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Your Ref:

16th May 2012

Mr M Lee
Wilts and Berks Canal Trust
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Bath
BA2 9AB

Dear Mr Lee

Melksham link – Berryfield Brook Culvert
Hydraulic modelling

We have completed the hydraulic modelling work relating to the proposed aqueduct on the Berryfield Brook, as requested in your instruction dated 14th June 2011 and detailed in our proposal letter dated 12th July 2011. The work undertaken is described below, along with the results of the analysis. We have also provided comment on the implications of the chosen design.

Given the vertical alignment of the proposed canal restoration the crossing of the Berryfield Brook is not straightforward and there are no simple options. Your option, as shown in Drawings No 11 and 12 (June 2011), shows a practical option which has formed the basis of this assessment.

Review and Update of Existing Hydraulic Model

An existing HEC-RAS hydraulic model was provided by the Environment Agency for the Berryfield Brook. This was constructed as part of the S105 Hydraulic Study of Forest, Clackers and Berryfield Brooks in 1997. The primary focus of this study was to produce Level 2 flood maps for the named watercourses.

A long-section profile of the entire length of the Berryfield Brook is shown below in Figure 1, along with the 1 in 100 annual probability flood level estimated during the 1997 study.

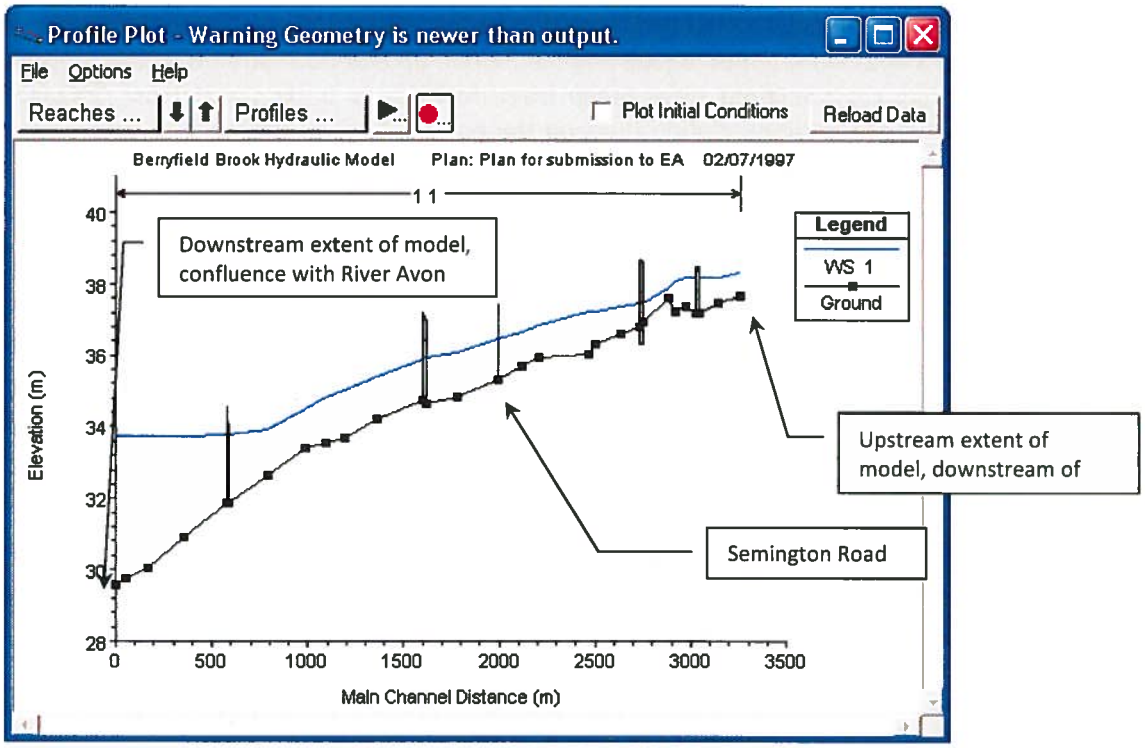


Figure 1: Long-Section profile of the Berryfield Brook

In the area of the proposed aqueduct (approximately 115m downstream of Semington Road) cross-sections were located on the upstream and downstream side of Semington Road and 240m further downstream, behind No.75 Berryfield Park.

