Mobile App for Hydrocensus and Groundwater Monitoring

Report to the

Water Research Commission

by

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EXECUTIVE SUMMARY

A mobile application was developed to capture borehole information. Essentially the application will serve as a continuous hydrocensus tool collecting borehole information over time. The application is aimed at both the groundwater professional, but also aims to engage the general public to partake in data collection, generally known as citizen science.

Public domain borehole information in South Africa is generally stored in the National Groundwater Archive (NGA) and the Groundwater Resources Information Project (GRIP) database. The Limpopo GRIP database used to be regularly updated by means of a term contract set up by the Department of Water and Sanitation (DWS). The NGA is known for a backlog of borehole information that still needs to be captured and the GRIP database should ultimately also form part of the NGA. The NGA database relies on users to upload captured borehole information to the database, but this is not happening for various reasons.

In 2018, the City of Cape Town experienced its worst drought in over a century. The water crisis peaked during mid-2017 to mid-2018 where water levels hovered between 15 to 30 per cent of total dam capacity. In late 2017, the first mentions of plans for “Day Zero” were made, a shorthand reference for the day when the demand for water to meet essential needs exceeds the supply. “Day Zero” would herald the start of Level 7 water restrictions, where municipal water supplies would largely be switched off and residents would have to queue for their daily ration of water, making the City of Cape Town the first major city in the world to potentially run out of water. During the ongoing drought people resorted to groundwater as a source of water. This resulted in an estimated 30,000 boreholes being drilled in and around the Cape Town. In general, a water use license is required for water use in South Africa under the National Water Act (No. 36 of 1998). However, the water law makes provision for water-use that is termed Schedule 1 use. Schedule 1 water uses are generally low-volume, low-impact activities that are consistent with domestic use, livestock watering, recreational use, and the use of water for emergencies. This water use is permissible and does not require licensing or registration. The concern from a water management point of view is the question: Is 30,000 boreholes near each other still a low-impact activity? A further concern is that since no licensing and registration is required for Schedule 1 water-use, the positions of most of these boreholes will not be known, unless the drilling contractors and consultants provide this information to the authorities.

As people were affected more and more by the water shortage, they took to social media platforms and started reporting rainfall and to a lesser extent water levels in the areas where they lived. The data resolution obtained in certain areas were astonishing – people had a vested interest to report on the status of water as this could assist in management. The problem with social media platforms is that the data is highly distributed and is cumbersome to collate for management purposes. This response from the public sparked the development of the borehole mobile app to assist with borehole identification and monitoring to enable better water management in future.

Various development tools were considered, but AppStudio from ESRI together with ArcGIS Online were favoured for the development. These development tools support cross-platform development, which implies that only a single source code is required and the product can be deployed to various operating systems. The mobile operating systems targeted in the project was Android and iOS as these operating systems dominate the mobile arena. The database was designed to accommodate common data between the NGA and GRIP databases which are largely based on the SGDs (Standard Geosite Descriptors). All data are stored in the cloud making use of an ArcGIS Online server and the mobile app connects to this could server.

Data verification and validation is always important to ensure the integrity of any database. Each user is assigned a star-rating which ranges from 0 to 5. The purpose of the star-rating is to use it to assign a pseudo confidence to the data as all data capture will be allowed and there is no control on the quality of the data. The system specifically targets the public as part of citizen science to assist in the data capture, but they might not have the necessary background to make informed decisions when capturing the data. New or novice users will be started off on a zero star-rating but will be able to capture all the data they want. Certain users who are regarded as professionals and trustworthy will be assigned a five-star rating. These users will typically be consultants, DWS officials and all organisations working actively in the groundwater industry. The star-rating is connected to how many times the localities that a user verified was also verified by other users. The premise is that if a user is active in verifying borehole localities, chances are good that they are also capturing quality data, therefore each user are afforded the opportunity to increase their star rating.

One of the objectives of the project is to promote fair use for data as all users will have access to the captured data. For this reason, a user credit system was implemented. The system allows you to download data if you are also a contributor. The system will allocate a certain number of credits for each type of record uploaded and consume a certain number of credits for each record downloaded.

A pilot study conducted in the Potchefstroom area resulted in borehole positions nearly doubling to that of what was available on the NGA at the time. The actual impact of this is even greater when considering the majority of the boreholes obtained from the NGA were all assigned to a farm centroid, making it impossible to identify them in the field. It should however be taken into consideration that people were identified and prompted to take part in the pilot study, which will skew the results. The challenge remains to keep the public motivated to actively make use of the mobile application, since a borehole is not an interesting object to study and if there is no immediate threat of limited water supply to users, monitoring is not a priority for them. An additional factor that could cause the public losing interest is the fact that specialized measuring equipment is required to measure a water level as an example. These types of measurements are more the domain of the groundwater professional. Currently the app allows the public to verify the borehole position and capture basic information through the use of selection lists based on visual inspection of the site. In any geohydrological study it is important to perform a hydrocensus to understand the aquifer system being studied. In the majority of cases information is only collected at a single point in time during the hydrocensus. In addition, it is time consuming and costly to search for boreholes when conducting these studies. Even if no other information is verified other than the borehole position and status, it will have a significant impact on the hydrocensus process which, in turn, lead to better management practices if implemented.

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Reference Group	Affiliation
Dr Shafick Adams	Water Research Commission
Mr Yazeed Van Wyk	Water Research Commission
Dr Kevin Pietersen	University of Western Cape
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Mr Johann Ungerer	Azuro Solutions
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ACRONYMNS & ABBREVIATIONS

AGO	ArcGIS Online
API	Application Program Interface
CBM	Community Based Monitoring
DWS	Department of Water and Sanitation
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
GPS	Global Positioning System
GRIP	Groundwater Resources Information Project
GUI	Graphical User Interface
GUID	Global Unique ID
MAP	Mean Annual Precipitation
NGA	National Groundwater Archive
NGS	National Groundwater Strategy
PoPI	Protection of Personal Information
PPSR	Public Participation in Scientific Research
RAD	Rapid Application Design
REST	Representational State Transfer
SDK	Software Developers Kit
SGD	Standard Geosite Descriptor
VGI	Volunteered Geographic Information

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Public domain borehole information in South Africa is generally stored in the National Groundwater Archive (NGA) and the Groundwater Resources Information Project (GRIP) database of which both are centralized databases. The Limpopo GRIP database used to be regularly updated by means of a term contract set up by the Department of Water and Sanitation (DWS). The NGA is known for a backlog of borehole information that still needs to be captured and the GRIP database should ultimately also form part of this database.

The NGA database relies on users to upload captured borehole information to the database, but this is not happening for various reasons. The flow of data for the current situation is depicted in Figure 1, where the partially filled arrows refer to the partial transfer of data. The partial transfer of data between the NGA and GRIP databases relates to the reluctance of users to transfer data for the following reasons:

- The GRIP users and administrators want to keep the GRIP database separate and don't want merging of data with the NGA since they perceive the NGA data to be substandard.
- Third parties are reluctant to upload data, since data has monetary value and if a person has a dataset which someone else does not, it is to that person's advantage.

The partial data transfer between the NGA and the users is mainly due to system and institutional constraints from the DWS. System constraints refer to the capability of the system to automatically send all query results to the users. Chemistry related queries are performed by a person rather than the system and users don't always get a response when querying chemistry data. Institutional constraints refer to backlogs that exist due to not having enough capacity to capture data.

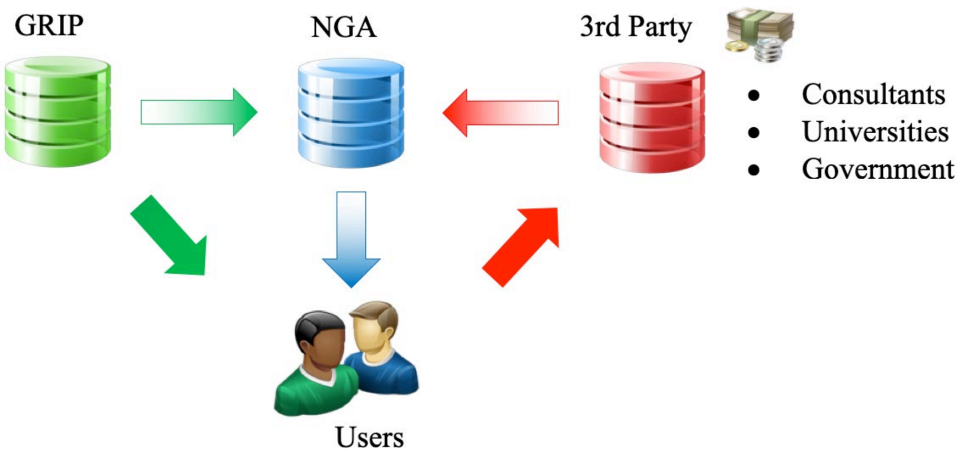

Figure 1: Current flow of data between entities

The combined borehole distribution of the NGA and GRIP databases in 2019 is presented in Figure 2.

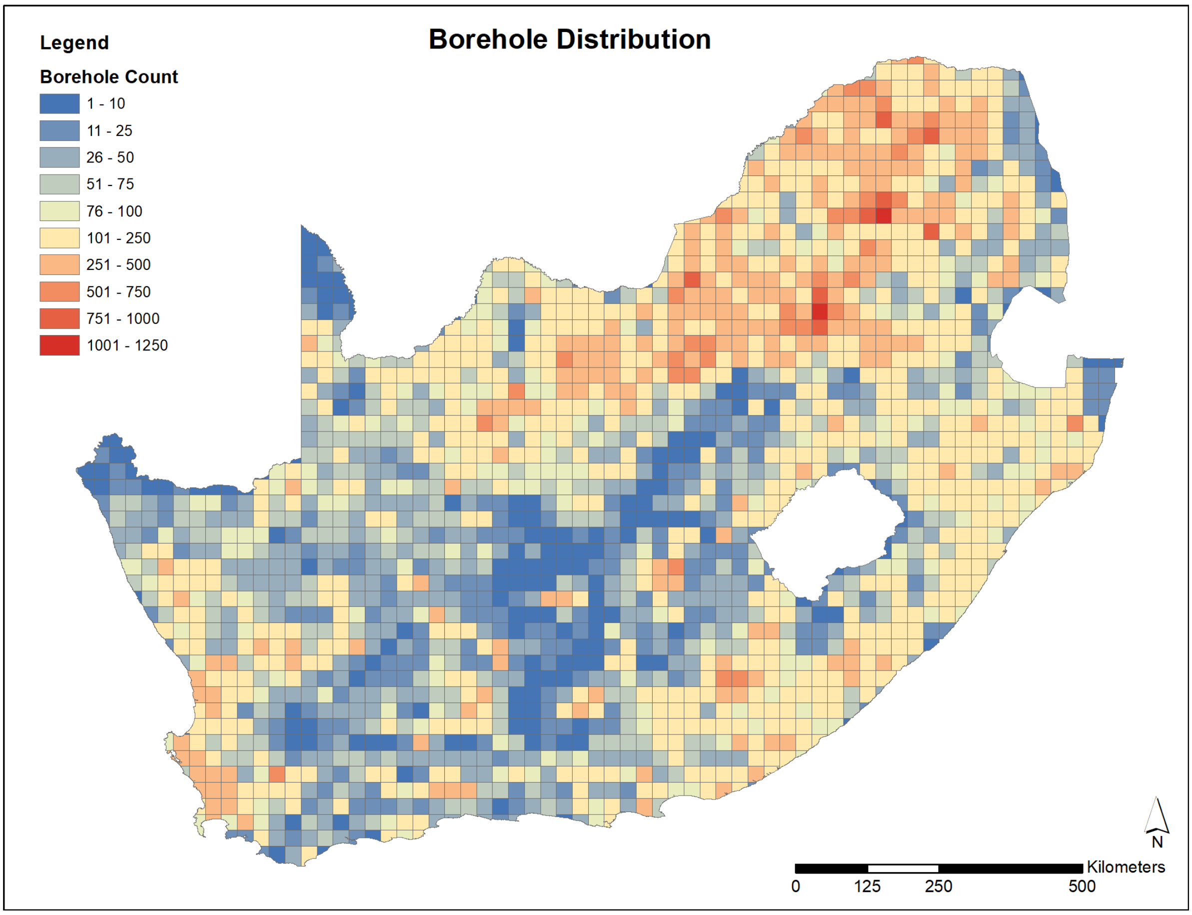

Figure 2: Borehole distribution of the NGA and GRIP databases (WRC, 2019)

1.2 CITIZEN SCIENCE

Citizen science is defined by the Oxford dictionary as the collection and analysis of data relating to the natural world by members of the public, typically as part of a collaborative project with professional scientists. Other aliases for "citizen science" include "amateur science", "crowd sourced science", "volunteer monitoring" and "public participation in scientific research" (SciStarter, 2019).

A "science by the people", citizen science is described by Bonney (2016) as the participation of the public in scientific research as well as a means of promoting public understanding of science. This recent definition should not negate the long history of collaborations between laypersons and professionals. Astronomy and ornithology are typical fields where amateur scientists and enthusiasts have assisted in tracking movement patterns as well as identifying unknown phenomena.

Presently, smartphones have expedited the sharing of information across the globe. They have empowered the citizen scientist with the sophistication of collecting data in various dimensions on a single device. These include:

- the audio-visual dimension through the capture of audio, images, and video
- the temporal dimension through time stamps and time-lapsed imagery, and
- the spatial dimension through georeferenced media using a global positioning system (GPS).

There are various means of conducting citizen science. Volunteered Geographic Information (VGI) is one such concept bearing reference in the collection and sharing of environmental data.

Significant growth of the citizen science projects has been recorded over the last decade (Figure 3) as indicated by the (SciStarter, 2019) repository, which keeps track of citizen science projects. The field of citizen science is largely decentralized, which makes the tracking of these projects difficult (Irwin, 2018). Some academics fear that the public is getting fatigued by all the options and noted that participation in some projects has declined (Irwin, 2018).

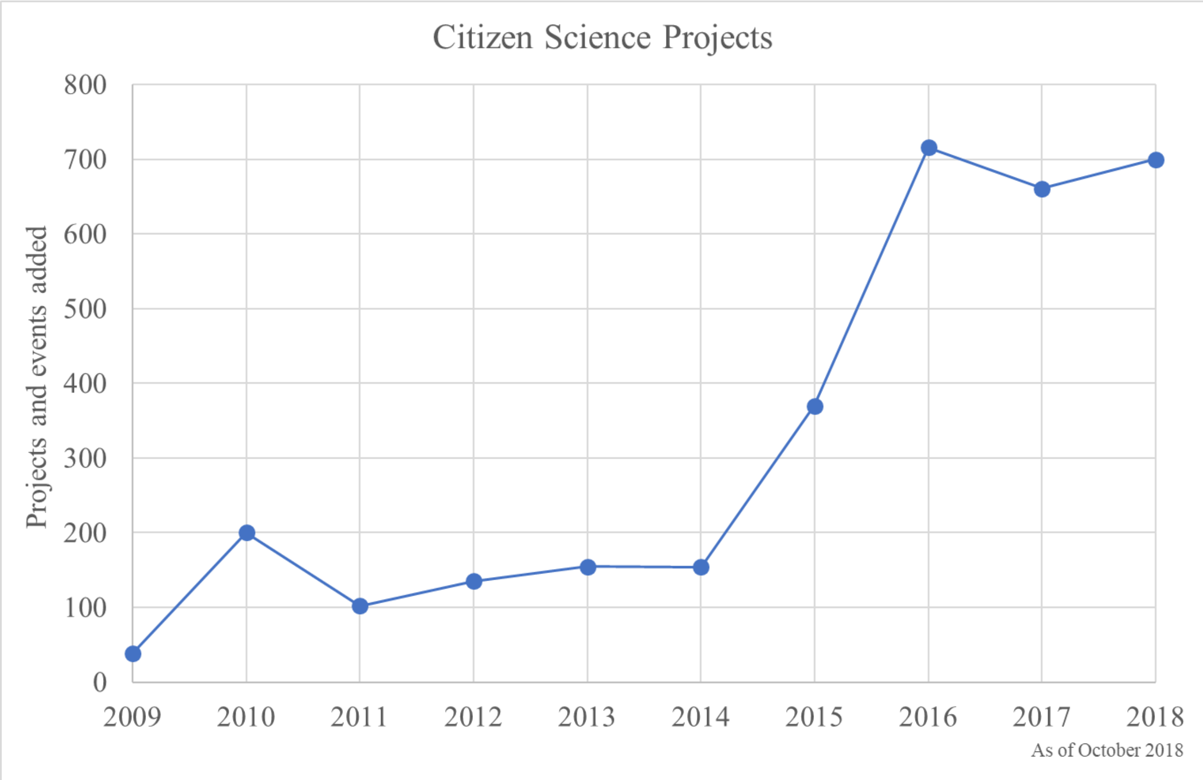

Figure 3: growth in citizen science projects (Garcia-Soto et al., 2018)

1.3 SIGNIFICANCE OF RESEARCH

The project engages citizen science in the collection and sharing of borehole data. Consequently, this research intends to contribute meaningfully to those outcomes.

The National Groundwater Strategy (NGS) has highlighted several challenges related to groundwater data. Among these the inaccessibility and decentralisation of private data and the harmonisation of public and private databases (DWS, 2016). Developing an online borehole database where users can enter or receive information in real time provides an alternative to the centrality, and inefficiencies, of the established databases. It will allow users to actively participate in information sharing of borehole information, giving them greater involvement as groundwater users. Also, the accessibility to remote areas is increased as the database operates on mobile devices.

Additionally, the development of an online borehole database enhances the involvement of citizens and professionals (water pump operators, geohydrologists, engineers) by allowing them to enter their logging information on site in a cloud-based DBMS. This reduces the steps of moving information between mediums and possible losses in time or information arising. Similarly, the need to keep records on site is vastly reduced as the information is stored as it is entered to the database.

The engagement of citizens in groundwater data collection and monitoring will assist in addressing the challenge of water resource management. Increasing the number sites observed, an improved assessment of groundwater can be undertaken supporting decision-making regarding sustainability of the resource.

CHAPTER 2: CITIZEN SCIENCE

2.1 BACKGROUND

As described in the introduction, citizen science is the voluntary involvement of ordinary people in science. Woolley et al. (2016) describe it as an all-encompassing term for activities where the public is involved in science. A lexicon of interchangeable and associated terms has emerged. Community science, crowdsourcing, citizen observatories, public participation in scientific research (PPSR) and volunteer-based monitoring are synonymous with citizen science; while civic science, volunteered geographic monitoring, community-based and volunteer biological monitoring are esoteric variations of the term (Muller, 2018; Njue *et al*., 2019).

Community based monitoring (CBM) is a method that pursues, and responds to, communal issues through the collaborative efforts of affected citizens government, academia, industry, and local organizations (Conrad & Hilchey, 2011). Civic science engages a cultural aspect to citizen science wherein knowledge unattainable from traditional scientific methods is possessed by citizens (Potshin & Haines-Young, 2006). Volunteered Geographic Information (VGI) describes the creation and sharing of geographic information by private citizen's "user generated content" (Goodchild, 2007). VGI is of particular interest as it related to map-based component of this study and is considered in the approaches of citizen science section.

The public's interest and participation in scientific matters, gathering and sharing their findings, plays in crucial role in the scientific process. The citizen scientist is more of an independent contributor in this regard, unlike the conventional scientist who is responsible for the planning, analysis, and interpretation of the results of a research study (Muller, 2018). However, there are variations to the extent of citizen contributions. Also, independent contributions of citizen scientists should not be twisted with exploitation.

In a retort to Cooper et al. (2007), Lakshminarayanan (2007) argues for a line to be drawn between using citizens to do science and partnerships with citizens in doing science. He explains that the common practice of field collectors (which tend to be laypersons) gathering data for the benefit of scientists to produce papers cannot be called "citizen science". Rather the actual participation and involvement of citizens, whose contributions should be held in equal regard to those of professional scientists, is citizen science in its truest form. Pocock et al. (2014) maintain that citizen engagement in the scientific process gives the layperson a sense of ownership in contributing to the process while bridging gap of understanding between professionals and their intended audiences. As such, the activity of citizen science should be collaborative in its conduct and deliver outcomes to the benefit of all involved. The aspects of participation, engagement and involvement overlap in this endeavour as presented in Figure 4.

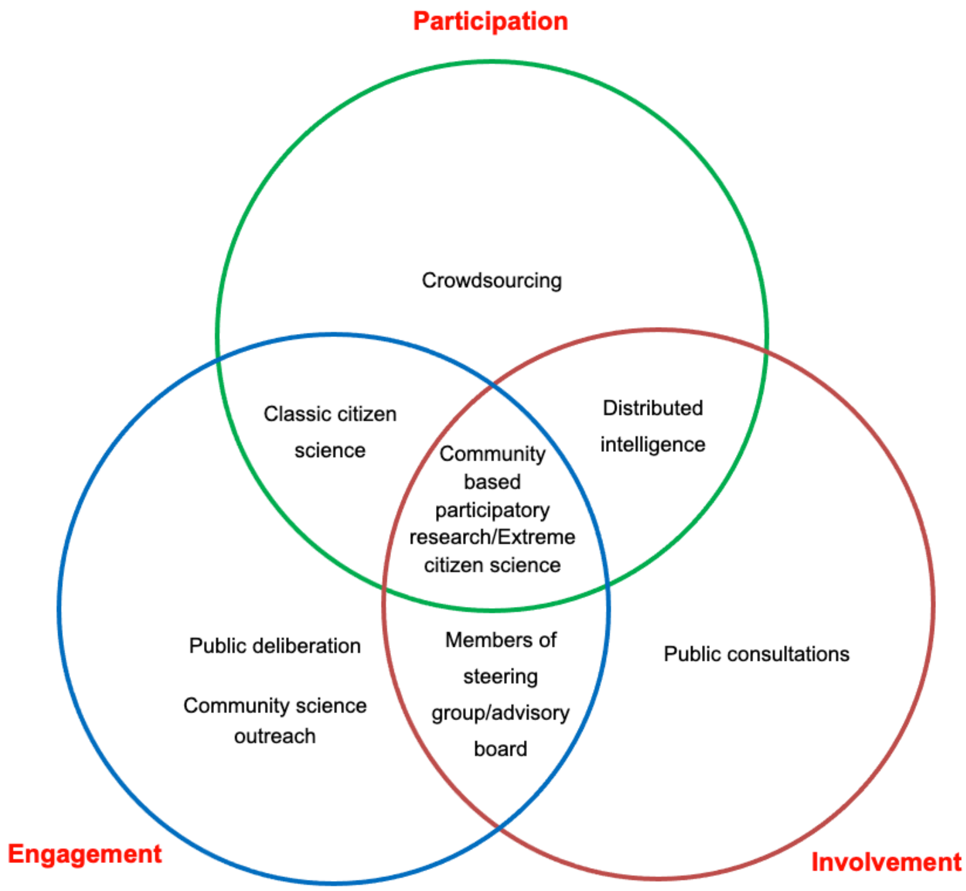

Figure 4: Overlap in engagement, involvement and participation (Woolley, 2016)

The *Ten Principles of Citizen Science* described by Robinson *et al*. (2018) highlight that a consensus is followed in good practice of citizen science. They state citizen science projects should have active participation of citizens (single or multi-stage), tangible scientific outcomes, benefit sharing between scientists and citizens, bias and limitation regulation, accessible information, acknowledgment of citizen contributions as well as legal and ethical considerations of their endeavour.

2.2 THE SMARTPHONE ERA

Some of the first citizen science projects started with bird counts in the early twentieth century. (Irwin, 2018). The phrase 'citizen science' itself was coined in the mid-1990s. Alan Irwin, a sociologist, defined it both as "science which assists the needs and concerns of citizens" and as "a form of science developed and enacted by the citizens themselves" (Irwin, 2018). From Irwin's definitions the citizens should have vested interest in the relevant project.

With the advent of mobile communication technologies such as smartphones, citizen science has become increasingly popular. Apple opened the door to this disruptive technology at the time in 2007, with the launch of the iPhone. Consumers and scientists alike, embraced this new technology and today a world without smartphones is unimaginable. The worlds of scientists and citizen science are now converging, with scientists harnessing the power of citizen science with newer and smarter technologies (Stoop, 2019).

The fact that a smartphone can take a photo and associate a Global Positioning System (GPS) coordinate and a time stamp with it allows for the collection of both spatial and temporal data, which prove invaluable in many scientific fields especially in the environmental sciences. Current day smartphones phones have an array of on-board sensors that can be used in various applications. Newer Japanese models are even fitted with radiation detection sensor (Stoop, 2019) Scientist are continuously developing new techniques to harness the power of the on-board sensors.

The integration of mobile devices, wireless internet access and GPS has introduced mobile GIS (ESRI, 2007). Mobile GIS technology extends GIS beyond the office and allows organisations to make accurate, real-time business decisions and collaborate in both field and office environments. Mobile GIS enables you to decrease task redundancy and keep data current. Benefits of mobile GIS include:

- Improves efficiency and accuracy of field operations
- Provides rapid data collection and seamless data integration
- Replaces paper-based workflows
- Helps you make timely and informed decision

Mobile GIS rely on the GPS functionality of the mobile device in question and is provided through satellites, therefore a GPS coordinate can be obtained from the device in the absence of a cellular or data network. Data transfer between the device and an online database can only take place if a data network is available which will generally be the cellular network. In areas where no cellular network is available, it is required that the mobile device can cache the captured information and upload to the online database once a data connection is re-established.

The technology presented by mobile GIS provides a range of benefits. These include the replacement of paper-based work environments and faster data collection. These in turn improve the accuracy and effectiveness of field operations and allow for informed decision making in real time.

Cellular networks are commonly used for mobile devices and tend to be out of range while doing remote field work. Mobile GIS enables GPS coordinates to be accessed from a device without the presence of an internet connection. The data collected on the device without a network connection can also be cached and transferred to the online database once a network connection is available.

VGI is the product of the “Web 2.0” phenomenon, a concept introduced in 2006 to define the advancement and convergence of application, technology, and socialisation streams in web development (Vossen & Hagemann, 2007). Through VGI, many private citizens have been involved in the creation of geographic information, i.e. anyone, anywhere with an internet connection can provide a description of a location and anyone can edit, review, and monitor this information for verification and relevance (Goodchild, 2007). This evolution has enabled unique ways to engage the public, share information and global observations.

Platform based VGI such as Google Maps and Google Earth have created sharing communities with access to spatial data that would alternatively been available to governments and professionals only (Verplanke *et al*., 2016). Several factors have enabled this phenomenon to thrive. Verplanke *et al*. (2016) highlight the cheaper technologies and mobile data exchanges, more user-friendly interfaces, and increased internet access in developing countries as some of the reasons for this. The avenues available for collecting VGI have also been enhanced through the tools provided by mobile GIS.

Concerns regarding the use of technology in citizen science projects have also been raised. Not all groups have access to this type of technology and therefore are excluded. The steadily increasing number of smartphone apps can also prove overwhelming for users unfamiliar with these tools (Garcia-Soto *et al.*, 2017).

2.3 SUITABILITY AND SUCCESS FACTORS

Both the suitability of the project and success factors should be considered when embarking on a citizen science project. Six broad areas to review the suitability is presented in Figure 5 and the associated questions to be answered for each of these areas is given in Table 1.

In addition to the six broad areas defined, a decision framework exists (Pocock *et al.*, 2014) to evaluate each considered project in terms of its potential to succeed as a citizen science project. The decision framework considers basic questions like online surveys, safety in making observations, are sensors required and the spatial scale of the project. Once these questions have been answered, the decision framework categorizes the project based on spatial and temporal requirements. Lastly, for each type of category, questions regarding access to sites, site types and protocols result in the final recommendation regarding potential of the project.

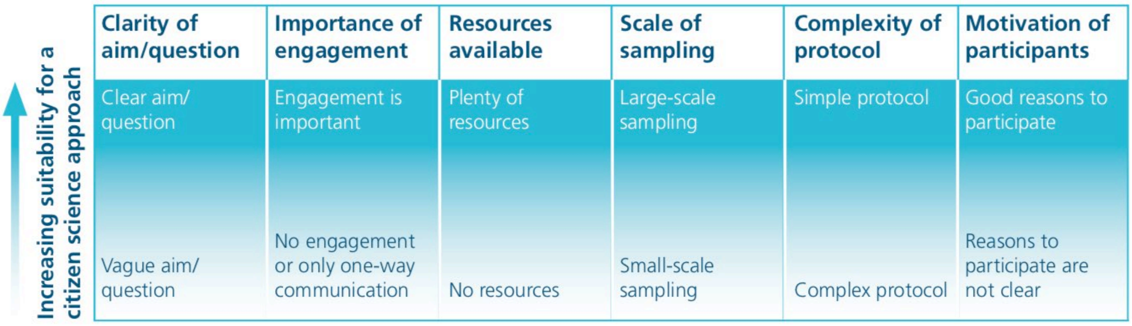

Figure 5: Suitability criteria for a citizen science project (Source: Pocock et al., 2014)

Table 1: Questions asked with respect to suitability criteria (Source: Pocock et al., 2014)

Suitability Criteria	Typical question to be answered
Clarity of the aim	Do you have a precise and clearly- defined aim for your citizen science project?
Importance of engagement	Can you extend your engagement activity into meaningful and relevant citizen science, or should you simply undertake excellent engagement for its own sake?
Resources available	Do you have sufficient resources available to ensure you can support your volunteers for the entirety of the project?
Scale of sampling	Do you need many people (or volunteer time or commitment) to achieve your aims?
Complexity of the protocol	Is your protocol practical for volunteer involvement? Are you expecting too much from the volunteers?
Motivations of participants	Does your project resonate with potential volunteers, and are there clear and appropriate triggers for people to make records?

Six success factors for citizen science were identified by Pocock *et al.* (2014) and are depicted in Figure 6. Although the aforementioned work was focused on coastal and ocean research, these principles are generic and applicable to all citizen science efforts. Most of these factors are interrelated at some level as illustrated in the short discussion that follows.

Figure 6: Factors of success in citizen science (Source: Garcia-Soto et al., 2018)

First and foremost, clear goals should be set for the project. Keep the project focussed and avoid the "big bang" approach, where it is attempted to collect all possible types of data just because it can be done. This in turn relates to the engagement of citizens – if the collection process is long and tedious, people will lose interest.

Reliable data is a prerequisite for an improved database and an improved database will contribute to the science through proper analysis of the acquired data. Data quality and verification underpin reliable data and most data quality problems can be addressed if they are properly anticipated. The simplest measure is training and communication to the network of people participating in the data collection.

2.4 CITIZEN SCIENCE IN HYDROCENSUS

In conducting a hydrocensus studies, the role of the public, in particular affected communities, is essential. It provides several advantages to both experts and the community. The Department of Water Affairs and Forestry (DWAF, 2004b) list some of these as:

- Improved awareness of groundwater contamination
- Using water information to empower communities
- The potential to inspire locally generated corrective actions, where groundwater is, or could be, polluted
- Exposing technical experts to community facilitation in providing inputs to water related projects and activities.

In terms of collecting borehole information, active citizen participation allows for an effective and efficient borehole data collection and dissemination. As most boreholes are not registered and are privately owned, participation from the public allows for a truly reflective hydrocensus to occur.

One of the major challenges in locating historic boreholes recorded on the national groundwater archive (NGA) is the fact that although military development of the GPS started in the late 1950s, GPS technology only became available to the public in the 1990s. The borehole positions captured in the NGA before GPS availability, was done by assigning the borehole to the relevant farm or plot centroid. The result of this, is that a few of these historic boreholes will be located in the field as the associated coordinate is the farm or plot centroid. It is therefore not uncommon to obtain multiple boreholes assigned to the same position (Figure 7), with a small offset to prevent duplicate coordinate positions in the database.

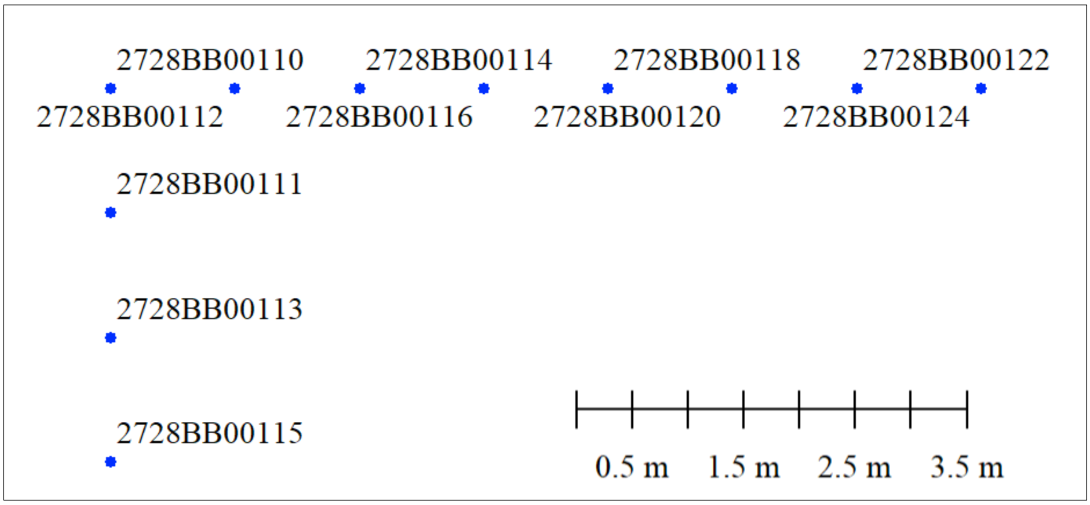

Figure 7: Boreholes with offset to prevent duplicate coordinates in database

Unfortunately, the fact of the matter is that some of the boreholes present in the NGA, will never be located. This does not mean that these boreholes should be removed, as associated data like geological logs do provide information on the surrounding area even though the exact position is unknown.

From a citizen science point of view, to identify a borehole position and take a photo is elementary. However, borehole measurements require specific equipment and training. The solution to this challenge is to present the public with selection lists to give an indication of the status of the borehole if they are not equipped to perform proper measurements. The critical data captured remains the borehole locality, so that the position is known, and the site can be revisited in future to carry out proper measurements. The hydrocensus form provided by the NGA is presented in Appendix A, and it is evident that the public will not be able to acquire most items listed on this form.

