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Concepts for Sudan Survey Act Implementations - Executive Regulations and Standards

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ABSTRACT

This paper aims to outline the executive regulations, survey standards, and specifications required for the implementation of the Sudan Survey Act, and for regulating and organizing all surveying work activities in Sudan. The act has been discussed for more than 5 years. The Land Survey Act was initiated by the Sudan Survey Authority and all official legislations were headed by the Sudan Ministry of Justice till it was issued in 2022. The paper presents conceptual guidelines to be used for the Survey Act implementation and to regulate the survey work practice, standardizing the field surveys, processing, quality control, procedures, and the processes related to survey work carried out by the stakeholders and relevant authorities in Sudan. The conceptual guidelines are meant to improve the quality and harmonization of geospatial data and to aid decision-making processes as well as geospatial information systems. The established comprehensive executive regulations will govern and regulate the implementation of the Sudan Survey/Geomatics Act in all surveying and mapping practices undertaken by the Sudan Survey Authority (SSA) and state local survey departments for public or private sector organizations. The targeted standards and specifications include the reference frame, projection, coordinate systems, and the guidelines and specifications that must be followed in the field of survey work, processes, and mapping products. In the last few decades, there has been a growing awareness of the importance of geomatics activities and measurements on the Earth's surface in space and time, together with observing and mapping the changes. In such cases, data must be captured promptly, standardized, and obtained with more accuracy and specified in much detail. The paper will also highlight the current situation in Sudan, the degree to which survey standards are used, the problems encountered, and the errors that arise from not using the standards and survey specifications.

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KEYWORDS: *Sudan Survey Works Organization SSWO, Sudan Survey Authority SSA, Global Navigation Satellite System GNSS, World Geodetic System 1984 (WGS84), International Terrestrial Reference Frame 2008 (ITRF2008), Universal Transverse Mercator (UTM), Uncertainty*

1. INTRODUCTION

Ultimately, the purpose of issuing the Sudan Survey Act is to organize and implement survey works in Sudan using defined regulations, and survey standards and to be, in line with the international best practice specifications. The Sudan Survey Act gave full responsibility for the management of the national survey activities to the Sudan Survey Authority (SSA) as well as the supervision of all federal and State government surveying works, implementing survey regulations that, control all surveying professions, and monitoring of all activities related to surveying work in Sudan. This study assessed the existing surveying practices and described the required surveying standards, specifications, procedures, regulations, and methods of implementation outlining approaches coupled with the international best practices.

The paper highlighted the importance of the development and implementation of surveying standards and specifications in Sudan, based on the adopted Sudan Survey Act, also nominated as, the "Sudan Survey Works Organization (SSWO) Act", which should outline and document the procedures, regulations and methods of implementation using a new approach coupled with international best practices. The paper also, intended to reflect the importance of unifying survey standards and specifications used in Sudan and to propose an organization of the Surveyors to be involved and the legalization in all aspects of the SSWO Act [20].

As worldwide the laws are very old, the daily use of highly accurate networks based on GNSS observations has been causing during the last three decades the revision of the laws concerning geospatial information and the surveyors' business. Originally, the survey acts were very focused on the cadastral survey. But, the land survey acts of today including the SSWO Act Act, have extended their area of jurisdiction and are now covering the surveying measurement, processes, and management, the geospatial information sharing, integration, and dissemination of the geospatial information [21], [22] The assessment of the quality of geographical information is no longer limited to geometric accuracy but includes other quality parameters such as completeness, logical consistency, temporal accuracy, thematic accuracy, and usability.

To assist the Sudan Survey Authority, in its efforts to unify and enhance the existing standards, specifications, and land survey executive regulations, the author has carried out a full assessment, through studies and investigations of the existing surveying works in Sudan in comparison with international best surveying practices. The work involved was organized into four sub-sections: Existing practices of surveys, analysis of organization involved in surveying, analysis of existing survey practices, and analysis of the gap between the actual organization, survey practices, and the needs, expectations, and requirements. For the success of such studies and investigations, a multidisciplinary approach needs to be considered:

- Technological approach: due to the various types of surveys: geodetic [23], topographic, photogrammetric, hydrographic, cadastral, public works, and engineering surveys
- Mathematical approach regarding the elements of statistical calculations to be implemented
- Legal approach: Legal Informatics, Civil Law, Land Law, planning legislation, and Real Estate Law.
- Cultural approach

The methodology to be adopted for the development and documentation of Sudan executive regulations, standards, and specifications, is to identify the key stakeholders, professional experts, policymakers, decision-makers, professional surveyors, and end-users, the tools used for the intervention, and others. The author also reviewed the organizational aspects related to how surveys are carried out, the analysis needs to shift to who is carrying out these activities to ensure that the required standards & specifications are met.

The needs also, identified for the Sudan Survey Authority to have control over all the survey providers (whether they supply data directly or indirectly to federal or state governments), which can be translated into the objective of organizing the Surveyors' trade and unifying regulations (legislation, policies) of the survey activities. To reach this objective, the following aspects need to be investigated and documented in the Survey Act executive regulations, such as:

- Education, degrees, and professional experience
- Surveyors Licensing & Registration
- Companies Licensing & Registration

As the Sudan Survey Authority is becoming a regulatory body, the focus will shift to the surveyors and surveying companies doing survey jobs, by reviewing the aspects related to their education, training, and licensing, and then reviewing the recruitment procedures both for federal and state government as well as inside other stakeholders' and private sector organizations.

2. Main Sudan Organizations involved in Survey activities

Sudan Federal and State government organizations are developing major urbanization projects that necessitate survey works and information, such as new towns, renovation and restructuring of town quarters, and infrastructures (roads, bridges, highways, trains, oil and gas pipelines, etc. For each of the phases of these major works (Master Plan, design, implementation, supervision, and execution), the Planner, the Designer, the Owner, the Engineer, and the Supervisor will have to manage survey and geospatial data. These geospatial data are the result of survey data capture using field survey works, measuring equipment, and processing software [17] and [18]. These data, can also, be the input or the output of geospatial databases each of the stakeholders maintains and of the shared SSA database. These works may not be standardized as it has been carried out in the absence of a regulated framework common to all the entities concerned. The targeted common framework should have several components, such as:

- Firstly, a juridical one through the law, by defining who is in charge of the reference systems, the positioning infrastructure, and the official and legal standards and by defining who is entitled to carry out surveys.

- Secondly a technical one, through the shared acceptance of the given land and marine spatial references, positioning infrastructure, aerial photography and processing and standards,
- Thirdly, an economical one, the development of activities that served many sectors.
- The paper tried to identify and formalize the current surveying needs, and to ensure that all survey works carried out or delivered for the various Sudan organizations are realized by trained, competent and qualified surveyors, to avoid:
  - Over-costs in case of poor workmanship and
  - Trial for disputes due to the mistakes in the surveys.

The triangular relationship "Client-Consultant-Contractor" should be considered to be at the core of all organizational issues. It should be the basis of the entire contracts' organization in Sudan. It is systematic insofar as it manages the system of decision-making, reporting, Quality Assurance, and Quality Control.

The author then studied and examined in detail the existing standards and procedures, those of which are related to SSA and those shared by the stakeholders. This paper is based on the official documentation provided by the Sudan Survey Authority and all its Departments, Sudan Information Center data models, Khartoum State General Survey Directorate, taking into consideration all other relevant stakeholders, such as:

- Standards and specifications defined for the various Surveys,
- Guidelines concerning Surveys and processes,
- Documents and information submitted by some Stakeholders.

Applying the principles on which this approach is based, the author worked closely with SSA staff to investigate all the existing survey activities and programs that relate in any significant way to geospatial information and services within the SSA and the Sudan States Survey Departments. For drafting applicable survey standards and specifications in Sudan, meetings are to be organized with all relevant government and private entities, as shown in Table (1), to agree on the survey standards and specifications and the method of their implementation, to have a clear view on what stakeholders' interactions are involved, concerning surveying activities.

Table 1: List of main SSA stakeholders and Partners

ENTITY	Full Name	ENTITY	Full Name
SSG	Sudan States Governments	MOA	Ministry of Agriculture
SCAA	Sudan Civil Aviation Authority	MOF	Ministry of Finance
MOG	Ministry of Oil and Gas	MOT	Ministry of Transportation
MOIWR	Ministry of Irrigation and Water Resources	MOM	Ministry of Mining
SSPC	Sudan Sea Ports Cooperation	MOI	Ministry of Interior
NEA	National Environment Authority	MOE	Ministry of Energy
NIC	National Information Centre	MOD	Ministry of Defense
MOTI	Ministry of Telecommunication & Inform.	NTA	National Tourism Authority
SNBC	Sudan National Boundary Commission	NLA	National land Authority

Figure 1 indicates the various stakeholders' surveying activities for the management of the urban and rural spaces and land management. Within the framework of their responsibilities, each of these organizations (Table 1) carries out surveys, either using their internal resources or by sub-contracting. The territories falling under the responsibilities of the various stakeholders are entangled, as sometimes they overlap. In urban space, the State Ministries of Urban Planning are in charge of setting up and implementing the development policies of Urban Planning in Sudan. Thus, they are in charge of ensuring the consistency of the following items:

- The boundaries of the cadastral parcels with each other
- The utilities' corridors with the parcel boundaries and the road extent
- The road extends with the parcels and the corridors.

