# " DESIGNING AND CONSTRUCTION OF UNCASED PIPELINE CROSSING BY HORIZONTAL DIRECTIONAL DRILLING"

A thesis submitted in partial fulfilment of the requirements for the Degree of Master of Technology
(Pipeline Engineering)

By

PRASHANT SINGH CHAUHAN

**R160207012**

Under the guidance of

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**College of Engineering**
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**Nandini Impex Pvt. Ltd.**
**New Delhi**



College of Engineering
University of Petroleum & Energy Studies
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# UNIVERSITY OF PETROLEUM & ENERGY STUDIES

*(ISO 9001:2000 Certified)*

# CERTIFICATE

UPES Guide has ascertained quality of the project – II, Anti Plag certification etc for asserting this high quality academic activity.

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Name ..............................................
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## TO WHOM EVER IT MAY CONCERN

This is to Certify that the work contained in this thesis title "**Design and construction for uncased crossing** by Horizontal Directional Drilling " has been carried by **Mr. prashant Singh Chauhan** under my/our supervision and has not been submitted elsewhere for a degree.

**Dr. Pinak Biswas**
**G.M (Oil & Gas)**
**Nandini Impex Pvt. Ltd.**

# Abstract

Gone are the days when the only option was to tear up the asphalt to lay new underground water, cable, and electric lines in developed areas. Now horizontal directional drilling (also known as trenchless technology and directional boring) goes under roads, driveways, wetlands, and other natural and man-made structures.

Horizontal directional drilling (HDD) is a versatile form of utility construction and has seen enormous growth in the last decade as it offers a clear alternative to conventional methods. Drilling is conducted in both the vertical and horizontal direction and can be steered within limits, dependent upon subsurface conditions. HDD can install utilities from 1" to 48" in diameter and up to 6000 feet in length. The major utilities (gas, petroleum product, electric, telecommunications and water/sewer) can be installed with this technology. The construction process (pilot hole, reaming and pullback) along with the major components (drill rig, drill pipe, slurry, slurry recycling, survey equipment, drill bits, reamers and pipeline materials) will be discussed. The advantages of cost reduction, and environmental, social and time benefits will be examined. The challenges of proper soils information, subsurface conditions, drilling fluids and binding of the drill pipe and reamer/bit will be discussed. Through constant innovation, HDD should remain state of the art for some time, and should be a consideration for the construction of any new utility within the size parameters.

This document provides best practices and recommended procedures for the investigation, planning and construction procedure of an HDD installation for pipeline construction.

It provides guidance on the regulatory, environmental, risk, economics, engineering, and construction considerations that must be evaluated prior to any final decisions to proceed with an HDD installation.

The purpose of this document is to assist pipeline companies, contractors and regulators in planning, evaluating and constructing HDD crossings.

## Acknowledgement

It has been an immense pleasure and truly enriching experience doing my Final year Project, at Ahmedabad, Nandini Impex Pvt. Ltd. (NIPL). I take this opportunity to thank all those people who have made this experience a memorable one. Firstly, I would like to thank my guide **Dr. Pinak Biswas (G.M, Oil & Gas)** who has been instrumental and a guiding force behind the completion of this project. He has been constantly eliciting insights and view points on the subject matter.

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PRASHANT SINGH CHAUHAN

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## Acronyms

| | |
|---|---|
| API | American Petroleum Institute |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society of Testing Material |
| CGCRI | Central Glass and Ceramic Research Institute |
| CNG | Compressed Natural gas |
| CP | Cathodic Protection |
| Cm | Centimeter |
| DFO | District Forest Officer |
| DOT | Department Of transportation |
| DRS | District Regulating System |
| EPP | Environment Protection Plan |
| FBE | Fusion Bond Epoxy |
| Gal | Gallon |
| Gpm | Gallon/min |
| GPR | Ground Penetrating Radar |
| Gr | Grade |
| HDD | Horizontal Directional Drilling |
| HDPE | High Density Polyethylene |
| Hp | Horse Power |
| IS | Indian Standard |
| Kw | Kilowatt |
| M | Meter |
| MAOP | Maximum Allowable Operating Pressure |
| Mm | Millimeter |
| MDPE | Medium Density Polyethylene |
| MMSCMD | Million Metric Standard Cubic Meter per Day |
| Mpa | Mega Pascal |
| Nm | Newton meter |
| O.D. | Outer Diameter |
| OISD | Oil Industry Safety Directorate |
| OSHA | Occupational Safety and Health Administration |
| PNG | Piped Natural Gas |
| Psi | Pound per square inch |
| QA/QC | Quality Assurance/Quality Control |
| Qt | Quart (measure volume unit traditionally) |
| RPM | Revolution per Minute |
| SV | Station Valve |
| TPIA | Third Party Inspection Agency |

# CHAPTER-1

## INTRODUCTION

## (1.1) Introduction:

Horizontal directional drilling (HDD) has emerged as a preferred crossing method in many situations for the installation of oil and gas pipelines as well as other utilities under watercourses, roads, rail lines, steep slopes and other obstacles.

This technology has been enthusiastically embraced by proponents, contractors and regulators as a potentially low impact construction technique. In many cases, however, the suitability of the HDD method must be evaluated and compared to more traditional open-trench construction techniques in order to ensure that an appropriate technique is chosen for the conditions and concerns present at a particular crossing. Recognition of the advantages, limitations and potential risks of HDD is an important step in this evaluation.

It is important to realize that an HDD may represent the critical path on the overall project schedule. In addition, an HDD may have the highest risk of The successful design and construction of an HDD is the result of a team effort combining the skills of the regulatory group, owner, engineering consultant, environmental consultant, inspection services and the specialist HDD contractor. Success in this endeavor is measured in more than the successful pull back of the pre-built pipeline drag section. It is the completion of the project for a reasonable cost with minimal environmental impact and in a manner that allows the contractor to make a fair profit. These should be the goals in any type of project including an HDD installation.
failure of any activities on a project. Therefore, all aspects of planning, design and construction for an HDD need to be assigned a high priority or importance value due to their potential effect on the overall project.

In the first section of this project report, we shall discuss about the planning of the horizontal direction drilling procedure, under which we shall mainly focus on the technical points related to the planning.

And second section of project describes the overall construction processes of HDD.

## (1.2) Basic definitions:

For the purpose of this project, following definition are given:

**Backreamer:** means a cutting head designed for the soil conditions and that is attached to the leading end of a drill string to enlarge the pilot bore during a pullback operation to enable installation of the product.

**Bore Path:** means a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

**Drilling Fluids:** means a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

**Drilling Fluid Fracture or Frac Out:** means a condition where the drilling fluid's pressure in the bore is sufficient to overcome the in situ vertical confining stress, thereby fracturing the soil and allowing the drilling fluids to migrate to the surface at an unplanned location.

**Entry Point:** means the location or excavation from which the bore is initiated for the installation of product.

**Exit Point:** means the location or excavation to which the bore is directed for the installation of product.

**Guidance System:** means an electronic system capable of locating the position, depth, and orientation of the drill head during the drilling process.

**Horizontal Directional Drilling (HDD):** means n directional boring or guided horizontal boring.

**Inadvertent Returns:** means the flow of unexpected fluids towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

**Loss of Circulation:** means the discontinuation of the flow of slurry in the bore back to the entry or exit point or other planned recovery points.

**Multi Product Installation:** means two or more products installed in the same bore path. The products may or may not have the same diameters.

**Pilot Bore:** means the initial bore to set horizontal and vertical alignment between the connecting points.

**Product:** means pipelines, conduits, cable, or ducts.

**Pullback:** means that part of the HDD method in which the drill string is pulled back through the bore path to the entry point, usually installing the product at the same time.

**Reaming:** means a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This could include multiple passes.

**Rock:** means natural beds or massive fragments of the hard, stable, cemented part of the earth's crust that are igneous, metamorphic, or sedimentary in origin, which may or may not be weathered, and includes boulders having a volume of 0.5 $m^3$ or greater.

**Single Product Installation:** means a single product installed into a bore path. The product may or may not have a tracer wire attached to it.

**Strike Alert:** means a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm is set off when the sensor contacts 42.5 volts or 0.5 amperes. The alarm may be audio or visual or both.

**Slurry:** means a mixture of soil cuttings and drilling fluid.

**Soil:** means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

# CHAPTER-2

## LITERATURE REVIEW

## (2.1) Horizontal Directional Drilling

The purpose of this document is to assist pipeline companies, contractors and regulators in the planning, evaluation and construction of HDD crossings. In particular, the document provides guidance for:

• Corporate regulatory personnel in determining the necessary course of action during permitting and approval of projects planning an HDD;
• Corporate engineering personnel in the planning, contracting and supervision of construction;
• Corporate environmental personnel in the planning and provision of support to the construction team;
• Contractor personnel in managing expectations of corporate and regulatory personnel; and
• Regulatory managers in determining realistic expectations of HDD technology.

### (2.1.1) Description of HDD:

Horizontal directional drilling is a trenchless construction method utilizing equipment and techniques from horizontal oil well drilling technology and conventional road boring. HDD construction is used to install petroleum pipelines (steel or plastic), fibre optic and electric cables, and water and waste water pipelines where conventional open trench construction is not feasible or will cause adverse disturbances to environmental features, land use or physical obstacles.

HDD technology is used in many situations, including the following:
• Lake crossings;
• Wetland crossings;
• Canal and watercourse crossings;
• Valley crossings;
• Sensitive wildlife habitat; and
• Road and railway crossings.

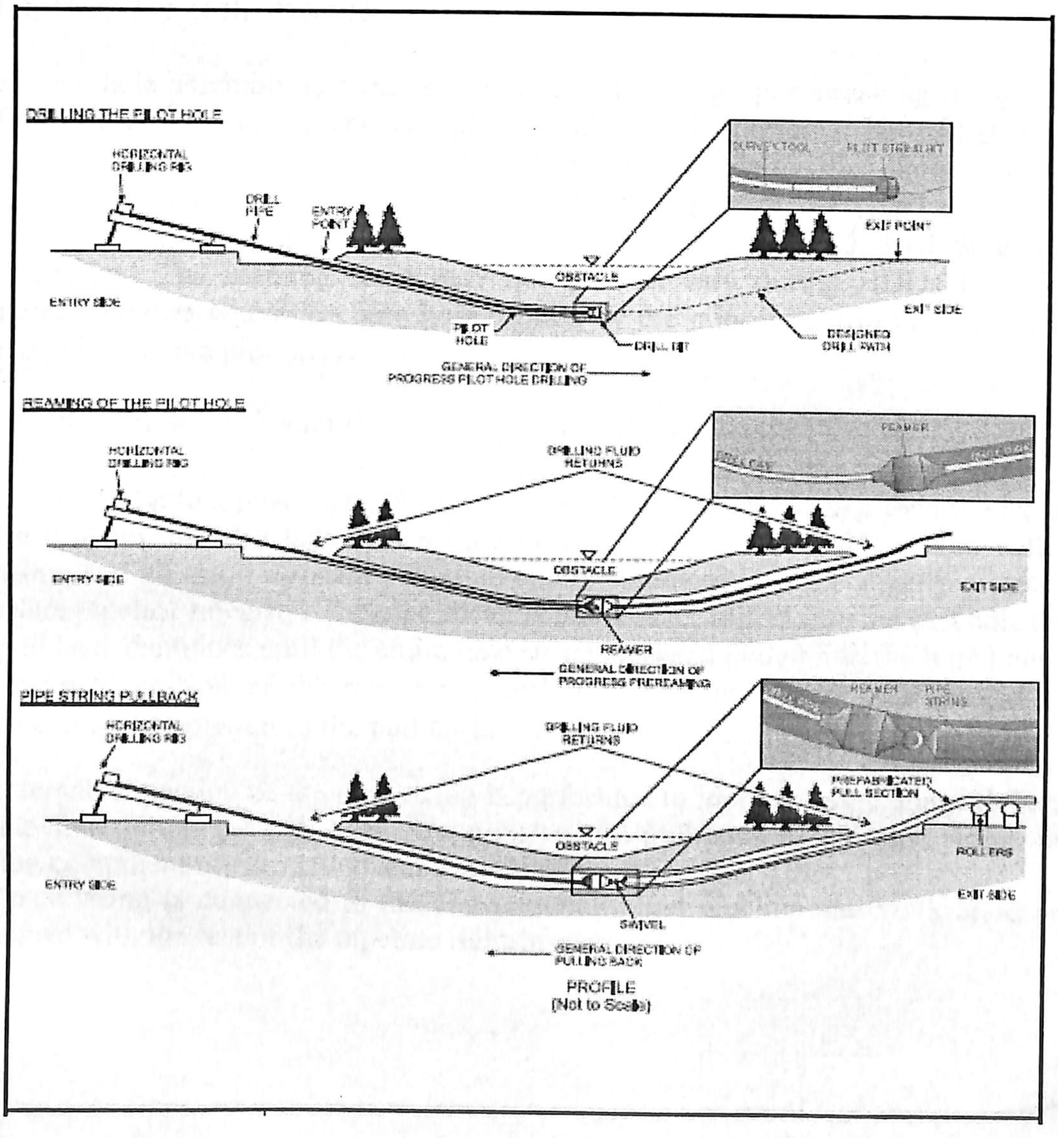
HDD installation involves four main steps:
1) Pre-site planning;
2) Drilling a pilot hole;
3) Expanding the pilot hole by reaming; and
4) Pull back of pre-fabricated pipe.

The following summarizes the main activities that take place during each phase of an HDD. Drilling of the pilot hole and pipe string pull back are illustrated on.

## (2.1.2) Pre-Site Planning:

A determination is made as to whether an HDD is technically and geotechnically feasible by studying existing geological data and conducting field investigations to assess the subsurface conditions and characteristics likely to be encountered during the drill. If an HDD is determined to be feasible, a drill path is designed to meet the requirements of the crossing and appropriate drill entry and exit locations are selected. An allowance is made in the design of the drill path for any potential changes in the obstacle (i.e., stream migration or cutoff development) to be drilled under and the drill entry and exit points are refined.

**<u>Figure-1→ Watercourse Crossing – Horizontal Directional Drill</u>**



### (2.1.3) Drilling the Pilot Hole:

An HDD drill rig and supporting equipments are set-up at the drill entry location determined during the pre-site planning phase. A pilot hole is drilled along the predetermined drill path. Periodic readings from a probe situated close to the drill bit are used to determine the horizontal and vertical coordinates along the pilot hole in relation to the initial entry point; the pilot hole path may also be tracked using a surface monitoring system that determines the down hole probe location by taking measurements from a surface point.

Drilling fluid is injected under pressure ahead of the drill bit to provide hydraulic power to the down hole mud motor (if used), transport drill cuttings to the surface, clean build-up on the drill bit, cool the drill bit, reduce the friction between the drill and bore wall, and stabilize the bore hole.

### (2.1.4) Reaming of the Pilot Hole:

The down hole assembly is removed from the drill string upon breaking the ground surface at the exit location and is replaced with a back reamer; The drill string is pulled back through the bore hole and the back reamer enlarges the diameter of the drill hole; The reamer may be pulled from the pipe side of the HDD crossing if additional passes with the reamer are required to achieve the desired bore hole diameter; and The reaming stage may not be necessary during HDDs for small diameter pipelines where the bore hole created by the pilot hole drill is of adequate size to pull back the pipe string.

### (2.1.5) Pipe String Pull back:

Pipe is welded into a pipe string or drag section, that is slightly longer than the length of the drill, on the exit side of the bore hole. The pipe is typically coated with a corrosion and abrasion resistant covering, and is commonly hydrostatically pretested to ensure pipeline integrity. The pipe string is pulled over rollers into the exit hole and the pull back continues until the entire pipe string has been pulled into the bore hole.
The external coating of the pipe string visible at the entry point is inspected for damage upon completion of the pull back.

An internal inspection of the pipe string is performed to identify any damage done to the pipeline during the pull back. Upon successful pull back of the pipe string, the drilling equipment is dismantled and demobilized.
The pipe string is connected to the conventionally laid pipeline and work areas are reclaimed with the rest of the pipeline right-of-way.

