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between

The Czech Republic
and
The Federal Democratic Republic of Ethiopia

"Geological and hydrogeological map compilation on a 1:1,000,000 scale for the entire territory of Ethiopia"

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List of Abbreviations:

AfDB – African Development Bank
CDF – Community Development Fund
CGS – Czech Geological Survey
CzDA – Czech Development Agency
DAG – Development Assistance Group Ethiopia
EGRAP – Ethiopian Groundwater Resources Assessment Program
FDRE – Federal Democratic Republic of Ethiopia
ERA – Ethiopian Roads Authority
GSE – Geological Survey of Ethiopia
GTP – Growth and Transformation Plan
HDI – Human Development Index
IDA – International Development Association
JICA – Japan International Cooperation Agency
MDGs – Millennium Goals
ODA – Official Development Assistance
One WASH – Water, Sanitation and Hygiene National Program
PASDEP – A Plan for Accelerated and Sustained Development to End Poverty
RWMEB – Regional Water, Mines and Energy Bureau
SDGs – Sustainable Development Goals
SNNPR – Southern Nation, Nationalities and People Region
UNDP – United Nation Development Program
UNICEF – United Nations Children's Fund
ZDA – Czech Development Assistance
ECRE – Embassy of the Czech Republic in Ethiopia
ZWMED – Zone Water, Mines and Energy Department

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1. Project summary

Natural resources in Ethiopia are poorly utilized, managed and allocated to the appropriate development sectors due to insufficient awareness and fragmented information across regional and local authorities. In the emergence of rapid population expansion, the problem becomes ever pressing because of the growing public demand for an improved quality of life. Increasing habitation of areas vulnerable to natural disasters has further aggravated the population's poor conditions for making a livelihood . It is undoubted, that the compilation of geoscience data such as geological, hydrogeological and soil environments will become essential for effective planning, protection and usage of natural resources and will ensure the sustainable socio-economic development of infrastructure in such scenarios.

This project is formulated in accordance with the policy of the Government of Ethiopia in its Strategy of Rural Development pursuant to climate resilient practices taking into account the recommendations forwarded by international organizations. The enhancement of the professional capacities of Ethiopian experts both at the federal and local administrative levels forms an integral part of the proposed project.

The main aim of the project is to create uniform and comprehensive information about the geological environment and groundwater resources at the national level. An integral part will be creating a harmonized geoscience information system for the growing demand of governmental institutions and the broader public that will foster principled, rapid, reliable and strategic regional natural resources management. In addition, the groundwater monitoring systems in five water wells in selected key localities will be realized in order to understand the groundwater dynamics and improve the quantitative inventory of the water budget. The project thus builds on the programme's previous and existing activities in the framework of the Czech development cooperation programme over recent years as carried out in Ethiopia.

These objectives will be met by processing the following outputs: (a) a general geological map covering the entire territory of Ethiopia at a 1: 1,000,000 scale that will reflect the current state of geological information. It should be noted that the general geological map is a necessary base for deriving other themed geoscience maps. (b) A hydrogeological map for the entire territory of Ethiopia at a similar scale of 1:1,000,000, which will significantly aid in addressing the acute rise in the demand of water supply for households as well as production purposes in various sectors ranging from industry to agriculture. (c) Enhancing the professional capacity of collaborating experts and government officials in the field of geology and related applications which will guarantee the effective usage of the compiled geoscientific information is sustainable at all levels.

In accordance with the overall implementation of map outputs, an interactive on-line map system will be created so that the map outputs are freely accessible to all interested in using the geoscience data. On-line map outputs will foster principled management of natural resources by supporting decision makers, planners and development workers, as a reference, for the rising complex socio-economic demands from the wider public.

These outputs will make a significant contribution as a base for managing and administering other environmental elements such as minerals, forest resources and natural hazards on a national scale. These are in line with the "Sustainable Development Goals (SDGs)" 6, 9 and 15 adopted by United Nations Member States in 2015 as a universal call to "action to end poverty, protect the planet and

ensure that all people enjoy peace and prosperity by 2030". These mainly stem in SDGs 6. "Clean water and sanitation" (6.1, 6.4, 6.6), SDGs 9. "Industry, Innovation and Infrastructure" (9.1, 9.2) and SDGs 15. "Life on Land" (15.1, 15.2, 15.3).

The project will be implemented through the long-standing cooperation of the promoting institutes, the Czech Geological Survey (CGS) and Aquatest a.s., together with the partner institute, the Geological Survey of Ethiopia (GSE). The GSE is a governmental organization established under the Ministry of Mines and Petroleum with the mandate to gather, archive and disseminate geo-science data in the country. The overall cost of the project is estimated to be ca. $ 1,100,000 where ca 59% is to be covered through a grant from the Czech Development Agency (CDA) while the remaining 41% will be covered by the government of Ethiopia in the form of in-kind contributions through the GSE and by the Czech Geological Survey.

2. Description of the initial status

2.1 Economic and social situation in the country, development strategy of the country

Ethiopia is the second most populous country in Sub-Saharan Africa. It currently has approximately 96.5 million people, of which only 17.8% live in cities, others live in rural areas[1]. With an annual increase of 2.6% of the population, Ethiopia is expected to reach 130 million in 2025 and be among the ten most populous countries by 2050[2]. The country is characterized by great variability in both topography and the prevailing climatic conditions. Most of the population (85%) lives in a temperate zone of mountain areas, while the population density of tropical and arid areas is significantly lower[3]. The territory of Ethiopia, covering an area of 1.13 million km^2, is divided into 2 self-governing urban areas and 9 federal states, the so-called regions, which are further divided into zones and woredas. The eight thousand woredas are further divided into 18 thousand kebeles, which form the basic administrative units of the country.

Ethiopia is one of the countries that have made the most progress in meeting the Millennium Development Goals (MDGs). The country has successfully achieved 6 out of 8 goals. Ethiopia did not meet the third and fifth objectives of promoting gender equality and women's empowerment and improving maternal health by the end of 2015, but it was close to meeting them[4]. Yet, according to HDI, Ethiopia ranked 184th out of 188 countries in 2014, and its current gross national income per capita (purchasing power parity of US $ 1428 for 2014) makes Ethiopia one of the world's poorest countries[5]. In addition to poverty, Ethiopia's population is facing inadequate infrastructure, high illiteracy in excess of 50% (of which 58.9% for women and 42.8% for men in 2015)[6] and, above all, very poor access to clean water (in 2014-2015 58% of Ethiopian residents had access to clean water resources)[7]. Despite these indicators, Ethiopia occupies an important geopolitical and economic position in the Horn of Africa as a result of its economic strength and has made Ethiopia a regional centre. The Ethiopian economy is one of the fastest growing in the world. Since the last decline in

[1] UNDP, 2015: Human Development Report. http://hdr.undp.org/sites/default/files/2015_human_development_report_1.pdf [ref 2016-03-31]
[2] The World Bank (2014): Project Apraisal Document. Dostupné z: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/03/06/000333037_20140306113645/Rendered/PDF/PAD6390P133591010Box382156B00OUO090.pdf [ref. 2016-03-30]
[3] The World Bank (2013): Ethiopia. http://data.worldbank.org/country/ethiopia [ref. 2016-03-]
[4] UNDP (2015): MDG Progress – Africa. http://www.undp.org/content/undp/en/home/librarypage/mdg/mdg-reports/africa-collection.html [ref. 2016-03]
[5] UNDP, 2015: Human Development Report. http://hdr.undp.org/sites/default/files/2015_human_development_report_1.pdf [ref. 2016-03-31]
[6] UNESCO (2014): Integrated Functional Adult Education: http://www.unesco.org/uil/litbase/?menu=4&programme=195 [ref. 2016-03-30]
[7] The Federal Democratic Republic of Ethiopia (2015): The Second Growth and Transformation Plan (GTP II).: https://www.africaintelligence.com/c/dc/LOI/1415/GTP-II.pdf [ref. 2016-03-30]

GDP in 2009, its economy has grown by 10.8% each year[8]. Ethiopia is doing extremely well compared to other countries in the region, which are averaging 5% growth[9]. Ethiopia's economic growth has also had a direct impact on population poverty. While 38.7% of Ethiopians lived in extreme poverty in 2004-2005, in 2012-2013 it was lowered to 26% (less by 13%)[10].

Significant strengthening of the country's economy was achieved mainly thanks to ongoing reforms and investments in sectors such as agriculture, education, health and infrastructure. Despite an increasing share of services and industry, agriculture is still the largest contributor to economic growth (contributing 42% of total GDP in 2014)[11], which is also an important sector for local manufacturing and export. Although the bulk of agricultural production is of a subsistence nature[12], agriculture can play another important role in reducing the country's poverty, as in Ethiopia almost 80% of the population[13] works in this sector. Smaller farmers, who face not only problems of market instability, but mainly soil degradation and the effects of natural disasters, account for 95% of the GDP generated by agriculture[14].

In order to improve the population's standard of living, the Ethiopian Government has adopted several strategic documents. The Ethiopian Government defined its current development priorities, namely economic development and poverty reduction, in the Growth and Transformation Plan (GTP II) the strategic document valid for 2015 / 16-2019 / 20. GTP II builds on the previous 2010 / 11-2014 / 15 Growth and Transformation Plan and other development documents such as the Plan for Accelerated and Sustained Development to End Poverty, hereinafter referred to as PASDEP I). Through this strategy paper, the government aims to achieve an average annual GDP growth of 11%, as well as a stable macroeconomic environment and rapid industrialization of the country, as well as its structural transformation. Increasing the quality and efficiency of productivity and building critical infrastructure that would contribute to strengthen competitiveness. Developing infrastructures in land and air transport, telecommunications and water supply and sustainable generation of energy are all given prime importance to attract foreign investors to the country. Ethiopia also is eager to actively address the increasing urbanization, human development and dissemination of democratic values, as well as the creation and strengthening of organic farming.

Currently, the whole territory of Ethiopia is covered by separate geological and hydrogeological maps giving only a relative local classification of the terrain and geological environment on a scale of 1:250,000. Moreover, these map outputs have been produced during a relative long time span and thus they have been processed by a different methodology, various teams and show uneven quality. Furthermore, many of these maps exist only in the form of a manuscript not freely available for the wider professional community. The only existing base geological map with a relatively uniform classification of the geological environment is over 25 years old (Mengesha et al. 1996; Chernet 1988; available at One Geologyhttp://portal.onegeology.org/OnegeologyGlobal/[15]) which is basically based on compilation of geological data from very limited area where the vast majority of the country was unexplored t the time and lacked quite a lot of detail and accuracy. The longer endeavor since then has put up an enormous data set in place. Nonetheless, the above mentioned independent mapping

[8] The World Bank (2014): GDP per capita.://data.worldbank.org/indicator/NY.GDP.PCAP.CD/countries/ET?display=graph [ref. 2016-03-30]
[9] The World Bank (2015): Ethiopia: Overview.://www.worldbank.org/en/country/ethiopia/overview [ref. 2016-03-30]
[10] UNDP (2015): National Human Development Network Ethiopia 2014. http://hdr.undp.org/sites/default/files/nhdr2015-ethiopia-en.pdf
[11] The World Bank (2014): Agriculture, value added. http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS [ref. 2016-03-30]
[12] EU, 2013: EUROPEAN UNION, JOINT COOPERATION STRATEGY FOR ETHIOPIA: http://www.entwicklung.at/uploads/media/EU_Joint_Cooperation_Strategy_01.pdf [cit. 2016-03-31]
[13] UNDP, 2015: Human Development Report.: http://hdr.undp.org/sites/default/files/2015_human_development_report_1.pdf [ref 2016-03-31]
[14] The World Bank, 2011: Additional Financing for the Ethiopia – Agricultural Growth Program.: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2011/10/24/000104615_20111025112543/Rendered/PDF/AGP0GAFSP0AF0PID0Sep02011.pdf [ref. 2016-03-31]
[15] OneGeology global initiative: http://portal.onegeology.org/OnegeologyGlobal

scheme also lacked clarity in connecting the various individual maps as each map covered only smaller area and hence prompted for review and compilation into a unified and coherent map covering the whole nation. In this context, there are 87 such maps that suffered often inconsistent geological classification across adjacent map grids that require professional modification and reclassification. These outputs are extremely essential for all aspects of basic and applied research in all fields of the geosciences and also for government decision-making on management of environmental protection and natural resources utilization, devising mining strategy, planning construction of infrastructure and protection of the population from natural disasters. The currently available 1:250,000 scale geological and hydrogeological maps although rich in the essential local information, they lack in giving the much-needed synoptic overview across the wider regional extents needed by the non-geoscientists end users including public workers and decision makers. Hence, the proposed compilation of the existing 1:250,000 scale maps into a uniform, more constrained and continuous coverage of the entire territory at a reduced scale of 1:1,000,000 will be a significant step to reduce the gap in information.

