RECLAMATION

Managing Water in the West

Testing GPS and GIS Enabled Devices to Modernize Data Collection, and Monitoring Facility Conditions and Natural Resources

Research and Development Office
Science and Technology Program
Final Report ST-2016-9652-1

U.S. Department of the Interior
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Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

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.

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Two types of GPS-enabled mobile devices were tested in the field to see which type would be more efficient and cost-effective for Reclamation field employees to use. Cost, ease of use, and accuracy in the field were evaluated for each device, including a Trimble GeoXT 6000 series (running Trimble TerraSync software) and an Apple iPad Air 2 (running the Collector for ArcGIS application). The results found that a GPS-enabled tablet, such as the Apple iPad Air 2, is the most suitable mobile device for a majority of field data collection. The large user-friendly touch screen, the ability to attach photos to collected data, and the lower price tag make the iPad a practical investment compared to the very expensive Trimble GPS units available. To increase the accuracy of the iPad, an external GPS receiver such as the Bad Elf Surveyor, would also be recommended. Reported findings will help

modernize the way Reclamation employees collect field data for projects, such as facility condition assessments.

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Peer Reviewer: I have reviewed the assigned items/sections(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

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Acronyms and Abbreviations

AGOL – ArcGIS Online
ArcGIS – Esri's GIS software suite
ESA – Endangered Species Act
GIS – Geographical Information Systems
GNSS – Global Navigation Satellite System
GPS – Global Positioning Systems
O&M – Operations and Maintenance
S&T – Science and Technology

Main Report

Testing GPS and GIS Enabled Devices to Modernize Data Collection, and Monitoring Facility Conditions and Natural Resources

Introduction/Background

The Bureau of Reclamation owns many facilities within the Western United States, including dams, buildings, bridges, canals, laterals, etc. Some facility locations are easy to find on an aerial photo, but the location and ownership of many other facilities is unknown and the information is not stored digitally. Due to recent events, such as the canal breach in the Kennewick Irrigation District and the Reclamation canal failure incident in the Fernley, NV area which spurred the Canals in Urban Areas project, the importance of identifying facility ownership, facility condition, and facility location have become a priority. GIS has been identified as a key tool in locating and storing pertinent attributes related to Reclamation facilities.

There are several methods to obtain facility locations. The most labor intensive method is to map out locations in ArcGIS using plat drawings and legal descriptions found in Reclamation's local, historical documents. Facility locations identified in legal descriptions and in pre-built drawings are not always reliable as facilities were often built in different locations due to topography and other land issues. Legal descriptions and drawings need to be compared with aerial photography in ArcGIS to determine actual facility locations. The best available method to collect facility locations is to use GPS in the field. Not only can GPS be used to locate facilities, but it can also be used to update information about existing facility conditions. This science and technology project assesses two different methods to GPS facility location and condition management.

Objective

The objective of this project was to assess mobile devices that may be used to modernize the way facility managers inspect Reclamation facilities in the field. There are several mobile devices that can make facility inspection and condition assessment more efficient. It would be extremely useful for facility inspectors to be able to locate a Reclamation facility on a tablet or smart phone in the field, and then update the facility condition or add a new facility to the database immediately. This project identified and tested two mobile devices in the field to evaluate which device would be the most useful to inspectors.

Methods & Equipment

The two mobile devices tested were the Trimble GeoXT 6000 series (Figure 1) and the Apple iPad Air 2 (Figure 2). Specifications for each of these units are outlined in Table 1. The Trimble GeoXT 6000 series (GeoXT) is a handheld device that has an internal GNSS receiver. With a real-time accuracy of 75 centimeters and a post-processing accuracy of 50 centimeters, the GNSS receiver is considered high accuracy.

Figure 1. Trimble GeoXT 6000 Series comes with an integrated hand strap on the back for easy transport. A stylus makes tapping and typing on the touch screen more efficient.

An Apple iPad Air 2 (iPad) is a popular, handheld tablet device with an integrated GPS receiver that has a real-time accuracy of 5-8 meters.

Figure 2. Apple iPad Air 2 device outfitted with a LifeProof Fre case that is water, dirt, snow, and shock resistant. The LifeProof case also has a hand strap attached in the back for easy transport.

For portions of testing, an external GPS receiver, the Bad Elf Pro (Figure 3), was used to improve the iPad's GPS accuracy to 2-3 meters. The Bad Elf uses Bluetooth technology to sync with the iPad.