The cross-sections downstream of Semington Road and behind No.75 Berryfield Park were reviewed and the bed and bank levels noted. The following long-section was derived (Figure 2):

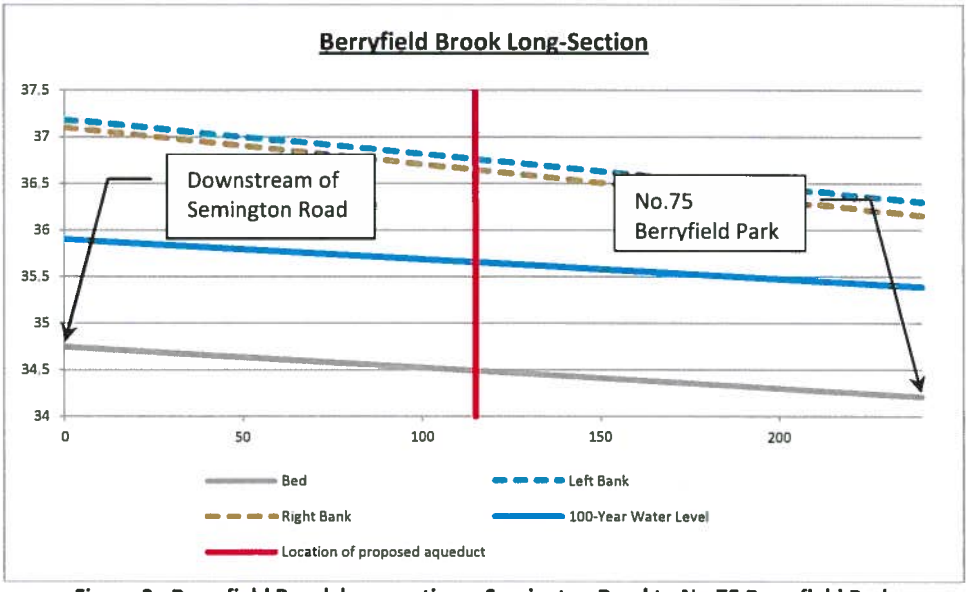


Figure 2: Berryfield Brook long-section – Semington Road to No.75 Berryfield Park

Some changes had to be made to the hydraulic model to enable the model to be run in the latest version of HEC-RAS (4.1.0).

To ensure that sufficient detail was provided in the area of interest, two additional cross-sections (1.084 and 1.081) were added to the original model, up and downstream of the proposed aqueduct. These existing cross-sections were taken from the Wilts & Berks Canal Trust Drawing No.12. The inclusion of these sections slightly reduced the baseline flood levels in the vicinity of the proposed crossing for a given flow.

Calculation of Flood Flows

A review was undertaken of the hydrological assessment undertaken as part of the 1997 S105 study. The hydrological assessment was based upon the Flood Studies Report methodologies, with adjustments made to account for the small size of the catchment and urban nature of the upper catchment.

A new high level hydrological analysis was undertaken for the Berryfield Brook based on the latest methodologies described in the Flood Estimation Handbook (FEH). As the key criteria of this study is to show that the proposed aqueduct does not increase flood risk in the area, the accuracy of defined annual probability flow values is of less importance. Therefore, the proposals were tested using a range of 1 in 100 annual probability flows estimates for the Berryfield Brook.

1 in 100 annual probability flows were generated for the Berryfield Brook using three methods - the FEH Statistical, the FEH Rainfall-Runoff and the Revitalised Rainfall-Runoff methodologies. The flows derived can be seen below in Table 1.

Methodology	Flow (m^3/s)
FEH Statistical	2.3
Revitalised Rainfall-Runoff	2.7
FEH Rainfall-Runoff	4.5

Table 1: 1 in 100 annual probability flow estimates

As the table above shows, there was a wide range in possible 1 in 100 annual probability flow estimates for this catchment, varying between 2.3 and 4.5m^3/s (the 1997 S105 study used a value of 3.6m^3/s). Based on experience of similar catchments in the area, it was considered that both the FEH Statistical and Revitalised Rainfall-Runoff methods were likely to underestimate flows for this type of catchment. Whilst it was possible that the FEH Rainfall-Runoff method was overestimating flows, it seemed prudent to base the hydraulic assessment on this 1 in 100 annual probability estimate to offer a worst case scenario.

