ANNUAL REPORT **2016**

GROUNDWATER WELLS INVENTORY AND SOIL SALINITY MAPPING

FOR ABU DHABI EMIRATE

مشروع حصر
آبار المياه الجوفية
Groundwater Well
Inventory Project

هيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

Dear Stakeholders,

We are proud to present the Environment Agency - Abu Dhabi's Groundwater Well Inventory Project and Soil Salinity Survey 2016 Annual Report. This project is a three- year effort to register and collect data from 105,000 groundwater wells throughout Abu Dhabi and to analyses soil salinity on our farms. This project builds a strong foundation from which we can better manage Abu Dhabi's groundwater and agriculture resources into the long-term future.

Our technical teams have been canvassing the Emirate to collect this data since January 2016 and will continue through 2017 - resulting in more than 24 months of technical fieldwork. This report is a midpoint summary of the data collection process.

In 2016 nearly 61,000 wells were surveyed and 2,250 soil samples collected and analyzed. With durable hand-held GPS-equipped computers, our teams recorded the location, type and depth of each well, and measured the flow rate, depth, salinity and hydro-chemical profile of groundwater at each well head. A registration plate was fixed to each well and the data is uploaded into a GIS database. Soil samples were collected from four different depths on selected farms and each was analyzed for soil type and salinity. A portion of these soil samples were also sent to a specialized laboratory for further and more detailed analysis.

In 2017 the teams have continued field surveys and have since completed recording data from an additional 34,200 wells and collected 400 additional soil samples for laboratory analysis. This work will continue through the remaining months of 2017 until more than 105,000 wells and 4000 soil samples have been analyzed.

This comprehensive effort is necessary to fully understand the state of Abu Dhabi's groundwater and soil resources and with this information Abu Dhabi will have the necessary information to be able to develop effective policies to manage these resources into the long-term future.

We know that Abu Dhabi's water and soil are threatened by over-extraction, over-irrigation and contamination. Furthermore, installation of packaged desalination equipment by many farm owners due to the deteriorating water quality in many areas, over-irrigation and poor irrigation practices caused a significant increase in salinity levels in the soil and surface level contaminants are percolating to the groundwater aquifers,

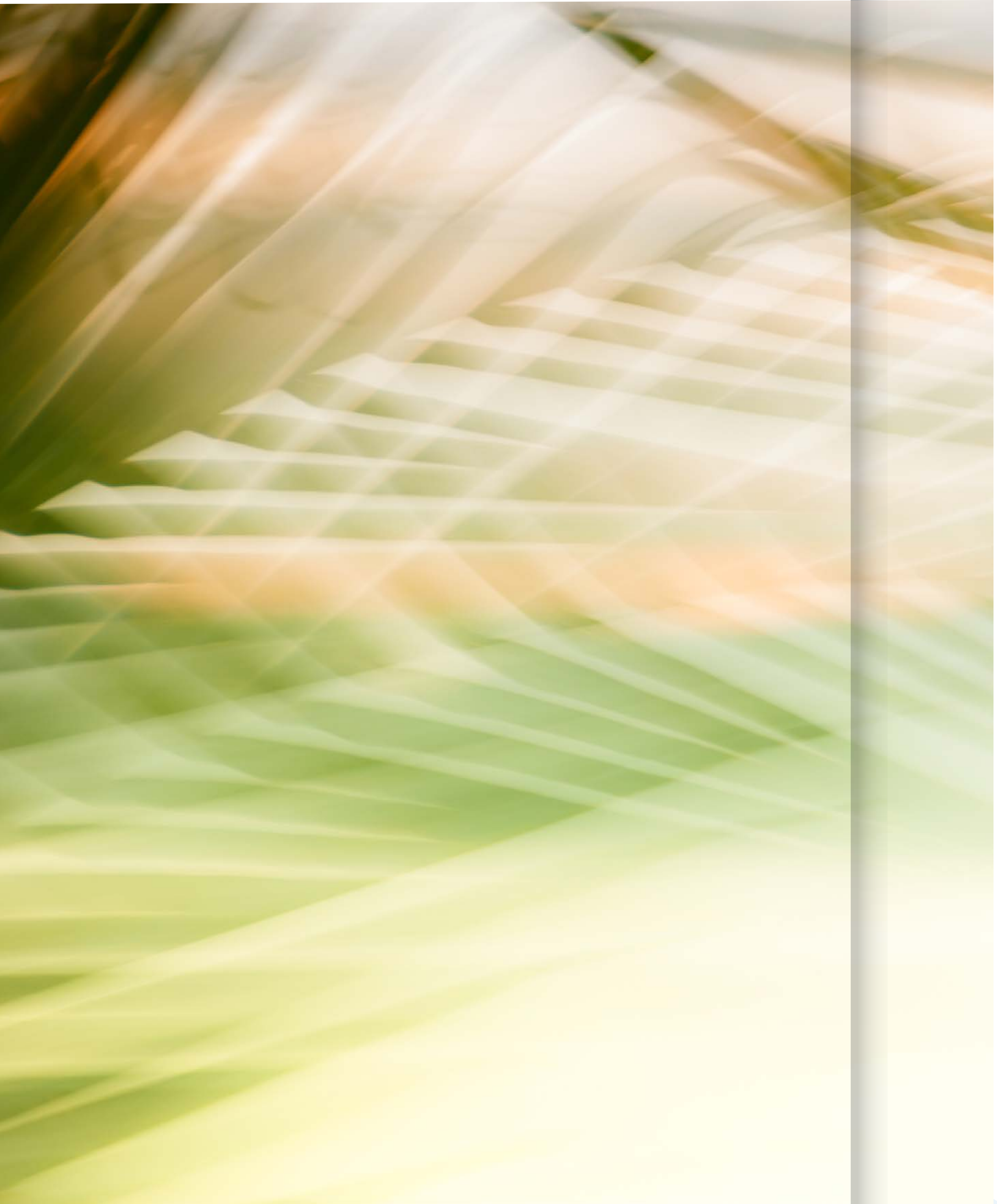
However, it is not too late. With well-planned and executed programs our aquifers can be saved. The Environment Agency Abu Dhabi is working with other government agencies to ensure our groundwater and soil are protected. Some of these programs include:

- Abu Dhabi Groundwater Law
- Liwa Strategic Water Reserve
- Groundwater Monitoring Programme
- Wastewater Optimization Programme
- Technological Innovation Programme
- Abu Dhabi Soil Quality Monitoring and Assessment Program

As we learn more about environmental issues, it becomes very clear that EAD cannot work alone. These issues require collective and integrated responses. Then, the set responses must be coordinated between federal and emirate-level authorities, as well as across Abu Dhabi government agencies such as the Abu Dhabi Food Control Authority, Farmer's Services Centre, Municipality, Urban Planning Council, Abu Dhabi Police and environmental court.

As with all complex problems we need to work together to solve these important issues for the safety and security of our country and the future well-being of future generations.

Shaikha Ahmed Al Hosani
Executive Director, Environment Quality Sector



Executive **Summary**

The Environment Agency - Abu Dhabi (EAD) is conducting the "Groundwater Wells Inventory and Soil Salinity Mapping for Abu Dhabi Emirate". For the Reporting Period the Project has completed the Municipality of Abu Dhabi, a majority of Al Ain Municipality and the remote areas near Al Shwaib. For Al Gharbia the central parts of the Liwa Crescent are under survey as well as the northwestern sector of this Municipality.

In addition to the mobilization phase of 2½ months and the on-going 15-month field survey phase, the Project has included a comprehensive well inventory and a farm soil salinity inventory.

Core components of the Project are:

- Satellite Aided Determination of Survey Locations
- Guided Surveys along Pre-Selected Routes
- Digital Field Data Collection along with Recording of Metadata
- Quality Assurance
- Streamlined Data Management

Well **Inventory**

Phase I: Review of Existing Data, Database and Design Inventory

The satellite aided determination of survey locations along with the compilation of all well data available was used to map land use with the help of digital field mapping devices. In 2016, using the land use map, 2,600 square kilometers (km^2) of irrigated areas (oasis, farmland and forests) within the 60,000 km^2 of terrestrial habitats were identified and well and well-field locations were determined to serve as the primary field destinations of the well inventory and survey.

The well inventory had to be coordinated with the deployment of the field teams. This implied that the sequence of survey areas had to be determined beforehand, and that the field teams had to follow pre-selected routes as determined by the project manager.

At each well visited in the field, the data collection consisted of recording well identification data, master data, well status data, groundwater abstraction data as well as depth to groundwater and groundwater quality information. In addition, digital photos of the wells were taken to facilitate data validation at a later stage as well as change detection.

The collection of well attribute data as well as the documentation of the water sampling was streamlined using a GPS-Aided Data Collection System. The core component of the system was a rugged Trimble Juno 3D handheld field computer with an integrated internal GPS receiver. All field data collected was immediately entered into the digital field data collection computer. User-friendly data input masks based on check boxes, scroll down lists, or sliders were created in advance requiring the surveyors to enter/pass through all data fields as pre-determined.

Aside from the collection of the principal data, metadata characteristics were also collected. This served as an aid in the identification, quality checking, and management of the principal data.

Each well was tagged with a metal registration plate with the well identification number (WIN), and the full name and logo of EAD was mounted on each inventoried well. Because there was no opportunity to produce plates on-site, the plates had to be pre-fabricated in batches for the anticipated number of wells prior to the well survey.

Quality assurance and quality control accompanied the entire well inventory, assessing the data collected by the field crews. The quality assurance was focused on spatial coverage checks, attribute validation, verification of accuracy and reliably, as well as monitoring field crews at work. Intelligent data management was applied to optimize the data flow between the mobile GPS-Aided Data Collection System and the project database.

Results: In total, 60,697 groundwater wells were registered, out of these 6,343 wells were identified in the Abu Dhabi Municipality (ADM) area, 53,464 wells in the Al Ain Municipality (AAM) area, and 753 Wells in the Western Region Municipality (WRM) area. Of the wells surveyed 43.9 percent were found operational. Most the wells belonged to agricultural areas, followed by forests and remote well fields. 141 wells were found in areas outside redefined municipal boundaries.

Depth to groundwater were measurements were recorded for 24,312 wells showing that approximately a third of the wells were dried-out. With an average depth of 102 meters (m) below surface, and large regional variations according to abstraction and apparent differences in hydrogeological setting.

The groundwater salinity was measured in 15,286 operating wells including some bailer samples. Both in the Al Khazna / Sweihan as well in the Al Hayer - Al Ain - Al Wagan areas slight to medium brackish groundwater is prevailing with better quality of water near the UAE - Oman border. Discharge measurements, carried out for 8,832 wells, showed an average discharge rate of approximately 16.15 m^3/h, ranging from a minimum of 0.13 m^3/h to a maximum of more than 180 m3/h.

Hydrochemical analyses of major anions/cation were carried out for 486 samples and transferred to the laboratory. 514 samples remain to be collected from sample group 1 and 2. Samples for trace elements, microbiological, pesticides and organic analyses will be collected in the remaining course of the project at 550 wells in coordination with EAD.

In order to enable the drawing of location maps showing name and extent of land use features supplied by a well, the data integration comprised the use of farm boundary data as supplied by stakeholder organizations such as DMA and ADFCA. Due to the slight inaccuracy of GPS positions, the positions of some wells close to plot limits fell outside the DMA farm boundaries. To identify which wells were in farm boundaries and which were not, auxiliary information was gathered and processed to fix of the number of supply wells per farm. In addition optical satellite data was used to identify targets in uncertain areas with on-screen digitizing in Google Earth and ADSDI supplied data of 0.6 m resolution.

To match EAD's well data recorded in the past with wells recorded by the well inventory team, the Project has provided to EAD the link between the new and the previous well names by applying GIS analysis incorporating previously permitted and recorded wells and reporting the survey data in three-month batches.

Effects of Re-scoping of Contract

The re-scoping of the contract in 2016 resulted in a changed maximum number of wells to be surveyed from 125,000 to 105,000 and the complementary survey and sampling activities were cut back. Sampling Group 3, Trace Elements, was reduced to 250 and DGPs Survey of wellheads was removed.

Outlook

The outlook for the upcoming second half of the project foresees the conclusion of the regular well survey by mid October 2017 with fulfilment of remaining tasks by the middle of December 2017.

Subsequently Phase III will see the completion and review of the database, and the evaluation of the results into the required reports, maps and statistics. All necessary database actions shall be undertaken to adapt and transfer the project data to EAD's AWRIS geo-coded well monitoring system.

Soil Salinity **Inventory**

Phase I: Review of Existing Data, Database and Design Inventory

The water resources of Abu Dhabi Emirate face severe depletion and quality deterioration. Similarly, farms find themselves lacking water of good quality and consequent salinization of their soil resources. The farm and soil component of the Well and Farm Inventory Project intends to make an inventory of the farms' water resources and soil condition with the aim to pinpoint problems and to come up with an adequate management plan.

The Farm and Soil Inventory part of the Well Inventory Project initially intended to map all of the Abu Dhabi Emirate's 25,000 farms (65,000 ha) for water and soil salinity as well as soil classification. A monitoring programme is being undertaken for 100 selected farms which are visited every four months with the intention to record the temporal variation in soil and water salinity.

Due to the re-scoping of the programme, the farm component has been reduced to 3,900 regular farms but has maintained the 100 monitoring farms.

The Farm and Soil Inventory makes use of available satellite imagery, the farm information of the DMAT, the soil information of the Abu Dhabi Soil Information System and Land Use Data. The previous soil mapping project of the Soil Survey of the Abu Dhabi Emirate had surveyed most areas of the Emirate with exception of the farm soils. So, while providing an important framework for the project, the Emirate's Soil Survey will benefit from the complementary mapping of the farms' soils.

The Soil Survey is accompanied by an extensive laboratory programme which is taking in samples from every tenth farm for laboratory analysis of EC (electrical conductivity), pH and cations to determine SAR (sodium adsorption ratio). In addition, the intensive baseline provided by the Monitoring Survey allows for the analysis of a full set of anions and cations as well as plant nutrients, gypsum and carbonates. Irrigation water samples are taken from every farm with soil samples to establish the relation of irrigation water and soil. Laboratory Analysis is undertaken by SGS laboratories of Jebel Ali.

The farm survey is described by a detailed SOP covering site selection, augering and sample taking.

• Farm Inventory description

Following the Inception Phase (Phase I), in which the previously stated procedures were established and approved, the second phase of the project deals with the actual implementation of the survey programme.

In this phase, the field survey data are recorded on the Trimble Juno unit. In addition, field data sheets cover the description of the farm inventory terms, the identity of the farm owner, the available farm infrastructure, the actual land use, the cropping pattern, the irrigation system used, and reservoirs. Based on this data, the water demand - water quantity used, can be deduced. Based on the combined field data sheets, Trimble data records and lab data a description and classification of the soils are done according to the UAE Key to Soil taxonomy - an adapted version of the US Soil Taxonomy.

Detailed soil sampling includes augering to 150 cm depth and recording of the soil depth and horizons, the texture, the color, the gravel content, soil humidity and reaction to HCl, as well as any other important diagnostic features. The soil samples for field analysis are taken from four standard horizons 0 - 25, 25 - 50, 50 - 100 and 100 to 150 cm depth. A suspension of 1 soil to 1 water (w:v) is prepared to be measured for EC and pH.

The soil samples for laboratory analysis are taken from every 10th farm and are routinely analyzed for EC in saturation extract, EC in 1 soil to 1 water (s:w) as well as Ca, Mg and Na in saturation extract for SAR.

Water samples of the corresponding irrigation water applied to the analyzed soils are tested for ECw, pH, and the parameters Na, Ca, Mg to establish SAR and the anions HCO3 and CO3 to determine RSC (residual sodium carbonate).

• Quality Control

One of the prerequisites for awarding the laboratory analysis contract to SGS was the establishment of a quality control programme. Apart from a range of laboratory internal QC measures, two laboratories, ICBA in Dubai and UEG Wetzlar in Germany, conducted an inter - laboratory comparison. The inter - laboratory comparison pinpointed some important procedural difficulties with the preparation of the saturation extract in sandy soil and the tendency of soils, poor in fine material and organic substance, to segregate, which could deliver different results when subdividing the soil sample for analysis.

• Salinity mapping

For the mapped areas in Al Khatim, Sweihan, Al Ajban and Al Wagan, salinity maps based on the field investigation were prepared. They show the salinity at a depth of 0 to 25 cm, 25 to 50 cm and cumulatively at the depth of 50 to 150 m. As a rule, high salinity in the top horizons diminishes with the depth of irrigated soils, while in natural soils or abandoned farms low salinity remains fairly constant with depth. Soils on dune land with permeable sands suffer less from irrigation-induced salinity, while soils with gypsum or calcic layers have a greater problem with permeability and consequently the leaching of salts.

The ratio of irrigation water quality with soil salinity (in the form of EC of soil water to irrigation water) is used to illustrate the quality of the irrigation process. Values greater than 1.5 indicate deficient irrigation management and values less than 1.5 indicate good irrigation management. The resultant maps in all regions show a highly random distribution, the management on similar soil depends on the irrigation water quality, irrigation method, type of crop and a great variety of irrigation practices.

• Relationship ECe to EC 1:1

Part of the intent of the farm and soil survey is to establish a reliable ratio between the EC method based on the saturation Extract (ECe) and the simpler measurement of the EC in a 1 to 1 suspension of 1 water:soil by weight and volume. For the 395 monitoring soil samples the laboratory ECe was compared with the EC 1:1 field results. The result yielded a ratio of 1: 3.17 with an acceptable r^2 value of 0.82.

Upon request of the technical committee, the laboratory ECe will be compared to the EC 1:1 again, but in the future the method will be applied to the soil samples not in the field but under controlled laboratory conditions and by application of the same field procedure.

• Gypsum requirement (alkalinity)

Soil alkalinity (sodicity) is denoted by an elevated Sodium Adsorption Ratio (SAR) value or high Exchangeable Sodium Percentage (ESP), usually above 15. Negative effects in agriculture are related to Na toxicity to susceptible crops and infiltration problems due to swelling action in fine soil material.

To control the problem the usual method is to provide soil amendments which can deliver Ca ions to be exchanged against Na ions on the exchange complex. One of the most common sources of Ca is gypsum. Based on the pH and soil texture, sodic soils in Abu Dhabi might require up to 1.5 tons / ha of gypsum to be applied into the top 15 cm of the soil.

• Water Quality classification

Irrigation water quality has been analyzed on water samples taken on the same farm as the soil samples. The results indicate a high salinity of the irrigation water, although there are regional differences. The Al Khatim and the Ajban areas both have an irrigation water salinity average of about 16,000 to 18,000 MicroS/cm, while the Sweihan and Al Wagan areas show an average of about 10,000 MicroS/cm. The SAR is generally above the critical level of 15 (mmole/l) with the exception of the Al Wagan area. The Residual Sodium Carbonates (RSC) are all in the safe negative range but with Al Khatim and Sweihan in the best range of highest negative values.

In conclusion it can be said, that the irrigation water is highly saline, causing yield decreases up to 50%. The SAR is high, which poses a problem for susceptible crops. Although infiltration problems can be anticipated, this is largely neutralized by high salinity and the permeable sandy character of the soils.

• Soil Classification

Soil classification for the Farm and Soil survey are based upon the Trimble data and the recorded field sheets. The modified United Arab Emirates Keys to Soil Taxonomy, based on the US Soil taxonomy have been applied to 1,715 surveyed farm soils in Al Khatim, Sweihan and Ajban areas. Ninteen different soil types at subgroup level have been distinguished, the Torripsamments (38%), and Haplocalcids (17%) being a major proportion.

• Data upload into UAESIS

The requirement to integrate the result of the Farm and Soil survey into the existing United Arab Emirates Soil Information System (UAESIS) database has begun. An initial mapping of the data fields has been performed and the corresponding data fields identified. Due to the need to integrate additional information, e.g. agricultural land use, in the database new data fields need to be established, while existing data fields need to be adjusted in units and magnitudes. Also for the final integration a range of lookup tables using SQL will be created to adopt uniform codes for the data mapping criteria. For the present, while the data uptake in the field has not been completed, it is necessary to maintain the present Access/Excel Database for data processing and cross checking of data. The final adaptation and transfer will thus be made in Phase III.

• Monitoring Procedure (Soil, Water, Laboratory)

One hundred farms have been selected throughout the agricultural areas of the Abu Dhabi Emirate representing a variety of soils and land-use patterns to ascertain the seasonal variation in salinity.

The sampling procedure for monitoring farms foresees the mixing of the standard depth samples from three random augerings taken from a farm plot with identical land use.

The baseline survey for monitoring, apart from the standard analysis of pH and ECe and EC 1:1 values, includes the determination of the saturation percentage, the complete set of main cations Ca, Mg, Na, K and anions Cl, SO4, HCO3 and CO3. The main plant nutrients N, P, K are analyzed by standard procedures to rate their plant availability. Gypsum contents is analyzed by precipitation with Acetone. Carbonates present are analyzed by reaction with acid to complement the measures. The repeat survey is restricted to sample taking and the analysis of the key parameters EC and pH as well as the cations necessary to calculate SAR.

Following a baseline survey in April 2016, in which water and soil samples were extensively analyzed in the laboratory, two repeat surveys were conducted in August '16 and December '16.

• Change analysis soil and salinity

The results of the soil salinity analysis show a marked fluctuation of salinity values with the seasons. The highest variations are recorded in the top horizons, while the lower horizons also react but in a much reduced manner.

Knowing that on average every mm of irrigation water (1l/m^2) at an EC of e.g. 16,000 MicroS/cm tends to add about 10 g of salt per m^2 of the soil. Further assuming a yearly value of 3500 mm for palm tree irrigation, about 35 kg of salt is applied per m^2. This amount of salt needs to be leached out by proper irrigation management.

The winter season shows the lowest value in salinity due to lower evapotranspiration and a higher proportion of the irrigation water contributing to the leaching of salt. Rainfall is not a key factor. During the summer season, due to higher evapotranspiration and less water infiltrating into the soil, salt tends to accumulate at the surface.

• Soil Management Plan

Recommended management of Abu Dhabi Water and Soil resources needs to be considered at two levels: First, at the technical level involving ADFCA and ADFSC concerned with the improvement of land management, introduction of salinity resistant crops, improvement of irrigation practices, and the support of new irrigation technologies.

Second, at the political decision-making level where the best available water resources should be matched with the best available soil resources. With deteriorating groundwater quality, Abu Dhabi is experiencing a corresponding deterioration to its soils. Available good groundwater resources should be used sustainably on suitable soils. In addition, a strategy for directing the three most important Abu Dhabi water resources (groundwater, desalinated water and TSE) to optimum use needs to be developed: e.g. well water for salinity resistant crops, while desalinated water should be restricted to high value vegetable crops, and TSE use should be expanded wherever possible and be directed to ornamentals and fruit trees (date palms) not coming into direct contact with human consumption.

• Outlook

The outlook for the upcoming second half of the project foresees the conclusion of the regular soil mapping in November 2017 and the termination of the last monitoring round in December 2017.

Subsequently, Phase III will see the completion and review of the database, and the evaluation of the results into the required reports, maps and statistics. All necessary database actions shall be undertaken to adapt and transfer the project data to UAESIS.

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Abbreviations

ADFCA	Abu Dhabi Food Control Authority
ADFSC	Abu Dhabi Farmers Service Centre
cm	Centimeter
DCI	Dornier Consulting International GmbH (formerly DCO)
DMAT	Department of Municipal Affairs
EAD	Environmental Agency - Abu Dhabi
EC	Electrical Conductivity
EHS	Environment, Health and Safety
ESP	Exchangeable Sodium Percentage
GWL	Groundwater Level
Ha	Hectares
K	Potassium
m	Meter
m.b.g.l.	Meters Below Ground Level
m.b.TOC	Meters Below Top Of Casing
N	Nitrogen
µ	Micro (scaling of numerical value)
P	Phosphorus
pH	Numeric scale used to specify the acidity or alkalinity of an aqueous solution
ppm	Parts per Million
QA	Quality Assurance
QC	Quality Control
S	Siemens
SAR	Sodium Adsorption Ratio
SCAD	Statistics Centre - Abu Dhabi
SOP	Standard Operating Procedure
TOC	Top of Casing
UAESIS	United Arab Emirates Soil Information System
WIN	Well Inventory Number
WL	Water Level

1 Introduction

This report of the project. ***"Groundwater Wells Inventory and Soil Salinity Mapping for Abu Dhabi Emirate"*** provides information of the achievements in the year 2016 and provides a brief description of the context of the activities undertaken for the well survey and soil salinity survey. Last year's work and achievements represent the first half of the designated time for data collection and recording. These efforts will be followed in 2017 with the remaining survey work and for 2018 with 8 months of analyses and reporting of the collected data according to the requirements of the contract.

1.1 Overall

Within the last decade, responsibility for, and information on water resources were scattered among numerous governmental agencies and third-party projects in the Emirate of Abu Dhabi. In March 2005, the Environmental Agency - Abu Dhabi (EAD), was appointed by the Abu Dhabi Executive Council, to undertake the overall management of groundwater and soil resources within the emirate.

A major task of groundwater and soil management in Abu Dhabi Emirate is to integrate and harmonies all related data. The most important primary information source is the characterization of existing wells/ farms/forests and soil salinity. For this reason, EAD issued the Project ***"Groundwater Wells Inventory and Soil Salinity Mapping for Abu Dhabi Emirate"*** (the Project),The Project started on 1st October 2015 and was scheduled to run for three years (36 months) until 30th September 2018. Its major objectives are:

- Conduct an inventory of all wells in Abu Dhabi Emirate,
- Conduct a farm/soil salinity survey of approximately every 1in10 farms in Abu Dhabi Emirate,
- Assess the volume of groundwater abstractions and its impact on groundwater and soils,
- Prepare databases, maps, and a groundwater atlas showing all data and results, and
- Develop a comprehensive action plan for management and reclamation of salt-affected farms.

The project is divided in three (3) phases:

- Phase 1 was scheduled for up to 4 months and comprises mobilization of survey teams, purchase of equipment, and the development of work procedures (data dictionaries, SOP's, EHS, and QA & QC).
- Phase 2 runs for 24 months and comprises the actual well & farm survey, including groundwater and soil sampling and analysis. This was restructured during the last Reporting Period.
- Phase 3 is scheduled for 8 months and comprises the interpretation of survey results, the preparation of databases, maps, and the groundwater atlas.

1.2 Project Overview

The project started on 01 October 2015. It runs for three years (36 months) until 30 September 2018. The project will be executed in 3 major project phases:

1. Initiation Phase - Information review and planning,
2. Field Survey Phase - Field inventory of wells/farms/forests, groundwater sampling, soil salinity sampling in the farms, and periodic monitoring of soil salinity, and
3. Data Analysis, Mapping, and Reporting Phase - Sample analysis, assessment, mapping, and upgrade of EAD's existing database systems.

The Initiation Phase was finished after 1½ months from project start instead of the planned 4 months. During the subsequent 24-month Survey Phase the entire field data collection will take place. The final Reporting Phase shall be executed within the remaining 8 months. Draft inception reports for Phase 1 were submitted on 15 December 2015. Subsequently, on 16 December 2015 for the well survey and 03 January 2016 for Soil Salinity Survey, Phase 2 was commenced by starting the teams' induction and field work with an initial well and farm/soil-salinity inventory.

Project Schedule	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Initiation Phase		4 months										
2. Field Survey Phase						24 months						
3. Data Analysis, Mapping and Reporting Phase											8 months	

Figure 1: Overall Project Schedule

During the Initiation Phase the staff conducting the survey was mobilized. The procurement of all necessary material, such as field computers, measurement devices, cars and office equipment was completed. Simultaneously, the inventory was planned according to the WHAT, HOW, WHERE and WHEN. It started by specifying data attributes to be collected (WHAT). The subsequent planning covered all technical aspects of the inventory (HOW). Areas to be investigated were identified (WHERE) and the sequence of areas to be surveyed was determined (WHEN). Detailed description of the method to be applied were given in the Inception Report and annexed relevant SOP's.

During the current Field Survey Phase, - the most staff intensive phase of the Project - the entire field data collection takes place. This phase is limited to 24 months and comprises the following major tasks:

- Groundwater well inventory, sampling for hydrochemical analysis and well tagging.
- Differential GPS survey and groundwater level measurement campaign.
- Farm inventory along with soil salinity sampling and forest well inventory.
- Periodic monitoring of soil salinity.

It is estimated that there are currently ±105,000 wells within the entire Abu Dhabi Emirate, out of which around 20,000 were already registered by the Groundwater Well Inventory Pilot Project or by EAD's well permitting system. These wells are also verified and recorded in the on-going project. The remaining ±85,000 wells will be registered in the course of the Project. At the present, the on-going survey indicates approximately 56% of the wells are non-operational or abandoned.

In addition, after changing the scope of work in 2016, 4,000 farms and their soil, water, and salinity properties will be surveyed and classified. These include 100 farms which were initially surveyed in a baseline study in April 2016. These 100 farms will be revisited 5 times at regular intervals for monitoring purposes in the 24 months of the field survey ending at the 31 December 2017.

In Phase 3 - Data Analysis, Mapping and Reporting - the final data sets will be developed and submitted. This phase comprises the analysis of acquired data, creation of new and update of existing databases, as well as the preparation of GIS thematic maps and a groundwater atlas.

Based on this processed information a reclamation and management plan for farm soils will be developed. The Reporting Phase is completed after submission and acceptance of the final report.

In addition to the core scope of work, EAD collaborates with the consultant throughout the Project in the following ways:

- Provision of a database of registered wells and associated data.
- Provision of details of well permits issued.
- Provision of satellite images.
- Liaison with Governmental Authorities/Agencies, well owners and farm owners.
- Development of leaflets and posters for display in public places.
- Preparation of advertisements in the media (newspapers, radio and TV).
- Preparation of other announcements.

In addition to the core project components, EAD organizes and conducts Public Relation campaigns associated with this project.

EAD's personnel and TC members will frequently travel with the inventory teams to observe and/or participate in the inventory. In addition, personnel from the groundwater metering project, crop calculation project, groundwater well permitting, and enforcement might participate in the inventory. Training of national manpower will be conducted throughout the survey phase.

1.3 Reporting Period

The present Annual Report covers the period from 16 December 2015 to 15 December 2016 ("Reporting Period" in the following) and shall provide the following information:

- Number of inventoried wells
- Number of inventoried farms
- Number of access denied
- Number of soil and water samples
- Number of desalination plants
- Findings
- Preliminary interpretations

2 Personnel and Logistics

The staff for the project are split into 3 levels. Staff for key functions such as project management and scientific advice forms the highest level. Followed by the senior supervisors and experts who are also key staff members. The senior supervisors organize and monitor the fieldwork of the survey teams forming the third level, see below **Figure 2**.

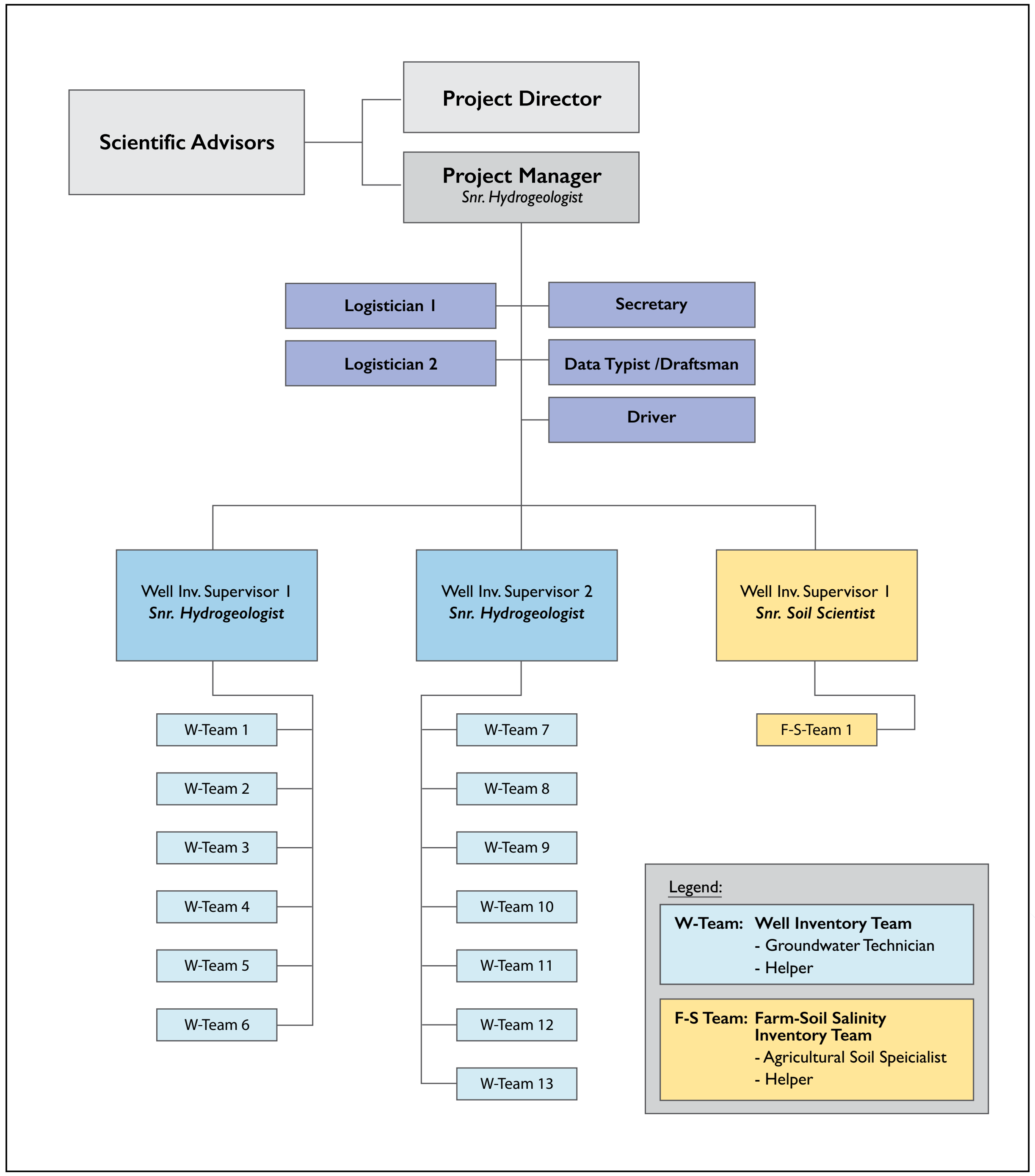


Figure 2: Project organization at the end of the Reporting Period.

2.1 Field Offices

A field office was established at the village Al Yaher on the outskirts of Al Ain. It was operational during the Reporting Period.

2.2 Well Inventory

The core component of the project is the 24-month Field Survey Phase to collect groundwater well data on the following categories:

- Well identification data,
- Master data,
- Well status data,
- Abstraction data, and
- Groundwater level and groundwater quality data.

The field inventory teams shall collect the groundwater well data solely in the field during the site visits. The following principal methods shall be applied for data acquisition:

- Interviewing the well owners/operators/laborers present at the site during the inspection,
- Inspecting the site and recording visible observations (e.g. well type, dimensions, casing material), and
- Carrying out measurements (i.e. water table, electrical conductivity, discharge rate).

The comprehensive data collection tasks are facilitated by the use of a GPS-Aided Data Collection System based on high performance GPS receivers combined with rugged handheld computers, see Figure 3.

Figure 3: Trimble Juno 3D - rugged handheld PC with internal GPS receiver and camera.

2.2.1 Data Dictionary/Input Masks

Gathering the field data is the most time-consuming part of the project and only a streamlined digital data acquisition process facilitates high efficiency. Due to a guided data entry, the surveyors are required to enter/pass through all data fields established in advance. This ensures complete recording of all requested attributes.

Typically, the data is entered into check-boxes, scroll down lists, or sliders, so that collecting well features and attributes is easy and accurate. By minimizing the alphanumeric data entry, errors will be minimized accordingly. An example of a data entry form is provided in the Figure 4.

The input masks to enter the well data in the field, are based on so called "data dictionaries" defining the well/farm/forest/soil attributes to be recorded. The data dictionary structures data collection, however, it does not contain the actual information collected in the field (positions and actual attribute values).

Data dictionaries comprise customized pick-lists, automatic repeat features, and numeric values. In the field, the data dictionary is used to control the recording of wells/farms/forests/soil samples and their attributes. It prompts the field crews to enter information and, in addition, sets limits as to what kind of data they enter.

An exemplary input mask used to enter the well data in the field into the GPS-Aided Data Collection System is shown in Figure 4.

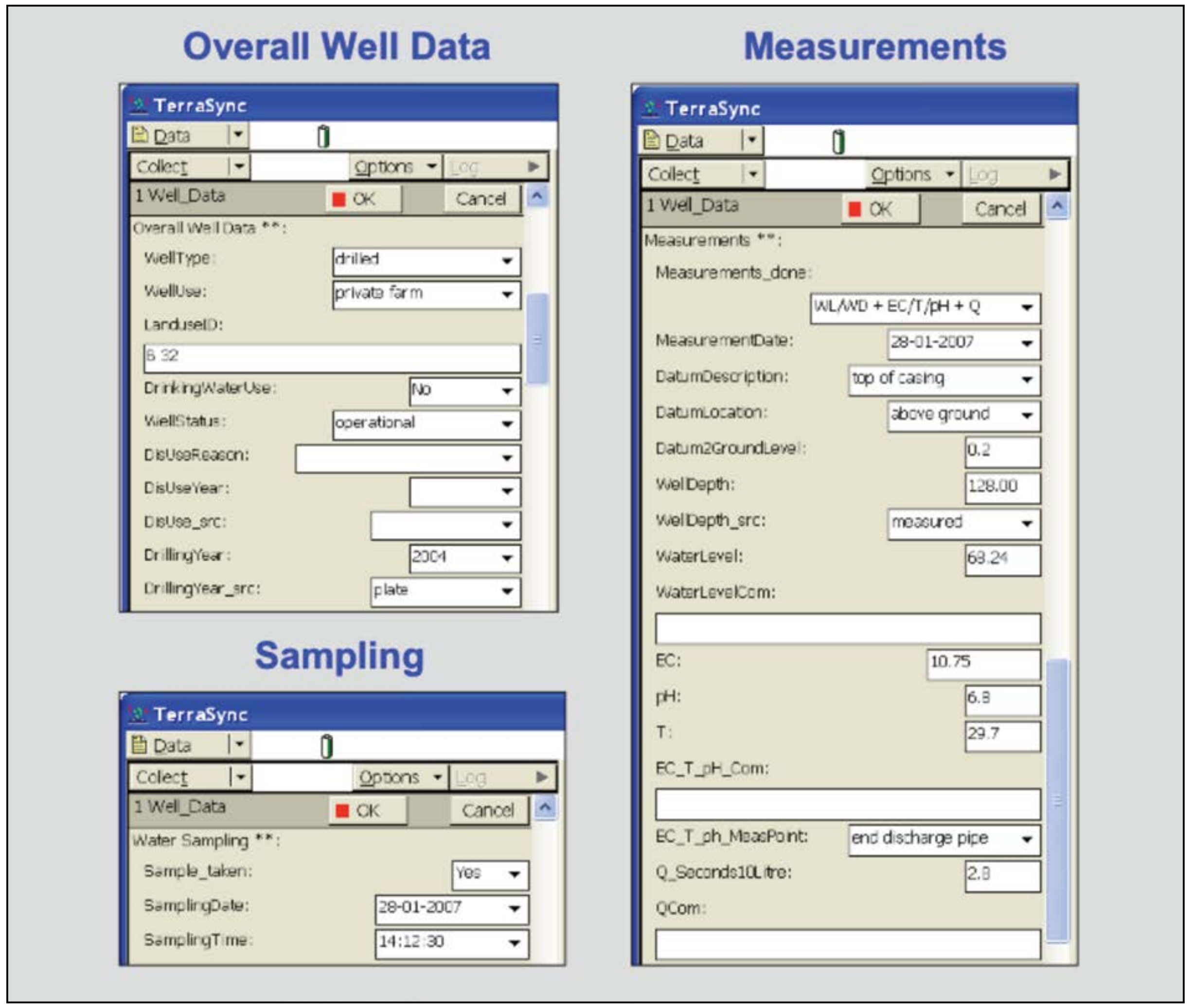


Figure 4: Exemplary input masks of the GPS-Aided Data Collection System to enter well data in the field. Entries marked with " * " are mandatory. Grey entries will be recorded automatically.

Aside from ensuring data integrity and compatibility with EAD's databases, the data dictionary makes collecting, updating, and processing data more efficient, easier and faster.

To create a data dictionary, Trimble's GPS Pathfinder Office software has been used. With GPS Pathfinder Office, files are imported from the EAD's GIS and database formats, so data can be taken to the field and back for verification and update.