2.5 HUMAN BEHAVIOUR IN A CRISIS

In 2018, the City of Cape Town experienced its worst drought in over a century. The water crisis peaked during mid-2017 to mid-2018 where water levels hovered between 15 to 30 per cent of total dam capacity. In late 2017, the first mentions of plans for “Day Zero” were made, a shorthand reference for the day when the demand for water to meet essential needs exceeds the supply (Ziervogel, 2019).

“Day Zero” would herald the start of Level 7 water restrictions, where municipal water supplies would largely be switched off and residents would have to queue for their daily ration of water, making the City of Cape Town the first major city in the world to potentially run out of water (City of Cape Town, 2019).

During the ongoing drought people resorted to groundwater as a source of water. This resulted in an estimated 30,000 boreholes being drilled in and around the Cape Town. In general, a water use license is required for water use in South Africa under the National Water Act (No. 36 of 1998). However, the water law makes provision for water-use that is termed “Schedule 1” use. Schedule 1 water uses are generally low-volume, low-impact activities that are consistent with domestic use, livestock watering, recreational use, and the use of water for emergencies.

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As people were affected more and more by the water shortage, they took to social media platforms and started reporting rainfall and to a lesser extent water levels in the areas where they lived. The data resolution obtained in certain areas were astonishing – people had a vested interest to report on the status of water as this could assist in management.

The problem with social media platforms is that the data is highly distributed and is cumbersome to collate for management purposes. This response from the public sparked the development of a borehole mobile app to assist with borehole identification and monitoring to enable better water management in future. The following quote from John Thorson never held truer than during the time of drought:

“Water links us to our neighbour in a way more profound and complex than any other.”

CHAPTER 3: PILOT STUDY

3.1 PREAMBLE

In addition to the initial evaluation of the citizen science project potential, a basic prototype was developed to test before detailed design were considered. The results of the evaluation of suitability as well as the results of the pilot study are presented in this section.

3.2 EVALUATION OF SUITABILITY AND POTENTIAL

The project potential as citizen science project, was evaluated by applying the suitability criteria and decision framework described by Pocock *et al.* (2014). The aforementioned is no guarantee to success of the final project, but merely provides guidance to success factors to be considered based on lessons learnt from other citizen science projects. The evaluation results are presented in Table 2.

Table 2: Suitability criteria

Criteria	Suitability
Clarity of the aim	☺
Importance of engagement	☺
Resources available	😐
Scale of sampling	☺
Complexity of the protocol	☺
Motivations of participants	😐

The results for resources and participant motivation warrant some explanation:

- *Resources available* – since an online database is used, there are certain costs associated with storage and use. Currently the development of the application is done within the realm of an academic license of a university. The development costs associated with the ESRI products used (App Studio® and ArcGIS® Online) are covered by an academic license. With the final release of the product a custodian needs to be appointed which will assume the responsibility of system, associated maintenance, and license costs.
- *Motivations of participants* – the challenge with a borehole is that special equipment is required for measurements. The public, however, can obtain the GPS location, take a photo, and answer some basic questions in the form of selection lists. The project will resonate with the public for typical reasons like a sense of jeopardy ("my water resources are under threat") or being part of a narrative ("I'm taking part with others"). In contrast to the public participants, professional participants will gain the most value from the project and motivation is a non-issue.

The project potential as citizen science project was also evaluated by applying the decision framework suggested by Pocock *et al.* (2014). The evaluation of the project potential was done considering only the public, with no measuring equipment. The result indicated that the project has very good potential for a mass participation citizen science approach.

A summary of how the success factors specified by Garcia-Soto *et al.* (2017) will be implemented or considered is presented in Table 3.

Table 3: Summary of success factors

Success Factor	Implementation / Consideration
Clear Goal	Determine borehole localities regardless of if other borehole parameters can be measured by specific user.
Engagement of Citizens	Engagement of geohydrologists is a non-issue, however, to keep the public interested, outside the realm of a water crises, rely on factors like being part of a narrative: “I’m taking part with others”
Reliable Data	Data verification is achieved by users, for users through a rating scheme.
Improved Database	By capturing actual borehole positions and associated data will result in an improved database.
Contribute to Science	An improved database with both spatial and temporal data will support future data mining for trend analysis to be used in management.
Good Communication	Training of users is funded by the Water Research Commission of South Africa – Project K5/2827.

With all these aspects considered, the project makes a compelling case to be employed as a citizen science project. Additionally, it has the potential to succeed as it attempts to address concerns it raises.

The manner which citizen science is conducted influences the outcomes of its purpose. Overlapping with the suitability and potential the clarity of goals guides the approached to be followed by the research. The project can be analysed through the various approaches presented by Shirk et al. (2012), Bonney et al. (2009), Haklay (2013), Wiggins & Crowston (2011) considering the levels of engagement and participation. From this, the approach followed in this project is assessed to be the hybrid of a contributory model with distributed intelligence and falling under the categories of investigative, conservational, and virtual citizen science.

The collaborative model is employed as the public is not leading the research (i.e. developing study questions, research methods, etc.). The public does, however, take part by collecting borehole data collection, analysing data (graphical representations of their data on the application) and the dissemination of data through the open access of the application to its users.

The mobile app was tested on a pilot study area (Potchefstroom, South Africa), by making it available to people interested in participating. The user group consisted of ordinary citizens living in Potchefstroom, university students and a local environmental consultant.

At the start of the pilot, the available data from the online database (mainly NGA data as GRIP does not apply to the study area) amounted to 46 boreholes. The spatial distribution of these 46 boreholes is shown in Figure 8(a) and Figure 8(b) respectively and most of the boreholes were historically assigned to the farm centroid at the time.

3.3 STUDY RESULTS

An additional 63 borehole positions were recorded which totals 109 boreholes in the area as shown in Figure 8(c). The borehole additions from the different users were 33 from the public, 19 from the student group and 11 from the local consultant. None of the existing boreholes (before commencement of the pilot study) were verified by any of the participating users. The consultant provided water level readings where the boreholes were not equipped. The public users together with the student group only provided basic information as shown in the example shown in Figure 9.

The results from testing the app in a pilot study area, showed that borehole positions nearly doubled from what was on the existing database and 52% of these added borehole positions came from the public. When considering the existing boreholes before the pilot study, 96% of the boreholes were assigned to the same locality, making it impossible to locate them in the field. By having the public identify boreholes not in the database, could result in consolidating the "new" position with that of a "misplaced" borehole if enough information can be gathered to support this association. This however was not the case with the pilot study. The pilot study is considered a success when considering the addition of new borehole localities that is verifiable in the field.

The main outcome of the pilot study was that if only the borehole position can be verified, it is considered valuable information since locating a borehole in the field for hydro-census purposes is time consuming. Once the localities are known, professional users can carry out proper measurements to be used for management purposes and all users contributing to the database have access to this information.

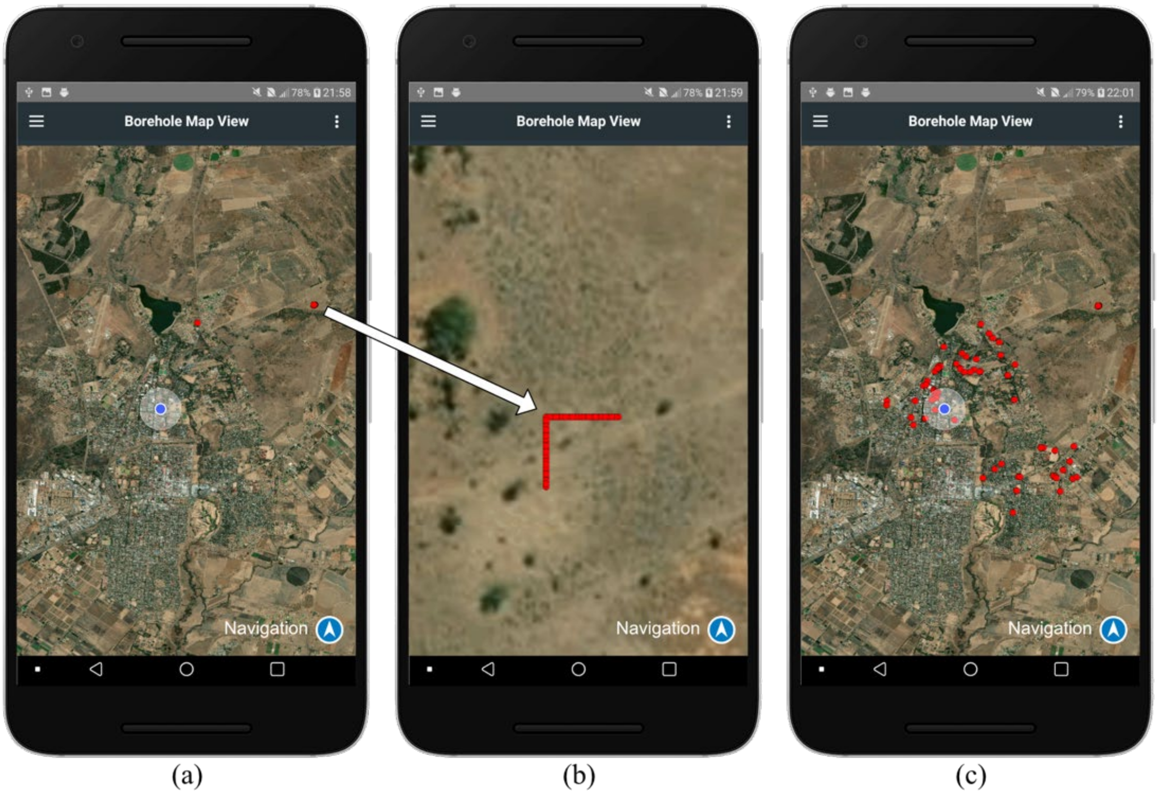
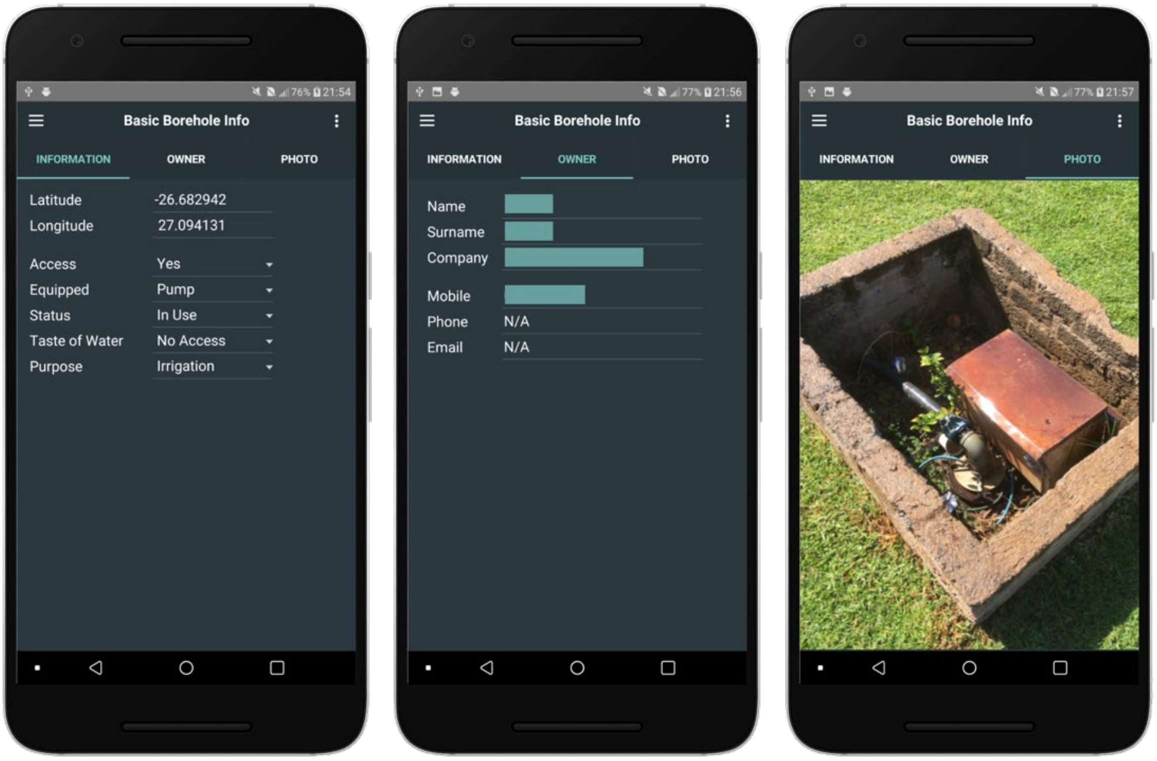


Figure 8: (a) before pilot study; (b) boreholes assigned to same location; (c) result of pilot study.



(a) (b) (c)

Figure 9: Basic borehole information. (a) locality and status; (b) owner; (b) photo

CHAPTER 4: SOFTWARE DESIGN

4.1 MOBILE APPLICATION

4.1.1 Preamble

The software design must facilitate the access to the database and keep in consideration the success factors discussed in a previous section. The challenge in the software design lies in the fact that the software mainly consists of a mobile application associated with limited screen real-estate and the database is comprehensive.

The factors to be considered in the design are as follows:

- The mobile app is not intended to replace any desktop analysis software and it must provide clear and concise information to the user.
- The interface must be intuitive and not overwhelm a user.
- The high-level implementation design of the mobile app is depicted in Figure 10 and two user types are distinguished in the design namely *General Public* and *Groundwater Professionals*. The major distinction between these two user types is the ability to perform proper borehole measurements.
- Reliable data which relates to an improved database are two of the identified success factors. Each user is issued a user rating with registration and is issued a zero-star rating at the beginning. The star rating of a user is used as an indication of the data quality. Multiple verifications lead to an increase of the star rating of a particular user, therefore active participants will see an increase in their user rating over time.

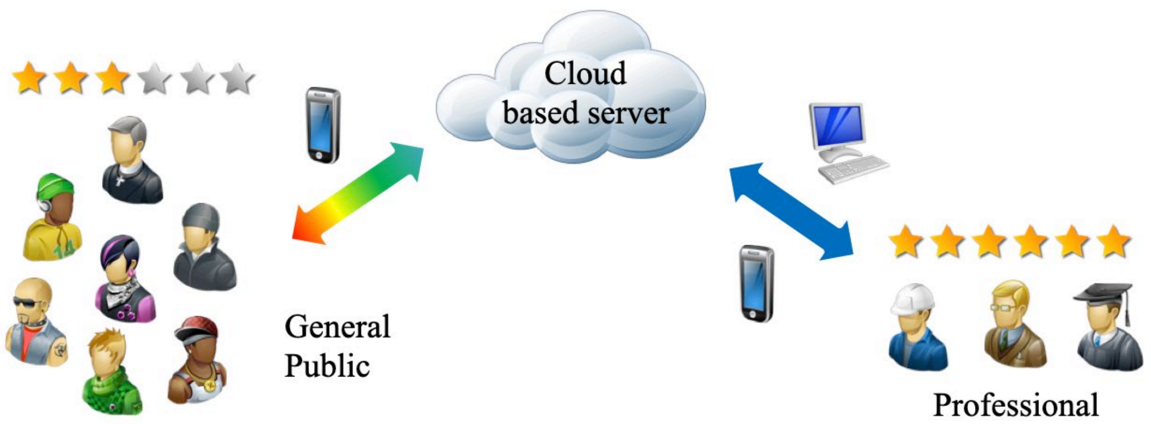


Figure 10: High-level implementation of the mobile app

4.1.2 Design Considerations

Various software development platforms are available for developing mobile apps. The focus of this project will be to mainly target Android and iOS mobile devices, since they comprise the bulk of the market as shown in Figure 11.

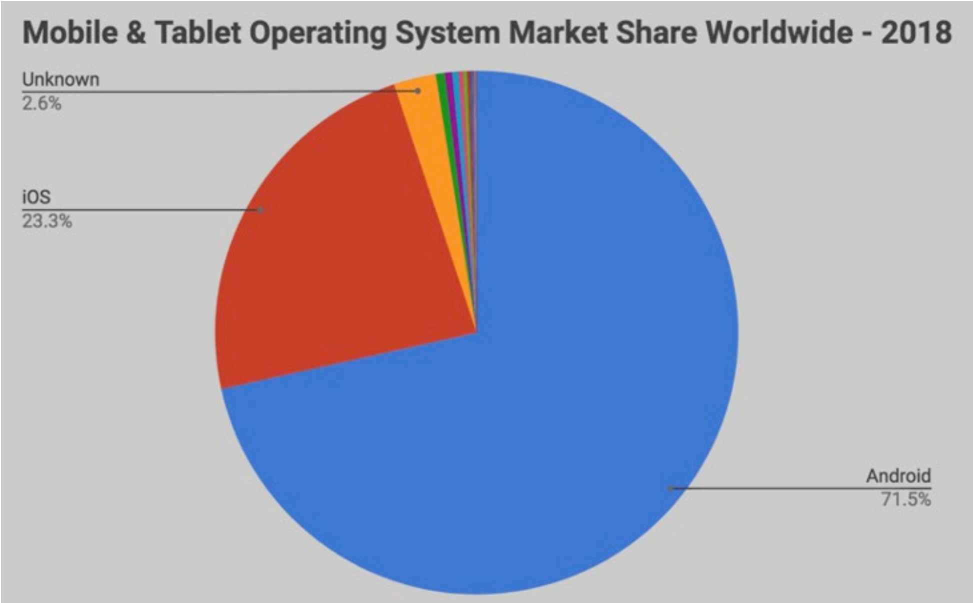


Figure 11: Android and Apple mobile market share in 2018 (Hafnar, 2018)

Within the Android and Apple mobile space, various software development platforms exist to deliver the required application. The following two requirements were identified for the project and will be discussed in more detail in the sections that follow:

i. The develop environment must support mobile GIS, with caching support where not mobile network is available.
ii. Cross-platform app development is required that will support both the Android and iOS

4.1.2.1 Cross-platform App Development

Cross-platform app development is a common approach among businesses today. It supports the development of custom mobile apps that are compatible across mobile platforms. The advantage of this approach is as follows:

- *Reusable Code*: the development team don't have to write unique code for different platforms. Instead, the program developed for one app gets used many times.
- *Speed:* The major advantage of cross-platform mobile app development is that it cuts down on development time. In this project the development time would probably double if two sets of source code must be developed.
- *Reduced Cost:* The use of single code base across platforms results in significant cost reduction.

Cross-platform apps are subject to disadvantages as well, e.g. inconsistent communication between the device native and non-native components. Users expect a certain look and feel from apps associated with a specific OS.

The following sections discuss two identified software development platforms that meet the requirements for the cross-platform development and compares the two solutions in the context of advantages and disadvantages, before making a recommendation.

4.1.2.1.1 *Embarcadero RAD Studio*

Embarcadero RAD Studio were considered as a possible development platform for the proposed mobile app for the following reasons:

- Support cross-platform development for both Android and iOS through its FireMonkey components.
- Support both the Delphi and C++ programming languages.
- Support mobile GIS through TatukGIS and their associated GIS FireMonkey component.
- Support cloud services through a REST API.
- RAD Studio will be used to develop the Desktop application that will be able to connect to the cloud database and manipulate the data on professional level.
- Custom development allows for full control of app functionality.

4.1.2.1.2 *ArcGIS App Studio*

ArcGIS App Studio is considered as a possible development platform for the proposed mobile app for the following reasons:

- App Studio has a runtime SDK for Qt. Qt is (pronounced "cute") is a free and open-source widget toolkit for creating graphical user interfaces as well as cross-platform applications with little or no change in the underlying codebase while still being a native application with native capabilities and speed.
- Build an app once, and it is automatically ready for Android, iOS, Windows, OS X, and Linux.
- Use pre-exiting templates to reduce development time.
- Leverage ArcGIS mobile technology.
- Future OS automatically supported.

4.1.2.1.3 *Comparison of RAD Studio and App Studio*

The comparison between the two considered development environments is done on both technical and financial level and these results are presented in Table 4 and Table 5 respectively.

Table 4: Technical comparison between RAD Studio and App Studio

TECHNICAL CONSIDERATIONS	
RAD Studio	**App Studio**
Advantages • Full control of development functionality • Accompanying desktop application developed in same environment • Can choose cloud storage service	**Advantages** • ESRI mobile solutions upgrade automatically with the release of new mobile operating systems • Maintenance and support of products • REST API should allow for 3rd party desktop app to connect

TECHNICAL CONSIDERATIONS	
RAD Studio	**App Studio**
Disadvantages • Maturity of solution • Development time • Active updates required for new mobile operating systems	**Disadvantages** • Does AppStudio SDK provide same level of developmental control? • ESRI committed to single cloud storage provider • AppStudio only for mobile applications – desktop solution will require other development platform

When ESRI App Studio was evaluated as a solution, the advantages of maturity of the solution, together with the ESRI support outweighs the possible disadvantages. A further advantage from App Studio that makes this development platform very attractive is the fact that as new mobile operating systems become available the ESRI solution upgrade automatically, reducing maintenance on the system.

Table 5: Financial comparison between RAD Studio and App Studio

FINANCIAL CONSIDERATIONS	
RAD Studio	**App Studio**
Advantages • If system load and database small enough, a free tier subscription could do the job	**Advantages** • Only pay for downloads, uploads free • Storage costs very low compared to other cloud services • Academic licenses allow full development of system
Disadvantages • As a small customer not in position to negotiate good pricing structure for single app • No cap on usage and large bill could result	**Disadvantages** • None identified to date

4.1.3 Graphical User Interface

The ESRI AppStudio development platform was chosen as the target development platform and was be used in this document to generate mock-ups, to present the look and feel of the mobile app.

4.1.3.1 Landing Page

The landing page is the first screen a user will see when launching the app. The design of the landing screen is show in Figure 12 and the user is presented with two options:

- **Create Public Account** – Any member of the public can register a public account with AGO which will allow them access to the app. This selection will take the user to the AGOL website where the registration takes place (Figure 13).
- **Sign-In** – this selection will allow users with an AGOL username and password to login to the app.

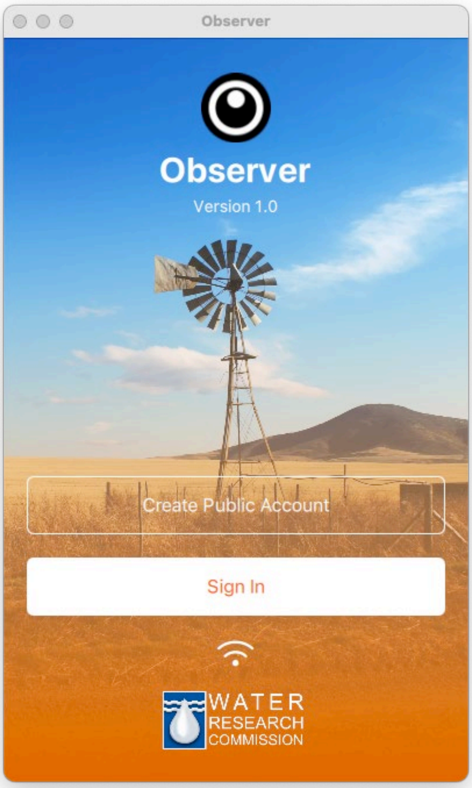


Figure 12: App landing page

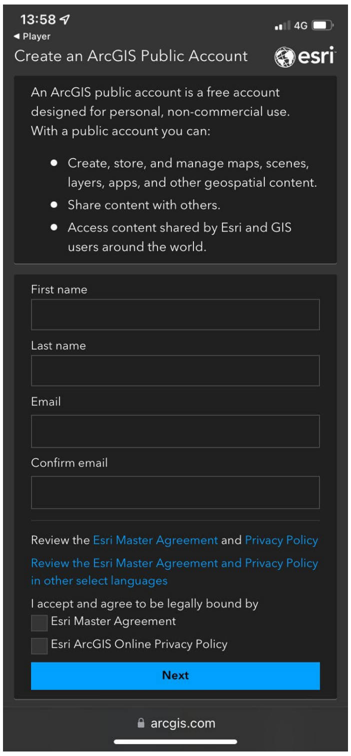


Figure 13: ArcGIS Online registration page

4.1.3.2 Sign-In Page

If the user selects the *Sign-In* option, the Sign-In page is launched where the AGOL username and password is required. The Sign-In page is shown in Figure 14. One a user has signed in the login credentials will be stored on the device for quick login in the future. If a user logs out of the system, the previous login credentials will be wiped. This allows for multiple users to make use of the same mobile device.

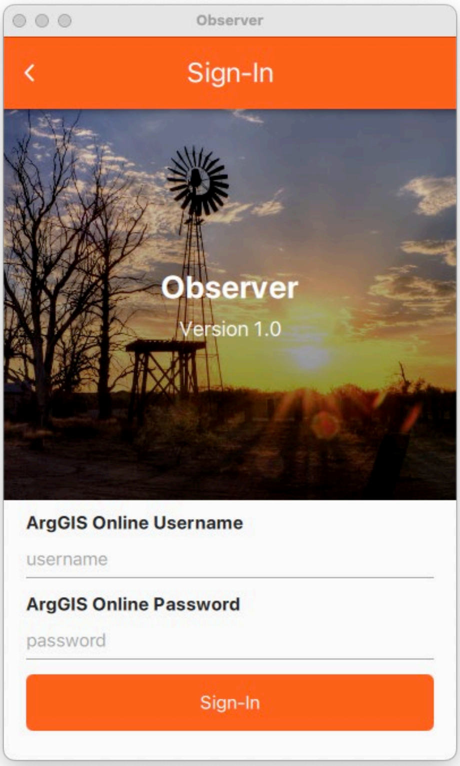


Figure 14: Sign-In page

4.1.3.3 Map Page

The layout of the map page which is also the main page of the app is shown Figure 15 and Figure 16. The interface consists of a main toolbar housing the menu button and various tool buttons. The menu button will display the Observer icon ⦿ when a user is not signed-in, otherwise the initials of the signed-in user will be used as an avatar (Figure 15).

The visibility of the various tool buttons depends on the current application state. The data layer is always present and reflect the positions of all sites (boreholes and rainfall stations) in the database. The selection of a particular base map will be discussed under the *Settings Page*. A summary of all the features labelled in Figure 15 and Figure 16 is presented in Table 6 with a short description.

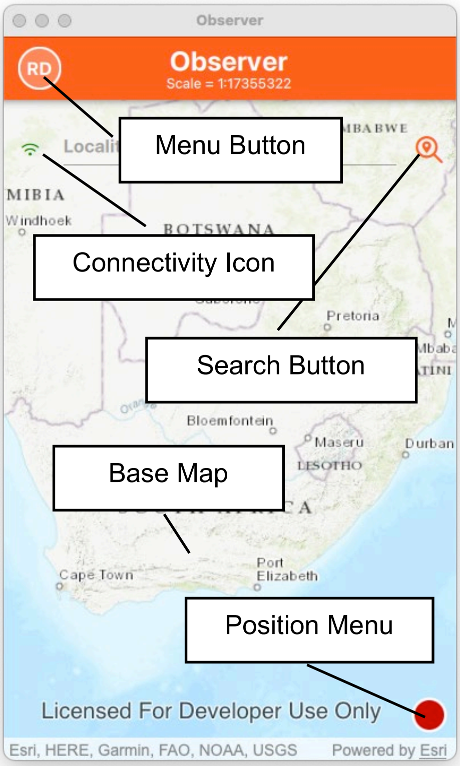


Figure 15: Layout of map page

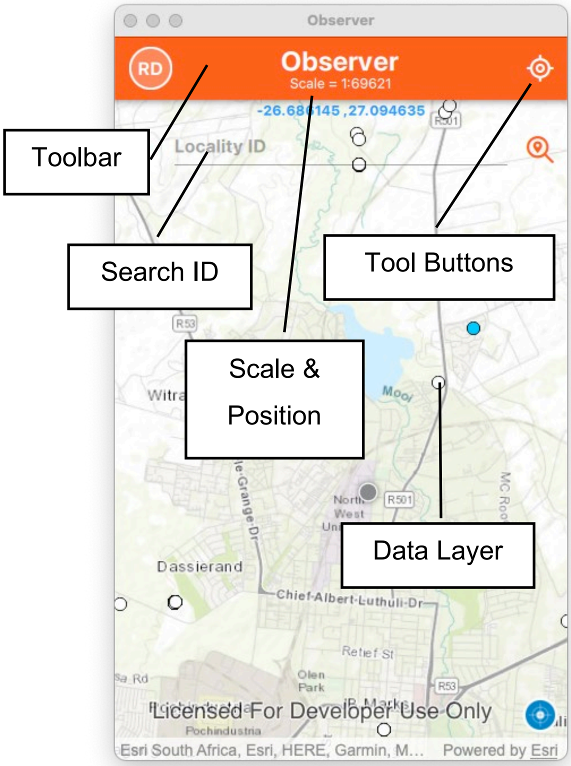


Figure 16: Layout of map page

Table 6: Summary of GUI features

Feature	Purpose
Toolbar	The toolbar houses the menu and tool buttons and show the current scale.
Menu Button	The menu button provides access to the user profile and settings menu.
Connectivity Icon	An indicator of the current connectivity of the device to a data network.
Search ID	The specific locality ID that will be searched for in the database.
Search Button	The button that runs the search on the given Search ID.
Base Map	The base is the selected map used as map background.
Position Menu	Allows the user to switch on the device position (see later section on this).
Scale & Position	Show the current map scale as well as the current device position.
Data Layer	The positions of the boreholes and rainfall stations in the database.
Tool Buttons	Each tool button represents a specific functionality and is summarised in Table 7 below.

Table 7: Summary of available tool buttons

Icon	Tool Button	Purpose
	Validate Site	Once a user is in close proximity to a selected site, the option is presented to validate the site position. This functionality is the focus of the citizen science drive.
	Reject Site	Once a user is in close proximity to a selected site, but the site is nowhere to be found, the option is presented to reject the site position. This functionality is the focus of the citizen science drive.
	Zoom Position	Before capturing a new site on the system, a certain zoom extent or scale is required to ensure the user are aware of the other data in the immediate vicinity. This could prevent a duplicate site being captured, since the GPS positioning will have drift in the field.
	Add New Site	Once the required scale or zoom is achieved the user may then proceed to capture the new site and specify its type.
	Link Site	Once a duplicate set of sites are identified in the field, the user has the option to indicate which site to link to another. Ultimately, the final execution of the linking, remains the system administrator's responsibility as this action cannot be rolled back once completed.
	Get Offline Data	If a user is planning to capture information in a remote area where no data network is available, the study area information can be downloaded for offline use in the field.
	Sync Offline Data	Once a data network is present again, the user can sync the offline data with the live data in the cloud.

4.1.3.4 Main Menu

The main menu is launched by clicking the menu button which could either be the user initials in a circle or the Observer icon depending on the signed-in state of the user. Once the menu button is clicked as side drawer will open displaying the menu page as shown in Figure 17.

The menu page is split into two sections namely the user profile and specific menu items and the following sections will describe each of these.

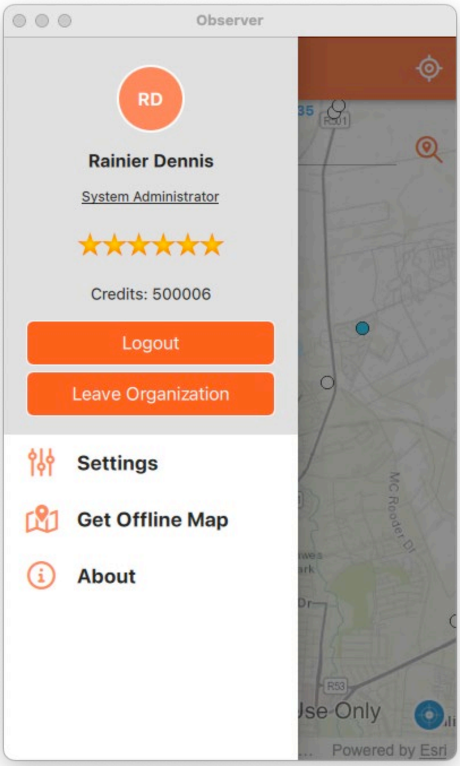


Figure 17: Main menu

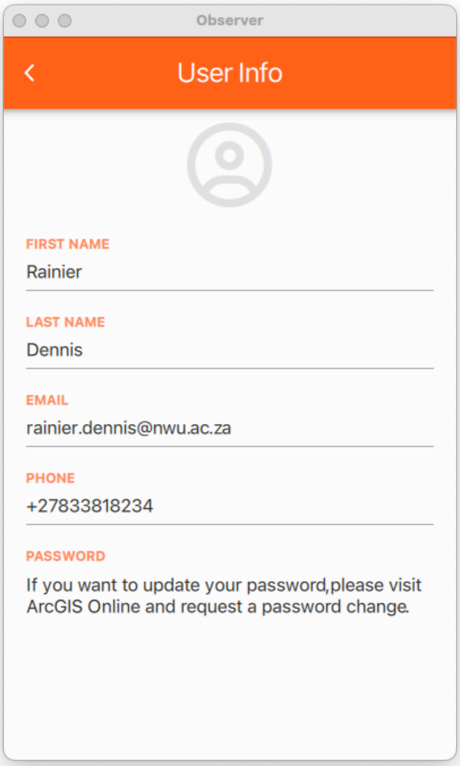


Figure 18: User page

4.1.3.4.1 User Profile

The user profile consists of the following sections:

- **User Avatar** – by clicking on the user avatar, the user can view and update the user information as shown in Figure 18. New users will first be directed to this page (Figure 18) before normal use of the app will commence.
- **User Name and Surname** – as obtained from the registration information.
- **User Organization** – a user can choose to join an organization in which case he will share and contribute credits as part of the organization and not as an individual user. Similar to the user information page (Figure 18), when clicking on the organization, the user will be presented with the organization detail, but only for viewing.
- **Star Rating** – every user has a star rating that can go to a maximum of five starts except for system administrators that is awarded a six-star rating. The star rating is discussed in detail in a later section.
- **Credit Count** – every user has a credit which get increased with information capture and decremented when downloading data. The credit count is discussed in more detail in a later section.
- **Logout Button** – one logged in, the app will store the login credentials on the mobile device, to allow for quick sign-in later. If more than one person is using the same mobile device, the user is required to logout, so that his current login credentials are removed from the device, so that another user cannot login with the same credentials.
- **Join / Leave Organization** – the user can apply to join a specific organization and choose one from those listed in the database or can choose to leave an organization if already a member of one.