The state infrastructure departments are, for example, responsible for the consistency between the Federal national highways and the State's Road networks, as well as the detailed planning and plans' approvals. In such cases, upon completion of some projects, a certain part of the infrastructure remains under the authority of entities, whilst another is "delivered" to the State Infrastructure Department or National Highway Authority to be in charge of their maintenance. This maintenance relates to the cadastral parcels, the corridors, and the roads.

For analysis purposes, two parameters were selected to model the Sudan Land Survey Act. The first parameter is very general or so detailed that it describes all the processes and procedures. The second parameter deals only with cadaster or to be more comprehensive by structuring all geographic information. The Sudan Survey Authority should follow the current international trends to make regulations that define the responsibilities of organizations in charge of implementing the practical provisions such as the Spatial Reference System, Positioning infrastructure, boards or authorities for examinations, licensing, and registration. Currently, government organizations are in charge of publishing, maintaining, and updating their infrastructure, the standards and guidelines, or the detailed rules for examination and licensing procedures.

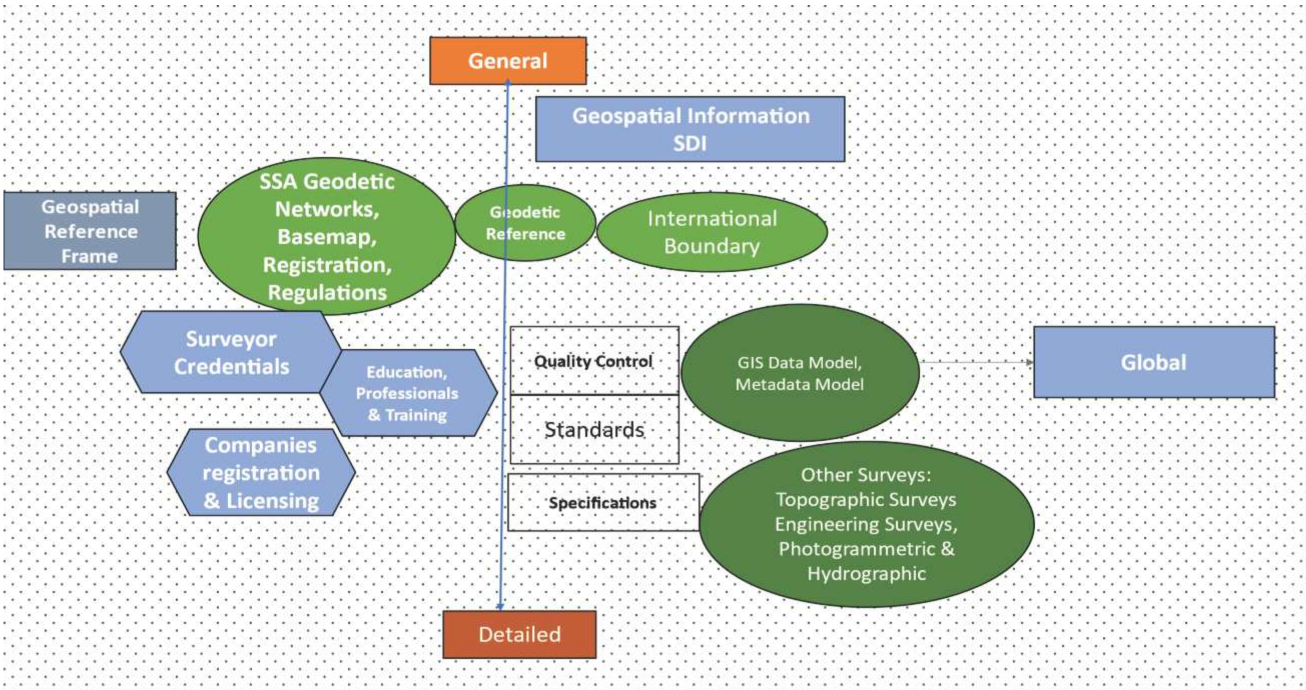

Figure 1: General outlines of SSWO Act regulations and standards

3. Sudan Geodetic and Geospatial Reference System

The Sudan geodetic and geospatial Reference System [19], is considered to be a consistent national reference frame and coordinate system that specifies latitude, longitude, height, scale, gravity, and orientation throughout the territory of Sudan as well as how these values change with time. Specifically, the identified regulations need to define units, geodetic reference, elevation reference, and geoid reference. The Sudan geodetic and geospatial Reference System also consists of the following components, table.2:

- A consistent, accurate, and up-to-date national boundaries and shorelines.
- A Geodetic Reference Frame and Networks.
- A network of permanently marked Geodetic Control Points and Benchmarks.
- A set of accurate models describing dynamic geophysical processes affecting spatial measurements [23].

Table 2: Sudan Geodetic and Geospatial Reference System

Horizontal Reference System	ITRF2008 epoch 2008.0	Geodetic Control points
Vertical Reference System	Alexandria or Port Sudan vertical datum	National benchmarks, Stakeholders' benchmarks, WGS84 ellipsoidal height + Sudan geoid
Gravimetry Reference System	GSN71	Reference Gravity Stations

The WGS84 ITRF2008 geocentric Cartesian coordinates (X, Y, Z) in metric units [2], are adopted as a geodetic and geospatial reference system for Sudan with its WGS84 ITRF2008 geodetic coordinates: Longitude, Latitude in angular units and the ellipsoidal height in linear units. The WGS84 ITRF2008 UTM coordinates (Easting, Northing) in linear units covering four UTM zones [1],[3].

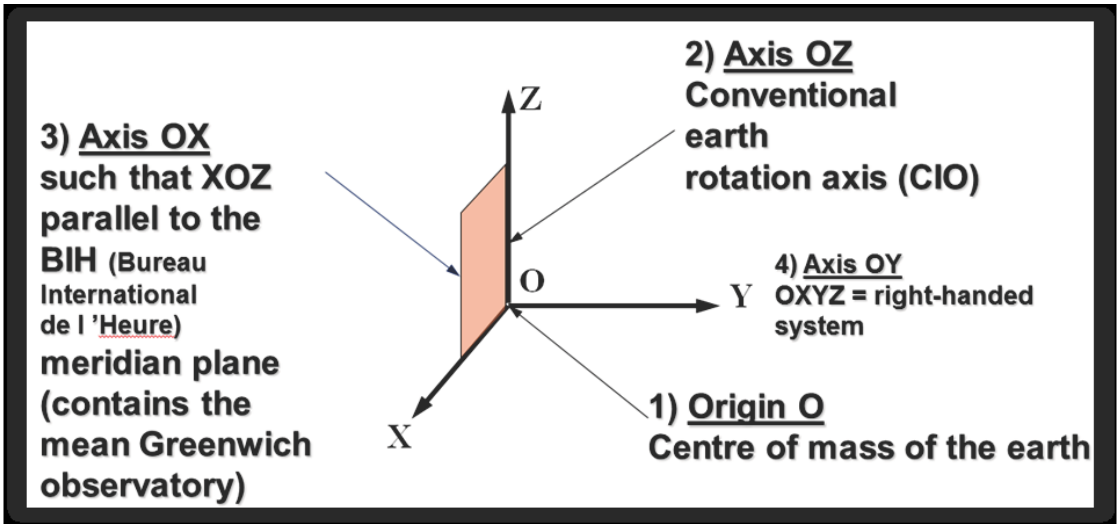

Figure 2: Geocentric coordinate reference system

Table.3: Parameters for UTM zones 34, 35, 36 and 37

Zone	34 north	35 north	36 north	37 north
Central Meridian (L0)	21° East of Greenwich	27° East of Greenwich	33° East of Greenwich	39° East of Greenwich
Latitude of Origin (Π0)	0°	0°	0°	0°
UTM Scale Factor (k0)	0.9996	0.9996	0.9996	0.9996
False Easting (E0)	500,000 m	500,000 m	500,000 m	500,000 m
False Northing (N0)	0 m	0 m	0 m	0 m

4. Common development process

A common frame of work has to be considered through the detailed survey regulation development process in Sudan, such as the planners or designers creating their plans, using software that generates an output set of coordinates in a given reference system (horizontal reference system, vertical reference system, projection), or orientations and relative distances between geographical features. To understand what the needs and expectations fulfilled by the survey business processes are the mission of the SSA and State Survey Departments needs to be revisited to understand what the axes of their mandates are, here below, four major axes can be identified:

- Ensuring consistency in terrestrial land planning
- Implementation of the planning policies such as town and urban planning.
- Management of the urban space (cadastre, utilities, corridors, routes)
- Protection of the people and properties (including in marine areas)

To structure the needs identified, the author has chosen to distinguish between the terrestrial and the marine issues, keeping the common denominator of geospatial reference, and then analyzed the relationship between the SSA and the stakeholders in terms of needs and expectations from each other (both ways).

The logic on which the needs and expectations assessment relies here revolves around the terms "why?" = need and the "how?" =function, knowing that this is a two-way path, as one provides the answer for the other.'

