Follum Utvikling AS

Follum Wood Processing Industry 3rd party review

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3.2	5/12/2023	All	All	Final report corrections	IR

Contents

List of Figures

List of Tables

Summary

Follum Utvikling AS is investigating re-establishing the pulp and paper processing industry at Follum in Hønefoss, Norway. Follum Utvikling have commissioned COWI to assess how the discharge will affect the receiving waterbodies with respect to water quality, ecology, and the Directorate Group Water Framework Directive (WFD) goals and status. To define baseline conditions and current chemical and ecological status in the receiving waterbodies COWI are undertaking a monitoring programme. APEM was commissioned by Follum Utvikling to provide a 3rd party review of the pre-implementation monitoring programme. This review considers the proposed methodology and provides expert evaluation and recommendations as to whether it meets the remit of providing robust baseline data.

The review confirmed COWI used correct field and laboratory methodologies to collect the baseline data and used recognised standard approaches to data analysis. The spatial structure of the monitoring programme is appropriate to establish current status and detect future environmental change. The main constraint of the monitoring programme is the short timeline, which is insufficient to quantify baseline natural interannual variation. This will limit the ability to reliably detect environmental change driven by the wood pulp production. Other recommendations included investigating fish spawning habitat distribution in the potential zone of impact.

1. Introduction

Follum Utvikling AS is investigating re-establishing the pulp and paper processing industry at Follum in Hønefoss, located in the Ringerike district, Norway. Historically, the site was active for 140 years prior to its closure in 2012. Once production is reinstated treated process wastewater will be discharged into the River Begna, which then flows into the River Storelva downstream, before discharging into Lake Tyrifjorden.

Follum Utvikling have commissioned COWI to assess how the discharge will affect the receiving waterbodies with respect to water quality, ecology, and ultimately how this may impact on the Directorate Group Water Framework Directive (WFD) goals and status.

In order to define baseline conditions and current chemical and ecological status in the receiving waterbodies COWI plan to undertake a monitoring programme to collect sufficient data. COWI will then assess the potential impacts of the discharge through dispersion modelling, which will then be used to predict if the planned discharge may affect ecological receptors (and ultimately WFD status).

APEM was commissioned by Follum Utvikling to provide a 3rd party review of the pre-implementation monitoring programme. This review considers the proposed methodology and provides expert evaluation and recommendations as to whether it meets the remit of providing robust baseline data on water quality and ecology which can be used to detect environmental change once the plant is recommissioned. A robust baseline dataset is key to assessing potential impacts of the discharge in terms of understanding natural conditions and variations.

2. Background and understanding

COWI provided four documents for review: Dalen *et al* (2022a), Dalen *et al* (2022b), Bentzen and Dalen (2022), and Mikkelsen *et al* (2022).

COWI also provided two historical reports from NIVA: Baekken *et al* (2011) and Baekken (2013) for information purposes.

2.1 Literature provided for review

The background to the proposed works and review of current gaps in knowledge/data available to support the assessment is outlined in Dalen *et al* (2022a). This report then outlines the proposed sampling regime for water chemistry, physico chemical monitoring, and ecology (benthic invertebrates, benthic algae and heterotrophic growth: of the fungi *Leptomitus lacteus* and/or the bacteria *Sphaerotilus natans*) based on the available monitoring data.

An assessment of predicted impacts on water quality (in terms of predicted increases in nutrient loadings (principally phosphorous and nitrogen), dissolved organic carbon (DOC), and suspended solids to receiving waters is given in Dalen *et al* (2022b). It was concluded that further work was required to determine the potential for any impact of the discharge on the ecological status of the receiving waterbodies.

Bentzen and Dalen (2022) describes the dispersion modelling techniques that will be used to estimate discharge parameters throughout the river and lake systems and ultimately determine if the planned discharge will affect the receiving waterbodies.

Mikkelsen *et al* (2022) summarises the available ecological and water quality data and presents the results of the most recent water quality and benthic invertebrate sampling which was carried out in 2022 at seven sites (Figure 2.1 and Table 2.1).

