Optimisation in Design

Our Presentations

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Agenda

- Who and What is SPA?
- Required Outcome and Timing
- Phasing of Work
- Model and Optimiser Setup
- Validation and Outputs
- Benefits of Optimiser

Who is SPA?

Project 13 programme made of 5 partners:	Farrans
	Jacobs
	Mott MacDonald Bentley
	Costains
	Anglian Water

Brought together to deliver the Water Resource Management Plan

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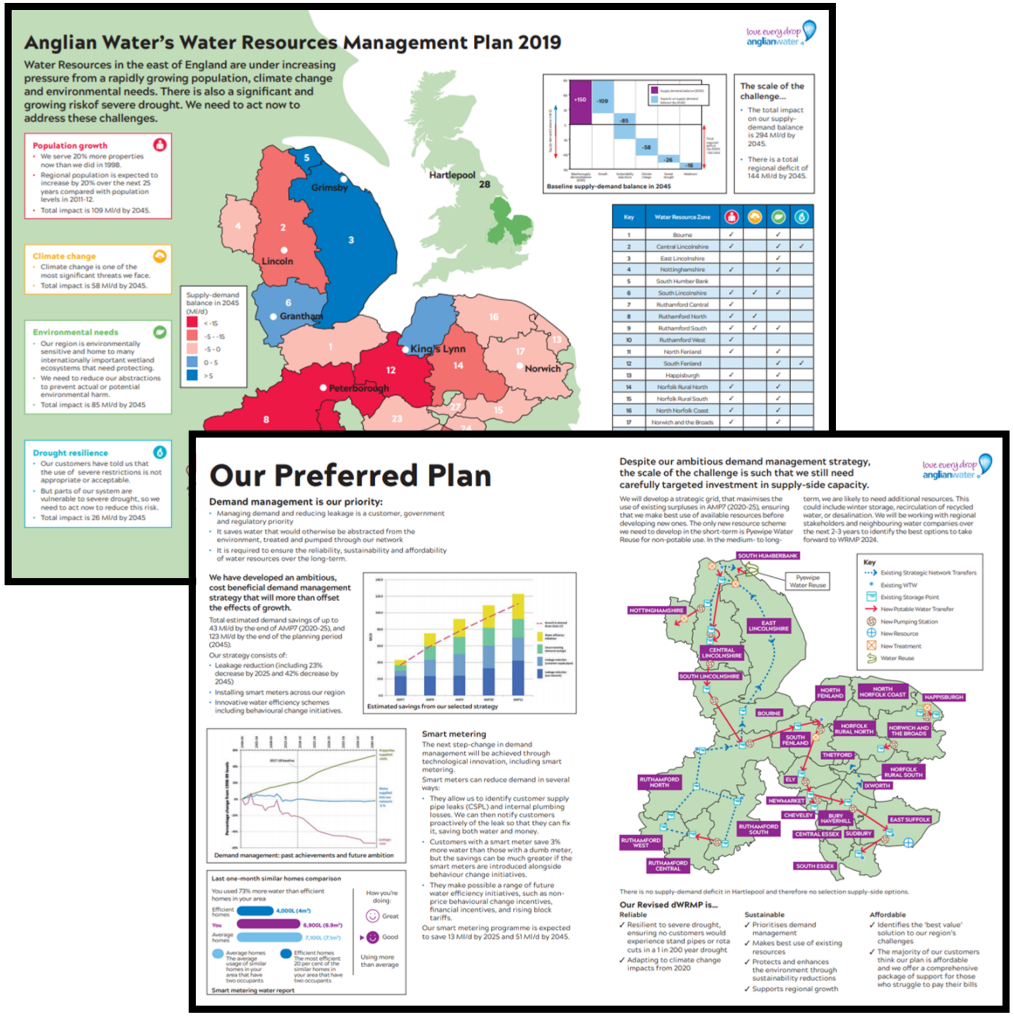

https://www.anglianwater.co.uk/siteassets/household/about-us/wrmp-report-2019.pdf

What is SPA?

Strategic Pipeline Alliance set up to address Anglian Water's WRMP19

Water Resource Management Plan needs as follows:

- Drought resistant (1:200) water supply
- Accommodate future Growth, Climate Change and Sustainability Reductions
- Provide Resilience to various water treatment works

How?

Pipeline interconnectors from Elsham to Colchester

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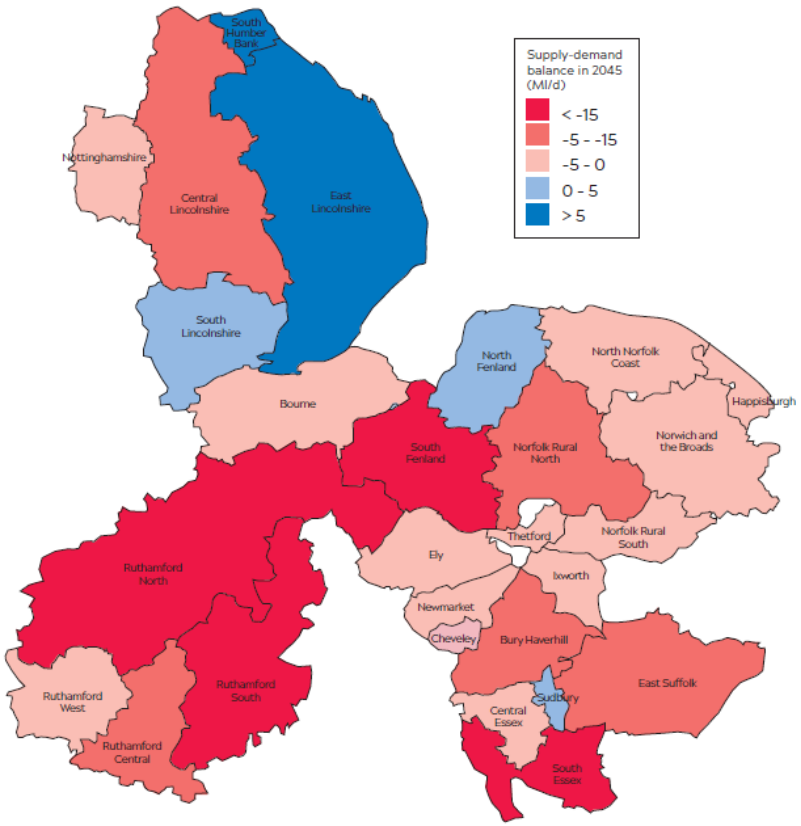
Outcomes Requirement

Baseline supply-demand balance in 2044-45 (DYAA scenario)



To meet the deficit in the following zones.

Provide resilience to 20 water treatment works by connecting into them.

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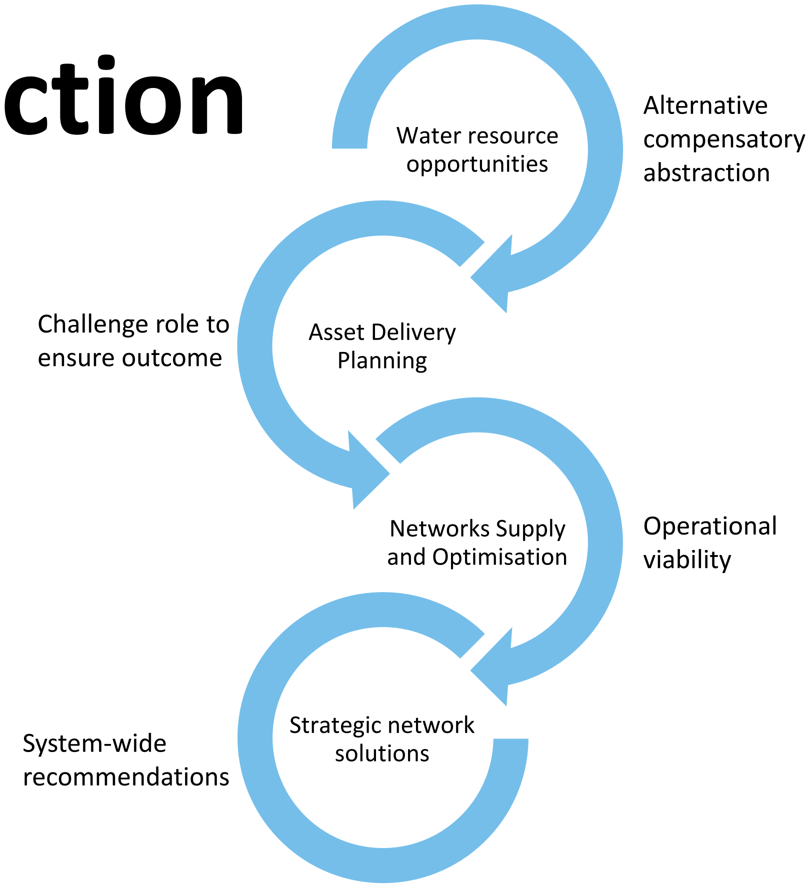
Timeline

- Sprint to construction required an accelerated timeline
- Impossible to achieve using traditional modelling approaches
- 4 months from WRMP flows to recommended sizing

Phase 1 - Outline Direction

- ✓ Strategic Pipeline Alliance set up to address WRMP19 needs as follows:
- ✓ Drought resistant (1:200) water supply
- ✓ Accommodate future Growth, Climate Change and Sustainability Reductions
- ✓ Provide Resilience to various water treatment works



Tiger team was together exploring opportunities in parallel activity streams

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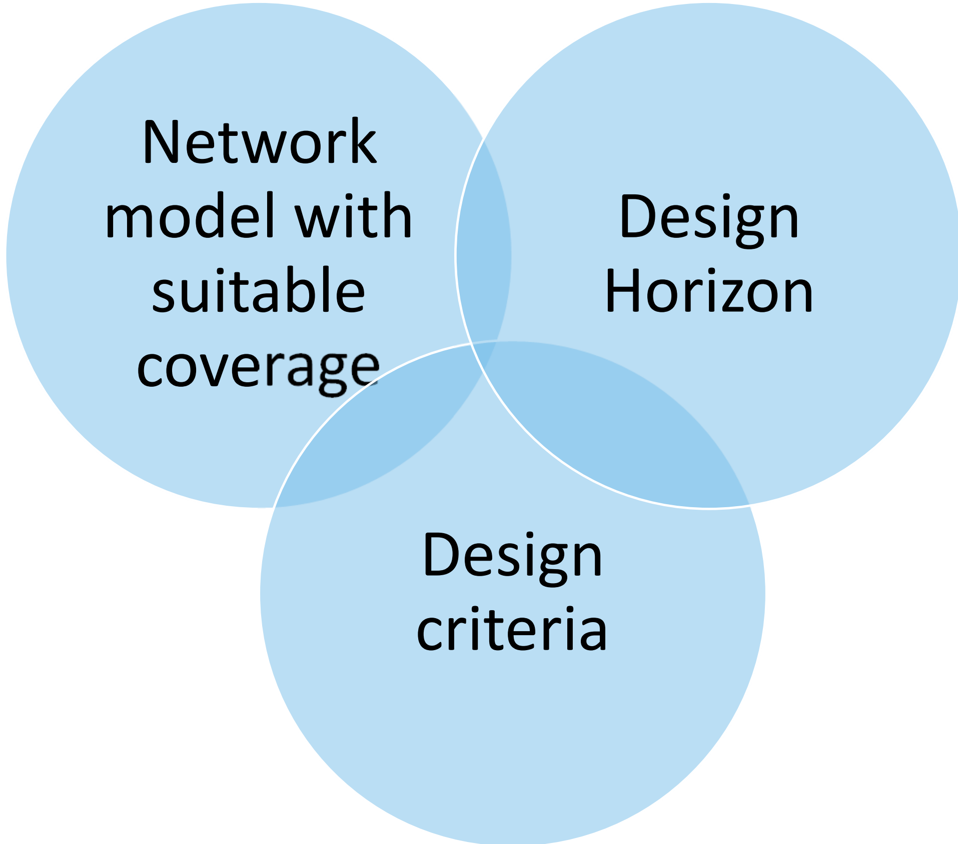
Phase 1 - Outline Direction

- We needed:
  - Aquator modelling
  - Network modelling
  - Operational buy-in
  - Governance procedure
  - Timescales

Phase 2 - Flows, model and formulation

On agreement on the general direction, we now needed:

- Suitable hydraulic network model
- The criteria to make a decision
  - Constraints
  - Costs (financial and carbon)
  - Scenarios
- A design horizon



Design Horizon

Water Resources Flows

Multiple runs to include Average Day demands, peak day demands, Resilience demands and failure modes.

