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Process Modelling of Bellozanne STW

Bellozanne Concept Design and Future Expansion

NEW BELLOZANNE STW

DEPARTMENT for INFRASTRUCTURE

DESIGN ISSUE

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1. INTRODUCTION

The existing Bellozanne Sewage Treatment Works (STW) is at the end of its original design life and experiencing numerous operational issues. An outline solution for replacing the STW has been agreed with the Jersey Department of Environment (DoE) based on carbonaceous removal to achieve a BOD/ TSS standard that allows for future population growth on the Island and the provision for further expansion to the works in the future if necessary to meet an additional ammonia or Total Nitrogen (TN) standard. This outline solution is referred to below as the Concept Design and includes the following main process stages: -

1. Tanker Import Facility with regulated flow,
2. Inlet Works and Storm Tanks,
3. Primary Settlement Tanks and Sludge Pumping,
4. Activated Sludge Process Plant,
5. Final Settlement Tanks and Sludge Pumping,
6. UV Treatment,
7. Odour Control.

The Concept Design for the new works is as depicted in the New Bellozanne STW Tender Information and is based on achieving carbonaceous removal to achieve a BOD/ TSS standard for a connected Population Equivalent (PE) of 118,000 as estimated for the year 2035. An additional annual average total nitrogen (TN) consent is to be added to this original design consent based on a ‘no deterioration’ DoE requirement from the current effluent discharge performance. It is understood that this TN consent will incorporate an absolute value to be met as an annual average concentration but may also include a percentage reduction across the plant. The latter is not preferred as a low TN concentration into the works as a result of high rainfall or dilution would give rise to a low TN concentration required in the discharge when based on a percentage reduction. This may well be below the absolute value guaranteed and taking into account that the denitrification and biological kinetics of the plant will decrease during periods of prolonged ‘weak’ sewage, a low TN standard will be hard if not impossible to achieve under these conditions.

To assess the predicted performance of the Concept Design, a process modelling study has been carried out by The Fluid Group, The Magdalen Centre, Oxford. This model has been run using the flows and loads as recorded for 2015 using the biological concentrations as determined by an accredited laboratory (Alcontrol Laboratories).

To predict the influent load to the works for the design PE of 118,000 as estimated for year 2035, the concentrations for 2015 from the Alcontrol Laboratory have been used with a pro-rated flow profile to allow for the increase in PE over that currently experienced by the STW. The model has been run on this estimated load variation to assess the STW’s performance in 2035.

The outputs from these runs are covered in The Fluid Group’s Report No: TFG-2015-1712-01-B, dated 31st July 2015 and is summarised below: -

1 Scenario 1: Concept Design using Alcontrol Lab data for 2015, i.e. current condition.
2 Scenario 2: Concept Design using Alcontrol Lab data for 2015 with the future plant expansion for ammonia and tighter total nitrogen consent (anoxic capacity of 12,100m^3 and an aerobic capacity of 16,630m^3 with nitrate recycle).
3 Scenario 3: Concept Design using the estimated flow and load profile for the future PE of 118,000.
4 Scenario 4: Concept Design using the estimated flow and load profile for the PE of 118,000 with the future plant expansion for ammonia and tighter total nitrogen consent (anoxic capacity of 12,100m^3 and an aerobic capacity of 16,630m^3 with nitrate recycle).

In addition to the Concept Design, two further scenarios have been run to assess the effect of adding an anoxic tank to give a total anoxic capacity of 2,200m^3 for the Final Design.

Whilst Climate Change will not affect the treatment process itself, current infiltration reduction works on the sewerage network will counter any increase in flows and resultant dilution of influent concentrations. In addition, the proposed design for the new activated sludge plant will optimise the energy used in the aeration process and since this is one of the main consumers of energy on the site this will reduce the energy consumed when compared to the current plant for an equivalent biological load into the works.

The outputs from the STW process model have had a 5% contingency applied to give a suggested value for the annual average TN concentration expected for each scenario. This contingency covers the percentage error in analysis and monitoring that will affect the model output.

2. CONCEPT DESIGN AND ANOXIC TANK ADDITION (FINAL DESIGN)

The initial proposed site layout for the Concept Design was based on carbonaceous removal to achieve a BOD/TSS standard for a PE of 118,000. This design is based on a suspended growth system, conventional activated sludge process (ASP), which provides a better clarity of effluent than the current MBBR/ ASP system.

The Concept Design utilises an anoxic selector of 450m^3. This is purely to provide a high F/M ratio to act as a selector zone and control the formation of filamentous bacteria. Its design intention is not to act as an anoxic zone to provide any denitrification.

Subsequent to the Concept Design, the addition of a 2,200m^3 anoxic tank was modelled and this has now been incorporated into the Final Design for the new STW. The anoxic tank is placed after the selector tank to take advantage of the organic carbon and low DO in the settled sewage.

