WELCOME

Applicability of Trenchless Technologies for Different Conditions

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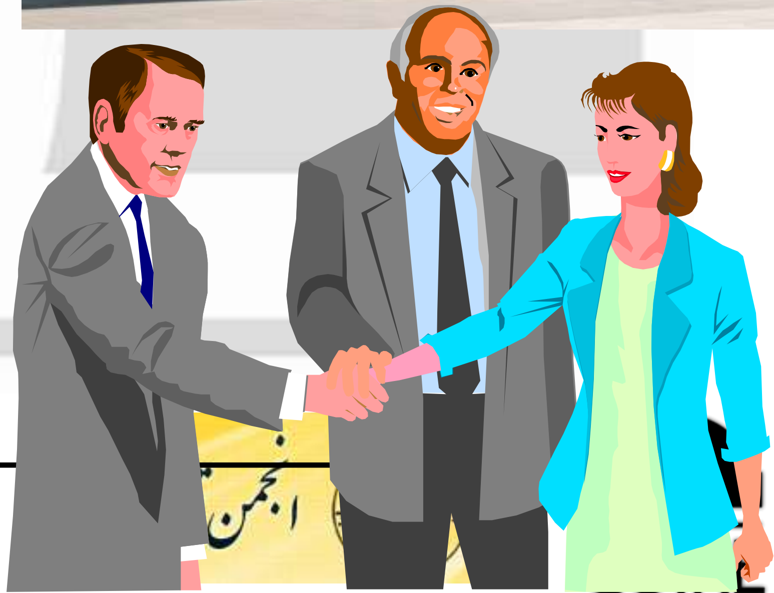
Agenda

- Introduction
- Underground Infrastructure
- Benefits & Limitations of Trenchless Technologies
- Where Trenchless Technologies are Applicable
- Trenchless Construction Methods
- Trenchless Renewal Methods
- Summary and Conclusions

Center for Underground Infrastructure Research & Education

Grouping of university, municipal, industrial, business and governmental representatives committed to the advancement of knowledge in materials, methods and equipment used in underground infrastructure.



CUIRE Facilities and Equipment

- Testing Machines
- Environmental Rooms
- Meeting Rooms
- Overhead Cranes
- Data Loggers and Data Acquisition Systems
- Hydrostatic Pressure Testing
- Pressure Gauges, Extensometers, etc.
- Geotechnical Testing
- Soil Resistivity Equipment
- Load Pit
- Finite Element Software (ANSYS, ABAQUS, PLAXIS)

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Publications

ASCE a better world by design

Journal of Pipeline Systems (JPS) Engineering and Practice

- New pipeline technologies,
- Planning, engineering, design, construction (conventional and trenchless),
- Renewal, safety, operation and maintenance,
- Asset management,
- Environmental aspects, and
- Sustainability of pipeline systems.

http://www.editorialmanager.com/jrnpseng/

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Center for Underground Infrastructure Research & Education

- CUIRE can be a resource for you:
  - Pipe/soil interactions
  - Physical testing & computer modeling
  - Review of design alternatives
  - Life-cycle cost analysis
  - Constructability
  - Trenchless technology
  - Education, training and certification courses

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Civil Engineering Department

- ❑ Total Number of Faculty: 24
- ❑ Total Number of Adjunct Faculty: 17
- ❑ Current Faculty Hires
  - ❑ Construction Engineering and Management
  - ❑ Structural Engineering
  - ❑ Water Resources Engineering

Civil Engineering Department

- Total Number of Students: 939
  - 425– Undergraduate
  - 410 – MS/ME/MCM
  - 104 – Ph.D.

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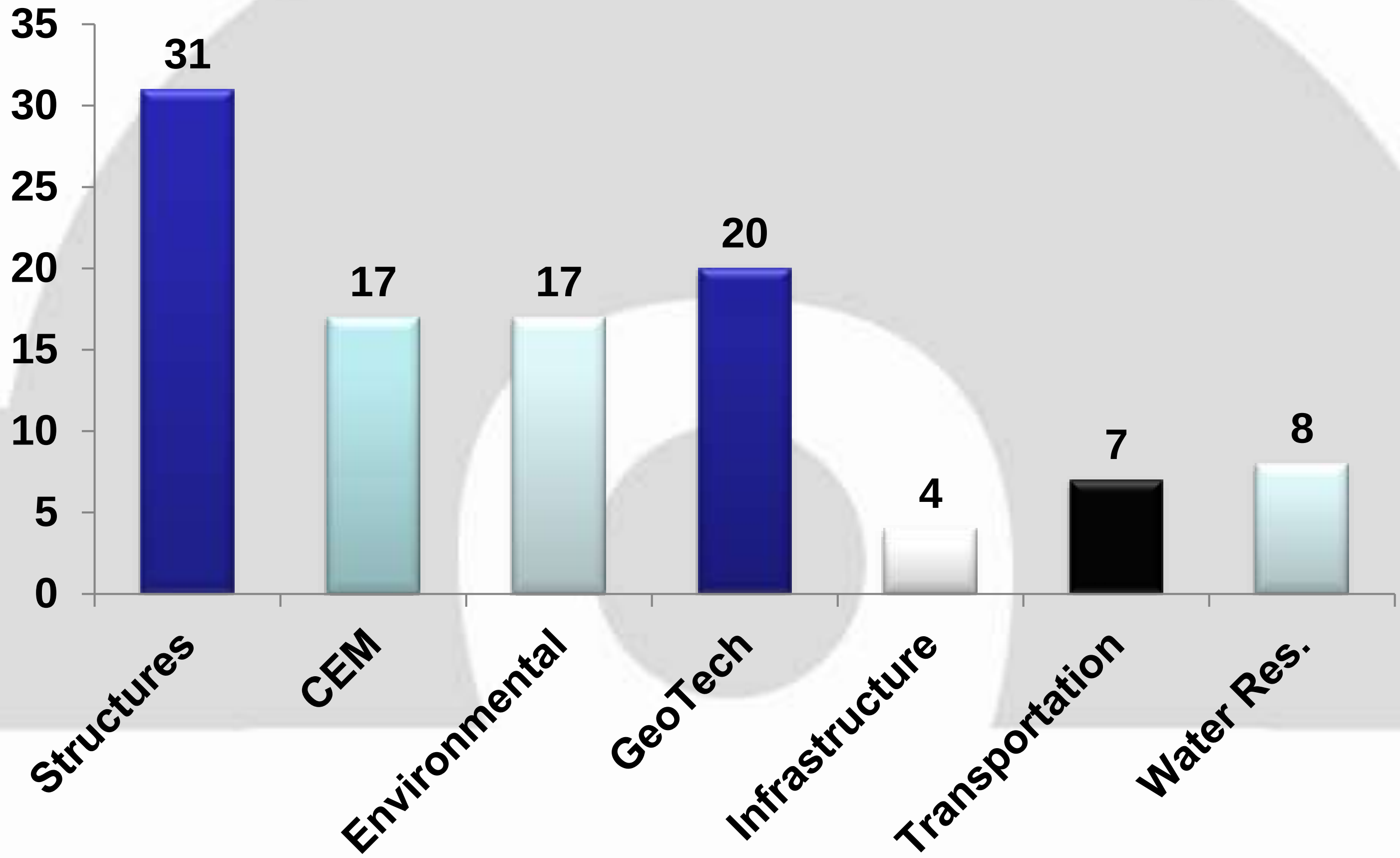
Ph.D. Students Enrollment



Total 104

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Civil Engineering Department

- **The only comprehensive Civil Engineering program in North Texas**
  - Bachelor of Science in Civil Engineering
  - Bachelor of Science in Architectural Engineering
  - Bachelor of Science in Construction Management
  - Master of Science in Civil Engineering
  - Master of Engineering in Civil Engineering
  - Master of Construction Management
  - Doctor of Philosophy in Civil Engineering

Fully Equipped CE Laboratory Facilities

Among the Best in the Nation

- Nedderman Hall Laboratories
  - Environmental Engineering
  - Geotechnical Engineering
  - Hydraulic Engineering
- Civil Engineering Laboratory Building (CELB)
  - Construction Engineering
  - Environmental Engineering
  - Geotechnical Engineering
  - Structural Engineering

Civil Engineering Laboratory Building

Established 2008

Construction Cost: $9.8 million

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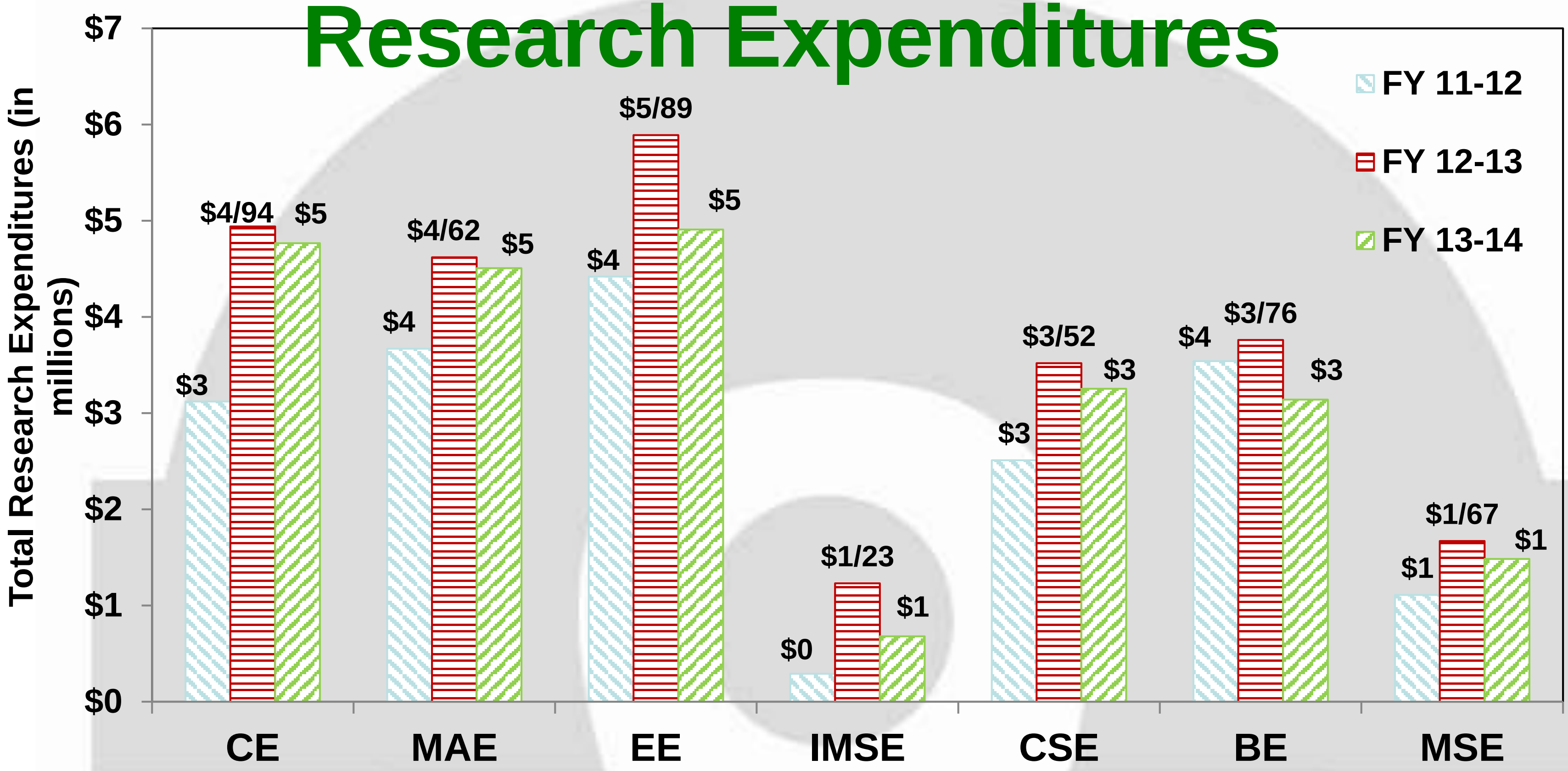
College of Engineering Total Research Expenditures



Notes

1) CE research funding has been among the top 2 in the College of Engineering for the past two years.
2) Funding sources: Federal, State, and Private

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2014-2015
Research Expenditures

- Civil Engineering Average:

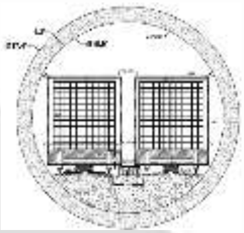
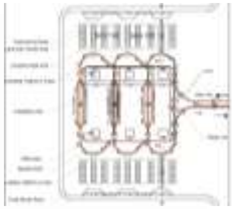
  $350,000 per faculty member

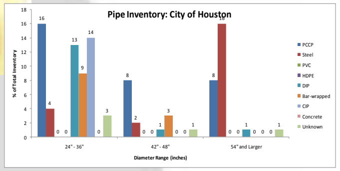
- College of Engineering Average:

  $221,000 per faculty member

CUIRE Research

1. **Integrating Underground Freight Transportation into Existing Intermodal System**
   - Agency: Texas Department of Transportation
   - Amount and Duration: $247,049 – 12 Months
2. **Innovation and Research for Water Infrastructure for the 21st Century: Structural Capabilities of No-Dig Manhole Rehabilitation**
   - Agency: Water Environment Research Foundation (WERF)
   - Amount and Duration : $251,000 – 19 Months
3. **24 in. and Larger Water Pipelines Failures**
   - Agency: Hanson Pipe & Precast
   - Amount and Duration : $20,000 – 18 Months
4. **Research and Testing on Large Diameter Water Transmission Pipeline Installation: Integrated Pipeline Project (IPL)**
   - Agency: Tarrant Regional Water District
   - Amount and Duration : $461,941 – 27 Months
5. **Research and Validation of Culvert Standard SCP-MD and Jack and Bore Issues**
   - Agency: Texas Department of Transportation
   - Amount and Duration : $148,595 – 18 Months
6. **Long-term Testing of SIPP Polyuria Formulation For Water Pipe Renewals**
   - Agency: 3M Water Infrastructure
   - Amount and Duration : $143,926 – 38 Months



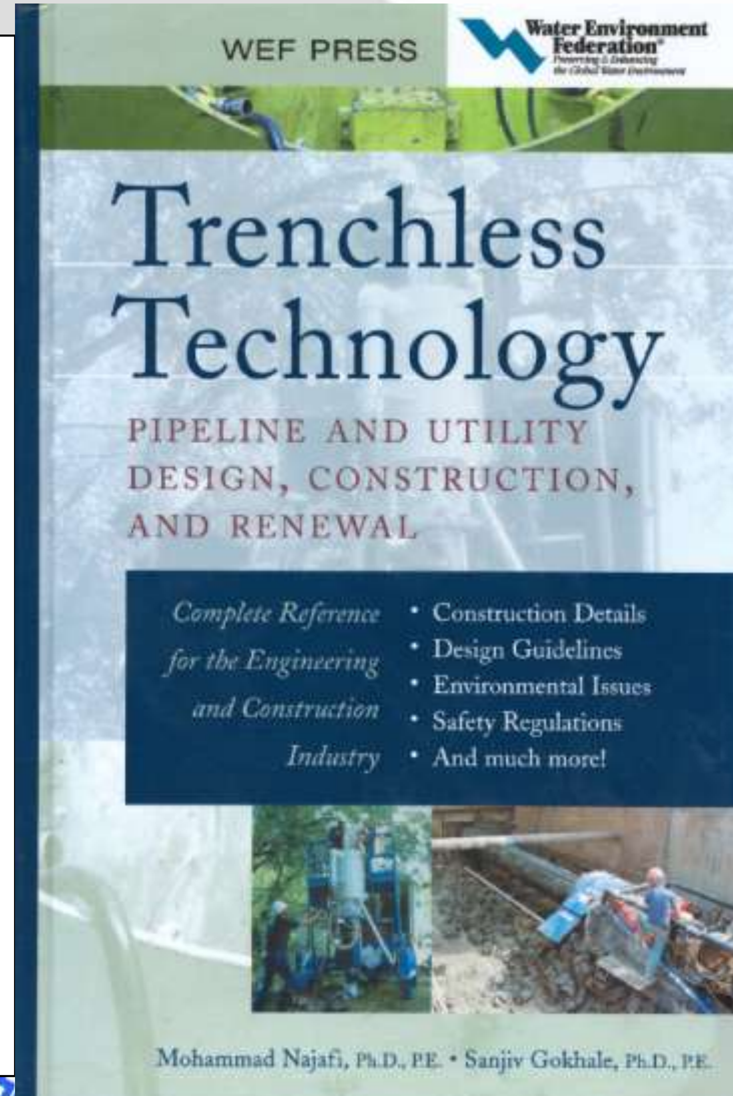




Trenchless Technology Methods

Trenchless Technology:

All methods of pipeline and utility installation and renewal with <u>minimum disruption of surface and subsurface</u>



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Benefits of Trenchless Technology

Do not assume open-cut is less expensive than trenchless technology!

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Benefits of Trenchless Technology

Comparison of Cost Factors Between Open-Cut & Trenchless Technology

	Open-Cut	Trenchless Technology
Depth	Major	Minor
Diameter	Moderate	Moderate
Soil Conditions	Major	Moderate to Minor
Obstructions	Major	Minor
Water Table	Major	Minor
Existing Utilities	Major	Major to Moderate
Damage To Pavement	Major	Minor
Reinstatement	Major	Minor
Traffic	Major	Minor
Safety Issues	Major	Minor
Productivity	Major	Minor
Environmental Issues	Major	Minor

General Considerations

Infrastructure Type	Pipe Geometry	Problem Type
Water Pipelines	Straight	New pipe installation
Sewer Pipelines	Pipes with bends	Pipeline renewal
Gas and Fuel Lines	Circular pipes	Local repairs
Electrical Cable and Fiber-optic lines	Non-circular pipes	Manhole renewal
Chemical or industrial pipes	Pipelines with varying cross-section	Lateral renewal
	Pipelines with deformations	Hydraulic problems
		Corrosion problems

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Should You Go Trenchless?

- Is the pipe 2 m deep or more?
- Is the pipe below water table?
- Is soil unstable?
- Is underground congested with other utilities?
- Is it in urban area?
- Are drive lengths more than 100 m?
- Is it under a roadway?
- Can the pipe be renewed or spot repaired?
- Is it in residential area?

If yes to 2 of above questions, consider trenchless technology!

Main Challenges for Trenchless Technology Projects

- Locating Existing Underground Utilities
- Lack of Standard Guidelines & Specifications
- Lack of Proper Geotechnical Investigations
- Matching the Correct Method to the Project Conditions
- Specification Interpretation
- Lack of Inspector & Operator Experience and Proper Training

Gas Explosion

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Old Trenchless Guidelines

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Trenchless Technology Methods

- **Trenchless Methods**
  - **Construction Methods**
    - **Utility Tunneling**
    - **Pipe Jacking**
    - **Horizontal Earth Boring**
      - **Horizontal Auger Boring**
      - **HDD**
      - **Pilot Tube Microtunneling**
      - **Microtunneling**
      - **Pipe Ramming**
  - **Renewal Methods**
    - Cured-in-Place Pipe
    - Close-fit Pipe
    - Thermoformed Pipe
    - Sliplining
    - Modified Sliplining
    - In-line Replacement
    - Localized Repair
    - Lateral Renewal
    - Coatings & Linings
    - Manhole Renewal

Introduction

- Successful TCM project requires surface & subsurface investigations to mitigate risks.
- During design phase, surface & subsurface survey information assist in determining suitable trenchless method.
- Accurate data will reduce possibility of installation problems & change orders.
- Accurate data will also minimize litigation and dispute

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Surface Survey

- Surface survey is required for design phase.
- Each project has a specific site requirements.
- A surface survey should be conducted along the centerline of proposed bore path.

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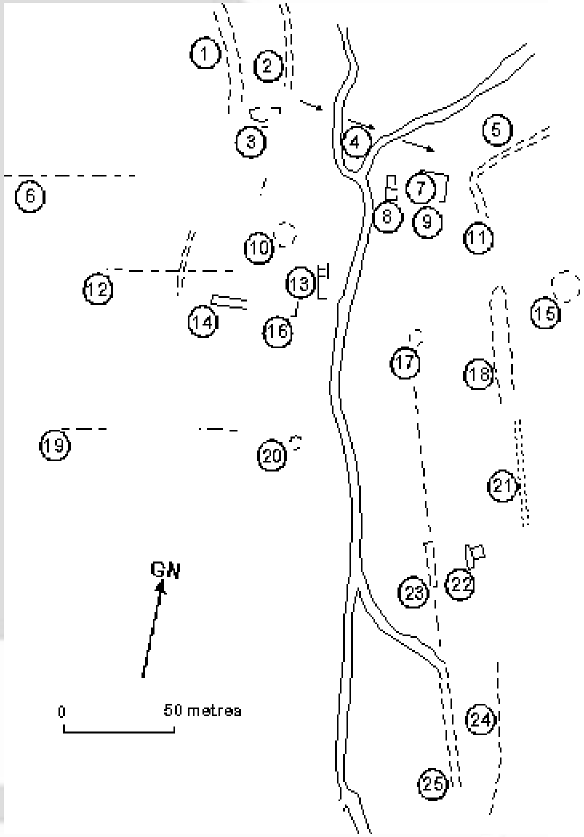
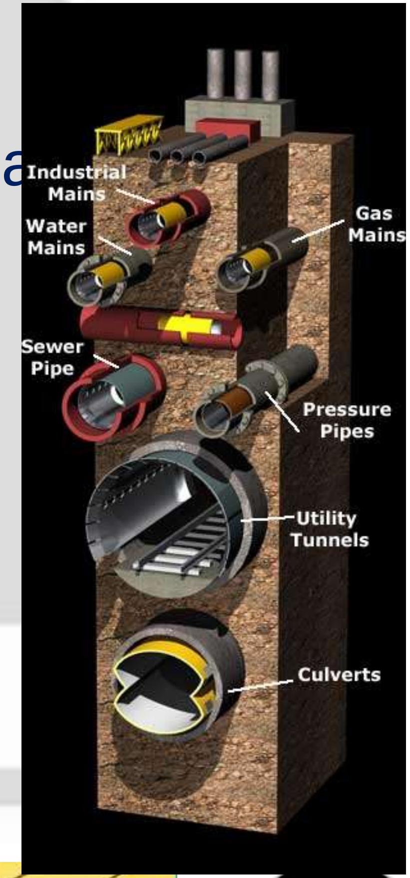
Surface Survey

- ❑ Design surface survey include:
  - ❑ Work area requirements
  - ❑ Existing grade elevation data
  - ❑ Surface features
  - ❑ Boring or test pit locations
  - ❑ Waterways & wetlands
  - ❑ Manholes, valve boxes, etc… as well as structures adjacent to path.



Subsurface Survey

- Subsurface investigation is the next step to surface survey.
- Subsurface considerations that impact design a therefore need proper investigations.
- Subsurface investigations include:
  - Presence of existing utilities
  - Manmade obstructions
  - Method of placement
  - Geotechnical Conditions



Subsurface Survey

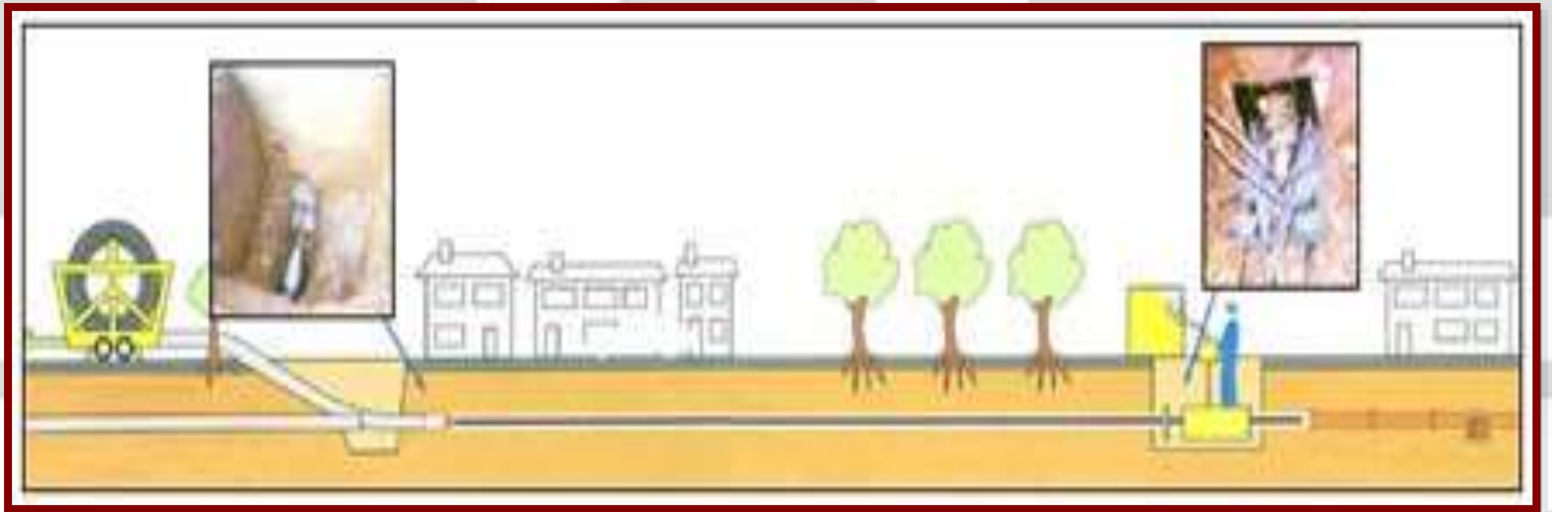
- **Existing Utilities**
  - Local "one-call" service or municipalities and utility companies should be contacted.
  - Methods of confirming subsurface utility locations include SUE, surface applied pipe locators, geophysical methods (ground penetrating radar (GPR), seismic method, etc.), vacuum excavation equipment, and test pits.
  - Location & elevation of existing utilities is especially critical in working pit locations.

Subsurface Survey Include (Contd.)

- **Geotechnical Investigations**
  - Determination of soil conditions.
  - Investigation for complex installation is carried out in two phases:
    - General Geotechnical Review
    - Geotechnical Survey.

Subsurface Survey (Contd.)

- **General Geotechnical Review Includes:**
  - Review & examining existing geotechnical data.
  - Data available from construction project records in the location (buildings, piers, bridges).



Subsurface Survey (Contd.)

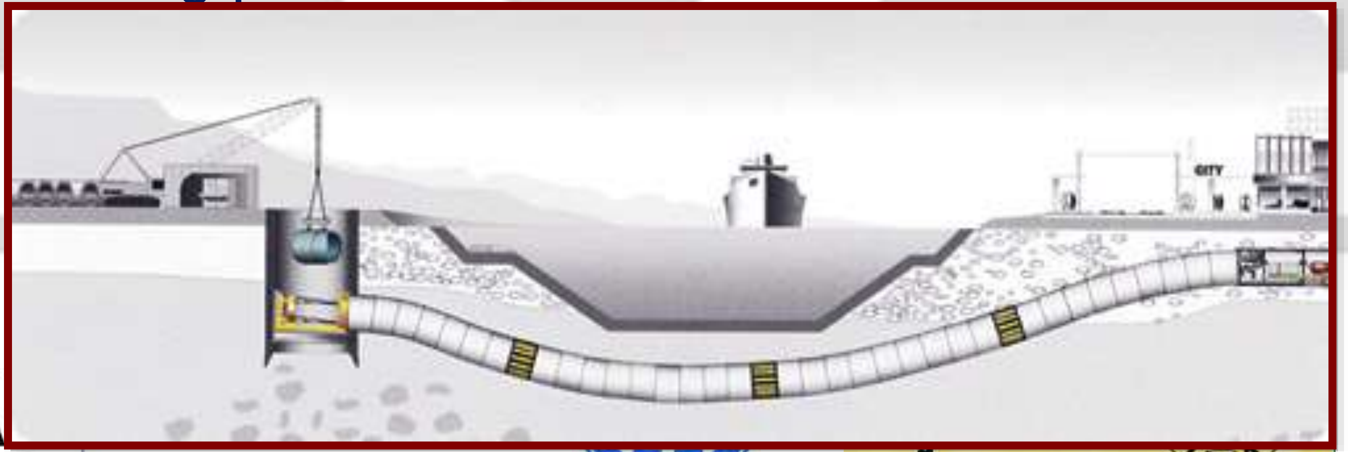
- **Geotechnical Survey Include:**
  - Determining the nature of soil at the site and its stratification.
  - Obtaining disturbed and undisturbed soil samples for visual identification and lab tests.
  - Determining the depth and nature of bedrock.
  - Perform in-situ field tests.