2.2 Government policy and donor activities in the sector

A large number of bilateral and multilateral donors are involved in Ethiopia. Ethiopia is one of the largest beneficiaries of development aid in Africa, but at the same time, it is still much lower than the average for sub-Saharan Africa[16]. The largest bilateral donors in the area of development policy are the United States of America, the United Kingdom, the European Union as a whole, Japan and Canada[17], and among the multilateral donors in particular the International Development Association (IDA) and the African Development Bank (AfDB)[17]. In general, there has been a recent trend towards a gradual increase in the effectiveness of development cooperation in Ethiopia, in which donors are leaving sectors that are too busy and reducing the number of sectors in which they are engaged. At the same time, there is a reduction in the number of individual development projects and their congregation into larger units / programmes

In line with the Paris Declaration on Aid Effectiveness, the Czech Republic coordinates its activities with other donors. Within the framework of donor cooperation, the Development Assistance Group Ethiopia (hereinafter referred to as the DAG) is a coordinating group in Ethiopia. In February 2011, upon request, the Czech Republic received observer status in the DAG working groups on education, water, economic rural development and food security, whose activities correspond to the sectoral focus of Czech development cooperation in Ethiopia. In the next stages of development cooperation with Ethiopia, the Czech Republic will strive for full membership in the DAG.

A large number of international organizations working in Ethiopia focus on water resources in their strategies because of its interdependence with other sectors - health, agriculture, education, industry, etc. These organizations are part of a coordinating body, the so-called water, sanitation and hygiene (WASH). The head of the cluster is UNICEF, which is tasked with coordinating all activities in the sector, providing information to implementing agencies and avoiding duplication of activities. UNICEF is also one of the largest donors in the water and sanitation sector in Ethiopia.

In the development of economic infrastructure, the provision of drinking water to urban and rural areas is crucial. The availability of safe water resources is also an important starting point for development in other areas and for economic growth. In 2014/15, drinking water was accessible to

[16] The World Bank (2013): Net ODA receiver per capita.: http://data.worldbank.org/indicator/DT.ODA.ODAT.PC.ZS/countries/1W-ET-ZF?display=graph [ref. 2016-03-31]
[17] DAG (2012/13): ODA to Ethiopia.: http://dagethiopia.org/new/oda-to-ethiopia[ref. 2016-03-31]

58% of the territory (59% in the countryside, 51%, in cities)[18], and the government plans to achieve an average of 83% coverage by 2019/2020 (85% in the countryside and 75% in cities)[18]. The Government wants to reduce the cost of building drinking water supply systems and to provide adequate financial and technical support for their further construction. Its current goal is primarily to create better conditions for collecting harmless groundwater, i.e. for well drilling and extraction. In addition to improve the availability of drinking water, improving sanitation and monitoring the quality and quantity of water resources is also crucial to the government. Other objectives set in the water and sanitation sector include mitigating the negative consequences of floods and surface water use and increase the use of groundwater presently provided from aquifers[19]. Aquifers are locations of water accumulation in the rock environment in the interstitials pores or fractures in them and constitute ca. 90 percent of industrial water supply, highlighting the importance of groundwater contrary to usage of surface water such as dams that is less reliable and meagre.

A major programme to improve the current situation is the Water, Sanitation and Hygiene National Program (One WASH), to which 4 Ethiopian ministries have committed themselves to support and comprehensively address the needs of individuals, communities, schools and health facilities with the signing of the Memorandum of Understanding. (Ministry of Water and Energy, Ministry of Health, Ministry of Education, Ministry of Finance and Economic Development). An important point of the One WASH programme, which is implemented in two phases, 07/2013 - 06/2015 and 07/2015 - 06/2020, is the harmonisation of donors and all inputs of financial support. Key donors favored support for the One WASH programme, which allows for more flexible and efficient project planning and financial management over other programmes that differ both in terms of time and geography. The core of the programme remains the level of coherence between all stakeholders, i.e. donors, communities, implementers, collaborates, etc. - One WASH strives to work together to achieve the set goals.

In the context of identifying groundwater resources, mention should be made of the Ethiopian Groundwater Resources Assessment Programme (EGRAP) of 2000. This program aims to map and explore all groundwater resources throughout Ethiopia and is implemented by the Ministry of Water Resources working with GSE. EGRAP is designed to address the urgent need to improve knowledge of groundwater resources and to make this information available for the sustainable development and management of groundwater resources.

Governmental strategies and methodologies such as the Climate Resilient Green Economy, Nutrition Sensitive Agriculture or Community Based Participatory Watershed Development are notable indications with regard to the government's efforts to natural environmental management. In parallel, the government has shown prioritization of the agricultural development strategy focused on the intensification of production to increase the yield of plant production (maize, teff, wheat, enset) through the utilization of mineral fertilizers or intensive tillage. The promotion of such inputs is surely vital requiring comprehensive and contiguous information on the territory. The other strategic focus of the government of Ethiopia is in areas of natural resources and land management as seen in the Natural Resources Management campaigns on communal spaces. Increased exposure to natural disasters has had its increasing stress on the well-being and safety of various communities that cost the government the loss of a stable and productive work force as well as loss of cost associated with rehabilitation and property loss. Landslides, frequent flooding, deforestation are some of the problems at large. An independent entity called the Disaster Risk Management and Food Security Sector has been established as one of the important sectors under the Ministry of

[18] The Federal Democratic Republic of Ethiopia (2015): The Second Growth and Transformation Plan (GTP II).: https://www.africaintelligence.com/c/dc/LOI/1415/GTP-II.pdf [ref. 2016-03-31]
[19] S. Kebede, 2013. Groundwater in Ethiopia: Features, numbers and opportunities. Berlin Heidelberg: Springer

Agriculture to tackle the impact of the natural disasters, which also highlights the emphasis given to the problem by the government of Ethiopia. The strategy in the current state is focused on a new approach to disaster management shifting the focus from crisis management in the past decades to that of risk management.

Several donors have worked to aid the various strategies of the government in various locations in the country including the African Development Bank, the European Commission, the Czech Development Agency, the Rift-Valley Fund Organization as well as the Global Environment Fund via the Ethiopian Environmental Protection Agency (EPA).

All use of natural resources, whether economic minerals or groundwater and soil, requires prior knowledge and adequate information on the geological make-up and characteristics of the area. Such information is readily made available for decision makers and beneficiaries through a variety of maps and the explanatory texts attached to the maps. This main task has been entrusted to the Geological Survey of Ethiopia that has been operating under different names since 1968 where the last proclamation (Proclamation No. 194/2000) established its current structure.

In an effort to improve infrastructure and accessibility in Ethiopia, it is important to foster sustainable development. However, due to geological factors regarding landslides in particular areas of the country, infrastructure development has proven difficult. The Japan International Cooperation Agency (JICA) implemented a capacity development project for countermeasures against Landslide in cooperation with the Ethiopian Road Authority (ERA) and the Geological Survey of Ethiopia from 2010 to 2012. Due to limited knowledge in management of hazards related to landslides in Ethiopia, the project was established to build capacity in the country. The stakeholders GSE and ERA directly took part in implementing the project.

The government of Ethiopia has recently given more attention to the preparation and inventory of natural resources through various stakeholder organizations. In the Geological Survey of Ethiopia (GSE) the recent undertaking of preparing a geochemical catalogue, covering the entire nation is being implemented following the international standard. Currently a new detail of geological mapping at a scale of 1:100 000 has been started in western and southern Ethiopia with the aim of upgrading the geological information system for exploration and infrastructure as well as natural resources utilization. The Geological Survey is also significantly increasing the geohazard assessment maps at scale of 1:250,000 to systematically cover all extents of the nation, which, so far, has reached about 50% in terms of coverage.

In an effort to enhance the skills for young geologists, Ethiopia has been one of the hosting partners to train young professionals from all over Africa, including Ethiopia, through the initiative of the European Commission support to African Geologists implemented by EuroGeoSurvey in the years 2018 to 2019.

2.3 Context of the Czech development cooperation in Ethiopia

The long-term goals of the Czech development cooperation in Ethiopia are given by the Strategy of International Development Cooperation of the Czech Republic for the period 2018 - 2030[20]. In accordance with this Concept, Ethiopia is a priority partner country of the Czech Republic with a cooperation programme. This position is based on the development needs of the partner country and reflects good interrelations and the results of previous development cooperation.

[20] Strategie zahraniční rozvojové spolupráce České republiky pro roky 2018-2030: http://www.czda.cz/editor/filestore/File/Koncepce.pdf

The Programme of Bilateral Development Cooperation between the Czech Republic and Ethiopia for the period 2018-2023 (hereinafter referred to as the Programme) defines two priority areas in which bilateral development projects will be implemented in the given years. Specifically, this concerns the sustainable management of natural resources, in particular water, agriculture and rural development[21].

Most of the Czech development projects in Ethiopia have so far been implemented in the area of SNNPR. Given the size of the SNNPR and the funds available, the Czech Republic targets its activities in accordance with the Programme primarily for the Sidama and Gamo Gofa zones identified together with the Ethiopian authorities. Furthermore, in the current programming period 2018-2023, the Czech Republic will concentrate a large part of development cooperation in the SNNP region, using the already established contacts with local authorities and the relatively good knowledge of local conditions (in comparison with other regions). However, parts of the interventions can also be implemented in other regions of the country as well as at the federal level.

Better access to quality water resources and sanitation are not only among the main objectives set by GTP II, but also the main objective of interventions within the water and sanitation sector of the Cooperation Programme between the Czech Republic and Ethiopia. An equally important sector that this Programme has focused on at its inception is the disaster prevention and preparedness sector, which aims, inter alia, to strengthen the GSE's capacity in hydrogeology and geology with a focus on geodynamic risk management. The disaster prevention and preparedness sector was gradually merged with the water and sanitation sector during the implementation of the Programme.

The project thus builds on the Programme's previous and existing activities within the above sectors. The projects "Capacity development in the field of environmental geology - mapping geo-risks including hydrogeological conditions in the areas of Dilla and Hosaina, Ethiopia" (2012-2014) and "Capacity development in the field of engineering geology and hydrogeology in Ethiopia "(2010-2012), and "Analysis of natural risks affecting agricultural production in selected areas of Southern Nations Nationalities and People's Region (SNNPR), Ethiopia" (2015-2018) are among the recent completed outputs in this context. But also the activities of the Development Cooperation Programme in Ethiopia "Increasing the capacities of experts working in geological fields for EFDR authorities" (2016-2018) as well as a complex project "Finalization of hydrogeological and hydrochemical mapping of the entire Ethiopian territory at a scale of 1:250,000" (2016-2019) have continued from the long standing programme (http://gis.gse.gov.et/hg_maps/index.html).

The hydrogeological maps so far produced on an individual map sheet at a 1:250,000 scale have been published and are available in an online application on the GSE website and have been disseminated to all the administrative regions of the country as well as other end users. The project, hence, aims to collate the existing standalone hydrogeological and hydrochemical maps at a 1:250,000 scale so that they will be interoperable and unified based on a geological map to be compiled at a 1:1,000,000 scale of the entire territory of Ethiopia.

The recommendation came from the Report from the Comprehensive Evaluation of Czech Development Cooperation in the Water and Sanitation Sector in Ethiopia (Ministry of Foreign Affairs of the Czech Republic, November 2014) concerning the Czech Development Cooperation Programme and Continuation and was addressed to the Czech Development Agency.

[21] MZV ČR (2018): Program dvoustranné rozvojové spolupráce České republiky a Etiopie 2018-2023.

Several collaborations and humanitarian assistance from the Czech Republic are also gaining momentum in Ethiopia. Mendel University has continued research in the forest development and the extraction of medicinal ingredients from indigenous trees. A vast implementation of water and sanitation programme have been pursued with the support of People in Need (PIN) in various parts of southern Ethiopia. Support through setting up a soil-testing laboratory and pilot farms and training the local youth and women for improved skills to earn income-using hand crafts are among the various efforts of PIN. In addition, the assistance provided by PIN through humanitarian assistance to displaced communities following the recent clashes between ethnic groups is also noteworthy.

