MAppFx:
Production Well Nitrates
Northern Guam Lens Aquifer

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Dannika Kate U. Valerio
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WATER AND ENVIRONMENTAL RESEARCH INSTITUTE
OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM

Technical Report No. 180
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Abstract

Interactive web map and graphs are the now and future of online interactive hydrologic database access. An interactive online application, MAppFx, demonstrates a map point and graph display feature. And a recent research product of Guam production well nitrate trends and analysis are the select dataset for developing this new interactive feature that expands the interagency web map products in the Guam Hydrologic Survey website. The product is an online map of Guam production wells as points with well names that upon selection displays a time graph of nitrate concentrations in a panel or over the map. Many scientists and water resource agencies have longed for an interactive database map as it is easy for everyone to use and access, especially for deciding water source protection and production management. The success here will pursue other interactive map and time graph products pertaining to Guam's water resources, such as the observation well dynamics, chloride and production, rainfall hydrology, and other field surveys.

The One Guam – Guam Hydrologic Survey (GHS) website (guamhydrologicsurvey.uog.edu) is Guam's online repository of pertinent hydrologic information, established through Guam public laws. The website is managed by WERI, UOG, and web server service is provided by UOG, Office of Information Technology, Web Team. The GHS website contains interagency partnership information, the public laws, outreach services (workshops and aquifer tour), hydrologic reports (technical, journal, professional papers, and workshop presentations), maps, Interagency Web MApps (new interactive web map application), borehole and production well chloride database, and an interactive map to the chloride and borehole databases. With the established website and new online interactive interface technology available, GHS Information Management Team are now inclined to pursue the expansion of hydrologic web products and field survey database. The ever-growing GHS website product is already a true testament to interagency collaboration, a great means of hydrologic information dissemination, and scientific information source for aquifer management.

Key Words: WERI MAppFx, data visualization, online information transfer, Northern Guam Lens Aquifer, nitrates

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CHAPTER 1

INTRODUCTION

Distribution of hardcopy reports and data analysis are becoming more and more of a thing of the past. The presence and availability of online data visualization tools provide the means to distribute and reference data analysis results. This project begins the online data visualization of Guam's water quality records of production wells, starting with nitrate-N concentration on an interactive map and graph web page. The records were organized from a recent nitrate analysis project. Now, an interactive map and graph interface called MAppFx is available online.

1.1 Nitrates in Guam's Production Wells

Guam is an island in the Western Pacific that is fortunate to have the Northern Guam Lens Aquifer as an abundant source of utility water. However, most of the island's population and activities sit on top of the aquifer, which may be vulnerable to contaminants from anthropogenic sources. Thus, the utility water quality is frequently monitored for nitrate-N and other contaminants. Nitrate-N concentrations are often used to indicate possible contamination from domestic wastewater, expected from dysfunctional septic tanks, leaky sewer lines, and overflow. Guam Environmental Protection Agency (GEPA) monitors water production quality and regulates nitrate-N concentrations above 10 mg/L. Guam Waterworks Authority's (GWA) nitrate records are maintained and shared with the Water and Environmental Research Institute of the Western Pacific, University of Guam for statistical analysis. About 100 production wells are currently active and 148 wells have nitrate-N concentration records (Figure 1.1).

1.2 Water Resource Data Availability Concern

Access to data is key in making important decisions in any circumstance. In water resources management and scientific research, data sharing and access is often cumbersome, misplaced in the depths of hard drive folders, requiring several days to prepare, and could be and should be greatly improved. Water sources protection and production agencies, legislature, stake holders, and scientists demand reliable and readily available scientific information to manage the resources, make scientifically informed recommendations, and determine sustainable management strategies.

The basic needs of these water resource agencies are quick access to useful maps and on demand historic graphs to all available survey points. This product is vital to all at stake in sustaining and developing our water source. The map and survey platform must be long lasting, easy to manage and update, easy to access, interactive, and intuitive. The map should employ the features of Google Earth's interface, a map zoom widget, search, select feature point to obtain survey information. The graph that "pops up" in the interactive map page should be interactive, readable, and with "zoom" feature as well. Today's workflow environment replaces hard copy products in this digital era. Online web products, such as web map applications and graphs, follow this ongoing transition to more electronic formats. Because these products reside in an