Geotechnical Survey (Contd.)

- Observing surface drainage conditions from and into the site.
- Assessing any special construction problems with respect to the existing structures nearby.
- Determining groundwater levels, sources of recharge, and drainage conditions.

Alignment Considerations

- Feasible trenchless technology alignments involve:
    - Evaluating available right-of-way
    - Easement acquisition issues
    - Determining the location of existing utilities
- Straight horizontal alignment are generally preferred for TT projects.
- A prospective alignment must have a adequate jacking and receiving pit.



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Alignment Considerations (Contd.)

- Pipelines constructed using trenchless technology methods can be located deeper, sometimes with only a small increase in construction cost.
- Deeper alignment can avoid existing underground utilities, potential conflicts, and utility relocations.
- Straight horizontal alignments are generally preferred because:
  - Provide for more accurate control of line-and-grade.
  - More uniform stress distribution on the pipe and joints reducing the risk of eccentric loads.

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Jacking and Receiving Pits

- Jacking and receiving pits are vertical excavation with shoring and bracing systems.
- **Shoring system commonly used:**
  - Sheet-pile systems
  - Internal bracing
  - Soldier pile
  - Circular steel rib systems
  - Timber lagging & internal bracing
  - Liner plate system with steel rib supports

Jacking and Receiving Pits

- An important factor in design of pits is groundwater control.
- Dewatering systems using deep wells or well points are frequently used.
- Prospective alignment must have ad receiving pit locations available.

Jacking and Receiving Pits

- Construction access to the jacking pit must be provided for transporting tunnel muck, pipe sections, and tunneling equipment.
- Traffic control requirements must be evaluated in selecting and laying out jacking pit sites.

Jacking and Receiving Pits

- A typical jacking pit site needs enough space for:
  - The jacking pit itself
  - Slurry tanks
  - Crane
  - Pipe storage
  - Support facilities (e.g., a generator, power pack, and bentonite lubrication unit).

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Maximum Distance of Installation

- **Maximum distance a pipe can be installed depends on:**
  - Pipe size
  - Structural capacity of the pipe
  - Thrust capacity of the thrust block and the main jacks
  - Soil conditions
  - Effectiveness of the bentonite lubrication system
  - Specific project conditions such as operators skills and steering the pipe.

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Calculating Jacking Force

JF = Total jacking (thrusting) force, (lb),

FP = Resistance of the MTBM (penetration resistance), (lb),

FR = Frictional resistance (loads acting in the direction of pipe axis) (lb).

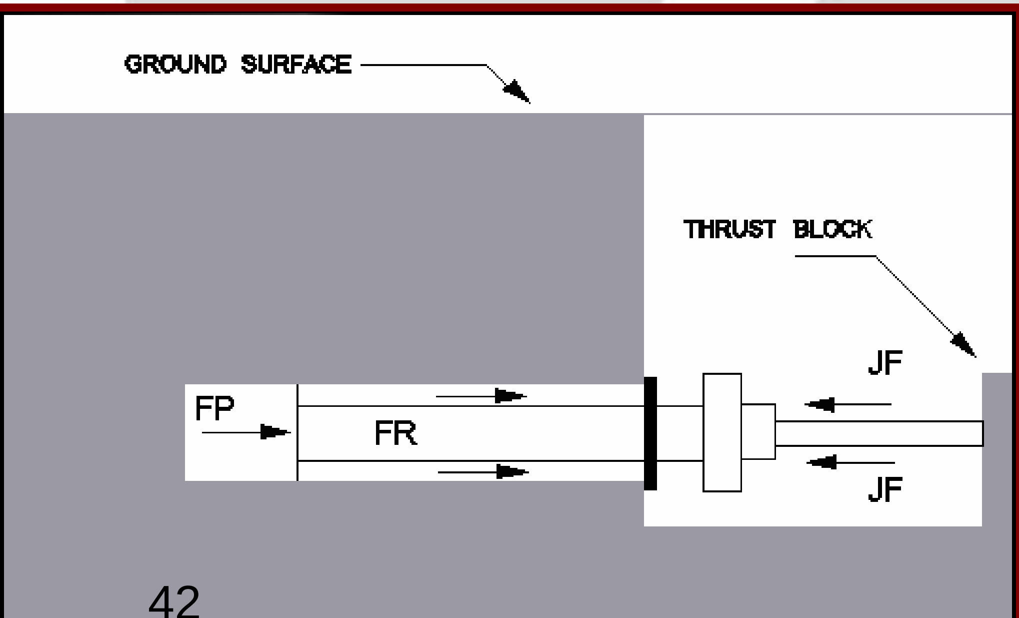
R = Circumferential frictional resistance (skin friction), (lb/in.2)

S = Perimeter of pipe cross section = (Outside diameter of pipe) x π, (in.)

L = Jacking (thrusting) distance, (in.)

$$JF = FP + \sum FR$$

$$FR = R \times S \times L$$



Resistance of the Leading Pipe

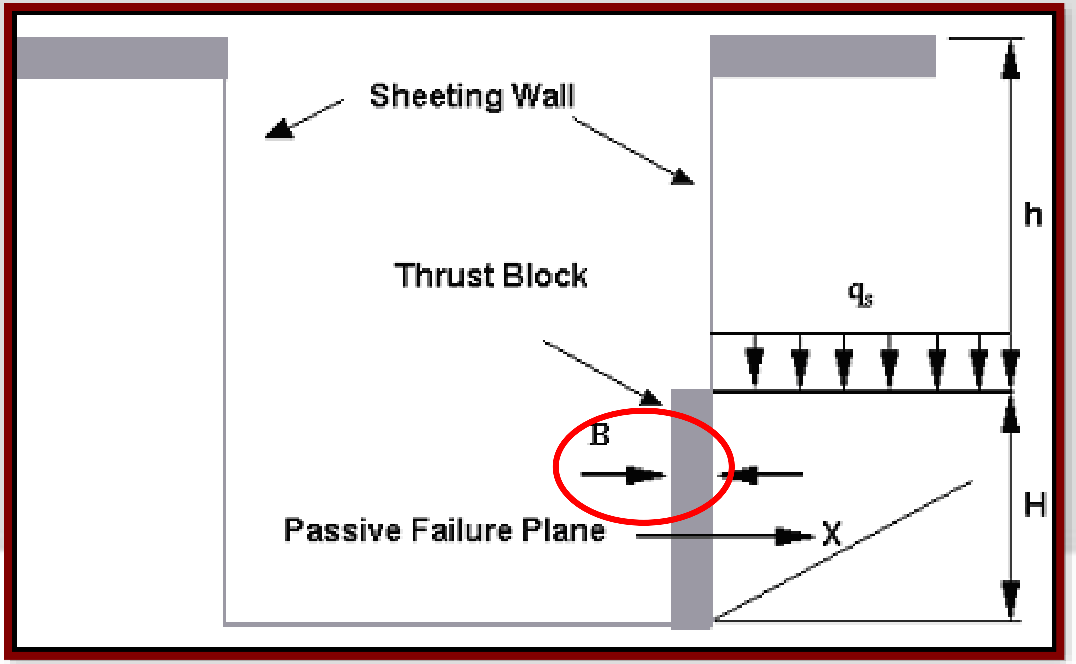
- For slurry shield microtunneling equipment, the value of the resistance of the leading pipe (FP) is calculated by:

$$FP = (P_e + P_w) \times (\frac{B_c}{2})^2 \times \pi$$

- Pe = Contact (point) pressure of the cutting head, (psi),
- Pw = Slurry pressure (psi), and
- Be = Outside diameter of the shield (boring) machine, (in.).

Rankine's Passive Soil Pressure Theory

- The allowable thrusting force (Q) of the thrust block is calculated by Rankin's passive soil pressure theory



Design

- Permanent works design
  - Routing Considerations
  - Materials
  - Ground Movement
- Temporary works design
  - Face Stability
  - Method and equipment selection
  - Jacking loads & their management
- Shafts

Routing Considerations

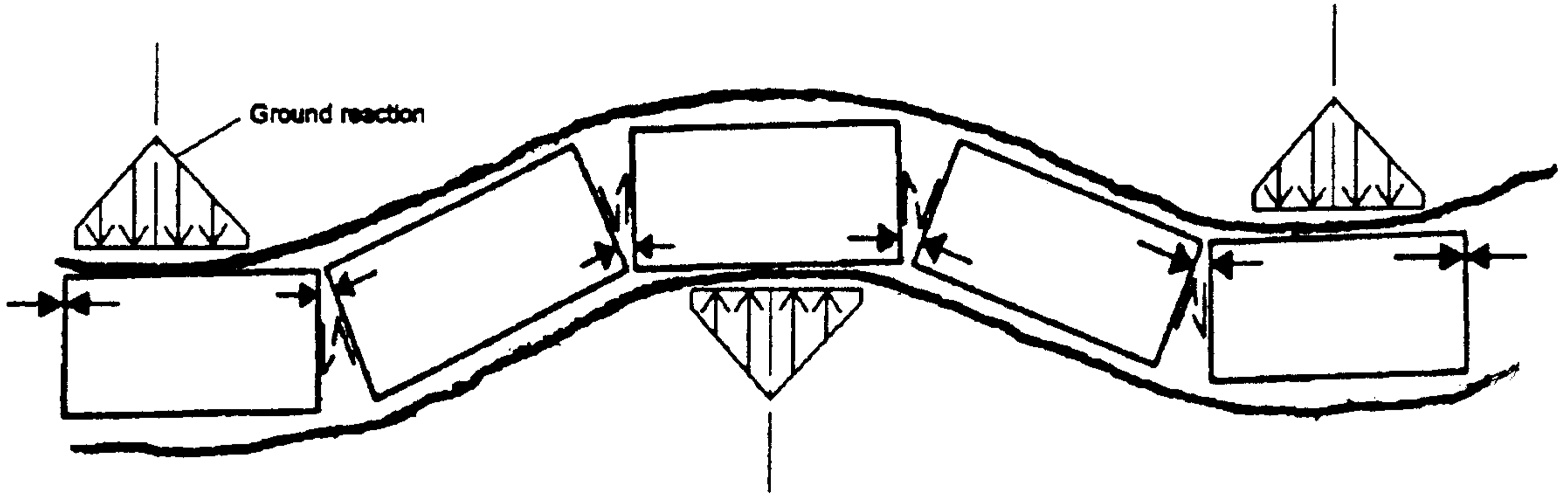
- Do not design as you would for open-cut
- Depth considerations

Pipes – Other Considerations

- Section Lengths
- Joints
- Injection Ports
- Special Pipes
  - Interjack Stations
  - Lead pipes
- Coatings / Linings

Pipe and Alignment

Pipes must withstand alignment error



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Preparation for Contract

- The Contract
- Construction Drawings
- Specifications and Standards
- Measured Work
- Prime Contractor / Subcontractor Issues
- Prequalification

Types of Contract

- Who should carry the Risk?
  - Traditional Design/Bid/Build
    - Fixed Price
    - Mixed Price
    - Incentives
    - Target Price
  - Design & Build Contracts
  - Shared Risk Contracts
  - Partnering

Timing

- Seasons
- Environmental
- Community
- Contractor or equipment availability

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Specifications and Standards

- Technical Specifications
  - Prescriptive or Performance
- Submittals
  - Strong submittals force project planning and management
- Standards

Measured Work

- Consider Payment Items carefully
  - – Pipe
  - – Installation by..
  - – Shafts
  - – Manholes or shaft conversions
  - – Incidentals e.g. grouting, ground monitoring
  - – Contingency issues

Construction

- Submittals
- Inspection and Monitoring
- Records
- Training
- Safety
- Risk Management & Problem Solving
- Contractual issues

The Role and Importance of Inspection

- The eyes of the Owner and the public
- Development of a working relationship
- Safety
- Records and reports
- Comprehension of risks
- Decision Making

Contract Administration

- Plans and specifications
  - Contractual requirements
  - Technical requirements
- Monitoring
  - Shafts
  - Tunnels
  - Elsewhere
  - Safety
  - Delays
- Records
  - Photographic
  - Written
    - Daily Records
    - Specific Reports
  - Samples
- Surveying
  - Position
  - Alignment
  - Settlement

Monitoring - Shafts

- Barriers
- Access
- Ground conditions & water
- Adherence to specs & method statement
- Over excavation – water issues
- Shoring integrity
- Build quality – permanent works considerations
- Settlement

Monitoring

- Ground conditions
- Over excavation
- Installation
  - Operators station data – (cover separately)
  - Slurry management
  - Pipe Joint integrity
  - Lubrication
- Surface settlement

Monitoring

- Damage away from the working areas
- Noise
- Dust
- Traffic management & barriers
- Public reaction to work/Public relations

Records

- Photographs
  - Surface features and close structures
  - Progress
  - Changing conditions
  - Potential claim or unusual items
- Samples
  - Representative material
- Written
  - Daily activity record
    - Start & finish times of shifts & work elements
    - Data and face logs
    - Alignment control data
    - Grouting records
    - Settlement monitoring
    - Labour & plant utilization
    - Material deliveries & deficiencies

Surveying

- Position
  - Shaft locations (Top & Bottom)
- Alignment
  - Horizontal and vertical alignment
    - Alignment control of tunnel
    - Ring build controls
    - Curves
  - Slope of drive
- Settlement
  - Monitoring requirements

What Can Go Wrong?!

- Risk analysis & Management
  - Collapse
  - Settlement
  - Damage
- Factors affecting cost
  - Delay
  - Change in conditions
- Overcoming the problem
  - Claims mitigation
  - Technical alternatives
- Contractor Claims
  - Basis under contract
  - Events leading up to claim
  - Overall contract picture

Factors Affecting Cost

- Variance in conditions
  - Face becomes unworkable
  - Major obstructions
- Delay
  - Slow progress resulting in extended contract period
  - Specific stoppages

SUBSURFACE UTLITY ENGINEERING (SUE)

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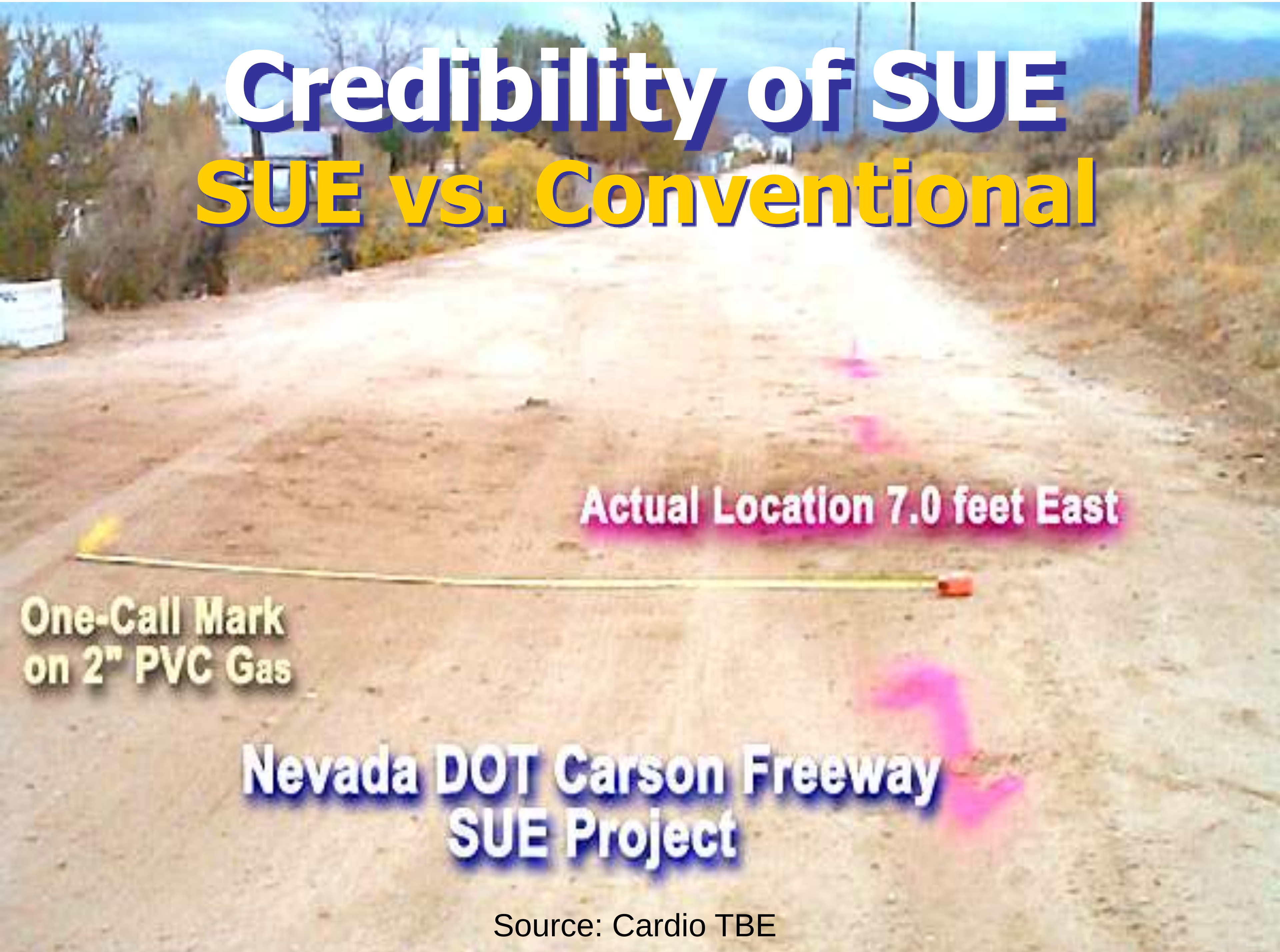
Credibility of SUE
SUE vs. Conventional



Source: Cardio TBE

What is SUE?

Accurate Utility Information

Designation

The process of using a surface geophysical method or methods to interpret the presence of a subsurface utility and to mark its approximate horizontal position (its *designation)* on the ground surface. (Note: Utility owners and contractors sometimes call this process "locating".) (ASCE Standard 38-02)

Locating

The process of exposing and recording the precise vertical and horizontal location of a utility.

Data Management

Surveying utility information obtained by designating and locating and entering it into the computer-aided design (CAD) system.

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Source: Cardio TBE

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SUE Applications

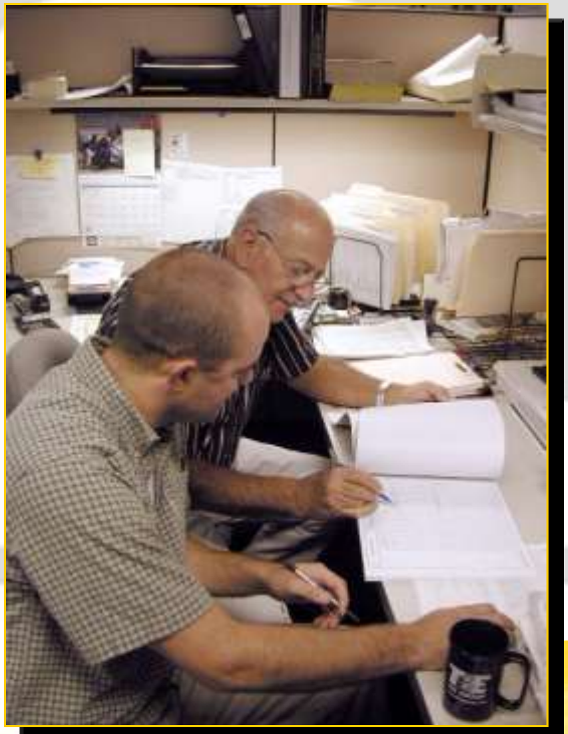
Questions:

- Potential project impact on utilities?
- How reliable are utility records?
- If utilities are not shown correctly, what impact will there be?
- Additional unidentified facilities?
- Is this project critical/in public spotlight?
- Are there safety risks?
- What if?

Source: Cardio TBE

Quality Level "D"

- Utility Contact Phase
- Records Review



Source: Cardio TBE

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Quality Level C Special Features

Source: Cardio TBE

Quality Level "B"

Determining Horizontal Alignment

Source: Cardio TBE

Quality Level "A"

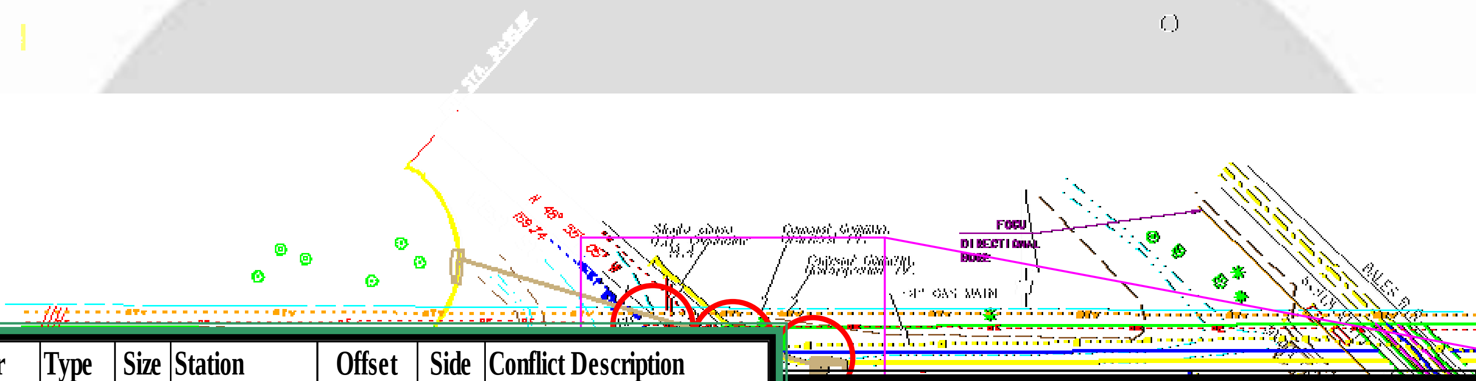
Utility Locating

- Utility Exposed
- Accurate X,Y, Z Locating
- Size, Material and Cross Section

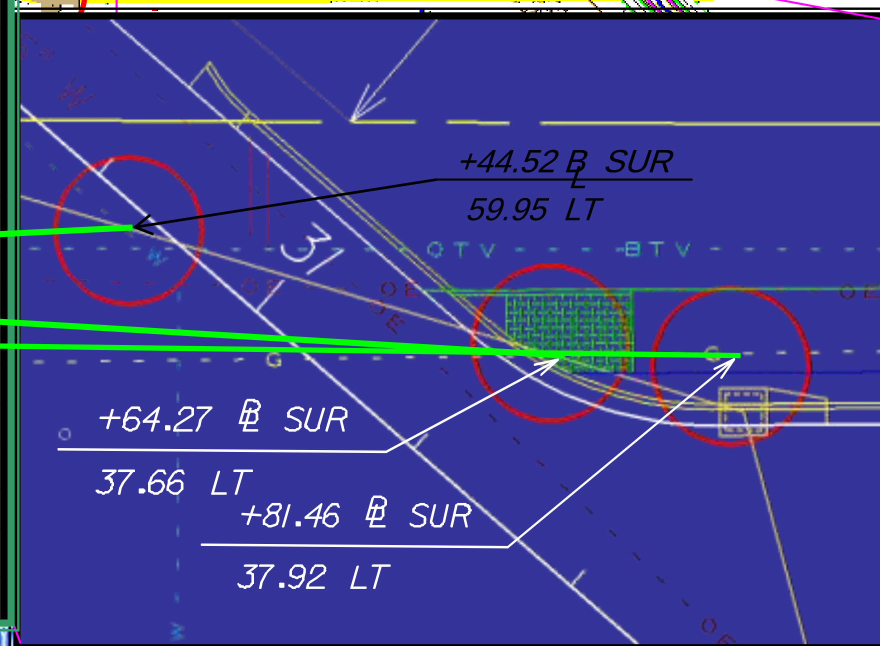
Source: Cardio TBE

Conflict Analysis

Build Conflict Matrix ***Identify Locations***



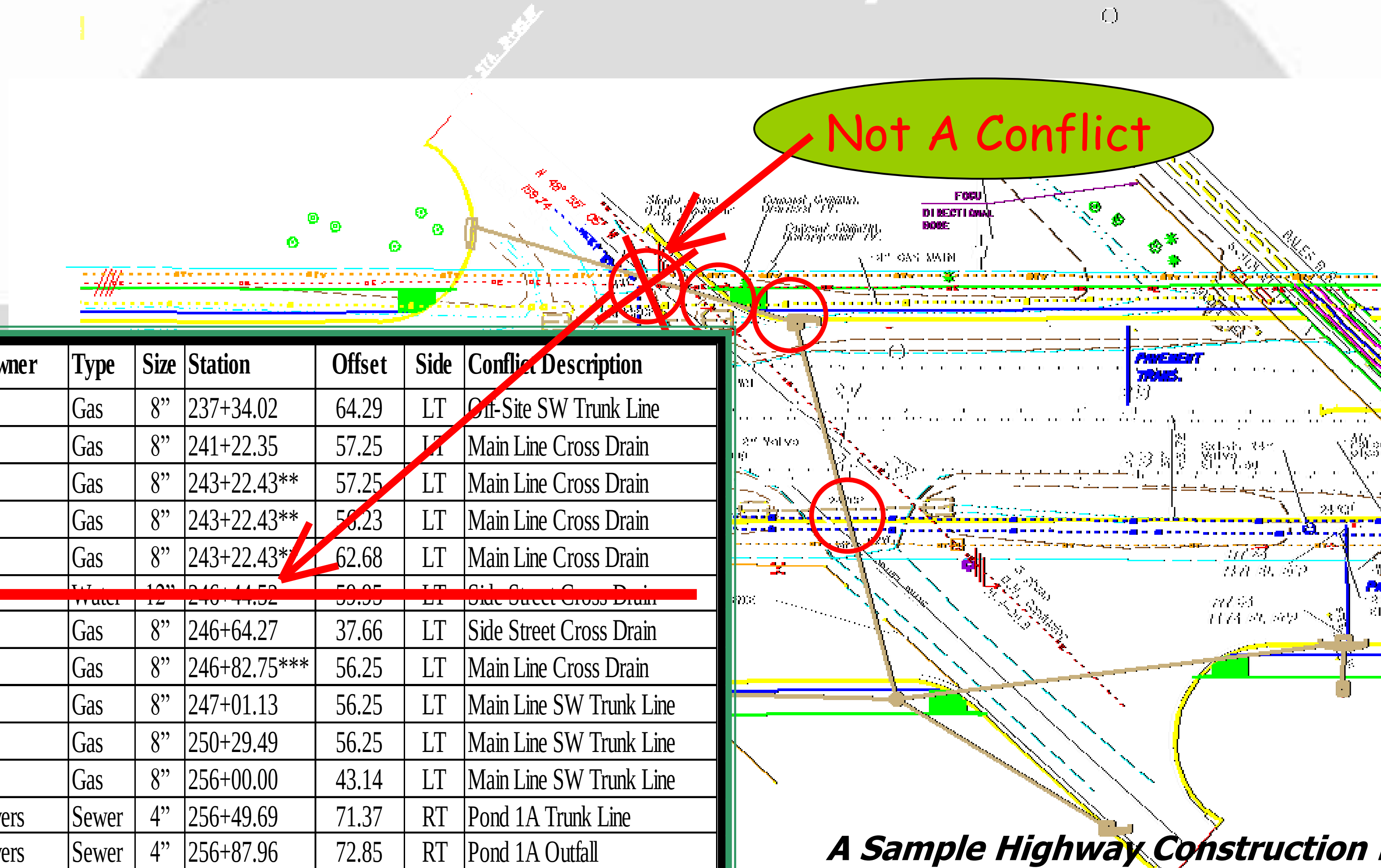
Utility Owner	Type	Size	Station	Offset	Side	Conflict Description
Teco	Gas	8”	237+34.02	64.29	LT	Off-Site SW Trunk Line
Teco	Gas	8”	241+22.35	57.25	LT	Main Line Cross Drain
Teco	Gas	8”	243+22.43**	57.25	LT	Main Line Cross Drain
Teco	Gas	8”	243+22.43**	56.23	LT	Main Line Cross Drain
Teco	Gas	8”	243+22.43**	62.68	LT	Main Line Cross Drain
Lee Co.	Water	12”	246+44.52	59.95	LT	Side Street Cross Drain
Teco	Gas	8”	246+64.27	37.66	LT	Side Street Cross Drain
Teco	Gas	8”	246+82.75***	56.25	LT	Main Line Cross Drain
Teco	Gas	8”	247+01.13	56.25	LT	Main Line SW Trunk Line
Teco	Gas	8”	250+29.49	56.25	LT	Main Line SW Trunk Line
Teco	Gas	8”	256+00.00	43.14	LT	Main Line SW Trunk Line
N. Ft. Myers	Sewer	4”	256+49.69	71.37	RT	Pond 1A Trunk Line
N. Ft. Myers	Sewer	4”	256+87.96	72.85	RT	Pond 1A Outfall
N. Ft. Myers	Sewer	4”	260+72.70^	57.58	LT	Main Line Cross Drain



