CHAPTER 4 – WATER LOSS CONTROL

4.1 Introduction

GWA has identified significant water losses estimated at over 50 percent of total system production, or 22.4 mgd. This magnitude of water loss points to making recovering these losses a top priority along with the estimated lost revenue of $ 4.088 million per year for water produced but not delivered to a metered customer.

As an urgent step in the right direction, GWA undertook a comprehensive program to identify leaks and illegal connections to its water transmission and distribution system in 2005. This first step allows for priority activity in making known leak repairs and ceasing of illegal use that will assist GWA in optimizing its operation and recover Guam's precious water resource.

Following identification of water leaks GWA needs to initiate the second step by establishing a prioritized water loss control program to recover the water and revenue that is being lost. This second step is to be based on findings from a water distribution system audit. This audit would include estimates of apparent and real water losses for the purposes of more accurately defining priorities for controlling water system water loss as defined by the International Water Association.

There was insufficient data available to conduct a water audit at the present time. Once factors are established through additional data collection activities, GWA will be able to perform a comprehensive audit with more detailed recommendations. For example, estimates for metering inaccuracies need to be understood to baseline or create the "bookends" of (1) the system inputs through production metering testing to better understand total source of supply and (2) total metered customer demand through a statistically sampling program and better information on meter repair and replacement programs. The following section, rather than detailing the outcomes of a detailed water distribution system, provides a description of key data collected to date and provides some general guidance on next steps for additional data collection and analysis.

Several key parameters such as the Infrastructure Leakage Index and Economic Level of Leakage as defined by the *Performance Indicators for Water Supply Services (IWA, 2000)* should be calculated for each of three potable water systems as part of a comprehensive water audit. These indicators will provide the level of cost-effective main replacement and leak repair within each system. For the interim, key activities may continue on-going such as active leak detection and repair program.

The value of this water loss control program must be understood by GWA's human infrastructure and incorporated into their mode of operation going forward to provide revenue enhancement, protect the investment of GWA's clients, reduce operational costs, and achieve their best in class utility goal.

4.2 Leak Detection Program Assistance and Recommended Future Actions

The goal for reducing water losses is to (1) reduce overhead costs and (2) enhance revenue stream which will fund additional system repairs. A general overview of an overall water loss optimization program overlaps several elements of the work effort GWA and the consultant project team has already undertaken. A summary list is provided below:

- **Overhead Reduction Tasks**
  - Leakage reduction

- Hydraulic controls
- Pipe repair and replacement
- Customer service line replacement
- Condition assessment and rehabilitation
- Energy management
- Staff resources management

- **Revenue Stream Enhancement Tasks**
  - Baseline Analysis
  - Meter population management
  - Meter testing and change-out
  - Correct meter sizing and change-out
  - On-going meter testing program
  - Automatic meter reading (AMR)
- **Billing Structure, Analysis and Improvement**
  - Nonpayment actions
    - Turn off supply
    - Reduce supply to minimum
    - Legal action
    - Prepayment schemes
    - Reduction of theft, fraud from illegal connections
    - Continuous field inspections
  - Rate management
  - Customer management
  - Modeling for efficient installation (from meter setting to billing payment - walk through schematic)
  - Modeling to ensure on-going rate adjustments for economic efficiency

Additionally, one of the key areas to recover water loss, a leak detection survey has already been conducted for the south, central and north systems. However, the study report indicates that losses were identified at only 0.56 mgd within the south, central and north systems. These study findings indicate that water loss control program needs to broaden to encompass other areas of uncovering sources of water loss.

4.2.1 Recommended Priorities for System Repairs and Data Collection

There are several key areas to start to investigate to uncover quantity of water losses by type and develop a strategy for tackling the recovering the highest dollar value and highest volume of lost most quickly. One key observation is that the most expensive water loss

should be recovered first by GWA, which is the water supply purchased from US Navy. This system area though not hydraulically disconnected from the central system can be a focus area for considering the creation of a "District Metered Area" to pinpoint most quickly the key water loss control measures to implement. The following list outlines the list of tasks to optimize water losses in an approximate order of priority that may be considered by GWA:

- Source meter testing for Navy purchased (most expensive) water supply.
- Storage tank overflows in the north and central systems fed by Navy water – resolve any potential overflows by concentrating on level switch and manual checking until SCADA system repairs completed. One known location to target repairs is the Nimitz Hills Upper Reservoir.
- Source meter testing for wells in the north and central systems.
- Storage tank overflows in north and central system fed by wells.
- Night-time pressure and flow measurements for assessing background water losses from "north" and "central" systems and secondary priority for the south system leading to better pressure management and targeting water savings from Navy purchased supply.
- Repair of largest leaks on transmission mains – focus on repairing leaks in the nearby vicinity to supply connection from Navy source and work outwards with returning with routine active leak detection and expedient repairs for the central and north systems.
- Large customer meter testing (larger than 1.5-inch connections or higher than $1,500 revenue per year would be cost effective to test every 6-months and $1,000 would be cost effective to test once per year).
- Inventory of date installed (if possible) and small meter testing (estimated percent of use).
- Cross-reference with billing system accounts to audit for illegal connections.
- Identification and stoppage of water theft.
- Repair of smaller service line leaks identified from leak detection survey or meter inventory (AMR installations), recommend planned new meter replacements and AMR installation on customers nearest the Navy connection first to ensure most accurate revenue collection and data measurement.
- Use AMR readings to best understand larger customers demands closest to the feed point and concentrate water conservation efforts for saving Navy supplies (see Volume 2, Chapter 5 – Water Conservation).
- Tracking customer meter billing systems to ensure fullest revenue recovery.
- Tracking illegal connections.
- Create a protocol and implementation for follow-up on water waste calls by customers using this highest value source and have a water waste ordinance in place to allow enforcement of warnings or fines. The objective being to emphasize to GWA's customers the necessity for preserving this most costly supply source through customer and village leadership outreach. The ultimate message is reduction

of water waste which will in turn help lessen planned rate increases by being more efficient with existing supplies.

4.2.2 Leak Detection Study Results

The Water Leak Detection Team prepared a detailed report, Guam Waterworks Authority – Water Leak Detection Study on All Three Public Water System, dated September 12, 2005. The results of the study show that GWA is losing approximately 566,000 gallons/day of water which equates to approximately $1,000 per day of loss revenue. A section of the report is included in Appendix 2B. Table 4-1, Water Leak Detection Study Summary, presents a summary of the major leaks found in the water system.

Table 4-1 – Water Leak Detection Study Summary

Water System	Water Loss GPD
Central	
Turner Road/Nimitz Hill	18,150
Cabras Area	35,858
Piti Village	38,000
Illegal connection	7,880
Piti Main Village	28,000
Santa Rita Village	
Chalan Kindo – Vicinity of House #180B	28,000
Minor leaks (6)	970
Anonas Court	*
Talisay Drive/Aga Drive House #191	*
Asan Village	
Consolation Street	*
Agat Village	
North Santa Cruz St/Tomas Rivera St	72,000
Calle de los Marteres St House # 148	14,400
Minor leaks (8)	2,160
Southern	
Umatac Village	
Umatac Mayor's Office	14,400
Umatac Subdivision	1,440
Minor leaks (2)	360
Rte 4 Next to Mobil Gas Station	14,400
Rte 2 Before Ishizaki Lane	*
Merizo Village	
Espinosa/Geus Rd	1,440
Off Rte 4 Across J Cruz House # 130	14,400
Jaotan or Barcinas Housing	14,400
Rte 4 – In front of House # 1145	36,000
Rte 4 – Before the bridge after Arriola Beach	28,000
Minor leak	144
Inarajan Village	
Minor leak	180
Talofofo Village	

Table 4-1 – Water Leak Detection Study Summary (continued)