Aquator has output over 130 years of historical hydrological trends against:

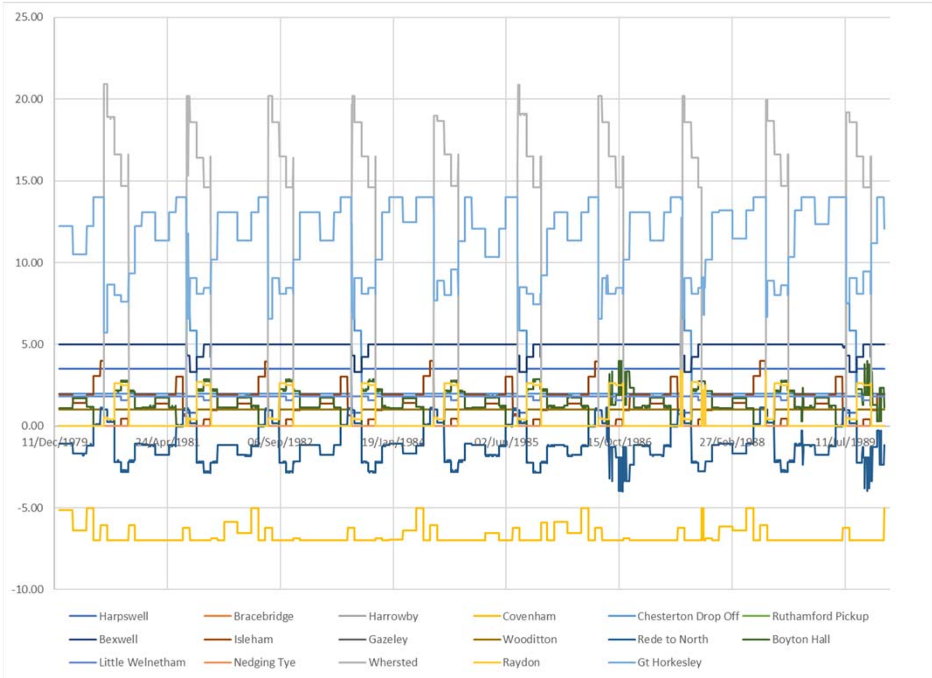
- ✓ DYAA
- ✓ NYAA
- ✓ Drought

Miser has given outputs regarding

- ✓ Resilience

The outputs show that the strategic grid will not be a static system, but rather a dynamic one that operates differently, not least of which time of year due to existing water source availability

Network modelling will need to overlay the above seasonal variations to further operational constraints



Design Horizon

Agreement of Flowrates

Broad mix of operating flows agreed with water resources and supply teams:

- 1:200 drought events
- Dry year and Normal year
- 2025 and 2045
- Seasonal variations
- Resilience scenarios

	DO	Operational	Interconnector capacity	H5 - NY 2025 Demand	H5 Winter	H5 Spring	H5 Summer	H5 Autumn	H5 Average	Runs 5	Runs 6	H6 - NY 2045 Demand	H6 Winter	H6 Spring	H6 Summer	H6 Autumn	H6 Average	Runs 7	Runs 8
					1.00	0.98	1.08	0.94	1				1.00	0.98	1.08	0.94	1		
Elsham to Welby			55		16	15	23	20	19	15.87	21.53		13	12	20	17	16	12.67	18.33
Notts	19.3			19.9	0.8	0.8	2.2	0.8	1.1	0.80	1.49	20.1	0.8	0.4	2.4	0.0	0.9	0.61	1.21
Lincoln				0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Grantham	31.0			25.8	0.0	0.0	0.0	0.0	0.0	0.00	0.00	23.8	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Welby to Etton			55		16	15	20	20	18	15.07	20.05		13	12	18	17	15	12.06	17.12
Bourne (Input)	47.7			41.9	-7.0	-7.0	-7.0	-7.0	-7.0	-7.00	-7.00	40.9	-7.0	-7.0	-7.0	-7.0	-7.0	-7.00	-7.00
Peterborough				0.0	-2.0	-2.0	-2.0	5.0	-0.3	-2.00	1.50	0.0	-2.0	-2.0	-2.0	5.0	-0.3	-2.00	1.50
Etton to Bexwell			40		25	24	29	22	22	24.07	25.55		22	21	27	19	20	21.06	22.62
Bexwell	23.0	3.2		29.1	2.9	2.3	5.2	1.2	2.9	2.63	3.21	27.9	1.7	1.2	4.0	0.1	1.7	1.45	2.01
Bexwell to Rede			25		22	21	24	20	22	21.44	22.33		20	19	23	19	20	19.61	20.61
Ely	20.9			18.4	0.0	0.0	0.0	0.0	0.0	0.00	0.00	18.6	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Newmarket	15.0			10.9	0.0	0.0	0.0	0.0	0.0	0.00	0.00	10.9	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Wooditton	1.6			1.9	0.3	0.2	0.4	0.2	0.3	0.26	0.30	1.7	0.1	0.1	0.2	0.0	0.1	0.09	0.13
Haverhill (Rede)	7.0			10.1	3.1	2.9	3.9	2.5	3.1	3.02	3.22	9.7	2.7	2.5	3.5	2.1	2.7	2.63	2.83
Rede to Lt Welnetham			25		18	18	20	18	18	18.16	18.82		17	17	19	16	17	16.89	17.66
Rushbrooke (Little Welnethan)	13.9			21.1	7.2	7.2	7.2	7.2	7.2	7.20	7.20	20.0	6.1	6.1	6.1	6.1	6.1	6.10	6.10
Thetford/Ixworth (Little Welnethan)	15.5			15.3	0.0	0.0	1.0	0.0	0.3	0.00	0.51	15.6	0.1	0.0	1.3	0.0	0.4	0.05	0.67
Lt Welnetham to Raydon / Wherestead			20		11	11	12	11	11	10.96	11.11		11	11	11	10	11	10.74	10.88
Ipswich	65.7			60.5	1.0	1.0	1.0	1.0	1.0	1.00	1.00	58.4	1.0	1.0	1.0	1.0	1.0	1.00	1.00
Raydon (or split between Semer & Raydon)	0.0	0.5		8.0	7.5	7.4	8.1	7.1	7.5	7.46	7.61	7.8	7.3	7.2	7.9	6.9	7.3	7.24	7.38
Raydon to Gt Horkesley			15		3	3	3	3	3	2.50	2.50		3	3	3	3	3	2.50	2.50
South Essex	56.0			56.7	2.5	2.5	2.5	2.5	2.5	2.50	2.50	57.7	2.5	2.5	2.5	2.5	2.5	2.50	2.50

	H7 - DY 2025 Demand	H7 Winter	H7 Spring	H7 Summer	H7 Autumn	H7 Average	Runs 9	Runs 10	H8 - DY 2045 Demand	H8 Winter	H8 Spring	H8 Summer	H8 Autumn	H8 Average	Runs 11	Runs 12
		1.00	0.98	1.08	0.94	1				1.00	0.98	1.08	0.94	1		
Elsham to Welby		55	33	37	54	45	54.46	34.99		54	33	35	54	44	53.87	34.20
Notts	21.1	1.8	1.3	3.4	0.5	1.8	1.12	2.38	21.1	1.8	1.4	3.5	0.5	1.8	1.17	2.43
Lincoln	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Grantham	27.5	0.0	0.0	0.0	0.0	0.0	0.00	0.00	25.9	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Welby to Etton		53	32	33	54	43	53.34	32.60		52	32	32	53	42	52.71	31.77
Bourne (Input)	44.9	-7.0	-7.0	-6.2	-7.0	-6.8	-7.00	-6.59	44.5	-7.0	-7.0	-6.6	-7.0	-6.9	-7.00	-6.82
Peterborough	0.0	30.0	10.0	7.0	33.0	20.0	31.50	8.50	0.0	30.0	10.0	7.0	33.0	20.0	31.50	8.50
Etton to Bexwell		30	29	32	28	25	28.84	30.69		29	29	32	27	25	28.21	30.09
Bexwell	31.0	4.8	4.2	7.3	3.0	4.8	3.89	5.75	30.4	4.2	3.6	6.7	2.4	4.2	3.32	5.14
Bexwell to Rede		25	25	25	25	25	24.95	24.94		25	25	25	25	25	24.89	24.95
Ely	20.0	0.0	0.0	0.7	0.0	0.2	0.00	0.33	20.4	0.0	0.0	1.2	0.0	0.3	0.00	0.58
Newmarket	11.9	0.0	0.0	0.0	0.0	0.0	0.00	0.00	11.8	0.0	0.0	0.0	0.0	0.0	0.00	0.00
Wooditton	2.0	0.4	0.3	0.5	0.3	0.4	0.31	0.43	1.8	0.2	0.2	0.4	0.1	0.2	0.16	0.26
Haverhill (Rede)	10.6	3.6	3.4	4.4	2.9	3.6	3.25	3.89	10.4	3.4	3.2	4.2	2.8	3.4	3.06	3.69
Rede to Lt Welnetham		21	21	19	22	21	21.39	20.29		21	22	19	22	21	21.67	20.41
Rushbrooke (Little Welnethan)	22.5	8.6	8.6	8.6	8.6	8.6	8.60	8.60	21.9	8.0	8.0	8.0	8.0	8.0	8.00	8.00
Thetford/Ixworth (Little Welnethan)	16.3	0.8	0.5	2.1	0.0	0.8	0.39	1.27	16.9	1.4	1.1	2.8	0.4	1.4	0.92	1.94
Lt Welnetham to Raydon / Wherestead		12	12	9	13	11	12.40	10.42		12	13	8	14	12	12.75	10.48
Ipswich	65.5	1.0	0.9	0.0	1.0	0.7	1.00	0.45	63.7	-3.1	-2.3	-7.2	-0.9	-3.4	-2.00	-4.75
Raydon (or split between Semer & Raydon)	8.3	7.8	7.7	8.5	7.4	7.8	7.60	8.07	8.5	8.0	7.8	8.6	7.5	8.0	7.75	8.23
Raydon to Gt Horkesley		3	4	0	5	3	3.80	1.90		7	7	7	7	7	7.00	7.00
South Essex	57.7	2.8	3.6	0.2	4.8	2.9	3.80	1.90	62.8	7.0	7.0	7.0	7.0	7.0	7.00	7.00

