DEVELOPMENT OF JUNCTION WATER DEMANDS FOR THE SAIPAN WATER DISTRIBUTION SYSTEM NUMERICAL MODEL

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Leroy Heitz
Shahram Khosrowpanah
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WERI
WATER AND ENVIRONMENTAL RESEARCH INSTITUTE
OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM

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Dr. Leroy Heitz, P.E.
Dr. Shahram Khosrowpanah, P.E.
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University of Guam
Water and Environmental Research Institute
of the Western Pacific
UOG Station, Mangilao, Guam 96923

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ABSTRACT

The Saipan water distribution system has been divided into 15 sub-regions. Each region is expected to operate somewhat independently. However, due to inadequate inflow to some of the sub-regions, system leakage, and lack of knowledge of the system behavior as a whole, the system is unable to provide 24-hour water services. A stated goal of the Commonwealth of the Northern Marianas Islands (CNMI) Government is to provide 24-hour water to all residents served by the Commonwealth Utility Corporation (CUC) water system. The CNMI Governor created a task force whose primary purpose is to find funding and oversee the CUC accomplishments toward the 24-hours water service goal. To assist in reaching their goals, the CUC commissioned the university of Guam Water and Environmental Research Institute of the Western Pacific (WERI) to develop a hydraulic model of the Saipan water system and to train CUC water division staff in the use of that model.

WERI researchers developed computerized models of each of the fifteen sub-regions of the CUC water system using the Haestad WaterCad water system modeling program. They also, developed a source, transmission and storage model of the Saipan water system. This includes a skeleton of the existing 15-region water system models that are joined together at the boundary points. For the model to provide optimal results, it is essential to have a good knowledge of the residential and commercial demands being placed on the distribution system. Without this knowledge it is impossible to have a well calibrated hydraulic model of the water system.

The specific objectives of this project were to:

1. Determine the average use rate for residential customers in Saipan and to determine the actual use rate for high commercial consumers such as Laundromats, commercial laundries, and hotels.
2. Using Geographical Information System (GIS) techniques determine all residential and commercial customer locations in Saipan and assign appropriate use rates to the water system model junction that is closest to each customer location.
3. Export the data developed in Step 2 into the Saipan Water System Hydraulic Model.

The improvements to the demand estimates used in the existing water system model will provide the CUC water division with the capability to better identify what changes in operation and system improvements are required in order to meet the goals of improved water quality and 24-hour water to all of the CUC customers.

KEYWORDS: Saipan, Commonwealth Utility Corporation, CUC, Water Distribution System Modeling, Water System Demands, WaterCAD for AutoCAD

ACKNOWLEDGMENTS

We thank the Engineering Staff of the Commonwealth Utility Corporation (CUC) for their support and assistance on this project. Special thanks goes to Mr. Mariano Iglecias and Mr. Larry Manacop who spent many hours working with the principal investigators improving the data that was input into the original water system models. Both were also helpful in securing water use data from existing CUC records.

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INTRODUCTION

The US Environmental Protection Agency (EPA) has recently stressed that the water distribution system in Saipan, CNMI is still in need of improvement. The EPA has acknowledged that the lack of safe drinking water has been among the top environmental challenges that the EPA found to be facing the CNMI, particularly Saipan. In a previous assessment, the EPA found Saipan to be the only municipality of its size in the United States without 24-hour water delivery.[1] The agency reported that the water on the island is not drinkable due to its high salinity, and water flows through the pipes only a few hours per day for almost half of the island's residents.

One important step in establishing 24-hour water and improving water quality in the system is for the Commonwealth Utility Corporation (CUC) to have a better understanding of how their distribution system delivers water to customers and what improvements are needed to meet operational and water quality goals. To assist in reaching their goals, the CUC commissioned The University of Guam Water and Environmental Research Institute of the Western Pacific (WERI) to develop a hydraulic model of the Saipan water system and to train CUC water division engineers in the use of that model. This model was completed and delivered to CUC in July of 2007.

In order to have a sound hydraulic model, it is necessary to have a good knowledge of the residential and commercial demands being placed on the distribution system. As mentioned by the US EPA, much of the water system is not supplying water on a 24-hour basis and many of the customers have never been metered. At this point in time there is little knowledge on the usage rate values and how this usage is spatially distributed across the water system. Without this knowledge it is impossible to have a well calibrated hydraulic model of the water system.

This project refined estimates of both the quantities and spatial distribution of water demands of both residential and commercial customers of the Saipan CUC water system. The resulting improvements to the demand estimates when used in the existing water system models will provide the CUC water division with the capability to better identify what changes in operation and system improvements are required in order to meet the goals of improved water quality and 24-hour water to all of the CUC customers.

OBJECTIVES

The specific objectives of this project were to:

1. Determine the average use rate for residential customers in Saipan and to determine the actual use rate for high commercial consumers such as laundromats, commercial laundries, and bottled water manufacturers.

2. Using Geographical Information System (GIS) techniques determine all residential and commercial customer locations in Saipan and assign appropriate use rates to the water system model junction that is closest to each customer location.

3. Export the data developed in Step 2 into the Saipan Water System Hydraulic Models

The resulting improvements to the demand estimates used in the existing water system models will provide the CUC water division with the capability to better identify what changes in operation and system improvements are required in order to meet the goals of improved water quality and 24-hour water to all of the CUC customers.

STUDY AREA

Geographic and Hydrologic Setting

The Island of Saipan is located in the Commonwealth of the Northern Marianas Islands (CNMI) which is part of the Marianas Chain of the Islands of Micronesia. As shown in Figure 1, Saipan is located at approximately 15° 11' North Latitude and 145° 45' East Longitude, or approximately 1500 miles south of Japan and approximately 3500 miles west of the Hawaiian Islands. Its closest neighbors are Tinian and Rota in the CNMI, and the Territory of Guam which is located approximately 135 miles south.

Elevations on the island rage from sea level to approximately 1400 ft on Mount Takpochao. The geology of the island varies from Limestone karst structures to structures of volcanic origin.[2] Ground water is a major source of water for the municipal water distribution system. Since the geo-hydrology of the island is highly complex, finding and developing groundwater successfully presents a great challenge to water managers. There are a few spring sources that have been developed for municipal use, and there are a few small streams on the eastern side of the island which presently are not used by the municipal water supply system.

Average rainfall in Saipan is approximately 77 inches per year at the airport. The rainfall is not evenly distributed. Approximately 67 percent of the rainfall occurs during the wet season months (July through December) and approximately 33 percent occurs during the dry season months (January through June).[3]

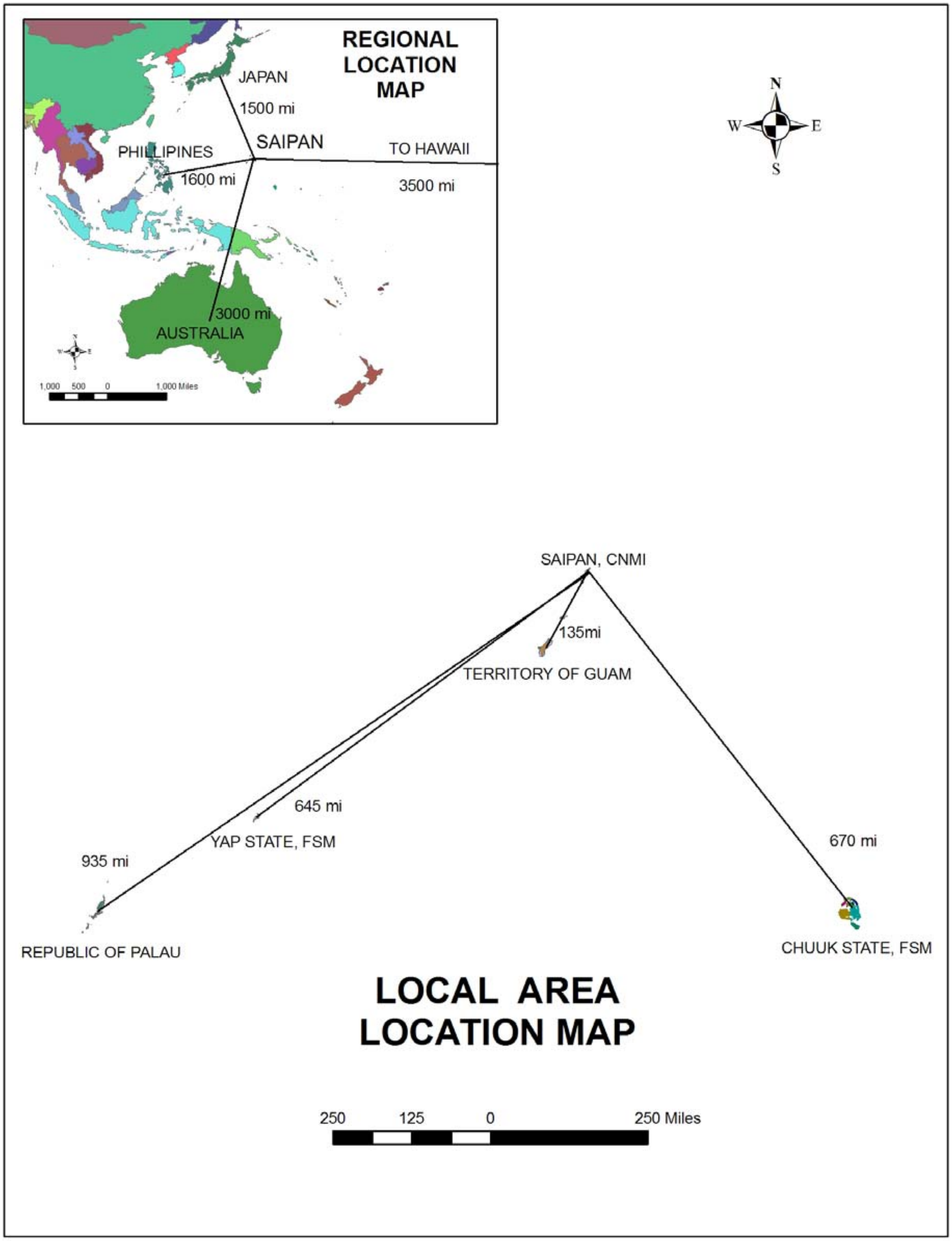

Figure 1 Location of Saipan, CNMI

Water System Description

Saipan's water distribution system, which is operated by the Commonwealth Utility Corporation (CUC), is divided into 15 sub-regions as shown in Figure 2. Each sub-region (I.D. numbers shown in red on Figure 2) can be operated as a separate entity or connected with adjacent regions. Each sub-system consists of well or spring sources, transmission piping, tanks for storage of water, and distribution system piping to deliver water to the CUC customers.

The Saipan water system serves a population of 62,400 people.[4] In 2006 CUC served a total of 14,600 customer accounts.[5] Table 1 lists the customers and estimates of use rates based on various per capita demands. Figure 3 shows the spatial distribution of the number of CUC customers by region.

WATER USE DEMAND CALCULATION
FOR
SAIPAN WATER DISTRIBUTION SYSTEM
Using CUC Routing System

Region	# Customers	# People	Water Use GPD/P	Water Use GPD/P	Water Use GPD/P	Water Use (gpm)	Water Use (gpm)	Water Use (gpm)
		6/customer	80	100	150	80	100	150
1	443	2658	212640	265800	398700	148	185	277
2	582	3492	279360	349200	523800	194	243	364
3	908	5448	435840	544800	817200	303	378	568
4	3163	18978	1518240	1897800	2846700	1054	1318	1977
5	249	1494	119520	149400	224100	83	104	156
6	1180	7080	566400	708000	1062000	393	492	738
7	1113	6678	534240	667800	1001700	371	464	696
8A	2078	12468	997440	1246800	1870200	693	866	1299
8B	1361	8166	653280	816600	1224900	454	567	851
8C	1211	7266	581280	726600	1089900	404	505	757
8D	180	1080	86400	108000	162000	60	75	113
8E	50	300	24000	30000	45000	17	21	31
9A	1545	9270	741600	927000	1390500	515	644	966
9B	164	984	78720	98400	147600	55	68	103
10	384	2304	184320	230400	345600	128	160	240
TOTAL	**14,611**	**87,666**	**7,013,280**	**8,766,600**	**13,149,900**	**4,870**	**6,088**	**9,132**

