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May 2022 Surface Water Monitoring Report

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1. Introduction

Surface water quality monitoring was undertaken to comply with the conditions as set out in the Tetra4 Water Use License (WUL) and Environmental Management Programme (EMPr). This report aims to present the surface water quality downstream and upstream of constructed gas pipeline crossings within the Sand River and Bosluisspruit and to compare water quality with the requirements as set out in the WUL and the targets of the EMPr. This report presents the results for surface water monitoring conducted on 20 May 2022 (Event 36).

The Tetra4 Virginia Production activities include:

- The drilling of exploration and production boreholes for the extraction of gas;
- The installation of pipelines for the collection and transport of gas; and
- The construction of processing facilities (including compression and storage) for the gas as a final product.

Cluster 1 pertains to the first phase of the proposed gas production within the Tetra4 Production Right, where Tetra4 connected new wells with existing wells towards the utilisation of viable natural gas resources. The production right issued covers a large area (~187 000 ha) to the west of Virginia in the Free State Province. This monitoring report relates to the installation of pipeline crossings underneath rivers, for the collection and transport of gas. The Cluster 1 construction phase commenced in November 2019 with site mobilization and site camp construction, followed by pipeline construction in January 2020.

1.1 Project Setting

The study area is situated near the town of Virginia in the Free State Province, within the Middle Vaal Water Management Area (WMA) in the C42K and C42L quaternary catchments. The rivers and streams running through the study area includes the Sand River, Bosluisspruit and Doring River. For this monitoring programme, the study area includes four surface water monitoring locations, where the gas pipeline was constructed across the Bosluisspruit and Sand River. Refer to Figure 1 for a layout map of the monitoring locations.

1.2 Monitoring Requirements

Tetra4 is conducting monthly monitoring of four surface water sites, where the constructed gas pipeline crosses underneath rivers and streams. Prior to and during construction, surface water sampling was conducted on a two-weekly basis, and after construction monthly. These requirements stem from the Tetra4 WUL (License No: 08/C42K/CI/8861) dated 22 January 2019 and approved Tetra4 Production Right EMPr, which has an objective of ensuring continued watercourse integrity and functionality.

Specific requirements of the WUL relating to this monitoring programme include the following:

- In-stream water quality must be analysed on a two-weekly basis during construction, otherwise monthly at monitoring points both upstream and downstream of the activities for the following variables, but not limited to:

- Suspended Solids: <20 mg/l;
- Total Dissolved Solids: <450 mg/l;
- Dissolved Oxygen: <6 mg/l; and
- Turbidity: <3 NTU

Specific requirements of the EMPr relating to this monitoring programme include the following:

- Samples are to be taken approximately 25 m upstream and 25 m downstream of the identified gas pipeline watercourse crossings.
- Parameters to be analysed for include Temperature, Barometric Pressure, pH, Oxidation/Reduction Potential, Dissolved Oxygen, Electric Conductivity, Resistivity, Total Dissolved Solids, Total Suspended Solids, Salinity and Turbidity.
- A target variation of <10 % in each water quality parameter between upstream and downstream sites was proposed.

1.3 Parameter Definitions

This section gives a brief overview of each parameter to be analysed for and how these parameters relate to water quality. Some of the parameters will not be directly affected through pipeline construction activities. However, most of these parameters are dependent on each other, and could lead to an indirect indication of changes in the water chemistry.

Temperature

Water temperature has a major influence on both biological activity and water chemistry. Temperature governs the type of organisms, which all have their own preferred temperature range, that can live in a waterbody. In terms of water chemistry, a higher temperature often leads to a higher rate in chemical reactions and vice versa. Higher temperature can lead to more dissolution of minerals which then affects the Electric Conductivity of the water body. Warmer temperatures also correlate to less dissolved oxygen in water. Water temperature is mostly dependant on seasonal changes, precipitation, and runoff from hot surfaces (USGS, 2020a).

