IV. GROUND WATER MONITORING AND ASSESSMENT

A summary of Guam's ground water monitoring and protection programs, ground water quality, ground water contamination sources, and groundwater/surface water interactions is provided in this section. The EPA 1997 guidelines, *Section 5, Ground Water Assessment* were used to report ground water monitoring data per the 2006 IR Guidance.

A. Overview of Ground Water Contamination Sources

1.0 Hydrogeology

Guam is comprised of two sub-equally sized hydrogeologic provinces. In the southern half of the island, fresh groundwater occurs in weathered volcanic rock of low permeability, unconsolidated sediments within river drainages, and along the eastern coast's fringing limestone formations. The water table in the southern province reaches elevations of hundreds of feet above sea level in the volcanic rock and unconsolidated sediments. Other than a few springs, groundwater production in southern Guam is restricted to the narrow fringing limestone along the eastern coast, where the water table rarely reaches elevations greater than a few feet above sea level. Brackish to saline groundwater occurs along the southern and western coasts of the southern province within fractured limestone, artificial fill, and unconsolidated marine and estuarine sediments.

The northern half of the island is comprised of a limestone plateau bounded on the west, north and east by near-vertical cliffs and fringing reefs and on the south by the Adelup Fault that stretches from Adelup to Pago Bay. Groundwater in northern Guam is contained within the aquifer termed the "Northern Guam Lens" (NGL). This aquifer was designated a "principle source aquifer" in 1978 by the U.S. Environmental Protection Agency, and is essentially the groundwater source for the island. The aquifer is contained within a fractured carbonate complex ranging in age from Tertiary to Pleistocene (Tracey, 1962). The carbonate rock sequence has been significantly altered by tectonic and geochemical processes that have resulted in the formation of multiple stages of porosity and permeability. The resulting aquifer is therefore comprised of primary porosity and dissolution features of varying scale, both of which have been modified and/or enhanced by fracturing.

Guam's northern limestone plateau was deposited subaqueously as a result of down faulting along the Adelup fault and is underlain by nearly impermeable volcanic rock that is exposed at the surface in southern Guam. The limestone plateau reaches thicknesses of approximately 1000 feet and extends below sea level over most of its extent. As a result sea water has intruded into the island producing a layer of saltwater that overlies the volcanic rocks and extends into the limestone plateau. Guam's fresh groundwater is contained in a modified Ghyben-Herzberg lens system underlying most of northern Guam, having been formed by infiltrating rainfall that collected on top of the more dense saltwater. The NGL has been estimated to be capable of supplying 60 million gallons per day (60 MGD) of fresh water (Camp, Dresser, and McKee, 1982). The aquifer is divided into six sub-basins, containing 47 management zones (Camp, Dresser and McKee, 1982).

The NGL has been formed from surface recharge in northern Guam percolating through soils to the underlying limestone where it accumulates in a lens, which "floats" on and displaces the denser seawater. A recent study has documented the dynamics of fresh water lens response to short- and long-term recharge events. The study, to be published soon, is an attempt to more clearly define the percentage of recharge that remains in storage within the NGL and is available for production as drinking water. The moderate to high permeability of the limestone permits the ready flow of fresh water toward areas of discharge along the coast. Mixing of fresh and saltwater at the base of the lens produces a transition zone in which groundwater becomes progressively more saline downward and seaward.

Groundwater that occurs in the manner described above is called *"basal"* groundwater, and results in a water table that rarely exceeds approximately ten feet elevation. Most groundwater in the NGL is present under these conditions. Where infiltrating precipitation encounters the volcanic basement at elevations greater than approximately ten feet, the resulting groundwater rests upon the impermeable volcanic rock and *"parabasal"* conditions exist. Groundwater under these conditions can be produced without significant threat of salt water intrusion. The NGL is the selected aquifer for this assessment due to the abundance of excellent drinking water it contains, the large demand placed on the water from this unit, and its obvious vulnerability.

2.0 Sources of Ground Water Contamination

Table B9, Appendix B identifies the following ten contaminant sources as the greatest threat to Guam's ground water quality. "Professional judgment" was used to complete the respective table. Each source of groundwater contamination is associated with factors considered in its selection and a contaminant(s).

- **animal feedlots**
- **fertilizer applications`**
- **pesticide applications**
- **underground storage tanks**
- **landfills**
- **septic systems/cesspools**
- **hazardous waste generators**
- **pipelines and sewer lines**
- **salt water intrusion**
- **urban runoff**

The two most common factors considered in the selection of these contaminant sources were human health and/or environmental risk (toxicity) and location of the sources relative to drinking water sources. The common contaminant in six of the ten sources was "nitrate".