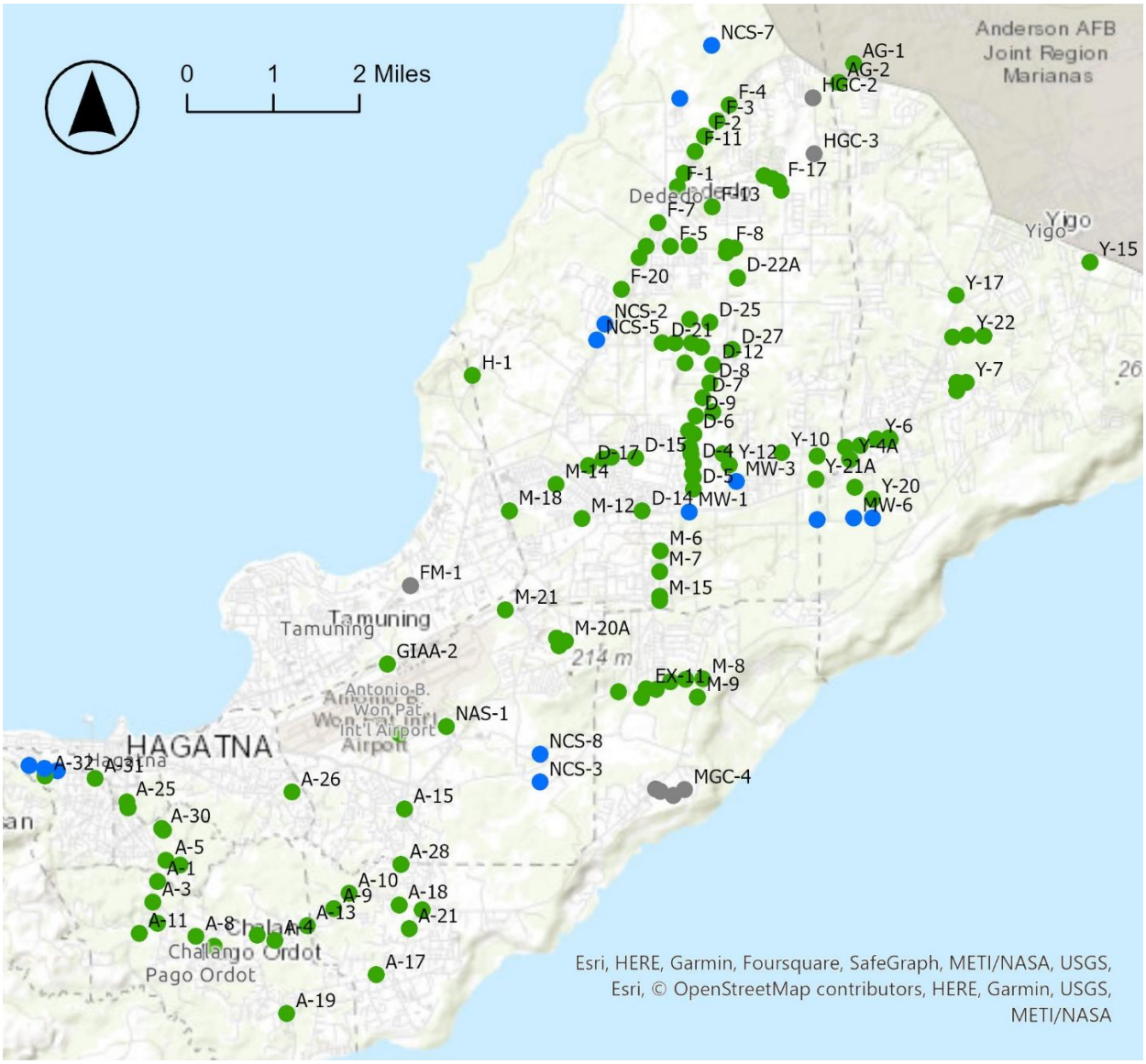


Figure 1.1. Map of Northern Guam Production Wells. The wells are colored by ownership accordingly: GWA (green), US Military (blue), private (gray).

online space, interaction between the user and the interface is at the forefront. The interactive nature of these products allows the user to print, list, draw, and select options given available "widgets." The features that allow for these interactions are well-developed and can be easily tailored to a streamlined user interface. It is imperative and integral that WERI, UOG move into acquiring this data sharing product to better serve the community and make hydrologic information available to everyone online.

1.3 Goals, Purpose, and Specific Objectives

The goal is to build MAppFx, an interactive map and graph web page interface. The map features production well nitrate concentrations in Guam. The purpose of this map and graph product is to share the information with agency partners, and anyone worldwide who is

interested in obtaining the information in an easy to use and access platform. This information is most useful for on demand reference and research. This project's specific objectives are:

1) Obtain the latest production well nitrates data and reorganize the dataset
2) Upload the data and configure web design for the map and chart interface
3) Make the nitrate map and charts available on the Guam Hydrologic Survey website
4) Provide training/workshop for the application of map and chart products

1.4 Scope

The scope of this project is delimited to Guam production wells with nitrate-N concentration records. This would include active and inactive production wells. Production well nitrate records are the collection of production well water quality test results provided by both the military and Government of Guam wells through the Guam Hydrologic Survey and Comprehensive Water Monitoring Programs (Guam P.L. 24-247). While there are other contaminants and constituents on record, nitrate-N was readily available and organized from a previous research study on wastewater (Bulaklak et al. 2021). Pump rate information are not made available in this project.

1.5 Benefits

MAppFx is easily shared with interagency partners since it is an online webpage application. Production well nitrate web map and graph will inform GEPA and GWA to determine development strategies and water resource protection. MAppFx is available on the Guam Hydrologic Survey website, under the Library Menu. The One Guam Water Resources Information Program (OGWRIP) GHS website is the premiere site and center for the island's hydrologic information. And this web map and graph product will pioneer the island's new means of data sharing, as the pilot for other map and graph of other survey points on the island.

Chapter 2

BACKGROUND AND RELATED LITERATURE

Online interactive data visualization requires select data of interest, available web JavaScript libraries for interactive mapping and graphing, and JavaScript coding for developing an intuitive user interface. This chapter covers some basic facts about the select data of interest and its relationship to water quality, which is production well nitrate-N concentration. That includes information about the data source and sampling methods known. Then, some background about the JavaScript resources to develop a MAppFx application, an online data visualization product in preparation for the development methods.

2.1 Nitrates

Nitrates in water source are the common indicator for wastewater. The nitrogen cycle lists several sources. The NGLA has several potential sources above the aquifer, from agriculture, fertilizers, legumes (*Leucaena leucocephala*, locally known as *tangan-tangan* trees), animal husbandry (pigs, chickens), feral animals, and wastewater. Nitrates in drinking water are known to cause methemoglobinemia or blue baby syndrome, and cyanosis. Mink (1982) reports 9 mg/L of nitrates in several wells, or about 2 ppm nitrate-N. Anything above 1-2 ppm nitrate-N is often concerning, suspicious of anthropogenic cause such as high concentration of wastewater sources from septic tanks, residential density of septic discharge, sewer main leaks, overflow of sewer systems (clogged lines, intense storm), and accumulation of wastewater into ponding basins or sinkholes. USEPA regulates nitrate-N MCL to 10 mg/L.

2.1.1 Related Research

McDonald (2001) and Bulaklak et al. (2021) are two in depth Guam production well data analysis of nitrates. McDonald applied linear regression and r-crit analysis to determine increasing trends. Bulaklak, repeated McDonald's work with the next 2 decades of nitrates data and additional statistical analysis to determine a ranking of wells and predictions. Bulaklak et al. also observed and identified a data plateau, revealing a change of trend from McDonald's early dataset (Bulaklak et al 2021) (see Figure 2.1). The trends as increasing, decreasing, or no significant trend are updated and mapped (Figure 2.2).

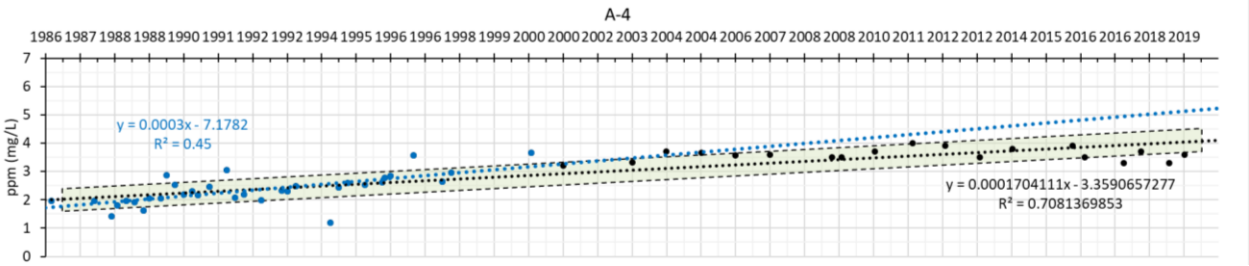


Figure 2.1 Nitrate-N history of increasing trend to flattening observed in some wells. Well A-4, early data (blue) shows an increasing trend (blue trend line). From 2000 on concentrations (black) appears to be flattening, and an overall declined rate of change (black trend line).