Barometric Pressure

Barometric pressure, also known as atmospheric pressure, can be described as the pressure at a specific location that is caused by the weight of air above that location. Barometric pressure is mainly influenced by factors such as altitude and weather conditions. A higher altitude will lead to less pressure (Rao, 2013).

pH

pH is defined by the negative logarithm of the hydrogen ion activity. pH has a big influence on the chemical equilibrium for most chemical reactions in a medium. It influences the solubility of elements and is a good indicator parameter of pollution in a waterbody. Natural waters tend to have a pH between 6 and 9. A pH value of 7 in a water sample is considered neutral, less than 7 indicates acidity and more than 7 indicates a base (Hulanicki and Glab, 2005).

Oxidation Reduction Potential

The Oxidation Reduction Potential (ORP) of a water source is a numerical index of the intensity of either oxidising or reducing conditions within that source. Positive ORP indicates oxidising conditions and negative ORP values indicate reducing conditions. ORP is influenced by the different ions within a water body (Meyers, 2019).

Dissolved Oxygen

Dissolved Oxygen (DO) is the amount of oxygen dissolved in a water source and can be measured in mg/l or given as a percentage. This parameter plays an important role for biological processes through its effect on the physiology of organisms. DO concentrations in water is dependent on chemical, physical (morphology) and biochemical activities. Oxygen is poorly soluble in water and its solubility is driven mainly by temperature and pressure. According to Patel and Vashi (2015), a minimum of 4 mg/l of DO should be available in water for living organisms.

Electric Conductivity

Electric Conductivity (EC) in a water source is defined as the ability of water to conduct an electric current. The EC in a water body is dependent on the ion concentration within that body. More ions will lead to a higher EC and vice versa. Distilled water is an example of a low EC environment. This parameter is calculated using TDS and salinity (Aquaread, 2020).

Resistivity

Resistivity can be described as the reciprocal of EC. This parameter measures a water body's opposition to the flow of an electric current over a distance. A higher ion concentration will lead to a lower resistivity (Fondriest, 2020).

Total Dissolved Solids

Total Dissolved Solids (TDS) in a water sample is the amount of organic and inorganic materials (minerals, ions and metals) dissolved within that sample volume. Excessive TDS can produce toxic effects to organisms living in a water body (Fondriest, 2020).

Salinity

Salinity is a measure of the concentration of dissolved salts in a water sample. This parameter contributes greatly to EC as the dissolved particles (ions) contain positive or negative charges (Fondriest, 2020).

Turbidity/ Total Suspended Solids

Turbidity is a measurement of the amount of scattered light by materials in water when light is shined through a water sample. Suspended Solids is the main cause of turbidity in a sample. These include among others clay, silt, organic and inorganic matter. During low flow or undisturbed conditions in a water body, the turbidity tends to be low (USGS, 2020b).

