.
- **Pressure data collection:** this task was designed to gather pressure data trends in each pressure zone to identify areas with low or high pressure, re-evaluate existing pressure zone boundaries, and assist GWA in future planning and hydraulic modeling efforts.

- **Training and technology transfer:** this task was designed to provide training and equipment to GWA operations staff to enable work to continue after completion of the initial GRH contract.

Field work commenced with the implementation of a pilot testing program for leak detection along with water line location, which involved locating and mapping, pressure data collection, and training and technology transfer. During this pilot testing program, field procedures were established and the following documents were produced and used in the field: Work Plan, Standard Operating Procedures (SOPs), and a Quality Assurance Project Plan (QAPP).

Following completion of pilot testing, full-scale production commenced during the last week of November 2011. The leak detection program continued through January 2013. The project mapped 131.3 miles of water system infrastructure including mains, valves, hydrants, and meters. In addition, 648 miles of water mains were surveyed with leak detection technology (99 percent of the system total, which includes lines 2-inches in diameter and greater, note that this total is greater than the total piping in the GIS and model listed in Table 2-1). A total of 486 leaks were found.

Table 9-1 summarizes the identified leaks, grouped by municipality or village. The table also includes an estimated flow rate of the total leaks in each municipality or village. Figure 9-1 shows the locations of the leaks found during the program.

**Table 9-1. Summary of Pinpointed Leaks (2011 – 2013)**

| Municipality/Village | Number of Pinpointed Leaks | Total Estimated Leak Flow Rate (gpm) |
|---|---|---|
| Dededo | 88 | 626 |
| Yigo | 71 | 465 |
| Tamuning/Tumon/Harmon | 38 | 470 |
| Santa Rita | 58 | 456 |
| Mongmong/Toto/Maite | 30 | 301 |
| Piti/Nimitz Hill | 24 | 277 |
| Barrigada | 25 | 251 |
| Mangilao | 25 | 251 |
| Hagåtña | 11 | 215 |
| Agat | 15 | 144 |
| Yona | 14 | 118 |
| Merizo | 9 | 87 |
| Ordot/Chalan Pago | 16 | 83 |
| Sinajana | 7 | 78 |
| Inarajan/Malojloj | 9 | 76 |
| Talofofo/Ipan | 7 | 73 |
| Agana Heights | 10 | 70 |
| Asan/Maina | 14 | 67 |
| Umatac | 4 | 30 |
| **Total** | **475** | **4,138 (average = 8.7 gpm per leak)** |

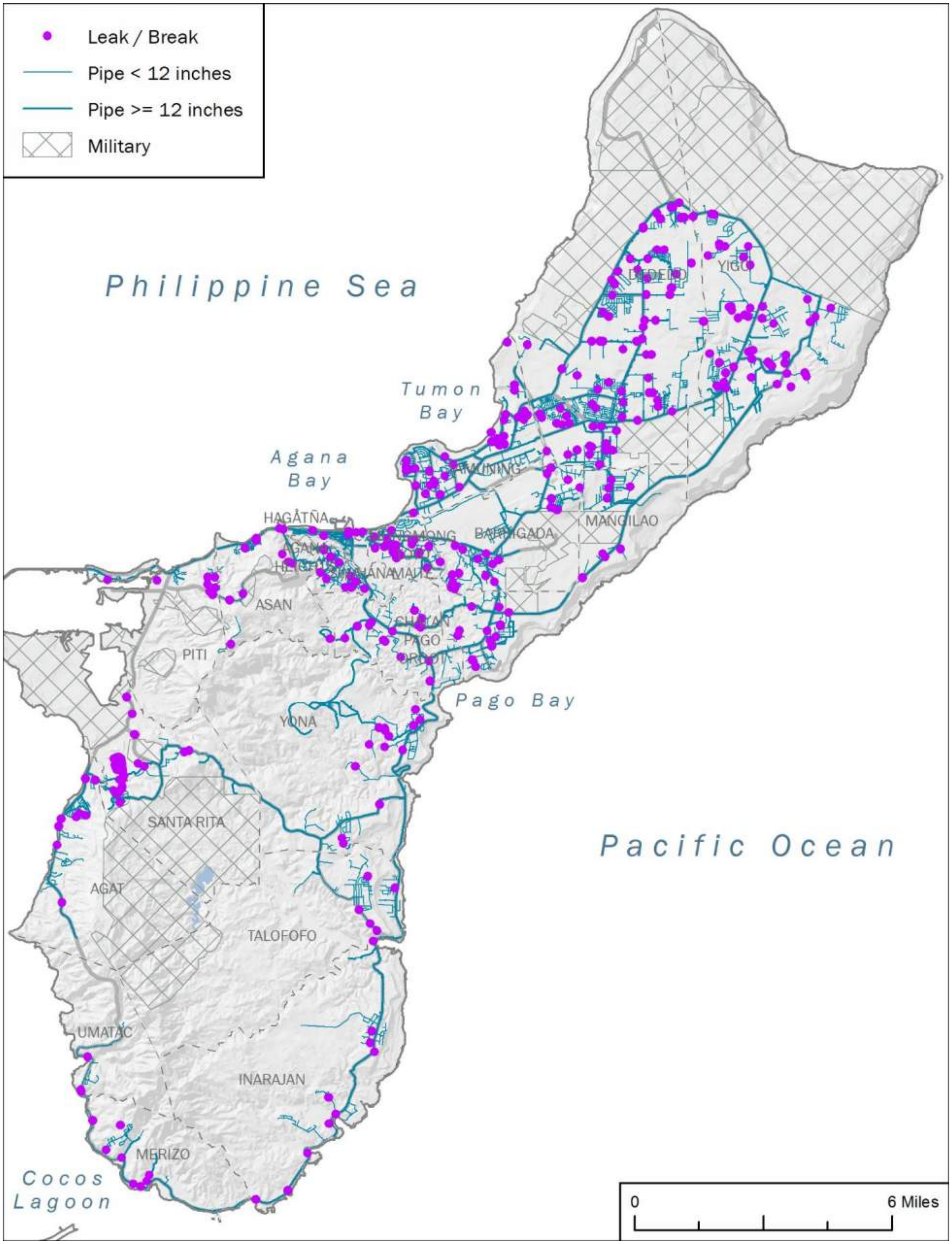


Figure 9-1. Location of Pinpointed Leaks (2011–2013)

### 9.1.2 2013–2015 Leak Detection Program

Following the completion of the leak detection program in January 2013, the leak detection and GPS locating equipment was turned over to GWA to continue the leak detection program. However, due to staffing issues, a consistent program was not established. Most of the leak detection performed after January 2013 was a result of personnel responding to calls made by the public to GWA's Trouble Dispatch.

The leak detection program has collected more consistent data since June 2015, and the data has been reviewed and uploaded into the GIS. Maps have been periodically created to show progress made by the leak detection crew over time. The leaks found during proactive leak detection are spread out across the island, but are heavily concentrated in Agat, Santa Rita, and Yigo where persistent issues have historically been present.

### 9.1.3 Planned Leak Detection Program

GWA has plans to allocate staff and resources to create a dedicated Leak Detection Crew. The newly formed Leak Detection Unit will have three crew members: Crew Leader, Leak Detection Technician 1, and Leak Detection Technician 2. Each crew member will have a specialized role with duties such as identifying water system assets to locate water mains, listening for leaks, traffic control, data recording, and GPS location gathering. The crew will proactively survey the island in a predetermined schedule and sequence with a goal to perform leak surveys of up to 10 miles per week, which would allow all water lines to be surveyed in approximately 16 months. An assessment was made of a proposed Leak Detection Crew in October 2016 and the crew met the goal of surveying about 10 miles per week.

After additional staff members are hired, GWA plans to create a second, three-person Leak Detection Crew. The Crew Leader from the original crew will be moved into a supervisor position, in charge of managing both crews. The newly created supervisor will also be responsible for entering leak and repair data into GWA's new Lucity CMMS.

The following items were noted during the October 2016 assessment:

- **Equipment:** to aid the crews, GWA purchased four new acoustic listening devices to replace the older, original acoustic listening devices. GWA will also need to acquire additional listening rods.
- **Mapping:** during the assessment, it was noted that the leak detection crew did not have mapping of the water system. The current plan is that the leak detection crew will coordinate weekly with the System Control Center (SCC), which will print mapping for leak detection. Eventually, computers will be purchased for the Leak Detection Crew to print their own mapping.
- **Downloading data:** data collected on the Trimble GPS unit by the Leak Detection Crew is downloaded after the unit is full, which occurs about once a month. When the crew is operating full time, the data will need to be downloaded more frequently, which will require coordination between the crew and GIS coordinator to download and verify the data.

### 9.1.4 Repair Crews

GWA currently has six, two-member pipeline repair crews. The repair crews are dispatched when a call is made to the Trouble Dispatch. A leak is assigned directly to a repair crew for smaller pipelines. For larger pipelines, the SCC helps to coordinate necessary equipment and with other utilities. A work order is generated for a repair crew, and after a repair is complete, the repair crew notifies the SCC so the work order can be closed.

During the October 2016 assessment, repair crews did not collect GPS locations of the repairs. Based on the assessment, GWA plans to collect GPS points, which can be integrated into the GIS.

There are currently between 60 and 80 active water main leaks throughout the water distribution system. While the repair crews fix up to eight leaks per day on average, as many as 10–15 new leaks are typically reported each day. Thus, the number of backlogged leaks to be repaired fluctuates each day. To help reduce the backlog, GWA should strive to repair newly reported leaks within three days or less.

### 9.1.5 Line-Locating Program

Line locating was implemented as part of the leak detection program, as discussed above. GWA staff were trained in line locating as part of that program. After completion of the leak detection program, line locating and GPS locating equipment was turned over to GWA along with the Work Plan, protocols, and SOPs that were developed.

However, GWA does not currently have a functioning line locating program, and has focused their limited resources and staff on leak detection. To restart a line locating program, GWA needs to update the line locating equipment, which has not been used or maintained since the conclusion of the leak detection program in 2012 and is not fully functional. There have also been advances in line locating technology since GWA's current equipment was purchased.

Recommended actions regarding a line locating program are summarized at the end of this section.

## 9.2 Water Meters

This section summarizes a calibration program to enhance the accuracy of all Navy meters, GWA's master meters, GWA's water production meters, and customer meters and recommends a testing frequency for future calibration of key meters in GWA's system.

### 9.2.1 Navy Source Meters

The Navy supplies water to supplement GWA's water production in a few locations, as discussed in Section 3. As of 2016, GWA was purchasing water from 3 of the 36 meters that the Navy maintains (listed in Table 3-1 as R-69, R-109, and R-110).

GWA has meters just downstream of the Navy meters in two locations: at the Naval Magazine in Santa Rita (meter R-22) and at the Veteran's Cemetery in Piti (meter R-91). These meters can be used to verify the readings from Navy meters. However, GWA is not currently using water from these meters. GWA does not operate meters adjacent to any of the other Navy meters that can be used to validate the data.

The meters maintained by the Navy are calibrated annually. The calibration schedule for these meters was proposed by the Navy and agreed to by GWA. The protocol states that the Navy and GWA need to be present during the calibration process, and that GWA is permitted to inspect and verify methods and procedures used by the Navy for water meter calibration. However, the contractor performing the calibration for the Navy has not been notifying GWA when calibration takes place; therefore, GWA staff have not been present during the calibrations and have been unable to inspect and verify calibration methods and procedures.

### 9.2.2 GWA Master Meters

GWA has begun implementing district metered areas (DMAs) to comply with a recommendation from the 2006 WRMP. DMAs are discrete areas in a water system separated by master meters that help to identify and measure water leakage. The master meters measure flow in and out of the DMAs. Unusually high flows at night can be identified from the meter data, which may indicate leaks. Additional leak detection can be performed on DMAs with high leakage, which could include subdividing the DMAs into smaller DMAs. GWA has constructed seven of the planned master meters throughout the water system.

It is recommended that GWA continue with the installation of the master meters. A study should be performed to review the planned master meter locations. The study should consider expanding on the DMAs that GWA has started implementing and verify that the DMAs are set up correctly. The master meters will help GWA locate and eliminate leaks and run the water system more efficiently. The DMA system should be implemented in conjunction with an island-wide system being developed by the Guam Power Authority (GPA) with their “Smart Meter” program.

### 9.2.3 GWA Water Production Meters

Meters are located on all 120 wells. The recent meter calibration program that GWA instituted for master meters has also been instituted for well meters. GWA intends to calibrate the well meters as part of a preventive maintenance plan. A meter that needs to be calibrated will be uninstalled and replaced with a spare meter while the meter is calibrated at GWA’s meter test facility. As the CMMS becomes fully operational, GWA will begin inspecting all deep well meters because they are the most critical. GWA has replaced 16 defective meters and will replace defective meters as they are found. GWA has 60 additional large production meters that can be used to replace broken meters and/or measure flows during the calibration process.

GWA also plans to monitor water production readings monthly for a drop off or increase in production. If flows appear to be deviating from the norm, meters will be systematically removed and recalibrated. GWA is in the process of reviewing the physical location of each meter to verify that all meters are installed with the upstream and downstream piping necessary to achieve the specified meter accuracy.

### 9.2.4 GWA Residential/Commercial Meters

GWA supplies approximately 47,845 accounts (see Section 4.2.1). GWA put a meter calibration program into place to check customer meters where there are questions of meter accuracy. GWA’s goal is to calibrate eight residential meters each working day and four commercial meters each month. At the time of this evaluation, GWA had 1,500 extra residential meters and 60 large meters (mentioned above for wells) that can be used to replace existing meters as they are calibrated. The customer meter calibration program will become part of the CMMS to verify proper implementation and documentation of the program.

The goal of the calibration program goes beyond simply calibrating every meter in the system on a rotating schedule and aims to look at areas where there has been a decline in revenue. In these areas, GWA will strive to test and calibrate 50 percent of meters to correct the revenue lost from meter inaccuracies.

## 9.3 Navy Water Purchases

As discussed in Section 3.4, GWA has been investigating options to reduce the amount of water purchased from the Navy. Actions related to water leaks include the following:

1. GWA has placed extra emphasis on performing leak detection and prioritizing leak repairs in Santa Rita, where the largest volume of Navy water is consumed. Of the 665 leaks repaired from July 2015 through July 2016, 45 of the repairs were in Santa Rita.
2. GWA plans to replace old steel and asbestos cement pipe in Santa Rita, especially piping that continues to leak.

## 9.4 Non-Revenue Water

GWA estimates NRW to be approximately 5,938 MG/year or 49 percent of the total water produced and imported. Table 9-2 summarizes the results of a water system audit performed for 2015. As shown in Table 9-2, the NRW was estimated at approximately 49 percent. The NRW was calculated to be approximately 58 percent using a direct correlation of ADD and average billing data for a slightly different period (see Table 4-2). The primary difference between the two sets of calculations was input volume, which was calculated using different methods. Regardless of the method used, the NRW is very high.

<table>
<tr><th colspan="5">Table 9-2. Water System Audit Results (February 2015 – January 2016) (MG/year)</th></tr>
<tr><td rowspan="10">Raw Water Sources + Imported Water = System Input Volume<br>11,448 +<br>659 =<br>12,107<br>(33.2 mgd)</td><td rowspan="4">Authorized Consumption<br>6,335.34<br>(17.36 mgd)</td><td rowspan="2">Billed Authorized Consumption<br>6,169</td><td>Billed Metered Consumption<br>6,148</td><td rowspan="2">Revenue Water<br>6,169<br>(16.90 mgd)<br>(51%)</td></tr>
<tr><td>Billed Unmetered Consumption<br>21</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption<br>166.34</td><td>Unbilled Metered Consumption<br>15</td><td rowspan="8">NRW<br>5,938<br>(16.27 mgd)<br>(49%)</td></tr>
<tr><td>Unbilled Unmetered Consumption<br>151.34</td></tr>
<tr><td rowspan="6">Water Losses<br>5,770.65<br>(15.81 mgd)</td><td rowspan="3">Apparent Losses<br>107.89</td><td>Unauthorized Consumption<br>30.27</td></tr>
<tr><td>Customer Metering Inaccuracies<br>62.25</td></tr>
<tr><td>Systematic Data Handling Errors<br>15.37</td></tr>
<tr><td rowspan="3">Real Losses<br>5,663.77</td><td>Leakage from Mains<br>Not Broken Down</td></tr>
<tr><td>Leakage and Overflows at Storage Tanks<br>Not Broken Down</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer Metering<br>Not Broken Down</td></tr>
</table>

As shown in the table, estimated NRW is based on available source data, consumption data, and loss data. Because not all sources are accurately metered, and because unbilled, unmetered consumption and all apparent losses are estimated, it is difficult to verify that the amount of NRW calculated is accurate.

In addition, billing adjustments performed at the end of each month typically create discrepancies between billed, metered consumption values reported by GWA Operations and GWA Finance Department and add additional uncertainty in the NRW calculations. To further complicate matters, the Finance Department estimates unbilled, unmetered consumption (water for firefighting and hydrant flushing) differently than GWA Operations, causing further discrepancies for this category.

GWA recently purchased ten Zenner Fire Hydrant Meters to be used temporarily during hydrant flushing. After a main break, the main is typically flushed after service is restored. However, GWA has been experiencing implementation problems with staff not using the equipment and not noting the amount of water used during flushing operations.

Another source of error comes from billed, metered consumption. This is often a straightforward statistic to capture; however, some aspects of GWA's water distribution system are unique and present challenges in obtaining accurate data. For example, some buildings have access issues that prevent the meters from being read, so meter reads are estimated. These access issues are not easily resolved due to private property and easement issues. However, GWA has started installing automatic meter readers, which will greatly reduce this source of error.

