APPENDIX I PIPELINE CONSTRUCTION

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Appendix I

PIPELINE CONSTRUCTION

1.1 GENERAL

This section describes the main activities and processes involved in constructing a large diameter onshore pipeline.

1.2 PRINCIPLES OF PIPELINE CONSTRUCTION

A pipeline can be broken down into three basic elements where different forms of pipeline construction method are used. They are:

(i) open cross-country areas, where the spread technique is used
(ii) crossings, where specialist crews and civil engineering techniques are used
(iii) special sections such as built up urban areas, restricted working areas, difficult terrain sections and environmentally sensitive areas

1.3 SPREAD TECHNIQUE AS USED IN OPEN CROSS-COUNTRY AREAS

The basic method of constructing steel, welded oil and gas onshore pipelines in open cross-country areas is generally known as the spread technique. The spread technique utilises the principles of the production line system, but in the case of a pipeline the product (the pipeline) is static and the individual work force, (crews) move along the pipeline track (right-of-way/spread). The implementation of the spread technique is conditional on the pipeline being welded above ground in maximum possible continuous lengths between obstructions/crossings (which can extend to lengths in excess of 10 kilometres). These welded pipe lengths are then immediately installed into unsupported/unobstructed trenches gradually in one continuous length utilising multiple (three or more) mobile lifting tractors (side-booms) in unison.

The breaks in the continuous main spread method of working result from the location of existing services, roads, railways, tracks, ditches, streams and river crossings, and are also dependent upon restricted working, time constraints and physical features/obstructions. These breaks in the main pipeline spread activities are undertaken by dedicated specialist crews utilising a variety of special construction techniques and are generally undertaken after the main pipeline sections have been installed.

The main pipeline spread installation is undertaken by dedicated crews undertaking one operation at a time commencing at one end of the pipeline and travelling forward to the other end at anything from 500m to 1,500m per day depending on the diameter of the pipe, terrain, soils, etc. There are a total of some 40 separate operations carried out in 7 main activity groups, as described in Sections 1.5.1 to 1.5.7 inclusive. The programme of activities and the start-up of the crews is dependent on available resources and the risk of one crew having an impact upon the following activities.

Because a pipeline is a production line, it is essential that the time periods between crews is such that there is no risk of one crew causing stoppage or disruption on the preceding or
subsequent crew. If the float between crews is not managed on a continuous basis, with the emphasis placed on the daily moving, then a concertina effect will result with substantial disruption and standby costs. Effectively, there can be up to a 4-week delay between crews to ensure that the concertina bunching effect of crews does not occur. Consequently, there are in the programme extended periods of time when there are no activities taking place along large sections of the pipeline route. The average time from start of ROW to commencement of land reinstatement is, typically, in the order of 10 to 15 weeks.

1.4 PRE-CONSTRUCTION ACTIVITIES

Pre-construction activities need to be carried out by the Installation Contractor prior to the start of the main pipeline installation activities. These activities include finalising the pipeline route, detailed design finalisation, mobilisation, notification of entry to landowners, setting-up of pipe yards and base camps, establishing temporary works requirements, setting-up of geographic positioning stations, design of land drainage in agricultural areas and reinstatement works, construction of temporary access roads, pre-environmental mitigation works, and agreeing with landowners any special requirements prior to entry onto their properties.

The Installation Contractor will carry out pre-entry surveys as-and-where required so as to record the condition of the land prior to the start of any work.

1.5 MAIN PIPELINE CONSTRUCTION ACTIVITIES

Once the pre-construction activities have been completed, then the main construction works can commence. Generally, operations are carried out in seven main activities groups, as described in the following sections:

1.5.1 Construction Activity Group 1 – Preparing Work Area
1.5.2 Construction Activity Group 2 – Layout Pipe and Weld above Ground
1.5.3 Construction Activity Group 3 – Excavate Trench and Installation of Pipe
1.5.4 Construction Activity Group 4 – Pipeline Crossings, Special Sections and Tie-Ins
1.5.5 Construction Activity Group 5 – Final Backfill and Reinstatement Works
1.5.6 Construction Activity Group 6 – Facilities and Pipeline Control
1.5.7 Construction Activity Group 7 – Testing and Commissioning

General details are shown in Figures 1 to 8.

1.5.1 Construction Activity Group 1 – preparing work area

The pipeline operations consist of:

1. Setting-out

The setting-out crews are the first personnel from the construction contractor’s workforce to enter the site to commence the main construction activities. The setting out of the works should be scheduled to commence at least four weeks prior to the remainder of the construction activity group 1 activities. This work will be carried out with small four man crews using GPS and surveying instruments. Setting-out pegs will be placed at all boundaries, changes in direction and intermediate sightings on the proposed centre line and the extremities of the working easement.
In areas of open country where good and level access is available along the pipeline route and it is anticipated the rock or ground is of sufficient strength that it could impede progress of the trench excavation, then initial ground investigations works will be carried out directly behind the setting-out crew.