To make an allowance for climate change, 20% was added to the FEH Rainfall-Runoff 1 in 100 annual probability flow estimate, giving a value of 5.4m^3/s, which was taken forward for use in the hydraulic assessment.

Modelling of Proposed Culvert

Details of the proposed aqueduct were provided by Wilts & Berks Canal Trust on 15th June 2011. The proposed aqueduct relates to Outline Design Rev3. This includes the following which have been taken from the Rev3 design notes and Wilts & Berks Canal Trust Drawing No.s 11 and 12:

- Installation of 2 rectangular culverts with total width of 7m and height of 0.75m (open width of each culvert taken as 3m with a 1m dividing wall);
- Culvert length of approximately 12m, skewed across the channel at an angle of approximately 45 degrees;
- Culvert soffit level of 34.85mAOD;
- Culvert invert level of 34.10mAOD;

- Lowering the existing bed level of Berryfield Brook locally by approximately 310mm (from 34.41mAOD to 34.10mAOD at both ends of the culvert);
- Installation of retaining walls in the approach channel and outlet channel (extending along the length of channel to be re-graded); and
- Armouring of channel bed with grouted block work or concrete slab for a length of approximately 15m up and downstream of the culvert.

The hydraulic model was revised to reflect the proposed aqueduct detailed above. Four additional cross-sections were added to the model, two upstream of the culvert and two downstream. The two cross-sections upstream of the proposed aqueduct represented the proposed cross-section B-B shown on the Wilts & Berks Canal Trust Drawing No.12 and represented the lined and re-graded channel upstream of the aqueduct, at approximately 15m in length. The two cross-sections downstream of the proposed aqueduct represented the proposed cross-section C-C shown on the Wilts & Berks Canal Trust Drawing No.12 and represented the lined and re-graded channel downstream of the aqueduct, again approximately 15m in length. Manning's 'n' values of 0.048 were applied to these four cross-sections to represent a relatively poorly maintained man-made channel, offering a worst case scenario.

The proposed aqueduct was represented in the model by two culverts with central wall. Each culvert was 3m x 0.75m. Manning's 'n' values of 0.02 were applied to the culverts, to represent an unmaintained culvert scenario. As with the lined channel up and downstream, this represents a worst case scenario. The deck level represented the coping level of the canal above the river at 36.95mAOD.

The configuration of the culverts can be seen in Figure 3 below.

