Predictive Axial Walking
An Evidence Based Approach

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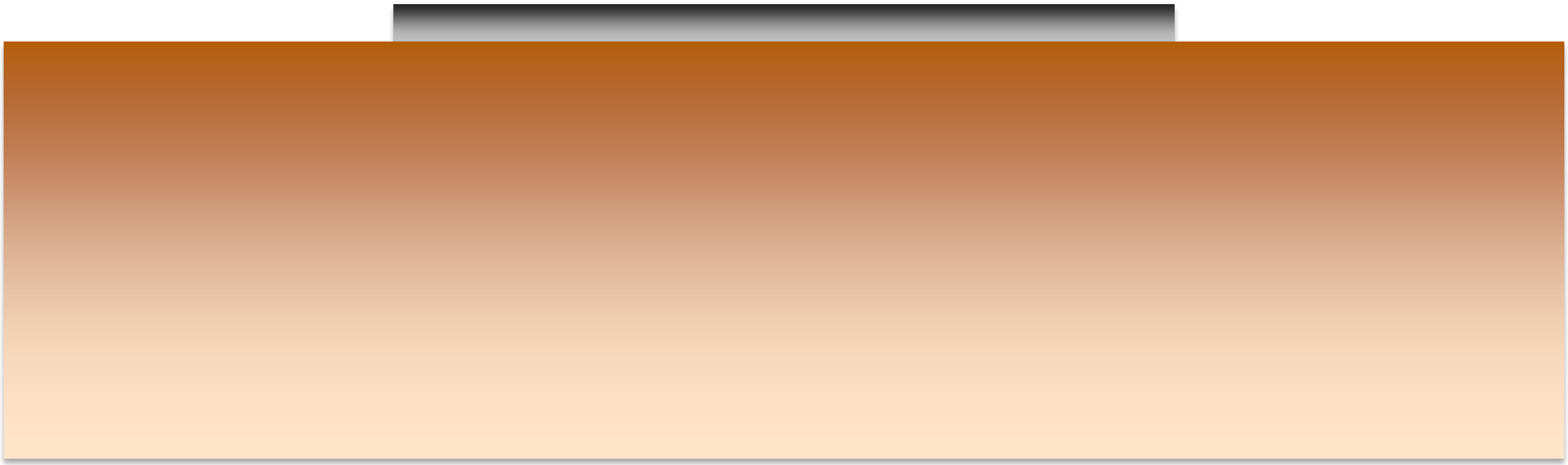
Summary

- Axial Walking
- Evidence Based Operations
  - Integrity Management
  - Learning
  - Operations Analogy
- Axial Walking Operations Tool
- Evidence Based Methodologies and Repair Strategies
  - Planning
  - Repair selection

