2.0 CHAPTER B – LOCATION AND TECHNOLOGY ALTERNATIVES AND REASONS FOR PREFERRING THE PROPOSED ALTERNATIVE

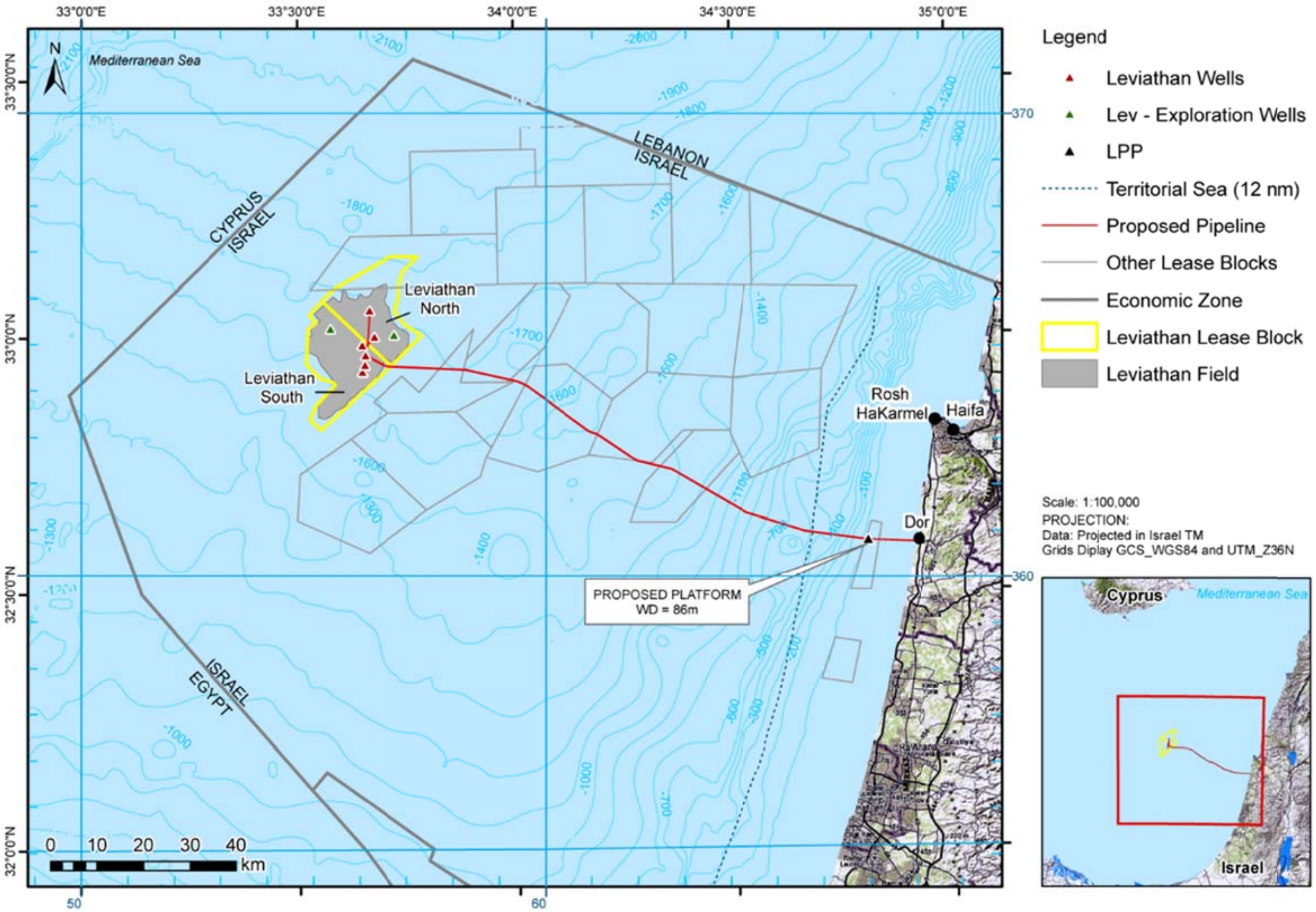
2.1 General

The Leviathan Field development plan calls for a subsea tie-back to a nearshore LPP, which will be a fixed facility (steel jacket) in Israeli Territorial Waters. The length of the pipelines connecting the infield infrastructure to the LPP is approximately 117.5 km. The feasibility of this concept has been proven by the recent Tamar Field development in Israel, which features an approximate 150 km multiphase tieback at similar water depth to a nearshore platform.

Development will require significant infield infrastructure to connect the development wells, initially eight (8), to an Infield Gathering Manifold for onward transmission to the LPP. In addition, development calls for three (3) multiphase production pipelines, two (2) by 18” and one (1) by 20” to transmit the gas from the infield infrastructure to the LPP. Further facilities required include pipelines and umbilicals to supply MEG, chemicals, and controls to the infield infrastructure.

The location of the Leviathan Field, the planned pipeline routing and the LPP location are shown in Figure 2-1. All transmission pipelines will be laid into single transmission corridor of up to 600m in width.

Figure 2-1: Location of the Leviathan Field



2.2 Location Alternatives

The LPP is to be installed within Israeli Territorial Waters on the western limit of the northern TAMA block, approximately 10 km from the coast of Dor. This location was determined under the TAMA process which applies to all oil and gas infrastructures proposed to lie within Israeli Territorial Waters.

TAMA blocks are areas that have been demarcated under Israeli legislation for oil and gas infrastructure installation. A review of the LPP location is not performed in this document as the LPP is not included within the scope of this assessment.