2.3 Survey Sequence of the Well Inventory

2.3.1 Overall Survey Sequence

The well inventory was started in the Al Ain Region. Eight regular teams were scheduled to operate over the entire survey period of 24 months, this number was reduced to seven during the Reporting Period. After, 12 months and surveying areas to the North and South of Al Ain, six teams were shifted to the Western Region for the remaining nine months.

2.3.2 Distribution of the Well Inventory Teams

During the Reporting Period, camps for labor accommodation were established at the urban centers of Al Hayer, Al Khazna, Al Wagan, Al Yaher and Sweihan (Figure 5 and Figure 6).

- Al Khazna was used for 6 well inventory teams, including 1 team for forestry plantations plus 1 Soil salinity team after June 2016.
- Sweihan and Al Hayer accommodations were operated for seven inventory teams until end of August 2016.
- Al Wagan was used as a center for seven inventory teams in the Period September to December 2016.

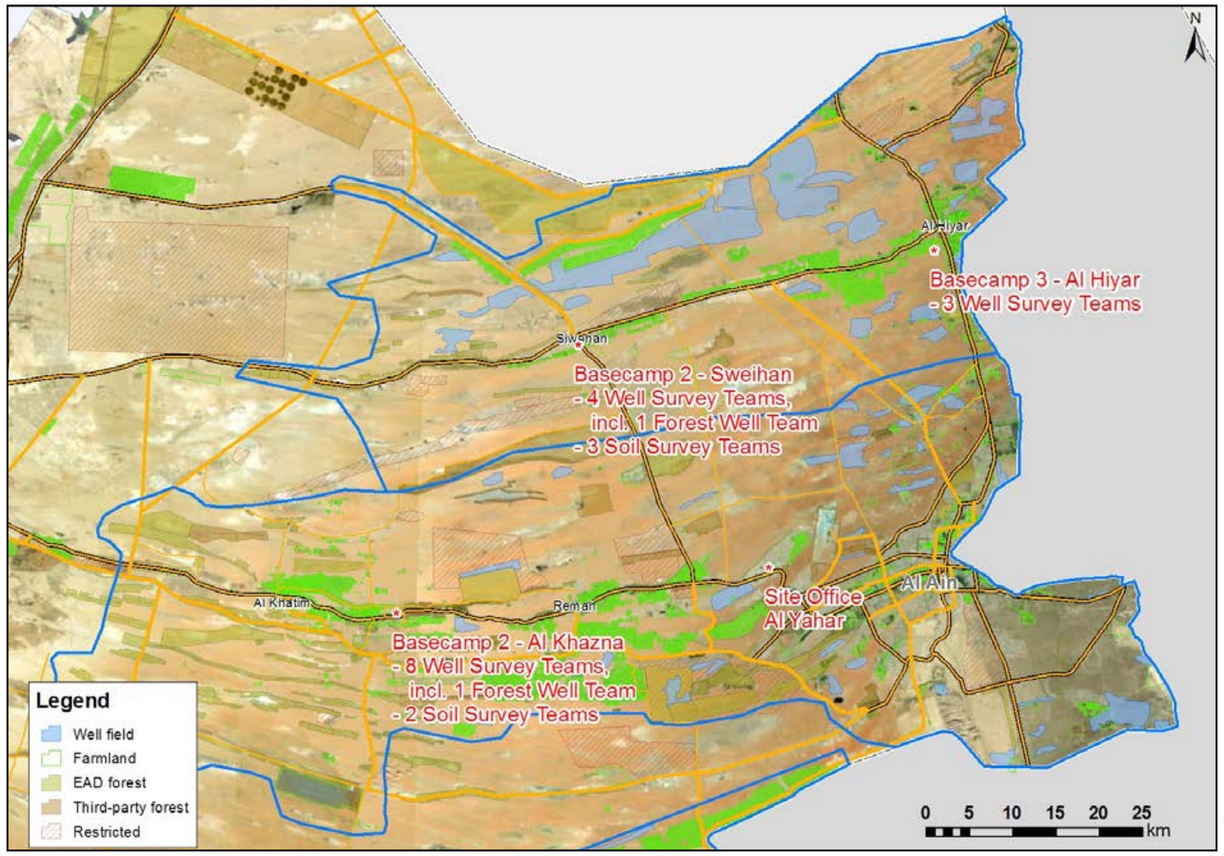


Figure 5: Team allocation of the well inventory since 15.02.2016.

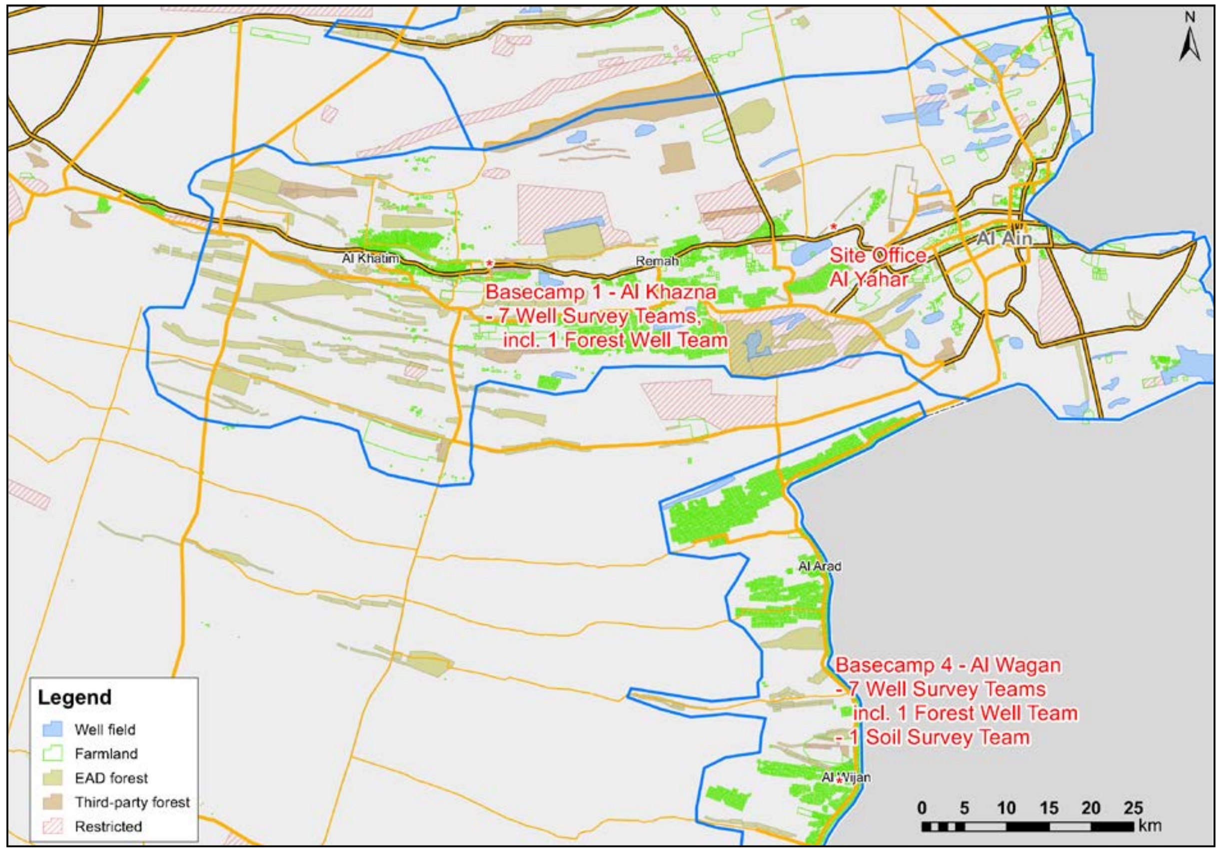


Figure 6: Team allocation of the well inventory since 01.09.2016.

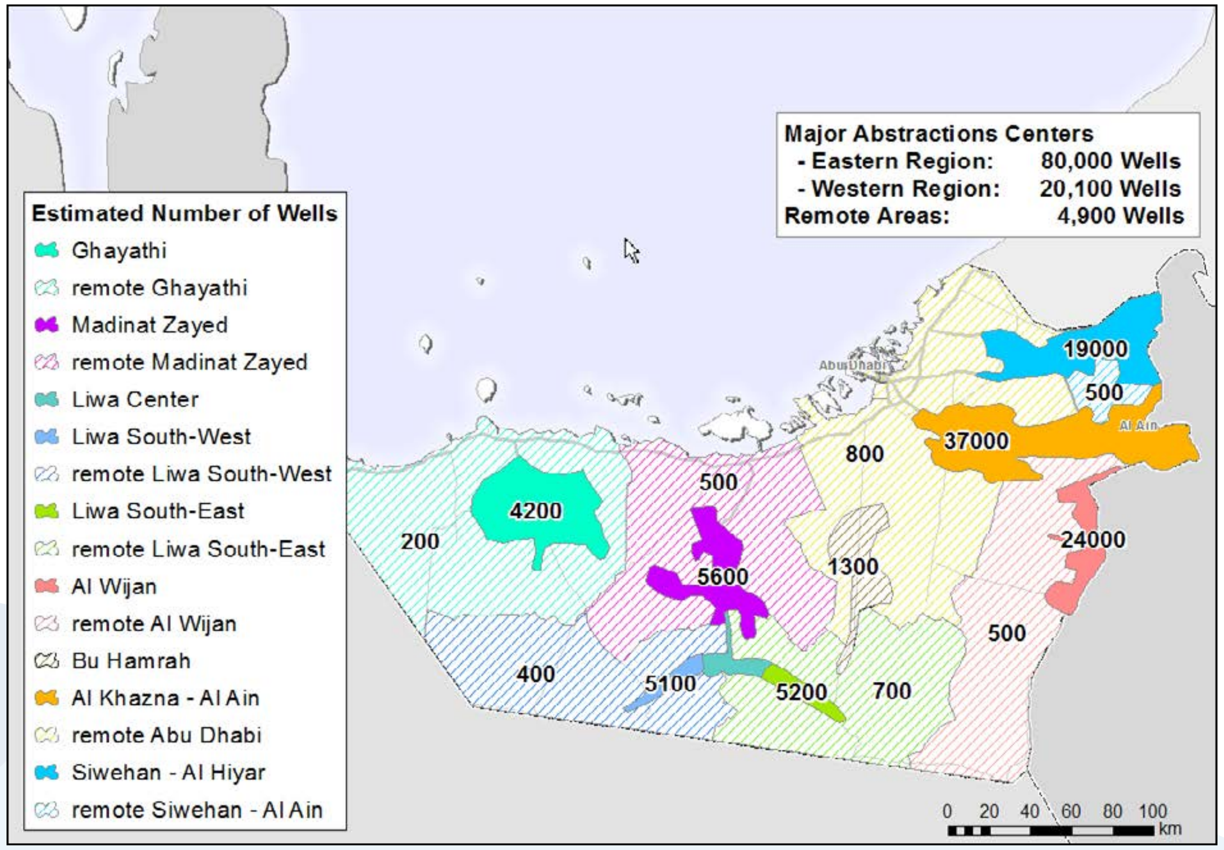


Figure 7: Estimated well numbers by areas.

2.3.3 Allocation of the Forestry Well Inventory Team

As part of the 13 to 15 regular well inventory teams, two teams were permanently assigned to the inventory of forestry wells. One team was based in Al Khazna later Al Yaher, the other one in Al Wagan.

2.4 Farm-Soil-Salinity Survey

The survey started January 2016 with five soil teams employed principally in the Al Khatim, Sweihan and Ajban region. Due to the re-scoping of work in June 2016, the soil teams had to be reduced to one. The single soil team, employed since July 2016 started soil monitoring in August 2016, followed by the regular soil survey, which had resumed on 03 September, but with the total number of regular farms reduced to 3,900, effectively translating into every 10th farm being surveyed for the remaining areas.

For this, the soil team had moved in the beginning of September to the Al Wagan area south and east of Al Ain, on the border with Oman, taking advantage of the Water team labor camp and facilities. By 30 November, about 530 farms have been surveyed in a total area of 16,600 ha. This covered the localities of Um Gafah, Az Zahir, Mezyed, Al Arad, Al Wagan and Al Qua'a.

The 3rd monitoring survey round started on schedule in December and covered all of the monitoring farms by the end of the year.

The progress of the surveys continues to be monitored on a weekly basis using records taken from the data collection devices.

Planning of the regular farm survey fieldwork was based on farms already covered including the monitoring farms. From the remaining farms, every tenth farm was visited during the survey and marked on overview maps and GPS devices.

From the 24,400 farms a total of 1,700 were previously mapped (leaving out 100 monitoring farms already base-line surveyed), so the 2,200 farms (out of a total of 3,900) had to be distributed over the remaining un-surveyed 22,600 farms.

To achieve an even distribution of farms and to maintain the statistical aim of randomness, a calculated one farm out of every 10.3 farms needs to be surveyed.

To identify the proposed farms, satellite pictures were overlaid with the GIS layer of the DMAT farm set, the farms already mapped, and the monitoring farms.

Leaving out the already surveyed areas and monitoring farms, the proposed farms were selected by counting out for practical purposes every 10th farm and marking it.

This method has been slightly relaxed in traditional farm areas such as Liwa or Al Ain, where very small and irregular shaped farms would cluster too many survey points close together, to the detriment of a good areal distribution.

Furthermore, areas were left out of the count, where the DMAT data set shows a farm grid, but the satellite picture and known field conditions indicate no farms.

3 Reporting for Remaining Project Period

3

In addition to the regular reporting, a further 19 tasks and reports were and will be developed to support functions that overlapped with the project such as well permitting related activities. The following tasks will be included in the remaining survey period (Table 1).

Table 1: Schedule of the deliverables

No.	Description	Submission date
1	Bi-weekly progress reports	1st and 15th of month
2	Data delivery of 4th quarter of Survey Phase, Wells, Soil and Monitoring Farms	15.03.2017
3	Phase 2 Quarterly Progress Report - 5	22.03.2017
4	Interim Report	07.04.2017
5	Data delivery of 5th quarter of Survey Phase, Wells, Soil and Monitoring Farms	15.06.2017
6	Phase 2 Quarterly Progress Report - 6	22.06.2017
7	Data delivery of 6th quarter of Survey Phase, Wells and Farms	15.09.2017
8	Phase 2 Quarterly Progress Report - 7	22.09.2017
9	Data delivery of 7th quarter of Survey Phase, Wells, Soil and Monitoring Farms	15.12.2017
10	Phase 2 Quarterly Progress Report - 8	22.12.2017
11	Data delivery of 8th quarter of Survey Phase, Wells and Soil	30.01.2018
12	Data delivery of 6th Monitoring Farm Survey	28.02.2018

4 Training and Capacity Building

4.1 Organised Training

Training of field staff started at the beginning of the field survey phase to take advantage of the possibility of matching the theoretical subjects with the application in the field through practical exercises. The water well/soil supervisors led the organised in-house trainings according to the status of the field activity and needs of field visits.

4.1.1 Organised Training for Well Inventory Teams

It was essential and mandatory to accompany the field trainings with theoretical trainings to avoid any discrepancy and to standardize the field measurements. In fact, the training provided all team members an insight and understanding of the techniques to be applied for a correct tagging, sample collection, soil analysis and classification, Trimble based data collection use etc. These theoretical trainings were provided by in-house knowledgeable staff.

4.1.2 Organised Training for the Farm/Soil-Salinity Inventory Teams

For the soil teams, apart from the organised training provided by soil supervisory staff, an organised offered by the Dubai institution ICBA was planned, that would provide a theoretical background to analyzing soils and applying soil classification.

Due to the re-scoping of the project and the retaining of only one field staff, the organised training was not offered and knowledge transfer was provided by the field supervisory staff

4.2 Training of EAD Staff

One of the main objectives of this project is the capacity building of the national manpower of EAD staff, to develop and improve staff proficiency in all practical and theoretical aspects of the project. The dates and subjects of trainings are listed below:

- EAD supervisory staff training January and February 2016
- AAM - ADFCA / ADFSC / EAD Meeting / Seminar, Al Ain, 17 December 2015
- EAD Site Survey Training for Wells and Soil Salinity, Al Ain, November 2016
- EAD Site Survey training for wells, Liwa - Mizeriah, December 2016

4.2.1 Well Survey

On-the-job training of EAD Hydrogeologists and ADFCA staff has been completed. The staff worked closely with field teams. The training followed the schedule of in-house training and on-the-job training as outlined in the sections below.

4.2.2 EAD Staff Training in Soil Matters

EAD staff seconded for the soil survey were similarly invited for the on-the-job training in the field. The EAD specialist is working closely with the teams in the field and participates in organised in-house training, as well as playing an active part in the EAD GIS processing of soil and salinity data.

4.2.3 In-house and On-the-job Training

The following in-house and on-the job training has been offered both for the well teams and for the soil teams.

Table 2: Field Data Collection Training

Course Title	Field Data Collection		
Participants	All project field technicians, and EAD supervisory staff		
Results	Standardise field measurement techniques		
Training objectives	Collect a precise and reliable field data		
Training Programme			
SCHEDULE	TRAINING THEMES	METHODS	MATERIALS
1st day	• data collection, • site measurements, • documentation (field form and tablet) and photography, • well numbering and tagging, • groundwater level measurement • Total well depth measurements • Electric Conductivity measurements and calibration of EC meter • pH measurements and calibration of pH meter • Well discharge rate	Presentation Discussions	Hand out material Power point Field equipment
2nd day	• Use of hand held GPS • Data entry using the Trimble handheld device • Familiarisation with the survey areas and the roads and farm/forestry access issues.	Presentation Exercises Discussions	Hand out material Power point Field equipment

Table 3: Water Sampling Techniques Training

Course Title	Water Sampling Techniques		
Participants	All Project field technicians, and EAD supervisory staff		
Expected results	Standardise water quality sampling in the field		
Training objectives	Collect and analyse representative sample		
Training Programme			
SCHEDULE	TRAINING THEMES	METHODS	MATERIALS

1st day	• Sampling Program
	  • Collect groundwater quality data
	  • Sample filtration and preservation
	• Hydrochemical Analysis
		Presentation
		Discussions
			Hand out material
			Power point

2nd day	• Samples collection and delivering • Wells Tags application	Presentation Exercises Discussions	Hand out material Power point

It is the responsibility and practice of the Project supervisors to hold the field activities and call field staff to meetings at the office (or at an assembly point in the field) to rectify any faulty data collection or activity that occurs in the field).

4.2.4 Soil Seminar and Practical Training

The soil training is accompanied by an in-house PowerPoint point-based soil and salinity seminar.

- Introductory seminar

Basic information is given in the introductory seminar (2 days) on:

1. Soil genesis
2. Basic soil profile structure
3. Soil salinity effects
4. Types of soil classification
5. UAE soil taxonomy
6. The field sheet explained (soil data dictionary)
7. The field sheet for the soil profile
8. Identification of soil texture
9. Estimation of farm water use in the field
10. Taking soil samples
11. Taking water samples
12. Field measurement of pH and EC
13. Salinity appraisal
14. pH
15. Sodium Absorption Ratio (SAR)
16. Guidelines for Interpretation of Water Quality for Irrigation
17. Field training

This theoretical background will be enhanced by practical field exercises such as:

1. Conducting the farm interview.
2. Using the Trimble Data collection device.
3. Using the soil auger.
4. Retrieving soil material and analyzing the soil profile.
5. Preparing the field samples for measurement.
6. Measuring water production at wells and reservoirs.
7. Collecting and labelling soil samples.
8. Collecting and labelling water samples.

5 Progress and Preliminary Results of the Well Inventory

5.1 Overall Progress

The well survey progress advanced as scheduled with some of the field works being slightly ahead of schedule, in large part due to the initial survey team. **Table 4** and **Figure 8** to **Figure 10** show the progress achieved during the Reporting Period. The area covered in **Figure 9** stretches from Al Faqah via Al Ain to the south and southwest of Al Qoa'a. The well survey works were conducted with 13 teams.

Table 4: Progress of the well inventory

Period	Total	Percent of completion	Value for completion
Wells surveyed (total)	60,697	58	105,000
Plates fixed	46,580	55	85,000
Already registered wells surveyed	10,245	34	30,000
* Backfilled wells (no plate fixed)	3,872	--	--
Wells in functional state	26,661	--	--
Depth to groundwater Measurements	24,312	61	40,000
EC Measurements	15,286	38	40,000
Desalination Units	649	--	--
Discharge Measurements	8,832	44	20,000
Samples for Laboratory analysis	486	49	1,000
Access denied	58	--	--

(*) Backfilled wells are only recorded with well identification data, well master data and well status data. No well ID plate will be mounted, and no measurements will be conducted.

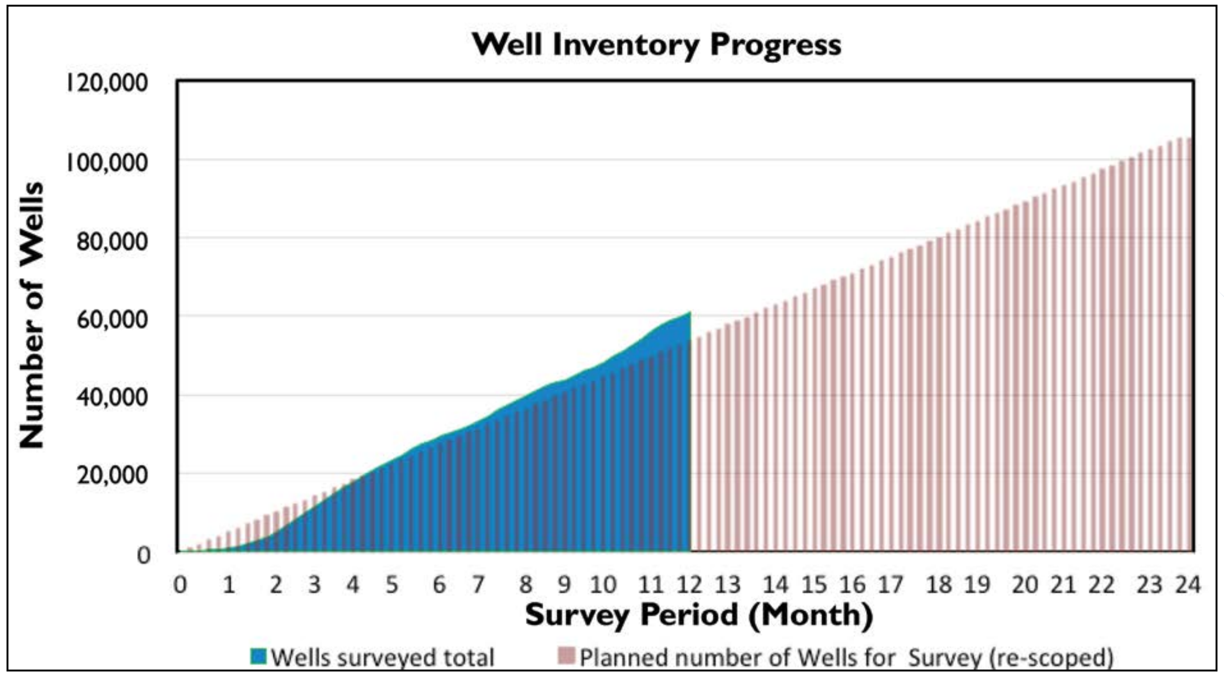


Figure 8: Well inventory and planned progress for the duration of the project.

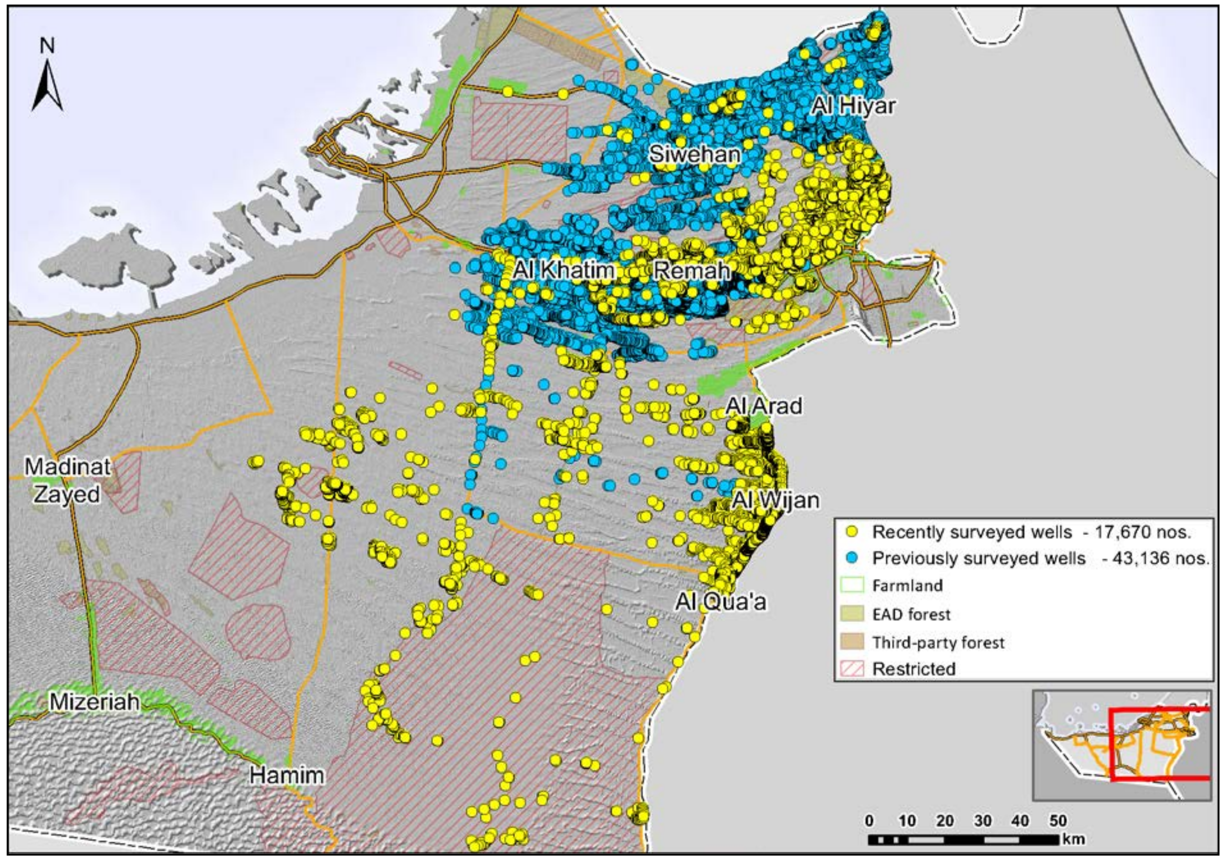


Figure 9: Wells inventoried until 12.2016 with last 3 months of the reporting period indicated in yellow.

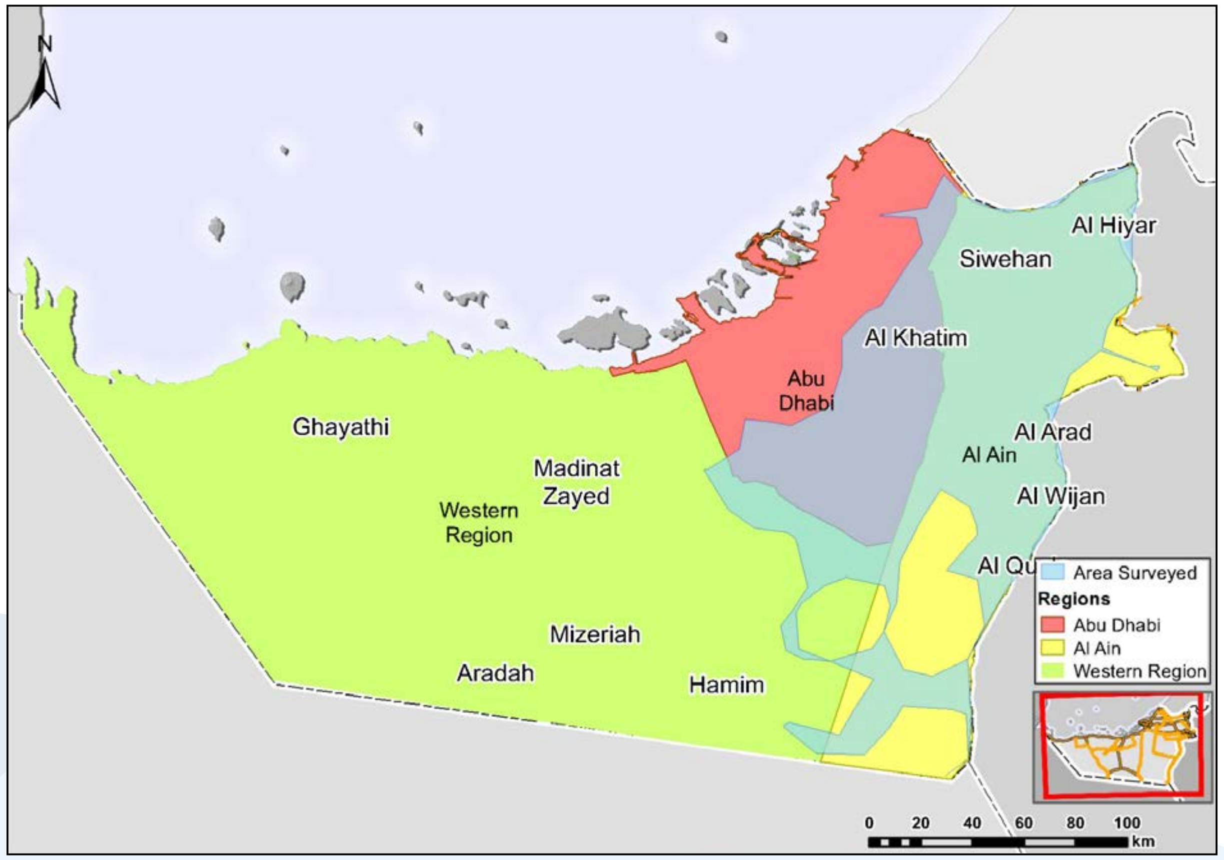


Figure 10: Project Area and Survey Coverage of the three Municipalities of Abu Dhabi.

5.2 Abstraction Centers - Draft

Data is presented in the following chapters for abstraction centers in a preliminary layout for illustrative purposes.. This layout of the abstraction centers uses the DMA farm data with a buffer of 1 km. and depicted zonification follows approximately changes in groundwater characteristics from west to east. This layout will be refined in the future to consider nearby forest wells and other pertinent information, such as declared well use near farm areas. Figure 11 shows the present spatial distribution.

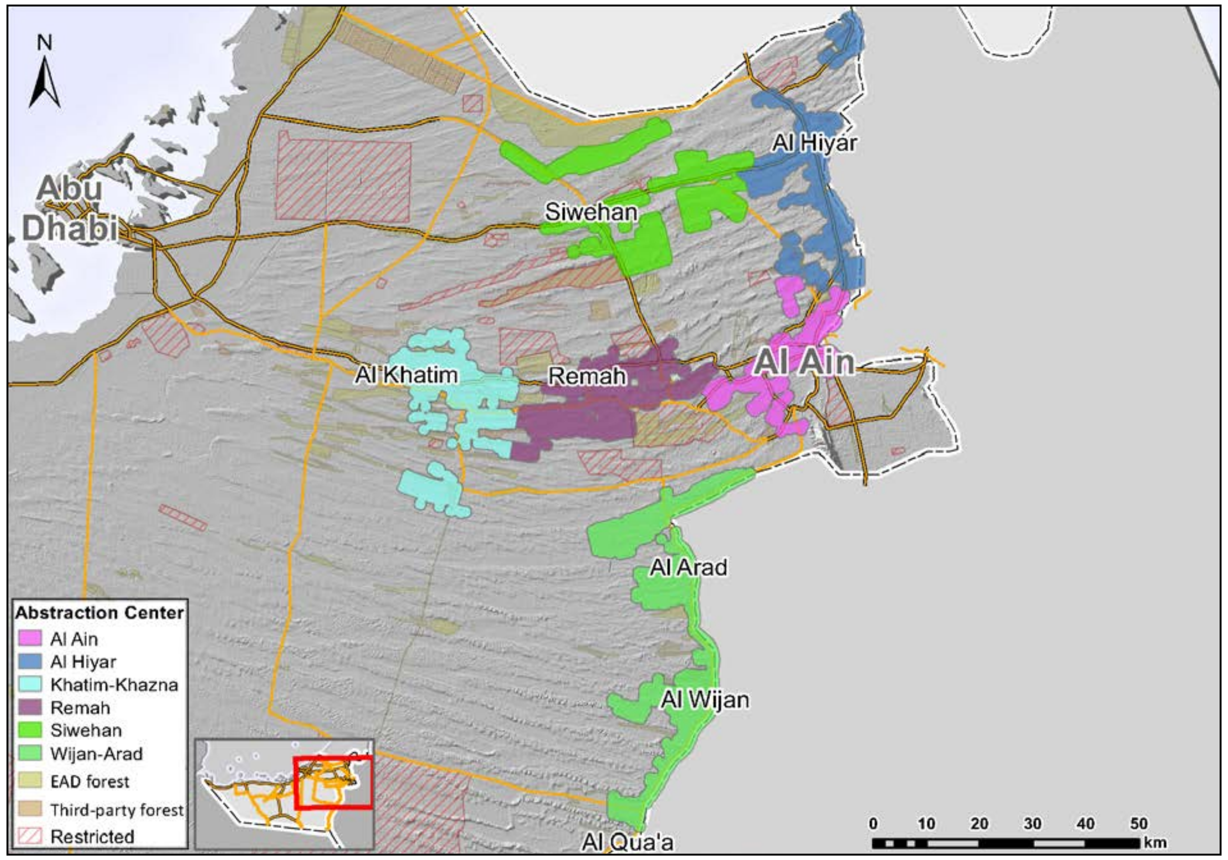


Figure 11: Abstraction center layout for better-differentiated water parameter patterns.

5.3 Well Identification Data

At each well visited in the field, the data collection recorded well identification data, including user information and well usage (Figure 12 and Figure 13). A large majority of sites surveyed represent farmland.

The following types of well use were identified for the abstraction centers; see also Figure 14 to Figure 19, as well as Table 5 and Table 6:

- Farm Wells - wells located within active or inactive farm properties.
- Forest Wells - associated with EAD forest plantations.
- Wellfield Wells - primarily associated with former Municipality water supply sites to such as Al Ain and Abu Dhabi, which are now disused or serving the farm water supply.
- Municipal Wells - wells on government properties not used for farming.
- Indistinct: wells located adjacent to residences, and wells used to raise farm animals (such as cows, sheep, horses, camels, and poultry) that are kept, raised, and used by people.

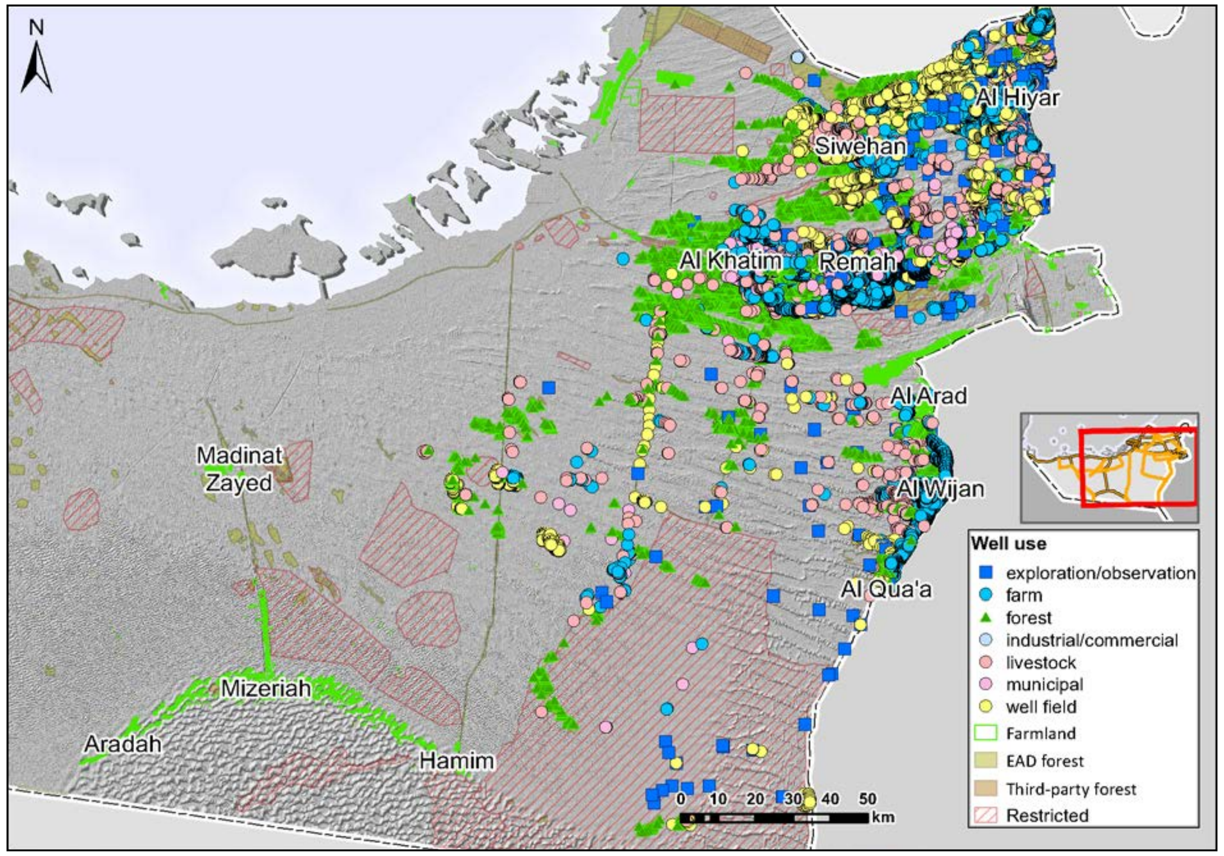


Figure 12: Well usage as surveyed until 12.2016.

Table 5: Well usage - encountered in abstraction centers and combined values of Sweihan, Al Hayer and Al Wagan areas for the Reporting Period

	Total		Sweihan		Al Hayer		Al Wagan	
Well usage	Wells	%	Wells	%	Wells	%	Wells	%
Amenity	16	0.06	8	0.09	6	0.08	2	0.02
Exploration / Observation	84	0.33	15	0.16	59	0.78	10	0.12
Farm	22,186	88.13	8,235	89.23	6079	80.25	7872	94.06
Forest	457	1.82	69	0.75	134	1.77	254	3.04
House Hold	34	0.14	17	0.18	13	0.17	4	0.05
Industrial	4	0.02	2	0.02	2	0.03	0	0.00
Live Stock	441	1.75	45	0.49	331	4.37	65	0.78
Municipal	33	0.13	0	0.00	23	0.30	10	0.12
Wellfields	1,385	5.50	815	8.83	532	7.02	38	0.45
Indistinct	533	2.12	23	0.25	396	5.23	114	1.36
Total	25,173	100	9,229	100	7,575	100	8,369	100

Table 6: Well usage - encountered in abstraction centers and combined values of Al Khatim / Al Khazna, Remah and Al Ain areas for the Reporting Period

Well Usage	Total		Remah		Al Khazna		Al Ain	
	Wells	%	Wells	%	Wells	%	Wells	%
Amenity	0	0.00	0	0.00	0	0.00	0	0.00
Exploration / Observation	46	0.18	33	0.19	6	0.09	7	0.80
Farm	22,005	88.49	16,243	95.08	5,124	74.14	638	73.08
Forest	864	3.47	156	0.91	627	9.07	81	9.28
House Hold	13	0.05	3	0.02	6	0.09	4	0.46
Industrial	1	0.00	0	0.00	0	0.00	1	0.11
Live Stock	227	0.91	62	0.36	95	1.37	70	8.02
Municipal	555	2.23	206	1.21	339	4.91	10	1.15
Wellfields	396	1.59	316	1.85	23	0.33	57	6.53
Indistinct	760	3.06	64	0.37	691	10.00	5	0.57
Total	24,867	100	17,083	100	6,911	100	873	100

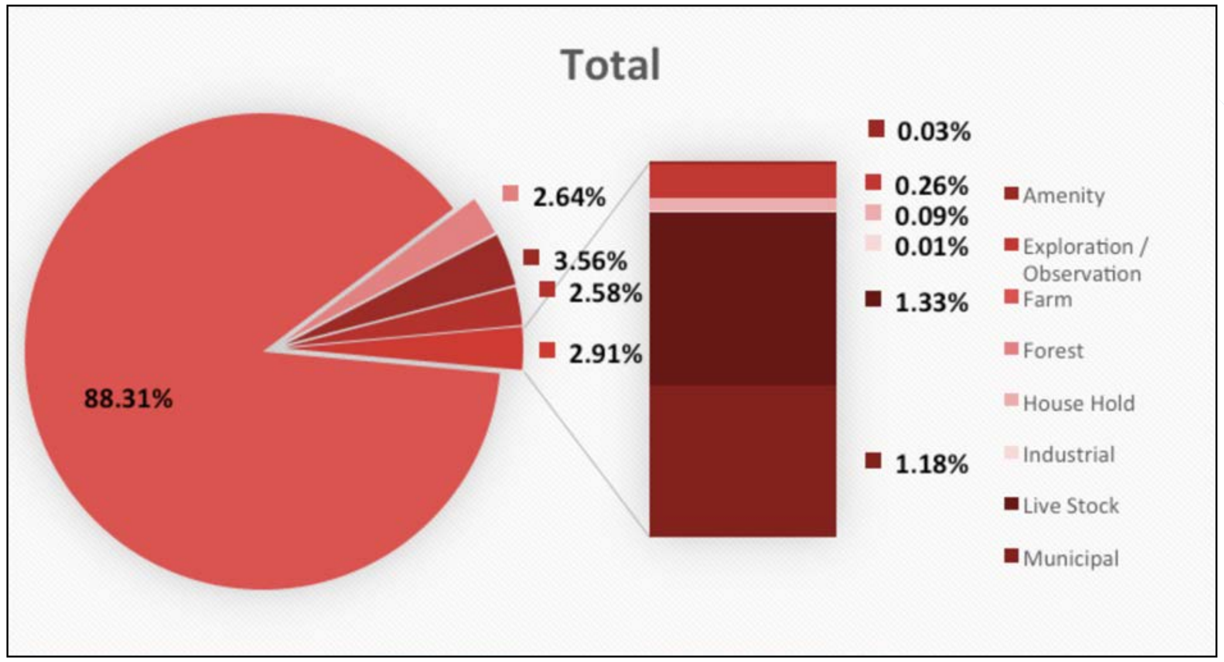


Figure 13: Well usage, combined total - encountered in all Abstraction Centers.

