NetworkRail

PIPE JACKING ASSOCIATION

NETWORK RAIL in association with the PIPE JACKING ASSOCIATION presents a seminar on:

Planning, design and construction of undertrack crossings and associated risk management

7th March 2018, Double Tree by Hilton, Coventry

PROGRAMME

10.00 - 10.30 am	**Registration and refreshments**
10.30 - 10.50 am	**Introduction** • An overview of Network Rail's new UTX standard • Background - Derailment at Stoke Lane Level crossing *Colin Sims, Professional Head of Mining and Tunnels, Network Rail* *Graeme Monteith, PJA Chairman, Tunnel Engineering Manager - Barhale Plc*
10.50 - 11.45 am	**Key contents of the new NR UTX standard highlighting additions and the reasons for their inclusion** *Jim Kirby, Technical Director, COWI* *Luigi Rocco, Senior Engineer, Network Rail*
11.45 - 12.00 noon	**Coffee break**
12.00 - 12.30 pm	**Pipe jacking overview and other trenchless options** *Graeme Monteith*
12.30 -1.00 pm	**Safety risks inherent in pipe jacking particularly when adjacent to or under railway lines** *Dr Donald Lamont, Managing Director, Hyperbaric and Tunnel Safety*
1.00 - 2.00 pm	**Lunch**
2.00 - 3.00 pm	**Health and safety legislation and risk management** *Dr Donald Lamont*
3.00 - 3.15 pm	**Afternoon tea**
3.15 - 3.45 pm	**Occupational health** *Dr Donald Lamont*
3.45 - 4.00 pm	**Atmospheric monitoring and contamination** *Dr Donald Lamont*

Planning, design and construction of undertrack crossings and associated risk management

Colin Sims, Professional Head of Mining and Tunnelling – Network Rail

Background - Derailment at Stoke Lane Level crossing and up grade of Standard NR/L2/CIV/044 Issue 3

The Stoke Lane Incident

At around 04:30 on the 27th August 2013 a freight train of 30 loaded tank wagons hauled by a Class 66 locomotive derailed at 53 mph at the Stoke Lane level crossing at Nottingham.

The rails had deformed over a void in the ground at the level crossing

This was the site of a recently constructed UTX using a small diameter TBM

The Stoke Lane Incident

The Stoke Lane Incident

The UTX was formed using a Micro TBM of the slurry type.

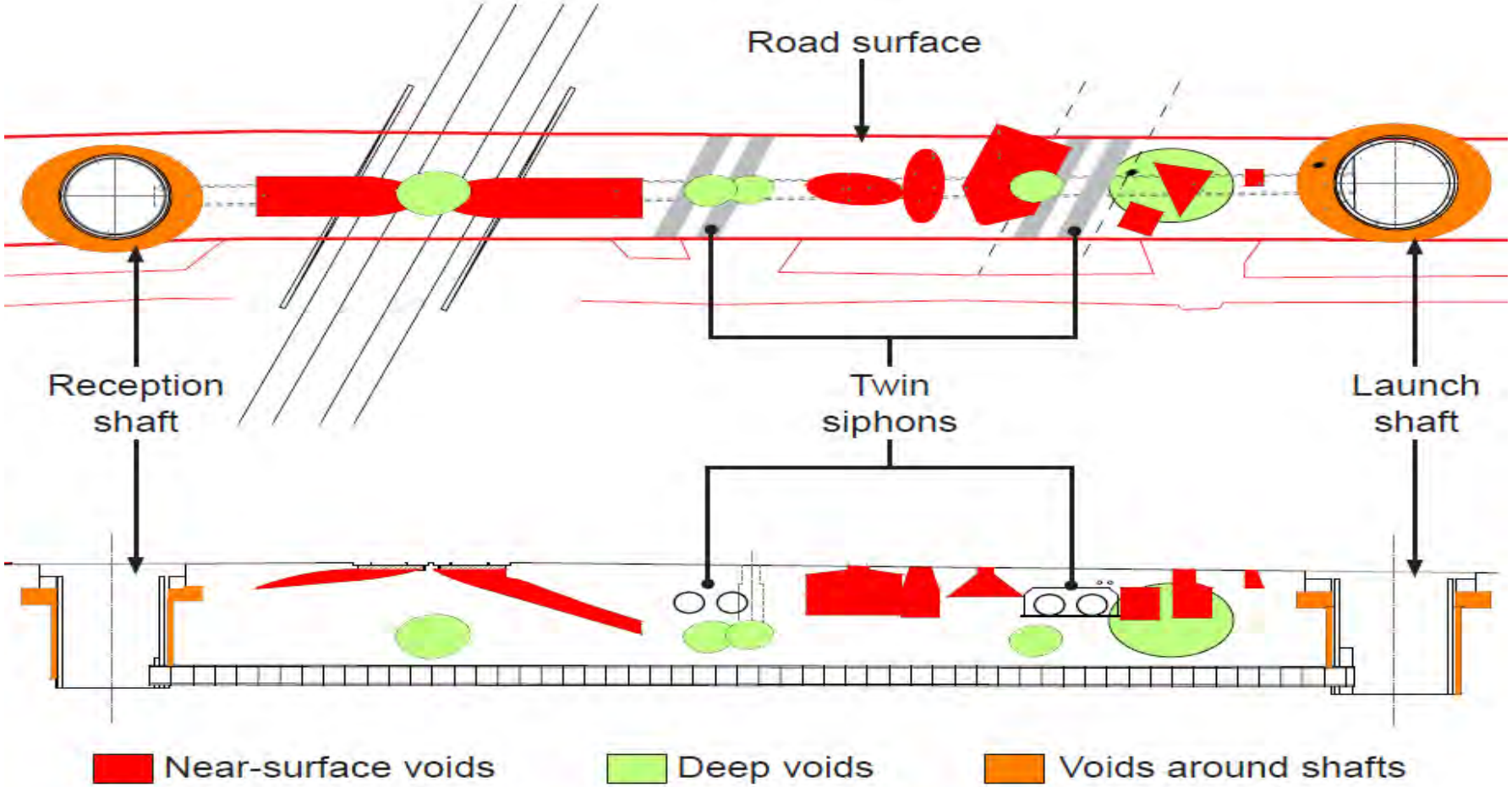
Following the incident a RAIB investigation stated that causal factors were:-

Large voids had developed under the track as a result of excessive ground loss during the construction of a micro tunnel under the road and level crossing. These voids left the track unsupported at the level crossing, and

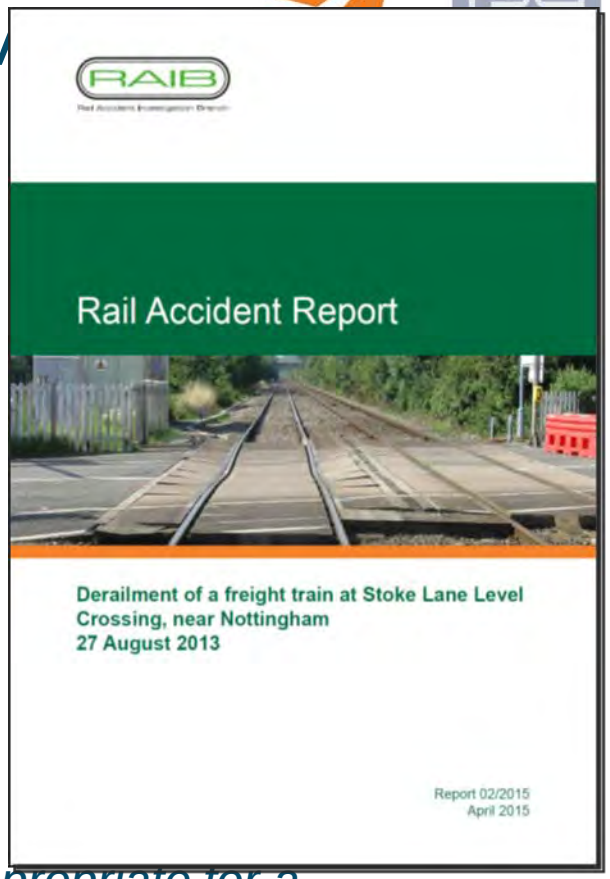
Normal train services had been allowed to resume following the tunnelling work, despite evidence of abnormal ground behaviour

The Stoke Lane Incident

Voids were mapped following site investigation works



Background to Standard NR/L2/CIV Issue 3


RAIB

Rail Accident Report

Derailment of a freight train at Stoke Lane Level Crossing, near Nottingham
27 August 2013

Report 02/2015
April 2015

The RAIB report also stated as underlying factors:-

Network Rail's procedures for UTXs and the way they were used did not provide adequate guidance for those involved in the design, scrutiny and construction of the UTX, and

The criteria used for monitoring settlement were not appropriate for a UTX under a level crossing and did not adequately alert the asset protection team to the severity of the developing problem

Background to Standard NR/L2/CIV/044 Issue 3

Ref:	NR/L2/CIV/044
Issue:	3
Date:	03 June 2017
Compliance date:	02 September 2017

Level 2

Business process

Planning, design and construction of undertrack crossings

Approvals

Content approved by:

Luigi Rocco,
Technical Lead

Content approved by:

Colin Sims,
Standard and Control Document Owner

Approved for publication by:

Mick McManus,
Standards and Controls Management

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Background to Standard NR/L2/CIV/044 Issue 3

Other associated standards

Monitoring track over or adjacent to building and civil engineering works:-
NR/L2/CIV/177

Design of Tunnels:-
NR/L3/CIV/169
Which will incorporate the requirements for tunnels under the track of greater than 2.0m

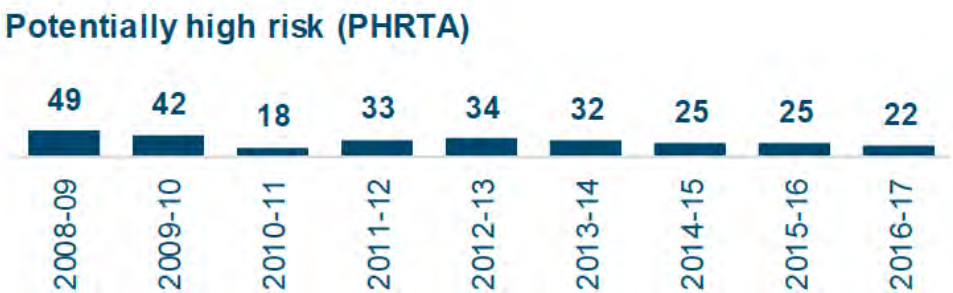
Network Rail Standard Development

Luigi Rocco

Senior Engineer, Network Rail

- 20,000 miles of track
- 28,000 bridges
- 22,000 retaining walls
- 21,000 culverts
- 9,000 miles of geotechnical
- 2,700 stations
- 220 miles of tunnels
- 200 miles of coastal defence

Train Accidents on the Mainline



Of the **22 PHRTAs on the mainline** in 2016-17

15 involved **at least one passenger train**

There were:

6 derailments

6 collisions with vehicles at level crossings

4 collisions between trains

6 other collisions

VIDEO
Learning from the past

In association with the PIPE JACKING ASSOCIATION

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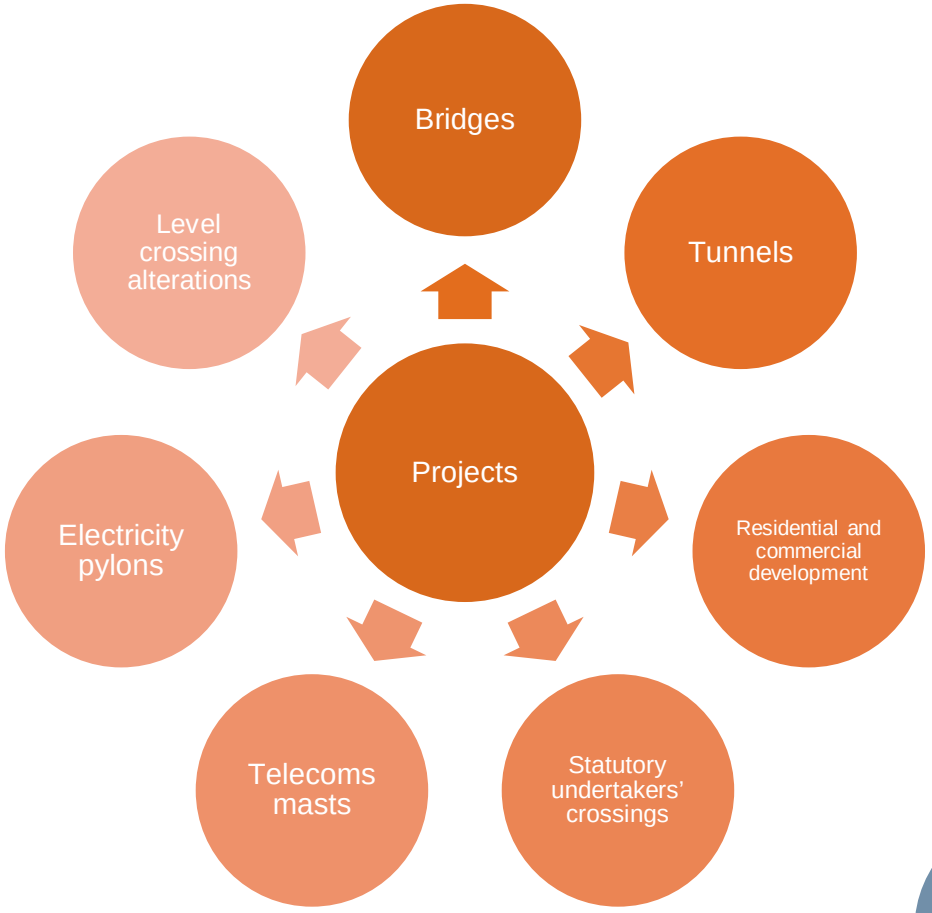
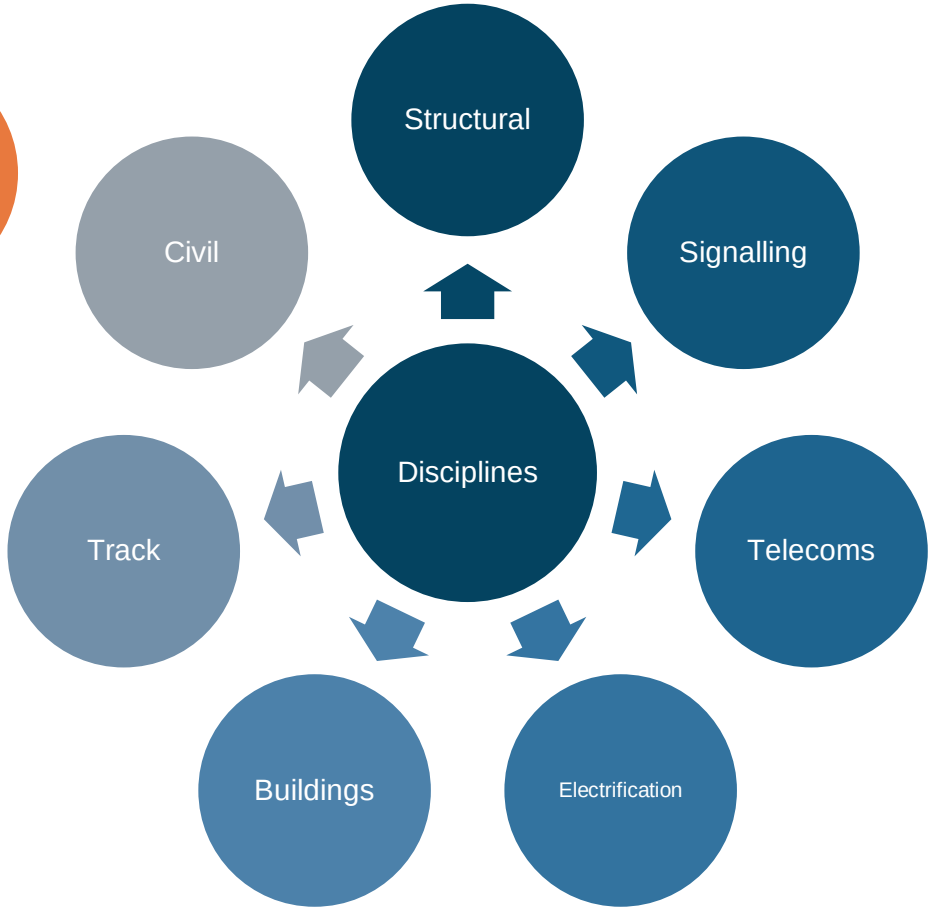


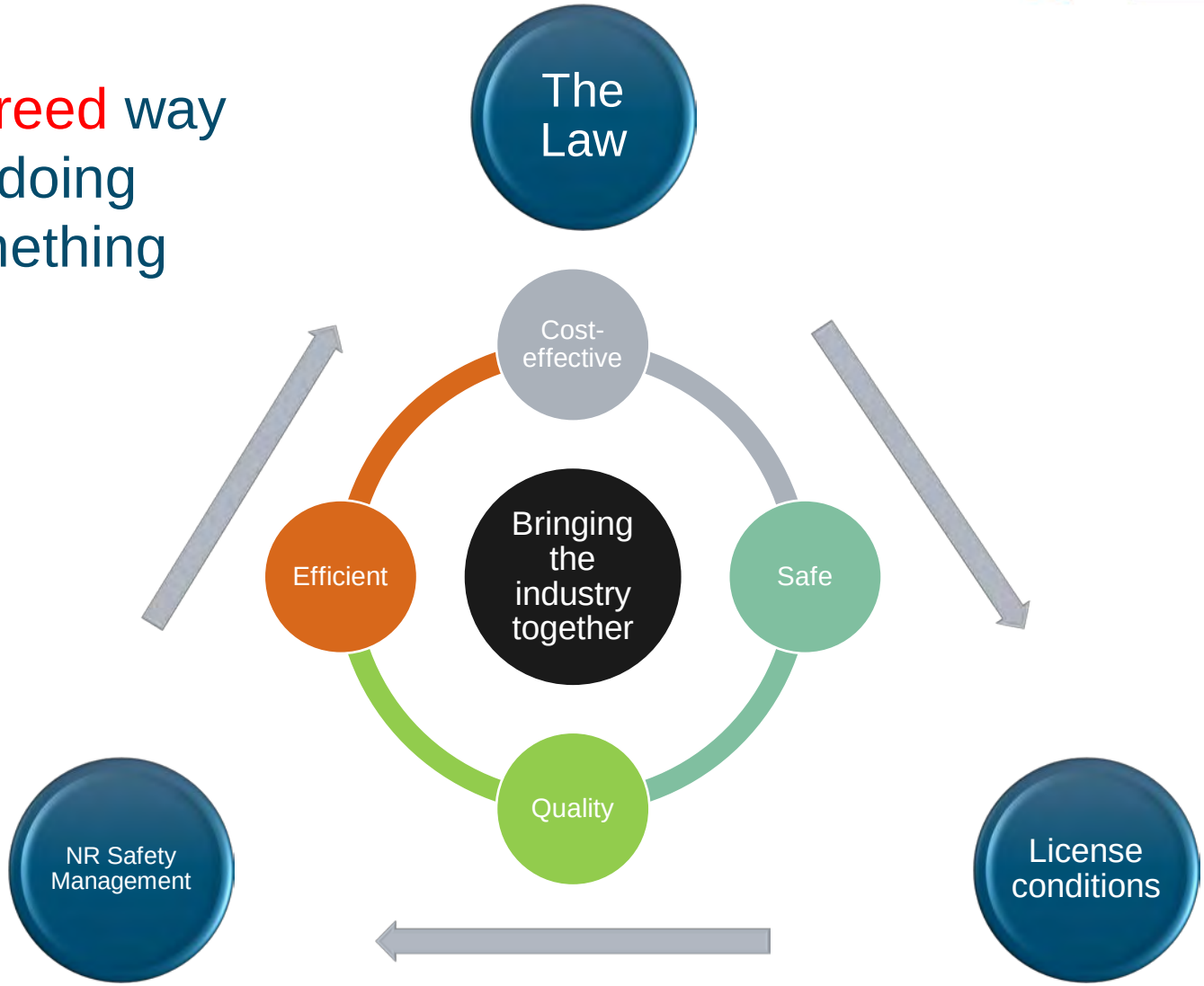


ASPRO TEAM

https://www.networkrail.co.uk/communities/lineside-neighbours/working-by-the-railway/contact-asset-protection-team/

Why standardise?