4.1.3.4.2 Menu Selections

The available menu selections are presented in the sections that follow.

Settings Page

The *Settings Page* (Figure 19) presents the user with some settings that will be sorted on the device, so that the user preferences remain the default settings.

- **Dark Mode** – allows the user to choose between light and dark theme for the app. The settings page is shown in Figure 19 and the same page is displayed in Figure 20 when dark mode is switched on.

Link Function – this setting determines if the linking function is switched on or off on the map page. Since this is not an action that will take place very often, the default is set to off, and this allows to de-clutter the map page. Should this functionality be required, it needs to be turned on here. The link function was also discussed in

- Table 7 and when a user chooses to link two sites the map page will show the features as presented in Figure 21.
- **No Cache on Request** – The features are always requested from the server and are never cached. Some performance issues may arise when used in this mode.
- **Proximity** – Specifies the distance a user needs to be from a site to add data or validate.
- **Basemap** – The user can also choose the base map base map displayed in the *Map Page.* Note that only one map can be displayed at a time and the options are Topographic, Street Map or Aerial Imagery and these are shown in Figure 22 to Figure 24 for the same study area.

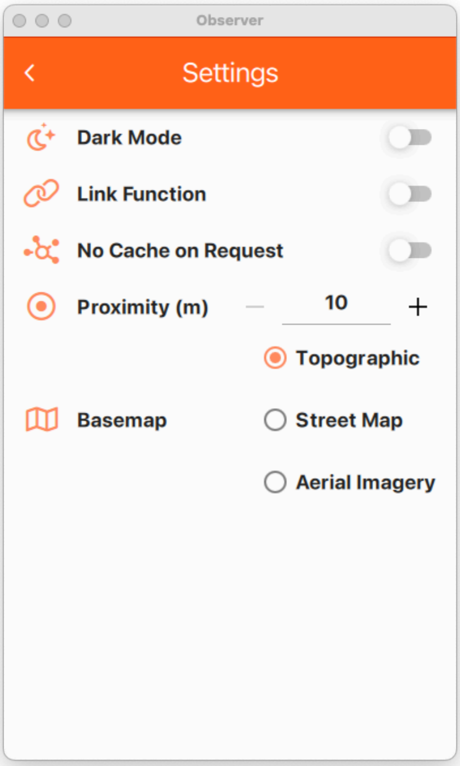


Figure 19: Settings page (light mode)

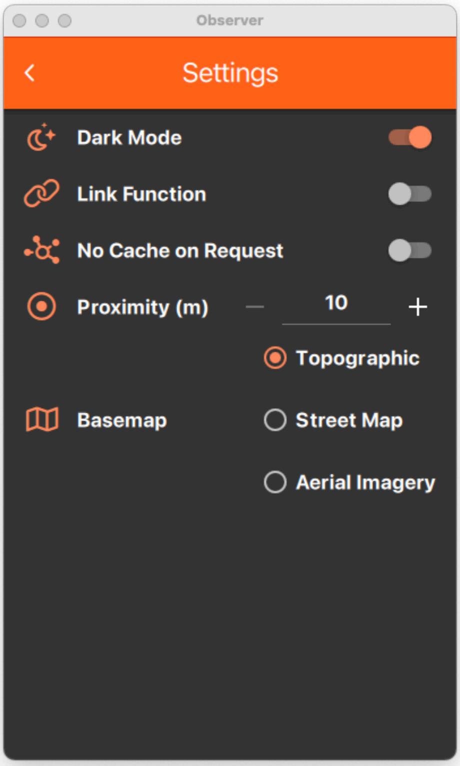


Figure 20: Settings page (dark mode)

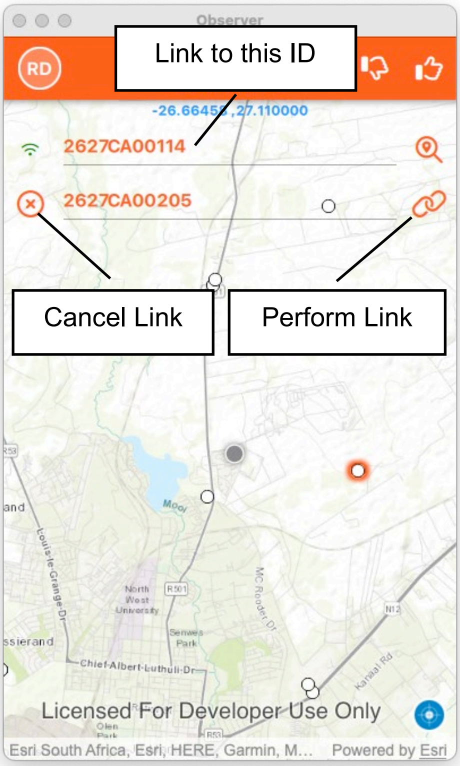


Figure 21: Link functionality

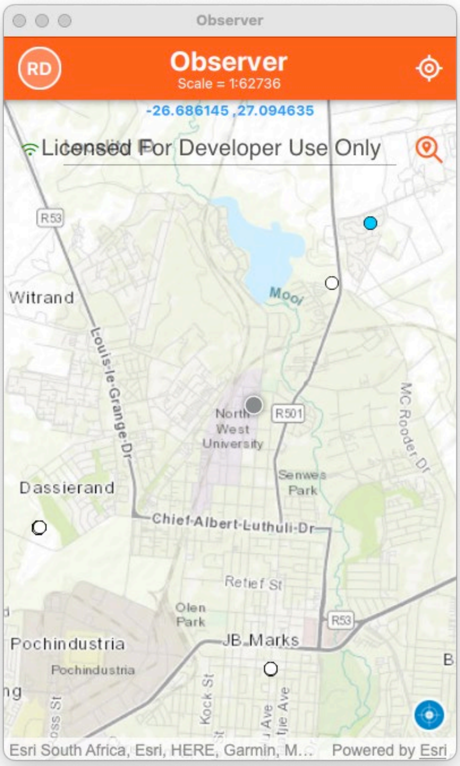


Figure 22: Topographic map

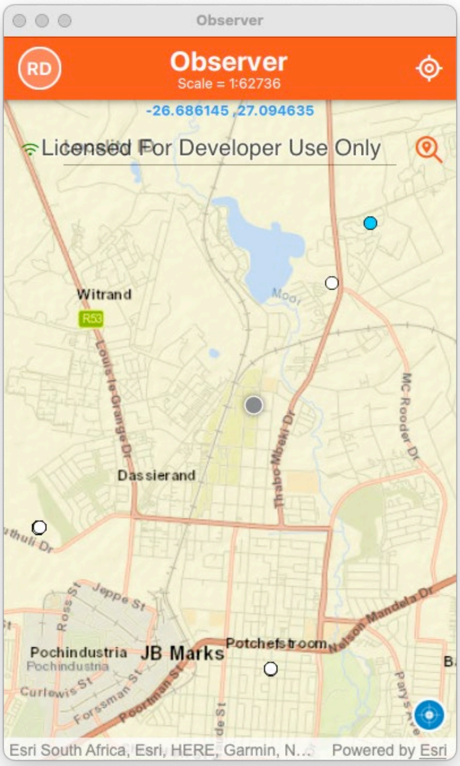


Figure 23: Street Map

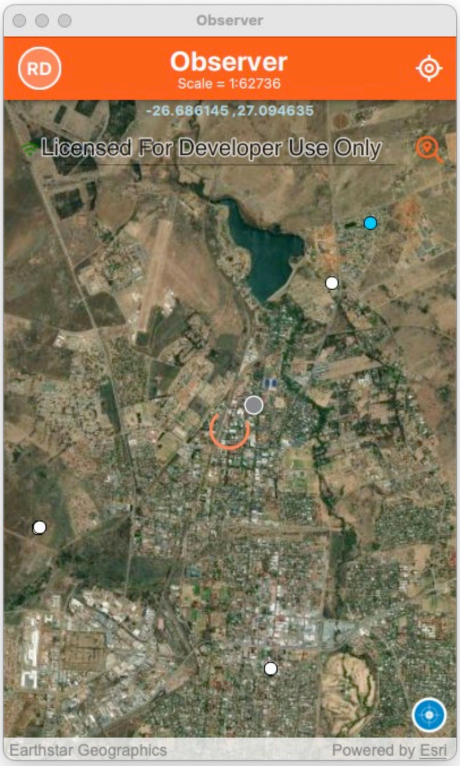


Figure 24: Aerial map

Get Offline Map

If a user is planning to capture information in a remote area where no data network is available, the study area information can be downloaded for offline use in the field. A rectangle will appear which represents the area of data capture. The user should zoom and pan the map until the area of interest is visible within the rectangle before downloading the data. The offline data capture screen is shown in Figure 25.

Once the dataset has been downloaded to a local database on the mobile device it can be synced to the live database in the cloud at any time as long as a data network is present again.

About Page

The is used to specify the version number of the software, give a short overview of the intended purpose of the project, and provides the acknowledgements of the project as shown in Figure 26.

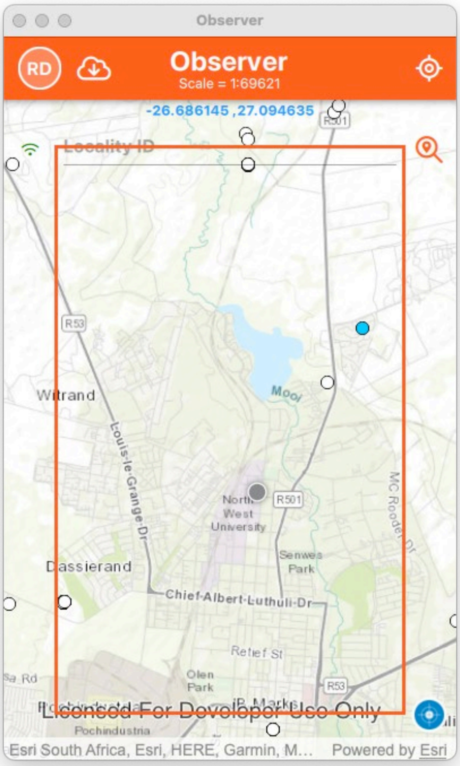


Figure 25: Get offline data

Figure 26: About page

4.1.3.5 Position Menu

The position menu controls the visibility of the mobile device on the map. The summary of the position menu functionality is given in Table 8 and the position menu is shown in Figure 27 and position on the map is then indicated with a blue or grey dot as shown in Figure 28.

Table 8: Summary of position menu functionality

Icon	Tool Button	Purpose
	Centre Location	Switch on the location marker on the map and centre map around location position.
	Position On	Switch on the location marker on the map.
	Position Off	Switch off the location marker on the map.
	Exit Menu	Close the location menu and return to the map.

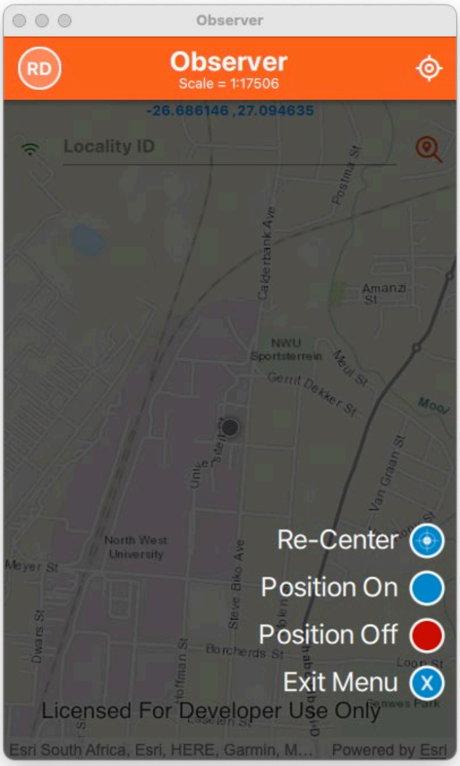


Figure 27: Position menu

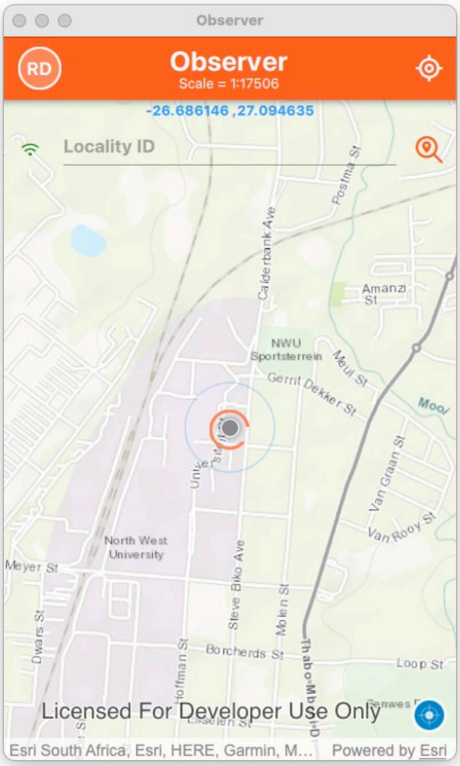


Figure 28: Device location on map

4.1.3.6 Locality Drawer

Once a site is selected a locality drawer will be visible at the bottom of the screen that has two tabs *Locality* and *Data* which will be discussed in the following two sections.

Locality Tab

The locality tab presents basic information about the selected locality. The information includes the following and examples is shown in Figure 29 and Figure 30:

- The unique ID associated with the site
- Type of site (borehole or rainfall)
- Status of site (not verified, verified, or rejected)
- Distance to site (km)
- Merge ID which represents which site should be linked to this specific site
- Editor Name and Date
- Creator Name and Date

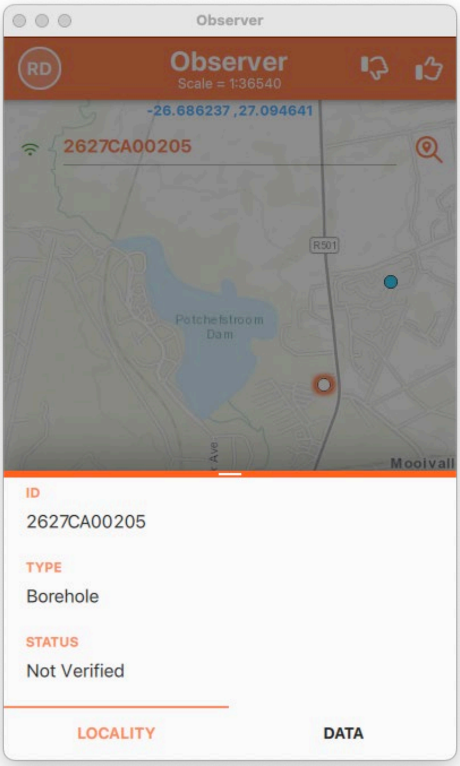


Figure 29: Locality tab

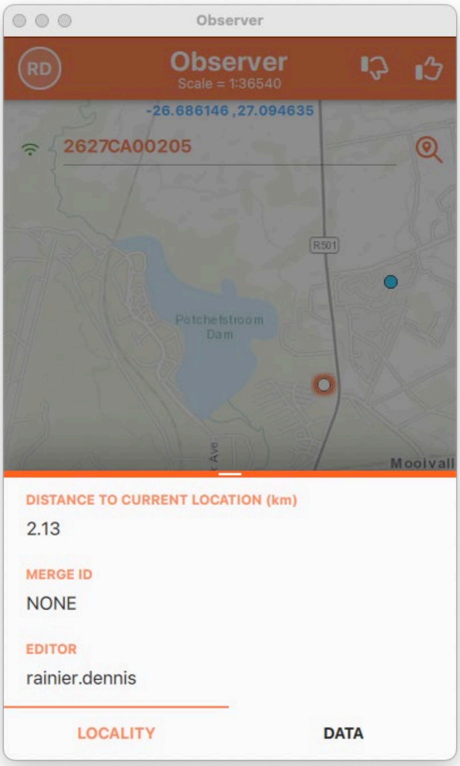


Figure 30: Locality tab

Data Tab

The information listed under the data tab represents all the information available in the data base for the specific site. The number of records for the selected site will be displayed next to each data entity so that the user can see where data is available. The data is organised based on the following categories and Figure 31 shows all datasets supported by the system:

- SITE RELATED
- LEVEL RELATED
- ABSTRACTION RELATED
- CHEMISRTY RELATED
- CONSTRUCTION RELATED
- EQUIPMENT RELATED

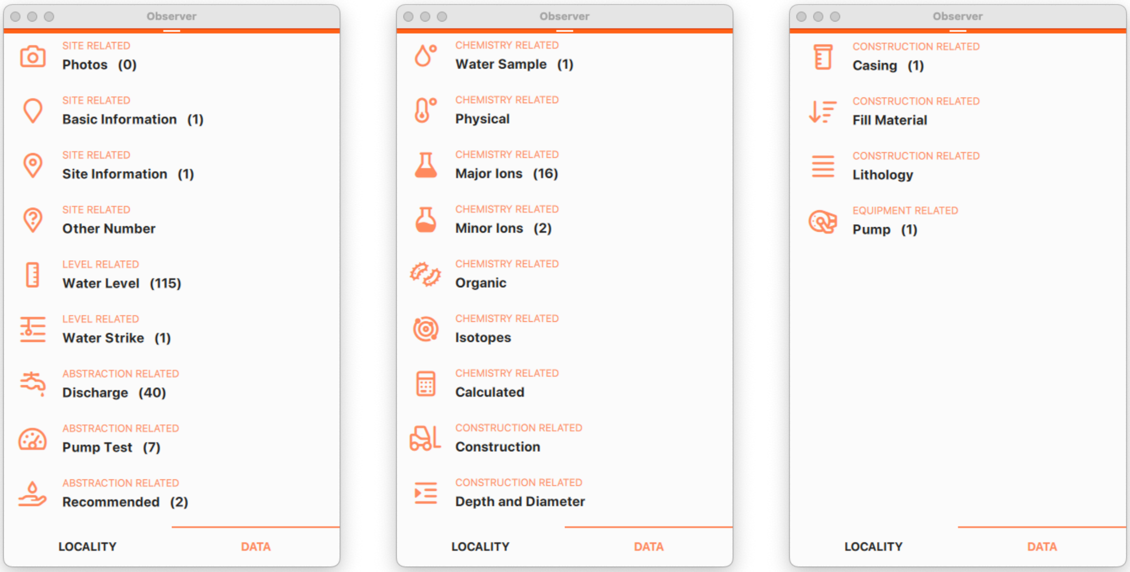


Figure 31: Locality data entities

Once a user selects a specific data entity the appropriate data page will be displayed and depending on the state of the application and user profile some of the tool buttons presented in Table 9 could be visible.

Table 9: Summary of available data buttons

Icon	Button	Purpose
	Back	Go back to previous screen.
	Edit	Edit selected record.
	Add	Add new record.
	Photo	Add photo.
	Delete	Delete changes made.
	Accept	Accept changes made.

Depending on the data entity type, the user will either be presented by a secondary page listing items to be selected from or taken to the data page.

An example of this is shown in Figure 32 and Figure 33 where the user selects Lithology for the selected site. Since a borehole may have more than one log associated with it as different users could capture the same log in the field, e.g. the driller and the pump test contractor, a distinction is required between these logs. The app creates a GUID for each log that is created but display the date and time of creation as a selection item to the user (Figure 32). Once the item is selected the data page containing the records associated with the selected item is shown (Figure 33).

By swiping left or right over the data page, the user can page through the different data records on the data page. For data screens also allow for scrolling up and down when more data entries are present than what can fit on a screen.

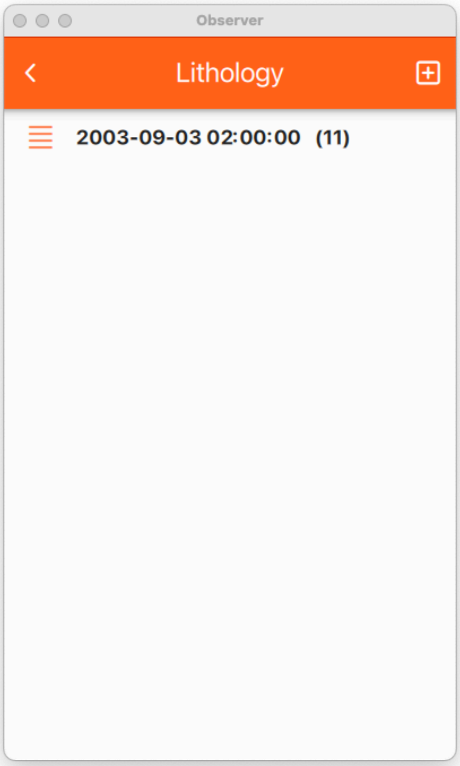


Figure 32: Example Lithology item

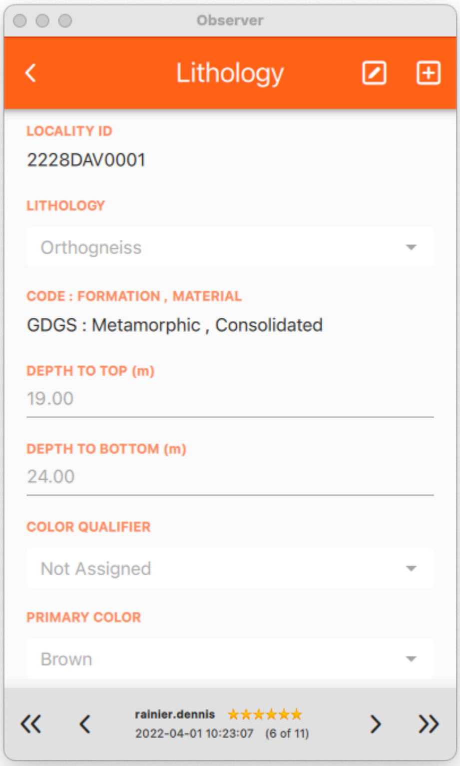


Figure 33: Example Lithology records

Data pages have a footer that show how many records are available and which one is currently selected. In addition, the last user that edited the current record and associated date is also displayed. By clicking on this information, the associated user information page will be displayed (Figure 18). The footer also provides navigation functionality, and the navigation button functionality is summarised in Table 10.

Table 10: Footer navigation buttons

Icon	Button	Purpose
	First	Move to first record in the result set.
	Next	Move to next record in the result set.
	Previous	Move to previous record in the result set.
	Last	Move to last record in the result set.

A design pattern is followed in presenting the data pages and two types of pages exist:

- **Data Screen** – a single page only displays the data fields for each record and the whole screen real estate is dedicated to this purpose as shown in Figure 33. A variation of this screen is where the data type is a photo as shown in Figure 34.
- **Split Screen** – the split screen relates to datasets where parameters are graphed in addition to showing the individual records. The split screen is therefore a combination of a data screen with the addition of a graph as shown in Figure 35.

All data display and entries take place through one of the following components which represents the entries in the data screen:

- **Image Field** – this component is only used to display site photos (Figure 34).
- **Read Only Field** – this component is used to display data that is for viewing only and no editing can take place on it.
- **Combo Box Field** – this component is used to present the user with lookup list options, so it only allows the user to make the appropriate selection from the list.
- **Text Field** – this component is used for the following data types and employs type checking when entering the data:
    - Text fields
    - Numerical fields
    - Date and Time fields

Figure 34: Data screen (photo)

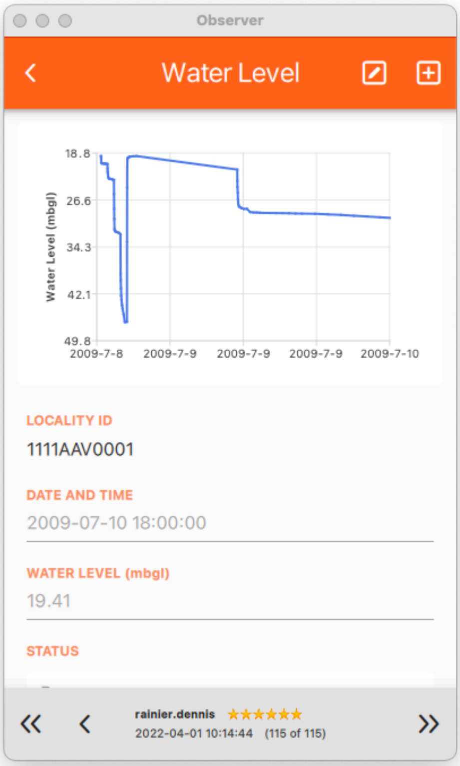


Figure 35: Split screen

The user may perform the following actions in the data pages based on the system rules:

- **View Data** – once a site selection is made, the user may select from any of the data entities available in the locality drawer to view the relevant data.

- **Edit Data** – the data being viewed may only edited if the editor of the data and the signed-in user in the app is the same. This rule prevents users from changing each other’s data. The user does not have to be in close proximity to the site to perform editing.
- **Add Data** – data can only be added to a site if the user is within the specified proximity of a site. The default proximity is 10 m (Figure 19), but users with a five-star rating and above has the ability to set the proximity range to enable them to add information to a site without being there physically. To determine the distance to the selected site, it is required that the device location is enabled otherwise the add functionality will not be enabled.

4.2 DESKTOP APPLICATION

4.2.1 Introduction

The purpose of the desktop software is purely to allow users to perform bulk uploads and downloads. The upload and download files are Excel files as most users are familiar with organising data in spreadsheet format.

Users are still required to sign-in with their AGO credentials as the system consume credits with downloads and replenish credits with uploads. This mechanism is in place to ensure fair use of the data and promote data sharing amongst users.

4.2.2 Graphical User Interface

The GUI of the desktop application is shown in Figure 36 and the functionality of each button is provided in Table 11. The status bar at the bottom of the page will reflect the signed-in user, the rating of the user as well as the available credits.

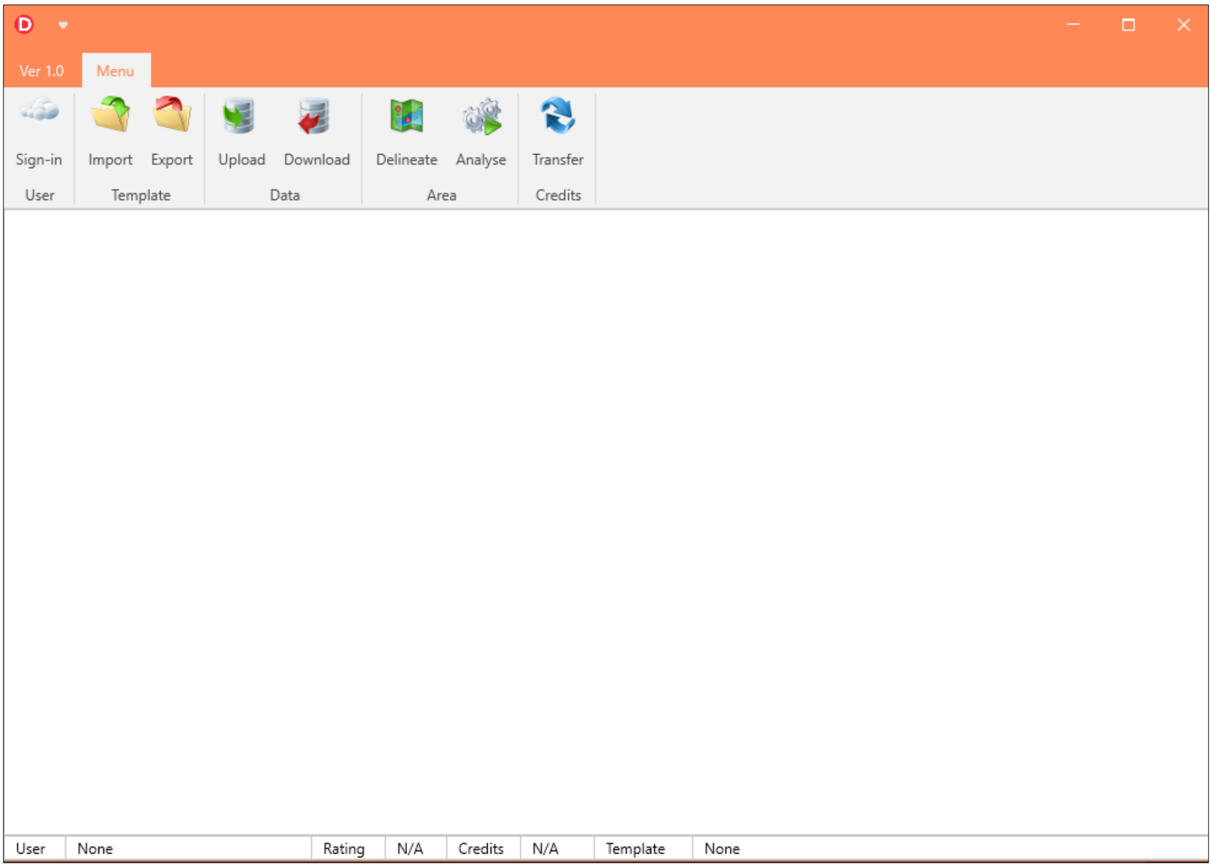
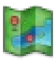


Figure 36: Desktop GUI

Table 11: Desktop application buttons

Icon	Button	Description
	Sign-in	Allows the user to sign-in to the system making use of their AGO credentials. If not signed in the only functionality available is generating the Excel template used for uploading data.
	Import	Import the populated template. The software will do some basic validation checks in the background and notify the user of possible errors before an upload can take place.
	Export	Export the data template which will be in an Excel format to allow users to easily manipulate the data.
	Upload	Upload the data to AOL. Will only be allowed if the basic checks have been passed.
	Download	Download data from selected area. The result will be an Excel file with the same structure as the template file.
	Delineate	Provide a Shape file or Google Earth KML of the area of interest that is targeted for download. Once loaded a map will be displayed with the given delineation so that the user can verify that it is the correct area.
	Analyse	The system will ask the confidence level required (star-rating) and will query the number of sites within the delineated area. A calculation will also be done ensure the user has sufficient credits to perform the download.
	Transfer Credits	Transfer credits to another user. This is useful when you have people in an organization that does the field work and upload data, i.e. they accumulate credits and another user analyse and download data, i.e. consumes credits.

4.3 CREDIT AND STAR-RATING CALCULATION

4.3.1 Introduction

The star-rating and credit system has been mentioned in previous sections and more detail regarding these features are presented in the following two sections.

4.3.2 Star-Rating

Each user will be assigned a star-rating which ranges from 0 to 5 stars and system administrators will receive a 6-star rating. The purpose of the star-rating is to use it to assign a pseudo confidence to the data as all data capture will be allowed and there is no control on the quality of the data. The system specifically targets the public as part of citizen science to assist in the data capture, but they might not have the necessary background to make informed decisions when capturing the data.

New or novice users will be started off on a zero star-rating but will be able to capture all the data they want. Certain users who are regarded as professionals and trustworthy will be assigned a five-star rating. These users will typically be consultants, DWS officials and all organisations working actively in the groundwater industry.

The star-rating is connected to how many times the localities that a user verified was also verified by other users. The premise is that if a user is active in verifying borehole localities, chances are good that they are also capturing quality data, therefore each user are afforded the opportunity to increase their star rating. The star-rating of a user is increased with the following two mechanisms:

1. If a user with a higher star-rating verifies the locality status captured by ‘n lower rated user, the lower rated user’s rating will be increased by half a star.
2. If a user with a lower star-rating verifies the locality status captured by ‘n higher rated user, there is a background count of these events that gets incremented. Once this background count reaches 10 the user’s star-rating is increased with half a star and the counter is reset.

4.3.3 User Credits

The purpose of user credits is to ensure fair use of data. The system allows you to download data if you contribute. The system will allocate a certain number of credits for each type of record uploaded and consume a certain number of credits for each record downloaded. This will not be a one-to-one ratio as users would want to download the data for a certain area in which they are performing a hydrocensus, but they might only be capturing data in a smaller area of the study area for which the data was downloaded.

The credit system is designed not to be restrictive as one of the main purposes of the system is to promote data sharing. Therefore, even a credit count of zero will still allow a certain amount of data to be downloaded.

Users can choose to join an organization in which case credits generated are pooled as part of the organizations credits and downloads will consume the organization credits rather than the user credits. This functionality was implemented to support organizations like consultants where the people doing the data capture in the field are not the same people doing the data analysis of the downloads.

4.4 ADMINISTRATIVE TASKS

Since the app is dependent on a database backend, certain administrative tasks are unavoidable and therefore a system administrator role is required. Although not all tasks are listed here, a few examples are presented to highlight the need for a system administrator:

1. The administrator is required to create other system administrators as required or revoke access to the system for users abusing it.
2. Although input screens do basic checks on the data, it is necessary to have an administrator review the latest input and determine the validity of it.
3. The workshop feedback (Appendix F) lists a valid concern about the upload of photos for public viewing. These photos need to be reviewed for content since they will be in the public domain.

CHAPTER 5: DATABASE DESIGN

5.1 BACKGROUND

The database design of the mobile app requires that the available data of both the NGA and GRIP databases be accommodated as far as possible. Although these databases contain similar data modelled on the SGDs (Standard Geosite Descriptors), the database design differs. Both databases are relational databases but have different tables to represent similar data.

The table definitions of the GRIP database obtained from a SQLite export is presented in Appendix B and the table definitions of the NGA database based on a reconstruction of the exported files obtained from the DWS NGA website (http://www3.dwa.gov.za/NGANet) is presented in Appendix C.