Table 1 Saipan Water Distribution System Estimated Water Demands by Region

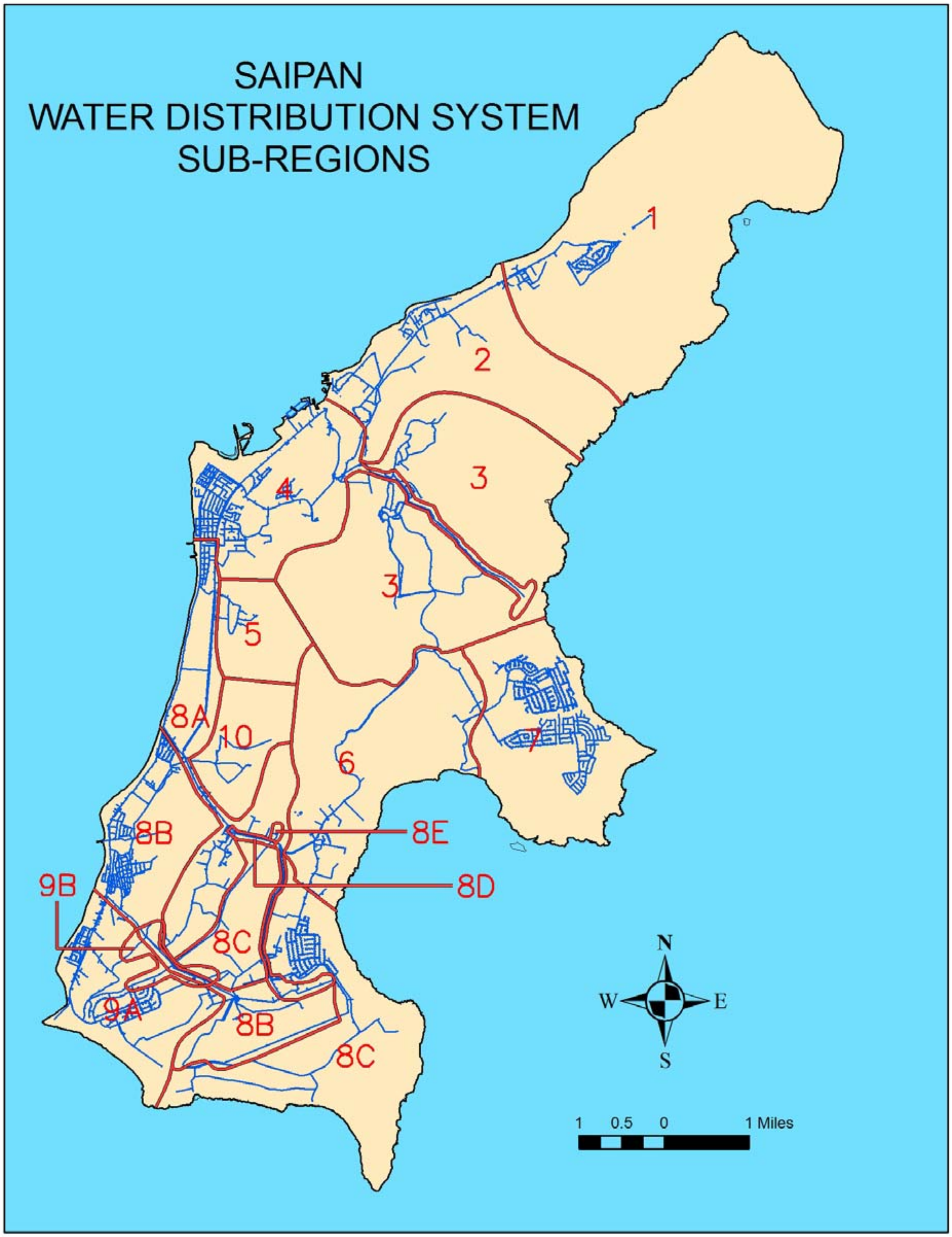

Figure 2 Saipan Water Distribution System, Water Delivery Sub-Regions

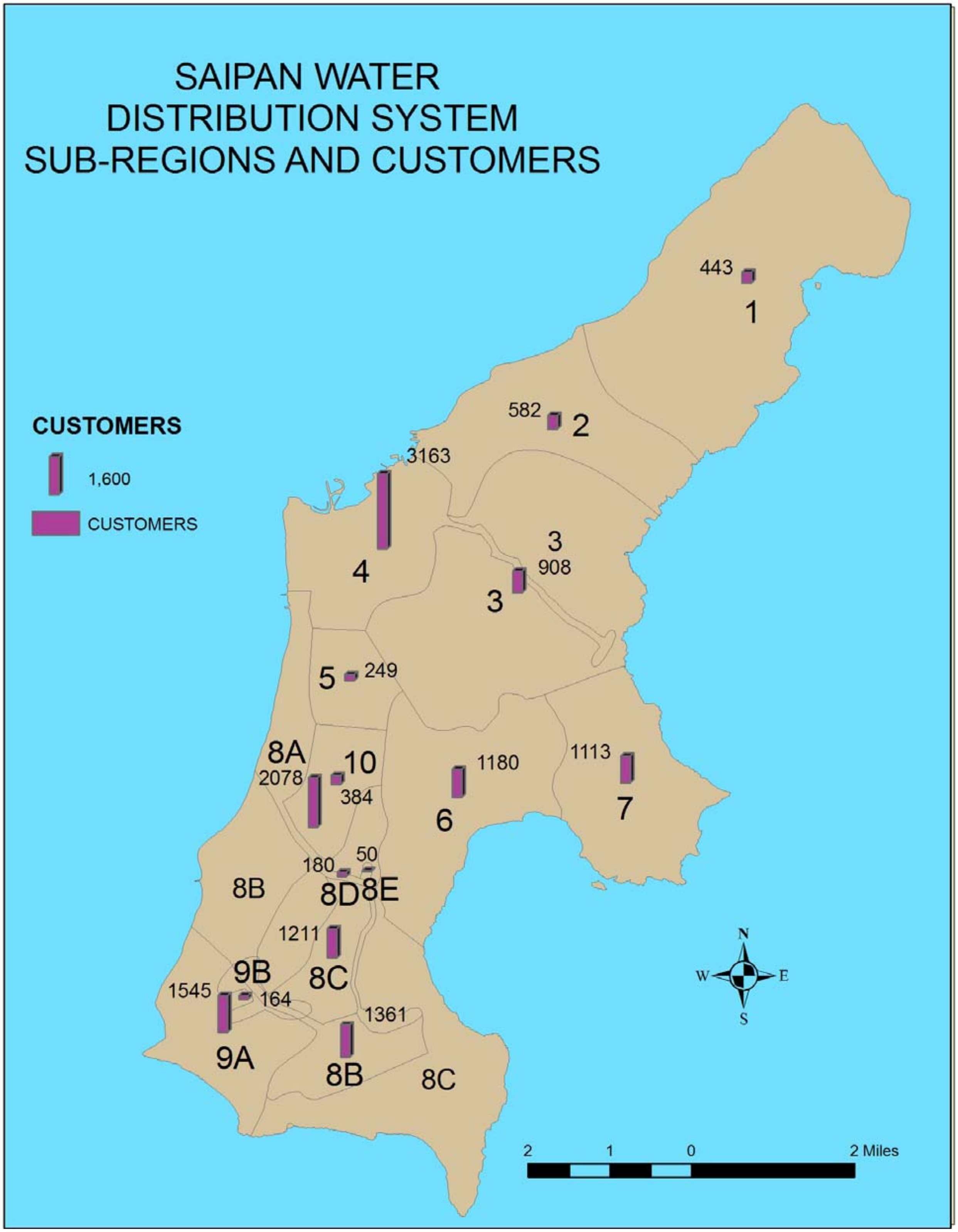

Figure 3 Estimated Number of Customers by Sub-Region

BACKGROUND

In earlier studies separate water distribution system models, using the Haestad WaterCAD for AutoCAD program were developed by WERI engineers for each of the fifteen sub-systems in the Saipan water distribution system. Engineers from the CUC Water Divisions and the Governor's task force were provided instruction in how to operate the models.

One important parameter that must be input to the model is the customer demands. These demands are input at the junction points in the models. Since much of the CUC system is un-metered, it was very difficult, in earlier studies, to estimate the quantity and spatial distribution of the demands (as of July 2007) throughout the system.

The major goal of this study was to refine estimates of demands to be applied to each of the junctions in the fifteen Saipan water distribution system sub-models using Geographic Information System (GIS) techniques.

PREVIOUS STUDIES

In previous studies by WERI the junction demands were developed using the data in Table 1. The final demands were computed using the column titled 100 gal/day/person (GPD/P). The junction demands were calculated by simply dividing the total demand by the number of junctions in each sub-system and then correcting this number by the appropriate unit conversion factors to get demands at each junction in average daily gallons per minute (gpm). While this gives a reasonable value for the overall demand on the system, it does not account for the effect of where these demands occur on the hydraulics of the water system. Therefore, improvements in assigning where demands occur will improve the accuracy of the water system models.

The major goal of this study was to refine estimates of demands to be applied to each of the junctions in the fifteen Saipan water distribution system sub-models using Geographic Information System (GIS) techniques. This was done by accounting for the relative location of each of the residential and high use customers to the junctions in the computer models of the system.

METHODS AND PROCEDURES

The major goal of this study was to refine estimates of demands to be applied to each of the junctions in the fifteen Saipan water distribution system sub-models using Geographic Information System (GIS) techniques. This was done by accounting for the relative location of each of the residential customers to the junctions in the computer model of the system. In order to accomplish this goal the following steps were required:

1. Gather latest population census data into a usable format
2. Digitize residence location from satellite imagery
3. Using GIS determine residents per house
4. Using GIS determine residents per junction
5. Use latest CUC metered data to get usage per residence
6. Determine average use rate per junction
7. Apply these use rates to the junctions in the hydraulic model

Extracting Census Data

The first step in determining the junction use rates for the Saipan system is to determine the number of people to assign to each junction point in the sub-systems. Once the number of people are assigned to each junction point various demands based on usage per day per person can be globally edited into the junction nodes by multiplying the number of people per junction by the demand per person and the appropriate conversion factor to get demands at the junctions in gallons per minute. The first step in the process is to use 2000 census data to determine the number of people in each unique census tract block group and to connect this data with a shape file of the census map. The census map and population data are downloaded directly from the US Census Bureau web site referenced below[6]. The following steps were accomplished to develop the required map data into shape file format.

1. Download http://www.census.gov/prod/2001pubs/dmd01cdpi.pdf and read it. This file contains information on how population data is gathered and organized.

2. Download http://www.census.gov/prod/cen2000/doc/sfcnmi.pdf and read it. This file contains information on how population data is organized in the data file that was downloaded in 4 below. This is a very large file. Only print figure 2-3.

3. Download the Northern Marianas Block Map files by bringing up the US Census Web site (http://www.census.gov/geo/www/cob/bg2000.html) From the Shape file section choose: N. Mariana Islands - bg69_d00_shp.zip (21,049 bytes). Unzip the required shape file data files into a separate folder. Note the projection for this shape file is specified as Latitude Longitude NAD 83.

4. Download the Northern Marianas Block data files by bringing up the US Census Web site (http://www2.census.gov/census_2000/datasets/Island_Areas/CNMI/) and download file: mpgeo_sfia.dat

5. Process the population into a useful dbf file

    a. Load the data into an excel spreadsheet program by parsing (separate the data into excel columns) using Excel "Text to Columns" feature in the data menu. Use Figure 2-3 downloaded in 2 above to get the correct columns for the data values. Use these starting columns and column widths to Parse (divide into columns) the data.

    b. Define the entire data on the sheet as "database" using the "Insert-Name-Define" Menu item. This will make it easier to do sorts on the data.

    c. Sort the database by "county". From the data definitions you will find that Saipan is county "110".

    d. Delete all the data except that for county 110. Save the deleted file with a new name such as "Saipan only raw data".

    e. Note that the total Saipan population is listed as 62,392 and the total housing units is 15,527 for an average per house population of 4.01 people/house.

    f. Delete unneeded columns of data. The important columns are labeled:

        i. Summary level

        ii. Tract

        iii. Block group

        iv. Name

        v. POP100

        vi. HU100

    g. Sort the file in levels by

        i. First, Summary Level

        ii. Next, Tract

        iii. Finally, Block group

    h. Delete all rows except those with Summary level values of 150

    i. Rename the rows "Saipan block group population summaries"

    j. Sum the POP100 and HU100 columns to be sure you have reasonable numbers (similar to 5e above)

k. Add a column to the right of the BLKGRP column and name it TRBLGCD for "Tract-Block Group-code"

l. Copy the following equation into the first cell of the TRBLGCD column. "=IF(MOD(F2,100)>0,F2*10+G2,F2/100*10+G2)" This will create a unique code for each Tract Block group combination. Copy this equation to all cells in the column. You will use this code to join this population data to the GIS map of the Tracts and Blocks.

m. Save this file. Then do a save-as and save the file in "dbf 4" format.

6. Adding the population and house data to the census map

   a. Start ArcMAP with a new map, and add the shape file census map that you downloaded in step 3 above. Its file name is "bg69_d00.shp". Please note that the documentation for the year 2000 data says that the shape file is suppose to be in NAD 83 geographic coordinates. The file projection that is set for the file is NAD 27. At this time it is uncertain which is correct. For this study we assumed that the projection used was NAD 83 and changed the provided projection to NAD 83.

   b. Put the file in edit mode and delete all the islands except for Saipan from the map. Save your edit and quit editing.

   c. Bring up the attribute data base and add and integer field to the database which is a long integer precision zero with name "trblgp" (track block-group). This column is used to join the dbasefile developed above to the shape file attribute data. Select the new column and use the calculate values button and add the following equation "[TRACT] *10 + [BLKGROUP]"

   d. Add two more fields to the attribute file for "bg69_d00.shp". Set both to data type "DOUBLE" with names of POP100 (population) and HU100 (housing units).

   e. Now join the database file of population values to the attribute file for the census map using the "Joins and relates" procedure.

   f. Calculate the fields POP100 and HU100 by applying the field calculator to the joined data from the census data database file for HU100 and POP100.

   g. Add a new field called"PEPERHS" people per house. Calculate this field by dividing the POP100 field by the HU100 field.

7. The next step is to project the Census data map (which is in Nad83, Latitude-Longitude Coordinates into the CUC coordinate system. We projected the Census Shape file into a UTM projection (zone 55n). Because of the low quality of the census map image we used the spatial adjustment tools to rubber-sheet the census map onto the CUC water system map. The completed map is shown in Figure 4.