2.2.1 Wellheads and Flowlines

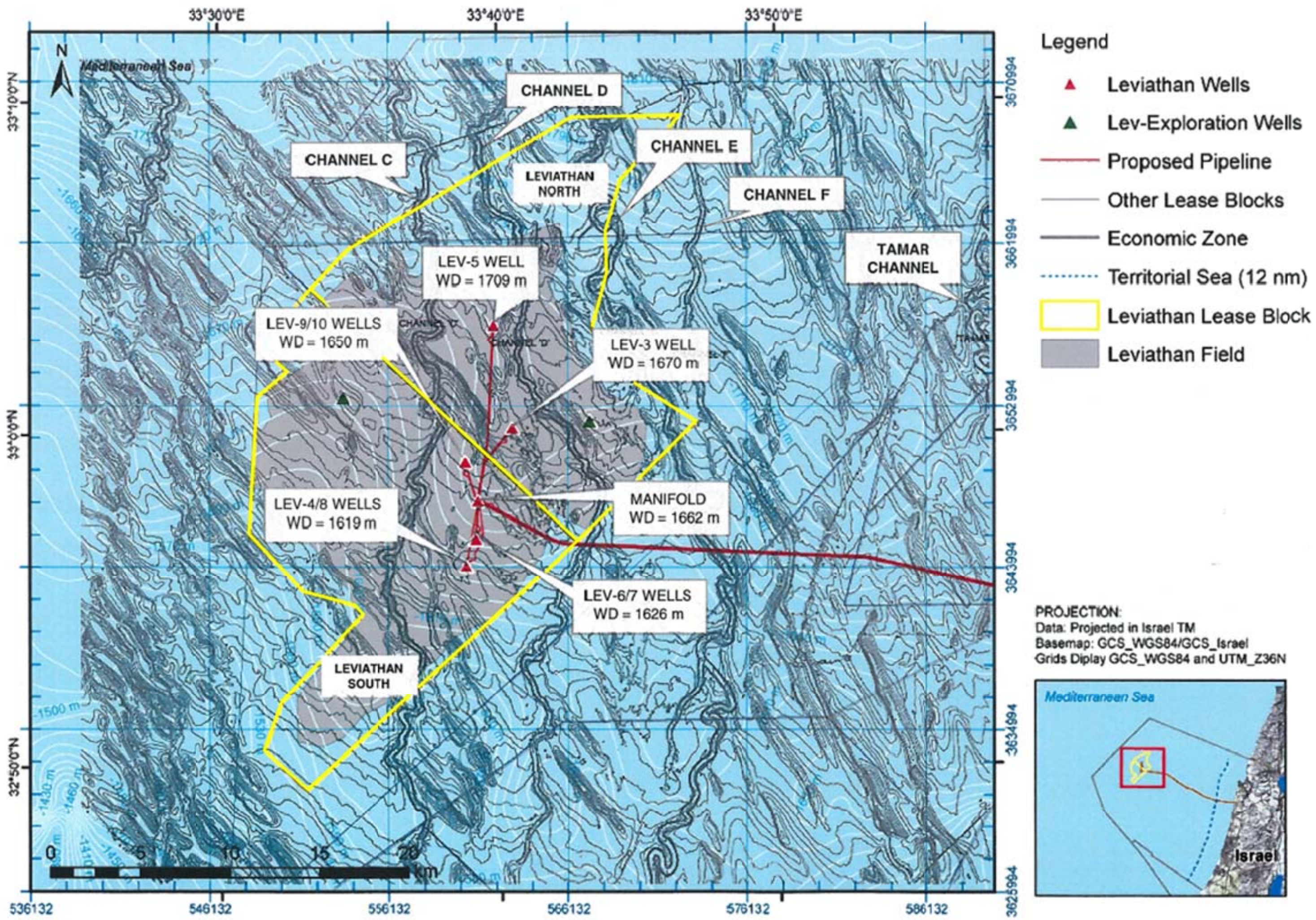
All subsea wellheads associated with the Leviathan Field development are to be located within the Leviathan North and South license area which makes up the “infield” area. Wellhead locations are driven by the Leviathan reservoir and the planned well design which has been set out in the Leviathan Drilling EIA (Noble Energy Mediterranean Ltd., 2016a). For the purpose of this assessment the top-hole locations are considered to be fixed at the locations provided in the Leviathan Drilling EIA.

Wellheads will be connected to the Infield Gathering Manifold (see Section 2.2.2) by way of flowlines. Where multiple wellheads are located within close proximity (less than 200 m), these will be produced by comingling production fluids from adjacent wellheads and routing via a single flowline to the Infield Gathering Manifold. This is beneficial from an environmental standpoint as it reduces the total land take and installation duration associated with the flowlines, as well decreasing commissioning discharge volumes of the infield infrastructure.

Where possible flowlines will be routed to minimize their total length by taking the most direct route between the wellheads and the Infield Gathering Manifold. As above, this will minimize the total land take, installation duration, and commissioning discharges associated with the infield infrastructure.

The proposed infield layout is provided in Figure 2-2 with the local bathymetry overlain for reference.

Figure 2-2: Infield Facilities and Seabed Channels



2.2.2 Infield Gathering Manifold

The Infield Gathering Manifold is proposed to be located approximately equidistant from the proposed Lev-6 and Lev-9 well sites in order to provide an appropriate balance between minimizing the infield flowline length while avoiding increasing the total transmission (production and MEG supply) pipeline length. Aside from minimizing overall seabed land take, there are no significant environmental drivers for determining the location of the Infield Gathering Manifold.

In its current location the infield flowlines are not required to cross any major seabed channels (see Figure 2-2); however, the transmission pipelines and umbilicals will have to cross, amongst others, the seabed channel labeled Channel D in Figure 2-2.

Moving the Infield Gathering Manifold location to the east of Channel D is not considered attractive from either an environmental or technical standpoint as although this would decrease the number of channel crossings for the transmission pipelines, this would be offset by the requirement for infield flowlines to cross the channel. Relocating the manifold either north or south of its current location is not perceived to offer any significant benefits.

2.2.3 Pipeline Route

The transmission pipeline corridor runs from the Infield Gathering Manifold to the LPP, the location of the aforementioned infrastructures define the start and end point of the corridor. The route taken between these points has been optimized during design to minimize total pipeline length, channel crossings, and interactions with existing infrastructure. Further optimization is expected as future survey work along the corridor is completed in specific areas where additional resolution is required. Planned survey activities are limited to side scan sonar which will assist Noble Energy in gaining a picture of the sea floor.

