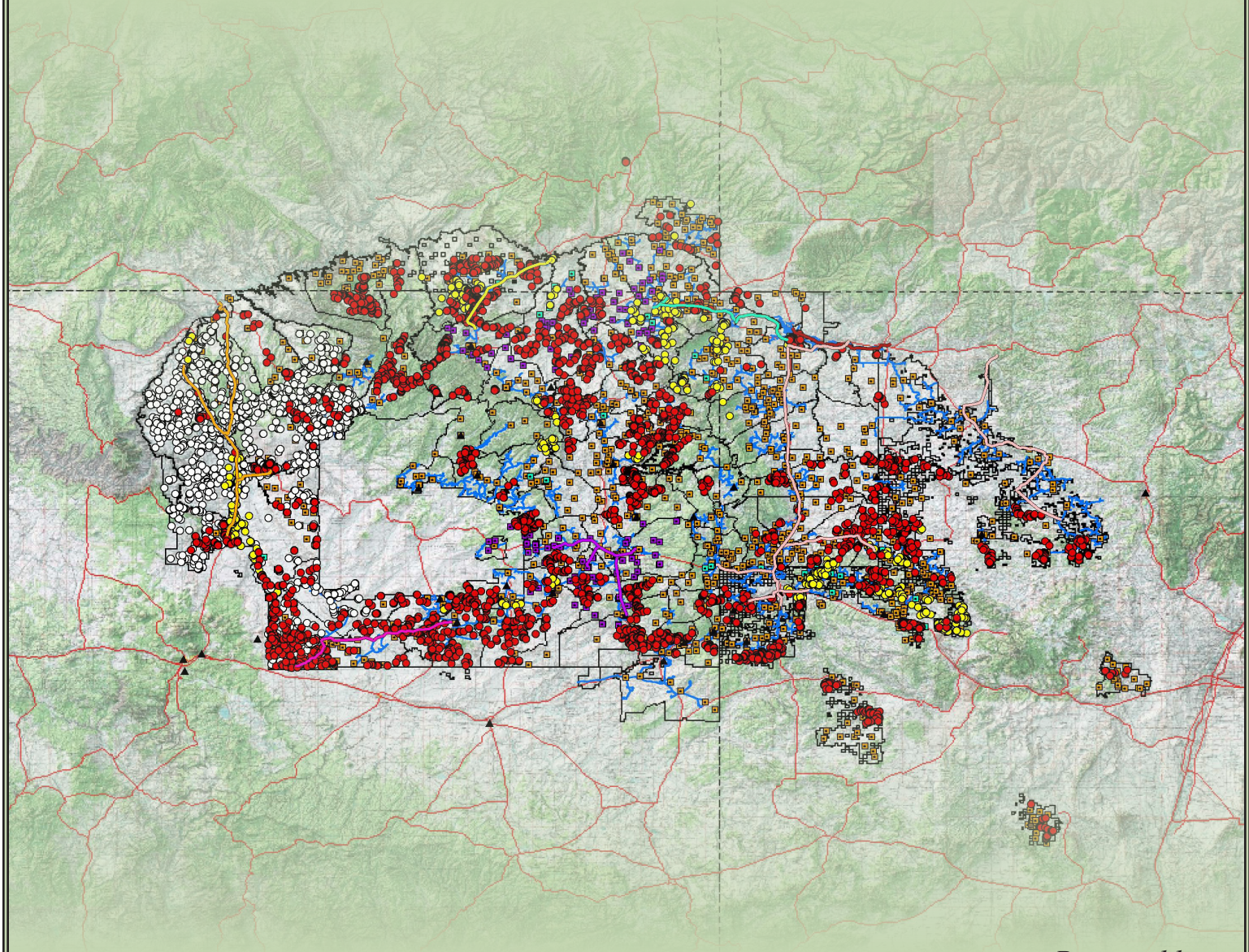
Project Summary

Mapping of Water Infrastructure and Homes Without Access to Safe Drinking Water and Basic Sanitation on the Navajo Nation

October 2010



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Navajo Access Workgroup Charged by
The Federal Infrastructure Task Force to Increase Access to
Safe Drinking Water and Basic Sanitation in Indian Country

Mapping of Water Infrastructure and Homes without Access to Safe Drinking Water and Basic Sanitation on the Navajo Nation
Project Summary Document

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See enclosed CD with GIS data layers and Section 8.0 for a list of all GIS data.

EXECUTIVE SUMMARY

The goal of this project was to map the locations of Navajo Nation homes without access to safe drinking water and/or basic sanitation in a Geographic Information System (GIS) format, and overlay them with existing and proposed water and wastewater infrastructure and other relevant data. The final map will assist the U.S. Environmental Protection Agency (EPA), the Indian Health Service (IHS), and other federal and tribal agencies to determine the best approach to provide potable water and adequate sewer facilities to these Navajo Nation homes. All data mapped under this project cover the Navajo Nation, situated on over 27,000 square miles of land within the states of Arizona, New Mexico, and Utah. The Navajo Nation is the largest reservation in the United States.

The data collection effort was conducted primarily by IHS and EPA, with support from other entities, including the Centers for Disease Control and Prevention (CDC), the Navajo Tribal Utility Authority (NTUA), the Navajo Public Water Systems Supervision Program, the Navajo Division of Community Development, and the Navajo Department of Water Resources (DWR). All data used for this mapping project were secondary data collected by other entities for different purposes, so data accuracy and completeness are difficult to estimate. These data should only be used at the pre-planning level.

Some data were collected in GIS format, but most data needed to be mapped following consistent mapping procedures based on the original data format (e.g., image, table). Home locations were mapped based on data from the IHS Sanitation Deficiency System (SDS) database, the IHS Home Information Tracking System (HITS), the Navajo Nation Community Development Former Bennett Freeze Recovery Plan, and the EPA Region 9 Superfund Program. Existing and proposed water and wastewater infrastructure data mapped for this project included existing drinking water wells and watering points provided by EPA and the Navajo DWR, existing water and wastewater service lines provided by NTUA, and proposed water supply projects provided by EPA. Table ES-1 provides a summary of the data mapped as part of this project.

Table ES-1. Data Mapped as Part of this Project

Homes without Access to Safe Drinking Water and/or Basic Sanitation from the IHS Sanitation Deficiency System	**Projects**	**Homes**
Total numbers	283	8,292
Total mapped as of September 2010	219 (78%)	4,636 (56%)
Other Potential Homes without Access to Safe Drinking Water and/or Basic Sanitation	**Structures/Homes**	
IHS Housing Inventory Tracking System (HITS) Homes	3,397	
Former Bennett Freeze buildings[1]	2,685	
Structures[1] within 1 mile of an Abandoned Uranium Mine (AUM)	2,171	
Well Data	**Wells**	
CDC-sampled wells mapped	152	
EPA-sampled wells mapped	55	
Regulated watering points	67	
DWR wells with Navajo operators	1,549	
Other Water Infrastructure	**Miles**	
NTUA Water Mains	6,176	
Proposed Pipeline Projects	609	

[1] *These buildings and structures represent potential homes without access to safe drinking water and/or basic sanitation. They exclude all buildings and structures within 100 feet of an NTUA water line.*

EPA and IHS also identified potential uses for the data collected and mapped. These beneficial uses included facilitating water and sanitation access, facilitating funding, and improving infrastructure design and installation. The completion of this project demonstrated the utility and ease with which multiple existing data can be integrated to provide a graphical picture of the need associated with homes that lack access to safe drinking water and/or basic sanitation on the Navajo Nation. IHS is currently working on updating their home inventory to include geo-referenced coordinates for all homes in Indian country.

1.0 INTRODUCTION

The 2008 Sanitation Deficiency System (SDS) update completed by the Indian Health Service (IHS) at the end of calendar year 2007 had estimated over 7,850 Navajo homes are without access to safe drinking water and/or basic sanitation, and approximately 95% of these homes (~7,525) are also without adequate sewer facilities.

For the purposes of this effort, access to safe drinking water and/or basic sanitation for the IHS SDS data is the total number of homes in a community with deficiency level 4 or 5, as captured by IHS during their annual update of SDS. The definitions of deficiency levels 4 and 5 are:

Deficiency Level 4: "An Indian tribe or community with a sanitation system which lacks ***either*** a safe water supply system or a sewage disposal system."