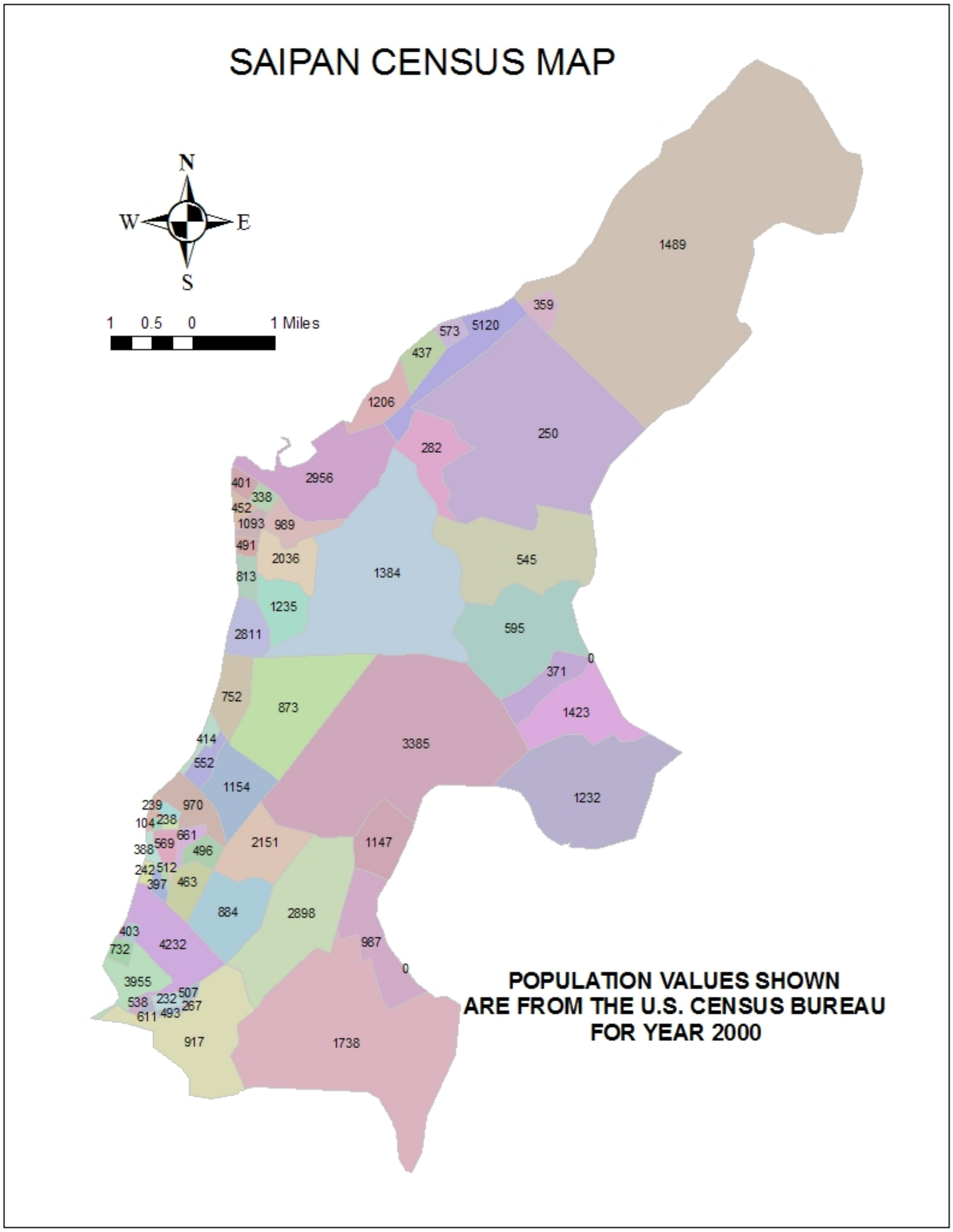

Figure 4 Saipan Census Data for Year 2000

8. The next step is to get a map of the residence location for Saipan. The 2005 Quick-Bird satellite imagery[7] is a good base map for this purpose. The imagery is visually examined and house locations are manually digitized using the imagery. A point shape file is developed for all of the houses in Saipan. Figure 5 shows the house file plotted over the Quick-Bird Satellite Imagery The raw shape file is modified using the calculate function on the attribute database. The ID field is calculated as the FID field. The ID field is used later in the analysis.
9. The next step is to determine the number of people residing in each of the housing units identified above. This involved combining the census data map and the housing map using GIS procedures. Since two projection systems are being used, it is important that the data frame projection be defined precisely and that a transformation between WGS 84 and the projection of the Saipan water system data must be provided. We assumed a projection definition of the AutoCAD water system data to be the same as that used by CNMI land management for Saipan but with distances measured in feet. We obtained the projection definition from Mr. Paul Camacho at CNMI Department of Land Management[8]. The projection is defined first with a Clark 1866 spheroid and the projection used is Equal Distance Azimuthal. The other parameters are as follows:
    1. False Easting 16041.994751
    2. False Northing 16041.994751
    3. Central Meridian 147.711781 degrees East Longitude
    4. Latitude of Origin 15.167551 North Latitude

In order to use WGS 84 based maps on the Saipan grid system defined above, it is necessary to provide a transformation scheme to the GIS software since no default is available. The transformation parameters were also obtained from Mr. Paul Camacho at CNMI Department of Land Management. The required parameters for a geocentric translation from WGS 84 to the Local Saipan System are:

1. dx -59.935 (minus)
2. dy -118.4 (minus)
3. dz 10.871 (plus)

If these parameters are used, the WGS 84 based maps should correctly overlay on the CUC data. This translation will also be helpful when trying to overlay field gathered data using GPS coordinates.

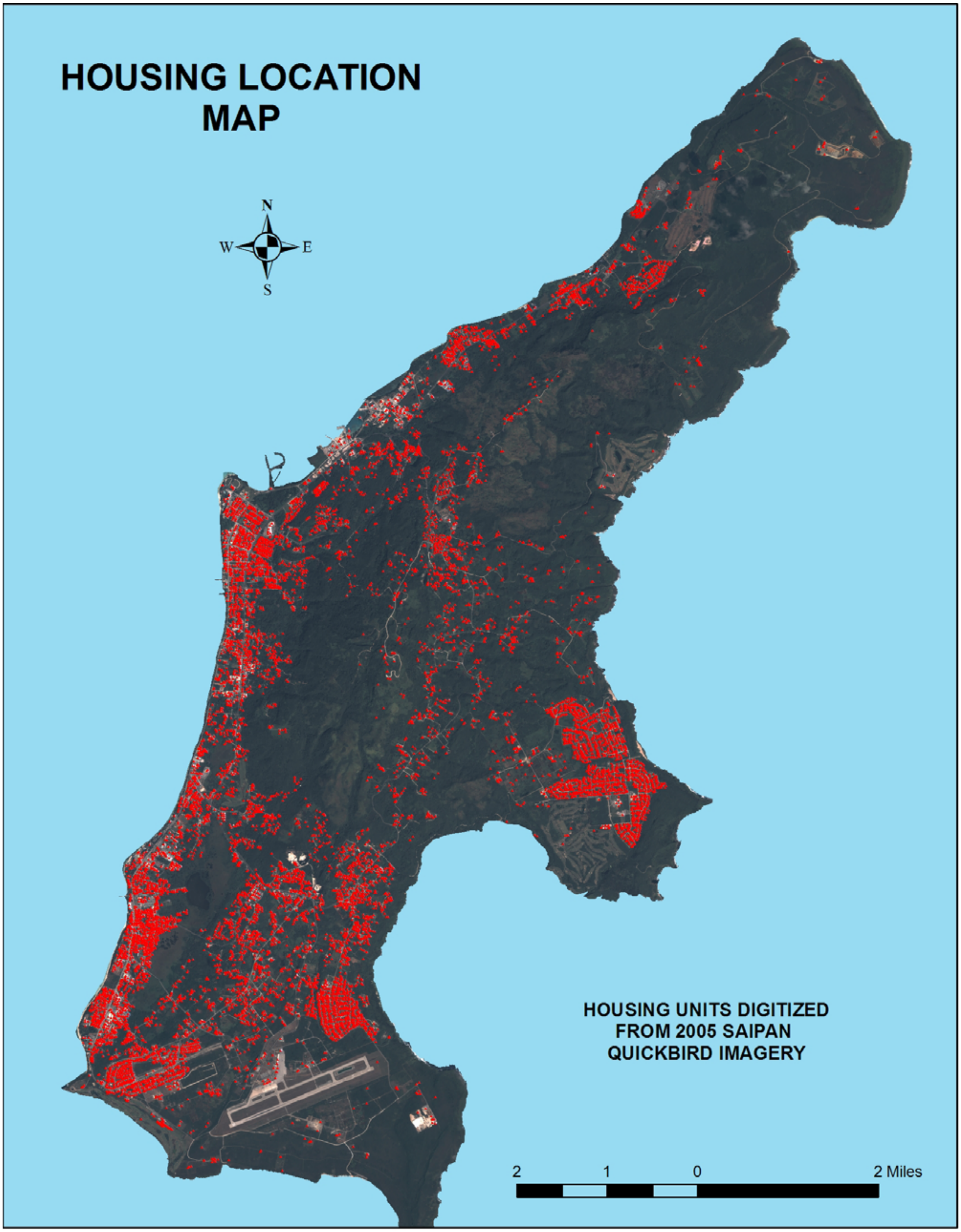

Figure 5 Housing Units Identified Using Satellite Imagery

The steps taken to determine the number of people residing in each of the housing units are as follow:

1. Perform a GIS intersection of the housing (point shape file) and the Census Population (polygon shape file). This will provide a new point shape file that will identify in which census tract-block group each housing unit is located. The new attribute data file will carry along all the attributes from the house point shape file and the census map polygon shape file. Figure 6 on the following page shows a plot of the housing units placed over the census map.

2. Perform a GIS Frequency analysis to determine the number of house units in each census block group. To do this first open the attribute table of the intersection map made in step 1 above. Right click on the block group heading and choose the summarize function. Choose the population field and choose sum for the function to apply. The product of this function is a database file that shows how many houses are in each census tract-block group.

3. The database from 3 above is joined to the attribute file for the Census block group data.

4. Create a new field in the Census Block Group shape file attribute file. This field should be of data type long integer and is used to make the number of houses permanent in the census data. Once the field has been made, calculate its value as being equal to the frequency field in the file that is joined to the Census Block Group data file.

5. Next add another field. This field will contain the calculation of how many people are in each house. The field should be set as a double precision variable with an 8 precision and a scale of 3. Use the calculate function to compute the value of the new field as the population in the census tract block group divided by the frequency in the joined database file (number of houses in the block). The number of houses and residents per house data are shown in Figures 7 and 8 respectively.

6. Next join the census-block-group attribute data table to the map which is the intersection of the houses and the original census map. Once the map is joined make a new field in the intersection map to hold the number of residents per house. This field should be double precision variable with precision = 8 and scale = 2. Using the calculate function make this field equal to the joined field containing the residents per house.

7. Next join the intersection file back to the original house file. Add two fields to the house attribute file. The first field will be used to store the census-tract-block group number. Make it a long integer. The second is used to store the population per residence values. Make it a double precision variable with precision = 8 and scale = 2. Use the calculator to move the joined tract-block group and population per houses values to the house file. Now we have a single shape files that has the location of each house along with which census tract-block – group in which it is contained and the average residents per house for that block group. This file will be used later when we assign population values to each of the junction nodes in the model. An example of a portion of the house map with residents per house is shown in Figure 9.