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12
	1:200 Drought				Whole Life Costs							
	1:200 Drought H8 DY2045 Drought in Notts, Lincoln, Bexwell, Ely, Newmarket, Wooditton, Haverhill, Rushbrooke and Thetford	1:200 Drought H8 DY2045 Drought in Ruthamford	1:200 Drought H8 DY2045 Drought in Ipswich	1:200 Drought H8 DY2045 Drought in Colchester	Winter/Spring NY 2025	Summer Autumn NY 2025	Winter/Spring NY 2045	Summer Autumn NY 2045	Autumn/Winter DY 2025	Spring/Summer DY 2025	Autumn/Winter DY 2045	Spring/Summer DY 2045
Drop Off Locations	Summer	Autumn	Autumn	Autumn								
Notts	2.30	0.53	0.53	0.53	0.80	1.49	0.61	1.21	1.12	2.38	1.17	2.43
Lincoln	20.00	-	-	-	-	-	-	-	-	-	-	-
Grantham	-	-	-	-	-	-	-	-	-	-	-	-
Bourne (Input)	- 7.00	- 7.00	- 7.00	- 7.00	- 7.00	- 7.00	- 7.00	- 7.00	- 7.00	- 6.59	- 7.00	- 6.82
Peterborough	-	40.00	33.00	33.00	- 2.00	1.50	- 2.00	1.50	31.50	8.50	31.50	8.50
Bexwell	15.00	2.40		2.40	2.63	3.21	1.45	2.01	3.89	5.75	3.32	5.14
Ely	2.66	-	-	-	-	-	-	-	-	0.33	-	0.58
Newmarket	2.00	-	-	-	-	-	-	-	-	-	-	-
Wooditton	0.50	0.10	0.10	0.10	0.26	0.30	0.09	0.13	0.31	0.43	0.16	0.26
Haverhill (Rede)	4.21	2.75		2.75	3.02	3.22	2.63	2.83	3.25	3.89	3.06	3.69
Rushbrooke (Little Welnethan)	10.00	-	-		7.20	7.20	6.10	6.10	8.60	8.60	8.00	8.00
Thetford/Ixworth (Little Welnethan)	2.80	0.41	0.41	0.41	-	0.51	0.05	0.67	0.39	1.27	0.92	1.94
Ipswich	- 7.20	- 0.90	10.00	- 0.90	1.00	1.00	1.00	1.00	1.00	0.45	- 2.00	- 4.75
Raydon (or split between Semer & Raydon)	8.63	7.51	7.51	7.51	7.46	7.61	7.24	7.38	7.60	8.07	7.75	8.23
South Essex	1.10	9.2	7.00	15.00	2.50	2.50	2.50	2.50	3.80	1.90	7.00	7.00
TOTAL (North)	55.0	55.0	51.6	53.8	15.9	21.5	12.7	18.3	54.5	35.0	53.9	34.2
TOTAL (Peterborough to Bexwell)	39.7	21.5	25.0	27.3	24.1	25.5	21.1	22.6	28.8	30.7	28.2	30.1
TOTAL (East: from Bexwell)	24.7	19.1	25.0	24.9	21.4	22.3	19.6	20.6	25.0	24.9	24.9	24.9

Design Criteria

Engagement

Start Up Workshop

Range of operation

- Max/min instantaneous and daily
- Diurnal variation
- Normal year average, dry year average

Storage turnover

Pump operating range

Flow Rates

Determined from DYAA and NYAA demand against regional DO

4 Drought periods

8 Dry and Normal periods

Cover maximum interconnector flow rates

2 key design horizons – 2025 and 2045

Model Extents

Key existing assets and networks included

Extensive enough to be useful yet efficient on runtime

Flow meter data downloaded and applied

Telemetry data used to verify model

Refreshed with latest route alignment

Network Model

The hydraulic model has been created from:

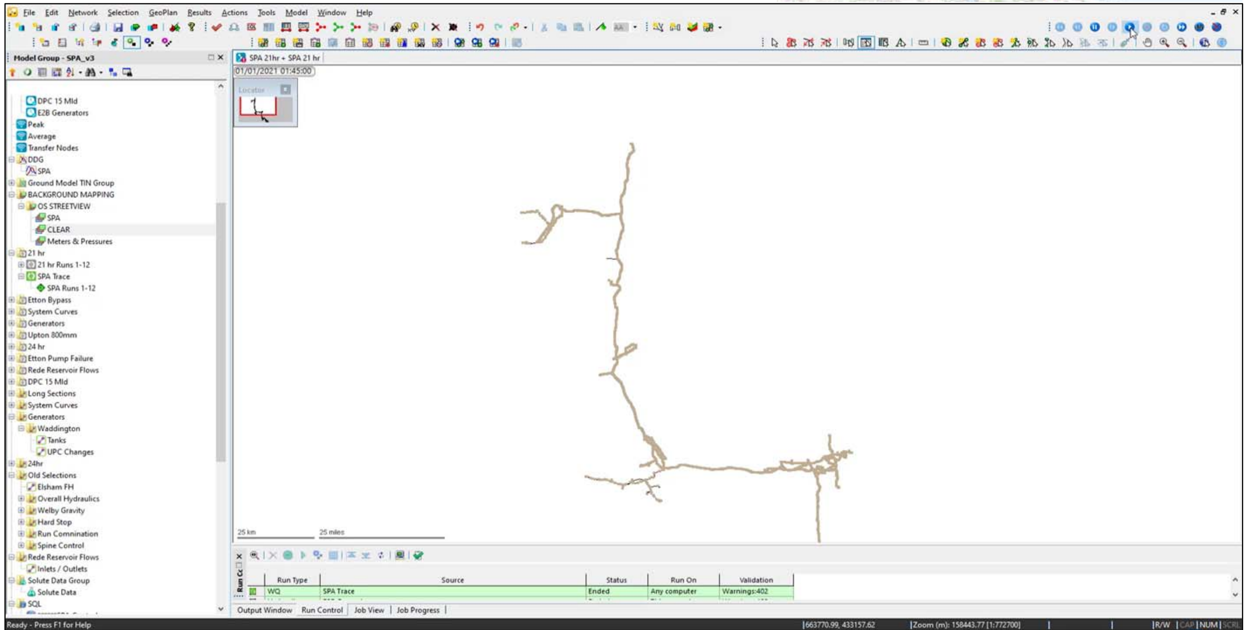
- The latest GIS extract of route alignment
- Existing regional network models captured collaboratively as to agreed extents
- Key existing sites included

The model has been verified against:

- Telemetry level, flow and pressure data

Existing Schemes Captured:

- Most onerous of options for the existing schemes have been included
- Detailed modelling for each region is a parallel workstream
- Parallel workstreams have been coordinated with



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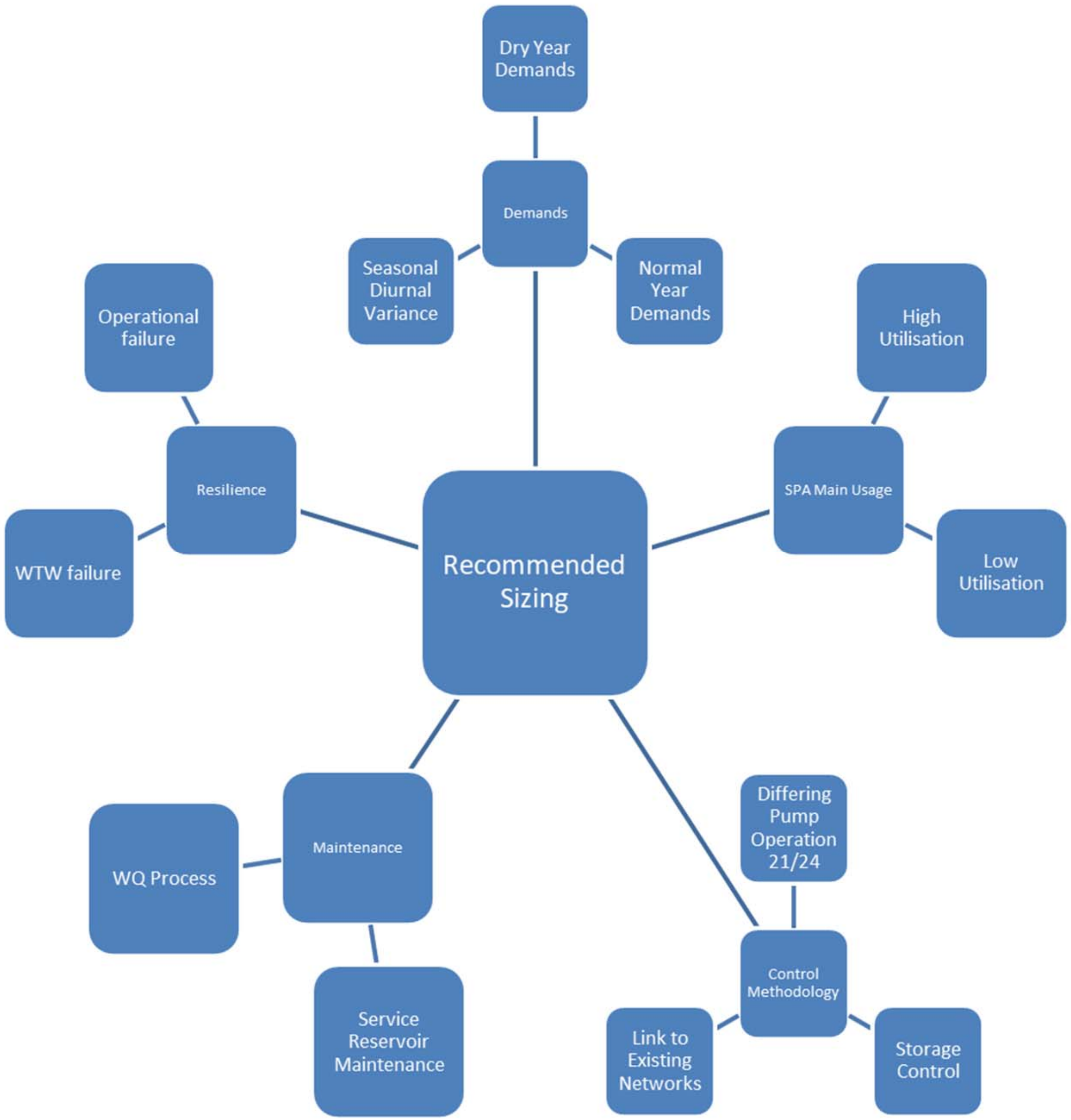

