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Technical note:
Updated calculation of nitrate loading from housing growth

1. Introduction

In 2018 Wood were commissioned to produce an Integrated Water Management Study (IWMS) for the Partnership for South Hampshire (PfSH). The IWMS considered, *inter alia*, the additional loading of nitrate and phosphorus that would be discharged from Wastewater Treatment Works (WwTWs) due to housing growth in the area, and the potential impact of these additional nutrient loadings on the water quality of the receiving waters. The primary focus of this aspect of the IWMS was on compliance with the Water Framework Directive or WFD (directive 2000/60/EC) and in particular assessing whether increased sewage discharges would cause a deterioration in WFD classification of the receiving waterbodies. For most inland waters phosphorus is the limiting nutrient, and so the IWMS considered phosphorus concentrations in receiving rivers. Only a high level calculation of the additional nitrate loading to Transitional and Coastal waters (TraCs) was included.

Along the south coast of England there are a number of sites designated under the Habitats Directive (directive 92/43/EEC), including the Solent Maritime Special Area of Conservation (SAC), Portsmouth Harbour Special Protection Area (SPA), Chichester and Langstone Harbours SPA and Solent and Southampton Water SPA. There are also a number of Sites of Special Scientific Interest (SSSIs) in the area. Parts of the Solent Maritime SAC have been assessed by Natural England as being in "unfavourable" condition due to elevated levels of nitrate.

Since the completion of the IWMS, advice from Natural England, on the basis of European case law, has determined that all housing development (or any development that would involve overnight stays, such as hotels, campsites, B&B etc.) that would result in increased sewage discharges to designated sites should be nitrate-neutral, meaning that after control at source and mitigation, the development should result in no net increase in nitrate to the site. This update to the IWMS has therefore looked in more detail at the estimated nitrate (or strictly, total oxides of nitrogen, TON[1]) loading that would result from projected housing development draining to the Solent. The original calculation has been revised based on more accurate housing projections, and the sensitivity of the calculated loading to underlying assumptions has been explored, with the aim of producing a more up-to-date and accurate assessment than that which was included in the 2018 report. The area included in the study has also been revised, and now includes the whole of the New Forest District and National Park, and hence a greater number of sewage discharges than were included in the 2018 study. Note, however, that the 2018 report included assessment of discharges from employment growth which have been excluded from this update, following Natural England guidance.

This technical note describes the basis of the revised figures, a review of the uncertainty in some aspects of the calculations, and presents updated and revised estimates of the TON loading from projected housing growth in the PfSH area.

[1] TON includes nitrate (NO_3) and nitrite (NO_2), although concentrations of nitrite are usually much smaller than those of nitrate.

2. Review of methodology and assumptions

2.1 Calculation methodology

The estimation of the TON loading from housing growth is carried out as follows. The increase in dry weather flow (DWF) to a WwTW is estimated as:

$$\Delta DWF = H \times P \times W$$

ΔDWF = increase in dry weather flow

H = number of new houses completed

P = occupancy rate (number of people per dwelling)

W = water use per person.

The TON loading associated with this increased DWF is then estimated based on an assumed TON concentration in sewage final effluent:

$$\Delta N = \Delta DWF \times C$$

ΔN = increase in TON loading

C = TON concentration in final effluent.

2.2 IWMS baseline calculation

The baseline calculation in the 2018 IWMS assumed an occupancy rate of 2.5 per dwelling and a per capita water consumption of 120 l/person/day. Information on projected housing growth was provided by the Local Planning Authorities, and in total it was estimated that 102,234 dwellings would be completed in the period to 2036.

The nitrate concentration in effluent from each WwTW was based on monitoring data (where available) or estimated based on the ammonium concentration from the works and comparison with data from a similar WwTW for which ammonium and nitrate monitoring data were available. It was assumed that works of a similar capacity and ammonium effluent quality would discharge with the same nitrate concentration as each other. In all, 23 WwTWs were included in the IWMS.

2.3 Updated calculation

The calculation presented in the IWMS was updated as follows:

- The number of WwTWs included was increased from 23 to 38, to include all works that discharge into the Solent either directly (e.g. via a long sea outfall) or indirectly (into a river that then flows into the Solent);
- Updated housing projections were provided by the Local Planning Authorities;
- The assumed occupancy rate of each dwelling was reduced to 2.4, in line with Natural England advice;
- Increases in nitrate discharge due to employment growth were not considered, as per Natural England guidance;

- Assumed per capita water use was reduced to 110 l/person/day, in line with the optional higher efficiency figure in the Building Regulations Part G.

Additionally, the basis of the assumed TON concentration in discharges from each WwTW was revised in line with Natural England advice:

- For works with a permit, a concentration equal to 90% of the permitted value;
- For works with no permit, a value based on monitoring data, where data are available;
- For works with neither monitoring data nor a permit, a value of 25 mg-N/l. This is based on Natural England's assessment of a typical "worst case" effluent concentration of 27 mg-N/l, reduced by 2 mg-N/l, that being a concentration of nitrate in the Solent considered compatible with good conservation status.