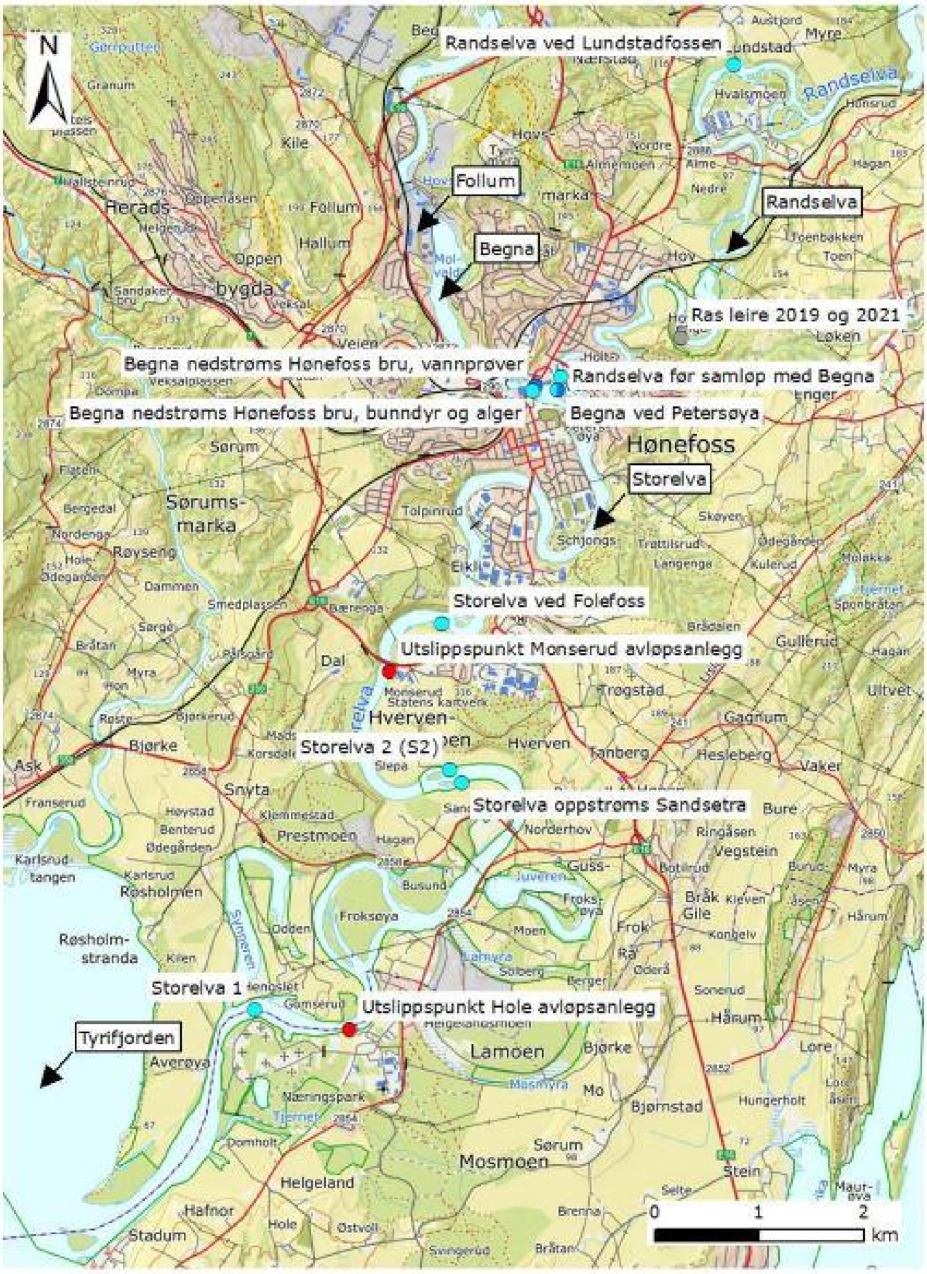

Figure 2.1. Overview of sampling stations) in Begna, Storelva, and Randselva rivers (adapted from Mikkelsen *et al* 2022, © The Norwegian Mapping Authority). Turquoise circles indicate sampling sites for benthic invertebrates while water sampling sites are indicated by blue circles. Locations of mudslides in Randselva in 2019 and 2021 are also indicated by grey circles, while the Monserud and Hole wastewater treatment plants (WWTPs) are indicated by red circles.