Optimatics

- The definition of this range of scenarios is a multi criteria analysis
- Optimatics has been designed with this MCA in mind
- We can achieve the majority of our sizing through spreadsheets or engineering judgement; however we need to prove it works

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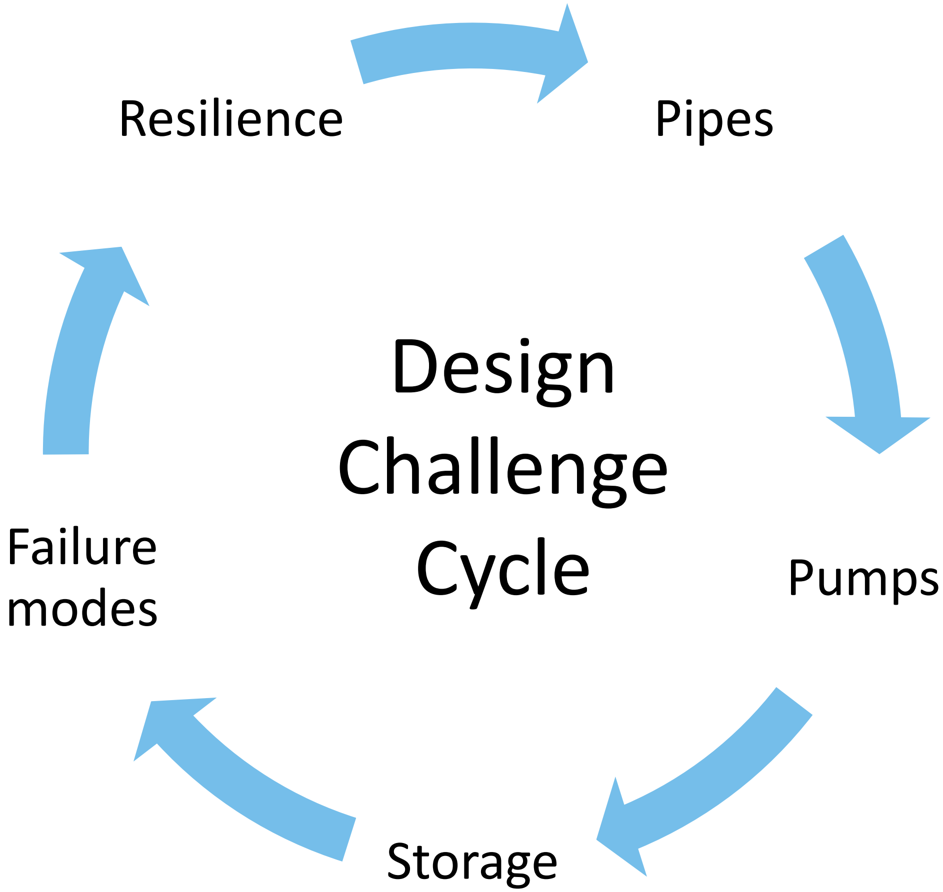
Phase 3 - Application and evolution

We now had:

- A dynamic network model
- Cost catalogues
- Penalty ranges
- Sizing criteria

The designs have a natural iterative nature

- Bigger pipes = smaller pumps
- Failure modes = bigger pipes
- Cost drives = smaller pipes



Translation to Optimatics

Network Model

Current contains Drought periods and Average flow periods

Demands vary dependant on season

Decision Criteria

Analyse optimal pipe size

Analyse optimal tank size

Analyse pump size

Determine combination of these, compared against:

- Network Model
- Defined Inputs
- Defined Metrics

Defined Inputs

Pipe size catalogue

Reservoir size range

Capital costs

Operational costs

Whole life cost calculation

Planned shutdown period

Performance Metrics

Minimum allowable pressure

Maximum pressure for the pipe

Required offtake flow

Reservoir level return

Maximum velocity

Whole Life Cost

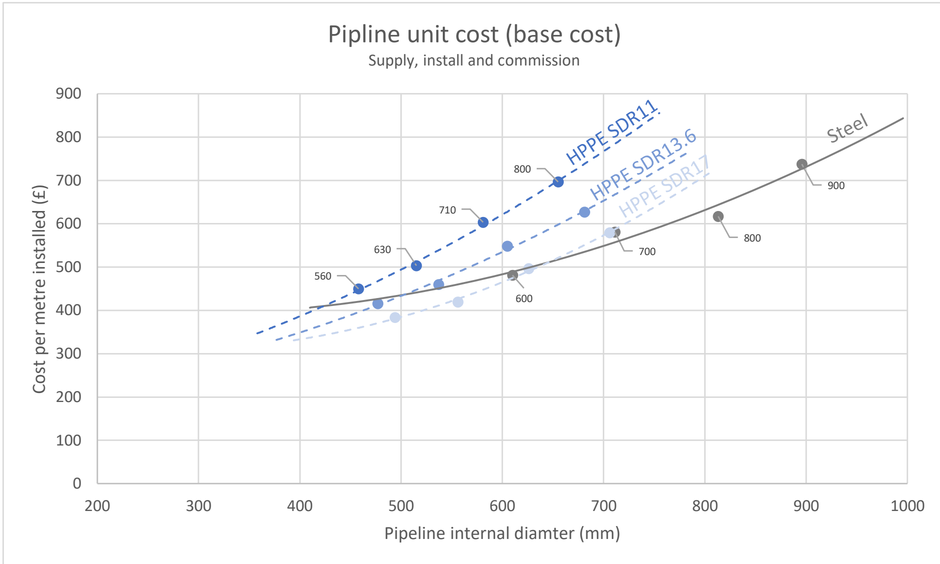
Conditioning v Other	Cond.	Other							
	0.5%	99.5%							
2025 v 2045	n/a	2025				2045			
	100.0%	25%				75%			
	100.0%	43%				57%			
Normal v Dry year	n/a	Normal year		Dry year		Normal year		Dry year	
	100.0%	71%		29%		71%		29%	
Seasonal	n/a	Winter/ Spring config.	Summer/ Autumn config.	Winter/ Autumn config.	Spring/ Summer config.	Winter/ Spring config.	Summer/ Autumn config.	Winter/ Autumn config.	Spring/ Summer config.
	100.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
Proportions within a "representative" year	0.5%	15.1%	15.1%	6.0%	6.0%	20.4%	20.4%	8.2%	8.2%
Conversion of daily energy opex to WLC	365.25								
	21.71								

Headline parameters:

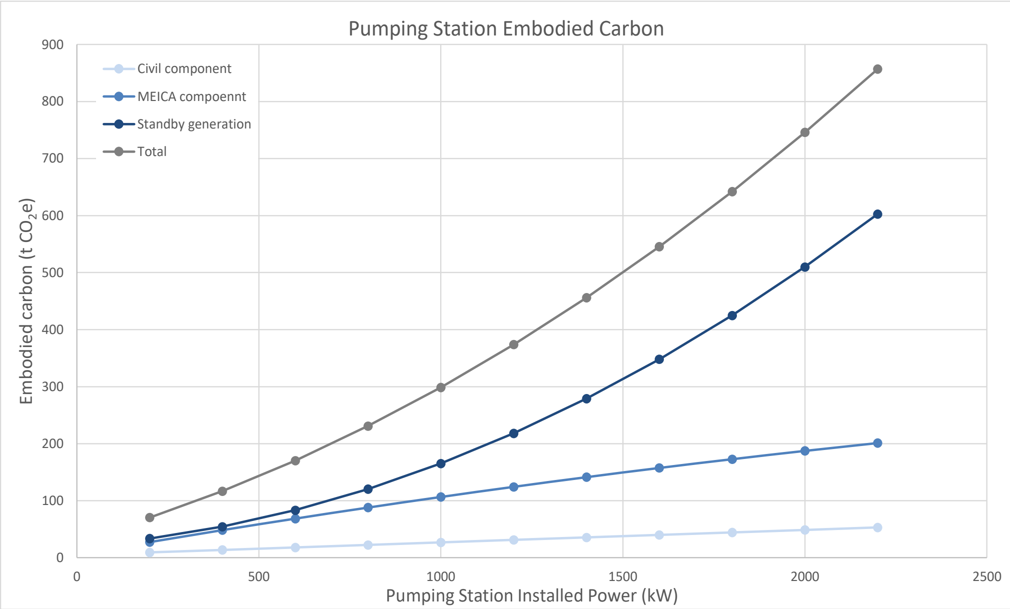
- SPA base CAPEX uplifted to outturn costs
- 40 year analysis period, 3.7% discount rate
- 2 days per year conditioning allowance
- Normal year : Dry Year ➔ 2 : 5
- Seasonal variation
- Power cost: 12.1 p/kWh
- Replacement periods:
  - Civil assets: 50 years
  - PS M&E assets: 25 years
  - PS ICA assets: 10 years

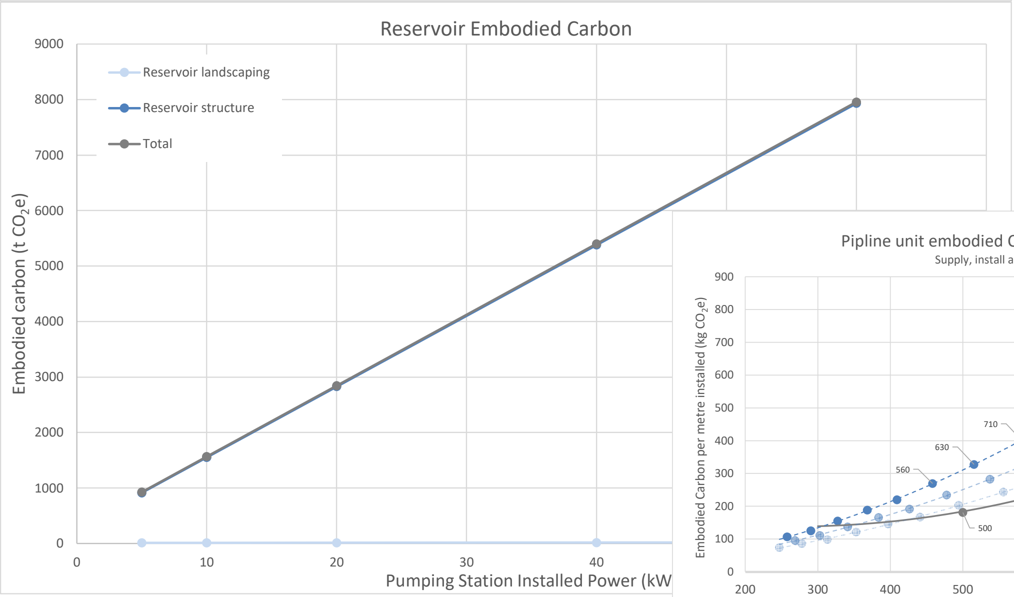
Other parameters:

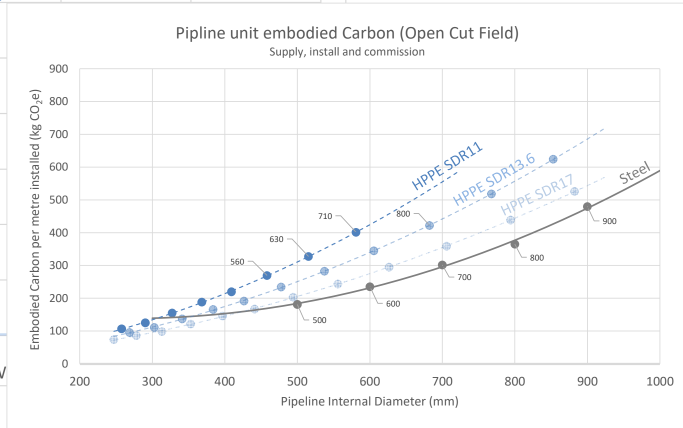
- PLM
- WR cleaning
- Insurance



Numbers above are not actual and only indicative.







