NEOM نيوم

ENGINEERING PROCEDURES

TOPOGRAPHICAL SURVEY PROCEDURE

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Document History

Revision code	Description of changes	Purpose of issue	Date
Rev 01.00	First Issue	Issued for Implementation	13.05.2020

Document Approval

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1. Purpose

This procedure provides technical specifications, procedural guidance and quality control criteria for conducting topographic survey works and developing site plans used for engineering, planning and design required to develop and deliver NEOM's assets.

2. Scope

There are different methods for mapping and recording topographical features with variable techniques, outputs, acquisition time and cost, such as:

- **Terrestrial Topographic Survey:**
  This is the conventional method for mapping and recording the existing features using conventional terrestrial instruments such as Total Station, GPS and Level and other methods such as mobile mapping. This conventional method is cost and time effective for medium sized areas with minimum requirements for clearances and permits and thus is traditionally used by the majority of surveying consultants and contractors.
- **LiDAR (Light Detection and Ranging):**

  LiDAR is a surveying method that measures distance to a target by illuminating the target with laser light and measuring the reflected light with a sensor. It is a precise method especially for large areas. This method is time efficient but with a relatively higher cost. It can also be utilized for areas of vegetation where accessibility on the ground is limited.
- **UAV (Unmanned Aerial Vehicle) Photogrammetric Mapping:**
  Mapping with fixed-wing aircrafts or drones is done using photogrammetry which makes measurements from photographs. Multiple overlapping photos are captured of the ground as the aircraft flies autonomously along a path that is user specified. It is cost effective, especially for large areas, and it can be used for areas that are not easily accessible.

The following method can be adopted if underground utility detection is required:

- **GPR (Ground Penetration Radar):**
  GPR is a geophysical method that uses radar pulses to map areas below the surface of the ground. It is non-destructive and is used to view elements underground. Inter-related studies and investigations include:
  - Geotechnical and Geophysical Investigations
  - As-built data received from various municipalities and authorities
  - GIS Data

The selection of the appropriate technique depends mainly on the project size, allocated budget and time, in addition to the end use of the required deliverables.

The following objectives are identified for all types of surveys required for the development and delivery of NEOM assets:

- Establishment of a control network of reference markers precisely surveyed, levelled and tied to a coordinate system approved by the Client / NEOM (currently Horizontally UTM-WGS84 is used and vertically EGM 2008). All vertical heights should be referenced to the Mean Seal Level (MSL). When using EGM2008 for transferring the ellipsoidal heights to MSL, the contractor should perform the required measurements, procedures and submit the required evidences that prove the obtain MSL heights accuracies are meeting the projects' specifications.
- Contractor should ensure proper connection of the survey works with national grid points provided by the Local authorities such as MOMRA (Ministry of Municipalities and Rural Affair).
- Details of the coordinate system are shown in the below table.

Table 1: Geodetic system

Parameter	Reference System
Geodetic Datum	WGS 84
Spheroid	WGS84
Semi major axis	6378137.000
Inverse Flattening	298.257223563
Projection	Universal Transverse Mercator
False Easting	500,000 m
False Northing	0 m
Vertical Datum	EGM 2008

- Capture of survey data in 3-D digital format including all surface details, existing physical features, structures, buildings, walls, fences, gates, above and below ground utilities, ancillary construction, vegetation, existing roads adjoining the site and existing public utilities along them as well as existing wadis/depressions and waterways.
  Preparation of site plan, at the required scale, showing surveyed features, topographic contours and spot levels.