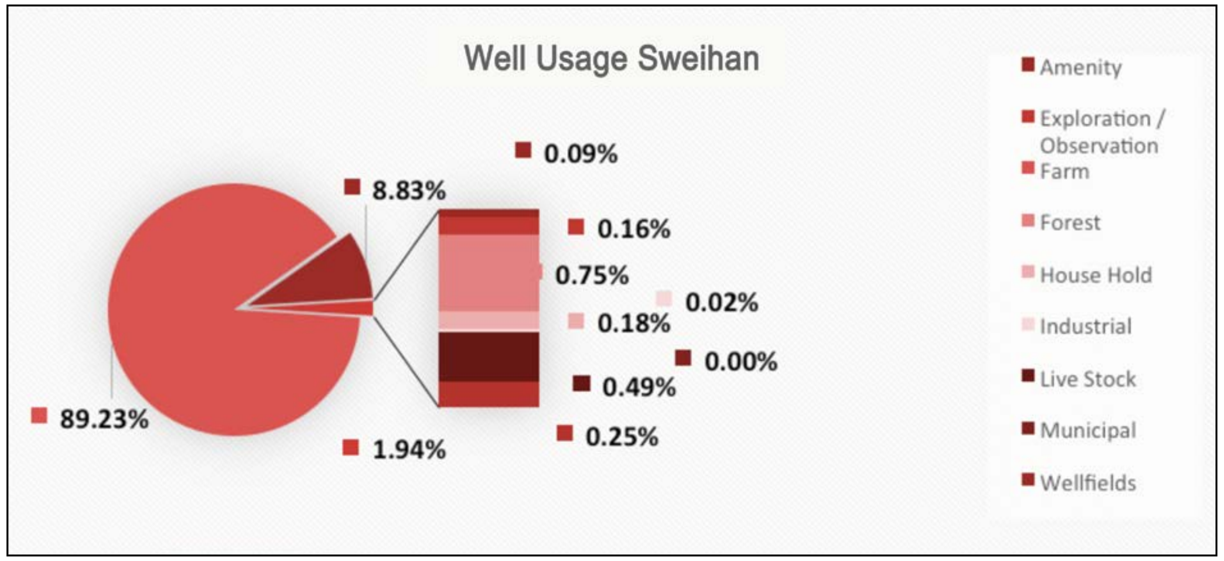


Figure 14: Well usage - encountered in Sweihan and neighboring districts.

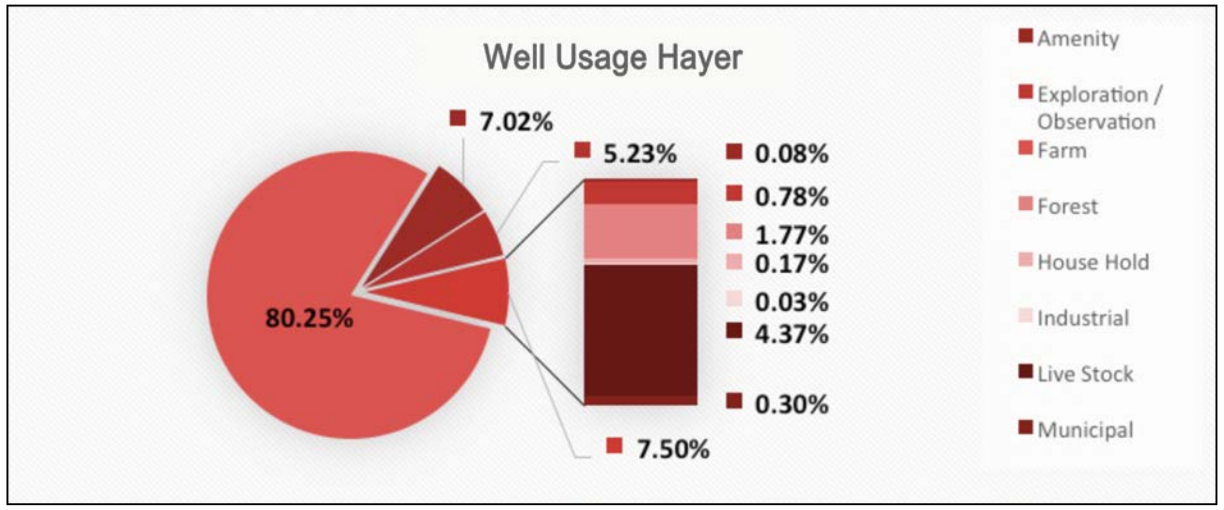


Figure 15: Well usage - encountered in Al Hayer and neighboring districts.

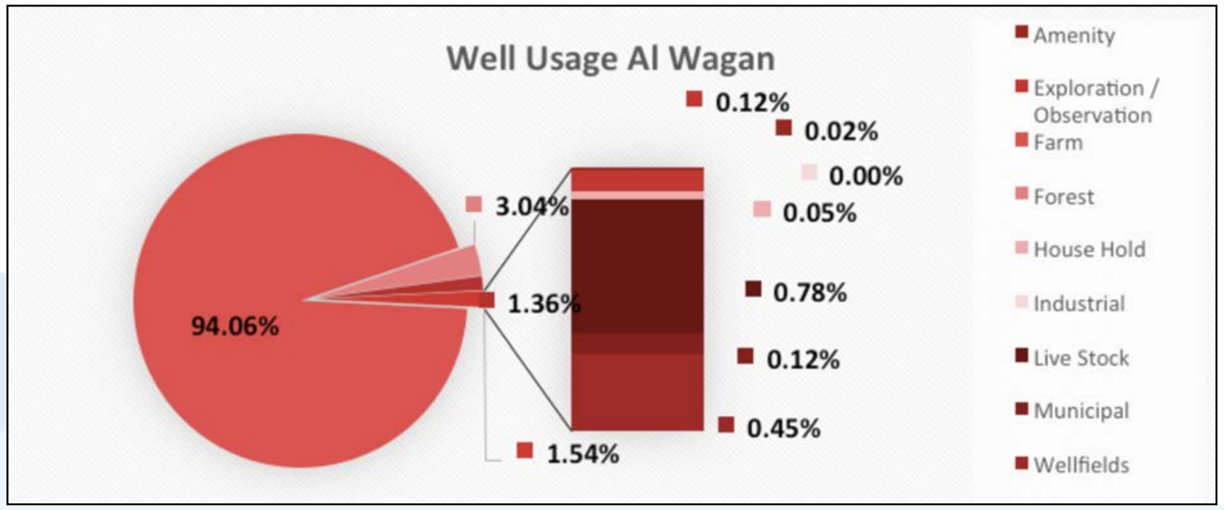


Figure 16: Well usage - encountered in Al Wagan and neighboring districts.

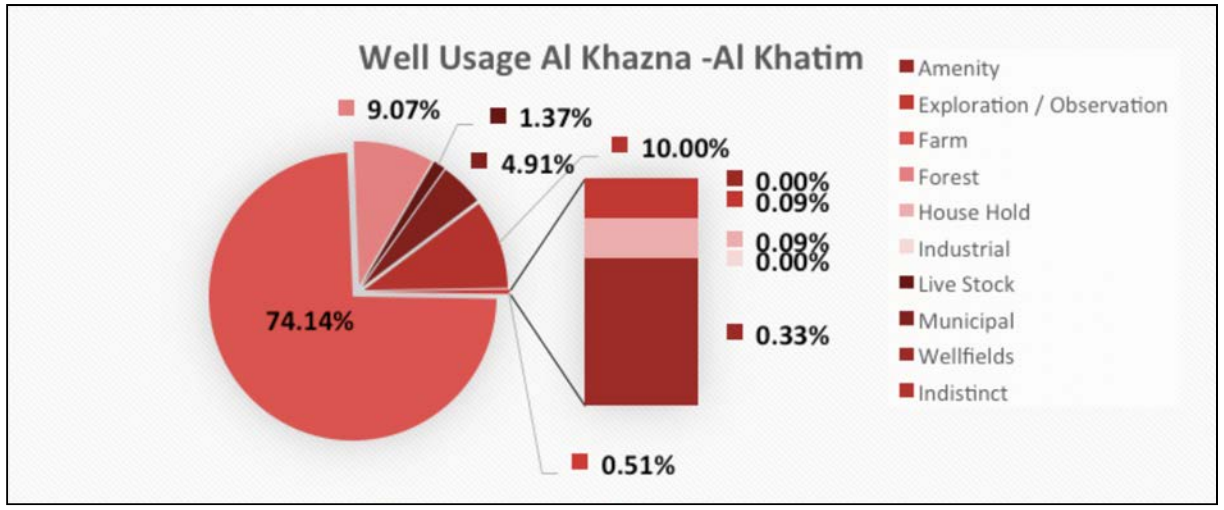


Figure 17: Well usage - encountered in Al Khazna - Al Khatim and neighboring districts.

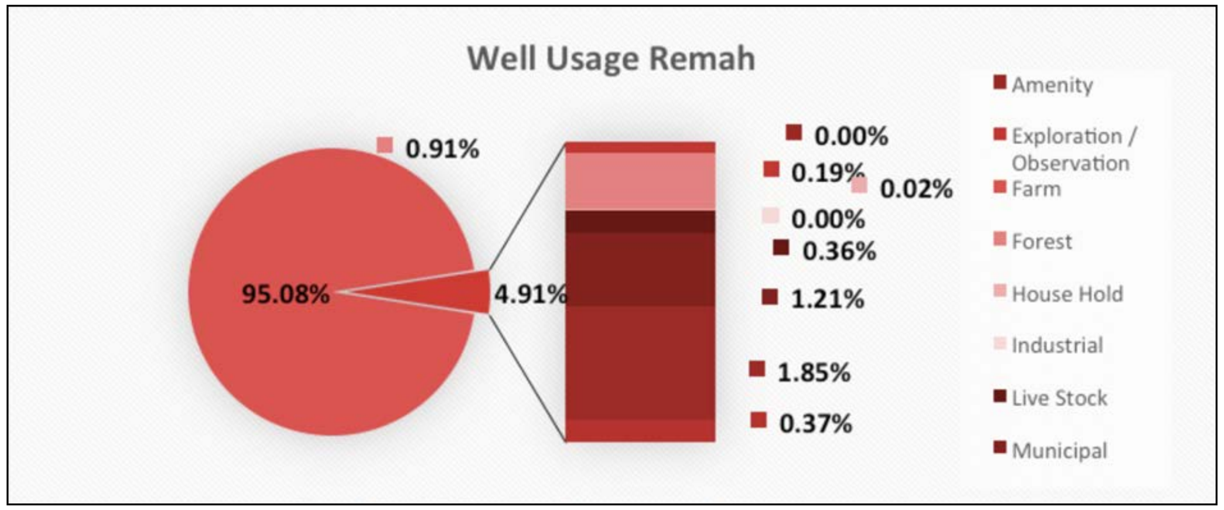


Figure 18: Well usage - encountered in Remah and neighboring districts.

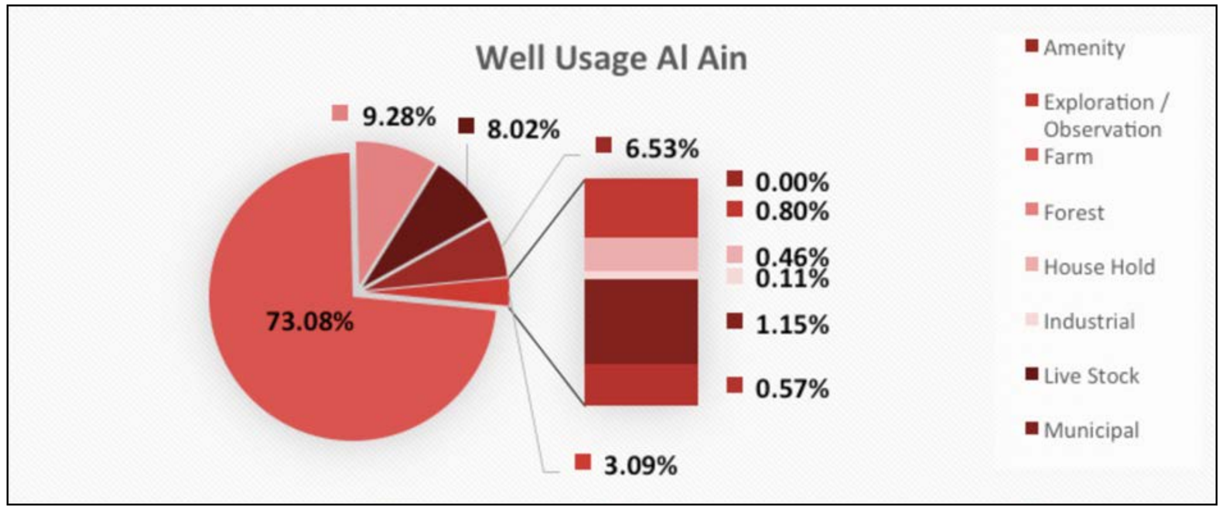


Figure 19: Well usage - encountered in Al Ain and neighboring districts.

5.4 Master Data

Master data includes static data that usually does not change over time. Well type data (**Tables 7** and **8, Figure 22**), and well dimensions belong to this category. Position data were recorded automatically by the GPS - Aided Data Collection System.

Well installation methods are divided into:

- Drilled - well installed via drill rig
- Dug - large diameter well dug by hand or using excavation equipment, , and
- Hybrid - well construction is a combination between borehole and dug hole, Figure 21.

Figure 20: Dug wells - open.

Figure 21: Hybrid wells - drilled well in dug well.

Table 7: Well type - encountered in abstraction centers and combined values of Sweihan, Al Hayer and Al Wagan areas for the Reporting Period

	Total		Sweihan		Al Hayer		Al Wagan	
Well type	Wells	%	Wells	%	Wells	%	Wells	%
Borehole	24,656	98.05	8,785	95.47	7,506	99.09	8,365	99.95
Dug Well	478	1.90	407	4.42	67	0.88	4	0.05
Hybrid	1	0.00	0	0.00	1	0.01	0	0.00
Structureless	0	0.00	0	0.00	0	0.00	0	0.00
Indistinct	11	0.04	10	0.11	1	0.01	0	0.00
Pit	0	0.00	0	0.00	0	0.00	0	0.00
Total	25,146	100	9,202	100	7,575	100	8,369	100

As illustrated in **Tables 7** and **8**, a large majority of wells are drilled wells, 86% to 98%, and dug wells represent a low to marginal count of the wells. Proportions are further highlighted in **Figure 23** to **Figure 28**.

Table 8: Well type - encountered in abstraction centers and combined values of Remah, Al Khatim / Al Khazna and Al Ain areas for the Reporting Period

	Total		Remah		Al Khazna		Al Ain	
Well Type	Wells	%	Wells	%	Wells	%	Wells	%
Borehole	21,455	86.28	16,735	97.96	3,868	55.97	852	97.59
Dug Well	3,003	12.08	172	1.01	2,813	40.70	18	2.06
Hybrid	162	0.65	58	0.34	102	1.48	2	0.23
Structureless	28	0.11	0	0.00	28	0.41	0	0.00
Indistinct	179	0.72	117	0.68	62	0.90	0	0.00
Other	40	0.16	1	0.01	38	0.55	1	0.11
Total	24,867	100	17,083	100	6,911	100	873	100

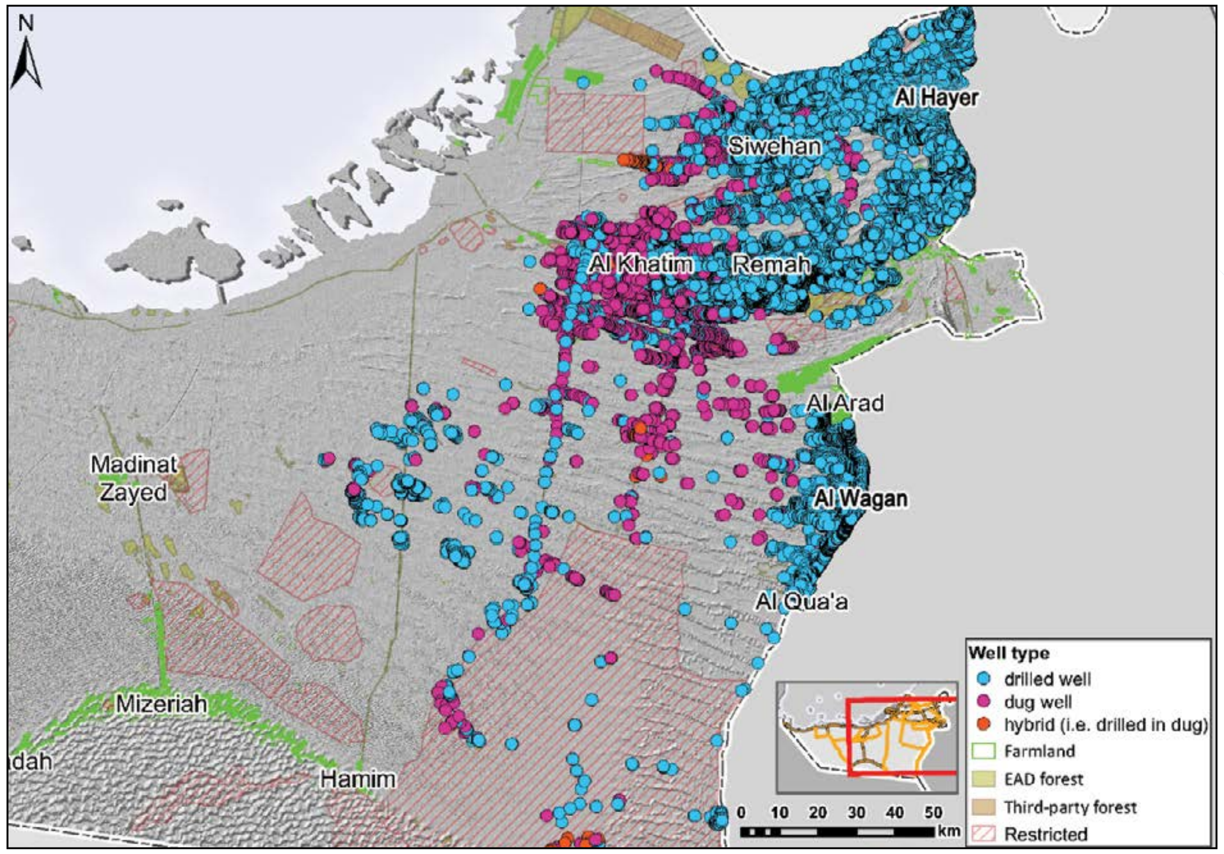


Figure 22: Distribution of well types as surveyed through 12.2016.

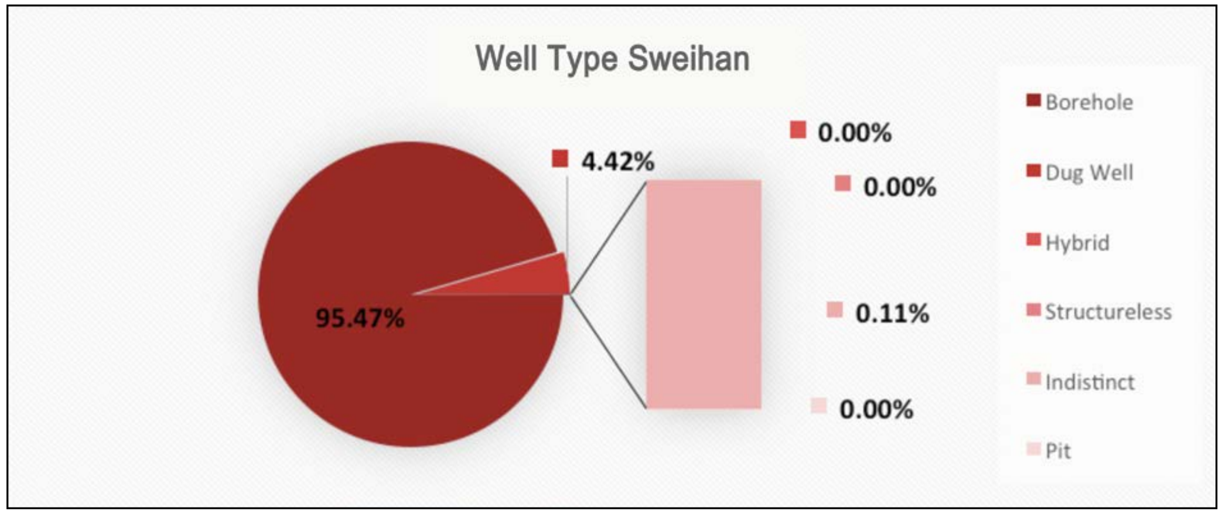


Figure 23: Well type - encountered in abstraction centers of Sweihan and neighboring districts.

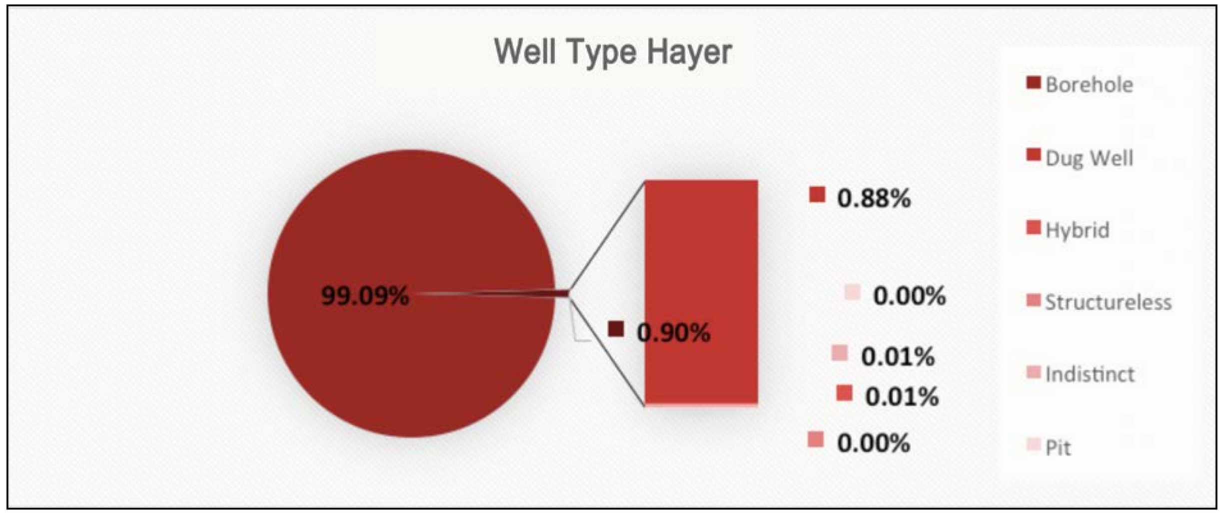


Figure 24: Well type - encountered in abstraction centers of Al Hayer and neighboring districts.

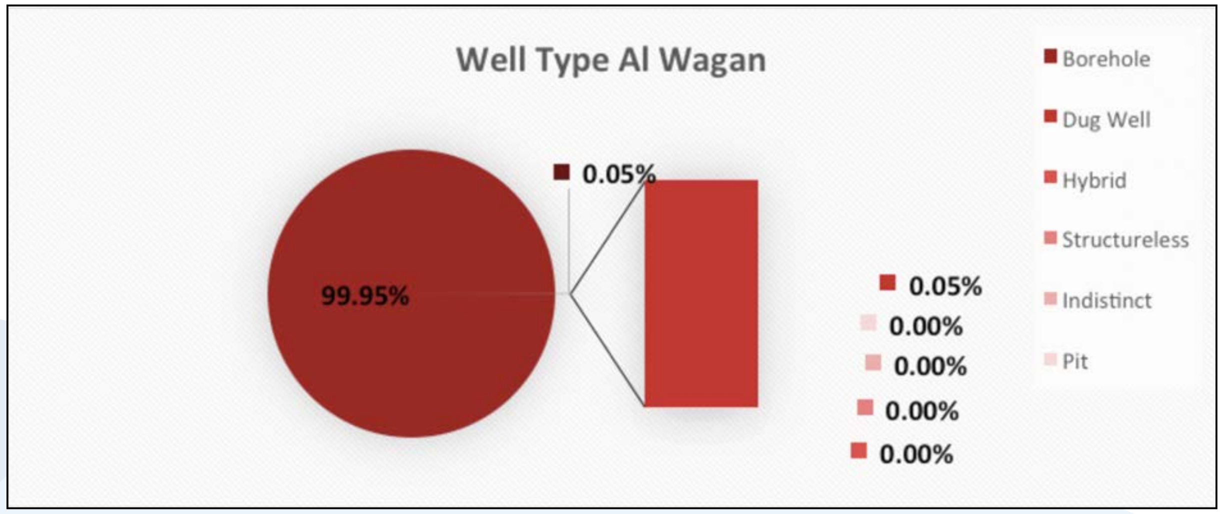


Figure 25: Well type - encountered in abstraction centers of Al Wagan and neighboring districts.

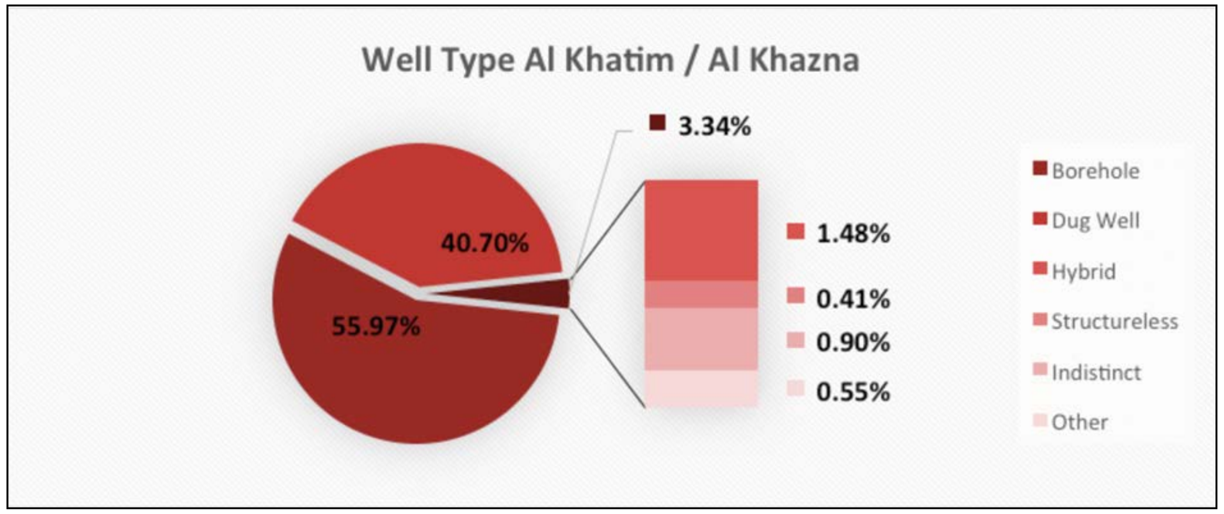


Figure 26: Well type - encountered in abstraction centers of Al Khatim / Al Khazna and neighboring districts.

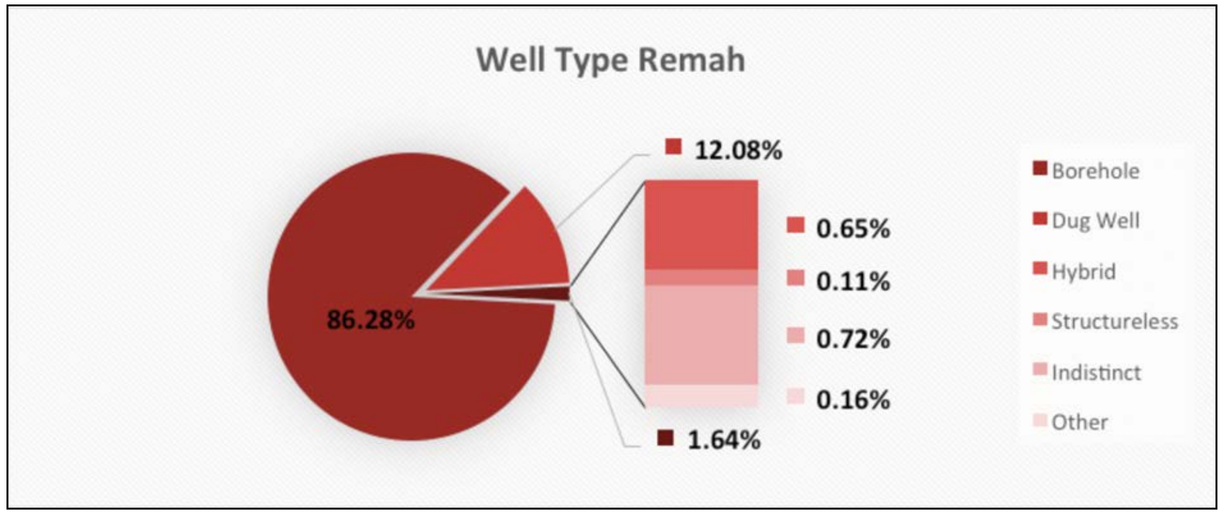


Figure 27: Well type - encountered in abstraction centers of Remah and neighboring districts.

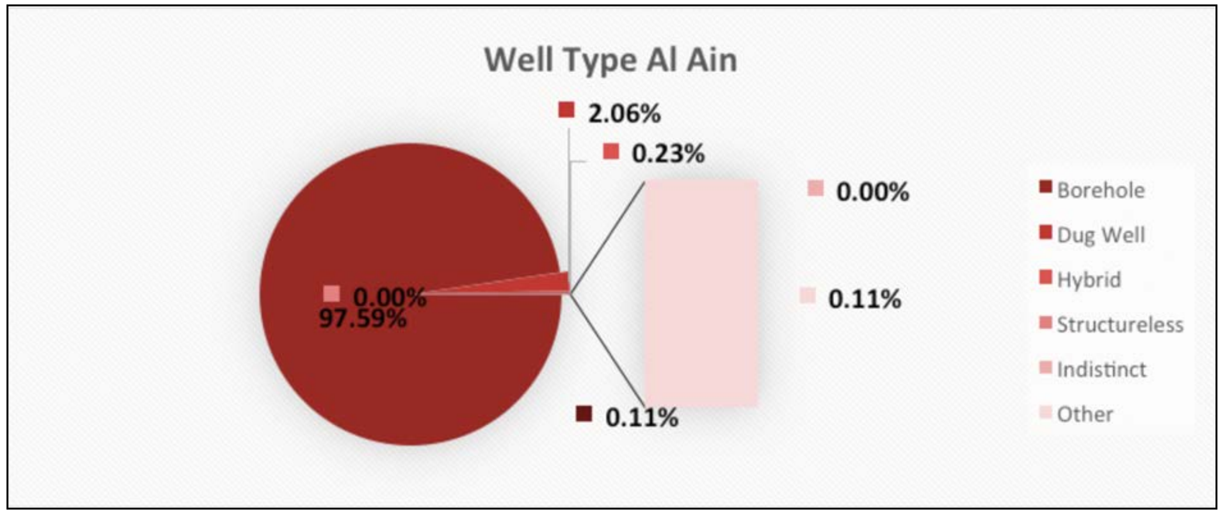


Figure 28: Well type - encountered in abstraction centers of Al Ain and neighboring districts.

5.5 Well Status Data

Well status data comprise data about the operational status of the well, such as drilling year, disuse year, and disuse reason.

The well status as reported below in **Figure 29** refers to:

- Operational - well currently used for abstraction.
- Disused - well not currently used for abstraction but could be, if repairs would take place.
- Backfilled - well that has been back-filled (man-made or by natural causes).
- Exploration / Observation - well is used for groundwater monitoring purposes.
- Under construction - well is being drilled/constructed by the time of visit.
- Indistinct - well status is unknown due to the lack of information available.

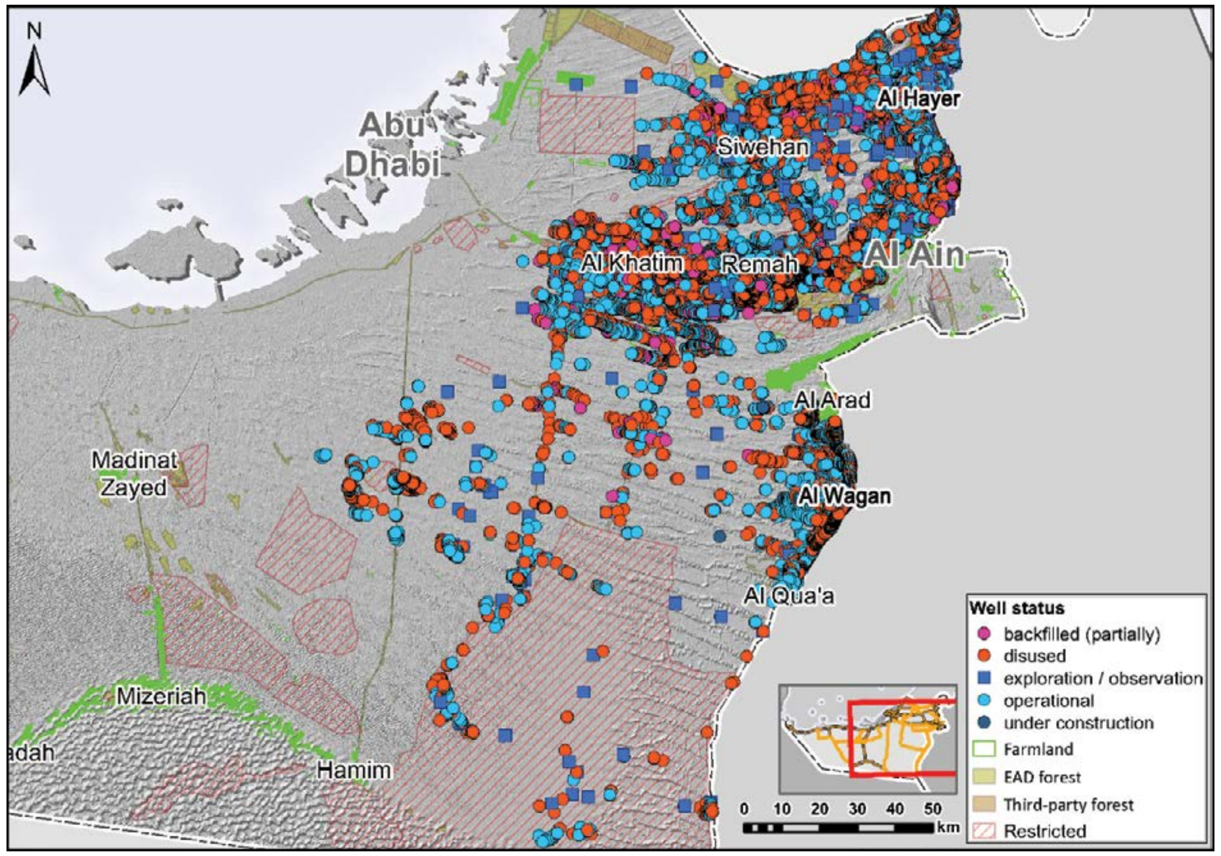


Figure 29: Distribution of wells as surveyed until 12.2016.

Table 9: Well status - encountered in abstraction centers and combined values of Sweihan, Al Hayer and Al Wagan areas for the Reporting Period

	Total		Sweihan		Al Hayer		Al Wagan	
Well Status	Wells	%	Wells	%	Wells	%	Wells	%
Operational	11,829	47.04	3,979	43.24	4,252	56.13	3,598	42.99
Operational under Maintenance	0	0.00	0	0.00	0	0.00	0	0.00
Under Construction	18	0.07	5	0.05	6	0.08	7	0.08
Exploration / Observation	122	0.49	30	0.33	75	0.99	17	0.20
Disused	11,618	46.20	4,054	44.06	2,822	37.25	4742	56.66
Backfilled	1,353	5.38	1,030	11.19	321	4.24	2	0.02
Indistinct	206	0.82	104	1.13	99	1.31	3	0.04
Total	25,146	100	9,202	100	7,575	100	8,369	100

Table 10: Well status - encountered in abstraction centers and combined values of Al Khazna / Al Khatim and Remah areas for the Reporting Period

	Total		Remah		Al Khazna		Al Ain	
Well Status	Wells	%	Wells	%	Wells	%	Wells	%
Operational	9,469	38.08	6,340	37.11	2,673	38.68	456	52.23
Operational under Maintenance	33	0.13	31	0.18	2	0.03	0	0.00
Under Construction	31	0.12	0	0.00	31	0.45	0	0.00
Exploration / Observation	85	0.34	63	0.37	15	0.22	7	0.80
Disused	10,338	41.57	7,110	41.62	2,863	41.43	365	41.81
Backfilled	4,800	19.30	3,514	20.57	1,246	18.03	40	4.58
Indistinct	111	0.45	25	0.15	81	1.17	5	0.57
Total	24,867	100	17,083	100	6,911	100	873	100

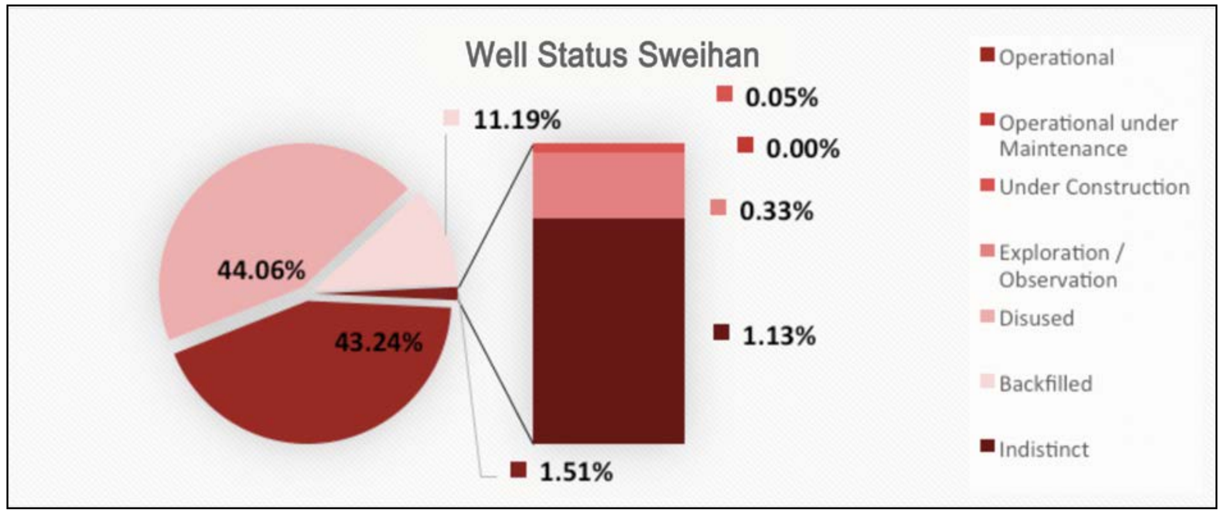


Figure 30: Well status - encountered in abstraction centers of Sweihan and neighboring districts.