Deficiency Level 5: "An Indian tribe or community that lacks a safe water supply ***and*** a sewage disposal system."

Many of the homes mapped in this project were approximately located on SDS image files of U.S. Geological Survey (USGS) topographic quadrangles, but these images were not geo-referenced, and geo-spatial information was lacking for most of the homes.

The goal of this project was to map the locations of homes without access to safe drinking water and/or basic sanitation in a Geographic Information System (GIS) format, and overlay them on existing and proposed water and wastewater infrastructure and other relevant data. The data collection effort was conducted primarily by IHS and the US Environmental Protection Agency (EPA), with support from other entities, including the Centers for Disease Control and Prevention (CDC), the Navajo Tribal Utility Authority (NTUA), the Navajo Public Water Systems Supervision Program, the Navajo Division of Community Development, and the Navajo Department of Water Resources (DWR). Data were mapped as they became available.

The final map will assist the EPA, the IHS, and other federal and tribal agencies to determine the best approach to provide potable water and adequate sanitation facilities to these Navajo Nation homes. The map will be used at a pre-planning level because the precision of home locations is not adequate for a detailed system design or cost estimation.

This document provides a summary of relevant project information, including data sources and formats (Section 2.0), mapping procedures for these data (Section 3.0), assumptions and data limitations (Section 4.0), mapping results (Section 5.0), mapping summary analysis tables (Section 6.0), suggested future data uses (Section 7.0), and a lot of appendices and files provided in the enclosed CD (Section 8.0).

2.0 DATA SOURCES AND FORMATS

All data mapped under this project are secondary data provided by a number of different sources. These data cover the Navajo Nation, situated on over 27,000 square miles of land within the

states of Arizona, New Mexico, and Utah. The Navajo Nation is the largest reservation in the United States.

SDS home locations were obtained from IHS (Section 2.1.1), and other potential homes without access to safe drinking water and/or basic sanitation included the following:

- Buildings in the former Bennett Freeze area identified by Navajo Division of Community Development (Section 2.1.2);
- IHS Housing Inventory Tracking System (HITS) homes (Section 2.1.3); and
- Structures within one mile of an abandoned uranium mine (Section 2.1.4) as mapped by the EPA Region 9 Superfund Program.

Existing and proposed infrastructure data included:

- Existing drinking water wells and watering points provided by the Navajo Public Water Systems Supervision Program and the Navajo DWR (Section 2.2);
- Existing water and wastewater service lines provided by NTUA (Section 2.3.1); and
- Proposed water supply projects provided by the Navajo DWR (Section 2.3.2).

Other relevant data used as part of this project were the geo-referenced USGS topographic quadrangles obtained from third-party sources. Data sources and their estimated collection dates are summarized in Table 1.

Table 1. Data Sources and Collection Dates

Data Name	Data Custodian	Date received for mapping	Estimated data collection date[1]	GIS Format	Comment
SDS home locations	IHS	• Nov. 2008 • Nov. 2009	• 11/6/2007 National Snapshot • Nov. 2009	No	Homes are not geo-referenced. Homes drawn on maps
HITS homes	IHS	May 2009	April 2009	No	Data include latitude/longitude
Former Bennett Freeze data	Navajo Department of Community Development	January 2010	N/A	Yes	Data include more than homes (i.e., other building types)
Structures within 1 mile of an Abandoned Uranium Mine (AUM)	EPA Region 9 Superfund	May 2009	October 1997 to March 2007	Yes	Data represent structures (not just homes)
EPA sampled wells (Uranium 5-Year Plan Well Sampling)	EPA Region 9 Superfund	October 2008	February/ March 2008	No	Many wells have latitude/longitude information
Drinking water exposure assessment	Center for Disease Control	• Oct. 2008 • Nov. 2008	2007	Not all	Some data in Excel files, others in GIS format
Livestock watering points	Navajo DWR	Nov. 2008	August 2008	No	Some watering points with latitude/longitude
Regulated watering points	Navajo Public Water Systems Supervision Program	December 2008	N/A	Yes	Data includes watering points outside Navajo Reservation
NTUA basemaps	NTUA	• Nov. 2008 • May 2010	• Dec. 2007 • May 2010	Yes	May 2010 data only includes water mains and laterals
Proposed regional water supply projects	Navajo DWR	• Dec. 2008 • March 2009	• Dec. 2008 • March 2009	• Yes • No	March 2009 Shiprock-Sweetwater pipeline alignment in PDF
USGS topographic quadrangles	• Geo Communities • ESRI	• Nov. 2008 • Online access	N/A	Yes	ESRI file available online, not for download

[1] *These dates represent a best estimate of when the various data were collected by the respective agencies.*

2.1. Home Information

The goal of this project was to provide a geographic representation of Navajo Nation homes without access to safe drinking water and/or sanitation, as well as the existing infrastructure

relative to these homes. Home locations were gathered from the IHS SDS database for deficiency level 4 and 5 homes. Home location data were also included from IHS HITS, former Bennett Freeze Recovery Plan buildings, and EPA Region 9 Superfund Program structures within one mile of an abandoned uranium mine were also gathered. These data are described below.

2.1.1. SDS database

The definition of a home without access to safe drinking water is a home with a water sanitation deficiency level of 4 in the community tab of the IHS database. The definition of a home without access to basic sanitation is a home that has a sewer sanitation deficiency level of 4 in the community tab of the IHS database. If a home has a sanitary deficiency level of 4 for both water and sewer this home's sanitation deficiency level is considered a 5, lacking access to both safe drinking water and basic sanitation facilities. The SDS database is updated at least on an annual basis by IHS.

In November 2008, IHS Headquarters provided approximately 1,800 files containing Navajo Nation home locations (deficiency level 4 and 5 projects only) grouped in 283 SDS projects. These data files were in a variety of formats, including PDF, Word, Excel, images (e.g., *.tif, *.jpg), and Computer Aided Design (CAD) drawings (*.dwg). Not all 1,800 files were relevant to the SDS home locations, as some files were cost estimates or support letters for SDS projects. None of the SDS project files were geo-referenced. Most files did not have metadata associated with them, and did not specify the date and way the home locations were derived.

Data availability varied widely across SDS projects: some SDS projects had no data associated with them, while others had sufficient data to conduct the mapping effort. Projects in the latter category included at least a project map showing home locations with either a home number or resident name, and a list of home numbers or resident names (name table). Project maps were in PDF, image, CAD, or Word (image pasted in Word document) formats, while name tables were in PDF, Excel, Word, and text files. For many projects, these name tables provided additional information such as home structure (e.g., Hogan, trailer), home deficiency (e.g., need bathroom addition, electricity), medical reference, or Navajo chapter. Appendix A provides a list of additional data fields.

In November 2009 after completing the mapping task for projects with sufficient data, the EPA contractor was provided access to the IHS Sanitation Tracking and Reporting System (STARS) Navajo Area database to download any data updates for projects with insufficient data to be mapped. The contractor did not review or download data for projects already mapped, but downloaded updated information in an attempt to map the remaining SDS projects. Files from the IHS SDS database were in the same format as the initial 1,800 files received from IHS.

2.1.2. HITS homes

The IHS maintains data about individual homes in a system called the HITS. The HITS data were originally collected from individual applicants at the time they applied for sanitation services. HITS homes data and SDS homes data may overlap. That is, homes may exist in both HITS and SDS databases. Although the SDS is intended to include all sanitation needs in the

Navajo Area for existing homes, it is possible that HITS homes may not be included on SDS projects due to incomplete data or recent home construction.

In May 2009, an Excel file dated April 29, 2009 was reviewed, identifying 3,397 IHS HITS homes for the Navajo Nation. Each entry (i.e., home) in the spreadsheet provided a first and last name (home occupant), and a service request number. Each of the 3,397 homes also included latitude and longitude information.

