SMALL COMMUNITY WASTEWATER FACILITIES PLAN
FOR THE
VILLAGE AND ISLAND OF AUNU'U, AMERICAN SAMOA

Submitted to

AMERICAN SAMOA ENVIRONMENTAL PROTECTION AGENCY
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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gdc

P.O. Box 1238
Trinidad, CA 95521
707-677-0123
gdcocn@earthlink.net

Executive Summary

The Village and Island of Aunu'u are currently serviced by a wastewater collection system delivered to a wet well with a grinder pump and discharged as untreated sewage through ocean outfall in shallow water on a fringing coral reef. The southeastern beaches of Aunu'u are subjected to chronic, ongoing, long-term bacterial contamination. The risk to public health indicates a critical need for developing a small community wastewater infrastructure plan. This wastewater facilities plan (WWFP) is targeted at identifying and developing, to a planning level, the most appropriate approach for wastewater management for Aunu'u.

The WWFP is a comprehensive document that addresses the anticipated wastewater characteristics, existing and future conditions, and a full range of wastewater management alternatives. Preliminary screening of alternatives identified preferred methods of wastewater treatment on Aunu'u Island. The preliminary screening identified three secondary treatment alternatives with two different disposal options. The three secondary treatment approaches were membrane bioreactor, sequential batch reactor, and constructed wetland treatment. Treated wastewater disposal would either be through a new ocean outfall or discharge to a natural wetland. Leaving the existing ocean outfall for an emergency bypass was considered an option for wetland disposal options.

The selected alternative was a constructed wetland treatment with wetland discharge and keeping the existing ocean outfall as an emergency bypass. The basis for the selection included cost, meeting established water quality goals, protection of public health, environment impacts, and social issues. Operational, maintenance, and construction issues, including risk and local capabilities, were also considered in the selection process. The existing operational wastewater collection system will be left in place. The wastewater treatment system will require construction of a new pump station and force main up the access road from the Village to the landfill that is located on the edge of the tuff cone. Primary treatment will be achieved by use of a septic tank system with associated sludge drying beds. Secondary level treatment will be achieved by the constructed wetland with discharge of treated wastewater to the Faimulivai Marsh.

Pre-design engineering, planning level cost estimates, a preliminary implementation plan, and an analysis of environmental impacts for the selected alternative are included in the WWFP. A description of current and future conditions was based on a detailed, on the ground, house-to-house survey. A detailed topographic land survey of the Aunu'u Village and access road corridor area was conducted and is considered sufficient for final design purposes. Some additional topographic data collection may be needed in the constructed wetland area and landfill area. Recommendations for additional studies that would be valuable for developing the basis of final design were presented.

The use of a constructed wetland for wastewater treatment in Aunu'u offers many advantages over conventional treatment. Constructed wetlands are aesthetically pleasing, more economical, provide wildlife habitat, and offer opportunities for environmental education and research.

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Section 1
INTRODUCTION

This report presents a small community wastewater facilities plan (WWFP) that includes evaluation, alternatives development and evaluation for wastewater treatment for the Village and Island of Aunu'u, American Samoa.

This WWFP final report follows two internal review draft reports submitted during the development of the WWFP. A 70% report was submitted for internal review to determine that the study progressed in the desired direction and to allow selection of a preferred alternative. The 70% report was reviewed internally by the American Samoa Government (ASG) American Samoa Environmental Protection Agency (ASEPA), the American Samoa Power Authority (ASPA), and the United States Environmental Protection Agency (USEPA). A 95% report was submitted to ASEPA and USEPA for final review for form and consistency.

Completion of this WWFP is one component of a comprehensive environmental monitoring and non-point source pollution remediation effort for American Samoa that is being planned and implemented by the ASEPA. This WWFP is being conducted under the Consolidated Environmental Program for American Samoa as funded by the United States Environmental Protection Agency (USEPA).

1.1 Purpose

This WWFP is intended to be a detailed planning document. Representatives of the ASEPA, ASPA, and the USEPA will use this WWFP to evaluate fundamental requirements for wastewater infrastructure for the Village and Island of Aunu'u located offshore of the south eastern shoreline of the Island of Tutuila that are currently served by a sewer collection system with no wastewater treatment. The goal of this wastewater facilities planning effort is to reduce or eliminate point source and non-point source wastewater impacts on groundwater and coastal waters and to improve the environmental and human health conditions within the Village. As a planning document this WWFP will be used to determine which infrastructure alternatives are appropriate in terms of potential funding sources and reasonable implementation schedules. The WWFP will also be used to support required funding requests, and will be used as a basis for design of the wastewater infrastructure.

1.2 Background

Aunu'u Island consists of a tuff cone (consolidated volcanic ash) and a coastal plain, which compose approximately equal portions of the eastern and western sides of the island, respectively. The total land area is very small, about 0.6 mi^2 (Figure 1-1). The Village of Aunu'u is located on the coastal plain portion of the Island. The year 2000 population of Aunu'u Village was 476 and it is the sole Village on the Island.

Water quality monitoring activities for Aunu'u Island and near-shore waters demonstrates that there is chronic bacterial contamination along the southwestern shoreline of Aunu'u because of the discharge of raw sewage from the Aunu'u Village wastewater collection system. Contamination is primarily the result of the discharge of untreated wastewater that is collected by a Village-wide sewer collection system that discharges from a wet-well through an ocean pipeline that terminates at the edge of the reef top discharging to surface waters. Currents and wind waves carry this contaminated water along the south shoreline recreational beaches and around to the western shoreline to recreational beaches and a small boat harbor which is used for boat (ferry-taxi) traffic and public swimming.

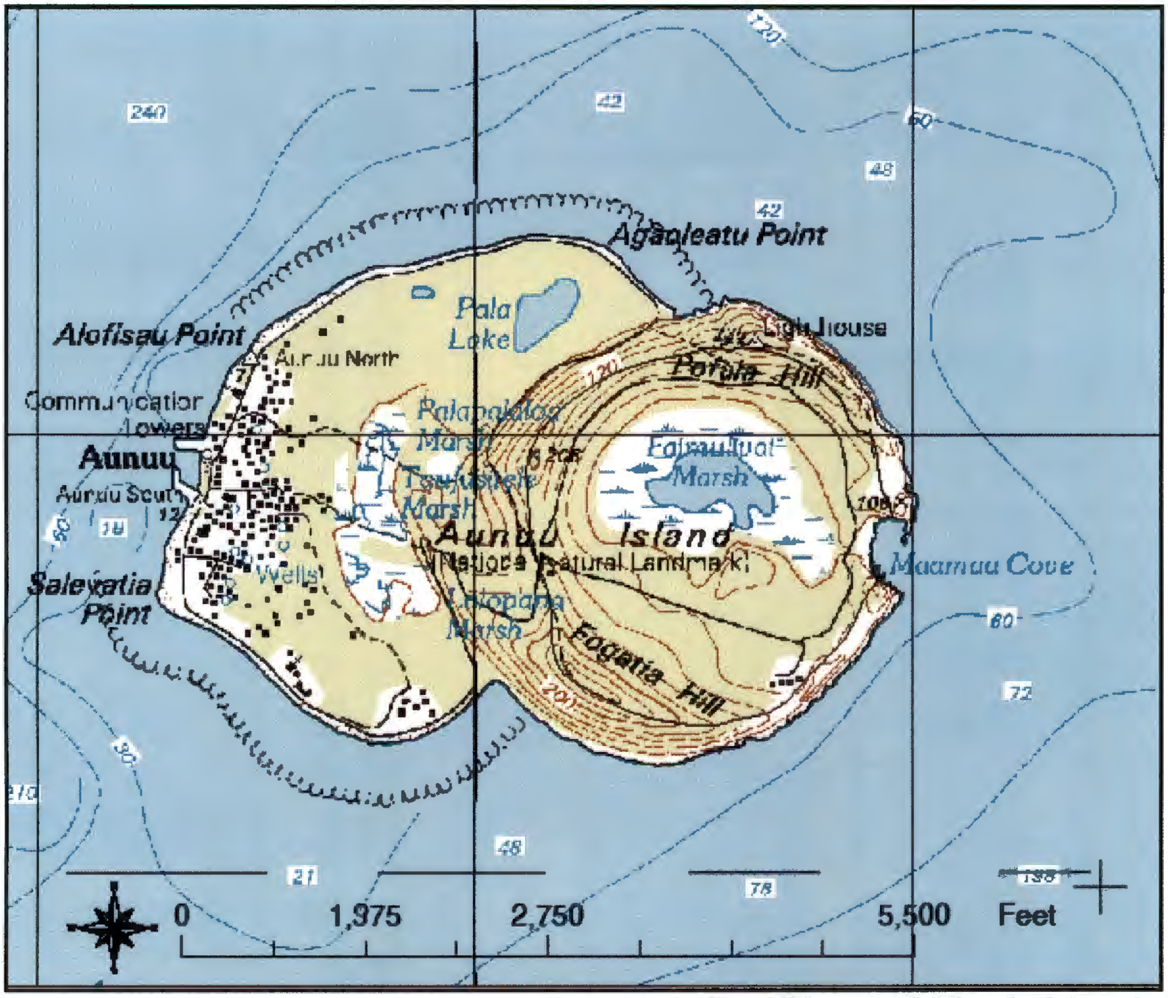

Figure 1-1. The Village and Island of Aunu'u

1.2.1 Need for the Study

Past water quality studies of Aunu'u Village have documented the impacts of nonpoint source wastewater on groundwater and drinking water resources. Although in terms of impacts to groundwater the existing sewer collection and discharge system has been documented as an improvement to the conditions prior to construction of the system, the current discharge of raw wastewater to the reef is considered unacceptable by ASEPA. The Village of Aunu'u, located on the coastal plain, suffers from high ground water levels combined with rapid recharge of the surface aquifer by large amounts of rainfall. This shallow aquifer is the only source of drinking water available to the residents of Aunu'u, except for a small reverse-osmosis (R-O) drinking water plant. However, the R-O unit is difficult for local utilities operators to maintain, and is often not functional. The aquifer of the coastal plain is the only reliable source of freshwater for Aunu'u. The infiltration wells, or Village water system, are readily affected by poor disposal and land use practices that can easily contaminate the aquifer or the water source for the wells.

The available water quality data for the Aunu'u beaches indicates bacterial contamination of near-shore waters from the untreated wastewater discharged through the ocean outfall. ASEPA regularly monitors Aunu'u beach water quality, and ASEPA inspection teams have documented many of the adverse and inadequate wastewater treatment impacts. By these investigations ASEPA has established a relationship between inadequate wastewater treatment and nearshore water quality degradation and high potential for human health effects.

Since the collection and discharge system was constructed the direct threat to groundwater resources has been reduced but the un-permitted raw sewerage discharge has exacerbated the degradation of nearshore water quality, as identified in recent studies by the ASEPA. Residents of Aunu'u routinely complain of foul odors and discolored water along beaches on the island's south and western shores. Fish and shellfish are regularly harvested from the Aunu'u reefs and the nearby nearshore shorelines. Residents also use these waters extensively for recreational activities. Given the lack of practicable on-site wastewater treatment for Aunu'u, the risks to public health from the raw sewage discharge, and the vulnerability of groundwater resources, it is imperative to mitigate wastewater impacts through one or more alternative treatment systems that incorporate centralized facilities for the island. Planning and developing alternatives for small community wastewater infrastructure to alleviate identified non-point source and point source pollution on the island of Aunu'u will be the focus of this Small Community Wastewater Facilities Plan.

1.2.2 Study Site

The United States Territory of American Samoa is a group of seven islands (five volcanic islands and two coral atolls) located in the South Pacific Ocean at latitude 14° south, longitude 171° west. Total land area of these islands is approximately 76 square miles. The five volcanic islands, which are the major inhabited islands of American Samoa, are Tutuila, Aunu'u, Ofu, Olosega and Ta'u. American Samoa's main port is Pago Pago Harbor located on the island of Tutuila, the largest and most populous island (approximately 58 square miles with a population of approximately 56,000) and the center of government and commerce. Aunu'u is a small island situated one mile off the southeast coast of Tutuila. The three islands of Ofu, Olosega, and Ta'u, collectively referred to as the Manu'a Islands, are 66 miles east of Tutuila. Rose Island is an uninhabited coral atoll located 135 miles east of Tutuila. Swains Island is a coral atoll with a population of ≈40, located 200 miles north of Tutuila.
As described above, Aunu'u Island consists of a tuff cone (consolidated volcanic ash) and a coastal plain, which approximately equally compose the eastern and western side of island, respectively. The total land area is very small, about 0.6 mi^2 (Figure 1-1). The Village of Aunu'u is located on the coastal plain portion of the Island. The year 2000 population of Aunu'u Village was 476 and it is the sole Village on the Island.

The coastal plain is split into two sections, the western or Village of Aunu'u section and the eastern or marsh section. Aunu'u Village lies predominantly along the western shoreline with the largest concentration of houses located between Alofisau Point and Salevatia Point. Interior to Aunu'u Village are located coastal plain freshwater marshes with Pala Lake located at the most northern end of the coastal plain interior. The coastal plain marshes to the south of the Pala Lake are in taro production which is the largest agricultural production on the Island.

The tuff cone lies easterly of the coastal plain, with the most prominent feature being the freshwater Faimulivai Marsh. The north and western flanks of the tuff cone are in banana production, with the remainder flanks in natural vegetation. On the southeastern side of the tuff cone, east of Fogatia Hill, is located the Aunu'u Village landfill, that will be evaluated as a potential waste treatment facility location.

1.3 Approach

There are two related objectives for this project. The primary objective of this WWFP is to develop alternatives for appropriate wastewater treatment for residents of Aunu'u, and to present one or a combination of alternatives, that will best effect an elimination of non-point source pollution impacts on groundwater, and elimination of the un-permitted ocean outfall in near-shore waters.

The secondary objective is that the results of this WWFP are intended to provide the basis for selection of the most cost-effective and practicable collection and treatment system or systems for the Village and Island of Aunu'u. The results of this WWFP will also be used as an important resource for future planning and management of wastewater infrastructure for other isolated coastal villages of American Samoa.

The problems associated with currently untreated wastes and unacceptable disposal practices will only be exacerbated with continuing population growth, and must be addressed in a timely fashion. However, it is also understood that the wastewater facilities planning model developed by this project can be applied elsewhere in American Samoa and other oceanic islands. Therefore, the alternatives to be addressed include a wide range of possible approaches, although it is recognized that site-specific constraints may quickly eliminate some of these from consideration for direct application to Aunu'u. This WWFP, to provide maximum utilization for both the site-specific and wider applications, will be based largely on the guidance provided in the Unites States Environmental Protection Agency's (USEPA) *Guidance for Preparing a Facility Plan: Municipal Wastewater treatment Works* (May 1975).

The general outline of the WWFP approach is as follows:

- Section 2 provides a description of the anticipated influent characteristics based on the influent to the Utulei WWTP on Tutuila Island. The permitting issues and limitations, along with water quality standards that must be met, and requirements for utilizing new secondary, tertiary, or created or natural wetlands treatment operations, are described.

- Section 3 provides a description of the planning area and the basic information required for conceptual development of the alternatives. The physical, biological, economic, and social environments are described based on existing information. A detailed land survey of the village was conducted to fully describe the physical environment. It is noted that this land survey was substantially more detailed than required to develop the conceptual alternatives or even for preliminary design of the selected alternative. The information was collected opportunistically since it is basic information that will be required for further design regardless of the selected alternative.

  Section 3 also includes a detailed description of demographic data required for the development of the WWFP. This data was based largely on a project specific house-to-house survey of the entire Aunu'u study area. Based on this survey, and using ancillary data available for water use patterns, a water use and wastewater flow volume estimate was developed.

- Section 4 provides an analysis of the existing Aunu'u collection and discharge system. The capacities of the unit processes are described and conclusions concerning the ability of the existing collection system to work into the future are discussed.

- Section 5 provides an assessment of future conditions based on the information provided in Sections 3 and 4, available data from appropriate sources such as census data and previous estimates of population and economic growth, and forecasts of wastewater flows over the defined planning period.

- Section 6 presents the various wastewater management alternatives. The alternatives include the no-action alternative, secondary and tertiary treatment alternatives, along with created and natural wetland treatment alternatives. All viable treatment options were considered at least to the minimum level of detail required to eliminate them from further consideration. The remaining options were developed to the level required to facilitate a final selection. The full range of disposal options was considered (reuse, existing ocean outfall, new ocean outfall, and other surface water discharge).

- Section 7 formalizes and applies the selection criteria, including rough order of magnitude (ROM) and planning level costs, environmental impacts (positive and negative), regulatory issues, and social issues. The criteria developed are applied to the range of practicable alternatives to evaluate feasibility and desirability. A recommendation is made for the preferred alternative.

- Section 8 provides a pre-design of the selected alternative including the rationale and key assumptions. The existing collection system stays in place and the old outfall becomes an emergency outfall. A new force main takes wastewater to the landfill area where a series of septic tanks are used to remove solids from the wastewater. The wastewater is then treated in a wetland treatment system.

- Section 9 includes a planning level cost estimate for the selected alternative. Estimated construction costs of the force main and septic sludge removal, pump stations, and wetland treatment systems are provided. Allowances, contingencies, and associated costs are addressed. Operation and maintenance costs are defined and estimated.

- Section 10 provides an implementation plan for the selected alternative. The implementation plan includes institutional responsibilities, and funding sources. An implementation plan and schedules is outlined.

- Section 11 provides a summary of environmental impacts of the selected alternative along with environmental evaluation procedures. Environmental issues are defined and mitigation measures are provided.

- Section 12 provides a listing of the references used in the wastewater facilities plan document.

1.4 Scope and Limitations

No sampling was conducted to evaluate potential influent loadings or constituent concentrations, and no bench testing of possible effluent stream sources was done to evaluate removal efficiencies. However, there is considerable information available concerning similar influent sewage sources from nearby locations served by the Utulei WWTP on Tutuila Island. It was assumed that chemical and biological characteristics of domestic wastewater on Tutulia are similar to the characteristics of wastewater on Aunu'u. This information was collected, complied, and presented in the WWFP

Finally the WWFP is intended to be used by an Architectural/Engineering (A/E) contractor as the basis for engineering design and architectural design work at detailed levels not addressed in the WWFP. Some elements of design are required to provide information for purposes of cost estimating and evaluation of alternatives, and these elements at the appropriate level of detail are included in the WWFP. Engineering and architectural drawings that are provided are intended to be conceptual, but fulfill the specific requirements of this WWFP. For the proposed alternative wastewater management system, appropriate drawings representing site layout and treatment facility elements are employed to evaluate alternatives and conduct a planning level design of the selected alternative.

Section 2
DISCHARGE CHARACTERIZATION

This section describes the expected Aunu'u effluent levels for the parameters of concern, required limitations that may be imposed by USEPA, and the potential for the discharge to meet the American Samoa Water Quality Standards (ASWQS). The expected effluent constituents are discussed based on existing available data from the service areas of the Utulei and Tafuna WWTPs on the Island of Tutuila. The development structure for the Tutuila services areas are similar to that expected on Aunu'u, i.e., moderate-to-low density residential. Both conventional and toxic effluent parameters are discussed. The predominant wastewater sources include the presence of raw sewage, gray water, and incidental piggery wastewater. Parameters of concern for domestic wastewater of this type typically include biological oxygen demand (BOD), total suspended solids (TSS), pH, ammonia-nitrogen, organic-nitrogen, nitrate- and nitrite-nitrogen, total and ortho-phosphorus, oil and grease, surfactants, heavy metals, and fecal coliform (and/or *Enterococci*) bacteria.

The degree to which effluent characteristics are of concern depend on their influent concentration, the removal efficiency during treatment, and the resultant effluent concentration, and the method of effluent disposal (discharge to open coastal waters, discharge to stream, reuse via land application, etc). To evaluate potential parameters of concern the possible sources of wastewater are considered and typical or expected substances and concentrations from these sources (domestic, agricultural, commercial, and industrial) are estimated. In Aunu'u, there is little other than domestic and agricultural waste. Expected removal efficiencies will be applied to the anticipated loadings, to describe anticipated effluent characteristics.

The effluent limitations are discussed in terms of discharge through a new facility that would be located within or nearby the Village of Aunu'u service area. Expected discharge flows are discussed in Sections 3 and 4. Based on the location and geomorphologic setting of the Village of Aunu'u service area, the most likely viable discharge options will be to the adjacent open coastal marine waters, or through the fresh surface water and wetlands of the interior of the tuft cone (Faimulivai Marsh) and ultimately into the marine waters of Maamaa Cove. Although other discharge scenarios are considered and briefly discussed, they are unlikely to be practicable and most of the discussion in this section concerns discharge to surface waters indicated above.

2.1 Conventional Parameters

The conventional parameters of particular interest are BOD and TSS because these are the wastewater constituents that define secondary treatment standards. The influent BOD and TSS values of any treatment system for Aunu'u are expected to be similar to those for Tutuila Island.

Figure 2-1 shows the influent concentrations of five-day BOD (BOD_5) at the Utulei WWTP based on discharge monitoring reports (DMRs) for the period April 1998 through December 2004. For this period, monthly average influent BOD_5 concentrations range from 50 mg/l to 130 mg/l. Daily minimum and maximum BOD_5 influent values over the same period of record range from 18 mg/l to 195 mg/l. There appears to be a trend of increasing concentrations with time. This may be because of better control of inflow and infiltration of the Utulei collection system, or some other factors*. The influent for Aunu'u is considered to be adequately characterized within the overall envelope described in Figure 2-1.