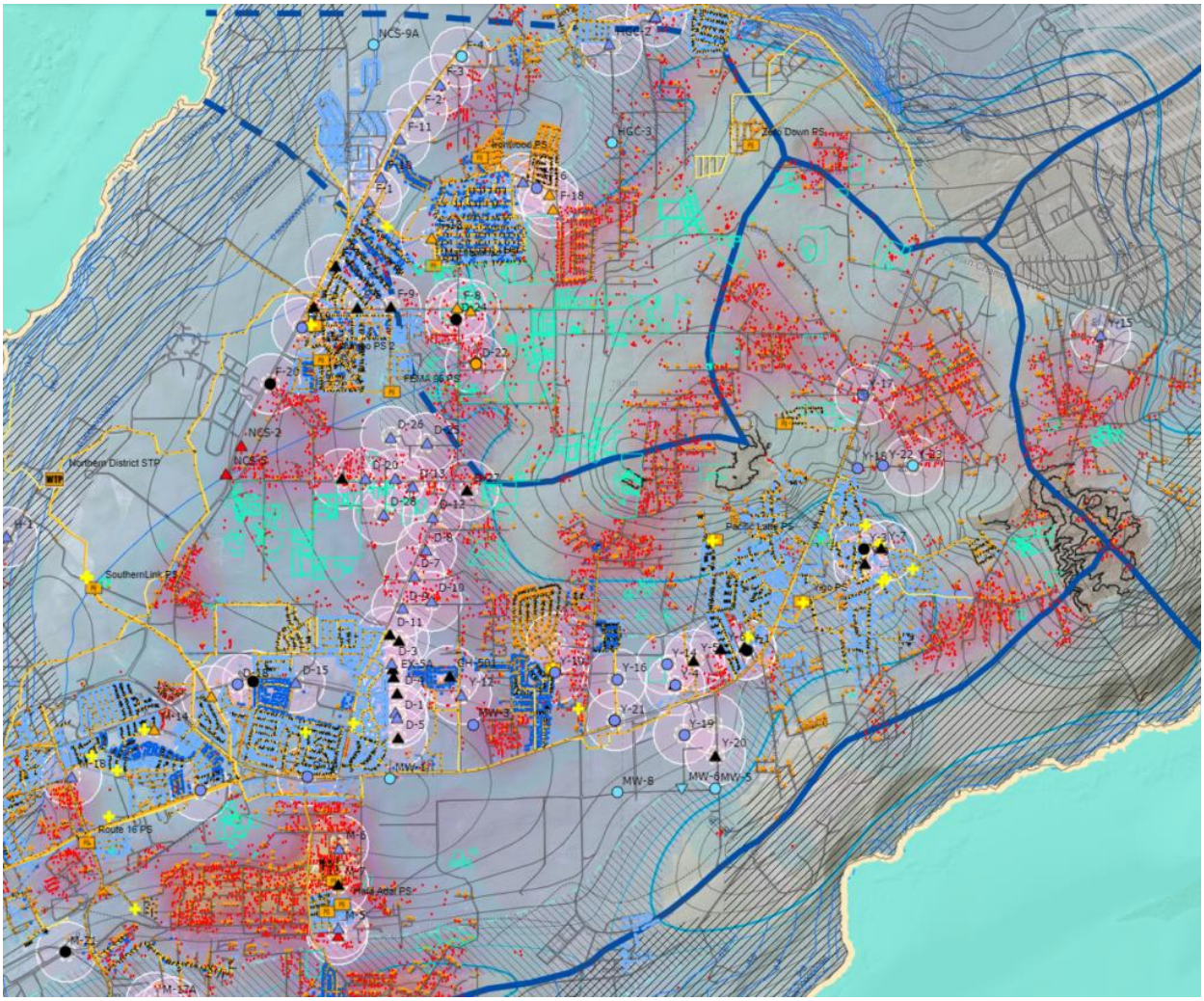


Figure 2.2 Nitrate-N analysis WERI Web MApp, online. This map is a combination of the NGLA Web MApp and WERI studies of potential nitrate-N sources and production well nitrate-N concentration. Symbology of trends are shown for production wells: increasing trends (upright triangles), decreasing (pointed-down triangles), and no significant trend (circles).

2.1.2 Nitrates Data

Guam Waterworks Authority operates about 90 to 100 production wells to maintain over 38 MGD of potable water for the island. More than 140 wells have nitrate-N records, with some records date back to the 1970s. From the 1990s onward, the nitrates are sampled from wells and tested using USEPA approved laboratory methods, recorded as nitrate-N concentration in mg/L (Cruz 2023, personal communications). From the 2000s onward, Nitrate-N concentrations are sampled and analyzed at least once a year as required by USEPA. WERI requests for nitrates data from GWA's Water Quality Laboratory to update its record sheets and analysis.

2.2 Online Data Visualization

The ever-growing presence of data has led to the advancement of data visualization tools and platforms, allowing for information to be readily and easily shared. One of the key components

behind the call to visualize data is JavaScript, which provides a website's sophisticated and interactive characteristics. The latter attribute, thanks to existing JavaScript libraries, such as AM Charts®, Leaflet®, Datawrapper®, and Plotly®, provides a streamlined experience for the user to interact with the data. One of the leading examples of these dashboard-like interfaces with map and graph components include Google Map®, Google Earth®, and stock market charts. The combination of these tools and features for user interaction is beneficial to science and research efforts. This is best achieved with a master web developer and scientist—or one with both skills. By using data visualization tools, research can neatly display big data analysis online and point to it as a reference, eliminating the need to include everything in the appendices.

To build a data visualization tool, WERI collaborated with Brigham Young University, who developed the Tethys Portal®, a collection of data visualization apps online. The big interest for WERI was to receive training from BYU to bring their data analysis of maps and graphs of production wells to an interactive online interface. In 2022, two projects were accomplished, streamflow hydrographs of the Ugum Watershed and the production well nitrate-N concentrations.

The WERI Information Management Team now develops its own customized data visualization interface, named MAppFx. MAppFx is developed as an HTML page with JavaScript controlling the dynamic user interface. The JavaScript libraries used to construct the interactive map and graph are Leaflet® and Plotly®, respectively. Both libraries come with ready-to-use and highly customizable widgets and controls. The web page is designed for intuitive use and adjustable area and data set range. The next chapter covers greater details into the organization, design, and development of MAppFx.

