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CONSULTING SERVICES FOR THE uMKHOMAZI WATER CONVEYANCE INFRASTRUCTURE (uMWP-1)

Design considerations and construction strategies

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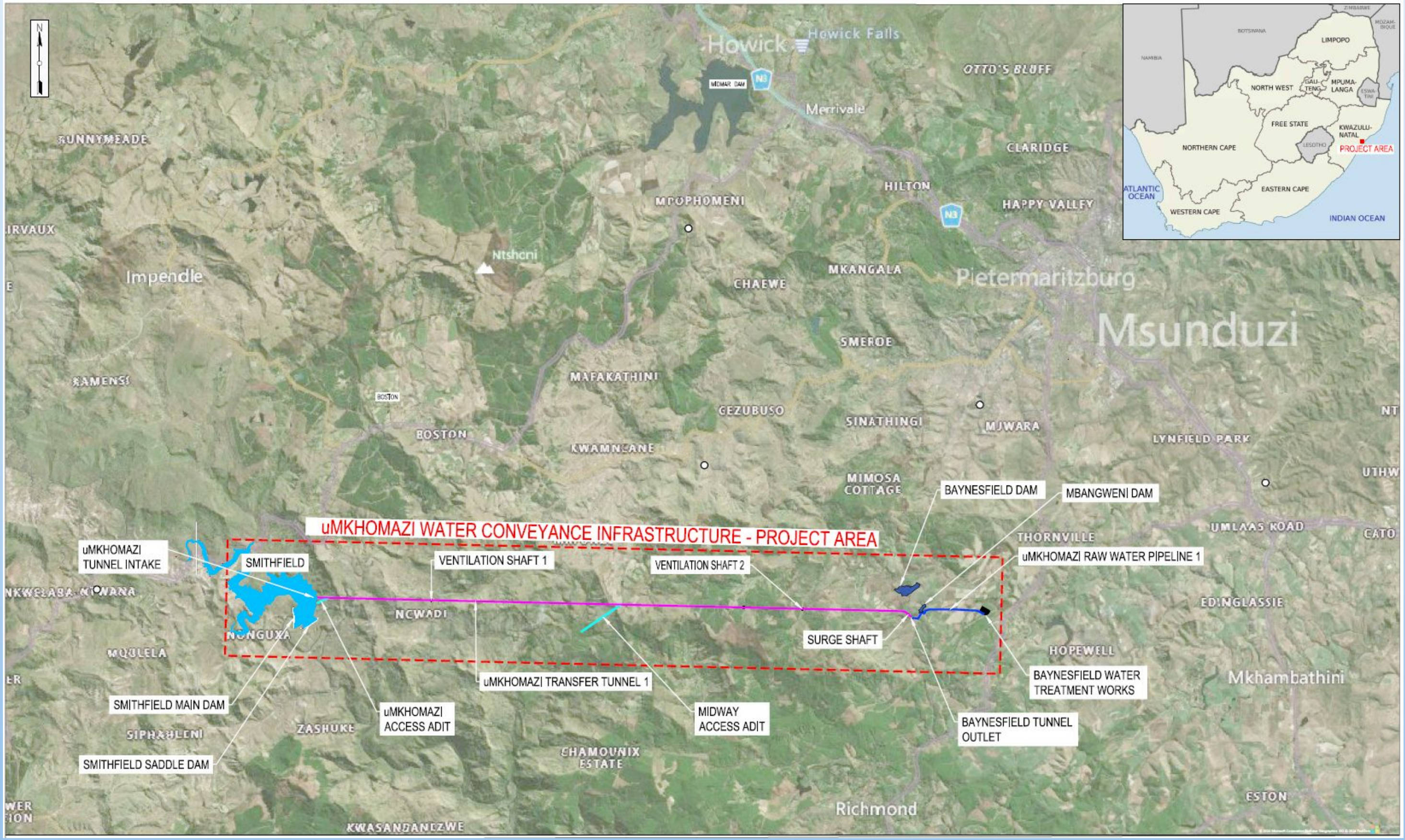
Unlocking Africa's Potential: Advances in Tunnelling in Civil Engineering and Mining