Billed, metered consumption error also comes from areas where the Navy has turned over the system to GWA. For example, individual properties are not metered in the old military housing in Tiyan. Instead, a meter reads flows at a downstream location, capturing meter data from many properties. In these cases, total flow is divided by the number of properties, and these properties are billed on a flat-rate basis. In addition, in some of these areas, distribution system piping was originally designed for agriculture use and is therefore prone to failure.

### 9.4.1 Well H01 Production Versus Billing Data

One possible extreme discrepancy was noted for the area served by Well H01, which includes the Harmon Cliffline area and Northern District WWTP. Average well production for the area was 262 gpm in 2015, and average billing data was 28 gpm (of which 19 gpm may be served from a neighboring zone). It is possible that the billing data does not include some large customers or the well meter records incorrect flows. GWA should investigate this discrepancy in more detail to determine whether water from the well is lost to leaks.

## 9.5 Recommendations

This section summarizes recommendations for leak detection and repair to reduce water losses.

### 9.5.1 Leak Detection and Repair

Recommendations for the leak detection and repair crews include the following:

- GWA should continue with the plans to create two Leak Detection Crews and appoint a supervisor, as described in Section 9.1.3.
- A prioritization schedule for leak detection should be established.
- The Leak Detection Crews should record the estimated leak rate and GPS coordinates at each verified leak and GPS coordinates for all activity connected with the repairs so that water loss and repair location data can be uploaded into the CMMS and GIS.
- The GIS department should download and process data collected on the GPS devices as described in Section 9.1.3. However, this would likely require additional staff, as discussed in Volume 1, Section 8 (GIS).
- The Leak Repair Crews should continue to work with the SCC to enter repair information into the CMMS and manage work orders. The Leak Detection Crew Supervisor will be responsible for entering repair information into the CMMS and managing work orders.
- GWA should set up a multi-year professional services contract for leak detection. The contractor should provide reports for each suspected leak and maps marked up with corrections from field observations. The contractor could possibly perform updates to the GIS and provide further equipment and training for the GWA leak repair crews.

### 9.5.2 Line Locating Crew

GWA should consider forming a dedicated line locating crew. The creation of a crew can begin with discussions between operations, engineering, and GIS on the feasibility of a multi-entity effort to initiate a line-locating program. After a strategy for program management and execution has been established, GWA should evaluate the latest technology in line locating equipment and procure the appropriate technology for use in the program. The existing Work Plan, protocols, and SOPs from the original leak detection program should be evaluated for possible modification and updates. The new line locating crew should then be trained on the line locating documents and how to perform line locating in the field.

### 9.5.3 Meter Calibration

Recommendations for meter calibration include the following:

- **Navy meters:** because the Navy has not informed GWA when meter calibration takes place, GWA should request documentation from the Navy on calibration methods and results.
- **GWA water production and master meters:** all well and master meters should be inspected annually. For well meters, priority should be given to deep wells. Meters must pass three water flows (low, middle, and high) and registration must be 95 percent or higher per AWWA standards. Based on the inspections, the meters should be repaired or calibrated as needed.
- **GWA residential/commercial meters:** as mentioned above, GWA's goal is to calibrate eight residential meters each working day and four commercial meters each month, with an emphasis on areas where there has been a decline in revenue. GWA should work toward reviewing and testing/calibrating all of meters in the system, regardless of whether they are in an area with declining revenue. While AWWA does not have a standard for calibration frequency for residential and commercial meters, a general rule of thumb for systems as large as GWA's

system is to calibrate approximately 20 percent of the system per year. Based on this metric, approximately 7,270 meters would need to be calibrated per year, or approximately 30 meters per day. To accomplish this, GWA will need to implement a much different calibration program in which meters are calibrated in-situ rather than being uninstalled and calibrated at the Meter Test Facility. If sufficient staffing is not available to calibrate the meters in-situ and reach the goal of calibrating 20 percent of the meters per year, a statistical sampling approach may need to be implemented instead. Statistical sample testing would allow GWA to monitor the overall accuracy of its meters to verify accurate reporting of billed, metered consumption. Statistical data is used and accepted throughout the business world as an excellent tool for making informed management decisions. Information developed from sample testing will provide GWA with data in which trend analysis can be made and performance levels for specific meters identified.

### 9.5.4 Other Recommendations

Recommendations to further reduce water leakage include the following:

- GWA should continue installing the master meters. A study should be performed to review the planned master meter locations. The study should consider expanding on the DMAs that GWA has started implementing and verify that the DMAs are set up correctly. The master meters will help GWA locate and eliminate leaks and run the water system more efficiently.
- The DMA system should be implemented in conjunction with an island-wide system being developed by the GPA with their "Smart Meter" program.
- The new Zenner Fire Hydrant meters should be used during all flushing operations and the amount of water used should be recorded on the fire hydrant flushing form. This form should be returned to the SCC so that the data can be recorded in the CMMS.

# Section 10

# Fire Hydrants

This section describes the condition of the water system's fire hydrants and outlines recommendations for repair and replacement.

## 10.1 Condition Assessment

GWA has approximately 3,800 fire hydrants throughout its water system. A condition assessment of the hydrants was performed in 2013 and 2014, which was based on a visual inspection. The hydrants were not physically opened to verify if they were functional and could provide water, and isolation valves in the street were not tested to determine whether they would isolate the fire hydrant from the water distribution system. Therefore, a good condition score means that the hydrant appeared to be in good shape, but it was unknown if the hydrant would operate. The following condition scores were applied to each hydrant (refer to Appendix I for more detail):

- **0 – Not found:** the hydrant was listed in GWA's inventory and could not be found or a condition assessment was not performed.
- **1 - Excellent overall condition:** no noticeable defects. Some aging or wear may be visible. The hydrant appeared to be fully functional, looked similar to when it was first installed and accepted, and may still be under warranty.
- **2 - Good overall condition:** only minor deterioration or defects were evident. Noticeable wear or aging was visible. The hydrant appeared to be fully functional. The hydrant may have had minor signs that maintenance has been provided, but did not appear to have been damaged.
- **3 - Fair overall condition:** some deterioration or defects were evident. Significant aging or wear was visible, but there were no signs of damage. Function is not significantly affected.
- **4 - Poor overall condition:** serious deterioration or defects in at least some portion of the hydrant. Extensive aging or wear was visible.
- **5 - Extremely poor overall condition:** extensive deterioration or defects in the hydrant and appeared to be beyond repair. The hydrant appeared to be barely functional or had failed.

Table 10-1 provides the condition scores of the fire hydrants by village. Appendix I lists the number of hydrants by manufacturer as found during the condition assessment.

**Table 10-1. Village and Fire Hydrant Assessment Scores**

| Village | Not Found (0) | Excellent (1) | Good (2) | Fair (3) | Poor (4) | Extremely Poor (5) | Total |
|---|---|---|---|---|---|---|---|
| Agat | 32 | 2 | 9 | 109 | 37 | 13 | **202** |
| Asan | 12 | 1 | 17 | 59 | 10 | 3 | **102** |
| Barrigada | 37 | - | 7 | 94 | 116 | 46 | **300** |
| Chalan Pago Ordot | 12 | 2 | 4 | 45 | 50 | 30 | **143** |
| Dededo | 60 | 3 | 44 | 77 | 501 | 101 | **786** |
| Hagåtña | 7 | 2 | 7 | 78 | 15 | 1 | **110** |

| Table 10-1. Village and Fire Hydrant Assessment Scores | | | | | | | |
|---|---|---|---|---|---|---|---|
| Village | Not Found (0) | Excellent (1) | Good (2) | Fair (3) | Poor (4) | Extremely Poor (5) | Total |
| Agana Heights | 47 | 1 | 6 | 42 | 23 | 1 | **120** |
| Inarajan | 6 | - | 14 | 63 | 21 | 3 | **107** |
| Mangilao | 26 | 2 | 20 | 91 | 87 | 28 | **254** |
| Merizo | 4 | - | - | 37 | 17 | 5 | **63** |
| Mongmong/Toto/Maite | 7 | 3 | 12 | 67 | 39 | 19 | **147** |
| Piti | 7 | 4 | 12 | 47 | 20 | 10 | **100** |
| Santa Rita | 16 | - | 7 | 84 | 28 | 3 | **138** |
| Sinajana | 4 | - | - | 52 | 13 | - | **69** |
| Talofofo | 11 | 1 | 1 | 29 | 51 | 25 | **118** |
| Tamuning | 21 | 9 | 29 | 165 | 138 | 60 | **422** |
| Umatac | - | - | - | 9 | 5 | - | **14** |
| Yigo | 23 | 1 | 1 | 40 | 279 | 38 | **382** |
| Yona | 30 | 5 | 14 | 58 | 98 | 32 | **237** |
| **Total** | **362** | **36** | **204** | **1,246** | **1,548** | **418** | **3,814** |
| **Percent of Total** | **9%** | **1%** | **5%** | **33%** | **41%** | **11%** | **100%** |

## 10.2 Repair and Replacement Program

In 2016, GWA installed a CMMS that interfaces with the GIS system to track the repair and replacement of fire hydrants. This system accumulates data over time that can be used to determine the condition of GWA's fire hydrant system and generate trends to provide fire hydrant repair and replacement decision tools for GWA. GWA will be able to evaluate the following for each hydrant:

1. History
2. Current condition and location
3. Criticality
4. Failure and failure rate
5. Scheduled replacement of fire hydrants associated with distribution piping replacement
6. Cost of repair and replacement
7. Future planning for repair and replacement

GWA is also in the process of developing a Fire Hydrant Replacement and Repair Program (FHRP). The proposed FHRP program is based on recommendations from the *Development for Long-Term Comprehensive Water Distribution System Program* (BC, April 2013a). Table 10-2 summarizes the recommendations for the program and the status of each recommendation.

| Table 10-2. FHRP Program Recommendations and Status | |
|---|---|
| **Recommendation** | **Notes** |
| Completed | |
| Incorporate fire hydrants into the CMMS | CMMS was populated |
| Incorporate fire hydrants into the GIS | Data is available in the GIS system |
| Generate GIS map of each hydrant's location, including location, elevation, accessibility, pressure zone, and condition score | Status was not determined |
| Identify facilities and/or development served | Data is available in the GIS system |
| Identify manufacturer, model, and type | Status was not determined |
| Identify installation date/age | Data is available in the GIS system |
| Currently in Progress by GWA | |
| Perform exercise and flow testing program | Guam Fire Department (GFD) currently performing this effort |
| Identify, locate, and apply a unique ID label to all fire hydrants | Status was not determined |
| Identify responsibility of GFD for each hydrant, including contact information and agreements on maintenance and flow testing | Status was not determined |
| Locate and identify condition of the fire hydrant's isolation valve | Being done as part of the fire hydrant preventive maintenance program |
| Identify condition of street location marker | Being done as part of the fire hydrant preventive maintenance program |
| Currently in Progress by GWA on a Continuous Basis | |
| Continuously monitor condition and criticality of the fire hydrants | Critical hydrants serve important facilities such as a hospital |
| Record failure, leakage, and repair history | Status to be determined |
| Perform preventive and corrective maintenance activities | Status to be determined |
| To Be Implemented | |
| Record normal operating pressures | Will be done by GWA and scheduled through the CMMS program |
| Test hydrant flow rates | Will be scheduled by GWA and added to the GIS system after data is available |
| Implement color coding to indicate flow capacity (recommended by NFPA 241) | Will be scheduled through the CMMS program when the flow capacity data is available from the fire hydrant flow testing program |

*NFPA = National Fire Protection Agency*

### 10.2.1 Repair and Replacement Decision Making Process

The following steps can be followed to inspect and make decisions regarding hydrant repair and replacement:

1. Generate a preventive maintenance work order from the CMMS to establish a specific fire hydrant that needs to be assessed. Hydrants with the worst condition scores should be assessed first.
2. Using the *GWA SOP 3010-10 Fire Hydrant Inspection Maintenance and Testing* (GWA, 2011) procedure, assess the fire hydrant and determine if it is operational. Inspections should be planned with the involvement of GFD if possible because they inspect and flow test most hydrants on the island.
3. Verify and update the condition score. If the condition has changed, change the condition score on the work order and note the reason for the change.

4. Set a priority for inspected hydrants for the action to be taken. For example, if a hydrant has a very poor condition score (5), it should receive a high priority level. A fire hydrant that needs general maintenance (score of 3) would be lower priority. Issue corrective maintenance work orders as necessary, and note on the work order the reason the hydrant failed and any other pertinent data associated with the fire hydrant.
5. GWA's corrective maintenance team should use the new FHRP program plan to determine additional actions that need to be taken.

When to repair or replace a fire hydrant is based on the actual condition of the hydrant, age of the hydrant, whether or not it is repairable, and time required to conduct the repair or replacement. The following decision process should be considered:

1. If a fire hydrant can be repaired at a cost less than half of the replacement costs and its life expectancy will be a minimum of five more years, repair is recommended.
2. If a fire hydrant cannot be repaired at a cost of less than half of the replacement costs, replacement is recommended. During replacement, the isolation valve should be evaluated and possibly replaced if excavation is required or the valve has failed.
3. If a water pipeline is being replaced, all valves and fire hydrants on that pipeline could be replaced at the same time.
4. If a failed fire hydrant is deemed critical (e.g. supports a hospital), it should be replaced as soon as possible.

## 10.3 Repair and Replacement Plan

Based on the condition scores of the hydrants, there are 410 fire hydrants that have failed or are close to being in a non-usable condition (score of 5) and 1,548 hydrants that are close to failure (score of 4). GWA has identified 300 of these 410 fire hydrants for replacement in the next five years. A more aggressive schedule is recommended so that all hydrants with scores of 5 are operational within five years.

Fire hydrants with a score of 4 should be re-evaluated using GWA SOP 3010 and scheduled for repair or replacement over the next 10 years. Those with a current score of 4 that are then re-scored as 5 should be moved to the aggressive program for repair or replacement.

It was assumed that hydrants with a score of 5 will be replaced within five years (at an average of 82 per year) and hydrants with a score of 4 will be repaired within 10 years (at an average of 155 per year). Repair and replacement could be done by GWA or through a subcontractor. Appendix I summarizes the number and type of hydrants with scores of 4 or 5 per village.

## 10.4 Other Recommendations

Additional recommendations to improve the condition of the water system's fire hydrants are described below.

### 10.4.1 Unique Identification

GWA's fire hydrants that were inspected and assessed do not have unique visual identification (ID). Each hydrant should have a unique ID assigned that relates to IDs in the GIS and CMMS. IDs can be attached to the hydrants by painting IDs on the hydrants or affixing a non-corrosive outdoor tag with the IDs. Figure 10-1 shows an example of a (non-GWA) hydrant with a painted ID.


**Figure 10-1. Fire Hydrant with Painted ID**

### 10.4.2 Color Coding

GWA should consider color coding hydrants to indicate fire flow as recommended by the National Fire Protection Agency (NFPA) standard 241 (as discussed in AWWA's *M-17 Fire Hydrants: Installation, Field Testing, and Maintenance*, AWWA, 2016). Table 10-3 summarizes coding information from the AWWA M-17 manual.

**Table 10-3. Color Scheme to Indicate Flow Capacity**

| Flow (gpm) at 20 psi | Color | |
|---|---|---|
| Greater than 1,500 | Light Blue | |
| 1,000–1,499 | Green | |
| 500-999 | Orange | |
| Less than 500 | Red | |

For the ranges listed in Table 10-3, flow is calculated at a residual of 20 psi with the actual residual on an adjacent non-flowing hydrant being 40 psi or greater. When the actual observed residual on the adjacent non-flowing hydrant is less than 40 psi, the color scheme should be based on one half of the observed flow. Figure 10-2 shows an example of a (non-GWA) fire hydrant with green-painted caps to indicate fire flow between 1,000 to 1,499 gpm at 20 psi. Note that the green waterproof tag is a fire hydrant inspection tag.

**Figure 10-2. Fire Hydrant Color Coded by Fire Flow**

### 10.4.3 Other Notes

GWA recently purchased 300 new hydrants and plans to advertise for a contractor to install these hydrants. GWA would like to replace hydrants that were determined to be in extremely poor condition. GWA should assign unique IDs to these hydrants prior to installation so that replacement work can be tracked and compared to the list of hydrants recommended for replacement in this section.

## 10.5 Recommendations

Recommendations for improvements to fire hydrants in GWA's water system are summarized below.

**Assessment and Scheduling**

- Follow GWA's SOP 3010-10 to assess all fire hydrants. Assess hydrants with scores of 5, followed by those with scores of 4.
- Revise the schedule and corresponding costs for repair and replacement work following GWA's re-assessment of the hydrants. Enter the latest hydrant scoring into the CMMS system. Use the CMMS system to produce reports, which should be produced and reviewed regularly.

**Repair and Replacement**

- Create a fire hydrant repair and replacement crew with the following functions:
  - Evaluate all fire hydrants per GWA's SOP 3010-10. Issue work orders as necessary with detailed information on each fire hydrant using GWA's CMMS.
  - Perform preventive maintenance on the hydrants.
  - Perform corrective maintenance including repair and replacement of the hydrants.
- Replace the hydrants with scores of 5 within the next five years, then begin repair or replacement of hydrants with scores of 4.

**Other**

- Although 30 different brands of fire hydrants were identified during the field verification, GWA should consolidate to two or three manufacturers and standardize on either wet or dry-barrel hydrants to reduce parts, tools, and increase efficiency of repairs. GWA should determine the most reliable brands in terms of field durability and function, spare parts accessibility, and minimum maintenance effort as part of their source selection criteria.
- Develop a unique ID and color-coding scheme for each fire hydrant. GWA has been coordinating with GFD on the method for assigning unique IDs. This process of developing unique IDs should be finalized after the CMMS is in place and fully operational.
- For future analysis, hydrant spacing should be analyzed as compared to population and land use data. Hydrants in a dense urban area should be spaced closer together than hydrants in agricultural land.
- Coordinate regularly with GFD. Based on the knowledge of the current condition of GWA's fire hydrants and their database of hydrant flow capabilities, GFD should be considered a partner in the overall FHRP. GWA can share GIS and CMMS information while GFD can assist with future assessments and hydrant flow volumes. A strong alliance between GWA and GFD can produce a more efficient and reliable system.