3. Problem analysis

For any nation knowledge and inventory of its natural resources and environmental set-up derives its long-term foresight on sustainable resource development allocation. Maps are very versatile and quick means for effectively visualizing and communicating these resources and base relevant decisions upon. In the case of Ethiopia, such information is although hugely invested on, not easily accessible and only available in fragmental manner. The existing individual series of geological maps on a 1:250,000 scale have different levels of classification of the terrain in terms of the geology and natural phenomena (Figure 1). The maps are products of long-term field mapping efforts by mainly local stakeholders (mainly GSE) and international endeavors. There is an older version of the geological map compiled for the entire nation in the 80's based on very limited data where the majority of the land was not fully explored and hence with significant gap in accuracy and credibility at 1:2,000,000 scale (Mengesha et al., 1996), a further inventory of the economic minerals in the country (Tadesse et al., 2003) and the hydrogeological setting of the country (Chernet 1989). Nevertheless, these maps can merely meet the current complex and higher level of demand by the expanding socio-economic conditions of the country it is experiencing in the recent years. The more detailed mapping efforts since the compilation of the older national scale maps on the other hand, although quite valuable in gathering the essential field and analytical data, resulted in varying focus areas and differing map quality making interoperability very limited. There are 87 individual map sheet series dividing the entire Ethiopian Territory into regular grids of 1.5° by 1° or 162 Km by 108 Km extent. Nevertheless, it should be noted that few of the maps, especially on the boundary of the Ethiopian territory, do not have a similar area due to the irregular outline of the border. The Geological Survey of Ethiopia has recently completed the individual field mapping of each map series at a scale of 1:250,000 both in geological hydrogeological context. Nevertheless, it has become even more difficult to use these individual standalone basic geological and hydrogeological maps to generate other derivative national scale maps such as natural disasters risk zonation, natural resources (groundwater, soil, economic minerals, etc.) distribution and environmental vulnerability. Further, a quick survey of the exiting maps demonstrates the availability of all these maps in offline (requiring personal collection from the Geological Survey of Ethiopia for nominal symbolic payments) partly in digital and partly in raster formats with potentially significant contribution to produce harmonized, interoperable and digital maps that can be transacted by interactive online application for ease of access for the wider public. The conversion nevertheless requires a careful detailed evaluation, correlation and harmonization of locally differently classified terrains and geological structures in individual map sheets to provide credible base line information of the geological and hydrogeological environment for the entire country.

In Ethiopia, the use of geological information is still at its infancy, where the information is used at a bare minimum during the relevant decisions and planning. The main factor is the lack of promotion about the existence of the maps, which is a result of the nature of the existing maps, which lack outreach and the flexibility and suitability for the growing needs of the users. Growing demand in expansion of infrastructure has posed dramatic constraints on the time and budget on almost all projects mostly attributed to unforeseen geological or ground conditions. These are testament to the

gap in usage of information about the natural environment and, in particular, the geology of a vast majority of the country. The recently completed 1:250,000 scale geological maps are less known to the public as they are less transferable across the boundaries of the individual stand-alone maps and even worse are not widely recognized that such maps even existed. The maps were also generated over extended period of time, which resulted in the different quality between individual 1:250,000 scale geological and hydrogeological maps. This has resulted in fragmented and unpractical use for end users and planners who have to manage a regional outlook rather than a specific locality for a far-reaching impact. Often the information contained is not uniform or standardized to give reliable interpretation for users. While first-hand information about the entire country has been put on the maps, it still lacked the necessary real characterization and genetic relationships that ought to be obtained from the map. These however required compilation of the individual 87 different map series that exist at the 1:250,000 scale into a single, harmonized map at a 1:1,000,000 scale, and at the same time publicize about its existence to the public for its utilization. The wealth of field and analytical data from multiple sources of research and projects also means there is a huge opportunity to pool together the accumulated knowledge and data into one place and vitalize the geological and hydrogeological map. The compilation of such regionally coherent and reliable maps also brings a further opportunity to derive secondary outputs directly dependent on the geological environment such as soil and construction resource, groundwater resource, geo-hazards risk, economic mineral potential zones etc.

Considering Ethiopia's wealth of water resources, most of it comes from groundwater, which is mainly used for domestic and industrial purposes. The latest available estimate of the groundwater availability ranges between 12 and 47.9 km^3/year, where the higher number is based on remote sensing data. A preliminary estimate of renewable groundwater reserves was around 2,600 million m^3 per year, but recent studies show much greater potential[22]. Groundwater is usually of high quality, due to its natural filtration; it is clean, free of staining and microbial contamination and does not require any further treatment. In addition, due to prolonged contact with rock sediments, it is rich in minerals, the volume of which depends on various factors (e.g. the mineral composition of a particular aquifer or the duration of water retention in a given aquifer). The problem may be a high salinity and high concentration of fluoride, whose concentration, especially in the Somali region and in the East African Rift Valley, exceeds the drinking water limit set by the World Health Organization as well as by Ethiopian standards.

The water supply limits set by the Ethiopian Government under the One WASH Program (Water, Sanitation and Hygiene National Program) are at least 20 l/person/day for urban and 15 l/person/day for the rural population, but these limits are due to a sharp increase in population as well as agricultural and industrial demands, however, limited financial resources fail to meet the equilibrium between demand and possibilities. In Ethiopia, less than 60% of the population has access to safe drinking water[23]. To meet the needs of all the population of the country by 2030 and to strengthen the social and economic development of all its regions, it is necessary to provide sufficient surface and groundwater resources. Surface water is not suitable for drinking without proper treatment and poses a health risk for the whole population, especially infants, since more than 80% of infectious diseases originate in contaminated water. In particular, the rural population obtains water from a variety of sanitary sources, such as shallow springs, watercourses, small rainwater storage reservoirs and unprotected hand-dug wells, and it is therefore desirable to further strengthen the infrastructure to supply residents from safe groundwater from greater depths. Polluted surface water should gradually be reserved only for commercial purposes, irrigation and for domestic animals.

[22] Ministry of Water, Irrigation and Energy.: http://www.mowr.gov.et/index.php?pagenum=2.2 [ref. 2016-06-30]
[23] The official Unied Nations site for Millennium Development Goals indicators.: http://mdgs.un.org/unsd/mdg/Data.aspx [ref. 2016-07-21]

The possibilities of effectively developing water resources are conditioned by knowledge about them, therefore the mapping and evaluation of water resources is essential for further development of the country. The Geological Survey of Ethiopia is the state institution entrusted with providing the geoscientific information for the country's strategic decision-making regarding the use and management of groundwater and economic mineral resources as well as natural disasters. Its tasks, in this regard, include not only preparing hydrogeological maps at various scales and mainly at the 1:250,000 scale for the entire country, but also providing advisory services in the field of hydrogeology. . The preparation of a series of hydrogeological and hydrochemical maps, including explanatory notes, constitutes a continuous conceptual activity of GSE in the public interest. Hydrogeological outputs are the basis for the performance of state administration and the development of evaluated (mapped) areas, which subsequently increase the efficient use of water resources and other natural resources as well as managing geohazards and environmental protection. The use of maps for the optimal use of water resources, their conservation and the preservation of a high-quality environment is a fundamental concern at the Federal level, federal regions and woredas up to the community at the Kebele level.

Hydrogeological and hydrochemical maps at a scale of 1:250,000 were compiled as maps derived from geological maps of the same scale by GSE. Hydrogeological and hydrochemical maps were compiled not only on the basis of complex field mapping, but the maps also incorporated other relevant data and information. These were mainly existing hydrological data (precipitation, flow rates), satellite data and digital topographic data. Not only does GSE provide primary geoscience data and information, but also secondary processed data from other entities (e.g. River flow measurement from the Ministry of Water Resources and Irrigation, water point data at boreholes, springs and lakes or ponds from regional and local water and mines offices, data generated by various stakeholders working on water resource development and management such as NGOs, drilling and consulting firms etc.

Completing the mapping in the required quality in the shortest possible time has been one of the highest priorities of the GSE. Complete and up-to-date information on the hydrogeological characteristics of the whole of Ethiopia, on the quality and volume of groundwater resources, will facilitate further planning of projects supported not only by state funds but also by other donors to achieve the SDG 6 (Sustainable Development Goal for 2030): “the availability and sustainable management of water and sanitation facilities for all”. Despite their use as the basis for making important regional prioritization and planning for water resources development and management, the recently completed maps at a scale of 1:250,000 are far from being sufficient for practical use in terms of water supply development schemes. In addition, the lack of efficient outreach of the information generated on all hydrogeological outputs to potential users is another outstanding issue. The GSE hence offers an ideal platform to ensure casting of such national level hydrogeological and geological data and/or map to be hosted by GSE’s website. The website can be used to provide complete information starting from country level information at a scale 1:1,000,000 through regional information at scale of 1:250,000 to more detailed local scales of 1:50,000 wherever the data are available. Continual development is hence implied here with incorporation of new projects and works continually enriching the data repository.

Complementary to the creation of the compiling the harmonized country wide hydrogeological map, it is vital to make sure that targeted users will be able to use the available hydrogeological information correctly and effectively, particularly for further replication during more detailed exploration of a smaller area. To this end, it is necessary to carry out training in the regions to build up adequate capacities for the state administration in the field of hydrogeology at the regional level, or that of the zones, especially with a focus on the practical interpretation of the resulting outputs (e.g. for planning the construction of hydrogeological wells). Further solutions to this issue at a more

detailed scale will enable a more detailed data base and thus a more substantiated assessment of hydrogeological characteristics in areas of strategic importance (e.g. areas with a rapidly growing population or areas susceptible to the negative impacts of climate change).

This particular task has the direct impact on curving the vulnerable groundwater resources in Ethiopia which is under increasing pressure from the continuous growth in demand for sufficient quantities of good quality water for all purposes. There is the actual need for action to protect groundwater resources from the qualitative as well as quantitative point of view. Groundwater resources are, in principle, renewable natural resources; in particular, the task of ensuring a good state of groundwater requires early action and stable, long-term planning of protective measures, owing to the natural time lag in its formation and renewal. Such a time lag for improvement should be taken into account in timetables when establishing measures aimed at achieving good quantitative and qualitative state of groundwater and reversing any significant and sustained upward trend in the concentration of any pollutant in groundwater or downward trend in ground water levels. All qualitative and quantitative evaluations must be conducted in hydrogeological zones (aquifers and/or groups of aquifers) that overlap the borders on the available hydrogeological map of 1:250,000. A new concept in hydrogeological zoning will be based on the results of recent regional and local hydrogeological and geological investigations and mapping, on groundwater hydrology and best practice in groundwater balance calculations and groundwater abstraction records as well as processing the new data.

A delineation of hydrogeological zones is needed in order to coordinate efforts to improve the protection of ground water environment in terms of quantity and quality, to promote sustainable water use, to contribute to the control of transboundary water problems, to protect aquatic and terrestrial ecosystems and wetlands directly dependent upon them, and to safeguard and develop the potential uses of community waters. Good water quality will contribute to securing the drinking water supply for the population.

The Geological Survey of Ethiopia compiled a hydrogeological map of Ethiopia at a scale of 1:2,000,000, which was compiled in the late 1980s by Tesfaye Chernet and later on published with an explanatory report (Chernet, 1988). Regional hydrogeological investigation of Northern Ethiopia at a scale of 1:1,000,000 was also part of the various endeavors (Asfaw 2003).

The existing Ethiopian Water Resources Master Plan is about 20 years old and there is no integrated information about existing groundwater resources for the entire Ethiopian territory that collates new data and information for the purpose of planning, development and protecting existing groundwater resources. The National Integrated Water Resources Management Program (NIWRMP) was drafted in August 2018[24].

Basin plans are also relatively old and there is a lot of new data and information from regional geological and hydrogeological mapping and drilling of various exploratory wells:

- DHV: Tekeze River Basin Integrated Development Master Plan Project, Interim Report (Nedeco 1997).
- BCEOM French Engineering Consultants in association with BRGM and ISL: Abbay River Basin Integrated Development Master Plan Project (Ministry of Water Resources 1998).
- Halcrow Group Limited and Generation Integrated Rural Development (GIRD) Consultants : Rift Valley Lakes Basin Integrated Resources Development Master Plan Study Project (Halcrow 2010).

[24] FDRE, 2018. National Integrated Water Resources Management Program.

- JICA: The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin (JICA 2012).
- WWDSE in association with MCE and WAPCOS: Wabi Shebelle River Basin Integrated Development Master Plan Study Project (Ministry of Water Resources 2003).
- Lahmeyer International GmbH: Genale-Dawa River Basin Integrated Resources Development Master Plan Study (Lahmeyer International and Yeshi-Ber Consult 2007).
- Richard Woodroofe and Associates: Omo-Gibe River Basin Master Plan Study (Woodroofe 1996)
- Soyuz Giprovodkhoz Institute, USSR, Moscow: Baro-Akobo master plan study of water and land resources of the Gambela Plain (EVDSA 1990).
- TAMS-ULG: Report of the Baro-Akobo River Basin Integrated development Master Plan Study (TAMS-ULG 1996).
- Halcrow, Sir William and Partners Ltd.: Master Plan for the Development of Surface Water Resources in the Awash Basin (Halcrow 1989).