## (2.2) Workspace Requirements:

Workspace for an HDD may require clearing and grading, depending on the entry and exit sites selected for the drill. Since the drill entry location or entry side accommodates the drill rig and supporting equipment, the entry side location requires satisfactory access as well as stable ground conditions to support heavy equipment (Figure 2). Equipment typically found on the entry side of a HDD includes:

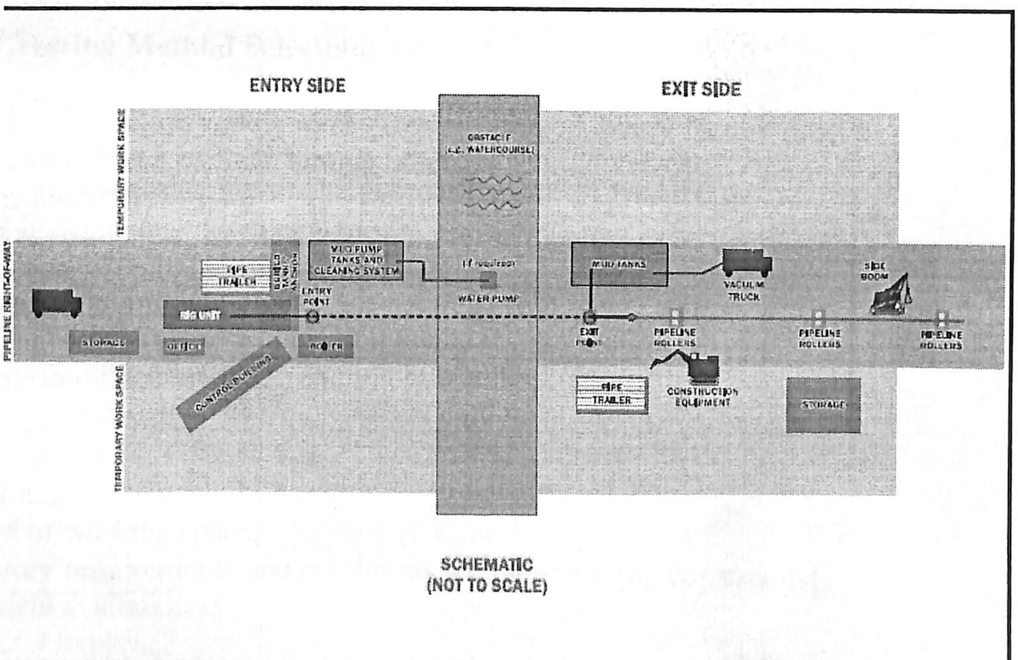
- The rig unit;
- Power unit and generators;
- Drill pipe rack and drill pipe;
- Water pump;
- Drill mud supply;
- Drill mud mixing tank;
- Drill mud pump; and
- Mud handling and cleaning system.

Since the drill exit side is the location for the fabrication of the pipe string as well as where the pipe string is inserted into the bore hole, the workspace required is typically longer to accommodate the pipe string (Figure 2) and may require extra temporary workspace outside of the right-of-way known as "false right-of-way".

Equipment typically found on the exit or pipe side of the HDD includes:

- Exit mud containment tanks/pits;
- Cuttings settlement tanks/pits;
- Pipe racks and product pipe;
- Rollers and pipeline handling equipment;
- Side booms and other heavy equipment; and
- Pipelines, welding, coating and testing equipment.

**Figure-2→ Horizontal Directional Drill Set-up**



## (2.3) Selection of HDD as the Prefered Crossing Method:

The decision to install an HDD crossing at a specific location is the result of a process that addresses the following:
• Overall pipeline route selection;
• Crossing location selection;
• Crossing method selection;
• Other selection criteria such as:
- Availability of access,
- Need for and suitability of vehicle crossings,
- Siting of entry and exit points,
-Dimensions of the No Drill Zone, and
- Availability of a water source.

### (2.3.1) Pipeline Route Selection:

The selection of a preferred water crossing location based on an overland pipeline routing assessment should also consider the method of crossing, alignment, and access for the HDD construction. The pipeline routing should allow for layout areas, entry/exit pads, access routes, and minimal points of inflection in the design drill path and the pipe string layout area.

### (2.3.2) Crossing Location Selection:

The selection of the crossing should be undertaken in conjunction with the route selection to allow the following:
• Flexibility in using various crossing methods, especially if the HDD fails and an alternative crossing technique is required;
• Flexibility to use various accesses or vehicle crossing methods; and
• Flexibility in refining the exact crossing location in the event that constraints prevent certain alignments.

### (2.3.3) Crossing Method Selection:

In selecting a pipeline watercourse crossing method, many factors must be taken into consideration. These include, among others:
• Pipeline diameter;
• Project schedule (*i.e.,* desired schedule for the pipeline to be operational);
• Watercourse crossing width, depth and flow;
• Environmental sensitivity and associated constraints;
• Geotechnical concerns;
• Substrate composition;
• Hydrological data;
• Costs of the various alternatives;
• Navigation;
• Amount of working space;
• Regulatory requirements and conditions including timing constraints;
• Equipment availability;
• Contractor expertise;
• Downstream water users;

- Landowner and community issues;
- Engineering constraints; and
- Construction season.

The selection of a crossing method is an exercise in striking a balance among the considerations listed above to derive the most practical solution. The method that is preferred is usually that which is geotechnically feasible and offers the required level of environmental protection for the lowest cost.

Selection of an HDD crossing when other methods are more cost effective, technically feasible and offer sufficient environmental protection may be inappropriate. If an HDD is the strongly preferred method by regulators and this method is considered to have a low likelihood of success or is otherwise impractical, the regulators should be provided detailed information on the crossing method selection process and the rationale for the rejection of the HDD method.

**(2.3.4) Other Selection Issues:**

Assuming that HDD has been selected as the preferred crossing method, the following other selection issues must be evaluated.

**(2.3.4.1) Access:**

Pipeline routing and drilling execution planning should consider that access to both sides of the drill will be required during the HDD construction process. If adequate access to the crossing cannot be provided on both sides of the watercourse and the watercourse is suitable for the installation of a crossing structure, a temporary crossing structure may need to be installed for vehicle and equipment traffic. As with the selection of the crossing method, selection of the vehicle crossing technique also involves striking a balance between many of the same considerations listed above for crossing method selection to derive the most practical solution. The technique that is preferred is usually one which offers the required level of environmental protection for the lowest cost.
Access will also be required:
- To a water source during the installation of the HDD
- For monitoring of the drill path; and
- During clean-up operations in the event of a drilling fluid release to surface.

Sediment and erosion control protection plans may be warranted to ensure that access creation or use do not result in adverse effects.

**(2.3.4.2) Drill Entry and Exit Site Selection:**

The selection of the drill entry and exit locations will need to consider the following:
- The terrain must be cleared, leveled and suitable for the work (sites with negligible longitudinal or side slopes are preferred);
- Entry and exit location should be of sufficient size and configuration to undertake the work safely1; this should include consideration of:

\- Drill rig entry and exit points (note that generally the entry point should ideally be at an equal or lower elevation than the exit point);

- Rig size and layout requirements;
- Pipe lay down area or false right-of-way (note that a straight approach to the exit point is preferred to avoid the need for false right-of-way);
- Fabrication area;
- Returns pit; and
- Bulk storage of materials;

• The resulting drill path must be feasible with a low risk of inadvertent returns; and
• Existing infrastructure and land use.

**(2.3.4.3) No Drill Zone:**

A No Drill Zone can be identified that addresses geotechnical issues and concerns at the proposed crossing site. As defined by the geotechnical engineer, the No Drill Zone is the upper limit of potential drill paths between specified entry and exit locations, intended to ensure that the bore is maintained within geological materials suitable for an HDD while providing sufficient cover to mitigate potential inadvertent return concerns.

As detailed in next section, definition of the No Drill Zone for a proposed HDD crossing is influenced by a number of factors, including:

• Crossing area terrain conditions, in terms of the difference in elevation between entry and exit locations and along the HDD alignment, that determine, in large part, the minimum recommended depth of cover;
• Subsurface soil and bedrock stratigraphic conditions, and the suitability of the various units for directional drilling;
• River engineering considerations, including depth of scour during the design flood event and potential for bank/meander migration and cut off development; and

*Note: In general, for small HDD applications, entry site should be approximately 40 m x 40 m, exit site approximately 30 m x 20 m. For larger HDD applications, entry site should be approximately 60 m x 60 m, exit site should be approximately 40 m x 30 m, excluding false right-of-way, if required. The contractor should be requested to provide his specific requirements prior to construction.*

• The presence of active, inactive and potential landslide features, and other geotechnical “problem” areas, which should be avoided by the design drill path.

All potential drill paths should be designed to pass outside of the No Drill Zone. While the No Drill Zone is typically defined in terms of geotechnical considerations, it may also be influenced by environmental and socio economic concerns, such as wildlife concerns, rare plant occurrences, social resources (*e.g.*, land use) and cultural resources (*e.g.*, archaeological sites), etc. Specific studies may be necessary to identify the presence of these environmental and cultural features. Relocation of the entry and/or exit point, thereby altering the length of the design drill path, may provide a means of mitigating some of these non geotechnical concerns.

### (2.3.4.4) Water Source:

The availability of a water supply to the HDD site should also be considered during the planning stage of the project. Water will be required for the following:
- Initial drilling fluid make-up;
- Additional drilling fluid as the drill progresses;
- Replacement fluid for drilling fluid escaping into the formation due to seepage or hydraulic fracture; and
- Pretesting, where warranted, of the pipe string.

Hydraulic fractures can greatly increase the water requirements during an HDD project. Water can be pumped from a water body to the drill site or hauled to storage tanks onsite. Factors to be considered in selecting a water supply are:
- Access to the water body;
- Flow restrictions;
- Regulator approval;
- Construction schedule (*i.e.,* air temperature, anticipated stream flow/volume and water quality); and
- Physical limitations such as the distance and/or elevation of the entry point from the water body.

## (2.4) Risk Considerations:

As with all construction techniques, a degree of risk and unpredictability is associated with the use of HDD applications. It is recommended that a project team be assembled early in the planning and design process in order to identify and assess potential risk, as well as develop plans to minimize the risks. Although HDD projects vary widely in complexity, most encounter site-specific characteristics that differ from previous projects. The project team may be composed of the proponent; engineering, geotechnical and environmental consultants; the HDD contractor and the pipeline contractor. Close consultation with regulators and land authorities can assist in the acquisition of initial approvals as well as ensure that alternate plans can be readily implemented if insurmountable problems arise.
Risk can generally be divided into three types: regulatory risks; construction risks; and operations risks.
Here we will discuss only construction and operation risks.

### (2.4.1) Construction Risk

Success of an HDD installation is dependent upon the ability of the project team to minimize the causes of failure. The risks associated with each crossing will vary according to many factors. These include but are not limited to:
- Inadequate planning;
- Lack of contingency planning;
- Inexperienced field personnel;
- Overestimation by the contractor in the firm's abilities;
- Insufficient quantity and size of equipment onsite; and
- Inadequate knowledge of subsurface conditions.

Construction risk on a project can be minimized by ensuring that sufficient planning is conducted and an adequate geotechnical investigation is carried out.
Another means of addressing risk on a project is through the type of contract that is used in next section.
Table 1 summarizes some of the more common problems associated with HDD and identifies the construction risks associated with each.

**Table 1 - Construction Risks Associated with an HDD**

| Potential HDD difficulty | Construction Risk |
| --- | --- |
| Loss of drilling fluid | Variable depending on volume and connectivity to surface or water body. |
| Loss of circulation | Complete loss of circulation indicates a loss of drilling fluid. |
| Drilling mud seepage directly into watercourse | Sediment load and deposition with possible adverse effects on fish, fish habitat, hydrology and downstream water users. |
| Drilling mud seepage onto land and then into watercourse | Sediment load and deposition with possible adverse effects on fish, fish habitat, hydrology and downstream water users. Additional adverse effects on wildlife, vegetation, soils, heritage resources and current land use may occur on land. |
| Collapsed hole | Loss of topsoil and unexpected widening of the area of disturbance. Extended duration of disturbance is likely. |
| Washout of cavities and Collapse of right-of-way. | Loss of topsoil and unexpected widening of the area of disturbance. |
| Stuck drill stem | An unexpected widening of the area of disturbance if a wide and deep excavation is necessary to retrieve the equipment. Extended duration of disturbance is likely. |
| Lost tools | Extended duration of disturbance and potential for a re-drill. |
| Damaged pipe or coating | Extended duration of disturbance and potential for a re-drill. |

### (2.4.2) Operations Risk:

The risks associated with an HDD installation during operations are generally considerable less that those of a traditional trenched crossing. In particular, the risk of the following problems is minimized or eliminated:
• Maintenance of disturbed banks or stream bed;
• Exposure of pipe during peak flow events or due to ice scour; and
• Damage of pipe due to anchors or other third party activities.

Increased risks include:
• Pipe is inaccessible for repairs due to depth of cover;
• Corrosion due to undetected damage to pipe coating;
• Subsidence at entry and exit points; and
• Visual leak detection is not possible.

## (2.5) <u>Environmental Considerations:</u>

HDD crossings are often undertaken to minimize the adverse environmental effects at watercourse crossings. Nevertheless, an HDD does not guarantee that all adverse environmental effects will be prevented. Common adverse effects are the result of:
• Inadvertent returns of drilling fluids into the aquatic, terrestrial or social/cultural environments; and, to a lesser extent,
• Disturbance of soils, vegetation, wildlife and social/cultural elements arising from either construction of drill sites, exit areas, access roads and temporary vehicle crossings, or the HDD activity.

### (2.5.1) Environmental Protection Plan:
An environmental protection plan (EPP) should be developed by the owner to address mitigative measures to be implemented during execution of the HDD. Environmental protection planning should cover all aspects of the execution of the HDD including land, water and access needs. The EPP should address the following aspects and be closely linked to the drilling execution plan:
• Notification and approvals;
• Identification of environmental exclusion areas to be incorporated into No Drill Zones;
• Environmental and social timing constraints;
• Equipment inspection and servicing;
• Clearing and grading of HDD sites and access;
• Erosion and sediment controls; and
• Monitoring.

In addition to having an EPP, it is essential to have qualified people onsite to enact the plan, to handle deviations to the plan and to report events properly to the authorities. Having an environmental specialist or biologist onsite to liaise directly with the DFO habitat biologist or other similar authority can prove useful. Effective communication of unintended events and subsequent mitigation actions to the authorities may reduce delays or unwarranted enforcement actions contingency planning, *e.g.*, inadvertent returns, and reclamation.

## (2.6) Engineering Design Considerations:

### (2.6.1) Design of Drill Path:

The design of the drill path should consider all of the information gathered for the crossing area. The physical limitations of the site as well as geotechnical, environmental (fish, wildlife, vegetation, land use, cultural) and hydrological information should be considered in the preparation of the drill path design.

#### (2.6.1.1) Limitations of HDD:

The feasibility of HDDs is dictated by the length of the bore hole to be drilled, the diameter(s) of the pipe string, as well as the subsurface soil/bedrock conditions. As of 2000, the longest drilled crossings have been recorded at approximately 1,800 m, with small diameter pipe. The largest pipe diameter to be drilled as of 2000 was a 1,219 mm O.D. project. HDD crossings with such a large diameter pipe are rare. Entry angles of HDDs vary from 8 to 18 degrees from horizontal, with longer crossings having a longer horizontal segment at the specified depth of cover. HDD equipment can adjust for different entry angles.

Existing HDD technology (*i.e.,* rig tools and drill pipe) and economic considerations are the primary factors limiting drill path length and pipe string diameter. The flexible nature of drill pipe limits the amount of pressure that can be applied to the drill string and, therefore, control of the front of the drill string decreases over longer bore lengths. The capacity of the drill pipe to transmit torque from the rotating surface to the down hole reamers is also a limiting factor.

Emergence of new HDD technologies to confront drill path length and product pipe diameter restrictions is also influenced by economics. The installation of large diameter pipe over long lengths is rare and the market for such technologies is small, thereby limiting the funding and research needed to acquire these new technologies. The nature of the subsurface soil and bedrock materials at a proposed crossing is one of the primary geotechnical limitations to the installation of a pipeline using an HDD. A high proportion of coarse-grained materials (*e.g.,* gravel, cobbles and boulders) as well as excessive bedrock strength and hardness are the main subsurface characteristics that may impair the use of HDD. Coarse-grained soils are not readily fluidized by drilling mud and can present a serious constraint to the feasibility of an HDD if encountered. Boulders or clusters of cobble remain in the drilled path and present an obstacle to the bit, reamer as well as the pipeline, while excessively hard rock makes all phases of the HDD difficult.

Extensive fracturing or jointed rock can present problems similar to those encountered with coarse granular deposits. Competent rock with an ideal unconfined compressive strength of approximately 15,000 psi (103 MPa) and a hardness, based on Moh's Scale of Hardness, greater than 7 can be negotiated with an HDD, given today's technology. One problem often encountered when facing such characteristics at depth is the tendency of the drilling string to deflect rather than penetrate the subsurface.

### (2.6.1.2) Depth of Cover:

Depth of cover requirements are dependent upon a number of factors such as subsurface conditions, type of drilling equipment, mud pressure (which is a function of the mud pump capacity), and the difference in elevation between the entry and exit points. Depth of cover is a factor used in the development of the No Drill Zone in above section and should be determined by the HDD project team.

### (2.6.1.3) maximum allowable pulling force:

**Table 2-HDD Rig Classification:**

| HDD system Type | Max. Pulling force (kN) | Max. torque (kNm) | Weight (t) |
|---|---|---|---|
| Mini | ≤ 150 | 10 – 15 | < 10 |
| Midi | ≤ 150 - ≤ 400 | 15 – 30 | 10 – 25 |
| Maxi | >400 - ≤ 2,500 | 30 – 100 | 25 – 60 |
| Mega | >2500 | >100 | >60 |

### (2.6.1.4) Entry and Exit Points:

Considerations related to the entry and exit points have previously been discussed in Section previous section.