Source: Cardio TBE

Identify Actual Conflicts

Analyze SUE Data
Update Conflict Matrix



Utility Owner	Type	Size	Station	Offset	Side	Conflict Description
Teco	Gas	8”	237+34.02	64.29	LT	Off-Site SW Trunk Line
Teco	Gas	8”	241+22.35	57.25	LT	Main Line Cross Drain
Teco	Gas	8”	243+22.43**	57.25	LT	Main Line Cross Drain
Teco	Gas	8”	243+22.43**	56.23	LT	Main Line Cross Drain
Teco	Gas	8”	243+22.43**	62.68	LT	Main Line Cross Drain
Lee Co.	Water	12”	246+44.52	59.95	LT	Side Street Cross Drain
Teco	Gas	8”	246+64.27	37.66	LT	Side Street Cross Drain
Teco	Gas	8”	246+82.75***	56.25	LT	Main Line Cross Drain
Teco	Gas	8”	247+01.13	56.25	LT	Main Line SW Trunk Line
Teco	Gas	8”	250+29.49	56.25	LT	Main Line SW Trunk Line
Teco	Gas	8”	256+00.00	43.14	LT	Main Line SW Trunk Line
N. Ft. Myers	Sewer	4”	256+49.69	71.37	RT	Pond 1A Trunk Line
N. Ft. Myers	Sewer	4”	256+87.96	72.85	RT	Pond 1A Outfall
N. Ft. Myers	Sewer	4”	260+72.70^	57.58	LT	Main Line Cross Drain

A Sample Highway Construction Project

Source: Cardio TBE

Conflict Resolution

- Modify Project Owner's Design
- Introduce Design Alternatives
- Identify Utility Relocations
- Utility Coordination

Source: Cardio TBE

Relative Cost Savings and Benefits

- Purdue Study
  - Commissioned by FHWA
  - 71 Projects Studied
  - Cost Savings of $4.62 per $1.00 spent
  - Un-quantifiable Savings Not Included
  - Only 3 Projects had Negative Return

Source: Cardio TBE

Relative Cost Savings and Benefits

- About 10% of Design Budget
- About 1% of Design/Construction Budget
- SUE Costs Higher
  for Urban than
  Rural Projects

Source: Cardio TBE

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Further Reading & Information

- **Periodicals –** Trenchless Technology Mag, No-Dig Intn'l, World Tunnelling, Underground Construction
- **Books/Manuals**
  - Trenchless Technology Book by Dr. Najafi
  - Pipe Jacking and Microtunneling - J Thomson - Blackie - ISBN 07514 0102 1
  - Guide to best practice for the installation of Pipe Jacks and Microtunnels - PJA - ISBN 0 9525982 05
  - ASCE Standard Construction Guidelines for Microtunneling
- **ASCE Pipeline Conference Papers**
- **Corporate Literature** (inc web sites)
- **NASTT**

Trenchless Technology Methods

- **Trenchless Methods**
  - **Construction Methods**
    - **Utility Tunneling**
    - **Pipe Jacking**
    - **Horizontal Earth Boring**
      - **Horizontal Auger Boring**
      - **HDD**
      - **Pilot Tube Microtunneling**
      - **Microtunneling**
      - **Pipe Ramming**
  - **Renewal Methods**
    - Cured-in-Place Pipe
    - Close-fit Pipe
    - Thermoformed Pipe
    - Sliplining
    - Modified Sliplining
    - In-line Replacement
    - Localized Repair
    - Lateral Renewal
    - Coatings & Linings
    - Manhole Renewal

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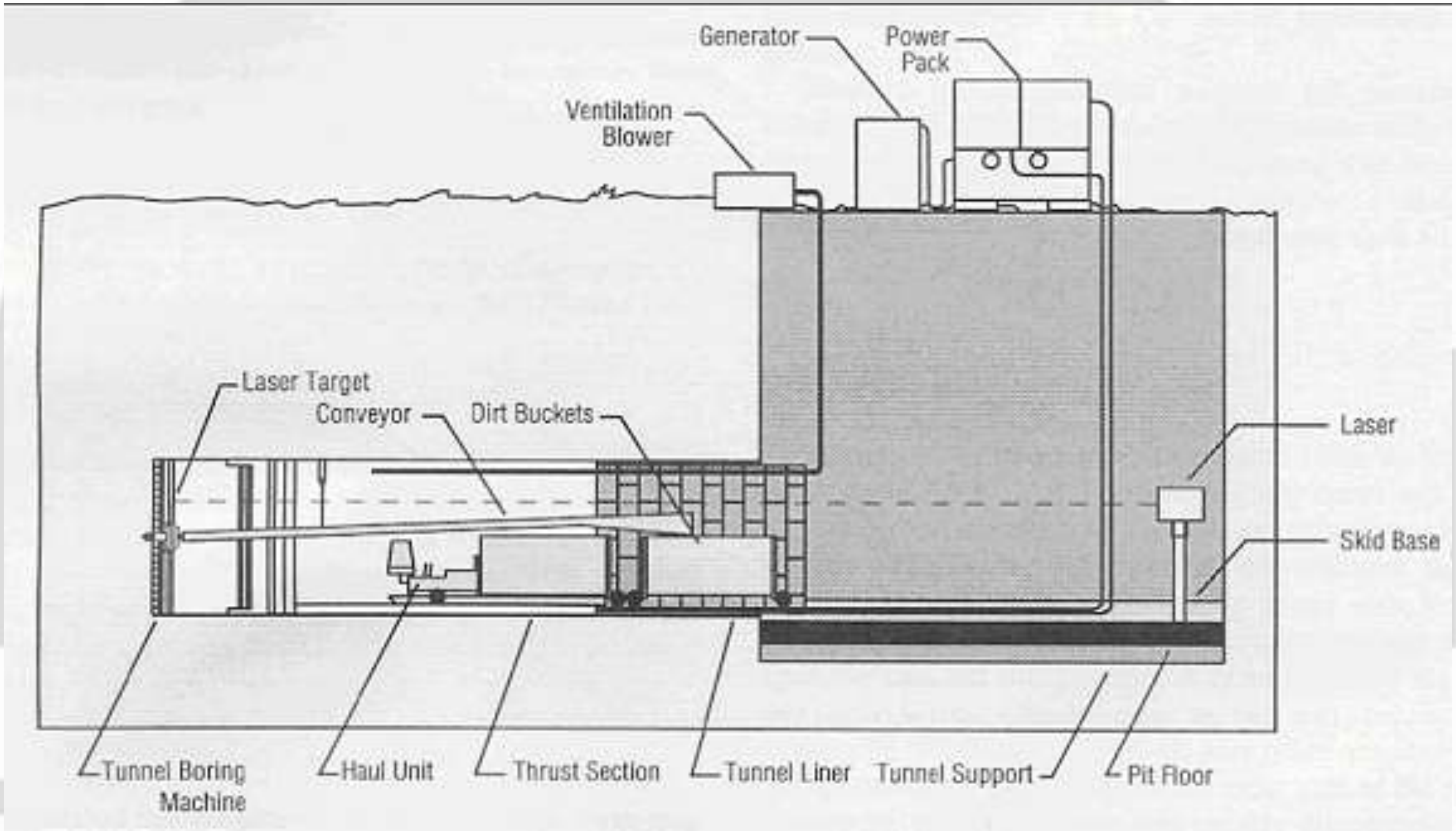
Utility Tunneling Method

- Utility Tunneling
  - **Performed in two steps**
    - Excavation & Installation of Primary Support
    - Installation of Secondary Support/Liner System
  - Product pipe sizes 1,000 mm & larger
  - Limitations on length & size based on logistical considerations & safety

Utility Tunneling Method

Characteristic of Utility Tunneling					
Method	**Diameter Range (mm)**	**Typical Installation (m)**	**Pipe Materials**	**Typical Applications**	**Accuracy (+ or -)**
Utility Tunneling	1,000 mm & larger	500	RCP, GRP, Steel	Pressure & Gravity Pipelines	~25 mm

Typical Components of Utility Tunneling Method



Utility Tunneling Method

Utility Tunneling Method

Possible Liners for Utility Tunneling

Wood Lagging

Tunnel Liner Plates

Utility Tunneling Method

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Utility Tunneling Method

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Trenchless Technology Methods

- **Trenchless Methods**
  - **Construction Methods**
    - **Utility Tunneling**
    - **Pipe Jacking**
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      - **Horizontal Auger Boring**
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    - Coatings & Linings
    - Manhole Renewal

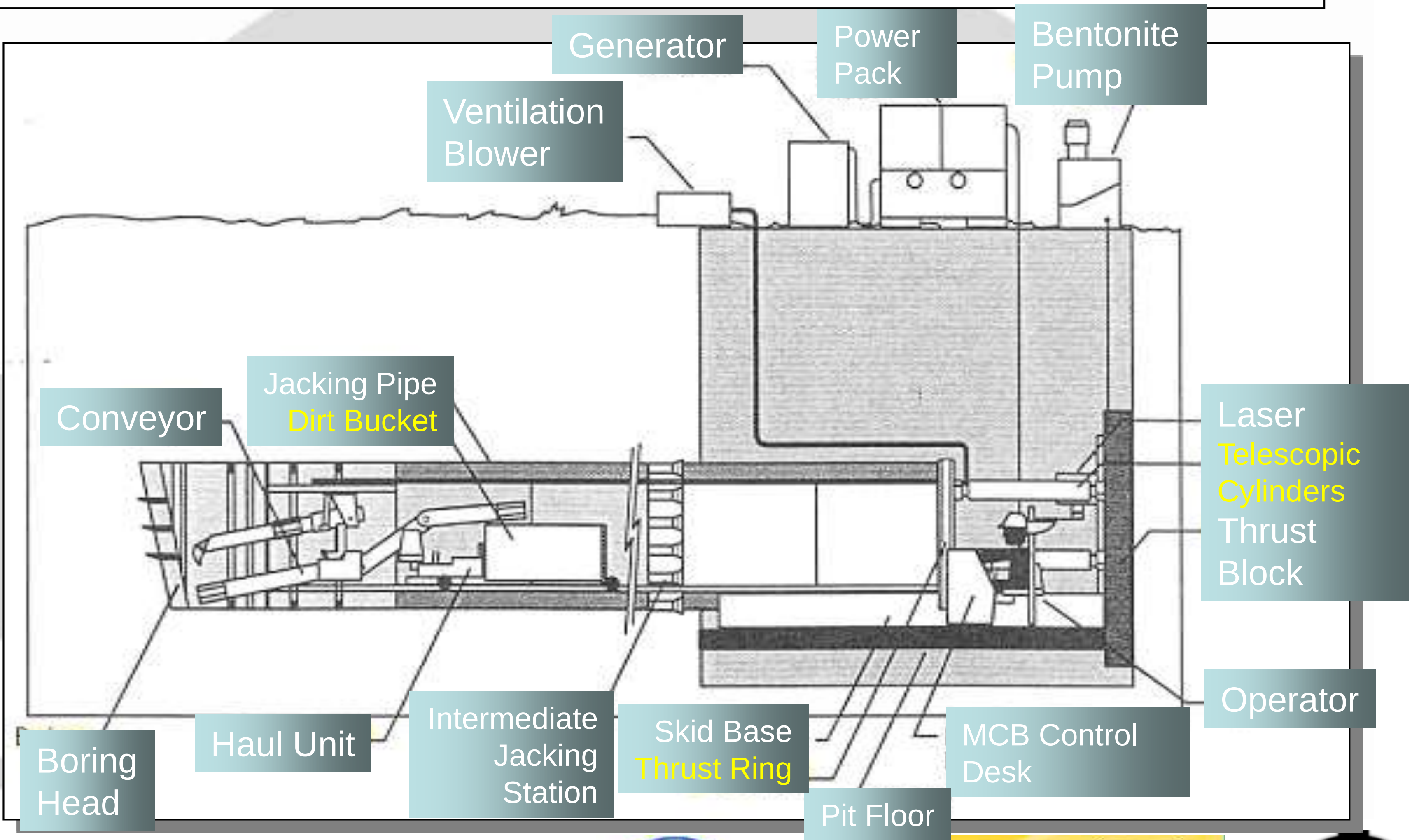
Pipe Jacking Method

- Pipe Jacking
  - Similar to Utility Tunneling, except **it combines the excavation & pipe installation into one step**
  - Product pipe sizes 1,000 mm & larger
  - Limitations on length & size based on logistical considerations & safety

Pipe Jacking Method

Characteristic of Pipe Jacking					
Method	**Diameter Range (mm)**	**Typical Installation (m)**	**Pipe Materials**	**Typical Applications**	**Accuracy (+ or -)**
Pipe Jacking	1,000 mm & larger	500	RCP, GRP, Steel	Pressure & Gravity Pipelines	~25 mm

Typical Components of a Pipe Jacking Operation



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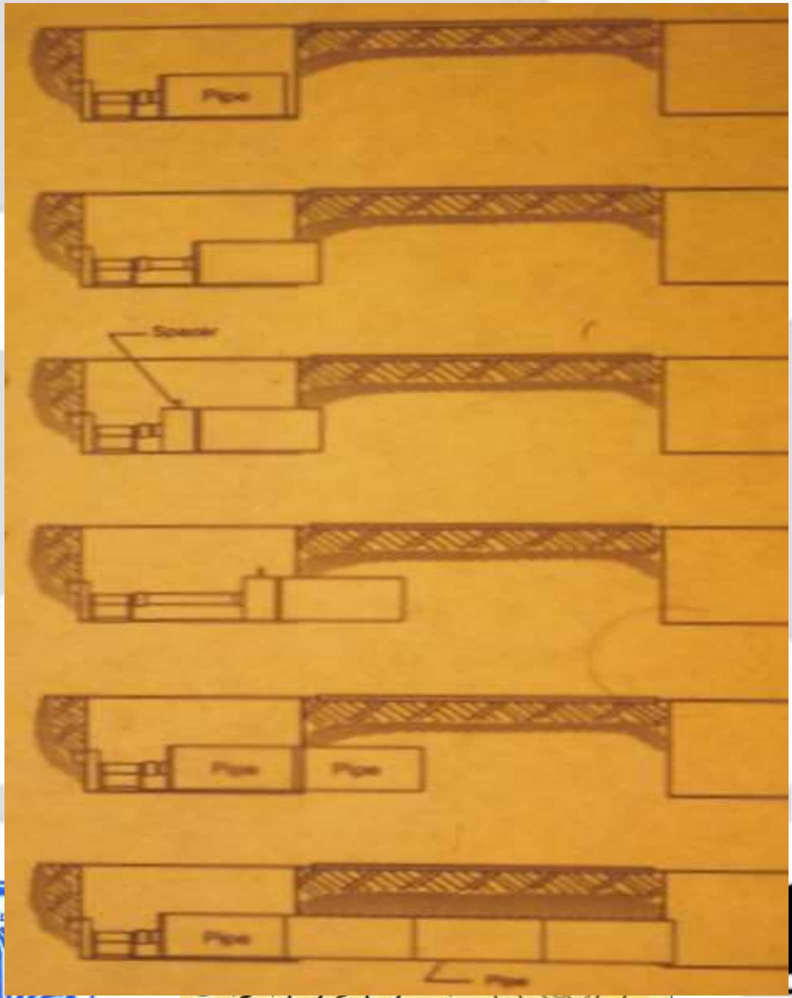
Pipe Jacking Method

- Pipe inserted & advanced into soil by rams from jacking shaft as soil is excavated ahead of leading pipe joint
- New pipes added as required until lead pipe joint reaches come out shaft



Pipe Jacking Equipment

Pipe jacking in progress inside the launch shaft

Arrival of the tunneling machine at the reception shaft

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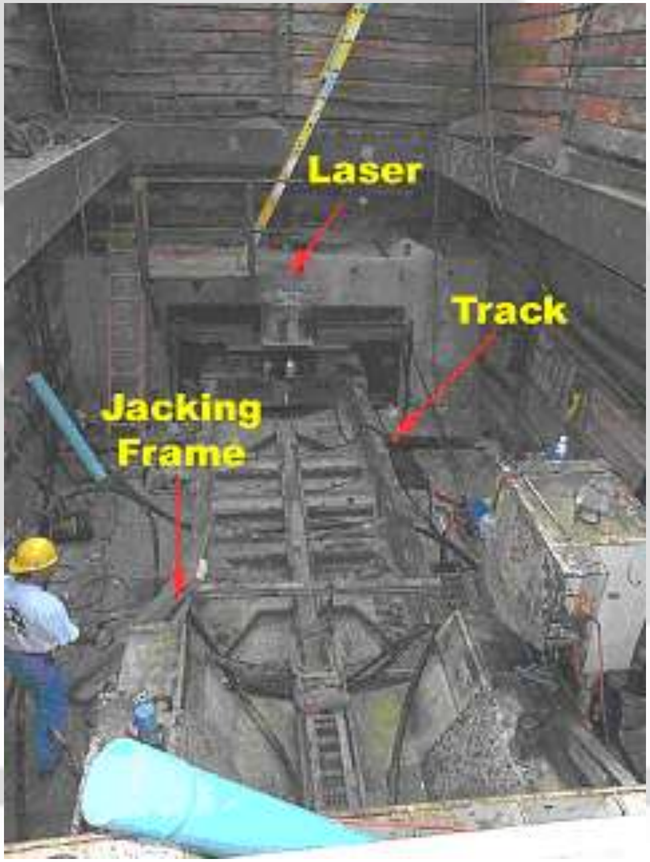
Pipe Jacking Equipment

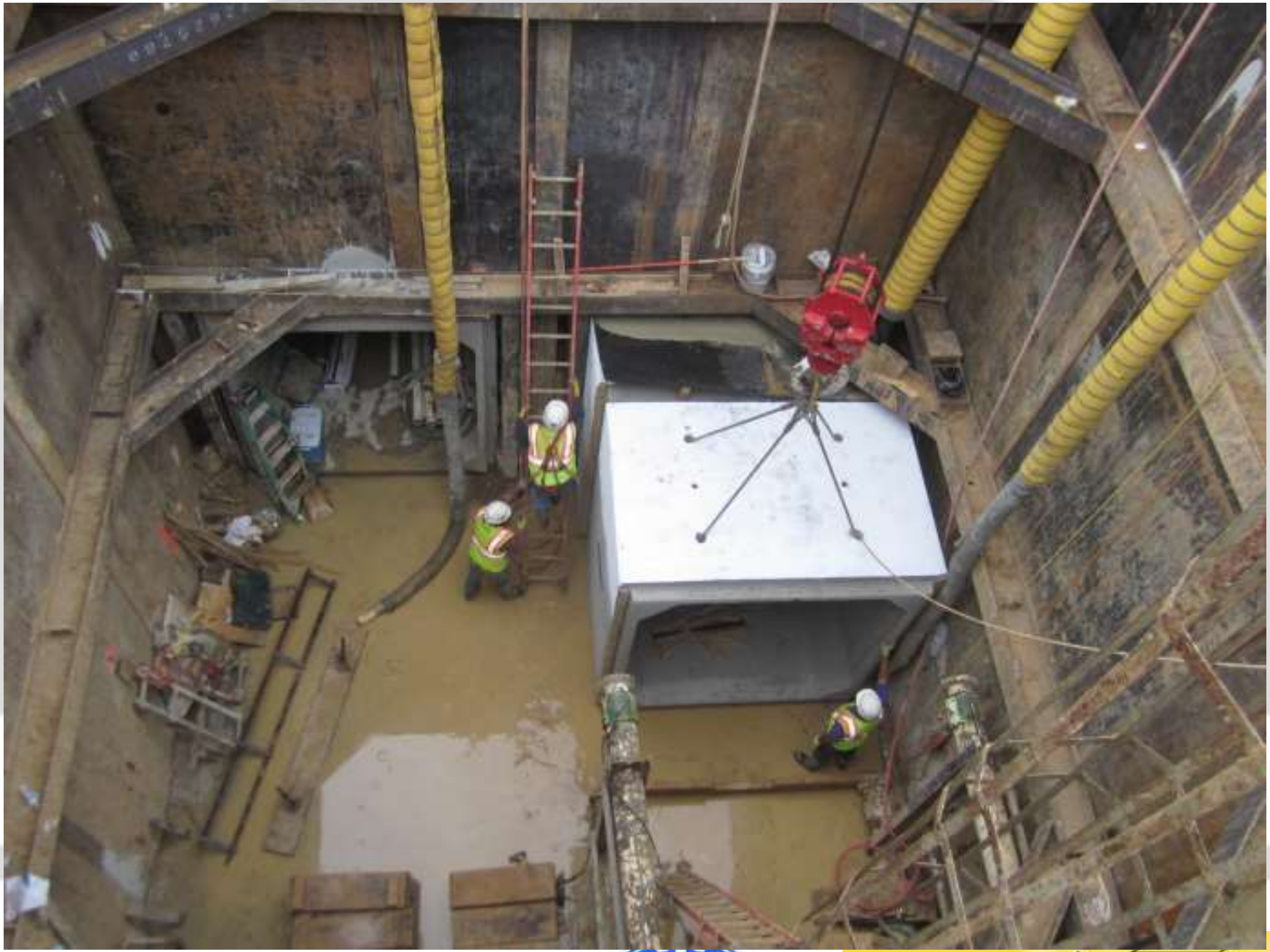
Laser Guidance System for Pipe Jacking



Intermediate Jacking Stations

Source: Akkerman, Inc.

Box Jacking



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Box Jacking

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Box Jacking

Box Jacking

Box Jacking

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Trenchless Technology Methods

- **Trenchless Methods**
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    - Manhole Renewal

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Horizontal Auger Boring Method

- Process of simultaneously jacking casing through the earth while removing the spoil inside the encasement by means of a rotating flight auger

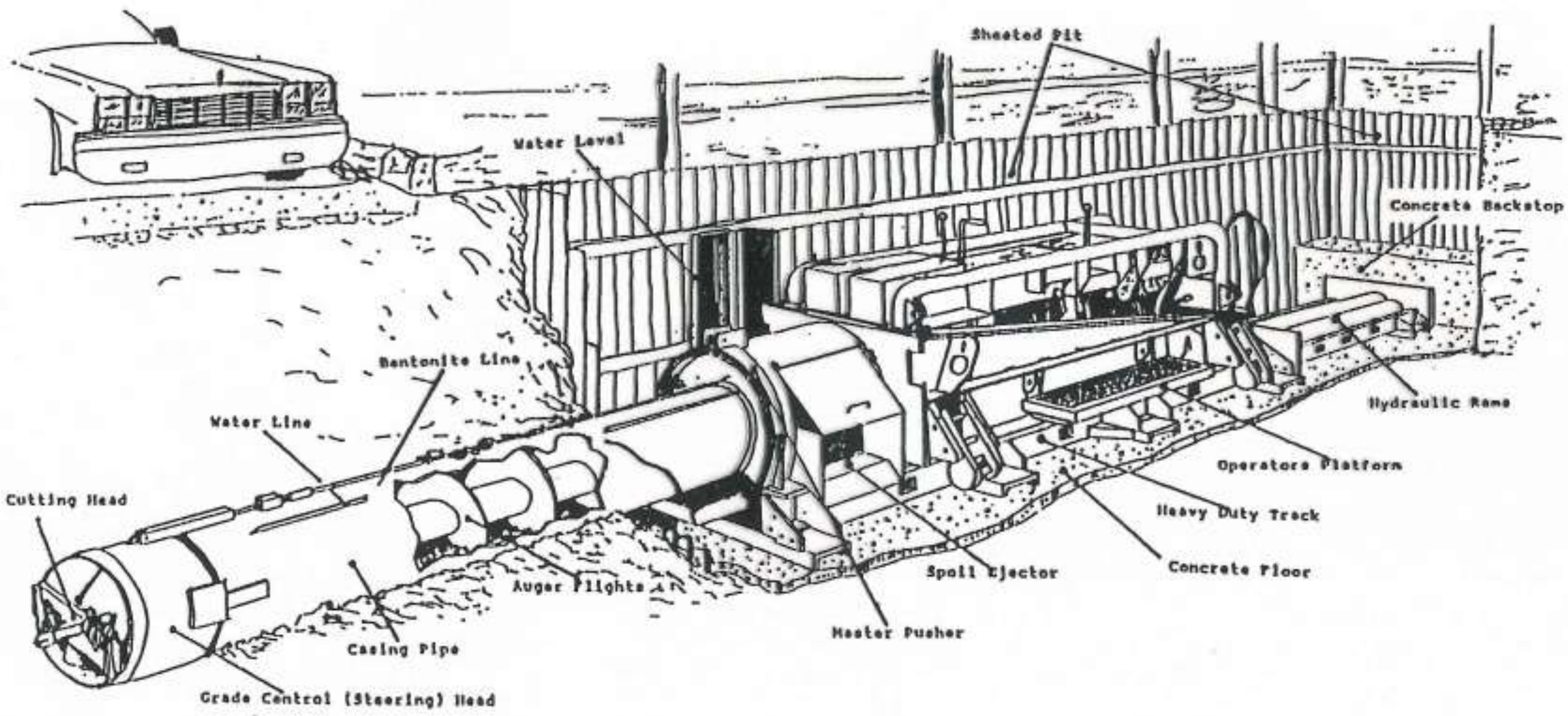
Horizontal Auger Boring Method

- Horizontal Auger Boring
  - Performed in two steps:
    - Excavation & installation of the casing pipe
    - Installation of carrier pipe & filling annular space with grout
  - Crossing technique
  - Available with
    - Dynamic grade control
    - Dynamic line & grade control

Horizontal Auger Boring Method

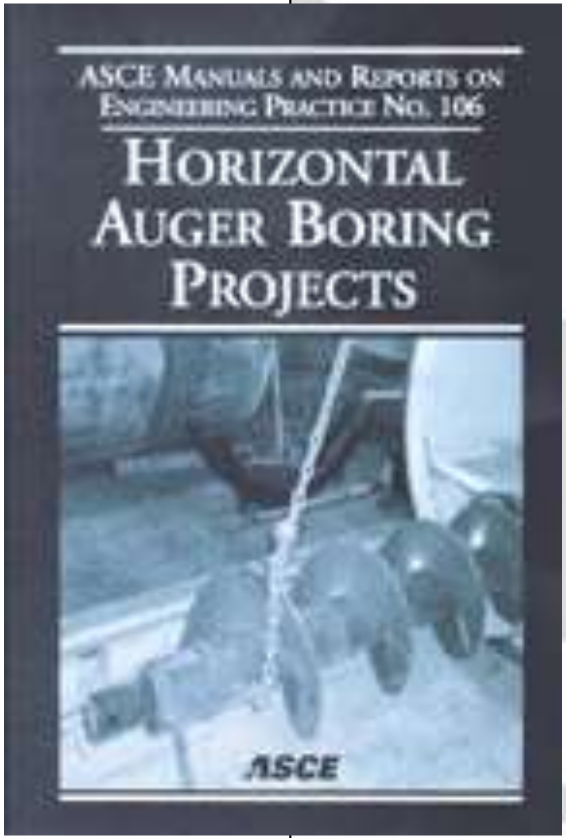
Characteristic of Horizontal Auger Boring					
Method	**Diameter Range (mm)**	**Maximum Installation (m)**	**Pipe Materials**	**Typical Applications**	**Accuracy (+ or -)**
Auger Boring	100-1,500	200	Steel	Road Crossings	1% of bore length
Auger Boring w/grade control	100-1,500	200	Steel	Road Crossings	300 mm
Auger Boring w/line & grade control	100-1,500	200	Steel	Road Crossings	300 mm