In Summary, while the hydrogeological maps are one of the primary concerns for the direct benefit of the community, geological mapping forms an integral part in making hydrogeological maps as well as having a far reaching indirect benefit for the community by forming the basis for a host of other thematic maps. The implementation of hydrogeological mapping and investigation is strongly dependent on information about the geological setting of the area. Geological maps form the base for assessing and predicting ground water conditions as well as other direct benefits for the community, from identifying artisanal mining areas to inviting foreign investment to explore and utilize natural resources. Such maps have multiple impacts across various sectors including agriculture and manufacturing where government is looking for import replacement, fertilizer production and protection of land for agriculture as well as reduction of natural disasters. Nevertheless, the establishment of the geological baseline is a demanding and complex task requiring years of endeavor and the challenging task of collecting field data. The recently completed mapping at a 1:250,000 scale for the entire territory poses a great opportunity to make a complete map for the entire country (Figure 1.). Nonetheless, the derivation of such unified and interoperable map between various map sheets requires a huge input of advanced and experienced expertise. The possible collaboration with more experienced partners with greater resources, working together while also exchanging the skills involved, will have a profound impact on both the output and sustainable continuation. This will lead to regularly updating and improving the maps as new data and information emerge from increasing investigations.

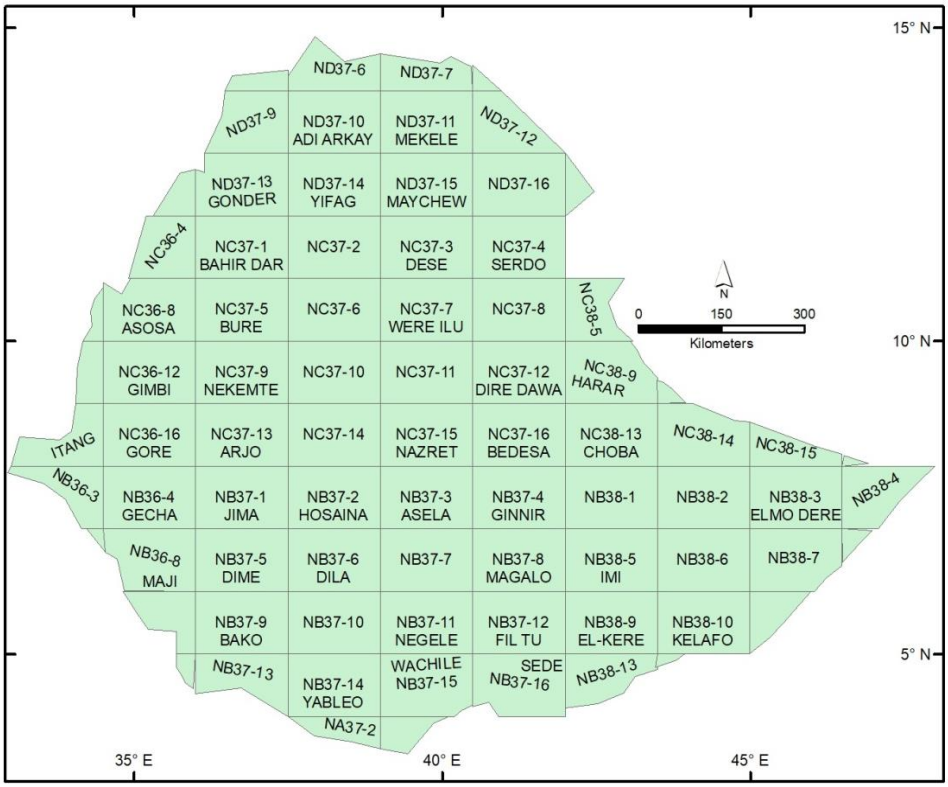

Figure 1. Scheme of archival 1:250,000 scale map series of Ethiopia

Overarching aspects of solutions for the identified problem:

Compiling a generalized geological map at a 1:1,000,000 scale (Output 1.)

The general geological map at a 1:1,000,000 scale will be processed on the basis of a re-interpretation of unpublished archive data from GSE (e.g. maps at various scales, reports and field documentation), (b) current knowledge about the geological environment of Ethiopia inferred mainly from published outputs and (c) results of the planned geological and geophysical survey in key areas. The map output will include a stratigraphic scheme, a geological legend, diagrams and explanatory notes summarizing the lithological and geological pattern of Ethiopia.

This map will be widely used by a wide professional community working in the field of geosciences and government officials in Ethiopia who need basic information about the geological environment. In addition, the geological map will serve as the base for other derivative maps for state and regional planning.

The geological map will be published in a total of 250 copies and will be feely accessible at the on-line web-map application on the GSE and CGS extranet.

Compiling generalized hydrogeological map at a 1:1,000,000 scale (Output 1.)

This part of the work will concentrate on processing the existing hydrogeological and hydrochemical maps at a scale of 1:250,000 and the related field hydrogeological data available, and to integrate it within the new geological map at a scale of 1:1,000,000, to be compiled as the first project objective. In addition, the main aquifers and hydrogeological zones across the country will be described along with the drilling of monitoring wells to be able to observe and make a quantitative evaluation of fluctuations in groundwater level which directly reflects changes in groundwater resources. The

hydrogeological map will be published in a total of 250 copies and will be feely accessible at the on-line web-map application on the GSE and CGS extranet.

Capacity building (Output 2.)

The establishment of sustainable capacity both for compiling national scale datasets in the form of maps and for using the outputs in all aspects of natural resources development and management is considered to be essential. In the process of the compilation work, a team of experts will take part and be involved in all levels of the map and data compilation as well as interpreting the monitoring data from boreholes in the case of experts in hydrogeology. On the other hand, training and awareness creating will be organized for experts from various administrative levels of the government and other stakeholders with a demonstration of how to use the map and dataset output from the project. The capacity instilled will support the continuation of regular groundwater monitoring using the new monitoring wells.

4. Stakeholder analysis

4.1 Project stakeholders / partners

The umbrella organization for foreign development cooperation in Ethiopia is the Ministry of Finance and Economic Cooperation (MoFEC), with whom the MoU is signed for all projects supported by the CzDA.

The main partner of the project is the Geological Survey of Ethiopia (GSE), which was involved in the identification of the project idea and the selection of stakeholders and will also participate in implementing and subsequently taking over the project outputs. The GSE is accountable to the Ministry of Mines and Petroleum and headed by the Director General and a Deputy Director (also called "Chief Geologist") who oversees the work of the core and supporting technical units in the organization. The GSE is legally responsible for collecting data and information on the rock environment, compiling maps in geosciences, and providing relevant documentation for decision-making to the Ethiopian state administration authorities. The GSE has five core directorates that work on specific themes: Geo-hazards Investigation, Groundwater Resources Assessment, Economic Minerals Evaluation, Basic Geoscience Mapping and Geothermal Resources Investigation. In addition, technical supporting units include Drilling Directorate, Central Scientific Geochemical Laboratory, Mineralogy and Petrophysical Laboratory, and Geo-Science Data Centre.

Ministry of Water Resources, Irrigation and Energy (MoWIE) will be a key stakeholder with regard to its plan to update the policy and strategy on the use of water resources. Particular attention will be paid to transboundary water resources including groundwater, which involves a number of cross-cutting issues by virtue of its connection with the management of other natural resources.

Regional and Zonal sectorial government administrations:

Water Mining and Energy Bureaus
Natural resources and Agriculture Bureaus
Environmental Protection Bureaus.
Basin Development Authorities (BDA)
Private sector – Civil Society Organizations

4.2. Target groups

The primary beneficiaries of the proposed mapping are public and private institutes that are responsible for developing sustainable infrastructures that guarantee rural and urban socio-economic needs. This includes:

- The state administration and eventually other organizations that will use the project outputs mainly for the purpose of supplying the population with reliable data and a baseline for providing safe drinking water and allocating natural resources as well as land for appropriate purposes.

- Safeguarding the living environment of communities from natural disaster risks and the preservation and efficient utilization of soil resources and the benefits of economic minerals in high potential areas (especially artisanal mining).

- Planners and federal and regional government decision makers responsible for regional and local development interventions.

- Non-governmental organizations that are active in the sectors of water supply, agriculture and rural development.

The final beneficiary of the project is the wider public (communities) living in areas that have an acute shortage of safe groundwater supply. They will benefit from the prepared maps which are crucial inputs for developing water supply schemes in their locality. It will help to reduce dependence on use of unclean and unsuitable water use for drinking and irrigation purposes. The geological map will also provide an opportunity for basing further prioritization of local development plans and natural resource management in a unified manner throughout the various regional states of Ethiopia.

4.3 Project support by the beneficiary country

The project was formulated on the basis of a request from the Ethiopian side, represented by the GSE, the main partner of the project. The GSE pledges to provide all the necessary information and cooperation in the processing of individual project outputs, including direct participation in the implementation of individual activities as well as financial contribution to the project in the form of in-kind contribution. The in-kind contribution refers to providing the available infrastructure and appropriate manpower involved in project implementation covering the salaries and other administrative expenses as well as arranging local permits and logistics plus a follow up on the work progress.

Agreement between the promoter and the partner would be signed at the start of the project. The Geological Survey of Ethiopia will hence:

- Provide offices, transport and related facilities as the basic requirements for the project.
- Ensure obtaining the necessary permits and letters for the project implementer.
- Provide GSE-owned data; these include, in particular, the provision of the available distance data, all archived geological maps and topographic data, hydrogeological, geophysical and climatic data.
- Ensure the selection of suitable experts for the joint working team and for training.
- Will actively participate at the joint field works to verify the main geological boundaries, regional tectonic structures and lithologies in key areas of entire region. Field work will take place in a total of 90 days.
- Provide the premises and technical facilities for the planned training and output processing (GSE building).

- On the basis of training and under permanent expert guidance of an external subject, the GSE staff will perform the basic digitization of the geological map.
- Create conditions for publishing outputs on their website, including installing an application showing groundwater level fluctuation on the organization's web site that will be accessible to public observers of the organization's data policy.
- Gather and pre-process basic geological and geophysical data.
- Will participate at the collection and interpretation of hydrogeological data from monitoring facilities and will realize five monitoring wells (100 - 200 m deep).
- Provide training in regions and other stakeholder organizations on how to interpret the results of groundwater resources monitoring.
- Plan for the future enlargement of a monitoring network and services in information about changes in groundwater resources for development planning, including abstraction permitting.

The above GSE support items included in the project in total amount to approximately 25% of the project budget funded by the CzDA. Capacity building by the GSE will be performed in the form of material purchasing for database, data collection and disseminations, and practical training in using of maps and monitoring results for GSE staff as well as professionals in regions.

5. Logical Framework of the Project

The main intent of the project is to fulfil the "Sustainable Development Goals (SDGs)" that were defined by United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030 (https://sustainabledevelopment.un.org/). These include mainly SDGs 6. "Clean water and sanitation" (chapters 6.1, 6.4, 6.6), SDGs 9. "Industry, innovation and infrastructure" (chapters 9.1, 9.2) and SDGs 15. "Life on land" (chapters 15.1, 15.2, 15.3).

The matrix of the Project's logical framework forms Attachment no. 1 and a comprehensive description of the intervention logic is given in this chapter.

5.1. Aim

The main aim of the project is to establish a basic, uniform, updated and interoperable geological information system between various map sheets that can address demands in the broader scope for natural resource utilization and environmental protection. In this regard the older geological map of Ethiopia at a scale of 1: 2,000,000 (Mengesha et al. 1996) as well as the hydrogeological map of Ethiopia at the same scale by Chernet (1988), which are based on very limited field and analytical data, will be significantly upgraded with the new knowledge obtained since then; this will affect its credibility as well as detail. Consequently, the new proposed maps at a scale of 1: 1,000,000 will be of prime importance in terms of strengthening various sectors. It will help foster principled and strategic regional management and planning for water resources and natural resources that will eventually contribute to efforts in improving access to clean water and the appropriate allocation of land in line with the SDGs of the United Nations Development Program.

With the unexpected occurrence of the COVID-pandemic and the downturn in the world economy, significant deterioration of social and economic conditions in Ethiopia can be expected. In the near future, the fastest possible path to recovery will be sought while minimizing the necessary costs. The modern and comprehensive processing of essential geoscience data in the form of hydrogeological and geological maps at scale of 1: 1,000,000 in printed and interactive on-line version with direct links to libraries and databases will enable the rapid acquisition of key information for anyone

working with geoscience data. These geoscience maps are an inventory of the state of the basic elements of the natural resources and terrain characteristics including basic rock types and their structures, surface and groundwater potential, soil conditions, the prevalence of natural disasters, and information on the land's suitability for infrastructure development.

