San Vitores Road

Flood Mitigation Project

The Guam Economic Development Authority (GEDA)

Final

January 2014

Stanley Consultants INC.

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Executive Summary

San Vitores Road (SVR) runs through a densely developed commercial/tourist district in the Tumon Bay area of Guam. The road and surrounding properties are prone to periodic flooding following heavy rainfall events. The Guam Economic Development Authority has contracted with Stanley Consultants, Inc. to provide preliminary engineering to develop and analyze alternatives for mitigating this problematic flooding issue.

An inspection and assessment of the project area and existing storm sewer system was completed. The project area includes roughly 180 acres west of Marine Corps Drive and north of Fujita Pond. This area is drained by a single storm sewer system with a triple box culvert trunk line running under SVR that outlets into Fujita Pond. Fujita Pond is an infiltration basin with no defined outlet structure. The storm sewer system is in very good condition but should be inspected and cleaned more frequently.

Much of the stormwater in the project area is infiltrated. Many of the developed properties along San Vitores Road have offline storm sewer systems that infiltrate stormwater runoff on their own property. Fujita Pond also is an infiltration basin. Infiltration is very effective for filtering stormwater runoff and improving water quality. This is demonstrated by weekly Tumon Bay water quality data which indicates infrequent elevated bacteria events.

The significant rains that occurred during September 19-21 and October 10, 2013 caused extended ponding at the low spot in SVR near the Sandcastle and Hyatt Properties. The rains also caused overtopping of Fujita Pond. A review of project area elevations established that the overtopping elevation of Fujita Pond is approximately 1 foot higher than the low spot on SVR so flooding in this area is controlled by the water level in Fujita Pond.

An analysis of the SVR storm sewer system was completed. Flooding for this project is defined by ponding extending more than half a traffic lane on SVR. There are two issues causing SVR flooding:

- Short duration SVR flooding during high intensity rainfall events: This flooding is caused by curb inlets lacking sufficient capacity to fully capture design storm events.
- Long Duration SVR flooding following extended rainfall events: This flooding is caused by Fujita Pond not having sufficient volume to handle the series of design storms without overtopping and causing extended ponding in the low areas of SVR.

Flood events tend to occur on the order of one to two times per year during normal precipitation patterns. Flooding will tend to occur in the low area of SVR following rainfall events greater than 3.5 inches which is similar in magnitude to the 10-Oct event. If water levels within Fujita Pond can be kept below the low area of SVR the flooding issue will be significantly improved.

Short Duration SVR flooding can be solved by installing 47 additional curb inlets to more effectively capture gutter flow along SVR at a cost of approximately $450,000. These additional inlets will provide nominal benefit unless Fujita Pond is also improved to maintain lower pond levels during flood events.

Six viable improvement alternatives were developed and evaluated for solving the Long Duration SVR flooding. Alternatives maintained lower Fujita Pond levels during flood events by either expanding the storage volume or providing an overflow outlet for excess stormwater.

- **Expanded Detention** involves expanding the overall detention volume of the SVR system through acquisition and construction of expanded storage area on property near the SVR corridor.
- **Gravity Ocean Outlet** involves constructing an overflow outlet from Fujita Pond that outlets into a gravity pipe extending under Tumon Bay and outletting beyond the reef at a depth of 30 feet
- **Gravity/Pumped Ocean Outlet** involves constructing an outlet similar to the Gravity Ocean Outlet but a pump station is also constructed to increase hydraulic head and reduce outlet pipe diameter.
- **Gravity Bay Outlet** involves constructing an overflow outlet from Fujita Pond that outlets into Tumon Bay.
- **Pump to Sink Outlet** involves constructing an overflow outlet from Fujita Pond where overflow is pumped up to the nearest sink formation near JFK High School.
- **Pump to Quarry Outlet** involves constructing an overflow outlet from Fujita Pond where overflow is pumped up to the abandoned Quarry site across SVR from the Hilton Hotel entrance.

Preliminary designs were advanced for the six improvement alternatives and alternatives were then evaluated based on a set of eight project criteria. All alternatives provide equivalent flood reduction for the associated design storm.

Project Costs are summarized in the following table:

Table E -1

Alternative Project Cost Estimates

Design Storm	**Alternative**					
	Expanded Detention	Gravity Ocean Outlet	Gravity/Pump Ocean Outlet	Gravity Bay Outlet	Pump to Sink	Pump to Quarry
2-year	$7.5 M	$18.4 M	$14.7 M	$4.8 M	$13.0 M	$14.2 M
5-year	$13.5 M	$24.9 M	$18.0 M	$5.2 M	$17.7 M	$18.4 M
10-year	$18.6 M	$26.0 M	$20.1 M	$5.7 M	$21.9 M	$22.0 M
25-year	$26.3 M	$27.1 M	$22.3 M	$6.1 M	$26.6 M	$26.0 M

The Gravity Bay Outlet is the most cost effective alternative and is the only alternative that is under the $12 million allocated for the SVR flood mitigation project.

Project improvement alternatives were compared, evaluated, and scored using a scoring matrix. Results of the improvement alternatives evaluation are summarized in the following table:

Scoring:
0 Criteria is negatively affected by alternative.
1 Criteria not affected by alternative.
2 Criteria is positively affected by alternative.
3 Criteria is more positively affected by alternative.

COMPARISON CRITERIA >>	REDUCE FLOODING	COST EFFECTIVE	OPERATION AND MAINTENANCE	SCHEDULE	CONSTRUCTABILITY	IMPACT TO ENVIRONMENT	PERMITTING REQUIREMENTS	PUBLIC PERCEPTION	**TOTAL**	
WEIGHT (NO.) >>	20	15	15	12	10	10	10	8	**100**	
WEIGHT (%) >>	20	15	15	12	10	10	10	8	**100**	
ALTERNATIVE	**SCORE**									**RANK**
Expanded Detention	1	1	3	1	3	3	3	3	**206**	**1**
Gravity Ocean Outlet	3	0	2	1	1	1	1	1	**140**	**3**
Gravity/Pump Ocean Outlet	2	0	0	0	1	1	1	1	**78**	**6**
Gravity Bay Outlet	3	3	2	2	3	0	1	0	**199**	**2**
Pump to Sink	2	0	0	1	1	1	2	2	**108**	**5**
Pump to Quarry	2	0	0	1	1	3	2	2	**128**	**4**

Expanded Detention was the highest scoring alternative followed closely by the Gravity Bay Outlet. Expanded Detention is easierst to construct and permit but may not be viable due to high cost of land near SVR. For Expanded Detention to be cost effective, land near SVR would need to be acquired at a price significantly below its current value. This alternative could also be delayed if historical remains/artifacts are discovered.

The Gravity Bay Outlet can be constructed under the $12 million project budget but there could be issues with water quality. Significant permitting and public involvement effort is required for this alternative but once design is contracted, the Gravity Bay Outlet could be operational within 2 years.

Other alternatives were too costly, required too much maintenance, and/or involved difficult and lengthy construction so scored lower relative to the Expanded Detention and Gravity Bay Outlet alternatives.

Table of Contents

Executive Summary
Alternative Project Cost Estimates iii

Section 1 - Data Collection 1-1
Introduction 1-1
Data Sources 1-2
References 1-3
Data Management System 1-3
Project Specific Data 1-5
Rainfall and Fujita Pond Level Logger Data 1-5
Site Inspection and Survey 1-7
GIS Database 1-7

Section 2 - Design Criteria 2-1
Introduction 2-1
Design Criteria 2-1
Recurrence Interval 2-1
Design Storm 2-3
Runoff Parameters 2-7
Tributary Area 2-7
Time of Concentration 2-7
Infiltration 2-8
Water Quality 2-9
Contributing Area 2-11
Horizontal and Vertical Datum 2-14

Section 3 - System Inspection and Assessment 3-1
Introduction 3-1
Objectives 3-1
Approach 3-1
Meetings with Stakeholders 3-2
Site Inspection 3-2
Findings and Recommendations 3-3

Field Verification of the Existing Drainage System 3-3
Field Verification Process 3-3
Fujita Pond Storm Sewer System 3-5
Condition of the Drainage System and Areas of Concern 3-7
Condition of the Drainage System 3-7
Areas of Concern 3-9
Areas of Missing or Inaccurate Data 3-14
Additional BMP Installation 3-15
Design Pollution Prevention BMP's 3-15
Runoff Treatment BMP's 3-15
Construction Site BMP's 3-16
Maintenance BMP's 3-16
Tumon Bay Water Quality 3-16
Coordination with Local Agencies and Stakeholders 3-18
Additional Field Tasks 3-19
Field Survey 3-19
ROV Camera Inspection 3-20
Rain Gages and Flow Meters 3-20
Summary of Findings 3-20

Section 4 - Flood Modeling 4-1
Introduction 4-1
Definition of SVR Flooding 4-1
Short Duration SVR Flooding 4-2
Long Duration SVR Flooding 4-4
XP-SWMM 4-9
Existing Condition Model 4-9
Storm Sewer Network 4-9
Storm Sewer Network 4-9
Catchment Areas 4-11
XP-SWMM Import 4-14
Additional Model Features 4-16
Inlet Capacity 4-16
Gutter Flow 4-16
Pipe Flow 4-16
Storage 4-17
Rainfall Events 4-19
Calibration 4-20
Model Results 4-23
Correlation of Rainfall and Tumon Bay Water Quality 4-25
Summary of Findings 4-28

Section 5 - Improvement Alternatives 5-1
Introduction 5-1
Development of Improvement Alternatives 5-1
Short Duration SVR Flooding 5-1
Long Duration SVR Flooding 5-2
Eliminated Alternatives 5-3
Raise Low Area of SVR 5-3
Injection Wells 5-3
Connect to Matapang Storm Sewer 5-3
Description of Alternatives 5-3

Expanded Detention 5-4
Gravity Ocean Outlet 5-4
Gravity/Pump Ocean Outlet 5-4
Gravity Bay Outlet 5-4
Pump to Sink 5-5
Pump to Quarry 5-5
Conceptual Design 5-5
Expanded Detention 5-5
Outlet Options 5-6
Labryinth Weir 5-6
Pump Station 5-8
Expanded Pond 5-10
Gravity Ocean Outlet 5-11
Sea Level 5-11
Design 5-12
Hydraulic Head 5-12
Construction Methods 5-12
Gravity/Pump Ocean Outlet 5-15
Design 5-15
Pump Station 5-16
Construction Methods 5-16
Gravity Bay Outlet 5-17
Design 5-17
Channel Easement Requirements 5-18
Bay Discharge Structures 5-18
Pump to Sink 5-21
Pump to Sink 5-21
Design 5-21
Sink Discharge 5-22
Pipe Layout 5-23
Pump Station 5-24
Pump to Quarry 5-24
Design 5-24
Quarry Discharge 5-25
Pipe Layout 5-26
Pump Station 5-26
Evaluation 5-26
Reduce Flooding 5-28
Cost Effective 5-29
Cost Effective 5-29
Sources 5-29
Cost Summary 5-29
Expanded Detention 5-30
Ocean Outlets 5-30
Pump Alternatives 5-31
Gravity Bay Outlet 5-31
Additional Inlets 5-31
Operation and Maintenance 5-32
Pump Alternatives 5-32
Other Alternatives 5-33
Schedules 5-33

Constructability 5-35
Expanded Detention 5-35
Gravity Bay Outlet 5-35
Gravity Ocean Outlet 5-35
Pump to Sink/Quarry 5-36
Impact to Environment 5-37
Expanded Detention 5-37
Ocean/Bay Outlets 5-37
Gravity Bay Outlet 5-37
Pump to Sink/Quary 5-38
Permitting Requirements 5-39
National Pollutant Discharge Elimination System (NPDES) 5-40
Section 401 Water Quality Certification (401 WQC) 5-40
Environmental Impact Assessment/Statement (EIA/EIS) 5-41
U.S. Army Corps of Engineers Permit 5-41
Guam Coastal Management Program 5-41
Timeline 5-42
Public Perception 5-42
Matrix Scoring 5-42
Summary of Findings and Recommendations 5-44

TABLES

Table E -1 iii
Table 1-1 - Data Sources 1-2
Table 2-1 - Stormwater Drainage Manual Design Criteria 2-2
Table 2-2 - NOAA Atlas 14 Rainfall Depths for SVR 2-6
Table 2-3 - DPW BMP Categories 2-10
Table 2-4 - Land Use Areas 2-13
Table 4-1 - Yearly SVR Flooding 4-8
Table 4-2 - Drainage Catchment Parameter Table 4-13
Table 4-3 - Fujita Pond Storage Parameters 4-18
Table 4-4 - Key Hydrologic and Hydraulic Results 4-24
Table 4-5 - High Bacteria Count Readings at Fujita 4-25
Table 4-6 - Largest Rainfalls and Subsequent Bacteria Counts at Fujita 4-26
Table 5-1 - Expanded Detention Area 5-6
Table 5-2 - Tidal Elevations 5-11
Table 5-3 - Gravity Ocean Outlet Pipe Sizing 5-12
Table 5-4 - Gravity/Pump Ocean Outlet Pipe/Pump Sizing 5-16
Table 5-5 - Gravity Bay Outlet Sizing 5-18
Table 5-6 - Pump to Sink Pump/Pipe/Sink Sizing 5-22
Table 5-7 - Pump to Quarry Pump/Pipe Sizing 5-25

Table 5-8 - Alternative Evaluation Criteria 5-27
Table 5-9 - Alternative Project Cost Estimates 5-30
Table 5-10 - Maximum Land Costs 5-30
Table 5-11 - Additional Inlet Options 5-32
Table 5-12 - Permit Requirements 5-40

FIGURES

Figure 1-1 - Gage Locations 1-6
Figure 2-1 - Photograph of Typical SVR Segment 2-3
Figure 2-2 - Rainfall-Recurrence Relationship for 1-Hour Storm 2-4
Figure 2-3 - Rainfall Distribution for 1-Hour Storm 2-4
Figure 2-4 - PFDS Point Location for Project Rainfall 2-5
Figure 2-5 - NRCS 24-hour Rainfall Distribution for Guam 2-6
Figure 2-6 - EIS Soil Map and Table 2-8
Figure 2-7 - Project Area Map 2-12
Figure 2-8 - Project Elevation Map 2-13
Figure 3-1 - Date Point Ma 3-4
Figure 3-2 - Offline Drainage Areas 3-6
Figure 3-3 - Maeda Pacific Phtographs 3-8
Figure 3-4 - Photograph of Cloffed Inlet by The Plaza 3-9
Figure 3-5 - Elevation Map 3-10
Figure 3-6 - September 19 Overflow of Fujita Pond 3-11
Figure 3-7 - Plan and Section of Fujita Pond 3-12
Figure 3-9 - 19-Sept Flooding on SVR and Sandcastle Property 3-13
Figure 3-9 - 19-Sept Manhole in front of Sandcastle Property 3-13
Figure 3-10 - GEPA 2013 Water Quality Readings at Fujita Road Station 3-17
Figure 4-1 - Insufficient Inlets 4-3
Figure 4-2 - 10-Oct Photos 4-4
Figure 4-3 - Definition of Rainfall Causing Fujita Pond Overflow 4-5
Figure 4-4 - Comparison of Typical Rainfall to Fujita Pond Overflow 4-7
Figure 4-5 - SVR Storm Sewer Network Map 4-10
Figure 4-6 - Project Area and Drainage Catchment Map 4-12
Figure 4-7 - XP-SWMM Model Layout 4-15
Figure 4-8 - Inlet Dimensional Parameters 4-16
Figure 4-9 - Ponding Area along SVR 4-17

Figure 4-10 - 10 Oct Fujita Pond. Rain versus Pond Level 4-19
Figure 4-11 - Rainfall Distribution Curves 4-20
Figure 4-12 - Fujita Pond Water Elevation 10-Oct Event 4-21
Figure 4-13 - XP-SWMM 19-Sept Ponding Area 4-22
Figure 4-14 - Photographs of 19-Sept Event 4-22
Figure 4-15 - Existing Condition Hydrographs 4-23
Figure 5-1 - Photograph of DuPage County Labyrinth Weir 5-7
Figure 5-2 - Labyrinth Weir State Discharge Curve 5-8
Figure 5-3 - Pump Station Photos 5-9
Figure 5-4 - Infiltration Chamber Area 5-10
Figure 5-5 - Open Cut Installation Method 5-14
Figure 5-6 - Channel with Pedestrian Bridge Example 5-19
Figure 5-7 - Lagoon Discharge Example 5-20
Figure 5-8 - Diffuser Structure Example 5-21
Figure 5-9 - Sink near JFK High School 5-22
Figure 5-10 - View of Quarry Area 5-25
Figure 5-11 - Alternatives Rating Matrix 5-28
Figure 5-12 - Summary Schedule 5-34
Figure 5-13 - Micro-Tunneling Operation 5-36
Figure 5-14 - Alternatives Rating Matrix 5-43

APPENDICES

Appendix A - Reference Citations A-1
Appendix B - Figures B-1
Appendix C - Conceptual Drainage Options C-1
Appendix D - Cost Estimate D-1
Appendix E - Schedule E-1

List of Acronyms

Acronym	Definition
BMP	Best Management Practice
BSP	Bureau of Statistics and Plans
CFS	Cubic Feet per Second
CHA	Clough Harbour & Associates
CORS	Continously Operating Reference Station
DMS	Data Management System
DPW	Guam Department of Public Works
EA	EA Engineering
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
GEDA	Guam Economic Development Agency
GEPA	Guam Environmental Protection Agency
GLUC/TSPC	Guam Land Use Commission and Seashore Protection Commissions
GPM	Gallons Per Minute
GVB	Guam Visitors Bureau
GVD	Guam Vertical Datum
GWA	Guam Water Authority
HDPE	High Density PolyEthylene
HP	Horsepower
JFK	John F. Kennedy
LiDAR	Light Detection and Ranging
MS4	Municipal Separate Storm Sewer System
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service

Acronym	Definition
PFDS	Precipitation Frequency Data Server
RCP	Reinforced Concrete Pipe
Rev	Recharge Volume
ROV	Remote Operated Vehicle
SHPO	State Historical Preservation Office
SVR	San Vitores Road
SWPPP	Stormwater Pollution Prevention Plan
TMDL	Total Maximum Daily Load
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USMC	United States Marine Corps
WERI	Water and Environmental Research Institute
WQv	Water Quality Volume

Section 1

Data Collection

Introduction

San Vitores Road (SVR) runs through a densely developed commercial/tourist district in the Tumon Bay area of Guam. The road and surrounding properties are prone to periodic flooding following heavy rainfall events. The Guam Economic Development Authority (GEDA) has contracted with Stanley Consultants, Inc. to provide preliminary engineering to develop and analyze alternatives for mitigating this problematic flooding issue. This project includes the following major tasks:

- Collect and organize project pertinent data (Section 1).
- Review and establish project analysis and design criteria (Section 2).
- Perform inspection and assessment of existing stormwater drainage system (Section 3).
- Conduct flood modeling of the existing stormwater drainage system (Section 4).
- Develop and evaluate flood mitigation improvement alternatives (Section 5).

The objective of this project is to develop potential solutions to mitigate flooding occurring along San Vitores Road north of the Fujita Pump Station. Tasks 1 and 2 provide the background information necessary to evaluate the flooding issue. Tasks 3 and 4 involve identifying causes and quantifying the magnitude of the flooding issue. Task 5 is the development and evaluation of potential solutions for mitigating the flooding issue.

Section 1 summarizes the initial data collection effort and provides the database structure for storage of collected data and project deliverables.

Data Sources

The SVR Flood Mitigation Project includes public utilities, public roads, private and public lands, stormwater runoff issues, water quality issues, and Guam specific drainage parameters and criteria. There is no single agency that holds all the background information necessary to execute the project. The initial data collection effort focused on canvassing a wide array of stakeholders, regulators, property/utility owners, and scientific organizations for relevant information.

Table 1-1 lists data sources, their role in the project, and project relevant data/information provided.

Table 1-1 Data Sources

Source	Role	Data/Information
Balagtas Surveyors	Surveyor	Property Surveys Future topographic survey
Bureau of Statistics and Plans (BSP)	Regulator	Coastal Management Program Guidance
Clough Harbour & Associates (CHA)	GEDA Program Manager	San Vitores Stakeholder Mtg Minutes NPDES Background Info.
Department of Public Works (DPW)	Owner/Manager Streets and Storm Sewer	2010 Storm Water Drainage Master Plan 2010 Guam Transportation Drainage Manual Project Interviews
EA Engineering (EA)	Project Subconsultant	Rain/Stage Gage Install and Collection
Guam Environmental Protection Agency (GEPA)	Water Quality Regulator	NPDES Requirements CNMI/Guam Stormwater Mgmt Manual Tumon Bay Water Quality Data
Guam Water Authority (GWA)	Owner/Manager Water/Sewage Facilities	San Vitores Road Drawings Marine Corps Drive Drawings Hagatna Outfall Documents
Maeda Pacific Contractors	Storm Sewer Cleaning Contractor	Photos and Extents of Cleaning Project
National Climatic Data Center (NCDC)	Climate Data Clearinghouse	Rainfall Gage Data
Natural Resource Conservation Service (NRCS)	Soils Data	Guam Soil Classification

Source	Role	Data/Information
National Oceanic and Atmospheric Administration (NOAA)	Rainfall Frequency Analysis/ Studies	Rainfall Frequency Data Topographic Data
United States Army Corps of Engineers (USACE)	Regulator	Guam Storm Drainage Manual
United States Geological Survey (USGS)	Surface Water Monitoring	Rainfall Gage Data
United States Marine Corps (USMC)	Planning for Military Relocation	Environmental Impact Study for Guam
Water and Environmental Research Institute (WERI)	Educational/Research Institute	Prior Tumon Bay Studies Infiltration Studies Rainfall studies
WB Flores and Associates	Engineering Consultant	Related Project Drawings

Source: Stanley Consultants, Inc.

References

The SVR Flood Mitigation Project utilized several specific references for background data, design criteria, rainfall frequency depths, and other scientific studies. Appendix A provides a summary of project references. Reference citations within this report are indicated by the number in brackets [#] with references listed in Appendix A.

Data Management System

A ProjectWise Data Management System was developed for storing all relevant project data and deliverables. The purpose of this Data Management System (DMS) is to provide a single, organized location for adding and accessing data and deliverables for the project team. Data and deliverables have been added to ProjectWise over the course of the project. The DMS is also provided on a DVD with the hardcopy of this report. The DMS file structure is as follows:

1- Drawings

- 1- DPW
- 2- AAFB
- 3- GWA
- 4- Maeda

2- Guidance_Manuals

- 1- DPW
- 2- CNMI
- 3- NOAA

    4- NRCS
    5- BSP
    6- USACE
3- GIS_Data
    1- ReferenceData
    2- GDB
    3- MXD
4- Photographs
    1- Site
    2- Structures
    3- Maeda_Inspection
    4- Rain_Events
5- Regulatory
    1- NPDES
    2- GEPA
    3- Agatna_Outfall
6- Data
    1- Precip
    2- EA_Data
    3- Beach_Monitoring
    4- Survey
7- Studies
    1- WERI
    2- USDA
    3- USGS
    4- USMC
8- Submittals
    1- Scope
    2- Communication
    3- Computations
    4- Reports
    5- Exhibits
    6- Cost Estimates
9- Transfer

Project Specific Data

The scope of this project includes field collection of several project specific data items that were used in analyzing the existing SVR storm sewer system and design of potential improvement alternatives.

Rainfall and Fujita Pond Level Logger Data

The existing condition and proposed improvements will be analyzed using XP-SWMM, which is a stormwater management model software package. With stormwater models, there are numerous combinations of methods and parameters for analyzing stormwater runoff and conveyance. The most effective way to select and adjust model parameters is to use actual recorded data so the model can attempt to replicate the event.

For the SVR storm sewer analysis, rainfall data will be collected at two locations (Fujita Pond and rooftop of the DFS Building) within the watershed using tip bucket rainfall gages and the level of Fujita Pond will be collected using a data level logger. These two pieces of data (rainfall and pond level) will help define the event (rainfall), response (change in pond level) relationship for the SVR storm sewer system. Rainfall data will be read on an hourly basis and the pond level will be read on a 15-minute basis. The relation between gage rainfall and pond level will be used to calibrate the XP-SWMM model. Gage locations are shown in Figure 1-1. Rainfall gage data and level logger gage data are stored under *6-Data* in the project DMS.

Gage Locations
Figure 1-1

Site Inspection and Survey

Existing storm sewer features for SVR and the Tumon Bay watershed were inspected and surveyed by Stanley Consultants between August 19th and 29th, 2013. A Trimble GeoXH 6000 series handheld GPS device, loaded with ArcPad (ver. 10), was utilized for the data collection and survey effort. Additionally, a Canon PowerShot SX260 HS GPS enabled digital camera was used to take geo-tagged photographs of existing storm sewer features and the project site area. All collected data was organized and stored in a GIS database.

GIS Database

The collected survey data from the field inspection was imported into a GIS database (ESRI personal geodatabase, ver. 10) to be used with ESRI's ArcGIS Desktop software as the GIS storm sewer asset management system. ArcGIS provides a mapping interface and a comprehensive toolset for the surveyed storm sewer features to be accurately modeled and linked to associated photographs, videos, as-built documents, etc.

The geodatabase contains storm sewer features including: manholes, catch basins, inlet grates, curb inlets, combination inlets, headwalls, outfall structures, pipe junctions, pipes, drainage ditches, ponds, road centerlines, GPS geo-located photos and as-built documents for the project area. Additionally, topographic data and orthographic satellite/aerial imagery were obtained and included as GIS reference data outside of the geodatabase.

Each feature also contains a multitude of relevant attribute data such as: latitude, longitude, rim elevation, invert elevations, pipe size, material, and field notes. Below is a list of important field names and descriptions for the storm sewer features in the geodatabase.

<u>Structures</u>

1. Structure ID – unique number used to identify each storm sewer structure
2. Type – structure type (manhole, catch basin, curb inlet, etc.)
3. Curb Inlet Size (inch) – curb inlet dimensions
4. Grate Size (inch) – grate inlet dimensions
5. Internal Structure Size (inch) – dimensions of inside of manhole or catch basin
6. Top of Water Depth (feet) – depth from top of water in structure to the rim
7. Owner
8. Pipe Count – number of pipe connections to a structure
9. Pipe Size (1-4 connections) – pipe size of connected pipe to structure
10. Comments – survey and inspection field notes
11. Rim Elevation (feet)
12. Invert Elevation (feet)

Pipes

1. Pipe ID – unique number to be used to identify each storm sewer pipe
2. Upstream Structure ID – upstream structure ID of pipe
3. Downstream Structure ID – downstream structure ID of pipe
4. Material – pipe material
5. Diameter (feet) – diameter of a round pipe
6. Height (feet) – height of box culvert
7. Width (feet) – width of box culvert
8. Slope – decimal value of pipe's slope percentage
9. Owner
10. Shape Length – 2D length of pipe

The project GIS database can be accessed under *3-GIS-Data* of the project DMS.

Section 2

Design Criteria

Introduction

Section 2 summarizes the engineering analysis and design criteria utilized on the project and provides an overview of the tributary drainage area.

Design Criteria

The SVR storm sewer system is owned and maintained by DPW. Current drainage design criteria/guidance for DPW stormwater infrastructure is provided by the following documents:

- Guam Transportation Stormwater Drainage Manual [1]
- CNMI and Guam Stormwater Management Manual [2]

The Guam Transportation Stormwater Drainage Manual (Stormwater Drainage Manual) defines stormwater quantity analysis and system design criteria as well as identifying preferred Best Management Practices (BMP)'s for stormwater projects. The Stormwater Drainage Manual references the CNMI and Guam Stormwater Management Manual (Stormwater Management Manual) for guidance relating to stormwater quality analysis and system design. These two manuals were the main resources used to define design and analysis criteria for the project. The two manuals are included in *2-Guidance Manuals* of the project DMS.

The existing SVR storm sewer system was constructed prior to the analysis and design requirements incorporated into the Stormwater Drainage Manual and Stormwater Management Manual. Deviations or adjustments to manual defined criteria are noted and discussed.

Recurrence Interval

Recurrence interval represents the probability of a given event being equaled or exceeded. For rainfall, the larger the rainfall event, the lower the probability of its occurrence. Rainfall

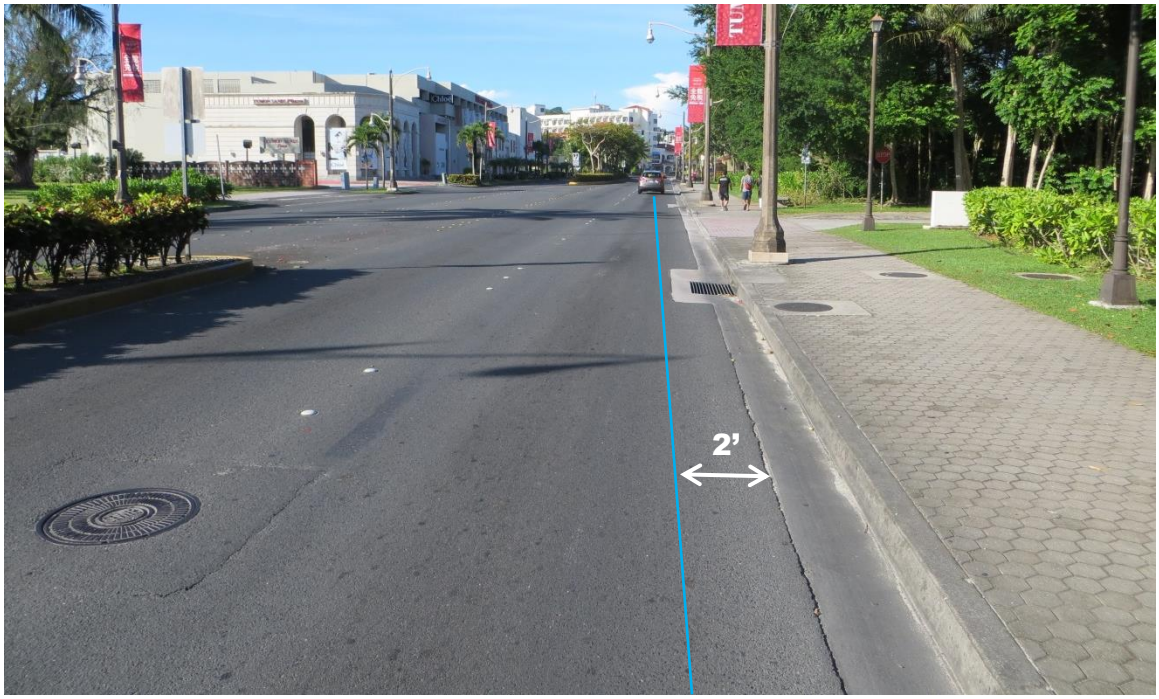
depths are determined for given recurrence intervals (aka storm frequency) using a statistical analysis of rain gage data. A 10-year storm represents a rainfall depth that has a 10 percent chance of being equaled or exceeded in a given year. A 100-year storm represents a rainfall depth that has a 1 percent chance of being equaled or exceeded in a given year. Table 2-1 shows the Stormwater Drainage Manual's recurrence interval criteria for drainage design.

Table 2-1 Stormwater Drainage Manual Design Criteria

Type of Structure	Storm Frequency (years)
Gutters	10
Storm Drain Inlets – On Longitudinal Slope	10
Storm Drain Inlets – Vertical Curve Sag	50
Storm Drain Laterals	10
Storm Drain Trunk Lines	25
Ditches – Roadside	10
Ditches – Outfall and canals	25
Culverts	50-year for main routes and 25-year for secondary routes.
Bottomless Culverts	50
Culverts – Check for Overtopping	100
Main Routes	10-year: Flow spread width not to exceed shoulder and 2 ft. of the adjacent lane. 100-year: No overtopping at bridges and culverts; one lane in each direction passable for emergency vehicles. Check for flow damage and provide protection as required.
Secondary Routes	10-year: Flow spread width not to exceed half of the inner lane. 100-year: Passable for emergency vehicles. Check for flow damage and provide protection as required.

Source: Stormwater Drainage Manual

SVR is considered a main route, so would be subject to maintaining a ponded width less than two feet in the lane adjacent to the gutter for a 10-year storm. Figure 2-1 shows a photograph of a typical segment of SVR.



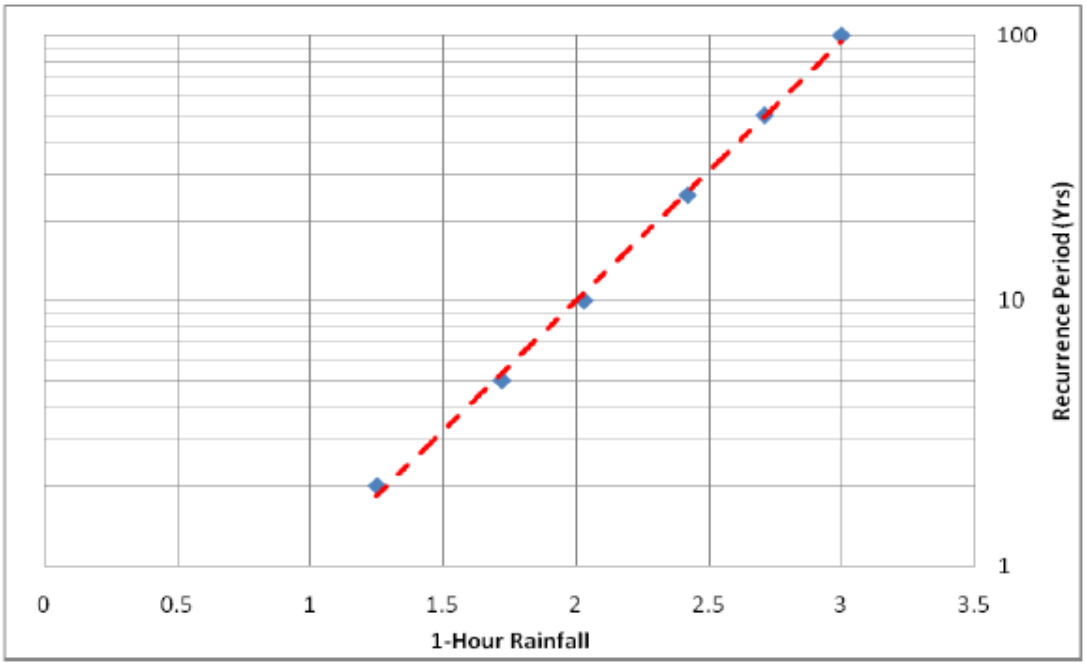
Photograph of Typical SVR Segment
Figure 2-1

As shown in Figure 2-1, there is limited width to pond water along SVR. The adjacent driving lane essentially starts at the edge of the gutter line, so ponding would be confined to the gutter line plus two feet. The SVR flood mitigation project involves improvement of an existing system. Table 2-1 lists the design standard for new drainage design. This project may be limited by the capacity and conditions of the existing SVR storm sewer system to meet DPW design criteria.

Design Storm

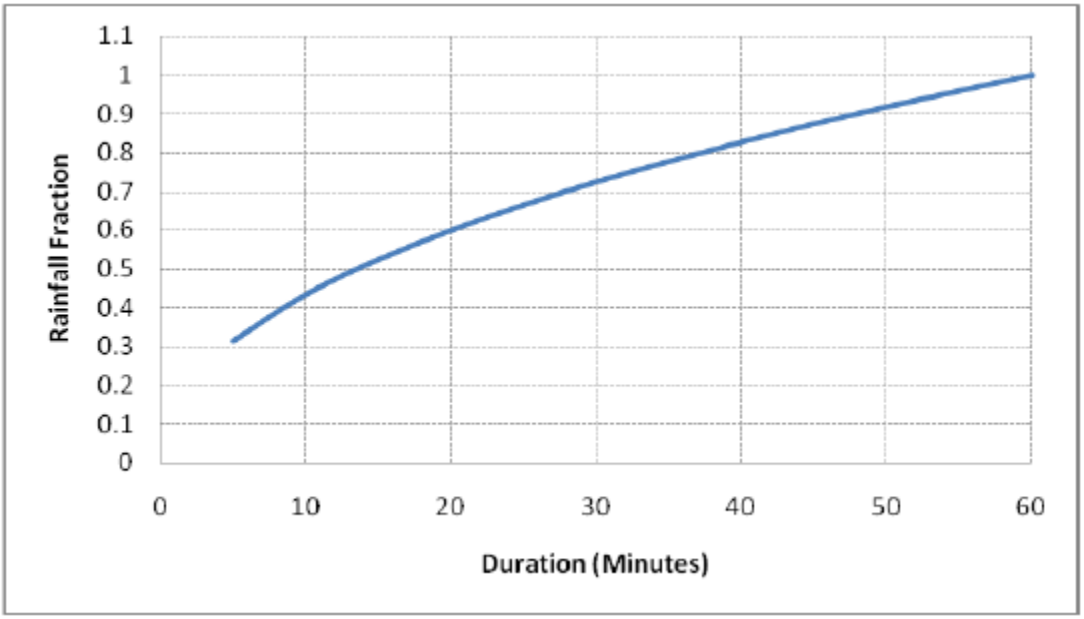
The Stormwater Drainage Manual recommends a 1-hour storm for design of stormwater facilities for Guam. The reason for a 1-hour storm as opposed to a 24-hour storm, which is more typical in stormwater design, is based on a statistical analysis that was completed during development of the Stormwater Drainage Manual which found that, "*most precipitation on Guam occurs during intense, short duration storms. The probability of getting storms longer than a 1-hour duration, as well as having more than one 1-hour storm in a day, is statistically remote.*"

The manual's rainfall-recurrence relationship for use in design is shown in Figure 2-2.



Rainfall-Recurrence Relationship for 1-Hour Storm
Figure 2-2

The distribution of this rainfall (i.e. the incremental fraction of the total rainfall over the 1-hour interval) defined by the Stormwater Drainage Manual is shown in Figure 2-3. Roughly 50 percent of the total rainfall occurs within the first 15-minutes of the 1-hour storm duration.



Rainfall Distribution for 1-Hour Storm
Figure 2-3

The 1-hour storm provides a sufficient rainfall event for design of street drainage systems such as roadside ditches, catch basins, and minor storm sewer systems. However, the SVR storm sewer receives runoff from a relatively large area and its only outlet is Fujita Pond, which is an infiltration basin. Longer duration rainfalls (i.e. greater than 1-hour) are more critical for the SVR storm sewer system because they are associated with a greater volume of runoff which cause Fujita Pond to fill up, overtop, and cause prolonged flooding of low areas. To represent this condition, a 24-hour storm was also used in this analysis.

The NOAA Atlas 14 [3] was used to establish rainfall depths for the 24-hour storm. Atlas 14 was published by NOAA in 2011 and provides precipitation frequency estimates for 5-minute through 6-day durations at average recurrence intervals from 1-year to 1000-year. Rainfall depths are obtained using the Precipitation Frequency Data Server (PFDS), which provides rainfall estimates for a given location. (http://hdsc.nws.noaa.gov/hdsc/pfds)

The location used to obtain 24-hour rainfall depths for the project is shown on Figure 2-4.

PFDS Point Location for Project Rainfall
Figure 2-4

The Atlas 14 rainfall depths for the project area are listed in Table 2-2.

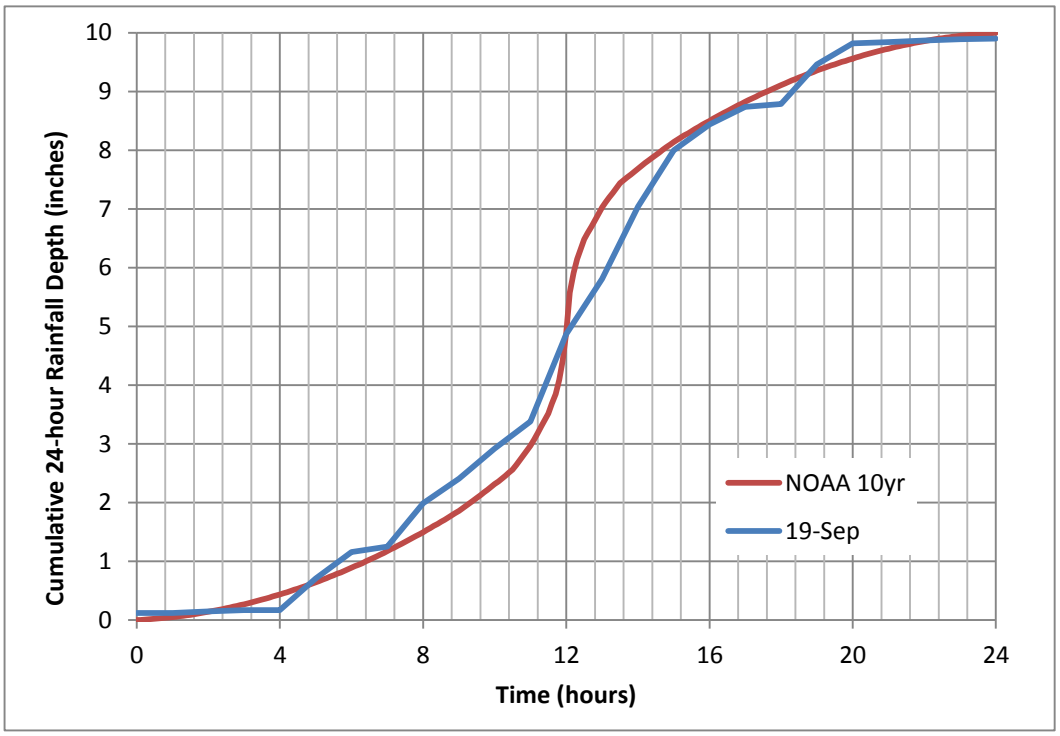
Table 2-2 NOAA Atlas 14 Rainfall Depths for SVR

Duration (hours)	Recurrence Interval Rainfall Depth (in)							
	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
24	6.2	8.3	10.0	12.3	14.1	16.0	17.9	20.5

Source: NOAA

The 24-hour rainfall depths were distributed using the NRCS publication, *Rainfall-Frequency and Design Rainfall Distribution for Selected Pacific Islands* [4]. The NRCS document provides a 24-hour storm distribution in 0.1 hour increments for Guam which was developed by the NRCS using a statistical analysis of Guam rainfall gages. Copies of the NRCS and NOAA studies are provided in *2-Guidance Manuals* of the project DMS.

On September 19, 2013 Guam received roughly 10 inches of rainfall in 24 hours (19-Sept), which is equivalent to the NOAA 10 year rainfall depth. Both NOAA Atlas 14 rainfalls and the 19-Sept rainfall were used in the analysis. Figure 2-5 provides a plot of the NOAA 10yr rainfall and the 19-Sept rainfall.



NRCS 24-hour Rainfall Distribution for Guam
Figure 2-5

As shown in Figure 2-5, roughly 40 percent of the NOAA rainfall occurs from 11 to 13 hours into the 24-hour duration. Therefore, with the 10-year design storm, 4 inches would fall during those 2 hours of most intense rainfall. Whereas the 19-Sept event produced a similar rainfall depth but it was distributed more uniformly over the 24 hour time range. At its most intense, the 19-Sept rainfall took almost 5 hours for 4 inches to fall. The 10-year design storm is more severe than the 19-Sept event.

Both the 1-hour and 24-hour storms were used in the drainage analysis. The 2, 5, 10, and 25-year rainfall events were analyzed. The Stormwater Drainage Manual 1-hour storm was used to analyze catch basin capacity and placement. The 24-hour storm was used to analyze the overall system, Fujita Pond, and proposed outfall improvements.

Actual rainfall events were also used in the analysis. Hourly rainfall depths were recorded at the Fujita Pond and DFS Building project gages. Gage rainfalls for the 19-Sept rainfall event as well as a smaller event that occurred on October 10, 2013 and also caused prolonged SVR flooding (10-Oct), were used in the analysis.

Runoff Parameters

Runoff parameters help define at what rate and volume rainfall is transformed into stormwater runoff once it hits the tributary drainage area. The main components defining stormwater runoff are the tributary area, time of concentration, and infiltration.

Tributary Area. The tributary drainage area for the SVR storm sewer system was delineated using LiDAR derived topographic information, construction drawings of the area, and findings from the Engineer Site Visit. The total drainage area was divided into catchments which were delineated based on what inlet or group of SVR inlets the catchment drained to. In developed areas, the catchment boundaries also tended to follow property lines because many of the developed areas have offline drainage systems that are not directly connected to the SVR storm sewer and capture and infiltrate stormwater runoff within their property.

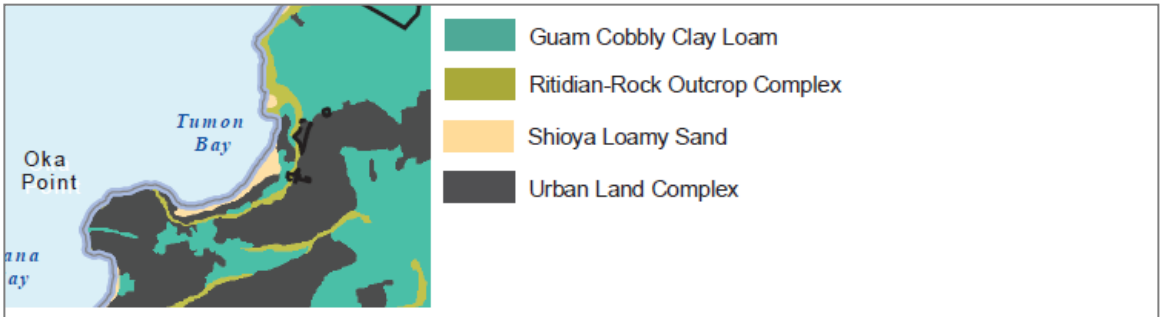
Time of Concentration. Time of concentration is the runoff parameter that defines how quickly rainfall is transformed into runoff and conveyed into the storm sewer system. Time of concentration was computed for each catchment area using the Watershed Lag Method from NRCS *National Engineering Handbook* [5]. This method uses the average watershed slope to estimate the time of concentration and is recommended by the NRCS. Using ArcGIS a flow path is defined and an average slope is computed for each catchment. The time of concentration is computed using these parameters and the representative runoff curve number for the catchment.

Several catchments consist primarily of a segment of SVR with adjacent developed areas that are directly connected to the SVR storm sewer system (i.e. no offline drainage/infiltration systems). These catchments drain to the SVR storm sewer very rapidly following rainfall events so a minimum time of concentration of 10 minutes was assumed for the SVR area catchments.

Infiltration. Infiltration represents the rate at which the catchment soil cover can percolate (i.e. absorb) rainfall. The greater the infiltration rate, the less rainfall that is transformed into stormwater runoff. There are several methods used to represent infiltration but a widely used method which is recommended by the Stormwater Drainage Manual is the NRCS runoff curve number method (aka TR-55 method) [6].

In the NRCS method, a representative runoff curve number is assigned to a catchment based on soil type and land use. The soil type provides an indication of the infiltration rate of the soil and the land use provides an indication of how land use impacts infiltration. A runoff hydrograph is then computed based on the area, time of concentration and curve number using the NRCS methodology which is included in most hydrologic software programs, including XP-SWMM.

Soil maps for Guam were difficult to locate and discussions with the local NRCS agent indicated that the assigned hydrologic soil groups were likely not representative of the actual infiltration rate of the soil. In 2010, the U.S. Marine Corps published their Final Environmental Impact Statement (EIS) for military relocation to Guam [7]. The EIS included an analysis of Geological and Soil Resources which included soil maps and descriptions. Figure 2-6 displays the soil map for the project area and soil description table. Relevant sections of the EIS are included in *7-Studies* of the project DMS.



Soil Class	*Soil Description*	*Runoff Rate*	*Permeability*	*Erodibility Factor (K)*	*Soil Category*
Guam Cobbly Clay Loam	Very shallow, well drained, nearly level to moderately sloping soils; on plateaus	Slow	5.0 – 15.0	0.05	Limestone Uplands
Ritidian - Rock outcrop	Very shallow, well drained, gently sloping to extremely steep soils, and rock outcrop; on plateaus, mountains, and escarpments	Very slow	5.0 – 15.0	0.02	Limestone Uplands
Shioya Loamy Sand	Deep, rapidly permeable, well drained soil on coastal strands.	Slow	15.0-50	0.15	Coastal Limestone Sands

EIS Soil Map and Table
Figure 2-6

Figure 2-6 shows that soils surrounding Tumon Bay are highly permeable and have slow to very slow runoff rates. These types of soils are typically classified as hydrologic soil

groups A (highest infiltration) or B (high infiltration). The NRCS indicates curve numbers for undeveloped land with these types of soils are typically in the range of 40-60.

Developed lands have higher curve numbers because they tend to have significant impervious area (paved, rooftops, etc.) which has no infiltration. The developed areas surrounding SVR are high density (i.e. more impervious area) residential, commercial, and hotel properties. However, the majority of these areas have offline drainage systems which infiltrate a portion of the stormwater runoff without discharging to the SVR storm sewer. For estimating runoff, a smaller volume of stormwater runoff leaves developed areas with offline drainage systems than what their land use would suggest. This means that these areas essentially function like undeveloped areas because they capture and infiltrate a larger portion of the stormwater runoff. Offline areas are assumed to have a similar curve number range as undeveloped land.

New property developments on Guam are required to provide infiltration of stormwater runoff. It is assumed that lands developed in the future will provide similar infiltration systems to other "offline" properties in the area. Therefore, curve numbers used to reflect existing conditions should be representative of future drainage conditions.

The curve numbers used for the undeveloped and offline areas will be used to calibrate the XP-SWMM runoff model. A representative curve number for these areas is somewhere between 40-60 and was adjusted based on calibration of the XP-SWMM model to project gage rainfall and Fujita Pond level logger data being collected for the project.

Roadway right-of-way and developed lands that drain directly to the SVR storm sewer have high curve numbers and these will not be adjusted by calibration. Per NRCS guidance, these areas were set at a curve number of 92 which reflects the high degree of impervious area and a more direct connection to the SVR storm sewer system.