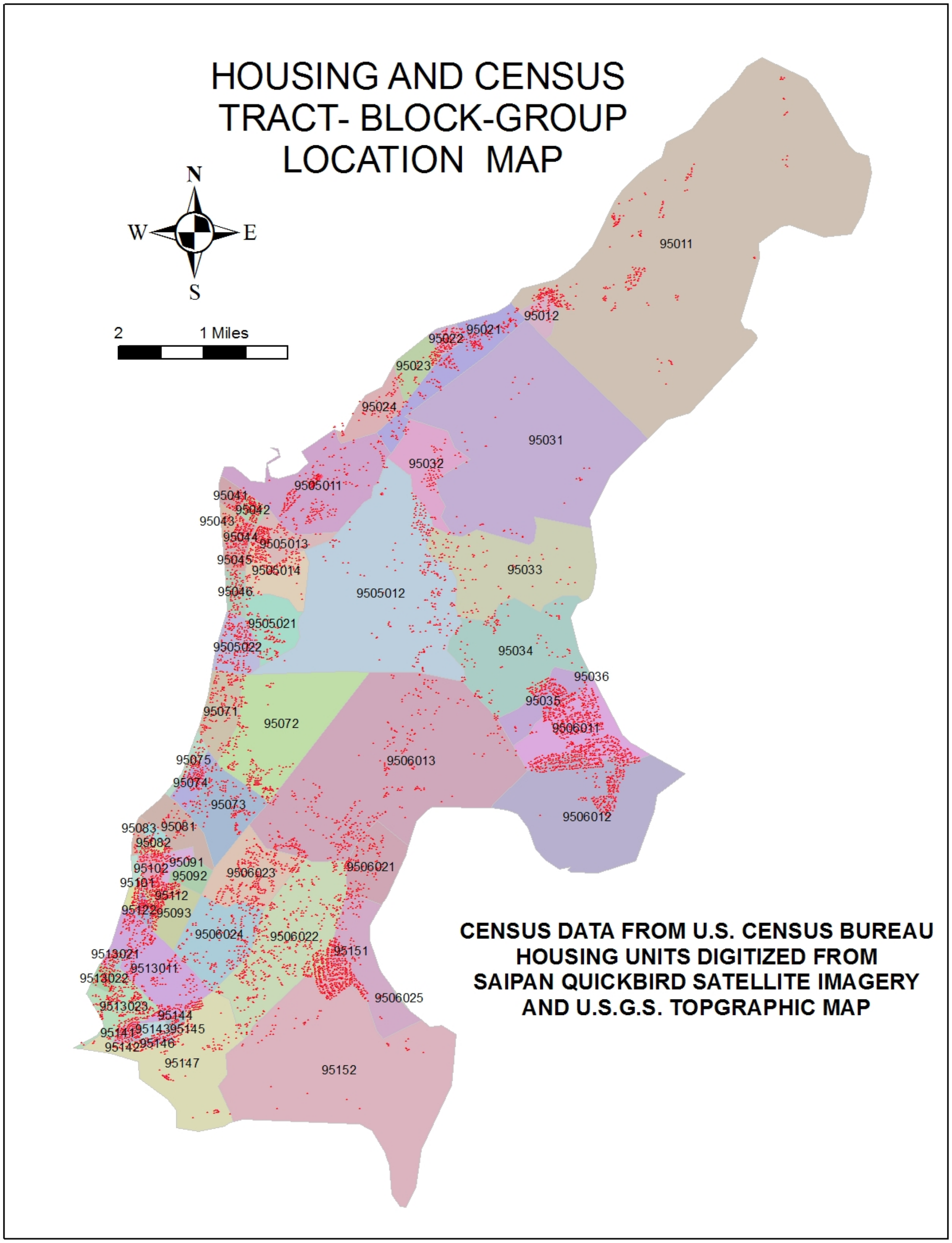

Figure 6 Housing Units and Census Tract-Block Groups

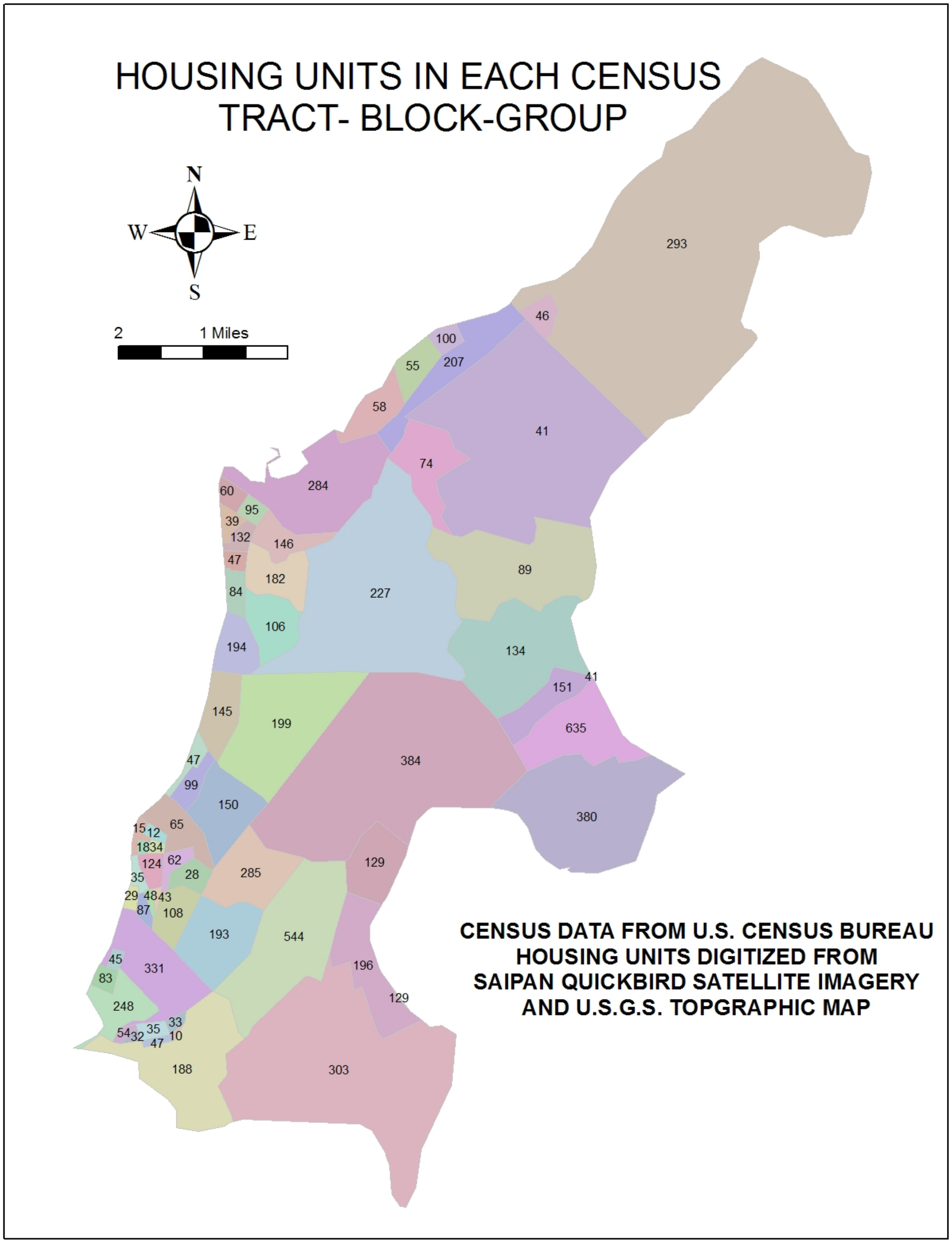

Figure 7 Housing Units in Each Census Tract-Bock-Group Area

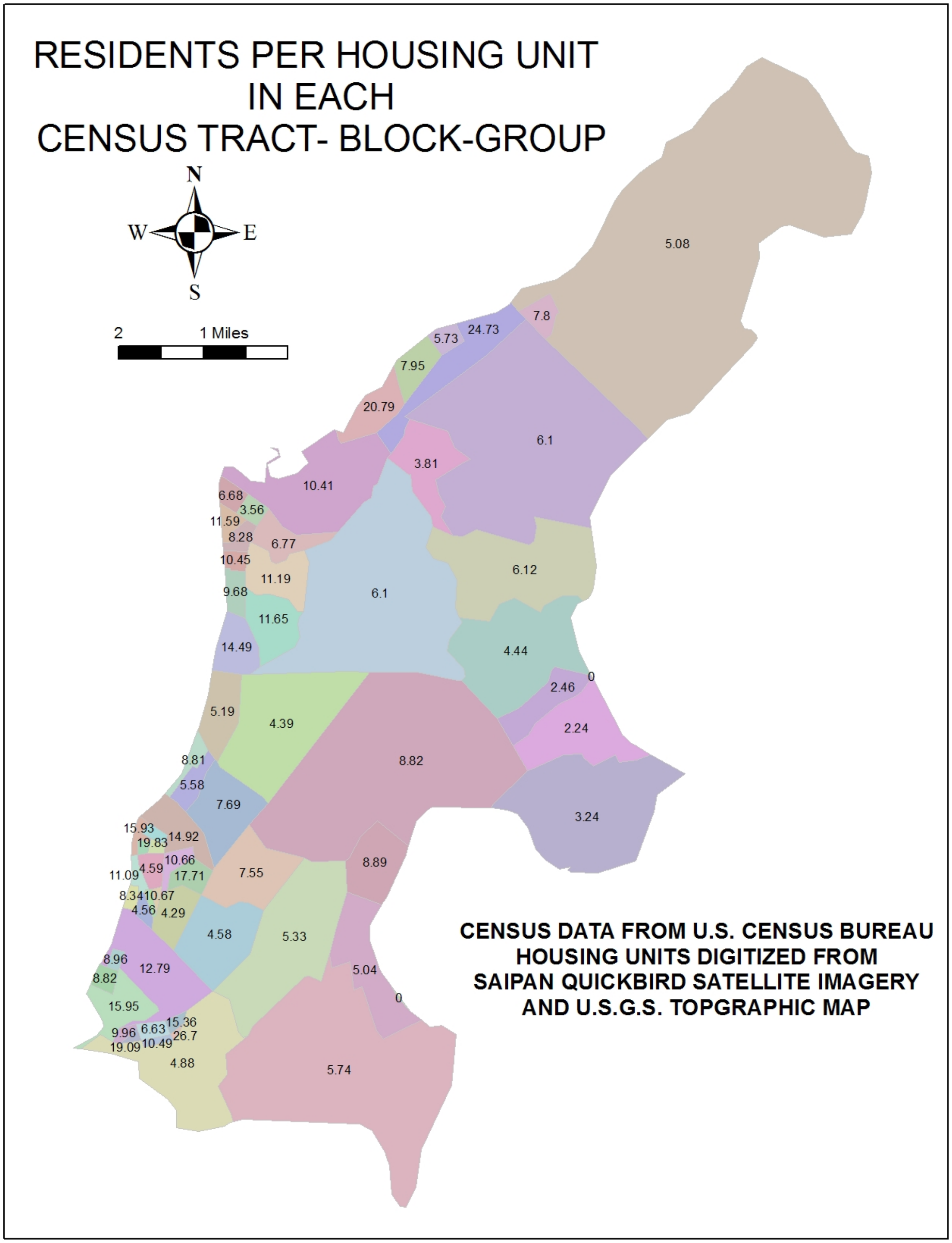

Figure 8 Residents per House in Each Census Tract-Block-Group Area

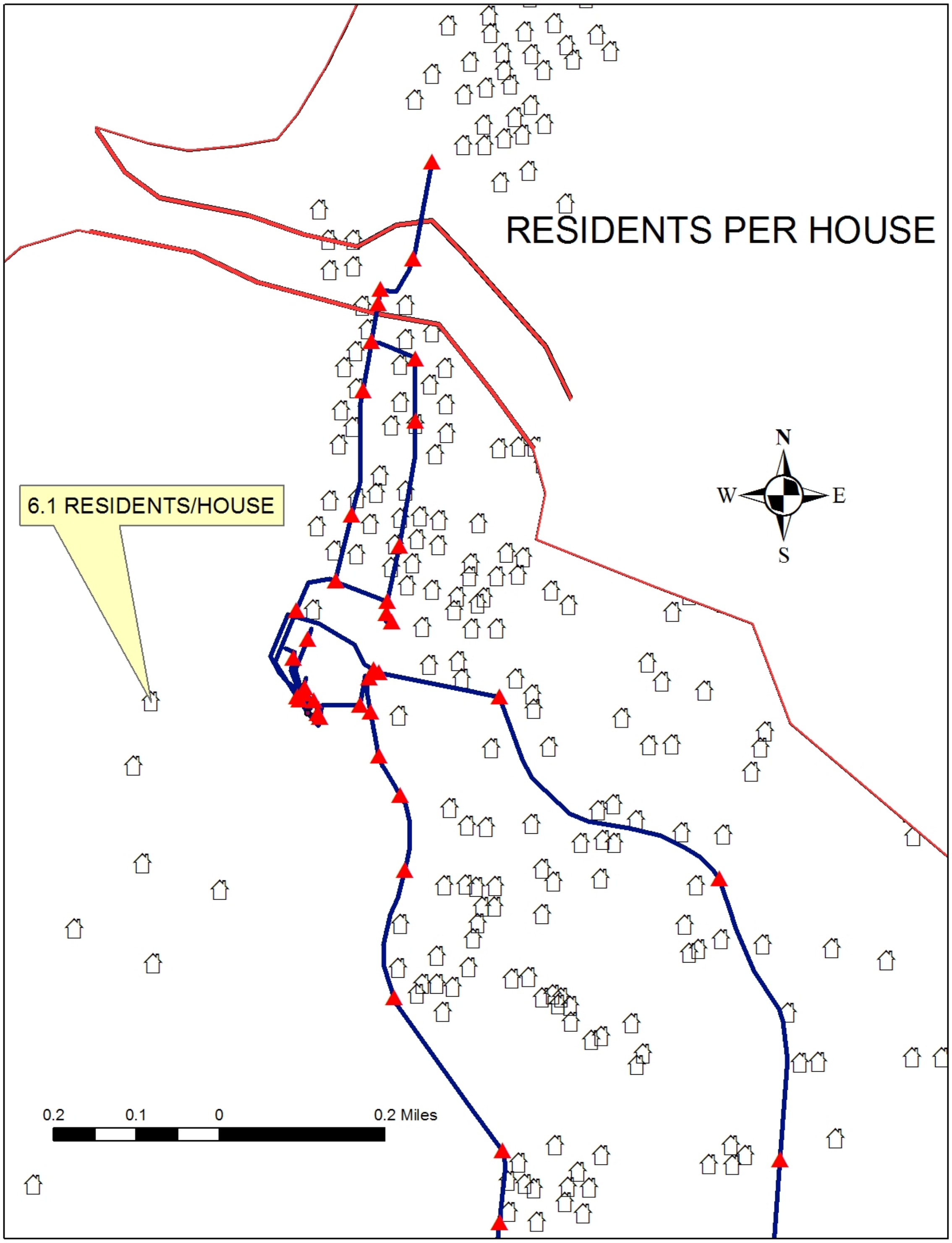

Figure 9 House with Residents per House Assigned to Each Residence

Assigning Population to Junctions

The next major step along the way is to develop a polygon shape file for each of the CUC water delivery zones. These are used to allocate residential structures to the junction nodes in each of the sub-region water distribution system models that have been previously developed.
The steps required are:

1. Translate the AutoCAD file that was obtained from CUC called “New Water Regions.dwg” turn off the coastline layer. Copy these layers to a shape file using a program such as “Cad To Shape”. Be sure and make two files, one for the lines and one for the text.