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# Section 11

# General System Recommendations

This section summarizes general system recommendations and relative project rankings for the GWA water system. Recommendations for specific components of the water system are provided at the end of Sections 5 through 10.

## 11.1 System-Wide Recommendations

The following are recommendations applicable to the entire water system, and not explicitly addressed elsewhere within this volume.

### 11.1.1 OneGuam Analysis

Volume 1, Section 5 discusses the OneGuam framework, which consists of a potential integration of DoD and GWA water resources and water system facilities. Recommendations to support the OneGuam framework over the planning horizon as outlined in Volume 1 include the following:

- Conduct a feasibility study to determine the potential for a singular, unified water utility.
- Model the proposed combined water system to properly analyze the water systems and identify locations where piping could be shared.
- Fund a rate study based on a combined utility.
- Develop a strategic plan for moving to a combined water utility.

While analyzing and developing recommendations for the GWA water system, OneGuam was considered by looking for areas where the GWA or DoD water system could be used to solve a deficiency in the other water system. Because the GWA and DoD water systems were not modeled together, the ability to identify beneficial shared locations was limited. The following facilities were considered:

- **Storage:** Two potential locations were identified and are discussed in the storage analysis in Section 6.1.2.
- **Piping:** There is a possibility of sharing some piping between systems. Modeling the systems together is recommended to properly analyze the systems as a whole and identify locations where piping could be shared. Example areas where piping could be shared include:
  - GWA and the DoD have discussed sharing water at Potts Junction (northern Guam at the intersection of Routes 9 and 3A). GWA would supply water to the Finegayan area for the buildup. GWA currently has sufficient water to supply projected demands at Potts Junction. However, as discussed in Section 5.1.2, GWA may have a supply shortfall in the near future without additional supply or a reduction in NRW. For this report, it was assumed that additional supply will need to be developed in the area to supply Finegayan.
  - GWA and the DoD have discussed sharing water in the Andersen South area. Water from Andersen AFB's seven Marbo wells in Andersen South is pumped north to Andersen AFB. This water could be shared with GWA in this area and GWA well water already in the north could be pumped to Andersen AFB. This concept would need to be studied to ensure that GWA has sufficient water in the North to share with Andersen AFB.

  - As another example, GWA currently has one pipeline to serve Santa Rita and Agat, the pipeline along Cross Island Road. However, the Navy owns piping between Piti and Santa Rita. A OneGuam approach could include sharing Navy piping to provide a redundant source to Santa Rita and Agat. This option would need to be modeled to understand if it would work operationally and what additional infrastructure would be necessary.
- **Supply:** GWA is currently using the Navy's Tumon Maui well as a supply source. No other supply source was considered because GWA is working to reduce dependence on DoD water supply.

### 11.1.2 2006 WRMP Recommended Projects

Recommended projects in the 2006 WRMP were analyzed and incorporated into this updated plan as appropriate. Some of the 2006 projects have been completed, some are still required, and others are no longer needed. Projects that are still required are incorporated into the recommendations listed in this section. Volume 1, Section 2 summarizes the status of each 2006 WRMP project.

### 11.1.3 Property Ownership

GWA currently operates some facilities on property not owned by GWA. As GWA has worked on expanding some of those facilities, the lack of property ownership has impeded the expansion projects. GWA developed a grant deed and assignment list in the mid-1990s and was going to survey the properties, which would have allowed the utility to take ownership. However, surveys were not performed at that time. GWA needs to resolve this issue through surveying and other legal means to verify ownership of the properties where they own facilities. A general project is included in Volume 1 to cover this ongoing work.

### 11.1.4 Backflow Prevention and Cross Connection Control Program

GWA is in the process of implementing a Backflow Prevention and Cross-Connection Control Program for GWA customers. The Program is planned to prevent contamination and/or pollution resulting from backflow and/or back-siphonage through uncontrolled plumbing connections and cross connections. "Cross-connections" are the links through which it is possible for contaminating materials to enter a potable water supply. Contamination can occur when water flows in the wrong direction from the customer location into the distribution system.

Cross-connections between drinking water supplies and sources of contamination can pose significant threats to public health and safety. Water utilities throughout the world have developed and implemented programs to mitigate the threat of cross-connections to the public water supply. To provide proper sanitary protection to GWA's water supply and to comply with the applicable regulations, Guam law Title 28, Guam Administrative Rules and Regulations (G.A.R.) Section 2114(a) requires that "no cross-connections with other water supplies, or other physical connections, shall exist, or be installed, located, maintained, or operated which could permit backflow of contaminated water or any other dangerous, impure, unsanitary, or unpotable substance from the customer's premises into GWA's water supply system". Guidance documents for cross-connection control are also published by both USEPA and AWWA.

The GWA Program is being developed to achieve the following goals:

- To protect the GWA and Guam public water supply from the possibility of contamination by isolating and containing, at the point of connection, any unwanted contaminants which could backflow or back-siphon into the public water system or within a customer's internal distribution system(s).
- To promote the elimination or control of cross-connections, actual or potential, between customer's in-plant drinking water system(s) and anything that could contaminate or pollute it.
- To provide for the maintenance of a cross-connection control program to effectively prevent the contamination or pollution of all drinking water systems.

To prevent cross-connections and backflow, "backflow prevention devices," are used to keep the water flowing in only one direction. The specific required backflow prevention device is determined by the hazard level posed to the public water supply by the property in question. For example, a hotel or a restaurant (where multiple sources of potential pollutants and cross-connections may be present) would require a form of backflow prevention that provides greater protection than one used for a home.

The final Program for implementation by GWA will include an introduction to backflow prevention and cross-connection control, discussion of the purpose and strategy of the Program, the regulatory basis for the Program, maintenance and inspection requirements, installer certification requirements, customer responsibilities related to this Program, and a discussion of approved backflow prevention devices and installation procedures. Public education will be a key component to the success of the program.

After the backflow prevention program is accepted, GWA will need to maintain staff to implement and monitor the procedures outlined in the program.

## 11.2 Projects Summary

Potential improvement projects were developed for the water system and costs were assigned to each project. Table 11-1 provides a complete list of proposed improvement projects with estimated planning costs. Each project was assigned a unique project number grouped by the system component. Detailed descriptions of each proposed project are included in Section 12. The cost estimates in this section and in Section 12 are for budgeting purposes only and are presented in 2017 dollars. Some of these projects are recurring projects that will be executed multiple times before 2037. Volume 1, Appendix D contains additional information for the cost estimates.

**Table 11-1. Water System Improvements Projects with Estimated Costs**

| Report Project Number | Report Project Name | Recurring Project [a] | Total Cost [b] |
|---|---|---|---|
| Pipeline Projects | | | |
| MP-PW-Pipe-01 | Astumbo Zone Piping | No | $4,850,000 |
| MP-PW-Pipe-02 | Route 1 Astumbo Zone Piping | No | $7,193,000 |
| MP-PW-Pipe-03 | Harmon Cliffline Piping to Route 1 | No | $424,000 |
| MP-PW-Pipe-04 | Hyundai Well Piping | No | $547,000 |
| MP-PW-Pipe-05 | Kaiser Zone Looping | No | $306,000 |
| MP-PW-Pipe-06 | Mangilao Pressure Zone Realignment | No | $344,000 |
| MP-PW-Pipe-07 | Mataguac BPS Suction Piping | No | $733,000 |

| Table 11-1. Water System Improvements Projects with Estimated Costs | | | |
|---|---|---|---|
| Report Project Number | Report Project Name | Recurring Project [a] | Total Cost [b] |
| MP-PW-Pipe-08 | Nimitz Lower BPS Piping | No | $1,590,000 |
| MP-PW-Pipe-09 | Yigo, Santa Rosa Zone Realignment | No | $2,342,000 |
| MP-PW-Pipe-10 | Miscellaneous Piping Projects | No | $2,082,000 |
| MP-PW-Pipe-11 | Miscellaneous Piping Connections | No | $582,000 |
| MP-PW-Pipe-12 | Rehabilitation and Replacement Program | Annual | $75,585,000 |
| MP-PW-Pipe-13 | 2-Inch Pipe Replacement Program | Annual | $33,250,000 |
| MP-PW-Pipe-14 | Asbestos Cement Pipe Replacement Program | Annual | $61,600,000 |
| MP-PW-Pipe-15 | PRV Rehab and Replacement | Annual (for 6 Years) | $8,808,000 |
| MP-PW-Pipe-16 | Valve Exercise, Repair, and Replacement Program | Every 2 Years | $2,500,000 |
| MP-PW-Pipe-17 | Cross Island Highway Piping | No | $1,666,000 |
| Storage Tank Projects | | | |
| MP-PW-Tank-01 | Agat-Umatac Tank | No | $330,000 |
| MP-PW-Tank-02A | Airport Tanks A | No | $11,900,000 |
| MP-PW-Tank-02B | Airport Tanks B | No | $12,876,000 |
| MP-PW-Tank-03A | Astumbo Tanks A | No | $1,584,000 |
| MP-PW-Tank-03B | Astumbo Tanks B | No | $9,612,000 |
| MP-PW-Tank-04 | Barrigada Tank | No | $0 (planned for after 2037) |
| MP-PW-Tank-05 | Chaot Tank | No | $5,714,000 |
| MP-PW-Tank-06 | Hyundai Tank | No | $8,198,000 |
| MP-PW-Tank-07A | Kaiser Tanks A | No | $1,716,000 |
| MP-PW-Tank-07B | Kaiser Tanks B | No | $0 (planned for after 2037) |
| MP-PW-Tank-08 | Malojloj Tank | No | $990,000 |
| MP-PW-Tank-09A | Manenggon Hills Tanks A | No | $1,716,000 |
| MP-PW-Tank-09B | Manenggon Hills Tanks B | No | $9,612,000 |
| MP-PW-Tank-10A | Nimitz Hill Tanks A | No | $479,000 |
| MP-PW-Tank-10B | Nimitz Hill Tanks B | No | $479,000 |
| MP-PW-Tank-11A | Tumon (Nissan) Tanks A | No | $8,198,000 |
| MP-PW-Tank-11B | Tumon (Nissan) Tanks B | No | $9,612,000 |
| MP-PW-Tank-12 | Pigua Tank | No | $990,000 |
| MP-PW-Tank-13 | Piti Tank | No | $8,870,000 |
| MP-PW-Tank-14 | Santa Ana Lower Tank | No | $990,000 |
| MP-PW-Tank-15 | Santa Rita Tank | No | $8,198,000 |
| MP-PW-Tank-16A | Santa Rosa Tanks A | No | $8,198,000 |
| MP-PW-Tank-16B | Santa Rosa Tanks B | No | $8,870,000 |
| MP-PW-Tank-17 | Sinifa Tank | No | $8,198,000 |

| Table 11-1. Water System Improvements Projects with Estimated Costs | | | |
|---|---|---|---|
| Report Project Number | Report Project Name | Recurring Project [a] | Total Cost [b] |
| MP-PW-Tank-18A | Ugum Tanks A | No | $1,716,000 |
| MP-PW-Tank-18B | Ugum Tanks B | No | $9,612,000 |
| MP-PW-Tank-19 | Umatac Subdivision Tank | No | $594,000 |
| MP-PW-Tank-20 | Windward Hills Tank | No | $990,000 |
| MP-PW-Tank-21 | Yigo Tanks | No | $1,716,000 |
| MP-PW-Tank-22 | Existing Tank Assessment Inspections | No | $428,000 |
| MP-PW-Tank-23 | Recurring Tank Inspections | Annual | $3,852,000 |
| BPS Projects | | | |
| MP-PW-BPS-01 | Rehabilitate and Replace BPSs | Annual | $2,968,000 |
| MP-PW-BPS-02 | Nimitz Hill Upper BPS | No | $48,000 |
| MP-PW-BPS-03 | Route 15 BPS | No | $1,136,000 |
| Water Production Projects | | | |
| MP-PW-SWTP-01 | Ugum SWTP River Intake Cleaning Project | No | $380,000 |
| MP-PW-SWTP-02 | Ugum SWTP Intake Modifications | No | $2,297,000 |
| MP-PW-SWTP-03 | Ugum SWTP Reliability Improvements | No | $1,980,000 |
| MP-PW-SWTP-04 | Ugum SWTP 7-Year Improvement Project | Every 7 Years | $6,336,000 |
| MP-PW-Well-01 | Well Rehabilitation Program | Every 2 Years | $52,272,000 |
| MP-PW-Well-02 | Well Equipment Overhaul Program | Every 2 Years | $12,144,000 |
| MP-PW-Well-03 | Capacity Enhancement – Well Exploration Program | Every 5 Years | $4,752,000 |
| MP-PW-Well-04 | Capacity Enhancement – Well Development and Construction Program | Every 3 Years | $26,005,000 |
| MP-PW-Well-05 | Wellhead Protection Program | Every 3 Years | $3,960,000 |
| MP-PW-Well-06 | Well Repair Program | Annual (for 10 Years) | $13,090,000 |
| Other Water Projects | | | |
| MP-PW-Misc-01 | South Guam Water Supply Study | No | $450,000 |
| MP-PW-Misc-02 | Master Meter Implementation and Ongoing Meter Replacement | Annual (for 6 Years) | $4,404,000 |
| MP-PW-Misc-03 | Hydrant Condition Assessment and Maintenance | Annual | $7,505,000 |
| MP-PW-Misc-04 | OneGuam Program | Annual | $550,000 |
| MP-PW-Misc-05 | Leak Detection Assistance | Every 5 Years | $1,540,000 |

*a. Annual costs (without a number of years in parenthesis) are annual costs for the entire 20-year planning period.*

*b. Costs are the total projected for the 20-year planning period in 2017 dollars.*

The following projects were existing water system CIP projects or were being designed at the time of this report, and are not included in the project rankings or project summary sheets since they are currently planned or in progress.

**Storage tanks, under construction:**

- Astumbo 1
- Yigo 1
- Yigo 3

**BPSs, under design:**

- Agfayan
- Hyundai
- Inarajan
- Yigo

**BPSs, planned for rehabilitation:**

- Access
- Asan Spring
- Barrigada (old Hyundai)
- Malojloj
- Santa Rosa

**Production well projects under design:**

- Series A and F Island Wide Well Rehabilitation Project
- Wells AG-10, AG-12, and Y-8

**Production well projects under construction:**

- D-Series Island Wide Well Rehabilitation Project

**Pipeline projects:**

- Agat-Umatac pipeline
- Airport Tank piping

## 11.3 Project Rankings

During the development of the water system improvement projects, a workshop was held with key GWA representatives to discuss the projects and develop a non-financial ranking system to prioritize implementation. The project rankings also provide a general sequence for which projects should be scheduled in the future financial plan. Each project was ranked with a score from 1 (lowest importance) to 3 (highest importance) for each of nine categories used in the rankings. Section 2 in Volume 1 describes the rankings in more detail. Based on the project ranking system and overall financial analysis, selected projects to pursue in the 20-year Master Plan time frame are included in Volume 1, Sections 11 and 12.