Historical monitoring information (with respect to benthic invertebrates Table 2.1) and water chemistry) from 1993 to 2012 was also provided in Baekken *et al* (2011) and Baekken (2013).

The available benthic invertebrate data are reproduced here in Table 2.1., while the water quality data are presented in Mikkelsen *et al* 2022. These data are discussed in more detail in the next sections.

Table 2.1. Benthic invertebrate sampling results considered in the review documents (Mikkelsen *et al* 2022) from 1993 to 2022. [1]

Station	nEQR for ASPT/BMWP/EPT								Comments/Site characteristics
	1993[2]	1997[2]	1998[2]	2003[2]	2010[2] Spring	2012[3] Autumn	2021[4] Spring	2022[5] Spring	
Begna nedstrøms Hønefoss bru (NIVA F3)	**0.09** 9 0	**0.23** 30 3	**0.21** 35 4	**0.57**	**0.48**	**0.60**	-	**0.66** 75 17	Begna downstream of Hønefoss Bridge, prior to confluence with Randselva. 10m wide, 0.7 m/s, Sa: 0.5, Gr: 0, St: 95, Bl 5 – adds to over 100? 0.3-0.4m deep 2010 samples taken in Spring 2012 samples taken in Autumn, 2022 in Spring (February
Begna ved Petersøya **Begna on Peter's Island**	-	-	-	-	-	-	-	**0.40**	Downstream confluence of Begna and Randselva. >10m wide, 0.4 m/s, Sa: <5%, Gr: 5, St: 90, Bl: 0. 0.3-05m deep Wood chips present in substrate.
Randselva ved Lundstadfossen (NIVA	-	-	-	-	**0.87**	-	-	**0.64**	Randselva at Lundstadfossen waterfall - Upstream control (?) (on Randselva rather than Begna). Upstream of 2019 and 2021 mudslides. >10m wide. >1 m/s. Sa: 0 , Gr: 10, St: 90, Bl: 0. 0.3-05m depth 2010 samples taken in spring
Randselva før samløp med Begna	-	-	-	-	-	-	-	**0.50**	Randselva prior to confluence with Begna >10m wide, >1 m/s. Sa:0, Gr: 10, St: 90, Bl: 0. Depth 0.3-0.5m. Fine particulates present (mudslides?)

[1] EQR is an ecological quality ratio, and nEQR is normalized EQR. EQR shows the relationship between the measured/observed average score per taxon (ASPT) value and the expected reference value/state of nature. Presented as nEQR corresponds to 1 reference value (best), while 0 is worst (bad). nEQR is divided into five classes, with 0.8–1 indicating High (marked in blue colour), 0.6– 0.8 indicating Good (green), 0.4–0.6 indicating Moderate (yellow), 0.2–0.4 indicating Poor (orange) and 0–0.2 indicating Bad (red), according to the Directorate Group Water Framework Directive (2018). Biotic index values where given refer to Biological Monitoring Working Party (BMWP) and EPT (total scores of ephemeroptera, plecoptera and trichopteran present) values are not subject to an EQR score.

Station	nEQR for ASPT/BMWP/EPT								Comments/Site characteristics
	1993[2]	1997[2]	1998[2]	2003[2]	2010[2] Spring	2012[3] Autumn	2021[4] Spring	2022[5] Spring	
Storelva ved Folefoss (Storelva 3 (S3)	-	-	-	-	-	-	**0.60**	**0.60**	Storelva at Folefoss . >10m wide, 1 m/s, Sa: 0, Gr: 30, St: 70, Bl: 0. 0.3-05m depth Clay on substrate
Storelva 2 (S2)	-	-	-	-	-	-	**0.54**	**0.61**	>10m wide, 0.4 m/s. Sa: 0, Gr: 30, St: 70, Bl: 0. 0.3-0.4 m depth.
Storelva oppstrøms Sandsetra	-	-	-	-	-	-		**0.65**	>10m wide, 1m/s, Sa: 0, Gr: 30, St: 70, Bl: 0. 0.25-0.35 depth. Fine particulate matter/clay
Storelva nedstrøms Hole avløpsanlegg	-	-	-	-	-	-	**0.60**	-	