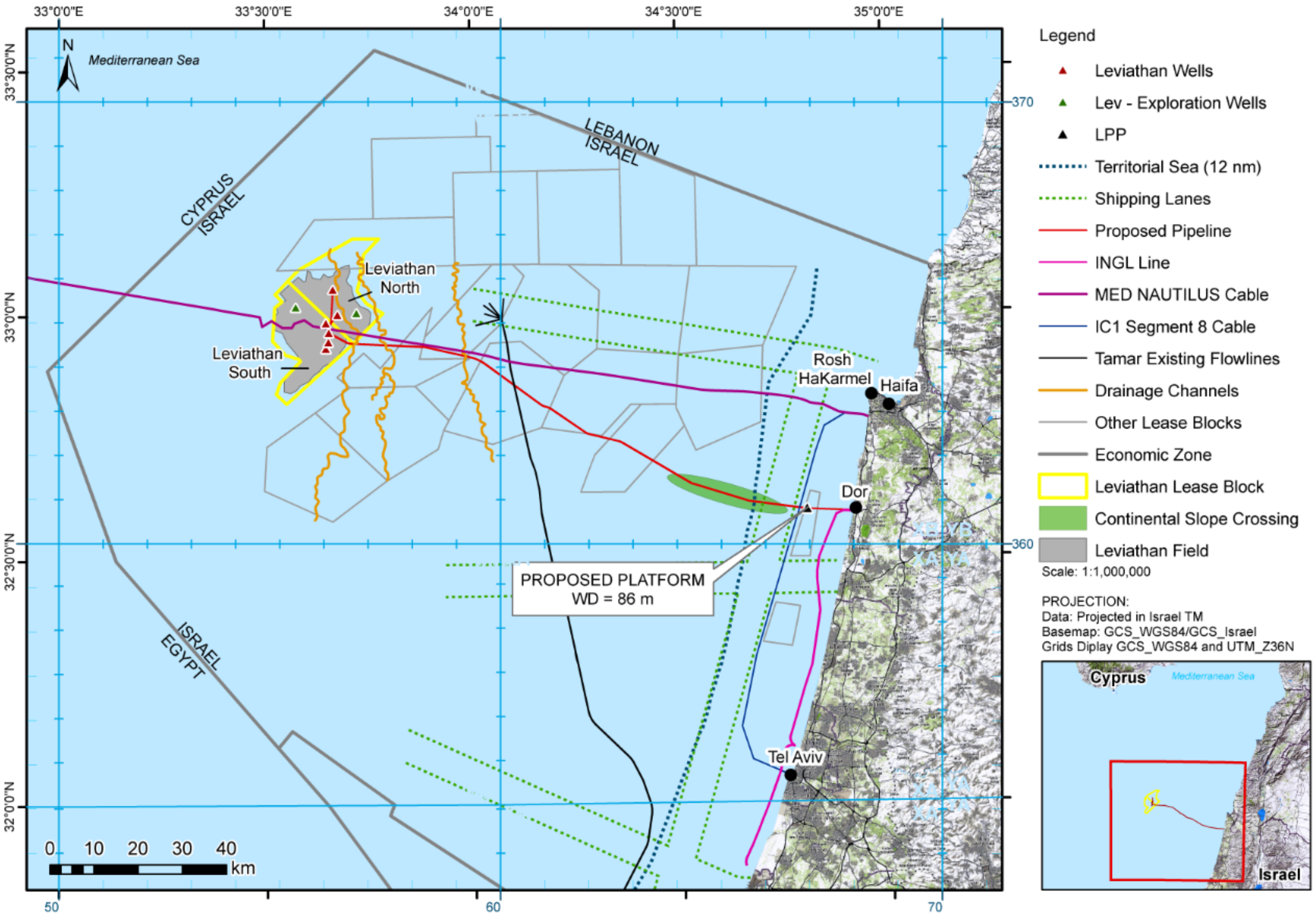
Key features between the Infield Gathering Manifold and the LPP are:

- Two significant south to north channels in close proximity to the Leviathan Field (Channel D and Channel E) - See Figure 2-2;
- The south to north Tamar channel approximately 30 km to the east of the Infield Gathering Manifold;
- The Tamar production infrastructure (i.e., pipelines, wellheads, and infield structures) located approximately 40 km to the east of the Infield Gathering Manifold;
- The MED Nautilus fiber optic cable which runs east to west from Haifa and passes through the Leviathan license area close to the proposed Lev-9/10 well site;
- The continental slope around the border of Israeli Territorial Waters where the water depth decreases from approximately 1,000 m to 100 m over a horizontal distance of 25 km;
- The north/ south shipping lanes from Hadera to Haifa, which lie approximately three (3) km west of the LPP; and
- The IC1 Segment 8 cable which lies approximately two (2) km to the west of the LPP.

As per the detailed description given in Chapter A, there are no areas of special natural, or ecological (e.g., fisheries) importance between the Infield Gathering Manifold and the LPP.

The preferred pipeline corridor is shown in Figure 2-3 with seabed features marked for reference. This route will require the transmission pipelines to cross all three (3) of the seabed channels (D, E, and Tamar – from west to east), the Tamar production pipelines, the continental shelf, and all items identified within Israeli Territorial Waters. The route runs to the south of the MED Nautilus fiber optic cable system and thus crossing of this infrastructure is not required.

Figure 2-3: Transmission Pipeline Route and Seabed Features



Aside from the Tamar pipelines, none of the features that the transmission corridor crosses can be avoided without substantial pipeline re-routing. Such re-routing is not considered appropriate where engineered crossings can be developed.

In order to avoid crossing the Tamar pipelines the transmission pipelines could be routed to the north of the Tamar Field; however, this would require crossing the MED Nautilus fiber optic cable and substantial incremental pipeline length (increasing from 117.5 km to approximately 135 km). Such a routing is not considered attractive from an economic, technical, or environmental standpoint as engineered pipeline crossings are a mature technology which do not present significant technical or environmental risk.

In order to avoid damage, all sites within the application area classified as archaeology findings, cultural resources, or other resources with potential archaeological significance will be afforded a minimum avoidance zone of 305 m between development activities and the site. Any further sites of significance located prior to, or during pipelay operations will also be afforded a 305 m avoidance zone.

Sites identified by sonar surveys that do not have sufficient evidence to be classed as culturally or archaeologically significant will be afforded a 31 m avoidance zone.

All information collected to date about side-scan sonar contacts with a high potential for historical or archaeological significance has been submitted to the Marine Archaeological Unit at the Israeli Antiquities Authority for further assessment and evaluation. Any further data collected on side-scan sonar contacts during the design and installation of the Leviathan Field production system will be passed onto the Marine Archaeological Unit in the same manner.

The alternative location information provided above for the pipelines also applies for the selection of the location for the umbilical as it will be installed in the same corridor.

2.3 Technology Alternatives

During the design work completed to date, a number of technology alternatives have been considered for the Leviathan development. Those technology selections that impact the subsea production facilities upstream of the LPP are described in the following sections.

2.3.1 Infield Submarine Infrastructure

Technology selections associated with the infield submarine infrastructure relate primarily to the flowlines, manifold and jumpers, and these are detailed below. Additionally, information pertaining to the infield distribution of MEG is included in Section 2.3.1.4.

2.3.1.1 Flowlines

Flowlines connecting the wellheads to the Infield Gathering Manifold will be constructed from carbon steel and of rigid construction.

Flexible flowlines were considered, but diameter restrictions associated with water depth and operating pressure, limit the number of qualified manufacturers. Since there are no environmental benefits associated with flexible flowlines, rigid flowlines are preferred.

2.3.1.2 Infield Gathering Manifold

The subsea configuration for the Leviathan development is focused around a central Infield Gathering Manifold which will tie all initial (and any future wells) into the production pipelines for transmission to the LPP. The Infield Gathering Manifold is to be a six (6) slot design allowing for six (6) flowlines to be connected directly to it.