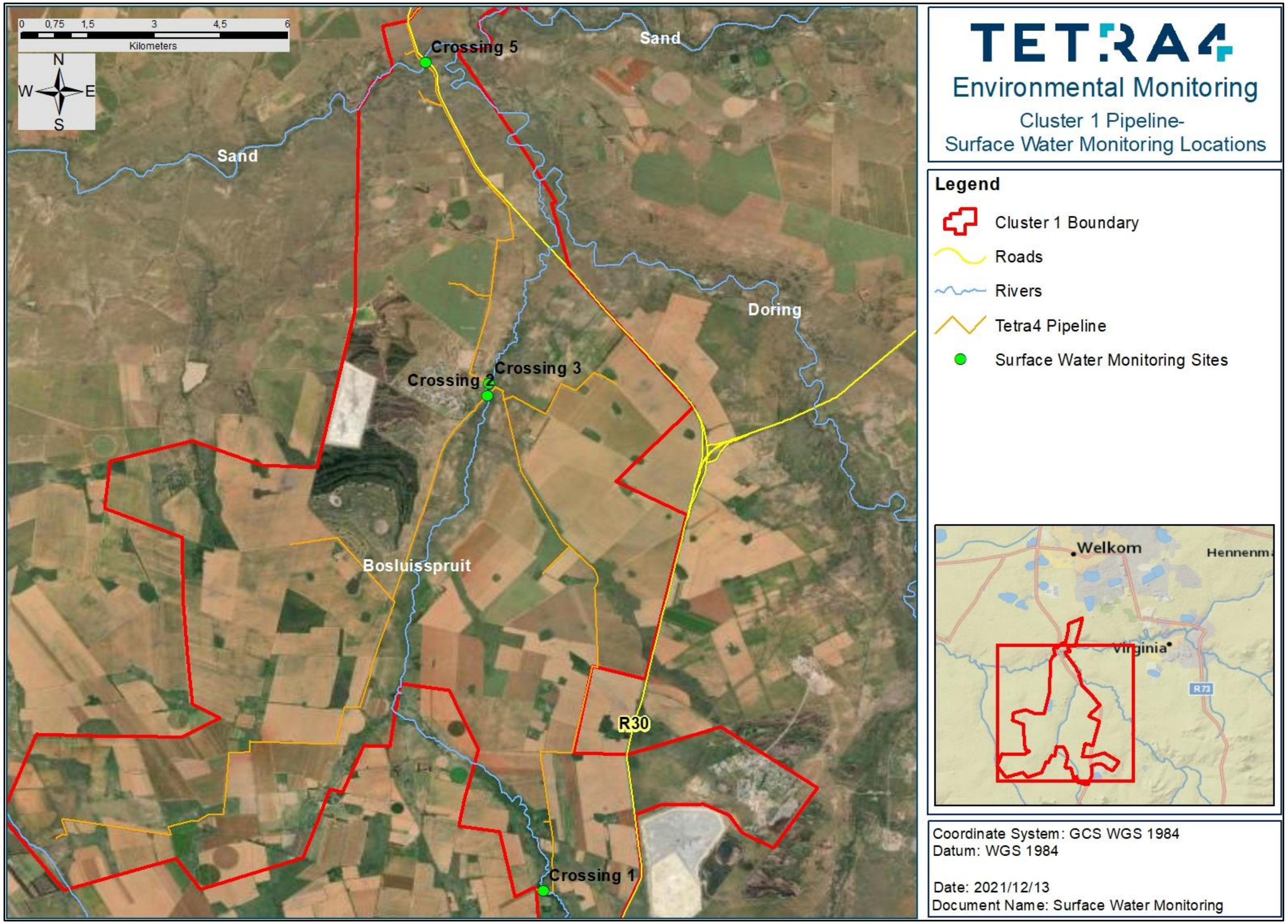


Figure 1: Surface Water Monitoring Locations

2. Study Design

2.1 Sample Locations

Samples were taken approximately 25 m downstream and 25 m upstream from the proposed pipeline crossing locations, as on Figure 1 above, with the specific sample site coordinates in Table 1 below. Please refer to the table of figures, Table 2, for site photos of the surface water monitoring locations.

Table 1: Surface Water Monitoring Sites

Sample ID	Site Description	Latitude	Longitude
Cross 5 D	This site is situated downstream from site Cross 5 U. The channel here is much deeper than at site Cross 5 U with slow moving water. The stream bed mostly consists of sediment. Reeds and tall grass cover the steep banks to both sides.	-28.118693	26.719306
Cross 5 U	This site is within the Sand River. It is situated downstream of a weir, underneath a bridge of the R30. This sampling site can be described as shallow with a strong flowing stream. The stream bed consists of a mix between pebbles and sediment. The stream here is surrounded by sandy banks. This site has been moved further downstream during event 6.	-28.118031	26.719516
Cross 3 D	Site Cross 3 D is located within the Bosluisspruit. A very thin stream flows in between dense reed. The channel is very shallow and flows adjacent to the R30. The stream bed here consists of sediment.	-28.183365	26.732374
Cross 3 U	Site Cross 3 U is located upstream from site Cross 3 D. The stream is fast-moving, shallow water and the stream bed here consists of sediment. The eastern bank is somewhat flat and clear with some bushes, and the western bank is steep and filled with reeds. This site has been moved further downstream for sampling during event 6.	-28.183781	26.731953
Cross 2 D	Site cross 2 D is overgrown with grass over the width of the stream. There is clear evidence of cattle regularly moving through this area, creating a marsh-like morphology. There is, however, a shallow, thin stream flowing through the marsh-like area, the main stream. The bed consists of sediment. This site has been moved further upstream during event 5.	-28.185625	26.731845
Cross 2 U	Site Cross 2 U is situated underneath a bridge. The stream here is relatively wide compared to the other sites and consists of shallow, stagnant water. The stream bed consists of rocks and deep sediment.	-28.185921	26.731898
Cross 1 D	This non-perennial site is completely dry if regular precipitation does not occur. Evidence that vehicles moved through the dry channel is clear. Evidence of rehabilitation of the channel banks were also evident. The banks were	-28.285844	26.742409