2.) Baekken *et al* (2011)
3.) Baekken (2013)
4.) Andersen *et al* (2021)
5.) Mikkelsen *et al* (2022

2.2 Ecology

2.2.1 *Historical baseline and recovery*

The results of previous benthic invertebrate monitoring, carried out on the River Begna downstream of Hønefoss Bridge, from 1993 until 2012, is presented in Table 2.1 (Bakken *et al* 2011, Bakken 2013). The impact of previous paper pulp production (for 140 years until it ceased in 2012) on the various metrics are most noted in the earliest sample from 1993 where the status derived from ASPT nEQR was Bad. There has then been a progressive recovery up to the present day (2022).

2.2.2 *Present day baseline*

COWI undertook benthic invertebrate sampling at seven sites in the spring of 2022 (Mikkelsen *et al* 2022). Data are included in Table 2.1., sampling sites are presented in Figure 2.1. Further sampling was undertaken at all these sites in autumn (September) 2022 with the decision to sample in the spring of 2023 confirmed (Dalen 2022 *pers. comm*.). The results of the Autumn surveys were not submitted for review.

2.3 Water quality

2.3.1 *Historical baseline and recovery*

Data on water quality in the River Begna between 2012 and 2017 are presented in Mikkelsen *et al* (2022) and summarised here. These indicate nutrient concentrations at High status (WFD equivalent) with mean values for total phosphorous (Tot-P) of 8.2 µg/L (n = 32) and total nitrogen (Tot-N) of 221 µg/L (n = 32). Low concentrations of organic matter were recorded; measured as Total Organic Carbon (TOC, mean 3.4 mg/l, n = 32) and suspended solids (STS, mean 1.1 mg/l, n = 16). However, maximum concentrations of these parameters show that much higher values can be recorded especially for TOC (maximum 4.7 mg/l) and Tot-P (maximum 38 µg/l). These maximum baseline values are important to consider when assessing any potential impact of the discharge on the receiving waters. No data are available for the period of historical paper pulp production which ended in 2012 on which to base an assessment of any previous impacts.

2.3.2 *Present day baseline*

COWI carried out water quality sampling with laboratory analysis for TOC, Tot-P, and Tot-N at two sites in 2022: with two samples taken on the River Begna downstream of Hønefoss Bridge and a single sample further downstream in Begna, but upstream of the confluence of the Begna and Randselva rivers (Figure 2.1). Results indicated that there was a slight reduction in mean Tot-P to 7.33 µg/L (n = 3) and a slight increase in mean Tot-N to 243 µg/L (n = 3) values when compared with the 2012 to 2017 data. This again corresponds to High ecological status for Tot-P. Mean TOC values were lower than in 2012-2017 (TOC, mean 2.4 mg/l, n = 3) while there was a slight increase in STS values at both sites. However, care in interpretation of any apparent trends of the above parameters is advised because the 2012-2017 period is based on 32 samples with mean, maximum and minimum values while 2022 is based on three samples only. It can nonetheless be stated that the 2022 values are within the range previously reported 2012-2017.

Field measurements of water chemistry were taken at the same sites as benthic invertebrates between February and April 2022. Dissolved oxygen values were at saturation (100%) at all sites; however, we note that possible inaccuracy of the measurement is considered. A depth profile undertaken at a site on the Storelva indicated no decrease in oxygen levels with depth.

3. 3rd party review

In the following sections the proposed sampling regimes for ecology and water quality are reviewed in turn. For both components it is assumed that the objective of the monitoring is to reliably inform of any changes that are likely to bring about deterioration in WFD status.

3.1 Ecology

3.1.1 Proposed ecological monitoring

COWI propose to use the 2022 ecological data (derived from spring and autumn 2022) and possibly spring of 2023 to establish the pre-production baseline. Although this monitoring captures seasonal variation, it does not allow to quantify year-on-year variation. This will limit the ability to identify impacts of wood pulp production versus natural variation.