In addition, the sensitivity of the calculations to these revised assumptions was explored through the following scenarios:

- Reducing the estimated increase in DWF to account for the possibility that some occupants of new houses may not be new to the PfSH area but may have migrated within the catchment. This was explored through review of ONS population projections at whole-borough level;
- Using projections of population growth based on demand forecasts developed by Southern Water Services;
- Changing the basis of the estimation of the nitrate concentration in sewage effluent, based on monitoring data or calculated over-performance against permits.

The results of these calculations are provided in Section 3.

2.4 Southern Water demand forecasts

As part of their Water Resource Management Plan[2] (WRMP19) Southern Water Services (SWS) have also produced demand forecasts which take into account projections in housing growth and new connections, household occupancy rates and per capita water use among their customers. This section reviews the assumptions and figures used in the WRMP in conjunction with the figures used in this update to the IWMS.

Per capita water use

- Average per capita consumption in 2017-2018 was 129 l/person/day. Per capita consumption has declined by over 11% since 2009-10 due to promotion of water efficiency measures by the company, and is forecast to continue to decline.
- SWS' Target 100 initiative aims to reduce per capita consumption to 100 l/person/day (company wide average) by 2040.
- Consumption in metered properties is significantly lower than in unmetered properties. It is estimated that customers who switched to a metered supply reduced their consumption by around 16.5%. All new developments will be fitted with water meters.
- It should be noted that these projections of water use are average figures across SWS' catchment, and include older, less water-efficient housing stock as well as new developments. New developments would be expected to be more efficient than the average, and as noted in

[2] https://www.southernwater.co.uk/media/2988/wrmp19-annex2-demand-forecast.pdf

Section 2.3, the updated calculations assume a water use of 110 l/person/day which is lower than the current average consumption but higher than the 2040 target figure.

The WRMP provides figures for average occupancy and water use per property broken down into three groups:

- Group 1: Detached houses with average consumption greater than 325 l/property/day;
- Group 2: Semi-detached and terraced houses with average consumption 250-325 l/property/day;
- Group 3: Flats and bungalows with average consumption less than 250 l/property/day.

Based on the assumed occupancy rates and water consumption figures provided in the WRMP it is possible to estimate approximate per capita water use in 2017-2018 as shown in Table 2.1.

Table 2.1 Average per capita water use 2017-2018 (SWS WRMP19)

	Occupancy	Household consumption (l/property/day)	Per capita consumption (l/person/day)
Group1	2.8	365.4	130.5
Group2	2.74[1]	299.15[1]	109.2
Group3	1.815[2]	220.8[2]	121.7

1. Average of the figures for semi-detached and terraced houses.
2. Average of the figures for flats and bungalows.

Overall, these figures suggest that the figure for assumed water use of 110 l/person/day in new developments that is used in this update is reasonable to include in LPA nitrate neutrality calculations as per NE guidance, but may be an overestimate of future water use in the period to 2040 as SWS' Target 100 initiative progresses.

Population growth

The WRMP shows forecasts of population growth from the base year of 2020-21 to 2044-45 and beyond, calculated using four different methods, and broken down into three supply areas. The Western supply area includes the catchment draining to the Solent.

Of the four calculation methods, the "plan-based forecast" has the highest estimated customer population in the base year, and the highest estimated population throughout the forecast period. The overall net growth over the forecast period predicted by each of the methods is, however, very similar, with all methods predicting growth of 16-17% over the forecast period to 2044-45. By inspection of the charts provided in the WRMP, predicted population growth in the Western supply area is estimated at around 11%, or about 100,000 persons.

Average household occupancy is predicted to decline over the forecast period. For the Western area, average occupancy is estimated to decline by 8% over the entire forecast period to 2044-45, and from around 2.42 in 2020-21 to around 2.34 in 2035-36.

It is not possible directly to compare these predictions of population growth with the figures derived from Local Plans and assumptions around occupancy rates, as the SWS Western supply area does not coincide precisely with the area covered by the updated IWMS. However, it is noted that SWS' estimate of population growth in the IWMS area is substantially lower than the estimate derived from projected housing growth and

an occupancy rate of 2.4 (see Section 3.2) and this is consistent with a decline in average household occupancy.

2.5 Nitrogen export coefficients

Natural England guidance on the calculation of nitrogen budgets for development sites (version 4, March 2020) includes a methodology for the estimation of total nitrogen inputs from private sewage treatment works (Package Treatment Plants, or PTPs). This is based on a nitrogen export coefficient (the quantity of nitrogen produced by one person in wastewater in one year) of 3.5 kg-N/person/year, which is originally derived from work by Lerner (2000)[3] and Chilton (1996)[4] on the estimation of nitrogen inputs to groundwater from septic tanks. The figure is based on water use of 160 l/person/day and effluent concentration of 60 mg-N/l, and in the Natural England guidance an illustrative reduction of 70% is then applied to account for losses through treatment resulting in an export coefficient of 1.05 kg-N/person/year (in the example given).