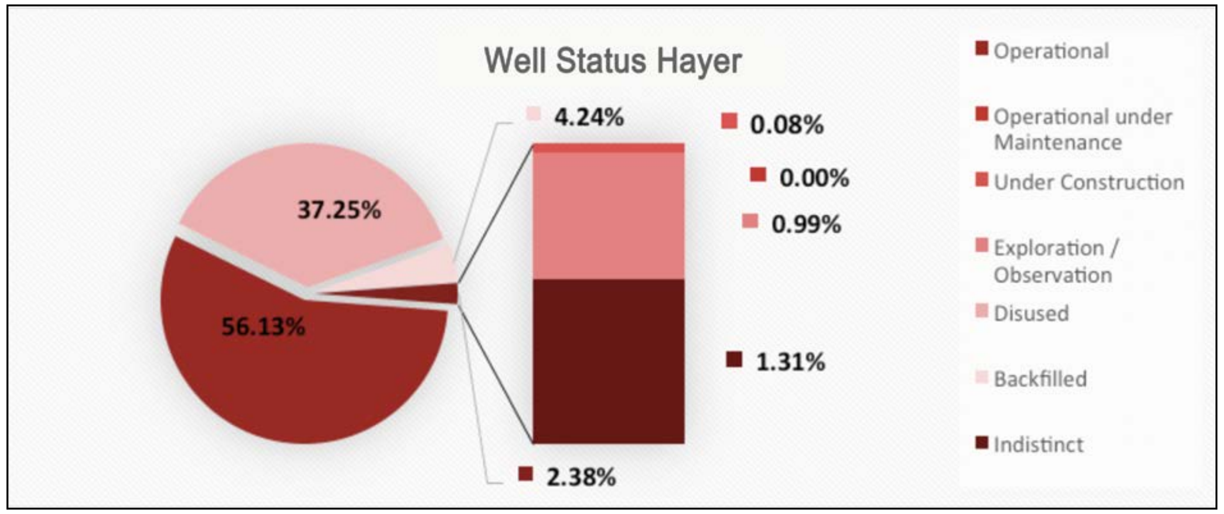


Figure 31: Well status - encountered in abstraction centers of Al Hayer and neighboring districts.

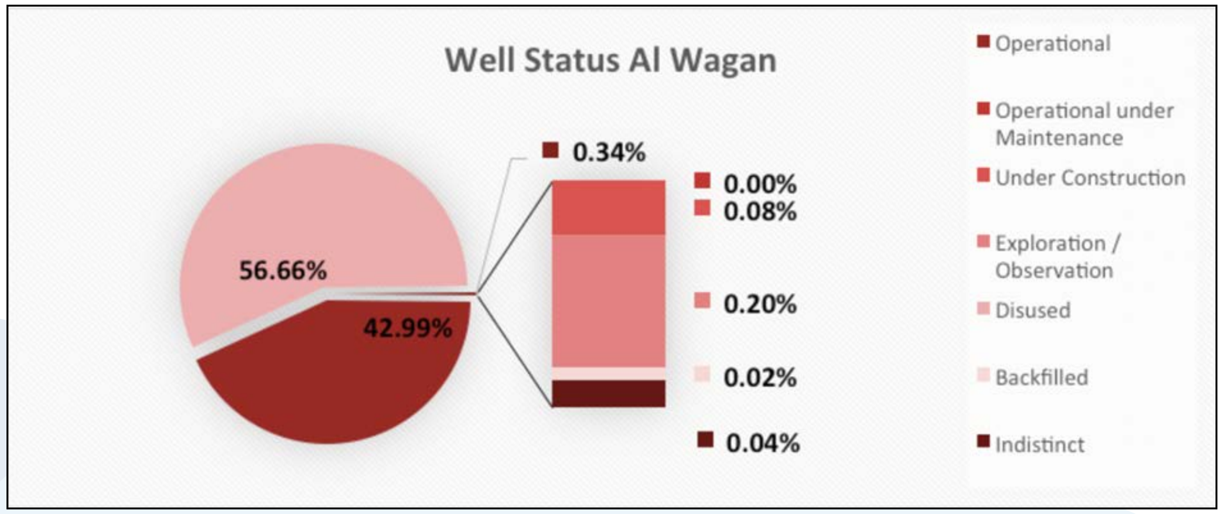


Figure 32: Well status - encountered in abstraction centers of Al Wagan and neighboring districts.

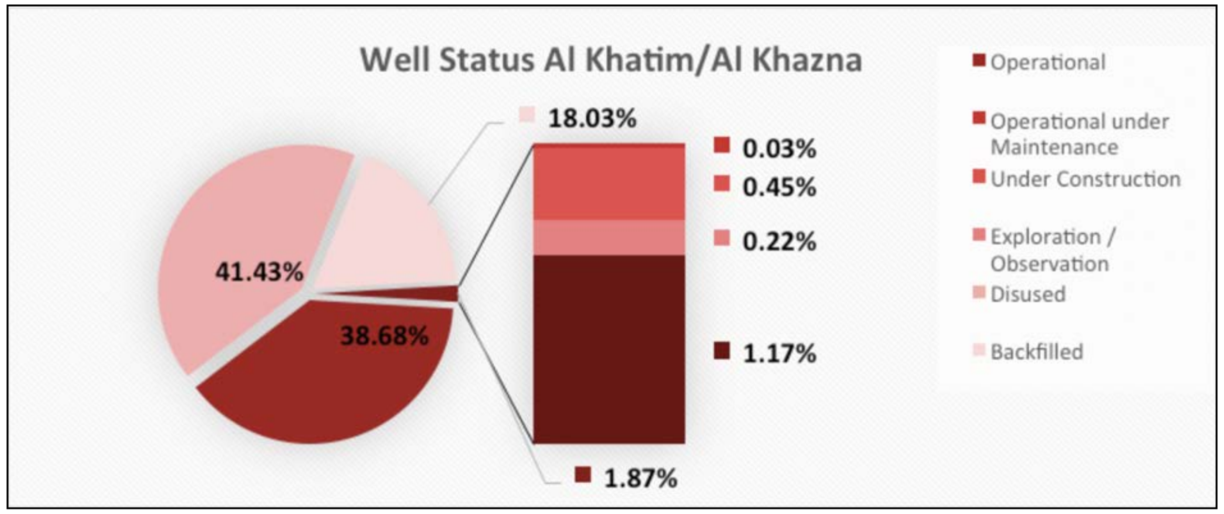


Figure 33: Well status - encountered in abstraction centers of Al Khatim / Al Khazna and neighboring districts.

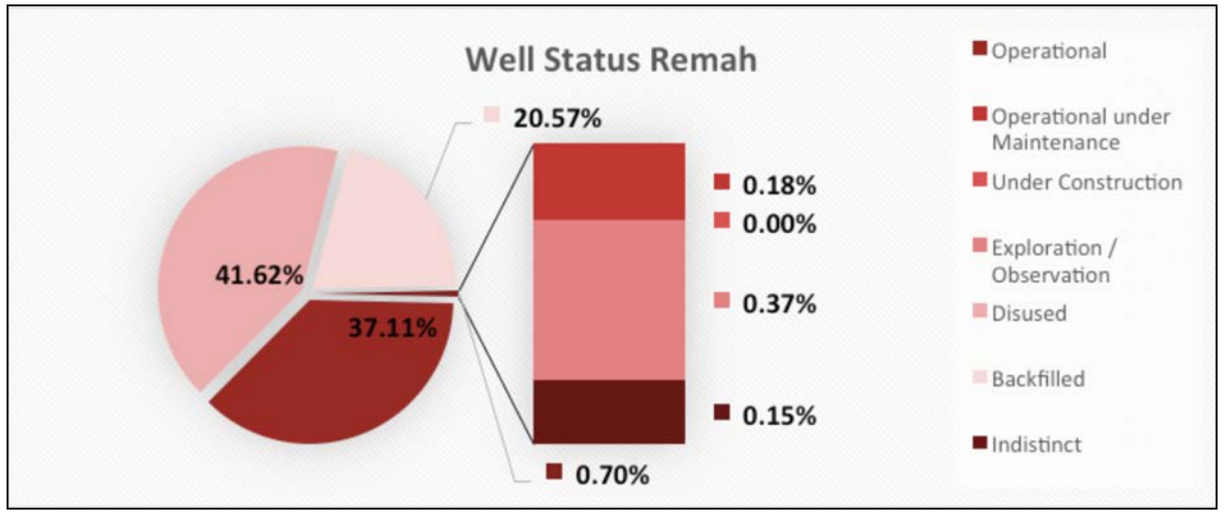


Figure 34: Well status - encountered in abstraction centers of Remah and neighboring districts.

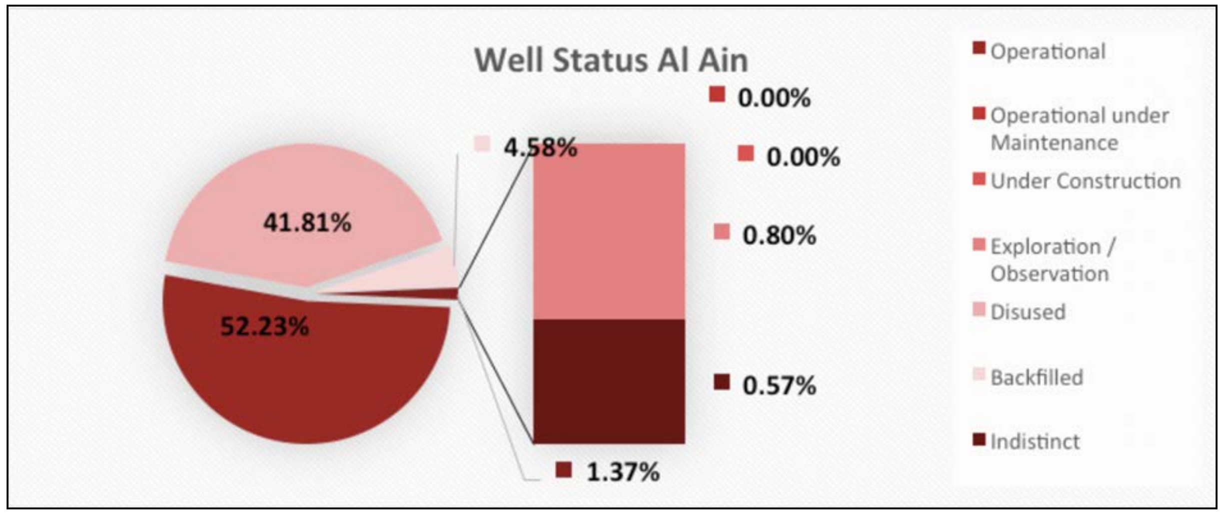


Figure 35: Well status - encountered in abstraction centers of Al Ain and neighboring districts.

5.6 Total Depth of Wells

The total depths recorded reflect the water abstraction process and groundwater availability in the corresponding areas of the Emirate, see **Table 11**. The distribution of well depth into classes for all records, and for the Sweihan, Al Hayer and Al Wagan and Remah, Al Khatim / Al Khazna and Al Ain areas are shown in **Figure 37** to **Figure 42**. Well depth, in general, increases from west to east as illustrated in **Table 12** and **Table 13**.

Further statistical information is given by:

Average: the arithmetic mean and is calculated by adding a group of numbers and then dividing by the count of those numbers.

Median: the middle number of a group of numbers; that is, half the numbers have values that are greater than the median, and half the numbers have values that are less than the median.

Mode: the most frequently occurring number in a group of numbers.

Table 11: Total depth of wells - encountered in abstraction centers and combined values of the survey

	Wells surveyed	
Well depth (m)	Wells	%
< 50	5,749	39.16
50 - 100	2,426	16.52
100 - 150	1,850	12.60
150 - 200	1,531	10.43
200 - 300	2,329	15.86
300 - 500	796	5.42
Total	14,681	100
Average (TOC)	115	
Median (TOC)	85	
Mode (TOC)	6	

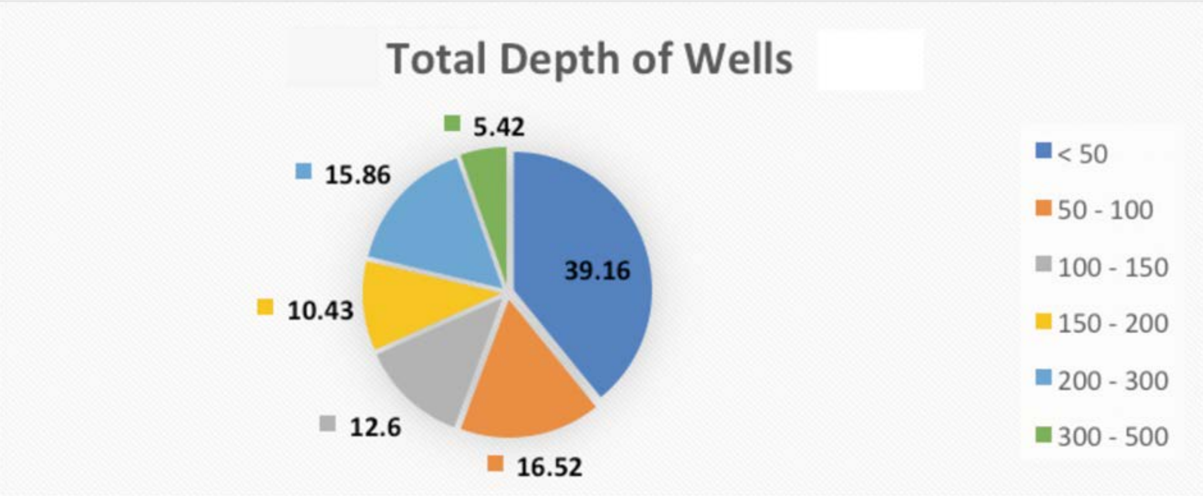


Figure 36: Chart of well depth classes - encountered in abstraction centers of Sweihan and nearby districts

Table 12: Total depth of wells - encountered in abstraction centers and combined values of Sweihan, Al Hayer and Al Wagan areas for the Reporting Period

	Total		Sweihan		Al Hayer		Al Wagan	
Well depth (m)	Wells	%	Wells	%	Wells	%	Wells	%
< 50	1,185	27.39	463	29.47	402	28.86	320	23.48
50 - 100	1,223	28.26	397	25.27	557	39.99	269	19.74
100 - 150	955	22.07	384	24.44	240	17.23	331	24.28
150 - 200	594	13.73	274	17.44	138	9.91	182	13.35
200 - 300	330	7.63	50	3.18	47	3.37	233	17.09
300 - 500	40	0.92	3	0.19	9	0.65	28	2.05
Total	4,327	100	1,571	100	1,393	100	1,363	100
Average (TOC)			92.26		85.52		122.85	
Median (TOC)			94.10		75.00		115.60	
Mode (TOC)			136.00		120.00		182.90	

Table 13: Total depth of wells - encountered in abstraction centers and combined values of Remah, Al Khatim / Al Khazna and Al Ain areas for the Reporting Period

	Total		Remah		Al Khazna		Al Ain	
Well Depth	Wells	%	Wells	%	Wells	%	Wells	%
>50	1,429	22.90	700	14.00	676	57.88	53	74.65
50 - 100	495	7.93	259	5.18	225	19.26	11	15.49
100 - 150	669	10.72	518	10.36	148	12.67	3	4.23
150 - 200	993	15.92	878	17.56	114	9.76	1	1.41
200 -500	2,653	42.52	2,645	52.90	5	0.43	3	4.23
Total	6,239	100	5,000	100	1,168	100	71	100
Average (TOC)			168		45		39	
Median (TOC)			300		100		22	
Mode (TOC)			185		25		7	

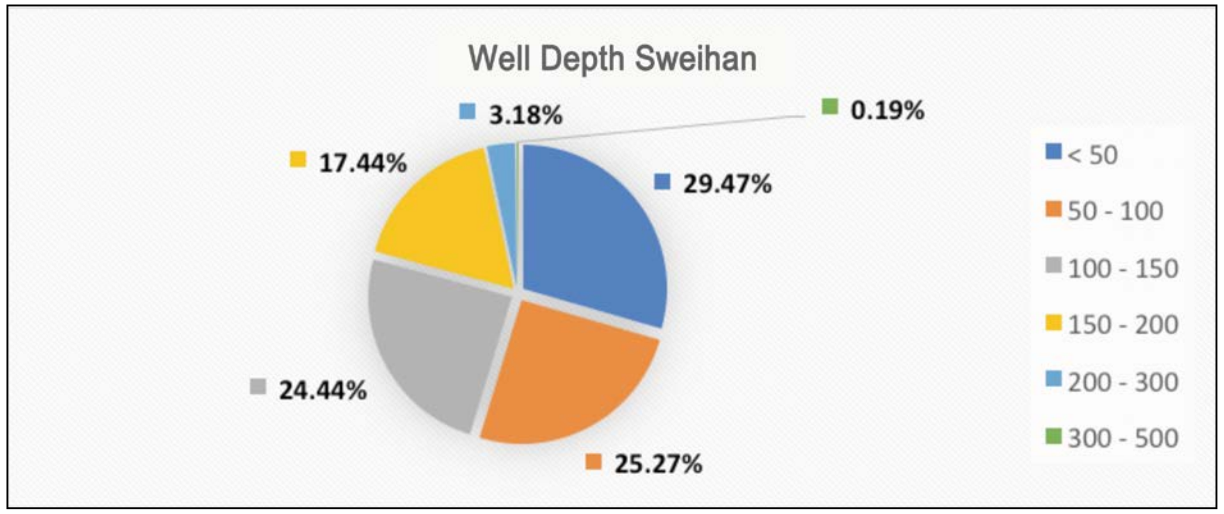


Figure 37: Chart of well depth classes - encountered in abstraction centers of Sweihan and nearby districts.

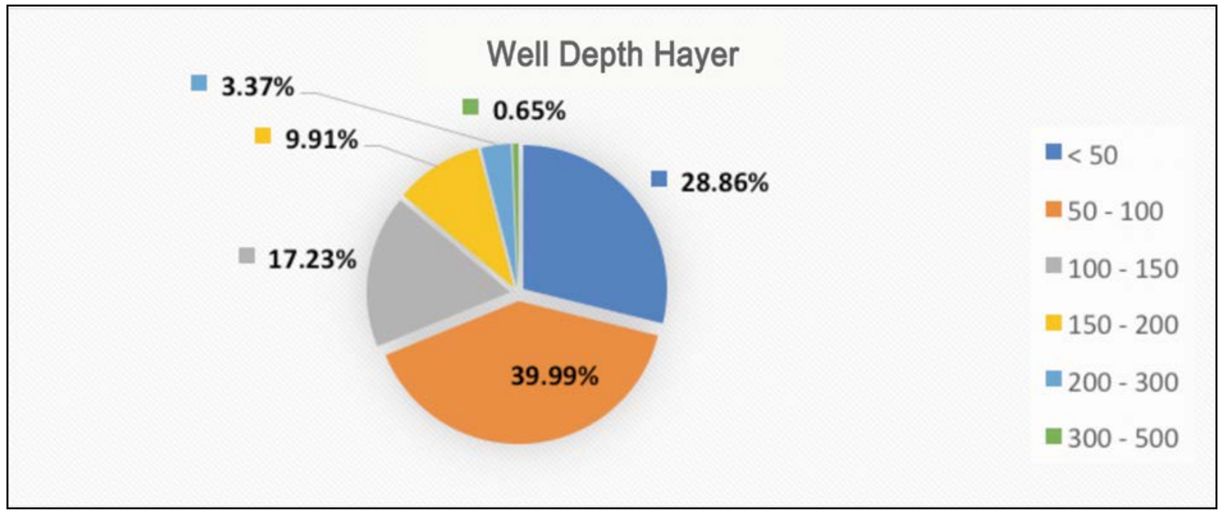


Figure 38: Chart of well depth classes - encountered in abstraction centers of Al Hayer and nearby districts.

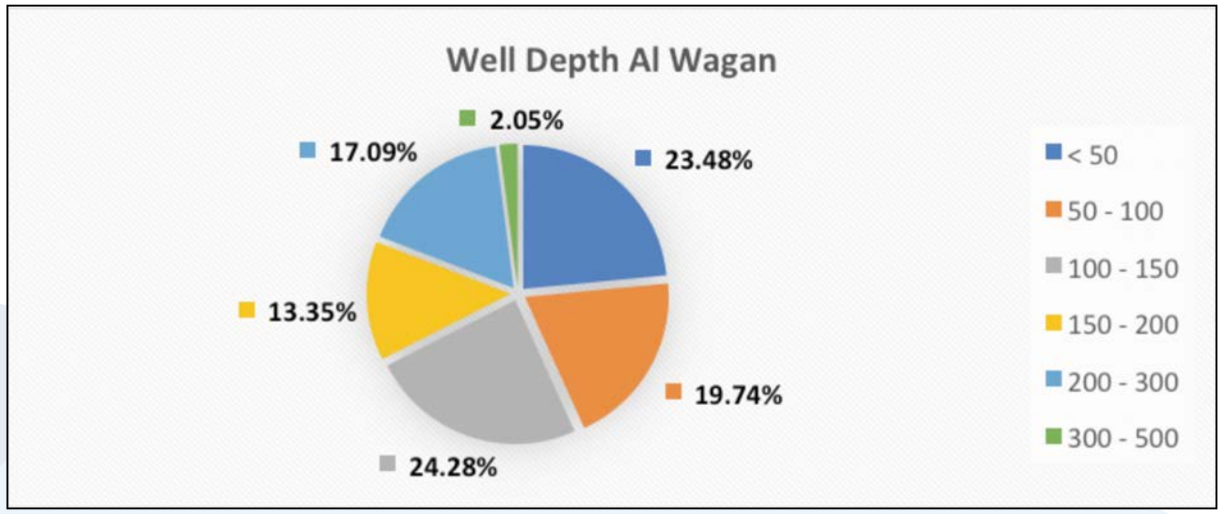


Figure 39: Chart of well depth [m.b.TOC] classes - encountered in abstraction centers of Al Wagan and nearby districts.

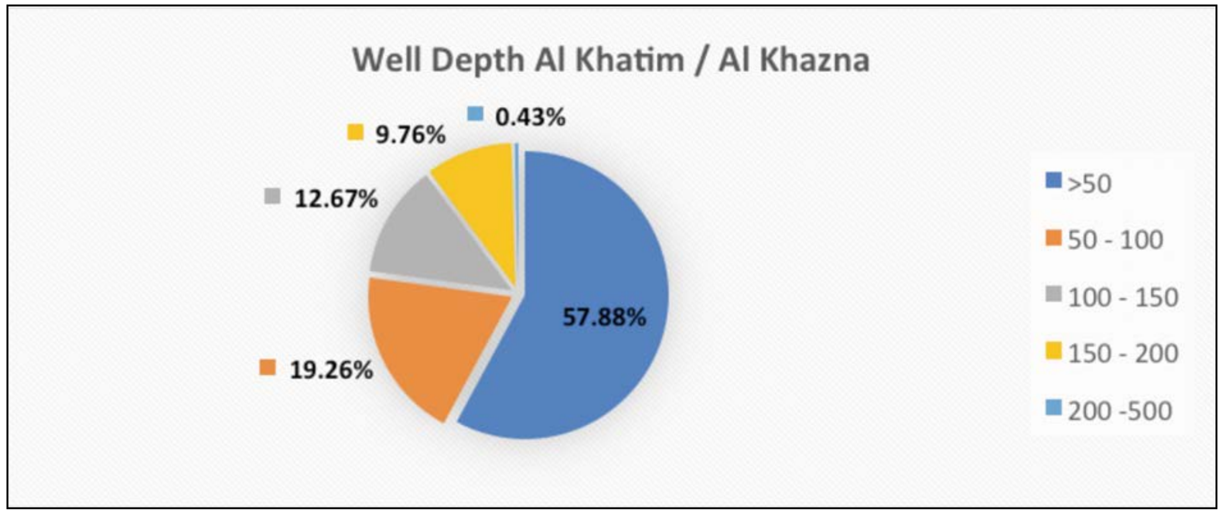


Figure 40: Chart of well depth [m.b.TOC] classes - encountered in abstraction centers of Al Khatim / Al Khazna and nearby districts.

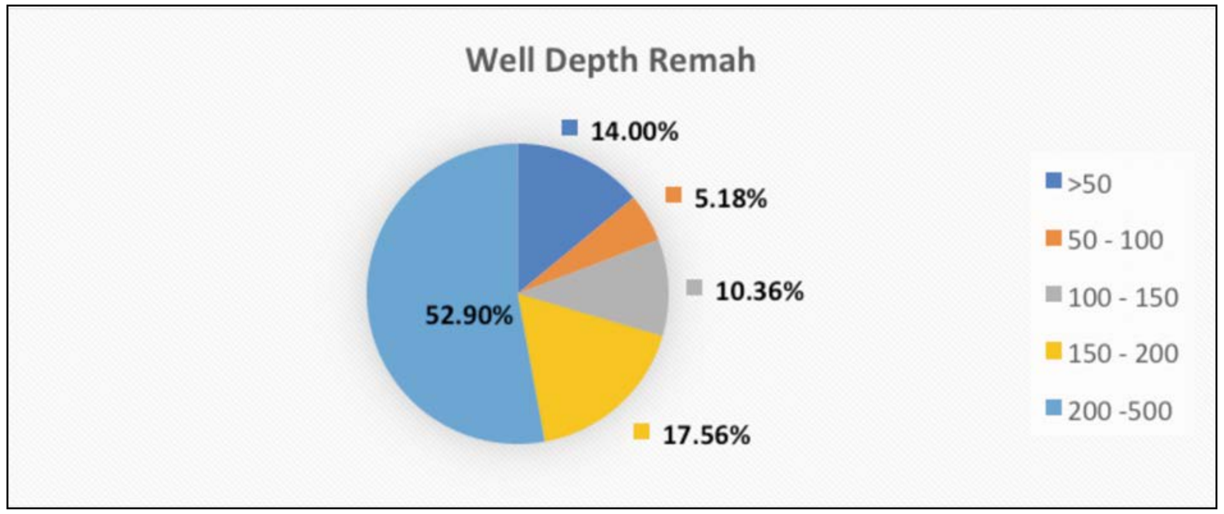


Figure 41: Chart of well depth [m.b.TOC] classes - encountered in abstraction centers of Remah and nearby districts.

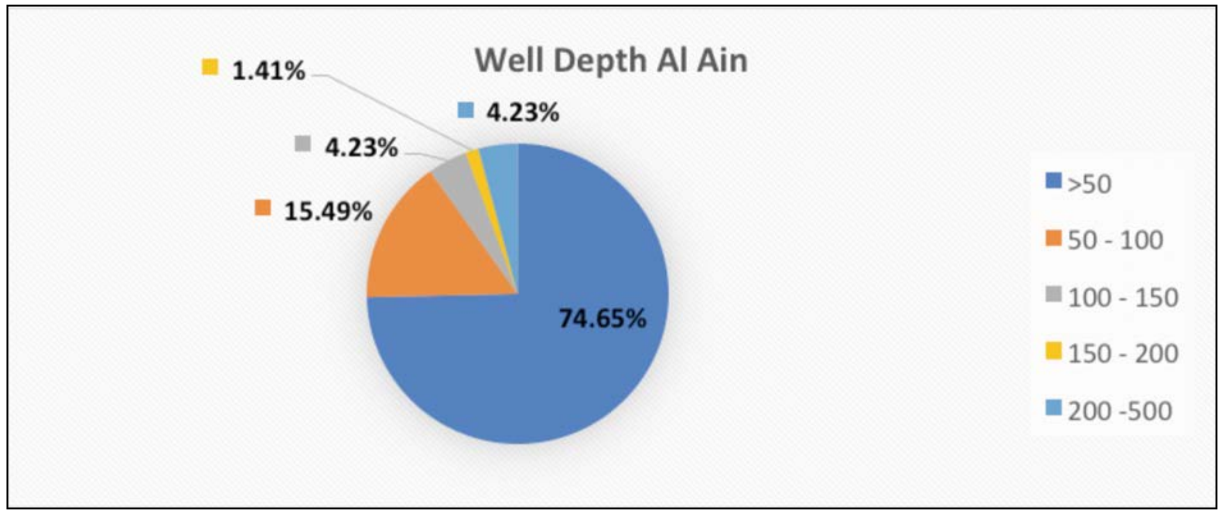


Figure 42: Chart of well depth classes [m.b.TOC] - encountered in abstraction centers of Al Ain and nearby districts.

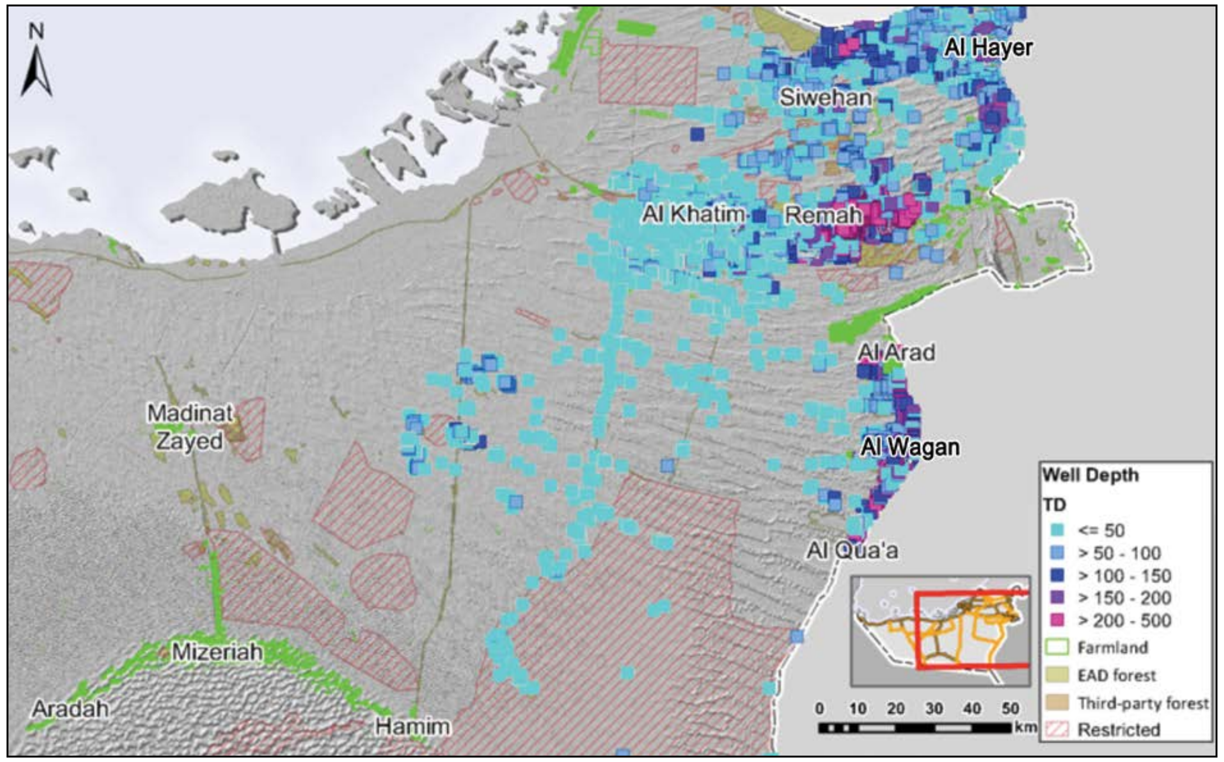


Figure 43: Well depth - distribution of wells as surveyed until 12.2016.

5.7 Depth to Groundwater

In total, 16,074 measurements of depth to groundwater (depth from measuring point or surface to groundwater table) were conducted, see **Figure 44**. 7,518 wells were identified to be dry, and 720 wells showed signs of a parched aquifer with seeping groundwater along the inner well casing (**Tables 14, 15** and **16**) as well as **Figures 45** to **50**.

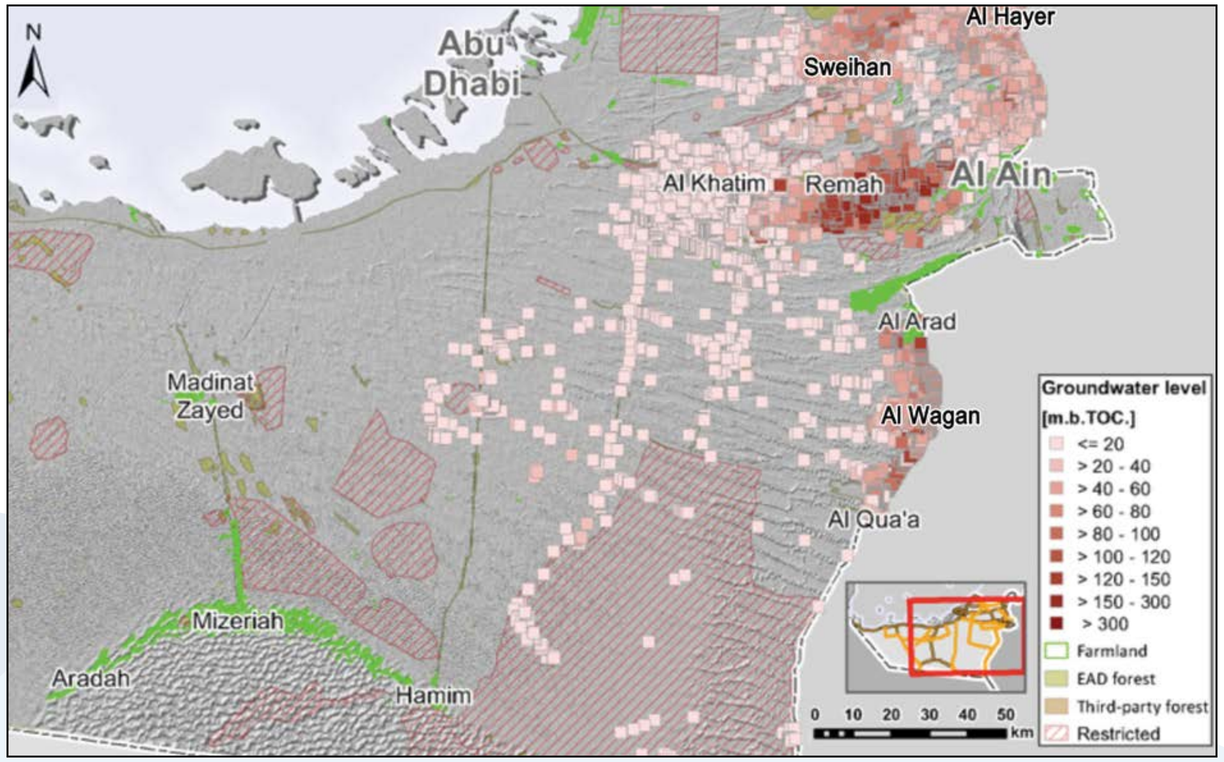


Figure 44: Groundwater level - distribution of wells as surveyed through 12.2016.

Table 14: Conducted groundwater measurements conducted through the Reporting Period

	Wells surveyed	
Depth to Groundwater (m.b.TOC)	Wells	%
< 20	2,865	17.82
20 - 40	2,588	16.10
40 - 60	2,838	17.66
60 - 80	2,367	14.73
80 - 100	1,372	8.54
100 - 120	669	4.16
120 - 150	815	5.07
150 - 300	2,496	15.53
300 - 500	64	0.40
Total	16074	100
Average	4	
Median	58	
Mode	80	

Table 15: Groundwater level below the top of casing for Sweihan, Al Hayer and Al Wagan

	Total		Sweihan		Al Hayer		Al Wagan	
Depth to GW (m. b.TOC)	Wells	%	Wells	%	Wells	%	Wells	%
< 20	271	4.26	193	6.37	24	1.59	54	2.96
20 - 40	1023	16.07	511	16.88	406	26.82	106	5.81
40 - 60	1985	31.18	826	27.28	710	46.90	449	24.60
60 - 80	1683	26.43	875	28.90	335	22.13	473	25.92
80 - 100	871	13.68	532	17.57	30	1.98	309	16.93
100 - 120	259	4.07	78	2.58	5	0.33	176	9.64
120 - 150	170	2.67	12	0.40	1	0.07	157	8.60
150 - 300	103	1.62	0	0.00	2	0.13	101	5.53
300 - 500	2	0.03	1	0.03	1	0.07	0	0.00
Total	6,367	100	3,028	100	1,514	100	1,825	100
Average			58.66		50.01		79.97	
Median			59.40		50.55		68.56	
Mode			63.00		54.60		60.00	

Table 16: Groundwater level below the top of casing for Al Kahtim / Al Khazna, Remah and Al Ain

	Total		AL Khatim/Khazna		Remah		Al Ain	
Depth to GW (m. b. TOC)	Wells	%	Wells	%	Wells	%	Wells	%
< 20	271	3.13	193	3.63	24	1.59	54	2.96
20 - 40	1023	11.83	511	9.62	406	26.82	106	5.81
40 - 60	1985	22.95	826	15.55	710	46.90	449	24.60
60 - 80	1683	19.46	875	16.48	335	22.13	473	25.92
80 - 100	871	10.07	532	10.02	30	1.98	309	16.93
100 - 120	259	2.99	78	1.47	5	0.33	176	9.64
120 - 150	170	1.97	12	0.23	1	0.07	157	8.60
150 - 300	2386	27.58	2283	42.99	2	0.13	101	5.53
300 - 500	2	0.02	1	0.02	1	0.07	0	0.00
Total	8,650	100	5,311	100	1,514	100	1,825	100
Average			25		155		24	
Median			50		300		25	
Mode			22		163		24	

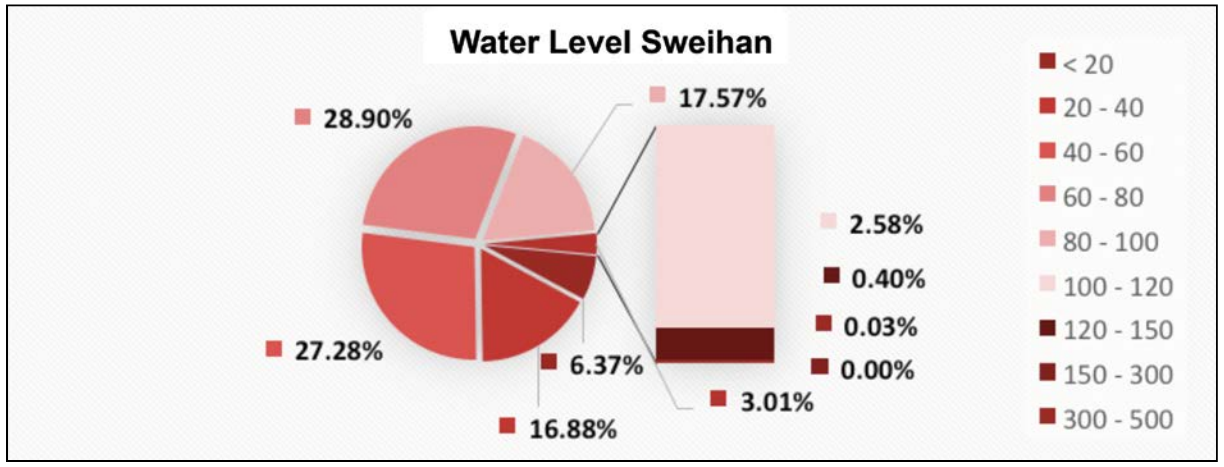


Figure 45: Depth to groundwater measurement [m.b.TOC] classes - encountered in abstraction centers of Sweihan and nearby districts.

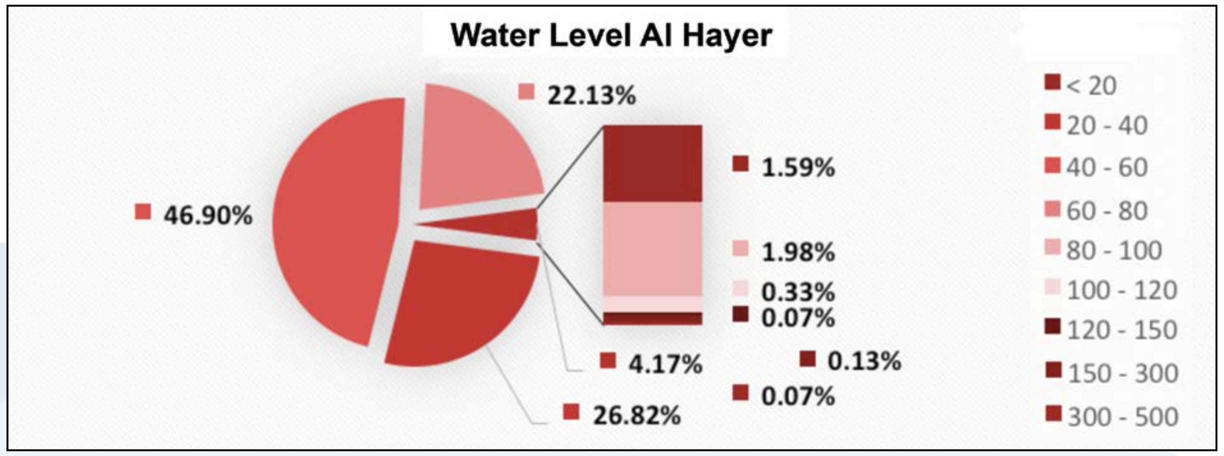


Figure 46: Depth to groundwater measurement [m.b.TOC] classes - encountered in abstraction Al Hayer and nearby districts.