	lined with strands of maize leaves compacted and held together with a fish-line mesh.		
Cross 1 U	This non-perennial site is completely dry if regular precipitation does not occur. Evidence that vehicles moved through the dry channel is clear. Evidence of rehabilitation of the channel banks were also evident. The banks were lined with strands of maize leaves compacted and held together with a fish-line mesh.	-28.285844	26.742409

Table 2: Sample Site Photographs

Cross 5 D	Cross 5 U
	
Cross 3 D	**Cross 3 U**
	

Cross 2 D	Cross 2 U
	
Cross 1 D	**Cross 1 U**
	

2.2 Sample Parameters

The parameters in Table 3 below were measured in situ using an Aquaread meter. Analysis for Total Suspended Solids was done by Midvaal Water Company. Please note that for event 7, 8, 9, 10, 11, 24, 25, 26, 27, 28 and 29, pH, Turbidity and Oxidation Reduction Potential was analysed by UIS laboratory. The pH/ORP electrode for the Aquaread was defective during these site visits and required replacement. Once replacement parts were received from the supplier, *in situ* measurements resumed for these parameters.

Table 3: Parameters Measured *In Situ*

Temperature	Barometric Pressure	pH	Oxidation Reduction Potential
Dissolved Oxygen	Electric Conductivity	Resistivity	Total Dissolved Solids
Salinity	Turbidity		

3. Field Sampling Procedure

Tetra4 is responsible for the monitoring, assessment, and evaluation components of this project. Sample analysis for Total Suspended Solids is performed by Midvaal Water Company (for events 7, 8, 9, 10, 11, 24, 25, 26, 27, 28 and 29, pH, ORP and Turbidity was analysed by UIS Organics Laboratory). Samples to be sent to the laboratory are collected in 500 ml plastic sample containers. Samples are grabbed starting from the downstream locations for each pipeline crossing site. Where possible an *in situ* Aquaread measurement is then taken (submerging the Aquaprobe completely) facing an up-stream direction, without disturbing the sediment at the bottom of the stream. Once all the parameters on the Aquaread meter stabilise, a measurement is taken. Where it was not possible to take a direct measurement with the Aquaread, because of low surface water level, a sample was taken in a vessel container into which the Aquaread was inserted to obtain a representative measurement of the site parameters.

4. Results

4.1 Sample Conditions

The following notes apply for Event 36 (20 May 2022):

- A fifth sampling location, Crossing 4, was sampled during the baseline, but is not being sampled anymore since there was no pipeline constructed across the watercourse at this location.
- Crossing 1 was completely dry.
- Water at sites Cross 5 U and Cross 5 D was muddy and non-transparent. Clear evidence of bank erosion was visible after heavy rain and flooding in recent months.
- The area received some rain the day prior to sampling.

4.2 Water Quality Results

The results for sampling Event 36 as in Table 4, were evaluated against the limits as set out in the WUL. Limits were only set for Dissolved Oxygen, Total Dissolved Solids, Total Suspended Solids and Turbidity. If a site exceeded the WUL limits for a specific parameter, it will be highlighted in red (the WUL limit given for Dissolved Oxygen is assumed to be a maximum concentration limit, thus this parameter will be highlighted if it is less than the WUL limit). The percentage difference was also calculated for upstream and downstream sites for each parameter. This is to evaluate the 10 % target variation as set in the EMPr between upstream and downstream sites for each parameter. If the percentage difference between an upstream and associated downstream site exceeded positive 10 % for a specific parameter, the percentage difference will be highlighted in yellow.