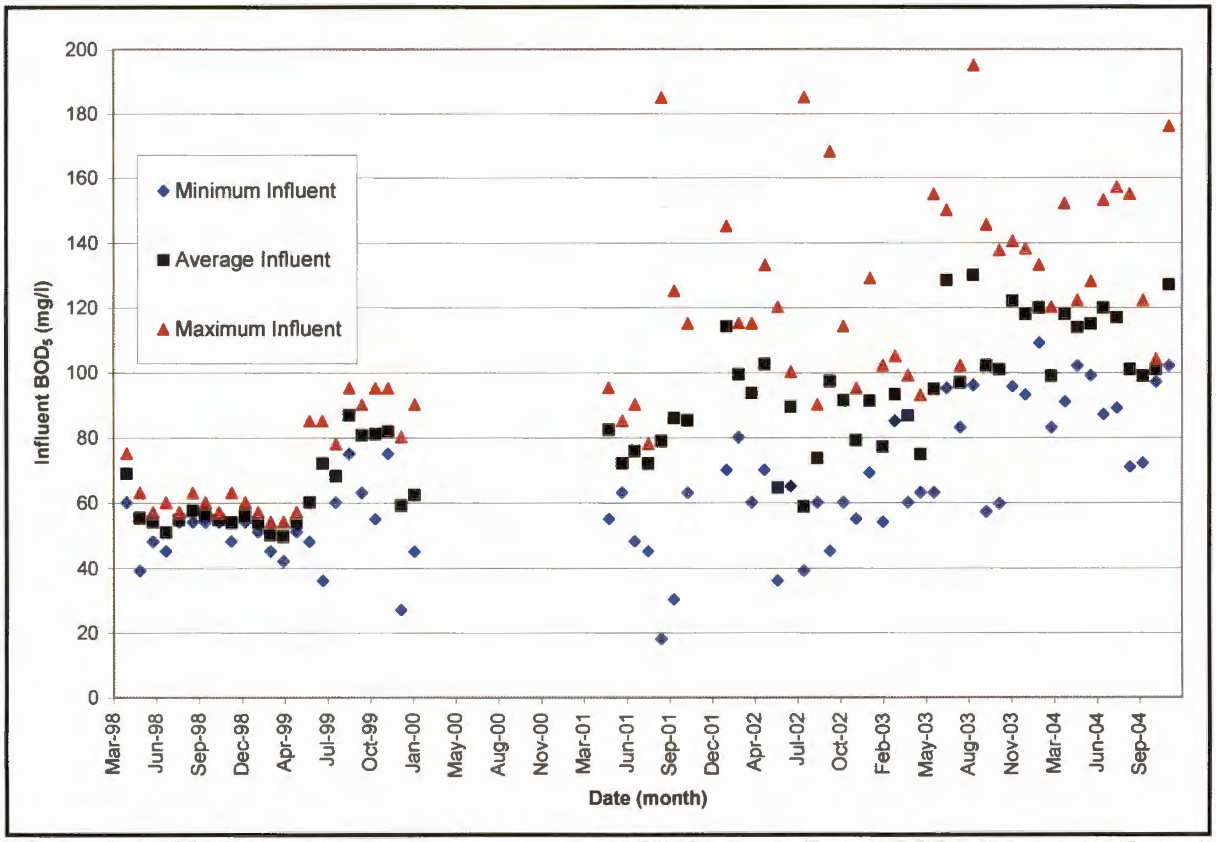

Figure 2-1. Monthly Maximum, Average, and Minimum Influent BOD_5 Concentration at the Utulei WWTP on Tutuila Island

Figure 2-2 shows the monthly average and daily minimum and maximum influent TSS concentration at the Utulei WWTP from the DMRs from April 1998 through December 2004. Monthly average influent concentrations of TSS range from 24 mg/l to 270 mg/l. Daily minimum and maximum influent TSS values over the period of record range from 8 mg/l to 666 mg/l (not shown on Figure 2-2). The higher value appears anomalous and the average monthly maximum TSS value is 144 mg/l over the period of record. The higher monthly average value (270 mg/l) occurred during the same month and is also anomalously high, with typical monthly TSS influent averages between 50 mg/l and 150 mg/l. There appears to be a relatively weak trend of increasing concentrations with time. The influent TSS for Aunu'u is considered to be adequately characterized within the overall envelope described in Figure 2-2.

* Examination of the Utulei WWTP DMR data indicates that neither flows nor BOD_5 loadings have similarly increased over the same time period. One possible, although speculative, explanation is that efforts to reduce infiltration/inflow (I/I) have been balanced by increased wastewater flows so that flow remains essentially constant and BOD_5 concentrations would therefore increase.

In addition to BOD and TSS, secondary treatment standards are also imposed on pH. The DMR's for the Utulei and Tafuna WWTPs do not list influent pH. However, examination of the detailed plant operations reports indicate that influent pH at the Utulei WWTP ranges from 6.8 to 7.8 and that influent pH is typically about 0.1 to 0.2 units higher than effluent pH. Figure 2-3 shows the daily minimum, daily maximum and monthly average effluent pH for the Utulei WWTP. The wastewater influent from the Aunu'u Village area is expected to be similar to that for the Utulei WWTP. The range of pH is within the secondary treatment standards discussed below.

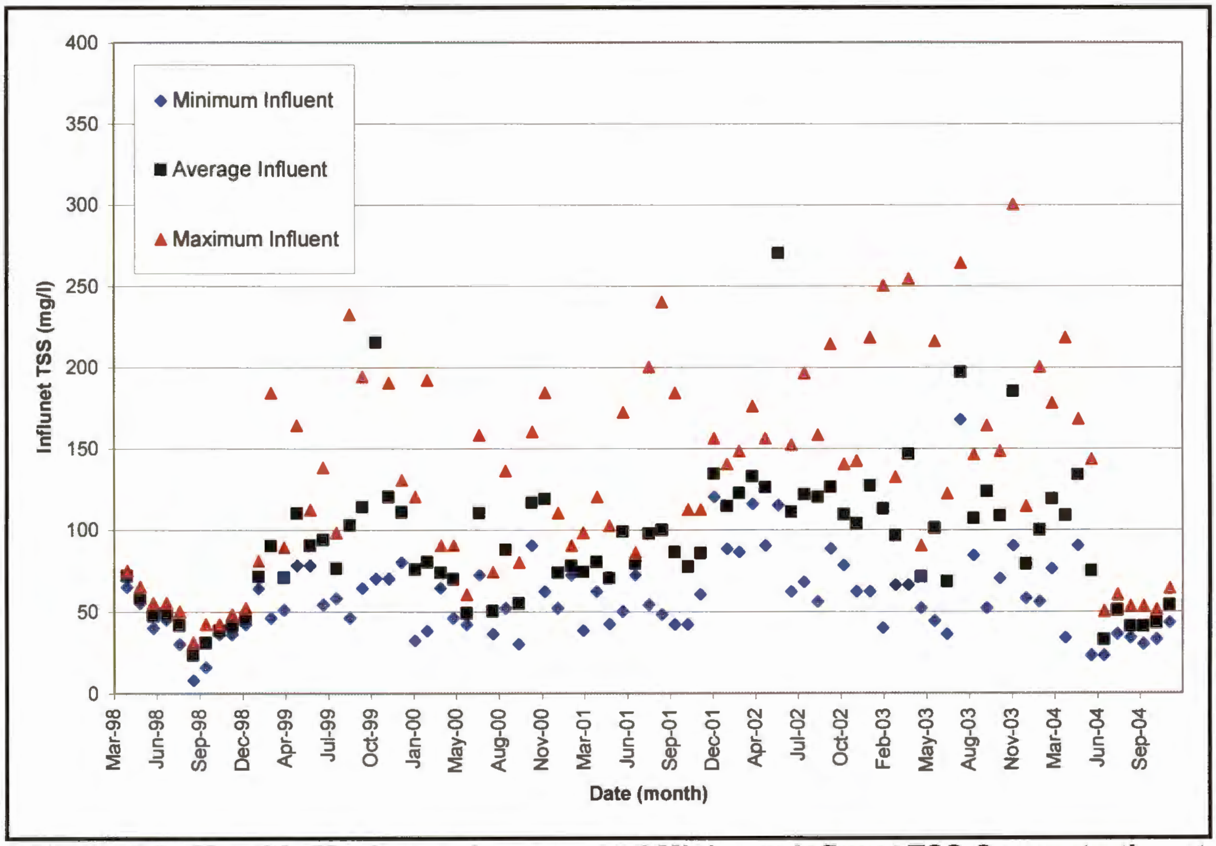

Figure 2-2. Monthly Maximum, Average, and Minimum Influent TSS Concentration at the Utulei WWTP on Tutuila Island

A limited amount of fecal coliform data for Utulei WWTP effluent is available prior to mid-2001. Measurement of coliform was discontinued after that time by agreement with ASEPA and USEPA. Since the effluent is not disinfected and the ASWQS for the receiving water is based on Enterococcus, and Enterococcus is included in the receiving water monitoring, the measurement of coliform was not considered necessary. The available data are not conclusive, but show typical values (on the order of 10,000 to 100,000 colonies per 100ml) of fecal coliform in the wastewater. It is expected that similar values will be observed in the wastewater from the village of Aunu'u.

There is no available information with which to characterize influent concentrations for other conventional parameters, but there are two recent priority pollutant data sets available for the

Utulei WWTP effluent. If the Aunu'u wastewater is treated to secondary standards, it is anticipated that the effluent values for these parameters at the Utulei WWTP would represent an upper limit. Table 2-1 shows the available data. It is noted that the effluent TSS levels from the Utulei WWTP are already close to those required by secondary treatment standards. Therefore, the effluent concentrations of other parameters would not be expected to be substantially different for an Aunu'u secondary treatment plant.

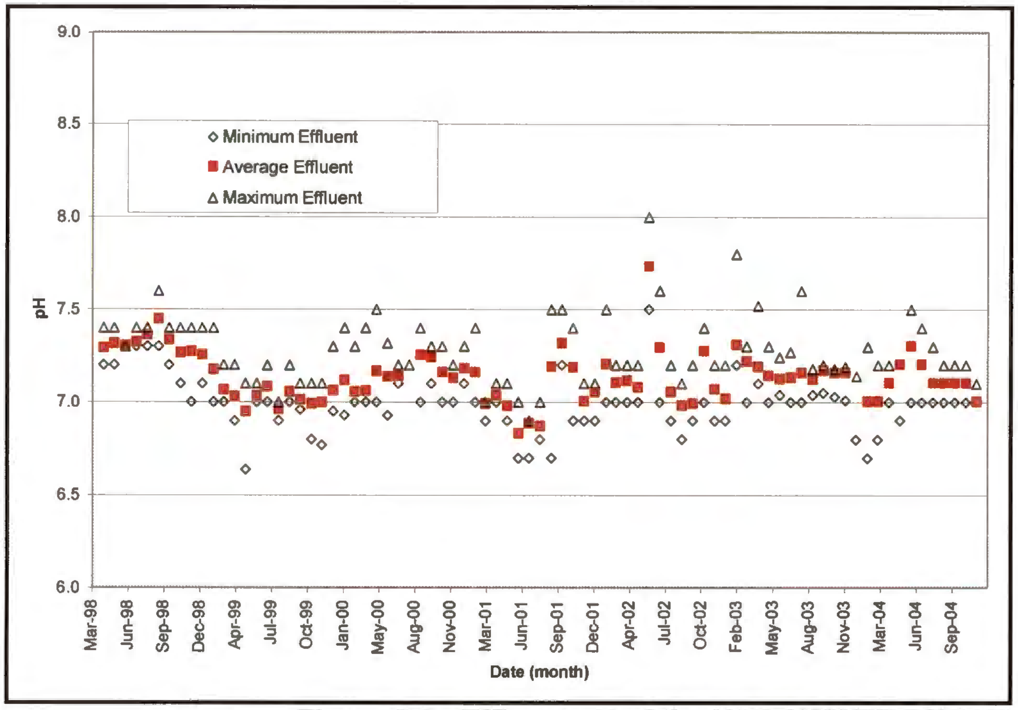

Figure 2-3. Effluent pH of the Utulei WWTP Effluent

Table 2-1. Conventional Pollutants in Utulei Effluent (mg/l)

Parameter	Utulei WWTP			
	Sept 2004		March 2005	
Sulfide, Total	8.34	=	0.1	=
Chemical Oxygen Demand	391	=	255	=
Bromide	6	U	2.9	=
Sulfate	240	=	118	=
MBAS	0.7	=	1.6	=
Phenolics, Total (method 420.1)	0.05	=	0.13	=
Nitrogen, Total Kjeldahl (TKN)	67.1	=	34.5	=
Ammonia as Nitrogen	21.7	=	23.3	=
Cyanide	0.003	U	0.003	U
Solids, Total Suspended	36	=	24	=
Carbon, Total Organic	36.1	=	26	=
Sulfite	13	=	31	=
Phosphorus, Total	2.63	=	2.81	=
Oil and Grease, Total	6.3	=	5.5	=

"=" indicates parameter detected at concentration shown
U indicates parameter not detected at concentration shown, which is the method detection limit (MDL)

The concentrations of nitrogen and phosphorous are of particular interest since there are stringent ASWQS for these nutrients. Concentrations in the Aunu'u wastewater are expected to be similar to the Utulei service area wastewater. Receiving water quality monitoring indicates that the Utulei (and Tafuna) discharges do not result in violations of the ASWQS, which are applied beyond the zone of initial dilution (ZID).

Parameters without specific ASWQS are regulated by the USEPA National Recommended Water Quality Criteria (NRWQC). Other conventional parameters of concern in Table 2-1 were either not detected (cyanide) or are expected to be reduced to the appropriate water quality standard (ammonia) at the point of discharge or the limit of the ZID, depending on the wastewater treatment approach selected.

2.2 Priority Pollutants

Information concerning expected concentrations of toxic pollutants is available for the Utulei WWTP effluent from the recent priority pollutant analyses. There is no information about the potential effluent concentrations for the Village of Aunu'u. However, as mentioned above, the effluent concentrations are expected to be well represented by those measured at the Utulei WWTP because of the close similarity of the service area characteristics.

Table 2-2 lists the results of Utulei WWTP metals analyses. Mercury and copper were detected above the ASWQS criteria. In both cases secondary level treatment and/or dilution through a high-rate diffuser are expected to reduce the concentrations below the criteria at the discharge point or within the ZID.

Table 2-2. Metals Concentrations for Utulei Effluent (μg/l)

Parameter	Utulei WWTP			
	Sept 2004		March 2005	
Aluminum	356	=	320	=
Antimony	40	U	20	U
Arsenic	5	U	1	U
Barium	24.4	=	15.3	=
Beryllium	0.4	U	0.2	U
Boron	554	=	276	=
Cadmium	5	U	2	U
Chromium	3	U	3	U
Cobalt	5	U	2	U
Copper	6.1	J	7	U
Iron	191	=	275	=
Lead	2	U	1	U
Manganese	36.8	=	36.8	=
Mercury	0.24	=	0.0647	=
Molybdenum	9	U	5	U
Nickel	20	U	3	U
Selenium	5	U	1	U
Silver	5	U	9	U
Thallium	5	U	1	U
Tin	50	U	6	U
Titanium	5	J	8.2	J
Zinc	27.7	=	28.5	=

= parameter detected at concentration shown
U compound was non-detect at or above the MDL (value shown)
J parameter detected below reporting limit and concentration is estimated

Table 2-3 lists the results of the pesticides and PCBs analyses. DDT was the only constituent of concern detected that exceeded the ASWQS. Available information indicates that this parameter is not detectable in the receiving water. Other parameters that were detected were either below the ASWQS or are not listed in the NRWQC.

Table 2-3. Pesticide and PCB Concentrations for Utulei Effluent (μg/l)

Parameter	Utulei WWTP			
	Sept 2004		March 2005	
alpha-BHC	0.011	J, P	0.01	U, i
beta-BHC	0.038	U, i	0.022	U
gamma-BHC (Lindane)	0.017	U, i	0.0049	U
delta-BHC	0.0052	J, P	0.016	U
Heptachlor	0.011	U, i	0.018	U
Aldrin	0.009	U, i	0.0038	U
Heptachlor Epoxide	0.011	U, i	0.11	U
Endosulfan I	0.00062	U	0.008	U
Dieldrin	0.0013	U, i	0.011	U
4,4'-DDE	0.011	U, i	0.015	U
Endrin	0.0015	U	0.015	U
Endosulfan II	0.002	U	0.014	U
4,4'-DDD	0.00084	U	0.03	U
Endrin Aldehyde	0.0013	U	0.018	U
Endosulfan Sulfate	0.0038	U, i	0.027	U
4,4'-DDT	0.018	=	0.019	J
Toxaphene	0.88	U, i	1.4	U, i
Chlordane	1.1	U, i	2.2	U, i
Aroclor 1016	0.11	U	0.015	U
Aroclor 1221	0.067	U	0.05	U
Aroclor 1232	0.045	U	0.085	U
Aroclor 1242	0.088	U	0.021	U
Aroclor 1248	0.018	U	0.019	U
Aroclor 1254	0.0088	U	0.028	U
Aroclor 1260	0.022	U	0.013	U

=	parameter detected at concentration shown
J	parameter detected below reporting limit and concentration is estimated
P	the GC or HPLC confirmation criteria was exceeded. The relative percent difference is greater than 40% between the two analytical results.
U	compound was non-detect at or above the MDL (value shown)
i	the MRL/MDL has been elevated because of a chromatographic interference

Table 2-4 lists the volatile and semi-volatile organic compounds that were detected in the Utulei effluent. Dioxins and furans are included in Table 2-4 as a separate category. Five volatile and seven semi-volatile compounds were detected above the method detection limit out of 90 constituents analyzed. These compounds are either not listed in the NRWQC or are reported at levels below the most restrictive criterion. Therefore, effluent can be expected to meet all ASWQS for such substances. Five types of dioxins and furans were detected. The most toxic (TCDD) was not detected. Those that were detected are among the least toxic of these compounds and the presence of all of them are attributable to the burning of plastics. Open burning of trash piles, including plastics, is a common and frequently observed practice in American Samoa. It is likely that levels of these dioxins will be lower on the Island of Aunu'u because of the lower population density.

Table 2-4. Concentrations of Organic Compounds Detected in Utulei Effluent

Parameter	Utulei WWTP			
	Sept 2004		March 2005	
Volatile Organic Compounds Detected from 33 Analyzed (µg/l)				
Dichloromethane (Methylene Chloride)	0.42	J	0.21	U
Chloroform	1.5	J	0.21	U
Toluene	0.51	J	2.3	J
Chlorobenzene	0.21	J	0.18	U
1,4-Dichlorobenzene	4.1	J	4.3	=
Semi-volatile Organic Compounds Detected from 57 Analyzed (µg/l)				
Phenol	12	J	32	=
1,4-Dichlorobenzene	1.8	J	3	J
4-Nitrophenol	13	J	3.1	U
Fluorene	1.2	U	0.38	J
Diethyl Phthalate	3.5	J	4.4	J
Phenanthrene	1.8	U	0.56	J
Bis(2-ethylhexyl) Phthalate	8.6	J	12	=
Dioxins and Furans Detected from 26 Analyzed (pg/l)				
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (HpCDD)	4.52	U	6.081	J
Octachlorodibenzo-p-dioxin (OCDD)	58.425	J	48.023	J
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)	5.472	J	0.778	J
Octachlorodibenzofuran (OCDF)	18.515	J	5.749	J
Heptachlorodibenzo-p-dioxins (HpCDD), Total	3.464	U	9.046	=
Hexachlorodibenzofurans (HxCDF), Total	5.472	=	0.696	U
Heptachlorodibenzofurans (HpCDF), Total	4.027	U	4.317	=

J parameter detected below reporting limit and concentration is estimated

U compound was non-detect at or above the MDL (value shown)

= parameter detected at concentration shown

2.3 Existing Aunu'u Collection and Discharge System

The existing collection system on Aunu'u was developed by, and is operated and maintained by, ASPA. The existing system conveys wastewater from all but one[1] of the homes and public buildings in the Village of Aunu'u to a wet well (Figure 2-4). The untreated wastewater is then pumped to an outfall that extends to the edge of the fringing reef and discharges in approximately 10 feet of water in open coastal waters. The pump does not run continuously. The existing system has greatly reduced the threat of contamination of the shallow ground water, but is not operated under an NPDES permit. As discussed in Section 4, the existing collection system appears to be in good condition and is considered to be adequate for use in future wastewater management strategies.

[1] During the house-to-house survey for this WWFP it was discovered that one house had disconnected from the wastewater collection system because the residents experienced back-ups from the collection system into their house.

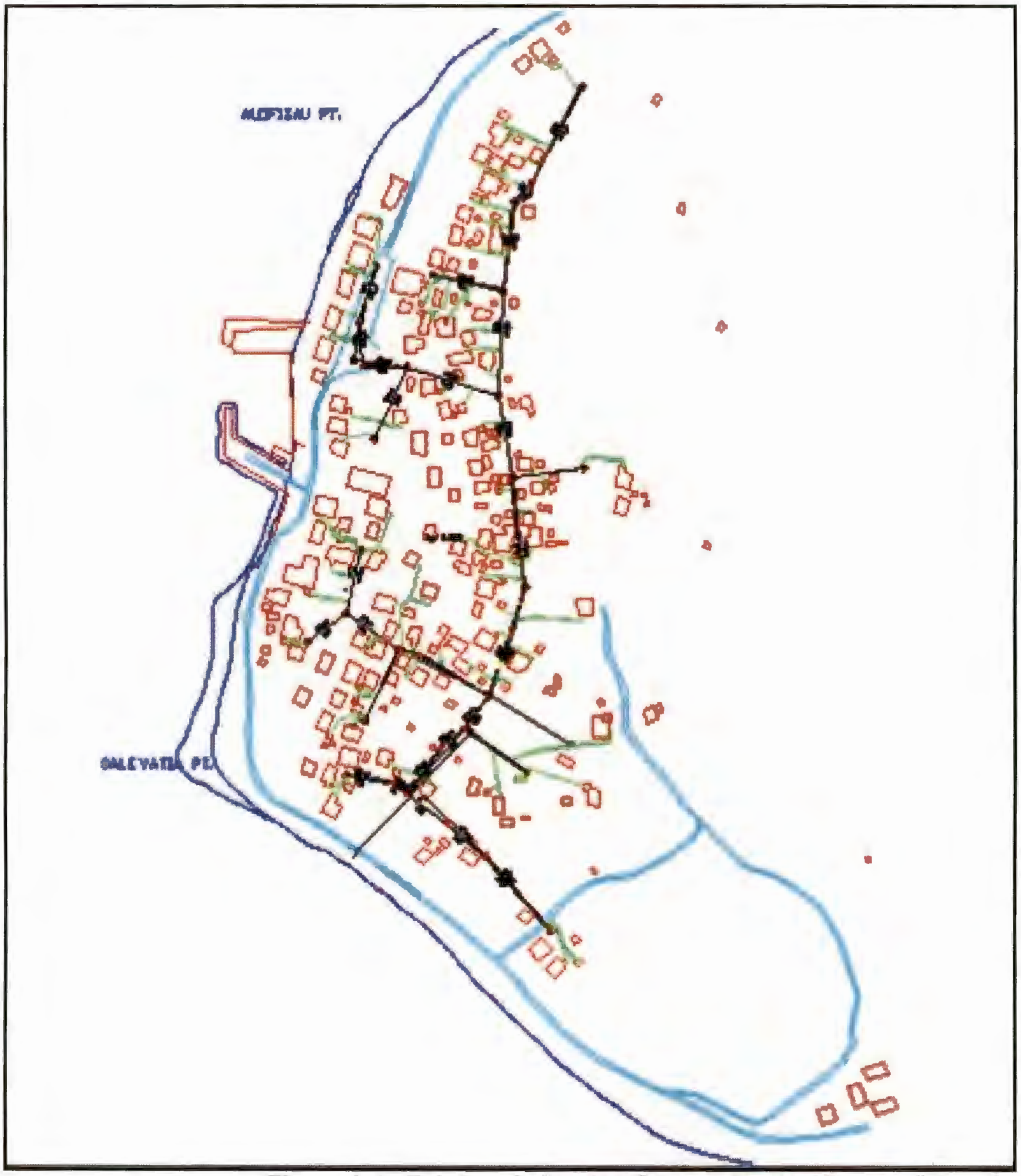

Figure 2-4. Existing Collection System for the Village of Aunu'u

2.4 Secondary Treatment Requirements

As mentioned above, a new treatment plant to treat the wastewater from the Aunu'u service area will have to meet secondary treatment standards and will require an NPDES permit. Secondary treatment is a minimum technology-based standard requirement for publically owned treatment works (POTWs). Secondary treatment means treatment beyond the settling of solids, removal of 85% of BOD and TSS, and proper acidity control (pH). All treatment facilities that discharge to waters of the United States that do not have issued or pending 301(h) waivers (Federal Water Pollution Control Act) must comply with the secondary treatment standards.[2] To meet the secondary treatment standards, in addition to the removal efficiency of 85%, the effluent quality must be maintained at the following levels:

- BOD cannot exceed 30 mg/l over a 30-day average and cannot exceed 45 mg/l over a 7-day average
- TSS cannot exceed 30 mg/l over a 30-day average and cannot exceed 45 mg/l over a 7-day average
- pH must be maintained between 6.0 and 9.0

Averages must be in consecutive days. The secondary treatment regulations require that, at a minimum, the chosen treatment process be a stabilization pond. Water quality standards, however, may require higher quality effluent (i.e., lower concentration of contaminants) be discharged. In particular, disinfection to reduce bacteria concentrations to acceptable levels may be required.