In fact, this dataset is essential for planning and prioritizing infrastructure construction (roads, railways, settlement expansion and land-use planning, constructing water supply and irrigation systems etc.) which promotes the protection and sustainable usage of natural resources. High-quality geoscience data will undoubtedly enable a significant reduction in enormous costs and the risks for public and private investments. This is especially true in the case of countries like Ethiopia that suffer from numerous unpredictable adverse geological conditions resulting from a complex geological environment of which there is fragmentary knowledge.

There will be comprehensive data and map documentation (first phase of the Project) that will lead to the creation of thorough territorial / groundwater monitoring plans (the second phase of the Project) in key aquifers in Ethiopia. The outputs of the initial phase will make it easier to cope with the adverse geological phenomena (tectonic and seismic activity, landslides, rock-falls, formation of suffusion sinkholes etc.), while also contributing to the effective utilization and management of groundwater resources and ensuring their sustainable exploitation. Moreover, the project aims to develop the expert capacities of a wide spectrum of professionals from the GSE. They will acquire skills in compiling various types of geological and hydrogeological maps and monitoring groundwater resources and their changes (natural fluctuations, over-extraction, climatic changes).

The final outputs, in the form of a map and explanatory notes on the current conditions, recommended measures and an introduction to certain significant trends affecting changes in groundwater resources over time, will be handed over to the federal, regional as well as local authorities and communities.

The objectively verifiable indicator of this Project having a positive impact will be a real grasp of the trends in the quantitative and qualitative status of groundwater resources. Furthermore, the publication of a 1:1,000,000 scale geological map and a 1:1,000,000 scale hydrogeological map of Ethiopia will be another indicator.

The outputs of the project will also benefit other international donors by providing valuable basic information for implementing development interventions in Ethiopia.

5.2. Targets and Outputs

The primary aim of the Project is to compile a unified and well-made interoperable geological map of various localities in Ethiopia that supports the development of sustainable groundwater resources in key aquifers in Ethiopia. The targets will be accomplished through the following outputs:

Output 1. Creating general geological and hydrogeological maps on a 1:1,000,000 scale

The general geological and hydrogeological maps at a 1:1,000,000 scale and explanatory notes will be processed on the basis of compiling all the archive maps and data (database of GSE), published literature as well as the current knowledge inferred from the results of geological and hydrogeological investigations in selected areas (an integral part of this project). The maps will be made using advanced GIS / cartographic methods and published.

In addition, the main aquifers and the hydrogeological zones will be described and supplemented with monitoring data from boreholes to observe fluctuations in groundwater level which reflects changes in groundwater resources.

Activities leading to Output 1:

Activity 1.1. Review and appraisal of the existing sets of archived maps and other literature

This working phase will be focused on evaluating and processing existing geological, hydrogeological and hydrochemical maps at a scale of 1:250,000 (or more detailed) and all of the archive documentation (database of GSE). In addition, all published literature, such as journals and reports, will be incorporated. Responsible person: K. Verner, L. Megerssa.

Activity 1.2. Creating a topographic base map

The necessary cultural and topographic base map will be derived from a detailed analysis of the Digital Elevation Model (DEM) and satellite images at a scale of 1:750,000. The current administrative structure of Ethiopia will be incorporated into the map. Responsible person: T. Hroch.

Activity 1.3. Geophysical data re-interpretation

Compilation and re-interpretation of existing regional geophysical data (database of GSE) to enhance the correlation and delineation of regional geological units and structures (e.g. faults) important for the overall geological pattern. Responsible person: J. Valenta.

Activity 1.4. A regular workshop on the progress of the working teams set up

Organizing a regular workshop to discuss and integrate the progressive results of individual working teams reflecting partial scientific topics (e.g. quaternary geology, sedimentology, volcanology, metamorphic and igneous petrology, tectonics) as explained in Chapter 5. The workshop will be organized twice per year in 2021, 2022 and 2023. Responsible person: K. Verner, L. Megerssa.

Activity 1.5. Field work in selected areas / transects

Field work (90 days in total for all working groups) at key transects in order to resolve unclear or doubtful geological and hydrogeological issues that need to be settled for map compilation. Responsible implementers: leaders of working groups (K. Verner, D. Burianek, R. Nadaskay).

Activity 1.6. Drilling groundwater monitoring boreholes (5 sites)

Drilling five monitoring boreholes in the most important aquifers (total drilling 800 meters) with data loggers using the drilling and laboratory capacity of the GSE. A detailed groundwater resources assessment will be made and the annual quantitative analysis will be processed and described in the guidebook. Responsible person: J. Šíma.

Activity 1.7. Creating a geological map at a 1:1,000,000 scale

The compilation of geological map at a scale of 1:1,000,000 for the entire territory of Ethiopia based on archive maps (activity 1.1. and 1.2), geophysical and remote sensing data (activity 1.3.) and new field geological data obtained based on regional transects (activity 1.5.). Responsible persons: leaders of working groups (K. Verner, D. Burianek, R. Nadaskay).

Activity 1.8. Creating a hydrogeological map at a 1:1,000,000 scale

The compilation of a hydrogeological map, including groundwater resources and the hydrochemical (groundwater quality) pattern of Ethiopia, at a 1:1,000,000 scale based on an integration of the overall geological pattern (activity 1.7.), existing 1:250,000 scale hydrogeological maps and hydrogeological data available (activity 1.1.), remote sensing data (activity 1.3), the field hydrogeological inventory including new boreholes (activity 1.5. and 1.6.). Responsible person: J. Šíma.

Activity 1.9. Compiling an explanatory booklet and groundwater monitoring reference guidebook

The explanatory notes (ca 50 pages in total) including a basic description of the lithology, stratigraphy, tectonics, hydrogeology, and the overall geological evolution of the country will be published. In addition, a guidebook (ca 50 pages in total) dealing with a detailed description of the groundwater resources in aquifers (e.g. natural variations, climate and pumping) will be processed separately. Responsible person: J. Šíma, K. Verner.

Activity 1.10. Interactive web-map application

An interactive web-map application, showing the geological and hydrogeological maps hosted on the GSE / CGS web-server linked with references to relevant literary works, existing maps and reports, will be created. This application will be freely accessible for all users. Responsible institution: GSE

Indicators and results tied to Output 1:

- Published maps (on-line interactive and hard-copy version; 250 in all).
- Published explanatory notes describing the overall geological and hydrogeological setting of the country (250 in all).
- A synoptic table of the fault network bearing attribute sources of information and the importance of structures (for any fault structures displayed on the map).
- A guidebook summarizing quantitative groundwater resources in Ethiopia including a definition of the hydrogeological zones (most important aquifers) and the groundwater quality (50 in all).
- Establishing a groundwater monitoring network in five selected aquifers.
- Interactive web-map application of the geological and hydrogeological maps at a 1:1,000,000 scale hosted by the GSE (CGS) server providing on-line information about geology and groundwater resources.
- The number of visitors to the on-line web-map application and references in wider spectra of professional / applied outputs.

Output 2. Increasing professional capacities and promoting output maps

The professional capacities of employees from governmental offices and collaborating experts will be increased through the processing and final promotion of the 1:1,000,000 scale geological and hydrogeological maps as well as a demonstration of the practical usage of all the outputs. The skills

for independently carrying out high level geoscientific data compilation that can be transferable to the wider public and high level decision makers will be achieved for at least 12 experts at partner institutions in Ethiopia (GSE, regional and federal authorities as well as ministries). Furthermore, awareness will be created for the expedient, routine utilization of the geoscience map outputs during the relevant decisions and planning. This will increase the professional capacity of collaborating experts and government officials in their planning and execution of development programs taking into consideration the natural resources at hand (geological environment including groundwater resources). Eventually, experts and decision makers from regional to federal sectoral authorities will be aware of the expedient, routine use of the geoscience map outputs during the relevant decisions and planning.

Activities leading to Output 2:

Activity 2.1. Counterpart experts' capacity building in compiling maps

There will be practical training for GSE / local sectoral experts such as geologists, hydrogeologists, GIS experts and hydrologists in all parameters of the project and the fields of competences (compiling and interpreting geoscience data, water well monitoring, data processing).

Activity 2.2. Enhancing the capacity of stakeholder experts in groundwater data management

Comprehensive training for hydrogeologists and water management experts from federal regions in order to effectively manage and protect groundwater resources.

Activity 2.3. Promotion and dissemination of the outputs

Dissemination and promotion of geoscience maps (output 1) to those experts concerned at the local and regional level (in printed and on-line interactive versions) in order to empower its usage at the regional offices, universities, and other institutes.

Indicators and results tied to Output 2:

- The number of development programs and published outputs in the country citing or referring the geoscientific maps will increase.
- An increasing number of experts that are able to independently carry out future and further high-level geoscientific data compilation that can be transferred to the wider public and high-level decision makers.
- Attendance lists and evaluating the results of co-operating experts, photographs and annual reports.

5.3. Technical specifications of the Project

The Ethiopian territory has three major lithotectonic domains relevant for the creation of a complete map: (a) Basement or metamorphic rocks and intrusive igneous rocks, (b) volcanic rocks that have a range of geological ages ranging from the older Ethiopian Plateau to the Main Ethiopian Rift (part of the Great East African Rift Valley) and (c) Sedimentary rocks of Palaeozoic to Quaternary age. Hence it is proposed to form three working groups with a specialization in each of these different terrains. These groups will constitute experts from the Ethiopian side as well as the Czech side. There will be additional support from experts in geology, who will also assist across the various disciplines of the

map. The above prescribed approach calls for a need to keep track of the changes and progress of the work carried out by each group, and hence joint workshops/meetings of the working groups will be held with options to hold short field check-up trips to key areas twice a year for the project duration, from 2020 to 2023.

Additional expertise will be contracted individually to strengthen the project team's capacities in various activities such as geophysical data interpretation to resolve major discrepancies, if they arise from a lack of essential information in the existing 250k maps.

The maps will be compiled in accordance with the international standard following the latest practice. The maps will form a semantically and technically interoperable geological dataset, harmonized for Ethiopia at a 1:1,000,000 scale. This will be implemented based on the geological data prepared for each of the 87 map sheet grids at the Geological Survey of Ethiopia. The individual maps at a 1:250,000 scale differ considerably with respect to their contents, description and geometry. To make these data interoperable will be the key task. The standard of the Geological Mapping at the Geological Survey of Ethiopia (RGGD Standard 2000) will be adapted as much as possible with amendments whenever a shortfall arises to ensure its updating and future extension by the Geological Survey of Ethiopia is sustainable. Furthermore, the maps will be digitally processed and adapted to an online web based interactive application for ease and a wider outreach to the public.

5.4. Methods to be used

All work on the project will be carried out using modern methodical procedures described below.

At first, the topographic base map will be created by ArcGIS tools based on Digital Elevation Model (DEM) and remote sensing data. Digital elevation model with a resolution of 30 m ASTER DEM and SRTM DEM will be used to generate relief map with hill-shade and main topographic features (contour lines and the drainage network). The topographic features including a drainage network, lakes urban agglomerations and infrastructure will be updated on the basis of available optical satellite images (Landsat and Sentinel). New administrative division of Ethiopia will be included.

Review and appraisal of the existing archive of geological maps

The map compilation mainly relies on existing published and unpublished archives of higher scale maps already available in the Geological Survey of Ethiopia at different scales. Generation of new primary analytical data will not be in the scope of the methodology rather depending on existing archive of data. The main set of data for the compilation will be the set of 1:250,000 scale geological and hydrogeological maps currently covering the entire territory of Ethiopia. In addition, other published maps and more detailed maps will be incorporated in the processing of the 1:1,000,000 scale geological and hydrogeological map. Geochronological, petrological and geochemical data from various projects and publication will form the source for analytical data needed for the characterization of the geological units in various domains. Geophysical exploration data from prospecting of oil, gas and geothermal resources in some of Ethiopia will also provide additional source of subsurface information as required. Satellite data of digital relief models and multispectral satellite images will be used for constraining morphological expressions of geological structures and lithological boundaries.

The regional gravity data assessment

The available regional gravity data from the host institute of the Geological Survey of Ethiopia covers almost the whole of the Ethiopian territory (Figure 1, archive of the Geological survey of Ethiopia).

Most of the data were collected along the main roads throughout the country which implies that large portions of the country remain unexplored. The exceptions are basin areas in the west and east of the country which were systematically sampled during oil prospecting. A review of the additional regional gravity data is made to shade some light on the various efforts of harmonizing and utilizing to discriminate various regional geological units (Woldetinsae and Götze, 2005).