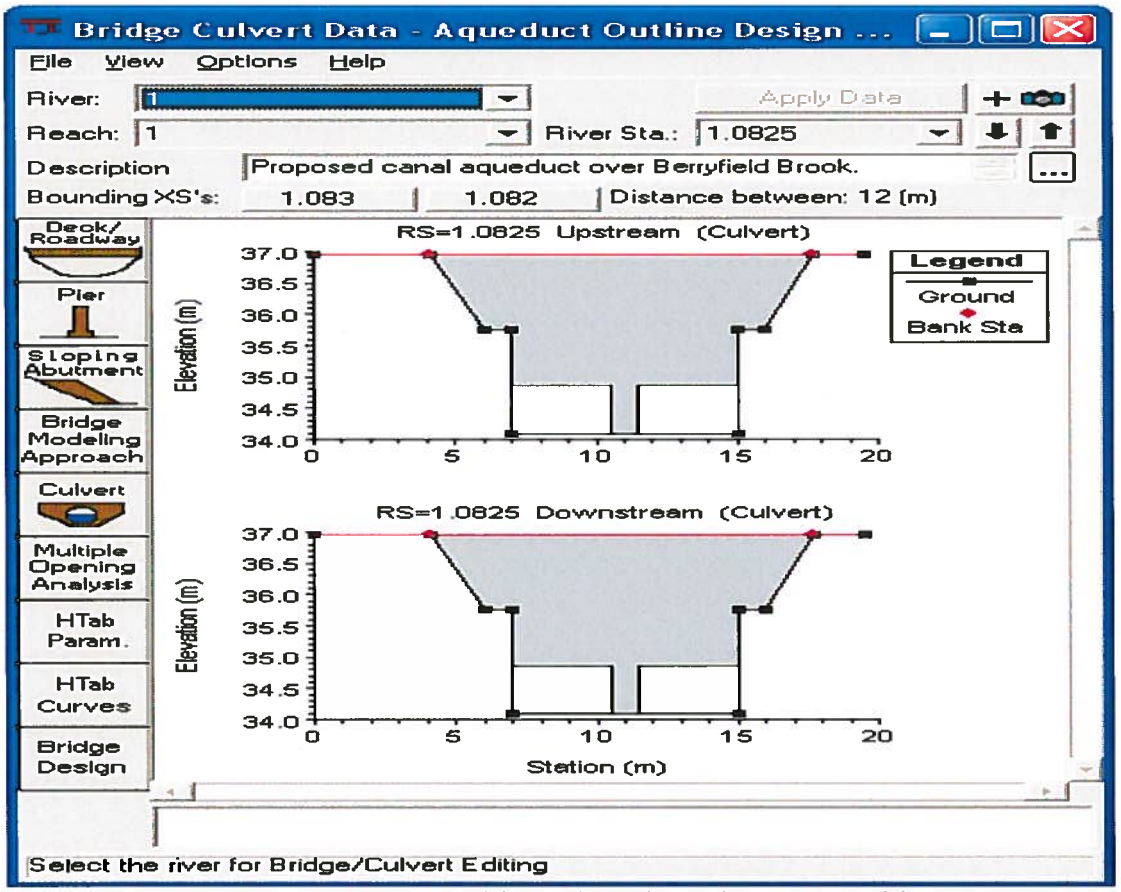


Figure 3: Representation of the canal aqueduct in the HEC-RAS model

Analysis

The updated baseline model and aqueduct model were run using the final 1 in 100 annual probability flow estimate including a 20% increase to allow for climate change (5.4m^3/s).

The results of the modelling indicate that the addition of the canal aqueduct reduces water levels between the proposed aqueduct and Semington Road, by up to 120mm compared to the existing situation (see Table 2) and water is retained well within bank (see Figure 4). Upstream of Semington Road water levels are reduced along a 150m length, by up to 100mm, and downstream of the proposed aqueduct, water levels reduce by up to 40mm. It is also noted that the water levels upstream of the proposed aqueduct are 1,070mm below the coping level of the aqueduct, which is proposed to be at 36.95mAOD.

The reduction in flood levels is primarily a result of the local regarding of the Berryfield Brook in the vicinity of the culvert. Because the channel is relatively incised even minor regarding can help reduce flood levels.

Cross-Section	1 in 100 Annual Probability Water Level (mAOD)		Difference (mm)
	Updated Baseline Model	Aqueduct Model	
1.100	36.31	36.28	-30
1.090	36.06	35.96	-100
1.085(downstream of Semington Road)	36.03	35.91	-120
1.084	35.90	35.88	-20
1.083 (upstream of proposed aqueduct)	-	35.88	-
1.082(downstream of proposed aqueduct)	-	35.83	-
1.081	35.87	35.83	-40
1.080(behind No.75 Berryfield Park)	35.74	35.74	0

Table 2: Comparison of water level results from the updated baseline model and the aqueduct model

