AECOM

Memorandum

To	John Haasen	Page	1
CC			
Subject	**Arva PS to Huron Transmission Main Twinning – Hydraulic Evaluation**		
From	Eppo Eerkes, P. Eng.		
Date	October 6, 2020	Project Number	60619503

The City of London is evaluating alternative routes for the transmission main from Arva Pumping Station (PS) to Huron St. (Arva to Huron feedermain). Seven (7) alternative routes are being evaluated as part of the EA. The hydraulic and transient screening evaluation was completed to assess each route alternative. The intent was to compare the relative hydraulic and transient performance of each alternative route with the baseline condition. The baseline condition included all future capital works based on the Water Master Plan, with the exception of the Arva to Huron feedermain. Sizing of the proposed main was based on the Water Master plan and was not evaluated or updated Response as part of this analysis.

Results are discussed in the following sections and are shown on Table 1 below.

The analysis evaluated hydraulic parameters, including system pressure, pipe velocity / head loss gradient, storage operation and pumping energy usage using the 2041 maximum day demand (MDD) scenario for the baseline and for each route alternative. The analysis also evaluated water age using the existing average day demand (ADD) scenario for each alternative. A hydraulic transient screening assessment was also completed for each route.

The following are the routes that were assessed:

- Route 1 - Richmond Route B - Sunningdale Connection
- Route 2 - Richmond Route B - Fanshawe Connection
- Route 3 - Richmond Route A - Sunningdale Connection
- Route 4 - Richmond Route A - Fanshawe Connection
- Route 5 - Adelaide Route - Sunningdale Connection
- Route 6 - Adelaide Route - Medway Connection
- Route 7 - Adelaide Route - Fanshawe Connection

<u>Design criteria</u>

The following hydraulic design criteria was utilized to evaluate the feedermain routing alternatives:

- Minimum pressure 275 kPa (40 psi).
- Maximum target high pressure 550 kPa (80 psi) under normal conditions and 690 kPa (100 psi). under any demand condition.

- Maximum watermain velocity 1.5 m/s.
- A maximum head loss gradient of 2.3 m/km was used.
- Minimum transient pressures below atmospheric (negative) were flagged for the route alternatives.

Hydraulic model set up

Model setup is discussed as follows:

- Hydraulics were evaluated for the 2041 MDD 24-hour extended period simulation (EPS), which includes the 2041 peak hour demand (PHD), as well as the 2021 ADD scenario.
- Each route alternative, as well as the baseline scenario was added as a separate scenario using the InfoWater scenario manager.
- The 2041 analysis included the 100 ML storage addition proposed at the Springbank Reservoir.
- Springbank Reservoir was initialized at 75%.
- Arva PS and SERPS pump operation was set to be constant for each alternative scenario.
- Results for normal operation are presented in Table 1.

The route alternative evaluation is discussed in the following sections.

Pipe Velocity / Headloss Gradient

For the baseline scenario under the 2041 MDD, as well as for all the alternative routes, with the exception of Route 6, the existing twin 1050 mm Arva feedermains north of Sunningdale Rd. largely exceed the velocity and head loss criteria discussed above. These would be within the criteria for the Route 6 alternative. This should be a significant factor in selecting the preferred route.

For the existing twin mains south of Sunningdale Road, the maximum velocity and headloss would be within the criteria for the baseline and for all of the alternative routes.

For the existing single 1050 mm main south of Fanshawe Park Rd., the maximum velocity and headloss slightly exceeds the criteria for the baseline scenario and are within the criteria for all of the alternative routes.

For the alternative routes, all of the proposed twin main alternatives would operate within the criteria. The Route 6 alternative would have the highest peak flow.

Pressure

As shown on Table 1, addition of the twinned feedermain will provide a slight pressure increase relative to the baseline to Chamber 13 and Clark / Huron.

The most critical area is the northeast corner of the system, or the area of the system bounded by Huron, Dundas, Highbury and Crumlin Sideroad. The highest junction elevation within this area is located at Huron St., east of Clarke Rd., with an elevation of 277.5 meters. There will be a marginal pressure drop within this area with the addition of the proposed main for all the alternatives except Route 6, which has a marginal pressure rise, however this will not be significant.

The lower pressures within the northeast corner of the system are slightly below the criteria. This is mainly due to the higher elevation above 275 meters, and as such, the addition of the new main will not significantly benefit this area in terms of pressures.

For the alternative routes assessed, Route 6 would provide the highest pressure, however by an insignificant amount. Therefore, based on the analysis, pressure criteria would not be significant factor in selecting the preferred route.