2.1 "Protecting and Restoring Guam's Waters" – *water resources protection and restoration, and pollution prevention approach*

In September 1999 Guam EPA documented its overall approach for managing water resources on Guam. This document, entitled "*Protecting and Restoring Guam's Waters*", identified the most significant threat to Guam's water quality as **development without adequate infrastructure support.** It further stated that such development "leads to a high density of septic systems over a high permeability substrate, an insufficient and poorly maintained sewage treatment system, erosion problems from poorly managed construction projects, groundwater well over-production, and groundwater impacts from inadequate environmental practices of poorly managed light industries."

This document identified its list of on-island sources of water pollutants which included:

X inadequate domestic waste water treatment (sewage treatment plants and septic tanks/leaching fields) contributing to elevated levels of bacteria and nitrates in our groundwater;
X urban storm water runoff, particularly in the north, contributing to nutrients in our near shore waters;
X unconfirmed sources contributing to elevated levels of TCE and TCA (solvents and degreasers), PCE (dry cleaners and degreasers); thallium (insecticides); and EDB (pesticides) in groundwater;
X aquaculture facilities and golf courses contributing to elevated nutrients and pesticide levels;
X accidental spills of pollutants and hazardous materials from sites with inadequate spill prevention control countermeasure plans;
X leaking above and under ground storage tanks and associated pipelines;
X construction without adequate erosion and sediment control measures;
X wildfires, and off-road vehicle use, particularly evident in the south, causing excess siltation, turbidity and sedimentation;
X leachate from landfills and agricultural runoff;
X past activities on military sites;
X recreational water craft, including jet-skis, which are damaging marine life; and
X inadequate enforcement.

The only difference between these two lists (of sources of water pollutants) was "salt water intrusion".

B. Overview of Guam's Ground Water Protection Program

Guam EPA manages different environmental programs which serve to protect ground water resources. Most programs are fully established but undergo continuous revision based on changes in statutes or regulations or to maintain effective control measures. **Table B10, Appendix B** summarizes the status of ground water protection programs in Guam. Related information is available at **www.guamepa.govguam.net.** Information about Guam's key ground water protection programs are presented in the following.

1.0 Northern Guam Lens Study

It has been long recognized that the NGL supply needed protection and in 1978 the groundwater lens in northern Guam was defined as a "sole source aquifer," by the EPA Administrator under Section 1424(e) of the Safe Drinking Water Act (SDWA).

In order to properly protect this "sole source aquifer", it was necessary to define the range or extent of the aquifer, the types of protection and/or controls needed, and the type of management system needed to monitor, control, develop, and protect this resource.

In 1979 Guam EPA initiated the Northern Guam Lens Study (NGLS), which was completed in December 1982. This study sufficiently defined the range or extent of the aquifer and the types of protection and/or controls needed. It also outlined the framework necessary for Guam EPA to implement the type of management system needed to monitor, control, develop, and protect this resource. This 21-year old study is still in use.

The Northern Lens Study concluded the following:

a. The aquifer and its recharge areas cover almost the entire northern half of the island and are divided into six major sub-basins based on the volcanic subsurface topography. These sub-basins are further divided into 47 management zones, which could provide an estimated sustainable yield of 59 million gallons a day.

b. The lens contains very high quality water but needs to be protected against both contamination from percolation of surface pollution through the very permeable soils and salt-water intrusion due to over-pumping of the lens.

c. The management system defines the necessary data to be collected, construction practices, the operation and maintenance practices needing modification, and the required legislative and legal measures that should be developed to properly implement the program.

2.0 Ground Water Legislation, Statutes, Rules, and/or Regulations

The statutory authority for water resources management programs fall under the provisions of 10 GCA, Chapter 46 (Water Resources Conservation Act). This and other pertinent rules and/or regulations can be found at **www.guamepa.govguam.net/regs/index.html**.

Public Law 24-247 provides matching funds to continue river gauging and the performance of salinity monitoring and water level measurements within the lens by the Department of Interior, USGS Water Data Management Program for Guam.

The Guam Hydrologic Survey Program (GHS) was mandated by the 24th Guam Legislature in October, 1997. Under the program, WERI has been charged with the responsibility to consolidate, inventory, and evaluate all of the current and historical

hydrologic data pertaining to Guam. WERI is also responsible for establishing and maintaining a permanent data library for instant data access and retrieval.

3.0 Wellhead Protection Program

Provisions for wellhead protection were adopted as part of the reauthorization of the Safe Drinking Water Act (SDWA), signed into law in June 1986. The legislation established a nationwide program to encourage states to develop systematic and comprehensive programs within their jurisdiction. Such programs were intended to protect water supply wells and well fields from all sources of anthropogenic contamination. Program submittals to EPA were due by June 19, 1989. Wellhead protection regulations have been revised as recently as March 4, 1993.