### (2.6.1.5) Alignment:

Angles in the easement/right-of-way alignment adjacent to an HDD crossing should be minimized. If difficulties are encountered during an HDD, it may be necessary to increase the drill length. Therefore, the entry and/or exit points would need to be moved farther back from the location being crossed. The approach alignment to the HDD crossing needs to allow for the potential need for lengthening of the crossing.

### (2.6.1.6) Right-of-Way:

The drill path should be aligned to lie within the right-of-way boundaries. If this is not feasible, new right-of-way must be acquired prior to commencement of the HDD. Temporary workspace is typically required at a crossing above and beyond that necessary for conventional pipeline construction. The pipe string will require additional workspace and, where the alignment on the exit side is not straight, additional workspace, typically referred to as false right-of-way, and may be required. This area should be of sufficient length and width to allow the pipe to be welded up and tested along the full length of the pipe string. It is highly recommended that the pipe string be fabricated in one complete section since any stoppage in pulling of the pipe string adds significant risk to the success of the project.

### (2.6.2) Land Issues:

The land issues listed below should be considered during the planning phase of an HDD project:

- Landowner consultation during the routing and crossing selection process, and when determining a water source for drilling activities;
- Landowner consultation when determining access to the water source;
- Landowner consultation to avoid conflict with land use practices (*e.g.*, drill in pasture when cattle have been rotated to another pasture or during the winter to avoid the crop year);
- Informing the landowner of HDD processes and applications to avoid potential issues;
- Landowner consent for access across lands not on the right-of-way for monitoring purposes and potential reclamation of inadvertent returns;
- Spills on the entry side and the pipe side of the drill may require reclamation and remediation as well as compensation to landowner and compensation for any habitats lost; and
- Trespass off the right-of-way due to inadequate marking of designated work areas or inadequate location or amount of workspace.

### (2.6.3) Casing:

Contractors often use a short section of casing that is 'dug in' at the start of construction. This casing is intended to prevent inadvertent near-surface returns, and allows for easy monitoring of drilling mud return levels. However, where unconsolidated deposits represent a risk of inadvertent returns on the entry side, the casing may need to be more extensive. The casing can either be driven in with a large hydraulic hammer or, possibly, in softer soils, pushed in with the drill rig.
Casing should be of sufficient length to seal into a suitable competent formation such as bedrock or cohesive stiff clay. The casing diameter should be greater than the final reaming pass to ensure down hole tools can easily enter the bottom of the casing throughout the entire drilling operation and pull back. It is preferable to remove any casing at the end of the crossing construction since it will shield the pipeline within the crossing from cathodic protection.

### (2.6.4) Pipe:

#### (2.6.4.1) Type:

Tensile and bending stresses that are induced on the pipe during an HDD installation should be analyzed to ensure the pipe is suitable for installation. This analysis is especially important when using thin wall steel pipe or plastic pipe.

#### (2.6.4.2) Number of Pipes:

In many instances it is proposed to install more than one pipe in the drilled crossing. The characteristics to consider are the size of the pull head, number of pipes, as well as the size of the individual pipes, including pipe coatings. These items will increase the final bore diameter and will dictate the minimum radius of curvature.

### (2.6.4.3) Coating:

As mentioned in above Section one operational risk that should be addressed is external corrosion due to damaged pipeline coatings. Protective coatings can often be damaged during pull through by the forces involved, and by contact with soils, rocks, and other debris present in the bore hole. The consequences of coating damage are multiplied by the nature of the HDD method. A pipeline installed by HDD will not be readily accessible to make future pipeline or coating repairs. External pipe coatings for HDDs must be carefully selected to minimize the risks.

Given the potential for coating damage it may be necessary to select a different coating system for the HDD section(s) of a pipeline. Coatings used for HDD drag sections must be flexible and have sufficient abrasion resistance to limit damage. The economic and environmental consequences of a future failure are significant. Cathodic protection (CP) compatible coatings will allow protective current to reach the pipe regardless of any damage to the coating. Certain coatings such as single or double layer extruded polyethylene, or polyethylene tape, can shield cathodic protection current when damaged. Such coatings should be avoided on HDD projects.

Often the most suitable coatings for an HDD project are Fusion Bond Epoxy (FBE) or similar liquid coatings. An additional layer of pipe coating should be applied for abrasive protection. This layer is often referred to as the abrasion resistant layer or the sacrificial layer. The exact type of coating should be selected based on a number of factors including the amount of abrasion expected.

The selection of field applied joint coatings also requires careful attention. It is recommended that the joint coatings be liquid epoxies with similar properties, especially abrasion resistance, as the main plant applied coating. Since the joint coatings are field applied, proper application methods, qualified workers/applicators, and qualified coating inspectors are recommended.

In addition to inspecting the coatings during the actual application process, a careful visual inspection should be made of the first few pipe joints at the exit location. Often these leading joints are believed to receive the most damage. If these joints are in good condition it is likely that the remaining coating is in similar or even better condition.

Another method of inspection is an in situ electrical method to determine the coating resistance. A competent cathodic protection technician can complete this work. This type of inspection can provide a relative understanding of the coatings efficiency. The field CP measurements must be done prior to completing any tie-in welds to the rest of the overland pipeline. Therefore, the timing of this work must be carefully coordinated.

Conventional two-layer extruded polyethylene coatings are not recommended due to their susceptibility of damage, and possible shielding of cathodic protection current. More recently available three-layer polyethylene coatings (FBE coating with a polyethylene topcoat) may be considered.

External concrete weight coatings are not recommended due to their brittleness, weight, and high coefficient of friction.

#### (2.6.4.4) Insulation

It is typical for some pipe to be specified with a thick layer of insulation. This will necessitate the final ream to be larger than an un insulated pipe.

#### (2.6.4.5) Limits of Curvature

The design of the drill path and selection of pipe must consider the following:
- The radius of the curves in the drill path; and
- The exit and entry angle.

The radius of the arc of the drill path should consider the diameter of pipe to be installed. The minimum radius for most drilling applications is:
- The diameter of the pipe to be installed in meters multiplied by 1200; or
- The pipe diameter in inches multiplied by 100 to obtain a radius of curvature in feet.

This formula is used to ensure a conservative radius of curvature that will allow for the easy installation of the pipe and minimize the bending stresses on the pipe. If the pipe is smaller than the drill string, the larger pipe size shall be used in the minimum radius calculations. This will ensure that the drill pipe will not be overstressed and the drill can proceed as planned. In most applications, the radius of curvature will not be lower than 250 m.

## (2.7) Construction Considerations:

### (2.7.1) Drilling:

#### (2.7.1.1) Types and Sizes of Rigs:

The size of HDD rigs can vary substantially. This range in sizes should be considered when planning and developing specifications for an HDD project. In general, rigs are sized according to their available pull force and rotary torque that can be applied to the drill stem and pipe string. The following are samples of rig sizes and the respective ranges of projects that can be completed.

| Rig Torque | Length of Drill | Diameter of Pipe |
|---|---|---|
| 0 – 54,000 Nm | up to 200 m | up to 168.3 mm |
| 54,000 – 108,500 Nm | up to 400 m | up to 273.1 mm |
| 108,500 – 217,000 Nm | up to 500 m | up to 323.9 mm |
| 217,000+ Nm | over 500 m | over 323.9 mm |

Note: Nm = Newton meters.

The capabilities of each rig should be assessed for each project. The assessment of rig capabilities should take into account the possibility that formations or other subsurface materials may be encountered that could cause difficulties with the HDD project.

**(2.7.1.2) Casing:**

Considerations related to casing are discussed in the previous section.

**(2.7.1.3) Drag Section:**

The pipe installation should be designed so that, wherever possible, the pipe string or drag section can be laid out and pulled back in one continuous section. The pipe will have to be lifted into place to match the exit angle of the drill to allow the drill rig to pull the section into place.
The pipe string is usually placed on rollers as it is pulled into the drilled hole. The drag section may be cradled through a vertical curve to achieve the proper angle at the exit point. This curvature should be no more than the limiting curvature of the pipe.

**(2.7.1.4) Steering / Survey of Drill Head:**

It is necessary to 'steer' the drill head or mud motor during the drilling of the pilot hole. A number of steering technologies are available. Two of the more common systems are known as the DigiTrak system and the TruTracker® system. The DigiTrak is a "walkover system" that is somewhat limited in the depth to which it is effective. The TruTracker® system is a "wireline steering tool system" and is utilized where the depth of the crossing is outside the range of the walkover system. Both of these systems provide effective steering.

**(2.7.1.5) Drilling Fluids:**

Drilling fluid is used for a number of tasks in the HDD process including:
- Cooling and lubricating the drill stem, mud motor and bit;
- Providing hydraulic power to the mud motor which in turn converts hydraulic power to mechanical power;
- Carrying cuttings out of the bore hole;
- Stabilizing the bore hole during the drilling process; and
- Sealing fractures in the formation.

Drilling fluid is usually a mixture of freshwater and bentonite. Bentonite is naturally occurring clay that is extremely hydrophilic (*i.e.*, has high swelling characteristics). Certain polymers may also be used that enhance the drilling fluid benefits.

A drilling fluid design plan should be established before the start of the project. This plan should also be modified, when warranted, throughout the project to ensure the drilling fluid is fulfilling its function. The contractors' drilling execution plan should identify the equipment to be maintained onsite to check drilling fluid properties. Alterations to the mix should be made, when warranted, to stay within the proposed boundaries in the drilling fluid management plan.
A mud handling system should be onsite to ensure drilling fluid parameters are within the set standards.
Given Appendices, respectively provide a pipe volume table and conversion factors that may be of use in the calculation of drilling mud volumes or other aspects of an HDD project.

**Additives**
Various chemical and materials can be added to the drilling fluid to adjust its properties. This is done to control:
• Density;
• Viscosity;
• Plugging and sealing capabilities; and
• Specific conditions such as swelling.
All additives should be environmentally safe. A number of additives have been recognized as safe for the water well drilling industry and, with the proper approvals, could be used for the HDD industry. All additives must be approved before use.

**(2.7.1.6) Drilling Fluid Disposal:**

Samples should be acquired of the drilling fluid/cuttings and analyzed for contamination before disposal. Permits/approvals are required in some provinces and territories for the disposal of drilling wastes.
Drilling fluid and cuttings can be disposed of in three ways:
• Mix and bury onsite;
• Land spread; and
• Haul to an approved site or disposal facility.

**(2.7.1.7) Buoyancy Control:**

When a drag section is pulled back through the bore, the buoyant weight of the pipe as well as the resulting drag forces between the pipe (pipe coatings) and the walls of the bore will act as resisting forces. The drag force can be severe enough to damage pipe coatings as well as collapse the pipe. Therefore, it is important to determine during the planning phase whether buoyancy control is needed. If buoyancy control is necessary (*i.e.*, for some long and large diameter drills), a buoyancy control plan needs to be implemented. Typically, buoyancy control is applied by adding water to the drag section during the pull back phase.

**(2.7.1.8) Monitoring:**

Monitoring and reporting are critical during an HDD since they provide a log of activities during the process to:
• Provide early identification of issues;
• Make appropriate changes;
• Provide a basis for mitigation; and
• Provide a record of decisions and actions to demonstrate due diligence.

It is important to ensure that sufficient records are maintained before, during and after construction to support subsequent reports prepared to satisfy contractor, owner or government reporting requirements. This should include detailed notes and photographs of all areas monitored.

### (2.7.1.9) Drilling:

The following monitoring and reporting activities should be reviewed for appropriateness for the size and complexity of the HDD crossing:

• Inspector daily records – a day-to-day account of the entire construction of the project;
• Contractor drilling records;
• Steering report;
• Drilling fluid volume balance report;
• Drilling fluid parameters;
• Drilling fluid additives list;
• Annular pressure modeling and reporting;
• Turbidity monitoring report;
• Surface monitoring report;
• Pull force monitoring; and
• Inadvertent return report.

### (2.7.1.10) Environmental:

An environmental monitoring and response plan should be prepared by the contractor to address all the issues outlined in the EPP or specific concerns in the permits. The drill path and surrounding area should be monitored up and downstream of the works. Where pressurized drilling fluids are used, monitoring should extend at a minimum 400 m up- and downstream of the crossing, and be conducted on a fixed interval basis as identified in the EPP. The exact distances will depend on the various issues at the site. Monitoring should be documented and any evidence of fluid on the surface should be reported to the owner and appropriate provincial, territorial and federal authorities as soon as possible.

Large water bodies and water bodies that are crossed when ice cover is present may warrant turbidity monitoring to identify whether inadvertent returns are entering the water body. The water body turbidity should be monitored regularly to ensure that a loss of fluid in the water body is detected as early as possible. The sample locations and sampling protocol including method and frequency of sampling, (including frequency under normal operating conditions and when loss of circulation occurs) and acceptable turbidity rates should all be determined in advance of the works by an aquatic specialist and specified in the EPP. The monitoring must be documented and any evidence of increased turbidity levels should be reported at once.
If a loss of circulation occurs during the drilling program, the frequency of monitoring should increase to detect any inadvertent returns to surface.

### (2.7.1.11) Indicators of Inadvertent Returns:

Inadvertent returns occur when drilling fluids disperse into surrounding soils or randomly discharge to the surface. Such inadvertent returns are a result of the drilling fluid following the path of least resistance. To help prevent such releases the drill path should be aligned to avoid or minimize soils or formations prone to inadvertent returns, casing at the entry hole may be installed and other drilling parameters are established to maximize drilling fluid circulation and minimize the potential for unintentional drilling fluid returns. Conditions where inadvertent returns have a higher potential to occur include:

- Fractured rock (pre-existing flow paths or presence of joints);
- Coarse grained permeable soils (gravel, cobble and boulders);
- Considerable elevation differences between the entry side and pipe side;
- Areas where HDD vertical depth of cover is insufficient; and
- Artificial features (existing exploratory bore holes).

**(2.7.2) <u>Failures:</u>**

**(2.7.2.1) Types and Causes:**

Many of the more common types of failures and their associated cause(s) are noted below in Table 2.

**<u>Table 3 - Types of HDD Failures and Their Cause</u>**

| Type | Cause |
|---|---|
| Loss of drilling fluid /Loss of circulation | • permeable deposits or jointed and/or fractured bedrock along the drill path<br><br>• excessive annular pressures for the bedrock formation or soils encountered |
| Drilling mud seepage directly into Watercourse | • permeable deposits or jointed and/or fractured bedrock along the drill path<br><br>• excessive annular pressures for the bedrock formation or soils encountered |
| Drilling mud seepage onto land and then into watercourse | • permeable deposits or jointed and/or fractured bedrock along the drill path<br><br>• excessive annular pressures for the bedrock formation or soils encountered<br><br>• suggests inadequate monitoring along drill path |
| Collapsed hole | • erosion or settling of the bore hole |

| | |
|---|---|
| Stuck drill stem or pipe string | • collapse of hole along the drill path, due to swelling of highly plastic clays, boulders, bentonic shales, coal seams<br><br>• inadequate reaming to obtain optimal bore diameter for pull back |
| Lost tools and/or drill stands | • twisting off of drill stem or metal failure of down hole tools |
| Damaged pipe or coating | • inadequate reaming to obtain optimal bore diameter for pull back<br><br>• excessive entry or exit angle for bend radius of the pipe string<br><br>• sharp objects or casing present in bore<br><br>• collapse of hole along the drill path |
| | |

**(2.7.2.2) Contingency Plans:**

A site-specific contingency plan should be prepared by the project team for each HDD. A well designed contingency plan should address the following:
- General measures;
- Equipment and personnel needs for containment and clean-up;
- Emergency response procedures;
- Plans for continuance of drilling or alternative plans;
- Time lines of acceptable response and notification;
- Clean-up methods and plans;
- Regulatory and stakeholder contacts;
- Monitoring plans; and
- Disposal plans.

**(2.7.2.3) Selection of Alternatives:**

Alternatives that may be available to allow continued use of an HDD method following an initial failure include:
- Down hole cementing to either seal off the problem zone for redrilling or seal off a large portion of the existing bore hole to a point where a new drill path (generally at a lower elevation) can be attempted; note that if reaming is necessary this method may not be successful since any reaming will remove localized cementing
- A new drill can be attempted at a steeper entry angle in an attempt to get below the problem area
- The drill can be moved and an attempt made to redrill from a new location (the revised drill path should be reviewed and revised accordingly prior to drilling); and

• The feasibility of conventional (*i.e.*, trenched) crossing methods should be considered if the drill fails; consult the appropriate project staff as well as regulatory authorities.

**(2.7.2.4) Clean-up and Remediation:**

An important decision may be required when developing plans to clean-up an inadvertent release of drilling mud. The decision can involve determination of whether or not clean-up and reclamation of a site will incur greater adverse effects on the environment than leaving the mud *in situ* and allow natural processes to reclaim the area. In some situations, a combination of minimal intervention and letting nature take its course can also be appropriate (*e.g.*, re-establishing a channel in a blocked wetland while leaving the wetland to reclaim itself).
The determination as to whether to clean-up or not must be made in conjunction with appropriate regulatory and land authorities. In many cases, this decision will be contrary to traditional practices and must be made after thorough examination of the advantages and disadvantages of each.

