RAPPORT L.NR. 7441-2019

The Norwegian river monitoring programme – water quality status and trends in 2018

Elveovervåkningsprogrammet – vannkvalitetsstatus og -trender 2018

Foto: Therese Fosholt Moe, NIVA

Norwegian Institute for Water Research

REPORT

Main Office
Gaustadalléen 21
NO-0349 Oslo, Norway
Phone (47) 22 18 51 00

NIVA Region South
Jon Lilletuns vei 3
NO-4879 Grimstad, Norway
Phone (47) 22 18 51 00

NIVA Region East
Sandvikaveien 59
NO-2312 Ottestad, Norway
Phone (47) 22 18 51 00

NIVA Region West
Thormøhlensgate 53 D
NO-5006 Bergen Norway
Phone (47) 22 18 51 00

NIVA Denmark
Njalsgade 76, 4th floor
DK 2300 Copenhagen S, Denmark
Phone (45) 39 17 97 33

Internet: www.niva.no

Title The Norwegian river monitoring programme – water quality status and trends in 2018 Elveovervåkningsprogrammet – vannkvalitetsstatus og -trender 2018	Serial number 7441-2019	Date 09.12.2019
Author(s) Cathrine Brecke Gundersen, Øyvind Kaste, James Sample, Hans Fredrik Veiteberg Braaten, John Rune Selvik, Dag Øystein Hjermann, Magnus Dahler Norling, Jose-Luis Guerrero Calidonio	Topic group Environmental monitoring	Distribution Open
	Geographical area Norway	Pages 94 + appendix

Client(s) Norwegian Environment Agency	Client's reference Gunn Lise Haugestøl
Client's publication: Miljødirektoratet report M-1508|2019	Printed NIVA Project number 16384

Summary

In the Norwegian River Monitoring Programme (Elveovervåkingsprogrammet) 20 rivers along the Norwegian coastline are monitored for chemical and hydrological parameters. It is a continuation of a former monitoring programme, having produced monitoring data since 1990. This report presents the current status (2018) and long-term (1990-2017) water quality trends.

Four keywords	Fire emneord
1. Rivers	1. Elver
2. Monitoring	2. Overvåking
3. Water quality	3. Vannkvalitet
4. Trends	4. Trender

This report is quality assured in accordance with NIVA's quality system and approved by:

Hans Fredrik Veiteberg Braaten	*Kari Austnes*	*Heleen de Wit*
Project Manager	Quality Assurance	Research Manager

ISBN 978-82-577-7176-8
NIVA-report ISSN 1894-7948

The Norwegian river monitoring programme – water quality status and trends in 2018

Preface

The Norwegian river monitoring programme is, in addition to being the basis for the fulfilment of Norway's obligations under the Oslo-Paris Convention (OSPAR), a main component of the Norwegian water authorities' surveillance monitoring in rivers, according to the requirements set by the EU Water Framework Directive (WFD). In 2017, the Norwegian Environment Agency commissioned the Norwegian Institute for Water Research (NIVA), in collaboration with consortium partners, to carry out the monitoring activities for the period 2017-2020. Results from the 2018 monitoring activities are presented in four thematic reports. This report presents results from the basic monitoring of 20 rivers across Norway, selected to represent the variability in river water quality and fluxes, and to cover a substantial fraction of the riverine flux from mainland Norway to the sea.

The monitoring in 2018 was a collaboration between NIVA and the Norwegian Institute of Bioeconomy Research (NIBIO), the Norwegian Water Resources and Energy Directorate (NVE), Eurofins Environment Testing Norway AS, Institute for Energy Technology (IFE), Lancaster Environment Centre (LEC), and UC Davis Stable Isotopes Facility (UC Davis SIF).

Hans Fredrik Veiteberg Braaten (NIVA) was project leader for the river monitoring programme in 2018. Other co-workers at NIVA responsible for the results in the present report include Cathrine Brecke Gundersen (report coordination and main author), Øyvind Kaste (evaluation of isotope, sensor and hydrology modelling data), James Sample (databases, calculation of riverine loads), José-Luis Calidonio (hydrological modelling), Rolf Høgberget (sensor monitoring), Dag Ø. Hjermann (climate and hydrology data), Liv Bente Skancke (coordination of local field work personnel, quality assurance of sampling and chemical analyses), John Rune Selvik (TEOTIL modelling), and Elisabeth Lie and Marit Villø (contact persons at NIVAlab). Quality assurance of the report has been carried out by Kari Austnes.

At NVE, Trine Fjeldstad has been responsible for the local sampling programmes, Stein Beldring has carried out the hydrological modelling, and Morten N. Due has been the administrative contact. Eurofins has carried out the mercury analyses, LEC and UC Davis Stable Isotopes Facility have analysed stable isotopes in phosphate and nitrate, respectively, and IFE has determined stable isotopes of oxygen.

Contact persons at The Norwegian Environment Agency have been Gunn Lise Haugestøl and Eivind Farmen. Thanks to all involved for a good collaboration.

Oslo, 09.12.2019

Cathrine Brecke Gundersen and Hans Fredrik Veiteberg Braaten

Table of contents

Summary

The programme

The Norwegian River Monitoring Programme (Elveovervåkingsprogrammet) features monthly sampling of 20 rivers distributed along the Norwegian coastline. The rivers drain to the four oceans Skagerrak, North Sea, Norwegian Sea, and Barents Sea. The rivers are monitored for various chemical, physical, and hydrological parameters. The monitoring programme is a main component of the Norwegian water authorities' surveillance of rivers, according to the requirements set by the EU Water Framework Directive (WFD), and it also forms the basis for the fulfilment of Norway's obligations under the Oslo-Paris Convention (OSPAR). The programme was established in 2017, replacing the former RID programme (Riverine inputs and direct discharges to Norwegian coastal waters) which had been running continuously since 1990. New features include higher sampling frequency for all rivers (but fewer rivers), an extended list of chemical variables, and the use of catchment models for simulation of climate effects and anthropogenic inputs on water quality. Results from the 2018 monitoring have been presented in four separate reports. In this report the current status (2018) and long-term water quality trends (1990-2018) for the 20 rivers will be presented and discussed.

Weather in 2018

In general, 2018 was a warm year with the national annual average temperature being +1.4 °C above the 1961-1990 normal. During all four seasons the average temperature was above the normal, and the largest deviation occurred during the summer, which was the 6th warmest since measurements started in 1900. Annual and seasonal precipitation for the country was close to normal, but with large regional differences: the annual average constituted 50 and 150% of the normal at regions in the south-east and the north of eastern Norway, respectively. During the autumn some areas in the south received as little as 25-50% of the normal precipitation, while some stations in the north received up to 200% of the normal.

Trends in climate, water temperature and water flow

Trend analyses of air temperature and precipitation measured from 1980 to 2018 at meteorological stations showed a significant increase in air temperature at nearly all sites, while precipitation was only significantly increasing at the station representing the northern River Alta. Water flow has increased significantly since 1990 in the southern and south-eastern rivers Glomma, Drammenselva, Skienselva and Orreelva. These trends of increasing temperature and water flow are in accordance with the general climate change predictions.

Water quality status 2018

The water chemistry generally follow a geographical pattern for most variables (east-to-west/south-to-north) which is related to e.g. the vegetation and soils types of the areas: the south-eastern rivers typically drain areas with boreal forest, the rivers in the south and south-west are influenced by slow weathering bedrock, more sparse vegetation, and barren rock, while the mid-to-northern rivers generally fall in-between the characteristics of the south-eastern and the south-western rivers. Two major exceptions include River Alna in the south-east and River Orreelva on the west coast. These are both heavily influenced by human activities through urbanization and agriculture, respectively. Other exceptions are evident in the metal concentrations which also result from local human activities.

The pH of the rivers in 2018 ranged from weakly acidic (pH 6.2) to basic (pH 8.0). The most acidic rivers were found in the south and south-west, which is related to the local geology and that these areas have received- and are still receives the highest loads of acid deposition in the country. Consequently, several of these rivers were low in calcium, and according to the Norwegian WFD typology fall into the categories *very low* (< 1 mg L^{-1})- and *low* (1-4 mg L^{-1}) with respect to calcium content. Weakly acidic-to-neutral pH was found in the south-eastern rivers while for the rivers in the mid-to-northern Norway, the pH was generally close to neutral. The highest pH values were in the two most anthropogenically influenced rivers, Alna and Orreelva (pH 8.0 and 7.8, respectively). Regarding calcium, River Alna was calcareous (> 20 mg L^{-1}), while the remaining rivers belonged to the calcium types low or moderate (4-20 mg L^{-1}).

Suspended material can strongly affect the water quality, e.g. through transport of nutrients and metals. The south-eastern rivers Glomma, Alna, and Numedalslågen were high in both turbidity and suspended particulate matter (SPM), while the rivers in the other regions were generally low (except from river Orre). Moreover, turbidity and SPM showed large inter-annual variability, likely driven by seasonal precipitation events. Silica is a type of colloidal material (in addition to silicates) and constitutes an important nutrient for a large group of algae (i.e. diatoms). For silica the highest levels were found in the northern rivers (Altaelva, Tanaelva, and Pasvikelva > 5 mg L^{-1}) and in the south-eastern river Alna.

Organic matter can also be a transporter of nutrients and metals and constitutes an important food source for various types of organisms such as bacteria. In general, the level in surface water is a result of vegetation and soil types of the area. Organic matter is quantified as total organic carbon (TOC), and based on the 2018 data, two of the rivers can be categorized as *humic* (Rivers Storelva and Orreelva > 5 mg L^{-1}), eleven as having *clear* water (2 mg L^{-1} < TOC < 5 mg L^{-1}), and the remaining seven rivers as having *very clear* water (TOC < 2mg L^{-1}), according to the Norwegian WFD typology. Note that the *very clear* rivers were located in the south-western part of the country. For all rivers, the dissolved organic carbon (DOC < 0.45 µm) was the dominant fraction of the TOC (74.4 – 97.5% DOC).

The nutrients phosphorus (P) and nitrogen (N), are important indicators of water quality, and in particular with regard to eutrophication. The highest levels of both total P (tot-P) and total N (tot-N) were found in the two rivers Alna and Orreelva, being influenced by urbanization and agriculture, respectively. According to the national thresholds for classification under the WFD, both rivers were in less than good ecological status for tot-P and tot-N for their respective water types. Among the remaining rivers, both Glomma and Numedalslågen were high in tot-P and tot-N, but neither exceeded the good/moderate boundary. With regard to tot-N, some rivers in southern and south-western Norway showed elevated levels, which can most likely be related to atmospheric deposition.

The bioavailability of the nutrients depends on which chemical form they exist and is generally reduced when the nutrient is bound to particles. The highly bioavailable fraction phosphate (PO_4) made up a significant part of the tot-P in most rivers (29 - 83%), and with the highest proportion in the urban river Alna. Particulate-P constituted 33-79% of the tot-P across all rivers, and this was probably causing the high inter-annual variability in the tot-P concentrations. With regard to tot-N, nitrate (NO_3) was generally the dominating fraction, followed by organically bound-N, and ammonium (NH_4). In several of the northern rivers the ammonium level was very low. Nitrogen does not have a high affinity for particles, and accordingly, particulate-N was an insignificant fraction in most rivers.

Regarding metal concentrations, a few rivers stood out from the rest by having higher concentrations of certain types of metals. Note that metals were analysed in unfiltered samples, while the WFD environmental quality standards and thresholds apply to filtered samples. The urban river Alna was high in arsenic, lead, cadmium, copper, zinc, chromium, and nickel, but with levels of both lead and copper being lower than the 5-year mean. In the north-eastern river Pasvikelva, higher levels of arsenic, lead, cadmium, copper, and nickel were observed. The 2018 average level of nickel was roughly 30% higher than the 5-year mean. River Pasvikelva is located close to a large metallurgical complex on the Russian side of the border and is affected by airborne pollution. Other rivers with slightly elevated metal concentrations constitutes Rivers Orkla (Cd, Cu, Zn, and Ni), Storelva (As, Pb, and Zn), and Orreelva (As, Cu, Zn, and Ni). Rivers Orkla and Storelva were likely influenced by runoff from old main tailings in the catchments, and River Orreelva from agricultural activities

The water chemistry from 10 additional rivers from the south-, south-west and middle Norway were included in this report. In general, the water chemistry confirmed the geographical patterns already observed for the 20 rivers of the regular programme, and none of the rivers seemed to have been affected by local human activities (e.g. agriculture or mining). The pH increased from the south to the north. Calcium levels were correspondingly low in the southern rivers. All the rivers were low in particulate material, except for Rivers Namsen and Saltdalselva, located in the middle of the country. The TOC concentration was relatively low for all rivers, but with two of the southern rivers categorized as humic (Nidelva and Mandalselva ≥ 5 mg L^{-1}). The nutrient levels (tot-P and tot-N) were relatively low, except for somewhat higher tot-P in River Namsen, which was likely associated with the higher particle content in this river. Metal concentrations were low in all rivers.

Trends in water chemistry, loads and concentrations
Trend analyses were conducted for the nine rivers with monthly, long-term (1990 – 2018) data. Trends were analysed for concentrations and loads of SPM, silica, TOC, and nutrients, as well as water discharge. For metals, a shorter time frame was used (2004 – 2018) due to a shift in the sensitivity of the methods used. The results showed increasing water discharge in rivers in south-eastern Norway. In River Drammenselva this had likely led to the observed increase in SPM, silica, and TOC loads, which can influence the coastal ecosystem at its outlet. In Scandinavia, there has been an increasing trend in TOC in surface waters over the past 25-30 years, which is explained by a combination of reduced acid deposition and climate change. Among the monitored rivers, only Drammenselva showed an increase in TOC. For several of the rivers, limited TOC data was available from the early 1990s, so the trend analysis was only run from 1999, which may have reduced the potential for capturing any significant trends.

In the south-eastern rivers Drammenselva and Numedalslågen there was an increase in the loads of tot-P and N, which was attributed to increasing phosphate and organically bound-N. With regards to tot-P, the organic- and particulate-P could also have contributed to the increase but had not been part of the long-term monitoring. For several rivers across the country, decreasing trends in loads and concentrations of both nitrate and ammonia were observed. The reduced levels could result from increased plant productivity, reduced atmospheric N-deposition, and/or, in some rivers, by increased water discharge (causing dilution). In River Vefsna, in mid-Norway, all nutrient fractions and SPM showed decreasing trends.

The short-term trend analysis for metals generally showed decreasing loads and concentrations. The only two exceptions were increasing nickel concentrations in Rivers Vefsna and Alta. The reason for the increase remains unknown, but with low concentrations the increasing trends warrants no concern at this point. River Orkla had the highest number of decreasing metal trends (loads of Pb, Cd, Cu, and Zn, and concentrations of Cu and Zn). This was positive, given that this river is affected by an abandon copper mine in the catchment.

Quality of dissolved organic matter

The quality of the dissolved organic matter (DOM) can have large impacts on various catchment processes (e.g. transport of contaminants). Spectroscopic indices have been used to describe the degree of aromaticity (sUVa) and molecular size (E2_E3) of the material. In general, the seasonal variability was larger than the differences between the four geographical regions (Skagerrak, North Sea, Norwegian Sea, and Barents Sea). During spring and autumn there was an increase in the concentration of TOC, and also in the indices representing aromaticity and molecular size of the material. This was linked to the hydrological events of spring snow melt and autumn intensive precipitation, both leading to increased surface runoff. More aromatic and larger sized DOM is generally associated with older and more humified material. Interestingly, when comparing the monthly averages of 2018 with those from 2017, it appeared that the warm and dry summers of 2018 had an impact on the quality of DOM. While the TOC concentrations in the two years were similar, the aromaticity during the summer was much lower in 2018, potentially caused by a higher degree of photodegradation. Geographically, the rivers on the west coast, draining to the North Sea, were most distinct from the rest: The TOC concentrations were low, and the relationship with aromaticity was higher than in the other regions. The reason for this is not known, but it is likely related to differences in hydrological conditions and/or source of DOM.

Stable nitrogen and oxygen isotopes in nitrate

Analysis of stable nitrogen and oxygen isotope ratios ($d^{15}N$ and $d^{18}O$) in nitrate (NO_3) can be a suitable tool for tracing sources for nitrate in surface water (e.g. atmospheric deposition, inorganic fertilisers, animal manure, urban wastewater). To test the method in a Norwegian river, three stations in River Alna were sampled during one campaign in 2017 and two campaigns in 2018. In both years, there were relatively small differences in the isotopic signatures between the stations, but the signals indicate that nitrate in the river might originate from soil N and septic waste. Results from the two campaigns in June and September 2018 demonstrated that the temporal variation within each site was larger than the between-site variability. This indicates that differences in metabolic activity over time creates a stronger isotopic signal than NO_3 source-related differences between the sites. This sounds reasonable bearing in mind that the stations are located along a relatively short river stretch heavily affected by urban runoff.

Stable oxygen isotopes in phosphate

In recent years, analysis of stable oxygen (O) isotopes in PO_4 ($d^{18}O_{PO4}$) has become available, providing an opportunity to differentiate between different sources of PO_4 in surface water (inorganic fertilisers, animal manure, urban wastewater). Samples for analysis of stable oxygen isotopes in PO_4 were collected in River Alna at the same sites and at the same dates as the samples for stable isotopes in NO_3. The most striking pattern was large differences between the observed $d^{18}O_{PO4}$ composition of samples from June compared to September. It probably reflects differences in metabolic activity and cycling of PO_4 between the sampling dates. It was a relatively large overlap in $d^{18}O_{PO4}$ signatures at the sampling stations, which indicates that all sites are affected by a combination of P sources. Thus, it can be challenging to use the method as a tool to determine sources in a complicated urban catchment like Alna.

Modelling of future hydrology and nitrogen loads in Storelva

In the River monitoring programme, River Storelva in southern Norway and River Målselva in Troms have been selected for closer studies of climate effects on water quality. As part of this, the hydrological model PERSiST and the Integrated Catchment model for nitrogen (INCA-N) was applied to simulate future hydrology and NO_3 concentrations in River Storelva. Both models were successfully calibrated against observed data, PERSiST with a Nash-Sutcliffe efficiency criterion (N-S) of 0.74 and INCA-N with a N-S value of 0.56. After calibration to historically measured data, PERSiST and INCA-N were run with future scenarios for air temperature and rainfall based on two greenhouse gas emission scenarios (RCP4.5 and RCP8.5) run by an ensemble with ten combinations of global (GCM) and regional (RCM) climate models.

Based on the mean of the 10 climate model predictions for the RCP4.5 and RCP8.5 scenarios, the annual mean temperature may increase from around 6.0°C today, to 8.0°C with RCP4.5 and 10.0°C with RCP8.5 towards 2100. The most extreme scenarios project annual mean temperatures to increase from today's level around 6°C to up to 12°C. The climate models project only a modest increase in precipitation amounts towards the end of this century. One explanation can be that the area has already experienced a significant increase in annual precipitation since 1990.

As precipitation is the main driver for water flow, simulation of future scenarios with the PERSiST model show no significant changes in water flow towards the end of this century. As noted for precipitation, the area has already experienced a significant increase in annual precipitation and water flow since 1990. Another factor is that the projected temperature increase will lead to higher evapotranspiration, so that a smaller fraction of the incoming precipitation will reach the river. Autumn is the only season when river flow is expected to increase in the future. In addition, the projections imply higher year-to year variation in flow volumes towards the end of the century, especially with the RCP8.5 scenario. The INCA-N model predicts a weak decline in NO_3 concentrations into the future – both on annual and seasonal basis. The scenarios assume that today's N deposition level and fertilisation use are kept constant into the future. The simulated decline in NO_3 concentrations towards the end of the century suggest that increased temperature will result in an increased net retention of N in the catchment. An uncertainty in this context is whether the supply of N from atmospheric sources is in balance with the plants' demand for N, or if long-term accumulation of excess N will eventually result in N saturation and increased leaching to surface waters.

Sensor data from River Storelva

To study short-term effects of climate variability on water chemistry, high-frequency data are collected in Rivers Storelva and Målselva. The sensor stations are located at the same spot as the manual sampling stations and are equipped with sensors that measure water temperature, pH, conductivity, turbidity and fluorescent dissolved organic matter (FDOM) on an hourly basis. The high-frequency data provides important information about physical and chemical dynamics and responses to climatic events, which are easily missed in monitoring programmes with manual sampling on a weekly or monthly basis.

The summer in 2018 was unusually hot and dry in River Storelva, and the first rainwater flood after summer occurred on September 10th. It caused pH to drop by almost one unit, from pH 7.0 to pH 6.0 within a few days, due to wash-out of oxidized sulphur that had accumulated in peaty soils during the long summer drought. At the same time, the Fluorescence Dissolved Organic Matter (FDOM), which is a measure of organic matter, increased from a base level around 30 quinine sulphate units (QSU) before the flood to nearly 80 QSU when the flood culminated. In River Målselva, the sensor data also provides valuable insight in physical and chemical responses during floods. Among other things, it nicely demonstrates that snowmelt floods in spring and rainwater floods in the autumn leads to very different responses among different water quality parameters. Whereas the first snowmelt flood usually dilutes the ionic content (conductivity) and organic matter (FDOM) concentrations, autumn floods are usually associated with peaks in conductivity, turbidity and FDOM.

Sammendrag

Tittel: Elveovervåkningsprogrammet – vannkvalitetsstatus og -trender 2018
År: 2019
Forfatter(e): Cathrine Brecke Gundersen, Øyvind Kaste, James Sample, Hans Fredrik Veiteberg Braaten, John Rune Selvik, Dag Øystein Hjermann, Magnus Dahler Norling, Jose-Luis Guerrero Calidonio
Utgiver: Norsk institutt for vannforskning, ISBN 978-82-577- 7176-8

Om programmet
Elveovervåkingsprogrammet omfatter månedlig prøvetaking av 20 elver fordelt geografisk langs norskekysten. Elvene drenerer til de fire havområdene Skagerrak, Nordsjøen, Norskehavet og Barentshavet. Elvene overvåkes for ulike kjemiske, fysiske og hydrologiske parametere. Elveovervåkingsprogrammet er en viktig del av norske myndigheters basisovervåking av elver i henhold til vannforskriften, i tillegg til at programmet oppfyller Norges forpliktelser i henhold til Oslo-Paris konvensjonen (OSPAR). Det nåværende Elveovervåkingsprogrammet ble etablert i 2017 som en erstatning for det tidligere Elvetilførselsprogrammet som pågikk kontinuerlig i perioden 1990-2016. Endringer i det nye programmet inkluderer hyppigere prøvetakingsfrekvens for alle elver (men færre elver), en utvidet liste med kjemiske analysevariabler og bruk av nedbørfeltmodeller for å simulere effekter av klima og miljøgifter på vannkvalitet. Elveovervåkingsprogrammets resultater fra 2018 presenteres i fire ulike rapporter. I denne rapporten diskuteres årets status og langtidstrender av vannkvalitet (1990-2018) for de 20 elvene.

Værforhold 2018
2018 var et varmt år der den gjennomsnittlige lufttemperaturen i Norge var 1.4° C over normalen for perioden 1961-1990. Lufttemperaturen var over normalen for alle fire årstidene, og sommersesongen avvek mest ved å være den sjette varmeste siden målingene startet i 1900. Nasjonalt var års- og sesongnedbør omtrent som normalt, men med store regionale forskjeller: det årlige gjennomsnittet var henholdsvis 50 og 150 % av normalen for individuelle stasjoner i Sørøst-Norge og nordlige deler av Øst-Norge. På høsten var nedbøren bare 25-50 % av normalen for stasjoner i Sør-Norge, mens stasjoner i Nord-Norge hadde nedbørsmengder opp til 200 % av normalen.

Trender i klima, vanntemperatur og vannføring
Trendanalyser av lufttemperatur og nedbør målt i perioden 1980 -2018 ved meteorologiske stasjoner, viser en signifikant økning i lufttemperatur ved så godt som alle stasjoner, mens for nedbør viste kun den nordlige stasjonen Alta lufthavn en signifikant økning. Vannføringen har økt signifikant fra 1990 i flere av de sørøstlige elvene (Glomma, Drammenselva, Skienselva), samt Orreelva. Disse trendene med økt temperatur og vannføring stemmer overens med generelle forventede effekter av klimaendringer.

Vannkvalitet i 2018
For de fleste kjemiske variabler følger vannkjemien i norske elver et geografisk mønster (øst-til-vest og sør-til-nord) relatert til nedbørfeltkarakteristika som vegetasjons- og jordtyper. Elvene i sørøst renner igjennom boreale skogsområder, elvene i sør og sørvest er influert av berggrunn med lav forvitringshastighet mer sparsom vegetasjon og karrig steingrunn, mens elvene fra midt- til Nord-Norge har karakteristikker som generelt sett faller mellom elvene i

sørøst og sørvest. To åpenbare unntak fra dette mønsteret er Alna i sørøst og Orreelva på vestkysten. Disse elvene er begge i stor grad påvirket av menneskelige aktiviteter gjennom henholdsvis urbanisering og landbruk. Andre unntak er gjeldene ved forekomst av metaller som i stor grad også er et resultat av lokale menneskelige aktiviteter.

pH i overvåkingselvene varierte fra svakt surt (pH 6.2) til basisk (pH 8.0). De sureste elvene var i sør- og sørvestlige deler av landet. Dette skyldes en kombinasjon av naturlig lav bufferkapasitet og det faktum at disse området er- og har vært utsatt for sur nedbør. Som et resultat av dette har disse elvene lave kalsiumkonsentrasjoner og typifiseres som svært kalkfattig (< 1 mg Ca L^{-1}) og kalkfattig (1-4 mg Ca L^{-1}), i henhold til Vannforskriften. pH-verdiene for elvene i Sørøst-Norge var svakt sure eller nøytrale og elvene lenger nord (midt- til Nord-Norge) var typisk nøytrale. De høyeste pH-verdiene ble observert i elvene som var mest påvirket av antropogene kilder: Alna (pH 8.0) og Orreelva (pH 7.8). Med henhold til kalsiumkonsentrasjon ble resten av elvene typifisert som enten kalkfattige eller moderat kalkrike (4-20 mg Ca L^{-1}), med unntaket Alna som var kalkrik (> 20 mg Ca L^{-1}).

Suspendert materiale påvirker vannkvaliteten i en elv gjennom blant annet transport av næringsstoffer og metaller. Glomma, Alna, Numedalslågen og Orreelva hadde høy turbiditet og høye konsentrasjoner av suspendert partikulært materiale (SPM), mens elvene fra andre regioner viste lavere nivåer. Generelt varierte turbiditet og SPM mye gjennom året, noe som sannsynligvis en effekt av nedbørepisoder. Silisiumdioksid, et kolloid som er en viktig næringskilde for alger (i tillegg til silikater), ble funnet i høyest konsentrasjoner i elvene i Nord-Norge (Altaelva, Tanaelva, og Pasvikelva > 5 mg L^{-1}) og i Alna (7.0 mg L^{-1}).

Organisk materiale (OM) kan også transportere næringsstoffer og metaller, i tillegg til å være en viktig næringskilde for heterotrofe organismer (f.eks. bakterier). Mengden OM i elver styres ofte av vegetasjon- og jordtyper i nedbørfeltet og bestemmes gjerne som totalt organisk karbon (TOC) i vannprøver. Basert på resultater fra 2018 kan to av elvene i programmet typifiseres som humøse (Storelva og Orreelva, TOC > 5 mg L^{-1}), 11 av elvene er klare (2 mg L^{-1} < TOC < 5 mg L^{-1}), mens de resterende 7 elvene hører til TOC-typen veldig klar (TOC < 2mg L^{-1}). Elvene som er veldig klare ligger sørvest i Norge. For alle elvene var den løste fraksjonen av OM (DOC < 0.45 µm) større enn den partikulære (74.4 – 97.5% DOC).

Næringsstoffene fosfor (P) og nitrogen (N) er viktige indikatorer for vannkvalitet, spesielt med tanke på eutrofiering. Alna og Orreelva hadde høyest konsentrasjoner av total-P (tot-P) og total-N (tot-N) i 2018, som et resultat av henholdsvis urbanisering og landbrukspåvirkning. Begge elvene overskred Vannforskriftens grense for god tilstand for sine respektive vanntyper, basert på både tot-N og tot-P. Flere elver i sør- og sørøstlige deler av landet hadde høye nivåer av tot-N, sannsynligvis et resultat av N-avsetning.

Biotilgjengeligheten av næringsstoffer avhenger av ved hvilken kjemisk form de foreligger, og den blir redusert når forbindelsene er bundet til partikler. Den meget biotilgjengelige fraksjonen fosfat (PO_4) utgjorde en betydelig del av tot-P i elvene (29 – 83 %), og med den høyeste fraksjonen i Alna. Partikulært P var også en signifikant del av tot-P i alle elvene (33-79 %), noe som sannsynligvis var en viktig årsak til den store sesongvariasjonen i tot-P. For N var nitrat (NO_3) den viktigste fraksjonen, etterfulgt av organisk bundet N og ammonium (NH_4). I flere nordlige elver ble det ikke detektert noe NH_4. N har lav affinitet for partikler og partikulært N utgjorde en ikke-signifikant fraksjon i elvene.

For metaller var det tydelige forskjeller mellom elvene i overvåkingsprogrammet (merk at metallene ble bestemt i ufiltrerte vannprøver, mens en sammenligning med grenseverdiene i

Vannforskriften krever filtrerte prøver). Som et resultat av nærliggende industriaktivitet hadde Alna høye konsentrasjoner av arsen, bly, kadmium, kobber, sink, krom og nikkel, men nivåene for både bly og kobber var lavere enn gjennomsnittet de siste 5 årene. I Pasvikelva ble det observert høye konsentrasjoner av arsen, bly, kadmium, kobber og nikkel, og for nikkel var konsentrasjon i 2018 30 % høyere enn snittet de siste 5 årene. Pasvikelva renner nære betydelig metallurgisk industriaktivitet i Russland, en sannsynlig hovedkilde til de høye konsentrasjonene som observeres. Andre elver som hadde forhøyede nivåer av metaller inkluderer Orkla (kadmium, kobber, sink, nikkel), Storelva (arsen, bly og sink) og Orreelva (arsen, kobber, sink og nikkel). Orkla og Storelva er sannsynligvis påvirket av avrenning fra historisk gruvedrift i nedbørfeltet, mens Orreelva er påvirket av landbruksaktivitet.

Vannkjemiske data fra ytterligere 10 elver (fra Tiltaksovervåking av kalkede laksevassdrag i Norge og Elveovervåkingsprogrammets Opsjon 3) i Sør-, Sørvest- og Midt-Norge ble inkludert i denne rapporten. Resultatene fra disse tilleggselvene bekreftet det geografiske mønsteret som ble dokumentert for de 20 elvene i grunnprogrammet, og ingen av elvene ser ut til å være særlig påvirket av antropogene aktiviteter. pH-nivået var svakt surt i sør og økte nordover. Kalsiumkonsentrasjonene var også lave i sør. Namsen og Saltdalselva i midt-Norge hadde høyere nivåer av SPM-konsentrajson sammenlignet med de andre elvene. TOC-konsentrasjonene var lave, kun to av elvene var humøse (Nidelva og Mandalselva ≥ 5 mg L^{-1}). Nivåer av tot-P og tot-N var lave, med unntak av Namsen der tot-P var høyere og sannsynligvis relatert til et høyere nivå av partikulært materiale. Metallkonsentrasjonene var lave i alle tilleggselvene.

Trender i vannkjemi, tilførsler og konsentrasjoner

For ni av elvene i programmet var frekvensen på overvåkingsdata tilstrekkelig til at trendanalyser lot seg gjennomføre for SPM, silisiumdioksid, TOC og næringsstoffer for perioden 1990-2018. For metallene ble trendanalysene utført for en kortere tidsperiode (2004-2018) på grunn av skifte i analysemetodenes sensitivitet. Resultatene viste økende vannføring i elvene i Sørøst-Norge. Drammenselva viste signifikant økende tilførsler av SPM, silisiumdioksid og TOC, hvilket kan påvirke marine økosystemer ved utløpet. I mange overflatevann i Skandinavia, inkludert innsjøer og mindre elver, er det dokumentert økende TOC-konsentrasjoner de siste 25-30 årene. Trenden forklares ved at kombinasjonen redusert sur nedbør og økt nedbør fører til økt utlekking av OM fra jordsmonnet i nedbørfeltene. For Elveovervåkingsprogrammet er det kun i Drammenselva at en signifikant økning i TOC-trender observeres. Mangel på signifikante trender kan skyldes at trendanalysene for flere av elvene ikke starter før 1999.

I Drammenselva og Numedalslågen øker tilførslene av total-P (tot-P) og total-N (tot-N), et resultat av økende tilførsler av henholdsvis fosfat og organisk N. For tot-P kan økningen også skyldes en økning i organisk- og partikulært-P, men disse fraksjonene har ikke vært en del av langtids overvåkningen. For flere elver var det en signifikant nedgang i både konsentrasjoner og tilførsler av NO_3 og NH_4. Dette kan ha ulike årsaker som økt opptak av planter, redusert atmosfærisk N nedfall, og/eller økt vannføring (vil gi fortynning). I Vefsna, i Midt-Norge, var det en signifikant nedgang i tilførsler for alle fraksjoner av næringsstoffene og SPM.

