DEPARTMENT WATER AND SANITATION

CHIEF DIRECTORATE WATER ECOSYSTEMS

DIRECTORATE RESERVE DETERMINATION

APPLY RELEVANT METHODS FOR GROUNDWATER AND SURFACE WATER INTERACTION FOR PROTECTION OF THE WATER RESOURCES IN THE UPPER VAAL

INCEPTION REPORT

December 2015

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APPLY RELEVANT METHODS FOR GROUNDWATER AND SURFACE WATER INTERACTION FOR PROTECTION OF THE WATER RESOURCES IN THE UPPER VAAL

WP10941

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1.0	RDM/WMA______	Inception Report

LIST OF ABBREVIATIONS

AMD	Acid Mine Drainage
CD: WE	Chief Directorate: Water Ecosystems
DWS	Department of Water and Sanitation
DWA	Department of Water Affairs (former DWS)
DWAF	Department of Water Affairs and Forestry (former DWS)
EC	Electrical Conductivity
IUA	Integrated Unit of analysis
IWRM	Integrated Water Resource Management
IWRMP	Integrated Water Resources Management Plan
MC	Management Class
NFEPA	National Freshwater Ecosystem priority areas
NWA	National Water Act
RDM	Resource Directed Measures
RHP	River Health Programme
RQOs	Resource Quality Objectives
RQS	Resource Quality Services
Swater	Surface Water
Gwater	Groundwater
ST-CB	Skills Transfer & Capacity Building
LoP	Life of Project
LHTS	Lesotho Highlands Transfer Scheme.

EXECUTIVE SUMMARY

This Inception Report is a deliverable from Task One of the Investigation; it describes the proposed activities and tasks that will be carried out during the duration of the investigation. The inception report has been produced to better define the scope of work for the study, document any changes to the scope of work from the proposal, describe the information available to support the study, highlight related considerations that could influence the study, confirm study programme and the associated study budget based on the initial assessments and reviews undertaken during the inception phase of the study.

The study area covers southern parts of the Upper Vaal Catchment (UVC) and specifically the flow path of the drainages conveying surface water discharged from the Lesotho Highland Transfer Scheme through the Upper Vaal Catchment (C83A-J).

The main objective of the study is to determine surface-groundwater interaction along the Ash River main channel from the Boston-A Dam, the Liebenbergsvlei River to the confluence with the Wilge River, upstream of the Vaal Dam. In addition, the deliverables would support efforts to identify sensitive areas where protection zoning of the surface water and groundwater is required.

Interaction between surface and groundwater resources has not been studied at a high-level in South Africa and mainly because of the diffuse nature of groundwater resources.

Due to the lack of surface water gauging structures in the tributaries feeding into the main stem system (i.e. the Liebenbergsvlei River), the discerning approach will be based on the hydrochemical characteristics of the main stem flux and whether changes in the water quality (i.e. total dissolved solids) downstream could indicate groundwater influx (i.e. an influent stream system).

The contrary (i.e. an effluent or losing steam system) may also apply due to the significant flow volume increase in the main stem system coming from the Lesotho Highland Transfer Scheme releases above the Boston A-Dam in the Ash River.

This study is primarily of a technical nature. The proposed professional service provider team includes the necessary technical and understanding of the quaternary catchment areas, as well as an ability to plan, manage and facilitate strategic processes to ensure that the requirements are met. The team is also in a position to ensure that there is strong integration and alignment to previous and current processes/initiatives that are underway.

The area is drained by several northerly flowing drainages; all contributing to the headwaters input of the Vaal River channel via the Vaal Dam; ~44 km downstream from the outlet of C83J quaternary catchment.

The nature of surface water-groundwater-surface water interaction is complex, especially in the southern African “hard rock” environment, partly due to the heterogeneous hydrogeological/hydraulic characteristics of the saturated zone and direct influences such as land use impacts on recharge/evapotranspiration and climate variability.

The aquifer systems in the study area are represented by the primary arenaceous sandstones and secondary fractures developed during the Jurassic dolerite intrusions.

An approach to analytical modelling of the main stem and tributaries will be based on the elementary salt load estimations between the Lesotho Highland Transfer Scheme tunnel outfalls and just upstream of the Liebenbergsvlei/Wilge Rivers confluence at Frankfort– based on the flow volume estimations at the DWS gauging stations and salt load concentrations.

A conceptual model of the Liebenbergsvlei drainage channel will be designed based on the local geological information and elevation sections at prescribed sites. This conceptual hydrogeological model will be converted into a numerical groundwater flow model, which is a mathematical approximation of the real word aquifer systems and its interaction with surface waters.

Relevant hydrological data/information sets received during the Inception Phase from the DWS archives. A first level assessment of the datasets has been completed which supported an information gas analysis. A data/information gap analysis indicated that borehole information (specifically “modern” aquifer water levels and quality characteristics) is spares and a special main stem hydrocensus will have to be conducted to address this shortfall. In addition, water quality and flow information of the major tributaries are not available and should be addressed through additional dry/wet period sampling/analysis using a specially designed monitoring network/programme for the life of project.

The impact of the Loch Athlone and Saulspoort Dams in the upper reaches of the Liebenbergsvlei main stem may influence the water quality signature in the main stem system. These dams will therefore be regarded as “mixing cells” in the water quality assessments.

Understanding the dynamics of surface and groundwater interaction is necessary and essential for the assessment and quantification of the two resources, especially in terms of conjunctive uses and when contribution from one to another takes place.

Several factors such as hydrogeological conditions (aquifer characteristics – hydraulic connections), climate variability and land use activities may modify the process of interaction between groundwater and surface water sources.

A wide spectrum of disciplines is required to address this level of hydrological studies and opens the opportunity for skills transfers and capacity building. A desktop and field skills transfer and capacity building programme has been developed and already implemented.

In conclusion, this surface water – groundwater interaction investigation will be based on the results of recent relevant studies done in South Africa. The application of hydrochemical signatures between surface water and groundwater is a new approach and will be correlated with those applications in most recent studies (DWAF, 2006 and Moseki, 2013).

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1. INTRODUCTION

The main objective of the study is to determine surface-groundwater interaction along the Ash River main channel from the Boston-A Dam to the confluence with the Wilge River, upstream of the Vaal Dam. In addition, the deliverables would support efforts to identify sensitive areas where protection zoning of the surface water and groundwater is required.

The study will be supported by team members who have been involved in a variety of studies for the DWS over the past 20 years, including several resources directed measures (RDM) related investigations.

Extensive experience and a proven track record in integrated water (surface and groundwater) resource management, resource protection, ecological baseline assessment, water resources planning and catchment management in South Africa and neighbouring countries are relevant to the study objectives.

Numerical 3D groundwater flow and transport modelling on catchment scale will be applied as an aid for understanding regional flows through aquifer systems and simulation of linkages to the surface water component.

The study area consists of nine (9) quaternary catchments (a total area of 5052 km^2). The success of appropriate scientific applications a will be a factor of the hydrological data coverage and integrity thereof. .

1.1 BACKGROUND AND CONTEXT

With the promulgation of The National Water Act (Act No. 36 of 1998) (NWA), water resources management in South Africa underwent a paradigm shift. The Department of Water and Sanitation (DWS) as custodian of the nation’s water resources is mandated to protect, use, develop, conserve, manage and control the nation’s water resources in a sustainable and equitable manner for the benefit of all South Africans. Sustainability encompasses both the long- and short-term protection of water resources to ensure that they can be developed and used efficiently into the future.

The NWA is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public/other water users and water resource protection. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of Resource Directed Measures (RDM).

Interaction between surface and groundwater resources has not been studied at a high-level in South Africa and mainly because of the diffuse nature of groundwater resources due to the different aquifer media involved. There is, however, evidence that interaction per say could play a significant role in the baseflow regime of most drainage channels, especially in the headwaters regions of large drainage systems such as the Vaal River.

The aquifer systems in the area consist of Karoo Supergroup formations; horizontally layered but intruded with various dolerite features (i.e. sills and dykes). Although the hydraulic characteristics of these formations do not indicate high yielding primary aquifers, interstratified high permeable horizons and secondary fracture zones may represent preferential flow paths for groundwater which may transects deeply incised surface water drainage channels.

Due to the lack of surface water gauging structures in the tributaries feeding into the main stem system (i.e. the Liebenbergsvlei Rivers), the discerning approach will be based on the hydrochemical characteristics of the main stem flux and whether changes in the water quality (i.e. total dissolved solids) downstream could indicate groundwater influx (i.e. an influent stream system) through a special designed monitoring network/programme for the LoP.

The contrary (i.e. an effluent or losing steam system) may also apply due to the significant flow volume increase in the main stem system coming from the Lesotho Highland Transfer Scheme (LHTS) releases above the Boston A-Dam in the Ash River.

1.2 PURPOSE OF THE STUDY

The purpose of this study is to assess the possibility of a effluent/influent conditions along the main stem Upper Vaal (Wilge) C83A-J WMA, i.e. the Ash and Liebenbergsvlei Rivers between the LHTS tunnel outfall and the Liebenbergsvlei River confluence with the Wilge River and introducing water resource protection zones.

Protection of the water resource has been reserved as an important management protocol as the water quality should be sustained in a manner not disadvantageous to downstream users.

The objectives/deliverables of the study is to:

- Assess/identify the interaction between surface and groundwater sources along the main river channel (stem), i.e. the Ash and Liebenbergsvlei Rivers supported by hydrodynamic assessment of the main stem and tributaries;
- modern' groundwater and surface water quality analyses will be collated and compared to available long-term historical datasets; and
- Delineate groundwater protection zones along the main stem and tributaries through establish/qualify hydraulic protection zoning based on a 3D flow/transport modelling approach.

This study leads on from the recently completed surface/groundwater interaction studies in South Africa, (2013, Moseki)

This study will focus on the following important aspects of the hydrological disciplines:

- Hydrochemical signatures of the surface and groundwater water bodies obtained from recent (2013) and historical data to establish seasonal and/or long-term trends. Water quality datasets from national water resources monitoring programmes and related investigations in the study area;
- Hydrodynamics of the main river channel and the timing of the flow contributions from the major secondary tributaries using the Hec-Ras model;
- Conduct an indirect (not on site) land use assessment along the main river channel of the study area. It has been observed that high-level agricultural activities are practised in the study area and correlations with the WARMS database will be conducted);

- Design a surface water quality monitoring network/programme along the main stem and tributaries to assess the surface water quality characteristics and time-related changes thereof.
- Implement a surface water sampling programme based on the above-mentioned monitoring network and collate physical data and hydrochemical analyses on an appropriate interval (e.g. bi-monthly)
- Establish a surface water quality profile along the main channel of the study area based on the natural hydrochemical signatures (i.e. electrical conductance, total dissolved solids and natural, conservative tracers).
- Hydrocensus of the groundwater levels and quality and potential gradients at selected sites along the main stem of the Liebenbergsvlei River and one or two main tributaries;
- Development of a conceptual hydrogeological model describing groundwater-surface water interactions for both scenarios, i.e. groundwater feeding into the drainage channel under natural gradients and the reversal where due to local over abstraction, surface water may be drawn in from the river channel;
- The development of a numerical model for the study area, which is a mathematical approximation of the real world aquifer channel and its interaction with surface waters. The numerical model will be developed to assess the spatial and seasonal likelihood and extent of surface-groundwater interaction and to inform management decisions such as annual water balance variations and water quality changes.
- Based on the numerical flow model, delineation of hydraulic and water quality protection zones will be developed based on the classical borehole protection zone concept.
- Skills development and capacity building of a group of DWS officials who have been selected and will participate in desktop and field activities of the investigation.

1.3 PURPOSE OF THE REPORT

This Inception Report is a deliverable from the Task One of the investigation. The inception describes the proposed activities and tasks that will be carried out. The inception report has been produced to improve the definition of the scope of work for the study, document any changes to the scope of work from the proposal anddescribes the information available to support the study. It highlights important aspects that could influence the study and confirms study programme. Consideration of factors that could influence the study based on the initial assessment and review of existing data and information are envisaged.

The study programme with the associated budget will be rolled out.