Figure 3. External GPS receiver, the Bad Elf Pro, is attached to a lanyard that you can wear around your neck. The Bad Elf must be within 10m of tablet device for Bluetooth connection to continue working.

Trimble TerraSync v5.61 (TerraSync) was used to collect GPS data on the GeoXT (Figure 4), while Trimble Pathfinder Office v5.6 software (Pathfinder) was used in the office to post-process the data collected with the GeoXT, as shown in Figure 5. The post-processed data was then viewed and edited using Esri's ArcMap software.

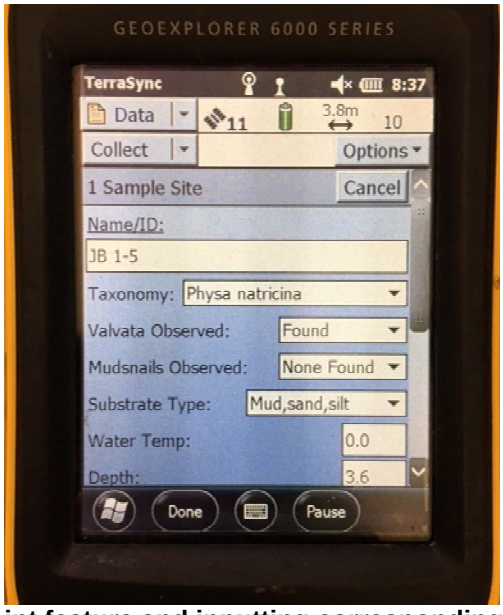

Figure 4. Adding a point feature and inputting corresponding attribute information in the data dictionary, using Trimble TerraSync v5.61 software on the GeoXT.

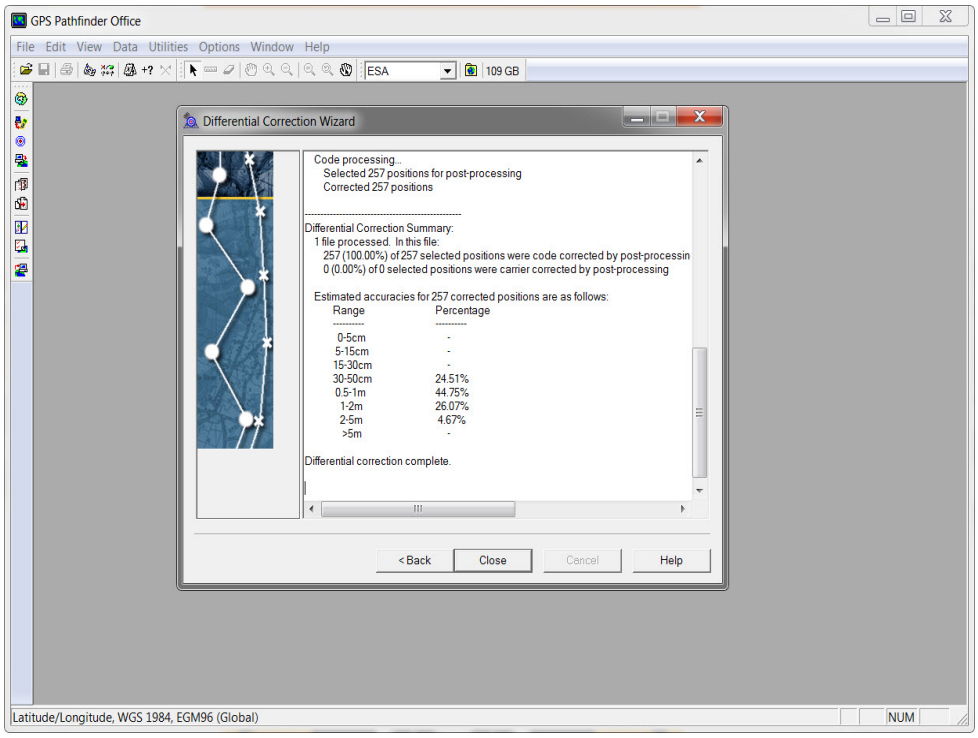

Figure 5. One step of post-processing GPS data collected with the GeoXT, is using the Differential Correction Wizard in Pathfinder Office. Differential correction enhances GPS locations by connecting to a known base station.

To collect GPS data on the iPad, the Collector for ArcGIS (Collector) application was used while Esri's ArcGIS Online (AGOL) application was used to view the GPS data collected on the iPad.