2.1.3. Former Bennett Freeze data

In January 2010, a number of GIS files were reviewed. These files were received from WH Pacific and collected as part of the Former Bennett Freeze Recovery Plan by the Navajo Nation Community Development Division. These files include data on buildings in the area, as well as roads, water features, and crossings. These files were reviewed as part of this project because they may indicate homes without access to safe drinking water and/or basic sanitation.

The building data from this dataset were reviewed to provide information about additional homes without access to drinking water and basic sanitation not included in the SDS data. The building data layer provided the location of 6,638 buildings both in and out of the former Bennett Freeze area, as well as additional information on certain buildings, including building type, condition, and water or sanitation service. Appendix B provides a description of the layer's data fields, which were then used to identify which buildings to display on the Navajo Reservation map alongside the homes with access to safe drinking water and/or basic sanitation, as described in Section 3.1.3.

2.1.4. Structures within One Mile of an Abandoned Uranium Mine

In May 2009, a GIS point file from the EPA Region 9 Superfund Program was reviewed identifying 4,046 structures within one mile of an AUM. These data were collected as part of the Navajo Nation Screening Assessment for the EPA Region 9 Superfund Report, and were reviewed as part of this project because they may indicate homes without access to safe drinking water and/or basic sanitation. The metadata received with this file suggests that these data were collected as part of a desktop project with limited field verification. It identifies the data date range as October 1997 through March 2007 and describes the dataset as follows:

> *This point shapefile documents the location of building structures within one mile of Abandoned Uranium Mines (AUM) on and within one mile of the Navajo Nation as mapped from various sources. This dataset covers the six (6) AUM Regions where uranium mining was documented to have occurred on the Navajo Nation. The locations of structures were mapped by photointerpreting US Geological Survey (USGS) Digital Orthophoto Quarter Quadrangles (DOQQs) and reviewing USGS Digital Raster Graphics (DRGs) for 1:24,000 scale topographic maps, and by limited field visits to establish photo interpretation keys. Utility meter locations (water, gas, electric) were provided by the Navajo Tribal Utility Authority (NTUA) and were used to locate "assumed" structures.*

The bulding structures within one mile of an AUM account for all building types in the area, including residential (e.g., homes) and non-residential buildings such as gathering locations (e.g., Chapter house, church). Based on the photo-interpretation, structures were grouped in the following three categories: structure, possible structure, and assumed structure. The metadata file further specifies that these structures "do not necessarily have people living in them, although, a majority of the mapped structures are assumed to be occupied."

2.2. Well Data

In addition to mapping homes without access to safe drinking water and/or basic sanitation, this project identified existing water and wastewater infrastructure in the Navajo Nation to provide a geographic reference of existing wells and water lines relative to the homes. Drinking water wells, regulated watering points, and unregulated water sources were mapped as part of the water infrastructure, and locations of these wells were gathered from EPA, CDC, and Navajo DWR. These data are described below.

2.2.1. EPA sampled wells

In November 2008, EPA Region 9 Superfund Program uranium five-year plan well sampling locations data were incorporated into the dataset. The data were made available in a spreadsheet format, with latitude, longitude, and 57 other data attributes including certain chemical concentrations. These data were also collected as part of the Navajo Nation Screening Assessment for potential uranium contamination. The spreadsheet indicated that these 55 wells were sampled in February/March 2008. Appendix C provides a list of data attributes for these wells.

2.2.2. CDC sampled wells

In November 2008, CDC drinking water exposure assessment data were also incorporated into the database. These data were collected in 2007. They include well sampling results at 152 well locations in a spreadsheet format with latitude, longitude, and 95 other data attributes. Follow-up data were received that included two GIS data layers for well locations sampled in 2006 and 2007. Spot checks of a dozen locations indicated that the 2007 GIS data layer likely corresponded to the 2007 well sampling spreadsheet. All CDC well data were also collected as part of the Navajo Nation Screening Assessment for potential uranium contamination. A list of all data attributes for these wells is provided in Appendix D.

2.2.3. Navajo Department of Water Resources Livestock Watering Sources

The Navajo DWR developed and updates a geo-referenced database of water resources for the Navajo Nation, including all watering sources (e.g., wells, springs). These data provide valuable information to this project because they show points from which certain people may haul water which is not regulated under the Safe Drinking Water Act (SDWA). Data from the Navajo DWR were received in December 2008. These data included a Livestock Watering Sources data file in GIS format showing 3,104 watering points, including watering points outside the Navajo reservation.

2.2.4. Regulated Watering Points

In November 2008, an Excel spreadsheet dated August 2008 was received from the Navajo Area IHS with Navajo EPA data on watering points regulated under the SDWA within the Navajo Nation. These data points are directly relevant to this project because they provide a visual reference of the number and location of regulated water sources available on the Navajo Nation where residences not connected to a public water system can access safe drinking water. IHS is looking at establishing additional watering points for people to haul water from in the future. The 67 points in the file included latitude and longitude information in addition to other data relevant to each watering point. The Excel file provided information for 18 data attributes described in Appendix E.

2.3. Water and Sanitation Infrastructure

To complete existing water and wastewater infrastructure in the Navajo Nation, this project included geo-referenced water and wastewater mains from NTUA and proposed water supply projects. These data are described below. It should be noted that the Navajo Nation has other water operators with separate distribution systems, but these were not included as part of this project.

2.3.1. NTUA data

As part of its facilities management, NTUA updates geo-referenced data of its facilities, distribution systems, and clients (e.g., water meter and other information). In November 2008, NTUA provided two geo-databases for water and wastewater services dated December 2007. These files include multiple GIS data layers describing the NTUA utility system, including layers for water and sewer mains, water meters and sewer discharge points, and other data relevant to the system that did not need to be mapped (e.g., sewer control valve, sewer manhole, Supervisory Control and Data Acquisition or SCADA sensor). A second, updated, dataset including only water mains and water laterals was received in May 2010.

2.3.2. Proposed water supply projects

In December 2008, pipeline alignments were provided in a GIS format for the following six proposed Navajo Department of Water Resources Regional Water Supply Projects:

- Farmington-Shiprock Water Supply Project;
- Ganado Groundwater Supply Project;
- Leupp-Dilcon Water Supply Project;
- Navajo-Gallup Water Supply Project;
- Utah Water Supply Project; and
- Western Navajo Pipeline Project.

In March 2009, a PDF file was received, showing a proposed pipeline for phases 1 to 5 of the proposed Shiprock to Sweetwater pipeline. These existing and proposed pipelines were mapped as they provide geographic reference to proposed public water supply distribution systems.

2.4. USGS quadrangle maps

The Navajo Nation covers a very wide area across three states, and individual geo-referenced USGS topographic quadrangles were cumbersome to use for mapping most SDS home locations. ESRI provides an online GIS layer composed of all USGS topographic quadrangles. The layer automatically displays the appropriate USGS quadrangles at the relevant scale (e.g., 1:25,000 vs. 1:100,000) based on the scale of the GIS map being created. This data layer cannot be downloaded, but is available to use by computers equipped with ESRI software and connected to the internet. The ESRI online data layer was used to provide the background topographical images for the mapping effort.

In addition, individual geo-referenced USGS quadrangles purchased from Geo Communities for the states of Utah, New Mexico, and Arizona were used to map SDS homes with initial maps in CAD format.

3.0 MAPPING PROCEDURES

3.1. Home Locations

3.1.1. Homes without Access to Safe Drinking Water and/or Basic Sanitation

An SDS map (or multiple maps for large areas) of home locations and its corresponding name table were required to map a project home in GIS. Many SDS projects did not include all homes shown on the map and most homeowner name tables did not include geographic information for the homes. Therefore, homes grouped in an SDS project that lacked a map, name table, or both were not mapped.

All homes with sufficient information within an SDS project were mapped one at a time by a single GIS analyst prior to the analyst moving onto the next SDS project to allow easy tracking of progress and to enable multiple GIS analysts to work concurrently. The resulting GIS file was named after the project number. All SDS homes were mapped in a North American Datum (NAD) 1927 geographic coordinate system. The mapping process for individual SDS projects started with formatting of the name table, followed by mapping of the home locations, and a final quality control process including joining the GIS file with the formatted name table to conserve all relevant home information for the project. Once all, or a sufficient number of GIS files representing homes within individual SDS projects were mapped, the multiple GIS files were merged into a single GIS file.