Carbon parameters

- Operational and Embedded Carbon
- Variation on pipe materials

“The entire pipeline has been designed to have the lowest carbon footprint possible in line with Anglian’s pledge to reach net zero carbon by 2030”

Significant financial saving for Anglian Water as part of their green bonds, requiring them to reach a carbon target of 65%

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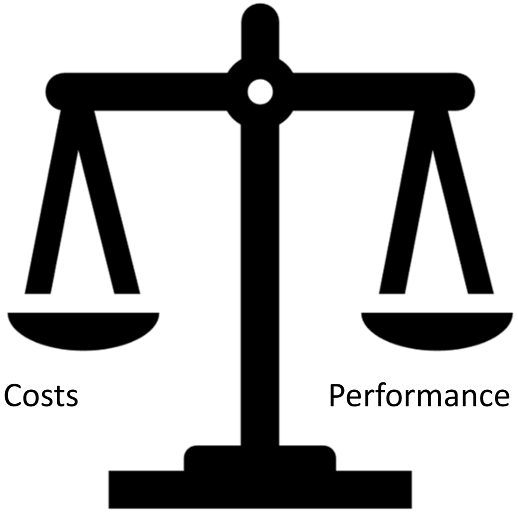
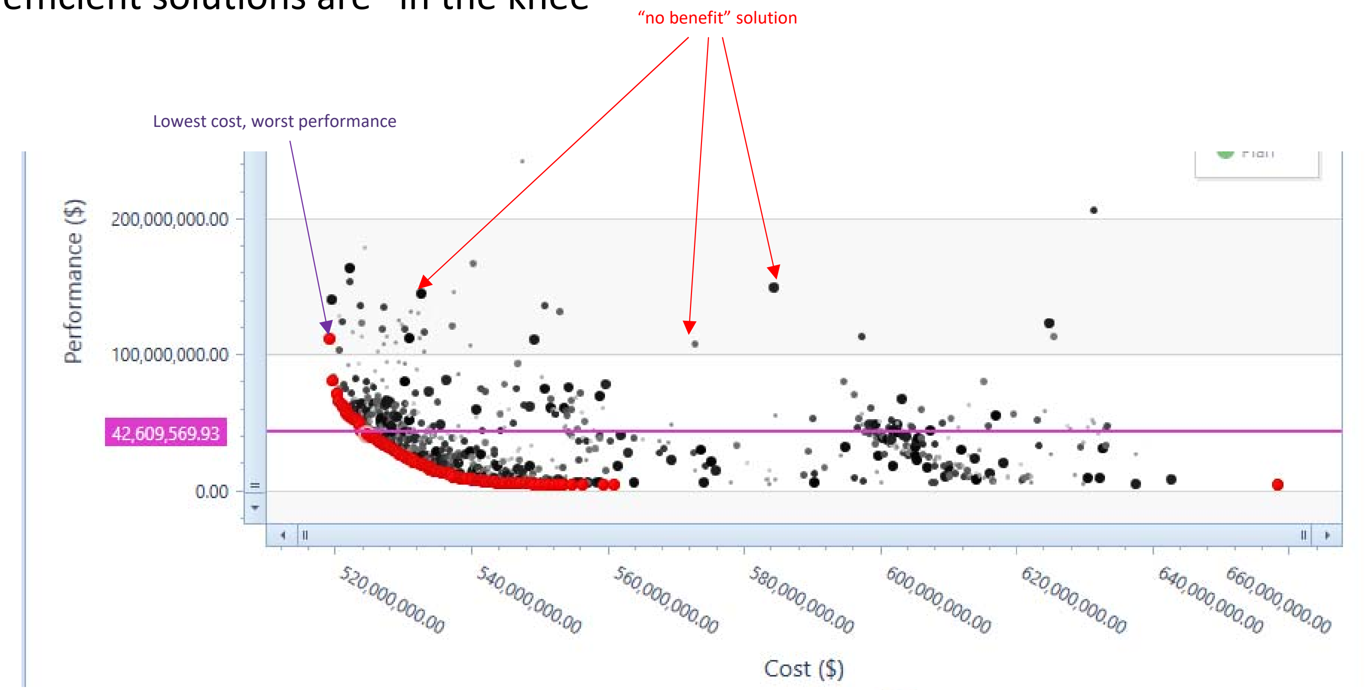
Optimatics Approach

The Optimatics algorithm will carry out analysis on all these criteria and inform on solution costs against performance within the hydraulic model

- For instance, the most expensive solution sacrifices nothing, but the cheapest solution doesn’t work
- The Pareto curve shows the most efficient solutions are “in the knee”
- Not a “black box”

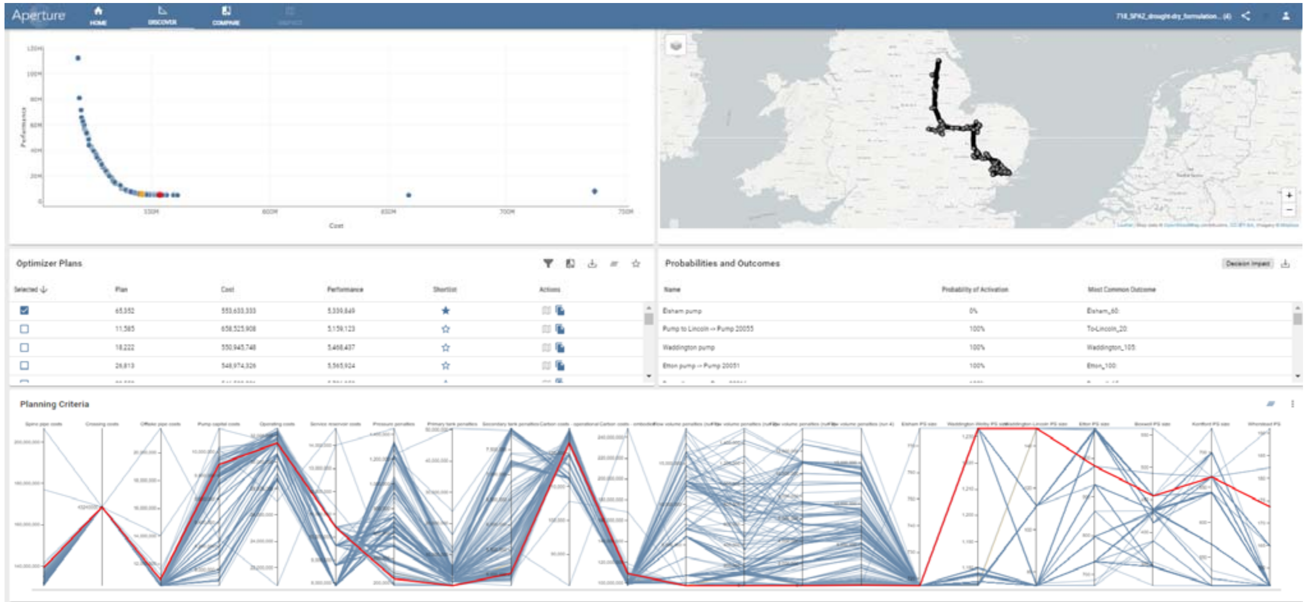




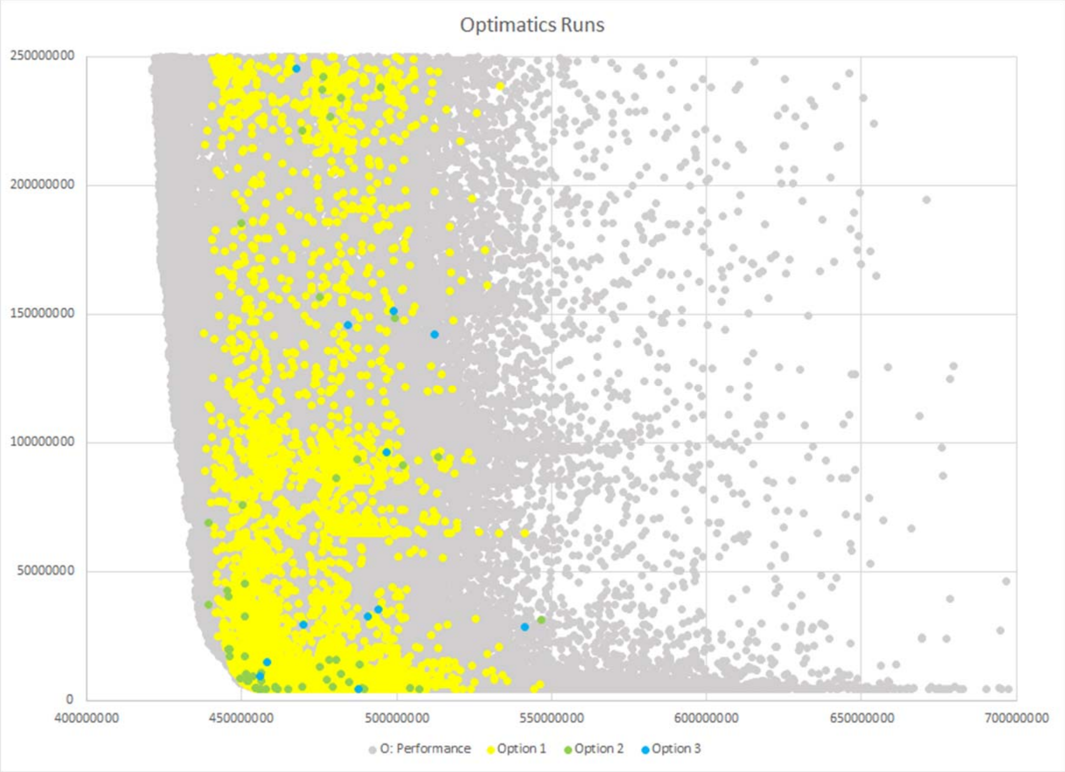
Optimatics – So how do we choose?