It is noted that the original research on which this figure was based relates to septic tank discharges to ground (rather than PTPs). There is some evidence to suggest that the effluent concentration in PTP discharges may be somewhat lower than that from septic tanks. However, attenuation rates in PTPs are highly variable. A literature review reported in Wood (2010)[5] suggests a per capita export coefficient for septic tanks of 1.64 kg-N/person/year, which is comparable with the figure derived by Lerner (2000) of 1.75 kg-N/person/year. Wood (2010) report a per capita export coefficient for PTPs of 1.1 kg-N/person/year, which is comparable with the figure in Natural England's guidance.

3. Updated nitrate loading calculations

3.1 Updated baseline calculation

Results

The Local Planning Authorities in the PfSH area provided updated projections of housing growth for the period 2018-2036. The basis and detail of the projections varied between the LPAs, but in general they were based on completions in the period to 2019 and projections in each period 2020-2025, 2025-2030 and 2030-2036. The updated housing projections comprise a total of 106,816 new dwellings in the period to 2018-2036, compared with the figure of 102,234 in the 2018 IWMS.

Projected developments were assigned to a WwTW on the basis of geographical proximity, recognising that there is uncertainty in these estimates and that new connections will be determined by Southern Water as details of developments are confirmed.

The results of the updated baseline calculation of TON loading from housing growth to 2036 are summarised in Table 3.1.

[3] Guidelines for estimating urban loads of nitrogen to groundwater. Project NT1845 final report, MAFF, 2000.
[4] https://www.gov.uk/government/publications/identification-and-quantification-of-groundwater-nitrate-pollution-from-non-agricultural-sources-literature-review
[5] Wood 2010 Cumulative Nitrogen and Phosphorus Loading to Groundwater Final Report (22 Nov 2010)

Table 3.1 Summary of updated baseline calculation

Variable	Updated value
Projected total new dwellings to 2036	106,816
Estimated increase in DWF (m^3/day) to 2036	28,199
Estimated increase in TON loading (kg/year) to 2036	149,158

Estimates for individual WwTWs are shown in Table 3.2. Note that complete data are not available for all works, and so the totals of the figures in Table 3.2 do not precisely match those in Table 3.1.

On average, over all the works shown, the percentage increase in TON loading over current (2018) levels is **11.1%.**

Table 3.2 Updated baseline calculations for selected WwTWs

WwTW	Housing Growth (2036)	Increase in DWF (m^3/d, 2036)	Assumed effluent TON concentration (mg-N/l)	Increase in TON (kg/yr, 2036)	Percentage increase in TON (2036)
Ashlett Creek	2615	690.48	25.00	6300.66	25.3
Bishops Waltham	1128	297.79	13.50	1467.37	7.6
Budds Farm	21707	5730.65	9.00	18825.18	5.0
Chickenhall Eastleigh	7422	1959.41	25.00	17879.60	6.2
Millbrook	7237	1910.57	9.00	6276.22	4.4
Peel Common	21645	5714.28	8.10	16894.27	7.5
Portswood	813	214.63	25.00	1958.52	0.9
Romsey	2567	677.69	25.00	6183.90	9.6
Slowhill Copse	6982	1843.37	12.60	8477.67	10.0
Southwick	0	0.00	25.00	0.00	0.0
Wickham	322	85.01	25.00	775.70	9.2
Woolston	1053	277.99	13.50	1369.81	2.1
Sandown	9849	2600.22	25.00	23727.02	6.0
Shalfleet	122	32.18	25.00	293.60	16.1
Shorwell	82	21.66	25.00	197.69	13.7
St Helens	207	54.70	25.00	499.12	13.9
Wroxall	265	69.93	25.00	638.10	8.8

WwTW	Housing Growth (2036)	Increase in DWF (m^3/d, 2036)	Assumed effluent TON concentration (mg-N/l)	Increase in TON (kg/yr, 2036)	Percentage increase in TON (2036)
Brighstone	97	25.53	25.00	232.92	4.9
Calbourne	81	21.45	25.00	195.74	16.5
Chale	81	21.45	25.00	195.74	8.0
Chillerton	81	21.45	25.00	195.74	8.5
Godshill	258	68.21	25.00	622.44	14.3
Roud	210	55.34	25.00	505.00	7.3
Pennington	5578	1472.61	8.55	4595.64	6.9
Fullerton	6031	1592.18	25.00	14528.68	7.8
Morestead Road Winchester	1787	471.77	25.00	4304.88	4.9
New Alresford	571	150.74	22.50	1237.99	18.5
Harestock	2208	582.91	25.00	5319.07	11.2
Thornham	2715	716.76	9.00	2354.56	7.4
Apuldram	1413	373.03	8.10	1102.87	2.6
Bosham	503	132.79	9.00	436.22	7.9
Flexford Lane, Sway	40	10.56	25.00	96.36	1.0
Petersfield	528	139.39	25.00	1271.95	2.3
Liss	38	10.03	25.00	91.54	143.7
South Harting	13	3.43	25.00	31.32	0.7
East Meon	19	5.02	25.00	45.77	2.0
Droxford	12	3.17	25.00	28.91	0.0
West Marden	0	0.00	25.00	0.00	0.0

Comparison with IWMS estimates

Direct comparison of projected new connections to each WwTW in the 2018 IWMS and this update is not possible, since the update includes additional WwTWs which were not included in the IWMS. However, for those WwTWs that are included in both, projected new connections are compared in Figure 3.1, estimated increases in DWF in Figure 3.2 (housing only) and Figure 3.3 (housing and employment) and estimated increases in TON loading in Figure 3.4. Table 3.3 compares key results for the 23 WwTWs included in the 2017 IWMS with the updated values.