The Concept and Final Designs have several improvements from the current STW, some of which are outlined below: -

2.1 Anoxic Tank

The addition of the anoxic tank stage in the Final Design provides the following benefits to the process: -

1. Conversion of some of the nitrate in the Return Activated Sludge (RAS) to nitrogen thereby reducing the TN concentration in the final effluent discharge,
2. Utilisation of the returned nitrate in the RAS to oxidise some of the influent carbonaceous BOD thereby reducing the BOD to the aeration stage of the activated sludge process and in turn reducing the required oxygen requirement and the overall energy requirement,
3. Recovery of alkalinity lost from the process during nitrification that takes place in the aerobic section of the activated sludge process. Approximately half of this alkalinity lost is recovered during denitrification thus helping to stabilise the process.

2.2 Reduction in Storm Spills

The incorporation of the storm tanks in the Concept Design has the following benefits to St Aubin's Bay: -

1. The existing inlet works and overflow arrangement at Bellozanne STW is such that the FFT at Bellozanne STW currently varies between 600 l/s and 700 l/s. In addition the maximum output from First Tower Pumping Station is 860 l/s. The difference between the FFT and the feed flow of 860 l/s spills to the UV plant after the primary settlement tanks and discharges via the existing outfall to St Aubin's Bay. It should also be noted that the first part of any spill is full strength settled sewage due to the current design of the inlet works.

   As part of the Concept Design for Bellozanne STW, the FFT is increasing to 815 l/s and the Department for Infrastructure have indicated that First Tower PS will also be upgraded and its operational regime altered. Following completion of the proposed works, First Tower PS will have a maximum capacity of 1,100 l/s. In addition, storm tanks will be incorporated to maximise full treatment at the STW and manage potential for overflows.

   In order to minimise overflows and thereby maximise the quantity of sewage being fully treated by the new STW, the flow pumped to the STW from First Tower PS is being smoothed out via new Variable Speed Drives (VSD's) so as to minimise any peaks in flow. During dry weather conditions three pumps will operate. These will be controlled by the sump level at First Tower PS, providing as steady a flow as possible to Bellozanne STW, whilst staying below the FFT flow limit. During dry weather conditions the maximum pump rate at First Tower PS will be 753 l/s, to allow for the 60 l/s from St John's gravity sewer. In wet weather, as long as the new STW storm tanks have spare capacity, all 4 pumps at First Tower PS will run at their maximum speed. The maximum total pump rate at First Tower PS will be 1100 l/s. When the storm tanks are full at the new STW, the pumps at First Tower PS will ramp down to the FFT flow limit. This causes the system to 'back-up' and spill to The Cavern via the Weighbridge Combined Sewer Overflow (CSO). During these conditions the maximum pump rate at First Tower PS will be reduced back to 753 l/s. When the Cavern is 90% full, the pumps at First Tower PS will ramp back up to full speed. The maximum pump rate at First Tower PS will return to 1,100l/s. This will cause the flow to pass through the inlet works and then overflow to the storm tanks that operate in series and act as settling tanks and then overflow to outfall via a UV treatment process instead of spilling to St Aubin's Bay via the Weighbridge CSO.

The return pump within The Cavern has been modelled as a fixed speed pump with a rate of 125 l/s (average pump rate). In the model the operation of this pump is inhibited until there is sufficient capacity available at the new STW to allow the Cavern to start to empty. This prevents any unnecessary spills from the storm tanks occurring at the new STW.

This control system ensures that there are less spills and that more sewage is treated by the new STW than is currently the case with the existing STW. The Table below (Table 1) is taken from the 'Jersey DAP – Needs Report 2015, Rev 2' and shows that the average annual volume of untreated or partially treated effluent discharging into St Aubin's Bay from the STW and main CSO's decreases from 486,770 m^3 to 46,074 m^3 with the frequency of spills from the STW reducing from 163 to only 3 events per annum. Frequency and volume of spills from the CSO's remains approximately the same.

Asset Name	Description	2014 System with Existing Bellozanne STW			2014 System with New Bellozanne STW		
		1 in 10 Year Volume (m3)	Average Annual Spill Frequency	Average Annual Volume (m3)	1 in 10 Year Spill Volume (m3)	Average Annual Spill Frequency	Average Annual Volume (m3)
Bellozanne STW Overflow	Spill to St Aubin's Bay from Overflow at Bellozanne STW	22,219	163	454,377	13,290	3	12,640
Weighbridge CSO	Spill to St Aubin's Bay	24,411	3	27,987	18,995	4	28,833
King Street CSO	Spill to St Aubin's Bay	4,469	14	4,406	5,230	15	4,601
TOTAL SPILLS TO ST AUBIN'S BAY		**51,099**		**486,770**	**37,515**		**46,074**
Total spills to The Cavern		**19,735**	**77**	**298,882**	**19,832**	**58**	**285,290**

Table 1 – Impact of Proposed Works at Bellozanne STW on Overflow Performance

Thus the reduction in volume associated with the 'Non Spills' is 440,000m^3 (486,770m^3 minus 46,074m^3). An estimate of the reduction in TN load to the bay as a result of the 'Non Spills' can be calculated by comparing the TN load for a settled sewage (existing system with spills from the existing STW and the cavern) against the load calculated for a fully treated effluent. The table below (Table 2) details the average TN concentration for the settled sewage and the final effluent for the years 2010 to 2014 and from the difference between these values and the 440,000m^3 saving in spill volume, calculates the reduction in TN load to the bay as a result of these Non Spills being treated in the STW.