1.4 STUDY AREA

The study area covers southern parts of the Upper Vaal Catchment (UVC) and specifically the flow path of the drainages conveying surface water discharged from the LHWP through the UVC: specifically:

- Ash River outfall (discharge from LHTS) at Clarens;
- To the confluence with the Liebenbergsvlei River (Bethlehem, Reitz and Tweeling); and
- To the confluence of the Liebenbergsvlei and Wilge River at Frankfort.
- The study area includes parts of the following nine (9) quaternary catchments:
    - C83A, C83B, C83C, C83D, C83E, C83F, C83G, C83H and C83J, as illustrated in Figure 1.

The natural characteristics of the study area are as follows:

1.4.1 Physiography and Climate

The study area falls in the Eastern Free State and runs from the foothills of the Maluti Mountains in the south (Clarens area) to the flat, plains areas in the north (Frankfort) with several low hills (mesas) represented by dolerite cappings.

The major towns in the study area are Bethlehem (in the south) and Frankfort (in the north); followed by smaller towns, i.e. Danielsrus, Reitz, Blydskap and Tweeling in between.

Agricultural activities comprise of dry land cash crops (mainly wheat), stock farming and sporadic irrigation schemes close to the main rivers/tributaries.

The climate is temperate and fairly uniform with a strong seasonal rainfall signature with MAP between 600 mm and 800 mm per annum.

1.4.2 Hydrology

The area is drained by several northerly flowing rivers/spruits; all contributing to the headwaters input of the Vaal River system into the Vaal Dam; ~44 km downstream from the outlet of C83J quaternary catchment. The elevation difference between the LHTS inlet, just upstream of the Boston-A Dam is ~250 m over a distance of ~220 km's, thus a fall of 0.12 m/100 m river stretch along the main drainage channel, i.e. the Liebenbergsvlei River.

Several sub-ordinate tributaries joins the Liebenbergsvlei River along the flow path, but is it the Wilge River which is fed from the Sterkfontein Dam system at Jagersrust, that represents the other main tributary to the Vaal River channel upstream of the Vaal Dam.

There are four dams in the study area, namely Boston A (at the LHTS Tunnel outfall), Loch Athlone and Sol Plaatje(at Bethehem), Loch Lomond and the Kransfontein Dam (in the Tierkloof River).

1.4.3 Hydrogeology

The geology of the study area consists of the upper Karoo Supergroup sequence consisting of the following formations:

Table 1 General Geological profile of study area.

Order		Lithostratigraphic Unit	Basic Lithology	Characteristics
3		Dyke/Sill Intrusive structures	Jurassic dolerites (Jd)	Igneous, hard rock but generated high permeable zone in contact aureole with mudstone and sandstone.
2		Mudstones and sandstone	Tarkastad Group (upper) of the Beaufort Group	Thick, high permeable sandstone layers.
1		Mudstone and subordinate sandstones	Adelaide Subgroup (lower) of the Beaufort Group.	Thin, permeable sandstone horizons in massive low permeable mudstone formations.

The nature of surface water-groundwater-surface water interaction is complex, especially in the southern African “hard rock” environment, partly due to the heterogeneous hydrogeological/hydraulic characteristics of the saturated zone and direct influences such as land use impacts on recharge/evapotranspiration and climate variability.

The aquifer systems in the study area are represented by the primary arenaceous Beaufort and Molteno Groups in association with secondary fractures developed during the Jurassic dolerite intrusions.

The sedimentary formation in the study area comprises of a mixture of mudstone and sandstone layers representing the upper Karoo Supergroup (see Table 1 above). These sediments represent two significantly different aquifer systems based on their hydraulic characteristics and play an important role in the general groundwater flow mechanism(s). In addition, bedding planes between thick mudstones and overlying sandstone could be regarded as preferential flow channels driving horizontal flows.

The dolerite intrusions take the form of sub-vertical dykes and sub-horizontal sills that have intruded into larger sub-vertical fractures/faults/joints and horizontal bedded sediments (mainly sandstone/mudstone contact zones representing primary planes of weakness).

The aquifer type is classified as an intergranular and fractured (Type d) aquifer system supporting borehole yields in the order of 2(0.5-2 L/s) and 3(2-5 L/s), i.e. d2 and d3 borehole yield class categories.

The geometry of the sedimentary formations in the study area is almost horizontal. Lon-term erosion and subsequent levelling have resulted in deep river incisions into these formations which may also intercepts aquifer zones.

In general, piezometric flow lines converge to local drainage systems; thus indicating groundwater flow towards deep river incisions and consequent discharges from an aquifer into the river channel.

The yields of the Karoo Supergroup aquifers may support local groundwater irrigation – may pivot irrigations systems were noted along the river channel and adjacent areas. High abstraction rates may result in reversing the piezometric heads, leading to discharges from the river channel into the aquifer and subsequently impacting of the surface water resource.

Impacts on the local groundwater quality resulting from extensive irrigation practices along the main drainage channel using artificial fertilizers needs to be acknowledge as well and could become a secondary focus point of this study.

A map of the study area is shown in Figure 1 below.

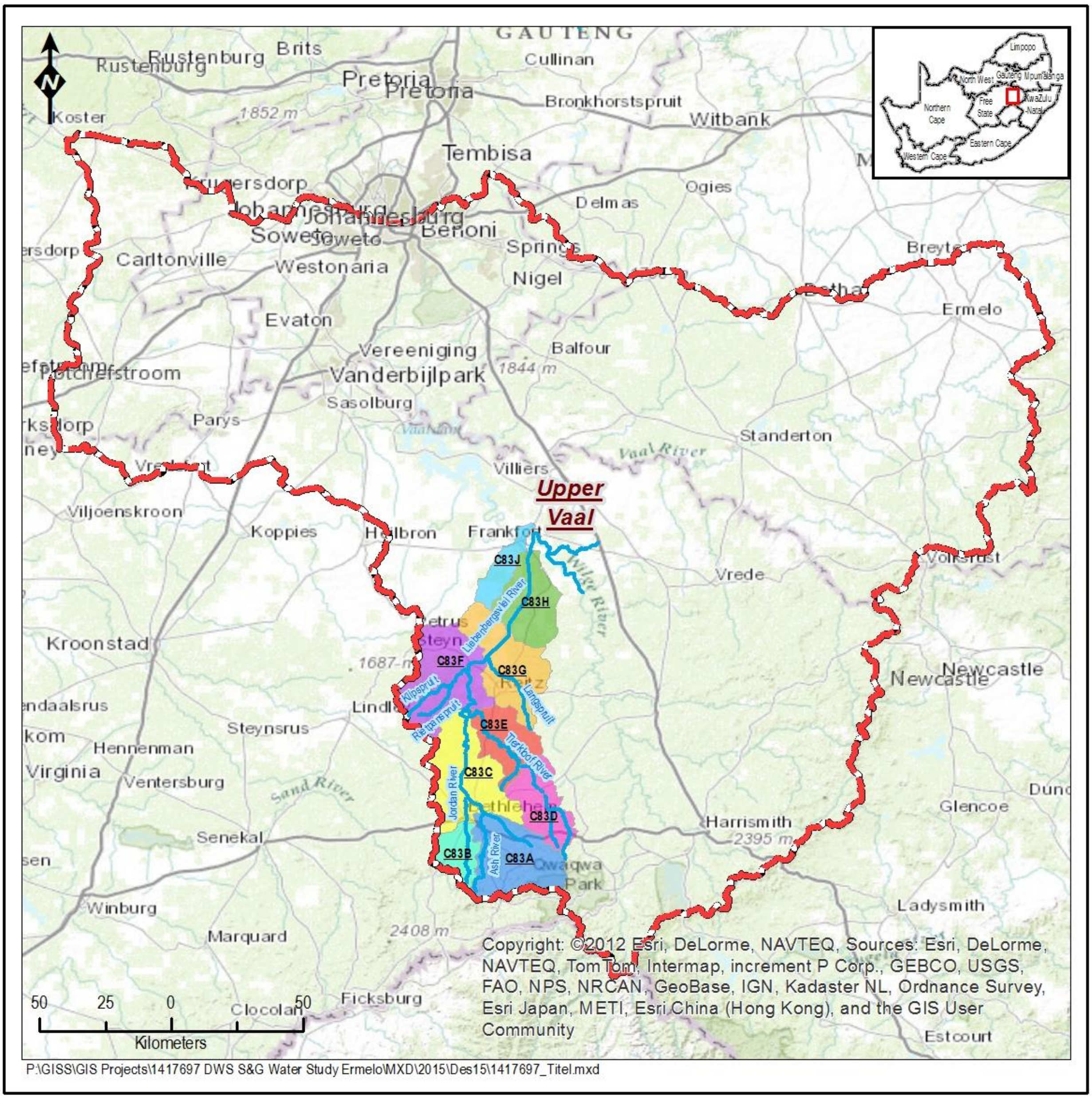


Figure 1 Showing study area in relation with Upper Vaal WMA

2 DATA / INFORMATION AVAILABILITY AND RELIABILITY

2.1 HYDROGEOLOGY

A search for reliable data on the surface and groundwater undertaken in this Inception Study has revealed that the following spectrum of data/information is available, mainly from the DWS information system:

- Borehole Information (basic, lithology, discharge, owner, water levels and water strikes);
- Groundwater quality (physical signatures and macro element concentrations, limited dataset);
- Groundwater WARMS data (updated to 2014 package);
- Groundwater level time series data sets (only limited data);
- Groundwater quality time series data sets (two National Groundwater Quality Monitoring Programme sites);
- Groundwater Occurrence (based on the 1: 500 000 National Geohydrological Map Series information, including a baseline Borehole Yield Classification cover).
- Surface water flow data (at five gauging stations on the main stem, including the tunnel outfall);
- Surface water quality data (weekly macro analyses at six gauging stations, incl. the Saulspoort and Loch Athlone Dams); and
- Surface water WARMS Data (updated to 2014).

2.2 HYDROLOGY

This component will address the hydrodynamics of the main stem channel based on the gauging station flow data. Assessment of the data will indicate to what accuracy the Hec-Ras model can be used. Flow contributions from the tributaries will be assessed.

A surface water quality monitoring network/programme (27-Bridges Monitoring Network) that will cover a more detailed level of the surface water systems (main stem and tributaries) will be designed using the road bridges in the study area. Flow indicator measurements and water quality analyses at these temporary monitoring sites will be collated over the LoP. It is required that at last two dry-period and two wet period water quality sampling runs will be conducted during LoP. These activities will be used as ST-CB exercises as well.

There are seven (7) DWS gauging stations in the study area. Station C8H001 (Wilge River) at Frankfort represents flow from the Liebenbergsvlei and Wilge Rivers; thus a combination of flows from the LHTS and the Vaal-Tugela System. Two of the remaining six (6) stations, i.e. C8R004 and C8R005 are at the Wolhuterskop and Saulspoort Dams in the Jordaan and Liebenbergsvlei Rivers respectively – now flow measurements are available at these C8R00X stations.

In conclusion, only four (4) flow-gauging stations are operational in the study area, including the Ash River LHTS tunnel outlet. Flow data from 1975 are available from gauging stations C8H020 (Liebenbergsvlei) and C8H001 (Wilge River at Frankfort).

2.3 GROUNDWATER

The status of the groundwater component in terms of its hydrochemistry signature and flow dynamics along the main stem (i.e. the Liebenbergsvlei River) is an important parameters required to qualify/quantify the potential interaction between the surface/groundwater systems. The current water quality dataset do not cover the study area in detail; however, based on the relatively undisturbed regional geological model, the background hydrochemistry signature remains in its pristine state, unless where land use activities (such as dry/wet land agriculture practices) may generate a measurable impact. Land use activity within a certain distance from the main stem and the tributaries is regarded as an important factor to consider.

2.4 ANALYTICAL MODELLING

An approach to analytical modelling of the main stem and tributaries will be based on the elementary salt load estimations between the LHTS's tunnel outfall and just upstream of the Liebenbergsvlei/Wilge Rivers confluence at Frankfort– based on the flow volume estimations at the DWS gauging stations and salt load concentrations. This covers a distance of almost 220 km's from Clarens in the south. The water quality information from the 27-Bridges Monitoring Network will play a decisive role. It was therefore required that an indication of the flow velocities of the tributaries should form part of the study parameters although the actual volumes will not be difficult to estimate due to the lack of any gauging stations on these streams.