Table 3.3 Comparison of the 2017 IWMS and the updated baseline calculation (23 WwTWs)

Variable	2017 IWMS value	Updated value
Projected total new dwellings to 2036	102,234	96,231
Estimated increase in DWF (m^3/day) to 2036	35,759	22,394
Estimated increase in TON loading (kg/year) to 2036	77,591	113,712

Figure 3.1 Comparison of projected housing growth in the 2018 IWMS and the 2019 update

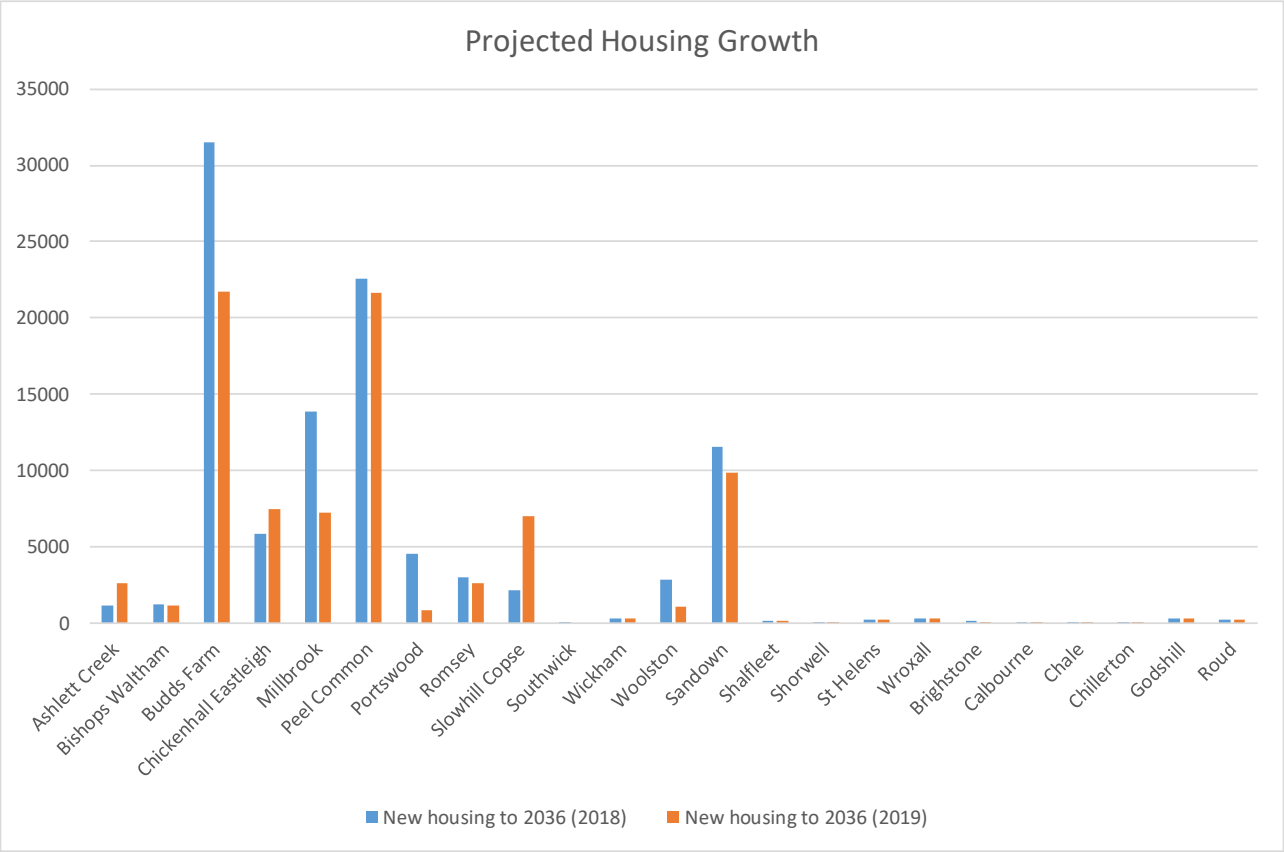


Figure 3.2 Estimated increase in DWF due to housing growth in the 2018 IWMS and the 2019 update