Ecological monitoring is focused on macroinvertebrates, benthic algae and heterotrophic growth. This is because macroinvertebrates are deemed to be the most sensitive receptors and the best indicators of overall ecological quality. It is appropriate, if only one ecological receptor is to be monitored, to focus on invertebrates. Nonetheless it should be noted that the use of multiple receptors (macroinvertebrates, plants, diatoms, fish, others) is always recommended when possible to capture the range of potential ecological impacts.

3.1.2 Benthic macroinvertebrates: Field methodology

Sampling of benthic macroinvertebrates (which are considered the most sensitive receptor) was carried out to appropriate standards. This involved taking a three-minute kick sample (comprised of 9x20 second sub-samples to ensure coverage across all available microhabitats in the survey area) and it appears that samples (for 2022 at least) were all taken across broadly consistent substrate characteristics and flow regime (with coarse substrates and fast flows).

3.1.1 Benthic macroinvertebrates: Laboratory methodology and analysis

Standard methods and best industry practice were observed with respect to preservation and identification to Family (TL2) level. The laboratory that processed the samples has an internal QA procedure. Uncertainties in ASPT score (due to varying sensitivities within TL2) were acknowledged in interpretation of the results.

The experimental design outlined in Mikkelsen *et al* (2022) is sound with good spatial coverage comprising two sites on the Begna, two on the Randselva, and three on the Storelva rivers. This will allow comparison of the effects of proposed discharge into the Begna and subsequent effects downstream in the Storelva with the two upstream sites on the Randselva providing 'controls' upstream of the Follum discharge. It is understood an additional station upstream of the discharge point on the River Begna has been included in the sampling regime since September 2022. This site will serve as an upstream control (Dalen 2022 pers. comm.).

Only two to three samples per site will be used to generate the baseline prior to permit application in 2023. It is understood that the proposed start date for production will not be until mid-2025 and that monitoring is expected to continue to this date (Dalen 2022 pers. comm.). This will provide a more robust baseline prior to discharge from the commencing. Invertebrate communities are likely to be subject to natural variation within seasons and across years (dependant of climate and flow effects) so ideally at least three years' worth of sampling data (from Spring and Autumn) would be required to build a robust baseline. Additionally, small-scale effects (such as the landslides noted on the Randselva in 2019 and 2021) may still be having an effect over short time periods.

The incorporation of the 2021 spring data from S3 and S2 on the Storelva will give additional data at these sites. If spring samples are taken at these sites in 2023, it will be possible to calculate the extent of seasonal variation across three years (for Spring). These values can be used to infer the extent of variation likely to be encountered at the other survey sites and give more confidence in the baseline.

The historical data presented in Baekken *et al* (2011) and Baekken (2013) indicate recovery of the macroinvertebrate community sampled in the river Begna downstream of Hønefoss Bridge from 1993 to 2012. It is worth noting that any temporal changes may be due to multiple signals (such as climate change or the influence of other discharges (e.g., from WWTP's). While these data are useful in informing historical trends in the Begna site they date back more than six years ago and are therefore unreliable to base any present-day baseline on.

EQR values for ASPT scores presented in Mikkelsen *et al* (2022) are subject to single threshold values used to determine ecological status across all streams and rivers in Norway, excepting those affected by glacial runoff (Dalen 2022 pers. comm.). This is unlike the UK based River Invertebrate Classification Tool (RICT) which considers local geographical (such as altitude, slope, and distance from source) and environmental (flow, alkalinity, depth, width etc) characteristics to model and predict the expected invertebrate communities. As such the Norwegian EQRs for ASPT may potentially be insensitive to local geographical and environmental variation and may over or under predict ecological quality at a given site. If the predicted value is too low, then there is the potential to undervalue a higher quality site while if too high, resources may be spent unnecessarily on-site improvements. However, under the Precautionary Principle the latter is the better scenario of the two. The lack of the extra predictive capacity of a tool such as RICT means that the reliability of EQRs for benthic invertebrates presented here is questionable (effectively this replicates the ASPT scores) and emphasises the need for more replication of data across multiple years to provide a reliable baseline to compare relative change.