Figure 6. Adding a point feature and inputting corresponding attributes, using Esri Collector for ArcGIS on the iPad.

A data dictionary, a customized form used to collect specific attributes, was created in Pathfinder and uploaded to the GeoXT so that along with the GPS location, the necessary attributes could be recorded simultaneously using TerraSync. For the iPad, a GIS layer was published from Esri ArcMap to AGOL and added to a web map that could be used with Collector.

The method of mobile data collection is fundamentally the same no matter which subject area (ex: bridges or well locations, potential trespass sites, habitat assessments, etc.) you are collecting data for. During this S&T project, the mobile devices were tested while collecting endangered species (ESA) data. Although the specific attributes that would be collected for a facility condition assessment would be different than the attributes collected for ESA data, the capabilities needed to meet field collection demands (ability to collect attributes and capture location) are the same, and therefore the results of this ESA testing is applicable to facility mapping.

The ESA project consisted of taking gravel samples from the bottom of the Snake River in two different locations to determine presence/absence of Snake River physa snails below Minidoka Dam, Idaho. Data collected for each sample included:

- Location
- Sample Name
- Number of live Snake River physa found
- Number of Snake River physa shells found
- Depth
- Substrate
- Other notes
- Date of Collection

The Snake River physa sampling project took place over a period of four days at two different locations on the Snake River. Each day, sample locations and associated data were collected using different mobile unit combinations.

- Day 1: Points taken on both GeoXT and iPad
- Day 2: Points taken on both GeoXT and iPad, in conjunction with Bad Elf Pro
- Day 3: Points taken on GeoXT only
- Day 4: Points taken on both GeoXT and iPad, in conjunction with Bad Elf Pro

Each day, data collected on the GeoXT was downloaded, post-processed, and exported to ArcMap. The data collected using Collector on the iPad required no post-processing and no downloading because it is available online, in real-time through the Reclamation AGOL organizational account. Field notes were taken each day on how easy each device was to use, average GPS accuracy, the daily conditions under which data was collected, and if any complications arose while using the devices.

Conclusion

The three most important aspects of mobile data collection are: accuracy, efficiency (user interface or ease of use), and device costs. Realistically, the best you can ever have is two out of three of these aspects. For example, you can have a high accuracy device that is very easy to use but may be very expensive. Because most Reclamation facilities tend to be large and visible on the ground and on an aerial photo, high accuracy GPS locations are not as important as other aspects. For the task of inspecting Reclamation facilities, a device that is easy to use and affordable seem to be the most essential aspects of data collection.

Both mobile devices tested during this process were user-friendly. However, in conjunction with the GPS data collection software, the iPad (Collector) was much easier to use than the GeoXT (TerraSync). Updating a feature in Collector was hassle-free, while navigating TerraSync to find similar tools was difficult. Another user-friendly feature of Collector was the ability to attach multiple photos to a feature without requiring another piece of software to perform this function, as is required with GPS data collected using the GeoXT. Data collected on the iPad in conjunction with the Bad Elf Pro, using Collector, did not require any post-processing, while upon return from the field, data collected using TerraSync had to be uploaded to a desktop and post-processed using Pathfinder Office software.

Using information generated by each software program, the high accuracy GeoXT was the most reliably accurate device (range 50cm-1m) by far, but was also the most expensive. The accuracy of the iPad when tested in the same environment, without the Bad Elf Pro, was more inconsistent than the GeoXT (range 3m-10m). A separate test was conducted with the iPad Air 2 in conjunction with the Bad Elf Pro and the accuracy results slightly improved (range 2m-3m). See Figure 7 for a spatial comparison of mobile unit accuracies in the field.

There were pros and cons to both devices tested during this process as detailed in Table 2.