**Clean-up of Returns:**

The impacts from clean-up activities in sensitive environments are dependent upon the level of activity and equipment required to remove the residual drilling mud, terrain and aquatic conditions and season.

**Containment:**

Several containment measures are commonly used for the uncontrolled release of inadvertent returns (Table 3). The measure(s) chosen to be used depend upon:
• The anticipated volume to be contained;
• Existing access to the site;
• Environmental sensitivity of the area contaminated and adjacent areas; and
• Soil and weather conditions

**Table 4 - Containment of Inadvertent Returns**

| Containment Measure | Conditions Used / Application |
|---|---|
| Silt fencing | • controls migration of drilling mud in wetlands;<br>• retains small volumes of sediment;<br>• decreases overland flow of drilling mud and fluids;<br>• minimizes total suspended sediment quantities of surface waters through filtration;<br>• suitable for wetlands and the banks and shorelines of water bodies |
| Hay or Straw Bales | • retains small volumes of sediment;<br>• decreases velocity of down slope runoff;<br>• suitable for vegetated wetlands, and the banks and shorelines of water bodies |

| | |
|---|---|
| Sand Bags | • contains high volume inadvertent returns by creating a dam;<br><br>• used where silt fences and bales are not effective |
| Floating Booms | • contains drilling mud in areas with a high flood potential where drilling mud returns may be spread by water flow throughout a water body;<br><br>• suitable in water bodies where water level exceeds 30 cm |
| Plywood Sheets | • contains deeper pooled inadvertent returns;<br><br>• suitable for water bodies where clean-up of returns cannot be completed before water flow disperses the returns |

## Clean-up:

It is important for the owner, contractor, appropriate environmental specialist(s), if warranted, and appropriate regulatory agency to discuss the clean-up goals for a site subjected to an inadvertent release of drilling fluids prior to commencement of clean-up activities. If a net gain is not anticipated as a result of clean-up, alternative measures may need to be implemented. Vehicles and equipment commonly used during the clean-up of a mud release are identified in Table 4.

**Table 5 - Potential Equipment and Vehicles Used During Drilling Mud Clean-up**

| **Equipment** | **Use** |
|---|---|
| Backhoe | • for executing containment pits at drill sites situated in upland areas |
| Vacuum trucks | • for the immediate collection of drilling fluids for recycling or offsite disposal;<br>• ground low-pressure tires may be placed on vacuum trucks to reduce footprint in sensitive areas |
| Dump trucks | • for removal of drilling mud to disposal areas, if required |
| Frac tanks | • for above ground storage of drilling fluids and to contain inadvertent returns prior to disposal;<br>• minimizes overall disturbance to the site, since sump pits are not required |

| | |
|---|---|
| Swamp mats | • for minimizing sedimentation caused by heavy traffic in waterways; reduces compaction and rutting by heavy equipment in areas of wet terrain during non frozen conditions |
| Plywood sheets | • for use as walk ways for crews in sensitive areas, reduces footprint to the site |
| Brooms, rakes, spades and shovels | • for manual removal of mud from vegetated areas, for use after majority of mud are cleaned-up by larger equipment |
| Squeegees | • can be useful in removing residual mud from vegetation, thin residual mud so that vegetation is able to break through the mud layer |
| Snowshoes | • useful for workers to access areas with thickly pooled released drilling mud to assess final clean-up requirements where heavy machinery is not allowed;<br>• reduces impact of foot traffic on vegetation |
| Water rinse | • softens hard or dry drilling mud |

### (2.7.3) <u>Reporting:</u>

#### (2.7.3.1) Monitoring Reports:

Prior to the start of construction, the contractor should be required to provide the proposed monitoring report forms as part of the drilling execution plan. Frequency and types of monitoring should also be presented in the drilling execution plan.

#### (2.7.3.2) As-Built Reports:

As part of project deliverables, the contractor should provide the owner an as built drawing in a format approved or determined by the owner. The contractor should also provide a set of the monitoring reports at the end of construction.

# CHAPTER-3

## EXPRIMENTAL DATA

## (3.1) Horizontal Directional Drilling At Jai Khodiyar Spur Pipeline Project:

**Introduction of project:**

**CLIENT:** SABARMATI GAS LIMITED

**CONSULTANT:** J.P KENNY WOOD (I) PVT. LTD.

**T.P.I:** GERMANISHER LLOYD INSPECTION AND SERVICES

**CONTRACTOR:** NANDINI IMPEX PVT. LTD.

(I) **Calculation for different Factors for Narmada canal Crossing:**

Calculations required in accordance with **ASME code B31.4** for Liquid Transmissions across Pipelines for the installation of pipes by HDD are as follows:

## A. INPUT VALUES AND PARAMETERS:

| | | | | |
|---|---|---|---|---|
| Pipe Dia | D | 16.8275 | cm | Given |
| Wall Thickness | t | 0.64 | cm | Given |
| Internal Dia | | 15.55 | cm | Calculated |
| Pipe Grade | | 52 | Grade | Given |
| Specified Min. Yield Strength | S | 3655.6 | $kg/cm^2$ | Given |
| Cross Sectional Area | As | 32.55 | cm2 | Calculated |
| Moment of Inertia | I | 1,067.72 | cm4 | Calculated |
| Polar Moment of Inertia | Z | 126.90 | cm3 | Calculated |
| Weight of empty Pipe in air | Wp | 0.26 | kg/cm | Calculated |
| Weight of Water Filled Pipe in air | Ww | 0.45 | kg/cm | Calculated |
| Modulus of Elasticity | E | 2039000 | $kg/cm^2$ | Given |
| Soil Friction Angle | | 30 | Degrees | Standard |
| Pre Hydrotest Pressure | Prh | 75 | $kg/cm^2$ | Calculated |
| Post Hydrotest Pressure | Poh | 75 | $kg/cm^2$ | Calculated |
| Operating Pr. Of Pipeline | Pop | 27.54 | $kg/cm^2$ | Given |
| Length of Crossing | L | 33000 | cm | Calculated |
| Entry Angle | | 11.3 | Degrees | Designed |
| Exit Angle | | 11.3 | Degrees | Designed |
| Poisson's ratio | $\mu$ | 0.3 | | Standard |
| Fluid drag coeff (betn slurry and pipe) | f | 0.0035 | $kg/cm^2$ | Standard |
| Coeff of friction between pipe and soil | f' | 0.3 | | Standard |
| Buoyant weight of pipe | w | (0.0001) | kg/cm | calculated |
| Density of mud used | Db | 0.00115 | $kg/cm^3$ | Standard |
| Max depth of crossing | h | 1110 | cm | Given |
| Column height from water level to bed level | Hw | 510 | cm | Given |
| Column ht. from Bed to Pipe | Hs | 400 | cm | Given |
| Soil Density | Ds | 0.00266 | $kg/cm^3$ | Geotech |
| Water Density | Dw | 0.001 | $kg/cm^3$ | Standard |
| Coeff of Linear Expansion | $\alpha$ | 0.0000117 | /°C | Standard |
| Difference in Temperature during operation | $\Delta$ | 10 | | Assumed |
| Proposed ROC | R | 25000 | cm | calculated |
| Hoop Stress Limitation | | 0.9 of SMYS | | Given |
| Bending Stress limitation | | 0.9 of SMYS | | Given |
| Surface Area of Pipe | | 2030021.8 | $cm^2$ | calculated |
| Rig Pulling Capacity | | 45 Tons | | To be Used |

Notes & Calculations

A. **GIVEN:**

To Install 16.8 cm x 0.64 cm W.T. API 5L Gr. X 52 steel pipelines by Horizontal Directional Drilling technique as per ASME B31.4

B. **PURPOSE:**

Pipelines to be used for oil transmission. P = 27.54 kg/ cm2

C. **REFERENCE:**

i) Specifications, ASME B31.4 for Liquid Transmissions in Pipelines
ii) Angle of Soil Shearing resistance ASTM D-3080 methods (30 degrees)
iii) Average coeff of friction between pipe & soil; recommended values between 0.21 to 0.30 (Maidla)
Maidla, EE: "Borehole friction assessment and. application to oilfield casing design in directional. wells", Ph.D. Thesis, Louisiana State University (1987)
iv) Drag Coeff of Friction taken as 0.05 psi (Empirical)
NEN 3650 - Requirements for steel pipeline transportation system. Dutch Standard – 1993
v) Soil Investigation data

*D. CALCULATIONS:*

1. **OVERBURDEN PRESSURE AND COLLAPSE PRESSURE**

The collapse pressure is determined from the theoretical elastic curve equation

$Pc = 2E / [(1-\mu^2)(D/t)(D/t-1)^2]$

Where: D/t = 16.8 / 0.64 = 26.29

= 266.42 $kg/cm^2$

**The collapse pressure, $P_c$** = 266.42 $kg/cm^2$

The maximum overburden pressure

Po = (h*Db + hs*Ds + hw*Dw)

$P_o$= 1110 x 0.00115 + 400 x 0.00266 + 510 x 0.001

= **2.85** $kg/cm^2$

Po/Pc = **1.07%**

**Since Overburden is only 1.07%** of Collapse Pressure, Pipe is safe

2. **BOUYANCY OF PIPE**

***Pipe Volume***

Displacement of pipeline in drilling mud where volume

V, = 3.14 (D)(D)/4

D = 16.8275 cm

V = 222.40 cc/linear cm.

***Buoyancy***

Buoyancy in drilling mud where mud density

B = 222.40 x 0.00115
= 0.256 kg/cm

***Net Buoyancy***

Net buoyancy when pipeline is empty and fully submerged
= B - W or 0.256 - 0.256
= 0.000
= 0.000 kg/m of downward force

**3. COATING STRESSES**

The maximum shear stress in the pipeline coating during installation depends upon relative movements of the pipeline and the surrounding soil. Using bentonite mud, the low-friction soil-coating interface will be at a minimum.

***Coating Failure Check***

PE coatings Resistance = 2.5 kg/sq.cm.
Longitudinal Soil Stress. $\tau$ = $\tau$ = N(2-sin $\delta$)tan $\delta$
where ,
N is the force normal to the pipeline due to buoyancy
= 0.00 kg/ cm
Friction Angle ($\delta$) = 30°, (as per soil investigation report)
N = N/(30/360*3.14*D)
= 1E-05 kg/sq.cm.
2-sin 30°= 1.5
T = (N x 1.5 x Tan 30°)
**= 0.000 kg/sq.cm.**
Which is negligible as compared to the adhesive force of 2.5 kg/sq.cm th 0.00 %
**So, Coating is safe.**

**4. Max Tensile Stress During Pull**

Allowable stress = 90% of SMYS
T = 0.9 x S x As
= 107080.6 **kg**

**Check for Tensile Stress**

Max long stress that can be applied by Ri = 45 Tons
= 45000 /As
= 1382.62 **kg/sq.cm.**
= 37.82 % of SMYS
Since Max. Tensile Stress is within limits and thus **SAFE**

**Check for Bending Stress**

For Long Bending Stress During installation at ROC = 25000 cm
= Ec/r
= 686.23 kg/cm2
= 18.77 % of SMYS

**Hence Long. Bending Sress at above radius is safe.**

## 5. Radius of Curvature Calculations

### A. Before Installation

| | | |
|---|---|---|
| Pulling Load | = | 0 |
| Bending Load | = | 90% of SMYS during Overbend or on rollers |
| Hoop Stresses | = | 90% of SMYS on ground before overbend |

**Before Installation**

Min Radius for Temporary Pipe Handling

| | | |
|---|---|---|
| Limiting SMYS | = | 90% |
| Bending Stress S | = | Ec/r |
| or R | = | 5214 cm |
| | = | 52.14 meters |

### B. During Installation

| | | |
|---|---|---|
| Max Pulling Load | = | 45 Tons |
| P=F/As | = | 1382.62 kg/sqcm |
| Bending Stress Radius 25000 cm | | |
| | = | 686.23 kg/sqcm |
| Hydrotest Stress | = | 0 |
| TOTAL Stress | = | 2068.85 kg/sqcm |
| Total Percent of SMYS= | | **56.6 %** |

### C. After Installation

| | |
|---|---|
| Bending Stress at ROC | = Ec/R |
| Longitudinal Stress at Test Pressure | = pd/4t |
| Pulling Load | = 0 |
| Min Radius for Permanent Pipe Installation | |
| As per ANSI B 31.4 factor of 1.85 | |
| Permanent Radius of Curvature - R | = Ec/(0.75.S.SMYS-pd/4t) |
| Where S is design factor of 0.72 | |
| | = 17155636.3 / [ 1974.02 - 492.99 ] |
| | = 11583.58 cm |
| | = 115.8 meters |

**Permanent Radius Calc Check:**

| | |
|---|---|
| Bending Stress at ROC | = Ec/R |
| | = 686.23 kg/sqcm |
| Longitudinal Stress at Test Pressure | = pd/4t |
| | = 492.99 kg/sqcm |
| Total Stresses | = 1179.22 kg/sqcm |
| Stresses as Percent of SMYS | = **32.26 %** |

**6. Combined Equivalent . Stresses**

***A: Before Installation***

| | | |
|---|---|---|
| Hoop Stress Sh | = | pd/2t |
| Test Pressure Pt | = | 75 kg/sqcm |
| | = | 985.99 kg/sqcm |
| | = | **27 % of SMYS** |

Bending Moment for Pipe at 800 cm Supports

| | | |
|---|---|---|
| | = | $Ww.L^2/12$ |
| | = | 23,769.00 kg-cm |
| Bending Stress Sb | = | BM/Polar MI |
| | = | 187.302 kg/sqcm |

| | | | | |
|---|---|---|---|---|
| Combined Long Stress Sl1 | = | μ x Sh + Sb | Or | μ x Sh - Sb |
| | = | 295.80 + 187.30 | = | 295.80 - 187.30 |
| | = | 483.10 $kg/cm^2$ | = | 108.49 $kg/cm^2$ |

**Resultant Eq. Stress**

| | | | |
|---|---|---|---|
| Resultant 1 | = Sqrt ($Sl_1 2$- $Sl_1$xSh+$Sh^2$) | Or | Sqrt ($Sl_1 2$- $Sl_1$xSh+$Sh^2$) |
| | = 853.95 $kg/cm^2$ | | 936.46 $kg/cm^2$ |
| | = **23.36 % of SMYS** | | **25.62 % of SMYS** |

***B: After Installation***

| | |
|---|---|
| Pressure at Final Hydrotest | = 75.00 $kg/cm^2$ |
| Hoop Stress Sh | = 985.986 $kg/cm^2$ |
| Bending stress at give radius Sb | = Ec/r |
| | = 686.23 $kg/cm^2$ |
| Combined Long Stress Sl1 | = μ x Sh – E α δT + Sb |
| = | 295.80 - 0.00 + 686.23 |
| | = 982.02 $kg/cm^2$ |
| Combined Long Stress Sl2 | = μ x Sh – E α δT - Sb |
| | = 295.80 - 0.00 - 686.23 |
| | = -390.43 $kg/cm^2$ |

**Resultant Eq. Stress**

| | |
|---|---|
| Resultant 1 | = Sqrt ($Sl_1 2$- $Sl_1$xSh+$Sh^2$) |
| | = 984.01 $kg/cm^2$ |
| | = **26.92 % of SMYS** |
| Resultant 2 | = Sqrt ($Sl_2 2$- $Sl_2$xSh+$Sh^2$) |
| | = 944.07 $kg/cm^2$ |

= **25.83 % of SMYS**

**C: During Operation**

Operating Pressure = 27.54 $kg/cm^2$

Hoop Stress Sh = pd/2t

= 362.1 $kg/cm^2$

Bending stress at give radius Sb = Ec/r

= 686.23 $kg/cm^2$

Combined Long Stress Sl1 = $\mu \times Sh - E\,\alpha\,\delta T + Sb$

= 108.62 - 238.56 + 686.23

= 556.28 $kg/cm^2$

Combined Long Stress Sl2 = $\mu \times Sh - E\,\alpha\,\delta T - Sb$

= 108.62 - 238.56 - 686.23

= -816.17 $kg/cm^2$

**Resultant Eq. Stress**

Resultant 1 = Sqrt ($Sl_1 2 - Sl_1 x Sh + Sh^2$)

= 489.01 $kg/cm^2$

= **13.38 % of SMYS**

Resultant 2 = Sqrt ($Sl_2 2 - Sl_2 x Sh + Sh^2$)

= 1045.33 $kg/cm^2$

= **28.60 % of SMYS**

**7. ROLLER SPACING DURING PULL**

Allowable Bending Moment for Roller Spacing = 90% SMYS

= 3290.04 $kg/cm^2$

Max Tensile force that can be applied = 45 tons

P=F/As = 1382.62 $kg/cm^2$

Available Stress for Bending Fb = 1907.42 $kg/cm^2$

Bending Moment = Z*Fb

242055.1 kg-cm

This bending moment will determine the roller spacing

**For Simple spans (In between Rollers) BM** = $wL^2/12$

Where w is the weight of pipe in air

Max spacing between rollers = L = sqrt (242055.1 x 12 / 0.26 )

= 3369.63 cm

= 33.7 meters

**For Cantilever (On last Roller)** **BM** = $wL^2/2$

Where w is the weight of pipe in air

Max spacing between rollers = L = sqrt ( 242055.1 x 2 / 0.26 )

= 1375.64 cm

= 13.8 meters

## 8 PULLING REQUIREMENTS

Pulling loads is divided into 3 main forces. Viz:

= Fluid Drag Resistance + Soil Drag Resistance + Fluid Weight on Pull Head

= pDLf + f'wL + DbhA

= 7105.08 + 0.71 + 283.9

= 7389.68 kg

= 7.39 Tons

Total Pulling Force Required = 7.39 Tons

% of Force Required to Rig Capacity = 16.42 %

## (3.2) Construction Procedure for HDD:

## (3.4) Preconstruction:

Prior to construction, geological conditions need to be assessed to determine equipment and material needs. Walk the site to identify potential hazards, sources of interference, and special conditions. Plan bore with adequate setup area, separation from utilities and obstructions and cover.