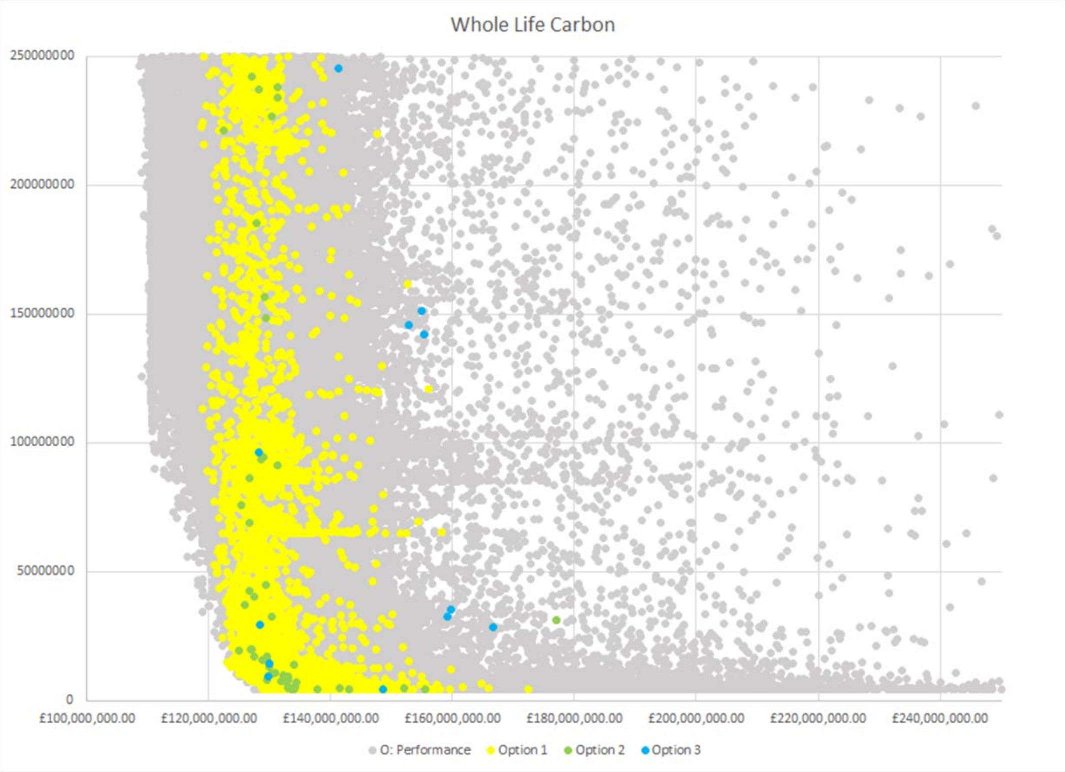
We have thousands of runs – how do we choose the right ones?

- Starting with Aperture
- We can decide what we are interested in
- We select those runs that meet it
- We can then dive further into those runs



WL Cost and Carbon Pareto Charts of Options





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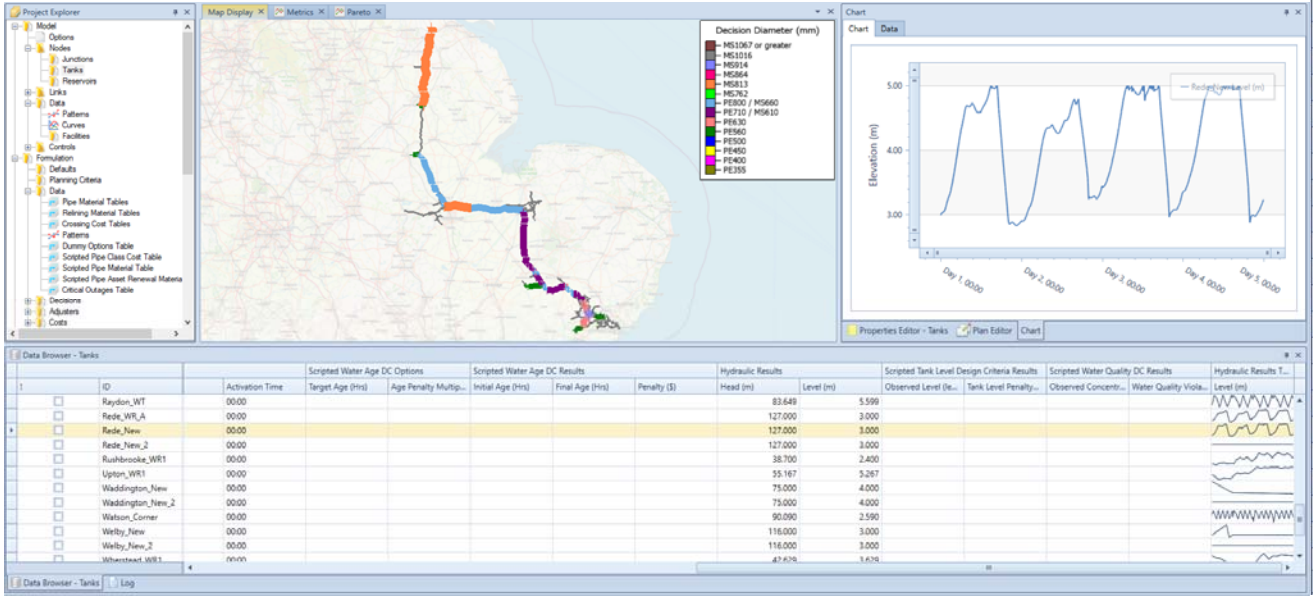
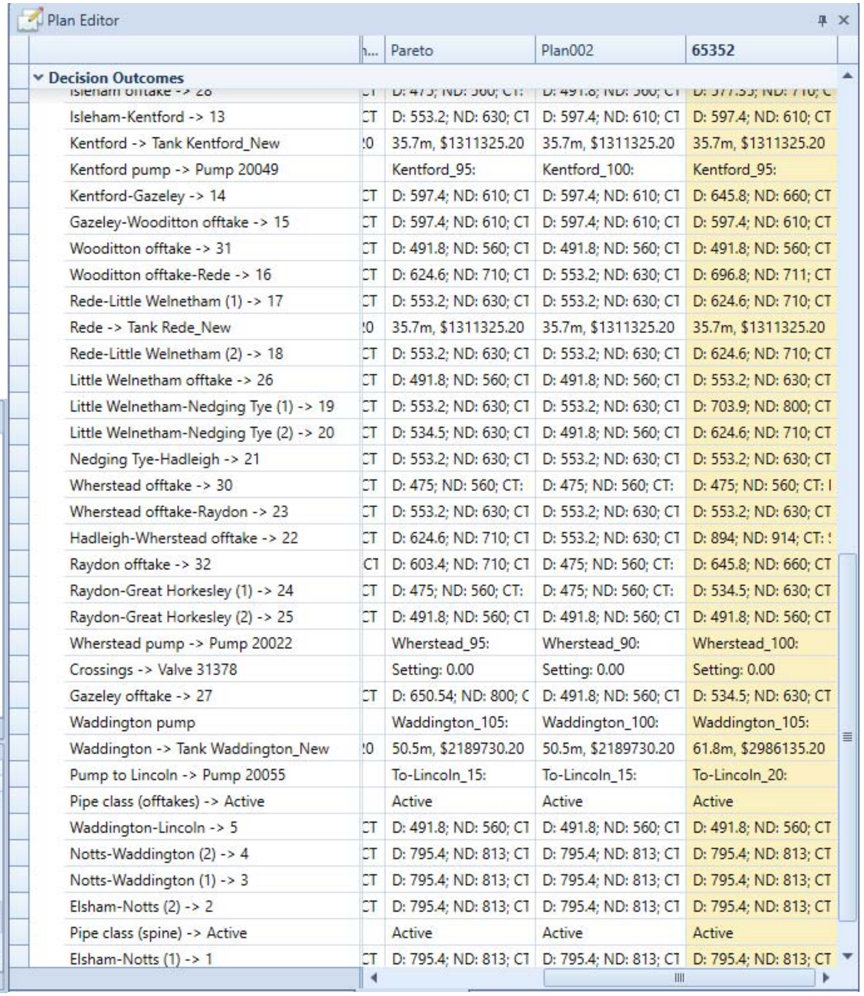
Optimatics – So how do we choose?

The software allows us to look at each plan in detail





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Validation

Optimatics

1000's of results produced in Optimatics

↓

Manual check of WLC calculation

↓

Shortlist options selected from pareto chart

↓

Validation in InfoWorks

Traditional method

One optimised scenario engineered to give lowest WLC and meet performance criteria

↓

Standard calculation QA

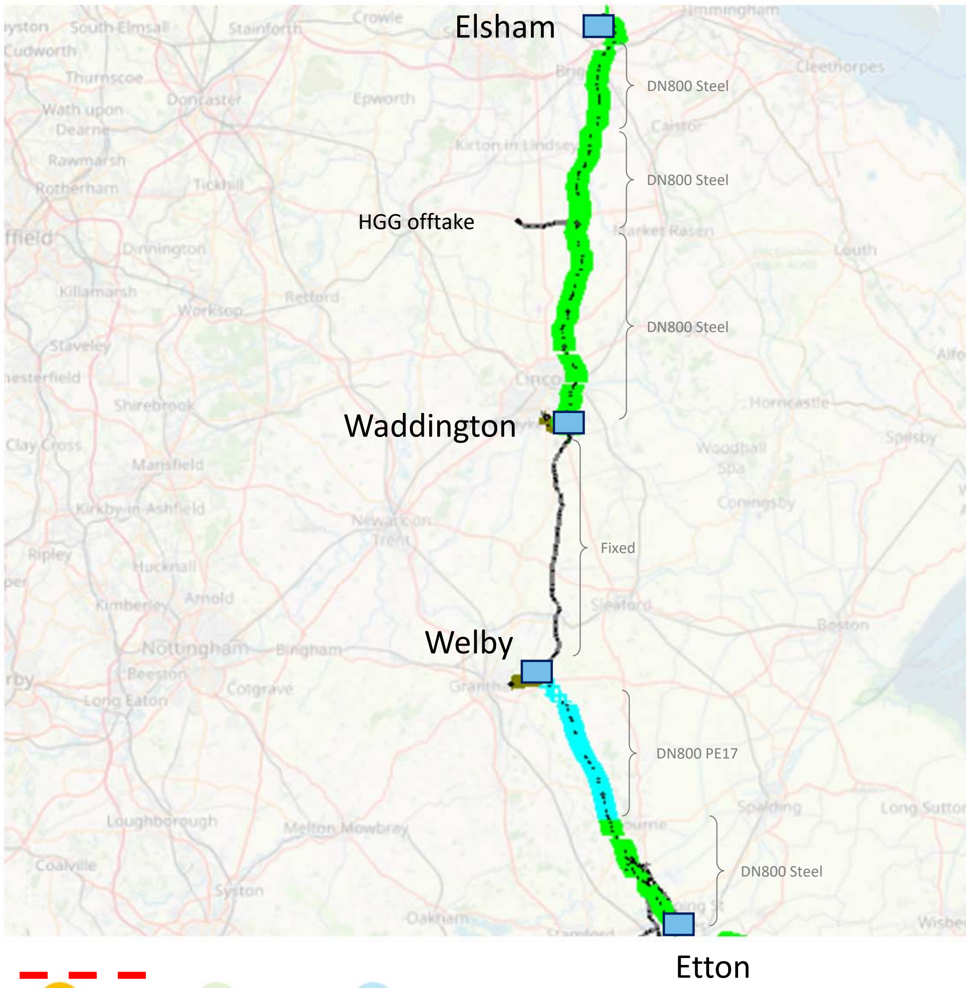
→ **ROV options**

Option 1 – Algorithm Solution

Section	Dia / Material
Elsham to Cadney	DN800 Steel
Cadney to HGG offtake	DN800 Steel
HGG offtake to Waddington	DN800 Steel
Welby to Etton (Part a)	DN800 PE17
Welby to Etton (Part b)	DN800 Steel