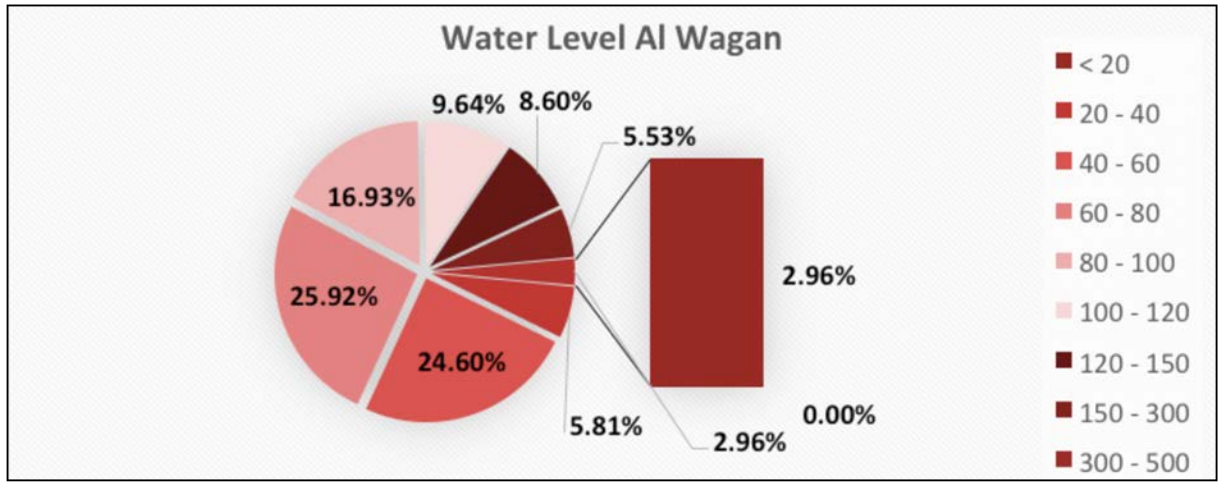


Figure 47: Depth to groundwater measurement [m.b.TOC] classes - encountered in abstraction centers of Al Wagan and nearby districts

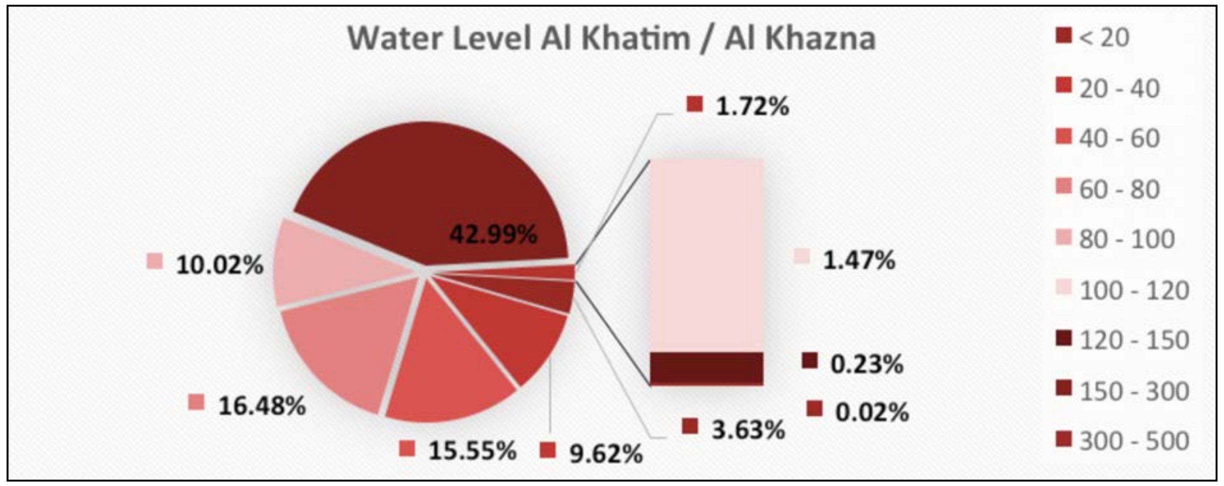


Figure 48: Depth to groundwater measurement [m.b.TOC] classes - encountered in abstraction centers of Al Khatim / Al Khazna and nearby districts.

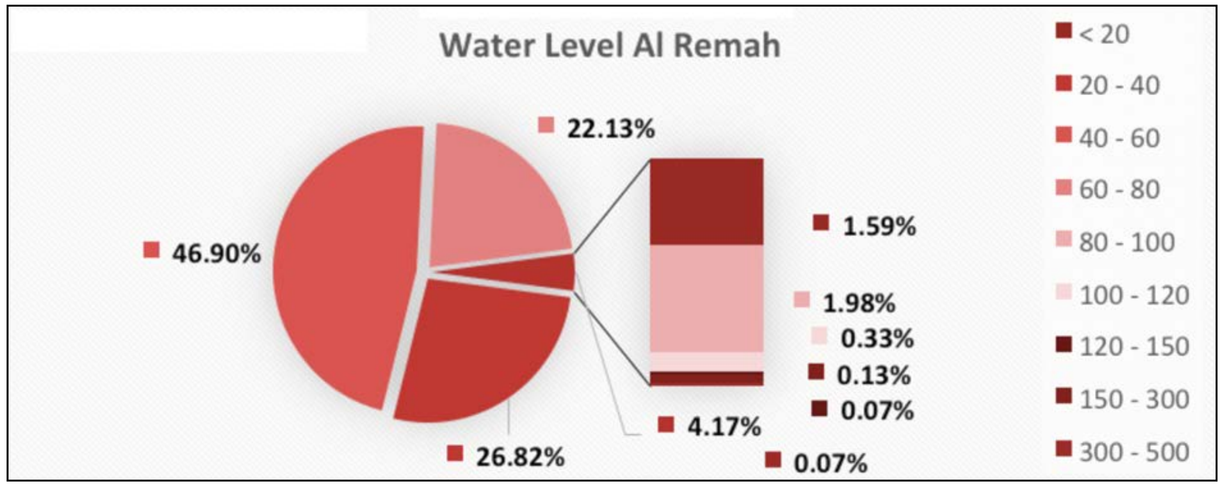


Figure 49: Depth to groundwater measurement [m.b.TOC] classes - encountered in abstraction centers of Remah and nearby districts.

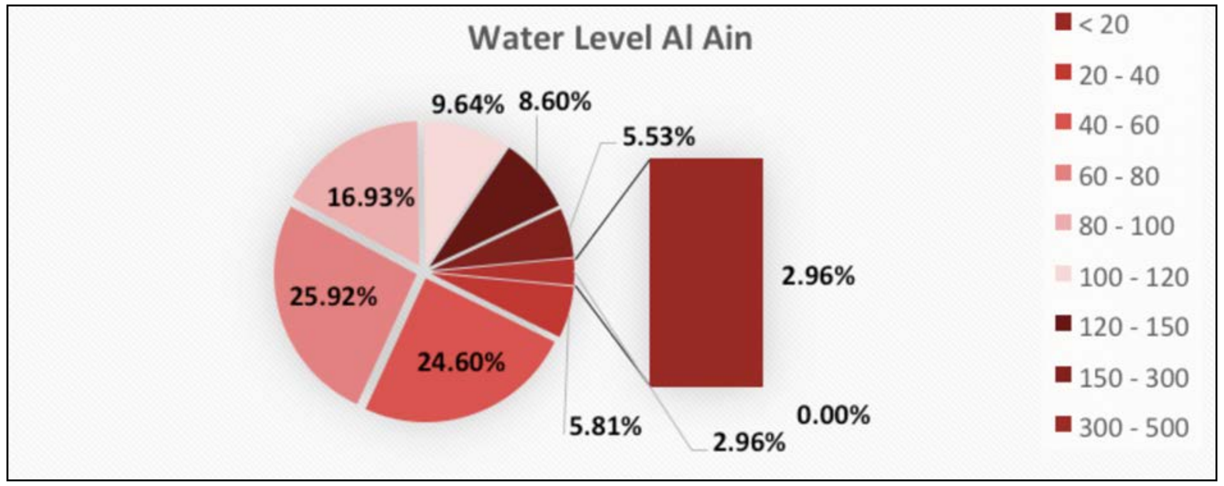


Figure 50: Depth to groundwater measurement [m.b.TOC] classes - encountered in abstraction centers of Al Ain and nearby districts.

As illustrated in **Figure 44**, water table depth generally increases from west to east. In addition, GWL in areas with many operating pumps is generally lower in the center relative to surrounding wells. This indicates overlapping cones of depression formed when groundwater abstraction is excessive and does not allow for recovery of aquifer levels..

5.8 Groundwater Quality

5.8.1 Salinity

Measurements of electrical conductivity (EC) were conducted at 7,999 wells. The preliminary distribution into groundwater salinity classes is shown in **Figures 51** to **57** and in **Tables 17, 18** and **19**.

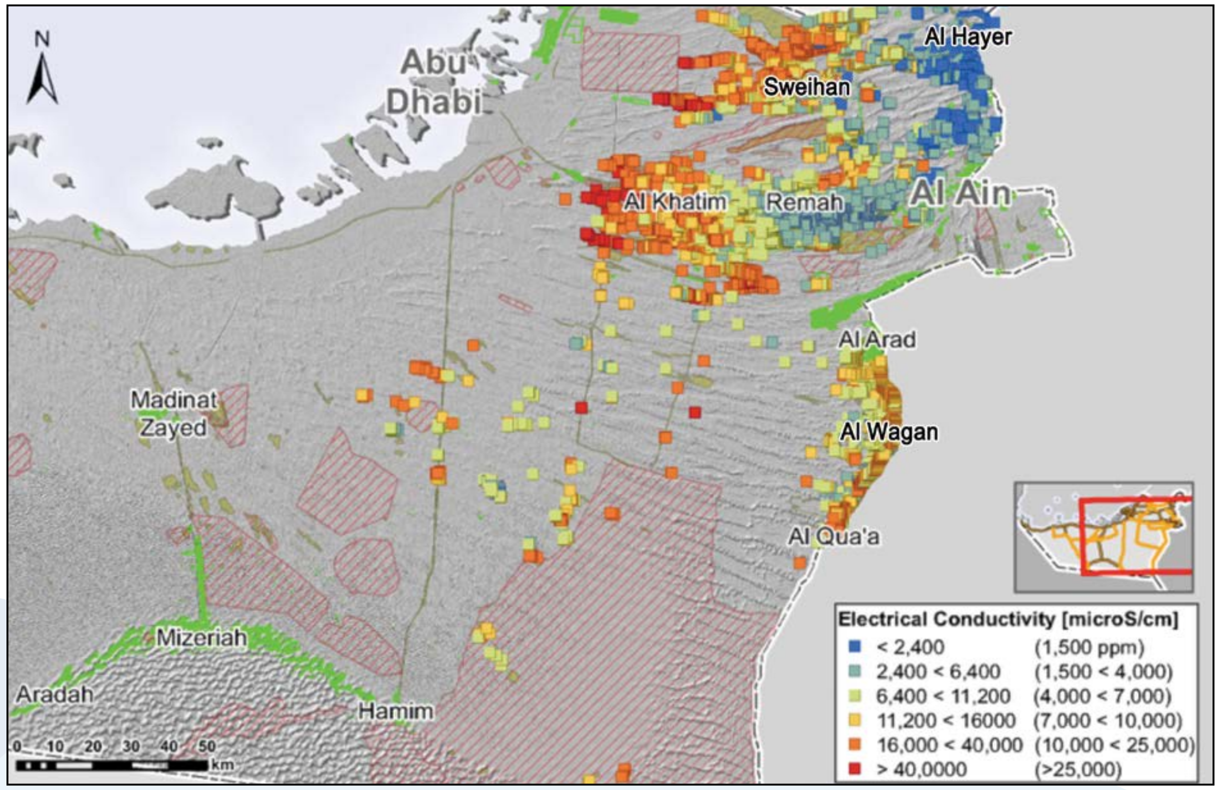


Figure 51: Electrical conductivity of the groundwater distribution of wells as surveyed through 12.2016.

Table 17: Electrical Conductivity - numbers and percentage total and for wells surveyed in the project.

		Wells surveyed	
GW Salinity TDS (ppm)	GW EC (µS/cm)	Wells	Percent
< 1,500	< 2,400	889	5.816
1,500 - 4,000	2,400 - 6,400	4,584	29.99
4,000 - 7,000	6,400 - 11,200	4,552	29.78
7,000 - 10,000	11,200 - 16,000	2,220	14.52
10,000 - 25,000	16,000 - 40,000	2,905	19
> 25,000	> 40,000	136	0.89
Total		15,286	100.00%
Average	(µS/cm)	10,739	
Median	(µS/cm)	8,340	
Mode	(µS/cm)	5,360	

Table 18: Electrical Conductivity - numbers and percentage total and for Sweihan, Al Hayer and Al Wagan areas

		Total		Sweihan		Al Hayer		Al Wagan	
GW Salinity TDS (ppm)	GW-EC (µS/cm)	Wells	Percent	Wells	Percent	Wells	Percent	Wells	Percent
< 1,500	< 2,400	734	13.35%	52	2.62%	662	55.54%	20	0.86%
1,500 - 4,000	2,400 - 6,400	829	15.08%	290	14.62%	442	37.08%	97	4.17%
4,000 - 7,000	6,400 - 11,200	1871	34.02%	435	21.94%	81	6.80%	1355	58.30%
7,000 - 10,000	11,200 - 16,000	1032	18.77%	395	19.92%	6	0.50%	631	27.15%
10,000 - 25,000	16,000 - 40,000	1027	18.68%	808	40.75%	1	0.08%	218	9.38%
> 25,000	> 40,000	6	0.11%	3	0.15%	0	0.00%	3	0.13%
Total		5,499	100.00%	1,983	100.00%	1,192	100.00%	2,324	100.00%
Average	(µS/cm)			14,771		2,802		10,920	
Median	(µS/cm)			13,620		2,150		10,020	
Mode	(µS/cm)			24,300		2,340		8,350	

Table 19: Electrical Conductivity - numbers and percentage total and for Al Khazna / Al Khatim, Remah and Al Ain areas

		Total		Remah		Al Khatim/Khazna		Al Ain	
GW Salinity TDS (ppm)	GW-EC (µS/cm)	Wells	Percent	Wells	Percent	Wells	Percent	Wells	Percent
< 1,500	<2400	24	0.33%	5	0.09%	3	0.15%	16	25.81%
1,500 - 4,000	2400 - 6400	3,317	45.10%	3,260	61.13%	19	0.97%	38	61.29%
4,000 - 7,000	6400 - 11200	1,985	26.99%	1,773	33.25%	206	10.52%	6	9.68%
7,000 - 10,000	11200 - 16000	716	9.74%	257	4.82%	459	23.43%	0	0.00%
10,000 - 25,000	16000 - 40000	1,251	17.01%	38	0.71%	1,211	61.82%	2	3.23%
> 25,000	> 40000	61	0.83%	0	0.00%	61	3.11%	0	0.00%
Total	Total	7,354	100.00%	5,333	100.00%	1,959	100.00%	62	100.00%
Average	(µS/cm)			6577		19543		4305	
Median	(µS/cm)			5360		24000		3310	
Mode	(µS/cm)			5790		18270		5300	

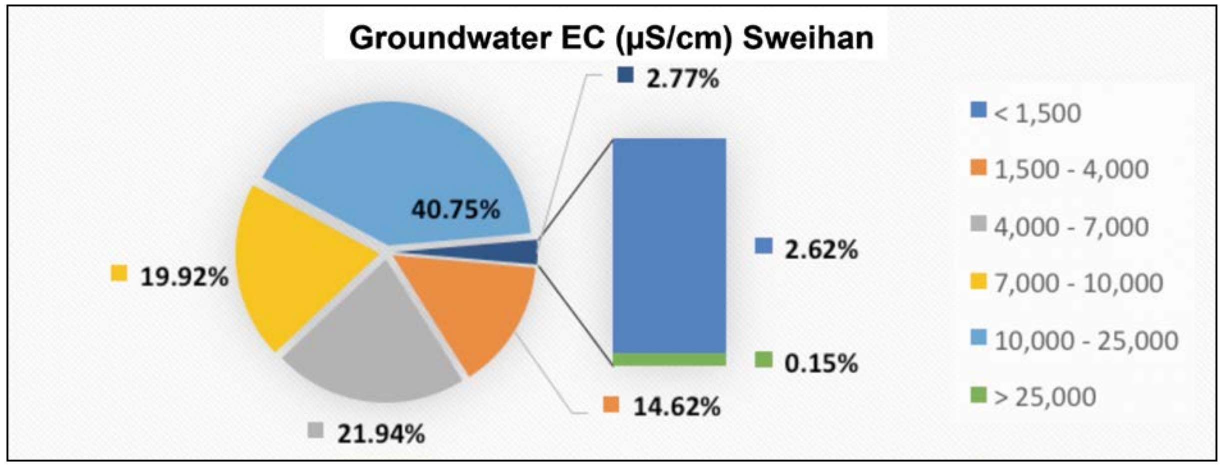


Figure 52: Percentages of groundwater salinity classes in Sweihan and nearby districts.

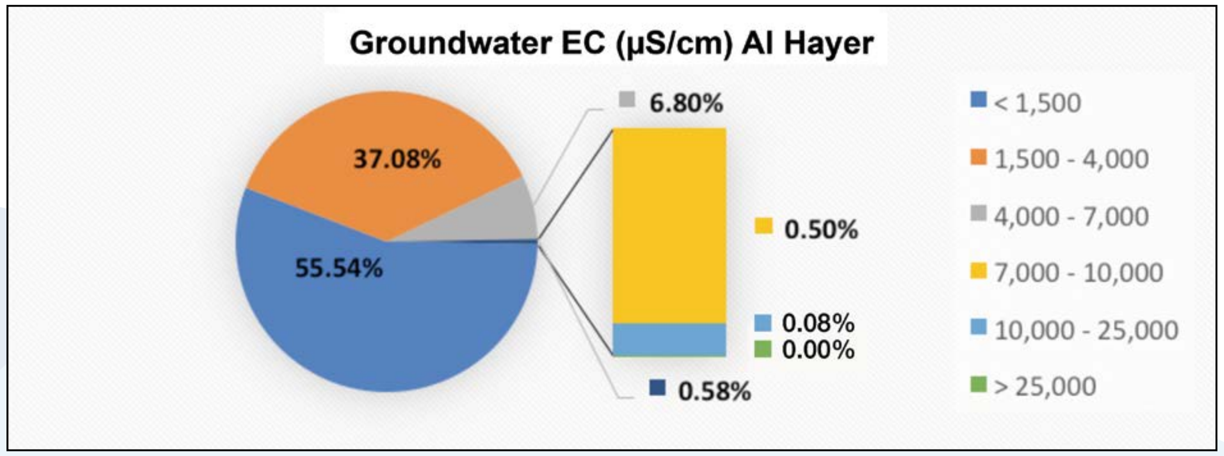


Figure 53: Percentages of groundwater salinity classes in Al Hayer and nearby districts.

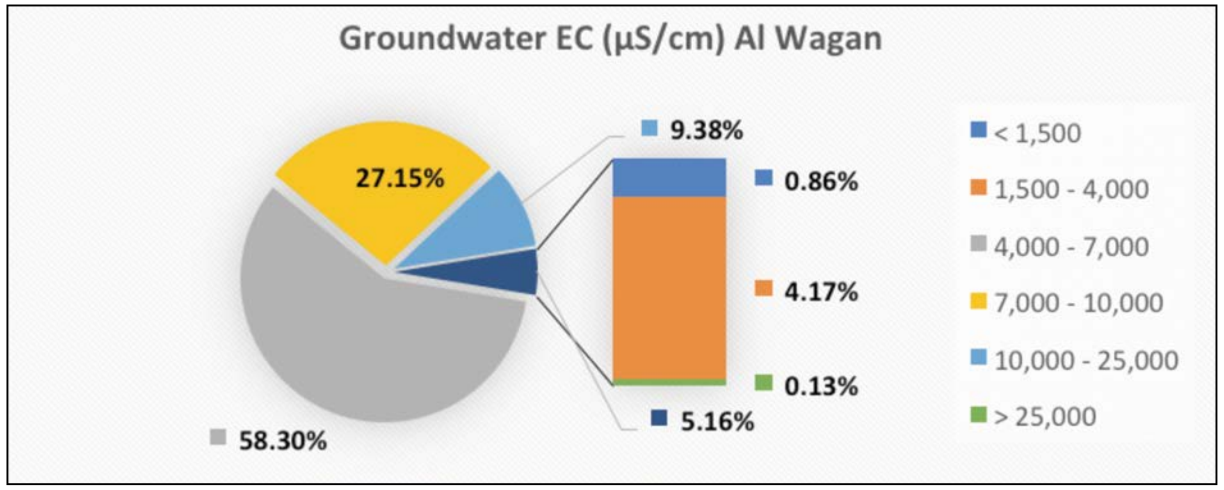


Figure 54: Percentages of groundwater salinity classes in Al Wagan and nearby districts.

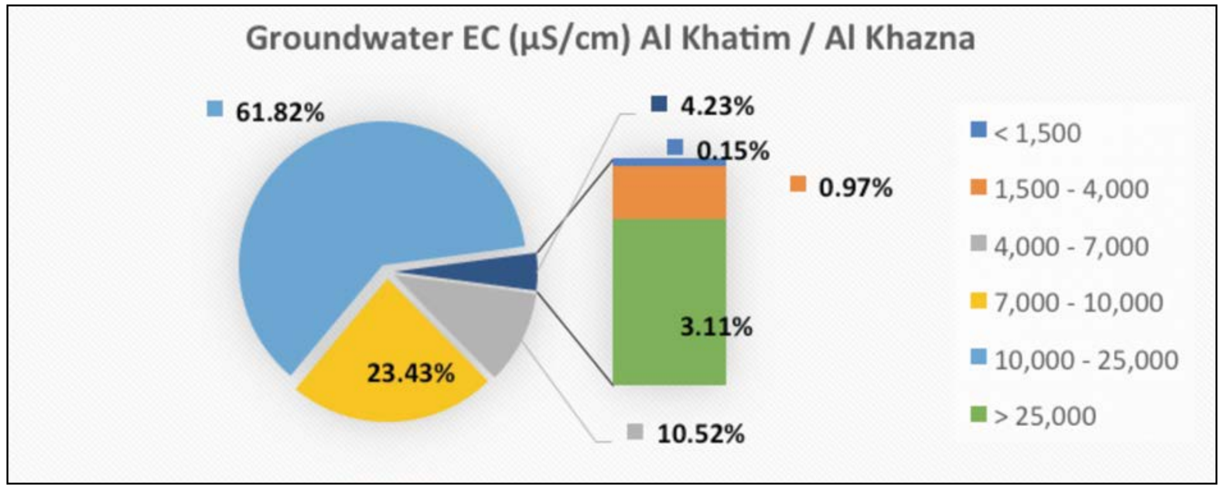


Figure 55: Percentages of groundwater salinity classes in Al Khatim / Al Khazna and nearby districts.

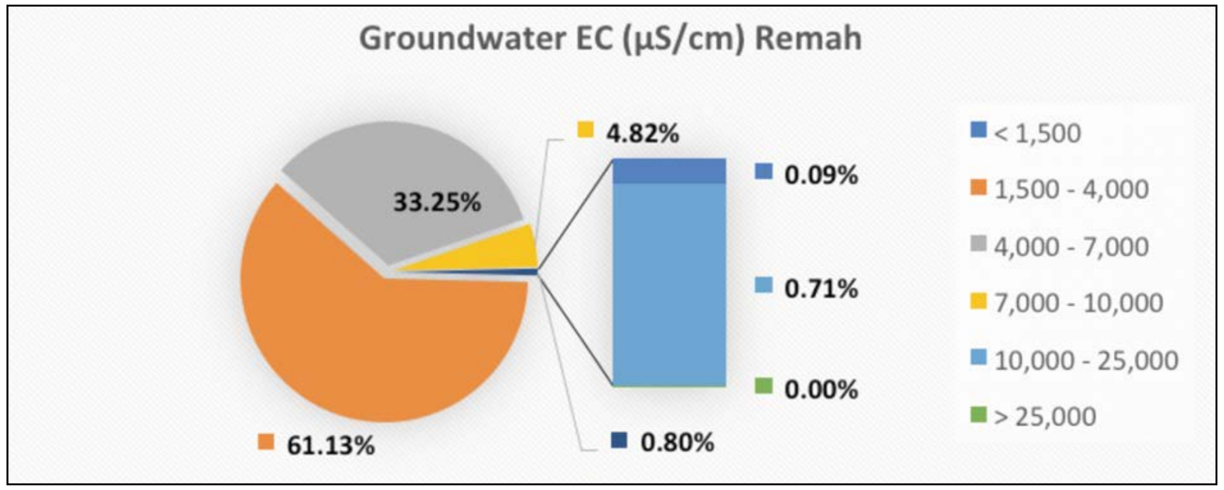


Figure 56: Percentages of groundwater salinity classes in Remah and nearby districts.

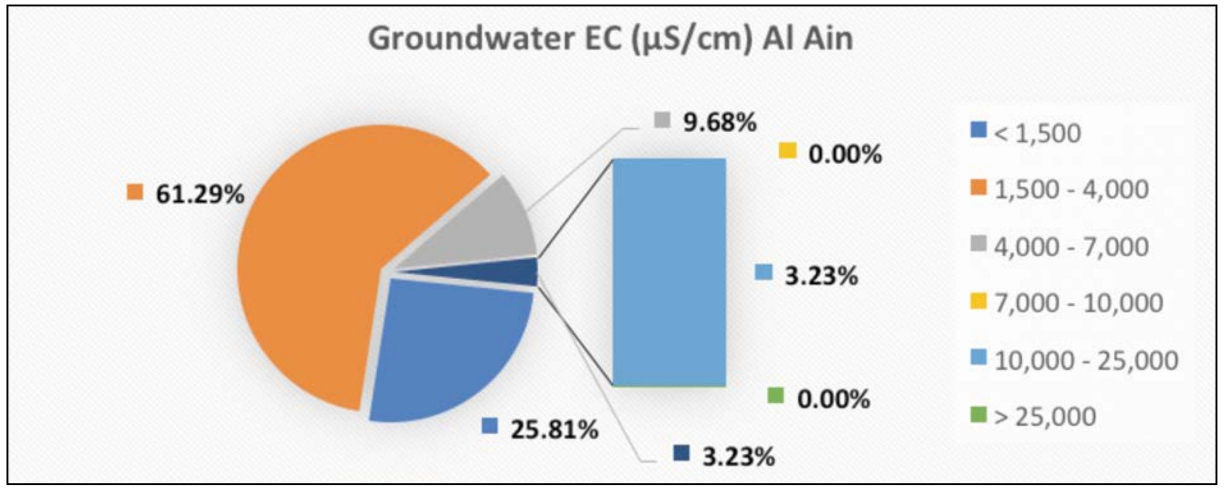


Figure 57: Percentages of groundwater salinity classes in Al Ain and nearby districts.

5.9 Desalination Plants

Farmers in the surveyed area use water from desalination plants due to the high salinity of the groundwater for irrigation within the surveyed areas in many parts of the conducted survey. In total, 665 desalination plants were identified that supply fresh water to crops and livestock. Figure 58 and Table 20 show the distribution and relative percentage of the desalination plants in the surveyed areas. Water supplied to desalination plants on site ranges from 1,200 to 47,100 µS/cm. Brine discharge observed ranges from 3,760 to 73,200 µS/cm.

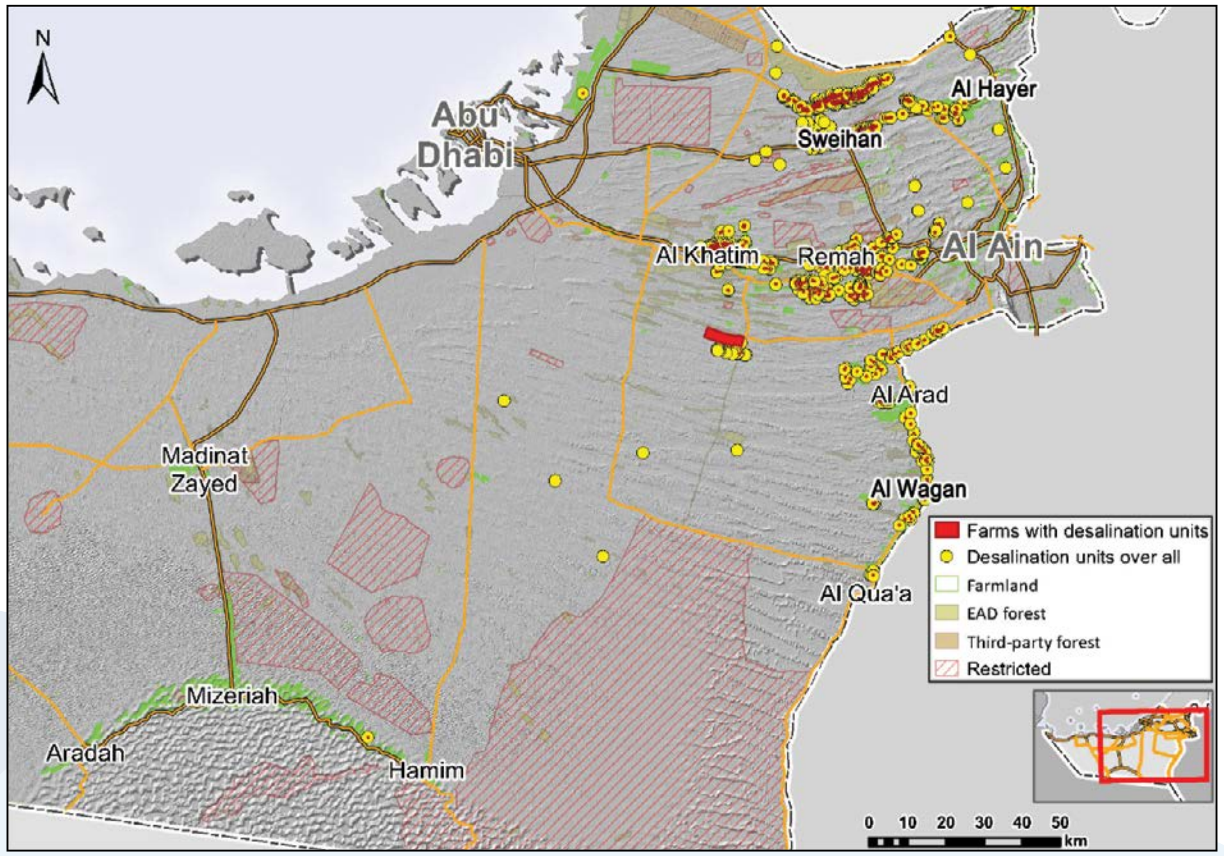


Figure 58: Distribution of the desalination plants.

Table 20: Desalination plants - the percentage of plants inventoried in the Al Khazna and Sweihan areas

	Total No. of Units	Farms
Desalination Plants	665	557

Brine discharge is released into various environments, such as back into a well, on the ground of the site, outside the site fence, and into collection and evaporation ponds (Figures 59 to 62).

Figure 59: Brine water discharges in water well.

Figure 60: Brine water discharges in (evaporation) ponds.

Figure 61: Brine water discharge on ground surface inside farms.

Figure 62: Brine water discharge on ground surface outside farms.

5.10 Groundwater Sampling for Hydrochemical Analysis

Groundwater samples were analyzed for the following parameter groups::

- Group 1 - physicochemical and organoleptic parameters, and m-alkalinity.
- Group 2 - major constituents and other parameters.

All groundwater samples were sent to an independent scientific laboratory for analysis. In the abstraction centers of Sweihan, Al Hayer, and Al Wagan 196 samples were collected (Table 21).

In the abstraction centers of Remah, Al Khazna, and Al Ain 212 samples were collected. Sampling was conducted in batches to ensure short holding times and to warrant appropriate distribution throughout the survey area.

Table 21: Water sampling of survey areas Sweihan, Al Hayer, and Al Wagan

	Total	Sweihan	Al Hayer	Al Wagan
Water sampling	Wells	Wells	Wells	Wells
Number of samples	196	104	41	51

Table 22: Water sampling of abstraction centers Remah, Al Khazna, and Al Ain

	Total	Remah	Al Khazna	Al Ain
Water sampling	Wells	Wells	Wells	Wells
Number of samples	212	177	35	0

Table 23: Water sampling of survey areas

	Total
Water sampling	Wells
Number of samples	515

A large majority of analyzed water samples show high concentrations of Sodium, Chloride, Sulphate and Calcium as predominant species. Several samples show contaminations consistent with nearby livestock farming..

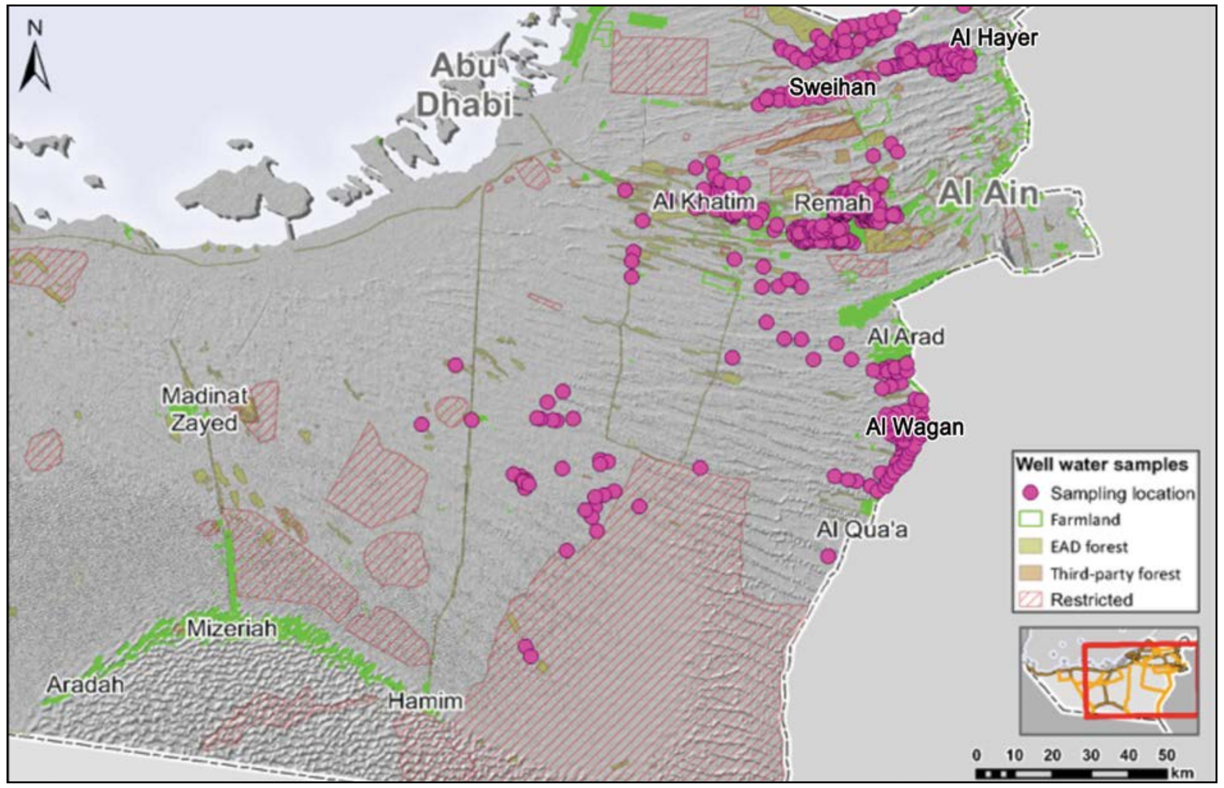


Figure 63: Sampling sites for hydrochemical analysis - distribution of wells as surveyed until 12.2016.

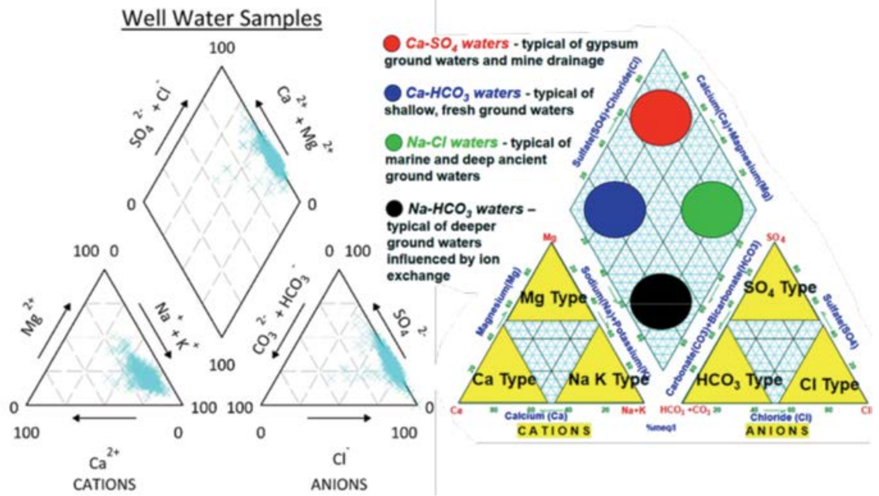


Figure 64: Well Water Type - Piper Diagram of analyzed samples.

Figure 64 illustrates the water chemistry of the sampled wells. The Piper diagram is suitable for comparing the ionic composition of a set of water samples. The water samples taken in the project show a strong concentration in the upper right of the diamond shaped plot. This indicates sodium chloride type groundwater with an extension towards gypsum groundwater type.

The ternary diagram in the lower left and right represents the cations and anions, respectively, and the diamond plot in the middle represents a combination of the two. Plot-normalized concentrations of each of the three cations of a sample are plotted on the lower left ternary diagram. This is repeated for the anions on the lower right ternary diagram. Following a line parallel to the outer axis of each ternary diagram, each point projects in the ternary diagrams upward until they intersect with one another in the diamond plot. This is where the intersection of the lines forms the third point. This is illustrated in the **Figure 65** below with the projecting colored axes.

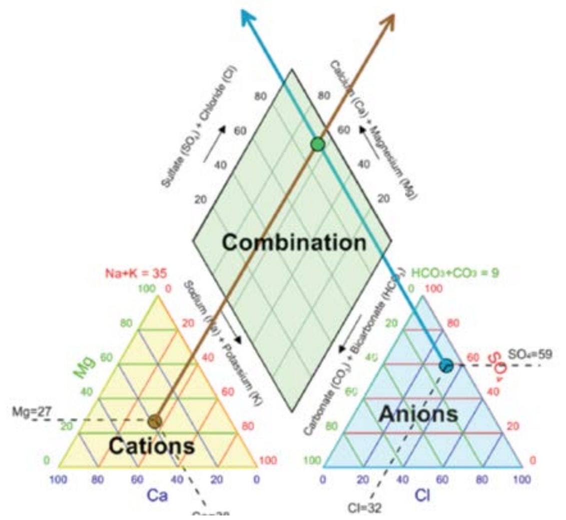


Figure 65: Piper plot as way of visualizing the chemistry of water sample(s).

5.11 Well Discharge Data

Figure 66 illustrates the groundwater abstraction data identified by the survey.