An approximate mapping of table entities between the NGA and GRIP databases is presented in Table 12. The following should be noted when studying the mapping between the NGA and GRIP entities (tables):

- The NGA tables have been used as basis for the mapping between the two databases, therefore some tables that exist in the GRIP database that do not have an equivalent table entity in the NGA.
- The GRIP database makes provision for a lot more entities than presented here. Only tables that contained data were considered in the mapping presented here.

Table 12: Database table entity mapping

Description	NGA Table Name	GRIP Table Name
Basic borehole information	*GeositeInfo*	*basicinf*
Abstraction	*Abstraction*	*mreading*
Casing information	*Casing*	*casing__*
Chemistry	*Chemistry*	*chem_000*
		chem_001
		chem_002
		chem_003
		chem_004
		chem_005
Comments	-	*comments*
Construction information	*Construction*	*constrct*
Depth and diameter information	*Depth*	*basicinf*
		holediam
Discharge information	*Discharge*	*discharg*
EC profile	*Field*	*eleccond*
Equipment information	*Equipment*	*installa*

Description	NGA Table Name	GRIP Table Name
		instdetl
Field chemistry information	*Field*	*Userchem*
		*fldmeas_*
Geosite status information	*GeositeStatus*	*basicinf*
Lithological information (borehole logs)	*Lithology*	*geology_*
Material information	*Material*	*holefill*
Operational information	*Operation*	*recommnd*
Other number information	*Other*	*otherid_*
Owner information	*Owner*	*nameownr*
Piezometer information	*Piezometer*	*piezomet*
Pump test information	*PumpTest*	*pumptest*
		testdetl
Reference information	*Reference*	*reference*
Screen information	*Screen*	*casing_*
Water level information	*WaterLevel*	*waterlev*
Water strike information	*WaterStrike*	*aquifer_*
Yield test information	*YieldTest*	*waterlev*

5.2 DESIGN CONSIDERATIONS

This section deals with design considerations as related to required functionality of the system.

5.2.1 Database Hosting

The chosen development platform for the mobile app is ESRI AppStudio and the associated database is an accompanying ArcGIS Online (AGO) database.

5.2.2 User Management

AGO already provides a user management system through its own portal interface for the online database. The mobile app and desktop app makes use of this login information to allow access to the system. Public users not belonging to an organization that already uses AGO can register a public account as shown in Figure 37.

Users can follow the prompt on the app to take them to the registration page or alternatively go directly to the following weblink:

https://www.arcgis.com/sharing/rest/oauth2/signup?client_id=arcgisonline&redirect_uri=http://www.arcgis.com&response_type=token

Both the desktop and mobile app requires a valid AGO login to have access to the system, so no support is given to anonymous users.

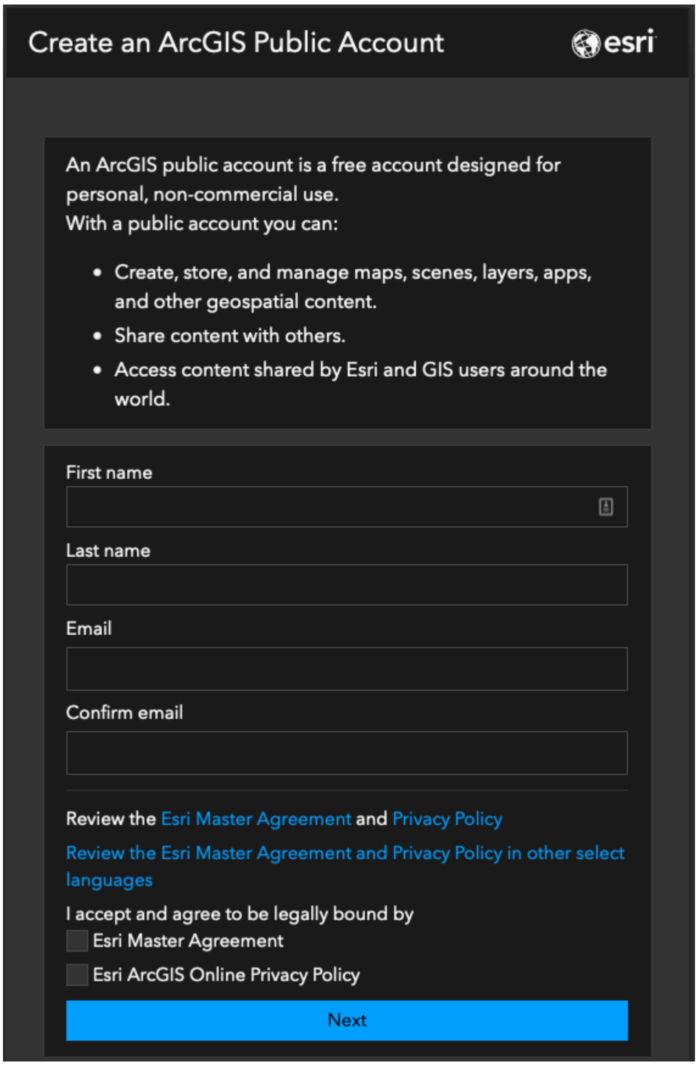


Figure 37: ArcGIS public account creation

This user management system is therefore adopted by the mobile application but requires extension to manage a credit and rating system associated with users as discussed in a previous section. For this purpose, two additional tables are created within the geodatabase to accommodate the credit and rating functionality. These additional tables are presented in Table 13 and Table 14.

The reason for repeating the capture of the user information that was already captured as part of creating an AGO account, is that the user can choose which personal information should be displayed in the app since the system has to take the Protection of Personal Information (PoPI) act into consideration.

Table 13: Observer table

OBSERVER	
Field Name	**Description**
AGOName	ID obtained from AGO login portal
FirstName	User first name that will appear on app
LastName	User last name that will appear on app
Email	User email that will appear on app
Phone	User phone number that will appear on app
Rating	User rating (0-10 stars = 0-5 starts, 11 = 6 stars)
Credits	User credits based on data contribution
OrgGUID	Organisation ID to link user to specific organisation
OrgStatus	Organisation status: 0 = User not linked to organization 1 = User linked to organization 2 = User request to organization pending

Table 14: Organization table

ORGANISATION	
Field Name	**Description**
OrgGUID	Organization GUID
AGO_Admin0	Administrator ID's (obtained from AGO UserID) that can approve users to the organisation.
AGO_Admin0	
AGO_Admin0	
Name	Organization name
Email	Organisation contact email
Phone	Organisation contact phone
Website	Organisation website
Credits	Credit pool

5.3 DATA STRUCTURE

5.3.1 Preamble

The existing table structures for both the NGA and GRIP databases consists of a relational database structure where a table represents a specific entity, and the table fields the associated properties. Some tables may have multiple attributes, but in the context of a mobile app, users might only update one attribute at a time, which could lead to a sparse database structure. In addition, from a mobile app perspective it is important that user changes and updates be tracked and that it is not allowed that one user can overwrite another user's data.

5.3.2 Geodatabase

A geodatabase is a database that is optimised for storing and querying data that represents objects defined in a geometric space. Most spatial databases allow the representation of simple geometric objects such as points, lines, and polygons.

The NGA and GRIP databases are relational databases where the borehole (point) is either in a 1:1 (one-to-one) or 1:M (one-to-many) relationship with various data entities represented by tables. The structure of the app geodatabase is presented in Figure 38 which relates each data entity in 1:M relationship with the locality information and data entities with lookup values are related 1:1 to the lookup table.

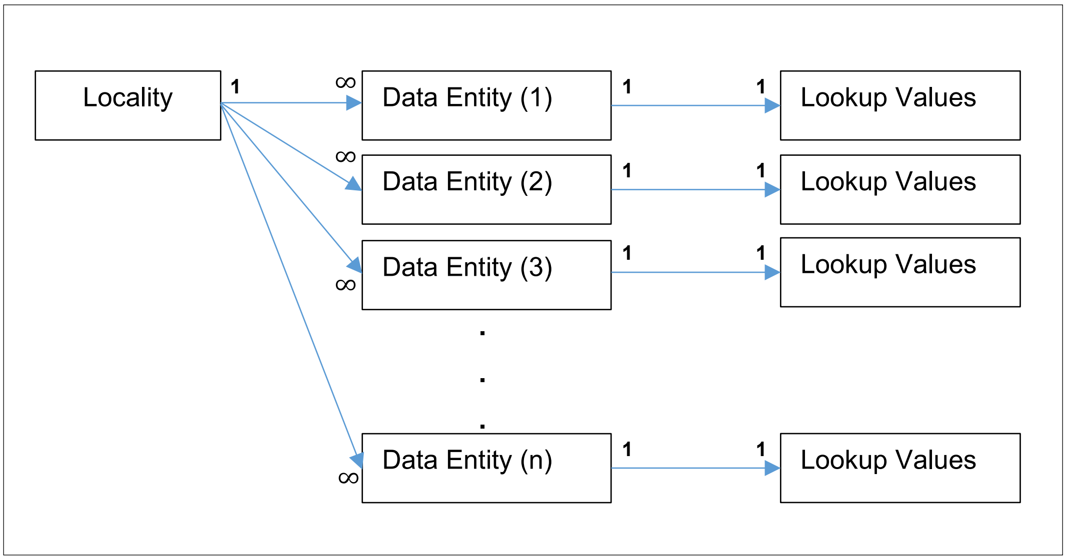


Figure 38: Geodatabase structure

The reason for this structure is that there is a requirement that one user cannot overwrite another users' data which implies a 1:M relationship of all data entities regardless of the physical relationship of such data entity.

Editor tracking is enabled on all database tables therefore the system managed fields presented in Table 15 will accompany all tables in the geodatabase.

Table 15: System managed editor tracking fields

Field Name	Description
Editor	UserID of editor (AGO system managed)
EditDate	Timestamp of edit (AGO system managed)
Creator	UserID of creator (AGO system managed)
CreationDate	Timestamp of creation (AGO system managed)

5.3.3 Generation Locality ID

Since both source databases NGA and GRIP allocated their own unique site id when new data was captured, these existing locality id's are preserved in the database. Similarly, the mobile app database requires a method to generate a unique ID for newly captured data and often the app might be operated in offline mode during new data capture. Various methods were considered including What-Three-Words, but the final implementation uses the latitude and longitude of a locality and converts it into a 12-digit ID which has a resolution of less than 10 cm on the ground.

The latitudinal and longitudinal and extent of South Africa is presented in Figure 39.

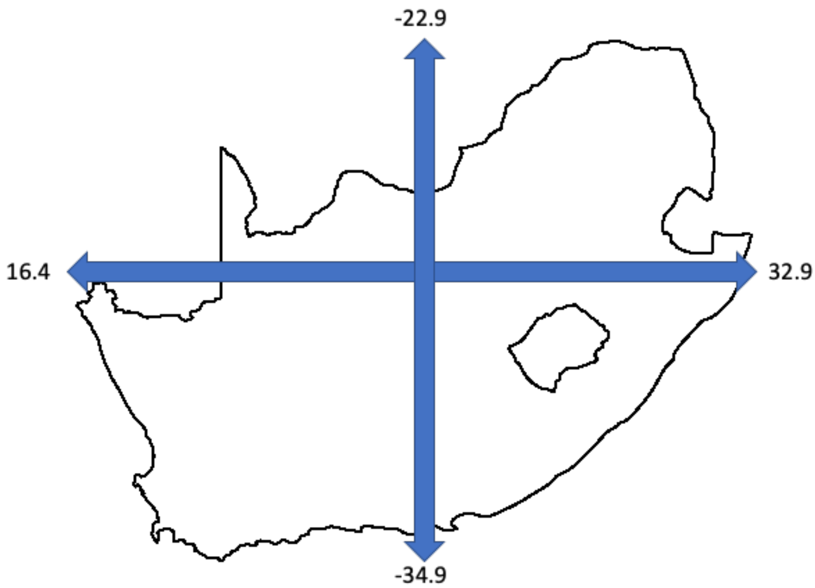


Figure 39: Latitudinal and longitudinal extent of South Africa

From Figure 39 it is clear that the difference in latitude is 12 degrees and the difference in longitude is 16 degrees when only considering the integer part of the calculation. Since a hexadecimal number has a maximum value of 16, we can represent the latitude and longitude integer part of any coordinate in South Africa with a hexadecimal character through the following formulation:

$$LatDegrees_{hex} = IntToHex(abs(DD) - 22) \tag{1}$$

$$LonDegrees_{hex} = IntToHex(DD - 16) \tag{2}$$

Where the coordinate pair is represented in decimal degrees as:

Latitude: -DD.dddddd

Longitude: DD.dddddd

The decimal part (6 decimals) of the latitude and longitude can also be converted to hexadecimal values as follows:

$$LatDecimals_{hex} = IntToHex(0.dddddd \times 1000000) \tag{3}$$

$$LonDecimals_{hex} = IntToHex(0.dddddd \times 1000000) \tag{4}$$

Finally, a concatenation of the obtained hexadecimal strings in the following format will deliver the generated locality ID:

$$LocalityID = LatDegrees_{hex} + LonDegrees_{hex} + LatDecimals_{hex} + LonDecimals_{hex} \tag{5}$$

As an example, consider the following coordinate and the generated ID based on the method described:

$$-34.820720\,,20.014630 \;\rightarrow\; C4C85F003926$$

The advantage of this approach is that the locality id can be generated in the field even if there is no data connection because the latitude and longitude will be available via the GPS module and secondly, the ID can be converted back to the exact coordinate pair used to generate it.

It can be argued that the latitude and longitude coordinate to 6 decimal places could have been used as is and would result in a 16-digit number which could also have been used. Although this is true, the described method has 4-digits less and this makes it easier to read as shown below:

$$3482072020014630 \;vs\; C4C85F003926$$

5.4 DATABASE ENTITIES

The following sections present the different data entities present in the geodatabase, with the exclusion of the Observer and Organization entities that was discussed in a previous section.

5.4.1 Lookup Entities

All tables comprising of lookup values have the same structure and is shown in Table 16. To avoid repetition, the table structure will only be presented here and only the content will be shown in subsequent sections as required.

Table 16: Generic lookup table structure

Locality Table	
Field	Type
ID	INTEGER
Description	TEXT (100)

By storing the lookup values in the geodatabase, it is convenient to add more selections or even change a description without having to change any source code of the software. The current values populated in these tables originate from the values obtained from the NGA and GRIP databases.

5.4.2 Locality

Locality data represent the physical site positions which is used to create the spatial feature layer in the geodatabase that is hosted in AGO. Currently these include boreholes and rainfall measurement points. Each site has a unique *LocalityID* which serves the primary key in the relationships to the other data entities. The locality layer for the merged result between the NGA and GRIP is shown in Figure 40 as it appears in AGO.

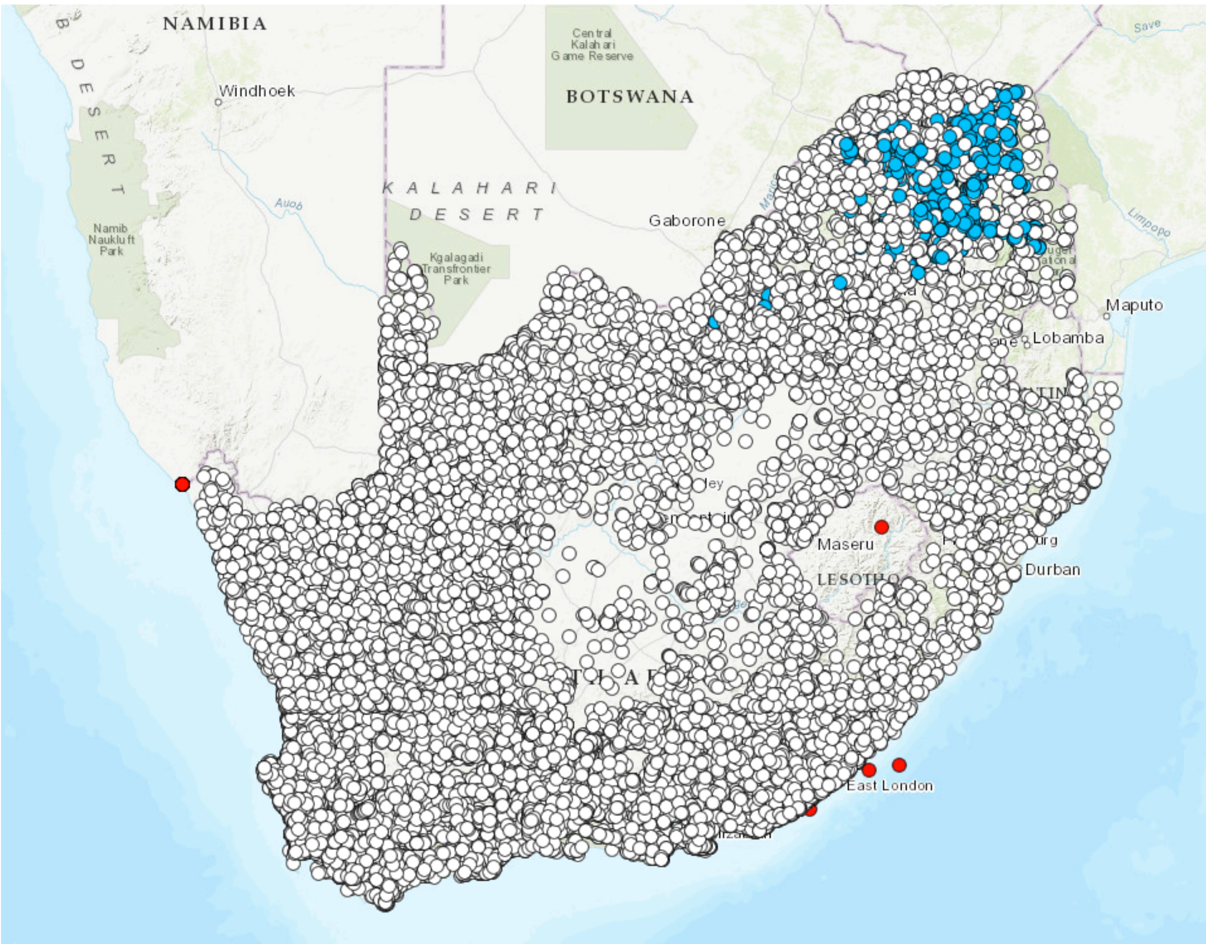


Figure 40: Locality feature layer

Newly created sites will automatically be added to the associated spatial layer with the attribute list presented in Table 17. All fields shown in bold refers to an ID associated with a lookup table and this convention is applied throughout the sections that follow.

Table 17: Locality table

Locality	
Field	Type
LocalityID	TEXT (24)
Latitude	REAL
Longitude	REAL
MergeID	TEXT (24)
TypeID	INTEGER
StatusID	INTEGER

The lookup values associated with the various IDs is presented in Table 18. The type combined with the status determine the map symbol that is displayed. The map legend based on these combinations is presented Figure 41 where BH refers to borehole and RG to rain gauge.

Table 18: Lookup fields associated with Locality

Type		Status	
0	Not Assigned	0	Not Verified
1	Borehole	1	Verified
2	Rain Gauge	2	Non-Existent
		3	Verified (Pending)
		4	Non-Existent (Pending)

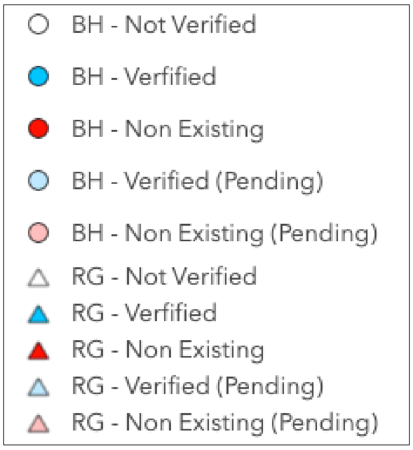


Figure 41: Locality feature layer map legend

5.4.3 Basic Information

The **BasicInfo** table is presented in Table 19 and this table mainly consist of lookup values for the user to select and is aimed at the novice user, not being able to measure specific parameters.

Table 19: Basic information table

BasicInfo	
Field	Type
LocalityID	TEXT (24)
StatusID	INTEGER
PurposeID	INTEGER
ConsumerID	INTEGER
PotabilityID	INTEGER
UseID	INTEGER

The lookup values associated with the various IDs are presented in Table 20 and Table 21.

Table 20: Lookup fields associated with BasicInfo

Status		Purpose		Potability	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Destroyed	1	Dewatering	1	Very good
2	Dry	2	Drainage	2	Fresh
3	In use	3	Exploration	3	Brack
4	Standby (Production)	4	Mine drainage	4	Salty
5	Unused	5	Observation	5	Good for human consumption (Class 0 & 1)
6	Abandoned	6	Other	6	Marginal for human consumption (Class 2)
7	Inaccessible	7	Production (water supply)	7	Unsuitable for all consumption (Class 3 & 4)
		8	Quality monitoring	8	For animals only
		9	Recharge	9	From chemistry
		10	Standby		
		11	Waste disposal		

Table 21: Lookup fields associated with BasicInfo (continued)

Consumer		Use	
0	Not Assigned	0	Not Assigned
1	Clinic	1	Agriculture
2	Communal Enterprise	2	Agriculture, Bulk Water Supply
3	Community Centre	3	Agriculture, Commercial
4	Drop In	4	Agriculture, Commercial, Mining
5	Emergency Medical Centre	5	Agriculture, Domestic
6	Farm(s)	6	Agriculture, Domestic, Bulk Water Supply
7	Farmer: Individual	7	Agriculture, Domestic, Bulk Water Supply, Public
8	Game / Nature Reserve	8	Agriculture, Domestic, Gardening
9	Garden(s)/Park(s)	9	Agriculture, Domestic, Mining
10	Government Building	10	Agriculture, Domestic, Public
11	Hospital	11	Agriculture, Industrial
12	Land Owner: Individual	12	Agriculture, Irrigation
13	Livestock	13	Agriculture, Irrigation, Domestic
14	Malaria Camp	14	Agriculture, Irrigation, Domestic, Bulk Water Supply, Gardening
15	Municipality: District	15	Agriculture, Irrigation, Domestic, Gardening
16	Municipality: Local	16	Agriculture, Irrigation, Stock Watering
17	Non-urban	17	Agriculture, Irrigation, Stock Watering, Domestic
18	Nursery	18	Agriculture, Irrigation, Stock Watering, Domestic, Bulk Supply, Gardening
19	One Stop Facility	19	Agriculture, Irrigation, Stock Watering, Domestic, Bulk Water Supply, Public
20	Other	20	Agriculture, Irrigation, Stock Watering, Domestic, Gardening
21	Place of Safety	21	Agriculture, Irrigation, Stock Watering, Domestic, Gardening, Industrial
22	Police Station	22	Agriculture, Irrigation, Stock Watering, Domestic, Conservation, Mining
23	Poultry	23	Agriculture, Stock Watering
24	Prison	24	Agriculture, Stock Watering, Domestic
25	Private	25	Agriculture, Stock Watering, Domestic, Public
26	Research Institution	26	Bulk Water Supply
27	School	27	Bulk Water Supply, Nature Conservation
28	Small-holder: Individual	28	Bulk Water Supply, Nature Conservation, Industrial

29	Sports Field/Complex	29	Commercial
30	Urban	30	Commercial, Mining
31	Water disposed	31	Domestic
32	Welfare Facility	32	Domestic, Bulk Water Supply
		33	Domestic, Bulk Water Supply, Public
		34	Domestic, Commercial
		35	Domestic, Gardening
		36	Domestic, Nature Conservation
		37	Domestic, Public
		38	Gardening
		39	Industrial
		40	Industrial, Mining, Power Station
		41	Irrigation
		42	Irrigation, Domestic
		43	Irrigation, Domestic, Gardening
		44	Irrigation, Gardening
		45	Irrigation, Gardening, Recharge
		46	Irrigation, Public
		47	Irrigation, Stock Watering
		48	Irrigation, Stock Watering, Domestic
		49	Irrigation, Stock Watering, Domestic, Gardening
		50	Mining
		51	Nature Conservation
		52	Power Generation
		53	Public
		54	Recharge
		55	Reservoir
		56	Stock Watering
		57	Stock Watering, Commercial
		58	Stock Watering, Domestic
		59	Stock Watering, Domestic, Bulk Water Supply
		60	Stock Watering, Domestic, Gardening
		61	Stock Watering, Domestic, Public
		62	Stock Watering, Domestic, Reservoir
		63	Stock Watering, Gardening
		64	Stock Watering, Nature Conservation

5.4.4 Casing

The structure of the **Casing** table is presented in Table 22. The GUID is used to group entries associated with the same casing.

Table 22: Casing table

Casing	
Field	Type
LocalityID	TEXT (24)
Date	DATE
GUID	TEXT (32)
CollarHeight	REAL
DepthToTop	REAL
DepthToBottom	REAL
MaterialID	INTEGER
OuterDiameter	INTEGER
InnerDiameter	INTEGER
Thickness	INTEGER
OpeningTypeID	INTEGER
OpeningMethodID	INTEGER
OpeningWidth	INTEGER
OpeningLength	INTEGER
OpeningDiameter	INTEGER

The lookup values associated with the various IDs are presented in Table 23.

Table 23: Lookup fields associated with Casing

Material		Opening Method		Opening Type	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Brass	1	Drilled	1	Bridge slotted casing
2	CasingMaterial	2	Electrical Cutting Rod	2	Louvre or shutter type screen
3	Concrete	3	Gas Cut	3	Mesh screen
4	Copper	4	Machine Cut	4	Open hole
5	Galvanized Iron	5	Punched	5	Perf. or slotted with fibre mesh
6	Galvanized Steel	6	Sawn	6	Perforated or slotted
7	Plain	7	Screen	7	Plain casing
8	Plastic	8	Well point	8	Retrieved after construction
9	PVC	9	Wire wound	9	Screen
10	Sheet Iron	10	Other	10	Well point
11	Stainless Steel			11	Other
12	Steel				
13	Other				

5.4.5 Chemistry Related

The structure of the various chemistry related tables is presented in Table 24 and this structure applies to the following tables in the geodatabase:

- ChemPhysical
- ChemMajor
- ChemMinor
- ChemOrganic
- ChemIsotope
- ChemCalc

Table 24: Chemistry related table

Chemistry Related	
Field	Type
LocalityID	TEXT (24)
DateTime	DATE
Symbol	TEXT (16)
Value	REAL

The Symbol field severs as a lookup ID in the **ChemSymbol** table which has the structure presented in Table 25 and the contents of the table is presented in Appendix D.

Table 25: ChemSymbol table

ChemSymbol	
Field	Type
Symbol	TEXT (16)
Description	TEXT (128)
Unit	TEXT (16)
UnitDesc	TEXT (32)
Type	TEXT (16)

5.4.6 Construction

The structure of the Construction table is presented in Table 26.

Table 26: Construction table

Construction	
Field	Type
LocalityID	TEXT (24)
Date	DATE
Contractor	TEXT (128)
MethodID	INTEGER
FinishingID	INTEGER
DevelopmentID	INTEGER
DrillingID	INTEGER
AdditivesID	INTEGER
SpecialID	INTEGER

The lookup values associated with the various IDs are presented in Table 27 and Table 28.

Table 27: Lookup fields associated with Construction

Method		Finishing		Development	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Cable Tool	1	Brickwork	1	Air lifted with inductor
2	Core Drilling	2	Filter (gravel pack with perforations)	2	Bailed
3	Direct Circulation (Mud Rotary)	3	Gravel pack with screen	3	Compressed air
4	Dug By Hand	4	Horizontal gallery	4	Jetted or washed
5	Hydraulic Rotary	5	Open bottom (partially cased)	5	Pumped
6	Jetting: Well Point	6	Open hole	6	Pumped with air lift
7	Odex	7	Perforated or slotted	7	Surged
8	Reverse Circulation (Mud Rotary)	8	Porous concrete		
9	Rotary Air Percussion	9	Screen		
10	Symmetrix	10	Well point		
11	Other	11	Other		

Table 28: Lookup fields associated with Construction (continued)

Drilling		Additives		Special	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Air	1	Surfactant, Water	1	Brushing
2	Air with Additives	2	Other	2	Chemical (acid, etc.)
3	Water			3	Dry ice
4	Water with Additives			4	Explosives
				5	Hydrofracturing
				6	Other

5.4.7 Depth and Diameter

The structure of the **Depth** table is presented in Table 29. The GUID is used to group entries associated with the same depth profile.

Table 29: Depth table

Depth	
Field	Type
LocalityID	TEXT (24)
Date	DATE
GUID	TEXT (32)
DepthToTop	REAL
DepthToBottom	REAL
Diameter	REAL
QualifierID	INTEGER

The lookup values associated with the various IDs are presented in Table 30.

Table 30: Lookup fields associated with Depth

Qualifier	
0	Not Assigned
1	Measured during Construction
2	Obtained during Site Visit

5.4.8 Discharge

The structure of the **Discharge** table is presented in Table 31.

Table 31: Discharge table

Discharge	
Field	Type
LocalityID	TEXT (24)
DateTime	DATE
Discharge	REAL
TypeID	INTEGER
MethodID	INTEGER

The lookup values associated with the various IDs are presented in Table 32
.

Table 32: Lookup fields associated with Discharge

Type		Method	
0	Not Assigned	0	Not Assigned
1	Airlift	1	Current meter
2	Bailer	2	Estimated
3	Flowing	3	Float Principle (Thalimedes)
4	Pump	4	Flow Meter
		5	Flume
		6	Submerged Orifice
		7	Totalling Meter
		8	Venturi Meter
		9	V-Notches
		10	Volumetric Measurement
		11	Weir
		12	Other

5.4.9 Fill Material

The structure of the **Fill** table is presented in Table 33.

Table 33: Fill table

Fill	
Field	Type
LocalityID	TEXT (24)
Date	DATE
GUID	TEXT (32)
DepthToTop	REAL
DepthToBottom	REAL
TypeID	INTEGER
OuterDiameter	REAL
InnerDiameter	REAL

The lookup values associated with the various IDs are presented in Table 34.

Table 34: Lookup fields associated with Fill

Type	
0	Not Assigned
1	Aggregate
2	Betonite
3	Betonite Sandy Clay Mix
4	Bottom closed (with plug)
5	Casing block
6	Clay

7	Clay/Sand
8	Collapsed material
9	Concrete
10	Drill Cutting
11	Filter pack
12	Gravel (> 2 mm)
13	Gravel Pack
14	Packer
15	Sand (< 2 mm)
16	Sanitary grout seal
17	Silica Sand

5.4.10 Lithology

The structure of the **Lithology** table is presented in Table 35.

Table 35: Lithology table

Lithology	
Field	Type
LocalityID	TEXT (24)
Date	DATE
GUID	TEXT (32)
DepthToTop	REAL
DepthToBottom	REAL
Code	TEXT (4)
PrimaryColorID	INTEGER
SecondaryColorID	INTEGER
ColorQualifierID	INTEGER
CompositionID	INTEGER
PrimaryFabricID	INTEGER
SecondaryFabricID	INTEGER
FabricAttributeID	INTEGER
TextureID	INTEGER
HardnessID	INTEGER
RoundnessID	INTEGER
SortingID	INTEGER
WeatheringID	INTEGER
FracturingID	INTEGER

The Code field severs as a lookup ID in the **LithologyCode** table which has the structure presented in Table 36 and the contents of the table is presented in Appendix E.

Table 36: LithiologyCode table

LithologyCode	
Field	Type
Code	TEXT (4)
Description	TEXT (64)
MaterialType	TEXT (16)
FormationType	TEXT (16)
DetailDescription	TEXT (512)

The lookup values associated with the various IDs are presented in Table 37 to Table 40.