4.0 Underground Injection Control (UIC) Well and UIC Permitting Program

The only type of injection well in Guam is the Class V well used primarily for drainage of storm water runoff. All injection wells in Guam have been issued permits and are inspected annually. At present, there are two hundred ninety-four (294) permitted wells. The breakdown of ownership is as follows:

1.	Andersen Air Force Base (USAF)	103
2.	Guam International Airport Authority (GovGuam)	31
3.	Department of Public Works (GovGuam)	46
4.	Guam Power Authority (GovGuam)	2
5.	University of Guam (GovGuam)	1
6.	Pacific Island Club (Private)	1
7.	Atkins Kroll (Toyota)	10
8.	Teleguam Holding, Inc. (GTA)	6
9.	Nissan Motors	3
10.	Mobil Oil Guam	6
11.	Other private permittees	85

The Guam EPA's Water Resources Management Program conducts annual compliance inspections to

- verify if the site or location of injection wells conform with its operating permit requirements and conditions;
- assure adequate maintenance of the wells to prevent groundwater contamination; and
- identify discrepancies or deficiencies between the inspected well and its permitted requirements and conditions.

A UIC permit is required for anyone who has constructed a well used primarily for drainage of storm water runoff. The permit provides a means of tracking all injection wells and insuring, through inspection, that such wells are properly maintained. Recent concern has developed over the proliferation and extensive use, in the last 10 years, by commercial establishments to contain stormwater runoff within its boundaries. These drainage systems, because of their configuration and purpose, are now considered injection wells requiring a UIC permit.

4.1 Underground Injection Control Monitoring

Guam EPA's UIC program has a Permit-driven water quality monitoring requirement for UIC well/system owners. As of September 2005, there were 34 UIC well owners operating a total of 294 individual wells/systems. With the exception of one UIC owner, the remaining UIC wells/systems are located over the northern Guam lens.

Table 24. UIC Sampling Parameters

	Chemical	MCL (mg/l)		Chemical	MCL (mg/l)
1.	MBAS	0.5	**11.**	Lead	0.015
2.	Oil and Grease*	N/D	**12.**	Benzene	0.005
3.	NO_3-N	10.0	**13.**	Ethylbenzene	0.7
4.	Endrin	0.002	**14.**	Xylene	10.0
5.	Lindane	0.0002	**15.**	Toluene	1.0
6.	Toxaphene	0.003	**16.**	Boron	5.0
7.	2, 4-D**	0.07	**17.**	COD	50.0
8.	2, 4, 5 -TP Silvex***	0.05	**18.**	pH	6.5-8.5
9.	Heptachlor	0.0004	**19.**	MTBE	0.02
10.	Methoxychlor	0.04			

***** Not Detected using 0.05 ppm MDL ****** 2,4 - Dichlorophenoxyacetic Acid
MCLs are based on the most current Guam Water Quality Standards.

The UIC well/system owners are required to perform water quality monitoring sampling semiannually on 19 chemicals. The owners are required to grab the first set of samples during the first significant rainfall between the months of April and July which represent the end of the dry season and the onset of the rainy season. This sampling event is scheduled during this period as a way of capturing the illusive *first flush.* The second set of samples is grabbed between the months of October and December which are the last three months of the rainy season. The 19 chemicals of concern and their respective MCLs are listed in **Table 24**.

5.0 Ground Water Assessment Monitoring

An ambient ground water monitoring system has been established for Guam ground water under Guam EPA. Pump rates and chloride concentrations of all production wells are currently being monitored. Guam EPA has been attempting to establish a monitoring well network that would allow the Agency to monitor lateral and vertical salinity trends within the aquifer.

This assessment monitoring program is an annual evaluation of groundwater chemical, physical and yield characteristics to track trends within the Northern Aquifer – the principal potable water supply resource for the island. The program is a judgmental sampling design which incorporates a sampling frequency based on Guam's two index periods. The sampling frequency is one sample event per production well (Total of 110)

per index period, resulting in a total of 220 samples per calendar year for each resource unit. Resource units are then rotated through a four year cycle.

The first index period on Guam is a dry season, which occurs from January through June. The island's wet season, July through December, makes up the second index period.

The goal of this program is specifically to provide the Guam EPA with baseline water quality data, to characterize and define trends in the, chemical, physical and yield conditions of the island's primary groundwater supply. It is also designed to identify new or existing water quality problems and to act as a triggering mechanism for focused studies, investigations, inspections and enforcement, or other appropriate actions by the Agency.

The specific objectives of this program are to:
1) Identify, document and predict the conditions of Guam's water resources; assist in determining the status of the aquifer's "environmental health".
2) Document potential problem areas;
3) Identify water quality changes over time in aquifer subbasin water bodies;
4) Provide information to managers, legislators, agencies and the public;
5) Determine the proportion of the state's water bodies that meet water quality criteria.

To meet its environmental goals and objectives, this program integrates a combination of chemical, physical, and yield indicators to monitor and assess site specific water quality conditions and aquifer long term water quality trends.