The selected transmission configuration for the project is a triple trunkline configuration (see Section 2.3.2.1) and as such the Infield Gathering Manifold will feature three (3) headers with remotely controlled valving allowing any of the six (6) slots to be routed to any of the headers. This enables operational flexibility as flowrates through production pipelines can be balanced to optimize recovery. Further, as wells deplete at different rates lower pressure wells may be routed to a dedicated low pressure production pipeline, while higher pressure wells may be routed to a high pressure production pipeline to maximize flowrates. Use of a single Infield Gathering Manifold is considered the most flexible and robust configuration to future expansion as the configuration may be expanded by either, daisy chaining wells at the infield PLETS, or if necessary, connecting a future manifold into the initial Infield Gathering Manifold.

The alternatives to a single infield manifold are either:

- Use a tie-in manifold/structure per production pipeline [three (3)]; or
- Use of a daisy chained architecture.

Both of the above would result in significantly reduced production flexibility as wells would be tied into specific pipelines with only limited facilities for cross over between the production pipelines. In both of the alternative options it would not be possible to route any specific well to a pipeline of the operators choice, meaning that low pressure wells would have to be shut-in prematurely or high pressure wells chocked back, thus impacting production. Further, a specific issue related to a daisy chain architectures is that should any well require intervention activities, all wells on the flowline branch upstream of the affected well would have to be shut-in due to the risk of dropped object impact on the flowline. If the affected well is the first in the flowline this would necessitate the complete shutdown of that production flowline. This has the potential to significantly impact production availability.

From an environmental prospective, neither of the alternative configurations are considered to present a significant change in the subsea land take. Further, the increased tie-in complexity associated with either multiple manifolds, or a daisychain architecture would likely increase the infield installation campaign with the potential to increase the environmental impact of these operations.

As a result of the increased operational flexibility, robustness to expansion and lack of environmental drivers for alternatives, a single Infield Gathering Manifold configuration is the preferred solution for the Leviathan Field development project.

2.3.1.3 Jumpers

Tie-ins between infield infrastructures and their associated flowlines will be made by way of carbon steel rigid jumpers. This is a common industry technique and is applied throughout the oil and gas production industry.

The alternative to rigid steel jumpers would be flexible jumpers. These have been considered by the project; however, as with the flowlines (see Section 2.3.1.1) diameter restrictions associated with the water depth and operating pressure limit the number of qualified manufacturers. This does not offer environmental benefit to the project; therefore, rigid steel jumpers are the selected jumper type for the Leviathan Field development.

2.3.1.4 MEG Supply (Infield)

MEG will distributed from the infield MEG SDU, to the relevant infield infrastructure (Infield Gathering Manifold and wellheads) by way of dedicated tubes within the infield umbilicals. Within each infield umbilical three cores will be dedicated to MEG supply with a further core of equivalent diameter will be available as a spare. This design provides redundancy in the infield MEG distribution system and allows the MEG supply infrastructure to be installed as part of the wider controls system.

The alternative to MEG supply through infield umbilical cores is to lay dedicated MEG flowline (either rigid or flexible) in the infield area. However, this solution would result in increased subsea land take and installation duration. Further, in order to maintain system redundancy dual MEG supply lines would be required to run from the MEG SDU to each wellhead, thus further increasing the land take and installation duration, as well as impacting project economics. Based on the above infield MEG supply through dedicated cores within the infield umbilicals is the preferred solution for the Leviathan Field development.

2.3.2 Transmission Infrastructure

Transmission pipelines will be laid between the LPP and the infield location for the purpose of routing production fluids from the Infield Gathering Manifold to the LPP, and supplying MEG from the LPP to the infield infrastructure. The basis for these pipelines is:

- Two (2) by 18” rigid production pipelines from the Infield Gathering Manifold to the LPP for supply of gas to the Domestic Supply Module (DSM);
- One (1) by 20” rigid production pipeline from the Infield Gathering Manifold to the LPP for supply of gas to the Regional Export Module (REM); and
- Two (2) by 6” rigid MEG supply lines from the LPP to an infield distribution unit to supply MEG to the infield infrastructure. These may be laid as either:
    - Standalone pipelines; or
    - Piggybacked onto the dual 18” DSM production pipelines.

Additionally a single primary umbilical will be installed within the transmission corridor to facilitate control and chemical injection at the infield locations from the LPP.

2.3.2.1 Production Pipelines

The installation of three (3) separate production pipelines is preferred from an operational standpoint as it will allow the REM and DSM to be operated broadly in isolation. Installation of fewer pipelines would be desirable from an environmental standpoint; however, this would present operational issues with respect to meeting daily demand swings from the Israeli domestic market. Further operational issues would be anticipated with respect to maintaining the pipelines above their minimum operable flowrate during periods of decreased domestic or regional demand. These operational issues (which could impact project feasibility) are considered to outweigh any environmental benefit of reduced pipeline land-take.

There is no environmental benefit to increasing the number of production pipelines running between the Infield Gathering Manifold and the LPP. As such, upward revision of the number of production pipelines has not been pursued.

2.3.2.2 MEG Supply Lines

Use of dual 6" MEG supply lines is planned as it offers redundancy to this production critical item. Each 6" pipeline will be capable of meeting the entire MEG supply requirements of the field.

The alternative to dual 6" MEG supply lines is to utilize a single 6" pipeline to supply the infield infrastructure. This would reduce the subsea land take associated with MEG supply; however, it would also removes the redundancy in this production critical system. As a result, if the MEG supply line became blocked or ruptured in any way, it would not be possible to supply MEG to the wellheads and production from the field would have to be shut-in until MEG supply could be reinstated. This would impact production availability, and by association Israeli energy supply security which is not acceptable to the project.

As with the production pipelines, there is no environmental benefit to increasing the number of MEG supply lines running between the LPP and the Infield Gathering Manifold, and as such this has not been pursued.

As a result of the above, use of dual 6" MEG supply lines is the preferred solution for the Leviathan Field development.

The MEG supply lines may be laid either as piggyback lines on the 18" DSM production lines, or as standalone lines within the transmission corridor. If the lines are laid as standalone lines then this will incur additional subsea land take and installation duration; however, project contracting strategies may drive towards a standalone solution. The final decision as to how the MEG pipelines will be installed is subject to contractor selection, which will not be made until the end of 2016. As such both installation options are considered in this assessment.

2.3.2.3 Materials of Construction

All transmission pipelines and infield production flowlines will be constructed from carbon steel. Carbon steel is selected as the production fluids from the Leviathan reservoir are expected to be "sweet" and thus present a low risk of significant internal corrosion. Corrosion of the production system due to trace levels of reservoir impurities will be managed through low does injection of a Corrosion Inhibitor (CI) at the subsea wellheads.