Springbank Storage Operation

The analysis evaluated Springbank storage balancing, or the difference between the initial and final level, as well as the maximum level attained during the day. This was completed for the 2041 maximum day demand scenario for each route. Results are as shown on Table 1.

For the baseline scenario, without the proposed feedermain, there is a net deficit of storage volume of 5% during the 24 hour simulation. The Route 6 alternative attains the highest maximum storage level and balances storage volume over the course of the simulation. The other routes show a slight storage improvement.

The storage operation criteria would be a moderate factor in selecting the preferred route.

Pumping Energy

Pumping energy usage for Arva PS was assessed for the feedermain routing alternatives. This was assessed based on pumping energy usage per water volume pumped (kW-Hr / ML), based on the model as shown on Table 1. These were compared with the baseline energy use without the proposed feedermain in place.

All of the alternatives considered showed a slight reduction in Arva PS pumping energy usage. The Route 6 alternative shows the lowest energy use, with a 3.6 percent reduction in energy per volume from the baseline scenario.

Pumping energy usage would be a moderate factor in selecting the preferred route.

Water Age

Water age was evaluated for the 2021 ADD scenario, including the baseline and the proposed route alternatives. Water age is defined as the residence time within the system as the water travels from Arva Reservoir to Chamber 13. This was assessed to determine the relative difference in water age for each route alternative relative to the baseline scenario, as well as to demonstrate the overall change in water age as a result of the implementation of the proposed main. The analysis was completed for a 7-day period.

Table 1 below shows the average water age during the 7-day simulation at Chamber 13 for each route alternative. This shows very slight age increase for most of the route alternatives, with the highest being Route 5, and the lowest being Route 7, however the water age would be acceptable at this location for each of the route alternatives, so water age considerations would not be a determining factor in the route selection.

Hydraulic Transients

Transients occur when the system changes from one steady state condition to another due to a control action at a hydraulic device. The change in flow velocity will cause a change in pressure (increase or drop). This can occur rapidly or gradually. Pressure fluctuations initiate at the transient source and propagate, reflect and oscillate through the system until dampened by friction or relief points.

A detailed transient analysis was completed for the existing system using the transient model, without the new main in place. This simulated a global power failure of Arva PS / SERPS pumps during high pumping conditions, which is likely the worst case.

Preliminary alternative route pipeline profiles were generated based on ground elevation for each route alternative. The model results of the existing system analysis, in terms of minimum and maximum transient pressures, was extrapolated to each route alternative for comparison purposes. This evaluated the impact to the proposed Arva to Huron feedermain, in terms of minimum and maximum surge pressures. The analysis did not specifically model each route alternative.

Table 3 below shows a summary of the transient screening review based on the preliminary alternative route profiles. Evaluation results are shown for the extent of each feedermain alternative.

The evaluation was based on the following criteria:

- Estimated maximum transient pressure.
- Estimated minimum transient pressure.
- The total length of each main alternative under negative transient pressure - Transient and water quality issues (e.g. groundwater intrusion) can occur during negative pressure conditions and should be avoided if possible. This can be mitigated by deepening the pipe in critical sections, however this will impact the overall cost of the alternative.
- The length of main with an elevation above 275 metres - Construction below 275 metres elevation will minimize the potential for negative transient pressures during the lifetime of the main.
- The number of air valves required was estimated based on the preliminary profiles. Air valves will have maintenance, reliability and water quality issues. It is noted that these are estimates only and that actual air valve requirements can often be reduced through design.

Results should be modelled with the preferred route selection. This evaluation is not intended as a formal transient analysis of the proposed main. This must be completed by others during detailed design.

Based on the evaluation, the following is noted:

- The results did not indicate maximum surge pressures exceeding the steady state HGL.
- Alternative Routes 1 and 3 are most likely to be susceptible to negative transient pressures. This would likely require extensive lowering of the pipe for the initial 1.5 km to mitigate the negative pressure potential.
- Although the analysis indicates positive downsurge pressures will occur, alternative Routes 5 and 6 are potentially susceptible to negative transient pressures, as they would have a portion of the main at an elevation above 275 meters. Route 5 has a significant portion, while Route 6 has a minor portion, which could be mitigated through pipe design.

Although the limitations discussed above regarding negative transient pressure potential can be mitigated during design of the pipeline, this would likely significantly add to the construction cost. Therefore, the transient potential as discussed above should be a significant factor in ruling out or selecting the preferred route.

Air valve Requirements

A preliminary evaluation of air valve requirements was also estimated based on the preliminary alternative feedermain elevation profiles for each route. Based on the preliminary profiles, Route 5 would require the most air valves, while Route 2 would have the least. This would only be a minor factor in route selection.