Formatting: To ensure GIS compatibility and consistency across all homes from multiple SDS projects, name tables in their initial format (e.g., PDF, word) for all projects with sufficient

information to be mapped were first converted to a table format (i.e., Excel file), and data fields were renamed to an 8-character name as listed in Appendix A.

Mapping: When starting a new SDS project, the GIS analyst entered his/her initials for the corresponding SDS project in a progress tracking spreadsheet (the progress spreadsheet) to indicate the project was being mapped, and printed the corresponding name table to track individual homes. For each mapped home the GIS analyst marked the home as mapped on the printed table and copy-pasted the home occupant name from the Excel name table into the GIS record to avoid typographical errors. Homes that could not be mapped and the reason for it were also tracked. This information is provided in Appendix F (see Appendix F tab in the Appendices Excel file in the enclosed CD).

Homes were mapped using dual screen computers, with one screen dedicated to displaying the initial map, and the other screen for the GIS map. Maps in CAD format were re-projected and/or re-aligned to the relevant coordinate systems and/or USGS quadrangles prior to being imported directly into GIS as a point file. Maps in all other formats were displayed on the screen, and homes were mapped one by one by creating a point location in GIS at the same approximate location as displayed in the initial map.

Quality Control: After all homes in an SDS project were mapped, a different GIS analyst conducted the following quality control tasks:

- Open the project files;
- Enter his/her initials in a separate field in the progress spreadsheet;
- Compare the GIS file to the original maps and name table to ensure all homes were mapped;
- Verify locations of at least three homes; and
- Join the formatted name table to the GIS project file.

Single SDS Home Locations File: After GIS data layers were created for all SDS projects, the data layers for these projects were combined into a single data layer in GIS: the SDS layer. This data layer included fields for all the data attributes identified within the name tables (see Appendix A). Projects with no data entered for a particular data attribute have blank cells under that data attribute.

3.1.2. HITS homes

In a NAD 1927 geographic coordinate system, a GIS point layer was created based on the latitude and longitude information available in the Excel file of all HITS homes described in Section 2.1.2. All HITS homes were mapped, and an overlap analysis with SDS homes was conducted to identify potential duplicates. A total of 131 SDS homes were found to be located within 100 feet of a HITS home. Based on home occupant names in the SDS and HITS databases, 87 homes were identified as duplicates, including homes for which names were spelled slightly differently.

3.1.3. Former Bennett Freeze data

As described in Section 2.1.3, the *Buildings* GIS layer from the former Bennett Freeze data was used to map potential homes lacking access to safe drinking water and/or basic sanitation, but not all buildings in the layer represent potential homes, as the layer includes commercial buildings, abandoned structures, and buildings with water and wastewater service. Using data available in the table behind the GIS *Buildings* layer, a five-step mapping process was developed, identifying:

1. Homes from other building types;
2. Occupied from unoccupied homes;
3. Homes without access to public water;
4. Homes without access to public sewer; and
5. Homes within 100 feet of already mapped homes and assumed to be already mapped.

Homes vs. Other Building Types: The "Type" data field describes building use, and can be used to identify residential buildings from other buildings. Most buildings in the data layer are associated with one of 20 types such as commercial, hospital, school, and residential types. Single and multi family residential buildings represent the largest number of buildings with known types. Buildings with residential, "other", and unknown (i.e., blank) types were selected, and a first data layer was created with all buildings from these types, excluding all others. This new layer is an attempt to exclude non-residential buildings from the map, as they are unlikely to represent SDS home locations.

Occupied vs. Unoccupied Homes: The "Ownership" field describes ownership for the building, and was used to identify abandoned buildings. Most residential buildings were associated with one of the following four ownership types: abandoned, owned by resident, rented, and unknown; remaining buildings have a blank field. Residential buildings were sorted according to the ownership field to exclude abandoned buildings, as abandoned homes do not require water or wastewater infrastructure.

Access to Public Water: The "Water" field describes water access for the building, and was used to identify buildings on public water. Most non-abandoned residential buildings are associated with one of the following seven water types: (i) Cistern, (ii) None, (iii) Public, (iv) Public Water, (v) Unknown, (vi) Water Cistern, and (vii) Water Well. Remaining buildings have a blank field. Buildings with "public" and "public water" fields were overlaid onto NTUA water lines to verify that all these buildings are within 100 feet of an existing water line. Buildings that do not have public water, and buildings identified as having public water but not located within 100 feet of an NTUA water line, were then sorted. This new layer is an attempt to exclude residential buildings with access to public water from the map, as they are unlikely to represent homes without access to safe drinking water. In addition, all buildings located within 100 feet of an existing NTUA water line were removed, as these are very unlikely to be homes without access to safe drinking water.

Sanitation: Similar to the "Water" field, the "Wastewater" field describes wastewater access for the building, and was used to identify buildings on public sewer. Most residential buildings from

the previous layer are associated with one of the following seven wastewater types: (i) None, (ii) Outhouse, (iii) Public, (iv) Public Sewer, (v) Septic, (vi) Septic Tank, and (vii) Unknown. Remaining buildings have a blank field. The Former Bennett Freeze homes layer was then created using buildings from the previous layer that do not have public sewer ("public" and "public sewer").

Homes Already Mapped: Within the GIS data layer, homes within 100 feet, and within 200 feet of a mapped SDS home were then identified and labeled in an additional GIS data attribute, but there were no unique identifiers between both databases (e.g., resident name) to verify if these homes are identical. A total of 144 Bennett Freeze homes were within 100 feet of a mapped SDS home, and 259 were within 200 feet. All Bennett Freeze homes were mapped, regardless of their location relative to SDS homes because verification could not be obtained for any home.

3.1.4. Structures within One Mile of an Abandoned Uranium Mine

The file received for structures within one mile of an AUM was already in GIS format, but similar to former Bennett Freeze buildings, these structures do not all represent home locations, and could potentially be abandoned buildings, or buildings with access to safe drinking water as some points are based on NTUA water meters. Buildings served by public water could potentially be removed from this file, but the data table behind the GIS file only provides that information in a "comment" field that would require a detailed analysis. However, structures within 100 feet of an existing NTUA water line were identified and removed them from the database, as these are very unlikely to represent homes without access to safe drinking water.

3.2. Wells

3.2.1. EPA sampled wells

EPA Region 9 Superfund Program sampled well data were initially in a spreadsheet format with latitude and longitude information available for all 55 well locations, as well as other relevant information. Data attributes for these wells were renamed with names of eight characters or less to ensure that the spreadsheet was compatible with GIS. Incompatible characters such as "/" and "-" were replaced with other compatible characters, such as "_" or with information in a different format (e.g., dates in a 01/01/2009 format were changed to a "Jan. 1, 2009" format).

In addition, any formulas embedded in cells from the spreadsheet were replaced with their result, as formulas cannot be readily interpreted by GIS software. Finally, if certain concentrations were reported as "ND" or non-detected in the spreadsheet, the text was replaced with a numerical value to ensure that the GIS software would import the concentration data as a numerical data attribute. Detection limits were not known for any of the chemical compounds so detection limits were set at least one order of magnitude lower than the smallest measurement, when available.

After these steps, the spreadsheet was imported into GIS in the same geographic coordinate system as the SDS home locations (NAD 1927). It should be noted that color coding of individual spreadsheet cells to identify well locations exceeding MCLs were lost when

converting the Excel file into a GIS format. A description of the data attributes and numerical detection limit replacements is available in Appendix C.

3.2.2. CDC sampled wells

These wells were mapped using a similar mapping process to the EPA sampled wells, where the spreadsheet and its data were formatted to a format acceptable to GIS, and imported into GIS in the same geographic coordinate system as the SDS home locations. It should be noted that the color coding of spreadsheet cells to identify well locations exceeding MCLs were lost when converting the Excel file into a GIS format. A description of the data attributes and numerical detection limit replacements for CDC sampled wells is available in Appendix D.