Table 37: Lookup fields associated with Lithology

ColorQualifier		**Composition**		**FabricAttribute**		**Fracturing**	
0	Not Assigned	0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Bright	1	Arenaceous	1	Highly	1	Highly
2	Dark	2	Argillaceous	2	Moderately	2	Moderately
3	Dull	3	Calcareous	3	Slightly	3	Slightly
4	Light	4	Calcitic			4	Unfractured
5	Lustrous	5	Carbonaceous				
		6	Cherty				
		7	Chloritic				
		8	Feldspathic				
		9	Ferrugeneous				
		10	Glaucontic				
		11	Graphitic				
		12	Heavy minerals bearing				
		13	Hornblende Rich				
		14	Kaolinitic				
		15	Micaceous				
		16	Mineralized				
		17	Peaty				
		18	Phosphorite bearing				
		19	Pyritic				
		20	Quartzitic				
		21	Siliceous				

Table 38: Lookup fields associated with Lithology (continued)

Hardness		**PrimaryColor**		**SecondaryColor**	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Hard	1	Black	1	Bluish
2	Moderate	2	Blue	2	Brownish

3	Soft	3	Brown	3	Dark
		4	Cream	4	Greenish
		5	Green	5	Greyish
		6	Grey	6	Light
		7	Orange	7	Olive
		8	Pink	8	Orange
		9	Purple (Magenta)	9	Pinkish
		10	Red	10	Purplish
		11	White	11	Reddish
		12	Yellow	12	Yellowish

Table 39: Lookup fields associated with Lithology (continued)

Roundness		PrimaryFabric		SecondaryFabric	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Angular	1	Arenaceous	1	Arenaceous
2	Angular To Subangular	2	Argillaceous	2	Argillaceous
3	Angular To Subrounded	3	Baked	3	Baked
4	Angular to Rounded	4	Banded	4	Banded
5	Rounded	5	Bedded	5	Bedded
6	Subangular	6	Brecciated	6	Brecciated
7	Subangular To Subrounded	7	Bright	7	Bright
8	Subangular to Rounded	8	Broken	8	Broken
9	Subrounded	9	Calcareous	9	Calcareous
10	Subrounded To Rounded	10	Carbonaceous	10	Carbonaceous
		11	Cemented	11	Cemented
		12	Chert rich	12	Chert rich
		13	Chloritic	13	Chloritic
		14	Clayey	14	Clayey
		15	Coarse	15	Coarse
		16	Coarse grained	16	Coarse grained
		17	Consolidated	17	Consolidated
		18	Cross-bedded	18	Cross-bedded
		19	Crystalline	19	Crystalline
		20	Dark	20	Dark
		21	Dull	21	Dull
		22	Feldspathic	22	Feldspathic
		23	Ferruginous	23	Ferruginous
		24	Fibrous	24	Fibrous
		25	Fine	25	Fine
		26	Fine grained	26	Fine grained
		27	Fractured	27	Fractured
		28	Fresh	28	Fresh
		29	Glauconitic	29	Glauconitic
		30	Granular	30	Granular
		31	Graphitic	31	Graphitic
		32	Gravel-bearing	32	Gravel-bearing

	33 Gravelly	33 Gravelly
	34 Gritty	34 Gritty
	35 Hard	35 Hard
	36 Heavy minerals	36 Heavy minerals
	37 Hornblende-rich	37 Hornblende-rich
	38 Interlaminated	38 Interlaminated
	39 Jointed	39 Jointed
	40 Kaolinitic	40 Kaolinitic
	41 Laminated	41 Laminated
	42 Light	42 Light
	43 Loose	43 Loose
	44 Lustrous	44 Lustrous
	45 Manganiferous	45 Manganiferous
	46 Massive	46 Massive
	47 Medium	47 Medium
	48 Medium grained	48 Medium grained
	49 Micaceous	49 Micaceous
	50 Mineralised	50 Mineralised
	51 Oolitic	51 Oolitic
	52 Peaty	52 Peaty
	53 Pebbly	53 Pebbly
	54 Phosphoritic	54 Phosphoritic
	55 Porphyritic	55 Porphyritic
	56 Primary	56 Primary
	57 Pyllitic	57 Pyllitic
	58 Pyritic	58 Pyritic
	59 Quartz-rich/quartzitic	59 Quartz-rich/quartzitic
	60 Sandy	60 Sandy
	61 Secondary	61 Secondary
	62 Shaly	62 Shaly
	63 Shelly	63 Shelly
	64 Siliceous	64 Siliceous
	65 Silicified	65 Silicified
	66 Silty	66 Silty
	67 Soft	67 Soft
	68 Solid	68 Solid
	69 Unconsolidated	69 Unconsolidated
	70 Weathered	70 Weathered

Table 40: Lookup fields associated with Lithology (continued)

Sorting	Texture	Weathering
0 Not Assigned	0 Not Assigned	0 Not Assigned
1 Moderately sorted	1 Coarse	1 Completely
2 Moderately to poorly sorted	2 Coarse and fine	2 Highly
3 Moderately to well sorted	3 Coarse and medium	3 Medium
4 Poorly sorted	4 Coarse to very coarse	4 Partially/Slightly

5	Poorly to moderately sorted	5	Coarse to very fine	5	Unweathered
6	Unsorted	6	Crypto		
7	Well sorted	7	Fine		
8	Well to moderately sorted	8	Fine and very fine		
		9	Fine to coarse		
		10	Fine to medium		
		11	Fine to very coarse		
		12	Medium		
		13	Medium and fine		
		14	Medium and very fine		
		15	Medium to coarse		
		16	Medium to very coarse		
		17	Micro		
		18	Very coarse		
		19	Very coarse and coarse		
		20	Very coarse and fine		
		21	Very coarse and medium		
		22	Very coarse and very fine		
		23	Very fine		
		24	Very fine to coarse		
		25	Very fine to fine		
		26	Very fine to medium		
		27	Very fine to very coarse		

5.4.11 Other Number

The structure of the **OtherNumber** table is presented in Table 41.

Table 41: OtherNumber table

OtherNumber	
Field	Type
LocalityID	TEXT (24)
OtherNumber	TEXT (24)
Description	TEXT (100)
TypeID	INTEGER

The lookup values associated with the various IDs are presented in Table 42.

Table 42: Lookup fields associated with OtherNumber

Type	
0	Not Assigned
1	Map Number
2	Observer Number
3	Other Number

5.4.12 Pump

The structure of the **Pump** table is presented in Table 43.

Table 43: Pump table

Pump	
Field	Type
LocalityID	TEXT (24)
InstallDate	DATE
TypeID	INTEGER
DepthToIntake	REAL
PowerSourceID	INTEGER
PowerRating	REAL
ManufacturerID	INTEGER
OtherManufacturer	TEXT (32)
Model	TEXT (32)
SerialNumber	TEXT (32)
RiserMaterialID	INTEGER
RiserDiameter	REAL

The lookup values associated with the various IDs are presented in Table 44.

Table 44: Lookup fields associated with Pump

Manufacturer		**PowerSource**		**RiserMaterial**	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Afridev Hand Pumps	1	Compressed Air	1	Flexible Hosing
2	Alstom - GEC Alsthom	2	Electricity	2	PVC
3	Andrag, P & Sons	3	Fuel	3	Steel
4	Aquapump (Pty) Ltd	4	Hand	4	Steel Galvanised
5	Barry Pumps	5	Solar	5	Steel Stainless
6	Briggs & Stratton	6	Wind		
7	Brisan Pumps	7	Other		
8	Bush Pump				
9	C.R.I. Pumps				
10	Cemo Pumps (Pty) Ltd				
11	Climax				
12	Dempster Industries Inc				
13	Denorco				
14	Elsumo				
15	Flowserve				
16	Franklin Electric SA (Pty) Ltd				
17	Gearing & Jameson Ltd				
18	Grundfos A/S				

19	Handmade		
20	Howden Pumps		
21	ITT Goulds Pumps		
22	Jaccuzi Borehole & Submersible		
23	Jooste Cylinder & Pump Co		
24	Jordan		
25	Lister Pumps		
26	LM & Gately Engineering Works		
27	Lowara Pumps		
28	Malcomes		
29	Meera Pumps (Pty) Ltd		
30	Mellor Pumps		
31	Mono Pumps Ltd		
32	National Pump Company		
33	Oasis Pumps Manufacturing		
34	Orbit Pump Manufacturing		
35	Playpumps International		
36	President Engineering		
37	Pumpmaker (Super D Pumps)		
38	Rapid Allweiler		
39	Salister Diesels (Pty) Ltd		
40	Salsub		
41	Southern Cross Industries		
42	Speroni Pompe		
43	Stewarts & Lloyds		
44	Versalite		
45	Yanmar		
46	Other		

5.4.13 Pump Test

The structure of the **PumpTest** table is presented in Table 45.

Table 45: PumpTest table

PumpTest	
Field	**Type**
LocalityID	TEXT (24)
GUID	TEXT (32)
TypeID	INTEGER
StartDateTime	DATE
EndDateTime	DATE
Duration	INTEGER
DepthToIntake	REAL
Discharge	REAL

The lookup values associated with the various IDs are presented in Table 46.

Table 46: Lookup fields associated with PumpTest

Type	
0	Not Assigned
1	Calibration
2	Constant Yield
3	Multi-Rate
4	Step
5	Slug Test
6	Specific Capacity

5.4.14 Pump Test Observation

The structure of the **PumpTestObservation** table is presented in Table 47. The GUID associates the *ObservationID* with a specific pump test and the *ObservationID* is the *LocalityID* of the borehole used as observation.

Table 47: PumpTestObservation table

PumpTestObservation	
Field	Type
LocalityID	TEXT (24)
GUID	TEXT (32)
ObservationID	TEXT (24)

5.4.15 Pump Test Parameters

The structure of the **PumpTestParams** table is presented in Table 48. The GUID associates the pump test analysis parameters with a specific pump test.

Table 48: PumpTestParams table

PumpTestParams	
Field	Type
LocalityID	TEXT (24)
GUID	TEXT (32)
Transmissivity	REAL
Permeability	REAL
Storage	REAL
SpecificCapacity	REAL

5.4.16 Rainfall

The structure of the **Rainfall** table is presented in Table 49.

Table 49: Rainfall table

Rainfall	
Field	Type
LocalityID	TEXT (24)
DateTime	DATE
Rainfall	REAL
MethodID	INTEGER

The lookup values associated with the various IDs are presented in Table 50.

Table 50: Lookup fields associated with Rainfall

Type	
0	Not Assigned
1	Non-Recording: Manual
2	Recording: Floating Type
3	Recording: Tipping Bucket
4	Recording: Weighing Bucket
5	Radar

5.4.17 Recommended

The structure of the **Recommended** table is presented in Table 51.

Table 51: Recommended table

Recommended	
Field	Type
LocalityID	TEXT (24)
Date	DATE
Priority	INTEGER
PurposeID	INTEGER
PumpID	INTEGER
PowerID	INTEGER
DepthToIntake	REAL
Abstraction	REAL
DutyCycle	INTEGER
DynamicLevel	REAL
CriticalLevel	REAL

The lookup values associated with the various IDs are presented in Table 52.

Table 52: Lookup fields associated with Recommended

Purpose		Pump		Power	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Monitoring	1	Airlift	1	Diesel engine
2	Production	2	Centrifugal pump	2	Electric motor
		3	Gravity suction	3	Hand
		4	Hand pump	4	Wind
		5	Jet	5	Other
		6	Mono Type Pump		
		7	No equipment		
		8	Observation tube		
		9	Piston pump		
		10	Positive Displacement		
		11	Powerhead		
		12	Recorder		
		13	Submersible Pump		
		14	Turbine		
		15	Windpump		
		16	Windpump with powerhead		
		17	Other		

5.4.18 Sample

The structure of the **Sample** table is presented in Table 53.

Table 53: Sample table

Sample	
Field	Type
LocalityID	TEXT (24)
DateTime	DATE
SampleNo	TEXT (24)
AltNumber	TEXT (24)
TypeID	INTEGER
MethodID	INTEGER
TimePumped	REAL
Depth	REAL
LabDate	DATE
LabID	INTEGER
LabOther	TEXT (40)

The lookup values associated with the various IDs is presented in Table 54.

Table 54: Lookup fields associated with Sample

Type		Method		Lab	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Drinking water	1	Airlift	1	OTHER
2	Effluent	2	Bail	2	ALS
3	Groundwater	3	Pumped	3	Aquactico
4	Irrigation water			4	ARC
5	Organic			5	Capricorn
6	Other source			6	Clean Stream
7	Pressed or pellet			7	CSIR
8	Rainwater			8	CVL
9	Recycled water			9	EcoAnalytica
10	Rock			10	Envirocare
11	Sewage			11	Enviroserve
12	Soil			12	ERWAT
13	Surface water (river/dam)			13	IGS
14	Water from dewatering			14	KGC
				15	Labserve
				16	M&L
				17	Midvaal
				18	MSA
				19	NECSA
				20	Rand Water
				21	Regen
				22	SABS
				23	Sedibeng
				24	Set Point
				25	SGS
				26	Simlab
				27	Talbot
				28	Testit
				29	UIS
				30	Vinlab
				31	Waterlab

5.4.19 Site Information

The structure of the **SiteInfo** table is presented in Table 55. The Latitude and Longitude presented in this table does not affect the coordinate of the site in the locality feature layer. These fields allow the user to capture the coordinate based on the selected survey method employed.

Table 55: SiteInfo table

SiteInfo	
Field	Type
LocalityID	TEXT (24)
Latitude	REAL
Longitude	REAL
Elevation	REAL
TypeID	INTEGER
CoordMethodID	INTEGER
ElevationMethodID	INTEGER
ElevationReferenceID	INTEGER
StatusID	INTEGER

The lookup values associated with the various IDs are presented in Table 56.

Table 56: Lookup fields associated with SiteInfo

CoordMethod		ElevationMethod		ElevationReference	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Differential GPS with Base Station	1	Altimeter	1	Casing Collar
2	Differential GPS without Base Station	2	Arcview / DEM	2	Concrete Block
3	District and Farm Name and Number	3	Differential GPS with Base Station	3	Ground Surface
4	Estimated 1:10 000 map	4	Differential GPS without Base Station		
5	Estimated 1:50 000 map	5	District and Farm Name and Number		
6	Estimated 1:250 000 map	6	Estimated 1:10 000 map		
7	Global Positioning System (Hand-held)	7	Estimated 1:50 000 map		
8	Surveyed	8	Estimated 1:250 000 map		
		9	Global Positioning System (Hand-held)		
		10	Google Maps API / Google Earth		
		11	Surveyed		

5.4.20 Water Level

The structure of the **WaterLevel** table is presented in Table 57.

Table 57: WaterLevel table

WaterLevel	
Field	Type
LocalityID	TEXT (24)
ReferenceID	INTEGER
Reference	REAL

MethodID	INTEGER
StatusID	INTEGER
Piezometer	TEXT (2)
DateTime	DATE
WaterLevel	REAL

The lookup values associated with the various IDs are presented in Table 58.

Table 58: Lookup fields associated with WaterLevel

Reference		**Method**		**Status**	
0	Not Assigned	0	Not Assigned	0	Not Assigned
1	Casing Collar	1	Airline	1	Affected by Pump (In Hole)
2	Concrete Block	2	Autographic Recorder	2	Affected by Pump (Nearby)
3	Ground Surface	3	Capacity Probe	3	Artesian
4	Intelligent Top Cap (ITC)	4	Dip Meter	4	Drawdown
		5	Electronic Data Logger	5	Obstructed
		6	Estimated	6	Recovery
		7	Geophysical Logging Unit	7	Static Water Level
		8	Pressure Gauge Measurement	8	Suspect Data
		9	Reported	9	Temporarily Dry
		10	Steel Tape		

5.4.21 Water Strike

The structure of the **WaterStrike** table is presented in Table 59.

Table 59: WaterStrike table

WaterStrike	
Field	Type
LocalityID	TEXT (24)
Date	DATE
GUID	TEXT (32)
DepthToTop	REAL
DepthToBottom	REAL
Yield	REAL
TypeID	INTEGER
MethodID	INTEGER

The lookup values associated with the various IDs are presented in Table 60.

Table 60: Lookup fields associated with WaterStrike

Type		Method	
0	Not Assigned	0	Not Assigned
1	Fractured	1	Estimated
2	Intergranular	2	Float Principle (Thalimedes)
3	Intergranular and Fractured	3	Flow Meter
4	Karst	4	Other
5	Cavity	5	Submerged Orifice
6	Contact Zone	6	V-Notches
7	Solution channel	7	Volumetric Measurement (Container and Stop)
8	Weathered basin	8	Current Meter
		9	Flume
		10	Venturi meter
		11	Weir

CHAPTER 6: CONCLUSIONS & RECCOMENDATIONS

The means of assessing whether this endeavour is appropriate and has the potential to prosper was to follow the suitability criteria designed by Pocock *et al.* (2014) and the success factors described by Garcia-Soto *et al.* (2017). The assessment was found to favour the project for citizen science for several reasons. It sets a clear purpose as to what the citizen science is intended for, i.e. to improve access to groundwater data for all stakeholders, assess groundwater status and facilitate informed decision-making in groundwater management. It initiates meaningful citizen engagement by enabling the public to contribute to, and draw from, the database. It also introduces a star rating mechanism to verify the quality of data on the database.

The two suitability criteria that were rated the lowest was the resources available to the project and the motivation of the participants. The issue of resources is easily overcome, but the challenge will be the motivation of participants. Various app's exists where citizen science is used to gather data, e.g. logging information about frogs and people find this exciting. The problem with a borehole is that the public might not find it as exciting as "chasing frogs".

Other deterrents include the complexity of data collection in the field as well as the usability of the application. The public may not have the technical acumen nor the instruments for collecting borehole data which professionals do. How would the public be incentivised to take part? Pocock *et al.* (2014) identify the public's affinity to becoming part of a narrative. The sense of community gained from sharing groundwater data with others may be a draw. A sense of jeopardy is also identified as an incentive. The water shortages in Johannesburg (Monama, 2016) and the prospect of a "Day Zero" in Cape Town (City of Cape Town, 2019) have given citizens a cause for concern which they have addressed with the construction of numerous boreholes (Philander, 2017). This sense of threat may be used to encourage the public to contribute to groundwater monitoring and consequently, assessment and management.

A workshop presented to a diverse audience, to illustrate the use of the mobile application also raised the question on how to keep participants motivated. It was also speculated that groundwater users who have not registered their boreholes will be reluctant to support the use of the system as it will reveal boreholes which authorities are not aware of.

As most boreholes reside in rural areas, a decision was made to also allow the capture of rainfall data since farmers in general keep good record of rainfall as their lively hoods depend on it. The hope is that people will target the app to also log rainfall data and once they see the benefit of that also log borehole information for proper management purposes.

The pilot study indicated that once the application was in use, boreholes captured to the database doubled in number with more than half the contributions coming from the public. Thus, in adding new borehole data to the database, the pilot study is considered as a success, but since it was driven as part of the project, the participation component of it is skewed and there is no assurance that the same results would have been obtained if users were not prompted to take part.

The ESRI products ArcGIS Online and AppStudio allowed for successful development of the mobile application. On final system implementation, when the Observer app will be available to the public a custodian and owner of the system needs to be in place. Since the backend is a database, an administrator is required to perform certain tasks to maintain the database.

The custodian/owner will have to obtain an ArcGIS online license for the hosting of the database and a license for the distribution of the mobile app. The ArcGIS online account is also based on a credit system and the owner buys credits as required. Credits are consumed for various operations, e.g. data storage, queries, etc. The mobile app was designed to only make use of the bare-bones functionality to keep credit consumption to a minimum. Functions like geoprocessing and routing consume a lot of credits and therefore this functionality was not targeted by the mobile app but is easily incorporated in the future should the need arise.

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APPENDIX A – NGA HYDROCENSUS FORM

water & sanitation
Department: Water and Sanitation
REPUBLIC OF SOUTH AFRICA

NGA GROUNDWATER HYDROCENSUS FORM

Mandatory fields are indicated with red text and an asterisk (*).
Conditional Mandatory fields are indicated with green text and a double asterisk (**)

Notes, Tips and/or Preferences are indicated within Brackets ( ).

Owner Information			
1	* Owner Surname * Organisation Name		
2	* Owner Initials, First Name Organisation Reg.No., Abbreviation		
3	* Visit Date (ccyy-mm-dd)		
	Home Address (Owner)		
4	Address Location	☐ Home	
5	Address Type	☐ Postal	☐ Physical
6	Address Text		
7	Suburb		
8	Town/City		
9	Postal Code		
	Business Address (Owner)		
10	Address Location	☐ Business	
11	Address Type	☐ Postal	☐ Physical
12	Building Name		
13	Office Number		
14	Street Name and Number		
15	Suburb		
16	Town/City		
17	Postal Code		
18	Telephone Number Location	☐ Business	☐ Home
19	Contact Type	☐ Switchboard ☐ Cellular ☐ Email	☐ Fax ☐ Telephone
20	Dialling code		
21	Telephone Number		
22	Extension		

Geosite Information			
1	* Data Owner	☐ Dept Water - Eastern Cape ☐ Dept Water - Free State ☐ Dept Water - Gauteng ☐ Dept Water - Kwazulu Natal ☐ Dept Water - Limpopo ☐ Dept of Agriculture ☐ DMR-Department Mineral Resources ☐ DWS - Compliance Monitoring: Industry	☐ Dept Water - Mpumalanga ☐ Dept Water - Northern Cape ☐ Dept Water - North West ☐ Dept Water - Pretoria ☐ Dept Water - Western Cape ☐ Groundwater Consulting Services ☐ Management Authority (COHWHS) ☐ Petroleum Agency South Africa
2	* Identifier		
3	* Reporting Institution		
4	* Geosite Type	☐ Borehole ☐ Drain ☐ Dug Well ☐ Lateral / Radial Arm Collector ☐ Mine	☐ Seepage Pond ☐ Sinkhole ☐ Spring ☐ Tunnel ☐ Well Point
5	* Reference Datum	☐ Cape Datum (Clarke 1880)	☐ Hartbeeshoek Datum (WGS 84)
6	* Latitude	DDMMSS	DD.ddddd
7	* Longitude	DDMMSS	DD.ddddd
8	* Coordinate Method	☐ Differential GPS with Base Station ☐ Differential GPS without Base Station ☐ District and Farm Name and Number ☐ Estimated 1:10 000 map	☐ Estimated 1:250 000 map ☐ Estimated 1:50 000 map ☐ Global Positioning System (Hand-held) ☐ Surveyed
9	** Coordinate GPS Accuracy (m) Estimated Position Error (EPE)		
10	* Elevation (mamsl)		
11	* Elevation Method	☐ Altimeter ☐ Differential GPS with Base Station ☐ Differential GPS without Base Station ☐ District and Farm Name and Number ☐ Estimated 1:10 000 map	☐ Estimated 1:250 000 map ☐ Estimated 1:50 000 map ☐ Global Positioning System (Hand-held) ☐ Surveyed
12	** Elevation GPS Accuracy (m) Estimated Position Error (EPE)		

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13	* Farm		
14	* Farm Number		
15	Geosite Status	☐ Abandoned ☐ Destroyed ☐ Dry ☐ In Use	☐ Inaccessible ☐ Not Drilled ☐ Standby (Production)
16	Date when Status Observed (ccyy-mm-dd)		
17	Map Number		
18	Province	☐ Eastern Cape ☐ Free State ☐ Gauteng ☐ Kwazulu Natal ☐ Limpopo	☐ Mpumalanga ☐ North West ☐ Northern Cape ☐ Western Cape
19	Quaternary Drainage Region		
20	Water Management Area	☐ Berg ☐ Breede ☐ Crocodile (West) and Marico ☐ Fish to Tsitsikama ☐ Gouritz ☐ Inkomati ☐ Limpopo ☐ Lower Orange ☐ Lower Vaal ☐ Luvubu and Letaba	☐ Middle Vaal ☐ Mvoti to Umzimkulu ☐ Mzimvubu to Keiskamma ☐ Olifants ☐ Olifants / Doorn ☐ Thukela ☐ Upper Orange ☐ Upper Vaal ☐ Usutu to Mhlatuze
21	Municipal District		
22	Geomorphology	☐ Alluvial Fan ☐ Flat / Gently Undulating Surface ☐ Hill / Mountain Top ☐ Low Gradient Hill Slope ☐ Near Sinkhole ☐ Raised Terrace	☐ Riparian Zone ☐ Steep Mountain Slope ☐ Unvegetated Shifting Dunes ☐ Valley Floor ☐ Vegetated Dunes ☐ Water Body (Wetlands, Pan, River, Spring)
23	Land Cover	☐ Barren Rock ☐ Cultivated: Commercial Dryland ☐ Cultivated: Permanent – Commercial Irrigated ☐ Cultivated: Permanent – Commercial Sugarcane ☐ Cultivated: Temporary - Commercial Irrigated ☐ Cultivated: Temporary – Commercial Dryland ☐ Cultivated: Temporary Semi-Commercial / Subsistence Dryland ☐ Degraded: Forest and Woodland ☐ Degraded: Grassland ☐ Degraded: Herbland ☐ Degraded: Shrubland and Low Fynbos ☐ Degraded: Thicket and Bushland (etc.) ☐ Dongas and Sheet Erosion Scars ☐ Forest plantations (Indicate Eucalyptus) ☐ Forest plantations (Indicate Pine)	☐ Forest plantations (Indicate Wattle) ☐ Grassland ☐ Herbland ☐ Mines and Quarries ☐ Natural Forest ☐ Natural Forest and Woodland ☐ Shrubland and Low Fynbos ☐ Thicket and Bushland (etc.) ☐ Urban / Built-Up Land: Commercial ☐ Urban / Built-Up Land: Industrial / Transport ☐ Urban / Built-Up Land: Residential ☐ Urban / Built-Up Land: Residential (Small Holdings: Bushland) ☐ Urban / Built-Up Land: Residential (Small Holdings: Grassland) ☐ Urban / Built-Up Land: Residential (Small Holdings: Shrubland) ☐ Urban / Built-Up Land: Residential (Small Holdings: Woodland)
24	Taste of Water	☐ Brack ☐ Fresh	☐ Salty
25	DWAF Geosite Purpose	☐ Dewatering ☐ Drainage ☐ Exploration ☐ Observation	☐ Production (Water Supply) ☐ Recharge ☐ Standby ☐ Waste Disposal
26	Observed / Actual Water Uses	☐ Agriculture ☐ Bulk Water Supply ☐ Commercial ☐ Domestic ☐ Gardening ☐ Industrial ☐ Irrigation	☐ Mining ☐ Nature Conservation ☐ Power Generation ☐ Public ☐ Recharge ☐ Reservoir ☐ Stock Watering

Other Number Information

	* Other Number Type	* Other Number		* Assignor
1	☐ Aquabase Number		17	N/A
2	☐ Borehole Number (BHNO)		18	
3	☐ Boring Branch Number (BBNO)		19	N/A
4	☐ Dept of Water Affairs Forestry Number		20	
5	☐ G Number		21	N/A
6	☐ Hydrocom Number (HYDR)		22	N/A
7	☐ Hydrological Station Number (HSTA)		23	N/A
8	☐ Monitoring Feature ID (MFID)		24	N/A
9	☐ Old Hydrological Station Number (OHST)		25	N/A
10	☐ NGDB Number (SITE ID)		26	N/A
11	☐ Regional Borehole Number (RBHN)		27	N/A
12	☐ T Number		28	N/A
13	☐ W Number		29	N/A
14	☐ Water Level Monitoring Point (WLMP)		30	N/A
15	☐ ZQC QUAL Number		31	N/A
16	☐ ZQM QUAL Number		32	N/A

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Reference Information			
1	* Reference Type	☐ NGA Groundwater Hydrocensus Form	☐ Consultants Report ☐ GH Report
2	* DWAF Library Report Number		
3	* Located at	☐ Dept Water - Eastern Cape ☐ Dept Water - Free State ☐ Dept Water - Gauteng ☐ Dept Water - Kwazulu Natal ☐ Dept Water - Limpopo	☐ Dept Water - Mpumalanga ☐ Dept Water - Northern Cape ☐ Dept Water - North West ☐ Dept Water - Pretoria ☐ Dept Water - Western Cape
4	* Report Name		
5	* Report Date		
6	Non DWAF-Registered Documentation Number		
7	Non DWAF-Registered Documentation Located at	☐ Dept Water - Eastern Cape ☐ Dept Water - Free State ☐ Dept Water - Gauteng ☐ Dept Water - Kwazulu Natal ☐ Dept Water - Limpopo	☐ Dept Water - Mpumalanga ☐ Dept Water - Northern Cape ☐ Dept Water - North West ☐ Dept Water - Pretoria ☐ Dept Water - Western Cape

Construction Completion Information			
1	Construction Completion Date (ccyy-mm-dd)		
2	Construction Cost (Rand)		
3	Construction Method	☐ Augered ☐ Cable Tool ☐ Core Drilling ☐ Direct Circulation (Mud Rotary) ☐ Driven Wells ☐ Dug By Hand ☐ Earth Augers: Bucket ☐ Earth Augers: Hollow-Stem ☐ Earth Augers: Solid Stem	☐ Excavated by Machine ☐ Hydraulic Rotary ☐ Jetting: Percussion Drilling ☐ Jetting: Well Point ☐ Reverse Circulation (Mud Rotary) ☐ Jetting: Well Point ☐ Rotary Air Percussion ☐ Tube Wells ☐ Other
4	Construction Company		
5	Construction Contractor		
6	Drilling Fluid	☐ Air ☐ Air With Additives ☐ Drill Foam	☐ Water ☐ Water With Additives
7	Water Additives	☐ Clay	☐ Polymers
8	Air Additives	☐ Clay ☐ Polymers	☐ Surfactant ☐ Water
9	Additional Additives		

Casing: Observed Information					
1	* Casing Column Number (1 - 9)				
2	Casing Collar Height (m)				
3	* Observed Casing Details	☒ Yes			
4	Casing Material	☐ Concrete ☐ PVC ☐ Other		☐ Stainless Steel ☐ Steel	
5	Other Casing Material				
6	Inner Diameter (mm)	☐ 053.60 mm (2.00") ☐ 063.80 mm (2.50") ☐ 076.60 mm (3.00") ☐ 079.80 mm (3.10") ☐ 093.60 mm (3.75") ☐ 099.92 mm (4.00") ☐ 100.00 mm (4.00") ☐ 103.00 mm (4.00") ☐ 110.80 mm (4.25") ☐ 114.20 mm (4.50")	☐ 123.00 mm (4.75") ☐ 127.00 mm (5.00") ☐ 130.00 mm (5.00") ☐ 141.00 mm (5.50") ☐ 145.00 mm (5.75") ☐ 146.00 mm (5.75") ☐ 150.00 mm (6.00") ☐ 156.00 mm (6.00") ☐ 164.40 mm (6.50") ☐ 167.00 mm (6.50")	☐ 169.00 mm (6.50") ☐ 170.38 mm (6.75") ☐ 175.00 mm (6.75") ☐ 181.60 mm (7.00") ☐ 203.00 mm (8.00") ☐ 205.00 mm (8.00") ☐ 209.00 mm (8.25") ☐ 220.00 mm (8.75") ☐ 227.00 mm (9.00") ☐ 254.00 mm (10.0")	☐ 255.00 mm (10.0") ☐ 261.00 mm (10.25") ☐ 266.70 mm (10.50") ☐ 296.00 mm (11.50") ☐ 305.00 mm (12.00") ☐ 312.00 mm (12.25") ☐ 337.00 mm (13.25") ☐ 344.00 mm (13.50") ☐ 387.00 mm (15.25") ☐
7	Outer Diameter (mm)	☐ 063.00 mm (2.50") ☐ 075.00 mm (3.00") ☐ 090.00 mm (3.50") ☐ 110.00 mm (4.25") ☐ 112.00 mm (4.50") ☐ 113.00 mm (4.50") ☐ 125.00 mm (5.00") ☐ 140.00 mm (5.50")	☐ 142.00 mm (5.50") ☐ 146.00 mm (5.75") ☐ 160.00 mm (6.25") ☐ 165.00 mm (6.50") ☐ 168.00 mm (6.50") ☐ 175.00 mm (6.75") ☐ 179.00 mm (7.00") ☐ 180.00 mm (7.00")	☐ 186.00 mm (7.25") ☐ 200.00 mm (7.75") ☐ 203.00 mm (8.00") ☐ 210.00 mm (8.25") ☐ 216.00 mm (8.50") ☐ 221.00 mm (8.75") ☐ 225.00 mm (9.00") ☐ 250.00 mm (9.75")	☐ 266.00 mm (10.50") ☐ 273.00 mm (10.75") ☐ 280.00 mm (11.00") ☐ 315.00 mm (12.50") ☐ 324.00 mm (12.75") ☐ 349.00 mm (13.75") ☐ 356.00 mm (14.00") ☐ 399.00 mm (15.75")

Depth & Diameter Information							
1	Measurement Date (ccyy-mm-dd)						
2	* Data Source						
3	Reporting Institution						
4	* Depth to Bottom (m)						
5	Penetration Information Available	☐ Yes					
6	Depth Qualifier						
7	Diameter (mm)	☐ < 100 (4.0") ☐ 127 (5.00") ☐ 152 (6.00")	☐ 165 (6.50") ☐ 203 (8.00") ☐ 216 (8.50")	☐ 219 (8.75") ☐ 250 (10.00") ☐ 254 (10.00")	☐ 305 (12.00") ☐ 312 (12.50") ☐ 324 (12.75")	☐ 356 (14.00") ☐ 406 (16.00") ☐ 451 (18.00")	☐ ☐ ☐

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Discharge Rate Information

	* Measurement Date (ccyy-mm-dd)	* Measurement Time (hh:mm)	* Discharge Rate (l/s)
1			
2			
3	Discharge Type	☐ Airlift ☐ Bailer	☐ Flowing ☐ Pump
4	Discharge Method	☐ Estimated ☐ Flow Meter ☐ Flume ☐ Submerged Orifice ☐ Totalling Meter	☐ Venturi Meter ☐ V-Notches ☐ Volumetric Measurement ☐ Weir
5	Data Source	☐ Check by Reporting Institution ☐ Driller's Log ☐ Geo Specialist's Record ☐ Memory	☐ Owner's Record ☐ Pump Operator's Record ☐ Report/File

Water Level Information

1	Reference Point	☐ Casing Collar ☐ Concrete Block	☐ Ground Surface ☐ Intelligent Top Cap (ITC) Platform
2	Piezometer Number		
3	Measuring Method	☐ Airline ☐ Autographic Recorder ☐ Capacity Probe ☐ Dip Meter ☐ Electronic Data Logger ☐ Estimated	☐ Pressure Gauge Measurement ☐ Reported ☐ Steel Tape
4	Water Level Status	☐ Affected by Pump (In Hole) ☐ Affected by Pump (Nearby) ☐ Artesian ☐ Obstructed	☐ Static Water Level ☐ Suspect Data ☐ Temporarily Dry
	* Measurement Date (ccyy-mm-dd)	* Measurement Time (hh:mm)	* Water Level (m)
5			
6			
7	Data Source	☐ Check by Reporting Institution ☐ Driller's Log ☐ Geo Specialist's Record ☐ Memory	☐ Owner's Record ☐ Pump Operator's Record ☐ Report/File

Site Visit Information

1	Visit Date (ccyy-mm-dd)		
2	Visit Reason		
3	* Site Visitor Surname		
4	* Site Visitor Initials		
	Home Address (Site Visitor)		
5	Address Location	☐ Home	
6	Address Type	☐ Postal	☐ Physical
7	Address Text		
8	Suburb		
9	Town/City		
10	Postal Code		
	Business Address (Site Visitor)		
11	Address Location	☐ Business	
12	Address Type	☐ Postal	☐ Physical
13	Building Name		
14	Office Number		
15	Street Name and Number		
16	Suburb		
17	Town/City		
18	Postal Code		
19	Telephone Number Location	☐ Business	☐ Home
20	Contact Type	☐ Switchboard ☐ Cellular ☐ Email	☐ Fax ☐ Land Line
21	Dialling code		
22	Telephone Number		
23	Extension		

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Equipment Installed Information (Monitoring)