Year	Annual Average Settled Sewage TN, mg/l	Annual Average Final Effluent TN, mg/l	TN Removed in STW, mg/l	Annual Reduction in TN Load to Bay, kg
2010	56.4	32.0	24.4	10,736
2011	51.8	32.0	19.8	8,712
2012	54.1	29.0	25.1	11,044
2013	56.4	26.0	30.4	13,376
2014	48.0	31.0	17.0	7,480

Table 2 – Estimate of TN Load Associated with the Non Spills

It can therefore be concluded that the decrease in spill volume of 440,000m^3 equates to a reduction of between 7.5 and 13.4 tonnes of TN per annum into the bay.

2. As well as the pumped flows from First Tower Pumping Station, other input flows to the works consist of the flow from the St John's sewer (60 l/s), the Coal Authority sewer (8 l/s) and the Pine Ridge Sewer (5 l/s) giving a total flow to the new STW of 1,175 l/s. The Concept Design includes 2 storm tanks of approximately 6,000 m^3 total capacity (24% of Cavern volume) such that any flow exceeding 815 l/s passes to the storm tanks after preliminary treatment. Flows in the range of 815 l/s and 1,175 l/s receive preliminary treatment and settlement within the storm tanks. Flows captured within the storm tank are returned for full treatment once the storm has abated. Therefore a storm water spill will only occur during a prolonged storm flow event as described in item 1 above. The Concept Design therefore has a considerable reduction in the frequency of storm overflows when compared to the existing works as well as having a higher flow to full treatment, FFT. One of the Storm Tanks will be used as a 'blind tank' to capture the flow from the first flush of a storm event and thus prevents any high strength liquor passing to the outfall.

   Given the significant reduction in spills of untreated or partially treated sewage and the associated significant reduction in Total Nitrogen discharged to St Aubin's Bay and the 'no deterioration' in discharge quality from the new STW in terms of annual average TN, it can be surmised that there will be no deterioration in the water quality of St Aubin's Bay due to TN levels as a result of the construction of the new STW and implementation of the new operating regime for the sewerage network.

2.3 STW Plant Design

The new STW design incorporates the following improvements: -

1. The existing STW utilises a combined fixed film/ suspended growth process whereas the Concept Design uses suspended growth alone. In fixed film processes the 'dead' biomass sloughs off the carrier giving rise to a larger particle distribution than seen in a suspended growth system. This higher solids distribution can give rise to a lower UV Transmissivity as there is more shielding of the bacteria. Thus changing to a suspended growth process will give a better solids distribution in the final effluent and result in a more reliable UV transmissivity and therefore a better overall Faecal Coliform kill than achieved at present.

2. The existing secondary treatment plant is a high rate process that results in excessive energy costs. The largest user of energy on a sewage works is usually the aeration system. The activated sludge system considered in the Concept Design is designed such that the aeration system follows the air demand of the biological system more closely thus minimising over aeration and energy wastage as well as improved treatment process.

3. The existing STW suffers from poor flow distribution that gives rise to periods of high suspended solids (SS) in the effluent. This is particularly prevalent due to the operational issues with filamentous bacteria on the site. These design issues are addressed in the new STW such that the flow distribution is improved between process units thereby providing a more robust and reliable process.

4. The existing STW suffers from shock loads into the works of both BOD and SS. The new STW addresses this issue by: -

    a. balancing the flow from First Tower PS as detailed in section 2.2.1 above; and,
    b. balancing the flow to the works from jetvac and tanker discharges via a new Tanker Import Facility (TIF).

    Currently the tanker and jetvacs are a source of high shock loads to the works and the new STW will incorporate a buffer tank at the TIF to smooth these out over a period of time, thus minimising any shock loads.

    This balancing of flow and load to the works will ensure a better and more consistent biological treatment and thereby improve the stability of the works.

5. The design of the new STW allows for future expansion of the secondary treatment stage such that an ammonia or tighter total nitrogen consent can be achieved in the future if required.

6. The incorporation of the 2,200m^3 anoxic tank in the Final Design means that a degree of denitrification will occur and a lower TN concentration in the final effluent should be realised as discussed in section 4.2.

7. The nitrogen in the existing STW is largely present as ammonia whereas the process modelling of the new STW indicates that the nitrogen in the final effluent will consist largely of nitrate thereby minimising any toxicity effects.

