BUREAU OF RECLAMATION

Geospatial Tool for Instrumentation Inventory and Collection and Evaluation of Readings

Science and Technology Program
Research and Development Office
Final Report No. ST- ST-2020-Project ID(20020)- Report Number (ST-2021-20020-01)

@Twin Buttes Dam – Photo taken by Thomas Michalewicz, Team Member: Oklahoma Texas Area Office

U.S. Department of the Interior **September 2020**

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
07-10-2020	Research	March 2020 to September 2020

4. TITLE AND SUBTITLE
Geospatial Tool for Instrumentation Inventory and Collection and Evaluation of Readings.

5a. CONTRACT NUMBER
RY.15412020.WI20020/ 20XR0680A1

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
1541 (S&T)

6. AUTHOR(S)
Matthew J. Gappa/ Civil Engineer

5d. PROJECT NUMBER
Final Report ST-2020-Project ID(20020)-Report Number (ST-2021-20020-01)

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Bureau of Reclamation
Missouri Basin Region
U.S. Department of the Interior
2021 4th Ave. North
Billings, MT 59101

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Science and Technology Program
Research and Development Office
Bureau of Reclamation
U.S. Department of the Interior
Denver Federal Center
PO Box 25007, Denver, CO 80225-0007

10. SPONSOR/MONITOR'S ACRONYM(S)
Reclamation

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
Final Report ST-2020-Project ID(20020)-Report Number (ST-2021-20020-01)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Final Report may be downloaded from https://www.usbr.gov/research/projects/index.html

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The current inventory of dam instruments at Reclamation dams is minimal. In addition, the gathering of dam instrument readings, transmission and review by Dam instrumentation personnel is a multi-day, multi-step, manual process. Data entry is a duplication of effort which makes it ripe for making mistakes. The process is outdated and inefficient. Geographic information system (GIS) and geospatial tools as well as field applications have become invaluable resources to collect, manage, process and display information.

This research project develops a GIS solution to getting an accurate inventory of Reclamation instrumentation, allows the timely and efficient gathering, transmission, and review of dam instrument data at three pilot project dams. It is the goal that eventually geospatial tools will allow for the inventorying of instruments at Reclamation dams, will allow personnel out in the field, during routine instrument readings to enter their instrument data and populate the current Data Acquisition and Management System (DAMS) database near real time.

15. SUBJECT TERMS
Dam Instrument GIS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*
U	U	U			

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Disclaimer

Information in this report may not be used for advertising or promotional purposes. The data and findings should not be construed as an endorsement of any product or firm by the Bureau of Reclamation, Department of Interior, or Federal Government. The products evaluated in the report were evaluated for purposes specific to the Bureau of Reclamation mission. Reclamation gives no warranties or guarantees, expressed or implied, for the products evaluated in this report, including merchantability or fitness for a particular purpose.

Acknowledgements

The Science and Technology Program, Bureau of Reclamation, sponsored this research. John Nelson, Paul Martin, Erin Bell, Thomas Michalewicz, and Jennifer Ostrowsky were instrumental in the success of this research project.

Peer Review

Bureau of Reclamation
Research and Development Office
Science and Technology Program

Final Report ST-2020-Project ID (20020)- Report Number (ST-2021-20020-01)

Geospatial Tool for Instrumentation Inventory and Collection and Evaluation of Readings

JEFFREY TICKNOR
Digitally signed by JEFFREY TICKNOR
Date: 2021.10.21 14:48:15 -06'00'

Prepared by: Matthew J. Gappa
Civil Engineer, Bureau of Reclamation
(Final Report was signed and submitted by Jeffrey Ticknor, Matthew's supervisor after his departure from Reclamation)

PAUL MARTIN
Digitally signed by PAUL MARTIN
Date: 2021.10.21 13:58:51 -06'00'

Peer Review by: Paul Martin - Natural Resource Specialist, Missouri Basin Regional Office in Billings, MT on 9/2/2021

Table of Contents

Overview

The S&T proposal was approved to develop a geospatial application for instrumentation inventory, collection, and validation of readings when in the field. Before the start of the research project, none of the regions within the Bureau of Reclamation maintained a complete spatial inventory of instruments nor a way in which routine instrument readings collected in the field could be validated or transmitted in near real time. The lack of a spatial inventory required employees to review dam diagrams to locate the instruments. This is time-consuming for new employees required to take instrument readings. Once the instruments are located in the field, the collection crew would record the readings using a pen and paper. When they returned to their site, the recorded readings would be emailed/faxed to a Reclamation employee at the area office to be entered into the Data Acquisition and Management System (DAMS). If the instrument was outside the performance parameter, the crew was expected to go back and take additional readings.