An agreed way of doing something



Isambard Kingdom Brunel

I am opposed to the laying down of rules or conditions to be observed in the construction of bridges lest the progress of improvement tomorrow might be embarrassed or shackled by recording or registering as law the prejudices or errors of today.

AZ QUOTES


ask
yourself
WHY

Ref:	NR/L2/CSG/STP001/04
Issue:	6
Date:	03 December 2016
Compliance date:	04 March 2017

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NR/L2/CSG/STP001

Module 04

Managing variations to Network Rail standards and control documents and Railway Group Standards

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This Network Rail document contains colour-coding according to the following Red–Amber–Green classification.

Red requirements - *no variations permitted*

- Red requirements are to be complied with and achieved at all times.
- Red requirements are presented in a red box.
- Red requirements are monitored for compliance.
- Non-compliances will be investigated and corrective actions enforced.

Amber requirements - *variations permitted subject to approved risk analysis and mitigation*

- Amber requirements are to be complied with unless an approved variation is in place.
- Amber requirements are presented with an amber sidebar.
- Amber requirements are monitored for compliance.
- Variations can only be approved through the national variations process.
- Non-approved variations will be investigated and corrective actions enforced.

Green guidance - *to be used unless alternative solutions are followed*

- Guidance should be followed unless an alternative solution produces a better result.
- Guidance is presented with a dotted green sidebar.
- Guidance is not monitored for compliance.
- Alternative solutions should be documented to demonstrate effective control.

Think

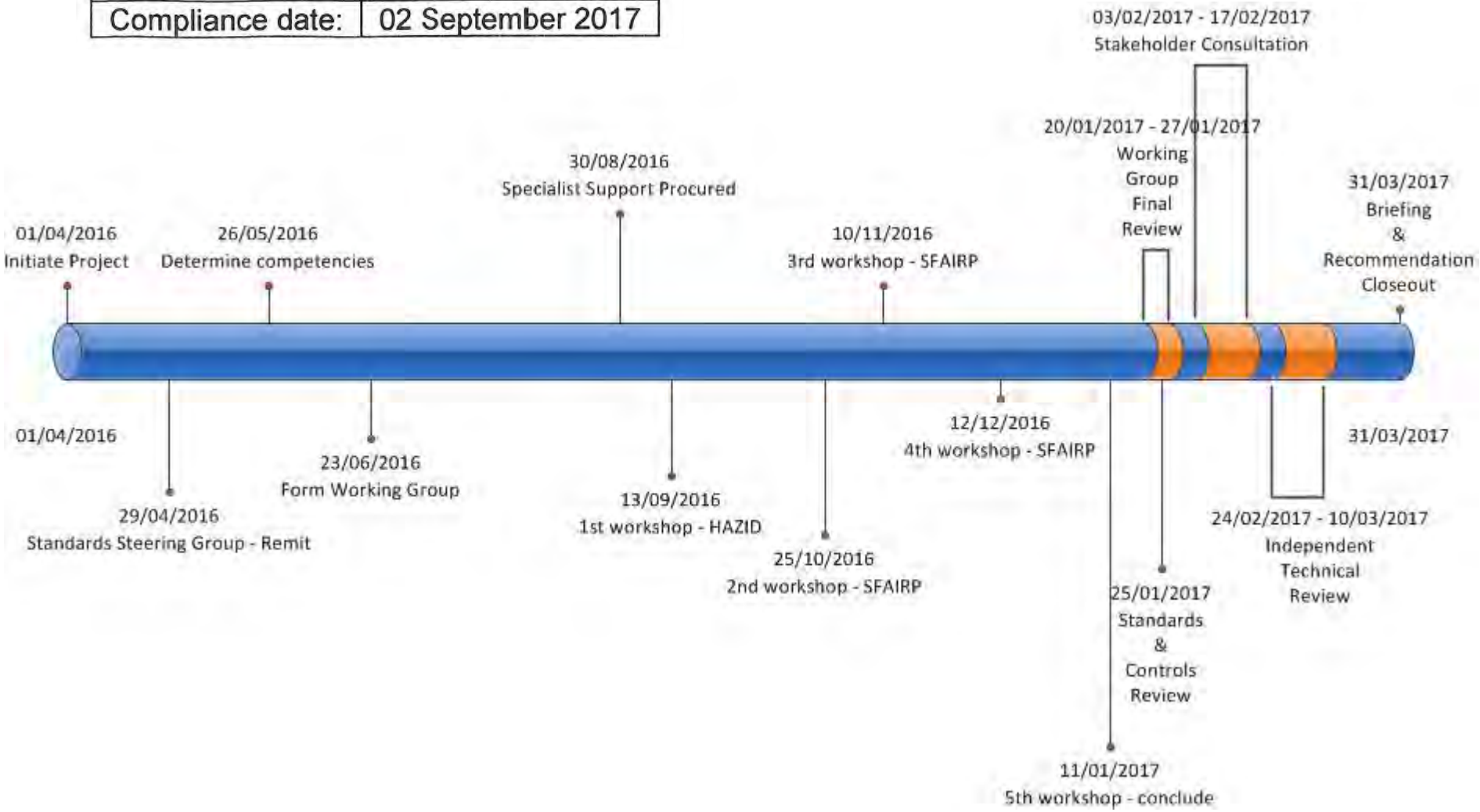
Feel

Do

Ref:	NR/L2/CIV/044
Issue:	3
Date:	03 June 2017
Compliance date:	02 September 2017

NetworkRail

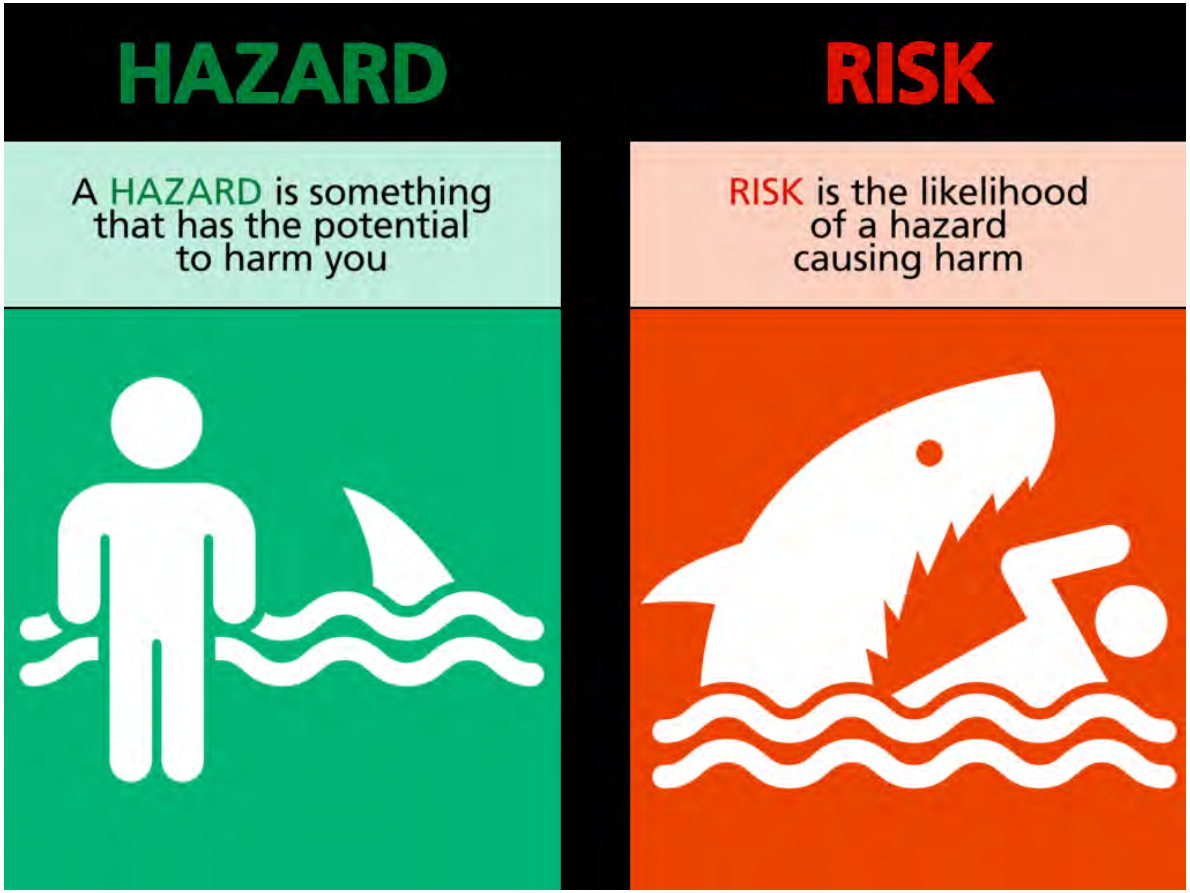
In association with the PIPE JACKING ASSOCIATION



Working Group

Name	Post
Colin Sims	Professional Head of Mining and Tunnels
Luigi Rocco	NR Technical Lead
Jim Kirby	Technical Director – COWI (Specialist)
Lisa Brown	Project Manager
Graeme Monteith	Pipe Jacking Association – Chairman
Tim Riggall	Engineering Manager Riggall & Associates (HDD)
Steve Williams	Senior Design Engineer [IP]
Alan Shaw	Senior Asset Protection Engineer
Eric Wainwright	Senior Asset Protection Engineer
Eifion Evans	Principal Engineer [Geotechnical]
Rob Eggleton	Engineer [Tunnels]
Jamil Raja	Senior Engineer [Drainage]
Stephen Richmond	Senior Engineer [Track]

HAZID



What would cause the accident to happen?

Risk Score = Impact x Likelihood

ALARP "at a glance"

"reasonably practicable allows us to set goals for duty-holders, rather than being prescriptive"

"challenging because it requires duty-holders and us to exercise judgement"

"we can decide by referring to existing 'good practice' by a process of discussion with stakeholders to achieve a consensus about what is ALARP"

"For high hazards, we can build on good practice, using more formal decision making techniques, including cost-benefit analysis, to inform our judgement."

everyone
home safe
every day

Network Rail Standard Development

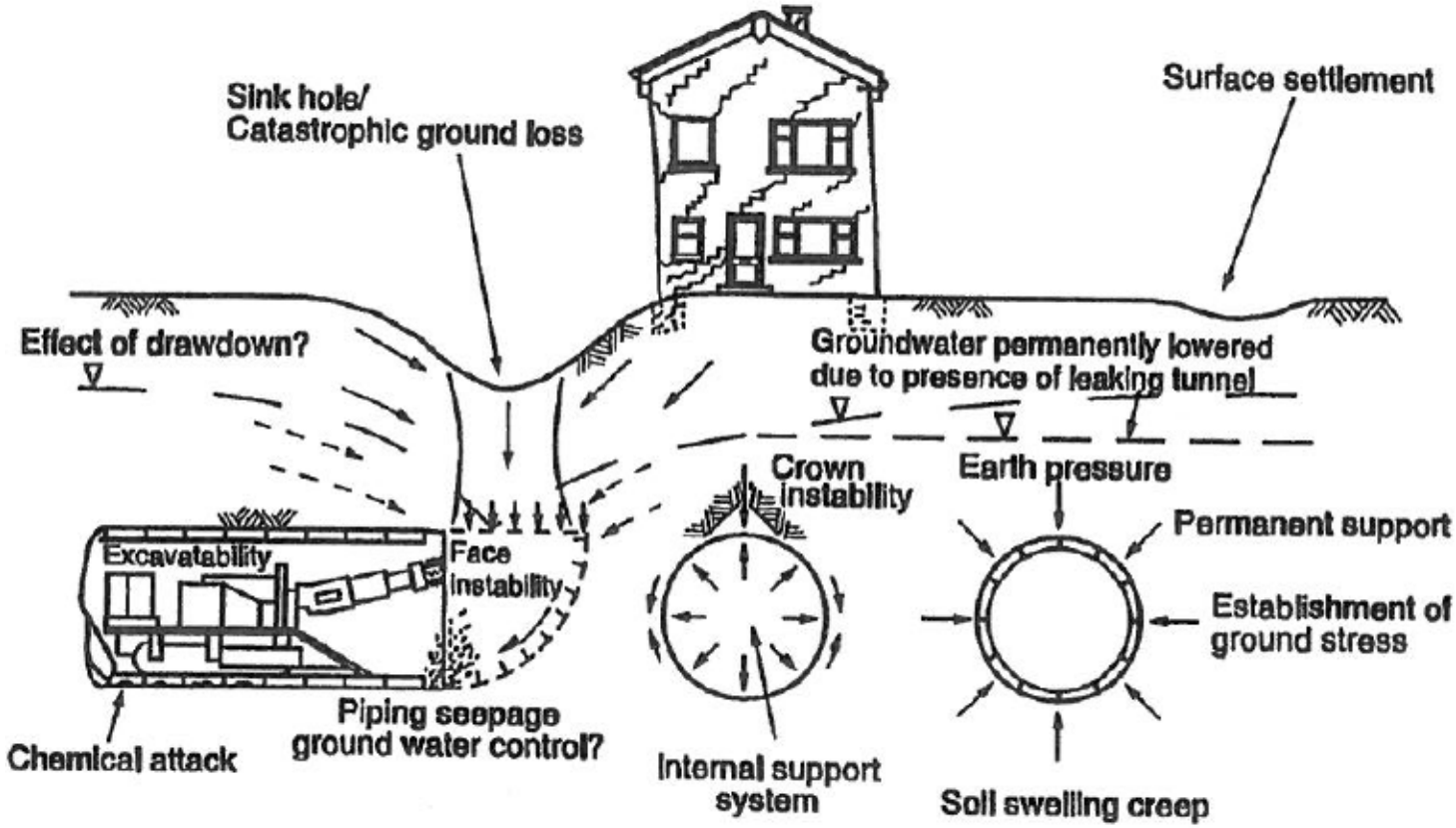
Jim Kirby

Technical Director, COWI UK Limited

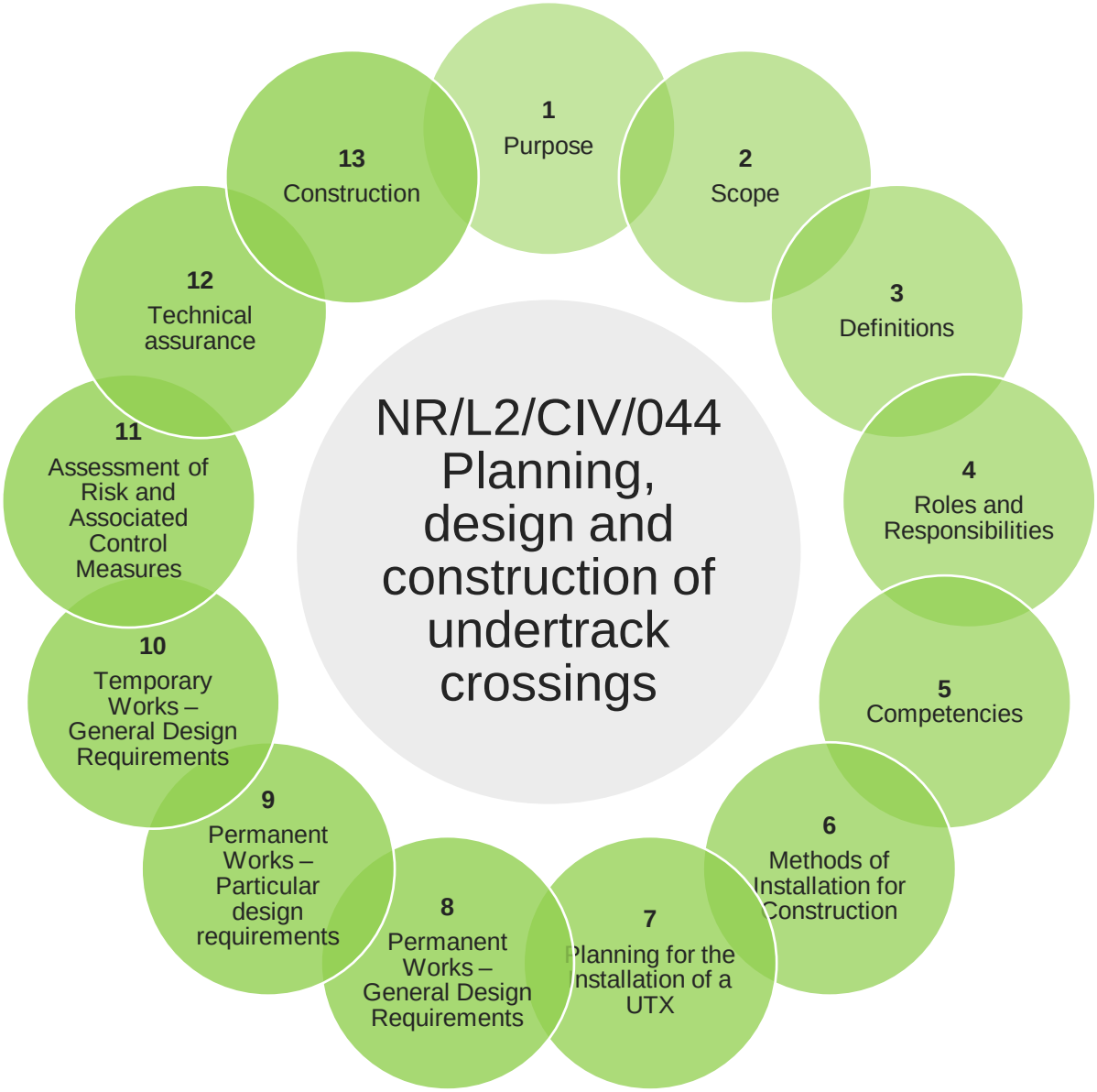
M: (07876) 213940

E: ajki@cowi.com

NR/L2/CIV/004 emphasises the need to understand risk, assess risk and manage risk through the implementation of robust control measures



Content of the Standard



Scope of the Standard

- The applicable requirements of NR/L2/CIV/044 should also be applied, as a minimum, as a safe means of control for the construction of culverts and tunnels.
- Structures works for undertrack crossings with an internal diameter greater than 2.0m shall also be managed in accordance with NR/CS/CIV/044 (Structure Category C).
- The standard has been prepared considering the most commonly adopted methods for UTX installations in the UK.
- This standard **does not** cover:

  a) the requirements for the undertrack crossing to carry the service within it or the performance of the service within the undertrack crossing;

  b) pipelines that are not carried in undertrack crossings;

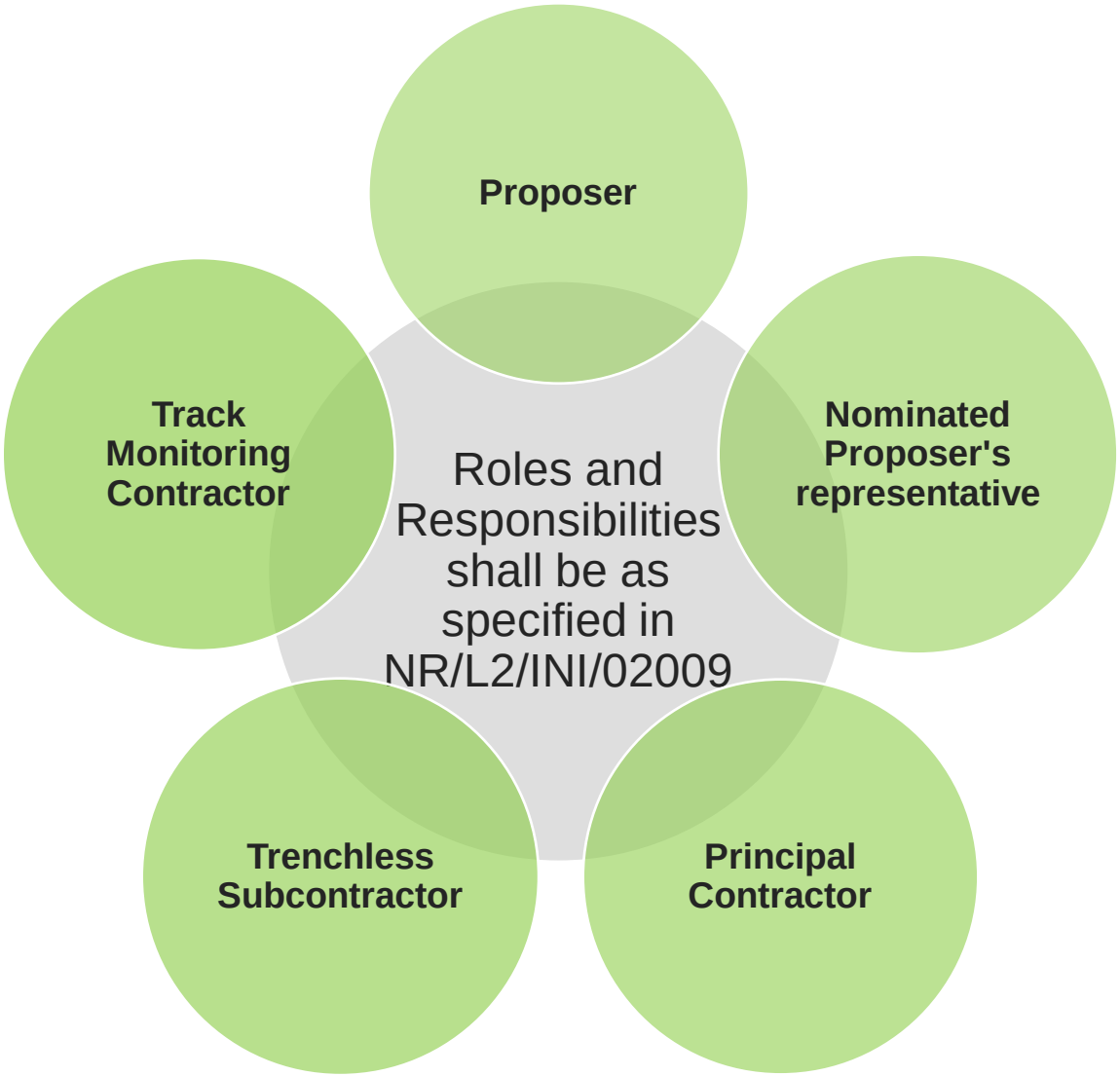
  c) surface laid cables and cables laid immediately below rail level.