Track Type Auger Boring Machine



Major Components

- Track System
- Machine
- Casing Pipe
- Cutting Head
- Augers



Horizontal Auger Boring Method

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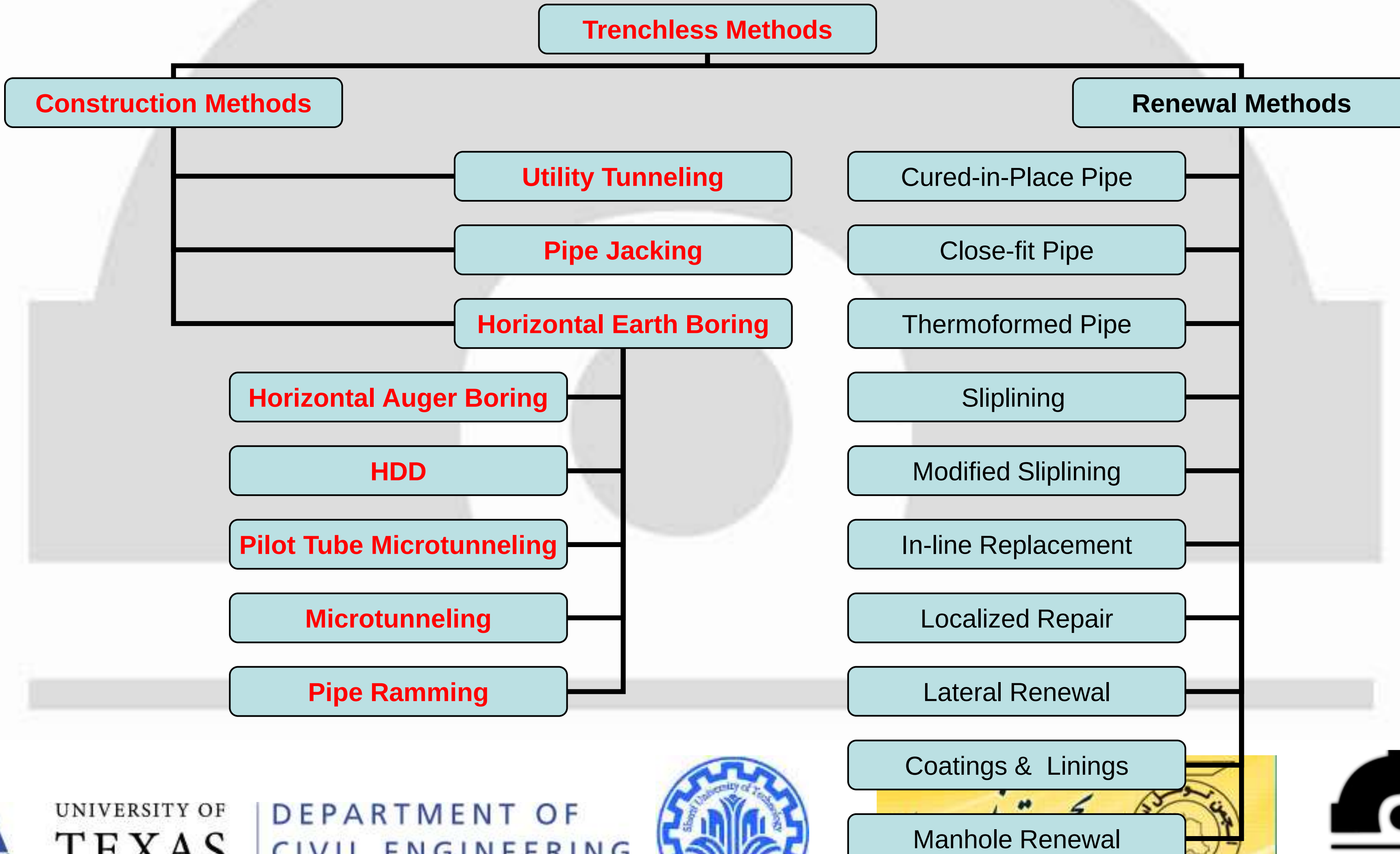
Horizontal Auger Boring Method

Horizontal Auger Boring Method

Trenchless Technology Methods



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Horizontal Directional Drilling Method (HDD)

- Horizontal Directional Drilling (HDD)
  - Performed in two (or more) steps
    - Drilling of pilot hole using a steerable drill head & guidance system
    - Backreaming to increase pilot hole diameter & pullback of product pipe
  - Product pipe sizes up to about 1,500 mm
  - Typically used for crossings

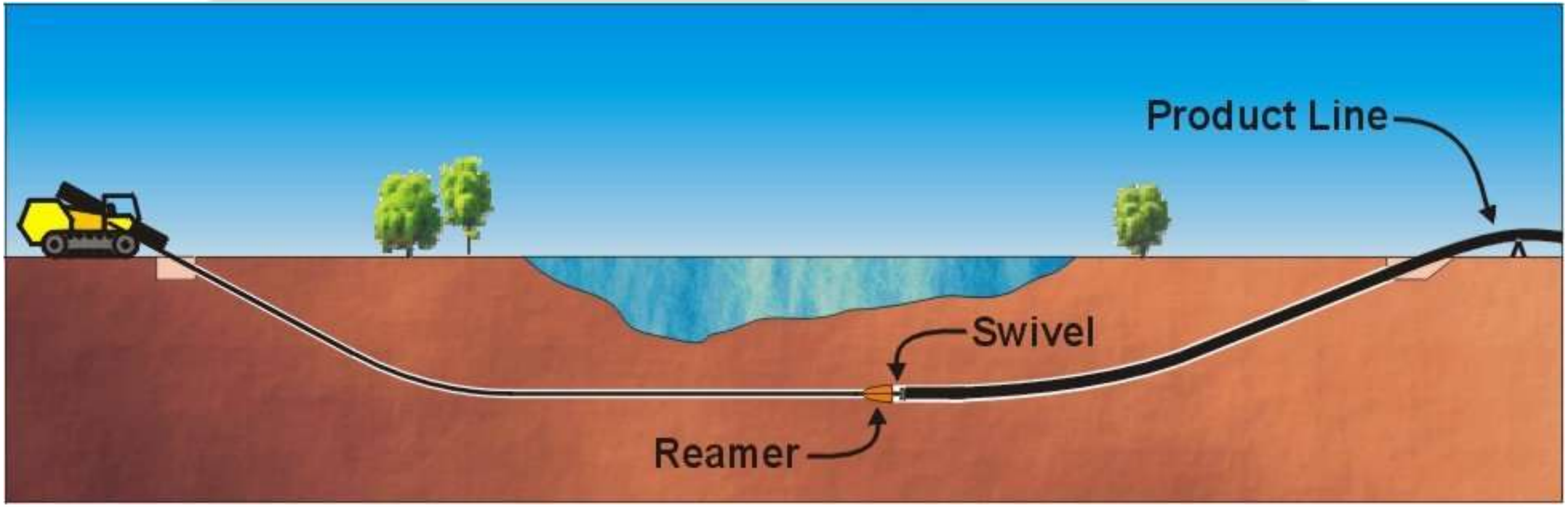
Horizontal Directional Drilling (HDD)

- Usually performed in two (or more) steps:
  - Drilling of pilot hole using a steerable drill head & locator system
  - Backreaming to increase pilot hole diameter & pullback of product pipe
  - Product pipe sizes up to about 1,500 mm
  - Typically used for road and river crossings

Horizontal Directional Drilling Method (HDD)

Characteristic of Horizontal Directional Drilling					
Method	**Diameter Range (mm)**	**Maximum Installation (m)**	**Pipe Materials**	**Typical Applications**	**Accuracy (+ or -)**
Mini-HDD	100 – 300	< 200	PE, Steel, PVC,	Pressure Pipe & Conduits	Varies
Midi-HDD	300 – 600	200– 600	PE, Steel, DIP	Pressure Pipe	Varies
Maxi-HDD	600 --1,500	600 – 2,000	PE, Steel	Pressure Pipe	Varies

Horizontal Directional Drilling Method (HDD)



Source: Hair & Associates

Horizontal Directional Drilling Method (HDD)

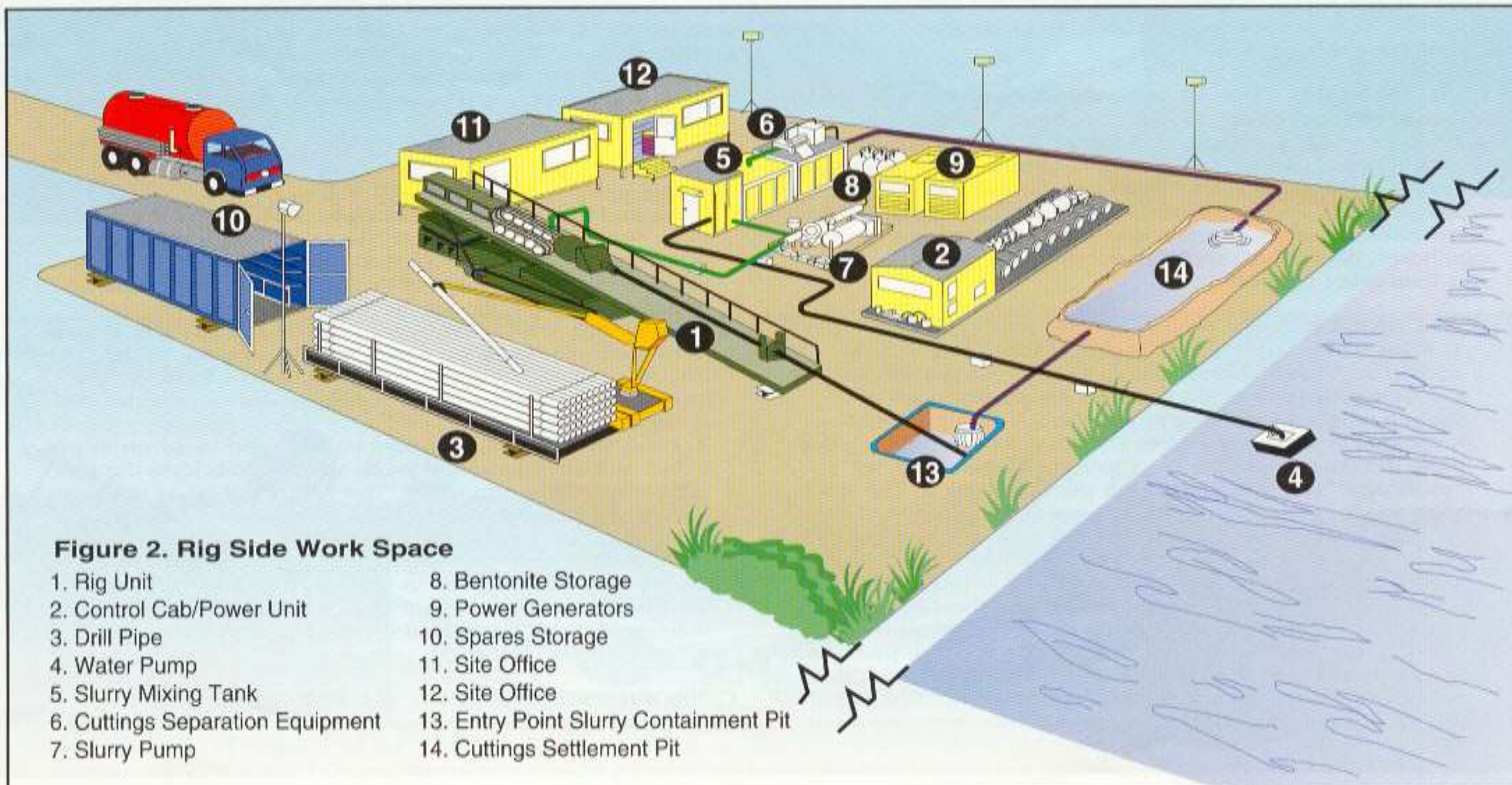


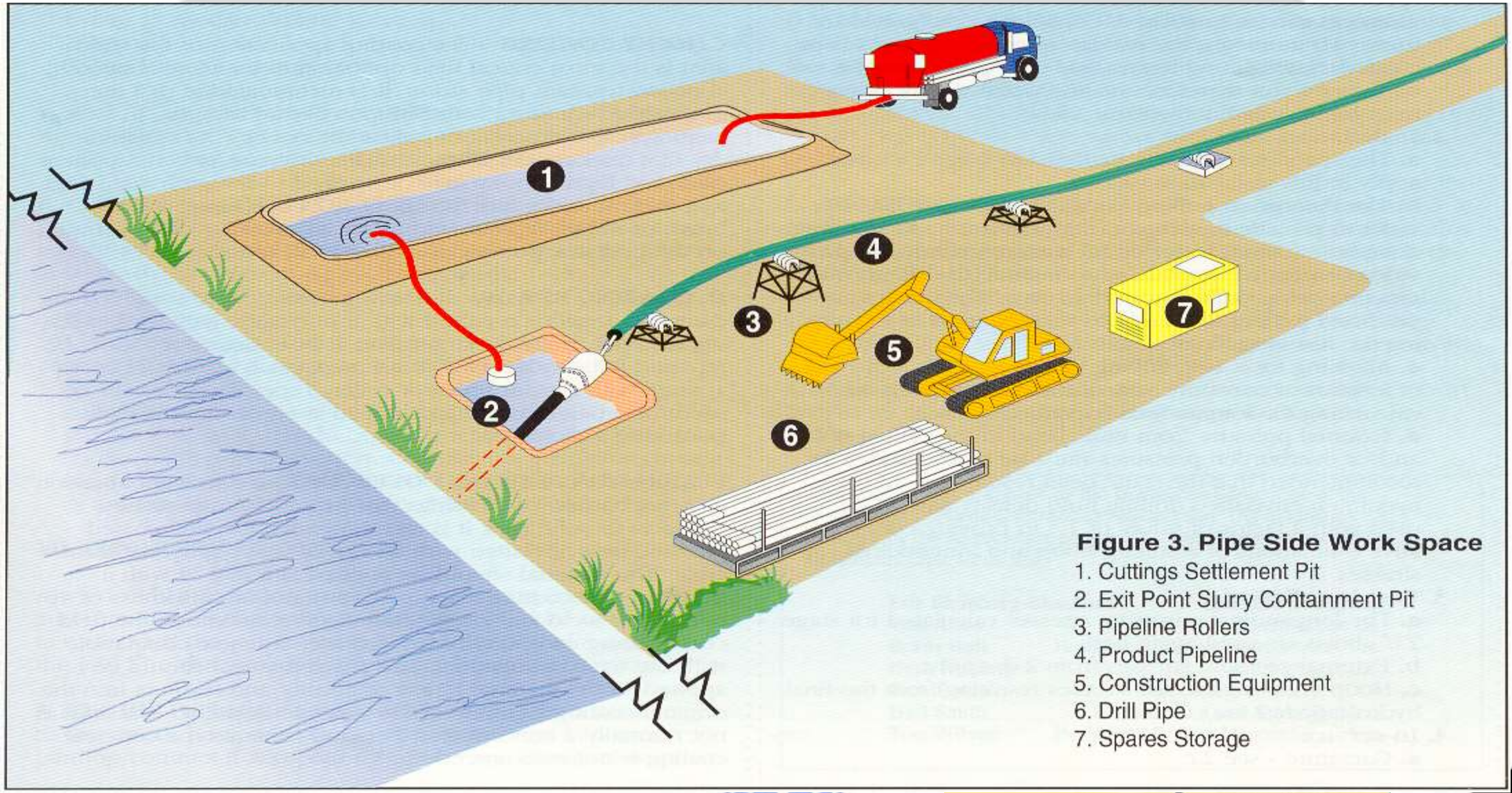
Figure 2. Rig Side Work Space

1. Rig Unit
2. Control Cab/Power Unit
3. Drill Pipe
4. Water Pump
5. Slurry Mixing Tank
6. Cuttings Separation Equipment
7. Slurry Pump
8. Bentonite Storage
9. Power Generators
10. Spares Storage
11. Site Office
12. Site Office
13. Entry Point Slurry Containment Pit
14. Cuttings Settlement Pit

DCCA 4 PIPELINE DIGEST AUGUST 1995

Source: Hair & Associates

Horizontal Directional Drilling Method (HDD)



Source: Hair & Associates

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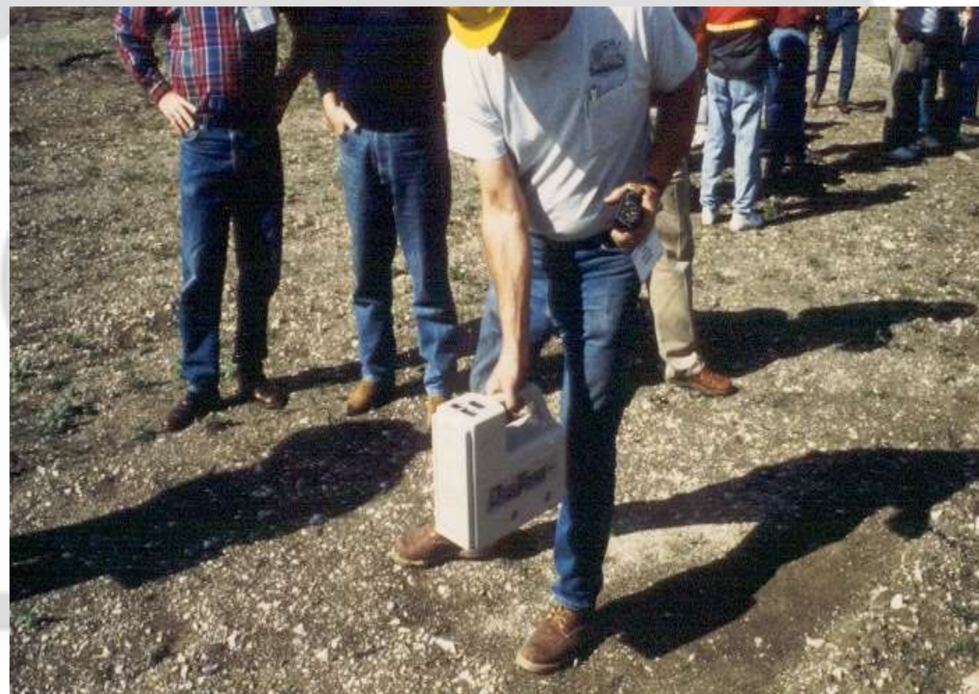
Horizontal Directional Drilling Method (HDD)



Source: Hair & Associates

Horizontal Directional Drilling Method (HDD)

Source: Hair & Associates

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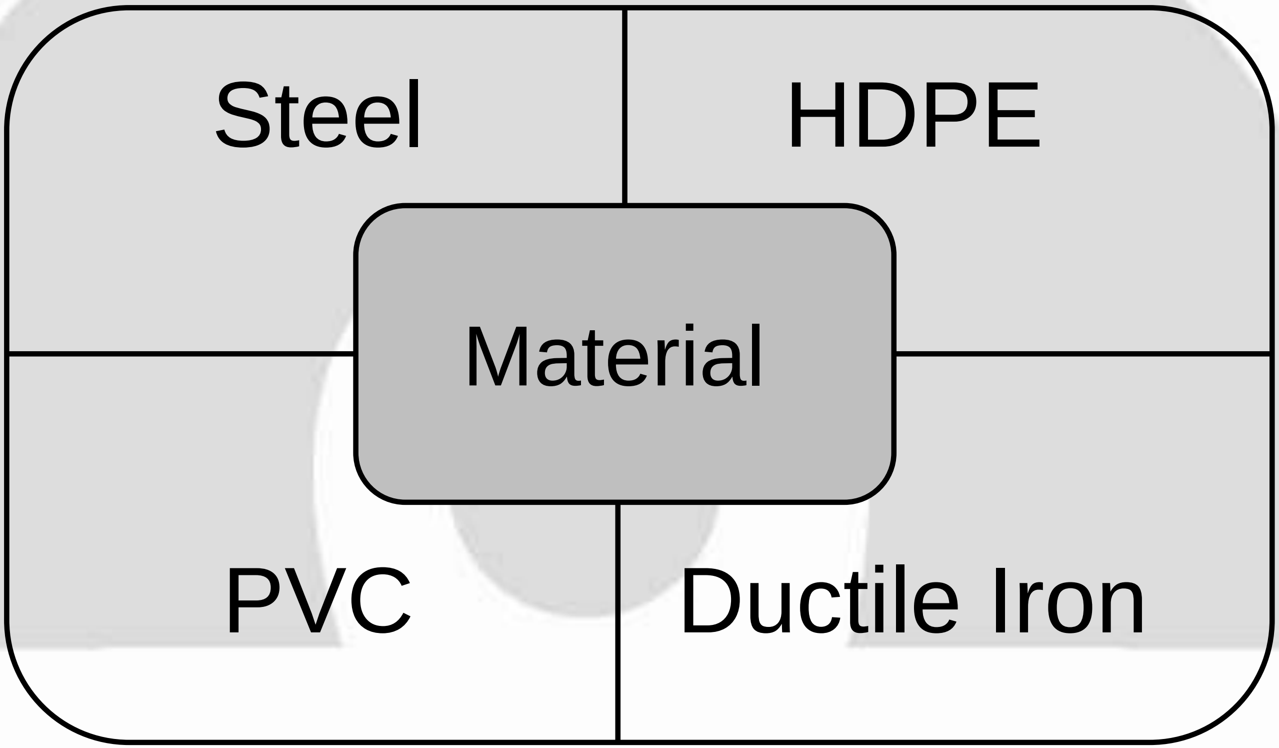
Horizontal Directional Drilling Method (HDD)

Source: Hair & Associates

Specifications – Material



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Specifications – Grade

Steel
- Grade B
- Grade X-?

HDPE
- PE 3408
- PE 4710

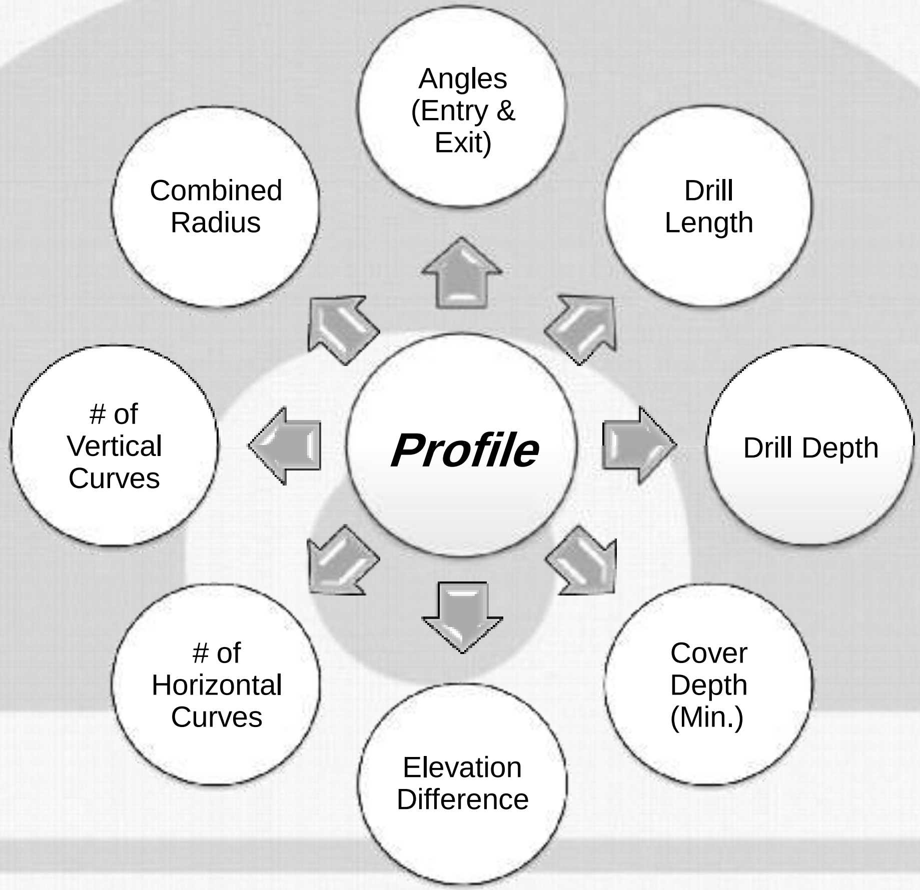
PVC
- C-900 or C-905
- ASTM

Ductile Iron
- American Flex-Ring
- US Pipe TR Flex

Pipe Comparison

Pipe	+	−
Steel	✓ Tensile Strength ✓ Diameter Range	✓ Corrosion Protection
HDPE	✓ Corrosion Protection ✓ Very Flexible	✓ Tensile Strength ✓ Diameter Range
Ductile Iron	✓ Familiarity ✓ Availability	✓ Tensile Strength ✓ Diameter Range
Fusible PVC	✓ Corrosion Protection ✓ Consistent Material ✓ Tensile Strength	✓ Limited Flexibility v. HDPE ✓ Diameter Range

Profile Geometry



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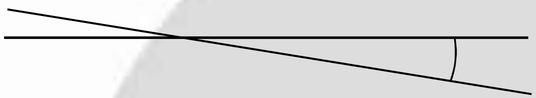
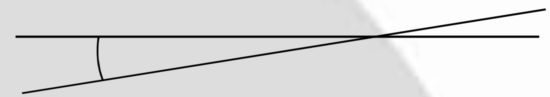
Geometry – Angles



Entry Angle

Optimum Range – 6° to 18°



Exit Angle

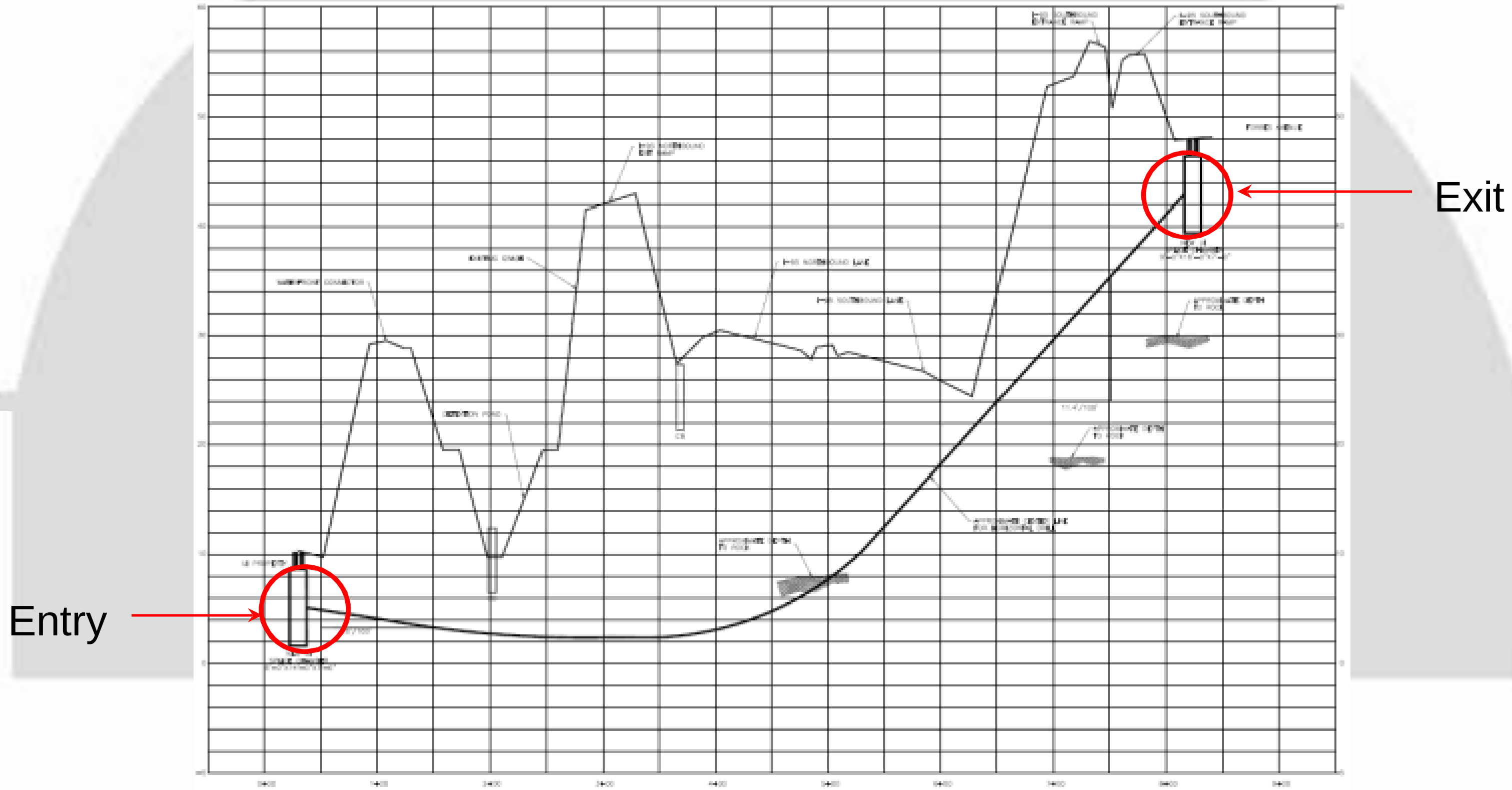
Optimum Range – 6° to 14°

Low Angles	***High Angles***
• Easy Access • Shallow Cover • Lower Bending Stress	• Challenging • Increased Equipment Requirements • Higher Bending Stress

Geometry – Drill Depth

Shallow	Deep
Reduced Cover Depth	Increased Cover Depth
Increased Frac-out Risk	Reduced Frac-out Risk
Reduced External Forces	Increased External Forces
Ease of Drilling	High Annular Pressure

Geometry – Elevation Difference



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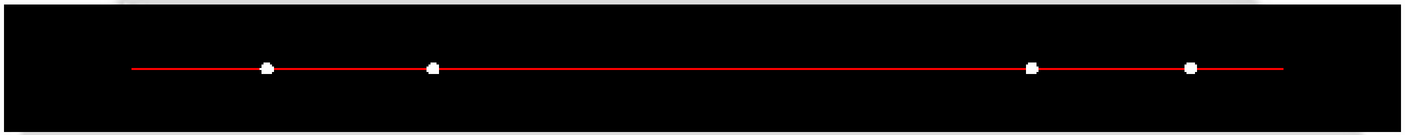
Geometry – Cover Depth

- Minimum 20' – 25' for Soils
- Can be less for Rock
- 5' is not PRACTICAL !!!

