3 ALTERNATIVES

3.1 Introduction

This section summarises the process undertaken during pre-front-end engineering and design (FEED) (design process before FEED) and FEED to evaluate the technically and financially feasible alternatives for the East African Crude Oil Pipeline (EACOP) project while considering environmental and social impacts. The alternatives have been broadly categorised as follows:

- project zero alternative
- pipeline routing
- facility siting
- technology
- construction techniques.

3.2 Overview

The project alternatives considered and the decisions taken by the EACOP project during the pre-FEED and FEED phases have led to the validation of the project base case as it is described in Section 2 Project Description. The objective of this section is to document how the project design was optimised to reduce environmental and social impacts while being technically and financially feasible. This is based on assessment of the alternatives for each of the key strategic alternative themes, i.e., the “zero” project alternative and the main alternative areas mentioned in Section 3.1.

While the base case concept for technology was defined during pre-FEED phase, routing and siting alternatives have been analysed progressively in the context of the engineering, environmental, socio-economic and cultural heritage constraints identified during baseline surveys undertaken as part of the environmental and social impact assessment (ESIA) process. It should be noted that there is a requirement to provide flexibility for construction contractors that will develop the most efficient and cost-effective construction techniques while ensuring compliance with project standards. As mentioned in Section 2.1.1, refinements to design may be made during the detailed engineering and pre-construction phases influenced by site-specific conditions.

3.3 Approach to Alternatives Assessment

The environmental impact assessment (EIA) regulations for Uganda require an examination of feasible project alternatives and an explanation of the rationale for selecting the proposed project scheme. The specific requirements are detailed below:

The Environmental Impact Assessment Regulation 13/1998 requires the EIA to provide:

- a description of the proposed site and reasons for rejecting alternative sites
- the technology and processes that shall be used, and a description of alternative technologies and processes, and the reasons for not selecting them,
- the environmental effects of the project including the direct, indirect, cumulative, short-term and long-term effects and possible alternatives,
- an indication of whether the environment of any other State is likely to be affected and the available alternatives and mitigating measures.

In addition, the International Finance Corporation (IFC) Performance Standards Guidance Note 1: Assessment and Management of Environmental and Social Risks and Impacts (Ref. 4.4), requires:

> "…an examination of technically and financially feasible alternatives to the source of such impacts, and documentation of the rationale for selecting the particular course of action proposed."

The alternatives assessment process is shown in Figure 3.3-1.

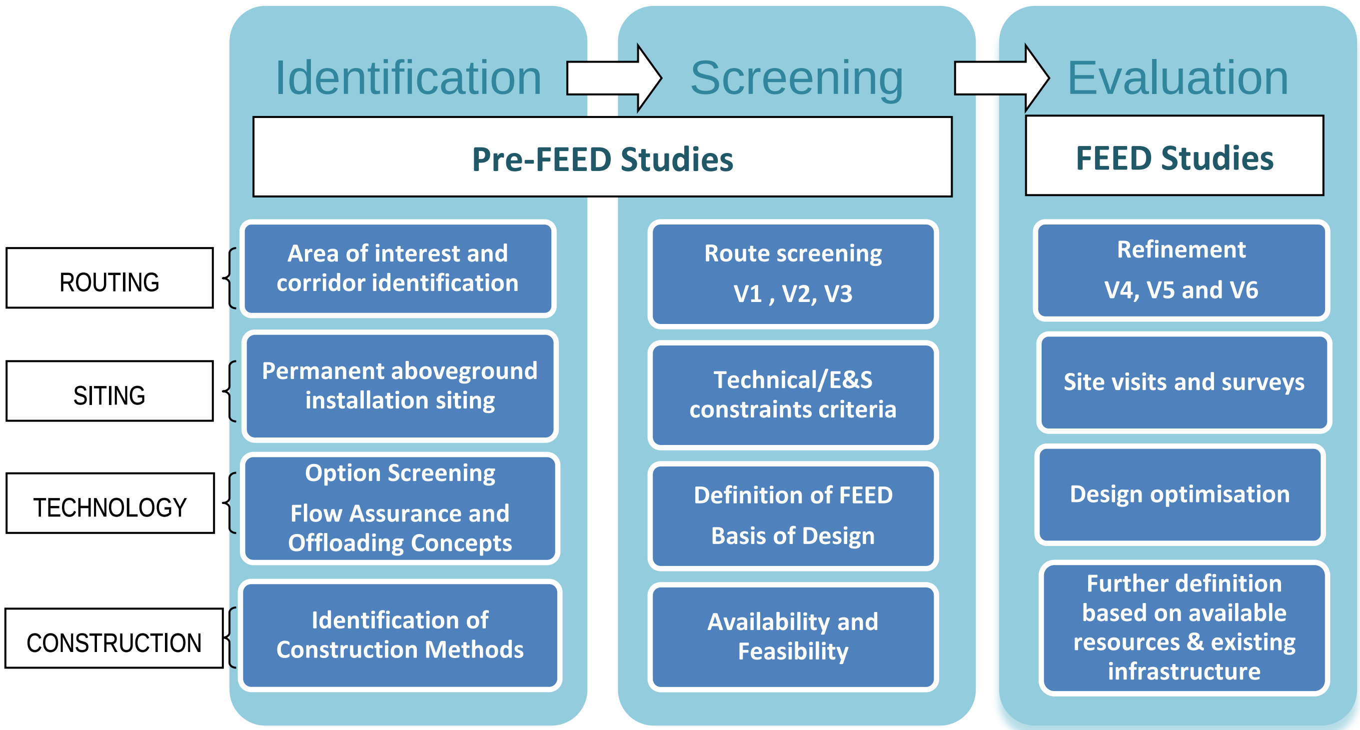


Figure 3.3-1 Alternatives Assessment Process

3.4 Zero Project Alternative

3.4.1 Overview

The "Zero Project Alternative" for the purposes of this alternatives assessment is the situation where the project, i.e., the EACOP System, does not proceed. The development of oil pipelines are large-scale projects and under the zero project alternative there would be no environmental or social impacts, on land or in associated waters because no construction nor operation activities would occur. However, the discovery of oil in the Albertine Graben area of Uganda and the opportunity to access global markets, provide a new resource revenue stream for Uganda and employment opportunities for the host countries. A decision not to proceed with the project would result in the absence of revenue from crude oil production, crude oil export sales and associated economic development. Furthermore, benefits for Uganda, and for the district level would not materialise from the opportunities that the project would provide such as employment, skills development, technology transfer and growth in other business sectors such as fabrication, construction and waste management.

As part of the zero project alternative assessment, other modes of crude oil transport were assessed.

3.4.2 Rail

Rail has been considered as a potential mode of crude oil transport from Uganda to international markets. There is an existing narrow-gauge rail link from Uganda to the Mombasa port. This link was constructed in the 1900s, as a narrow-gauge rail system. Narrow gauge rail is considered less stable and therefore slower than a standard gauge rail system and transporting the projected peak production of 216 thousand barrels per day (kbpd) would be a significant challenge. The network would require extensive upgrades, risks would be associated with carriage stability and the network capacity would not be sufficient for the planned transportation rate of approximately 350 tank cars per day of oil. These combined factors resulted in the decision to consider alternative crude oil transport modes.

3.4.3 Road

Road transport via Kenya to the Indian Ocean coast was considered as a potential mode of transporting oil. It was estimated that it would take approximately 14 days for a shipment to travel from Hoima to Mombasa. There are large sections of the existing road infrastructure that are in poor condition in both countries and it would require extensive upgrades over large areas to ensure un-interrupted transportation. To export the projected amount of oil would require 1000 trucks on the road, which would create a substantial amount of traffic over the lifetime of the project and would result in increased emissions, disturbance and public road safety risks. These combined factors resulted in the decision to consider alternative crude oil transport modes.

3.4.4 Summary

A pipeline provides a well-established, comparatively safe system for the long-term export of oil. In addition, design specifications for pipeline systems are supported by robust international standards. Construction of a pipeline can be completed in a relatively short time. Once operational, pipelines have limited impacts that are localised and can be managed. A buried pipeline system provides the most efficient and dependable method of transport while minimising EIAs during the operational phase. Consequently, the project made the decision to progress the oil transportation project as a buried pipeline (see Section 3.7.2 for information on the consideration of aboveground versus buried pipeline).

3.5 Pipeline Routing

3.5.1 Overview

Several alternative pipeline routes were identified during pre-FEED. The routing process began with the identification of starting point and a flexible end point, which was then followed by numerous screening studies. This work culminated in the selection of eleven 50-km-wide corridor combinations for evaluation. Secondary information was then used to assess the potential corridors using geographic information system and three main corridor options were selected:

- Kenya North
- Kenya South
- Tanzania.

Using higher-resolution satellite imagery, the corridors were further refined by using several constraints criteria including environmental and social, geohazards, constructability and terrain (river crossings and slopes). Further to consideration of the study of the three identified corridors, the Government of Uganda announced the selected Uganda–Tanzania route on 23 April 2016 as shown in Figure 2.3-1. This section provides an overview of the route alternatives considered.

3.5.2 Prior Front-End Engineering and Design

3.5.2.1 Initial Pipeline Corridor Options

Routing studies of a crude oil export pipeline from a fixed point at Lake Albert in Uganda to several terminal options situated at multiple end point locations on the East African coastline were conducted. The resulting area of interest was defined for the preliminary routing and included areas in Uganda, South Sudan, Kenya and Tanzania. The common starting point of all potential routes studies was northeast of Hoima with the end points at Malindi (Kenya), Tanga (Tanzania), Juba (South Sudan), Lokichogio (Kenya) and Lamu (Kenya).

Exclusion criteria were applied to the area of interest which included slopes over 45°, elevation above 2500 m; lakes, active volcanoes, protected areas, cities and a 1-km buffer around cultural, archaeological and touristic sites. The resulting area of interest and exclusions zones are shown in Figure 3.5-1.

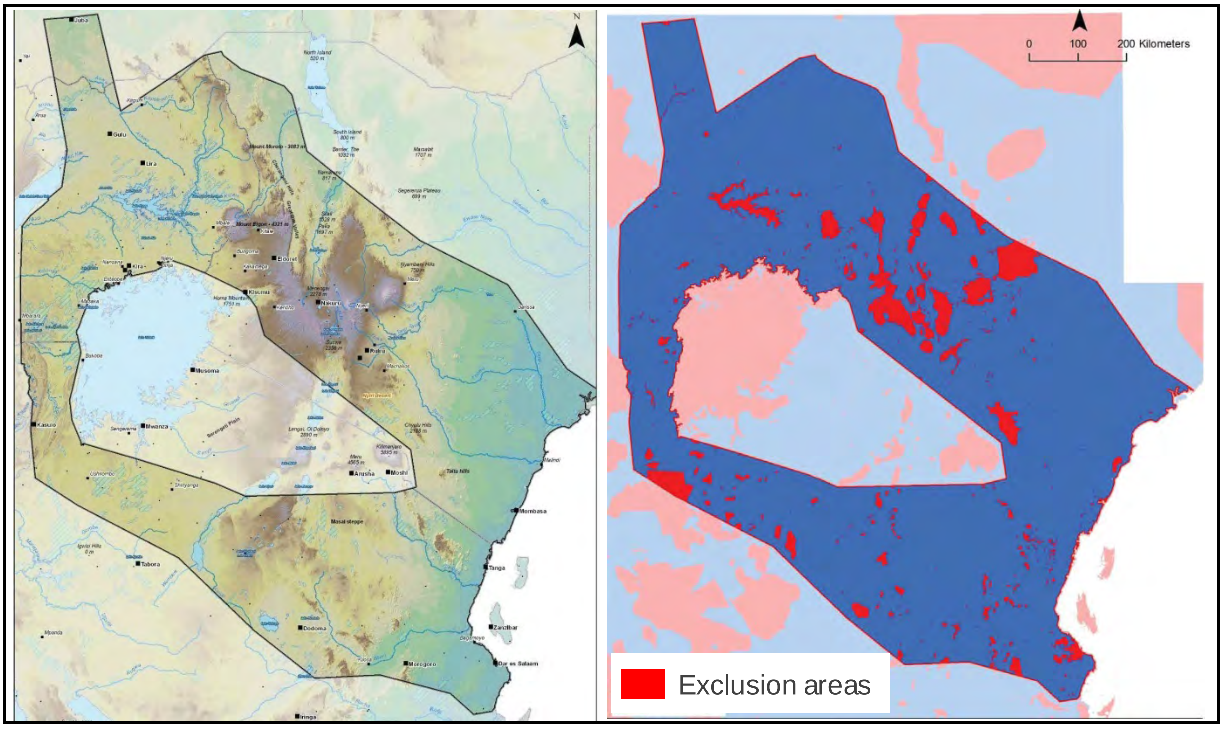


Figure 3.5-1 Routing Area of Interest (left) and Excluded Areas (right)

As a result of the spatial multi-criteria analysis, 11 potential 50-km-wide corridor combinations were identified as shown in Figure 3.5-2. Following route optimisation and offloading potential solutions were evaluated using the corridor and siting criteria, corridors 3 (South Kenya), 6 (Tanzania) and 11 (North Kenya) were selected as the most viable options and were recommended for further study.