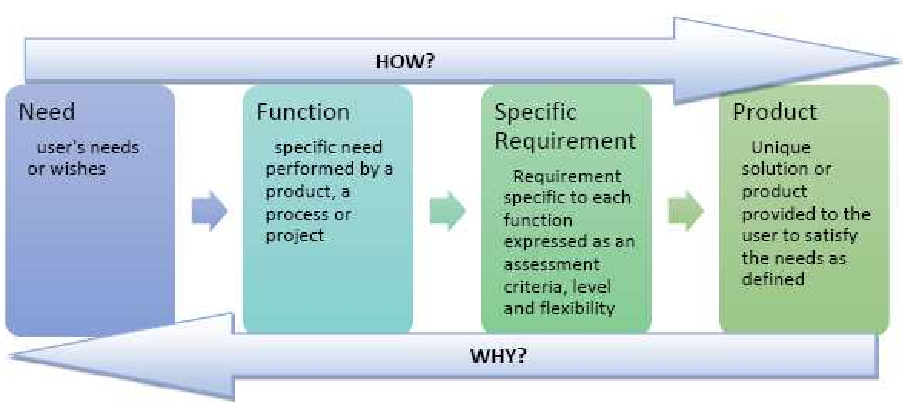

Figure 3: Functional analysis methodology

4.1. SSA and Sudan State terrestrial needs

To identify the needs, the business processes of the SSA and state governments' objectives concerning surveying and geospatial information, existing land, and topographic survey procedures are to be reviewed. Thus, based on the existing business process the following needs can be identified:

- Densification and maintenance of Positioning Infrastructure by SSA and its stakeholders
- Computation and adaptation of a gravimetric geoid model
- SSA and Stakeholders' demarcation surveys
- Stakeholders Routes surveys such as:-
  - Corridor alignment and surveys
  - Road route selection and surveys
  - SSA Base map creation and update by land topographic surveys, transactional as-built, or aerial and satellite imagery surveys

4.2. Marine needs

Considering the SSA and state governments' objectives for the planning of the coastal sea [11] and river areas, it is clear that the main axis involved is risk prevention and management. Looking into what exactly those risks are, that need to be modeled to prevent risks caused by:

- Extreme weather phenomena.
- Urbanization of coastal areas.
- Changing currents in the harbor engineering.

Going back to the "why?" "How?" logic path of the functional analysis described above (Figure 3), if the path of translating these needs into functions is followed, the conclusion reached is that what is required for the SSA and its stakeholders to be able to achieve their set objectives is ultimately specific databases for each of the risk factors identified:

- The database "bathymetry".
- The database "sedimentology".
- The database "Tides and tidal currents".

4.3. SSA Stakeholders' needs and expectations

After analyzing the information obtained from the relevant stakeholders, the conclusion reached was that the common ground in terms of needs and expectations of the stakeholders from SSA, federal and state government entities is the reliable referenced data, which is particularly true in the case of the stakeholders involved, such as in utility management services. As far as the SSA is concerned, its needs and expectations from the stakeholders mainly consist of all organisms using the same references, as this is the only way to ensure consistency throughout the datasets in use (WGS84 ITRF 2008 epoch 2008.0 for the horizontal reference system and Alexandrea/or Port Sudan for the vertical datum).

5. Existing business processes and survey practices

In the analysis of the existing practices for survey across the business processes identified, it has been studied how the surveying activities are carried out at the level of the federal and state governments as well as the stakeholders and private sector organizations, both in terms of land and sea surveys, the methods and specifications used to assess whether the required accuracies can be met are to be established.

As a general rule, all survey activities fall under the responsibility of the SSA and state governments, whose mission is to ensure:

- Managing the processes, the detailed planning, and the division of urban uses as well as the issuance of policies and relevant rules.
- Management of the establishment, distribution, updating, and maintenance of geospatial data.
- Issuance of building and construction permits.
- Management of paths and segments of different routes and service corridor lines.

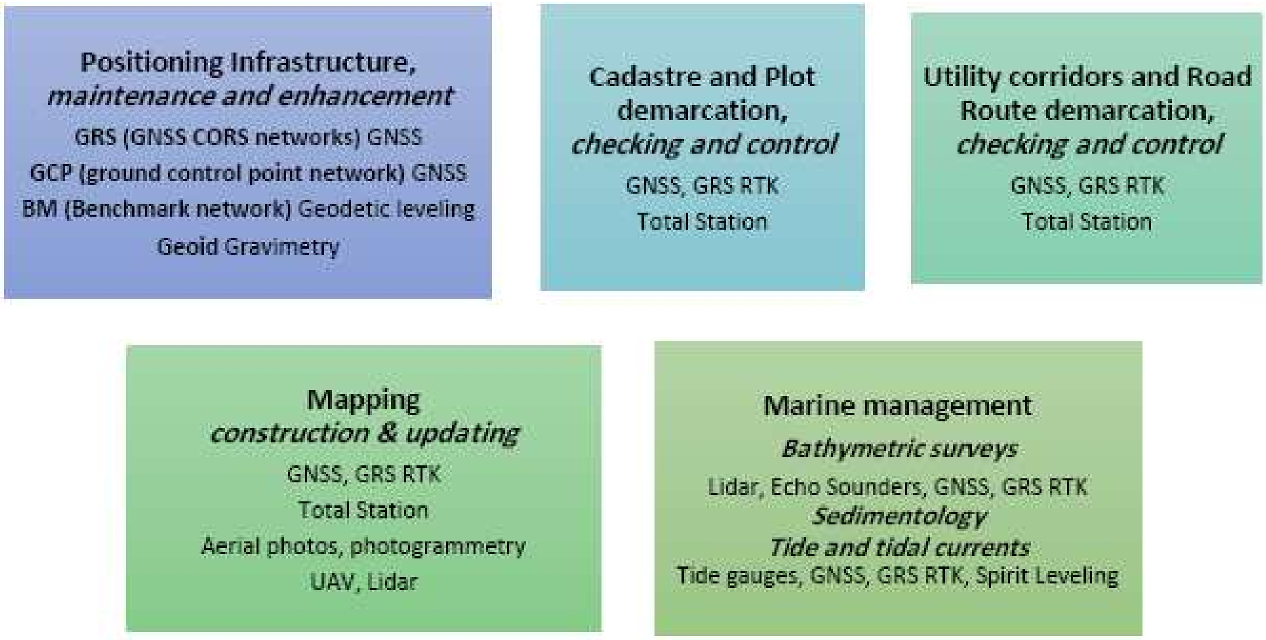

Figure. 4: Existing survey business processes and survey practices

The overall responsibility of SSA is:
- Establishing and maintaining Geodetic Ground Control Point Networks [3].
- Supervision of GNSS Reference Station using CORS, Maintaining and Running
- Providing international and national administrative boundary and demarcation surveys.
- Carrying out standardized federal geomatics and surveying activities
- Providing technical support and services in all surveying and geospatial-related matters
- Producing fundamental geospatial data in the form of base maps and integrated geospatial information.

The sample of the relevant business processes (Figure 4) identified the business processes that involve surveying activities and the types of surveys used for each of them.

5.1. Positioning Infrastructure

The primary customers for whom the geodetic control point networks are provided are surveyors working for the federal, state government, and private sectors. To carry out various types of surveys and calculate positions in the Sudan geodetic and geospatial Reference System [19], as well as to maintain the data in an integrated GIS, geodetic networks are essential for all the surveying business processes, whatever the type of survey involved is. In addition to the accuracy constraints, the SSA and state government should constantly take care of the challenges faced in carrying out surveys efficiently and cost-effectively to make the best of the public funds available and increase customer satisfaction. This requires the use of [9]:
- Advanced techniques such as GNSS static observations or CORs network (for increased productivity), and
- A geoid model to carry out leveling by GNSS, in such an instance, the geoid model is a link between the geometrical aspects and the physical aspects of geodesy [6], [7] and [11].

The existing Sudan Positioning Infrastructure and the way to use it are outlined in Figure 5.

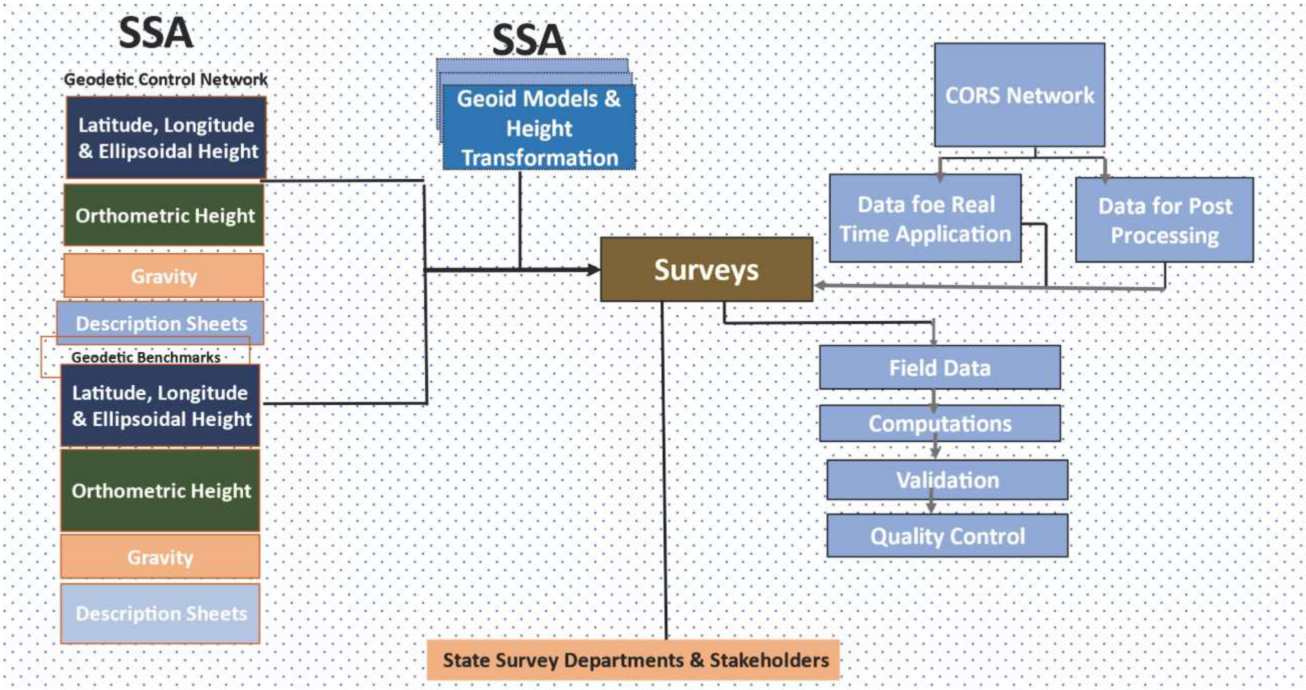

Figure. 5: Overview of Existing Positioning Infrastructure in Sudan

The primary customers for whom these geodetic networks are provided are surveyors working on projects where positional accuracy must match with its given accuracy standards. Currently, sometimes non-permanent networks, with coordinates calculated in different reference systems from the SSA and government entities, are built to answer particular needs, but to obtain data sharing and geospatial integration, these networks are to be transformed to Sudan Geospatial Reference System that is to say WGS84 ITRF2008.