Key Changes from Revision 2

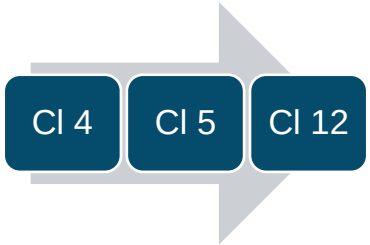
NR/L2/CIV/004 Revision 3 outlines specific requirements in respect of the following:

- Roles and responsibilities
- Design life
- Position and effects on adjacent infrastructure
- Depth of cover
- Assessment of ground movement
- Design checking
- Technical assurance (key stage deliverables)
- Track monitoring
- Works monitoring

Roles & Responsibilities



- Details of the interface with the Network Rail Route Asset Manager (RAM) and Track Maintenance Engineer (TME) shall also be recorded
- Details of the organisation proposed to undertake any track defect rectification shall be outlined for agreement with Network Rail



Design Life

- Design for the assets intended operational life – which should consider and account for routine maintenance

- Design working life to be in accordance with NR/L2/CIV/003/F1990

  Note – if the UTX is not a bridge or culvert it shall be considered as:

1. An ancillary structure (with an internal diameter up to and including 2000mm);

2. A tunnel

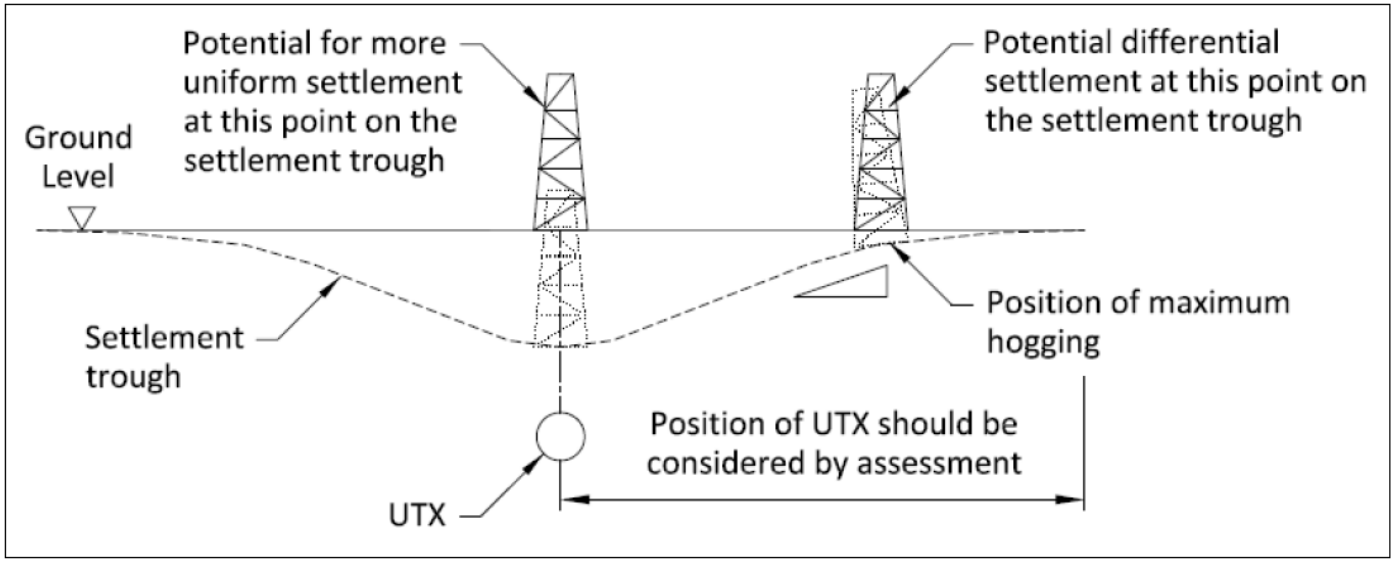
- Design life shall be stated in the Form 001 (Approval in Principle Submission)

Cl 8.1 | Cl 8.5 | Cl 12.2

Position and effects on adjacent infrastructure

The location shall:

- Minimise risks to the operational railway;
- Maintain the stability and integrity of adjacent infrastructures and lineside apparatus;
- Minimise the effect on the horizontal and vertical alignment of the track.



Cl 8.2 | Cl 8.3 | Cl 8.5

The proposed position of the UTX shall be determined by quantitative assessment.

Depth of cover

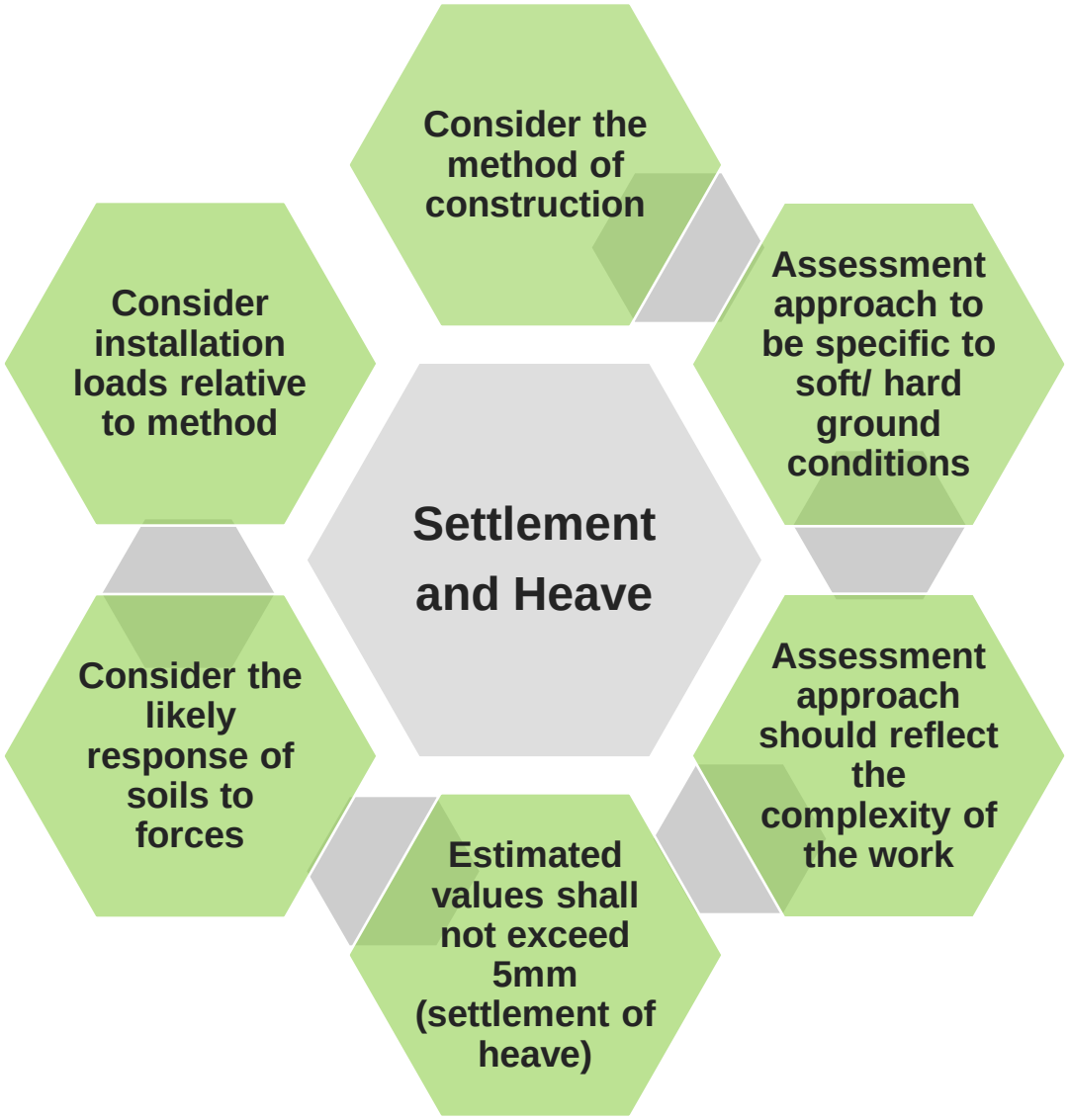
'The vertical distance from the underside of a sleeper to the top surface of the buried service (including any surround or ducting) or undertrack crossing'

- The depth of cover is directly linked to the potential for ground movement (settlement/ heave), which could arise as a result of the UTX installation.
- Depth is therefore a key control against a number of risks.

Method of Installation	Criteria
Open cut	• NR/CIV/SD/FORMA/610 and NR/CIV/SD/FORMB/610 are applicable; • The minimum depth of cover shall be 900 mm, provided between the underside of the sleeper and the crown of the pipe/ ducts; • Direct bury cables shall not be used.
Trench-less	• The depth of cover of the proposed UTX shall be positioned at a level where the anticipated maximum settlement is less than or equal to 5mm • An absolute minimum dimension of 1.8 m shall be provided between the underside of the sleeper and the crown of the pipe/ ducts; • Direct bury cables shall not be used.

Cl 8.4 → Cl 10.3 → Cl 13.8

Assessment of ground movement



Cl 10.3 | Cl 10.4 | Cl 10.6

Design checking

The design check for structural pipe design shall apply

Checks to include for settlement assessment; any dewatering operations and temporary ground support

Permanent Works

Temporary Works

All permanent works shall be subject to a design check in accordance with the requirement of NR/L2/CIV/003

All permanent works shall be subject to a design check in accordance with the requirement of NR/L2/CIV/003

Cl 5.1 | Cl 8.10 | Cl 10.8

Technical assurance (key stage deliverables)

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Appendix A Key documents to be prepared

ID	Document Required	Project Stage					Paragraph Reference
		F001	F002	F003	Prior to site	Following works	
A	Appointments to accord with NR/L2/INI/02009 (including CVs)	•					5.1
B	Project Organisation Chart	•		•	•		5.2/ 12.5
C	Communication plan	•					5.3
D	Wayleave application (if applicable)	•					7.1
E	Approval in Principle (F001)	•					12.2
F	Statement of Design Intent (F002)		•				12.3
G	Certificate of Design and Checking (F003)			•			12.4
H	Asset Management Plan (AMP)				•		12.8
I	Design Drawings	•		•			12.2
J	Approved for Construction Drawings				•		12.4
K	Designers Risk Assessment (DRA)	•	•	•	•		12.6
L	Geotechnical summary		•				8.3
M	Geotechnical Investigation Report (GIR)			•			8.3
N	Geotechnical Design Report (GDR)			•			8.3
O	Construction Risk Assessment and Method Statement (RAMS)				•		12.7
P	Track Monitoring Plan (TMP)				•		12.9
Q	Works Monitoring Plan (WMP)				•		12.9
R	Contingency Plan				•		12.10
S	Emergency Plan				•		12.10
T	Inspection and Test Plan (ITP)				•		14.2
U	Health & Safety files and as-built information					•	14.2

NOTE This table should be read in conjunction with appendix B: Key technical requirements to be demonstrated.

Technical assurance (key stage deliverables)

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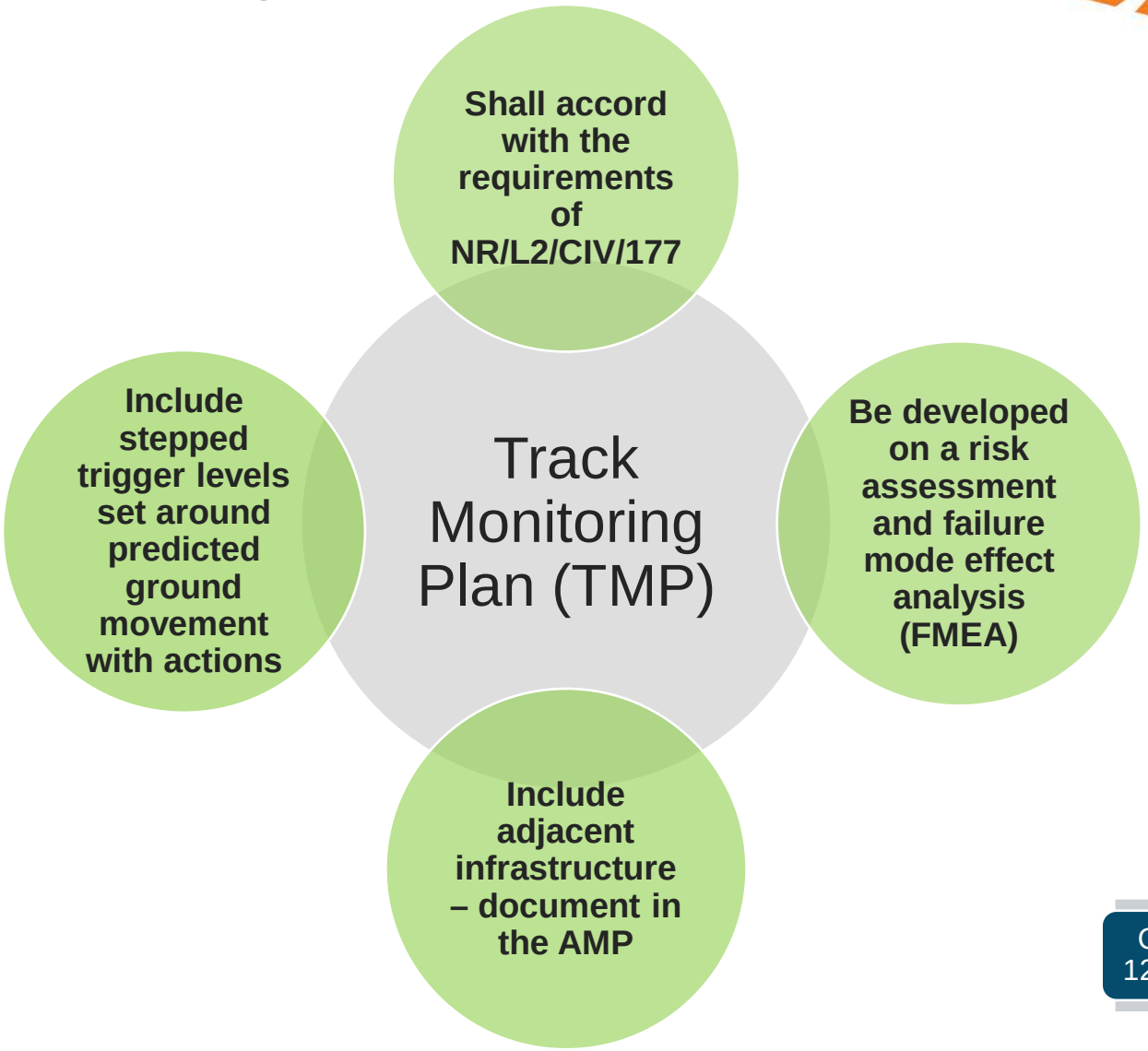
Appendix B Key technical requirements to be demonstrated

ID	Technical Requirement	Project Stage					Paragraph Reference
		F001	F002	F003	Prior to site	Following works	
Constraints							
1	Physical features (e.g. rivers, buildings)	•					7.2
2	Ground conditions (e.g. existence of land-fill and/ or historic mining)	•					7.2
3	Outside party considerations and restrictions	•					7.2
4	Working area restrictions	•					7.2
5	Programme restrictions (e.g. highways moratorium)	•					7.2
6	Interface with existing infrastructure	•					7.2
7	Alterative options and option assessment	•					7.2
Desk-study							
8	General site topography	•					7.3
9	Local geology (not necessarily site specific)	•					7.3
10	Review historical GI for potential geotechnical problems/ parameters	•					7.3
11	Review of historical GI to understand local groundwater conditions	•					7.3
12	Review previous land use	•					7.3
13	Expected design and construction risks	•					7.3
14	Inform the proposed ground investigation and requirements	•					7.3
Buried Services							
15	Buried services identification according to NR/L2/INI/CP1030	•					7.4/ 7.5
Track Layout							
16	Baseline track survey		•				7.5

Technical assurance (key stage deliverables)