3. RAW SEWAGE DATA

Two laboratories have been used to analyse the biological concentrations of the influent and settled sewage samples taken. These are the local Jersey laboratory and Alcontrol Laboratory whose details are noted below: -

Alcontrol Laboratories
Unit 7-8 Hawarden Business Park
Manor Road (off Manor Lane)
Hawarden
Deeside
CH5 3US.

The results from the local Jersey laboratory give rise to a very low C/N ratio for the influent. In addition the Fluid Group have expressed concerns over the validity of some of the raw data in the 2013 results as the sample results (across the range of determinants) towards the end of 2014 increase without there being an obvious reason for this upturn in terms of connectivity in the network or population change.

The Alcontrol Laboratory data is considered to be more reliable as this is an accredited lab and gives results closer to those expected for a sewage works that mainly consists of domestic influent. This has therefore been used to predict the performance of the Concept and Final Designs and the future potential design of 12,100m^3 anoxic zone/ 16,630m^3 aerobic zone for the PE of 118,000.

4. NITROGEN REMOVAL TO ACHIEVE A TN STANDARD

4.1 Nitrogen Removal and C/N Ratio

Nitrogen is removed from the influent sewage by two mechanisms: -

1. **Assimilation**: -The amount of nitrogen that can be removed by this mechanism is limited by the amount of net growth of biomass, which in turn depends on the carbonaceous organic content of the waste water. Typically about 8-10% of the influent N load can be removed.

2. **Nitrification and De-nitrification:** - Further Nitrogen removal requires nitrification and de-nitrification to occur. Nitrification is the conversion of ammonia to nitrate in the aerobic zone of the secondary treatment stage. Denitrification is the conversion of nitrate to nitrogen gas and this takes place in the anoxic zone of the secondary treatment stage. Denitrification consumes carbon and the rate of reaction is very dependent upon the C/N ratio. The lower the C/N ratio, the lower the efficiency of the de-nitrification process and the higher the TN concentration in the effluent. The table below details the C/N ratio for the Bellozanne STW alongside the typical range for a UK sewage plant and Enniskillin, a plant that has been operating for approximately 7 years in Northern Ireland.

	C/N Ratio	
	Raw	**Settled**
Bellozanne STW (Jersey Lab 2010 data)	2.1	1.5
Bellozanne STW (Jersey Lab 2012 data)	2.8	2.0
Bellozanne STW (Jersey Lab 2013 data)	2.9	2.0
Bellozanne STW (Jersey Lab 2014 data)	3	1.7
Bellozanne STW (Jersey Lab 2015 data)	2.9	1.8
Alcontrol Data 2015	5.1	3.4
Enniskillin STW	8.9	4.9
Typical range	5 to 6	3.5 to 6.0

Table 3: C/N ratio for the raw sewage at Bellozanne STW.

This shows that the C/N ratio for Bellozanne STW (calculated by dividing the raw sewage BOD by the raw sewage TN) is continuously low compared to the UK norm and this will affect the level of nitrogen removal that is achievable and thereby the TN standard achievable unless either external carbon is added to the system or conversely nitrogen is reduced in the influent.

The average raw sewage BOD as measured by the Alcontrol lab data over the period 22nd September 2014 to July 31st 2015 is 238mg/l which is around the value expected for a medium strength sewage. However the raw sewage annual average TN measured between 2010 and 2015 has been consistently within 50 to 60 mg/l which is well above the typical TN concentration of 40 mg/l expected for medium strength sewage.

Clearly any method of reducing the nitrogen entering the STW would have a positive impact on the C/N ratio and thereby the nitrogen removal achievable in the new STW. It is therefore imperative that every effort is made to ensure that the incoming level of nitrogen is reduced by further controls at the source.

4.2 TN Achievable

The Concept Design was based on a carbonaceous removal plant and the design load as estimated for 2035.

Due to the advantages listed in section 2 and to provide enhancement to the overall scheme, an anoxic tank of 2,200m^3 capacity will now be incorporated in the Final Design of the new STW. The effluent quality standard achieved by the new STW has therefore been examined for the Concept Design and for the Final Design with this anoxic tank included.

4.2.1 Concept Design

The effluent quality standard detailed for the Concept Design will be achieved even when the anoxic tank is taken out of service for maintenance and therefore the Concept Design provides the consent requirement for the new STW on the basis of 'no deterioration' in effluent quality, as agreed with the Regulator.

Based on the current influent data recorded for 2015, the Concept Design for the new STW will achieve nitrification and a small degree of denitrification in the anoxic selector tank. The predicted annual average TN standard including the 5% contingency, based upon an arithmetic mean of all of the daily sample results during the year for this scenario for both the current and future population values is shown in Table 4.

Scenarios 1 & 3	**Annual Average TN, mg/l**	
	Current Influent Load (2015)	Design Load (118,000PE)
Concept Design	31	35

Table 4: Predicted Annual Average TN Concentration using the Concept Design at Bellozanne STW.