2.5 Created and Natural Wetlands Treatment/Discharge Requirements

A number of the potential wastewater management alternatives for Aunu'u involve the discharge of wastewater to wetlands and overland flow. The ASWQS specifically address some of these issues and the pertinent points are discussed below.

2.5.1 Discharge to Wetlands

Wetlands are defined for regulatory purposes under the Clean Water Act as "areas that are inundated or saturated by ground or surface water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions"[3]. Wetlands generally include, but are not limited to, swamps, marshes, mangroves, streams, springs, cultivated marshes, and similar areas. Aunu'u wetlands include mangrove swamps, freshwater and brackish water marsh, forested wetlands, and cultivated wetlands.

The ASWQS prohibits point source discharges of pollutants to wetlands and the siting of septic tanks within 50 feet of wetlands. Additionally, the ASWQS require that all wetlands

[2] Exception are granted only for certain Native Alaskan villages.
[3] EPA Regulations at 40 CFR 230.3 (t)

remain in as near their natural state as possible and be protected to support specific uses including, the propagation of indigenous aquatic and terrestrial life, recreation and subsistence fishing, food cultivation and gathering, and recharge of ground waters.

2.5.2 Discharge to Ground Waters

The ASWQS designates ground waters as either Class 1G if they are current or potential potable water sources (less than 10,000 mg/l naturally occurring salinity) or Class 2G if they are waters with naturally occurring salinities of 10,000mg/l or more. The ASWQS prohibits the direct discharge of wastewater (through injection wells) to Class 1G ground waters and prohibits surface or subsurface discharge of wastewater to Class 1G and Class 2G ground waters except through treatment or disposal devices approved by ASEPA.

2.5.3 Water Quality Degradation

The ASEPA anti-degradation policy requires that existing water uses and the level of water quality necessary to protect existing uses be maintained. A summary of protected uses for various water bodies is shown in Table 2-5 below. The Environmental Quality Act (Title 24, ASCA), sets forth specific provisions that allow water quality degradation when it is necessary to accommodate important economic or social needs of the Territory. However, under no circumstance may water quality be degraded to an extent that it would interfere with or become injurious to existing uses.

Table 2-5. Summary of ASWQS Uses of Waters

Use	Water Classification					
	Ocean Waters	Open Coastal Waters	Fresh Surface Waters		Ground Water	Wetland
			Class 1	Class 2		
Potable Water Supply			✓		✓	
Support/Propagation of Aquatic/Terrestrial Life	✓	✓	✓	✓		✓
Recreation (contact or non-contact)	✓	✓		✓		✓
Scientific Investigation	✓	✓				
Groundwater Recharge						✓
Flood Control						✓
Food Cultivation						✓
Fish Harvest	✓	✓				✓
Aesthetic Enjoyment	✓	✓	✓			✓

2.6 ASWQS Requirements for Ocean and Freshwater Discharge

The ASWQS have specific numerical standards for various water body classifications including open coastal waters and fresh surface waters for a limited number of parameters. All other parameters are established by reference to the most recent USEPA National Recommended Water Quality Criteria. It is noted that the ASWQS prohibits discharge of wastewater to class 1 surface waters (potable water sources) and ground water of less than 10,000 mg/l salinity (thorough injection wells). Discharge of treated wastewater to other ground waters is permittable only through treatment or disposal devices approved by the

ASEPA. For the purposes of this WWFP, ASEPA has indicated that no direct disposal options for discharge into ground water would be permitted.

The discharge of wastewater from a WWTP on the Island of Aunu'u must comply with the ASWQS for the receiving water body. It is noted that the ASWQS does allow zones of mixing (ZOMs) in the open coastal waters, but not in fresh surface waters. A ZOM is an area within the receiving water within which the ASWQS may be exceeded, but ASWQS must be met at the boundary of the ZOM. The current ASWQS for open coastal and fresh surface waters are shown in Table 2-6.

Table 2-6. Summary of ASWQS Numerical Criteria for Various Water Bodies

Parameter	Units	Water Classification [A]	
		Open Coastal	Fresh Surface Waters
Turbidity	NTU	0.25	5.0
Total Phosphorus	µg/l	15.0	150.0
Total Nitrogen	µg/l	130.0	300.0
Total Suspended Solids	mg/l		5.0
Chlorophyll-a	µg/l	0.25	
Light Penetration	feet	130.0	65.0
Ammonia	mg/l	Varies with temperature, salinity, and pH as described in the ASWQS, Appendix A	
Dissolved Oxygen	mg/l	5.5	6.0
Dissolved Oxygen	% sat	80%	75%
pH minimum	SU	8.6	6.5
pH maximum	SU		8.6
pH deviation from natural	SU	0.2	0.2
Enterococci (geomean)	per 100ml	35	33
Enterococci (maximum)	per 100ml	124	151
E. coli (geomean)	per 100ml		126
E. coli (maximum)	per 100ml		576
Arsenic [B]	µg/l	36	10
Mercury [C]	µg/l	0.05	0.05
Total residual chlorine	µg/l	7.5	11

[A] Only those classifications of interest for the Aunu'u disposal options are included. Other narrative standards are included in the ASWQS that apply to all water classification.
[B] The criterion for arsenic for marine waters are based on the criteria for the protection of marine life found in the NRWQC. The criterion for fresh water is the ASWQS human health standard.
[C] The criterion for the protection of human health based on methylmercury in fish tissue in the NRWQC is also included by reference in the ASWQS.

Section 3
EXISTING CONDITIONS

The existing conditions within the Aunu'u facilities planning area are provided in Section 3.1 in terms of the physical, biological, and social, cultural, and economic characteristics. A description of present day demographics and land use is given in Section 3.2, which includes the planning area boundaries, political jurisdictions, and economic characteristics. Additional information is provided in Section 3.3 concerning the existing conditions of water quality and beneficial uses. Special environmental considerations in the planning area are provided in Section 3.4.

3.1 Planning Area Description

The physical and biological environmental characteristics of the planning area that may be affected by the construction of wastewater transmission and treatment systems are discussed below. Demographic, social, cultural, and economic characteristics include descriptions of the human population currently inhabiting Aunu'u and the archeology or ancient and historical population artifacts that may be present. Demographic and economic characteristics of the planning area are also provided as a basis to aid in understanding wastewater flow estimates given existing conditions and for forecasting future wastewater flows (described in Section 5.4).

3.1.1 Physical Environment

The physical environmental characteristics of the planning area include topography, meteorology, oceanography, hydrology, geology, and soils. Many of the physical environmental features of Aunu'u are provided in the descriptions below. Figure 1-1 shows many of the features described below.

Topography The total area of Aunu'u is about 375 acres and the coastal plain encompasses about 140 acres with the remaining 235 acres represented in the tuft cone. The Faimulivai Marsh is the most significant feature in the tuft cone and represents about 36 acres. About 40 acres of the coastal plain is inhabited with Aunu'u Village, about 30 acres are in taro production, about 45 acres are in freshwater marsh, and the remaining 25 acres are in terrestrial vegetation. With the exception of parts of the coastal road the coastal plain is generally higher on the north side than the south side. The elevations on the north side of the coastal plain vary between 5 feet and 13 feet (American Samoa Datum, 1962). South coastal plain elevations vary between 2.5 feet and 11 feet (AS Datum, 1962). Some house owners have intentionally had their foundations raised higher than the surrounding area making it difficult to determine which elevations are natural and which have been modified.

The access road to the Aunu'u Island tuff cone goes along the southern shoreline of the coastal plain and then rises up the southwestern flank of Fogatia Hill, which ranges in elevation between 10 ft at the base and 220 ft. at the crest. The access road lies below the Fogatia summit and achieves an elevation of 115 feet at the junction with the circular crater road. The most used portion of the circular crater road lies on the southern side of the crater and joins with the northern crater road at Maamaa Cove on the far east side of the crater. There are very few vehicles on Aunu'u and the crater road is in poor condition. The ASPA garbage truck does haul trash to a new landfill located near the southeastern ridge of Fogatia Hill, three days per week.

New Topographic Surveys The scope of work for this wastewater facilities plan required collection of new topographic data to be collected on Aunu'u Island. The new survey work was intended to provide more recent topographic information that can be used in this facilities plan, for conceptual design of the selected alternative, and later for final design and construction of the wastewater transmission lines and siting of the wastewater treatment facility. The topographic survey records conducted by McConnell Dowell are provided in the Appendix in electronic format.

The survey plans conducted for this facilities plan were based on providing a contour interval of 1 foot in the coastal plain that can be manipulated in AutoCAD and printed out at any scale needed. The new topographic surveys were conducted in three sections of Aunu'u Village and Island. Section one was the survey of the main coastal shoreline roadway that follows the shoreline of the Aunu'u coastal plain. Section one also included the survey of the entire Aunu'u Village using 1-foot contour intervals with 0.10-foot spot elevations. Section two was a survey of the crater access road going up the southwestern slopes of Fogatia Hill with a 5 foot contour interval as specified in the project scope of work, as the slope is greater than 25%. Section three was the survey of three ingresses located approximately equidistant between the crater access road summit and Maamaa Cove. Each ingress was to be surveyed from the access road to the crater lake water's edge. Ingress 3 was inadvertedly not surveyed to the crater lake waters edge as the surveyors mistakenly stopped at a small hibiscus swamp adjacent to the crater lake. However, assumptions regarding elevations for this small un-surveyed section will suffice for planning purposes.

The outlet culvert from the Faimulivai Marsh at Ma'amaa Cove elevation was also surveyed. The survey also included the open (non vegetated) area of the landfill.

Meteorology American Samoa has a tropical marine climate with abundant rainfall and warm, humid days and nights. Rainfall varies greatly over small distances because of topography. Rainfall on Tutuila Island at Pago Pago, at the head of the Pago Pago Harbor is nearly 200 inches a year, typically falling as showers. The crest of the mountain range surrounding Pago Pago Harbor receives in excess of 250 inches of rainfall annually. The airport located on the Tafuna coastal plain, less than 4 miles from Pago Pago, is drier and receives about 125 inches a year. The Village of Tula, located on the easternmost tip of Tutuila receives 70 to 80 inches annually. In most years, the airport records about 300 days with a trace or more of rain and about 175 days with at least 0.1 inch. The driest months in American Samoa are June through September and the wettest are December through March. The seasonal rainfall totals may vary widely from year-to-year, and heavy showers and long rainy periods can occur at any time of the year.

Rainfall data for Aunuu is very limited and therefore this facilities plan relies on records for sites close by on Tutuila Island. Three sites on Tutuila are Afono, Aasufou and Tula with characteristics similar to Aunu'u (Izuka, S.K., 1999; PRISM). During the period October 1987 through September 1997 mean annual rainfall in Afono was 164 inches and 210 inches was measured at the gage in Aasufou. Rainfall in the 12-month period from October 1996 through September 1997 totaled 210 inches at the Afono gage and 234 inches at the Aasufou gage. The Tula site is closest to Aunu'u and has about 80 inches per year of rainfall. The Tula site is the Earth System Research Laboratory of NOAA Global Monitoring Division (formerly Climatic Monitoring and Diagnostics Laboratory). The recently completed and published PRISM precipitation atlas for American Samoa is the most recent rainfall distribution document. The atlas indicates that the average annual rainfall for Aunu'u was approximately 100 inches per year for the record period 1979-2000.

For temperature, June, July and August are the coolest months and January, February, and March, the warmest. However, annual variability in temperature is relatively small: daily highs generally range from the upper 80s (°F) in the summer to the mid 80s (°F) in winter, while nighttime lows temperatures vary from the mid 70s (°F) in the summer to the low 70s (°F) in winter. The highest temperatures recorded at the airport are in the low 90s (°F) and lowest near 60 °F.

The prevailing winds throughout the year are the easterly Trades. These tend to be predominantly from east-northeast and east-southeast during most of the year. The Trade winds are less prevalent in the Austral summer than in winter and more directly from the east in December through March. The Trades are interrupted more often in summer than in winter and westerly to northerly winds are more frequent between December and February.

Hydrology The hydrology of Aunu'u Island is closely tied to the geomorphology of the Island. The coastal plain aquifer is composed mostly of coralline and volcanic debris. The most comprehensive hydrologic analysis of Aunu'u was conducted by USGS based on field studies made from July 1996 through February 1997 (Gingerich, S.B., S.K. Izuka, and T.K. Presley, 1998). They found that water-supply wells withdrew water with chloride concentrations as high as 1,960 mg/l. Since chloride is a measure of saltiness of the water these high values indicated that seawater was being drawn from a transition zone located below the freshwater lens of water below the Island. The three production wells on Aunu'u have been pumped at various rates less than 0.1 million gallons per day and had chloride concentrations usually in excess of 500 and often in excess of 1,000 milligrams per liter (Izuka, S.K., 1999).

The most common source of freshwater for the residents of Aunu'u are the ASPA horizontal wells known as infiltration-gallery wells. These wells operate by skimming water from the thin freshwater lens in the groundwater aquifer and are designed to reduce upconing of the brackish water in the transition zone (Gingerich, S.B., et al., 1998). The water production from the three ASPA gallery wells has averaged about 53,000 gal/day since their installation in 1992 (Gingerich, S.B., et al., 1998). These wells are primarily used for showers and toilet flushing because of the high chloride content (200 to 2,000 mg/l) and for taro irrigation.

The areal extent and vertical thickness of the ground water aquifer is an important factor that can affect the volume of freshwater available for use. Gingerich, S.B., et al., (1998) indicate the following:

> "The freshwater lens on the coastal plain of Aunuu reflects the general shape of the plain and attains a maximum thickness of at least 27 ft. The lens is thickest and widest in the interior of the coastal plain at the base of the tuff cone where the taro fields are located. The water pumped (from ASPA wells) has chloride concentrations above 250 mg/L because the freshwater lens is thin near the wells and the sump and infiltration galleries of the wells are located in the transition zone. Excessive pumping of the (ASPA) wells has caused the freshwater lens to become thinner in these areas."

Some of the ASPA infiltration gallery well water is put through a reverse osmosis (R/O) treatment to reduce chlorides and contaminants in the well water. As further treatment the ASPA R/O water is chlorinated to inactivate bacteria that may develop in the R/O holding tank. The ASPA R/O water is intended to be a reliable source of drinking water for Aunu'u residents.

Two hand dug brick lined infiltration wells (Village wells) are still used by Aunu'u Village residents[1] as a primary source of drinking water, which they greatly prefer over the ASPA R/O water. During the Nov 2006 house-to-house survey almost all of the residents indicated they liked the taste of the hand dug Village infiltration water wells over that of the ASPA R/O water. Residents complained of "getting sick" from the ASPA R/O water when the R/O plant was first built [2]and /or not liking the chlorine smell of the water.

Soils The U.S. Soil Conservation Service's *Soil Survey for American Samoa* characterizes soils on Aunu'u and describes soil suitability limitations for engineering, agricultural, and recreational uses (USSCS, 1984). Aunu'u soils are shown in Figure 3-1 and described in Table 3-1. Upland soils on the island are dominated by two soil series: Ngedebus and Ofu. Soils of the Ngedebus series are deep, often cobbly, coral sands and are the principal soils on the coastal plain portions of the island. The high permeability, poor filtering capacity, and high water table of these soils severely limits their use for any application that could affect the drinking water aquifer lying below the western portion of the Island.

The Ofu series are silty clays derived from volcanic tuff that dominates the eastern half of the Island. Despite relatively high clay content, these soils are described by USGS (1984) as exhibiting a moderately high permeability of between two and six inches per hour. Permeability of volcanic tuff soils is a function of many complex factors, making field verification essential (Robert Gavenda, NRCS, Guam, personal communication). If the permeability of these soils is as described in the soil survey, it severely limits the use of these soils for unlined impoundments, but does not significantly limit their use for soil-based wastewater treatment. Most of these soils are located on slopes of between six and forty percent and this range of slopes presents severe limitations for soil-based wastewater treatment. However, reconnaissance by project staff as well as topographic surveys

[1] Originally there were three Village infiltration wells, but one well was closed by ASEPA as being chronically contaminated by bacteria.

[2] Steve Anderson, ASEPA, personal communication, indicated that when the ASPA R/O water plant was first built there were some problems with bacteria growing in the holding tank, a problem that is now corrected with clorination.

conducted by McConnell Dowell indicate that significant areas on the south side of the crater that are mapped in the soil survey as "Ofu variant 6-20 percent slope" lie on slopes of five percent or less. Subject to field verification of soil properties, these areas may be suited for soil-based wastewater treatment.

Organic soils dominate Aunu'u wetlands. For example, the Ngerungor variant mucky peat in the vicinity of Pala Lake, Mesei Variant Peat in interior wetlands of the coastal plain, and Mesei variant, a deep, acid peat in the central portions of the volcanic crater. Like most wetland soils, these soils are severely limited for most uses other than recreation and wildlife habitat.

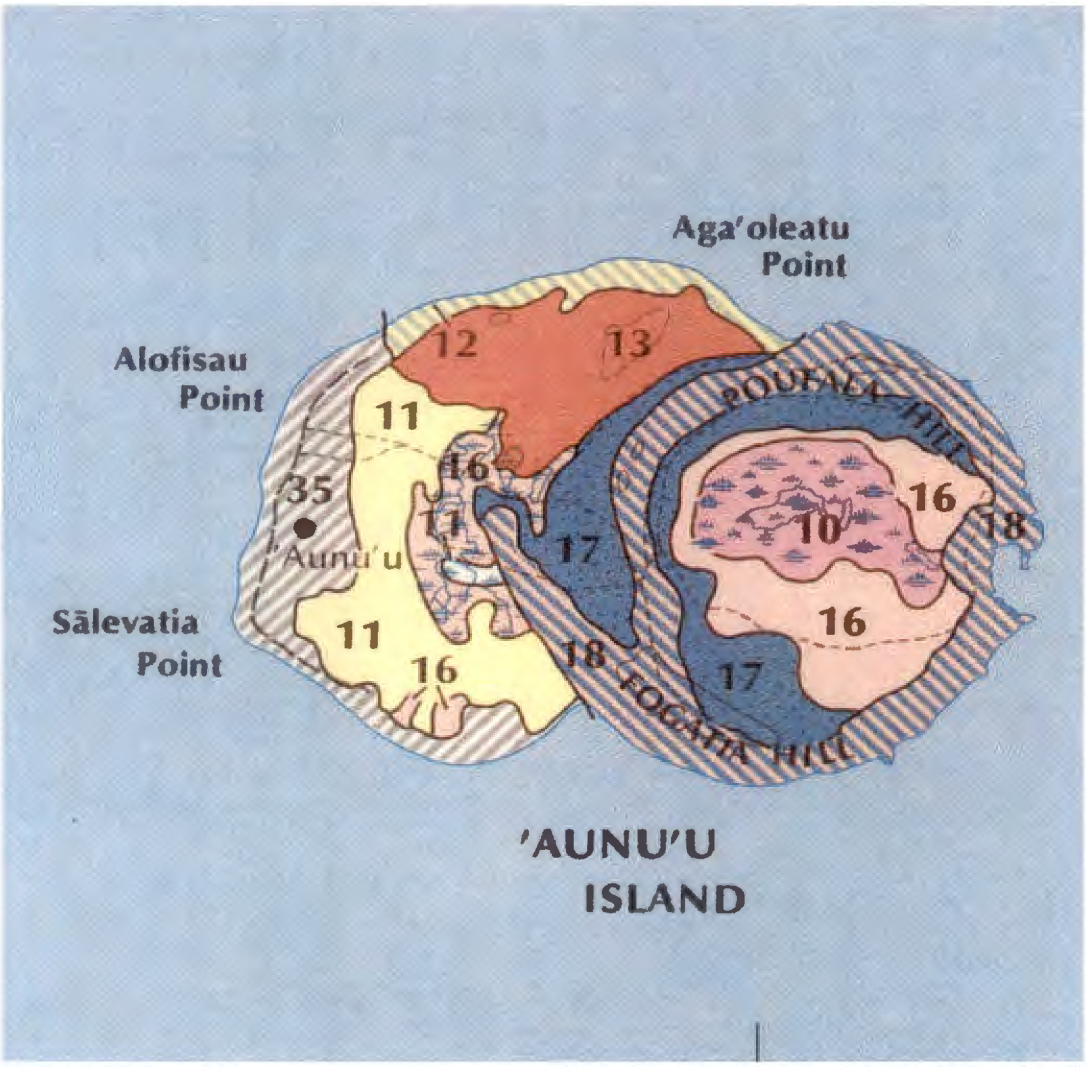

Figure 3-1. Aunu'u Soils Map (USDA)

Table 3-1. Aunu'u Soils Characteristics		
Soil Number	Soil Name	Soil Slopes
10	Mesei Variant peat	
11	Ngedebus mucky sand	
12	Ngedebus Variant extremely cobbly sand	0-5 percent
13	Ngerungor Variant mucky peat	
16	Ofu Variant silty clay	6-20 percent
17	Ofu Variant silty clay	20-40 percent
18	Ofu Variant-Rock outcrop complex	40-70 percent
35	Urban Land-Ngedebus complex	0-1 percent in Aunu'u

Oceanography American Samoa lies in a region influenced by the westward flowing South Equatorial Current and the eastward flowing South Equatorial Counter Current. The predominant current off the south shore of Tutuila and Aunu'u is westward. However, instabilities caused by the shear of these two currents and the influence of local and regional scale wind fields can produce eastward flowing currents, which are not uncommon . Tides are semi-diurnal with a range of about 2.5 feet and little diurnal inequality. Relatively strong tidal currents are common in the pass between Tutuila and Aunu'u. The west (inhabited coastal area) of Aunu'u is bordered by fringing reef that transition from nearly horizontal reef flats to a steep reef face that descends into water depths of 200 to 300 feet to the west and north. Nafanua Bank extends in a southwesterly direction at depths of 30 to 60 feet for about two miles, paralleling the shoreline of Tutuila. Although protected by Tutuila Island to the northwest, Aunu'u is subject to waves generated by the prevailing tradewinds as well as swell from southern ocean storms. Wave action is typically high and there is no dependably protected shoreline area.