Water System	Water Loss GPD
Southern	
Enrique San Nicolas – 2nd Hydrant	1,440
Ugum 2 million reservoir valve box	720
Ugum Dam Pump #1	540
Minor leaks (3)	630
Yona Village	
Water Booster Pump Station 25	28,880
Jota Road Across House # 386	56,000
Minor leaks (4)	900
Chalan Pago/Ordot Village	
Access Road 2 defective FH Left side	1,440
Justice Monissa Lujan Road	1,440
Corner of Tun Bihue/Ramirez Drive	1,440
Main Road to Judge Sablan St behind JM Store	1,440
Rte 4 between Chalan Untalan and Chalan Laia	*
Rte 4 Chalan Asusana Front of House # 568	*
Gogue Drive Across House # 188	*
Minor leaks (4)	900
Sinajana Village	
Lemai Court front of House # 399	14,400
Minor leaks (9)	1,260
Agana/Agana Heights Village	
West O'brien Drive/Chalan Santo Papa	1,440
Padre Palomo St/Hesler Place	1,440
Minor leaks (4)	360
Mangilao Village	
Astrom Circle - Across 3MLS Bldg	1,440
Washington Dr - Across Puti Tai Nobia Lane	1,440
Main entrance Spotsa lane left side	1,440
Minor leaks (6)	1,170
Barrigada Village	
Minor leaks (10)	1,890
Hatgana and Tamunin Rte 30	
Hatgana - Ada Commercial Bldg Paradise Fitness	1,440
Pas St - Back side of Guam Premium Outlet	2,880
Minor leaks (8)	1,980
Tamuning - Governor C.G. Camacho - Rte 30- Rte 14	
Minor leaks (4)	720
Dededo - Liguan Terrace	
South Hasmin Court	180
Dededo	
East Liguan and Diseplina Court	1,440

Table 4-1 – Water Leak Detection Study Summary (continued)

Water System	Water Loss GPD
Northern	
Macheche/Dededo - Mogfog - Rte26	
Ahau Lane - House # 141D	1,440
Minor leaks (6)	1,620
Dededo - Rte3	
Minor leaks (3)	1,440
Dededo - Wusstig Road Left side	
Minor leaks (2)	720
Northern	
Dededo Village	
Minor leaks (2)	360
Dededo - Astumbo Subdivision	
Minor leaks (4)	1,800
Dededo - Ysengsong Road	
Ysengsong Road adjacent to House # 1624	1,440
Dededo - Old Kaiser - Ysengsong Road	
Minor leaks (4)	720
Dededo Village - Kaiser Housing	
Minor leaks (2)	360
Dededo Main Village	
Santa Barbara St - Ysengsong Road	*
Yigo Village	
Chalan Donne St - Across House #134	1,440
Chalan Tun Luis Takano	28,000
Rte 1 - Infront of Well Y-21A	14,880
Pacita Villa	1,440
422 Chalan Padiron Lagu	1,440
Minor leaks (10)	1,690
Yigo – Rte 9 Agafu Gumas	
Azud Ave	1,440
Yigo – Machananao	
Gill - Baza Subdivision	4,800
Total	566,302

- Follow up assessment required
- Minor leak - <1000 gpd

4.2.3 Develop Information Necessary to Complete a Comprehensive Water Distribution System Audit

The International Water Association audit format is currently being developed into an updated American Water Works Association updated Manual M36. The following section provides an outline of the Water Audit format in section by section that corresponds to the master table input values and definitions to aid in calculations in the form of a summary containing general guidelines, definitions, place-holder text and recommendations for completing this audit format. Data collected by GWA staff in 2006 that follow

recommendations listed above and pertain to specific sections listed below should be done in the future to continue to track "non-revenue" water and achievements to reduce water losses.

The following discussion and table outlines the format of an International Water Association's guidance for a water distribution system audit. Data limitations are hindering the calculation of key parameters for the water audit at the current time. As a result, the following discussion is focused on specific recommendations for gathering the necessary data to complete the water audit in the future.

Table 4-2 - International Water Association Water Audit Format[1]

<table>
<tr><td rowspan="5">Raw Water Sources
____
MGD
____
MG/YR
1</td><td rowspan="5">System Input

MGD

MG/YR
2</td><td rowspan="2">Authorized Consumption
____
MGD
____
MG/YR</td><td>Billed Authorized Consumption
___
MG/YR</td><td>Billed Water Exported 6</td><td rowspan="3">Revenue Water
____
19</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
___</td><td>Billed Metered Consumption 7</td></tr>
<tr><td>Billed Unmetered Consumption ? 8</td></tr>
<tr><td rowspan="3">Water Losses
___MGD
___%
4</td><td>Apparent Losses ? 12</td><td>Unbilled Metered Consumption 10</td><td rowspan="3">Non-Revenue Water

