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Pipe liner technology for bulk water pipeline rehabilitation – A strategic framework for South African water boards

N Muller, C Ramcharan-Kotze, A Mpofu, F Gouws and A Shah

South Africa's water sector faces a deepening infrastructure crisis. Rand Water, Umgeni Water, Lepelle Northern Water, Magalies Water, Amatola Water and other water boards collectively manage tens of thousands of kilometres of bulk water transmission mains, rising mains and distribution pipelines, much of it ageing, operating beyond design life, and under increasing mechanical stress from load-shedding-driven pump cycling. Non-revenue water (NRW) losses cost the country an estimated R7.3 billion annually, with pipeline leakage a primary driver.

This position paper draws on the findings of WRC Study C2024/2025-01617 (Muller et al., 2026), a comprehensive investigation into pipe liner technology for bulk water pipeline rehabilitation, to set out a strategic framework for water boards. The paper argues that trenchless pipe liner technologies, including cured-in-place pipe (CIPP), spray-in-place pipe (SIPP) and close-fit sliplining, offer significant potential to reduce NRW, extend asset service life and lower lifecycle costs, but that their adoption in South Africa requires a structured approach to technology selection, independent testing, skills development and regulatory alignment.

KEY POSITIONS

1. Trenchless pipe liner technologies represent a viable, cost-effective complement to open-cut replacement for South Africa's ageing bulk water infrastructure, but are not a universal solution.

2. A structured, evidence-based pipeline repair / rehabilitation selection framework, incorporating condition assessment, liner classification, hydraulic impact analysis, potable water safety verification and lifecycle cost analysis, is essential before deployment.

3. South Africa lacks dedicated full-scale physical pipeline testing capacity. Establishing a national Water Pipeline Testing Facility, modelled on Australia's Monash University platform approach and co-funded by DWS, DSTI/NRF and water board levies, is a strategic priority for both pre- and post-installation testing and monitoring.

4. Skills development, local contractor capacity and regulatory standardisation must accompany technology adoption to ensure sustainable, long-term outcomes.

THE SOUTH AFRICAN CONTEXT: AN INFRASTRUCTURE CRISIS

Scale of the Challenge

South Africa's water infrastructure deficit is well documented. The Department of Water and Sanitation's National Water Resources Strategy III (DWS, 2023) identifies deteriorating bulk infrastructure as a critical threat to water security. Water boards manage trunk mains predominantly constructed of asbestos cement, unlined cast iron, mild steel and pre-stressed concrete – materials that are corrosion-prone, pressure-sensitive and frequently used beyond their intended service lives of 30–50 years.

Amatola Water in the Eastern Cape exemplifies the national challenge. Its pipeline network traverses varied terrain, serves predominantly rural and peri-urban communities with limited service redundancy, and faces compounding stress from power outages that cause destructive pressure transients – water hammer events – on every pump restart. This study documented extensive pipe bursts across the Eastern Cape, with emergency repairs and water tankering costs accounting for a significant proportion of operational budgets.

Non-revenue water and the cost of inaction

Non-revenue water losses in South Africa are estimated to exceed 37% of total water produced nationally (Farouk et al., 2023). At a direct financial cost of approximately **R7.3 billion per annum**, the scale of leakage from ageing pipelines represents not only an economic burden but a threat to water security in a water-scarce nation. The DWS Blue and No Drop reports consistently identify bulk transmission main integrity as a primary intervention priority. Syal et al. (2023) further demonstrate that proactive rehabilitation strategies can achieve NRW reductions of 20–40% compared to a reactive repair-only approach.

Loadshedding as an accelerating failure mechanism

South Africa's electricity supply crisis introduces a failure mechanism not commonly addressed in international pipeline rehabilitation literature: cyclical pump trip and restart events. Each power interruption followed by restoration subjects bulk water mains to pressure surges – water hammer – that propagate axially along the pipeline. For pipes already weakened by corrosion, joint deterioration or material fatigue, these events are catastrophic triggers. The WRC study identified this as a context-specific consideration that must inform both the urgency of rehabilitation and the structural class of liner selected for pressurised mains.