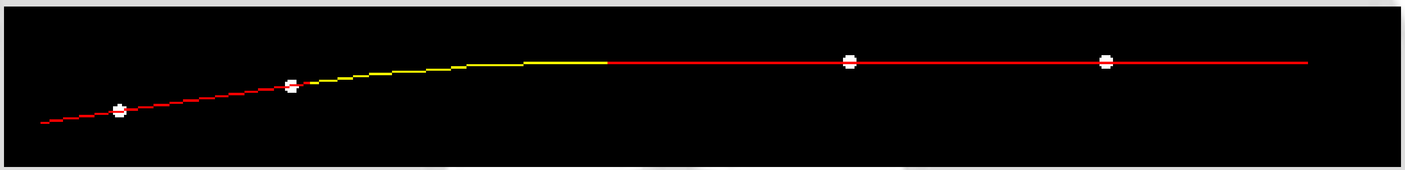
Geometry – No. of Horizontal Curves

0	• Straight Profile • No Steering Issues
1	• Horizontal Radius Consideration • Possibility of a Compound Curve
2	• Might Complicate the Steering • Possibility of a Compound Curve
3	• Unusual and Should be Avoided • Complicated Steering

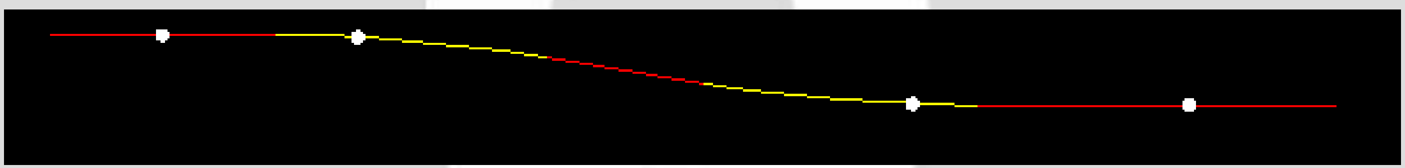
Geometry – No. of Horizontal Curves



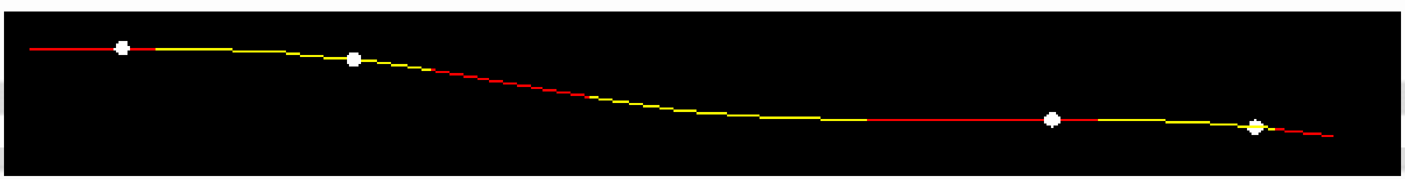
No Horizontal Curve



1 Horizontal Curve



2 Horizontal Curves



3 Horizontal Curves

Geometry – No. of Vertical Curves

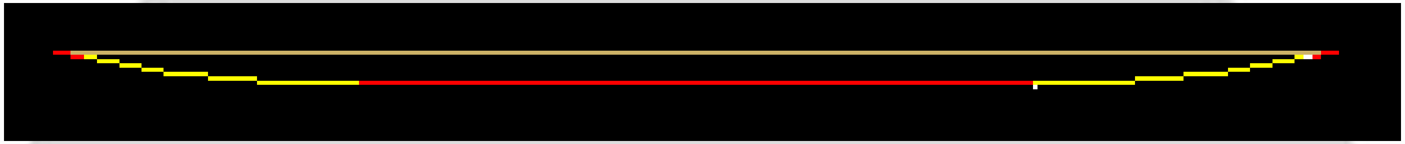
2
- Standard Scenario
- Might be Challenging with Compound Curve

3
- Increased Pull Load on Pipe
- Challenging Steering Conditions

4
- Increased Pull Load & Drag Forces on Pipe
- Unusual Case but Possible

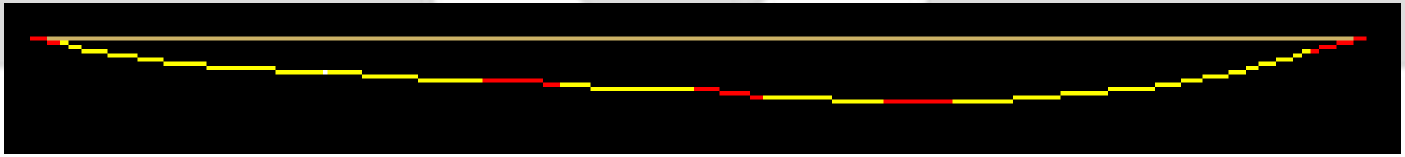
5
- Really ???

Geometry –No. of Vertical Curves



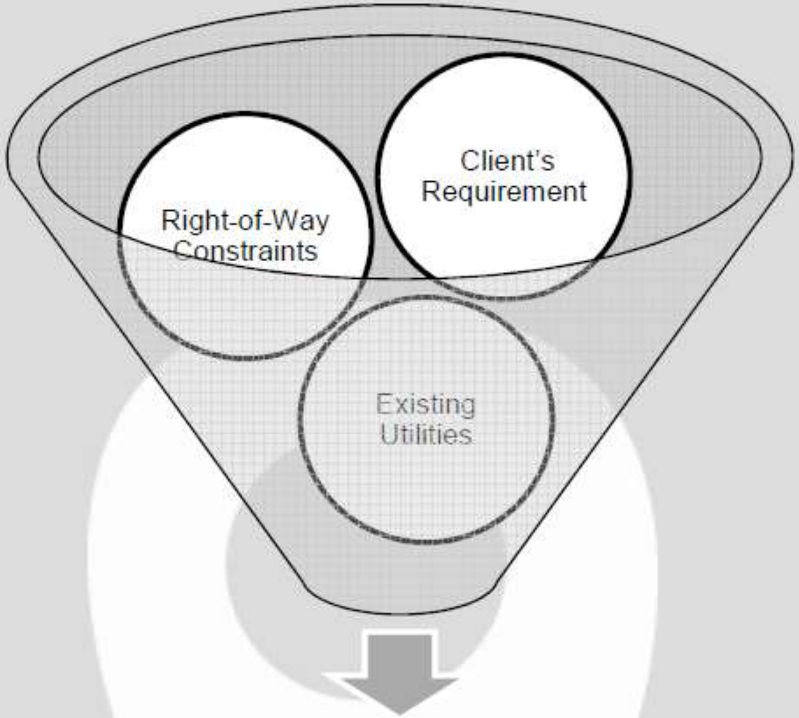
2 vertical Curves

3 Vertical Curves



4 Vertical Curves

Grade & Alignment Tolerances



Limited Margin for Errors

Buoyancy

- Buoyant Force on Pipe
  a. Pipe Weight (Upwards or Downwards)
  b. Ballast Weight (Downwards)
  c. Buoyant Force (Upwards)

- Net Buoyant Force = c – (a + b)

Can be Upwards or Downwards

Buoyancy

- 16” Dia. Steel Pipe, API 5L X42, 0.50” thick 2,400’ Long

Parameters	Pulled back Empty	Pulled back Filled
Weight of Empty Pipe (↓)	62.64 lb./ft.	62.64 lb./ft.
Buoyant Force on Pipe (↑)	99.22 lb./ft.	99.22 lb./ft.
Weight of Water Filled Pipe (↓)	141.79 lb./ft.	141.79 lb./ft.
Net Buoyant Force on Pipe	36.58 lb./ft. (↑)	- 42.57 lb./ft. (↓)
Pull Load on Pipe	106,479 lb.	126,103 lb.

Buoyancy

Empty Pipe in Filled Pilot Hole → Filled Pipe in Filled Pilot Hole → Balanced Approach → Filled Pipe in Filled Pipe

External Pressure

- Condition 1: Borehole is Stable

Pressure due to Drilling Fluid − Internal Pressure = Net External Pressure

- Condition 2: Borehole is Deformed or Collapsed

Earth Pressure + Pressure due to Drilling Fluid + Pressure due to Ground Water − Internal Pressure = Net External Pressure

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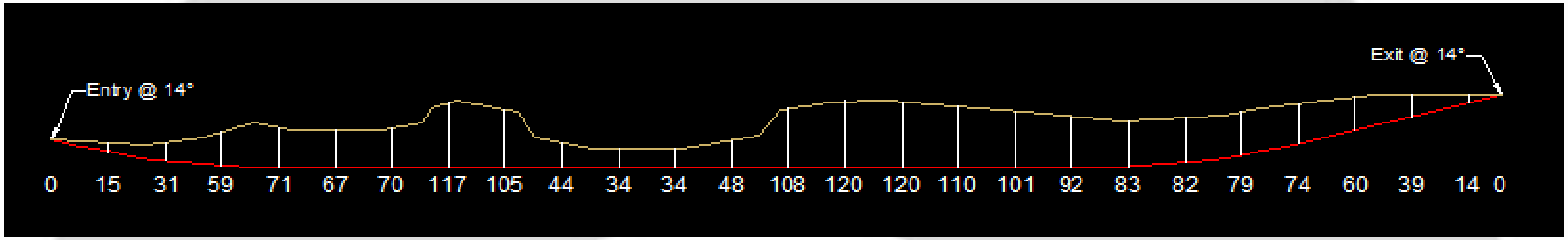
Steering with Walkover System



Incomplete Information → Provides Relative Depth → Stake Out for Actual Profile

Trenchless Technology Methods

- **Trenchless Methods**
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    - Manhole Renewal

What is Microtunneling?

- Tunneling - horizontal earth boring
- Laser Guided – line & grade
- Pipe Jacked
- Continuously Supported
- Suited for Gravity Sewer Line
- No Size Limitations for North American Definition – not "micro"

ASCE American Society of Civil Engineers
PUBLICATIONS

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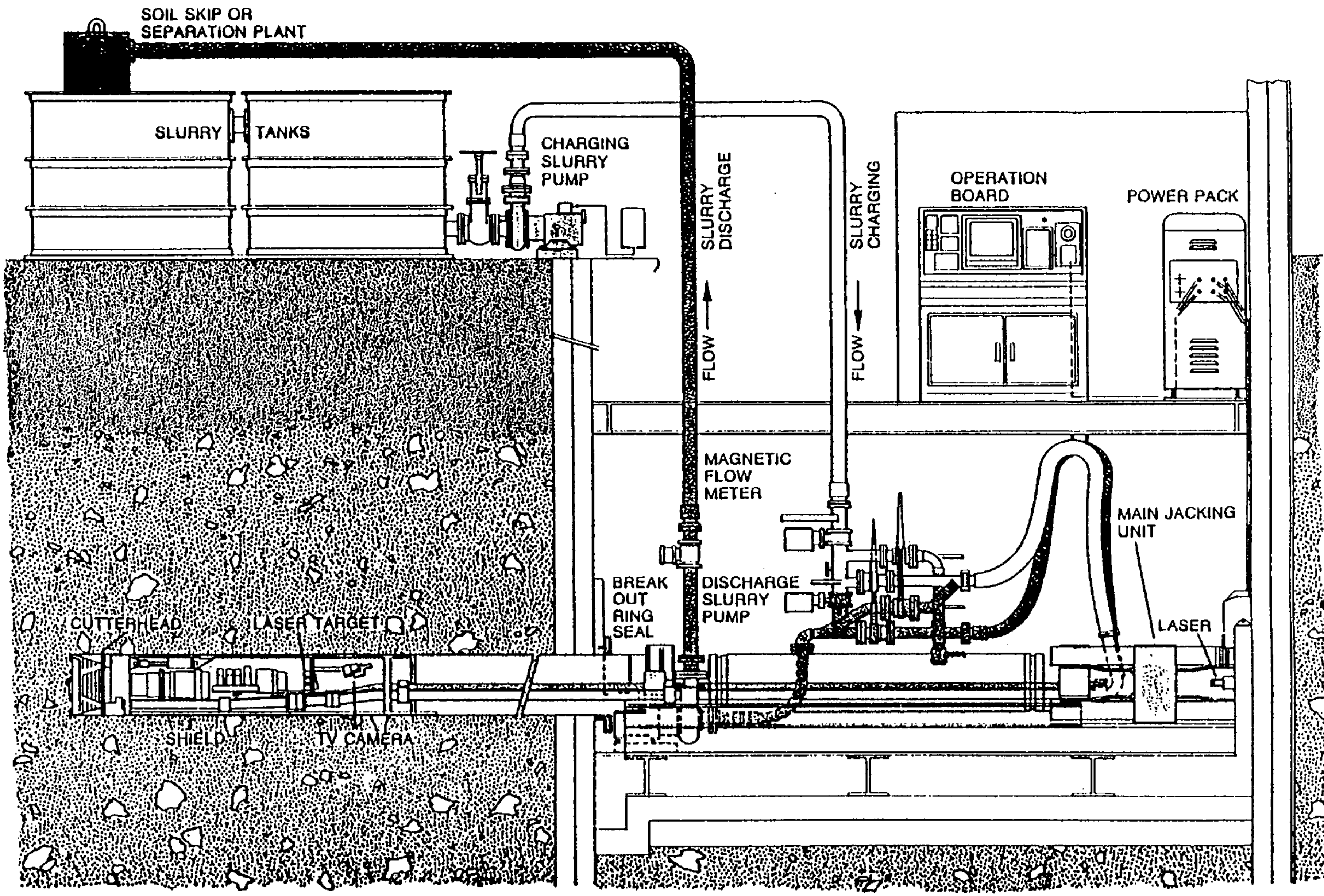
Microtunneling Method

- Microtunneling
  - Also known as remote-controlled pipe jacking
  - Product pipe sizes 300 mm & larger
  - Uses automation for processes performed by workers within the tunnel on pipe jacking
    - Remote controlled MTBM
    - Remote controlled excavation & spoil removal
    - Remote controlled guidance system

Microtunneling Method

Characteristic of Microtunneling					
Method	**Diameter Range (mm)**	**Typical Installation (m)**	**Pipe Materials**	**Typical Applications**	**Accuracy (+ or -)**
Microtunneling	> 300	500	RCP, GRP, VCP, Steel, PCP	Gravity Pipelines	~ 25 mm

Microtunneling

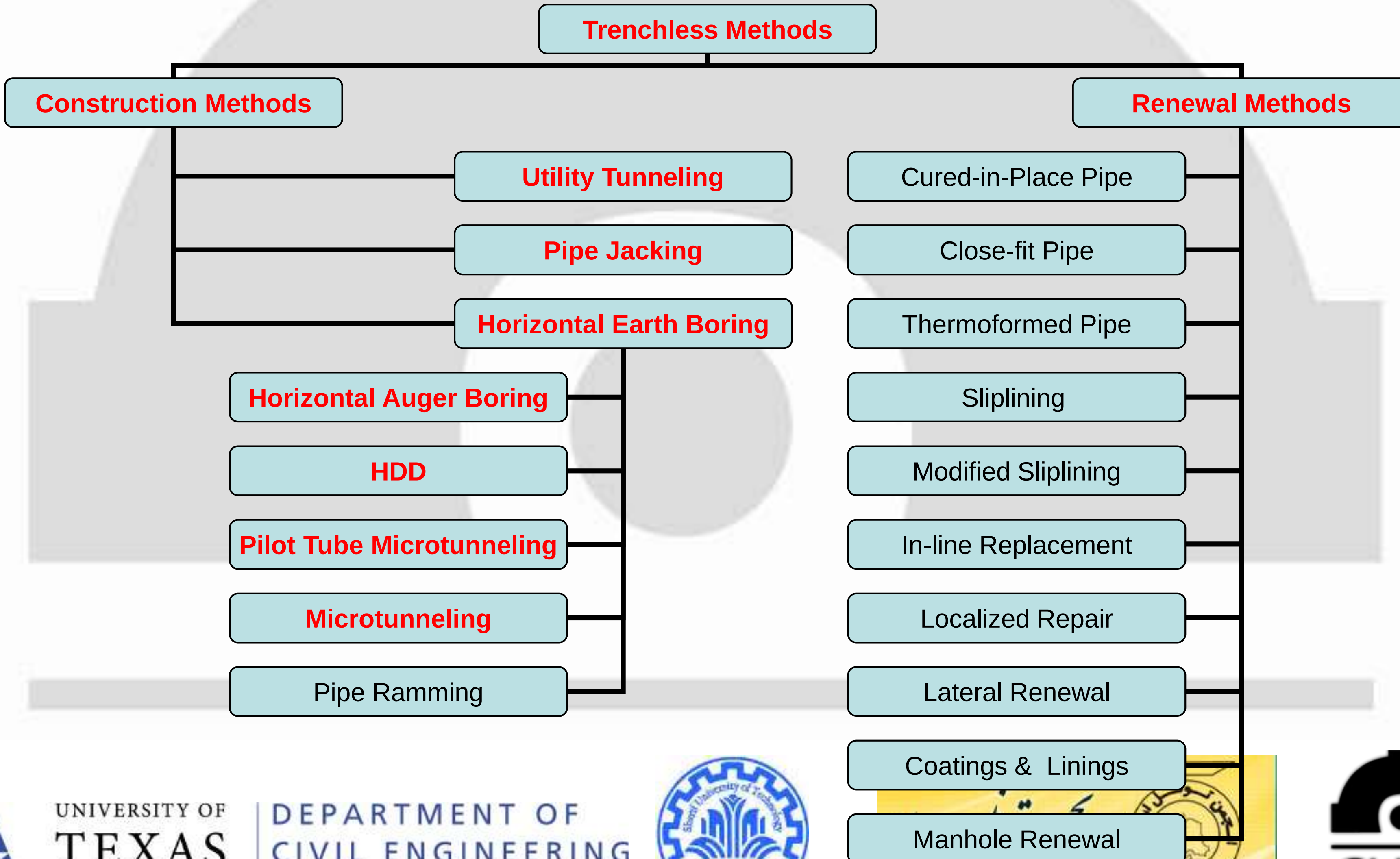


Microtunnel Boring Machine (MTBM)

Microtunneling Method

- Guidance systems based on a laser set in jacking shaft
- Types of guidance systems
  - Passive
  - Active

Trenchless Technology Methods



Pilot Tube Method

- Pilot Tube Microtunneling
  - **PTMT**
- Guided Boring Method
  - **GBM**
- Guided Auger Boring
  - **GAB**

Trenchless Technology Methods

- Pilot Tube Microtunneling
  - Alternative to conventional microtunneling
  - Combines the features:
    - Accuracy of microtunneling
    - Steering mechanism of HDD
    - Spoil removal system of auger boring
  - Typically used in soft soils at relatively shallow depths for smaller diameter water lines & gravity sewers

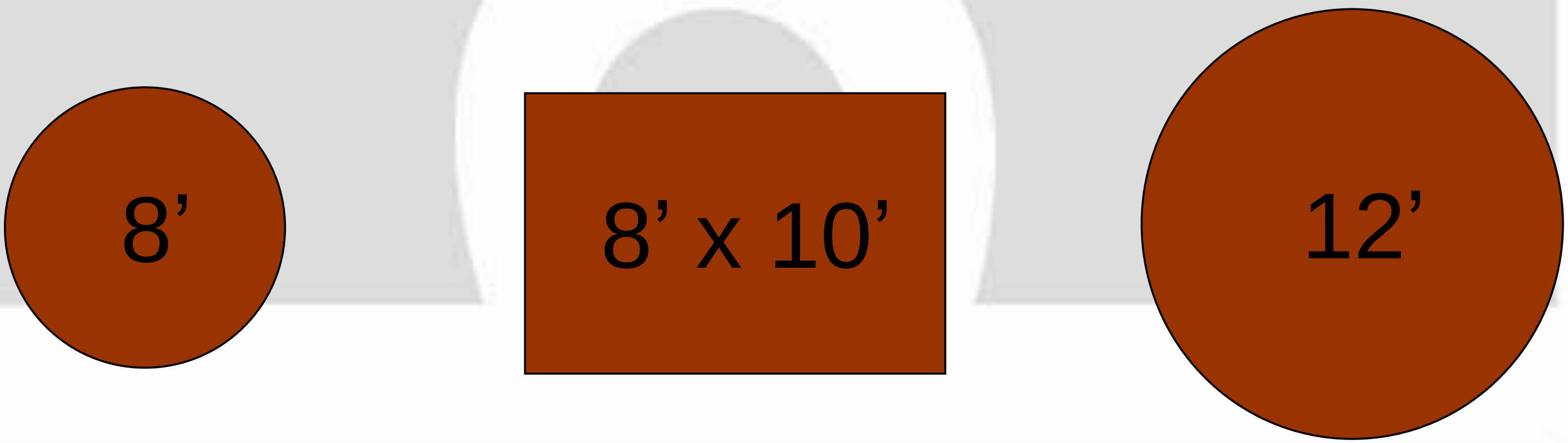
Trenchless Technology Methods

Characteristic of Pilot Tube Microtunneling					
Method	**Diameter Range (mm)**	**Maximum Installation (meters)**	**Pipe Materials**	**Typical Applications**	**Accuracy (+ or -)**
Pilot Tube Microtunneling	150 – 300	100	RCP, GRP, VCP, Steel, PCP	Smaller diameter gravity pipes	~25 mm

Shaft Lining

Shaft Sizes

- Working space or foot print depends on jacking frame, pipe OD and pipe length.



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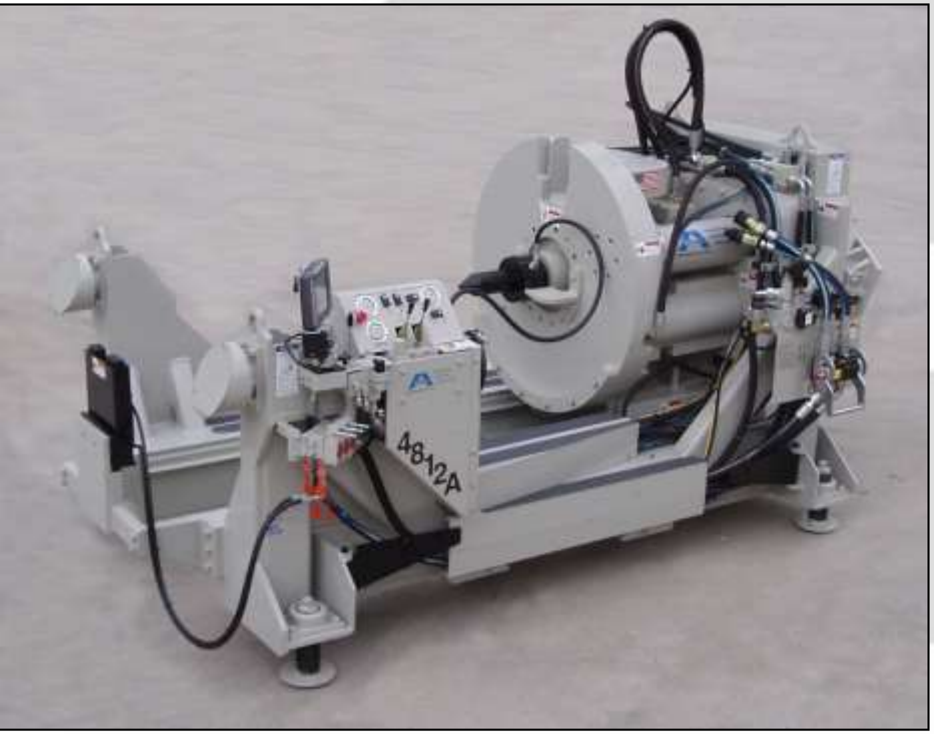
Latching Frame 100 Ton Machines

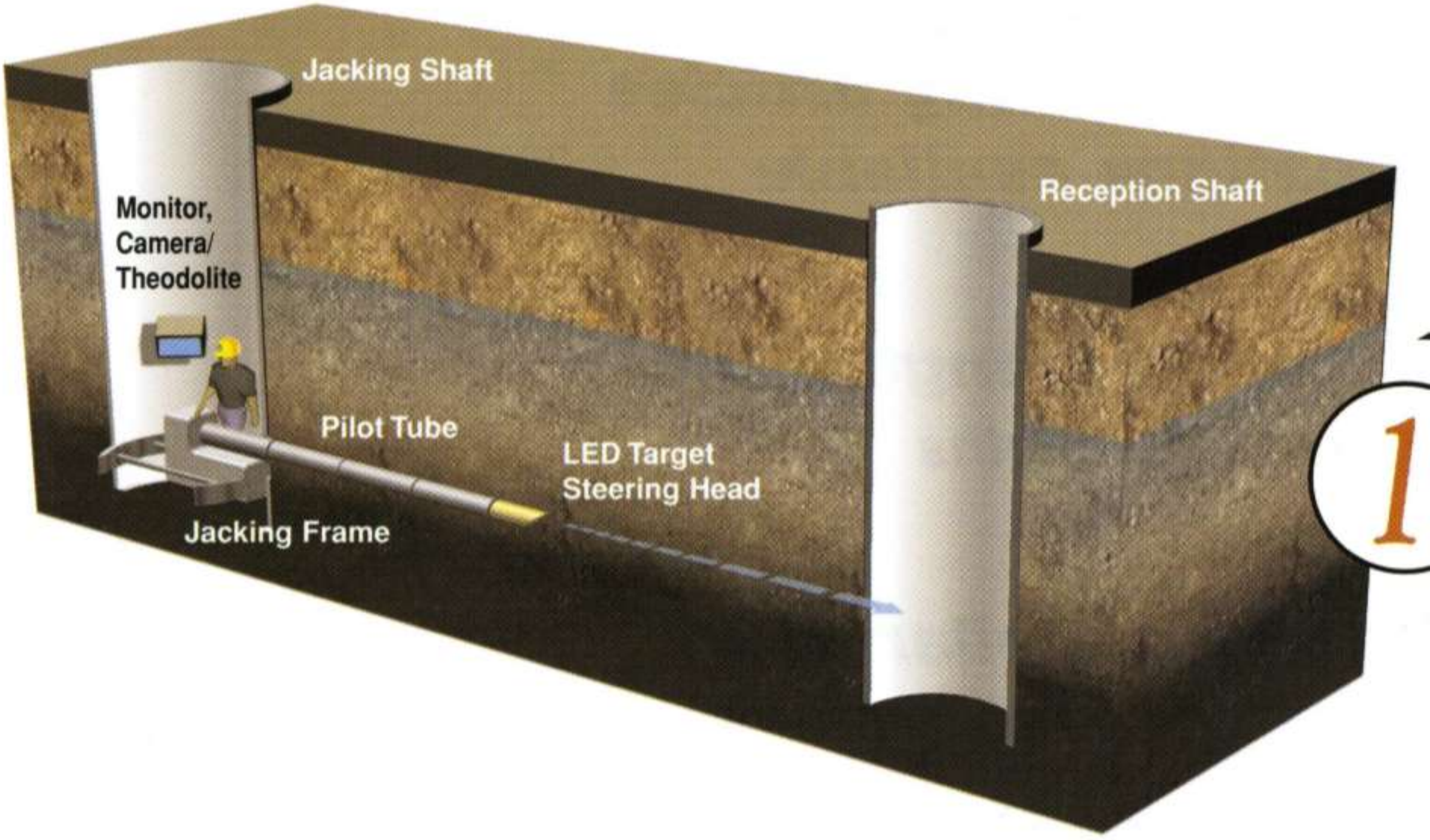
- Capable of 11” thru 30” O.D. pipe in an 8’ shaft.
- One meter pipe lengths

Large Diameter PTMT



- Capable of 11” thru 48” O.D. pipe in a 12’ shaft.
- Can handle up to 2 meter lengths.
- “Extension Cans” can be added to jack longer length pipes. However, longer shafts would be required.