3. Definitions and Abbreviations

Table 2: Table of definitions

Term	Definition
As-built	As-built documents, including drawings and notes that depict the final as-constructed state.
Asset	Refers to the required physical buildings or infrastructure such as residential, business facilities, commercial & retail facilities, media center, recreation, entertainment & sports facilities, marinas, hospital, medical clinics, religious facilities, school, library, fire stations, roads/streets/bridges, infrastructure system, and utility networks. Also, it relates to components of buildings and structures that need to tracked and managed.
Surveying Contractor	The surveying company that will be assigned to take over the required/requested surveying activities.
Department	Different entities and divisions constituting NEOM organization, which may include the Project Department, Operations Department, Proponent/Sponsor, Urban Department, Environment Department, Loss Prevention & Fire Safety Department, etc.
Digital Elevation Model	Digital Elevation Model is a bare-earth raster grid referenced to a vertical datum filtered out of all natural and built features.
Digital Terrain Model	Typically augments a DEM, by including vector features of the natural terrain, such as rivers and ridges.
NEOM Representative	Appointed Project Management Consultant, Supervision Consultant, other Consultants or NEOM Departments.
Project	Refers to the development and delivery of an NEOM Asset or a group of NEOM Assets.
Unmanned Aerial Vehicle	Is an aircraft the can be fully or partially autonomous but are more often controlled remotely by a human pilot.

Term	Definition
Works	Encompass all associated engineering, services, procurement, construction (including temporary and permanent), installation, pre-commissioning, commissioning and performance tests that are essential to accomplish the required Asset.

Table 3: Table of abbreviations

Abbreviation	Description
BM	Bench Mark
DEM	Digital Elevation Model
DTM	Digital Terrain Model
E	Easting
GPR	Ground Penetration Radar
GPS	Global Positioning System
H	Elevation
KM	Kilometer
LiDAR	Light Detection and Ranging
MSL	Mean Sea Level
N	Northing
PRM	Permanent Reference Mark
RMSE	Root Mean Square Error
UAV	Unmanned Aerial Vehicle

4. Related NEOM Documents

The requirements contained in the following documents apply to the extent specified in this procedure.

Table 4: Table of NEOM engineering procedures

Document Code	Document Name
NEOM-NEN-PRC-005	Design Stages Deliverables Procedure
NEOM-NEN-PRC-008	Document Numbering and Revision Procedure
NEOM-NEN-PRC-009	BIM & GIS Procedure
NEOM-NEN-PRC-010	Drawing and Drafting Procedure

5. Procedure

5.1. Stages of Topographical Survey

5.1.1. Stage 2 - Master Planning & Asset Brief

During the Master Plan phase, small scale maps, satellite imagery, Digital Elevation Model (DEM) can be used for initiating master plan activities. This data can be obtained from several sources such as:

- Concerned mapping authorities,
- Aerial/satellite photographs,

- DEM Data.

The scope of work at Master Plan phase is initiated by a desk study which provides a high level study to:

1. Identify and evaluate the site environment,
2. Map of the existing topography,
3. Identify site conditions and characteristics,
4. Determine accessibility,
5. Identify natural terrain and/or manmade features that may impact the development and delivery of NEOM assets.

Alternatively, site reconnaissance must be conducted to achieve these objectives. Site reconnaissance will also provide essential information for planning and determining the proper survey methods to be used to carryout detailed topographic surveys.

5.1.2.Stage 3 - Design & Tendering

Prior the design & tendering design stage, the objective of conducting topographic surveys is to collect detailed survey data about natural and man-made features, in addition to site contours. This data will be used to determine if the existing conditions are in accordance with the design assumptions made at the Master Plan stage.

Designers will use the results of the topographic survey to:

- Develop the design,
- Tailor the design to suit the existing conditions and thus optimising project cost and time,
- Utilise the existing contours to maximise the efficiency of the design.

Consequently, the main objectives of conducting a topographic survey include, but are not limited to, the following:

- Establishment of ground control stations' fixation, observation, adjustment and connection to the adopted grid coordinate system. These control stations shall be used for all the survey activities, setting out of the design elements and mapping.
- Identifying and surveying the geographical location and elevation of the surface features.
- Identifying and surveying existing utilities.
- Identification of the land use.
- Developing project site mapping at an appropriate scale.

5.1.3.Stage 4 - Construction, Handover & Close-out

Topographic surveys shall be conducted during construction to verify that the design parameters are in-line with the prevailing topography conditions. This is crucial in terms of: (1) collecting information to determine if the executed works are in accordance with the design; (2) monitoring the progress of the Works; (3) identification of any deviation from the design; and (4) highlighting any required adjustments to works constructed. After construction works are completed the Surveying Contractor shall undertake the as-built survey and required mapping to record the completed status before the Operation & Maintenance (Stage 5) commences.