3.2.3. Navajo Department of Water Resources Livestock Watering Points

The initial GIS file representing livestock watering points included 3,104 data points representing over 300 operators, including NTUA and certain Navajo Chapters, with some data points outside the Navajo Reservation. Not all watering points in the file were necessarily operated by or for the Navajo Nation. IHS provided guidance on certain operators, and submitted a list of approximately 40 operators of sources likely constructed for the purpose of providing water to families and communities. Based on the IHS operator list, a subset of the watering points operated by the 40 operators was mapped, but this list may not be comprehensive as IHS noted that all drinking water sources could not definitively be identified based only on an operator list.

3.2.4. Regulated Watering Points

Regulated watering point data for 67 locations were initially in a spreadsheet format with latitude and longitude information, as well as other relevant information. Data attributes were renamed with names of eight characters or less to ensure that the spreadsheet was compatible with GIS. Similar to the EPA sampled wells, incompatible characters were also replaced with other compatible characters, and formulas were replaced with their result. After these steps, the spreadsheet was imported into GIS in the same geographic coordinate system as the SDS home locations. A description of the data attributes is available in Appendix E.

3.3. Water and Sanitation Infrastructure

3.3.1. NTUA water lines

The December 2007 geo-databases for NTUA water and sewer service are large files with very detailed information (e.g., water meter data) that is not all relevant to a planning-level project. Therefore, the GIS line files representing water distribution mains and laterals were merged into a single GIS line file. The size of this file was further reduced by removing details such as individual pipe sizes and materials, irrelevant at the scale of this project. The resulting "water" file was then used as a representation of NTUA water lines. The process was then repeated with the updated May 2010 NTUA water mains and laterals.

3.3.2. Proposed water supply projects

The six GIS files for the proposed Navajo DWR Regional Water Supply Projects listed under Section 2.3.2 were left unchanged and added to the GIS map. The proposed pipeline alignments for phases 1 to 5 of the Shiprock to Sweetwater pipeline were available in PDF format only. An image version of the PDF file was therefore imported into GIS, and the image was geo-referenced so that geographic features in the image aligned with features (e.g., roads, rivers) from geo-referenced USGS topographic quadrangles. Line files for each project phase were then created by drawing over the pipeline alignment in GIS.

4.0 DATA LIMITATIONS

All data used for this mapping project were secondary data collected by other entities for different purposes, so data accuracy and completeness are difficult to estimate, and these data should only be used at the pre-planning level. Additional data are needed to complete a project design. This section discusses data accuracy and completeness, as well as potential data overlap from multiple sources.

4.1. Data Accuracy

Data mapped using latitude and longitude information from a spreadsheet can only be as accurate as the initial geographic positioning, and the number of significant digits reported in the data. This information was not reported for any of the EPA or CDC well locations, or the HITS homes. Data mapped using digital images of maps and home locations, such as from the SDS data, have an additional degree of potential inaccuracy, because initial data are first transcribed to a paper or digital image, then taken from that image, and approximated by a point drawn in a GIS file based on approximately geo-referenced USGS quadrangles. Certain digital images were too blurry to locate homes, as illustrated in Figure 1, taken from SDS project NM23573-0601. Other projects showed home locations on large scale maps such that potential home locations spanned hundreds of feet, as illustrated in Figure 2, taken from SDS project NM17467-0603.

The best accuracy was most likely obtained for SDS projects with maps provided as CAD files, because proposed project pipelines for these home locations were most likely combined with CAD files from existing distribution system designs. The transfer of home locations from CAD to GIS was also less prone to approximations from the data analysts. These home locations should still not be used for project design, but rather at a pre-planning level.

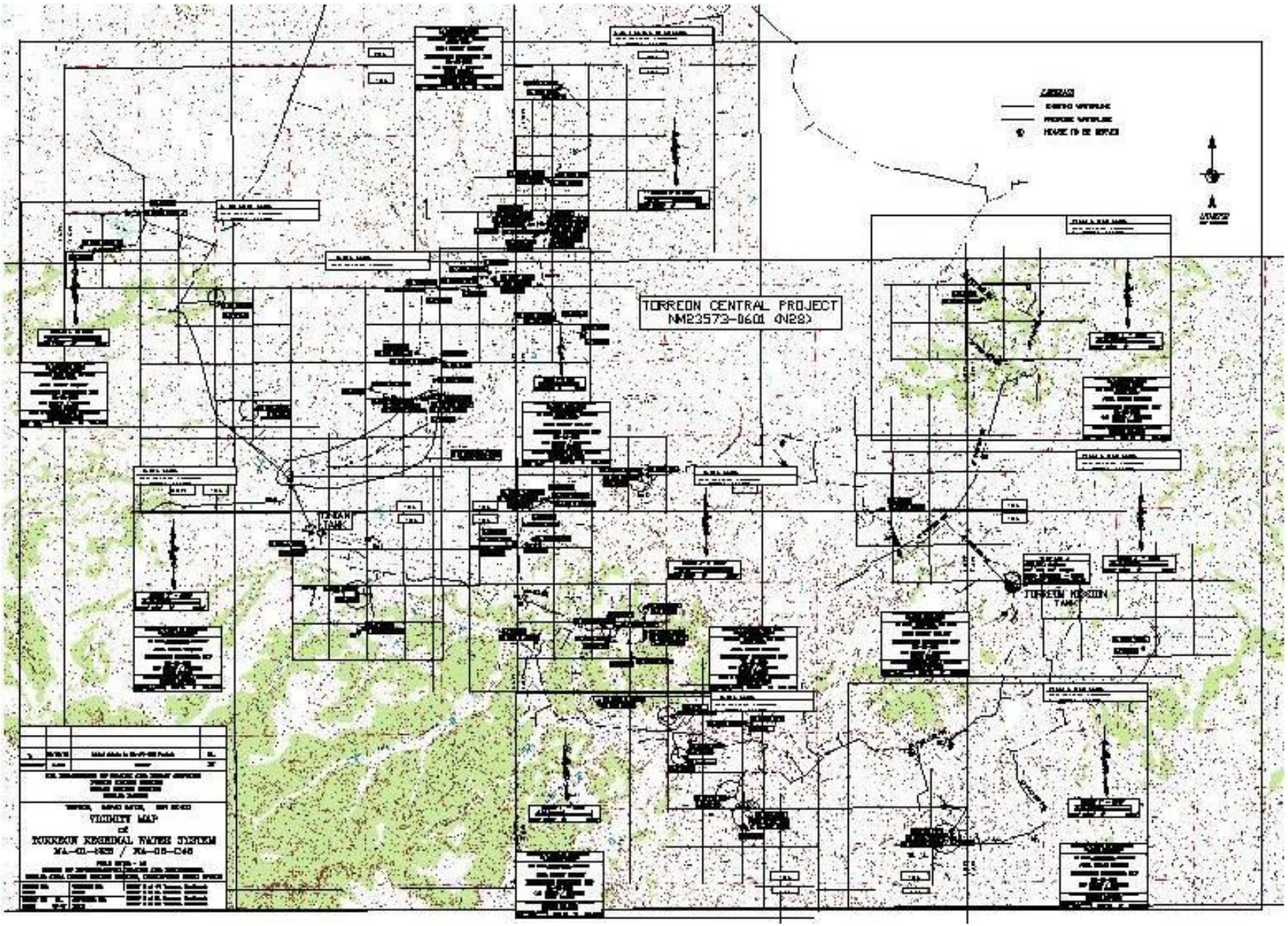


Figure 1. Very low-resolution map (blurry and pixelized) for project NM23573-0601