Trendanalysene for metaller viste generelt nedgang i både tilførsler og konsentrasjoner. De eneste unntakene var nikkelkonsentrasjonene i Vefsna og Alta, der trenden er økende. Årsakene til dette er vanskelig å fastslå, men med lave konsentrasjoner er det ikke grunn til bekymring foreløpig. I Orkla, en elv som mottar avrenning fra tidligere gruveområder, var det signifikant nedgang i tilførsler av bly, kadmium, kobber og sink og nedgang i konsentrasjoner av kobber og sink.

Kvalitet av organisk materiale
Kvaliteten av løst organiske materiale (DOM) i elver kan ha stor innvirkning på ulike nedbørfeltprosesser, for eksempel transport av miljøgifter. Spektroskopiske indekser har blitt brukt for å beskrive graden av aromatisitet (sUVa) og molekylstørrelse (E2_E3). Generelt var sesongvariasjonene større enn forskjellene mellom ulike geografiske regioner (Skagerrak, Nordsjøen, Norskehavet og Barentshavet). Både vår og høst var det økende TOC-konsentrasjoner, økende aromatisitet og økende molekylstørrelse. Dette skyldes snøsmelting om våren og intense perioder med nedbør om høsten, som fører til økt transport av organisk materiale fra skogbunn og øvre jordlag til elvene. Økende aromatisitet og større DOM-molekyler er assosiert med eldre og mer humøst materiale. En sammenligning av data fra 2018 med 2017-data avslører en mulig effekt av den varme og tørre 2018-sommeren på DOM-kvalitet. Mens TOC-konsentrasjonene om sommeren var ganske like i 2017 og 2018, var aromatisiteten mye lavere i 2018, sannsynligvis som en følge av høyere grad av fotonedbryting. Geografisk sett skilte elvene som drenerer til Nordsjøen seg fra de andre elevene: TOC konsentrasjonene var lave samtidig som aromatisiteten var høy. Årsaken til dette er ikke kjent, men kan skyldes forskjeller i hydrologi og/eller kilder til DOM.

Stabile nitrogen- og oksygen-isotoper i nitrat
Analyser av stabile nitrogen- og oksygenisotoper (d^{15}N and d^{18}O) i nitrat (NO_3) kan være et egnet verktøy for å spore kilder til NO_3 i vann (som f.eks. atmosfærisk deposisjon, kunstgjødsel, husdyrgjødsel og husholdningskloakk). For å teste metodikken i en norsk elv, ble det tatt prøver for analyse av stabile isotoper på tre stasjoner i Alna, ved én anledning i 2017 og ved to anledninger i 2018. Begge årene ble det målt relativt små forskjeller i isotopsignaturene på de tre stasjonene, men resultatene indikerte at hovedandelen av NO_3 i vannet stammet dels fra jord/jordvann og dels fra kloakkpåvirkning. Resultatene fra de to prøvetakingsrundene i juni og september 2018 viste at variasjonen over tid på hver enkelt stasjon var større enn variasjonen mellom stasjonene. Dette indikerer at metabolsk aktivitet (biologisk omsetning av NO_3 i elva) påvirker isotopsignaturene i større grad enn isotopsignalet fra ulike NO_3-kilder, noe som virker rimelig i og med at alle de tre undersøkte stasjonene ligger langs en forholdsvis kort elvestrekning som er sterkt påvirket av urban avrenning.

Stabile oksygen-isotoper i fosfat
I senere år er det også utviklet en metode for å analysere stabile oksygenisotoper i fosfat (PO_4). Dette gir en mulighet til å spore kilder til PO_4 i vann (som f.eks. kunstgjødsel, husdyrgjødsel og husholdningskloakk)). Som en test av metodikken ble det i 2018 samlet inn prøver i Alna for analyse av stabile oksygenisotoper i fosfat (d^{18}O$_{PO4}$). Prøvene ble tatt på samme tid og sted som prøvene for nitratanalyse. Det mest åpenbare mønsteret i resultatene var stor forskjell i observerte d^{18}O$_{PO4}$-verdier på hver enkelt stasjon over tid (fra juni til september). Som antydet for NO_3, reflekterer dette sannsynligvis at metabolsk aktivitet (biologisk omsetning av PO_4 i elva) i tiden mellom prøvetakingene påvirket isotopsignaturene gjennom isotopfraksjonering (diskriminering mellom lette og tyngre oksygenisotoper). Det var ganske stort overlapp i d^{18}O$_{PO4}$-verdiene som ble målt på de tre stasjonene, noe som indikerer at alle er påvirket av en blanding av ulike PO_4-kilder. Det kan derfor være utfordrende å bruke metodikken som et kildesporingsverktøy i et såpass komplisert urbant nedbørfelt som Alna.

Modellering av fremtidig vannføring og nitrogenkonsentrasjoner i Storelva
Storelva på Sørlandet og Målselva i Troms er i Elveovervåkingsprogrammet valgt for nærmere studier av klimaeffekter på vannkvalitet. Som et ledd i dette er det gjennomført et modellarbeid i Storelva, hvor den hydrologiske modellen PERSiST og nedbørfeltmodellen INCA-N er anvendt for å simulere mulige fremtidige klimaeffekter på vannføring og nitrogen-

konsentrasjoner i elva fram mot år 2100. Begge modellene ble kalibrert i forhold til målte tidsserier for vannføring og nitratkonsentrasjoner i vann, og i begge tilfeller ble det oppnådd god overensstemmelse mellom målte og simulerte verdier (Nash-Sutcliffe verdier på 0.74 og 0.56 for hhv. vannføring og nitrat). Etter kalibrering ble to ulike utslippsscenarier for klimagasser (RCP4.5 og RCP 8.5) kjørt med et «ensemble» av 10 ulike globale og regionale klimamodeller brukt som input til PERSiST og INCA-N.

Basert på simuleringene fra de 10 klimamodellene og de to utslippsscenariene, vil årlig gjennomsnittlig lufttemperatur kunne øke fra dagens nivå på omkring 6°C i Storelva til omkring 8°C ved RCP4.5 og omkring 10°C ved RCP8.5. De mest ekstreme modellkjøringene indikerer at årsmiddeltemperaturen kan øke fra dagens nivå omkring 6°C til hele 12°C mot slutten av dette århundret. Når det gjelder nedbør så predikerer klimamodellene bare en beskjeden økning i tiden fram mot 2100, både ved RCP4.5 og RCP8.5. En medvirkende årsak til dette er at området allerede har opplevd en signifikant økning i årlig nedbør siden 1990.

Simuleringene av fremtidig vannføring med PERSiST viser ingen signifikant økning i årlig middelvannføring fram mot 2100. Som for nedbør har området allerede hatt en signifikant økning i vannføring siden 1990. I tillegg vil den predikerte temperaturøkningen fram mot 2100 føre til økt fordamping, slik at en mindre del av nedbøren vil bidra til vannføringen i elva. Høsten er den eneste årstiden da det er ventet en liten økning i fremtidig vannføring. I tillegg antyder klimascenariene at det kan forventes større år-til-år variasjon i vannføring mot slutten av dette århundret. Dette gjelder spesielt med RCP8.5 scenariet. Simuleringene fra INCA-N modellen indikerer at det kan forventes svakt nedadgående konsentrasjoner av nitrat i elva fram mot 2100 – både på sesong- og årsbasis. Scenariene er basert på at N deposisjon og gjødslingsnivå videreføres på dagens nivå inn i framtiden. Hovedårsaken til den nedadgående trenden er trolig at økt temperatur vil føre til større opptak og tilbakeholdelse av nitrogen i jord og vann. En usikkerhetsfaktor er imidlertid om historisk og framtidig tilførsel av nitrogen fra atmosfæriske kilder kan føre til at nedbørfeltet etter hvert kan bli mettet på nitrogen, slik at lekkasjen av nitrat fra jord til vann vil øke igjen.

Sensor-overvåking i Storelva og Målselva

For å studere korttidseffekter av klimavariasjon på vannkjemi er det registrert timesverdier for vanntemperatur, pH, konduktivitet, turbiditet og løst organisk materiale (FDOM) i Storelva og Målelva. Sensorstasjonene er lokalisert på samme sted som der de manuelle prøvene tas i Elveovervåkingsprogrammet. Sensordataene kan bidra med kunnskap og dokumentasjon på hvordan fysiske og kjemiske variable responderer på klimahendelser som en lett går glipp av i tradisjonelle overvåkingsprogrammer hvor prøvetakingsfrekvensen ofte er for lav.

Sommeren 2018 var uvanlig varm og tørr i Sør-Norge, og i Storelva førte den første regnvannsflommen etter sommeren til at pH falt med en hel enhet, fra omkring 7.0 til 6.0. Forholdet er observert tidligere i andre vassdrag og skyldes utvasking av svovelsyre fra myrer som er blitt tørrlagt i løpet av den varme og nedbørfattige sommeren. Samtidig med pH-fallet ble også konsentrasjonen av løst organisk materiale (målt som FDOM) nesten tredoblet (fra 30 til 80 QSU) i løpet av noen få dager. I Målselva ga også sensordataene et interessant innblikk i hvordan vannkvalitetsparametere endrer seg dynamisk i løpet av en flom. De viste blant annet hvordan ulike typer av flommer, i dette tilfellet snøsmeltingsflommer om våren og regnvannsflommer om høsten, kan ha vidt forskjellige effekter på vannkvaliteten. Mens den første snøsmeltingsflommen om våren ofte fører til en fortynning av oppløste ioner (målt som konduktivitet) og løst organisk materiale (målt som FDOM), vil regnvannsflommene om høsten typisk føre til topper i konduktivitet og FDOM.

1. Introduction

The Norwegian river monitoring programme comprises monitoring of 20 rivers (Table 1 and Figure 1) for various chemical, physical, and hydrological parameters. The main features of the programme are; i) relatively high sampling frequency (monthly at all sites and for all parameters, except for metals), ii) an extended list of chemical variables (including stable isotopes, emerging contaminants, and priority substances), iii) the use of catchment models for simulation of climate effects and contaminant discharges on water quality, and iv) sensor monitoring in selected rivers (determining water temperature, pH, conductivity, turbidity and fluorescent dissolved organic matter (FDOM)). The River monitoring programme (Elveovervåkingsprogrammet) was established in 2017, replacing the former RID programme (Riverine inputs and direct discharges to Norwegian coastal waters) that had been running since 1990. The 20 monitored rivers were all part of the previous programme, but the monitoring frequency has changed: minimum monthly since 1990 for 11 of the rivers (with two exceptions where monitoring started later); quarterly since 1990 for 8 of the rivers; and annually from 1990 to 2003 for 1 of the rivers (Braaten et al., 2017). For more information on the differences between the current and the past programme, see the report for the 2017 river monitoring results (Kaste et al., 2018).

1.1 Monitoring objectives

The Norwegian river monitoring programme is the basis for fulfilment of Norway’s obligations under the Oslo-Paris Convention (OSPAR) and is also a main component of the Norwegian water authorities’ surveillance monitoring in rivers, according to the requirements set by the EU Water Framework Directive (WFD).

The main objectives for the Norwegian river monitoring programme, formulated by the Norwegian Environment Agency, are to:

1. Document status and long-term trends for nutrient and contaminant concentrations in Norwegian rivers
2. Obtain data for classification of Norwegian rivers according to the requirements of the WFD
3. Reveal water quality changes that can be attributed to climate change or other human influences
4. Increase the knowledge base on climate processes affecting water
5. Increase current knowledge related to the fates of emerging contaminants in aquatic ecosystems
6. Provide data that may explain changes in eutrophication and contaminant levels along the Norwegian coast
7. Estimate riverine inputs and direct discharges of nutrients and contaminants to Norwegian coastal waters (for reporting under the OSPAR Convention)

The River monitoring programme also includes three additional reports in 2018. The present report addresses objectives 1, 3, 4, and partly 6 and 7 by providing the current status (2018) and long-term water quality trends (1990-2018) for 20 rivers selected to represent most of the Norwegian drainage area. The other reports constitute: i) "Klassifisering av økologisk og kjemisk tilstand i norske elver i tråd med vannforskriften – Elveovervåkingsprogrammet 2018" (M-1510) which addresses objective 2, ii) «Kildefordelte tilførsler av nitrogen og fosfor til norske kystområder i 2018 – tabeller, figurer og kart» (NIVA report) addresses partly objective 7, and iii) «Priority substances and emerging contaminants in selected Norwegian rivers» (M-1509) that addresses objectives 1, 5, 6 and 7.

Table 1. Rivers included in the programme.

River name	UTM (east)	UTM (north)	UTM zone	Catchment (km^2)	Waterbody code ID
Glomma*	621600	6573156	32	41918	002-1519-R
Alna*	600213	6642144	32	69	006-71-R
Drammenselva*	556636	6624287	32	17034	012-2399-R
Numedalslågen*	561346	6551822	32	5577	015-33-R
Skienselva*	534726	6562938	32	10772	016-769-R
Storelva**	498897	6503307	32	408	018-127-R
Otra*	438737	6449755	32	3738	021-28-R
Bjerkreimselva	325246	6487028	32	705	027-92-R
Orreelva*	299152	6515475	32	105	028-16-R
Vikedalselva	325319	6599745	32	118	038-11-R
Vosso*	336048	6727293	32	1492	062-219-R
Nausta	327402	6826450	32	277	084-218-R
Driva	477383	6948637	32	2487	109-54-R
Orkla*	237185	7018935	33	3053	121-56-R
Nidelva	569352	7030201	32	3110	123-29-R
Vefsna*	418710	7292351	33	4122	151-36-R
Målselva	406570	7660047	34	3239	196-275-R
Altaelva*	586586	7759686	34	7373	212-63-R
Tana	543964	7791926	35	16389	234-124-R
Pasvikelva	386937	7709634	36	18404	246-65242-L

* "Main rivers" in the previous RID programme, monthly monitoring since 1990 (except Rivers Vosso and Alna, monthly from 2008 and 2013, respectively)

** Also denoted "Vegårdselva" in the RID database

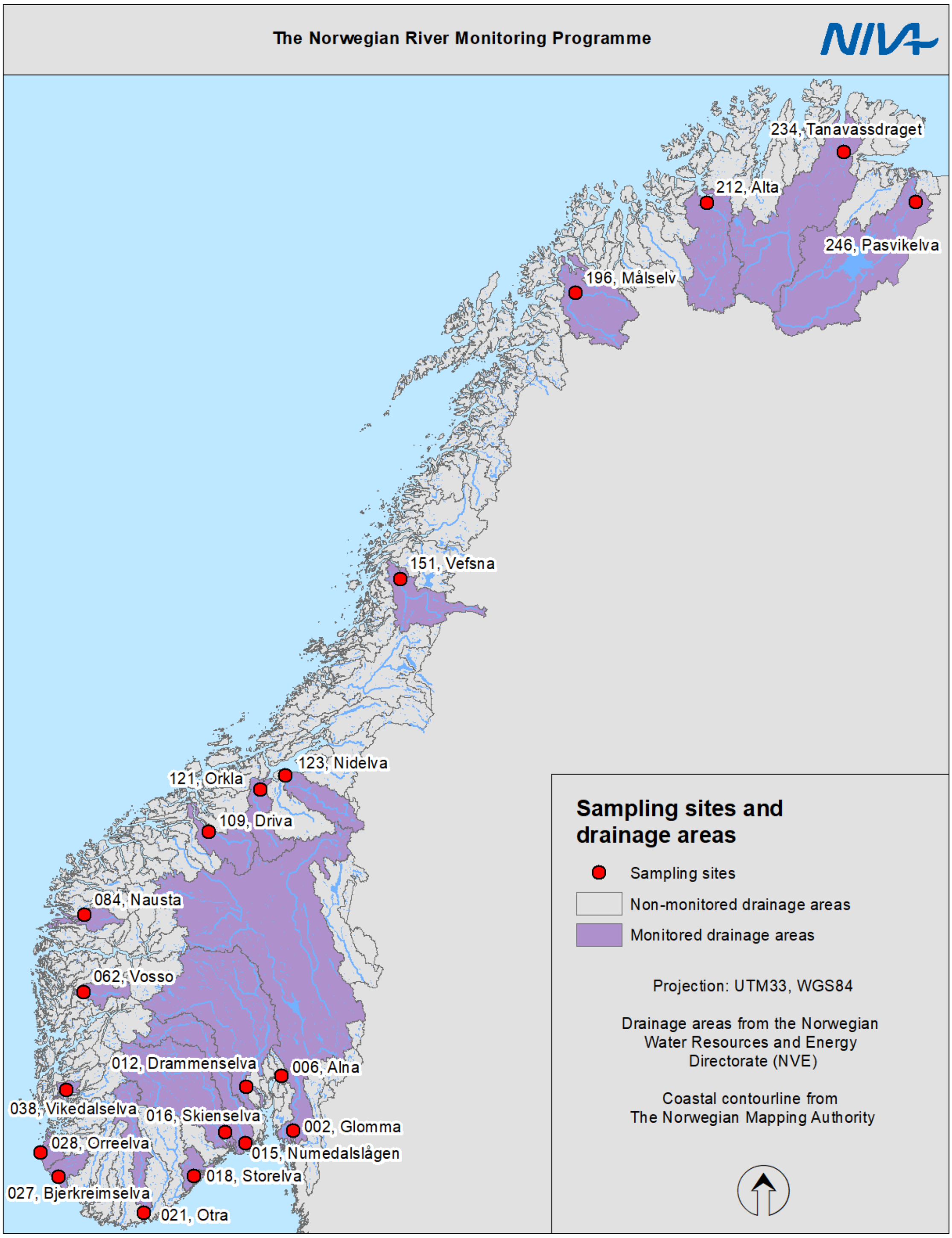

Figure 1: Map showing the location of the rivers in the Norwegian river monitoring programme, including drainage areas (purple) and the sampling sites (red dot).

1.2 Additional Rivers

This year's report also covers the water chemistry (2018) for nine additional rivers (Table 2 and Figure 2). These rivers were part of either the National monitoring program for limed rivers (Tiltaksovervåking av kalkede laksevassdrag i Norge) or the 2018 classification of ecological and chemical status (Opsjon 3, M-1510). The National monitoring program for limed rivers covers rivers in the south and south-western Norway that are limed to counter the effects from acid deposition. Although acid deposition has decreased enormously since the 1970s, the critical load for acid deposition (especially in the form of nitrogen) is still exceeded for these catchments. In the 2018 assessment of ecological and chemical quality parameters, the status of rivers located in the middle of Norway were classified according to the WFD. In this report, the water chemistry from four of these rivers will be discussed. For more information on the additional rivers we refer to Norwegian Environment Agency (2018) and Kile and al. (2019).

Table 2. Additional rivers included in the report

River name	UTM (east)	UTM (north)	UTM zone	Catchment (km^2)	Waterbody ID
Nidelva	478798	6474111	32	4025	019-398-R
Tovdalselva	449503	6456437	32	1885	020-183-R
Mandalselva	413351	6453264	32	1809	022-654-R
Lygna	390778	6454254	32	663	024-412-R
Suldalslågen	344680	6596924	32	1463	036-92-R
Ekso	325747	6737576	32	414	063-181-R
Saltdalselva	516596	7440168	33	1529	163-13-R
Namsen	346864	7150153	33	6061	139-34-R
Strynelva	68947	6891884	33	523	088-13-R
Sira	6493441	-518	33	1891	026-691-R

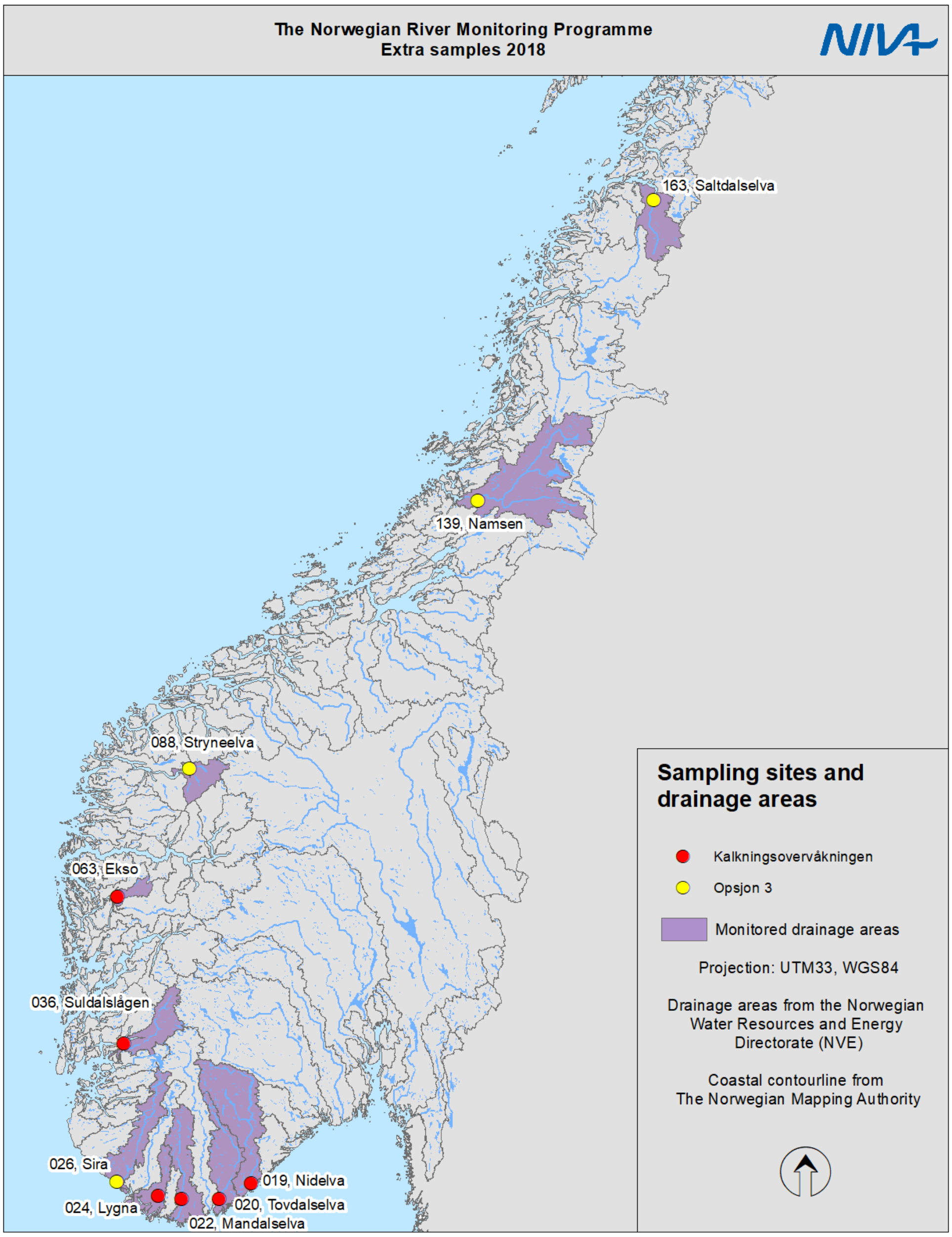

Figure 2: Map showing the location of the additional rivers included with water chemistry in this report. Drainage areas are illustrated with purple shading and the sampling sites from the liming programme and from the 2018 classification of chemical and biological status in red and yellow, respectively.

2. Methods

2.1 Water discharge

For 11 of the rivers (the “main rivers” of the previous RID programme plus Alna, Table 1) discharge data was downloaded from Norwegian Water Resources and Energy Directorate (NVE, Hydra-II database). Since the hydrological stations are usually not located exactly at the same site as where the water samples were collected, the water discharge has been calculated by up- or downscaling, proportional to the respective drainage area. For the remaining 9 rivers, water discharge has been simulated with a spatially distributed version of the HBV-model (Beldring et al., 2003). The use of this model was introduced in 2004, and Skarbøvik et al. (2017) gives more information on the methodology.

2.2 Water temperature

Data on water temperature is acquired from four different sources (Table 3): Sensor monitoring (hourly time-step, see ch. 2.8), TinyTag temperature loggers (hourly time-step), manual measurements with a thermometer in connection with the monthly water quality sampling and NVE temperature logging (daily averages from bi-hourly measurements). For the former three the measurements were made at the water quality sampling sites, while the NVE loggers were at stations located in close vicinity to these sites. The TinyTag loggers were secured to land and deployed in the river at the water quality sampling site. They were routinely replaced each autumn to ensure enough battery capacity.

Since temperature measurements have only been part of the river monitoring programme since 2013, data from NVE has been used for long-term trend analysis. This includes data for rivers were other data sources are used for the current monitoring (to get data from the actual sampling sites). Details on the time series from the closest NVE station in each river are presented in Table 4. Long-term data series of water temperature typically contain some missing data. Prior to trend analysis, the data was filtered to remove years for which >90% of the daily observations were missing.

Table 3. Sources for water temperature data in monitored rivers

Data source	**Sites**
Sensor-based	Storelva
Tiny Tag loggers	Skienselva, Otra, Numedalslågen, Altaelva, Vefsna, Orreelva and Vosso
NVE station	Orkla and Vikedalselva
Manual measurement	Drammenselva, Driva, Glomma, Alna, Bjerkreimselva, Nausta, Nidelva, Målselva, Tana, Pasvikelva

Table 4. Stations with available long-term data on water temperatures. The stations are operated by the Norwegian Water Resources and Energy Directorate (NVE).

St. ID	River name	Water temperature station	Start	End
29617	Glomma	2.1078.0.1003.1 Glomma ovf. Sarpefossen	Sept-2007	2018
36225	Alna			
29612	Drammenselva	12.298.0.1003.4 Drammenselva v/Døvikfoss	Dec-1986	2017*
29615	Numedalslågen	15.115.0.1003.1 Numedalslågen v/Brufoss	Nov-1984	2018
29613	Skienselva	16.207.0.1003.2 Skienselva ndf. Norsjø	Nov-1989	2018
30019	Storelva			
29614	Otra	21.79.0.1003.1 Otra v/Mosby	Jan-1986	2017*
29832	Bjerkreimselva	27.29.0.1003.1 Bjerkreimselvi v/Bjerkreim	Apr-1986	2017*
29783	Orreelva			
29837	Vikedalselva	38.2.0.1003.1 Vikedalselva utløp	Oct-1985	2018
29821	Vosso	62.30.0.1003.3 Vosso ovf. Evangervatnet	Jun-1987	2017*
29842	Nausta	84.23.0.1003.3 Nausta v/Hovefossen	Dec-1989	2017*
29822	Driva	109.44.0.1003.2 Driva ndf. Grøa	Jul-2000	2015
29778	Orkla	121.62.0 Orkla v/Merk Bru	Mar-1989	2018
29844	Nidelva			
29782	Vefsna	151.32.0.1003.3 Vefsna v/Laksfors	Sept-1993	2018
29848	Målselv	196.35.0.1003.1 Malangfoss	May-1997	1997
29779	Altaelva	212.68.0.1003.1 Alta v/Gargia	Sept-1980	2018
29820	Tanaelva	234.19.0.1003.1 Tana ovf. Polmakelva	Jul-1990	2017*
29819	Pasvikelva	246.11.0.1003.1 Pasvikelva v/Skogfoss kraftstasjon	Mar-1991	2018

*Updated temperature was not available for 2018 at time.

2.3 Water quality sampling and analyses

2.3.1 Sampling methodology

Monthly sampling was conducted by grab sampling, undertaken by local fieldworkers (Skarbøvik *et al.*, 2017). In Rivers Glomma and Drammenselva, both receiving a substantial part of their water discharge from high-elevation areas, additional sampling was conducted during May and June to get a better representation of the high-flow period following snowmelt.

2.3.2 Chemical parameters – detection limits and analytical methods

The parameters monitored in 2018, including information on methodology and limits of detection (LOD) and quantification (LOQ) are given in Table 5. The metals (Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn) were only analysed on a subset of the monthly samples (quarterly).

Table 5. Analytical methods, limits of detection (LOD) and quantification (LOQ)

Parameter	**LOD/LOQ**	**Analytical Method**
pH	n.a.	NS-EN ISO 10523
Conductivity (mS/m)	0.03/0.1	NS-ISO 7888
Turbidity (FNU)	0.1/0.3	NS-EN ISO 7027
Suspended particulate matter (SPM) (mg/L)	0.1 mg/l when 1 L is filtered	NS 4733 modified
Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC) (mg C/L)	0.03/0.1	NS 1484 modified
Total phosphorus (tot-P) and total dissolved phosphorus (TDP) (µg P/L)	0.3/1	NS 4725 - Peroxodisulphate oxidation method modified (automated)
Orthophosphate (PO4-P) (µg P/L)	0.3/1	NS 4724 - Automated molybdate method modified (automated)
Total nitrogen (tot-N) (µg N/L)	3.3/10	NS 4743 - Peroxodisulphate oxidation method
Nitrate (NO_3-N) (µg N/L)	0.7/2	NS-EN ISO 10304-1
Ammonium (NH_4-N) (µg N/L)	0.7/2	NS-EN ISO 14911
Calcium (mg/L)	0.0017/0.005	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified
Particulate Organic Carbon (POC) and particulate Nitrogen (PN)	Dep. on blank & vol. filtered	NS-EN ISO/IEC 17025, Test 009
UV-visible absorbance spectrum	n.a.	Internal method
Silicone (Si) (Si/ICP; mg Si/L)	0.008/0.025	NS-EN ISO 16264 modified
Silver (Ag) (µg Ag/L)	0.0007/0.0020	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified
Arsenic (As) (µg As/L)	0.008/0.025	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified
Cadmium (Cd) (µg Cd/L)	0.0010/0.0030	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified
Chromium (Cr) (µg Cr/L)	0.008/0.025	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified
Copper (Cu) (µg Cu/L)	0.013/0.040	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified
Mercury (Hg) (µg Hg/L)	0.0003/0.001	NS-EN ISO 12846 modified
Nickel (Ni) (µg Ni/L)	0.013/0.040	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified
Lead (Pb) (µg Pb/L)	0.0017/0.005	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified
Zinc (Zn) (µg Zn/L)	0.05/0.15	NS-EN ISO 17294-1 and NS EN ISO 17294-2 modified

2.3.3 Quality assurance and direct on-line access to data

Data from the chemical analyses were transferred to the NIVA database and quality checked against historical data by researchers with long experience in assessing water quality data. If any anomalies were found, the samples were re-analysed. The data are available on-line at www.aquamonitor.no/RID, where users can view values and graphs for each of the monitored rivers. In Table 6, information on the total number of samples analysed and the fraction of measurements below the LOQ for the various parameters are summarised.

Table 6. Proportion of analyses below limits of quantification (LOQ) in 2018

Parameter	Number of samples	Number below LOQ	% below LOQ
Conductivity	248	0	0.0
pH	259	0	0.0
Ca	259	0	0.0
SiO_2	248	0	0.0
SPM	247	14	5.7
TOC	247	0	0.0
TOT-P	248	1	0.4
PO_4-P	248	76	31
TOT-N	248	0	0.0
NO_3-N	248	6	2.4
NH_4-N	248	79	32
As	79	2	2.5
Pb	79	1	1.3
Cd	79	19	24
Cu	79	0	0.0
Zn	79	5	6.3
Cr	79	0	0.0
Ni	79	0	0.0
Hg	79	70	89
Ag	79	65	82

2.3.4 Additional rivers

The additional rivers were sampled in the same way as the regular rivers of the programme; monthly grab sampling by local fieldworkers. The samples from the National monitoring program for limed rivers programme were analysed at Vestfold laboratory while the samples from the 2018 classification of chemical and biological status were analysed at the NIVA laboratory (although for fewer parameters than the regular rivers of the programme). In Table 7, the number of samples analysed and the fraction of the samples being below the LOQ for the various parameters are summarised for the additional rivers.

Table 7. Proportion of metal analyses below limits of quantification (LOQ) for the additional rivers in 2018

Parameter	Number of samples	Number below LOQ	% below LOQ
As	64	0	48
Pb	64	31	70
Cd	64	45	22
Cu	64	22	34
Zn	64	2	3
Cr	64	14	22
Ni	64	28	44
Hg	64	64	100
Ag	64	62	97

2.4 Calculation of riverine loads

Estimates of annual riverine loads were done according to the formula below, which follows recommendations in OSPAR Agreement 2014:04; §6.13b. The method handles irregular sampling frequency and allows flood samples to be included in the annual load calculations.

$$Load = Q_r \frac{\sum_{1}^{n} Q_i \bullet C_i \bullet t_i}{\sum_{1}^{n} Q_i \bullet t_i}$$

where:

Q_i represents the water discharge at the day of sampling (day i);

C_i the concentration at day i;

t_i the time period from the midpoint between day i-1 and day i to the midpoint between day **i** and day i+1, i.e., half the number of days between the previous and next sampling; and

Q_r is the annual water volume.