5.2. Quality Assurance / Quality Control

5.2.1.Survey Works

Prior to commencing survey works, the Surveying Contractor shall submit a QA/QC plan to the NEOM Representative for review and approval. The Surveying Contractor shall comply with the NEOM Representative's comments while undertaking the survey works.

The Surveying Contractor shall provide and submit copies of current calibration certificates for all measuring equipment used.

5.2.2. Survey Data

The QA/QC plan shall detail the frequency, the acceptance criteria, the controlling document and the record created for every survey measurement required. Survey data accuracy shall be verified horizontally and vertically by comparing their values in the data set with the values obtained from an independent source of higher accuracy.

If the verification does not meet the accuracy, under each survey method specified herein, data shall be corrected by the Surveying Contractor at his own expense. The Surveying Contractor shall have a system established and maintained during the project to control all the documents and data necessary for the performance of the work.

5.3. Field Work

5.3.1. Control Network and Traverse Survey

Horizontal control points shall be used to establish the Easting, Northing and Elevation for each element of the project, and for the staking out the designed elements.

The national PRMs grid data sheets shall be reviewed before use. All data concerning the adopted national grid, scale factor and the horizontal / vertical transformation parameters used shall be reported.

Survey works are specified and classified based on the horizontal (linear) point closure ratio or the vertical elevation difference as summarized in the following table:

Table 5: Survey projects classification

Classification	Closure Distance Ratio	Elevation Closure (mm)
First-Order	1:100,000	3√K
Second Order, class I	1:50,000	4√K
Second Order, class II	1:20,000	6√K
Third Order, class I	1:10,000	8√K
Third Order, class II	1:5,000	12√K

√k = square root of total length of survey loop in Kilometres

Source: Federal Geographic Data Committee, FGDC-STD-007.4-2002.

Traversing

The traverse design shall identify the number of control points so that the length of any traverse leg between two traverse stations shall not exceed the maximum distances outlined in the following table:

Table 6: Survey projects classification

Classification	Station spacing not less than (km)	Minimum number of network control points
First-Order	10	4
Second Order, class I	4	3
Second Order, class II	2	2
Third Order, class I	0.5	2
Third Order, class II	0.5	2

Source: FGCC 1984, federal Geodetic Control Committee Standards and Specifications for Geodetic Control Points

The accuracy of the traverse shall be as follow:

- Accuracy of 1:2,500 -1:5,000: Acceptable for earthwork, dredging, embankment, beach fill, and levee alignment stakeout and grading, and some site plan, curb and gutter, utility building foundation, sidewalk, and small roadway stakeout.
- Moderate accuracy (1:5,000): Acceptable for most pipeline, sewer, culvert, catch basin, and manhole stakeouts, and for general residential building foundation and footing construction, and highway pavement.
- Higher accuracies (1:10,000 - 1:20,000): Acceptable for aligning longer bridge spans, tunnels, and large commercial structures.
- For extensive bridge or tunnel projects, 1:50,000 or even 1: 100,000 relative accuracy alignment work may be required.

5.3.2.Survey Control using Global Positioning System (GPS)

5.3.2.1. Network Planning

The technique of GPS networking highly depends on the required application and subsequently affects the accuracy achieved, as indicated in the below table 7:

Table 7: GPS tracking techniques

Technique	Applications	Accuracy
Static (Post-processing)	Control surveys (that require high accuracy)	Sub-centimeter level
Rapid Static (Post-processing)	Control surveys (that require medium to high accuracy)	Sub-centimeter level
Kinematic (Post-processing)	Continuous topo Location surveys	Centimeter level
Stop & Go Kinematic (Post-processing)	Medium accuracy control surveys	Centimeter level
Real Time Kinematic/On-The-Fly Kinematic (Real-time or post-processing)	Real-time high accuracy hydro surveys Location surveys Medium accuracy control surveys Photo control Continuous topo	Subdecimeter level

Source: US Army Corps of Engineers, Engineering and Design, NAVSTAR Global Positioning System Surveying – Engineer Manual

The criteria for survey data acquisition using GPS can be summarized in the below table:

Table 8: GPS survey design, geometry, connection, and observing criteria

Criteria	Classification Order				
	First	**Second, I**	**Second, II**	**Third, I**	**Third, II**
Existing National control points to be checked	Yes	Yes	Where feasible	Where feasible	Where feasible
NGRS control points required	2				
New points spacing not less than (m)	1,000	1,000	500	200	100
Maximum distance to the nearest control point (km)	50				
Minimum obstruction angle above horizon, deg	15				
Maximum number of baselines/loops	10	10	20	20	20
Maximum loop length, km, not to exceed	50	100	200	Not Required	Not Required
Two frequency L1/L2 observations required: < 50-km lines > 50-km lines	 Yes Yes	 No Yes	 No Yes	 No Yes	 No Yes
Recommended minimum observing time (per session), min	120	60	45	30	30

Source: US Army Corps of Engineers, Engineering and Design, NAVSTAR Global Positioning System Surveying – Engineer Manual

- At least four (4) healthy satellites should be observed in common at all simultaneously occupied stations.
- The Positional Dilution of Precision (PDOP) or Geometric Dilution of Precision (GDOP) should be less than 10 m/m -- optimally 4-5 m/m during any GPS survey observations
- The network should be designed so that closed loops are created from baselines observed in two or more sessions. Each loop should have at least one baseline in common with another loop.

The Surveying Contractor should submit the proposed network design to the Engineer for approval before commencing the field works.

5.3.2.2. Field Observations

1. Antenna Setup

For all surveys, tribraches allowing for levelling of the antenna together with an optical or mechanical device permitting accurate centring over the mark must be used. The cantering device must be checked before and after the survey as well as every week for the duration of the survey

The height of the antenna's phase centre above the station marker must be measured and recorded to the nearest millimetres before and after each observing session. All measurements taken to derive the total height of the antenna phase centre above the marker must be recorded in the field log and the procedure should be described by a sketch in order to allow verification of the computation.

If the receiver is to remain at the same station for two or more observing sessions, the antenna must be re-positioned between each session, and the antenna height re-measured and recorded at the beginning and end of each session. This will ensure the independence of each observing session.

2. Length of Observation Session

The minimum observations session length for any static dual GPS observation should be at least 30 minutes. For lines over 20 km the observation session length should be increased by 2 minutes per 1 km of GPS baseline length behind 20 km. The final observations session length should also consider the number of satellites available, network configuration, predicted PDOP and the used GPS manufacturer guidelines.

3. Field Notes

A detailed field log, either digital or on paper, must be maintained. The minimum information that must be included is:

- Date of observations (year, month, and day).
- Session identification.
- Station identification.
- Height of antenna phase centre above the marker (to 1 mm) and all measurements taken to derive that height (a sketch depicting the procedure is also recommended).
- Antenna offset from marker, if any (distance and azimuth).
- Starting and ending time of observations.
- All problems or unusual behaviour with equipment or satellite tracking. An obstruction diagram, showing any obstructions at elevations greater than 15° as seen from the antenna location, may also be added to the field log.

5.3.2.3. Data Processing

The software used for processing the data must produce relative positions or coordinate differences for stations observed simultaneously and associated rigorous variance-covariance statistics which can be used as input to a three-dimensional network adjustment program.

The software used for the adjustment must provide observation residuals (or the equivalent) which should be examined to ensure that no systematic effects remain. It must also be capable of producing the full formal covariance matrix of all the estimated coordinates.

Software and processing procedures must be successfully tested by processing data sets collected on the validation network before being adopted for a production survey.

In order to quickly identify any problems with the data and to take the appropriate corrective action, the data should be processed as soon as possible after the observing session. All processing stages and unusual events, inconsistencies or errors must be logged. The following procedures provide information regarding the consistency and reliability of the data and should be carried out as frequently as possible (preferably daily).

The differences in repeated baseline measurements must be computed to check for blunders and to obtain initial estimates of the internal consistency of the GPS network. The differences should not exceed the accuracy requirement with respect to baseline length.

Wherever available, previously established baselines (between two control points for example) should be compared with the GPS network solution baseline. Discrepancies larger than those specified by the accuracy requirement for the survey should be investigated.

All processing stages and unusual events, inconsistencies or errors encountered must be logged.