The Concept Design therefore meets an annual average TN standard of 35mg/l under design conditions.

A table has also been produced to assess the effluent concentrations month by month for the Concept Design based upon the 2014 to 2015 Alcontrol data, i.e. current flows and loads (see Table 5 below). It should be noted that inherent errors within the sampling and analysis will become more pronounced as the time period being examined gets smaller, i.e. the percentage error per month is greater than that for an annual average. The values below therefore provide guidance as to the expected performance of the Concept Design under the current plant loadings.

			Concept Design Average Effluent					
	Average Flow l/s	Average flow m3/d	Ammonia mg/l	Nitrite mg/l	Nitrate mg/l	TN mg/l	BOD mg/l	COD mg/l
Jan	430	37152	0.2	0	24.9	25.1	5.6	37.6
Feb	430	37152	0.2	0	26.9	27.1	6.1	34.5
March	430	37152	0.2	0	28.5	28.7	6.5	35.0
April	430	37152	0.2	0	27.8	28.1	7.2	38.0
May	260	22464	0.3	0.3	28.8	29.4	5.1	37.6
June	260	22464	0.4	0.5	29.7	30.5	4.7	39.0
July	260	22464	0.3	0.7	29.6	30.6	4.6	38.1
Aug	260	22464	0.3	0.8	37.5	38.6	6.3	35.8
Sept	260	22464	0.2	0.7	37.5	38.3	6.4	35.2
Oct	430	37152	0.3	0	33.8	34.1	7.8	36.8
Nov	430	37152	0.2	0	29.7	29.9	7.6	34.9
Dec	430	37152	0.2	0	27.0	27.1	5.4	36.5

Table 5: Predicted Monthly Effluent Concentration under Current Flow and Loads using the Concept Design at Bellozanne STW.

This can be compared with the table below that shows the final effluent analytical results for 2014 achieved by the existing STW. These show that the predicted performance of the Concept Design when treating the current flow and loads (Table 5) is similar to that achieved by the existing works (Table 6). The annual average TN from the model (Table 5) is 30.6mg/l compared to a TN of 31.2mg/l and a DAIN (Dissolved Available Inorganic Nitrogen) of 27.1mg/l as shown in the table below (Table 6) for the existing works.

	Existing Works Average Effluent						
	Ammonia mg/l	Nitrite mg/l	Nitrate mg/l	TN mg/l	DAIN mg/l	BOD mg/l	COD mg/l
Jan	13.44	0.2	5.3	22.5	18.9	3.0	26.9
Feb	10.69	0.2	4.3	17.5	15.1	2.3	26.8
March	23.45	0.2	3.3	30.5	27.0	3.9	37.3
April	28.50	0.2	3.0	35.3	31.8	4.5	39.7
May	21.1	0.6	5.4	31.1	27.1	4.4	40.2
June	22.1	1.1	7.6	34.6	30.8	6.6	39.1
July	18.3	0.9	8.7	33.0	27.8	3.3	42.7
Aug	21.5	0.9	6.2	34.0	28.6	6.6	48.4
Sept	22.1	1.8	6.0	35.2	29.9	6.0	50.1
Oct	27.9	1.4	3.7	38.6	33.0	6.3	50.4
Nov	18.3	0.8	5.1	27.5	24.2	3.7	33.8
Dec	26.2	0.5	4.4	34.3	31.1	6.0	29.1

Table 6: Existing Works Average Effluent Concentrations for 2014.

To get a comparison over a broader period of time in order to assess the monthly variation in the existing plant and the process model in terms of TN, the monthly average for the years 2010 to 2014 has been examined. This gives the following: -

Month	Monthly Average TN Concentration, mg/l					
	2010	**2011**	**2012**	**2013**	**2014**	**Model**
Jan	30.2	30.5	25.7	16.1	22.5	25.1
Feb	35.3	32.7	33.2	20.9	17.5	27.1
March	27.1	-	30.1	25.7	30.5	28.7
April	35.2	-	30.3	28.7	35.3	28.1
May	48.1	-	24.0	33.4	31.1	29.4
June	32.2	-		32.5	34.6	30.5
July	28.5	-		24.8	33.0	30.6
Aug	31.6	-		29.9		38.6
Sept	30.8	-		26.9		38.3
Oct	30.3	-		22.9		34.1
Nov	23.7	-		21.5		29.9
Dec	-	-		29.4		27.1

Table 7: Monthly Variation in TN Concentration compared to the Concept Design Model Output

The cells shaded are the months where the measured TN concentration from the existing works exceeds that predicted by the model. Certain months, such as February 2014, in the existing plant data show very low TN concentrations and these tend to correlate with periods of high rainfall experienced during these periods. This high rainfall has two effects. Firstly, it dilutes the sewage entering the works and thereby the TN concentration measured at the outfall, thus resulting in much lower concentrations than would be seen under typical conditions. Secondly, the high volumes of water entering the sewers can result in overflows of 'raw' sewage directly into the bay resulting in a higher TN load to the bay. The TN load from the overflows is not included in the above tabled concentrations as they only cover the STW discharge.