Table 4: Event 36 Monitoring Results and Comparisons

Parameter	WUL Requirement	Unit of Measure	Cross 2 D	Cross 2 U	%Diff	Cross 3 D	Cross 3 U	%Diff	Cross 5 D	Cross 5 U	%Diff
Barometric Pressure	N/A	mb	868	868	0.00	869	869	0.00	873	873	0.00
Dissolved Oxygen	6	mg/l	9.13	7.85	16.31	7.46	8.22	-9.25	6.29	6.55	-3.97
Electric Conductivity	N/A	uS/cm @ 25 degrees	2401	2404	-0.12	2270	2278	-0.35	788	782	0.77
Oxidation Reduction Potential	N/A	mV	144.8	146.7	-1.30	158.5	159.6	-0.69	187.7	186.5	0.64
pH	N/A	0	9.13	9.54	-4.30	8.12	8.19	-0.85	7.94	7.71	2.98
Resistivity	N/A	Ohms/cm	568	572	-0.70	585	588	-0.51	1560	1572	-0.76
Salinity	N/A	ppt	1.21	1.21	0.00	1.15	1.15	0.00	0.33	0.33	0.00
Temperature	N/A	Degrees C	11.05	10.7	3.27	12	11.75	2.13	15.2	15.2	0.00
Total Dissolved Solids	450	mg/l	1560	1562	-0.13	1475	1480	-0.34	512	508	0.79
Total Suspended Solids	20	mg/l	11	8	37.50	15	16	-6.25	10	26	-61.54
Turbidity	3	NTU	0	0.2	-100.00	4.8	3.6	33.33	32.2	33.4	-3.59

4.3 Baseline Statistics

Events 1 to 14 forms part of the baseline for this report, except for site Cross 5 U and Cross 5 D of which only events 1 to 6 forms the baseline. Cross 1 D and Cross 1 U which has no representative baseline as the stream was consistently dry before and during construction will not be included in this table. Construction of the pipeline has been completed at all sites. Basic statistics were done on the baseline events and are presented in Table 5 below. The statistics included a calculation of the mean and standard deviation from the mean for each parameter at each site during baseline. From these, a Coefficient of Variance (CV), presented as a percentage, was calculated for each parameter at each site sampled. The CV is an indication of the dispersion of data points around the baseline mean. A low CV percentage indicates that there is a low level of dispersion or high central tendency of the individual samples around the mean and vice versa. The greater the dispersion of data points around the mean, the less likely it is representative of the baseline mean and vice versa.

Table 5: Baseline Statistics

Parameter	Statistic	Monitoring Site					
		Cross 2 D	Cross 2 U	Cross 3 D	Cross 3 U	Cross 5 D	Cross 5 U
Number of Baseline Recordings		**14**	**14**	**14**	**14**	**6**	**6**
Barometric Pressure	Mean	874.99	875.06	875.13	875.27	880.98	880.81
	Stdev	4.80	4.88	5.15	5.26	6.22	6.12
	CV%	0.55	0.56	0.59	0.60	0.71	0.69
Dissolved Oxygen	Mean	10.50	9.03	9.90	10.04	10.50	10.59
	Stdev	4.12	1.92	2.31	2.18	4.15	4.38
	CV%	39.20	21.25	23.34	21.67	39.56	41.38
Electric Conductivity	Mean	2837.51	2892.16	1941.36	1917.07	2992.90	3003.59
	Stdev	1553.12	1549.81	1091.79	1066.64	524.48	509.55
	CV%	54.74	53.59	56.24	55.64	17.52	16.96
Oxidation Reduction Potential	Mean	305.67	277.58	337.07	349.66	217.48	223.75
	Stdev	179.97	178.67	202.51	229.59	82.41	78.76
	CV%	58.88	64.37	60.08	65.66	37.89	35.20
pH	Mean	7.40	7.46	7.31	7.46	7.52	7.49
	Stdev	0.56	0.52	0.75	0.58	0.41	0.53
	CV%	7.61	6.92	10.29	7.84	5.41	7.05