Cost component	£m
CAPEX (whole spine, pipeline, PS + WR)	£384.1
OPEX (energy only NPV)	£15.2
OPEX (other, NPV)	£10.6
Whole Life Cost	**£409.9**

Carbon component	t CO_2e
Emb. carbon (whole spine, pipeline, PS + WR)	102,730
Carbon (operational)	22,621
Whole Life Carbon	**125,351**



Number above are not actual and only indicative.

1 Algorithm Solution
2 Modelled All Steel
3 Modelled DN700 North

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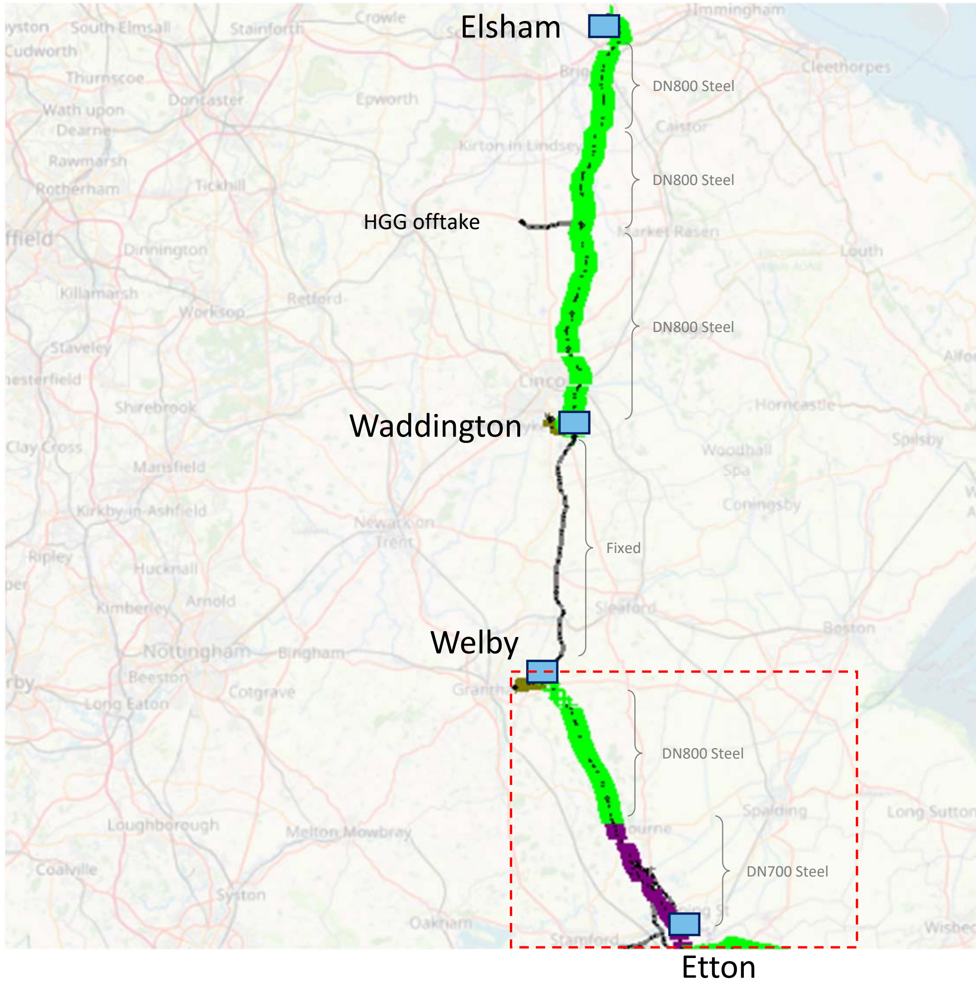
Option 2 – Modelled All Steel

Section	Dia / Material
Elsham to Cadney	DN800 Steel
Cadney to HGG offtake	DN800 Steel
HGG offtake to Waddington	DN800 Steel
Welby to Etton (Part a)	DN800 Steel
Welby to Etton (Part b)	DN700 Steel

Cost component	£m
CAPEX (whole spine, pipeline, PS + WR)	£424.1
OPEX (energy only NPV)	£15.2
OPEX (other, NPV)	£10.6
Whole Life Cost	**£449.9**

Carbon component	t CO_2e
Emb. carbon (whole spine, pipeline, PS + WR)	101,651
Carbon (operational)	23,621
Whole Life Carbon	**124,172**

Number above are not actual and only indicative.



1 Algorithm Solution

2 Modelled All Steel

3 Modelled DN700 North

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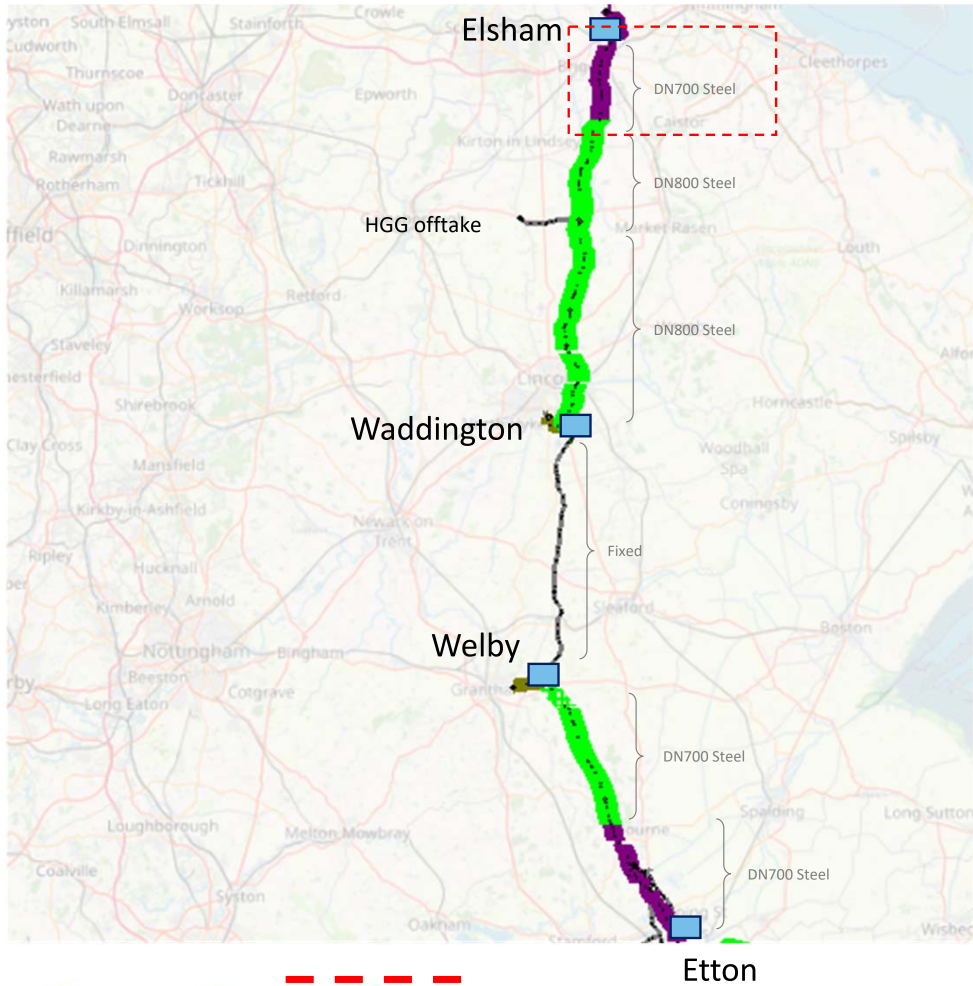
Option 3 – DN700 Steel North

Section	Dia / Material
Elsham to Cadney	DN700 Steel
Cadney to HGG offtake	DN800 Steel
HGG offtake to Waddington	DN800 Steel
Welby to Etton (Part a)	DN800 Steel
Welby to Etton (Part b)	DN700 Steel

Cost component	£m
CAPEX (whole spine, pipeline, PS + WR)	£413.7
OPEX (energy only NPV)	£36.3
OPEX (other, NPV)	£10.8
Whole Life Cost	**£430.8**

Carbon component	t CO_2e
Emb. carbon (whole spine, pipeline, PS + WR)	100,851
Carbon (operational)	24,380
Whole Life Carbon	**124,231**

Number above are not actual and only indicative.



1 Algorithm Solution
2 Modelled All Steel
3 Modelled DN700 North

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Option summary – Cost and Carbon

	1 Algorithm Solution	2 All Steel	3 DN700 North
CAPEX	£404.1 m	£424.1 m	£413.7 m
WL Cost	£409.9 m	£449.9 m	£430.8m
WL Carbon	125,351 t CO_2e	124,172 t CO_2e	124,231 t CO_2e

Note: The above table is for the entire scheme, however only the northern scope is being changed between the options.

Number above are not actual and only indicative.