Water Quality

Both the Stormwater Drainage Manual and the Stormwater Management Manual provide guidance on stormwater quality and treatment criteria and design. Stormwater management can be separated into two phases:

1. Construction stormwater management (temporary)
2. Post-construction stormwater management (permanent)

Stormwater management and treatment is achieved through the design and installation of specific stormwater treatment methods or BMP's. The Stormwater Drainage Manual separates BMP's into four different categories which are shown in Table 2-3.

Table 2-3 DPW BMP Categories

BMP	Description
Design Pollution Prevention BMPs	Minimizing flow and quality impacts by improved design and planning
Runoff Treatment BMPs	Permanent quality treatment and flow control devices and facilities
Construction Site BMPs	Temporary sediment and waste control during the construction process
Maintenance BMPs	Long term regular maintenance of the transportation facilities and associated BMPs

Source: Stormwater Drainage Manual

The SVR flood mitigation project design will include Construction Site BMP's in development of the construction Storm Water Pollution Prevention Plan (SWPPP) which guides stormwater management during construction. The project design will also include Runoff Treatment BMP's as they relate to the installation of proposed improvements.

Runoff Treatment BMP sizing is based on four criteria: Recharge, Water Quality, Channel Protection, and Overbank Flood Control. The Stormwater Management Manual identifies the following acceptable BMP's for meeting the treatment standards: ponds, wetlands, infiltration practices, filtering systems and open channels. Runoff Treatment BMP's are typically designed for the 10-yr frequency storm event.

BMP design for a developed site's tributary drainage area includes meeting the following criteria:

1. Can capture and treat the full Water Quality Volume (WQ_v) and Recharge Volume (Re_v).
2. Is capable of removing 80 percent of TSS.
3. Is capable of meeting management objectives for specific resource protection.
4. Has acceptable longevity in the field.

The existing SVR system has two types of Runoff Treatment BMP's. Fujita Pond serves as a retention/infiltration pond, which has no outlet. Adjacent to the pond, is an infiltration system consisting of underground chambers. Throughout the watershed, additional offline infiltration systems also exist on developed areas, so these function as separate Runoff Treatment BMP's for their tributary area.

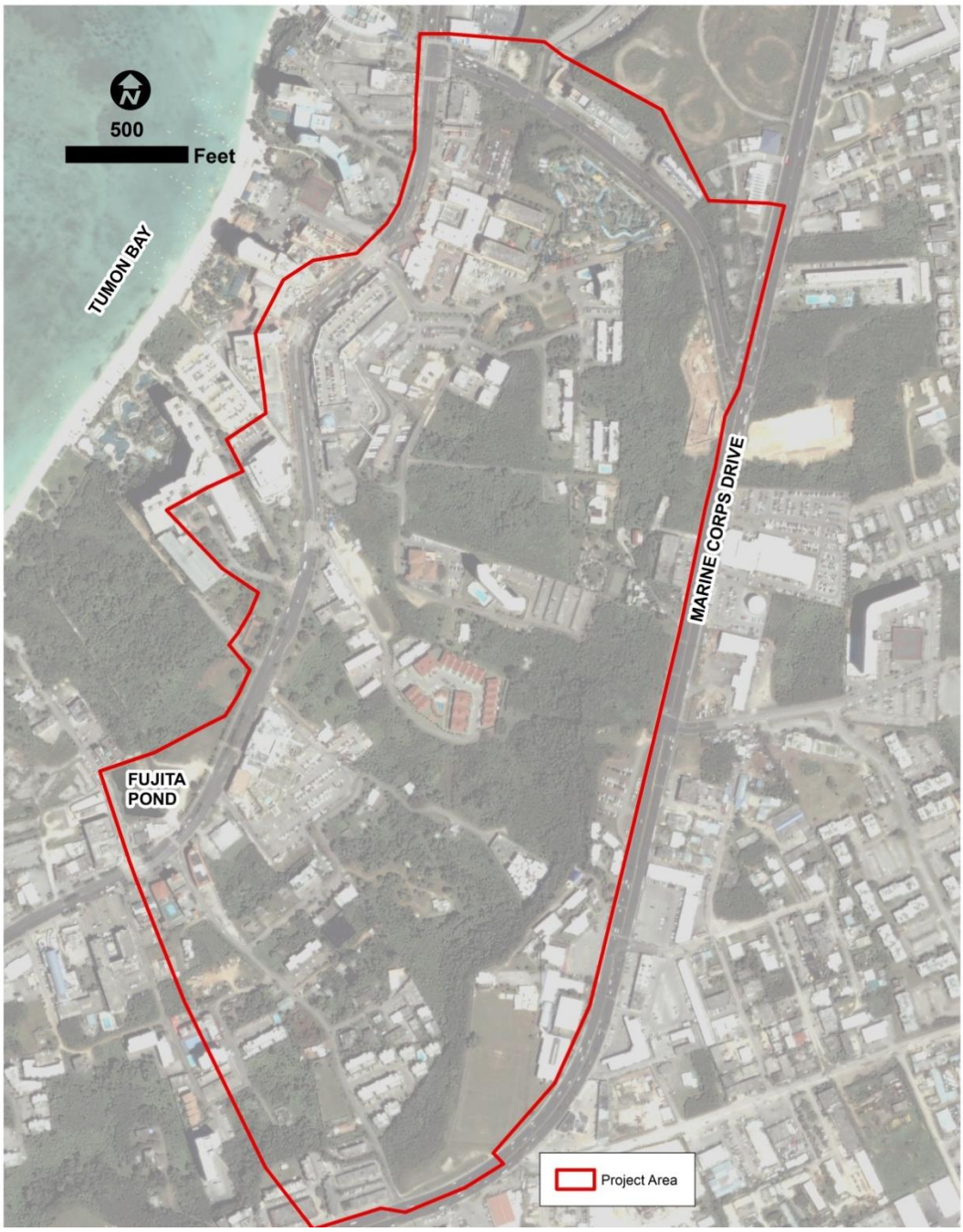
The water quality and recharge requirements for the Fujita Pond tributary area are established by the downstream waterbody. Fujita Pond currently does not have a defined outlet but the surrounding topography indicates that its overflow would eventually drain to Tumon Bay. The Stormwater Management Manual designates Tumon Bay as a "moderate quality" or M2

marine recharge zone. For discharge to an M2 designated water body, the Stormwater Management Manual requires a Recharge Volume, Re_v (i.e. infiltration) and Water Quality Volume, WQ_v (i.e. detention) based on a specific rainfall depth over the directly tributary area. The recharge volume is determined using a 1.5-inch rainfall event and the Water Quality Volume is based on a 0.8-inch rainfall event.

The SVR flood mitigation project is an infrastructure improvement project, not new development. The layout of stormwater quantity and quality improvements is controlled by the existing system and surrounding developments and land use. Any modifications to the SVR storm sewer system will require meeting applicable water quality requirements but the scale of improvements will be controlled by the existing storm sewer layout and limited GovGuam property within the project area.

Contributing Area

The contributing drainage area is defined by the area draining to Fujita Pond. Generally this area extends from Fujita Pond northward with Marine Corps Drive forming the boundary on the eastern side, the east-west portion of San Vitores Road that connects to Marine Corps Drive forming the northern boundary and Tumon Bay forming the western boundary. This area is 180.4 acres, consisting of the highly developed SVR corridor and the area between SVR and Marin Corps Drive. The area between SVR and Marine Corps drive is less developed consisting of some areas of fully developed residential/commercial properties and other properties that are vegetated and undeveloped. Figure 2-7 displays a project area map.



Project Area Map
Figure 2-7

Much of the project area is developed but many of these properties have their own offline drainage systems which capture and infiltrate a portion of their stormwater runoff. Similar to the undeveloped areas, the offline systems will capture and infiltrate much of the precipitation that occurs during normal rain events. However, during extreme and/or long duration rainfall events, the natural soil cover and the offline infiltration systems will not have capacity to infiltrate the

full volume of rainfall which will then flow towards and into the SVR storm sewer. Table 2-4 summarizes the land use areas draining to the project.

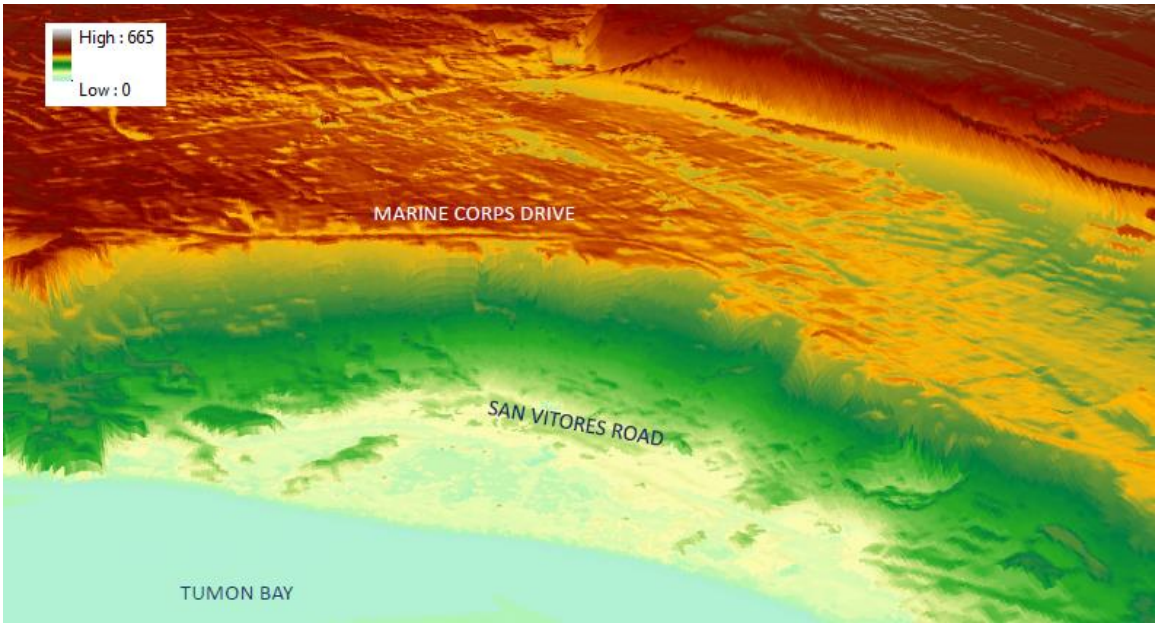
Table 2-4 Land Use Areas

Contributing Area	Area (ac)	% Area	% Runoff
Public Roadways	17	9%	17%
Adjacent Properties	9	5%	9%
Offline Properties	84	47%	40%
Undeveloped Properties	68	38%	32%
Marine Corps Drive	2	1%	2%
Total	*180*	*100%*	*100%*

Source: Stanley Consultants, Inc.

Most of the contributing area is comprised of undeveloped or offline properties. Adjacent properties are the older developments adjacent to SVR that drain directly to the SVR storm sewer system. The runoff rate for the various land uses were evaluated and converted to a contributing percent of runoff. As shown in Table 2-4, the more impervious areas such as roadways and adjacent properties contribute a higher fraction of runoff to the system than their area fraction.

An isometric perspective view of the project area was developed using the project topography and ArcGlobe. Figure 2-8 displays the Tumon Bay area.



Project Elevation Map
Figure 2-8

As shown on Figure 2-8, the Tumon Bay area sits in a "bowl" with steep grades down from the area west of Marine Corps Drive all sloping down to a lower flat area along the highly developed commercial area of SVR. Marine Corps Drive runs along a ridge line along the Tumon Bay area, where areas to the west of Marine Corps Drive drain down towards Tumon Bay and areas east of Marine Corps Drive drain to the south. There is a slight ridge (2 to 3 feet) between much of SVR and Tumon Bay. SVR runs along the lowest portion of the project area and so is a collection corridor for stormwater runoff. When stormwater runoff exceeds the capacity of the SVR storm sewer and Fujita Pond, the road area and any adjacent areas that are at similar or lower elevations will flood because there is nowhere else for the water to go.

Horizontal and Vertical Datum

The horizontal datum for the project (i.e. mapping/location coordinates) is NAD83 HARN Guam Map Grid – US Feet. The HARN Guam Map Grid is a standard, projected coordinate system for the Guam region.

The vertical datum for the project is a localized datum, based on the 2000 Tumon Bay Infrastructure and Beautification Project drawings. The conversion to 2004 Guam Vertical Datum (2004 GVD), a standard regional datum is:

- Project Datum = 2004 Guam Vertical Datum + 1.84
- Units of measurement for the project are US Feet.

Section 3

System Inspection and Assessment

Introduction

Section 3 summarizes the Engineer Site Visit system inspection and provides an overview of information collected and assessment of the SVR storm sewer system and tributary area.

Objectives

Stanley Consultants conducted the Engineer Site Visit between August 17th and August 29th, 2013 to inspect the SVR storm sewer system and assess potential issues with development of improvements. The area of concern extends from the Fujita Pump Station northward along SVR to its intersection with Marine Corps Drive. The objectives of the Engineer Site Visit were to:

- Field verify the existing storm drainage system
- Evaluate the condition of the drainage system and areas of concern
- Verify data accuracy
- Obtain missing data
- Identify and inspect areas that may benefit from BMP installation
- Coordinate with local agencies and stakeholders for additional project data
- Collect information to define scopes for:
  - Topographic survey (Balagtas)
  - Installation of rain gages and flow meters (EA)

Approach

The following individuals from the project team participated in the Engineer Site Visit:

- Stanley Consultants, Inc.
  - Craig Johnson – Project Manager
  - Andrew Judd – Senior Water Resources Engineer
  - Drew Rotschafer – GIS Analyst
- Sam O. Hirota, Inc
  - Jami Hirota –NPDES Permitting
- EA Engineering
  - Bob Shambach – Rain/Flow Gages
- Balagtas &Associates
  - Dennis Balagtas – Surveyor
  - Ding Balagtas – Surveyor

The two main tasks during the Engineer Site Visit were to meet with stakeholders to collect project information and perform a detailed site inspection of the storm sewer system.

Meetings with Stakeholders

The San Vitores Flood Mitigation Project involves a wide range of interested and impacted stakeholders. The project is funded by GEDA but involves a DPW owned/maintained storm sewer system and roadway. With its location in a densely developed retail/commercial area, the project has the interest of several owners of adjacent hotel and retail properties and the Guam Visitors Bureau (GVB) who have been advocates of the project. The project has been studied previously by WERI. Fujita Pond is located adjacent to a GWA sewage pump station so there are potential impacts to nearby water/sewer utilities. Guam's municipal separate storm sewer systems (MS4's) were recently designated for coverage under the National Pollutant Discharge Elimination System (NPDES) permit and Tumon Bay is designated as a marine preserve so improving the water quality of stormwater runoff discharging to the bay is a concern that involves GEPA and Guam's Coastal Management Program.

During the Engineer Site Visit, meetings were conducted with the project stakeholders to collect reference data and gain additional perspective on project issues.

Site Inspection

The inspection involved verifying the existing storm sewer system and recording locational and sizing information for development of an ArcGIS-based storm sewer map. This data was then used to develop the XP-SWMM model of SVR and contributing areas which was used to define specific system issues and potential solutions.

Stanley Consultants conducted a structure-by-structure inspection of manholes/catch basins using a high accuracy GPS handheld to establish the layout and condition of the San Vitores storm sewer system draining to Fujita Pond.

Measurements such as structure geometry, pipe sizes and inverts, and flow direction were taken and recorded for each accessible structure. Photos of structures and the general site were taken using GPS enabled cameras. Additional structure and pipe information was collected using a pole camera that was lowered into the structure and allowed an extended viewing length along connecting pipe segments.

The site inspection also included a review of contributing areas and properties for potential BMP retrofitting or installation.

Findings and Recommendations

The discussion of findings and recommendations are organized by the set of objectives listed at the beginning of this section.

Field Verification of the Existing Drainage System

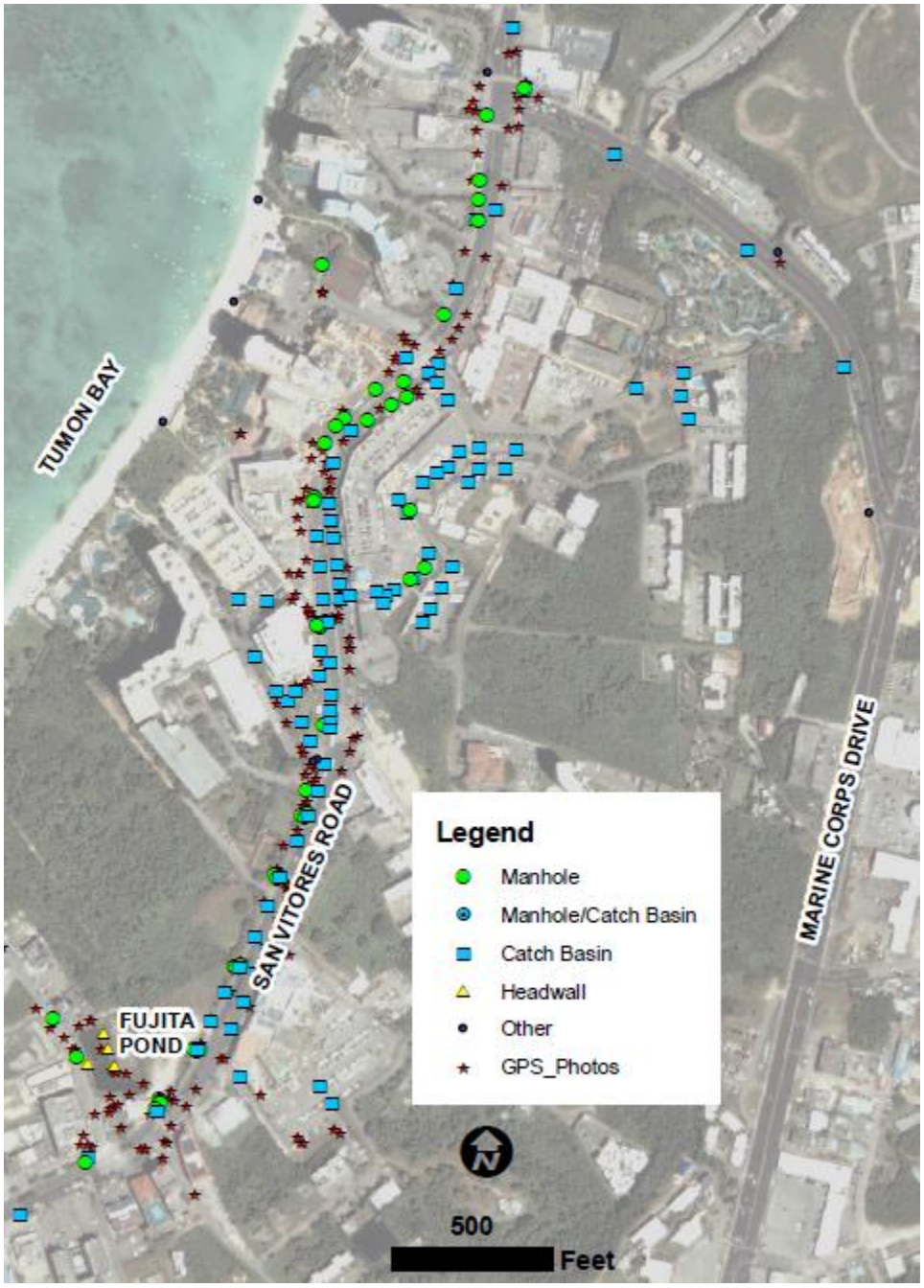
The field verification consisted of locating and pulling manhole and drainage structure covers and taking point locations, structure measurements, and photos. Through this process the location, extent, and dimensions of the existing storm sewer system were established. The field verification was substantiated by construction drawings for the 2000 Tumon Infrastructure and Beautification Project [8], which included reconstruction of SVR and associated utilities, including storm sewer.

Field Verification Process. A Trimble GeoXH 6000 series GPS unit was used to collect attributes such as pipe size, invert elevations, depth, pipe connections, conditions, dimensions, and comments for each storm sewer feature on-site. Following completion of the GPS field survey, GPS data was post-processed, against the GUAM, 1 second interval Continuously Operating Reference Station (CORS) located near Andersen AFB which increases locational accuracy. Storm sewer point features (i.e. manholes and catch basins) were used as the framework for connecting pipes to form a storm sewer network data model integrated into the XP-SWMM modeling software.

Photos were taken using the Trimble GPS unit's built-in camera and a Canon PowerShot SX260 HS GPS enabled digital camera. Photos were taken for each feature and were r linked in ArcGIS to their respective feature for reference. PDF's of As-built and construction drawings were also linked to their respective location. A point feature class was generated in the ESRI personal geodatabase for the GPS photo locations using the latitude and longitude coordinates derived from the GPS camera.

Quickview, a telescoping pole camera designed by Envirosight specifically for sewer manhole inspections, was also utilized to inspect 4 manhole/pipe connections and routes that were difficult to determine from surface observation. Video footage was recorded into MPEG format and is linked to the respective storm sewer feature(s) in the ArcGIS personal geodatabase.

All field data collected during the site visit is stored under *3-GIS_Data* and photographs stored under *4-Photographs* of the project DMS. Figure 3-1 provides a map view of ArcGIS-based data points collected during the site visit.



Data Point Map
Figure 3-1

Fujita Pond Storm Sewer System. The field study of SVR established that SVR north of Fujita Pond is drained by a single storm sewer system that outlets into Fujita Pond. North of the Underwater World complex, the trunk line of the Fujita Pond storm sewer system consists of a single Reinforced Concrete Pipe (RCP) ranging in size from 30-inch to 36-inch diameter. This RCP then connects into a triple 6-foot wide by 3-foot high reinforced concrete box culvert line where the SVR profile flattens out, near the north end of the Sandcastle property. The triple box culvert increases in size to from a triple 6-foot wide by 3-foot high to a triple 6-foot wide by 4-foot high box culvert approximately 200 feet downstream of the north end of the Sandcastle Property. Generally, the triple box culvert runs under the west curb line of SVR and is accessible through manholes located near the sidewalk area, although several manholes are in the street. The triple box culvert is approximately 2000 feet long and outlets into Fujita Pond through a headwall at the southeast corner of the pond. Fujita Pond is an infiltration basin and has no defined surface outlet. There are three headwalls on the east side of Fujita Pond that connect via short pipe segments to an annex underground infiltration chamber located east of the pond.

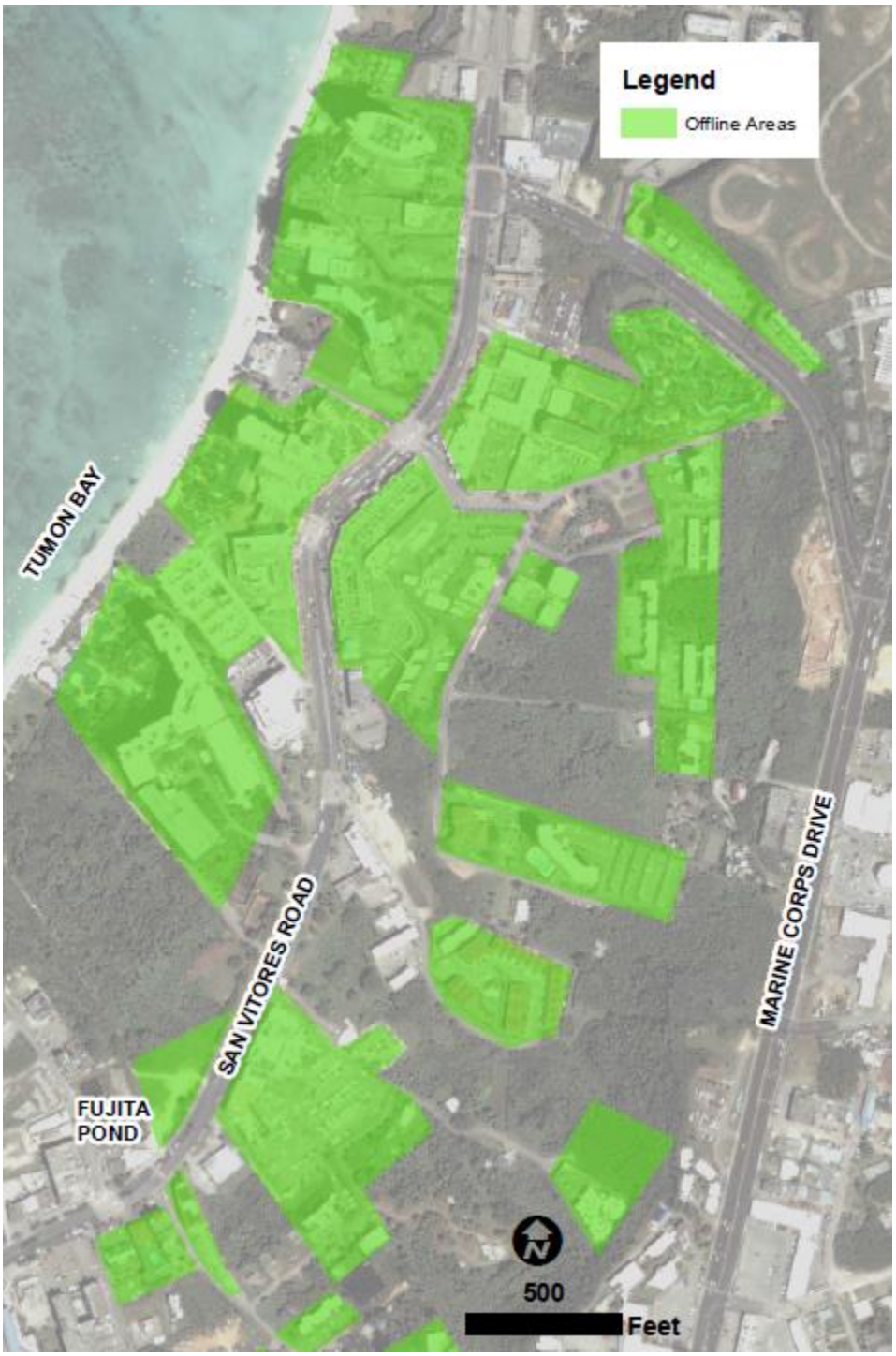
Fujita Pond is a wet pond. The pond bottom varies but is approximately 2 feet below the normal water table. The pond level rises with inflow from the SVR storm sewer. As the pond level rises above the normal water table, water percolates through the pond bottom and sides. If the inflow is sufficient to raise the pond level by over 3 feet, water flows into the annex underground infiltration chambers adjacent to the pond. If the inflow rate exceeds the percolation rate for a long enough duration, then Fujita Pond overtops at its northeastern corner and flows into the undeveloped property to the northeast.

South of Fujita Pond, SVR drainage is captured and conveyed by a 36-inch RCP trunk line that flows south to an underground infiltration chamber in the parking lot of Matapang Park. Generally, the area tributary to Fujita Pond extends north of Fujita Pond and west of Marine Corps Drive, with the top of the hill near the Westin and intersection with Gun Beach Road creating a drainage divide at the north end.

Stormwater runoff enters the Fujita Pond storm sewer system via inlets along SVR. The storm sewer inlets consist of curb inlets, grate inlets or combination curb/grate inlets. The inlets are either located at manholes along the trunk line or connect into the trunk line via storm sewer laterals (short, 12-inch to 18-inch RCP segments). In most segments, SVR tends to be the lowest area in the vicinity, so runoff from the higher areas between SVR and Marine Corps Drive flows down and collects in the SVR corridor.

The field verification found that many of the developed properties in the area have their own offline (i.e. not directly connected to Fujita Pond) storm sewer systems that infiltrate stormwater runoff on the individual property. The nature of the offline systems varies, but generally they are comprised of a series of inlets and pipes that drain to open bottom wells or trench drains where the collected stormwater infiltrates into the ground. As discussed in Section 2, the natural ground in the vicinity is well-drained. These offline systems are likely sufficient for to capture and infiltrate runoff from normal rain events

but overflow during large flood magnitude rainfalls. Figure 3-2 displays a map of the properties in the project area where offline drainage systems were identified.



Offline Drainage Areas
Figure 3-2

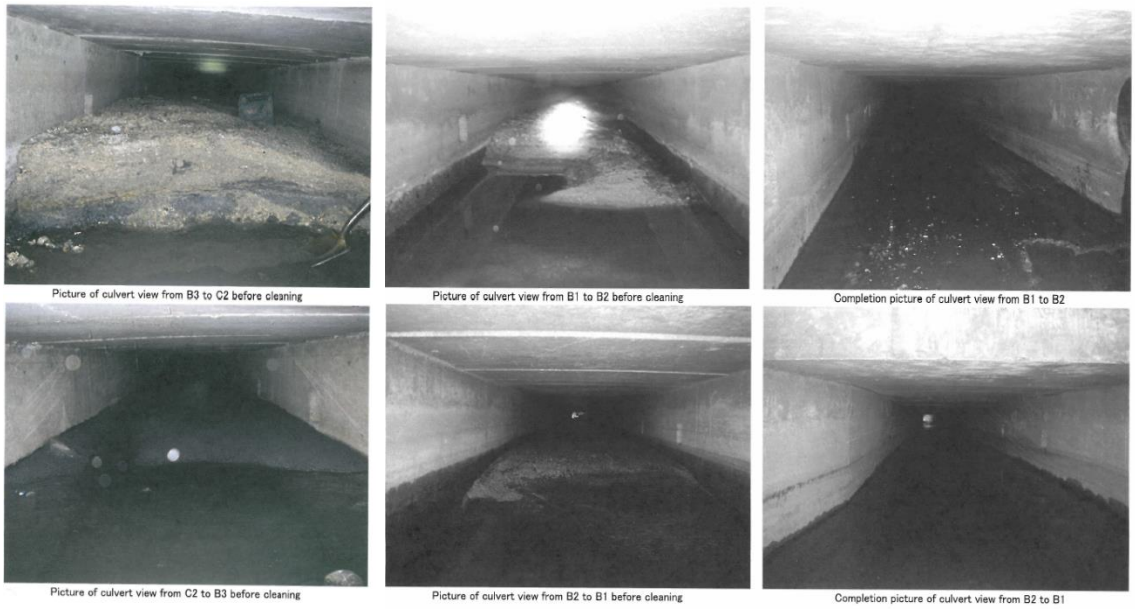
Guam has had developing ordinances in place since the early 1980's requiring stormwater storage and/or infiltration. It is understood that the 1980 USACE Guam Storm Drainage Manual [9] was used as the standard design guide for design of offline systems prior to the Stormwater Management Manual. In review USACE manual the prior design standard for infiltration design was to maintain discharge from the site at predevelopment levels and have capacity to capture and infiltrate the runoff from impervious areas for the 5-year design storm. The USACE standard would provide a similar capture and treatment volume to the Stormwater Management Manual. It is assumed that properties with offline storm sewer systems provide adequate treatment of stormwater runoff to meet the applicable standards of the Stormwater Management Manual. The USACE manual is provided in *2-Guidance Manuals* of the project DMS.

Condition of the Drainage System and Areas of Concern

The field verification also included evaluating the general condition of the storm sewer system and identifying areas of concern. This evaluation primarily focused on items that could impact the function of the system and areas that appeared prone to flooding. Weather during the site inspection was mostly sunny. Two small rain events occurred during the inspection, but were not significant enough to observe the function of the storm sewer system during a heavy rain event. However, following the Engineer Site Visit, Guam experienced significant rains from September 19-21, 2013 with over 24 inches falling over the three days and over 10 inches in a single day. Observations from the Guam-based project team during the 19-Sept event and 10-Oct event have been included in the drainage system evaluation.

Condition of the Drainage System. Overall, the general condition of drainage conduits and structures along SVR appeared very good. Drainage structures appeared to be in very good condition. Most manholes covers were easily lifted and grates and curb openings were not significantly damaged or clogged with debris. Portions of conduits that were viewable also appeared to be in good condition with sealed connections to drainage structures and minimal cracking or delaminating of the inside conduit surface.

The construction contractor Maeda Pacific cleaned a portion of the storm sewer system prior to the Engineer Site Visit. Stanley Consultants met with Maeda Pacific during the Engineer Site Visit and discussed the cleaning project. Cleaning operations extended from Underwater World to the south end of the Sandcastle property, roughly 700 feet. Maeda Pacific then ceased operations, citing more difficult/costly cleaning operations than what was indicated in their original contract. Photos of the cleaning operation are provided under *4-Photographs* of the project DMS. A selection of the Maeda Pacific photos is provided in Figure 3-3.



Maeda Pacific Photographs
Figure 3-3

The photographs indicate the trunk line of the SVR storm sewer had extensive silt/sand deposits in several segments prior to the cleaning operation. These deposits restrict the flow area within the culverts so reduce the overall hydraulic capacity of the storm sewer system. During the field verification, silt depths were checked in all accessible manholes along the trunk line. Silt depths varied from 1-4 inches, with the deepest silt being at the downstream end of the triple box culverts near Fujita Pond. These silt depths would suggest that the cleaning operation removed much of the silt/sand deposits and the storm sewer system can now convey near its full hydraulic capacity.

Much of the silt/sand appears to have collected near the upstream end of the box culverts. This is likely due to much flatter slope of the box culverts relative the upstream storm sewer pipes which, similar to SVR, are fairly steep north of the Sandcastle property. Once storm flow reaches the box culverts, its velocity decreases which allows the silt and sand particles to settle out onto the floor of the box culverts.

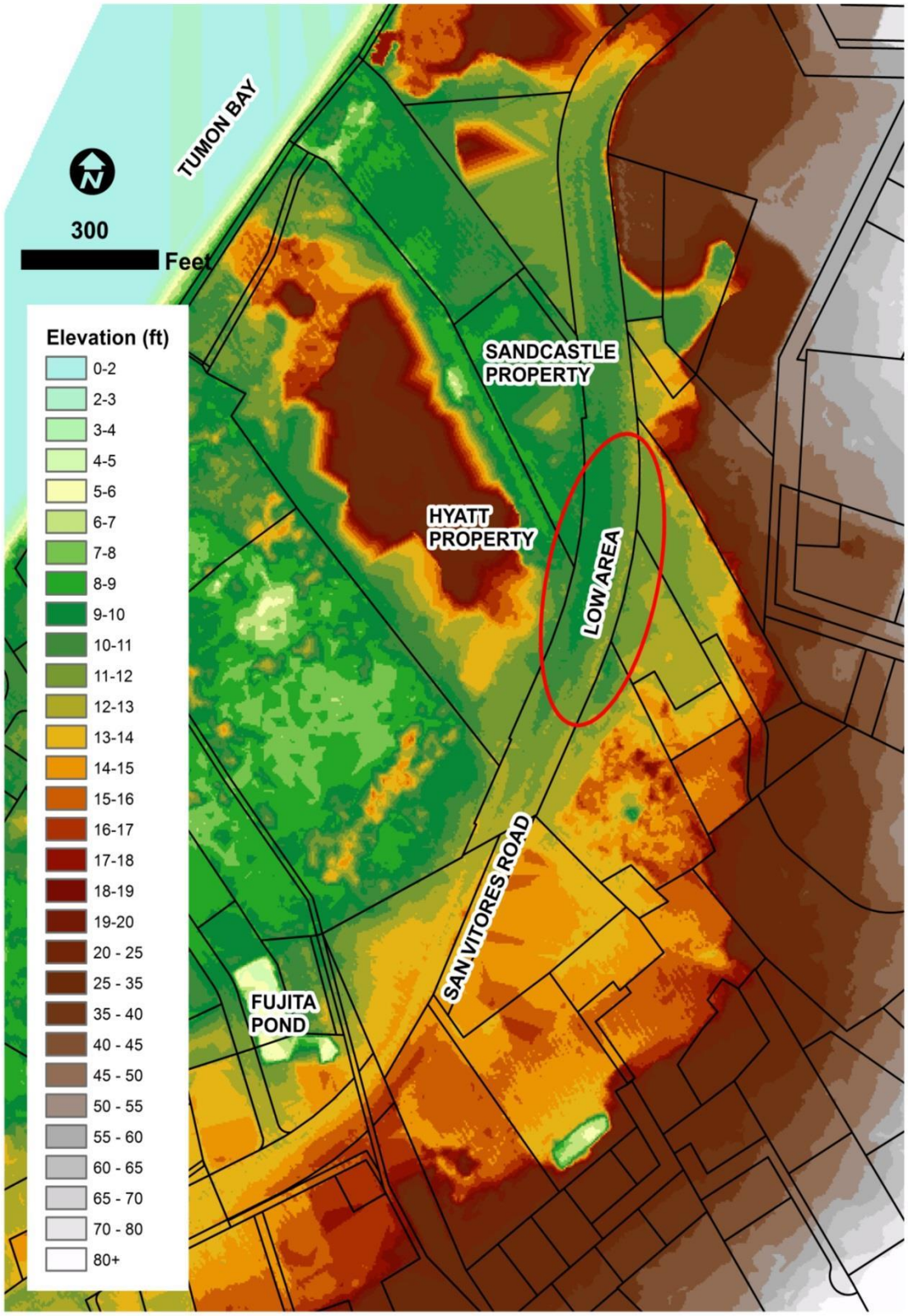
Out of the forty-five inlets inspected along SVR, only one was found to have significant clogging and debris. The grate inlet adjacent to the The Plaza shopping center and across the street from the DFS was fully clogged. Figure 3-4 shows a photo of the inlet.

Photograph of Clogged Inlet by The Plaza
Figure 3-4

From discussions with project stakeholders it was determined that the Maeda Pacific cleaning was likely the first cleaning operation since the box culverts were constructed over 10 years ago. The following is recommended for more frequent inspection/maintenance of the Fujita Pond storm sewer:

- Inspect several manholes along trunk line, especially at upstream end of triple box culverts near Sandcastle property:
  - Prior to rainy season
  - Following rainy season
  - Following very heavy rainfall events (>8" in 24 hours)
- If silt/sand deposits increase to depths over 6", a system cleaning should be scheduled.
- Periodic inspection will help establish the optimum cleaning frequency. Many municipalities schedule cleaning a minimum of once every 5 years.

Areas of Concern. From discussions with project stakeholders and observations during the 19-Sept and 10-Oct flooding, the most severe area of flooding is near the Sandcastle and Hyatt properties. This is also the lowst area of the project, which is shown on Figure 3-5.



Elevation Map
Figure 3-5

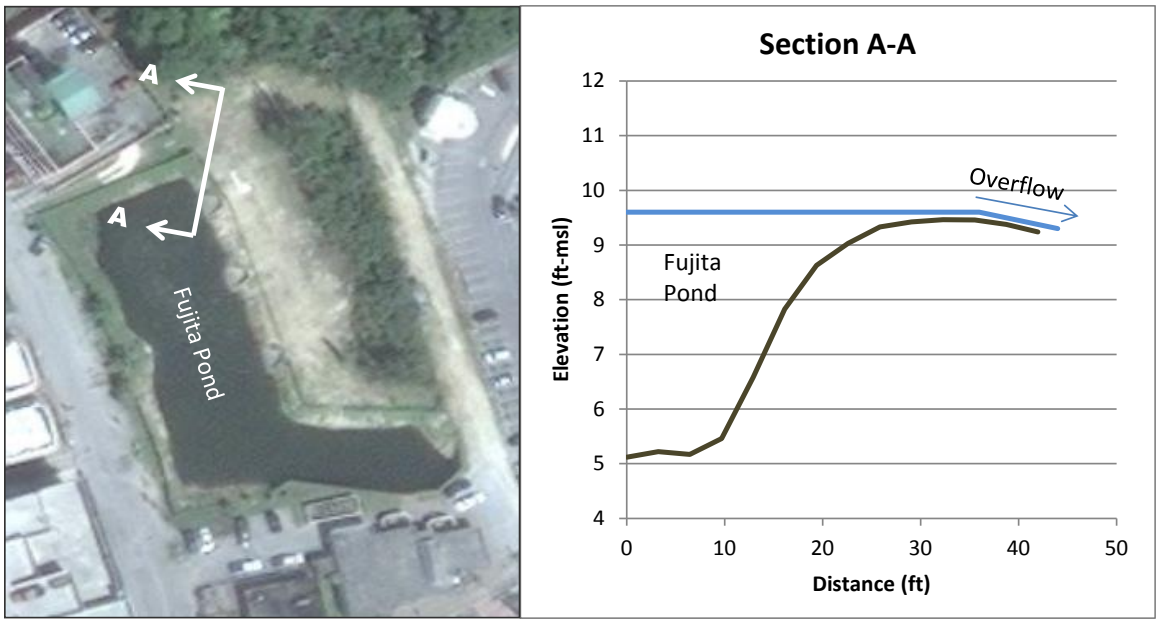
The Figure 3-5 Elevation Map was developed using Light Detection and Ranging (LiDAR) derived topography obtained from the NOAA. The LiDAR topography is provided under *3-GIS-Data* of the project DMS. The elevation datum was adjusted to the project vertical datum and checked against the project survey obtained by Balagtas Surveryors. Ground elevation shots between the two sources corresponded well.

The LiDAR and survey topography indicates the elevation of this low area to be roughly 9 feet. There is no overflow due to the higher elevations of the surrounding properties. The only outlet is through the triple box culvert trunk line.

During dry conditions roughly 1-2 feet of water sits in the bottom of the triple box culverts. This water level reflects the water level within Fujita Pond. During rainfall events, as Fujita Pond fills up and the water level rises within the pond, so does the water level in the box culverts. As shown in Figure 3-6, the 19-Sept rainfall event was significant enough that Fujita Pond overflowed its northeast corner.

September 19 Overflow of Fujita Pond
Figure 3-6

A check of the LiDAR topographic data for the project area indicates that the Fujita Pond overflow is at roughly elevation 9.5 feet. As shown in Figure 3-7, this means that the pond elevation was likely approaching 10 feet during the 19-Sept and 10-Oct overflow.



Plan and Section of Fujita Pond
Figure 3-7

A water elevation of 10 feet in Fujita Pond means that the water elevation in the upstream box culverts was also at least 10 feet. As shown in Figure 3-6, the low area on SVR near the Hyatt and Sandcastle properties is at roughly elevation 9 feet, which is 1 foot below the estimated water elevation in Fujita Pond. The result is standing water in this low area that will only go down when the water level within Fujita Pond goes down. Figure 3-8 and 3-9 show photos of the 19-Sept flooding in this area.

19-Sept Flooding on SVR and Sandcastle Property
Figure 3-8

19-Sept Manhole in front of Sandcastle Property
Figure 3-9

The lowest elevation area on SVR is near the south entrance to the Sandcastle property. As shown on Figure 3-8, this is where ponding is deepest on the roadway and where ponded water overtops the curb and driveway and enters the Sandcastle property. There are three combination curb/grate inlets at this location so stormwater can be captured here but if water levels within Fujita Pond are near or above the road elevation, the water has nowhere to go. Further north along the property, the ground and road elevation is slightly higher so was not flooded, but as shown in Figure 3-9, inspection of one of the box culvert manholes shows that the water elevation was near the top of the structure.

One of the main objectives of the improvement alternatives is to maintain the water level within Fujita Pond during the design rainfall event at a low enough elevation to contain stormwater within the SVR right-of-way and at the same time minimize flooding of the roadway travel lanes.

Another area of focus will be a more effective capture of stormwater runoff. The field inspection located forty-five inlets along SVR in the project area. However, given the intensity of rainfall, more inlets may be needed at key locations such as intersections, cross-slope transition sections, and flatter areas to reduce ponding into the roadway travel lanes.

Areas of Missing or Inaccurate Data

No major gaps were found in project data needed to perform the analysis and develop improvement alternatives. Several key pieces of data were obtained during and following the Engineering Site Visit that allowed subsequent tasks to proceed.

- Field located and measured drainage structures and conduits along SVR (i.e. storm sewer system).
- Construction drawings for SVR storm sewer system.
- Limits of tributary areas and storm sewer system draining to Fujita Pond.
- Project topographic survey of key structures and elevations.
- Rain gage and Fujita Pond level gage data.

The technical basis for analyzing the storm sewer system and developing improvement alternatives is the XP-SWMM model of the storm sewer system. The more representative the XP-SWMM model is of the actual condition, the more effectively the model can be used to identify issue locations and propose solutions. The field inspection yielded inlet locations, type, pipe sizes, and structure elevations. These were then compared to the construction drawings and topographic survey of the storm sewer system to verify the field inspection, fill in any missing information, and solve discrepancies between the drawings and the field inspection.

The SVR storm sewer system drawings are construction drawings and not as-built drawings so were not adjusted to reflect what was actually constructed (i.e. post-project). Most discrepancies between the field inspection and construction drawings are minor but several

items were verified by project survey. Copies of reference drawings obtained for the project are in *1-Drawings* of the project DMS

Additional BMP Installation

BMP's are structural or non-structural methods meant to reduce the movement of sediment and pollutants into surface water systems. Evidence of areas in need of BMP's would include:

- Bare or eroded ground subject to concentrated stormwater runoff
- Areas of significant sediment deposition
- Areas of ponded water due to clogged drainage structures
- Storm sewer inlets or structures in close proximity to pollutant sources

During the field inspection, Stanley Consultants representatives spent several days inspecting and observing the drainage conditions in the SVR project area. Stormwater quality is a major concern due to SVR's proximity to Tumon Bay which is a marine preserve and an attraction for residents and visitors.

The Stormwater Drainage Manual provides four categories of BMP's which were evaluated for the existing project area.

Design Pollution Prevention BMP's. Due to site development requirements that have been in place for several decades, many of the developed areas have offline drainage systems that are effective existing measures protecting water quality. In addition to providing inspection and maintenance of the SVR storm sewer system DPW should communicate with property developers and managers on effective maintenance of offline storm sewer systems. Checking in on the private offline systems will encourage property managers to maintain their storm sewer and infiltration systems which will reduce the opportunity for those systems to overflow and bring additional flow and pollutants into the SVR system.

Runoff Treatment BMP's. Fujita Pond is an infiltration system and does not outlet directly into Tumon Bay. The existing pond is undersized and periodically overtopped but does provide effective treatment of tributary runoff through settling and infiltration of stormwater.

The project area was reviewed for potential installation of additional runoff treatment measures. No GovGuam properties were located in the SVR project area. Given the high real estate value in the area, all properties adjacent to SVR are privately owned or fully developed (i.e. Fujita Pond/Pump Staion/Police Station). Likewise the SVR right of way does not have sufficient width for the installation of more linear water quality oriented BMP's such as infiltration swales, filter dams, etc.

Construction Site BMP's. Detailed design of improvements to the SVR storm sewer system will include development of a SWPPP. In addition to erosion control drawings and permit documentation, SWPPP's provide site and project specific measures for the construction contractor to follow during various stages of project construction. Typical measures include temporary and permanent seeding requirements, soil stockpile guidance, silt fence and silt curtain installation procedures, inlet protection staging, dust control and street cleaning requirements, and inspection forms and schedule.

Maintenance BMP's. One of the most effective BMP's for storm sewer systems is maintenance. As shown in the photos from Maeda Pacific, a significant amount of debris and sediment had accumulated in the SVR storm sewer inlets and trunk line prior to the cleaning operation. Fujita pond is another location where debris and sediment collect which could reduce the infiltration rate of the pond and contribute to more frequent flooding. As mentioned in the drainage system condition assessment, periodic inspection, maintenance, and removal of sediments and debris should be a part of any BMP program.

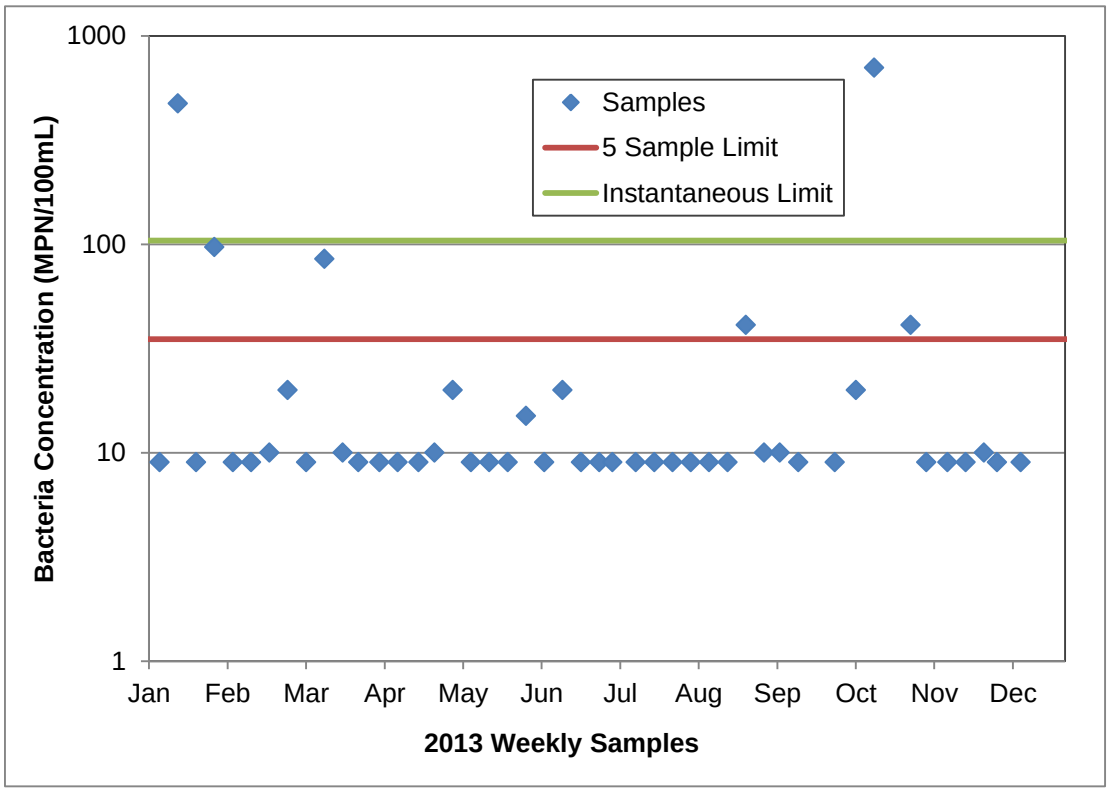
Tumon Bay Water Quality

The Guam Stormwater Management Manual designates Tumon Bay as a "moderate quality" marine water for stormwater discharge purposes. The major pollutant of concern for Tumon Bay is bacteria which poses a risk to human recreational activities and aquatic life. A draft Total Maximum Daily Load (TMDL) report was developed for Tumon Bay in 1999 for GEPA [10]. A copy of the report is provided under *5-Regulatory* of the project DMS.