2. Open the AutoCAD file that we obtained from CUC called “SAIPANDEQMAP-Sam’s Revison”. Turn off all layers with the exception of the layer coastline. Save the file with a new name and then turn the CAD file to a shape file using a program such as “Cad To Shape”.

3. Bring both of the shape files developed in steps 1 and 2 above into ArcVIEW. The resulting map should look like that shown in Figure 10.

4. Output a set of Shape files for each of the CUC sub-region models using the shape file export function available in AutoCAD for WaterCAD. Figure 11 shows the pipe and junction shape file for Sub-Region 3. Before exporting the junction data to shape files a special user defined variable named “PEOPLE” is created for the junctions of each of the sub-region models. This variable is used to hold permanently the number of people assigned to that junction in the GIS analysis. The following data is created for each shape file:
    a. Junctions (including label, demand, elevation, and people data)
    b. Pipes (including label, diameter Material, CH values, and length data)
    c. Pumps (including, label, description, and discharge data)
    d. Reservoir (including label, and elevation data)
    e. Tanks (including label, storage, and initial elevation data)

    The Sub-Region 3 exported pipe and junction water system shape files are shown in Figure 11.

5. Next a polygon Shape file is developed for each of the water system sub-regions. This is done by creating a new blank polygon map in ArcCatalog for each sub-region. Then, using the trace function, create the polygons from the line feature shape files that came from the AutoCad Files of the sub-regions. The areas provided by CUC were modified somewhat to reflect the housing areas actually supplied by the sub-systems. Figure 12 shows the modified areas developed for each of the sub-regions. Figure 13 is a more detailed view of the modified areas supplied by waterlines in Sub-Region 3.