When the results recorded were less than the limits of detection (LOD) the following estimate of the concentration has been used:

Estimated concentration = ((100%-A) • LOD)/100

Where A = percentage of samples below LOD. This procedure is in accordance with OSPAR Agreement 2014:04 (the updated RID Principles). According to these principles (http://www.ospar.org/documents?d=33689), the analytical method should give at least 70% positive findings (i.e. no more than 30% of the samples below the detection limit). In 2018, mercury and silver did not reach this requirement, which was also the case in 2017 (Kaste et al., 2018).

2.5 Trend analyses

Trend analysis has been conducted both for weather data (air temperature, precipitation, and water temperature) and the water chemical parameters covered in the monitoring programme. For the trends in weather data, information regarding stations and time ranges used are presented together with the results. Details on the water chemistry and water discharge trend analysis are given below, but note that the general trend analysis methodology described is applied also for the weather data.

2.5.1 Trend analysis methodology

Trend analyses in this report describe overall loads to the sea, but are less suited to discuss changes in upstream sources, because inter-annual variability in water discharge strongly affects fluxes, and might therefore mask changes in source emissions. The Mann-Kendall test (Hirsch and Slack, 1984) has been used to test for monotonic trends (including linear trends; Sen slope) in annual riverine inputs and concentrations. Trends are regarded as statistically significant at the 95% significance level ($p < 0.05$, double-sided test).

2.5.2 Selection of rivers

Trend analysis for water chemical parameters was conducted for nine of the former “main rivers” where monthly monitoring data was available since 1990 (Table 8). The remaining two rivers included as “main rivers” in the former RID programme, Rivers Alna and Vosso, did not have enough years with monthly monitoring (see Table 1). River Alna also had a shift in monitoring methodology for water discharge. River Storelva was not monitored at the current sampling site during 2004-2016, and only once a year from 1990-2003. The remaining rivers all had lower than monthly sampling frequency during 1990-2016. Trend analysis for water discharge was conducted for the nine rivers listed in Table 8, and also for an additional nine rivers with discharge data (modelled) since 2004.

2.5.3 Selection of parameters and time-periods

The water chemical parameters included in the trend analyses were suspended particulate matter (SPM), silica (SiO_2), total organic carbon (TOC), total nitrogen (tot-N), ammonium (NH_4-N), nitrate (NO_3-N), total phosphorus (tot-P), orthophosphate (PO_4-P), copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), and nickel (Ni). Trends for the remaining metals have not been calculated due to the combination of a large proportion of the samples having levels below LOQ and changes in the analytical methods during the time period; see Skarbøvik *et al.* (2010) for details.

The trend analyses cover both long-term (1990-2018) and short-term (2004-2017) trends depending on the availability and quality of data for the various parameters. For most parameters, long-term trend analysis has been conducted (SPM, SiO_2, TOC, Tot-N, NH_4, NO_3, tot-P, and PO_4), while for the metals (Cd, Cu, Ni, Pb, and Zn) only short-term trend analysis was considered valuable. The reason for this was a change in the method used to determine metals, leading to increased analytical sensitivity with time. Such a transition, making it possible to detect lower concentrations in the rivers, could result in a false declining trend. Note that for TOC the trend analysis started in 1999 (instead of 1990) for certain rivers (Rivers Numedalslågen, Orreelva, Altaelva, Vefsna, and Skienselva), due to infrequent measurement in the early years of the monitoring. The statistical power of the trend analysis decreases when applied to shorter time-series.

Hence, for 2018 the following trend analyses have been performed for the nine former “main rivers”, including Glomma, Drammenselva, Numedalslågen, Skienselva, Otra, Orreelva, Orkla, Vefsna and Altaelva:

1. Long-term trends in concentrations and loads for nutrients, SPM, TOC, and silica for the entire monitoring period (1990-2018), as well as water discharge. Long-term trend analysis for TOC for some of the rivers start in 1999.
2. Short-term trends (2004-2018) in concentrations and loads for metals, as well as water discharge. Note that for metals, the rivers have only been monitored four times per year in 2017 and 2018.

Table 8. An overview over the rivers, parameters, and historical frequency of measurement for the nine rivers included in the trend analysis.

			Sampling frequency (times yr^{-1})			
Short name	Rivers/parameters	Parameters***	1990-2003	2004-2016	2017	2018
“Monthly monitored since 1990”	Glomma*, Drammenselva*, Numedalslågen, Skienselva, Otra, Orreelva, Orkla, Vefsna and Altaelva**	Nutrient fractions, SPM, TOC, silicate	12	12	12	12
-«-	-«-	Metals	12	12	4	4

* Rivers Glomma and Drammenselva have often been sampled 16 times per year, or even more frequently (e.g. during the 1995-flood).

** In River Altaelva, the sampling was less frequent during 1990-1998.

*** In 1999-2003 samples were analysed at a different laboratory, and for this reason, concentrations of total phosphorus and mercury data in 1999-2003 are excluded from the time series, whereas the loads are modelled. A more detailed overview of excluded data from historical records is given in Skarbøvik *et al.* (2010).

2.6 Stable isotopes in nitrate and phosphate

Samples for isotope analysis were collected during two periods (June and September) at three stations in River Alna in 2018 (Figure 3):

1. Kværnerparken (UTM-east: 600213, UTM-north: 6642144, UTM-zone: 32)
2. Alfaset at Bring (UTM-east: 602970, UTM-north: 6645226, UTM-zone: 32)
3. Fossumbekken (UTM-east: 605378, UTM-north: 6647070, UTM-zone: 32)

Station 1 is the station defined for Alna in the main programme (Table 1).

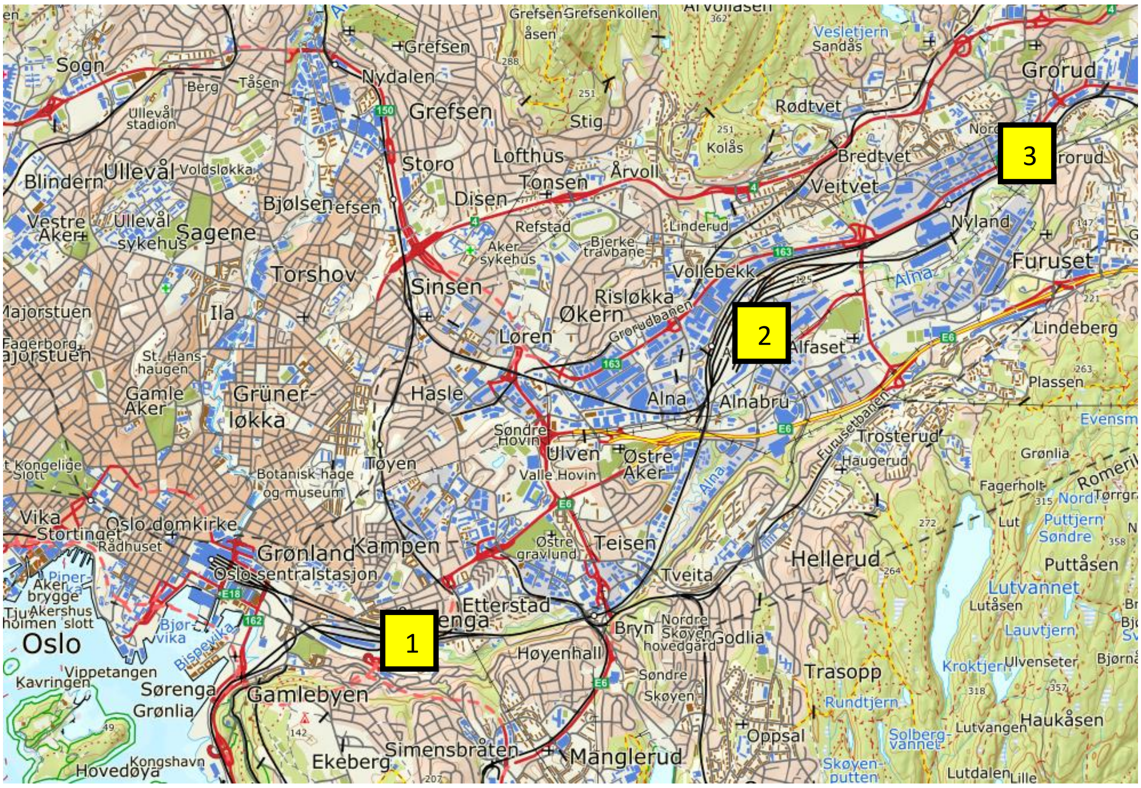

Figure 3: Map showing sampling sites for the stable isotope analyses.

$d^{15}N$ and $d^{18}O$ in nitrate

Altogether, 12 samples were collected from the three stations during June and August 2018 and stored in 100 mL nitrate-free, freezable, wide-mouthed, screw-top containers. Shortly after arriving at NIVA's lab, the samples were filtered (<0.45 micropore) and a sub-sample collected for nitrate (NO_3^-) and nitrite (NO_2^-) analysis. Nitrate concentrations should be in the range 2-1500 µmol as NO_3^- (30 – 21000 µg N/l) to allow stable isotope analysis with the bacterial denitrifier method (Sigman *et al.* 2001). The method does not discriminate between nitrate (NO_3^-) and nitrite (NO_2^-), and for samples expected to contain nitrite, it should be removed with sulfamic acid (Granger and Sigman 2009). The remaining water sample (at least 20-30 ml) was stored frozen and shipped frozen to the UC Davis Stable Isotope Facility (SIF) in California.

Analysis at the UC Davis SIF (according to their own description): The isotope ratios of ^{15}N and ^{18}O are measured using a trace gas concentration system linked to an isotope-ratio mass spectrometer (IRMS). Gas samples are purged from vials through a double-needle sampler into a helium carrier stream. The gas sample passes through a CO_2 scrubber and N_2O is trapped and concentrated in two liquid nitrogen cryo-traps operated in series such that the N_2O is held in the first trap until the non-condensing portion of the sample gas has been replaced by helium carrier, then passed to the second, smaller trap. Finally, the second trap is warmed to ambient temperature, and the N_2O is carried by helium to the IRMS via a capillary column that separates N_2O from residual CO_2. A reference N_2O peak is used to calculate provisional isotope ratios of the sample N_2O peak. Final $\delta^{15}N$ values are calculated by adjusting the provisional values such that correct $\delta^{15}N$ values for laboratory reference materials are obtained. The calibration standards are the nitrates USGS 32, USGS 34, and USGS 35, supplied by NIST (National Institute of Standards and Technology, Gaithersburg, MD). Additional laboratory reference materials are included in each batch to monitor and correct for instrumental drift and linearity. The LOQ for ^{15}N and ^{18}O of N_2O from NO_3 by bacterial denitrification in water is 2 - 1500 µM NO_3 with precisions of 0.4 ‰ for ^{15}N and 0.5 ‰ for ^{18}O.

d^{18}O in water and phosphate (PO_4)

Samples for d^{18}O analysis in water and phosphate (d$^{18}O_W$ and d$^{18}O_{PO4}$) were collected at the same dates and the same stations as for the nitrate analysis described above.

A subset of the 12 samples was shipped to Institute for Energy Technology (IFE) for analysis of d$^{18}O_W$. Description of the method (by IFE): $H_2O(l)$ was equilibrated with $CO_2(g)$ at 30ºC for 24 hours. The d^{18}O composition of CO_2 will then reflect the isotope composition of the original water sample. Impurities were separated from CO_2 before on-line determination of d^{18}O, using a Thermo Scientific Delta V isotope mass spectrometer. B2193 (Elemental Microanalysis) was analysed as an unknown to verify the instrument calibration. Repeated measurements of B2193 together with the samples yielded d$^{18}O_{VSMOW}$[1] = -12.35 ± 0.02 ‰ (one standard deviation). The "true"/certified value is -12.34 ± 0.13 ‰.

Water samples for d$^{18}O_{PO4}$ analysis were collected in 2x5 L Nalgene bottles and transported to NIVA's laboratory for extraction. To calculate the volume of water needed to extract at least 0.4 mg of PO_4-P, a sub-sample was analysed for PO_4-P before further processing. The method used to extract phosphate from the water samples and analysed for d$^{18}O_{PO4}$ is described in McLaughlin (2004) and Gooddy et al. (2015) and just briefly summarised here. Dissolved organic matter was first removed from the sample using an organic exchange resin and phosphate was then isolated from the remaining matrix by adsorption onto an anion-exchange resin. The resins were then shipped to Lancaster Environment Centre (LEC), UK, for further processing. Contact person at LEC was Dr. Ben Surridge. At LEC PO_4 was eluted and chromatographically separated from other anions using a KCl eluent. Eluted fractions containing the PO_4 were combined and processed to yield a silver phosphate precipitate (Ag_3PO_4) that was analysed for d$^{18}O_{PO4}$ by Isotope-ratio mass spectrometry (IRMS). The equilibrium oxygen isotope fractionations between dissolved phosphate and water were then calculated using an empirical relationship between water temperature and the d$^{18}O_{VSMOW}$ value provided for each sample by IFE (Chang and Blake, 2015).

---

[1] VSMOW - Vienna Standard Mean Ocean Water

2.7 Catchment modelling in River Storelva

Coupled catchment-river models can be valuable tools to describe and to synthesize key processes that determine the temporal and spatial variation in hydrology and hydrochemistry in river systems. When successfully calibrated to historical (measured) data, the models can be applied to simulate possible effects of future changes in environmental or climatic factors.

In this report, we have applied the hydrological model PERSiST and an Integrated Catchment model for nitrogen (INCA-N) to simulate future hydrology and nitrogen loads in River Storelva.

PERSiST
PERSiST is a daily-time step, semi-distributed rainfall-water discharge model designed specifically for use with INCA models (Futter et al. 2014). It takes daily air temperature and precipitation amounts and generates daily discharge, hydrologically effective rainfall and soil moisture deficit at the catchment scale. PERSiST shares many conceptual characteristics with the HBV model (Bergström 1976) but uses the same conceptual representation of water storage as the INCA models. Coupling PERSiST with INCA then allows a consistent conceptual model of the water discharge generation process for both hydrological estimations and water chemistry simulations.

INCA-N
The process-based and semi-distributed Integrated Nitrogen in Catchments model (INCA-N) integrates hydrological inputs from PERSiST with catchment/river N processes and simulates daily concentrations and loads of NO_3 and NH_4 at predefined sites along river stretches (Wade et al. 2002). The term semi-distributed means that the land surface is not modelled in a detailed manner but represented by sub-catchments accounting for gradients in environmental factors as one moves from the headwaters towards the river outlet. Sources of N include atmospheric deposition, terrestrial water discharge and direct discharges. The key N processes modelled in the soil water zone are nitrification, denitrification, mineralisation, immobilisation, N fixation and plant uptake. Rate coefficients of N processes are temperature and moisture dependent.

Data collection
Precipitation and temperature were obtained from the Nordic Gridded Climate Dataset (NGCD) provided by the Norwegian Meteorological Office. The catchments were derived from a 25x25m Digital Elevation Model (DEM) obtained by reclassifying a 10x10m DEM provided by Kartverket. The reclassified DEM was processed using the TauDEM package in combination with diverse gdal and postgis utilities in order to obtain catchment boundaries. Both gridded precipitation and gridded temperature were averaged over the obtained catchment.

Evapotranspiration and snow parameters in PERSiST were manually adjusted to get a good water balance and snow depth based on observations. Some soil condition parameters such as field capacity were set based on rough domain knowledge because they are hard to constrain otherwise. Other parameter such as soil and groundwater retention time, baseflow index and parameters having to do with in-stream flow conditions were obtained using an autocalibration routine (Nelder-Mead based). The metric used in the calibration was the sum of squares error between the observed and modeled reach flow in the outlet.

Inputs to INCA-N: Data on atmospheric deposition were obtained from the Birkenes observatory, which is operated by the Norwegian Institute for Air Research and located about

60 km southwest of the Storelva catchment (Aas et al. 2019). Nitrogen inputs from wastewater treatment plants and scattered dwellings were obtained from the TEOTIL model (Selvik and Sample 2018). Application of nitrogen fertilizer on agricultural fields was based on data from 1991-1993 (Kaste et al. 1995), linearly scaled until 2015 according to a trend-line corresponding to Statistics Norway's sales statistic for mineral N fertilizer during the calibration period 1993-2015.

Calibration
Calibration of the PERSiST hydrological model was done by adjusting parameters to obtain the best possible fit between modelled data and river flow measured at NVE's station 18.4.0 Lundevann, which is located at the river outlet. Ten years of daily hydrological data are available, and we used the whole period from 2009 to 2018 in the calibration process. The next step in the modelling procedure was to calibrate INCA-N. We used chemical data from the monitoring station Nes Verk, which is located 6 km upstream from the river outlet. Nes Verk is part of the National monitoring program for limed rivers (Norwegian Environment Agency, 2018). Totally 23 years of chemical data were available, and we used the whole time series from 1993 until 2015 for calibration.

Climate scenarios
After calibration to historically measured data PERSiST was run with future scenarios for air temperature and rainfall based on two greenhouse gas emission scenarios (RCP4.5 and RCP8.5) run by an ensemble with ten combinations of global (GCM) and regional (RCM) climate models. The datasets cover the period 1971-2100, are provided by EURO-CORDEX (Jacob et al. 2014; http://www.eurocordex.net/) and are also possible to download from Norsk Klimaservicesenter (https://klimaservicesenter.no). After running the climate scenarios with PERSiST, the results were used as input to the INCA-N model.

2.8 Sensor monitoring in Rivers Storelva and Målselva

The rivers Storelva and Målselva sensor stations are located at the same sites as the manual sampling sites (Table 1). Water from the river is pumped a few meters to an instrument container with flow cells equipped with sensors that measure water temperature, pH, conductivity, turbidity and fluorescent dissolved organic matter (FDOM). Data are recorded on an hourly basis, transferred to NIVA's server and made available online at www.aquamonitor.no/LandSjo/.

Water flow data are obtained from the Norwegian Water Resources and Energy Directorate (NVE) real-time stations 18.4.0. Lundevann, which is located close to the NIVA station in River Storelva, and 196.35.0 Målselvfossen, which is located 15 km upstream of the NIVA station in River Målselva.

A QA routine has been set up by flagging data that are obviously wrong, due to e.g. interrupted power supply, clogging, etc. Flagged data are not visible online or downloadable but are kept in the database. The sensors need repeated inspection during the year, and the stations are visited at regular intervals for service and maintenance. Temperature correction of the FDOM data for River Storelva was done in accordance with Ryder et al. (2012). The intercept constant was set to 100, and the slope intercept was chosen as to give the best correlation between temperature corrected FDOM and dissolved organic carbon (DOC) concentration for the time period 2015-2018. In River Målselva, temperature correction of FDOM was omitted as it did not improve the fit with DOC.

3. Results and Discussions

3.1 Climate and hydrology: status and trends

3.1.1 Air temperature and precipitation in 2018

The 2018 average **air temperature** for Norway was 1.4 °C above the 1961-1990 normal, and it was the 15th warmest year since the measurements started in 1900. The highest deviation from the temperature normal (+2.0 – 3.0 °C) was in the south-eastern parts of the country and also in the farthest north-east region (Figure 4, left). The average air temperature was above the normal in all four seasons, with +0.6 °C during winter (December 2017 – February 2018), +1.0 °C during spring (March – May), +1.8 °C during summer (June – August), and +1.9 °C during autumn (September – November). The summer season was the 6th warmest on record since measurements started in 1900.

Precipitation in 2018 was close to normal for the country as a whole, but with regional deviations towards both extremes; from receiving 50% of the normal precipitation in some areas in south-eastern Norway to as much as 150% of the normal in parts of mid-southern Norway and in Finnmark county (farthest north-east) (Figure 4, right side panel). Seasonally, levels were higher than the normal during winter (105%), summer (110%), and autumn (110%), while during spring the precipitation was lower than normal (85%). There was generally large difference between the southern and the northern parts of Norway during the seasons. For example, the lower-than-normal precipitation during autumn was caused by stations in southern Norway, receiving as little as 25-50% of the normal precipitation, while some stations in the north received up to 200% of the normal.

For more details on the weather in 2018, see Grinde et al. (2019).

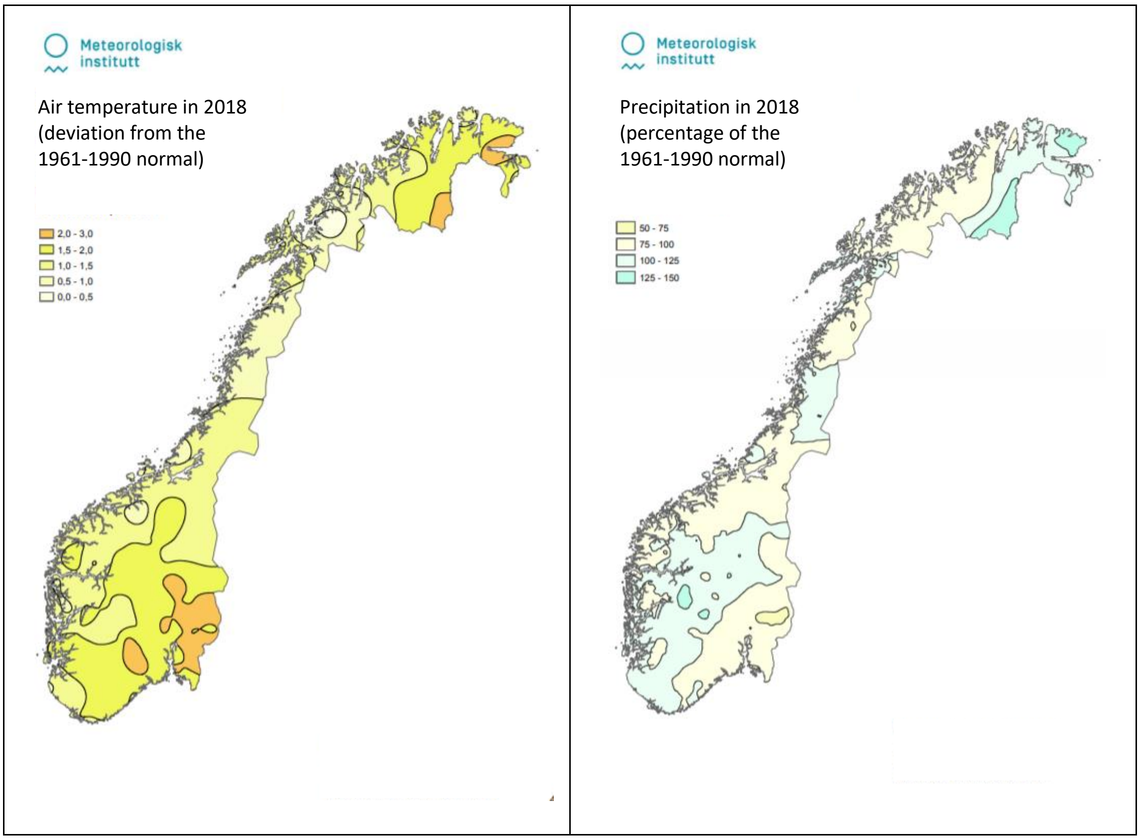

Figure 4: Air temperature (left) and precipitation (right) in Norway in 2018 as deviation from or percentage of the normal values (1961-1990), respectively. Maps edited from Grinde et al. (2019).

3.1.2 Trends in air temperature and precipitation 1980-2018

Table 9 shows trends in air temperature and precipitation since 1980 (1981 for Vosso and 1983 for Drammenselva) at meteorological stations located in the near vicinity of the river monitoring sites. The results show a significant increase in air temperature at nearly all the stations. For precipitation, only the station near Altaelva showed a significant trend (increasing). Large year-to-year variation in precipitation could potentially explain the lack of significant trends. Comparing with the results in the previous report (Kaste et al., 2018), the temperature trend at the station near river Drammenselva has changed from no trend to an increasing trend, while at the Målselva station there was no longer a significant temperature increase and at the Alna station the precipitation was no longer significantly increasing when including 2018 data.

Table 9. ***Trends in air temperature and precipitation 1980-2018. Data from the Norwegian Meteorological Office (met.no).***

River name	Temperature				Precipitation			
	St.no	**Years**	**Temp. trend (p-value)**	**Temp change (°C)**	**St. no**	**Years**	**Precip. trend (p-value)**	**Precip. change (mm)**
Glomma	SN700	1980-2018	0.014	+1.4	SN3780	1980-2018	0.246	+109
Alna	SN18700	1980-2018	0.000	+1.9	SN18700	1980-2018	0.140	+128
Drammenselva	SN19710	1983-2017	0.031	+1.0	SN19710	1983-2018	0.294	+93
Numedalslågen	SN27470	1980-2010	1.00	+1.6	SN30000	1980-2018	0.559	-51
Skienselva	SN27470	1980-2010	1.00	+1.6	SN30260	1980-2015	0.149	+133
Vegårdselva	SN36560	1980-2018	0.000	+1.5	SN36560	1980-2018	0.054	+303
Otra	SN39040	1980-2018	0.002	+1.3	SN39040	1980-2016	0.156	+247
Bjerkreimselva	SN44560	1980-2018	0.000	+1.5	SN43360	1980-2017	0.365	+129
Orreelva	SN44560	1980-2018	0.000	+1.5	SN44190	1980-2018		+94
Vikedalselva	SN46910	1980-2011	0.003	+1.4	SN46850	1980-2018	0.075	+598
Vosso	SN52290	1981-2007	0.026	+1.0	SN51250	1980-2018	0.327	+376
Nausta	SN58070	1980-2017	0.004	+1.2	SN57480	1980-2018	0.425	+200
Driva	SN64550	1980-2007	0.003	+1.3	SN63530	1980-2017	0.314	-101
Orkla	SN69100	1980-2018	0.011	+1.2	SN66210	1980-2009	0.915	+38
Nidelva	SN69100	1980-2018	0.011	+1.2	SN68270	1980-2018	0.439	+97
Vefsna	SN85380	1980-2018	0.000	+1.7	SN78850	1980-2007	0.244	+244
Målselva	SN89350	1980-2018	0.045	+1.1	SN89350	1980-2018	0.406	+53
Altaelva	SN93140	1980-2018	0.000	+1.6	SN93140	1980-2017	0.024	+125
Tana	SN96800	1980-2012	0.008	+1.7	SN96970	1980-2018	0.798	+17
Pasvikelva	SN99370	1980-2017	0.000	+2.1	SN99500	1980-2018	0.299	+44

Red – significantly increasing p<0.05. There were no significantly decreasing trends.

3.1.3 Water temperature – status 2018 and trends

Table 10 shows the monthly mean water temperature measured in the monitored rivers in 2018, and in Figure 5 the monthly temperatures for each river are presented. Generally, the water temperatures show a strong seasonal pattern and typically vary from the north to the south, and can be influenced by whether the river catchments range from mountain to fjord (e.g., river Vosso) or mainly consist of lowland areas (e.g., river Orreelva and river Alna). The water temperatures from July were particularly high in the south-eastern rivers (e.g. 23.8 °C in Storelva).

Table 10. Monthly water temperature measured in the monitored rivers in 2018

River name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Glomma	0.3	0.1	0.9	1.2	9.1	16.9	21.5	20.2	15.6	10.6	6.1	4.5
Alna	2.7	0.9	0.1	3.8	6.3	12.3	14.1	14.3	12.6	7.8	7.8	3.8
Drammenselva	1.0	0.1	0.2	0.7	7.7	17.2	18.8	21.7	16.2	9.7	6.7	4.1
Numedalslågen	0.2	0.2	0.2	2.1	10.8	17.9	21.6	17.9	13.1	7.8	4.1	0.5
Skienselva	2.9	2.1	1.2	2.3	5.2	13.1	18.6	19.1	14.6	10.6	7.3	4.6
Storelva	1.6	1.1	0.8	2.8	15.7	21.4	23.8	20.2	15.3	10.7	7.5	4.1
Otra	1.2	0.4	0.6	3.1	14.1	18.2	20.9	19.1	13.5	9.2	6.1	2.9
Bjerkreimselva	3.2	1.3	1.2	7.8	16.3	20.0	20.0	20.4	-	-	8.0	0.5
Orreelva	4.8	4.6	3.7	7.5	12.1	16.5	18.1	17.2	13.6	10.1	7.2	4.0
Vikedalselva	1.5	0.8	0.8	3.5	11.0	16.4	19.5	15.6	12.0	8.4	5.2	3.1
Vosso	1.1	1.1	1.3	2.1	6.0	12.4	15.9	14.8	10.9	7.4	5.5	3.5
Nausta	-0.2	-0.1	-0.2	0.0	3.3	11.8	15.7	14.0	11.1	6.5	5.2	1.5
Driva	1.5	1.9	1.5	2.0	3.0	9.0	14.0	12.7	8.1	-	4.0	4.0
Orkla	0.4	0.5	0.6	2.0	7.9	11.1	14.6	12.5	9.3	4.3	1.7	0.8
Nidelva	2.6	1.2	0.7	1.3	5.0	8.9	11.3	16.0	13.4	6.8	5.7	4.3
Vefsna	0.1	0.0	-0.3	0.1	4.9	9.3	16.4	13.3	9.5	4.3	1.9	-0.4
Målselva	0.0	0.0	0.0	0.0	4.4	7.1	13.9	13.0	8.6	2.8	0.8	0.0
Altaelva	-0.1	0.0	0.0	0.1	2.7	7.0	10.9	13.6	10.3	5.0	2.1	1.5
Tana	0.0	0.0	0.1	0.1	0.5	8.6	12.9	14.5	13.0	3.1	0.3	1.0
Pasvikelva	0.0	0.0	0.1	0.4	0.6	10.1	19.8	17.4	14.1	4.0	2.8	0.1

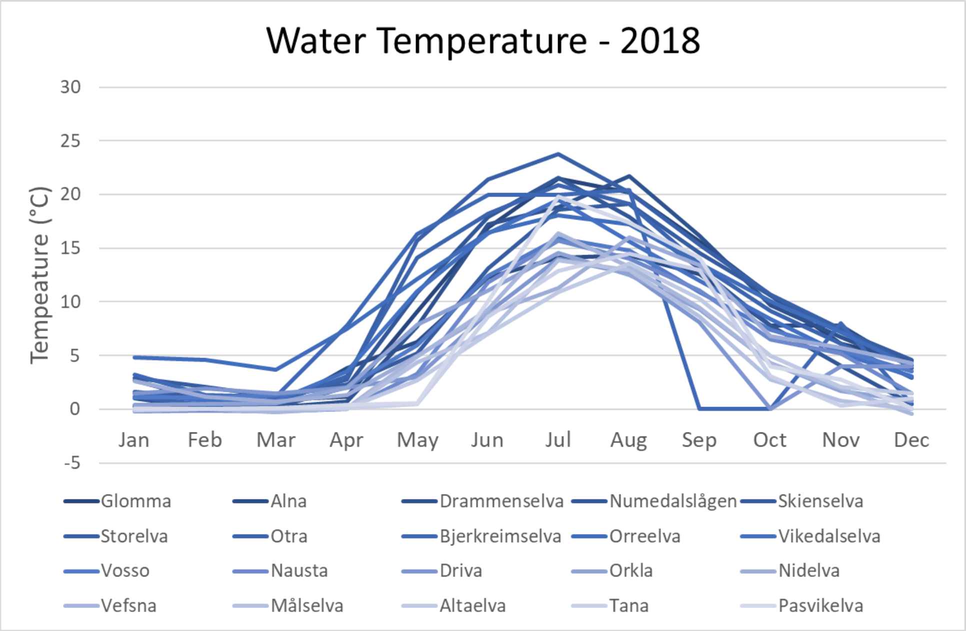

Figure 5: Monthly measured temperature in the rivers. Note that the shade of the lines indicates geographical location (South-eastern rivers are darker while the northern are the lightest). Data presented in Table 10.

The stations included in the long-term water temperature trend analysis are given in Table 11 and with details on the time series in Table 4. (Note that eight of the rivers have not been included since they either do not have a temperature station nearby or since the available long-term data series is incomplete.) 2018 data had not been made available by the time of the data analysis (marked by "*" and text in grey) for six of the stations. For the remaining six rivers the inclusion of the 2018 water temperature did not lead to any major changes in the trends. The two northern rivers Altaelva and Pasvikelva displayed significantly increasing trends in water temperature, which agrees with the 2017 results (Kaste et al., 2018). None of the other rivers showed significant trends.

Table 11. Trends in annual mean water temperature, in rivers with available long-term data.

River name	Years with data	p-value
Drammenselva	20*	0.056
Numedalslågen	12	0.837
Skienselva	22	0.080
Otra	23*	0.833
Bjerkreimselva	27*	0.045
Vikedalselva	29	0.149
Vosso	20*	0.496
Nausta	15*	0.276
Orkla	21	0.487
Altaelva	24	0.004
Tana	15*	1.00
Pasvikelva	22	0.013

Red – significantly upward p<0.05. There were no significantly decreasing trends.

*data from 2018 had not been made available at the time of analysis.