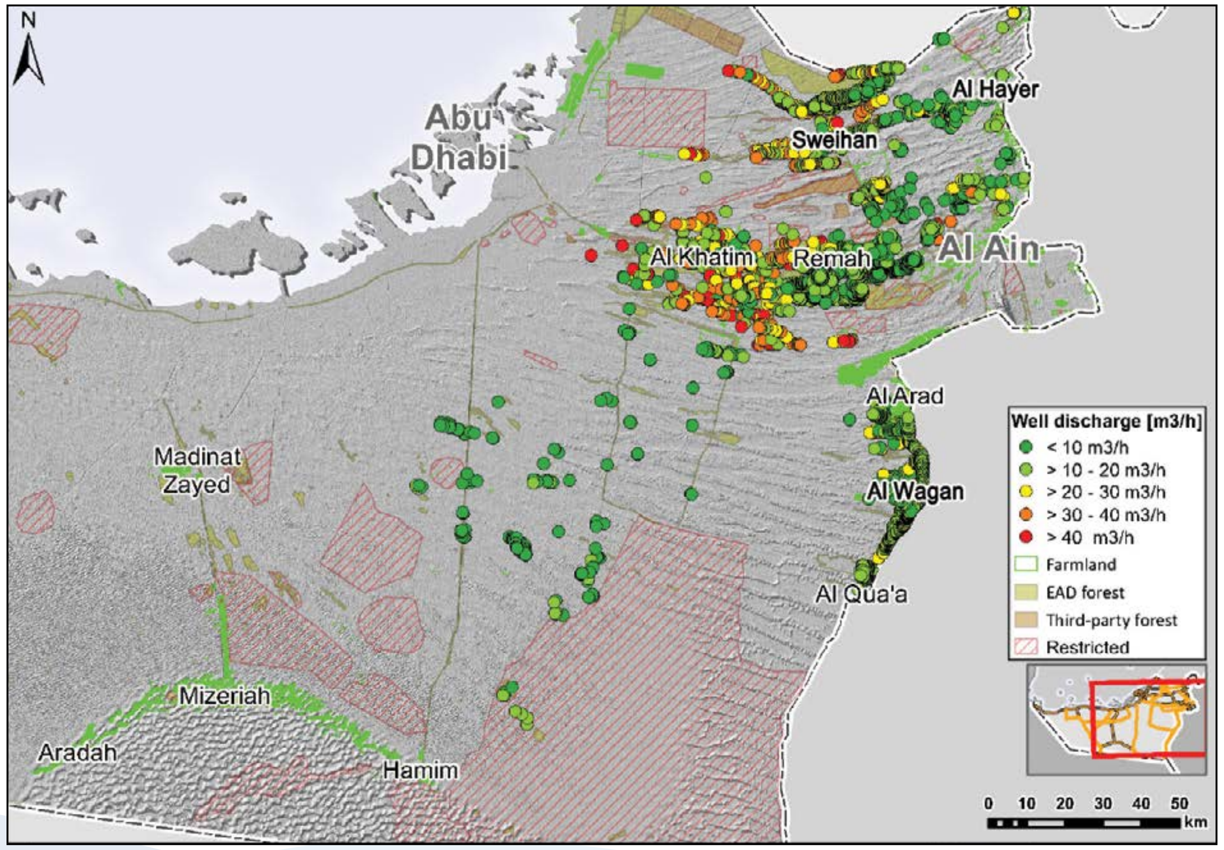


Figure 66: Well discharge distribution of wells as surveyed until 12.2016.

Discharge measurements are summarized in **Tables 24, 25,** and **26** as well as **Figures 67** to **72,** and were carried out in all survey areas. Deep wells such as in Remah farm area have frequently a lower production compared to the shallower well setting. Investment in pumping equipment and power supply are correspondingly higher to operate and maintain.

Table 24: Well discharge - number and percentage of classes of wells surveyed

	All surveyed	
Discharge (m³/h)	Wells	Percent
< 10	3,334	37.54
10 - 20	4,001	45.46
20 - 30	1,066	12.11
30 - 40	252	2.86
> 40	178	2.02
Total	8832	100.00%
Average (m³/h)	16.15	--
Median (m³/h)	12.41	--
Mode (m³/h)	12.00	--

Table 25: Well discharge - number and percentage of classes of wells in Sweihan, Al Hayer and Al Wagan areas

	Total		Sweihan		Al Hayer		Al Wagan	
Discharge (m³/h)	Wells	Percent	Wells	Percent	Wells	Percent	Wells	Percent
< 10	769	29.81%	199	21.44%	104	56.22%	466	31.77%
10 - 20	1,476	57.21%	529	57.00%	75	40.54%	872	59.44%
20 - 30	313	12.13%	179	19.29%	5	2.70%	129	8.79%
30 - 40	18	0.70%	17	1.83%	1	0.54%	0	0.00%
> 40	4	0.16%	4	0.43%	0	0.00%	0	0.00%
Total	2,580	100.00%	928	100.00%	185	100.00%	1,467	100.00%
Average (m³/h)			15.46		9.75		12.50	
Median (m³/h)			15.65		8.57		12.41	
Mode (m³/h)			18.00		15.00		13.85	

Table 26: Well discharge - number and percentage of classes of wells in Al Khatim / Al Khazna, Remah and Al Ain

	Total		Remah		Al Khazna		Al Ain	
Discharge (m³/h)	Wells	Percent	Wells	Percent	Wells	Percent	Wells	Percent
< 10	2,031	40.72%	1,836	49.64%	189	14.85%	6	37.50%
10 - 20	2,121	42.52%	1,550	41.90%	566	44.46%	5	31.25%
20 - 30	542	10.87%	179	4.84%	360	28.28%	3	18.75%
30 - 40	216	4.33%	131	3.54%	83	6.52%	2	12.50%
> 40	78	1.56%	3	0.08%	75	5.89%	0	0.00%
Total	4,988	100.00%	3,699	100.00%	1,273	100.00%	16	100.00%
Average (m³/h)			7		35		15.3	
Median (m³/h)			8		21		16.5	
Mode (m³/h)			6		18		22.5	

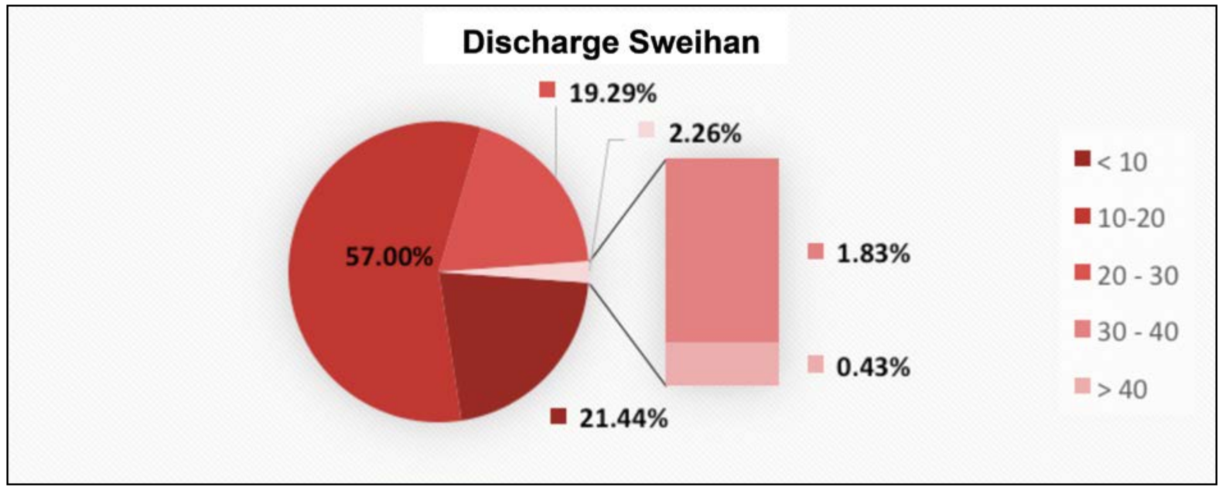


Figure 67: Well discharge class percentages - in Sweihan and nearby districts.

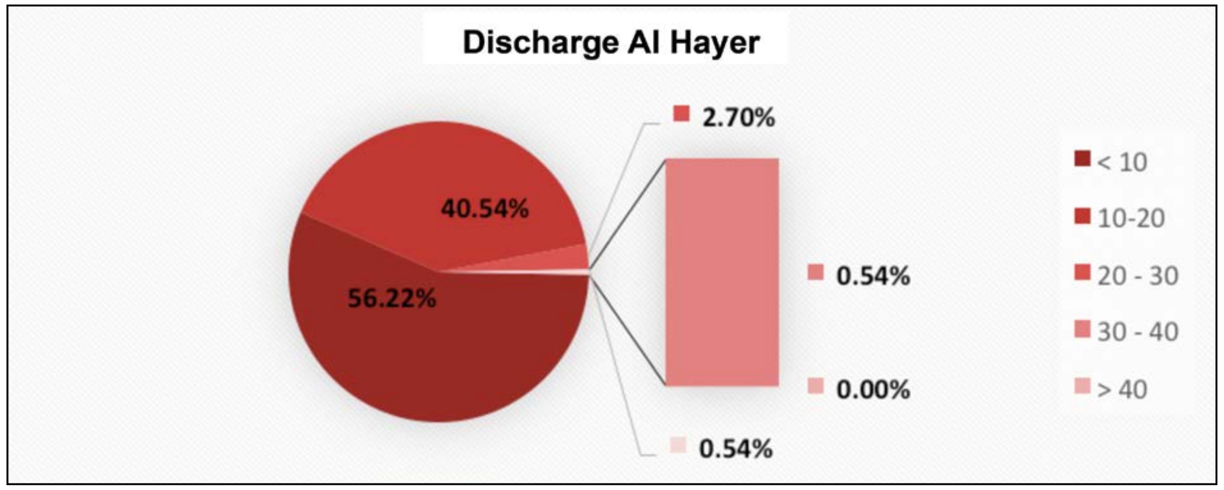


Figure 68: Well discharge class percentages - in Al Hayer and nearby districts.

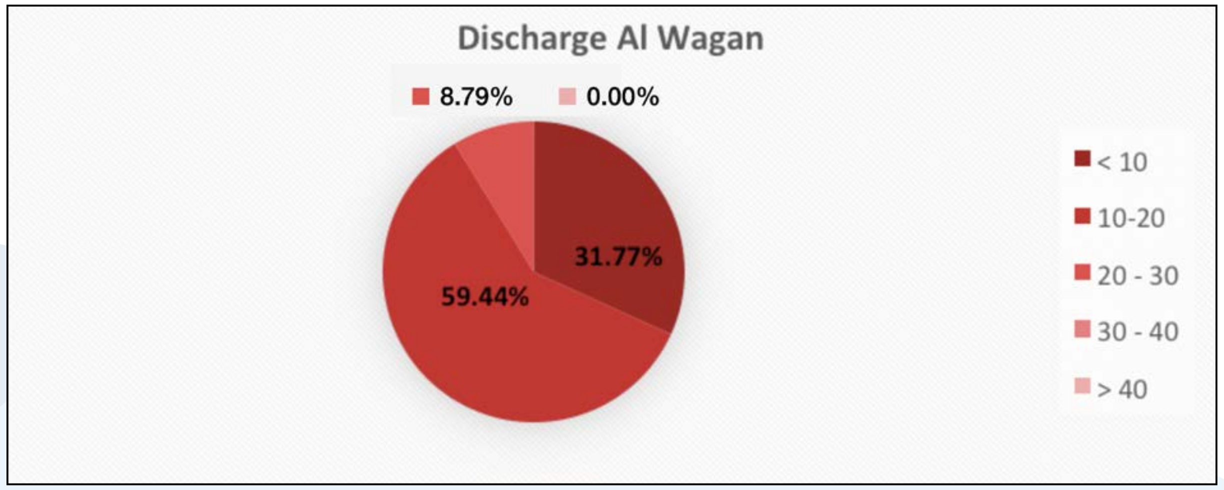


Figure 69: Well discharge class percentages - in Al Wagan and nearby districts.

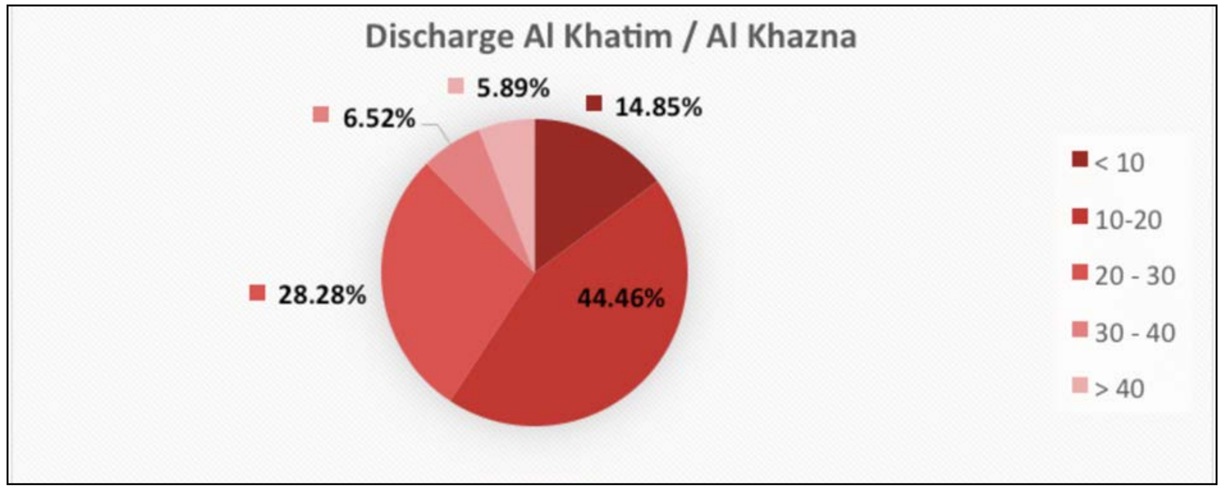


Figure 70: Well discharge class percentages - in Al Khatim / Al Khazna and nearby districts.

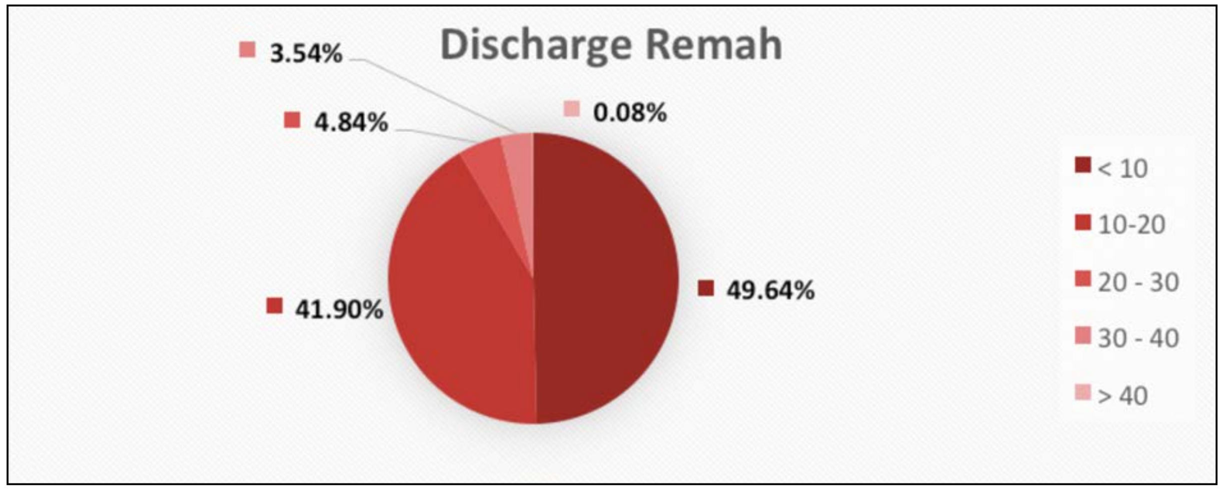


Figure 71: Well discharge class percentages - in Remah and nearby districts.

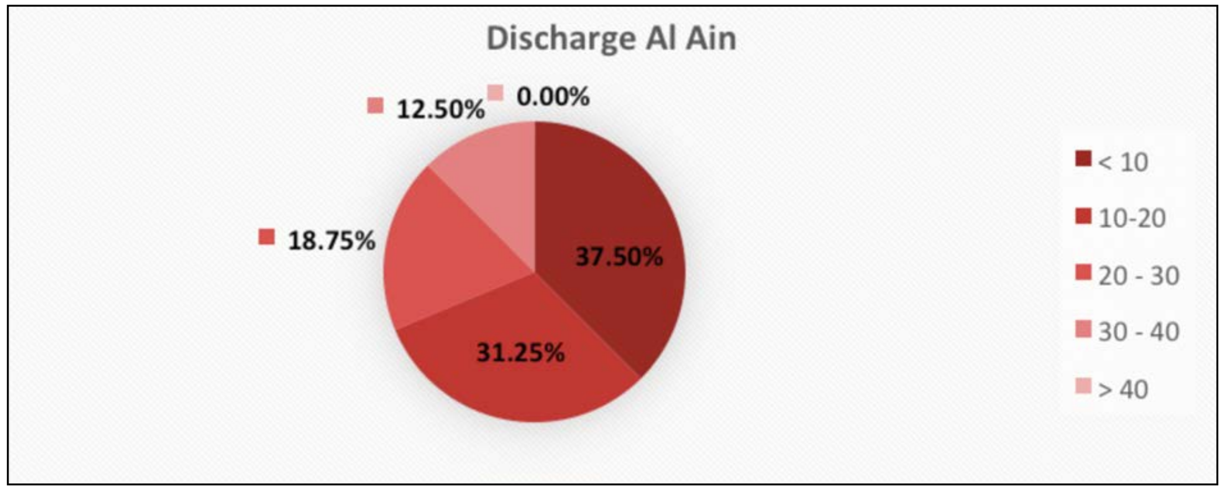
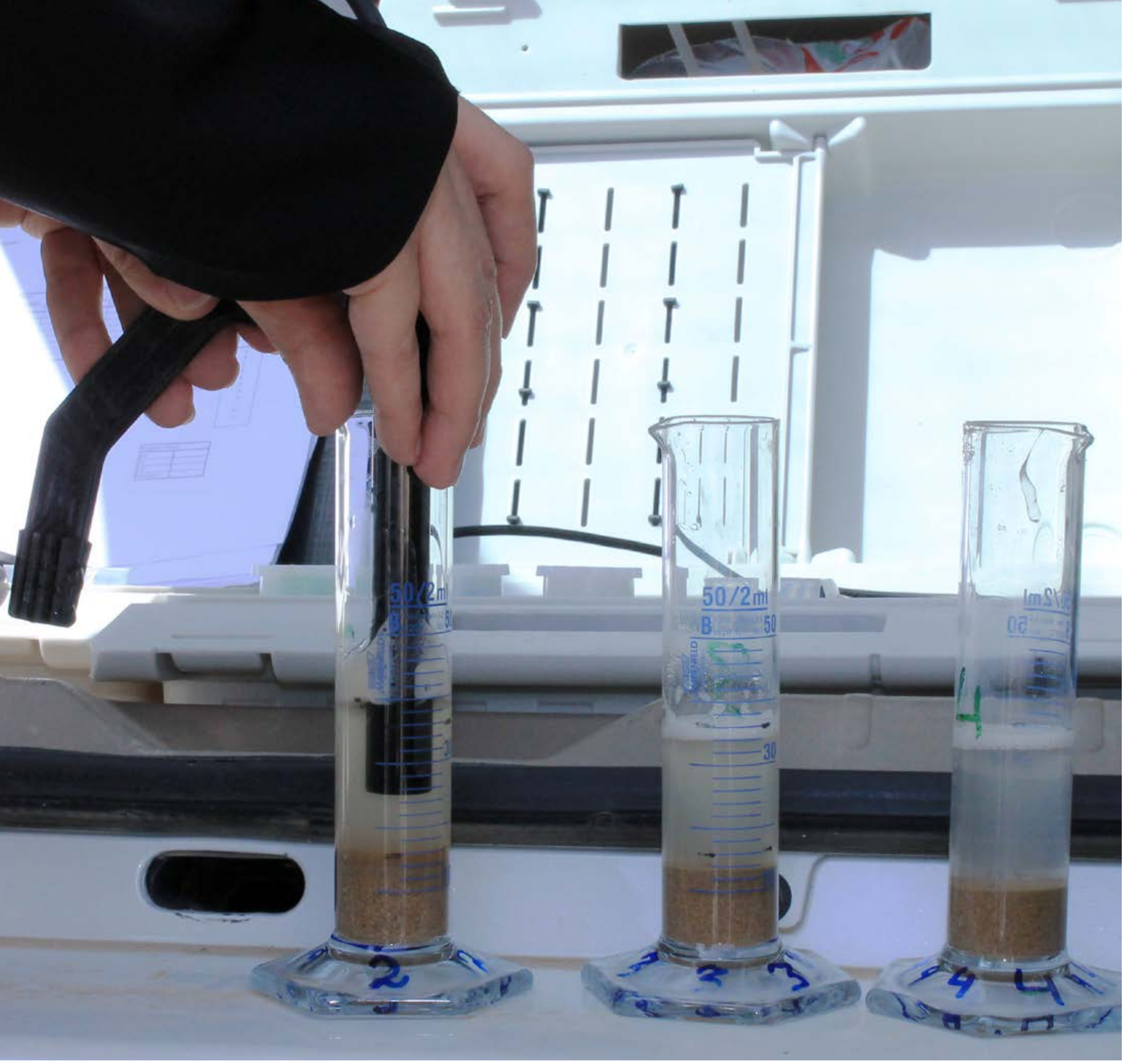


Figure 72: Well discharge class percentages - in Al Ain and nearby districts.



6 Progress and Preliminary Results of the Farm / Soil-Salinity Inventory

6.1 Overall Progress

The soil salinity survey is divided into two parts: The regular farm soil salinity survey and the soil salinity monitoring program. The regular survey, has progressed to about 57% completion based on the 3,900 farms. Each farm is surveyed once. As for the monitoring program, a number of 100 farms are periodically sampled every four months for two years. During the first year, 3 monitoring programs were conducted with a progress of about 50%.

6.2 Farm and Soil-Salinity Inventory

Table 27 shows the achieved progress in the regular farm survey through 10 January 2017.

Table 27: Progress of the Regular Farm/soil salinity survey in total

Period	Total	Not accessible	Percent of completion	Value for completion
Date from - to	10.01.16 - 04.01.2017	--	50	30.12.2017
Farms surveyed (including 1694 before re-scoping)	2238	--	57	3.900
Soil Augerings	2240	--	57	3.900
Desalination Units	238	--	--	--
Reservoirs	2046	--	--	--
EC/pH irrigation water, field measurement	1958	284	50	3.900
EC 1:1, pH soil field measurement	9.693	443	54	15.600
Irrigation water samples, lab analysis	191		49	390
Soil samples for lab analysis	737	5	47	1.560

The intention is to collect soil information, such as EC and pH measured in the field, at four standard depths at 3,900 farms, totaling 15,600 measurements each. Due to regional augering impediments such as rock or hardpans, the full depth could not be reached on occasion, at which less than four measurements were collected. Correspondingly the number of measurements is slightly lower than fourfold.

In addition, no results could be obtained for irrigation water at abandoned farms.

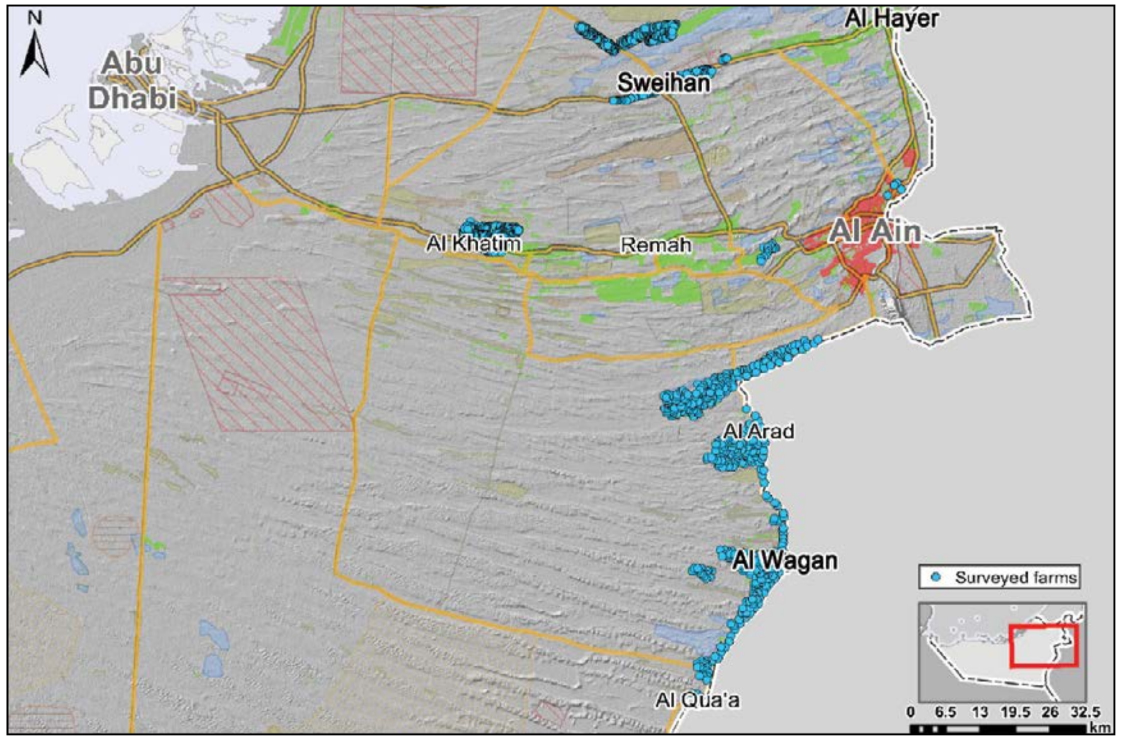


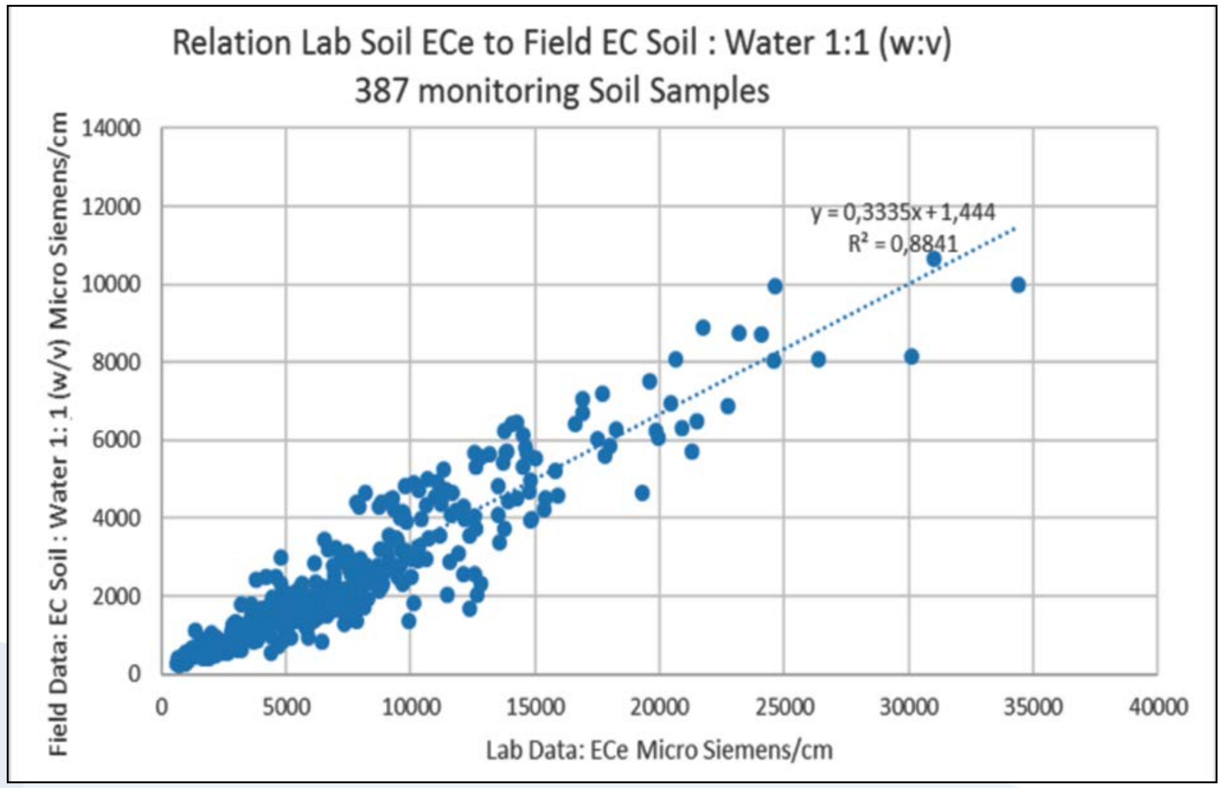
Figure 73: Farms inventoried up to the end of the reporting period.

6.1.1 Preliminary Results of the Farm and Salinity Inventory (regular survey)

The following represent the preliminary results of the farm/soil salinity inventory through year 2016:

1. The distribution of soil salinity measured from three depths (0-25cm, 25-50cm and 50-150cm) for the Al Khatim, Sweihan and Al wagan-AlAraad was mapped **(Figures 76-78)**.
2. The levels of salinity management in Al Khatim, Sweihan, and Al Wagan - Al Araad (well managed "ECe/ECw is < 1.5", not managed "ECe/ECw is > 1.5") were mapped **(Figure 73)**. **Figure 74** shows the percentages of both classes including farms not irrigated.
3. The Individual salinity distribution at the four standard depths in the regions of Al Khatim, Al Wagan and Sweihan were determined as shown in **Figure 81, 83 and 85.** Moreover, the proportion of salinity classes differentiated according to regions was determined as shown in **Figure 82, Figure 84,** and **Figure 86.**
4. A Reliable ratio between the EC method based on the saturation Extract (ECe) and the simpler measurement of the EC in a suspension of 1:1water: soil by weight and volume was established. The result yielded a ratio of 1:3.17 with an acceptable r2 value of 0.82. **Figure** 74 demonstrates the relationship after comparing field values EC 1:1 to laboratory analysis for ECe, from 387 soil samples out of 99 monitoring farm profiles, which were evenly distributed through all the irrigated farm areas in the Abu Dhabi Emirate. This ratio is used presently to perform quick analysis at field level or to establish a relationship between irrigation water quality and resultant soil salinity. The Project will investigate further the relationship between ECe to EC 1:1 by continued comparison of field and laboratory values to achieve additional confirmation.

Figure 74: Relation of Laboratory Soil EC and Field Soil EC as measured in a 1:1 Soil:Water (w:v) suspension.



6.1.2 Soil Salinity (ECe) Maps and Illustrations

Soil profile and classification data are noted down on separate recording sheets, in the continuous process to be digitized.

For the regular survey, the following data is recorded through the Trimble device:

- Routine data - farm identity, position, survey team, primary and secondary land use, land use at the augering site.
- Water infrastructure - type of irrigation, irrigation time, reservoir size and filling time.
- Desalination - position, size of tanks and the disposal of desalination brine.
- Water and soil sampling - EC and pH of the irrigation water as well as the same for the soil at the four standard depth intervals.

A weekly record has been presented regularly on the number of farms surveyed, the number of augerings done, reservoirs analyzed, desalination plants recorded, the number of soil and water samples taken and sent to the laboratory, as well as EC and pH measurements performed in the field. Information has been provided of farms that could not be surveyed either through the absence of owner or staff and due to outright access denied.

The results of the farm survey have yielded field EC 1:1 soil:water (w/v) at four different depth intervals. These are 0 to 25 cm, 25 to 50 cm, 50 to 100 cm, and 100 to 150 cm. The ultimate depths have only been omitted when augering barriers such as rock or hardpans have been encountered.

The results of the field salinity measurement 1:1 have been multiplied by the empirical factor 3.17 established by comparison with accurate laboratory ECe data. This has been displayed in a map in intervals of 0-2000, 2000-4000, 4000-8000, 8000-16000, 16000-40000, > 40000 µS/cm.

The preliminary results for the mapped areas in Al Khatim, Sweihan, as well as Al Wagan - Al Araad are being displayed. A summary of salinity distribution for all soil samples at all four depths for the entire 2016 survey is shown in **Figure 75.**

For 2016, the separate soil salinity at three standard depths intervals is being shown for the principal three surveyed areas **(Figure 76, Figure 77** and **Figure 78).**

For the year's survey results, the soil/irrigation water salinity relationship for the surveyed Al Wagan - Al Araad is shown (see **Figure 79).**

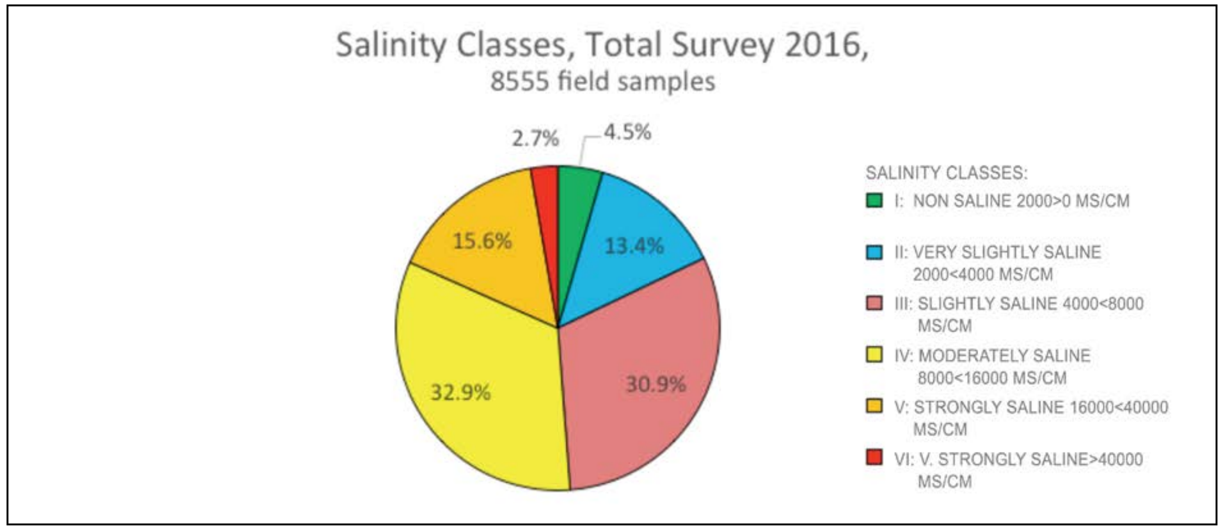


Figure 75: Percentage of salinity classes for the survey 2016, 8555 field samples from all depths.

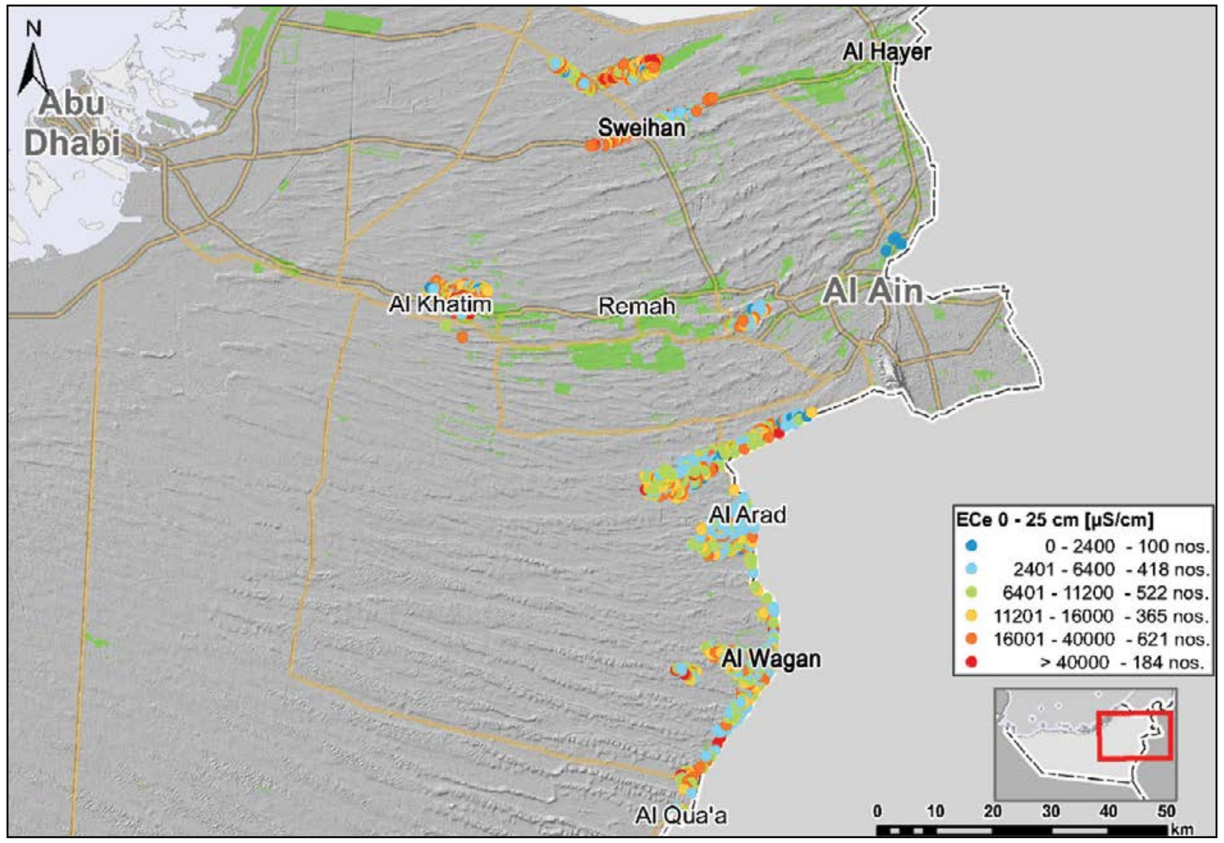


Figure 76: Survey area 2016, Soil Salinity in ECe (calculated) of the soil horizon 0 -25 cm (EC 1:1 Water:Soil w:v, multiplied by factor 3.17).

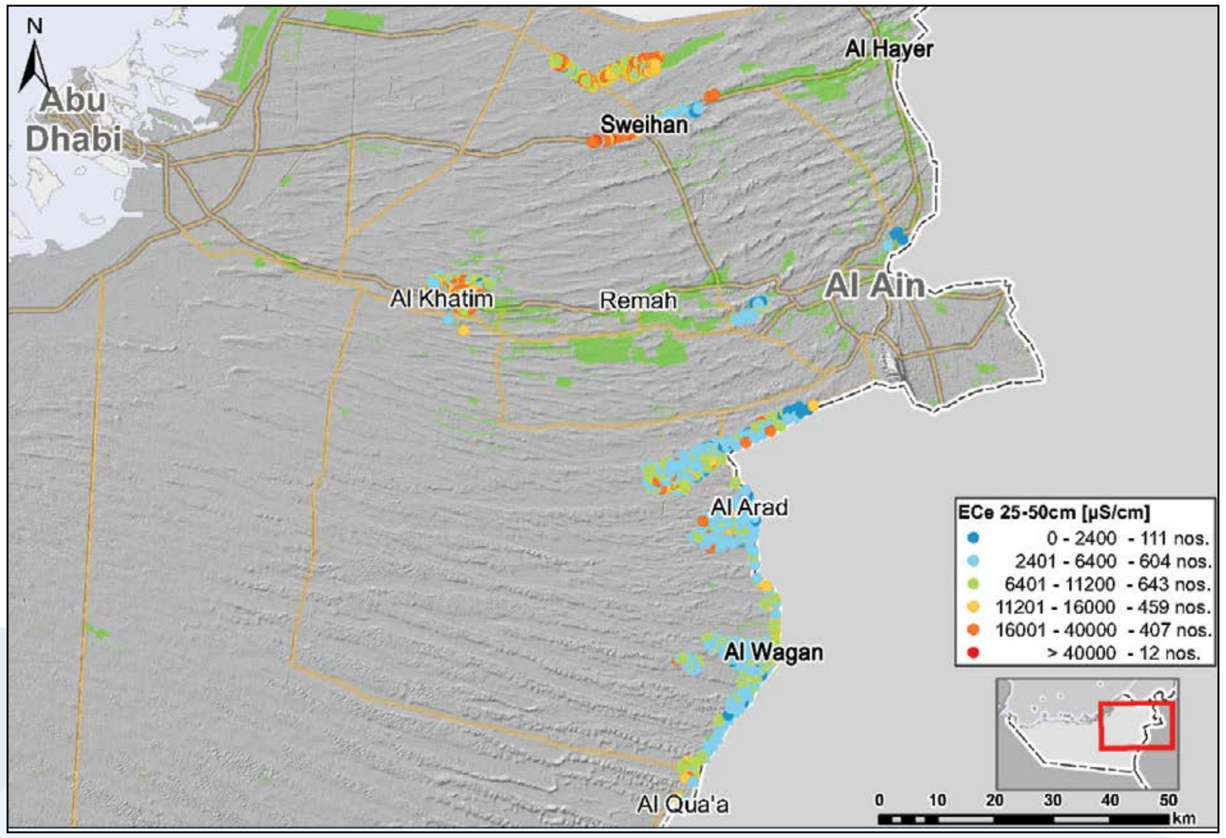


Figure 77: Survey area 2016, Soil Salinity in ECe (calculated) of the soil horizon 25-50 cm (EC 1:1 Water:Soil w:v, multiplied by factor 3.17).