PIPE LINER TECHNOLOGY: STATE OF THE ART

Overview of trenchless rehabilitation options

The research team conducted a comprehensive scan of 50 pipe liner technologies globally, identifying cured-in-place solutions as the most prevalent category (19 of 50 technologies). The core trenchless rehabilitation technologies applicable to bulk water pipelines are summarised below.

Technology	Structural class	Best suited for	Key limitation
CIPP (Cured-in-Place Pipe)	Class II–IV	Pressure mains DN150–DN1200; corrosion protection and full structural renewal	Resin curing variability; chemical leaching risk; specialist equipment needed
SIPP (Spray-in-Place Pipe)	Class I–III	Localised repairs; smooth bore restoration; fast turnaround	Thickness consistency; adhesion on wet surfaces; limited gap-spanning
Sliplining (HDPE / GRP)	Class III–IV	Long runs in accessible terrain; gravity and low-pressure mains	Annular space sealing; hydraulic capacity reduction
Close-Fit / Fold-and-Form	Class III–IV	Medium-to-large diameter; near-full bore restoration	Complex bends; limited local contractor experience
Cementitious / ECC Spray	Class I–II	Steel and cast iron mains; corrosion protection; potable water-safe	No structural benefit; requires intact host pipe
External Composite Wrap	Class II–III	Spot repair of defects, dents, corrosion patches	Requires access excavation; point repair only

Table 1: Summary of key trenchless rehabilitation technologies (adapted from Muller et al., 2026; Wu et al., 2021)

Structural classification: The critical design parameter
The structural classification framework (Class I–IV) is the fundamental design decision gateway for any liner project. International standards, including ASTM F1216, AWWA M28, WSA 150/151 (Australia) and ISO 11296, prescribe the liner class based on the degree of host pipe deterioration and the pressure regime. Misclassification of the pipeline infrastructure conditions is the most common cause of premature liner failure in pressurised systems.

For South African water boards, this classification carries particular weight. Ageing mains that have experienced repeated water hammer events may exhibit microcracking and joint separation not visible in standard CCTV surveys. The study recommends that all pressurised main rehabilitation projects commission independent structural condition assessment, including pressure testing, wall thickness measurement and acoustic monitoring, before liner class selection is finalised.

Notable technologies with South African market presence
The WRC study identified several technologies with demonstrated applications in the South African context. The ASOE BulletLiner System, implemented by ORSCO (Pty) Ltd, completed an emergency repair for the West Coast District Municipality on a DN500 potable main (Muller et al., 2026; ORSCO, 2025). The City of Cape Town has deployed the Wavin Compact Pipe close-fit sliplining system on steel pipelines, with findings that informed the WRC study's local feasibility assessment (City of Cape Town, 2024). Nu Flow's patch repair technology has been applied to DN500 potable lines on an emergency basis (Nu Flow, 2023). These case studies demonstrate proof of concept, but also highlight the absence of standardised procurement, specification and verification frameworks at the national level.

A STRUCTURED SELECTION FRAMEWORK FOR WATER BOARDS

Why an ad hoc approach is insufficient
It has been shown documented that decisions to deploy pipe liner technology in South Africa have, to date, been largely reactive, driven by emergency failure events rather than proactive asset management strategies. In this mode, liner technology is selected on the basis of contractor availability and cost rather than structural suitability, with limited pre-installation testing and almost no post-installation monitoring. This approach carries significant risk: an incorrectly specified liner in a pressurised potable water main can fail catastrophically, result in potable water contamination or create a leakage pathway between liner and host pipe that is difficult to detect.

The three-phase decision process
Drawing on the WRC study's recommended protocol and international best practice (Calderon et al., 2024; Wu et al., 2021), water boards should adopt a three-phase structured decision process, as described in Table 2.

