NEPAD SANWATCE SCIENTIFIC PROPOSAL
WAter and COoperation within the ZAmbezi River Basin (WACOZA)
Hydrogeology and Groundwater Quality Team

Inception Report

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Project Data

Project location	Zambezi River Catchment
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General

The Groundwater hydrology and quality group is one of the five themes of the Water-Energy-Food-Ecosystem (WEFE) nexus among the following:

A. Climate variability and extreme events

B. Hydrology, hydropower and dams optimization

C. Agriculture and water

D. Groundwater hydrology and quality

E. Water governance, cooperation and information systems

Terms of Reference assigned to University of Western Cape

The ACE II project identified the following tasks to be completed at the end of the project on the Zambezi River Basin scale:

GW.1.1 Report on river basin scale groundwater hydrology characterization of ZRB, based on

- Literature review and identify available data sources
- Existing data compilation,
- Generation of a reference database.

GW.1.2 Database of maps relevant to ZRB

- Groundwater reserve characterization
- Groundwater quality characterization

GW.1.3 Capacity Building material (Theory, Practice, Results presentation) Governance

1. Executive summary

1.1. General progress

Catchment-wide groundwater resource occurrence and groundwater quality evaluation is one of the priority areas highlighted within the Zambezi River Catchment African Centres of Excellence (ACE) Water 2 Project. To this end, the University of Western Cape is assigned to coordinate collating, integrating, interpreting and extracting as well as displaying groundwater resource occurrence and groundwater quality information within the Zambezi River Catchment.

During the last few weeks, considerable time was dedicated in an effort to contact individuals and identifying the responsible institutions who possesses hydrogeological data and information. The following institutions are identified as possible data sources:

- Southern Africa Development Community (SADC) - Groundwater Institute (GWI)
- USGS HydroSheds
    - http://www.hydrosheds.org/page/hydrobasins
    - http://www.hydrosheds.org/page/hydrolakes
- Freshwater Data Biodiversity Portal
    - http://data.freshwaterbiodiversity.eu/shapefiles
- WaterBase
    - http://www.waterbase.org/download_data.html
- Zambezi Water Resources Information System
    - http://zamwis.zambezicommission.org/ The Zambezi Watercourse Commission: Zamcom
- The Zambezi River Authority (Managed by the Governments of Zimbabwe and Zambia)
- The Council for Geoscience (South Africa)
- Groundwater Division of the South African Geological Societyhttp://sadc-gmi.org/regional-hydrogeological-database/
- SADC Groundwater Projects
- Groundwater and Drought Management Project
- Hydrogeological Mapping Project
- International Association of Hydrogeologists (IAH)
- National Groundwater Association (NGWA)
- University of the Free State (RSA) – Institute for Groundwater Studies
- University of Pretoria (RSA) – Department of Geology
- University of Zimbabwe
- University of Zambia
- Water Ministries in the SADC Region
    - Angola
    - Malawi
    - Mozambique
    - Namibia

Few semi-processed spatial data on geology, topography and river network were secured from NUST covering the Zimbabwean portion of the catchment. Unfortunately, not even a single raw data of borehole information and water quality was obtained from all the individuals and institutions contacted so far. It appears that institutions are reluctant to share data for a number of reasons and a way had to be found to address the issues hopefully through the secretariat. All email communications were forwarded to the secretariat to follow-up with the institutions. Moreover, digital elevation model and average slope spatial data was secured from the USGS Hydroshed platform.

Various old reports were secured from archives compiled by the Groundwater Division of the Geological Society of South Africa on a country level. Most reports are outdated from colonial times and may not represent the current condition but nevertheless provide background information especially on all countries of the catchment.

1.2. Introduction

The Zambezi River Catchment is the fourth-largest river basin in Africa, covering an area of 1,359,000 Km^2 draining roughly 5% of the surface area of the continent in southern Africa. The river begins its 2650 km journey in the mountainous region close to the borders of the Democratic Republic of Congo and Angola in the north-eastern province of Zambia. The Zambezi River flows south for roughly 650 km before it turns east until it reaches the Indian Ocean with mean annual discharge of roughly 94 billion m^3.