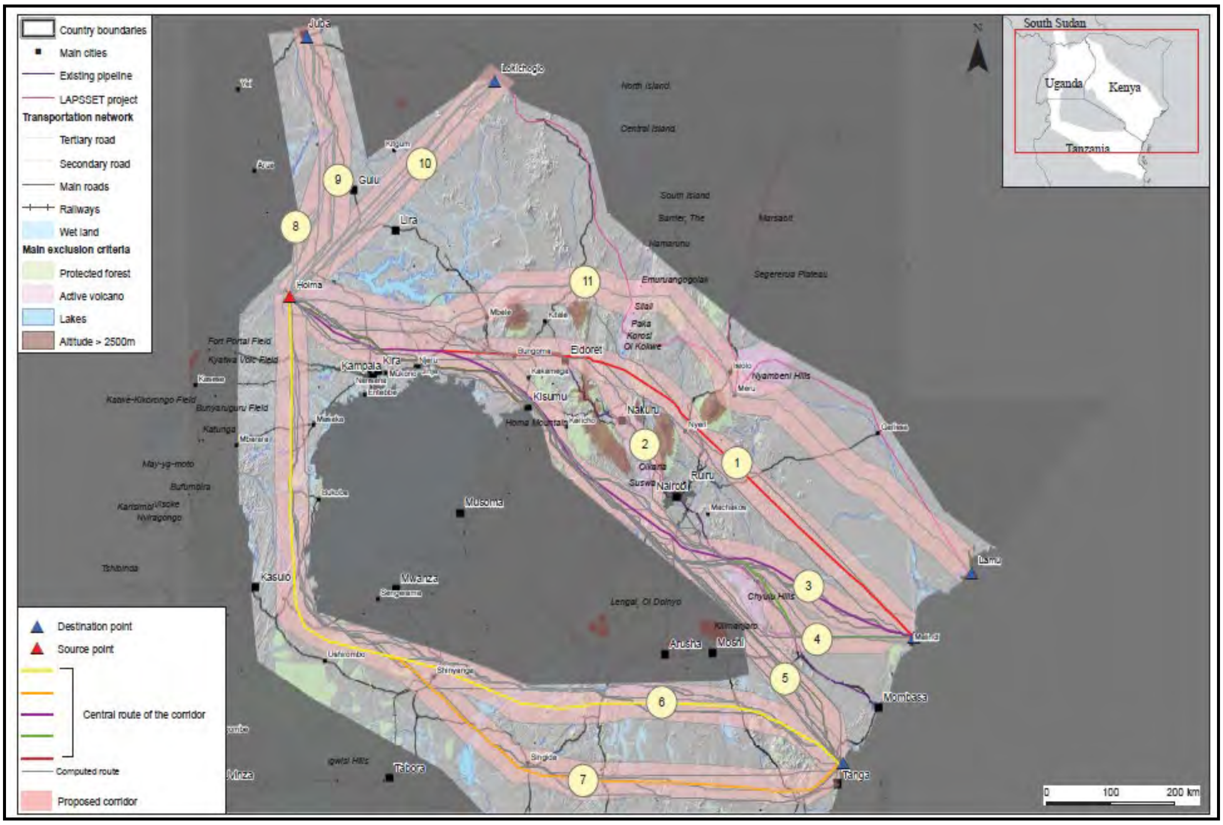


Figure 3.5-2 Pipeline Corridors

3.5.2.2 Corridor Options Screening

Corridors 3 (South Kenya), 6 (Tanzania) and 11 (North Kenya) were screened by applying biological, geological, physical, and socioeconomic criteria and using a range of secondary data. The screening assessment considered physical factors including topography, climate, hydrology and hydrogeology, geology and geohazards and soils.

The screening assessment identified some disadvantages of Kenya routing alternatives:

- North Kenya (Corridor 11) was routed through the northern portion of Kenya where there is a lack of existing transport and communications infrastructure, vast wetlands north of Lake Kyoga, proximity to active volcanoes and large areas of flash flooding (scour risks) potential.
- South Kenya (Corridor 3) would utilise the existing refined product pipeline corridor from Mombasa to Eldoret. The corridor would then pass through a highly populated region of Uganda along the north side of highway A104 into Uganda and then traversing northwest and south of Lake Kyoga toward Kabaale. The corridor does pass through densely populated areas and where encroachment within the corridor has occurred both in Mombasa and near Eldoret. The use of this corridor would lead to more extensive impacts on local population.

Feasibility studies highlighted the potential benefits of pipeline corridor options in Tanzania, which involves routing the Uganda section of the pipeline west of Lake Victoria in a southerly direction. After further investigation of corridor 6 it was identified that the corridor was in proximity to two national parks, and therefore it was abandoned for the lengthier corridor 7. In particular, corridor 7 was found (as shown in Figure 3.5-2) to:

- be closer to existing infrastructure (roads, railway)
- reduce the number of river crossings
- provide a more suitable elevation profile for pipeline hydraulic design.

In early 2015 the project concluded that corridor 6 was not viable owing to the difficult mountainous terrain, remote areas, nationally protected biodiversity areas and touristic areas within Tanzania. Although the Uganda section of the EACOP pipeline for corridors 6 and 7 are the same (see Figure 3.5-2), the southern Tanzania option (corridor 7), was selected as the base case from Kabaale in Uganda (pipeline eventual starting point at kilometre point [KP] 0) to Tanga, Tanzania, and was subsequently used to develop route version V1.

The V1 route avoids most environmentally sensitive zones, i.e., protected land – forest reserves (FRs), wildlife reserves and national parks. An environmental and social screening study was then conducted that confirmed that constraints along the route were considered less substantial than the other routing options. For example, the South Kenya route crossing the Tsavo National Park and both Kenyan routes crossing the Nile River.

While there are some constraints (several rivers, Forest Reserves, cultivated areas and the presence of archaeological and heritage sites) in proximity of the pipeline route, much of the route traverses areas with low or negligible sensitivity.

The screening study also concluded that the pipeline constructability risks are substantially less because of the proximity of most of the route to existing transportation infrastructure. By avoidance of the technically challenging and environmentally sensitive areas, the pipeline operability is likely to be high, resulting in secure, dependable flows of crude oil through the lifetime of the pipeline.

3.5.2.3 Route Refinement

Figure 3.5-3 shows the selection process undertaken from pre-FEED versions V1, V2 and V3 through the FEED phase versions V4 to V6. With the inputs from detailed mapping, multidisciplinary studies and site visits, the pipeline corridor width was incrementally narrowed down from several kilometres through to 2000 m (V3) to 100 m (V4 and V5) and finally to a 30-m right-of-way (RoW) (V6) with a centreline.

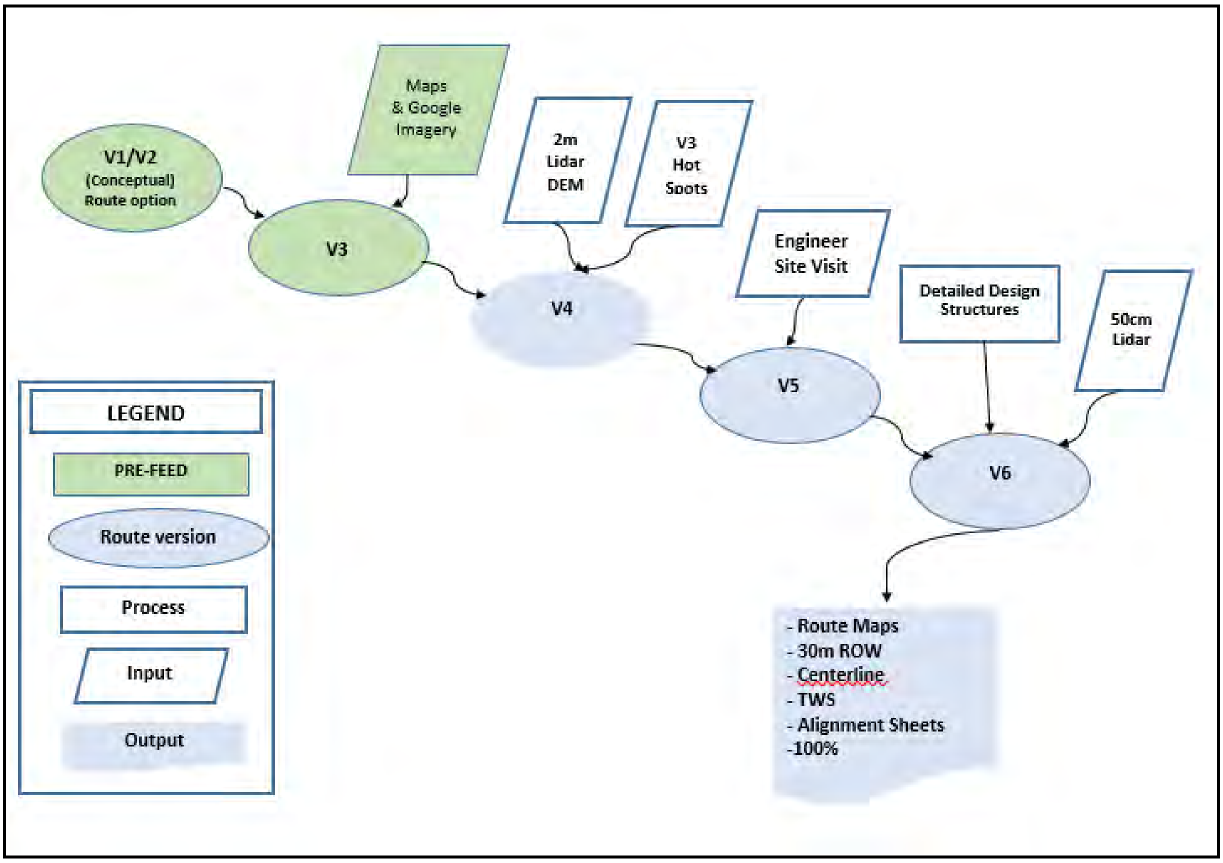


Figure 3.5-3 Route Refinement Process

The main routing criteria used to assess potential routes are shown in Table 3.5.1.

Table 3.5.1 Route Refinement Criteria

Technical Criteria	Environmental Criteria	Socio-economic and Cultural Heritage Criteria
Route length Lateral slope (>10° No Go unless very short distance or single instance) Front slope (>20° No Go unless very short distance or single instance) Number of cold bends and tie-ins due to terrain undulations Shallow bedrock (granite, gneiss – No Go) Wetlands (permanent and seasonal) River and stream crossing Road and track or rail crossing Fault crossing Other types of crossings Flooding hazard Landslide hazard Karsts, tunnels and mines (settlement hazard) Seismic zone with liquefaction risk (No Go) Earthquake zone Geological features Infill land and waste disposal sites, including those contaminated by disease, radioactivity or chemicals	Internationally Protected Areas (Ramsar sites, UNESCO World Heritage Sites) (No Go) Nationally Protected Areas (national park, wildlife reserve, wildlife sanctuary, FR, community wildlife management area, high biodiversity wilderness area) Waterbodies (lake, reservoir) (No Go) Internationally Designated Protected Areas (IUCN Category Ia, Ib and II) Internationally and Nationally Designated Protected Areas (IUCN III, IV, V and VI) Critical habitats[1] Natural habitats[2] Other notable biodiversity areas	Industrial areas (mines, factories, power plants) (No Go) Social and community infrastructure (including places of worship) RoW of existing or planned linear facilities Transport infrastructure Settlements (urban area, town, village) Structures within 50 m of corridor centreline Trees and timber forest Cash crop (e.g., tea, coffee plantation, sisal, sugar cane, banana) Water points, sources and wells Cultural heritage sites Tourism facilities and sites

Application of the criteria highlighted key routing constraints. These include routing around extensive shallow bedrock, passages between protected areas and through hilly terrain. For the sections of the pipeline route external to these constraints, further optimisation was implemented with the aim to balance pipeline length proximity to existing roads and the length of new access roads required. The route that best met the criteria was selected as the base case and was identified as version V2.

[1] Critical habitats are areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and Endangered species; (ii) habitat of significant importance to endemic or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species or congregatory species; (iv) highly threatened or unique ecosystems; or (v) areas associated with key evolutionary processes (IFC PS6, 2012).

[2] Natural habitats are defined as areas composed of viable assemblages of plant and animal species of largely native origin, or where human activity has not essentially modified an area's primary ecological functions and species composition (IFC PS6, 2012).

3.5.2.4 Pre-Front-End Engineering and Design Route Optimisation (V2 to V3)

The V2 route was evolved to V3 route during pre-FEED as a result of multidisciplinary workshops including engineering, environmental and social input. The focus and effort to optimise the route was intended to improve the side and front slopes, avoid nationally protected areas, reduce impacts to perennial rivers and wetlands, and where possible, reduce the overall length. Improvement of the side and front slopes along the route is important for several reasons:

- During construction, the rate of elevation change (i.e., front slope) can increase the pipeline’s cost and create challenges for accessibility to the RoW.
- Elevation difference is important, as it affects system hydraulics.
- Side slopes require side cuts and fills necessary for construction equipment to safely manoeuvre and install the pipeline. During operation, the RoW will tend to retain water which can destabilise the ground supporting the pipeline.

Route optimisation also identified pinch points where routing options are restricted as shown in Figure 3.5-4.