Existing 1050 mm main offline

Analysis was also completed to compare the above hydraulic results for the route alternatives for the case with a portion of the existing single 1050 mm main offline at Fanshawe Park Road. This is presented in Table 2.

Based on the evaluation, the following is noted:

- With this portion of the main off-line, route Alternative 6 shows the highest pressure improvement at Chamber 13.
- Route 6 has the highest improvement in Springbank Reservoir filling, however by only a minor margin.
- Route 6 has similar results for velocity and headloss as discussed above.
- With the existing main offline, velocity and headloss will be higher for the twinned section for all the alternatives.

Table 1 - Hydraulic Screening of Route Alternatives

Route	Route Alternative		Minimum Pressure			Springbank Storage Level (m) (1)		Arva Main N. Sunningdale		Twinned Main			Arva Energy / Volume (kW-Hr/ML/d)	Average Water Age (Hrs.)
			Chamber 13 Pressure (psi)	Clark / Huron Pressure (psi)	NE Corner - High Node Pressures (psi)	Maximum Level (% Full)	Difference (m)	Max Velocity (m/s)	Max HLG (m/km)	Max Flow (L/s)	Max Velocity (m/s)	Max HLG (m/km)		Chamber 13
Baseline			87	48	39	81%	0.38	2.0	3.19	0	0.0	0.00	137.4	10.6
1	Arva to Huron Trans Main - Richmond Route B - Sunningdale Connection	Twins main from north of Sunningdale to Ch. 13	88	47	38	82%	0.19	2.0	3.44	985	1.1	0.99	134.9	11.7
2	Arva to Huron Trans Main - Richmond Route B - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	88	47	38	82%	0.22	2.0	3.39	901	1.0	0.84	135.3	11.6
3	Arva to Huron Trans Main - Richmond Route A - Sunningdale Connection	Twins main from north of Sunningdale to Ch. 13	88	47	38	82%	0.19	2.0	3.43	926	1.1	0.89	135.0	11.7
4	Arva to Huron Trans Main - Richmond Route A - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	88	47	38	82%	0.22	2.0	3.38	897	1.0	0.84	135.4	11.4
5	Arva to Huron Trans Main - Adelaide Route - Sunningdale Connection	Twins main from Sunningdale to Ch. 13	88	47	38	82%	0.20	2.0	3.42	848	1.0	0.75	135.1	11.7
6	Arva to Huron Trans Main - Adelaide Route - Medway Connection	Full twinning main from south of Arva PS to Ch. 13MP route	88	48	39	83%	0.00	1.5	2.04	1096	1.3	1.20	132.4	11.7
7	Arva to Huron Trans Main - Adelaide Route - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	88	47	38	82%	0.23	2.0	3.38	844	1.0	0.75	135.4	11.1

Notes
(1) S/B initial level 75%
Assumed 1050 mm for all routes, notwithstanding the MP used 900 mm for portions of Route6
(2) Water age based on 2021 ADD scenario

Table 2 - Hydraulic Screening of Route Alternatives – Existing Main off-line

Route	Route Alternative		Minimum Pressure			Springbank Storage Level (m) (1)		Arva Main N. Sunningdale		Twinned Main			Arva Energy / Volume (kW-Hr/ML/d)
			Chamber 13 Pressure (psi)	Clark / Huron Pressure (psi)	NE Corner - High Node Pressures (psi)	Maximum Level (% Full)	Difference (m)	Max Velocity (m/s)	Max HLG (m/km)	Max Flow (L/s)	Max Velocity (m/s)	Max HLG (m/km)	
Baseline			78	51	42	78%	1.30	1.6	2.24	0	0.0	0.00	151.5
1	Arva to Huron Trans Main - Richmond Route B - Sunningdale Connection	Twins main from north of Sunningdale to Ch. 13	86	48	39	81%	0.42	1.9	3.14	1370	1.6	1.83	139.9
2	Arva to Huron Trans Main - Richmond Route B - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	86	48	39	81%	0.40	1.9	3.16	1438	1.7	2.00	139.6
3	Arva to Huron Trans Main - Richmond Route A - Sunningdale Connection	Twins main from north of Sunningdale to Ch. 13	87	48	39	81%	0.40	1.9	3.16	1406	1.6	1.92	139.6
4	Arva to Huron Trans Main - Richmond Route A - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	87	48	39	81%	0.37	2.0	3.19	1473	1.7	2.10	139.2
5	Arva to Huron Trans Main - Adelaide Route - Sunningdale Connection	Twins main from Sunningdale to Ch. 13	86	48	39	81%	0.44	1.9	3.11	1333	1.5	1.74	140.1
6	Arva to Huron Trans Main - Adelaide Route - Medway Connection	Full twinning main from south of Arva PS to Ch. 13MP route	86	49	40	82%	0.35	1.3	1.58	1140	1.8	2.76	138.9
7	Arva to Huron Trans Main - Adelaide Route - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	87	48	39	81%	0.42	1.9	3.13	1354	1.6	1.79	139.9