5.3.2.4. Raw Data and Field Notes

All original observational data collected in the field must be provided. These include:

1. All measurement data (raw data) collected during the campaign. Data should also be provided in RINEX (Receiver Independent Exchange) format.
2. The original field logs in paper or digital form.
3. Any conventional survey field notes.

5.3.2.5. Processing Procedures

A detailed description of the procedures used for processing and verifying the data in the field or at the office must be presented. The information provided must include but not limited to:

1. Computer and Software (version number and date) used in the data processing and adjustment.
2. Information and explanations about data editing performed including percentage of data rejected for each station and criteria for rejection.

5.3.3.Survey Control using Total Station (TS)

5.3.3.1. Traverse/Network Design

The traverse design should consider the following;

1. Traverse must start and end at known stations.
2. Due to effects of curvature and refraction, the instrument to target distance must be kept relatively short. A good role of thumb is not to exceed 300 m.
3. Geometric design of the traverse should be relatively strong (angles greater than 30˚ and less than 150˚).
4. If the instrument station is visible from more than two stations, all distances to those stations are required.

5.3.3.2. Data Processing

1. All networks or traverses shall be adjusted using a Least Squares adjustment.
2. The traverse error shall be stated clearly at the end of each traverse calculation sheet.

5.3.4.Permanent Reference Marks (PRMs)

PRMs shall be constructed at the locations approved by the NEOM Representative. The distance between PRMs shall not normally exceed 1,000 meters but their final locations shall be agreed with the NEOM Representative.

All PRMs shall be both horizontal and vertical control monuments.

Except where otherwise specifically allowed in writing by the NEOM Representative, the levelling of PRMs shall be undertaken by direct spirit levelling in both directions. All reduced levels shall be obtained by spirit levelling from at least two specific elevated National Grid system stations. The reduced level of any marker shall be at the top of the marker.

The allowable error for the spirit levelling shall be according to project classification and closure distance ratio table above. Errors within the allowable limits shall be spread evenly over the whole length in proportion to the distance.

Monuments should be set in firm ground away from the travelled way to avoid potential damage from traffic or other hazards.

The related monuments must be preserved for the full construction period of the NEOM asset. If the monument network control cannot be preserved in its original position during construction, a secondary monument control network must be established using the original control as a basis. This secondary network would then be used to set out all construction.

The PRMs shall be constructed in accordance with the standards approved by the authorities having jurisdiction. Otherwise the PRMs shall consist of ribbed steel bar of length up to 1m which can be driven into the ground with a lump hammer. The bar is fitted with an anchor to provide a stable station and attached to a coloured washer secured to the top of the marker with a domed stud. Example of this PRM type is shown in the Figure 1 below.

Figure 1: Ribbed steel bar with washer

Stations in hard surfaces can be marked with a P-K masonry pin which is 6mm in diameter and up to 64mm in length. To identify the station, it should be used with a steel marking washer. If greater stability is required the steel pin can be set in 200mm concrete encasement or a reinforced pillar as shown in Figure 2 below.