### (3.4.1) Determine geological conditions:

The type of soil in the path of the installation determines the type of equipment and materials that are best suited for the job and whether HDD is a suitable tool for installing the utility. Depending on the job size a geological survey may or may not be conducted by an experienced geotechnical engineer. If no geotechnical survey has been preformed, the contractor should look for existing records associated with nearby construction sites, as well as other public records. Visual inspection of site geology and soil characteristics at the entry and exit pits also provide information on local geology.

### (3.4.2) Hazards, Obstructions and Utility Location:

The installation of underground utilities using trenchless methods limits visual verification of conditions near and surrounding the installation. As with any underground construction, every means should be used to locate and verify existing conditions. These means include contacting the local one-call service and area utilities, reviewing records, having a locating service locate utilities, use locating equipment such as ground penetrating radar (GPR) and electrical field sensing equipment to locate underground utilities and objects.
Prior to installation, walk the bore path with the locating receiver to look for active electrical interference. When operating near existing utilities or potential hazardous conditions, potholing should be used to verify the exact location of the existing utility and bore path.

### (3.4.3) Drilling Fluids:

Among other things, drilling fluids stabilize the hole, which mitigates hydro-fracturing and allows the product to be pulled-in more easily. The proper mix of drilling fluids is determined by the soil conditions and characteristics of the water mixed with the drilling fluid. Geotechnical information should be gathered in advance of the project and soils extracted from the hole should be tested from time-to-time during the installation to verify that the proper drilling fluid mix and additives are being used. Water should be checked and adjusted for pH and the presence of calcium.

### (3.4.4) Down-hole Equipment:

The type of down-hole equipment to be used in an HDD installation depends on the soil conditions, depth of the installation, and size and type of the product being installed. Different bits and reamers work better in different soil conditions, downhole transmitters come with different signal strengths, which should be matched for the depth of the installation. In addition, certain installations may require that breakaway swivels be used to protect the product being installed.

### (3.4.5) Rig and Mud Circulation & Recycling Equipment:

The rig size, and mud system / recycling equipment capacity should be matched to the job. A rig with inadequate torque and trust capability will cause the installation to be more difficult than it should be, putting the installation at risk. Similarly, an under capacity mud circulation system, i.e., inadequate tank or pump capacity, or recycling system, can have the same consequences.

### (3.4.6) Installation:

A successful installation should follow the planned bore with a resultant as-built that approximates the planned path, maintain specified clearance from hazards and other utilities, stays within easement, minimize and deals with inadvertent drilling fluid returns, and installs the product without damage at the surface or to the product being installed.

### (3.4.7) Recordkeeping:

Tracking systems may provide electronic records of the product location but some older systems do not. In the event that the tracking system does not record installation information electronically, accurate records must be maintained to verify location and compare against plan. Newer systems provide planning software as well as recording of installation. In addition, real-time record should be kept in a driller log of pitch and depth of each drill string, the drilling fluids used and any special conditions encountered in installation. This information provides a record for verification of pipe location and drilling operations.

### (3.4.8) Fluid Monitoring:

Monitoring drilling fluid returns is also an important QA/QC procedure. Generally, drilling fluid, which carries soils from down-hole, should exit the hole at the entry or exit end of the installation. Drilling fluid flow provides visual verification that the hole is open and that the fluids are not inadvertently escaping. Lost circulation may be an indication that something is wrong. Field tests that measure the drilling fluids viscosity and weight can help determine the need to adjust drilling fluid mix and the rate at which a product can be safely installed. If the drilling fluid is being recycled, the recycling equipment should be inspected regularly to make sure that it is removing solids from the drilling fluid. Field tests can be run that provides the percent solids in the drilling fluid. If the percent solids in the fluid become excessive, adjustments in the system operation must be made to avoid damaging equipment.

### (3.4.9) Bits and Reamers Safety:

Changing bits and reamers can be a potential safety hazard. Always use proper communications procedures and equipment such as breakout wrenches when changing bits and reamers.

**(3.4.10) Pipe Products:**

HDD can be used to install a number of products. The most common are plastic pipe and communications cables. But HDD can be, and is, used to install steel and cast-iron pipe. Each of these products has specific QA/QC procedures for joining their product. In addition, sometimes break away swivels are required during installation to protect the product from being over stressed when pulled-in.

**(3.4.11) Post-Installation:**

A successful installation using HDD is largely determined during the installation process. If plastic pipe is being installed, tension monitors or breakaway swivels may be specified by owner. The pipe or product condition at the exit end of the installation should be examined to gouges, cuts or abrasions.
Water and gas pipelines should be tested against leaks with water or as specified by the owner. HDPE fusion welds should be tested using bent trap or other tests. Steel pipe welds should be tested as specified by manufacturer. The job site should be restored. All materials including drilling fluids should be disposed of as required by local ordinance or as specified by the owner.

## (3.5) Site Preparation:

1. Prior to any alterations to work-site, Contractor shall photograph or video tape entire work area. One copy of which shall be given to CLIENT/TPIA Representative and one copy to remain with Contractor for a period of following the completion of the project.

2. Contractor shall abide by the Common Ground Alliance, Best Practices Version 1.0 or most recent, unless exceptions are specifically agreed to by CLIENT. Once the locate service has field marked all utilities, the Contractor shall verify each utility (including any service laterals, i.e. water, sewer, cable, gas, electric, phone, etc.) and those within each paved area. Verification may be performed utilizing Ground Penetrating Radar, hand dig, or vacuum excavation. Prior to initiating drilling, the Contractor shall record on the drawings both the horizontal and vertical location of the utilities off of a predetermined baseline. The Contractor shall utilize the Ground Penetrating Radar over the projected bore path whether utilities are located in the horizontal drill pathway or not, in order to reduce the opportunity of conflicting with any unforeseen obstructions.

3. Work site shall be graded and filled to provide a level working area. No alterations beyond what is required for operations are to be made. Contractor shall confine all activities to designated work areas.

4. Following drilling operations, Contractor will de-mobilize equipment and restore the work-site to original condition. All excavations will be backfilled and compacted to 95% of original density (at a minimum).

## (3.6) Material:

**(3.6.1) Pipe:** Pipe used in this method should be smooth, flexible and have sufficient strength to resist tension, bending and external installation pressure loads. This method requires structurally strong joints that resist elongation or cross section reduction. High density polyethylene (HDPE) or steel pipes are normally used for this method. However, recently other pipe materials such as fusible PVC, restrained joint PVC, and ductile iron pipe have become available for this method.

HDPE pipes shall conform to the current ASTM D1248, ASTM D3350 and ASTM F714. Steel pipe shall conform to the current ASTM A 53-97 and ASTM 139-96.

**(3.6.1.1) Allowable forces:** Allowable pulling forces for all diameters shall be determined depending on the pipe size, wall thickness, manufacturer, field conditions, pull distance, manhole, integrity, bearing capacity of soils, adjacent infrastructure, related equipment, cable strength and all other conditions.

### (3.6.1.2) Pipe dimensions:

(1) Pipe shall be round. Steel pipe shall have a roundness tolerance, so that the difference between the major and minor outside diameter shall not exceed 1% of the specified nominal outside diameter, or 6mm, whichever is less. Likewise HDPE, ductile iron and PVC pipe shall have similar roundness tolerances.

(2) Pipe shall have square and machine beveled ends. The pipe end maximum out of square tolerance shall be 1mm [measured across the diameter].

(3) Pipe shall be straight in most cases. The maximum allowable straightness deviation over any 3.3mm likewise ductile iron and PVC pipe shall have similar straightness tolerances. HDPE pipe does not need to be straight.

(4) Pipe shall be without any significant dimensional or surface deformities. All pipes shall be free of visible cracks, holes, foreign material, foreign inclusions, blisters, or other deleterious on injurious faults or defects. Any section of the pipe with a gash, blisters, abrasion, nick, scar or other deleterious faults greater in depth than 10% of the wall thickness , shall not be used and shall be immediately removed from the site.

(5) Any of following defects warrants pipe rejection:

A) Concentrated ridges, discoloration, excessive spot roughness and pitting.
B) Insufficient or variable wall thickness pipe damage from bending, crushing, stretching or other stress.
C) Pipe damage that impacts the strength, the intended use, the internal diameter of the pipe and internal roughness characteristics.
D) Any other defect of manufacturing or handling.

(6) Protecting Coating (Steel Pipe):

The product pipe may be exposed to significant abrasion during pull back. Therefore, a coating to provide a corrosion barrier as well as an abrasion barrier is required. The coating shall be bonded well to the pipe and have a hard smooth surface to resist soil stresses and reduction friction. A mill-applied fusion bonded for steel pipes.

## (3.7) Equipment requirements:

### (3.7.1) General:

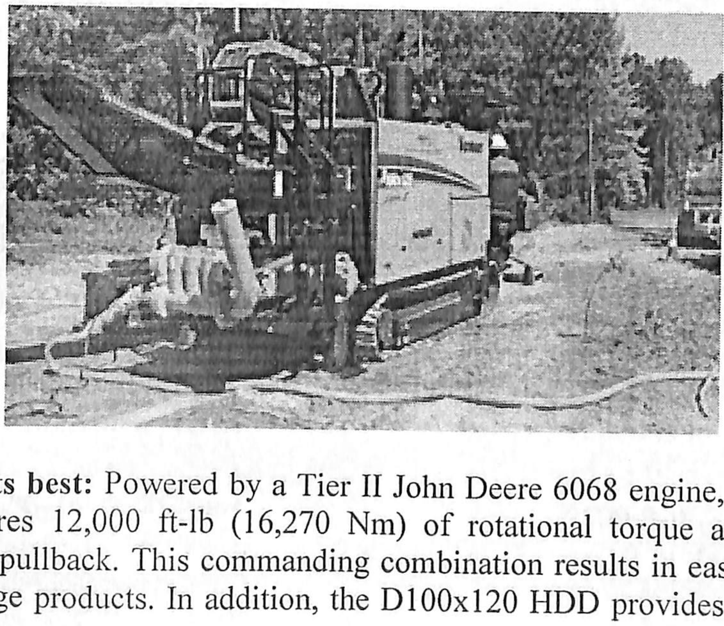
The directional drilling equipment shall consist of a directional drilling rig of sufficient capacity to perform the bore and pullback the pipe, a drilling fluid mixing, delivery and recovery system of sufficient capacity to successfully complete the drill, a drilling fluid recycling system to remove solids from the drilling fluid so that the fluid can be re-used, a guidance system to accurately guide boring operations, a vacuum truck of sufficient capacity to handle the drilling fluid volume, trained and competent personnel to operate the system. All equipment shall be in good, safety operating condition with sufficient supplies, materials and spare parts on hand to maintain the system in good working order for the duration of this project.

### (3.7.2) Drilling System:

#### (3.7.2.1) Drilling Rig:

The directional drilling machine shall consist of a power system to rotate, push and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill (bore) head. The power system shall be self contained with sufficient pressure and volume to power drilling operations. Hydraulic system shall be free of leaks. Rig shall have a system to monitor and record maximum pull-back pressure during pull-back operations. The rig shall be grounded during drilling and pull-back operations. There shall be a system to detect electrical current from the drilling string and an audible alarm which automatically sounds when an electrical current is detected.

**Figure-4→ Vermeer machine-D100x120 Series II - Full Specifications**



**Efficiency at its best:** Powered by a Tier II John Deere 6068 engine, the D100x120 Series II features 12,000 ft-lb (16,270 Nm) of rotational torque and 100,000 lb (45,359 kg) of pullback. This commanding combination results in ease and efficient handling of large products. In addition, the D100x120 HDD provides high mudflow with a 200 gpm (757 L/min) on-board pump for backreaming efficiency and powering of downhole mud motors. The D100x120 takes operator efficiency to a new level with a state of the art operator's station. The unique operator's station can be swiveled with the push of a button. Dual joystick controls integrate mud flow, breakout vise and throttle control functions into the thrust and rotation controls providing the operator with fingertip control of these functions. Drilling pressure gauges, a flow meter, and a drilling fluid pump monitoring system are all strategically located between the operator and the bore path.

| | | |
|---|---|---|
| Dimensional | | |
| Maximum Length | 410 " | 1041 cm |
| Height | 118 " | 300 cm |
| Weight w/drill rod | 39400 lbs | 17871.5 kg |
| Width (fixed tracks) | 93 " | 236 cm |
| Engine | | |
| Make & Model | John Deere 6068 | |
| Rated RPM | 2400 rpm | |
| HP Gross | 225 hp | 167.78kw |
| HP Net | 203 hp | 151.38kw |
| Operational | | |
| Thrust | 100000 lbs | 45359.2 kg |
| Pullback | 100000 lbs | 45359.24 kg |
| Maximum Spindle Speed @ max engine RPM | 120 rpm | |
| Minimum Bore Diameter | 5 " | 13 cm |
| Maximum Ground Drive Speed @ max engine RPM | 3.2 mph | 5.1 km/h |
| Maximum Carriage Speed @ max engine RPM | 175 ft/min | 53.3 m/min |
| Maximum Carriage Speed in low @ max engine RPM | 78 ft/min | 23.8 m/min |
| Drill Rack Angle | 22-33% | |
| Automated Rod Loader | Yes | |
| Spindle Torque (Stall) @ 60 RPM | 12000 ft-lb | 16269.84 Nm |
| Spindle Torque (Stall) @ 90 RPM | 9000 ft-lb | 12202.38 Nm |

| | | |
|---|---|---|
| Spindle Torque (Stall) @ 120 RPM | 6000 ft-lb | 8134.92 Nm |
| Maximum Spindle Torque | 12000 ft-lb | 16269.8 Nm |
| Fluid Capacities | | |
| Fuel Tank | 75 gal | 283.9 L |
| Engine crankcase w/Filter | 32.8 qt | 31.04 L |
| Hydraulic Tank | 85 gal | 321.8 L |
| Drilling Fluid System | | |
| Maximum Flow | 200 gpm | 757.08 Lpm |
| Maximum Pressure | 1100 psi | 75.84 bar |
| Drill Pipe | | |
| Type | Firestick II | |
| Length | 20 ' | 6.1 m |
| Joint Diameter | 4.175 " | 11 cm |
| Pipe Diameter | 3.5 " | 9 cm |
| Weight | 330 lbs | 149.69 kg |
| Minimum Bend Radius | 197.4 ' | 60.17 m |
| Rod Carrying Capacity | 300 ' | 91.44 m |
| Clip Weight (9 rod) | 3400 lbs | 1542.21 kg |
| Clip Weight (15 rod) | 5500 lbs | 2494.76 kg |
| Features | | |
| Breakout System | Yes- power vise | |
| Drilling Lights | Yes | |
| Flow Indicator | Yes | |
| Stakedown System | No | |

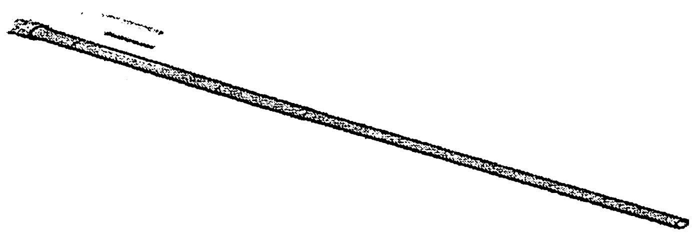
### (3.7.2.2) Drill Head:

The drill head shall be steerable by changing its rotation and shall provide the necessary cutting surfaces and drilling fluid jets.

### (3.7.2.3) Mud Motors (if required):

Mud motors shall be of adequate power to turn the required drilling tools.