The rankings for the water projects are listed in Table 11-2.

| Table 11-2. Water System Improvements Projects Ranking | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Report Project Number | Report Project Name | Score out of 100 | Health and Safety | Regulatory or Mandated | Reliability and Redundancy | Capacity | Operation, Maintenance, and Rehabilitation | Environmental Impact and Resource Use | Revenue and Expenditures | Customer Service and Stakeholder Confidence | Economic Development |
| Pipeline Projects | | | | | | | | | | | |
| MP-PW-Pipe-01 | Astumbo Zone Piping | 69 | 2 | 1 | 3 | 3 | 1 | 1.3 | 1 | 1 | 2 |
| MP-PW-Pipe-02 | Route 1 Astumbo Zone Piping | 69 | 2 | 1 | 3 | 3 | 1 | 1.3 | 1 | 1 | 2 |
| MP-PW-Pipe-03 | Harmon Cliffline Piping to Route 1 | 69 | 2 | 1 | 3 | 3 | 1 | 1.3 | 1 | 1 | 2 |
| MP-PW-Pipe-04 | Hyundai Well Piping | 69 | 2 | 1 | 3 | 3 | 1 | 1.3 | 1 | 1 | 2 |
| MP-PW-Pipe-05 | Kaiser Zone Looping | 67 | 2 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| MP-PW-Pipe-06 | Mangilao Pressure Zone Realignment | 67 | 2 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| MP-PW-Pipe-07 | Mataguac BPS Suction Piping | 67 | 2 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| MP-PW-Pipe-08 | Nimitz Lower BPS Piping | 67 | 2 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| MP-PW-Pipe-09 | Yigo, Santa Rosa Zone Realignment | 67 | 2 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| MP-PW-Pipe-10 | Miscellaneous Piping Projects | 67 | 2 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| MP-PW-Pipe-11 | Miscellaneous Piping Connections | 67 | 2 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| MP-PW-Pipe-12 | Rehabilitation and Replacement Program | 100 | 3 | 1 | 3 | 3 | 3 | 3 | 2 | 3 | 2.7 |
| MP-PW-Pipe-13 | 2-Inch Pipe Replacement Program | 100 | 3 | 1 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |
| MP-PW-Pipe-14 | Asbestos Cement Pipe Replacement Program | 88 | 3 | 1 | 2.7 | 1.7 | 2.7 | 2.7 | 2.3 | 2.3 | 1 |
| MP-PW-Pipe-15 | PRV Rehab and Replacement | 99 | 2.7 | 1 | 3 | 2.7 | 3 | 3 | 3 | 3 | 2.7 |
| MP-PW-Pipe-16 | Valve Exercise, Repair, and Replacement Program | 85 | 2.7 | 1 | 3 | 1 | 3 | 2.7 | 2 | 2 | 1.7 |
| MP-PW-Pipe-17 | Cross Island Highway Piping | 74 | 2 | 1 | 3 | 3 | 1.7 | 1.3 | 2 | 1 | 2 |
| Storage Tank Projects | | | | | | | | | | | |
| MP-PW-Tank-01 | Agat-Umatac Tank | 81 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-02A | Airport Tanks A | 83 | 2 | 3 | 2.3 | 2.7 | 1.3 | 1 | 1 | 2 | 2.7 |
| MP-PW-Tank-02B | Airport Tanks B | 60 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1.7 | 2 |
| MP-PW-Tank-03A | Astumbo Tanks A | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-03B | Astumbo Tanks B | 62 | 2 | 1 | 2.3 | 2 | 1 | 1 | 1 | 1.7 | 2 |
| MP-PW-Tank-04 | Barrigada Tank | 59 | 2 | 1 | 2 | 1.7 | 1 | 1 | 1 | 1.7 | 2 |
| MP-PW-Tank-07A | Kaiser Tanks A | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-07B | Kaiser Tanks B | 61 | 2 | 1 | 2.3 | 1.7 | 1 | 1 | 1 | 1.7 | 2 |
| MP-PW-Tank-08 | Malojloj Tank | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-09A | Manenggon Hills Tanks A | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-09B | Manenggon Hills Tanks B | 79 | 2 | 3 | 2.3 | 2 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-10A | Nimitz Hill Tanks A | 79 | 2 | 3 | 2.3 | 2 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-10B | Nimitz Hill Tanks B | 79 | 2 | 3 | 2.3 | 2 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-11B | Tumon (Nissan) Tanks B | 64 | 2 | 1 | 2.3 | 2.3 | 1 | 1 | 1 | 1.7 | 2.7 |
| MP-PW-Tank-12 | Pigua Tank | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-13 | Piti Tank | 77 | 2 | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 2 |

| Table 11-2. Water System Improvements Projects Ranking | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Report Project Number | Report Project Name | Score out of 100 | Health and Safety | Regulatory or Mandated | Reliability and Redundancy | Capacity | Operation, Maintenance, and Rehabilitation | Environmental Impact and Resource Use | Revenue and Expenditures | Customer Service and Stakeholder Confidence | Economic Development |
| MP-PW-Tank-14 | Santa Ana Lower Tank | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-15 | Santa Rita Tank | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-16B | Santa Rosa Tanks B | 61 | 2 | 1 | 2.3 | 1.7 | 1 | 1 | 1 | 1.7 | 2 |
| MP-PW-Tank-17 | Sinifa Tank | 79 | 2 | 3 | 2.3 | 2 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-18A | Ugum Tanks A | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-18B | Ugum Tanks B | 78 | 2 | 3 | 2 | 1.7 | 1.7 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-19 | Umatac Subdivision Tank | 79 | 2 | 3 | 2.3 | 2 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-20 | Windward Hills Tank | 76 | 2 | 3 | 2 | 1.7 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-21 | Yigo Tanks | 77 | 2 | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 2 |
| MP-PW-Tank-22 | Existing Tank Assessment Inspections | 100 | 3 | 3 | 3 | 1.7 | 3 | 1 | 2 | 2 | 1.7 |
| MP-PW-Tank-23 | Recurring Tank Inspections | 100 | 3 | 3 | 3 | 1.7 | 3 | 1 | 2 | 2 | 1.7 |
| BPS Projects | | | | | | | | | | | |
| MP-PW-BPS-01 | Rehabilitate and Replace BPSs | 84 | 2.7 | 1.3 | 3 | 2.3 | 3 | 1 | 2 | 1.7 | 1 |
| MP-PW-BPS-02 | Nimitz Hill Upper BPS | 51 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1.3 | 2 |
| MP-PW-BPS-03 | Route 15 BPS | 54 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 1.3 | 2 |
| Water Production Projects | | | | | | | | | | | |
| MP-PW-SWTP-01 | Ugum SWTP River Intake Cleaning Project | 92 | 2 | 1 | 3 | 2.7 | 3 | 3 | 2.7 | 3 | 2.3 |
| MP-PW-SWTP-02 | Ugum SWTP Intake Modifications | 93 | 2 | 1 | 3 | 3 | 3 | 2.7 | 2.7 | 3 | 3 |
| MP-PW-SWTP-03 | Ugum SWTP Reliability Improvements | 91 | 2 | 1 | 3 | 2.7 | 3 | 2.7 | 2.7 | 3 | 2.7 |
| MP-PW-SWTP-04 | Ugum SWTP 7-Year Improvement Project | 90 | 2 | 1 | 3 | 2.3 | 3 | 2.7 | 2.7 | 3 | 2.7 |
| MP-PW-Well-01 | Well Rehabilitation Program | 94 | 3 | 1 | 3 | 2.7 | 3 | 2.3 | 2 | 2.7 | 2 |
| MP-PW-Well-02 | Well Equipment Overhaul Program | 87 | 2 | 1 | 3 | 2.3 | 3 | 2.7 | 2.3 | 2.7 | 2 |
| MP-PW-Well-03 | Capacity Enhancement – Well Exploration Program | 84 | 2 | 1 | 3 | 3 | 2.3 | 2.3 | 2 | 2.3 | 2.3 |
| MP-PW-Well-04 | Capacity Enhancement – Well Development and Construction Program | 84 | 2 | 1 | 3 | 3 | 2.3 | 2.3 | 2 | 2.3 | 2.3 |
| MP-PW-Well-05 | Wellhead Protection Program | 73 | 2.7 | 2.3 | 1 | 1 | 1.3 | 3 | 1 | 1.3 | 1 |
| MP-PW-Well-06 | Well Repair Program | 85 | 2.3 | 2.3 | 2.3 | 1.7 | 2 | 3 | 1.7 | 1.3 | 1.3 |
| Other Water Projects | | | | | | | | | | | |
| MP-PW-Misc-01 | South Guam Water Supply Study | 78 | 2 | 1 | 2.7 | 2.7 | 1 | 2 | 2 | 3 | 2.7 |
| MP-PW-Misc-02 | Master Meter Implementation and Ongoing Meter Replacement | 62 | 1 | 1.3 | 2 | 1.3 | 2.3 | 1.7 | 2.3 | 1.7 | 1.3 |
| MP-PW-Misc-03 | Hydrant Condition Assessment and Maintenance | 77 | 3 | 1 | 3 | 1 | 2 | 1 | 1 | 3 | 1.3 |
| MP-PW-Misc-04 | OneGuam Program | 57 | 1 | 1 | 2.3 | 2 | 1.3 | 1.7 | 2 | 1 | 1 |
| MP-PW-Misc-05 | Leak Detection Assistance | 73 | 1.7 | 1 | 2 | 2 | 3 | 2.3 | 2 | 2 | 1.3 |

## Section 12

# Recommended Project Sheets

This section contains a project sheet for the proposed improvement projects developed for GWA's water system (listed in Table 11-1).

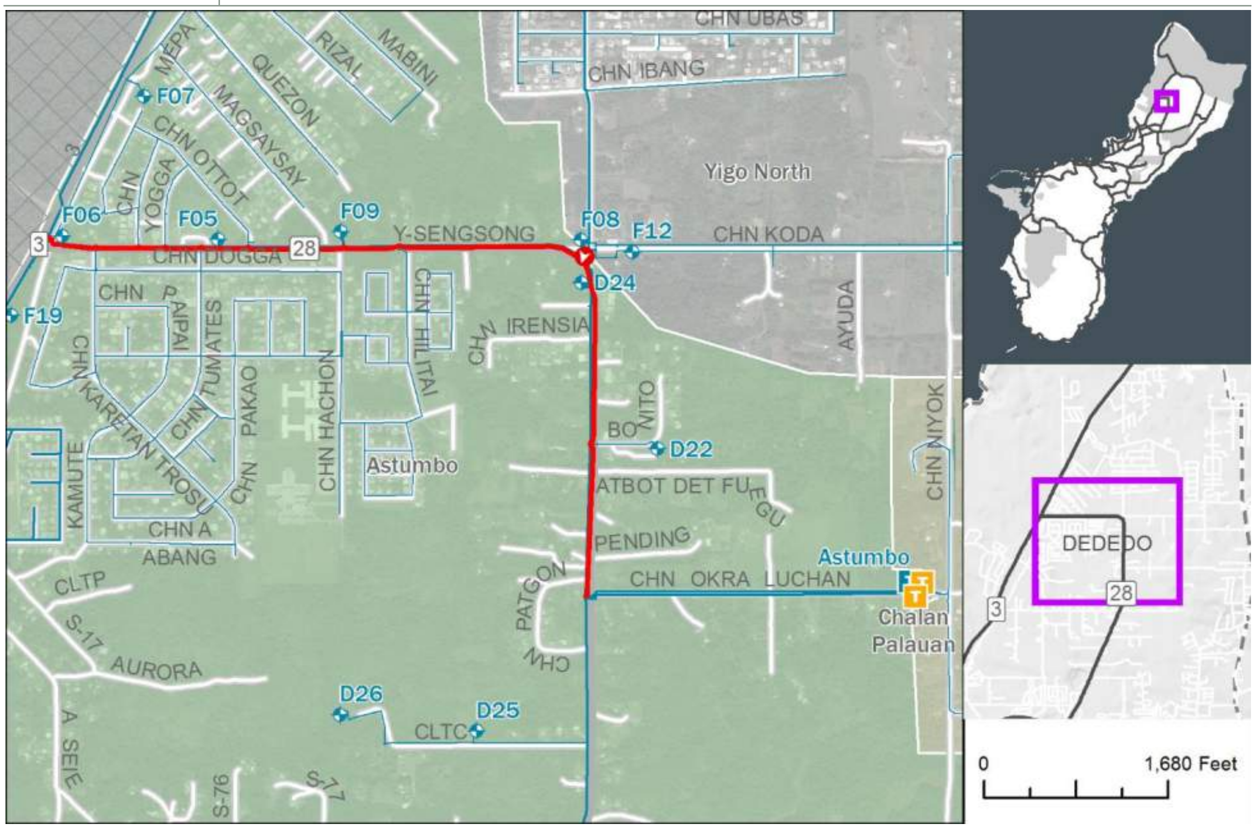
The proposed projects are subject to change and are based on information available at the time of this report. Projects will generally include an engineering study, field verification, detailed design and construction services to refine exact project scope. Engineering staff will lead the design for new or rehabilitated facilities with assistance from operations staff. The project schedules shown are based on the recommended CIP program included in Volume 1 Section 11.

## 12.1 Pipeline Projects

The following legend is for the figures shown in the project sheets in this section.

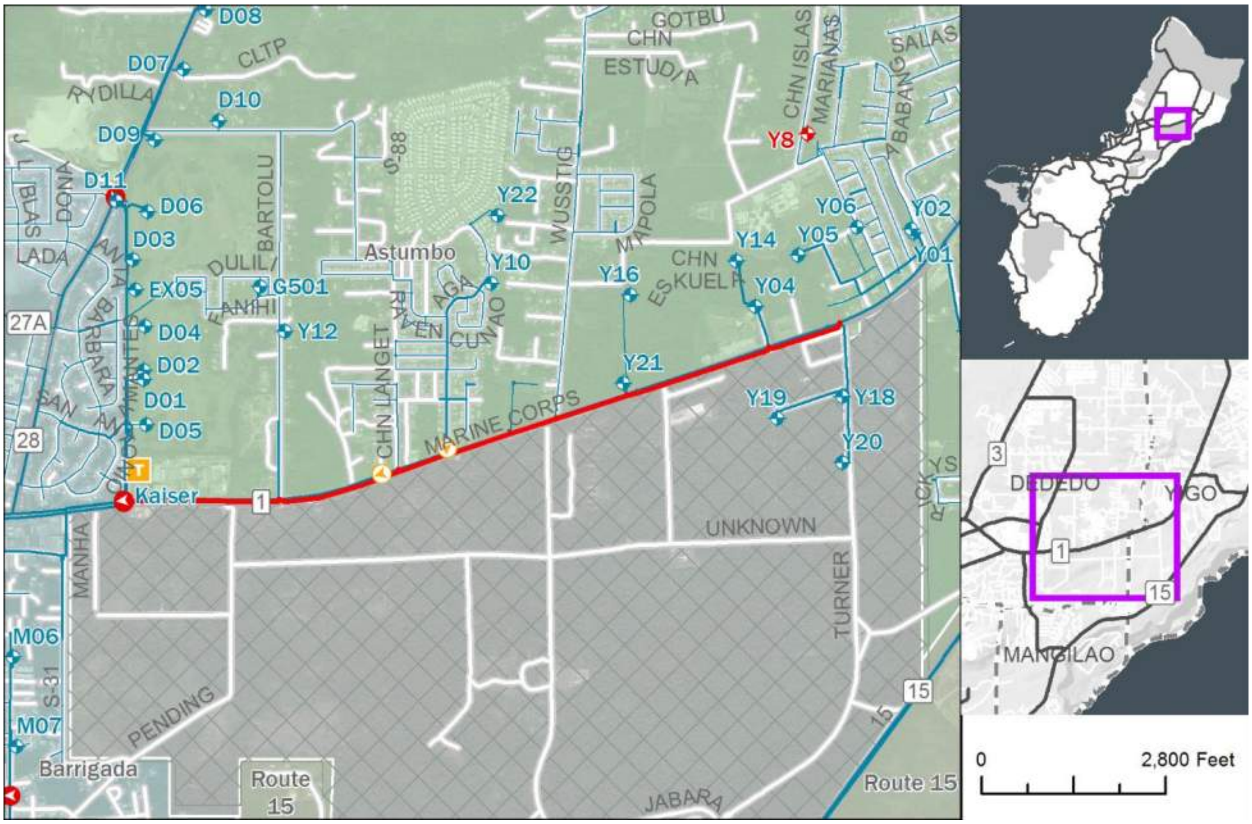
| *Exist* | *Future* | |
|---|---|---|
| | (dashed box) | New Zone Boundary |
| T (blue) | T (red) | Tank |
| | T (orange) | Future Tank, Existing Site |
| P (blue) | P (red) | BPS |
| (blue) | (red) | Well |
| (blue) | (red) | PRV |
| | (orange) | PRV to Abandon |
| thin blue line | thin red line | Pipe < 12 inches |
| thick blue line | thick red line | Pipe >= 12 inches |
| | orange line | GWA Planned Piping |

| Astumbo Zone Piping | |
|---|---|
| **Project Number** | MP-PW-Pipe-01 |
| **Description** | Replace the existing 12-inch pipeline along Ysengsong from Route 3 to the Astumbo tanks. |
| **Justification** | Existing piping is undersized to convey flows from the wells and to/from the Astumbo tank. |
| **Proposed Schedule** | 2022–2023 (1 year of design, 1 year of construction) |
| **Cost Estimate** | $4.85M |
| **Reference Documents** | WRMPU Volume 2, Table 8-15 and Appendix H (Detail 10) |



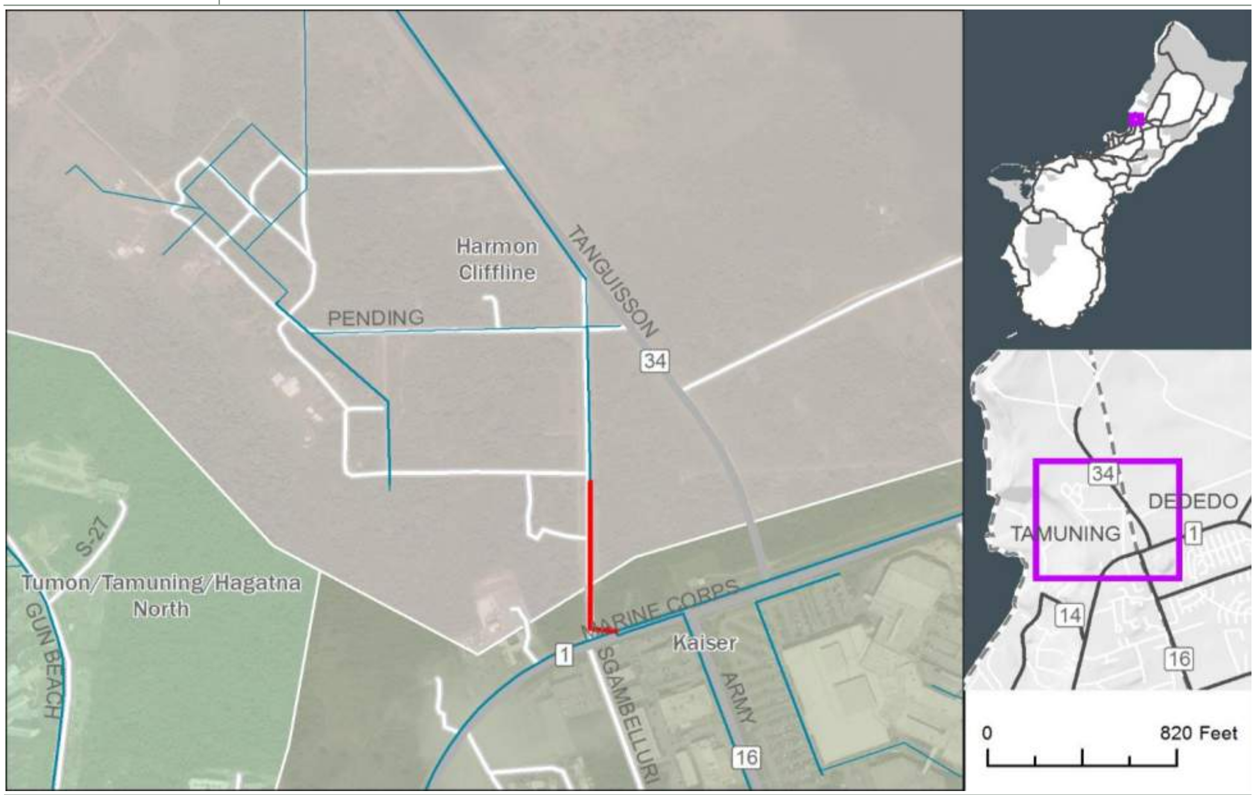

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Route 1 Astumbo Zone Piping | |
|---|---|
| Project Number | MP-PW-Pipe-02 |
| Description | Replace the existing 12-inch pipeline along Route 1. |
| Justification | Existing piping is undersized to convey the full permitted flow rates from the existing wells that pump into distribution piping that flows into this line. |
| Proposed Schedule | 2023–2025 |
| Cost Estimate | $7.19M |
| Reference Documents | WRMPU Volume 2, Table 8-15 and Appendix G (Figure G-6) |