3.1.2 Biological Environment

The biological environment of Aunu'u can readily be described in terms of terrestrial and aquatic habitats. The terrestrial habitat is land based and can be described in terms of vegetation (flora) and fauna. Aquatic habitat is water based and can be described in terms of coral reef ecology.

Terrestrial Habitat The vegetation of Aunu'u has been described by Cole et al. (1988), Biosystems Analysis, Inc. (1992), and Whistler (2002). Populated areas on the western portion of the island are characterized by village type vegetation with a variety of cultivated trees, shrubs, and ornamentals. Unpopulated uplands on the eastern half of the island are primarily mixed second growth forest or coconut plantation, often with a banana understory.

Four distinct wetlands occur on Aunu'u. On the northwest edge of the island is the 45-acre Pala Lake wetland. Pala Lake proper is devoid of vegetation, but is surrounded by a dense ring of oriental mangrove (*Bruguiera gymnorrhiza*). Inland portions of the Pala Lake wetland support Tahitian chestnut (*Inocarpus fagifer*), beach hibiscus (*Hibiscus tileacea*), swamp fern (*Acrostichum aureum*), and a variety of herbaceous species. This wetland is relatively undisturbed.

South of the Pala Lake wetlands in the interior of the island, approximately 25 acres of marshy wetlands have been converted to taro fields. A variety of weedy herbaceous species occur in these wetlands, which continue to serve as habitat for a number of fish species and waterfowl.

School Swamp, on the southeast of Aunu'u is a small (approximately 3 acres), disturbed mangrove swamp. The swamp has been partially cleared and used for trash disposal. The dominant plant species is the oriental mangrove, but the swamp also supports small numbers of puzzlenut tree *(Xylocarpus moluccensis)*, a species of very limited distribution on Samoa.

The center of the volcanic crater is occupied by a 35-acre marsh referred to as crater lake or Faimulivai Marsh. The marsh is dominated by water chestnut (*Eleocharis dulcis*), swamp fern, and marsh fern (*Cyclosorus interruptus*). This wetland is recognized as the largest marsh of its type in Samoa. The proportion of vegetated marsh to open water in this wetland appears to vary, possibly in response to catastrophic weather events such as cyclones. Whistler (2002) reported the wetland to be mostly covered in dense vegetation prior to cyclone Ofa in 1990, but mostly open water in 2001. The wetland was approximately 70 percent vegetated in May 2006. The marsh is surrounded by a narrow (<100') strip of forested wetland consisting mostly of beach hibiscus and *Barringtonia*.

Fauna Aunu'u, like the rest of Samoa, is relatively depauperate of land animals. There are no native land mammals except for fruit bats and the sheath-tailed bat (Craig, 2005). Introduced mammals include rats, pigs, dogs, and cats. The island has several native species of lizards, geckos and skinks, but neither native nor introduced snakes. The introduced giant marine toad thrives on the island, especially in and around the taro fields and Faimulivai Marsh.

Freshwater fish diversity is also relatively low. Native fish include the freshwater eel, and a number of gobies. Introduced fish such as tilapia and mosquitofish are abundant in the wetlands.

Aunu'u shares many species of birds with Tutuila. Conspicuous birds on Aunu'u include the pacific pigeon, banded rail, purple swamp hen, and reef heron. The Australian grey duck has been observed nesting on Faimulivai Marsh. This duck is rare on Samoa, and is in decline throughout its range due to habitat loss and competition with introduced ducks. There are no introduced ducks on Aunu'u.

Marine Aquatic Habitat The coastal plain shoreline of the Aunu'u Island is faced with reef flats extending about 300 to 600 feet offshore. The reef flats are often referred to as "coral" reef flats although the flats are dominated by calcareous algae and not coralline species. One of the earliest geologists (Daly, 1924) visiting Pago Pago Harbor described the Island of Tutuila reef flats as follows:

> "A recent [in terms of geological time] fringing "coral" reef occupies the shores of the harbor, and the dominance of calcareous alga makes the reef more properly an algal reef than a coral reef, while the fragile *Halimeda* (green algae) is abundant on the reef flat."

The condition of the reef flats in Aunu'u is directly related to success of the reef to remain free of sedimentation (in the absence of direct anthropogenic disturbances such as harvesting and fishing). As the soils in the coastal plain are very porous erosional events on Aunu'u do not supply a great deal of terrestrial sediment to the ocean.

The reef slopes in Aunu'u are occupied by combination of soft and hard corals, with over 200 known species occupying American Samoan waters. Over 890 species of fish are known to occupy American Samoan waters and the channel between Aunu'u and Tutuila Islands is known as one of the best drift dives in American Samoa.

3.1.3 Social, Cultural, and Economic Environment

The Aunu'u Village area is primarily residential with a few small stores located centrally. In general families live in close proximity to each other, and large extended families share in family life. In terms of wastewater facilities, almost all houses have indoor plumbing. During the house-to-house survey no dishwashers were found in Aunu'u. Only one house was found to be not hooked up to the sewer and a few abandoned houses were noted as having broken sewer pipes.

Schools and churches are also located in Aunu'u, and contribute to the wastewater load. School children and members of churches associated with those institutions were not counted in the population numbers, to avoid double counting the population. It is common practice in Aunu'u to place graves in close proximity to family homes. Old and new graves are often found scattered between the houses.
On an economic basis most residents of Aunu'u Island must travel to Tutuila Island for employment. Transport by water taxi is on demand and during stormy conditions not available. A few families spend the bulk of the work week on Tutulia Island, with friends and families, in order not to miss work and school. There is an elementary school in Aunu'u Village but high school students must travel by water taxi and then school bus to the closest high school on Tutulia.

3.2 Demographics and Land Use

It is critical to understand the population size and distribution along with the land use patterns in order to correctly estimate the volume and quality of wastewater generated on Aunu'u. Some pertinent information was available from the American Samoa Department of Commerce (ASDOC) and is used in this section of the WWFP. The most recent U.S. census conducted was for the Year 2000. Census data for American Samoa was available from the ASDOC in summary format. Other data was available on-line from the U.S. DOC. However, this WWFP also required a house-to-house survey be designed and conducted on Aunu'u because some critical information was either not available or was not available on the scale necessary to evaluate, design, and construct a wastewater transmission, and treatment system.

3.2.1 House-To-House Survey

The house-to-house survey was designed to be administered in either English or Samoan as shown in Figures 3-2 and 3-3, respectively. The survey teams were composed of two two-person teams with a Samoan native speaker on each team. The requirement for a Samoan speaker greatly facilitated the survey. The survey was administered by interview with individuals at home at the time of survey. The interviewers filled out the forms immediately, rather than leaving a form behind with residents to fill out. The form was shown to interviewees, if requested, to alleviate concerns about names, phone numbers, or other personal information being recorded. Repeat visits were made to houses where no one was home until an interview was completed. The response rate was approximately 99 percent with the only homes not in the survey being those that were vacant or with long-term absent tenants (as established by talking with neighbors).

The house-to-house surveys were conduced during November 2006. Although the surveys provide a "snapshot in time", questions were designed to encompass typical or "normal" conditions. For example, the question was asked, "How many people live in this house?" but the question was also asked "How many people visit here, from where, and how long do they stay?" which better quantifies the actual number of transient persons in the house. The survey was also designed to quantify many previously unknown water resource issues on the island, such as water sources and water reliability, wastewater discharge practices, and stormwater runoff locations. Land use types and distributions are addressed in Section 3.2.2. ASEPA had in 2006 completed a piggery survey on Aunu'u, so no additional questions concerning piggery impacts to water supply were asked during this survey.

Population The Year 2000 US Census is the most recent survey of population in American Samoa. Staff of the ASDOC conducts the US Census. In the US Census an attempt is made to determine the number of persons per household. The definition of what composes a household is a cumbersome but seemingly necessary measure that is required by many of the US Government agencies including those that provide funding for important health and human services programs.

The US Census definition of household[3] is:

> "…a household includes all of the people who occupy a housing unit".

A housing unit is defined as:

> "…is a house, an apartment, a mobile home, a group of rooms, or a single room occupied (or if vacant, intended for occupancy) as separate living quarters".

Average household size is:

> "…a measure obtained by dividing the number of people in households by the total number of households".

Householder is defined based on the relationship of Person 1 (the Head of the Household) to Person 2 (next person in household) and higher number of persons (subsequent persons in household) within housing units. The householder is defined as the:
"…person or one of the people, in whose name the house is owned, being bought, or rented. If there is no such person in the household, any adult household member 15 years old and over could be designated as the householder (i.e., Person 1).

[3] Definition of Household Type and Relationship are found on Page B-17 through B-20 of the *American Samoa: 2000 Census of Population and Housing, Social, Economic, and Housing Characteristics*, Issue June 2003.

American Samoa EPA Aunu'u Wastewater Project House Survey Form/Questionnaire								
House Number	Grid Number			Electric Meter Number				Recorder
Description:	Type of Structure/Land Use?	Residential	Commercial (type)	Church	School	Garden	Piggery	Other (Note)
	Primary Land Use?							
	Secondary Land Use?							
	Tertiary Land Use?							

How Many People Live in This House?							
How Many People Who Live Here Leave During The Week?		How Long Do They Stay Away?					
How Many People Visit Here From Tutulia?		How Long Do They Stay?					
How Many People Visit Here From W. Samoa?		How Long Do They Stay?					
How Many People Work For The Canneries?		Birthdays	Holidays	Fa'alavelave	Sunday Meals	Other (Note)	
How Many People Attend Gatherings Here?							
Number of Times per Year?							

Source(s) of Water?	Village Well	House Well	Rain Catchment	ASPA Office	Store Bottled	Other (Note source)	
Reliability of Water Supply?	Do You Have Water All the Time?		Yes	No	Frequency Not Available?	Days	Weeks

Wastewater Discharge		Sewer	Cesspool	Pit	Composting	Gray Water Use	Diversion	To Where (Exit Location)
Flush Toilets	In main house							
	In another structure							
	Outside							
Privy/ Outhouse	In another structure							
	Outside							
Shower/ Bath	In main house							
	In another structure							
	Outside							
Kitchen	In main house							
	In another structure							
	Outside							
Laundry	In main house							
	In another structure							
	Outside							
Other (Car Wash)								
If improved wastewater treatment were provided would you have your house hooked up to it?					Yes	No	If No, Reason Why?	

Stormwater Runoff from Yard	Drains directly to stream	Drains to catchment	Drains to road	Drains to other (Note)	Notes:
Stormwater Runoff from House (roof/gutters)	Drains directly to stream	Drains to catchment	Drains to road	Drains to other (Note)	

Figure 3-2. House-to-House Survey Form/Questionnaire Used for the Aunu'u WWFP: English Version

American Samoa EPA Aunu'u Wastewater Project House Survey Form/Questionnaire			
House Number	Lou pusa meli	Electric Meter Number	Recorder

Fa'amatala auiliili:	Ituaiga Fausaga Fale/ Fa'aaogaina le eleele	Nofo'a'ia	Fale Pisinisi (ituaiga)	Fale Sa	Aoga	Togalaau	Aoga	Leisi (Note)
	Fa'aaogaina muamua?							
	Fa'aaogaina lona lua							
	Seisi Fa'aaogaina							

E fia le aofa'i o tagata o lo'o fa'amautu i'inei?							
How many people that live here leave during the week?		Le umi e masani o na nonofo ai?					
E to'afia se aofa'iga o tagata e masani o na asiasi mai i lou maota?		Le umi e masani o na nonofo ai?					
E to'afia se aofa'iga o tagata e masani o na asiasi mai i lou maota?		Le umi e masani o na nonofo ai?					
E fia le aofa'I o lo'o faigaluega i le kamupani?		Malolo	Aso	Fa'alavelave	To'onai Aso Sa	Leisi	
E to'afia e masani ona auai i ini fa'atasiga i lou maota?							
Number of times per year?							

Fa'apefea ona auala lo outou suavai?	Vai nu'u	Fa'atanoa a oe lava	Vai timu	ASPA Office	Vai fa'atau	Vai Fanua	Leisi	
E te fa'a tuatuaina le auala o lou suavai?	E maua pea e oe le suavai i taimi uma?		Ioe	Leai	O le se umi sa' e le maua ai se suavai?		Aso	Vaiaso

Fa'aaluga o le suavai leaga		Sewer	Cesspool	Pit	Composting	Gray Water Use	Diversion	To Where (Exit Location)
Fale mamao papalagi	Fale tele							
	I leisi Fale							
	Fafo							
Leisi	I leisi Fale							
	Fafo							
Fale ta'ele	Fale tele							
	I leisi Fale							
	Fafo							
Umukuka	Fale tele							
	I leisi Fale							
	Fafo							
Fale ta lavalava	Fale tele							
	I leisi Fale							
	Fafo							
Leisi (ta avale fa'amamaina)								
Pe fa'amata e te talia se fesoasoani mo oe pe a ofa'ina atu?				Ioe	Leai	A leai, aisea?		

O fea e aga'I ai le suavai mai ou lau fanua pe a timu?	Tafe sa'o i le vai tafe	Fa'aputuina	Tafe sa'o I le auala tele	Le mautinoa	Fa'amaumauga:
O fea e aga'I ai le suavai e tafe mai I luga o lou maota pe a timu?	Tafe sa'o i le vai tafe	Fa'aputuina	Tafe sa'o I le auala tele	Le mautinoa	

Figure 3-3. House-to-House Survey Form/Questionnaire Used for the Aunu'u WWFP: Samoan Version

For the Aunu'u house-to-house survey data on the number of persons were based on the actual number of persons occupying a housing unit, independent of relationship to each other. All housing units on Aunu'u were classified as being single-family homes. Each structure on Aunu'u was inventoried and classified as to land use, such as house, store, school, church, or other establishment.

For the Aunu'u survey the question was asked "How many people live in this house?" independent of number of "households" or "head of household" present in the house. The goal of the house-to-house survey was to estimate the population for purposes of estimating the quantity of wastewater that is generated under existing conditions.

Table 3-2 shows the results of the Aunu'u house-to-house survey for population. For comparison the US Census population numbers are provided for the most recent complete census for the Year 2000, along with the 1990, 1980, and 1970 Year Censuses.

Visitors and Transient Population Another important factor for estimation of wastewater flows is the number of short-term and long-term visitors and guests. The house-to-house survey included questions on the number of visitors from both Tutulia and Western Samoa, including length of stay. The survey also asked about the number and frequency of gatherings such as for holidays, birthdays, Fa'alavelava's, and Sunday meals. Table 3-3 provides a summary of the results of the interviews in terms of the Aunu'u population.

Table 3-2. Aunu'u Village Population Comparisons, 1970 - 2006

Source of Population Data	Population
House-to-House Survey – Nov 2006	446
US Census - 2000	476
US Census 1990	463
US Census 1980	414
US Census 1970	425

The number of visitors was enumerated in terms of the number of visitor days such that frequency and duration of visits were included. For example if one visitor stayed for three days that would be included as three visitor days. The total of visitor days was then divided by 365 days per year to determine the number of equivalent residents on an annual basis.

Table 3-3. Visitor Days and Resident Equivalents for Aunu'u Village Population

Visitor Days and Equivalent Residents/Yr		Aunu'u Village
Number of Visitors Days Per Year For Visitors From Tutuila	Number of Visitor Days	9862
	Equivalent Residents/Yr	27
Number of Visitors Days Per Year For Visitors From Western Samoa	Number of Visitor Days	3640
	Equivalent Residents/Yr	10
Total Equivalent Residents/Yr		37
Total Residents		446

Land Use Land use types directly affect water use and thereby the generation of wastewater. Land use on Aunu'u is predominantly residential, with small amounts of commercial and recreational uses. Agriculture represents a large land use on the coastal plain with extensive taro production in former freshwater marshes. Aunu'u taro production is larger than any other location in American Samoa (Gengerich S.B., et al., 1998). Aunu'u agriculture is also present in the tuff cone basin. Banana production is located on the north and west slopes and coconut production is located on the east and south slopes of the tuff cone.

The numbers of dwelling units along with the number of public and private non-housing units (schools, churches, and other structures) are shown in Table 3-4.

Table 3-4. Land Use in Aunu'u Village

Land Use	Number of Structures	Notes
Residential	112	Not including 4 separate storage sheds
Fales	20	
Commercial	2	Snack shops, stores
School	1	
Church	3	

3.2.2 Water Use and Wastewater Generation

The domestic water supply on Aunu'u can't readily be separated from the agricultural water use. The average volume of ASPA water pumped daily from the infiltration wells was 53,000 gal/day in 1992, and has remained at about similar levels since then (Izuka S.K. 1996). This water volume assumes domestic and agricultural uses. If the value for domestic water use developed for the Pago Pago Harbor East Side Villages of 100 gallons per person per day[4] is applied for Aunu'u, the total domestic production would equal 44,600 gal/day for domestic use and 8,400 gal/day for agriculture and ASPA R/O water combined.

3.3 Water Quality and Beneficial Uses

The water quality of Aunu'u adjacent open coastal waters is typically very good, based on Pago Pago Harbor's offshore reference station. Water quality standards for Pago Pago Harbor reference station location are consistently achieved. Tutuila beaches near streams are always among the highest in the incidence of bacterial non-compliance of those monitored by ASEPA (2004) on Tutuila. The only notable exception to overall water quality compliance are in areas of the Harbor immediately adjacent to stream mouths. Water quality samples from the mouth of Faimulivai Marsh on Anuu'u (Table 3-5 and 3-6) discharge to the ocean also indicates non-compliance with bacteria and nutrient water quality standards.

On Aunu'u the protected (beneficial) uses of the waters of the open coastal areas are, with the exception of the untreated wastewater discharged to the edge of the reef flat, are currently not compromised. The implementation of adequate wastewater treatment for the Aunu'u service area is expected to improve the water quality of the beaches and nearshore waters and contribute to the attainment of beneficial uses.

Water quality samples were collected from the outlet of Faimuluvai Marsh in November 2006. Table 3-5 presents the results of the sampling. Nutrients such as nitrates and phosphates exceed the ASWQS for fresh surface waters. Marsh samples for bacteria *Enteroccus sp.* levels were higher than acceptable for fresh surface waters.

Beach samples for bacteria *Entercoccus sp.,* were taken inshore and west of the existing ocean outfall (Table 3-6). The bacteria values indicate compliance with ASWQS for recreational beaches. However, it should be noted that the low levels of bacteria during this sampling event may simply be a coincidental result of stage of the tide, wind, and waves at the time of sampling. The location and depth of the existing outfall indicate the potential for unacceptable bacterial levels along these beaches, and it is expected that this would be reflected in additional sampling.

3.4 Special Considerations in the Planning Area

There are three issues identified thus far in the WWFP process that need to be addressed. One concerns the status of hook-up to existing collection system. Another is the status of the Aunu'u Island tuff cone designation as a National Natural Landmark. Lastly is the unknown status of rock walls and foundations inside the tuff cone.

3.4.1 Existing Treatment System

Allmost all toilets in Aunu'u discharge to the sewer collection system. No existing residential septic systems were confirmed during the house-to-house survey. Wastewater from the school in Aunu'u appears to drain into a septic tank. The Aunu'u sewer as built

[4] GDC. 2007. Small Community Wastewater Facilities Plan for Leloaloa, Aua, and Onesosopo. Prepared for American Samoa Environmental Protection Agency.

drawings from ASPA do not show a sewer hook-up to the school. Antidotal information from ASPA workers on Aunu'u indicate that the elementary school is hooked up to the existing sewer system.

Table 3-5. Results of Water Quality Samples at the Outlet of Faimulivai Marsh on Aunu'u, November 15, 2006

Parameter	Result	MRL	MDL	ASWQS Fresh Surface Water (mg/l)	ASWQS Open Coastal Water (mg/l)
Chlorophyll-a (mg/m^3)	1.6	0.8	.05		0.00025
TDS (mg/L)	281	5	5		
TDS (DUP) (mg/L)	275	5	-		
TSS (mg/L)	5	5	5	5.0	
TSS (DUP) (mg/L)	ND	5	-		
COD (mg/L)	59	5	2.5		
COD (DUP) (mg/L)	61	5	-		
Total Phosphorous (mg/L)	0.19	0.01	0.003	0.1500	0.0150
TP (DUP) (mg/L)	0.19	0.01	-		
Nitrate+Nitrite as N (mg/L)	0.02	0.05	0.006		
NOx (DUP) (mg/L)	0.07	0.05	-		
Ammonia (mg/L)	0.01	0.01	0.002		≅ 2
Ammonia (DUP) (mg/L)	0.01	0.01	-		
TKN (mg/L)	0.52	-	0.10		
Total Nitrogen (mg/l)	0.54			0.3000	0.1300
Enterococcus 01	1333	-	10	151/100ml	124/100 ml
Enterococcus 01 (DUP)	1299	-	10	151/100ml	124/100 ml
Enterococcus 02	1112	-	10	151/100ml	124/100 ml
Enterococcus 02 (DUP)	1203	-	10	151/100ml	124/100 ml
MRL= Method Reporting Limit; MDL= Method Detection Limit					

Table 3-6. Results of Water Quality Samples at the Coastal Plain Beach west of the Ocean Outfall on Aunu'u, November 15, 2006

Parameter	Result	MRL	MDL	ASWQS Fresh Surface Water	ASWQS Open Coastal Water
Enterococcus B1	0	-	10	151/100ml	124/100 ml
Enterococcus B1 (DUP)	20	-	10	151/100ml	124/100 ml
Enterococcus B2	0	-	10	151/100ml	124/100 ml
Enterococcus B2 (DUP)	52	-	10	151/100ml	124/100 ml
MRL= Method Reporting Limit; MDL= Method Detection Limit					

3.4.2 National Natural Landmark Status of Aunu'u Tuff Cone

The tuff cone crater and Faimulivai Marsh are designated as a National Natural Landmark. This landmark status is granted (under 36CFR Ch.1 Part 62) by the U.S. Federal Government to areas of exceptional natural value to the nation as a whole rather than to one state or locality. Owners of natural landmarks under this status are encouraged to voluntarily observe preservation status. This landmark status is granted to preserve natural areas that best illustrate the biological and geological characteristics of the United States. The purpose is to enhance the scientific and educational values of preserved areas. Status is given to areas that are outstanding examples of major biological and geological features found within the boundaries of the United States or its Territories or on the Outer Continental Shelf.