**Figure-5→5 1/2 SWB Mud Motor**



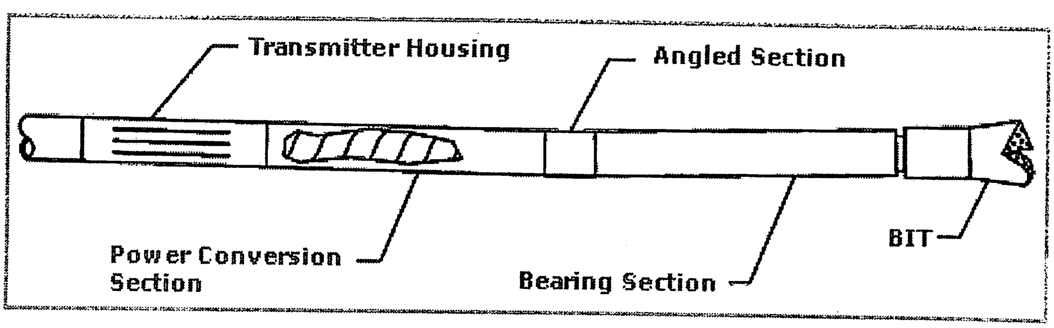



**Figure-6→ Typical mud motor drilling configuration.**

**Another HDD innovation:** The patented Vermeer 5.5" (14 cm) Survey While Boring (SWB) Mud Motor features an innovative upfront transmitter that allows the operator to know the current location of the bit in the bore path. The 5.5" SWB supports a variety of larger Vermeer Navigator HDDs including the D50x100A, D55x100, D80x100, D80x120 and D100x120.

| | | |
|---|---|---|
| General | | |
| Diameter-Housing | 5.5 " | 14 cm |
| Length with Transmitter Housing | 17 ' | 5.2 m |
| Weight with Transmitter Housing | 1175 lbs | 533 kg |
| Operating Torque | 1800 ft-lb | 2440.5 Nm |
| Stall Torque | 2600 ft-lb | 3525.1 Nm |
| Bit Diameter-Minimum | 6.5 " | 17 cm |
| Bit Diameter-Maximum | 7.875 " | 20 cm |

| | | |
|---|---|---|
| Flow-Minimum | 40 gpm | 151.4 Lpm |

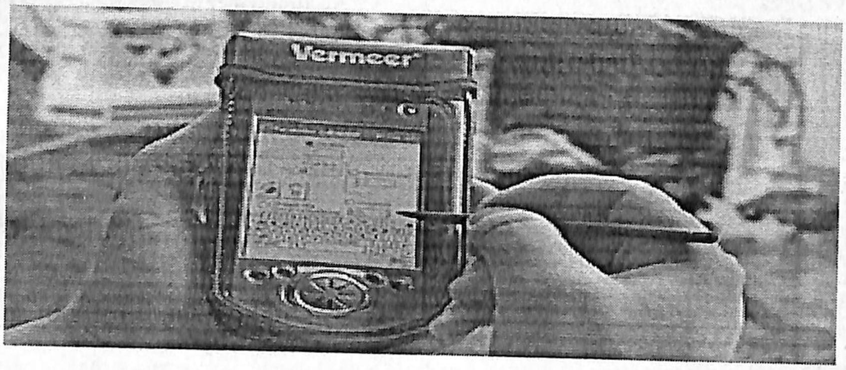
**(3.7.3) Guidance System:**

A Magnetic Guidance System (MGS) or proven gyroscopic system shall be used to provide a continuous and accurate determination of the location of the drill head during the drilling operation. The guidance shall be capable of tracking at all depths up to eighty feet and in any soil condition, including hard rock. It shall enable the driller to guide the drill head by providing immediate information on the tool face, azimuth (horizontal direction), and inclination (vertical direction) The guidance system shall be accurate to +/-2% of the vertical depth of the borehole at sensing position at depths up to one hundred feet and accurate within 1.5 meters horizontally. The Guidance System shall be of a proven type and shall be operated by personnel trained and experienced with this system. The Operator shall be aware of any magnetic anomalies on the surface of the drill path and shall consider such influences in the operation of the guidance system if using a magnetic system.

**(3.7.3.1) Field Calculator**

**Feature:** Product Pullback Calculator
**Benefit:** Calculates the minimum minutes per rod it will take during pullback to help prevent out-running mud and getting the product stuck down hole. In addition, it will calculate the hole volume, entire bore path volume, and the mud volume for the backream.

**Figure-7→Field Calculator**




**Big power in a palm-sized program!** The Field Calc system is the latest, easy-to-use bore-planning and mapping tool available from Vermeer. This software boasts features that include setback distance calculation, point-to-point bore path calculation, pullback time estimation, outside diameter and orientation configuration of multiple, same-sized ducts, and a pre-drill checklist reminder.

### (3.7.3.2) Interragator EZ GPR

<u>**Figure-8→Interragator EZ GPR**</u>

**The quick and easy way to locate buried utilities:** The Interragator EZ GPR System is designed with the needs of the utility contractor and locating personnel in mind. The Interragator EZ offers the latest advancements in ground penetrating radar electronics with a simple to use operator interface. The system is lightweight and compact and can be quickly set up in a few minutes. GPR data is displayed in real-time during a survey and the reverse cursor allows immediate and accurate utility marking. A depth calibration routine makes system calibration easy.

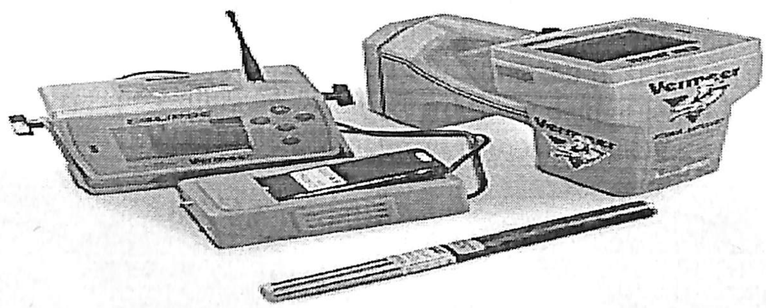
| | | |
|---|---|---|
| Processing/Data analysis | | |
| Min. Pipe Diameter Detectable | Depth dependent | |
| Max. Target Depth | 20 ft - Soil Dependent | |
| Minimum Target Depth | Less than 4 inches | |
| Penetrate Shallow Rebar Measure | Yes | |
| Good Multiple Target Detection | Yes | |
| Ghost Images | No | |
| Max. Target Depth Observed | 25 ' | 7.5 m |
| Min. Target Depth Observed | 4 " | 10 cm |
| Effective at Mapping Targets | Yes | |
| Max. Angle Between Line & Utility | 90 deg | |
| Antenna Performance | Good or Better signal penetration & utility detect | |

### (3.7.4) Bore Tracking and Monitoring:

At all times during the pilot bore the Contractor shall provide and maintain a bore tracking system that is capable of accurately locating the position of the drill head in the x, y, and z axes. The Contractor shall record these data at least once per drill pipe length or every twenty-five (25) feet, whichever is most frequent.

(3.7.4.1). Deviations between the recorded and design bore path shall be calculated and reported on the daily log. If the deviations exceed plus or minus 5 feet (horizontal or vertical deviation) from the design path, such occurrences shall be reported immediately to client. The Contractor shall undertake all necessary measures to correct deviations and return to design line and grade.

**Figure-9→Eclipse Drill Head Locator**




**The Vermeer Eclipse locator** is a revolutionary tracking system for the HDD industry, being the first of its kind to display drill head location and locate points in a real-time, bird's eye view. A patented 3-D antenna configuration enables the unit to see locate points and the transmitter's position - allowing the operator to walk directly to the drill head. Additionally, the receiver provides 3-D left/right and up/down remote steering information.

Receiver

| | | |
|---|---|---|
| Frequency | Proprietary | |
| Remote Steering Function | Target depth and direction can be set by the user | Shows left/right and up/down deviation |
| Locating Method | Over the head or front/rear locate points | Walk to the drill head directly from any location |

## (3.7.5) Tooling for backreaming in rock with HDD:

As with all horizontally drilled bores, a successful pilot bore in rock is only the first challenge in a complete utility line installation. Tooling for backreaming is also specialized and is selected in accordance with the encountered rock formation and the drilling unit being utilized.

### (3.7.5.1) Drag-type or scraping backreamers:

These reamers typically feature carbide buttons or carbide tipped teeth on a reamer body which is rigidly attached to the drill pipe to rotate in conjunction with the pipe. As the reamer rotates, the carbide segments scrape along the face of the borehole to break or gouge away the rock. A couple examples of drag-type reamers are shown in Figures 6A and 6B. These reamers will be used with directional drilling unit.

The heavy construction of reamer Figure 6B and progressive spiral shape of this reamer are particularly effective in cutting through cobble formations and tightly packing the hole walls to provide smooth entry for the installed product.

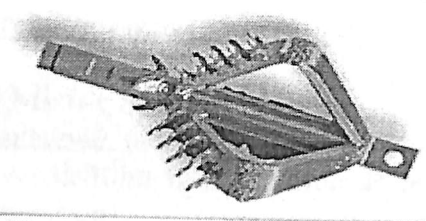


**Figure 10A.**
**Three Wing Rock reamer from Kodiak Ditch Witch.**

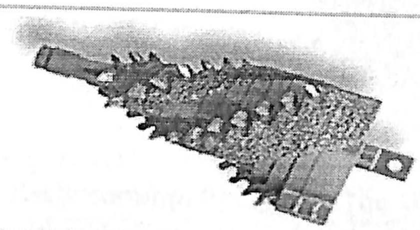


**Figure 10B.**
**Cobble reamer from Ditch Witch.**

### (3.7.5.2) Rolling element backreamers:

For solid rock formations whose compressive strengths render the drag-type reamers ineffective, the use of rolling element reamers is common. These reamers fracture the rock in much the same way as a tri-cone bit for pilot drilling. As the reamer is pulled into the face of the excavation and rotated, hardened steel teeth or carbide buttons embedded in steel "cones" roll across the rock face and create small compression fractures in the rock surface at each tooth/rock interface. A couple types of rolling element reamers are shown in Figures A1 and A2.

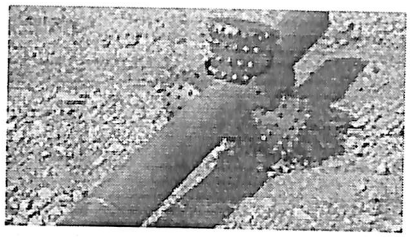


**Figure A1.**
**Replaceable cone hole**

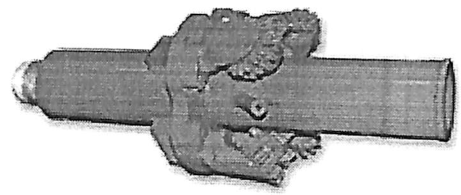


**Figure A 2.**
**Split-bit type reamer. opener.**

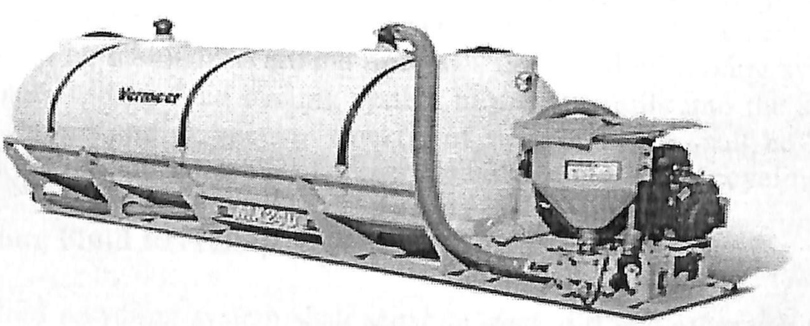
The reamer of Figure A1 is typically referred to as a hole opener and features specially shaped cones which may be readily replaced as they wear. The buttons on this reamer which contact the rock to fracture it. Hole openers with carbide inserts, or TCI reamers, are used for harder, more abrasive rock formations. The reamer of Figure A2 is commonly known as a "split-bit" reamer.

**(3.7.5.3) Drilling Fluid Pressures and Flow Rates:**_
Drilling fluid pressures and flow rates shall be continuously monitored and recorded by the Contractor. The pressures shall be monitored at the pump. These measurements shall be made during pilot bore drilling, reaming, and pullback operations.

**(3.7.6) <u>Drilling Fluid (Mud) System:</u>**

**(3.7.6.1) Mixing System:**
A self-contained, closed, drilling fluid mixing system shall be of sufficient size to mix and deliver drilling fluid. Mixing system shall continually agitate the drilling fluid during operations.

**<u>Figure-11→MX240</u>**



**High performance and Flexible mounting options:** The MX240 Modular Drilling Fluid System is designed to provide fast mixing of high volumes of drilling fluid for large-diameter and long-distance HDD applications. The system features a 25 hp (18.6 kw) Kohler gas or 22 hp (16.4 kw) Hatz diesel engine and can support either a

750 gallon (2839 L) or 1000 gallon (3785 L) mixing tank.
The modular design provides flexibility for a variety of mounting configurations to meet your specific needs. A new venturi design features a direct injection hose, which allows the operator to inject drilling additives directly into the tank or hopper.

| | | |
|---|---|---|
| Power Pack | | |
| Gas Engine Option | Kohler CH25 | |
| Gas Engine Option Horsepower | 25 hp | 18.6 kw |
| Diesel Engine Option | HATZ 2G40 | |
| Diesel Engine Option Horsepower | 22 hp | 16.4 kw |
| Gross Horsepower | 22 hp | 16.4 kw |
| Mixing Action | Venturi/Recirculation | |
| Integrated Mixing Hopper | Round Plastic | |

**(3.7.6.2) Drilling Fluids:**

Drilling fluid shall be composed of clean water, appropriate additives and clay. Water shall be from an authorized source with a minimum pH of 6.0. Water of a lower pH or with excessive calcium shall be treated with the appropriate amount of sodium carbonate or equal. The water and additives shall be mixed thoroughly and be absent of any clumps or clods. No potentially hazardous material may be used in drilling fluid.

**(3.7.6.3) Delivery System:**

The delivery system shall have filters in-line to prevent solids from being pumped into the drill pipe. Connections between the pump and drill pipe shall be relatively leak-free. Used drilling fluid and drilling fluid spilled during drilling operations shall be contained and conveyed to the drilling fluid recycling system. A berm, minimum of 12" high, shall be maintained around drill rigs, drilling fluid mixing system, entry and exit pits and drilling fluid cycling system to prevent spills into the surrounding environment. Pumps and or vacuum truck(s) of sufficient size shall be in place to convey excess drilling fluid from containment areas to storage and recycling facilities.

**(3.7.6.4) Drilling Fluid Recycling System:**

The drilling fluid recycling system shall separate sand, dirt and other solids from the drilling fluid to render the drilling fluid re-usable. Spoils separated from the drilling fluid will be stockpiled for later use or disposal.

**(3.7.6.5) Control of Drilling Fluids:**

The Contractor shall follow all requirements of the Frac-Out and Surface Spill

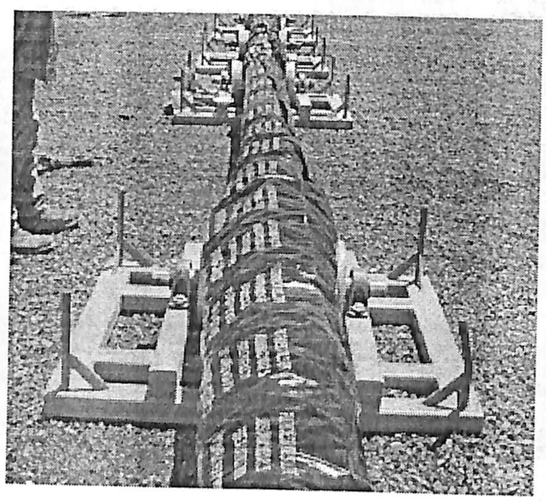
Contingency Plan as submitted and approved and shall control operational pressures, drilling mud weights, drilling speeds, and any other operational factors required to avoid hydro fracture fluid losses to formations, and control drilling fluid spillage. This includes any spillages or returns at entry and exit locations or at any intermediate point. All inadvertent returns or spills shall be promptly contained and cleaned up. The Contractor shall maintain on-site mobile spoil removal equipment during all drilling, pre-reaming, reaming and pullback operations and shall be capable of quickly removing spoils. The Contractor shall immediately notify client of any inadvertent returns or spills and immediately contain and clean up the return or spill.

**(3.7.7) Other Equipments:**

**(3.7.7.1) Pipe Rollers:**

Pipe rollers, if utilized, shall be of sufficient size to fully support the weight of the pipe while being hydro-tested and during pull-back operations. Sufficient number of rollers shall used to prevent excess sagging of pipe.

**Figure-12→Pipe Rollers**



**(3.7.7.2) Pipe Rammers:**

Hydraulic or pneumatic pipe rammers may only be used if necessary and with the authorization of client Representative.

**(3.7.7.3) Restrictions:**

Other devices or utility placement systems for providing horizontal thrust other than those defined above in the preceding sections shall not be used unless approved by the client Representative prior to commencement of the work. Consideration for approval will be made on an individual basis for each specified location. The proposed device or system will be evaluated prior to approval or rejection on its potential ability to complete the utility placement satisfactorily without undue stoppage and to maintain line and grade within the tolerances prescribed by the particular conditions of the projects.