In international practice, the lead agency responsible for the coordination, management, and dissemination of geodetic data in a country should be the surveying and mapping authority. In Sudan, the SSA maintains a distinct national geodetic network (GCPs and Benchmarks) within the national, geodetic, and geospatial Reference frames. However, its density does not allow public and private sector entities to work efficiently, and even some of these geodetic marks cannot meet the needs of the surveying standards of today.

5.2. Cadastre and plot control

Demarcation surveys have a profound impact on society as they are related to assisting in the protection of government and individual rights and properties, and settlements of disputes of deeds. The government entities are using topographic surveys, the main techniques used are the RTK, Total Stations, photogrammetry, and aerial surveys for cadastral application. Two types of demarcation surveys might be distinguished as follows [4] [5]:

- (Cadastral) Plot boundaries are defined by planning data as available from the database (stakeout), reflecting the currently approved property documentation [8].
- Existing identifiable boundaries or survey existing features that are to be measured in the field.

They include surveys for locating and identifying the plots, plot demarcation surveys for residential, commercial, and industrial, as-built surveys, and demarcation of public facilities. As far as the state government is concerned (Khartoum State as an example), regarding demarcation surveys, the following are usually considered:

- The required horizontal accuracy is 5 cm at the 95% confidence level for most survey types.
- The required vertical accuracy is 10 cm at the 95% confidence level.

In Sudan, cadastral surveys are carried out by the Survey Departments of state governments based on plans from the Urban Planning Departments, which are in charge of strategic developments in the State, including Master Plans and the development review. These plans shall be detailed and implemented by the local planning division within the States. Activities, including detailed site and building designs, describing in detail the building site treatment, signage and infrastructure, public spaces, and pedestrian amenities, must be submitted for approval and checked against the Master Plan (which includes specific plots, land uses, densities, heights, sitting requirements, parking), the general process being as follows:

Properties applicants have to present detailed phasing plans and construction, maintenance, and service provision responsibilities, under continuous observation done by the urban planning services and Survey units in the State localities [16].

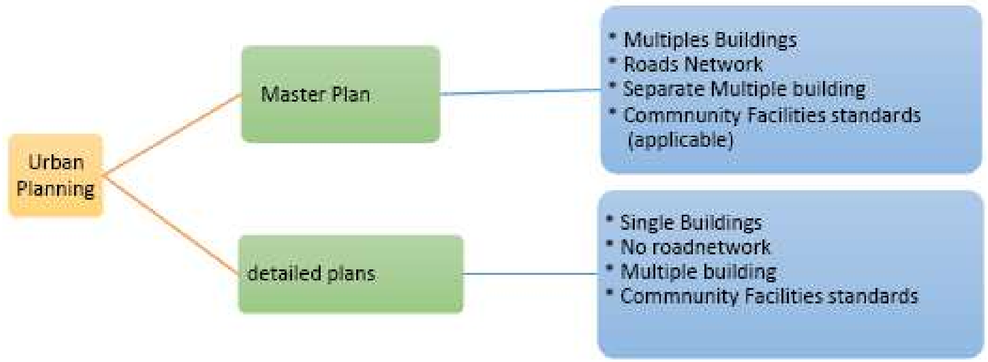

Figure. 6: Buildings and Construction Permits in Sudan

5.3. Utility Control

Corridor survey datasets are of interest because they include many elements critical to the public and private infrastructure, and provision of government services in the daily life of citizens. The reliable functioning of the increasingly complex, inter-connected, and inter-dependent utility infrastructures [16], [21], including electricity, water, and gas supply systems, wastewater systems, and communications, is vital for the security, economic prosperity, and social well-being of the nation.

The utility (service) corridor represents the area above and below ground where utilities reside. It is an area of highway right of way designated or any part of the land used or intended to be used for the location of utilities, either public or private. Corridors are also used for the marine:

- Marine Utility corridor: an area of sea/ocean floor including the upland/ shore areas designated or any part of the land used or intended to be used for the location of utilities or associated structures, either public or private, in the marine areas.
- Marine Utility corridor: a stretch of land, sea, or ocean floor within the marine utility corridors reserved or identified for accommodating a specific utility line, either a pipeline or a cable.
- Marine Structure /Marine Facilities: components of the marine utility network from which utility lines either originate or terminate.

The state governments in Sudan, are not directly in charge of all utilities, which are under the responsibility of authorities and/or companies in charge of electricity, gas, irrigation, street lights, sewage, communications, and fiber cable. These authorities and companies have their survey units with their surveyors and/or sub-contractors. However, certain mechanisms are to be set in place between them and the state governments, as they should require from them:

- The corridor site is dedicated to the pipes or tubes;
- The approval of routes setting out and design;
- The approval after work of the as-built

In the above phases, the survey departments of the state government must be in charge of supervising and checking the surveying, mapping, and demarcation processes and the measurements of the corridor routes and as-built drawings.

Corridor surveys are meant to measure the coordinates of certain features in the field or stake out given coordinates in the field. All coordinates must be in the Sudan geodetic and geospatial Reference System. Utilities may include Electricity, Gas, Irrigation, Street lights, Sewage, Water supply and drainage. The utilities laid on the seabed can be grouped into Cables – consisting of Telecommunications and Electric lines, and pipes and pipelines – consisting of Oil, and Gas. The utility data sets contain: Utility point device features located along utilities; utility line features involved in the transmission and distribution of oil, gas, electric, or telecommunications commodities; and polygon "plant" features involved in the generation, treatment, refining, or storage of oil, gas, or electric commodities.

5.4. Topographic mapping and base map updating

The base maps are established and maintained by the SSA and provide to all stakeholders through the Sudan National Basemap System [15], the appropriate geospatial data needed to accomplish their missions. These data have been continuously improved and updated. So, the base maps fall under the responsibility of SSA, which already initiated the unification of the geospatial models and the specifications of the base map. Traditionally, aerial surveys have been used in Sudan, mostly for large and medium-scale mapping, but never for cadastral purposes. So far, UAV airborne and Lidar mapping started to be used by the public as well as the private sectors.

5.5. Marine management

Sudan's mainland and the Red Sea coastline are approximately hundreds of kilometers long, and here the main responsibility of SSA and the relevant stakeholders is to provide products (digital model of terrain, map, seabed topography) to other departments to serve as decision support. The main tasks are:

- Creating and updating charts and the Marine Information Section (MIS) database;
- Carry out studies and research on seawater column movements, modeling of tide, currents, and wave effects, risk assessment, and disaster prediction;
- Sea rise and sediment migration,
- Pollution,
- Discovered upwelling (impacts on flora and fauna),
- Impact of human actions (port extensions, outfalls, marinas, waterfront, bridges)
- Digital models of bathymetry, foreshore and littoral, tide, currents (tidal, general), and sedimentology.

Considering the objectives set, the Marine Information entities should manage a database containing at least the following items:

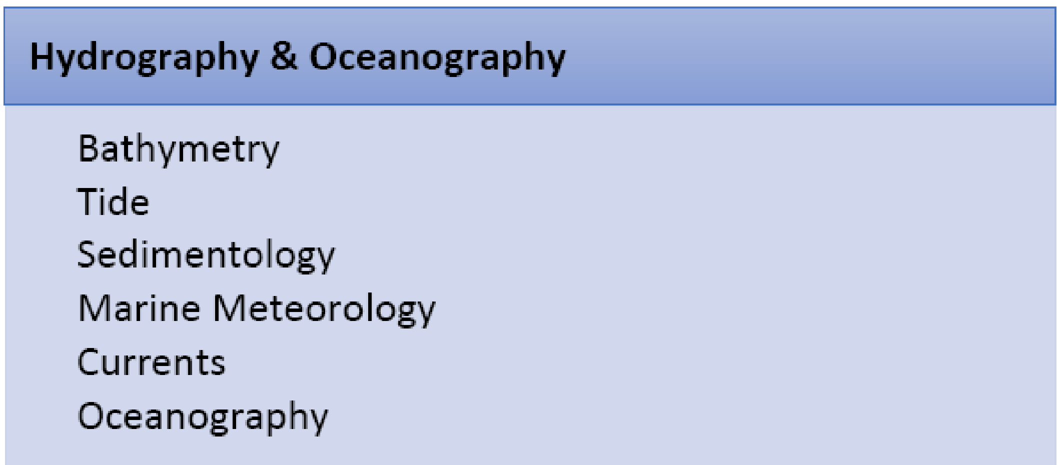

Figure. 7: Required content for MIS database

However, there is a lack of historical marine data in Sudan. The hydrographic surveys and tides were conducted and observed on the Sudan territorial and offshore (temporary tide gauge set up on Sudan territory red sea waters) since the 1950s by:

- The United Kingdom Hydrographic Office (UKHO),
- The U.S. Navy,
- The Hydrographic and Oceanographic Office of the French Navy (SHOM),
- Oil companies
- Offshore works international companies,
- State authorities such as the Marine Military Survey, The Department of Transport (DoT), Sudan Seaport Authority, etc.