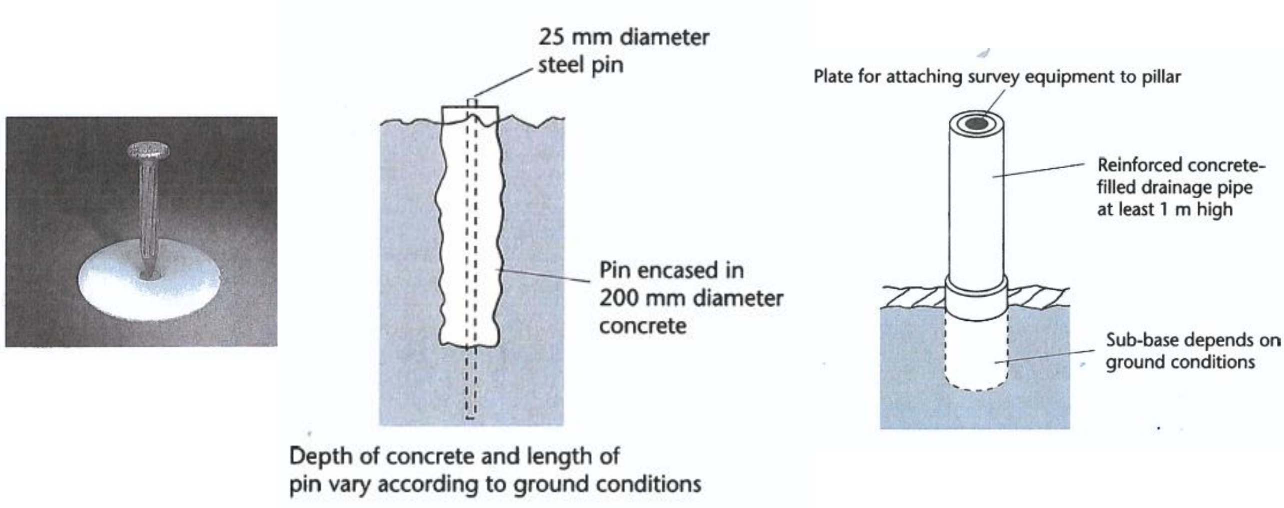

Figure 2: P-K masonary pin with concrete encasement

All primary horizontal and vertical control stations shall be monumented and described in addition to the navigation coordinates by hand held receiver GPS as latitude and longitude.

5.3.5.Topographic/Utilities Survey Details

The following features in addition to all underground utilities and associated information as required shall be surveyed in 3D (Easting, Northing and Elevation) and shall be shown on the topographic maps:

- All natural and manmade features.
- Location and size of all gas lines and oil/water separators.

- Softscape: Any plant, type, approximate height, diameter and trees' trunks calliper/diameter.
- Roads, tracks, footpaths (Street names, curb line or edge of surfacing to carriageways, steps, pedestrian crossings, traffic islands, parking or amenity areas).
- Street furniture (electricity poles, lighting columns, traffic signals, road signs, gullies, manhole covers, etc.).
- Buildings (outline, names or numbers of plots and threshold elevation).
- Structures (bridges, culverts, retaining walls, sign and signal gantries, etc.).
- Boundary features (fences, gates, walls, hedges, etc.).
- Search shall be made for all underground utilities.
- Wet utilities networks and structures (including sanitary sewer lines, storm sewer lines, drainage ditches and ponding areas).
- Water and drainage features (watercourses, wadis, wells, reservoirs, ditches, channels, sewer outfalls, etc.).
- Location and size of communication and electric lines, including all transformers and number of wires or cables. Provide a detailed sketch of manholes, illustrating the size of ducts, number of wires in each duct, spacing of ducts, and distance from the floor and wall to the centreline of ducts and its alignment to the North.
- Low levels of any electric / high tension lines crossing the proposed route.
- Slopes and earthworks (cuttings and embankments, quarries, refuse tips, cliffs, etc.).
- Number and size of ducts and the spare capacity in each duct bank segment.
- Types and dimensions (internal and external) of each manhole type.

5.4. General Specifications for Alternative Methods

5.4.1. LiDAR (Light Detection and Ranging):

1. Point density data.
    - The point density data shall be collected at a minimum density of 1 pls/m^2
2. Accuracy
    - Minimum accuracy of elevations in processed data shall be ± 0.10m.
    - Minimum position accuracy shall be ± 0.05m.

5.4.2. GPR (Ground Penetration Radar):

1. Accuracy
    - The horizontal accuracy shall be ±15 cm, while vertical accuracy shall be ±15% of the detected depth.

5.4.3. UAV Photogrammetric Mapping:

1. Point density data
    - The point density data shall be collected at a minimum density of 1 point/m^2
2. Accuracy
    - Minimum accuracy of elevations in processed data shall be ± 0.03m.
    - Minimum position accuracy shall be ± 0.03m.
    - Minimum geo-referenced ortho rectified mosaics imagery the image resolution shall be ± 0.01m.