Part of the setting-out crew’s duties is to identify any existing services that cross or are in close proximity to the pipeline and supervise the trial hole crew. The trial hole crew will hand excavate to expose, identify and determine the exact location of all existing services. This data will be recorded and transferred to the engineers for incorporation into the final pipeline design.

2. Advanced archaeology major works

This applies to locations where there are substantial/concentrated archaeology remains, which could involve extensive excavations. Provided access is available or requires minimal work along the ROW from an established entry point, a separate advanced ROW and topsoil/top cover crew will be mobilised to enable the archaeology works to commence in advance of the mainline and be completed before front-end crews pass. The topsoil/top cover at archaeology locations will be stripped by back-actors to avoid any disturbance to the stripped subsoil.

3. Right of Way/easement boundary demarcation – secondary ground investigation option 1

This will commence after the setting-out. A crew of personnel and equipment comprising mainly large heavy tracked plant will form the right of way access onto the land. The operations will include the removal of all hedging for disposal off site, bridge or flume pipe access across field ditches, protection of existing services by protection mattresses, re-grading of existing ground contours to assist access, the erection of goalpost and safety signs at overhead electric power lines and telecommunication cables, the placement of hard standings as required for car parking and the blasting/removal and re-grading of rock areas or outcrops to provide a level and safe excavation line/running track along the entire pipeline route.

Additional crews will be provided to install offsite ROW accesses along the pipeline route to enable the ROW crew to gain access to the working areas, where access from the public road is not available or would cause a safety risk, or as a result of locked out locations or environmental concerns. Agreement with the landowners involved in any offsite access must be finalised prior to pipeline commencement.

Where temporary ROW fencing is required then additional crews will be required to erect this fencing to delineate the working area.

During the ROW and fencing operation it will be possible to undertake ground investigation works by the excavation of trial pits at 100 metre intervals to determine actual ground substrata, trench stability, ground water levels and seepage. These investigations, however, can only take place at this time on open areas where restrictions due to land use (agricultural) and environment do not exist.

4. Pre-construction terrain and ground stability (excluding dewatering)

At locations where there is a risk of ground movement that could result in safety risks to the construction activities and/or undermine the pipe during installation and the period prior to final
reinstatement then permanent stability of the affected terrain needs to be undertaken. This work can be separated into two elements:

- Removal of material such as the overburden at the top of ravines and the removal of loose material that could move during the installation works
- Addition of material such as Bentonite, which is injected under pressure into gravels with high and fast water tables and deep mining areas to provide a protective curtain around the pipe. It also includes the adding (placement) of boulders/ground at the toe of steep gradients on forwarded and side slopes in the second element

5. Trench excavation in rock areas

In areas where rock is confirmed as such by the initial ground investigation works then the trench is excavated ahead of any pipe operations. This sequence of working is undertaken to ensure that the excavation of the trench cannot cause any damage to the pipe and/or pipe coating and provide an extended safe working width for the excavation crews allowing double-sided trench working by excavators/ breakers.

Following the review of the data from the initial ripper and trial hole surveys, the ground will be classified in ease of excavation into five groups defined by the method of removal. These are (i) utilising standard excavation, (ii) larger more powerful excavators (face shovels converted to back-actors), (iii) ripping/hydraulic hammer and excavation, (iv) blasting/hydraulic hammer and excavation and (v) rock trenchers (saw and blade). The finished trench should be to the correct depth and width to suite the pipe diameter, plus any bedding and pipe cover. The trench should also be in a straight line so that the pipe can lay central in the trench without coming into contact with the trench sides. All loose and jagged outcrops, which could come in contact with the pipe during lay operations, will be removed.

The excavation will commence with dedicated crews immediately following the ROW operation. The forward progress will be dependent upon the ground strength, grain structure, terrain, access, method of removal and number of crews/equipment employed.

6. Pre-construction cut-off drains

All cut-off drainage works, which comprise the connection of existing drains to a new header pipe, will commence immediately after the right of way and fencing operations.

Cut-off drainage works will be undertaken at locations where there are existing concentrated drainage schemes on agricultural land and where agreement is reached with the landowners and/or occupiers to their installation. This work will be resourced taking account of the scope of work and the requirement to achieve pipeline installation progress of, say, 500 to 1,500 metres per day along the pipeline route.

7. Topsoil strip -secondary ground investigation Option 2

Topsoil strip operations commences after cut-off drainage operations and is scheduled to allow adequate time for completion of the drainage works in the event that unforeseen obstacles or circumstances are highlighted during the execution of the drainage installation operations.

The topsoil operation consists of 1 crew with plant comprising up to 8 excavators/ bulldozers removing the topsoil to its full depth (typically, ≤ 300mm) and storing in a single stack on the
opposite side of the easement to the trench excavation material. The topsoil is stripped with 2 to 3 excavators along the easement boundary on the opposite side to the topsoil stack area. This provides a subsoil interface/cutting edge for the dozers to work from in pushing the topsoil across the easement.