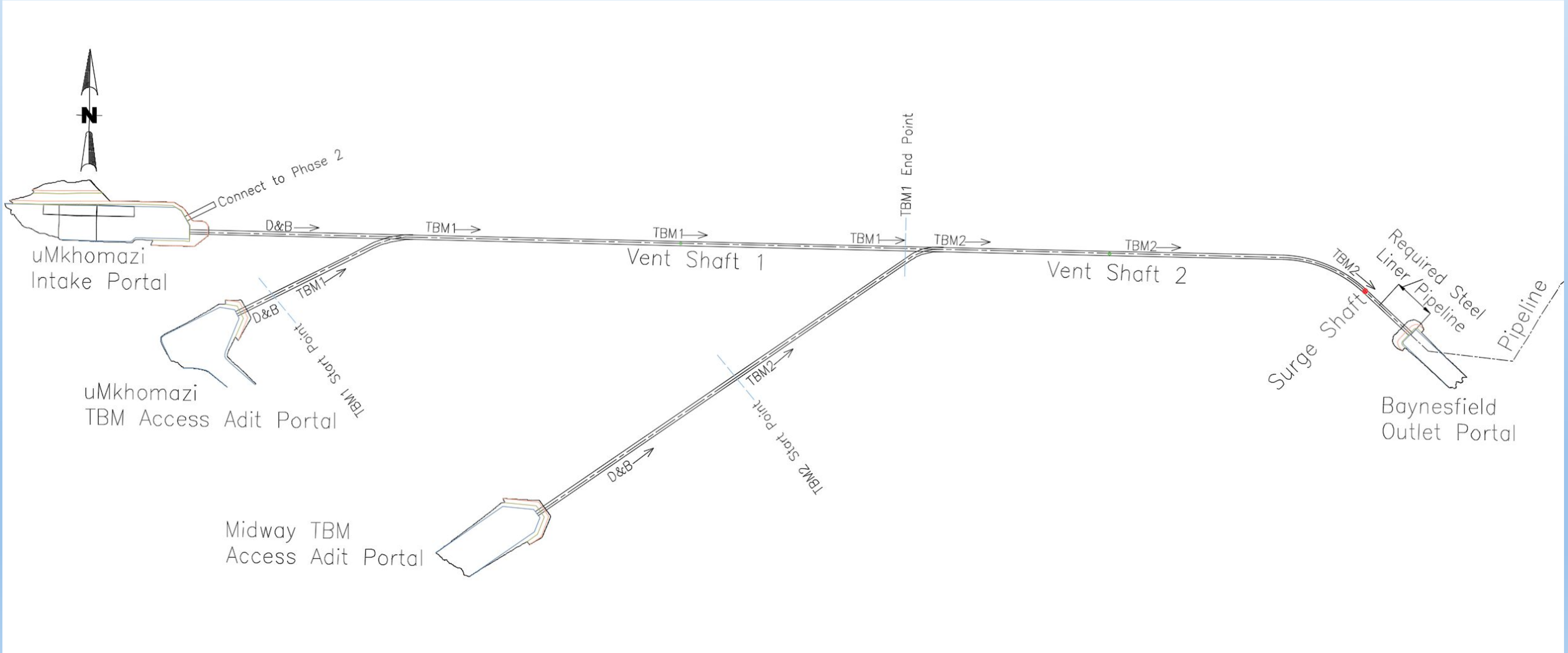
Presentation Outline

- Project Overview and Tunnel Configuration
- Key Engineering Challenges
- Design Philosophy
- Logistics Systems and Design Requirements
- Tunnel Diameter Sensitivity Assessment
- Access Adit Constraints
- TBM Breakthrough Constraints
- Preferred TBM Removal Solution
- Key Conclusions