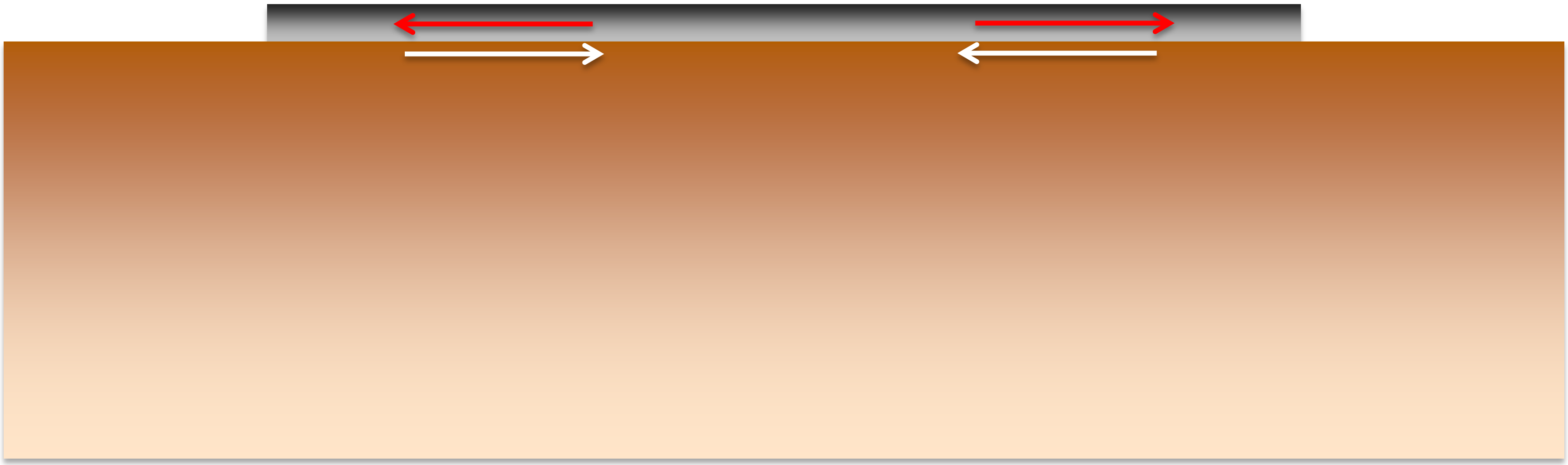
Pipeline Expansion on Seabed

T = Amb
P = Amb
μ = 0.7

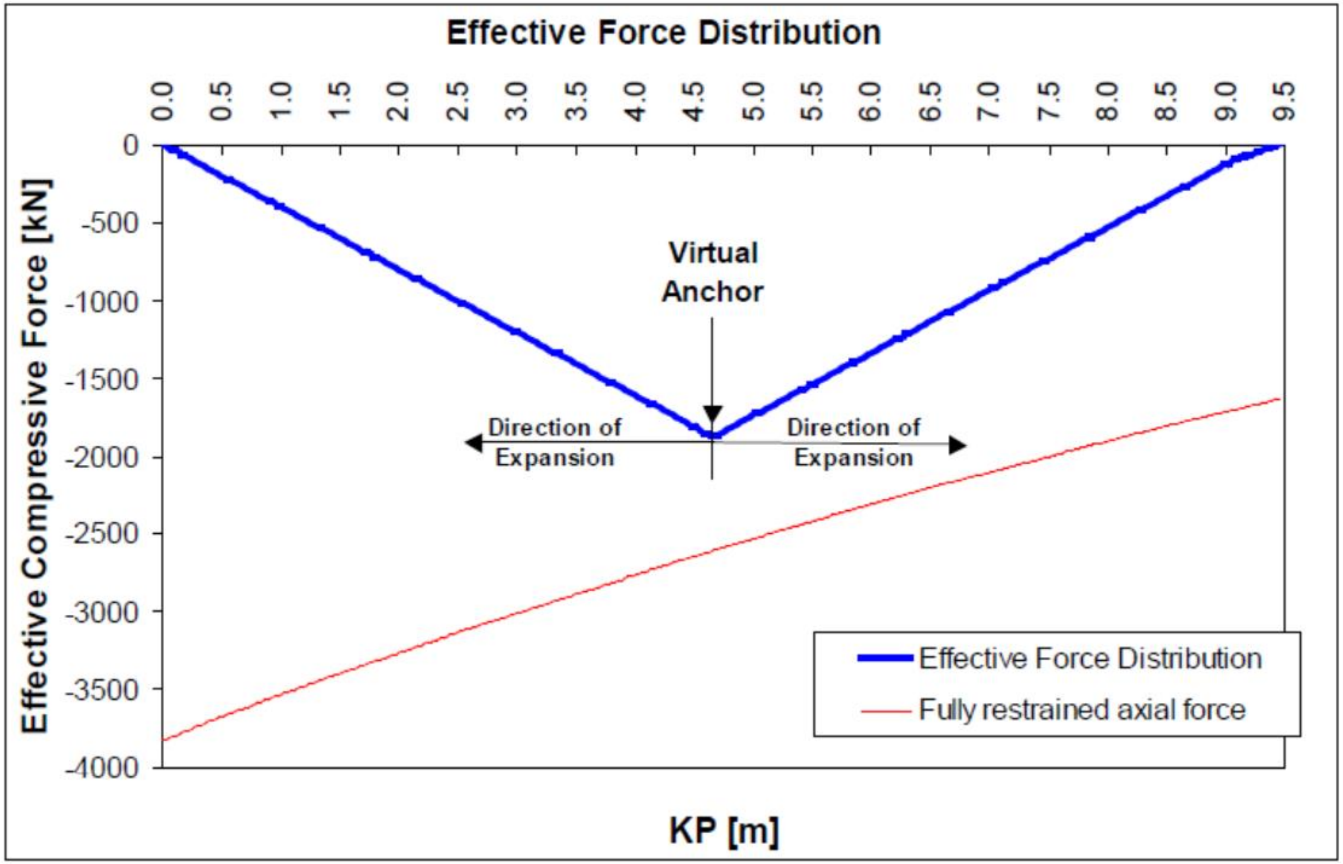


Pipeline Expansion on Seabed

T = HT
P = HP
μ = 0.7



Axial Walking

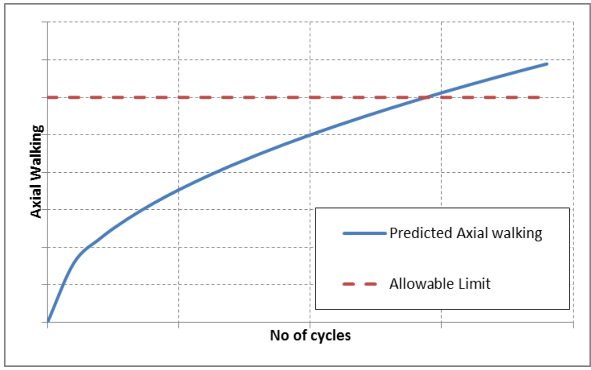


- Short Pipeline – Does not reach the fully restrained effective axial force

Axial Walking

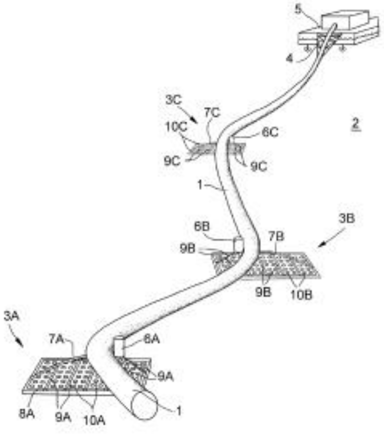
- *Short* pipelines expand and contract about their virtual anchor point
- How do we get axial walking?
- Asymmetry in some way that moves the virtual anchor point from the middle
  - Seabed slope (walk down the hill)
  - Steel catenary riser (walk towards the end being pulled)
  - Thermal transients (walk towards the ‘cold’ end)
  - Ratcheting of lateral buckles for long pipelines
  - Or combinations of the above…

- Need to produce a system that can either prevent axial walking or allow for the axial walking over the asset life
  - Anchors
  - Large spools or sliding termination assemblies