First Step in a 3-step PTMT



Guidance System

- Video camera transmits the target image to the PC display

Guidance System

- Consists of a LED illuminated target located in the steering head.


Nikon
HA:
-0.50 %
0°00'00"
%/VA
R/L
HOLD
RESET

Installing the Pilot Tube

- Operator is looking at the digital display on the PC to maintain line and grade on the pilot tube.

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Pilot Tubes

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Pilot Tube

- Double Wall Pilot Tube

Pilot Tube Steering

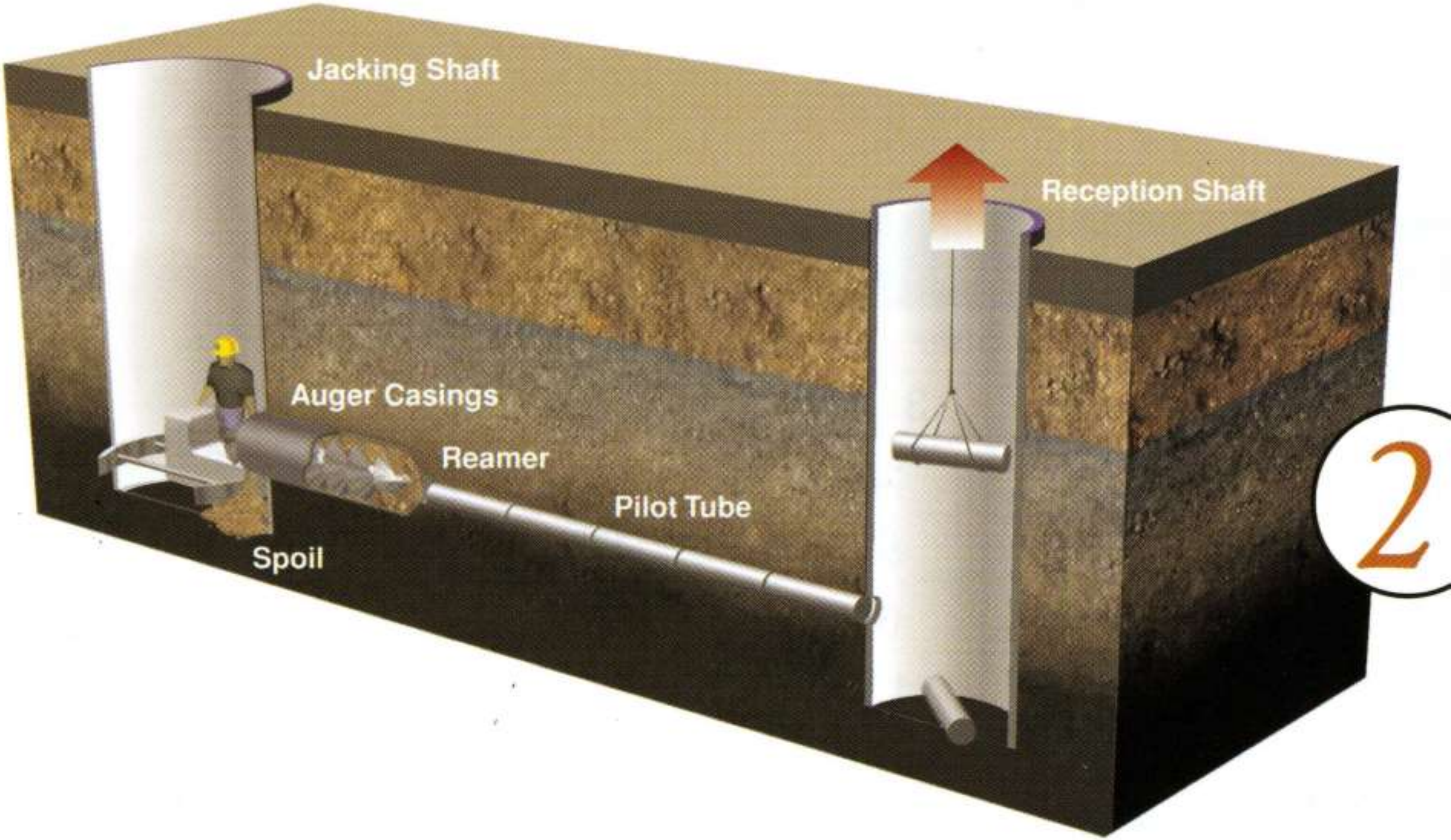
Bullet – Very hard – high blow count soils

45° – For soft or low blow count soils

30° – For medium density soils

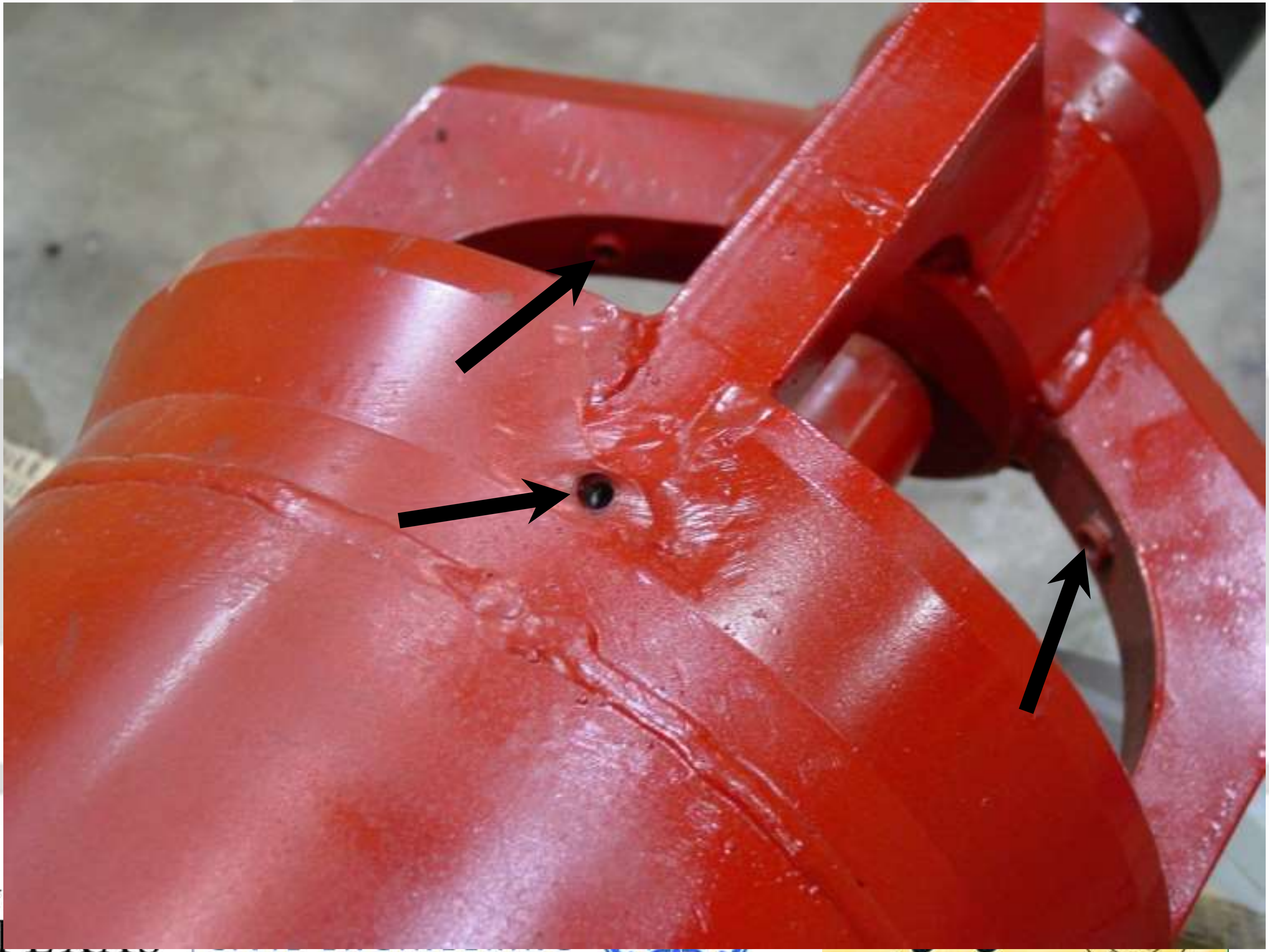
Changing Steering Heads

Second Step in a 3-step PTMT



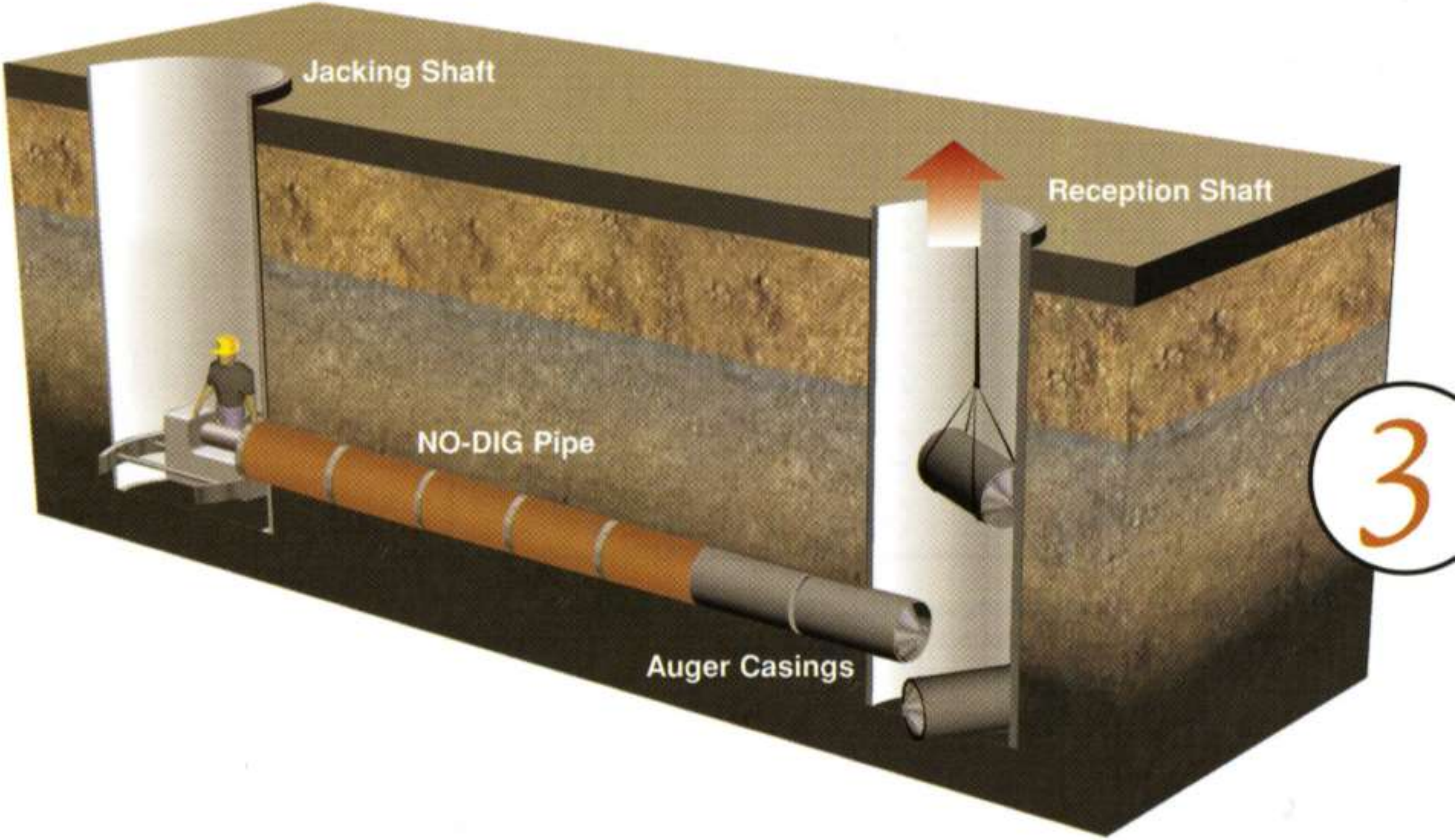
Reaming Head Configurations


Reaming Head Lubrication Port



Lubrication Line To Reaming Head

Final Step in a 3-step PTMT



3rd Step- Installation of Product Pipe

Spoil Removal

Manhole/ Invert installation upon drive completion


Mall of America: 2074 LF 18 inch, Bloomington Minnesota

Mall of America: 2074 LF 18 inch, Bloomington Minnesota

Logan, Utah

200 LF 15 inch pilot tube: Robinson Construction
40,000 LF TOTAL in Cape Girardeau Missouri

SAVINGS USING PILOT TUBE

MICROTUNNELING AT CAPE GIRARDEAU, MO

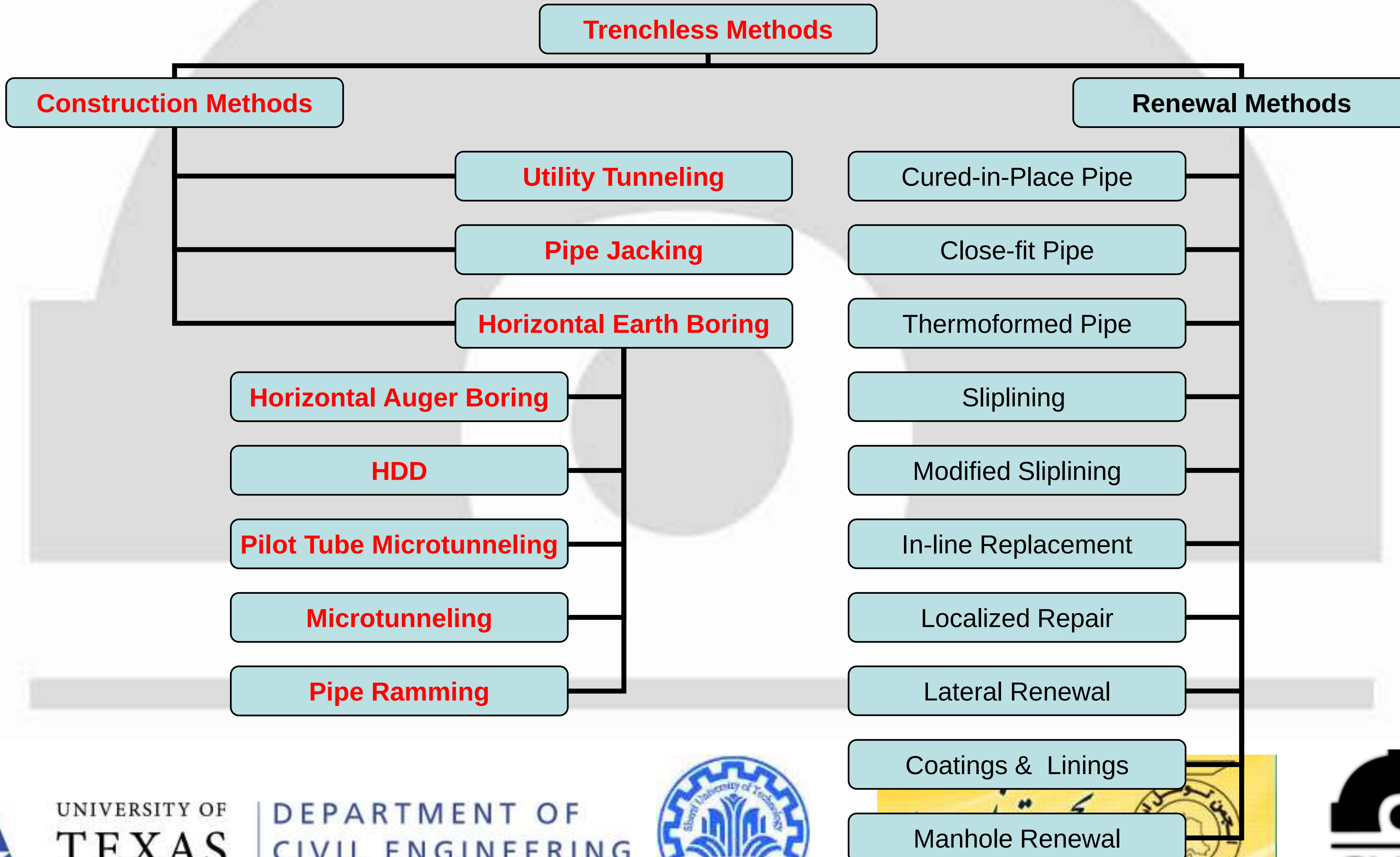
PROJECTS	ENG EST. $	2ND LOW BID Open Cut	PTMT BID	$ SAVED	%SAVED
Walnut/Henderson 12/95 4000 ft Sanitary (8" to 12") 230 ft Storm (12")	$ 837,992	$ 598,646	$ 556,832	$ 41,814	7.0%
College/Henderson S. 1/96 15,000 ft Sanitary (8" to 15") 800 ft Storm (12" to 18")	$ 3,207,719	$ 2,971,450	$ 2,764,264	$ 207,186	7.0%
Fort D 6/97 9,200 ft Sanitary (8" to 15") 2,100 ft Storm (12" to 24")	$ 2,450,000	$ 2,931,523	$ 2,187,000	$ 744,523	25.4%
College/Henderson N. 10/97 15,900 ft Sanitary (8" to 12") 2,000 ft Storm (12" to 18")	$ 5,000,000	None	$ 4,698,000	$ 302,000	6.0%
Main CSO 8/ 98 +- 50% Tunneled 1,800 ft Sanitary (8" to 18") 9,900 ft Storm (12" to 42")	$ 3,870,800	$ 4,725,000	$ 3,890,000	$ 835,000	21.6%

Total Savings Compared to Open Cut = $ 2,130,523 15.1%

Information per Mark Lester, PE, City of Cape Girardeau, Missouri

10 ft X 10 ft Asphalt Surface Restoration

Trenchless Technology Methods



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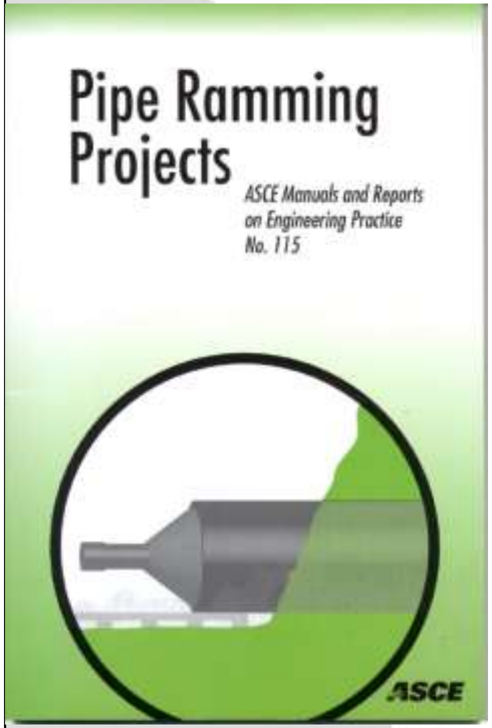
Pipe Ramming Method

- Pipe Ramming
  - Installed in two steps:
    - Installation of the casing pipe by using an air hammer from a drive pit
    - Use closed-end casing (< 203 mm diameter)
    - Use open-end casing for > 203 mm, clean spoil from casing after drive completed
    - Installation of carrier pipe & filling annular space with grout
  - Best suited for road crossings



Pipe Ramming Method

Characteristic of Pipe Ramming					
Method	**Diameter Range (mm)**	**Typical Installation (m)**	**Pipe Materials**	**Typical Applications**	**Accuracy (+ or -)**
Pipe Ramming	< 1,500	100	Steel	Road Crossings	Depends on setup

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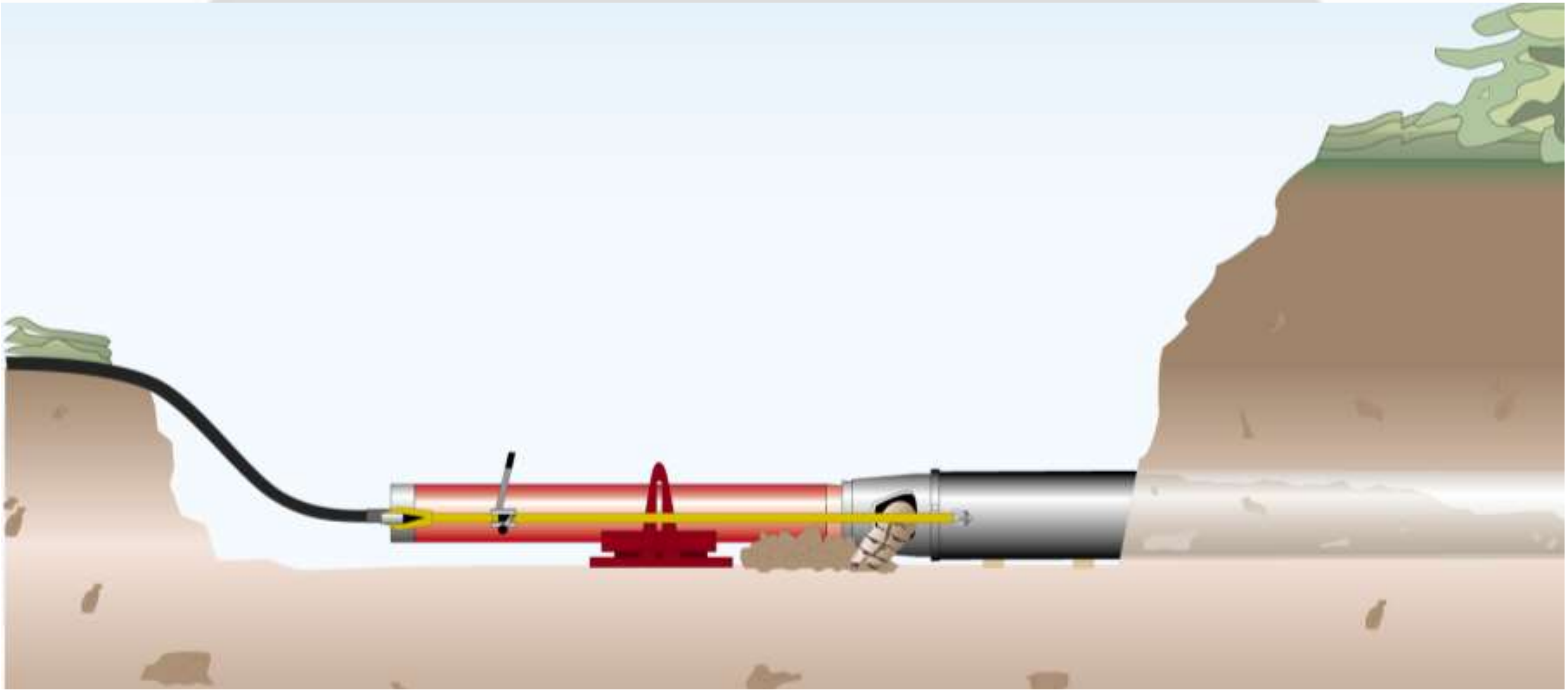
THE PROCESS: Typical Pipe Ramming Configuration