Notes
(1) S/B initial level 75%
Assumed 1050 mm for all routes, notwithstanding the MP used 900 mm for portions of Route6

Table 3 - Transient Screening of Route Alternatives

Route	Route Alternative		Total Length New Main (m)	Estimated Values based on Interpolated Model Results: Maximum SS Pressure (psi)	Minimum SS Pressure (psi)	Min Transient Pressure (Estimated) (psi)	Length of Main under Negative Pressure (m)	Length of Main above 275 metres elevation (m)	Number of Air Valves Required (1)	Evaluation
1	Arva to Huron Trans Main - Richmond Route B - Sunningdale Connection	Twins main from north of Sunningdale to Ch. 13	6,300	114	49	-2.6	300	1,406	4	Susceptible to negative transient pressures
2	Arva to Huron Trans Main - Richmond Route B - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	4,800	110	86	35.8	0	0	3	
3	Arva to Huron Trans Main - Richmond Route A - Sunningdale Connection	Twins main from north of Sunningdale to Ch. 13	6,600	116	49	-2.2	300	1696	4	Susceptible to negative transient pressures
4	Arva to Huron Trans Main - Richmond Route A - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	5,100	115	86	36.0	0	0	5	
5	Arva to Huron Trans Main - Adelaide Route - Sunningdale Connection	Twins main from Sunningdale to Ch. 13	6,600	113	56	1.2	0	936	8	Potentially susceptible to negative transient pressures
6	Arva to Huron Trans Main - Adelaide Route - Medway Connection	Full twinning main from south of Arva PS to Ch. 13	9,900	108	60	0.4	0	285	4	Potentially susceptible to negative transient pressures
7	Arva to Huron Trans Main - Adelaide Route - Fanshawe Connection	Only twins single main portion south of Fanshawe Pk. to Ch. 13	5,113	108	90	35.2	0	0	6	
	Importance		H	M	L	H	H	M	L	
			Evaluate cost vs. hydraulic benefit - see evaluation	Affects pipe class	Maintain City pressure criteria	Transient and water quality issue (intrusion); Can be mitigated by deepening pipe in critical sections		Construction below 275 metres will minimize the potential for negative transient pressures for the main lifetime	Maintenance, reliability and water quality issues; Could be reduced through design	