Project Overview and Tunnel Configuration

- Strategic bulk water transfer scheme in KwaZulu-Natal
- Supports urban, industrial, agricultural user
- Enhances long-term regional water security
- ~34 km waterway tunnel
- 3.5 m internal diameter
- TBM and drill-and-blast methods (two TBM)



Key Engineering Challenges

- Long tunnel length
- Relatively small internal diameter (3.5m)
- Steep access adits (~8% gradient)

This combination results in:

- Limited space for equipment and services
- Strong dependency on logistics efficiency
- High sensitivity to delays over long distances

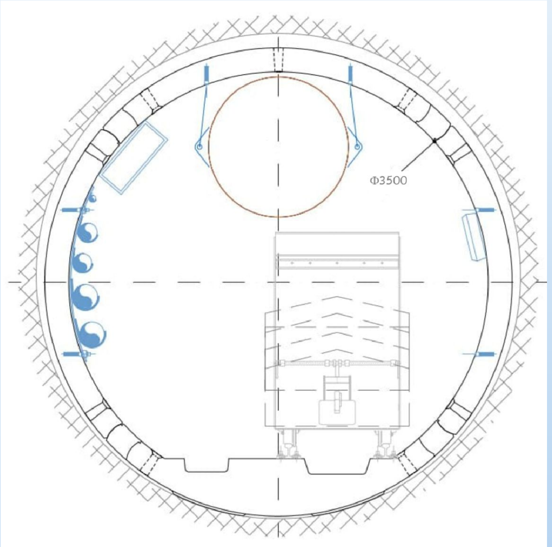
Small inefficiencies → major programme impact

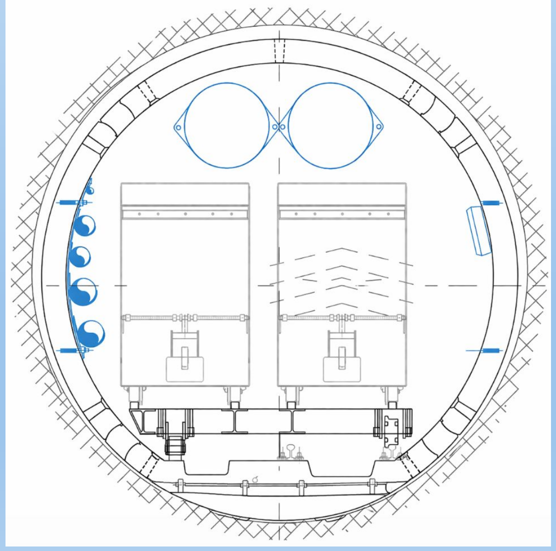
Cross-Sectional Constraints

Within a 3.5 m internal diameter, the tunnel must accommodate:

- TBM shield and segment erector
- Backup gantries
- Transport system
- Ventilation ducts
- Booster stations (where required)
- Electrical, water, and communication services