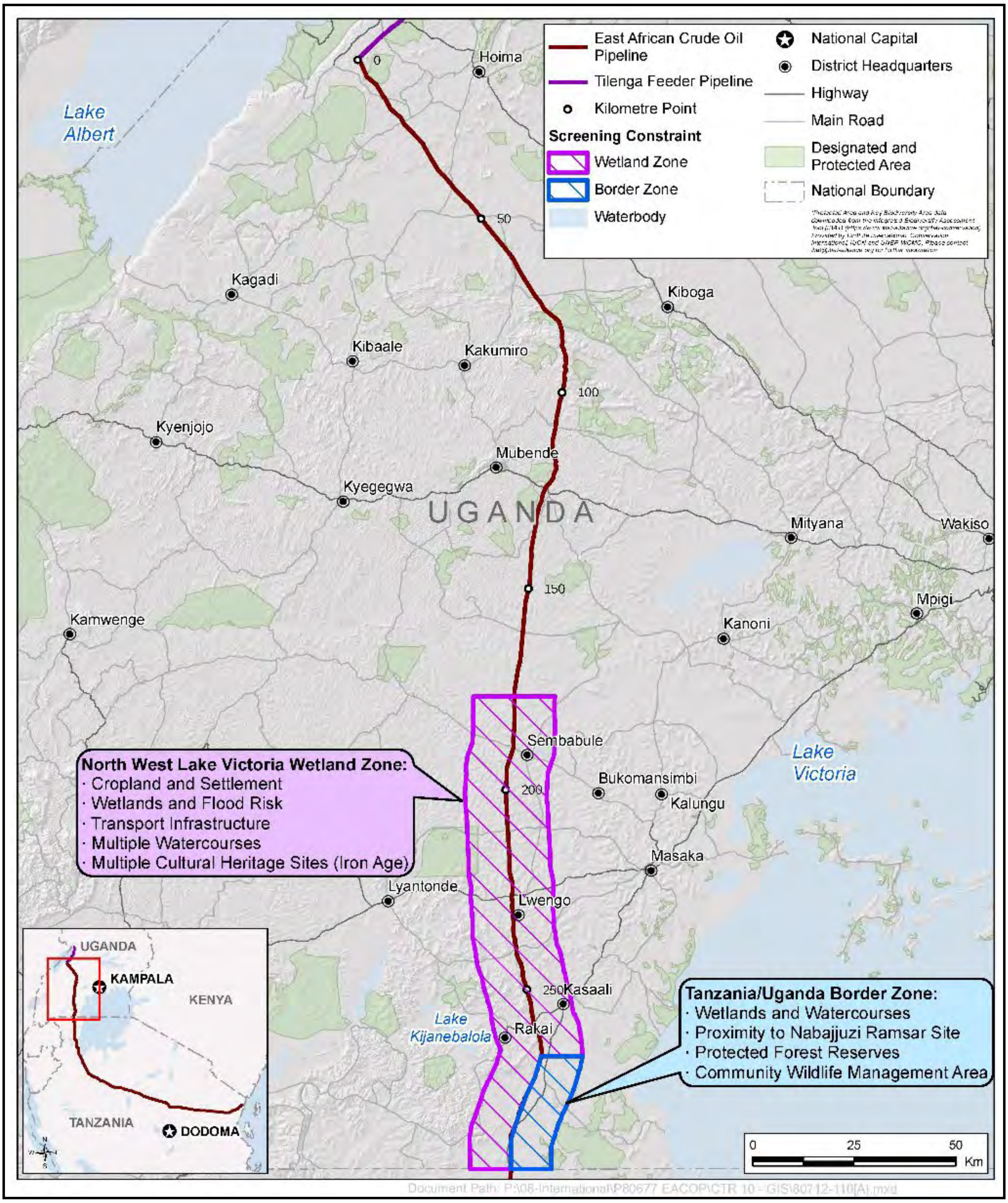


Figure 3.5-4 Pre-Front-End Engineering and Design Corridor EACOP Uganda Corridor Summary Constraint Zones

3.5.3 Front-End Engineering and Design

3.5.3.1 (V4 and V5) Routing Refinements

Version V3 was a 2000-m-wide corridor to guide the light detection and ranging (LIDAR) survey from the Kaabale industrial area to the Uganda–Tanzania border.

The LIDAR survey data produced a digital elevation model, which was used, along with other routing tools to select and refine the route. The DEM was used, along with other routing tools to select and refine the route. This included using satellite imagery to identify dwellings and other structures to aid routing. The output of this work was route version V4. The V4 corridor was then mapped with a 100-m-wide corridor, suitable for technical verification during engineering site visits to Uganda.

Data collected and ground truthing performed during an engineering site visit (April 2017) by a multidisciplinary team including environmental and social specialists was used to establish a centreline within the 100-m-wide corridor and to advance the V4 route to V5. Route V5 was then used:

- to produce route maps with a 100-m-wide corridor and a centreline
- as a basis for engineering, i.e., procurement of essential materials and long lead items, such as pipe, heat tracing, valves and hot bends
- to prepare the EACOP Uganda Scoping Report.

The following environmental and social constraints were applied during FEED to refine the pipeline corridor through route versions V4 to V5:

- avoid:
  - physical resettlement of local population to the greatest extent possible
  - creation of access roads to otherwise inaccessible areas
  - cultural heritage and archaeological sites to the greatest extent possible
- reduce:
  - economic resettlement, disruption to livelihood of local population
  - combustion, metal vapour emissions
  - project footprint (including the RoW, aboveground installations [AGIs], work sites, access roads)
  - land take; habitat and agricultural land lost
  - project disturbances (such as noise, light, vibration, dust)
  - groundwater abstraction and discharge
- restore habitats and hydrogeological regimes after construction.

Consistent application of this criteria has been of paramount importance while narrowing the study corridor from 2000 m down to the 100-m wide corridor with pipeline centreline (V5) and the 30-m-wide RoW (V6), see Section 3.5.2.3.

Route version V5 was used to support the ESIA scoping report, risk assessment, site-specific geotechnical and geophysical surveys, and in development of the main scope of work for detailed engineering.

An example of route V4 to V5 refinements for EACOP Uganda are shown in Figure 3.5-5 and include:

- minor route changes to avoid structures, villages, road crossings, tree plantations and to improve slope crossings
- slight route adjustment to accommodate the location of the proposed site for PS2.

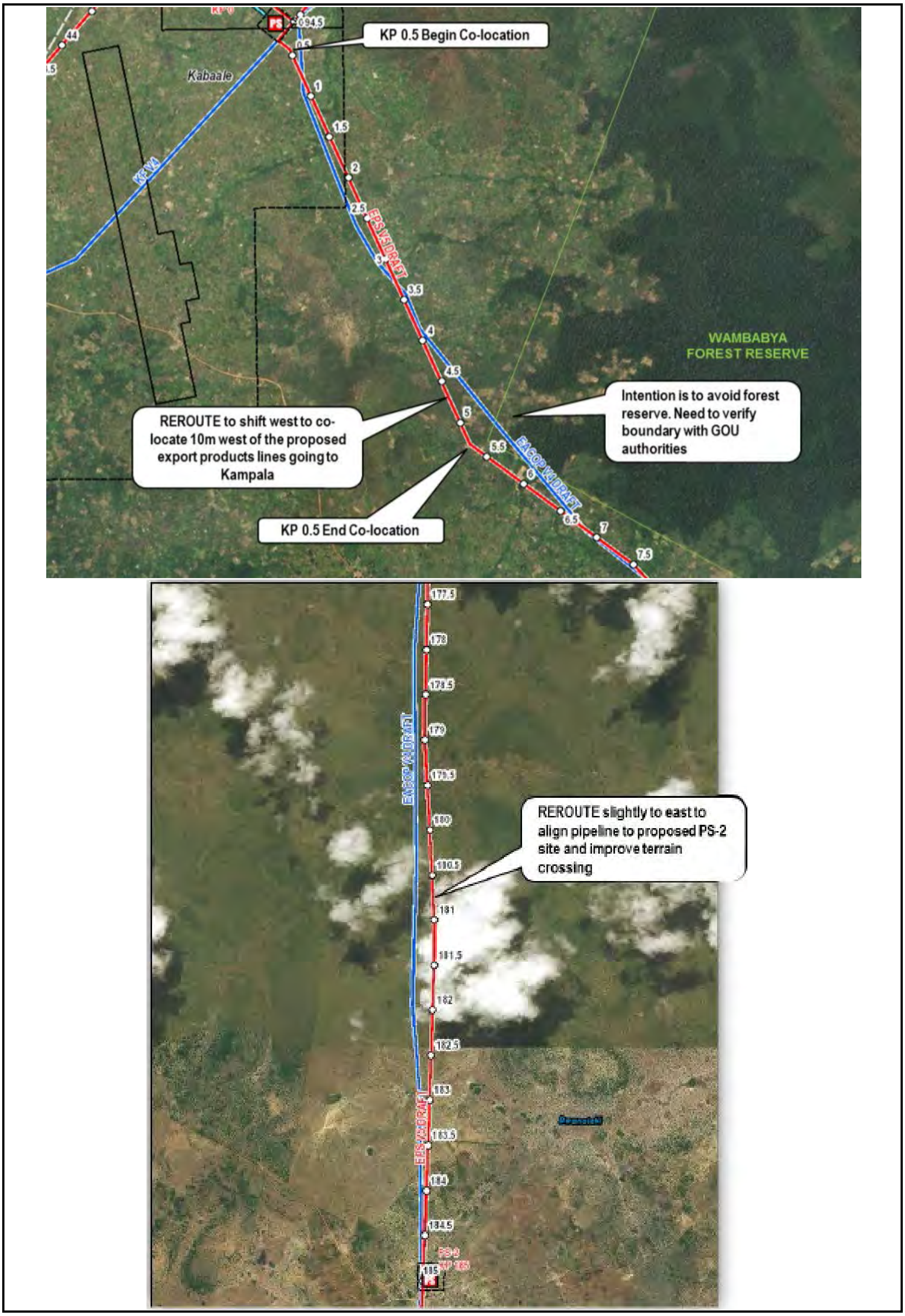


Figure 3.5-5 EACOP Uganda Route Refinements V4 to V5

In addition, specific consideration was given to potential impacts on chimpanzees. Preliminary studies demonstrated that the area west of Wambabya Forest Reserve traverses an area known as chimpanzee habitat.

The EACOP route passes in between Wambabya and Bugoma FRs which is an important chimpanzee migration corridor. In considering the potential effects in the area, two alternative routes circumventing the FRs were investigated and are shown in Figure 3.5-6 and are detailed below:

- northern alternative route toward the north of Wambabya FR and then travel southeast and reconnect with EACOP at KP20
- southern alternative route traversing south from Kabaale (instead of east between Wambabya and Bugoma FRs) and run parallel to Bugoma FR before turning east near the southern end of Bugoma and continuing along to travel in a north-easterly direction to connect back with the main alignment at KP58.

The study found evidence of chimpanzee presence along both northern and southern route alternatives, concluding that these alternatives would not provide better avoidance of chimpanzee disturbance. The main proposed route (V5 at the time of the study) was found to be the most viable option in conjunction with robust mitigation measures to reduce chimpanzee disturbance during pipeline construction (see Section 8 for proposed mitigations in the area).

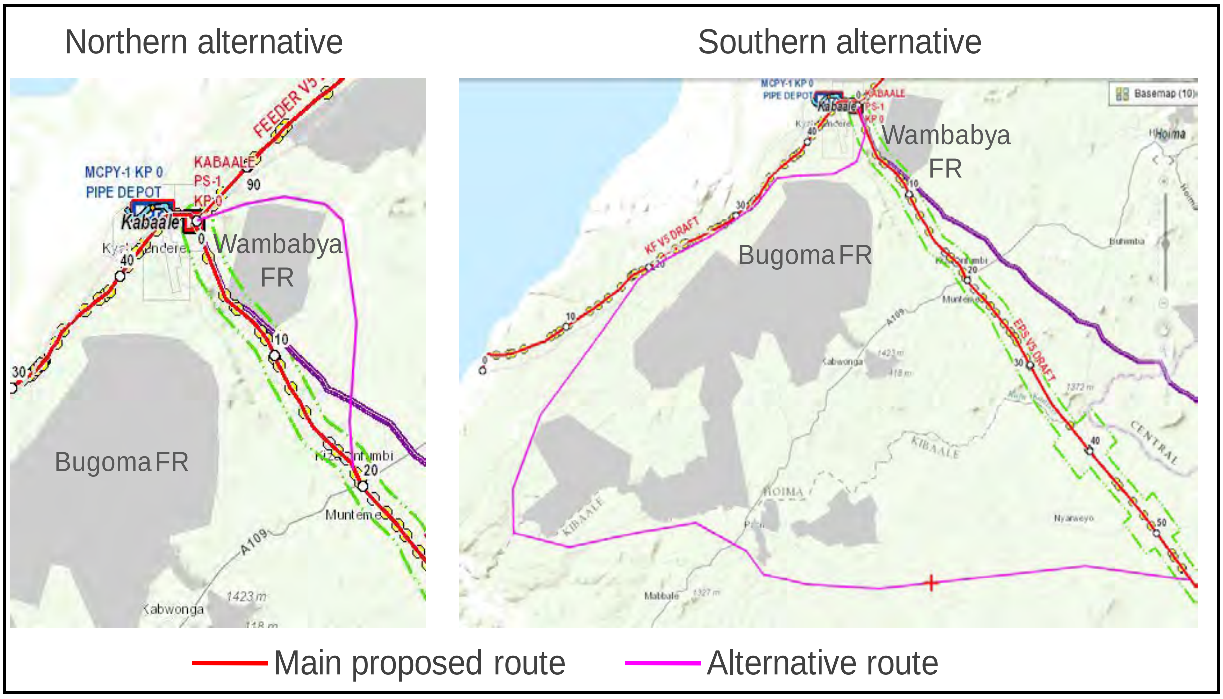


Figure 3.5-6 Alternative Routes around Wambabya and Bugoma Forest Reserves

3.5.3.2 V5 to V6 Routing Refinements

All refinements were minor, with most pertaining to constructability considerations and avoidance of structures, ecologically sensitive areas and watercourses. Updates in route version V6 also included:

- location and size of AGIs
- locations of the main line block valves, most of them aligned with intermediate electrical substations
- locations of construction camps and pipe yards.