Identifying the location of dam instruments, taking readings, transmission of the readings and review by dam instrumentation personnel is a multi-day, multi-step, manual process. In most cases, data entry is a duplication of effort that contributes to clerical mistakes when entered in the office. The process of manually entering data twice is outdated and inefficient. Improvements in geospatial technologies including geospatial tools and mobile data collection applications have the potential for collecting instrumentation readings while out in the field in near real time.

The main goals of this research project are to develop and demonstrate a process for getting an accurate spatial inventory of Reclamation's dam instrumentation and improve the data collection and validation process. The project will demonstrate that geospatial tools can be used to increase the efficiency of readings instruments in the field by providing faster accesses to dam instrument locations, by developing a single-entry mobile application, near real time evaluation of performance parameters, and by transmission of the data in near real time. The mobile application will allow personnel to enter readings in a mobile device while in the field, validate the data based on DAMS performance parameters, and transmit their data. The transmitted instrument reading will reside in ArcGIS Online (AGOL) and be transferred to the DAMS database based on the schedule increment.

Near real time data entry/validation allows personnel at the facility to make appropriate timely decisions particularly when dams are at elevated emergency response levels. Near real time entry of instrument readings should significantly reduce late delinquent instrumentation readings (ROIDCAT), and most importantly, it increases overall efficiency in the acquisition of instruments and validation of readings.

This project benefits Dam Safety, Emergency Management, Asset Management, and Engineering Operation and Maintenance. The project enables us to meet Reclamation's mission statement by providing a more efficient system for gathering and analyzing data, which in turn lowers operating costs and provides a positive benefits/cost savings. It improves and modernizes data collection and with the data residing in ArcGIS Online (AGOL), upper management could better identify problems, monitor change, manage and respond to events, perform forecasting, set priorities, and understand trends through the use of web apps and maps.

Objective

The objectives of this research project are to develop a spatial inventory of dam instrumentation and automate the data collection process. To meet these objectives will require the development of data schemata, automated tasks, web applications and mobile applications. The first product developed will be a mobile application for collecting the dam instrumentation inventory. This will be followed by developing some automated tasks by DAMS to input a csv file of instrument reading order and to output a csv file that contains the instrument ID and performance parameters based on specifications provided by the mobile development group. The spreadsheet will be processed by a script that generates the input parameters required by the Environmental Systems Research Institute (ESRI), Survey123 app. Once the Survey123 form is generated it will be deployed to ArcGIS Online (AGOL). The form (Mobile Application) will be used to enter, validate, and transmit instrumentation readings in near real time. When the data arrives in AGOL additional scripts will be developed to import the data into DAMS. An additional mobile application will be developed using ESRI's, Collector and Survey123 application. This mobile application will be developed to provide an alternative method for collecting data in the field. This application will rely on the DAMS database to do the instrumentation validation but provides a geospatial spatial link between the instrumentation host feature layer in AGOL and readings.

Scope of Work

The priority will be to develop a spatial inventory of dam instrumentation (latitude and longitude of each instrument). To accomplish this, a free mobile device data collection application will be used, and the required mobile collection hardware, purchased. Reclamation staff will be trained in using the mobile application and the supporting hardware to collect the instrument locations. For dams that have existing spatial inventories, a Geographic Information System (GIS) Specialist will work with the engineers to transfer data into the instrumentation database. QA/QC will be performed on the data to make sure it follows the instrumentation naming convention used by DAMS.

This will be followed by the development of two mobile data collection applications. They will serve as two options to choose from for collecting instrument readings. One application will rely on DAMS to validate the instrumentation performance parameters, while the other application will do the validation in the field.

Security Considerations

Due to security considerations (firewalls), there is currently no way within Reclamation to transmit dam instrument readings taken in the field directly into the DAMS database. Lacking this capability, we are optimistic that future technology will prove a mechanism to achieve this. In the meantime, we can upload the instrument readings based on a scheduled interval to DAMS, currently nightly.