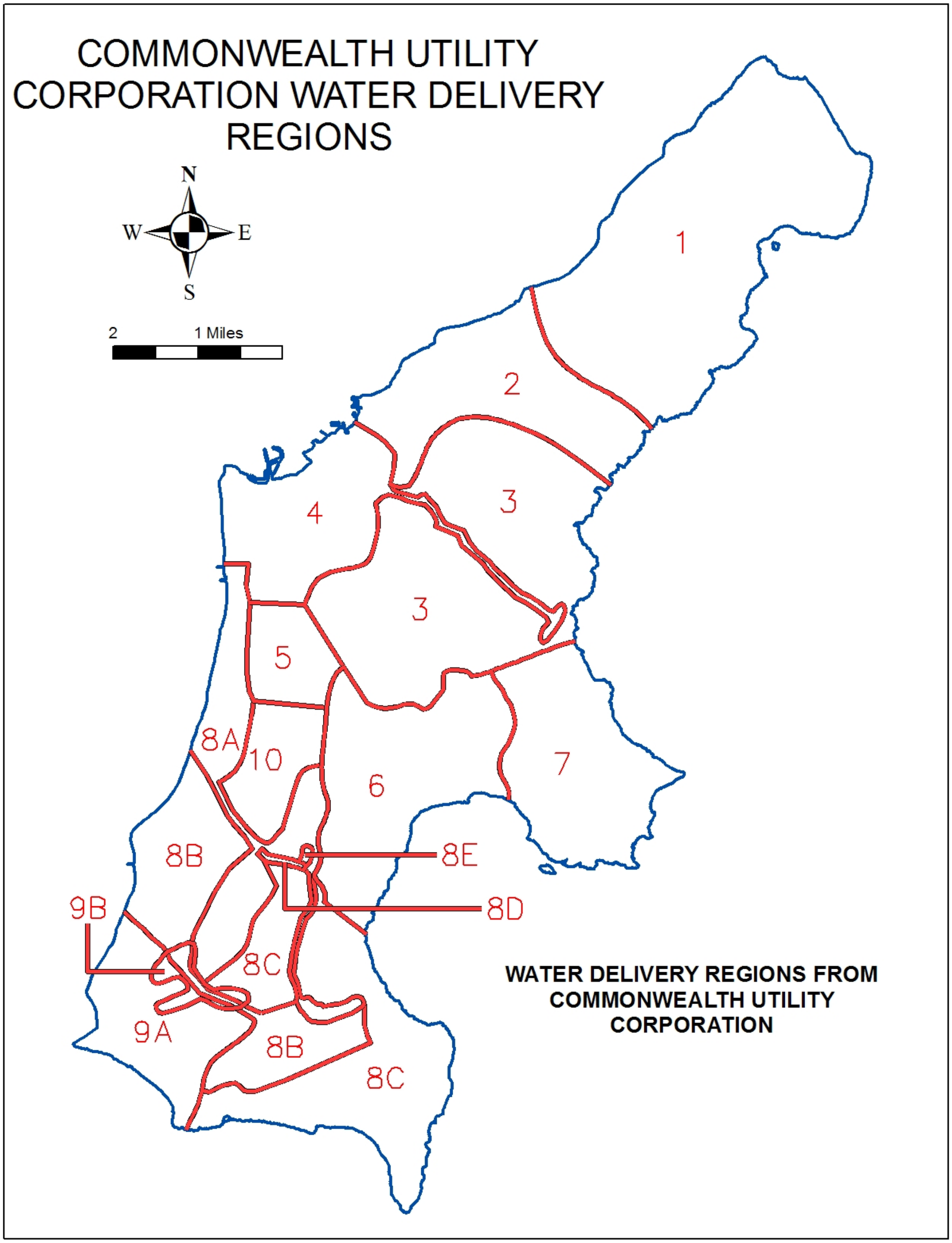

Figure 10 CUC Water Delivery Sub-Regions

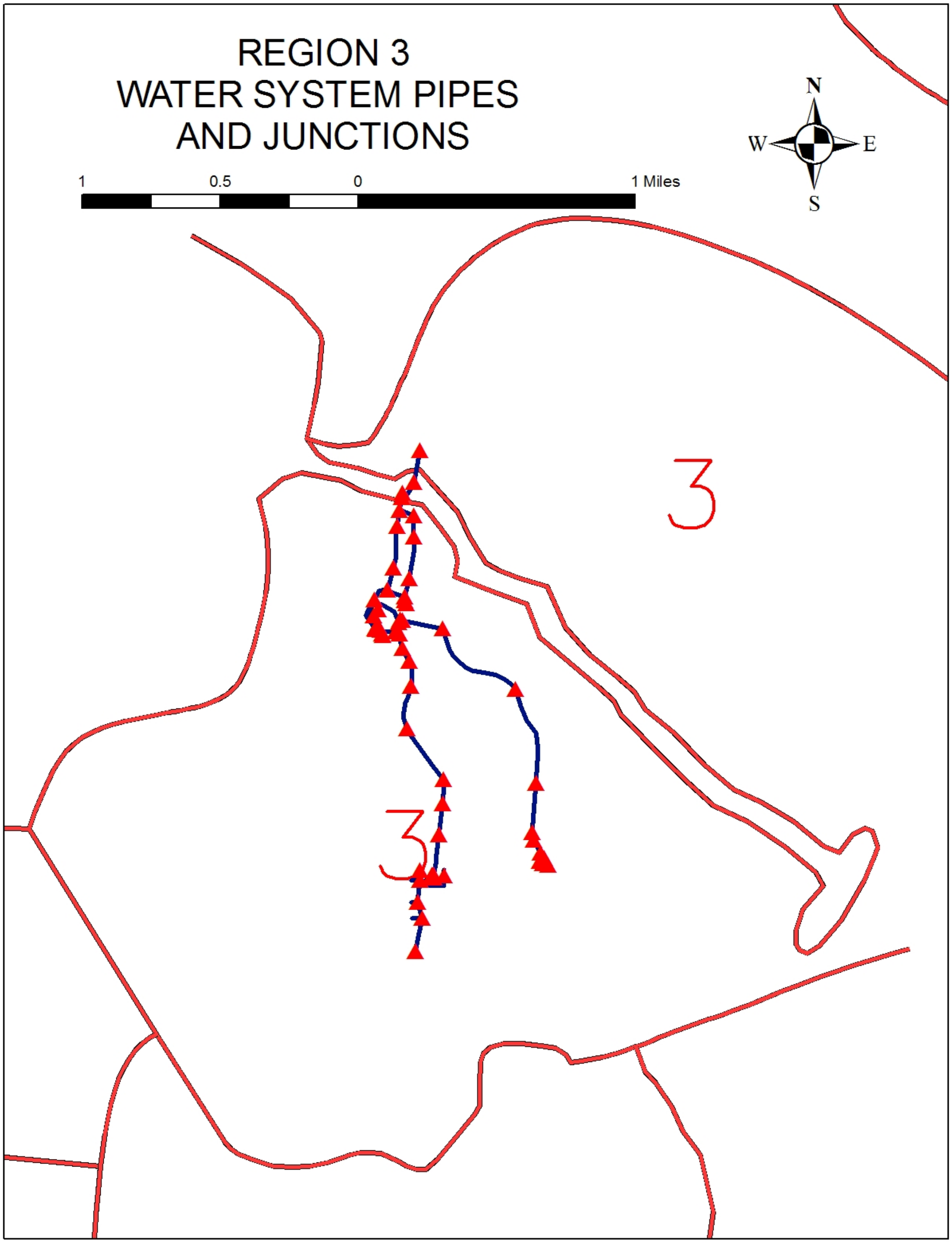

Figure 11 Sub-Region 3 Pipes and Junctions

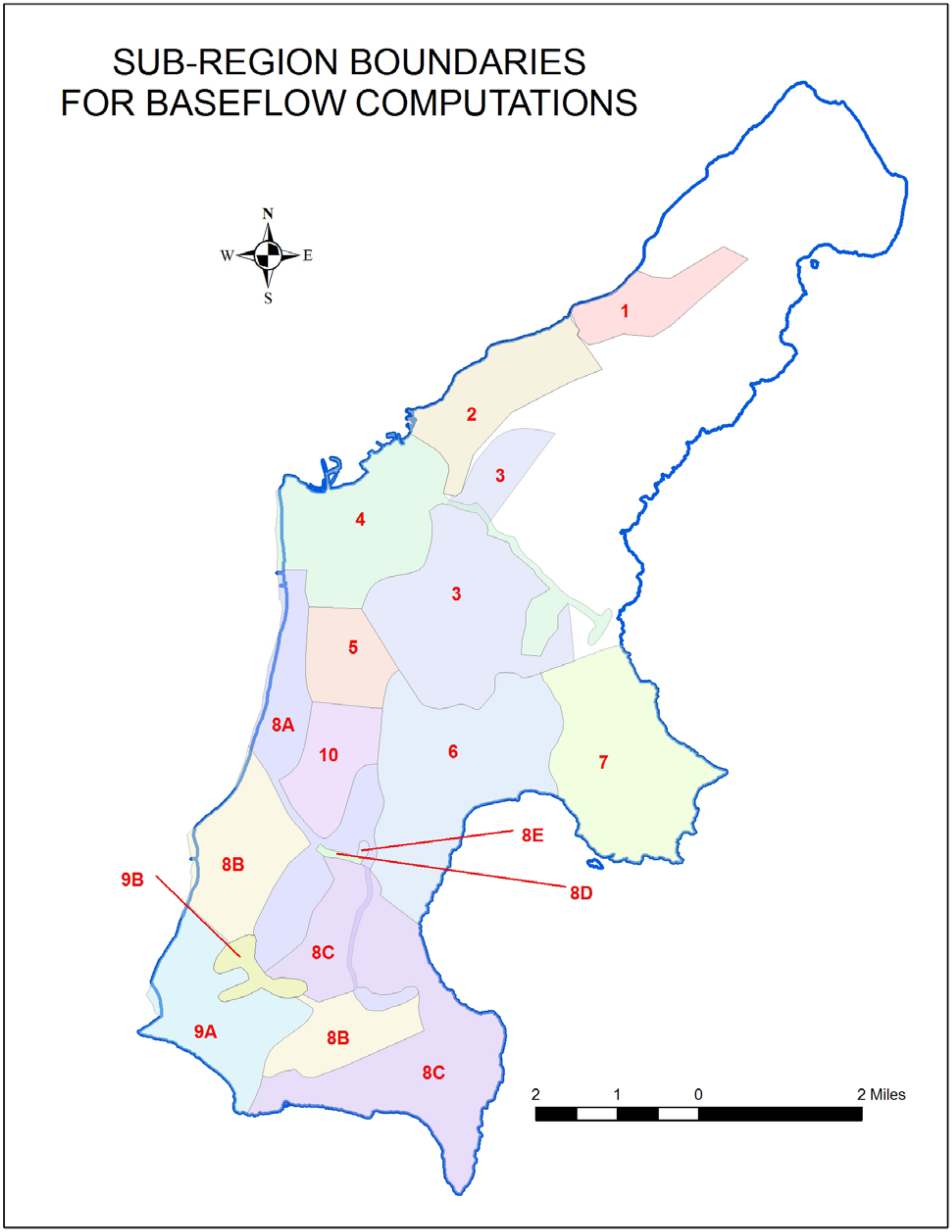

Figure 12 Sub-Region Boundaries for Base flow Demand Computations

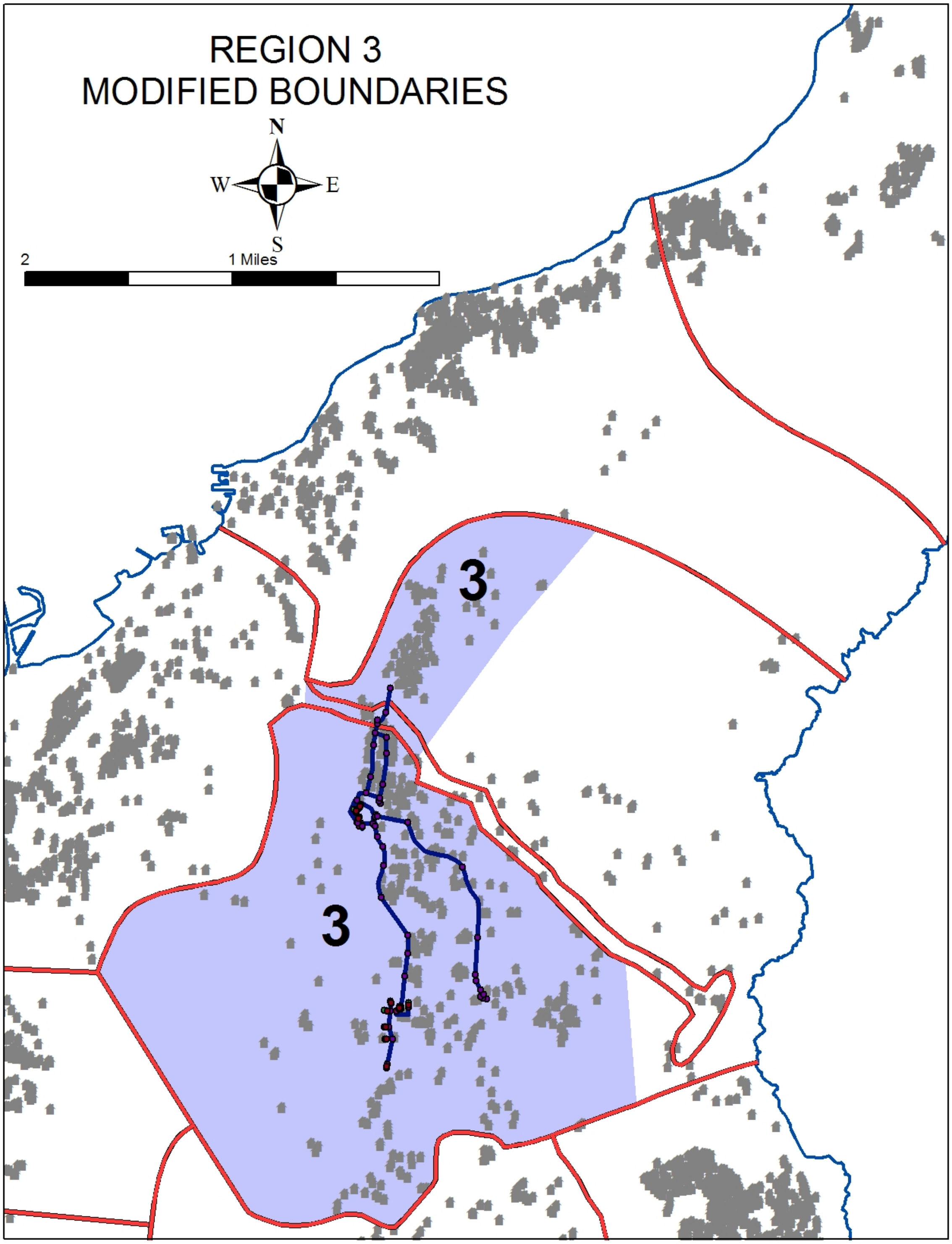

Figure 13 Sub-Region 3 Modified Boundaries

6. Next a Euclidian allocation function is applied to the sub-region junctions. The result for Sub-Region 3 is shown in Figure 14. The Euclidean allocation is similar to the Thiessen Polygon technique where areas are allocated to each junction based on their proximity to that junction. Each junction is assigned an area that is closest to that junction. Since only the areas in the sub-region being analyzed are applicable to the particular sub-region system, the environmental settings for the Euclidian Allocation should be set with the Raster Analysis Mask stipulated to use the Sub-Region Boundary shape file. If the Euclidian allocation environment is set correctly and the resulting raster turned to a polygon shape file the results are as shown in Figure 15.

The next step is to determine the total number of people assigned to the houses that are in each of the allocation polygons developed in the previous steps. The total number of people will them be assigned to the appropriate junction for that polygon.

The steps that are taken to determine the number of people residing in each of the housing units are as follow:

1. Perform a GIS intersection of the housing (point shape file) and the junction allocation (polygon shape file). This will provide a new point shape file that will identify in which junction allocation polygon each housing unit is located. The new attribute data file will carry along all the attributes from the house point shape file and the junction attribute polygon shape file. Figure 15 shows a plot of the housing units plotted over the junction allocation polygon shape file.

2. Perform a GIS Frequency analysis to determine the number of house units in each of the junction polygon areas. To do this first open the attribute table of the intersection map made in step 1 above. Right click on the “GRIDCODE” heading and choose the summarize function. Choose the “RES_PER_HOUSE” field and choose sum for the function to apply. The product of this function is a database file that shows the sum of how many people are in each junction allocation area. This database is then joined to the attribute file for the junction polygon allocation shape file. Figure 16 shows a plot of the Sub-Region 3 junction allocation polygon with the sum of people in each polygon.