In summary:

Pros of the GeoXT unit

- Very high accuracy after post-processing (50cm-1m)
- Water resistant

Cons of the GeoXT unit

- Small touch screen (4.2”), difficult to type and hard to see in direct sunlight
- Heavy and clunky to carry around

- Poor camera resolution (5mp)
- All work is done offline, however there are other Trimble GPS units that do have built-in cellular modems available, such as the Trimble Geo 7 series
- Requires post-processing software
- Expensive ($6,500 + annual software licensing & warranty $500/year)

Pros of using an iPad

- Large touch screen (9.7”), easy to type
- Good camera resolution (8mp)
- Cellular enabled for Internet access and real-time data collection
- Offline capability in areas with poor cellular network availability
- Inexpensive ($750 + $52/month cellular network service fee)
- Free software applications, such as AGOL and Collector

Cons of using the iPad

- Poorer accuracy (3m-10m), but can be improved with the use of an external GPS receiver such as the Bad Elf Surveyor
- Issues with overheating in direct sunlight
- Difficult to meet location accuracy requirements at times
- Not water proof or water resistant and easy to drop (can purchase accessories to ruggedize, such as a waterproof Lifeproof case)

Recommendations

After weighing the pros and cons (Table 2), it is recommended for a majority of Reclamation’s field work, which includes monitoring the condition of Reclamation’s facility infrastructure, that a GPS-enabled tablet such as the Apple iPad be used along with the Esri’s Collector for ArcGIS application. The large user-friendly touch screen, the ability to attach photos to collected data, and the lower price tag make the iPad a practical investment compared to the very expensive Trimble GPS units. To increase the accuracy of the iPad, an external GPS receiver such as the Bad Elf Pro, would also be recommended. The external GPS receiver adds to the overall cost, but not enough to justify buying a Trimble GPS unit. There are certain data collecting projects that may require higher GPS accuracy, and in that scenario a high-accuracy GPS device such as the GeoXT would be an appropriate device to purchase.

Though the results of this project were fairly conclusive, there is still more work to be done in regards to facility infrastructure management. The following are recommendations for future Reclamation facility management in GIS:

- Create a Reclamation facilities core schema, or a common attribute list, for GIS data creation

- Create a Reclamation facilities data dictionary to be used for GPS field data collection if using Trimble products
- Further mobile unit testing
    - Use higher accuracy external GPS receivers in conjunction with Apple iPad Air 2 or other mobile devices
    - Use Apple iPhone
    - Use Apple iPad Air 2 in more remote field areas that require offline work

For More Information

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Tables

Table 1. Specifications of mobile units tested.

	Trimble GeoXT 6000 Series (Trimble Navigation Limited, 2011)	**Apple iPad Air 2** (Apple Inc., 2016)	**Bad Elf Pro** (Bad Elf, 2016)
Internal Storage	256 MB	64 GB	-
SD Card Storage Available	Yes (Range 2GB-512GB)	No	-
Wi-Fi Enabled	Yes	Yes	-
Cellular Enabled	No	Yes	-
Bluetooth Enabled	Yes	Yes	Yes
Screen Size	4.2”	9.7”	1.6”
Weight	2 lbs	1 lb	3.2 oz
Waterproof	No, Water resistant	No, Case available	No, Case available
Camera	5mp	8mp	-
Battery Life at Fully charged	11.5 hours	10 hours	100 hours
GPS Accuracy	Sub-meter	5-8 m	2.5m
GPS Software/App Used	Trimble TerraSync v5.61	Esri Collector for ArcGIS	-
Post-Processing Software/App Used	Trimble Pathfinder Office v5.6	-	-
Cost of Device	$6,500	$750	$299
Maintenance Cost	$500/yr software updates and equipment warranty	$52/mo cellular network bill	-

Table 2. Pros & Cons of the Trimble GeoXT 6000 Series and Apple iPad Air 2.

	Pros	**Cons**
Trimble GeoXT 6000 Series	Water resistant	Small touchscreen, 4.2”
	Accuracy 50cm-1m	Camera resolution, 5mp
		No built-in cellular modem, all work is offline
		Unit cost - $6,500
		Annual software license & warranty - $500/yr
Apple iPad Air 2	Large touchscreen, 9.7”	Water resistant with purchase of rugged case
	Camera resolution, 8mp	Accuracy 3-4m, can be improved with purchase of external GPS receiver
	Built-in cellular modem for online work	Monthly cellular fee - $52/month
	Unit cost - $750	Temperature sensitive