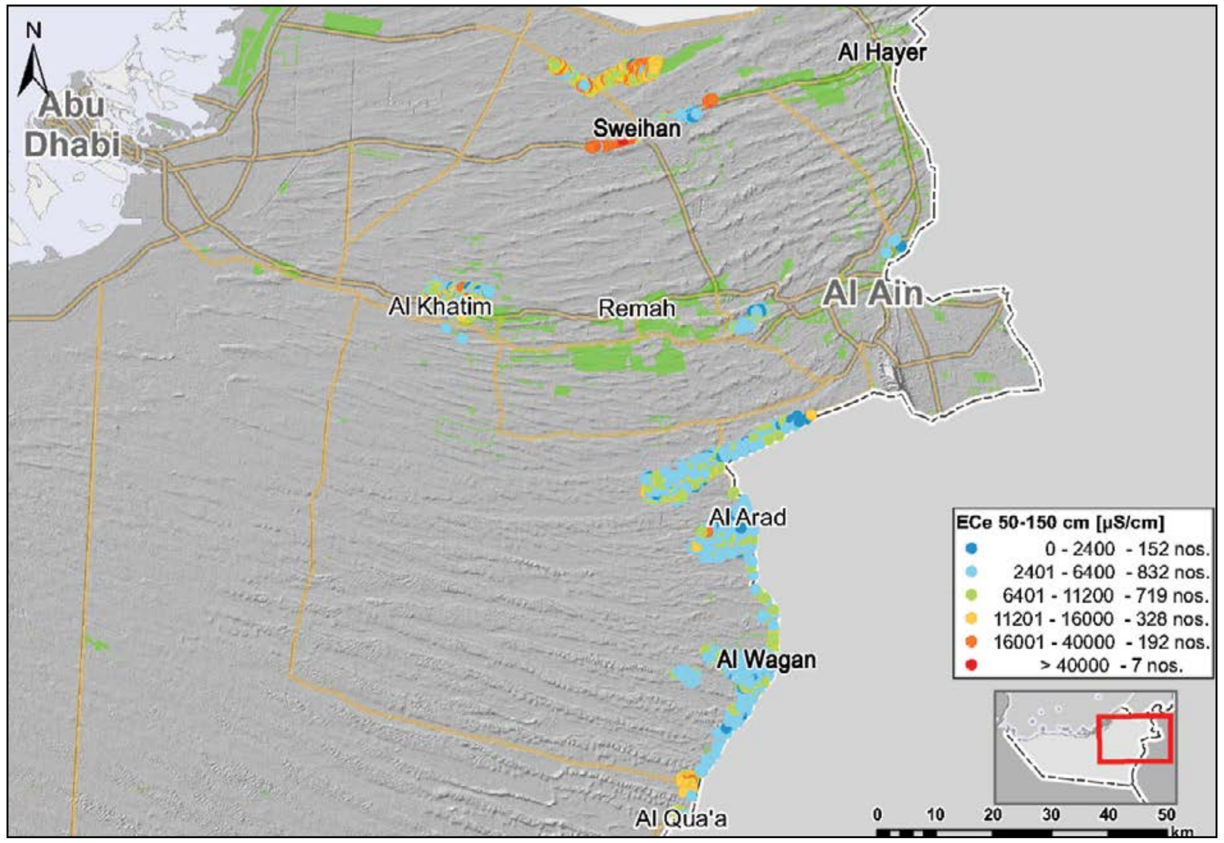


Figure 78: Survey area 2016, Soil Salinity in ECe (calculated) of the soil horizon 50 -150 cm (EC1:1 Water:Soil w:v, multiplied by factor 3.17).

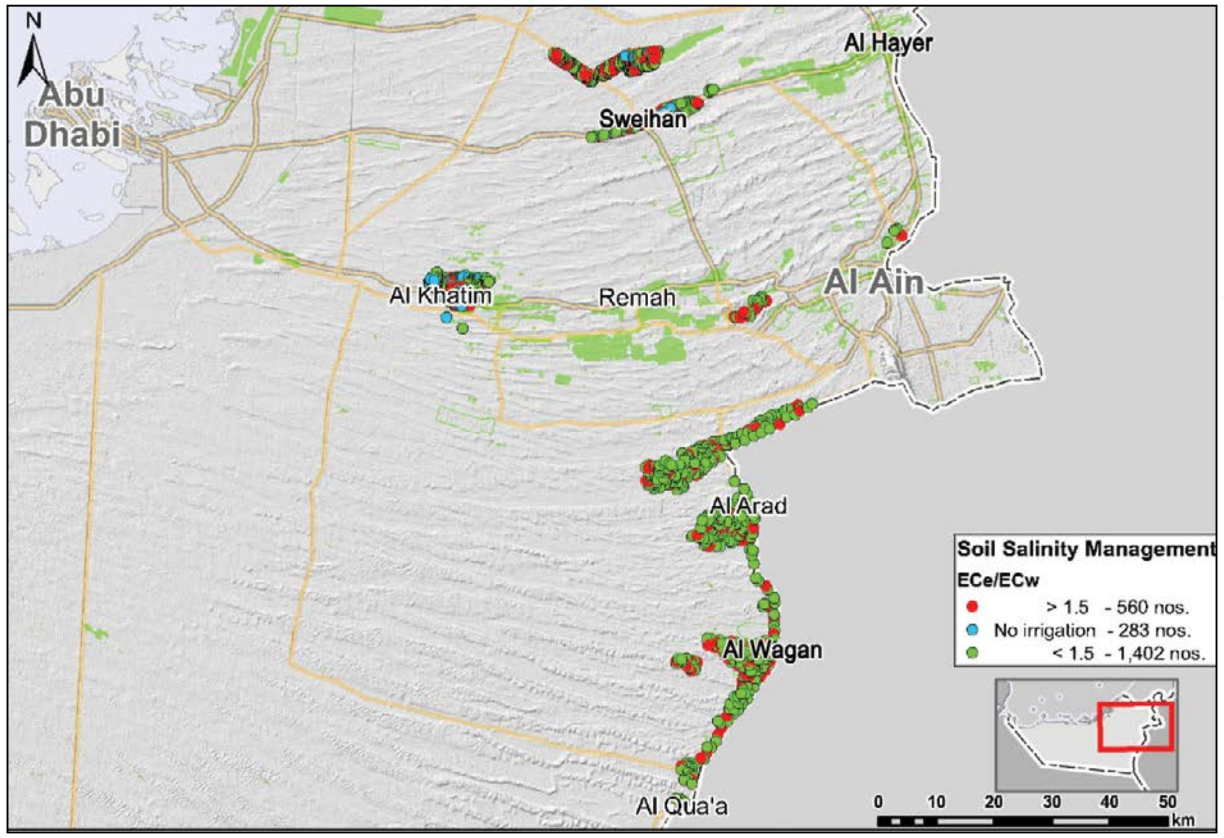


Figure 79: Survey area 2016, the relation of Soil Salinity ECe to Irrigation Water Salinity ECw of the soil horizon 0-25 cm. (for ECe = EC 1:1 Water:Soil w:v, multiplied by factor 3.17).

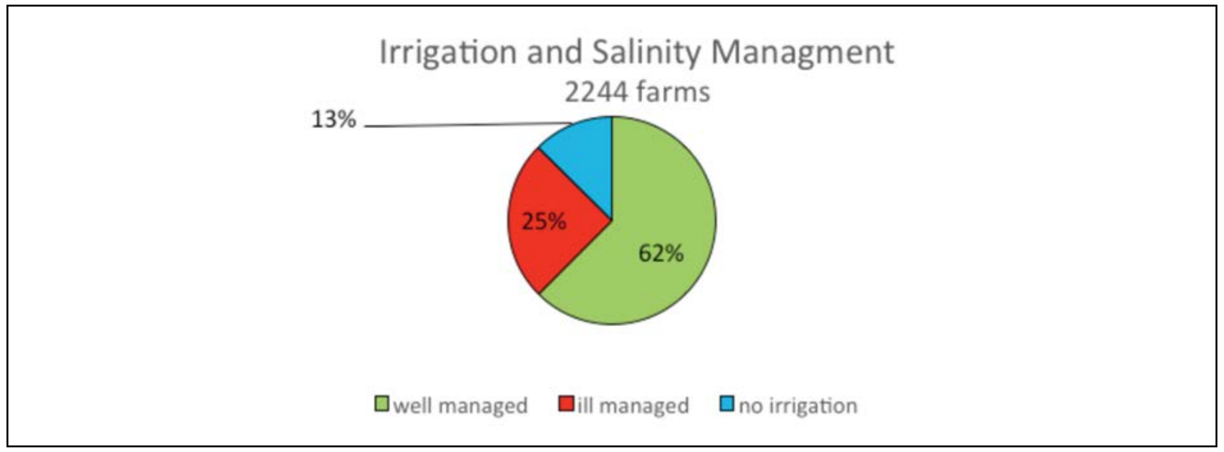


Figure 80: Relation of well managed (when ECe/ECw is < 1.5) to ill-managed farms (ECe/ECw > 1.5) and abandoned farms without irrigation.

Figure 81, Figure 83 and Figure 85 display the salinity distribution according to the six defined classes in the principal depths 0 to 25 cm, 25 to 50 cm, 50 to 100 cm and 100 to 150 cm. The percentage distribution of all salinity classes per mapped region is displayed in the corresponding pie charts found in Figure 82, Figure 84 and Figure 86.

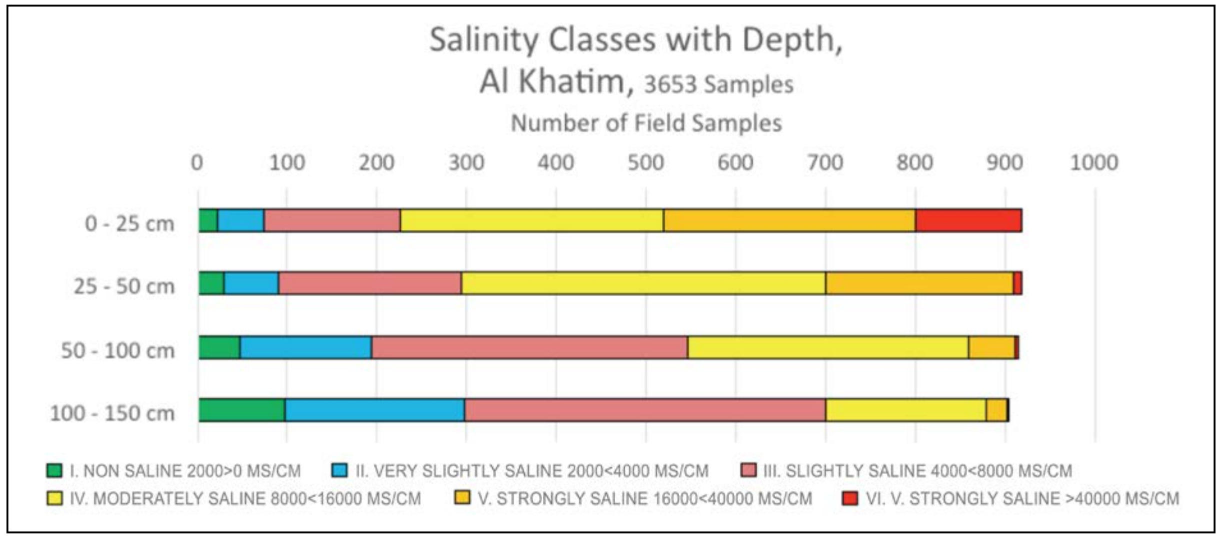


Figure 81: Salinity distribution at 4 standard depths for soils in the Al Khatim area.

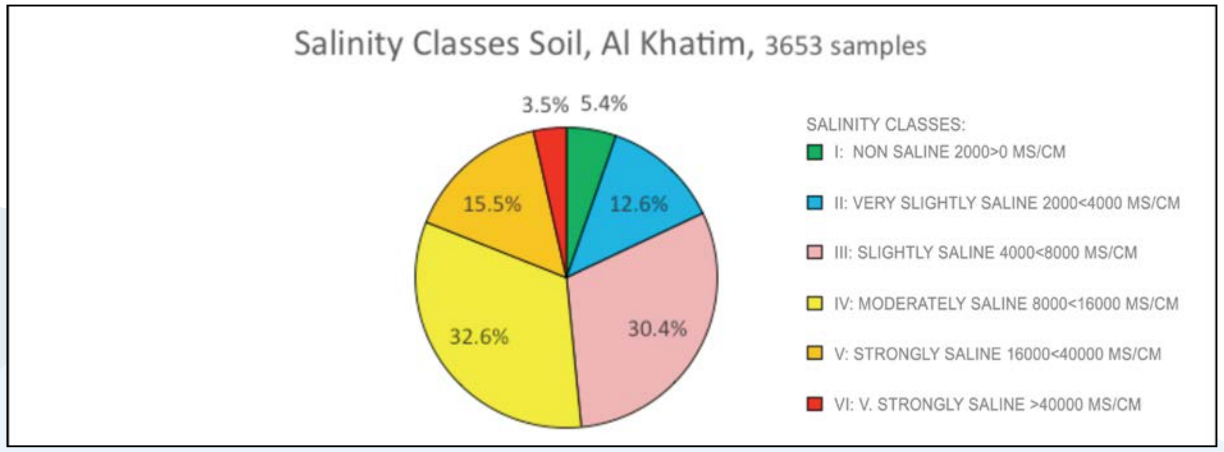


Figure 82: Percentage of salinity classes for the Al Khatim area, field samples from all depths.

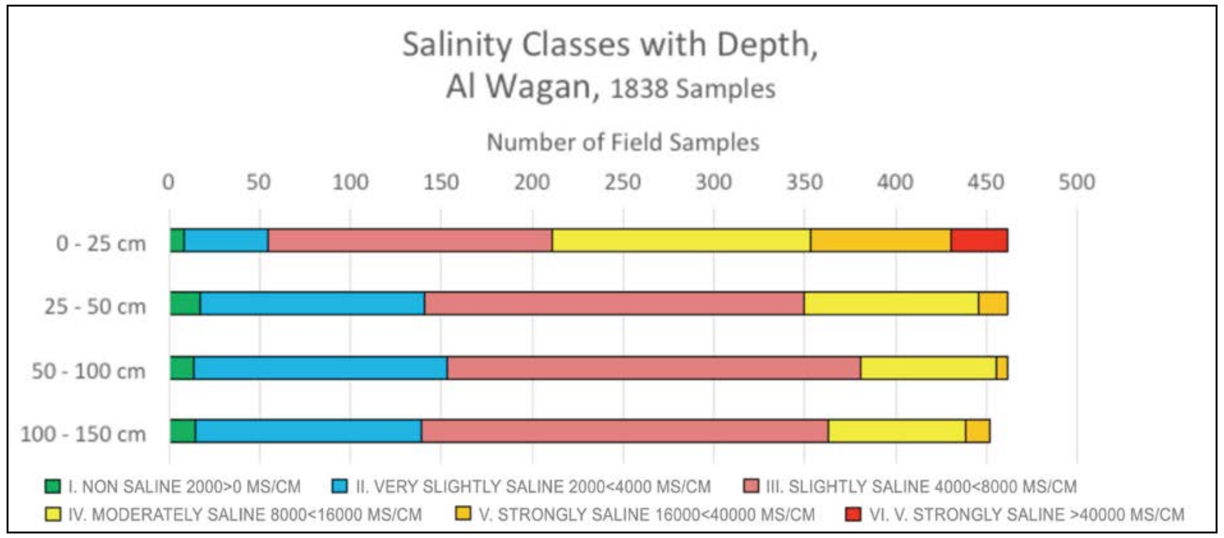


Figure 83: Salinity distribution at 4 standard depths for soils in the Al Wagan area.

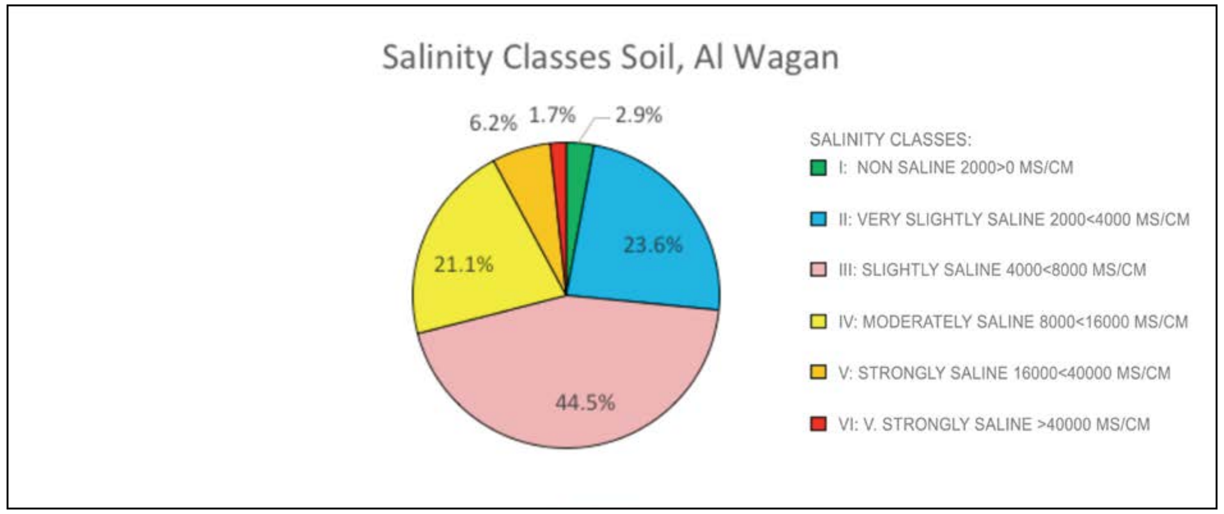


Figure 84: Percentage of salinity classes for the Al Wagan area, field samples from all depths.

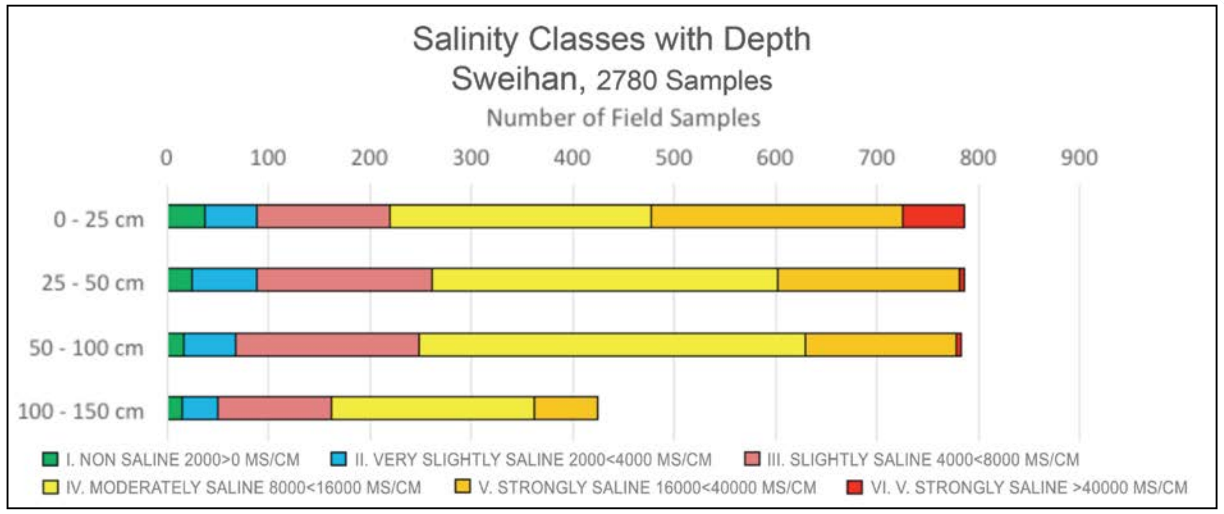


Figure 85: Salinity distribution at 4 standard depths for soils in the Sweihan area. The lower number of field samples in the fourth horizon is the result of frequent hardpans from 100 cm depth downwards.

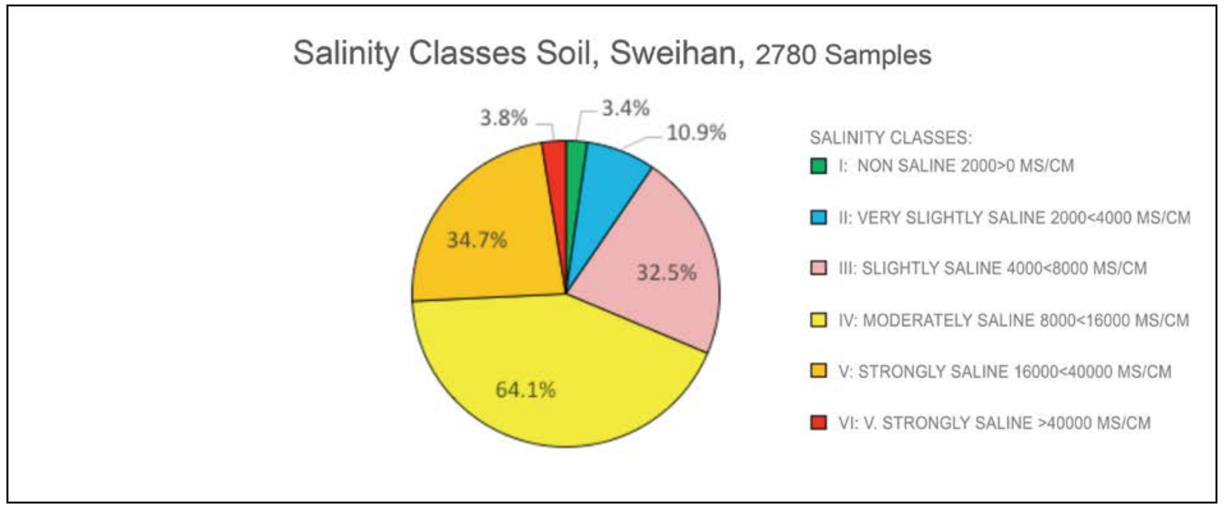


Figure 86: Percentage of salinity classes for the Sweihan area, field samples from all depths.

The preliminary interpretation of the above data indicates that salinity distribution with depth varies with the type of soil profile encountered.

While the Al Wagan Area shows a high proportion of low to middle class salinity due to mainly permeable sandy dune soils, the Sweihan area with frequent drainage impeding mainly gypsum hardpans shows a much higher proportion of Class IV salinity. The Al Khatim area contains middle class salinities due to the presence of well-drained sandy soils mixed with drainage impeding mainly calcareous soils.

6.2 Monitoring

Table 28 shows the achieved progress in the soil salinity monitoring programme in 2016.

Table 28: Progress of the Monitoring Farm/soil salinity survey in total

Period	Total	Not accessible	Percent of completion	Value for completion
Date from - to	08.01.16 to 04.01.17	--	50	30.12.2017
Monitoring Farms Survey round	3	--	50	6
Monitoring Farms Survey visits	300	--	50	600
Monitoring Soil Augerings	900	--	50	1,800
Desalination Units (in monitoring farms)	10	--	--	--
Reservoirs (in monitoring farms)	80		--	--
Field EC/pH in irrigation water	300		50	600
EC 1:1/pH soil field measurement	1184	16%	50	2,400
Irrigation water samples, monitoring, lab analysis	300		50	600
Monitoring Soil samples, lab analysis	1184	16%	50	2,400

6.2.1 Objectives and Selection criteria

a) Objectives:

The aim of farm salinity monitoring is to put the dynamics of farm soil salinity into perspective to the deterioration of irrigation water quality in order to develop a nationwide concept in how to optimize available water and soil resources while providing farmers still with a perspective and a role of supplier of healthy local farm goods.

The monitoring programme establishes a baseline on the behavior of soil, helping to establish key performance indicators for a future management plan to be implemented.

b) Selection criteria:

In general, a monitoring farm should be a unit, which is actively cultivating perennial or annual crops, which is representative of the soil landscape region and whose water source can be readily accessed and measured quantitatively and qualitatively. Furthermore, farms should be:

- Geographically of equal distribution through the agricultural regions
- Representative of soil and groundwater conditions (Appendix 4)
- Representative of cultivation type: Oasis falaj, farm permanent crop, farm annual crop, greenhouse
- Representative of Irrigation type: falaj, drip irrigation, sprinkler, center pivot, flood irrigation
- Representative of Water source: well, canal, pipeline, recycled wastewater
- Representative of farm size: regular size (3 - 4 ha); smaller farms, larger farms

The list of 100 designated monitoring farms was initially selected on 15 February 2016, and then sites were jointly confirmed with contact details of the 100 sites by EAD, ADFSC, and ADFCA on 15 March 2016 (See Figure 87).

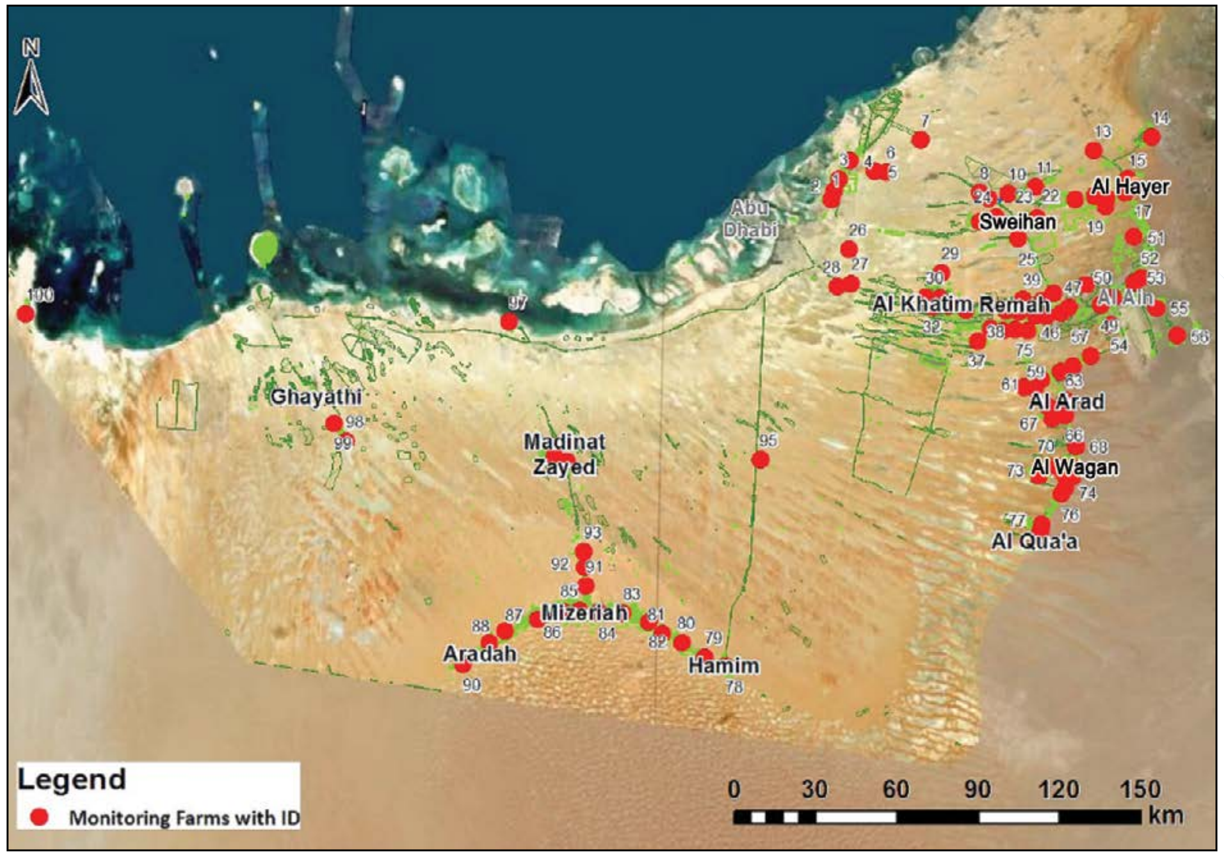


Figure 87: Monitoring farms regularly surveyed.

6.2.2 Monitoring Activities

The two initial soil teams tasked with the monitoring activities visited the selected and designated 100 monitoring farms in the Eastern and Western Region in April 2016.

Monitoring activities during this baseline survey of the 100 farms embraced the survey works of routine farm survey (refer to **Figure 87**), but were complemented by specialized monitoring procedures:

Apart from a first augering at a representative soil site, two more augerings have been done to the same depth (150 cm) within a uniformly managed agricultural plot or plantation. Soil material from the three augerings has been mixed before field measurement of EC and pH in 1:1 water: soil (w/v), and composite sample for laboratory analysis have been taken at the four pre-defined depth intervals. The soil samples are being analyzed in the laboratory as a priority with an extended programme of parameters: Texture with detailed sand (5), silt (2) and clay classes, organic substance (wet incineration), N-total, Carbonates, P-Olsen, available K, Gypsum (if present), saturation %.

For the 100 farms that have undergone the repeat survey in August, the collection of farm data and extensive analysis of the soil profile has been dispensed with. The monitoring team has visited the previously mapped site guided by GPS, identified the location of the previous uniformly cultivated and irrigated plot (or palm tree plantation) and have taken three random samples within that plot. Soil from equivalent depths from the three augering sites have been collected into buckets, mixed and have been subject to field measurement of EC and pH in soil: water suspension 1:1 (w:v). Simultaneously the corresponding irrigation water has been measured for EC and pH on site.

Soil samples have been collected to be analyzed for EC, anions, and cations in saturation extract, EC also in 1:1 soil:water (w:v), and pHs in the saturated soil paste. SAR and ESP are being calculated.

In addition, water samples of the irrigation water have been taken and are analyzed by the standard parameters ECw, pH, anions, cations, with SAR, ESP and RSC calculated. At the time of reporting soil analysis results have been received for all 100 of the baseline Monitoring farm samples and have been evaluated for soil classification.

6.2.3 Monitoring Results

Laboratory analysis from the third monitoring round is still in the process of confirmation. Thus, this preliminary evaluation is based on the field salinity data available through year 2016, but is sufficient to show important effects and conclusions:

Table 29: Number of Farms with changes in soil salinity class in the upper horizon

Apr - Aug	Aug - Dec	
No of samples		Change in salinity class, 0 to 25 cm
39	17	Increase by one class or more
37	38	No change
24	45	Decrease by one class or more

Table 30: Principal classes of salinity

Salinity Classes µS/cm	
I	0 - 2 000
II	2 000 - 4 000
III	4 000 - 8 000
IV	8 000 - 16 000
V	16 000 - 40 000
VI	>40 000

Analyzed soil horizons have shown marked changes in their salinity starting from the first baseline monitoring in April 2016 and the second round of monitoring in August. As seen in **Table 29**, almost 40% of soils have undergone an increase in salinity class, while the same amount displayed no change. On 20% of the soil, a decrease in salinity has occurred. In the interval August to December 45 farms show decreases in soil salinity, while only 17 show an increase.

The definition of the salinity classes is shown in **Table 30.**

The actual average salinity change (calculated ECe) in the four main depth intervals between the three monitoring rounds is shown in **Figure 88** below. Most salinity increases occur in the top layer, while the lower layer salinity remains fairly constant.

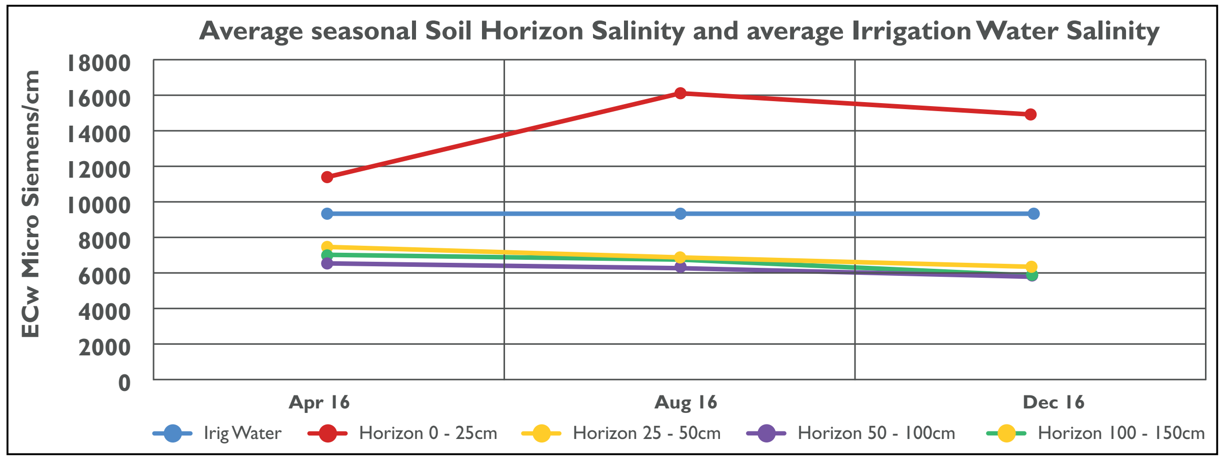


Figure 88: Average ECe in four soil depth intervals in April, August and December 2016.

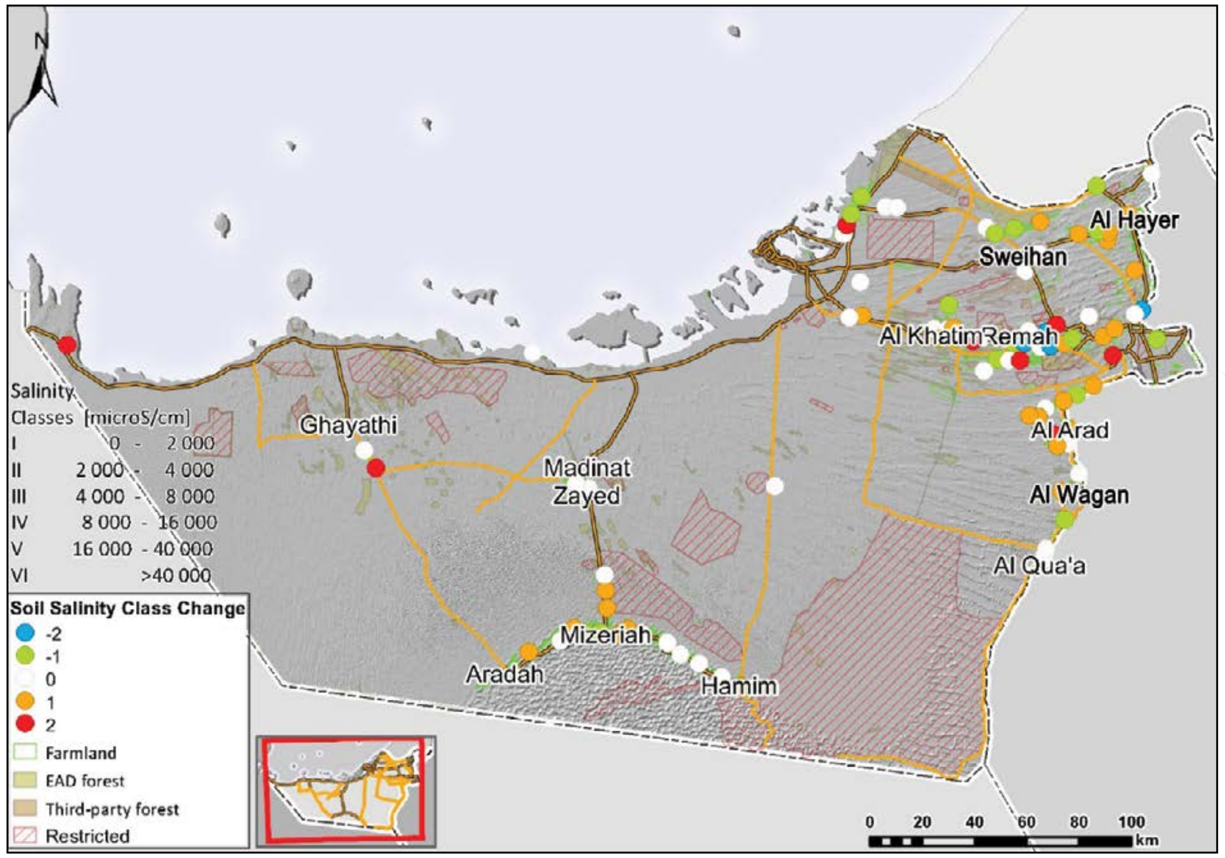
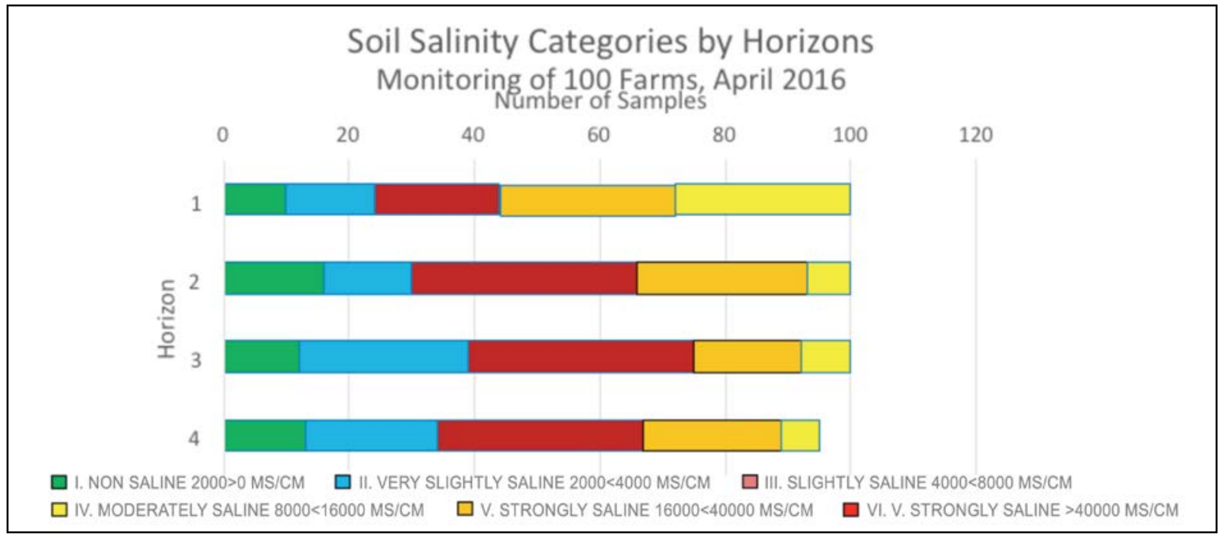
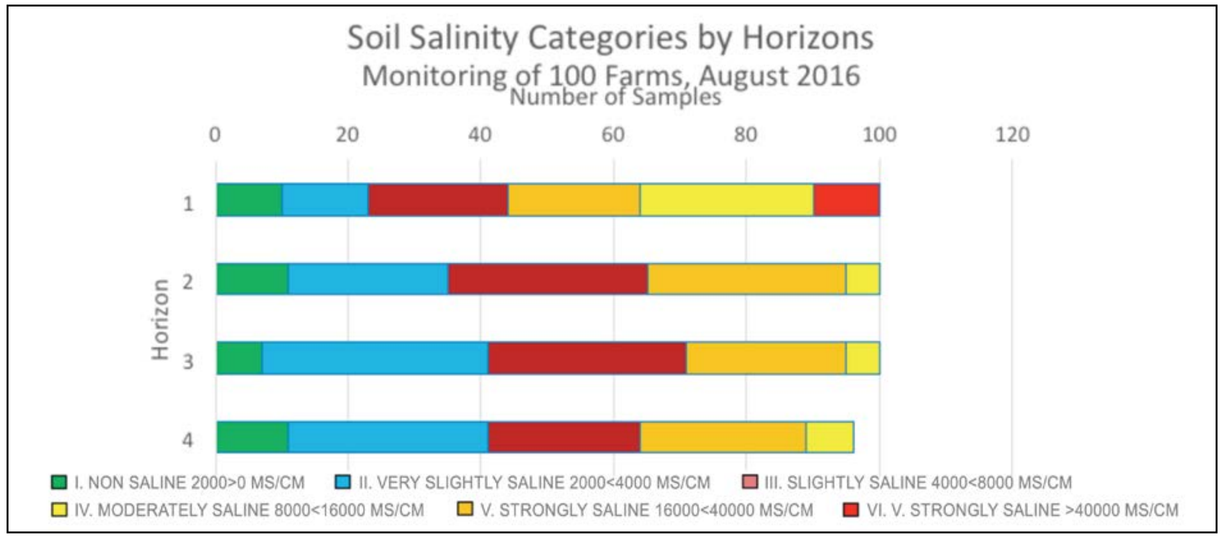


Figure 89: Soil Salinity Class Change between April and August 2016, 100 monitoring farms.