The TMDL report indicates the following bacteria standard for Tumon Bay:

- 5 Sample Mean < 35 MPN/100mL: Concentrations of enterococci bacteria shall not exceed 35 enterococci/100 mL based upon the geometric mean of five (5) sequential samples taken over a period of thirty (30) days.
- Instantaneous Reading < 104 MPN/100mL: No instantaneous reading of enterococci bacteria concentration shall exceed 104 enterococci/100 mL.

GEPA conducts a recreational beach monitoring program which includes weekly sampling of bacteria levels at several stations along Tumon Bay. Sampling data from 2006 to the present was obtained from GEPA for the Tumon Bay stations. A copy of the data provided by GEPA is under *6-Data* of the project DMS. The nearest station to the project area is where Fujita Road ends at the beach. Figure 3-10 shows a figure with weekly readings at the Fujita Beach station for 2013.



GEPA 2013 Water Quality Readings at Fujita Road Station
Figure 3-10

Figure 3-10 shows that during 2013 Tumon Bay water quality near Fujita Road significantly exceeded the instantaneous limit of 104 MPN/100mL for two samples and approached the instantaneous limit for two samples. The five sample mean of 35 MPN/100mL was not exceeded, meaning the high bacteria counts were short term incidents. The highest bacteria count was 703 MPN/100mL on October 10, 2013, coinciding with the 10-Oct rain event. The bacteria count following the 19-Sept rain event was 9 MPN/100mL, which is the normal low reading. Additional analysis of water quality data is provided in Section 4.

During the 19-Sept flooding, the beach segment closest to Fujita Pond was inspected to see if the overflow was reaching Tumon Bay, but no evidence of direct flow into the bay was found. The overflow was likely collecting and infiltrating on the privately owned, undeveloped property separating the pond from the beach. The current overflow condition is not sustainable over the long term because at some point in time the undeveloped property between Fujita Pond and the beach will likely be developed.

In terms of pollutant protection, the biggest advantage of the Fujita Pond system is that it is essentially a closed system. Most pollutants that make their way into the stormwater system are settled out in Fujita Pond. Fujita Pond is in infiltration basin which is a very effective BMP for filtering storm water. The adjacent storm sewer system that drains to the underground chamber at Matapang Park is also an infiltration system. The effectiveness of these systems was analyzed by the 2003 WERI study of Tumon Bay [11] which concluded through a series of water quality samples of Tumon Bay following

rainfall events that the "quality of stormwater collected was generally high by world standards."

The GEPA weekly water quality samples show that the Fujita segment of Tumon Bay exceeded the applicable water quality standards twice in 2013. The TMDL report for Tumon Bay identifies several potential sources including high rainfall/runoff events, high winds (mobilizes sediments and elevates bacteria levels), and sanitary sewer blockages/overflows.

A specific area of concern for Fujita Pond water quality is the pond's proximity to the GWA Fujita sanitary sewer pump station. Historically, Fujita Pond has been contaminated by the pump station when the pump station broke down and sewage spilled into the pond. With recent replacement of the pumps and a backup generator, the risk for contamination has been significantly reduced. This is supported by the limited number of elevated bacteria counts at the Fujita water quality station in recent years.

Periodic elevated bacteria levels are fairly common for modern developed coastal areas. So the 2003 WERI assessment of Tumon Bay water quality is valid. However, the objective of the TMDL being established by GEPA for Tumon Bay is to maintain bacteria counts within the instantaneous and five sample mean limits. Ongoing improvements to storm drainage systems, sanitary sewer systems, building and development codes, public education, construction and landscaping practices and other contributing factors will be necessary to eventually meet the TMDL limits.

Any improvement alternatives that include discharge of stormwater from Fujita Pond will need to include treatment and protection systems to meet applicable water quality standards.

Coordination with Local Agencies and Stakeholders

Several meetings were held with agencies, stakeholders, project team members, and others. A list of the meetings and information and/or items obtained is provided by the following:

- DPW: Provided project history and insight on management of storm sewer system. Indicated DPW does not want XP-SWMM license as indicated in original project scope. Conducted site walk with field inspection team and provided perspective on recent cleaning operation.
- GWA: Provided construction and as-built drawings of 2000 SVR reconstruction project. Discussed operation of Fujita sanitary sewer pump station and improvements that have minimized sewage spills to Fujita Pond.
- GEPA: Discussed potential issues requiring GEPA approval or involvement and provided progress on MS4 designation. Provided beach water quality sampling data. Discussed water quality concerns and permitting requirements associated with any beach or ocean outfall.
- Coastal Management: Discussed potential project issues requiring Coastal Management approval or involvement.

- State Historical Preservation Office (SHPO): Discussed potential issues that could impact project including the Tumon Historic District which is known to contain an extremely large number of prehistoric sites. Excavation within the portion of land underneath SVR and towards the ocean could cause delays in construction if evidence of prehistoric objects is found.
- Maeda Construction: Discussed cleaning operation project and general condition of storm sewer system before and after. Maeda provided photo documentation of the cleaning operation.
- WERI: Discussed 2003 study of Tumon Bay and general assumptions and parameters used. Obtained contact information for rainfall and infiltration experts. Obtained copies of the 2003 Tumon Bay study and the 2004 Dye Trace study of Harmon Sink.
- Adjacent Landowners: Met with owners/managers of Sandcastle, Hyatt, DFS and other nearby properties. Obtained their perspective on the project and experience with flooding issues.

Additional Field Tasks

In addition to the Engineering Site Visit, three additional field tasks were defined in the original project scope of work. These tasks were:

- Field survey – To determine key elevations and fill in any missing storm sewer information.
- Remote Operated Vehicle (ROV) Camera Inspection – To inspect any sections of storm sewer in poor condition and verify unknown connections or outfalls.
- Rain Gages and flow meters – To log onsite rainfall data and flow data to help establish relationship between rainfall depth and stormwater runoff volume and assist in XP-SWMM model correlation.

Following the Engineer Site Visit the original scope for these tasks was adjusted according to findings and missing information.

Field Survey. The field survey was completed by Balagtas Surveyors who have surveyed several SVR developments in the project area. The survey included:

- Verifying key drainage elevations
  - Box culvert flowline
  - Manhole rim elevations
  - Fujita Pond
    - Top of headwall elevation
    - Annex infiltration chamber inflow elevation
    - Pond overflow elevation

- Providing topographic survey of SVR
  - Roadway cross-sections extending to the right of way from Outrigger to Fujita Pond.

A copy of the AutoCAD survey file and the survey exhibits are provided in *6-Data* of the project DMS.

ROV Camera Inspection. Prior to the Engineer Site Visit, the amount of information available on the SVR storm sewer system was unknown. DPW indicated that SVR drawings had been lost in typhoon related flooding and the extent of the Fujita Pond storm sewer and number of outfalls was unknown. The ROV inspection by CorrTech would have provided an extra measure for verifying outfall locations and storm sewer connections not available by inspecting the system via manholes and inlets from above. During the Engineer Site Visit construction drawings were obtained and the field verification was completed which resolved unknowns on the storm sewer condition, connections and outfall locations. It was determined the ROV Camera Inspection was no longer needed and would not add significant value to the project so it was eliminated from the project scope.

Rain Gages and Flow Meters. Stanley Consultants met with EA several times during the Engineer Site Visit to discuss project objectives and scout gage/meter installation locations. EA installed two rain gages on September 11, 2013, one at the DFS Shopping Center and the other at Fujita Pond. Gages will remain in place for roughly 6 months and collect hourly readings of rainfall depths.

During the Engineer Site Visit it was established that Fujita Pond is the single outlet for the SVR storm sewer in the project area. After subsequent discussion on what data would be most beneficial to the project, it was determined that a level logger installed at Fujita Pond would provide more useful data than flow meters. Because the pond has no outlet, the level logger can provide a more accurate record of flow entering the pond and also estimate the infiltration rate of the pond by recording how quickly the pond level drops, which will be another key piece of data. EA installed the level logger on September 24 on the headwall at the southeast end of the pond. The level logger will also remain in place for roughly 6 months and collect hourly readings of the pond level.

Summary of Findings

The system inspection and assessment of the existing SVR storm sewer system established the following:

- The project area (north of Fujita Pond) is drained by a single storm sewer system with a triple box culvert trunk line running under SVR that outlets into Fujita Pond. Fujita Pond is an infiltration basin with no defined outlet structure.
- Many of the developed properties along San Vitores Road have offline storm sewer systems that do not connect to the San Vitores Road storm sewer but collect and infiltrate stormwater runoff on their own property.

- Generally, the storm sewer was found to be in very good condition but from review of Maeda Pacific cleaning photos should be inspected and cleaned more frequently.
- In terms of pollutant protection, the biggest advantage of the Fujita Pond system and the offline storm sewer systems is that they are essentially closed systems. Infiltration is a very effective BMP for filtering stormwater runoff.
- Tumon Bay water quality data indicates that there are infrequent elevated bacteria events which pose a risk to human recreational activities and aquatic life. These events cannot be attributed to a single source. Generally the water quality of Tumon Bay is good, but needs continued improvement to meet applicable water quality standards.
- The significant rains that occurred during September 19-21 and October 10, 2013 caused extended ponding at the low spot in SVR near the Sandcastle and Hyatt Properties. The rains also caused overtopping of Fujita Pond. A review of project area elevations established that the overtopping elevation of Fujita Pond is approximately 1 foot higher than the low spot on SVR so ponding in this area was controlled by the water level in Fujita Pond.

Section 4

Flood Modeling

Introduction

Section 4 summarizes the flood modeling completed for the project which involved:

- Defining SVR flooding.
- Analyzing short duration SVR flooding
- Analysis long duration SVRflooding
- Development, calibration, and analysis of an XP-SWMM drainage model of the tributary area, design/recorded rainfalls and existing storm sewer system.
- Reviewing the relationship between flood magnitude rainfall and Tumon Bay water quality issues.

Findings from the flood modeling were then applied to development of improvement alternatives.

Definition of SVR Flooding

Flooding for this project is defined by ponding due to stormwater runoff extending more than half a traffic lane on SVR. There are two issues causing SVR flooding:

- Short duration SVR flooding during high intensity rainfall events: This flooding is caused by curb inlets lacking sufficient capacity to fully capture high intensity storm events.
- Long Duration SVR flooding following extended rainfall events: This flooding is caused by Fujita Pond not having sufficient volume to handle the series of design storms without overtopping and causing extended ponding in the low areas of SVR.

Short Duration SVR Flooding

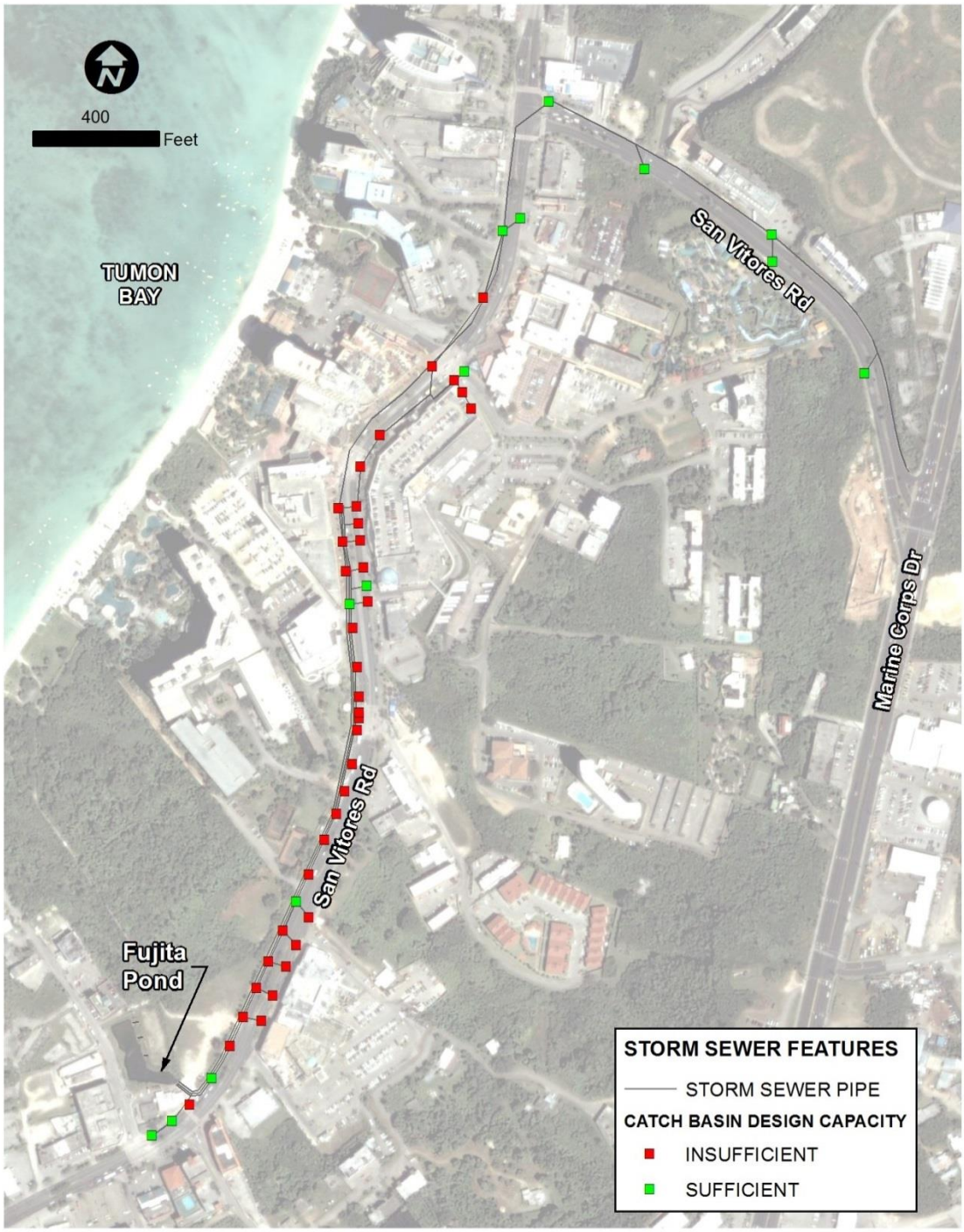
During short duration, high intensity rainfall events, stormwater ponds in the gutters along SVR and extends out into travel lanes. Short duration street flooding is caused by curb inlets lacking sufficient capacity to capture the gutter flow and convey it into the SVR storm sewer. As it travels down SVR, gutter flow bypasses curb inlets and the ponded width increases as stormwater flows down SVR.

The capacity of storm sewer inlets along SVR was analyzed to identify locations where inlets have insufficient hydraulic capacity. The location and size of SVR storm sewer inlets was established by field survey during the Engineer Site Visit. The inlets were analyzed to determine how effectively they captured tributary stormwater runoff.

The existing storm sewer collection system along SVR from where it intersects with Marine Corps Drive down to approximately the Outrigger Hotel consists of combination grate and curbs inlets along the curb line of the road that drain to two separate storm sewer pipe lines. Both storm sewer pipe systems then connect into the SVR box culverts between the Outrigger Hotel and Sandcastle property. Curb inlets along the SVR box culverts drain directly into the box culverts.

The existing system was analyzed using the Stormwater Drainage Manual based on the existing inlet contributing areas (street and upland properties) and using the rational method to compute peak design flows. The peak runoff flows were determined for the 10- Year, 1 hour design storm and also reviewed for the 25-Year, 50-Year, and 100-Year, 1 hour storms. The captured flows for each inlet were calculated along with the corresponding bypass flow at each inlet (i.e. flow not captured). The bypass flow was then added to the next downstream inlet. A ponded width was computed for the peak flow (includes tributary area and bypass flow) coming to each inlet.

As mentioned in Section 2, the allowable ponded width indicated in the Stormwater Drainage Manual is approximately two feet off the gutter line. For the limited shoulder width of SVR this would be very difficult to achieve even with a new roadway installation considering the size of the offsite drainage area. A common criterion for 4-lane roadways is to allow ponding of a single lane adjacent to the curb, allowing traffic to pass through the two middle lanes during flood events. In this analysis inlets were identified as insufficient if the ponded width for the 10-year storm extended out more than one lane, which is approximately 12 feet. Figure 4-1 provides a map of insufficient inlets identified by the analysis.



Insufficient Inlets
Figure 4-1

As Figure 4-1 shows, many inlets along SVR are undersized for the 10-year design storm. Insufficient inlet capacity can be attributed to short-term flooding of travel lanes, but not the several hours of ponding conditions experienced during the 19-Sept and 10-Oct events. All bypass flow ends up in the low area of SVR. The low area of SVR includes seven inlets located

along the west curb line of SVR between the Hyatt driveway and the middle driveway of the Sandcastle property. Each inlet has capacity to capture approximately 10 cfs, so roughly 70 cfs total within the low area. These inlets do not have sufficient capacity to immediately capture all tributary and bypass flow but could drain this area in a matter of minutes (not hours). The prolonged SVR flooding is due to the high water level within Fujita Pond, which does not allow the existing inlets within the low area to drain.

Long Duration SVR Flooding

Fujita Pond is the key parameter for defining long duration flooding on SVR in the project area. Roughly 180 acres flows into the SVR storm sewer system north of Fujita Pond. This entire storm sewer system then drains into Fujita Pond. When water levels reach the top of Fujita Pond, stormwater backs up into the trunkline box culverts and low areas upstream. Meaning, Fujita Pond sets the water elevation upstream and determines the magnitude and duration of flooding is in the project area.

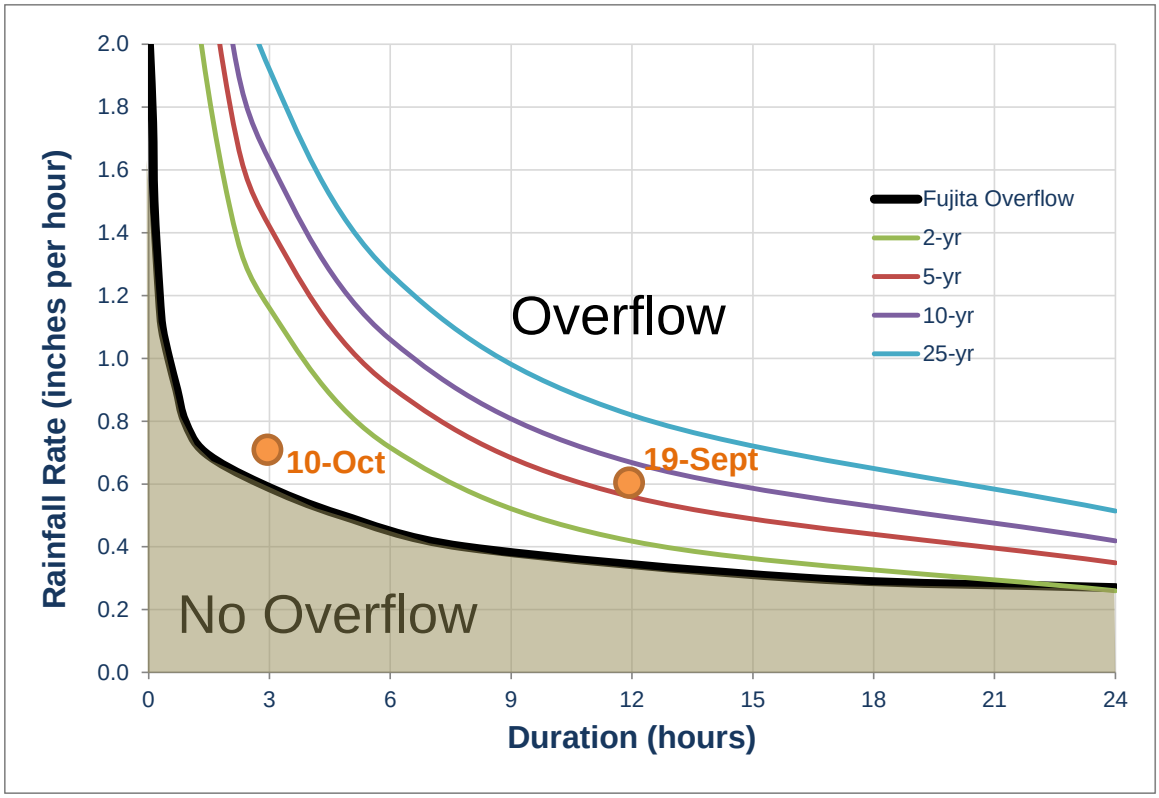
The 10-Oct event is generally considered to be the threshold for when SVR flooding will occur. On the morning of October 10, approximately 3 inches of rain fell between midnight and 9 am, with over 2 inches falling between 6 am to 9 am. The series of photos from 10-Oct shown in Figure 4-2 illustrate how the water level in Fujita Pond impacts flooding in the SVR area.

10-Oct Photos
Figure 4-2

As shown in Figure 4-2, the 10-Oct rainfall was sufficient to completely fill and overtop Fujita Pond, the upstream result was several inches of standing water in the low area of SVR near Sandcastle. By afternoon, as the water level in the pond decreased, so did the standing water in the upstream low area of SVR.

The relationship between rainfall and Fujita Pond overflow was examined by comparing the rainfall runoff rate to the storage capacity and infiltration rate of Fujita Pond. When the tributary rainfall runoff rate (i.e. rainfall that is not infiltrated by natural ground or offline drainage systems) exceeds the infiltration rate of Fujita Pond, Fujita Pond begins to fill up.

If the rainfall continues, Fujita Pond will fill up and overtop as it did on 10-Oct. The heavy portion of the 10-Oct rainfall extended over three hours (~0.7in/hr for 3 hours) and then stopped which caused the pond to overtop for a brief period of time. When the rainfall stopped, infiltration continued and as shown on Figure 4-2 by the afternoon Fujita Pond had gone down by several feet. Rainfall on 19-Sept extended over a longer duration, roughly 0.6 in/hr over 12 hours. The degree and duration of flooding for the 19-Sept event was more extensive than the 10-Oct event. This relationship is expressed graphically on Figure 4-3, which shows the approximate threshold of the rainfall intensity (in/hr) and duration (hours) which causes overtopping of Fujita Pond and extended flooding of the low areas of SVR.



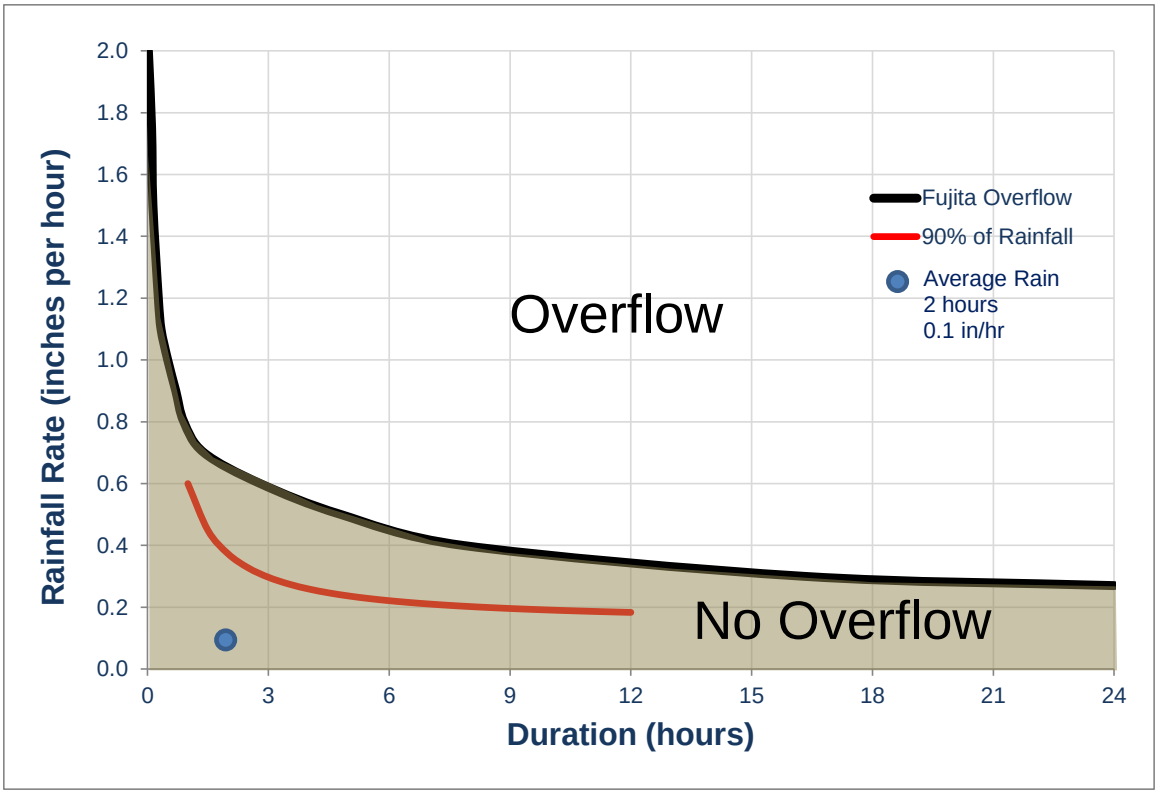
Definition of Rainfall Causing Fujita Pond Overflow
Figure 4-3

Figure 4-3 illustrates how the rainfall rate (aka intensity) and duration contribute to flooding. The shaded "No Overflow" area includes rainfall events that would likely not cause SVR flooding. For instance, a rainfall of less than 0.25 inches per hour could continue in perpetuity without causing flooding. However, a rainfall of 0.5 inches per hour would likely cause flooding if it occurred for more than 4 hours.

Figure 4-3 includes points defining the rainfall rates that occurred during the 19-Sept and 10-Oct events. The further away the point is from the Fujita Overflow line, the greater the flooding. As discussed previously, the 19-Sept event was a more extreme rainfall event so is further from the Fujita Overflow line. Lines representing design rainfall rates are also shown. All design rainfalls analyzed are above the Fujita Overflow line so would be expected to cause SVR flooding.

Design rainfalls represent extreme, lower probability events. A 10-year design rainfall has a 10 percent chance of being exceeded in a given year. Statistically this implies that in 9 out of 10 years, all rainfall events would be expected to be less severe (lower intensity and accumulation) than the 10-year design rainfall. In reality, it does not usually work that way and Guam could experience 10-year design magnitude rainfalls two years in a row or at less or more frequent intervals depending on if the region is in a wet or dry cycle. However, over a longer long time frame such as 100 years, where wet and dry cycles balance out, 10 percent of those years (i.e. 10 years) would likely have rainfalls exceeding the 10-year design rainfall.

In their 1997 Technical Report, *Sizing of Surface Water Runoff Detention Ponds* [12], WERI completed an analysis of rainfall gage data that characterized typical rainfall events on Guam. The study determined that the average rainfall event duration for Guam is approximately 2 hours and the average rainfall event depth for Guam is approximately 0.2 inches. The study also examined the relationships between storm duration, time between storms, and rainfall depth. The results of the study indicated that approximately 90 percent of rainfall events have intensities less than 0.6 in/hour for shorter duration events (i.e. less than 1 hour) and less than 0.2 inches per hour for longer duration events (i.e. roughly 12 hours). Figure 4-4 provides a comparison of the average rainfall event and relationship between 90 percent rainfall intensity and duration to the Fujita Pond Overflow line.



Comparison of Typical Rainfall to Fujita Pond Overflow
Figure 4-4

Figure 4-4 shows that the average Guam rainfall (blue circle) and 90 percent of Guam rainfall (red line) are below the Fujita Pond Overflow line. Meaning, Fujita Pond has sufficient capacity to handle the majority of rainfall events without overtopping and causing extended flooding of SVR and surrounding properties.

Fujita Pond does overtop following significant high intensity and/or long duration rainfall events. To evaluate how often Fujita Pond has overtopped historically the daily rainfall gage records for nearby gages were reviewed and correlated to Fujita Pond Overflow and SVR flooding events. The Guam International Airport gage was used as the primary gage with USGS/WERI gages located at Dededo and Chachao used to fill in gaps or invalid entries. Rainfall gage data is provided in *6-Data* of the project DMS.

The threshold for SVR flooding was determined to be approximately 3.5 inches of daily rainfall. As discussed previously and shown on Figure 4-3, the 10-Oct event was slightly larger than the capacity of Fujita Pond. The 10-Oct rainfall was recorded as 3.8 inches at the Fujita Pond project rain gage and 4.2 inches at the Guam International Airport gage. On October 18, 2013 a daily rainfall of 3.3 inches was recorded at Fujita Pond and 3.7 inches at the Guam International Airport. The Fujita Pond level logger indicated that the October 18 event was slightly below the overtopping/flooding elevation. These observations led to the daily rainfall of 3.5 inches being defined as the threshold for SVR flooding. Table 4-1 displays the number of probable SVR flooding events based on rain gage data using the 3.5 inch daily rainfall threshold for the last 25 years.

Table 4-1 Yearly SVR Flooding

Year	SVR Flood Events
1989	3
1990	4
1991	3
1992	4
1993	0
1994	2
1995	1
1996	3
1997	4
1998	0
1999	1
2000	1
2001	1
2002	4
2003	2
2004	4
2005	1
2006	0
2007	0
2008	0
2009	1
2010	0
2011	2
2012	1
2013	3
Average	**1.8**

Source: Stanley Consultants, Inc.

As shown in Table 4-1, the number of Fujita Pond Overflow and SVR flood events varies from year to year. Some years there was likely no flooding and other years up to four flood events occurred. Over the 25 years analyzed, the average number of flood events is 1.8 per year. These numbers suggest that SVR flooding is not frequent, but on a normal precipitation year does occur on the order of one to two times per year.

XP-SWMM

XP-SWMM is a software platform developed by XP Solutions, Inc. SWMM stands for Storm Water Management Model. It provides dynamic modeling (i.e. varied over time and space) of storm sewer and natural drainage systems. XP-SWMM was created 25 years ago and is now an established industry utilized software for analyzing complex drainage/storm sewer systems. XP-SWMM was chosen for this project for the following reasons:

- Simulates time variability of rainfall, runoff, and system hydraulics. This is an important factor when modeling systems that involve storage of stormwater such as the SVR storm sewer system.
- Simulates both watershed rainfall/runoff characteristics and detailed hydraulic parameters such as inlet capacity, pipe hydraulics, infiltration, channel flow, and storage. Many models perform either watershed or hydraulic modeling, while XP-SWMM combines both functions into a single model.
- Works with ArcGIS software so the storm sewer model network can be geographically referenced and delineated in ArcGIS mapping software and then imported into XP-SWMM. This provides more efficient and accurate storm sewer model development.

Existing Condition Model

An existing condition model of the SVR storm sewer system was developed using XP-SWMM version 2013. The purpose of the existing condition model is to:

- Evaluate the capacity of the existing drainage system.
- Allow calibration of the XP-SWMM model using rainfall/pond level data.
- Provide a starting point for developing proposed improvement alternatives.

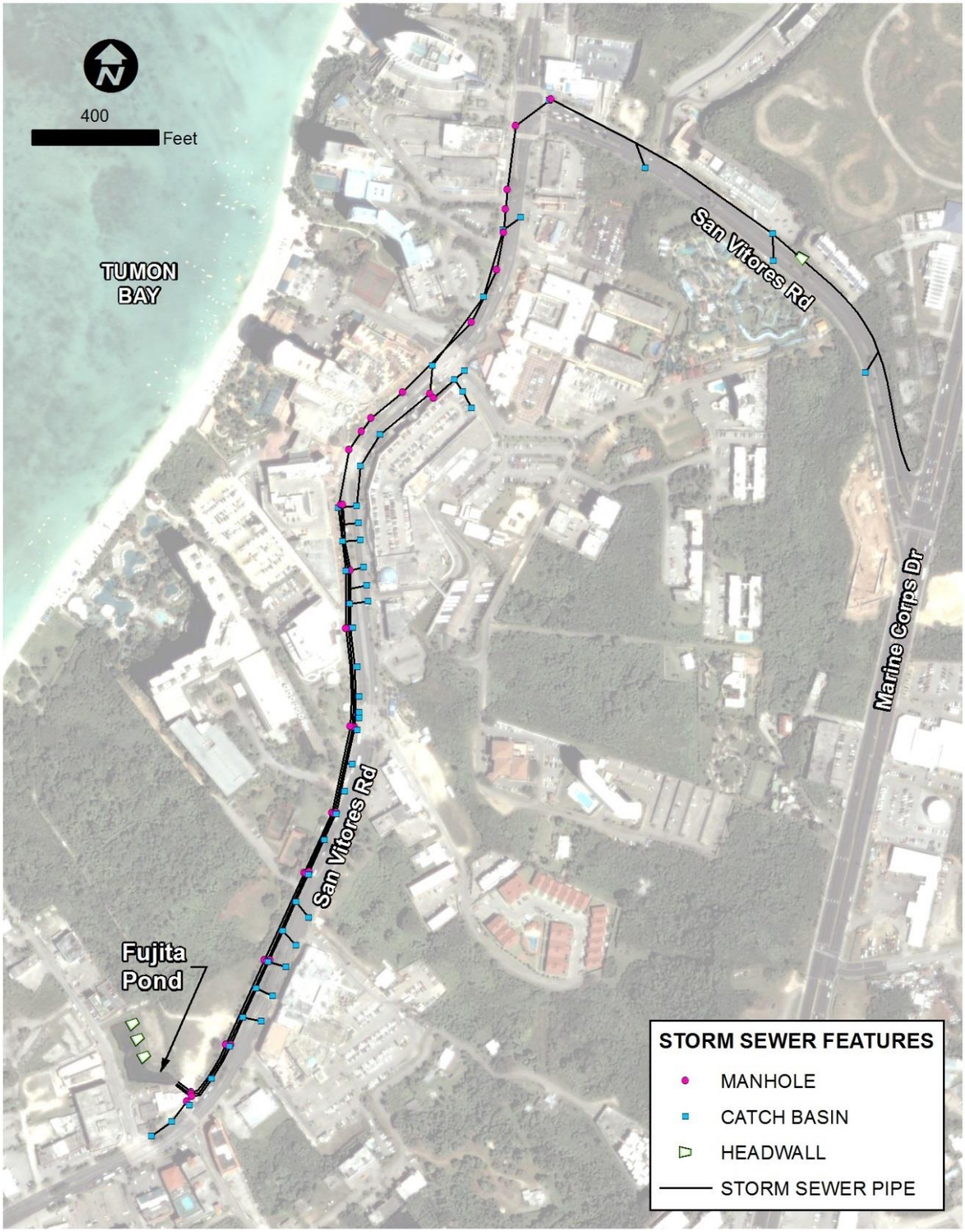
The model includes both rainfall/runoff (hydrologic) and storm sewer (hydraulic) elements and parameters. A summary of the model development is provided in the following subsections.

Storm Sewer Network

The initial step in establishing the SVR storm sewer existing conditions model was to set up an ArcGIS based storm sewer network. The SVR storm sewer network was established using data collected during the Engineer Site Visit (discussed in Sections 1 and 3). The storm sewer network is made up of drainage structures (catch basins, manholes, etc.) and pipe segments.

The location, depth, and size of the drainage structures and pipes were established during the Engineer Site Visit. The sizing and elevation were then reviewed and adjusted using SVR Construction and As-Built Drawings [8]. This information was further refined using project survey data collected by Balagtas Surveyors.

Figure 4-5 displays a map of the SVR storm sewer network.



SVR Storm Sewer Network Map
Figure 4-5

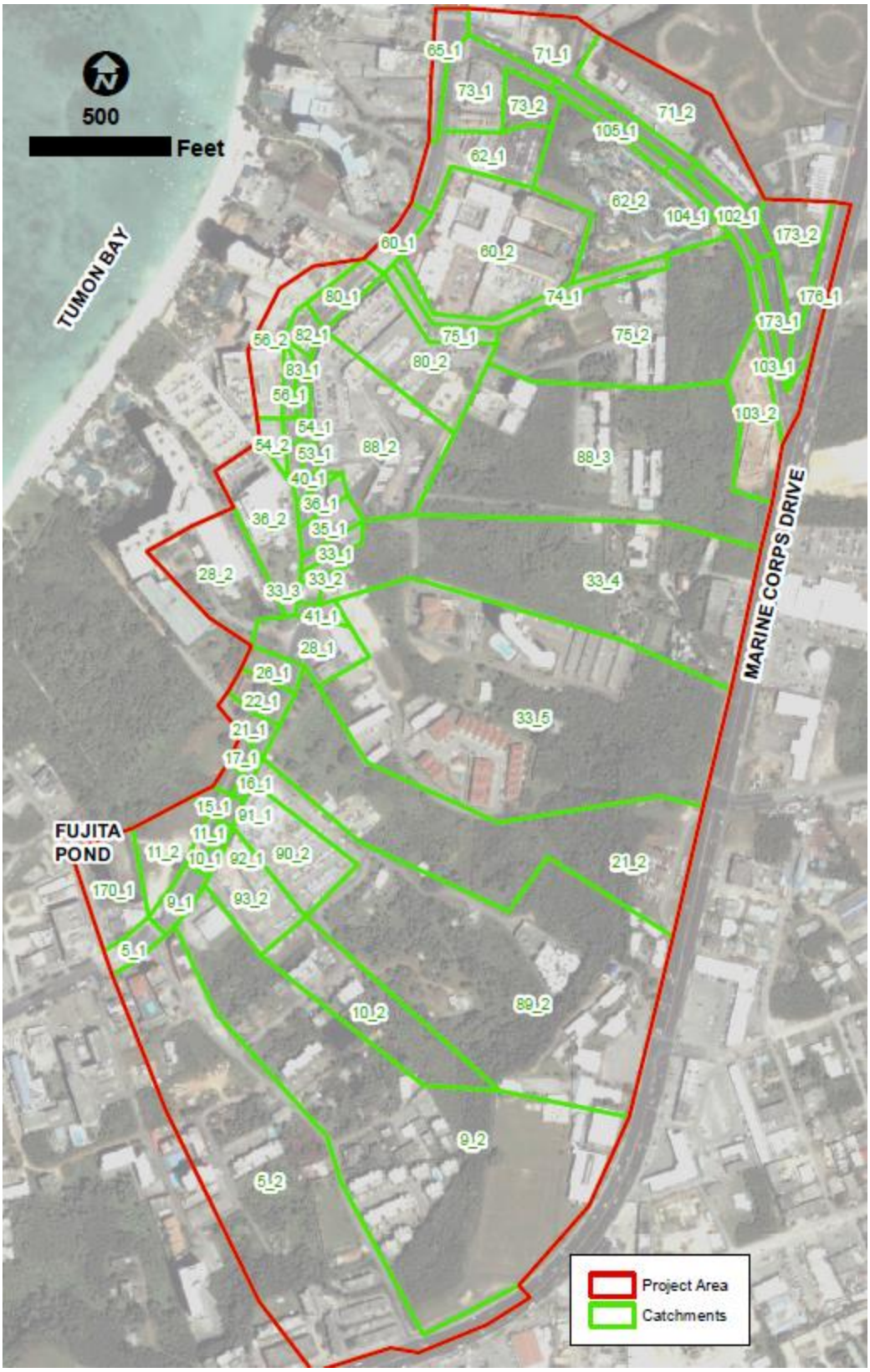
Catchment Areas

The project catchment areas were defined based on the SVR storm sewer inlet locations. Runoff parameters were established using the methods described in Section 2.

SVR drainage inlet locations were assigned an identification number during the Engineer Site Visit. Drainage catchment nomenclature is based on the identification number of the drainage inlet they were tributary to. Catchments within the SVR right-of-way are directly tributary to a single inlet. These catchments all have the identification of XX_1. The larger drainage catchments covering areas outside of the SVR right-of-way were identified by the drainage inlet their outflow was nearest to. These catchments have the identification of XX_2,3,etc.

Some SVR inlets have a large tributary area. However, the XP-SWMM model is able to distribute these flows to multiple adjacent inlets. This is similar to how the stormwater runoff distributes itself in reality, where excess runoff from outer undeveloped or offline areas flows onto SVR via driveways, alleys, or sheetflow and then flows to the nearest SVR inlets following the gutter line.

Figure 4-6 displays the project drainage catchment areas. The runoff parameters are summarized in Table 4-2.



Project Area and Drainage Catchment Map
Figure 4-6

Table 4-2 Drainage Catchment Parameter Table

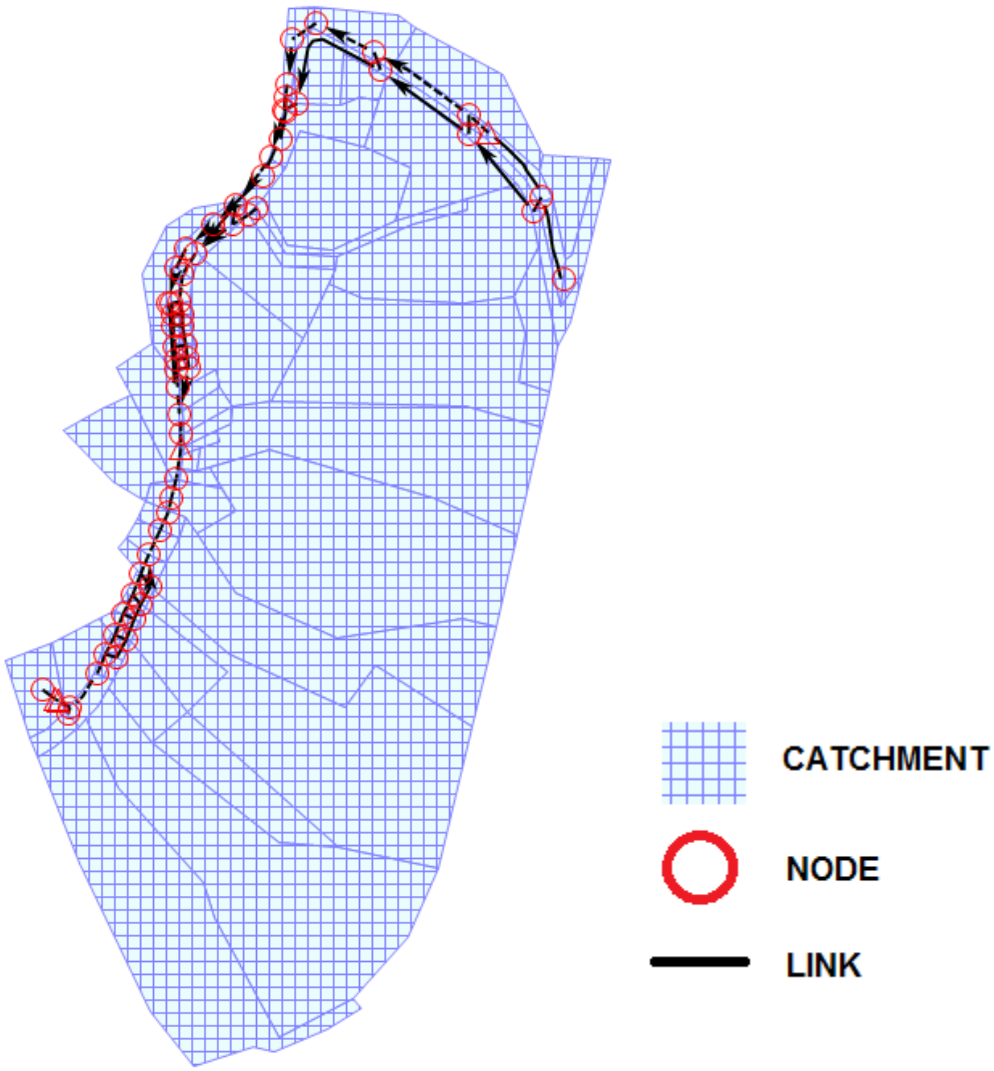
Catch ID	Sub-Catch ID	Curve Number	Time of Conc. (min)	Area (ac)	Offline System?	Ave. Slope (%)
5	1	92	10	0.44	No	1.3
5	2	50	38	15.61	Yes	10.3
9	1	92	10	0.52	No	1.3
9	2	50	42	19.75	Yes	10.8
10	1	92	10	0.13	No	1.2
10	2	50	17	3.51	Yes	13.1
11	1	92	10	0.11	No	1.2
11	2	50	21	1.34	Yes	1.2
15	1	92	10	0.22	No	1.0
16	1	92	10	0.15	No	0.9
17	1	92	10	0.16	No	0.8
21	1	92	10	0.47	No	0.9
21	2	50	28	10.90	Yes	11.1
22	1	92	10	0.58	No	0.9
26	1	92	10	0.45	No	0.9
28	1	92	10	1.41	No	1.1
28	2	50	28	2.73	Yes	1.5
33	1	92	10	0.33	No	10.3
33	2	92	10	0.17	No	3.9
33	3	92	10	0.15	No	1.6
33	4	50	25	12.02	Yes	13.1
33	5	50	24	19.67	Yes	13.3
35	1	92	10	0.53	No	10.5
36	1	92	10	0.38	No	12.2
36	2	50	24	2.27	Yes	1.9
40	1	92	10	0.21	No	6.4
41	1	92	10	0.24	No	1.4
53	1	92	10	0.13	No	2.2
54	1	92	10	0.11	No	2.5
54	2	50	10	0.31	Yes	2.3
55	1	92	10	0.11	No	2.9
56	1	92	10	0.11	No	3.5
56	2	50	10	1.53	Yes	3.2
60	1	92	10	0.52	No	8.7
60	2	50	16	5.70	Yes	8.7
62	1	92	10	1.85	No	13.6
62	2	50	10	4.89	Yes	15.5
65	1	92	10	0.73	No	6.9
71	2	50	10	3.24	Yes	37.5

Catch ID	Sub-Catch ID	Curve Number	Time of Conc. (min)	Area (ac)	Offline System?	Ave. Slope (%)
71	1	84	10	2.33	No	15.9
73	1	92	10	1.71	No	14.7
73	2	50	10	0.73	No	13.1
74	1	92	10	0.97	No	9.8
75	1	92	10	0.62	No	5.6
75	2	50	14	7.59	Yes	17.3
80	1	92	10	0.65	No	7.0
80	2	50	16	3.21	Yes	6.3
82	1	92	10	0.35	No	4.5
83	1	92	10	0.19	No	5.6
84	1	92	10	0.06	No	7.3
85	1	92	10	0.06	No	10.1
86	1	92	10	0.11	No	7.8
87	1	92	10	0.07	No	14.7
88	1	92	10	0.06	No	9.4
88	2	50	28	4.77	Yes	7.6
88	3	50	12	12.25	Yes	12.5
89	1	92	10	0.09	No	1.0
89	2	50	25	17.49	Yes	16.1
90	1	92	10	0.07	No	1.1
90	2	50	26	2.17	Yes	1.6
91	1	92	10	0.11	No	1.1
92	1	92	10	0.10	No	1.3
93	1	92	10	0.11	No	1.2
93	2	50	21	1.76	Yes	1.7
102	1	92	10	0.60	No	22.0
103	1	92	10	0.84	No	9.9
103	2	50	10	1.83	Yes	13.3
104	1	92	10	0.52	No	19.6
105	1	92	10	0.47	No	11.6
170	1	84	10	1.72	No	1.2
173	2	50	10	1.54	Yes	9.9
173	1	92	10	0.60	No	18.7
176	1	92	10	0.97	No	2.7

XP-SWMM Import

Structure and pipe segment identification numbers, size, material, elevation and other relevant data are stored within attribute tables of the ArcGIS SVR storm sewer network. The drainage catchment data is also stored within the attribute table of the ArcGIS delineated shapefiles. Importing the SVR storm sewer network and catchment areas to XP-SWMM

involved setting up the XP-SWMM model to read relevant pipe/structure and catchment attributes. Then the ArcGIS shapefiles were imported to XP-SWMM with much of the SVR storm sewer and catchment areas already defined. Figure 4-7 shows a the XP-SWMM model layout schematic. It essentially matches the storm sewer network and catchments shown on Figures 4-5 and 4-6. Tributary areas are called "Catchments", Drainage structures are represented as "Nodes" and pipes and other conveying features are called "Links". Drainage structures share the same ID's as the GIS storm sewer database and the model is geographically referenced so distances between structures, pipe lengths, and catchment sizes correctly scale to their geographic location and size.

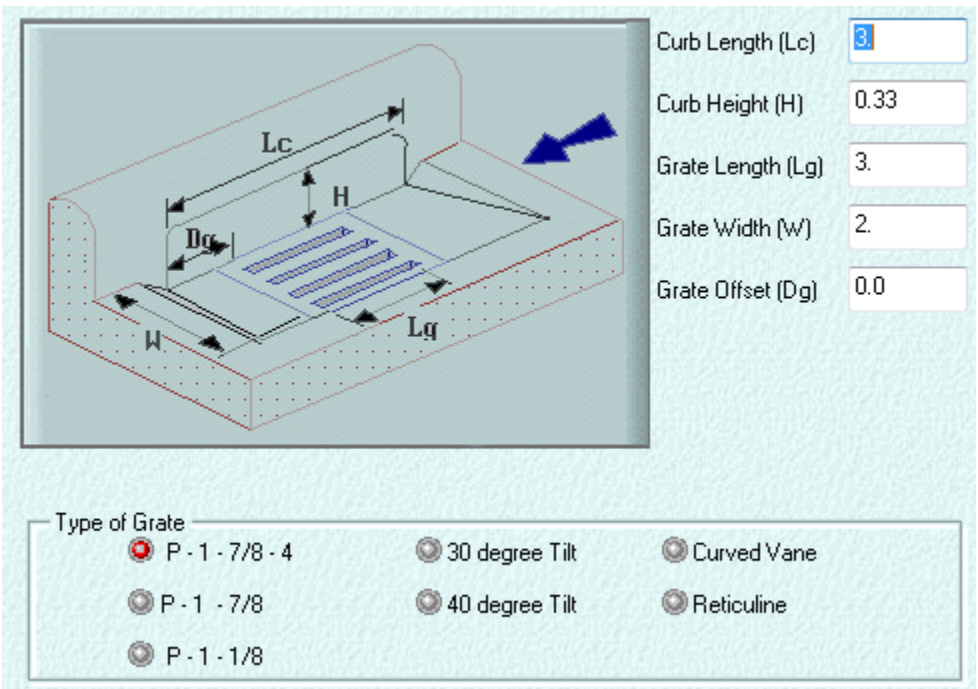


XP-SWMM Model Layout
Figure 4-7

Additional Model Features

The ArcGIS to XP-SWMM import provides the basic layout, sizing, and parameters of catchment, pipe and drainage structure features. Additional features are defined to complete the Existing Condition model.