In the unpublished archive data of the Geological Survey of Ethiopia, the distance between measured points along the main roads generally varies between 3 to 5 km, although there are several places where the data sampling is halved. The distance between samples in the high-density measured areas is, again, 3 to 5 km in both (NE) directions making roughly up to 8 points per 10 km^2. The spatial gravity data sampling and distribution implies that, although the data could be recalculated to a regular grid for the entire Ethiopian territory (Figure 2. and 3.), there are areas with low or even no coverage (e.g. along the boundary of the Oromia-Somali region). The gridded data could be used to calculate derived datasets (e.g. horizontal derivatives, Figure 4.) directly applicable for geological interpretation. Within the areas with a high data coverage (e.g. the westernmost part of the Gambela area) the maxima of the gradient could be directly used for mapping the lithological boundaries. The 2D geological models (sections) should hence be limited to profiles following the roads along which the data were collected and avoid crossing unexplored areas.

Reliability of gravity data depends on several factors. Leaving aside the skills of the operator, the key factors are the quality of the gravity meter and the accuracy of the elevation measurements. Whereas the former (the gravity meter quality) seems to be sufficient, the latter (the quality of elevation measurements) is uncertain. In the case of the unpublished archived data of the Geological Survey of Ethiopia, not much information about the error of measurements and calculations are available and hence only a general overview of the data set are highlighted in this proposal that would be resolved in the process of the actual implementation of the mapping. The report accompanying the datasets explicitly states that sometimes the field elevation measurements were taken from the Digital Elevation Model (DEM) or 1:50 000 maps which are less reliable. Hence, it can be assumed that the errors in elevations can reach up to a value of 1 meter (or more) which makes an error of approximately 1 mGal. Such accuracy is adequate for regional modelling but could lead to problems during a local high-resolution interpretation. Another point concerns calculating terrain corrections which according to the accompanying report states that the terrain corrections were calculated based on a DEM with a 1 km cell size. This might not be sufficient for the hilly areas, hence it is suggested to recalculate them using a more detailed DEM. Moreover, part of the dataset is missing the corrections completely (approximately 10% of the data points), which prompts for recalculation of the corrections in the data processing.

In conclusion, the present dataset could be used for small-scale geological mapping (e.g. 1:1,000,000 scale) where it can be used for delineating geological units and, above all, 2D modelling along selected profiles. The density of the data points and questionability of the elevation measurements, however, do not allow the data to be used for detailed mapping (with the exception of the Western and eastern sedimentary basins and the central Main Ethiopian Rift).

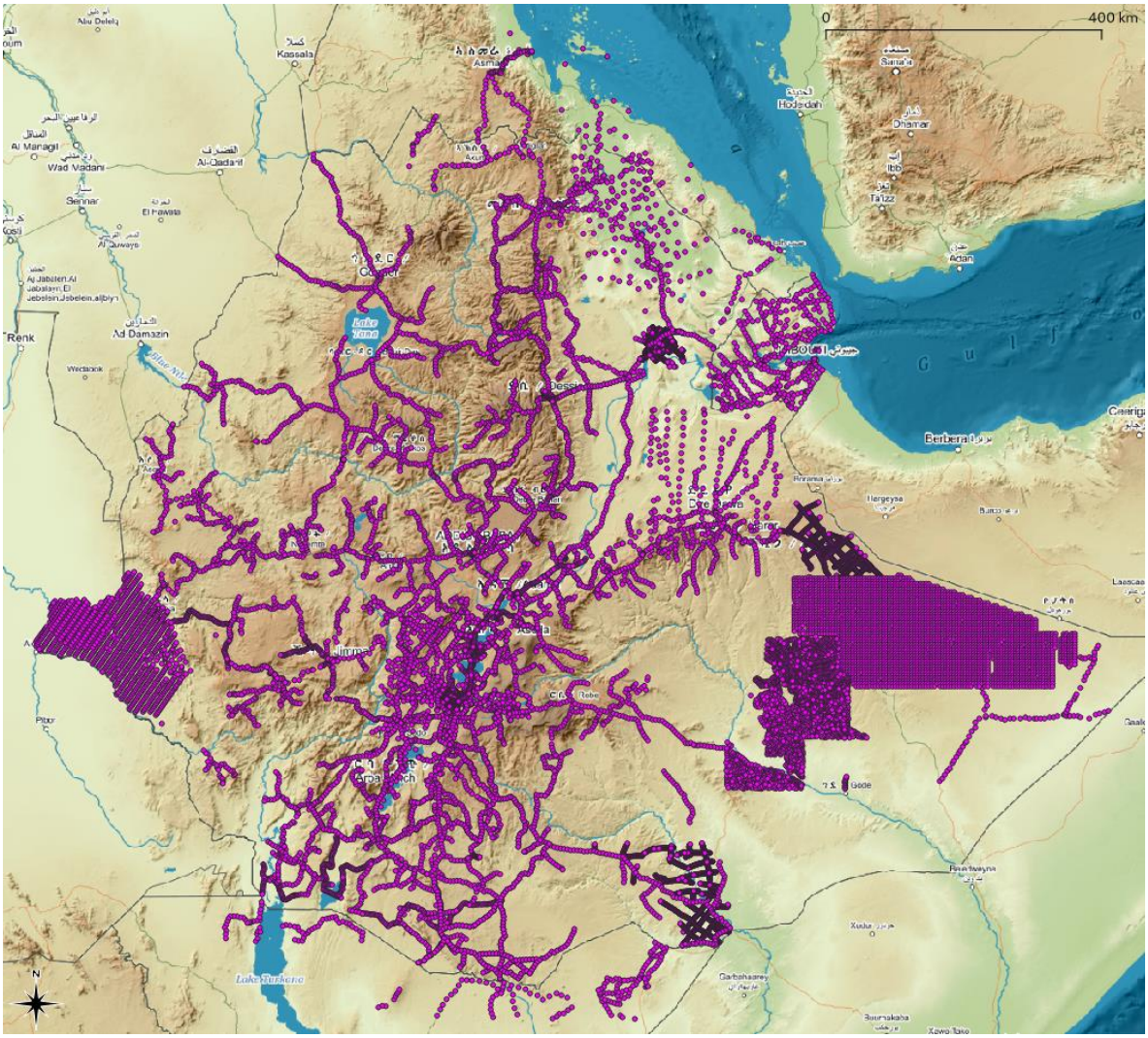

Figure 2: The coverage of the Ethiopian territory with the gravity data (the magenta dots). Most of the data were collected along the main roads and hence large areas of the country remain unexplored (data source: Unpublished archive of the Geological Survey of Ethiopia).

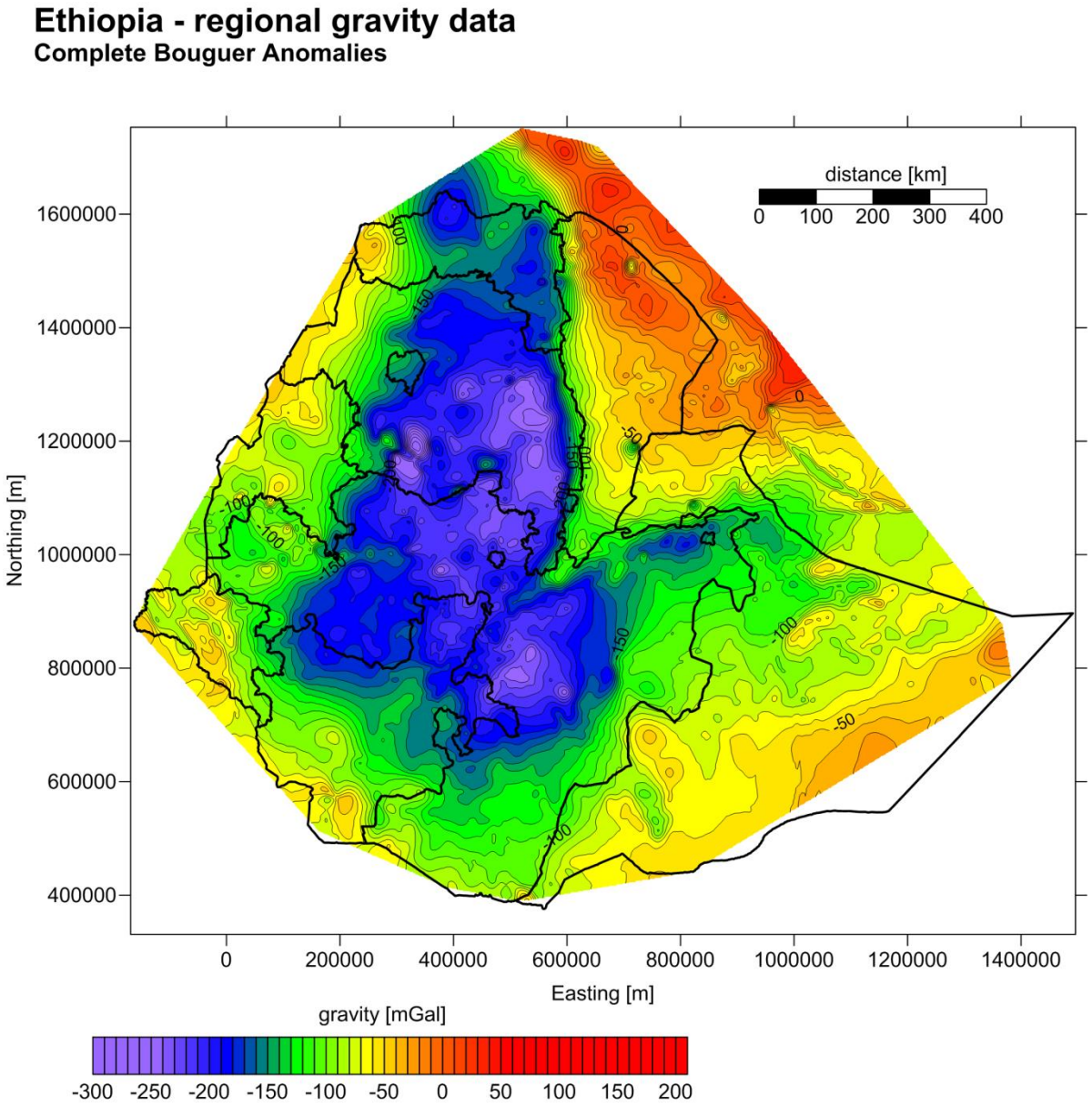

Figure 3: Bouguer anomaly map of the Ethiopian territory based on the available gravity data. The most pronounced is the gravity high corresponding to the low-lying areas of the rift with the newly formed oceanic crust flanked by the gravity lows of the Ethiopian highland. Map coordinates – UTM37N (data source: Unpublished archive of the Geological Survey of Ethiopia).