Besides Reclamation, transferred works facilities do not have direct access to the DAMS database nor AGOL. To have access to AGOL, transferred works facilities personnel will need to be authorized by a Reclamation GIS Data Manager to have a collaborator account. Improving the AGOL authorization process and providing access to DAMS would improve the efficiency of submitting instrument readings to DAMS by transferred works facilities.

Requirements

Standardized Data Schemata

Information collected using geospatial tools represents data that is used by staff in the Instrumentation Group, by staff in the regional office, by staff in the area office, and by field personnel out at the dam. The data collection applications each have a standardized schema that matches the DAMS naming convention. This will allow the data to be related based on the dam ID and instrument name and remain consistent across Reclamation.

Standardized Workflows

The data management/collection workflows would consist of storing standardized data sets within Reclamation GIS. The data is stored in standardized hosted features to ensure data integrity with respect to security (FISMA Low), backup, and recovery. The instrumentation readings will also be transferred and stored in the DAMS database.

Recommended Hardware and Standardized Software

The Trimble R1 GNSS Receiver is the recommended Global Positioning System (GPS) receiver. The Receiver comes with an optional antenna that is recommend for improved accuracy. The R1 receiver is a compact, lightweight GNSS receiver that provides professional-grade positioning information to any connected mobile device using Bluetooth connectivity. The receiver is capable of sub meter accuracy.

ESRIS's Survey123 and Collector App for ArcGIS. Survey123 is a simple and intuitive form-centric data application solution that simplifies creating, sharing, and analyzing surveys. With Survey123, everything starts with the survey (Forms). Survey123 is designed to replace unreliable paper-based data collection with a digital solution that fits the needs of fieldworkers in diverse environments. Survey123 enables field data collection on smart devices, laptops or desktops. Well-designed surveys enable rapid data collection based on predefined questions that use advanced logic such as skipping, cascading, easy-to-fill fields, audio recording, and image capture. Survey123 is a collaborative tool that is integrated with the BORGIS's enterprise GIS solution. Collector is the ideal mobile application for capturing assets when in the field. This application will be used when capturing new instruments and selecting an instrument for Survey123.

The recommended collection devices are government issued smart phones for reserved works facilities or smart phones for transferred works facilities. The phones would then download the free Collector and Survey123 apps and transfer the readings over Wi-Fi once an authorized Reclamation employee user account has been established.

Results

The Columbia Pacific Northwest (CPN) region established a standardized instrumentation schema and mobile data application before the S&T project was selected and fully funded. CPN began using the application within their region to populate the new database. CPN's mobile device lead provided the application and instructions on how to use it to the Missouri Basin (MB) region while actively seeking participation from other regions. The field collection and transmission of the locations was done through an Apple device and transmitted using a wireless connection. For the dams that already had spatial locations, the data was inputted and updated to meet the existing standard. The data was reviewed and corrected, if necessary. This resulted in twenty-five (25) percent of the instrumentation locations being collected to date.

When starting development of the field data collection app, the mobile application development team ran into an issue when trying to add the performance parameters. Neither Collector nor Survey123 were developed to allow for dynamic input. The mobile development team met with the project lead about developing two field data collection programs, one that followed ESRI's design convention excluding the performance parameters, and the other that stretched the boundaries of Survey123 by including performance parameters. The issue was also discussed with the BORGIS development team, resulting in a similar conclusion that a program needed to be developed that could generate instrumentation performance parameters dynamically. The Project lead agreed to the development of the two-field data collection programs. The mobile application lead in CPN continued the development of the mobile field app excluding the performance parameters. The mobile application team members in MB would try to develop a program to dynamically format the data for Surevy123.

The mobile application lead had another issue with multiple instruments located at the same location but was able to address the issues and have an application ready in a couple weeks. The field app met the requirement specification excluding performance parameters. The application uses Collector to select the instrumentation and Survey123 to enter the instrument readings. The schema used by the application follows DAMS or BORGIS naming conventions to facilitate the ability to relate the data to other features. The readings are stored as one record per reading. This allows the data to be related directly to the instrumentation hosted feature layer. The application is fully functional and takes about a half hour to develop for a dam.