5.5. Mapping

The information to be shown on the finished maps includes the following:

1. Map Scale
2. Contours
3. Spot Heights

5.5.1. Map Scale

Horizontal (Planimetric) accuracy criteria: RMSE is the cumulative result of all errors introduced by the process of ground control survey and map compilation. The limiting RMSE shown below are the maximum permissible values for each specified map scale:

Table 9: RMSE maximum permissible values

Target Map Scale	Planimetric Accuracy RMSE (m)		
	Class 1	Class 2	Class 3
1:500	0.125	0.25	0.375
1:1000	0.25	0.50	0.75
1:2000	0.5	1.00	1.5
1:5000	1.25	2.5	3.75

Source: "Geospatial positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy," Federal Geographic Data Committee, FGDC-STD-007.3-1998

5.5.2. Contours

Vertical (topographic) accuracy criteria: Vertical accuracy is traditionally relative to the required contour interval for a map.

Table 10: Vertical accuracy RMSE

Target Contour Interval (m)	Vertical Accuracy RMSE (m)		
	Class 1	Class 2	Class 3
0.5	0.17	0.33	0.5
1.0	0.33	0.66	1
2	0.67	1.33	2
2.5	0.83	1.65	2.5

Source: US Army Corps of Engineers, Engineering and Design, Control and Topographic Surveying – Engineer Manual

5.5.3. Spot Heights

Spot heights shall be given at the following locations:

1. At relevant points such as hilltops and bottoms of depressions.
2. Along the edges and centre of all roads and public accesses, at road intersections and significant changes of gradient and curvature.
3. At water level, watercourses, and ditches at intervals of approximately 50 m.
4. At any other positions indicated on the Contract drawings.
5. Along all features listed under "**Topographic/Utilities Survey Details**".

Spot heights shall be used for building a DTM model, a DEM model and for creating contours.

The density of the surveyed points for spot levels in open areas shall be as outlined in Table 11 below:

Table 11: Density of surveyed points

Contour Interval (m)	Density of Spot Levels (Points/Hectare)			
	Flat terrain: 0-1%	Slope terrain: 1-5%	Hilly terrain: 5-10%	Steep Terrain >10%
0.5	25	300	1100	As required to delineate feature
1	16	150	500	
2	8	80	250	
2.5	4	40	120	

Source: US Army Corps of Engineers, Engineering and Design, Control and Topographic Surveying – Engineer Manual

5.6. Presentation

The band of detail shall generally be set out on the drawing to run from left to right across the full width of each sheet irrespective of the North point. The band of detail shall be placed in the upper or lower part of the sheet and a North point shall be added.

Names and annotations shall be aligned parallel to the general axis of the route except for names relating to linear features which shall be aligned parallel to those features. Names need not be realigned on sheets with unusual orientations and overlaps.

All survey results shall be produced as drawing files on electronic media in AutoCAD format and on hard copies (standard sheets of A1 size).

All final drawings shall be provided with a standard border and heading.

All Layering and annotations shall be aligned with NEOM's Drawing and Drafting Procedure (NEOM-NEN-PRC-010).

All PRMs, National Grid triangulation stations, and other survey information within the area to be mapped, shall be indicated and referenced on the final drawings in accordance NEOM's Drawing and Drafting Procedure (NEOM-NEN-PRC-010). The coordinates and heights of traverse points and heights of BMs shall be shown on the final drawings.

All details specified above shall be represented on the final drawings by opaque lines, symbols and annotations.

Contours shall be shown by continuous lines with a thicker line for every fifth contour and contours shall be differentiated from other details by half tone screening. The value of each contour shall be indicated along the contours at intervals not exceeding 200mm.

5.7. Satellite Imagery

If required, the Surveying Contractor is required to obtain recent cloud free satellite imagery with resolution not more than 1m. This imagery shall be correlated with the topographic survey at the same coordinate system.

5.8. Survey Data and Deliverables

This task consists of the supply of all project output and supporting data. Documents produced shall be reviewed and checked by authorised personnel prior to issue. The checking status shall appear on each hard copy document and it shall be apparent by visual inspection that all specified checking has been completed.

5.8.1. Hardcopy Documents Related to the PRMs

The following shall be compiled and submitted in hardcopy:

1. Schedules of PRMs giving the reference number, heights above MSL and coordinates.
2. A location sketch for each PRM showing its location, descriptions of PRMs giving the type of markers constructed, location sketches accomplished by a photograph, and distances to a minimum of three points of reference of permanent detail.
3. Copies of the most recently available National Grid triangulation points with description for each point used for the Works, giving the reference number, National Grid coordinates, height above MSL and description of position.
4. Diagrams of the PRMs network indicating the connections between PRMs and National Grid bench marks with misclosures.