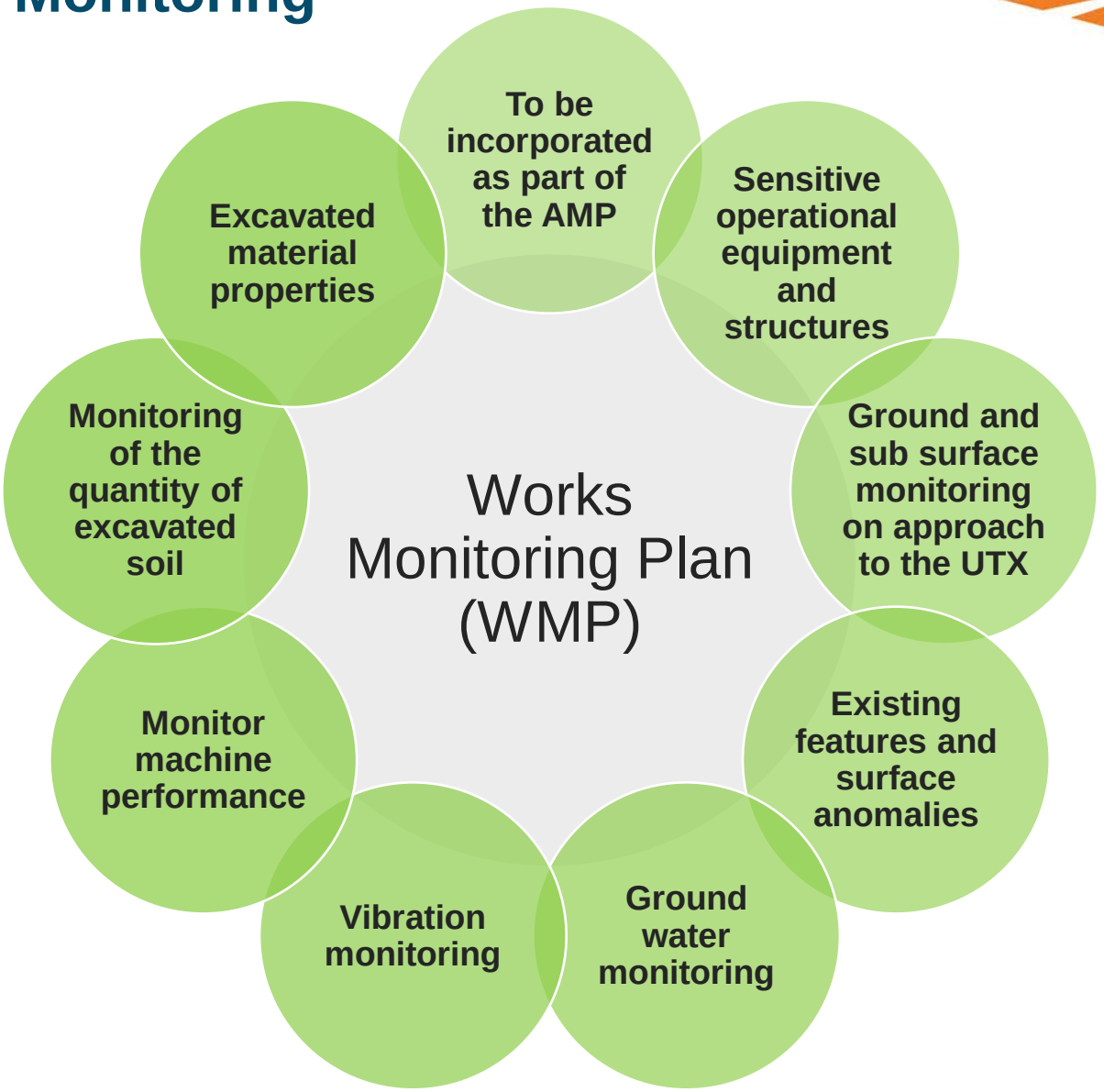
ID	Technical Requirement	Project Stage					Paragraph Reference
		F001	F002	F003	Prior to site	Following works	
Site Investigation							
17	GI Summary		•				8.3
Drawings and Calculation							
20	Calculation: Settlement assessment	• Preliminary		• Final	• AFC Issue		12.2 - 12.4
21	Calculation: Heave assessment	• Preliminary		• Final	• AFC Issue		12.2 - 12.4
22	Calculation: Structural pipe design/ pipe loading assessment	• Preliminary		• Final	• AFC Issue		12.2 - 12.4
23	Drawing: Site location and plan layout	• Preliminary		• Final	• AFC Issue		12.2 - 12.4
24	Drawing: Longitudinal section and geological profile	• Preliminary		• Final	• AFC Issue		12.2 - 12.4
25	Shaft/ Pit general arrangements (where required)	• Preliminary		• Final	• AFC Issue		12.2 - 12.4
Compliance of Construction Works							
26	Material compliance certification (as-built record)					•	13.1/14.2
27	Spoil reconciliation daily sheets (as-built record)					•	13.5
28	As-built record drawings					•	14.2
Design for future operation and maintenance							
29	Statement on operational maintenance	•					8.8
Other Assessments							
30	Statement and/ or assessment of face/ bore stability		•				10.6
31	Statement on the selection of the proposed construction method		•				10.1
32	Statement on monitoring slurry volumes and excavated material	•					13.5
33	Statement and/ or assessment of lubrication and support fluids		•				10.7
34	Monitoring plan and monitoring action plan			•			12.6/ 12.9

Track Monitoring



Cl 12.9 | Cl 12.10 | Cl 13.3

Works Monitoring



Cl 12.9 | Cl 13.4 | Cl 13.5

Pipe jacking overview and other trenchless options

Graeme Monteith, PJA Chairman, Tunnel Engineering Manager – Barhale Plc

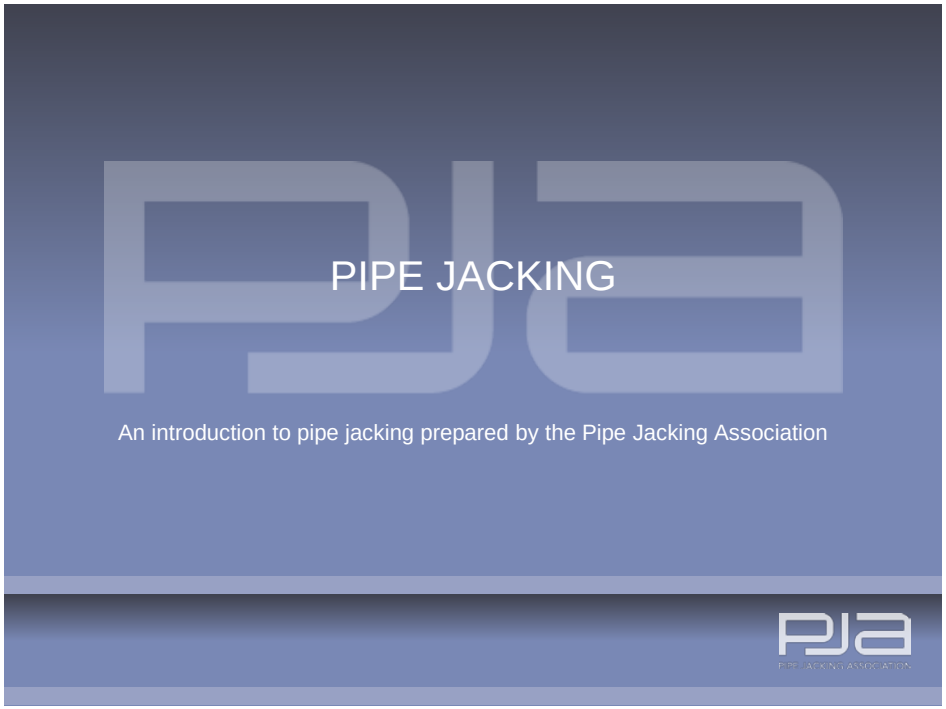
Pipe jacking overview

Trenchless Technology Systems

- There are a variety of trenchless systems that are available to the civil engineering industry
- These can generally be summarised as horizontal directional drilling, ploughing, pipe ramming, auger boring and pipe jacking and segmental tunnelling
- These systems all have their respective merits and applications but only pipe jacking offers the continuous support and engineering integrity that is a fundamental requirement for the provision of larger service ducts under rail track infrastructure
- This presentation focuses on the basic design considerations and an overview of pipe jacking, generally referred to microtunnelling below 1 metre

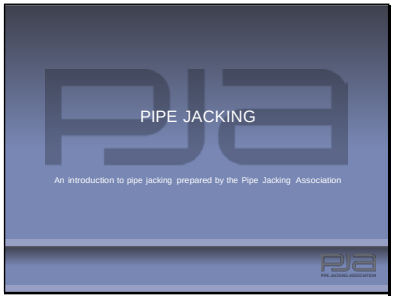
Pipe jacking overview

The following presentation is available for download from the presentations section of the Pipe Jacking Association website: www.pipejacking.org



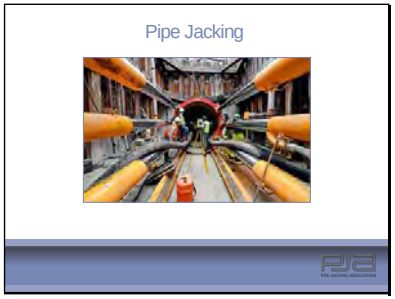
Pipe jacking overview

Slide 1



This introduction to pipe jacking has been prepared by the Pipe Jacking Association as an aid to engineers and others seeking an introduction to the science and art of pipejacking.

Slide 2



Pipe jacking is a tunnelling technique for the installation of pipes using powerful hydraulic jacks to drive purpose designed pipes through the ground at the same time as excavation is taking place at the face.

Slide 3

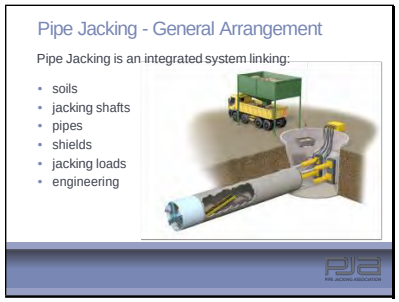
A range of machines are available, to suit varying ground conditions, to install pipes typically in the range 150 to 2,400 mm or greater if required. Lengths of up to a kilometre or more can be jacked depending on ground conditions and pipe diameter. Drives can be either in a straight line, to a radius or a series of radii. Concrete, Grp, clay and steel pipes can be jacked.

Pipe jacking overview

Slide 4

In smaller non-man entry diameters, generally one metre and below, the system is often referred to as microtunnelling although this term is also used to describe automated tunnelling operations in larger diameters.

Slide 5



The integrity of a pipe jacking operation is dependent upon the inter-relationship of a number of factors: soil investigation and interpretation; jacking shaft design; pipe design; pipejack shield selection; hydraulic considerations; and laser engineering and control.

Slide 6

The latest tunnelling technology has been incorporated into pipe jacking excavation systems and a range of machines are available for pipejacking in most ground conditions from soft water bearing strata to hard rock.

Pipe jacking overview

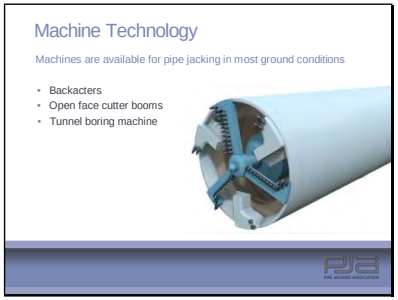
Slide 7

A backacter – an open face shield in which a mechanical backacter is mounted for excavation purposes.

Slide 8

An open face cutter boom – an open face shield in which a cutter boom is mounted for excavation purposes.

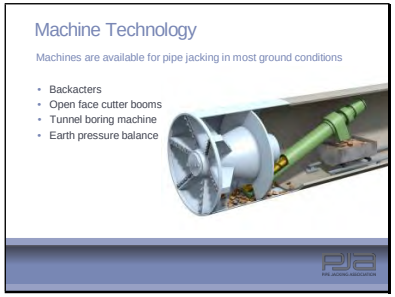
Slide 9



A tunnel boring machine – a shield having a rotating head. Various cutting heads are available to suit a broad range of ground conditions.

Pipe jacking overview

Slide 10

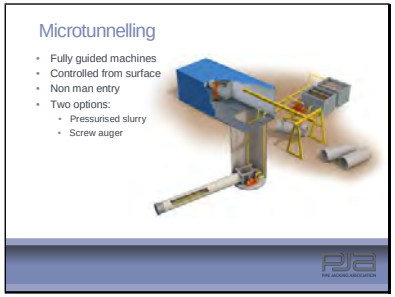


An earth pressure balance machine or EPBM – a full-face tunnel boring machine in which the excavated material is transported from the face by a balanced screw auger or screw conveyor. The face is supported by excavated material held under pressure behind the cutter head in front of the forward bulkhead. Pressure is controlled by the rate of passage of excavated material through the balanced screw auger or valves on the screw conveyor.

Slide 11

A slurry machine - another full-face tunnel boring machine in which the excavated material is transported from the face suspended in a slurry. Various cutting heads are available to suit a broad range of ground conditions and may incorporate internal crushers to deal with cobbles and small boulders. The pressure of the slurry is used to balance the groundwater and face pressure.

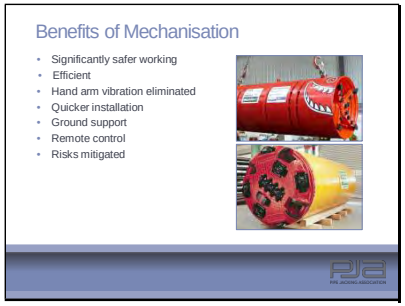
Slide 12



These fully guided machines are remotely controlled from the surface. There are generally two types, both having face support capability, pressurised slurry and auger machines.

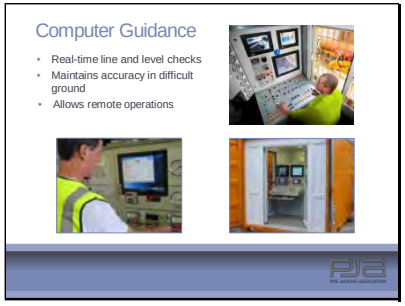
Pipe jacking overview

Slide 13



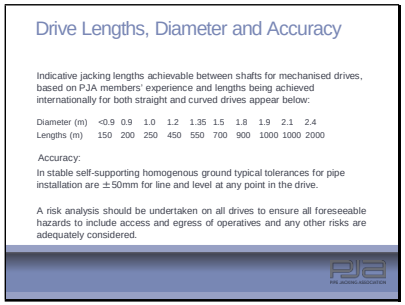
To summarise, the range of mechanised excavation systems available offer a combination of rapid excavation and safety mechanisms to control potentially unstable ground conditions. In addition remote controlled pipe jacking in contaminated ground avoids risks to operatives.

Slide 14



Guidance systems linked to an operator console enable continual line and level checks. Far greater control of accuracy and tolerance compliance is ensured even in the most difficult ground. The requirement for man-entry into the pipejack is minimised with surveying operations managed from the surface.

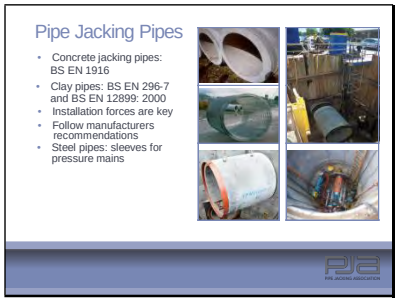
Slide 15



Tunnelling technology enables mechanised drives up to a kilometre or greater to be undertaken depending on pipe diameters. When operatives are working within the tunnel a risk analysis must be undertaken to ensure all hazards are assessed to include access and egress. In stable, self-supporting homogenous ground, typical tolerances for pipe installation are ±50 mm of line and level.

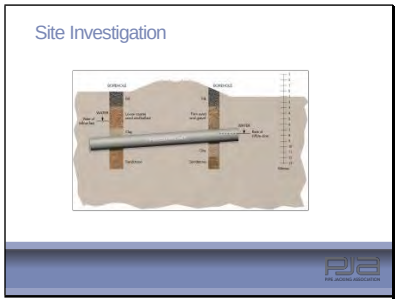
Pipe jacking overview

Slide 16



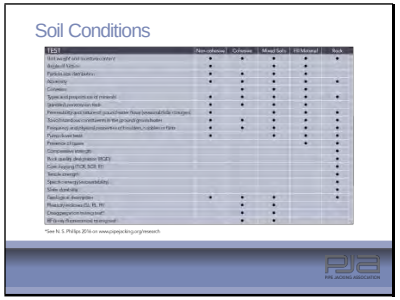
A range of materials are used as pipe jacking linings to include concrete, grp, clay and steel. Concrete jacking pipes which usually incorporate reinforcement, and have flexible joints, and clay pipes, should be manufactured in accordance with relevant standards.

Slide 17



Site investigation is the most important pre-requisite for any tunnelling project. This should be carried out by a suitably qualified geotechnical specialist or geotechnical adviser with considerable experience of tunnelling schemes, under the general direction of the tunnel designer.

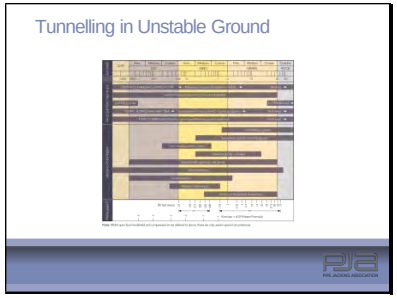
Slide 18



The choice of excavation method will depend on ground conditions. Unstable ground at the face of the tunnel must be controlled to prevent ground loss, and to enable mining to take place safely. This can be achieved using a suitable tunnelling machine or by stabilising the face using appropriate geotechnical processes.

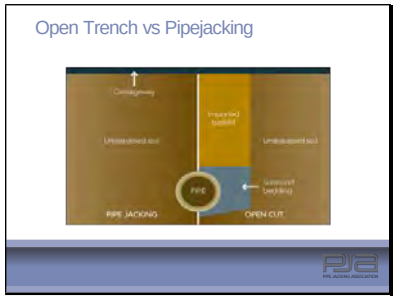
Pipe jacking overview

Slide 19



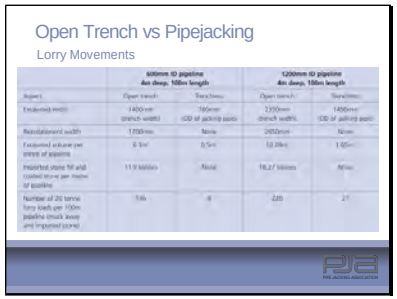
Tunnelling method selection depends on ground stability. Unstable ground can be managed either by suitable machine selection to control face pressures or by stabilising the ground using geotechnical processes. When tunnelling in unstable ground specialist geotechnical advice should be sought.

Slide 20



Comparing open-cut with pipejacking it shows that disruption is largely eliminated. The requirement for excavation is dramatically reduced as there is no requirement for imported fill.

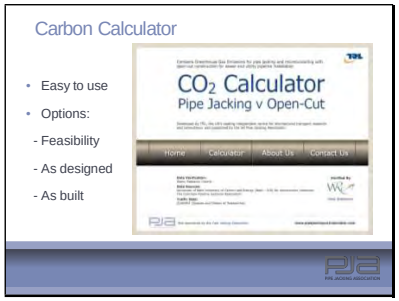
Slide 21



On an average contract, vehicle movements are reduced by 90%, excavated material is only around 8-10% of open cut volumes, and no additional quarried materials are required, so protecting the environment.

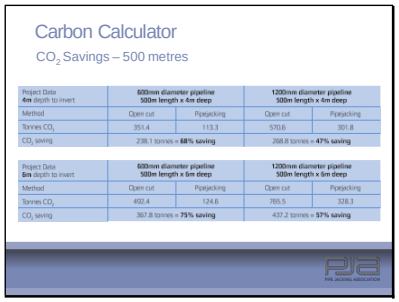
Pipe jacking overview

Slide 22



The Transport Research Laboratory has developed a web-based tool for the PJA to compare greenhouse gas emissions for pipe jacking and microtunnelling with open-cut for sewers and utility pipeline installation. The data sources and methodology has been peer reviewed by the Water Research Centre.

Slide 23



Carbon Calculator

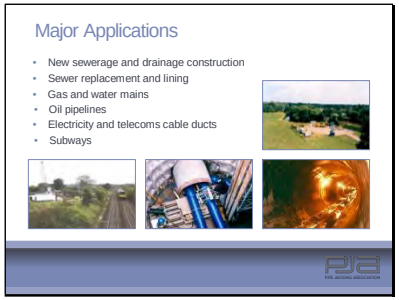
CO_2 Savings – 500 metres

Project Data 4m depth to invert	600mm diameter pipeline 500m length x 4m deep		1200mm diameter pipeline 500m length x 4m deep	
Method	Open cut	Pipejacking	Open cut	Pipejacking
Tonnes CO_2	351.4	113.3	570.6	301.8
CO_2 saving	238.1 tonnes = **68% saving**		268.8 tonnes = **47% saving**	

Project Data 6m depth to invert	600mm diameter pipeline 500m length x 6m deep		1200mm diameter pipeline 500m length x 6m deep	
Method	Open cut	Pipejacking	Open cut	Pipejacking
Tonnes CO_2	492.4	124.6	765.5	328.3
CO_2 saving	367.8 tonnes = **75% saving**		437.2 tonnes = **57% saving**	

This example demonstrates the significant carbon savings that can be achieved over 500 metres.

Slide 24



A major application for pipejacking is for new foul and surface water drainage, culverts and watercourses. It is also used for crossings under roads, railways, rivers and canals for the installation of gas and water mains, oil pipelines, electricity and telecommunications cable ducts, and subways

Pipe jacking overview

Slide 25

Pipe jacking provides the best engineered, safest and most cost effective form of tunnel lining available and is applicable in a wide range of ground conditions.

Slide 26

Pipe jacking and microtunelling are inherently safe tunnelling systems. Man hours worked are substantially reduced as are the risks of utility strikes. Surface disruption is minimised and the finished structure is maintenance free.