CHAPTER 3

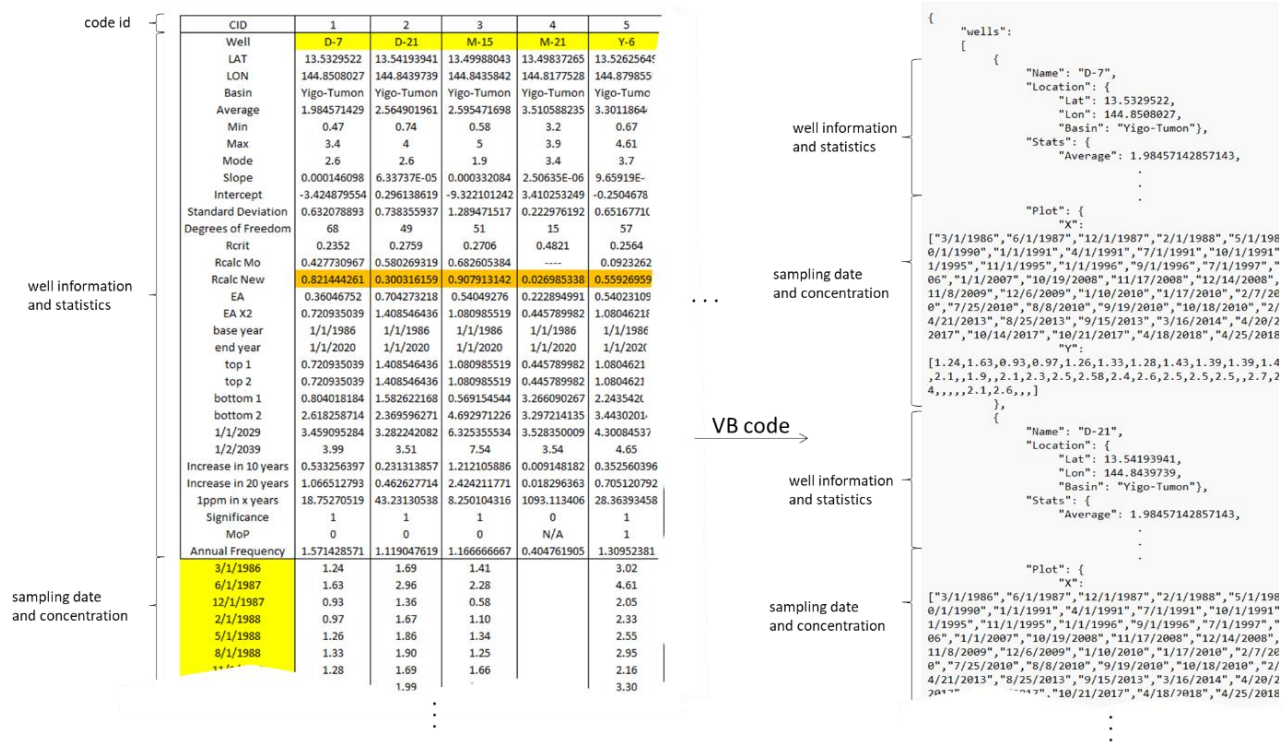
METHODOLOGY

From Chapter 1, the goal is to build MAppFx with nitrate-N data and the specific objectives, 1-3 in order, refer to the methods to build the interactive web app. Those objectives are covered in this chapter as data organization and programming concept and flow.

3.1 Data Organization

MAppFx requires a database to pinpoint the well location on a map and to identify the dataset, well information, and statistics. The data must be in a JavaScript Object Notation (JSON) format. JSON is simply a text data form that applies brackets, comas, and colons, to separate data and may use nested sets for complex grouping of information. The text notation is a way to have a simple and "lightweight" (low in bytes, thus portable) dataset. This notation is easily transferred into JavaScript variables and arrays that can be used by the JavaScript code in a Hypertext Markup Language (HTML) web page.

To create the JSON file, a Visual Basic code is written to convert an Excel spreadsheet into the JSON format. GWA often provides data in Microsoft® Excel since it is the easiest to use and share data among interagency partners. The data often undergoes statistical analysis. The WERI Information Management Team organizes the data in a specific format to JSON using Excel's Visual Basic Developer, Visual Basic code (Figure 3.1).