Phase	Activity	Key outputs
Phase 1 Condition Assessment	Pipeline inspection (CCTV, UT wall thickness, acoustic monitoring, pressure testing); risk ranking; remaining service life estimation; identification of failure modes	Pipeline risk register; structural condition classification; go/no-go for rehabilitation vs. replacement
Phase 2 Technology Selection	Liner class determination; hydraulic capacity modelling; potable water safety screening of candidate materials; cost-benefit and lifecycle cost analysis; contractor capacity assessment	Specification document; procurement brief; LCCA summary; candidate technology shortlist
Phase 3 QA/QC and Monitoring	Material qualification testing (pre-approval); installation compliance testing (project-specific); post-installation potable water quality verification; long-term performance monitoring	Test certificates; SANAS-accredited laboratory reports; ongoing monitoring protocol (pipe liner infrastructure and potable water quality)

Table 2: Three-phase structured decision process for water board pipe liner projects (adapted from Muller et al., 2026)

Lifecycle cost analysis: Beyond capital cost
A recurring finding of the WRC study is that water board procurement decisions are frequently driven by capital cost alone, without incorporating lifecycle costs, environmental costs, indirect social costs or risk-adjusted failure probability. Zhao and Rajani (2002) established that trenchless rehabilitation is generally more cost-effective than open-cut replacement for pipelines up to approximately 900 mm diameter, but that cost parity is reached for very large diameter mains (>1800 mm). Kaushal and Najafi (2020) demonstrate that even where direct construction costs are comparable, trenchless methods yield significantly lower greenhouse gas emissions, surface disruption costs and traffic delay costs.

For South African water boards operating in urban environments, Rand Water's Johannesburg supply zone, Umgeni's eThekwini delivery corridors, the indirect cost avoidance from minimised road closures, service disruptions and surface reinstatement represents a substantial proportion of total project value. Geisbush et al. (2023) confirm that lifecycle cost analysis shifts the comparative advantage of trenchless methods substantially in urban settings.

POSITION: LIFECYCLE COST ANALYSIS MUST BE MANDATORY

Water boards should embed lifecycle cost analysis (LCCA) as a mandatory component of all pipeline rehabilitation project approvals above a defined threshold (recommended: replacement value >R5 million or pipe diameter >DN300). LCCA must incorporate direct construction cost, indirect social and environmental costs, risk of service disruption, remaining service life, carbon footprint and future maintenance requirements. The WRC's existing LCCA framework (van Vuuren and van Dijk, 2006) provides a suitable starting point for standardisation.

POTABLE WATER SAFETY: A NON-NEGOTIABLE REQUIREMENT

The contamination risk from liner materials

The application of pipe liner technology inside potable water mains introduces the risk of chemical migration from liner materials into the water supply. This risk is not hypothetical: Rajasarkkä et al. (2016) documented leaching of bisphenol A, styrene and other compounds from epoxy-lined pipes in European drinking water networks. The nature and magnitude of leaching risk varies substantially between liner systems, resin-based CIPP liners (epoxy, polyester, vinyl ester), polyurethane and polyurea spray systems, cementitious linings and thermoplastic slipliners present different risk profiles.

Regulatory framework and South African gaps

In South Africa, the benchmark for potable water quality is SANS 241 (SABS, 2015). However, unlike the United Kingdom (Drinking Water Inspectorate Regulation 31; DWI, 2022), Australia (WSA 150/151) and the United States (NSF/ANSI 61; NSF International, 2023), South Africa does not have a product approval or certification scheme specifically for materials in contact with drinking water in rehabilitation applications. This gap means that liner products marketed and installed in South African water mains may not have undergone the migration testing required in other jurisdictions.

The WRC study identifies this as a critical regulatory gap and recommends that DWS, SABS and SANAS jointly develop a South African product approval pathway equivalent to NSF/ANSI 61 or UK DWI Regulation 31. Until such a framework is in place, water boards are advised to require NSF/ANSI 61 or equivalent international certification as a minimum procurement condition for any liner product installed in potable water applications.