Any project located in proximity to the National Landmark must examine the negative impacts and positive benefits of the project. However, natural wetlands treatment that does not degrade the landmark should be viewed as an acceptable alternative to eliminate discharge to, and adverse impacts on, the coral reef. Refer to Section 11 below for a more detailed discussion of the environmental effects of the project.

3.4.3 Structures in the Aunu'u Tuff Cone

During field operations in Aunu'u it was discovered that there are abandoned rock walls, structures, and piggeries within the Aunu'u tuff cone. The age and importance of these structures is unknown. Further field work by the ASPA archaeologist should clarify this issue.

Section 4
ANALYSIS OF EXISTING AUNU'U COLLECTION AND DISCHARGE SYSTEM

The results from the house-to-house survey (Section 3) reported that essentially all households in the entire Village of Aunu'u are presently connected to the existing sanitary sewer collection system. This collection system is an integral component of all of the potential future wastewater management approaches. Limited analysis of adequacy is included in this WWFP as ASPA believes the collection system currently provides waste collection services for the Village.

4.1 General Description of the Aunu'u System

A general layout of the existing Aunu'u collection system is presented in Figure 2-4. The collection system consists of a network of plastic piping and manholes serving the entire village area.* The collection system was reportedly installed beginning early in the 1970s. Collected sewage flows by gravity through a network of 8-inch diameter pipes to a centrally located wet well and pump station. From this point, the sewage is pumped through a 6-inch diameter high-density polyethylene (HDPE) ocean outfall.

The pump station is located in a village neighborhood several hundred feet inland from the shoreline. The pump station consists of two submersible centrifugal pumps located in a common concrete wet well. The pumps are electrically driven, constant speed pumps that are started and stopped based on float switches inside the wet well. Each pump is a Flygt Model 3085 with a Type 463 (136 millimeter diameter) impeller and can require as much as 2.8 horsepower at low total dynamic head (TDH) requirements, based on the pump curves supplied by ASPA.

4.2 Adequacy of the Existing Collection System

A pump test was conducted on July 7, 2006 to measure both the inflow of wastewater into the pump station as well as the output of the pump station. The results of the test indicated that the average sewage inflow during the test was approximately 56,000 gallons per day, which is consistent with predicted flows discussed in Section 3. The pump station delivers approximately 460 gallons per minute to the ocean outfall. This is nearly the maximum rated capacity of the pump, suggesting that there is very low discharge head during the pumping cycle. Cycle times ("pump on" to "pump on") varied from 21 to 39 minutes during this trial, within the range of acceptable pump station performance. This suggests that the current wet well size, pumping rates, and level settings are adequate for current and anticipated future flows.

A construction drawing for the collection system was made available to the project team and is assumed to adequately represent the as-built condition of the system (Figure 2-4). With

* However, Figure 2-4 does not show that the school on the southeast side of the village is connected to the existing collection system.

the possible exception of the pumps themselves, the existing collection system appears adequate for the future-planning horizon for the following reasons:

1. The collection system is constructed of corrosion-resistant materials that will last indefinitely in the marine environment that dominates Aunu'u.

2. No signs of structural problems in the manhole structures were noted during site visits.

3. Insufficient information was available to know the detailed as-built characteristics of the conveyance system. Assuming that the 8-inch sewage mains were laid at a slope of 0.44 percent (the minimum slope necessary to meet the Design Standards for the City and County of Honolulu), the conveyance capacity of a single pipe is over 300 gallons per minute. This flow is much higher than the expected peak flow for the entire service area. In addition, there were no reports of overflows or other conveyance related problems in the existing collection system[1] or pump station, which suggests that existing pipe sizes are adequate.

4. There are no obvious signs of odors or elevated maintenance requirements in the existing system, which suggests that slopes are adequate and that there are no "dead spots" in the conveyance system.

5. Sewage flows were minimal during an inspection of the wet well during the field visit, which indicate that infiltration is not excessive. The field visit was made during dry conditions, so inflow could not be evaluated first hand. However, it does not appear that inflow could be excessive.

The existing pumps are low head pumps. While they appear to be in good operational order, they are inadequate for delivering discharge pressures greater than approximately 8 pounds per square inch (18 feet) of head and still meet peak sewage flow conditions. A selected alternative that requires pumping sewage further than the existing ocean outfall will likely require new pumps.

The outfall is 6-inch diameter. This size should be adequate for current and anticipated future flows within the service area.

4.3 Recommended Design Loading from Existing Service Area

Information on the current wastewater design loadings is not available. Water usage information is available, as discussed in Section 3.2.2. Assuming that 8,400 gal/day (16 percent) of the 53,000 gal/day estimated water use is used for non-domestic purposes, 44,600 gal/day is used for domestic purposes. Since almost all houses are connected to the

[1] During the house-to-house survey one respondent indicated that after being connected to the system the wastewater backed-up numerous times into the house and the problem could not be resolved by ASPA. The owner could only rectify the problem by disconnecting from the system. A broken wastewater pipe exposed on the surface was noted from an abandoned house on the periphery of the Village.

collection system, essentially all water would be expected to end up in the sanitary sewer. This would suggest that wastewater generation is 100 gal/day per person, equal to the wastewater generation rate found in the recently completed East Side Villages Facility Plan (**gdc**, 2007).

Other than the potential use of reverse osmosis treated water for drinking and cooking[2], the lifestyle of the population on Aunu'u does not appear dramatically different from that of other villages in American Samoa. Since there is no specific information upon which to specifically base Aunu'u loadings, it is recommended that the design loadings from the existing system area should be based on the same assumptions made for similar service areas on the adjacent Island of Tutuila, as follows:

- Flow loading of 100 gal/day per person
- Additional flow allowance for infiltration/inflow (I/I)
- BOD and TSS loadings of 0.22 pounds/day per person

Further discussion of the recommended design loadings is provided in Section 5.0.

4.4 Capacity of Unit Processes

Aside from the collection system, pump station, and outfall, which are discussed above, there are no unit processes to treat or dispose of wastewater or wastewater solids on the island of Aunu'u. A landfill exists in a remote unpopulated portion of the island that may be an asset to future wastewater and biosolids management options. In addition, relatively large sections of the island are undeveloped; although much of the undeveloped area either has steep (> 20 percent) slopes or consists of wetlands.

[2] As noted in Section 3, reverse osmosis drinking water is available but generally not utilized by most of the population of the Island

Section 5
Assessment of Future Conditions for Aunu'u

This section provides information required to define the estimated future conditions for the planning area. These data will be used to evaluate alternatives and to prepare preliminary design for the selected alternative. The selected planning period is established, the land use and population changes anticipated over the planning period are projected, and the forecasted wastewater flows and loads used to determine the facilities required to serve the Village and Island of Aunu'u through the selected planning period, are developed.

5.1 Planning Period

There are a variety of "planning periods" that can be identified. In terms of wastewater treatment facility operations and regulation, a planning period of five years is appropriate to match the length of the required NPDES permit for wastewater discharge. For engineering design purposes, the nominal design life of the facility is appropriate, and is typically assumed as 20 years. When long-term planning issues are of significant concern, a planning horizon of virtually any time scale can be employed. One useful planning horizon is the length of time expected before a fully developed and stable community, with little local growth, is established.

For this WWFP the appropriate planning period is considered to be the design life of the constructed facilities; 20 years from the time the system is completed and operational. It is noted that infrastructure will likely remain operational for longer than 20 years with adequate maintenance. The design life is primarily used as a planning horizon within which to predict changes in wastewater flows and loads in response to population and economic growth. The size and capacity of the Aunu'u wastewater treatment facilities will be based on the ability to treat the wastewater volume and loads expected at 20 years into the future, from the time the system becomes operational.

5.2 Land Use

A review of current and past land use patterns indicates little anticipated change within the Village of Aunu'u over the planning period. This is based on the following observations:

- There is limited developable land for commercial enterprises in the Village of Aunu'u area and there is no potential for shoreline industrial development.

- Although surveys within Aunu'u indicate sufficient room for additional residential units, the limiting factor at the present time may be, in part, available and dependable electrical power. Also, there is no economic base or employment on Aunu'u and the need to cross to Tutuila Island for employment and household supplies probably inhibits growth.

- A change in land ownership patterns in American Samoa would be required before investors or developers from outside the Territory would consider economic conditions suitable for speculative development. Such a change is considered highly unlikely.

- Population growth or changes in land use patterns as a result of economic stimulus from tourism is not anticipated. There is little or no room for industrial development and a lack of conventional attributes typically attractive to tourists precludes development of a tourist industry.

Based on these observations and information from previous studies, land use on the Island of Aunu'u is expected to remain consistent over the planning period: i.e. generally residential with travel to Tutuila Island for high school and employment.

5.3 Demographic and Economic Projections

Population changes over the planning period are difficult to assess. There are uncertainties in future economic opportunities within the Territory as a whole, particularly if the tuna canneries do not continue operations. However, this would likely have little effect on the resident population on Aunu'u. The recent population data for Aunu'u is shown in Figure 5-1; the years 1970. 1980, 1990, and 2000 census numbers, and the results of the 2006 house-to-house survey conducted for this facilities plan are shown.

For the five-decade period of record shown, the data appears to indicate an oscillation of roughly 10% about a population mean of 445. Alternatively, the population numbers in Figure 5-1 indicate a relatively stable or slowly increasing population. Interpretation of past growth patterns will affect the population projection for this facilities plan. Projecting the apparent cyclic trend for a twenty-year period results in a maximum population estimate of about 500 people. Recent population growth in the more densely populated areas of Tutuila Island, around Pago Pago Harbor, is estimated to be about 1.5% to 1.7% per year. At a growth of 1.5% per year for twenty years the population of Aunu'u would be about 620 people and may be a realistic estimate if the trend of increasing population is accepted as valid. However, the data does not indicate that Aunu'u is similar to Tutuila in population growth rate and the economic factors that affect Tutulia growth are absent from Aunu'u. A stable population of about 500 people over the twenty-year planning period is considered realistic; using a higher number would be conservative in terms of design of wastewater management alternatives. Using the slightly higher value does require a greater commitment of economic and personnel resources. Design population should be reexamined during the final design process.

The recent growth in American Samoa in general, and in the Aunu'u area, is a reflection of the relatively unique cash economy of the Territory compared to other Pacific Islands and surrounding regions. This growth is, at least in part, driven by in-migration attracted by the operation of the tuna canneries, and the inflow of financial aid from the United States. No new stimuli to the economy are foreseen, and it is not unreasonable to predict a slowing of the population growth.

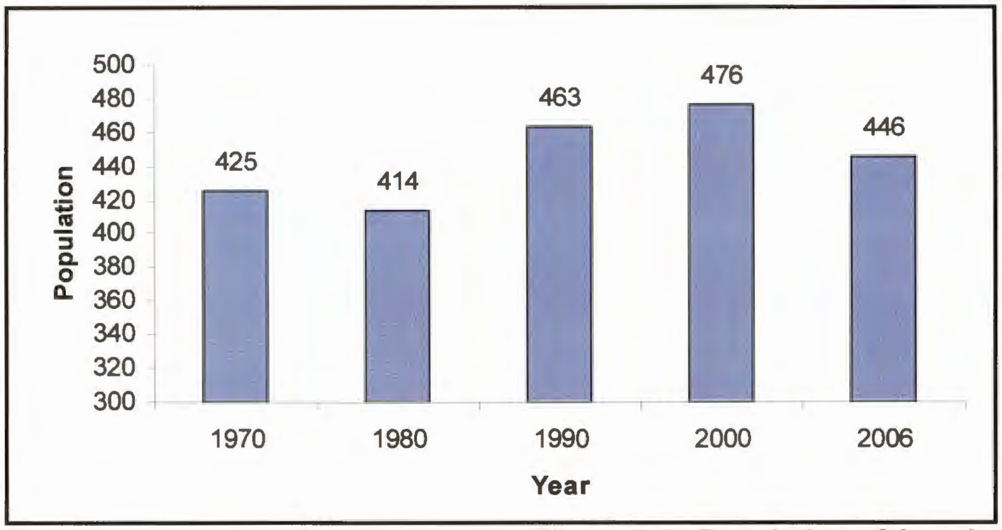

Figure 5-1. Population of Aunu'u
(1970, 1980, 1990, and 2000 census data and 2006 survey data)

5.4 Wastewater Flow and Load Projections

This section estimates the future flows and loadings associated with the Aunu'u service area. The design flows and loads are based on the projected wastewater flows and appropriate factors to account for flow variability.

5.4.1 Existing Flow

The present day average wastewater flow was developed in Section 3.4 and is based on population and water use. An average daily flow of 0.045 mgd is estimated for the existing (2006) conditions.

The maximum wastewater flow is defined as the average wastewater flow multiplied by a flow factor. A flow factor of 5.0 was derived for this facilities plan, based on an average daily flow of 0.045 mgd (*Design Standards of the Department of Wastewater Management, City and County of Honolulu*). The maximum expected wastewater flow from the Aunu'u service area is therefore 0.22 mgd, or 155 gpm.

Infiltration/inflow (I/I) is a term that describes water entering a wastewater collection system as the result of groundwater leaking into the system through pipe joints or manholes, and surface water entering the system through leaking manhole covers, roof drains connected to the sewer, etc. The I/I allowance for system design shown in Table 5-1 taken from *Design Standards of the Department of Wastewater Management, City and County of Honolulu.* Sewers for Aunu'u will likely be laid both above and below the normal ground water table. Assuming that half of the sewers are laid above and half are laid below the normal water table, the average dry weather I/I is estimated at 20 gallons per capita per day. Assuming 446 people, the additional dry weather I/I is 8,920 gallons per day.

Table 5-1. Estimated Infiltration and Inflow (based on Honolulu Standards)		
Climatic Condition	**Sewers Laid Below Normal Ground Water Table**	**Sewers Laid Above Normal Ground Water Table**
Dry Weather	35 gallons per capita per day	5 gallons per capita per day
Wet Weather	2,750 gallons per acre per day	1,250 gallons per acre per day

Assuming the average of dry and wet weather conditions, the wet weather flow rate using the Honolulu standards is 2,000 gallons per acre per day. The Aunu'u service area encompasses approximately 41.3 acres, so wet weather I/I is expected to be 82,600 gallons per day. This is approximately 185% of the average daily wastewater flow without I/I.

An I/I estimate based on the Honolulu wet weather approach seems high for relatively modern sewer systems. The State of Washington's *Criteria for Sewage Works Design* indicates that no additional I/I allowance is needed for systems built with modern construction techniques. The manual does recommend an I/I allowance where there is high groundwater, or where illicit connections may exist. Since there is high groundwater in the service area and a history of informal connections in American Samoa, an I/I allowance is probably warranted.

Previous analyses done on the Island for Tutuila assumed an I/I allowance of 1,250 gallons per acre per day. Applying this value to the 41.3 acre service area yields a wet weather I/I allowance of 51,625 gallons per day. This value is slightly higher than the expected average flow rate without I/I and seems reasonable for use for the purpose of this WWFP.

The peak hourly wastewater flow is defined as the maximum flow generated in the service area over a one hour period over the evaluation period. This value is used to select pipe size and pump station capacity, and the hydraulic capacity of the treatment plant. It is equal to the existing maximum wastewater flow rate plus the expected wet weather flow. The peak flow rate for the base year 2006 is therefore 0.27 mgd (191 gpm). The average flow rate for the base year 2006 including I/I is 0.070 mgd (49 gpm) (assumes annual average I/I is half of the wet weather I/I).

5.4.2 Existing Wastewater Loads

Wastewater samples were not taken in the service area for this plan. However, given the character of the service area, the expected concentration of wastewater will likely be similar to wastewater in the Utulei WWTP system on Tutuila Island (Section 2). Influent BOD and TSS concentration for the Utulei WWTP average less than 100 mg/l. If 100 mg/l is used, the average concentration in the service area is 0.11 lb. of BOD or TSS per capita per day. Published values for modern households indicate per capita rates of twice this value. The Utulei WWTP loads are lower than typical design standards. This is possibly because, in part, of high levels of I/I. Life style differences between American Samoa and the United States may also contribute to lower BOD and TSS.

The exact reason for lower than expected BOD and TSS loadings cannot be determined. Therefore, to be conservative, it is considered prudent to use a higher value for design purposes. A base year load of 98 lb/day BOD and TSS (0.22 lb/day per person) will be used for planning purposes. This will result in an annual average concentration of 167 mg/l of BOD and TSS. Concentrations will be lower during wet weather conditions and higher during dry weather conditions.

5.4.3 Future Flows and Loads

Flows in the future will rise as a function of population growth. As mentioned above, for purposes of design and evaluation of alternatives, it is considered prudent to assume a reasonable potential population growth although it is considered more likely that population will remain at near static conditions. A 1.45 percent per year population growth was assumed. Based on this rate of growth, the resulting population in 2026 is estimated to be 595 persons, approximately 33 percent greater than the estimated current population. Based on this population growth the projected wastewater flows and BOD and TSS loads are shown in Tables 5-2 and 5-3. This facilities plan will accommodate the flows and loads throughout the approximate 20-year planning cycle. As mentioned above, projected population and future flows should be re-examined during final design.

Table 5.2 Flow Predictions

Year	Population[1]	Average Wastewater Flow without I/I (mgd)	Average Wastewater Flow with I/I (mgd)[2]	Average Wet Weather Monthly Flow (mgd)[3]	Peak Wastewater Flow with I/I (mgd)[4]	Peak Wastewater Flow with I/I (gpm)
2006	446	0.045	0.070	0.096	0.27	191
2007	452	0.045	0.071	0.097	0.28	193
2008	459	0.046	0.072	0.098	0.28	195
2009	466	0.047	0.072	0.098	0.28	198
2010	472	0.047	0.073	0.099	0.29	200
2011	479	0.048	0.074	0.100	0.29	202
2012	486	0.049	0.074	0.100	0.29	205
2013	493	0.049	0.075	0.101	0.30	207
2014	500	0.050	0.076	0.102	0.30	210
2015	508	0.051	0.077	0.103	0.31	212
2016	515	0.052	0.077	0.103	0.31	215
2017	523	0.052	0.078	0.104	0.31	217
2018	530	0.053	0.079	0.105	0.32	220
2019	538	0.054	0.080	0.106	0.32	223
2020	546	0.055	0.080	0.106	0.32	225
2021	553	0.055	0.081	0.107	0.33	228
2022	562	0.056	0.082	0.108	0.33	231
2023	570	0.057	0.083	0.109	0.34	234
2024	578	0.058	0.084	0.110	0.34	237
2025	586	0.059	0.085	0.110	0.34	240
2026	595	0.059	0.085	0.111	0.35	242
2027	603	0.060	0.086	0.112	0.35	245
2028	612	0.061	0.087	0.113	0.36	249
2029	621	0.062	0.088	0.114	0.36	252
2030	630	0.063	0.089	0.115	0.37	255

[1] Annual growth rate of 1.45%
[2] Average I/I of 0.026 mgd
[3] Wet weather I/I of 0.052 mgd
[4] Peaking Factor = 5.0

Table 5.3 TSS and BOD Load Predictions						
Year	Population[1]	Average Wastewater Flow with I/I[2] (mgd)	Total BOD Load[3] (lb/day)	Total TSS Load[3] (lb/day)	Average BOD Concentration (mg/L)	Average TSS Concentration (mg/L)
2006	446	0.070	98	98	167	167
2007	452	0.071	100	100	168	168
2008	459	0.072	101	101	169	169
2009	466	0.072	102	102	170	170
2010	472	0.073	104	104	170	170
2011	479	0.074	105	105	171	171
2012	486	0.074	107	107	172	172
2013	493	0.075	109	109	173	173
2014	500	0.076	110	110	174	174
2015	508	0.077	112	112	175	175
2016	515	0.077	113	113	176	176
2017	523	0.078	115	115	176	176
2018	530	0.079	117	117	177	177
2019	538	0.080	118	118	178	178
2020	546	0.080	120	120	179	179
2021	553	0.081	122	122	180	180
2022	562	0.082	124	124	181	181
2023	570	0.083	125	125	181	181
2024	578	0.084	127	127	182	182
2025	586	0.085	129	129	183	183
2026	595	0.085	131	131	184	184
2027	603	0.086	133	133	185	185
2028	612	0.087	135	135	185	185
2029	621	0.088	137	137	186	186
2030	630	0.089	139	139	187	187

[1] Annual growth rate of 1.45%
[2] Average I/I of 0.026 mgd
[3] BOD and TSS load of 0.22 lbs/day/person

Section 6
WASTEWATER MANAGEMENT ALTERNATIVES

A range of wastewater management alternatives are described below. Those alternatives that appear to be feasible and applicable to the site-specific constraints for the Village and Island of Aunu'u are identified and carried forward for more detailed evaluation in Section 7. All community based treatment and disposal alternatives considered below incorporate the existing collection system that conveys wastewater to a common collection point. Because this system is in place and operational, alternative collection systems are not considered.

6.1 No-action Alternative

The no-action alternative would leave the existing collection and disposal system as it currently operates with no treatment prior to disposal. The existing system is a considerable and significant improvement over the previous condition, and protects the shallow aquifer. However, this approach can not be recommended and is not considered a viable long term option. From a regulatory perspective, it is a non-permitted and non-permittable discharge and violates both Territorial and State laws and regulations. From an environmental perspective, the discharge of raw sewage in shallow water at the edge of the reef is a potential threat to both human health and aquatic life. The no-action alternative is not considered further in the evaluations below.

6.2 Alternatives not Considered

Some possible alternatives were not considered for additional evaluation; these included those listed in Sections 6.3 and 6.4 that were not carried forward for evaluation in Section 7 and the following classes of alternatives:

- Bulk transport of wastewater for treatment off-site was rejected as too costly, unreliable, and difficult because of limited vessel operations and no appropriate docking infrastructure

- Composting toilets and similar approaches were not considered because of economic and cultural reasons. This approach would not likely be acceptable to the residents, would be difficult to enforce, and would still require the treatment and disposal of grey water.

- Individual septic tanks with leach fields cannot be used because of the very shallow ground water.

- Alternative and experimental approaches were not considered, primarily because of difficulty in implementation and potential regulatory unacceptability. For example, recirculating sand filters, which are being used in a number of tropical settings, were not considered because of the probable lack of the correct quality and quantity of materials needed. The use of fine calcareous sands may be questionable, as is the availability of such sand.