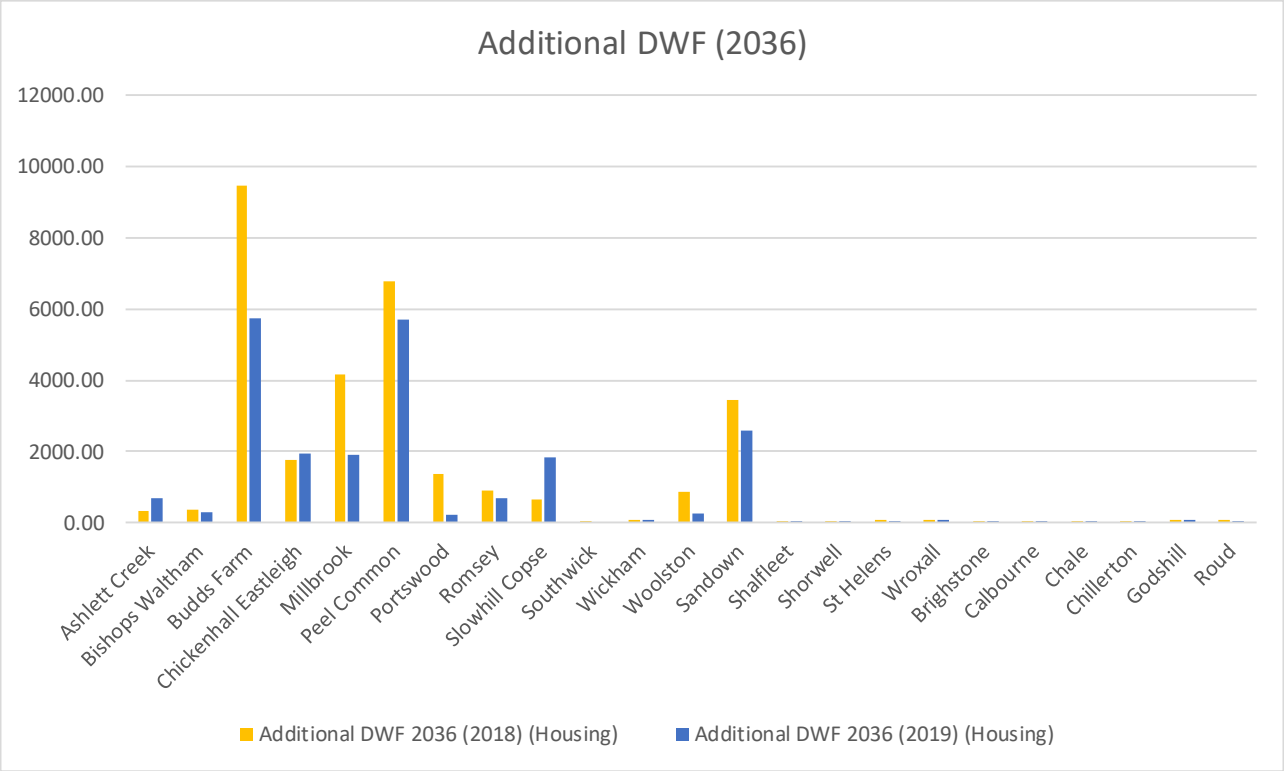


Figure 3.3 Estimated increase in DWF due to housing and employment growth in the 2018 IWMS and due to housing growth only in the 2019 update