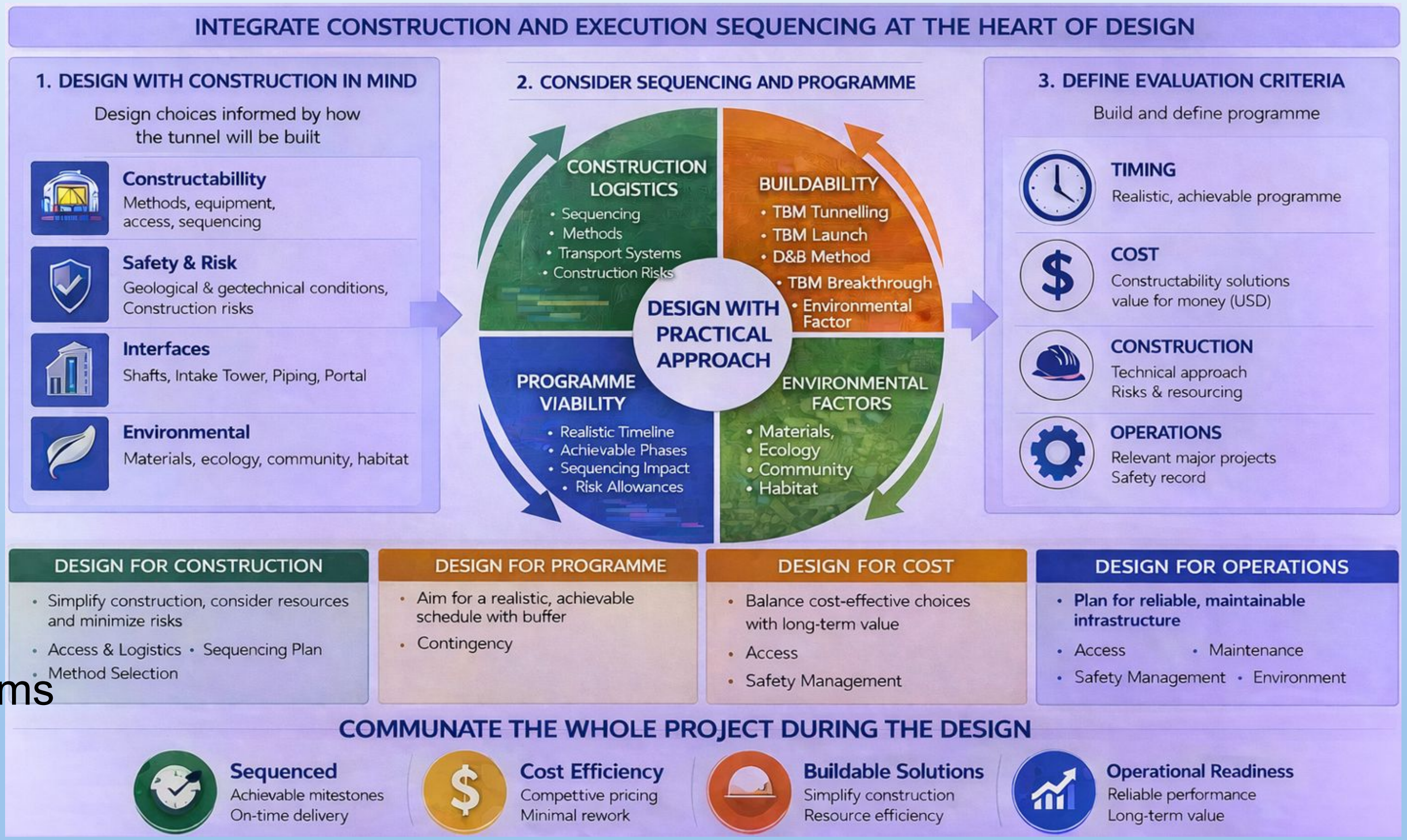
This creates a highly constrained environment where **spatial optimisation is critical**.





Design Philosophy

- Constructability was treated as a primary design driver
- Integrated logistics into the design from an early stage
- Construction sequencing and execution programme.



The objective is to ensure that all systems work efficiently within the constrained tunnel environment.

Logistics Systems and Design Requirements

TBM performance governed by logistics efficiency.

Continuous operation requires:

- Muck removal
- Segment delivery
- Material and service supply

All systems must operate simultaneously within a confined tunnel cross-section.