Slide 27

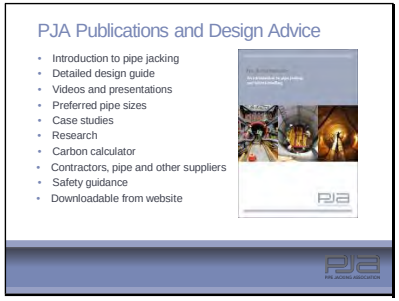
Compared to open-cut trenching, pipe jacking and microtunnelling systems reduce the social and environmental disturbance for the installation of services in urban areas

Pipe jacking overview

Slide 28

Research has been carried out at leading universities to include the design and performance of jacking pipes, the interaction between the soil and pipes using a variety of lubricants, and the effect of various conditioners on the efficiency of the overall jacking process, including excavation. Full details of research activities are available on the PJA website.

Slide 29



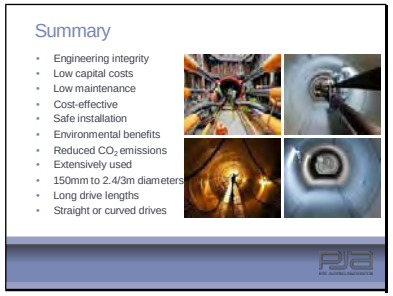
The PJA produce a range of publications to include a general overview, a detailed design guide, case studies, guidance for designers, videos and presentations. These are downloadable from the PJA website.

Slide 30

In addition to conventional conduits pipe jacking has a variety of specialist applications. These include box sections for subways and roadways, bridge foundations for bridge slides and also jacked arches.

Pipe jacking overview

Slide 31



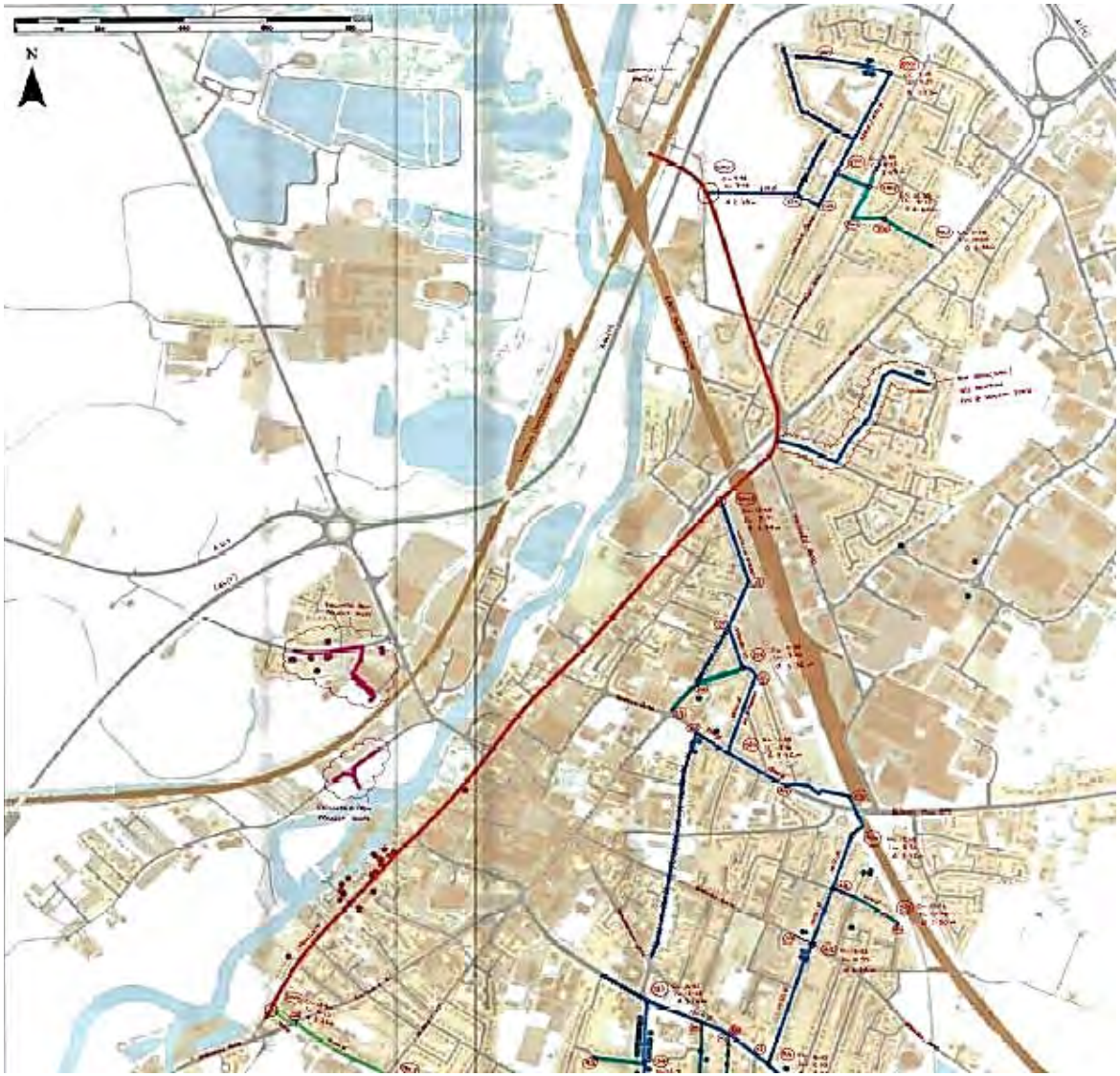
To summarise: pipe jacking is a proven system used extensively for sewerage infrastructure and other utility installations. Pipe diameters typically range from 150mm to 2.4 metres and can be greater when required. Drive lengths of up to 1,000 metres are readily achievable and considerably longer lengths have been successfully jacked. Drives can be either in a straight line, to a radius, or a series of radii. Pipe jacking delivers improved engineering performance and integrity over alternative tunnelling systems.

Slide 32

Case study – NEWARK WWFS

The Newark Waste Water Improvement project consists of approximately 4Km of 2.85mID segmental tunnelling and associated shafts including a crossing of the East Coast Mainline and a smaller 2.1m ID crossing of the Nottingham and Barnet Line (NOB) using a pipe-jack. There is also a spur connection to the main tunnel consisting of approximately 2000m of 1500m ID microtunnel along with some open-cut pipework, with the overall value of the project at circa £60M.

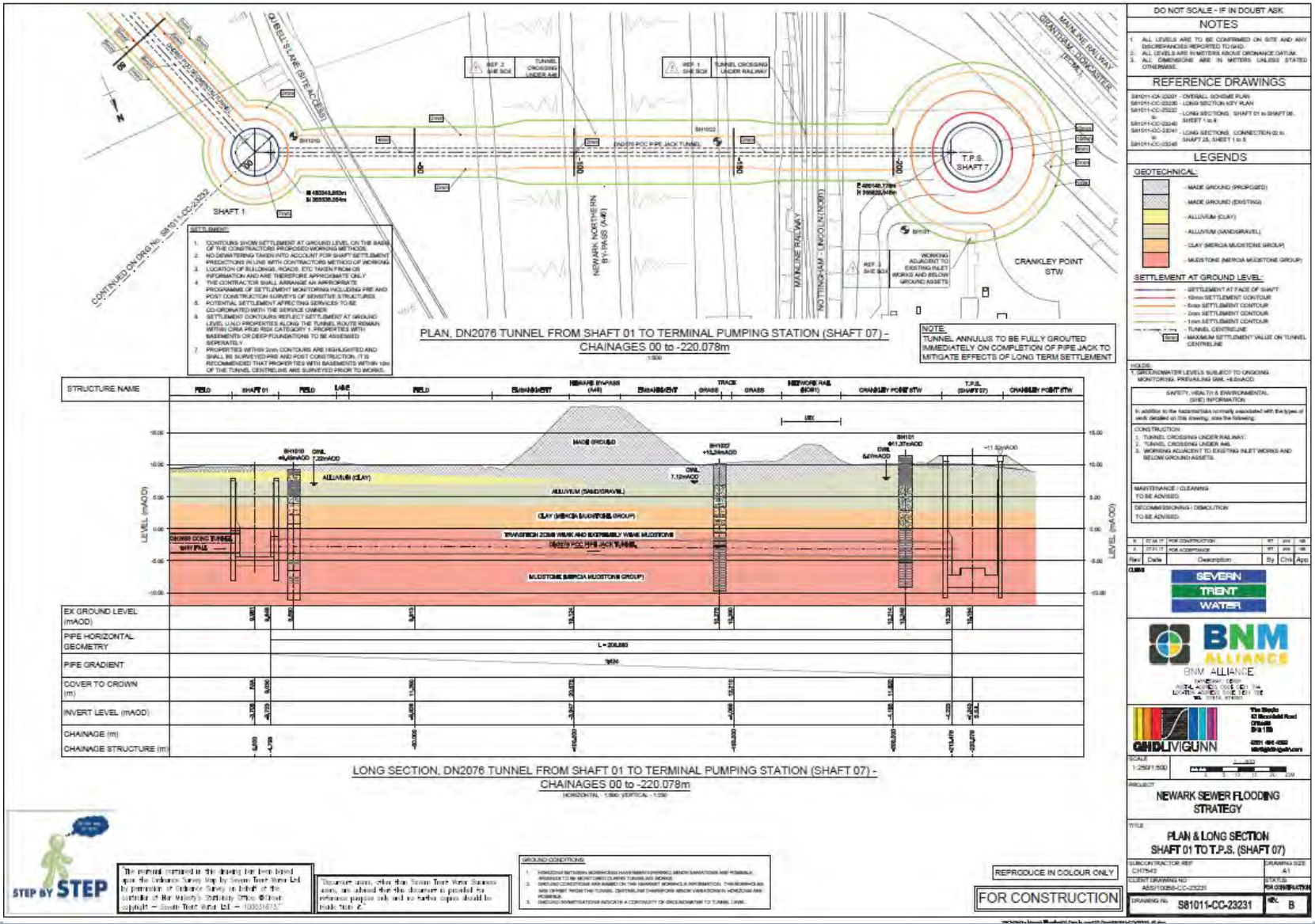
Case study – NEWARK WWFS



Case study – NEWARK WWFS

NetworkRail

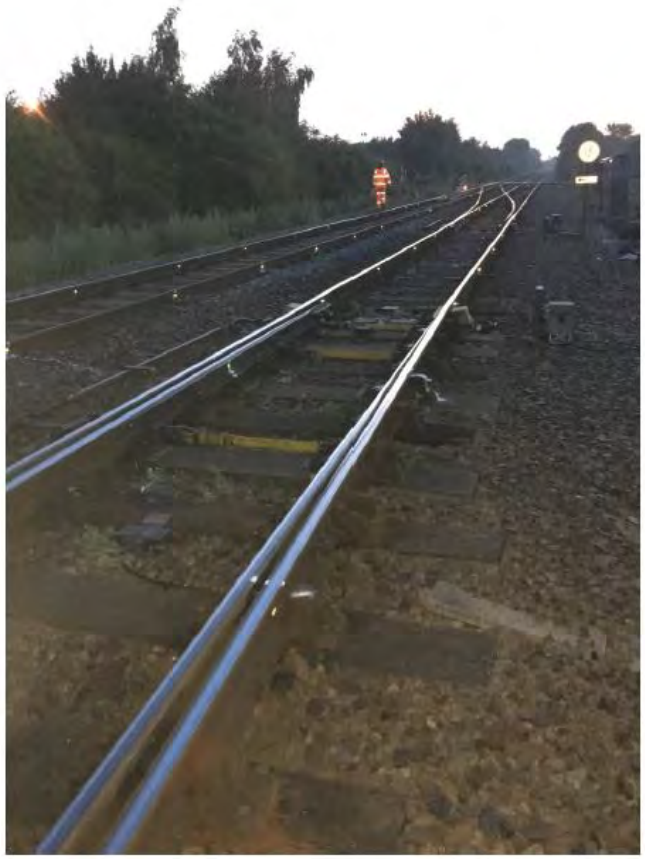
In association with the PIPE JACKING ASSOCIATION



Case study – NEWARK WWFS

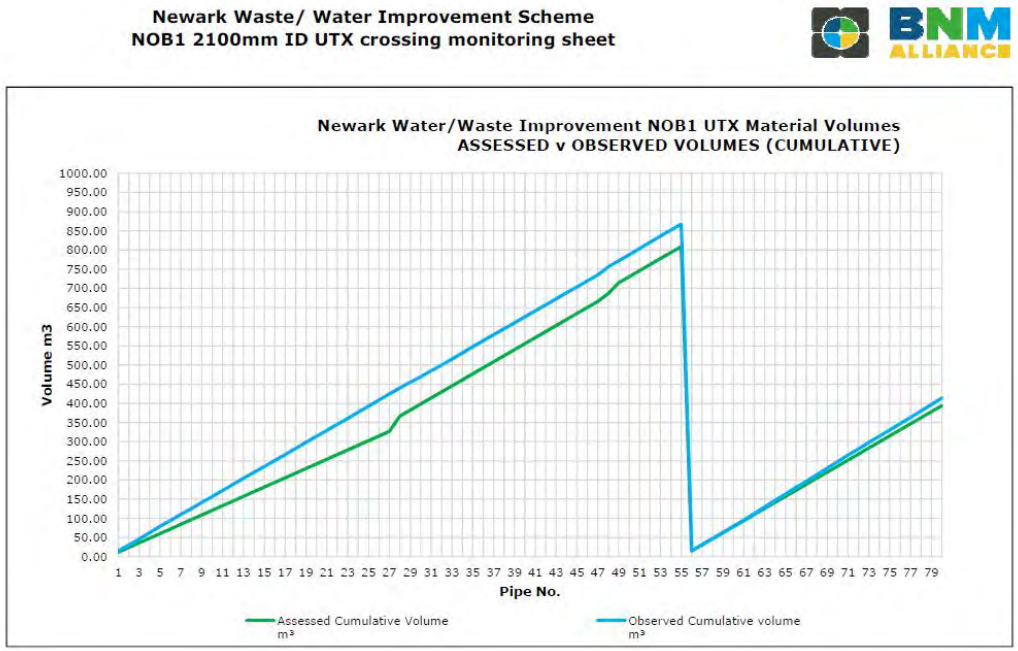
Typical View #1 – Low Mileage

Typical View #2 – High Mileage



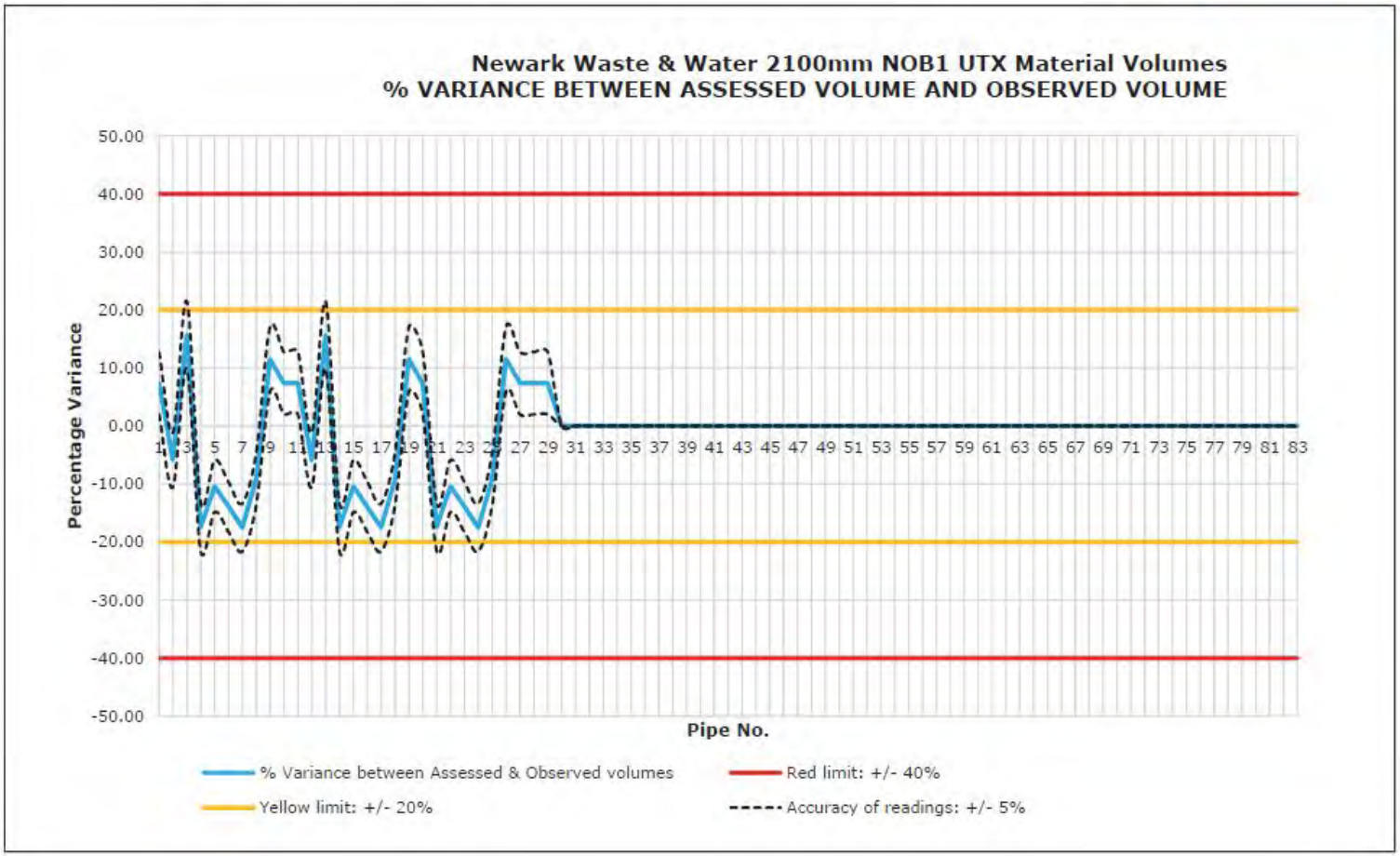
Case study – NEWARK WWFS

Case study – NEWARK WWFS

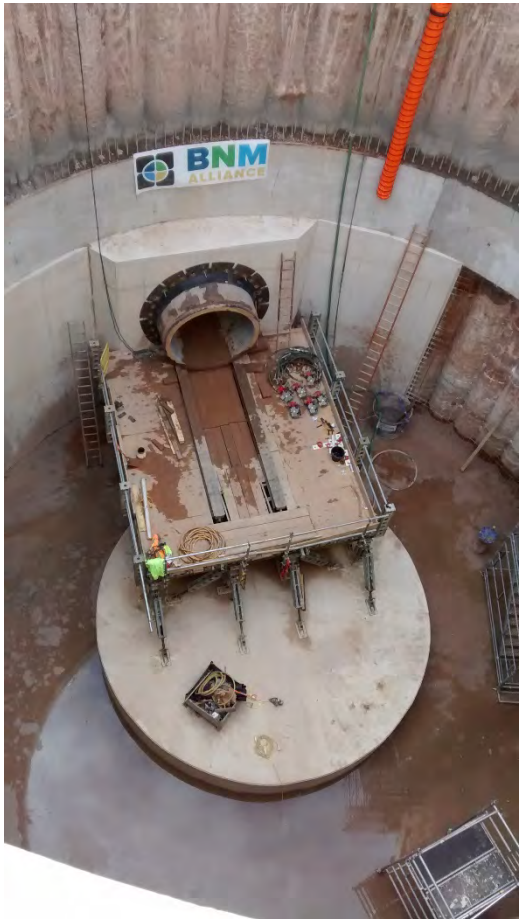


Case study – NEWARK WWFS

Newark Waste/ Water Improvement Scheme
NOB1 2100mm ID UTX crossing monitoring sheet



Case study – NEWARK WWFS



Case study – NEWARK WWFS

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In association with the PIPE JACKING ASSOCIATION

Safety issues in pipejacking

Dr Donald Lamont C.Eng FICE

Managing Director

Hyperbaric and Tunnel Safety

Safety benefits of pipejacking

In association with the PIPE JACKING ASSOCIATION

There are potential safety benefits from pipejacking compared with open trench construction or tunnelling, for the workforce, for those members of the public affected by the work and for the environment.