In areas where topsoil removal is required then the ground investigation works are undertaken following the removal of the topsoil as this avoids any risk of topsoil contamination with the subsoil. The investigation works are as those detailed in the ROW section and comprise the excavation of trial pits at 100 metre centres to determine actual ground sub-strata, trench stability, ground water levels and seepage.

### 1.5.2 Construction Activity Group 2 – layout pipe and weld above ground

The pipeline operations consist of:

1. **Project mechanical procedures/testing of welders**

   Prior to the start of any mechanical works the Contractor will issue for Client approval a full set of mechanical procedures for bending, welding, x-ray and coating. These procedures will address how the Contractor intends to undertake the work in accordance with the project specifications detailing equipment and specific mandatory requirements. The procedures, particularly with regard to welding and x-ray will be sufficient to cover the full ranges of the various parameters characteristic of the project in terms of diameter, wall thickness and technique. Once the documented procedures are approved then full trials for each element of the works will be carried out, fully inspected and witnessed by the Client. The welding will include non-and full destructive testing to ensure that the procedure welds are undertaken in strict compliance with the contract requirements and fully comply with the minimum strength, hardness and quality requirements of the relevant specifications.

   Once the procedures have been approved then the welders will be tested to ensure that they can comply with the requirements of the procedure welds. A register will be maintained of the welders employed on the project with the various welding techniques they are approved to work on.

2. **Double-jointing**

   Double-jointing of the single approximately 12 metre long pipes into 24 metre lengths will, if considered economically viable by the project, be carried out in the pipe yards prior to pipeline stringing. Double-jointing permits the doubling of the welding progress with the same basic welding resources or allows the same production with a much smaller crew.

   In considering double-joints due consideration needs to be given to the use of specialist pipe bogies for the moving of the 24 metre pipes, the capability of the local road system to accommodate the vehicles and the requirement for special road movement permits. The double-jointing can be placed on the easement but this results in additional cost due to double handling of the pipe and the need to continually move the double joint equipment, which can offset any savings from increased welding production.
3. Pipe stringing

The pipes and pre-formed bends will be scheduled to be delivered to, and stock piled at, the proposed pipeline pipe yards some 4 to 8 weeks in advance of stringing operations. The pipe supply should ensure that the various grades, wall thicknesses and coatings are supplied in sufficient and correct quantities to meet the programme.

Immediately following ROW or topsoil strip or excavation in rock areas, the pipe stringing operations will commence, which involves laying the pipe lengths along the easement length using pipe trailers. A typical crew will consist of two cranes - one at the base camp loading the pipe trailers and the other on the pipeline easement off-loading the pipe trailers.

In the event that ground conditions do not permit travel down the easement with standard or special heavy-duty pipe trailers then the pipes will be loaded on to tracked pipe carriers at the public roads or at a point where the change in ground conditions occurs and permits the turning of the wheeled pipe trailers.

4. Forming field bends (cold bending)

Once the pipe has been strung along the easement, engineers will follow to determine the location of all bends required in order that the pipeline can follow the contours of the land and the required line and level as detailed on the drawings. There are two types of bends normally used ie hot pre-formed or forged bends which are manufactured off site in a factory and are to a radius of 5 or 3 times the pipe diameter and cold bends which are to a radius of 40 times the pipe diameter and are formed in the field.

A typical cold bending crew consists of a four-man team together with a bending machine and a side boom tractor. The bending machine is towed along the pipeline route by the side boom and includes “formers” consisting of 20 – 150 ton hydraulic rams, which bend the pipe to the required radius and angle. The side boom acts as a lifting device and has a fixed jib attached to a tracked dozer with a capability of lifting between 15 to 120 tons, dependent upon the size of the machine used.

The number of cold bends required depends on the route and contours of the pipeline. Typically, they can range from 1 pipe in 10 in developed regions to 1 pipe in 50 in open country. The cold bend angle that can be achieved ranges from maximum angles of 12 degrees (42” pipe) to 40 degrees (12” pipe).

5. Welding of the linepipe

The welding of the pipeline will commence a few days after the cold bending crew. The welding crew will weld the pipeline in continuous lengths between features such as roads, watercourses, tracks, railways, services and other underground obstacles that prevent the linepipe being continuously installed in the trench.

There are primarily two methods of welding which are manual or automatic. As the names imply manual welding involves the welding of the pipe by welders and automatic involves a semi-automatic system. At present, and with the correct welding experience, there is no substantial difference in quality or production.
Automatic welding is used primarily for three main reasons:

- Ensure welding quality
- Increase/sustain a high daily production rate
- Reduce the overall manpower requirements

Manual welding is used where:

- A supply of experienced welders is readily available
- Difficult terrain, weather and site conditions exist
- Special sections and areas with a high percentage of tie-ins
- High production rates cannot be achieved

Both systems generally (although certain automatic systems can now do single pass complete welds) operate on a front-end/back-end principle. The front-end consists in a manual operation with, say, 3 separate welding stations placed on CAT D6 carriage consisting of a HIAB for the welding shelter (used in inclement weather or windy conditions), 4 welding bullets and a compressor. The welding stations work on 3 separate joints and complete one pass before moving on with the sequence being the bead (2 - 4 welders), immediately followed by the hot pass (2 – 3 welders) and then hot fill (2 welders). With the automatic process, 1 machine deposits sufficient weld metal equivalent to the 3 manual passes. The weld is allowed to cool after the front-end passes and then sufficient welders working in pairs or multiple automatic machines follow on to fill and cap that day’s production.