The alternative to carbon steel with corrosion inhibitor injection is to construct all pipelines from an appropriate Corrosion Resistant Alloy (CRA). While this would remove the requirement for corrosion inhibitor injection and simplify the asset integrity management program, this is not considered to be the Best Available Technique (BAT) due to the negative economic impact of utilizing CRA. Selection of carbon steel with corrosion inhibitor injection for production of "sweet" hydrocarbons is common practice throughout the offshore oil and gas industry.

All pipelines, flowlines, and subsea structures will be protected from external corrosion through a combination of sacrificial anodes and corrosion resistant coatings.

2.3.2.4 Controls System

The infield architecture will be controlled from the LPP, with ROV intervention facilities available in case of a control systems failure. The controls system will be an open loop, electrohydraulic design with a single main umbilical (multiplexed) running from the LPP to an infield Controls Subsea Distribution Unit (SDU). From the SDU, controls will be distributed by way of infield umbilicals (again multiplexed electrohydraulic) to the infield structures with remotely operated valves. This is analogous to the design applied on the Tamar development.

Controls Configuration

Use of a multiplexed electrohydraulic design is the industry standard for long distance, multi-well, deepwater applications. This design relies on subsea distribution of hydraulic fluid from an SDU which is controlled electronically from the host facility. Alternative field proven designs include:

- Direct Hydraulic: It relies on a direct hydraulic linkage between the host facility and each actuated valve in the subsea system. This is primarily suited to small fields with limited infield infrastructure.
- Piloted Hydraulic: It is a variation on the Direct Hydraulic system, which improves on valve response time when compared to Direct Hydraulic, but is still primarily suited only to small fields with limited infield infrastructure.
- Direct Electrohydraulic: It is a simplification of the Piloted Hydraulic system whereby the number of hydraulic cores within the umbilical is reduced by using electrically actuated pilot valves.

All of the above alternatives require some level of direct connection between every actuated valve on the controls system and the host facility. For large fields such as Leviathan, this renders these alternatives unfeasible due to the number of cores required, which would result in an excessively large umbilical design.

All-electric controls systems are a relatively novel development in the field of subsea controls systems, which removes entirely the requirement for hydraulic fluid for valve actuation. Instead, subsea valves are actuated by way of electromagnetic actuators, which are powered through an electrical linkage to the host facility. This system is, in theory at least, capable of providing controls to large subsea developments with substantial infield infrastructure. However, all-electric controls systems have not been field proven at either the water depth or scale, and as such this design is not considered feasible for the Leviathan Field.

As such the selected controls system is of a multiplexed, electrohydraulic configuration with infield subsea distribution.

Umbilical Sparing

A single primary umbilical will be installed to convey chemicals and controls signals from the LPP to the infield area. Redundancy will be built into the umbilical by way of core sparing to allow continued operation in the event of a blockage or loss of integrity affecting individual cores within the umbilical. The umbilical itself will be designed such that it can resist environmental impacts and forces and as such the requirement for redundancy of this element is minimized.

Use of dual umbilicals in place of a single primary umbilical may offer some project benefits with regards to increasing redundancy of the production critical umbilical; however, this would come at an increased cost and environmental impact as a result of subsea land take. Additionally, the provision of spare cores within the proposed single primary umbilical can affectively provide the equivalent redundancy within a single umbilical.

As a result of the above a single primary umbilical is the preferred solution for the Leviathan Field development.

Open Versus Closed Loop Controls

An open loop controls system relies on venting hydraulic fluid to the marine environment via vent lines located locally to the actuated valves. Venting only occurs when a valve is allowed to move to its fail safe position (either open or closed) as this drives the fluid out of the actuator. Hydraulic fluids in open loop systems are water based (e.g., MacDermid Oceanic HW540P) and pose little threat to the marine environment.

The alternative to an open loop design is a closed-loop configuration whereby hydraulic fluid that would otherwise be vented, is routed back to the host facility by a return line in the umbilical. This removes the periodic venting of hydraulic fluid to the marine environment and any environmental impacts associated with it. However, for a closed loop system to operate in this water depth and offset distance, a pump system and possibly a storage tank would be required at each subsea tree, manifold and Subsea Distribution Unit (SDU), all equipment with Subsea Control Module (SCMs). In addition to a larger umbilical for return hydraulic tubes (tubes which would be quite large) and a power cable (or umbilical) to run the pumps. The environmental risk would be increased due to additional controls and pumping equipment required to return the fluid to the host. If the return fluid equipment failed (i.e., pump failed), all fail-close valves may not be able to close due to back pressure in the system. As a result there is a risk the Surface Controlled Subsurface Safety Valves (SCSSVs) or Underwater Safety Valves (USVs) would not be able to close in an emergency situation. The reliability of the overall subsea system would be greatly reduced with the additional controls equipment required to implement a closed loop control system.

The potential use of a closed loop system has been considered by the project team; however, on balance, an open loop controls system is preferred. Such a system is typical for the vast majority of subsea oil and gas developments throughout the world and is considered acceptable on the provision that an appropriate water based hydraulic control fluid is selected. Any environmental benefits that could be gained with a closed loop system are considered to be balanced by the increased land-take associated with the larger umbilical diameter. Further, the potential negative safety impacts associated with a closed loop control system (as mentioned above) are considered to outweigh any (if any) environmental benefit of the system.

It should be noted that the controls system for the SubSea Isolation Valves (SSIVs) on the production pipelines (local to the LPP) will be of a closed loop configuration. This is enabled by the limited complexity of controls on this system, and the reduced water depth and distance from the LPP, which minimize the negative impacts on valve motion.

Hydrate Inhibition

Leviathan production will be reliant on continuous Monoethylene Glycol (MEG) injection at the subsea wellheads to prevent hydrate formation in the production system. Without appropriate hydrate inhibition, hydrates (ice like crystals) will form in the pipeline system due to the combination of low ambient temperatures, elevated operating pressures, and the presence of water in the production fluids. Alternatives to MEG inhibition in subsea pipeline systems include:

- Thermodynamic Hydrate Inhibition through Methanol injection;
- Low Dosage Hydrate Inhibitor (LDHI) injection; or
- Insulation/heating to maintain bulk temperature above the hydrate appearance temperature.

Use of methanol in place of MEG (also a Thermodynamic Hydrate Inhibitor (THI)) is not considered attractive as dosage rates for methanol are broadly equivalent to those for MEG. As such there will be no significant reduction in subsea infrastructure requirements. Further, methanol shows an increased tendency to partition into the gas phase during processing and will require removal prior to gas sales, potentially incurring additional processing equipment on-board the LPP.