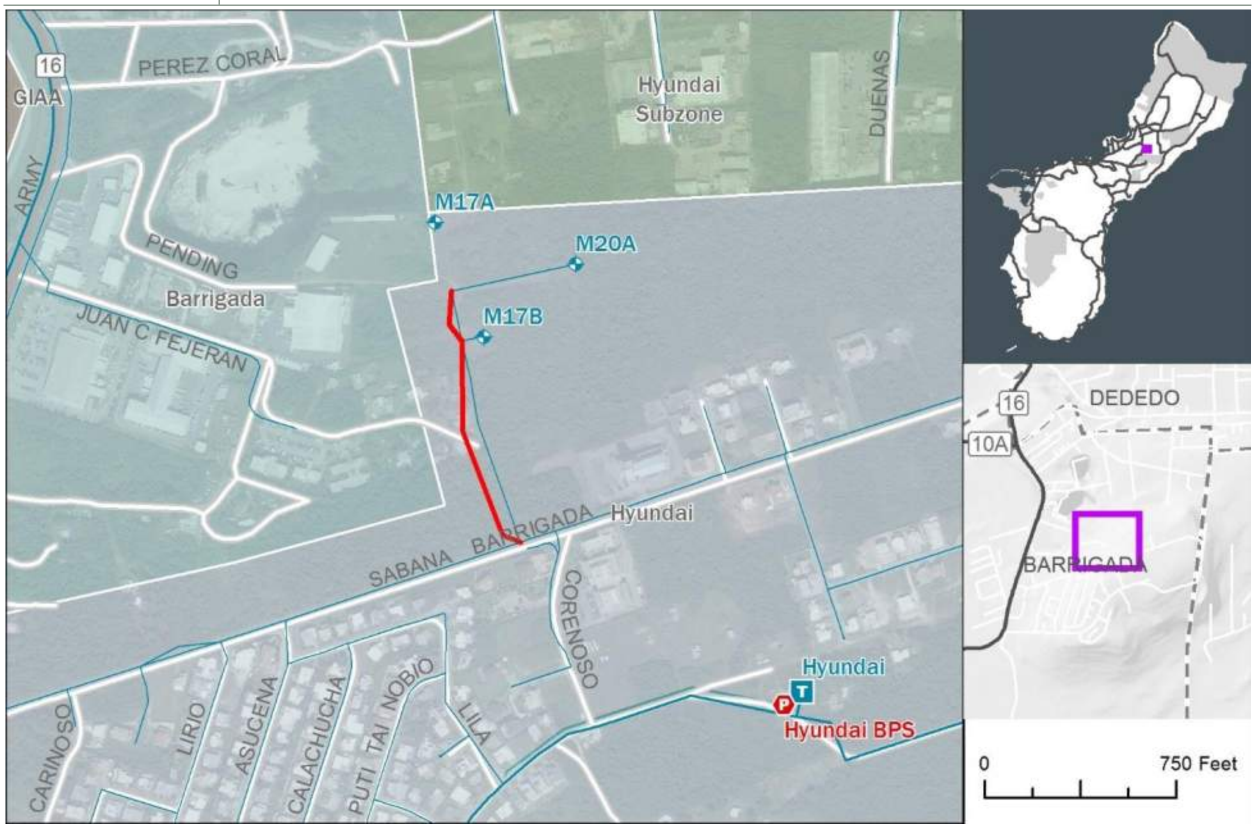

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Harmon Cliffline Piping to Route 1 | |
|---|---|
| Project Number | MP-PW-Pipe-03 |
| Description | Construct new piping to connect the Harmon Cliffline zone to the rest of the distribution system on Route 1. The piping shown in red below is not in the GIS but there may be an existing connection to Route 1. This project may change into a different project to verify if the piping exists and to locate leaks believed to exist on in the Harmon Cliffline area. |
| Justification | Well H01 has more capacity than needed in the Harmon Cliffline zone. Connecting the Harmon Cliffline zone to the rest of the system will allow well H01 to pump extra flow into the rest of the system. A connection will also provide storage from the main system back to the Harmon Cliffline zone. |
| Proposed Schedule | 2023 |
| Cost Estimate | $424,000 (for new piping, assuming it does not exist) |
| Reference Documents | WRMPU Volume 2, Table 8-15 and Appendix H (Detail 36) |




*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Hyundai Well Piping | |
|---|---|
| Project Number | MP-PW-Pipe-04 |
| Description | Replace the existing 6-inch piping from wells M17A, 17B, and 20A. |
| Justification | The existing 6-inch piping does not have sufficient capacity to allow the 3 wells to pump their full permitted flow rates. |
| Proposed Schedule | 2020 |
| Cost Estimate | $547,000 |
| Reference Documents | WRMPU Volume 2, Table 8-15 and Appendix H (Detail 40) |

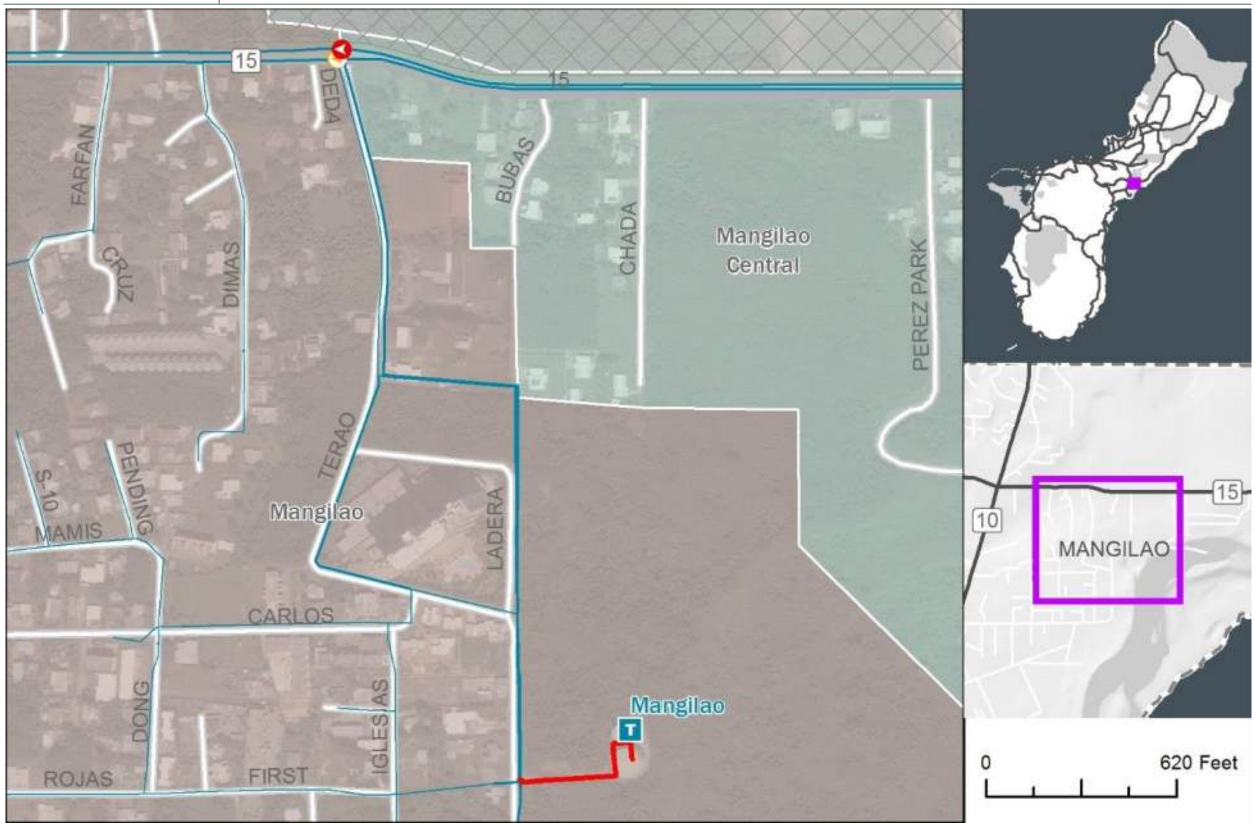



*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Kaiser Zone Looping | |
|---|---|
| **Project Number** | MP-PW-Pipe-05 |
| **Description** | Construct new piping from north of the Kaiser tank to Route 1. |
| **Justification** | The piping will provide looping to improve flow around the Kaiser tank for the newly realigned Barrigada zone. |
| **Proposed Schedule** | 2020 |
| **Cost Estimate** | $306,000 |
| **Reference Documents** | WRMPU Volume 2, Table 8-15 and Appendix H (Detail 22) |


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Mangilao Pressure Zone Realignment | |
|---|---|
| Project Number | MP-PW-Pipe-06 |
| Description | Construct new 24-inch piping to connect two lines in Route 15. Construct a new 12-inch pipeline from Ladera to the Mangilao tanks to serve as an inlet line and the existing 16-inch inlet/outlet line will become an outlet line. |
| Justification | These piping changes are needed to implement the pressure zone realignment for the new Mangilao pressure zone. |
| Proposed Schedule | 2020 |
| Cost Estimate | $344,000 |
| Reference Documents | WRMPU Volume 2, Table 8-15 and Appendix H (Details 58, 59, 60) |

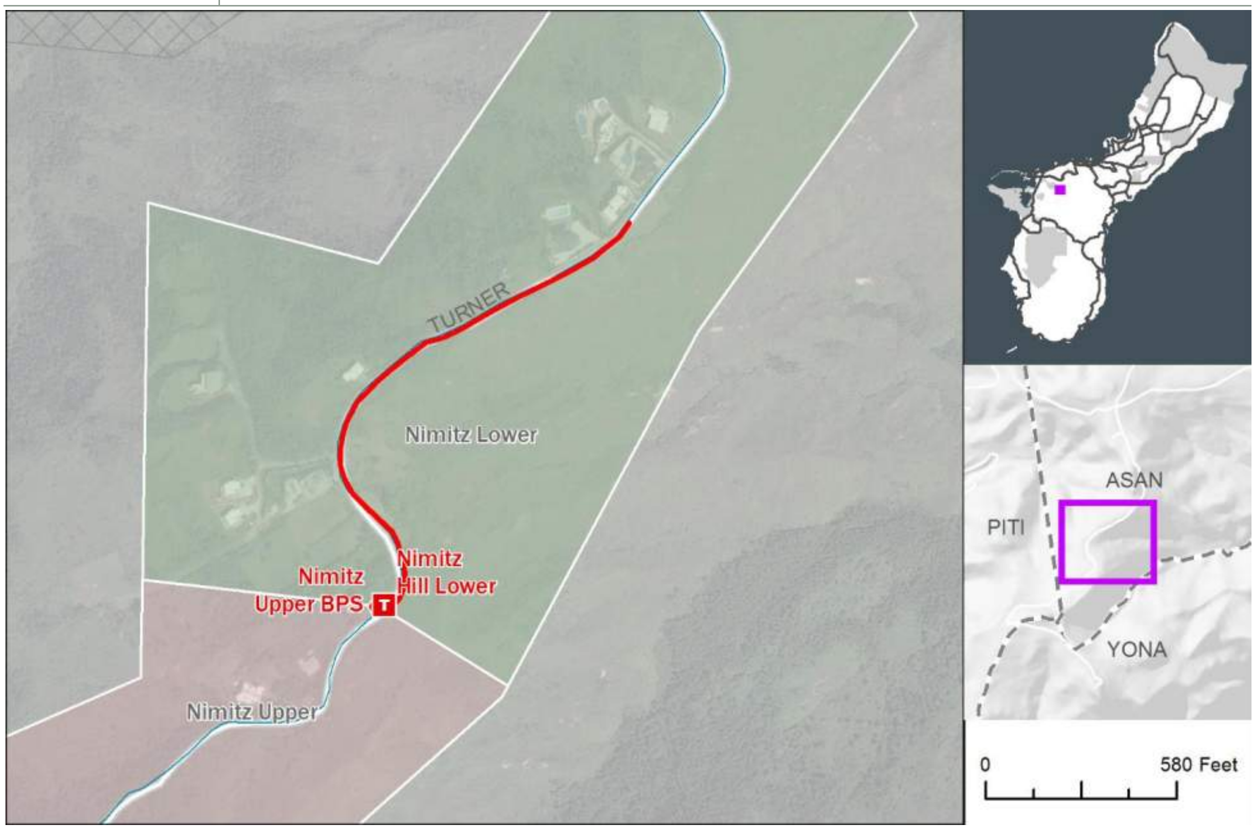



*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Mataguac BPS Suction Piping | |
|---|---|
| **Project Number** | MP-PW-Pipe-07 |
| **Description** | Replace existing 6-inch piping on the suction side of the Mataguac BPS. |
| **Justification** | Existing piping is undersized to handle peak flows, which causes low suction pressures at the Mataguac BPS. |
| **Proposed Schedule** | 2021 |
| **Cost Estimate** | $733,000 |
| **Reference Documents** | WRMPU Volume 2, Table 8-15 and Appendix H (Detail 6) |


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Nimitz Lower BPS Piping | |
|---|---|
| Project Number | MP-PW-Pipe-08 |
| Description | Construct parallel piping on the discharge side of the proposed Nimitz Hill Upper BPS. The size of the new piping will depend on whether the piping will serve fire flow demands. |
| Justification | This piping is needed when the Nimitz Hill pressure zone is divided into two pressures zones. Customers just downhill of the proposed lower tank would have low pressures if connected to the tank. The piping would serve customers below the tank by extending the upper zone downhill. |
| Proposed Schedule | 2023–2024 |
| Cost Estimate | $1.59M |
| Reference Documents | WRMPU Volume 2, Table 8-15 and Appendix H (Detail 71) |




*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Yigo, Santa Rosa Zone Realignment | |
|---|---|
| **Project Number** | MP-PW-Pipe-09 |
| **Description** | Construct a new 12-inch pipeline parallel to the existing 12-inch pipeline. The new pipeline will run from the Yigo tanks and connect to the existing 12-inch pipeline on Route 1. The 8-inch pipeline on Route 1 will be connected to the Santa Rosa zone. |
| **Justification** | This piping is needed for the realignment of the Yigo and Santa Rosa pressure zones, and will help connect the Yigo tanks to the Yigo zone south on Route 1. |
| **Proposed Schedule** | 2022–2023 |
| **Cost Estimate** | $2.34M |
| **Reference Documents** | WRMPU Volume 2, Table 8-15 and Appendix H (Detail 6) |


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Miscellaneous Piping Projects | |
|---|---|
| **Project Number** | MP-PW-Pipe-10 |
| **Description** | Small pipe projects for several pressure zones as the pressures zones are realigned. |
| **Justification** | These projects are primarily to connect piping within new pressure zone boundaries and to loop piping. |
| **Proposed Schedule** | 2020–2022 |
| **Cost Estimate** | $2.08M |
| **Reference Documents** | WRMPU Volume 2, Table 8-15 and Appendix H |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Miscellaneous Piping Connections | |
|---|---|
| **Project Number** | MP-PW-Pipe-11 |
| **Description** | Construct connections between piping throughout the system. |
| **Justification** | The connections will connect piping at intersections or connect parallel piping. |
| **Proposed Schedule** | 2020–2022 |
| **Cost Estimate** | $582,000 |
| **Reference Documents** | WRMPU Volume 2, Table 8-15, Appendix G, and Appendix H |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Rehabilitation and Replacement Program | |
|---|---|
| **Project Number** | MP-PW-Pipe-12 |
| **Description** | Implement an annual program to rehabilitate and replace piping based on the condition assessment risk analysis. New piping should be sized to handle fire flow demands. Pipe replacement includes but is not limited to replacement of fire hydrants, PRVs, valves (isolation valves, air lease valves, blow off valves, etc.), vaults, and line segment replacement. Replaced piping should be properly abandoned so they do not remain in service, with the potential for leaks. |
| **Justification** | The piping risk analysis showed that GWA must begin with a pipe renewal program to replace piping that will reach the end of its service life. Sites with substantial leaks have been identified through the current leak detection project. This project is a continuation of CIP PW 09-03. |
| **Proposed Schedule** | Annual |
| **Cost Estimate** | Target $5.0M/year |
| **Reference Documents** | WRMPU Volume 2, Section 8.5 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| 2-Inch Pipe Replacement Program | |
|---|---|
| **Project Number** | MP-PW-Pipe-13 |
| **Description** | Implement an annual program to replace 2-inch pipes throughout the island. Replaced pipelines should be abandoned in place or removed. New piping should be sized to handle fire flow demands with a minimum diameter of 6 inches. |
| **Justification** | 2-inch pipelines need to be replaced for the following reasons:<br>• The pipelines are too small to convey even minimal fire flows.<br>• Many of the pipelines are at the ground surface, where they are susceptible to damage and corrosion, which leads to pipe breaks and leaks. |
| **Proposed Schedule** | Annual – Starting in 2019 |
| **Cost Estimate** | $1.75M/year |
| **Reference Documents** | WRMPU Volume 2, Section 8.5.3 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Asbestos Cement Pipe Replacement Program | |
|---|---|
| **Project Number** | MP-PW-Pipe-14 |
| **Description** | Implement an annual program to replace AC pipes throughout the island. Replaced pipelines should be abandoned in place or removed. New piping should be sized with the same or greater size as the piping to be replaced and should be sized to handle fire flow demands. |
| **Justification** | GWA has worked towards replacing all remaining AC piping throughout the water system. GWA has noted that failure rates for AC piping is higher than for other piping in the system. |
| **Proposed Schedule** | Annual – Starting in 2022 |
| **Cost Estimate** | $3.85M/year |
| **Reference Documents** | WRMPU Volume 2, Section 8.5.3 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