3.1.4 Water discharge – status 2018 and trends

For the southern rivers (from Glomma to Vikedalselva), the 2018 annual water discharge was lower than the mean of the five preceding years (Figure 6). This could be explained by the elevated temperature this year, and for the rivers in the southeast also by the low precipitation. For a few of the rivers the water discharge was even lower than the "normal" range in water discharge from the five preceding years (illustrated by error bars), including Alna, Numedalslågen, and Målselva. For both the southeast of Norway (Alna, Numedalslågen) and in the region where Målselva is located, the temperature was higher and the precipitation was lower than normal in 2018, although not to the same extent. Rivers diverging from this trend include Nausta, having 2018 water discharge identical to its 5-year mean, and Driva, Orkla, Vefsna, and Tana where the 2018 water discharge was higher than the 5-year mean (not exceeding the 95% variation). Again, this is in accordance with the precipitation data, showing elevated levels in the middle-to-northern parts of southern Norway (Driva and Orkla), the northern parts of middle Norway (Vefsna) and in Finnmark county (Tana). The geographical variation in the 2018 water discharge followed the same patterns as for the previous five years: In southern Norway the water discharge increased when going from east to the west (from Glomma to Nausta), in middle Norway it decreased from south to north (from Driva to Vefsna), and in northern Norway it decreased from south-west to north-east (Målselva til Pasvikelva).

Long-term trend analysis (1990-2018) of water discharge for the rivers with monthly monitoring since 1990 is presented in Table 12. For three rivers located in the south-east, Rivers Glomma, Drammenselva, and Skienselva the water discharge has been increasing by 18, 33, and 22%, respectively. This could be a result of increased precipitation which is an expected response to a changing climate (MET, 2015). Although the precipitation trends in this study does not show a significant increase (Table 9), other studies of longer time periods and higher geographical resolution confirm. For example, MET (2015) found an annual national increase in precipitation of 18% compared to the 1900 level. None of the other rivers showed any trends in annual water discharge. This is the same pattern as observed in the previous report. Among the rivers where water discharge data was available from 2004 there was a significant increasing trend for river Tana, while no trends were detected in the remaining rivers. This was also in accordance with the findings in the previous report.

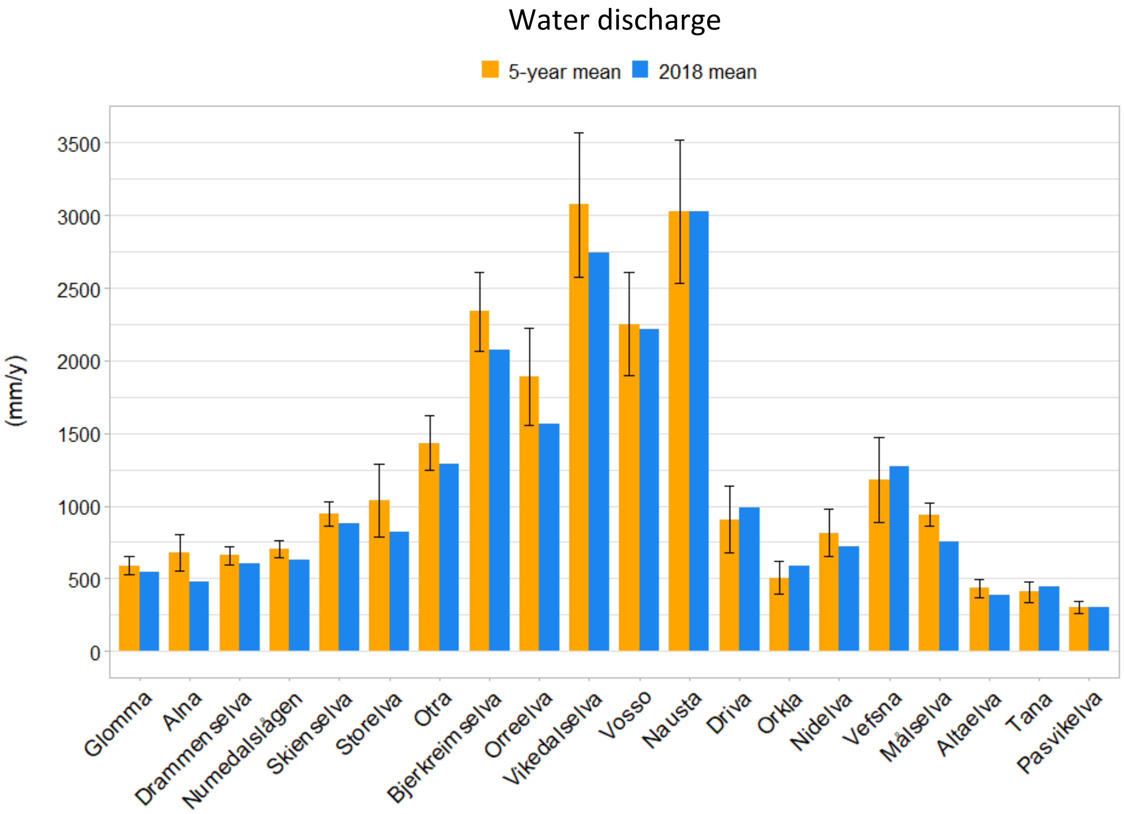

Figure 6: Average annual water discharge for the five preceding years (2013-2017, orange) and annual water discharge in 2018 (blue) for the monitored rivers. Error bars illustrate annual variation in the five-year mean (± stdev).

Table 12. Trends in annual water discharge. Showing p-values

River	Long-term 1990-2018	River	Short-term 2004-2018
Glomma	0.049	Bjerkreimselva	0.692
Drammenselva	0.013	Vikedalselva	0.843
Numedalslågen	0.129	Vosso	0.373
Skienselva	0.049	Nausta	1.00
Otra	0.268	Driva	0.235
Orreelva	0.063	Nidelva	0.198
Orkla	0.420	Målselva	0.553
Vefsna	0.320	Tana	0.0133
Altaelva	0.302	Pasvikelva	0.138

Red – significantly increasing p<0.05. There were no significantly decreasing trends.

3.2 Water quality status 2018 The River monitoring programme

The Norwegian river monitoring programme is designed so that the results can be used also for classification of ecological and chemical status according to the principles in the EU Water Framework Directive (WFD). Thresholds for achieving good ecological status for individual quality elements (and underlying parameters) and good chemical status are given in the Norwegian classification guidance (Direktoratsgruppen 2018). Throughout this chapter the results will be evaluated with respect to these thresholds. The classification is only relevant for the water body where the monitoring site is located (Table 1).

3.2.1 pH and calcium

Levels of pH and calcium typically follow each other in the river water. The acidity of the rivers show a clear regional pattern with the highest values (> 7.0) in south-eastern Norway and northwards from Trøndelag (Figure 7), and with the most acidic rivers (pH < 7) in the southern and western parts of Norway (Otra, Bjerkreimselva, Vikedalselva, Vosso, and Nausta). The latter can be explained by the naturally slow-weathering bedrock and low buffering capacity in the surface waters in this region. Additionally, the southern- and western parts typically has received and still receive the highest level of acid deposition in the country. Many of the largest rivers are routinely limed to protect brown trout and Atlantic salmon populations (including Storelva, Bjerkreimselva, and Vikedalselva). Smaller scale liming of mainly lakes of the area can also affect the rivers in those watersheds, but the effect from this on the overall water chemistry is typically small. An exception in the south-west region is Orreelva, which is a lowland river draining agricultural areas, giving generally alkaline waters (pH > 7.5). The annual average pH of 2018 was very similar to the average for the five preceding years for all the rivers (Figure 7).

Variation in the levels of calcium among the rivers follow the same pattern as observed for the pH (Figure 8). The 2018 levels of calcium were similar to the 2017 levels. Note that calcium was introduced in the programme in 2017. According to the Norwegian typology for classification under the WFD, the types with respect to calcium content are very low (< 1 mg L^{-1}), low (1-4 mg L^{-1}), moderate (4-20 mg L^{-1}), or calcareous (> 20 mg L^{-1}). Three rivers were found to be *very low* (Nausta, Otra, and Vosso), eight rivers were *low* (Bjerkreimselva, Vikedalselva, Skienselva, Vegårdselva, Pasvikelva, Numedalslågen, Nidelva, and Drammenselva), eight were *moderate* (Driva, Tanaelva, Glomma, Altaelva, Orkla, Vefsna, Målselva, and Orreelva), and the one urban river was calcareous (Alna).

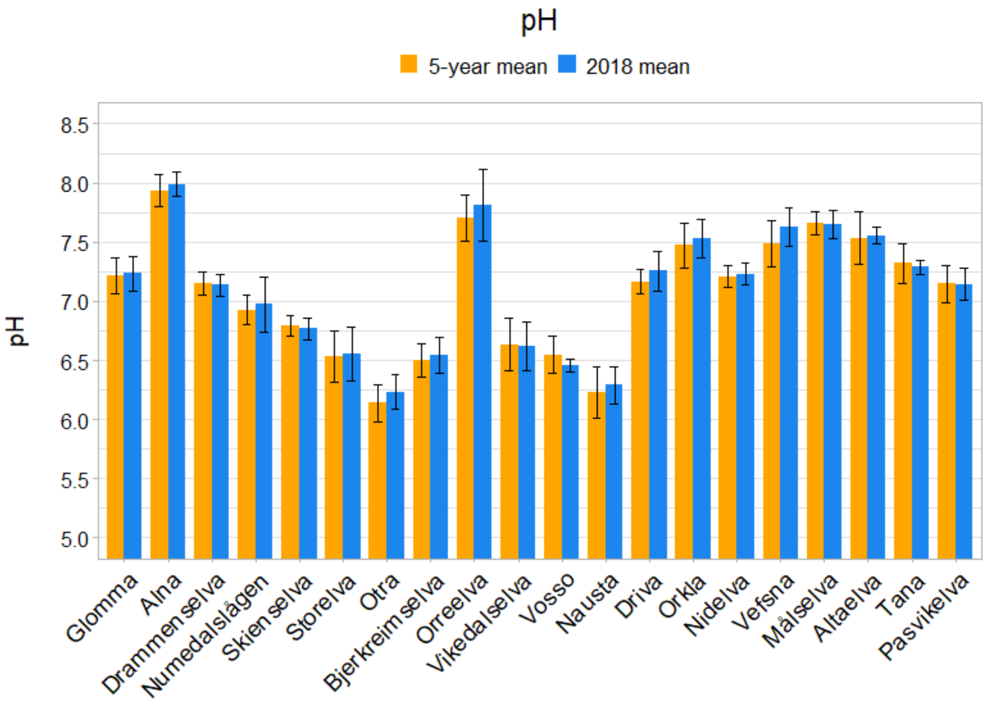

Figure 7: Average annual pH for the five preceding years (2013-17, orange) and annual average for 2018 (blue) for the monitored rivers. Error bars illustrate interannual variability (± stdev) for the 5-year mean and intra-annual variability for the 2018 mean (± stdev). Mean values and standard deviation are based on pH values, not the H⁺ concentration. This represents a negligible error when pH values are above 6.0.

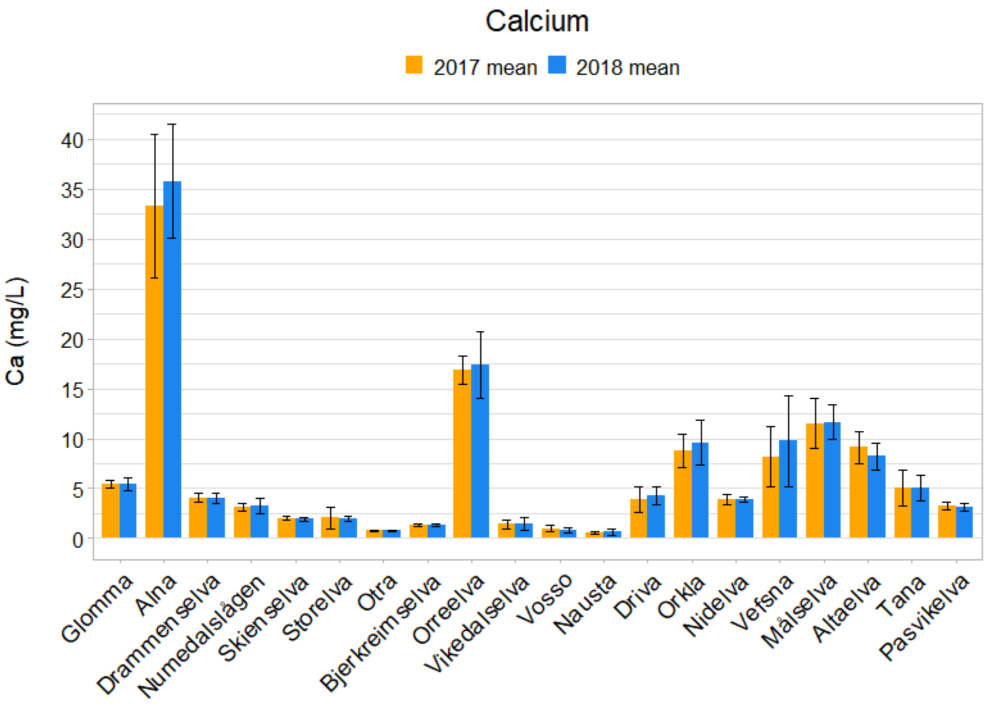

Figure 8: Average calcium concentrationn 2017 (orange) and 2018 (blue) for the monitored rivers. Error bars illustrate intra-annual variation (± stdev).

3.2.2 Suspended matter (turbidity, SPM, and silica)

Turbidity is an optical measure of material in the water that can scatter light. Turbidity covers both suspended particulate matter (0.4 µm < SPM < 2 µm) and colloidal material (<0.4 µm, e.g. silica). These parameters are important for the water quality by influencing processes such as light penetration and transport of metals/nutrients.

The highest levels of both turbidity and SPM were found in the south-eastern rivers Glomma, Alna, and Numedalslågen, and in addition the agricultural river, Orreelva (Figure 9 and Figure 10, respectively). These rivers are all influenced by easily erodible clay soils. Individual maximum measurements of SPM were very high in river Alna (116 mg/L), while for the other rivers high in SPM the 2018 levels were moderate (< 30 mg/L) compared to the previous measurements during flood events. According to the 5-year mean, River Orkla has previously had some relatively high SPM measurements, but this was not the case for the 2018 annual mean. This river is partly located in the lowland and is also affected by tailings from an abandoned copper mine. Both SPM and turbidity were generally associated with high inter-annual variation (>200%) which is likely du to variability in seasonal precipitation events. The 2018 levels of turbidity and SPM were similar to the means for the five preceding years.

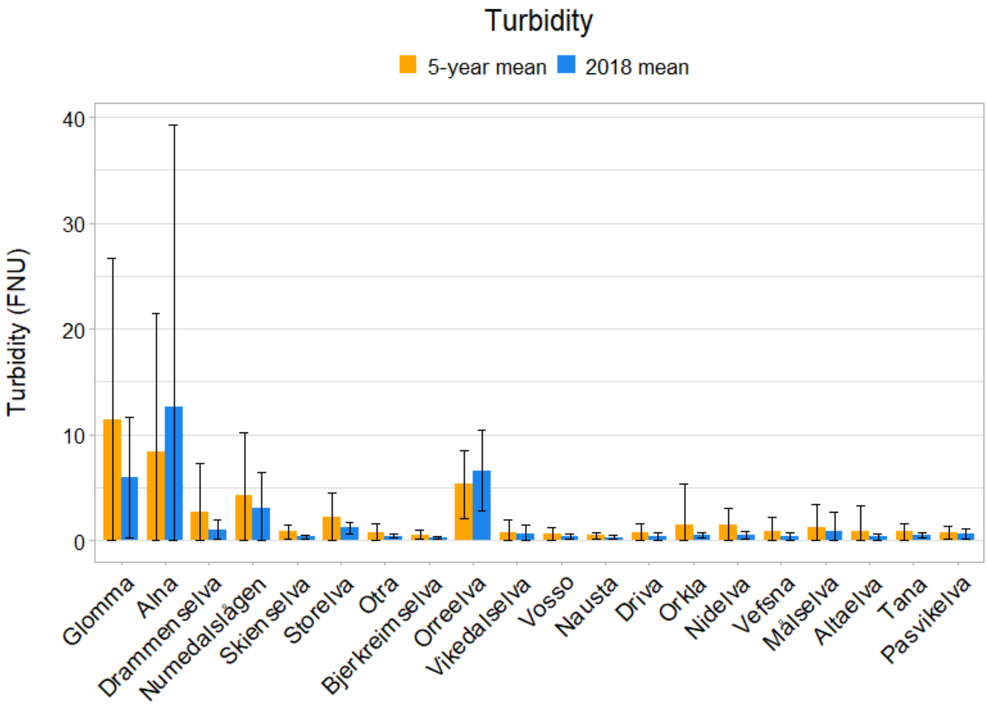

Figure 9: Average annual turbidity for the five preceding years (2013-17, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate interannual variability (± stdev) for the 5-year mean and intra-annual variability for the 2018 mean (± stdev).

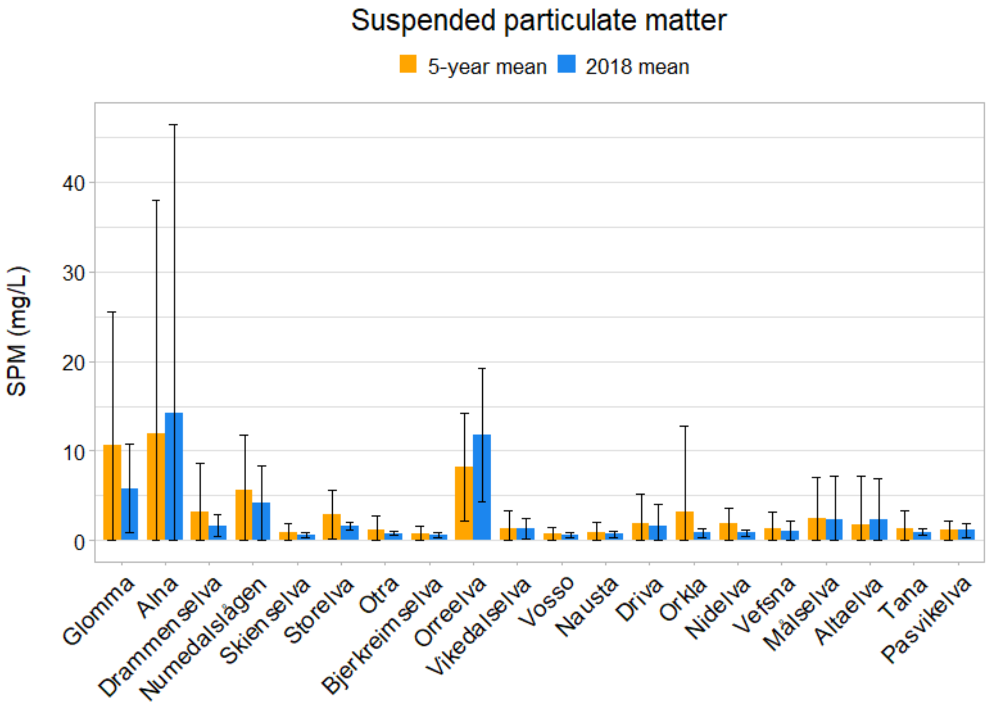

Figure 10: Average annual suspended particulate matter (SPM) concentration for the five preceding years (2013-17, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate interannual variability (± stdev) for the 5-year mean and intra-annual variability for the 2018 mean (± stdev).

Silica is a major component of sand and clay and can therefore enter surface water through erosion. It is an essential nutrient for diatoms, which is an important phytoplankton group. Thus, changes in levels of silica can, together with nutrient information, provide an indication on potential eutrophication. Note that in the method used, Si was measured which will also include soluble silicates. The lowest silica concentrations were, similar to calcium, found in areas with slow-weathering bedrock, which is typical for southern and western parts of Norway (Figure 11). The highest concentrations (above 5 mg L^{-1}) were measured in River Alna (7.0 mg L^{-1}) and in the three northernmost rivers; Altaelva (4.9 mg L^{-1}), Tana (8.0 mg L^{-1}) and Pasvikelva (4.9 mg L^{-1}). The 2018 silica levels consistently followed those of the 5-years means.

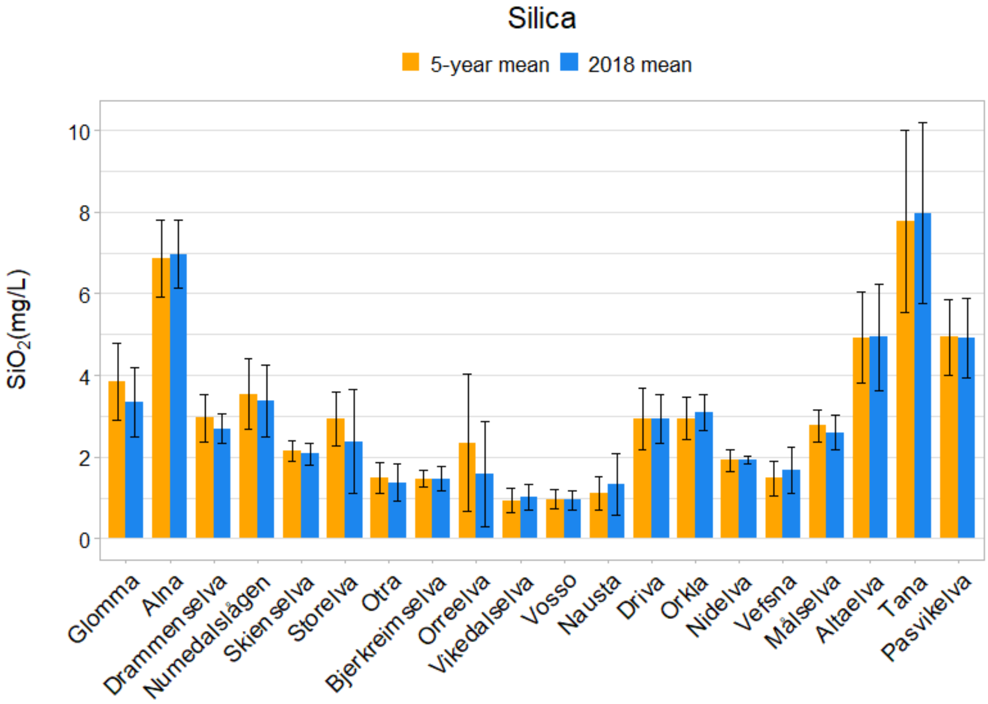

Figure 11: Average annual silica (SiO_2) concentration for the five preceding years (2013-17, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate interannual variability (± stdev) for the 5-year mean and intra-annual variability for the 2018 mean (± stdev).

3.2.3 Organic carbon

Total organic carbon (TOC) is a quantitative measure for the organic matter, typically consisting of 60% carbon (followed by oxygen, hydrogen, and nitrogen). Organic matter originates mainly from dead terrestrial material, and the level in surface water largely reflects the vegetation and soil type of the area (Garmo and Skancke 2018).

In 2018, TOC showed a geographical distribution similar to the 5-year mean (Figure 12). The highest levels (4.5 – 5.8 mg L^{-1}) were found in the south-eastern rivers with forest dominated catchments, while the lowest levels (1 – 2 mg L^{-1}) were found in the western rivers, where the catchments typically have thin soils and much exposed bedrock. Medium TOC levels were observed in middle and northern Norway which generally have vegetation and soil types in-between those of the south-east and west. One exception to the pattern was Orreelva, which was high in TOC despite being located in western Norway. In this river effluent inputs and diffuse water discharge from agriculture are likely to contribute to the higher TOC concentration. According to the Norwegian WFD typology, seven of the rivers can be characterized as having *very clear* water (TOC < 2mg L^{-1}: Bjerkreimselva, Vikedalselva, Vosso, Nausta, Vefsna, and Målselva), eleven rivers as *clear* (2 mg L^{-1} < TOC < 5 mg L^{-1}), whereas two rivers as *humic* water (TOC > 5 mg L^{-1}: Storelva and Orreelva) with respect to TOC type.

Figure 13 presents the 2018 average distribution of dissolved and particulate organic carbon in the rivers. The results suggest that TOC largely consists of the dissolved fraction (74.4 – 97.5% DOC). The highest proportion of particulate organic carbon was seen in Rivers Orre and Alna (25.6 and 23.2% POC), which also had the highest SPM concentrations in 2018.

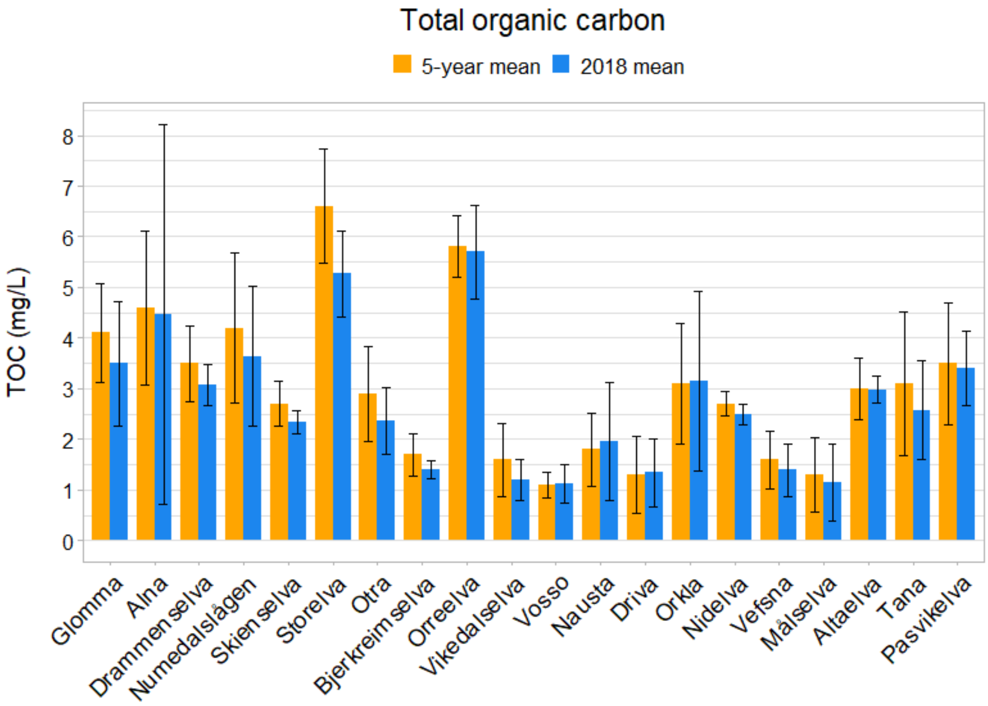

Figure 12: Average annual turbidity for the five preceding years (2013-17, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate interannual variability (± stdev) for the 5-year mean and intra-annual variability for the 2018 mean (± stdev).

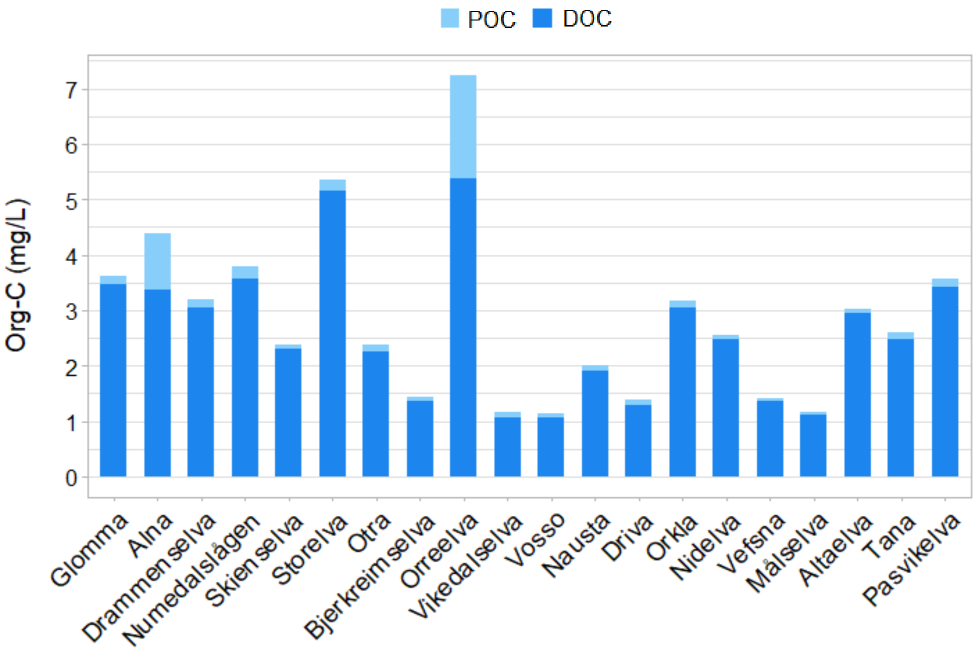

Figure 13: Average particulate (POC, light blue) and dissolved (DOC, dark blue) organic carbon concentration for 2018 in the monitored rivers. Note that the sum of POC and DOC equals to TOC. Any deviation from the TOC in Figure 12 result from analytical uncertainties in the individual methods used to determine POC and DOC.

3.2.4 Nutrients

Phosphorus

Excess input of phosphorus (P) is regarded as the main driver for eutrophication in Norwegian water bodies. Major sources include agricultural activities, water discharge from urban areas, and weathering of P-containing minerals (e.g. apatite). In the river water, the bioavailability of phosphorus will depend on which chemical form it resides and on whether it is bound to particles or freely dissolved in the water.

Rivers Alna and Orreelva had the highest levels of total phosphorus (tot-P, 69 and 56 µg L^{-1}, Figure 14). These rivers are influenced by urban areas and agriculture, respectively. Both rivers in less than good ecological status according to the good/moderate boundary for tot-P for their respective water types (Direktoratsgruppen 2018). Among the other rivers, Rivers Glomma and Numedalslågen were high in tot-P (10 – 13 µg L^{-1}), but still below the good/moderate boundary. All the remaining rivers had average tot-P concentrations below 7 µg L^{-1}. The relatively large variation in tot-P was associated with particle bound phosphorus transported to the rivers in connection with seasonal discharge events. In fact, most rivers had a relatively high proportion of particulate-P (Figure 15, 33-79%), and especially those rivers associated with higher SPM concentration (Alna, Glomma, Numedalslågen, Orreelva, and Målselva). When bound to particles, the bioavailability of P is reduced. Phosphate (PO_4) is an inorganic form of tot-P which is easily available for algae and other primary producers. The highest annual mean phosphate concentration was found in River Orreelva (22 µg L^{-1}, Figure 16), likely resulting from the agricultural activities. For most rivers, the inorganic fraction (phosphate) of the dissolved P was higher than the organic fraction (PO_4: 29 - 83% of tot-P).

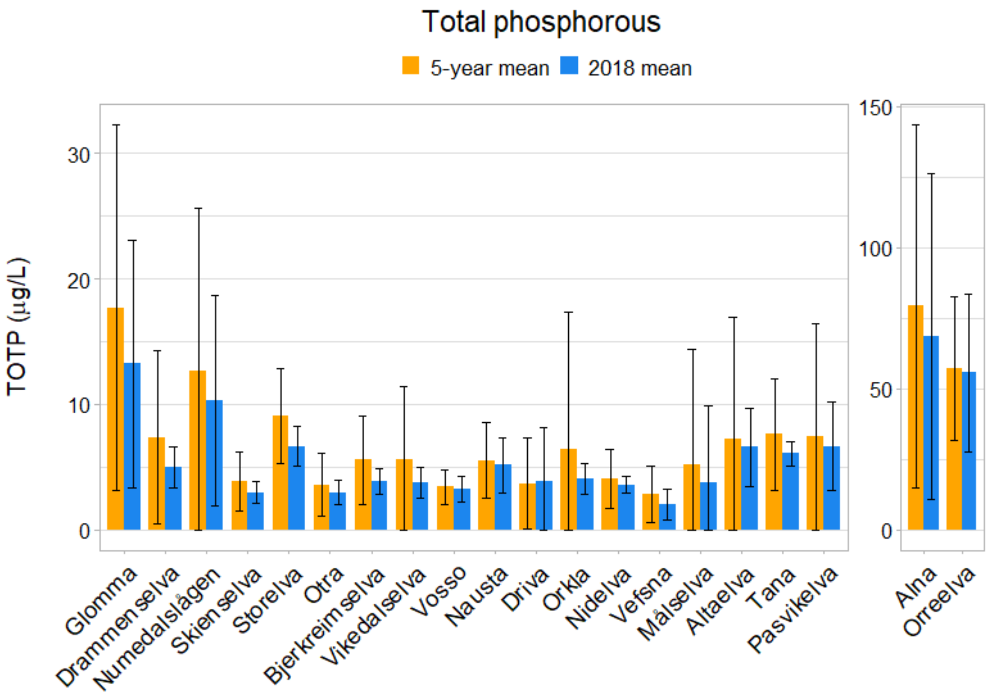

Figure 14: Average concentration of total phosphorous (tot-P/TOTP) for the five preceding years (2013-17, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate interannual variability (± stdev) for the 5-year mean and intra-annual variability for the 2018 mean (± stdev). Note the different y-scale range on the right-side panel.