The general list of Indicators is listed below, with a complete list in **Table C5, Appendix C.**

- General water chemistry (chlorides, nitrates)
- Organic and Inorganic Constituents
- Physical Parameters (Water Level, Yields)

Another component of this plan is the Production Well chemical monitoring required as part of the Safe Drinking Water permits for a Public Water Supply System (PWSS). The schedule on the previous page, **see Table 25**, is an example for Organic and Inorganic Monitoring preformed by the PWSSs. This data is also used to track trends and provide data for more detailed investigations.

6.0 Man-Made Impoundment Monitoring

The Man-Made Impoundment Monitoring Plan primarily evaluates chemical data sampled from man-made impoundments very much like the UIC plan. **Table 26** presents the locations and schedule for surface impoundment (i.e. ponding basins) sampling. At present, this plan focuses on surface impoundment impacts to groundwater. This plan will be extended to the surface impoundments of Southern Guam that affect surface water quality of receiving streams and other water bodies.

Table 25. Groundwater Source & Water Distribution System: Organic & Inorganic Sampling Schedule

2006	GWA/Earth Tech Production Wells	GWA Water Distribution System
1st Quarter	A-1, A-2, A-3, A-4, A-5, A-6	Agana Heights Mayor's Office
2nd Quarter	D-2, D-3, D-4, D-5, D-6, D-7	GWA Laboratory, Dededo
3rd Quarter	F-2, F-3, F-4, F-5 F-6, F-7	Northern District Sewage Treatment Plant
4th Quarter	M-12, M-14, M-15, M-17a, M-17b, M-18	Mangilao Mayor's Office
2007	**GWA/Earth Tech Production Wells**	**GWA Water Distribution System**
1st Quarter	A-7, A-8 A-9, A-10, A-11, A-12	Sinajana Mayor's Office
2nd Quarter	D-8, D-9, D-10, D-11, D-12, D-13	Merizo Mayor's Office
3rd Quarter	F-8, F-9, F-10, F-11, F-12, F-13	Finegayan Elementary School
4th Quarter	M-20a, M-21, M-22, M-23, MJ-1, MJ-5	Inarajan Middle School
2008	**GWA/Earth Tech Production Wells**	**GWA Water Distribution System**
1st Quarter	A-13, A-14, A-15, A-17, A-18, A-19	Piti Mayor's Office
2nd Quarter	D-14, D-15, D-16, D-17, D-18, D-19	Umatac Mayor's Office
3rd Quarter	F-15, F-16, F-17, F-18, F-19, F-20	Tamuning Mayor's Office
4th Quarter	NAS-1, Y-1, Y-2, Y-3, Y-4, Y-5	Santa Rita Spring
2009	**GWA/Earth Tech Production Wells**	**GWA Water Distribution System**
1st Quarter	A-21, A-23, A-25, A-26, A-28, A-29	Barrigada Mayor's Office
2nd Quarter	D-20, D-21, D-22a, D-23a, D-24, D-25	Agueda Johnston Middle School
3rd Quarter	GH-501, H-1, HGC-2, M-1, M-2, M-3	Toto Mayor's Office
4th Quarter	Y-6, Y-7, Y-9, Y-10, Y-12, Y-14	Yigo Mayor's Office
2010	**GWA/Earth Tech Production Wells**	**GWA Water Distribution System**
1st Quarter	A-30, A-31, A-32, AG-1, AG-2a, D-1	Asan Mayor's Office
2nd Quarter	D-26, D-27, D-28, EX-5a, EX-11, F-1	Yona Mayor's Office
3rd Quarter	M-4, M-5, M-6, M-7, M-8, M-9	Talofofo Elementary School
4th Quarter	Y-15, Y-17, Y-18, Y-19, Y-20, Y-21a, Y-22	Upi Elementary School, Yigo

Table 26. Man-Made Impoundment Area WQM Schedule.