INTERNATIONAL STANDARD: NSF/ANSI 61	SOUTH AFRICAN REQUIREMENT: SANS 241 COMPLIANCE
NSF/ANSI 61 (NSF International, 2023) sets health effects requirements for drinking water system components in the USA and is widely adopted internationally. Products certified under NSF/ANSI 61 have been tested for migration of contaminants including total organic carbon, volatile organic compounds, semi-volatile compounds and metals. Water boards should require NSF/ANSI 61 or equivalent (ACS, WRAS, AS/NZS 4020) certification for all liner materials.	Post-installation potable water quality testing against SANS 241 (SABS, 2015) must be undertaken for all liner projects in potable water mains, using SANAS-accredited laboratories. Testing should cover total organic carbon (screening), volatile organic compounds (including styrene), semi-volatile compounds (including bisphenol A and phenols) and metals. A structured flushing and sampling protocol — aligned with Phase C of the WRC study's recommended QA framework — should be adopted as standard practice.

THE TESTING AND STANDARDS GAP: A NATIONAL CAPABILITY DEFICIT

What does not exist in South Africa

The study identifies a critical gap in South Africa's water infrastructure ecosystem: no independent, accredited, full-scale physical pipeline testing facility exists on the African continent. This gap has direct consequences for water boards:

- Pipe and liner products are procured based on supplier-provided data sheets and international certifications that may not reflect local material batches, installation conditions or operational regimes.
- Failure investigations following liner installation problems have no reference testing facility to conduct controlled physical testing of failed specimens.
- Composite repair products and locally manufactured lining materials cannot be independently validated, limiting local manufacturing development.
- There is no facility capable of replicating South Africa's specific operational stresses, water hammer from loadshedding events, high-temperature cycling in surface-laid mains, aggressive soil chemistry in dolomitic areas, to physically test liner performance under representative conditions.

The standards deficit

South Africa's national trenchless technology standard, SASTT-TS-TT4:2021 (SASTT, 2021), addresses CIPP lining for gravity pipelines but does not cover pressurised water mains. The gap between existing standards and the needs of pressurised bulk water rehabilitation leaves water boards without clear specification, procurement or quality assurance guidance. Van Vuuren (2012) and van Vuuren and van Dijk (2006, 2012) provide WRC-published guidance on grouted lining, hydraulic design and lifecycle costing, but these predate the current generation of trenchless liner technologies and do not address CIPP or SIPP for pressurised applications.

A national water pipeline testing facility

This position paper proposes that South Africa establish a dedicated national Water Pipeline Physical Testing Facility, modelled on the integrated technology platform approach pioneered by Monash University in Australia. Monash's Cooperative Research Centre for Smart Linings for Pipe and Infrastructure (CRC-P Smart Linings) demonstrates how a university-anchored platform, co-funded by government, research councils and water utilities, can produce both fundamental research outputs and practical tools directly usable by water authorities (Shannon et al., 2021; Fu et al., 2020).

Testing capability	Specification
Full-scale hydrostatic / burst	Pipe sections up to DN1200 at 1.5x MAOP; joint and coupling validation per SANS / ISO 7268; 6–24 m spool configurations
Transient / water hammer	Pressure surge simulation from pump trip and valve closure; cyclic pressure rigs replicating load-shedding restart cycles
Fatigue cycling	20–50 year equivalent load history simulation; programmable waveform control; combined axial load and internal pressure
Environmental chambers	Accelerated corrosion in aggressive groundwater chemistry; soil-stress simulation; cathodic protection performance
Lining and repair validation	Full-scale burst and fatigue testing of CIPP, SIPP, HDPE lining and composite repair systems; qualification per ISO 25780 / AWWA C303
Non-destructive evaluation	Integrated UT phased array, acoustic emission, GPR correlation; digital twin data capture; ILI tool validation