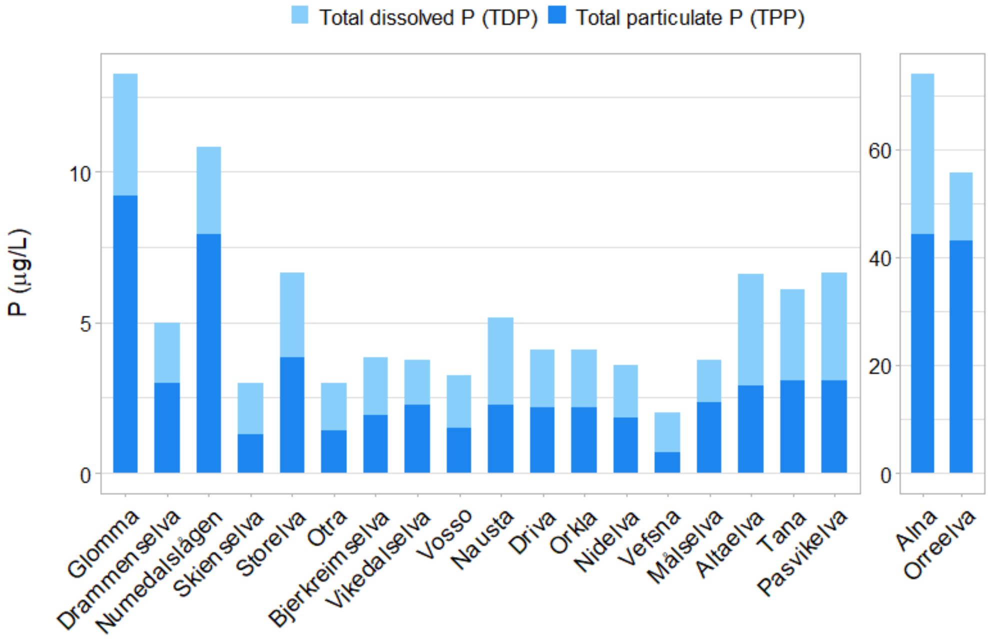

Figure 15: Distribution of the 2018 average concentration of total dissolved (TDP, light blue)- and total particulate phosphorus (TPP, dark blue) in the monitored rivers. Note that the sum of TDP and TPP equals to tot-P. The TPP was calculated as the difference between tot-P and the TDP. Note the different y-scale range on the right-side panel.

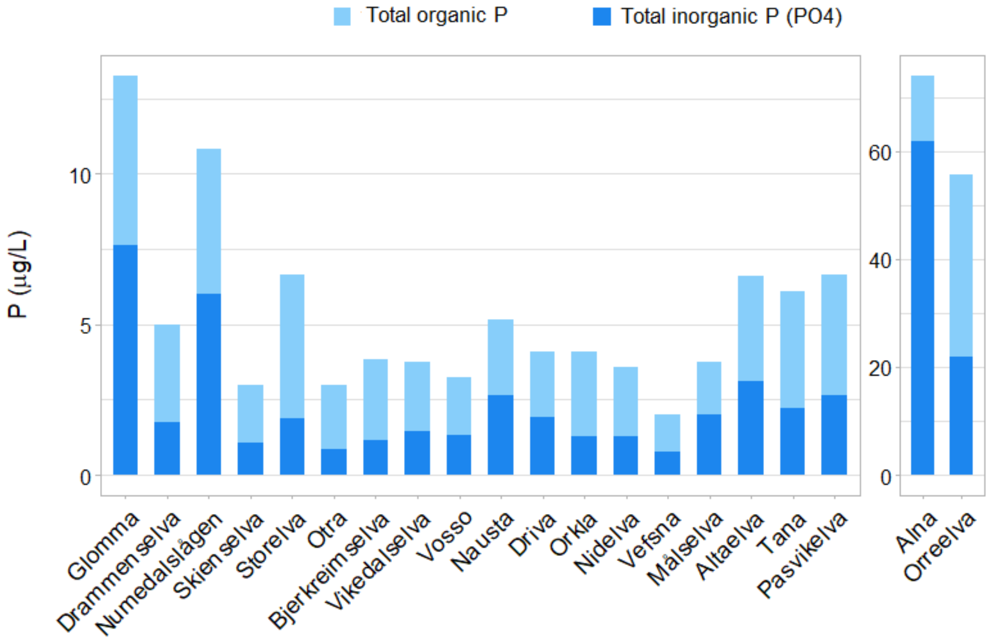

Figure 16: Distribution of the 2018 average concentration of inorganic (light blue)- and organic phosphorus (dark blue) in the monitored rivers. The organic P fraction has been calculated as the difference between tot-P and phosphate and can also include tightly bound inorganic P. Note the different y-scale range on the right-side panel.

Nitrogen

The major sources for nitrogen (N) in river basins are water discharge from agriculture, atmospheric deposition, scattered dwellings, urban wastewater, and diffuse water discharge from upland areas. As for phosphorus, nitrogen can also exist in different chemical forms and be either freely dissolved or associated with particulate material.

The highest 2018 levels of total nitrogen (tot-N) was, as for tot-P, found in Rivers Alna and Orreelva (1493 and 1312 µg L^{-1}, Figure 17). The concentrations exceeded the good/-to-moderate boundary for tot-N for their respective water types (Direktoratsgruppen 2018). Relatively high levels of tot-N were also evident for several of the rivers in the south-western part of Norway (Bjerkreimselva and Vikedalselva), which is likely due to atmospheric deposition (Garmo and Skancke 2018).

The two forms of nitrogen readily available for plant uptake are nitrate and ammonium. Nitrate is typically the dominant fraction of tot-N in Norwegian surface waters, except in humic waters where the organically bound-N (TON) can dominate. The highest NO_3:tot-N ratio (0.74) was found in River Bjerkreimselva, whereas Rivers Tana and Pasvikelva were at the other end of the range with ratios of 0.28 and 0.30, respectively (Figure 18). Ammonium (NH_4) concentrations are usually low in Norwegian surface waters, except for highly polluted sites or in waters with low oxygen content. It was therefore not surprising that the highest ammonium levels were found in Rivers Alna and Orreelva. In several of the western and northern rivers the ammonium levels were close to zero. The fraction of nitrogen bound to organic matter is usually highest in low N-deposition areas and in water with high TOC concentrations. The highest TON:tot-N ratios (>0.65) were found in the northern rivers Altaelva and Tanaelva (Figure 18). Nitrogen has less affinity to particles than phosphorus, and as illustrated in Figure 19, the dissolved N is the dominant fraction. It was the "particle-rich" Rivers Alna and Orreelva that had the highest concentrations of particulate N.

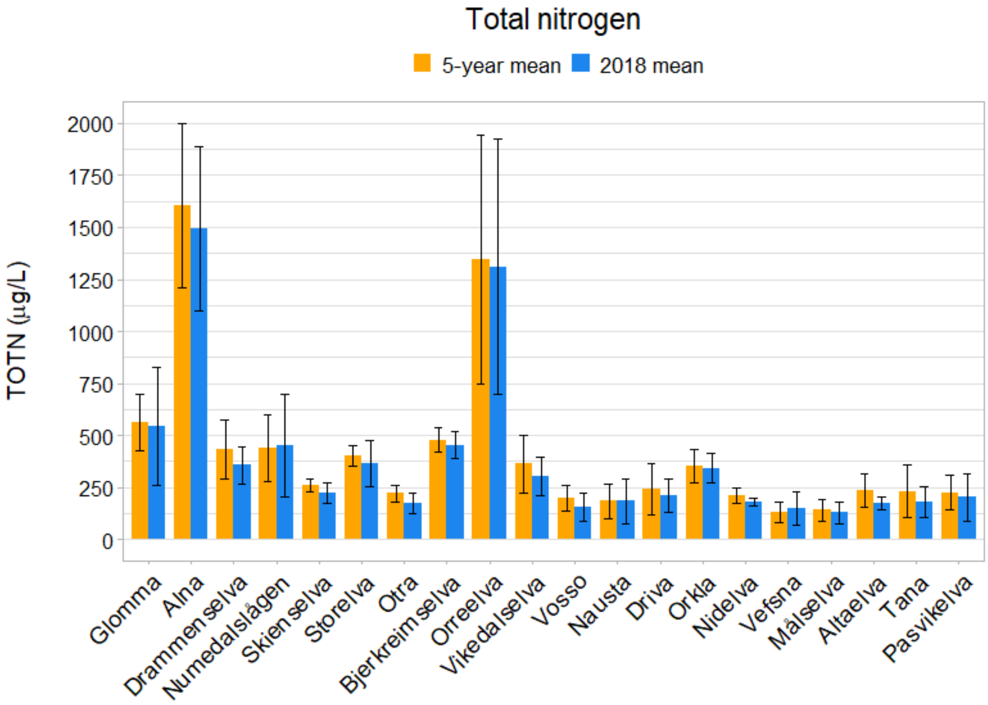

Figure 17: Average annual concentrations of total nitrogen (TOTN/tot-N) for the five preceding years (2013-2017, orange) and the 2018 average (blue) for the monitored rivers. Error bars illustrate interannual variability (± stdev) for the 5-year mean and intra-annual variability for the 2018 mean (± stdev).

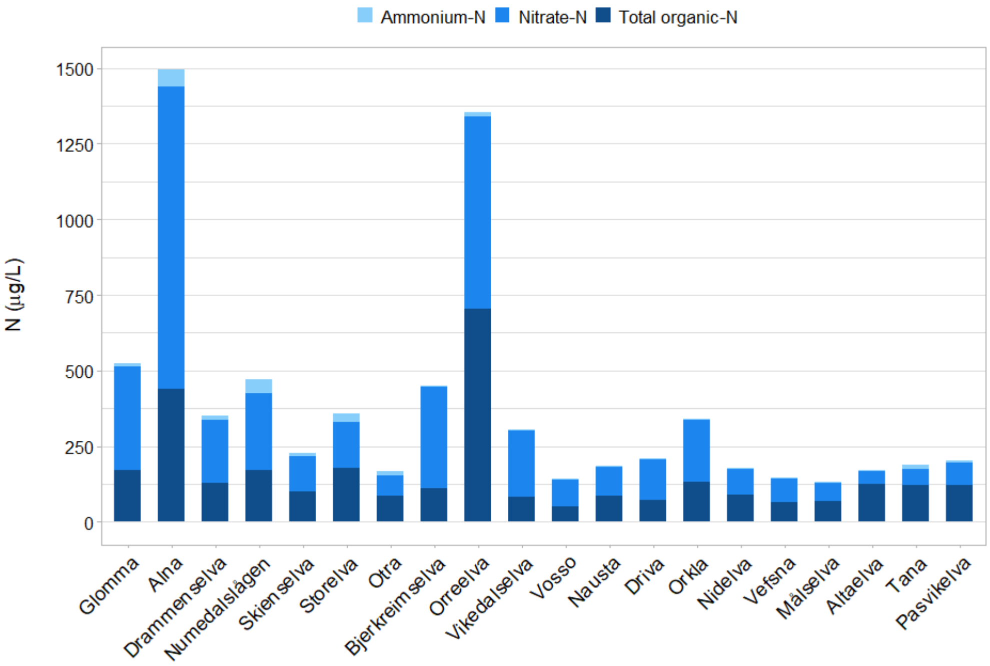

Figure 18: Distribution of the 2018 average concentration of ammonium-N (light blue), nitrate-N (blue), and organic-N in the monitored rivers. The organic-N fraction was calculated as the difference between tot-N and the two inorganic fractions (ammonium-N and nitrate-N).

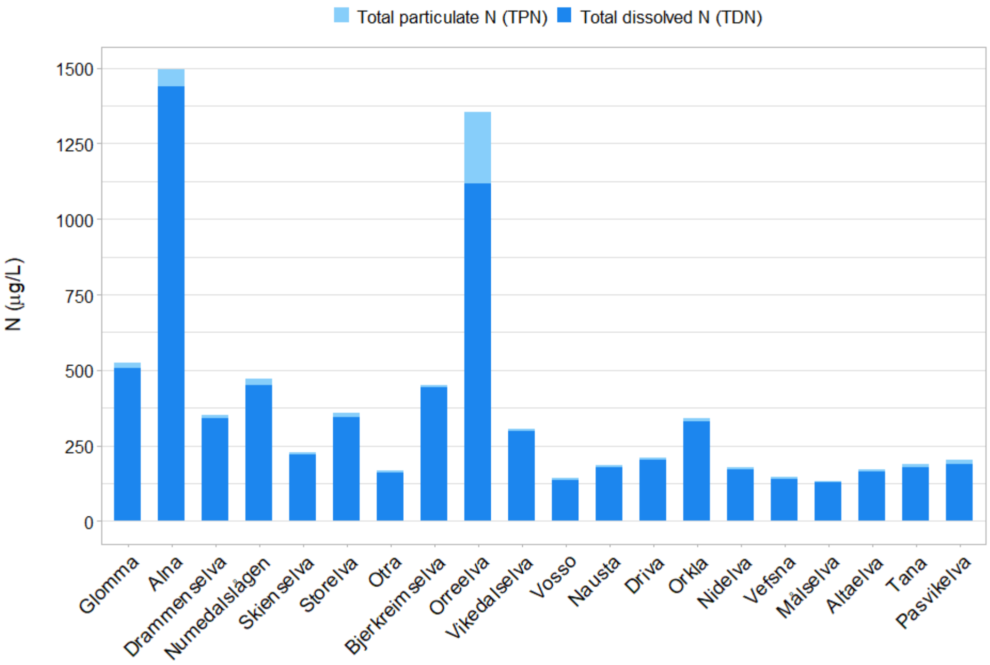

Figure 19: Distribution of the 2018 average concentration of total particulate-N (TPN, light blue) and dissolved-N (TDN, dark blue) in the monitored rivers. The TPN was calculated as the difference between tot-N and TDN.

3.2.5 Metals

Metals in surface waters are mainly associated with human activities such as mining operations, industry, urban areas. Natural sources such as weathering of bedrock typically constitutes minor contributions. Most metals are not readily soluble in typical Norwegian downstream surface waters (close to neutral pH). However, when bound to particles or dissolved organic matter the metal concentration in waters can be elevated.

The samples analysed for metals were unfiltered, meaning that the results cannot be assessed directly against the WFD environmental quality standards for priority substances and river basin-specific pollutants in freshwater, which requires analyses of filtered samples (Direktoratsgruppen 2018). Given that unfiltered samples often have higher concentrations (dissolved + particulate fractions) it implies that it is possible to state if the annual mean concentrations are below – but not above - the threshold concentrations. Unfiltered samples were analysed to capture the total metal export to the oceans, in accordance with OSPAR RID. Moreover, by analysing unfiltered samples the recent data can be compared with the long trend series that have been obtained on unfiltered samples, to look e.g. for effects from climate change. Note that results from unfiltered samples analysed for arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc are presented in one of the other 2018 reports from the River monitoring programme: “Priority substances and emerging contaminants in selected Norwegian rivers” 2018 (M-1509).

Table 13: Threshold concentrations for metals in Norwegian surface waters (annual averages, filtered samples) (Direktoratsgruppen 2018)

Metal	As	Pb	Cd	Cu	Zn	Cr	Ni	Hg
Limit (µg L^{-1})	0.5	1.2	0.08[2]	7.8	11	3.4	4	0.047

Note that the annual mean values for 2018 (and 2017) were based on quarterly samples, whereas the 5-year mean for eleven of the rivers (“main rivers” from the previous RID programme, Table 1) includes years with monthly samples (2013-2016). In general, less frequent sampling is associated with higher uncertainty.

Arsenic (As)

River Alna had the highest mean arsenic (As) concentration in 2018 (0.35 µg L^{-1}), followed by Rivers Pasvikelva, Orreelva, and Storelva (~0.3 µg L^{-1}). The remaining rivers were all below 0.2 µg L^{-1}(Figure 20). The elevated As levels in Alna and Orreelva can be explained by the high local anthropogenic influence on these rivers. River Pasvik is likely influenced by pollution from the large metallurgical complex (Nornickel, Russia) located in close vicinity to the river. In fact, elevated levels of arsenic and other heavy metals (nickel, copper, and cobolt) have been measured in the air close to the Pasvik river (Berglen et al., 2019). Higher metal concentrations in River Storelva may be linked to former mining and smelting industries within the catchment. Transport of metals to the surface waters may also to a larger extent be facilitated by dissolved organic matter in this river, given the relatively high content of dissolved organic carbon (5.2 mg C L^{-1}). All of the average annual As concentrations were below the threshold level (Table 13), but individual measurements form Alna and Pasvikelva were at (0.5 µg L^{-1}) or above (0.8 µg L^{-1}) the threshold, respectively. Given the relatively high particle content in River Alna, the dissolved fraction of As is likely to be low. For River Pasvikelva, on the other hand, the particle

---

[2] For water with calcium concentration < 16 mg/l. In more alkaline waters, the threshold value is higher (cf. Direktoratsgruppen 2018)

content was low and thus the occasionally high As concentration gives more reason for concern. The 2018 average levels were similar to the 5-year means for all rivers, except for River Vikedalselva which was 40% lower in 2018 compared to the 5-year mean.

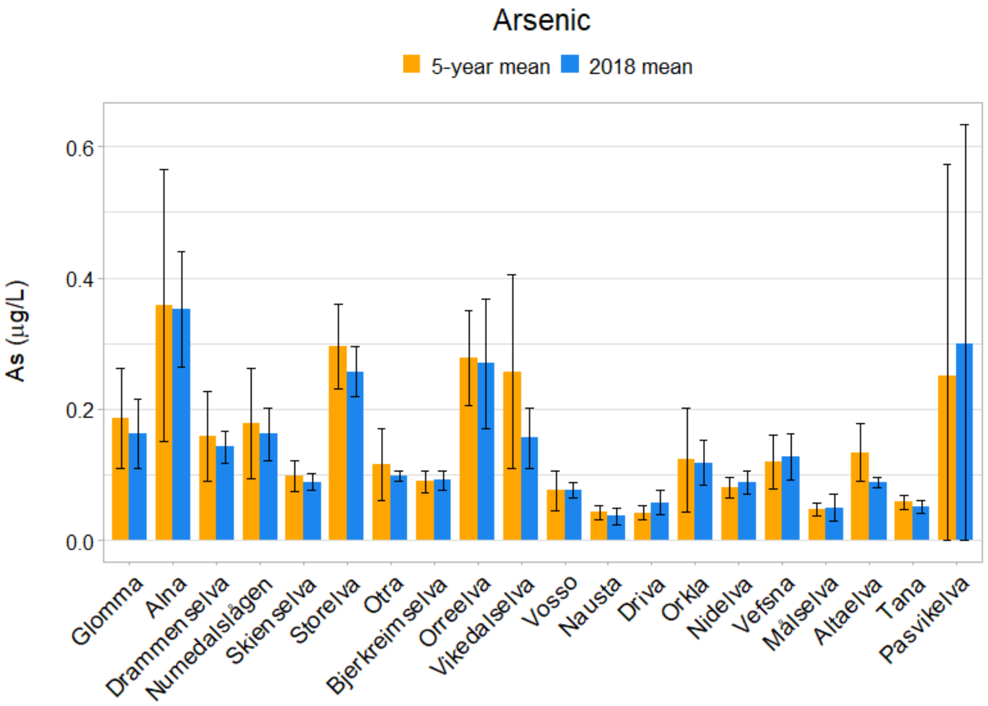

Figure 20: Average annual concentration of arsenic for the five preceding years (2013-2017, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate annual variation for the 5-year mean (± stdev) and monthly variation for the 2018 mean (± stdev).

Lead (Pb)

Riverine lead (Pb) concentrations showed a geographical pattern with higher levels in the southern and eastern parts, and then decreasing levels towards the west and north (Figure 21). Interestingly, the 2018 levels of Pb were generally lower than the 5-year means, and especially for the high-Pb rivers such as Alna, Drammenselva, and Storelva. Lead, like other metals is typically transported with particles. The pattern of declining lead could be an artefact from the less frequent measurements conducted in 2018 (and 2017) compared to the previous years (from annual to quarterly). With less frequent measurements, pulses of elevated lead concentrations, caused by an increased particle content, might have been missed. In fact, for River Drammenselva (with a potential 87% decline in Pb), the quarterly measurements missed two of the highest monthly SPM concentration and several of the medium SPM containing samples (data not shown). River Pasvikelva was higher in Pb than the other northern rivers (0.12 µg L^{-1}), which was likely due to the close proximity to the metallurgical complex on the Russian side of the border. In 2018, none of the rivers showed Pb levels exceeding the threshold concentration (1.2 µg L^{-1}, Table 13).

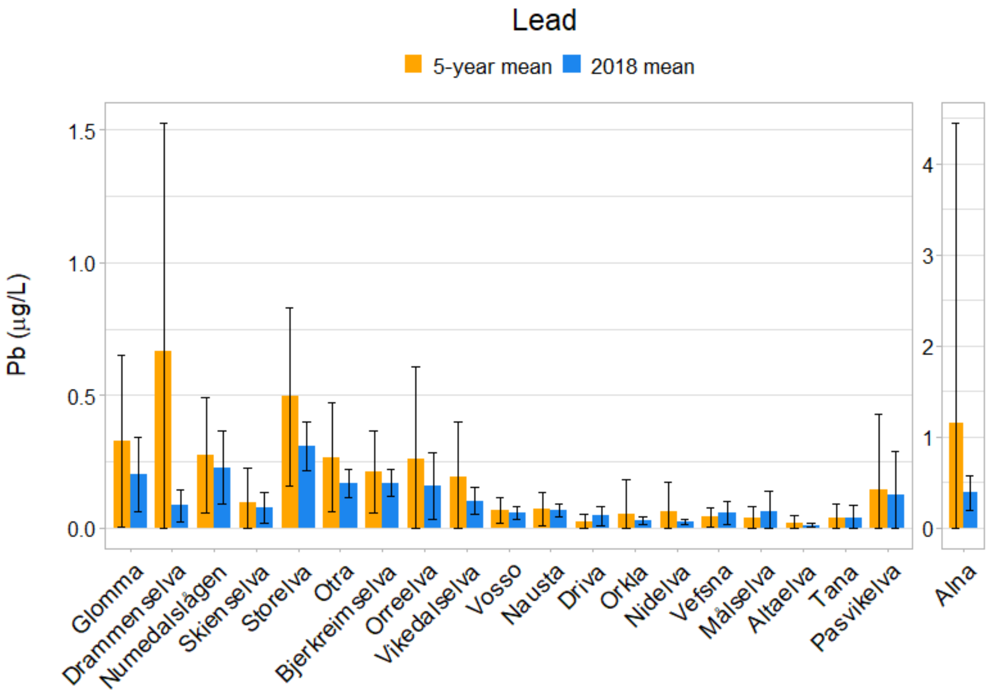

Figure 21: Average annual concentration of lead for the five preceding years (2013-2017, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate annual variation for the 5-year mean (± stdev) and monthly variation for the 2018 mean (± stdev).

Cadmium (Cd)

River Orkla had the highest annual cadmium (Cd) concentrations (0.036 µg L^{-1}, Figure 22), which was likely resulting from water discharge from an abandoned copper mine in the catchment. Rivers Alna and Storelva were also relatively high in Cd (0.032 µg L^{-1}). Notably, the Cd level in Alna was in 2018 only around 50% of the 5-year mean. Among the northern rivers, Pasvikelva had elevated Cd (0.023 µg L^{-1}), again likely due to airborne pollution from the industry on the Russian side of the border. The remaining rivers were all low in Cd (< 0.02 µg L^{-1}) and with levels similar to the previous years. During 2018 all measurements of Cd concentrations were below the threshold concentration (0.08 µg L^{-1}, Table 13).

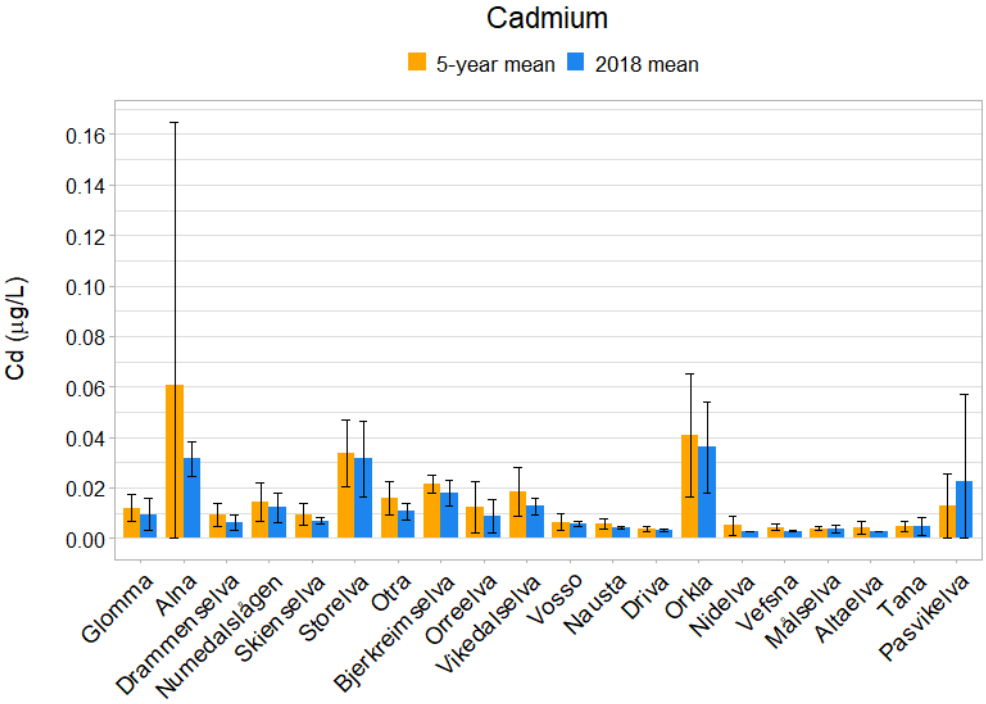

Figure 22: Average annual concentration of cadmium for the five preceding years (2013-2017, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate annual variation for the 5-year mean (± stdev) and monthly variation for the 2018 mean (± stdev).

Copper (Cu)

The highest annual average copper (Cu) concentration in 2018 was found in the northern river Pasvikelva (10.6 µg L^{-1}, Figure 23). Considering the low content of SPM and TOC in this river, it can be hypothesized that a large fraction of this reside in the dissolved form, and thereby likely exceeding the threshold level (7.8 µg L^{-1}, Table 13). Moreover, the 2018 annual average in River Pasvikelva was approximately 60% higher than the 5-year mean. The high level was likely caused by air-pollution from the metallurgical complex located in close vicinity on the Russian side of the border. River Orkla had the second highest Cu concentration (4.9 µg L^{-1}), followed by Alna, Orreelva, and Glomma, and all with levels below the threshold concentration. The elevated level in River Orkla can result from the abandoned copper mine in the area. Notably, in River Alna, the concentration in 2018 was around 30% lower than the 5-year mean.

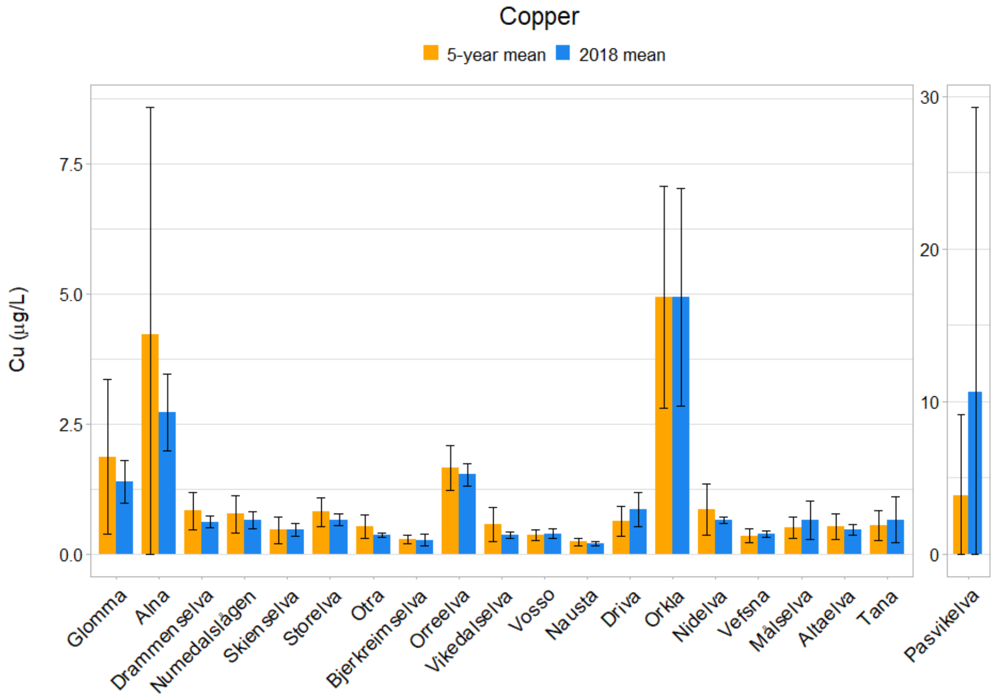

Figure 23: Average annual concentration of copper for the five preceding years (2013-2017, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate annual variation for the 5-year mean (± stdev) and monthly variation for the 2018 mean (± stdev). Note the different y-scale range on the right-side panel.

Zinc (Zn)

The highest average zinc (Zn) concentration in 2018 was found in River Orkla (11 µg L^{-1}, Figure 24). Considering that some of the Zn will be bound to particulate material, the dissolved concentration of Zn is likely to be below the threshold value (11 µg L^{-1}, Table 13). The elevated Zn may be explained by water discharge from old mine tailings in the area. River Alna also showed high individual Zn measurements, also likely associated with the high particle content of this river. The three rivers with the highest 5-year mean, Alna, Orkla, and Glomma, were all much lower in 2018 (River Glomma was only 30% of the 5-year mean). The reason for this is likely due to the reduced sampling frequency in 2018 (and 2017) compared to the previous years, as already discussed for lead. Metals are typically transported with particles, and particles generally show a high monthly variation. For example, for River Glomma, among the monthly samples analysed for particle content, four of the five highest particle samples were not analysed for zinc. Moreover, among the four samples analysed both for particle and zinc concentration there was a tendency of correlating variation (data not shown).

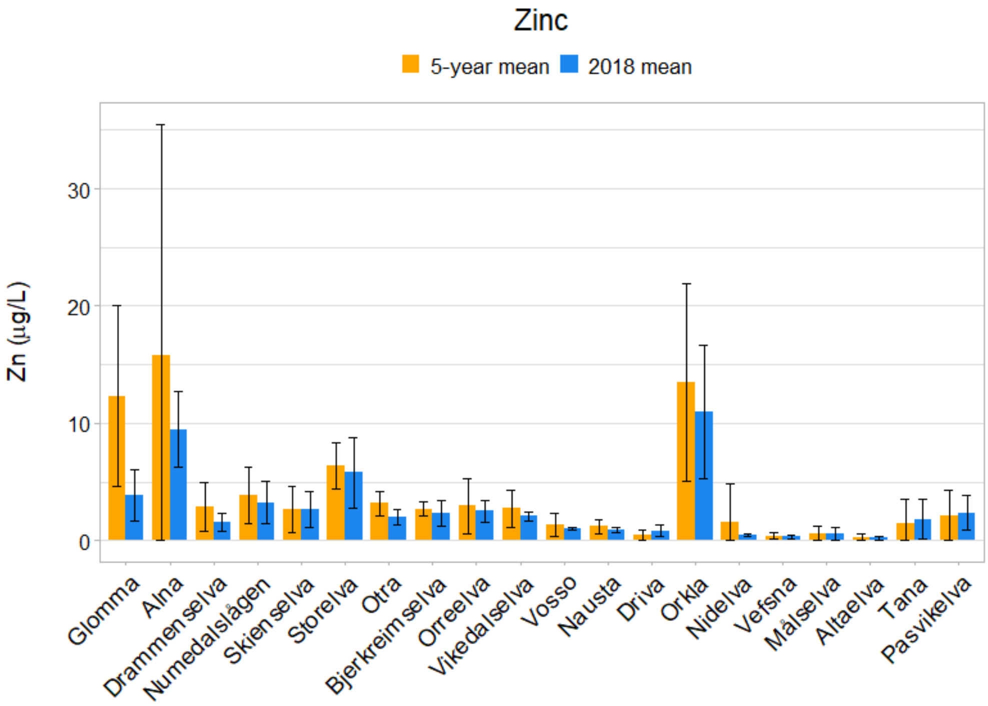

Figure 24: Average annual concentration of zinc for the five preceding years (2013-2017, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate annual variation for the 5-year mean (± stdev) and monthly variation for the 2018 mean (± stdev).

Chromium (Cr)

The average riverine chromium (Cr) concentrations for 2018 (Figure 25) were all low (< 0.4 µg L^{-1}) and well below the threshold concentration (3.4 µg L^{-1}, Table 13). The highest annual Cr was found in River Alna (0.39 µg L^{-1}), followed by Rivers Orkla (0.24 µg L^{-1}), and Glomma (0.22 µg L^{-1}). For a few of the rivers the 2018 mean was lower than the 5-year mean, and with the largest difference for Alna, where the 2018 mean was less than 50% of the 5-year mean.