The crew will achieve progress in the order of one weld approximately every 3 to 5 minutes or up to 90 to 150 welds per day, which is equivalent to 1,000 to 1,500 metres of linepipe on 12 metre pipes and up to twice that if double-jointed pipes are used.

6. Welding of fabrication pipework

As the mainline welding crew is set up for speed and any reduction in the speed will increase costs and could cause delays to following operations then any fabrications or pipework involving bends or difficult set-ups or welds that require more than the bead before lowering off (creating cracks) will be left out. These fabrications are welded together by a small dedicated crew who complete these welds prior to the field joint coating crew.

7. NDT inspection

All welds on the pipeline are generally subjected to inspection by radiography. This is achieved on the main pipeline by an internal x-ray tube travelling along the inside of the pipe carrying out x-rays at each weld for approximately 2 minutes per weld. On completion of the x-ray the film is taken to a dark room and processed in time for the results to be available for inspection at the end of the day or early the next day. Welds, which do not meet the required acceptance criteria, are either repaired or cut out and re-welded.

Experienced and qualified x-ray specialists undertake the radiography under controlled conditions. Before the operation is started, the section of pipeline is cordoned off by marker tape to stop entry by non x-ray personnel and audio/flashing warning alarms are activated during all times when the x-ray tube is energised. The x-ray personnel are on constant surveillance to ensure that the workforce and members of the public are aware of the x-ray activities and only authorised access is permitted.
Welds completed by semi-automatic welding processes are examined using automatic ultrasonic testing (AUT) techniques. This consists of an assembly that traverses the circumference of each completed weld in order to detect any defects. The results of each ultrasonically inspected weld are automatically recorded and are used to determine whether a weld repair is required and if so what type.

8. **Weld rectification (repairs)**

A weld rectification (repair) crew follows immediately behind the NDT inspection activities to either carry out repairs to or cut out any defective weld. On completion of all repairs a further x-ray is carried out on the weld to ensure that the finished weld conforms to the standard required. The x-ray of repair welds is usually carried out from the outside of the weld by a two-man crew.

9. **Field joint coating**

The coating of the pipeline field joints to prevent corrosion starts a few days after the welding. This extended period is to allow for any repairs or cut-outs to be completed without prejudicing the coating crew’s operations.

### 1.5.3 Construction Activity Group 3 – excavate trench and installation of pipe

The pipeline activities consist of:

1. **Trench excavation**

   In areas other than rock, trench excavation commences a few days after the field joint coating operation. A typical trench excavation crew consists of 5 - 8 excavators working in line. This operation only excavates the length of open cut trench sufficient to install the main line welded pipe; it does not excavate any roads, ditches, services or obstacles. The number of excavators employed will be such that the amount of trench excavated in a single day matches the rate of progress of the welding crew. The spoil from the trench will be stored adjacent to the trench on the opposite side of the ROW from the topsoil stack.

   The finished trench will be to the correct depth and width to suit the pipe diameter, plus any bedding and pipe cover. As far as possible, the trench should also be in a straight line so that the pipe can lay central in the trench without touching the trench sides. All loose and jagged outcrops, which could come into contact with the pipe during laying operations, will be removed.

2. **Trench excavation archaeology watching brief**

   As part of normal good practice an archaeologist will be present during the main trench excavation undertaking a watching brief of the material being excavated. The archaeologist will have the authority (subject to safety constraints) to stop the trenching works if he considers the excavation has encountered a major archaeological find.

3. **Finalise drainage design**

   In agricultural land, the Contractor will record the existing drainage system actually intercepted by the pipeline. The information will be reviewed taking account of the intended proposals and
any final amendments to the system finalised at this stage following discussion with the Owners or Occupiers.

4. Pipe installation (lower and lay) – above ground tie-in sections

The linepipe will be positioned approximately 5 metres from the trench centre-line and will be installed into the open unobstructed trench utilising a number of side-booms. This operation will usually be carried out immediately following the excavation crew.

As the linepipe is being installed a coating crew will be present who will holiday detect the pipe to detect any damage to the pipe coating just prior to the pipe entering the trench. Any holidays (damage) detected will be repaired by a fast setting repair coating.

In areas of rock, the pipe installation will commence anything from 5 to 15 days after the welding crew.

If there are any above ground breaks in the mainline due to access openings across the ROW, expansion breaks or bend breaks, then these will be welded above ground, x-rayed and coated during the excavation and lowered-in as part of the mainline lower & lay operation. This will optimise the use of the side-booms within the lower & lay crew and reduce the number of below ground tie-ins.