Both methanol and MEG may be readily separated from the bulk oil phase by a combination of gravity and cyclonic separation. As such continuous injection of methanol for hydrate inhibition is discarded as it is not considered to offer any positive impact in place of continuous MEG injection.

Low Dosage Hydrate Inhibitors (LDHIs) are a relatively recent development in the offshore industry that in certain circumstance may be beneficial in comparison to THI injection. LDHIs function by either slowing the formation of hydrate crystals (Kinetic Hydrate Inhibitors - KHIs) or preventing hydrate crystals from adhering to each other (Anti-Agglomerates - AAs). The primary advantage of LDHIs over traditional THIs is the reduced dose rates required to effectively manage hydrates under normal operating conditions, this can reduce topsides space requirements, energy consumption (reduced regeneration/pumping) and supply line size. However, use of LDHIs has been limited to date due the fact that they either: only provide protection for a limited time (KHIs); or require an oil phase to be present to carry the un-agglomerated hydrates (AAs). As a result it is often necessary to implement alternative management strategies for unplanned shut-down scenarios. Further, LDHIs are tailored chemicals, which are both expensive and often present a significant environmental hazard in the event of a release to the marine environment. As a result, use of LDHIs for hydrate management at the Leviathan Field is not considered preferential to the use of continuous MEG injection.

The alternative to hydrate inhibition through chemical injection is to maintain the fluid temperature above the hydrate formation temperature throughout the subsea system. This is not feasible with insulation alone due to the length of the subsea production system at the Leviathan Field. Electrically heated systems are not considered field proven at either the project water depth or tie-back distance. As a result, a chemical injection scheme is the only feasible hydrate management solution for the Leviathan Field.

Due to its proven record in industry, minimal environmental footprint, and lack of viable alternatives, use of continuous MEG injection for hydrate management is the preferred solution for the Leviathan Field development.

2.3.3 Entry into Territorial Waters

The selected corridor for transmission lines from the Leviathan Field to the nearshore LPP in the northern TAMA zone has been presented previously in Figure 2-1. This corridor has been surveyed in segments at varying times during previous phases of the Tamar and Leviathan projects. Additional survey work (side scan sonar) to confirm seabed features in areas that have not been sufficiently surveyed previously are anticipated to be completed during summer 2016.

During the previous phase of the Leviathan project a number of routes were assessed for gas export from a deepwater hub to the northern TAMA zone. Assessment included Autonomous Underwater Vehicle (AUV) surveys designed to detect geological and shallow hazards. This work identified an acceptable pipeline route from the location of the potential deepwater hub to the southwestern boundary of the northern TAMA zone. The eastern portion of the pipeline route from a deepwater hub may be considered as an alternative route into the northern TAMA block for future developments. This enters Israeli Territorial Waters approximately 4.5 km south of the Leviathan corridor, and joins the corridor approximately 40 km west of Israeli Territorial Waters in 1,400 m of water. The identified alternative route is shown in Figure 2-4 (in black) and overlain on the Leviathan transmission corridor route for reference

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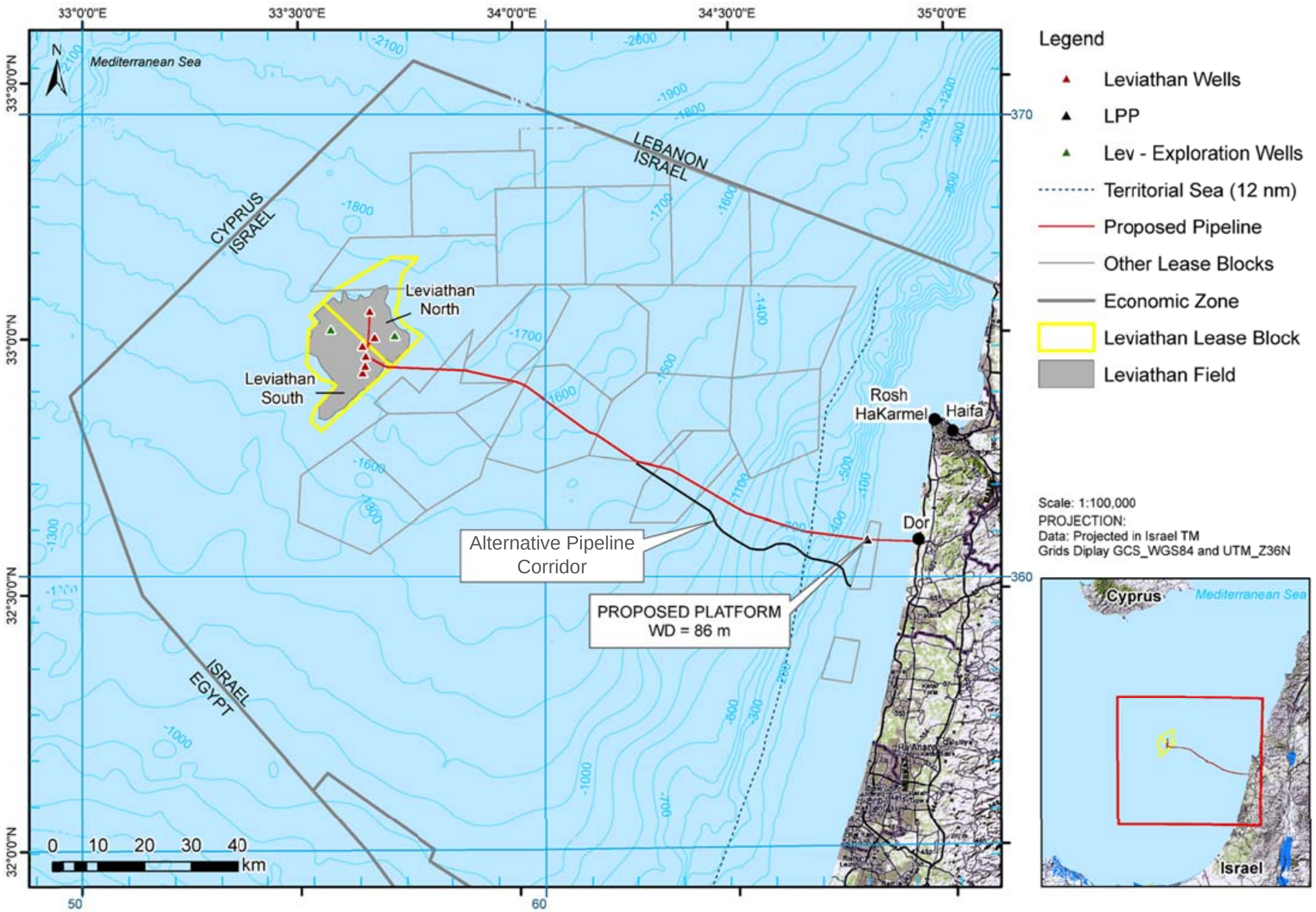
Figure 2-4: Alternative Pipeline Entry Point into TAMA Block



2.3.4 Alternatives Summary

The following table presents a summary of the alternatives presented in this chapter.