Cycle	SIA Name	Site No.	Location	Cycle Sampling Year	Plus One Site Each from Other Four Cycles
I	GHURA 501	43	Behind Dededo Transfer Station	2006	2007
	Potts Junction	12	Rte 9; 500 Feet West of Well HGC-3	2006	2008
	Marianas Terrace	36A	Gayinero Street, Yigo	2006	2009
	Airport road Extension	72A	Route 10A (South Side)	2006	2010
II	GHURA 502	20	Route 3 (Astumbo Gardens)	2007	2006
	Ypaopao Estates	42B	Behind PUAG Pump Station	2007	2008
	Hatsuho Golf Course	12E	Route 3 (Near Club House)	2007	2009
	Harmon Sinkhole	71	Route 10A (Near Hotel Mai'Ana)	2007	2010
III	Agana Hts. Injection Wells	79	F. Xavier Dr./Salamon Dr., Agana Hts	2008	2006
	Guam Community College	76A	Sesame Street, Mangilao	2008	2007
	GHURA 503	15	Route 3 (Fern Terrace)	2008	2009
	Guam Intl. Airport Terminal	72	Route 10A (Across Airport Parking Lot)	2008	2010
IV	Barrigada 76 Gas Station	74	Route 10 & Route 8 Intersection	2009	2006
	GHURA 35	48B	Near Northern Public Health Center	2009	2007
	Macheche Subdivision	55A	Macheche Avenue, Dededo	2009	2008
	GHURA 505	41	Atsadas Street, Yigo	2009	2010
V	Sinajana Baseball Field	79B	Chalan Guma' Yuus, Sinajana	2010	2006
	Latte Heights	56A	Gardenia Ave. & Carnation Ave.	2010	2007
	GHURA 506	38	Near Simon Sanchez High School	2010	2008
	Dededo Public Park	47A	Rte. 1 & Ysengsong Rd. Intersection	2010	2009

7.0 Special Projects 2004-2005

Some special projects implemented during the reporting period are presented in this narrative.

7.1 ***Ground-Water Monitoring and Numerical Model Development, Northern Guam Lens Aquifer (October 2003-September 2005)***

Guam EPA contracted the U.S. Geological Service (USGS) to study four monitoring wells in the Yigo sub-basin. Results of that study have demonstrated that the aquifer responds to heavy rainfall within fifteen (15) hours. Additional studies, on a smaller scale, are needed to define the aquifer characteristics in order to develop a more effective management groundwater program. A description of the complete project can be found at **http://hi.water.usgs.gov/projects/project_guam_epa.htm**.

7.2 *Water and Environmental Research Institute (WERI) Ground Water Projects*

The Institute lists one groundwater project implemented in 2005. This and past projects can be reviewed on their web site: **www.weriguam.org/reports/index.php**. There is current work being done on a "Groundwater Modeling Project" which Dr. John Jenson has described as follows: "WERI researchers are mapping the key hydrogeologic features of northern Guam, including plateau and basement topography, faults, fractures, sinks, and coastal seeps and springs. Maps of natural the features are combined with GIS-based maps of precipitation data and human hydrologic modifications of the surface, including storm drainage and ponding basins, urban and suburban housing developments, and large airfields. These data provide the basis for a comprehensive surface hydrologic model, which will enable more accurate estimates of groundwater recharge and the potential effects of surface development. WERI is coupling the surface model with a numerical groundwater flow/salt water intrusion model. The coupled model will provide means for assisting planners, managers, and regulators with estimates of groundwater discharge into coastal waters as well as aquifer responses to increased extraction and natural or anthropogenic changes in recharge." The results of this and other future projects will be included in the next integrated report.

C. Summary of Ground Water Contamination Sources

The top ten contaminant sources presenting the greatest threat to Guam's ground water quality were identified earlier in this section and reference can be made to related contaminant information in **Table B9, Appendix B**. Guam EPA includes the following narrative on major contaminant sources and groundwater locations most at risk on Guam.

1.0 Septic Systems

Significant portions of developed areas on Guam do not have sewers, particularly in Northern and Central Guam above the Northern Guam Lens (designated as a sole source aquifer). Lack of wastewater collection in these developed areas is endangering the integrity of the NGL.

2.0 CERCLA Sites Overlying the NGL

There are three CERCLA sites, which overlie the NGL: Andersen Air Force Base (AAFB), Tiyan (the former Naval Air Station, Agana), and the Navy Construction Battalion (CB) Landfill .

Andersen Air Force Base was listed on the National Priority List (NPL) in October 1992. Groundwater beneath the site has been investigated in accordance with the Federal Facility Agreement (FFA) since that time. Prior to NPL listing, groundwater was investigated under the Department of Defense, Installation Restoration Program (DoD,

IRP) beginning in 1986.

Groundwater beneath Tiyan has been investigated since 1986 under the DoD, IRP. Groundwater contamination beneath Tiyan has been detected in the form of TCE and PCE. One production well (NAS-1) exists on the former base and a water sample collected in January 1991 exceeded the MCL for TCE. Subsequent groundwater sampling of monitoring wells under the BRAC has shown the presence of an extensive area of contamination of PCE and TCE. Contamination in NAS-1 is currently being remediated through wellhead treatment through activated carbon filtration. GIAA has plans to install four (4) production wells on Tiyan. If these wells become impacted by the TCE/PCE contamination plume, GIAA will conduct wellhead treatment with activated carbon filtration.

The Navy Construction Battalion (CB) Landfill continues to be investigated under the Navy=s IR Program. It is currently being monitored with no signs of groundwater contamination. Closure of the CB Landfill has been completed which included the placement of a non-permeable cap as a presumptive remedy under the CERCLA process. Groundwater contaminants have been detected in site monitoring wells but remained below action levels for six sampling rounds. Hydraulic communication between the site and a down gradient freshwater pond (which is used for swimming and shrimp harvesting) and coastal springs has been established. Long-term monitoring has been modified to exclude and close all site monitoring wells and include down gradient coastal springs. The final Record of Decision (ROD) for the site is currently under evaluation.