Source: TT Technologies

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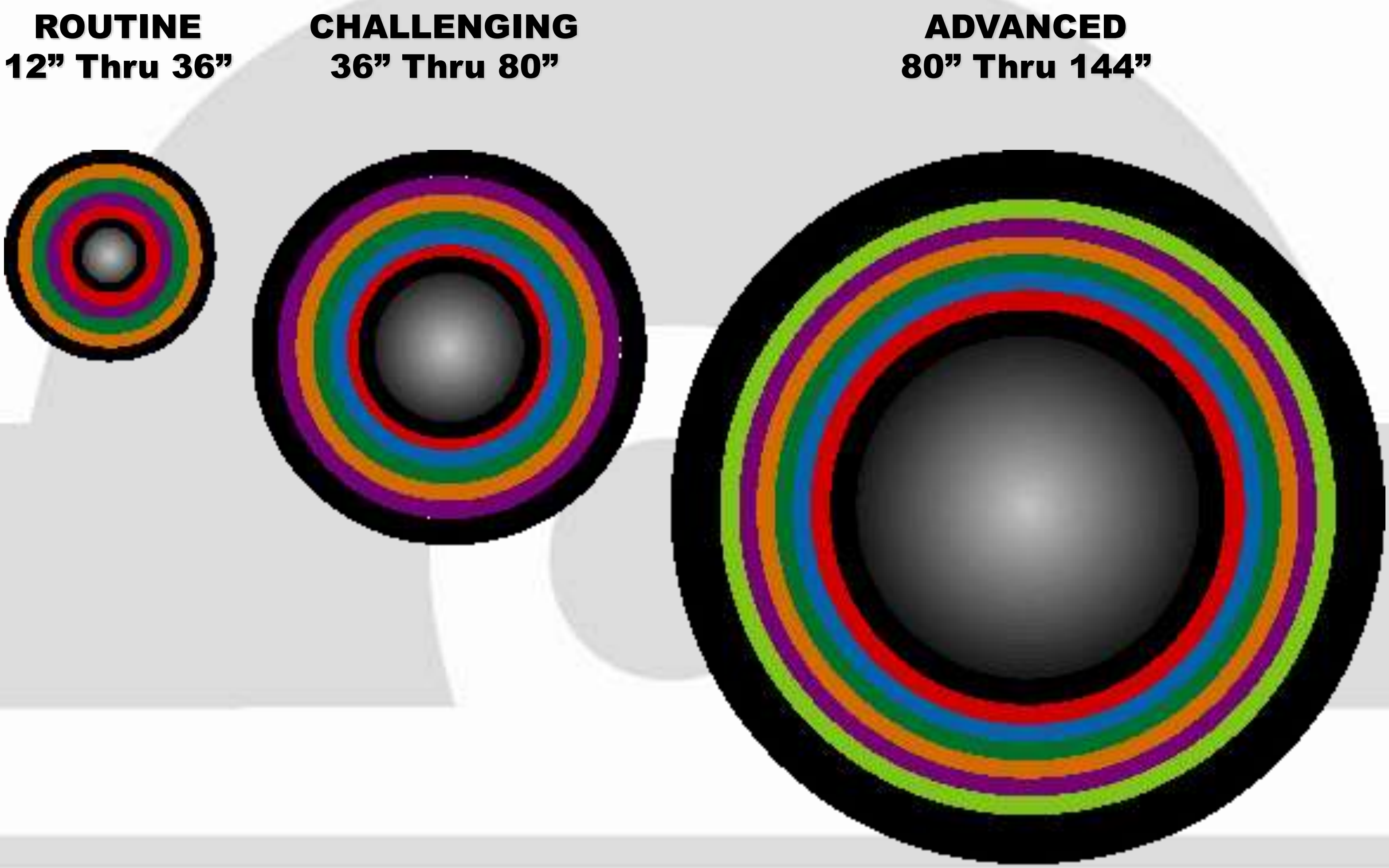
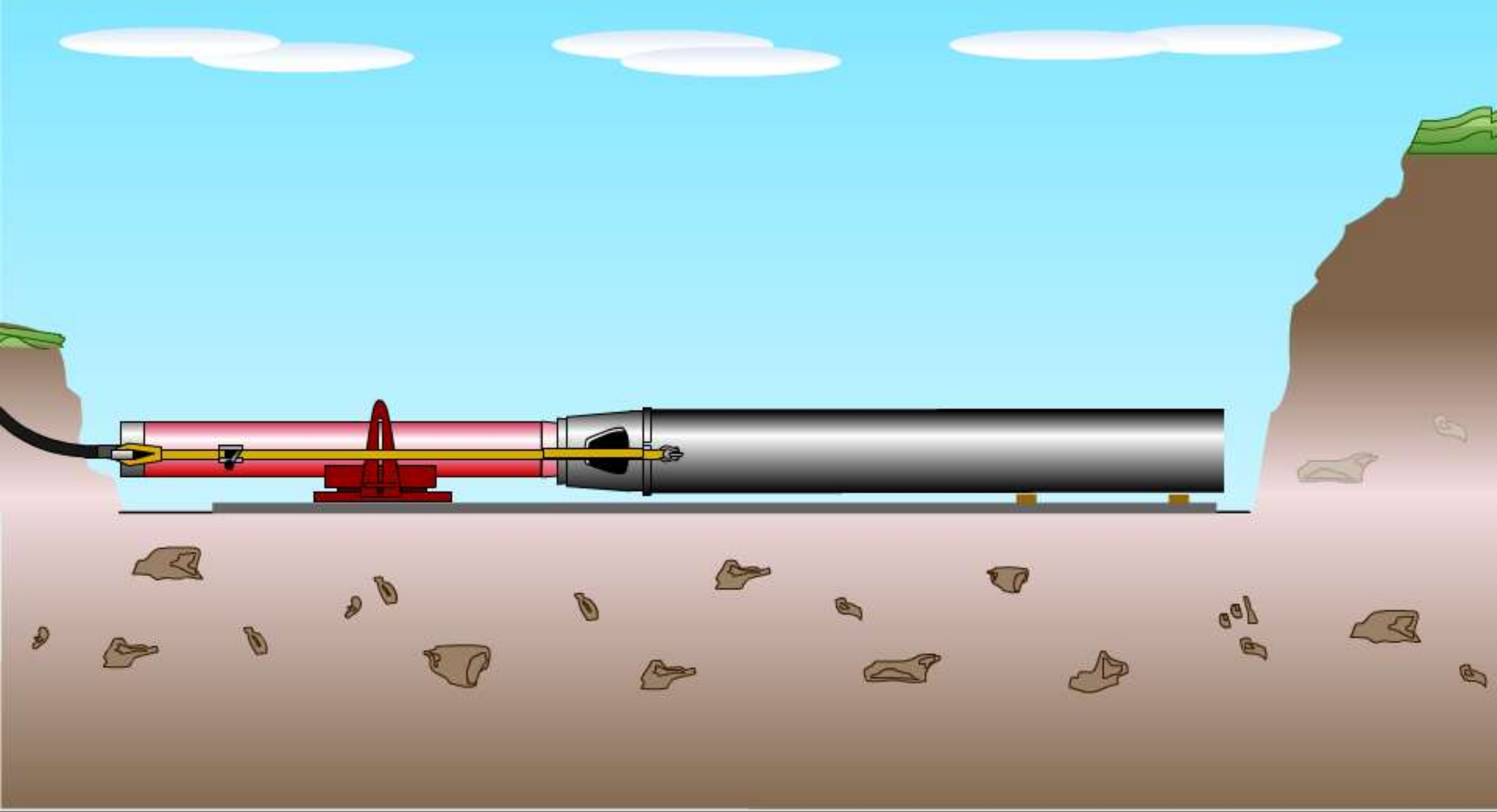


Source: TT Technologies



Source: TT Technologies

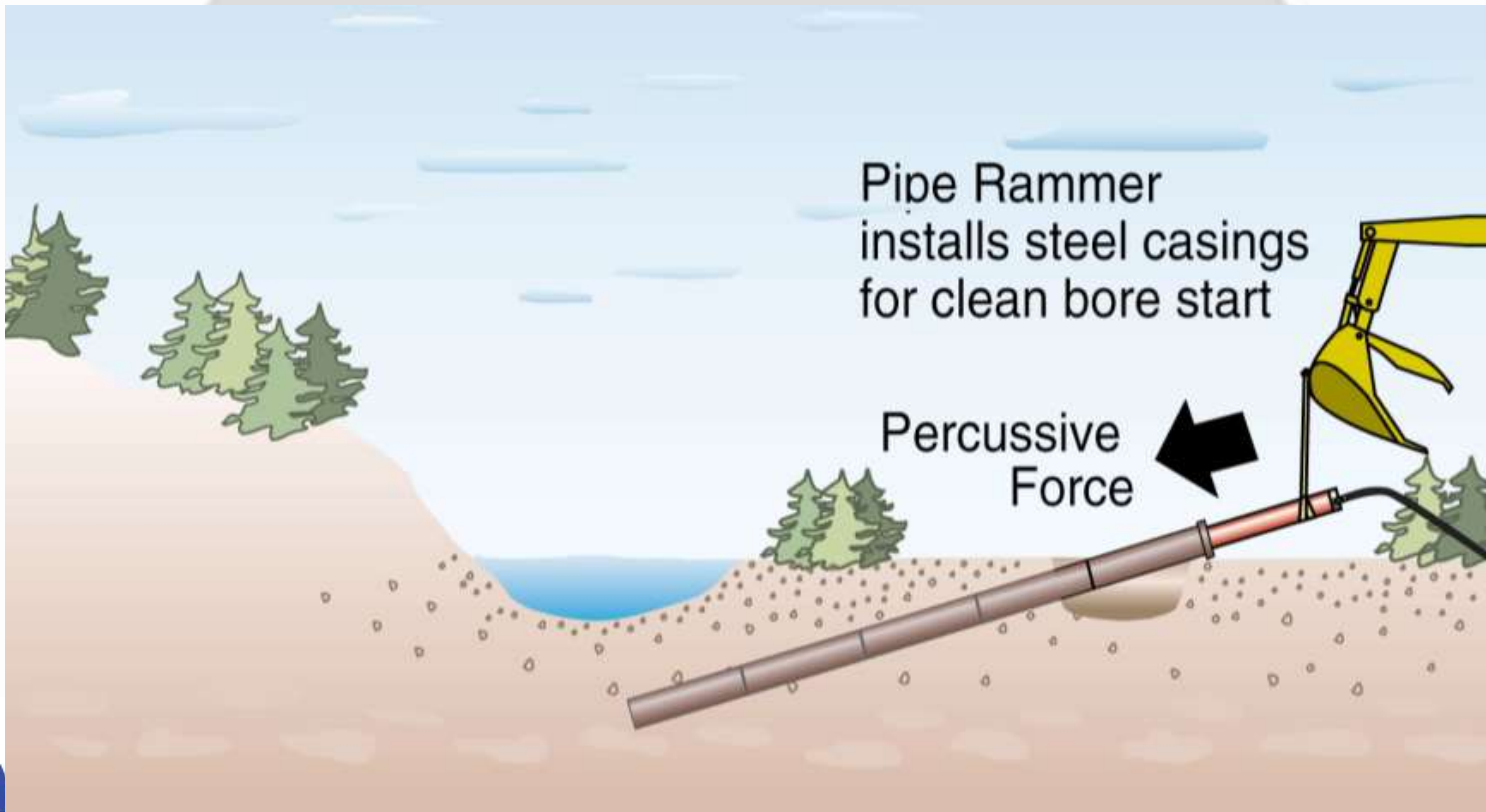
Pipe Ramming Method

Source: TT Technologies

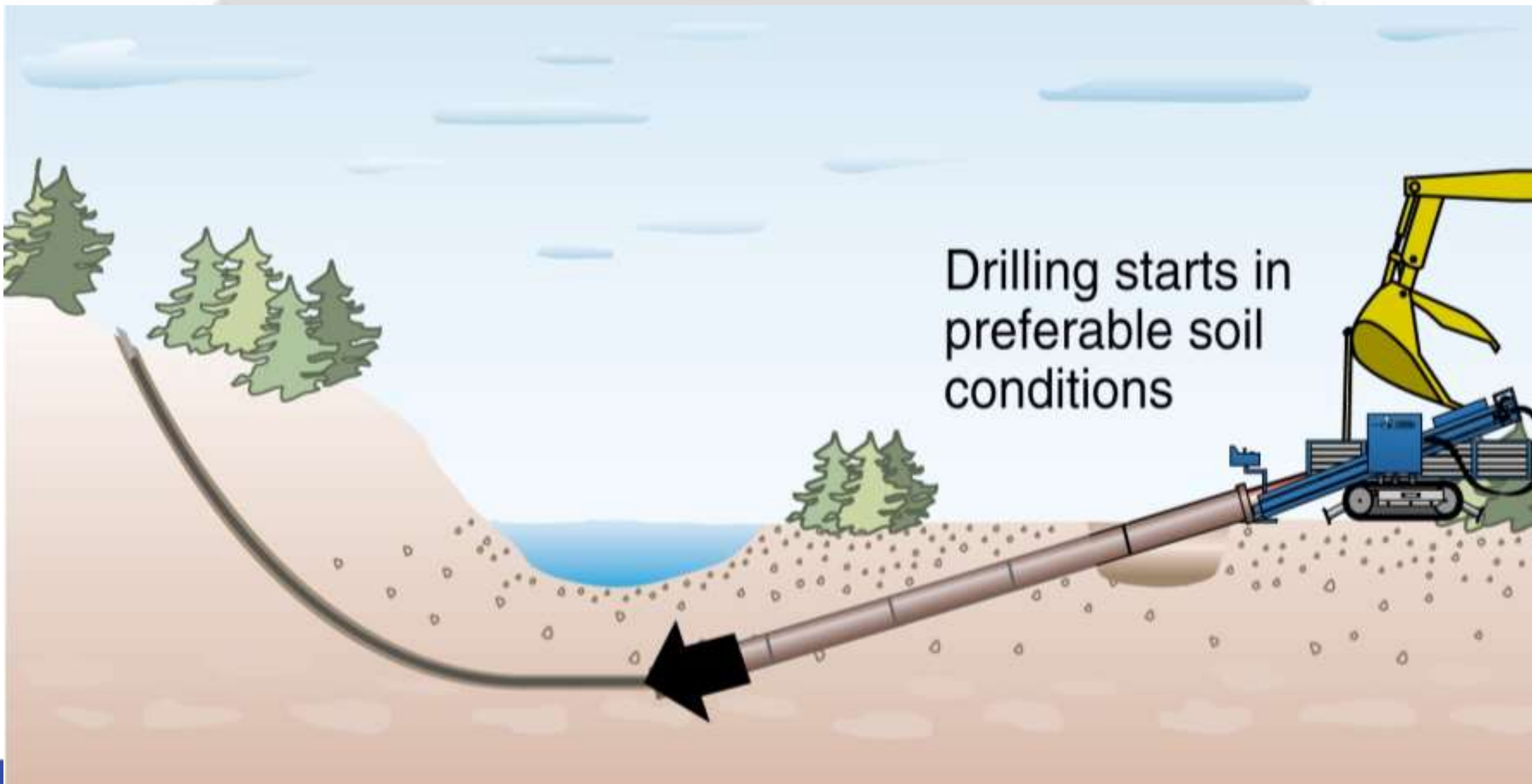
VERTICAL RAMMING

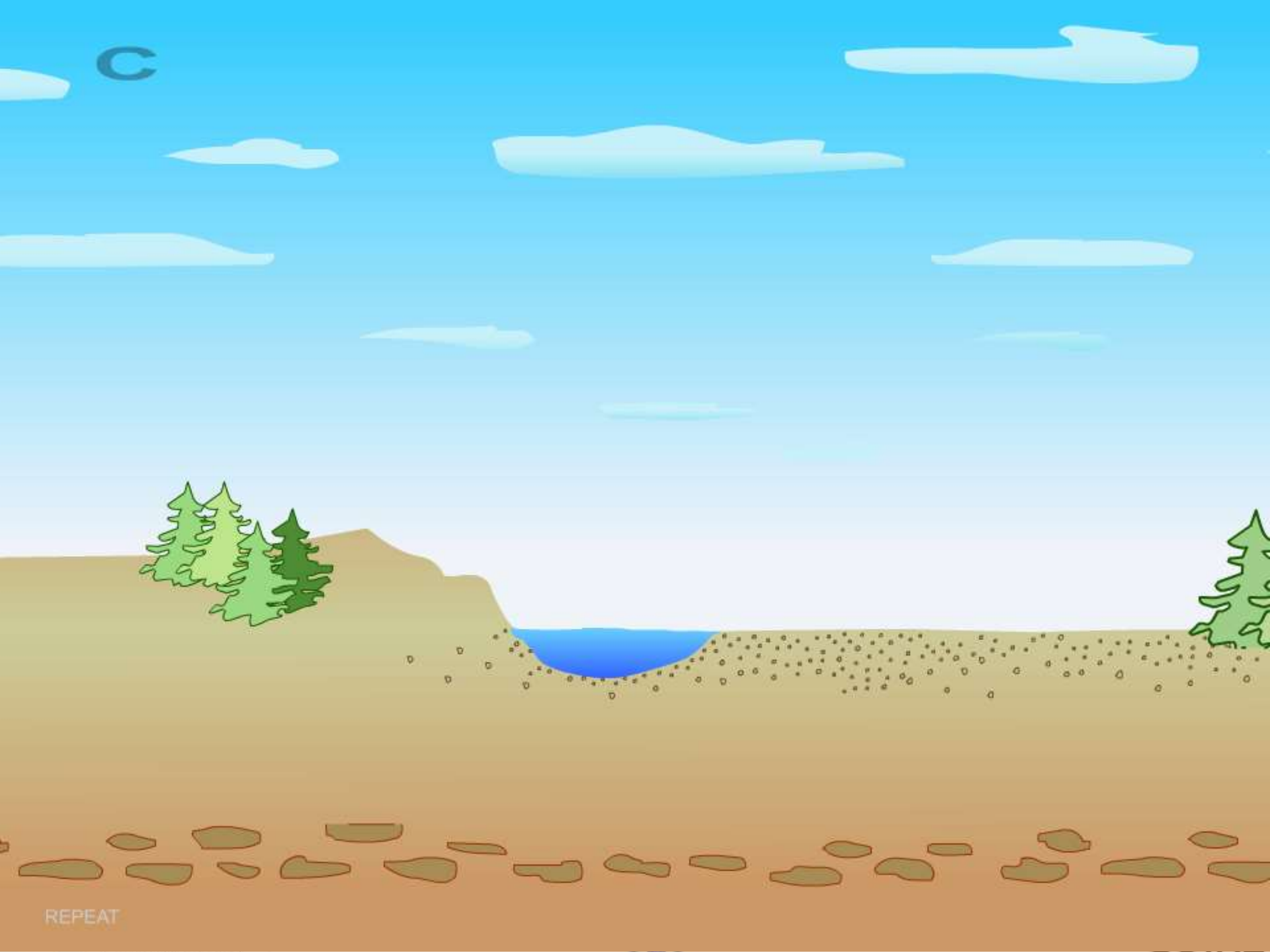
- Ideal for Difficult Soil Conditions
- “Swallow Up” Large Obstructions
- Access Areas Where Larger Equipment Can’t
- “Rat-Hole” Casings for Oil Field Applications

Conductor Barrel Step 1-Job Site



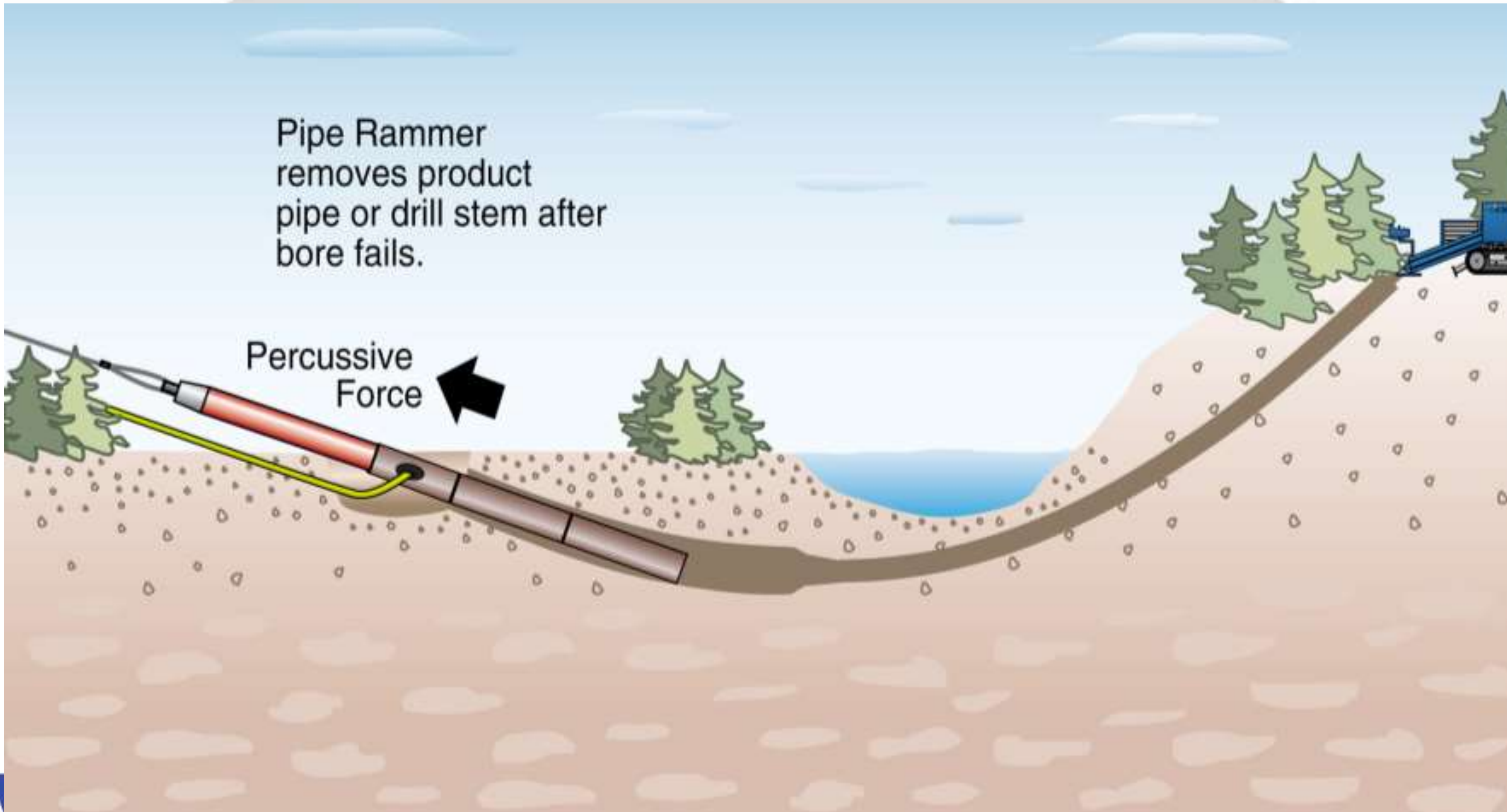
Conductor Barrel Step 2-Job Site




C
REPEAT

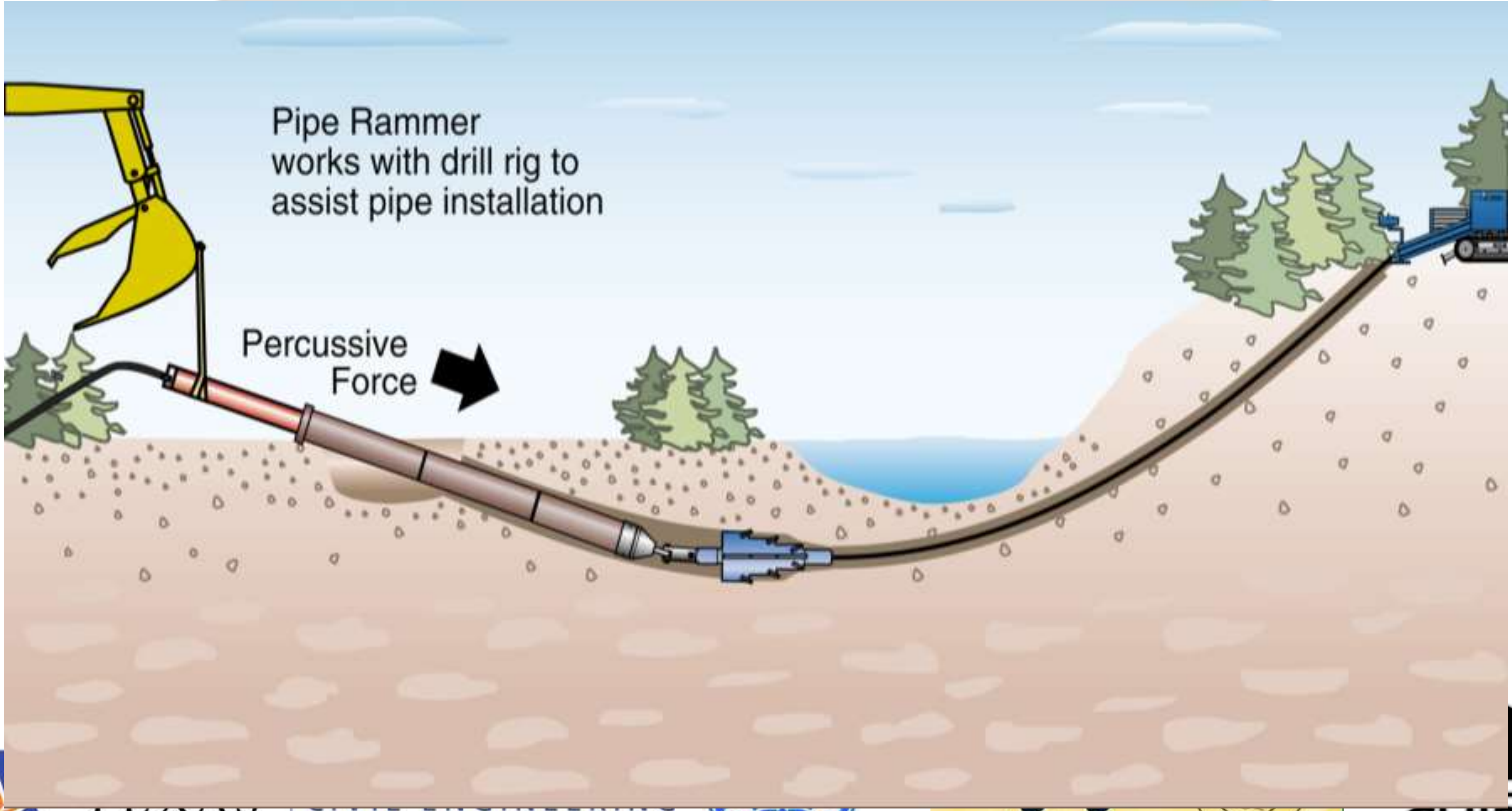

D
REPEAT

Product Pipe Removal/Bore Salvage-Job Site



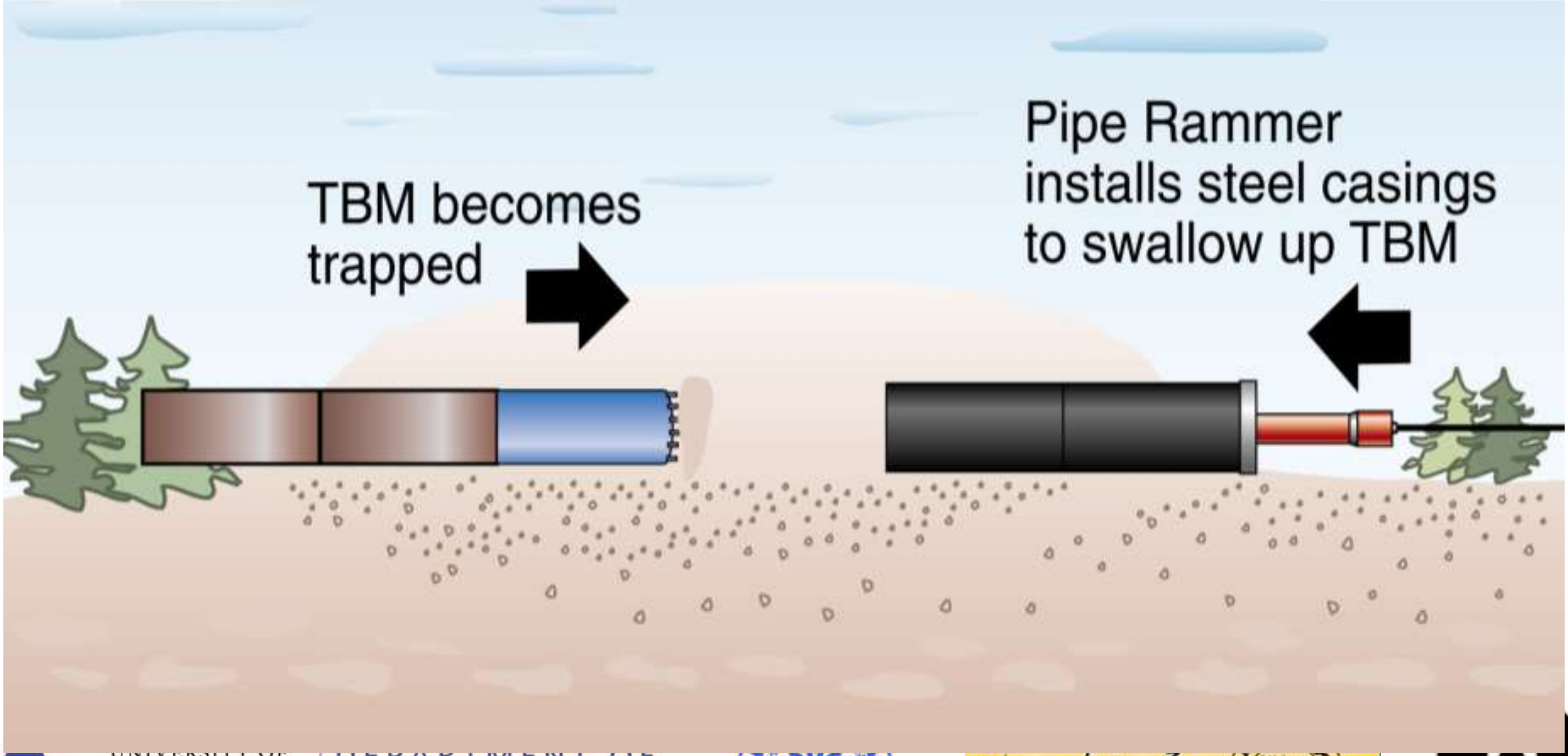

B
REPEAT

Pullback Assist-Job Site




REPEAT

Pipe Ram Rescue-Job Site



TRENCHLESS TECHNOLOGY APPLICATIONS FOR CULVERT INSTALLATIONS

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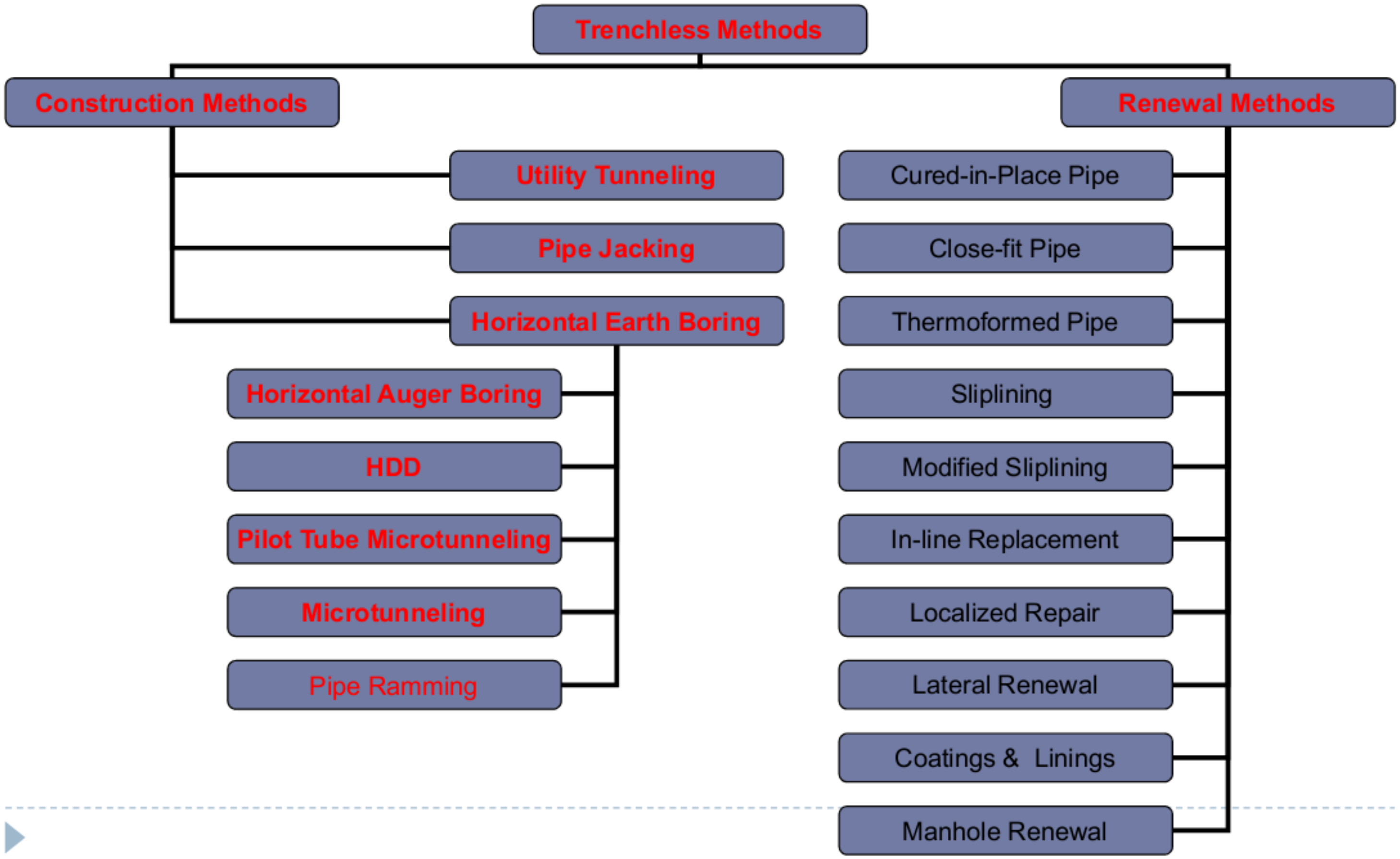
Texas Department of Transportation (TxDOT)