It should be noted that the New Bellozanne STW design treats a higher Flow to Full Treatment and this, combined with the addition of Storm Tanks and alterations to the control of First Tower PS, means that the number of storm spills will be greatly reduced.

Caution should be exercised when analysing the comparative data in detail. Whilst Table 7 indicates that the monthly final effluent TN concentration is predicted to be generally similar to that of the existing works, the predicted TN FE concentration is lower in the first 6-7 months of the year and higher in the months of August to October. It should be noted that there is very limited existing data for the latter period and this makes it more difficult to obtain a robust comparison. Clearly, the analysis of fewer data points means that any errors or anomalies in the data have a more pronounced impact on the results.

It is also important to note that whilst the overall TN in the effluent is approximately the same, the speciation of the TN alters. Based on the current flows and loads, the existing plant produces a TN that largely consists of ammonia whereas in the Concept Design, nitrification occurs and the TN consists largely of nitrate.

4.2.2 Final Design

The Final Design now considers incorporating an anoxic tank onto the Concept Design with a view to reduce the TN in the effluent further as an effluent quality objective. Similar to the Concept Design, a table has also been produced to assess the effluent concentrations month by month for the Final Design based upon the 2014 to 2015 Alcontrol data, i.e. current flows and loads (see Table 8 below).

			Final Design Average Effluent					
	Average Flow l/s	Average flow m3/d	Ammonia mg/l	Nitrite mg/l	Nitrate mg/l	TN mg/l	BOD mg/l	COD mg/l
Jan	430	37,152	0.2	0	19.1	21.0	5.1	37.6
Feb	430	37,152	0.2	0	21.8	22.6	5.7	34.2
March	430	37,152	0.4	0	22.3	23.3	6.0	34.2
April	430	37,152	0.3	0	20.0	23.5	6.6	36.8
May	260	22,464	0.3	0.3	20.2	21.7	4.6	36.8
June	260	22,464	0.3	0.5	21.1	23.0	4.2	38.0
July	260	22,464	0.3	0.7	19.8	24.0	4.1	37.8
Aug	260	22,464	0.3	0.8	27.4	28.7	5.7	35.5
Sept	260	22,464	0.2	0.7	26.8	28.1	5.8	34.6
Oct	430	37,152	0.3	0	24.5	26.5	7.1	35.9
Nov	430	37,152	0.2	0	23.1	24.0	7.0	34.1
Dec	430	37,152	0.2	0	22.3	23.4	4.9	35.8

Table 8: Predicted Monthly Effluent Concentration under Current Flow and Loads for the Final Design.

This can be compared with the final effluent analytical results for 2014 achieved by the existing STW. These show that the predicted performance of the Final Design when treating the current flow and loads (Table 8) is slightly better than that achieved by the existing works (see Table 6 above) although the uncertainty relating to the low C/N ratio should be noted.

The annual average TN from the model (Table 8) is 24.5mg/l compared to a TN of 31.2mg/l and a DAIN (Dissolved Available Inorganic Nitrogen) of 27.1mg/l as shown in Table 6 for the existing works.

To get a comparison over a broader period of time in order to assess the monthly variation in the existing plant and the process model in terms of TN, the monthly average for the years 2010 to 2014 has been examined as given in Table 9 below.

Month	Monthly Average TN Concentration, mg/l					
	2010	2011	2012	2013	2014	Model
Jan	30.2	30.5	25.7	16.1	22.5	21.0
Feb	35.3	32.7	33.2	20.9	17.5	22.6
March	27.1	-	30.1	25.7	30.5	23.3
April	35.2	-	30.3	28.7	35.3	23.5
May	48.1	-	24.0	33.4	31.1	21.7
June	32.2	-		32.5	34.6	23.0
July	28.5	-		24.8	33.0	24.0
Aug	31.6	-		29.9		28.7
Sept	30.8	-		26.9		28.1
Oct	30.3	-		22.9		26.5
Nov	23.7	-		21.5		24.0
Dec	-	-		29.4		23.4

Table 9: Monthly Variation in TN Concentration compared to the Final Design Model Output

The cells shaded are the months where the measured TN concentration from the existing works exceeds that predicted by the model and a commentary is provided below Table 7.

In summary, it is likely that an improved effluent quality objective could be achieved in the Final Design. Hence, the Target Annual Average TN Concentration for the Final Design as estimated in Table 10 forms an effluent quality objective for the new STW.

Scenarios 1 & 3	Annual Average TN, mg/l	
	Current Influent Load (2015)	Design Load (118,000PE)
Final Design	25	28

Table 10: Target Annual Average TN Concentration for the Final Design

4.2.3 Future Plant Extension

The Concept Design examined the plant expansion possible to achieve a tighter TN standard in the future should it be required. This future provision would utilise the existing plant area that will become available once the final settlement tanks have been demolished and replaced with the increased anoxic and aerobic volumes to a capacity of 12,100m^3 and 16,630m^3 respectively.