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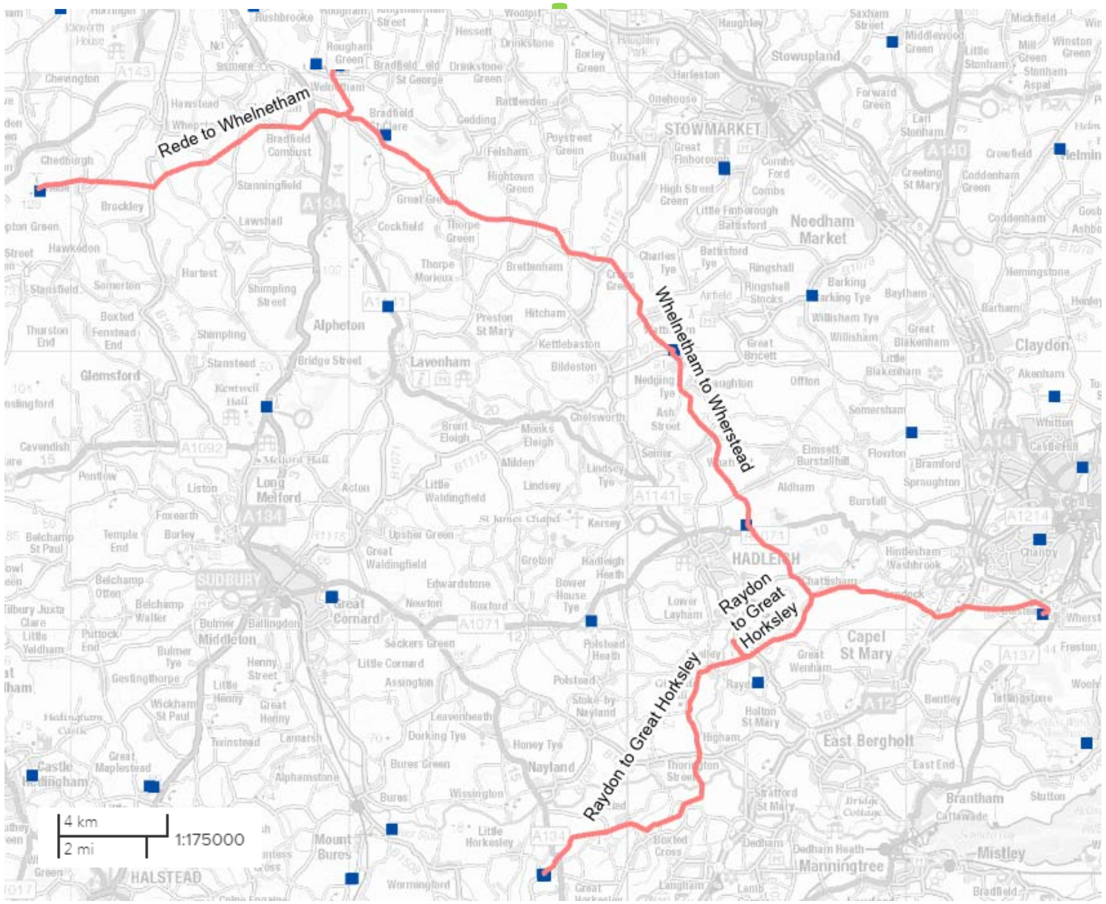
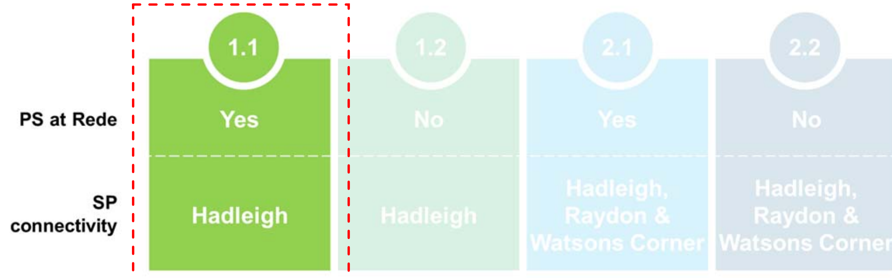
Option 1.1: PS at Rede, Hadleigh



Cost components	£m
CAPEX (whole spine, pipeline, PS + WR)	56.088
OPEX (NPV, 40 years, 3.7%)	2.826
Whole Life Cost	**58.914**

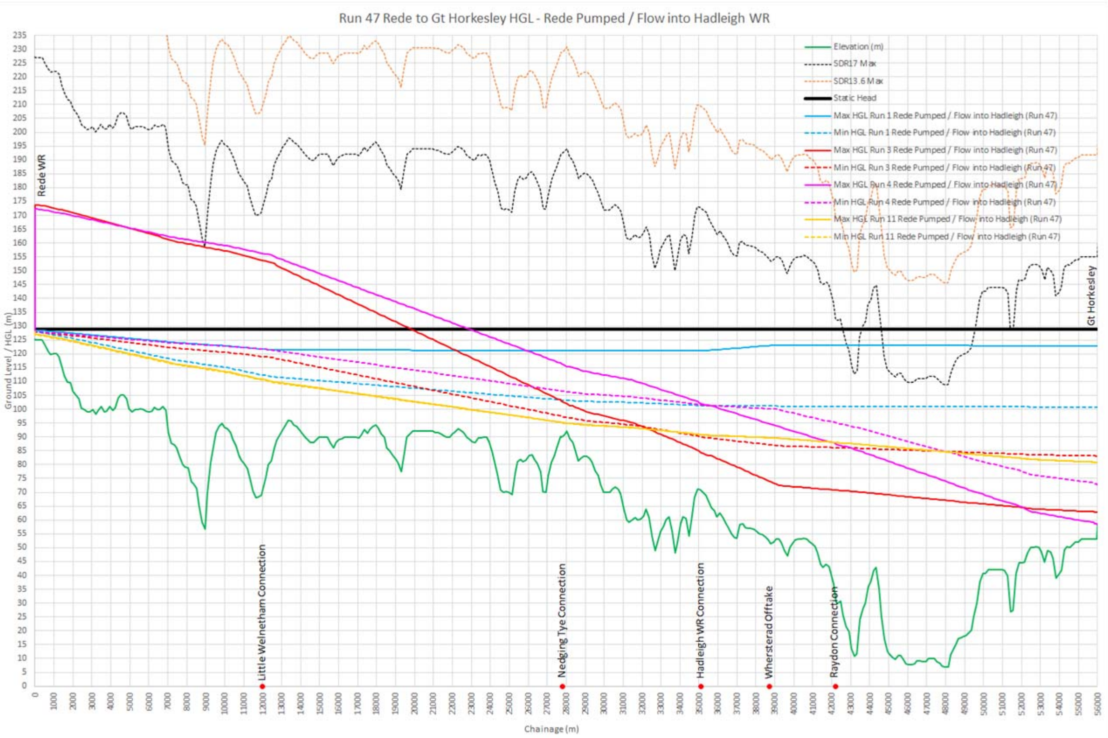
Carbon components	t CO_2e
Emb. carbon (whole spine, pipeline, PS + WR)	13,317
Carbon (operational energy, 40 year)	609
Whole Life Carbon	**13,926**

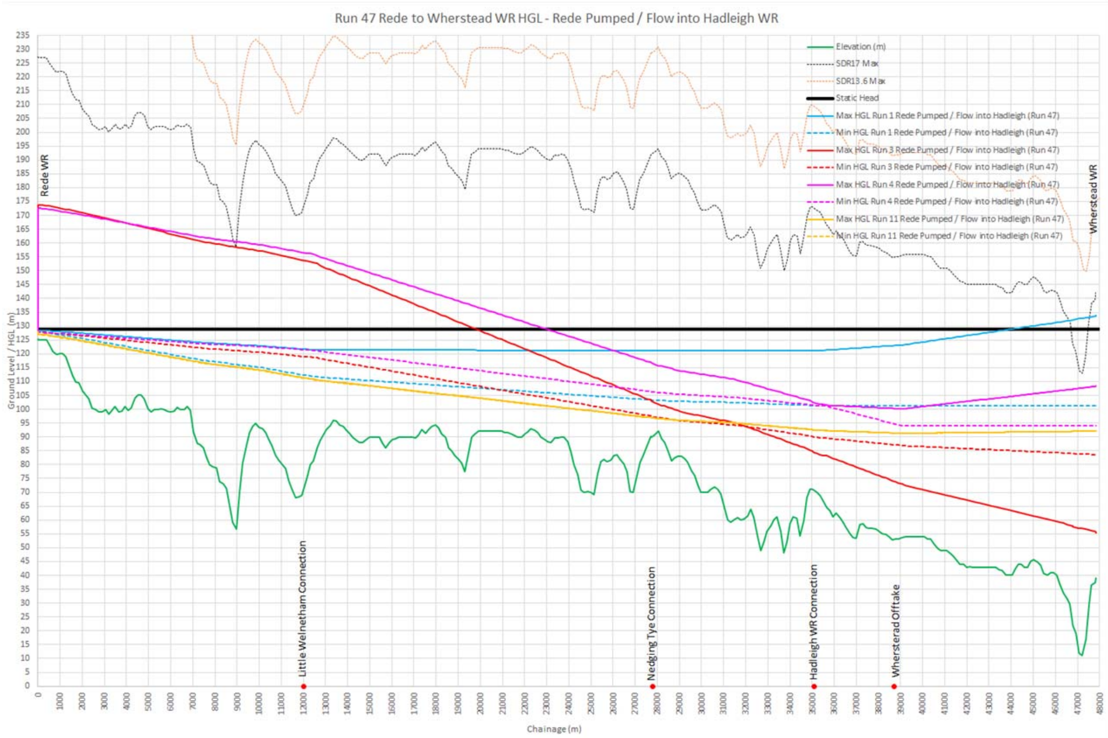


Number above are not actual and only indicative.

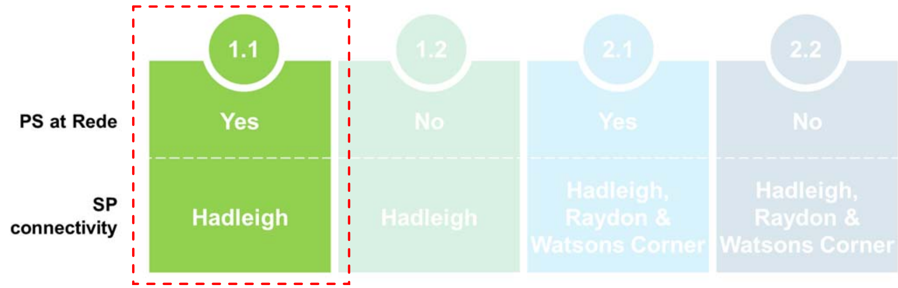
Option 1.1: PS at Rede, Hadleigh

(run 47)





Pipeline hydraulic profiles



Benefits – Outputs of the Modelling Optimisation

- Reduced pipe size and length £57.7m
- Reduced storage – total 66ML to 32ML - £7.8m
- Reduced carbon – 13,350 Tonnes of CO_2e
- Reduced pump sizes – £7.4m

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Optimatics Benefits

Activities could be carried out traditionally, so why use this software?

- Tight timescales required quick turnaround of options
  - The design challenges meant sizing needed to be robust
  - Did we analyse all options thoroughly?
  - Do we understand the impact on the existing networks?
- The quantity of criteria
  - The system became more complex as we progressed south
  - An estimate of manual effort with the number of options for the south region was equal to 1.1 million modeller hours
- Sizing and costing for carbon and TOTEX were carried out together

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Any questions?

Jacobs
Challenging today.
Reinventing tomorrow.

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Thank you for listening