The Zambezi River sub basin around the source is named Upper Zambezi flowing southwest into Angola where Luena and Chifumaga rivers merges before it enters dense dry forest. In western Zambian grasslands where Chavuma and Victoria Falls are located, the area is called Middle Zambezi. Important tributaries in Middle Zambezi are Kabompo and Lungwebungu rivers where Barotse floodplain begins as the landform starts becoming relatively less undulating (Fig. 1). The Luangwa and the Kafue are the two largest tributaries of the Zambezi. The Kafue joins the main river in a quiet deep stream about 180 m wide. At the confluence of another tributary the Luangwa River is where the Zambezi enters Mozambique territory where it becomes the lower Zambezi, and flow 650 km from Cahora Bassa to the Indian Ocean. The Zambezi receives the drainage of Lake Malawi through the Shire River. Elevation ranges from sea level near the Zambezi River mouth to over 1500 m above mean sea level (amsl) in the basin boundaries (Fig. 1).

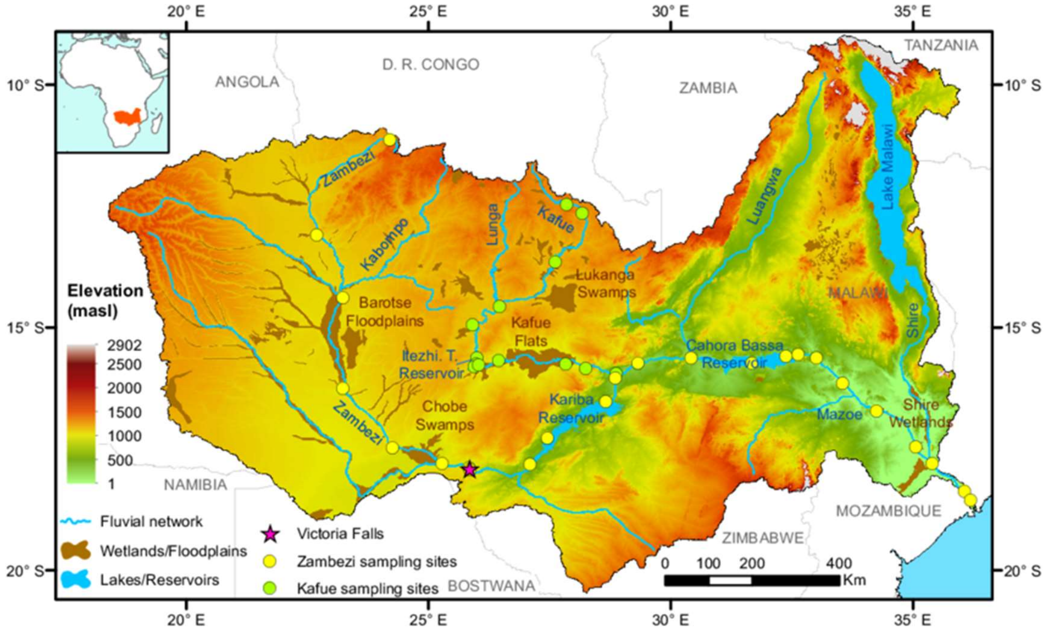

Figure 1 Zambezi catchment map with major tributaries, wetlands and surface waters (lakes and reservoirs) as well as average elevation.

2. Geology

The region drained by the Zambezi River, is a vast plateau of up to 1500 m high, mainly composed of Tertiary to Quaternary Kalahari sediments, Archaean basement complex with subordinate coverage of Precambrian carbonates, Palaeozoic Karoo sediments and volcanic rocks, as well as Quaternary alluvium along the flood plains of major rivers (Fig. 2). On the lower Zambezi, thin strata of grey and yellow sandstones, with an occasional band of limestone, crop out on the bed of the river in the dry season, and these persist beyond Batoka Gorge where they are associated with extensive seams of coal. The western portion of the river basin shows a surface geology that is dominated by the Tertiary – Quaternary Kalahari sediments with few patches of Quaternary alluvium around river flood plains and wetlands (Fig. 2). Archaean basement complex units dominate the eastern and central portion of the basin with other units mainly of Precambrian carbonates and other units comprising the surface geology (Fig. 2).