The other mobile application was proving more difficult and time consuming to develop. Each new instrument type required some modification to the code. The code was becoming unwieldly and difficult to maintain. This led to a discussion with the DAMS programmer about ways to improve

the existing code. The suggestion was that DAMS would output each dams unique Id, instrument name, and performance parameters in a specified csv format that could easily be processed into a Survey123 form. This method proved more efficient and standardized the way performance parameters were outputted. This drastically reduced the amount of code required to process the csv file and reduced the time required to generate a survey from multiple hours to about 1 hour. The mobile application stores the collected readings in a single record that can be linked to the dams hosted feature layer in AGOL but not the instrumentation hosted feature.

During the development of the mobile collection application, the project lead suggested that we incorporate Hydromet elevation values. This was accomplished by using a Java script that retrieved the elevation values through a web service. The Java code was integrated into both mobile collection applications to provide near real-time elevation values when the application has a connection to Wi-Fi. If a Wi-Fi connection is unavailable, the elevation value can be manually entered into the application.

The last step in the development process consisted of transferring the readings from AGOL to DAMS. This was accomplished with the help of the DAMS programmer and the BORGIS architect. The process consists of downloading a csv file of the dam's current instrument readings. A script will periodically check the download folder for new files and import them into the DAMS database. This is accomplished using a scheduled task, which executes a Python script nightly. The Python script scans each dams survey data uploaded into AGOL looking for new survey submissions nightly. If it locates a new record, it exports the data as a csv file and records the information in a status tracking table. The data is then harvested and imported into DAMS.

The results demonstrated that we were able to collect instrumentation geospatial location data in the field and import that data into a hosted feature in AGOL. The hosted feature can now be used for analysis, visualization, or used to locate instruments when in the field. The field data collection of instrument readings modernizes the antiquated pen and paper/double entry process. Not only does it modernize the process, it can be used to determine if the instrument is within its performance parameters when out in the field.

Implementation of the Geospatial Tools Reclamation-wide

If Reclamation chooses to pursue the use of the geospatial tools at each of the dams it oversees it would meet Reclamation's mission statement by providing a more efficient system of gathering and analyzing data, which in turn lowers operating costs and provides a positive benefits/cost savings. Sharing of the geospatial tools will also help in the partnering with other federal agencies.

Workload and Staffing Implications

Management and maintaining this geospatial/tabular database/tool will add workload and budget requirements for the Instrumentation Group. It is expected that at a minimum 1 GIS/Programmer specialist would be required to support this program. The GIS/Programmer could be employed by the Instrumentation Group or one of the program offices within the TSC.

Lessons Learned

Lessons learned from this research project include:

- Incorrect Instrument Performance Parameters.
- No direct ability to transmit instrument data directly into the DAMS database.
- Real time versus Near real time. Until a solution is found in which instrument data can be transmitted directly from the field into the DAMS database, evaluation and transmission of the data will take place in near real time.
- The allowing of transferred works facilities to transmit data into AGOL without first becoming a collaborator.
- The ability to inventory instruments (latitude and longitude) within a Concrete Dam.
- Imperative that Data management workflows be implemented on a Reclamation-wide scale.
- Standards for the inventorying of instruments are implemented Reclamation-wide and the inventory is stored in one location.

Team Members, Partners, Contributor, and Reviewers

Table 1.-Project Team Members

Name	Role	Mail Code
Matt Gappa	Principal Investigator	MB-2400, 406-247-7778
John Nelson	Team Member: GIS model development support	MB-4200, 406-247-7746
Paul Martin	Team Member: GIS model development support	MB-4200, 406-247-7722
Erin Bell	Team Member: GIS model development support	PNRO CPN 6609, 208-378-5285
Thomas Michalewicz	Team Member: Oklahoma Texas Area Office	TX-Michalewicz, 512-899-4166
Jennifer Ostrowsky	Team Member: Provo Area Office	PRO-399, 801-379-1160
Lee Jacobs	Contributor: Programming & design support	TSC, 86-68320
Kevin Foley	Contributor: Programming support	MB-4600
Greg Gault	Contributor: Server & design support	PNRO CPN
Deb Hall	Team Member: review	MB-2400, 406-247-7639