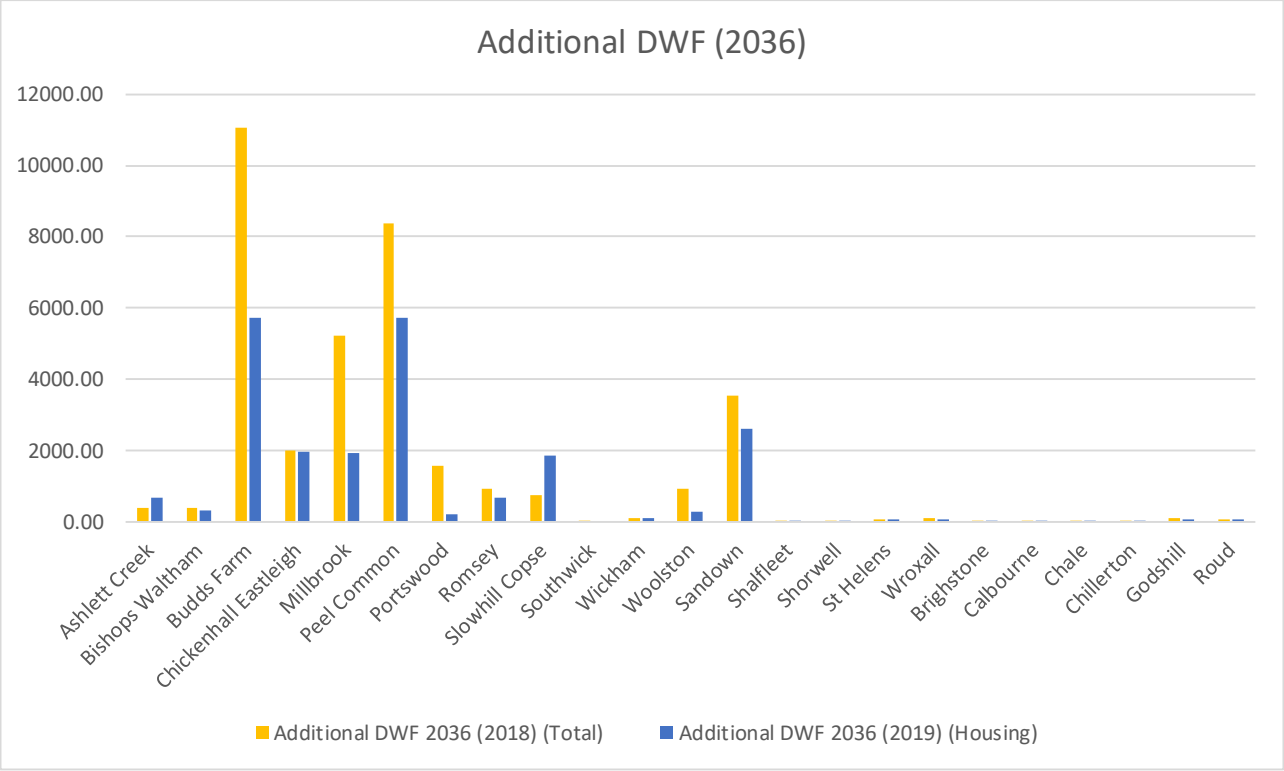
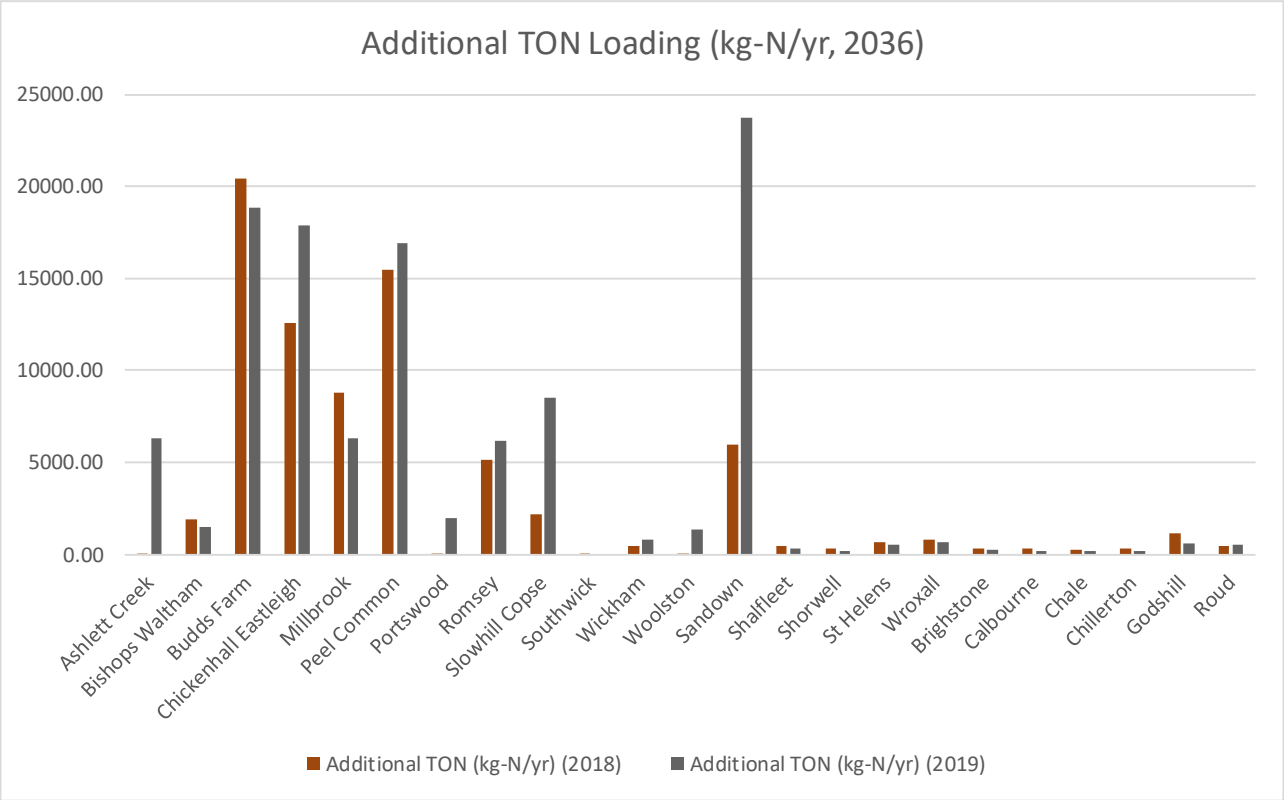


Figure 3.4 Estimated increase in TON loading in the 2018 IWMS and the 2019 update