1	* Monitoring Type	☐ Abstraction Monitoring ☐ Non Monitoring	☐ Rainfall Monitoring ☐ Water Level Monitoring
	Water Level Monitoring		
2	* Installed Date (ccyy-mm-dd)		3 Decommissioned Date (ccyy-mm-dd)
4	Data Source	☐ Check by Reporting Institution ☐ Driller's Log ☐ Geo Specialist's Record ☐ Memory	☐ Owner's Record ☐ Pump Operator's Record ☐ Report/File
5	* Equipment Type	☐ Autographic Recorder ☐ Electronic Data Logger ☐ Hand ☐ Other	☐ No Equipment ☐ Volumetric Meter (Cummulator)
6	* Electronic Data Logger	☐ Airline bubbler OTT Orphimedes ☐ Other ☐ Shaft encoder OTT Thalimedes ☐ Transducer Aquanaut (OTT) ☐ Transducer: Eijkelkamp Baro ☐ Transducer: Eijkelkamp Diver (CTD) ☐ Transducer: Eijkelkamp Diver (OTD)	☐ Transducer: Eijkelkamp Diver (TD) ☐ Transducer: OTT Mini Orpheus ☐ Transducer: Solinst Barologger ☐ Transducer: Solinst Levellogger LT ☐ Transducer: Solinst Levellogger LTC ☐ Transducer: STS
7	** Other Electronic Data Logger Type		
8	Electronic Data Logger Manufacturer	☐ Eijkelkamp ☐ Other	☐ OTT ☐ STS
9	** Other Electronic Data Logger Manufacturer		
10	Serial Number (Data Logger)		
11	Measurement Method	☐ Airline (Orphimedes) ☐ Echosounder ☐ Other	☐ Float Principal (Thalimedes) ☐ Transducer
	Rainfall Monitoring		
2	* Installed Date (ccyy-mm-dd)		3 Decommissioned Date (ccyy-mm-dd)
4	Data Source	☐ Check by Reporting Institution ☐ Driller's Log ☐ Geo Specialist's Record ☐ Memory	☐ Owner's Record ☐ Pump Operator's Record ☐ Report/File
5	* Equipment Type	☐ Electronic Data Logger ☐ Hand	☐ Volumetric Meter (Cummulator) ☐ Other
6	** Other Equipment Type		
	Abstraction Monitoring Pump		
2	* Installed Date (ccyy-mm-dd)		3 Decommissioned Date (ccyy-mm-dd)
4	Data Source	☐ Check by Reporting Institution ☐ Driller's Log ☐ Geo Specialist's Record ☐ Memory	☐ Owner's Record ☐ Pump Operator's Record ☐ Report/File
5	* Pump Type	☐ Jet ☐ Mono Type Pump ☐ Positive Displacement	☐ Submersible Pump ☐ Turbine
6	Depth to Pump Intake (m below surface)		
7	Pump Power Source	☐ Compressed Air ☐ Electricity ☐ Fuel	☐ Hand ☐ Sun ☐ Wind
8	Power Rating (kW)		
9	Pump Manufacturer		
10	Serial Number		
11	Riser Main Material	☐ Flexible Hosing ☐ uPVC	☐ Steel
12	Riser Diameter (mm)		
	Abstraction Monitoring Meter		
2	Installed Date (ccyy-mm-dd)		3 Decommissioned Date (ccyy-mm-dd)
4	Data Source	☐ Check by Reporting Institution ☐ Driller's Log ☐ Geo Specialist's Record ☐ Memory	☐ Owner's Record ☐ Pump Operator's Record ☐ Report/File
5	Meter Type	☐ Hour Meter (h) ☐ Power Meter (kWh)	☐ Water Meter (m^3)
6	Serial Number		
7	Supplying Company		
8	Supplying Contractor		

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Equipment Installed Information (Non-Monitoring)

1	* Installed Date (ccyy-mm-dd)		2 Decommissioned Date (ccyy-mm-dd)
3	Data Source	☐ Check by Reporting Institution ☐ Driller's Log ☐ Geo Specialist's Record ☐ Memory	☐ Owner's Record ☐ Pump Operator's Record ☐ Report/File
4	* Pump Type	☐ Jet ☐ Mono Type Pump ☐ Positive Displacement	☐ Submersible Pump ☐ Turbine
5	Depth to Pump Intake (m below surface)		
6	Pump Power Source	☐ Compressed Air ☐ Electricity ☐ Fuel	☐ Hand ☐ Sun ☐ Wind
7	Power Rating (kW)		
8	Pump Manufacturer		
9	Serial Number		
10	Riser Main Material	☐ Flexible Hosing ☐ uPVC	☐ Steel
11	Riser Diameter (mm)		

Field Measurement Information

	Sampling point	☐ NON - STATION	☐ STATION
	* Sample #		
1	* Measurement Date (ccyy-mm-dd)		
2	* Measurement Time (hh:mm)		
3	Measurement Depth (m)		
4	* Electrical Conductivity (EC) (mS/m)		
	OR		
5	* pH (values 0-14)		
	OR		
6	* Temperature (° C)		
	OR		
7	* Bicarbonate (HCO_3) (mg/l)		
8	Data Source	☐ Check by Reporting Institution ☐ Driller's Log ☐ Geo Specialist's Record	☐ Owner's Record ☐ Pump Operator's Record ☐ Report / File
9	Piezometer Number		
		Water Sample For Chemical Analysis	
1	Sampling Type	☐ Groundwater ☐ Surface water	☐ Rainfall water
2	Sampling Method	☐ Irregular Interval GRAB ☐ Pumped	☐ Flowing
3	Analyse for	☒ Macro (Normal) ☐ Micro (Cl < 5 mg/l) ☐ Macro + Boron (B) ☐ Macro + Turb ☐ Al + Fe ☐ Total Organic Carbon (TOC)	☐ Macro + KN +TP ☐ Macro + B + KN +TP ☐ Toxicity ☐ Hg ☐ Trace Elements ☐ Li
		radio isotopes	
		☐ Carbon ^{14}C (radioactive) ☐ Tritium (Hydrogen ^{3}H (radioactive)) ☐ Chlorine ^{36}Cl (radioactive)	☐ Strontium ^{87}Sr ☐ Radon ^{222}Rn (radioactive)
		stable isotopes	
		☐ Deuterium (Hydrogen ^{2}H) ☐ Oxygen ^{16}O, ^{18}O ☐	☐ Carbon ^{12}C, ^{13}C ☐ Nitrogen ^{14}N ^{15}N ☐
4	Preserve Type	☐ Unpreserved ☐ Hg Cl_2 ☐ HNO_3	☐ H_2SO_4 ☐ Na OH ☐ Cooling
5	Sampler Name & Initials		
6	FOR OFFICE USE ONLY	Sample number	☐☐☐☐☐☐☐☐☐☐☐
			☐☐☐☐☐☐☐☐☐☐☐
			☐☐☐☐☐☐☐☐☐☐☐

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APPENDIX B – GRIP DATABASE TABLES

pumptest	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
DATE_ENTRY	VARCHAR (8, 0)
REP_INST	VARCHAR (4, 0)
METH_TESTD	VARCHAR (1, 0)
DEPTH_INTK	REAL (30, 15)
DATE_START	VARCHAR (8, 0)
TIME_START	VARCHAR (4, 0)
DATE_END	VARCHAR (8, 0)
TIME_END	VARCHAR (4, 0)
TRANSMIS_0	REAL (30, 15)
STORATIV_0	REAL (30, 15)
OBS_HOLE_1	VARCHAR (11, 0)
OBS_HOLE_2	VARCHAR (11, 0)
OBS_HOLE_3	VARCHAR (11, 0)
OBS_HOLE_4	VARCHAR (11, 0)
OBS_HOLE_5	VARCHAR (11, 0)
OBS_HOLE_6	VARCHAR (11, 0)
DIST_HOLE1	REAL (30, 15)
DIST_HOLE2	REAL (30, 15)
DIST_HOLE3	REAL (30, 15)
DIST_HOLE4	REAL (30, 15)
DIST_HOLE5	REAL (30, 15)
DIST_HOLE6	REAL (30, 15)
TRANSMIS_1	REAL (30, 15)
TRANSMIS_2	REAL (30, 15)
TRANSMIS_3	REAL (30, 15)
TRANSMIS_4	REAL (30, 15)
TRANSMIS_5	REAL (30, 15)
TRANSMIS_6	REAL (30, 15)
STORATIV_1	REAL (30, 15)
STORATIV_2	REAL (30, 15)
STORATIV_3	REAL (30, 15)
STORATIV_4	REAL (30, 15)
STORATIV_5	REAL (30, 15)
STORATIV_6	REAL (30, 15)
RECC_ABSTR	REAL (30, 15)
NOTES_YN	VARCHAR (1, 0)
NOTE_PAD	BLOB(0, 0)
NGDB_FLAG	INTEGER(0, 0)
CONTRACTOR	VARCHAR (4, 0)

basicinf	
OGR_FID	Integer(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
NR_ON_MAP	VARCHAR (12, 0)
REGION_BB	VARCHAR (8, 0)
ALT_NO_1	VARCHAR (7, 0)
ALT_NO_2	VARCHAR (7, 0)
FARM_NR	VARCHAR (8, 0)
SITE_NAME	VARCHAR (60, 0)
TOPO_SETTG	VARCHAR (1, 0)
Y_COORD	REAL (30, 15)
X_COORD	REAL (30, 15)
QUADRANT	VARCHAR (1, 0)
COORD_ACC	VARCHAR (1, 0)
COORD_METH	VARCHAR (1, 0)
DRAINAGE_R	VARCHAR (4, 0)
ALTITUDE	REAL (30, 15)
SURV_METH	VARCHAR (1, 0)
SITE_TYPE	VARCHAR (1, 0)
SITE_SELEC	VARCHAR (3, 0)
BH_DIAM	REAL (30, 15)
COLLAR_HI	REAL (30, 15)
DEPTH	REAL (30, 15)
DATE_COMPL	VARCHAR (8, 0)
INFO_SOURC	VARCHAR (1, 0)
SITE_STATU	VARCHAR (1, 0)
SITE_PURPS	VARCHAR (1, 0)
USE_CONSUM	VARCHAR (1, 0)
USE_APPLIC	VARCHAR (2, 0)
REP_INST	VARCHAR (4, 0)
EQUIPMENT	VARCHAR (1, 0)
POTABILITY	VARCHAR (1, 0)
REGN_TYPE	VARCHAR (3, 0)
REGN_DESCR	VARCHAR (36, 0)
DATE_ENTRY	VARCHAR (8, 0)
DATE_UPDTD	VARCHAR (8, 0)
NOTES_YN	VARCHAR (1, 0)
NOTE_PAD	BLOB(0, 0)
LONGITUDE	REAL (30, 15)
LATITUDE	REAL (30, 15)
NGDB_FLAG	Integer(0, 0)
GEOMETRY	POINT(0, 0)

geology_	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
DATE_ENTRY	VARCHAR (8, 0)
INFO_SOURC	VARCHAR (1, 0)
DEPTH_TOP	REAL (30, 15)
DEPTH_BOT	REAL (30, 15)
LITH_CODE	VARCHAR (4, 0)
UNIT_NAME	VARCHAR (18, 0)
PRIM_COLOR	VARCHAR (1, 0)
SECO_COLOR	VARCHAR (1, 0)
TEXTURE	VARCHAR (2, 0)
PRIM_FEATR	VARCHAR (2, 0)
SECO_FEATR	VARCHAR (2, 0)
FEATR_ATTR	VARCHAR (1, 0)
SORTING	VARCHAR (2, 0)
ROUNDNESS	VARCHAR (2, 0)
CLAY	INTEGER(0, 0)
SILT_FINE	INTEGER(0, 0)
SILT_MEDIU	INTEGER(0, 0)
SILT_COARS	INTEGER(0, 0)
SAND_FINE	INTEGER(0, 0)
SAND_MEDIU	INTEGER(0, 0)
SAND_COARS	INTEGER(0, 0)
GRANULAR	INTEGER(0, 0)
PEBBLY	INTEGER(0, 0)
COBBLY	INTEGER(0, 0)
BOULDERS	INTEGER(0, 0)
NOTES_YN	VARCHAR (1, 0)
NOTE_PAD	BLOB(0, 0)
NGDB_FLAG	INTEGER(0, 0)

chem_001	
CHM_REF_NR	Integer(0, 0)
PH	REAL (30, 15)
EC	REAL (30, 15)
TDS	REAL (30, 15)
CA	REAL (30, 15)
MG	REAL (30, 15)
NA	REAL (30, 15)
K	REAL (30, 15)
SI	REAL (30, 15)
PALK	REAL (30, 15)
MALK	REAL (30, 15)
MACID	REAL (30, 15)
PACID	REAL (30, 15)
CL	REAL (30, 15)
SO4	REAL (30, 15)
N	REAL (30, 15)
F	REAL (30, 15)
CO3	REAL (30, 15)
HCO3	REAL (30, 15)
AL	REAL (30, 15)
FE	REAL (30, 15)
MN	REAL (30, 15)

piezomet	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
PIEZO_NR	Integer(0, 0)
DATE_CONST	VARCHAR (8, 0)
DEPTH_TOP	REAL (30, 15)
DEPTH_BOT	REAL (30, 15)
DIAMETER	REAL (30, 15)
MATERIAL	VARCHAR (1, 0)
THICKNESS	REAL (30, 15)
COMMENT	VARCHAR (12, 0)
OPEN_TYPE	VARCHAR (1, 0)
OPEN_LEN	REAL (30, 15)
OPEN_WIDTH	REAL (30, 15)
OP_HOR_DIS	REAL (30, 15)
OP_VER_DIS	REAL (30, 15)
OPEN_MADE	VARCHAR (1, 0)
OP_COMMENT	VARCHAR (12, 0)
NGDB_FLAG	INTEGER(0, 0)

aquifer_	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
DATE_ENTRY	VARCHAR (8, 0)
REP_INST	VARCHAR (4, 0)
INFO_SOURC	VARCHAR (1, 0)
DEPTH_TOP	DOUBLE(0, 0)
DEPTH_BOT	DOUBLE(0, 0)
YIELD	DOUBLE(0, 0)
METH_MEAS	VARCHAR (1, 0)
AQUI_TYPE	VARCHAR (1, 0)
AQUI_CODE	VARCHAR (6, 0)
COMMENT	VARCHAR (24, 0)
NGDB_FLAG	INTEGER(0, 0)

mreading	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
REP_INST	VARCHAR (4, 0)
SOURCE	VARCHAR (1, 0)
DATE_ENTRY	VARCHAR (8, 0)
TYPE_MEAS	VARCHAR (1, 0)
UNIT_MEAS	VARCHAR (1, 0)
DATE_MEAS	VARCHAR (8, 0)
TIME_MEAS	VARCHAR (4, 0)
READING	REAL (30, 15)
COMMENT	VARCHAR (12, 0)
NGDB_FLAG	INTEGER(0, 0)

userchem	
CHM_REF_NR	Integer(0, 0)
CPARAMETER	VARCHAR (24, 0)
PARAM_REF	VARCHAR (12, 0)
UNIT	VARCHAR (12, 0)
READING	REAL (30, 15)
COMMENT	VARCHAR (24, 0)
NGDB_FLAG	INTEGER(0, 0)

basicimg	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
DATE_CREAT	VARCHAR (8, 0)
TIME_CREAT	VARCHAR (4, 0)
IMG_DESCRI	VARCHAR (48, 0)
SITE_IMAGE	BLOB(0, 0)
NGDB_FLAG	INTEGER(0, 0)

waterlev	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
METH_MEAS	VARCHAR (1, 0)
LEVEL_STAT	VARCHAR (1, 0)
PIEZOM_NR	VARCHAR (1, 0)
INFO_SOURC	VARCHAR (1, 0)
DATE_MEAS	VARCHAR (8, 0)
TIME_MEAS	VARCHAR (4, 0)
TIME_SEC	REAL (30, 15)
WATER_LEV	REAL (30, 15)
COMMENT	VARCHAR (12, 0)
NGDB_FLAG	INTEGER(0, 0)

otherid_	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
OTHER_ID	VARCHAR (12, 0)
ASSIGNOR	VARCHAR (42, 0)
NGDB_FLAG	INTEGER(0, 0)

comments	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
REP_INST	VARCHAR (4, 0)
NOTE_PAD	BLOB(0, 0)
NGDB_FLAG	INTEGER(0, 0)

referenc	
ID	INTEGER(0, 0)
SITE_ID_NR	VARCHAR (11, 0)
REP_INST	VARCHAR (4, 0)
NOTE_PAD	BLOB(0, 0)
NGDB_FLAG	INTEGER(0, 0)

chem_002
CHM_REF_NR: Integer(0, 0)
N_AMONIA: REAL (30, 15)
SB: REAL (30, 15)
ARSENIC: REAL (30, 15)
BA: REAL (30, 15)
BI: REAL (30, 15)
B: REAL (30, 15)
CD: REAL (30, 15)
CR: REAL (30, 15)
CO: REAL (30, 15)
CU: REAL (30, 15)
CN: REAL (30, 15)
PB: REAL (30, 15)
HG: REAL (30, 15)
MO: REAL (30, 15)
NI: REAL (30, 15)
NO2: REAL (30, 15)
PO4: REAL (30, 15)
SR: REAL (30, 15)
SULF: REAL (30, 15)
TI: REAL (30, 15)
ZN: REAL (30, 15)

chem_003
CHM_REF_NR: Integer(0, 0)
COD: REAL (30, 15)
CFR: REAL (30, 15)
DOC: REAL (30, 15)
DOX: REAL (30, 15)
ECOL: INTEGER(0, 0)
FAEC_ECOL: INTEGER(0, 0)
TOTAL_COL: INTEGER(0, 0)
SPC: INTEGER(0, 0)
FAEC_STREP: INTEGER(0, 0)
TVO: INTEGER(0, 0)
H2S: REAL (30, 15)
KJED: REAL (30, 15)
OIL: REAL (30, 15)
PHEN: REAL (30, 15)
SOAP: REAL (30, 15)
BOD: REAL (30, 15)
TOC: REAL (30, 15)
SOM_COLI: INTEGER(0, 0)
ENT_VIRUS: INTEGER(0, 0)
PROTO_PARA: INTEGER(0, 0)
TOT_THM: REAL (30, 15)

chem_005
CHM_REF_NR: Integer(0, 0)
BE: REAL (30, 15)
CE: REAL (30, 15)
AU: REAL (30, 15)
BR: REAL (30, 15)
I: REAL (30, 15)
LI: REAL (30, 15)
PT: REAL (30, 15)
SE: REAL (30, 15)
AG: REAL (30, 15)
TE: REAL (30, 15)
TL: REAL (30, 15)
W: REAL (30, 15)
U: REAL (30, 15)
V: REAL (30, 15)
SN: REAL (30, 15)
PD: REAL (30, 15)
ZR: REAL (30, 15)
LA: REAL (30, 15)
NB: REAL (30, 15)
TA: REAL (30, 15)
ND: REAL (30, 15)

chem_000
SITE_ID_NR: VARCHAR (11, 0)
SAMPLE_NR: VARCHAR (12, 0)
SAMPL_TYPE: VARCHAR (1, 0)
DATE_SAMPL: VARCHAR (8, 0)
TIME_SAMPL: VARCHAR (4, 0)
METH_SAMPL: VARCHAR (1, 0)
ALT_NR_1: VARCHAR (8, 0)
ALT_NR_2: VARCHAR (8, 0)
ALT_NR_3: VARCHAR (8, 0)
ALT_NR_4: VARCHAR (8, 0)
TIME_PUMP: INTEGER(0, 0)
DEPTH_SAMP: REAL (30, 15)
DATE_ANAL: VARCHAR (8, 0)
LAB: VARCHAR (14, 0)
COMMENT: VARCHAR (63, 0)
DATE_ENTRY: VARCHAR (8, 0)
DATE_UPDTD: VARCHAR (8, 0)
CHM_REF_NR: INTEGER(0, 0)
NGDB_FLAG: INTEGER(0, 0)

testdetl
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
DESCRIPTN: VARCHAR (24, 0)
DATE_START: VARCHAR (8, 0)
TIME_START: VARCHAR (4, 0)
DEPTH_INTK: REAL (30, 15)
DURATION: INTEGER(0, 0)
DISCH_RATE: REAL (30, 15)
DRAWDOWN: REAL (30, 15)
RECOVERY: REAL (30, 15)
PERC_RECOV: INTEGER(0, 0)
DURA_RECOV: INTEGER(0, 0)
TRANSMISS: REAL (30, 15)
PERMEABIL: REAL (30, 15)
STORAGE: REAL (30, 15)
SPEC_CAP: REAL (30, 15)
COMMENT: VARCHAR (24, 0)
NGDB_FLAG: INTEGER(0, 0)

instdetl
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
DATE_ENTRY: VARCHAR (8, 0)
DATE_INSTL: VARCHAR (8, 0)
P_PUL_DIAM: REAL (30, 15)
P_RPM: REAL (30, 15)
TYPE_RISER: VARCHAR (1, 0)
CLAS_RISER: VARCHAR (5, 0)
DIAM_RISER: REAL (30, 15)
E_MANUF: VARCHAR (12, 0)
E_MODEL: VARCHAR (12, 0)
E_SERIALNR: VARCHAR (20, 0)
E_PUL_DIAM: REAL (30, 15)
TYPE_ENCL: VARCHAR (1, 0)
MAT_ENCL: VARCHAR (1, 0)
COST_EQUIP: REAL (30, 15)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

installa
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
INFO_SOURC: VARCHAR (1, 0)
DATE_ENTRY: VARCHAR (8, 0)
DATE_INSTL: VARCHAR (8, 0)
TYPE_INSTL: VARCHAR (1, 0)
DEPTH_INTK: REAL (30, 15)
TYPE_POWER: VARCHAR (1, 0)
POWER_RATG: REAL (30, 15)
MANUFACTUR: VARCHAR (18, 0)
SERIAL_NR: VARCHAR (12, 0)
POWER_METR: VARCHAR (12, 0)
MONIT_FACI: VARCHAR (1, 0)
SIZE_RESER: REAL (30, 15)
RESER_TYPE: VARCHAR (1, 0)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

casing__
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
DATE_INST: VARCHAR (8, 0)
DEPTH_TOP: REAL (30, 15)
DEPTH_BOT: REAL (30, 15)
DIAMETER: REAL (30, 15)
MATERIAL: VARCHAR (1, 0)
THICKNESS: REAL (30, 15)
COMMENT: VARCHAR (12, 0)
OPEN_TYPE: VARCHAR (1, 0)
OPEN_LEN: REAL (30, 15)
OPEN_WIDTH: REAL (30, 15)
OP_HOR_DIS: REAL (30, 15)
OP_VER_DIS: REAL (30, 15)
OPEN_MADE: VARCHAR (1, 0)
OP_COMMENT: VARCHAR (12, 0)
NGDB_FLAG: Integer(0, 0)

constrct
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
INFO_SOURC: VARCHAR (1, 0)
DATE_ENTRY: VARCHAR (8, 0)
DATE_CONST: VARCHAR (8, 0)
CONTRACTOR: VARCHAR (24, 0)
CONST_METH: VARCHAR (1, 0)
TYPE_FINIS: VARCHAR (1, 0)
METH_DEVEL: VARCHAR (1, 0)
DURA_DEVEL: INTEGER(0, 0)
SPEC_TREAT: VARCHAR (1, 0)
COST_CONST: REAL (30, 15)
DEPTH: REAL (30, 15)
COLLAR_HI: REAL (30, 15)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

recommnd
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
DATE_REC: VARCHAR (8, 0)
PRIORITY: Integer(0, 0)
REC_EQUIPM: VARCHAR (1, 0)
DEPTH_INTK: REAL (30, 15)
TYPE_POWER: VARCHAR (1, 0)
DISCH_RATE: REAL (30, 15)
DUTY_CYCLE: REAL (30, 15)
WATER_QUAL: VARCHAR (24, 0)
DYN_WLEV: REAL (30, 15)
CRIT_WLEV: REAL (30, 15)
NOTES_YN: VARCHAR (1, 0)
NOTE_PAD: BLOB(0, 0)
NGDB_FLAG: INTEGER(0, 0)

maintnce
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
DATE_ENTRY: VARCHAR (8, 0)
DATE_VISIT: VARCHAR (8, 0)
REP_INST: VARCHAR (4, 0)
INFO_SOURC: VARCHAR (1, 0)
COND_PUMP: VARCHAR (1, 0)
COND_RISER: VARCHAR (1, 0)
COND_ENGIN: VARCHAR (1, 0)
COND_ENCL: VARCHAR (1, 0)
COND_RESVR: VARCHAR (1, 0)
MAINTAINED: VARCHAR (1, 0)
C_CURRENCY: VARCHAR (3, 0)
COST_MAINT: REAL (30, 15)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

chem_004
CHM_REF_NR: Integer(0, 0)
COLR: REAL (30, 15)
MBAS: REAL (30, 15)
ODR: REAL (30, 15)
SPECGRAV: REAL (30, 15)
TST: REAL (30, 15)
TEMP: REAL (30, 15)
TUR: REAL (30, 15)
SUSP_SOLID: REAL (30, 15)
RCARBON: REAL (30, 15)
DEUTERIUM: REAL (30, 15)
TRITIUM: REAL (30, 15)
OXYGEN18: REAL (30, 15)
CI2: Double(0, 0)

fldmeas_
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
INFO_SOURC: VARCHAR (1, 0)
DATE_ENTRY: VARCHAR (8, 0)
DATE_MEAS: VARCHAR (8, 0)
TIME_MEAS: VARCHAR (4, 0)
PARM_MEAS: VARCHAR (1, 0)
READING: REAL (30, 15)
DEPTH_MEAS: REAL (30, 15)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

discharg
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
INFO_SOURC: VARCHAR (1, 0)
DISCH_TYPE: VARCHAR (1, 0)
METH_MEAS: VARCHAR (1, 0)
DATE_MEAS: VARCHAR (8, 0)
TIME_MEAS: VARCHAR (4, 0)
DISCH_RATE: REAL (30, 15)
COMMENT: VARCHAR (20, 0)
NGDB_FLAG: INTEGER(0, 0)

nameownr
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
DATE_FROM: VARCHAR (8, 0)
DATE_TO: VARCHAR (8, 0)
NAME_OWNER: VARCHAR (40, 0)
ADDRESS_1: VARCHAR (40, 0)
ADDRESS_2: VARCHAR (40, 0)
ADDRESS_3: VARCHAR (40, 0)
ADDRESS_4: VARCHAR (40, 0)
TELEPHONE: VARCHAR (15, 0)
NGDB_FLAG: INTEGER(0, 0)

penetrat
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
DATE_ENTRY: VARCHAR (8, 0)
REP_INST: VARCHAR (4, 0)
INFO_SOURC: VARCHAR (1, 0)
DEPTH_TOP: REAL (30, 15)
DEPTH_BOT: REAL (30, 15)
DIAMETER: REAL (30, 15)
PENET_RATE: REAL (30, 15)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

holefill
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
DEPTH_TOP: REAL (30, 15)
DEPTH_BOT: REAL (30, 15)
FILL_TYPE: VARCHAR (1, 0)
DATE_CONST: VARCHAR (8, 0)
COMMENT: VARCHAR (12, 0)
OUTDIAM: REAL (30, 15)
INDIAM: REAL (30, 15)
NGDB_FLAG: INTEGER(0, 0)

holediam
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
DEPTH_TOP: REAL (30, 15)
DEPTH_BOT: REAL (30, 15)
DIAMETER: REAL (30, 15)
DATE_CONST: VARCHAR (8, 0)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

eleccond
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
INFO_SOURC: VARCHAR (1, 0)
DATE_MEAS: VARCHAR (8, 0)
DEPTH: REAL (30, 15)
READING: REAL (30, 15)
NGDB_FLAG: INTEGER(0, 0)
TIME_MEAS: VARCHAR (4, 0)

watersam
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
REP_INST: VARCHAR (4, 0)
DATE_ENTRY: VARCHAR (8, 0)
DATE_MEAS: VARCHAR (8, 0)
TIME_MEAS: VARCHAR (4, 0)
SAM_NUMBER: VARCHAR (8, 0)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

member__
ID: INTEGER(0, 0)
SITE_ID_NR: VARCHAR (11, 0)
DATE_FROM: VARCHAR (8, 0)
DATE_TO: VARCHAR (8, 0)
MEMBER_ID: VARCHAR (10, 0)
DESCRIPTN: VARCHAR (20, 0)
COMMENT: VARCHAR (12, 0)
NGDB_FLAG: INTEGER(0, 0)

APPENDIX C – NGA DATABASE TABLES

GeositeInfo

Field	Type
Identifier	text(20, 0)
GeositeType	integer(0, 0)
Latitude	real(0, 0)
Longitude	real(0, 0)
MineType	integer(0, 0)
Confidential	integer(0, 0)
ReferenceDatum	integer(0, 0)
CoordinateMethod	integer(0, 0)
CoordinateGPSAccuracy	real(0, 0)
Elevation	real(0, 0)
ElevationMethod	integer(0, 0)
ElevationGPSAccuracy	real(0, 0)
ElevationReferencePoint	integer(0, 0)
FarmName	text(100, 0)
FarmNumber	text(20, 0)
Town	text(100, 0)
Portion	text(100, 0)
Village	text(100, 0)
MapNumber	text(6, 0)
Province	integer(0, 0)
RegistrationDistrict	text(50, 0)
QuaternaryDrainageRegion	text(4, 0)
WaterManagementArea	integer(0, 0)
MunicipalDistrictNew	integer(0, 0)
HydrogeologicalRegion	integer(0, 0)
WaterUserAssociation	text(100, 0)
Geomorphology	integer(0, 0)
SurfaceGeology	integer(0, 0)
LandCover	integer(0, 0)
TasteOfWater	integer(0, 0)
IntendedGeositePurpose	integer(0, 0)
ObservedActualWaterUses	integer(0, 0)
WaterConsumer	integer(0, 0)
DataOwner	integer(0, 0)

Lithology

Field	Type
Identifier	text(20, 0)
DescriptorDesignation	integer(0, 0)
DescriptorName	text(50, 0)
EventDate	text(10, 0)
DepthToTop	real(0, 0)
DepthToBottom	real(0, 0)
Code	text(4, 0)
PrimaryColour	integer(0, 0)
ColourQualifier	integer(0, 0)
SecondaryColour	integer(0, 0)
CompositionQualifier	integer(0, 0)
FabricQualifier	integer(0, 0)
FabricAttribute	integer(0, 0)
LossPercentage	real(0, 0)
LossReason	integer(0, 0)
TextureQualifier	integer(0, 0)
HardnessQualifier	integer(0, 0)
ParticleShape	integer(0, 0)
Sorting	integer(0, 0)
BoulderPercentage	real(0, 0)
CobblePercentage	real(0, 0)
PebblePercentage	real(0, 0)
GranulePercentage	real(0, 0)
SandPercentage	real(0, 0)
SiltPercentage	real(0, 0)
ClayPercentage	real(0, 0)
WeatheringDegree	integer(0, 0)
FracturingDegree	integer(0, 0)

Equipment

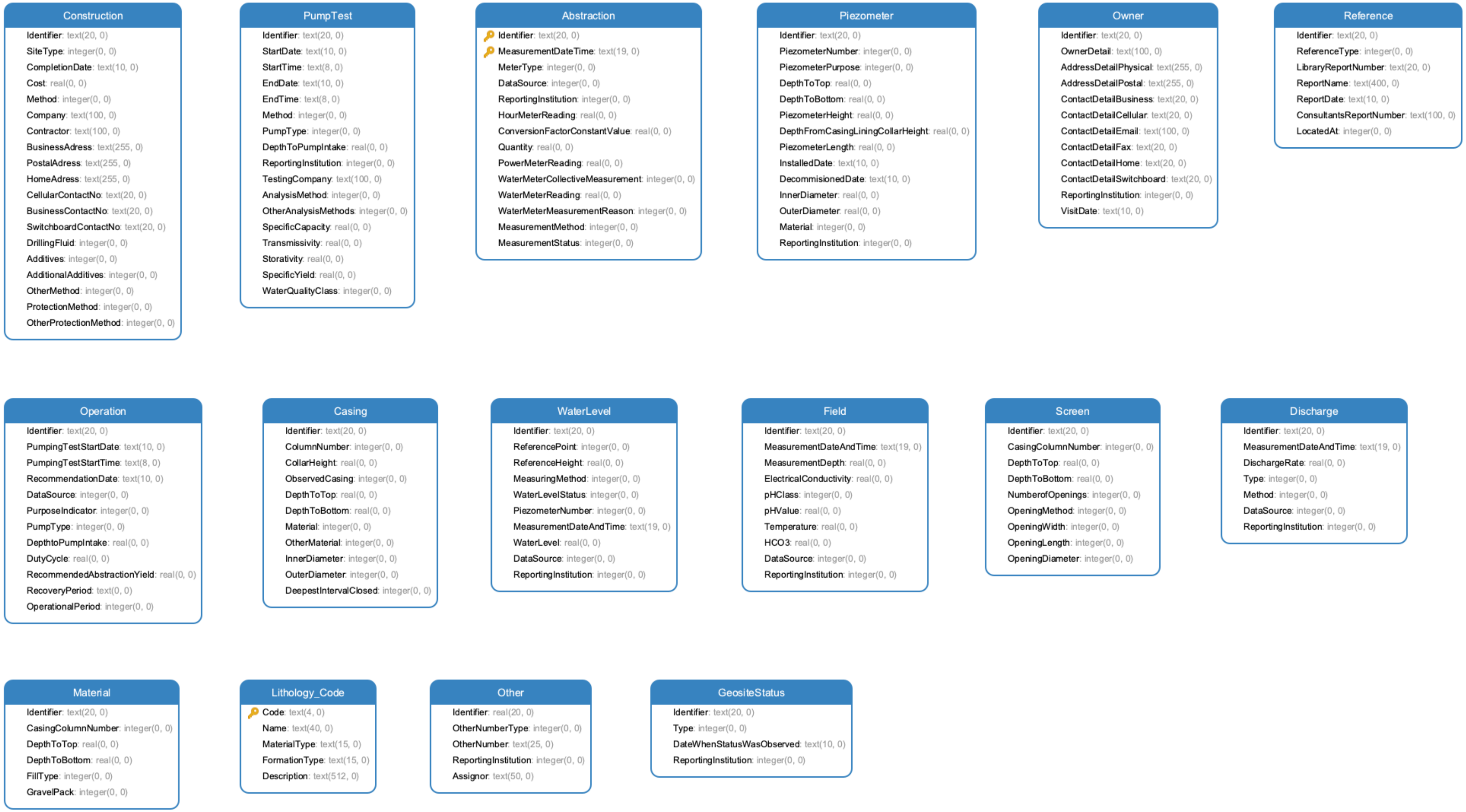
Field	Type
Identifier	text(20, 0)
MonitoringEquipmentType	integer(0, 0)
InstallationDate	text(10, 0)
DecommissionedDate	text(10, 0)
DataSource	integer(0, 0)
ReportingInstitution	integer(0, 0)
PumpType	integer(0, 0)
DepthtoPumpIntake	real(0, 0)
PumpPowerSource	integer(0, 0)
PumpPowerRating	real(0, 0)
PumpManufacturer	integer(0, 0)
PumpSerialNumber	text(20, 0)
PumpRiserMainMaterial	integer(0, 0)
PumpRiserDiameter	real(0, 0)
MeterType	integer(0, 0)
MeterSerialNumber	text(20, 0)
WaterMeterBulkIndicator	integer(0, 0)
WaterMeterMaximumMeasurementValue	real(0, 0)
RainfallMonitoringEquipmentType	integer(0, 0)
ElectronicDataLogger	integer(0, 0)
OtherElectronicDataLoggerType	integer(0, 0)
ElectronicDataLoggerManufacturer	integer(0, 0)
OtherElectronicDataLoggerManufacturer	integer(0, 0)
ElectronicDataLoggerSerialNumber	text(20, 0)
MeasurementMethod	integer(0, 0)
OtherMeasurementMethod	integer(0, 0)
WaterLevelMonitoringEquipmentType	integer(0, 0)