Unfortunately, no marine data or information was shared with the Sudan government based on the well-known marine laws and international treaties for marine information dissemination.

6. Standard and specifications

Standards are suggested to be handled with three scenarios:

- **S1:** For each type of survey, description of the accuracy expected, processes requirement, and the quality checking
- **S2:** Description of the level of accuracy expected without any requirement on the process to follow, but with the description of the way to assess the final dataset quality by statistical sampling using a process twice more accurate.
- **S3:** Mixing of S1 and S2.

6.1. Confidence level

In the recent past, the scale of the produced documents dictated the required accuracy. The relation between the map scale for example and the target accuracy used to be established by the common rule of the 1/10 mm. For instance, on a scale of 1: 1 000, one- tenth of mm on the map represents 10cm on the ground, so one used to have a target and expected accuracy of less than 10cm.

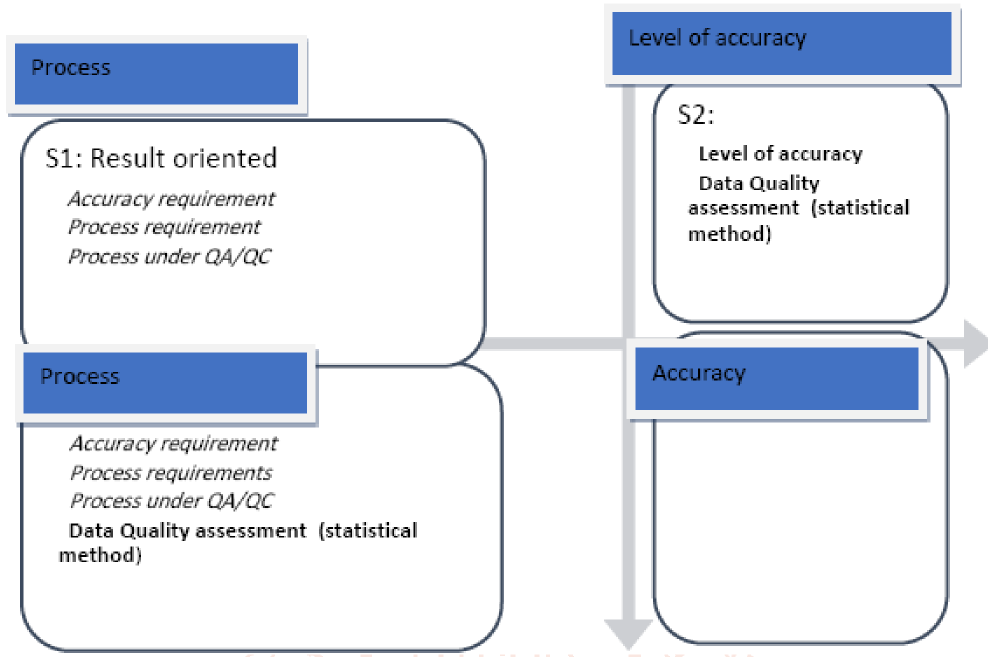

Figure. 8: Processes and levels of Accuracy standards

Table.4: The traditional relationships between map scale and accuracy

Scale of map	Tenth of mm	Target Accuracy at One Sigma
1: 1000	0.10 m	8 cm
1: 5,000	0.50 m	16 cm
1: 10,000	1.00 m	80 cm
1: 25,000	2.50 m	2m

This is less true as geospatial systems replace printed documents. So, in the specifications, the trend to ask for the maximum achievable accuracy regardless of the actual needs is to be identified. One of the goals of the paper was to clarify and highlight the level of confidence associated with the accuracies, and to understand whether it was one sigma level, or 95% level [12]. This is an important issue since the multiplying factors to change from a one-sigma confidence level to a 95% confidence level are usually given as:

Table 5: Confidence level multiplying factor

1.96	if one-dimensional (vertical)
2.45	if two-dimensional (horizontal)

Practically, it can be found that some of the required accuracies were not realistic, given the techniques and methods used in the field. For instance, one cannot get a 3 cm accuracy from a total station survey based on ground control points established with GNSS RTK [13]. The purpose of control surveys is to provide a uniform framework of reference for the coordination of all surveying activities within a given area. They consist of horizontal and vertical controls, which require fundamentally different methods of establishment, although some control points may be common to both control networks. The basic well-known rule is that the accuracy of the control should be superior to that of the surveys it coordinates.

Different types of surveys produce different types of data, which are stored in different layers of the GIS. As a result, the accuracy associated with the data becomes very important since, when the different layers are superimposed and overlaid, one has to keep in mind the different accuracies involved.

6.2. Existing Accuracy Level

In terms of the accuracy requirements as from the documentation provided Khartoum State Survey Department, for terrestrial surveys, the required horizontal accuracy is

- 7 cm at the 95% confidence level for most survey types.
- 40 cm at the 95% confidence level for the base map surveys (urban area)

The required vertical accuracy is not clearly defined, except for the State Base map (GIS) and the Digital Terrain Model (DTM) determination, where it is stated in some areas as 10 cm at 95%. Table 6 sums up the values for the main business processes in Khartoum State.

Table 6: Accuracies for Khartoum State Government business processes

Type of survey	95% confidence level Horizontal (2d)	95% confidence level Vertical (1d)
CORS densification	2.5 cm	3 cm
GCP densification/maintenance	5 cm	6 cm
Geodetic leveling Benchmarks	3 cm	4mm√K (K distance in kilometers)
Demarcation surveys	7 cm	10 cm
Route surveys	10 cm	3 cm
Base map surveys	40 cm	40 cm

Based on the analysis carried out on the Sudan existing survey practices a listing of the issues that need to be addressed has been established, based on the organization by business process approach, integrating the cross-disciplinary issues related to the reference system [13], and the techniques used. Thus, the regulation analysis and standards should be focused on the problems related to:

- Geospatial Reference System
- Projection
- CORS and geodetic control networks
- Cadastre and building permit
- Utility
- Roads
- Marine
- Topographic mapping and base map update

7. Geoid Model Realization

The SSWO Act shall re-enforce the Sudan geodetic and geospatial Reference System, as the official and legal vertical reference for the entire Sudan territory. In the minds of many users who are not professional surveyors, there is confusion between these "elevation" and "ellipsoid heights". This confusion can have disastrous consequences, as sometimes designers in the case of the construction of a house or a road realize two different projects working, one using ellipsoid height and the other one using elevation in their design [6]. The difference between elevations and ellipsoid heights can be ranged around ± 6 m in Sudan territory.

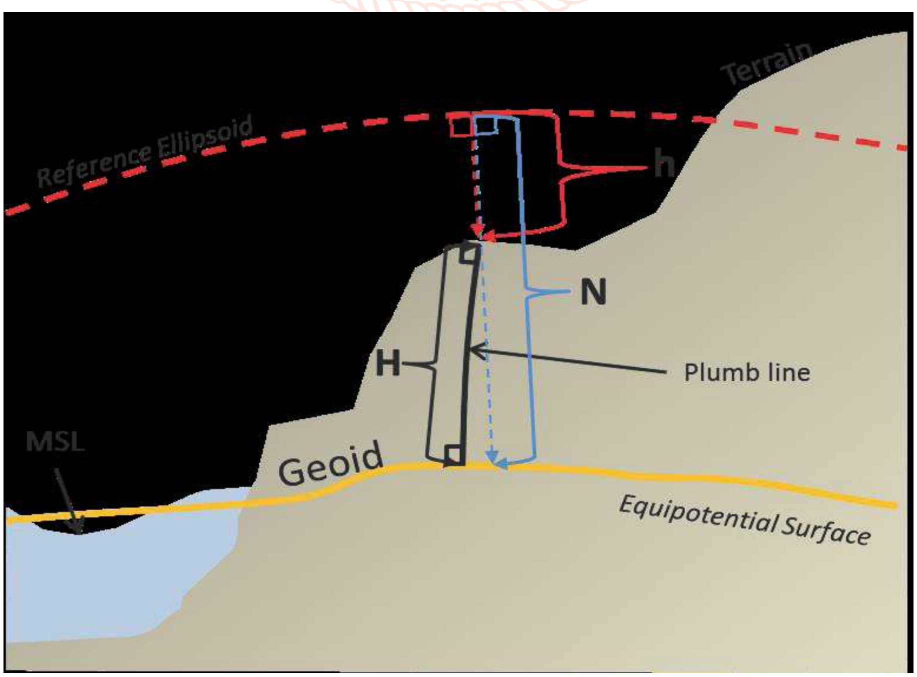

Figure 9: Elevation and Ellipsoid Height Relationship

As an example, the EGM2008 Geoid (Figure 10) shows the values of the differences between elevation and ellipsoid height in the Khartoum area.