3.5.3.3 V6 Base Case Route

The base case route of the 30 m RoW is shown in Figure 2.3-1. However, as investigations are on-going at the time of writing this ESIA, e.g., geophysical and geotechnical surveys, small-scale adjustments may still be made.

3.6 Facility Siting

3.6.1 Overview

This section describes the main alternatives assessed for the number, location, layout and footprint of the following facilities:

- AGIs
- construction facilities.

The functional requirements of the surface facilities have been the main driver for the identification, screening and final location selection.

The selection of appropriate sites for the PS was determined during pre-FEED by pipeline hydraulic studies. Additional imagery and site visits were used to establish locations during FEED. Siting of the electric substations is ongoing and will be refined based on further electrical studies, whereas the block valve locations have been defined based on detailed technological risk analysis.

The functional requirements vary for each type of facility and are described in this section. The selection process has also considered relevant safety, environmental and social constraints.

3.6.2 Aboveground Installations

The main driver for the type, number and location of the AGIs has been the technical specifications. In particular, the pumping station (PS) locations have been selected based on pipeline hydraulic requirements (design pressure and maximum operating pressures). However, additional criteria have been considered:

- thermal design requirements
- safety and environmental risk factors
- site physical conditions (topography, accessibility, proximity to existing infrastructure)
- environmental and social constraints.

3.6.2.1 Pumping Stations

During pre-FEED, three hydraulic design scenarios were considered. The requirement to maintain the hydraulic profile was the main influencing factor in determining the number and location of the PSs (see Figure 3.6-1).

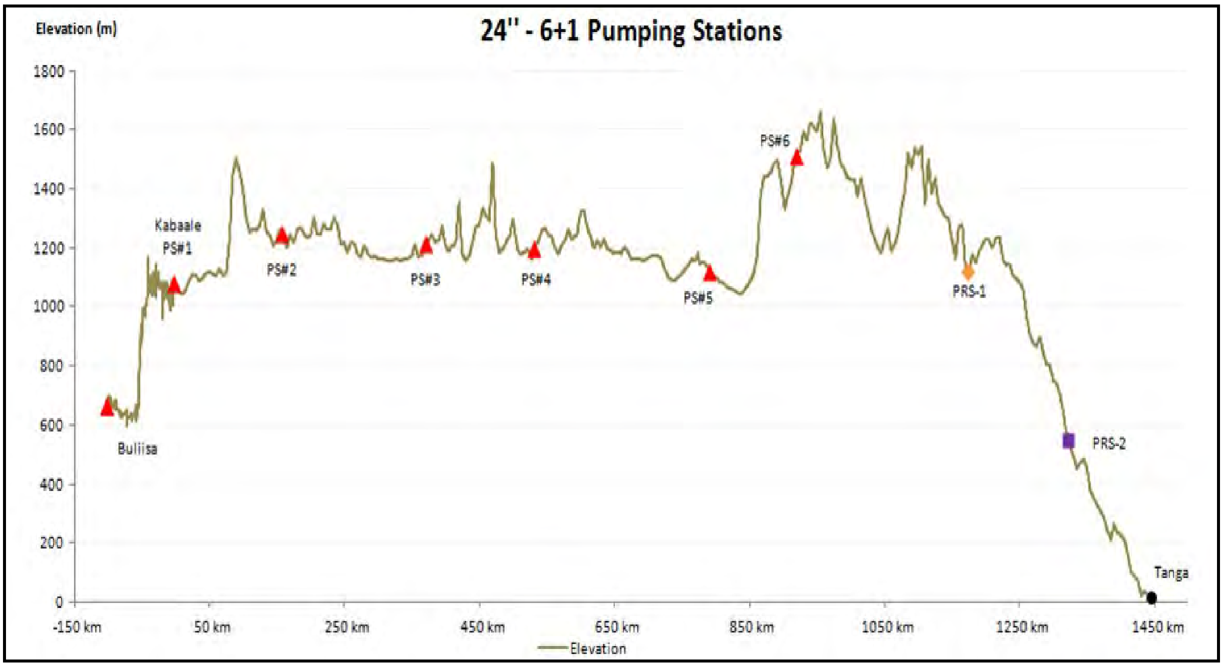


Figure 3.6-1 Pressure Profile and Pumping Station Locations

The PS locations (PS1 at Kabaale Industrial Park and PS2 for EACOP Uganda) have been identified by the points on the pipeline where at maximum flow, the pressure in the pipeline falls to approximately 6 barg; regard was also taken of topographical profile so as not to locate the PS in a deep dip.

Table 3.6.1 summarises the design alternatives considered for the pipeline. Case 2 was assessed to reduce design pressure and Case 3 was assessed to reduce the number of PSs.

Table 3.6.1 Pipeline Design Cases During Pre-Front-End Engineering and Design

Design Case	Scenario	Key Drivers
Case 1 Base Case	24 in. 6 PSs	Confirmed base case for FEED
Case 2 – Design Pressure Reduction Case	26 in. 6 PSs	Reduce design pressure to continue with Class 600 piping
Case 3 – PS Reduction Case	24 in. 5 PSs	Reduce number of PSs

The studies concluded that Case 1 should be maintained as the base case for FEED.

Preliminary locations based on hydraulic modelling are shown in Table 3.6.2. The actual location of the PSs has been amended iteratively concurrently with pipeline route refinement. In addition, a site visit was undertaken in May 2017 to validate the proposed locations of the AGIs based on the following:

- accessibility and distance to infrastructure (suitable access roads)
- geotechnical information (expected ground conditions, presence of escarpments, wetlands, flood potential, seismic data)
- societal impact (population displacement and land use).

The initial locations of PSs during pre-FEED, summary of site visit findings and iterations undertaken with the routing team are summarised in Table 3.6.2.

Table 3.6.2 Preliminary and Final Pump Station Locations for EACOP Uganda

	PS1	**PS2**
KP (Concept Study, Route V1)	0	228
Results of Site Visit May 2017	Access to PS1 will require 5 km of access road Steep (7%) grade leading to PS1 site	PS2 to be moved to south (KP181 – KP182) Shorter access and wider high ground.
KP (Final Route V6)	0	184.5

3.6.2.2 Electric Substations

As described in Section 2.3.3.3, the electric substations house transformers required for power transmission through the high voltage cable and step down transformers to provide the required voltage for the electrical heat tracing (EHT) system. The rationale for siting of electric substations is based on the overall number of substations required by the trace heating system, i.e., maximum cable length of 30 km and therefore, the maximum distance between power supplies required would be 60 km.

During FEED, the siting of the electric substations was reviewed and, where possible, combined with the AGIs and block valves. The number of substation combinations with AGIs and block valves, and the standalone substations are shown in Table 3.6.3.

Table 3.6.3 Electric Substation Siting – Combined and Standalone

Facility	**EACOP Uganda**
Standalone electric substations	1
Substations combined with AGI	2
Substations combined with block valves	4
Total	7

3.6.3 Block Valves

The primary function of block valves is to isolate sections of the pipeline and the number and location of block valves is based on ASME B31.4 (434.15), which requires that block and isolating valves shall be installed to:

- limit hazard and damage from accidental discharge
- facilitate maintenance of the piping system.

The number and location of valves has also been informed by risk assessment based on safety and environmental risk considerations. Preferred locations include:

- upstream side of major river crossings and public water supply reservoirs
- at other locations appropriate for the terrain features
- at remotely controlled pipeline facilities to isolate segments of the pipeline
- on the inlet and outlet of pump stations whereby the pump station can be isolated from the pipeline
- in industrial, commercial, and residential areas where construction activities pose a risk of external damage to the pipeline.

Based on these preferences, block valves were sited at:

- every PS
- long continuously ascending or descending elevation profile
- on each side of wetlands and major water crossings (> 30 m wide)
- at each river or stream < 30 m wide, where downstream impacts from a pipeline leak could impact populations, reservoirs, waterways and sensitive areas.

Further evaluation and optimisation of block valve locations was undertaken when the list of electric substations required for the pipeline heat tracing system became available during FEED. Additional work was then performed to combine the locations for block valves and electric substations as much as possible to optimise facilities' footprint and access requirements.

The results of the optimisation process of block valve placement for EACOP Uganda pipeline are as follows:

- elimination of 8 block valves
- combining 4 block valves with electric substations
- 15 standalone block valve stations along the RoW
- total of 19 block valves in the RoW.

3.6.4 Construction Facilities

There is a requirement to establish four main camp and pipe yards (MCPY) within Uganda to support construction operations. The construction facilities site selection process has taken into consideration the requirement to:

- minimise land acquisition
- reduce distance from existing road networks
- avoid populated and protected areas
- take cognisance of the terrain type and topography suitability
- water availability.

In September 2016, a construction site overview was undertaken to assess locations proposed for the V3 route. The locations were subject to preliminary assessment based on the criteria in Table 3.6.4.

Table 3.6.4 Construction Facility Location Selection Criteria

Technical	Environmental	Social
Facilitate access to RoW for the MCPY Facilitate access for pipes from main roads and rail for coating facility (CF) Availability of water Availability and capability of local contractors to undertake the required scopes	Limit footprint and impact by minimising requirements for temporary roads Avoid nationally protected sites and internationally recognised sites of conservation interest and critical habitats Topography Terrain type (avoiding wet areas) Potential geo-hazards (such as flood zones, faults)	Avoiding resettlements or limiting extent of resettlement Clear of villages and schools Social and community infrastructure (including places of worship) Settlements (urban area, town, village) Cash crop (e.g., tea, coffee plantation, sisal, sugar cane, banana) Water points, sources and wells Cultural heritage sites, Tourism facilities and sites Land use Avoid the clearance of trees/timber forests, existing crops and bush in dry areas (where crops would be easier to restore) Clear of military facilities

The three criteria for construction facility location as shown above were applied together with the relevant criteria used for the pipeline route selection as shown in Table 3.6.4.

Each of the MCPY locations identified in Uganda have been evaluated and the optimum locations selected and as shown in Figure 2.3-9. During the construction site overview, for each of the MCPY locations three options were identified:

- V3 route suggestion identified in early FEED
- Alternate 1
- Alternate 2.

The location selection process for the main camps is provided below.

3.6.4.1 MCPY 1

Figure 3.6-2 shows the three alternative locations considered for MCPY1.

Alternative 1

Alternative 1 is in Kigujula village, Kakumiro district near KP49 and approximately 1.8 km west of the EACOP RoW along Nkoko-Nalweyo road (Figure 3.6-3). Houses are within the footprint of Alternative 1; to avoid physical resettlement, this site was not selected.

Alternative 2

Alternative 2 is close to the EACOP RoW at KP39 (Figure 3.6-4). The footprint for Alternative 2 includes several houses and is close to the Kasambya trading centre. To avoid physical resettlement and the potential to impact negatively on the Kasambya trading centre, this site was not selected.

Alternative 3

Alternative 3 is in Kasambya village, Kakikara subcounty, Kakumiro district near KP39.3 along the Buhimba–Nalweyo road (Figure 3.6-5). Alternative 3 was selected as the MCPY 1 location because it does not include houses thus avoiding physical resettlement. The location is also near the main road (currently being upgraded to tarmac), the pipeline RoW and level terrain used for farming, and therefore is of low biodiversity value.