2.5 CONCEPTUAL/NUMERICAL MODELLING

A conceptual model of the Liebenbergsvlei drainage channel will be designed based on the local geological information and elevation sections at prescribed sites. Local groundwater elevations will be a critical parameter and a field hydrocensus in selected areas will be required to obtain these parameter inputs. The borehole dataset obtained from the National Groundwater Archive contains the basic parameters, including relevant positions on the parent farms in the study area. Water table contouring at these selected areas will identify not only the direction of groundwater flow with relation to the main stem, but may provide guidance in terms of whether the interaction subscribes to effluent/influent conditions.

The conceptual hydrogeological model for the main stem will be converted into a numerical groundwater flow model, which is a mathematical approximation of the real word aquifer systems and its interaction with surface waters. The level of accuracy of the model will depend on the quality of the available input data and might therefore vary spatially (areas of higher and lower confidence within the model domain).

Considering the objective of the study, it is envisaged to calibrate the groundwater flow model not only against observed groundwater levels respectively derived contours, but also against cumulative baseflow gains or losses between gauging stations (if any, i.e. surface water discharge changes due to baseflow gains or infiltration losses) as well as qualitatively against areas of groundwater baseflow contributions as delineated based on the observed hydrochemical parameters on the main stem.

2.6 WATER RESOURCE PROTECTION

Two parameters will suffice in terms of water resource protection, i.e. groundwater quality protection zones and hydraulic protection zones. These parameters will be based on the calibrated flow model, and applied to delineate groundwater protection zones along the main stem and its major tributaries.

2.7 INFORMATION GAP ANALYSIS

An information gap analysis based on an assessment of the available hydrological datasets has identified the following critical parameters for the study:

- Groundwater Levels: Preferably along a few profiles across the main stem in selected areas, supported with groundwater quality information. Regional groundwater levels will also augment a catchment wide groundwater piezometric map – currently drawn from historic water level information (NGA dataset);
- Piezometric gradients in the main stem area: Based on the hydrocensus information, this input is important to classify whether the main stem drainage system is influent (losing to groundwater) or effluent (gaining from groundwater);
- Borehole information along the main stem of the Liebenbergsvlei is limited and a special hydrocensus of private boreholes is required;
- Diurnal surface water quality trend: The day/night biological activity in the flowing surface water body in the main channel may influence the alkalinity values to such a level that the TDS values, which is used for the surface-groundwater hydrochemical differentiation as currently observed with the 27-Bridges Monitoring Programme, is not practical. If this is the case, the bi-monthly 27-Bridges Monitoring Programme will be downgraded to a Dry (July-August)/Wet (January-February) interval.
- Flow releases from Loch Athlone and Saulspoort Dams: The DWS surface water gauging station list indicates that flow measurements are available at five (5) surface water-monitoring sites only, viz. the gauging weirs only. It seems therefore that no flow measurements are recorded at these two dams.

It should be noted that much emphasis has been placed on the study results of Dr MC Moseki in his doctoral thesis: *"Surface water – Groundwater interactions: Development of methodologies suitable for South African conditions*". During the course of his investigation it became clear that due to unavailability of adequate information on surface-groundwater interaction and resources, the development of South African methodologies could not be achieved. As a result, identification and recommendation of methodologies suitable for South African conditions were addressed and a relevant framework for choosing suitable methodologies was developed.

2.8 SKILLS TRANSFER-CAPACITY BUILDING

Understanding the dynamics of surface and groundwater interaction is necessary and essential for the assessment and quantification of the two resources, especially in terms of conjunctive uses and when contribution from one to another takes place.

Several factors such as hydrogeological conditions (aquifer characteristics – hydraulic connections), climate variability and land use activities may modify the process of interaction between groundwater and surface water sources.

A wide spectrum of disciplines is required to address this level of hydrological studies and opens the opportunity for skills transfers and capacity building. The following aspects of this study allows for practical exposure to these disciplines and how they are processed, i.e.

- Data/information processing,
- Hydrological assessment
- Land use assessment;
- Quaternary Catchment elevation profiling;
- Water resources monitoring (surface water component);
- Planning/execution of spot hydrocensus surveys;
- Introductory sessions to analytical and numerical methods and
- Participate with hydrological data processing (time series water levels and water quality data) to support the Close Out Report.

3 STUDY METHODOLOGY

A water balance will be developed using the available measured surface water flow data in the river and the discharge from the LHTS into the Ash River. The data will be analysed to determine the flow statistics and the base flow values using the edited data from four (4) DWS gauging stations along the Liebenbergsvlei River. The Hec-Ras hydrodynamic flow model will be set up for the Ash and Liebenbergsvlei Rivers using the available flow data. The flow measured at the gauges down the river system will be input into the model for the base flow situation to undertake a volume balance along the river. This analysis will indicate where there are gains or losses from the river and to provide in-stream water elevations and flow rates to provide input to the surface-groundwater interaction.

This study is primarily of a technical nature. The proposed professional service provider team includes the necessary technical and understanding of the quaternary catchment areas, as well as an ability to plan, manage and facilitate strategic processes to ensure that the requirements are met. The team is also in a position to ensure that there is strong integration and alignment to previous and current processes/initiatives that are underway.

The inception phase has been used as an introduction to the current status regarding the goals, role players, project management structure, work program information, objectives of the study, short falls (information gaps) that may develop and skills transfer/capacity building.

A preliminary groundwater-surface water flow concept will be included based on a hydrogeological model of the study area. It is foreseen that the hydrogeological model will be finally reviewed with the client after consultation with persons/institutions familiar with the water resource occurrences and conditions in the study area.

Arrangements for ST-CB has been initiated already during the inception phase the client has identified officials that will participate in the review and research phases of the project at the Golder Offices in Midrand and Hatfield. Where physical field work will take place such a hydrological monitoring, this group will participate in the field activities with Golder staff. It must just be noted that a special HaSP (Health and Safety Plan) has been developed by Golder and will apply to all participants. Personal protective equipment (PPE's) – hazard jacket, hard/safety hat and industrial boots are required and should be arranged by the client.

All sources of literature on GW-SW interaction will be part of a review phase and specifically "modern" scripts will be consulted. However, as a baseline application, we will use the 2012 GRDM document (2nd Edition), but augmented by international and local documents such as the DWS Literature Study (DWAF, Surface-Groundwater Interaction Methodologies by Witthüser, 2006) and Surface water – Groundwater interactions: development of methodologies suitable for South African conditions (Moseki, 2013[?]) and . In addition, water resources studies such as WR2102 and any updates (i.e. ISP's and reconciliation strategies) will be consulted as well.

National hydrological and climatological datasets will be included. Specific data evaluation tools such as CHART (2005) will be used for trend and spatial variation evaluations of the historical water quality characteristics. The methodology described in the 2012 GRDM document will be applied in the study, as well. Study area specific research documents such as the latest updated ISP's will be considered and well as document related to national and local strategic assessments.

The physical part of the study is the actual on-site investigation(s) in the study and will be conducted around guidance from the inception phase. It is, however, envisaged that the following aspects will be crucial to the success and implementation of the recommendations related to GW-SW interaction in South Africa. The PSP project team will include a subconsultant who will be responsible for the development of a surface-groundwater analytical/conceptual/numerical model.

The proposed GW-SW interaction methodology for the WP10941 study can be summarized as follows:

- Hydrochemical signatures of the surface and groundwater water bodies obtained from recent (2013) and historical data to establish possible seasonal trends and possible long-term trends;
- Hydrodynamics of the main river channel and the timing of the flow contributions from the major secondary tributaries using the Hec-Ras model;
- Conduct an indirect (not on site) land use assessment along the main river channel of the study area (it has been observed that high-level agricultural activities are practised in the study area and correlations with the WARMS database will be conducted);
- Conduct a channel water quality profile along the main channel of the study area. This exercise will be based on natural, conservative tracers. This will indicate site specific zone where

groundwater-surface water interaction may occur and minimize the effect of dilution from the LHWP system;

- Development of a concept hydrogeological model describing groundwater-surface water interactions for both scenarios, i.e. groundwater feeding into the drainage channel under natural gradients and the reversal where due to local over abstraction, surface water may be drawn in from the river channel;
- The conceptual hydrogeological model for the study area will be converted into a numerical groundwater flow model, which is a mathematical approximation of the real world aquifer channel and its interaction with surface waters. The numerical model will be developed to assess the spatial and seasonal likelihood and extent of surface-groundwater interaction and to inform management decisions such as annual water balance variations and water quality changes.
- ST-CB will be conducted throughout the project time line and it is recommended that interaction between the PSP and the client's identified officials as stated in the inception phase.

Consultations with person(s)/institutions who have recently conducted studies on groundwater surface water interactions and delineation of protections zones where surface water bodies are involved will form part of the project. It is foreseen that valuable information and guidance will be provided from this interaction.

Any suggested changes to this process will be made under guidance from the client. As this is a detailed approach, efforts will be made to streamline the process where possible after discussions with the client.

3.1 DATA AVAILABILITY AND ACCESSIBILITY

All the relevant hydrological data has been received during the Inception Phase. A first level assessment of the datasets has been completed which supported an information gas analysis. This information gap analyses has been submitted to the DWS project manager during the inception phase and is discussed under section 2.7 above.

3.2 LIAISON WITH WATER RESOURCE EXPERTS

Hydrological data in the study area has been generated by the DWS as part of national hydrological monitoring programmes. Liaison with officials from the Bloemfontein Regional Office, who is responsible for the physical surface water monitoring at the dams and gauging stations have started during the Inception Task already.

Long-term surface water quality data from the Directorate Resource Quality Services (Roodeplaat Dam) has been received following correspondence with the Free State Regional Office.

Discussions with DWS's River Health Officials at the Directorate Resource Quality Services (Roodeplaat Dam) regarding water surface quality monitoring along the main stem of the

Liebenbergsvlei and major tributaries have started during the Inception Task.

Prof. KT Witthüser, who has been appointed by Golder as the groundwater-modelling expert, is part of a Technical Task Group (TTG) for assessing the 27-Bridges Monitoring Programme datasets.

3.3 MODEL LIMITATIONS

The development of a surface-groundwater interaction model for the Liebenbergsvlei River is guided by the preamble: “A decision often must address the fact that something bad may happen. We may be willing to pay a price to reduce the likelihood of its occurrence. How much we are prepared to pay depends on the cost of its occurrence and the amount by which its likelihood can be reduced through pre-emptive management. The role of modelling in this process is to assess likelihood.” (Australian groundwater modelling guidelines, Barnett et al. 2012)”.

The numerical model will be developed to assess the spatial and seasonal likelihood and extent of surface-groundwater interaction and to inform management decisions. The groundwater flow model will in this regard be utilized to delineate groundwater protection zones along the Vaal River and its major tributaries to prevent the potential pollution of surface water via groundwater baseflow or the reversal of prevailing groundwater gradients towards surface waters by over-abstraction.

The conceptual hydrogeological model for the Liebenbergsvlei River will be converted into a numerical groundwater flow model, which is a mathematical approximation of the real word aquifer systems and its interaction with surface waters.

The level of accuracy of the model will depend on the quality of the available input data and might therefore vary spatially (areas of higher and lower confidence within the model domain).

4 SCOPE OF WORK

The sections to follow reflect the scope of work Figure 2 summarises the study tasks, each of which are discussed in greater detail and highlight specific aspects of the methodology considered by the study team. The Study Management task will continue throughout the study period. The tasks and activities envisaged for the study are described below in the respective sections.

4.1 TASK 1 – STUDY INCEPTION

Task 1 entails the inception phase of the study. The study team views the inception phase as critical since it provides a platform for assessing and understanding the nature of the scope of the project to ensure alignment between DWS’s expectations for the study and the actual product delivered by the study team.

The purpose of this component is to clearly define the specific project scope to ensure the DWS and PSP agree on the process, what is expected and the final outcomes. It will include the definition of the role-players, project scope and critical timing benchmarks for interfacing with other initiatives and budget.

All relevant information that is currently available on the study area will be sourced and documented. The specific linkages and alignment with the classification study activities will be confirmed and made during this phase. The shared activities will be identified and a plan developed to detail what, when and how the activities will be aligned and integrated. A gap analysis will be performed and results and recommendations thereof documented.