The model has been run with these increased capacities using both the 2015 data to indicate the plant performance under current flows and loads and the PE of 118,000 to assess the performance of this arrangement using the loads for the PE of 118,000.

The predicted annual average TN concentration, including the 5% contingency, achieved for each of these scenarios is summarised in Table 11 below.

Scenarios 2 & 4	Annual Average TN, mg/l	
	Current Influent Load (2015)	Design Load (118,000PE)
12,100m^3 anoxic zone and 16,630m^3 aerobic zone.	16	17

Table 11: Predicted Annual Average TN Concentration using the Future Expansion of the Concept Design at Bellozanne STW.

In order to achieve TN consents lower than those indicated above, addition of a carbon source (e.g. methanol or acetic acid) has been considered. This would be added to the anoxic zone in order to increase the C/N ratio and allow the required degree of de-nitrification to take place. For the future plant, 450 l/h of methanol would be required in order to achieve an annual average TN standard of 10 mg/l. This clearly adds substantial operating cost to the scheme as well as the sustainability issues of importing large quantities of carbon source to the Island.

The use of an on-site fermenter has also been considered but this only reduces the annual average TN standard by approximately 1 mg/l. Considering the operational issues and the potential for odour release from a fermenter this will not be pursued at this stage.

4.2.4 Return Liquors Plant

The existing sludge treatment plant utilises anaerobic digestion in order to produce a Class A sludge and biogas which in turn powers a CHP. The liquors resulting from the dewatering of the sludge are high in ammonia. Although a Liquors Treatment Plant is not part of the Concept Design and would incur additional capital and operating cost to that currently assessed, it has been considered so as to treat the ammonia in the centrate liquors and thereby reduce the nitrogen load entering the sewage works.

The load from the centrate has assumed a dewatered cake of 26% dry solids average and an ammonia concentration of 800 mg/l. This gives a nitrogen load of around 20-25% of the total load seen for 2015 raw sewage. The Return Liquors Plant would only reduce a proportion of this 20-25% and therefore the TN load to the STW would still be approximately 85% of the existing load. Thus at this stage the effect of a return liquors plant is limited. For a new build such as Bellozanne, other alternatives for reducing the TN may be preferable although the return liquors plant will be worth further investigation should a tighter TN standard be applied in the future as the extra nitrogen removed may be critical at that stage.

Regardless of where in the process the nitrogen is treated, the overall TN to be treated is the same and therefore the carbon required will be the same for a conventional process. Systems such as Annamox can be utilised that would require less carbon but the C/N ratio in the raw sewage to the main works would still be low and the issues detailed above would still apply.

5. HISTORICAL RESULTS FOR NH_3-N AND TN FROM EXISTING STW

The effluent from the existing works has been analysed by the local Jersey Laboratory as part of the regular monitoring of the works and provide in Table 12 below.

Year	**Annual Arithmetic Mean, mg/l**	
	Existing Plant Performance	
	NH_3-N	TN
2007	-	31
2008	-	28.5
2009	-	36.5
2010	19	32
2011	25	28
2012	17	29
2013	15	26
2014	21	31
2015	29	40

Table 12: Historical Results for ammonia (NH_3-N) and total nitrogen (TN) from the existing STW.

It is noted that the result for 2015 is high in the existing plant performance data as one secondary treatment stream has been out of service for maintenance for a prolonged period. This has therefore been ignored in the average.

It should also be noted that the above results for the existing plant only apply to a Flow to Full Treatment, FFT, of 650 l/s. Flows in the range of 600 to 860 l/s receive preliminary and primary treatment only and then overflow to outfall and therefore do not receive any treatment to remove TN.

The new STW will receive a higher flow from First Tower Pumping Station (1,100 l/s compared to 860 l/s) and treat a higher flow to full treatment, 815 l/s compared to approximately 650 l/s as at present. As well as a higher volume of raw sewage being captured and fully treated by the new STW, there will also be fewer storm spills from the system as already discussed in 2.1.

6. CONCLUSIONS

6.1 Predicted Discharge Standards (Alcontrol Lab Influent Data)

The process model for the new STW Concept Design predicts that the annual average TN standard achieved based on the raw sewage influent as determined by the Alcontrol laboratory for 2015 is 31 mg/l TN. This allows a 5% contingency over the actual value predicted in the model.

The future design PE is 118,000 as opposed to the current PE of around 100,000 during summer. As the PE increases, so too does the biological load to the works with the result that the extent of nitrification will decrease and the TN concentration of the effluent will increase slightly unless the C/N ratio improves. This increase will occur regardless of whether the new build is carried out or not.