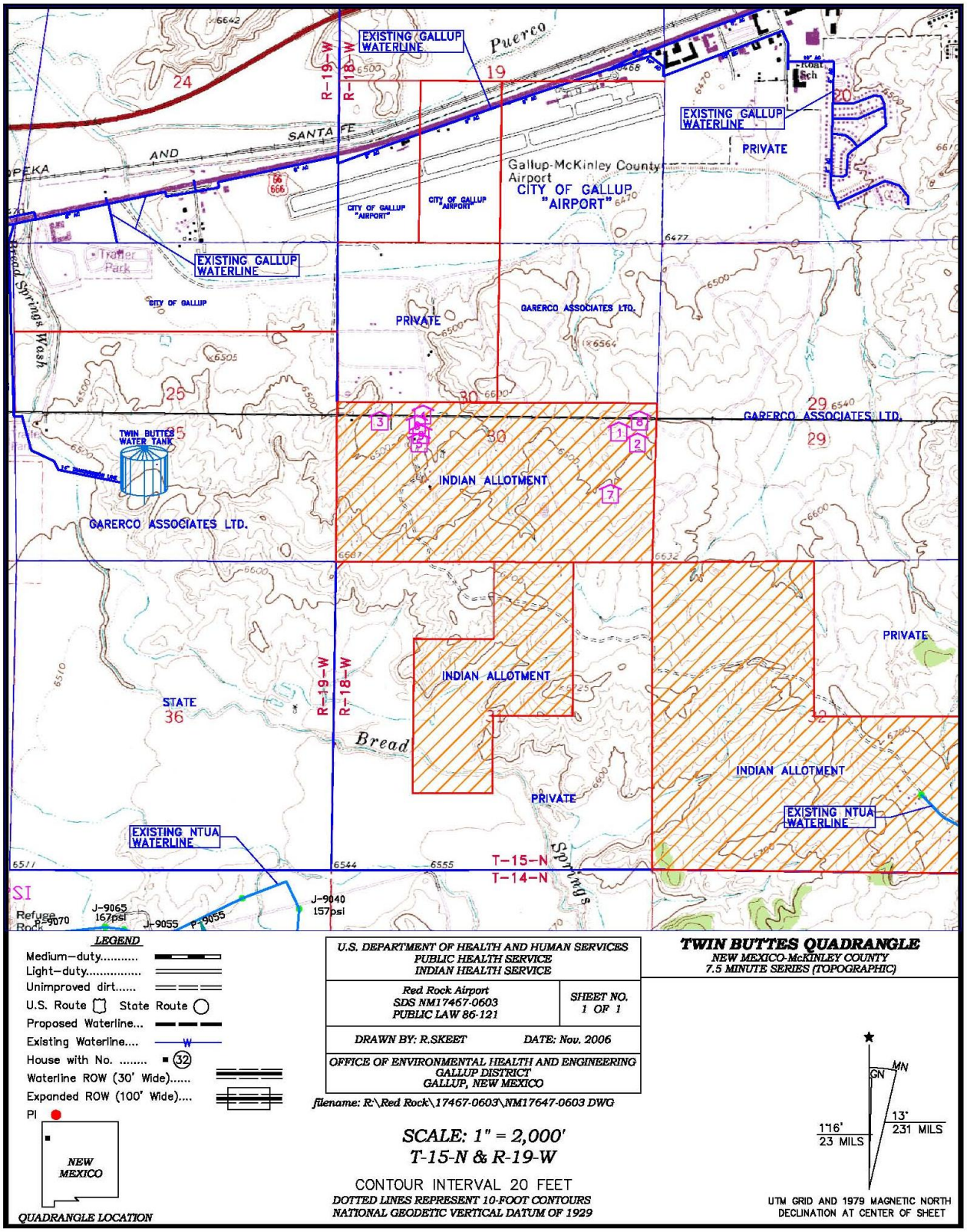


Figure 2. Approximate home locations due to large scale map for project NM17467-0603 (homes represented with a magenta symbol and home number)

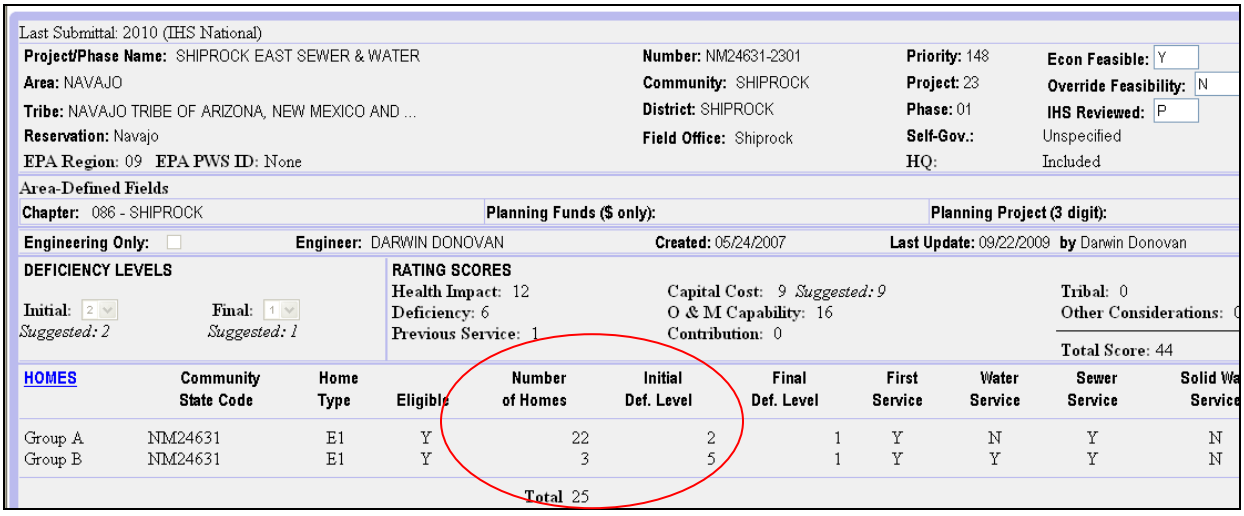
4.2. Data Completeness

4.2.1. Insufficient data

As discussed under Section 3.1.1, some SDS home locations could not be mapped due to a lack of legible project maps, or project name tables. These projects were not mapped, but some of the mapped projects also included homes that could not be mapped. Unmapped homes within a mapped project occurred most often because the home was not represented on the initial map or because the home number or resident name was not legible.

In addition, some mapped projects resulted in a higher number of mapped homes than were originally listed under the project number in the SDS project database provided by IHS in November 2008. With the information available at the time, the reason for these additional homes could not be determined, and it was not possible to identify which homes were "over-mapped." Based on additional data available through the STARS database after November 2009, the EPA contractor deduced that homes with different SDS deficiency levels (i.e., not only deficiency levels 4 and 5) could be part of the same SDS project, but not all homes within that project were necessarily considered to be SDS level 4 or 5 deficient.

Project # NM24631-2301 provides a good illustrative example. The project has only three homes based on the initial IHS project database list (received from IHS Headquarters with the original 1,800 related to Navajo SDS home locations), but the SDS project shows a total of 25 homes, split into Groups A and B. Figure 3 shows a snapshot of the SDS project as it appears in the STARS database. There are three homes under Group B, which shows an initial deficiency level of 5, and the remaining 22 homes are under Group A with an initial deficiency level of 2 (i.e., homes that have both water and sewer facilities, but the sewer facilities are less than adequate). In this case, all 25 homes were mapped.


Last Submittal: 2010 (IHS National)

Project/Phase Name: SHIPROCK EAST SEWER & WATER | **Number:** NM24631-2301 | **Priority:** 148 | **Econ Feasible:** Y
Area: NAVAJO | **Community:** SHIPROCK | **Project:** 23 | **Override Feasibility:** N
Tribe: NAVAJO TRIBE OF ARIZONA, NEW MEXICO AND ... | **District:** SHIPROCK | **Phase:** 01 | **IHS Reviewed:** P
Reservation: Navajo | **Field Office:** Shiprock | **Self-Gov.:** Unspecified
EPA Region: 09 **EPA PWS ID:** None | **HQ:** Included

Area-Defined Fields

Chapter: 086 - SHIPROCK | **Planning Funds ($ only):** | **Planning Project (3 digit):**

Engineering Only: | **Engineer:** DARWIN DONOVAN | **Created:** 05/24/2007 | **Last Update:** 09/22/2009 **by** Darwin Donovan

DEFICIENCY LEVELS
Initial: 2 *Suggested: 2* | **Final:** 1 *Suggested: 1*

RATING SCORES
Health Impact: 12 | **Deficiency:** 6 | **Previous Service:** 1
Capital Cost: 9 *Suggested: 9* | **O & M Capability:** 16 | **Contribution:** 0
Tribal: 0 | **Other Considerations:** 0
Total Score: 44

HOMES	Community State Code	Home Type	Eligible	Number of Homes	Initial Def. Level	Final Def. Level	First Service	Water Service	Sewer Service	Solid Waste Service
Group A	NM24631	E1	Y	22	2	1	Y	N	Y	N
Group B	NM24631	E1	Y	3	5	1	Y	Y	Y	N
				Total 25						

Figure 3. STARS database snapshot for project NM24631-2301

Former Bennett Freeze buildings and structures within one mile of an AUM are not necessarily a home without access to safe drinking water or basic sanitation, but this could not be determined due to lack of information for many of these buildings and structures. Some of these buildings and structures may also be "over-mapped."