3.1.1 Fish

Fish were not surveyed in the 2022 surveys. Large trout from Lake Tyrifjorden utilising the Storelva to spawn are mentioned in Dalen *et al* (2022a, 2022b). There is potential for fouling of these spawning sites via enrichment from effluent. Also, resident river fish are not considered. These may be subject to accessibility issues but information on barriers was not provided in the texts reviewed.

It is therefore recommended that some study of available spawning habitats for those sites accessible to migratory or resident fish within the Storelva and upstream is undertaken.

3.2 Water quality

3.2.1 Proposed water quality monitoring

COWI propose to carry out monthly sampling at the River Begna nedstrøms Hønefoss bru, vannprøver station (Dalen *et al* 2022a).

Sampling will be undertaken from February 2022 to no later than January 2023, hence at this date most sampling has taken place. Samples will be analysed for Tot-P, Tot-N, TOC, Dissolved Organic Carbon (DOC), BOD5 (Biochemical Oxygen Demand, five days), Chemical Oxygen Demand (COD: both permanganate and dichromate methods; COD_{Mn} and COD_{Cr} respectively), STS, Suspended Substances Incandescent Residue, and pH. Measurements of water temperature, oxygen and conductivity will also be taken on site on a monthly basis. Sampling will not be carried out in Lake Tyrifjorden which was scoped out from likely impacts in Dalen *et al* (2022a, 2022b).

Field measurements of water temperature, dissolved oxygen, pH, and conductivity will also be taken on site when for benthic macroinvertebrates are sampled.

Dalen *et al* (2022a) state that the available nitrogen and phosphorous data from the river Begna is limited to 32 samples from 2012 – 2017 and identify the need for further sampling.

With regards to the River Storelva a total of 105 individual measurements (for the suite of water quality determinands described above) have been taken between 2015 and 2020. However, the exact sampling details (site location and sampling time) are unclear in Dalen *et al* (2022a), but COWI deem this data to be sufficient baseline monitoring. There is additional nutrient monitoring carried out on the Storelva associated with WWTPs in the Ringerike and Hole municipalities which may provide additional data to compare against the upstream Begna discharge once it is operational.

In addition, dispersal modelling will be carried out to assess how much the planned discharge will affect the ecological status of the receiving waters. This approach is outlined in Bentzen and Dalen (2022).

3.2.2 Standard determinands methodology and review

The proposed baseline survey outlined in Dalen *et al* (2022a) is intended to understand the existing water quality before the new site operation starts discharging waste water in the second half of 2025.

Sites

The water quality monitoring programme needs to be carried out at several sites, including one site upstream and as far downstream until water quality impacts are not present. Ideally there should be a water quality monitoring site selected upstream of the discharge point to act as a control (on the River Begna upstream of the Follum plant discharge). Ideally water quality monitoring should be carried out at the same sites used for ecological sampling or as near to them as possible and (where appropriate).

Monitoring downstream should include a monitoring point immediately downstream of the discharge mixing zone at the first suitable site (i.e. where it is safe to collect samples). The site at the confluence of the Begna and Randselva rivers sampled in 2022 described in Section 2.3.2 would be ideal for this purpose. Further monitoring points should be selected downstream until there are no effects of the discharge. The downstream extent of monitoring might be identified by there no longer being any wood fibres present in the sediment and/or no changes to water chemistry compared to the control monitoring point. From the reviewed literature it is expected that downstream monitoring on the Storelva will utilise the data available from monitoring carried out by Ringerike and Hole municipalities (associated with WWTP).

There should be several downstream sites, a single site will not be sufficient to determine the impact of the discharge. The wastewater from paper pulp manufacturing plants typically contains substances that are broken down in the environment only slowly. A reduction in dissolved oxygen due to the wastewater may not occur immediately downstream of the site, and due to biochemical and chemical processes, will be detected much further downstream. The distance to monitor downstream needs to be established by data collected at several sites until no change in water quality is found. The monitoring sites associated with the WWTP's (and the use of 3rd party data) downstream on the Storelva should provide the minimum monitoring requirement but ideally these sites should correspond with the benthic ecology sites.