5. Cross trench drainage connections

In agricultural land, the permanent reinstatement of the existing land drains to be replaced across the pipeline trench is carried out prior to the trench backfill operations. The replacement drains extend for a short distance into undisturbed ground.

On completion of inspection of the reinstatement works, the trench is backfilled and compacted in layers to the underside of the drain. This work is only undertaken in extreme locations to supplement the main pre- and post-drainage schemes.

6. Installation of permanent cathodic protection system test posts

Either as part of the fabrication welding crew activities (if the location of the CP test posts are known) or as the pipe is being installed Cathodic Protection lugs are welded to the pipe. These lugs which can be 50mm square plate are welded on the pipeline using low hydrogen welding rods where test posts will be installed to check the ground/pipe to soil potential. The test posts are placed at about 1km distances along the pipeline and located at fixed boundaries such as road crossings or other locations, which have relatively easy access. Cables are attached to the lugs the whole area coated, checked for holidays and the cables brought to ground level during backfilling and left. During the reinstatement activities the Cathodic Protection test posts are installed with the cable running up through a duct in the test post and tied off. The test post is then concreted into the ground directly above the pipeline.

7. Temporary cathodic protection system

As the pipeline may be buried for the full construction period before the permanent Impressed Current Cathodic Protection (CP) System is activated, then some form of temporary system needs to be installed prior to the backfilling of the pipe. The temporary system, typically,
comprises a number of zinc anodes attached to the pipeline at regular intervals. These are buried parallel to and at a distance of, say, 3 metres from the pipe.

8. Backfill of the pipeline trench

Trench backfill starts immediately following the placement of the linepipe in the trench and the undertaking of a survey of the pipe levels by the engineers to confirm that the required pipe cover has been achieved. There is a requirement that the initial backfill around the pipe and to 300mm above the crown be of loose and relatively fine particles, which can be readily compacted and do not damage the pipe coating. In areas of rock it will be necessary to place the pipe on a 150mm bed of similar material. In order to provide this material it may be necessary to import sand/soft material offsite, sieve the excavated material or crush the excavated material. The sieve and crusher equipment will be portable machines, which will be transported along the pipeline ROW.

The pipe is backfilled over the entire length except for, say, 30 metres at each end of the pipeline work section, which is left free to facilitate the tie-in to the crossing/line break pipe work.

1.5.4 Construction Activity Group 4 – pipeline crossings, special sections and tie-ins

The pipeline operations consist of:

1. Crossings

The crossings are carried out by a number of different and dedicated crews simultaneous with the main trench excavation works and final tie-in to the main pipe installation being carried out by subsequent tie-in crews following completion of the crossings and main pipeline installation works. The crossings are undertaken by two distinct methods of construction consisting of either:

- Open cut
- No dig technique

There are various options to the two methods of working and the actual method employed at any given location will be dependent upon the ground conditions, pipe diameter, local environment, third party restrictions and the type of obstruction being crossed.

The extent of a crossing in design terms is normally defined from fixed locations, which extends either side of the crossing land take or boundary fencing. However, the length of a crossing in terms of construction includes the crossing plus any temporary works to facilitate the installation, the swan neck offsets to bring the pipe back to normal cover and the tie-in pipes to connect the crossing to the mainline.

A key aspect in the determination of the method of construction that will be used at any crossing will be the requirements of the regulatory authority/owner that has jurisdiction over the crossing. Part of the approval process with the regulating authority will be the issue of detailed plans and calculations of the design, which will be supported by fully detailed construction method statements.
Details of the various crossing methods are described herewith and are taken in the order of ease of construction and cost.

**Open cut**

Open cut is generally by far the most cost effective way of crossing obstacles that cause breaks in the mainline and is undertaken by crossing the obstruction by means of an open excavation. The trench excavation at the obstruction, whether it be a ditch, a road, a railway, a river, or a service is excavated for the full length of the crossing prior to the installation of the pipe. Accordingly, in order to minimise the time for which the crossing trench is open, the welding, NDT inspection and field joint coating of the section of pipe required for the crossing is completed in advance of excavating the trench. An open cut crossing can very often be installed in one working day and the road or ditch temporary reinstated sufficiently to fulfil the function for which it is required prior to the crew-leaving site for the day.

**No-dig technique**

At locations where open cut methods are impractical or not permitted for whatever reason, then no-dig techniques have to be implemented. No-dig techniques can be classified into two main groups - sleeve or ‘bare’ line pipe. The actual method that will be used is determined by the ground conditions, third party restrictions, length of crossing, diameter, and design/safety requirements.

The different options available for no-dig techniques are described briefly below:

- **Auger Bore** is a term used to define a method where the pipe is supported by cranes/side-booms in a pit and a cutting head removes the spoil at the face, this is transported by flights down the pipe and is discharged into the pit through the auger machine which is positioned at the rear of the pipe being bored.