3.0 AAFB Main Base TCE Ground Water Contamination - Building 18006

Building 18006 has been operational since the 1960's. AAFB started looking at this site after its status was converted from an Area Of Concern (AOC) to an Installation Restoration (IR) site in the beginning of CY 2005. This was done to access funding to start an investigation into whether Building 18006 may be contributing to the groundwater TCE contamination

The facility is currently being looked at as a "potential site" for TCE contamination based upon groundwater sampling results from IRP wells 3, 39, 50, and USGS-150 and the fact that the facility is located up-gradient of the wells in addition to historic knowledge that the facility used TCE . A 1970 report with photos revealed discharge(s) of TCE into a UIC well.

Test borings have been drilled to evaluate the subsurface conditions around Building 18006. However, as it currently stands, there has been no "smoking gun" found yet to implicate Bldg. 18006 as the source of TCE contamination in the groundwater on AAFB main base. AAFB will be developing the physical scenario with all the information gathered as this investigation moves forth.

4.0 Air Force Marbo Groundwater Impacted by TCE and PCE

The groundwater table beneath the Andersen Air Force Base MARBO Annex ranges from approximately 281 to 400 feet below ground surface. There are water production wells within the MARBO Annex area. This water is blended with water from other production wells and is distributed to various villages. As a consequence of past Air Force activities at MARBO Annex, the groundwater beneath the Annex area has been impacted by trichloroethylene (TCE) in the northern portion and tetrachloroethene (PCE) in the vicinity of the former MARBO Laundry facility. This contamination was first detected in MARBO groundwater when appropriate groundwater sampling and analysis was initiated some 30 years ago. As a result, Andersen Air Force Base has been identified as the responsible party for the groundwater contamination and has since implemented some actions to address the situation.

AAFB's selected alternative for the MARBO Annex Groundwater is *Monitored Natural Attenuation with Institutional Controls* to achieve the remediation goal of decreasing trichloroethylene (TCE) and tetrachloroethene (PCE) concentrations in the aquifer to levels below Maximum Contaminant Levels (MCLs). The timeframe to achieve this cleanup goal is 45 years or maybe even longer based upon uncertainties of the total mass of TCE/PCE that may exist in the subsurface. However, the levels of TCE/PCE at shallow depth appear to be responding at a very slow rate to natural attenuation in contrast to the concentrations at deeper depths which continue to show no significant change. *Natural Attenuation* of the TCE and PCE in the groundwater is expected to occur primarily as a result of the physical processes of dispersion and dilution and not of biochemical dechlorination processes.

In a letter to AAFB (dated Jan 12, 2006), Guam EPA stated that based upon groundwater sample results, there has been no significant decline in the TCE concentrations at depth and that *Natural Attenuation* is not an effective remediation strategy. Therefore, Guam EPA recommends that AAFB not rely solely on *Natural Attenuation*, but rather seek other treatment technologies to accelerate the breakdown of the TCE in the groundwater. To date, the levels of contamination continue to persist with groundwater sample results showing very little change. Guam EPA has identified three alternative treatment options that have been demonstrated to be effective in reducing concentrations of chlorinated organic contaminants in groundwater. Andersen Air Force Base is now evaluating each option to determine which is best to address the MARBO groundwater TCE/PCE contamination. Guam EPA's position is that to leave untreated chlorinated solvents in a sole-source drinking water aquifer for an estimated 75 years is unacceptable.

As a side note, the Long-Term Groundwater Monitoring Program (LTGM) was initiated in October 1995 with the goal of:

- Continuing to expand the baseline groundwater data at monitoring and production wells,
- Continue evaluating baseline data and identifying critical sampling locations,
- Installing new monitoring wells, and
- Determining modifications to monitoring points, monitoring frequency, and analytical methods.

The institutional controls that are in place include:

- Land Use Restrictions to monitor and restrict groundwater access from areas impacted by TCE/PCE,
- Groundwater Monitoring to continue tracking the TCE/PCE contaminant plumes, and
- Planning for Wellhead Treatment, or discontinue production from wells found to be contaminated to ensure that there is no public health risk at existing Air Force production wells.

5.0 Ground Water Conditions in the Vicinity of the Orote "Landfill"

The Orote "Landfill" was an uncontrolled Navy dump throughout its operational history. Contaminants initially detected in soil and buried waste at the facility include PCBs, dioxins (including 2,3,7,8 TCDD) and furans, polychlorinated aliphatic hydrocarbons, volatile organic compounds (including TCE, PCE, TCA, DCA, and BTEX), metals, and pesticides. These same contaminants have also been detected in groundwater in monitoring wells in and around the dump, coastal fresh water springs and marine waters, and marine sediments and organisms (including fish).