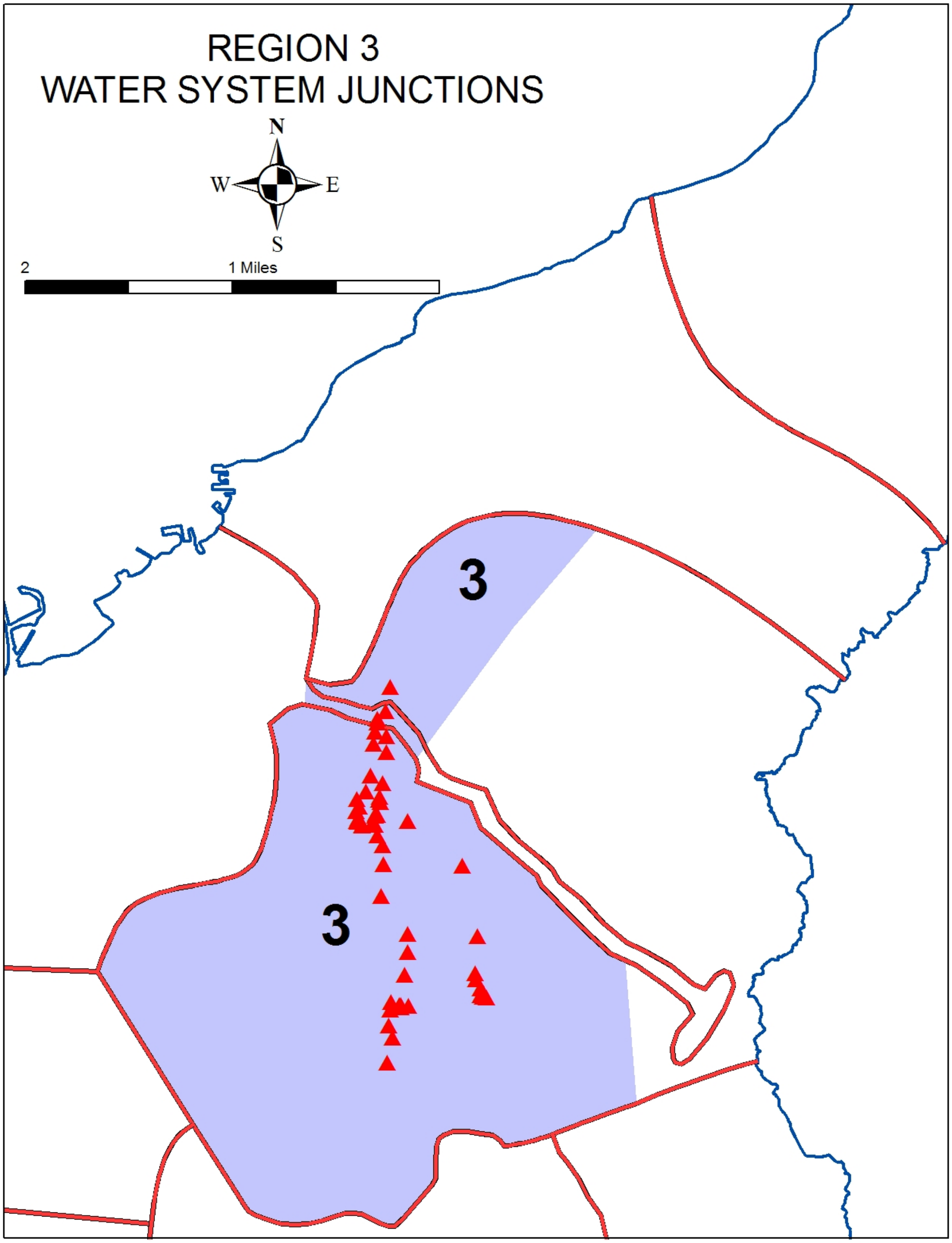

Figure 14 Sub-Region 3 Water System Junctions

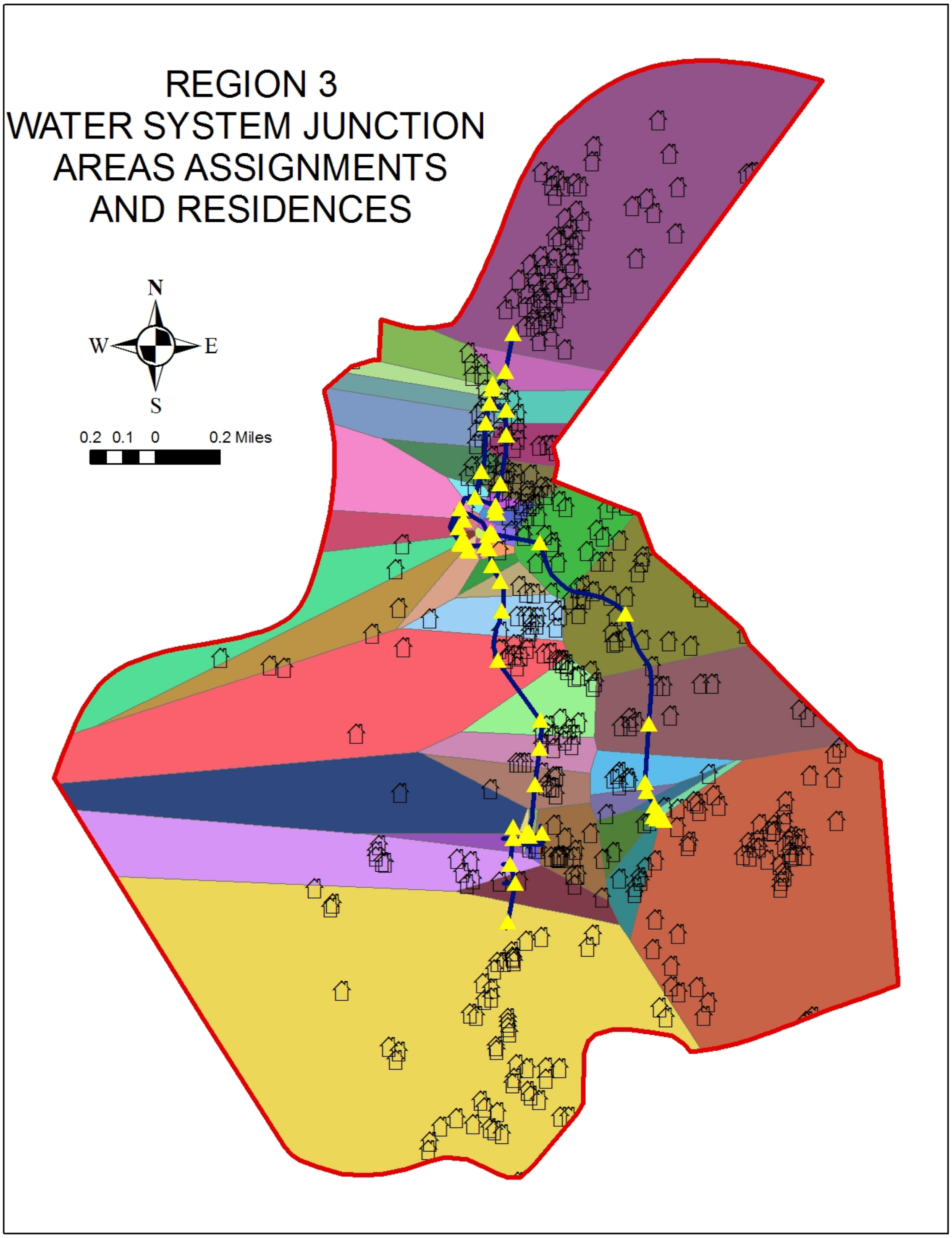

Figure 15 Junction 3 Area Assignment Polygon Shape File With Residences

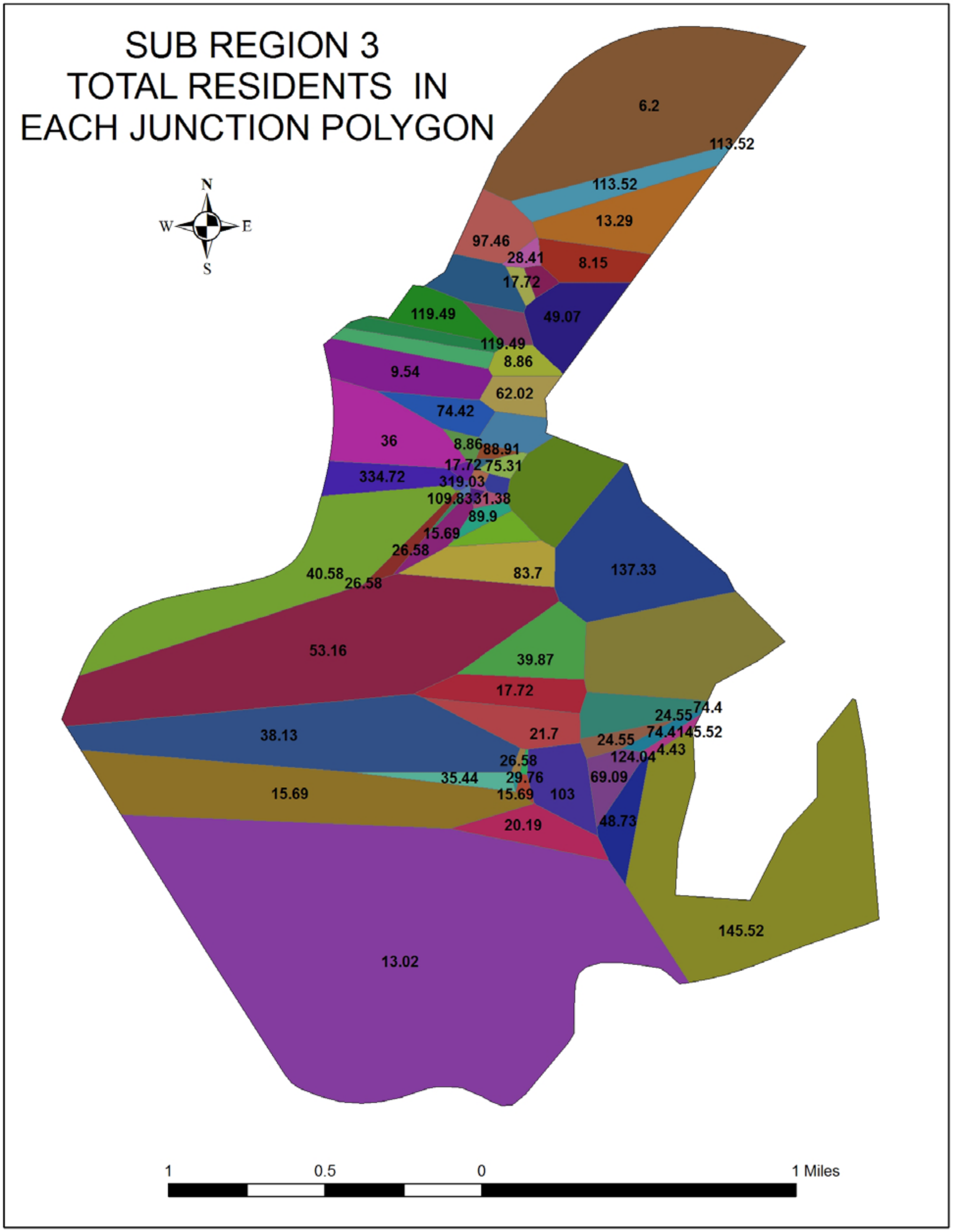

Figure 16 Junction 3 Area Assignment Polygon Shape File With Computed Total Population in Each Polygon

3. Next this database is joined to the attribute file for the point shape file for the junctions. Join the files based on the GridID in the database and the ID in the junction shape file attribute file. Next open the attribute file for the junctions for the sub-region being analyzed. Using the calculate function set the "BASEFLOW" column equal to the sum of the "Joined" residents column created in the previous step. Also do a similar calculation for the People Column in the junction attribute file. You will have then assigned the number of people for that junction in the base flow field and the people field. The people field is used to maintain a constant value that can be later used to adjust the base flow values after they has been changes to gallons/minute (gpm) units. Figure 17 shows a plot of the Sub-Region 3 junctions labeled with the number of people assigned to each junction.

4. Next open the AutoCAD for WaterCAD program. Open the sub-region under study and synchronize the shape file to which you added the base flow value. To do this you will use the Synchronize-Shape file-Connections dialog box that is available under the main file menu. When the Shape file connection manger appears choose the original shape file connection used to create the Junction shape file and "Synchronize in" the data. Be sure and look at the base flow values to see that the changes have been made. A sample junction table for Sub Region 3 is shown in Figure 18.

5. The Final step required is to change the base flow value assigned to each junction from "number of people assigned to the junction" to "outflow in gallons/minute (gpm). This will involve choosing an estimate of consumption rate per person and multiplying that by the number of people assigned to the junction which is now contained in the base flow field. This will result in a value of demand in gallons per day. The program is expecting demands in gallons/minute (gpm). To get the correct units it is necessary to divide the gallons per day value by 24 hours/day and 60 minutes /hours. These calculations are easily accomplished using the "Global Edit" function in the Junction Report. No matter what changes are made to the Base Flow Column the original number of people assigned to the junction is maintained in the People "user defined" field. This value can be used to verify if the correct calculations have been made if use rates per person are changed for subsequent studies.

The consumption rate per person is an important parameter in determining the final demands assigned to the junctions. Presently CUC water division is in the process of carrying out a major project to install water meters through out the island. When data begins to be collected from the meters more work should be carried out to verify the actual consumption rates around the island. In absence of better data, we used metered data that were gathered for an earlier WERI sponsored rooftop rain water catchment study, to verify individual use rates.[9] The values obtained are shown in Table 2 and were provided by CUC.

The average rates varied from 30 gal/person/day to 224 gal/person/day. The average value was approximately 96 gal/person/ day. The high value was probably due to leakage in the house after the meter. The low value was probable measured in a house that had supplementary sources of water such as a rooftop rain water catchment system. We are recommending a use rate of 100 gallons/person/day until further studies can be made to refine this estimate.

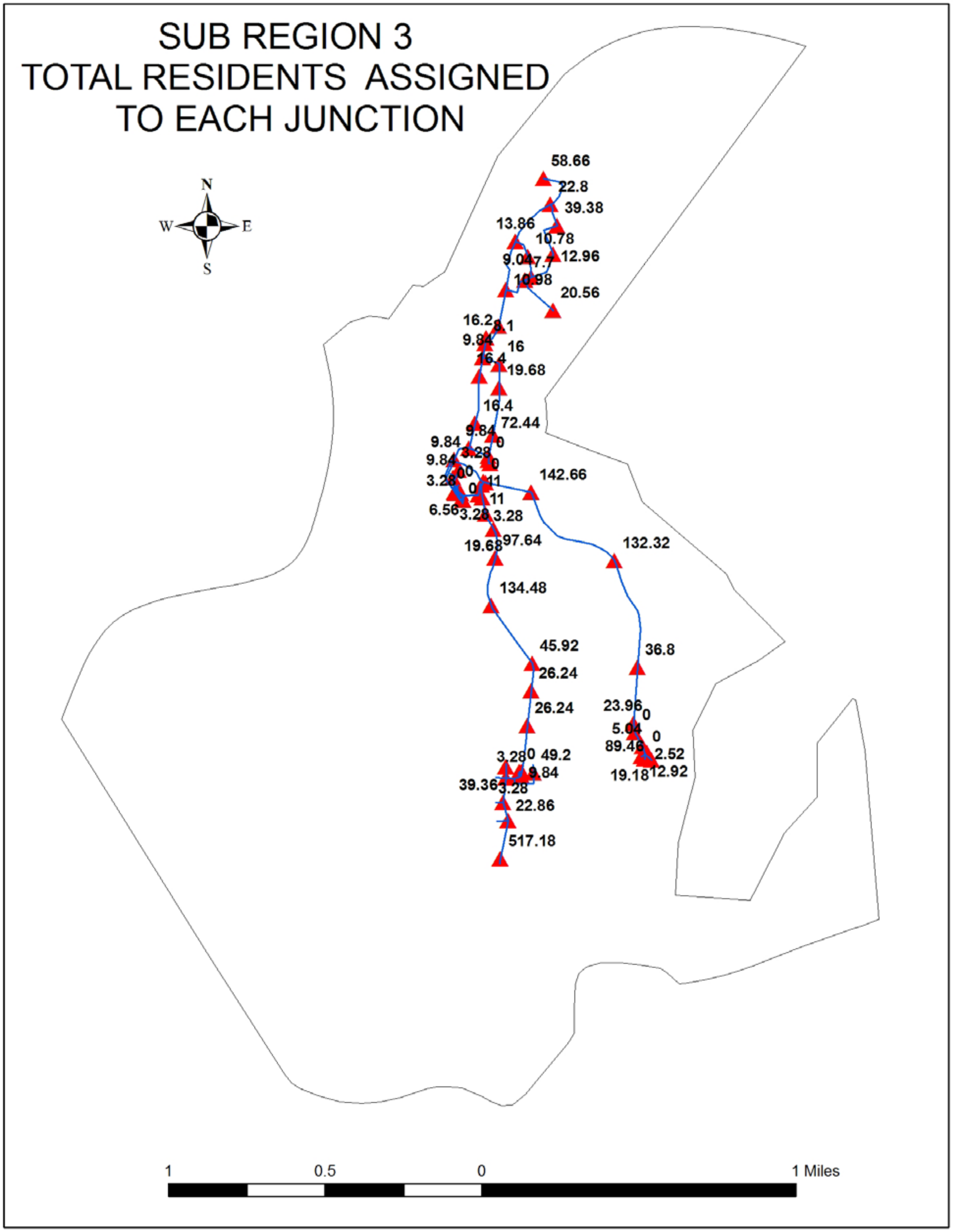

Figure 17 Sub-Region 3 Junctions Labeled With Number of People Assigned to Each Junction

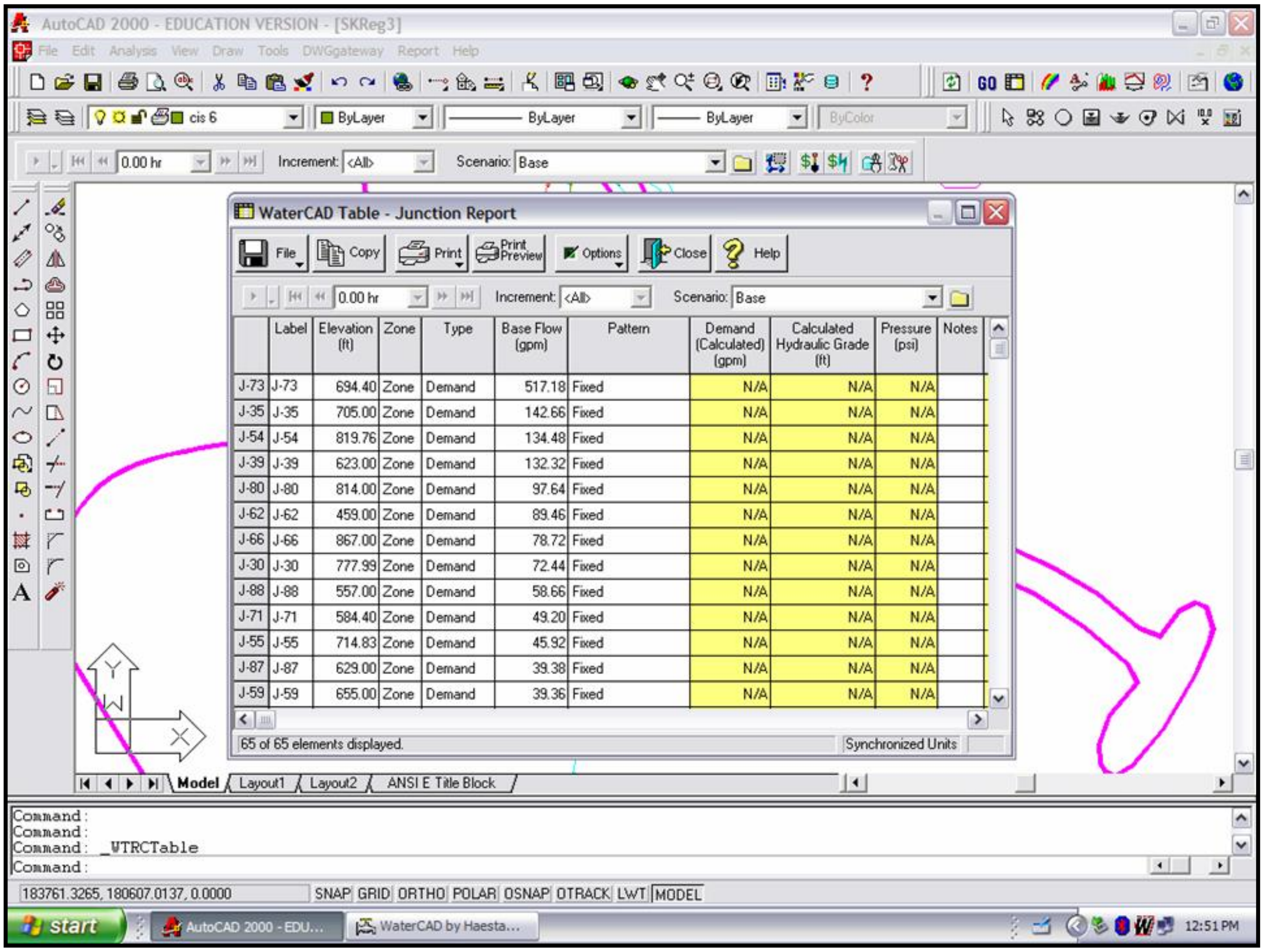

Figure 18 Watercad Junction Report for Sub-Region 3 After Base Flow Values Have Been Import-Synchronized From the Junction GIS Shape Files