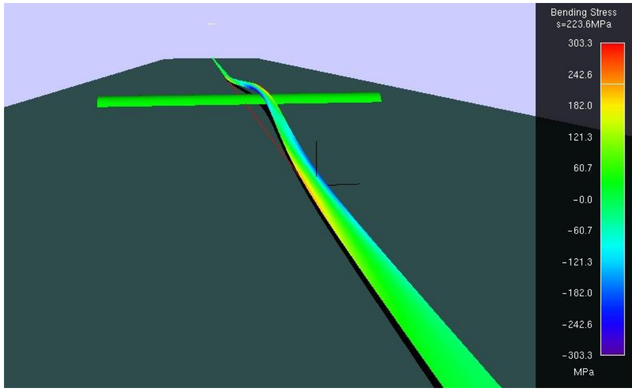


Axial Walking Predictions – Design Phase

- Requires Finite Element Analysis in the Design Phase
- Complicated models
    - Operational cycles
    - Material properties
    - Pipe / soil interaction
    - Seabed undulations / slopes
    - Etc.



- Time consuming process to develop a suitable prediction of axial walking.

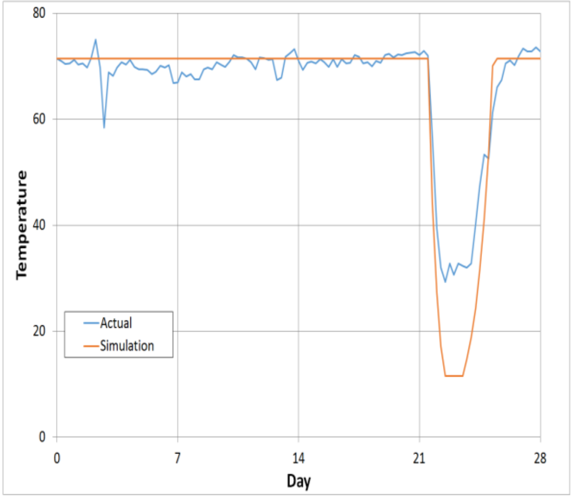


Design to Operations

Operations **is** our 1:1 scale model

As with all *“testing”* we should utilise the data produced

Validates the design behaviour and that our operating and integrity limits are acceptable



Integrity Management

The art of proving consistent behaviour

How do we prove consistent **behaviour**?

By collecting **evidence**.

So what **evidence** is important?

All **evidence** is **important**.

“Evidence”

Provides insight to actual behaviour and substantiates predictive behaviour

What is difficult about evidence?