In 2001 the beach area immediately adjacent to the dump was cleaned up of metallic debris, a sea wall was constructed to minimize further erosion of contaminated soil and buried waste, and an impermeable cap was constructed over the dump in an attempt to isolate contaminated waste from the groundwater and marine water beneath and adjacent to the dump.

Subsequent sampling of groundwater, spring and marine waters, and off-shore biota indicate that the contaminants persist in the local environment. A study of the effects of storm-induced waves, tides, and heavy rains on the water table in the vicinity of the capped dump has demonstrated that groundwater rises into buried waste and probably remobilizes contaminants thought to have been isolated from the groundwater and marine environment by the cap and seawall. It was also determined that storms cause temporary reversals of the water table and groundwater flow direction, thus continuing to disperse contaminants away from the dump through the groundwater pathway.

Continued investigations and discussions with the U.S. Navy are ongoing to determine what actions are required to ensure protection of human health and the environment.

6.0 Other CERCLA Sites

There are several CERCLA sites located in the Southern Guam hydrogeologic province not over the NGL: the Ordot Landfill and numerous sites belonging to the Navy.

The Ordot Landfill is listed on the NPL, but no groundwater contamination resulting from activities at the site has been documented. However, leachate impacts to the Lonfit River have been documented and it is suspected that the Lonfit River is in hydraulically connected with the southern-most extension of the NGL. Therefore, impacts to the NGL from Ordot leachate are possible.

The Navy sites are being addressed by Naval Forces Marianas (formerly NAVACTS, FISC, SRF, and NCTAMS), and Navy Public Works Center, Guam. The following sites are currently being addressed by the Navy under their IR program:

USS Proteus Fire Fighting Training Area (fuel contamination);
PWC Building 3009 PCB Remediation (PCB contamination);
Orote Point Dump, (PCB contamination)
Area Behind Fenceline, SRF (PCB=s, PAH=s, metals);
Dry Cleaning Shop (metals, fuels, PAH=s)
Tenjo Vista Abandoned Pipeline (fuel contamination); and
Lower Sasa Fuel Burning Pond (fuel and solvent contamination).

The Navy is also addressing several other sites under their RCRA program. These sites include:
Orote Power Plant (diesel fuel contamination);
Sasa Fuel Storage Tanks (diesel fuel contamination);
Tenjo Vista Storage Tanks (diesel fuel contamination);
PWC Landfill; and
Old DRMO PCB Remediation

These sites are all located above the coastal brackish and saline waters characteristic of the Apra Harbor area. Collectively, these sites may contribute to groundwater degradation, and therefore, it is recommended that the sites be periodically evaluated as new data becomes available.

Recently, it has been determined that PCBs have gotten into the food chain off shore from the Orote Landfill site. The source(s) of the PCBs has yet to be determined. However, PCBs as well as other chemicals are present in buried material at the landfill, which makes the site a potential source. Therefore, monitoring wells and other sampling techniques are planned to confirm or deny the Orote Landfill as a source of the contamination.

Building 3009 (Navy facility), located on COMNAVMAR, Guam, was used for electrical transformer maintenance from 1952 through 1977. Contaminated soil was removed from the site, but upon confirmation sampling it was determined that additional PCB contamination persists. The contamination was identified within the location of Building 3009 as well as the storm water drainage swales leaving the site. The investigation establishes a pathway of contamination that lead to Inner Apra Harbor via the storm water swales. The US Navy will conduct an additional removal of the contaminated soil as well as investigation of Inner Apra Harbor.

D. Summary of Ground Water Quality

The overall ground water quality of the NGL is good, however, it is significantly vulnerable to contaminants, including chloride contamination induced from over

pumping of water supply wells. These threats increase the NGL's contamination potential.

During the last quarter of 2005 Guam EPA under the lead of its Safe Drinking Water Program, investigated requirements of "Ground Water Under the Direct Influence of Surface Water" because of the contamination of several GWA ground water wells and possibly U.S. Navy wells. Staff suspected that these wells were potentially influenced by surface water or raw sewage from leaking sewer pumps or sewer pipes. The Agency has formulated draft guidance to determine the source if the groundwater is under the influence of surface water.

The preservation of the Northern Guam Lens Aquifer is a priority because of its designation as Guam's Sole Source Aquifer and because of the magnitude of incidences observed in which the levels of pollutants (Bacteria, Nutrients, Chlorides, and Toxic Contaminants) exceeded Guam Water Quality Standards. The Agency will facilitate assessment, planning, or pollution control activities necessary to improve water quality such that it complies with local standards. The degree of public interest in or concern about the water body is extremely high.