YieldTest

Field	Type
Identifier	text(20, 0)
TestStartDate	text(10, 0)
TestStartTime	text(8, 0)
TestType	integer(0, 0)
StaticWaterLevel	real(0, 0)
ConstantTestTotalDurationHours	real(0, 0)
ConstantTestTotalDurationMinutes	real(0, 0)
AnalysisMethod	integer(0, 0)
SpecificCapacity	real(0, 0)
Transmissivity	real(0, 0)
Storativity	real(0, 0)
SpecificYield	real(0, 0)
WaterQualityClass	integer(0, 0)
StepNumber	integer(0, 0)
StepDuration	real(0, 0)
AverageDischargeRate	real(0, 0)
MeasurementDateTimeType	integer(0, 0)
ActualMeasurementDate	text(10, 0)
ActualMeasurementTime	text(8, 0)
WaterLevelType	integer(0, 0)
WaterLevel	real(0, 0)
WaterLevelStatus	integer(0, 0)
DischargeRate	real(0, 0)

Depth

Field	Type
Identifier	text(20, 0)
MeasurementDate	text(10, 0)
DataSource	integer(0, 0)
ReportingInstitution	integer(0, 0)
DepthToBottom	real(0, 0)
PenetrationInformationAvailable	integer(0, 0)
DepthQualifier	integer(0, 0)
Diameter	integer(0, 0)



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APPENDIX D – CHEMISTRY SYMBOLS

Symbol	Description	Unit	UnitDesc	Type
ASAR	ADJUSTED SODIUM ADSORPTION RATIO	null	NONE	CALC
CORR	CORROSIVITY INDEX	null	NONE	CALC
HARD-CaCO3	HARDNESS AS CACO3 CALCULATED	mg/L	MILLIGRAM PER LITRE	CALC
HARD-Mg	HARDNESS MAGNESIUM CALCULATED	mg/L	MILLIGRAM PER LITRE	CALC
LANGL	LANGLIER INDEX	null	NONE	CALC
pHsat	PH AT SATURATION WITH RESPECT TO CaCO3	null	NONE	CALC
RYZNAR	RYZNAR	null	NONE	CALC
SAR	SODIUM ADSORPTION RATIO	null	NONE	CALC
C-13	CARBON13/CARBON12 RATIO IN DISSOLVED INORGANIC CARBON	d%oSMOW	PER MILLE RELATIVE TO SMOW	ISOTOPE
C-14	CARBON14/CARBON12 RATIO IN DISSOLVED INORGANIC CARBON ALSO KNOWN AS RADIOCARBON	pMC	PERCENT MODERN CARBON	ISOTOPE
H-2	DEUTERIUM ALSO KNOWN AS 2H/1H RATIO	d%oSMOW	PER MILLE RELATIVE TO SMOW	ISOTOPE
H-3	TRITIUM ATOM RATIO WITH RESPECT TO HYDROGEN (3H/1H)	TU	TRITIUM UNITS (118 MB/L)	ISOTOPE
O-18	OXYGEN18/OXYGEN16 RATIO	d%oSMOW	PER MILLE RELATIVE TO SMOW	ISOTOPE
Al	ALUMINIUM	mg/L	MILLIGRAM PER LITRE	MAJOR
Ca	CALCIUM	mg/L	MILLIGRAM PER LITRE	MAJOR
Cl	CHLORIDE	mg/L	MILLIGRAM PER LITRE	MAJOR
CO3	CARBONATE	mg/L	MILLIGRAM PER LITRE	MAJOR
Eh	REDOX POTENTIAL	mV	MILLIVOLTS	MAJOR
F	FLUORIDE	mg/L	MILLIGRAM PER LITRE	MAJOR
Fe	IRON	mg/L	MILLIGRAM PER LITRE	MAJOR
HCO3	BICARBONATE	mg/L	MILLIGRAM PER LITRE	MAJOR
K	POTASSIUM	mg/L	MILLIGRAM PER LITRE	MAJOR

MALK	METHYL ORANGE ALKALINITY	mg/L	MILLIGRAM PER LITRE	MAJOR
Mg	MAGNESIUM	mg/L	MILLIGRAM PER LITRE	MAJOR
Mn	MANGANESE	mg/L	MILLIGRAM PER LITRE	MAJOR
Na	SODIUM	mg/L	MILLIGRAM PER LITRE	MAJOR
PALK	PHENOLPHTHALEIN ALKALINITY	mg/L	MILLIGRAM PER LITRE	MAJOR
Si	SILICON	mg/L	MILLIGRAM PER LITRE	MAJOR
SO4	SULPHATE	mg/L	MILLIGRAM PER LITRE	MAJOR
TAL	TOTAL ALKALINITY AS CALCIUM CARBONATE	mg/L	MILLIGRAM PER LITRE	MAJOR
TDS	TOTAL DISSOLVED SOLIDS / DISSOLVED MAJOR SALTS	mg/L	MILLIGRAM PER LITRE	MAJOR
EC	ELECTRICAL CONDUCTIVITY	mS/m	MILLISIEMENS PER METRE	MAJOR / FIELD
pH	PH	pH units	UNITS OF PH	MAJOR / FIELD
TEMP	TEMPERATURE	°C	DEGREE CELCIUS	MAJOR / FIELD
Ag	SILVER	mg/L	MILLIGRAM PER LITRE	MINOR
As	ARSENIC	mg/L	MILLIGRAM PER LITRE	MINOR
Au	Aurum	mg/L	MILLIGRAM PER LITRE	MINOR
B	BORON	mg/L	MILLIGRAM PER LITRE	MINOR
Ba	BARIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Be	BERYLLIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Bi	BISMUTH	mg/L	MILLIGRAM PER LITRE	MINOR
Br	BROMINE	mg/L	MILLIGRAM PER LITRE	MINOR
Cd	CADMIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Ce	CERIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Cl2	CHLORINE GAS	ppm	PARTS PER MILLION	MINOR
CN	CYANIDE	mg/L	MILLIGRAM PER LITRE	MINOR
Co	COBALT	mg/L	MILLIGRAM PER LITRE	MINOR

Cr	CHROMIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Cu	COPPER	mg/L	MILLIGRAM PER LITRE	MINOR
Hg	MERCURY	mg/L	MILLIGRAM PER LITRE	MINOR
I	IODINE	mg/L	MILLIGRAM PER LITRE	MINOR
La	LANTHANUM	mg/L	MILLIGRAM PER LITRE	MINOR
Li	LITHIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Mo	MOLYBDENUM	mg/L	MILLIGRAM PER LITRE	MINOR
Nb	NIOBIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Nd	NEODYMIUM	mg/L	MILLIGRAM PER LITRE	MINOR
NH3	AMMONIA UN-IONISED 25 °C	mg/L	MILLIGRAM PER LITRE	MINOR
NH4	AMMONIUM NITROGEN	mg/L	MILLIGRAM PER LITRE	MINOR
Ni	NICKEL	mg/L	MILLIGRAM PER LITRE	MINOR
NO2	NITRITE NITROGEN	mg/L	MILLIGRAM PER LITRE	MINOR
NO3	NITRATE NITROGEN	mg/L	MILLIGRAM PER LITRE	MINOR
NO3+2	NITRATE + NITRITE NITROGEN	mg/L	MILLIGRAM PER LITRE	MINOR
O	OXYGEN ABSORBED	mg/L	MILLIGRAM PER LITRE	MINOR
P	TOTAL PHOSPHORUS	mg/L	MILLIGRAM PER LITRE	MINOR
Pb	LEAD	mg/L	MILLIGRAM PER LITRE	MINOR
Pd	PALLADIUM	mg/L	MILLIGRAM PER LITRE	MINOR
PO4	ORTHO PHOSPHATE AS PHOSPHORUS	mg/L	MILLIGRAM PER LITRE	MINOR
Pt	PLATINUM	mg/L	MILLIGRAM PER LITRE	MINOR
Sb	ANTIMONY	mg/L	MILLIGRAM PER LITRE	MINOR
Se	SELENIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Sn	TIN	mg/L	MILLIGRAM PER LITRE	MINOR
SO3	SULFITE	mg/L	MILLIGRAM PER LITRE	MINOR

Sr	STRONTIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Ta	TANTALUM	mg/L	MILLIGRAM PER LITRE	MINOR
Te	TELLURIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Ti	TITANIUM	mg/L	MILLIGRAM PER LITRE	MINOR
Tl	THALLIUM	mg/L	MILLIGRAM PER LITRE	MINOR
U	URANIUM	mg/L	MILLIGRAM PER LITRE	MINOR
V	VANADIUM	mg/L	MILLIGRAM PER LITRE	MINOR
W	TUNGSTEN	mg/L	MILLIGRAM PER LITRE	MINOR
Zn	ZINC	mg/L	MILLIGRAM PER LITRE	MINOR
Zr	ZIRCONIUM	mg/L	MILLIGRAM PER LITRE	MINOR
BOD	BIOCHEMICAL OXYGEN DEMAND	mg/L	MILLIGRAM PER LITRE	ORGANIC
CHL-A	CHLOROPHYLL A	ug/L	MICROGRAM PER LITRE	ORGANIC
COD	CHEMICAL OXYGEN DEMAND	mg/L	MILLIGRAM PER LITRE	ORGANIC
DOC	DISSOLVED ORGANIC CARBON	mg/L	MILLIGRAM PER LITRE	ORGANIC
DOX	DISSOLVED OXYGEN	mg/L	MILLIGRAM PER LITRE	ORGANIC
ECOLI	ESCHERICHIA COLI	cfu/100 mL	COLONY FORMING UNIT PER 100 ML	ORGANIC
EVIRUS	ENTERIC VIRUSES	copies/mL	GENOMIC COPIES PER LITER	ORGANIC
FCOL	FAECAL COLIFORM COUNT	cfu/100 mL	COLONY FORMING UNIT PER 100 ML	ORGANIC
FECOLI	FAECAL ESCHERICHIA COLI	cfu/100 mL	COLONY FORMING UNIT PER 100 ML	ORGANIC
FSTREP	FAECAL STREPTOCOCCI COUNT	cfu/100 mL	COLONY FORMING UNIT PER 100 ML	ORGANIC
H2S	HYDROGEN SULFIDE	ppm	PARTS PER MILLION	ORGANIC
KJEL-N	KJELDAHL NITROGEN	mg/L	MILLIGRAM PER LITRE	ORGANIC
OC	ORGANIC CARBON	mg/L	MILLIGRAM PER LITRE	ORGANIC
OIL	OIL	ppm	PARTS PER MILLION	ORGANIC
PHAEO	PHAEOPHYTIN A	ug/L	MICROGRAM PER LITRE	ORGANIC

PHEN	PHENOL	mg/L	MILLIGRAM PER LITRE	ORGANIC
PROTO	PROTOZOA	cfu/100 mL	COLONY FORMING UNIT PER 100 ML	ORGANIC
SOAP	SOAP	ppm	PARTS PER MILLION	ORGANIC
SOMCOL	SOIL ORGANIC MATTER COLIFORMS	cfu/100 mL	COLONY FORMING UNIT PER 100 ML	ORGANIC
SPC	STANDARD PLATE COUNT	cfu/mL	COLONY FORMING UNIT PER 1 ML	ORGANIC
TCOL	TOTAL COLIFORM COUNT	cfu/100 mL	COLONY FORMING UNIT PER 100 ML	ORGANIC
THM	TRIHALOMETHANES	ug/L	MICROGRAM PER LITRE	ORGANIC
TOC	TOTAL ORGANIC CARBON	ppm	PARTS PER MILLION	ORGANIC
TVO	TOTAL VIABLE ORGANISM	cfu/mL	COLONY FORMING UNIT PER 1 ML	ORGANIC
COLR	COLOUR	CU	COLOR UNITS	PHYSICAL
ODOR	ODOR	TON	THRESHOLD ODOR NUMBER	PHYSICAL
TSS	TOTAL SUSPENDED SOLIDS	mg/L	MILLIGRAM PER LITRE	PHYSICAL
TUR	TURBIDITY	NTU	NEPHELOMETRIC TURBIDITY UNITS	PHYSICAL

APPENDIX E – LITHOLOGICAL CODES

Code	Name	MaterialType	FormationType	Description
AOLN	Aeolianite	Consolidated	Sedimentary	Cemented, wind-blown sediment. The clasts may be grainz of quartz, calcium carbonate, gypsum, etc. and the cement commonly calcium carbonate, although other water soluble minerals such as gypsum have been described.
AGAT	Agate	Consolidated	Igneous	Agate is characterized by multiple, thin laminations of chalcedony(micro- crystalline quartz) that define distinct banding.
AGLM	Agglomerate	Consolidated	Igneous	Agglomerates (from the Latin 'agglomerare' meaning 'to form into a ball') are coarse accumulations of large blocks of volcanic material that contain at least 75% bombs
ALVM	Alluvium	Unconsolidated	Sedimentary	Alluvium is loose, unconsolidated (not cemented together into a solid rock) soil or sediments, which may again be eroded, deposited, and reshaped by water in some form in a non-marine setting.
APBL	Amphibolite	Consolidated	Metamorphic	Amphibolite is a black metamorphic rock composed almost entirely of amphibole minerals, usually hornblende, produced by the regional metamorphism of mafic and ultra-mafic rocks.
ADST	Andesite	Consolidated	Igneous	A dark coloured, fine grained extrusive rock that, when porphyritic , contains phenocrysts composed primarily of zoned sodic plagioclase and one or more of the mafic minerals(biotite, hornblende, pyroxene), with a groundmass composed generally of the same minerals as the phenocrysts.
ANDR	Anhydrite	Consolidated	Sedimentary	Anhydrite is the dehydrated form of gypsum. The crystals are typically colourless and flat, platy or tabular. Anhydrite can also occur either as a secondary mineral or as an evaporite mineral.
ANRS	Anorthosite	Consolidated	Igneous	Is a phaneritic, intrusive igneous rock characterized by a predominance of plagioclase feldspar (90-100%), and a minimal mafic component (0-10%). Pyroxene, ilmenite, magnetite, and olivine are the mafic minerals most commonly present.
APTT	Apatite	Consolidated	Mineral	A group of variously coloured hexagonal minerals consisting of calcium phosphate together with fluorine, chlorine, hydroxyl or carbonate in varying amounts. Apatite occurs as an accessory mineral in almost all igneous rocks, in metamorphic rocks and in veins and other ore deposits.
QZAR	Arenite	Consolidated	Sedimentary	Arenite (Latin Arena, sand) is a sedimentary clastic rock with sand grain size between 0.0625 mm (0.00246 in) and 2 mm (0.08 in) and contain less than 15% matrix.[1] The related adjective is arenaceous.
ARGL	Argillite	Consolidated	Sedimentary	A hard, slightly metamorphosed, detrital sedimentary rock with particles ranging from 0.01 to 0.05 mm.
ARKS	Arkose	Consolidated	Sedimentary	Arkose is a detrital sedimentary rock, specifically a type of sandstone containing at least 25% feldspar.

BSLT	Basalt	Consolidated	Igneous	Basalt is an extrusive igneous rock. It is the bedrock of the ocean floor and also occurs on land in extensive lava flows
BAUX	Bauxite	Consolidated	Sedimentary	An earthy rock composed almost wholly of aluminium hydroxide, often formed by the intense chemical weathering of existing rocks in the tropics under high rainfall.
BNTN	Bentonite	Consolidated	Sedimentary	A soft, plastic, porous, light coloured rock composed essentially of clay minerals of the montmorillonite group plus colloidal silica and produced by devitrification and accompanying chemical alteration of a glassy igneous material usually tuff or volcanic ash.
BTTE	Biotite	Consolidated	Mineral	Biotite is an iron-magnesium bearing member of the mica group of minerals. It is characteristically black, dark brown to red-brown and the crystals form very thin paper like layers that are stacked one on top of the other.
BLAS	Blastomylonite	Consolidated	Metamorphic	A mylonitic rock in which some recrystallization and / or neomineralization has taken place.
BLCL	Boulder Clay	Unconsolidated	Sedimentary	In geology, is a deposit of clay, often full of boulders, which is formed in and beneath glaciers and ice-sheets wherever they are found, and was the typical deposit of the Glacial Period in northern Europe and North America
BLDR	Boulders	Unconsolidated	Sedimentary	A rounded rock fragment with a diameter > 256 mm.
BLSD	Boulders & Sand	Unconsolidated	Sedimentary	A boulder is a rounded rock fragment with a diameter > 256 mm. Sand is a naturally occurring granular material composed of finely divided loose rock and mineral particles and has a grain size which ranges in between 2.00-0.0625 mm.
BLSC	Boulders, Silt & Clay	Unconsolidated	Sedimentary	A boulder is rounded rock fragment with a diameter > 256 mm. Silt is a sediment with particles in size range of 0.0625-0.0039 mm .Clay is a sediment with particles less than 0.0039 mm in size.
BRCC	Breccia	Unconsolidated	Sedimentary	Is a coarse-grained clastic rock, composed of angular broken rock fragments held together by a mineral cement or in a fine-grained matrix, which differs from conglomerate in that the fragments have sharp edges and unworn corners.
BNZT	Bronzitite	Consolidated	Igneous	An igneous rock containing bronzite and lesser augite and calcic plagioclase, found in layered intrusions.
CALU	Calcilutite	Consolidated	Sedimentary	Calcilutite is a type of limestone that is composed of predominately, more than 50 percent, of either clay-size or both silt-size and clay-size detrital (transported) carbonate grains
CARU	Calcirudite	Consolidated	Sedimentary	Calcirudite is a type of limestone that is composed predominately, more than 50 percent, of carbonate grains that are larger in size than sand (2 mm in diameter).
CLCT	Calcite	Consolidated	Mineral	The most common carbonate mineral, principle component of limestone and marbles. It is common in numerous ore deposits and caves as vug and vein fillings in lavas and dolerites.
CLCR	Calcrete	Consolidated	Sedimentary	A powdery, nodular to highly indurated, near surface terrestrial material mainly composed of calcium carbonate, resulting from cementation and the introduction of calcite into the soil, sediment and rock by groundwater in arid to semi-arid regions.

CBNT	Carbonatite	Consolidated	Igneous	An igneous rock containing >50% carbonate minerals. Occurs as lava flows, dykes and sills and commonly associated with alkaline igneous rocks within rift systems. Formed by the derivation of carbonate rich fluids from ascending magmas.
CATL	Cataclasite	Consolidated	Metamorphic	Cataclasite is a type of cataclastic rock that is formed by fracturing and comminution during faulting. It is normally cohesive and non-foliated, consisting of angular clasts in a finer-grained matrix.
CHLK	Chalk	Consolidated	Sedimentary	A very fine-grained, white, porous limestone containing coccoliths (carbonate micro- organisms).
CNKT	Charnockite	Consolidated	Igneous	An orthopyroxene bearing quartz feldspar rock formed at high temperature and pressure, commonly found in granulite facies metamorphic terrains.
CHRT	Chert	Consolidated	Sedimentary	Chert is extremely fine-grained (crypto-crystalline) silica, typically grey to grey- white, or dark grey to black. It is hard and has a conchoidal fracture pattern. If chert contains a large amount of iron, it forms red jasper. Chert can form inorganically from the deposition of silica rich fluids or from siliceous oozes.
CHCL	China-Clay	Consolidated	Sedimentary	China clay is kaolinised feldspar - they are highly valued for their whiteness, hence their use in bone china.
CHRM	Chromitite	Consolidated	Igneous	Chromitite is an igneous cumulate rock composed mostly of the mineral chromite. It is found in layered intrusions such as the Bushveld Igneous Complex in South Africa and the Stillwater igneous complex in Montana.
CLAY	Clay	Unconsolidated	Sedimentary	A sediment with particles less than 0.0039 mm in size
CLSD	Clay & Sand	Unconsolidated	Sedimentary	A sediment with particles less than 0.0039 mm in size and particles which range in between 0.0625 mm and 2 mm.
CLSN	Claystone	Consolidated	Sedimentary	A clastic sedimentary rock with the composition of shale but without its characteristic lamination and fissility.
CLPX	Clinopyroxenite	Consolidated	Igneous	Pyroxenite is an ultramafic igneous rock consisting essentially of minerals of the pyroxene group, such as augite and diopside, hypersthene, bronzite or enstatite
COAL	Coal	Consolidated	Sedimentary	Is a combustible black or brownish-black sedimentary rock usually occurring in rock strata in layers or veins called coal beds or coal seams and formed from compaction and induration of variously altered plant remains similar to those in peat.
COBB	Cobbles	Unconsolidated	Sedimentary	A cobble is a clast of rock with a particle size of 64 mm to 256 mm.
COSD	Cobbles & Sand	Unconsolidated	Sedimentary	Cobble and Sand is clasts of rock with a particle sizes of 256 mm to 64 mm and not smaller than 0.0625 mm.
COSC	Cobbles, Silt & Clay	Unconsolidated	Sedimentary	A cobble, silt and clay is clasts of rock with a particle size of 256 mm to 64 mm through to a particle size of silt which is less than 0.0625 mm and through to clay which is less than 0.0039 mm in size.
CLVM	Colluvium	Unconsolidated	Sedimentary	Colluvium is sediment that has moved downhill to the bottom of the slope without the help of running water in streams. Gravity, in the form of soil creep, and sheetwash during rain storms are the predominant agents. These yield an unsorted sediment of mixed composition.

CLGM	Conglomerate	Unconsolidated	Sedimentary	A conglomerate is a rock consisting of individual clasts that have become cemented together within a finer-grained matrix. Conglomerates are sedimentary rocks consisting of rounded fragments and are thus differentiated from breccias, which consist of angular fragments.
CQMA	Coqunia	Unconsolidated	Sedimentary	Coquina is a sedimentary rock that is composed either wholly or almost entirely of the transported, abraded, and mechanically sorted fragments of the shells of either molluscs, trilobites, brachiopods, or other invertebrates.
DACT	Dacite	Consolidated	Igneous	Dacite is an igneous, volcanic rock. It has an aphanitic to porphyritic texture and is intermediate in composition between andesite and rhyolite.
DIBS	Diabase	Consolidated	Igneous	Diabase is a synonym for dolerite. Dolerite is the intrusive equivalent of gabbro with the same chemical and mineral composition. Diabase is typically dark grey and hard.
DMCT	Diamictite	Consolidated	Sedimentary	Diamictite is a classification of sedimentary rock distinguished by a high consistency of stones, gravel size or larger, up to 25%, so thoroughly mixed and various in form that they can only be classified into the unsorted group. Diamictites are typically deposited in glacial environments.
DIAZ	Diatomaceous-Ooze	Unconsolidated	Sedimentary	A pelagic, siliceous sediment composed of more than 30% diatom tests, up to 40% calcium carbonate, and up to 25% mineral grains.
DIAT	Diatomite	Consolidated	Sedimentary	Diatomite, also known as diatomaceous earth, is the naturally occurring fossilized remains of diatoms. Diatoms are single-celled aquatic algae. They belong to the class of golden brown algae known as Bacillariophyceae.
DORT	Diorite	Consolidated	Igneous	Is a plutonic rock that is something between a granite and a gabbro. It consists mostly of white plagioclase feldspar and black hornblende.
DLRT	Dolerite	Consolidated	Igneous	Is the preferred term used for diabase.
DLMT	Dolomite	Consolidated	Sedimentary	Dolomite is composed of a calcium-magnesium carbonate mineral species. Dolomite can be formed by evaporation of saline water, many limestones become dolomitised by magnesium rich saline solution that percolate through the limestone and chemically replace the limestone.
RSDM	Dolomite	Consolidated	Sedimentary	Dolomite is composed of a calcium-magnesium carbonate mineral species. Dolomite can be formed by evaporation of saline water, many limestones become dolomitised by magnesium rich saline solution that percolate through the limestone and chemically replace the limestone.
WAD	Dolomite	Consolidated	Sedimentary	Dolomite is composed of a calcium-magnesium carbonate mineral species. Dolomite can be formed by evaporation of saline water, many limestones become dolomitised by magnesium rich saline solution that percolate through the limestone and chemically replace the limestone.
DOLO	Dolostone	Consolidated	Sedimentary	A rock made up of dolomite.
DNSD	Dune Sand	Unconsolidated	Sedimentary	A sand dune is a mount, hill or ridge of sand that lies behind the part of the beach affected by tides.

DNTE	Dunite	Consolidated	Igneous	Dunite is a granular, green igneous rock composed of coarse grains of olivine, and often hosts the world's supply of chromium minerals.
DURI	Duricrust	Consolidated	Sedimentary	A general term for a hard crust on the surface of, or layer in, the upper horizons of a soil in a semi-arid climate.
ECGT	Eclogite	Consolidated	Metamorphic	A coarse grained metamorphic rock comprising pink, pyrope rich garnet, green omphacite-kyanite, of deep seated origin.
ELVM	Eluvium	Unconsolidated	Sedimentary	In geology, eluvium or eluvial deposits are those geological deposits and soils that are derived by in situ weathering or weathering plus gravitational movement or accumulation.
EVPR	Evaporite	Consolidated	Sedimentary	Evaporite is a rock made up of minerals formed by precipitation from concentrated brines.
FBRC	Fault Breccia	Consolidated	Metamorphic	Fault breccia, or tectonic breccia, is a breccia (a rock type consisting of angular clasts) that was formed by tectonic forces.
FGOU	Fault Gouge	Unconsolidated	Metamorphic	Fault gouge is an unconsolidated tectonite (a rock formed by tectonic forces) with a very small grain size. Fault gouge has no cohesion, it is normally an unconsolidated rock type, unless cementation took place at a later stage
FLDA	Feldspathic Arenite	Consolidated	Sedimentary	Feldspathic Arenites are sandstones that contain less than 90% quartz, and more feldspar than unstable lithic fragments, and minor accessory minerals
FLST	Felsite	Consolidated	Igneous	A dense igneous rock consisting almost entirely of feldspar and quartz
FNTE	Fenite	Consolidated	Metamorphic	Is a country rock which has been subject to metasomatism by the emplacement of alkaline or carbonatite intrusive rocks.
FRCT	Ferricrete	Consolidated	Sedimentary	A conglomerate consisting of surficial sand and gravel cemented into a hard mass by iron oxide derived from the oxidation of percolating solutions of iron salts.
FGSN	Flagstone	Consolidated	Sedimentary	A sandstone containing mica, which enhances its fissility.
FLNT	Flint	Consolidated	Sedimentary	A term used for microcrystalline silica found in the chalk, equivalent to chert in other rocks.
FYTE	Foyaite	Consolidated	Igneous	A variety of nepheline syenite with equal amounts of nepheline and potash feldspar and a subordinate mafic mineral, e.g. aegirine.
FULE	Fuller's Earth	Consolidated	Sedimentary	An absorbent clay composed of calcium montmorillonite used in decolourizing oils.
GBBR	Gabbro	Consolidated	Igneous	Gabbro is an intrusive igneous rock that is black in colour and has a composition similar to basalt.
GBNR	Gabbro-Norite	Consolidated	Igneous	Gabbro is a plutonic, mafic igneous rock. Norite is similar to gabbro but contains a different orthopyroxene, namely hypersthene. Both gabbro and norite are dark rocks, usually black with some white flecks of plagioclase feldspar.
GLCL	Glacial	Unconsolidated	Sedimentary	An adjective referring to a glacier. A period of glaciation.

GNSS	Gneiss	Consolidated	Metamorphic	Gneiss is a common and widely distributed type of rock formed by high-grade regional metamorphic processes from pre-existing formations that were originally either igneous, volcanic or sedimentary rocks.
GEOT	Goethite	Consolidated	Mineral	A rust-coloured hydrated oxide of iron produced by the weathering of iron minerals.
GRNT	Granite	Consolidated	Igneous	Granite is a common and widely occurring type of intrusive, felsic, igneous rock composed of feldspar, quartz and a mafic mineral.
GRDR	Granodiorite	Consolidated	Igneous	Is an intrusive igneous rock similar to granite, but containing more plagioclase than orthoclase-type feldspar. Officially, it is defined as a phaneritic igneous rock with greater than 20% quartz by volume where at least 65% of the feldspar is plagioclase.
GRNF	Granofels	Consolidated	Metamorphic	A medium-to coarse-grained metamorphic rock possessing a granoblastic fabric and either lacking foliation or lineation entirely or exhibiting such characteristics only indistinctly.
GNPR	Granophyre	Consolidated	Igneous	A fine to medium grained commonly porphyritic, acidic, felsic rock characterised by a groundmass containing intergrown quartz and alkali feldspar
GRNL	Granulite	Consolidated	Metamorphic	A metamorhpic rock formed in the high temperature, high pressure granulite facies, characterised by a mineral assemblage of plagioclase and pyroxene-garnet, quarts, anhydrous aluminosilicates, alkali feldspar, calcite and fosterite rich olivine, commonly with a crystalloblastic fabric.
GRPT	Graphite	Consolidated	Sedimentary	A soft, grey-black, low pressure form of carbon
GRVL	Gravel	Unconsolidated	Sedimentary	A sediment of variable composition with a grainsize larger than sand, i.e. 2 mm
GRCL	Gravel & Clay	Unconsolidated	Sedimentary	A gravel and clay is a sediment of variable composition with a grainsize larger than sand, i.e. 2 mm to 0.0039 mm in size
GRDS	Gravel, Sand & Silt	Unconsolidated	Sedimentary	A gravel and sand & silt is a sediment of variable composition with a grainsize larger than sand, i.e. 2 mm and includes particles sizes smaller than 2 mm to 0.0039 mm
GRSC	Gravel, Silt & Clay	Unconsolidated	Sedimentary	A gravel, silt and clay is a sediment of variable composition with a grainsize larger than sand, i.e. 2 mm to 0.0039 mm and smaller.
GRCK	Graywacke	Consolidated	Sedimentary	A term used to describe an immature sandstone with >15% clay minerals
QZWK	Graywacke	Consolidated	Sedimentary	A term used to describe an immature sandstone with >15% clay minerals
GNST	Greenstone	Consolidated	Metamorphic	A general term for a dark green, altered, low to medium grade, metamorphosed basic igneous rock such as spilite or dolerite, the green colour reflecting the greenschist facies mineral assemblage.
GRSN	Greissen	Consolidated	Metamorphic	A light-coloured metamorphic rock consisting mainly of quartz, white mica, and topaz formed by the pneumatolysis of granite.
GRIT	Grit	Unconsolidated	Sedimentary	A coarse-grained siliceous rock, usually with sharp, angular grains.

GANO	Guano	Consolidated	Sedimentary	A substance composed chiefly of the dung of sea birds or bats, accumulated along certain coastal areas or in caves and used as fertilizer.
GPSM	Gypsum	Consolidated	Sedimentary	Gypsum is a common, soft, colourless to white mineral that cleaves very easily. It's composed of calcium sulphate and has a hardness of 2.
HRDP	Hard Pan	Consolidated	Metamorphic	A layer of iron oxyhydroxides above the water table formed by the reprecipitation of minerals leached from the overlying vadose zone.
HZBG	Harzburgite	Consolidated	Igneous	A rock of the peridotite group consisting essentially of olivine and orthopyroxene.
HEMA	Hematite	Consolidated	Mineral	Hematite is a relatively common mineral that can occur as very finely disseminated grains, forming banded iron formation rocks. It is composed of iron oxide, has a hexagonal crystal system, red to brownish red streak and a metallic to sub metallic lustre.
HRNB	Hornblendite	Consolidated	Igneous	Hornblendite is a plutonic rock consisting mainly of the amphibole hornblende.
HNFL	Hornfels	Consolidated	Metamorphic	Hornfels is a fine-textured metamorphic rock formed by contact metamorphism. Contact metamorphism occurs when a mass of hot magma intrudes into pre-existing rock, whether by injecting itself into a crack or by ascending in a large body (e.g. pluton).
IGBR	Ignimbrite	Consolidated	Igneous	A poorly sorted, pyroclastic rock, comprising mainly pumice and ash, possibly with broken phenocrysts and dismembered vent wall material, of large volume (1kmÂ³-2000kmÂ³)
IJLT	Ijiolite	Consolidated	Igneous	A plutonic rock with >90% nepheline and mafic minerals, usually pyroxene, and also amphibole, sphene, apatite and melanite. Normally has a normal igneous texture, particularly subophitic and comb structure. Forms concentric intrusions and dykes in continental areas.
BDIS	Ironstone	Consolidated	Sedimentary	Ironstone is a sedimentary rock, either deposited directly as a ferruginous sediment or created by chemical replacement that contains a substantial proportion of an iron compounds from which iron either can be or once was smelted commercially.
JSPR	Jasper	Consolidated	Sedimentary	A granular, microcrystalline variety of quartz, usually coloured red by the presence of hematite.
JPLT	Jaspilite	Consolidated	Metamorphic	An iron rich sediment with layers of chert or silica and iron minerals, 5-30 mm thick and laminated at millimetric or submillimetric scale.
KLNT	Kaolinite	Unconsolidated	Sedimentary	A common clay mineral formed by the weathering or hydrothermal alteration of feldspars and other aluminous silicate minerals.
KBLT	Kimberlite	Consolidated	Igneous	A serpentinized, carbonated, commonly brecciated, porphyritic mica-peridotite made up of phenocrysts of olivine and phlogopite in a fine-grained groundmass of olivine, phlogopite, pyrope, iron-titanium oxide, perovskite plus serpentinite, chlorite and carbonates. The main source of diamonds.
KMTE	Komatiite	Consolidated	Igneous	An ultramafic, volcanic rock that is primarily composed of the minerals pyroxene and olivine.