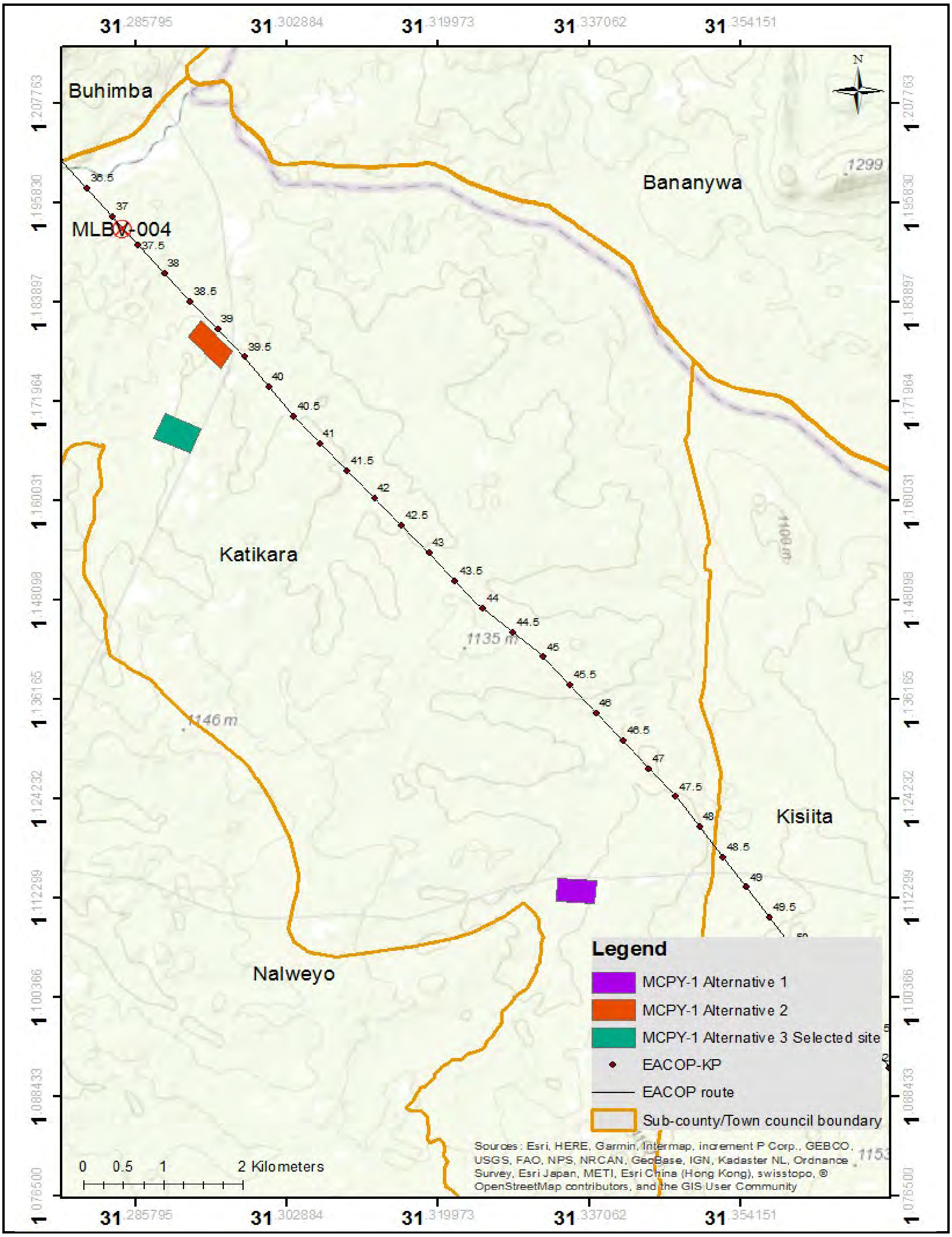


Figure 3.6-2 Main Camp and Pipe Yard 1 Alternative Locations

Figure 3.6-3 Main Camp and Pipe Yard 1 Alternative 1

Figure 3.6-4 Main Camp and Pipe Yard 1 Alternative 2

Figure 3.6-5 Main Camp and Pipe Yard 1 Alternative 3 – Selected Location

3.6.4.2 MCPY 2

The three alternative locations considered for MCPY2 are shown on Figure 3.6-6.

Alternative 1

Alternative 1 at KP122 (Figure 3.6-7) was rejected because of the presence of rock outcrops, a community access road and uneven terrain within the site footprint, and a settlement directly outside the fence line.

Alternative 2

Alternative 2, near KP122 in Lugala LC1 village, Kagoma parish, Kitenga subcounty, Mubende district (Figure 3.6-8), was also rejected. Although the site is level and well drained, it overlays coffee and banana plantations and a graveyard with six graves (see Figure 3.6-9), with one house in and another eight directly outside the fence line. Access to this location would require relocation of houses close to the road or acquisition of land for a 2.7-km long new road. This location was not selected owing to cultural and social constraints.

Alternative 3

Alternative 3, directly adjacent to Alternative 1 (Figure 3.6-7), is along the Mubende–Kampala road in Mijunwa village, Kitenga subcounty, Mubende district. This location was selected for MCPY2 owing to its proximity to a sealed (tarmac) road near the RoW, a key requirement for the safe and reliable delivery of construction materials. The location has some terrain and drainage challenges, but these can be addressed through engineering designs that allow ample room for maintaining natural drainage (see Section 2.3.3.2 for general surface water design for site layout and Section 2.3.4.1 for location-specific surface water management considerations).

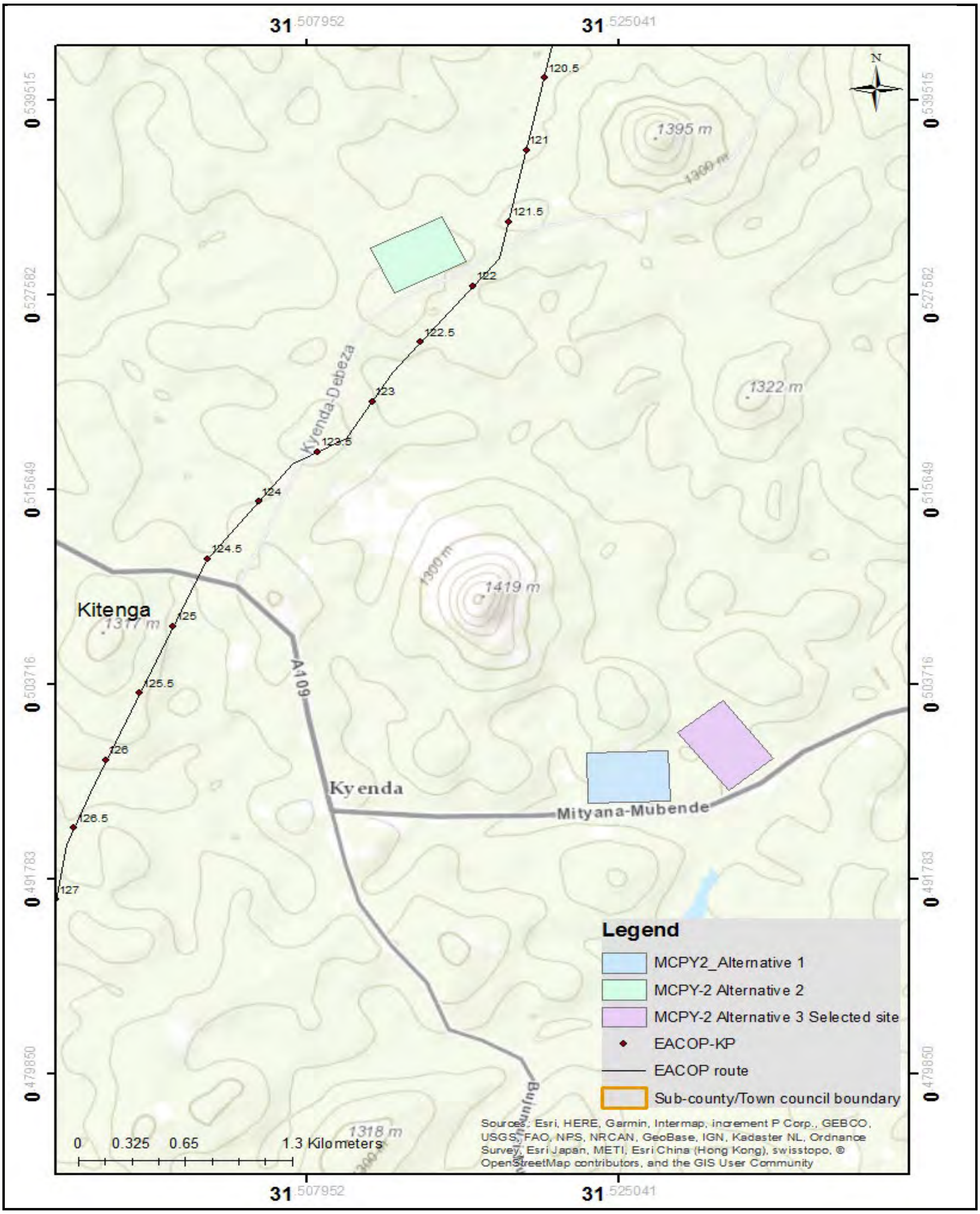


Figure 3.6-6 Main Camp and Pipe Yard 2 Alternative Locations

Figure 3.6-7 Main Camp and Pipe Yard 2 Alternative 1 and 3 - Selected Location

Figure 3.6-8 Main Camp and Pipe Yard 2 Alternative 2

Figure 3.6-9 Main Camp and Pipe Yard 2 Alternative 2 – Graveyard

3.6.4.3 MCPY3

The three alternative locations considered for MCPY3 are shown on Figure 3.6-10.

Alternative 1

Alternative 1 is 360 m south of Villa road in Sembabule district near KP190 (Figure 3.6-11). During the location selection process, there was a much larger coffee plantation at this location. The location was not selected because of the potential livelihood and social impacts.

Alternative 2

Alternative 2 is near Villa road in Sembabule town council (Figure 3.6-12). As a section of the location lies within a floodplain, which poses flood and drainage risks, this location was not selected.

Alternative 3

Alternative 3 is in Sembabule district near KP191.2 (Figure 3.6-13). The location is level and, since completion of the location selection process, coffee plantations have been established within the footprint. However, with due consideration that adequate and fair compensation and livelihood restoration will be provided to the PAPs, this location was the selected MCPY3 location owing to its advantages over the other two alternatives.