4.2.2. Static data

As indicated in Table 1, all data used as part of this mapping project were collected at a given point in time, and are static. They provide a snapshot of the situation at some point in past, but should be updated regularly. As additional water and wastewater projects are funded, some of these home locations should be removed from the SDS GIS file, and all other data should be updated, including NTUA water and wastewater infrastructure.

4.3. Data Overlap

In an effort to capture all potential homes lacking access to safe drinking water and/or basic sanitation, this project also mapped HITS homes, Former Bennett Breeze buildings, and structures within one mile of an AUM. There may be duplication between these data sources, and certain home locations may be mapped more than once. These home, building, and structure locations are all saved as separate data files, but they do not all have single identifiers (e.g., home occupant name) that would enable the identification of duplicate locations.

5.0 MAPPING RESULTS

IHS provided data regarding a total of 283 SDS projects (deficiency level 4 and 5 projects) comprising 8,292 homes. As of the completion of the mapping effort in September 2010, 219 projects (78%) comprising 4,636 homes (56%) had been mapped based on data received from IHS in November 2008, and downloaded from the STARS database in November 2009. Based on an extensive review of both data sources, it is estimated that only 64 projects have insufficient information and cannot be mapped at this time. Among those 64 projects:

- Three projects were funded in 2009, comprising 87 homes;
- Five projects represent five phases of a single large infrastructure project (AZ01058-1001 to -1005: *Shiprock to Sweetwater*) designed to address a water quality issue (high arsenic in the source water) at 1,001 homes – the first phase (AZ01058-1001) is already funded; and
- Two projects represent two phases of another large infrastructure project (AZ09158-0501 to -1002: *Dilkon Clinic and Community Water Plan*) designed to address insufficient quantity or water pressure for 590 homes in the community.

These ten projects account for a total of 1,678 of the remaining 3,656 homes. In addition, this project resulted in the mapping of a number of wells and watering points, as well as buildings and structures from other data sources. Table 2 provides summary statistics of the mapping accomplished under this project. Figure 4 (see enclosed, folded 24x36 poster-size figure) provides a summary map of the data.

Table 2. Mapped Homes without Access to Safe Drinking Water and/or Basic Sanitation Wells, and Other Data

SDS Data	Projects	Homes
Total numbers	**283**	**8,292**
Total mapped as of May 2010	219 (78%)	4,636 (56%)
Funded in 2009	3	87
Associated with Community Water System with MCL exceedance or pressure/quantity issues	7	1,591
Remaining to map (insufficient information)	**54 (19%)**	**1,978 (24%)**
Well Data	**Wells**	
CDC-sampled wells mapped	152	
EPA-sampled wells mapped	55	
Regulated watering points	67	
DWR wells in database	3,104	
DWR wells with Navajo operators	1,549	
Other Data	**Structures/Homes**	
HITS Homes (total)	3,397	
Former Bennett Freeze buildings[1] (potential homes without access to safe drinking water and/or basic sanitation)	2,685	
Structures within 1 mile of an AUM[1] (potential homes without access to safe drinking water and/or basic sanitation)	2,171	

[1] *These buildings and structures represent potential homes without access to safe drinking water and/or basic sanitation. They exclude all buildings and structures within 100 feet of an NTUA water line.*

6.0 MAPPED DATA SUMMARY ANALYSIS TABLES

Below are summary analyses that demonstrate the utility of the data mapped in a GIS format.

WATER MAIN OR LATERAL

Table 3 provides a comparison of total length of pipe, and pipe segments for the NTUA data received in 2008 (dated December 2007 in the file name), and the recent data update (April 2010).

Table 3. NTUA Pipe Length Comparison between 2007 and 2010 Data

	December 2007 data	April 2010 data
Total length (miles)	5,863.4 miles	6,176.6 miles
Number of segments	158,981	166,467

BENNETT FREEZE HOMES

Table 4 provides information on Bennett Freeze buildings identified as potential homes without access to public water or wastewater, and within 100 or 200 feet of a mapped SDS home or an NTUA water line.

Table 4. Bennett Freeze Building Analysis

	A mapped SDS home	An NTUA water line
Buildings within 100 feet of	144	1,003
Buildings within 200 feet of	259	1,444

HITS HOMES

Table 5 provides information on HITS homes within 100 or 200 feet of a mapped SDS home or an NTUA water line.

Table 5. HITS Homes Analysis

	A mapped SDS home	An NTUA water line
Homes within 100 feet of	152	438
Homes within 200 feet of	300	767

STRUCTURES WITHIN ONE MILE OF AN AUM

Table 6 provides information on structures identified as potential homes without access to public water, and within one mile of an AUM within 100 or 200 feet of a mapped SDS home or an NTUA water line.

Table 6. Analysis of Structures within One Mile of an AUM

	A mapped SDS home	An NTUA water line
Structures within 100 feet of	45	1,874
Structures within 200 feet of	101	2,197

MAPPED HOMES WITHOUT ACCESS TO SAFE DRINKING WATER AND/OR BASIC SANITATION

Table 7 provides information on homes without access to safe drinking water and/or basic sanitation within a certain distance of an NTUA water line, a regulated watering point, and a Navajo DWR livestock watering point.

Table 7. SDS Home Analysis

	An NTUA water line	Regulated Watering Point	Navajo DWR Livestock Watering Point
Homes within 100 feet of	119	0	2
Homes within 200 feet of	186	0	7
Homes within 1 mile of	672	56	1,089
Homes within 5 miles of	3,276	993	4,333
Homes within 10 miles of	4,249	3,091	4,599

7.0 SUGGESTIONS FOR FUTURE DATABASE USE

This section provides suggestions of potential uses of the completed database, including facilitating water and sanitation access, facilitating funding, and improving infrastructure design and installation.

Water and sanitation access to homes could be facilitated through the optimization of projects and design. The available geographic location of homes without access to safe drinking water and/or basic sanitation relative to existing infrastructure could enable a planning workgroup to count homes within a certain distance of a watering point, or a water line to optimize potential water or sewer line extensions. If water or sewer line extensions are not feasible, the geographic information could still be used to develop and optimize potential water hauling routes. In both case of infrastructure extension and water hauling route development, available geographic information would facilitate preliminary cost estimates.

Geographic information of homes without access to safe drinking water and/or basic sanitation relative to existing infrastructure could also facilitate funding by assisting with grant applications, and potentially coordinating funding, design, and construction efforts with other agencies and NGOs (e.g., cost sharing across multiple agencies). This information could help reduce costs, and potentially improve infrastructure design and installation.

In addition to facilitating future access projects, geographic information can be beneficial for existing projects and maintenance prioritization for existing infrastructure. Maintenance activities of certain watering points and other sources could be prioritized based on potential homes using these points.

Geographic information of homes lacking basic sanitation facilities and existing infrastructure across the entire Navajo Nation could help target neighborhoods that lack access for public health and educational programs, such as a field sanitation program, or the prioritization of vaccinations in the case of a potential pandemic. People without access to safe drinking water and sanitation are at higher risk of contracting diseases and infections and may need to be placed on a priority list for vaccinations.

8.0 NAVAJO REPORT APPENDICES AND GIS DATA

Appendices and data files associated with this project are provided in the enclosed CD. Appendices are grouped in a single Excel file, with a tab for each appendix. GIS files are grouped in the "GIS data" folder on the CD. The GIS map provided as Figure 4 in this report is also included on the CD in PDF and GIS formats. The GIS map can be opened in ESRI's software is linked to all GIS files from the "GIS data" folder, and uses ESRI's online USGS quadrangle layer.