LMPT	Lamproite	Consolidated	Igneous	Lamproites are ultrapotassic mantle-derived volcanic and subvolcanic rocks. They have low CaO, Al2O3, Na2O, high K2O/Al2O3, a relatively high Mg0 content and extreme enrichment in incompatible elements.
LMPH	Lamprophyre	Consolidated	Igneous	Lamprophyre (rock), any of a group of dark gray to black alkaline intrusive igneous rocks that generally occur as dykes.
LPIL	Lapilli	Consolidated	Igneous	Pyroclastic fragments between 2 mm and 64 mm in size
LTRT	Laterite	Consolidated	Sedimentary	A highly weathered red subsoil rich in secondary oxides of iron and/or aluminium, nearly devoid of base metal compounds and primary silicates, and commonly with quartz and kaolinite. It develops in tropical and warm-temperate climates.
LATT	Latite	Consolidated	Igneous	Latite is an igneous, volcanic rock, with aphanitic-aphyric to aphyric-porphyritic texture. Its mineral assemblage is usually alkali feldspar and plagioclase in approximately equal amounts.
LAVA	Lava	Consolidated	Igneous	Molten rock material at the earth's surface.
LEUT	Leucitite	Consolidated	Igneous	Leucite is a rock-forming mineral composed of potassium and aluminium tectosilicate.
LHZT	Lherzolite	Consolidated	Igneous	Lherzolite is a type of ultramafic igneous rock. It is a coarse-grained rock consisting of 40 to 90% olivine along with significant orthopyroxene and lesser calcic chromium rich clinopyroxene
LGNT	Lignite	Consolidated	Sedimentary	A soft, low rank, earthy, brown-black coal, sometimes with a massive sapropelic form but more commonly composed of humic material with wood and plant remains in a finer grained, organic groundmass.
LMSN	Limestone	Consolidated	Sedimentary	A rock comprising > 50% calcium carbonate, which since Cambrian times could be partly or wholly of biogenic origin.
LMDM	Limestone & Dolomite	Consolidated	Sedimentary	Limestone is a rock comprising > 50% calcium carbonate, which since Cambrian times could be partly or wholly of biogenic origin. Dolomite is a calcium- magnesium carbonate mineral species. Dolomite can be formed by evaporation of saline water, or many limestones become dolomitized by magnesium rich saline solution that percolate through the limestone and chemically replace the limestone with secondary dolomite.
LIMN	Limonite	Consolidated	Mineral	A general term for a hydrated iron oxide mineral.
LOAM	Loam	Unconsolidated	Sedimentary	A soil containing approximately equal proportions of sand, silt and clay.
LOSS	Loess	Unconsolidated	Sedimentary	Silt of aeolian derivation, often forming extensive, thick deposits.
MGST	Magnesite-Stone	Consolidated	Sedimentary	Magnesite is a magnesium carbonate mineral, whose colour is normally grey or white, which can also be tinted with brown or yellow. The stone has the look of marble. On the Mohs scale of hardness, it is a 4 to 4.5.
MAGN	Magnetite	Consolidated	Mineral	An oxide mineral with the spinel crystal structure; the most common ferrimagnetic mineral.
MGGB	Magnetite Gabbro	Consolidated	Igneous	Magnetite is an oxide mineral with the spinel crystal structure; the most common ferrimagnetic mineral. Gabbro is an intrusive igneous rock that is black in colour and has a composition similar to basalt.

MRBL	Marble	Consolidated	Metamorphic	Marble is a metamorphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite.
MARL	Marl	Consolidated	Sedimentary	A friable, calcareous mudstone.
MRLS	Marlstone	Consolidated	Sedimentary	Indurated marl.
MEBA	Melilitite-Basalt	Consolidated	Igneous	An ultramafic plutonic rock comprising of melililite, pyroxene and olivine.
MTFT	Metafelsite	Consolidated	Metamorphic	Defined as a metamorphosed felsite containing 65% or more felsic minerals and 35% or less mafic minerals. The word 'felsic' is a mnemonic adjective derived from feldspar, feldspathoid and silica and has been used for igneous rocks having abundant light coloured minerals. The rock is mostly very fine-grained.
MICA	Mica	Consolidated	Mineral	Any member of a group of minerals, hydrous silicates of aluminum with other bases, chiefly potassium, magnesium, iron, and lithium, that separate readily into thin, tough, often transparent, and usually elastic laminae.
MCSC	Mica Schist	Consolidated	Metamorphic	A schist rich in mica, commonly muscovite.
MGMT	Migmatite	Consolidated	Metamorphic	A metamorphic rock composed of a mixture of paleosome (source rock) and neosome (melt) material.
MNZT	Monzonite	Consolidated	Igneous	A granular igneous rock composed of plagioclase and orthoclase in about equal quantities usually together with quartz, augite and biotite
MUD	Mud	Unconsolidated	Sedimentary	A sediment with particles < 0.0625 mm.
MDSN	Mudstone	Consolidated	Sedimentary	Mudstone (also called mudrock) is a fine-grained sedimentary rock of which the original constituents were clays or muds
MSCV	Muscovite	Consolidated	Mineral	Muscovite (white mica) is a common rock forming mineral. There are two varieties, tiny sericite crystals and bright green, chromium rich fuchsite.
MLNT	Mylonite	Consolidated	Metamorphic	A fine grained, foliated fault rock with a recrystallised texture with 50-90% matrix and a strong lineation caused by shear in a major ductile fault of shear zone.
NPHL	Nephelinite	Consolidated	Metamorphic	A feldspathoid found mainly in plutonic and volcanic rocks and in pegmatites associated with nepheline syenites.
FULT	FAULT	None	None	None.
N.S.	NO SAMPLE	None	None	None.
NORT	Norite	Consolidated	Igneous	Norite is a mafic intrusive igneous rock composed largely of the calcium-rich plagioclase labradorite and hypersthene with olivine.
NRAR	Norite-Anorthosite	Consolidated	Igneous	Norite is a mafic intrusive igneous rock composed largely of the calcium-rich plagioclase labradorite and hypersthene with olivine. Anorthosite is a phaneritic, intrusive igneous rock characterized by a predominance of plagioclase feldspar (90-100%), and a minimal mafic component (0-10%). Pyroxene, ilmenite, magnetite, and olivine are the mafic minerals most commonly present.

OVDR	Olivine Diorite	Consolidated	Igneous	Olivine is the name for a series between two end members, fayalite and forsterite. Fayalite is the iron rich member with a pure formula of Fe_2SiO_4. Forsterite is the magnesium rich member with a pure formula of Mg_2SiO_4. The two minerals form a series where the iron and magnesium are substituted for each other without much effect on the crystal structure. Diorite is a plutonic rock that is something between a granite and a gabbro. It consists mostly of white plagioclase feldspar and black hornblende.
OLPY	Olivine-Pyroxenite	Consolidated	Igneous	An olivine rich pyroxenite is an ultramafic igneous rock consisting essentially of minerals of the pyroxene group, such as augite and diopside, hypersthene, bronzite or enstatite.
GRGN	Orthogneiss	Consolidated	Metamorphic	Light-pinkish-white- to buff-white-weathering, greenish-gray, medium-grained, moderately foliated rock consisting of two distinct phases: hornblende syenite gneiss containing microcline microperthite, oligoclase, hornblende, and opaque minerals; and pyroxene syenite gneiss containing microcline microperthite, oligoclase, clinopyroxene, accessory amounts of titanite, and opaque minerals.
GDGS	Orthogneiss	Consolidated	Metamorphic	Light-pinkish-white- to buff-white-weathering, greenish-gray, medium-grained, moderately foliated rock consisting of two distinct phases: hornblende syenite gneiss containing microcline microperthite, oligoclase, hornblende, and opaque minerals; and pyroxene syenite gneiss containing microcline microperthite, oligoclase, clinopyroxene, accessory amounts of titanite, and opaque minerals.
SNGS	Orthogneiss	Consolidated	Metamorphic	Light-pinkish-white- to buff-white-weathering, greenish-gray, medium-grained, moderately foliated rock consisting of two distinct phases: hornblende syenite gneiss containing microcline microperthite, oligoclase, hornblende, and opaque minerals; and pyroxene syenite gneiss containing microcline microperthite, oligoclase, clinopyroxene, accessory amounts of titanite, and opaque minerals.
ORTF	Orthogranofels	Consolidated	Metamorphic	An orthogranofels lacks any obvious foliation or layering and is commonly characterised by a granoblastic texture. On this basis it does not meet the definitions of schist or gneiss. The term granofels has been proposed by the IUGS Subcommission and can be translated literally as granular rock.
ORPY	Orthopyroxenite	Consolidated	Igneous	Orthopyroxenite is an ultramafic and ultrabasic rock that is almost exclusively made from the mineral orthopyroxene, the orthorhombic version of pyroxene and a type of pyroxenite. It can have up to a few percent of olivine and clinopyroxene.
ORSC	Orthoschist	Consolidated	Metamorphic	"An orthoschist is defined as a medium-grained strongly foliated rock that can be readily split into flakes or slabs due to the well-developed preferred orientation of the majority of the minerals present, particularly those of platy or prismatic habit. It is formed through the retrogressive metamorphism of an igneous rock."
OTSH	Outwash	Unconsolidated	Sedimentary	Sand and gravel deposited by meltwater streams in front of glacial ice.
OBDN	Overburden	Unconsolidated	Sedimentary	Loose, unconsolidated material resting on bedrock; the unwanted rock overlying material of value, such as an orebody.
PAPH	Para-Amphibolite	Consolidated	Metamorphic	Term used for rocks composed largely of hornblende and plagioclase is para- amphibolite. Note that the prefix 'para' indicates that the amphibolite is thought to have a sedimentary protolith in contrast to ortho-amphibolite, which has an igneous protolith. Amphibolite is used where the nature of the protolith is unknown.

PAGN	Paragneiss	Consolidated	Metamorphic	A metamorphic rock formed from high grade metamorphism of sedimentary rocks.
PEAT	Peat	Unconsolidated	Sedimentary	A mass of dark brown, partly decomposed, fibrous plant debris. The precursor of coal, requiring substantial vegetation, standing water that would prevent oxidation or bacterial destruction, and an absence of introduced detrital sediment.
PGMT	Pegmatite	Consolidated	Igneous	A pegmatite is a very coarsely crystalline, intrusive igneous rock composed of interlocking crystals usually larger than 2.5 cm in size; such rocks are referred to as pegmatitic.
PLTE	Pelite	Consolidated	Metamorphic	Sedimentary rock composed of fine fragments, as of clay or mud.
PERI	Peridotite	Consolidated	Igneous	A peridotite is a dense, coarse-grained ultramafic igneous rock, consisting mostly of the minerals olivine and pyroxene.
PNLT	Phonolite	Consolidated	Igneous	A fine-grained volcanic igneous rock consisting of alkaline feldspars and nepheline.
PHST	Phosphorite	Consolidated	Sedimentary	A phosphate rock which occurs in beds from centimetres to tens of metres thick, composed of grains of cryptocrystalline carbonate fluorapatite or collophane and det0rital material.
PLLT	Phyllite	Consolidated	Metamorphic	A regionally metamorphosed, foliated, pelitic rock.
PHYT	Phyllonite	Consolidated	Metamorphic	A metamorphic rock occupying an intermediate position between phyllite and mylonite.
PCTE	Picrite	Consolidated	Igneous	A coarse-grained ultrabasic igneous rock consisting of olivine and augite with small amounts of plagioclase feldspar.
PORL	Porcelainite	Consolidated	Sedimentary	Baked clay or shale found in burned-out coal mines
PPHY	Porphyry	Consolidated	Igneous	An hypabyssal igneous rock containing phenocrysts, commonly of feldspar.
QZPR	Porphyry	Consolidated	Igneous	An hypabyssal igneous rock containing phenocrysts, commonly of feldspar.
PSMT	Psammite	Consolidated	Metamorphic	A metamorphosed sandstone, arkose, or quartzite, extremely rich in the mineral quartz.
PDGP	Pseudogranophyre	Consolidated	Igneous	An igneous rock similar to granite in composition and appearance, but containing larger crystals of quartz and feldspar in a matrix of finer grains.
PSTY	Pseudotachylite	Consolidated	Metamorphic	A very fine-grained or glass-like black fault rock, formed by rapid displacement and melting by shear generated heating, commonly associated with meteorite impact structures.
PSLO	Psilomelane	Consolidated	Mineral	A botryoidal mass of manganese oxide minerals, of which romanechite is a major constituent.
PYRT	Pyrite	Consolidated	Mineral	Iron sulfide mineral (FeS). Forms silvery to brassy metallic cubes or masses. Common in many rocks. Also known as "Fool's Gold". Weathing of pyrite produces limonite (iron oxide) pseudomorphs, and stains rock brown or yellow.
PRXN	Pyroxenite	Consolidated	Igneous	Pyroxenite is an ultramafic igneous rock consisting essentially of minerals of the pyroxene group, such as augite and diopside, hypersthene, bronzite or enstatite.

QRTZ	Quartzite	Consolidated	Metamorphic	Quartzite is a metamorphic rock derived from sandstone by heating and pressure usually related to tectonic compression within orogenic belts.
MTQZ	Quartzite	Consolidated	Metamorphic	Quartzite is a metamorphic rock derived from sandstone by heating and pressure usually related to tectonic compression within orogenic belts.
QZSY	Quartz-Syenite	Consolidated	Igneous	Commonly porphyritic and mesoperthitic; contains biotite and, locally, fayalite, hastingsite, hornblende, or ferrohedenbergite.
RDOZ	Radiolarian-Ooze	Unconsolidated	Sedimentary	Siliceous mud of the bottom of deep seas composed largely of skeletal remains of radiolarians.
RDTE	Radiolarite	Consolidated	Sedimentary	Radiolarite is a siliceous, comparatively hard, fine-grained, chert-like, and homogeneous sedimentary rock that is composed predominantly of the microscopic remains of radiolarians.
RYDT	Rhyodacite	Consolidated	Igneous	Rhyodacite is an extrusive volcanic rock intermediate in composition between dacite and rhyolite. It is the extrusive equivalent of granodiorite.
RYLT	Rhyolite	Consolidated	Igneous	Rhyolite is an igneous rock in the class designated as "felsic" rock. This class of rock crystallizes from silicate minerals at relatively low temperatures and with a relatively high percentage of silica.
RBBL	Rubble	Unconsolidated	Sedimentary	Anthropogenic waste, usually building material, etc.
SAND	Sand	Unconsolidated	Sedimentary	Sand is a naturally occurring granular material composed of finely divided loose rock and mineral particles (0.625-2 mm in diameter).
SDCL	Sand & Clay	Unconsolidated	Sedimentary	Sand and clay is a naturally occurring granular material composed of finely divided rock and mineral particles (0.625-2 mm in diameter) to a clay particle size of less than 0.0039 mm in size.
SDGL	Sand & Gravel	Unconsolidated	Sedimentary	Sand and gravel is a naturally occurring granular material composed of finely divided rock and mineral particles (0.625-2 mm in diameter) and up to a grainsize larger than sand, i.e. 2 mm.
SDST	Sand & Silt	Unconsolidated	Sedimentary	Sand is a naturally occurring granular material composed of finely divided rock and mineral particles (0.625-2 mm in diameter) and silt is a sediment with particles in size range of 4-62.5 um.
SDBC	Sand And Basal Conglomerate	Unconsolidated	Sedimentary	A conglomerate is a rock consisting of individual clasts within a finer-grained matrix that have become cemented together and sand is a naturally occurring granular material composed of finely divided rock and mineral particles (0.625-2 mm in diameter).
SGVC	Sand, Gravel & Clay	Unconsolidated	Sedimentary	Sand , gravel and clay is a naturally occurring granular material composed of finely divided rock and mineral particles (0.625-2 mm in diameter) and up to a grainsize larger than sand, i.e. 2 mm to a clay particle size of less than 0.0039 mm in size.
SNDS	Sandstone	Consolidated	Sedimentary	A clastic sedimentary rock with > 25% by volume of clasts of sand grade (0.625-2 mm in diameter).
CSSC	Sandstone	Consolidated	Sedimentary	A clastic sedimentary rock with > 25% by volume of clasts of sand grade (0.625-2 mm in diameter).

SDSL	Sandstone & Shale	Consolidated	Sedimentary	Sandstone- A clastic sedimentary rock with > 25% by volume of clasts of sand grade (0.625-2 mm in diameter). Shale- A fine-grained siliciclastic rocks containing variable proportions of clay and silt, but containing at least 33% clay.
SCST	Schist	Consolidated	Metamorphic	A class of fissile metamorphic rocks whose constituent mineral grains (micas or other platy minerals) have a parallel, well-foliated arrangement.
QZSC	Schist	Consolidated	Metamorphic	A class of fissile metamorphic rocks whose constituent mineral grains (micas or other platy minerals) have a parallel, well-foliated arrangement.
SCRE	Scree	Unconsolidated	Sedimentary	Scree, or talus, is accumulation of broken rock fragments at the base of crags, mountain cliffs, or valley shoulders.
SETE	Semipelite	Consolidated	Metamorphic	Crystalloblastic metasedimentary rock (grain size & protolith undefined); modal composition <10% calc-silicate/carbonate minerals, 60-80% Q+F, 20-40% and other minerals (mica/chlorite/garnet/cordierite/staurolite/andalusite/kyanite/sillimanite).
SPTC	Serpentine Talc	Consolidated	Metamorphic	Serpentine Talc is a hydrated magnesium silicate mineral with a characteristic soft and greasy feel, hence its alternative name, soapstone.
SRPN	Serpentinite	Consolidated	Metamorphic	Serpentinite is a rock composed of one or more of the serpentine group of minerals. Minerals in this group are formed by serpentinization, a hydration and metamorphic transformation of ultramafic rock from the Earth's mantle. The alteration is particularly important.
SHLE	Shale	Consolidated	Sedimentary	Shale is a fine-grained siliciclastic rock containing variable proportions of clay and silt, with at least 33% clay. Avoid using this category, except in cases where the proportions of clay and silt are not known.
SHSL	Shale & Siltstone	Consolidated	Sedimentary	Shale- fine-grained siliciclastic rocks containing variable proportions of clay and silt, but containing at least 33% clay. Siltstone is a lithified silt with particles in size range of 0.0625 to 0.0039 mm.
SLCT	Silcrete	Consolidated	Sedimentary	A silicified rock formed through cementation of any sediment or rock at or near the surface by silica-rich groundwater.
SILT	Silt	Unconsolidated	Sedimentary	A sediment with particles in size range of 0.0625 to 0.0039 mm.
STCL	Silt & Clay	Unconsolidated	Sedimentary	Clay and Silt are sediments with particles in the range from 0.0625 mm to less than 0.0039 mm in size.
SLSN	Siltstone	Consolidated	Sedimentary	A lithified silt.
SLSH	Siltstone & Shale	Consolidated	Sedimentary	Shale- fine-grained siliciclastic rocks containing variable proportions of clay and silt, but containing at least 33% clay. Siltstone- A lithified silt with particles in size range of 0.0625 to 0.0039 mm.
SNTR	Sinter	Consolidated	Sedimentary	A chemical sediment or crust, e.g. porous silica, deposited by a mineral spring
SKAM	Skarn	Consolidated	Metamorphic	An irregularly shaped, replacement ore deposit, usually formed at high temperature in metamorphosed, carbonate rich sediments at the contacts with medium to large igneous bodies.

SLTE	Slate	Consolidated	Metamorphic	A fine grained, low grade or regionally metamorphosed mudrock with a well-developed penetrative cleavage. The cleavage is a foliation in which sub microscopic phyllosilicate minerals are in well developed, parallel alignment so that the rocks splits into platy sheets.
SMCY	Smectite-Clay	Consolidated	Sedimentary	These are a family of clays that swell when immersed in water or some organic liquids (those which, like water, have polar molecules). Formerly they were known as the montmorillonite group; that name is now only used for one mineral in the smectite group.
SOIL	SOIL	Unconsolidated	None	None.
SPTE	Spiculite	Consolidated	Sedimentary	A sedimentary rock or sediment composed largely of sponge spicules.
SSPO	Sponge-Spicular Ooze	Unconsolidated	Sedimentary	Predominantly composed of sponge spicules
SYNT	Syenite	Consolidated	Igneous	Syenite is a coarse-grained intrusive igneous rock of the same general composition as granite but with the quartz either absent or present in relatively small amounts (<5%).
TALC	Talc	Consolidated	Mineral	A phyllosilicate formed by the hydrothermal alteration of ultrabasic rocks or the thermal metamorphism of siliceous dolomites.
TLUS	Talus	Unconsolidated	Sedimentary	A sloping accumulation of loose clasts of granule grade of larger, generally in the form of a wedge, metres to hundreds of metres in height, at the base of a steep rock face from which the clasts fall as a result of weathering and erosion.
TPHA	Tephra	Consolidated	Igneous	Tephra is fragmental material produced by a volcanic eruption regardless of composition, fragment size or emplacement mechanism
TPHT	Tephrite	Consolidated	Igneous	Tephrite is an igneous, volcanic (extrusive) rock, with aphanitic to porphyritic texture. Mineral assembly is usually abundant feldspathoids (leucite or nepheline), plagioclase, and lesser alkali feldspar. Pyroxenes (clinopyroxenes) are common accessory minerals.
TILL	Till	Unconsolidated	Sedimentary	Glacial debris deposited directly from ice, comprising a wide variety of grain sizes.
TLLT	Tillite	Consolidated	Sedimentary	A conglomerate of glacial origin, formed from lithification of till.
TNLT	Tonalite	Consolidated	Igneous	Tonalite is an igneous, plutonic (intrusive) rock of felsic composition, with phaneritic texture
TRCT	Trachyte	Consolidated	Igneous	Trachyte is an igneous volcanic rock with an aphanitic to porphyritic texture. The mineral assemblage consists of essential alkali feldspar; relatively minor plagioclase and quartz or a feldspathoid such as nepheline may also be present.
TRAV	Travertine	Consolidated	Sedimentary	A hard dense variety of tufa. It also occurs in caves as stalactites and stalagmites (synonymous with calcareous sinter).
TROC	Troctolite	Consolidated	Igneous	Troctolite is a plutonic igneous rock composed of essential olivine and plagioclase feldspar.

CCTF	Tufa	Consolidated	Sedimentary	A thin, surficial, soft, spongy, semifriable encrustation around the mouth of springs, seeps or streams carrying calcium carbonate in solution and in exceptional instances as a thick deposit along lake shores.
TUFF	Tuff	Consolidated	Igneous	Tuff (from the Italian tufo) is a type of rock consisting of consolidated volcanic ash ejected from vents during a volcanic eruption
TFBC	Tuff-Breccia	Consolidated	Igneous	Tuff (from the Italian tufo) is a type of rock consisting of consolidated volcanic ash ejected from vents during a volcanic eruption. Tuff is sometimes called tufa, particularly when used as construction material.
UCCT	Ultracataclasite	Consolidated	Metamorphic	A cataclasite that is the very finest, hardest, most glassy of the cataclasites
UMYT	Ultramylonite	Consolidated	Metamorphic	A more thoroughly deformed and fine-grained rock containing more than 90% matrix and less than 10% relict grains. Ultramylonites are mylonites taken to the edge of recognition.
VNQZ	Vein-Quartz	Consolidated	Mineral	A vein filled with quartz either of igneous origin or deposited from solution.
WCKE	Wacke	Consolidated	Sedimentary	Wacke (sandstone), sedimentary rock composed of sand-sized grains (0.063-2 mm) with a fine-grained clay matrix.
WBTE	Websterite	Consolidated	Igneous	A pyroxenite with > 95% orthopyroxene and clinopyroxene. Occurs within ultramafic intrusions and ultramafic xenoliths in basalt.
WHTE	Wehrlite	Consolidated	Igneous	A peridotite with > 95% clinopyroxene and olivine (>40%) and minor orthopyroxene. Occurs within ultramafic intrusions and as ultramafic xenoliths in basalt.
ASBS	ASBESTOS	None	None	None.
ASHF	ASH	None	None	None.
BFIL	BACKFILL	None	None	None.
BIGN	BIOTITE GNEISS	None	None	None.
BIGR	BIOTITE GRANITE	None	None	None.
CCSH	CARBONACEOUS AND CARBONACEOUS SHALE	None	None	None.
FCRT	FERRICRETE	None	None	None.
HNBL	HORING BLEND GRANITE	None	None	None.
MGTE	MAGNETITE	None	None	None.
MIGN	MIGMATITE GNEISS	None	None	None.
PEBB	PEBBLES	None	None	None.

PRXT	PYROXENITE	None	None	None.
SABO	SAND AND BOULDERS	None	None	None.
SACB	SAND CLAY BOULDERS	None	None	None.
SSSM	SAND/SILT/MUDSTONE	None	None	None.

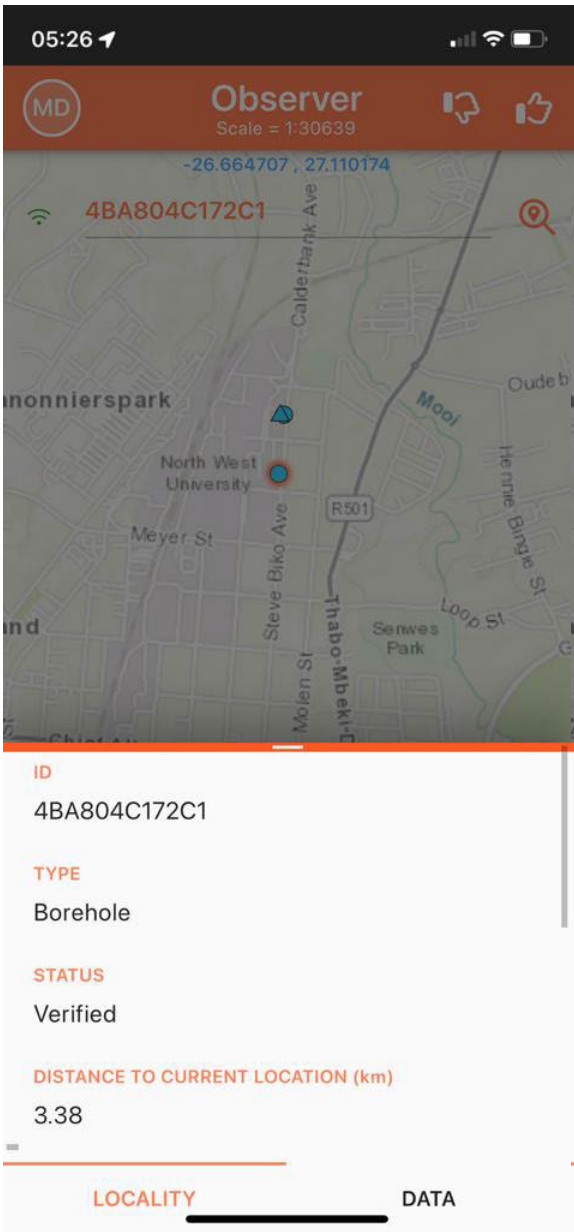
APPENDIX F – WORKSHOP COMMENTS

The following comments were obtained from a workshop where a diverse profile of people attended. The age group ranged between 21 and 67 and included groundwater consultants, a geophysical manufacture, an ex-municipality member, farmers, students, a member of the department of education and private citizens.

Workshop Comments

- Incentives will have to be provided for the average citizen to motivate to capture borehole locations.
- Borehole owners of unregistered boreholes might be reluctant to capture their borehole positions.
- Limit the number of photos a user can capture and implement review process before photo is publicly available.
- Don't show equipment to public – makes theft easy if people know where pumps are installed as an example.
- Implement water level measurement for novice users and provide simple ways of making a dip meter.
- Provide hints on how to take measurements as well as photos.
- The 12-digit unique number could also be a 16-digit number, which could be the UTM coordinate or latitude/longitude pair to 6 decimals.
- Accommodate different rainfall types:
    - Daily
    - Monthly
    - Events

The following screenshots were taken during the field exercise that accompanied the workshop: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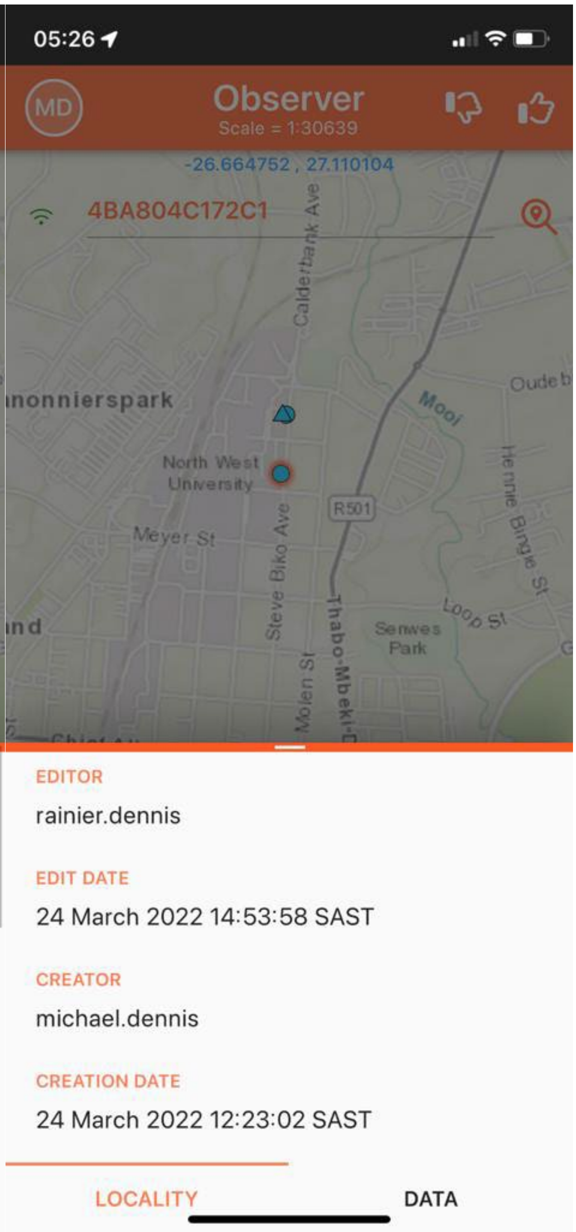
LOCALITY
DATA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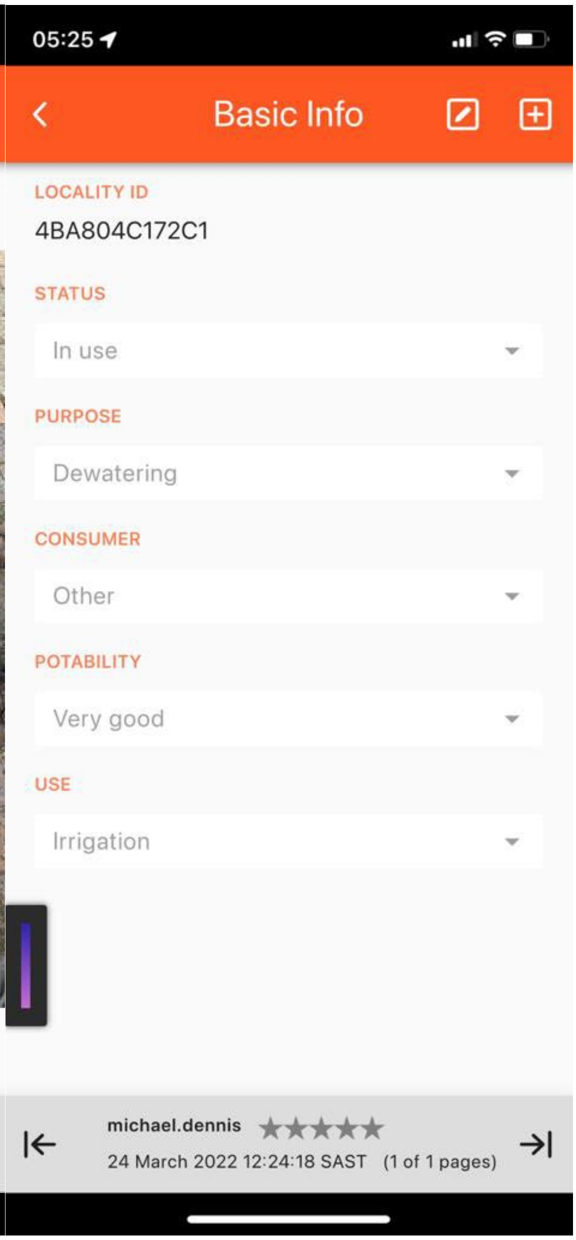
rainier.dennis
EDIT DATE
24 March 2022 14:53:58 SAST
CREATOR
michael.dennis
CREATION DATE
24 March 2022 12:23:02 SAST
LOCALITY
DATA


05:25
Photos
1517
IMG_1648117706399.jpg (1 of 1 pages)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PURPOSE
Dewatering
CONSUMER
Other
POTABILITY
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USE
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michael.dennis
24 March 2022 12:24:18 SAST (1 of 1 pages)