METERED USE RATES SAIPAN CUC WATER DISTRIBUTION SYSTEM

SITE NUMBER	TOTAL PEOPLE	METER START READING	METER END READING	GALLONS USED	METER START DATE	METER END DATE	PERIOD	USE/DAY	USE/DAY/PERSON
2	6	2393950	2597530	203580	11/12/98	10/12/99	334	609.52	101.5868263
3	8	587190	717390	130200	11/18/98	10/20/99	336	387.50	48.4375
4	6	14260	177290	163030	11/10/98	10/12/99	336	485.21	80.86805556
9	8	868920	1056770	187850	11/5/98	10/6/99	335	560.75	70.09328358
10	12	520550	781110	260560	11/5/98	11/9/99	369	706.12	58.84372177
11	5	2124970	2317160	192190	11/6/98	10/6/99	334	575.42	115.0838323
17	2	382950	522880	139930	11/16/98	11/16/99	365	383.37	191.6849315
26	4	5333910	5488420	154510	11/27/98	10/26/99	333	463.99	115.9984985
27	11	719100	952550	233450	10/28/98	10/29/99	366	637.84	57.98559364
31	4	5490	130070	124580	11/10/98	10/12/99	336	370.77	92.69345238
34	4	286240	444120	157880	11/17/98	10/20/99	337	468.49	117.1216617
41	6	0	124600	124600	12/7/98	12/9/99	367	339.51	56.5849228
47	4	0	46860	46860	11/27/98	11/26/99	364	128.74	32.18406593
50	4	0	111730	111730	12/8/98	12/27/99	384	290.96	72.74088542
52	7	0	238880	238880	12/17/98	12/22/99	370	645.62	92.23166023
53	6	0	113010	113010	12/17/98	12/16/99	364	310.47	51.74450549
55	9	0	31800	31800	8/17/99	12/13/99	118	269.49	29.94350282
56	3	0	84770	84770	12/16/98	12/13/99	362	234.17	78.05709024
57	2	0	144526	144526	12/17/98	12/20/99	368	392.73	196.3668478
58	3	0	244090	244090	11/30/98	11/29/99	364	670.58	223.525641
60	4	0	169090	169090	11/30/98	11/30/99	365	463.26	115.8150685
61	5	0	195000	195000	12/4/98	12/3/99	364	535.71	107.1428571
MAX	**12**		**MAX**	**260560**			**MAX**	**706.12**	**223.53**
MIN	**2**		**MIN**	**31800**			**MIN**	**128.74**	**29.94**
AVERAGE	**5.5909091**		**AVERAGE**	**156914.3636**			**AVERAGE**	**451.37**	**95.76**

Table 2 Measured Water Consumption for Customers in the CUC Water System

Determining Customer Use Rates

The final portion of this project involved identifying high use customers and determining their demands so they could be added to the appropriate junctions in the system. The first step was to make a Global Positioning System (GPS) reconnaissance study of the island to determine the location of high use customers such as laundromats, commercial laundries, and bottled water suppliers. The location of each of each of these sites was determined with GPS equipment. A map of these sites is shown in Figure 19. A more detailed view of the high use customer locations is shown in Figure 20. Table 3 contains a listing of the daily demands for these customers that were obtained from the CUC Water Division.[10] These demands were added to the residential demands at the closest junction to the high use location.

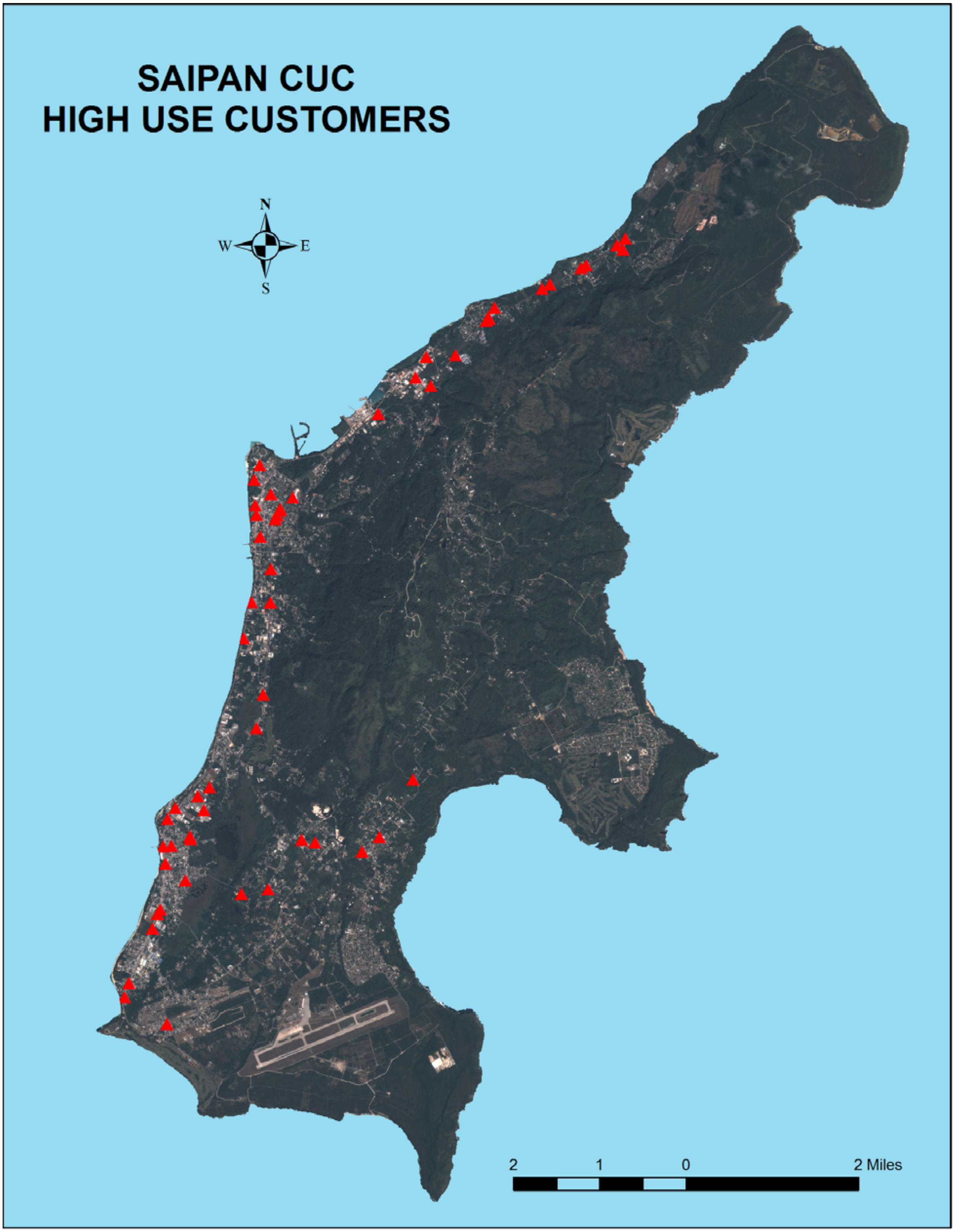

Figure 19 Location of High Use Customers in the CUC System

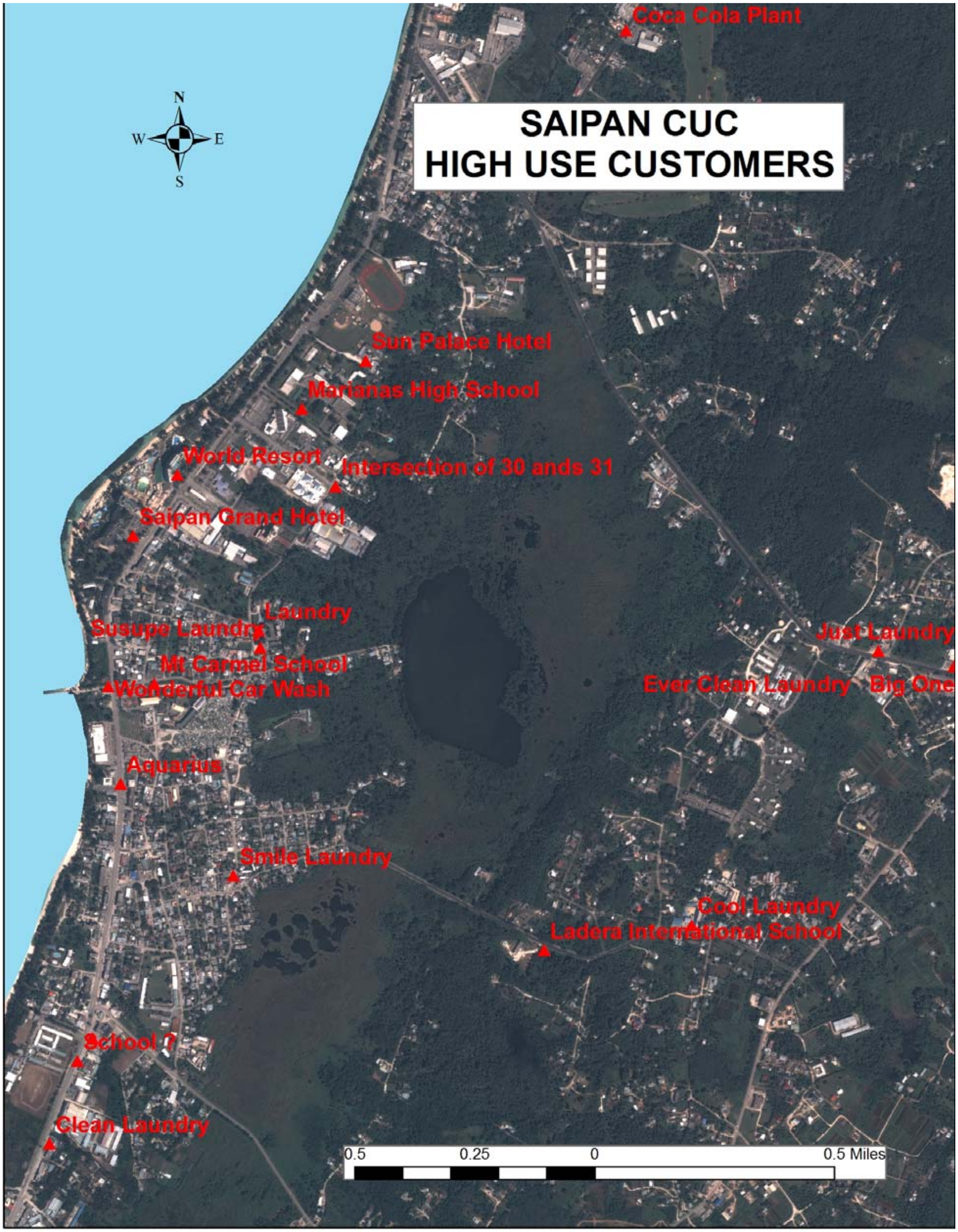

Figure 20 Detailed View of High Use customer Locations

Monthly gallons used by the CUC Commercial Customers

Commercial Customers	January	February	March	April	May	June	Total days	Used/Day
Laundromat	18000		131543	137297	124159	113196	153	3426
Seoul Washland		5902	167443	112600	123666	75567	151	3213
Hwa Sun Laundry	50000	74985	26880	114601	111698		153	2472
Kagman Elem. School	181600	129400	89800	161600	204000	227200	182	5459
San Antonio School	21043	14839	15553	23024	23864		151	651
WSR Elem. School	161395	156623	158024	165131	202890	2455162	182	18128
Ocean View Hotel	52000	82588	16709	25314	29184	27218	182	1280
MMC-CK Beach Club	89948	64438	94667	108945	99027	102525	182	3074
Century Hotel	140504	177656	189926	124281	75110	75680	182	4303

Table 3 Measured Water Consumption for High User Customers

RESULTS AND DISCUSSIONS

The junction demands developed for this project reflect a vast improvement over the demands that were assigned during the development of the original sub-models. The new estimates consist of a more accurate value for the number of people in each sub-region. Also now the population is better distributed to the sub-region junction nodes. In the original analysis the customers were simply spread evenly to all nodes. The results of this study have assigned demands to the nodes based on the relative location of the demanding residences to the junctions. After the new demands have been applied, the resulting models will be able to provide more accurate hydraulic simulations. These more accurate simulations will allow engineers to better explore what system improvements are needed. These improvements could consist of new construction or variations in the present operation of the system.

FUTURE STUDIES

While the junction demands that were developed for this study provide much improvements over the original demands that were assigned to the junction in the 15 sub-region models, there is still much room for improvement. The consumption rate per person is an important parameter in determining the final demands assigned to the junctions. Presently CUC water division is in the process of carrying out a major project to install water meters through out the island. When data begins to be collected from the meters more work should be carried out to verify the actual consumption rates around the island.

The next logical step is to begin work at improving estimates of the supply side of the system. The estimates of average discharge and variability of discharge at each well needs to be studied. Again CUC is in the process of updating their monitoring equipment at each of the well sites. When data begins to be collected from this instrumentation, more work should be carried out to verify the actual pumping rates around the island. The rates should be carefully compared with demands in the sub-regions and storage available to determine optimal operating schemes for the island water distribution system. Further refinements should also be made at each of the booster pump station. The piping at these stations is fairly complex and most of the automatic controls have been deactivated. Actual flow measurements should be made at each of the stations and the pump curves input to the sub-model for these stations should be compared to actual pumping rates.

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