Table 2-1: Summary of Alternatives – Production EIA

Subject	Proposed Action	Alternatives Evaluated and Ratings	Reference
Location Alternatives			
LPP Location	The LPP is proposed to be located in the northern TAMA block approximately 10 km from the coast of Dor. This location has been determined as part of the TAMA process and is considered fixed for the purpose of this assessment.	No alternatives are considered in this assessment.	Section 2.2
Wellhead Locations	Wellhead locations have been determined based on reservoir targets and the well design previously presented in the Leviathan Drilling EIA (Noble Energy Mediterranean Ltd., 2016a). Drilling is outwith the scope this assessment and wellhead locations are considered fixed.	No alternatives are considered in this assessment	Section 2.2.1
Flowline Routing	Flowlines connecting the subsea wellheads to the Infield Gathering Manifold will be routed by the most direct route where practicable to minimize overall length and the associated impacts.	No credible alternatives to the proposed flowline routings have been determined associated with this assessment.	Section 2.2.1
Infield Gathering Manifold Location	The Infield Gathering Manifold is a critical item of the subsea production system. The selected location is central amongst the initial development wells and provides a balance between infield flowline and transmission pipeline lengths.	**Located East of Channel D – Rating: Less Acceptable.** Moving the Infield Gathering Manifold to the east of channel D would remove the requirement for the transmission pipelines to cross the channel; however, infield flowlines would have to cross it instead. This provides no clear benefit and would increase infield flowline length. **Relocated North / South or West – Rating: No Benefit.** Relocating the Infield Gathering Manifold either north, south, or west of its current location is not considered to present any significant environmental benefit. Any reduction in individual flowline lengths achieved would be offset by increases in length of other flowlines or the transmission lines.	Section 2.2.2

Subject	Proposed Action	Alternatives Evaluated and Ratings	Reference
Transmission Pipeline Route	The transmission pipelines will be routed to minimize overall length, while avoiding unnecessary seabed hazards where possible. The selected route will cross three (3) major deepwater channels and the Tamar production system.	**Routed North of Tamar Field – Rating: Less Acceptable.** The only significant seabed feature between the Leviathan Field and the proposed LPP that can be avoided by a credible pipeline re-routing is the crossing of the Tamar production infrastructure. This would remove the requirement for an engineered crossing of the existing pipelines and umbilical. However, such a rerouting would add approximately 17.5 km to each transmission line (15%) and would necessitate crossing the MED Nautilus fiber optic cable system as well. The incremental pipe length and cable crossing are considered to outweigh the benefit of not crossing the Tamar production system.	Section 2.2.3

Subject	Proposed Action	Alternatives Evaluated and Ratings	Reference
Technology Alternatives – Infield Infrastructure			
Infield Flowline Construction	The infield flowlines will be of rigid construction in carbon steel.	**Flexible Pipe for Infield Flowlines – Rating: Less Acceptable** Flexible flowlines were considered, but diameter restrictions associated with water depth and operating pressure, limit the number of qualified manufacturers. Since there are no environmental benefits associated with flexible flowlines, rigid flowlines are preferred. .	Section 2.3.1.1
Infield Gathering Manifold	The subsea configuration for the Leviathan development will be centered on a single six (6) slot Infield Gathering Manifold with three (3) production headers. Flowlines will tie each drill center (five (5)) back to the Infield Gathering Manifold. Cross connections and valving will be supplied within the manifold such that any of the six (6) slots may be routed to any of three (3) production headers as operations require. This presents significant operational flexibility and robustness to future system expansion.	**Tie-in Manifold/Structure per Production Pipeline – Rating Less Acceptable** Use of a dedicated manifold or tie-in structure per production pipeline (two (2) by DSM and one (1) by REM) have been considered. However, such a configuration would substantially reduce operational flexibility and the capacity of the system to manage wells depleting at varying rates. This configuration is not considered to offer any environmental benefit compared to the selected configuration. **Daisy Chain Architecture – Rating Less Acceptable** Use of a daisy chain subsea configuration where wells are tied into specific production pipeline has been considered as an alternative to an Infield Gathering Manifold. However, such a configuration presents significant operational restrictions similar to those associated with using a dedicated Tie-in Manifold per pipeline.. There is no clear environmental benefit to a daisy chain architecture.	Section 2.3.1.2
Jumpers	Tie-ins between infield infrastructure and their associated flowlines will be made with jumpers of a rigid construction in carbon steel.	**Flexible Pipe Tie-ins – Rating: Less Acceptable** Flexible jumpers were considered, but diameter restrictions associated with the water depth and operating pressure limit the number of qualified manufacturers. This does not offer environmental benefit to the project; therefore, rigid steel jumpers are the selected jumper type for the Leviathan Field development.	Section 2.3.1.3

Subject	Proposed Action	Alternatives Evaluated and Ratings	Reference
MEG Supply (Infield)	MEG will be distributed from the infield MEG SDU to the relevant infield infrastructures by way of dedicated tubes within the infield umbilicals. Spare cores will be allowed for in the umbilicals to provide redundancy to the production critical MEG system.	**Dedicated Infield MEG flowlines – Rating: Less Acceptable** Dedicated infield MEG flowlines (standalone) from the MEG SDU to the relevant infrastructures were considered; however, this would increase seabed land take by virtue of the presence of additional infield flowlines. Further, in order to maintain redundancy in the MEG supply system dual MEG flowlines would be required between the MEG SDU and each relevant infield infrastructure. This would further increase land take.	Section 2.3.1.4