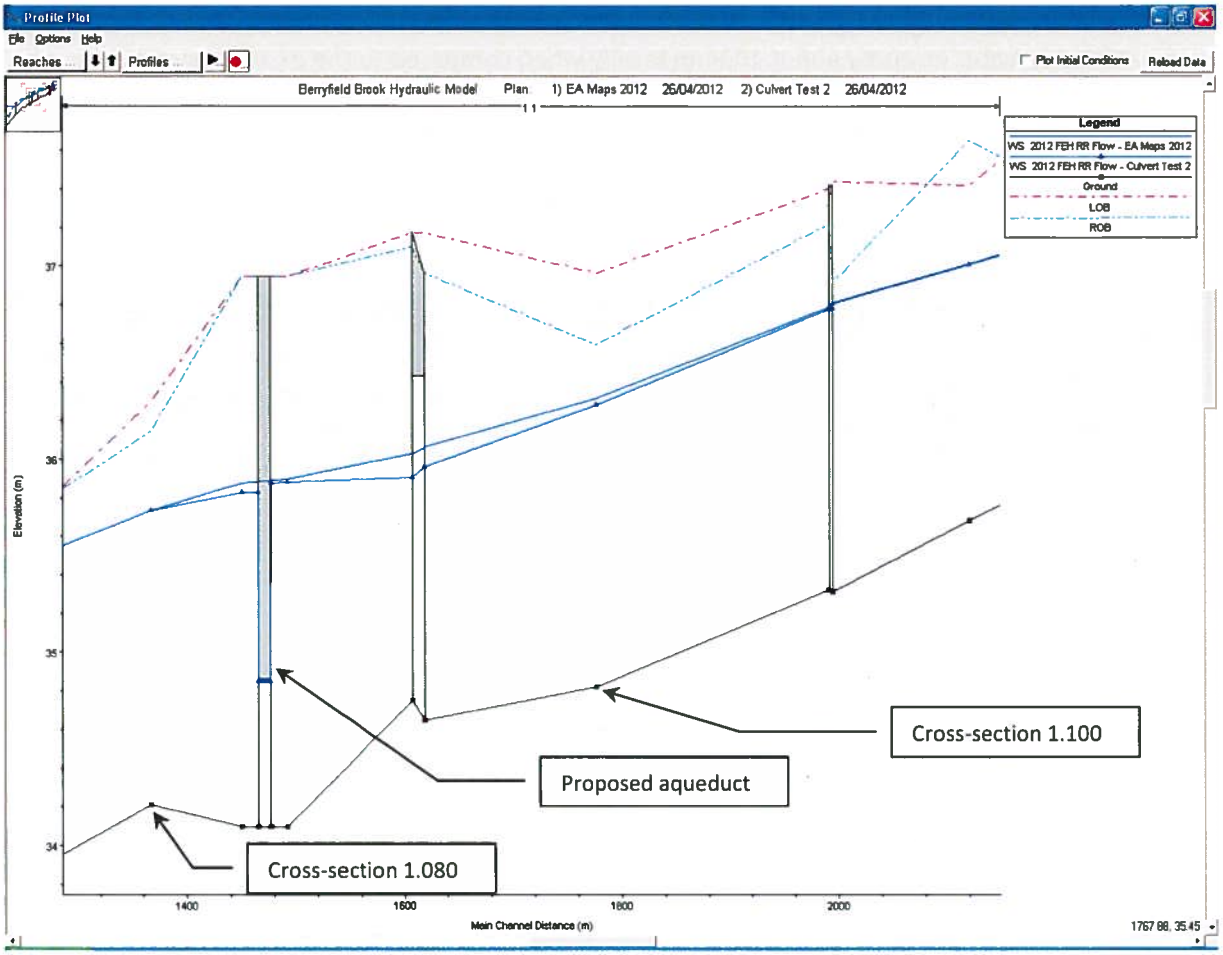


Figure 4: Comparison of peak water levels in the baseline and unmaintained culvert option when considering peak flows of 5.4m^3/s

Blockage Assessment

The geometry of the proposed culverts is not ideal from a blockage perspective given the wide but low profile of the culvert. This situation is inevitable given the vertical alignment of the canal.

Consideration has been given to blockage of the aqueduct culverts. It has been assumed for this assessment that blockage would occur at the top of the culverts through the collection of debris against the soffits. However, it is noted that it is possible that blockage will also occur at the bottom of the culverts through siltation of the culvert, particularly at the entrances.

Tests were undertaken to consider 10%, 25%, 50% and 90% blockage of both culverts.

The blockage scenarios described above were represented in the HEC-RAS model by reducing the culvert heights by 10%, 25%, 50% and 90% respectively, whilst retaining the original invert levels.

The blockage scenarios were tested using the highest 1 in 100 annual probability flow estimate including climate change (5.4m^3/s). The increase in water levels for all scenarios can be seen below in Table 3.

A 10% blockage of the aqueduct culverts had a negligible effect on water levels, when compared with the clear culvert condition. With 25% blockage, water levels were increased by up to 50mm between the aqueduct culverts and Semington Road, rising to a 210mm increase in the 50% blockage scenario.

Because of the local re-grading of the channel in the vicinity of the new culvert even a 50% blockage only increases water levels by about 100mm locally when compared to the existing conditions.

Upstream of Semington Road the increase in water levels is negligible in the 25% blockage scenario but increases are up to70mm in the 50% blockage scenario, for a distance of approximately 160m upstream of Semington Road. However with these three blockage scenarios water continues to be retained well in bank.