Discussion

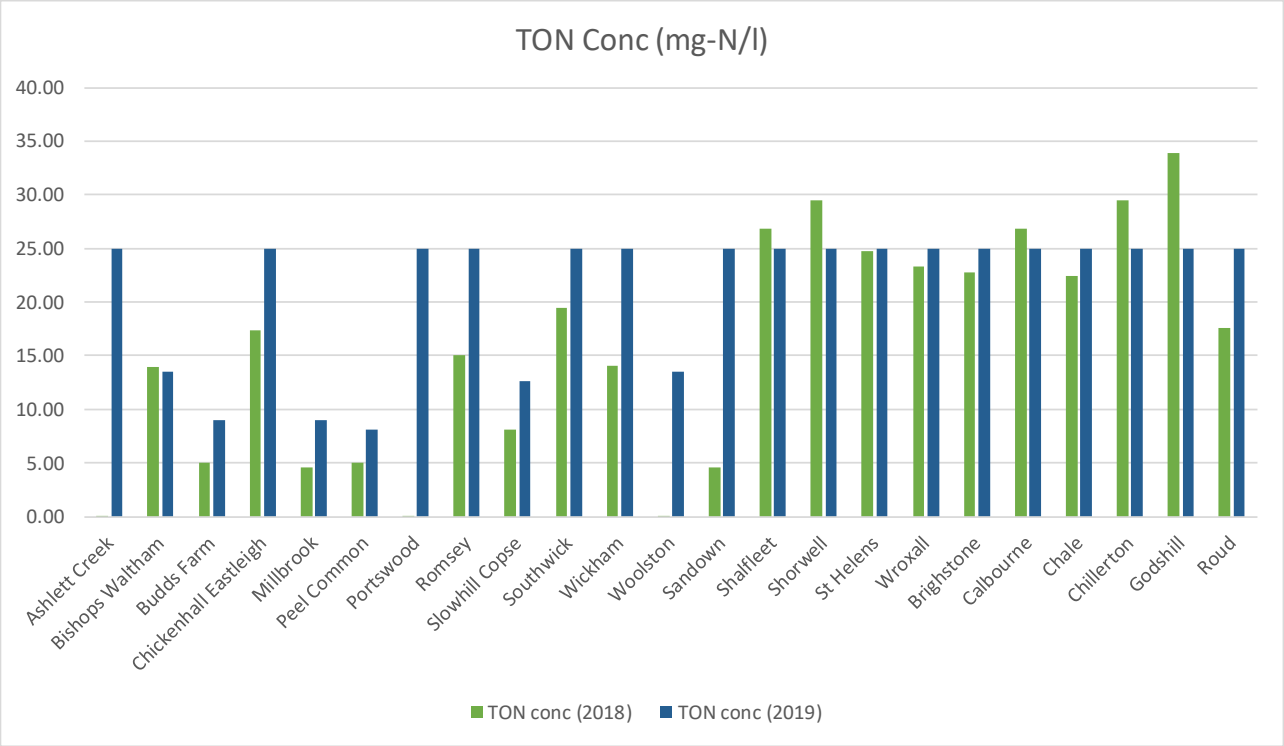
The changes in predicted TON loadings from individual WwTWs are due to changes in housing projections, occupancy rates and estimated per capita water use. However, the largest factor causing changes in predicted TON loading at some works is a change to the assumed TON concentration in sewage effluent. It will be recalled that in the IWMS, concentrations were in many cases estimated by comparison with another works of similar capacity and ammonium effluent quality. In this update, and in line with Natural England guidance, concentrations were estimated on the basis of permits or monitoring data, where available, or a default concentration of 25 mg-N/l. This has resulted in some large increases in assumed TON concentrations in sewage effluent (e.g. Sandown, Chickenhall Eastleigh), as shown in Figure 3.5.

The majority of the WwTWs included in the study do not have permits governing the maximum permitted nitrate or TON concentration in effluent. As such, most are not routinely monitored as there is no requirement to demonstrate compliance with a permit. Hence, with no permit in place and no monitoring data, the default concentration of 25 mg-N/l is assumed, as per Natural England guidance. In many cases this figure is much larger than the figure used in the IWMS.

This is clearly an area of significant uncertainty, and it is understood that Southern Water have agreed to put in place routine monitoring at those WwTWs that are not currently monitored in order to enable more robust estimates to be made of final effluent quality.

Based on the information currently available, the WwTWs at **Budds Farm, Millbrook** and **Peel Common** discharge at the lowest TON concentrations (see Figure 3.5), and development connecting to these works would therefore require the lowest levels of mitigation to achieve nitrate-neutrality.

Figure 3.5 Estimated TON concentration in sewage effluent in the 2018 IWMS and the 2019 update



3.2 Scenario evaluation

Results

This section presents the results of scenario calculations, based on varying some of the assumptions underpinning the baseline calculation of TON loading arising from housing development, as described in Section 2.3. The scenarios are described in more detail as follows.