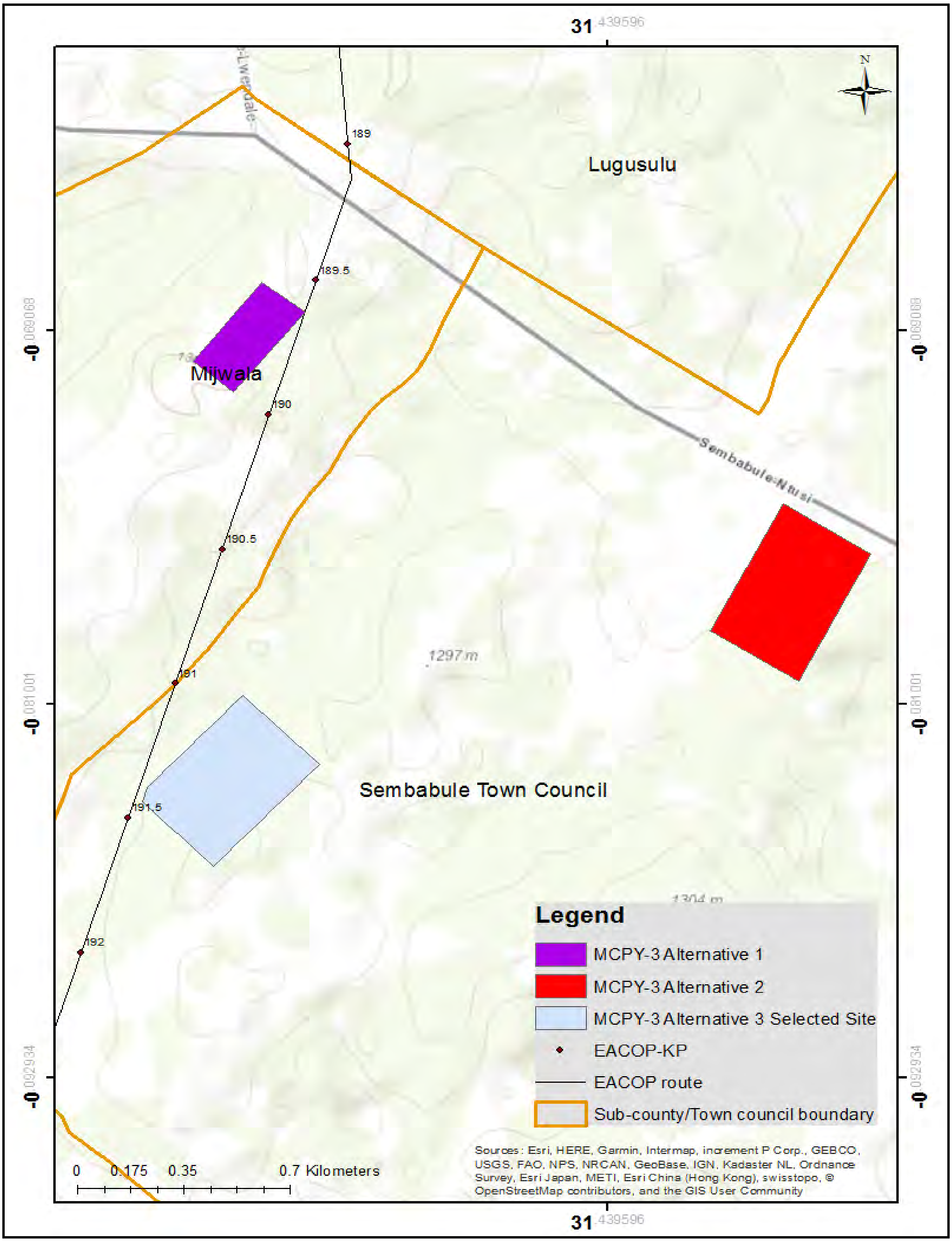


Figure 3.6-10 Main Camp and Pipe Yard 3 Alternative Locations

Figure 3.6-11 Main Camp and Pipe Yard 3 Alternative 1

Figure 3.6-12 Main Camp and Pipe Yard 3 Alternative 2

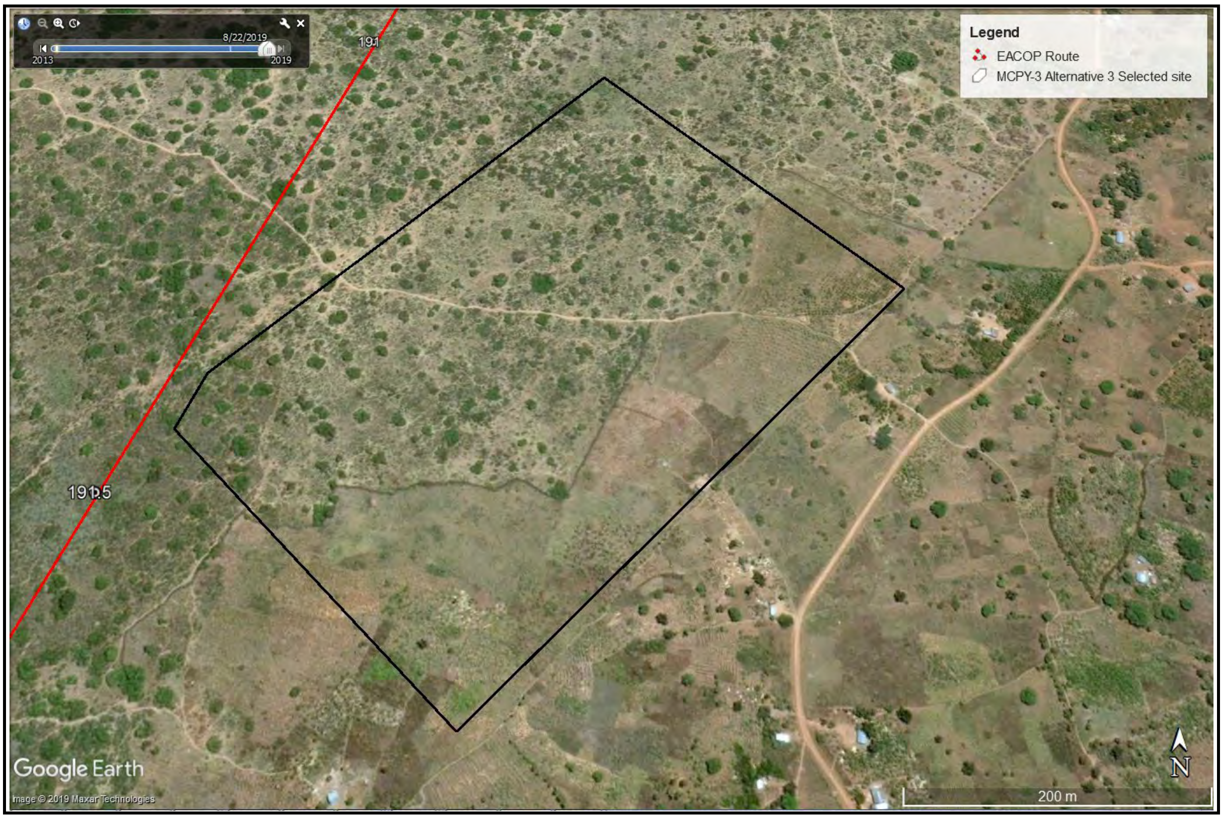


Figure 3.6-13 Main Camp and Pipe Yard 3 Alternative 3 – Selected Location

3.6.4.4 MCPY4

A four-phase process was undertaken for selecting a location for MCPY4:

- Phase 1: A selection process undertaken in 2016 identified a preferred location at KP259.5 shown on Figure 3.6-14.
- Phase 2: Subsequent Alternative 1 at KP258, shown on Figure 3.6-15, and Alternative 2 at KP262.5, shown on Figure 3.6-16, were identified following subsequent social and environmental constraints and constructability studies. Considerations of these alternatives included:
  - identified houses, crops and terrain constraints at the original site location. Alternative 1 proposed at KP258
  - area between KP261 and 262.5 was acceptable for Alternative 2
  - Phase 2 Alternative 1 and 2 may require some resettlement
  - Phase 2 Alternative 2 is on higher ground than the other locations
  - relocation to KP258 recommended: large flat area (groves of wild coffee) east of RoW (Alternative 1, sandy ground showing white on Figure 3.6-15) with good track access)
- Phase 3: Construction facilities assessment work undertaken during FEED identified further constraints associated with flood risk, increased infrastructure requirements and societal impact owing to proximity to population; therefore, an additional site was identified at KP288. The location at KP288 as shown in Figure 3.6-17 was found to be generally level with no, or limited, agricultural activity, required no relocation of structures and had good access to a main tarmac road. Although there are ecologically valuable habitats adjacent to the

site, the avoidance of population, seasonal wetlands, fewer impacts from shorter access roads and the avoidance of agricultural lands was considered an appropriate compromise. Therefore, this location was chosen as the optimum location for MCPY4.

- Phase 4: In mid-2018, the KP288 location had to be rejected because of a dispute between two landowners and the identification of caves on the location that serve as habitat for an endangered species of butterfly. Alternative 1 at KP283, as shown Figure 3.6-18, and Alternative 2 at KP282, shown on Figure 3.6-19, were identified. Considerations of these alternatives included:
  - o Phase 4 Alternative 1 is mainly used for cattle grazing with a small portion of the area used for crop cultivation and forestry. The cultivated area represents approximately 10% of the area, is flat and is not near a protected area.
  - o Phase 4 Alternative 2 has a neighbouring Catholic church and several homesteads. About 90% of the land is used for community crop cultivation, and the soils within the location are quite fertile.
- Because of the potential impacts to community livelihood and local food security and livelihood restoration risks associated with Phase 4 Alternative 2, Phase 4 Alternative 1 has been selected as the optimum location for MCPY4.

Figure 3.6-14 Phase 1 Location Selected for Main Camp and Pipe Yard 4 at KP259.5

Figure 3.6-15 Phase 2 Alternate 1 for Main Camp and Pipe Yard 4 at KP258

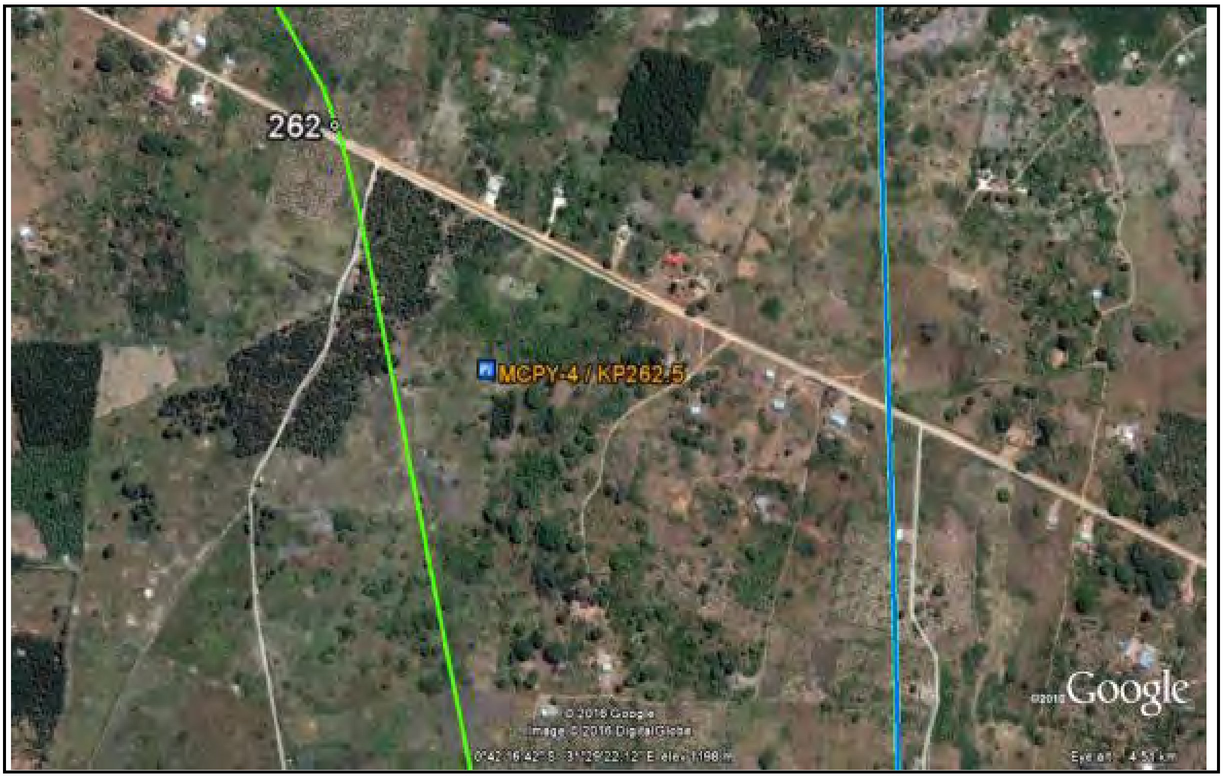


Figure 3.6-16 Phase 2 Alternate 2 for Main Camp and Pipe Yard 4 at KP262.5

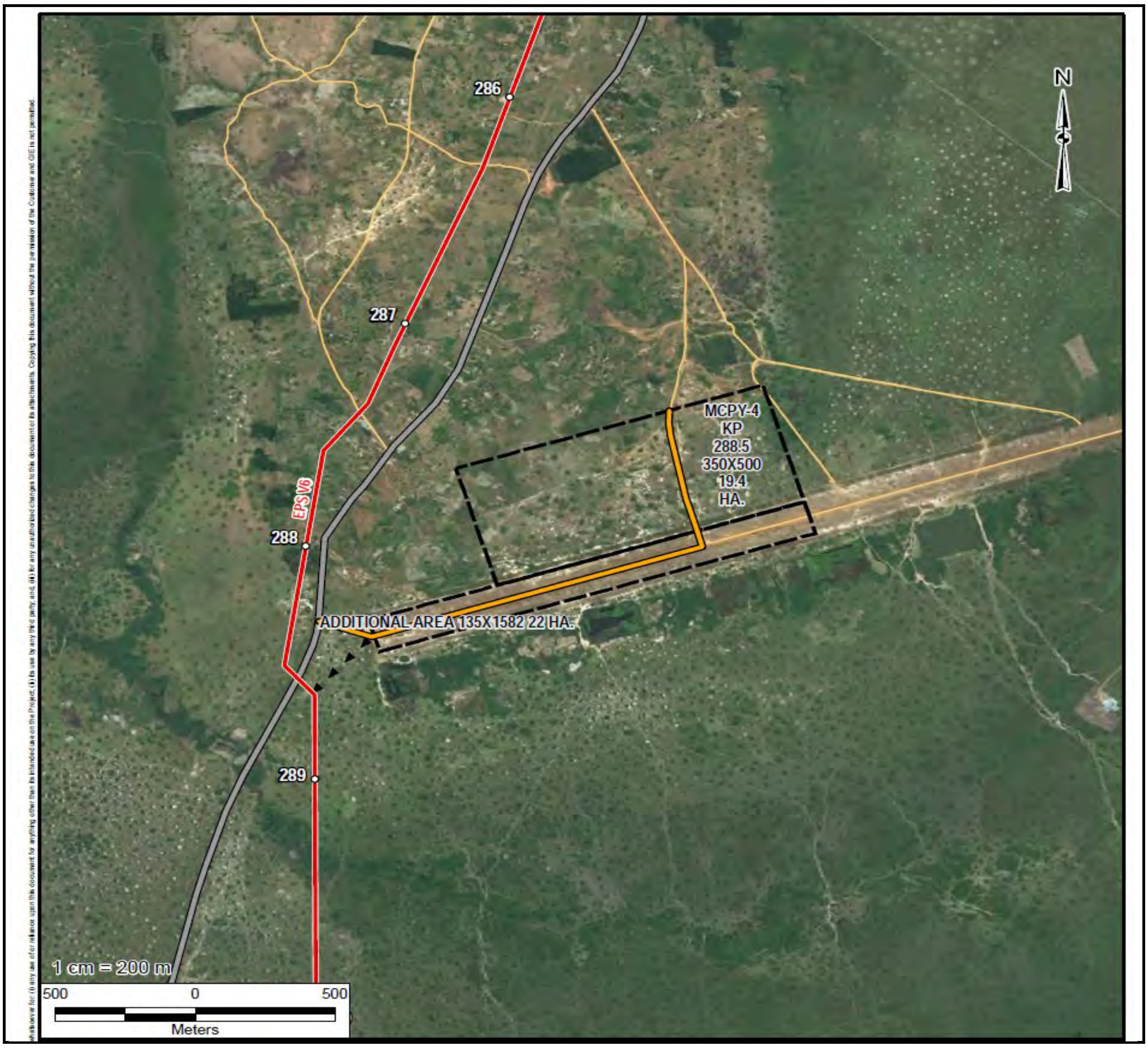


Figure 3.6-17 Phase 3 Main Camp and Pipe Yard 4 Location at KP288

Figure 3.6-18 Phase 4 Alternative 1 for Main Camp and Pipe Yard 4 at KP283 – Selected Location

Figure 3.6-19 Phase 4 Alternative 2 for Main Camp and Pipe Yard 4 at KP282

3.7 Technology

3.7.1 Overview

This section describes the main design alternatives to the project base case as described within Section 2.3. The pre-FEED phase focused on the screening and option evaluation of the main technology alternatives while FEED has concentrated on further refinement. The process has focused on the following elements of the design:

- pipeline (diameter and wall thickness)
- pumps
- power generation
- insulation
- heating.