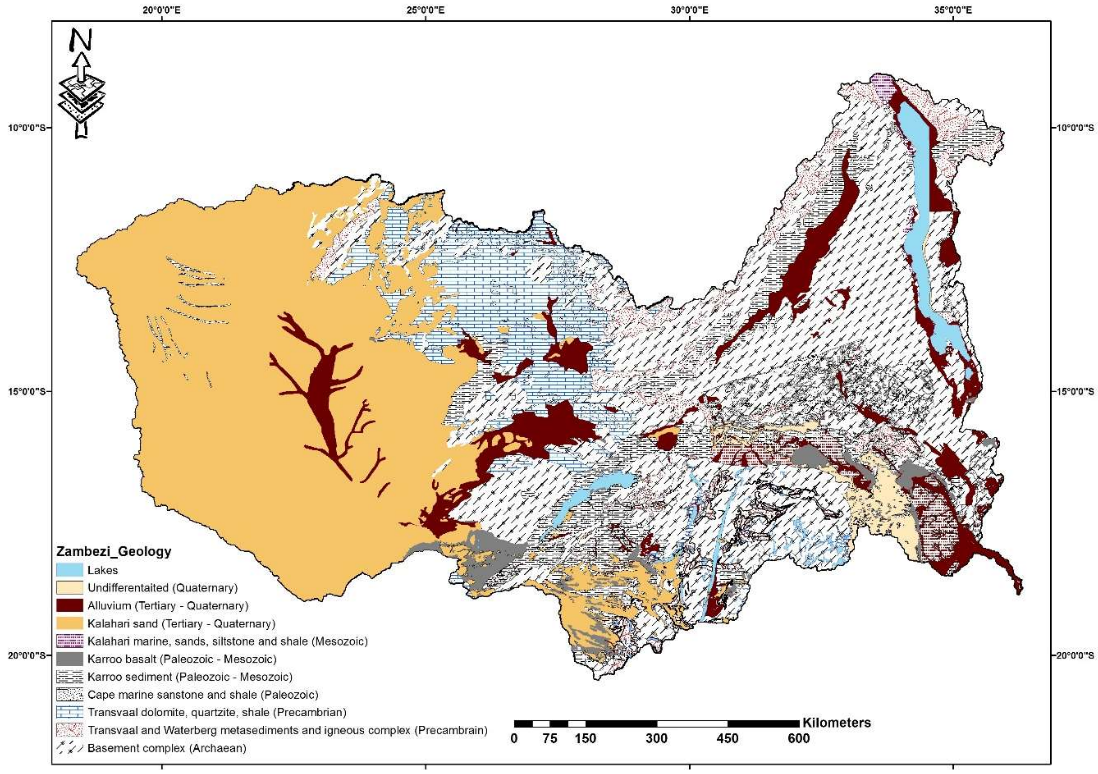

Figure 2 Simplified geology of the ZRB

It's been agreed that the configuration of the Zambezi and tributaries has evolved over time, and that the modern course of the river reflects the interplay of a complex history of geomorphic events (Moore et al., 2007). Moore and Latkin (2001) postulated that the vast sediment cover in the western portion of the ZRB is deposited during early Cretaceous when the upper Zambezi, Cuando and the Okavango rivers flows southwest forming the headwaters of the Paleo Limpopo River (Moore et al., 2007). The argument is evidenced with sharp bend of the Cuando, Kafue, and Luangwa rivers suggesting capture elbows and other lithological correlations (Fig. 3). The Upper Zambezi was probably linked to the Limpopo via the Shashe River, which is over 1 km in width near the confluence of the latter two rivers, indicating a marked overfit with the ephemeral modern flow regime. The palaeo-Limpopo drainage system was disrupted by late Cretaceous to early Tertiary crustal flexuring of the subcontinent along an arcuate line termed the Okavango–Kalahari–Zimbabwe (OKZ) Axis by Moore (1999). Uplift along this flexure severed the link between the Lower Limpopo and the former south-east-flowing headwater tributaries. These tributaries, including the Zambezi, now became a senile endoreic drainage system that supplied sediment to the inland Kalahari Basin. Rifting within the Okavango area created an inland delta, and eventual head-ward erosion of the other rivers coupled with early Tertiary crustal uplifting diverts the Cuando and Upper Zambezi to eventually merge with the Middle Zambezi River Course. During the transitional time when the waters of Cuando River, the Upper Zambezi River and other tributaries in the region were blocked from flowing to Paleo Upper Limpopo, a Lake named Palaeo-Makgadikgadi (Thomas and Shaw, 1991) was created with a surface area of the order of 120 000 km^2. Grove (1969) calculated that it is not possible to account for the existence of a lake of such proportions by any realistic increase in precipitation.