- **Thrust Bore** is a term used to define the installation of pipes by the manual excavation of the face with the pipe pushed forward from a thrust pit with hydraulic rams off a thrust wall at the back of the pit. Due to the risk of a potential face collapse upon the miners, the face has to be self-supporting. Accordingly, this method is used primarily in stable/hard ground conditions where the strata or strength precludes auger bore. As labour has to work at the face then the minimum pipe diameter normally considered is 36”.

There are two options with the thrust bore method of working:

- **Concrete Sleeve.** This method comprises the pre-installation of concrete sleeve pipes, which are typically 2.5 metres in length. Following installation of the concrete sleeve, linepipe in lowered into the thrust pit and pushed/pulled along the sleeve to a point where the next pipe can be lowered, welded, x-rayed, coated and then pushed/pulled along the sleeve.

- **‘Bare’ Linepipe.** This method comprises the installation of similar equipment to that for the concrete sleeve except that the linepipe is used for the thrust pipe rather than a concrete sleeve.

- **Tunnels** are not expected to be used on this project and, as such, are not discussed further.
• Horizontal Directional Drill (HDD) is a term used to define the method of installing a pipeline in long sections without taking entry onto the land. The method involves the welding of the pipeline into a continuous string above ground on one side of the crossing and pulling this string through a pre-drilled hole to the other side. The pipe will be welded, inspected, coated, tested and sitting on heavy-duty rollers prior to the drill operation commencing on site. Normally, a pre-installation hydrostatic test of, say, 4 hours duration, is carried out on the completed string to confirm the pipe integrity.

− The drilling machine will be positioned on the opposite side to the welded pipe string. The profile of the crossing will consist of five main elements - the entry angle, the radius of the sag bends, any side bend configuration, the exit angle and the intended reamer size. The accuracy of the drill can be maintained within a tolerance of 0.1% of the proposed profile at any point during the drilling process. The drill machine will be positioned at the drill entry point and at an angle from the horizontal of around 5 degrees for a 42” pipe)

− The drill will then commence with a 3 or 5-inch drill rod installed in 3 or 5 metre sections to drill a pilot hole along the proposed drill profile. The position of the drill head will be continually monitored via the on site computer system. Bentonite under pressure (20 bar) is forced out at the drill head to make a route through the ground, allow steering and to support the annulus walls. Once the pilot hole is complete further passes are then carried out with reamer heads which increase the hole size to around 150% of the pipe diameter to allow pipe installation

− On completion of the reaming the leading pipe of the weld string (to which a swivel pull head has been welded) is connected to the drill rods and the process of pulling the pipe into the annulus begins. During this operation the drill rods are removed as the pipe progresses forward towards the drill side. Ideally, the pipe pull is carried out in one continuous operation without any delays. When the pipe pull is complete the pipe coating integrity is checked by placing an electric current down the pipe to ensure that it is within the required limits and the equipment then removed from site with the Bentonite disposed of in an approved manner

2. Special sections

A special section is a term used to define any section of the pipeline that (i) cannot be undertaken by the spread technique, (ii) is a break in the mainline that does not conform to the definition of a crossing as described above, (iii) locations where time restrictions apply, (iv) environmentally sensitive areas where third party specific constraints apply, (v) restricted working, (vi) difficult directional drills or (vi) urban areas. By designating a section of the pipeline as a special section it highlights the fact that the section is more complicated than the mainline and will involve unique methods of working, generally low production and higher than average project costs.

There are four basic forms of construction methods that are used in special sections:

• Pull/Push Method of Construction is mainly used in unstable ground areas where the ground would not support the construction traffic and/or where the batter angle of repose of the excavated trench is below 25 degrees. The method involves installing the pipeline across an obstacle by welding the pipe which has concrete weight coating on heavy duty rollers in a continuous length and pulling the pipe with winches at one end, whilst at the same time side-booms/excavators push the weld string along the rollers into
a pre-dug flooded trench with tie-in between sections undertaken in fully supported (piles or boxes) pits

- **Mainlay Operation** which involves the installation of the pipeline in the trench one pipe (single or double-jointed) at a time. This method of pipe installation is used in locations of narrow ROW, unstable ground and/or urban areas and utilises a single, complete crew which carries out all operations including excavation, pipe installation, welding, NDT inspection, coating and backfilling. Mainlay techniques are used at locations where the spread method cannot be employed

- **Horizontal Directional Drill** – see above

- **Above Ground Pipework** is not expected to be used on this project and, as such, is not discussed further

3. **Tie-ins**

Tie-ins are the welds generally undertaken in the trench that connect two sections of pipeline together. Once the crossing/special sections and the main pipeline either side are installed, tie-in crews are then employed to tie the crossing and special sections to the main line. The tie-in crews consist of excavators to prepare the trench for entry by the welders, side-booms to lift and set up the pipe for welding, mobile welding crews, mobile NDT inspection crews and mobile coating crews.