Resistivity	Mean	417.75	441.73	594.63	603.99	450.00	451.02
	Stdev	2138.66	1705.20	2099.67	2260.57	41.09	40.97
	CV%	511.95	386.03	353.10	374.27	9.13	9.08
Salinity	Mean	1.42	1.45	0.94	0.95	1.56	1.55
	Stdev	0.86	0.85	0.60	0.57	0.28	0.27
	CV%	60.22	58.78	63.42	60.28	18.29	17.67
Temperature	Mean	15.92	12.10	17.29	17.13	11.07	10.89
	Stdev	6.10	7.08	5.79	5.83	3.87	3.61
	CV%	38.28	58.53	33.46	34.03	34.97	33.11
TDS	Mean	1842.75	1878.70	1260.73	1244.73	1944.88	1951.98
	Stdev	1009.61	1007.26	709.72	693.22	340.89	331.13
	CV%	54.79	53.61	56.29	55.69	17.53	16.96
TSS	Mean	550.34	520.75	360.17	354.89	401.89	401.80
	Stdev	268.10	282.34	138.92	138.47	63.79	65.09
	CV%	48.72	54.22	38.57	39.02	15.87	16.20
Turbidity	Mean	20.75	26.34	18.62	22.81	8.79	10.88
	Stdev	81.77	80.47	88.72	87.89	18.06	22.26
	CV%	394.12	305.48	476.36	385.28	205.43	204.58

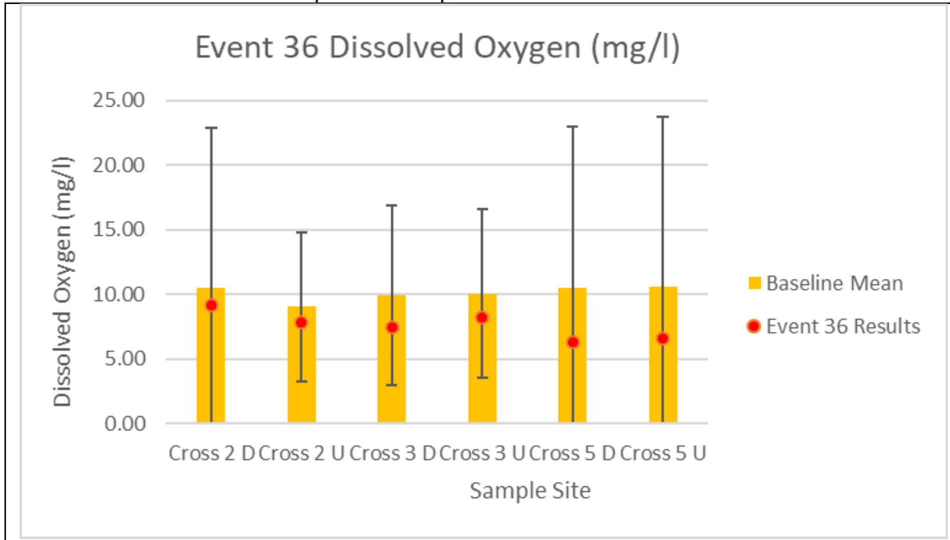
4.4 Baseline Comparison Graphs

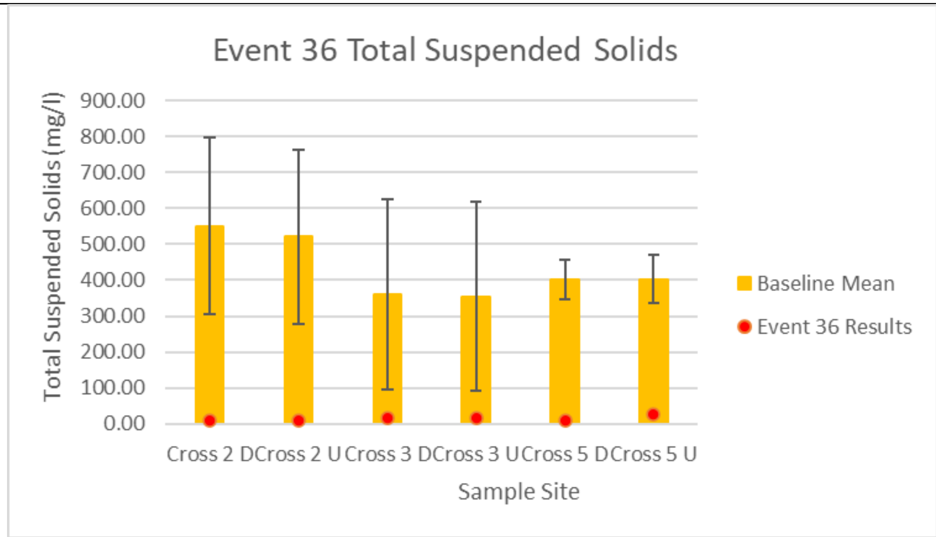
Parameters of Potential Concern (POPCs) are chosen chemical parameters which indicated either an exceedance of the WUL requirements or a more than +10 % variation during construction between some of the up- and downstream sites (see Table 4). The approach taken in this section is to compare baseline results with that of identified POPC during the construction/ production phase monitoring events. This approach assumes that three times the standard deviation from the baseline mean (assuming normal distribution of the baseline data), for each parameter at every site sampled, is within the natural variance within each site. Three times the standard deviation was assumed to be adequate because mostly high CV values (see Table 5) indicated that there is high level of dispersion (low central tendency) of the individual sample values around the mean for certain parameters at the different sampled sites during baseline. Further to this, construction and production sampling took place during both the dry and wet seasons (baseline only occurred during the dry season), which is why it is assumed that more variability around the mean would exist if the baseline was representative of both dry and wet seasons.