1. The updated baseline scenario, as described in Section 3.1.
2. With assumed inward migration to the area of 58% (i.e. 42% of the occupants of new housing are not new to the area but have moved from elsewhere within it). This figure is based on analysis of ONS population projections to 2036[6] for the Boroughs covering the area, compared with estimates of the population increase that would result from housing growth in the Boroughs at an occupancy rate of 2.4. The ONS figures are, on average, 58% of those derived from housing projections.
3. With assumed inward migration to the area of 79% (i.e. 21% of the occupants of new housing are not new to the area but have moved from elsewhere within it). This figure is the average of the figure derived from ONS statistics (58%) and 100% (i.e. all occupants of new housing are new to the area) and is chosen to represent a conservative "best estimate" of population increase.
4. Using population projections developed by Southern Water in developing their PR14 submission. These figures equate to 70% of the baseline population increase estimated from housing projections.
5. Assuming effluent TON concentration based on monitoring data (where available) rather than 90% of permit concentration. Monitoring data is available for 10 WwTWs. For WwTWs with no monitoring data, the default concentration of 25 mg-N/l continues to apply.

[6] https://www.gov.uk/government/statistical-data-sets/live-tables-on-household-projections#based-live-tables

6. Assuming effluent TON concentration of 65.5% of permit concentration. This figure is derived from analysis of monitoring data for WwTWs with permits, which shows that, on average, works achieve a final effluent concentration of 65.5% of maximum permitted levels. For WwTWs with no monitoring data and permit, the default concentration of 25 mg-N/l continues to apply.

Table 3.4 presents the results of the scenario calculations.

Table 3.4 Results of scenario calculations

	Scenario	Current (2018) TON loading, all works, kg/year	2036 projected change in TON loading, kg/year	2036 projected TON loading, all works, kg/year	Percentage increase from 2018
1	Updated baseline calculation	2,490,441	149,158	2,639,599	6.0%
2	With 58% assumed inward migration	2,490,441	86,511	2,576,953	3.5%
3	With 79% inward migration	2,490,441	117,835	2,608,276	4.7%
4	Based on SWS population projections	2,490,441	112,871	2,603,312	4.5%
5	Using monitoring data instead of 0.9xpermit	2,490,441	140,256	2,630,697	5.6%
6	Concentration based on average overperformance vs permit	2,490,441	132,026	2,622,467	5.3%

Discussion

The scenarios explored above all result in lower estimates of increases in the TON loading to the Solent from projected housing growth. The most significant reductions when compared with the updated baseline are related to assumptions around population growth (as distinct from housing growth) and it is noticeable that both SWS and ONS population forecasts predict a smaller increase in population than that found from a simple multiplication of projected housing growth and occupancy rate of 2.4. This is due to a forecast decline in occupancy rates to levels below 2.4, and the likelihood of some internal migration within the PfSH area (which amounts to the same thing). (These results are presented for illustration and it is not suggested that lower occupancy rates are used in future estimates of TON loadings).

It is of note that SWS' forecast of population growth (Scenario 4) results in a predicted increase in TON loading that is quite similar to that obtained with an assumption of 79% inward migration (Scenario 3), which lends some weight to the assertion that inward migration to the catchment will be lower than simply (housing x 2.4) but may be higher than ONS statistics would suggest.

In all cases, the estimated TON loading is very sensitive to the estimated effluent quality from works with no nitrogen permit. The current default value is 25 mg-N/l and in this scenario (Scenario 1) WwTWs that are assumed to discharge at this concentration contribute to 33% of the overall predicted increase in DWF but 58% of the predicted increase in TON loading.

4. Summary and conclusions

- This note has presented the results of an updated calculation of the increase in TON loading to the Solent that could potentially result from projected housing growth in the PfSH area.

- The updated baseline calculation predicts an increase of 6% in TON loading from WwTW discharges over the period 2018 to 2036, equivalent to 149 tonnes-N/year.
- The updated baseline assumes population growth equal to housing growth multiplied by an assumed occupancy rate of 2.4. Both ONS population forecasts and Southern Water's WRMP demand forecasts suggest lower rates of population growth.
- The calculations are very sensitive to the assumed effluent quality of unmonitored WwTW discharges, and monitoring at these works will help to reduce the uncertainty in the projected increase in TON.

5. Future work

As described within this Technical Note, the Natural England guidance requires that where monitoring data for a given STW is not available that a default value of 25 mg-N/l is applied, and that this has likely resulted in the calculations providing an over-estimate of the current and projected TON loading. This applies to the calculations of TON loading for 17 of the 23 STWs considered in this document.

To address this source of uncertainty Southern Water have initiated additional monthly analysis of water samples from those 17 STWs for TON. This monitoring commenced in April 2020 and will result in a complete 12-month record of results in April 2021. Once the 12 months of TON monitoring data is available for all the STWs, then the calculations within this Technical Note should be updated to reflect those data, and therefore provide a more refined estimate of TON loading. This should be conducted as follows:

- Review of data quality e.g. to check that all data are provided and that there are no outliers.
- Annual average TON concentration values should be calculated for each of the STWs of interest.
- The calculated annual average concentration values should then be inserted into the TON loading calculations to replace the default values (25 mg-N/l)
- The calculated values should then be reviewed and the results incorporated into an updated Technical Note. The revised values will then provide an improved basis for assessing the increase to TON loading for developments at each timestep and under different scenarios.

Should further information become available then additional updates to the calculations could be undertaken. This may include updates or alterations to the development schemes, improvements on understanding which schemes tie in to specific STWs, or updates to monitoring data for the other STWs.

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