Safety benefits of pipejacking

Pipejacking provides flexibility coupled with safety as it:-

- Allows small diameter services to be installed remotely using non man entry techniques.
- Provides an alternative lining technique in the 1.8 – 4 m diameter range eliminating the use of segments.
- Allows automated/remote construction in hostile environments.
- Allows for non-circular cross sections to be installed.
- Can be used above or below watertable.

Safety benefits of pipejacking

Non man entry techniques

- Good excavation control along with directional control can be achieved using microtunnelling machine.
- Avoids open trench and associated excavation safety risks for workforce.
- Avoids open trench and associated disruption to traffic, pedestrians and the environment.
- Can reduce contact with contaminated ground.

Safety benefits of pipejacking

Non man entry techniques

- Use of mechanised excavation eliminates the occupational health risks associated with hand excavation including noise, vibration, heat strain, manual handling and confined space working.
- Worker activity confined to pit bottom and around shaft top.
- Containerised and hence rapid set up and readily transportable.

Small pipejack under railway

Safety benefits of pipejacking.

Alternative lining technique to precast segments in the 1.8 – 4m diameter range

- Removes need for ring building along with risks associated with segment transport and handling underground.
- Allows for automated/remotely controlled excavation at contractors discretion.
- Spoil transport by slurry system leads to clean pipestring.
- Otherwise safety issues within pipestring and with TBM are similar to tunnelling.

Pipejack rig

- Managing services whilst adding pipes
- Makes work in compressed air more challenging

Safety benefits of pipejacking

Boxjacking for non-circular shapes and large cross-sections

- Allows installation of non-standard shapes and sizes.
- Safety issues as for large diameter pipejacks or tunnels.
- Depend on excavation technique used.
- Low ground cover solutions available.

Box jacking

NetworkRail

In association with the PIPE JACKING ASSOCIATION

Tunnelling and Pipejacking: Guidance for Designers

This document is a best practice consensus agreed between the Health & Safety Executive, the Pipe Jacking Association and the British Tunnelling Society

Not Acceptable
Avoid
Acceptable

Internal dimensions for pipejacks and tunnels below 3.m diameter and indicative drive lengths

Table 1 – Nominal internal diameter of pipeline or tunnel linings

Excavation technique	<0.9m	0.9m	1.0m	1.2m	1.35m	1.5m	1.8m	>1.8m
Pipejack – machine; remote operation from surface	Acceptable (See Table 2)							
Pipejack – machine; operator controlled below ground	Not Acceptable			Acceptable				
Pipejack – hand dig	Not Acceptable			Avoid				
Tunnel – machine operator controlled + mechanical erector	Not Acceptable					Avoid		Acceptable
Tunnel – hand dig + mechanical erector	Not Acceptable					Avoid		
Timber heading – hand dig	Not Acceptable			Avoid				

Table 2 – Indicative drive lengths (e.g. between shafts) and maximum number of drives

Excavation technique	<0.9m	0.9m	1.0m	1.2m	1.35m	1.5m	1.8m	>1.8m
Pipejack – machine; remote operation from surface	Drive length limited only by capacity of jacking system			250m		400m	>500m (See note 7)	>500m (See note 7)
	Man entry not acceptable		Avoid man entry					
Pipejack – machine; operator controlled below ground	Not Acceptable			125m	200m	300m	500m	>500m (See note 7)
Pipejack – hand dig (See note 6)	Not Acceptable			*25m – 2 drive lengths	*50m – 2 drive lengths	*75m – 2 drive lengths	*100m – 1 drive length. Plan to use minidigger if over 2.1m dia	
Tunnel – machine operator controlled + mechanical erector	Not Acceptable					*250m	*500m	>500m (See note 7)
Tunnel – hand dig + mechanical erector (See note 6)	Not Acceptable					*50m – 1 drive length	*100m – 1 drive length. Plan to use minidigger if over 2.1m dia	
Timber heading – hand dig (See note 6)	Not Acceptable			*25m – 2 drive lengths Minimum cross section inside frames 1.2m high x 1.0m wide				

Notes to tables - Definitions

Acceptable – designers should undertake an assessment of the risks normally associated with small size pipejacking/tunnelling and specify the appropriate mitigation measures.

Avoid – designers should undertake a robust technical assessment and risk assessment to justify decisions to deviate from “acceptable” criteria. Designers should identify appropriate risk mitigation measures. They should seek advice from CDM-C and only proceed if CDM-C is satisfied that due attention has been paid to health and safety in undertaking the design and that appropriate risk mitigation measures have been identified. Contractors being asked to construct a pipejack/tunnel in this category should also seek advice from the CDM-C on the adequacy of their risk mitigation measures.

Not acceptable – designers should not specify the use of pipejacking/tunnelling of this size and construction method. An alternative design solution should be sought.

CDM-C = Principal Designer

Guidance - compliance with code

Does not relieve designer of CDM duties.

Does not relieve the designer of the duty to ensure safe access and egress along with adequate working space.

Min. diameter required for construction may be determined by criteria above rather than by hydraulic requirements or intended use of the pipejack/tunnel.

Pushing the boundaries

Designers should note that for entries not marked * it is **acceptable** to exceed the indicative drive lengths by up to 25% however exceeding these lengths by over 25% should be **avoided**. Exceeding the indicative lengths by over 75% should be considered to be **not acceptable**.

Drive lengths exceeding 1000 m should be considered **not acceptable** unless the pipe/tunnel is of sufficiently large cross section to allow the contractor to incorporate an access envelope 0.9m wide by 2.0m high within the pipe/tunnel and clear of services including ventilation duct and spoil conveyor.

Conclusion - size matters!

For diameters <1.2m non-man entry pipejacking is required.

For diameters >1.2 and <1.8m man-entry or non man entry pipejacking preferred to tunnelling.

For 1.8m diameter and above, man-entry or non man entry pipejacking competes with tunnelling.

Alternative techniques

- Large diameter horizontal directional drilling
- Auger boring
- Combined technologies e.g. Herrenknecht Direct Pipe

Alternative to pipejacking

Large diameter HDD

- Requires multiple passes
- Hole unlined - stability maintained only by bentonite or mud
- Not suited to near horizontal alignment between drive and reception pit
- Good for long drives in open ground e.g. river crossings
- Limitations as alternative.

Alternative to pipejacking

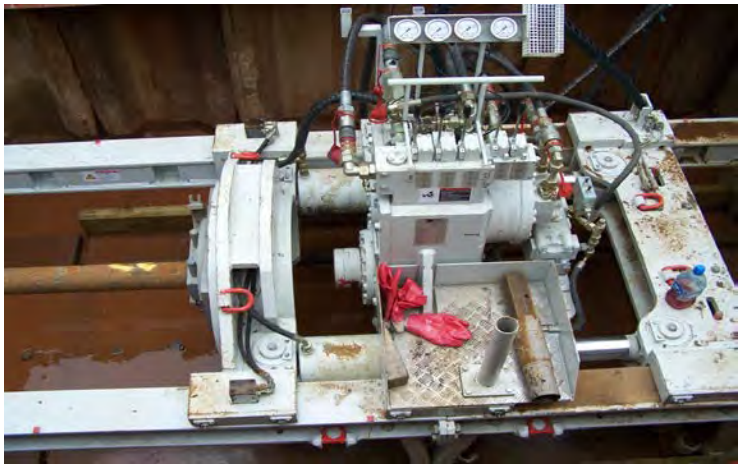
Auger boring

- Auger within pipestring.
- Simple cutterhead at front.
- Drive head jacks itself along trackway.
- Requires open trench for trackway.
- Suited to road/rail pipe sleeve crossings in open land only.

Auger boring variant

Machinery safety working close to rotating parts

- Poor guarding of rotating parts
- Trapping risk
- Poor layout of controls



Variant of pipejacking?

The Herrenknecht hybrid directional drilling/ pipejacking system

Microtunnelling machine at the head of a steel pipestring.

Drivehead can be pulled back

Over excavation and ground loss

Very important issue for safety of third party assets

Pipejacking has advantages over open hole systems such as horizontal directional drilling – lined hole compared with open hole.

- Prevention of over excavation and ground loss has become a major issue in recent years particularly with urban tunnelling and pipejacking under railways.
- Requirement in BS 6164 clause 23 for belt weigher on EPB machines in tunnelling.
- Need to reconcile advance rate with excavated volume.
- Difficult to do accurately in small diameter excavations.
- Use of skips or similar to catch material coming off screens

Over excavation can also can result in settlement of utility services and pipe fracture.

Machinery safety

EN 16191 applies to pipejacking machinery – both the tunnelling machine and the jacking rig.

Currently a number of requirements in EN 16191 refer specifically to pipejacking –

- use of spacers and thrust rings,
- jacks to be perpendicular to thrust ring.
- reduced speed mode for auger extension,
- guards to prevent entry in small sizes,
- oxygen and methane monitoring.

Machinery safety

Many of the other provisions of EN 16191 also apply including

- Hydraulic systems to meet BS EN ISO 4413
- Electrical systems to meet BS EN 60204
- Control functions specified in EN 16191.

Machinery safety

Revision of EN 16191 planned for 2018 under the leadership of Werner Burger (Herrenknecht). This will consider the need for better coverage of machine safety risks in pipejacking

- Slurry circuits
- Noise
- Separation plants?
- Safety of chemical handling and storage.

- PJA involvement?

Machinery safety

Other CEN proposals

- Revision of EN 12110 – Air lock safety under the leadership of D.R. Lamont to start in 2018.
- To start New CEN standard for multi-service vehicles – 2019?
- New CEN standard for refuge chambers – 2019?
- Technical report to implement ISO 19296 in tunnelling – 2019?
- Inclusion of shotcrete spray robots in EN 12001 – 2018?

Machine and process safety

BS 6164 is also being revised at present

- Deals more with process than with the machine

Clauses 7 and 8 on excavation and lining not yet tackled

Clause 20 – requires sealing system at shaft eye.

Clause 22 – Access - refers to BTS/HSE/PJA guidance for designers

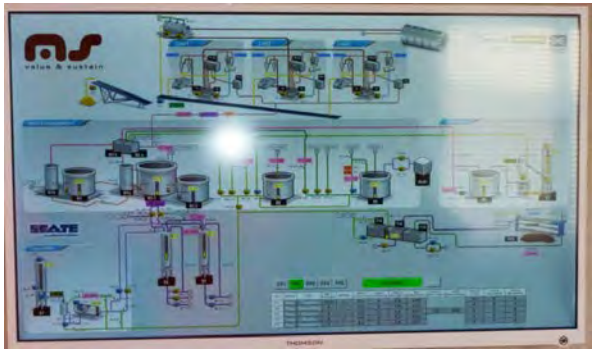
Clause - 23 – Materials handling - various requirements specifically for pipejacking

Clause 25 – now requires means of switching on/off power in or near pit bottom.

Slurry separation plant

- Important part of tunnelling machinery
- Often forgotten about
- Chemical and machinery hazards

Slurry separation plant



NetworkRail

In association with the PIPE JACKING ASSOCIATION

Aspects of Legislation and Risk Assessment

Dr Donald Lamont MBE C.Eng FICE

Managing Director

Hyperbaric and Tunnel Safety

Objective - legislation

- To highlight some less well known aspects of H&S legislation which may be relevant to PJA members
- To highlight changes and trends in enforcement which could affect PJA members

Useful website

PHILIP POYNTER
CONSTRUCTION SAFETY

http://www.ppconstructionsafety.com

HSW Act 1974

S2 – Duties of employers to employees

- General duty to ensure H&S of employees
  - “so far as is reasonably practicable” (sfairp)

S3 – Duties of employers and the self employed to non-employees

S4 – Duties of those in control of premises

Reasonable practicability

NetworkRail In association with the PIPE JACKING ASSOCIATION PJA

Reasonable practicability

- Fundamental concept in UK H&S law
- Not recognised in Europe
- Requires a balance between the benefits achieved and costs/difficulties of a requirement
- Requires defendant to demonstrate they did all that was reasonably practicable in the circumstances

Practicability

Practicability

- Must be done at any cost
- Requirement of older legislation e.g. Factories Act
- Largely phased out but not completely.
  - Don’t get caught out

HSW Act 1974

S7 – General duties of employees

- Take reasonable care of yourself and others affected by your work
- Cooperate with employer to assist him to comply with his statutory duties

S8 – Duty not to interfere or misuse

S9 – Duty not to charge employees

HSW Act - 1974

Section 33 - Offences

- This section creates the offences under HSW Act.
- Often a press report will quote a “breach of Section 2 and Section 33 of HSW Act”
- The reference to Section 33 is a legal technicality

HSW Act 1974

S37 – Consent and connivance

- Where an offence by a company is proved to have been committed with the consent or connivance of, or due to neglect by any director, manager etc he as well as the company shall be guilty of that offence and shall be liable to be proceeded against and punished accordingly

Manslaughter

Not a H&S offence

This is general criminal law

Targets individuals or companies

Police have primacy in investigation following a fatality

CPS decides on charges

HSE will assist if asked

- May put forward alternative charges based on H&S law

Manslaughter

Gross negligence manslaughter charge appropriate for major breach of duty resulting in a fatality.

Also if in addition to general failings leading to a fatality

- Failure to heed repeated warnings or advice
- Wilful breach of prohibition notice
- Deliberate removal of guard from machine
- Deliberate removal of guardrails on scaffold
- Cost avoidance/profit maximisation

Corporate Manslaughter

Corporate Manslaughter and Corporate Homicide Act 2007

"An organisation to which this section applies is guilty of an offence if the way in which any of its activities are managed or organised by its senior managers —

(a) causes a person's death, and

(b) amounts to a gross breach of a relevant duty of care owed by the organisation to the deceased."

- Specifically covers construction work

Corporate Manslaughter

Intended to target the major companies

- Previously difficult to establish links between the failings and the individual “controlling minds”
- Easier to prove in small companies where director involvement is clearer and more directly link to work activity

Corporate Manslaughter

Penalties

- fine,
- a Publicity Order,
- a Remedial Order
- or any combination .

Sentencing Guidelines propose a fine in the range £180k to £20m but the maximum is “unlimited”.

Notices 2015-16

Total PNs served	PNs in Construction	% in Construction
2934 + 7 (def) (3110)	1876 + 2 (1900)	63.9% 61.1%
Total INs Served	INs in Construction	% in Construction
5830 (6330)	1168 (1229)	20.0% 19.4%

Prosecutions 2015-16

259 (258 in 14/15) prosecutions in construction

242 or 98% resulted in one or more guilty verdicts

Fines imposed totalled £7.8 m (£3.98m in 14/15)

- Effects of Sentencing Council Guidelines for Feb-Mar 2016

Sentencing Council Guidelines

Apply to all sentencing after 1st February 2016

Penalty must reflect

- Culpability
- Harm
- Size and turnover of firm
- Other factors
- Guilty plea

Sentencing Council Guidelines

Culpability – from a flagrant breach of law to a minor isolated failing.

Harm - three components considered

- risk of injury from the offence – severity and likelihood;
- number at risk;
- actual consequences of offence.

Turnover – lack of information indicative of ability to pay any fine

Other factors

Aggravating factors

Previous convictions

Cost cutting at expense of safety

Breach of statutory notice

Poor H&S record

Targeting vulnerable victims

Mitigating factors

No previous convictions

Remedied problem voluntarily

Good H&S record

Effective H&S procedures in place

Sentencing Council Guidelines

Large company >£50m turnover very high culpability and high harm, basic fine £4m but range £2.6m - £10m

Micro company <£2m turnover low culpability and low harm, basic fine £200 but range £50 - £2000.

Sentencing Council Guidelines

Individuals very high culpability and high harm, custody and expect 18 months but range 1 – 2 years

Individuals low culpability and low harm, expect Band A fine but range is conditional discharge or Band A fine (25% – 75% weekly income)

Gross negligence

Demolition of roof with fragile roof lights

Method changed by subcontractor from mechanical demolition to hand work

20th January – man falls but does not go through roof light

21st January (morning) – another man falls through roof light and breaks spine

21st January (afternoon) – first man falls through roof light again and is killed this time

Gross negligence - penalties

Subcontractor – Director 6 years imprisonment; £400k fine and £55k costs.

- Company also guilty

Principal contractor guilty of HSW Act S2, CDM Regs and WAH Regs offences – fined £90k and £45k costs

Exacerbating factors – “profit before worker safety”, directors pleaded not guilty and “hid behind companies”

New sentencing regime penalties

Fatal fall of ~2.8m through faulty self-closing gate.

Judge “breathtaking failure to recognise hazard”

No previous convictions

Fine £3.3m reduced to £2.2m for guilty plea

Regulations

Principles of prevention

Eliminate hazard/Avoid risk

Combat risk at source

Adapt work to individual

Adapt to technical progress

Substitute by less/non dangerous

Collective protection over individual protection

Instructions and training

Legal requirements for machinery safety at point of supply

Supply of Machinery (Safety) Regulations 2008 (SM(S)R) apply to

- (a) the manufacturer of the machinery or partly completed machinery; or
- (b) the manufacturer's authorised representative.
- or contractor importing machine into Europe

Legal requirements for machinery safety at point of supply

Supply of Machinery (Safety) Regulations 2008 (SM(S)R)

- Reg 7 (4) Machinery which is manufactured in conformity with a harmonised European standard shall be presumed to comply with the essential health and safety requirements covered by that standard.

Use of machinery/equipment

Provision and Use of Work Equipment Regs 1998 (as amended) (PUWER)

- Duties on employer to provide safe work equipment
- Reg 11 has the absolute requirement to “guard to the extent that it is practicable to do so”.
- Schedules of technical requirements
  - Reflect Machinery Directive ESRs
  - Similar technical requirements to those in SM(S)R

CDM - the 4 "abilities"

The "**ability"** of designers to reduce the risk to the health and safety of those for whom the design is done.

The 4 "**abilities"** of designers are to improve:-

- Build**ability**
- Access**ibility**
- Us**ability**
- Maintain**ability**

CDM 2015 – Pt 4

CDM Pt 4 has requirements in respect of

- Safe access and egress; adequate working space
- Excavations, shafts, tunnels
- Work on/over water
- Traffic routes
- Caissons cofferdams
- Explosives
- Demolition; unsafe structures; premature collapse
- Welfare

CDM - Principal contractor duty

Reg 13(1) - "Principal contractor must plan, manage and monitor the construction phase in a way which ensures that, so far as is reasonably practicable, it is carried out without risks to health or safety"

CDM - Contractor duty

Reg 15(2) ”A contractor must plan, manage and monitor construction work carried out either by the contractor or by workers under the contractor’s control, to ensure that, so far as is reasonably practicable, it is carried out without risks to health and safety”.

Variation in requirements

Beware of the variation in requirements in CDM Pt4 – duties qualified by

- “suitable and sufficient steps”
- “all practicable steps”
- “so far as is reasonably practicable”

Variation in requirements

CDM Reg 19 - all practicable steps must be taken to prevent danger to persons from collapse of structures due to construction work.

- “structure” includes any building, timber, masonry, metal or reinforced concrete structure, road, bridge, railway line or siding, tramway line …… .

Variation in requirements

CDM Reg 22 - all practicable steps must be taken to prevent danger to persons, including the provision of supports or battering, from —

- excavation collapse;
- dislodgement of material from walls or roof of excavation.
- “excavation” includes any earthwork, trench, well, shaft, tunnel or underground working

Charging for services

HSE charges for services “Fee for Intervention (FFI)” as from October 2012 “where matters of significant concern are found”

- i.e. where letter or notice issued
- ~£130 per hour
- appeals against charge to be heard by HSE and if notice upheld HSE can reclaim appeal costs also

Notices of contravention

Year	Notices of contravention Construction sector	Fee for Intervention value
2013	6960	£2.55m
2014	6075	£3.11m
2015	6990	£4.22m

Effect on enforcement notices

Year	No of notices issued in construction sector (INs + PNs)
2013	3625
2014	3244
2015	2713
2016	3046

Objectives – risk assessment

In association with the PIPE JACKING ASSOCIATION

To highlight a range of techniques which can be used in construction

To draw attention to common problems with techniques used.