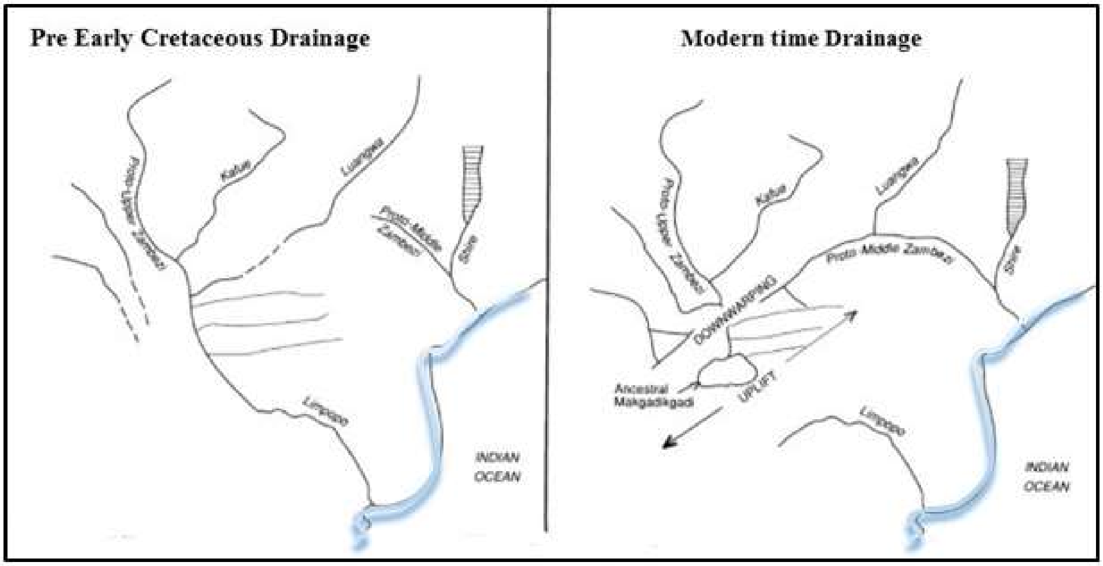

Figure 3 Drainage evolution of the Zambezi River Basin, adapted from Moore et al., 2007.

3. Hydrogeology

The Quaternary alluviums and the Palaeozoic carbonate geologies represent the high potential aquifers for groundwater storage and productivity. The Tertiary – Quaternary Kalahari sediments and the Archaean basement complexes, comprising roughly 75% of the surface geology, are ranked to be poor aquifers in terms of groundwater resource potential but also provides poor productivity boreholes when developed. Groundwater resource storage and permeability in the majority of the aquifers is governed by local and regional tectonics as the aquifers are fractured type with only the alluviums and Kalahari sediments with inter-granular type aquifers. Moreover, high spatial and temporal variable recharge is apparent from the complex geological structure and non-uniform rainfall. Therefore, high degree of spatial and temporal variability in groundwater storage and productivity is evident. Lithology based aquifer map has not been compiled before and it is thought that it can be compiled during the ongoing project. There has been reports of high salinity groundwater in the Tertiary-Quaternary Kalahari aquifer although field data is yet to be secured in the near future. Regional groundwater flow can be inferred from the surface topography although it may not necessarily true that the groundwater flow is a subdued replica of surface water flow. Major geological structures can significantly modify the groundwater flow through creating permeable zone in extensional tectonic areas and/or closing pores and considerably diminishing permeability to create no flow zones (shear zones). Groundwater flow generally appears to be north to south in the far eastern corner of the basin and the upper Zambezi region in the upper west portion. South-easterly flow is evident in the bottom western portion whereas in the central portion local groundwater varies depending on the local landform. It would be very beneficial to have access to recharge information in the area where available even though it is expected that accelerated recharge occurs along the flood plains of rivers, wetlands and in the western areas covered with portion of the Kalahari sediments which do not have significant coverage of surface calcrete deposit.

4. Conceptual Framework

Old reports, maps, site physiography, geology, hydrology, climate, land use and land cover, population, aquifer geometry, groundwater quality, vegetation as well as current groundwater abstraction for all economic activities will be scanned and electronically captured.

Existing electronic data on aquifer and groundwater data will be reformatted in a standardized template and stored for future processing.

Base maps incorporating catchment boundary, river network, geology, rainfall, land-use/land-cover, major aquifer types will be generated by doing spatial data processing with Geographic Information System (GIS) software. A catalogue of spatial data is archived and properly formatted for access to the general public (Fig. 4).