The challenges associated with flow assurance as well as the requirement to select the most suitable option for storage and loading have been the main considerations throughout pre-FEED and FEED with respect to technology selection. Several design alternatives have been subject to screening and evaluation as described in the following sections.

3.7.2 Pipeline

A partially aboveground pipeline alternative was considered during early pre-FEED but was discounted for numerous reasons including concerns associated with security and safety, risk of interference by third parties, permanent land take, visual impacts and impacts to large wildlife movement. Furthermore, pipeline design codes that would later be adopted by the EACOP project require pipelines to be buried. Therefore, the concept selected for study at pre-FEED was a trenched and buried pipeline.

Two strategies were considered to enhance oil flow required by the oil characteristics:

- a cold transport option requiring the partial removal of paraffinic components ensuring that gelling of the oil is prevented. This requires some oil processing and is extremely expensive. Consequently, this alternative was screened out.
- a hot transport option aimed at maintaining the fluid temperature above 50ºC with the use of thermal insulation, and a combination of heating options. Hot transport was selected as the base case for further study.

Various studies considered the alternative pipeline options and recommended the most suitable and practical means to be taken forward for study during FEED. The key consideration at that stage was the hydraulic design concept, namely:

- Case 1 (Base Case): 24’’ – six PS
- Case 2 (Design Pressure Reduction): 26’’ – six PS
- Case 3 (PS Reduction): 24’’-26’’-24’’ – five PS.

The main conclusions from the pre-FEED studies were that Case 1 (24 in. with 6 PS) should be taken forward as it is the most balanced option in terms of meeting technical and economic criteria. Case 1 is also considered to be the most suitable case for phasing of bulk heaters as no heating is required at commissioning, ramp up and production plateau.

3.7.3 Pumps

3.7.3.1 Type

The pump technology selection has been determined by the characteristics of the Albertine Graben fluid (viscous with no GVF[3]), which means that volumetric pump types are not viable. Therefore, centrifugal pumps are considered the most suitable design for the fluid type because they are proven technology, robust, and cost effective.

3.7.3.2 Number and Configuration

During pre-FEED, the number of PSs for the EACOP System was optimised from seven to six. The effect of removing a PS was studied to evaluate the impact on the maximum design pressure. It was decided to eliminate one PS from the design and relocate PS3 and PS4 to compensate for the eliminated PS.

[3] Gas Volume Fraction

The crude oil pump configuration was optimised during FEED from four with an operating capacity of 33% per pump (3+1) to three with an operating capacity of 50% per pump (2+1). This was possible through a review of the pump sizes required for the standard pumping requirements for PS1 to PS5, and for the higher manual of practice requirements at PS6. The study concluded that the 3 x 50% configuration requires a smaller overall footprint owing to the removal of one pump.

3.7.4 Power Generation

The power generation for the EACOP Uganda facilities is described in Section 2.3.3.2 and its primary function is to:

- provide power for pumps
- energise the EHT.

The pre-FEED for power generation studies confirmed that PS2 to PS6 would be self-contained with individual crude oil fired power generation units. For EACOP Uganda, an optimisation study was undertaken during FEED. The objective of the study was to clarify the interfaces between Tilenga upstream and EACOP projects in terms of power supply considering that both PS1 and PS2 could be powered from the Tilenga CPF. The outputs from the flow assurance studies were reviewed and the consequences on power requirements (in terms of design and operation) on the Tilenga CPF were assessed mainly with regard to:

- power demand under flowing mode (3 × pumps at 216 kbpd)
- power demand during preservation mode with EHT
- essential power required for EACOP during shutdown of Tilenga CPF.

The main conclusions from the study are as follows:

- Under flowing conditions, PS1 and PS2 are supplied from Tilenga CPF power generation package and shall be designed for full load under “normal” operating conditions.
- Under static conditions (preservation mode), the normal power generation of Tilenga Project CPF must be designed to preserve the pipeline and will thus meet the load demand of the EHT at 30 W/m.
- No standalone power generation at PS1, provision shall be made at PS1 for connection of a temporary generator to meet EHT demand in preservation mode if necessary.
- No standalone power generation at PS2, provision shall be made at PS2 for the connection of a temporary generator to meet EHT demand in preservation mode if necessary.

The study conducted during FEED allowed the requirement for standalone power generation at PS1 and PS2 to be removed from project scope thus reducing emissions, visual impact and footprint at the PSs for power generation facilities.

Power generation for the MCPYs will be provided by generators. The project evaluated the option of power supply from the grid, but this was not taken forward due to the lack of required infrastructure in the vicinity of the camps as well their temporary nature. However, the use of generators for power supply will be reassessed by the responsible contractor prior to camp construction.

If generators are selected, they will meet the PES for noise and emissions.

3.7.5 Thermal Insulation

The pre-FEED assessed insulated and un-insulated pipeline options. The steady state analysis concluded that heat losses with the un-insulated case would require 35 separate crude fired heating stations resulting in high crude consumption, larger project footprint, larger environmental impact and operational costs. Conversely, applying thermal insulation on the pipeline concluded the heating requirements could be optimised with power for heating being provided from six stations with lower crude consumption, lower project footprint, less requirement for facilities, higher initial cost, but more economical over the lifetime of the project.

Several existing pipe thermal insulation alternatives were screened in terms of thermal efficiency, availability and constructability as summarised in Table 3.7.1. The decision was taken to incorporate poly-urethane foam (PUF) as the base as it offers the highest thermal efficiency with lowest Capex.

Table 3.7.1 Insulation Alternatives

Insulation Type	Characteristics		Conclusion
PUF	Lower thermal conductivity New coating plant required with high productivity Two methods possible for foam application: spray or moulding Excess foam material above heat tube or raceway is to be removed with spray process Polyethylene jacket added over foam to provide mechanical protection Many references of pipeline in service		Accepted as base case
Glass	Higher thermal conductivity makes it less efficient Conventional pipeline construction including bends Field applied in long lengths with glue or resin and external membrane High manpower requirement making it not suitable for long pipelines Very limited references essentially for piping in plants Pre-cut grooves fit over pipe or channel/heat tape		Not selected for main line because of lower thermal efficiency and lack of references – possible use at field cold bends (approx. 4000 pipe joints, i.e., 70 km) Under evaluation vs cold bending of high-density PUF application

Table 3.7.1 Insulation Alternatives

Insulation Type	Characteristics		Conclusion
Pipe in Pipe (PIP)	High linear weight making it suitable for wetlands Water ingress risk very low owing to welded construction Field bends possible with care External steel sleeve implies additional welding and coating		Not selected because of higher Capex

3.7.6 Heating

The temperature management principles of the pipeline are to:

- maintain operating temperature above 50°C at all times during export conditions (normal, transient and degraded modes)
- ease commissioning and ramp-up phases by maintaining fluid temperature above 50°C
- under no flow condition, i.e., preservation, temperature shall be maintained by the EHT above 50°C
- allow a cold restart from minimum ambient temperature up to 50°C.
- no bulk heating (BH) will be required during production plateau, providing the fluid export temperature from Tilenga Project CPF is exported at 80°C
- after plateau and throughout production decline, BH may be introduced to support EHT in maintaining the crude oil temperature above 50°C in flowing conditions to provide a more energy efficient solution overall for the low flow cases. EHT will still be required for cold restart.

Three heating configurations were considered to maintain the oil temperature above 50°C:

- Case 1 – EHT only case
- Case 2 – BH only
- Case 3 - EHT + BH (mixed heating architecture).

EHT is considered the optimal design case during commissioning, ramp up and production plateau for flowing conditions as it provides numerous operational advantages by providing:

- active heating to maintain fluid temperature continuously in all export modes
- preservation management to maintain temperature above 50°C during no flow condition
- the only method of heating the pipeline in the event of cold restart.

For Case 1, although EHT is considered less efficient than BH in terms of crude consumption, the implementation of EHT is mandatory from a flow assurance perspective. A screening exercise was undertaken during pre-FEED to assess operating the pipeline with EHT only throughout field life. Although the study concluded that EHT can provide the heat required throughout field life, the use of combined BH and EHT is considered more efficient during operations to compensate crude oil temperature during the latter stages of production with low flow cases.

Case 2 includes localised heating at each station with a discharge temperature such that the fluid arrival temperature at the next station is maintained above the minimum (50°C). This type of heating has large heat losses in comparison to EHT as shown in Figure 3.7-1. It is estimated that up to 13 BH stations would be required along the pipeline route. The study concluded that the flow assurance requirement for EHT was deemed to be the most critical factor and this option was discounted.

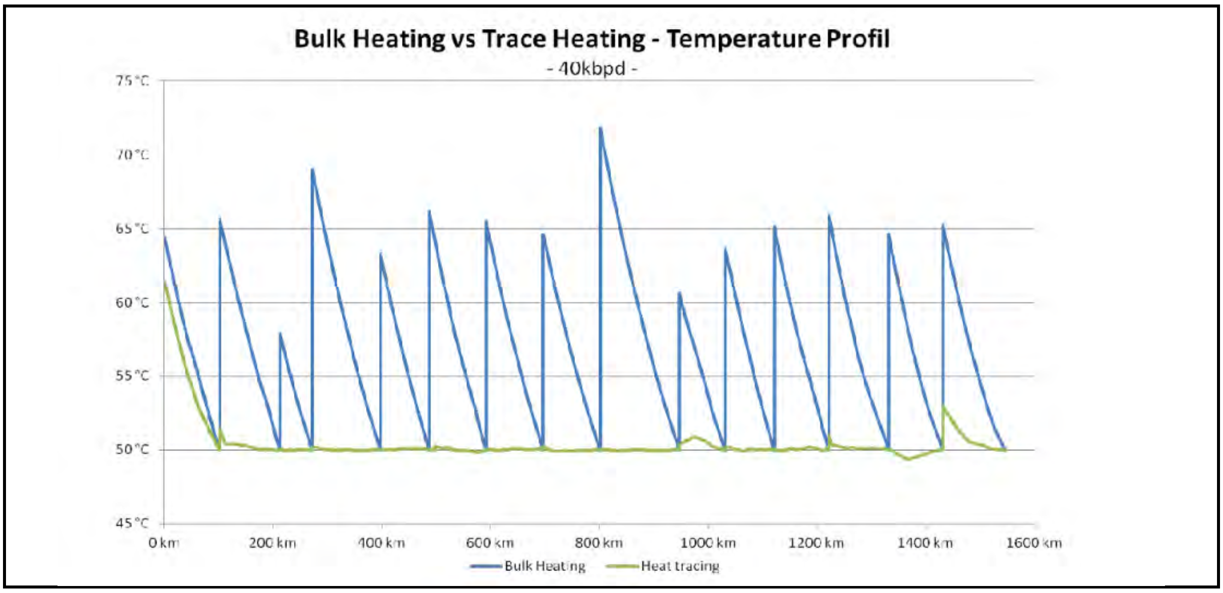


Figure 3.7-1 Bulk Heating vs Electric Heat Trace Heat Loss

Case 3 (combination of EHT and BH) was assessed to address the heat losses as production comes off plateau. It shows that that the use of BH is required to maintain crude oil temperatures above 50°C minimum (above wax appearance temperature), 80°C maximum and EHT to maintain temperatures above 50°C in no flow conditions. Although BH has larger heat losses than EHT, there is less overall crude consumption and it is therefore favoured (both environmentally and economically) as the primary source of heat after production plateau.

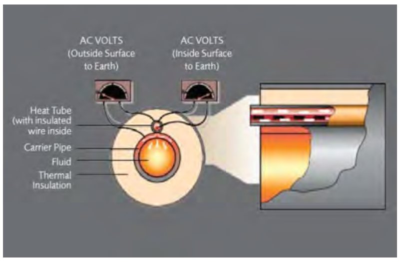
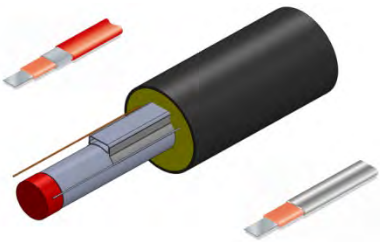
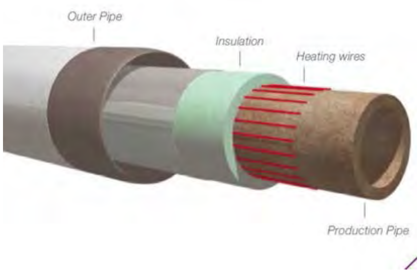
The overall conclusions from the study were:

- EHT only to be adopted as the base case design for commissioning, ramp-up and plateau
- BH may provide additional heating inputs used in combination with EHT after production plateau
- EHT will provide active heating throughout field life for maintaining temperature above 50°C in combination with BH and ensuring temperature above 50°C in no flow conditions and allowing cold restart.

3.7.6.1 Electrical Heat Tracing System Types

Several EHT alternatives were screened during pre-FEED as both primary and secondary sources of heat input. Aspects of the screening study are shown in Table 3.7.2. The three systems reviewed were skin effect heat tracing (SEHT), long line heat tracing (LLHT) and pipe in pipe (PIP).