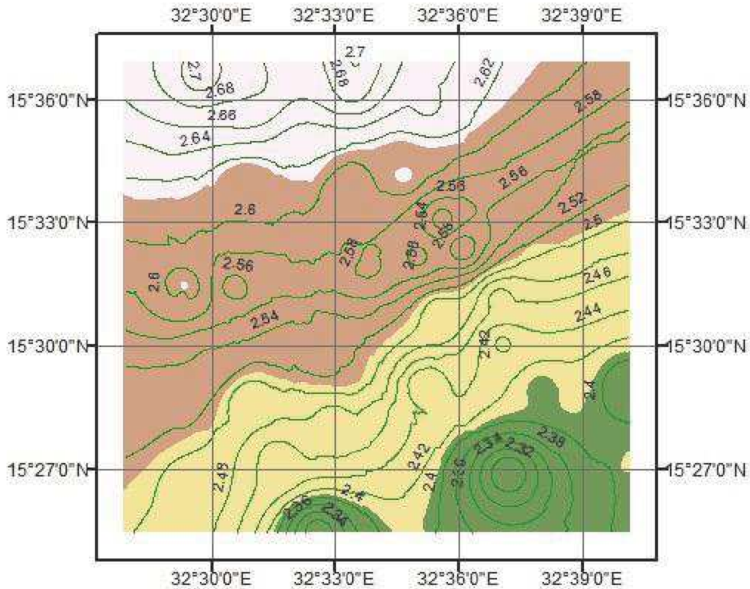

Figure.10: Sudan EGM2008 Geoid Model at Khartoum State [16]

7.1. Map Projection

Every map projection creates distortion, the scale is true only on specific locations such as the equator, and particular meridian [10]. The scale factor of the map projection describes the amount of distortion in length (ellipsoidal distance /distance between projected points) [1]. For conformal map projections (e.g. UTM), angles are preserved. The scale factor has the same value in all directions around the same point but it varies from point to point. Scale is also affected by other factors like height above the ellipsoid.

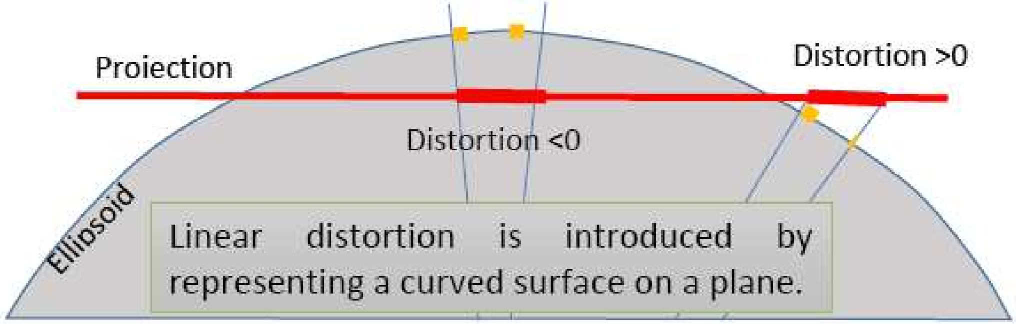

Figure 11: Linear distortion introduced by representing a curved surface on a plane

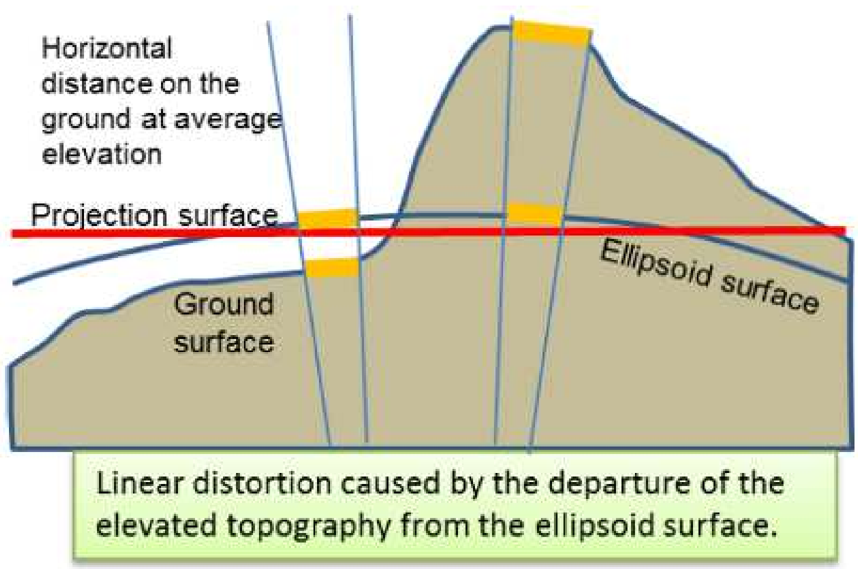

Figure 12: linear distortion due to elevated topography

No map projection can maintain the correct scale throughout the area under consideration. On large-scale maps, distortion is not evident to the eye, but it becomes apparent upon careful measurement and analysis [10].

7.1.1. UTM projection

The Sudan Survey Authority adopted the UTM projection, which is based on the Transverse Mercator projection. The UTM properties [1] [2], are the Grid Scale factor (Figure.11) is 0.9996 along the central meridian of the zone. The scale is deliberately reduced so that the mean scale of the entire area is more correct, the origin of E, coordinates is the equator, and the N, coordinates are the central meridian (+500 km). The grid scale factor increases as going away from the central meridian reaches a value of 1 and then increases beyond a value of 1 (at constant latitude). Along the same meridian, the scale factor decreases when latitude increases.

The distance measurement correction that the surveyor should use with the total station is composed of:

- Correction of the prism target used
- Meteorological correction (temperature and atmospheric pressure)
- Reduction to ellipsoid (scale factor caused by topography). Also known as the Elevation factor or Orthometric Height scale. It depends on ellipsoidal height and mean radius of curvature of the earth
- And linear distortion due to the projection

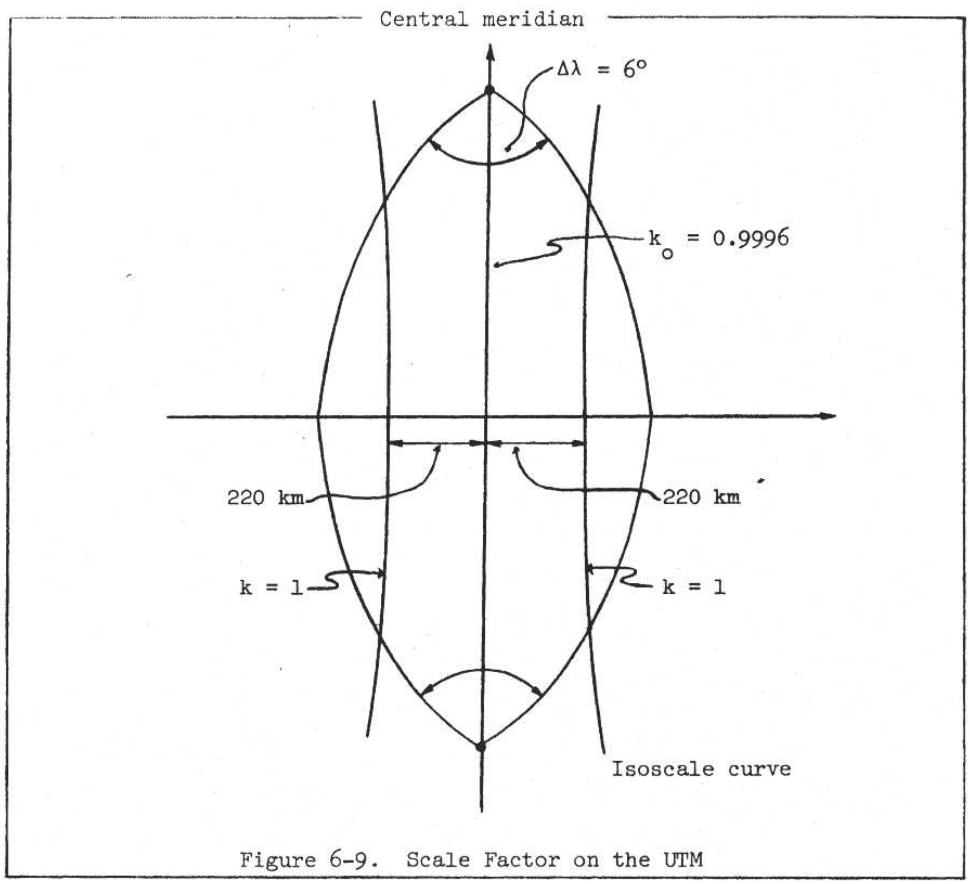

Figure 11: Scale Factor on the UTM

The total (combined) scale factor is the product of all scale factors. The issues related to the projection, scale factor, and linear distortion, have a direct impact on the surface of the plots and engineering works. The legal surface of property generally refers to a computerized surface relative to the legal projection used. GNSS processes transform plan cartographic coordinates in GNSS coordinates and vice-versa. Each distance measured on the field is normally corrected by the scale factor to be "drawn" on the projected map; otherwise, the demarcation is wrong because the scale factor is not negligible when the accuracy requested is equivalent to the error in distance measurement due to the value of this scale factor.

To sum up, all surveying entities, and particularly, the state governments, utility stakeholders, and GIS users should realize that [14]:

- The surface of a plot or a piece of land is always computed with the legal projection used whatever the scale factor of the legal projection is. For example, in any place, when the legal projection is changed, means that the total surface of the area, says the agricultural land used will change.