Systems evaluated:

- Multi-Service Vehicles (MSVs)
- Conveyor-based systems
- Rail-based transport

MSV and Conveyor Systems

MSVs-Based System:

- Can reduce TBM waiting time
- Require passing ramps (~0.8 m height)
- Insufficient clearance in 3.5 m tunnel

Conveyor-Based System:

Advantages:

- Continuous muck removal
- Efficient for long tunnels

Limitations:

- Requires dedicated space
- Interferes with segment transport system
- Requires booster stations

Selected Logistics Strategy

Rail-Based System

Locomotive-hauled rolling stock was selected for both:

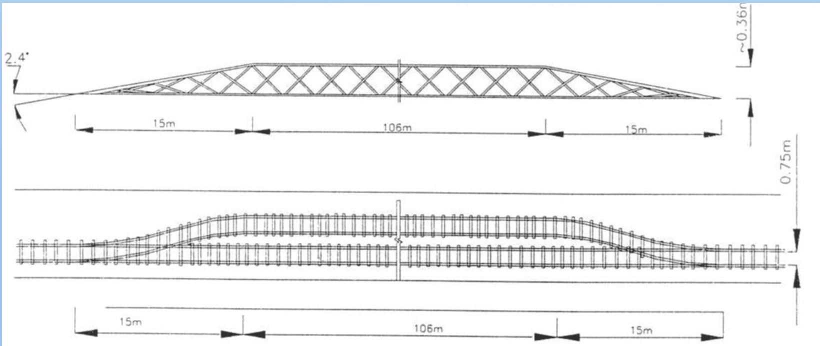
- Muck removal
- Segment delivery

Key advantages:

- Lower profile
- Compatible with services and ventilation
- Proven reliability over long distances

Constraints:

- Single shared system → requires careful scheduling



Tunnel Diameter Sensitivity

A sensitivity analysis was conducted to evaluate the impact of increasing tunnel diameter from 3.5 m to 4.7 m. Objective:

- Improve logistics efficiency
- Increase advance rates
- Justify additional cost

Increasing the tunnel diameter provides more space for logistics systems, however:

- TBM cycle time remains largely unchanged, overall productivity increases by only ~5%
- Higher excavation volumes
- Larger TBM and equipment
- Increased lining quantities
- Greater material handling requirements

Overall cost increase: ~20%

Access Adit Constraints

The TBM access adits have gradients of approximately 8%, which limits transport options.

Options evaluated:

- Rubber-tyred systems → limited reliability in wet and steep conditions
- Winch systems → impractical for long distances
- Rack-and-pinion (cog-wheel) rail → selected solution

Cog-wheel systems provide:

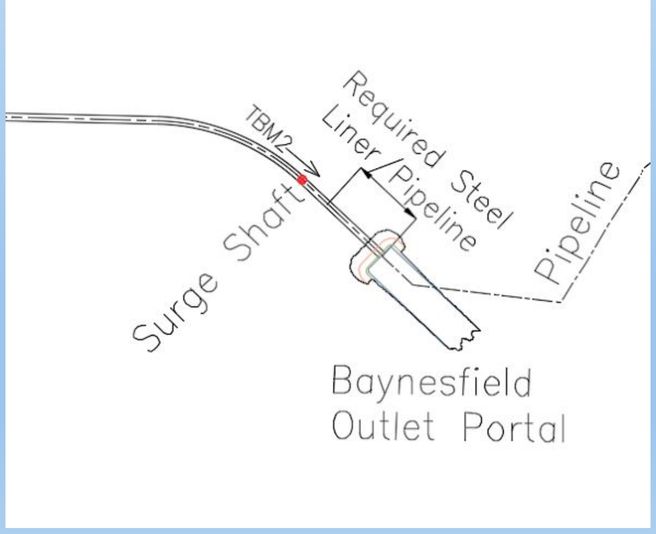
- Reliable traction
- Compatibility with waterway tunnel rail system
- Continuous segment delivery

TBM Breakthrough Constraints

The removal of TBM2 at the Baynesfield outlet represents a key project milestone with direct impact on the construction programme.