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The assemblage of evidence

Knowing how discrete pieces of evidence interact to yield the overall result

Knowing what you are looking at and how it interacts can be the difference between success or not

Understanding the system behaviour in real life conditions allows appropriate intervention to be undertaken

Fit For Purpose Tools

Design Tools

- Assumed Scenario
- Prediction & Estimation
- Upper & Lower Bound
- Unknowns
- Step by Step Approach
- Design Basis & Assumptions
- Generalised Data

Design

Provides capacity limit

THE GAP

Operations Tools

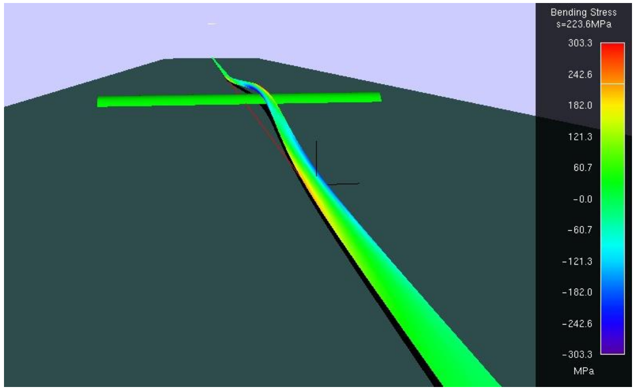
- Actual & Reality
- Predictable vs Not Predictable
- Actual Data Change
- Known Unknowns
- Monitoring
- Actual Operating Data
- No Generalisation

Operations

Utilises available capacity

How best to utilise the Evidence?

- For axial walking one option is to feed the data collected back in to the design tool.
- Complicated models
    - Operational cycles
    - Material properties
    - Pipe / soil interaction
    - Seabed undulations / slopes
    - Etc.
- Limited evidence of actual behaviour



- Time consuming and labour intensive process to match behaviour of the model with the observed behaviour of the actual pipeline.

Axial Walking Operations Tool

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- Alternative approach developed to use the available evidence of past behaviour to directly predict future behaviour.

Actual (Based on Survey Data)

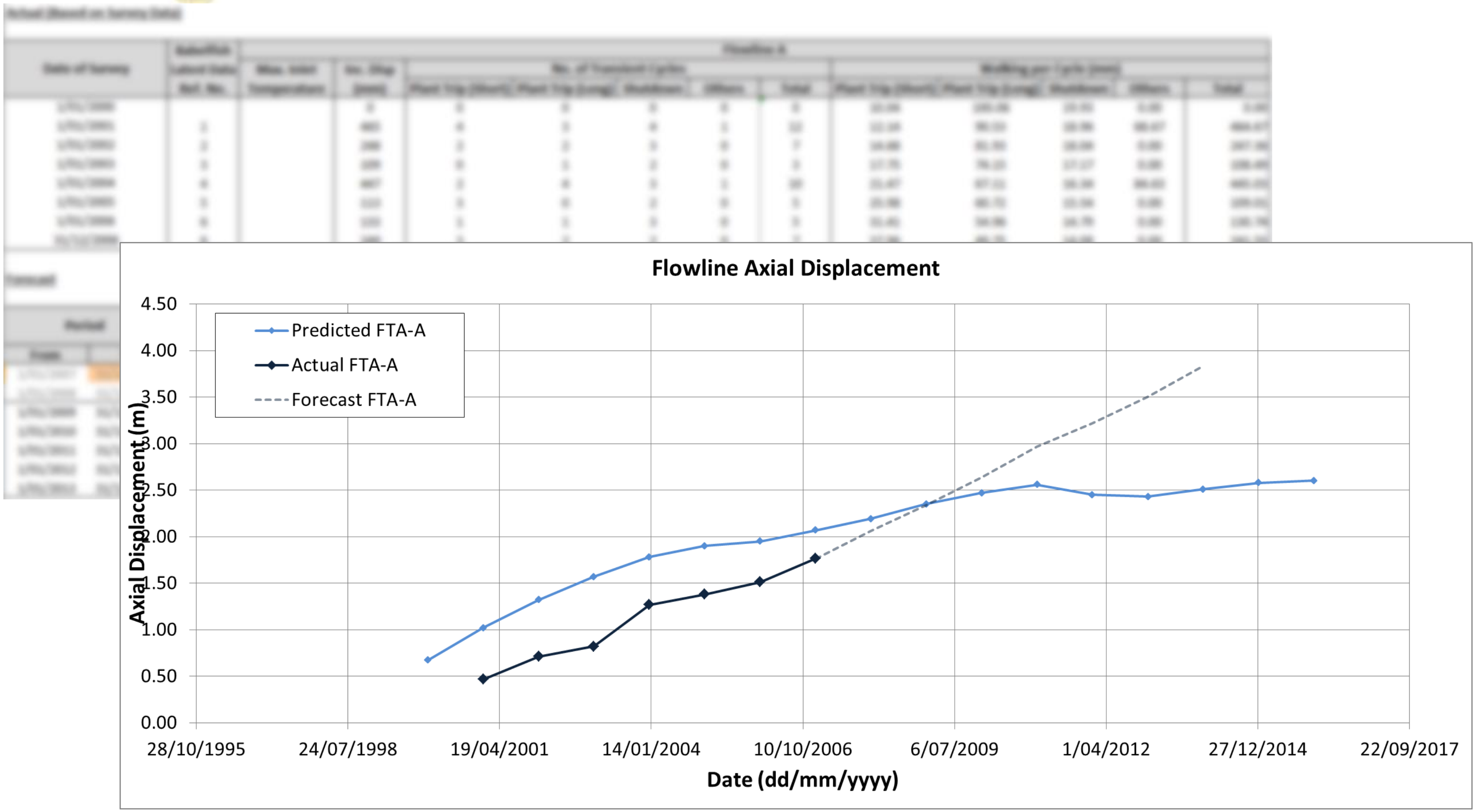
Date of Survey	Babelfish Latest Data Ref. No.	Flowline A											
		Max. Inlet Temperature	Inc. Disp (mm)	No. of Transient Cycles					Walking per Cycle (mm)				
				Plant Trip (Short)	Plant Trip (Long)	Shutdown	Others	Total	Plant Trip (Short)	Plant Trip (Long)	Shutdown	Others	Total
1/01/2000			0	0	0	0	0	0	10.04	100.06	19.93	0.00	0.00
1/01/2001	1		465	4	3	4	1	12	12.14	90.53	18.96	68.67	464.67
1/01/2002	2		248	2	2	3	0	7	14.68	81.93	18.04	0.00	247.36
1/01/2003	3		109	0	1	2	0	3	17.75	74.15	17.17	0.00	108.49
1/01/2004	4		447	2	4	3	1	10	21.47	67.11	16.34	84.63	445.03
1/01/2005	5		113	3	0	2	0	5	25.98	60.72	15.54	0.00	109.01
1/01/2006	6		133	1	1	3	0	5	31.41	54.96	14.79	0.00	130.74
31/12/2006	6		249	3	2	2	0	7	37.96	49.75	14.08	0.00	241.55
								49					