Inlet Capacity. The capacity of curb inlets and catch basins were defined using the HEC-12 method in XP-SWMM. HEC-12 uses the type and dimensional characteristics of the inlet, along with cross-slope and gutter slope to estimate the flow capture capacity and flow bypass of each inlet. This information was collected during the Engineer Site Visit and entered for each inlet structure. Figure 4-8 shows the required inlet dimensional parameters.



Inlet Dimensional Parameters
Figure 4-8

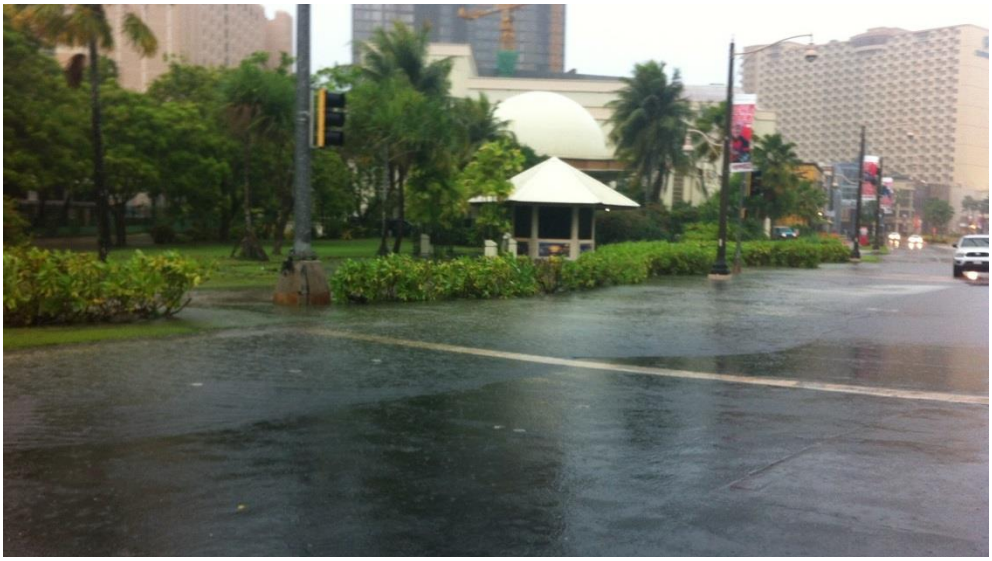
Gutter Flow. Given the size of flood events being modeled inlets were analyzed to determine whether they have sufficient capacity to fully capture their tributary flow. XP-SWMM allows the modeler to define a surface flow conduit (in this case a gutter) that allows excess storm flow to bypass the inlet and flow to the next inlet downstream. Gutter channels were defined for each drainage inlet that was not in a sag (low point) to allow excess flow to be redistributed along SVR to the next downstream inlet.

Pipe Flow. All pipes within the SVR storm sewer network are concrete. North of the Underwater World complex in the steeper segment of SVR, stormwater is conveyed by

concrete storm sewer pipes which then flow into the concrete triple box culvert which conveys flow from north of the Sandcastle Property to Fujita Pond. Friction losses within the concrete conduits were represented by a Manning's number of 0.013. The field inspection verified that the concrete triple box culverts are continuous so minimal expansion and contraction losses were applied. Pipe flow is connects to the gutter flow via inlets along SVR. Gutter flow not captured by inlets, flows down to the low area of SVR near the Sandcastle property. It is this gutter flow which ponds during very intense, short duration rainfall events.

Storage. Incremental stormwater storage volume was defined for Fujita Pond and for roadway surface storage in the low area of SVR near the Sandcastle property. Storage was entered by corresponding depth and area measurements for the two locations which were established using ArcGIS topography and project survey.

The storage area for SVR near the Sandcastle property does not provide significant storage volume but is the key parameter for defining flooding of SVR. The low point of this storage area is defined as the curb inlets on the west side of the road between the two Sandcastle property driveways. This is the lowest point along SVR and is where ponding starts as water levels reach the top of Fujita Pond. Figure 4-9 shows the area during the morning of the September 19, 2013 rain event.



Ponding Area along SVR
Figure 4-9

In the XP-SWMM model, when water gets above a few inches at this location, it indicates that ponded conditions similar to what are shown in Figure 4-9 are occurring. With modeling, this result was used to:

- Calibrate the XP-SWMM model by checking that the XP-SWMM model adequately represented the 19-Sept and 10-Oct flooding.

- Determine initial effectiveness of proposed improvement alternatives. Minimal ponded depths in the XP-SWMM results indicated that the proposed improvement alternative was effective for the given flood event.

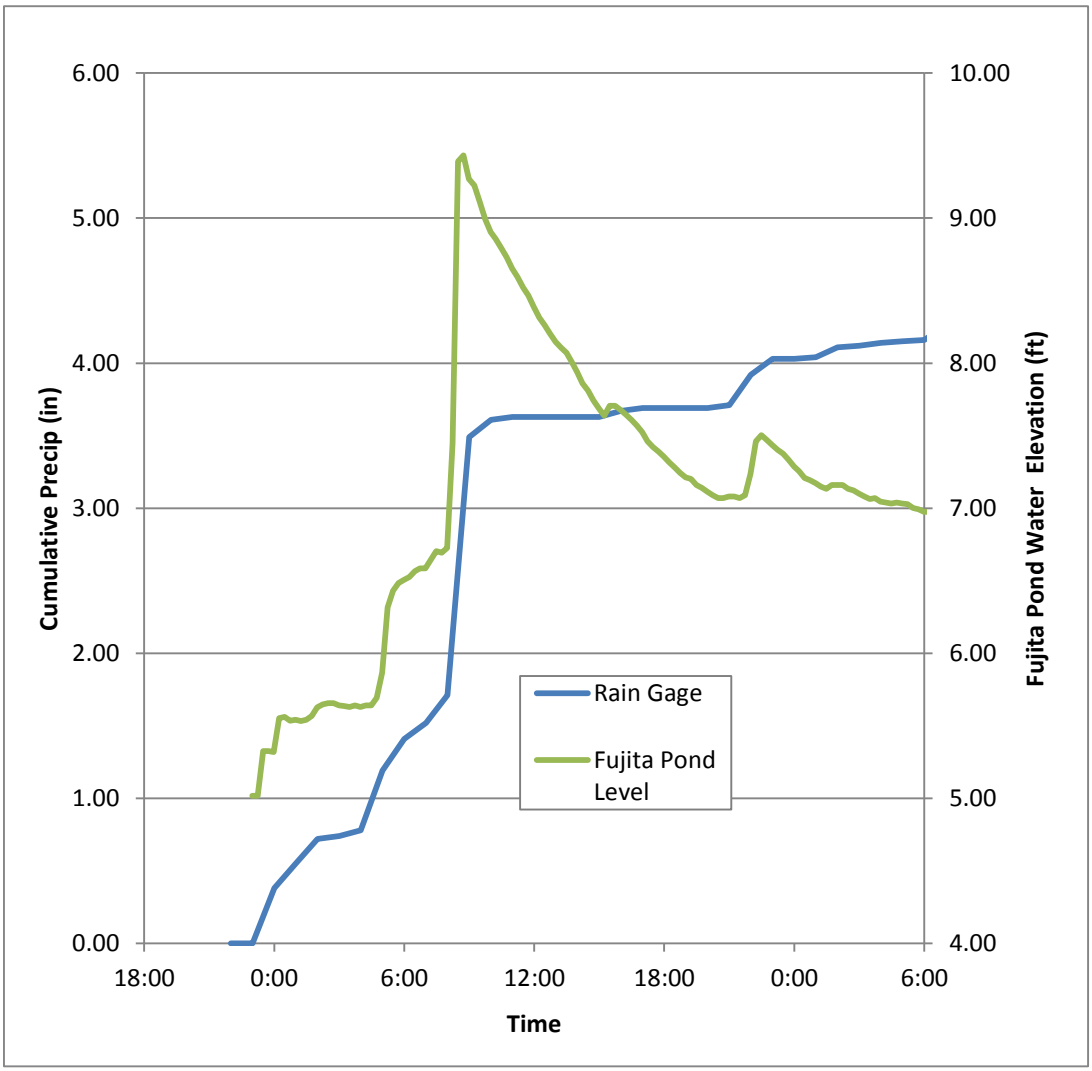
The storage area for Fujita Pond was computed using elevation contours established by the project survey. The normal waterline elevation of Fujita Pond is roughly 5 feet and fluctuates with rainfall, groundwater inflow, and tide levels. Fujita Pond also includes an annex underground storage chamber that is accessed by three 36-inch diameter culverts with invert elevations at approximately 7.6 feet. This storage chamber provides additional storage volume and infiltration. Fujita Pond has no defined outlet and infiltrates stormwater. When inflow exceeds storage and infiltration it overtops its northeast corner (discussed in Section 3) at elevation 9.5 feet. Table 4-3 provides a summary of its storage parameters.

Table 4-3 Fujita Pond Storage Parameters

Elevation	Area (ac)			Storage Volume	
(ft)	Pond	Chamber	Total	Incr (ac-ft)	Cum (ac-ft)
2	0.25	0.00	0.25		
3	0.27	0.00	0.27	Permanent Storage	
4	0.30	0.00	0.3		
5	0.35	0.00	0.35		
6	0.39	0.00	0.39	0.37	0.37
7	0.42	0.00	0.42	0.40	0.77
8	0.45	0.25	0.7	0.55	1.33
9	0.48	0.25	0.73	0.71	2.04
10	0.51	0.25	0.76	0.74	2.79
11	0.90	0.00	0.9	0.83	3.62
12	3.00	0.00	3	1.85	5.47

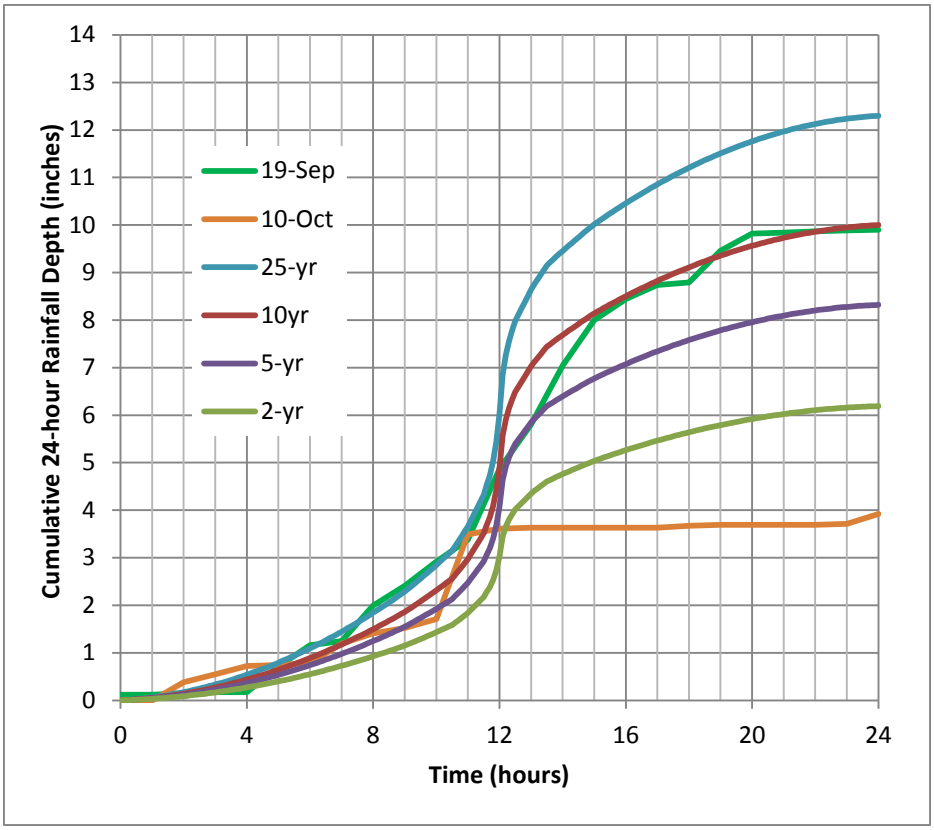
Source: Stanley Consultants, Inc.

Fujita Pond infiltration was estimated using the pond level logger gage which reads the water level in Fujita pond at 15-minute intervals. Pond infiltration can be observed following rainfall events as the water level decreases once stormwater flow stops entering Fujita Pond. Infiltration at Fujita Pond is estimated to be approximately 7 inches per hour. Figure 4-10 provides a plot of the pond level fluctuation during the 10-Oct rainfall event.



10 Oct Fujita Pond, Rain versus Pond Level
Figure 4-10

Rainfall Events. As discussed in Section 2, the 2-yr, 5-yr, 10-yr, and 25-y design rainfall events for a 24-hour storm were analyzed in this study. In addition, using rainfall gage data, the 19-Sept and 10-Oct rain events were also analyzed to assist with calibration and evaluate the effectiveness of the improvement alternatives using actual recorded storm/flooding events. Figure 4-11 displays the rainfall distributions (time versus cumulative rainfall) that were input into XP-SWMM to model the various design and actual rainfall events.



Rainfall Distribution Curves
Figure 4-11

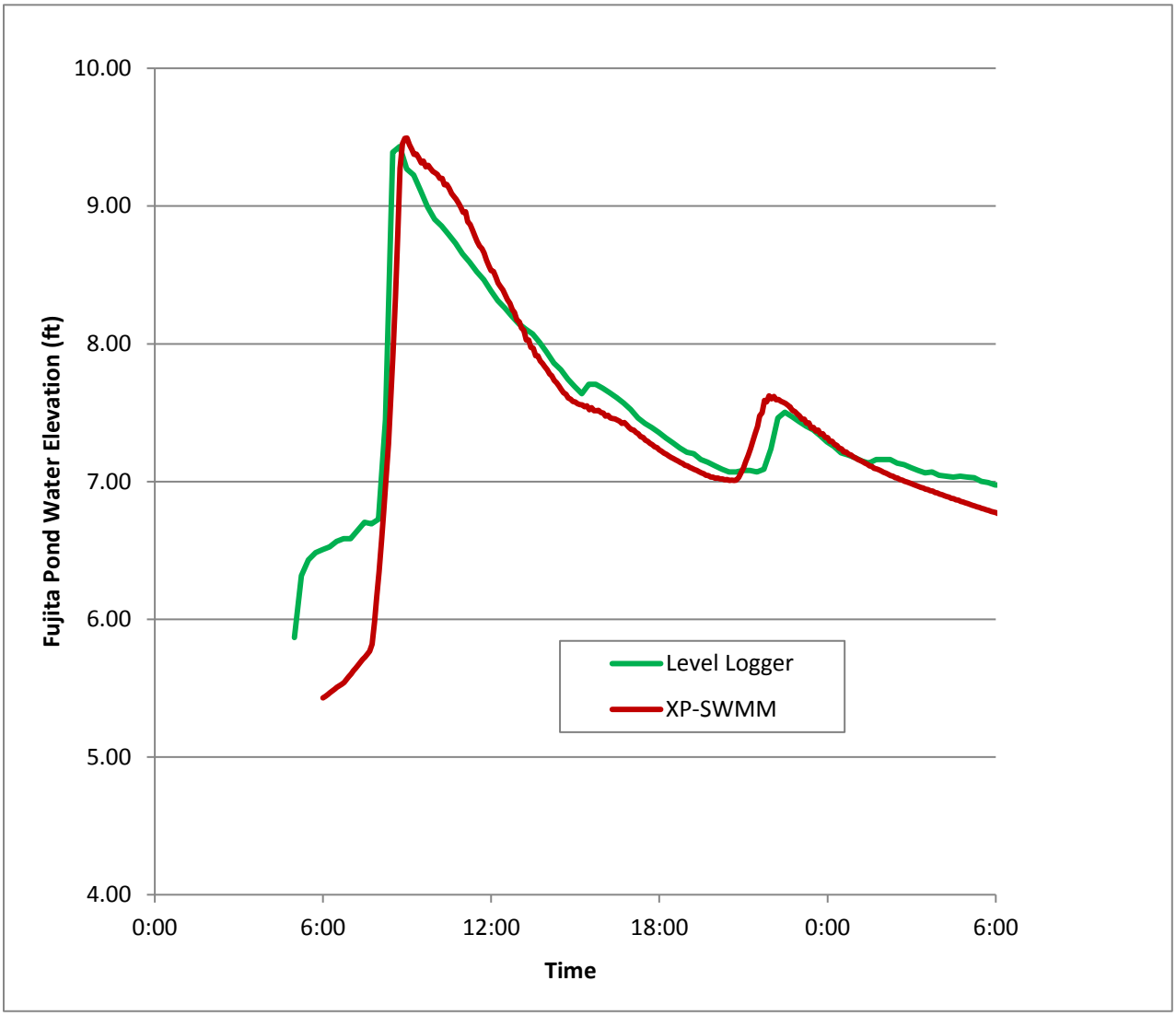
Calibration. The existing condition XP-SWMM model was calibrated using the 19-Sept and 10-Oct events. The 10-Oct event was used for the initial calibration because both the local rain gages and Fujita Pond level gage were operational during this event. The 10-Oct rainfall was 3.5 inches in 6 hours which correlates to roughly a 1-year storm and appears to be approximately the threshold for when extended ponding occurs on SVR.

The XP-SWMM model was run using fractions of the 10-Oct rainfall and the model indicated that rainfall events below 3.5 inches (i.e. 90 percent of Oct-10 rain) did not result in prolonged flooding. In reality, this will be dependent upon several factors including ground saturation, rainfall intensity, rainfall variability within the watershed, and the pre-rain Fujita Pond level. But this finding supports the previous determination of 3.5 inches of rainfall as the threshold for extended SVR ponding.

The 19-Sept event was used to check the calibration and further refine the existing conditions XP-SWMM model. The XP-SWMM calibration involved adjusting Curve Number values, the Fujita Pond infiltration rate, inlet parameters and system storage volumes until the XP-SWMM modeled 19-Sept and 10-Oct event matched the degree and duration of flooding that occurred during the actual rainfall and flooding events in the project area. Significant adjustments included:

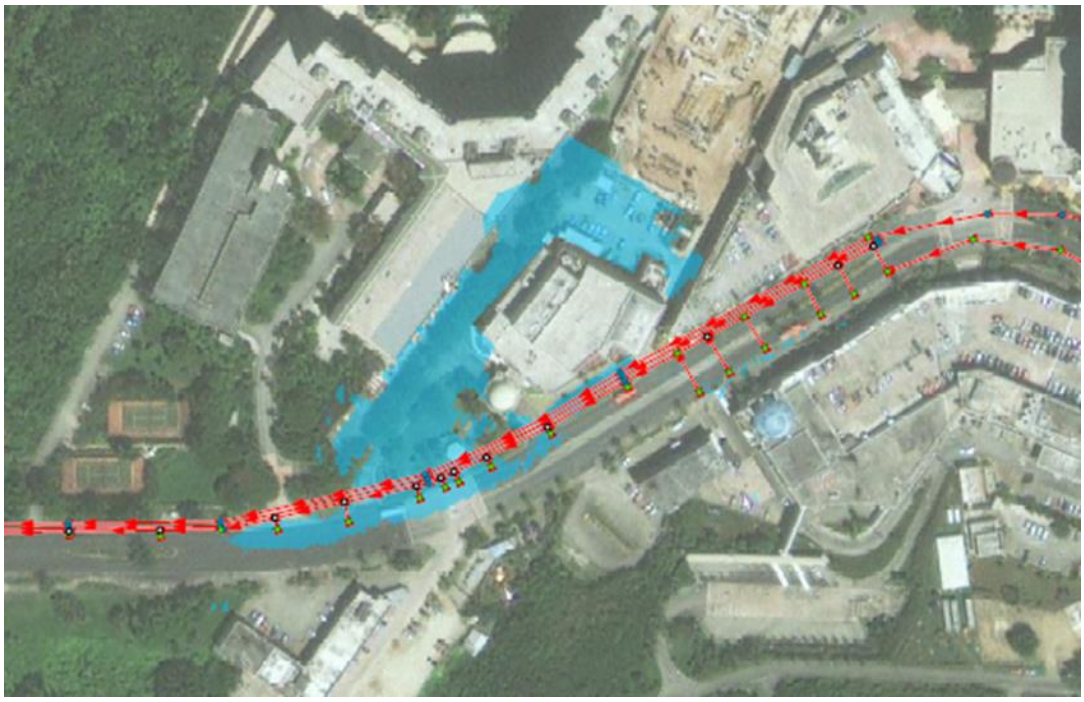
- Adjusting offline and undeveloped area Curve Numbers to a representative value of 50.
- Adjusting the infiltration rate of Fujita Pond to 7 in/hr.
- Increasing storage volumes near Sandcastle to better represent ponded volume including the road and surrounding properties.

Figure 4-12 compares the XP-SWMM output and Fujita Pond gage for the 10-Oct event.



Fujita Pond Water Elevation 10-Oct Event
Figure 4-12

Figure 4-12 demonstrates that the XP-SWMM model is able to closely represent the degree and duration of flooding (i.e. high water in Fujita Pond) for the 10-Oct event. The XP-SWMM model results were also reviewed for the 19-Sept Event. Figure 4-13 shows the extent of ponding computed by XP-SWMM for the 19-Sept Event and Figure 4-14 shows a photo taken of the ponding near the low area of SVR. The two ponded areas for the 19-Sept event match closely.

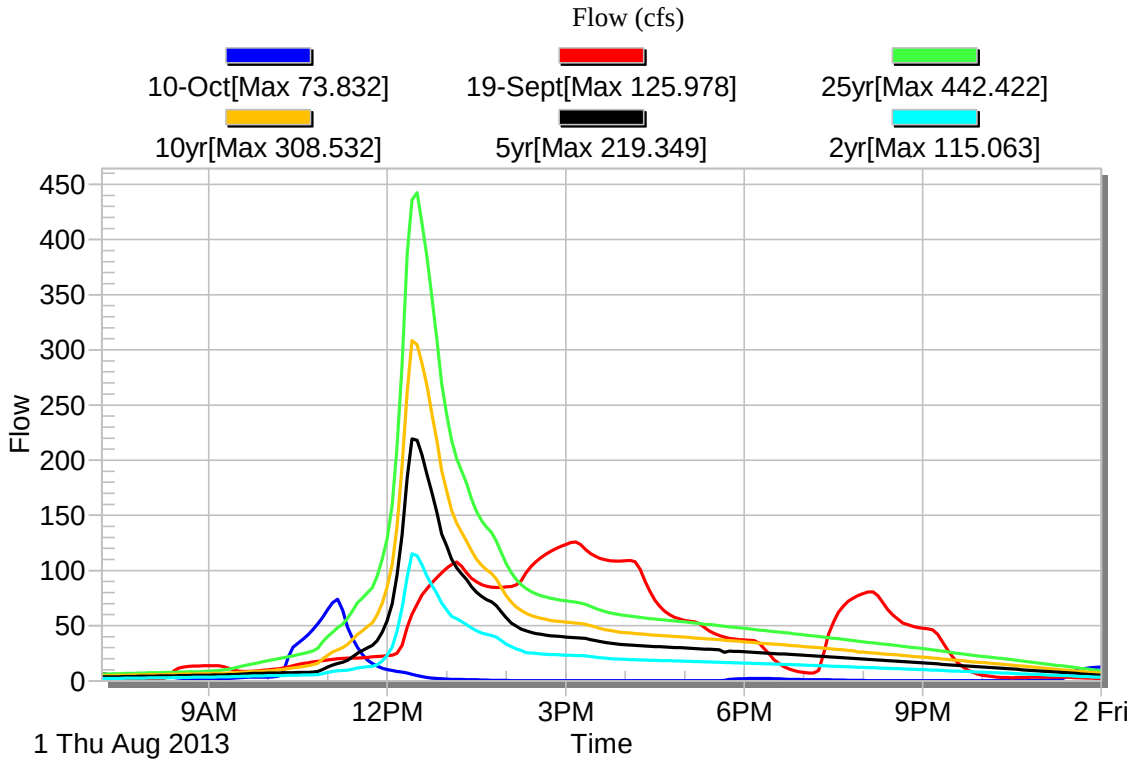


XP-SWMM 19-Sept Ponding Area
Figure 4-13

Photographs of 19-Sept Event
Figure 4-14

Model Results

Following calibration, the existing conditions XP-SWMM model was run for the 2-year, 5-year, 10-year, 25-year, 19-Sept, and 10-Oct storm events. Figure 4-15 displays the flow hydrographs for the total area draining to Fujita Pond.



Existing Condition Hydrographs
Figure 4-15

Peak design flows vary from approximately 440 cfs for the 25-year flood down to 115 cfs for the 2-year flood. As discussed in Section 2, although the 19-Sept event had a similar rainfall to the 10-year flood, its peak flow of 126 cfs was less than half the peak flow of the 10-year flood of 309 cfs. However, as shown on Figure 4-15, the duration of high flows during the 19-Sept event extends over 4 hours whereas high flows during the 10-year flood are confined to approximately 2 hours. The lowest peak flow computed was 74 cfs for the 10-Oct event which was less than a 2-year flood. The major hydrologic and hydraulic results for each of the flood events are summarized in Table 4-4.

Table 4-4 Key Hydrologic and Hydraulic Results

Flood	Total Rain (in)	Peak Inflow (cfs)	Peak El. Fujta (ft)	Peak El. SVR (ft)	Peak Fujita Overflow (cfs)	Total Runoff Vol. (ac-ft)
2-yr	6.2	115	9.65	9.7	54	25.5
5-yr	8.3	219	9.73	11.3	69	45.3
10-yr	10.0	309	9.81	12.0	86	62.9
25-yr	12.3	442	9.92	12.6	110	89.3
19-Sep	9.9	126	9.75	11.7	74	61.9
10-Oct	3.9	74	9.49	9.5	28	9.4

Source: Stanley Consultants, Inc.

The total runoff volume is shown in the far right column. Even though the peak flows for the 10-year flood and the 19-Sept flood differ, their total runoff volumes were within 2 percent of each other. This demonstrates the impact of rainfall intensity on peak flows. Higher intensities can drive up peak flows, even though rainfall amounts and runoff volumes are similar.

The total runoff volume for the 10-Oct event was approximately 9.4 acre-feet. The flood storage volume of Fujita Pond is approximately 2.5 acre-feet at its overtopping elevation. As Fujita Pond fills up, it infiltrates stormwater, so some of this volume is offset. But the infiltration flow rate is approximately 3 cfs, significantly smaller than the stormwater inflow. The 10-Oct volume of 9.4 acre-feet was sufficient to overtop Fujita Pond and cause ponding in the low area of SVR. The 10-Oct volume is roughly 35 percent of the 2-year flood volume and 20 percent of the 5-year flood volume. A comparison of the storm flow rates and runoff volumes to the Fujita Pond infiltration rate and storage volume shows that Fujita pond is undersized to detain and infiltrate the stormwater that is draining to it.

Table 4-4 compares the peak water elevations of Fujita Pond and the low area of SVR. For all storms analyzed, Fujita Pond overtops and the low area of SVR ponds water in the street. For the 2-year and the 10-October event, the peak elevations of Fujita Pond and the low area of SVR are similar and only a few inches above the gutter elevation of SVR (i.e. limited flooding). For larger magnitude flood events (5-year and up) the water elevation in the low area of SVR is approximately 1 to 2 feet higher than the water elevation in Fujita Pond (i.e. extended flooding). This is due to two factors:

- The inlet capacities along SVR are undersized for peak design flows so water ponds in the low area of SVR.
- A greater difference in water elevation between upstream (low area of SVR) and downstream (Fujita Pond) is necessary to create sufficient hydraulic head to force the water through the SVR culverts.

The hydraulic head issue can be solved by reducing the water level in Fujita Pond during flood events so the upstream water elevation stays below the ground elevation of the low area of SVR.

The triple box culvert has sufficient hydraulic capacity to convey the full range of design storm events, but the water level in Fujita Pond must be kept atleast 1 foot below the low elevation of SVR to create sufficient hydraulic head to convey flow through the SVR culverts without flooding the low area of SVR.

When water levels within Fujita Pond are kept below the low area of SVR, the flooding issue is significantly improved. The XP-SWMM model is provided in *8-Submittals* of the project DMS. Improvements to solve the extended flooding issue due to Fujita Pond are discussed in Section 5.

Correlation of Rainfall and Tumon Bay Water Quality

With its proximity to Tumon Bay, water quality is an important component of this project. To assess the impact of Fujita Pond overflow on Tumon Bay water quality, the correlation between rainfall and increased bacteria counts at the Fujita beach water quality station was evaluated. Weekly water quality sampling records were provided by GEPA for 2006 to 2013. The water quality sampling tests for enterococci bacteria concentrations, which can be of human (i.e. sanitary sewer) or animal (i.e. areas of uncontained dog or other animal feces) origin that are harmful to humans and aquatic life. These water quality sample results were compared to the Guam International Airport daily rainfall gage data to evaluate the correlation between rainfall events and high bacteria counts in Tumon Bay near the Fujita Road area.

The first comparison was between high bacteria counts and the amount of rainfall prior to the water quality sample. Table 4-5 displays all Fujita beach water quality station readings that exceeded the 104MPN/100mL single sample maximum and the rainfall that occurred 3 days prior to the sample grab.

Table 4-5 High Bacteria Count Readings at Fujita

Sample Date	Sta N23 Tumon Bay (Fujita Rd)	Guam Airport Gage Daily Rainfall (in) Prior to Sample			
	MPN/100mL	3 days	2 days	1 day	0 days
4/1/2010	3654	0.00	0.00	0.02	0.02
8/2/2012	1520	0.01	0.10	0.00	0.84
7/26/2012	1467	0.05	0.22	0.00	1.09
3/1/2007	1376	0.00	0.00	0.00	0.01
8/25/2011	1250	2.83	0.94	1.97	0.59
9/7/2006	836	0.00	0.00	0.00	0.05
5/7/2009	748	0.18	0.06	0.93	0.05
10/10/2013	703	1.62	0.00	0.32	4.18
2/7/2008	671	0.58	0.08	0.02	0.00
1/17/2013	473	0.02	0.00	0.04	0.00

Sample Date	Sta N23 Tumon Bay (Fujita Rd)	Guam Airport Gage Daily Rainfall (in) Prior to Sample			
	MPN/100mL	3 days	2 days	1 day	0 days
7/12/2007	420	1.40	0.49	0.03	0.08
6/23/2009	315	0.05	0.03	0.00	0.08
5/10/2012	294	0.10	0.01	0.29	1.20
6/5/2008	201	0.00	0.17	0.05	0.00
6/2/2011	201	0.10	0.00	0.32	0.01
3/22/2007	199	0.00	0.00	0.00	0.00
6/24/2010	179	0.03	0.06	1.05	1.63
9/21/2006	176	0.02	0.00	0.00	0.14
3/11/2010	158	0.02	0.05	0.04	0.00
7/23/2009	121	0.06	0.51	0.16	0.00
7/14/2011	120	0.00	0.60	2.82	3.06
2/24/2011	109	0.03	0.00	0.00	0.29

Source: Stanley Consultants, Inc.

Out of the twenty-two samples that exceeded the single sample maximum, ten did not have significant rainfall (greater than 0.5 inches) prior to the high bacteria count. This result suggests that the trigger for high bacteria counts in Tumon Bay is more complex than just rainfall. An additional comparison was made between the largest daily rainfalls over the 2006-2013 water quality sampling period. Table 4-6 displays the daily rainfalls compared to the subsequent water quality sample at the Fujita station.

Table 4-6 Largest Rainfalls and Subsequent Bacteria Counts at Fujita

Rainfall Date	Guam Airport Gage Daily Rainfall (in)	Tumon Bay (Fujita) Water Quality Sample After Event (MPN/100mL)
9/19/2013	10.19	9
9/2/2011	5.06	9
8/7/2012	4.73	9
7/28/2011	4.29	41
10/10/2013	4.18	703

Rainfall Date	Guam Airport Gage Daily Rainfall (in)	Tumon Bay (Fujita) Water Quality Sample After Event (MPN/100mL)
8/1/2009	4.01	20
10/18/2013	3.68	41
8/5/2009	3.61	20
9/3/2007	3.46	9
8/4/2007	3.43	9
11/24/2007	3.37	9
1/4/2009	3.34	42
12/2/2009	3.23	9
8/6/2006	3.19	52
10/7/2006	3.11	9
7/14/2011	3.06	120
10/14/2011	2.96	9
8/22/2011	2.83	1250
11/19/2007	2.72	9
8/13/2009	2.69	10
7/8/2008	2.63	10

Source: Stanley Consultants, Inc.

Out of the twenty one largest daily rainfalls between 2006 and 2013, three were associated with bacteria counts exceeding the single sample maximum of 104MPN/100mL. The Table 4-6 comparison finds even less correlation between significant rainfall and significant increases in Tumon Bay bacteria near Fujita Road. This is not to suggest that rainfall and high Tumon Bay bacteria levels are not related. One of the highest bacteria readings was 704 MPN/100mL following the 10-Oct event. However the bacteria readings following the 19-Sept event which caused a greater degree of flooding was 9 MPN/100mL. These discrepancies may be due to the fact that Fujita Pond does not outlet directly into Tumon Bay or that stormwater only contains elevated bacteria levels some of the time. Likely, rainfall is just one of several factors contributing to when elevated bacteria levels occur in Tumon Bay.

The city of Venice Beach, Florida is a coastal city with several stormwater outlets into the Gulf of Mexico. Coastal stormwater outfalls were discussed with the Stormwater Engineering Manager. The Florida Department of Health does weekly bacteria sampling of Venice Beach. Similar to

Tumon Bay, rainfall is not directly correlated to high bacteria counts. The biggest spikes in bacteria levels typically occur during the dry season, where there are extended periods between rainfall events and bacteria has an opportunity to build up on land and within the stormwater system. Venice Beach periodically has high bacteria counts, some of which have been traced to specific stormwater outfalls. To determine the bacteria source, the City of Venice Beach performed DNA testing of their stormwater and determined that some of the bacteria within their stormwater was from animal sources (i.e. not sanitary sewer), meaning elevated bacteria counts are not just caused by sanitary sewer leaks and overflows. High bacteria counts lead to beach closures, but there has not been a record of damage to coastal aquatic life associated with these incidents.

Summary of Findings

The flood modeling and analysis of the existing SVR storm sewer system established the following:

- Flooding for this project is defined by ponding due to stormwater runoff extending more than half a traffic lane on SVR.
- Many inlets along SVR are undersized. This contributes to but is not the critical factor in the extended flooding that occurs following heavy rainfall events.
- Fujita Pond is undersized for the volume of stormwater draining to it. This is the main cause of the extended flooding that occurs following heavy rainfall events.
- Flood events tend to occur on the order of one to two times per year during normal precipitation patterns.
- Flooding will tend to occur in the low area of SVR following rainfall events greater than 3.5 inches which is similar in magnitude to the 10-Oct event.
- The existing conditions XP-SWMM model provides a good representation of flooding conditions at Fujita Pond and SVR.
- If water levels within Fujita Pond can be kept below the low area of SVR the flooding issue will be significantly improved.
- Flood events do not appear to be directly correlated to high bacteria samples in Tumon Bay near Fujita Road.

Section 5

Improvement Alternatives

Introduction

Section 5 summarizes the evaluation of improvement alternatives. Using findings of the XP-SWMM storm sewer system modeling, six improvement alternatives were developed and analyzed for SVR. Conceptual level construction cost estimates and schedules were developed for each alternative. Permitting requirements were assessed. Alternatives were compared and evaluated using a matrix of project criteria.

Development of Improvement Alternatives

Improvement alternatives for the SVR storm sewer system were developed to reduce the frequency and duration of SVR flooding. SVR flooding is defined by ponding in the roadway greater than half a travel lane. There are two issues causing SVR flooding:

- Short duration SVR flooding during high intensity rainfall events: This flooding caused by curb inlets lacking sufficient capacity to fully capture design storm events.
- Long Duration SVR flooding following extended rainfall events: This flooding is caused by Fujita Pond not having sufficient volume to handle the series of design storms without overtopping and causing extended ponding in the low areas of SVR.

Short Duration SVR Flooding

Solving the short duration SVR flooding issue involves installing additional curb inlets to more effectively capture gutter flow along SVR. Adding more inlets will solve the issue of short term flooding along gutters due to intensive rainfall but will not solve the extended flooding issue due to high water levels in Fujita Pond.

Proposed inlets were located to reduce the gutter flow and ponded width along SVR during intensive rainfall events. It was assumed that new inlets would be constructed adjacent to existing inlets to provide an easy connection to the SVR storm sewer, reduce construction impacts, and minimize costs.

Three different inlet improvement options were analyzed based on design objectives.

- Option A – Maintaining a maximum flow depth of 6 inches or less and a spread of half the driving lane where possible.
- Option B – Maintaining a maximum flow depth of 6 inches or less and a spread over one driving lane where possible.
- Option C – Bare Minimum, inlets only added at low points in SVR

For each option, inlets were added at different locations along SVR until the design objective was accomplished. The final results of the above options are:

- Option A – 47 new inlets needed along SVR
- Option B – 34 new inlets needed along SVR
- Option C – 16 new inlets needed along SVR

Option B and C do not meet the design requirements of the Stormwater Drainage Manual. Option A meets the applicable roadway design requirement but reducing gutter spread from one lane to half a lane provides more passable width during the 10-year design event but not enough to provide two full lanes of traffic. However, the additional inlets of Option A will provide supplemental capacity if several inlets are partially clogged during a design magnitude event. Figures B-1 through B-6 in Appendix B display the additional inlet locations for the three options.

Long Duration SVR Flooding

The water level in Fujita Pond is the key parameter that defines long duration flooding. Flooding durations will be significantly reduced if the Fujita Pond water elevation can be kept below the SVR low area elevation. Fujita Pond does not have a defined overflow, it overtops and sheet flows into the adjoining property to the northeast. With the exception of the SVR and Fujita Road corridors, Fujita Pond is surrounded by privately owned property. There are no nearby drainage channels, creeks, tidal rivers, wetland areas or other typical receiving waters to directly discharge Fujita Pond overflow. With that understanding, an initial set of improvement alternatives was developed:

- Expand Detention
- Gravity Ocean Outlet
- Gravity/Pumped Ocean Outlet
- Gravity Bay Outlet
- Raise Low Area of SVR

- Pump to Sink
- Pump to Quarry
- Injection Wells
- Connect to Matapang Storm Sewer

Eliminated Alternatives

The initial set was reviewed for feasibility (i.e. can it be constructed?) and effectiveness (i.e. will it work?). Out of the initial set, three alternatives were eliminated.

Raise Low Area of SVR. This alternative would involve raising the low area of SVR above the overflow elevation of Fujita Pond. If the low area of SVR is raised sufficiently above the Fujita Pond overflow, then the pond could overtop as it does currently without also flooding SVR. This alternative was eliminated because raising SVR enough to effectively reduce flooding is not possible. The low area of SVR is at elevation 9.5 feet which is roughly the overtopping elevation of Fujita Pond. To provide an effective reduction in flooding, the low area of SVR would need to be raised by at least two feet to an elevation of 11.5 feet. The maximum feasible raise of the SVR low area was determined to be approximately one foot. The SVR corridor in this area is densely developed. Raising the roadway higher than one foot would result in significant impacts to the surrounding area including impacts to building entrances and driveways from the Sandcastle property to the Outrigger hotel. In addition to raising a busy 4-lane roadway, the required two foot road raise would involve significant reconstruction of building entrances, utilities, parking lots, driveways, walkways. The extensive area of impact would escalate project costs and have impacts to numerous private properties and businesses.

Injection Wells. Injection wells collect surface water (i.e. water in Fujita Pond) and discharge the water into the pervious soil layers below ground. This was eliminated as a viable alternative due to the water table only being a few feet below the ground elevation and the dense development of the project area which could carry risks with development of high volume injection wells.

Connect to Matapang Storm Sewer. The SVR storm sewer system adjacent to the Fujita Pond system is the Matapang system. The Matapang storm sewer system collects surface runoff and conveys it to a series of underground storage/infiltration chambers beneath the Matapang Park parking lot located approximately 1600 feet south of Fujita Pond along SVR. The excess stormwater volume from the Fujita Pond system is too much for the Matapang system to handle so connecting to the Matapang system is not a viable option.

Description of Alternatives

The following describes the set of improvement alternatives analyzed for the project.

Expanded Detention. This alternative involves expanding the overall detention volume of the SVR system. With the exception of the GovGuam property including Fujita Pond, property within the SVR corridor is privately owned. Expanding detention will require acquisition of property near the SVR corridor. Any structures on the acquired property would be demolished and additional pond area excavated to expand the stormwater storage volume.

Gravity Ocean Outlet. This alternative would involve constructing an overflow outlet pipe for Fujita Pond. The outlet pipe would be separated from Fujita Pond by a weir, set at approximately elevation 8 feet. Fujita Pond would continue to function as an infiltration basin during smaller rainfall events and then the weir would overtop during significant rainfall events providing an outlet for excess stormwater. The outlet pipe would be constructed using open cut methods along Fujita Road following the alignment of an existing abandoned storm sewer line along Fujita Road towards Tumon Bay. Where Fujita Road dead ends near the beach of Tumon Bay, the outlet pipe would either be microtunneled or installed via open cut to a point beyond the reef area. The outfall location would be beyond the reef and at a depth of approximately 30 feet below sea level.

Gravity/Pump Ocean Outlet. This alternative is identical to the Gravity Ocean Outlet except pumps would be provided to increase discharge rates and reduce the outlet pipe size.

Gravity Bay Outlet. This alternative would involve constructing an outlet pipe for Fujita Pond that discharges to Tumon Bay instead of outside of the reef. Similar to the Ocean Outlet, the outlet conduit would be separated from Fujita Pond by a weir. There are several viable engineering options for the outlet conduit. If this option moves forward, selection of the outlet conduit alignment and features should be established through the stakeholder/public involvement process.

The closed conduit option would be constructed using open cut methods along Fujita Road following the alignment of an existing abandoned storm sewer line along Fujita Road towards Tumon Bay. This option would likely use box culverts to reduce the depth of construction. The culverts would outlet at the end of Fujita Road. Potential outlet structure options include:

- An outlet channel resembling a tidal river with a pedestrian bridge over the channel to allow foot and light vehicle crossing.
- A diffuser structure, which is a concrete box with an open end facing the beach covered by a grate. Two to three feet of the structure would be above the sand and another two to three feet of the structure would be buried. When Fujita Pond overflowed, the discharge would push away the sand in front of the structure to allow discharge through the full opening. Sand would be replenished following discharge events. Public amenities such as benches or tables could be included on top of the structure to create a dual benefit.

- A lagoon outlet, which would involve constructing a natural looking lagoon feature behind the beach where the box culverts outlet. During significant overflow events the discharge would flow over the beach and into the bay. Sand would be replenished following discharge events to rebuild the beach.

The open conduit option would be constructed to follow the bull-cart path off the northeast corner of Fujita Pond, near where it currently overtops. A wide vegetated channel would be constructed that incorporated the bull-cart path. The channel would outlet at the beach. The channel outlet or lagoon outlet would be suitable for this option.

Pump to Sink. Similar to the Ocean Outlets, the pump alternatives also utilize a weir discharge from Fujita Pond. With this alternative the weir would discharge to a pump intake. Excess stormwater would be pumped approximately 6500 feet via pipe to one of the sink areas near Marine Corps Drive where it would infiltrate. The majority of the pipe alignment would be constructed within roadway right of way.

Pump to Quarry. This alternative is similar to Pump to Sink, except the proposed pipe would discharge into the abandoned quarry approximately 8400 feet south of Fujita Pond along SVR.

Conceptual Design

A series of conceptual designs were advanced for each alternative. Using XP-SWMM, improvement alternatives were sized and scaled up to determine the size of system required to handle the series of project design storms (i.e. 2, 5, 10, 25-year storms). This approach allowed a range of construction costs and quantities to be evaluated for each alternative. The design alternative designated 2-year means that it has capacity to handle storms up to the 2-year event. A 5-year designation means 5-year storm design capacity and so on. The concept designs were also evaluated for the 19-Sept and 10-Oct events. Descriptions of the improvement alternative conceptual designs are provided in the following section.

Expanded Detention

Expanded Detention involves increasing the stormwater storage volume within the SVR system to effectively store a given design storm volume without overflowing Fujita Pond and flooding SVR. The Expanded Detention volume was computed using the design storm inflow hydrograph to Fujita Pond. The normal pool elevation of Fujita Pond is approximately 5 feet. Flooding conditions occur on SVR when the pond level exceeds an elevation of 9 feet. To compute the required storage volume for the given design storm, the Fujita Pond area was incrementally increased until the peak pond water level stayed below elevation 9 feet (or within 4 feet of the normal pool elevation). The Fujita Pond infiltration rate of 7 inches per hour was assumed for the entire Expanded Detention area. The total detention area required for each design storm is summarized in Table 5-1.

Table 5-1 Expanded Detention Area

Design Storm	Pond Size (acre)
2-yr	2.7
5-yr	5.0
10-yr	7.0
25-yr	10.0

Source: Stanley Consultants, Inc.

Exhibit 1 in Appendix C provides a map view of the required detention area over Fujita Pond. As a point of reference the existing Fujita Pond detention area is 0.5 acres. The 19-Sept event would require the 10-year expanded pond to store and infiltrate the rainfall event without flooding SVR. The 10-Oct event could be handled by the 2-yr expanded pond.

This analysis did not attempt to select specific parcels or properties for locating Expanded Detention. As discussed in Section 3, the Fujita Pond parcel is the only GovGuam owned property within the project area. This alternative will require acquisition of one or more parcels within the project area to contain the required detention area. These parcels need not be directly adjacent to Fujita Pond, but could be hydraulically connected via pipe connection to the SVR system. The parcels would need to be in the low area of the watershed adjacent to SVR so the entire detention volume can be provided at an elevation below the flood elevation of 9 feet.

Given the high water table in the vicinity, a wet pond, similar to Fujita Pond is recommended. Additional aesthetic enhancements could be provided. The pond could be shaped to look more like a natural feature with landscaping and trails surrounding. Another potential option would be to provide some of the Expanded Detention in the form of a large infiltration chamber, similar, but significantly larger than the system at Matapang Park. Parkland or parking areas could be developed over the top of the infiltration chamber to provide dual use. These chambers require periodic maintenance to maintain performance.

Outlet Options

The remaining five alternatives include some kind of overflow outlet. There are several common improvements that would be constructed at Fujita Pond for the five overflow outlet alternatives. Figure B-7 in Appendix B shows a schematic drawing of the Fujita Pond improvements. A description is provided by the following.

Labryinth Weir. A labyrinth weir would function as the overflow structure for Fujita Pond. This structure would separate the outlet from the pond and only discharge when water levels in Fujita Pond exceeded the top elevation (i.e. overflow elevation) of the labyrinth weir.

A labyrinth weir is a concrete wall aligned in a "zig-zag" form which allows significantly greater weir length (i.e. more discharge capacity) to fit in a narrower section than if a straight line weir is used. For instance, the Fujita Pond labyrinth weir structure is approximately 80 feet long by 20 feet wide. A 260 foot long labyrinth weir fits within this area, which can discharge approximately 300 cfs with only 6 inches of flow going over the weir. An 80 foot long straight line weir can discharge approximately 90 cfs with 6 inches of flow. Figure 5-1 shows a photo of a labyrinth weir constructed by DuPage County, Illinois for one of their flood storage facilities. The Fujita Pond labyrinth weir would look similar but during normal conditions there would be approximately 3 feet vertical difference between the water level and the top of weir. Also, the Fujita Pond labyrinth weir could be constructed without the pedestrian bridge over the top.

Photograph of DuPage County Labyrinth Weir
Figure 5-1

The normal water elevation of Fujita Pond is approximately 5 feet. The weir would overtop once Fujita Pond elevation exceeds 8 feet. The labyrinth weir configuration maximizes the storage/infiltration function of Fujita Pond by setting the overflow elevation as high as possible without causing upstream flooding. During less intensive rainfall events, Fujita Pond would continue to function as an infiltration basin. The pond would fill approximately 3 feet above its normal water level prior to discharging out of the pond. Once overtopped, the labyrinth weir can discharge design floods within approximately 6 inches of its crest elevation of 8 feet. This provides sufficient hydraulic capacity to discharge design floods without the Fujita Pond water level rising above the low elevation of SVR. Figure 5-2 displays a stage discharge curve for the labyrinth weir conceptj

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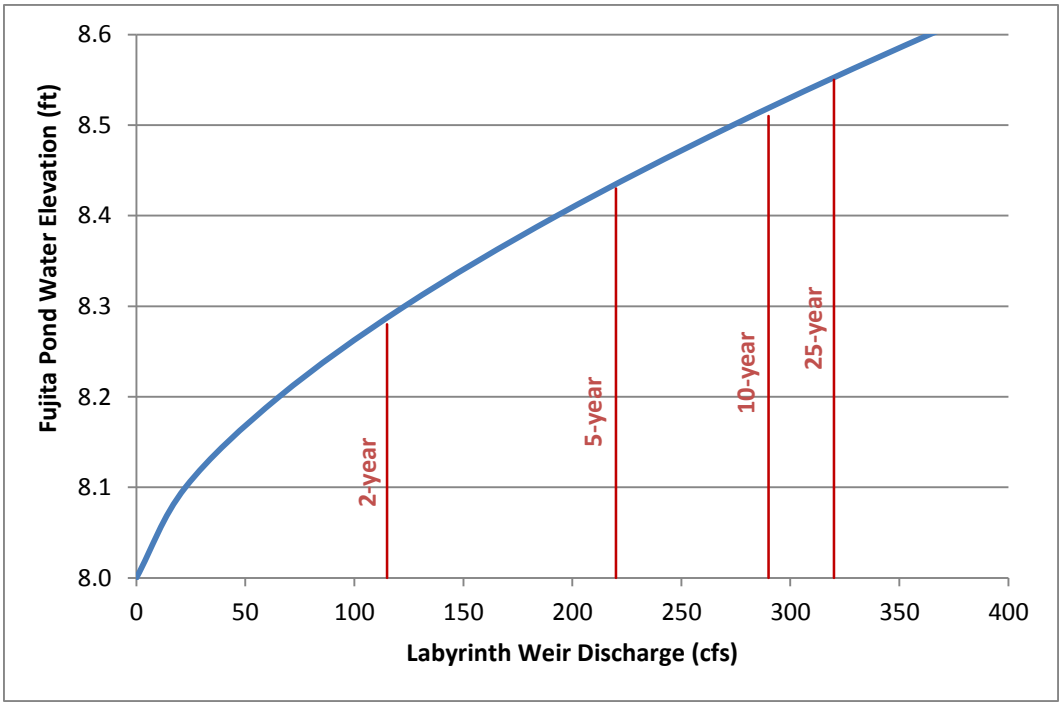


Labyrinth Weir Stage Discharge Curve
Figure 5-2

As shown on Figure B-7 in Appendix B, the labyrinth weir would be located in the southwest corner for the gravity outflow alternatives (ocean and bay outlet) and discharge directly to the gravity outlet. For the pump outflow alternatives (ocean pump, pump to sink, pump to quarry) the labyrinth weir would flow into a pump station.