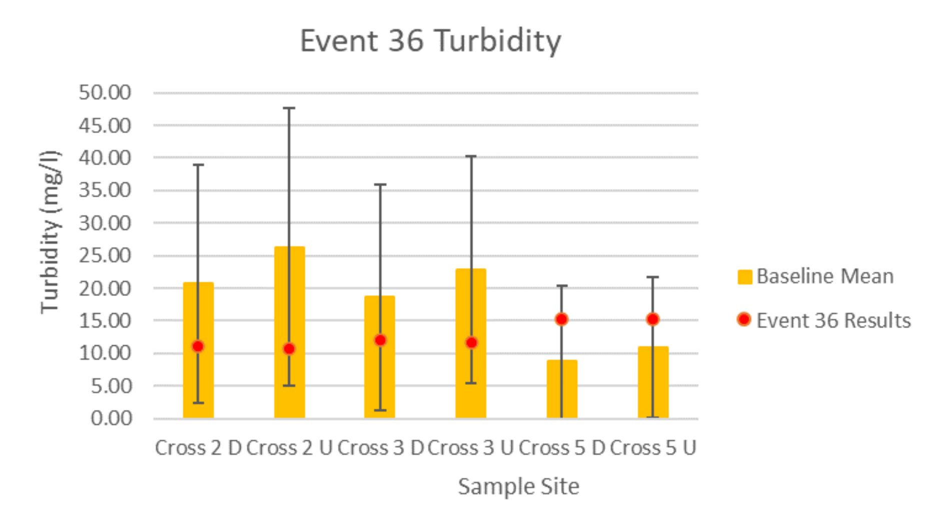
For this approach, a parameter will only require further investigation and will be flagged as a Parameter of Concern (POC) at a specific site during construction phase if it exceeds positive three times the standard deviation from the mean of the baseline results. The baseline comparison graphs below (see the table of figures, Table 6), indicate the mean baseline results, each fitted with error bars that indicate three times the standard deviation of that mean. The red points on the graph indicate the results for each parameter at each site as obtained during Event 36. If one of the points fall outside of three times the standard deviation, that parameter will be flagged as a POC at that site.

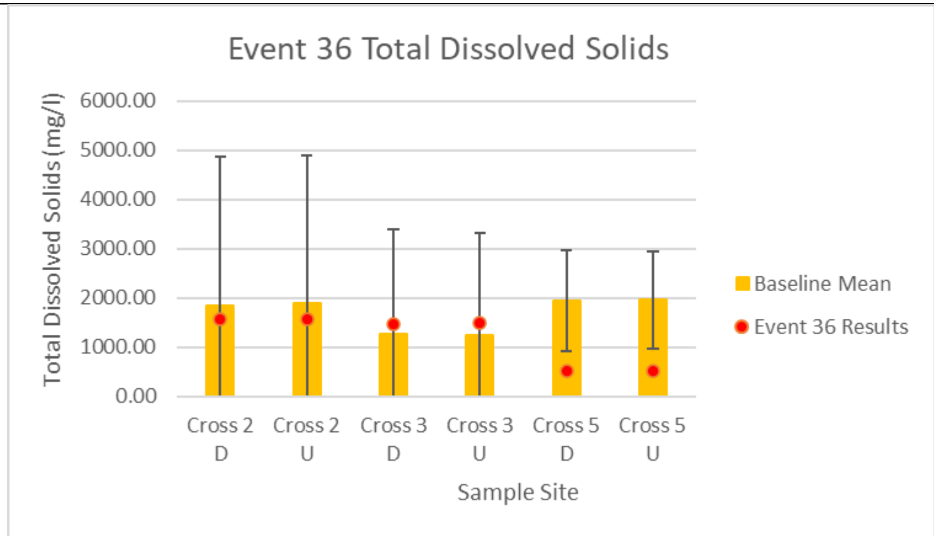
Although construction has already been completed at Crossing 1, this site will not be included as part of the graphs, as there is no representative baseline to compare the construction phase results with.