It is recommended that samples are collected from 30cm below the surface of the water. If the water body is deep (over 3m deep) it is recommended that a depth profile is carried out.

This should be carried out using a calibrated multi parameter probe to measure pH, temperature, conductivity, dissolved oxygen and ammonium.

Analysis suite

In terms of the analysis suite the programme set out in Dalen *et al* (2022a) indicates this will include Tot-P, Tot-N, TOC, COD_{Cr} (dichromate), and COD_{Mn} (permanganate).

The recommended monitoring suite is shown in Table 3.1.

We recommend that assessments of the water quality data use the environmental quality standards from the WFD where possible, or previous legislation for determinands which are not included in the WFD. This approach requires environmental quality standards (EQR) to be set as site specific standards in some cases. This applies to dissolved oxygen, total ammonia, biochemical oxygen demand, temperature, heavy metals and phosphorus.

In situ measurements of dissolved oxygen, pH, temperature and conductivity taken via WTW Multi 3630 IDS meter will be carried out at the same time as benthic invertebrate sampling (in the spring or autumn). We recommend that these parameters are also recorded during the water quality sampling.

Frequency

The programme set out in Dalen *et al* (2022a) indicates that monthly sampling for water quality will be undertaken. Monthly sampling is considered appropriate. This should cover the need to sample at low, normal and high flows.

Table 3.1 List of determinands relevant to water quality monitoring associated with paper pulp discharges. Intended monitoring, schedules and location descriptions are given in subsequent columns

Determinand	Proposed to be carried out in monitoring study	Frequency	Location
Dissolved oxygen (as % saturation and mg/l)	Y	Spring/Summer	Invertebrate sites
Temperature	Y	Spring/Summer	Invertebrate sites
Chemical Oxygen demand (COD)	Y	Monthly – Feb 2022 - Jan 2023	Begna plus 3rd party data for Storelva
Biochemical Oxygen Demand (BOD)	Y (from April 2022)		
Total ammonia as N	N		
Suspended solids	Y	Monthly – Feb 2022 - Jan 2023	Begna plus 3rd party data for Storelva
Total residual oxidants	N		
Heavy metals: Aluminium, dissolved copper, dissolved iron and dissolved manganese	N Comments: eight metals (arsenic, lead, cadmium, copper, chromium, mercury, nickel and zinc) have been included in two samples in 2022 (April and October)		
Acrylamide (only if polyacrylamide polymers (polyelectrolytes) are used in the treatment process to aid flocculation)	N		
pH	Y	Spring/Summer	Invertebrate sites
Hydrogen sulphide	N		

Determinand	Proposed to be carried out in monitoring study	Frequency	Location
Sulphate, magnesium, calcium and chloride	N		
Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC)	Y – both DOC and TOC	Monthly – Feb 2022 - Jan 2023	Begna plus 3rd party data for Storelva
Reactive phosphorous as P	N (included in the December sample)		
Total phosphorus as P (Tot-P)	Y	Monthly – Feb 2022 - Jan 2023	Begna plus 3rd party data for Storelva
Hydrocarbons			
Total Oxidised Nitrogen (Tot-N)	Y	Monthly – Feb 2022 - Jan 2023	Begna plus 3rd party data for Storelva

Mikkelsen *et al* (2022) provided evidence of wood fibre accumulation (gathered by substrate excavation and photography) in sediments downstream of the Follum plant. We therefore recommend that sediment samples are collected and measured for the same list of determinands as shown in Table 3.1 above. In addition, in suitable locations where the water body has soft sediment free from rocks, a sediment oxygen demand test should be carried out. This will determine if the sediment is contaminated by organic matter leading to low oxygen conditions at the sediment/water boundary.

The characteristics of wastewater discharged from paper pulp production are likely to contain material that only breakdowns slowly. The potential for oxygen depletion, toxicity and other effects (such as discolouration) can affect water bodies for a long distance downstream.

The production of paper pulp involves the use of chemicals under pressure and at high temperature, which may lead to effluent that is toxic to aquatic organisms. Paper pulp production should recover as much of the chemicals as possible. The use of chemicals means there will be a risk of accidental spills so measures should be taken to ensure any spills are contained on site.