Pump Station. A pump station is a housing structure for the intake, pumps, generators and associated mechanical and electrical utilities required to power, operate, and maintain the pumps. This equipment is housed within a structure to provide security, prolong equipment life, and allow easier maintenance. A pump station would only be required for the pump assisted alternatives. The gravity outlet alternatives would have a simple headwall structure connecting the outlet conduit to the labyrinth weir.

There is already a GWA sanitary sewage pump station adjacent to Fujita Pond that pumps sanitary sewage from the Tumon Bay area to the Northern District Sewage Treatment Plant. Figure 5-3 shows a photo of the exterior of the GWA sanitary sewage pump station at the Fujita Road, SVR intersection and a photo of the interior of a stormwater pump station owned by the City of West Jordan, Utah, which provides a good display of the scale of pump and associated equipment layout common in stormwater pump stations.

Pump Station Photos
Figure 5-3

The size of the Fujita Pond stormwater pump station would vary with the number and size of pumps and generators. Previous pump station design experience indicates that approximately 700 square feet per pump is required for housing the larger size pumps and associated equipment required for stormwater pumping.

As shown on Figure B-7 in Appendix B, the stormwater pump station would be located adjacent to Fujita Road and share the parking lot with the Fujita sanitary sewage pump station. Figure B-7 shows the approximate size of the pump station with four pumps. If

additional pumps are required the length of the pump station would be extended along Fujita Road towards Tumon Bay to house all pumps required.

The volume of Fujita Pond filled by the pump station will be offset by the volume gained by removing the infiltration chambers and excavating the east end of Fujita Pond.

Expanded Pond. The existing infiltration chambers located off the eastern edge of Fujita Pond provide approximately 0.25 acres of additional storage area. The additional storage volume provided by the infiltration chambers is estimated to be roughly 0.5 acre-feet. The advantage of using underground infiltration chambers is that the area above can be surface for parking, green space or other uses. Currently the area is not being used for any purpose. A photograph of the area is shown in Figure 5-4.

Infiltration Chamber Area
Figure 5-4

A more efficient use of the space for providing stormwater storage would be to expand the pond towards the eastern property line. This could create an additional 1.5 ac-ft of storage volume, roughly three times the volume being provided by the storage chambers. This additional flood storage volume would also count towards the regulatory water quality and recharge volume. The expanded pond area and grading contours are shown on Figure B-7 in Appendix B.

The Fujita Pond water quality volume was analyzed for the proposed improvements. Following guidelines of the Stormwater Management Manual, the water quality and recharge requirements for SVR and its tributary drainage areas can be satisfied using the

expanded Fujita Pond. Tumon Bay is designated as an M2, moderate marine quality recharge zone. For discharge to an M2 designated water body, the Stormwater Management Manual requires a Recharge Volume, Re_v (i.e. infiltration) and Water Quality Volume, WQ_v (i.e. detention) based on a specific rainfall depth over the directly tributary area. The Re_v is determined using a 1.5-inch rainfall event and the WQv is based on a 0.8-inch rainfall event.

As an infiltration basin, Fujita Pond can satisfy both requirements simultaneously. The larger Re_v is the controlling design criteria. As established in Section 2, a significant portion of the contributing drainage area is undeveloped or has offline infiltration systems. These areas are already treating stormwater so do not require additional treatment further downstream. Areas that do not have stormwater treatment include the public roadway and adjacent properties which drain directly into the SVR storm sewer system without detention or infiltration. Combined, this area is approximately 26 acres. Using the 1.5-inch rainfall and an impervious percentage of 70, the required Re_v is 2.25 acre-feet. The expanded Fujita Pond has approximately 3 acre-ft of available stormwater storage volume so can meet the treatment volume requirements of the Stormwater Management Manual

Gravity Ocean Outlet

This alternative would involve constructing an overflow outlet pipe for Fujita Pond that discharges beyond the reef of Tumon Bay. The outlet pipe would be separated from Fujita Pond by the labyrinth weir, which would then flow into an outlet conduit extending from the northwest corner of Fujita Pond to an outflow point beyond the edge of the Tumon Bay coral reef and at a depth of over 30 feet below mean sea level.

Sea Level. Given the low elevation of SVR and the Fujita Pond area, sea level is a significant hydraulic parameter in analysis and design of the gravity outlet alternatives. The nearest longterm tidal gage to Tumon Bay is the NOAA Apra Harbor tidal gage (station 1630000). Benchmarks of tidal designations (i.e. Mean High Water, Mean Tide Level, Mean Sea Level, Mean Low Water) were established by NOAA for the gage using data collected from 1983 to 2001. Table 5-2 displays the tidal benchmark elevations established for the Apra Harbor tidal gage in the 2004 GVD and Project vertical datums.

Table 5-2 Tidal Elevations

Tidal Designations	Elevation (ft)	
	2004 GVD	Project
Mean High Water	2.2	4.04
Mean Tide Level	1.42	3.26
Mean Sea Level	1.37	3.21
Mean Low Water	0.61	2.45

Source: NOAA

For design of the gravity outlet alternatives a higher sea level is the more conservative condition. A sea level of 4 feet was assumed for all ocean/bay discharge alternative analysis and design to represent discharge during a higher sea level condition such as high tide or wave run-up during a storm event.

Design. A proposed XP-SWMM model was created for preliminary design of the Gravity Ocean Outlet alternative. The series of design storm events were analyzed. For each design storm the ocean outlet pipe diameter was incrementally increased until the outlet had sufficient hydraulic capacity to convey the given design event and maintain Fujita Pond below an elevation of approximately 8.5 feet. Exhibit 2 in Appendix C, displays a conceptual layout of the proposed Gravity Ocean Outlet alternative. Table 5-3 shows the ocean outlet pipe diameter required to discharge the series of design storm events.

Table 5-3 Gravity Ocean Outlet Pipe Sizing

Design Storm	Ocean Outlet Pipe Dia. (inches)	Pipe Length (feet)	Maximum Discharge (cfs)
2-year	60	2800	104
5-year	72	2800	194
10-year	84	2800	288
25-year	96	2800	331

Source: Stanley Consultants, Inc.

For the pipe diameters shown in Table 5-3, concrete pipe provides the most cost efficient construction so was assumed for all designs. The analysis of the 2013 flood events found that the 2-year design option has sufficient capacity to discharge the 10-Oct event. The 5-year design option would be required to discharge the 19-Sept event without flooding.

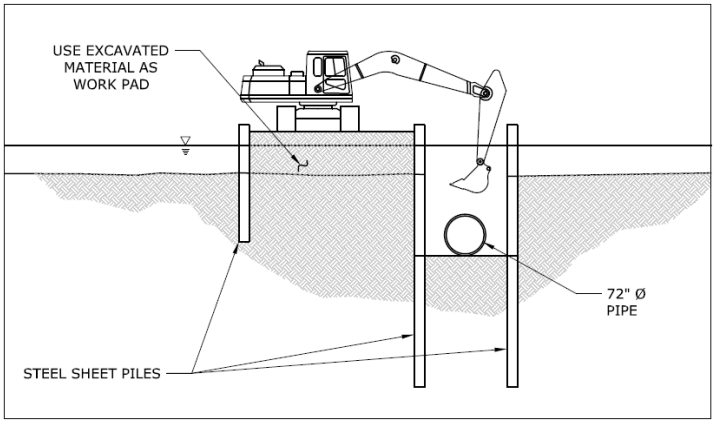
Hydraulic Head. The large required diameter for the ocean outlet pipe is due to the relatively small amount of hydraulic head between Fujita Pond and the established sea level. At its shortest distance the edge of the Tumon Bay coral reef is approximately 2800 feet from the northwest corner of Fujita Pond. As discussed in the labyrinth weir section, the maximum water surface elevation of proposed Fujita Pond is approximately 8.5 feet. Sea level was assumed to be 4 feet. This condition provides a water surface elevation difference (i.e. hydraulic head) between Fujita Pond and the ocean outlet of 4.5 feet. When adjusted for frictional head loss, there is a reduction in hydraulic head on the order of two to three feet, leaving only one to two feet of net hydraulic head for discharging the Fujita Pond overflow.

Construction Methods. The Gravity Ocean Outlet would have a labyrinth weir in the northwest corner of Fujita Pond. The labyrinth weir structure would connect to a concrete headwall at the entrance of the ocean outlet pipe. The ocean outlet pipe would be constructed along Fujita Road using open cut methods for approximately 1000 feet

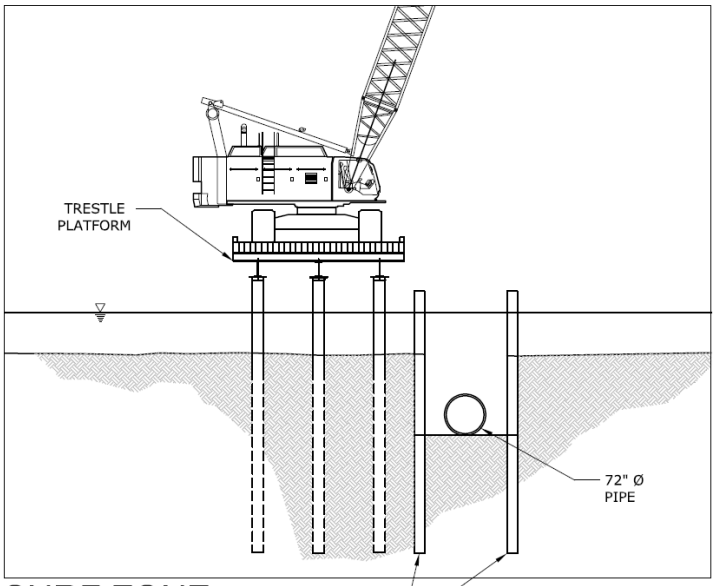
following the alignment of an unused storm pipe from Fujita Pond to the end of Fujita Road at the Tumon Bay (aka Naton) beach. At the end of Fujita Road, the ocean outlet pipe would be advanced approximately 1800 feet to a point out beyond the Tumon Bay coral reef. As shown on Exhibit 2, the limits of the coral reef were established using the NOAA Ocean Bottom Classifications.

Two installation options are shown on Exhibit 2, trenchless installation and open cut installation. The 60-inch pipe diameter designated for the 2-year storm could be installed using trenchless methods. Trenchless methods would utilize a remotely operated micro-tunneling unit to bore an opening underneath the floor of Tumon Bay without disturbing the beach and coral features above. Because trenchless installation has no surface disturbance, the pipe alignment would be set to minimize the installation length. Currently the maximum pipe diameter that can be installed using a micro-tunneling unit is 60-inches. The larger diameter pipe required to convey the 5-year, 10-year, and 25-year design storms would be installed using open cut methods.

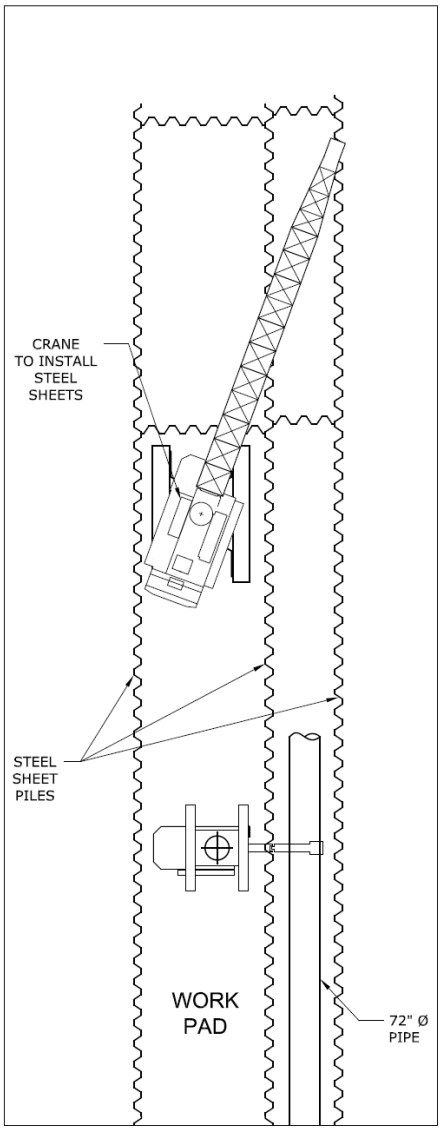
Open cut methods would require excavating a trench in Tumon Bay for installing the ocean outlet pipe. Sheetpile could be used to create a confined pipe trench and working pad. Figure 5-5 displays a construction method concept provided by Healy Tibitts Builders, Inc., a heavy marine contractor that has an office in Guam and provided input on this project.



CALM WATER ZONE
NOT TO SCALE



SURF ZONE
NOT TO SCALE



CALM WATER ZONE
NOT TO SCALE

Open Cut Installation Method
Figure 5-5

As shown in Figure 5-5, open cut installation would consist of a working pad and trench. The excavated material would be used to create the work pad, providing an above water surface to run installation equipment and a place to store excavated material. Healy Tibbits assumed a 72” diameter pipe for their concept, but this method is valid for larger pipe diameters as well. At the surf zone (closer to the reef), a trestle platform would be required to maintain stability over rougher waters. The open cut method is confined but would still create a roughly 30 foot wide surface and visual disturbance across Tumon Bay. As shown in Exhibit 2, the open cut alignment was adjusted to minimize impact to coral features. This will extend the installation length but reduce the amount of coral removal and mitigation required.

At its downstream end, the ocean outlet pipe would come through the ocean floor at approximately 30 feet below sea level. This depth would allow separation between the discharge point and the shallow waters of Tumon Bay. The pipe end would be stabilized using piling and screened to prevent fish from swimming into the outlet pipe.

Gravity/Pump Ocean Outlet

This alternative would be almost identical to the Gravity Ocean Outlet except a pump station would be constructed at Fujita Pond to provide additional head for discharging Fujita Pond Overflow. The pumps for this project are large and expensive pieces of equipment but using pumps to assist discharge can reduce the diameter of the outlet pipe relative to the gravity option. As with other outlet alternatives, the overflow system would be used once or twice a year in a typical precipitation year. Most of the overflow events will be discharged via gravity, but pumps will be used to discharge larger overflow events, on the order of once every three to five years.

Design. A proposed XP-SWMM model was created for preliminary design of the Gravity/Pump Ocean Outlet alternative. For each design storm the ocean outlet pipe diameter and number of pumps was incrementally increased until the outlet had sufficient hydraulic capacity to convey the given design event and maintain Fujita Pond below an elevation of approximately 8.5 feet.

A maximum design velocity of approximately16 feet per second was used to establish the ocean outlet pipe size. 12 feet per second is typically used in pump system design when the system will be operating frequently. This system will only operate a handful of times per year so a higher pipe velocity is acceptable and will allow use of smaller diameter pipe which saves on cost.

There are a variety of pump sizes and types that could be used. Given the range of design storms being analyzed it was decided to evaluate pumps in flow increments of 15,000 gallons per minute (gpm) which is 33.4 cfs. A 15,000 gpm pump is not bought off-the-shelf but requires custom order and manufacturing. Fairbanks Nijhuis, a subsidiary of Pentair and manufacturer of large custom pumps for municipal and industrial applications was consulted to assess potential pump types, size, and cost.

The ocean outfall option is a low head pumping application (less than 10 vertical feet). Fairbanks Nijhuis recommended a combination of 15,000 gpm and 30,000 gpm propeller pumps.

Exhibit 2 in Appendix C, also reflects the conceptual layout of the proposed Gravity/Pump Ocean Outlet alternative. Table 5-4 shows the ocean outlet pipe and pump sizing required to discharge the series of design storm events.

Table 5-4 Gravity/Pump Ocean Outlet Pipe/Pump Sizing

Design Storm	Ocean Outlet Pipe Dia. (inches)	Pipe Length (feet)	30K GPM Pumps	15K GPM Pumps	Discharge Capacity (cfs)
2-year	36	2800	1	1	100
5-year	48	2800	2	2	200
10-year	54	2800	3	2	267
25-year	60	2800	4	2	334

Source: Stanley Consultants, Inc.

Table 5-4 shows the sizing of the ocean outlet pipe and pumps required to discharge the range of design storms varies from 36 inches (3 feet) to 60 inches (5 feet). This is a 3 foot reduction in pipe diameter from the gravity outlet alternative for each design storm. Similar to the gravity alternative, concrete pipe provides the most cost efficient construction so was assumed for all designs.

The number of pumps varies from two for the 2-year design storm up to 6 for the 25-year design storm. Note that the pumping capacity of the 2-year design option is 100 cfs and the pumping capacity of the 25-year design option is 334 cfs due to use of 15K gpm and 30K gpm pumps.

The analysis of the 2013 flood events found that the 2-year design option has sufficient capacity to discharge the 10-Oct event. The 5-year design option would be required to discharge the 19-Sept event without flooding

Pump Station. The labyrinth weir would be constructed between Fujita Pond and the stormwater pump station, located along Fujita Road. Stormwater overtopping the labyrinth weir would enter an intake chamber situated below the pump station.

The pumps would cycle on and off based on water level within the intake chamber. For small Fujita Pond overflow events (i.e. similar to 10-Oct), the pumps may not even cycle on and the system will discharge via gravity. For design magnitude events, as the water level within the intake rises, pumps will incrementally cycle on to discharge the increasing overflow. As the Fujita Pond overflow decreases pumps will cycle off as the water level within the intake goes down.

The pump station would not just house pumps. Additional equipment includes backup diesel generators in case the power goes out during a flood event, diesel fuel tanks, pump instrumentation and controls, electrical wiring and paneling, mechanical ventilation and ducts, pump intake chamber, sluice gates, water piping, and maintenance space.

Construction Methods. All outlet pipes for the Gravity/Pump Ocean Outlet alternative can be installed using trenchless methods. Similar to the Gravity Ocean Outlet alternative, the outlet pipe would follow Fujita Road and be installed using open cut

methods. At the end of Fujita Road, a tunneling pit would be constructed and the downstream 1800 feet of outlet pipe would be installed using micro-tunneling.

Gravity Bay Outlet

This alternative would involve constructing a gravity overflow outlet from Fujita Pond that discharges into Tumon Bay. This design eliminates construction of a pipe through Tumon Bay which is the most costly and difficult segment of construction. Tumon Bay is a valuable natural and economic resource for the island. It is understood that if this alternative moves forward, detailed design will need to include a more substantial public education and involvement component than would be required for other options. For this reason, the Gravity Bay Outlet is being proposed with several potential alignment and discharge options. The preferred Gravity Bay Outlet configuration would then be finalized through regulator, stakeholder, and public input.

Design. A proposed XP-SWMM model was created for preliminary design of the Gravity Bay Outlet alternative. Two options were analyzed for the conduit:

- A shallow box culvert following Fujita Road
- A wide, vegetated open channel following the bull-cart path to the north

For each conduit option the size was incrementally increased until it had sufficient hydraulic capacity to convey the design storm event. There are several options for the discharge structure at Tumon Bay. The following discharge options were reviewed:

- Discharge channel across beach with pedestrian bridge or boardwalk crossing
- Lagoon setback from beach that overtops during discharge events
- Diffuser structure that flows across beach during discharge events

Hydraulically, the discharge options are similar. The discharge channel consists of an open channel that conveys the culvert flow across the beach and into Tumon Bay. Prior to discharge, the Lagoon and Diffuser Structure options do not have a channel but the initial outflow will cut a channel through the top layer of beach sand. To maintain simplicity the Gravity Bay Outlet discharge structure was modeled as a channel.

Exhibit 3 in Appendix C displays a conceptual layout of the proposed Gravity Bay Outlet alternative. Table 5-5 shows the outlet conduit sizing required to discharge the series of design storm events.

Table 5-5 Gravity Bay Outlet Sizing

Design Storm	Culvert Option Size	Channel Option Size	Length (feet)	Maximum Discharge (cfs)
2-year	4' w x 4' h	10' btm w/ 4h:1v sides	1000	104
5-year	8' w x 4' h	15' btm w/ 4h:1v sides	1000	213
10-year	12' w x 4' h	20' btm w/ 4h:1v sides	1000	290
25-year	16' w x 4' h	25' btm w/ 4h:1v sides	1000	342

Source: Stanley Consultants, Inc.

The culvert options used a culvert opening height of 4 feet and were widened as required to convey the given design flow. The culvert would be constructed using open cut methods along Fujita Road.

The channel option requires additional width relative to the culvert option. This is because the channel will be shallower (approximately 3 feet full depth) and because it is vegetated, the channel creates more friction so will be less hydraulically efficient. The channel would be located along the existing bull-cart path that connects SVR to Tumon Bay Beach, just north of Fujita Pond. The labyrinth weir would be constructed in the northeast corner of the pond. The labyrinth weir would overtop and flow into a short concrete basin that would transition to an earthen, vegetated channel.

The channel would be excavated four to five feet into the existing ground. The bull-cart path would be located at the top of one of the channel banks. In addition to maintaining existing beach access, the bull-cart path will provide maintenance access for the channel. The 4h:1v side slopes are gradual enough that the vegetated channel sides could be traversed for debris removal, regrading, seeding and periodic mowing..

Channel Easement Requirements. GEPA indicated in project meetings that bull-cart paths are permanent public easements so there could be an opportunity to use the nearby bull-cart easement to develop the project. In review of the surrounding parcel boundaries it appears that the bull-cart path has a width of 12 feet, which can only contain the narrowest channel bottom and not the full channel width. The full channel (bottom and sides slopes) will require an additional 50 to 60 feet of acquisition width along the bull-cart path to accommodate the bull-cart path (10 feet) and the overflow channel (50 to 60 feet).

Fujita Road is a public roadway so no property acquisition is required for the culvert installation if it is installed underneath the road.

Bay Discharge Structures. Both conduit options will discharge at Tumon Bay. Three different bay discharge structures were reviewed during preliminary design. Each configuration is viable and they all provide the same hydraulic capacity so one does not more effectively solve the flooding issue than the other. Selection of a bay discharge

structure would need to come through regulatory, stakeholder and public input to establish the preferred structure.

The channel bay discharge option would involve excavating a shallow channel across the beach. The channel would be 20 to 30 feet wide and 4 feet deep. There are several aesthetic options for channel surfacing. A more stable channel requiring less maintenance would have walled sides with an armored bottom (i.e. articulated concrete block or equivalent). The side walls could be made of concrete block and look like natural stone and the bottom could be covered in sand so the armoring is hidden. This channel configuration would be more conducive to a pedestrian bridge or other crossing structure. If no crossing structure is preferred, the entire channel could be constructed using articulated concrete block with more gently sloping sides. The channel would be buried under a layer of sand and look similar to a tidal river. During heavy discharge events the sand would erode but only a thin layer because of the channel armoring. The discharge channel could also be constructed using limited structural material, but would require more maintenance following significant overflow events due to sand loss. Figure 5-6 shows an example of a channel with a pedestrian bridge.

Channel with Pedestrian Bridge Example
Figure 5-6

The lagoon discharge option would involve excavating a shallow lagoon behind the beach area. The culverts or channel would discharge into the lagoon. During significant overflow events the lagoon would overtop the beach and flow into the bay. The lagoon option is not feasible with the Fujita Road alignment. Property acquisition would be needed near the beach to create an area for lagoon construction. The lagoon does not have to be large but would need a minimum area of 40 feet by 40 feet to allow full construction.

The culverts or channel would flow into the lagoon. The lagoon would be deep enough that it would always have water. It could be sand-bottom and have vegetated sides to look like a natural feature. Small overflow events may not even overtop the beach and instead seep through the sand and into the bay. Larger overflow events would overtop the beach and flow into the bay. Beach sand replenishment would be required following the larger overflow events. Figure 5-7 shows an example of a lagoon discharge feature constructed by the City of Venice Beach, Florida.

Lagoon Discharge Example
Figure 5-7

The lagoon discharge feature was discussed with the Stormwater Manager for the City of Venice Beach. He indicated that the system has been in place for several years and works well relative to their pipe stormwater outlets. During significant overflow events, the stormwater erodes one to two feet of sand during discharge. However, wave action is sufficient at Venice Beach to restore the beach sand within several days of the overtopping event without additional maintenance. Given the limited wave action along Tumon Bay, manual beach restoration should be anticipated for the Gravity Bay Outlet.

The diffuser structure is a concrete box with a grated opening facing the beach. This structure would be used with the culvert option but not with the channel option. The box is wider than the culverts and has energy dissipation blocks inside to reduce velocity and spread the flow over a wider area. For the Fujita Pond overflow, the diffuser structure would be roughly 25 feet wide. The diffuser structure would be partially buried in the sand. During significant discharge events the initial outflow would push excess sand into the bay, exposing the full structure opening. Beach sand replenishment would be required following the larger overflow events.

Aesthetic enhancements could be made to the diffuser structure to allow it to blend in with the surroundings and/or serve dual use. The concrete could be stamped or painted to look like natural stone. The top of the diffuser structure could be used as a public picnic

or observation deck with benches and tables. Figure 5-8 shows an example of a diffuser structure also from Venice Beach.

Diffuser Structure Example
Figure 5-8

Both the conduit and channel options will have slopes and hydraulic grade lines less than 0.4 percent due to the small elevation difference between Fujita Pond and sea level. The gradual slope, along with the wider layout of the bay discharge options will keep overflow velocities below 3 to 4 feet per second. This magnitude of velocity is sufficient to move beach material, but not severe enough to create deep scour holes or other issues that could cause extensive damage to the beach and surrounding structures. Maintenance tasks will predominantly involve beach replenishment so hauling, moving and spreading beach sand.

Pump to Sink

This alternative would involve pumping Fujita Pond overflow up to one of the sink features near Marine Corps Drive. A pump station would be constructed at Fujita Pond and a new pipeline installed to carry flow from Fujita Pond to the sink. The sink would be used to percolate Fujita Pond overflow without discharging directly to the ocean or bay.

Design. A proposed XP-SWMM model was created for preliminary design of the Pump to Sink alternative. For each design storm the pipe diameter and number of pumps was incrementally increased until there was sufficient hydraulic capacity to convey the given design event and maintain Fujita Pond below an elevation of approximately 8.5 feet. Similar to the pumped ocean outlet, a maximum design velocity of approximately16 feet per second was used to establish the pipe diameter. The required percolation area at the sink was also estimated for each design flood.

The 15,000 gpm increment was used sizing pumps using the type and pricing provided by Fairbanks Nijhuis. The sink outfall option is a high head pumping application, the

nearest sink is approximately 80 vertical feet above Fujita Pond. Fairbanks Nijhuis recommended a combination of 15,000 gpm and 30,000 gpm vertical turbine pumps.

Exhibit 4 in Appendix C displays the conceptual layout of the proposed Pump to Sink alternative. Table 5-6 shows the pipe, pump, and sink area sizing required to discharge and percolate the series of design storm events.

Table 5-6 Pump to Sink Pump/Pipe/Sink Sizing

Design Storm	Pipe Dia. (inches)	Pipe Length (feet)	15K GPM Pumps	Sink Area	Discharge Capacity (cfs)
2-year	36	6500	3	1.1	100
5-year	48	6500	6	2	200
10-year	54	6500	8	2.7	267
25-year	60	6500	10	3.8	334

Source: Stanley Consultants, Inc.

Sink Discharge. The pipe length and pump sizing is controlled by the sink location. There are several sink formations located near Marine Corps Drive south of Fujita Pond. The nearest formation was determined to be roughly 1500 feet southwest of John F. Kennedy (JFK) High School. Figure 5-9 shows a photo of the sink area used in Pump to Sink preliminary design.

Sink near JFK High School
Figure 5-9

Stanley Consultants has been involved with percolation tests on the north end of Guam at similar sink formations. Based on results of percolation tests a rate of 20 inches per hour was assumed for the sink formation. A maximum ponded depth of 8 feet was assumed based on the layout of the existing sink. The sink area required for each design storm event was then calculated using the discharge hydrograph and increasing the sink area size until the maximum ponded depth was below 8 feet.

The existing fenced sink area shown in Figure 5-9 is less than 1 acre. As shown in Table 5-6, the design storm events would require a sink area ranging between 1.1 to 3.8 acres, so all except the 2-year design would require land acquisition and expansion of the sink area. Note the required area was computed without assuming additional stormwater inflow from other areas. The proposed sink area may be slightly larger due to the volume of stormwater already entering the sink from surrounding properties. If the Pump to Sink alternative moves forward, soil borings and percolation tests of the proposed sink area would be needed to more accurately establish the required discharge area.

Several other sink formations were located at distances further away from Fujita Pond. Similar to the proposed sink discharge location, all were surrounded by development and did not provide enough additional area to avoid land acquisition.

Pipe Layout. Public right-of-way (i.e. roadways, public property) was used to the extent possible in establishing the preliminary alignment of the proposed pipeline from Fujita Pond to the sink area. The alignment shown on Exhibit 4 is approximately 6500 feet long, so a significantly longer pipe than required by the ocean outlet alternatives.

The pipe diameter varies from 36 inches to 60 inches. Concrete pipe was assumed for all design storms. High Density PolyEthylene (HDPE) could be another option but would have minimal impact on schedule and pricing so is not significant to this analysis. Approximately 3800 feet of pipe would be installed along SVR. The pipe is pressurized so a constant downstream flow line profile is not required and the pipe profile can vary to minimize utility impacts. The remaining 2700 feet would be installed through the JFK High School property under the athletic fields and local roadways leading to the sink area.

Pipe construction along SVR will be challenging. There is dense development and the roadway is a major transportation route for residents and tourists. The pipe alignment will encounter numerous utility crossings which will require moving either the pipe or the existing utility. There is a waterline, two sanitary sewer lines (one in service, one for future development), a storm sewer line, and other conduits (electrical, telephone, cable, etc.). There are numerous businesses lining SVR and all have connections to these utilities. Given that its diameter is 36 inches or larger, the proposed pipe will need to be set below most of these utilities. Construction will require closing two lanes of SVR and reducing traffic from four lanes to two lanes. Staging and routing traffic during construction will be a major design and construction task.

Pipe installation across the JFK high school property will be more straightforward but may need to be scheduled minimize disruption of athletic facilities during the school

session. As shown on the Exhibit 4 surface elevation profile, the high school property sits at approximately elevation 140 feet. The proposed pipeline will either need to ascend the steep slope up to the property or could potentially be directionally drilled at a 40 to 50 foot depth and daylight near the sink location at elevation 90 feet. The proposed pipe would then outlet into the expanded sink area.

Directional drilling is also a possibility for the SVR portion of pipe installation. However, this construction will be more expensive than the open cut method so was not included in the analysis.

Pump Station. The pump station for the Pump to Sink alternative would be a similar layout to the Gravity/Pump Ocean Outlet. The pump station would be located along Fujita Road and pump Fujita Pond Overflow into the proposed pipeline route following SVR.

Pumping to a sink will require a higher head pump than the Gravity/Pump Ocean Outlet. In consultation with Fairbanks Nijhuis, pricing was obtained for a 15K gpm pump and a 30K gpm pump with 100 feet of head. The 30K gpm pump was roughly three times the cost of the 15K gpm pump, so only 15K gpm pumps were used for the Pump to Sink alternative.

Three to ten pumps would be required to sufficiently discharge the 2-year to 25-year design storm event. High head, high flow pumps require significant power to start and run at full capacity. Each 15K gpm pump would have a 450 horsepower (HP) motor. Given the large power demand and with pumps needing to run during adverse weather conditions, the decision was made to supply power using diesel generators housed within the pump station rather than connecting to the Guam power grid. Using generators removes the risk of power failure but it adds another set of equipment that will require inspection and maintenance.

The series of pumps would cycle on and off based on water level within the intake chamber. All overflow events would need to be pumped. There is no gravity outlet that could convey Fujita Pond Overflow. This puts an even greater dependence on maintaining pumps and generators in operating condition. Similar to the other Fujita Pond overflow alternatives, the Pump to Sink system may only run one to two times per year, but if the pumps do not work, the system will provide no flood relief.

Pump to Quarry

This alternative would involve pumping Fujita Pond overflow up to the abandoned quarry between the Hilton Hotel entrance and the SVR roundabout. A pump station would be constructed at Fujita Pond and a new pipeline installed to carry flow from Fujita Pond to the quarry. Similar to the sink alternative, the quarry would be used to percolate Fujita Pond overflow without discharging directly to the ocean or bay.

Design. A proposed XP-SWMM model was created for preliminary design of the Pump to Quarry alternative. For each design storm the pipe diameter and number of pumps was incrementally increased until there was sufficient hydraulic capacity to convey the given

design event and maintain Fujita Pond below an elevation of approximately 8.5 feet. Similar to other pumped outlets, a maximum design velocity of approximately16 feet per second was used to establish the pipe diameter.

Exhibit 5 in Appendix C, displays the conceptual layout of the proposed Pump to Quarry alternative. Table 5-7 shows the pipe and pump sizing required to discharge and infiltrate the series of design storm events.

Table 5-7 Pump to Quarry Pump/Pipe Sizing

Design Storm	Pipe Dia. (inches)	Pipe Length (feet)	15K GPM Pumps	Discharge Capacity (cfs)
2-year	36	8400	3	100
5-year	48	8400	6	200
10-year	54	8400	8	267
25-year	60	8400	10	334

Source: Stanley Consultants, Inc.

Quarry Discharge. The quarry has an area of approximately 8 acres so it is significantly larger than the sink formations. The quarry is over 50 feet deep so provides more than enough capacity to receive, store, and infiltrate the Fujita Pond overflow for the full range of design storm events. Figure 5-10 shows a photograph of the quarry area.

View of Quarry Area
Figure 5-10

The quarry is owned by a single private entity and the site would need to be acquired to develop the stormwater percolation area. In its current state, the site could not easily be developed. Most of the property sits over 50 feet below the surrounding area. Quarry land could likely be purchased at a lower price than nearby undeveloped property. Some clearing and grading were assumed for installation of the outflow structure. Access down to the outflow area would also need to be constructed. For the flood mitigation project, no further clearing or construction was assumed on the property, but development of the stormwater outflow area could also include repurposing the site for natural habitat or recreation. There is sufficient area and depth that the percolation rate is not a critical issue. If this alternative moves forward though, soil borings and percolation tests should be taken of the area to establish the subsurface condition.

Pipe Layout. The proposed pipe alignment follows SVR from Fujita Pond to the Quarry. The alignment shown on Exhibit 5 is approximately 8400 feet long, approximately 1900 feet longer than the Pump to Sink alternative. The Quarry alignment has less vertical difference though so it requires more pipe, but would require slightly less pump head than the Pump to Sink alternative.

Similar to other pump alternatives, the pipe diameter varies from 36 inches to 60 inches. Approximately 8000 feet of pipe would be installed along SVR. As discussed with the Pump to Sink alternative, pipe construction along SVR will be challenging. Development density decreases west of the Pacific Islands Club, but there is little reduction in vehicle traffic. With 4000 feet of additional installation length along SVR, the extent and duration of impacts to SVR traffic and businesses will be more with the Pump to Quarry than the Pump to Sink alternative.

Pump Station. The pump station for the Pump to Quarry alternative would have a similar layout, pump requirements and power supply as the Pump to Sink alternative.

Similar to the Pump to Sink, there is no gravity outlet for the Pump to Quarry alternative. If pumps are inoperable or malfunction, the system will provide no flood relief from the existing condition.

Evaluation

The improvement alternatives were evaluated using a weighted alternatives rating matrix of project criteria. Eight project criteria were chosen to represent the range of project impacts (monetary and non-monetary). Each alternative provides a feasible solution, but has certain advantages and disadvantages in regards to its impacts. Each criteria included in the matrix was assigned a weight to represent its significance relative to other criteria. Table 5-8 lists the alternative evaluation criteria and associated weights.

Table 5-8 Alternative Evaluation Criteria

Criteria	Weight
Reduce Flooding	20
Cost Effective	15
Operation and Maintenance	15
Schedule	12
Constructability	10
Impact to Environment	10
Permitting Requirements	10
Public Perception	8

Source: Stanley Consultants, Inc.

Alternatives were compared using the evaluation criteria and scored based on the following scoring system:

0 – Criteria is negatively affected by alternative

1 – Criteria is not affected by alternative

2 – Criteria is positively affected by alternative

3 – Criteria is more positively affected by alternative

The alternatives rating matrix provides a quantitative method for evaluating and ranking alternatives. Each alternative is provided a score under each criteria. The scores and weights are then combined in the alternatives rating matrix and the alternatives are ranked. Figure 5-11 shows the blank alternatives rating matrix for the project.

COMPARISON CRITERIA >>	REDUCE FLOODING	COST EFFECTIVE	OPERATION AND MAINTENANCE	SCHEDULE	CONSTRUCTABILITY	IMPACT TO ENVIRONMENT	PERMITTING REQUIREMENTS	PUBLIC PERCEPTION	**TOTAL**	
WEIGHT (NO.) >>	20	15	15	12	10	10	10	8	**100**	
WEIGHT (%) >>	20	15	15	12	10	10	10	8	**100**	
ALTERNATIVE	**SCORE**									**RANK**
Expanded Detention										
Gravity Ocean Outlet										
Gravity/Pump Ocean Outlet										
Gravity Bay Outlet										
Pump to Sink										
Pump to Quarry										

Alternatives Rating Matrix
Figure 5-11

Discussion of the various alternative improvements under project criteria categories is provided in the following section.

Reduce Flooding

Reduction in the magnitude and duration of SVR flooding can be accomplished by:

- Providing additional inlet capacity to more effectively capture gutter flow before it reaches the low area of SVR.
- Providing an overflow outlet or additional storage volume for Fujita Pond that maintains a lower water elevation during flood events.

All six improvement alternatives were designed to provide an equivalent degree of flood mitigation. Installation of additional curb inlets along SVR was assumed for all improvement designs. The expanded detention and outlet alternatives maintain the same peak water level in Fujita Pond for the range of design flood events. However, the ocean and quarry outlet alternatives provide a slight advantage because they discharge to receiving waters that have additional capacity above the design flood events. The ocean and the quarry have significantly more volume available for receiving flood discharge than the expanded detention and sink areas. If a flood larger than a 25-year magnitude occurs, alternatives

discharging to the ocean and quarry will not be constrained by the volume of stormwater being received by either of these discharge areas. Whereas, the sink and expanded detention have a limited stormwater storage volume available so have less capacity to handle storm events exceeding their design volume.

Combined with the Fujita Pond overflow or expanded detention, the additional inlets will reduce the ponded width along SVR during high intensity rainfall events. Three options were analyzed. Option A which has the most conservative design objective of keeping the ponded width to one half a travel lane for the 10-year design storm provides the most effective reduction in flooding conditions. Note that there will be minimal benefit to adding inlets without also completing the Fujita Pond overflow or expanded detention to maintain a lower Fujita Pond level during flooding. Without the Fujita Pond improvements, many of the additional inlets will be submerged during a flood event because the flood level will be controlled by the water level in Fujita Pond not by the inlet capacity.

Cost Effective

At the outset of this study, GEDA indicated that approximately $12 million had been set aside for funding SVR flood mitigation. That $12 million was set as a benchmark comparison for estimated project costs for each alternative.

Sources. Alternative costs were estimated using cost input and data from a variety of sources. Healy Tibitts Builders, Inc provided a rough order of magnitude cost for Tumon Bay portion of the pipe installation for the ocean outlet options. Fairbanks Nijhuis provided pump sizing and pricing for the ocean outlet and sink/quarry options. Caterpillar, Inc. provided costs for the diesel generator and starter units required for the pump options. Stanley Consultants, Inc. has completed several construction projects on Guam and reference costs from prior projects were applied to the alternative cost estimates. Labor and material costs were discussed with Black Construction Corporation, a contractor that has completed numerous large projects on the island. Land costs were estimated based on discussions with a local Guam realty company who provided a range of square meter costs based on geographic location.

Cost Summary. The cost for the range of design events for each alternative is summarized in Table 5-9. Detailed cost estimate tabs are provided in Appendix D. Cost estimates include a 12 percent markup for engineering and permitting and a 20 percent contingency markup for undeveloped design details.

Table 5-9 Alternative Project Cost Estimates

Design Storm	Alternative					
	Expanded Detention	Gravity Ocean Outlet	Gravity/Pump Ocean Outlet	Gravity Bay Outlet	Pump to Sink	Pump to Quarry
2-year	$7.5 M	$18.4 M	$14.7 M	$4.8 M	$13.0 M	$14.2 M
5-year	$13.5 M	$24.9 M	$18.0 M	$5.2 M	$17.7 M	$18.4 M
10-year	$18.6 M	$26.0 M	$20.1 M	$5.7 M	$21.9 M	$22.0 M
25-year	$26.3 M	$27.1 M	$22.3 M	$6.1 M	$26.6 M	$26.0 M

Source: Stanley Consultants, Inc.

The Gravity Bay Outlet is the only alternative that can provide flood mitigation for the range of design storm events under the $12 million benchmark. The other pumping and outlet alternatives are significantly more expensive.

Expanded Detention. Land prices control the cost of the Expanded Detention alternative. In discussions with Guam-based realtors, the typical land value near SVR is approximately $500 per square meter. $500 per square meter translates to $2.3 million per acre. With each design event requiring between 2 to 10 additional acres of flood storage, the project cost is significant. If GovGuam can negotiate a land swap or other non-monetary compensation with one of the nearby property owners the Expanded Detention alternative cost will decrease significantly. Table 5-10 shows a summary of the maximum land cost for the series of design storm events that would keep the Expanded Detention alternative below $12 million.

Table 5-10 Maximum Land Costs

Design Storm	Pond Size (acre)	Land Cost	
		Per m^2	Per acre
2-yr	2.7	$500	$2.3M
5-yr	5.0	$430	$2.0M
10-yr	7.0	$290	$1.4M
25-yr	10.0	$190	$0.9M

Another cost associated with Expanded Detention is loss of future development and tax revenue. Expanded Detention will use several acres that could otherwise be used for hotels, shops, or other commercial or recreational uses. The property will be GovGuam owned so will provide no tax revenue in an area of high value, high revenue property.

Ocean Outlets. The major item defining ocean outlet costs is the pipe installation under Tumon Bay. Healy Tibbidts estimated a minimum of $12.6 million for marine pipe

installation for the micro-tunneling option and a minimum of $17.3 million for the open cut option. GWA supplied some of its documents for the Hagatna Ocean Outfall project which involved installation of a new outfall for the Agana Sewage Treatment Plant. The project involved horizontal directional drill installation of approximately 2200 linear feet of 42 inch HDPE in Hagatna Bay so a similar project size to the Ocean Outlet alternatives. The accepted bid price for the project was $17.6 million in 2006 which is a similar cost magnitude to the Heally Tibbidts estimate.

Pump Alternatives. The major item defining the pump alternatives is pipe and pump installation. Pipe installation along SVR will be complex and costly. The pipe trench will uncover numerous utility crossings as well as removing two traffic lanes from service along the construction area. Rerouting traffic and numerous utility conflicts drive up the pipe installation cost. When applied over several thousand feet of pipe alignment, the pipe installation costs alone range from $8-$11 million. Pump costs were significant as well. The low head pumps for the ocean outlet were more economical at $180,000 for the 15K gpm unit ($12/gpm) and $250,000 for the 30K gpm unit ($8/gpm). The high head pumps were more expensive with $230,000 for the 15K gpm unit ($15/gpm) and $750,000 for the 30K gpm unit ($25/gpm). The jump in price for the 30K gpm high head pump was because it required a two stage pump. This meant using more pumps for the Pump to Sink and Pump to Quarry alternatives which drove up pump station building costs. Due to their large power requirement the Pump to Sink and Pump to Quarry alternatives also used massive diesel generators which were $3-4 million just for the generator systems.

Gravity Bay Outlet. The Gravity Bay Outlet is more economical because construction is landward of Tumon Bay. Installation will either follow an existing storm sewer alignment (culvert option along Fujita Road) with limited traffic or undeveloped land (channel option along bull-cart path) which will keep conduit installation costs lower than other alternatives. At 1000 feet the pipe installation length is several thousand feet less than other pipe alternatives. Pipe/channel installation costs for this alternative are significantly lower per linear foot than other alternatives. A shorter length with less expensive installation costs provides a significant reduction in total project cost. The Gravity Bay Outlet also does not use any mechanical equipment so there is no procurement or associated power hookup or supply cost. The cost of land acquisition and bay discharge structure construction is smaller relative to other alternatives and could be completed for less than $3 million.

Additional Inlets. Three inlet options were priced for the potential improvement alternatives. The inlet design objectives and estimated installation costs are summarized in Table 5-11.

Table 5-11 Additional Inlet Options

Option	Design Objective	Additional Inlets	Cost
A	Pond < ½ lane	47	$450,000
B	Pond < 1 lane	34	$350,000
C	Add inlets at low points	16	$150,000

Source: Stanley Consultants, Inc.

Option A meets the applicable roadway design requirements and most effectively reduces flooding. The cost for installing Option A was added to each of the improvement alternatives and is reflected in the total estimated project costs. Detailed quantity and cost estimates for the additional inlet options are provided in Appendix D.

Operation and Maintenance

Alternatives can be grouped into two categories for operation and maintenance.

- Pump Alternatives: High Operation and Maintenance Requirements
- Other Alternatives: Low Operation and Maintenance Requirements

Pump Alternatives. The pumps and associated equipment are large, complex mechanical systems. Their ability to operate when needed (i.e. during flood events) is totally dependent upon periodic maintenance and testing. The Fujita Pond stormwater pumps would only operate a few times a year and some years they would not operate at all. As seen during the 19-Sept and 10-Oct events, flooding can occur within an hour or two of the first rainfall. If maintenance slides or pumps are inoperable when that rainfall occurs, there is not enough time to repair pumps prior to flooding low areas of SVR. If pumps do not operate during a flood event, there will be no reduction in flooding compared to the existing condition and a large sum of money will have been spent without benefit.

Maintenance of the pumping system would involve periodic inspection, testing, and cleaning of equipment on the order of two to three times per year. Design of the pump alternatives would include development of an operation and maintenance manual that would provide step-by-step procedures and scheduling for the operation and maintenance tasks. As a public system it would be GovGuam's responsibility to designate staff to perform and keep record of operation and maintenance tasks. If testing indicates potential issues with equipment, GovGuam would contract with repair personnel to fix the issue immediately so the system remains fully operational. Operation and maintenance could also be contracted but would increase yearly costs of the project.

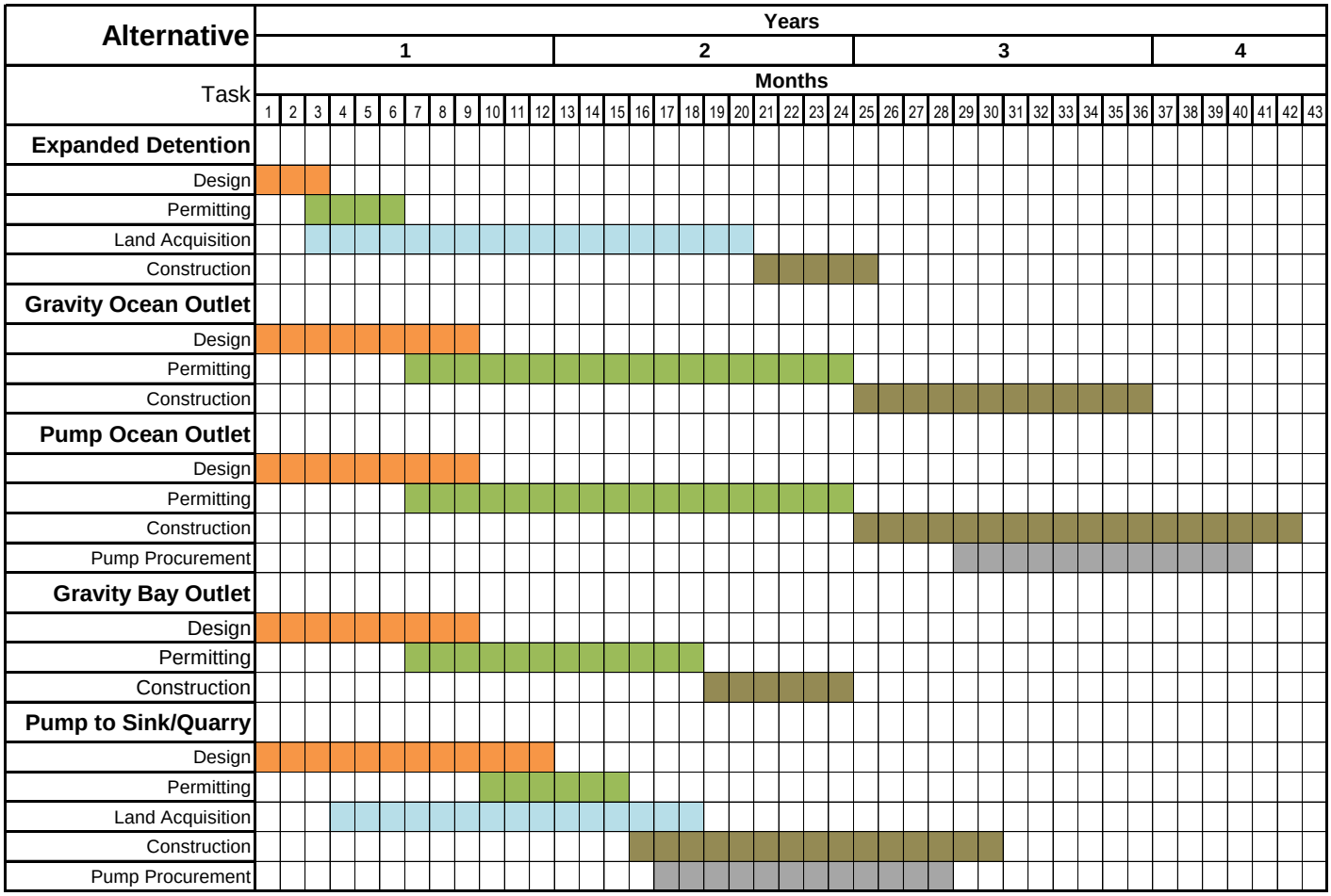
Other Alternatives. The Expanded Detention, Ocean Outlet, and Bay Outlet alternatives are relatively low operation and maintenance systems. Expanded Detention involves creating a larger Fujita Pond. If aesthetic improvements are made to the Expanded Detention such as landscaping or trails, these will need to be maintained similar to any other public recreation facility. In addition to stormwater, detention/infiltration ponds receive sediments and other particles that settle out as the stormwater percolates. Over a period of years these sediments build up on the bottom of the pond and reduce the infiltration rate and decrease water quality. Many municipalities with stormwater ponds have a maintenance plan that includes draining and removing excess sediment every 5 years. In between sediment removal, maintenance is fairly minimal and can include measuring sediment depths, taking periodic water quality samples, mowing, and removal of floating debris.