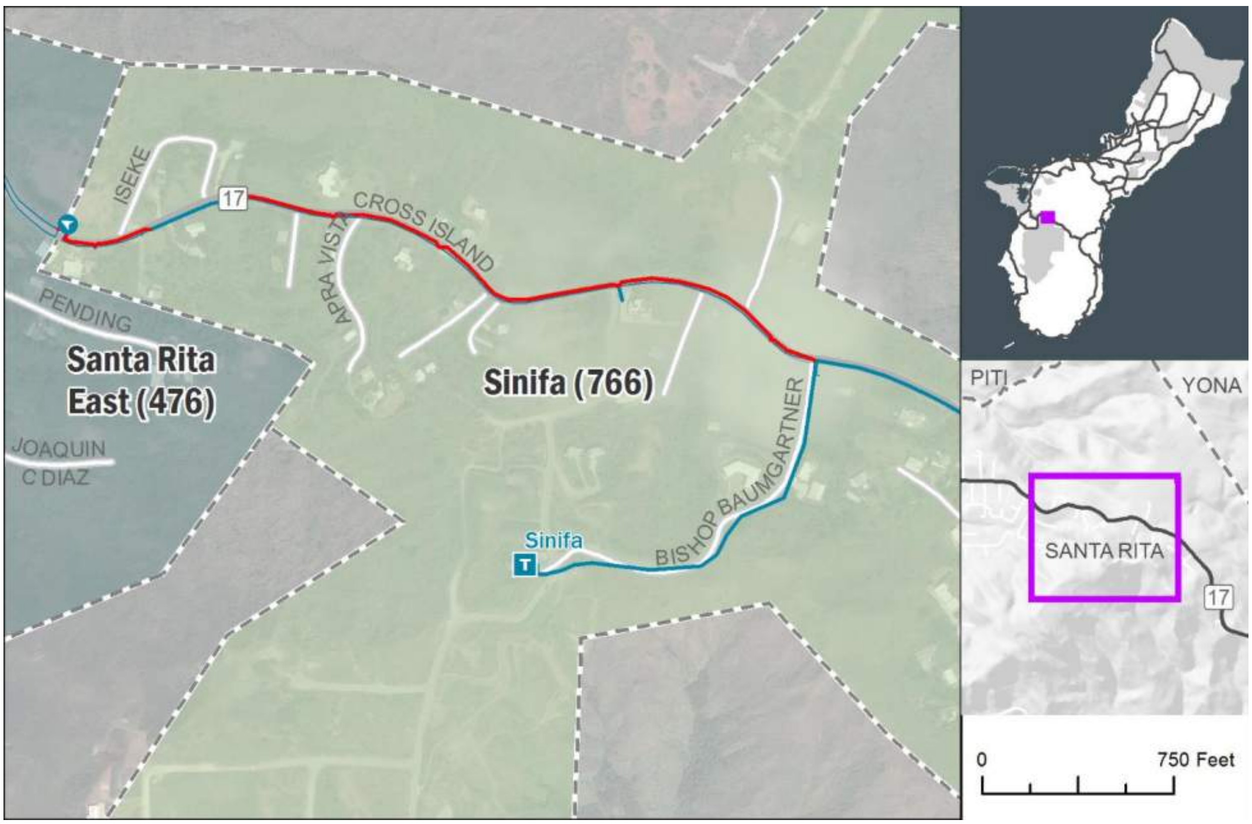
| PRV Rehab and Replacement | |
|---|---|
| **Project Number** | MP-PW-Pipe-15 |
| **Description** | Rehabilitate existing PRVs and construct new PRVs for the pressure zone realignment. New master meters should be added to each new or rehabbed PRV, if possible. The following list includes the number of PRVs anticipated to serve each pressure zone. Locations and numbers of PRVs may change depending on site conditions such as the location of existing piping within a road and utility conflicts.<br>• Astumbo (new=3)<br>• Barrigada (rehabilitation=1, new=4)<br>• Barrigada Subzone (new=3)<br>• Harmon Industrial (rehabilitation=2, new=1)<br>• Hyundai Subzone (new=1)<br>• Inarajan/Merizo (new=1)<br>• Kaiser (new=3)<br>• Manenggon Hills (rehabilitation=1)<br>• Mangilao (new=2)<br>• Mangilao Central (new=2)<br>• Mangilao North (rehabilitation=3)<br>• Nimitz Estates Lower (rehabilitation=1)<br>• Nimitz Estates Middle Lower (rehabilitation=1)<br>• Nimitz Estates Middle Upper (rehabilitation=1)<br>• Ordot/Sinajana (rehabilitation=1, new=2)<br>• Pago Bay (new=1)<br>• Santa Ana Lower (rehabilitation=3, new=1)<br>• Santa Rita Central (rehabilitation=1)<br>• Santa Rita East (rehabilitation=1)<br>• Tiyan (new=1)<br>• Tumon/Tamuning/Hagåtña (rehabilitation=1, new=5)<br>• Umatac (rehabilitation=1) |
| **Justification** | PRVs are needed for the proposed pressure zones to function properly. PRVs allow pressure zones to maintain pressures within GWA's high- and low-pressure criteria. |
| **Proposed Schedule** | 2019–2024 |
| **Cost Estimate** | $8.80M ($1.468M/year) (assumes full replacement of all PRVs) |
| **Reference Documents** | WRMPU Volume 2, Section 8.2 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Valve Exercise, Repair, and Replacement Program | |
|---|---|
| **Project Number** | MP-PW-Pipe-16 |
| **Description** | Implement an isolation and air relief valve exercise, repair, replacement, and maintenance program with the following:<br>• Purchase a valve exercise machine.<br>• Document broken valves as they are located. After a number of broken valves are identified, group the valves into a project and put out to bid to be fixed by a qualified contractor. |
| **Justification** | Locating and opening closed and choked valves is important to properly implement the pressure zone realignment and allow operations staff to fix broken valves. Valves must be exercised regularly to ensure they are operational when need. |
| **Proposed Schedule** | Bi-Annual |
| **Cost Estimate** | $250,000 |
| **Reference Documents** | WRMPU Volume 2, Section 8.3 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Cross Island Highway Piping | |
|---|---|
| Project Number | MP-PW-Pipe-17 |
| Description | Replace the existing 8-inch pipeline with a 12-inch pipeline along Cross Island Road between the Sinifa tank and the Sinifa PRV. |
| Justification | Existing piping is undersized to convey flows along Cross Island Road from Windward Hills to Agat and Santa Rita. The rest of the Cross Island pipeline from the Windward Hills BPS is 12-inch piping. |
| Proposed Schedule | 2021–2022 (1 year of design, 1 year of construction) |
| Cost Estimate | $1.66M |
| Reference Documents | WRMPU Volume 2, Table 8-15 |




*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

## 12.2 Storage Tank Projects

| Agat-Umatac Tank | |
|---|---|
| Project Number | MP-PW-Tank-01 |
| Description | Inspect and repair the existing 200,000-gallon tank. If it is determined that the tank cannot be repaired after inspection, the tank may need to be replaced. This project would then need to be expanded to include the design and construction of a new tank. |
| Justification | The existing tank is in poor condition. |
| Proposed Schedule | Begin Design: 2018 |
| Cost Estimate | $330,000 |
| Reference Documents | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Airport Tanks | |
|---|---|
| **Project Number** | MP-PW-Tank-02A and 02B |
| **Description** | Tank-02A: Abandon the existing 1-MG tank and construct 1 new approximately 3-MG tank.<br>Tank-02B: Construct 1 new approximately 3-MG tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Tank-02A - Begin Design: 2020<br>Tank-02B - Begin Design: 2029 |
| **Cost Estimate** | Tank-02A - $11.9M<br>Tank-02B - $12.88M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Astumbo Tanks | |
|---|---|
| **Project Number** | MP-PW-Tank-03A and 03B |
| **Description** | Tank-03A: Abandon the existing 1-MG tank and inspect and repair the existing 2-MG tank. If it is determined that the 2-MG tank cannot be repaired after inspection, the tank may need to be replaced. This project would then need to be expanded to include the design and construction of a new tank.<br>Tank-03B: Construct 1 new approximately 2-MG tank. Note that this project does not include the Astumbo 1 tank, which was under construction at the time of this report.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tanks are in poor condition. |
| **Proposed Schedule** | Tank-03A - Complete Repairs for Existing Tank: 2018<br>Tank-03B - Begin Design: 2029 |
| **Cost Estimate** | Tank-03A - $1.58M<br>Tank-03B - $9.61M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tanks in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Barrigada Tank | |
|---|---|
| **Project Number** | MP-PW-Tank-04 |
| **Description** | Construct 1 new approximately 2-MG tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. |
| **Proposed Schedule** | Begin Design: After 2037 |
| **Cost Estimate** | $9.61M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tanks in 2016*


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Chaot Tank | |
|---|---|
| **Project Number** | MP-PW-Tank-05 |
| **Description** | Construct 1 new approximately 500,000-gallon tank. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. |
| **Proposed Schedule** | Begin Construction: 2018 |
| **Cost Estimate** | $5.71M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Hyundai Tank | |
|---|---|
| Project Number | MP-PW-Tank-06 |
| Description | Abandon the existing 1-MG tank and construct 1 new approximately 1-MG tank. |
| Justification | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| Proposed Schedule | Begin Construction: 2018 |
| Cost Estimate | $8.2M |
| Reference Documents | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Kaiser Tanks | |
|---|---|
| **Project Number** | MP-PW-Tank-07A and 07B |
| **Description** | Tank-07A: Inspect and repair the existing 2.5-MG tank. If it is determined that the tank cannot be repaired after inspection, the tank may need to be replaced. This project would then need to expand to include the design and construction of a new tank.<br>Tank-07B: Construct 1 new approximately 3-MG tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Tank-07A - Complete Repairs for Existing Tank: 2019<br>Tank-07B - Begin Design: after 2037 |
| **Cost Estimate** | Tank-07A - $1.71M<br>Tank-07B - $12.82M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Malojloj Tank | |
|---|---|
| **Project Number** | MP-PW-Tank-08 |
| **Description** | Repair the existing 1-MG tank. |
| **Justification** | The existing tank is in poor condition. |
| **Proposed Schedule** | Begin Design: 2018 |
| **Cost Estimate** | $990,000 |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Manenggon Hills Tanks | |
|---|---|
| **Project Number** | MP-PW-Tank-09A and 09B |
| **Description** | Tank 09A: Repair the existing 2-MG tank.<br>Tank-09B: Construct 1 new approximately 2-MG tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Tank-09A - Complete Repairs for Existing Tank: 2019<br>Tank-09B - Begin Design: 2018 |
| **Cost Estimate** | Tank-09A - $1.71M<br>Tank-09B - $9.61M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Nimitz Hill Tanks | |
|---|---|
| **Project Number** | MP-PW-Tank-10A and 10B |
| **Description** | Tank-10A: Abandon the existing small upper tank and construct 1 new approximately 35,000-gallon upper tank.<br>Tank-10B: Construct 1 new approximately 35,000-gallon lower tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Tank-10A - Begin Design: 2019<br>Tank-10B - Begin Design: 2019 |
| **Cost Estimate** | Tank-10A - $479,000<br>Tank-10B - $479,000 |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Offline existing old Lower tank next to Upper tank in 2013*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Tumon (Nissan) Tanks | |
|---|---|
| Project Number | MP-PW-Tank-11A and 11B |
| Description | Tank-11A: Construct 1 new approximately 1-MG tank.<br>Tank-11B: Construct 1 new approximately 2-MG tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| Justification | New storage is required to meet operational/equalization, emergency, and fire storage requirements. |
| Proposed Schedule | Tank-11A - Begin Construction: 2018<br>Tank-11B - Begin Design: 2029 |
| Cost Estimate | Tank-11A - $8.2M<br>Tank-11B - $9.61M |
| Reference Documents | WRMPU Volume 2, Table 6-2 |

*Existing, offline Nissan tank from Google Street View (2017)*


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Pigua Tank | |
|---|---|
| **Project Number** | MP-PW-Tank-12 |
| **Description** | Inspect and repair the existing 500,000-gallon tank. |
| **Justification** | The existing tank is in poor condition. |
| **Proposed Schedule** | Begin Design: 2019 |
| **Cost Estimate** | $990,000 |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Piti Tank | |
|---|---|
| **Project Number** | MP-PW-Tank-13 |
| **Description** | Purchase land and construct 1 new approximately 1-MG tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. |
| **Proposed Schedule** | Begin Design: 2019 |
| **Cost Estimate** | $8.87M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank from above*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Santa Ana Lower Tank | |
|---|---|
| Project Number | MP-PW-Tank-14 |
| Description | Inspect and repair the existing 1-MG tank. |
| Justification | The existing tank is in poor condition. |
| Proposed Schedule | Begin Design: 2019 |
| Cost Estimate | $990,000 |
| Reference Documents | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Santa Rita Tank | |
|---|---|
| **Project Number** | MP-PW-Tank-15 |
| **Description** | Abandon the existing 1-MG tank and construct 1 new approximately 1-MG tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Begin Construction: 2018 |
| **Cost Estimate** | $8.2M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Santa Rosa Tanks | |
|---|---|
| **Project Number** | MP-PW-Tank-16A and 16B |
| **Description** | Tank-16A: Abandon the existing 1-MG tank and construct 1 new approximately 1-MG tank.<br>Tank 16-B: Construct 1 new approximately 1-MG tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Tank-16A - Begin Construction: 2018<br>Tank-16B - Begin Design: 2029 |
| **Cost Estimate** | Tank-16A - $8.2M<br>Tank-16B - $8.88M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Sinifa Tank | |
|---|---|
| **Project Number** | MP-PW-Tank-17 |
| **Description** | Abandon the existing 1-MG tank and construct 1 new approximately 1-MG tank. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Begin Construction: 2018 |
| **Cost Estimate** | $8.2M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Ugum Tanks | |
|---|---|
| **Project Number** | MP-PW-Tank-18A and 18B |
| **Description** | Tank-18A: Construct 1 new approximately 2-MG tank.<br>Tank-18B: Inspect and repair the existing 2-MG tank. If it is determined that the tank cannot be repaired after inspection, the tank may need to be replaced. This project would then need to expand to include the design and construction of a new tank.<br>The number, size, and timing of proposed tanks may change based on property issues and the actual rate of population growth in the area. This project may include pipe and PRV modifications that are near or in the same pressure zone as the tanks. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Tank-18A - Complete Repairs for Existing Tank: 2020<br>Tank-18B - Begin Design: 2019 |
| **Cost Estimate** | Tank-18A - $1.72M<br>Tank-18B - $9.61M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2017*


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Umatac Subdivision Tank | |
|---|---|
| **Project Number** | MP-PW-Tank-19 |
| **Description** | Inspect and repair the existing 500,000-gallon tank. If it is determined that the tank cannot be repaired after inspection, the tank may need to be replaced. This project could then be expanded to include the design and construction of a new tank. |
| **Justification** | The existing tank is in poor condition. |
| **Proposed Schedule** | Begin Design: 2019 |
| **Cost Estimate** | $594,000 |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Windward Hills Tank | |
|---|---|
| Project Number | MP-PW-Tank-20 |
| Description | Inspect and repair the existing 1-MG tank. If it is determined that the tank cannot be repaired after inspection, the tank may need to be replaced. This project could then be expanded to include the design and construction of a new tank. |
| Justification | The existing tank is in poor condition. |
| Proposed Schedule | Begin Design: 2018 |
| Cost Estimate | $990,000 |
| Reference Documents | WRMPU Volume 2, Table 6-2 |

*Existing tank in 2016*

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Yigo Tanks | |
|---|---|
| **Project Number** | MP-PW-Tank-21 |
| **Description** | Repair the existing 2.5-MG tank and abandon the existing 500,000-gallon tank. If it is determined that the 500,000-gallon tank cannot be repaired after inspection, the tank may need to be replaced. This project could then be expanded to include the design and construction of a new tank. Note that this project does not include the new Yigo 1 or Yigo 3 tanks which were under construction at the time of this report. |
| **Justification** | New storage is required to meet operational/equalization, emergency, and fire storage requirements. The existing tank is in poor condition. |
| **Proposed Schedule** | Begin Design: 2018 |
| **Cost Estimate** | $1.72M |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*Existing tanks in 2013*