When available, field data on groundwater points (boreholes and springs) such as location, surface elevation, depth to water level, aquifer geometry and aquifer parameters will be collated and archived in a database.

Basin-wide spatial data updating will be conducted and various maps showing groundwater resource potential and groundwater quality information with newly acquired data.

From spatial distribution of relevant groundwater components, data gaps will be identified and recommendation be provided on ways of filling the missing information in the next phase of the project. A proposal would come out of this phase of the project so that groundwater storage and quality information can be integrated with other aspects such as potential irrigation areas to form a platform upon which aquifer suitability ranking can be generated. Provided that data is available, potential recharge areas can be delineated, qualitative assessment groundwater suitability for water supply or agricultural purpose be done on the basis of various water quality and depth to water level for ease of groundwater abstraction by low income subsistence farmers and other users.

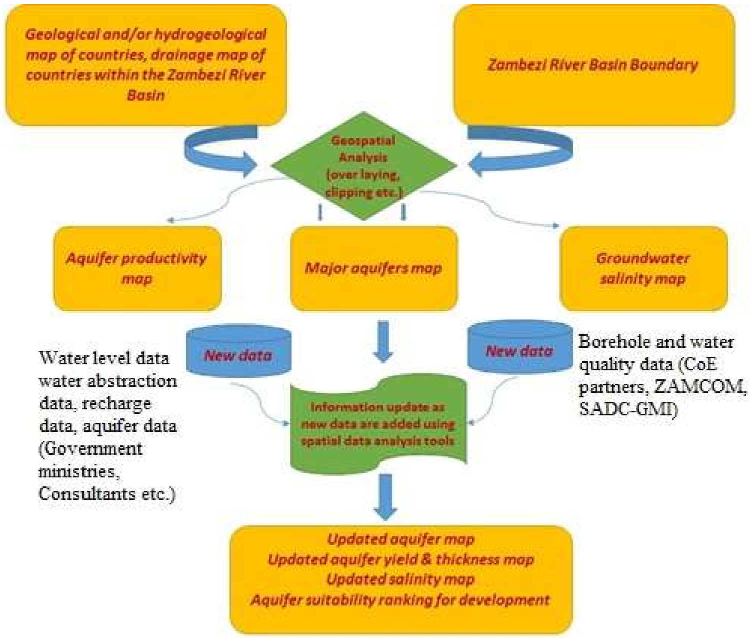

Figure 4 Simplified work flow chart showing the various activities to be undertaken during the implementation of the project. All project output (reports, maps, spatial and raw vector data would be catalogued and merged into the WACOZA database managed by JRC.

5. Problems encountered

The Zambezi Catchment lies within the national borders of eight countries which makes accessing any available groundwater data very difficult as the countries greatly vary in their institutional capacities that manage groundwater related data. In Zimbabwe, groundwater data are available and comparatively can be accessed through NUST (the National University of Science and Technology). To that end, NUST provided some semi-processed data although raw water quality data is yet to be provided. The other partner institution (the University) of Zambia is yet to respond to any processed and/or raw groundwater data. Our Namibian partners were contacted few days ago awaiting for their response. We have yet to secure any institution or individual to data in Tanzania and Angola. The most difficult challenge to accomplish the task is lack of commitment from some member countries to provide raw data when available.

Few countries within the Zambezi Catchment, lack institutional capacity to archive groundwater data in a centralized manner where the public can have a free access. In some countries such as Malawi and Mozambique, there is a high level of confidence to capture national level data as it is currently being done. Data collection and filling of identified data gaps is not planned nor budgeted. Data collection is a very time consuming activity calling for several skilled personnel, which also necessitate huge budget. Uniform and standardized data interpretation and display of information hangs on the minimum data available countries as there is a need to scale down the level of detail for countries with improved data availability. Decentralized data availability could also delay the timely completion of the project because basin-wide data interpretation requires input data for the whole regions no matter what the detail is.

There is also low level of confidence in the quality of data in terms of accuracy and completeness. In the geology map, many data gaps, which are designated as unknown, are encountered over a large area of the ZRB. Some existing semi-processed spatial data lack metadata descriptions and complied in different templates.