### 1.5.5 Construction Activity Group 5 – final backfill and reinstatement works

The pipeline operations consist of:

1. **Special backfill requirements** for washout, stabilisation, geotechnical protection

   These are needed at locations to ensure long-term trench stability, or where it is considered that additional stability is required following trench excavation. Special backfill requirements are essential to control the effects of water on a trench line and mitigate against natural hazards that could result in pipeline failure or extensive operational remedial costs due to exposure and movement such as seismic conditions, erosion, mining subsidence. In order to deliver a full life-cycle cost effective pipeline system due allowance must be made to ensure those elements that could result in extensive pipeline operational costs are addressed and the necessary permanent works undertaken as part of the pipeline construction activities.

2. **Final backfill and clean up**

   On completion of the tie-in work activities on the mainline, a final backfill and grade crew will progress along the pipeline. This crew will inspect the coating of the exposed pipe and any holidays (coating defect) will be repaired as necessary and the section of exposed pipe backfilled to ground level. All temporary materials, trench supports including piles, surplus excavations, rubbish, etc will be systematically removed from the construction easement area and then the sub soil levelled to its original contour or as determined by operational requirements.
3. Post construction lateral drains

In areas where pre construction header drains have been installed or where additional drainage is required following trench excavation, then lateral drains will be installed either side of the pipeline to collect and remove surface water from the pipeline ROW area.

4. Subsoil cultivation

In agricultural land, the subsoil cultivation involves the final surface preparation of the subsoil including reforming of open cut ditch banks and other features which may have inadvertently been affected by the right of way operation in gaining access.

Once all the features have been returned to their original condition and the surface re-levelled, the subsoil over the whole working area will be broken up into a fibrous condition. Any shallow land drains will be marked and the subsoil carefully “ripped” parallel to those drains to avoid any damage to the shallow drainage installation. Having broken up the subsoil into a fibrous condition the entire area is then worked and levelled with bulldozers without inducing any unnecessary compaction.

5. Permanent works for post construction terrain stabilisation

At locations where a risk is considered to exist then additional works will be undertaken immediately following ground final backfill and clean up. For example, surface ditches will be dug parallel to the pipeline with outfalls to existing surface water systems in areas where the backfill is susceptible to water disintegration or can become air blown in heavy winds it will be encased within stone paving. Final ground and/or trench stabilisation will be addressed with the final grading/reshaping of forward and side slopes and smoothing out any ground removal undertaken on the initial ROW operations in order to provide protection against run off water into the trench.

6. Reinstate offsite roads and provide operational access

There will be a general commitment to either leave the temporary roads or remove them with a provision for retaining sufficient temporary roads to ensure safe operation. The road crew will commence out of sequence with the main operations working as and when required in removing/upgrading/reinstating existing and temporary roads that are to be retained, also, as part of the operation, reinstating as much as possible of the route but permitting access to the final reinstatement crews. New roads in ecologically-sensitive areas will be removed.

7. Topsoil replacement and final reinstatement

The topsoil replacement and final reinstatement of the pipeline easement area immediately follows the subsoil preparation and cultivation activities. This operation consists of a number of activities, which have to be carefully monitored to avoid unnecessary compaction of the soil strata, and includes:

- Removal of all temporary access equipment
- Final formation of ditch banks
- Clean up/patch up any damage to highways
- Replacement of topsoil
- Final level on open country
• Erection of new permanent replacement boundary fencing and new hedging
• Erection of marker, aerial and Cathodic Protection posts

Wherever possible, the final reinstatement will be undertaken in dry conditions.

On completion of final reinstatement the easement land will be brought back to its original condition, as follows:

• Open country – Any fencing will be removed and the land left for immediate occupation
• Special sections/isolated areas – Any fencing removed, access roads reinstated to the agreed level with security barriers erected if required/agreed and the land left for immediate occupation
• Arable land -Fencing will be removed and the land fit for immediate planting
• Grassland - The temporary easement fencing will remain erected and the ground left ready for re-seeding at the earliest growing season. The temporary easement fencing will then be removed

1.5.6 Construction Activity Group 6 – facilities and pipeline control

The main items consist of:

• Block valve sites
• Pumping stations
• Offtake facilities
• Cathodic protection system
• SCADA and leak detection system
• Electrical power supply
• Telecommunications system
• Control centres

The work associated with these facilities and systems will, in the main, be carried out by separate contractors to the Pipeline Installation Contractor. However, all work involved with these facilities will be co-ordinated with main pipeline construction to ensure that the overall schedule for the project is achieved whilst optimising in-country logistics and ensuring that the requisite HSE standards are maintained.

It is not considered necessary to discuss these activities in detail as, to a large extent, they are carried out independently of the main pipeline construction.

1.5.7 Construction Activity Group 7 – testing and commissioning

The pipeline operations consist of hydrostatic testing, pre-commissioning and commissioning of the pipeline. The last two activities are considered outside the scope of main pipeline construction activities and, as such, are not discussed further.
1. Hydrostatic testing

The post-pipeline construction testing operations are carried out to ensure that the installed pipeline complies with the appropriate regulations and can be declared fit for its intended use. The testing of the pipeline is undertaken on completion of all pipeline construction work including if possible final reinstatement, which is weather dependent.