Relevant information from parallel studies, databases and reports will also be collated. The necessary study committees will also be determined and confirmed during the inception phase. The study team will prepare a study inception report to serve as a roadmap for the study roll out.

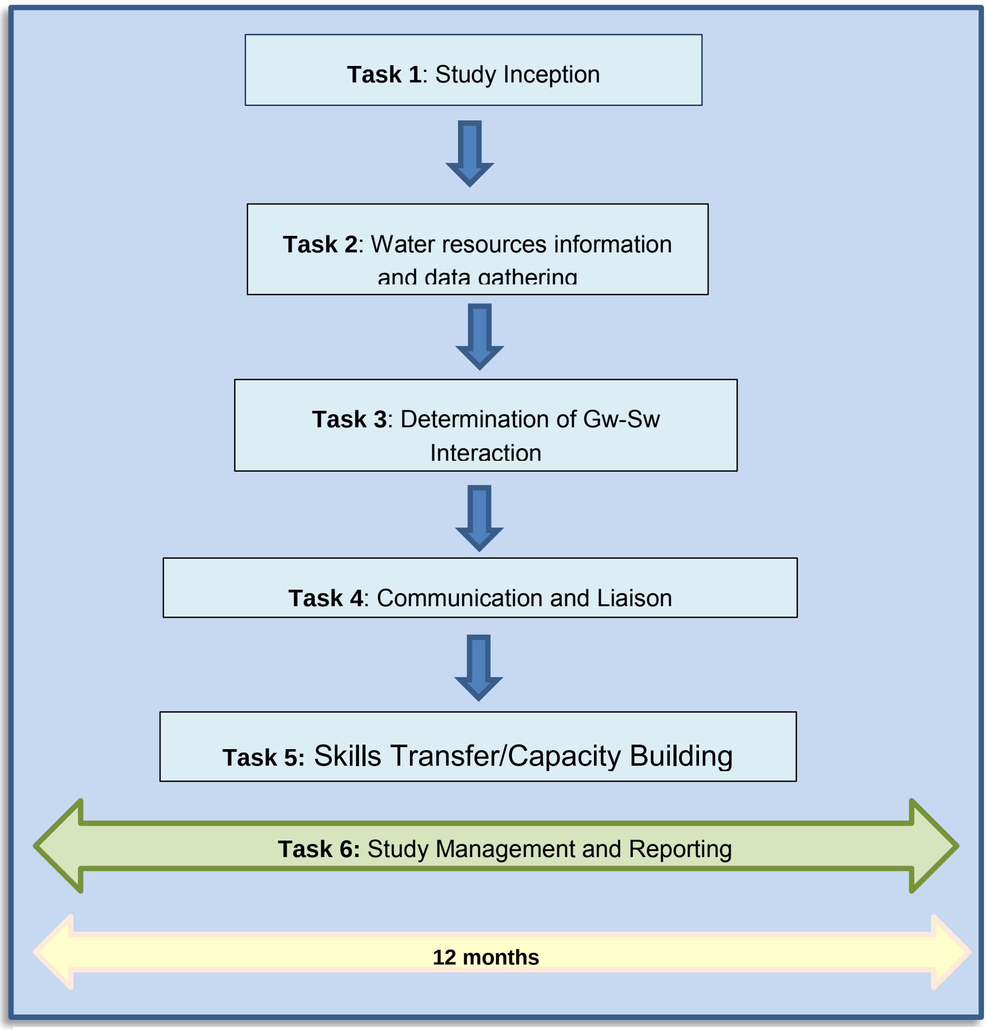


Figure 2 Scope of Work

Acapacity-building programme containing necessary measures has been implemented and included in this report. It is also important that the stakeholder engagement, communication and implementation actions are defined during the inception phase.

A ST-CB programme containing necessary measures is included in this inception report under section 4.7. The stakeholder engagement, communication and implementation actions are defined during the inception phase.

Details of Task 1 Deliveries are illustrated in the text box below.

Task 1 Deliverables:

- **Study Inception Report, including the following topics:**
  - **Integrated Work Programme,**
  - **Capacity Building and Mentor programme; and**
  - **Monthly expenditure projections.**

Note: Remainder of Inception Report topics included under Task 2 below.

4.2 TASK 2 – WATER RESOURCE INFORMATION AND DATA GATHERING

The purpose of this task will be to review existing literature, reports, time series water quality and water levels, hydrogeological maps and any other relevant information on the study area that is supportive and required for the determination of study area.

Information from previous studies of the relevant resources, i.e. WR 2012, CHART 2012, GRA II 2005 and the NGA, as well as specialist studies on the topic will be assessed.

Specialist reports that will be consulted include the following:

- GRDM 2012 Edition by Water Research Commission (TT506/12);
- Ph.D. Thesis by Dr. C Moseki (2013);
- National/International handbook on groundwater-surface water interaction; and
- Individual literature from South African specialist, i.e. Prof Kai Witthueser.

Water quality, stream flow stage heights and groundwater levels will be collated from the DWS monitoring programs. Information of the National Groundwater Quality Monitoring Program and it's assessment tool CHART will be used to augment the historical time series water quality trends in the study area.

Delineation of groundwater resource units primarily based on the hydraulic characteristics and probably sub-divisions based on their groundwater quality criteria will be done. As mentioned above, the presence of secondary geological features (dykes, faults, sills and large fracture zones) will be included and if representing a significant role in the regional flow path, these features will be treated as unique entities in the larger groundwater flow regime.

Consideration of other related studies in the catchment and/or any relevant data that can aid in producing the results and improving the confidence level of the study results will be consulted.

Specific recommendations will be made as to the collection of additional fieldwork data and/or the extension of existing data.

It is envisaged that an initial main channel water quality profile done on the correct time during the current and forth coming hydrological cycles and may generate sufficient information to identify potential terrains where GW-SW interaction takes place. This source information will guide a final approach for the groundwater hydrocensus covering the water quality characteristic of the groundwater management units. This will be discussed with the client before finalization.

The available flow data and Hec-Ras hydrodynamic Flow Model application will be required to model the hydrodynamics of the main stem and flow contributions from the major secondary tributaries. Flow data records from pre- and post LHTS tunnel outfall contributions will the assessed and corrected/patched where possible for Task 3.

This will be assessed against the land use mapping to find if there could be significant abstractions from the river system or alluvial aquifers that could account for significant river losses. The results of this assessment will be used to identify any additional work needed so that it is incorporated into the project plan and final study budget components.

All the above will be used to identify any data and information shortfalls and to plan the collation of a specific dataset required for the quantification on the surface and groundwater interaction. Shortfalls in the water resources monitoring program(s) will be established.

Details of Task 2 Deliveries are illustrated in the text box below.

4.3 TASKS 3 & 4: GROUNDWATER-SURFACE WATER INTERACTION

This activity is sub-divided between Golder and Delta-H and includes aspects of the Hydrocensus and Field Survey Deliverables (Hydrocensus and Field Survey Reports).

Task 2 Deliverables:

- **Study Inception Report, including the following topics:**
  - **Status and availability of hydrological and hydrogeological information;**
  - **Data/Information Gap Analysis; and**
  - **Recommendations to address outstanding data requirements.**
- **Hydrocensus Report, including the following topics:**
  - **Design and implement of project specific hydrological monitoring network/programme for surface water (i.e. The 27-Bridges Monitoring Network);**
  - **Hydrogeological resource assessment analyses (groundwater knowledge assessment to verify outstanding data/information for which special surveys are required);**
  - **Recommendations to address outstanding data requirements (implement groundwater hydrocensus in specified areas);**
  - **Baseline delineation of the study area into groundwater management units**
  - **Evaluate applicable methodology for addressing GW-SW Interaction in river channel/aquifer concept based on existing South African based literature (Moseki/Witthüser methodologies);**
  - **Baseline approach to (i) Analytical, (ii) Conceptual and (iii) Numerical Modelling procedures;**
  - **Assessing the current surface water and groundwater monitoring network/programme in the study area – reporting on the datasets received during Monitoring Runs # 1 and 2 during July and August 2015;**
  - **Reporting/addressing shortfalls in current water resources monitoring programs for the study area;**
  - **Perform groundwater hydrocensus in selected areas to augment groundwater dataset required for conceptual/numerical modelling**

Note: Remainder of Hydrocensus Report topics included in Task 3 below.

4.4 TASK 3 – SURFACE WATER AND GROUNDWATER INVESTIGATION (GOLDER'S ACTIVITIES).

The purpose of the investigation is to identify terrains where groundwater- surface water interactions may occur and qualification of contribution mechanism (i.e. effluent/influent conditions). The estimated contribution between the two water bodies will be estimated over a specified interval (monthly/annually) and subsequently support the generation of protocols to design and implement protection zone demarcations. These terrains will be in addition to a set of groundwater management units (based on the general hydrogeological characteristics).

The relevant groundwater quality character (based in time and space) of aquifer channel will be required to specify the protection zone(s) in space, and the hydraulic parameters of the aquifer channel will be required to specify the impact on the surface water resource (contribution of typical aquifer water into a fresher surface water system. It is regard necessary to develop a surface monitoring network and observe the water quality signatures in the main stem and main stem tributaries.

Estimation of baseflow along the main river channel will be addressed using assessment of the DWS river gauging station information where available using applicable hydrological models.

It is expected that application of the water balance approach along the main channel of the Ash and Liebenbergsvlei Rivers will not be sufficient due to technical difficulties and the low coverage of gauging weirs along the flow path. However, observing the physical water quality signatures along the main stem could indicate areas where mixing between groundwater and surface water may occur – these will be based on conservative hydrochemical tracers. Once identified, these areas will be investigated in more detail, i.e. detail hydrocensus and satellite image assessments.

Quantification of the groundwater contribution through physical measurements will have to done during actual low-flow conditions in the study area, viz. contribution from secondary contributories will have to be at is lowest input – meaning that "dry/low flow" and "wet/high flow" periods will be established and the monitoring programme planned accordingly. It is foreseen that a conceptual model(s) of potential areas where interaction may be possible will be developed based on the observed field data.

Assessment of all collated surface water and groundwater data/information will be addressed during Task 3 and will contain, but not limited to the following aspects:

- Hydrogeological baseline status (GRA II data, Geohydrological Mapping for baseline conceptual understanding – input for numerical modelling);
- Assessing DWS surface water monitoring data – Ash and Liebenbergsvlei flow dataset and water quality dataset from six (6) gauging stations/dam spillways;
- Assessing surface water flow along main stem (for Hec-Ras Model application);
- Assessing DWS baseline groundwater information on boreholes and groundwater quality;
- Select and implement groundwater (borehole) hydrocensus in selected areas (based on availability of borehole information and potential resource effluent/influent areas;
- Assessing WARMS (2014) dataset and establish water use figures and abstraction sites (river stations and boreholes);

- Assessing ground surface and groundwater level profiles (piezometric surfaces) to locate potential main stem channel-piezometric surface interceptions;
- Assess and interpreted 27-Bridges Surface water quality data and hydrochemical analyses; and
- Evaluate the best practical methodology approach towards quantifying the interaction between the surface water and groundwater components in the main stem section of the quaternary catchments involved.

During Task 3, it is foreseen that the groundwater investigation will indicate the actual areas and qualification of the surface water – groundwater interaction. If the baseline hydrogeological information is not sufficient, or limited in a specific area of interest, outstanding field surveys will have to be established/implemented to verify specific hydrological attributes (i.e. depth to groundwater levels, specific main stem channel flows, groundwater quality signatures and ground surface – groundwater level profiling).

It should be noted that any outstanding surveys should only be required for applying to most economical and practical methodology for estimating surface water – groundwater interaction per say.

4.5 TASK 4 – ANALYTICAL/CONCEPTUAL/NUMERICAL MODELLING/ASSESSMENT (DELTA-H ACTIVITIES)

The assessment of a catchment wide water resource interaction approach will be based on:

- An analytical model approach (load input at LHTS Tunnel Outfall versus the load output just before the Liebenbergsvlei – Wilge confluence at Frankfort;
- A conceptual hydrogeological model (based on an interpretation of the groundwater information of the study area using the available dataset); and
- A numerical groundwater flow model, which is a mathematical approximation of the real word aquifer systems, its interaction with surface waters and the reverse case(s) as well.