The Southern Africa Development Cooperation – Groundwater Management Institute (SADC – GMI) have access to few processed (shape) files but access to the raw database requires long procedures of getting the permission. The response of SADC – GMI is still pending and the email correspondences were forwarded to the Secretariat for further follow-up. The response so far is slow and cumbersome and further delays in the timely delivery of the data would have a negative consequence for the timely completion of the project.

6. Technical Components

The basin scale groundwater resource and quality assessment falls under the Water-Energy and Food Ecosystems nexus niche. The focus of the groundwater assessment component is to collate, integrate, update and generate major aquifer as reserves of groundwater resource potential, aquifer productivity and groundwater quality database as well as building groundwater spatial database.

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6.1. Identifying custodians of groundwater hydrological data

6.1.1. Country wide (Angola, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe) public, government and consultancy firms

6.1.2. ZAMCOM (Zambezi Watercourse Commission)

6.1.3. SADC.

6.1.4. Personal communication (Prof Mazvimavi)

- World slope and Digital Elevation Maps (DEM) were obtained from USGS HydroSheds.
- Shape files on the Zambezi River Basin Catchment boundary was provided from the Zambezi Water Resources Information System after registry
- Geoprocessing with ArcGIS 10.3 creates DEM and average slope map within the ZRB catchment boundary.
- SADC lithology map lacks metadata and not detailed enough to be incorporated in the updated ZRB. Countrywide lithological data of Zimbabwe will be used to up-dated the Zimbabwean potion of the ZRB. Not all nations within the ZRB has similar information to be incorporated in the ZRB. Groundwater quality raw and processed data is lacking; it seems that the information either is not properly documented or the data custodians are reluctant to share the data.
- Generally, noticeable progress was made to identify possible data sources and several attempts to start contact, but the success is marginal as contacted people do not necessarily respond (University of Zambia, Namibia Department of Water and Minerals, University of Malawi, SADC_IWS, Council for Geoscience). Contacts to responsible parties in Angola, Tanzania and Mozambique is yet to be established.
- The objectives of this project can be achieved if partners and other institutions willingly share data and information on a timely manner. A required portal registration by SADC data centre is yet to be approved. It turns out that the online registration by USGS HydroShed is very easy and quick.

6.2. Availability of raw data

Data, regardless of its quality or sufficiency, is available under the custody of various institutions, which in some instances do not share and integrate similar data types under two different government or public entities. In some countries, data is properly archived in a centralized manner but it is not the case in every ZRB countries. Therefore, access to existing data is entirely dependent on institutions of ZRB countries as well as availability of a network in the partnership. However, it has been experienced that even in the presence of a partner institution within a CoE, repeated request for access to data is yet to be responded.

6.3. Data Requirement

- Water physico-chemical data (pH, EC, T etc.)
- Major cations and anions
- Microbial data (especially from areas)
- Trace metal data (from urban areas)
- Borehole location
- Depth to water level
- Aquifer test data (Transmissivity and storage coefficient data
- Recharge data
- Lithology based aquifer classification

6.4. Envisaged progress until next report.

- It is envisaged that aquifer and water chemistry data of the Malawian portion of the Zambezi Catchment could be obtained from Council for Geoscience as there is a World-Bank funded project on integrated water resource management is ongoing. Groundwater spatial information from Zimbabwe was obtained from NUST however, groundwater chemistry and physico-chemical data is pending. The Zambia portion of the data is missing albite repeated request through a partner from the University of Zambia. The team is yet to secure a partner in Angola and the sliver portion of the Namibian territory within the Zambezi Catchment.
- All collated water point and water chemistry and spatial data created and compiled would be archived and made available for public use in future (Fig. 5).
- Critical data gap identification will be conducted.
- Basin-wide generation updated map of aquifer distribution, aquifer productivity, water quality, depth to water level would be generated at appropriate scale on the basis of data availability.
- It was agreed that the University of Zambia focusses on the aquifer vulnerability mapping of selected areas (few mining areas and urban centres such as Lusaka).
- NUST would also cover to look at aquifer vulnerability mapping of selected areas in Zimbabwe (old coal mine related pollution of the Bulawayo area mainly focusing on the carbonate aquifer).
- Data and information would be exchanged among the participating institutions including identifying of data gaps and striving to fill the identified data gaps as much as possible.
- All collected data would be properly catalogued and archived for future access as part of deliverable with the final report (Fig. 5).
- One critical output of the project is identification of data gaps and perhaps a proposal of strategy to fill the identified data gaps.