A major constraint is the interface with the outlet connecting tunnel, particularly:

- The last ~200 m of tunnel requires steel lining due to low overburden and hydrofracturing risk
- Installation of the steel liner and connection to the downstream pipeline must be carefully sequenced
- Delays in TBM removal can directly impact:
  - Steel liner installation
  - Bulkhead and bifurcation construction
  - Final commissioning



TBM Removal Strategies and Options

Strategy 1: Surface Disassembly

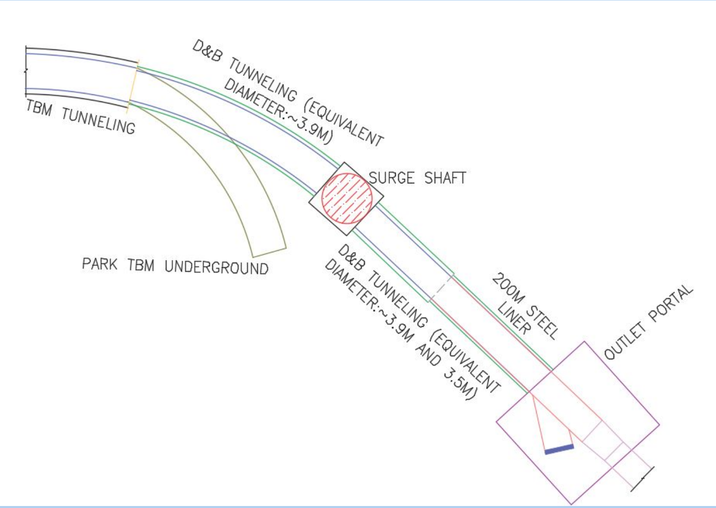
- TBM driven or transported to outlet portal
- Disassembly performed in open cut
- Minimises underground work

Strategy 2: Underground Disassembly

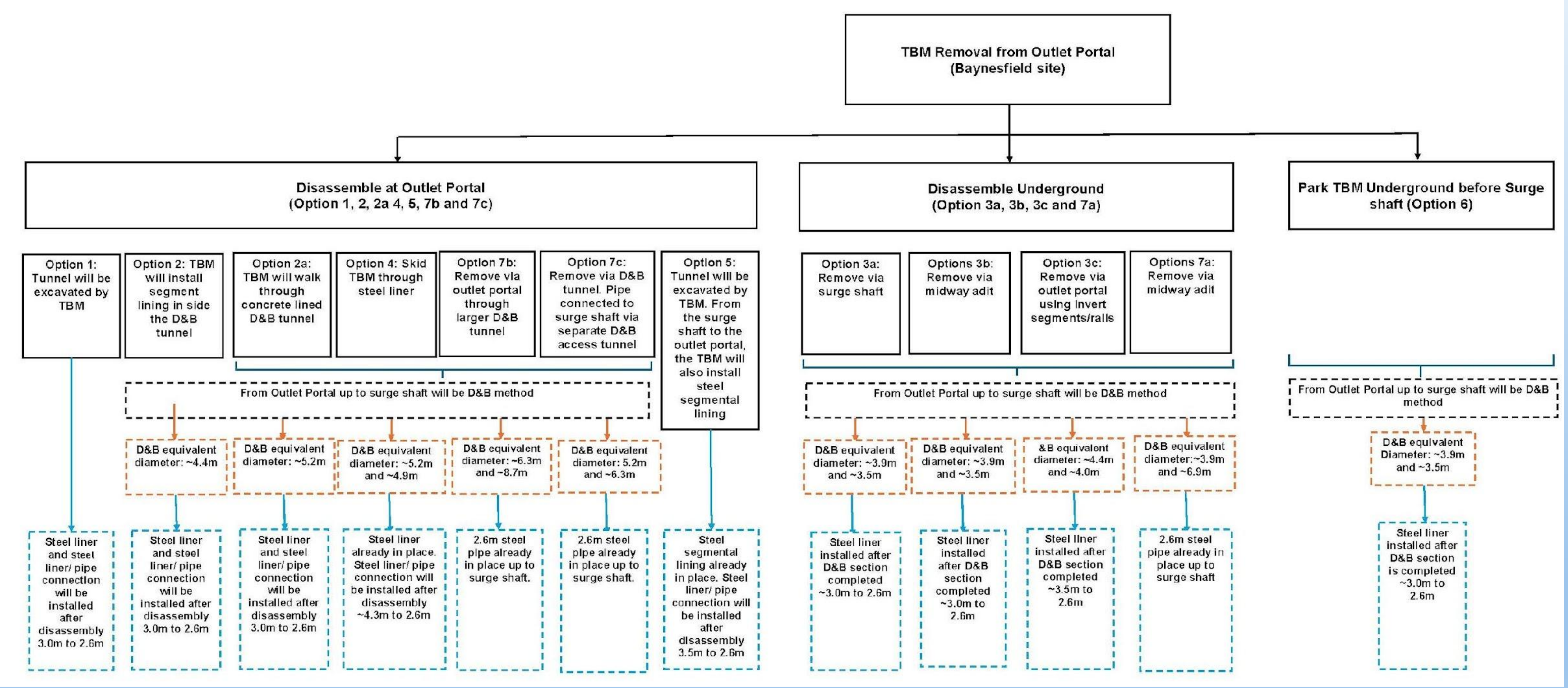
- TBM dismantled in chamber near surge shaft
- Components removed via: Surge shaft, Access adits and connection Tunnel