5.8.2. Survey Drawings and Documents

The following documents are to be delivered progressively:

1. One (1) proof set high quality, along with two (2) sets of prints of all drawings scale 1:1000 and if necessary further copies until approved. The size of any drawings shall not exceed standard sheets of A1 size. Surface contours shall be drawn at 0.50 m contour intervals and be referenced to the MSL. All details / features shall be identified and shown on the survey drawings in addition to the PRMs.
2. The calibration reports for all survey instruments (e.g. GPS receivers, total stations, etc...) used to conduct the survey.
3. The specifications sheets for the survey instruments used.
4. All calculation sheets related to the network / traverse adjustment.

5.8.3. Electronic Deliverables

The following documents shall be provided on at least two solid–state drive (SSD) and may require to be uploaded to the project collaboration website:

1. AutoCAD (dwg) and Adobe Reader (pdf) format files of the individual survey drawings. The drawings shall utilize layer naming conventions, line type and line weights as per NEOM Drawing and Drafting Procedure NEOM-NEN-PRC-010.
2. List of all survey points (spot levels), including point numbers, description, Easting, Northing, and Height. This list shall be provided in EXCEL format and shall be shown on the AutoCAD files as three-dimensional 3D CAD points associated with their point number, description and elevation each on its specific layer.
3. 3D break-lines (3D polylines) shall be located for all natural or man-made features outlines. These include but not limited to road edges / centre lines, tops and toes of ditches and canals, and levee features. Any condition where a change in grade can be detected should be located. The break-lines shall be located by Easting, Northing and Height coordinates each on its specific layer.
4. A 3D Digital Terrain Model (DTM) of the site and all features surveyed utilizing a modelling software that is compatible with Civil-3D and shall include all breakpoints, break-lines, slopes, grades and elevation.

5.8.4. Survey Report (Soft and Hardcopy)

The Survey Report shall cover the work carried out and deliverables, including all the information necessary to evaluate the satisfactory completion of the project objectives.

Sufficient information must be provided in the report to enable reprocessing of the raw data, if required.

A short description of the objectives of the project, location of the survey and number of stations positioned must be submitted. A map, or map overlay, showing all markers occupied must also be submitted. The overlay shall be to scale and must show the baseline observations complete with the observation dates and times and must show common baselines between sessions.

The report shall include a clear description of the survey procedures used in the field. The information provided should include, but is not limited, to the following:

1. A summary of the equipment used, including serial numbers, and a brief description of characteristics and principles of operation.
2. A summary indicating for each session, the occupied stations, their respective start and end time of data collection and the satellites simultaneously observed.
3. Logistical information including: means of transportation, equipment deployment scheme, personnel involved and their duties, and difficulties encountered and how they were overcome.
4. Narrative description of the project which summarizes the project conditions, objectives, methodologies, QC/QA procedures, and conclusions.
5. A discussion of observation plan, equipment used and any problems encountered.
6. Full information about the adopted coordinates reference framework used, datum, map projection used, scale factor, accuracy and transformations parameters used… etc.
7. List of the existing ground controls, which were used as a base for the survey traverse.
8. All field observations recorded in a suitable Traverse Field Book format.
9. Traverse/network calculations and adjustment sheets.
10. For Least squares adjustment both the input/output files are required.
11. List of adjusted coordinates with its all-relevant data.
12. Include a diagram of the project stations and control points at an appropriate scale. Descriptions for each monument should be included and accompanied by a photograph.

6. References

1. FGCC 1984, Federal Geodetic Control Committee Standards and Specifications for Geodetic Control Points.
2. “Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy,” Federal Geographic Data Committee, FGDC-STD-007.3-1998.
3. “Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management," Federal Geographic Data Committee, FGDC-STD-007.4-2002.
4. US Army Corps of Engineers, Engineering and Design, Control and Topographic Surveying – Engineer Manual.
5. US Army Corps of Engineers, Engineering and Design, NAVSTAR Global Positioning System Surveying – Engineer Manual.