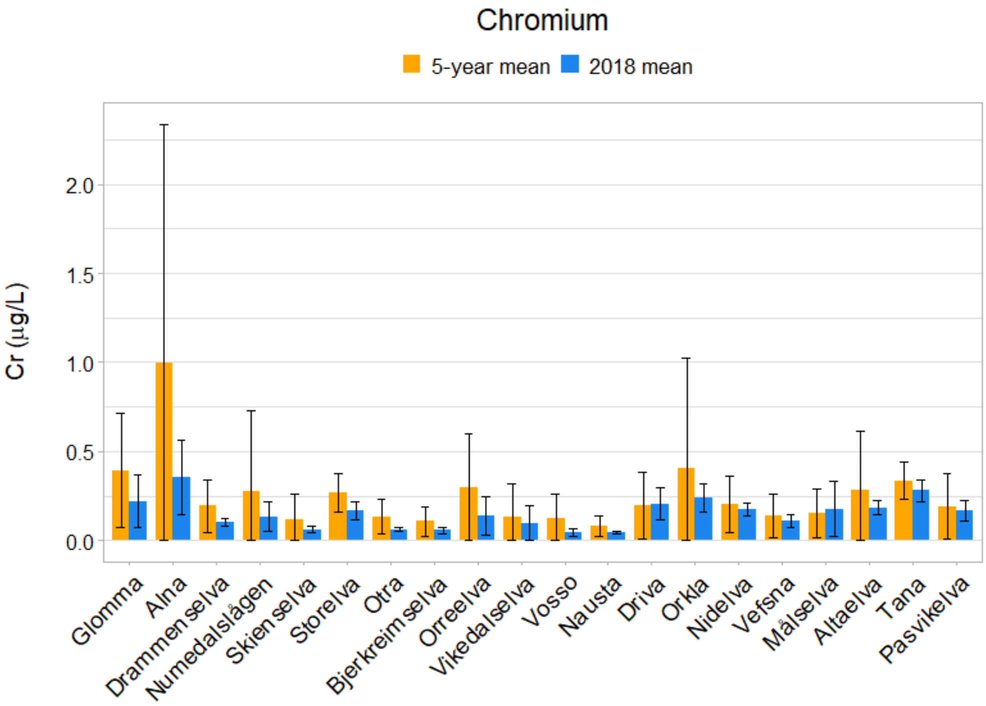

Figure 25: Average annual concentration of chromium for the five preceding years (2013-2017, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate annual variation for the 5-year mean (± stdev) and monthly variation for the 2018 mean (± stdev).

Nickel (Ni)

River Pasvikelva stands out with the highest nickel (Ni) concentrations, with an annual mean at 11.3 µg L^{-1} (Figure 26). Moreover, the 2018 average was 30% higher than the 5-year mean. Since this river had low SPM and TOC concentrations, it is likely that the threshold concentration (4 µg L^{-1}, Table 13) was exceeded in this river. The nickel contamination in Pasvikelva results from heavy influence from the Norilsk nickel plant, which is located a few kilometres away on the Russian side of the border. There was large variation in the Ni concentration in River Pasvikelva throughout the year, ranging from 0.4 to 35.4 µg L^{-1}, which can be associated with varying industrial activity and potentially changing winds. Water discharge was not found to explain the large variation in nickel since the low discharge during the four months of 2018 (42 – 53 mm y^{-1}) coincided both with the *second lowest* (1.29 µg L^{-1}) and the *highest* (35.4 µg L^{-1}) nickel concentrations measured. Among the other rivers, annual concentrations were well below the threshold values. The highest concentrations were found in Orreelva (1.0 µg L^{-1}), and followed by Orkla, Alna, Nidelva, and Glomma.

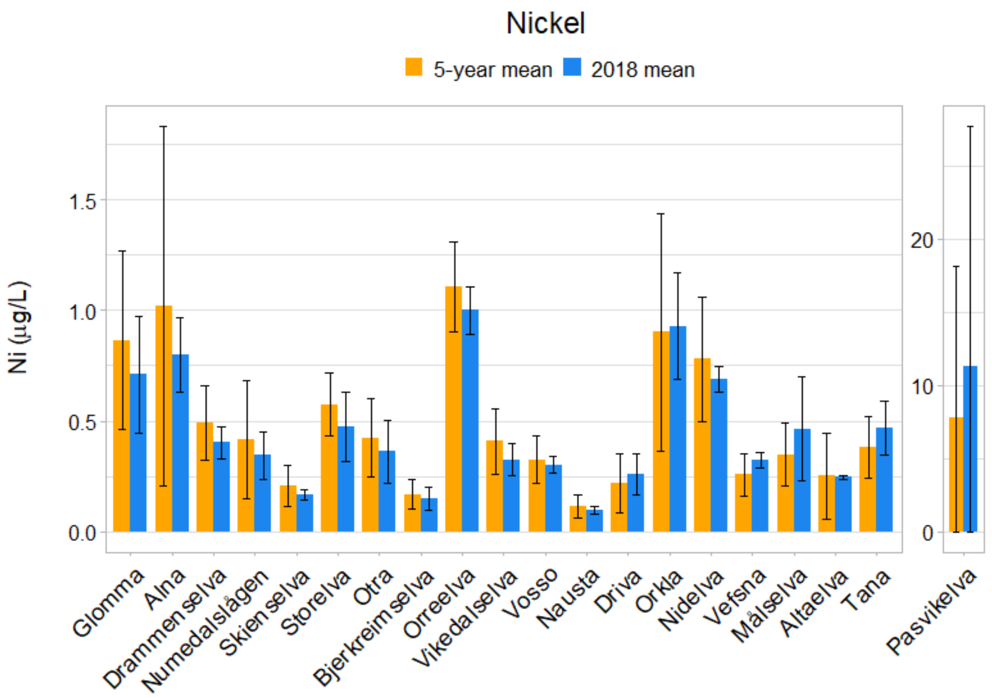

Figure 26: Average annual concentration of nickel for the five preceding years (2013-2017, orange) and average for 2018 (blue) for the monitored rivers. Error bars illustrate annual variation for the 5-year mean (± stdev) and monthly variation for the 2018 mean (± stdev). Note the different y-scale range on the right-side panel.

Mercury (Hg)

Mercury (Hg) is very toxic, has high potential for bioaccumulation, and has correspondingly the lowest threshold level among the metals (0.047 µg L^{-1}, Table 13). Hg levels in Norwegian rivers are naturally low and close to the LOQ of the analytical method currently used, at 1 ng L^{-1} (1 * 10^{-3} µg L^{-1}). This makes quantifying Hg challenging and almost impossible some places. Out of 79 analysed samples in 2018 (~4 from each river), 70 had Hg concentrations below the LOQ (1 ng L^{-1}). Nine of the rivers (Alta, Orreelva, Vosso, Bjerkreimselva, Målselva, Vegårdselva, and Alnaelva) had Hg levels at or slightly above the LOQ for one or two out of the four annual samples. Data from the past five years are correspondingly incomplete and associated with large uncertainties. See Braaten et al. (2018) for more info on this.

Although the riverine levels are below the threshold concentration, as expected, bioaccumulation can cause Hg levels in fish to accumulate. At several sites in the country the Hg level in fish (both freshwater and marine) exceeds the recommended dietary intake. Starting from 2019, a new method for determination of Hg, with a lower LOQ (0.2 ng L^{-1}), will be employed in the river monitoring programme 2019.

3.3 Additonal Rivers - Water quality status 2018

The water chemistry from ten additional rivers have been included to compliment the picture established by the 20 main river of the programme. The additional rivers have been the focus in other parts of the monitoring programme; six rivers from the National monitoring program for limed rivers (Kalkningsovervåkningen) and four rivers from the 2018 classification of ecological and chemical status (Opsjon 3). The samples from the latter program has been analysed at a different lab (Vestfold lab) than the other samples (NIVA lab). Since these rivers have not been routinely monitored with fully matched parameter lists there exist no complete 5-year means for comparison. The rivers from the National monitoring program for limed rivers are from the south- and southwestern Norway while the three other rivers are from the mid- to north of Norway (Figure 2).

3.3.1 pH and calcium

The lowest average pH was observed for River Sira in the south of Norway (pH 5.7). The other rivers in southern Norway all had pH above 6, and further north (Rivers Namsen and Saltdalselva) it was neutral or just above (Figure 27, top panel). This was in accordance with the geographical distribution of pH in the 20 rivers of the regular monitoring programme. In correspondence with the pH, the riverine concentrations of calcium were very low (< 1 mg L^{-1}), in Rivers Suldalslågen and Sira, low (1-4 mg L^{-1}) in most rivers, and moderate (4-20 mg L^{-1}) in River Saltdalselva (Figure 27, bottom panel), according to the Norwegian typology for classification under the WFD.

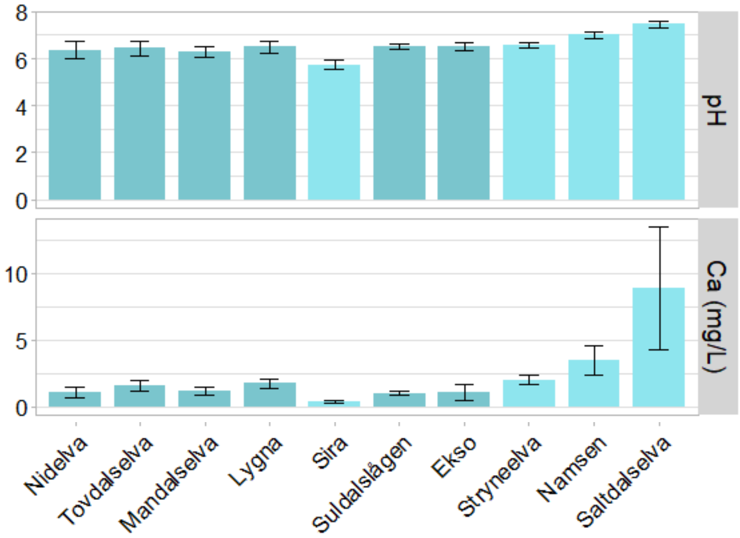

Figure 27: Average pH (top) and calcium concentration (bottom) for 2018 for the ten additional rivers included from the National monitoring program for limed rivers programme (dark turquoise) and the 2018 classification of ecological and chemical status (light turquoise). Error bars illustrate interannual variability (± stdev). Mean values and standard deviation are based on pH values, not the H^+ concentration. This represents a negligible error when pH values are above 6.0.

3.3.2 Suspended matter, (turbidity, SPM, and silica)

Suspended particulate matter (SPM) concentration was measured in all the additional rivers, whereas only samples from the seven rivers from the National monitoring program for limed rivers were analysed for turbidity (Figure 28). All rivers from southern and south-western Norway were low in SPM (≤ 1 mg L^{-1}). The turbidity of the southern rivers was correspondingly low (≤ 1 FNU). Higher SPM concentration was found in the two rivers from the middle of the country, Namsen (12 mg L^{-1}) and Saltdalselva (6 mg L^{-1}). For silica, the geographical pattern was similar to that of the 20 rivers in the regular monitoring (Figure 28, lower panel): lowest concentrations in the west (< 1 mg L^{-1}), medium levels in the south (1 – 2 mg L^{-1}) , and highest levels when moving towards the north (2 - 3 mg L^{-1}).

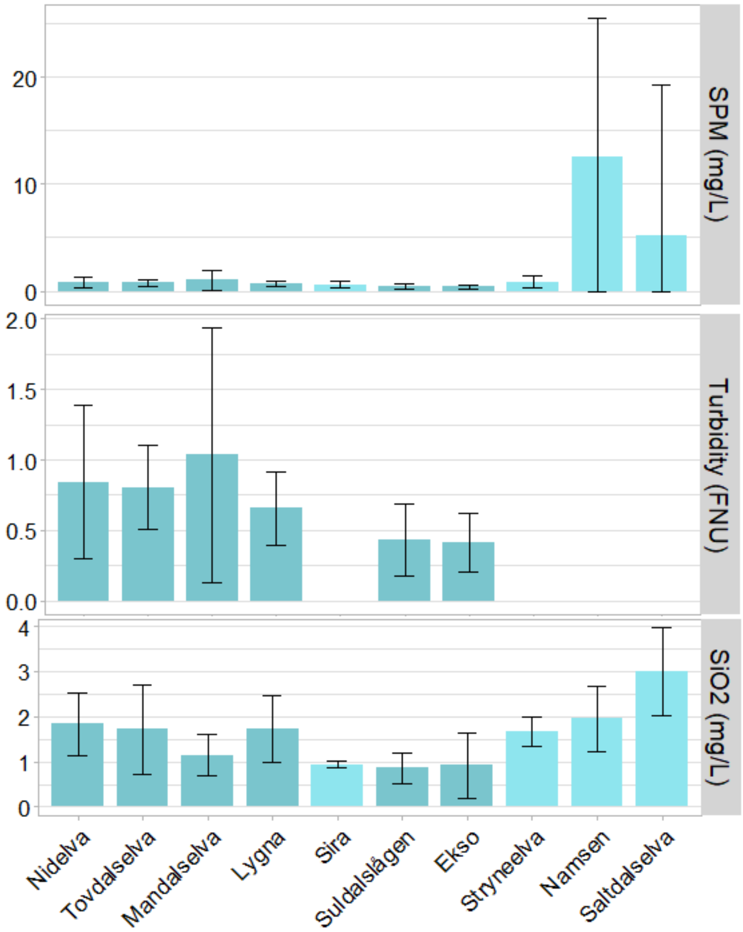

Figure 28: Average suspended particulate matter concentration (SPM, top), turbidity (middle), and silica concentration (bottom) for 2018 for the ten additional rivers included from the National monitoring program for limed rivers (dark turquoise) and the 2018 classification of ecological and chemical status (light turquoise). Error bars illustrate interannual variability (± stdev).

3.3.3 Organic carbon

All the additional rivers have been analysed for TOC concentration whereas only the seven rivers from the National monitoring program for limed rivers have been analysed for the dissolved and particulate organic carbon fractions. Based on the annual average concentration of TOC (Figure 29), Rivers Tovdalselva and Mandalselva were categorized as humic (> 5 mg L^{-1}), Rivers Ekso, Namsen, Lygna, and Nidelva as clear (2 mg L^{-1} > TOC < 5 mg L^{-1}), and Rivers Sira, Suldalslågen, Stryneelva, and Saltdalselva were categorized as very clear (< 2 mg L^{-1}) according to the Norwegian WFD typology. In all rivers analysed for particulate and dissolved organic carbon, the dissolved fraction was the dominant (Figure 30), but with a significant fraction of particulate in most rivers. This contrasted with the 20 rivers in the regular programme, where the particulate fraction was negligible in most cases. The reason for this is not known.

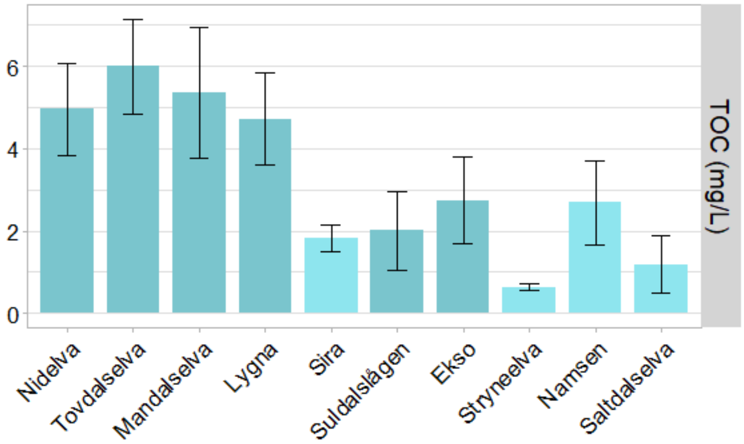

Figure 29: Average total organic carbon (TOC) concentration for 2018 for the ten additional rivers included from the National monitoring program for limed rivers (dark turquoise) and the 2018 classification of ecological and chemical status (light turquoise). Error bars illustrate interannual variability (± stdev).

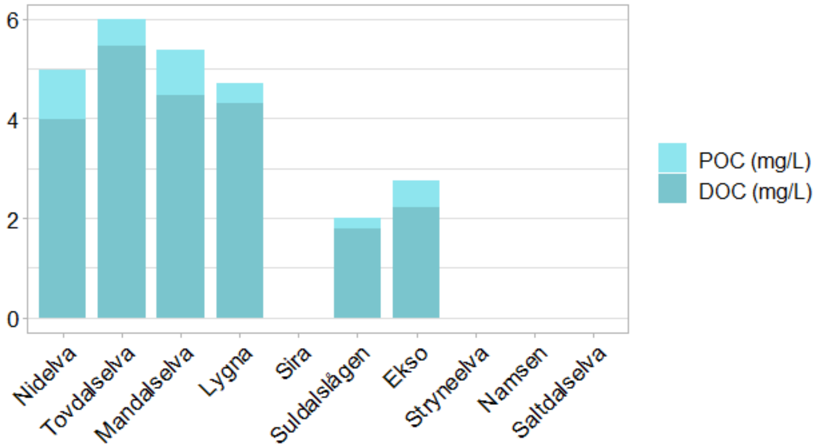

Figure 30: Average 2018 distribution of particulate (POC, light turquoise)- and dissolved organic carbon (DOC, dark turquoise) for the six additional rivers included from the National monitoring program for limed rivers (dark turquoise). Any deviation from the TOC in Figure 29 result from analytical uncertainties in the individual methods used to determine POC and DOC.

3.3.4 Nutrients

Total phosphorus (tot-P) concentrations were relatively low for most of the additional rivers (< 6.5 µg L^{-1}), except for River Namsen, with somewhat higher average concentration in 2018 (14 µg L^{-1}, Figure 31, top panel). River Namsen is impacted by agricultural activities, and the phosphorus was likely associated with the relatively high SPM concentration in this river. For total nitrogen (tot-N, Figure 31 lower panel) the picture looks different, with the highest levels in the southern rivers (Nidelva, Tovdalselva, Mandalselva, Lygna, and Sira, 224 - 428 µg L^{-1}). This is likely a result of atmospheric deposition, from which the southern and western rivers have been and are most severely impacted. The high variability in tot-N concentration in River Nidelva was due to a sudden increase during July; about ten times higher than what was measured in the other months. Looking into the distribution of the various nitrogen fractions, it was apparent that the high tot-N value was caused by an increase in ammonium-N (2000 µg L^{-1}). Ammonium-N is typically low in Norwegian rivers, and the sudden increase could have resulted from manure application or a spill. For the remaining rivers, the distribution of the various N-fractions was in accordance with what was seen for the 20 rivers in the regular programme: dominated by nitrate-N, followed by organic-N, and with low levels of ammonium-N (Figure 32).

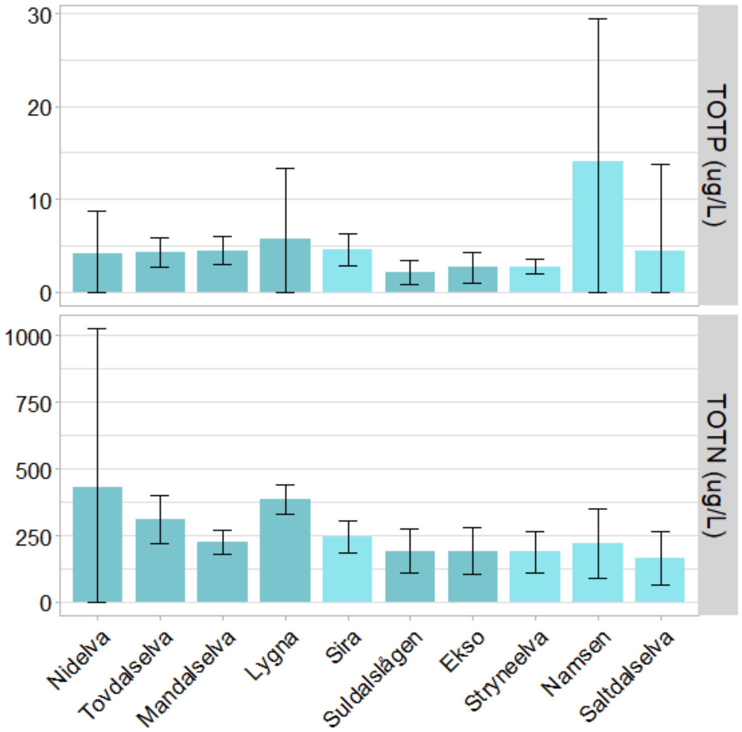

Figure 31: Average 2018 concentration of top: total phosphorus (TOTP/tot-P) and bottom: total nitrogen (TOTN/tot-N) for the ten additional rivers included from the National monitoring program for limed rivers (dark turquoise) and the 2018 classification of chemical and biological status (light turquoise). Error bars illustrate monthly variation (± stdev).

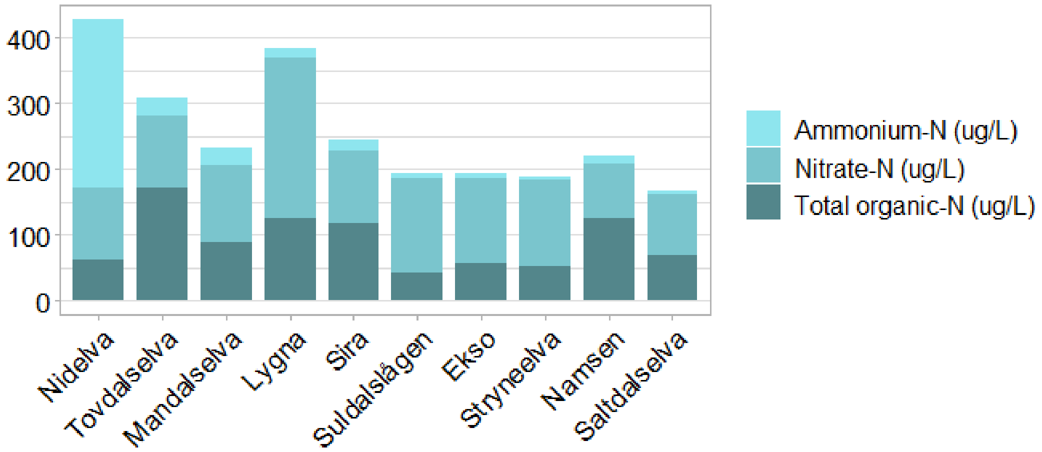

Figure 32: Average 2018 distribution of the following nitrogen fractions: ammonium-N (light turquoise), nitrate-N (medium turquoise), and total organic-N (dark turquoise) for the ten additional rivers included from the National monitoring program for limed rivers and the 2018 classification of chemical and biological status.

3.3.5 Metals

Metals was only measured in the six rivers from the National monitoring program for limed rivers. These analyses were conducted by another laboratory (Vestfold lab), at which the LOQs of the methods were higher than at the NIVA lab. Thus, for several of the rivers, many of the metals were not detected (Table 7). Annual average levels of Cd, Zn, and Cr are presented in Table 14. For Cd, the average level in Nidelva was at the threshold concentration (0.08 µg L^{-1}). However, when considering the contribution from SPM the concentration of dissolved Cd was likely below the threshold. For Zn, some relatively high concentrations were found in Tovdalselva, Mandalselva, and Lygna (> 10 µg L^{-1}). In comparison, these were levels similar to those found in the two rivers Alna and Orreelva, heavy influenced by human activities. The reason for the high Zn is not known. As reported in an earlier report (Skarbøvik *et al.* 2016) for many of the examined rivers, the zinc loads show relatively low inter-annual variability compared with many of the other metals. Levels of Cr were generally low for all rivers (≤ 0.36 µg L^{-1}).

Table 14. 2018 average metal concentrations ± stdev for additional rivers.

River	Cd	Zn	Cr
Nidelva	0.08 ± 0.1	8.28 ± 5.6	0.25 ± 0.2
Tovdalselva	0.03 ± 0.02	14.3 ± 19.3	0.36 ± 0.3
Mandalselva	0.02 ± 0.01	13.6 ± 20.1	0.19 ± 0.08
Lygna	0.03 ± 0.02	9.16 ± 10.6	0.2 ± 0.2
Suldalslågen	0.02 ± 0.01	3.77 ± 2.4	0.18 ± 0.1
Ekso	0.03 ± 0.02	6.98 ± 10.8	0.2 ± 0.2

3.4 Trends in riverine loads and concentrations

The trend analyses have been conducted for both loads (riverine transport of dissolved and particulate matter per unit of time) and concentrations. Loads are important for assessing transport to coastal waters, whereas concentrations will give an indication of the water quality. By evaluating the trends in loads and concentrations together with those in water discharge, it can be possible to reveal whether the trends in loads are related to changes in the emissions of the chemical substance or in the water discharge.

3.4.1 Long-term trends (1990-2018) in loads and concentrations of SPM, silica, TOC, and nutrients

The results (p-values) from the long-term trend analysis (1990-2018) of loads and concentrations of SPM, silica, TOC, and nutrients are presented in Table 15 and Table 16, respectively. Trends in water discharge (Q) have also been included for comparison, while these results were discussed in Chapter 3.1.4. Note that for TOC, the trends for certain rivers represent a shorter time period (1999 – 2018), due to limited observations during the early 1990's. Only trends of significance ($p < 0.05$) will be discussed.

Suspended materials (SPM and silica) and TOC

In River Drammenselva, there were increasing loads of SPM, silica, and TOC (Figure 33), likely driven by the increase in water discharge (Figure 33 and Table 15). An elevated export of particulate and suspended material to the marine waters can have a negative impact on the ecology in these systems (McGovern et al., 2019). Particles can influence light penetration and can also transport nutrients and pollutants. Silica and organic matter (measured as TOC) constitute the main nutrient and carbon substrates for the diatoms and heterotrophs, respectively, and can thereby affect the foodweb structure.

Among the other rivers, decreasing trends in SPM were found for the load in Vefsna and for the concentration for several other rivers (Skienselva, Otra, Orkla, Vefsna, and Altaelva). On the contrary, several rivers (Numedalslågen, Skienselva, and Orreelva), in addition to Drammenselva, were increasing in both loads and concentrations of silica (except Orreelva). Interestingly, in Rivers Skiensela and Orkla, the concentrations of SPM and silica showed opposite trends, implying that different processes govern the transport of these materials to the rivers. With regard to TOC, the only significant trend in 2018 was the increasing load in River Drammenselva (Figure 33). In recent years, there has been documented increasing concentrations of TOC and colour in southern Scandinavian and North American surface waters ("browning effect") (Monteith *et al.* 2007). This has been attributed to the combination of reduced acid deposition and climate change (de Wit *et al.* 2007, de Wit *et al.* 2016). There are several factors likely explaining the lack of observed browning in the monitored rivers. In Norway, the largest effect of browning is in the south- and south-eastern part of the country. For a few of the rivers in this region, e.g. Glomma and Otra, a potential increase in TOC can be masked by other factors influencing the hydrology, such as glacier dynamics and hydropower activities, respectively. Moreover, the largest increase in TOC due to the reduction in acid rain was observed before the year 2000. In this year's report the start of the TOC trend analysis was set to 1999 for several of the rivers (Numedalslågen, Orreelva, Vefsna, and Altaelva), due to limited data from the early 1990s, and thereby missing data from the most increasing years. In general, trend analyses will be influenced by extreme observations, and especially when occurring towards the beginning or end of a time series. The year 2000 was extreme in certain regions of Norway for having very high precipitation, resulting in high water discharge and correspondingly high TOC levels (see Figure 33 for example from Drammenselva). For those rivers starting the TOC trend analysis with 1999, the extreme year of 2000 will likely influence the trend analysis results.

In comparison with the trend analyses in the previous report, the following changes were observed when including the 2018 data: i) loads of SPM and silica were no longer significantly increasing in Rivers Numedalslågen and Glomma, respectively, ii) SPM concentrations were no longer decreasing in River Skienselva, and iii) silica concentrations were no longer increasing in Rivers Glomma and Orkla. With regards to TOC, several of the rivers had no longer a significant increase in TOC concentration and/or load after excluding the years of very few measurements from 1990 to 1999.

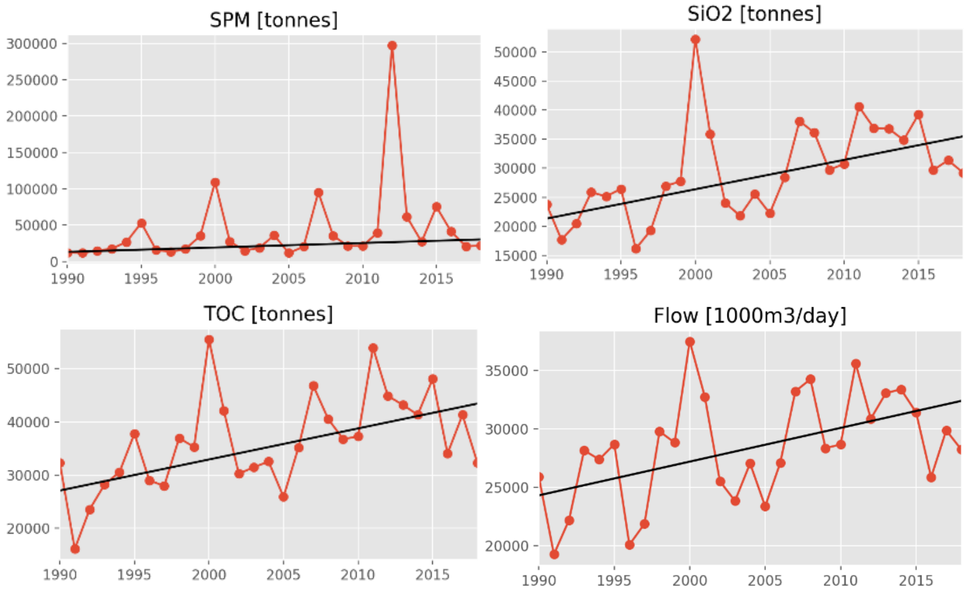

Figure 33: For River Drammenselva loads of, top left: Suspended particulate matter (SPM), top right: silica (SiO_2), and bottom left: total organic carbon (TOC), and bottom right: water discharge (flow) from 1990 to 2018. Sen's slope estimates in black line.

Nutrients (phosphorus and nitrogen)

For the south-eastern rivers Drammenselva and Numedalslågen, there was an increasing trend in loads of both tot-P and tot-N while no trends were apparent in the corresponding concentrations. For River Drammenselva this could be explained by increased water discharge, while the cause in Numedalslågen is not known. The increase in tot-P was attributed to the increasing phosphate (PO_4) and could also have been caused by an increase in organic-P and/or particulate-P which have not been part of the long-term data. For tot-N the increase was linked to an increase in the organic-bound N, and with the reason being that neither nitrate nor ammonia showed any increase during the time period. In fact, both nitrate and ammonia showed decreasing trends in loads and/or concentrations in several of the rivers (See Figures 34 and 35 for time series for Rivers Skienselva and Vefsna). Ammonia is normally quickly assimilated by plants or converted to nitrate by microbes, and nitrate is also readily available for plants. The reduced levels could result from increased biological activity, reduced atmospheric N-deposition, and/or, in some rivers, by increased water discharge (causing dilution). Note that for River Vefsna there have been decreasing trends in both loads and concentrations of all nutrient fractions, as well as SPM. The reasons for the many decreasing trends observed here are not known. However, the most significant sources of nutrients include agriculture, wastewater, sewage emissions from scattered dwellings and mineralisation. In general, there has been a huge effort to implement measures aimed towards minimising nutrient losses from agriculture and sewage in the last decades. In addition, there have been reductions in atmospheric deposition of long-range transported nitrogen compounds since 1990 (Garmo and Skancke, 2019).

The trends in loads of nutrients were the same when including 2018 in the analysis, but the trends in concentrations differed as follows: i) tot-P was no longer increasing in River Numedalslågen, ii) phosphate was no longer increasing in Rivers Drammenselva, Skienselva, and Orreelva, while it was now decreasing in River Altaelva, iii) tot-N was no longer increasing in River Numdalslågen, and iv) nitrate was now decreasing in River Drammenselva, but no longer in Rivers Orreelva and Altaelva.

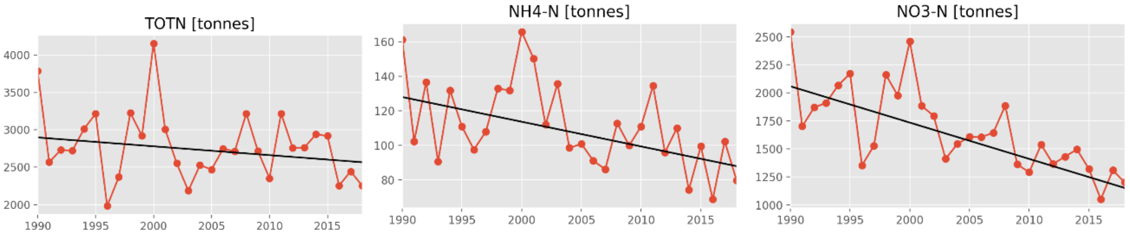

Figure 34: Long-term trends in loads of total nitrogen (TOTN/tot-N), ammonia (NH_4-N), and nitrate (NO_3-N) for river Skienselva from 1990 to 2018, and with respective Sen’s slope estimates (black line).