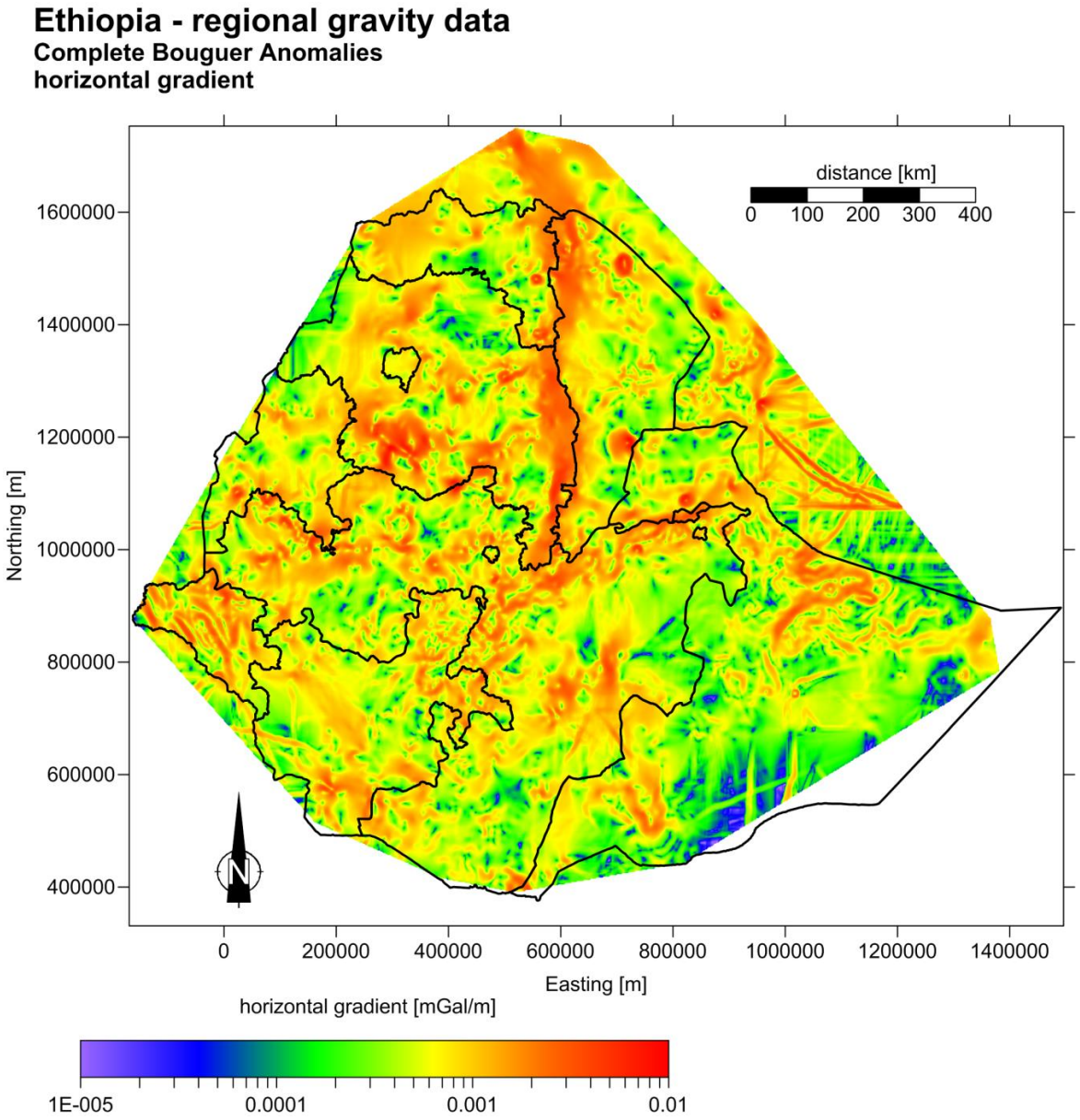

Figure 4: Horizontal gradient of the Bouguer gravities. In the high-density mapped areas (e.g. the westernmost part of the Gambela region) the gradient data could be used for the direct mapping of lithological boundaries. Map coordinates – UTM37N (data source: Unpublished archive of the Geological Survey of Ethiopia).

The compilation of 1 :1,000,000 scale maps

For compiling the geological map, six reputable experts having knowledge of basement units, volcanic rock assemblage and sedimentary cover were selected from the Czech side (see chapter 6.8.). In addition, six Ethiopian counterparts assigned by the local host institute – the Geological Survey of Ethiopia and six experts from other collaborating institutions will be included in the working team counting 18 experts in total. Three working groups will be established according to the professional focus of the experts. The task will proceed with each group working independently to process a geological map of selected units according to the regional-geological division (basement units, sedimentary units and rift-related volcanic assemblage). The working groups will meet twice a year for 1 week. At each event, all members of the three groups will analyse and integrate their individual outputs, and jointly put together the map units and interpretations. This will constitute the core of the project's implementation. The initial stage will be focused on evaluating and assessing the

existing archive data / maps. This will help to pinpoint areas requiring further inquiry. The next step will include field verification in key areas / transects. The geological units will then be re-interpreted fully respecting the concepts and current international rules and norms of modern geological maps (Hanžl and Verner eds. 2018). The legend with detailed information on the new units of the lithology and structures will be incorporated into the map, including informative stratigraphic columns of various domains and conceptualized models explaining the evolution of the terrain in general over the years covered by the rock units in the territory.

The basis for a hydrogeological map at a 1:1,000,000 scale will be derived from the geological map. The information necessary for the hydrogeological interpretation comes from the extensive database of the completed hydrogeological archive maps (1:250,000 scale) and an additional inventory of new water points. The final version of the hydrogeological map will be processed based on a common methodical approach summarized in the guidebook Hanžl and Verner eds. (2019).

The final map outputs will be submitted for review and approval by an international scientific committee and published. For the sake of clarity, the geological map will be published on 3 separate sheets so that the scale of 1:1,000,000 will be easily readable in hard copy when printed.

Both map outputs will have complete metadata and an extended legend that will make it easier for the lay public to understand the various features of the map. The final map will be digitally coded for use on the Internet and distribution in digital copies according to the data policy of GSE, the main partner of the project.

Conversion of the compiled draft of 1:1,000,000 scale geological and hydrogeological maps to digital format and making it available on an online server.

The final map will be sent for conversion to GIS processing and lay out preparation. The final maps will also be customized for online use. Identification and verification of existing literary works (maps, data, and reports, diagrams) will be carried out and indexed in a structure that will allow efficient geographic integration and linkage to the map that will be compiled at a 1:1,000,000 scale. This is envisaged to be implemented in the following manner. A user would click a particular area of interest in the on online digital geological or hydrogeological maps that will raise a query guiding the user through an exploration of the underlying linked geological reports and/or maps available in some proximity to the area. Hence, the user will only get the references to the available detailed information which can be later obtained by digitally submitting a request and fulfilling the requirements pursuant to the data policy of the host organization (the Geological Survey of Ethiopia), which should prepare the requisite items and send them back to the user in time.

5.5. Overall time schedule for the project

The overall time schedule of the project forms Attachment no. 3 of this project document. Below is the narrative expanding on Attachment no. 3:

I. phase (July to November 2020)

First meeting of working teams from all sides in Addis Ababa, for a minimum of 7 days to evaluate the archived geological data and base maps as well as a division of tasks for the following period (see below).

Working groups for 3 thematic areas corresponding to metamorphic terrains, sedimentary terrains and volcanic terrains will be established with experts from reputable institutes and individuals with

extensive experience in the respective fields, 2 from the Czech Republic and 4 from the Ethiopian side as counterparts. Additional support experts and coordinators will be assigned from the Geological Survey of Ethiopia. Concept work in the field of hydrogeology – revision of previous regional hydrogeological maps and existing 1:250,000 maps and reports – site selection for drilling boreholes to monitor the prominent aquifers.

A detailed review of existing data such as geophysical and remote sensing will be undertaken in parallel with an evaluation of the existing completed individual geological maps at a 1:250,000 scale. Regional faults will be outlined as derived from the integration of previous maps, geophysical data and remote sensing data.

The preparation of official topographic data and cultural features, which will be presented together with the geological map, will be prepared at a nominal scale of 1:750,000 to have as much detail as possible displayed on the final geological map. The creation of a basic topographic map based on a detailed relief analysis (DRM) using state of the art GIS tools (ArcGIS) at a scale of 1:750,000.

Uniform legend processing and its harmonization will be carried out in tandem with all geological units represented in the completed standalone individual map sheets at a scale of 1:250,000 and new accumulated analytical data in publications since the publication of the last national geological and hydrogeological maps of Ethiopia at a 1:2,000,000 scale in the 1990s.

The creation of a coherent fault network based on an evaluation of the available archive data, an evaluation of the existing geophysical data and an analysis of the relief model and remote sensing.
The existing literature (maps, data, and reports, diagrams) will be identified and verified to allow efficient geographic integration and linkage to the maps that will be compiled at a 1:1,000,000 scale.

II. – IV. phase (December 2020 to June 2022)

Individual working groups' activities will be carried out where there will be meetings (3 x 15 days in Addis Ababa) organized to compile the progress and identify problem areas for a brief field check-up. Each working group prepares its plan and selects key field areas to resolve outstanding problem areas in terms of compiling the work and undertakes a field check during this period. At the end of this period a project progress report with all aspects will be prepared. Based on the previous 1.5 years, the individual groups' compilation results, a hand drawn sketch of a harmonized draft geological map at a 1:1,000,000 scale will be put together during this period. Based on the draft geological map, the hydrogeological units and elements will be delineated in tandem with the archive 1:250,000 scale hydrogeological maps and field transects will be identified for additional data to fill in missing gaps.

The groundwater balance of Ethiopia, the drilling of monitoring boreholes and the installation of data loggers will be prepared. Data from a data logger will be downloaded twice a year (end of dry season and after rainy season) and published in the form of water level fluctuation graphs (for time series data collection and producing a hydrograph of the ground water). The creation of a Monitoring Manual for groundwater balance in the main aquifers based on monitoring groundwater level fluctuation.

Continued identification and verification of the existing literature for indexing will be carried out and structures in a manner efficient for geographic linkage to the map that will be compiled at a 1:1,000,000 scale.

V. phase (July to November 2022)

The draft 1:1,000,000 scale geological and hydrogeological maps will be put out for a round of review by stakeholders in Ethiopia and a panel of experts at the Czech Geological Survey. The recommendations and suggestions will be incorporated during this period to improve any shortcomings as necessary.

Each of the working groups in the specific domains will start with the correlation and/or re-classification of the existing geological units. Issues arising due to incompatibility or a mismatch between various map sheets, which are not resolved based on the archive maps and literature in each work group domain, will be selected and brought up at the joint meetings for discussion. If no resolution can be found, a field reconnaissance will be made to key sites. The final completed individual map domains will be jointly put together for the creation of the draft initial map. GSE and external subject will digitize the final united and revised draft maps under the supervision of the CGS. The information system will be designed by IT experts from the CGS and optimized for digitization, cartographic processing and final on-line publication in the form of a web map on the map servers of the GSE and CGS.

The first results of hydrogeological monitoring will be presented to the Regional Water Bureau experts and representatives of Regional Governments in the regions (8).

Continued identification and verification of the existing literature for indexing will be carried out and structures in a manner efficient for geographic linkage to the map that will be compiled at a 1:1,000,000 scale.

VI. – VII. phase (December 2022 to November 2023)

A concise description of the elements in both map outputs will be prepared with a nominal range of ca 30 pages. Selected tabular data of the geochronological and other specific available data sets from various sources will be supplied in electronic form for various interest groups. After comments and review, the finalized draft maps will be submitted for further refinement and standard cartographic and digital processing. The establishment of an online server for making the output available through the internet will also be implemented during this period.

The finalization of the description and definition of the hydrogeological zones (main aquifers) with an assessment of the groundwater resources will be provided. Selected tabular data of the monitoring results and borehole logs from monitoring wells will be supplied in electronic form for various interest groups.

After the review at the CGS and GSE, the finalized draft maps will be submitted for further refinement and standard cartographic and digital processing. The establishment of an online server for making the output available through the Internet will also be implemented during this period.

The indexed and verified existing literature will be linked with the 1:1,000,000 scale geological and hydrogeological maps out based on the geographic position of any place in the map wherever the data is available.

Graphic finalization and editing of all map outputs and the explanatory notes, ready to be published (at least 250 copies). Processing of the electronic interactive on-line version that will be available to all users on the GSE server.

6. Quality and sustainability regarding the results of the project

6.1. Recipients' participation and ownership of the projects

The Geological Survey of Ethiopia (GSE) is the key partner for the implementation of the Project. The project proposal as well as this project document has been processed on the basis of the GSE's initiation document named "Letter of Interest" and the results of the mission formulation. The exact definition of the requisite outputs and the comprehensive time schedule have been defined. The implementation of the Project will be carried out with the active participation of the GSE, and, if deemed by the GSE to be necessary, senior former employees of the GSE with extensive experience in the different terrains of Ethiopia. The GSE will be considerably involved in the activities, while being the main recipient of particular outputs of the Project. All equipment obtained within the Project will be handed over to the GSE for further relevant use at the end of the Project. The GSE considers the implementation of the submitted Project as one of the ultimate goals to improve the availability of comprehensive geological and hydrogeological information for the entire nation, and thus its maximum support is anticipated.

6.2. Secondary effects of the Project

Apart from the generation of the geological and hydrogeological map and groundwater resources assessment the project will also serve as a base for further compilation or adoption of nationwide thematic maps ranging from environmental protection to the potential utilization of economic minerals or an evaluation of susceptibility to geological hazards as well as a delineation of the soil environment. In addition, there is the reputation and experience created in terms of the skills involved in compiling secondary data for a common platform. It will also alleviate the discrepancy in the lack of sufficient geological information on various terrains of the country for planning regional development priorities and creating public awareness about the environment.

6.3. Social and cultural factors

The aim of the Project takes into consideration the local specifications within the region, the relations between all the interested parties, the definition of working relationships, customs and other relevant factors in order to minimize the risks. In the long term, the Project will contribute to improving the geological and hydrogeological information system, the protection and sustainability of the groundwater and natural resources for the community and thus to strengthen overall social stability. Informed decisions and management of the various land uses respecting the availability of suitable geological and water resources will help to increase better use of natural resources for the manufacturing initiative as well as agricultural practices. Such endeavors are likely to facilitate a transition to food self-sufficiency as well as to increase the incomes of households.