Paper ID#C-6-02

Outline

- Introduction
- Ringgold project
- Trenchless new installation methods
- Selecting construction alternatives
- Influencing factors
- Discussion
- Results
- Conclusions and recommendations

Introduction to Trenchless Technology



(Najafi and Gokhale, 2005)

Example:
Ringgold Project

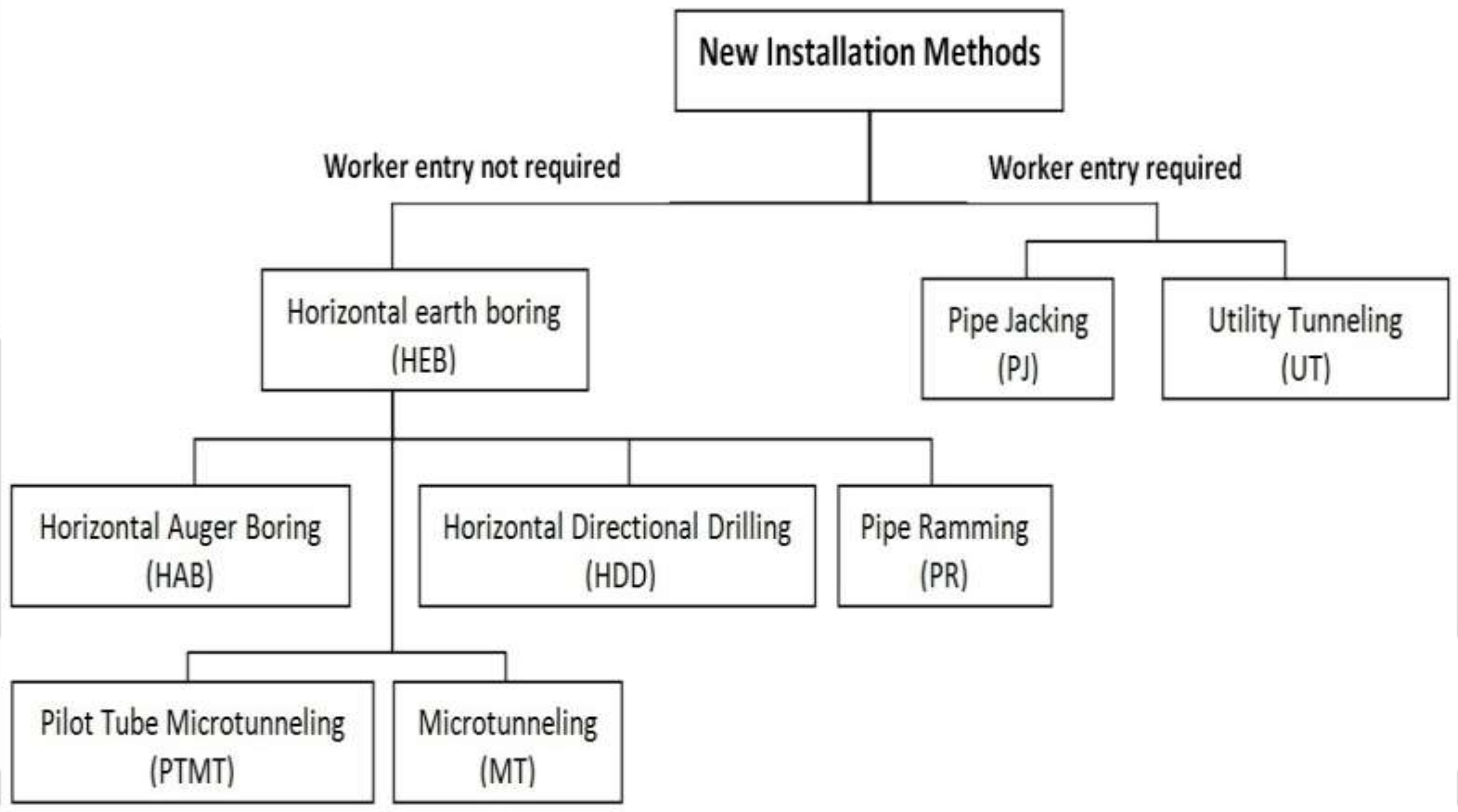
(Modified from Google Maps)

Ringgold Project

(Modified from Google Maps)

Number of Culverts	**3 (each)**
Diameter of Culverts	**36 (in.)**
Length	**110 (ft)**
Slope	**-0.28%**
Proposed Pipe Spacing	**18 (in.)**
Top of the Pipe from Surface	**2 (ft)**

Classification of TCMs for New Installations

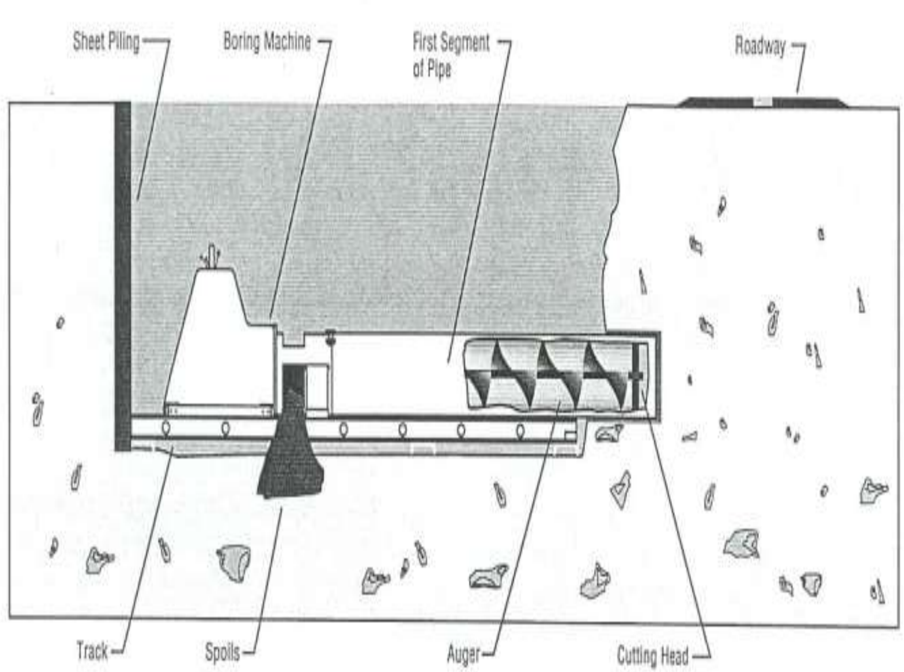


(Najafi and Gokhale, 2005)

Selecting Construction Alternatives

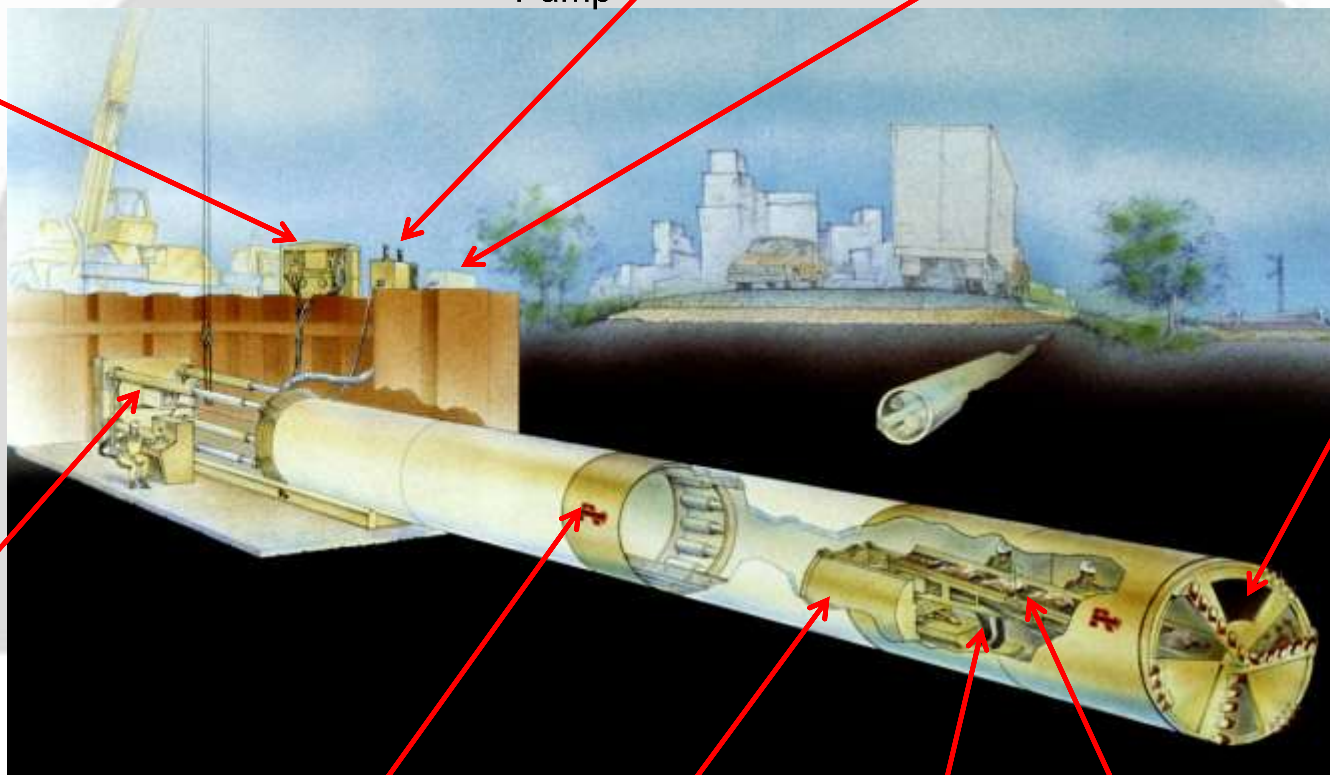
- Horizontal Auger Boring (HAB)
- Pipe Jacking (PJ)
- Microtunneling (MT)
- Pipe Ramming (PR)
- Pilot Tube Microtunneling (PTMT)

Horizontal Auger Boring



(Najafi and Gokhale, 2005)

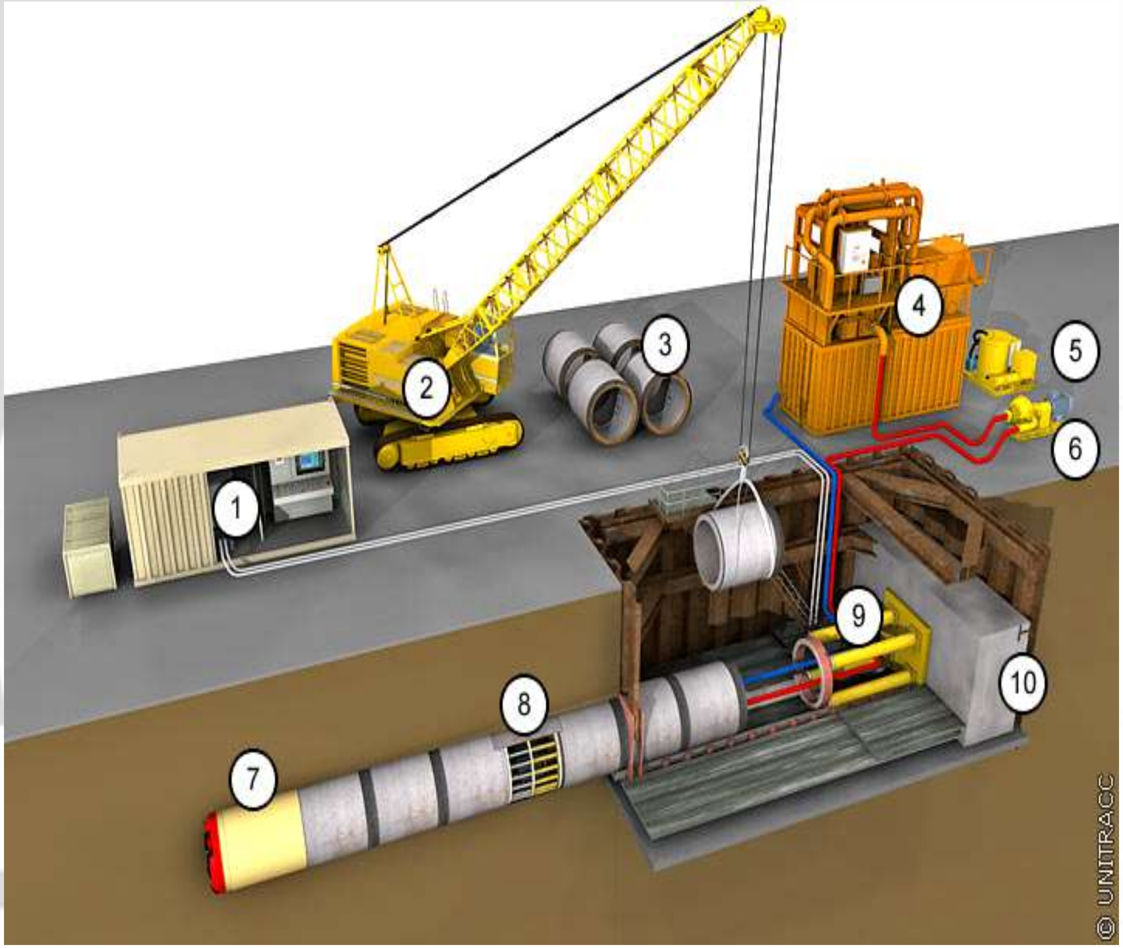
Pipe Jacking



(Akkermann Inc. ,2012)

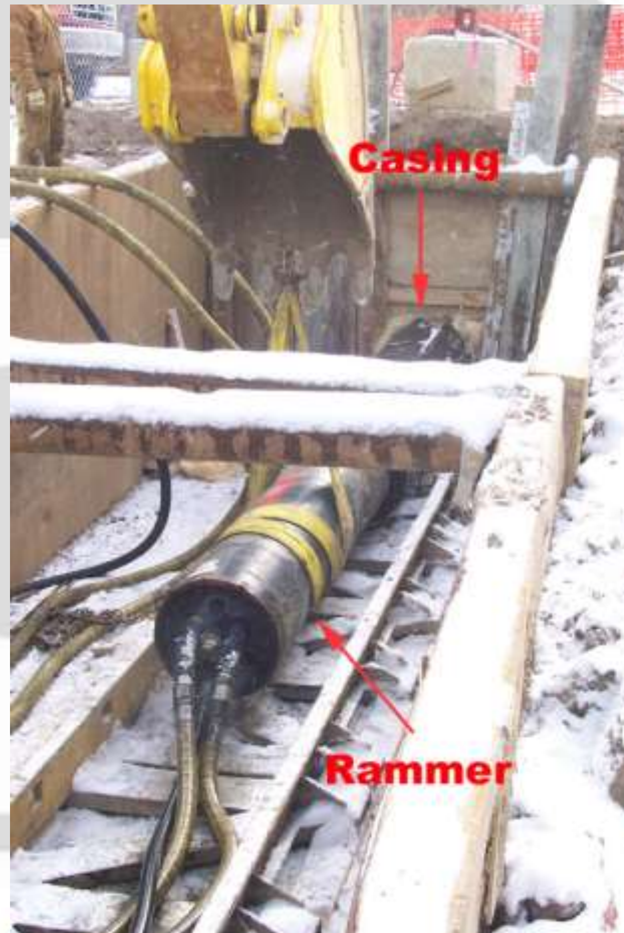
Microtunneling

1. Control and steering desk
2. Crane
3. Jacking pipes
4. Separation plant
5. Mixing plant
6. Supply pump
7. Shield machine
8. Intermediate jacking station
9. Main jacking station
10. Abutment (thrust block)



(Stien, 2008)

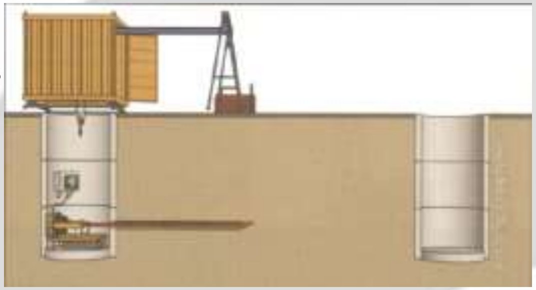
Pipe Ramming



(Purdue University, 2005)

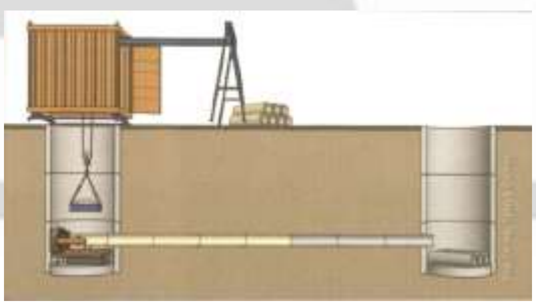
Pilot-Tube Microtunneling

1st phase:
pilot boring by means of soil displacement

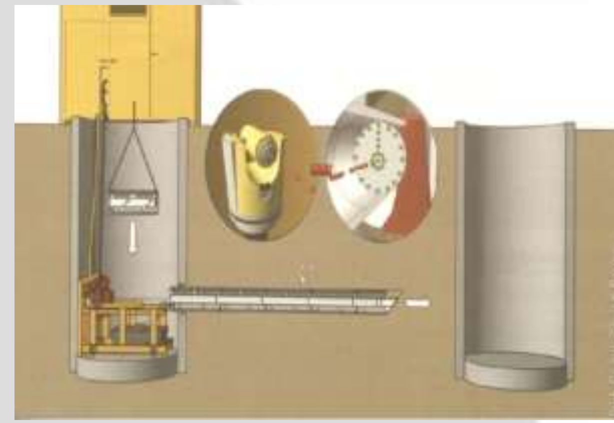


2nd phase:
reaming boring by means of soil removal and jacking of the temporary pipes

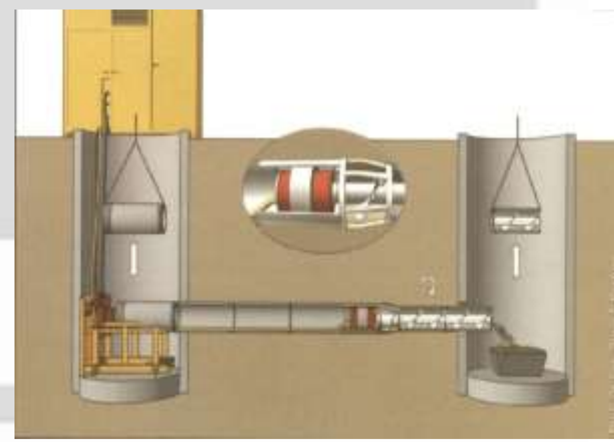
3rd phase:
Pushing-in the product pipes with simultaneous pushing-out of the temporary pipes



1st phase:
pilot boring by means of soil removal



2nd phase:
reaming boring and jacking of the product pipes



(Stien, 2008)

Assessment Criteria

- Soil Conditions
- Required Work Space
- Drive Length
- Depth of Installation
- Diameter of Pipe
- Type of Pipe
- Construction Productivity
- Costs

Soil Conditions

Soil Type	Cohesive Soils(Clay)			Cohesionless Soil (Sand/Silt)			High Ground Water	Boulders	Full-Face Rock
N Value (Standard Penetration Value as per ASTM D-1452)	N<5 (soft)	N=5-15 (firm)	N>15 (stiff-hard)	N<10 (loose)	N=10-30 (medium)	N>30 (dense)			
Horizontal Earth Boring (HEB)									
Horizontal Auger Boring (HAB)	M	Y	Y	M	Y	Y	N	≤ 33%D[1]	≤ 12ksi
Microtunneling (MT)	Y	Y	Y	Y	Y	Y	Y	≤ 33%D[1]	≤ 30ksi
Pilot Tube Microtunneling (PTMT)	M	Y	Y	M	Y	Y	M	≤ 33%D[1]	≤ 12ksi
Pipe Ramming (PR)	Y	Y	Y	Y	M	M	M	≤90% D[1]	N
Pipe Jacking (PJ)									
W/ TBM	M	Y	Y	M	Y	Y	M	M	≤ 30ksi
W/ Hand Mining (HM)	N	Y	Y	M	Y	Y	N	≤ 95% D[1]	Y

Y: Applicable N: Not Applicable M: Marginal

(This table is based on the assumption that the work is performed by experienced operators using proper equipment)

[1] Size of largest boulder versus minimum casing diameter (D)

Site Soil Conditions

Soil Depth (ft)	Field Moisture Content, %	Soil Gradation,%				Atterberg Limits,%		USCS Classification		pH
		Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Group Name	Group Symbol	
0.5-4.0 2.5-4.0	4.2	0	53	47	0	Non Plastic		Silty Sand	SM	8.9
5.0-6.5	7.4	0	43	56	2	Non Plastic		Sand Silt	ML	8.9
18.5-20.0	16.0	0	95	5	0	Non Plastic		Poorly Graded Sand	Sp	9.6

*Based on the site soil conditions,
there is no limitations to use any of the above methods

Required Work Space

Method	Required Work Space (ft)	Description
HAB	15 ft wide and 35 ft long	Typically, casing segments are 10-ft, 20-ft, or 40-ft in length.
PJ	15 ft wide and 35 ft long	The drive shaft size, can range from 10 to 15 ft by 17 to 40 ft.
MT	15 ft wide and 35 ft long	The drive shaft size, can range from 10-ft by 3-ft to 50- ft by 100-ft.
PR	8 ft wide and 40 ft long	The working space at the drive pit typically is 6- to 12-ft in width by 33- to 66-ft in length.
PTMT	8 ft wide and 15 ft long	For smaller pipe sections the workspace can be an 8-ft diameter shaft.

*No space limitation exists, as the road right-of-way provides adequate space

Drive Length

Methods	HAB	PJ	MT	PR	PTMT
Length (ft)	100-600	500-1,500	500-1,500	50-400	50-300

*The required length is approximately 110 ft, which presents no limitations to any of above methods.

Depth of Installation

Pipe Diameters (in.)	Soil Conditions	PJ/UT	HAB (ft)	HDD (ft)	MT	PTMT	PR (ft)
Small (<12)	Clayey	6 ft of cover or 3 times outside diameter whichever is more	**4**	4	6 ft of cover or 3 times outside diameter whichever is more	4 ft of cover or 3 times outside diameter whichever is more	2
	Silty		**4**				
	Sandy		**6**				
	Gravely		**6**				
Medium (12~24)	Clayey		**6**	8			3
	Silty		**8**				
	Sandy		**12**				
	Gravely		**20**				
Large (>24)	Clayey		**10**	25			4
	Silty		**14**				
	Sandy		**20**				
	Gravely		**25**				

*Due to shallow depth, open face methods cannot be used in this project, thus HAB is omitted from selected alternatives.

Diameter of Pipe

Methods	HAB	PJ	MT	PR	PTMT
Diameter (in.)	4-60	42-Up	12-136	**4-120**	6-36

*There is no diameter limitation to use any of these alternative construction methods

Type of Pipe

- Steel pipe (SP)
- Reinforced concrete pipe (RCP)
- Vitrified clay pipe (VCP)
- Ductile iron pipe (DIP)
- Glassfiber reinforced polyester (GRP)

*For Ringgold project only reinforced concrete pipe (RCP)can be used.

Thus, HAB and PR cannot be selected.

Construction Productivity

Method	**Productivity** (ft/8-hour shift)	Description
HAB	100	4 person crew, 3 to 4 hours to set up the auger boring equipment
PJ	40	Productivity ranges 33 ft to 60 ft per 8-hour shift with a four or five person crew
MT	40	A crew of four to eight can obtain a production rate of 30 ft to 60 ft per 8-hour shift
PR	160	2 -3 person crew, the typical rate of penetration ranges from 2 in./min to 10 in/min
PTMT	30	4 person crew can obtain a production rate of 25 ft to 45 ft per 8-hour shift

*It is expected that a productivity of about 30 ft per 8-hour shift would be acceptable to TxDOT road work schedule, so all the above methods are feasible

Costs

Methods	**HAB**	**PR**	**PJ**	**PTMT**	**MT**
Cost ($)	390	450	650	750	**1,150**

*According to TxDOT, the only method exceeding the budget is MT, and all other methods are acceptable.

Method Selection Summary:

Criteria \ Methods	HAB	PR	MT	PTMT	PJ
Soil Conditions	Y	Y	Y	Y	Y
Required Working Space	Y	Y	Y	Y	Y
Depth of Installation	N	Y	Y	Y	Y
Drive Length	Y	Y	Y	Y	Y
Diameter of the pipe	Y	Y	Y	Y	M*
Types of pipe	N	N	Y	Y	Y
Productivity	Y	Y	Y	Y	Y
Cost Feasibility**	Y	Y	N	Y	Y
Feasible Method	N	N	N	Y	M*

Y: Applicable N: Not Applicable M: Marginal

* For the short distance it is possible to use this method.

** Within project budget.

Conclusions and Recommendations

- Selecting correct construction methods for new stormwater culvert installations requires a thorough investigation of project specific conditions.
- Capabilities and limitations of each trenchless construction method must be evaluated against project surface and surface conditions.

Summary

- Selection of the best method is a function of many issues including:
  - Size (diameter)
  - Shape
  - Alignment
  - Environment (fluid & temperature)
  - Structural needs
  - Loads (overburden, hydrostatic, surface)
  - Flow capacity (hydraulics)
  - Others????

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Summary

- Due to nature of trenchless technology projects, the Inspector and the Engineer must work with the contractor to understand the project's expectations and work through potential problems.

QUESTIONS

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