The project team proposes making use of the commercially available modelling software package SPRING, which is able to simulate steady and non-steady flow in 3D aquifers of irregular dimensions, as well as confined, unconfined and unsaturated flow conditions or a combination thereof. The recommended software is therefore capable of deriving quantitative results for groundwater flow and transport problems in the saturated and unsaturated zones of an aquifer, which are considered especially important for the accurate simulation of multi-scale flow (shallow and deeper aquifer systems) and the interaction with surface waters.

An example of the 3D application is illustrated in the Text Box below.

Using integrated waterway linkage (surface water coupling), SPRING allows furthermore the balancing of exchange volumes between surface and groundwater. The yield balance approach limits the seepage volumes for surface water stretches to the volume of water entering the stretch from upstream watercourses or external discharges.

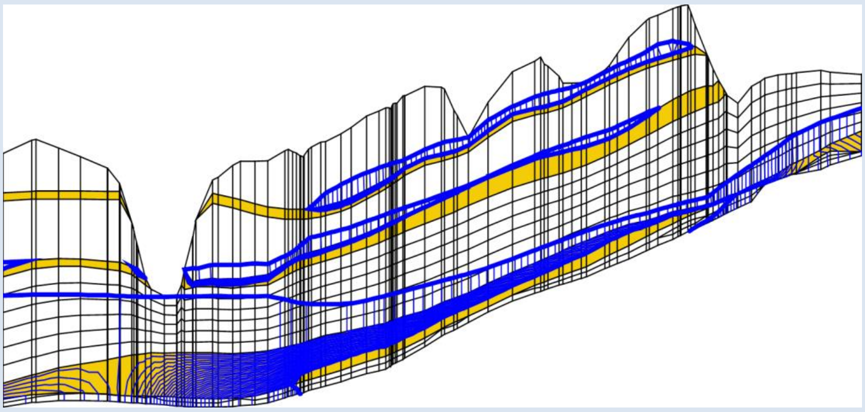
Furthermore, SPRING allows model layers with varying thicknesses as well as pinching-out model layers, enabling for example a close representation of complex geological settings along river stretches (alluvial aquifers overlying weathered and fractured aquifers), while the remainder of the upstream groundwater catchment might be represented by a single model layer (with an effective transmissivity reflecting the weathered and fractured aquifers). In doing so, model run times for the large catchments are not significantly compromised (SPRING was for example use to simulate groundwater surface water interactions for an entire province in Germany).

Considering the objective of the study, it is envisaged to calibrate the groundwater flow model not only against observed groundwater levels respectively derived contours, but also against cumulative baseflow gains or losses between gauging stations (if any, i.e. surface water discharge changes due to baseflow gains or infiltration losses) as well as qualitatively against areas of groundwater baseflow contributions as delineated based on the conductivity profiling of the Upper Vaal. The latter can obviously be only qualitatively, but ensures an agreement of groundwater discharge areas between the conceptual and numerical model.

TEXT BOX: EXAMPLE:

In SPRING the numerical modelling of a partly unsaturated groundwater aquifer can be carried out. This is carried out on the basis of the pressure-saturation functions and the function of the relative permeability for Van Genuchten.

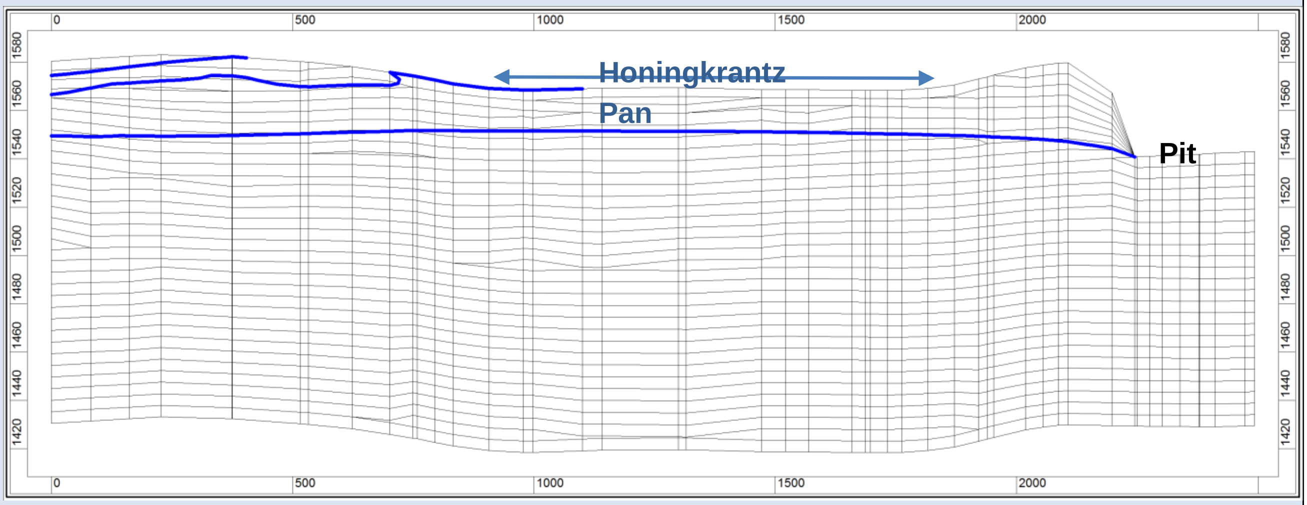
Multiple free groundwater tables can be computed in the SPRING modelling package.



EXAMPLE: Honingkrantz Pan (and associated valley bottom and hill slope wetland assessment)

The developed model was used to estimate this reduction of groundwater leakage into the delineated Honingkrantz Pan and its associated hill slope wetland due to the potential development of the different mine pit revisions.

The low pre-mining groundwater contribution of around 2 L/s towards the water balance of the pan indicate that the Honingkrantz Pan is likely to be driven primarily by shallow interflow and rainfall run-off and only to a limited extent by groundwater seepage. This minor regional groundwater seepage into the pan is cut-off once the water table is drawn down due to a lower regional drainage elevation imposed by the nearby mine voids. The remaining groundwater seepage into the pan originates then from a locally perched aquifer, disconnected by layers of lower conductivity from the deeper, regional water table (Refer to Figure below) drawn down by seepage into the pits.



Considering the objective of the study, it is envisaged to calibrate the groundwater flow model not only against observed groundwater levels respectively derived contours, but also against cumulative baseflow gains or losses between gauging stations (if any, i.e. surface water discharge changes due to baseflow gains or infiltration losses) as well as qualitatively against areas of groundwater baseflow contributions as delineated based on the conductivity profiling of the Upper Vaal. The latter can obviously be only qualitatively, but ensures an agreement of groundwater discharge areas between the conceptual and numerical model

Once the flow model is calibrated, it will be utilised to delineate groundwater protection zones along the Vaal River and its major tributaries. The hydraulic protection zones aim to prevent a reversal or unacceptable reduction of prevailing groundwater gradients towards gaining river stretches, i.e. the prevention of excessive interception of baseflow towards surface waters or induced leakage from surface waters by groundwater abstractions. The zones are therefore essentially minimum catchment areas required to sustain baseflow (product of recharge rate and catchment for specific river stretches) or minimum groundwater elevations respectively maximum allowed water table drawdown. The minimum catchment areas of gaining river stretches will be delineated using the calibrated groundwater model.

The water quality protection zones will be based on the classical borehole protection zone concept (e.g. 50 day travel time). If requested by the client, other considerations for the delineation of protection zones will be accommodated. SPRING allows the calculation of contaminant transport with an inverted flow field for the accurate determination of catchment areas. The applied methodology calculates the probability of a water particle arriving in a river stretch under consideration of advective and dispersive-/diffusive- processes, while conventional methods of velocity tracing reflect only advective processes and reflect therefore not all heterogeneities. While the water quality protection zones will be delineated on a map (and provided as a shape or dxf file to the client), the hydraulic protection zones will be delineated on a map and minimum water table elevations per river stretch visualized as annotations in the map and supplied as a shape or dxf file (with numeric values for each river stretch) to the client.

The framework for the final project report (The Close out Report) will be structured during Task 3.

Details of Task 3 Deliveries are illustrated in the text box below.

Task 3 & 4 Deliverables:

- **Hydrocensus Report, including the following topics:**
  - **Reporting on resource water quality and quantity based on historical information and modern data collation;**
  - **Determination of the surface water flow characteristics of the main channel running through the study area and applying a statistical analysis process (i.e. yield model);**
  - **Determination of the contribution and water quality impact on the main channel from the secondary tributaries;**
  - **Initial development of conceptual model;**
  - **Testing 2015 surface water monitoring dataset for application of analytical model**
  - **Translate conceptual model to numerical model;**
  - **Indicating possible areas where GW-SW interaction may occur.**
  - **Initial numerical modelling of the surface-groundwater interaction;**
- **Field Survey Report, covering the following topics:**
  - **Confirmation of applicable South African methodologies for assessing surface water – groundwater interaction**
  - **Run a series of Flow and Transient model simulating the flow/quality impact on the main channel from secondary contributories;**
  - **Investigate/report the hydraulic mechanism(s) for groundwater-surface water interaction process(es) in the study area;**
  - **Report and mapping of protection zones**
  - **Delineated terrains where protection of the receptor water body (e.g. surface water) is foreseen;**
  - **Confirming applicable water resources protection measures; and**
  - **Reporting changes to the current surface water and groundwater resources monitoring network/program;**
- **Close Out Report, covering the following topics:**
  - **Initiate Close Out Report scoping;**
  - **Setting of report framework; and**
  - **Identify possible gaps through numerical modelling scenarios.**

4.6 TASK 5 – COMMUNICATION AND LIAISON

The Study Team is responsible for the function and arrangement of the meetings for the specialist task groups, workshops, Project Management Committee (PMC) and *ad-hoc* liaison. PMC meetings have been scheduled on a bi-monthly interval accordance with the study execution and deliverable schedule. Meeting members will be kept informed and updated as and when required. The following sub-tasks will be undertaken.

Task 5a: Preparation for meetings/skills transfer/capacity building sessions.

- Invitation letter and agendas will be prepared and circulated; and
- The meeting venues, document and registers will be organised.

- Skills transfer – capacity building sessions with identified DWS officials to be help on a monthly interval (see Skills Transfer and Capacity Building for details);
- clear objectives for the meeting / capacity building sessions and will be defined and communicated ; and
- stakeholders/specialists will receive notification of technical meeting dates and its objectives at least three weeks in advance.

Task 5b: Dissemination of meeting documentation:

- Meeting minutes will be prepared and distributed, as well any reports/technical information as required, and
- Copies of the data/information datasets will be submitted to the DWS Project Manager for uploading to the project database.

Task 5c: Project Management Committee (PMC):

- A PMC has been established and the first meeting (kick-off meeting, DWS-Golder contract hand-over) was conducted on the 6th of August; and
- Follow-up PMC meetings will be:
  - 19 October 2015; and
  - Bi-monthly after above-mentioned date.

Task 5c: Project Steering Committee (PSC):

- A tentative list of participants for this committee has been established and listed in Table 2 below.
- Two project steering committee meetings have been arranged and will take place at a specified venue in Frankfort.
- First planned PSC meeting will take place during October 2015 (provisionally planned for the 22nd of October'15).

Details of Task 5 Deliveries are illustrated in the text box below.

Task 5 Deliverables:

- **Field Survey Report, covering the following topics:**
  - **Meeting agendas and schedules;**
  - **PMC, task teams, specialists;**
  - **Meeting minutes, invitation letters and reply sheets, attendance registers;**
  - **Meeting presentations, documentation;**
  - **Compile technical reports and main project report;**
  - **Meeting progress reports as required;**
  - **All arrangements for ST-CB (Golder and Delta-H);**
  - **Records of Communications; and**
  - **Electronic information and data packages.**
- **Close Out Report, covering the following topics:**

  Initiate/verify framework of the Close Out Report.

4.7 TASK 6 – SKILLS TRANSFER AND CAPACITY BUILDING

The study team is cognisant of the DWS's and specifically the CD: RDM's imperative to build capacity and transfer skills in water resource management and protection.