- UTM Projection is a “conformal” map projection preserving angles locally, but not “equal-area” i.e. preserving areas.
- Therefore, if all the surfaces of properties in the State government are computed following the legal projection of Sudan, nobody can dispute the surface of his land in front of the court.
- For the UTM Zone projection, the scale factor value is 0.9996 at the central meridian of the zone. There are two meridians with a value equal to 1, one West and the other East of the central meridian of the zone
- The linear distortion varies according to the variation of the value of the scale factor.
- For surveys using measurement of angles and distances (Total Station), a correction shall be applied to the distance measurement to be able to "draw" the results of the survey in a projection map.
- The correction is called "scale factor". Nevertheless, for the modern total station, this correction includes prism correction, temperature correction, pressure correction, altitude, and linear distortion due to the projection used. With UTM Zones in Sudan,34, 35, 36, and 37, all the corrections are almost negligible compared to the linear distortion.
- If this correction is not correctly applied on the field, the demarcation will be wrong. A specific procedure has to be devised and followed on the field to check that issue.
- For GNSS measurements, the process of transforming projection coordinates to GNSS coordinates takes into account the projection parameters.

8. Quality Assurance/Quality Control

One of the key aspects related to the organization of a survey is how Quality Assurance and Quality Control are handled. Generally, two approaches are possible:

- Process-oriented: Quality Assurance
- Result-oriented: Quality Control

The approach used by the state government about quality may not be quite qualified as result-oriented, as the Quality Control carried out after the handing over is limited to checking the formats. In the rare instances where attempts to check the accuracy are made. The major risk identified in terms of Quality Assurance lies precisely in the surveying functioning model used, and its uncontrolled ramifications. The survey pattern can be reproduced several times as each of the entities meant to execute the survey. It is nearly impossible to assess the qualifications of the surveyors who carry out the survey. Therefore, the state government has in the end very little control over the quality of the results they are being delivered, other than this Quality Control on handing over which is not carried out in depth.

8.1. Accuracy issues

Figure 12 extracted from the RICS leaflet about accuracy [24], introduces the notion of absolute or relative accuracy: All engineering activity needs a given level of accuracy; too much can be expensive, and too little can be disastrous. The skill of surveying is in deciding just what level of accuracy is needed for any particular task and then building a methodology to ensure that it is reached. Figure 12 shows, in simple terms, the difference between accuracy and precision. Think of the center of the targets as the true value of the measurement, as: -

- Absolute accuracy is the accuracy of the measurement concerning a defined coordinate system, for example, a and b in Figure 12.
- Relative accuracy is the accuracy of measurements between points on the survey (c in Figure 12).
- Geometric fidelity concerns the accuracy of shapes (d in Figure 12).

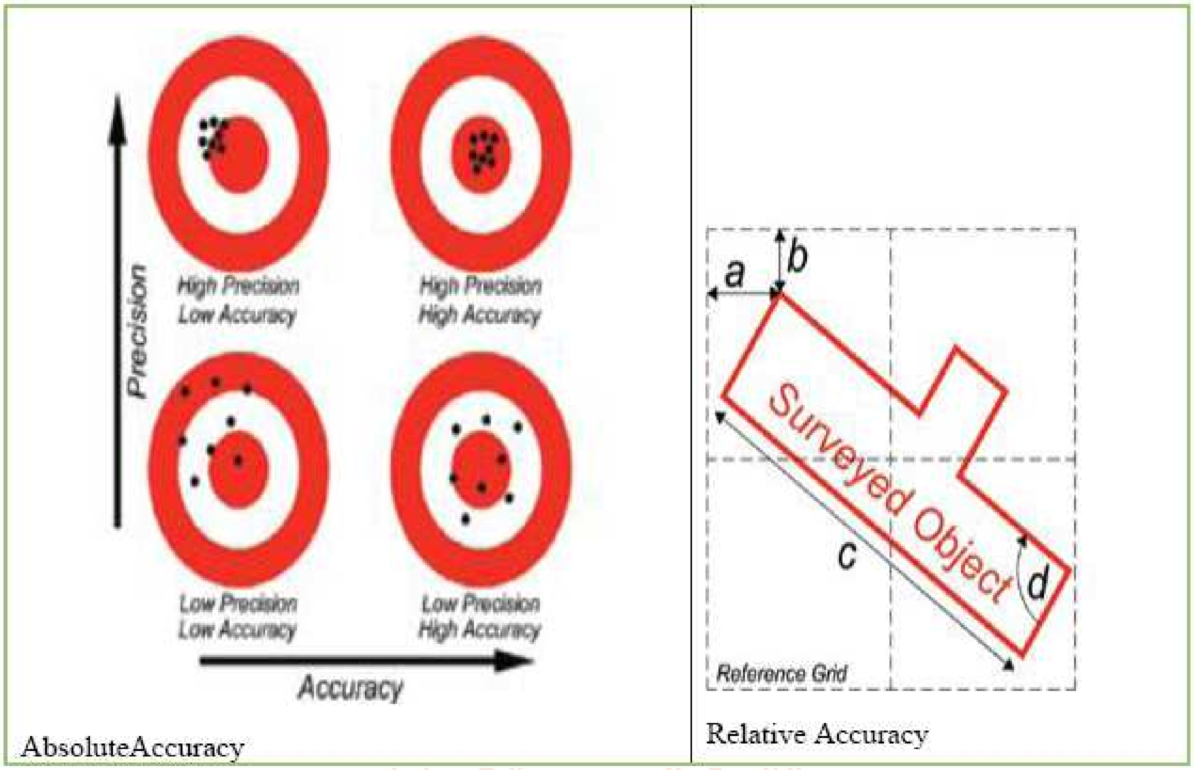

Figure 12: The RICS leaflet introduces the notion of absolute or relative accuracy [24].

Australia uses the uncertainty concepts: Uncertainty means doubt about the validity of a measurement or result of a measurement (e.g. a coordinate). It is an indication of how wrong a value may be and is used in their standards to quantify the level of survey quality. Uncertainty is expressed as a standard deviation in the International System of Units (SI) expanded to the 95% confidence level. The following notions were introduced:

Table 7: Positional. Relative and Survey Uncertainty

Positional Uncertainty, (PU)	The uncertainty of the horizontal and/or vertical coordinates of a survey control mark concerning datum.
Relative Uncertainty, (RU)	The uncertainty between the horizontal and/or vertical coordinates of any two survey control marks. RU can be expressed in SI units at the 95% confidence level, or in a proportional form such as a ratio of uncertainty per unit length or survey misclosure.
Survey Uncertainty, (SU)	The uncertainty of the horizontal and/or vertical coordinates of a survey control mark independent of datum. That is the uncertainty of a coordinate relative to the survey in which it was observed, without the contribution of the uncertainty in the underlying datum realization.

Quality can have different interpretations (Table 8), depending on where in the production and usage life cycle the reference data is.

Table 8: Interpretation of quality in different phases of production

Phase	Quality documentation	Goal for quality	Quality method	Level
Before production	Specification -> quality model	Define quality requirements	Investigation of customer requirements	Feature type level
During production	Database-> Process history	Meet the specification, Record the expected quality to the database	Inspection	Feature instance (e.g. dates, positional accuracy)
After production	Metadata, Test reports	Measure conformance to quality requirements	Evaluation, Reporting	Dataset level

Before production, it is important to specify quality requirements (Figure 13) for data sets. This can be done by describing a quality model. In the quality model, quality elements should be specified including goals for quality at the feature type level. ISO 19100 series does not specify the content of a quality model but the same principles can be used to organize the content of a quality model.

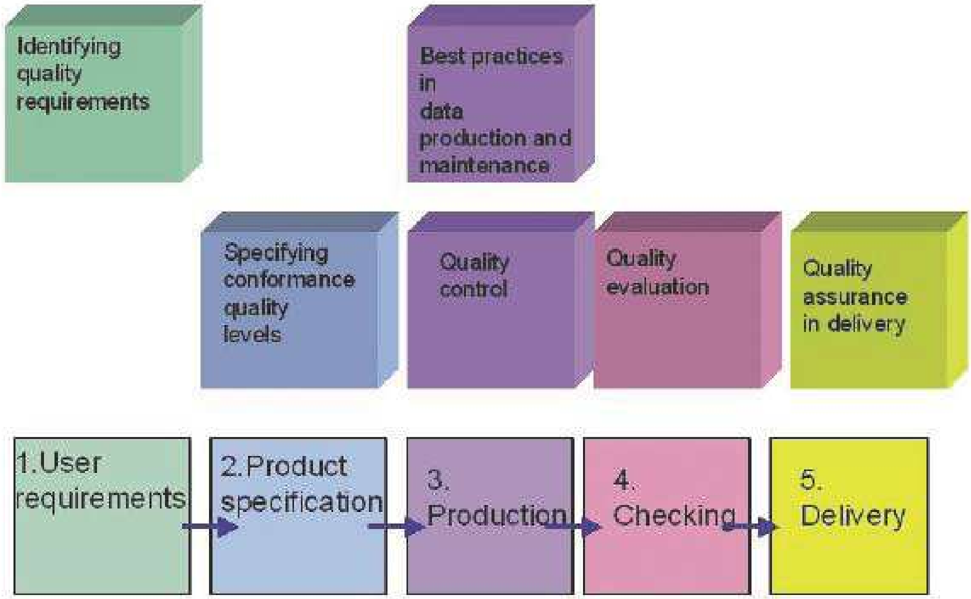

Figure 13: Quality in a general production process

Data quality is the difference between a dataset and a universe of discourse. Producers and users may use different universes of discourse, and will thus assess differently the quality of the same dataset (figure.14).