CID	1	2	3	4	5
Well	D-7	D-21	M-15	M-21	Y-6
LAT	13.5329522	13.54193941	13.49988043	13.49837265	13.5262564
LON	144.8508027	144.8439739	144.8435842	144.8177528	144.879855
Basin	Yigo-Tumon	Yigo-Tumon	Yigo-Tumon	Yigo-Tumon	Yigo-Tumo
Average	1.984571429	2.564901961	2.595471698	3.510588235	3.3011864
Min	0.47	0.74	0.58	3.2	0.67
Max	3.4	4	5	3.9	4.61
Mode	2.6	2.6	1.9	3.4	3.7
Slope	0.000146098	6.33737E-05	0.000332084	2.50635E-06	9.65919E-
Intercept	-3.424879554	0.296138619	-9.322101242	3.410253249	-0.2504678
Standard Deviation	0.632078893	0.738355937	1.289471517	0.222976192	0.6516771(
Degrees of Freedom	68	49	51	15	57
Rcrit	0.2352	0.2759	0.2706	0.4821	0.2564
Rcalc Mo	0.427730967	0.580269319	0.682605384	----	0.0923262
Rcalc New	0.821444261	0.300316159	0.907913142	0.026985338	0.55926959
EA	0.36046752	0.704273218	0.54049276	0.222894991	0.54023109
EA X2	0.720935039	1.408546436	1.080985519	0.445789982	1.0804621
base year	1/1/1986	1/1/1986	1/1/1986	1/1/1986	1/1/1986
end year	1/1/2020	1/1/2020	1/1/2020	1/1/2020	1/1/202(
top 1	0.720935039	1.408546436	1.080985519	0.445789982	1.0804621
top 2	0.720935039	1.408546436	1.080985519	0.445789982	1.0804621
bottom 1	0.804018184	1.582622168	0.569154544	3.266090267	2.243542(
bottom 2	2.618258714	2.369596271	4.692971226	3.297214135	3.4430201
1/1/2029	3.459095284	3.282242082	6.325355534	3.528350009	4.3008453
1/2/2039	3.99	3.51	7.54	3.54	4.65
Increase in 10 years	0.533256397	0.231313857	1.212105886	0.009148182	0.352560396
Increase in 20 years	1.066512793	0.462627714	2.424211771	0.018296363	0.705120792
1ppm in x years	18.75270519	43.23130538	8.250104316	1093.113406	28.36393458
Significance	1	1	1	0	1
MoP	0	0	0	N/A	1
Annual Frequency	1.571428571	1.119047619	1.166666667	0.404761905	1.30952381
3/1/1986	1.24	1.69	1.41		3.02
6/1/1987	1.63	2.96	2.28		4.61
12/1/1987	0.93	1.36	0.58		2.05
2/1/1988	0.97	1.67	1.10		2.33
5/1/1988	1.26	1.86	1.34		2.55
8/1/1988	1.33	1.90	1.25		2.95
	1.28	1.69	1.66		2.16
		1.99			3.30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                                .
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4/21/2013","8/25/2013","9/15/2013","3/16/2014","4/20/2
2017","10/21/2017","4/18/2018","4/25/2018
```


Figure 3.1. Excel and JSON file format. Left, Excel file format of production well nitrate-N data is converted using a Visual Basic code to a JSON format.

3.2 Programming Concept and Flow

The programming concept involves functions and methods that successfully retrieve the JSON data, and then parse the data to populate a map with production wells and plot data points (i.e., the nitrate-N concentrations) onto a time series graph.

The concept design of the user interface includes the map of production wells, where upon selection of a particular well on the map, results in a pop-up with a button that opens a side panel with information that includes the statistics and graph for the selected well. The side panel is scrollable with the option to view a list of the full calculated statistics. At the bottom of the panel, an option to open an enlarged view of the graph is positioned center, which opens a separate window of the graph, overlaying the map. Both the map and graphs are interactive.

The design prototype was drafted with Figma® (design prototype), an interface design and prototyping tool (Figure 3.2 and 3.3). The tool allows for interactive features as well. With the design prototype, MAppFx was created using HTML and JavaScript components.