Cross-Section	Baseline (incl. clear culvert) (mAOD)	10% Blockage (mAOD)	Difference (mm)	25% Blockage (mAOD)	Difference (mm)	50% Blockage (mAOD)	Difference (mm)	90% Blockage (mAOD)	Difference (mm)
1.170	37.76	37.76	0	37.76	0	37.76	0	37.79	+30
1.165	37.74	37.74	0	37.74	0	37.74	0	37.77	+30
1.160	37.64	37.64	0	37.64	0	37.64	0	37.69	+50
1.150	37.55	37.55	0	37.55	0	37.55	0	37.62	+70
1.140	37.52	37.52	0	37.52	0	37.52	0	37.59	+70
1.130	37.16	37.16	0	37.16	0	37.16	0	37.35	+190
1.120	37.01	37.01	0	37.01	0	37.01	0	37.28	+270
1.110	36.81	36.80	0	36.81	0	36.82	+10	37.21	+400
1.105	36.78	36.78	0	36.78	0	36.79	+10	37.19	+410
1.100	36.28	36.28	0	36.29	+10	36.35	+70	37.15	+870
1.090	35.96	35.97	+10	36.00	+40	36.14	+180	37.13	+1170
1.085	35.91	35.92	+10	35.95	+40	36.11	+200	37.11	+1200
1.084	35.88	35.89	+10	35.93	+50	36.09	+210	37.11	+1230
1.083	-	35.89	-	35.93	-	36.09	-	37.11	-

Table 3: Water level comparison of blockage versus baseline

When considering the extreme 90% blockage scenario, water levels are increased significantly in the channel and the increase in water levels extends as far upstream as the A365.

Conclusions & Recommendations

The results of the hydraulic assessment have indicated that the proposed aqueduct and associated local channel improvements offer some betterment compared to the existing situation, with water levels reducing upstream by up to 120mm in the 1 in 100 annual probability event including climate change. This can be attributed to the increase in cross-sectional area that is being proposed up and downstream of the aqueduct.

The results of the blockage assessment indicate that substantial blockage of the culvert would need to occur to force water out of bank upstream of the proposed aqueduct, or to overtop the canal itself. The risk of blockage occurring has been considered. With the Semington Road bridge being located only a short distance upstream from the proposed aqueduct, the risk of the culvert becoming blocked by large pieces of vegetation is reduced, and if a large tree for example did make its way to the entrance of the culverts, the likelihood of such debris aligning itself across the culvert entrances is also low. The culverts are likely to suffer the risk of blockage from smaller branches. However there is little evidence of urban debris in the vicinity of the proposed aqueduct. Regardless or the cause of any blockage, the assessment does illustrate how important it will be to maintain the channel between Semington Road and the aqueduct culverts. Any debris at the culvert entrances should be removed on a frequent basis and the culvert entrances should be checked during any flood events.

In conclusion:

1. The proposals including the new culverts and associated localized channel improvements marginally reduce flood risk in the clear culvert condition.
2. Whilst 50% blockage does increase flood risk slightly when compared with the existing condition the increased risk is small and localized.
3. High blockage would be unacceptable and mitigation measures should be undertaken to avoid this problem and options are discussed below.

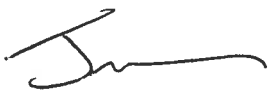
Recommendations:

To avoid blockage of the culvert beneath the proposed canal the following works are recommended for consideration:

1. Good access must be provided to the upstream face of the culvert to allow debris to be removed. Based on a site visit and available survey information this can be achieved. Vehicle access adjacent to the upstream face can be constructed. Steps or other access to the upstream face can be built.
2. It will be necessary to put in place an appropriate management system to ensure that debris is cleared as required. This is not a liability the Environment Agency would wish to adopt.
3. A simple course trash screen upstream of the proposed culvert could be constructed. This would help facilitate removal of debris and help reduce the risk of blockage during a flood event.
4. Consideration should be given to the installation of telemetry to inform the canal managers of any problems at the culvert by forwarding flood level data.

Should you have any questions on the above or wish to discuss any of the items further, please do not hesitate to contact me.

Yours sincerely



Jack Mason
Principal Engineer
Black & Veatch Ltd