_____
20</td></tr>
<tr><td rowspan="2">Real Losses
_____</td><td>Unbilled Unmetered Consumption ?11</td></tr>
<tr><td>Unauthorized Consumption ? 13
Customer Metering Inaccuracies 14
Leakage on Mains 16
Leakage and Overflows at Storages 17
Leakage on Service Connections up to Customer Metering 18</td></tr>
</table>

Note: ***Leakage – miles of pipe by density of connections – I have tables that you can measure leakage and losses by leaks on laterals.
1. Source: AWWA Journal Volume 95:8. August 2003. Peer-Reviewed. Committee Report: Applying worldwide BMPs in Water Loss Control.

Future GWA Activities:

The following subsections will need to be updated and Table 4-2 above completed by GWA upon completion of a Comprehensive Water Distribution System Audit. The following subsections provide more detailed definitions per each area of the water audit and recommendations for next steps in data collection.

4.2.3.1 *Raw Water Sources/System Input*

- *Sum of all potable water entering the system that includes the well stations, reservoirs tunnels, shafts and other sources adjusted for transmission system losses, meter accuracy, and downstream diversions. Average daily pumpage for 2005 was 43.34 mgd.*

Adjustments:

- *Contributions from reservoirs for this audit have not been included from the study because the telemetered data were missing or in some cases reading above the flowmeter readings and in some cases under registering.*
- *The recommendation for 2006 is to complete one cycle of checking all facilities throughout the island to gather baseline information for future years. This may need to be performed by consultant staff. Secondly, a regular source meter calibration program needs to be developed, adopted and implemented preferably by the GWA staff.*

- *Meter inaccuracy has not been determined on the average through calibration factors used on models, though a small pilot may compare the telemetered data (SCADA) with ultrasonic and magnetic flow tests at the facilities when the SCADA system is back operational. The typical estimated differences can range up to +/- 5% to 10%. These validations have not been completed by GWA. Upon completion of this evaluation/calibration the following information will be collected:*
  - *The average meter readings that are under registering are about ___% and the average percent of over registering is ___%. It is difficult to apply this across the island because each well station contributes different amounts of flow that range from ___ gpm pumps to some as large as ___ gpm.*
  - *Expressing the magnitude of potential impact of source meter information, the apparent loss of the over and under registration of meters is applied across the board and results in the following:*
    - *Under registered source meter flow = _____ mgd*
    - *Over registered source meter flow = _____ mgd*

4.2.3.2 Authorized Consumption

The authorized consumption is the sum of all billed and unbilled authorized consumption, including GWA use, fire flow and other identified uses.

4.2.3.2.1 Billed Authorized Consumption. Billed water exported and billed metered consumption (including estimates for inaccuracy in residential meter readings and in large meter readings based on a testing protocol.

- *Total billed authorized consumption from GWA is 21mgd for 2005.*
- *Does not include reservoir fill and depletion rates/quantities for this audit. The assumption is made that these fill and depletion rates will balance each other out.*
- *Distribution water loss without adjustments is 22.34 mgd or 51.5%.*

Adjustments:

- *Meter accuracy*
  - *Residential meter error +/- ___% due to the accuracy of AMR and the age of the meters – majority under ___ years of age)*
  - *Large meter error +/- ___% (partially due to age to human error in reads) and have approximately _____ large meters that make up about ___% of GWA consumption flow.*
  - *Recommendation is to continue to communicate with the _____ manager for large meters and work to establish meter accuracy.*
- *Expressing the magnitude of potential impact of meter accuracy, the apparent loss of the over and under registration of residential and large meters is applied across the board and results in the following:*
  - *+ / - ___ mgd (residential ___ mgd + large _____ mgd)*