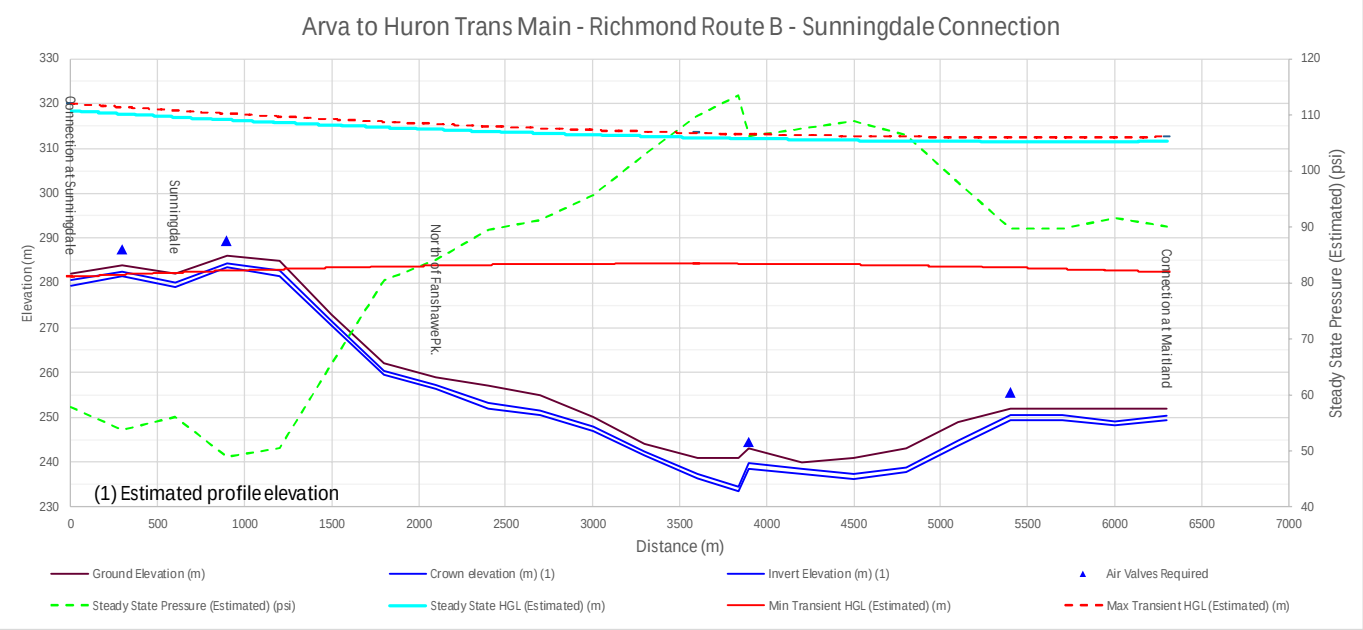

Figure 1 – Feedermain Alternative Route 1 Approximate Transient Profile

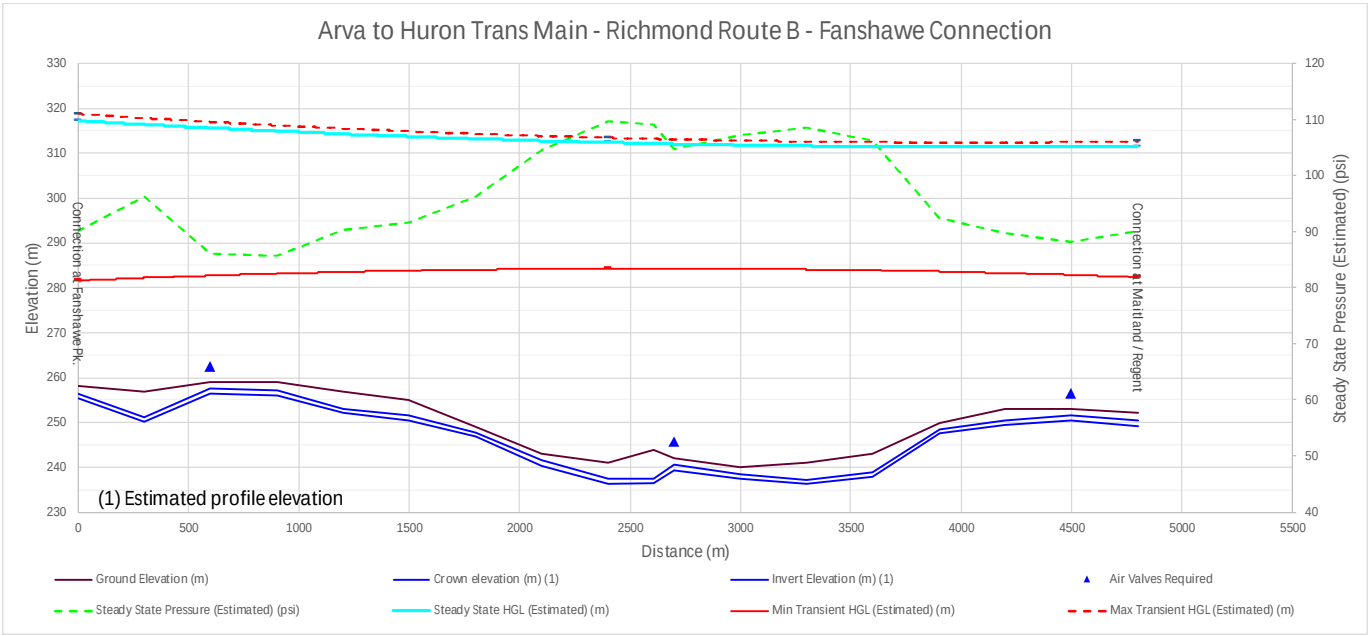

Figure 2 – Feedermain Alternative Route 2 Approximate Transient Profile