Table 3.7.2 Electrical Heat Tracing Alternatives

System	Characteristics		Conclusions
SEHT	Current flows through centre of insulated wire and returns though heat tube Requires special transformers Welding and coating for tubing increases cost and schedule Coverage 9–12 km maximum with one tube Field proven used for most of trace heating pipelines		Not selected on basis of less coverage over long distances, more cabling required and more electric substations required More power consumption (as one phase out of the three is not used) Higher Capex than LLHT
LLHT	Experience of use on plants and some buried pipelines All three phases used Requires transformers Uses standard pipe Coverage up to 30–50 km		Selected as base case as greater coverage over long distances, less core cable quantities and less electrical substations required (lower overall project footprint)
PIP	Application for short subsea lines with steel pipe encased in large diameter steel pipe Multiple cables (24) provide redundancy Pre-constructed lengths welded and heating cables jointed on site. Includes insulation (needs to be dry)		Not selected because not considered suitable for length of line Will require an extra 1550 km of at least 28 in. steel pipe to serve as external jacket to 24 in. pipe Highest Capex of the three options

3.7.6.2 Bulk Heater Technology

Several BH alternatives were screened during pre-FEED. A summary is shown in Table 3.7.3. The types of heaters considered were direct heating, indirect heating and steam boilers. The indirect method was selected as the most feasible based on experience and technical challenges faced by direct heating and steam boilers.

Table 3.7.3 Bulk Heater Alternatives

System	Characteristics	Conclusions
Direct heating	Crude oil is extracted at 50°C from the pipeline heated and reintroduced at 80°C 6 heating stations	Not selected for pipeline owing to acid corrosion concerns
Bulk heaters (indirect heating)	Fired heaters using heating medium at higher temperature (water or oil) to heat the crude oil 6 heating stations	Selected as base case as proven technology
Steam boilers	Use of steam turbines for crude oil pumping fed by steam generated in steam boilers. Boilers less efficient but less NOx Concerns with water treatment	Not selected owing to matters associated with water treatment and efficiency

3.8 Construction Techniques

3.8.1 Overview

This section describes the various construction techniques considered during pre-FEED and FEED phases. The most critical factors in defining the construction strategy are:

- route optimisation and siting
- logistics strategy (optimisation of road and rail networks)
- weather conditions and seasonal constraints
- biodiversity-related seasonal constraints
- availability and proximity of existing infrastructure for material transport and for siting of facilities
- sequencing of pipeline insulation and coating activities with pipelay
- availability of materials and labour
- trenchability, including blasting requirements.

This section identifies the main alternatives reviewed during pre-FEED that have culminated in the definition of the constructions strategy as described in Section 2.4.2.

3.8.2 Strategy and Logistics

A traditional “spread” construction approach is proposed for the EACOP facilities. During FEED, numerous site visits and surveys along the pipeline route made important observations on the approach to construction and concluded that most of the pipeline is on relatively flat or rolling hill areas, which present few construction difficulties. However, several different options for scheduling were considered during an early constructability study during pre-FEED. Two initial options were identified for construction execution:

- 36-month schedule utilising five spreads, one for EACOP in Uganda
- 42-month schedule utilising three spreads.

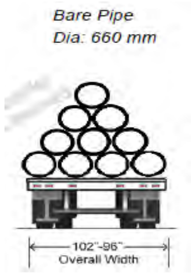
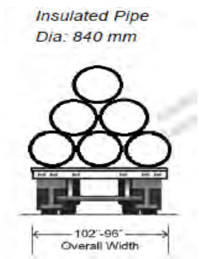
The study concluded that, owing to constraints on the sizes, length and particularly the type of thermal insulation, efficient coordination of insulation and coating activities with the pipelay schedule are the most critical factors for construction execution. In addition, the study identified the requirement to ensure fully free access to the RoW to prevent delays to mobilisation for construction. The conclusions from the study have been used to develop the base construction strategy, and schedule as presented in Section 2.6.

The logistics strategy has been developed during the pre-FEED and FEED phases based on the following principles:

- achieve early enough, but not too early, material delivery (knowledge of all material flows is the key to a smooth transportation plan)
- provide smooth equipment replenishment to avoid unnecessary costs as well as delays.
- synchronise material supply with the construction schedule to make reliable estimation of material requirement and locations where the material required
- align the equipment resourcing and transportation plan with fuel supply strategy to reduce delay
- estimate the optimum storage capacity to reduce the cost of storage while maintaining reliability of timely material supply to the project
- eliminate or reduce potential unpredicted delays at border crossings, custom clearance and other logistics bottlenecks by making realistic predictions and observing local/country capacity and calendar
- ensure availability of trucks and site transportation and plan for importing or sourcing adequate equipment and vehicles to fulfil the project requirements
- determine the season dependency of the road conditions, availability of transportation vehicles and border crossing times, and prepare for it.

An example of logistics optimisation is the transportation of line pipe. Three options were reviewed as described in Table 3.8.1.

Table 3.8.1 Line Pipe Transportation Options

Transportation Method	Advantages	Disadvantages
Bare pipe, insulated at CF 	More pipes per truck load, reducing number of cross country trips by approx. 1/3 Lower shipping cost as transported from pipe mill to port of entry Opportunity to utilise local content and optimise schedule by combining insulation application activities with CF Overall the most cost effective when considering all logistics constraints and coating plant costs	Insulation costs may become more expensive owing to requirement for dedicated facility Additional transportation between insulating facility and pipe yard Additional schedule constraint with land access, construction, set up and qualification of insulation facility
Insulated pipe 	Transportation directly to site for lay	Less pipe per truck load increases no of trips by 1/3 Higher shipping costs (transported to insulating facility and then to port of entry)
Bare pipe shipped and insulated at port of entry	Maximum use of local content Lower shipping costs Not as cost effective as coating plant near to mid-way of pipeline route.	Cost and schedule constraints associated with land access, set up and qualification of insulation facility at port of entry Less pipe per truck load increases no of trips by 1/3

The review concluded that transportation of bare line pipe is the best solution on the basis that more pipes can be transported (thus reducing shipping costs and truck movements) while providing maximum opportunity to utilise local content.

3.8.3 Pipeline Construction

3.8.3.1 Construction Techniques

The pipelay sequence is described in Section 2.4.2.2 and is comprised of three main aspects:

- open areas where the spread technique is utilised, i.e., pipe storage, RoW clearing and grading, stringing, bending, welding and trenching
- crossing locations where specialist crews and specific techniques are used, e.g., auger boring
- special sections such as restricted working areas, difficult terrain and environmentally and socially sensitive areas.

During pre-FEED the spread technique was considered the most suitable for onshore pipe lay and therefore no other alternative construction strategies were considered during FEED.

3.8.3.2 Blasting and Micro-blasting

In rocky sections of the pipeline route, where normal excavation is not possible, blasting may be required to fracture the rock and enable pipeline trench excavation.

Micro-blasting avoids rock projectiles and creates less noise and vibrations but can only be used under certain conditions. Sections suitable for micro-blasting will be identified during construction, based on geology, the proximity to infrastructure and environmentally sensitive features.

3.8.3.3 Crossings

Several pipeline crossing methods exist, i.e., open cut and trenchless (auger boring, horizontal directional drilling (HDD), and micro-tunnelling). EACOP will choose from these alternatives as described below. The crossing alternatives are provided in Table 3.8.2.

Watercourses and Wetlands

The pipeline route crosses numerous watercourses and wetlands, some of which are permanent and others are of a seasonal nature. Open-cut is considered the default method for all rivers, streams and wetland crossings in Uganda based on the FEED concept design. However, the final site-specific watercourse and wetland crossing method will be chosen during detailed design and site evaluation by the selected construction contractors. Identification of the appropriate technique will be based on a systematic assessment of each site using the following criteria:

- nature of the crossing (length, location, terrain, geotechnical and hydrogeological constraints)
- environmental aspects (ecological value including critical habitat qualifying features, e.g., presence of species of conservation concern, protected and iconic species)
- social attributes (community water use, wetland resource utilisation, commercial use, e.g., fishing)
- constructability (access restrictions, size of construction spread required).

In the event that another method other than open cut is chosen as the preferred method, EACOP will conduct an environmental and social assessment of the crossing based on the chosen method. This will subsequently serve as supporting documentation for the river/wetland crossing permit application to the relevant regulatory authority.

Infrastructure and Utilities

The GoU and the project have agreed on the following infrastructure crossing arrangements in the draft Host Government Agreement (HGA):

- For crossing infrastructure that exists on the project land before the land acquisition for the EACOP System, the relevant State Authority and the project will enter into a crossing agreement. The GoU and the project agree that the integrity of the existing crossing infrastructure must be maintained.

- For crossing infrastructure that may need to be installed by the State/State Authority after the land has been acquired for the EACOP System, then the State/State Authority will submit a request to cross the project land in writing. The GoU and the project agree that the integrity of the EACOP System must be maintained. If the State/State Authority and the project agree that the proposed crossing infrastructure is acceptable, then they will enter into a crossing agreement.
- If the State/State Authority and the project do not reach agreement on the proposed crossing infrastructure because of the technical aspects (access to and the safety and integrity of the EACOP System, conduct of the project activities) then an independent expert will determine these technical aspects in accordance with draft HGA and thereafter the parties will enter into a crossing agreement as provided for under the draft HGA.

The pipeline will cross existing infrastructure such as roads, buried utilities and railways. Railways, main tarmacked national and district roads will be crossed by auger boring. Non-tarmacked national and district roads, smaller local and private roads will be crossed by open cut methods. The ESIA has considered this the base case. Site conditions could require a change in method in which case an assessment using the selection criteria provided above will be undertaken prior to final choice of an appropriate method. Any changes will be communicated to the relevant regulatory authority.

Table 3.8.2 shows the finalised crossing list for EACOP Uganda.

Table 3.8.2 Crossing Alternatives

Criteria	Open Cut	HDD	Micro-tunnel	Auger Boring
Summary	Excavation of a trench, installation of a pre-fabricated section of pipes (potentially concrete weight coated), backfilling and restoration of watercourse banks and wetlands	Drilling of an annulus, along a pre-determined alignment, and installing pre-fabricated length of pipeline from the opposite side of the crossing back through the drilled annulus Can be used for crossing distances of up to 1.5 km	Circular precast concrete pipe sections being pushed (hydraulically jacked) through the ground behind a tunnel boring machine along a predetermined alignment to create a tunnel for installation of the product pipe. Can be used for potentially longer distances than HDD	Well proven technique that requires excavation of pits on either side of the crossing to aid the installation of the pipeline. The depth of the pits depends on the physical characteristics of the crossing. Can be used for crossing distances of up to 120 m
Cost	Lowest potentially	Low (in comparison with micro-tunnelling)	Highest (expected to be 50% more than HDD)	Low (comparable with HDD)

Table 3.8.2 Crossing Alternatives

Criteria	Open Cut	HDD	Micro-tunnel	Auger Boring
Logistics	Logistically challenging. Requires several types of equipment. Deep well-point dewatering potentially being required depending on hydrogeological conditions.	Logistically challenging requiring mobilisation of drilling rig, associated power and mud management plant	Logistically challenging requiring mobilisation of concrete caissons or steel sheet piled cofferdam for construction of the tunnelling shafts, tunnel boring machine, associated power plant, mud management plant, excavators, cranes and personnel	Simplest logistically based on required equipment and personnel
Environment	Potential risk from sedimentation but can be controlled with appropriate mitigation. Best undertaken in dry season	Risk of hydrofracture*[4] Lowest spoil generated from process, however, potentially challenging waste management. Larger construction footprint for spread	Risk of hydrofracture* Highest spoil generated Larger construction footprint for spread	Minimal construction footprint required

3.8.3.4 Water Sourcing

Construction activities requiring water comprise mainly concrete mixing and dust suppression. These activities do not require potable water, although potable water must be available for consumption by construction workers (it is assumed bottled water will be provided).

To reduce water abstraction and discharge, the reuse of treated sewage effluent is a viable alternative for industrial water supply. It has been established that it is economically feasible to truck treated effluent to the zone of pipeline construction activity within a range of approximately 10 km of a camp. Potential sources of surface water abstraction for construction activities were identified using satellite imagery analysis. These are water bodies which appear to be perennially available and within approximately 10 km of truckable distance of the pipeline route. Potable water to serve the camps will be sourced through a variety of methods including borehole installation and the purchase of water from water districts and water boards.

[4] The inadvertent seepage of drilling mud onto the ground or into surface waters through fractures in the subsurface. Hydrofracture can occur when using pressurised crossing construction methods such as HDD.

3.8.3.5 Waste Management

Alternative solid waste management solutions are dependent on local, existing recyclers and waste management facilities with capacity to manage project waste.

The EACOP project will follow good international industry practice for waste management and follow the waste management hierarchy (as described in Section 2.4.2.8) of reduce, reuse, recycle/recover. This will be achieved by working with existing recyclers and waste management facilities.

Project waste will be managed as described in Section 2.4.2.8 while pollution prevention measures described in the pollution prevention plan will prevent project solid and liquid waste being a source of pollution to land, water or air.

Project wastewater (e.g., domestic wastewater, vehicle wash) will be treated using onsite water treatment plants at each camp; project wastewater discharges will be compliant with relevant discharge standards included in Appendix F.