Chance and luck

Risk = likelihood x consequence

Chance and luck can be important aspects

Consequences of an adverse event can depend on chance – wrong place at wrong time - near miss or disaster e.g. Stokes Lane

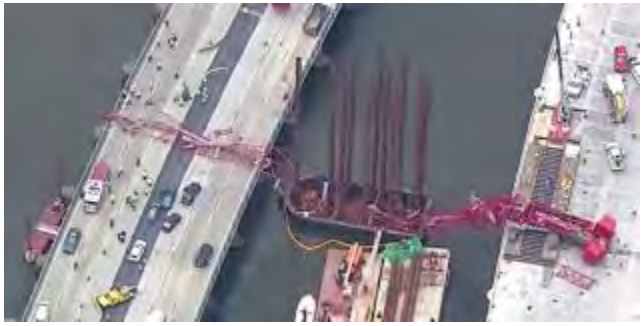
Sometimes nothing can be done to mitigate the consequences once the adverse event begins.

Initiating event can be trivial and completely unconnected with consequences – very difficult to predict.

Chance and luck

Sometimes nothing can be done to mitigate the consequences once the adverse event begins.

Only 1 fatality and 5 injured



Chance and luck

Initiating event can be trivial and completely unconnected with consequences.

Balloon landed in substation

Shorted and melted main busbars.

Reliability and diversity

Reliability - reduced likelihood of error

Diversity – different ways of doing something

Both are important in reducing risk

Reason's Swiss Cheese model

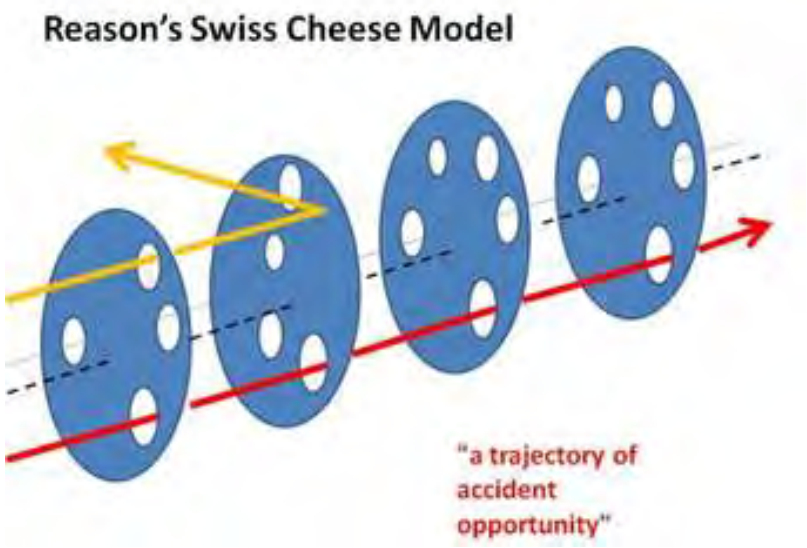
James Reason, Manchester University

Numerous barriers

Each barrier is flawed

If/when flaws align then accident opportunity occurs

More a concept than method



- Add diverse barriers – through path more complex
- Make each barrier more reliable – reduce holes.

Risk assessment methods

Qualitative

- More common in construction
- Simpler to use
- Subjective

Quantitative

- Requires large amounts of data on which to base analysis
- QRA or NRA (numerical risk assessment)
- Objective

Risk assessment - qualitative

Often based on consequence x likelihood matrix

Frequently used in construction

Can have numbers associated with each cell

- This is not recommended by HSE

Often mixes project risk with H&S risk

Site risk assessment

ACTIVITY	HAZARD/RISK	EXISTING RISK LEVEL			SAFETY CONTROL MEASURES	IMPLEMENTED BY	RESIDUAL RISK LEVEL			MONITORED BY
		LH	S	RR			LH	S	RR	
					• Calibrated relief valves					
Transfer MGSW to/from living habitat from/to shuttle (de-clamping and clamping	**Uncontrollable loss of pressure due to improper clamping**	3	5	15	• Strictly follow clamping procedure • No transfer should be carried out unless the safety clamping interlock is working properly • Leak test of the clamping system • Carry out regular check prior to transfer • The connection system should be examined by vessel examiner prior to use • Mechanical interlock. Appendix 26	S&L Specialist S&L Specialist S&L Specialist E&M Technician Hydrokarst S&L Specialist	1	5	5	HOM HOM HOM HOS HOS HOM
Pull the shuttle by friction wheels to open area prior to lifting	**Fall & slip inside shuttle**	2	2	4	• MGSW should remain on the seat and fasten the safety belt • Ensure the routing without any obstruction • Anti-slip device should be installed inside TUP Shuttle	MGSW S&L Specialist Hydrokarst	1	2	2	S&L Specialist HOM/HOS HOM
	Failure of electric winch	3	2	6	• Pre-use visual check to the electric winch • Electrical motor preventive maintenance according to manufacturer recommendations • Install guarding to the moving / revolving parts • Arrange RPE to check the winch and obtain the statutory certificates	E&M Technician E&M Technician E&M Technician Area Foreman	1	2	2	S&L Specialist S&L Specialist S&L Specialist HOM
	Shuttle strike to others during transfer	2	3	6	• Only working crew is allowed to stay in the operating area • Appointed qualified and trained shuttle followers to perform the task	S&L Specialist Shuttle follower/HOS	1	3	3	HOM S&L Specialist
Lift the shuttle onto Specialized Shuttle Transfer Vehicle by crane	**Fall & slip inside shuttle**	2	2	4	• MGSW should remain on the seat and fasten the safety harness • Ensure the routing without any obstruction • Anti-slip device should be installed inside TUP Shuttle	MGSW S&L Specialist Hydrokarst	1	2	2	S&L Specialist HOM/HOS HOM

LH = Likelihood		S = Severity		RR = Risk Rating	Acceptability
1	Rare – very rare to occur	1	Insignificant – first aid at most and fully recoverable	1 to 4 = Acceptable	✓
2	Unlikely – unlikely to occur	2	Minor – recoverable with short sick leave	5 to 10 = Acceptable with Close supervision	✓
3	Possible – occur once during contract	3	Moderate – partially recoverable with long sick leave		
4	Likely – ≤10 times during contract	4	Major – serious & irreversible injury	11 to 19 = Intolerable	×
5	Almost Certain – >10 times during contract	5	Catastrophic – Multi fatality / casualty	20 to 25 = Activity Prohibited	×

Site risk assessment

Tends not to reflect reality

- Allocated frequency is normally higher than in reality

Seldom covers occupational health risks

Seldom addresses use of plant and plant safety risks or temporary works

3x3 matrix – for discussion

Consequence			
High – fatality or large monetary loss			
Medium – serious injury or monetary loss			
Low – minor injury or monetary loss			
Likelihood of occurrence	Low - unlikely during project	Medium - once during project	High - many times during project

- Green - acceptable, yellow - mitigate; red - unacceptable
- Cell definitions and allocation are subjective

3x3 matrix

Lack of sensitivity – multiple fatalities

Is any fatality ever acceptable?

Should a high frequency of minor accidents be unacceptable?

Technique probably acceptable for ranking risks

5 x 5 Matrix

Consequence					
Very high – multiple fatalities					
High – fatality					
Medium – serious injury/ long term ill-health effect. Requires medical treatment. Possible incapacity for work					
Low – minor injury or ill-health effect. Requires first aid or medical attention					
Very low – negligible consequence or first aid only					
Likelihood of occurrence during project lifespan	Very low – very unlikely	Low – unlikely	Medium – once during project	High – occasionally (<10 times)	Very high – consistently or frequently (> 10 times)

High risk - unacceptable and work should not proceed. Reassessment required along with application of General Principles of Protection	
Medium risk – work continues but reassessment required along with application of General Principles of Protection	
Low risk – generally acceptable but keep under review	

5 x 5 Matrix

More appropriate for construction

Political unacceptability of very high consequence events

- Hazard elimination replaces risk assessment

Consequence can be defined in terms of injury, financial loss, loss of service etc. Don’t forget ill-health! Consider plant and temp works

Very high frequency but very low consequence events can also be unacceptable.

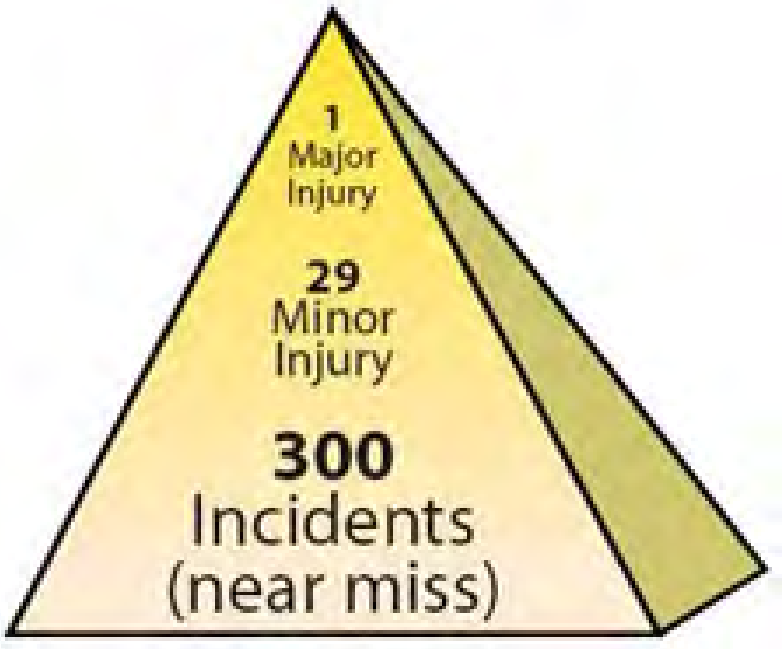
Heinrich's Pyramid

Devised by Herbert W Heinrich in 1931

Heinrich was an insurance inspector

Based on analysis of industrial insurance claims in the USA.

Ratios have been challenged



Heinrich's Pyramid

Eliminate the top event by eliminating the near misses at the bottom of the pyramid.

Hence importance of mitigating high frequency low consequence risks.

Behavioural safety techniques used to modify behaviour of workers.

Must be a causal link between top and bottom events

Does not apply well to health risk or high consequence events

Accident Frequency Rate

Most commonly used measure in UK construction

(NRA/ANE) x 100,000 (HSE version)

NRA = Number of RIDDOR reportable accents in 12 months

ANE = average no of employees over 12 months

Accident Frequency Rate

Some authorities base AFR on man-hours worked (100,000 or 1,000,000).

Takes no account of near misses

Ignores ill health

Ignores non-conformance with safety guidance and standards

But contractors like it!

Hazard analysis

Identifying hazards which are likely to occur

- Sometimes referred to as “Hazan”

Hazard and operability study

Hazop is the structured analysis of a complex system by a team familiar with it looking at process parameters – flow, pressure, temp, time, level etc.

Examines consequences on each item in system based on guide words

- Guide words include – none, more, less, as well as, other than, early, late, reverse, before, after

HAZOP

More important for civil engineers than often realised

Less structured applications of technique often used without awareness by those using it

- The “What if” approach.

Andy Mitchell CEO Tideway, NCE Nov 2017, “describes himself as inquisitive and creative, unable to resist the lure of asking himself ‘**What** happens **if** I do this?’”

HAZOP assessment of TBMs being asked for by HS2.

Bow-tie analysis

Done as a group activity to take greatest advantage of available expertise.

The diagrams clearly display the links between the potential causes, preventative and mitigative controls and consequences of a major incident.

Simple tool for communicating risk assessment results to employees at all levels.

Bow tie analysis

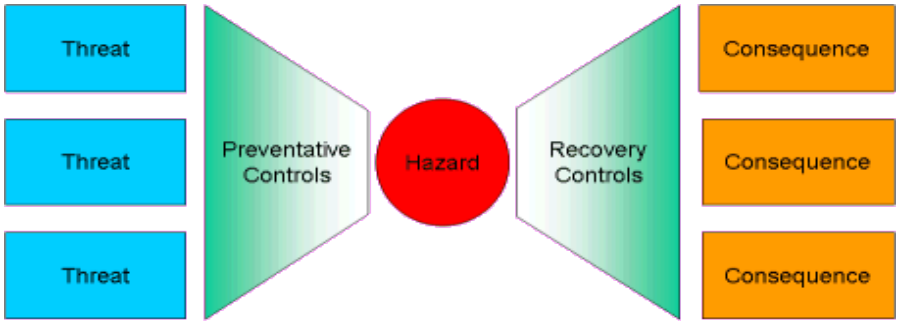
Threats on far left

Preventative controls on left

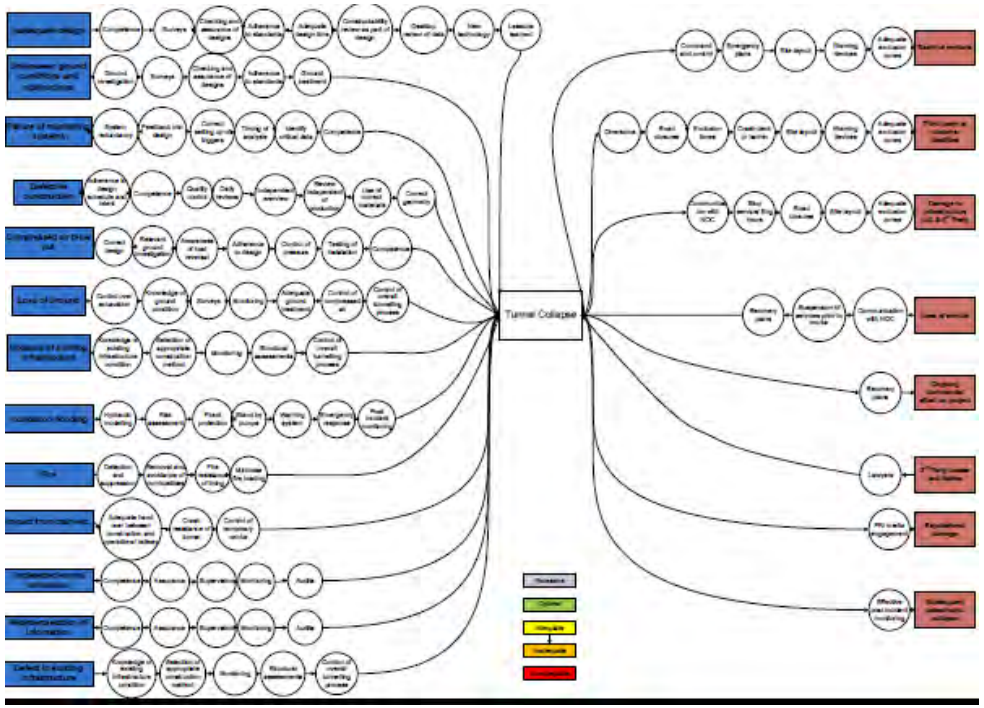
Hazard/event is in the middle

Mitigating measures on right

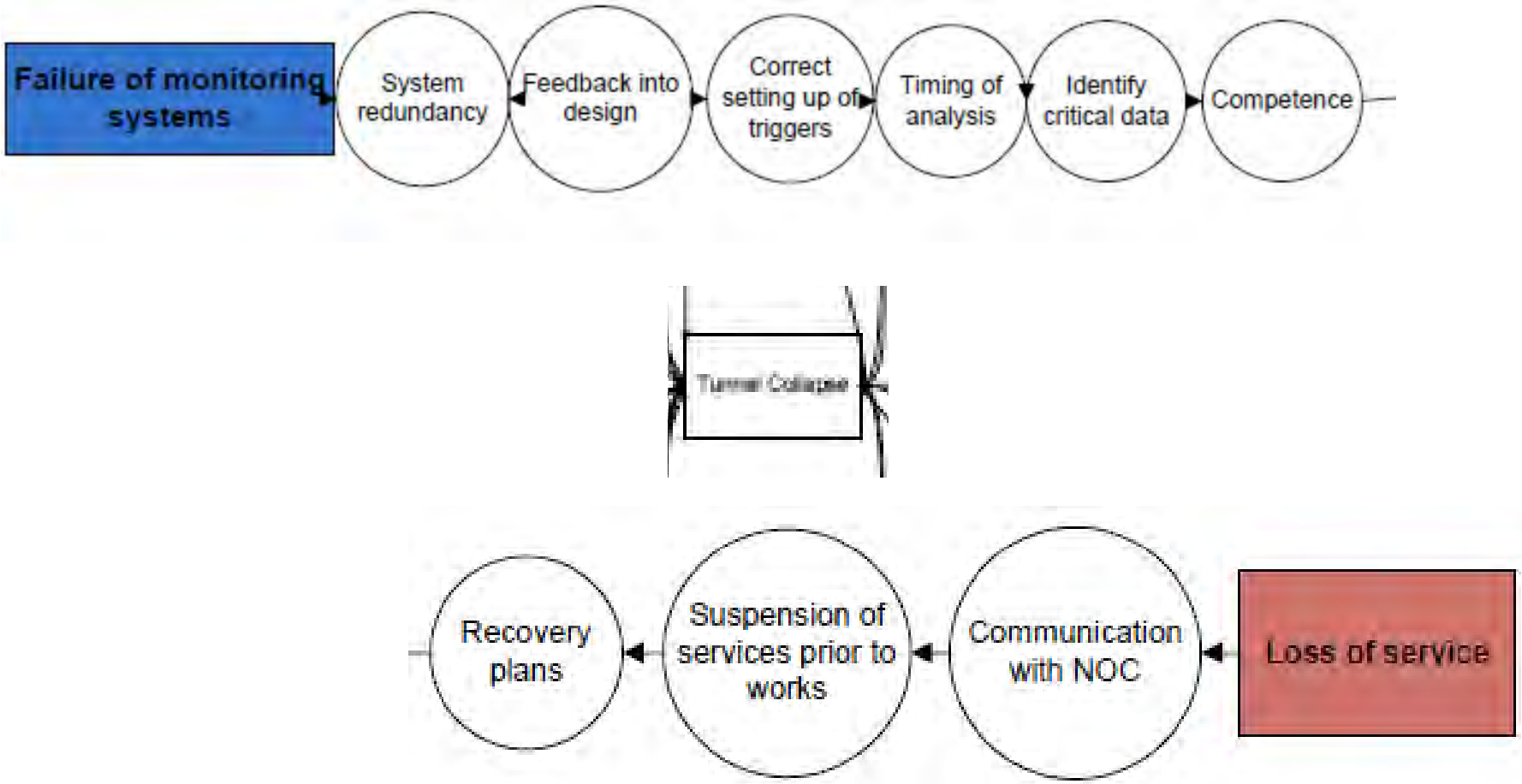
Consequences on far right in order of severity



Bow tie analysis



Bow tie analysis – tunnel collapse



Occupational health and welfare

Dr Donald Lamont C.Eng FICE
Managing Director
Hyperbaric and Tunnel Safety

Occupational health and welfare

By an engineer for engineers!

This short presentation will cover two issues

- Fitness for work
- Ill health due to work

Why ill-health is economically important

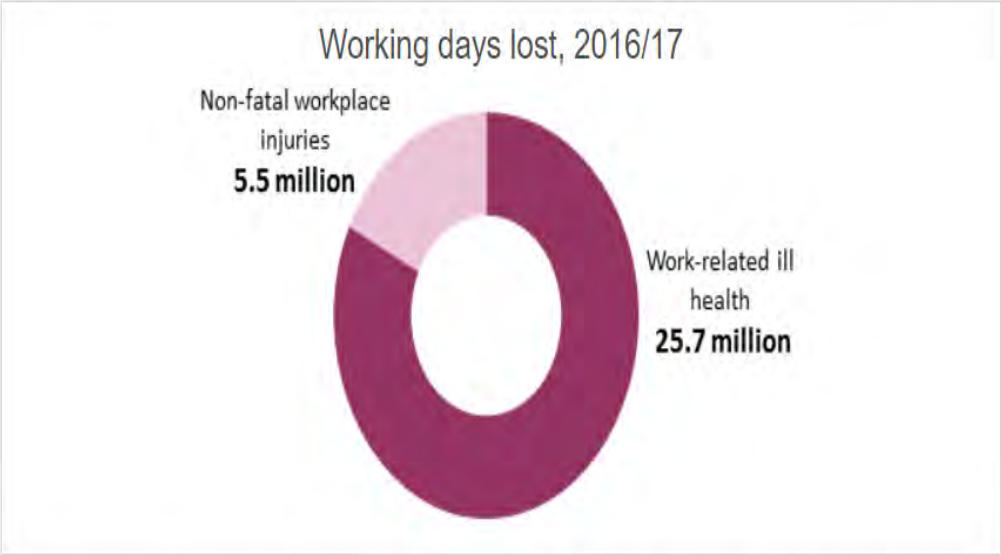
Figures for “all industries”

- construction represents 7%

-5 times more days lost due to ill-health

Working days lost

31.2 million Working days lost
due to work-related ill health and non-fatal workplace injuries in 2016/17



Stress, depression or anxiety and musculoskeletal disorders accounted for the majority of days lost due to work-related ill health, 12.5 million and 8.9 million respectively.