Figures

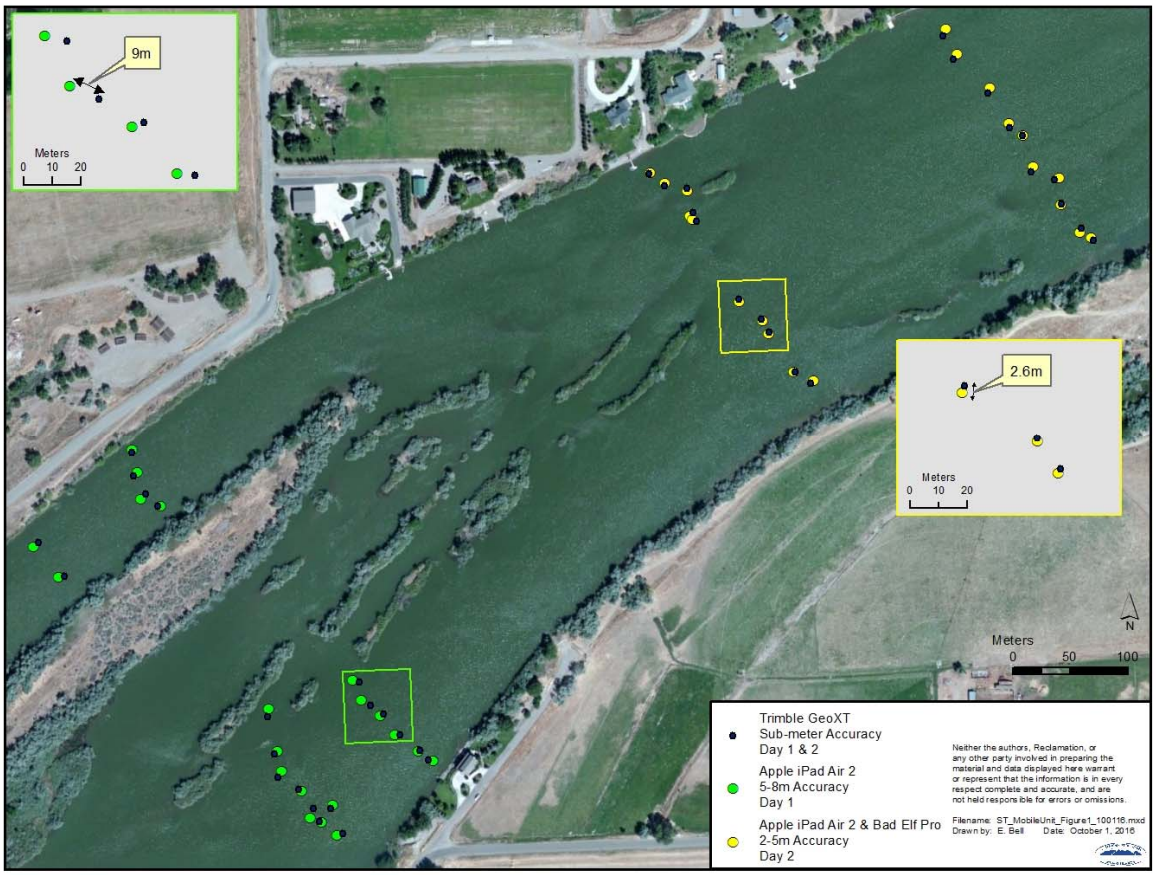

Figure 7. A map showing mobile device accuracy comparisons of the GeoXT, the iPad without the Bad Elf, and the iPad in conjunction with the Bad Elf.

References

Apple Inc. (2016). *iPad Air 2*. Retrieved from Apple: http://www.apple.com/ipad-air-2/specs/

Bad Elf. (2016). *Products*. Retrieved from Bad Elf: https://bad-elf.com/pages/products

Trimble Navigation Limited. (2011). *Geoexplorer 6000 Series GeoXT Handheld Datasheet.* Retrieved from Trimble: www.trimble.com

Data Sets that support the final report

Field Notes:
Ibr1srefpgis001\GIS\gis_data\Edit_Data\E_Bell\S&T\FieldNotes_083116.docx
Google Drive Folder, "9652 – Develop GPS/GIS enabled Tablet Applications to Modernize Resources and Monitor Facility Condition"

Trimble Data Dictionary Location:
Ibr1srefpgis001\GIS\gis_data\Z_Support_Files\Ancillary_To_All\DataDictionaries

Snail Sample Data Location:
Ibr1srefpgis001\GIS\gis_data\Final_Data\2Thematic\3ESA\DATA\Snails\Snail_Data.gdb

Esri Collector for ArcGIS: http://usbr.maps.arcgis.com/home/organization.html
Group: Collector (PN, USFO)

Keywords: Science and Technology, Mobile Device, Esri Collector for ArcGIS, Snail Sampling

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