The STW process model predicts that the Concept Design will achieve an annual average TN standard of 35 mg/l when receiving the flow and loads estimated for a PE of 118,000. **This is the design condition for the plant and the proposed discharge consent for TN when the new Works are fully commissioned.**

The process model for the Bellozanne STW Final Design predicts that the annual average TN standard achieved based on the raw sewage influent as determined by the Alcontrol laboratory for 2015 is 25 mg/l TN. This allows a 5% contingency over the actual value predicted in the model. It also predicts that the Final Design will achieve an annual average TN of 28 mg/l as an effluent quality objective when receiving the flow and loads estimated for a PE of 118,000.

However, given that these consent standards cannot be achieved during periods when the Anoxic Zone is taken out for maintenance and servicing and there is uncertainty over some of the critical influent parameters such as the C/N ratio, the design condition for the plant will be based on the Concept Design.

6.2 C/N Ratio

The C/N ratio in the influent is a limiting factor at the Bellozanne STW. This affects the efficiency of the denitrification process and the ability of the plant to remove TN. Even allowing for the future expansion of the works in line with the anoxic and aerobic capacities indicated in the New Bellozanne Feasibility Report and modelled above, carbon dosing may well be needed if a low TN standard (less than 15mg/l on an annual average basis) is required in the future, unless the level of nitrogen in the influent can be reduced.

6.3 Future 'TN Standard' Plant

The future modification of the Concept Design layout as detailed in the Feasibility Report to achieve an enhanced TN standard consists of an anoxic tank of 12,100m^3 and an aerobic capacity of 16,630m^3.

Using these volumes the STW process model predicts that an annual average TN standard of 16 mg/l will be achieved with the current influent. This increases to 17 mg/l when based on the 2035 predicted biological load. Any less than 17mg/l for the 2035 design horizon will require either additional plant or carbon dosing. Additional plant may include processes such as a fermenter or return liquors treatment facility to reduce the TN concentration below 17mg/l but there is significant capital cost associated with this as well as possible operational issues. This allows a 5% contingency over the actual value predicted in the model.

An annual average TN standard of less than 15mg/l in the future will almost certainly require additional carbon dosing into the anoxic tank.

6.4 Existing Plant Discharge

The analysis of the effluent from the existing STW shows that the annual average TN standard of the current works as an arithmetic mean ranges from 26 mg/l in year 2013 to 36.5 mg/l in 2009. The effluent results for 2015 have been ignored as one activated sludge lane has been out of service for a prolonged period.

As a comparison, the STW process modelling predicts that the Concept Design will achieve an annual average TN standard of 31mg/l based on the current loads and 35 mg/l based on the 118000PE design values. These allow a 5% contingency over the actual value predicted in the STW process model. The current predicted annual average TN concentration of 31mg/l is therefore within the range of that actually measured over the last few years.

In addition the average monthly TN concentration of the discharge from the new STW as predicted by the process model indicates similar levels to those seen on the existing works over the last few years. As mentioned in the main text, the data output from the model and the data from the existing plant becomes less reliable the smaller the time frame being considered so caution should be exercised when carrying out detailed comparisons on the monthly data.

If the new STW is to provide no deterioration in TN on an annual average basis to that achieved by the existing plant and no deterioration in the water quality in St Aubin's Bay, then bearing in mind that the Concept Design treats a higher flow and quantity of sewage than the existing works, that there are less storm water spills, and the effluent quality standard detailed for the Concept Design will be achieved even when the anoxic tank is taken out of service for maintenance, a consent standard equivalent to that predicted by the STW model for the Concept Design would seem appropriate.

As for the Final Design, the STW process modelling predicts that the new STW will achieve an annual average TN standard of 25 mg/l based on the current loads and 28 mg/l based on the PE of 118,000 design values as an effluent quality objective. These allow a 5% contingency over the actual value predicted in the STW process model. The current predicted annual average TN concentration of 25mg/l is less than that measured over the last few years. This forms the effluent quality objective for TN to maintain better quality of effluent from the new STW but given that these consent standards cannot be achieved during periods when the Anoxic zone is taken out for maintenance and servicing and the fact that the low C/N ratio in the influent adds greater uncertainty the tighter the TN consent gets, they will not form the basis of the design condition.

6.5 New Plant Discharge

On the basis of the above and for loads up to that predicted for a PE of 118,000, the Concept Design for the new STW is to achieve the following discharge consent for the FFT flow of 813 l/s based on daily composite samples.

- Biological Oxygen Demand (BOD): 25 mg/l (95%ile)
- Chemical Oxygen Demand (COD): 125 mg/l (95%ile)
- Total Suspended Solids: 35mg/l (95%ile)
- Total Nitrogen (TN): 35mg/l as total N based on an annual average.
- Disinfection of all final effluent and storm overflows by UV measured applied dose of 30 $mW.s.cm^{-2}$ at 254nm.

However, the target effluent quality objective for TN would be 28mg/l as total N based on an annual average value for the design PE of 118,000 on the basis of the Final Design.