Once installed, the Gravity Ocean Outlet will have the least maintenance requirements. Maintenance will mostly involve periodic inspection. The discharge point beyond the reef should be inspected by divers on a yearly or biyearly basis to look for screen blockage or potential for clogging from shifting sand beds. The outflow pipe will be submerged but could be inspected by remote operated vehicle every few years. Fujita Pond and the labyrinth weir can be visually inspected by maintenance staff. Similar to the Expanded Detention, Fujita Pond should be cleaned out every 5 years.

The Gravity Bay Outlet will have more maintenance than the Gravity Ocean Outlet due to its discharge across the Tumon Bay beach. Following every overflow event, the discharge area will require inspection and then sand replenishment and grading to restore the sand that will have been pushed into the water by the bay discharge. Beach replenishment will be relatively simple and inexpensive. Additional sand will be hauled in via truck. A small front end loader could be used to spread the sand and may be able to scrape sand near shore back into place to minimize new sand placement. Smaller overflow events could likely be restored using wheelbarrows and rakes. Given the heavy use of Tumon Bay it will be important to perform beach replenishment as soon as possible following the overflow event. During a wet year, these overflow events could occur several times, so personnel should be identified and adequately supplied to carry out beach restoration in a timely manner.

Schedules

Schedules for each alternative were estimated using construction quantities and task duration estimates. Detailed schedules are provided in Appendix E. Figure 5-12 displays a summary schedule showing basic project tasks.



Summary Schedule
Figure 5-12

The Expanded Detention and Gravity Bay Outlet alternatives have the shortest estimated schedule at approximately 2 years. The Expanded Detention schedule could be reduced further if land acquisition negotiation progresses efficiently. There is also a risk that the Expanded Detention schedule could be delayed if construction uncovers historical remains or artifacts that require mitigation. All ocean and bay outlet schedules assume long permitting tasks due to the number of agencies involved in ocean discharge and water quality concerns. The Pump to Sink and Pump to Quarry alternatives have a shorter permitting schedule because they do not discharge into the Ocean. However, the pump alternatives involve more complex design and construction as well as procurement of pumps so that extends the project schedule out to 2.5 years. The longest schedules are for the two ocean outlets. It is assumed that permitting will take over a year and then due to the length of pipe and complexity of construction, construction will also take over a year. The estimated schedule for ocean outlet alternatives is 3+ years.

Constructability

Constructability refers to the degree complexity and risk associated with project construction.

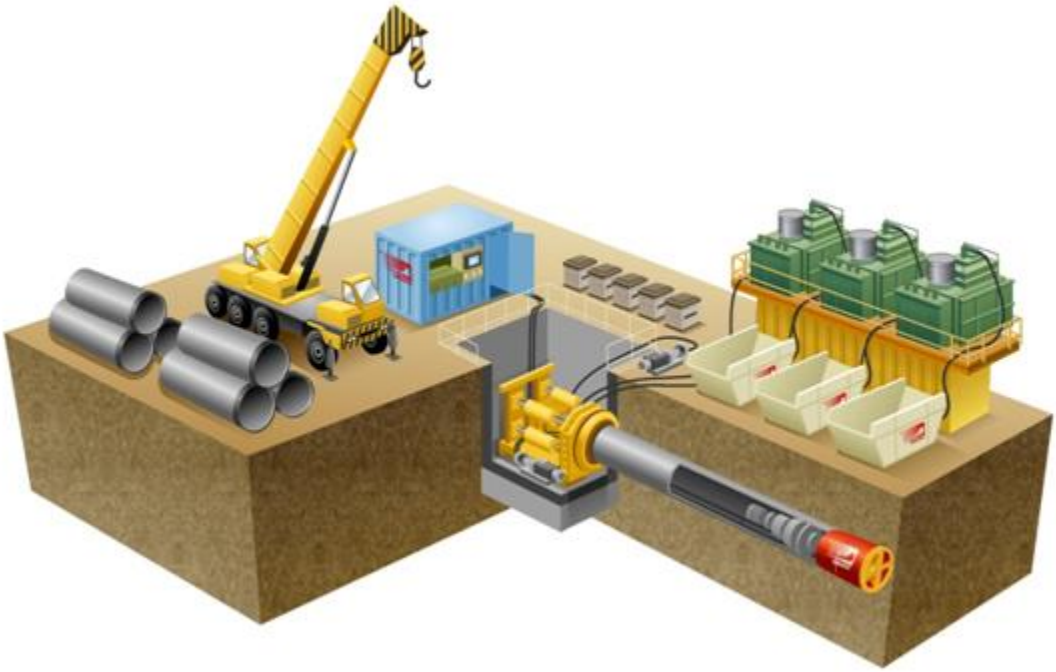
Expanded Detention. By far, the simplest alternative to construct would be Expanded Detention. Construction tasks for this alternative would involve grading and culvert installation. There are several contractors located on Guam that would be qualified to complete this work. Complexity and risk are low.

Gravity Bay Outlet. The Gravity Bay Outlet alternative is similar. There are more regulatory tasks associated with this alternative but construction involves labyrinth weir construction, culvert installation or channel grading, and construction of a simple discharge feature. The labyrinth weir is a concrete wall with a rounded top so is not a difficult feature to construct. Culvert installation and channel grading along the Gravity Bay Outlet alignments are construction tasks that any small grading or street construction contractor has capacity to complete. The discharge feature is set back from the water line so can be completed with basic erosion and sediment control measures protecting the bay.

Gravity Ocean Outlet. The Gravity Ocean Outlet is similar to the Gravity Bay Outlet until the end of Fujita Road. From Fujita Road to outside the Tumon Bay Reef, the open cut or trenchless micro-tunnel pipe installation methods are specialized construction that will likely require an off-island contractor to complete. As evident by the multi-million dollar cost, marine pipe installation is complex and is associated with a higher level of risk than pipe installation on dry land.

The Hagatna Ocean Outfall project provides several examples of the risk associated with marine construction. When the original pipe alignment was 75 percent complete a pipe section became stuck in the borehole and could not be removed. The remaining pipe was removed and an entirely new pipe alignment drilled at significant delay and additional cost to the project. The remotely operated boring machine also encountered an unknown metal object that was thought to be an unexploded device. Divers were sent down to investigate and verified that the object was not dangerous but the project was delayed by several weeks.

The trenchless method provides more efficient installation (i.e. faster) and less disturbance of Tumon Bay but has a higher degree of risk due to unknown subsurface conditions. The open cut method provides less efficient installation (i.e. slower) and greater disturbance of Tumon Bay, but has less associated risk due to fewer unknowns. Both methods would require significant equipment and expertise for ocean outlet construction. Figure 5-13 shows a schematic of a micro-tunneling operation from www.terratec.com.au.



Micro-Tunneling Operation
Figure 5-13

Pump to Sink/Quarry. The Pump to Sink and Pump to Quarry alternatives involve fairly standard municipal construction. However, given the length of the project, the significant development surrounding much of the pipe alignment, and the construction staging and traffic routing, project construction becomes much more complex than a pipe installation through less developed areas. Specialized contractors are not needed for standard open cut pipe installation in the street. However, the complexity of the job will require an experienced and organized contractor to manage the construction efficiently.

The pump station housing is similar to a small industrial warehouse or storage structure. Pumps and associated equipment will be procured from manufacturers who will ship the equipment to the site and can also provide technical staff to assist with installation and equipment start-up. Installation of pumps and generators is not specialized construction and there are several mechanical and electrical subcontractors on Guam that can provide installation services. A thorough installation and startup process will be key to providing a functioning pump station. Shortcuts, missed steps, or misplaced information during construction will cause future issues with operation and maintenance so having an organized and competent general contractor managing the variety of subcontractors and vendors involved with installation and setup is important.

Impact to Environment

Currently when Fujita Pond fills up following significant rainfall events, SVR floods and Fujita Pond overtops its northeast corner. The proposed improvement alternatives mitigate the flooding but the excess stormwater has to go somewhere so each improvement alternative has its own set of impacts to the surrounding environment.

Expanded Detention. Expanded Detention provides additional area and volume to store and infiltrate stormwater. This is how stormwater currently leaves Fujita Pond during non-flood conditions so Expanded Detention just increases the infiltration area. This alternative will have minimal change in impact from the existing condition. The major impact associated with Expanded Detention will be during excavation. In discussions with SHPO and developers in the area, there is a high probability that the proposed excavation associated with expanding Fujita Pond will encounter and disturb historical remains and artifacts. A mitigation plan will be necessary and if required, mitigation could increase the project schedule by several months.

Ocean Outlets. Currently, the stormwater draining to Fujita Pond ends up in Tumon Bay. The majority of stormwater enters Tumon Bay through groundwater infiltration but a small volume enters Tumon Bay when Fujita Pond overtops and flows towards Tumon Bay. The ocean and bay outlets will be similar in that during most rainfall events Fujita Pond will infiltrate stormwater. During rainfall events exceeding 3.5 inches, Fujita Pond will overflow and discharge via the ocean or bay outlets. These alternatives provide a more direct connection to Tumon Bay. The Ocean Outlet alternatives discharge beyond the reef and at a depth where the stormwater discharge will be significantly diluted prior to reaching the surface waters so their potential impact is less than the Gravity Bay Alternative.

Gravity Bay Outlet. The Gravity Bay Alternative will discharge across the beach and into Tumon Bay. What overflows the labyrinth weir in Fujita Pond will flow into Tumon Bay. The channel option will provide some filtering via vegetation lining the channel but not enough if stormwater is contains significant pollutants. The Fujita Pond sanitary sewage pump station had a history of overflowing into Fujita Pond. GWA indicated that the pumps and backup generators were upgraded several years ago and the risk of sewage spills from the pump station has been significantly reduced. Review of Fujita beach water quality monitoring indicates there have been limited elevated bacteria counts in Tumon Bay and none of the level that would be associated with that scale of spill. This is not to suggest that the risk does not exist. Or that there is not the possibility for smaller contamination via sanitary sewer manholes overflowing during flood events.

Stanley Consultants and EA Engineering have begun a Fujita Pond water quality testing program to assess water quality in Fujita Pond over a range of rainfall and flow conditions. Samples will be taken during dry periods, following light rainfall events, and following heavy rainfall events to establish a pattern of stormwater quality in Fujita Pond. If the pond sampling results in water samples that consistently exceed GEPA criteria for stormwater, the Gravity Bay Outlet will either be eliminated from consideration or coupled with additional water quality treatment measures. If pond sampling results in

water samples that meet GEPA criteria for stormwater, then the decision will need to be made if the benefit gained by flood mitigation sufficiently offsets the risk to Tumon Bay.

Coastal outfall water quality was discussed with the Stormwater Engineering Manager of the City of Venice Beach, Florida. The City of Venice Beach maintains ten coastal stormwater outfalls into the Gulf of Mexico. Most of their stormwater outfalls are directly connected to the storm sewer system, meaning all storm sewer flow discharges into the gulf. The biggest spikes in bacteria counts are experienced during the dry season, so following the first flush of stormwater discharge into the Gulf. The Gravity Bay Outlet will only discharge following significant rainfalls, so the fact that it is an overflow system reduces the frequency of discharge events relative to a direct outlet system.

The types of coastal outfalls maintained by the City of Venice Beach vary, some are pipe outfalls and others are lagoons or detention areas. Outlets with lagoons or detention areas are associated with fewer elevated bacteria incidents than the pipe outlet systems. Systems that are associated with the most elevated bacteria incidents are closed pipe systems that continually hold stormwater. The closed system allows the stormwater to become anaerobic (i.e. oxygen starved) which allows proliferation of bacteria. Open air systems, such as ponds have less opportunity for anaerobic conditions and can provide some settling and biotreatment to maintain lower relative bacteria levels. With Fujita Pond, the Gravity Bay Outlet is an open air system because stormwater is discharged from the top of the pond via the labyrinth weir. Surface weeds and algae diminish the oxygenation of the pond so to maintain higher water quality an aeration system (i.e. bubbler) or more frequent removal of surface weeds at Fujita Pond may be necessary.

Open air systems are still at risk of elevated bacteria levels if there is a connection or overflow from the sanitary sewer system. Management of the Gravity Bay Outlet should include periodic sampling of Fujita Pond to monitor pond bacteria levels. Sunlight, sedimentation, and infiltration are known to reduce bacteria levels. Fujita Pond has all of these features. If high bacteria levels are detected during dry conditions, the pond water could be disinfected using chlorine or ozone. However, a more direct connection to sanitary sewer such as overflow during a rainfall event could elevate bacteria levels and result in discharge prior to potential treatment of bacteria. There will always be potential for stormwater with elevated bacteria levels discharging into Tumon Bay, but there are several features of the Gravity Bay Outlet and potential maintenance options that can reduce the opportunity.

Pump to Sink/Quary. The environmental impact associated with the Pump to Sink and Pump to Quarry options are primarily at the discharge locations. The improvements at Fujita Pond and the pipe installation impact developed areas so will have minimal environmental impact once constructed. Construction will have a significant impact to traffic and local businesses along the pipe alignment, but the impact is only temporary.

The Pump to Sink alternative will discharge excess stormwater to an existing sink formation near Marine Corps Drive. These sink formations have historically been used as stormwater discharge areas and have a high capacity for infiltrating stormwater. Sinks

provide filtering of stormwater but they are likely not a failsafe for preventing contaminants from reaching Tumon Bay. In their 2004 dye trace study [13] WERI concluded that "observations of rapid dye transport to the coast indicated that initial pulses of contaminants released into the water table at the airport or into Harmon Sink could discharge into recreational waters of Agana and Tumon Bays in a matter of days." Relative to the bay and ocean discharge alternatives the sink alternative provides a reduction in the potential impact to Tumon Bay water quality but it does not eliminate the risk of Tumon Bay contamination.

A sink is not engineered or constructed, it is a natural feature. Its capacity for receiving the 40+ ac-ft of stormwater from the Fujita Pond pump station and potential response is not certain. The nearby sink formations are surrounded by development. There is always the risk that additional, intensive stormwater inflow could create larger fractures and pathways in the sink formation, causing an expansion of the sink that could extend towards developed properties.

The environmental impacts at the Quarry location are less than the Sink location. The Quarry is large and deep enough that the stormwater inflow from the Fujita Pond will have less impact to the underlying rock and soils because it can be distributed over a larger area. The Quarry has already been excavated approximately 50 feet below the surrounding topography so there is negligible risk of finding historical remains or artifacts during construction. The infiltration rates at the Quarry are unknown. Periodically inundating the low area of the Quarry may kill off some vegetation if this area holds water for several days. The lowest area could be cleared, graded and seeded with water tolerant vegetation so the stormwater inflow has minimal impact on surrounding areas. If the Quarry does have lower infiltration rates, then it may provide improved water quality protection for Tumon Bay over the Pump to Sink Alternative because the stormwater will have a longer residence time. Similar infiltration rates to the Sink formation will suggest that there is a more direct connection between subsurface Quarry fractures and Tumon Bay.

Permitting Requirements

All improvement alternatives will require receiving regulatory approval through a series of permits. The Ocean/Bay Outlet alternatives require more permits than other alternatives due to their discharging into Federal Waters. Table 5-12 shows required permits and permitting timeframe for the improvement alternatives.

Table 5-12 Permit Requirements

Alternative	Permit					Estimated Permitting Timeframe
	Guam EPA NPDES	Guam EPA 401 WQC	Guam EPA EIA	USACE Permit	Guam Coastal Mgmt	
Expanded Detention	X		X	X	X	4 months
Gravity Ocean Outlet	X	X	X	X	X	18 months
Pump/Gravity Ocean Outlet	X	X	X			18 months
Gravity Bay Outlet	X		X		X	18 months
Pump to Sink	X		X			6 months
Pump to Quarry	X		X			6 months

Source: Stanley Consultants, Inc.

National Pollutant Discharge Elimination System (NPDES). NPDES is a federal permit for all storm water and point source pollution discharges. Guam EPA reviews and certifies NPDES permits for compliance with all local regulations and policies and in accordance with the Guam Water Quality Standards. Then the U.S. EPA coordinates, drafts and issues the permit for the project. Due to their discharge to water of the U.S. Ocean/Bay outlet options will receive higher scrutiny. NPDES Permit issuance for those projects may take between one to two years. The Expanded Detention and Pump to Sink/Quarry alternatives discharge to detention/infiltration basins so their NPDES permitting process is anticipated to be much more streamlined and only take a matter of months.

The NPDES program also regulates stormwater discharge during construction. The construction associated with all improvement alternatives will require obtaining coverage under the U.S. EPA issued General Permit for Discharges from Construction Activities (General Permit). Compliance with the General Permit requires development of a SWPPP, erosion control plan and other measures to provide instruction to the contractor for minimizing the potential for pollution due to construction activities. The process is fairly streamlined and the required documentation can be developed during detailed design and then the contractor can typically receive coverage between selection and mobilization.

Section 401 Water Quality Certification (401 WQC). A number of federal permits, most of which are identified in the Federal Clean Water Act, for construction, fill, dredging, and discharges to Waters of the U.S. and Guam Waters require Guam Section 401 WQC from Guam EPA. 401 WQC issuance identifies that construction or operation of a proposed project or facility will be conducted in a manner consistent with the Guam Water Quality Standards. All federal permits for work in marine waters, rivers, streams and wetlands require 401 WQC. Note that this permit covers construction, not discharge

within water of the U.S. and Guam. Only the Ocean Outlet Alternatives require work below the mean tide level so they need a 401 WQC. The NPDES permit and Guam Coastal Management review are the process used to regulate discharge.

Environmental Impact Assessment/Statement. Environmental Impact Assessments (EIAs) are required for all zone change, variance, wetland, seashore, and conditional use permits submitted to the Guam Land Use Commission and Seashore Protection Commissions (GLUC/TSPC). Environmental Impact Statements (EIS) may be required if anticipated impacts will cause the significant loss, damage or degradation of resources. These plans require comprehensive mitigation plans. EIA's may be required for other significant development proposals on a case by case basis, outside the scope of the Executive Order, by the Administrator.

The Ocean/Bay outlets will require more substantial environmental review than the Expanded Detention and Pump to Sink/Quarry Alternatives. An EIS is a much more substantial and time-consuming process than an EIA. EIA's can be completed in a matter of months. An EIS can take over a year. The decision as to whether a project requires and EIS, EIA or minimal impact assessment is made by GLUC/TSPC on a case by case basis. The assumption made for the permitting timeline is the Ocean/Bay outlets would require an EIS or more detailed EIA and the Expanded Detention and Pump to Sink/Quarry alternatives would require a smaller scale EIA or minimal environmental assessment.

As mentioned previously, the Expanded Detention project could be slowed down if historical remains or artifacts are discovered within the project area. A preliminary archaeological study that includes "potholing" and evaluating the potential for artifacts within the area is recommended during the permitting and design process. The additional time to perform mitigation of the proposed project area has not been included in the project schedule.

U.S. Army Corps of Engineers Permit. A USACE permit is required for projects that involve work within Waters of the U.S. There are two permitting tracks for USACE permits:

- Nationwide Permit: Issued for smaller scale, standard construction projects with minimal environmental risk. Timeline is typically less than 30 days.
- Individual Permit: Issued for larger scale or complex construction projects with greater environmental risk. Individual permits see closer scrutiny and have longer review periods. Timeline is typically 60 to 120 days, potentially longer for controversial projects.

The Ocean/Bay Outlet alternatives will require a USACE Permit. The permitting track will likely be through the Individual Permit.

Guam Coastal Management Program. The entire island of Guam has been designated a "coastal zone". The Guam Bureau of Statistics and Plans, has been designated as the lead agency of the Guam Coastal Management Program and is responsible for conducting

federal consistence review for activities that require a Federal permit (i.e. discharging to the Waters of the U.S.).

In addition to the permitting agency, all permitting documents will also be routed through the Guam Coastal Management Program for review and comment. This only applies to the Ocean/Bay Outlet alternatives which would impact the coastal zone.

Timeline. The Ocean/Bay Outlet alternatives will go through a more substantial regulatory review process than the Expanded Detention and Pump to Sink/Quarry alternatives. As such, the permitting timeline for the Ocean/Bay Outlet alternatives is approximately 1 year longer. The Gravity Bay Outlet requires fewer permits than the Ocean Outlet but its review process is anticipated to have a similar schedule due to substantial environmental study that will be required.

With all alternatives it will be important to engage agencies early in the design and review process so issues are resolved early rather than later in the project where design changes and delays could be more detrimental to the project.

Public Perception

Public perception of the proposed improvement alternatives was gaged during presentations of the preliminary project findings. A presentation of the six improvement alternatives was given to several agencies, stakeholders, and business owners during the week of December 16, 2013. The response to the improvement alternatives was fairly consistent between groups. Expanded Detention was the preferred alternative followed by the Pump to Sink, Pump to Quarry options. The Ocean/Bay Outlet alternatives caused concern over potential impacts to Tumon Bay. The potential impact of the Gravity Bay Outlet was a discussion topic amongst all groups and was least favored as a general concept, but not necessarily opposed.

Public perception does not necessarily dictate which alternatives are viable but it does highlight the degree of public education and involvement that will be required to bring alternatives to construction. Expanded Detention could likely be brought to construction without having to shift public perception of the project. The Gravity Bay Outlet would likely require significant public education and involvement to address concerns over the potential impact of the project and shift public perception towards acceptance.

Matrix Scoring

Scoring was assigned to the improvement alternatives for each project criteria. Scoring was based on the discussion covered in the previous sections. Certain alternatives have specific advantages over other alternatives and this scoring provides a method to compare and rank the alternatives quantitatively in addition to providing a narrative comparison. Figure 5-14 displays the alternative rating matrix for the project.

Scoring:
0 Criteria is negatively affected by alternative.
1 Criteria not affected by alternative.
2 Criteria is positively affected by alternative.
3 Criteria is more positively affected by alternative.

COMPARISON CRITERIA >>	REDUCE FLOODING	COST EFFECTIVE	OPERATION AND MAINTENANCE	SCHEDULE	CONSTRUCTABILITY	IMPACT TO ENVIRONMENT	PERMITTING REQUIREMENTS	PUBLIC PERCEPTION	**TOTAL**	
WEIGHT (NO.) >>	20	15	15	12	10	10	10	8	**100**	
WEIGHT (%) >>	20	15	15	12	10	10	10	8	**100**	
ALTERNATIVE	**SCORE**									**RANK**
Expanded Detention	1	1	3	1	3	3	3	3	**206**	**1**
Gravity Ocean Outlet	3	0	2	1	1	1	1	1	**140**	**3**
Gravity/Pump Ocean Outlet	2	0	0	0	1	1	1	1	**78**	**6**
Gravity Bay Outlet	3	3	2	2	3	0	1	0	**199**	**2**
Pump to Sink	2	0	0	1	1	1	2	2	**108**	**5**
Pump to Quarry	2	0	0	1	1	3	2	2	**128**	**4**

Alternatives Rating Matrix
Figure 5-14

As shown in Figure 5-14, Expanded Detention is the highest ranked alternative followed closely by the Gravity Bay Outlet. Expanded Detention is easy to permit and construct, has less impact to the environment and would likely be accepted by the public. For flood reduction, the disadvantage of Expanded Detention is that its flood mitigation is based upon storage volume and not overflow. If a rainfall occurs that exceeds its design storm (i.e. 50-year storm, 100-year storm, etc.), it will cause similar flooding to what currently occurs on SVR. Expanded Detention also will not be a viable alternative unless land can be acquired or swapped at a discount. The project is land cost driven. The project will cost upwards of $15 million at current land value estimates which exceeds the original project allotment of $12 million. A 2-year design could be constructed for $7.5 million but would only create an incremental decrease in flooding frequency. SVR flooding would still occur on the order of once every two years unless the 10-year or 25-year design is constructed. Relative to the other alternatives, Expanded Detention could be permitted and constructed in a shorter

timeframe. However, if remains or artifacts are discovered during construction, the schedule could be delayed significantly.

The Gravity Bay Outlet alternative is ranked second in the evaluation. This alternative is easy to construct and is by far the most economical. The disadvantage of the Gravity Bay Outlet is its potential environmental impact. With all alternatives, stormwater ultimately ends up in Tumon Bay, but the Gravity Bay Outlet has the most direct connection between Fujita Pond and Tumon Bay. The outlet will only discharge on the order of one to two times per year, but the potential risk and public perception of the project will require additional study of water quality to remain a viable alternative. The Gravity Bay Outlet is the only alternative that can be constructed within the project budget of $12 million. Many coastal communities have nearshore stormwater outlets, but Tumon Bay has significant recreational and natural value. The benefit of flood mitigation will need to be balanced against the risk to water quality.

The Gravity Ocean Outlet and Pump to Quarry Outlet are a close third and fourth ranking. The Gravity Ocean Outlet has the advantage of discharging beyond the reef which diminishes environmental impacts but its high project cost, difficult construction and significant regulatory requirements make it less preferable to the Gravity Bay Outlet. Likewise, the pump to Quarry alternative has a very suitable discharge site in the Quarry, but the high cost, long pipe alignment, and significant operation and maintenance requirements make it less preferable than the lower maintenance, easier construction options that precede it in the alternative ranking.

Pump to Sink is ranked fifth, behind the Pump to Quarry alternative. The limited size of the sink area, unknown response of the sink to additional stormwater inflow, and marginal decrease in cost relative to the Pump to Quarry alternative make it less preferable.

The combined Gravity/Pump Ocean Outlet is ranked sixth. This alternative combines the high cost of both the marine construction and pump station construction along with the high maintenance requirements of a stormwater pump system. Relative to the other alternatives it is the least preferable.

Summary of Findings and Recommendations

The following summarizes findings and recommendations of the improvement alternatives evaluation:

- There are two issues causing SVR flooding:
  - Short Duration SVR flooding caused by high intensity, short duration rainfall.
  - Long Duration SVR flooding caused by large rainfall events exceeding 3.5 inches.
- Short duration SVR flooding can be solved by installing 47 additional curb inlets to more effectively capture gutter flow along SVR at a cost of approximately $450,000.
- Additional inlets will provide nominal benefit unless Fujita Pond is also improved to maintain lower pond levels during flood events.

- Six viable improvement alternatives were developed and evaluated for solving the Long Duration SVR flooding. Alternatives maintained lower Fujita Pond levels during flood events by either expanding the storage volume or providing and overflow outlet for excess stormwater.
- Outlet alternatives include construction of a labyrinth weir overflow structure that can discharge the peak flow of all analyzed design floods within 6 inches of its overflow elevation. Overflow events will be on the order of one to two times a year during a typical precipitation year.
- Outlet alternatives also include expansion of Fujita Pond by removal of the underground storage chambers on the north side of the pond. The expanded Fujita Pond satisfies water quality/recharge volume requirements for the untreated watershed area.
- Preliminary designs were advanced for the six improvement alternatives and alternatives were then evaluated based on the following criteria:
  - Reduce Flooding
  - Cost Effective
  - Operation and Maintenance
  - Schedule
  - Constructability
  - Impact to Environment
  - Permitting Requirements
  - Public Perception
- All alternatives provide equivalent flood reduction, however the outlet alternatives have a slight advantage because they can provide more effective flood reduction if their design capacity is exceeded relative to Expanded Detention.
- The Gravity Bay Outlet is the most cost effective alternative and is the only alternative that is under the $12 million set aside for the flood mitigation project. For Expanded Detention to become cost effective, land near SVR would need to be acquired at a price significantly below its current value
- The non-pump alternatives provide the lowest operation and maintenance requirements. Pump alternatives would require significant maintenance for dependable operation.
- Expanded detention provides the shortest permitting and construction schedule but could be delayed if historical items are discovered. Ocean/Bay outlets have long permitting schedules, but the Gravity Bay Outlet has a relatively short construction schedule. Pump to Sink/Quarry alternatives have shorter permitting schedules but will take longer to construct due pump procurement and dense development along the pipe alignment.
- Expanded detention would be the easiest to construct, followed closely by the Gravity Bay Outlet. Ocean outlet construction would require a specialized marine contractor which increases schedule. Pump to Sink/Quarry alternatives involve standard construction but

will require numerous subcontractors for pump installation and complex staging due to pipe construction along SVR.

- The stormwater discharge from all alternatives ultimately ends up in Tumon Bay. Expanded Detention has the least potential to impact water quality but high potential to impact buried historical items. Pump to Sink/Quarry alternatives also have low Tumon Bay water quality impact but the response of the Sink formation to additional stormwater is unknown. Ocean outlets have limited impact to Tumon Bay water quality. Gravity Bay Outlet has the most direct connection to Tumon Bay so the highest potential for water quality impacts.
- Anticipated permitting schedules vary from 4 months to 18 months, with Expanded Detention being the least and Ocean/Bay outlets having the longest permitting schedule.
- Public perception was gaged during December 2013 stakeholder presentations. Expanded Detention and Pump to Sink/Quarry had the most positive reception. Ocean/Bay Outlets caused concern so would require public education and involvement to improve public perception.
- Expanded detention was the highest scoring alternative followed closely by the Gravity Bay Outlets. Expanded detention is easy to construct and permit but may not be viable due to high cost of land near SVR. It could also be delayed if historical remains/artifacts are discovered. The Gravity Bay Outlet can be constructed under the $12 million project budget but there could be issues with water quality. Other alternatives were too costly, required too much maintenance, and/or involved difficult and lengthy construction.

Appendix A

Reference Citations

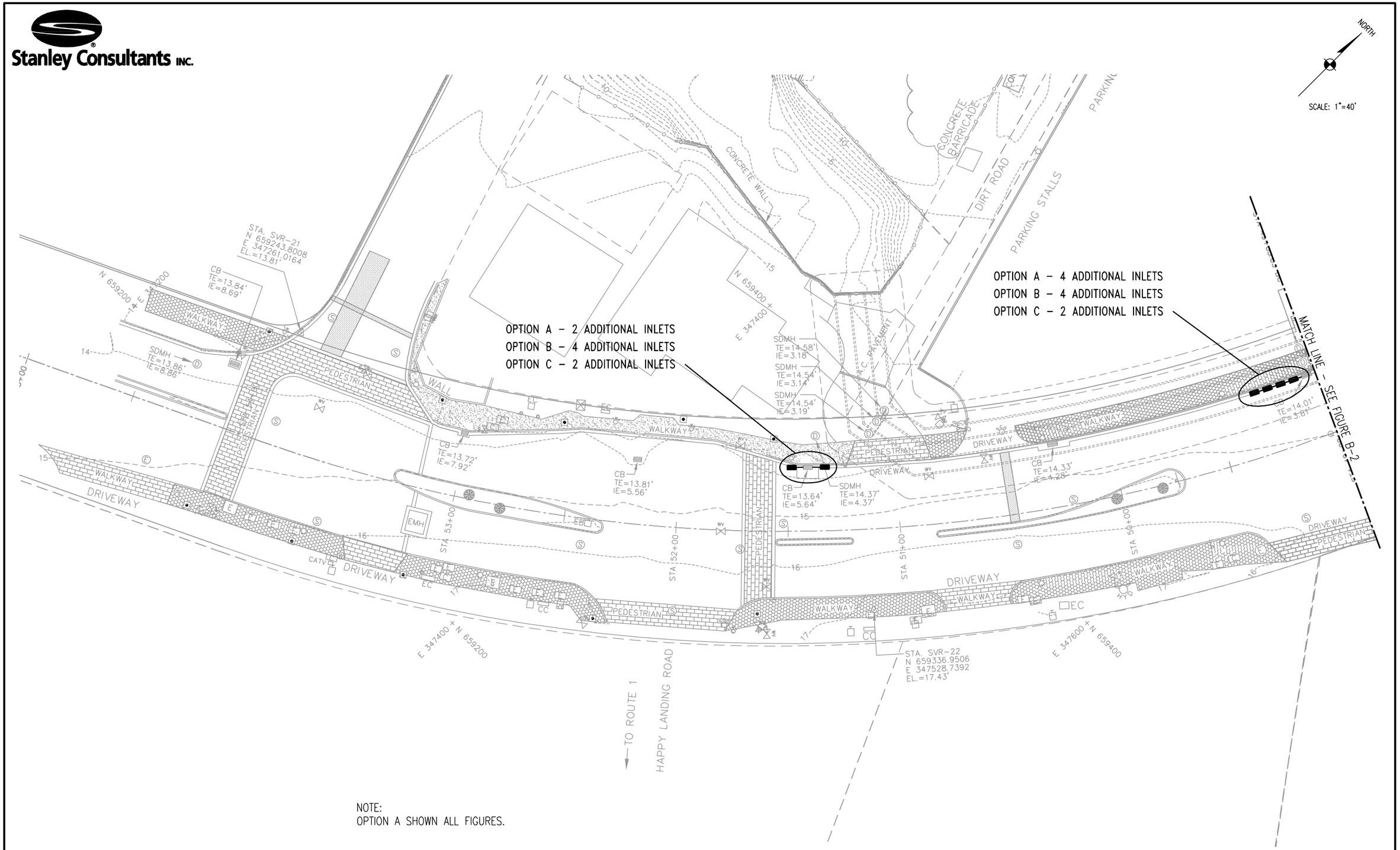
Appendix A - Reference Citations

Number	Author	Title	Year
1	Guam Department of Public Works	Guam Transportation Stormwater Drainage Manual	2010
2	Horsley Witten Group, Inc.	CNMI and Guam Stormwater Drainage Management Manual	2006
3	National Oceanic and Atmospheric Administration	Atlas 14 - Precipitation-Frequency Atlas of the United States - Volume 5, Version 3.0: Selected Pacific Islands	2011
4	Natural Resources Conservation Service	Rainfall-Frequency and Design Rainfall Distribution for Selected Pacific Islands	2008
5	Natural Resources Conservation Service	National Engineering Handbook, Part 630 Hydrology	2010
6	Natural Resources Conservation Service	Urban Hydrology for Small Watersheds, Technical Release 55	1986
7	U.S. Marine Corps	Guam and CNMI Military Relocation, Final Environmental Impact Statement	2010
8	Guam Department of Public Works	Tumon Infrasturcture and Beautification Project No. GU-TBIB-001-L-TAM Phases 1 and 2	1999
9	U.S. Army Corps of Engineers	Guam Storm Drainage Manual	1980
10	Guam Environmental Protection Agency	Development of Guam Northern Watershed Bacteria TMDL's DRAFT	2009
11	Water and Environmental Research Institute of the Western Pacific University of Guam	The Assessment of Environmental Effects of Changes to Southern Tumon Bay's Drainage System due to Phase II of the Tumon Redevelopment Project	2003
12	Water and Environmental Research Institute of the Western Pacific University of Guam	Sizing of Surface Water Runoff Detention Ponds	1997
13	Water and Environmental Research Institute of the Western Pacific University of Guam	Dye Trace of Groundwater Flow from Guam International Airport and Harmon Sink to Agana Bay and Tumon Bay, Guam	2004

Appendix B

Figures

Stanley Consultants INC.



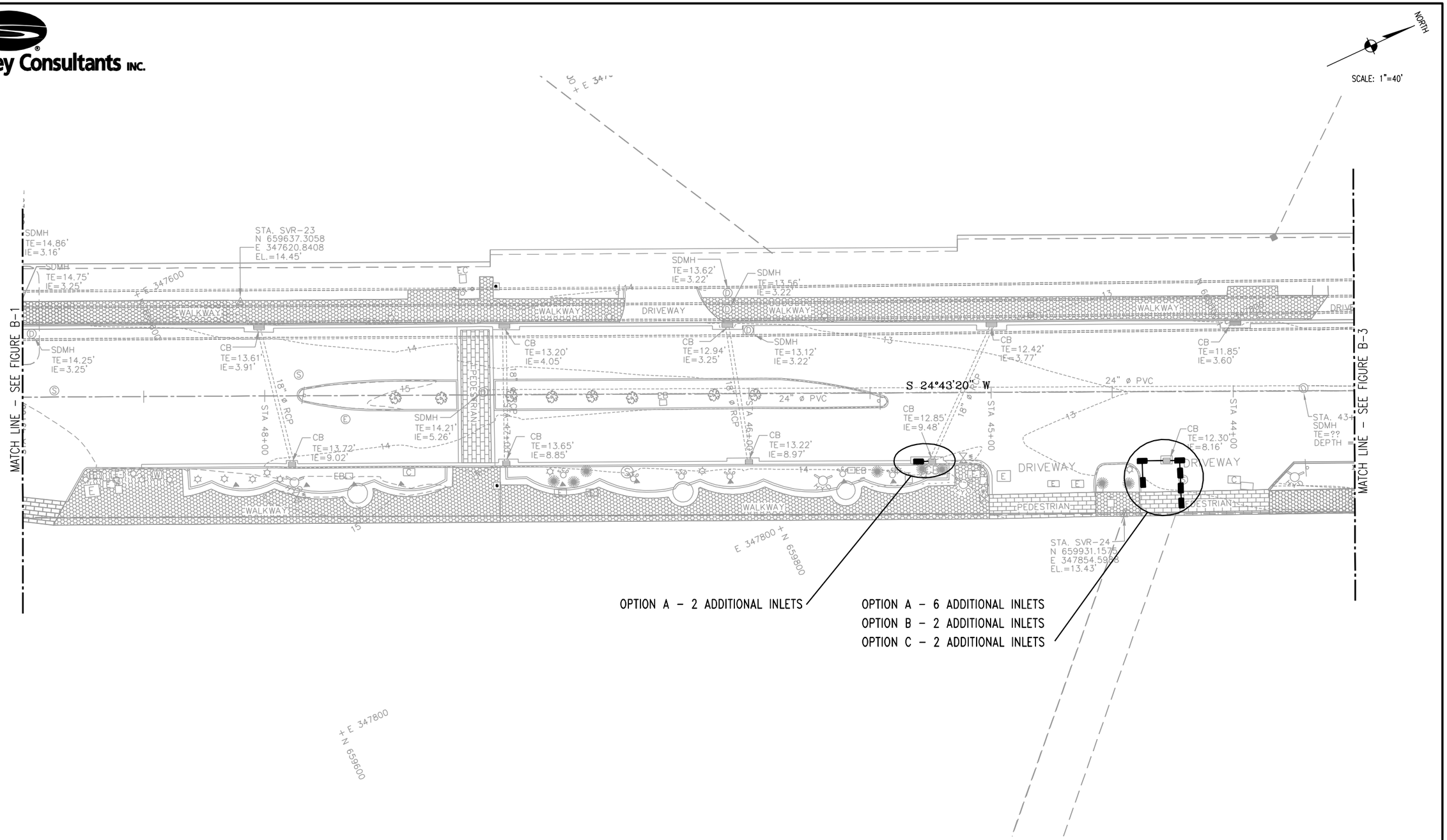
NOTE:
OPTION A SHOWN ALL FIGURES.

GUAM ECONOMIC DEVELOPMENT AUTHORITY (GEDA)
SAN VITORES ROAD FLOOD MITIGATION PROJECT

FIGURE B-1

CADD D4-R3

Stanley Consultants INC.



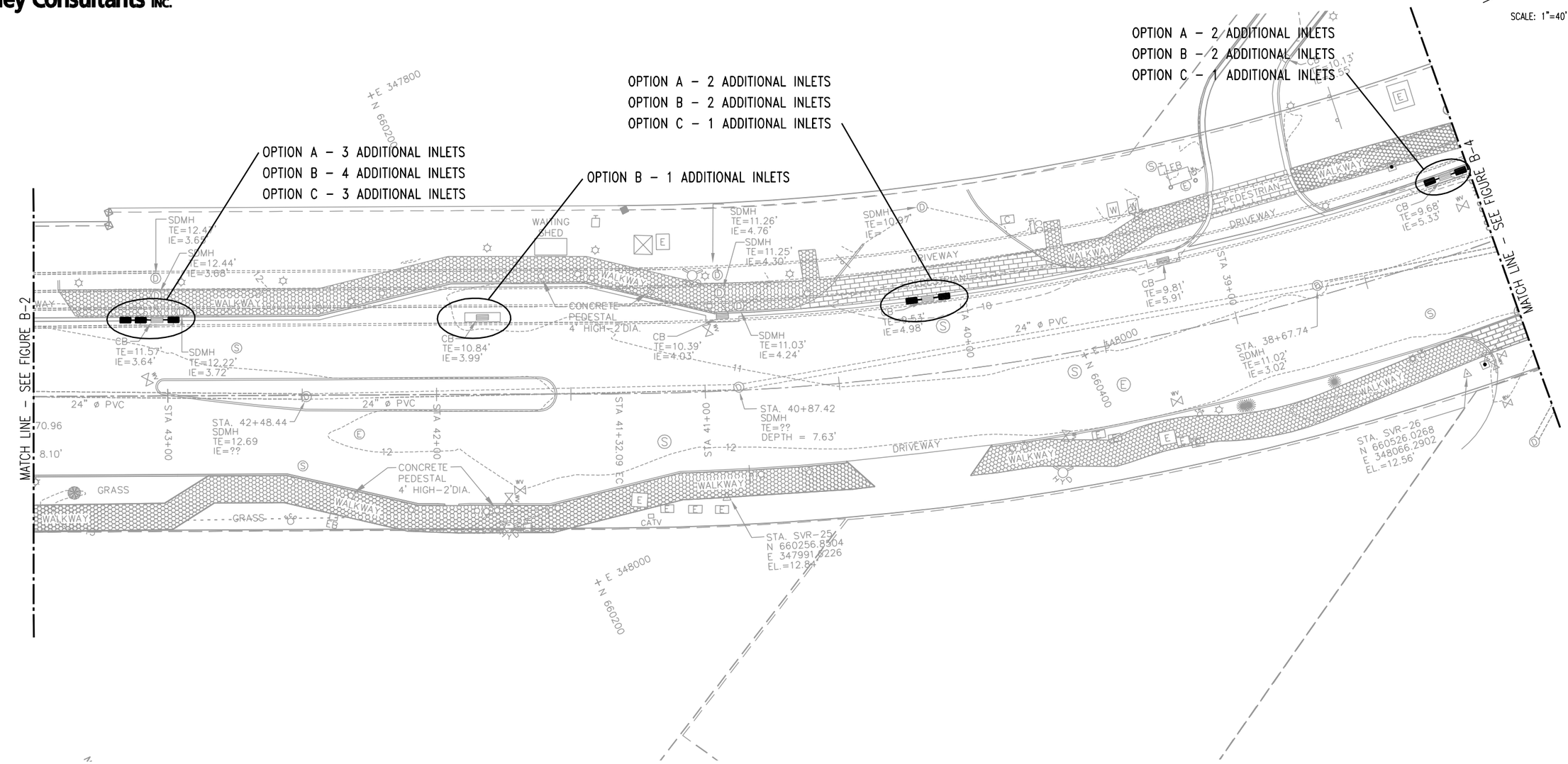
NOTE:
OPTION A SHOWN ALL FIGURES.

GUAM ECONOMIC DEVELOPMENT AUTHORITY (GEDA)
SAN VITORES ROAD FLOOD MITIGATION PROJECT

FIGURE B-2

CADD D4-R3

Stanley Consultants INC.



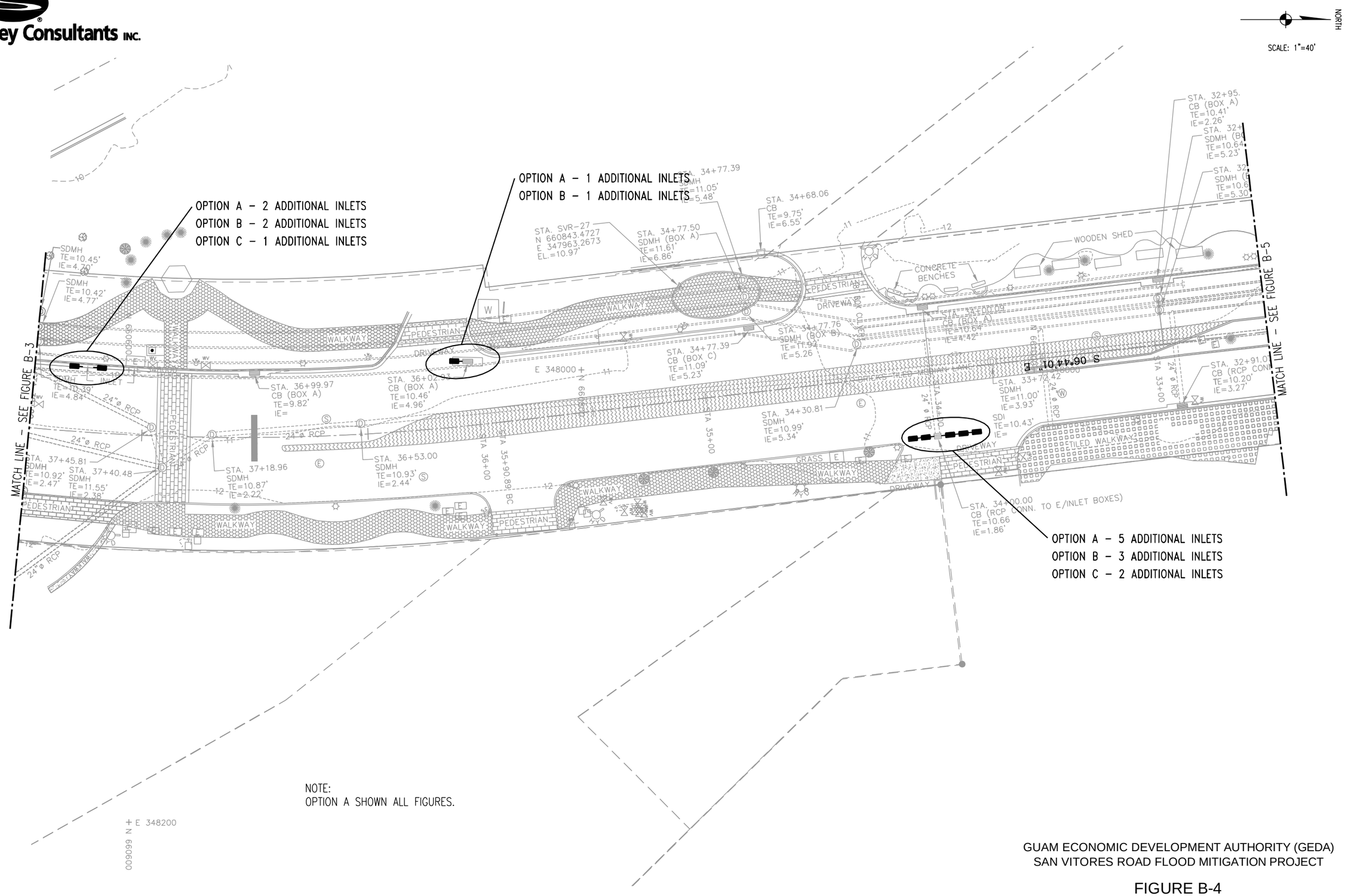
NOTE:
OPTION A SHOWN ALL FIGURES.

GUAM ECONOMIC DEVELOPMENT AUTHORITY (GEDA)
SAN VITORES ROAD FLOOD MITIGATION PROJECT

FIGURE B-3

CADD D4-R3

Stanley Consultants INC.



NOTE:
OPTION A SHOWN ALL FIGURES.