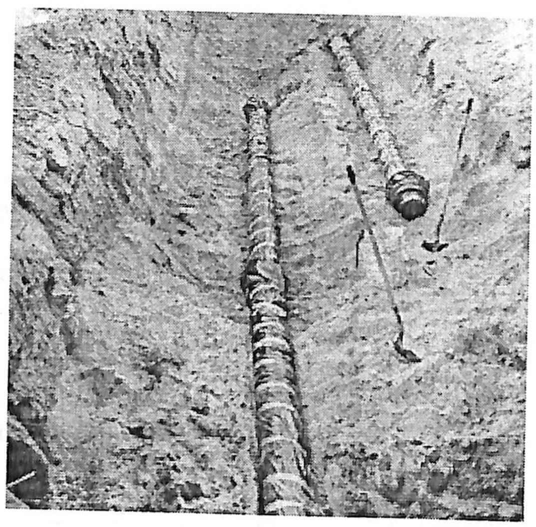
## (3.8) Installation Methods for HDD of Pipe:

### (3.8.1) Cartridge Method:

The cartridge method involves connecting the joints during installation, one at a time, and is preferred in locations where rights of way (ROWs) or easements are limited. Ductile Iron pipe restrained joint systems can be quickly assembled as the drill string is retracted.

During pull-back the joint assembly normally requires little more time than it takes to disassemble the drill stem sections and store them on the rack. This installation method requires significantly less space or right-of-way requirements than the assembled-line method.

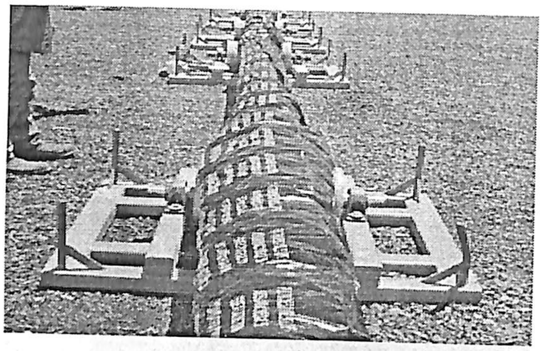
**Figure-13→Cartridge Method**

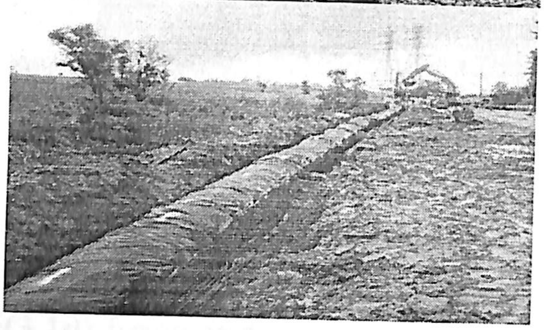


### (3.8.2) Assembled-Line Method:

The assembled-line method involves stringing out the connected pipe on the ground prior to pull-back. With this method it is necessary to have substantial space available to pre-string the pipe above ground (generally on rollers) in direct alignment with the end of the drill path. This is normally the only option for welded-steel and fused-joint polyethylene pipe due to the significant time required to position and properly weld or fuse individual pipe sections.

**Figure-14→Assembled Line Method**





**(3.9) Drilling Mud:**

"Drilling mud" is normally utilized to lubricate the cutting head during the drilling operation and stabilize the reamed bore path prior to and during pull-back. The "drilling mud" usually consists of a mixture of fresh water and bentonite clay; however, other materials—such as polymers—are sometimes used.
Bentonite is a naturally occurring clay mineral that forms a mud when mixed with water. Drilling fluids are characterized by their viscosity, gel strength, filtration, fluid loss, fluid density, pH, and lubricity. The principal functions of drilling fluids used in HDD are:

1. Transporting drill cuttings to the surface by suspending and carrying them in slurry that flows in the annulus between the bore wall and the drill/product pipe.

2. Cleaning build-up on drill bits or reamer cutters by directing fluid streams at the cutters.

3. Cooling the down hole tools and electronic equipment.

4. Lubricating to reduce the friction between the drill pipe/ product and the bore wall.

5. Stabilizing the bore path, especially in loose or soft soils, by building a low-permeability filter cake and exerting a positive hydrostatic pressure against the bore path wall. The filter cake and positive hydrostatic pressure reduce obstruction of the bore path and prevent formation fluids (i.e., groundwater) from flowing into the bore, or drilling fluids from exiting the bore path into the formation (loss of circulation).

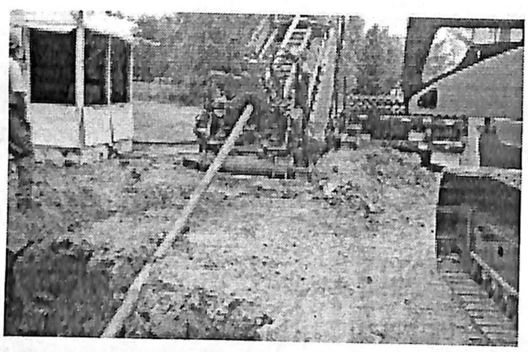
6. Providing hydraulic power to down hole mud motors. For HDD, the proper drilling fluid mixture and delivery pressure is heavily dependent upon the type of soil encountered. It must be formulated for the anticipated geological conditions. For simplicity, soil conditions may be defined as either a coarse soil (sand and gravel) or a fine soil (clay, silt, and shale). In general, for coarse soils bentonite should be used,

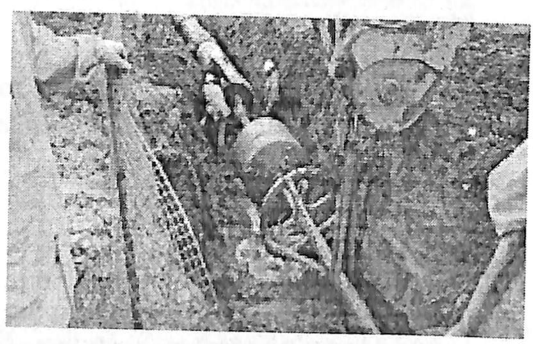
while for fine soils polymers (possibly added to a bentonite base) are recommended.

**Figure-15→Drilling Mud/Bentonite Solution**

## (3.10) Procedure:

HDD is a trenchless construction method that involves drilling a small pilot hole, using technology that allows the drill to be steered and tracked from the surface. The pilot bore is launched from the surface at an angle between 8 and 20 degrees to the horizontal, and transitions to horizontal as the required depth is reached. A bore path of very gradual curvature or near-straight alignment is normally followed to minimize friction and to stay within the allowable joint deflection and the allowable curve radius for the pipe. This minimizes the chance of getting the pipeline "hung up" in the soil or damaging the pipe.





The pilot hole is enlarged (usually approximately 1.5 times the largest outside diameter of the new pipe) by pulling back increasingly larger reamers, or reaming heads, from the pipe insertion point to the rig side.

To achieve the appropriate bore path size it may be necessary to perform several reaming operations. Generally, all reaming procedures prior to the actual product installation are referred to as pre-reams, and the final ream to which the product pipe is attached is referred to as the back ream.

After the pre-reams, the pulling head and connecting product pipe are attached to the reamer using a swivel, a device that isolates the product pipe from the rotation of the HDD drill pipe. The product pipe is then pulled behind the final reamer back through the horizontal directional drill path to the exit pit on the rig side.

**(3.10.1) Pilot Hole:**

The pilot hole shall be drilled along the path shown on the plans and profile drawings or as directed by the client/TPIA Representative in the field. Unless approved otherwise by CLIENT, the pilot-hole tolerances shall be as follows:

(3.10.1.1) Elevation:
As shown on the plans.

(3.10.1.2) Alignment:
±5 feet and within 3 feet of right-of-way or easement boundary.

(3.10.1.3) Curve Radius:

The pilot hole radius shall be no less than 80% of the maximum bending radius as recommended by the pipe manufacturer of the pipe being installed. In no case shall the bending radius be less than 30 pipe diameters, unless approved otherwise by CLIENT/TPIA.

(3.10.1.4) Entry Point Location:

The exact pilot hole entry point shall be within ±5 feet of the location shown on the drawing or as directed by the CLIENT/TPIA Representative in the field.

(3.10.1.5) Exit Point Location:

The exit point location shall be within ± 5 feet of the location shown on the drawing or as directed by the CLIENT/TPIIA Representative in the field.

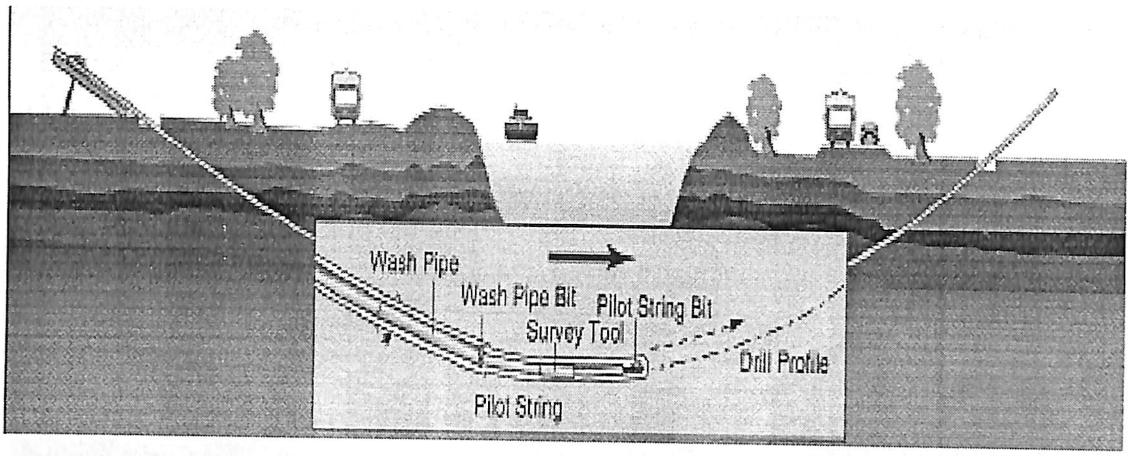
(3.10.1.6) Limitations on Depth:

If not noted on the plans, 6" steel pipe and smaller shall be installed with a depth of 3 to 5 feet and 8"steel pipe thru 12" pipe shall be installed with a depth of 3 to 6 feet unless it is required to install the pipe deeper due to utility conflicts. Steel pipe larger than 12" shall be specifically designed by the engineer and approved by CLIENT/TPIA. Where utilities cross under DOT roads, the depth of cover shall comply with applicable DOT permit.

(3.10.1.7) Water Main and Non-Water Main Separation Requirements:

The minimum separation requirements between steel water main and a non-water main shall be as outlined in next section.

**Figure-16→Pilot Hole Process**




**(3.10.2) Reaming process:**

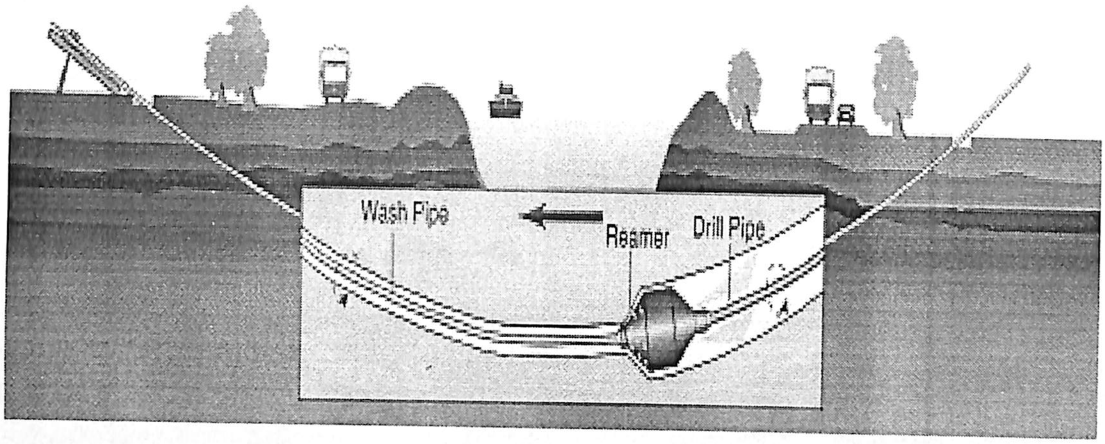
The general "rule of thumb" is to ream the drill hole to 1.5 times the outside diameter including coating and insulation of the pipe to be installed. This diameter will generally provide for an adequate allowance for the installation of the pipe. The multiplier may be reduced for large pipe diameters (>36"/914 mm O.D.)

The number of reaming passes that will be determined by the hardness of the material being reamed and the ability to remove cuttings from the hole.

Consider product pipe and reamer diameter requirements;

| Product Diameter | Reamer Diameter |
|---|---|
| <8" | Product + 4" |
| 8" to 24" | Product * 1.5 |
| >24" | Product + 12″ |

**Figure-17→Reaming Process**




**(3.10.3) Pull Back:**

After successfully reaming bore hole to the required diameter, Contractor will pull the pipe through the bore hole. In front of the pipe will be a swivel and reamer to compact bore hole walls. Once pull-back operations have commenced, operations must continue without interruption until pipe is completely pulled into bore hole. During pull-back operations Contractor will not apply more than the maximum safe pipe pull pressure at any time. Maximum allowable tensile force imposed on the pull section shall be equal to 80% of the pipe manufacturer's safety pull (or tensile) strength.

1. Torsional stress shall be minimized by using a swivel to connect a pull section to the reaming assembly.

2. The pullback section of the pipeline shall be supported during pullback operations so that it moves freely and the pipe is not damaged.

3. External pressure shall be minimized during installation of the pullback section in the reamed hole. Damaged pipe resulting from external pressure shall be replaced at no cost to the CLIENT/TPIA.

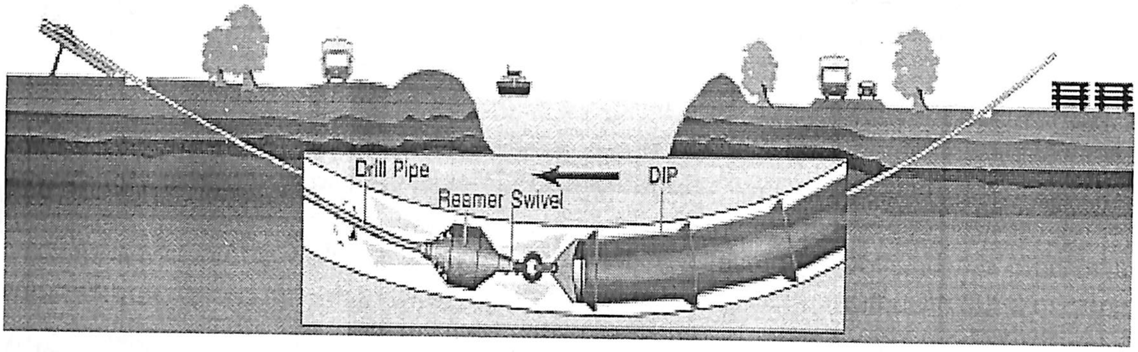
4. Buoyancy modification shall be at the discretion of the Contractor and shall be approved by the CLIENT/PTIA Representative. The Contractor shall be responsible for any damage to the pull section resulting from such modifications.

5. In the event that pipe becomes stuck, Contractor will cease pulling operations to allow any potential hydro-lock to subside and will commence pulling operations. If pipe remains stuck, Contractor will notify CLIENT/TPIA Representative. CLIENT Representative and Contractor will discuss options and then work will proceed

accordingly.

6. Contractor shall provide a break-away link between the swivel and the pipe or a combination swivel and break link. Break-away link shall be rated at 80% of pipe manufacturer's safe pull (tensile) strength. Break pins shall be color coded for easy identification. Contractor shall provide rated break-away link for each material and pipe size(s) for the project.

**Figure-18→Pull Back Process**




## (3.11) Work site restoration:

1) Access pits and excavation shall be backfield with suitable material, and in a method approved by the owner's Engineer/Inspector.
2) The disturbed grass-surface area shall be top soiled, seeded, fertilized, mulched and anchored according the owner's specification for construction. Slopes steeper than 1-on-3, shall be sodded. If a final site restoration is not completed within 5 days after completion of the operation, the installation of temporary soil erosion and sedimentation control measures shall be required.
3) Upon completion of the work, the contractors shall remove and properly dispose of all excess materials and equipment from the work site.
4) The permit, including the surety requirements, shall remain in effect for a minimum of one year after completing the work to monitor for settlements of the pavements and / or slope.