Due to logistical requirements (access to Golder's database, infrastructure and location), the venue for the capacity building sessions will be at Golder's Hatfield Offices; although more official-focussed sessions may be required and such sessions may be convened at the DWS Head Office.

PMC meetings will take place at the DWS Head Office, unless otherwise required due to logistical requirements from the study team.

The modelling capacity building component of the project will entail formal introductory presentations on study area specific applications for groundwater and surface water studies, hands-on training sessions (e.g. analytical/conceptual/numerical model applications). The project team of Golder/ Delta H is well acquainted in the transfer of knowledge during capacity building sessions.

A group of twelve (12) DWS officials has been selected from a range of disciplines in the department and will participate – their names/disciplines are listed in Table 4. This will ensure the broadening of the skills base in terms of surface and groundwater interactions and protection of water resources in this regard.

Table 2 List of DWS Officials participating in the capacity-building programme - WP10941 (GAA:1417697).

Surnames	Initials	Disciplines
Netshitanini	E	Hydrocensus and modelling.
Gonah	T	Hydrocensus, modelling and water quality assessments.
Maluleke	H	Hydrocensus and modelling.
Pule	MC	Hydrocensus, modelling and water quality assessments.
Mazibuko	M	Hydrocensus and modelling.
Ndima	M	Hydrocensus and modelling.
Nzama	S	Hydrocensus, modelling and water quality assessments.
Chokoe	C	Hydrocensus, modelling and data base operations.
Khoza	P	Hydrocensus and modelling.
Morekgure	K	Hydrocensus and modelling.
Netshiendeulu	N	Hydrocensus and modelling.

Specific opportunities have been explored in the inception phase already and consist of the following activities:

- Project Management Committee meetings (4);
- Project Steering Committee meetings (1);
- Hydrological dataset evaluations (available surface and groundwater datasets);
- Assessing/interpretation of time series based datasets (flows, water levels and hydrochemistry datasets);
- Satellite image assessment of land use activities in study area;
- Land surface elevation assessment of study area;
- Analytical/Conceptual/Numerical Modelling procedures;
  - Conceptual to numerical model development;
  - Verification;
  - Scenario modelling; and
  - Project driven limitations.
- Practical field work:
  - Participate in the 27 Bridges Monitoring programme:
    - Collection of monitoring data at monitoring sites; and
    - Measurements of "on-site" water quality parameters with water quality probe(s).
  - Participate in borehole hydrocensus survey:
    - Measurements of water levels;
    - Sampling of groundwater using grab samplers; and
    - Measuring field water quality parameters at borehole.

Details of Task 6 Deliveries are illustrated in the text box below.

Task 6 Deliverables:

- **Skills Transfer and Capacity Building (ST-CB), covering the following topics:**
  - **Follow aspects of the capacity building programme;**
  - **Special work sessions with the Golder study team to address the technical activities of the study (e.g. verification and assessment of datasets and field data);**
  - **Land use and catchment elevation survey (desktop activity);**
  - **Arrange special field session to coincide with the planned Project Monitor Programme (i. e. the 27 Bridges Monitoring Network); and**
  - **Progress included in Quarterly Progress Report; and**
  - **If time and funds allow, it is envisage to perform individual sessions with members of the ST-CB team who requires advice on subjects of the study that may be incorporated for further academic studies, i.e. B-Tech/Hons Degrees**

4.8 TASK 7 – STUDY MANAGEMENT AND CLOSE OUR REPORTING

Mr Trevor Coleman is the Study Manager responsible for overall project direction and management. Mr Coleman is supported by Mr. Collen Monokofala with the coordination of the study. Dr Eddie van Wyk is responsible for the hydrogeological direction and planning of project activities and deliverables, supported by Mrs Priya Moodley and Mrs Amelia Basson for the surface water input. Fieldwork is done by Messrs Manganyi, Mashaba and Lerwele

The project management committee (PMC) has been constituted during the inception phase of the project, reference to our initiation meeting on the 6th of August 2015 at DWS Head Office. It is foreseen that four (4) PMC meetings over the project duration. One of these meetings will be translated to a project steering committee (PSC) meeting to be help in Frankfort – a preliminary date for this meeting has been decided on, i.e. the 22nd of October 2015. The PSC meeting should support finalising the project objectives and lead the way for the execution of the project over the study period.

Four project related ad hoc technical meetings will be held with all technical team members, i.e. the Technical Task Group (TTG) and will be linked to the capacity building sessions.

In order to ensure effective management of this study with the appropriate guidance from various levels of DWS the following management structures will be used for both guidance and review:

Task 7a: Client liaison.

Liaison with the DWS Project Manager will include the following activities:

- Arrange Project Management Committee (PMC) over the course of the Study as required.
- Establishing interim communication (between meetings) to advise the Project Manager of, inter alia, important events or problem situations, possible changes to the scope of work, appointment of sub-consultants, etc.
- Compiling and updating the “Record of Decisions” and “Record of Administrative Requests” for the Study Manager and ensuring that all recorded actions are attended to within the specified budget and time limits of the Study.

Task 7b: Coordination of Study Team

The PSP Project Manager will be responsible for overall coordination of the Study Team and activities will include:

- Serving as link between DWS Project Manager and Study Team.
- Ensuring that the task leaders and specialists are properly briefed prior to commencing with work.
- Monitoring and control of performance, programming and cost of study, including revision of the Study Programme, if and when necessary.

Task 7c: Study administration and managing committee meetings.

Study administration duties to be performed will include:

- Compiling, certifying and submitting monthly invoices to the Client. The Client will be presented with a monthly invoice from the Study Team. The Study Leader will arrange payment to the other members of the Study Team after receiving the same from the Client.

- The DWS Project Manager will provide a secretariat to perform the required duties for the Project Management Committee.
- Arranging and taking minutes of PMC and TTG.
- Keeping minutes of meetings with the Client and other stakeholder bodies and distribution thereof to the interested parties, as required.
- Assisting with the compilation of quarterly progress reports as well as progress reports for the PMC and PSC Meetings.
- Ensuring that all project files are kept up to date and accessible to the Client if and when required; and
- The DWS Project Manager will provide a secretariat to perform the required duties for the PMC.

Task 7d: Financial Reporting

A financial control system, comprising an interactive spreadsheet, will be used to monitor and control costs. Budgets have been assigned to the key activities for each main Task. Actual costs incurred will be correlated with completion targets to ensure compliance with progress. Should deviations from the allocated costs for the key activities become evident, the PSP Project Manager shall assess the reason/s and impact of such deviations and in liaison with the DWS Project Manager, institute corrective action as required.

Where additional work may be required, the PSP Project Manager shall obtain a detailed motivation and budget (both time and costs) from the relevant Task Leader for such additional activities for assessment and submission to the DWS Project Manager for consideration and approval. No additional expenses outside the approved budget will be allowed without the prior written approval of the Client.

Task 7e: Reporting

A reporting system will be instituted whereby progress reports, technical memoranda and other material necessary to inform the client will be prepared. Monthly progress reports will be submitted to the Client to advice on progress and status of the project.

The study closure will involve finalising all deliverables: final reports, photographs, GIS maps, datasets used in the study in spreadsheet format. All electronic data and reports will be collated onto CDs and PDF versions of the final reports will be prepared.

Task 7f – Final Study/Close Out Report

The results of all the scientific/technical components of the WP10941 DWS study will be processed and assembled in the Final Study Close Out Report, due the 14th of July 2016.

The report will be structured as follows:

- Project Objectives;
- Summaries of the following interim reports (Deliverables):
  - Hydrocensus Report (baseline dataset/information); and
  - Field Survey Report (2015 & 2016 monitoring datasets/information and hydrocensus information).
- Over view of appropriate methodologies for SA;

- Baseline and “modern” datasets;
- Main stem (Liebenbergsvlei River) flow characteristics;
- Water resources quality/quantity status;
- Water quality/quantity protection protocols/zoning;
- ST-CB procedure and results; and
- Future water resources monitoring network/programmes.

Peer Review

Expert peers in the field will be approached to peer review the content and suitability of the deliverables where identified. These reviews will be identified through the project management team.

The PMC will agree on a peer reviewer; although the study team would like to propose Dr. R Titus for this purpose.

Details of Task 7 Deliveries are illustrated in the text box below.

Task 7 Deliverables:

- **Study Management and Casual Reporting, covering the following topics:**
  - **Progress reports documenting work progress against programme and actual expenditure against cash flow estimates;**
  - **Monthly Progress Reports (incl. expenditure profiles)**
  - **Minutes of the PMC and PSC meetings; and**
  - **Study invoices (with progress report and cash flow reports).**
  -
- **Final Study/Close Out Report: covering the following topics:**
  - **Overview of recommended South African Swater-Gwater Interaction Methodologies;**
  - **Data/Information availability/gaps;**
  - **Water resources characteristics;**
  - **Analytical/Numerical modelling scenario’s;**
  - **Actual findings of the Swater-Gwater Interaction based on the “Best Practice” South African Methodology applied;**
  - **Applicability for other Swater-Gwater studies throughout South Africa;**
  - **Confirm the mechanism of Swater-Gwater interaction, based on the applied methodology;**
  - **Confirm the degree of Swater-Gwater interaction in the study area;**
  - **Upgrading of the Moseki Framework for Assessment of Surface water – Groundwater Interaction;**
  - **Delineated groundwater protection zones along the main stem (Liebenbergsvlei) and major tributaries, i.e.:**
    - **Hydraulic Protection Zones; and**
    - **Swater-Gwater Quality Zones**
  - **An overview of the general water resources qualities of the relevant QC’s;**
  - **ST-CB: Lessons learned and recommendations; and**
  - **Status and recommendations regarding water resources utilisation; and**
  - **Hydrological monitoring networks/programmes (overview of current and proposed).**

5 SUMMARY OF DELIVERABLES

The summary of deliverables for the study as outlined per task is included in Table 3 below.

Table 3 Summary of Deliverables – Project WP10941 (GAA 1417697).

DELIVERABLE	*TASK LEADER*
Task 1: Study Inception	**T Coleman; E van Wyk; C Monokofala; G Manganyi, B Khumale**
▪ PMC, ST-CB initiation, DWS contract, study team initiation and study framework.	
▪ Study Inception Report.	
Task 2: Water Resource Information and Data Gathering	**C Monokofala; G Manganyi; A Basson; ST-CB Group**
▪ All water resources data/information from DWS, internal/external reports.	
▪ Obtain scientific studies and reports.	
▪ Assess current water quality monitoring programmes.	
Task 3: Gwater-Swater Interaction (Golder)	**E van Wyk, J Lerwele, G Manganyi, A Basson, T Skinner (GIS), Delta-H WSM, ST-CB Group, P Moodley, L A Boyd, M Brink.**
▪ Assess literature.	
▪ Design/implement additional monitoring programmes.	
▪ Swater/Gwater Hydrocensus planning/execution.	
▪ Conceptualization of the Swater-Gwater Flow Regime	
▪ Hydrocensus Report.	
▪ Field Survey Report	
Task 4: Gwater-Swater Interaction (Delta-H)	**C Monokofala, T Coleman, E van Wyk, T Skinner (GIS), Delta H-WSM, Golder Team, ST-CB Group.**
▪ Assess water resources datasets/information (flow analysis)	
▪ Analytical/Conceptual/Numerical Model development	
▪ Numerical Model verification and scenario modelling	
▪ Field Survey report	
Task 5: Communication and Liaison	**E van Wyk, T Pietersen; S Moyakhe, B Khumalo**
▪ Arrangements for PMC, PSC, ST-CB Sessions and field work programmes	
▪ Project administration, financial management and monthly/quarterly reporting	
Task 6: Skills Development and Capacity Building (ST–CB)	**Co Monokofala, E van Wyk, A Basson, K Lupankwa, Delta H WSM, J Lerwele, ST-CB Group**
▪ Scoping/programming of activities.	
▪ Participation in PMC/PSC and ST-CB Sessions	
▪ Data/Information verification and management	
▪ Field operations (monitoring and hydrocensus)	

▪ Reporting (included in Close Out Report	
Task 7: Study Management and Reporting	**C Monokofala, A Basson Delta H–WSM, T Coleman, E van Wyk ST-CB Group,**
▪ Client Liaison, Coordination, administration, casual reporting and Peer Reviewer (Dr R Titus)	
▪ Scientific assessments and finalisation of Swater-Gwater Interaction methodology and scenario modelling.	
▪ Final Study/Close Out Report	

6 STUDY TEAM

6.1 GENERAL

The study team consists of the Golder Associates Africa and Delta-H WSM, joined by the DWS ST-CB Group (see **Error! Reference source not found.**).