The shift in soil salinity from the three monitoring records for the four standard horizons of the monitoring farms is shown in **Figure 89.**





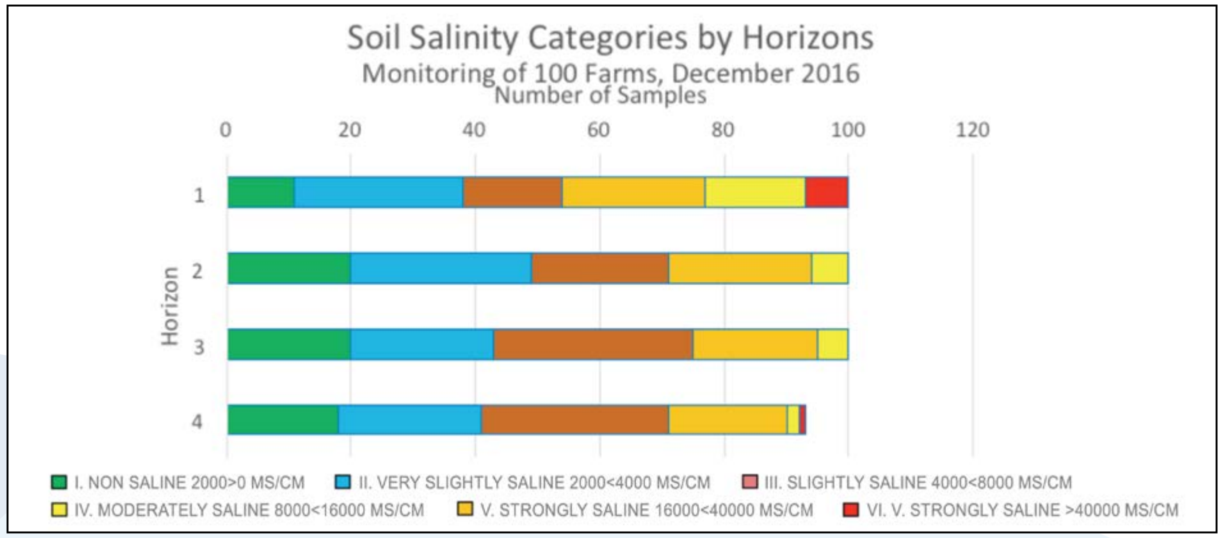


Figure 90: Shift of Soil Salinity in the 4 standard soil horizons between the month of April, August and December 2016.

Main observations are:

Period April to August:

- Class IV salinity decreases and is replaced by Class VI in the top horizon
- In the second and third horizon Class I is replaced by Class II, while Class III becomes Class IV

Period August to December:

- Class V and class VI salinity reverts to class IV salinity in the top horizon
- In both third and fourth horizon Class II salinity reverts to Class I salinity

The reasons for the seasonal soil salinity dynamics affecting mainly the top soil horizon, as demonstrated for the month of April, August and December, are various:

Precipitation:

In April, salt free rainwater (if rain has occurred) or heavy dew from previous winter season has leached salt down, reducing surface salinity. The process is supported in Abu Dhabi by the sandy permeable soils. The action of rain, though rare, is important, as can be seen in abandoned farms, which have reverted to original low salinity content after a number of years.

Leaching fraction:

The proportion of irrigation water which is able to infiltrate into the soil and to wash out salts out of the root zone is dependent on evaporation and plant activity: In December and April, more irrigation water is able to infiltrate into the soil and to contribute to leaching, because of less evaporation and plant use.

Ascending capillary action of dissolved salts:

Surface soils dry out more easily in hot summer. Stored soil humidity tries to replace the water from lower levels by rising capillary action, which transports dissolved salts to the surface.

Irrigation management:

Higher irrigation is necessary in August and introduces more salt into the soil. Salt accumulation occurs at the surface because of evaporation-induced upward capillary action bringing up salty water and prevented leaching. Conversely, less irrigation is required in December and April (depositing less salt), and water penetrates more easily into the soil and may leach salt downward out of the root zone.

Over-irrigation and impermeable layers:

A perched groundwater table can form either through an impermeable subsoil layer, by over-irrigation in less permeable soils or occasionally by leaking underground irrigation pipes. In these situations, salty water will rise by capillary action to the surface and deposit salt. In addition, leaching of salts out of the root zone is not possible. Seasonal effects will render the situation more serious.

Management recommendations need to deal with the above principal factors:

- Use of the cooler and wetter season to leach out salts accumulated in summer by dedicated leaching irrigation.
- Use the best quality irrigation water available. The soil cannot be lower in salinity than the applied irrigation water.
- Break the crust of the soil surface and apply a mulch covering to prevent capillary action, evaporation and salt deposit at the surface.
- Avoid irrigation beyond crop water requirements in summer to avoid salt deposition, perched water tables and capillary rise of salts.
- For annual crops, apply crop rotation within the farm: leave a proportion of the surface fallow for some years to give the soil a chance to revert to lower salinity.

6.4 Soil Classification

Soil classification has been performed based on the evaluation of the Trimble field data (EC and pH measurements in water:soil suspension 1:1 w:v) and the recorded field sheets. On the field sheets, the soil texture, gravel content, soil matrix and mottling color, profile humidity, reaction to HCl 10% and observation suffixes were recorded. On this basis, the horizontation and depths, as well as master horizons, were determined. Most importantly, the observation suffixes were utilized to modify master horizons and to determine the diagnostic horizons and their characteristics. In the absence of accurate laboratory data for ECe and pHs, the field measurements of EC and pH soil water suspension 1:1 (w:v) were used to determine salinity suborder and subgroups. To adequate them to Soil Taxonomy requirements (based on ECe), the field results for EC 1:1 (w:v) were multiplied by the preliminary factor 3. The recently established factor 3.17, pending further confirmation, will be utilized to convert field EC water: soil suspension 1:1 (w:v) to ECe measurement.

The United Arab Emirates Keys to Soil Taxonomy 2014 was used throughout, following the detailed elimination key down to the soil phase level.

6.4.1 Classification for the regular farm survey results

A portion of the Al Ajban area to the Northwest of Sweihan, covering about 157 farms, equivalent to about 600 ha (**Figure 91** and legend in **Table 31**) was selected to illustrate soil classification results.

The superimposition of the soil classification map (Soil Map of the Abu Dhabi Emirate) shows the influence of the underlying materials: the clearly discernible dune ranges crossing the area are characterized by Torripsamments, In contrast, the Haplogypsids and calcids are typical of the surrounding plains formed under past climatic conditions, such as in Al Qa'a, Suweihan, Al Rahba and Ajban.

The salinity characteristics the more salt-free areas are concentrated with the dune sand Torripsamments, due to their higher permeability.

Large earth movements involving levelling and terracing to establish farming areas have changed many soil substrates and destroyed original soil profiles. In addition, soil amendments of sweet soil and dune sands have altered the surface layers. Therefore, soils in farm areas are not immediately comparable the surrounding unaltered soils displayed in the UAE Soil map.

In addition, the mapping and classification of the farms' soils indicated that irrigation may change the original surrounding soil type from the Typic Subgroup, into the Salidic Suborder or the Salidic Subgroup.

Soil classification can also change for the same soil site, depending on the seasonal variation of soil salinity within the year.

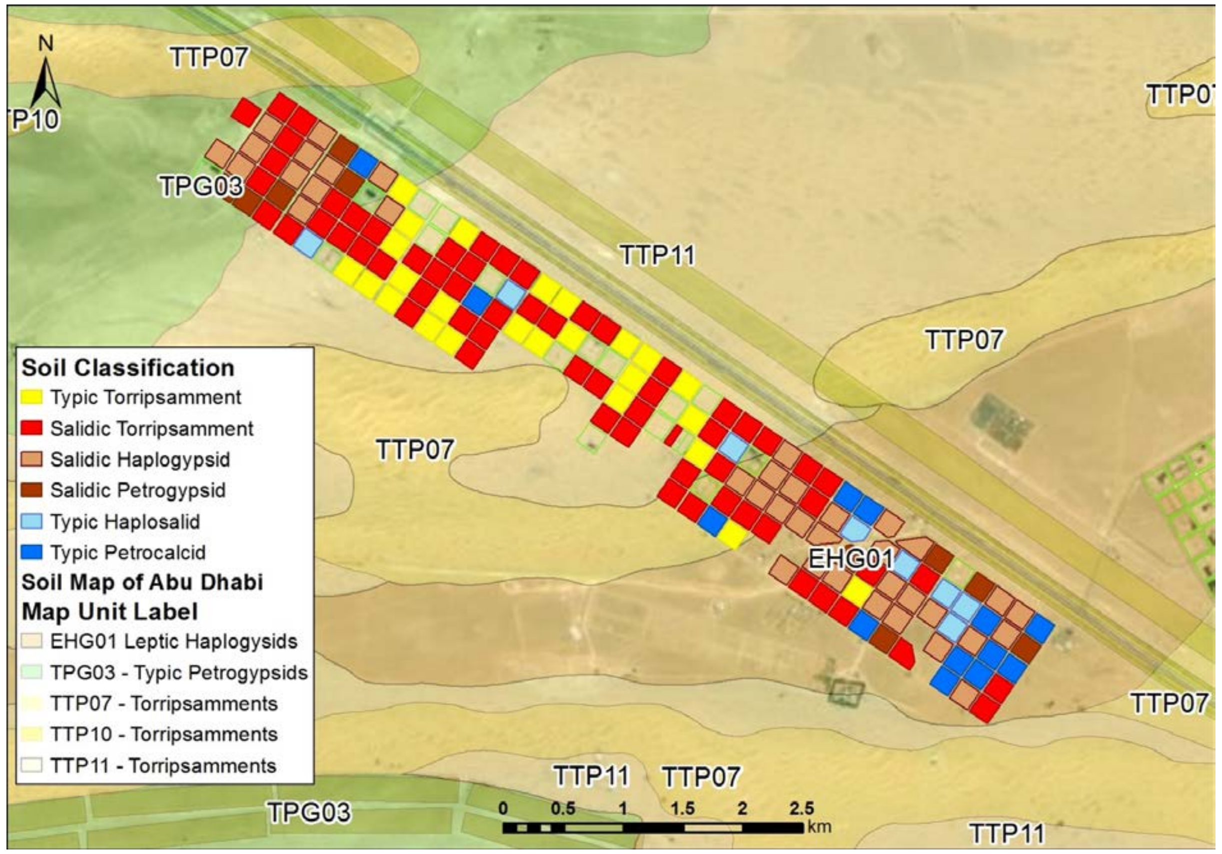


Figure 91: Soil Classification for 157 farms in Al Ajban, northwest area of Sweihan.

The following main families were distinguished **(see Table 31)**.

Table 31: Soil taxonomic classification of the Al Ajban Northwest area

Unit Number	Soil Name	Percent of Surface
1	Typic Torripsamment	22%
2	Salidic Torripsamment	48%
3	Salidic Haplogypsid	19%
4	Salidic Petrogypsid	6%
5	Typic Haplosalid	3%
6	Typic Petrocalcid	2%

6.4.2 Classification of the monitoring farms

The laboratory field data from 395 soil samples across 100 monitoring farms has been used to classify Monitoring Farm soil profiles.

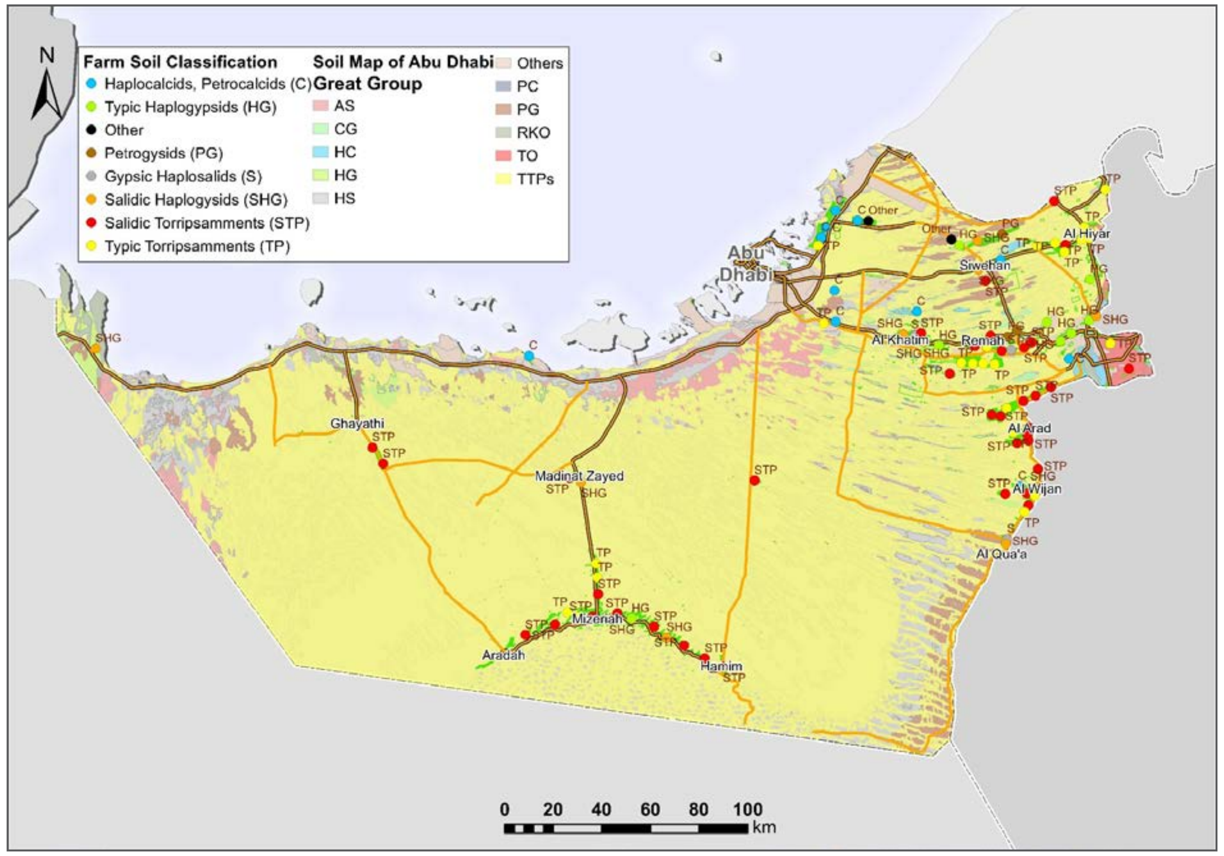


Figure 92: Monitoring Soil Classification superimposed upon the Soil map of the Abu Dhabi Emirate.

Table 32: Comparison between the legend of the Soil Map of Abu Dhabi Emirate, and soil types of the Monitoring Survey

Soil Type AD Soil Survey		Soil Types of Monitoring Survey		
TTPs	Torri ps amments	●	STP	Salidic Torripsamments
		●	TP	Typic Torripsamments
HG	Haplogypsids	●	HG	Haplogypsids
		●	SHG	Salidic Haplogypsids
CG	Calcigypsids			
HC	Haplocalcids	●	C	Haplocalcids, Petrocalcids
PC	Petrocalcids			
PG	Petrogypsids	●	PG	Petrogypsids
HS	Haplosalids	●	S	Gypsic Haplosalids
AS	Aquisalids			
TO	Torriorthents	●	Others	
RKO	Rock outcrops			

For a detailed comparison, the location and classification of the 100 monitoring soil sites have been superimposed on the "Soil Map of the Abu Dhabi Emirate" (**Figure 92** and legend **Table 32).**

The superimposition of the soil classification map (Soil Map of the Abu Dhabi Emirate) shows the influence of the underlying materials: the clearly discernible dune ranges crossing the country are characterized by Torripsamments, such as in the Liwa crescent in the Northern parts of the Al Wagan Al Araad area. In contrast, the Haplogypsids and-calcids are typical of the characteristics of the surrounding plains, such as in Al Qoa'a, Sweihan, Al Rahba and Ajban.

6.5 Irrigation Water Quality (EC, SAR, RSC) Classification

Since the start of the project, a total of 425 irrigation water samples have been delivered to the laboratory, of which by the end of the year 366 results have been received.

Out of the above total number of water samples, 300 were taken from the monitoring farms, of which 200, all from the two previous monitoring campaigns, have been analyzed to date.

Out of the total number of samples, 191 have been compiled for the regular farms' survey.

Results for 231 analyses have been processed (131 from the regular survey and 100 from the baseline monitoring farm survey).

Typical irrigation water quality is shown for the 231 irrigation water samples from farms collected in the Survey area during the Reporting Period:

Table 33: Irrigation water key laboratory parameters for 231 farms in Abu Dhabi

	µS/cm ECw	pH	(mmoles/l)$^{0.5}$ SAR	RSC
Average	12 113	7,62	18,08	-47,99
Maximum	32 776	9,01	37,94	0,06
Minimum	89	6,68	0,33	-427,80
Median	11 236	7,60	17,10	-44,90

The irrigation water quality shows little variation within the three regions Al Khatim, Sweihan and Al Wagan and is comparable in quality, thus they are not further differentiated according to region in the **Table 33** above.

The low minimum values are explained by the occasional use of desalinated water on the farms for irrigation or the mixing of the highly saline well water with municipal drinking water.

Table 34: Guidelines for Interpretation of Irrigation Water Quality, FAO and USDA

Guidelines for Interpretation of Water Quality for Irrigation (FAO, 1985)				
		Degree of Restriction on Use		
Potential Irrigation Problem	Units	None	Slight to Moderate	Severe
Salinity (affects crop water availability)				
Ecw	MicroS/cm	< 700	700 - 3000	> 3000
TDS	mg/l	450	450 - 2000	>2000
SAR (effect on infiltration rate)				
SAR in combination with ECw	Ecw			
0 -3	MicroS/cm	> 700	700 - 200	< 200
3 - 6		> 1200	1200 - 300	< 300
6 - 12		> 1200	1900 - 500	< 500
12 - 20		> 2900	2900 - 1300	< 1300
20 - 40		> 5000	5000 - 2900	< 2900
SAR (Na Toxicity, sensitive crops)				
Surface Irrigation	SAR	< 3	3 - 9	> 9
Sprinkler irrigation (Na)	meq/l	< 3	> 3	
pH		Normal Range 6.5 to 8.4		
RSC (USDA)	meq/l	< 1,25	1,25 - 2.50	> 2.50

The irrigation classification of the average values, according to the above indicators (**Table 34**), is shown below (**Table 35**):

Table 35: Irrigation classification for soil and water combination

	SAR	SAR	
Classification	Infiltration hazard	Ion toxicity	RSC
C4/S4	None	Severe	Harmless

The average irrigation water sampled in the all the investigated areas show high salinity (very much greater than ECw 3000 MicroS/cm, equivalent to the Richards Diagram C4 very high class (see **Figure 95**). This poses severe restrictions to irrigation and crop yield, and only the most salinity resistant crops (date palm trees, Rhodes grass, barley, berseem are likely to yield an economic crop. Yield reductions of about 50% are to be expected even for these crops.

The pH is high and the Sodium Adsorption Ratio (SAR) and related Exchangeable Sodium Percentage (ESP) are high (Richards Diagram S3 to S4), both indicating sodium ion toxicity for susceptible plants like fruit trees and vegetables. However, the infiltration hazard posed by the high SAR is counterbalanced by the high salinity content, due to the primarily sandy soils and corresponding high infiltration rates. This contributes to the absence of Sodium hazard, which is confirmed by the RSC (the difference between the sum of Bicarbonates and Carbonates and the sum of Calcium and Magnesium). An RSC of less than 1.25 (including negative values) is considered harmless, while RSC greater 2.5 is harmful. In this case, the sum of Calcium and Magnesium considerably outweigh the sum of Carbonates and Bicarbonates, rendering the RSC negative, and in effect harmless.

The relation between ECw and contents of Cations in meq/l for 231 samples indicates that the contents of cations rise linear with increasing ECw values encountered in the survey area (see **Figure 93**).

This is also reflected by the relation ECw and SAR, in which the SAR value rises steadily with ECw (see **Figure 94**), indicating that Na+ is a dominant component of the dissolved cations.

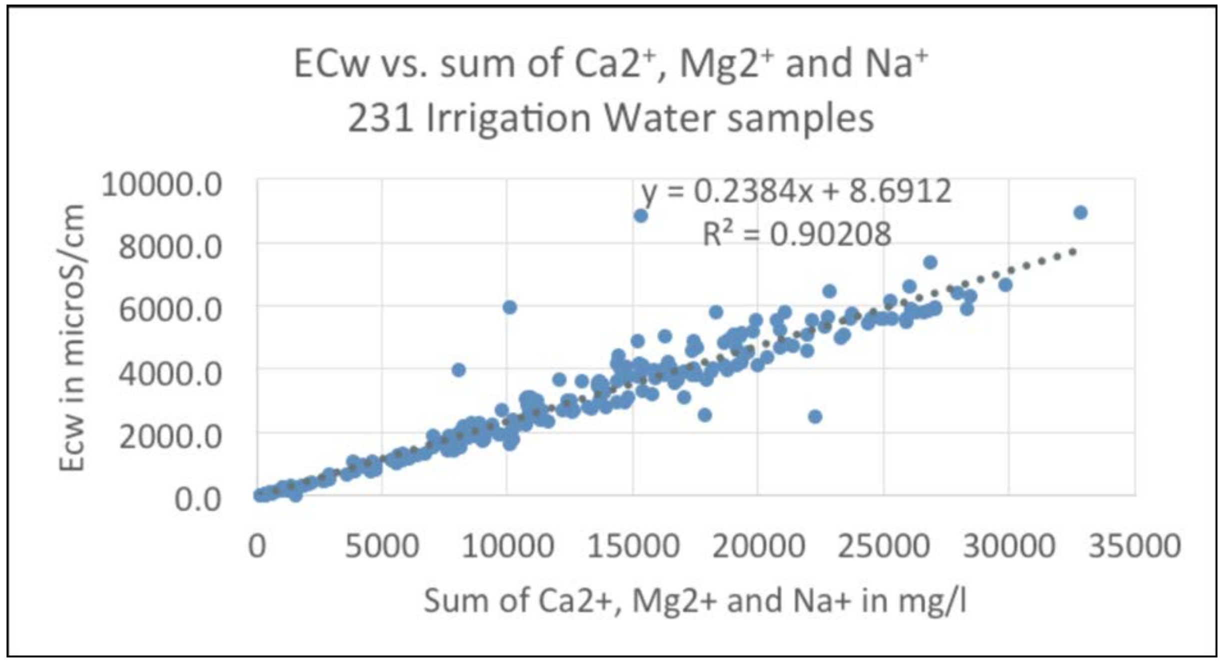


Figure 93: Analysis of 231 irrigation water samples in the survey area: the relation between ECw and Cations.

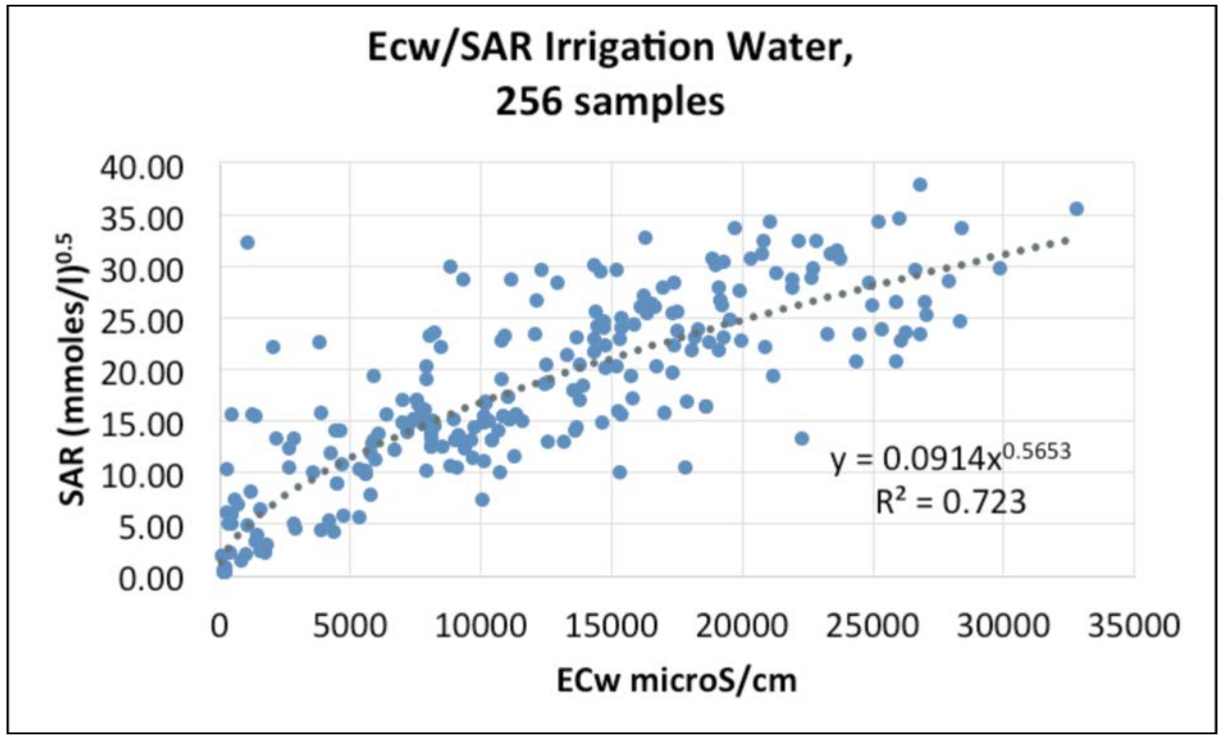


Figure 94: Analysis of 256 irrigation water samples in the survey area: the relation between ECw and Sodium Adsorption Ratio shows the dominance of sodium with increasing salinity.

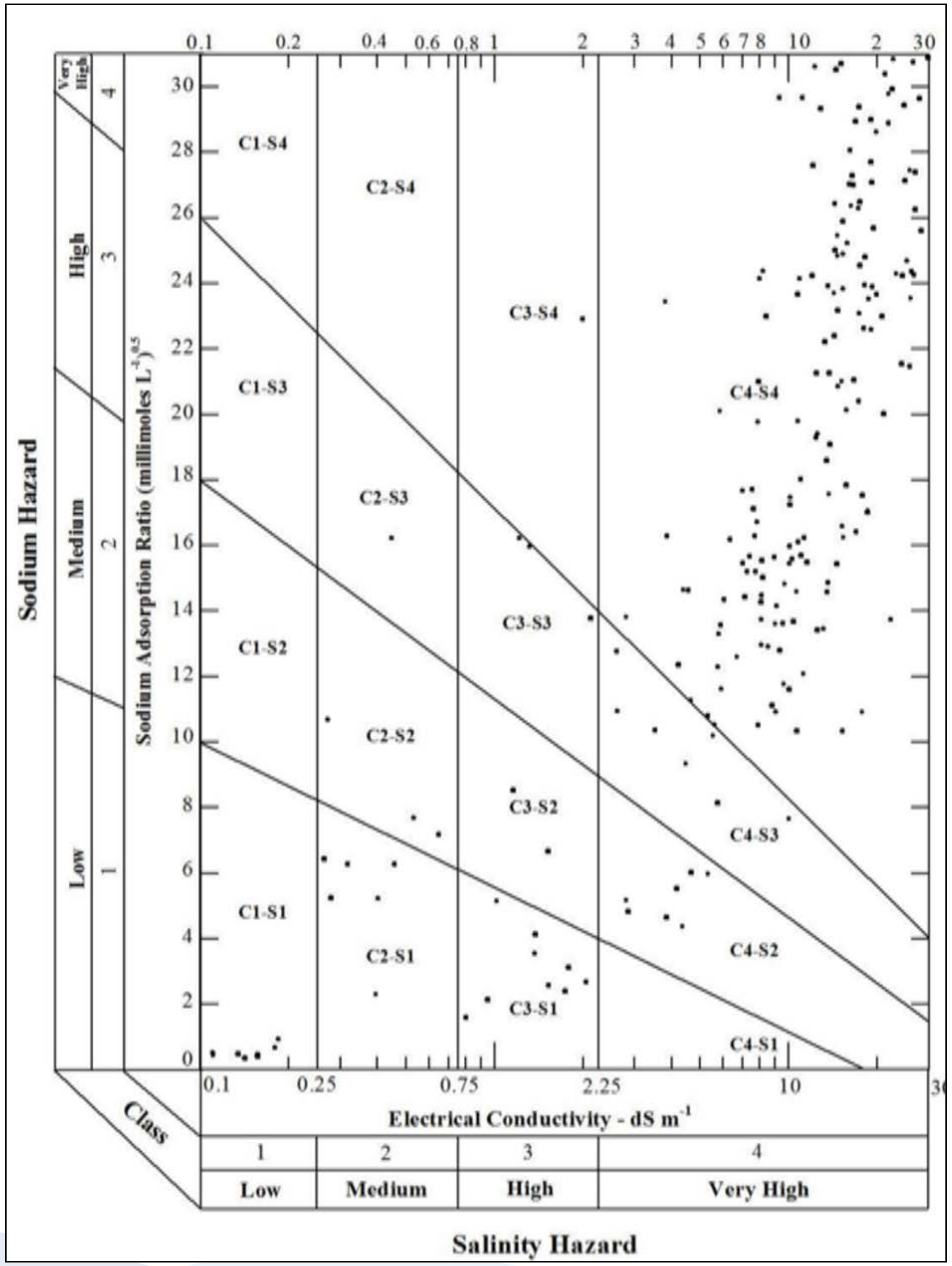


Figure 95: Extended Richards Diagram, Salinity vs. SAR, 256 Irrigation Water Samples.

6.6 Quality control

As indicated in the SGS Quality Control proposal, the results received by the SGS laboratory Jebel Ali are subject to SGS in-house quality control, including:

- Blank results, compared to the limit of reporting,
- Spike recovery in %, percentage of analyte recovered from the sample, compared to the amount of analyte spiked into the sample.
- Duplicate analysis, relative percent difference measured against the original sample according to the formula: absolute difference of the two results divided by the average of the two results as a percentage.

Wherever possible, crosschecks have been performed on the results, including ion balance and EC versus total ions.

For the monitoring farm survey, where a full set of Cation and Anion analyses of the soil saturation extract was available, the following values were obtained for the ion balance and the relation TDS to EC (**Table 36** and **Figure 96**). Based on 395 soil samples, the difference between the sum of Anion and Cations in meq/l on average is 6.8% with a standard deviation of 7.7%.

The average value for the relation ECe to TDS is 0.638 and linear. The resulting R2 value is calculated at 0.98.

Table 36: Comparison of the Sum of Anions and Cations for 395 monitoring soil samples

		meq/l	meq/l	meq/l	%
	Ratio ECe (µS/cm)/ TDS (mg/l)	Sum Cations	Sum Anions	Abs. Diff	Difference
Average	0.638	83.71	79.07	4.6	6.8
Max	0.943	404.31	445.71	41.14	50.28
Min	0.389	5.50	4.67	-41.40	-11.05
St Dev	0.069	66.04	64.48	7.39	7.71
Median	0.653	65.83	61.54	3.72	7.77

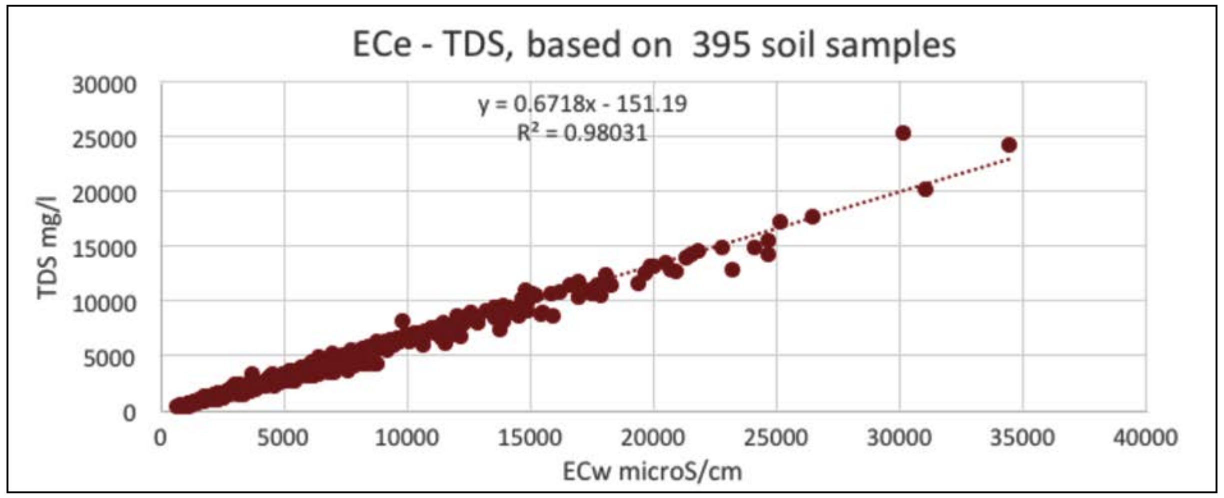


Figure 96: Relation between ECe and TDS for 395 monitoring soil samples.

7 Outlook

7.1 Well Inventory

In the Northern Area and Northeastern Area, the majority of farm and forest wells have been already recorded. Therefore, in the next Reporting Period (December 2016 to 15th December 2017), the survey will increasingly focus on the western region and remote dune areas. In the Al Ain area, the survey will further progress from West to East and from South to North in the Al Wagan area.

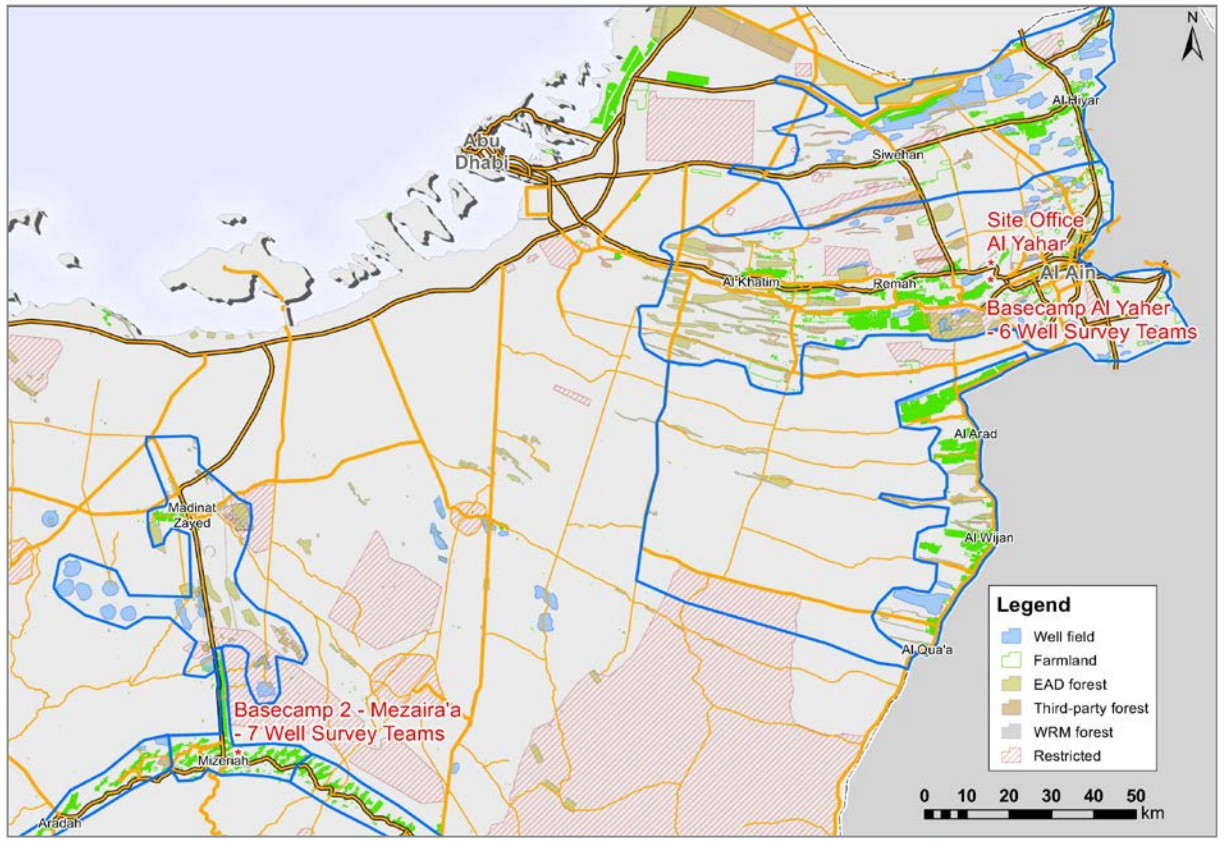


Figure 97: Planned team allocation of the well inventory during the fifth Reporting Period. The teams operating in the SE' Area shall be mobilized to the WR.

The Northern Area, Sweihan to Al Shweib, was completed in August for only for minor works still conducted into October by a single well inventory team. The teams located in the South-Eastern Area (see **Figure 97**) centered in Al Wagan will be relocated in early January 2017 to the Liwa Crescent and conduct the survey there.

The remaining teams will continue the survey in the Eastern Areas to cover suburban and central part of Al Ain.

The teams working in remote areas will receive upgraded cars for improved driving on sand, shall take advantage of the cooler season, and improved driving conditions prevailing for the coming Reporting Period.

7.2 Subsequent Farm and Soil Salinity Inventory

The regular farm survey will be resumed in the beginning of January 2017 and continued until April 2017.

The actual and planned survey progress and localities for both types of survey are shown in **Table 37** below:

Table 37: Survey progress plan for the 100 monitoring farms and 3,900 regular survey farms

Year	Month	Survey type	Monitoring Farms	Regular Farms	Location
	Previous		100	1682	
2016	July				
	August	2nd Monitoring	100		
	September	Regular farm survey		184	Al Wagan
	October	Regular farm survey		190	Al Wagan
	November	Regular farm survey		188	Al Wagan
	December	3rd Monitoring	100		
2017	January	Regular farm survey		184	Al Kaznah
	February	Regular farm survey		184	Al Kaznah
	March	Regular farm survey		184	Al Kaznah
	April	4th Monitoring	100		
	May	Regular farm survey		184	Western region
	June	Regular farm survey		184	Western region
	July	Regular farm survey		184	Western region
	August	5th Monitoring	100		
	September	Regular farm survey		184	Sweihan, Nahel
	October	Regular farm survey		184	Sweihan, Nahel
	November	Regular farm survey		184	Sweihan, Nahel
	December	6th Monitoring	100		
2018	January				
	Sum		600	3900	

7.2.1 Foreseen Progress

The monitoring survey is intended to be implemented every four months until the end of December 2017. The regular survey will be implemented in the three months between the monitoring campaigns. The next monitoring campaign will start in April 2017. The duration with one team engaged in monitoring activities will be one month to complete one monitoring cycle of 100 farms. The monitoring team (one team for one month) is planned to cover four monitoring farms per day, despite time-consuming triple augerings and the large travelling distances between farms. The regular farm survey is planned with the same team surveying nine farms per day due to less augering effort and smaller travel distances.

7.2.2 Expected Results

For the regular survey, as previously detailed, a record will be kept of farm and soil survey results on the Trimble recording device and soil profile and soil profile data on separate recording sheets, later also to be digitized.

During the monitoring campaigns, a weekly record will be presented regularly on the number of farms revisited, the number of augerings done, changes in cropping and water supply noted, soil and water samples were taken and sent to the laboratory as well as EC and pH measurements performed in the field

7.2.3 Soil Laboratory Results and Water Analyses Results

Soil samples for the monitoring survey will be collected for every monitoring farm and delivered to the SGS laboratory. Per monitoring cycle four samples are being collected for every farm (one per standard depth); in total 394 (missing samples due to inaccessible fourth horizon). The scope of the lab analysis has been reduced, following the detailed investigation during the baseline survey, which has been used to produce the soil classification. Due to the repetitive nature of the subsequent surveys, the measurements have been reduced to ECe, pHs, and the analysis needed for the determination of SAR and RSC.

A large backlog of regular farm soil survey material has so far prevented the second round of monitoring survey material to be analyzed completely. The investigation of these monitoring soil samples will be a priority in the upcoming Reporting Period. The analysis of monitoring water samples (100 per monitoring cycle) is up to schedule.

Every 9th to 10th farm soil sample will be collected along with the corresponding water samples during the coming Reporting Period. About 650 farms will be mapped, in which approximately 70 farms will be sampled with a total of (4x70) 280 soil samples. In parallel, about 70 irrigation water samples will be collected for analysis.

All current samples from the farm survey have been taken over by SGS laboratory and analysis is on-going. EAD has enforced certain quality measures including inter-lab comparison program with both local and international laboratories and emphasized to use the testing methods of the TOR.

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