Forecast

Period		Period Length (days)	Flowline A										
			Est. Max. Inlet Temperature	Est. No. of Transient Cycles					Est. Walking per Cycle (mm)				
From	To			Plant Trip (Short)	Plant Trip (Long)	Shutdown	Others	Total	Plant Trip (Short)	Plant Trip (Long)	Shutdown	Others	Total
1/01/2007	31/12/2007	365	0.0	4	2	2		8	45.91	45.03	13.39	0.00	300.477612
1/01/2008	31/12/2008	366		3	2	2		7	55.54	40.74	12.74	0.00	273.6006275
1/01/2009	31/12/2009	365	59.8	3	2	2		7	67.17	36.87	12.13	0.00	299.4960577
1/01/2010	31/12/2010	365	60.0	3	2	2		7	81.22	33.37	11.54	0.00	333.4818574
1/01/2011	31/12/2011	365	60.3	2	1	2		5	98.21	30.20	10.98	0.00	248.5936817
1/01/2012	31/12/2012	366	60.5	2	1	2		5	118.83	27.33	10.45	0.00	285.8783496
1/01/2013	31/12/2013	365	60.8	2	1	2		5	143.69	24.73	9.94	0.00	332.0009577

- Excel based tool
- Advanced tool utilises a VBA/Python interface to automate the multi-criteria optimisation for the walking prediction

Axial Walking Operations Tool



Repair Strategies

- Design is the base case plan
- Things do not always go to plan

- Intervention required
    - Repair
    - Replace
    - Mitigate.

Repair Strategies

Reliable data and a learned predictive behaviour can help optimise intervention work

Suitable intervention methodology

Scheduling

Is intervention required?

Situation specific information

Uses company knowledge

Summary

- Predictive tool
- Utilises current knowledge to drive the predictive tool
- The tool learns and can improve the axial walking prediction
- Provides assurance in the design
- Aid in determining if intervention work is required

- The predictive nature of the tool allows potential issues to be spotted early allowing increased planning time for intervention strategies
- Provide input to the design of the intervention strategy.

THANK YOU