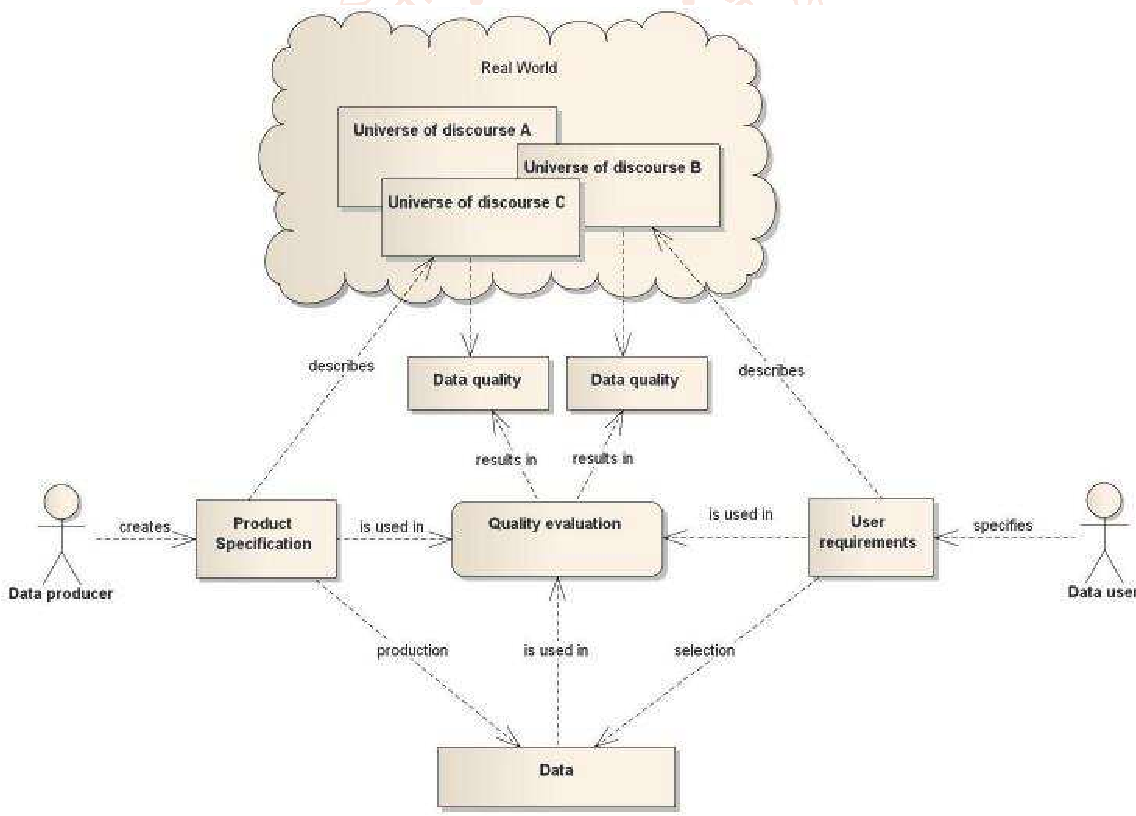

Figure 14: Framework of data quality concepts

The ISO 19157:2013 standard does not specify how to measure the differences between a dataset and a universe of discourse. It defines a taxonomy of the various kinds of differences that are usually measured [12], those various kinds of differences being called quality elements and sub-elements. It also describes how to identify whether these elements and sub-elements apply to one given dataset, how to create additional elements and sub-elements, and how the reporting of quality assessment should be performed. The data quality elements described by the ISO 19157:2013 are the following: a. Completeness b. Logical consistency c. Positional accuracy d. Temporal accuracy e. Thematic accuracy and f. Usability.

Regarding Positional accuracy, to be able to evaluate the data quality of a dataset, a subset of this dataset must be compared to « true positions ». To simulate true positions, one must measure again with a technique at minimum twice as accurate (a compromise between cost and accuracy).

The following quantities are examples of the data quality measures for the data set (ISO 19157:2013) among more than 50 existing [12]:

- Standard deviations of residuals
- Mean value of positional uncertainties
- The mean value of positional uncertainties excluding outliers
- Number of positional uncertainties above a given threshold
- Root means square error

ISO 1957:2013 provides a table (Table 9) to determine the size of the sample and the rules to determine the value of the final accuracy of the dataset.

Table 9: ISO 19157:2013 statistical numbers for testing standard deviation, 95% confidence level

Population size		Sample size (n)	$\sqrt{F_{0.05,n-1,\infty}}$
From	To		
26	50	5	1,54
51	90	7	1,45
91	150	10	1,37
151	280	15	1,30
281	400	20	1,26
401	500	25	1,23
501	1200	35	1,20
1201	3200	50	1,16
3201	10000	75	1,13
10001	35000	100	1,12
35001	150000	150	1,09
150001	500000	200	1,08
> 500000		200	1,08

8.2. Standards analysis and comparison

ISO provides the standards definition as: "A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes, and services are fit for their purpose. Generally, it is well known that a standard is an agreed way of doing something. The general benefits of a standard are safety, quality, interchangeability, and consistency.

The standard options can be varied from expression of needs to operating instructions. It has been proposed to sort standards by level of abstraction and detail, based on the expression of needs and going to the detailed operating instructions when it is necessary. The proposed method of work and organization is based on the expression of needs, for example: -

- What are the activities and business processes that generate the survey activities?
- What is the accuracy level expected to satisfy the needs?
- How to meet this accuracy level?
- What type of surveys can fulfill the accuracy level?
- What technical process and procedure can fulfill the accuracy level?

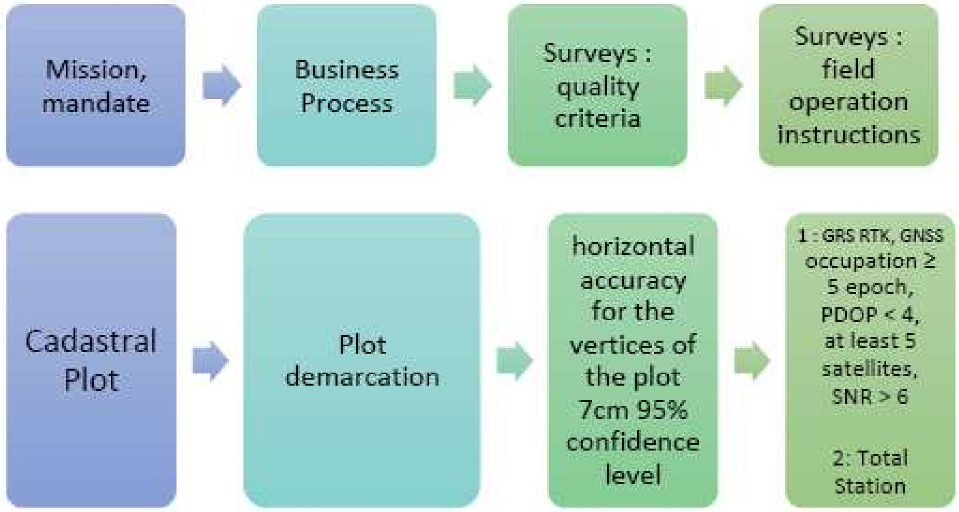

Figure 14: Technical Processes and Procedures Option

Two approaches are possible: By business process or by discipline in which, the first level may be organized by business process or geomatics discipline. As far as possible, we should avoid mixing the two approaches. In any case, the two potential inputs are linked in the expected or required accuracies. The expected accuracy is dependent on the need and therefore on the associated activity. For a topographic survey, depending on the type of activity, the expected planimetric accuracy can vary from a few centimeters to 1m or more.

For some surveys, the business process is not necessarily clearly identified, but in this case, there is an implicit or explicit need. It is proposed that the specification work be divided into the steps: Define required accuracy for each business process; identify surveying techniques and identify procedures to meet the required accuracy. For instance, for the plot showing the survey, the expected accuracy is around 10cm at the 95% confidence level. To reach this accuracy, the GNSS RTK measurement of 5 epochs is sufficient using at least five GNSS satellites.

8.3. QA/QC: Process-oriented and product-oriented

To increase the level of confidence in the output of the surveys, one must ensure that, the processes are complying with standards and best practices but also to be able to assess the quality of the final dataset. One can sum up the two complementary approaches as follows (Section 6):

- Quality Assurance is process-oriented; it increases the level of confidence in the process to reach the expected level of accuracy.
- Quality Control is product-oriented or result-oriented, it checks that the final result is fully satisfying the initial need for the required accuracy level.

9. Conclusions

This paper aims to outline the executive regulations, survey standards, and specifications required for the implementation of the Sudan Survey Act for regulating and organizing all surveying work activities in Sudan. The paper presents conceptual guidelines to be used by the Sudan Survey Authority and its stakeholders for the implementation of the Survey Act and to regulate the surveying and geospatial work practices, standardizing the field surveys, processing, quality control, procedures, and the processes related to survey work to be carried out by relevant authorities in Sudan. The conceptual guidelines are meant for unifying and improving the quality and harmonization of geospatial data, and to aid decision-making processes as well as geospatial information systems. The targeted standards and specifications may include, the reference frame, projection, and coordinates systems, and the guidelines and specifications that must be followed in the fields of survey work, processes, and mapping.

The Sudan Survey Authority has to develop a comprehensive set of survey regulations and standards. These standards are to be classified into several levels and categories, and their structure should be based on the expression of the needs of the SSA and the stakeholders. To satisfy needs and expectations, different levels of quality (mainly accuracy levels) have to be defined. To get the expected results, it is essential to adopt the best practices that consider the need and the level of quality required to satisfy that need rather than the technology or the processes.

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