- Stand-alone primary treatment was not considered because it could not be permitted under existing federal and territorial laws and regulations.

6.3 Conventional/Mechanical Secondary Wastewater Treatment Systems

Conventional wastewater processes use mechanical means to facilitate treatment. A diagram showing conventional wastewater treatment is shown in Figure 6-1. General terms are used to describe different degrees of treatment, in order of increasing treatment level, including preliminary, primary, secondary, and tertiary (advanced) wastewater treatment. Disinfection to remove pathogens is typically the final treatment step.

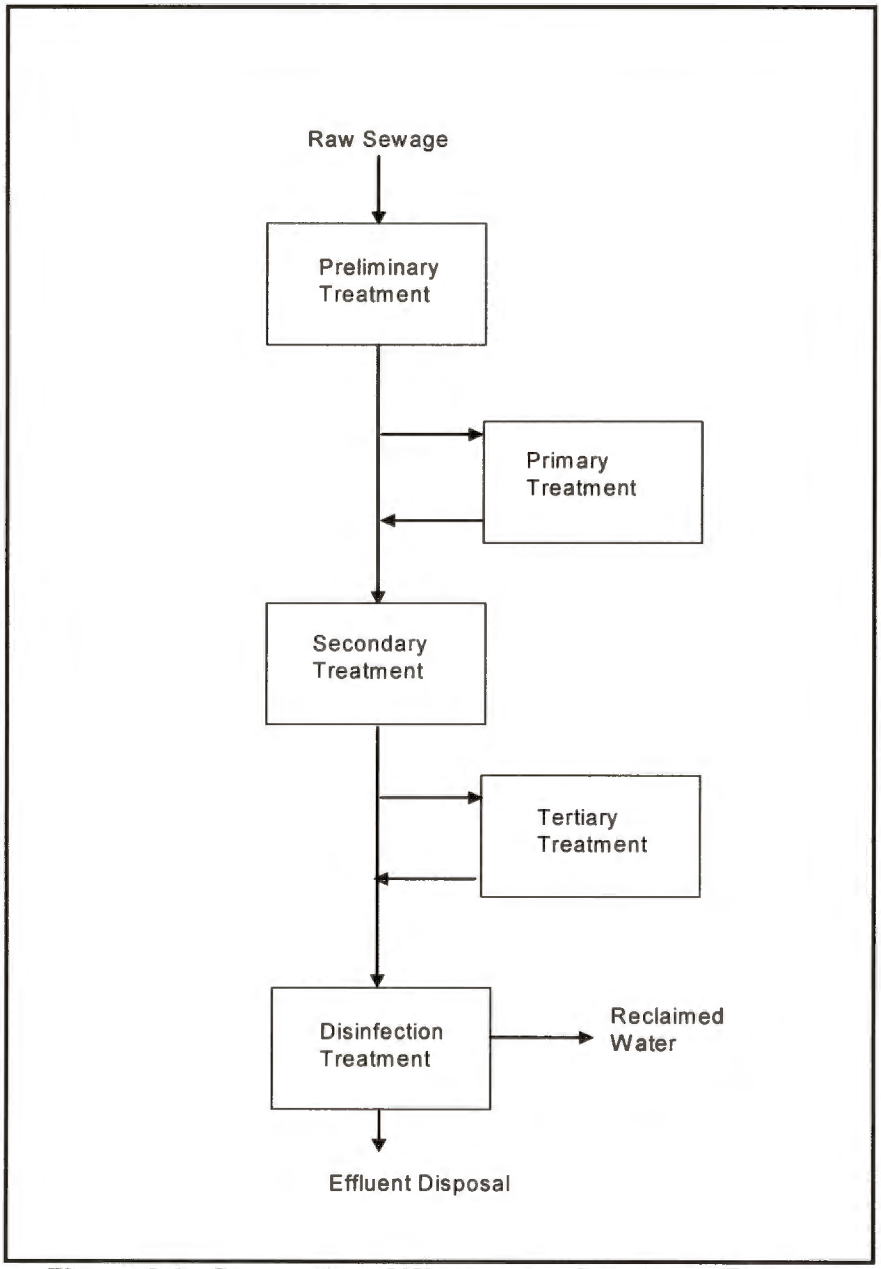

Figure 6.1. Conventional Wastewater Treatment Processes

Not all treatment steps are used at all wastewater facilities. While some form of preliminary treatment is common to nearly all facilities, primary treatment is typically not required for small secondary treatment plants or those with various kinds of secondary treatment processes. Tertiary treatment is used when final effluent quality requirements dictate a higher level of treatment than that which can be achieved by secondary treatment. Tertiary treatment processes are increasingly integrated into upstream processes, such as the use of membranes instead of secondary clarifiers. Descriptions of common treatment processes that should be considered for this facility plan are described below.

Preliminary treatment: The objective of preliminary treatment is the removal of coarse solids and other large materials often found in raw wastewater. Removal of these materials is necessary to enhance the operation and maintenance of subsequent treatment units. Preliminary treatment processes are located in the "headworks" of a wastewater treatment plant.

Preliminary treatment typically includes coarse screening, fine screening, grit removal, and/or comminution. Screens remove large materials from entering the system. In grit chambers, the velocity of the water through the chamber is maintained sufficiently high, or air is used, so as to prevent the settling of most organic solids. Grit removal is not included as a preliminary treatment step in some small wastewater treatment plants, such as at the Utulei WWTP. Comminutors are sometimes used to supplement coarse screening and serve to reduce the size of large particles (using maceration) so that they will be removed in the form of sludge in subsequent treatment processes.

Primary Treatment: The objective of primary treatment is the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. Typically, approximately 25 to 50% of the incoming biochemical oxygen demand (BOD), 50 to 70% of the total suspended solids (TSS), and 65% of the oil and grease can be removed by primary treatment. Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are also removed by primary treatment but colloidal and dissolved constituents are not removed. The effluent from primary sedimentation units is referred to as primary effluent.

Primary sedimentation tanks or clarifiers can be round or rectangular basins, typically 10 to 18 feet deep, with hydraulic retention time at average flow rates between 2 and 3 hours. Settled solids (primary sludge) are normally removed from the bottom of tanks by sludge rakes that scrape the sludge to a central well from which it is pumped to sludge processing units. Scum is swept across the tank surface by water jets or mechanical means into hoppers from which it is either pumped to sludge processing units, or as at the Utulei WWTP, enters directly into the anaerobic digester that is located directly below the clarifier unit.

In many larger treatment plants, and at the Utulei WWTP, primary sludge is processed biologically by anaerobic digestion. In the digestion process, anaerobic and facultative bacteria metabolize the organic material in sludge, thereby reducing the volume requiring ultimate disposal. Anaerobic digestion also makes the sludge stable and less odorous and improves its dewatering characteristics. Digestion is carried out in covered tanks called anaerobic digesters that are typically 20 to 50 feet deep. The residence time in an anaerobic digester may vary from a minimum of about 10 days for high-rate digesters to 60 days or more in standard-rate digesters. Gas containing about 60 to 65% methane is produced during digestion and can be recovered as an energy source.

In small sewage treatment plants, primary sludge is processed in a variety of ways including: aerobic digestion, storage in sludge lagoons, direct application to sludge drying beds, in-process storage (as in stabilization ponds), and land application. Recent regulations require a certain degree of stabilization before sludge disposal can occur.

Primary treatment is occasionally not used if the incoming wastewater flow is small (average below <0.5 mgd) and/or certain types of secondary treatment are used. In sewage treatment plants where primary treatment is not practiced, the size of the secondary treatment units would be larger, since more BOD and TSS is sent to the secondary treatment. However, only a single sludge is produced, simplifying operations.

Secondary Treatment: The objective of secondary treatment is to remove biodegradable dissolved and colloidal organics and suspended solids either created in the secondary treatment process or carried into the process with the incoming wastewater. In most cases, secondary treatment uses aerobic biological processes. Aerobic biological treatment is performed in the presence of oxygen by aerobic microorganisms (principally bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end products (principally CO_2, NH_3, and H_2O). Several types of aerobic biological processes are used for secondary treatment, differing primarily in the manner in which oxygen is supplied to the microorganisms, the rate at which organisms metabolize the organic matter, the manner in which the microorganisms grow in the treatment reactor, and the method of solids removal employed.

The microorganisms must be separated from the treated wastewater by sedimentation to produce secondary effluent relatively free of suspended solids. The separation can occur through settling in the aeration tank itself, by using a membrane or, most commonly, by gravity sedimentation in a separate sedimentation tank. The sedimentation tanks used in secondary treatment, often referred to as secondary clarifiers, operate in the same basic manner as the primary clarifiers described previously. The biological solids removed during secondary sedimentation, called secondary or biological sludge, are normally combined with primary sludge (if any) for sludge processing.

Secondary treatment processes include *suspended growth processes*, such as conventional activated sludge, oxidation ditches, aerated lagoons, membrane bioreactors, and sequencing batch reactors (SBRs), where the microorganisms are mobile in the bulk liquid. Alternately, *attached growth processes*, such as trickling filters and rotating biological contactors (RBCs), may be used. In attached growth processes, the microorganisms grow on a media that is fixed inside the treatment unit.

Suspended Growth Processes: Suspended growth processes, have one or more aeration tanks or basins containing a suspension of the wastewater and microorganisms. This mixture is called "mixed liquor".

In the *conventional activated sludge* process, the aeration tanks or basins are round or rectangular with typical depths of 6 to 20 feet. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension. Aeration devices can either be submerged diffusers that release compressed air or mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks or basins usually ranges from 3 to 8 hours. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluent. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system.

Oxidation ditches: Oxidation ditches vary from activated sludge in that the aeration tank is a ring- or oval-shaped channel equipped with rotating brush type aerators that propel the mixed liquor around the channel at a velocity of 0.8 to 1.2 feet per second. Like the conventional activated sludge process, the oxidation ditch process uses secondary clarification to settle biosolids and return sludge to the aeration tank.

Aerated lagoons: Aerated lagoons are relatively large tanks or basins in which aeration is provided. No secondary clarifier is used, and sludge is not returned to the aerated tank or basin. Enough oxygen should be transferred to satisfy the BOD loading of the wastewater and to provide sufficient mixing to maintain uniform dissolved oxygen levels throughout the system. Instead of hydraulic retention times measured in hours, wastewater is held for days. For consistent treatment efficiency, a retention period of 30 days is recommended. Ordinarily, the liquid depth should be between 10 feet and 20 feet to allow the aeration system to function efficiently. In addition, a minimum additional freeboard of 2 feet should be provided.

For an aerated lagoon system, a minimum of two ponds consisting of a treatment pond and a polishing pond is recommended. The ponds should be of equal dimensions with approximately 70% or more of the aeration capacity typically installed in the first pond. Air requirements are greater in the first pond to match the higher oxygen demand of raw wastewater. Solids settling occurs to some extent in the treatment pond and to a larger extent in the polishing pond, avoiding the need for a secondary clarifier. Sludge is occasionally dredged from the ponds to preserve capacity.

Membrane Bioreactors (MBRs): MBRs are a more recent technology consisting of suspended growth aerated biological reactor(s) in which membranes are integrated with an ultrafiltration membrane system. Essentially, the membrane system replaces the solids separation function of secondary clarifiers in a conventional activated sludge system. Preliminary treatment in the form of fine screening is needed but primary treatment is typically not used. Membranes are installed in the aeration tank, in direct contact with mixed liquor. Through the use of a permeate pump, a vacuum is applied to a header connected to the membranes. The vacuum draws the treated water through the membranes. Permeate is then directed to disinfection or discharge facilities. Intermittent airflow is introduced to the bottom of the membrane module, producing turbulence that scours the external surface of membrane. This scouring action transfers rejected solids away from the membrane surface.

MBR technology effectively overcomes the problems associated with poor settling of sludge that frequently occurs with other secondary treatment processes. Considerably higher mixed liquor solids concentrations (typically 8,000 to 10,000 mg/l) can be maintained compared to conventional activated sludge systems that are limited by sludge settling. Elevated biomass concentrations allow for highly effective removal of both soluble and particulate biodegradable material in the waste stream. By combining all operations into a single process with high biomass concentrations, a high quality effluent is consistently produced in a very small footprint.

Sequential batch Reactors (SBRs): SBRs combine all functions of the aeration tank and secondary clarifier into one tank in which a series of sequential operations is applied to treat the wastewater. Since all functions occur in one tank, no return sludge pumps are needed. Multiple tanks can be used in parallel with each other to add redundancy. During the fill stage, wastewater fills the tank, mixing with biomass that settled during the previous cycle. During the react stage, air is added to the tank to aid biological growth and facilitate subsequent waste reduction. Mixing and aeration stop during settling stage to allow solids to settle to the bottom of the tank Then, the treated wastewater can be removed from the upper portion of the tank during the decant stage. Finally, sludge removal can occur during the idle stage.

Attached Growth Processes: In a *trickling filter*, instead of an aeration basin, wastewater enters a tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Oxygen is supplied to the film by the natural or a fan-induced flow of air either up or down through the media. The thickness of the biofilm increases as new organisms grow. Periodically, portions of the film 'slough' off the media. The sloughed material is separated from the liquid in a secondary clarifier and discharged to sludge processing. A portion of the clarified liquid from the secondary clarifier is recycled to the tower to improve hydraulic distribution of the wastewater over the filter.

Rotating Biological Contactors (RBCs): RBCs are fixed-film reactors, similar to trickling filters, in which organisms are attached to support media. In the case of the RBC, the support media are slowly rotating discs that are partially submerged in flowing wastewater in the reactor. Oxygen is supplied to the attached biofilm from the air when the film is out of the water and from the liquid when submerged, since oxygen is transferred to the wastewater by surface turbulence created by the discs' rotation. Sloughed pieces of biofilm are removed in the same manner described for trickling filters.

After secondary treatment, over 85 percent of the BOD_5 and SS originally present in the raw wastewater will be removed. In general, properly operated suspended growth processes have the ability to produce an effluent of slightly higher quality, in terms of these constituents than attached growth processes. When coupled with a disinfection step, these processes can provide substantial but not complete removal of bacteria and viruses.

Tertiary Wastewater Treatment: Tertiary wastewater treatment is employed when specific wastewater constituents which cannot be removed by secondary treatment must be removed. Individual treatment processes may be necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals, and dissolved solids. Tertiary treatment processes are sometimes combined with primary or secondary treatment (e.g., chemical addition to primary clarifiers or aeration basins to remove phosphorus) or used in place of secondary treatment (e.g., overland flow treatment of primary effluent). For example, the enhanced removal of nitrogen and phosphorous can be achieved by either adding chemicals or modifying the process conditions in primary or secondary treatment processes.

In many situations, where the risk of public exposure to the treated water is high, the intent of tertiary treatment is to minimize the probability of human exposure to enteric viruses and other pathogens. Effective disinfection of viruses is believed to be inhibited by suspended and colloidal solids in the water; therefore these solids must be removed by tertiary treatment before the disinfection step. The sequence of treatment often is: secondary treatment followed by chemical coagulation, sedimentation, filtration, and disinfection. This level of treatment can produce an effluent low in bacteria and viruses that is suitable for reuse.

Disinfection: Disinfection has traditionally involved the injection of a chlorine solution at the influent end of a chlorine contact chamber. The chlorine dosage depends upon the strength of the wastewater and other factors, but dosages of 5 to 15 mg/l are common. Contact time in the chlorine contact chamber is typically 30 minutes. However, to meet advanced wastewater treatment requirements for some reuse applications, a chlorine contact time of up to 120 minutes is sometimes required for specific irrigation uses of reclaimed wastewater. The bactericidal effects of chlorine and other disinfectants are dependent upon pH, contact time, organic content, and effluent temperature.

Due to the undesirable formation of chlorinated organic materials and potential harm to biota in the receiving water environment, there is increasing use of disinfectants other than chlorine. Ozone and ultraviolet (UV) irradiation can also be used for disinfection. While more sophisticated than chlorination, a benefit is that these disinfection processes do not require chemical handling.

Effluent Storage: Although not typically necessary when wastewater will be disposed of through an outfall, effluent storage is typically needed when effluent is to be reused for the following reasons:

1. To equalize daily variations in flow from the treatment plant and to store excess when average wastewater flow exceeds reuse demand.

2. To meet peak reuse demands in excess of the average wastewater flow.

3. To minimize the effects of disruptions in the operations of the treatment plant and reuse system. Storage is used to provide insurance against the possibility of unsuitable reclaimed wastewater entering the reuse system and to provide additional time to resolve temporary water quality problems.

Wastewater treatment and reuse systems should contain both design and operational requirements necessary to ensure reliability of treatment. Reliability features such as alarm systems, standby power supplies, treatment process duplications, emergency storage or disposal of inadequately treated wastewater, monitoring devices, and automatic controllers are important. From a public health standpoint, provisions for adequate and reliable disinfection are the most essential features of the advanced wastewater treatment process.

Conventional Treatment Comparison: A matrix of evaluation criteria for each of the above categories of conventional treatment options is shown in Table 6-1. Each evaluation criterion is potentially an important consideration, but no attempt was made to rank the relative importance of the various criteria. A numerical scoring of the various criteria was made for each of the treatment options. The following relative scores were used: 1 = Poor, 2 = Fair, 3 = Good, 4= Very Good and 5 = Excellent. The sums of the individual scores for each treatment option were added and are shown in the last column of Table 6-1. Many options scored closely but some general trends were observed.

Table 6-1. Comparison of Secondary Treatment Technologies

Treatment	Criteria									Total
	Plant Performance			Economic Factors						
	BOD Removal	TSS Removal	Nutrient Removal	Simple, Inexpensive Construction	Simple Operation	Land Requirements	Maintenance Costs	Energy Demand	Sludge Removal Costs	
Conventional Activated Sludge	4.5	4.5	4	2	2	3.5	2	3	3	28.5
Oxidation Ditch	4.5	4.5	4.5	2	2	3	2	3	3	28.5
Aerated Lagoon	3	3	3	4	4	2	4	2.5	4	29.5
Membrane Bioreactor	5	5	5	1	4	5	2	3	5	35
Sequencing Batch Reactor	4.5	4.5	4.5	3	3	4	3	2	3	31.5
Trickling Filter	3	4	3	3.5	4	4	3	3	3	30.5
Rotating Biological Contactor	3.5	3.5	4	3.5	4	4	3	3	3	31.5

Of the conventional treatment options, membrane bioreactors (MBRs) ranked the highest in Table 6-1 and are the newest technology on the market. They are now commercially proven and are growing in popularity for the following reasons:

- MBR systems are very competitive to other secondary treatment system concepts for the anticipated Aunu'u flow rate. There are at least three competitors selling this technology, including Kubota, U.S Filter, and Zenon.

- MBR systems have very low operator requirements, because the membrane system is a positive barrier to suspended solids loss in the effluent. Process control is minimal. Many systems run virtually unattended.

- MBR systems are very compact, requiring the least space of any option, due to the system's ability to carry high mixed liquor concentrations and the lack of need for a primary clarifier and a separate digester.

- After disinfection, MBR effluent produced is amenable to reuse options, ranging from use as wash down water at the WWTP, to irrigation. There is no need for a sludge-dewatering step, because the concentration of the mixed liquor can be increased to 2.5 percent into the treatment system before harvesting excess solids and subsequent transport to other sludge management operations.

- An MBR system can be designed with a long solids retention time to allow aerobic sludge digestion as part of the liquid treatment process itself. This is not possible in most other secondary treatment systems, as "old" sludge is difficult to settle.

- MBR systems are available in pre-manufactured, packaged form with minimal field assembly required. They are also modular, allowing expansion as flows increase.

- The influent to the Utulei WWTP on the island of Tutuila is relatively dilute, averaging around 100 mg/l BOD and TSS. The new NPDES permit will require an average of at least 85 percent removal of BOD and TSS each month. If influent concentrations in the Aunu'u influent are as dilute as at Utulei, the effluent must average 15 mg/l or lower BOD and TSS to meet the 85 percent removal criterion. A properly operated and maintained MBR should have no problem producing this effluent quality; other secondary treatment processes are not as well equipped to consistently deliver TSS less than 15 mg/l.

The primary drawback of the MBR system is the level of sophistication required for maintaining membranes. They must be cleaned with a chlorine solution twice a year. Membranes must be replaced every 3 to 15 years. Specialized replacement membranes must be ordered in advance and be available before replacement is needed.

If a lower level of operational sophistication is considered more appropriate, a sequencing batch reactor (SBR) is a compelling alternative to an MBR. The characteristic that sets these systems apart from other highly ranked systems is that, like MBRs, SBRs do not require much land area. Operations are simple, and controls can be simple. Controls do not need to be microprocessor based; they can be timers and relays similar to the pump station controls that the ASPA operators are familiar with. However, more process control and operations adjustments are needed with SBRs compared with MBRs, and sludge must be digested prior to being placed on drying beds. Conceptual layouts of MBR and SBR wastewater treatment plants are shown in Figures 6.2 and 6.3.

To meet requirements for a pathogen free effluent, disinfection will be required for virtually all secondary treatment alternatives. Disinfection alternatives involving chemical use may be a problem based on logistical difficulties in transporting chemicals to Aunu'u. For this reason, use of an ultraviolet light disinfection system has been assumed for each secondary treatment alternative.

To get more specific information on the costs of the MBR and SBR systems, vendors of these technologies were contacted. Based on the information provided by the vendors, conventional secondary treatment alternatives using both MBRs and SBRs are included in Section 7.

6.4 Natural Wastewater Treatment Systems

Natural low-rate biological treatment systems are available for the treatment of municipal sewage and tend to be lower in cost and less sophisticated in operation and maintenance than conventional wastewater treatment systems. Such processes tend to be land intensive by comparison with the conventional high-rate biological processes described above. Among the natural biological treatment systems available, stabilization ponds, land treatment, and wetland treatment have been used widely around the world and a considerable record of experience and design practice has been documented.

6.4.1 Natural Wastewater Treatment Systems Overview

Primary Treatment Prior to Natural Treatment System: Many natural treatment systems including those identified as practicable for use at Aunu'u require primary treatment, which as previously described in Section 6.3.1 involves the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. Natural treatment processes can generally handle only limited quantities of particulate matter. Primary treatment makes the wastewater more amenable to treatment by natural processes, as well as reducing the size and greatly increasing the useful life of the natural treatment system.

Three possible primary treatment technologies could be used:

1. A conventional primary clarifier, or a combination primary clarifier and anaerobic digester (called a "Clarigester") such as that used at the Utulei and Tafuna wastewater treatment plants.