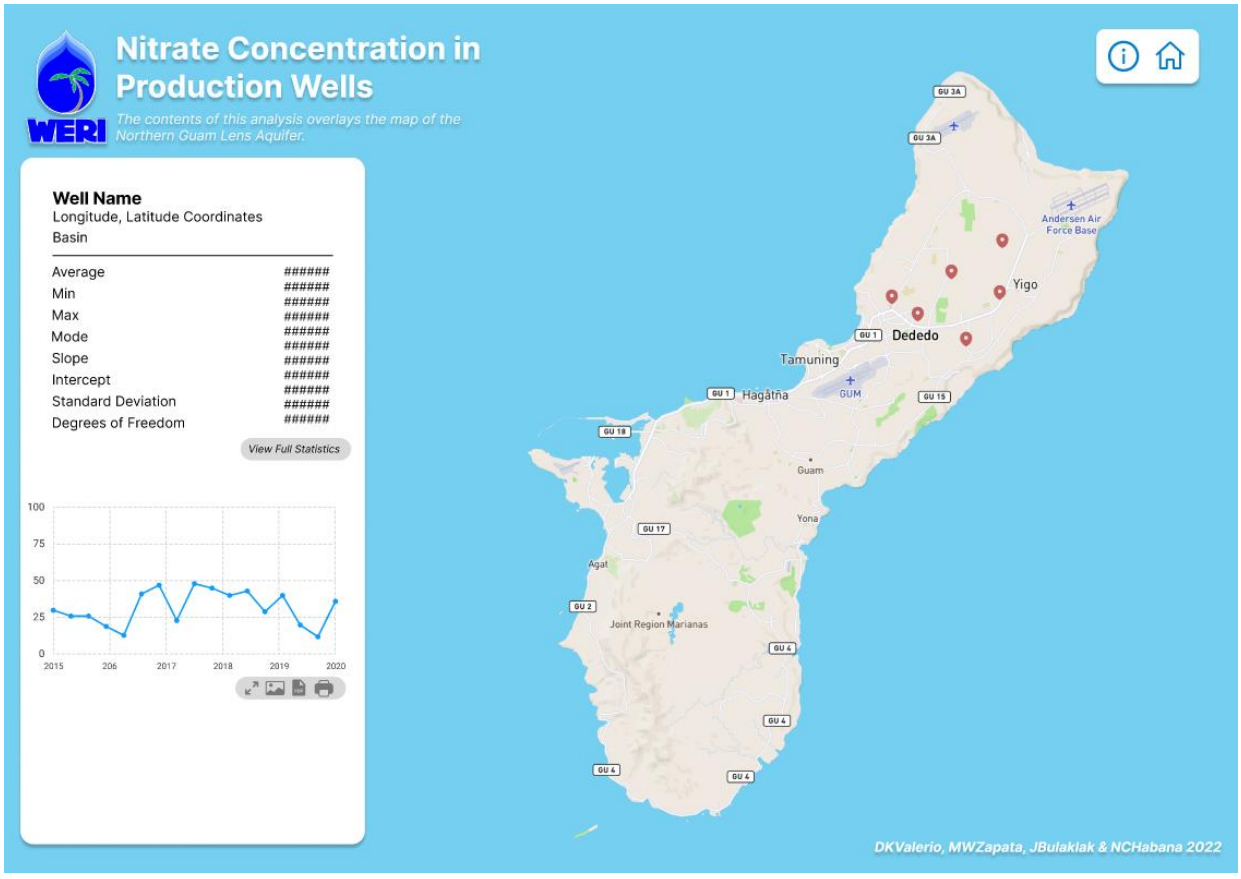

Figure 3.2. Interface designed with Figma. A well point was selected and a panel on the left appears.

The MAppFx program begins with the HTML file (Figure 3.4). The HTML document has two main sections—the head and the body. The head (<head> content </head>) section of the HTML document contains links to the hosted versions of JavaScript libraries and plugins, namely Leaflet® and Plotly®. It also links the styling of the page and frontend framework, which include the Cascading Style Sheet (CSS) and Bootstrap®. The driver JavaScript code (main.js) is also linked in this section of the HTML file.

The body (<body> content </body>) contains key features, most particularly, the map; the side panel providing a summary of statistics and a time series plot of nitrate-N levels for a selected well; and a small navigation widget housing general information about the map as well as links to the Guam Hydrologic Survey (GHS) and WERI websites.

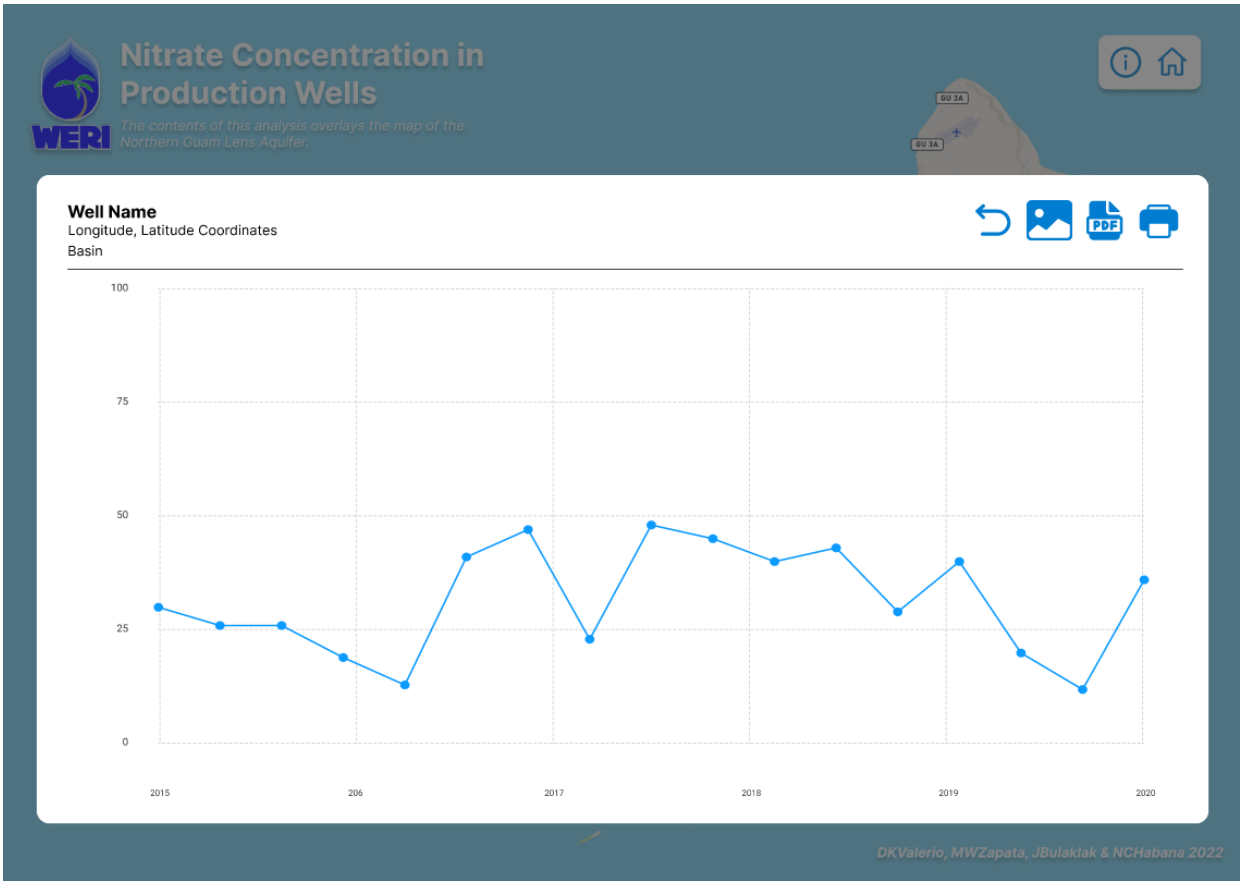

Figure 3.3. Expanding the interactive graph. The interactive panel has an expand widget, a button of below the graph with opposing diagonal arrows icon, upon selection opens the enlarged graph in front of the map.

The JavaScript code (main.js) has several program functions (Figure 3.4). It first calls upon the Leaflet® library to create the base map. Here, the map is focused on an overview of Guam and the visibility range is set for the marker names. The interactive map controls, specifically the drawing toolbar used to create shapes, are then built with Leaflet® plugins and are placed on the map. Then, a call is made to retrieve the JSON file (data file, Section 3.1) using the JavaScript Fetch Application Programming Interface (API).

Upon receiving a response, that is, a successful retrieval of the JSON file, the JSON data is processed, and the markers are then positioned on the map alongside their tooltip information popups. Following this process, the interactive features of the markers are activated using calls to the function that loads the side panel full of statistics and plots the nitrate-N concentration data on a time series graph. This leverages the Bootstrap® frontend framework, customizing the off-canvas component, (i.e., the left side panel) and pop-up modals (i.e., the window containing an enlarged view of the generated plot). This is also where the Plotly® JS library is utilized, providing the materials to plot the data point and customize the display of graphical information.

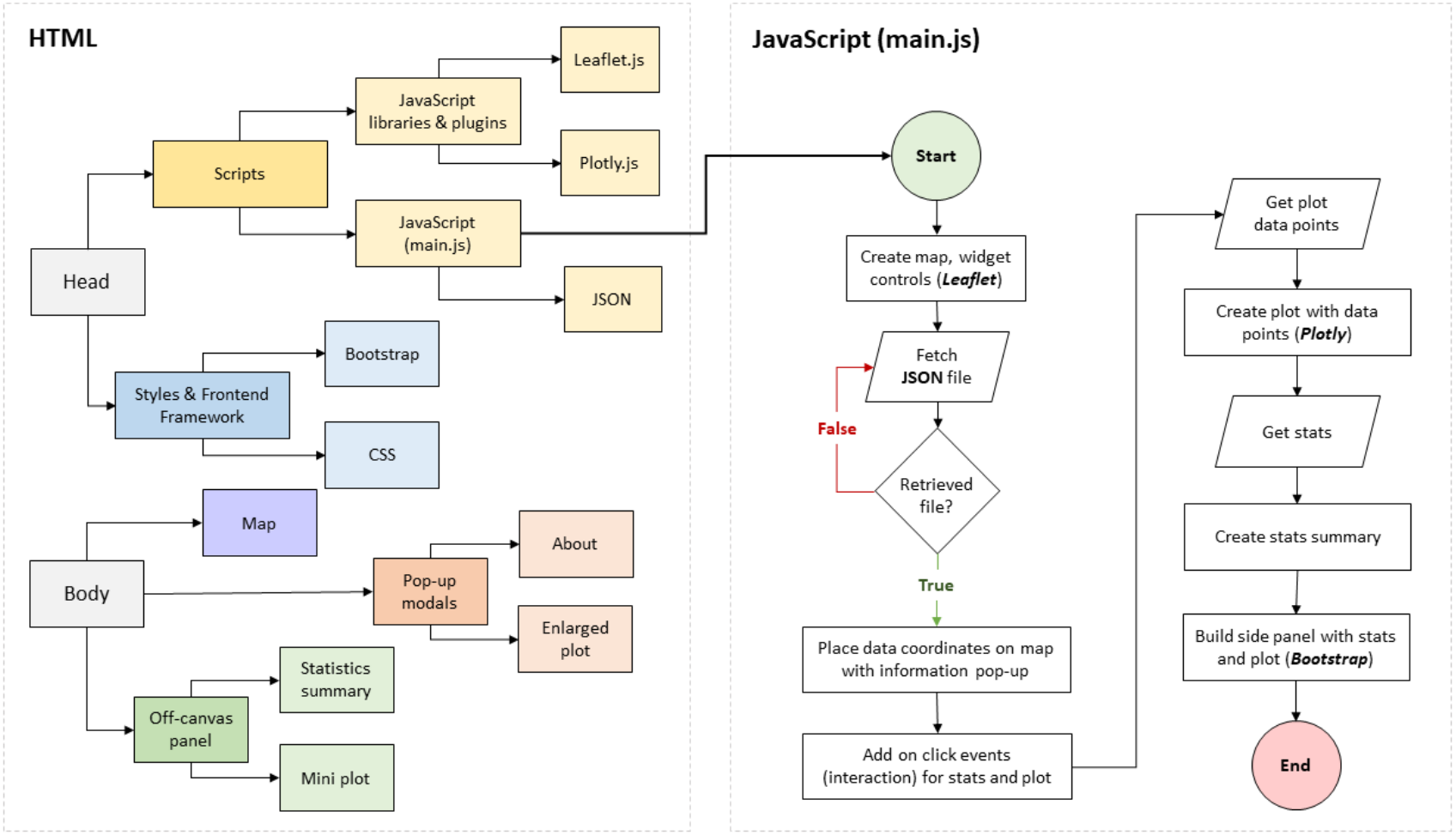

Figure 3.4. Programming flow diagram. The MAppFx package has several files: HTML document, JSON file, JavaScript code, JS libraries and plugins, CSS, and Bootstrap.

Chapter 4

RESULTS AND DISCUSSION

MAppFx, production well nitrate-N concentrations, is now available online at the Guam Hydrologic Survey (GHS) website. The GHS website (guamhydrologicsurvey.uog.edu) hosts a collection of maps, reports, database, and web applications (WERI Web MApps), and now, MAppFx. This chapter discusses the resulting online product, access, and user interface.

4.1 Production Well Nitrates Online

MAppFx as its first version (v1.0.0) is now live online. Figure 4.1 shows the finished product to date. The GHS website hosts this first product and can be accessed in the following links:

- GHS/Library: MAppFx: Production Well Nitrate-N Concentration
- Direct link to MAppFx web app

On the GHS home page, MAppFx is currently placed in the Library drop down menu as *MAppFx: NGLA Well Nitrates*. This page contains additional information of collaborations, links to design prototype, programming code, and product. As more MAppFx products are developed, site reorganization is in plan.

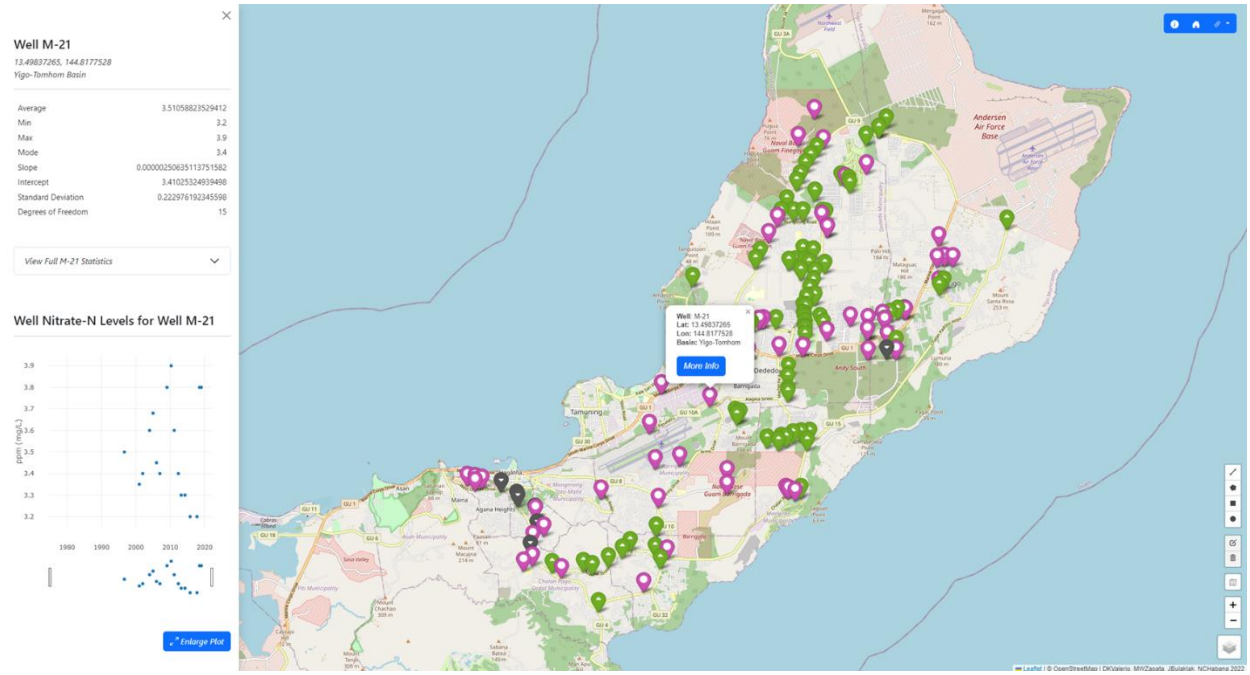

Figure 4.1. MAppFx: Production Well Nitrates, online.

4.2 User Interface

The user interface is designed to be intuitive, allowing the space for the user to easily interact with the page. Upon opening MAppFx, a map (of northern Guam) of colored point markers

appears as production well sites. Figure 4.2 shows the widget (mini application command buttons) components on the map, Bootstrap® widgets (top right) and Leaflet® library widgets (bottom right). The top right widgets, left to right, are the about (circle i), WERI website homepage (house), and WERI or GHS dropdown menu links (chain link). The bottom right widgets, top to bottom, are drawing tool cluster (line, polygon, square, and circle), layer edit and delete cluster, map reset, zoom in (+) and out (-), and layer selection (Open Street Map®; ESRI® imagery, topographic, and World Street Map; and GWA production wells layer). Not shown in the figure, top left corner is a well search tool (magnifying glass).

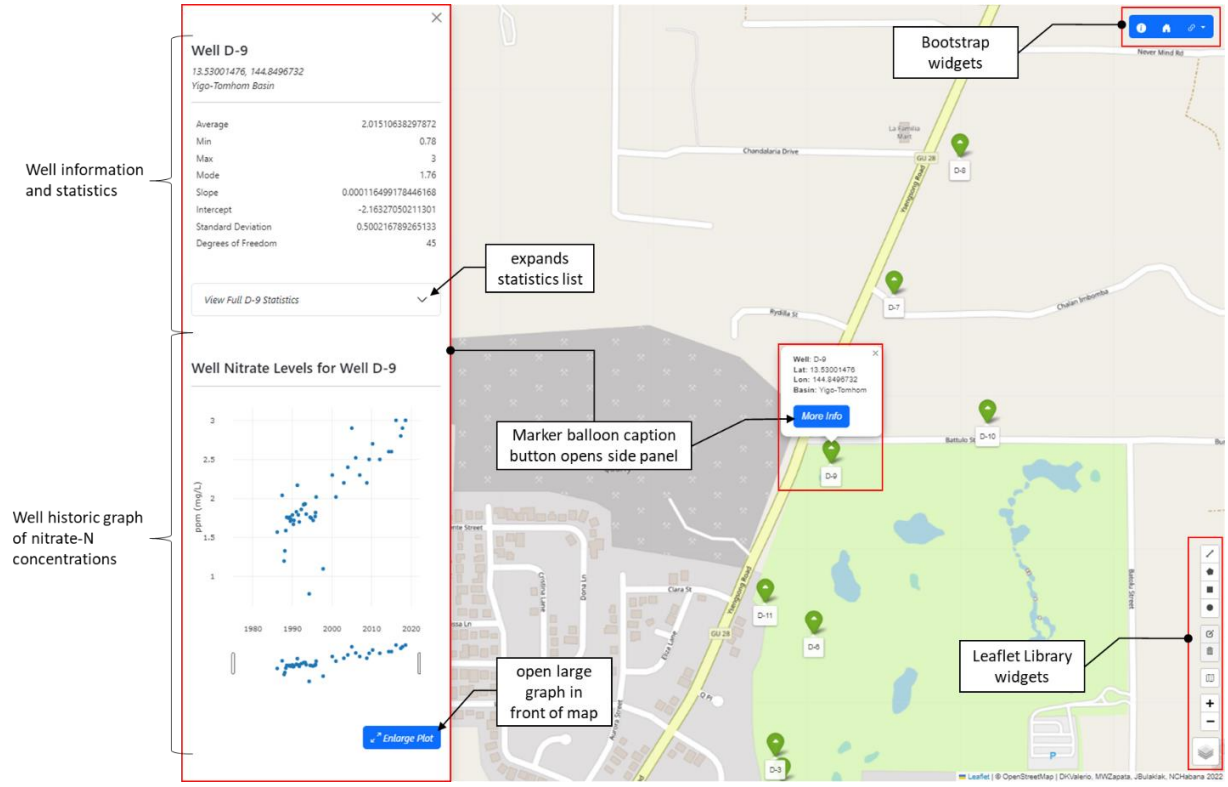

Figure 4.2. MAppFx interface.

Mouse scroll allows the user to zoom in and out of the map. Zoom in to a well of interest and well name labels appear below the markers (see Figure 4.2). Select the marker (well of interest, e.g. Well D-9) and a figure caption appears that has the well name, coordinate position, groundwater basin, and a *More Info* option (blue button). Selecting that button activates the side panel that slides from the left, over the map. This side panel lists that well's (D-9's) information and statistics, and a historic graph of nitrate-N concentrations. In the panel, boxed *View Full D-9 Statistics* with an arrowhead down marker, upon selection expands the statistics listing. As it expands, a scroll bar appears to the right of the panel to move down to the graph. The mini graph on the panel is interactive, and moving the mouse over the graph will make (Plotly®) widgets appear and mouse pointer changes to a double head arrow (↔). The graph's widgets are photo, zoom, pan, select, zoom, scale, and reset. On the graph, with the mouse pointer and left mouse button, allows the user to select within the graph points, holding the left mouse button to initiate, moving from left to right, and end (release) to select the data set focus range. The mouse scroll, with the mouse icon above the graph, applies a graph centered narrow or wide range zoom. For either action, the graph below the main chart displays the focus window, a date domain frame.

Below the side panel mini graph set is a blue button with two diagonal, outward pointing arrows, labeled *Enlarge Plot*. Upon selection of this button, it opens a larger version of the side panel graph, overlaying the web app page (Figure 4.3). As in the side panel graphs, similar icon widgets are available in the top right corner, and a row of a year span widget (e.g., with buttons labeled 1y, 5y, …) on the top left of the graph.