The Golder Project Manager for the study will be Collen Monokofala who has worked extensively on water resource projects over the years 5 years. He will be supported by Eddie van Wyk who has extensive experience with water resources management and scientific assessment of groundwater resources in South Africa. From the surface water component, Collen Monokofala will be supported by Trevor Coleman, Priya Moodley and Amelia Basson.

E van Wyk and Amelia Basson will undertake the ST-CB activity for office based sessions and Golden Manganyi, Michael Mashaba and James Lerwele for the fieldwork (monitoring and hydrocensus). A student from IGS (Free State University) may be contracted for casual investigations/fieldwork support).

The study team will be supported by Prof KT Witthüser and Dr M Holland (Delta – H Water Systems Modelling) for the analytical/conceptual/numerical modelling and support to the ST-CB activity.

The study leader will be Trevor Coleman responsible for the liaison with the client and the general supervision and co-ordination of the study.

6.2 TEAM MEMBERS

Details of the members that will be involved in the study are listed in Table 4 below.

Table 4: Team members involved in study

Name	Study role	Company	Hourly rate (R/h)
Trevor Coleman	Study Director, Technical Advisor Water Resources	Golder	1450
Lee Ann Boyd	Study Manager	Golder	1100
Collen Monokofala	Hydrogeological Assessment	Golder	900
Priya Moodley	Study Co-ordinator, Surface water quality and IWRM	Golder	900
Eddie van Wyk	Groundwater Resources – Advisor/Assessments (Mentor)	Golder	1200
Amelia Basson	Surface water assessments and ST&CB.	Golder	600
Keretia Lupankwa	Water quality assessments and capacity building drive.	Golder	750
Tracy Skinner	GIS applications	Golder	450
Golden Manganyi	Field operations, monitoring and hydrochemical assessments	Golder	500
James Lerwele	Field operations and monitoring	Golder	330
Michael Mashaba	Hydrological monitoring and stream flow measurements	Golder	350
Kai Witthüser	Analytical/Conceptual/Numerical Modelling development	Delta-H WSM.	830
Martin Holland	Numerical Modelling: Verification and scenario modelling	Delta-H WSM.	830

6.3 ORGANISATIONAL STRUCTURE

The organisational structure related to task components is presented in Appendix A below.

7 STUDY COSTS

The cost for the total study, including the costs to the sub-consultant responsible for the numerical modelling is R 1 862 490 (inclusive of VAT). The costs are summarized below.

7.1 SUMMARY COSTS

The cost estimates presented in this section are based on the tasks and are applicable to the study period, which has been programmed for 12 months, 14 July 2016. Table 5 represents the summary of the total study costs, with the breakdown of the different costs being reflected in the following sub-sections.

Table 5 Summary of total project costs

Cost item	Costs (R)			% of Total
	Excl. VAT	VAT	Incl VAT	
Professional fees	R 1 473 763	R 206327	R 1 680 090	90%
Disbursement costs	R 160 000	R 22 400	R 182 400	~10%
Total	**R 1 633 763**	**R 228727**	**R 1 862 490**	**100%**

A summary of the monthly and quarterly budget is included in Appendix A.

7.2 SUMMARY COST BREAKDOWN PER STUDY TASK

A summary of the breakdown of the costs for the seven identified study tasks is provided is provided in Table 6. A summary of manpower, cost and time schedule for the study is in provided Appendix E.

Table 6: Summary of cost breakdown per study task

Task	Cost		
	Excl VAT	VAT	Incl VAT
Task 1: Project Inception	77 170.00	10 803.80	87973.80
Disbursements	10 000.00	1 400.00	11400.00
Total	**87 170.00**	**12203.80**	**99373.80**
Task 2: Water Resource Information and Data Gathering			
Golder (Prof Fees)	158 568.00	22 199.52	180767.50
Delta-H (Prof. Fees)	50 400.00	7 056.00	57456.00
Disbursements	0.00		
Total	**208 968.00**	**29255.52**	**238223.52**
Task 3: GW-SW Interaction (Golder)			

Task	Cost		
	Excl VAT	VAT	Incl VAT
Golder (Prof Fees)	298 911.00	41 847.54	340758.54
Delta-H (Prof. Fees)	36 000.00	5 040.00	41040.00
Disbursements	110 000.00	15 400.00	125400.00
Total	**444 911.00**	**62287.54**	**507198.54**
Task 4: GW-SW Interaction (Delta-H only)	252 000.00	35 280.00	287280.00
Disbursements	0.00	0.00	0.00
Total	**252 000.00**	**35280.00**	**287280.00**
Task 5: Communication and Liaison			
Golder (Prof. Fees)	62 318.00	8 724.52	71042.52
Delta-H (Prof. Fees)	25 200.00	3 528.00	28728.00
Disbursements	40 000.00	5 600.00	45600.00
Total	**127 518.00**	**17852.52**	**145370.52**
	-		
Task 6: Skills Transfer and Capacity Building			
Golder (Prof. Fees)	247 648.00	34 670.72	282318.72
Delta-H (Prof. Fees)	25 200.00	3 528.00	28728.00
Disbursements	0.00		
Total	**272 848.00**	**38198.72**	**311046.72**
Task 7: Study Management and Close Out Reporting			
Golder (Prof. Fees)	204 348.00	28 608.72	232956.72
Delta-H WSM (Prof. Fees)	36 000.00	5 040.00	41040.00
Disbursements	0.00		
Total	**240 348.00**	**33648.72**	**273996.72**
SUB TOTAL PROFESSIONAL FEES			
Golder (Prof. Fees)	1 048 963.00	146 854.82	1 195 817.82
Delta–H (Prof. Fees)	424 800.00	59 472.00	484 272.00
TOTAL DISBURSEMENTS	160 000.00	22 400.00	182 400.00
TOTAL STUDY COST	**1 633 763.00**	**228 726.80**	**1 862 489.82**

7.3 DISBURSEMENTS

The proposed disbursement costs for the Study are R 160 000 (excl. VAT) and are allowed for in this study as lump sum amounts. Disbursements will be charged to the Client without mark-up and economy air travel will be used in all cases. The standard government rates for car travel will be used and any other similar items will be agreed with the Client.

7.4 CONTINGENCIES

No allowance for contingencies has been made and any changes in costs will first have to be approved and then dealt with as variation orders.

7.5 CASH FLOW PROJECTION

A cash flow projection is provided in Appendix B.

7.6 PROPOSED MONTHLY DELIVERABLES

A projection of the monthly deliverables is included in Appendix C.

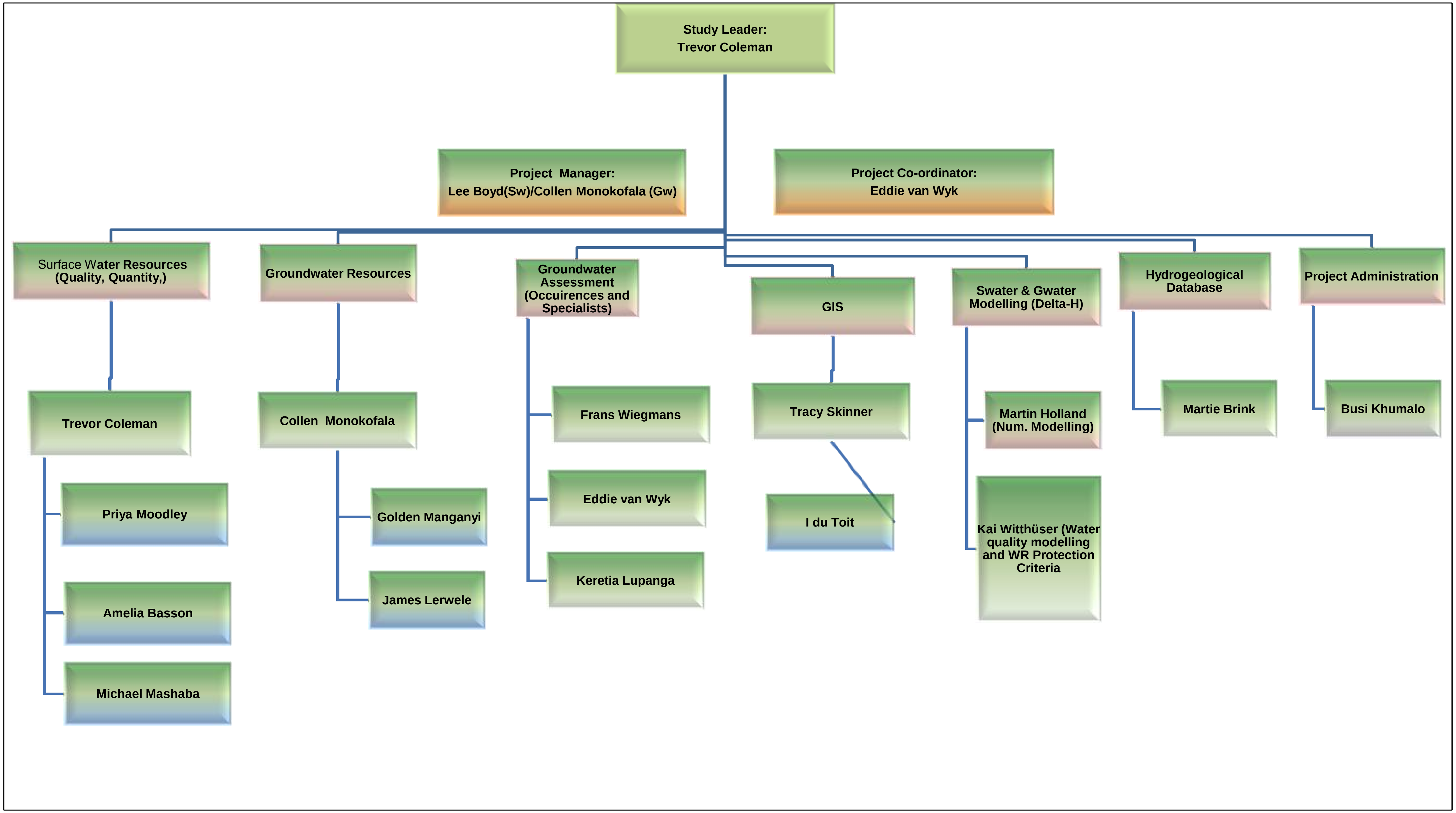
8 REFERENCES USED IN THIS INCEPTION REPORT

Moseki, M.C., 2013. Surface water – Groundwater interactions: Developments of methodologies suitable for South African conditions. Ph.D. Thesis, Faculty of Natural Sciences and Agriculture, Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa.

Department of Water Affairs and Forestry, 2006. Surface-groundwater interaction methodologies – literature study by K.T. Witthüser, K.T. Planning reference No. 14/14/2/3/8/1, SD:PS Ref. No. Study 18.