Table 6: Baseline Mean Comparison Graphs









5. Discussion and Conclusion

During Event 36, all sites exceeded the WUL requirements for Total Dissolved Solids and Cross 5 U for Total Suspended Solids. Sites Cross 3U, Cross 3 D, Cross 5 D and Cross 5 U exceeded the WUL requirements for Turbidity. When analysing the percentage difference in results between upstream and downstream sites, Total Suspended Solids exceeded the target +10 % variation from the corresponding upstream sites at Cross 2 D with 37.5 % (3 mg/l). Dissolved Oxygen exceeded the target +10 % variation from the corresponding upstream site at Cross 2 D with 16.31 % (1.38 mg/l) and Turbidity exceeded the target 10 % variation from the corresponding upstream site at Cross 3 D with 33.33 % (1.2 NTU). As reported previously, it was evident during the baseline that a lot of exceedances of the targets occurred even before any construction had started.

The results are indicative of unattainable targets relating to the WUL concentration requirements for certain parameters, as well as the EMPr target of less than 10 % in difference between upstream and downstream sites for each parameter. The EMPr states that additional investigation needs to be conducted if a more than the 10 % variation exists between upstream and associated downstream sites for each parameter. The more than 10 % variance was investigated and can be attributed to the differences in stream morphology between most of the upstream and associated downstream sites. Different site characteristics could lead to a difference in most water quality parameters. This, along with runoff from rainfall prior to sampling could introduce further variation between sites.

For the above-mentioned reasons, a different approach was introduced into the monthly report. This approach assumes that three times the standard deviation from the mean of the baseline data (assuming normal distribution of the baseline data), for each parameter at every site sampled, is within the natural variance within each site. Three times the standard deviation was assumed to be adequate because high CV values indicated that there is high level of dispersion (low central tendency) of the individual sample values around the mean for certain parameters at the different sampled sites during baseline. Further to this, construction and production results were acquired during both the dry and wet seasons, opposed to only dry season baseline sampling, where wet season baseline sampling would have possibly lead to a higher variation during baseline. For this approach, a POPC will only be flagged for further investigation and termed a POC at a specific site if it exceeds 3 times the standard deviation from the mean of the baseline values for that parameter at each site.

The baseline sampling at site Crossing 5 was completed during event 6 and the baseline sampling at sites Crossing 2 and Crossing 3 during event 14. Construction has been completed at all these sites. Note that no baseline for Crossing 1 exists, as the stream is non-perennial and mostly dry. Construction was also already completed at this crossing. For this reason, only POPC at sites Crossing 2, Crossing 3 and Crossing 5 were compared to the mean baseline results. Total Dissolved Solids, Turbidity, Total Suspended Solids and Dissolved Oxygen were identified as POPC and were compared to the baseline results (see table of figures, Table 6). No POC were identified, as none of identified POPS exceeded three times the standard deviation from the mean.

Changes can be attributed to natural variance due to stream morphological differences and rainfall experienced prior to this monitoring event. Further investigation should not be required at this stage in the monitoring programme.

No evidence exists that construction of the pipeline caused exceedances during this monitoring event. Exceedances of the WUL targets and the EMPr 10% variation already existed during baseline at all sites. The study area is subject to historical mining and agricultural activity, which could lead to contamination and poor water quality within the surface water features in the area.

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