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Existing Tank Assessment Inspections | |
|---|---|
| **Project Number** | MP-PW-Tank-22 |
| **Description** | Inspect the following storage tanks:<br>• Agat-Umatac 1 (0.2 MG)<br>• Astumbo 2 (2 MG)<br>• Kaiser 1 (2.4 MG)<br>• Malojloj 1 (1 MG)<br>• Manenggon Hills 1 (2 MG)<br>• Nimitz Hill Upper 1 (10,000 gallons MG)<br>• Pigua 1 (0.5 MG)<br>• Santa Ana Lower 1 (1 MG)<br>• Ugum 1 (2 MG)<br>• Umatac Subdivision 1 (0.5 MG)<br>• Windward Hills 2 (1 MG)<br>• Yigo 2 (2.5 MG) |
| **Justification** | Each storage tank needs to be inspected to determine whether each tank should be rehabilitated or replaced. |
| **Proposed Schedule** | Inspect between 2018 and 2020 |
| **Cost Estimate** | $428,000 |
| **Reference Documents** | WRMPU Volume 2, Table 6-2 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Recurring Tank Inspections | |
|---|---|
| **Project Number** | MP-PW-Tank-23 |
| **Description** | Inspect all storage tanks every 5 years. Based on the condition of the tanks, some tanks may need more frequent inspections, such as the existing steel tanks. Deficiencies should be noted and fixed, such as required cleaning and painting of the tanks, valves, and piping at each tank site. Assuming there will be about 33 tanks active in 2020, about 6 tanks should be inspected per year. |
| **Justification** | Frequent inspections and maintenance of the storage tanks will extend the life of the storage tanks and protect the large investment GWA has been making in the storage tanks. This is a continuation of projects CIP PW 09-09 and PW 09-10. |
| **Proposed Schedule** | Annually – Starting in 2020 |
| **Cost Estimate** | $214,000/year (inspection of 6 tanks per year) |
| **Reference Documents** | WRMPU Volume 2, Section 6.3 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

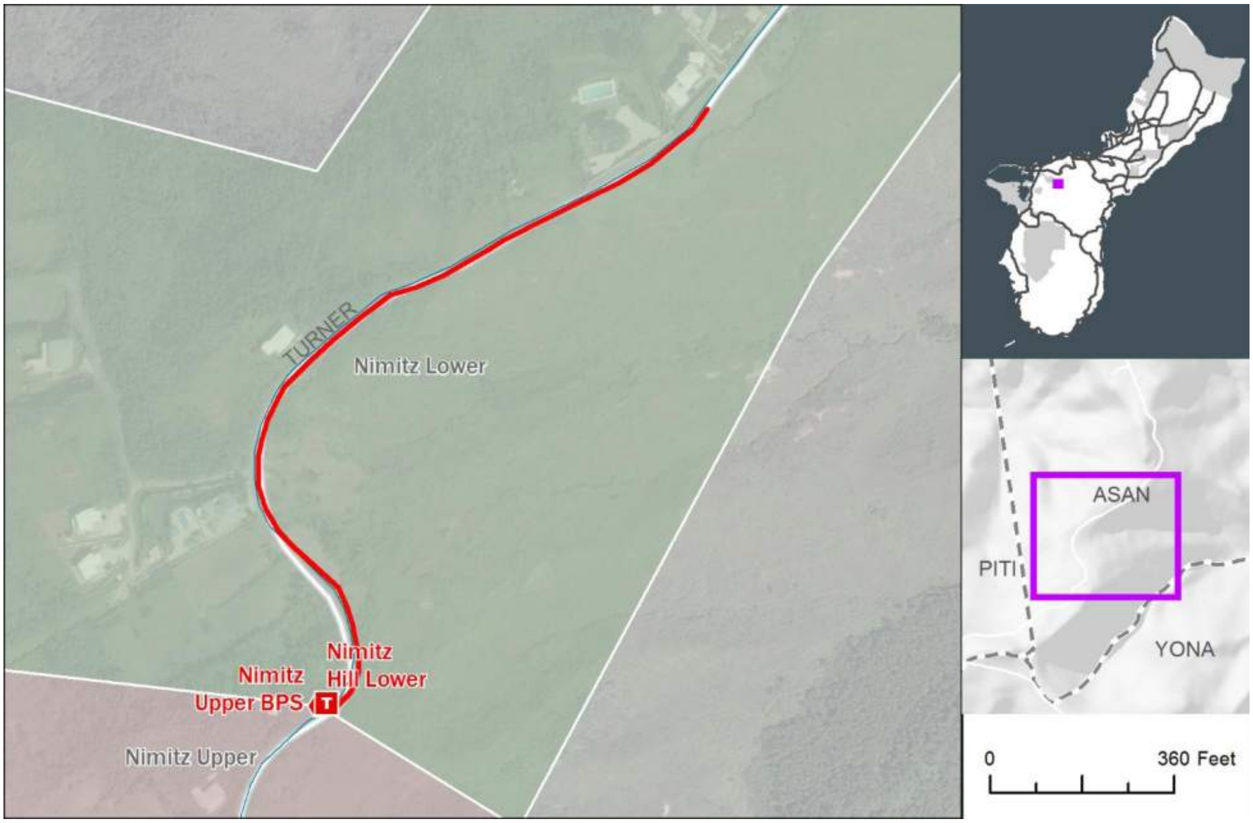
## 12.3 Booster Pump Station Projects

| Rehabilitate and Replace BPSs | |
|---|---|
| **Project Number** | MP-PW-BPS-01 |
| **Description** | Includes the following work for BPSs:<br>• Gayinero BPS: replace the BPS at a new location<br>• Geus BPS: rehabilitate the BPS<br>• Mataguac BPS: rehabilitate the BPS and increase capacity<br>• Nimitz Hill Lower BPS: rehabilitate the BPS<br>• Santa Ana BPS: rehabilitate the BPS and increase capacity<br>• Santa Rita Spring: rehabilitate the BPS and tank<br>• Toguan BPS: rehabilitate the BPS and increase capacity<br>• Umatac 1 (WBP 1) BPS: rehabilitate the BPS and increase capacity<br>• Umatac 2 (WBP 2) BPS: rehabilitate the BPS and increase capacity<br>• Rehabilitation or replacement of any other BPSs that need rehabilitation or replacement. |
| **Justification** | The BPSs are in poor condition and several do not have sufficient capacity for peak demands if the largest pump goes out of service. |
| **Proposed Schedule** | Begin Design: 2019 |
| **Cost Estimate** | $2.97M |
| **Reference Documents** | WRMPU Volume 2, Section 7.3 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

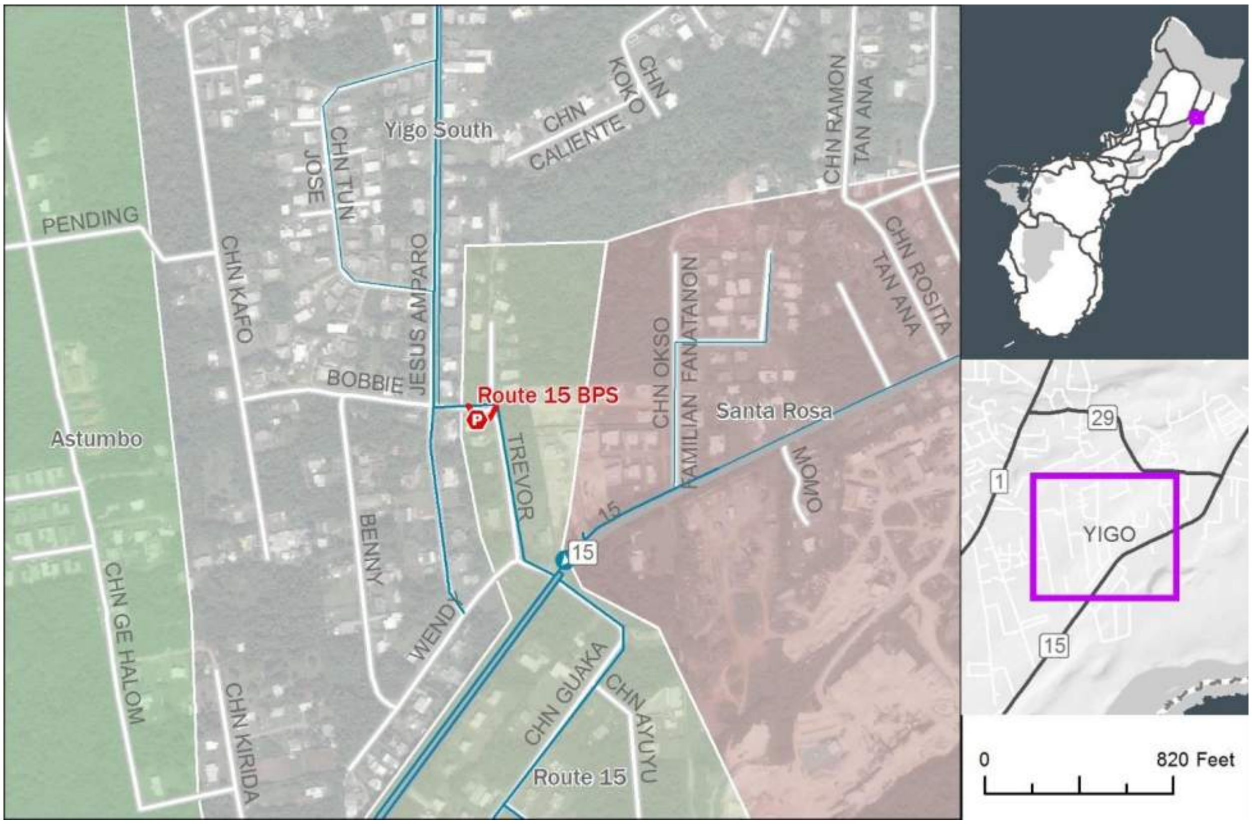
| Nimitz Hill Upper BPS | |
|---|---|
| Project Number | MP-PW-BPS-02 |
| Description | Construct a new Nimitz Hill BPS up the hill from the lower BPS. |
| Justification | A second BPS is needed on Nimitz Hill to keep pressures within 35 to 90 psi. |
| Proposed Schedule | 2019 |
| Cost Estimate | $48,000 |
| Reference Documents | WRMPU Volume 2, Section 7.3 |

*The piping in red is shown in a separate project sheet.*




*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Route 15 BPS | |
|---|---|
| **Project Number** | MP-PW-BPS-03 |
| **Description** | Construct a new BPS to increase pressures along Route 15. |
| **Justification** | There is not currently adequate pressure to send sufficient flow over the hill on Route 15. The new BPS will allow for sending more flow along Route 15 to meet peak flows. |
| **Proposed Schedule** | Begin Design: 2024 |
| **Cost Estimate** | $1.14M |
| **Reference Documents** | WRMPU Volume 2, Section 7.1.2 |




*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

## 12.4 Water Production Projects

| Ugum SWTP River Intake Cleaning Project | |
|---|---|
| **Project Number** | MP-PW-SWTP-01 |
| **Description** | Remove sedimentation/silt accumulation in the area upstream of the Ugum dam and at the Ugum SWTP intake. |
| **Justification** | The project will improve operations by reducing the amount of maintenance required at the intake and that is carried into the Raw Water Pump Station. Silt causes a variety of operating issues included excessive pump wear and high raw water screen clogging/backwash rates. |
| **Proposed Schedule** | 2019 |
| **Cost Estimate** | $380,000 |
| **Reference Documents** | WRMPU Volume 2, Section 5.5.2 |


*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Ugum SWTP Intake Modifications | |
|---|---|
| **Project Number** | MP-PW-SWTP-02 |
| **Description** | Detailed design and construction for the raw water intake structure at the Ugum SWTP selected under project CIP PW 09-01. This project may also include planning for future treatment capacity and projects that increase plant capacity. The scope will also include vehicles, equipment, software, hardware, training, engineering, and operation and maintenance of the treatment plant. |
| **Justification** | The existing intake is susceptible to siltation and requires frequent maintenance. The project will allow for GWA to efficiently and safely extract Ugum water even during high silt periods and operate at low river conditions. This is a continuation of project PW 09-01. |
| Proposed Schedule | Begin Design: 2018–2019 |
| **Cost Estimate** | $2.3M |
| **Reference Documents** | WRMPU Volume 2, Section 5.5.2 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

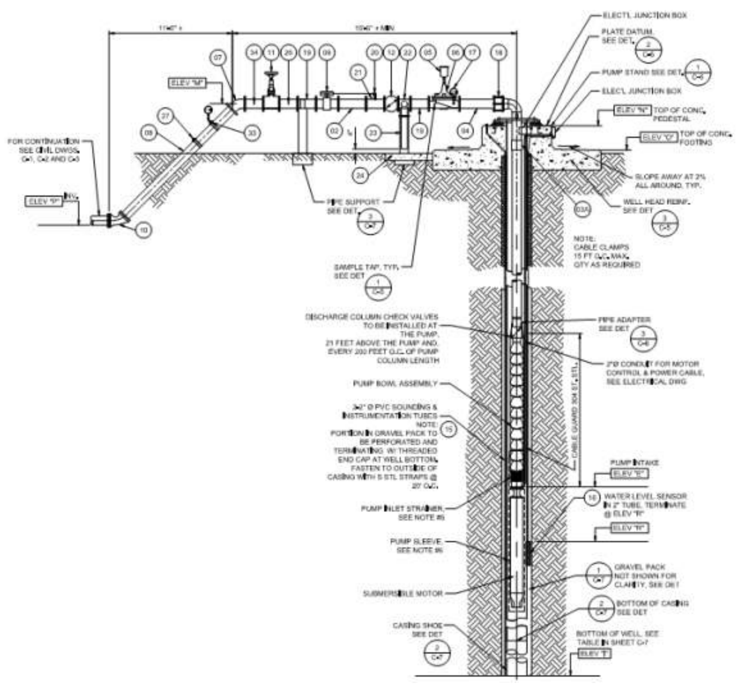
| Ugum SWTP Reliability Improvements | |
|---|---|
| **Project Number** | MP-PW-SWTP-03 |
| **Description** | Refurbishment and upgrade of existing equipment and systems at Ugum SWTP that need repair, replacement, or modification to improve plant capacity and maintain plant operability. The project will generally include the following or similar items:<br>• Add capacity at and potentially other pump improvements at the Raw Water Pump Station<br>• Enclose the Raw Water Pump Station MCC and VFDs in an air-conditioned room.<br>• Repair the SCADA communications line from the raw water intake facilities to the control center.<br>• Replace or upgrade the existing Siemens PLC for plant control<br>• Repair the No. 2 Coagulation Basin sludge collection system.<br>• Complete replacement of the membrane modules.<br>• Replace the No. 1 air compressor.<br>• Replace the backwash clarifier No. 2 collections system.<br>• Complete other plant operational improvements.<br>• Install an Ugum river stream gauge at or near the diversion structure. |
| **Justification** | The current condition of the equipment limits the plant capacity and operating flexibility and requires significant operator input to work around the marginal or non-functioning equipment. |
| **Proposed Schedule** | 2019–2020 |
| **Cost Estimate** | $1.98M |
| **Reference Documents** | WRMPU Volume 2, Section 5.5.2 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Ugum SWTP 7-Year Improvement Project | |
|---|---|
| **Project Number** | MP-PW-SWTP-04 |
| **Description** | Replacement or refurbishment of items scheduled for major overhaul/refurbishment or replacement. This is a recurring project required for plant operations. |
| **Justification** | The expected operational life of the treatment membranes averages approximately 7 years when they are due for the next expected replacement. This project would also overhaul any other major plant equipment that requires major maintenance. Expected items would be 1 or more of the raw water pumps, sludge collection mechanisms, process blowers, process pumps, chemical systems, electrical improvements, and potentially other equipment as defined at this 7-year interval. |
| **Proposed Schedule** | Begin Project: 2024 |
| **Cost Estimate** | $3.168M (every 7 years) |
| **Reference Documents** | WRMPU Volume 2, Section 5.5.2 |

*This proposed project is subject to change. Projects will generally include an engineering study, detailed design, and field verification to refine the exact project scope and budget. Costs are presented in 2017 dollars and do not account for increases due to inflation and escalation. See Volume 1, Appendix D for cost estimate assumptions.*

| Well Rehabilitation Program | |
|---|---|
| **Project Number** | MP-PW-Well-01 |
| **Description** | Rehabilitation of existing GWA water supply wells on a recurring basis. Project anticipates a rehabilitation project for 4 wells every 2 years. |
| **Justification** | Maintaining wells in operation is critical to GWA Operations. Nearly 60 wells will be more than 50 years old by 2036. More than 65 wells are also only 8-inch diameter wells. This project is intended to cover major overhaul work at all wells. The work could include new boreholes, new pumps, new drives, new piping components, updates to the electrical system, site and building improvements, etc. This project would also include new wells where abandonment of an existing well is required. GWA would select each set of wells for inclusion based on age, operational issues, capacity, criticality, etc. |
| **Proposed Schedule** | Begin Project: 2020, recurs every 2 years |
| **Cost Estimate** | $5.81M (every 2 years) |
| **Reference Documents** | WRMPU Volume 2, Section 5.4<br>Well operating and maintenance records<br>Capacity and chloride records |

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| Well Equipment Overhaul Program | |
|---|---|
| **Project Number** | MP-PW-Well-02 |
| **Description** | Repair and replace worn out equipment and structures every 15 years. This project will address routine equipment overhaul and maintenance such as pump overhaul or replacement, valves, instrumentation, chlorination equipment, electrical issues, etc. on a recurring basis. Base program includes 6 wells every 2 years. |
| **Justification** | Equipment operating in the production well environment typically has an average life expectancy of 15 years. This project will address all wells not included in the major well rehabilitation under project MP-PW-Well-01. |
| **Proposed Schedule** | Begin Project: 2022, recurs every 2 years (alternates years with project MP-PW-Well-01) |
| **Cost Estimate** | $1.5M (every 2 years) |
| **Reference Documents** | WRMPU Volume 2, Section 5.4<br>Well operating and maintenance records |