APPENDIX A

Organisational Structure



Study Leader:
Trevor Coleman
Project Manager:
Lee Boyd(Sw)/Collen Monokofala (Gw)
Project Co-ordinator:
Eddie van Wyk
Surface Water Resources (Quality, Quantity,)
Groundwater Resources
Groundwater Assessment (Occuirences and Specialists)
GIS
Swater & Gwater Modelling (Delta-H)
Hydrogeological Database
Project Administration
Trevor Coleman
Collen Monokofala
Frans Wiegmans
Tracy Skinner
Martin Holland (Num. Modelling)
Martie Brink
Busi Khumalo
Priya Moodley
Golden Manganyi
Eddie van Wyk
I du Toit
Kai Witthüser (Water quality modelling and WR Protection Criteria
Amelia Basson
James Lerwele
Keretia Lupanga
Michael Mashaba

APPENDIX B

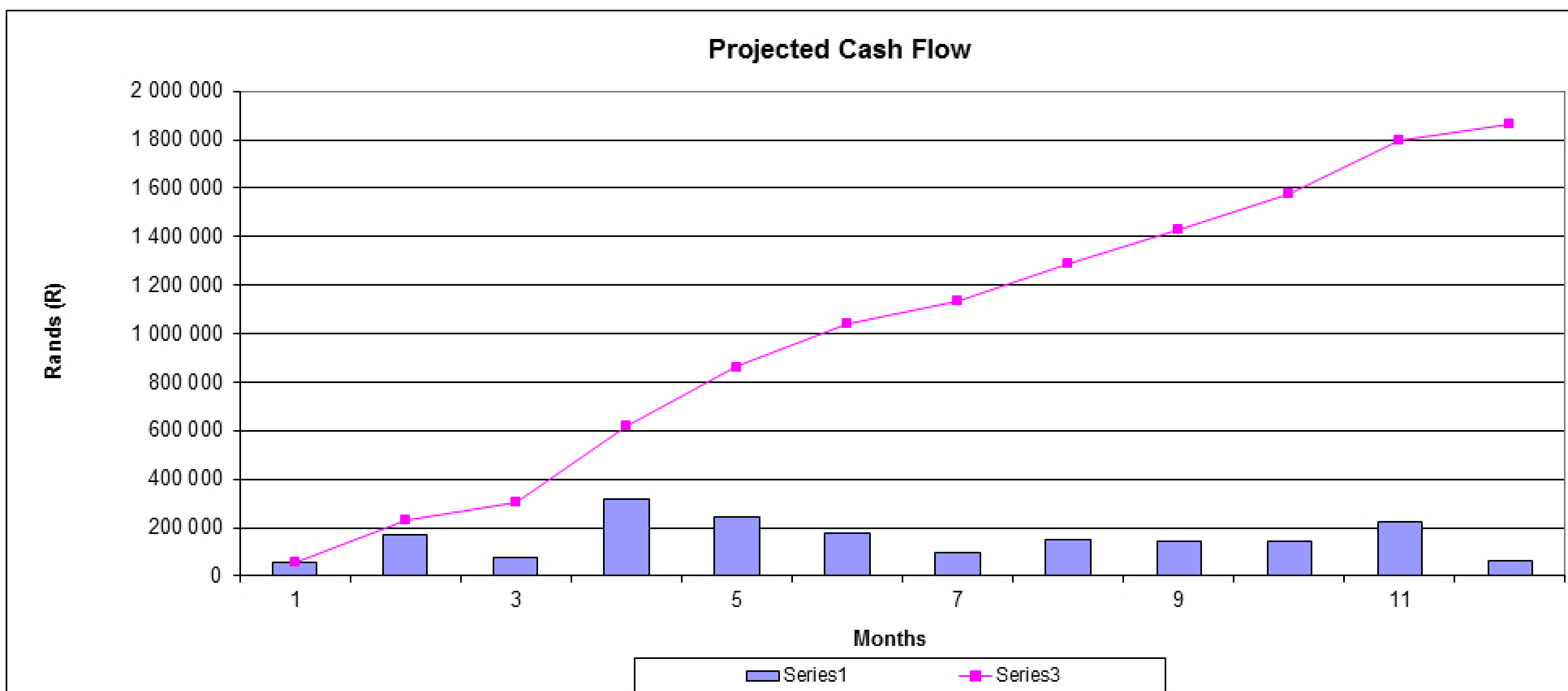
Cash-Flow Projections

TABLE C:PROJECTED CASH FLOW

QUATERLY DELIVERABLES	Q3-15	Q4-15	Q1-16	Q2-16
	BP Q2: INCEPTION REPORT	BP Q3: HYDROCENSUS REPORT	BP Q4 FIELD SURVEY REPORT	BP Q5: CLOSE OUT REPORT

PROJECTED CASH FLOW

Task	Description	Jul 2015 Month 1	Aug 2015 Month 2	Sep 2015 Month 3	Oct 2015 Month 4	Nov 2015 Month 5	Dec 2015 Month 6	Jan 2016 Month 7	Feb 2016 Month 8	Mar 2016 Month 9	Apr 2016 Month 10	May 2016 Month 11	Jun 2016 Month 12
1	Study Inception	51 940	25 230	0	0	0	0	0	0	0	0	0	0
2	Water Resource Information and Data Gatheri	0	52 620	60 412	67 517	17 762	0	10 657	0	0	0	0	0
3	GW-SW Interaction (Golder Team)	0	0	0	38 178	83 524	73 602	35 800	35 524	28 700	17 983	21 600	0
4	GW-SW Interaction (Deltah Subconsultant)	0	0	0	56 839	43 872	23 624	28 419	0	42 629	0	46 181	0
5	Communication and Laiason	0	6 850	6 850	13 562	16 831	5 131	12 209	12 209	0	14 659	0	24 417
6	Skills Transfer and Capacity Building	0	53 100	0	42 308	0	40 724	0	37 172	0	40 724	33 620	0
7	Study Management and Reporting	0	0	0	0	0	0	0	35 300	44 000	54 950	83 675	32 861
8		0	0	0	0	0	0	0	0	0	0	0	0
Total professional fees		51 940	137 800	67 262	218 403	161 990	143 080	87 085	120 204	115 329	128 316	185 076	57 278
Disbursement costs			10 000		60 000	50 000	10 000		10 000	10 000		10 000	
Total cost excl. VAT		51 940	147 800	67 262	278 403	211 990	153 080	87 085	130 204	125 329	128 316	195 076	57 278
Total cost incl. VAT (Monthly)		**59 212**	**168 492**	**76 679**	**317 380**	**241 668**	**174 512**	**99 277**	**148 433**	**142 875**	**146 280**	**222 387**	**65 297**
Total cost incl. VAT (Cumulative)		**59 212**	**227 704**	**304 383**	**621 762**	**863 430**	**1 037 942**	**1 137 219**	**1 285 651**	**1 428 526**	**1 574 806**	**1 797 193**	**1 862 490**
QUATERLY COSTS				304 383			733 559			390 585			433 964
													1 862 490



APPENDIX C

Monthly deliverables from July 2015

Table: WP10941_Monthly deliverables_Mar'15

Month	Actual Quarter	Milestone as per DWS BP	Due Date	Monthly deliverables	Estimated cost
July 2015	Q2-‘15	Draft Inception report	30 September 2015	Study inception (planning and structuring) Sw-Gw Monitoring programme (planning - CP)	R 304 383-00
August 2015				Study inception (report & integrated work programme) WR information and data research (hydrogeological background) Sw-Gw Monitoring (21 bridges sampling - CP) Inception Report (compilation & draft) Communication and liaison (general)	
September 2015				Communication and liaison (interim progress). WR information and data research (hydrological background)	
October 2015	Q3-‘15	Hydrocensus Report	31 December 2015	Hydro(water)census (Sw & Gw components - CP) Gw-Sw Interaction Survey (Dry season survey - CP) Sw-Gw Monitoring (21 bridges sampling - CP) Communication and liaison (capacity building)	R 733 559-00
November 2015				WR information and data research (applications) Sw-Gw Interaction (hydrology/geohydrology conditions and compilation) Hydrocensus report (compliation) Sw-Gw Interaction (modelling development) Sw-Gw Interaction (modelling approach - CP)	

Month	Actual Quarter	Milestone as per DWS BP	Due Date	Monthly deliverables	Estimated cost
December 2015	Q3-‘15	Hydrocensus Report	31 December 2015	Sw-Gw Monitoring (21 bridges sampling - CP) Capacity building and Mentor Programme Sw-Gw Interaction Modelling (calibration/verification) Communication and liaison (interim progress). Hydrocensus reporting	
January 2016	Q4-‘15	Field survey report	31 March 2016	Updating water resource information Application of methodologies for estimation of interaction (Sw & Gw components) Sw-Gw Interaction Modelling(Scenario testing)	R 390 585-00
February 2016				Sw-Gw Monitoring (21 bridges sampling - CP) Verification of methodologies for estimation of interaction (Sw & Gw components) Field survey report (compilation) Communication and liaison (interim progress).	
March 2016				Sw-Gw Interaction Modelling (Quantification processing) Field Survey reporting	
April 2016	Q1-‘16	Close out report	30 June 2016	Sw-Gw Monitoring (21 bridges sampling - CP) Monitoring dataset compilation and assessment –CP) Close out report (structuring) Communication and liaison (interim progress)	R 433 964-00
May 2016				Sw-Gw Field & Monitoring Data Compilation (Database-CP) Sw-Gw Modelling report (draft – final) Sw-Gw Hydrology and hydrogeology Report (compilation)	

Month	Actual Quarter	Milestone as per DWS BP	Due Date	Monthly deliverables	Estimated cost
	Q1-‘16	Close out report	30 June 2016	Close out report (compilation) Communication and liaison (modelling and hydrology/hydrogeology report presentations)	
June 2016				Sw-Gw Monitoring (21 bridges sampling - CP) Sw-Gw Interaction (Capacity Building - reporting) Sw-Gw Hydrology and hydrogeology Report (draft - final).	
WR	Water resources			**Project Costs (incl VAT)**	R **1 862 490**
CP	Capacity building (interaction during field operations, modelling exercises and field data interpretations)				

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Table: WP10941_Proposed monthly deliverables from July'15 to July 2016

Month	Actual Quarter	Milestone as per DWS BP	Due Date	Monthly deliverables	Estimated cost
July 2015	Q2-'15	Draft Inception report	30 September 2015	Study inception (planning and structuring) Sw-Gw Monitoring programme (planning - CP)	R 304 383-00
August 2015				Study inception (report & integrated work programme) WR information and data research (hydrogeological background) Sw-Gw Monitoring (21 bridges sampling - CP) Inception Report (compilation & draft) Communication and liaison (general)	
September 2015				Communication and liaison (interim progress). WR information and data research (hydrological background)	
October 2015	Q3-'15	Hydrocensus Report	31 December 2015	Hydro(water)census (Sw & Gw components - CP) Gw-Sw Interaction Survey (Dry season survey - CP) Sw-Gw Monitoring (21 bridges sampling - CP) Communication and liaison (capacity building)	R 733 559-00
November 2015				WR information and data research (applications) Sw-Gw Interaction (hydrology/geohydrology conditions and compilation) Hydrocensus report (compliation) Sw-Gw Interaction (modelling development) Sw-Gw Interaction (modelling approach - CP)	

Month	Actual Quarter	Milestone as per DWS BP	Due Date	Monthly deliverables	Estimated cost
December 2015	Q3-'15	Hydrocensus Report	31 December 2015	Sw-Gw Monitoring (21 bridges sampling - CP) Capacity building and Mentor Programme Sw-Gw Interaction Modelling (calibration/verification) Communication and liaison (interim progress). Hydrocensus reporting	
January 2016	Q4-'15	Field survey report	31 March 2016	Updating water resource information Application of methodologies for estimation of interaction (Sw & Gw components) Sw-Gw Interaction Modelling(Scenario testing)	R 390 585-00
February 2016				Sw-Gw Monitoring (21 bridges sampling - CP) Verification of methodologies for estimation of interaction (Sw & Gw components) Field survey report (compilation) Communication and liaison (interim progress).	
March 2016				Sw-Gw Interaction Modelling (Quantification processing) Field Survey reporting	
April 2016	Q1-'16	Close out report	30 June 2016	Sw-Gw Monitoring (21 bridges sampling - CP) Monitoring dataset compilation and assessment –CP) Close out report (structuring) Communication and liaison (interim progress)	R 433 964-00
May 2016				Sw-Gw Field & Monitoring Data Compilation (Database-CP) Sw-Gw Modelling report (draft – final) Sw-Gw Hydrology and hydrogeology Report (compilation)	

Month	Actual Quarter	Milestone as per DWS BP	Due Date	Monthly deliverables	Estimated cost
				Close out report (compilation) Communication and liaison (modelling and hydrology/hydrogeology report presentations)	
June 2016	Q1-'16	Close out report	30 June 2016	Sw-Gw Monitoring (21 bridges sampling - CP) Sw-Gw Interaction (Capacity Building - reporting) Sw-Gw Hydrology and hydrogeology Report (draft - final).	
WR	Water resources			**Project Costs (incl VAT)**	R **1 862 490**
CP	Capacity building (interaction during field operations, modelling exercises and field data interpretations)				

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