Guam's aquifer is the main source of Guam's potable water supply. Two Air Force wells (Tumon Maui and MW-1), one Navy well (NAS-1) and one GWA well (F8) have been closed in recent years because of toxic contaminants, while a few wells have increasing chloride levels from saltwater intrusion. Two private wells (Guam Plaza Hotel) have shown TCE concentrations above Safe Drinking Water levels.

- TCE is found in solvents and degreasers. Guam Waterworks Authority's NAS-1 well came into violation for high levels of TCE in March 1995 and was shut down. A granular activated carbon filter was installed at the wellhead and it was placed in operation in August 1997 to remediate the groundwater.

- PCE is used in the dry cleaning industry and is also found in degreasers. In 1996, the Air Force's Tumon Maui well came into violation of the Safe Drinking Water Standards when PCE was detected above the Maximum Contaminant Level (MCL) of 5 µg/l, with concentrations of 10.8 µg/l in October 1995, 8.58 µg/l in November 1995, and 8.0 µg/l in December 1995. The well was shut off until an air stripper was installed at the Booster Pump Station No. 2 and was placed in operation in January 1997 to remediate the groundwater at Tumon Maui and AAFB production well MW-1. In July 1997, AAFB informed Guam EPA that the air stripper was taken off-line for maintenance and operation would resume in approximately 30 days. However, the Air Force decided that maintenance procedures were too complicated compared with the need for groundwater production and to date the wells remain shut down.

- EDB is found in fumigants, pesticides and leaded gasoline. However, EPA suspended the use of EDB fumigant in 1983, and the use of leaded gasoline in cars was

gradually discontinued beginning in the late 1970s. In 1996, GWA water samples taken from its F-8 well exceeded the EDB, TCE, TCE, and MTBE MCLs. Well F-8 was shut down in October of 1996 (when final test results were received). Carbon filtration has being installed at the wellhead for F-8, and the well is back in operation. The source of contamination of F-8 is, as of yet, unknown.

- Two production wells were installed at the Guam Plaza Hotel (GPH) located in Tumon, near the Tumon Maui well in 1997. Beginning with the first water samples collected from the wells in December 1997, PCE and TCE have been detected. Since then, TCE has exceeded Safe Drinking Water standards in well GPH-1 and in well GPH-2. The hotel was given the option to apply for an operator's permit to include the installation of a treatment system to remove the contaminants or to shut the wells down. The hotel opted to install the treatment system and has been operating their wells under this compliance order. Monitoring reports indicate that the wells are producing water which meets water quality standards. However, Guam EPA will be evaluating the effectiveness of Guam Plaza Hotel's well compliance monitoring activities during the next reporting period. The results of this assessment will determine if it is necessary for the Hotel to continue operating their wells under the current compliance order.

Gasoline from a leaking underground storage tank (LUST) was discovered when an old underground storage tank was being removed from a former Exxon service station in 1998. A total of fourteen (14) monitoring wells were installed to delineate the extent of the plume. A potable GWA well, approximately 700 feet from the LUST has never had a detection of petroleum product. Remediation of the well consists of four (4) pumps and treat wells, six (6) soil vapor extraction (SVE) wells and five (5) sparge wells. The SVE system is very effective in the cleanup/removal of the contaminants. While the pump and treat wells are rather ineffective, they have been kept in operation to keep the plume from migrating to the potable well.

E. Summary of Ground Water-Surface Water Interactions

Guam EPA has a growing awareness of ground water-surface water interactions and their contribution to water quality problems.

Another aspect of groundwater is spring discharge along the coast in the inter- and sub-tidal zones. These springs comprise the discharge of the NGL aquifer. A recently completed study has characterized the chemistry of discharge from selected springs into Tumon Bay. The study consisted of sampling eight Tumon Bay springs during four discrete sampling events. Total discharge estimated for the seven springs is 17 million gallons per day.

A two-year study of spring water discharge into Tumon Bay has recently been completed. The study was funded with Clean Water Action Plan money through the Watershed Planning Committee and consisted of four sample rounds of eight springs along the Bay during both the wet and dry seasons. Chemicals detected above Guam EPA water quality

standards included Tetrachlorethene, Trichloroethene, Aluminum, Antimony, Arsenic, Magnesium, Chloride, Sulfate, Oil & Grease, Total Coliform and Fecal Coliform. Pesticides Dieldrin, Alpha-Chlordane, and Gama Chlordane were also detected in spring discharge. However no Guam EPA water quality standards currently exist for these compounds. Impacts from the chemicals on Tumon Bay are planned to be mitigated by locating and eliminating sources of the chemicals.

Efforts will continue to be made in the evaluation and interpretation of groundwater – surface water interactions.

The Northern Watershed (and therefore the NGL) is designated by the Watershed Planning Committee as one of the priority watersheds targeted for the development and implementation of a restoration strategy.