Table 3: Proposed testing capabilities for a South African Water Pipeline Physical Testing Facility

POSITION: ESTABLISH A NATIONAL WATER PIPELINE TESTING FACILITY

The University of Pretoria (primary host), CSIR Built Environment (operations and SANAS quality management) and DWS / Water Research Commission (regulatory endorsement and co-funding) should establish a national Water Pipeline Physical Testing Facility. Phase 1 (~R70 million, 3 years): hydrostatic/burst rigs, transient pressure chambers, NDE suites, SANAS accreditation. Phase 2 (~R40 million, years 4–5): fatigue cycling, lining/repair qualification and environmental chambers. Funding should be secured through DSTI Research Infrastructure grants, DWS infrastructure levy contributions via WRC, and water board consortium membership fees.

SKILLS DEVELOPMENT AND LOCAL CAPACITY

The skills gap as a technology adoption barrier

Muller et al., 2026 identify a genuine shortage of skilled labour in the South African water sector as a significant, and underappreciated, barrier to the adoption of advanced pipe liner technologies. The sector faces an ageing workforce, with a substantial proportion of experienced engineers and technical personnel approaching retirement. The remaining workforce is overburdened with operational demands, leaving limited bandwidth for technology upskilling or professional development. This creates a paradox: the technologies most needed to address South Africa's infrastructure deficit are precisely those that require the highest levels of technical competence to specify, procure, install and verify correctly. Calderon et al. (2024) identify skills capacity as one of the top three barriers to trenchless technology adoption across emerging market water utilities globally.

Opportunities within the technology adoption cycle

The WRC study frames skills development not merely as a challenge but as an opportunity. The introduction of advanced rehabilitation technologies offers a platform to attract young professionals to the water sector, create specialised technical roles that did not previously exist, and build local manufacturing and installation capacity. Several of the technologies reviewed in the study offer training pathways: some technology developers provide training as a complementary service to material supply, while others have developed installation partner networks with structured competency programmes. South Africa's existing trenchless technology sector, represented through the Southern African Society for Trenchless Technology (SASTT), provides an institutional home for practitioner certification and standards development. SASTT's existing framework for CIPP in gravity pipelines (SASTT-TS-TT4:2021) could be extended to pressurised water mains with appropriate WRC and DWS support.

Recommendations for skills development

- Water boards should incorporate contractor competency requirements — including SASTT certification or equivalent — into all pipe liner procurement specifications.
- DWS and WRC should fund a national trenchless technology skills programme, linked to the proposed national testing facility and targeting accredited training for inspectors, installation crews and quality managers.
- University engineering programmes — particularly at UP, Wits and SU — should incorporate trenchless rehabilitation modules at postgraduate level, linked to industry-funded research projects with water board partners.
- Water boards should establish a peer-learning network — facilitated by WRC — for sharing operational experience with liner technologies, including failure case studies that would ordinarily remain undocumented.

IMPLEMENTATION PATHWAY FOR WATER BOARDS

Near-term actions (0–2 years)

- Commission a portfolio-level condition assessment of bulk transmission mains, prioritising pipes older than 40 years and those subject to frequent pump cycling.
- Adopt the WRC study's three-phase decision framework as the standard methodology for all rehabilitation project planning.
- Require NSF/ANSI 61 or equivalent certification as a minimum procurement condition for all liner materials used in potable water applications.
- Establish a centralised incident reporting system for pipe liner performance (successes and failures) across all water board members, coordinated through the Water Boards Forum.
- Initiate pilot projects, minimum two per technology class, across at least three different water board geographies, with independent technical monitoring and structured evaluation protocols.

8.2 Medium-Term Actions (2–5 Years)

- Formalise and co-fund the national Water Pipeline Physical Testing Facility through a tripartite agreement between DWS/WRC, a university host institution and the water board consortium.
- Develop a South African product approval framework for liner materials in contact with potable water, aligned with NSF/ANSI 61 and UK DWI Regulation 31.
- Extend SASTT-TS-TT4 to cover pressurised water main rehabilitation, with water board input into the standard-setting process.
- Develop and publish standardised LCCA models for the South African context, incorporating load-shedding risk factors and local contractor mobilisation costs.