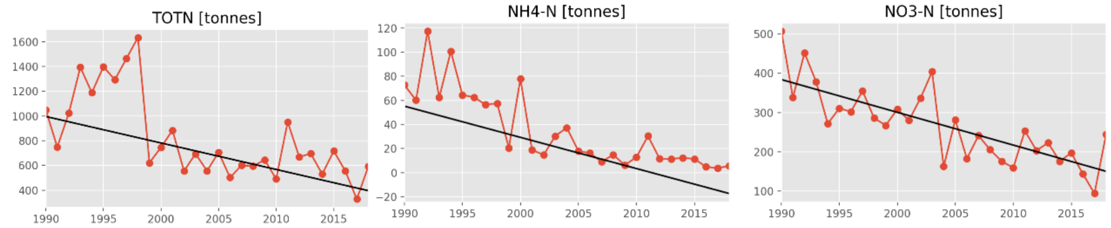

Figure 35: Long-term trends in loads of total nitrogen (TOTN/tot-N), ammonia (NH_4-N), and nitrate (NO_3-N) for river Vefsna from 1990 to 2018, and with respective Sen’s slope estimates (black line).

Table 15. Long-term trends (1990-2018) in water discharge (Q) and loads (transport) of suspended particulate matter (SPM), silica (SiO_2), total organic carbon (TOC), total phosphorus (tot-P), and phosphate (PO_4), total nitrogen (Tot-N), ammonium (NH_4), nitrate (NO_3), in rivers. p-values are shown.

River	Q	SPM	SiO_2	TOC*	Tot-P	PO_4	Tot-N	NH_4	NO_3
Glomma	0.049	0.536	0.063	0.159	0.722	0.041	0.023	0.000	0.149
Drammenselva	0.013	0.006	0.001	0.003	0.003	0.003	0.031	0.004	0.129
Numedalslågen	0.129	0.063	0.002	1.00*	0.014	0.007	0.004	0.053	0.223
Skienselva	0.049	0.985	0.003	0.538*	0.237	0.398	0.268	0.010	0.000
Otra	0.268	0.253	0.302	0.561	0.536	0.209	0.561	0.103	0.000
Orreelva	0.063	0.095	0.045	0.820*	0.075	0.088	0.666	0.253	0.488
Orkla	0.420	1.00	0.837	0.320	0.511	0.807	0.896	0.000	0.837
Vefsna	0.320	0.007	0.196	0.721*	0.0002	0.002	0.001	0.000	3.6e-6
Altaelva	0.302	0.955	0.866	0.347*	0.268	0.378	0.985	0.119	0.442

Red – significantly increasing $p<0.05$, green – significantly decreasing $p<0.05$

*Trend analysis started in 1999 due to limited data in the period from 1990

Table 16. Long-term trends (1990-2018) in concentrations of suspended particulate matter (SPM), silicate (SiO_2), total organic carbon (TOC), total nitrogen (Tot-N), ammonium (NH_4), nitrate (NO_3), total phosphorus (tot-P), and phosphate (PO_4) in rivers. p-values are shown.

River	SPM	SiO_2	TOC*	Tot-P	PO_4	Tot-N	NH_4	NO_3
Glomma	0.084	0.096	0.828	0.940	🟥 0.001	0.970	🟩 0.000	0.189
Drammenselva	0.252	🟥 0.027	0.259	0.701	0.124	0.866	🟩 0.001	🟩 0.008
Numedalslågen	0.091	🟥 0.005	0.974*	0.278	0.057	0.084	0.835	0.881
Skienselva	🟩 0.028	🟥 0.008	0.323*	0.812	0.204	🟩 0.000	🟩 0.003	🟩 0.000
Otra	🟩 0.004	0.691	0.937	🟩 0.003	0.563	🟩 0.009	🟩 0.019	🟩 0.000
Orreelva	0.488	0.503	0.059	0.709	0.065	0.420	0.196	0.088
Orkla	🟩 0.002	🟥 0.002	0.123	0.242	0.968	🟥 0.012	🟩 0.000	0.358
Vefsna	🟩 0.002	0.070	0.896*	🟩 0.002	🟩 0.042	🟩 0.018	🟩 0.000	🟩 0.000
Altaelva	🟩 0.024	0.691	1.00*	0.121	🟩 0.043	0.420	🟩 0.023	0.560

Red – significantly increasing $p<0.05$, green – significantly decreasing $p<0.05$

*Trend analysis started in 1999 due to limited data in the period from 1990

3.4.2 Short-term trends (2004-2018) in loads and concentrations of metals

The results (p-values) from the short-term (2004-2018) trend analyses of loads and concentrations of the metals lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), and, nickel (Ni) are presented in Table 17 and Table 18, respectively. The shorter time period was selected due to an increase in the sensitivity of the analytical methods (lower LOQ) over time, i.e. it has become possible to detect lower concentrations. Thus, without excluding the data prior to 2004, the trend analysis could potentially have showed false decreasing trends (see Skarbøvik *et al.*, 2007 and Stålnacke *et al.*, 2009, for details). Note that the reduced sampling frequency in the past two years (from monthly to quarterly) can introduce uncertainty to the trend analysis. This is especially the case for highly polluted rivers for which the variability can be substantial.

Interestingly, almost all significant trends show decreases in both the loads and the concentrations of the metals. Two exceptions were Rivers Vefsna and Altaelva in middle and northern Norway, for which the concentrations of nickel were increasing. However, the Ni levels in these two rivers are low and thus the increasing trend does not warrant major concern at this point. The river with the largest number of decreasing metal load trends was River Orkla (Figure 36. Pb, Cd, Cu, and Zn all showed decreasing trends in loads and Cu and Zn concentrations were also decreasing). The same tendency was observed in the previous report, and this is positive, given that this river is affected by water discharge from an abandon copper mine in the catchment. The decreasing trends in metal concentrations in Rivers Glomma, Drammenselva, and Skienselva can partly be explained by the long-term increasing water discharge in these rivers (Table 15).

The trends were very similar to those observed in the previous report, except that the decreasing trends for loads of Cu in River Glomma, Ni in River Skienselva, and Zn in River Otra are now significant. There was no longer a significant increase in Zn concentration in River Glomma, while Rivers Drammenselva, Vefsna, and Alta now showed significant declines in Cd concentration, River Numedalslågen a significant decline in Cu concentration, and Altaelva a significantly decline in Zn concentration. For some rivers the significant trend disappeared, such as Orkla in Pb concentration.

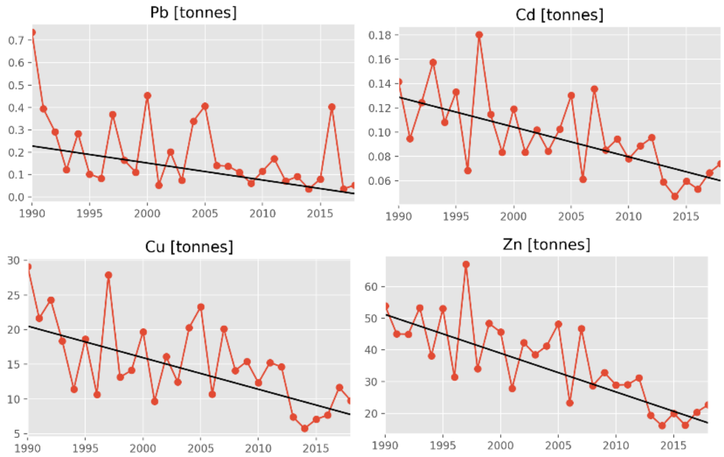

Figure 36: Long-term trends in loads of lead (Pb), cadmium (Cd), copper (Cu), and zinc (Zn) for river Orkla from 1990 to 2018.

Table 17. Short-term trends (2004-2018) in metal loads in rivers monitored monthly since 1990. p-values are shown.

River	Pb	Cd	Cu	Zn	Ni
Glomma	0.921	0.138	0.048	0.235	0.553
Drammenselva	0.553	0.621	0.166	0.276	0.166
Numedalslågen	1.00	0.428	0.166	0.322	0.843
Skienselva	1.00	0.428	0.235	0.621	0.029
Otra	0.767	0.113	0.013	0.023	0.048
Orreelva	0.373	0.767	1.00	0.692	1.00
Orkla	0.013	0.029	0.008	0.013	0.428
Vefsna	0.198	0.298	0.138	0.003	0.843
Altaelva	0.488	0.840	0.198	0.276	0.373

Red – significantly upward p<0.05, green – significantly downward p<0.05.

Table 18. Short-term trends (2004-2018) in metal concentrations in rivers monitored monthly since 1990. P-values are shown.

River	Pb	Cd	Cu	Zn	Ni
Glomma	0.921	0.612	🟩 0.010	0.166	0.621
Drammenselva	0.586	🟩 0.020	🟩 0.0005	🟩 0.003	0.124
Numedalslågen	0.276	0.581	🟩 0.018	🟩 0.010	0.456
Skienselva	0.180	🟩 0.0004	🟩 0.023	🟩 0.020	🟩 0.0006
Otra	0.692	0.118	🟩 0.006	🟩 0.001	🟩 0.033
Orreelva	0.487	0.450	0.297	1.00	0.232
Orkla	0.180	0.102	🟩 0.009	🟩 0.023	0.181
Vefsna	0.457	🟩 0.010	0.102	🟩 0.001	🟥 0.010
Altaelva	0.418	🟩 0.005	🟩 0.0001	🟩 0.002	🟥 0.009

Red – significantly upward p<0.05, green – significantly downward p<0.05.

3.5 Quality of dissolved organic matter

The dissolved organic matter (DOM < 0.45 µm) is considered as the most bioavailable and reactive fraction of the organic matter. The quality of DOM, and not only the quantity, is important to understand how DOM influences various processes in the water. Spectroscopic techniques such as absorbance within the UV and visible region of the light spectrum are commonly used to characterize the quality of DOM. Light absorption at a certain wavelength can be attributed to specific molecular segments or functional groups, and hence several spectral indices have been defined to describe characteristics such as the degree of aromaticity (sUVa) and molecular size (E2_E3) (Peuravuori & Pihlaja, 1997; Weishaar *et al.*, 2003, see Table 19 for details). The quality of DOM is governed by its source material, hydrological and climatic conditions, in addition to various local transformation processes. Generally, older and more degraded DOM has higher aromaticity and larger molecular size compared to fresh DOM (Kalbitz *et al.*, 2003; Marschner & Kalbitz, 2003).

For this analysis, seasonal and regional patterns in DOM quantity (TOC) and quality (sUVa and E2_E3) have been investigated. The rivers have been grouped geographically according to the four major drainage basins in Norway (Barents Sea, Norwegian Sea, North Sea, and Skagerrak). Note that 2017 was the first year with DOM quality analysis in the River monitoring programme.

Table 19. Overview of the absorbance indices used to describe DOM quality

	Name	Definition	Characteristic
sUVa	Specific UV absorbance	(Abs 254nm / DOC[3])*100	Aromaticity (positive relationship)
E2_E3		250 nm /365nm	Aromaticity (negative relationship) Molecular size (negative relationship)

---

[3] TOC has been used instead of the DOC (< 0.45 µm) due to more extensive data availability.

Seasonal variation

Seasonal variation in DOM quantity and quality are presented in Figure 37, both by regional (colour coded)- and national (dotted line) monthly averages. The national average TOC concentration peaked during spring and autumn, which can be attributed to increased surface flow during the seasonal events of snow melt and intensive autumn rain. The southern rivers draining to the Norwegian Sea and Skagerrak showed the largest seasonal fluctuation in TOC, while in the rivers in the North Sea region, the TOC peaked only during autumn and in the Barents Sea region the TOC levels remained relatively stable from spring to autumn.

Looking at the quality parameters, all regions portrayed DOM of elevated aromaticity and molecular size during spring (later onset in the Barents Sea region). This is likely caused by older material being transported to the rivers with the snow melt. During summer there was a remarkable drop in DOM aromaticity, and particularly for the southern regions (Skagerrak and North Sea).

In Figure 38 the national monthly averages of TOC, sUVa, and E2_E3 are compared with those from the previous year. While there was no significant difference in the TOC concentrations between the two years, there was a significant difference in the quality of the DOM: In 2017 the aromaticity remained relatively stable from spring to autumn, which contrasts the drop observed during the summer in 2018. The summer of 2018 was very warm and dry, and this may have impacted the quality of the DOM. More days with sunshine and longer water residence time can increase the rate of photodegradation, resulting in less aromatic DOM at the outlet of the rivers. This can be an indication of future trends, since predictions indicate warmer and dryer summers, at least in parts of the country. Less aromatic DOM is generally more biodegradable, which could lead to higher emission rates of carbon dioxide (CO_2) from increased heterotrophic activity in the river. However, additional years of data will be needed to verify that the drop in aromaticity during the summer of 2018 was a consequence from the dry and warm summer.

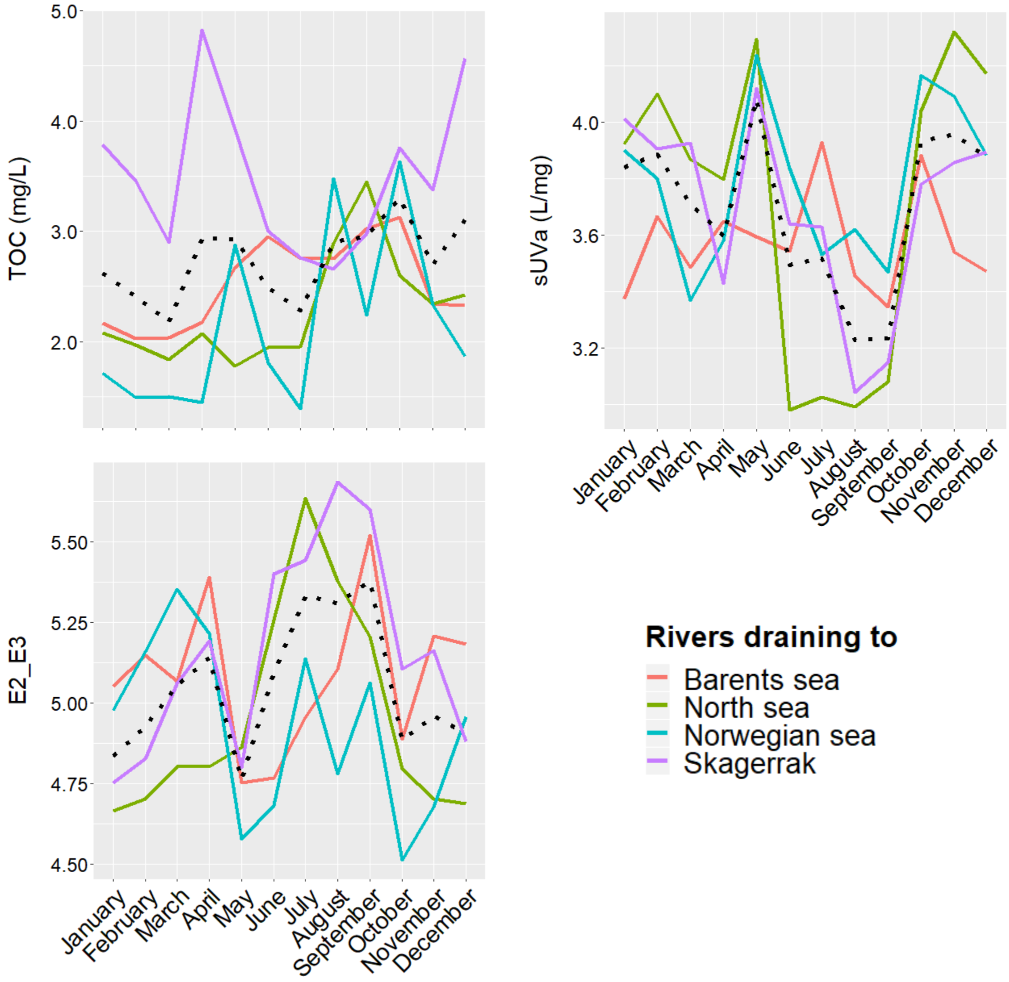

Figure 37: Monthly average values of TOC concentration, aromaticity (sUVa), and molecular size (E2_E3) for rivers in the four regions Barents Sea (red, n = 4), North Sea (green, n = 5), Norwegian Sea (blue, n = 4), and Skagerrak (purple, n = 7). Monthly averages for all the rivers are illustrated by dashed line of black colour (n = 20).

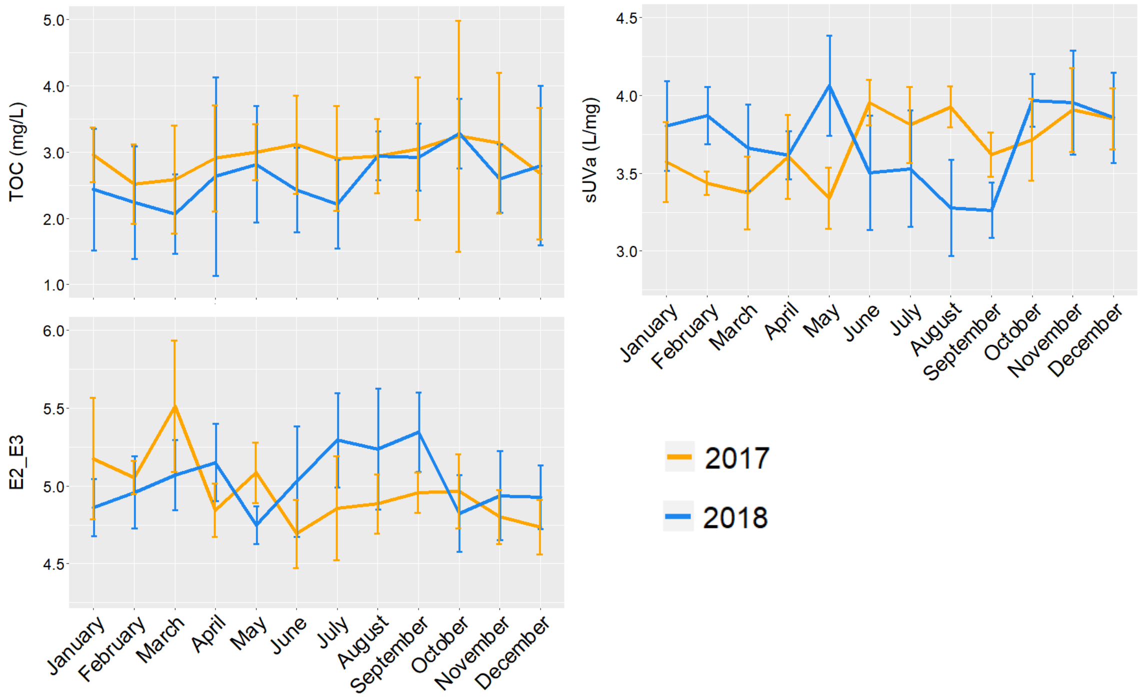

Figure 38: Monthly averages values of TOC concentration, aromaticity (sUVa), and molecular size (E2_E3) for 2017 (orange) and 2018 (blue) for all 20 rivers in the monitoring programme. Error bars illustrate the variability in the data (± stdev).

Regional variation

In Figure 39 monthly averages of DOM quality, expressed as i) sUVa and ii) E2_E3 are plotted against DOM quantity (TOC concentration), and iii) the TOC concentration is plotted against water discharge. It was decided to use monthly values rather than annual averages that were used in the previous report due to the high seasonal variation in the data. Note that Rivers Alna and Orreelva have been excluded from this analysis since they are atypical of their regions (high particle load from human influence).

Interestingly, the rivers in the North Sea region (green) were most different from the others. The TOC levels were generally lower which could result from the higher water discharge in this region, causing dilution. Moreover, there was a different relationship between concentration and quality of the DOM in the North Sea region compared to the other regions: For these relatively low TOC levels, the aromaticity was high and the molecular size was at the same level as for higher TOC-containing rivers in other parts of the country. The three other regions showed a more similar and/or overlapping relationship between TOC, DOM quality, and discharge. The different relationship observed for the North Sea region was also seen in 2017. The reason for this is not known, but it could be related to differences in hydrological conditions and/or source of DOM. In the literature, DOM of relatively higher aromaticity and larger size range is associated with more humified and degraded material, see e.g. Marschner and Kalbitz (2003).

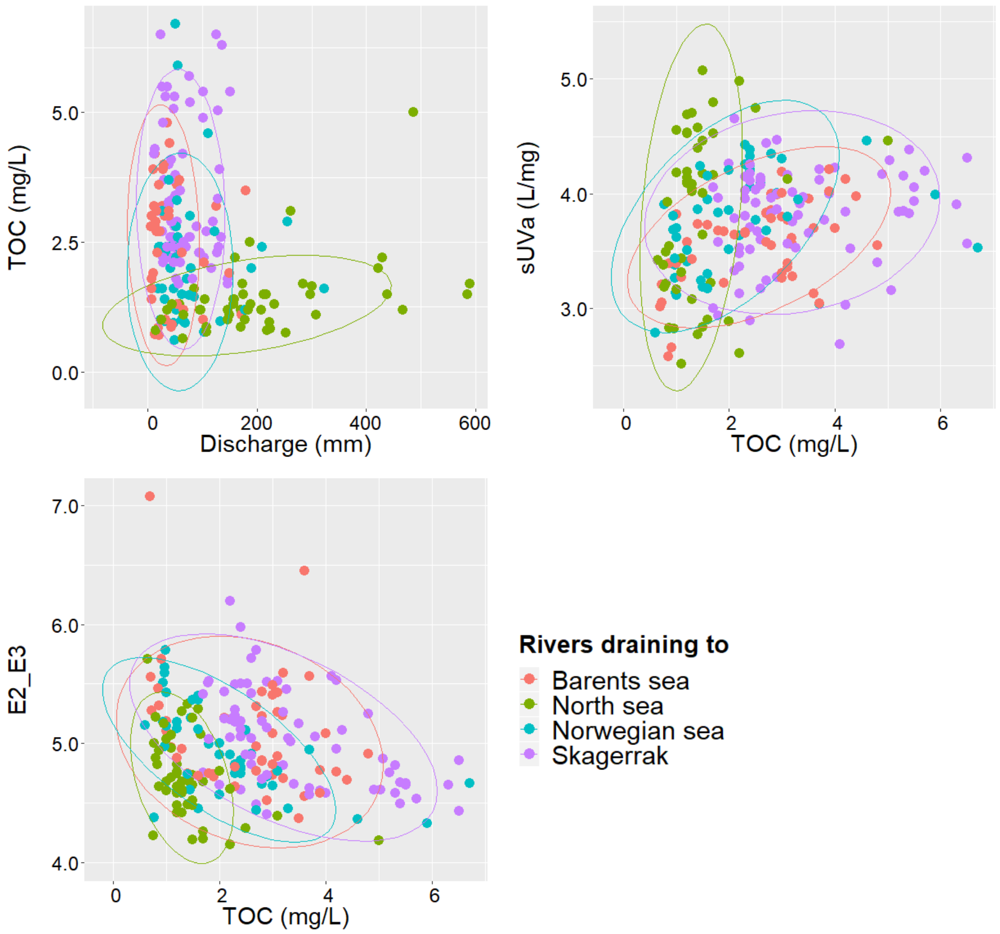

Figure 39: Relation between monthly TOC concentration and discharge (top left), aromaticity (sUVA) and TOC concentration (top right), and molecular size (E2_E3) and TOC concentration (bottom left) for rivers draining to the Barents Sea (red, n = 4), the North Sea (green, n = 4), the Norwegian Sea (blue, n = 4), and Skagerrak (purple, n = 6). Note that Rivers Alna (Skagerrak) and Orreelva (North Sea) have been excluded from the figures.

3.6 Stable isotopes in nitrate and phosphate

3.6.1 Stable nitrogen and oxygen isotopes in nitrate

Different sources of nitrate (NO_3) often have distinct nitrogen (N) and oxygen (O) isotopic compositions (Figure 40). Hence, identification of stable nitrogen and oxygen isotope ratios ($d^{15}N$ and $d^{18}O$) in NO_3 can be a suitable tool for tracing sources of NO_3 in surface water (Kendall, 1998). Biological cycling of NO_3 often changes isotopic ratios in a predictable manner owing to isotope fractionation, i.e. discrimination between light and heavy isotopes during the transformation process. Hence, in many cases it may be possible to reconstruct the origin and history of exported NO_3 from the isotopic compositions of N and O.

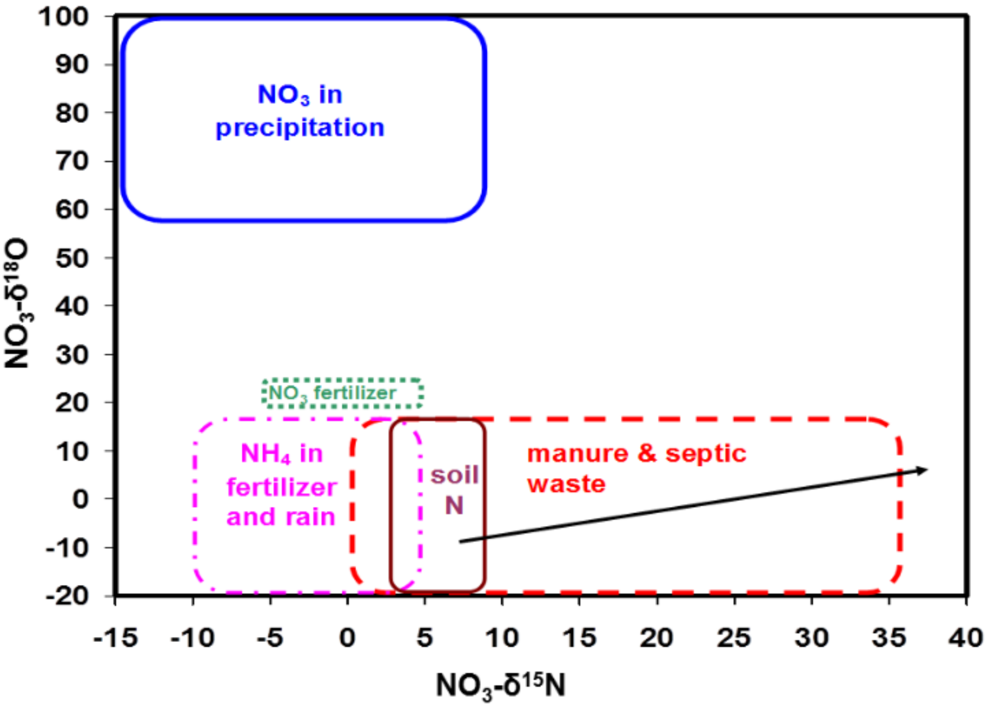

Figure 40: Typical ranges of $d^{15}N$ and $d^{18}O$ values of nitrate from various sources (from Kendall 1995).

N isotope ratios have been applied in many studies to discriminate between point sources (manure, sewage) and non-point sources (atmospheric deposition, synthetic fertiliser, soil organic matter) in river basins (Mayer *et al.*, 2002). However, N isotopes alone cannot differentiate between the various sources, especially the non-point sources (atmospheric deposition, synthetic fertiliser, soil nitrogen), because they usually have overlapping $d^{15}N$ values (Figure 40). Therefore, the method of measuring both N and O isotope ratios of NO_3 (the dual-isotope technique) can be quite useful (Amberger and Schmidt 1987; Revesz *et al.* 1997, Silva *et al.* 2000). The combined analysis of both $d^{15}N$ and $d^{18}O$ of NO_3 in many cases provides a valuable tool for differentiating between diffuse NO_3 sources in lowland rivers (fertiliser vs. manure; natural soil N vs. fertilizer and/or manure) and in upland catchments enriched with atmospheric N (natural soil N vs. atmospheric deposition).

Twelve samples were collected at three stations in River Alna during June and August 2018; six from station 1 (Kværnerparken), four samples from station 2 (Bring at Alfaset) and two samples from station 3 (Fossumbekken). All stations are located within the Oslo urban area, with station 1 being identical to the site that is sampled in the main programme (Table 1). Measured NO_3 concentrations at station 1 were in the range 1020-1400 µg N/l (N=5) from June 5th until October 3rd in 2018.

Results from the stable isotope analysis in 2018 are shown in Figure 41. As in 2017 (Figure 42) there were relatively small differences in isotopic signatures at the three stations. If projected into the example diagram in Figure 40 the isotopic signatures indicate soil N and septic waste as the primary sources.

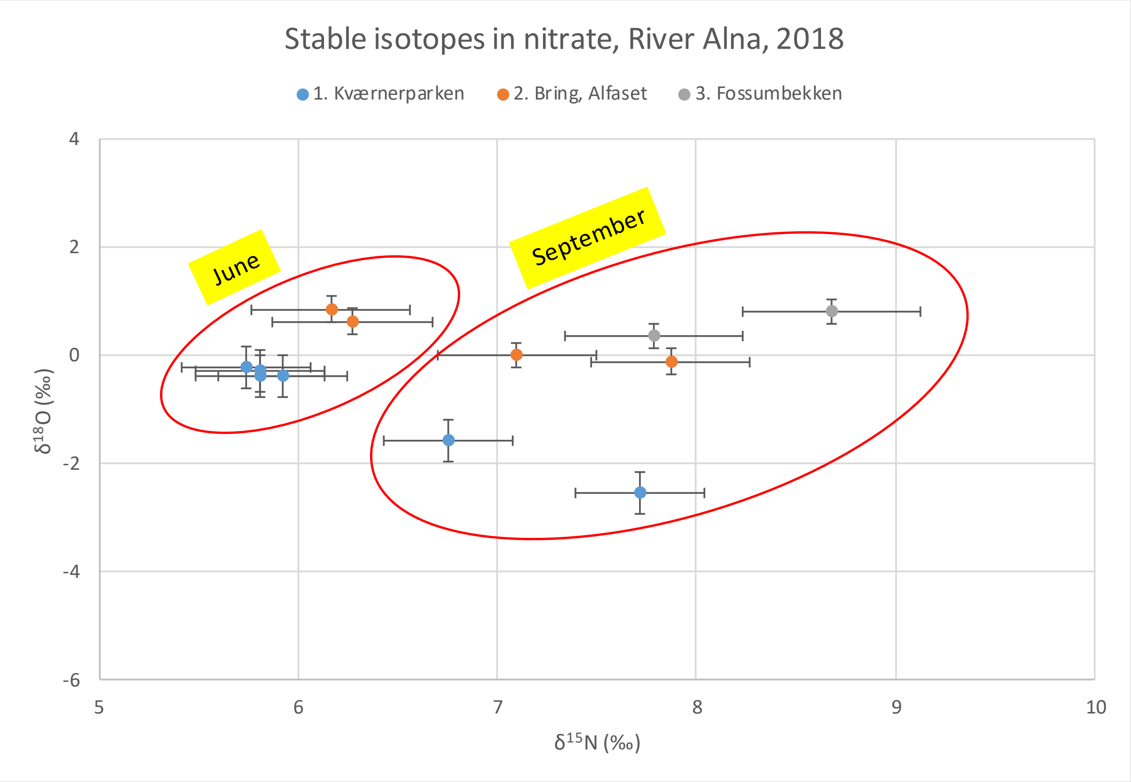

Figure 41: d^{15}N and d^{18}O values in samples from River Alna collected in June and September 2018. Standard error bars are indicated. The locations of the stations are shown in the map in Figure 3.

Station 1 was separated from the two other stations by having slightly lower d^{18}O. The most striking pattern, however, was that all stations were more enriched in d^{15}N in September compared to the samples taken in June, probably due to higher metabolic activity (faster cycling of available NO_3) during the summer period. The highest d^{15}N value, 8.68‰ was found in Fossumbekken on September 19th. Five days later the isotopic signal was reduced to 7.79‰. The same pattern (lower d^{15}N values on September 24th compared to the 19th) was also found at the other two stations. A minor peak in water flow occurring between the 19th and the 24th September (data not shown) carrying “fresh” (less biologically cycled) NO_3 could be one explanation for this general pattern.