4.2.3.2.2 Billed Unmetered Consumption. None on record of knowledge.

4.2.3.2.3 Unbilled Authorized Consumption

4.2.3.2.4 Unbilled Metered consumption

- *GWA facilities = _____ / year*
- *Others = ___ mg / Year*
- *Total = ___ mg / Year*
- *Some special rate customers are labeled as free service and will continue to be tracked and documented for water audit purposes.*
- *There are other known situations of unbilled and unmetered service as in the case of the ___ industry or military uses. To date, GWA has not registered or documented any of this use.*
- *Recommendation is to issue out a policy from the consultant team that all water is to be metered regardless if the service is free. The customer will need to be issued a meter just like a contractor would. This is a quick and economical recommendation using the procedures developed by other utilities as examples for issuing out temporary meters.*

4.2.3.2.5 Unbilled Unmetered Consumption. The sum for unbilled unmetered consumption is estimated use from GWA facilities (including hydrant and pipeline flushing) and certain fire fighting and training uses. Fire department water use should be estimated in MG/YR.

- *Recommendation is to meet with fire chief and communicate the need for all battalions to track their water usage and explain the purposes of the audit.*
- *Pipeline Flushing (low confidence in these values) – estimated in MG/year. GWA followed the Water System Operator requirements for flushing water lines at 2.5 ft/s and estimated the duration of the flush as indicated on the records to be 6 hours each day for 3 consecutive days. Recommendation is to ultimately have each flush metered. In the interim: have each inspector at the job take notes on the actual duration of the flush and estimated gpm through inspection or through a meter if possible.*
- *There are also mains that are flushed regularly for water quality reasons. These flushes are not measured.*
- *Recommendation is to have each main that is flushed regularly be logged down by the person opening and closing the valve. A staff from GWA is to schedule a date to go out there when the particular main is being flushed and should measure this flow and apply the flowrate each time the main in flushed (monthly, weekly ,etc.)*

4.2.3.3 Water Losses

Sum of all apparent losses, including unauthorized consumption from theft and meter inaccuracy, plus all real losses from distribution system overflows and leakages (i.e. mains, storage tanks, laterals, service connections, etc.) up to the customer meter.

4.2.3.3.1 Real Losses. Real Losses equal the sum of all unbilled water uses whether accounted for or not; includes estimates of known losses such as leakage from open-cut reservoirs and other facilities, reservoir overflows, unavoidable pipeline leakage, and service and main breaks. The term "water loss" replaces a portion of the previous "unaccounted-for-water" terminology used in historic statistical reports.

4.2.3.3.2 Leakage on Mains. Leakage on mains equals the sum of all water losses due to transmission and distribution pipeline leakage and breaks.

- *Estimated # of non-visible leaks (high confidence) totaling an estimated losses in MG/YR. This includes lateral leaks as well as distribution main leaks.*
- *Estimated losses from main failures (high confidence in the values) in MG/YR. Using Greely formula and have tested this in situations where could compare with SCADA data. The recommendation is to roll out the main failure process of collecting auditing values to all three water systems.*

4.2.3.3.3 Leakage and Overflows at Storage Reserviors. Sum for leakage and overflows at storage reservoirs is total estimated or measured water loss from storage tanks and terminal storage reservoirs. Record documented events estimated in MG /YR (between data on reservoir levels started to drop and estimated isolation time).

4.2.3.3.4 Leakage on Service Connections up to Customer Meter. Estimated and measured water loss on laterals from main to customer meter.

For this calendar year, these lateral leaks are included in the total for leakage of mains and not separated out. Recommendation: Retrieve a baseline of how much lateral leaks contribute to overall leakage in the system, and target the central area with a high number of large meters using Navy purchased water and estimate how much leakage is detected on the laterals vs. distribution mains and will conduct a similar test in a residential area.

Total Real losses = _____ MG / YR

4.2.3.3.5 Apparent Losses. Sum of all losses due to customer meter error or theft from measured and estimated values. Replaces a portion of the previous "unaccounted-for-water" terminology used in historic statistical reports.

- *Unauthorized Consumption – sum of all unauthorized use from theft including illegal taps, unmetered fire hydrant use, and hydrant openings. This has not been addressed at this time. GWA does know that there are unauthorized taps out there. If GWA can get someone to verify where these taps are, then consultant team could do some estimates on volume and revenue losses.*
- *Customer Metering Inaccuracies – estimated water loss due to meter error adjustments.*
  - *Residential meter error (____% AMR and ___% non-AMR)*
  - *Large meter error ___%-___%*