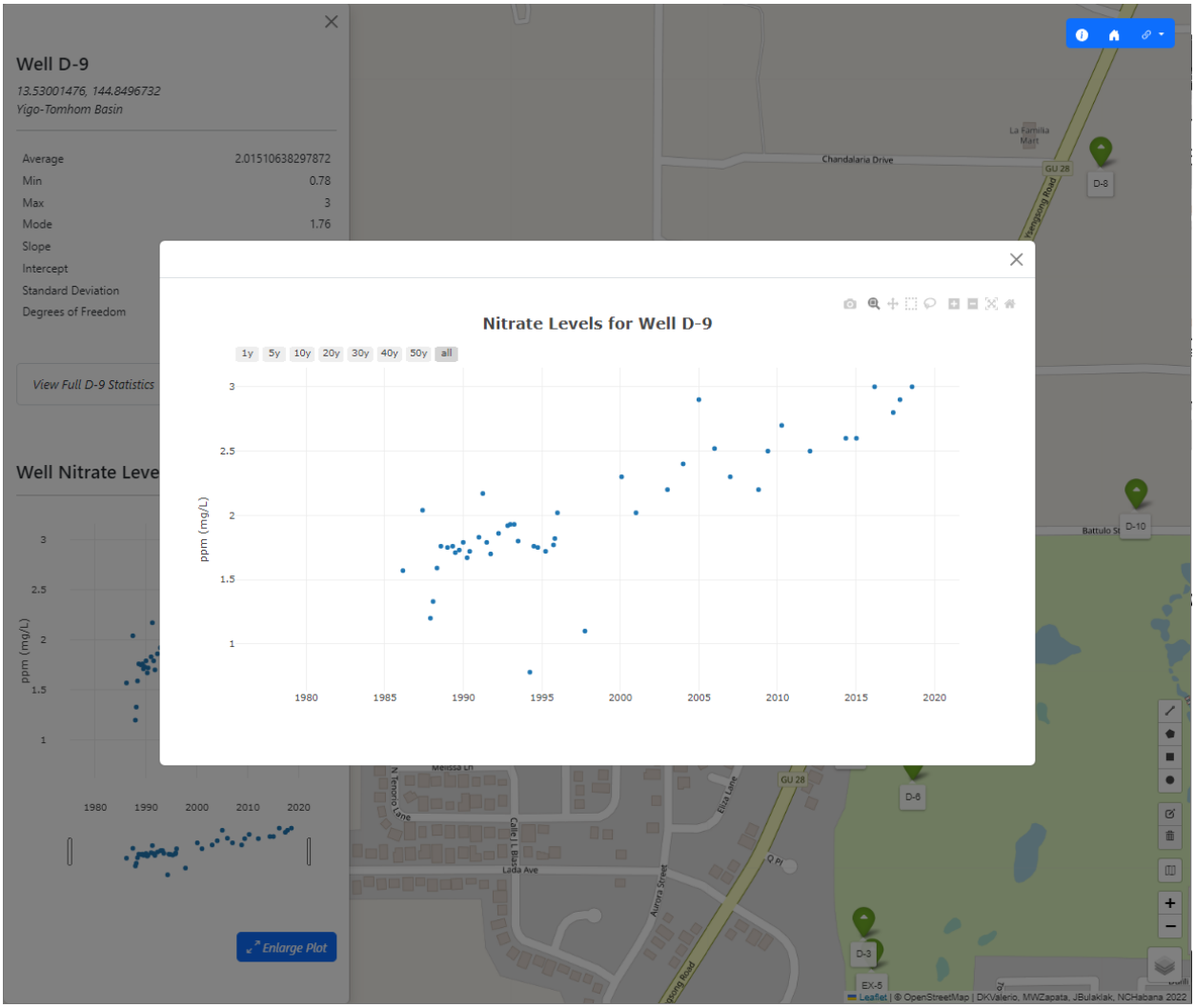

Figure 4.3. Production well D-9, nitrate-N history, large graph. Selection of *Enlarge Plot* button opens an enlarged Plotly® graph of historic nitrate-N concentration in front of the web application.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

A new data visualization product, MAppFx of Guam's production well nitrate-N concentrations, for information transfer is live online and now available worldwide. The goal, purpose, and specific objectives of this project (Chapter 1) were all accomplished. This chapter provides a summary conclusion of the product and recommendations.

5.1 Summary Conclusion

MAppFx is a data visualization product that provides a map of Guam's production wells with nitrate-N data and its graph. Both map and graphs are interactive. WERI's (UOG) information management and online development team attended BYU's Tethys Portal training, and from that, they developed the customized data visualization web application page named MAppFx. To activate the graph, the user selects a well marker of interest on the map to show the well information, nitrate-N data statistics, and historic concentrations on a graph. MAppFx is now available online on the Guam Hydrologic Survey website (see Chapter 4). The first training was provided at the WERI Water Resources Forum on Guam in November 2022. Chapter 4 also provides a user interface guide. MAppFx is designed to use JSON as its data source, which is easily produced by an Excel and Visual Basic Developer code to update the file. WERI interagency partners, such as Guam Waterworks Authority, Guam Environmental Protection Agency, NAVFAC Marianas, Legislature, Guam Department of Education, and private consultants have longed for an intuitive online data visualization product. Interagency partners may easily refer to this online product to discuss, strategize, and manage water source protection. With this major accomplishment as a technologic means of information transfer, other MAppFx production well information products are now possible and will soon be available for everyone.

5.2 Recommendations

As a new product, introduction, presentation, and training is key for interagency partners to find the usefulness of MAppFx as a database and means of information transfer. WERI has several outreach platforms to make this product known, available, and useful for many. WERI plans to present this product in 2023 in its workshop, advisory council meeting, and forum.

MAppFx is a great way to store and transfer information. It can be customized for specific data visualization interface designs and needs. WERI plans to attend more JavaScript innovations training in the future to keep up with this rapidly improving technology and to be able to expand and design intuitive data transfer services. For laboratories (GWA, GEPA, and WERI), MAppFx may be the means to store and easily access water quality data. MAppFx's easy to update JSON data file can be customized for ease of management, maintenance, and record update. For research, especially ones with large data, MAppFx will be useful as an online data reference and may eliminate the need to place them in the appendices in reports and theses. MAppFx will be the platform for data sharing and information transfer of many USGS 104-B and Guam Hydrologic Survey projects.

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