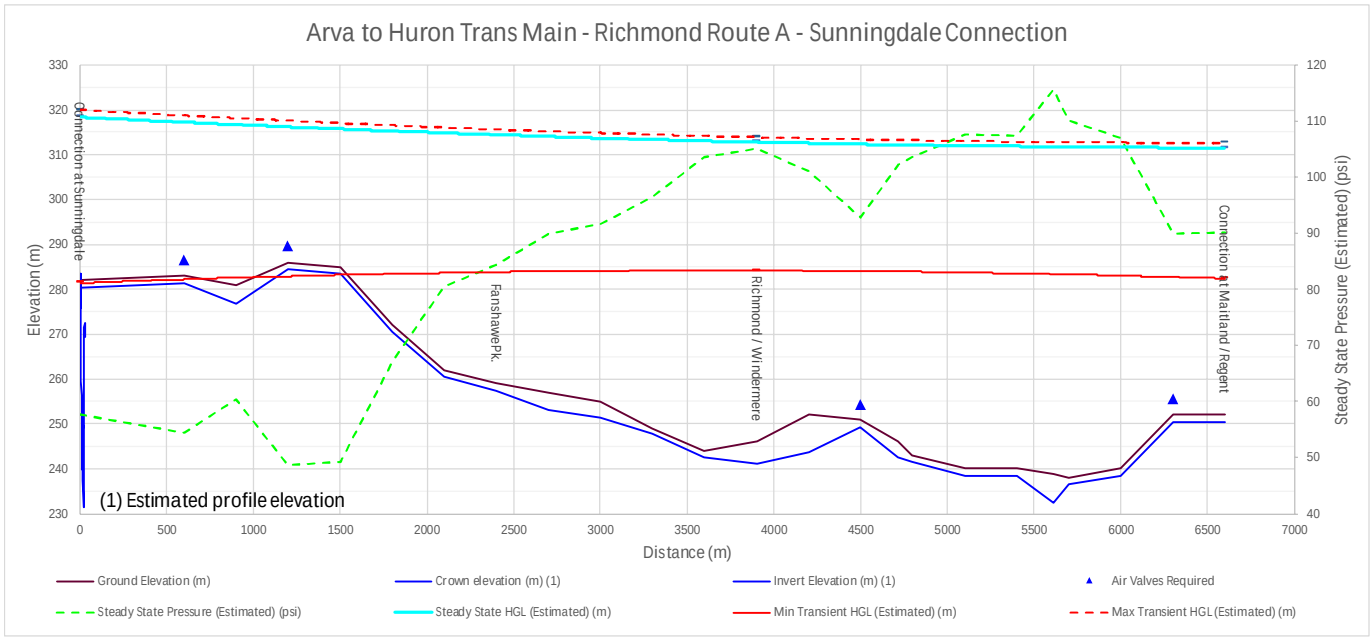

Figure 3 – Feedermain Alternative Route 3 Approximate Transient Profile

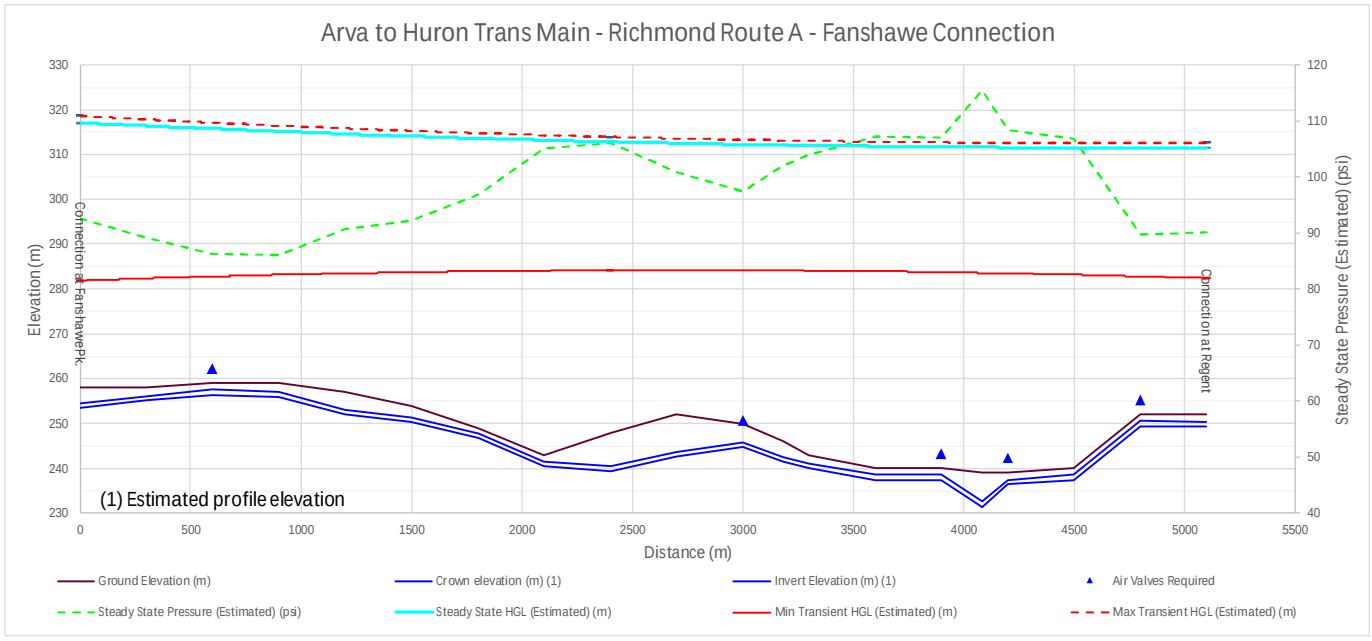

Figure 4 – Feedermain Alternative Route 4 Approximate Transient Profile