6.4. Equal opportunities for women and men

The outputs of the project will have concrete recommendations and assessments as well as prioritization of the groundwater resource and its utilization that will alleviate the burden of many women in rural areas of the nation. The available information will help to identify priority areas needing immediate attention. In addition, there is the potential economic benefit from other natural resources such as artisanal mining or farmland suitability identification (with respect to the underlying rocks that form the soil environment). Moreover, it can serve as an alternative means for earning income for women and youth where the unemployment rate is very high.

6.5. Suitable technologies

The utilization of modern methodical procedures and a multidisciplinary approach during the resolution of the Project will allow the effective creation of all the defined outputs (geological and hydrogeological maps). Part of the solutions for the Project is represented by training in and teaching about modern methodologies for Ethiopian professionals, who will carry out the processing on their own in the future. The know-how shared will benefit the participants of the project on the recipient's side.

A commonly available technology will be an expansion of the pilot online hydrogeological map at a fragmented 1:250,000 scale so that it has a digital vector data and incorporates the geological base map of a similar 1:1,000,000 scale on the online server. This will support the effort of the GSE to increase its outreach to end users of the geological and hydrogeological information in an easy and transparent way. In addition, expansion of automated monitoring of groundwater quality and dynamics with online information is a key step in providing timely and practical information for users.

6.6. Environmental impacts

In all, the implementation of the Project will have a positive impact on the environment and its use, while contributing to meeting the targets of The United Nations Framework Convention on Climate Change (adaptation) and The United Nations Convention to Combat Desertification. The creation of geological, hydrogeological and other subsequent thematic maps will lead directly to the design of landscape plans that will include the measures related to the more efficient use of farmland, reduction of soil degradation as well as the adverse effects of floods, landslides and deforestation.

6.7. Economic and financial viability of the Project

The implementation of the Project is financially dependent on the stability of financing from the sources of Foreign Development Cooperation of the Czech Republic and sufficient financial backing from the GSE, the partner institution, from the national budget of Ethiopia during the implementation of the Project as well as afterwards. Given the declared priority of the measures, it is possible to predict a high probability of their maintenance and subsequent development. The long-term maintenance of outputs and the effects of the Project will also be ensured by a continuous transfer of outputs to the local partner and recipients of the Project. The initiation of the Project reflects the long-term priorities of the Ethiopian policies in the areas of the water sector and the management of natural resources.

6.8. Management and organization

The Czech Geological Survey and Aquatest a. s. have a long-term tradition of working in Ethiopia since 2010 and 2001 respectively through projects in the fields of natural resource management, education, water, development of agriculture and land protection. Cooperation with the partner institution of the Project is necessary for its successful implementation; this is provided by mutual communication, inspection of task fulfilment and effective use of finances. The works within the Project will be managed by two subjects simultaneously – the leader of the Project nominated by the CGS and the counterpart nominated by the GSE where they will be designated as editors. The processing teams will be under these working leaders, where the Czech experts are under the Project leader nominated by the CGS, being responsible for the completion of map activities (work of the editor), while the Ethiopian professionals are under the Project leader nominated by the GSE, being responsible for the assurance and implementation of map compilation as well as the coordination of the intervening workshops. Three teams, i.e. one team for each of the metamorphic, sedimentary and volcanic terrain will constitute a team with 2 geologists from the Czech side and 4 geologists

from the Ethiopian side. In total, 18 experts, all with strong and deep experience in the particular terrain, will participate on the Project and act as co-authors of the map. Additional studies and expertise needed from outside of the main authors will be outsourced through individual contracts with the specific objective such as geophysical interpretation, remote sensing interpretation and digital cartographic development.

The list of selected cooperating persons including their basic professional characteristics is given in the table below.

Implementer name	**Field of expertise and function**	**Practical experience**	**Responsibility for particular outputs**
Assoc. Prof. Dr. Kryštof Verner, Ph.D.	Main coordinator of the Project. Expertise: Structural geology and geological mapping	16 years of experience in the fields of structural geology and geological mapping, 7 years of resolving a Foreign Development Cooperation (FDC) project in Ethiopia, 1 year in Mongolia, research projects in the United States and Austria. 14 years of teaching experience in the fields of petrology and geoscientific mapping at the Faculty of Science, Charles University in Prague.	Responsible implementer of the Project in terms of finances and expertise. The guarantor for outputs and main editor of the geological map.
Dr. Jiří Šíma Aquatest	Deputy coordinator of the Project. Expertise: Hydrogeology	40 years of experience in the field of hydrogeology in Africa.	Leader of the hydrogeological mapping team. The guarantor for outputs and main editor of the hydrogeological map.
Dr. Vladimír Žáček	Expertise: Geological mapping, petrology of rock complexes, mineralogy.	34 years of experience in the fields of geological mapping, mineralogy and petrology. A member of research mapping teams in various FDC projects in Africa (Zambia, Namibia, Ethiopia) and South Central America.	Co-editor of the geological map (member of the team).
David Buriánek, MSc., Ph.D	Expertise: Geological mapping, petrology of rock complexes, rock geochemistry.	18 years of experience in the fields of geological mapping and petrology of metamorphous complexes Research projects in Central America, Mongolia and the Czech Republic.	Co-editor of the geological map (rift-related volcano-sedimentary sequences terrain; team leader)

Karel Martínek, MSc., Ph.D.	Expertise: Sedimentology and remote sensing analysis.	24 years in the field of sedimentology, 18 years in the fields of remote sensing and geo-information systems, FDC projects in Ethiopia, British Guyana and Afghanistan, other geological expeditions in Iran and Argentina. 22 years of teaching experience at the Faculty of Science, Charles University in Prague.	Interpretation of the remote-sensing data, compilation of the platform sedimentary cover units (member of the team).
Roland Nadaskay, MSc.	Expertise: Sedimentology and geological mapping of sedimentary formations	8 years of experiences years in the field of sedimentology	Co-editor of the geological map responsible for compilation of the platform sedimentary cover units (team leader)
Tomáš Hroch, MSc.	Expertise: Quaternary geology, geomorphology and geological hazards	13 years in the fields of sedimentology, geological hazards and geomorphology, 8 years of resolving FDC projects in Peru, 7 years of resolving FDC projects in Ethiopia, 6 years of teaching experience at the Faculty of Science, Charles University in Prague	Accuracy of outputs for the part of geological quaternary cover and remote sensing analysis.
Leta A. Megressa, MSc. et MSc. (Ethiopian nationality)	Expertise: Tectonics, engineering geology and geological hazards	10 years of experience in the fields of engineering geology and geological hazards. Former Director of Geological Hazards Department at GSE. Currently a doctoral student at the Faculty of Science, Charles University in Prague.	Geoscientific mapping, leader of the Ethiopian mapping team. Assistance with administration of the Project. Implementation of outputs and management of workshops
Ondřej Noll, MSc.	Expertise: Hydrogeology	16 years of experience in hydrogeology and modelling 10 years of experience in Ethiopia and Peru	Chapter hydrology, water balance recharge installation of data loggers
Otmar Petyniak, MSc.	Expertise: GIS	5 years of experience of IT-GIS expert at CGS.	Final cartographic map processing.

7. Risks and assumptions analysis

The primary assumptions for a successful resolution of the Project include the lasting interest of the Government of Ethiopia as well as the partner institution.

The following parameters are considered as the primary assumptions for achieving the aim of the Project:

- The lasting interest of the Government of Ethiopia, partner institution in sustainable natural resource utilization.
- Priority of water sector in the development plan of the country
- All information campaigns supported by international organizations will be positively received by all subjects.
- Visible interest of GSE employees in terms of the implementation of new procedures

Specific risk factors that may affect the resolution of the Project are given in the table below.

Risks	Possible influence	Strategy how to overcome adverse effects
The partner institution will no longer be willing to cooperate, fulfil its duties and support necessary and relevant documentation (particularly the declared in-kind and expert contribution of the partner GSE)	Significant	The disinterest of the local institutions and individual officers of the local administration will be tackled through the implementers working intensively with local experts, communities as well as local institutions. The implementer has great experience in this field; therefore, it is possible to assume that the Project could be solved by own means on the basis of compensation related to the stoppage of the in-kind cooperation.
A considerable change in the exchange rate of the CZK against the ETB.	Significant	The change in exchange rate of the CZK against the ETB represents an unavoidable risk with regards to the recent development of this rate. The possible significant changes in this rate will be resolved by an agreement between the Czech Development Agency, the recipient and the Project implementer by changes in the scope of the Project and shortening/prolonging the period of the implementer's stay in Ethiopia etc.

The Project will not be approved in time by the relevant Ethiopian authorities and the agreement with FDR Ethiopia (Ministry of Finance) will not be signed.	Medium	So far, the implementer has been successful in obtaining the necessary permissions in Ethiopia (including the signature of an agreement with FDR Ethiopia; Ministry of Finance) for the implementation of projects within the given territory (SNNPR) with no time prolongations.
The implementer will not be granted the funding needed for the entire duration of the implementation of the Project.	Significant	So far, the implementer has been able to obtain the necessary funding needed for the implementation of projects within the particular territory. In the opposite case, it would be inevitable to reconsider the implementation of the Project.
Spreading of a pandemic and associated health / travel restrictions in the region of interest (e.g. Covid-19 international as well in between Ethiopian regions).	Medium (first part of the project) / Significant (second part of the project)	The first part of the project is mainly focused on processing the archived data. In case of travel restrictions, it is mostly possible to work online in joint CZ-ET teams.
Failure or shortage in running and maintenance of the GSE website hosting the on-line interactive map applications.	Medium	Will be solved by using a CGS server at the cost of adjusting costs.

List of attachments

Attachment no. 1 – Project matrix (log-frame)
Attachment no. 2 – Overall time schedule
Attachment no. 3 – Budget Aggregate (2020-23)
3a – Budget Phase I. (2020)
3b – Budget Phase II.-III. (2021)
3c – Budget Phase IV.-V. (2022)

List of References

Asfaw, B., 2003. Hydrogeological map of northern Ethiopia (1:1,000,000 scale). Geological Survey of Ethiopia.

Chernet, T., 1988. Hydrogeological map of Ethiopia (1:2,000,000 scale). Ethiopian Institute of Geological Survey.

Halcrow, G., 2010. Rift Valley Lakes Basin Integrated Resources Development Master Plan Study Project. Draft Phase, 2.

Halcrow, S.W., 1989. Master plan for the development of surface water resources in the Awash basin. Ethiopian Valleys Development Study Authority.

Hanžl, P., Verner, K., Buriánek, D., Šíma, J., Janderková, J., Kryštofová, E., Paleček, M., Hroch, T., Martínek, K., Megerssa, L., Hrdličková, K., Metelka, V. (2018): Basic principles of geological and thematic mapping. 107 p. Czech Geological Survey. Prague

JICA, 2012. The Study on Groundwater Resources Assessment in the Rift Valley Lakes Basin in the Federal Democratic Republic of Ethiopia. Japan International Cooperation Agency, Kokusai Kogyo Co., Ltd., Ministry of Water and Energy of the Federal Democratic Republic of Ethiopia (Main Report).

Lahmeyer International and Yeshi-Ber Consult 2007. Genale-Dawa River Basin Integrated Resources Development Master Plan Study. The Federal Democratic Republic of Ethiopia, Ministry of Water Resources.

Mengesha, T., Chernet, T., Haro, W., 1996. Geological map of Ethiopia (1:2,000,000 scale). Geological Survey of Ethiopia.

Ministry of Water Resources, 1998. Abbay river basin integrated development master plan project. Phase 2: data collection—site investigation survey and analysis.

Ministry of Water Resources, 2003. Wabi Shebele river basin integrated master plan study project. Vol. VII Water resources, Part 3 Hydrogeology.

Nedeco, N., 1997. Tekeze river basin integrated development master plan project. Second phase report.

Tadesse, S., Milesi, J.P., Deschamps, Y., 2003. Geology and mineral potential of Ethiopia: a note on geology and mineral map of Ethiopia. Journal of African Earth Sciences, 36(4), 273-313.

TAMS-ULG (1996). Baro–Akobo river basin integrated development master plan project. Addis Ababa: Ministry of Water Resources (Main report).

VDSA (1990). Baro–Akobo river basin master plan study of water and land resources of the Gambela plain. Addis Ababa: Ethiopian Valleys Development Study Authority and Selkhozprom Export (Final Report, 1-XII).

Woldetinsae, G., Götze, H.J., 2005. Gravity field and isostatic state of Ethiopia and adjacent areas. Journal of African Earth Sciences, 41(1-2), 103-117.

Woodrofe, K., 1996. Omo-Gibe River Basin Integrated Development Master Plan Study, Vol. VI, Ministry of Water Resources.