Occupational hygiene

"The science behind minimising the risk of ill health in the workplace" – BOHS definition

- Monitoring techniques, control strategies, PPE

Control of exposure to

- *Harmful dusts, toxic metals*
- *Gases solvents/organic vapours*
- *Thermal environment, noise, vibration, lighting*
- *Ventilation*
- *Radiation*

Fitness for work

Tunnelling and pipejacking work can be a physically demanding activity. Sometimes it is undertaken in a confined space underground. Sometimes the working environment can be hot and humid, occasionally it can be cold.

- Good practice suggests that all persons working in tunnelling and pipejacking should undergo basic occupational health surveillance
- Higher level of fitness required for safety critical occupations

Basic occupational health surveillance

Pre-employment screening

- To assess basic medical fitness for work
  - Height, weight, blood pressure, heart/lungs, sight, hearing, diabetes, smoking, alcohol consumption
- To identify pre-existing occupational ill-health conditions
  - Noise induced hearing loss, HAVS

Periodic reassessment

Post employment screening

Working patterns

Long shifts
- Physically tiring

Shift work – standard practice in tunnelling
- Affects body clock

HSE has a fatigue calculation tool
- Can be used to compare fatigue effects of different shift patterns

Both situations covered by Working Time Regulations

Both require a higher level of fitness for work

Stress

Effects of pressure to complete challenging project to budget and on schedule

- Some stress can improve performance
- Too much can damage mental health

An increasingly common occupational health issue

Drug and alcohol screening

Substance abuse can result in unfitness to work

- Physical and mental fitness
- What levels of impairment are acceptable?

Is choice of recreational drugs influenced by retention period in body?

Safety critical occupations

Vehicle operators

- Crane operators, plant operators, loco drivers

- Not obviously unwell e.g. heart disease
- Diabetes and epilepsy
- Eyesight,
- Colour blindness
- Hearing

Statutory fitness for work

Work in Compressed Air Regulations

- Only those medically fit can enter compressed air tunnels
- Medical fitness for work in compressed air assessed by "Appointed Doctor"
  - Comprehensive annual medical
  - Periodic long bone MRI/X-ray
  - Periodic checks depending on pressure
    - 28 days for exposures >1 bar and 3 months for <1 bar

PPE – not the preferred or easy option

Remember the MHSW Regulations hierarchy

Ensure the correct selection, use, maintenance, compatibility, storage and replacement of PPE can be a complex management task

Technically diverse range of PPE available.

Involve an occupational hygienist if necessary

Be aware of PPE overload

Human factors in training and use

"**One size definitely does not fit all**"

Noise

Consequences of excessive exposure

- Hearing impairment
- Diminished quality of life
- Incapacity for work
- No obvious physical disability
    - Extent and severity of problem not recognised by society

50% of miners may have significant hearing impairment – JLE study

Noise

Control of Noise at Work Regulations 2005

- Set out exposure action and limit values for noise exposure and for peak sound pressure
- Require
  - risk assessment
  - elimination or reduction of exposure to noise by engineering control (sfairp)
  - measures, excluding the provision of PPE to be taken at the upper exposure action values
  - designation Hearing Protection Zones
  - health surveillance
  - information, instruction and training

Noise reduction - EN 16191

Noise reduction shall be an integral part of the design process taking into account measures at source

Pumps and motors shall not be mounted directly on the steel structure of the machine but shall be separated from the structure by vibration isolation mountings;

Motors >250 kw to be water cooled

Machines of 3.5 – 6 m dia hydraulic power packs to be enclosed

Fans which are part of the permanent ventilation system of the tunnelling machinery shall be fitted with silencers;

Control cabin with noise protection

Noise

Mitigation
- Noise enclosures
  - Now mandatory on TBMs
- Good maintenance

Health surveillance
- Audiometry

PPE
- Hearing protection

Vibration

HAVS - Signs and symptoms

- Tingling, numbness and loss of feeling in the fingers
- Loss of strength in your hands (inability to pick up or hold heavy objects).
- In the cold and wet, the tips of fingers going white then red and being painful on recovery (vibration white finger).

Control of Vibration at Work Regulations 2005

Exposure limit values and exposure action values (8 – hour average)

Risk assessment

Risk from exposure to vibration should be eliminated at source (sfairp)

Employees shall not exposed above ELV

Measures, excluding the provision of PPE to be taken at the upper exposure action values

Health surveillance

Information, instruction and training

HAVS Exposure calculation aids

NetworkRail

In association with the PIPE JACKING ASSOCIATION

There are various exposure calculation aids

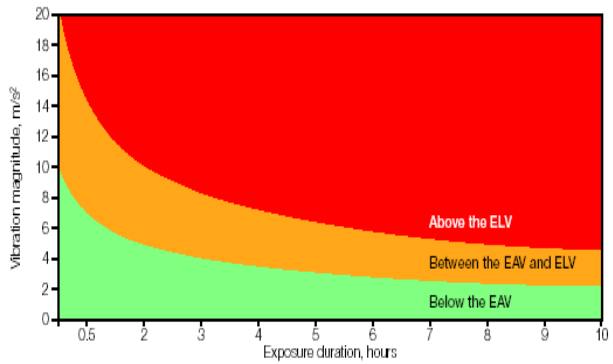


Figure 1 How vibration level and duration affect exposure

Tool vibration (m/s^2)	3	4	5	6	7	10	12	15
Points per hour (approximate)	20	30	50	70	100	200	300	450

Multiply the points assigned to the tool vibration by the number of hours of daily 'trigger time' for the tool(s) and then compare the total with the exposure action value (EAV) and exposure limit value (ELV) points.

100 points per day = exposure action value (EAV)
400 points per day = exposure limit value (ELV)

Table 2 Simple 'exposure points' system

Tool type	Lowest	Typical	Highest
Road breakers	5 m/s^2	12 m/s^2	20 m/s^2
Demolition hammers	8 m/s^2	15 m/s^2	25 m/s^2
Hammer drills/combi hammers	6 m/s^2	9 m/s^2	25 m/s^2
Needle scalers	5 m/s^2	-	18 m/s^2
Scabblers (hammer type)	-	-	40 m/s^2
Angle grinders	4 m/s^2	-	8 m/s^2
Clay spades/jigger picks	-	16 m/s^2	-
Chipping hammers (metal)	-	18 m/s^2	-
Stone-working hammers	10 m/s^2	-	30 m/s^2
Chainsaws	-	6 m/s^2	-
Brushcutters	2 m/s^2	4 m/s^2	-
Sanders (random orbital)	-	7-10 m/s^2	-

Table 1 Some typical vibration levels for common tools

Vibration

Mitigation

- Elimination of vibration at source
- Good tool maintenance
- Job rotation
- Keep hands warm
- Not considered a machine risk (EN 16191)

Health surveillance

- Physical examination

PPE

- Anti-vibration gloves
  - Of doubtful value

Manual handling

Much manual handling is eliminated by the use of pipejacking

Occurrence otherwise

- Hand excavation, erection of segments, general tunnelling activity
- Handling of cutters and tools

Manual handling

Consequences of excessive exposure

- Musculo-skeletal disorders
  - Work related upper limb disorder
- Incapacity for work
- Obvious physical disability

Manual Handling Operations Regulations 1992

Mitigation measures include making things too heavy to lift manually, mechanical excavation and provision of lifting points and aids

Pressure - Work in compressed air

Work in compressed air is seldom undertaken in pipejacking work.

When it is required, follow the BTS “Guide to the Work in Compressed Air Regulations”

Dust

Dust is a major problem in conventional tunnelling but much less so in pipejacking.

Inhalable dust

- Enters nose, mouth and respiratory tract
- 10 mg/m^3 exposure 8-hour TWA limit

Respirable dust

- Enters gas exchange region of lungs
- 4 mg/m^3 TWA

Respirable crystalline silica

- 0.1 mg/m^3 limit

Monitoring regime and limits may change in revision of BS 6164

Dust/silica

Consequences of excessive dust exposure

- Chronic Obstructive Pulmonary Disease (COPD)
  - Irreversible lung damage, breathlessness
  - Loss of quality of life
  - Incapacity for work
  - Death
- Silicosis
  - Death

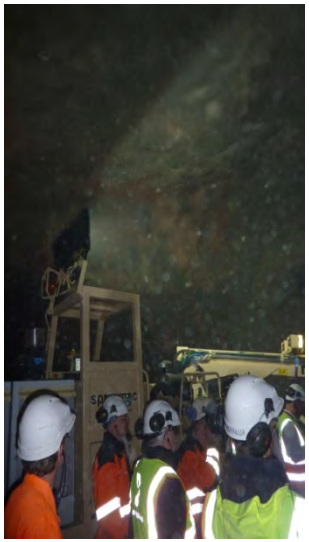
Dust

Monitoring

- Air sampling
- Personal samplers
- Dust lamp

Regulations

- COSHH
- Application of COSHH principles



Dust

Mitigation

- Dust suppression and capture
  - Dust is a mix design parameter for SCL
  - Wet mix robot spraying
- Ventilation
  - Extraction preferred

Dust

Health surveillance

- Lung function/spirometry
- X-ray/MRI scanning

PPE

- Dust masks

Ill health effects significantly exacerbated by smoking

Diesel Particulate Matter

Diesel particulate matter is now a contaminant of concern

DPM - real time monitoring based on 15 min averages

- Must be able to differentiate between DPM and mineral dust
- Limits still being discussed but HSE proposes 100 µg/m^3

Cement/resins/chemicals etc

Cements, resins, soil conditioners, waterproofing, slurry treatment

Dermatitis/skin damage

- Can be very incapacitating
- Not always obvious to society

Lung damage

- Sensitisation

Cement/resins/chemicals etc

Mitigation

- Choice of materials
- Avoid contact
  - Gloves/boots etc
- Barrier creams
- Good personal hygiene/welfare

Health surveillance

- Physical examination

Asbestos

Occurrence – in older tunnels as PC4 or similar caulking material

Legislation

- Control of Asbestos Regulations 2012

Consequences of excessive exposure

- Asbestosis
  - Lung damage
  - Incapacity for work
  - Severe loss of quality of life
- Mesothelioma
  - Malignant lung disease
  - Death

Asbestos

Mitigation

- Asbestos surveys in old tunnels
- Use of licensed contractors for removal

Health surveillance

- Medical examinations at intervals of 2 years and health record to be maintained

Statutory medical examination

PPE

- High efficiency masks

Lead

Occurrence – lead caulking of SGI segments, red lead paint in older tunnels

Regulations - Control of Lead at Work Regulations 2002

Consequences of excessive exposure

- General ill health - range of symptoms
- Kidney damage
- Neurological damage

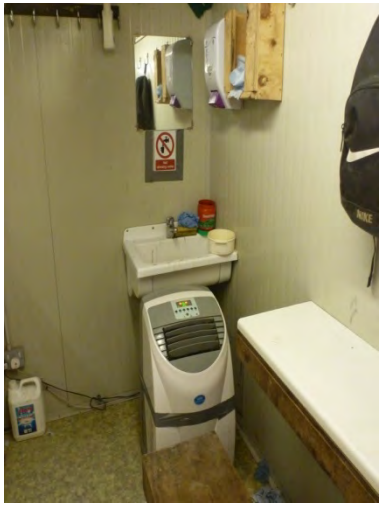
Welfare

Basic toilet facilities
Washing facilities
Drinking water
Messing facilities
First aid
Problems of remote sites
Problems of short duration work

Welfare

Benefits

- Respect for people
- Reduction in low level ill health
  - Improves performance of workforce and hence safety



Atmospheric Monitoring and Ground Contamination

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Atmospheric monitoring

Standard practice in all underground work

Electronic monitoring equipment should be used

Records should be kept of all results obtained not just of abnormalities.

BS 6164 gives guidance on monitoring, alarm settings and exposure limits.

Gas monitoring in pipejacking

Methane in the pipe string or pit-bottom

- Risk of flammable atmosphere and ignition from machinery

Oxygen deficiency in pit-bottom

Hydrogen sulphide if working on sewerage schemes

Contamination can come from

- existing utilities e.g. gas mains, contents of sewers,
- ground being excavated.

For non-man entry pipejacks atmospheric monitoring still relevant as gas can still accumulate in pipe string and spill into the pit bottom

Proposed changes to exposure limits

Implementation of 4th Indicative Occupational Exposure Limit Value Directive

Changes proposed for August 2018

- Transition period for tunnelling and mining till August 2023

Carbon monoxide

- Reduced long term and short term limits
- 30 ppm reduced to 20 ppm; 200 reduced to 100 ppm

Proposed changes to exposure limits

Nitrogen monoxide

- Adopt a long term limit of 2 ppm.
- Currently BTS guidance is aim for 3 long term but keep below 5 ppm based on discussions with HSE when CHAN revoked.
- Always keep below 15 ppm short term limit

Nitrogen dioxide

- Adopt a long term limit of 0.5 ppm and 1 ppm short term limit
- Currently no formal limit but 1 ppm as considered acceptable.

HSE keen to engage with industry to discuss costs of implementation

- If no response will assume assent from industry for changes

Dust

Dust is probably less of a hazard in pipejacking than tunnelling

Problem in tunnelling is the wide variation in dust levels during the production cycle

Instantaneous monitoring should be used to quantify the peak rates

Light scattering photometry emerging as a useful measuring technology

- Can differentiate on particle size

Real time monitoring

Real time monitoring now a reality for respirable dust.

Inhalable dust monitoring being worked on.

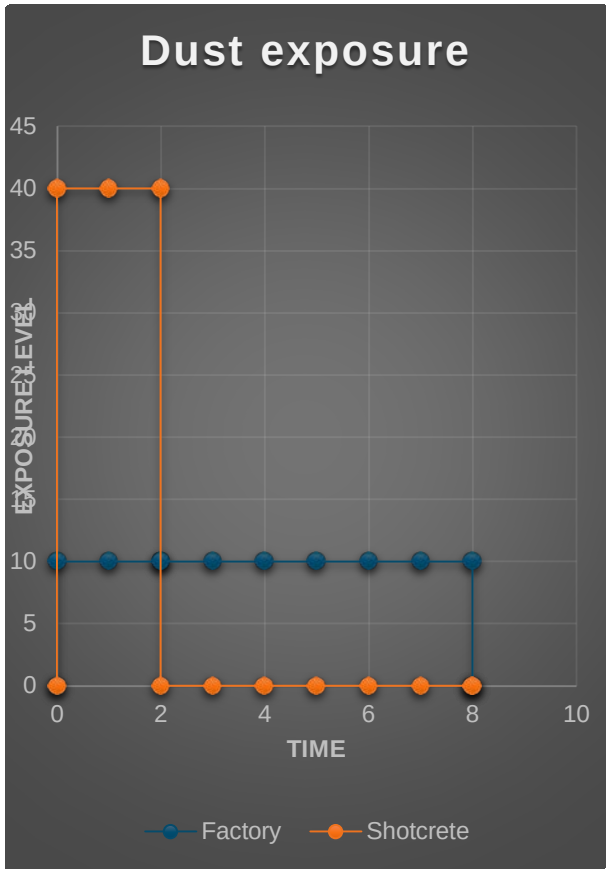
This is a major advance in dust exposure control

Exposure comparison

Both exposures equate to 10 mg/m^3 over 8 hours

Is RPE required?

- Legally – no
- Current thinking – yes
- Select on peak value/15 minute average not 8 hr average value



IOM recommendations

Inhalable dust 10 mg/m^3

- IOM recommendation 5 mg/m^3

Respirable dust 4 mg/m^3

- IOM recommendation 1 mg/m^3

Respirable crystalline silica – 0.1 mg/m^3

- no change

Diesel Particulate Matter

Lack of international consensus on standards.

Results from incomplete combustion of hydrocarbon fuels.

Soot particles with hydrocarbon droplets adsorbed on the surface.

Size range <1 µm

Carcinogenic + respiratory damage.

Can be monitored in real time

Diesel Particulate Matter

Diesel particulate matter - real time monitoring based on 15 min averages

- Measurement principle – some form of real time light scattering particle counting technology.

Limits still being discussed but HSE proposes 100 µg/m^3

Ground contamination

Industrial legacy

Tends to occur at shallow levels

Can be water borne

Hence more likely to occur in pipejacking than in tunnelling

Non man entry pipejacking techniques may reduce risks compared with tunnelling

Soil and water contamination

Rule 1 – avoid pipejacking in contaminated soil

Rule 2 – get specialist advice asap

Rule 3 – cooperation between contracting parties not confrontation needed to overcome problem

Soil and water contamination

Contamination sources

- Fuel leaks and spills
- Industrial legacy – coke, tar, gas *etc*.
- Industrial leaks and spills
- Waste dumping and disposal

Normal location

- In near surface layers such as made ground
- In ground water or floating on ground water
  - Can form plumes

Soil and water contamination

Common contaminants

- Total petroleum hydrocarbons (TPH)
- Polycyclic aromatic hydrocarbons (PAH)
- Polychlorinated biphenyls (PCB)
- Volatile Organic compounds (VOC)
- Heavy metals

Soil and water contamination

Both an occupational and environmental contamination issue

Ground investigation should differentiate between environmental occurrence in the soil for environmental exposure (mg/kg) and airborne occurrence for occupational exposure (mg/m^3).

H&S compliance must be against occupational exposure limits

Environmental limits can give order of magnitude indication of problem

See EH 40 for how to determine limits

Apply COSHH principles if no limit exists

Total Petroleum Hydrocarbons

- Complex mixtures
- Result from fuel spill
- Contain benzene, ethylbenzene, toluene, xylene (BTEX)
- Lighter hydrocarbons evaporate off with time – residue becomes less volatile
- Occupational exposure limit for TPH
- Detected by PID or soil/water analysis

Total Petroleum Hydrocarbons

Don't forget the explosive risk if high concentrations of light TPH found

As residues become "heavier" *i.e*. high carbon number with age, volatility reduces and so does explosion risk

Explosive limits are much lower than for methane – typically ~1% by volume

Low odour threshold

Polycyclic Aromatic Hydrocarbons

Naturally occurring but occur in hydrocarbon residues

A group of 16 defined compounds including pyrenes, anthenes, anthracenes and naphthalene

All are carcinogenic

Not very volatile so limited risk of atmospheric contamination

Polycyclic Aromatic Hydrocarbons

Identified by soil or water analysis

Risk based on “Slope factor” – i.e. the cancer potential relative to Benzo(A)pyrene

- weighted by mixture proportions to give total risk from mixture for given exposure period

Cancer risk from exposure must be < 1×10^{6}

If not “COSHH principles” apply

- Eliminate, reduce, control etc

Polychlorinated biphenyls

PCBs are a group of around 200 related chemicals

Was used a dielectric fluid in transformers – banned by BS 6164 1991

Occurs from deliberate or accidental spillage

Carcinogenic

Very persistent environmental pollutant – difficult to dispose of

WEL = 0.1 mg/m^3

Skin absorption also

Very difficult to handle above background levels

- Environmental occurrence stated in µg/kg

Volatile Organic Compounds

Industrial solvents and cleaning processes

- Tetrachloroethylene, acetone, methylene chloride, benzene, formaldehyde etc

Carcinogenic, skin irritant, neurological disturbance, kidney damage

Heavy metals

Lead, chromium, arsenic, nickel, *etc*.

Neurotoxic and/or carcinogenic

Will normally occur in dust

Detect by soil and/or water analysis

Control dust to control exposure

EH40 sets limits

Lead – Control of Lead at Work Regs