2. Anaerobic pond(s).

3. Septic tank(s).

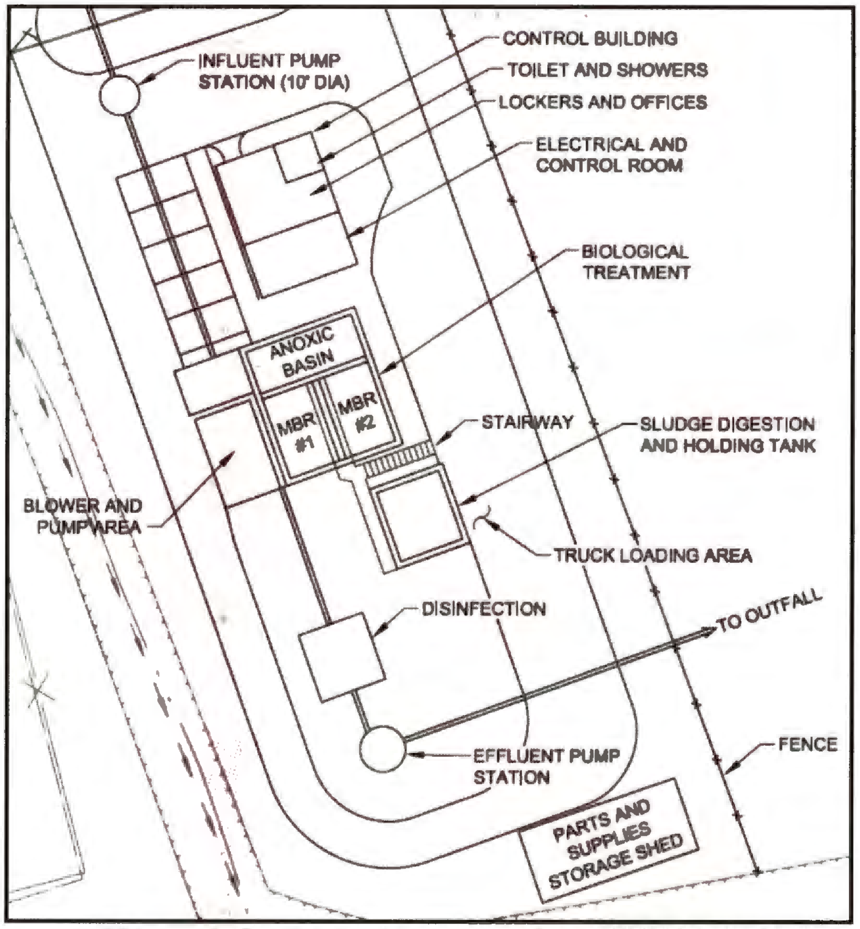

Figure 6-2. Typical Layout of an MBR Installation

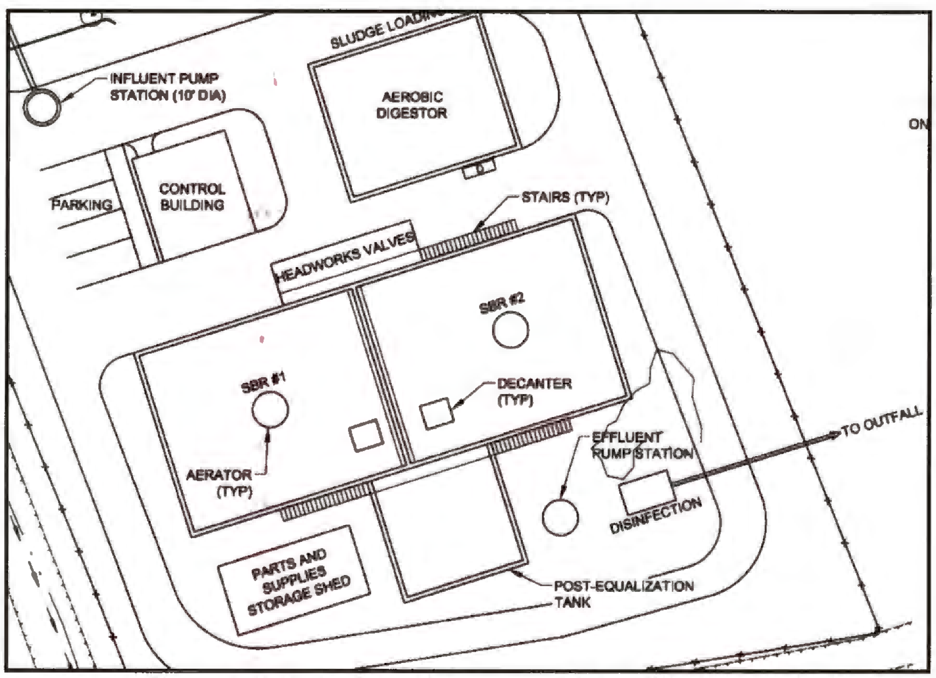

Figure 6-3. Typical Layout of an SBR Installation

A Clarigester requires day-to-day operator attention. It may be difficult to contruct and maintain a Clarigester on Aunu'u. This technology is also generally used in larger applications.

Anaerobic ponds are applicable, especially for larger natural treatment systems. Their disadvantages include a large footprint and since they are exposed to the atmosphere, potential odor and disease vector problems. The anaerobic ponds would likely need to be lined to prevent groundwater contamination.

A septic tank can be considered an underground anaerobic pond. The potential for odors, negative visual impacts, and transmission of diseases through human or animal contact is greatly reduced. Groundwater will be protected if the septic tank is in a watertight installation. Given the relatively small wastewater flows and loads, a septic tank is the correct choice for primary treatment prior to natural treatment on Aunu'u.

Stabilization Ponds: Wastewater stabilization pond systems are designed to achieve various forms of treatment using up to three stages in series, depending on the organic strength of the input waste and the effluent quality objectives. For ease of maintenance and flexibility of operation, at least two trains of ponds in parallel are incorporated in the design. Strong wastewaters, with BOD_5 concentration in excess of about 300 mg/l, will frequently be introduced into first-stage anaerobic ponds, which achieve a high volumetric rate of removal. Weaker wastes or, where anaerobic ponds are environmentally unacceptable, even stronger wastes (up to 1000 mg/l BOD_5) may be discharged directly into primary facultative ponds. Effluent from first-stage anaerobic ponds will overflow into secondary facultative ponds that comprise the second-stage of biological treatment. Following primary or secondary facultative ponds, if further pathogen reduction is necessary, maturation ponds can be used to provide tertiary treatment.

Anaerobic ponds: Anaerobic ponds are very cost effective for the removal of BOD, when it is present in high concentration. Normally, a single, anaerobic pond in each treatment train is sufficient if the strength of the influent wastewater is less than 1000 mg/l BOD_5.

Anaerobic ponds normally have a depth between 6 and 20 feet and function as open septic tanks with gas release to the atmosphere. The biochemical reactions which take place in anaerobic ponds are the same as those occurring in anaerobic digesters, with a first phase of acidogenesis and a second slower-rate of methanogenesis. Ambient temperatures in hot equatorial climates are conducive to these anaerobic reactions. Other environmental conditions in the ponds, particularly pH, must be suitable for the anaerobic microorganisms.

In certain instances, anaerobic ponds become covered with a thick scum layer, which is thought to be beneficial but not essential, and may give rise to increased fly breeding. Solids in the raw wastewater, as well as biomass produced, will settle out in first-stage anaerobic ponds and it is common to remove sludge when it has reached half depth in the pond. This usually occurs after two years of operation at design flow in the case of municipal sewage treatment.

Facultative Ponds: The effluent from anaerobic ponds will require some form of aerobic treatment before discharge or use. In natural treatment systems, aerobic treatment occurs in facultative ponds. Primary facultative ponds can be used instead of anaerobic ponds for the treatment of weaker wastes and in sensitive locations where anaerobic pond odors would be unacceptable. Solids in the influent to a facultative pond and excess biomass produced in the pond will settle out forming a sludge layer at the bottom. The benthic layer will be anaerobic and, as a result of anaerobic breakdown of organics, will release soluble organic products to the water column above.

Organic matter dissolved or suspended in the water column will be metabolized by heterotrophic bacteria, with the uptake of oxygen, as in conventional aerobic biological wastewater treatment processes. However, unlike in conventional processes, the dissolved oxygen utilized by the bacteria in facultative ponds is replaced through photosynthetic oxygen production by microalgae, rather than by aeration equipment. Especially in treating municipal sewage in hot equatorial or other warm climates, the environment in facultative ponds is ideal for the proliferation of microalgae. High temperature and ample sunlight create conditions which encourage algae to utilize the carbon dioxide (CO_2) released by bacteria in breaking down the organic components of the wastewater and take up nutrients (mainly nitrogen and phosphorus) contained in the wastewater. This symbiotic relationship contributes to the overall removal of BOD in facultative ponds.

To maintain the balance necessary to allow this symbiosis to persist, the organic loading on a facultative pond must be strictly controlled. Even under satisfactory operating conditions, the dissolved oxygen concentration (DO) in a facultative pond will vary diurnally and over depth. Maximum DO will occur at the surface of the pond and will usually reach supersaturation in tropical regions at the time of maximum radiation intensity. From that time until sunrise, DO will decline and may reach zero completely for a short period. For a typical facultative pond depth of 5 feet, the water column will be predominantly aerobic at the time of peak radiation and predominantly anaerobic at sunrise. The pH of the pond will also vary diurnally as algae utilize CO_2 throughout daylight hours and respire, along with bacteria and other organisms, releasing CO_2 during the night.

Wind is considered important to the satisfactory operation of facultative ponds. Wind mixes the contents, which helps to prevent short-circuiting. Mixing of organic substrate and the degrading organisms is important in any biological reactor but in facultative ponds wind mixing is considered essential to prevent thermal stratification.

The removal of BOD_5 in facultative ponds is related to BOD_5 loading and usually averages 70-80% of the influent BOD. Retention time in a properly designed facultative pond will normally be 20-40 days and, with a depth of about 5 feet, the area required will be significantly greater than for an anaerobic pond. Land area requirements are also greater than for constructed wetlands. The effluent from a facultative pond treating municipal sewage in the tropics will normally have a BOD_5 between 50 and 70 mg/l as a result of the suspended algae.

Maintenance of properly designed facultative ponds will be limited to the removal of scum mats, which tend to accumulate in downwind corners, and the cutting of grass on embankments. To ensure efficient operation, facultative ponds should be regularly monitored but, even where this is not possible, ponds have a reputation of being relatively trouble-free.

Maturation Ponds: The effluent from a facultative pond treating municipal sewage will generally require further treatment in maturation ponds to reach effluent or reuse standards. The effluent from facultative ponds treating municipal sewage or equivalent input wastewater will normally contain at least 50 mg/l BOD_5 and if an effluent with lower BOD_5 concentration is required it will be necessary to use maturation ponds. For sewage treatment, two maturation ponds in series, each with a retention time of 7 days, have been found necessary to produce a final effluent with $BOD_5 < 25$ mg/l when the facultative pond effluent had a $BOD_5 < 75$ mg/l.

Pond-based wastewater treatment is a feasible option on Aunu'u. However, this treatment method tends to be less efficient on an area basis than wetland systems, especially with respect to suspended solids and pathogen removal.

Overland treatment of wastewater: Apart from the use of effluent for irrigation of crops, termed 'slow rate' land treatment in the US Environmental Protection Agency's *Process Design Manual for Land Treatment of Municipal Wastewaters* (EPA 1977), the EPA manual discusses 'overland flow' as a wastewater treatment method. In overland flow treatment, effluent is distributed over gently sloping grassland on fairly impermeable soils. Ideally, the wastewater moves evenly down the slope to collect in ditches. Water-tolerant grasses are an essential component of the system.

This form of land treatment requires alternating applications of effluent (usually treated) and resting of the land, to allow soil reaction and grass cutting. The total area utilized is normally broken up into small plots to allow intermittent operation and yet achieve continuous treatment. Although this type of land treatment has been widely adopted in Australia, New Zealand and the UK for tertiary upgrading of secondary effluents, it has only been rarely used for the treatment of primary effluent (e.g., Werribee, Australia).

Application rates range from 0.3 to 2.0 inches per day. The low end of this range applies to raw or primary treated wastewater, while the higher end applies to secondary effluent or higher quality wastewater. Application rates are also a function of the physical and biochemical activity in the near-surface environment. It is unlikely that a sufficient area of suitable soil and topography for overland treatment can be located on the island.

Rapid infiltration: Rapid infiltration (RI) also referred to as high rate land application uses permeable soils for discharge to ground water. Filtering provided by the soil, and biological activity in upper soil strata provide removal of particulate pollutants and to a lesser degree, nutrients. Slopes of less than 10 percent are considered appropriate for rapid infiltration. Loading rates are a function of soil permeability and depth to ground water. Depending on ground water levels, recommended hydraulic loading rates range from 2 – 20 percent of measured soil permeability. It is unlikely that sufficient area with suitable slope, ground water, and soil conditions for rapid infiltration can be located on Aunu'u.

Floating macrophyte treatment: Maturation ponds that incorporate floating or submerged aquatic plant species are termed *macrophyte ponds* and these have been used in recent years for upgrading effluents from stabilization ponds. Macrophytes take up large amounts of inorganic nutrients (especially nitrogen [N] and phosphorus [P]) and heavy metals (such as Cd, Cu, Hg and Zn) as a consequence of the growth requirements and decrease the concentration of algal cells through light shading by the leaf canopy and, possibly, adherence to biofilms which grow on plant roots.

Floating macrophyte systems in Florida that utilize water hyacinth and receive primary sewage effluent have achieved secondary treatment effluent quality with a 6 day hydraulic retention time and a water depth of 2 feet. Similar results had also been observed for artificial wetlands using emergent macrophytes. In Europe, the land area considered to be necessary for treatment of preliminary-treated sewage is estimated at 22 to 54 square feet per population equivalent to achieve a secondary effluent quality.

Fly and mosquito breeding is a problem in floating macrophyte ponds but this can be partially alleviated by introducing larvae-eating fish species and maintaining open water areas in the ponds.

The macrophytes can be collected by floating harvesters. Harvested plants can be fed to livestock, used as a green manure in agriculture, composted aerobically to produce a fertilizer and soil conditioner. Biomass can also be converted into biogas in an anaerobic digester, in which case the residual sludge can be applied as a fertilizer and soil conditioner. Freshly-harvested water hyacinth contains approximately 95 percent water making management of biomass extremely problematic in humid climates. Problems associated with biomass handling have resulted in the discontinuation of numerous floating macrophyte treatment projects. Consequently, floating macrophyte treatment, while feasible, is not a recommended solution for Aunu'u.

Wetland Treatment Systems: In recent years, constructed wetlands and marshes have been widely used for wastewater treatment. Constructed wetlands are designed to maximize performance by providing the optimum conditions for emergent macrophyte growth. Two types of constructed wetlands have been used—subsurface flow and free water surface wetlands. The former involve plants growing in a bed of gravel or other permeable material, with wastewater flowing through the substrate, and no surface water flow. The latter are more similar to natural wetlands, with plants growing in surface water. Subsurface flow wetlands are more difficult to engineer and more costly to construct that free surface wetlands. The report will discuss only free surface wetlands. Key features of these systems are:

- Wastewater BOD and nitrogen are removed by microbial activity; aerobic treatment takes place in epiphyton biofilms on and around plant stems, in the water column, and to a limited extent in the rhizosphere. Anoxic and anaerobic treatment taking place in the sediment and anaerobic portions of the water column.

- Suspended solids in the sewage are aerobically composted in the above-ground layer of vegetation formed from dead leaves and stems.
- Phosphorus and metals are removed by plant uptake and subsequent accretion of sediment.
- Underground parts of emergent vegetation grow vertically and horizontally in the soil or gravel bed, opening up 'hydraulic pathways'.
- Oxygen passes from the atmosphere to the rhizosphere via the leaves and stems of the reeds through the hollow rhizomes and out through the roots.

Pollutant assimilative capacity of emergent macrophytes is a function of wastewater loading rate, plant density, climate, and management factors.

Maintenance and construction requirements for constructed wetlands are similar to those for pond systems, but treatment efficiencies are typically somewhat better. Land requirements are similar to those for pond systems, and are substantially lower than for overland flow or rapid infiltration. For these reasons, as well as factors described above, a constructed wetland system is the preferred natural treatment option for Aunu'u.

6.4.2 Constructed Wetland Design and Construction

Because of the factors described above, a constructed free water surface wetland has been identified as an appropriate natural treatment alternative to meet wastewater disposal needs on Aunu'u. Siting of the constructed wetland requires a relatively flat topography with less than 5% slope. Slopes greater than 5% present prohibitively high construction complexity and costs. While the coastal plain has a favorable flat topography, proximity to the village and vulnerability of the potable water source preclude construction of a wetland on this portion of the island. The eastern, volcanic crater portion of the island consists mostly of steep upland slopes and the pristine natural marsh wetland. The flattest upland portion of the crater is located to the south of the marsh. This is the preferred location for a constructed wetland. Based on the limited topographic information currently available, this discussion will assume a constructed wetland footprint of approximately 300 feet x 600 feet (approximately 4.5 acres including berms, or about 3 acres of water surface), with an east-west orientation parallel to the hillslope. This assumption is subject to modification based on more detailed topographic data.

Conceptual Design: Figures 6.4 and 6.5 present a conceptual layout for a constructed treatment wetland located south of the natural crater wetland. It is important to note that this is only one of a number of possible design configurations. It should also be noted that the actual layout will likely deviate from the strict rectangular dimensions presented here in order to conform to the natural contours and maximize use of available land.

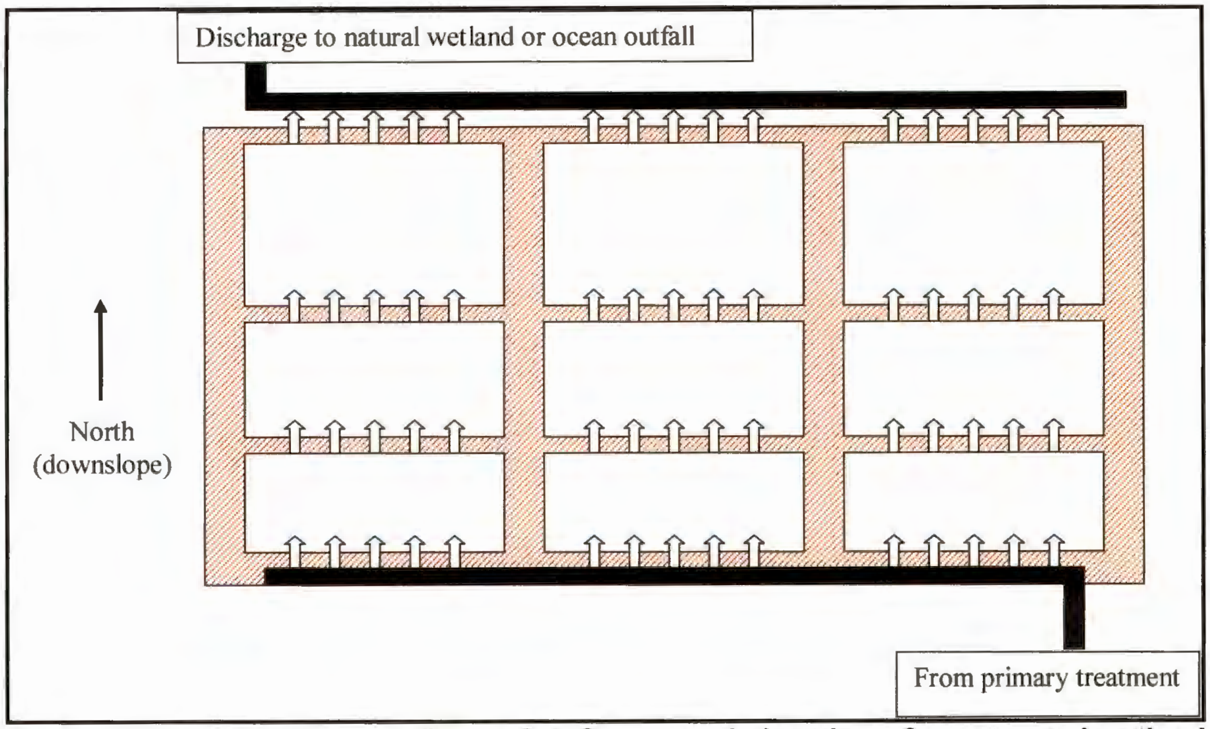

Figure 6-4. Conceptual plan view of constructed wetland

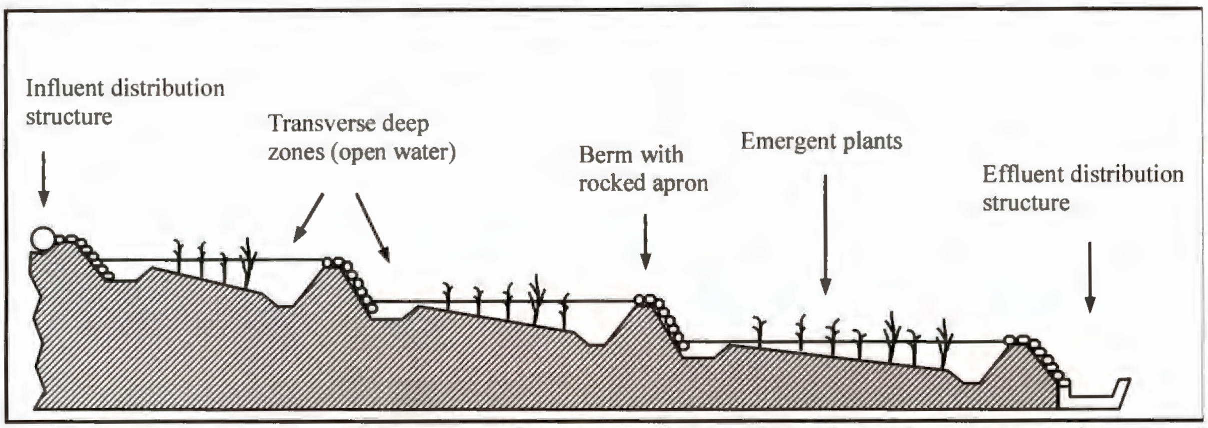

Figure 6-5. Conceptual elevation view of constructed wetland

The general configuration presented here is a series of three parallel treatment trains each consisting of three cells, each with an average water surface of about one-third acre. Parallel treatment trains improve system hydraulics and allow operational flexibility including the ability to take any single train offline for maintenance as needed. Input to each treatment train is through a distribution manifold from the primary treatment works.

Individual cell configuration utilizes the natural slope to provide varying water depth within each cell. The shallower upslope portions of each cell are planted with emergent wetland species, and the deeper downslope portions are open water. Water depths should range from nearly zero to three feet or more—too deep for most types of emergent plants to become established. As illustrated, upslope cells are shorter than those downslope to maximize utilization of the natural slope. The alternation of shallow and deep habitats provides a mixture of anaerobic and aerobic environments, significantly enhancing treatment efficiencies.