Strategy 3: Permanent Burial

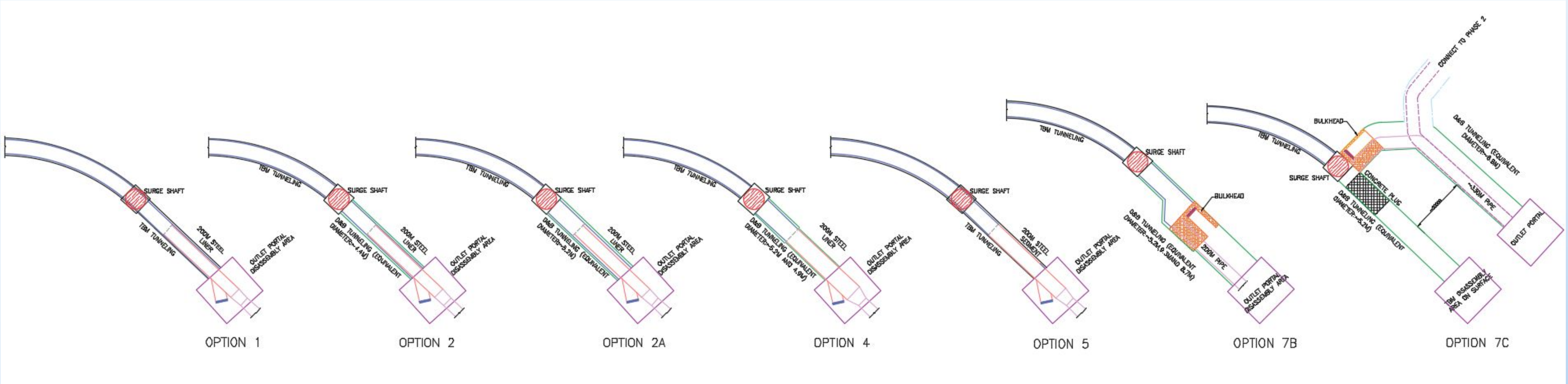
- TBM abandoned upstream of surge shaft
- Backup system removed separately
- Tunnel completed afterward