First of all, the pipeline is cleaned and filled with fresh water by the use of internal pigs. The use of the pigs ensures that all air is removed from the pipe. The pipeline is then tested, depending on the code and type of pipeline (oil, gas, etc), to, say, 125% of the maximum operating pressure for a continuous period of 24 hours. On acceptance of the pressure test the water will be removed by the use of the internal pigs propelled by air.

The first task in testing is to establish the number of test sections required for the pipeline. This is determined based on:

- availability of suitable water and location of sources
- location of suitable disposal sites for test water
- variation in altitude which affects the actual test pressure and allowable hoop stress
- length of section, which should be based on a risk assessment on the effect the considerable volumes of water, following a failure, could have on the local environment at any sensitive area

Under normal circumstances, test sections are limited by 100-metre change in altitude and 100km in length.

It may be that, due to conservation or supply difficulties, water will have to be transferred from one test section to another along the pipeline. If this is the case then careful consideration of the installation programme should be undertaken with completion taking full account of water supply and disposal requirements. The transfer of test water from one section to another will be via hard (steel) pipework so that no water is lost or spilled. As the water is transferred from one section to the next, it will be filtered and its chemical composition checked and modified as necessary.

In addition, it may be necessary to chemically treat the water to prevent biological growth in the water or inhibit oxidation of the internal pipe surface (rusting). The selection of chemicals will be subject to very strict evaluation prior to the start of the hydrostatic testing and will be based on chemical and physical analysis of the water at the actual sources. The addition of the chemicals to the test water will be subject to close scrutiny and control and the water will be checked periodically to ensure that it remains within the specified compositional limits. An environmental permit will be obtained for all water abstraction and discharge associated with the hydrostatic test(s).

Temporary pig traps will be installed at both ends of the pipeline section to be tested. These traps will be fully certified for the proposed test pressures. The temporary equipment at the ‘upstream’ end of the test section (where the water will be introduced into the pipeline) includes, large volume/low pressure filling pumps, break or settling tank(s), low volume/high pressure testing pumps, chemical injection tanks and pumps, hard (steel) pipework, compressors, temperature, pressure and volumetric flow instrumentation, pig traps, testing cabins, power supply generators, filters/filtration units, office and telecommunications facilities. Similar equipment will also be installed at the ‘downstream’ end although the type and amount
will depend on whether the test water is being disposed of transferred to the next pipeline section.

All the temporary equipment needed for the hydrostatic testing operation will be fully certified for the test pressure(s) concerned and copies of the certificates will be available onsite for inspection prior to the start of the programme.

Normally, the block valves will be tested in-line with the valves ‘locked’ open and any instrumentation disconnected for the testing operation.

Once a test section has been completed mechanically and is declared ready for testing, the temporary equipment will be installed at both ends of the section. The section will initially be pigged with a bi-directional swabbing pig propelled by air to ensure that all debris is removed from the line. The pipeline will then be filled with water utilizing a 2 possibly 3-pig train with, typically, a 500 metre long slug of water between the 1st, 2nd and 3rd pigs. The high volume/low pressure pumps will be used for this activity and the volume of water entering the pipeline will be controlled and measured to give a linefill rate of, say, 1km per hour.

It is normal practice (and sometimes a requirement of the relevant code) for one of the pigs to have an aluminium gauge plate attached to check for pipe ovality/dents. The gauge plate is circular and has a diameter equal to 95% of the internal pipe diameter (bore).

Once the line is filled it will be left to stand to allow the water temperature to equalize to the surrounding ground conditions; this is typically 3 to 5 days but, as expected, is extremely variable. Once the temperature is stable the test will commence with an initial rise in pressure to 35 bar to ensure that the air content is less then that required by the design code (normally 0.2%). The low volume/high pressure pumps are used to add this water into the pipeline.

With the air content confirmed, the test pressurisation continues to the test pressure at a steady rate of, typically, no faster than 1 bar per minute. Once the test pressure is reached it shall be held for the required time, which for this Project is likely to be 24 hours. During this ‘hold’ period, the pressure and temperature will be measured, monitored and recorded continuously.

Small leaks during the testing operation can be difficult to detect and locate. A change in the water/pipe temperature may give the appearance of a leak. If the temperature of the pipe/water decreases, the test pressure decreases and vice versa for a rise in pipe/water temperature. To prevent unnecessary concerns in this respect, the effects of temperature change on pressure can and will be pre-determined so that the integrity of the pipeline can be confirmed during the testing period.

On completion of the ‘hold’ period and successful acceptance of the test the water is removed from the pipeline by swabbing pigs propelled by dry/oil free compressed air. The water will either be sent to an approved disposal site (evaporation pond/lagoon or river depending on water quality and chemical composition) or into the next test section via solid cross-over piping.

On completion of the initial de-watering, additional pigging runs will be carried out using a combination of swabbing and foam pigs to remove as much free water as possible from the pipeline. This sequence will continue with all other test sections.
Once the dryness of two adjacent sections has been accepted, these sections will be tied-in by welding a short section of linepipe between them to form a complete pipeline between permanent pig trap sites.