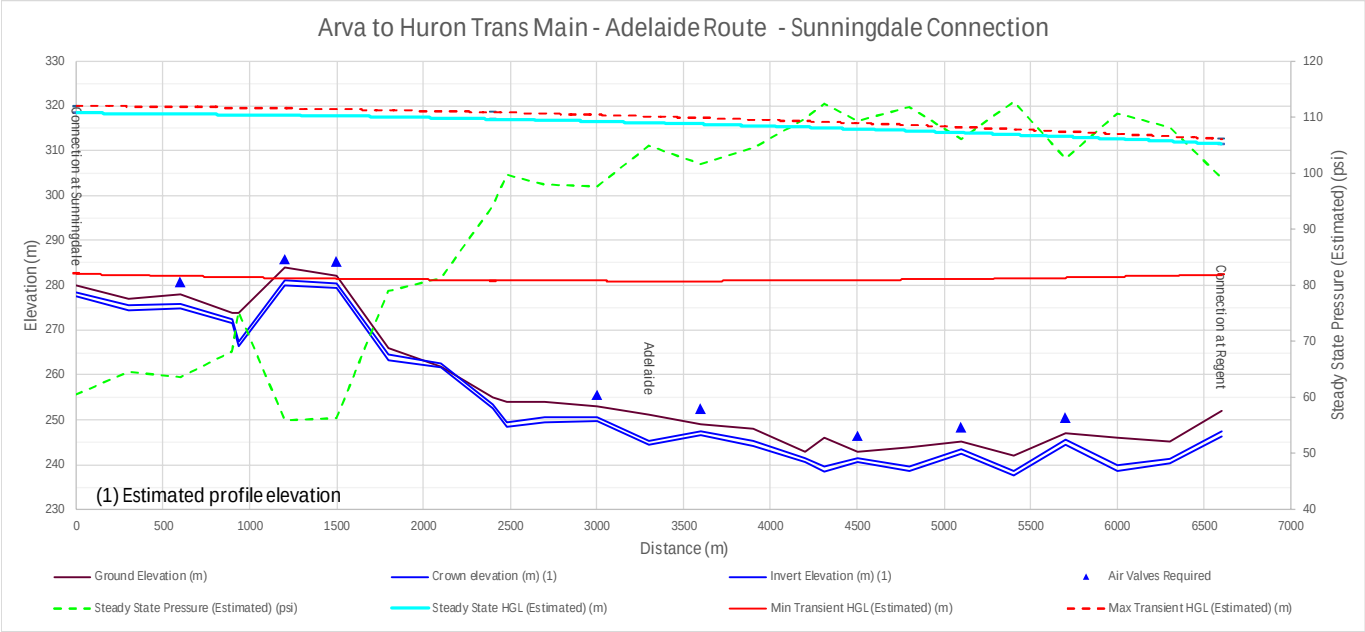

Figure 5 – Feedermain Alternative Route 5 Approximate Transient Profile

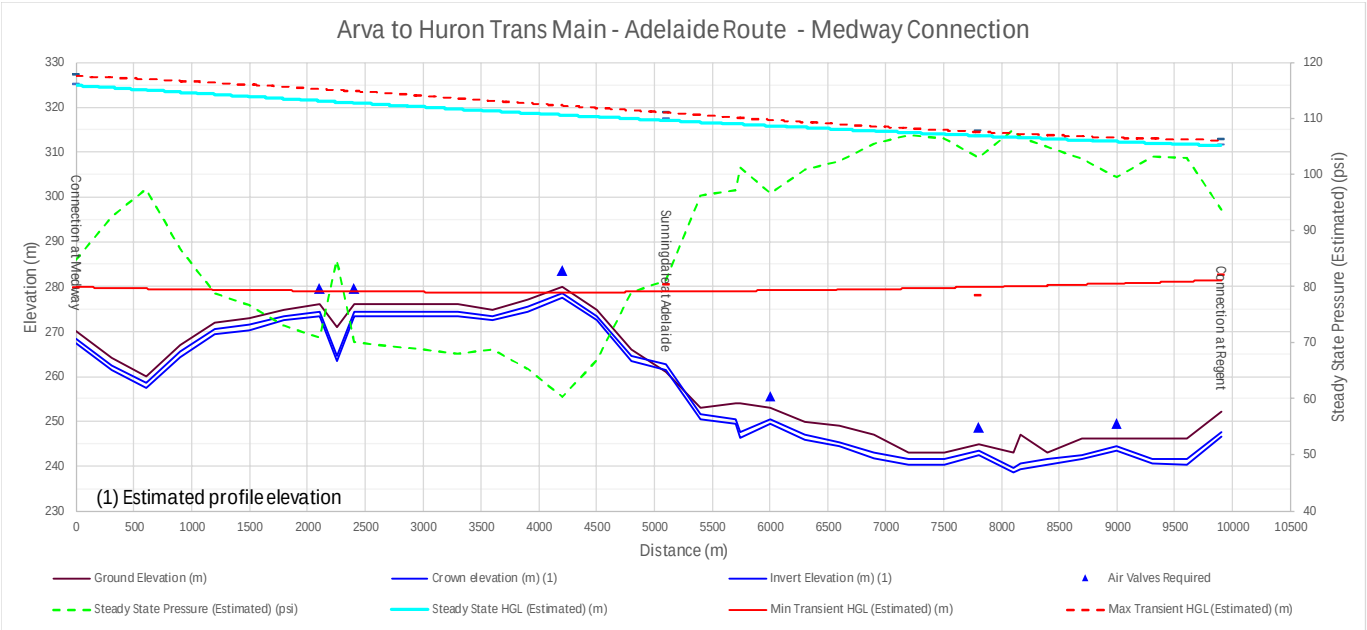

Figure 6 – Feedermain Alternative Route 6 Approximate Transient Profile