Subject	Proposed Action	Alternatives Evaluated and Ratings	Reference
Technology Alternatives – Transmission Infrastructure			
Production Pipeline Configuration	The production pipeline configuration will be 2x 18” DSM pipelines and 1x 20” REM pipeline. This configuration is preferred as it offers increased operational flexibility, while retaining segregated flow to the REM thus isolating it from the impact of domestic demand swings.	**Fewer Production Pipelines – Rating: Less Acceptable** Reducing the number of production pipelines from three (3) to two (2) is not preferred as this will result either in comingled REM/DSM production, or use of a single transmission line for DSM purposes. Both options will reduce operational flexibility and the capacity of the system to respond to demand swings in the Israeli domestic gas market. **More Production Pipelines – Rating: Less Acceptable** Increasing the number of production pipelines will result in increased project CAPEX and environmental footprint with no significant benefit identified. As such, this is not a preferred alternative.	Section 2.3.2.1
MEG Supply Lines	Dual 6” MEG supply lines will be utilized to supply MEG from the LPP to the infield MEG SDU. This configuration offers redundancy (2 x 100%) in this production critical system. MEG supply lines may be laid either in a piggyback configuration on the 18” DSM production pipelines, or as standalone lines within the transmission corridor. Final decision on installation will be made following contract award.	**Fewer MEG supply lines – Rating: Less Acceptable** Use of a single MEG line is less acceptable to the project as although it may reduce environmental impact it will remove redundancy in this production critical element of the system. If a single supply line were utilized a blockage or rupture of the line would result in a full field shutdown until the situation could be resolved, thus impacting production availability and Israeli energy security. .	Section 2.3.2.2

Subject	Proposed Action	Alternatives Evaluated and Ratings	Reference
Materials of Construction	All production and MEG pipelines, and infield production lines will be constructed from carbon steel. Corrosion protection from trace levels of reservoir impurities will be by corrosion inhibitor injection. External corrosion protection will be through the application of an external corrosion resistant coating with sacrificial anodes in place for added protection.	**Alternative Pipeline Material (CRA) – Rating: Less Acceptable** Use of CRA for pipeline construction would remove the requirement for corrosion inhibitor injection at the subsea wellheads. This would reduce operational use of chemicals and presents a minor environmental benefit due to reduction in subsea chemical inventory. However, the subsea corrosion inhibitor injection system will be a closed loop system with no normal discharge to the environment and as such the environmental benefit associated with a CRA solution is considered negligible. While the selection of CRA may be beneficial through the removal of the requirement of corrosion inhibitor injection, this is not considered to be BAT due to the negative economic impact of utilizing CRA. Selection of carbon steel with corrosion inhibitor injection in preference to CRA is common practice throughout the offshore oil and gas industry.	Section 2.3.2.3
Controls System – Controls Configuration	A multiplexed, electrohydraulic controls system will be utilized to provide controls and chemicals to the infield infrastructure from the LPP. This will enable monitoring and actuation of subsea valves via a single primary umbilical that is within installation and logistical constraints.	**Alternative Hydraulic Controls Configuration – Rating: Not Acceptable.** Non-multipexed hydraulic/electrohydraulic controls systems are not appropriate for the Leviathan development due to the complexity of the subsea production system. This would result in an unacceptably large primary umbilical. **All Electric Control System – Rating: Not Acceptable.** An all-electric controls system is potentially advantageous due to the removal of hydraulic fluid and the associated environmental discharges arising with an open loop system. However, this technology is not field proven and thus presents an unacceptable technology risk to the project.	Section 2.3.2.4

Subject	Proposed Action	Alternatives Evaluated and Ratings	Reference
Controls System – Umbilical Sparing	A single primary umbilical will run from the LPP to the infield controls SDU. Redundancy will be built into this umbilical by way of core sparing. The umbilical as a whole shall be designed and constructed to resist environmental impacts and loads.	**Dual Primary Umbilicals – Rating Less Acceptable** Dual umbilicals were considered by the project in order to increase controls availability by increasing redundancy. However, use of dual umbilicals would increase the seabed land take associated with the controls system rendering it less attractive from an environmental standpoint. Further, the provision of spare cores in a single primary umbilical (as selected) is considered to offer sufficient redundancy that provision of an additional umbilical is not necessary.	Section 2.3.2.4
Controls System – Open versus Closed Loop System	An open loop controls system will be utilized on the Leviathan Field development due to benefits associated with reduced umbilical cores and increased valve response associated with this design. This will generate intermittent discharges of hydraulic fluid when valves move to the fail-safe positions, these are considered to be diminutive, water-based, and with minimal environmental impact.	**Closed Loop Multiplexed System – Rating: Less Acceptable.** A closed loop controls system is technically feasible for the Leviathan development. However, implementation of a closed loop system will result in decreased valve response as a result of backpressure in the return line. Inclusion of a return line in the umbilical will also increase overall umbilical diameter (and associated land take) and increase project CAPEX. Further, the implementation of a closed loop system at the project water depth and step-out distance may raise the potential for the system to fail to respond adequately in an emergency scenario where valves are required to fail closed. The above concerns are considered to outweigh any minor environmental benefit of removing intermittent low volume water based hydraulic discharges.	Section 2.3.2.4

Subject	Proposed Action	Alternatives Evaluated and Ratings	Reference
Hydrate Inhibition	The selected hydrate management strategy for the Leviathan Field development is continuous thermal hydrate inhibition through MEG injection at the subsea wellheads.	**Continuous Methanol Injection – Rating: Less Acceptable** Methanol is a THI which is applied in the same way as MEG. For the Leviathan development, it does not offer any benefit with regards to reduced subsea infrastructure or significantly reduced dosage rates. Methanol is less favored than MEG due to its increased volatility and potential challenges associated with carryover into the gas processing system. **Continuous LDHI Injection – Rating: Less Acceptable** Use of LDHIs would offer decreased chemical injection rates during normal operation, thus potentially reducing power consumption on the LPP and the subsea distribution infrastructure. However, lack of analogues projects where LDHIs have been applied, increased purchase costs (as OPEX), and the potential for environmental harm as a result of an unintended release of these chemicals renders them less attractive than the commonly applied MEG solution. **Temperature Maintenance – Rating: Not Acceptable** Use of a thermal solution for the prevention of hydrates in the Leviathan production system is not considered feasible due to the length of the tie-back and the depth at the infield location. An insulation only solution will not provide sufficient heat retention during normal operations, while electrical pipe heating technologies are not field proven at these depths or tie-back lengths.	Section 2.3.2.4

Alternatives – Entry into Territorial Waters		
Future Entry in to Northern TAMA Block	The selected route for the transmission pipelines from the Infield Gathering Manifold to the LPP utilizes an entry point into the Northern TAMA zone that is approximately due west of the LPP location. This route enters Israeli Territorial Waters at a location that is west north west of the LPP location. An alternative pipeline route into the Northern TAMA zone has been identified based on work performed during previous phases of study on the Leviathan development. This route enters into the southern end of the northern TAMA block, having entered Israeli Territorial Waters approximately 5 km south of the selected entry point for the Leviathan development. From Israeli Territorial Waters, this route runs a broadly north west direction for approximately 40 km where at it meets the selected pipeline route for the proposed Leviathan development.	Section 2.3.3