GUAM ECONOMIC DEVELOPMENT AUTHORITY (GEDA)
SAN VITORES ROAD FLOOD MITIGATION PROJECT

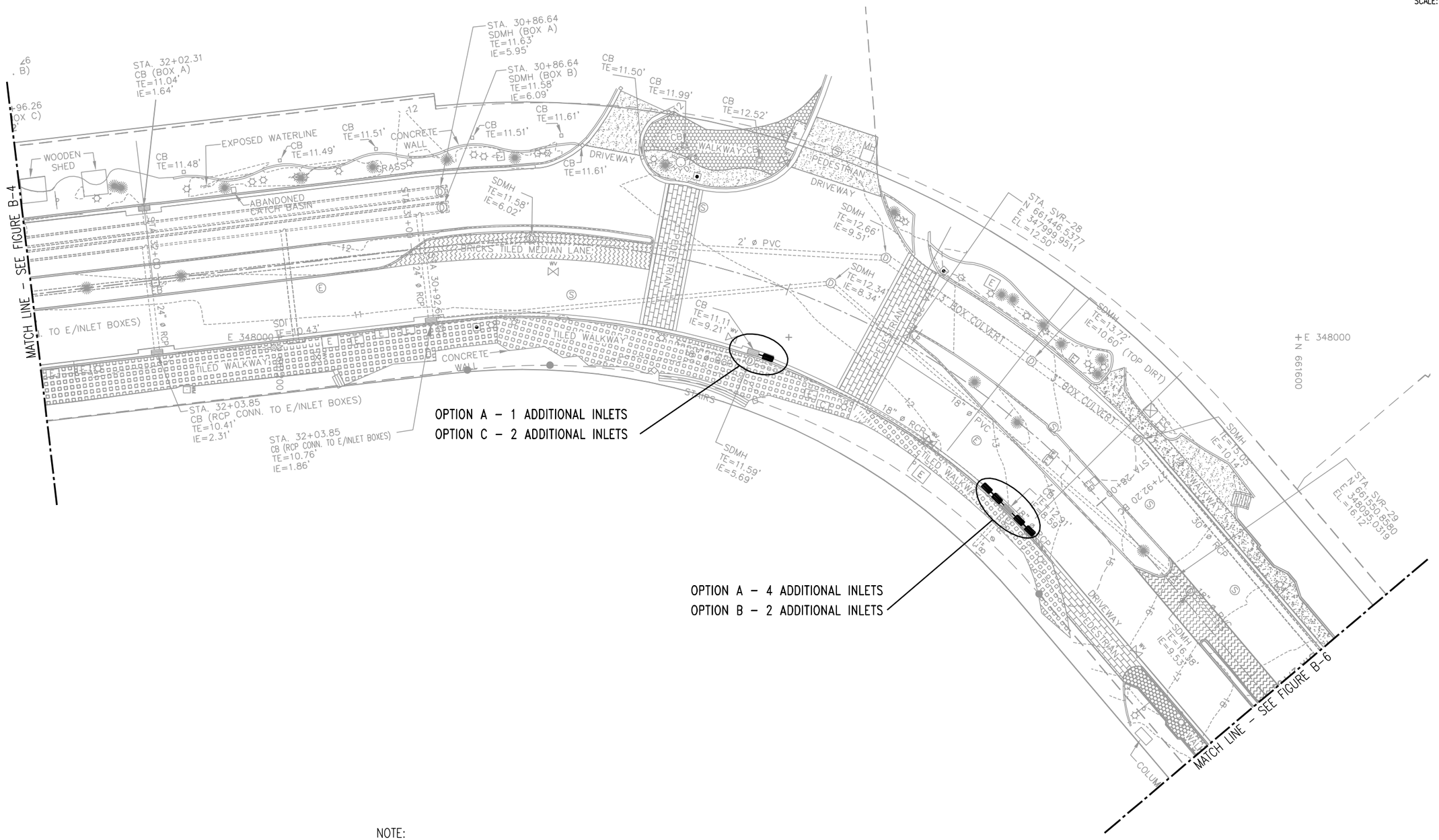
FIGURE B-4

CADD D4-R3

Stanley Consultants INC.

NORTH

SCALE: 1"=40'



NOTE:
OPTION A SHOWN ALL FIGURES.

GUAM ECONOMIC DEVELOPMENT AUTHORITY (GEDA)
SAN VITORES ROAD FLOOD MITIGATION PROJECT

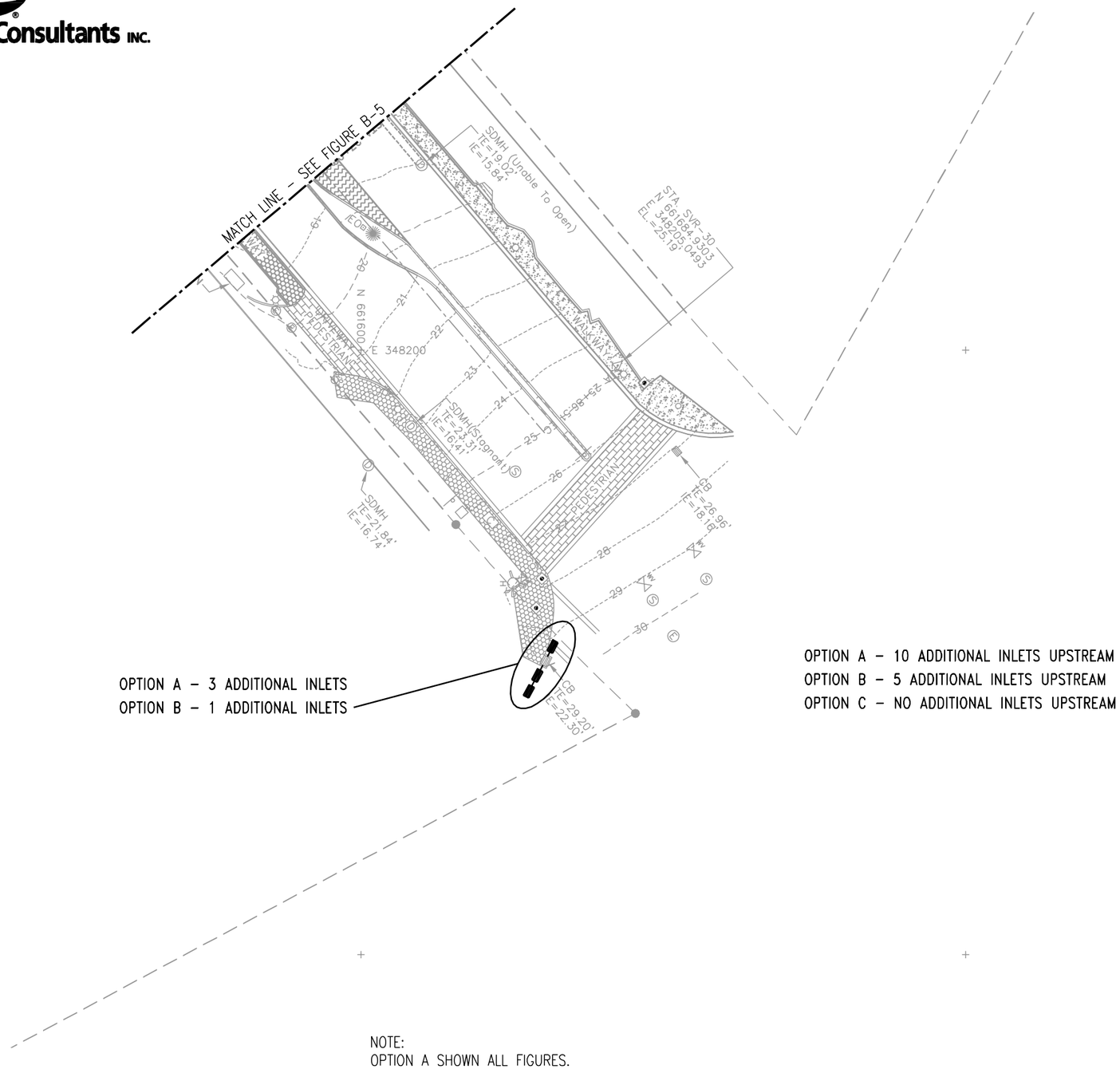
FIGURE B-5

CADD D4-R3

Stanley Consultants INC.

NORTH

SCALE: 1"=40'



OPTION A - 10 ADDITIONAL INLETS UPSTREAM
OPTION B - 5 ADDITIONAL INLETS UPSTREAM
OPTION C - NO ADDITIONAL INLETS UPSTREAM

NOTE:
OPTION A SHOWN ALL FIGURES.

GUAM ECONOMIC DEVELOPMENT AUTHORITY (GEDA)
SAN VITORES ROAD FLOOD MITIGATION PROJECT

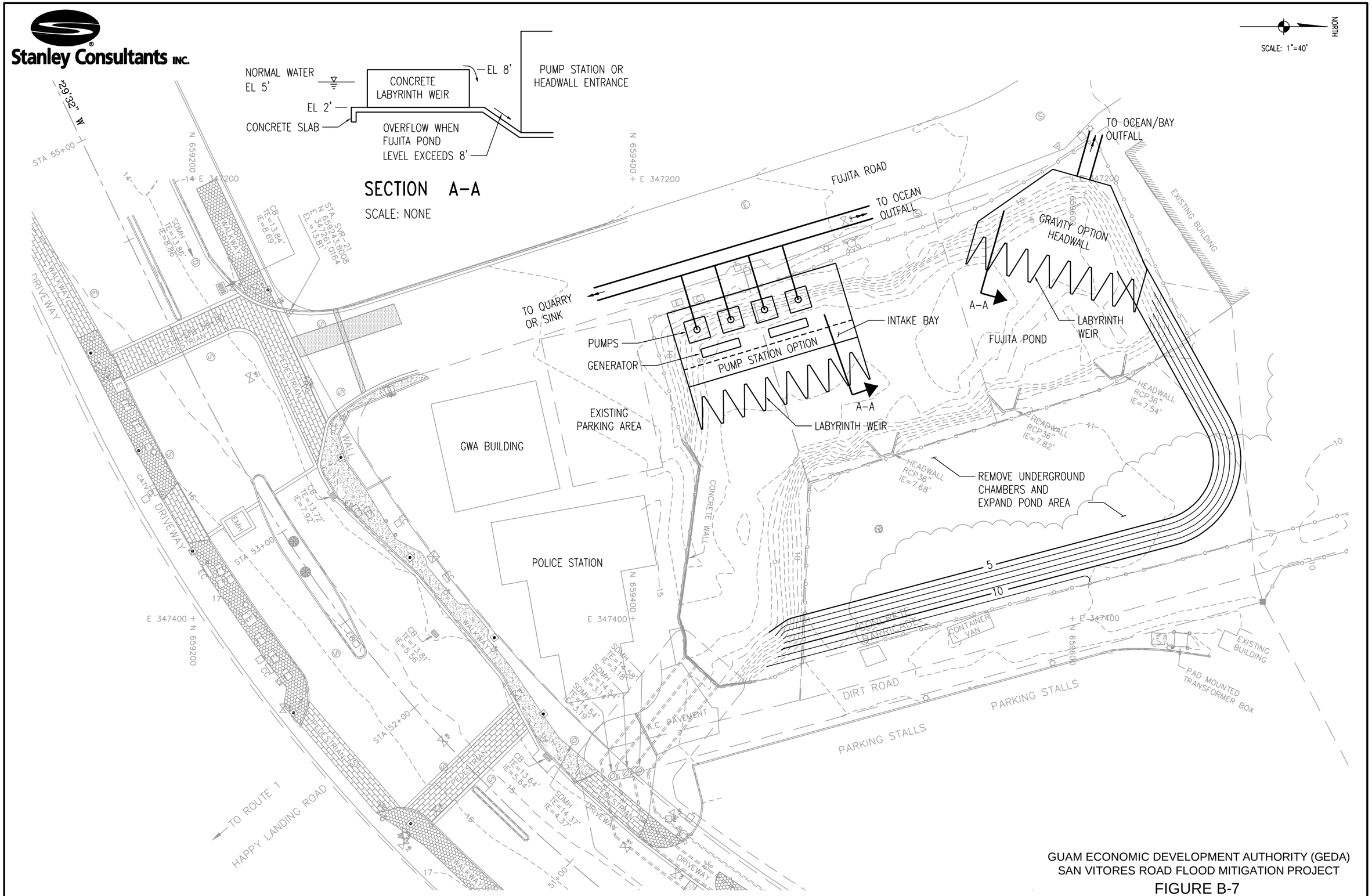
FIGURE B-6

CADD D4-R3

Stanley Consultants INC.

NORTH

SCALE: 1"=40'



GUAM ECONOMIC DEVELOPMENT AUTHORITY (GEDA)
SAN VITORES ROAD FLOOD MITIGATION PROJECT

FIGURE B-7

CADD D4-R3

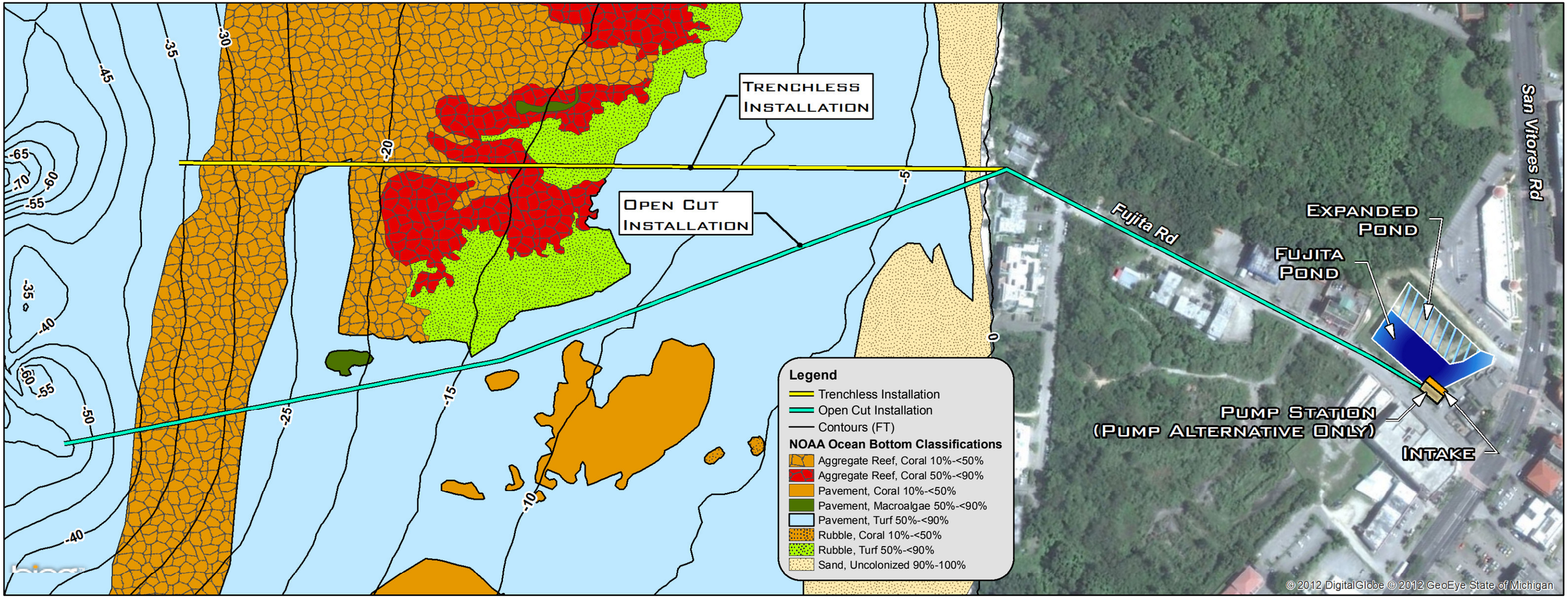
Appendix C

Conceptual Drainage Options

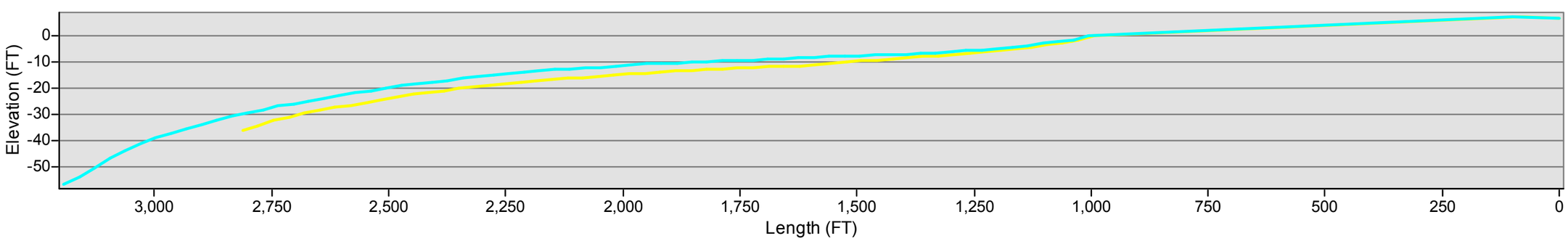
Stanley Consultants INC.

0 75 150 300 Feet

Exhibit 1 - San Vitores Road
Conceptual Flood Mitigation Alternatives
Expand Detention



Surface Elevation Profile - Fujita Pond Outfall Pipe(s) to Tumon Bay

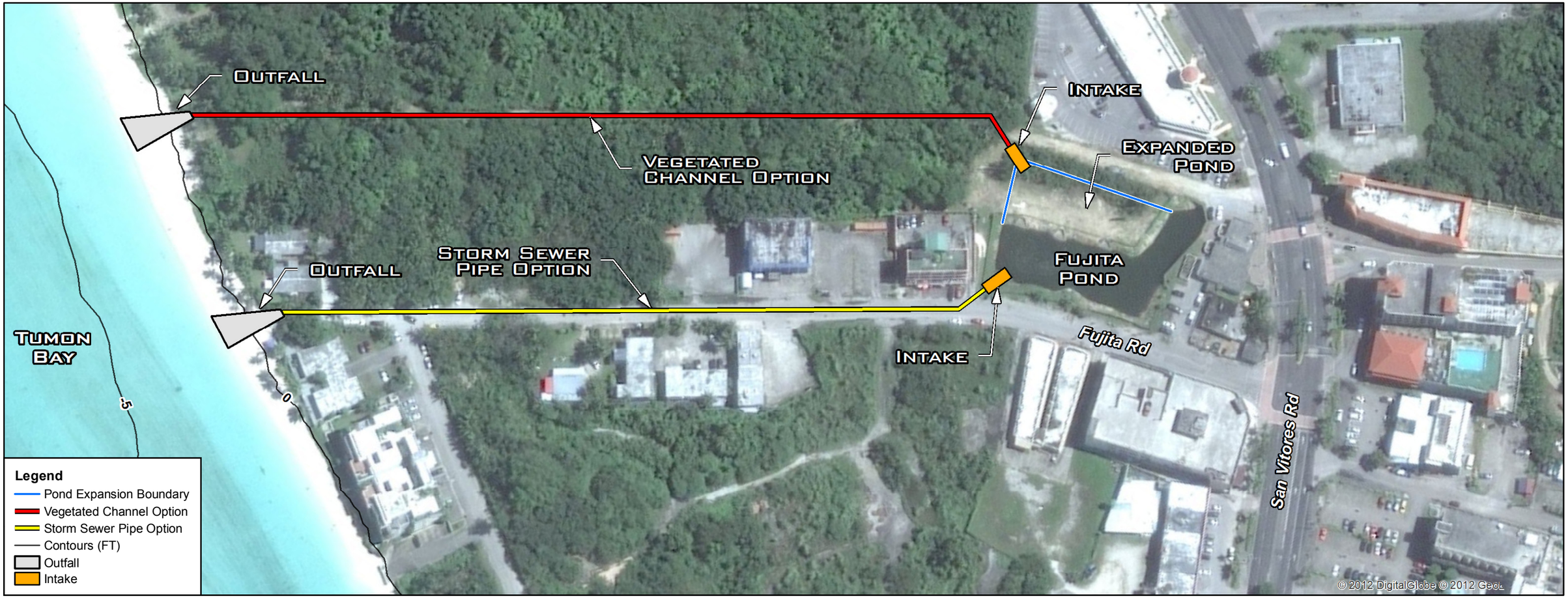


Elevation Data Source: NOAA - DEM, October 2008

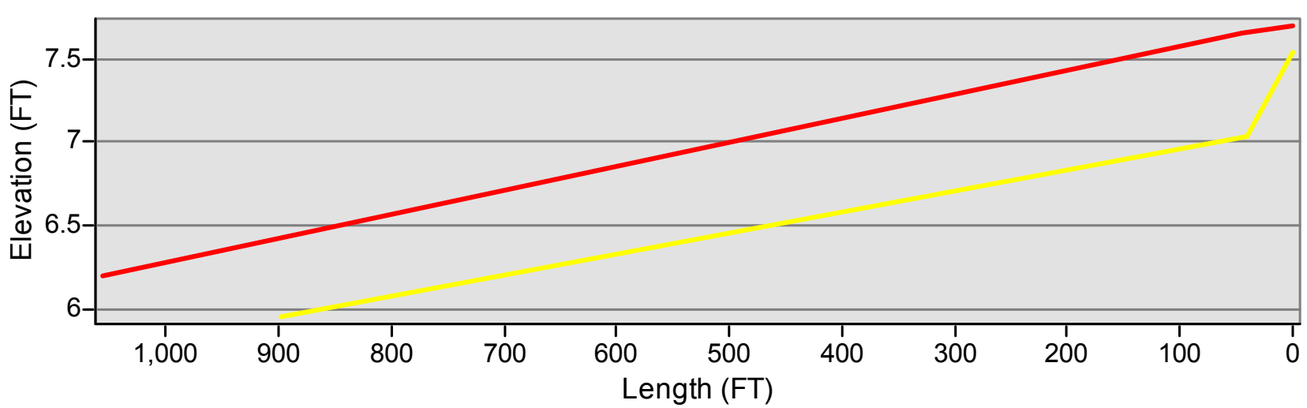
Stanley Consultants INC.

0 250 500 Feet

Exhibit 2 - San Vitores Road
Conceptual Flood Mitigation Alternatives
Gravity Ocean Outfall and Pumped Ocean Outfall



Surface Elevation Profile - Fujita Pond to Gravity Bay Outfall

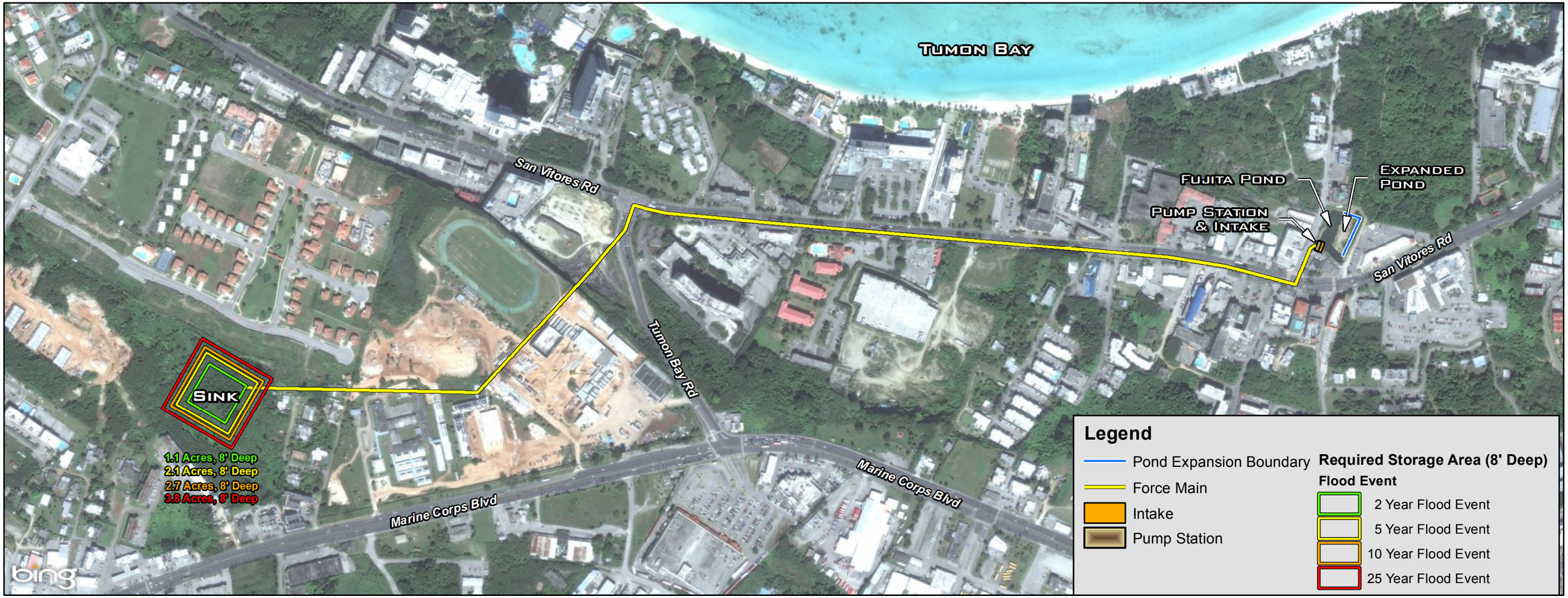


**Elevation Data Source: NOAA - LiDAR, 2007*

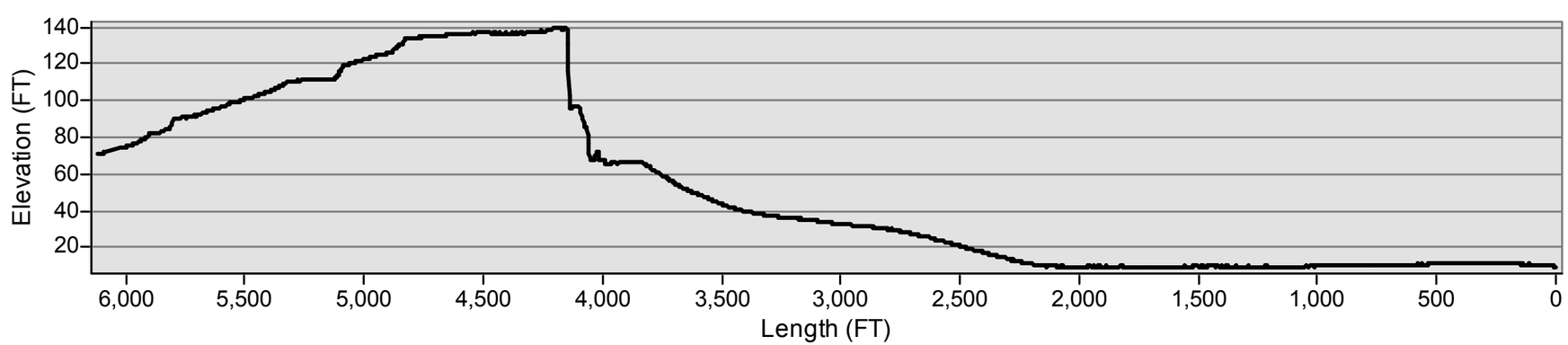
Stanley Consultants INC.

0 125 250 Feet

Exhibit 3 - San Vitores Road
Conceptual Flood Mitigation Alternatives
Gravity Bay Outfall



Surface Elevation Profile - Fujita Pond to Sink



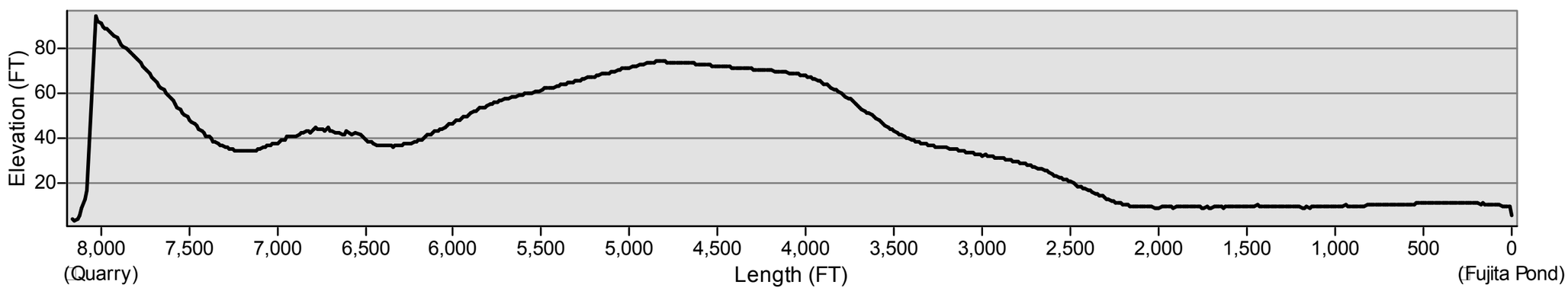
Elevation Data Source: NOAA - LiDAR, 2007

Stanley Consultants INC.

0 600 1,200 Feet

Exhibit 4 - San Vitores Road
Conceptual Flood Mitigation Alternatives
Pump to Sink

Surface Elevation Profile - Fujita Pond to Quarry



Elevation Data Source: NOAA - LiDAR, 2007

Stanley Consultants INC.

0 600 1,200 Feet

Exhibit 5 - San Vitores Road
Conceptual Flood Mitigation Alternatives
Pump to Quarry

Appendix D

Cost Estimate

		Option	Expanded Detention					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth (FT)	Size (ACRE)	Length	Size
		2-yr			4	2.7		
		5-yr			4	5		
		10-yr			4	7		
		25-yr			4	10		
Existing ponding/infiltration area			39849	Square feet				
Engineering/Permitting	12%							
Contingency	20%				Land cost	$ 500.00	$/sq meter	
2 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	2.7	$6,330,032
Ancillary Pond Structures	Acre					$ 120,000.00	2.7	$324,000
Pond Grading	Acre					$ 55,000.00	2.7	$148,500
Weir Intake	LS					$ 200,000.00	0	$0
Outfall Structure	LS					$ 150,000.00	0	$0
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$0
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	0	$0
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$0
SVR Trench Restoration	LF					$ 75.00	0	$0
Fujita Road Trench Restoration	LF					$ 40.00	0	$0
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$0
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$0
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator	LS					$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	0	$0
2000 KW Generator	LS					$ 1,100,000.00	0	$0
								$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 7,252,532.29
Engineering/Permitting	12%							$110,700
Contingency	20%							$184,500.00
TOTAL								$ 7,547,732.29
5 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	5	$11,722,282
Ancillary Pond Structures	Acre					$ 120,000.00	5	$600,000
Pond Grading	Acre					$ 55,000.00	5	$275,000
Weir Intake	LS					$ 200,000.00	0	$0
Outfall Structure	LS					$ 150,000.00	0	$0
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$0
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	0	$0
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$0
SVR Trench Restoration	LF					$ 75.00	0	$0
Fujita Road Trench Restoration	LF					$ 40.00	0	$0
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$0
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$0
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator						$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	0	$0
2000 KW Generator	LS					$ 1,100,000.00	0	$0
						$ -		$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 13,047,282.02
Engineering/Permitting	12%							$159,000
Contingency	20%							$265,000.00
TOTAL								$ 13,471,282.02

		Option	Expanded Detention					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth (FT)	Size (ACRE)	Length	Size
		2-yr			4	2.7		
		5-yr			4	5		
		10-yr			4	7		
		25-yr			4	10		
Existing ponding/infiltration area			39849	Square feet				
Engineering/Permitting	12%							
Contingency	20%				Land cost	$ 500.00	$/sq meter	
10 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	7	$16,411,195
Ancillary Pond Structures	Acre					$ 120,000.00	7	$840,000
Pond Grading	Acre					$ 55,000.00	7	$385,000
Weir Intake	LS					$ 200,000.00	0	$0
Outfall Structure	LS					$ 150,000.00	0	$0
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$0
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	0	$0
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$0
SVR Trench Restoration	LF					$ 75.00	0	$0
Fujita Road Trench Restoration	LF					$ 40.00	0	$0
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$0
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$0
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator	LS					$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	0	$0
2000 KW Generator	LS					$ 1,100,000.00	0	$0
						$ -	0	$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 18,086,194.83
Engineering/Permitting	12%							$201,000
Contingency	20%							$335,000.00
TOTAL								$ 18,622,194.83
25 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	10	$23,444,564
Ancillary Pond Structures	Acre					$ 120,000.00	10	$1,200,000
Pond Grading	Acre					$ 55,000.00	10	$550,000
Weir Intake	LS					$ 200,000.00	0	$0
Outfall Structure	LS					$ 150,000.00	0	$0
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$0
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	0	$0
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$0
SVR Trench Restoration	LF					$ 75.00	0	$0
Fujita Road Trench Restoration	LF					$ 40.00	0	$0
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$0
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$0
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator	LS					$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	0	$0
2000 KW Generator	LS					$ 1,100,000.00	0	$0
						$ -		$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 25,644,564.05
Engineering/Permitting	12%							$264,000
Contingency	20%							$440,000.00
TOTAL								$ 26,348,564.05

		Option	Gravity Ocean Outlet					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth	Size	Length	Size
		2-yr					2800	60"
		5-yr					2800	72"
		10-yr					2800	84"
		25-yr					2800	96"
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%							
2 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	0	$ -
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	0.25	$ 13,750.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 7,000.00	1800	$ 12,600,000.00
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	1000	$ 500,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 40.00	1000	$ 40,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$ -
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$ -
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
								$ -
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 13,953,750.00
Engineering/Permitting	12%							$1,674,450
Contingency	20%							$2,790,750.00
TOTAL								$ 18,418,950.00
5 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	0	$0
Ancillary Pond Structures	Acre					$ 120,000.00	0	$0
Pond Grading	Acre					$ 55,000.00	0.25	$13,750
Weir Intake	LS					$ 200,000.00	1	$200,000
Outfall Structure	LS					$ 150,000.00	1	$150,000
Discharge Pipe - Ocean Trenchless installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Ocean Open Cut Installation	LF					$ 9,600.00	1800	$17,280,000
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 700.00	1000	$700,000
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$0
SVR Trench Restoration	LF					$ 75.00	0	$0
Fujita Road Trench Restoration	LF					$ 70.00	1000	$70,000
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$0
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$0
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator						$ 200,000.00	0	
500 KW Generator	LS					$ 350,000.00	0	$0
2000 KW Generator	LS					$ 1,100,000.00	0	$0
						$ -	0	$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 18,863,750.00
Engineering/Permitting	12%							$2,263,650
Contingency	20%							$3,772,750.00
TOTAL								$ 24,900,150.00

		Option	Gravity Ocean Outlet					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth	Size	Length	Size
		2-yr					2800	60"
		5-yr					2800	72"
		10-yr					2800	84"
		25-yr					2800	96"
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%							
10 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	0	$ -
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	0.25	$ 13,750.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 10,000.00	1800	$ 18,000,000.00
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 800.00	1000	$ 800,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 80.00	1000	$ 80,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$ -
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$ -
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
						$ -	0	$ -
Street Storm Improvements	LS					$ 450,000.00	1	$ 450,000.00
SUBTOTAL								$ 19,693,750.00
Engineering/Permitting	12%							$2,363,250
Contingency	20%							$3,938,750.00
TOTAL								$ 25,995,750.00
25 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	0	$ -
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	0.25	$ 13,750.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 10,400.00	1800	$ 18,720,000.00
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 900.00	1000	$ 900,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 90.00	1000	$ 90,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$ -
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$ -
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
						$ -	0	$ -
Street Storm Improvements	LS					$ 450,000.00	1	$ 450,000.00
SUBTOTAL								$ 20,523,750.00
Engineering/Permitting	12%							$2,462,850
Contingency	20%							$4,104,750.00
TOTAL								$ 27,091,350.00

		Option	Gravity/Pumped Ocean Outlet					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth	Size	Length (FT)	Size
		2-yr	3	15K GPM			2800	36"
		5-yr	6	15K GPM			2800	48"
		10-yr	8	15K GPM			2800	54"
		25-yr	10	15K GPM			2800	60"
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%							
2 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	0	$ -
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	0.25	$ 13,750.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	1800	$ 9,000,000.00
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 250.00	1000	$ 250,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 25.00	1000	$ 25,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	1	$ 420,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	1	$ 180,000.00
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$ -
100 HP, 30K gpm pump	EA					$ 250,000.00	1	$ 250,000.00
250 KW Generator	LS					$ 200,000.00	1	$ 200,000.00
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
								$ -
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 11,138,750.00
Engineering/Permitting	12%							$1,336,650
Contingency	20%							$2,227,750.00
TOTAL								$ 14,703,150.00
5 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	0	$0
Ancillary Pond Structures	Acre					$ 120,000.00	0	$0
Pond Grading	Acre					$ 55,000.00	0.25	$13,750
Weir Intake	LS					$ 200,000.00	1	$200,000
Outfall Structure	LS					$ 150,000.00	0	$0
Discharge Pipe - Ocean Trenchless installation	LF					$ 6,000.00	1800	$10,800,000
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 300.00	1000	$300,000
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$0
SVR Trench Restoration	LF					$ 75.00	0	$0
Fujita Road Trench Restoration	LF					$ 30.00	1000	$30,000
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	1.5	$630,000
75 HP, 15K gpm pump	EA					$ 180,000.00	2	$360,000
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$0
100 HP, 30K gpm pump	EA					$ 250,000.00	2	$500,000
250 KW Generator						$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	1	$350,000
2000 KW Generator	LS					$ 1,100,000.00	0	$0
						$ -		$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 13,633,750.00
Engineering/Permitting	12%							$1,636,050
Contingency	20%							$2,726,750.00
TOTAL								$ 17,996,550.00

		Option	Gravity/Pumped Ocean Outlet					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth	Size	Length (FT)	Size
		2-yr	3	15K GPM			2800	36"
		5-yr	6	15K GPM			2800	48"
		10-yr	8	15K GPM			2800	54"
		25-yr	10	15K GPM			2800	60"
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%							
10 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	0	$ -
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	0.25	$ 13,750.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 6,500.00	1800	$ 11,700,000.00
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 400.00	1000	$ 400,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00		$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 40.00	1000	$ 40,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	2	$ 840,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	2	$ 360,000.00
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$ -
100 HP, 30K gpm pump	EA					$ 250,000.00	3	$ 750,000.00
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	1	$ 350,000.00
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
						$ -		$ -
Street Storm Improvements	LS					$ 450,000.00	1	$ 450,000.00
SUBTOTAL								$ 15,253,750.00
Engineering/Permitting	12%							$1,830,450
Contingency	20%							$3,050,750.00
TOTAL								$ 20,134,950.00
25 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	0	$ -
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	0.25	$ 13,750.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 7,000.00	1800	$ 12,600,000.00
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	1000	$ 500,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 40.00	1000	$ 40,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	2.5	$ 1,050,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	2	$ 360,000.00
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$ -
100 HP, 30K gpm pump	EA					$ 250,000.00	4	$ 1,000,000.00
250 KW Generator	LS					$ 200,000.00	1	$ 200,000.00
500 KW Generator	LS					$ 350,000.00	1	$ 350,000.00
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
						$ -		$ -
Street Storm Improvements	LS					$ 450,000.00	1	$ 450,000.00
SUBTOTAL								$ 16,913,750.00
Engineering/Permitting	12%							$2,029,650
Contingency	20%							$3,382,750.00
TOTAL								$ 22,326,150.00

		Option	Gravity Bay Outlet					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth	Size	Length	Size
		2-yr					1000	4'x4'
		5-yr					1000	8'x4'
		10-yr					1000	12'x4'
		25-yr					1000	16'x4'
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%							
2 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	1	$ 2,344,456.40
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	1	$ 55,000.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 400.00	1000	$ 400,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 40.00	1000	$ 40,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$ -
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$0
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator	LS					$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
								$ -
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 3,639,456.40
Engineering/Permitting	12%							$436,735
Contingency	20%							$727,891.28
TOTAL								$ 4,804,082.45
5 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	1	$2,344,456
Ancillary Pond Structures	Acre					$ 120,000.00	0	$0
Pond Grading	Acre					$ 55,000.00	1	$55,000
Weir Intake	LS					$ 200,000.00	1	$200,000
Outfall Structure	LS					$ 150,000.00	1	$150,000
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$0
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 700.00	1000	$700,000
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	
SVR Trench Restoration	LF					$ 75.00	0	$0
Fujita Road Trench Restoration	LF					$ 70.00	1000	$70,000
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$0
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$0
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator						$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	0	$0
2000 KW Generator	LS					$ 1,100,000.00	0	$0
						$ -		$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 3,969,456.40
Engineering/Permitting	12%							$476,335
Contingency	20%							$793,891.28
TOTAL								$ 5,239,682.45

		Option	Gravity Bay Outlet					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth	Size	Length	Size
		2-yr					1000	4'x4'
		5-yr					1000	8'x4'
		10-yr					1000	12'x4'
		25-yr					1000	16'x4'
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%							
10 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	1	$ 2,344,456.40
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	1	$ 55,000.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 1,000.00	1000	$ 1,000,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 100.00	1000	$ 100,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$ -
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$ -
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
						$ -		$ -
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 4,299,456.40
Engineering/Permitting	12%							$515,935
Contingency	20%							$859,891.28
TOTAL								$ 5,675,282.45
25 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 2,344,456.40	1	$ 2,344,456.40
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	1	$ 55,000.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 1,300.00	1000	$ 1,300,000.00
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,400.00	0	$ -
SVR Trench Restoration	LF					$ 75.00	0	$ -
Fujita Road Trench Restoration	LF					$ 130.00	1000	$ 130,000.00
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	0	$ -
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	0	$ -
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	0	$ -
						$ -		$ -
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 4,629,456.40
Engineering/Permitting	12%							$555,535
Contingency	20%							$925,891.28
TOTAL								$ 6,110,882.45

		Option	Pump to Sink					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth (FT)	Size (ACRE)	Length	Size
		2-yr	3	15K GPM	8	1.1	6500	36"
		5-yr	6	15K GPM	8	2	6500	48"
		10-yr	8	15K GPM	8	2.7	6500	54"
		25-yr	10	15K GPM	8	3.8	6500	60"
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%			Land Cost		200	$/sq meter	
2 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 937,782.56	1.1	$ 1,031,560.82
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	1.1	$ 60,500.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 250.00	0	$ -
Discharge Pipe - SVR Open Trench Installation	LF					$ 800.00	6500	$ 5,200,000.00
SVR Trench Restoration	LF					$ 80.00	6500	$ 520,000.00
Fujita Road Trench Restoration	LF					$ 25.00	0	$ -
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	1	$ 420,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	3	$ 690,000.00
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	1	$ 1,100,000.00
								$ -
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 9,822,060.82
Engineering/Permitting	12%							$1,178,647
Contingency	20%							$1,964,412.16
TOTAL								$ 12,965,120.28
5 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 937,782.56	2	$1,875,565
Ancillary Pond Structures	Acre					$ 120,000.00	0	$0
Pond Grading	Acre					$ 55,000.00	2	$110,000
Weir Intake	LS					$ 200,000.00	1	$200,000
Outfall Structure	LS					$ 150,000.00	1	$150,000
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$0
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 250.00	0	$0
Discharge Pipe - SVR Open Trench Installation	LF					$ 900.00	6500	$5,850,000
SVR Trench Restoration	LF					$ 90.00	6500	$585,000
Fujita Road Trench Restoration	LF					$ 25.00	0	$0
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	1.5	$630,000
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	6	$1,380,000
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator						$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	0	$0
2000 KW Generator	LS					$ 1,100,000.00	2	$2,200,000
						$ -		$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 13,430,565.12
Engineering/Permitting	12%							$1,611,668
Contingency	20%							$2,686,113.02
TOTAL								$ 17,728,345.96

		Option	Pump to Sink					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth (FT)	Size (ACRE)	Length	Size
		2-yr	3	15K GPM	8	1.1	6500	36"
		5-yr	6	15K GPM	8	2	6500	48"
		10-yr	8	15K GPM	8	2.7	6500	54"
		25-yr	10	15K GPM	8	3.8	6500	60"
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%			Land Cost		200	$/sq meter	
10 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 937,782.56	2.7	$ 2,532,012.92
Ancillary Pond Structures	Acre					$ 20.00	0	$ -
Pond Grading	Acre					$ 55,000.00	2.7	$ 148,500.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	0	$ -
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,000.00	6500	$ 6,500,000.00
SVR Trench Restoration	LF					$ 100.00	6500	$ 650,000.00
Fujita Road Trench Restoration	LF					$ 40.00	0	$ -
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	2	$ 840,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	8	$ 1,840,000.00
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	3	$ 3,300,000.00
						$ -		$ -
Street Storm Improvements	LS					$ 450,000.00	1	$ 450,000.00
SUBTOTAL								$ 16,610,512.92
Engineering/Permitting	12%							$1,993,262
Contingency	20%							$3,322,102.58
TOTAL								$ 21,925,877.05
25 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 937,782.56	3.8	$ 3,563,573.74
Ancillary Pond Structures	Acre					$ 20.00	0	$ -
Pond Grading	Acre					$ 55,000.00	3.8	$ 209,000.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 1,100.00	0	$ -
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,100.00	6500	$ 7,150,000.00
SVR Trench Restoration	LF					$ 110.00	6500	$ 715,000.00
Fujita Road Trench Restoration	LF					$ 40.00	0	$ -
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	2.5	$ 1,050,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	10	$ 2,300,000.00
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	4	$ 4,400,000.00
						$ -		$ -
Street Storm Improvements	LS					$ 450,000.00	1	$ 450,000.00
SUBTOTAL								$ 20,187,573.74
Engineering/Permitting	12%							$2,422,509
Contingency	20%							$4,037,514.75
TOTAL								$ 26,647,597.33

		Option	Pump to Quarry					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth (FT)	Size (ACRE)	Length	Size
		2-yr	3	15K GPM	8	1.1	8400	36"
		5-yr	6	15K GPM	8	2	8400	48"
		10-yr	8	15K GPM	8	2.7	8400	54"
		25-yr	10	15K GPM	8	3.8	8400	60"
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%			Land Cost		50	$/sq meter	
2 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 234,445.64	1.1	$ 257,890.20
Ancillary Pond Structures	Acre					$ 120,000.00	0	$ -
Pond Grading	Acre					$ 55,000.00	1.1	$ 60,500.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 250.00	0	$ -
Discharge Pipe - SVR Open Trench Installation	LF					$ 800.00	8400	$ 6,720,000.00
SVR Trench Restoration	LF					$ 80.00	8400	$ 672,000.00
Fujita Road Trench Restoration	LF					$ 25.00	0	$ -
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	1	$ 420,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	3	$ 690,000.00
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	1	$ 1,100,000.00
								$ -
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 10,720,390.20
Engineering/Permitting	12%							$1,286,447
Contingency	20%							$2,144,078.04
TOTAL								$ 14,150,915.07
5 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 234,445.64	2	$468,891
Ancillary Pond Structures	Acre					$ 120,000.00	0	$0
Pond Grading	Acre					$ 55,000.00	2	$110,000
Weir Intake	LS					$ 200,000.00	1	$200,000
Outfall Structure	LS					$ 150,000.00	1	$150,000
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$0
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$0
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 250.00	0	$0
Discharge Pipe - SVR Open Trench Installation	LF					$ 900.00	8400	$7,560,000
SVR Trench Restoration	LF					$ 90.00	8400	$756,000
Fujita Road Trench Restoration	LF					$ 25.00	0	$0
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	1.5	$630,000
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$0
450 HP, 15K gpm pump	EA					$ 230,000.00	6	$1,380,000
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$0
250 KW Generator						$ 200,000.00	0	$0
500 KW Generator	LS					$ 350,000.00	0	$0
2000 KW Generator	LS					$ 1,100,000.00	2	$2,200,000
						$ -		$0
Street Storm Improvements	LS					$ 450,000.00	1	$450,000
SUBTOTAL								$ 13,904,891.28
Engineering/Permitting	12%							$1,668,587
Contingency	20%							$2,780,978.26
TOTAL								$ 18,354,456.49

		Option	Pump to Quarry					
			Pumps		Pond		Pipe	
		Flood	No.	Size	Depth (FT)	Size (ACRE)	Length	Size
		2-yr	3	15K GPM	8	1.1	8400	36"
		5-yr	6	15K GPM	8	2	8400	48"
		10-yr	8	15K GPM	8	2.7	8400	54"
		25-yr	10	15K GPM	8	3.8	8400	60"
Existing ponding/infiltration area								
Engineering/Permitting	12%							
Contingency	20%			Land Cost		50	$/sq meter	
10 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 234,445.64	2.7	$ 633,003.23
Ancillary Pond Structures	Acre					$ 20.00	0	$ -
Pond Grading	Acre					$ 15,000.00	2.7	$ 40,500.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	0	$ -
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,000.00	8400	$ 8,400,000.00
SVR Trench Restoration	LF					$ 100.00	8400	$ 840,000.00
Fujita Road Trench Restoration	LF					$ 40.00	0	$ -
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	2	$ 840,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	8	$ 1,840,000.00
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	3	$ 3,300,000.00
						$ -		$ -
Street Storm Improvements	LS					$ 450,000.00	1	$ 450,000.00
SUBTOTAL								$ 16,693,503.23
Engineering/Permitting	12%							$2,003,220
Contingency	20%							$3,338,700.65
TOTAL								$ 22,035,424.26
25 YEAR STORM EVENT COSTS								
Item	**Unit**					**Unit Cost**	**Quantity**	**Cost**
Land Acquisition	Acre					$ 234,445.64	3.8	$ 890,893.43
Ancillary Pond Structures	Acre					$ 20.00	0	$ -
Pond Grading	Acre					$ 15,000.00	3.8	$ 57,000.00
Weir Intake	LS					$ 200,000.00	1	$ 200,000.00
Outfall Structure	LS					$ 150,000.00	1	$ 150,000.00
Discharge Pipe - Ocean Trenchless installation	LF					$ 5,000.00	0	$ -
Discharge Pipe - Ocean Open Cut Installation	LF					$ 7,000.00	0	$ -
Discharge Pipe - Fuj. Rd. Open Trench installation	LF					$ 500.00	0	$ -
Discharge Pipe - SVR Open Trench Installation	LF					$ 1,100.00	8400	$ 9,240,000.00
SVR Trench Restoration	LF					$ 110.00	8400	$ 924,000.00
Fujita Road Trench Restoration	LF					$ 40.00	0	$ -
Pump Station (Base SF 2800 for 4- 100 hp pumps)	EA					$ 420,000.00	2.5	$ 1,050,000.00
75 HP, 15K gpm pump	EA					$ 180,000.00	0	$ -
450 HP, 15K gpm pump	EA					$ 230,000.00	10	$ 2,300,000.00
100 HP, 30K gpm pump	EA					$ 250,000.00	0	$ -
250 KW Generator	LS					$ 200,000.00	0	$ -
500 KW Generator	LS					$ 350,000.00	0	$ -
2000 KW Generator	LS					$ 1,100,000.00	4	$ 4,400,000.00
						$ -		$ -
Street Storm Improvements	LS					$ 450,000.00	1	$ 450,000.00
SUBTOTAL								$ 19,661,893.43
Engineering/Permitting	12%							$2,359,427
Contingency	20%							$3,932,378.69
TOTAL								$ 25,953,699.33