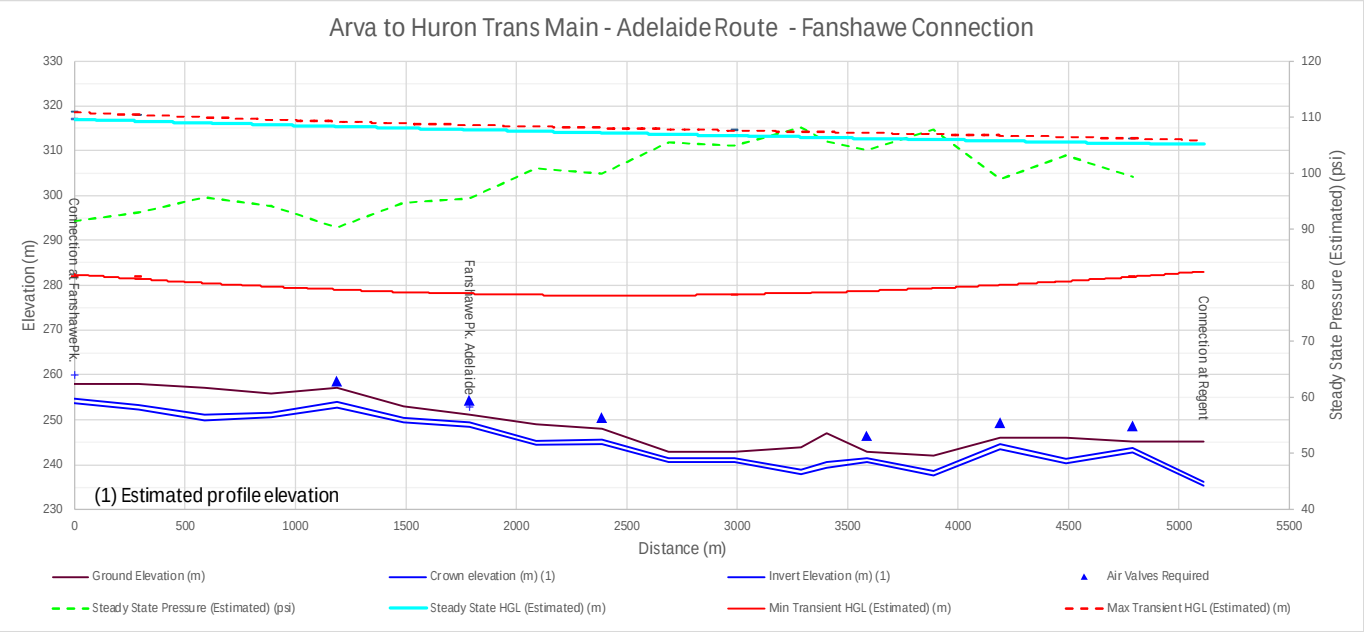

Figure 7 – Feedermain Alternative Route 7 Approximate Transient Profile

Report Prepared By:

Eppo Eerkes, P. Eng.
Senior Hydraulic Modelling Engineer