## (3.12) Comparison over other trenchless construction methods and Open-Cut construction method:

HDD offers several advantages when compared to other trenchless construction methods:

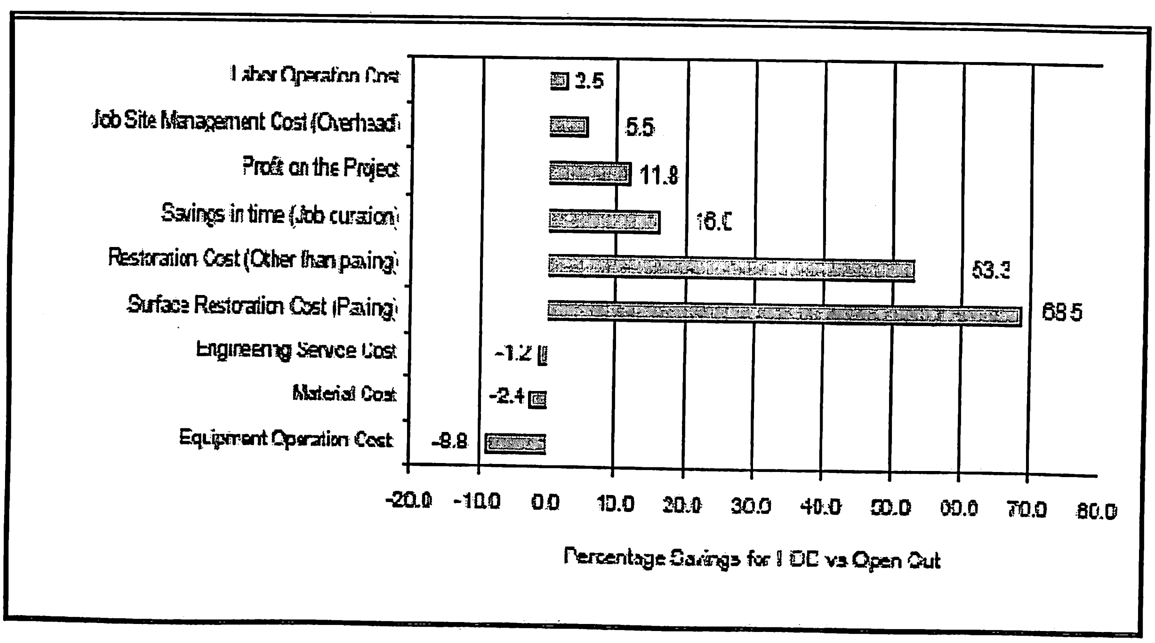
- Complicated crossings can be quickly and economically accomplished with a great degree of accuracy since it is possible to monitor and control the drilling operation.
- Sufficient depth can be accomplished to avoid other utilities.
- In river crossing applications, danger of river bed erosion and possible damage from river traffic is eliminated.
- Requires only a small construction footprint.

**Comparison over Open-Cut construction methods:**

On the basis of the following points HDD can be compared with open-cut construction methods.

1. Three of the nine cost factors considered indicated open cut to be slightly cheaper than HDD. The averages of the respondents indicate that contractors spend approximately nine percent more on equipment operational costs for HDD than open cut. Material costs were also found to be nearly three percent higher. The engineering service costs on a project are generally expected to be similar for HDD as open cut.

**Figure 19: Cost factors for HDD vs. open cut (positive value reflecting savings in HDD)**




2. The following table indicates that HDD has a significant reduction on the projects environmental factors. Dust pollution on an open cut project was found to be almost

three times the impact than on an HDD project. Travel effect on the public, effect on business sales, and the impact on the ecological system have considerable advantages when HDD is utilized. It should be noted that HDD scored higher for removal of waste materials. This is due in large part to the fact that it can be very difficult to find waste sites that accept drilling fluid. On open cut projects; however, if soils are removed, disposal of waste materials is usually non-problematic.

**Table-6- Impact of eco-social factors**

| Eco-Special Impacts | HDD | Open Cut | Difference |
|---|---|---|---|
| Dust Pollution | 2.4 | 7.2 | -4.8 |
| Travel effect on general public | 3.4 | 7.7 | -4.3 |
| Effect on the ecological system | 3.2 | 6.8 | -3.6 |
| Vibration | 3.2 | 6.3 | -3.2 |
| Effect on business sales | 4.3 | 6.4 | -2.1 |
| Noise Pollution | 4.9 | 6.6 | -1.7 |
| Operational costs by contractor | 5.4 | 6.4 | -1 |
| Maintenance costs by contractor | 6.9 | 6.1 | .8 |
| Disposal of waste material | 6.6 | 4.6 | 2 |

3. The next table, which indicates that having a detailed understanding of the soil conditions, is much more critical for HDD. Also, having the proper information and quantity of existing utilities in the construction area is as important for open cut as it is for HDD. As would be expected, the ground water table and the weather conditions are much more critical on an open cut project. The impact of surface obstructions for open cut is much more important however buried obstructions such as timber and concrete have a greater importance for HDD. Safety issues for both types of construction were surprisingly similar, even though HDD was expected to have a lower rating due to a significant reduction of open trenching and a reduction of fatalities.

**Table-7- Consideration factor comparison**

| Project Consideration Factors | HDD | Open Cut | Difference |
|---|---|---|---|
| Surface Obstructions | 5.1 | 8.6 | -3.5 |
| Ground WATER Table | 5.2 | 8.5 | -3.3 |
| Weather Conditions (Rain/Snow/Heat) | 4.8 | 7.3 | -2.5 |
| Traffic Restrictions | 5.7 | 7.8 | -2.1 |
| Safety Issues | 7.4 | 8.0 | -0.6 |
| Density of Existing Utilities | 8.5 | 8.3 | 0.2 |
| Availability of existing utilities info. | 8.7 | 8.0 | 0.7 |
| Buried Obstructions (i.e., timber, concrete, etc) | 7.6 | 6.6 | 1.1 |
| Soil Condition/ Properties | 8.5 | 6.9 | 1.5 |

**Other advantages:**

- Significantly reduced construction time:
  With the elimination of costly and time-consuming excavation and restoration associated with open trenching, installations can be performed in less time. Additionally, the mobility and quick times of the directional drill reduce costs as well.
- Saves expensive or historic landscapes and structures:
  Directional drilling minimizes the need to remove expensive landscaping or endanger historic structures with excavation.
- Eliminates unsightly excavation and trenching activity:
  Conventional trenching operations require many pieces of equipment, all of which contribute to noise and sight pollution on site, as well as litter the environment with spoil pipes and trenches. Only the drill, with a minimal amount of support equipment, is required on horizontal directional drilling projects – and trenches are eliminated.
- Reduced impact on residents and business around construction site:
  There is no need to close roads or redirect traffic around the construction site, thus maintaining normal traffic patterns and access to businesses and residential property.
- Reduction in long-term costs associates with settlements:
  Installations utilizing directional drilling reduce and in some cases eliminate settlements above the new pipe or conduit. This is particularly advantageous when installations are conducted beneath roads, highways, rail lines and foundations.
- Minimum disruption to road, rail and other service users.
- Minimum reinstatement costs.

# CHAPTER-4

## ECONOMIC PHASE

## (4.1) Economic Considerations:

### (4.1.1) Potential Economic Advantages of HDD:

The development of guidance systems specifically for HDD use has made HDD technology increasingly efficient and productive. Experience acquired by HDD contractors and operators during the early period of HDD use has resulted in more competent operating directional equipment as well as more knowledgeable contractors. There are several potential economic advantages of employing HDD construction techniques as opposed to conventional pipeline installation techniques including:

- Increased use of HDD technology has resulted in associated equipment and labour costs being spread over multiple projects, making individual projects more affordable;
- High installation performance;
- No additional expense arising from closed streets, irrigation canals or railways;
- Minimal to non-existent reclamation costs to the obstacle crossed since surface disruption along the alignment drilled is minimized (inadvertent drilling mud release still requires mitigation);
- The need for removal, restoration, monitoring, maintenance and other long-term costs associated with trench settlement is eliminated through the use of HDD crossings;
- Road cuts, which are expensive to restore, are minimized;
- HDDs are possible year-round (instream timing restrictions may apply to conventional construction methods); and
- HDD can be faster than conventional crossing methods.

### (4.1.2) Costs of HDD Applications:

The costs associated with an HDD are influenced by:
- Location;
- Access;
- Environmental setting;
- Geological characteristics;
- Obstacle to be crossed;
- Required rig size to complete the drill;
- Total length of the drill; and
- Pipe diameter(s) to be installed.

The types of costs associated with HDDs, as with any construction activity, are direct costs, indirect costs and potential risks to the public. Operating and maintenance costs of completed projects should also be considered for HDD Projects.

### (4.1.3) Direct Costs and Benefits of HDD Applications:

Direct costs are readily identified within the scope of a project and are paid for directly from the budget of a project (*i.e.,* the cost of the project itself). Considerable direct costs are often associated with conventional pipeline construction installation methods. Common costs related to conventional construction methods include:

- Excavating equipment required for trenching;
- Labour;
- Topsoil and spoil handling;
- Backfill costs; and
- Reclamation and restoration costs.

Where conventional construction impacts traffic volumes, water bodies or environmentally sensitive areas, direct costs are often substantially increased. HDD technology can be used to avoid environmentally sensitive areas, areas of large traffic volumes and water bodies, and minimizes the requirements for moving and handling large quantities of topsoil, spoil and backfill. Consequently, there are often some costs saving advantages over conventional installation techniques. In addition, the costs of using trenchless technology do not increase with depth of cover as dramatically as with conventional construction methods, thereby reducing overall costs.

### (4.1.4) Indirect Costs and Benefits of HDD Applications:

Indirect costs are tangible and intangible costs which cannot be included in the project costs. Indirect costs accumulated by the proponent on a project depend upon the work site and the issues present or encountered. Factors affecting indirect costs include:

- Traffic obstruction;
- Road damage;
- Environmental damage;
- Air and noise pollution;
- Project delays; and
- Social costs.

With the potential to reduce the approval period and construction duration, and avoid or reduce overall disturbance, HDD applications appeal to indirect cost reduction by minimizing interference with community activities and operations, and adverse environmental effects. Air and noise pollution may also be minimized due to the often reduced installation time. Traffic obstruction and road damage are avoided, since the roads are not affected on the surface by construction. Safety issues and costs associated with HDD applications may also be less than those related to conventional construction techniques (*i.e.,* open excavation), and fewer people are required onsite for HDDs, reducing the chance of injury in the workplace.

# CHAPTER-5

## CONCLUSION AND RECOMMENDATION

## (5.1) Conclusion and Recommendation:

### (5.1.1) Conclusion:

Horizontal Directional Drilling is a useful tool that is available for the installation of Pipeline crossings across Rivers, Canals, Railways, Roads, and Sewers etc., given the correct conditions. The selection of the appropriate method of construction is often determined by site condition permit both open cut and HDD, consideration should be given to tendering both alternatives.

By the designing calculation, we determined that the pipeline used in this project is suitable, that can resist the all type of stresses, which act on pipe during construction and operation period.

The successful design and construction of an HDD is the result of a team effort combining the skills of the regulatory group, owner, engineering consultant, environmental consultant, inspection services and the specialist HDD contractor. Success in this endeavor is measured in more than the successful pull back of the pre-built pipeline drag section. It is the completion of the project for a reasonable cost with minimal environmental impact and in a manner that allows the contractor to make a fair profit. These should be the goals in any type of project including an HDD installation.

It is important to realize that an HDD may represent the critical path on the overall project schedule. In addition, an HDD may have the highest risk of failure of any activities on a project. Therefore, all aspects of planning, design and construction for an HDD need to be assigned a high priority or importance value due to their potential effect on the overall project.

**(5.1.2) Recommendations:**

i. Along drill path monitoring shall be adequate to prevent the drilling Mud seepage on to land and than in to water course.
ii. Bentonite solution shall be appropriate to prevent the collapsed hole along drill path.
iii. To prevent the pipe damage or coating damage adequate reaming should be done to obtain optimal bore diameter for pull back.
iv. Control migration of drilling mud in wet lands.
v. Retain small volume of sediment.
vi. In the case of an instream release, the downstream movement of drilling mud should be prevented if possible by isolating the release point or diverting higher velocities around the release.
vii. Drilling activities will not be resumed until a site specific drill continuance plan and monitoring program have been approved by the owner.
viii. All the equipment shall be verified by the Owner/TPIA.
ix. Construction risk on a project can be minimized by ensuring that sufficient planning is conducted and an adequate geotechnical investigation is carried out.

# References

(1) Canadian Association Of Petroleum Producers:: Planning Horizontal Direction Drilling for Pipeline Construction. (September-2004).

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(4) Standard Specifications Section 02446:: Horizontal Direction Drilling.

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(6) The City Of Overland Park (KANSAS):: Horizontal Direction Drilling Guidelines Handbook- Updated:: May 2002.

(7) Horizontal Direction Drilling With Ductile Iron Pipe:: By-Richard W.Bonds, P.E. (DIPRA Research and Technical Director).

(8) Standard Operating Procedure of **ADANI ENERGY LIMITED.**

(9) www.vermeer.com .

(10) www.wkconstruction.com .

# Appendix-1 - Glossary

| | |
|---|---|
| *annular pressure* | *fluid pressure acting on the formation measured in the space between the drill stem and the wall of the bore* |
| *arc* | *curved section completed at a predetermined radius of curvature* |
| *Atterberg Limits* | *the water content of a soil when it passes from a semi-solid to a plastic state and from a plastic to a liquid state; and can be empirically correlated with clay content and its propensity to swell.* |
| *bentonite* | *a clay mineral, primarily montmorilonite, with high swelling properties that forms the primary component in drilling muds used in HDDs* |
| *bottom hole assembly (BHA)* | *tools used in directional drilling including the bit, bent sub, mud motor, steering tool, annular pressure tool, and connections to provide directional control, information gathering and drilling power* |
| *bore* | *earth removed from between the surface entry and exit points along the drill path* |
| *casing* | *pipe installed through problematic near surface materials such as gravels and cobbles to provide a conduit for the BHA and other down-hole tools and drilling fluid* |
| *deleterious substance* | *any substance that would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water;* <br><br> *any water that contains a substance in such quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water* |
| *drill stem* | *steel drill pipe approximately 10 m long and 114.3 to 168.3 mm O.D., used to control and transfer fluid in an HDD* |
| *drill bit* | *a device that cuts into the formation and progresses the bore* |

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|---|---|
| *drill cuttings* | *ground and subsurface material broken by the drill bit* |
| *drilling mud/fluid* | *fluid created by mixing water and bentonite as well as other additives to facilitate drilling and transport of drill cuttings from drill bit to the surface* |
| *down-hole tool* | *tools that are used at the end of the drill string to physically complete the bore and to provide directional and other information* |
| *entry point or rig side* | *the side of the HDD where the drill rig is situated and where the pilot hole is started* |
| *exit point or pipe side* | *the side of the HDD where the pilot hole exits the crossing; where the pipeline to be installed into the bore is fabricated* |
| *harmful alteration, disruption or destruction (HADD)* | *HADD of fish habitat is defined by DFO as "any change in fish habitat that reduces its capacity to support one or more life processes of fish."*<br>*HADD applies when determining if or whether any of the three conditions (i.e., harmful alteration, disruption, and destruction) are likely to result from a project.* |
| *hydraulic fracture* | *the process of annular pressure inducing a fracture or opening up an existing fracture in the formation during the drilling process* |
| *inadvertent return* | *drilling fluid and cuttings that migrate from the drilled hole to the surface, along a joint, fracture or any other path of least resistance* |
| *measured depth* | *total bore length as measured from the surface to the lowest point on the drill path* |
| *Moh's scale of hardness* | *a scale of hardness devised to aid the identification of minerals* |
| *mud motor* | *mechanical device that transforms hydraulic power to mechanical power to turn the drill bit and maintain the progress of the bore* |
| *No Drill Zone* | *upper limit of the drill path as defined by the geotechnical engineer, between potential or specified entry and exit locations. Intended to ensure the bore is maintained within geological formations suitable for directional drilling with suitable cover to assist in minimizing the potential form inadvertent returns.* |
| *pilot hole* | *the initial bore drilled along the drill path* |
| *pipe string* | *pipe to be installed through the bore at the completion of the HDD drill to carry product through the crossing* |

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|---|---|
| *radius of curvature* | *the bend radius of the drill or pipe string* |
| *reaming pass* | *subsequent pass(es) through the pilot hole to increase the diameter of the pilot hole to the required size to accomodate pipeline pullback* |
| *small HDD project* | *generally an HDD of length less than 300 m and / or pipe less than 323.9 mm O.D.* |
| *steering / guidance tool* | *specific tools providing steering direction information to the driller* |

# Appendix-2 - HDD Related Conversion

| MULTIPLY | BY | TO OBTAIN |
|---|---|---|
| Acre feet | 43560 | Cubic feet |
| Acre feet | 1233.48 | Cubic metres |
| Barrel | 35 | Imperial gallons |
| Barrel | 42 | U.S. gallons |
| Barrel | 0.1193 | Cubic metres |
| Cubic foot | 0.0283 | Cubic metres |
| Cubic foot | 6.229 | Imperial gallons |
| Cubic foot | 7.481 | U.S. gallons |
| Cubic metre | 264.17 | U.S. gallons |
| Cubic metre | 35.3144 | Cubic feet |
| Cubic metre | 220.1 | Imperial gallons |
| Cubic metre | 6.289 | Barrels |
| Cubic metre | 1000 | Litres |
| Cubic metre | 2204.6 | Pounds of water |
| Cubic metre | 1000 | Kilograms of water |
| Cubic foot/sec | 0.02832 | Cubic metres/sec |
| Foot | 0.3048 | Metres |
| Hectare | 2.471 | Acre |
| Kilogram | 2.2046 | Pounds |
| Kilograms/hectare | 0.892 | Pounds per acre |
| Kilopascals | 0.145 | Pounds per square inch |
| Metre | 3.2808 | Feet |
| Mile | 1.609 | Kilometres |
| Pound | 0.45359 | Kilograms |
| Pounds per square inch | 6.895 | Kilopascals |
| Pounds per acre | 1.121 | Kilograms/hectare |