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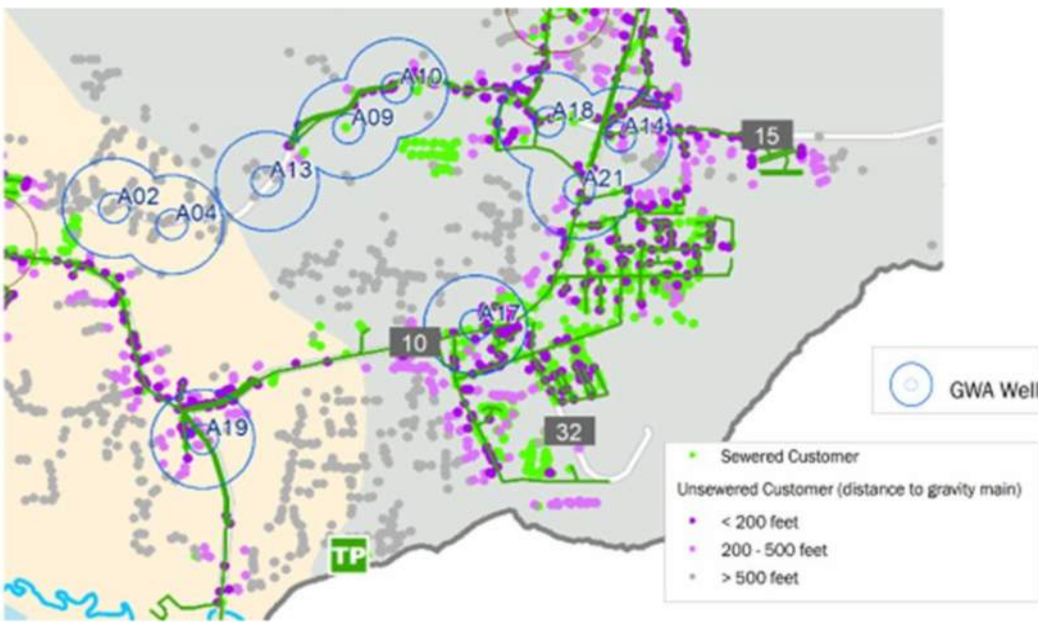
| Capacity Enhancement – Well Exploration Program | |
|---|---|
| **Project Number** | MP-PW-Well-03 |
| **Description** | Future planning project for additional water supply wells. Project will include evaluation of potential well locations based on the position in the aquifer and current and planned land use. Pilot holes will be drilled at selected locations until well locations with adequate capacity are located. These well locations will then be used for future well construction projects. It is expected that the project would identify four new viable well sites every five years based on a reduction in NRW of 10%. |
| **Justification** | New wells will be required for GWA to meet projected water demands. This project will lay out the next series of wells to be developed under the well development projects. The future planning will allow GWA to select the best location for wells and obtain the required property for the proposed wells in advance of the design and construction projects. |
| **Proposed Schedule** | Begin Project: 2019, recurs every 5 years |
| **Cost Estimate** | $1.2M (every 5 years) |
| **Reference Documents** | WRMPU Volume 2, Section 5<br>NGLA Maps<br>Land Use and Zoning Maps<br>WERI Reports |

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| Capacity Enhancement – Well Development and Construction Program | |
|---|---|
| **Project Number** | MP-PW-Well-04 |
| **Description** | Construct 13 new water supply wells by 2037. The estimated well quantity is based on achieving a 10% reduction in NRW. The new wells will be constructed at locations as determined under project MP-PW-Well-02. It is expected that the average capacity of the new supply wells would be 300 gpm. Each project will develop an average of 2 wells. |
| **Justification** | Additional water supply will be necessary primarily in Northern Guam to meet the project water demands through 2037. This project allows GWA to construct wells as demand increases and in areas where the capacity is required. |
| **Proposed Schedule** | Begin Study: 2022, recurs every 3 years |
| **Cost Estimate** | $4.58M (every 3 years) |
| **Reference Documents** | Potential well locations determined under MP-PW-Well-02. |

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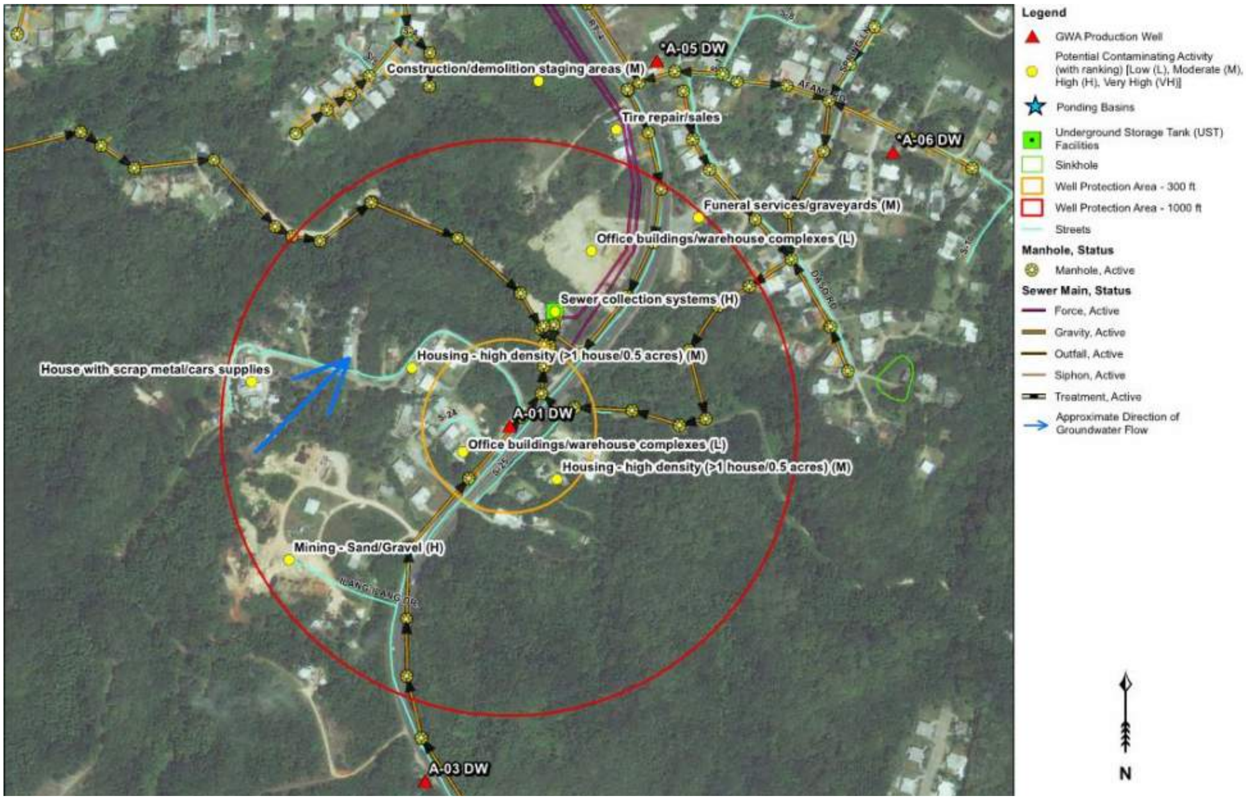
| Wellhead Protection Program | |
|---|---|
| **Project Number** | MP-PW-Well-05 |
| **Description** | Implementation of the Wellhead Protection Plan including:<br>• Abandonment of up to 11 wells. Some wells in the GWA system have been abandoned and need to be properly capped and abandoned per Guam EPA requirements<br>• Land purchase to control land use within the wellhead protection areas.<br>• Development and implementation of a contingency plan for water supply.<br>• Properly securing and decommissioning exploratory boreholes and abandoned wells.<br>• Extending collection systems to facilitate the elimination of septic/cesspool properties currently located within wellhead protection zones.<br>• Point source management, and financial support for spill prevention and response programs within wellhead protection zones.<br>• Public education and outreach, postings, and signage identifying wellhead protection areas<br>• Increased involvement by GWA personnel to advocate for the implementation of existing water resources protection codes and regulations and enforcement of existing zoning requirements that restrict location of new high-risk PCAs, such as onsite sewage disposal systems or ponding basins within designated distances from a water supply.<br>• Increased involvement by GWA personnel in the Territorial land use planning, and permit review process to ensure that concerns involving the protection of the drinking water source are addressed prior to permitting of new land uses within wellhead protection zones.<br>• Increased involvement by GWA personnel with developers at the planning stage to ensure that easements exist, land for infrastructure is assigned, and the wellhead protection plan is adhered to.<br>• Implement study to evaluate options to connect existing sewer customers near existing sewer lines. Study should include reviewing methods of financial assistance for the homeowner with the connection costs as well as looking at options for enforcement of the regulations requiring connection. |
| **Justification** | A Drinking Water Source Assessment and Protection (DWSAP) Program and Wellhead Protection Plan (WHPP) was completed in 2015. The DWSAP program was prepared in accordance with the 1996 reauthorization of the federal Safe Drinking Water Act (SDWA), which requires states and territories to develop comprehensive programs to assess sources of drinking water to determine system susceptibility to identified sources of contamination and ensure that related information is publicly available. The DWSAP and WHPP lay the foundation for protection of GWA-supplied water quality from contamination in northern Guam. The OneGuam Framework for DOD and GWA system integration includes budgeted funding for wellhead protection.<br>The existing abandoned wells are potential contamination sources as they provide a direct path from the surface to the aquifer below and need to be properly closed. |
| **Proposed Schedule** | Ongoing |
| **Cost Estimate** | $660,000 every 3 years |
| **Reference Documents** | WRMPU Volume 1, Section 5.2.6<br>2015 Guam Drinking Water Source Assessment and Protection Program and Wellhead Protection Plan<br>WRMPU Volume 2, Section 5.4.3IV for Abandoned Wells |

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| Well Repair Program | |
|---|---|
| **Project Number** | MP-PW-Well-06 |
| **Description** | Many of GWA's wells are nearing their design life and repairs are necessary to maintain the wells in operation until a major rehabilitation project can be completed for the well. This project will cover items described in Table 5.3 as well as correct any other well deficiencies such as correcting well production meter installations. This project will also cover urgent equipment repair/replacement needed at any wells to continue their operation.<br>Project anticipates completing the identified repairs in 10 years. Following the repairs future rehabilitation will be completed under projects MP-PW-WELL-01 and MP-PW-WELL-02. |
| **Justification** | Maintaining wells in operation is critical to GWA Operations. This project is intended to cover current immediate repair needs identified in various well inspection projects. |
| **Proposed Schedule** | Begin Project: 2018; Target Completion: 2028 |
| **Cost Estimate** | $1.3M annually for 10 years |
| **Reference Documents** | WRMPU Volume 2, Section 5.2<br>Well operating and maintenance records |

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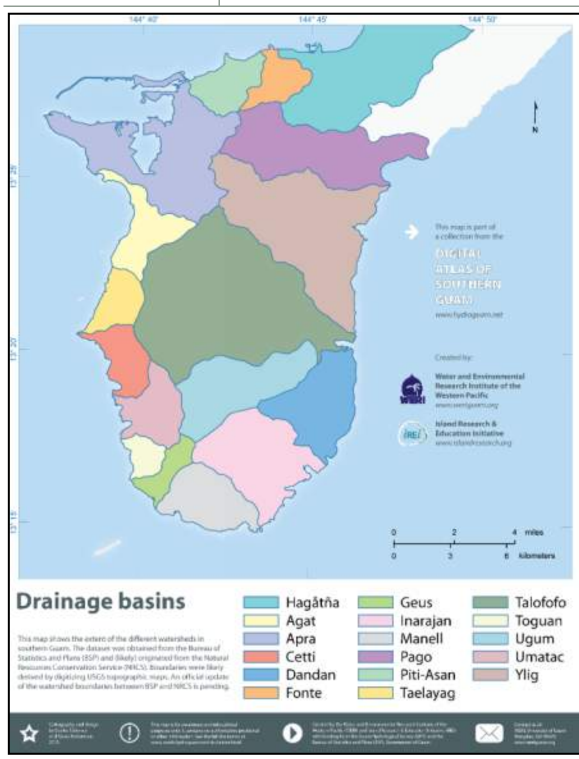
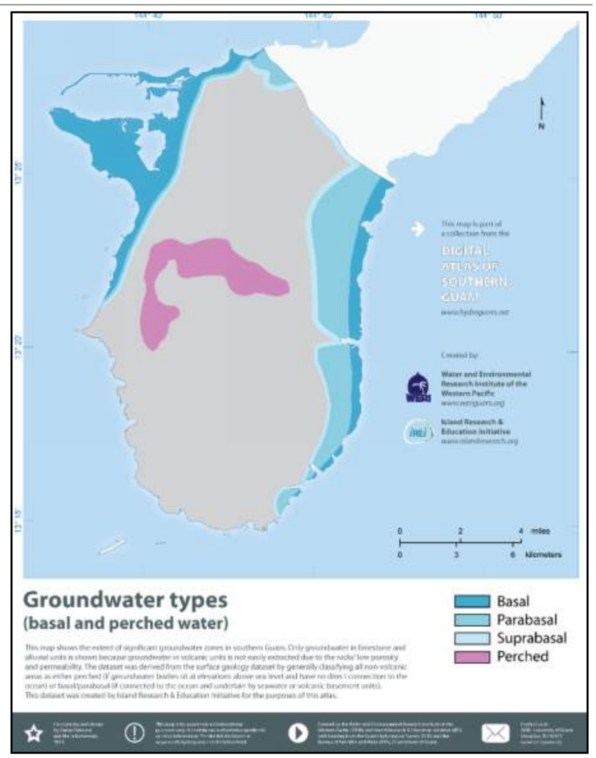
## 12.5 Other Water Projects

| South Guam Water Supply Study | |
|---|---|
| **Project Number** | MP-PW-Misc-01 |
| **Description** | A detailed study of options to deliver adequate and reliable water supply for South Guam (including maximizing output from the Ugum SWTP). |
| **Justification** | The study will examine options to increase the quantity and reliability of water supply to south Guam. Project components will include:<br>• Analysis of historical water sources and evaluation of the development or re-development of southern spring, ground, and surface water resources (including Laelae spring, Geus river, Silgin spring, Malojloj wells, Tolayeus diversion, etc.).<br>• Analysis of impact of transporting water (with transportation costs, estimated losses, and impact on production) from central or north Guam including the ongoing analysis for “closing the loop” from Agat to Umatac.<br>• Analysis of impact of water loss control efforts and strategic raw/treated water storage on supply and distribution including pipeline replacement.<br>• Analysis of alternate sources to supply water to the Ugum SWTP with the intent of maximizing Ugum production capabilities. Options include a new diversion or reservoir on the Talofofo River and a raw water reservoir on the Ugum river.<br>• Feasibility study for long-term utilization of Fena Reservoir treated and/or raw water supply.<br>• Suggestions for contingency planning in South Guam, including 1.2 oversupply capability for system resilience.<br>• Cost-benefit analysis/business case evaluation for preferred option(s), including preliminary estimates for land, permitting, and access. |
| **Proposed Schedule** | Begin Study: 2018 |
| **Cost Estimate** | $450,000 |
| **Reference Documents** | WRMPU Volume 1, Sections 5.3 and 5.5 |

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| Master Meter Implementation and Ongoing Meter Replacement | |
|---|---|
| **Project Number** | MP-PW-Misc-02 |
| **Description** | A study to select master meter locations. Following the study, installation of the master meters will continue. This project will also continue replacement of any old, underperforming and broken meters, customer and production meters. This project also includes the continuation of the water meter improvement program and its components |
| **Justification** | Master meters are needed to help find and reduce non-revenue water and for the hydraulic model. Continued improvement in water metering will help address the current non-revenue water rate. This project is a partial continuation of previous projects PW 05-07 and PW 05-16. |
| **Proposed Schedule** | 2019–2024 |
| **Cost Estimate** | $734,000 annually for 8 years |
| **Reference Documents** | WRMPU Volume 2, Section 9.5.4 |

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| Hydrant Condition Assessment and Maintenance | |
|---|---|
| **Project Number** | MP-PW-Misc-03 |
| **Description** | Repair and replace hydrants throughout the water system using a new three-person fire hydrant replacement and repair crew. The costs include repairing an average of 155 hydrants per year and replacing an average of 82 hydrants per year (including a combination of dry and wet barrel hydrants). |
| **Justification** | Approximately 52 percent of water system hydrants were in poor or extremely poor shape as of a condition assessment in 2013 and 2014. The hydrants need to be repaired or replaced and a program needs to be instituted to continue to perform condition assessment and maintenance on all hydrants. This is a continuation of project CIP PW 14-01. |
| **Proposed Schedule** | Annual – Starting in 2022 |
| **Cost Estimate** | $531,000 per year for repair for 10 years<br>$970,000 per year for replacement for 5 years |
| **Reference Documents** | WRMPU Volume 2, Section 10 |

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| OneGuam Program | |
|---|---|
| **Project Number** | MP-PW-Misc-04 |
| **Description** | In conjunction with the DoD, studies in accordance with the OneGuam System Integration Action Plan. The following are recommended:<br>• Feasibility study to determine potential for a singular, unified water utility.<br>• Combined water system model.<br>• Strategic plan for the movement to a combined water utility.<br>• Rate study based on a combined utility. |
| **Justification** | Investigative work is necessary to pursue the objectives of the OneGuam concept, which consists of a potential integration of DoD and GWA water resources and water system facilities. |
| **Proposed Schedule** | 2018–2028 |
| **Cost Estimate** | $50,000/year |
| **Reference Documents** | WRMPU Volume 2, Section 11.1 |

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| Leak Detection Assistance | |
|---|---|
| **Project Number** | MP-PW-Misc-05 |
| **Description** | This project will provide assistance to GWA's Leak Detection program and allow an outside professional services contract for leak detection if necessary. The project may also include the purchase of leak detection equipment and provide training in leak detection methods, equipment, and water system analysis tools that aid in leak detection capability. |
| **Justification** | Reduction of non-revenue water is a GWA priority. A contractor will help GWA to find and eliminate the sources of non-revenue water and continue to train GWA crews. Up-to-date leak detection equipment can improve the efficiency of the Leak Detection Crews. This incorporates the components of PW 05-09. |
| **Proposed Schedule** | Initial Inspection: 2020 |
| **Cost Estimate** | $385,000 (every 5 years) |
| **Reference Documents** | WRMPU Volume 2, Section 9 |

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## Section 13

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