7. Future plans

The following activities will be completed within the duration of the project, provided that raw data access and data availability challenges are addressed:

7.1. Borehole and spring database.

Customized data storage template will be prepared using Microsoft Access™ and will be used to archive existing and newly acquired data, which includes Borehole ID, borehole location, surface elevation, casing collar height, borehole depth, lithological description, depth to water level, time and date of measurement, water strikes during drilling. Ease of data access is ensured during data and information sharing among all partner Centre of Excellences.

7.2. Groundwater and spring water quality database

7.3. Aquifer hydrology and water quality spatial database.

7.4. Groundwater resource occurrence and quality assessment maps

7.5. Qualitative conjunctive use of groundwater and surface water; spatial estimation can be performed by delineating wetlands.

7.6. Potential use of shallow groundwater for agriculture: all river alluvial plains qualify as target areas suitable for such shallow groundwater developments.

Data and information would be shared among the Centre of Excellences through the Secretariat of the SANWACE in accordance with the data disclosure agreement of the original owner of the data.

Complete tentative work breakdown structure is compiled on the assumption that some of the challenges stipulated earlier would be addressed in time (Fig. 5).

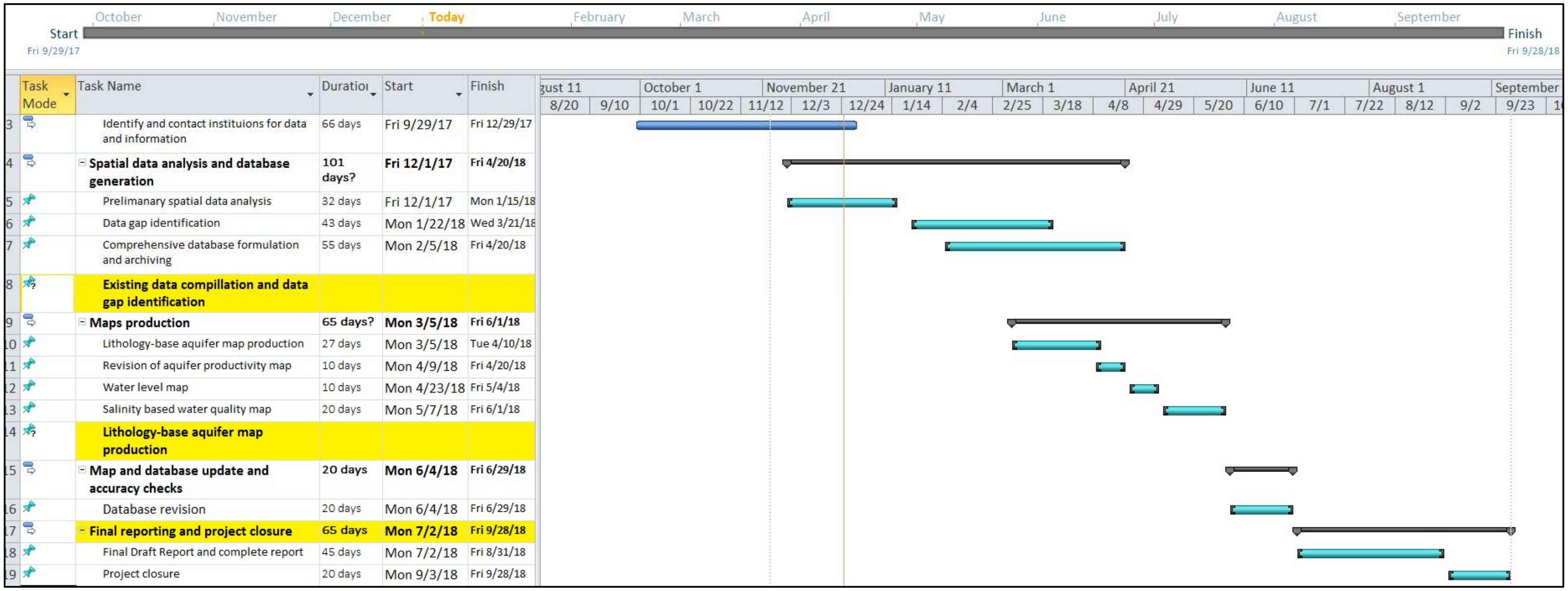

Figure 5 Tentative work breakdown structure showing major tasks to be implemented and time line of completion. Highlighted tasks are the milestones of the project.

Reference

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