Appendices A through E provide details on the data attributes associated with a number of the GIS files, including:

- SDS homes (Appendix A);
- Former Bennett Freeze buildings (Appendix B);
- EPA sampled wells (Appendix C);
- CDC sampled wells (Appendix D); and
- Regulated watering points (Appendix E).

Appendix F provides mapping details for each of 283 SDS projects, including:

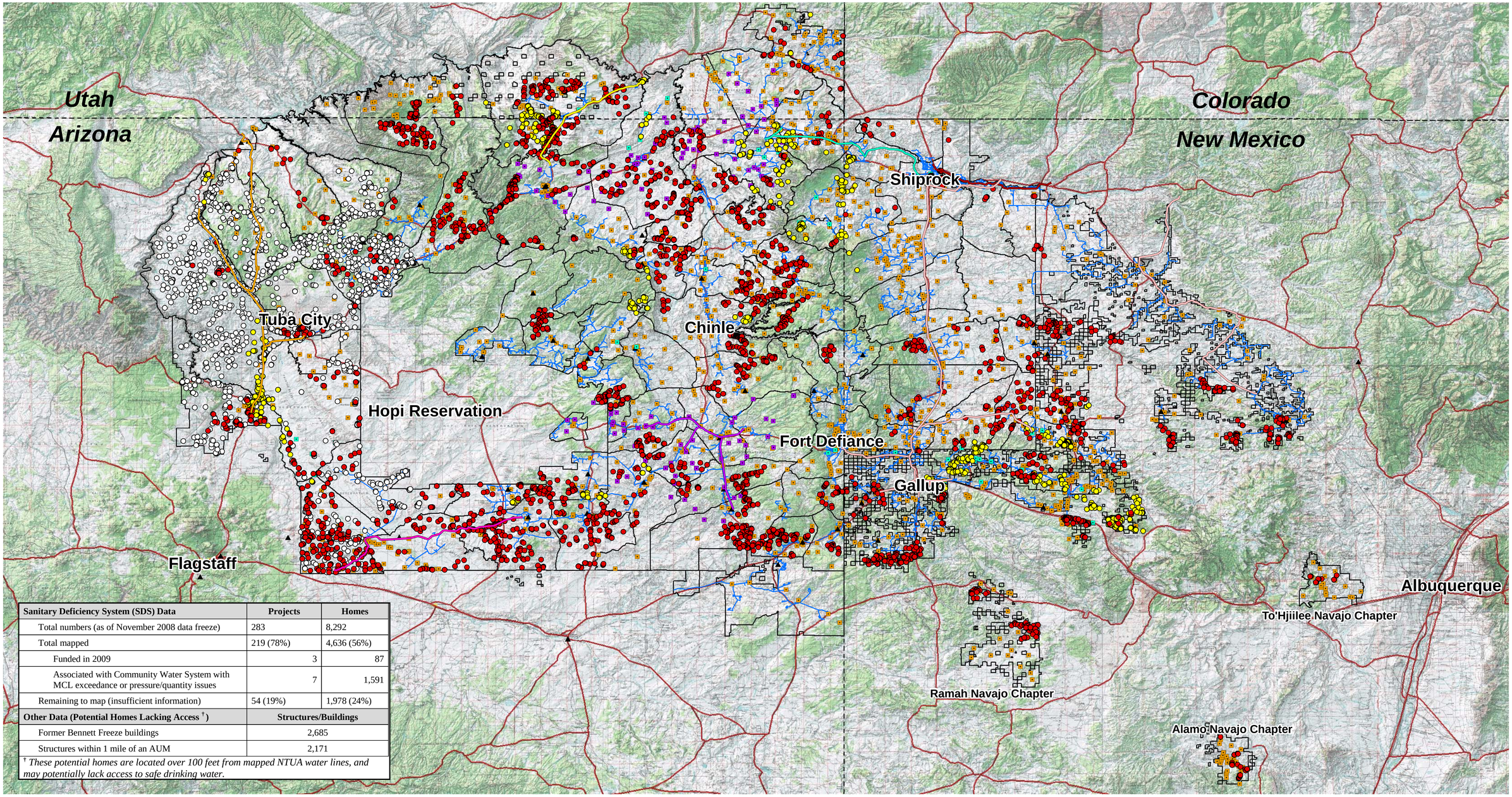
- Project number;
- Project name;
- Economic feasibility;
- Special condition for lacking access;
- Mapping feasibility (i.e., can the project be mapped);
- Reason for mapping feasibility or infeasibility;
- Number of homes listed in project name table; and
- Number of homes successfully mapped.

GIS files available in the CD include the following data:

- SDS homes (file name: SDS_Homes);
- HITS homes (file name: HITS_Homes);
- Former Bennett Freeze buildings (file name: FormerBennettFreeze_Homes);
- Structures within one mile of an AUM (file name: Structures_In1Mile_AUM);
- EPA sampled wells (file name: EPA_SampledWells);
- CDC sampled wells (file name: CDC_SampledWells);
- Unregulated livestock watering points (file name: UnregLivestockWateringPts);
- Regulated safe drinking water hauling points (file name: RegSafeDrinkingWaterHaulingPts);
- NTUA existing pressurized water mains (file name: NTUA_WaterMains);
- Proposed water distribution lines:
    - Western Navajo Pipeline Project (file name: ProposedWesternNavajoWater);
    - Navajo-Gallup Water Supply Project (file name: ProposedNavajoGallupWater);
    - Leupp-Dilcon Water Supply Project (file name: ProposedLeuppDilcon);
    - Utah Water Supply Project(file name: ProposedUtahWater);
    - Ganado Groundwater Supply Project (file name: ProposedGranadoWater);

- Farmington-Shiprock Water Supply Project (file name: ProposedFarmingtonShiprockWater); and
- Shiprock to Sweetwater Pipeline Project (file name: ProposedShiprockSweetwaterWater).

The CD and GIS map also include GIS files representing state lines, Navajo Chapters, and major roadways, but these were not developed as part of this project and are included for visual reference only.



Sanitary Deficiency System (SDS) Data	Projects	Homes
Total numbers (as of November 2008 data freeze)	283	8,292
Total mapped	219 (78%)	4,636 (56%)
Funded in 2009	3	87
Associated with Community Water System with MCL exceedance or pressure/quantity issues	7	1,591
Remaining to map (insufficient information)	54 (19%)	1,978 (24%)
Other Data (Potential Homes Lacking Access †)	**Structures/Buildings**	
Former Bennett Freeze buildings	2,685	
Structures within 1 mile of an AUM	2,171	

† *These potential homes are located over 100 feet from mapped NTUA water lines, and may potentially lack access to safe drinking water.*

Legend

- State Line
- Navajo Chapter
- Major Roadway
- Home without Access to Safe Drinking Water and/or Basic Sanitation *
- Former Bennett Freeze Home Potentially not Connected to a Public Water System (PWS) **
- Structure within 1 Mile of Abandoned Uranium Mines (potential homes without connection to a PWS) **
- EPA Sampled Well
- CDC Sampled Well
- Regulated Safe Drinking Water Hauling Point
- Unregulated Livestock Watering Point
- Navajo Tribal Utility Authority Existing Pressurized Water Main
- Proposed Western Navajo Pipeline Project
- Proposed Navajo-Gallup Water Supply Project
- Proposed Utah Water Supply Project
- Proposed Leupp-Dilcon Water Supply Project
- Proposed Ganado Groundwater Supply Project
- Proposed Farmington-Shiprock Water Supply Project
- Proposed Shiprock to Sweetwater Pipeline Project

N

Miles

10

* *This map does not represent all the known homes lacking access to safe drinking water or basic sanitation in the IHS database. These are only those that had sufficient information to be mapped at the time of this study.*
** *Former Bennett Freeze homes, and Structures within 1 mile of Abandoned Uranium Mines were sorted to identify potential homes without access to safe drinking water and/or basic sanitation.*

EPA

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Navajo Nation: Homes without Access to Basic Sanitation Facilities