The cells are separated by earthen berms with membrane liners to ensure berm integrity. External berms and berms between treatment trains need to have adequate freeboard to prevent overtopping during rain events or lateral flow between trains. Berms within treatment trains (i.e., between upslope and downslope cells) are constructed to allow gravity flow over weir structures across the top of each cell. The top and downslope faces of each berm are covered with rock riprap to enhance aeration between cells and provide additional aerobic surface for microbial decomposition of pollutants.

The wetland should be planted in herbaceous species that are already found on the island. These may include water chestnut (*Eleocharis dulcis*), grasses (e.g., *Paspalum spp.*), or sedges (e.g., *Rhynchospora spp.*). The literature on wetland treatment is not consistent regarding relative treatment efficiencies of different wetland species, but it appears that most aggressive herbaceous species work well. More important than reported efficiencies is assuring that the selected species grow robustly in the constructed wetland. Planting a mixture of species helps ensure a desirable dense vegetative cover. The wetland should also be stocked with small fish captured from the natural wetland in order to minimize mosquito problems.

Plant growth in the wetland cells will result in slow accumulation of organic sediment. This is partially offset by in-situ sediment decomposition. Net accumulation rates are typically on the order of a few millimeters per year, and wastewater treatment wetlands often function for 40 years or more before sediment removal is required.

It is not anticipated that the constructed wetland will need to be lined with impermeable materials as long as infiltration is sufficiently slow to maintain a free water surface under the expected hydraulic loading rates. Moderate infiltration can enhance treatment efficiency through mass removal of pollutants from the wetland and by facilitating pollutant treatment in the underlying soil. Optimum soil permeability and ground water levels can potentially allow sufficient infiltration to design a non-discharging wetland, or a wetland that discharges only during wet weather. Reduction of wastewater volume though I/I reduction or other means would make this scenario more likely. More information on soil and ground water conditions are necessary to determine if this is even a feasible option.

Discharge should be through a flow distribution structure that allows sheetflow to the portion of the natural wetlands adjacent to the constructed wetland. Part or all of the effluent can be diverted via swales to other parts of the natural wetland. Both swales and sheetflow provide modest additional treatment prior to the discharge reaching the natural wetland.

Hydraulics: Treatment expectations described below will assume a wastewater load of 0.119 MGD as presented for wet season flows in Section 5. This represents an areal hydraulic loading rate of 1.3 in/day for the proposed water surface area of three acres. The hydraulic balance for the constructed wetland will also depend on rainfall, evapotranspiration (ET), and infiltration. USGS (1998) has estimated an average annual rainfall of less than 120 inches (10 inches per month) on Aunu'u. An average ET of approximately 60 inches per year (5 inches per month) has been estimated for extreme eastern Tutuila (USGS 2005), and we assume that ET is similar on Aunu'u. Significant seasonal and inter-annual variations in rainfall have been described for American Samoa, and it is not uncommon for rainfall to be nearly double the annual average for periods longer than one month (USGS 1996). Based on these considerations, we assume a wet season net hydraulic loading from rainfall and ET of 15 inches per month, or 0.5 in/day. Total hydraulic loading during the wet season is therefore assumed to be 1.8 in/day. (Rainfall on an exposed, plug flow system such as a constructed wetland actually results in more complex hydraulics than described here, since the rainfall enters the system throughout its length. The simplifying assumption made here that all rainfall enters at the headworks of the wetland is conservative with respect to treatment efficiency.)

Infiltration is a function of soil permeability and depth to ground water. Neither of these parameters is well described at the proposed constructed wetland location. For the purposes of treatment efficiency estimations, we make the conservative assumption that infiltration is zero.

Upslope drainage must be routed around the constructed wetland to avoid excessive hydraulic loading during storm events. The diverted stormwater runoff requires energy dissipation measures at its outfall location to avoid excessive erosion or rilling.

Estimated Treatment Efficiencies: Constructed wetlands are highly complex in terms of biology, hydraulics, and water chemistry. While many constructed wetlands in both tropical and temperate climates have been described in the literature, few specific performance equations have been published. General performance equations have been described by Kadlec and Knight (1996) and Reed et.al, (1995). This report will utilize Kadlec and Knight's first-order areal model, which assumes that pollutant removal is a function of pollutant concentration and areal hydraulic loading rate. The model can be described as follows:

$$\ln(Co\text{-}C^*/Ci\text{-}C^*) = -(k/q)$$

where Co is outflow concentration (mg/l), Ci is inflow concentration (mg/l), C* is the background pollutant concentration—the lowest concentration the wetland can achieve under any loading circumstances (mg/l), k is first order areal rate constant (in/day), and q is hydraulic loading rate (in/day). This model reflects the widely reported observation that wetland treatment efficiencies for most constituents are a function of wetland surface area, not water depth.

Rate constants can be estimated from median values reported in the North American Treatment Wetland Database (NATWD; Knight 2000), adjusted for such factors as temperature, aeration status, and general vegetation type. Values for C* can be estimated from the database or in the case of natural treatment wetlands, from background data observations. Estimated influent and effluent concentrations for pollutants of concern are presented in Table 6-2.

Table 6-2. Estimated Constructed Wetland Treatment Efficiencies					
Constituent	Raw Wastewater Concentration	Primary Effluent Concentration	Percent Removal	Constructed Wetland Effluent Concentration	Percent Removal
Total N (mg/l)	26	26	0	1.7	94
Total P (mg/l)	4	4	0	2.0	49
BOD (mg/l)	128	90	30	9.7	92
TSS (mg/l)	128	65	49	12.6	90
Fecal Coliforms (CFU/100ml)	10^6	10^6	0	4,800	> 99
Enterococcus (CFU/100ml)	2.5×10^5	2.5×10^5	0	16,500	93

It is important to note that removal efficiencies are a function of many factors that cannot be predicted for a specific site without extensive study and preferably a pilot-scale demonstration project. The rate constants used for the removal estimates described below are based on conservative assumptions and are subject to significant error. In addition, the estimates are for average removal rates, and short-term rates can vary considerably in response to weather and other factors.

BOD removal: Assumed BOD concentration in primary (septic tank) effluent is 90 mg/l, given a raw wastewater concentration of 129 mg/l (Table 5.3) and 30 percent removal during primary treatment. Dilution from rainfall (based on 1.3 in/day of wastewater input and 0.5 in/day of rainfall, as described above) yields a net BOD concentration of 65 mg/l entering the constructed wetland.

BOD removal in wetlands occurs through microbial decomposition. This process is relatively rapid in wetland systems, especially in tropical climates. The NATWD describes average BOD removal rate constants of about 3.7 in/day, and average C* values of 6 mg/l. We estimate that the rate constant in the present case will be somewhat higher than the averages given in the NATWB, due primarily to higher than average temperatures and favorable aeration status. Therefore a rate constant of 5 in/day is assumed, with a C* of 6 mg/l, yielding an effluent BOD concentration of 13.5 mg/l.

TSS removal: Assumed TSS concentration in primary (septic tank) effluent is 65 mg/l, based on a raw wastewater concentration of 129 mg/l (Table 5.3) and 50 percent removal during primary treatment. Dilution from rainfall yields a net TSS concentration of 47 mg/l entering the constructed wetland.

Suspended solids removal in wetlands is accomplished through settling and trapping of solids in the litter layer and on epiphyton biofilms on plant stems. Immobilized solids are then either decomposed by sediment microbes or accreted in the sediment. Removal rates are very rapid, with rate constants on the order of feet per day. For this reason TSS in effluent from constructed wetlands is usually equal to residual background TSS, or C*. For wetlands receiving wastewater, C* has been empirically defined as:

$$C^*=C_o=5.1+0.16C_i$$

with terms as defined above. Based on this equation, an influent TSS concentration of 47 mg/l results in an effluent concentration of 12.6 mg/l.

Nitrogen removal: Total nitrogen concentrations in raw wastewater typically equal about 20 percent of BOD concentrations. The nitrogen concentration of raw wastewater after I/I is therefore assumed to be 20 percent of 128, or about 26 mg/l. Primary treatment does not reduce nitrogen concentrations, so total nitrogen leaving the entering primary treatment will also be 26 mg/l. After correction for rainfall dilution the concentration entering the wetland is assumed to be 19 mg/l.

Nitrogen in wastewater typically consists of about 60% ammonia and 40% organic nitrogen. Rapid ammonia removal can be achieved in wetlands through nitrification and subsequent denitrification, provided that sufficient aerobic habitat is available for nitrifying bacteria. The end product of denitrification is atmospheric nitrogen, which is biologically unavailable, and can be considered to have been permanently removed from the system. The constructed wetland design described here provides abundant aerobic habitat, and is likely to be very efficient at ammonia removal. Organic nitrogen removal is accomplished through microbial mineralization to ammonia with subsequent nitrification/denitrification. Mineralization is usually the limiting step in this process. The nitrogen cycle in wetlands is further complicated by simultaneous re-uptake of ammonia and nitrate as well as ammonia volatilization and other processes.

Because of the difficulty of describing the complex kinetics of the wetland nitrogen cycle, empirically derived total nitrogen rate constants are often used. Total nitrogen removal rate constants described in the NATWD[1] range from less than 0.1 to greater than 6.5 in/day. For the present system, we assume a value of 5 in/day, near the high end of the published range due to favorable habitat structure, near-neutral soil pH, and high temperatures. A value of 0.5 mg/l for C* is assumed, based on outfall data from the natural wetland. These assumptions yield an estimated effluent concentration of 1.7 mg/l total N.

Phosphorus removal: Phosphorus levels in raw wastewater are typically 4 percent of BOD. Using the logic applied above for nitrogen, the phosphorus input to the constructed wetland after accounting for dilution from I/I and rainfall is 4 mg/l.

Phosphorus differs from the other pollutants discussed in this section in that it is a conservative constituent, and is subject to conservation of mass laws—under equilibrium conditions, input is equal to output. The primary mechanism for phosphorus removal in wetlands is uptake by plants and subsequent sequestration in accumulated sediments. For this reason, long-term net phosphorus removal potential is quite limited without periodic plant harvest or sediment removal. Harvest is not anticipated in the case proposed here.

[1] North American Treatment Wetland Database

Phosphorus removal rates in non-harvested systems tend to be low, and independent of temperature. The median phosphorus removal rate constant presented in the NATWB is 1.3 in/day, and we assume this rate for the present system. A C* value of 0.2 mg/l is assumed, based on the observed concentration at the natural marsh outfall. These assumptions yield an expected effluent concentration of 2.0 mg/l total phosphorus.

Pathogen removal: Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic bacteria, viruses, and protozoans that also live in human and animal digestive systems. The most commonly tested fecal bacteria indicators are total coliforms, fecal coliforms, *Escherichia coli*, and *Enterococci*.

Fecal coliform (FC) concentrations in septic tank effluent can vary a great deal, but are typically in the range of 10^6 colony-forming units (CFU) per 100 ml. This is the assumed input concentration to the constructed wetland.

Fecal coliforms, and the pathogens for which FC serve as indicators, are removed from wetlands by several different mechanisms, including mortality from sunlight, predation, or unfavorable water chemistry, and sedimentation. Removal efficiencies are generally quite high relative to many other types of natural treatment systems due to the complex structure and biota of wetlands. Removal efficiencies tend to increase significantly with increasing temperatures. Reported FC removal rate constants typically range from 1.5 to 12 in/day. Because the proposed system will operate at consistently high temperatures, and taking into account the favorable alternation of aerobic and anaerobic zones, a rate of 10 in/day is assumed. Values of C* are a function of internal pathogen production by warm-blooded animals living in the wetland. It is difficult to predict how attractive the constructed wetland will be to wildlife, so a conservative C* of 1,000 CFU/100 ml is assumed. This rate constant and C* value yield an effluent FC concentration of 4,900 CFU/100 ml.

Wetland systems are less efficient at removing *Enterococcus*. Rate constants are typically about one-half those reported for FC. *Enterococcus* concentrations in raw waste are typically about one quarter of FC concentrations. Assuming an *Enterococcus* rate constant of 5 in/day, an influent concentration of 250,000 CFU/100 ml, and a C* of 1,000 (consistent with data collected from the crater wetland outfall), an effluent concentration of 16,500 CFU/100 ml is calculated.

Operation and Maintenance: The most critical operational requirements for constructed wetlands are during the initial start-up of the system. It is important to maintain water levels sufficient for establishment of a dense wetland plant community. The soil must be continuously wet, but water levels cannot be so high as to completely inundate young plants. This requires adjustment of overall flow rates, and possibly fine-tuning of distribution structures to ensure uniform wetting. In Samoa's climate plants should be established in less than six months. After plants are well established, operation can be essentially passive, simply allowing gravity flow from system headworks to the discharge point. It can be desirable, but is not essential, to employ adjustable weirs between cells to vary water levels in each cell and provide a degree of flow equalization during heavy rain events.

Once established, constructed wetlands generally require very little routine maintenance. The primary requirements are removal or mowing of vegetation on dry portions of the system (berms, access roads) and periodic inspections for leaks, flow obstructions, and short-circuits. It may be desirable to remove wetland vegetation on an infrequent basis (usually not more once every few years) if growth becomes so thick as to impede even water flow.

Summary: A constructed treatment wetland located on the south edge of the natural crater wetland would be capable of meeting secondary wastewater treatment standards for most parameters, and exceeding secondary requirements for nutrients. Construction costs would likely be relatively high due to site topography, but operation and maintenance costs would be relatively low. The preliminary footprint and treatment efficiencies described here are subject to modification based on acquisition of more detailed information on the topography, soils, and hydrology of the site.

6.5 Biosolids Handling

The residuals from wastewater treatment operations are generally called "biosolids." Biosolids will be generated from both mechanical and natural treatment systems. These biosolids will require disposal, either on a routine or non-routine basis. Septage from septic tanks (if applicable) will also require disposal. The disposal of biosolids or septage is regulated by the requirements of 40 EPA Part 503.

This rule designates two classifications of biosolids – Class A and Class B. These designations relate to pathogen density. The 40 EPA Part 503 rule also contains requirements for vector attraction reduction.

The type of biosolids having the fewest disposal restrictions is Class A biosolids. There are six prescribed alternatives for treating biosolids to Class A quality, including thermal treatment, high pH-high temperature, composted, heat dried, thermophilically digested, irradiated, or pasteurized. None of these processes are deemed feasible on the island of Aunu'u. Processes that meet equivalent levels of pathogen reduction may be considered if sufficient testing for pathogens (specifically *Salmonella sp.* or fecal coliform bacteria, enteric viruses, and viable helminth ova) is conducted before the biosolids are prepared for sale or are given away. .

Class B biosolids are more easily produced than Class A biosolids. Technologies that could be considered include aerobic or anaerobic digestion, air drying, or lime stabilization. Of these, aerobic digestion (for mechanical treatment-derived biosolids) or air drying (for natural treatment-derived biosolids or septage) appear the most viable.

There are 12 options contained in the 40 EPA Part 503 rule that can be used for vector attraction reduction. These include additional aerobic or anaerobic digestion, alkali addition, drying, incorporation into soil within 6 hours of placement, and covering solids in a surface disposal site each operating day.

It is assumed for the purposes of this facility plan that if the septic tank or aerobically digested biosolids are air dried on sludge drying beds and stockpiled for a prolonged period prior to final disposition, testing will show that they will meet both Class A and vector attraction reduction requirements. This tactic was successfully used for the biosolids produced at both the Utulei and the Tafuna Wastewater Treatment Plants. A covered drying bed could be constructed at the present landfill site on Aunu'u.

6.6 Disposal Options

6.6.1 Ocean Outfall

Disposal through an ocean outfall would require improvements to the existing outfall. These improvements would almost certainly require extending the outfall to a depth below the primary zone of coral growth (> 100 feet) and terminating the outfall with a high rate diffuser (dilutions > 100:1). The steep slope of the reef face and the high wave action make this type of installation difficult and requires periodic and expensive maintenance. However, the option of maintaining the existing outfall as an emergency bypass is a prudent approach if wetlands discharge is selected as the disposal option. This would require little additional construction cost and, since the existing outfall is buried across the reef flat, only minor maintenance. It would be expected, given the small diameter of the existing outfall, that marine growth could easily block the end of the pipe after the discharge ceases. To use the outfall as an emergency bypass some action to account for this is required. The most reasonable approach may be to install a cap on end of the existing outfall that could be removed if needed in the future.

6.6.2 Discharge to Wetlands or Lake

Assuming the regulatory constraints described in Section 2.5 can be overcome, the crater wetland, Faimulivai Marsh, is an obvious option for discharge from a nearby constructed wetland or conventional secondary treatment. The crater wetland would provide significant additional treatment prior to ultimate discharge to the ocean. As described in Section 3.1.2, Faimulivai Marsh is an *Eleocharis*-dominated wetland of approximately 35 acres. It is roughly oval in shape, oriented east-west, with an outfall to the ocean on the eastern edge. The simplest option would be to discharge from the constructed wetland to the southeast edge of the marsh directly adjacent to the constructed wetland site. This option would likely limit or eliminate any discharge impacts to the western end of the marsh. Alternately, constructed wetland effluent could be routed to the west end of the natural marsh. This would enhance additional treatment provided by the marsh prior to ocean outfall, but would increase the area of potential impacts to the marsh.

Faimulivai Marsh has been described as pristine by a number of authors (Cole et al. 1988, Biosystems Analysis 1992, Whistler 2002). While BOD and TSS at the levels expected from the constructed wetland are very unlikely to have a significant impact on the marsh, it is unclear what impacts might be in the case of nutrients. The nutrient status of the marsh is not known, but it appears that the wetland currently receives little or no anthropogenic nutrient inputs. Measured nutrient concentrations at the wetland outfall are 0.19 mg/l total P and 0.59 mg/l total N. These values are consistent with a pristine, nitrogen-limited system. If the wetland is in fact N-limited, then even modest additional N loading may have a significant biological impact. However, since concentrations of contaminates in the discharge from the constructed wetland is expected to be only marginally higher than background concentrations in the marsh, and N uptake in the marsh is likely to be rapid, it is likely that any impacts would be relatively localized. Characterization of soil, plant tissue, and water nutrient levels in the wetland, as well as biological assessment will be required to fully evaluate potential impacts of additional nutrient loading.

Pathogen levels in the constructed wetland effluent are high enough to constitute a public health concern. Human contact with this portion of the wetland is apparently rather limited, but measures such as signage or fencing to exclude human entry to the portion of the marsh receiving wastewater will be required.

The water balance of the crater wetland is poorly understood. The wetland may either gain from (as speculated by Biosystems Analysis, 1992) or lose water to ground water. Depending on soil characteristics, runoff from the surrounding crater may be very high or relatively minor. For the purpose of estimating treatment efficiencies, it is assumed that the net gain from runoff and ground water seepage is zero, and net input to the marsh equals the rainfall falling on the marsh minus evapotranspiration. As stated in the discussion of constructed wetland design, net rainfall (rainfall minus ET) is assumed to be 15 inches per month during the wettest months, or one half inch per day.

Natural wetland treatment efficiencies are estimated in this report in the same manner as for the proposed constructed wetland, using the same rate constants and background (C*) pollutant levels. (The single exception is TSS, where C* for the natural wetland is based on observed TSS levels at the ocean outfall, rather than on the equation shown in the constructed wetland discussion.) Effective treatment area is estimated as 6 acres, based on discharge to the southeastern edge of the wetland, and a general eastward flow gradient toward the ocean outlet.

It is assumed that water from the remaining 29 acres of marsh will flow through the effective treatment area, providing dilution prior to the ocean outfall. Hydraulic loading is assumed to be the sum of the wastewater load from the constructed wetland (5.4 acre-in/day), plus one half inch per day of net rainfall on the 6 acres of effective treatment area (3 acre-in/day), plus flow from the remaining 29 acres of the marsh that do not receive wastewater (14.5 acre-in/day). Effective influent concentrations were calculated by weighting concentrations in these sources (i.e., constructed treatment effluent, rainwater, and background water from the marsh) by their relative hydraulic contribution to the treatment wetland. Estimated final concentrations of BOD, TSS, TN, TP, fecal coliforms, and *Enterococcus* at the ocean outfall are given in Table 6-3. Concentrations of all constituents approach background levels, but exceed ASWQS coastal standards by a significant margin.

Treatment of Aunu'u wastewater via a constructed wetland followed by discharge to the natural crater wetland appears to be a viable option, but will likely face regulatory challenges. Existing natural conditions of the Marsh appear to exceed the ASWQS for surface freshwater, and the do not meet ASWQS water quality standards for open coastal waters. However, the parameters of concern will likely approach background wetland concentrations. It is noted that the ASWQS has a provision for site-specific criteria based on ambient background concentrations.

Table 6-3. Estimated Natural Wetland Treatment Efficiencies

Constituent	Constructed Wetland Effluent Concentration	Natural Wetland Effluent Concentration	Percent Removal	Natural Wetland Background Concentration [A]	ASWQS Open Coastal
Total N (mg/l)	26	0.64	61	1.7	0.130 (N)
Total P (mg/l)	4	0.49	76	1.9	0.0150 (P)
BOD (mg/l)	128	6.0	38	9.7	
TSS (mg/l)	128	5.0	60	12.6	
Fecal Coliforms (CFU/100ml)	4,800	1,057	78	4,800	
Enterococcus (CFU/100ml)	16,500	1,950	88	16,500	35 (geo mean) 124 (single sample)

[A] Based on one sample.

Many conservative assumptions were made in this analysis. However, better understanding of the hydrology, soils, and topography of the crater wetland and surrounding areas is needed to fully assess the feasibility of a natural treatment system in this location. Soil permeability should be determined at the proposed site of the constructed wetland. Recording piezometers installed in transects at the location of the constructed wetland and at other locations in the crater will facilitate understanding of crater hydrology and allow more accurate estimation of the effectiveness of the proposed constructed wetland as well as the impact of wastewater discharge on Faimulivai Marsh.

6.6.3 Reuse

Reuse has become more widely accepted and used than in the past, particularly in arid regions or areas where water shortages are common. American Samoa has adequate rainfall and water shortages are not expected, so a compelling need for reuse does not exist. Indeed, there is no identifiable need for reclaimed water for irrigation, stream augmentation, or other applications. Re-use will not be considered further for this facilities plan because applications for reuse are limited in American Samoa.

6.7 Treatment Alternatives and Disposal Options for Further Consideration

Based on the preliminary evaluations described in this section three treatment alternatives, SBR, MBR, and constructed wetlands, are considered for further evaluation in Section 7. In addition two disposal options, ocean disposal through an extended outfall and disposal to natural wetlands are considered feasible for each of the three treatment alternatives and are consider in Section 7.