Engineer's Opinion of Cost
Option A
23-Oct-13

	Item	Unit	Qty	Unit Price	Total
	Storm Sewer Collection				
1	Remove concrete sidewalk	SF	3000	$ 3.00	$ 9,000.00
2	Remove Bituminous Pavement	SY	1600	$ 10.00	$ 16,000.00
3	Remove Concrete Driveway Pavement	SY	400	$ 10.00	$ 4,000.00
4	Remove Concrete Curb and Gutter	LF	780	$ 7.00	$ 5,460.00
	Trench Excavation	LF	680	$ 5.00	$ 3,400.00
5	15" RC Pipe	LF	350	$ 40.00	$ 14,000.00
6	18" RC Pipe	LF	270	$ 45.00	$ 12,150.00
7	24" RC Pipe	LF	60	$ 65.00	$ 3,900.00
8	Install Catchbasin	EA	47	$ 3,500.00	$ 164,500.00
9	Install Catchbasin Frame and Grate	EA	47	$ 500.00	$ 23,500.00
10	Connect to Ex Storm Structure	EA	20	$ 1,000.00	$ 20,000.00
11	Aggregate Base material	CY	609	$ 50.00	$ 30,436.67
12	Concrete Curb and Gutter	LF	780	$ 20.00	$ 15,600.00
13	4" Concrete Walk	SF	600	$ 7.00	$ 4,200.00
14	4" Textured Colored Concrete Walk	SF	2400	$ 10.00	$ 24,000.00
15	6" Concrete Driveway Pavement	SY	400	$ 60.00	$ 24,000.00
16	Bituminous Patching	SY	1600	$ 50.00	$ 80,000.00
17	Sod	SY	147	$ 5.00	$ 733.33
	Subtotal				$ 454,880.00

Option B

	Item	Qty		Unit Price		Total
	Storm Sewer Collection					
1	Remove concrete sidewalk	2880	$	3.00	$	8,640.00
2	Remove Bituminous Pavement	1600	$	10.00	$	16,000.00
3	Remove Concrete Driveway Pavement	311	$	10.00	$	3,111.11
4	Remove Concrete Curb and Gutter	540	$	7.00	$	3,780.00
	Trench Excavation	490	$	5.00	$	2,450.00
5	15" RC Pipe	290	$	40.00	$	11,600.00
6	18" RC Pipe	180	$	45.00	$	8,100.00
7	24" RC Pipe	20	$	65.00	$	1,300.00
8	Install Catchbasin	34	$	3,500.00	$	119,000.00
9	Install Catchbasin Frame and Grate	34	$	500.00	$	17,000.00
10	Connect to Ex Storm Structure	18	$	1,000.00	$	18,000.00
11	Aggregate Base material	457	$	50.00	$	22,826.79
12	Concrete Curb and Gutter	540	$	20.00	$	10,800.00
13	4" Concrete Walk	120	$	7.00	$	840.00
14	4" Textured Colored Concrete Walk	2760	$	10.00	$	27,600.00
15	6" Concrete Driveway Pavement	178	$	60.00	$	10,666.67
16	Bituminous Patching	1278	$	50.00	$	63,888.89
17	Sod	80	$	5.00	$	400.00
	Subtotal				$	346,003.46

Option C

	Item	Qty		Unit Price		Total
	Storm Sewer Collection					
1	Remove concrete sidewalk	1080	$	3.00	$	3,240.00
2	Remove Bituminous Pavement	533	$	10.00	$	5,333.33
3	Remove Concrete Driveway Pavement	133	$	10.00	$	1,333.33
4	Remove Concrete Curb and Gutter	240	$	7.00	$	1,680.00
	Trench Excavation	260	$	5.00	$	1,300.00
5	15" RC Pipe	170	$	40.00	$	6,800.00
6	18" RC Pipe	90	$	45.00	$	4,050.00
7	24" RC Pipe	0	$	65.00	$	-
8	Install Catchbasin	16	$	3,500.00	$	56,000.00
9	Install Catchbasin Frame and Grate	16	$	500.00	$	8,000.00
10	Connect to Ex Storm Structure	7	$	1,000.00	$	7,000.00
11	Aggregate Base material	192	$	50.00	$	9,591.85
12	Concrete Curb and Gutter	220	$	20.00	$	4,400.00
13	4" Concrete Walk	0	$	7.00	$	-
14	4" Textured Colored Concrete Walk	1080	$	10.00	$	10,800.00
15	6" Concrete Driveway Pavement	133	$	60.00	$	8,000.00
16	Bituminous Patching	533	$	50.00	$	26,666.67
17	Sod	27	$	5.00	$	133.33
	Subtotal				$	154,328.52

Option A - Quantity Tabulation

	New Catch Basin ID #	Location STA.	Remove concrete sidewalk	Remove Bituminous Pavement	Remove Driveway Pavement	Remove Concrete Curb and Gutter	15" RC Pipe	18" RC Pipe	24" RC Pipe	Trench Excavation	Install Catchbasin	Install Catchbasin Frame and Grate	Connect to Ex Storm Structure	Aggregate Base material	Concrete Curb and Gutter	4" Concrete Walk	4" Textured Colored Concrete Walk	6" Concrete Driveway Pavement	Bituminous Patching	Sod
			SF	SY	SY	LF	LF	LF	LF	LF	EACH	EACH	EACH	CY	LF	SF	SF	SF	SY	SY
1	103 A	4+63 LT	120	33		20	20			20	1	1	1	12	20	120			33	13
2	103B		120	33		20	10			10	1	1		12	20	120			33	13
3	105A	14+40 LT	120	33		20	10			10	1	1	1	12	20		120		33	13
4	73A	20+00 LT	120	33		20	10			10	1	1	1	12	20		120		33	
5	65A	20+60 RT	120	33		20		20		20	1	1	1	12	20		120		33	
6	65 B	20+70 RT	120	33		20	10			10	1	1		12	20		120		33	
7	65C		120	33		20	10			10	1	1		12	20		120		33	
8	62A	22+85RT	120	33		20		20		20	1	1	1	12	20		120		33	13
9	62B	22+95RT	120	33		20	10			10	1	1		12	20		120		33	13
10	62C	23+00 RT	120	33		20	10			10	1	1		12	20		120		33	13
11	74A	25+00 LT	120	33		20	20			20	1	1	1	12	20	120			33	
12	75A	25+50 LT	120	33		20		20		20	1	1	1	12	20		120		33	
13	75B		120	33		20	10			10	1	1		12	20		120		33	
14	75C		120	33		20	10			10	1	1		12	20		120		33	
15	80 A	28+60 LT	120	33		20		20		20	1	1	1	12	20		120		33	
16	80 B	28+70 LT	120	33		20	10			10	1	1		12	20		120		33	
17	80 C		120	33		20	10			10	1	1		12	20		120		33	
18	80 D		120	33		20	10			10	1	1		12	20		120		33	
19	82A	29+50 LT	120	33		20	20			20	1	1	1	12	20		120		33	
20	88A	34+00 LT		33					30	30	1	1	1	9					33	
21	88B			33				20		20	1	1		9					33	
22	88C			33			10			10	1	1		9					33	
23	88D			33			10			10	1	1		9					33	
24	88E			33			10			10	1	1		9					33	
25	5A	51+40 RT	120	33		20		20		20	1	1	1	12	20	120			33	
26	5B		120	33		20	10			10	1	1		12	20	120			33	
27	9A	49+00 RT	120	33		20		20		20	1	1	1	12	20		120		33	
28	B	48+90 RT	120	33		20		10		10	1	1		12	20		120		33	
29	C	48+80 RT	120	33		20	10			10	1	1		12	20		120		33	
30	D	48+70 RT	120	33		20	10			10	1	1		12	20		120		33	
31	90A	45+20 LT		33		20	10			10	1	1	1	9	20				33	13
32	89A	44+10 LT		33	44	20			30	30	1	1	1	21	20			44	33	
33	89B			33	44	20		20		20	1	1		21	20			44	33	
34	89C			33	44	20	10			10	1	1		21	20			44	33	
35	89D			33	44	20		20		20	1	1	1	21	20			44	33	
36	89E			33	44	20	10			10	1	1		21	20			44	33	
37	89F			33	44	20	10			10	1	1		21	20			44	33	
38	21 A	42+90 RT		44				20		20	1	1	1	11					44	
39	21B	42+80 RT		44			10			10	1	1		11					44	
40	21C	42+70 RT		44			10			10	1	1		11					44	
41	28 A	39+90 RT		33	44	20		20		20	1	1	1	21	20			44	33	
42	28B			33	44	20	10			10	1	1		21	20			44	33	
43	32 A	37+90 RT		33		20		20		20	1	1	1	9	20				33	13
44	32 B	37+80 RT		33		20	10			10	1	1		9	20				33	13
45	33 A	37+50 RT		33		20		20		20	1	1	1	9	20				33	13
46	33 B	37+40 RT		33		20	10			10	1	1		9	20				33	13
47	36A	36+10 RT		33	44	20	20			20	1	1	1	21	20			44	33	
	TOTALS		3000	1600	400	780	350	270	60	680	47	47	20	609	780	600	2400	400	1600	147

Option B - Quantity Tabulation

	New Catch Basin ID #	Location STA.	Remove concrete sidewalk	Remove Bituminous Pavement	Remove Driveway Pavement	Remove Concrete Curb and Gutter	15" RC Pipe	18" RC Pipe	24" RC Pipe	Trench Excavation	Install Catchbasin	Install Catchbasin Frame and Grate	Connect to Ex Storm Structure	Aggregate Base material	Concrete Curb and Gutter	4" Concrete Walk	4" Textured Colored Concrete Walk	6" Concrete Driveway Pavement	Bituminous Patching	Sod
			SF	SY	SY	LF	LF	LF	LF	LF	EACH	EACH	EACH	CY	LF	SF	SF	SF	SY	SY
1	67A	19+70	120	33		20	20			20	1	1	1	12	20	120			33	
2	65 A	20+50 RT	120	33		20	20			20	1	1	1	12	20		120		33	13
3	62A	22+65RT	120	33		20	20			20	1	1	1	12	20		120		33	
4	61A	23+50 RT	120	33		20		20		20	1	1	1	12	20		120		33	
5	61B		120	33		20	10			10	1	1		12	20		120		33	
6	74 A	25+00 LT	120	33		20	10			10	1	1	1	12	20		120		33	
7	75A	25+50 LT	120	33		20	10			10	1	1	1	12	20		120		33	13
8	80 A	28+60 LT	120	33		20	20			20	1	1	1	12	20		120		33	
9	80 B	28+70 LT	120	33		20	10			10	1	1		12	20		120		33	
10	88A	34+10 LT	120	33	44			20		20	1	1	1	22			120		78	
11	88 B		120	33	44		10			10	1	1		22			120		78	
12	88C		120	33	44		10			10	1	1		22			120		78	
13	5A	51+40 RT	120	33		20		20		20	1	1	1	12	20		120		33	
14	5B		120	33		20	10			10	1	1		12	20		120		33	
15	5C		120	33		20	10			10	1	1		12	20		120		33	
16	5D		120	33		20	10			10	1	1		12	20		120		33	
17	9A	48+90 RT	120	33		20			20	20	1	1	1	12	20		120		33	
18	9B	48+80 RT	120	33		20		20		20	1	1		12	20		120		33	
19	9C	48+70 RT	120	33		20	10			10	1	1		12	20		120		33	
20	9D		120	33		20	10			10	1	1		12	20		120		33	
21	89A	44+10 LT		33	44			20		20	1	1	1	20				44	33	
22	89B			33	44		10			10	1	1		20				44	33	
23	21 A	42+90 RT	120	33		20		20		20	1	1	1	12	20		120		33	
24	21B	42+80 RT	120	33		20	10			10	1	1		12	20		120		33	
25	21C	42+70 RT	120	33		20		20		20	1	1	1	12	20		120		33	
26	21 D	42+60 RT	120	33		20	10			10	1	1		12	20		120		33	
27	22 A	41+90 RT		33			10			10	1	1	1	9					33	
28	28 A	39+90 RT		33	44	20	10			10	1	1	1	21	20			44	33	
29	28B			33	44	20	10			10	1	1		21	20			44	33	
30	32 A	37+90 RT		33		20		20		20	1	1	1	9	20				33	13
31	32 B	37+80 RT		33		20	10			10	1	1		9	20				33	13
32	33 A	37+50 RT		33		20	20			20	1	1	1	9	20				33	13
33	33 B	37+40 RT		33		20	10			10	1	1		9	20				33	13
34	36A	36+10		44				20		20	1	1	1	11					44	
	Totals		2880	1144	311	540	290	180	20	490	34	34	18	457	540	120	2760	178	1278	80

Option C - Quantity Tabulation

	New Catch Basin ID #	Location STA.	Remove concrete sidewalk	Remove Bituminous Pavement	Remove Driveway Pavement	Remove Concrete Curb and Gutter	15" RC Pipe	18" RC Pipe	24" RC Pipe	Trench Excavation	Install Catchbasin	Install Catchbasin Frame and Grate	Connect to Ex Storm Structure	Aggregate Base material	Concrete Curb and Gutter	4" Concrete Walk	4" Textured Colored Concrete Walk	6" Concrete Driveway Pavement	Bituminous Patching	Sod
			SF	SY	SY	LF	LF	LF	LF	LF	EACH	EACH	EACH	CY	LF	SF	SF	SF	SY	SY
1	82 A	29+50 LT	120	33		20	20			20	1	1	1	12	20		120		33	
2	82 B		120	33		20	10			10	1	1					120		33	
3	88A	34+00 LT		33			20			20	1	1	1	9					33	
4	88 B			33			10			10	1	1		9					33	
5	5A	51+40 RT	120	33		20	20			20	1	1	1	12	20		120		33	
6	5B		120	33		20	10			10	1	1		12	20		120		33	
7	9A	49+00 RT	120	33		20		30		30	1	1	1	12	20		120		33	
8	9B		120	33		20	10			10	1	1		12	20		120		33	
9	89A	44+20 LT		33	44			20		20	1	1	1	20				44	33	
10	89B			33	44		10			10	1	1		20				44	33	
11	21 A	42+90 RT	120	33		20		20		20	1	1	1	12	20		120		33	
12	21B	42+80 RT	120	33		20	10			10	1	1		12	20		120		33	
13	21C	42+70 RT	120	33		20	10			10	1	1		12	20		120		33	
14	28A	40+00 RT		33	44	20		20		20	1	1	1	21	20			44	33	
15	32 A	37+90 RT		33		20	20			20	1	1		9	20				33	13
16	33 A	37+50 RT		33		20	20			20	1	1		9	20				33	13
	Totals		1080	533	133	240	170	90	0	260	16	16	7	192	220	0	1080	133	533	27

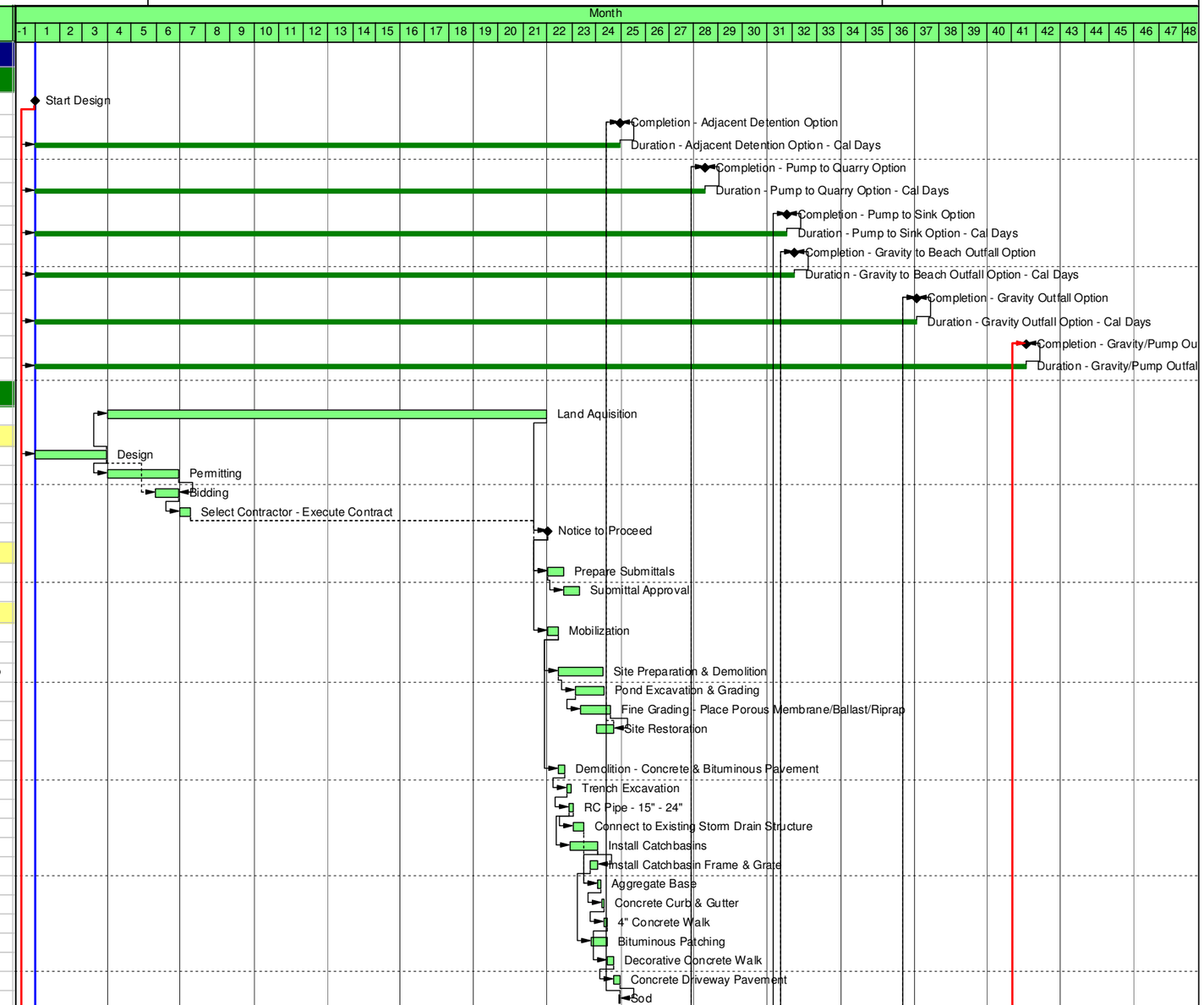
Appendix E

Schedule

San Vitores Road Conceptual Flood Mitigation Options

Conceptual Schedule Timeline of Options

Activity ID	Activity Name	Est Dur	Notes - Assumptions
San Vitores Road Conceptual Flood Mitiga		883	
Project Administration		1235	
105	Start Design	0	
110	Completion - Adjacent Detention Option	0	
115	Duration - Adjacent Detention Option - Cal Days	730	
150	Completion - Pump to Quarry Option	0	
155	Duration - Pump to Quarry Option - Cal Days	835	
140	Completion - Pump to Sink Option	0	
145	Duration - Pump to Sink Option - Cal Days	938	
160	Completion - Gravity to Beach Outfall Option	0	
165	Duration - Gravity to Beach Outfall Option - Ca	946	
120	Completion - Gravity Outfall Option	0	
125	Duration - Gravity Outfall Option - Cal Days	1099	
130	Completion - Gravity/Pump Outfall Option	0	
135	Duration - Gravity/Pump Outfall Option - Cal D	1235	
Expand Detention		522	
200	Land Aquisition	548	
Design & Bid		456	
A100	Design	90	
A110	Permitting	90	
A120	Bidding	30	
A130	Select Contractor - Execute Contract	14	
A140	Notice to Proceed	0	
Submittals & Procurement		41	
A200	Prepare Submittals	21	
A210	Submittal Approval	21	
Construction		66	
A250	Mobilization	10	
Site & Grading		49	
A300	Site Preparation & Demolition	40	8 ac - Clearing/Grubbing & Demolition of some Bldg & Pav
A310	Pond Excavation & Grading	27	8.3 Acres = 361,500 sf x 4' = 53,500 cy @ 2,000 CY/d
A315	Fine Grading - Place Porous Membrane/Ballas	27	8.3 Acres Concurrent and follows Excavation
A320	Site Restoration	16	8 Acres @ 2d/Acre
Storm Sewer Improvements		56	
A410	Demolition - Concrete & Bituminous Pavement	7	22,000 sf @ 3,000 sf/d
A420	Trench Excavation	5	980 lf @ 200' /d
A430	RC Pipe - 15" - 24"	4	680 lf @ 200' /d
A460	Connect to Existing Storm Drain Structure	10	20 @ 2/d
A440	Install Catchbasins	24	47 @ 2/d
A450	Install Catchbasin Frame & Grate	8	47 @ 6/d
A470	Aggregate Base	3	609 cy @ 200 cy/d
A480	Concrete Curb & Gutter	3	780 lf @ 300 lf/d
A490	4" Concrete Walk	2	600 sf @ 600 sf/d + 1d prep
A520	Bituminous Patching	15	14400 sf @ 1000 sf/d
A500	Decorative Concrete Walk	6	2400 sf @ 500 sf/d + prep
A510	Concrete Driveway Pavement	7	3600 sf @ 600 sf/d + 1d prep
A530	Sod	2	1,323 sf



- Remaining Level of Effort
- Remaining Work
- Critical Remaining Work
- Milestone

San Vitores Road Conceptual Flood Mitigations Study Options

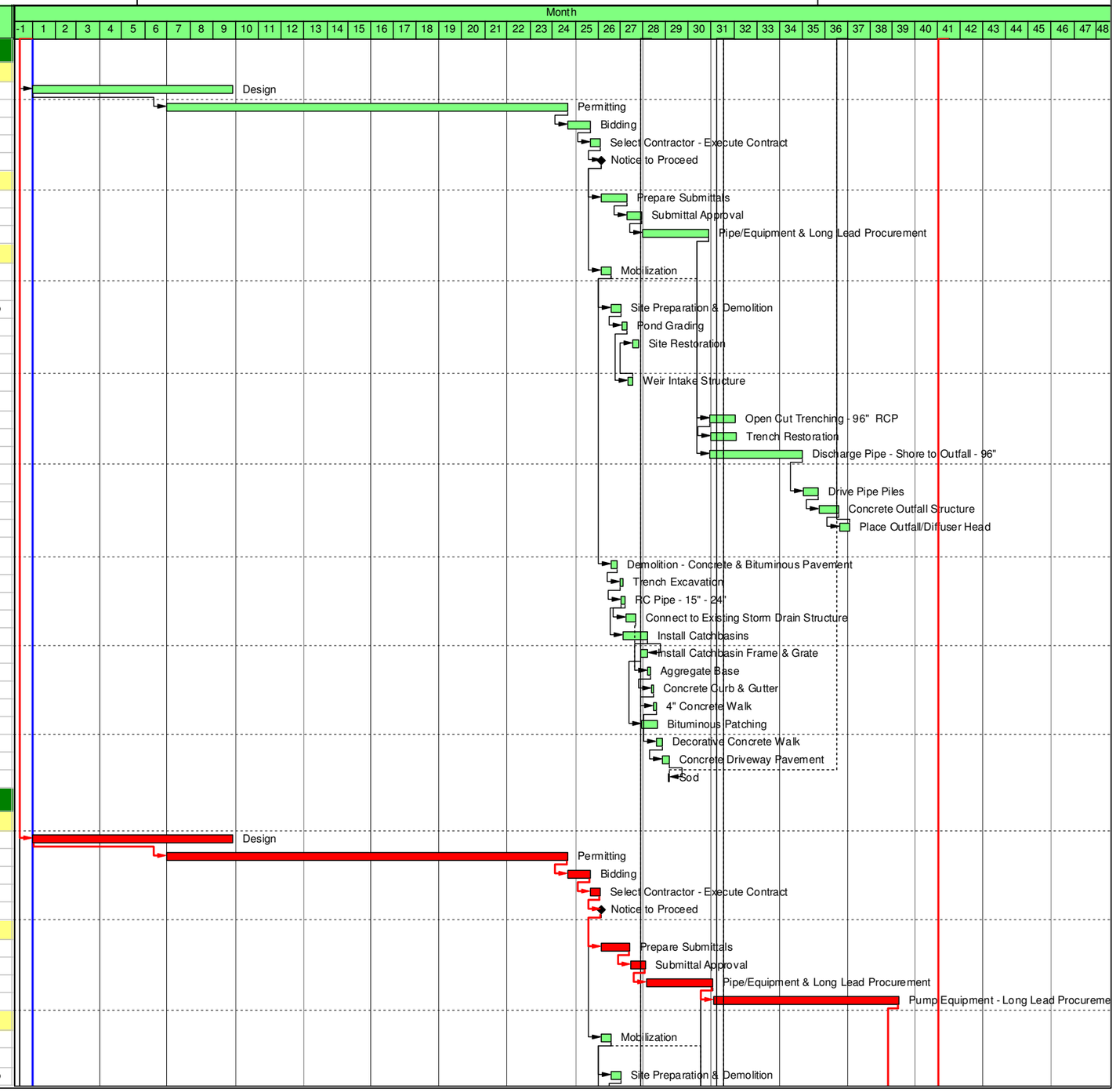
Date	Revision	Checked	Approved
03-Dec-13	Rev 1.00 - Draft Schedule		
06-Dec-13	Rev 1.01 - Backcheck 1		

Stanley Consultants INC.

San Vitores Road Conceptual Flood Mitigation Options

Conceptual Schedule Timeline of Options

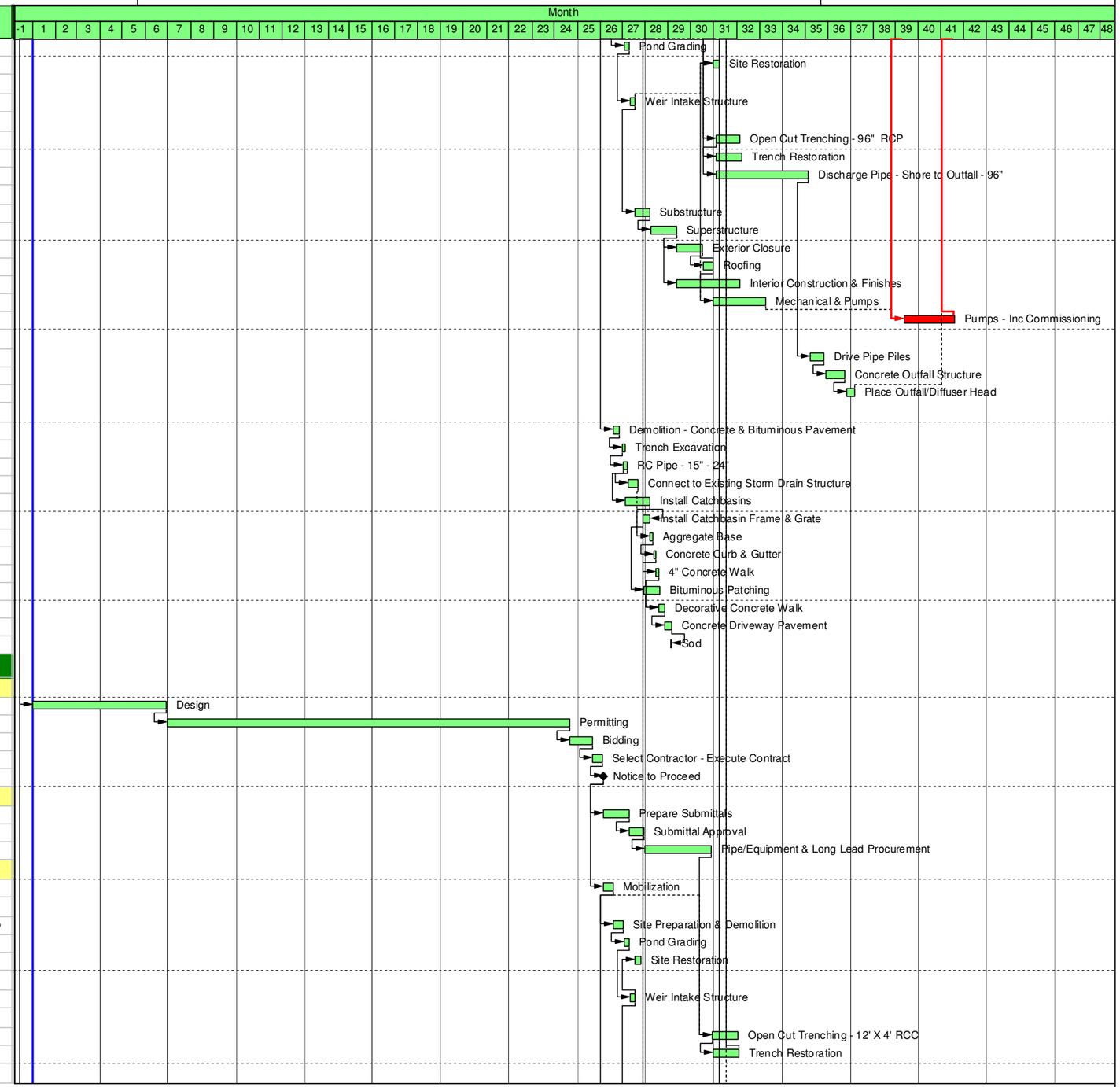
Activity ID	Activity Name	Est Dur	Notes - Assumptions
Gravity Ocean Outlet		785	
Design & Bid		546	
B100	Design	270	
B110	Permitting	540	
B120	Bidding	30	
B130	Select Contractor - Execute Contract	14	
B140	Notice to Proceed	0	
Submittals & Procurement		146	
B200	Prepare Submittals	35	
B210	Submittal Approval	21	
B220	Pipe/Equipment & Long Lead Procurement	90	
Construction		239	
B250	Mobilization	10	
Site & Grading		27	
B300	Site Preparation & Demolition	10	2 ac - Clearing/Grubbing & Demolition of some Bldg & Pav
B310	Pond Grading	6	1 ac - aprox 6,300 cy @ 1,000 cy/d
B320	Site Restoration	6	2 ac @ 3d/ac
Intake Structure		5	
B400	Weir Intake Structure	5	220 cy @ 60 cy/d + 1d prep
Pipe Construction		90	
B600	Open Cut Trenching - 96" RCP	25	Residential - Traffic Ctrl-Street Demo 1,000 lf @ 40 lf/d
B630	Trench Restoration	25	1,000 lf -
B620	Discharge Pipe - Shore to Outfall - 96"	90	1,800 lf @ 20 lf/d
Outfall Diffuser Construction		45	
B800	Drive Pipe Piles	15	Estimate - No Drawings
B820	Concrete Outfall Structure	20	Estimate - No Drawings
B810	Place Outfall/Diffuser Head	10	Estimate - No Drawings
Storm Sewer Improvements		56	
B830	Demolition - Concrete & Bituminous Pavement	7	22,000 sf @ 3,000 sf/d
B840	Trench Excavation	5	980 lf @ 200' /d
B850	RC Pipe - 15" - 24"	4	680 lf @ 200' /d
B880	Connect to Existing Storm Drain Structure	10	20 @ 2/d
B860	Install Catchbasins	24	47 @ 2/d
B870	Install Catchbasin Frame & Grate	8	47 @ 6/d
B890	Aggregate Base	3	609 cy @ 200 cy/d
B900	Concrete Curb & Gutter	3	780 lf @ 300 lf/d
B910	4" Concrete Walk	2	600 sf @ 600 sf/d + 1d prep
B940	Bituminous Patching	15	14400 sf @ 1000 sf/d
B920	Decorative Concrete Walk	6	2400 sf @ 500 sf/d + prep
B930	Concrete Driveway Pavement	7	3600 sf @ 600 sf/d + 1d prep
B950	Sod	2	1,323 sf
Gravity/Pumped Ocean Outlet		883	
Design & Bid		546	
C100	Design	270	
C110	Permitting	540	
C120	Bidding	30	
C130	Select Contractor - Execute Contract	14	
C140	Notice to Proceed	0	
Submittals & Procurement		287	
C200	Prepare Submittals	40	
C210	Submittal Approval	21	
C220	Pipe/Equipment & Long Lead Procurement	90	
C230	Pump Equipment - Long Lead Procurement	180	
Construction		337	
C250	Mobilization	10	
Site & Grading		102	
C300	Site Preparation & Demolition	10	2 ac - Clearing/Grubbing & Demolition of some Bldg & Pav



San Vitores Road Conceptual Flood Mitigation Options

Conceptual Schedule Timeline of Options

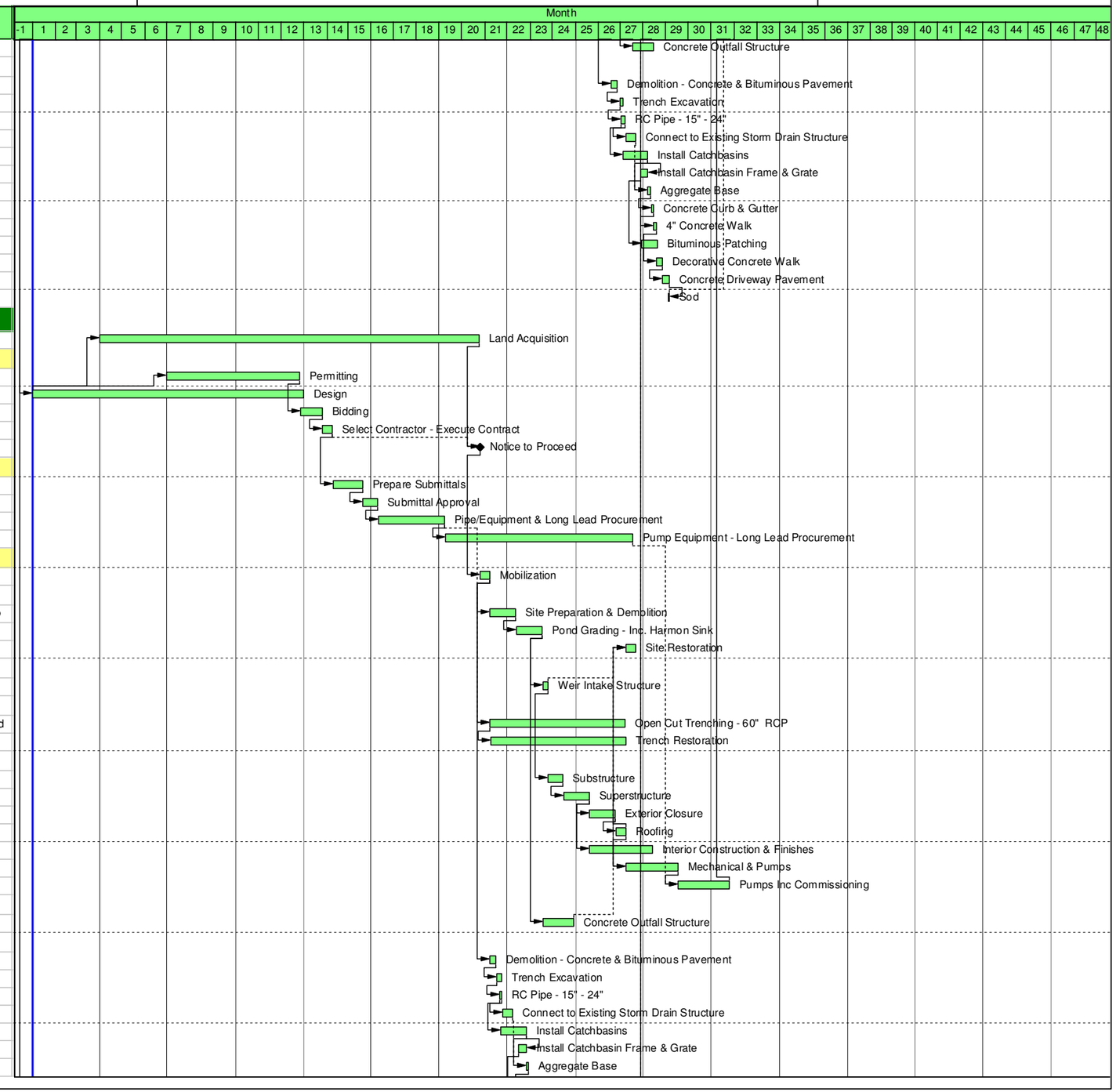
Activity ID	Activity Name	Est Dur	Notes - Assumptions
C310	Pond Grading	6	1 ac - aprox 6,300 cy @ 1,000 cy/d
C320	Site Restoration	6	2 ac @ 3d/ac
Intake Structure		5	
C400	Weir Intake Structure	5	220 cy @ 60 cy/d + 1d prep
Pipe Construction		90	
C600	Open Cut Trenching - 96" RCP	25	Residential - Traffic Ctrl-Street Demo 1,000 lf @ 40 lf/d
C630	Trench Restoration	25	1,000 lf -
C620	Discharge Pipe - Shore to Outfall - 96"	90	1,800 lf @ 20 lf/d
Pump Station Construction		306	
C700	Substructure	15	Estimate - No Drawings - 2800 sf - 4 pump
C710	Superstructure	25	Estimate - No Drawings - 2800 sf - 4 pump
C720	Exterior Closure	25	Estimate - No Drawings - 2800 sf - 4 pump
C730	Roofing	10	Estimate - No Drawings - 2800 sf - 4 pump
C740	Interior Construction & Finishes	61	Estimate - No Drawings - 2800 sf - 4 pump
C750	Mechanical & Pumps	50	Estimate - No Drawings - 2800 sf - 4 pump
C760	Pumps - Inc Commissioning	50	
Outfall Diffuser Construction		45	
C800	Drive Pipe Piles	15	Estimate - No Drawings
C820	Concrete Outfall Structure	20	Estimate - No Drawings
C810	Place Outfall/Diffuser Head	10	Estimate - No Drawings
Storm Sewer Improvements		56	
C500	Demolition - Concrete & Bituminous Pavement	7	22,000 sf @ 3,000 sf/d
C505	Trench Excavation	5	980 lf @ 200' /d
C510	RC Pipe - 15" - 24"	4	680 lf @ 200' /d
C525	Connect to Existing Storm Drain Structure	10	20 @ 2/d
C515	Install Catchbasins	24	47 @ 2/d
C520	Install Catchbasin Frame & Grate	8	47 @ 6/d
C530	Aggregate Base	3	609 cy @ 200 cy/d
C535	Concrete Curb & Gutter	3	780 lf @ 300 lf/d
C540	4" Concrete Walk	2	600 sf @ 600 sf/d + 1d prep
C555	Bituminous Patching	15	14400 sf @ 1000 sf/d
C545	Decorative Concrete Walk	6	2400 sf @ 500 sf/d + prep
C550	Concrete Driveway Pavement	7	3600 sf @ 600 sf/d + 1d prep
C560	Sod	2	1,323 sf
Gravity Bay Outlet		676	
Design & Bid		546	
F100	Design	180	
F110	Permitting	540	Unknown - May not be Possible\
F120	Bidding	30	
F130	Select Contractor - Execute Contract	14	
F140	Notice to Proceed	0	
Submittals & Procurement		146	
F200	Prepare Submittals	35	
F210	Submittal Approval	21	
F220	Pipe/Equipment & Long Lead Procurement	90	
Construction		130	
F250	Mobilization	10	
Site & Grading		27	
F300	Site Preparation & Demolition	10	2 ac - Clearing/Grubbing & Demolition of some Bldg & Pav
F310	Pond Grading	6	1 ac - aprox 6,300 cy @ 1,000 cy/d
F320	Site Restoration	6	2 ac @ 3d/ac
Intake Structure		5	
F400	Weir Intake Structure	5	220 cy @ 60 cy/d + 1d prep
Pipe Construction		26	
F600	Open Cut Trenching - 12' X 4' RCC	25	Residential - Traffic Ctrl-Street Demo 1,000 lf @ 40 lf/d
F630	Trench Restoration	25	1,000 lf -
Outfall Diffuser Construction		20	



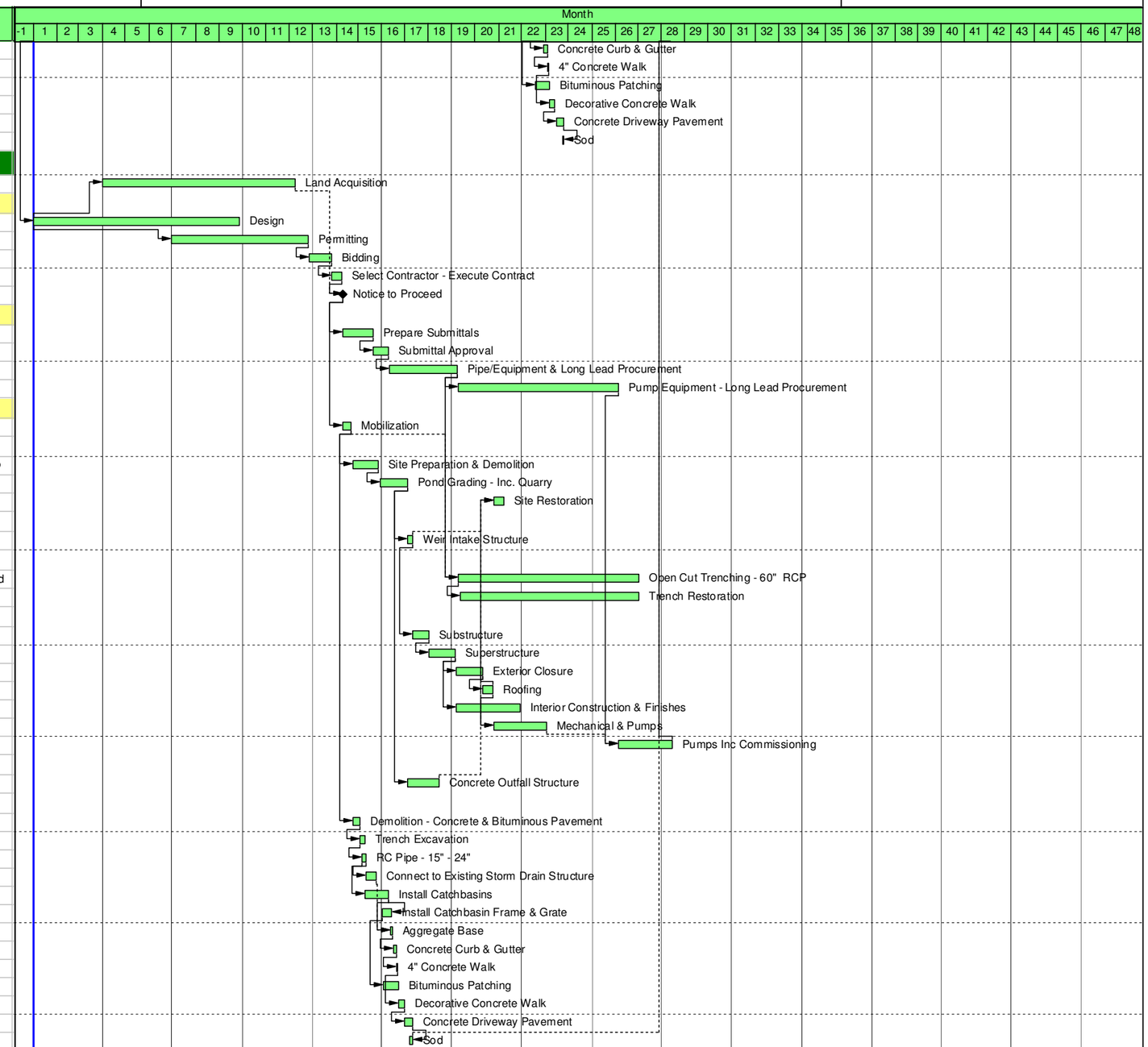
San Vitores Road Conceptual Flood Mitigation Options

Conceptual Schedule Timeline of Options

Activity ID	Activity Name	Est Dur	Notes - Assumptions
F820	Concrete Outfall Structure	20	Estimate - No Drawings
Storm Sewer Improvements		56	
F830	Demolition - Concrete & Bituminous Pavement	7	22,000 sf @ 3,000 sf/d
F840	Trench Excavation	5	980 lf @ 200' /d
F850	RC Pipe - 15" - 24"	4	680 lf @ 200' /d
F880	Connect to Existing Storm Drain Structure	10	20 @ 2/d
F860	Install Catchbasins	24	47 @ 2/d
F870	Install Catchbasin Frame & Grate	8	47 @ 6/d
F890	Aggregate Base	3	609 cy @ 200 cy/d
F900	Concrete Curb & Gutter	3	780 lf @ 300 lf/d
F910	4" Concrete Walk	2	600 sf @ 600 sf/d + 1d prep
F940	Bituminous Patching	15	14400 sf @ 1000 sf/d
F920	Decorative Concrete Walk	6	2400 sf @ 500 sf/d + prep
F930	Concrete Driveway Pavement	7	3600 sf @ 600 sf/d + 1d prep
F950	Sod	2	1,323 sf
Pump to Sink		670	
210	Land Acquisition	365	
Design & Bid		429	
D110	Permitting	180	
D100	Design	365	
D120	Bidding	30	
D130	Select Contractor - Execute Contract	14	
D140	Notice to Proceed	0	
Submittals & Procurement		289	
D200	Prepare Submittals	40	
D210	Submittal Approval	21	
D220	Pipe/Equipment & Long Lead Procurement	90	
D230	Pump Equipment - Long Lead Procurement	180	
Construction		241	
D250	Mobilization	10	
Site & Grading		141	
D300	Site Preparation & Demolition	25	5 ac - Clearing/Grubbing & Demolition of some Bldg & Pav
D310	Pond Grading - Inc. Harmon Sink	26	8 Acres = 350,000 sf x 4' = 52,000 cy @ 2,000 CY/d
D320	Site Restoration	10	5 ac @ 2d/ac
Intake Structure		5	
D400	Weir Intake Structure	5	220 cy @ 60 cy/d + 1d prep
Pipe Construction		131	
D600	Open Cut Trenching - 60" RCP	130	Residential/Bus - Traffic Ctrl-Street Demo 6,500 lf @ 50 lf/d
D630	Trench Restoration	130	6,500 lf
Pump Station Construction		175	
D700	Substructure	15	Estimate - No Drawings - 2800 sf - 4 pump
D710	Superstructure	25	Estimate - No Drawings - 2800 sf - 4 pump
D720	Exterior Closure	25	Estimate - No Drawings - 2800 sf - 4 pump
D730	Roofing	10	Estimate - No Drawings - 2800 sf - 4 pump
D740	Interior Construction & Finishes	61	Estimate - No Drawings - 2800 sf - 4 pump
D750	Mechanical & Pumps	50	Estimate - No Drawings - 2800 sf - 4 pump
D760	Pumps Inc Commissioning	50	
Outfall Diffuser Construction		30	
D820	Concrete Outfall Structure	30	100 yd Conc @ 50 yd/d + 1d prep
Storm Sewer Improvements		56	
D500	Demolition - Concrete & Bituminous Pavement	7	22,000 sf @ 3,000 sf/d
D505	Trench Excavation	5	980 lf @ 200' /d
D510	RC Pipe - 15" - 24"	4	680 lf @ 200' /d
D525	Connect to Existing Storm Drain Structure	10	20 @ 2/d
D515	Install Catchbasins	24	47 @ 2/d
D520	Install Catchbasin Frame & Grate	8	47 @ 6/d
D530	Aggregate Base	3	609 cy @ 200 cy/d



San Vitores Road Conceptual Flood Mitigation Options

Conceptual Schedule Timeline of Options

Activity ID	Activity Name	Est Dur	Notes - Assumptions
D535	Concrete Curb & Gutter	3	780 lf @ 300 lf/d
D540	4" Concrete Walk	2	600 sf @ 600 sf/d + 1d prep
D555	Bituminous Patching	15	14400 sf @ 1000 sf/d
D545	Decorative Concrete Walk	6	2400 sf @ 500 sf/d + prep
D550	Concrete Driveway Pavement	7	3600 sf @ 600 sf/d + 1d prep
D560	Sod	2	1,323 sf
Pump to Quarry		597	
230	Land Acquisition	180	
Design & Bid		288	
E100	Design	270	
E110	Permitting	180	
E120	Bidding	30	
E130	Select Contractor - Execute Contract	14	
E140	Notice to Proceed	0	
Submittals & Procurement		259	
E200	Prepare Submittals	40	
E210	Submittal Approval	21	
E220	Pipe/Equipment & Long Lead Procurement	90	
E230	Pump Equipment - Long Lead Procurement	150	
Construction		309	
E250	Mobilization	10	
Site & Grading		141	
E300	Site Preparation & Demolition	25	5 ac - Clearing/Grubbing & Demolition of some Bldg & Pav
E310	Pond Grading - Inc. Quarry	26	8 Acres = 350,000 sf x 4' = 52,000 cy @ 2,000 CY/d
E320	Site Restoration	10	5 ac @ 2d/ac
Intake Structure		5	
E400	Weir Intake Structure	5	220 cy @ 60 cy/d + 1d prep
Pipe Construction		169	
E600	Open Cut Trenching - 60" RCP	168	Residential/Bus - Traffic Ctrl-Street Demo 8,400 lf @ 50 lf/d
E630	Trench Restoration	168	8,400 lf
Pump Station Construction		243	
E700	Substructure	15	Estimate - No Drawings - 2800 sf
E710	Superstructure	25	Estimate - No Drawings - 2800 sf
E720	Exterior Closure	25	Estimate - No Drawings - 2800 sf
E730	Roofing	10	Estimate - No Drawings - 2800 sf
E740	Interior Construction & Finishes	61	Estimate - No Drawings - 2800 sf
E750	Mechanical & Pumps	50	Estimate - No Drawings - 2800 sf
E760	Pumps Inc Commissioning	50	
Outfall Diffuser Construction		30	
E820	Concrete Outfall Structure	30	100 yd Conc @ 50 yd/d + 1d prep
Storm Sewer Improvements		56	
E500	Demolition - Concrete & Bituminous Pavement	7	22,000 sf @ 3,000 sf/d
E505	Trench Excavation	5	980 lf @ 200' /d
E510	RC Pipe - 15" - 24"	4	680 lf @ 200' /d
E525	Connect to Existing Storm Drain Structure	10	20 @ 2/d
E515	Install Catchbasins	24	47 @ 2/d
E520	Install Catchbasin Frame & Grate	8	47 @ 6/d
E530	Aggregate Base	3	609 cy @ 200 cy/d
E535	Concrete Curb & Gutter	3	780 lf @ 300 lf/d
E540	4" Concrete Walk	2	600 sf @ 600 sf/d + 1d prep
E555	Bituminous Patching	15	14400 sf @ 1000 sf/d
E545	Decorative Concrete Walk	6	2400 sf @ 500 sf/d + prep
E550	Concrete Driveway Pavement	7	3600 sf @ 600 sf/d + 1d prep
E560	Sod	2	1,323 sf