3.2.1 Dispersion modelling

The proposed methodology is sound. The models are widely used and run with an industry standard software.

3.3 Recommendations

3.3.1 Ecology

The EQR values presented in the reports reviewed may be unreliable due to local geographic and environmental variability not accounted for in calculation. Care should therefore be taken in interpretation as they may be subject to over or underestimation of ecological status. If this is the case, then under the precautionary Principle is best to assume that the former (i.e. the observed quality is actually higher than the EQR derived value).

Ideally three years' worth of benthic macroinvertebrate data (across spring and autumn seasons) should be collected to inform the pre-commissioning baseline. If this is not possible the extent of inter annual variation should be quantified to give confidence in the consistency of the baseline values.

Assessment of the extent to which large trout from Lake Tyrifjorden utilise the Storelva for spawning has not been carried out. It may be good practice to carry out fish habitat or redd surveys (during the spawning season from September onwards) to establish a baseline for spawning activity prior to reinstating the plant.

There are no data on fish at the discharge point in the Begna. Fish passage from Tyrifjorden through the Storelva to the Begna is complicated by a number of barriers, and information on fish passage was not available for this review. Nonetheless it is expected that the Begna will have at least a resident fish population. As fish are a highly sensitive receptor, while also having socioeconomic value, it is recommended that some fish assessment is made in the Begna. A fishing survey would identify the abundance and diversity of fish species in the recipient reach. A fisheries habitat walkover survey would help identify key patches of spawning habitat that could be impacted by effluent fouling. A survey of salmonid redds would confirm use of spawning habitat by fish and is important because the egg and fry stages of salmonids are particularly sensitive to water quality.

3.3.2 Water quality

In order to best compare the immediate impacts of the discharge on the river Begna an upstream control site should be monitored for all the determinands outlined in Dalen *et al* (2022a) with possible additions from the list in Table 3.1.

Lake Tyrifjorden was scoped out from analysis but robust justification for this was not provided. It is understood that this is due to information held about the water environment in Lake Tyrifjorden by COWI (Dalen 2022 *pers. comm*.) which we have not received for review. In the. We would recommend that and future monitoring of water quality in Lake Tyrifjorden considers this information.

For consistency is recommended that in situ measurements of physico chemical parameters are taken at the same sites and times as all other determinands.

Care should be taken in the use of 3rd party data to ensure it is reliable, both in terms of methodology and that it has been sampled within appropriate time and comparable river states.

The list of extra determinants in Table 3.1. is offered for consideration and may provide a more robust baseline to compare future changes against.

4. References

Andersen, J.R., Henninge, L.B., and Helland, A. 2021. Knowledge acquisition in Storelva 2020. Assignment number A221578. 46 p.

Bækken, T. 2013. Recipient survey in Begna near Follum in Hønefoss in 2012. Report 6465-2013, NIVA. 17 p.

Bækken, T., Kile, M.R., Skryseth, L.M., and Eriksen, T.E. 2011. Recipient survey of Begna, Randselva and Tyrifjorden in 2010 in connection with emissions from Norske Skog Follum ASA and Huhtamaki Norway AS. Report NIVA 6189-2011. 56 pp.

Bentzen, T.R., and Dalen, H. 2022. Dispersion modelling for discharge to Begna, Storelva and Lake Tyrifjorden. Note COWI, assignment number A242134-RIM-NOT-034. 19p.

Dalen, H., Mikkelsen, K.O. and Torgersen. P. 2022a. Programme to obtain sufficient knowledge for recipient assessment of Begna and Storelva. Note COWI, assignment number A231755. 11 p.

Dalen, H., Berg, G., Saunes, H. and Mølmann, E. 2022b. Assessment of Begna and Storelva as recipients of emissions from the pulp and paper industry. Note COWI, assignment number A231755. 19 p.

Mikkelsen, K, O., Torgersen, P., and Dalen, H. 2022. Preliminary note on survey of benthic invertebrates and water in Begna, Randselva and Storelva in 2022. Note COWI, Assignment number A231755. 32 p.