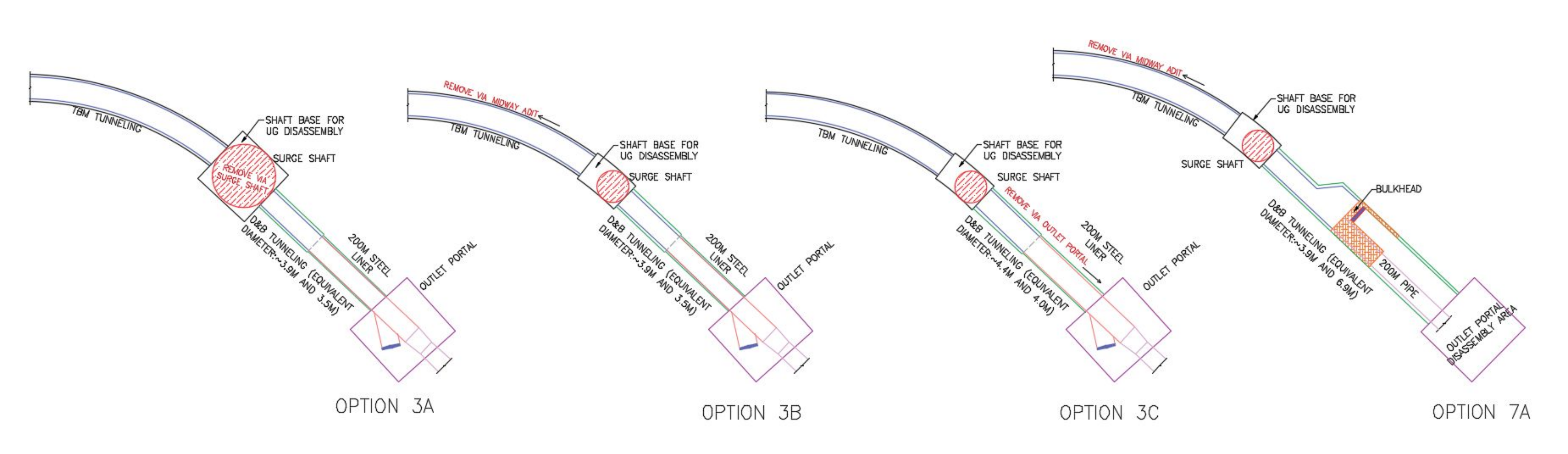


TBM Removal Strategies and Options



TBM Removal Strategies and Options





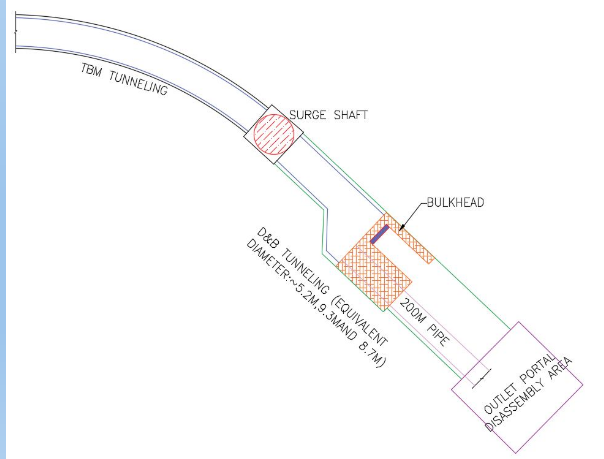
Preferred TBM Removal Solution

Structured evaluation performed using **Multi-Criteria Assessment (MCA).**
Criteria:

- Constructability
- Cost
- Programme
- Environmental impact
- Risk

Selected Option: Option 7b (TBM removal via enlarged D&B outlet connecting tunnel)
Key Advantages:

- Minimises underground dismantling risk
- Best programme performance
- Lowest overall cost
- High constructability



Key Conclusions

- Logistics governs TBM productivity in long tunnels
- Constructability must drive design decisions
- Rail-based logistics enables operation within 3.5 m ID
- The 3.5 m internal diameter remains the optimal solution because it:
  - Meets hydraulic performance requirements
  - Minimises capital cost
  - Remains constructible with proper logistics design
- TBM removal must be integrated into early design

Thank you