8.3 Long-Term Actions (5–10 Years)

- Develop local manufacturing capacity for CIPP liner tubes and SIPP resin systems, supported by the testing facility's product qualification function and SABS type approval.
- Establish a national digital pipeline asset registry, linked to condition assessment data, liner installation records and water quality monitoring, to support evidence-based asset management decisions.
- Target a measurable NRW reduction of 10 percentage points nationally within 10 years, with pipe liner rehabilitation contributing alongside pressure management, active leakage control and system renewal.

PRIORITY RESEARCH AGENDA

The WRC study identified several research gaps that, if addressed, would substantially improve the evidence base for pipe liner adoption in South Africa. This paper endorses the following as priority research areas for WRC funding:

1. Condition assessment methods for pressurised water mains

Development and validation of combined inspection protocols, acoustic emission, UT wall thickness, pressure transient analysis and CCTV, calibrated against physical burst test data from the proposed national testing facility. Machine learning approaches to predictive failure modelling (referenced in Muller et al., 2026, citing Calderon et al., 2024) offer particular promise for portfolio-level risk prioritisation.

2. Long-term liner performance monitoring

Systematic post-installation monitoring of CIPP and SIPP liners in South African potable water applications, covering structural performance (pressure integrity, adhesion), hydraulic capacity and potable water quality (migration testing). This research is essential to build the local evidence base needed to move beyond reliance on overseas performance data.

3. Water hammer and liner interaction

Physical testing of liner behaviour under transient pressure loading representative of South African load-shedding conditions. No international standard currently addresses the specific frequency and magnitude of pressure transients associated with grid-connected pump stations under loadshedding, a genuine research gap with direct practical relevance.

4. Lifecycle cost modelling for the South African context
Updating and extending the WRC's existing LCCA framework (van Vuuren and van Dijk, 2006) to incorporate current liner technology costs, load-shedding risk premiums, local contractor mobilisation costs and indirect social costs relevant to South Africa's urban and rural infrastructure settings.

5. Regulatory and standards development
Development of a South African product approval pathway for materials in contact with drinking water, a pressurised water main rehabilitation standard under SABS/SASTT, and a national qualification framework for trenchless technology practitioners.

CONCLUSIONS

South Africa's water boards face a critical juncture. The combination of ageing infrastructure, escalating NRW losses, load-shedding-induced mechanical stress, constrained capital budgets and a fragmented regulatory environment creates conditions in which the continued default to emergency repair and open-cut replacement is neither financially nor operationally sustainable.

Pipe liner technology – in its various forms from CIPP through sliplining to spray-applied systems – offers a proven, internationally validated complement to traditional replacement. The WRC study by Muller et al. (2026) provides the most comprehensive South African assessment of these technologies to date, and its findings are unambiguous: the technologies work, local case studies demonstrate proof of concept, and the economic case, when lifecycle costs and indirect benefits are properly accounted for, is compelling.

However, the path from proof of concept to systematic, reliable deployment at scale requires deliberate institutional investment: in testing infrastructure, in standards and regulatory frameworks, in skills and practitioner competency, and in the evidence base needed to guide selection decisions with confidence. The three priority institutional actions this paper proposes, namely mandatory LCCA, a national testing facility, and a South African product approval pathway for potable water liner materials, are mutually reinforcing and should be pursued in parallel rather than sequentially.

The Monash University CRC-P Smart Linings model demonstrates what is possible when government, research institutions and water utilities commit to a shared evidence-generating infrastructure. South Africa has the academic depth, the institutional partners and — in its water boards — the demand to build an equivalent capability. The WRC study provides the intellectual foundation. This position paper calls for the institutional will to act on it.

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