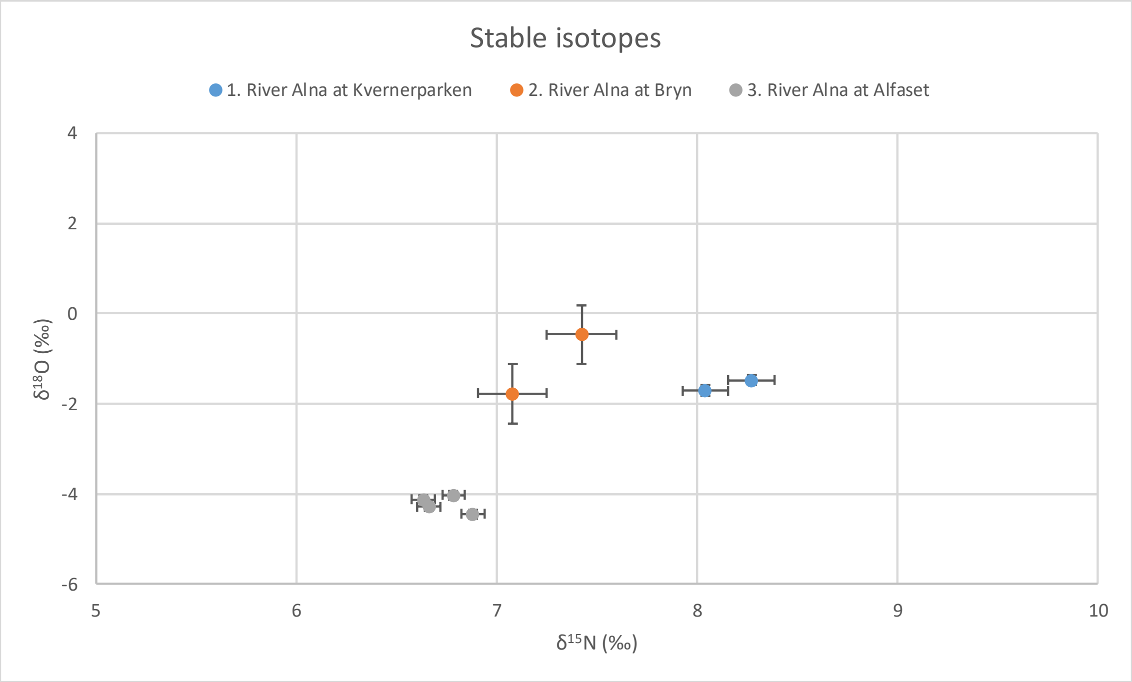

Figure 42: $d^{15}N$ and $d^{18}O$ values in samples from River Alna collected on September 28th 2017. Standard error bars are indicated. The locations of the stations are shown in the map in Figure 3.

The results show that the temporal variation within each site was larger than the between-site variability. This indicates that differences in metabolic activity over time creates a stronger isotopic signal than NO_3 source-related differences between the sites. This sounds reasonable bearing in mind that the stations are located along a relatively short river stretch heavily affected by urban runoff.

It is also important to underline that, given the small number of samples and the small differences in the isotopic signatures, results should be interpreted with caution. In river catchments, multiple NO_3 sources, a mosaic of land-use types and complex hydrology can easily result in overlapping isotopic signals. Natural abundance isotope studies may therefore be more suitable as a complementary method than a stand-alone method under such conditions. However, it may still add value to more traditional chemical assays and source apportionment methods.

3.6.2 Stable oxygen isotopes in phosphate

Phosphorus (P) is usually the limiting nutrient for primary production (growth of plants and algae) in Norwegian rivers and lakes, and phosphate (PO_4) is the P fraction which is most easily available for the primary producers. In recent years, analysis of stable oxygen (O) isotopes in PO_4 has become available, providing an opportunity to separate between different sources of PO_4 in surface water. The theoretical background is that biological cycling of PO_4 changes isotopic ratios in a predictable manner owing to isotope fractionation, i.e. discrimination between light and heavy isotopes during the transformation process. Hence, the method has the potential to offer an insight into the relative importance of different sources of PO_4, and the extent to which PO_4 from individual sources is linked to metabolic activity and cycling within aquatic ecosystems (Davies et al., 2014). That said, the use of the $d^{18}O_{PO4}$ technique in freshwaters is relatively new, and there is a relatively limited number of studies that have contributed to the “global” database of $d^{18}O$ signatures for different sources of PO_4 (Figure 43).

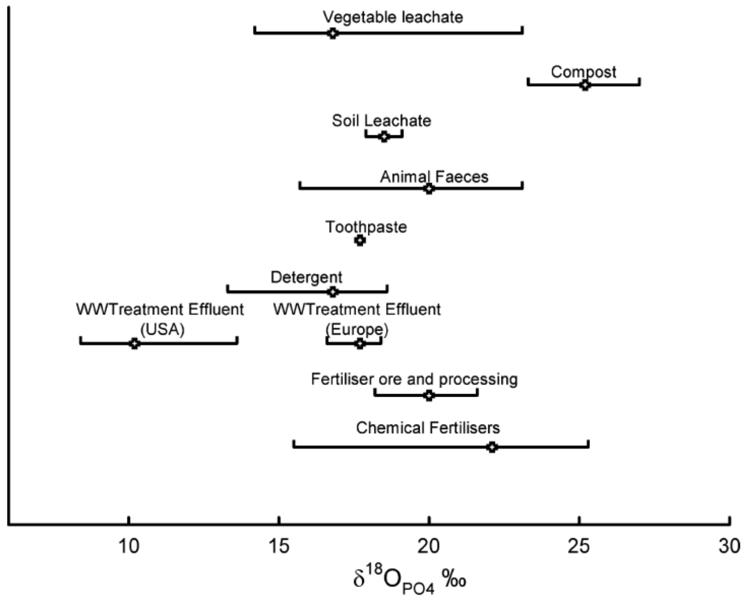

Figure 43. Range of d$^{18}O_{PO4}$ in sources of P to the environment. From Davies et al. (2014) and Gooddy et al. (2015). (2015).

Table 20. d^{18}O in water and phosphate analysed in samples from River Alna during June and September 2018.

Station	Date	$\delta^{18}O_W$ (‰ VSMOW)	Water temp (°C)	$\delta^{18}O_{PO4}$ (‰ VSMOW)	Eq $\delta^{18}O_{PO4}$ $^{1)}$ (‰ VSMOW)	Difference ($\delta^{18}O_{PO4}$ vs. eq $\delta^{18}O_{PO4}$)
1. Kværnerparken	19/06/2018	-9.64	12.3	13.70	14.43	-0.73
1. Kværnerparken	19/06/2018	-9.66	12.3	13.98	14.41	-0.43
1. Kværnerparken	19/09/2018	-9.59	12.7	19.70	14.41	5.29
1. Kværnerparken	24/09/2018	-9.30	9.3	20.40	15.32	5.08
2. Bring, Alfaset	20/06/2018	-9.88	11.5	11.54	14.33	-2.79
2. Bring, Alfaset	20/06/2018	-9.88	11.5	11.97	14.33	-2.36
2. Bring, Alfaset	19/09/2018	-9.80	n.d.	n.d.	n.d.	n.d.
2. Bring, Alfaset	24/09/2018	-9.44	9.3	15.42	15.18	0.24
3. Fossumbekken	26/06/2018	-10.07	n.d.	n.d.	n.d.	n.d.
3. Fossumbekken	19/09/2018	-10.07	12.7	19.15	13.92	5.23
3. Fossumbekken	24/09/2018	-9.64	9.3	20.04	14.97	5.07
3. Fossumbekken	24/09/2018	-9.65	n.d.	n.d.	n.d.	n.d.

$^{1)}$ Equilibrium d$^{18}O_{PO4}$ calculated from d$^{18}O_W$ and water temperature, based on an equation from Chang and Blake (2015).

n.d.: not able to generate enough silver phosphate for analysis

Samples for analysis of stable oxygen isotopes in PO_4 were collected at the same sites and at the same dates as the samples for stable isotopes in NO_3 (Figure 3). Altogether, 12 samples were collected; four samples from each of the three stations. All samples were analysed for d^{18}O in water (d^{18}O$_W$), whereas three samples (one from station 2 and two from station 3) had too little silver phosphate for analysis of d^{18}O in PO$_4$ (d^{18}O$_{PO4}$). Measured PO$_4$ concentrations at station 1 were in the range 34-54 µg N/l (N=5) from June 5th to October 3rd in 2018. The sampling on June 19th and September 24th took place right after minor flow peaks in the river, whereas the sampling on September 19th was under low-flow conditions.

Results from the analysis of d^{18}O$_W$ and d^{18}O$_{PO4}$ are displayed in Table 20. The most striking pattern is that there were quite large differences between the observed d^{18}O$_{PO4}$ composition of samples from June (11.54-13.98‰) compared to September (15.42-20.40‰). Given the relatively large overlap in d^{18}O$_{PO4}$ signatures of different sources of P (Figure 43) it is challenging to use the method as a source apportionment tool. Especially in River Alna, where all the stations probably are affected by a mixture of P sources.

However, the large differences in d^{18}O$_{PO4}$ signals observed at all stations between June and September probably reflect differences in metabolic activity and cycling of PO$_4$ between the sampling dates. Column 7 in Table 20 shows the difference between the observed d^{18}O$_{PO4}$ composition (column 5) and the composition expected at equilibrium (column 6). Negative figures indicate observed values below the expected equilibrium (isotopically depleted samples indicating low metabolic activity), whereas positive figures indicate observed values above the expected equilibrium (isotopically enriched samples indicating high metabolic activity).

In general, the June data are isotopically depleted and are below the expected equilibrium value, whereas the September data are isotopically enriched and above the expected equilibrium. This indicates either a shift in the sources of phosphorus contributing to these samples between June and September and/or differences in the metabolic processes affecting PO$_4$ within the river between these two sampling dates (Ben Surridge, pers. comm).

Further, there are some relatively large differences between sites on certain sampling events, both in terms of the observed d^{18}O$_{PO4}$ composition and the difference compared to equilibrium. In June, the samples from station 2 are isotopically depleted and further from equilibrium compared to the station 1 samples. In September, the station 2 samples are again isotopically depleted and this time much closer to equilibrium than either the station 3 or station 1 samples (Ben Surridge, pers. comm).

It is important to note that the samples from River Alna only represent a few snapshots in time, and that the isotopic signals captured during these short campaigns may change significantly over annual, seasonal or daily timescales. Results should therefore be interpreted with caution.

3.7 Modelling future hydrology and nitrogen loads in River Storelva

In this chapter, we have applied the hydrological model PERSiST and the Integrated Catchment model for nitrogen (INCA-N) to simulate future hydrology and NO_3 concentrations in River Storelva.

3.7.1 Model calibration

Stream water flow

The first step in the modelling exercise was to calibrate the PERSiST hydrological model. This was done by adjusting parameters to obtain the best possible fit between modelled data and river flow measured at NVE's station, which is located at the river outlet (Figure 44). We were able to obtain a good fit between modelled and measured data, with a Nash-Sutcliffe efficiency criterion (N-S) of 0.74, and a coefficient of determination (R^2) of 0.74. N-S and R_2 values of 1.0 indicate a perfect fit, whereas values above 0.7 are regarded as satisfactory within hydrological modelling.

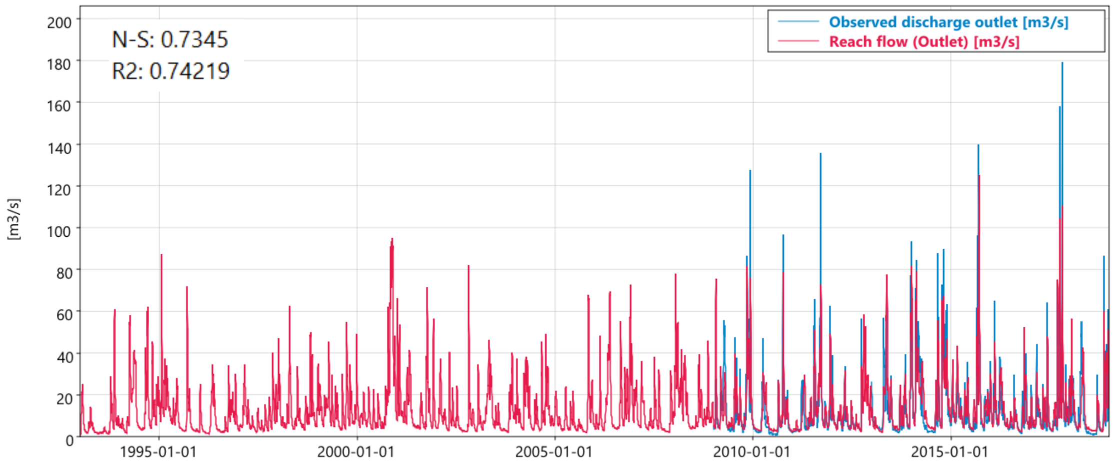

Figure 44: Calibration of water flow in River Storelva with the PERSiST model. Calibration period 2009-2018, corresponding to the years with measured data at NVE's gauging station 18.4.0 Lundevann. The Nash-Sutcliffe efficiency criterion (N-S) and the coefficient of determination (R^2) between modelled and measured data are displayed.

Stream water nitrogen

The next step in the modelling procedure was to calibrate the INCA-N model. As nitrate concentrations in rivers are a result of complex interactions between several processes in the terrestrial and aquatic parts of a catchment, the calibration process is more challenging than for the hydrology. Despite this, we were able to obtain a reasonably good fit between modelled and measured nitrate concentrations in the river, with a N-S value of 0.56 and a R^2 value of 0.58. This must be regarded as very good, as there in many instances can be challenging to obtain a N-S value above 0.3-0.4 in calibration of catchment models for nutrients. Despite the good calibration result, we were not able to reproduce the declining NO_3 trend after 2006. One possible reason for this could be that the downward N deposition might have been more pronounced in the Storelva catchment than at Birkenes, which is located 60 km to the southwest. Another possible explanation could be abandonment of agricultural land or a greater reduction of fertiliser use on agricultural fields than anticipated (the calibration is based on a 20% reduction in N fertiliser use between 1993 and 2015).

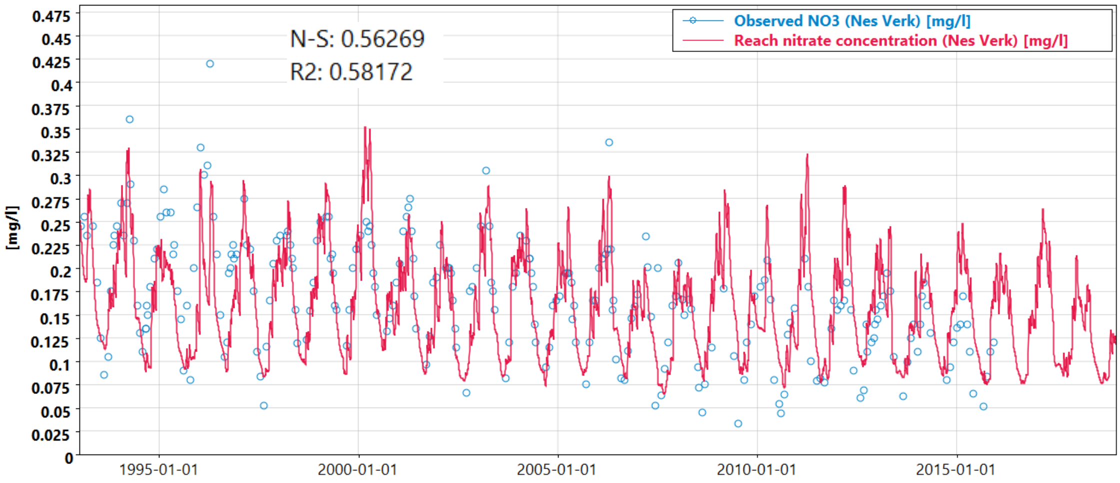

Figure 45: Calibration of NO_3 concentrations in River Storelva with the INCA-N model. The calibration period is 1993-2015, the years with measured data at the monitoring station Nes Verk. Data from Nes Verk are from the National monitoring program for limed rivers ((Norwegian Environment Agency, 2018). The Nash-Sutcliffe efficiency criterion (N-S) and the coefficient of determination (R^2) between modelled and measured data are displayed.

3.7.2 Projections for future hydrology and nitrogen loads

After calibration to historically measured data, PERSiST and INCA-N were run with future scenarios for air temperature and rainfall based on two greenhouse gas emission scenarios (RCP4.5 and RCP8.5) run by an ensemble with ten combinations of global (GCM) and regional (RCM) climate models. The results from the scenario runs are shown in Figure 46 (annual mean values) and Figure 47 (seasonal mean values).

Air temperature

The climate models project a steady increase in air temperatures towards the end of this century. Based on the mean of the 10 climate model predictions for the RCP4.5 and RCP8.5 scenarios, the annual mean temperature will increase from around 6.0°C today, to 8.0°C with RCP4.5 and 10.0°C with RCP8.5 towards 2100. The most extreme scenarios project annual mean temperatures ranging from around today's level (6°C) to 12°C. If splitting the scenarios into seasons, the temperature slopes are relatively similar, or slightly steeper during the summer and winter periods. Changes in air temperature will have a direct effect on the water temperature during the ice-free season.

Precipitation

The climate models project only a modest increase in precipitation amounts towards the end of this century. One explanation for this is that the area already has experienced significant increase in annual precipitation since 1990 (Table 9, precipitation trends). It is not a big difference in the two scenarios' (RCP4.5 and RCP 8.5) representation of future precipitation. On a seasonal basis, the models project slightly dryer spring and summer periods, while autumns and winters are projected to become somewhat wetter. Also, for the seasonal projections, there is not a big difference between the two scenarios.

River flow

As precipitation is the main driver for water flow, simulation of future scenarios with the PERSiST model show no significant changes in annual water flow towards the end of this century. However, changed snow accumulation in a future climate will ultimately alter the seasonal flow pattern. As noted for precipitation, the area har already experienced a significant increase in annual precipitation and water flow since 1990 (ref. Table 9 precipitation trend**s;** Table 12**,** trends in water discharge/stream flow). Autumn is the only season when river flow is expected to increase in the future. In addition, the projections imply higher year-to year variation in flow volumes towards the end of the century, especially with the RCP8.5 scenario. It should also be noted that there is a great variability in the projections produced by the 10 different climate models in the ensemble – which in turn illustrates that there are substantial uncertainties associated with the predictions of future water flow.

River nitrate concentrations

As mentioned under the calibration section, there was a significant decrease in the river NO_3 concentrations from 1993 to 2015, mainly as a result of decreasing deposition of long-range transported air pollution. In addition, there has been a reduction in use of nitrogen fertiliser on agricultural fields. After 2015, we assume that the N deposition level, fertiliser use and land use (proportion of forest and agricultural land) to remain constant in the future. Nevertheless, the INCA-N model predicts a weak decline in NO_3 concentrations – both on annual and seasonal basis.

The main underlying factor for the simulated decline in NO_3 concentrations in the future seems to be temperature, which is a fundamental driver for nitrogen processes in soil and water. Increased temperature will speed up the mineralisation of organic to inorganic N. This will increase the amount of NH_4 and NO_3 available for plants and potentially also increase the risk of NO_3 leaching to surface waters. However, increased temperature will also increase the N uptake through increased plant growth and longer growing season. In addition, higher temperatures will potentially increase losses of N to the atmosphere via denitrification (microbial conversion of NO_3 to N_2O and N_2) if the soils don’t get too dry. The simulated decline in NO_3 concentrations towards the end of the century suggest that increased temperature will result in an increased net retention of N in the catchment. An uncertainty in this context is whether the supply of N from atmospheric sources is in balance with the plants demand for N, or if long-term accumulation of excess N eventually will result in N saturation and increased leaching to surface waters (cf. Aber et al. (1989)).

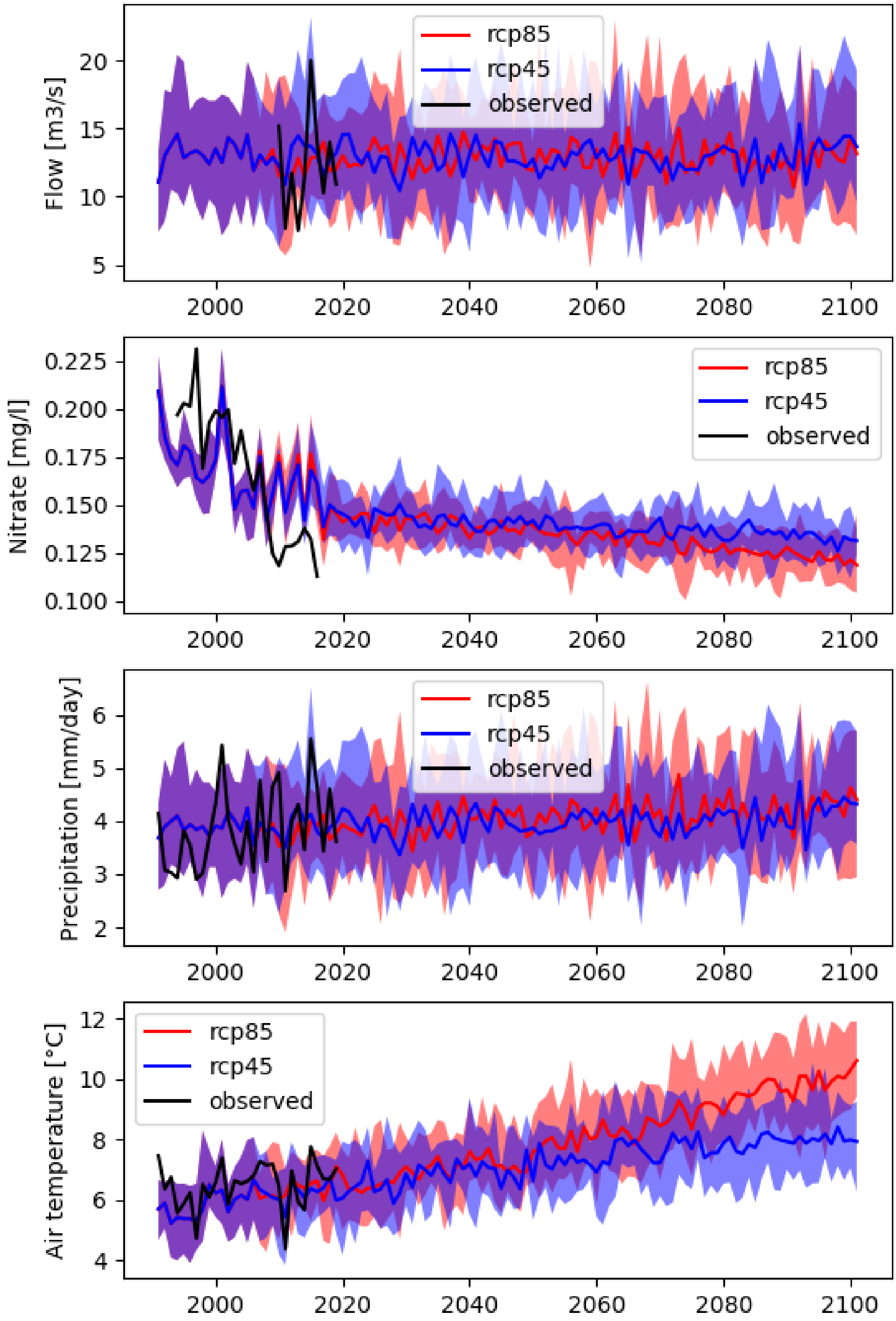

Figure 46: Simulation of future flow and nitrate concentrations (annual mean values) in River Storelva, based on the PERSiST and INCA-N models run with an ensemble of climate scenarios. The blue and red lines represent the mean of the 10 climate model predictions for the RCP4.5 and RCP8.5 scenarios, respectively. Coloured areas represent min- and max-values for the simulated scenarios. The two panels in the bottom show the projected change in precipitation and air temperature.

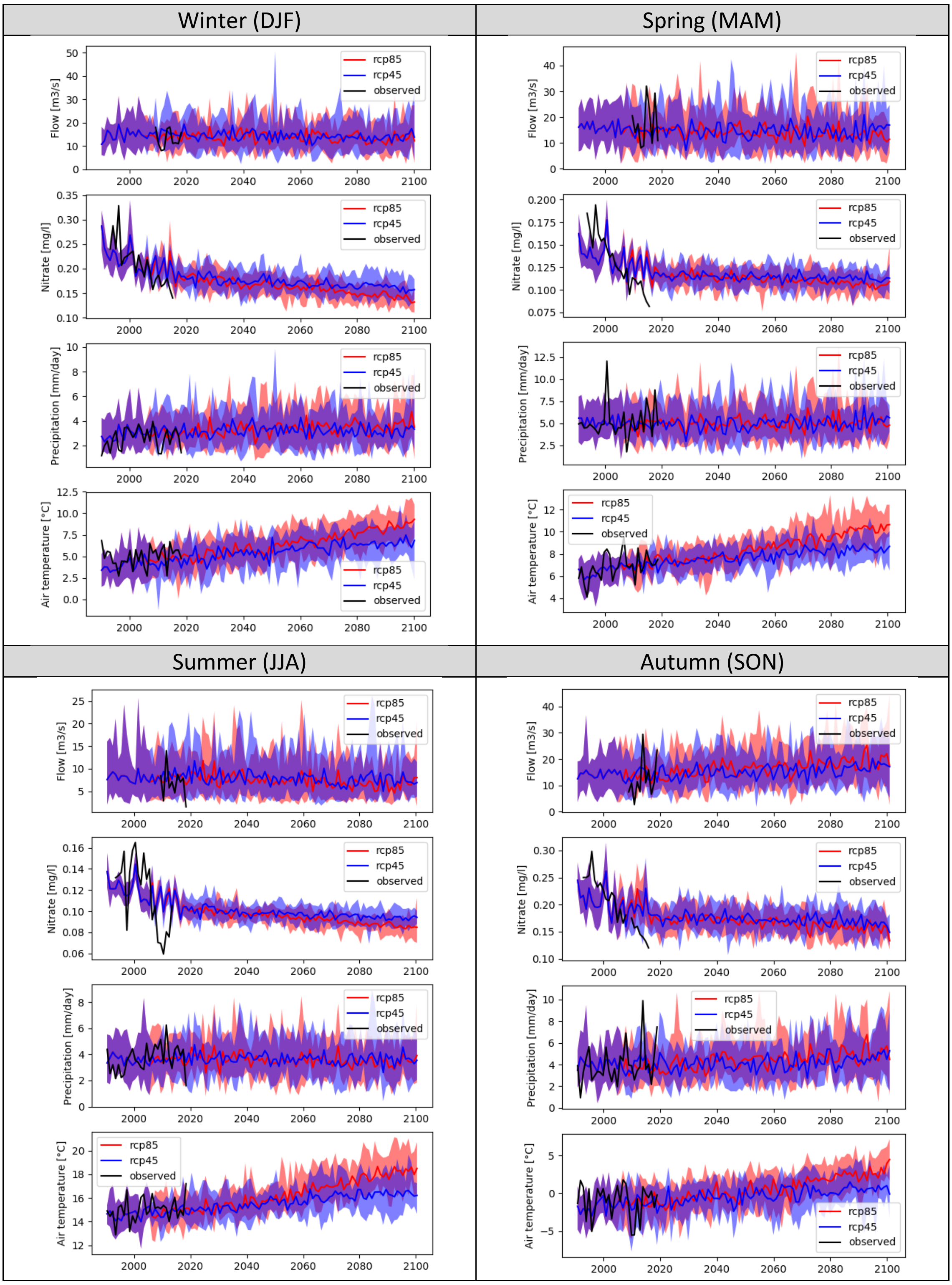

Figure 47: Same panels as in Figure 46, but separated into seasons

3.8 High-frequency monitoring in Rivers Storelva and Målselva

Rivers Storelva and Målselva were elected for more detailed studies on the effects of climate variability and climate change on rivers. To study short-term effects of climate variability on water chemistry, sensors that measure water temperature, pH, conductivity, turbidity and FDOM are deployed in both rivers. The sensor stations are located at the same spot as the manual sampling stations, and the data is collected on an hourly basis.

3.8.1 River Storelva

Water flow

The flow dynamics in River Storelva are characterized by rapid responses to precipitation events with a relatively quick return to the baseline level after the flood peak. There is no distinct seasonal pattern, and flood events can occur in all seasons, also during winter. In 2018, there was a snowmelt flood in late April. The summer in 2018 was very dry, and the first rainwater flood occurred on September 10th. Later there were three medium-sized floods during November and December.

Water temperature

The water temperature in 2018 exceeded 10°C on May 8th, which was about two weeks later than the year before (Figure 48). Due to the extraordinary warm and dry summer in 2018, the water temperature exceeded 20°C from mid-May until the last part of August. The only exception was a week in late June when the temperature temporarily dropped below 20°C. The temperature fell below 10°C around October 25th, which was about the same time as the year before.

pH

River Storelva has been heavily affected by acidification due to long-range transported air pollution and since the 1990s the river has been limed to protect the salmon and sea trout populations from toxic waters (Norwegian Environment Agency, 2018). The target pH value for the liming varies throughout the year and is highest (6.4) during the smolt migration period in the spring (usually set to the period from April 1st to June 15th). In other parts of the year the pH should be kept above 6.0. The continuous pH monitoring shows that the pH was kept above 6.0 most of the time and that there was relatively good accordance between the sensor data and pH measured in grab samples (Figure 49).

Since the lime addition is automatically regulated by water flow and pH downstream the lime dozer, pH values in the river rarely drop significantly during flood events. However, under the relatively large and long-lasting snowmelt flood in April and early May it was challenging to keep the pH above the target value of 6.4. It is also worth noting the sudden pH drop in September that occurred during the first flood after the long and dry summer. A similar pattern was observed at the Birkenes catchment in Aust-Agder (Garmo and Skancke, 2019) and is probably caused by wash-out of oxidized sulphur that has accumulated in peaty soils during a long period with summer drought.

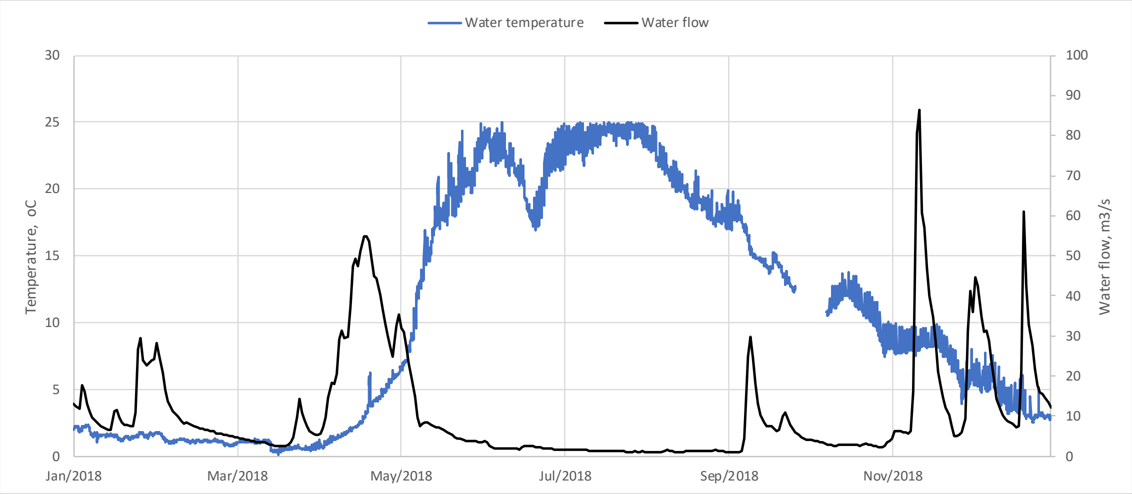

Figure 48: Water temperature and water flow at the outlet of River Storelva in 2018. The water flow data are from NVE's station 18.4.0. Lundevann.

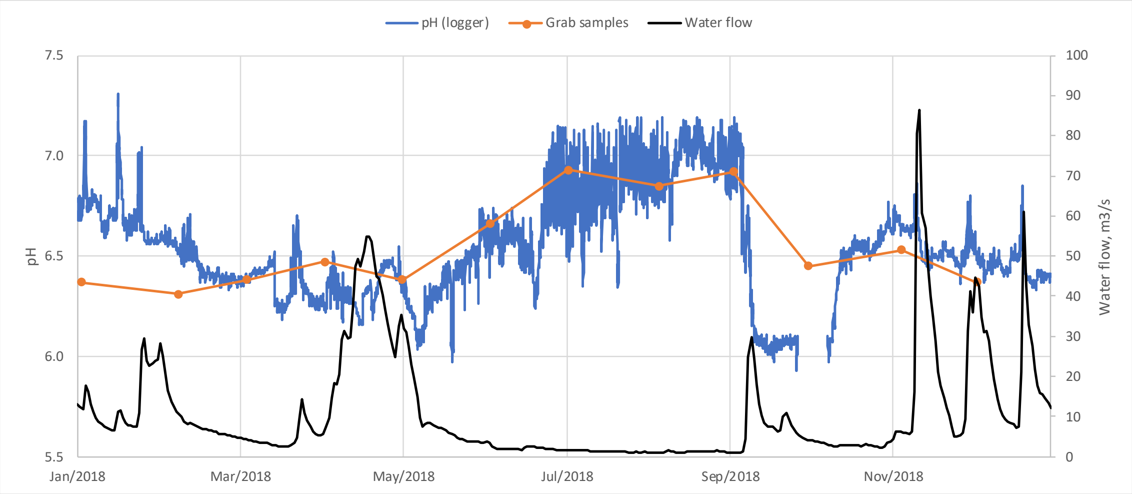

Figure 49: pH and water flow at the outlet of River Storelva in 2018. The water flow data are from NVE.

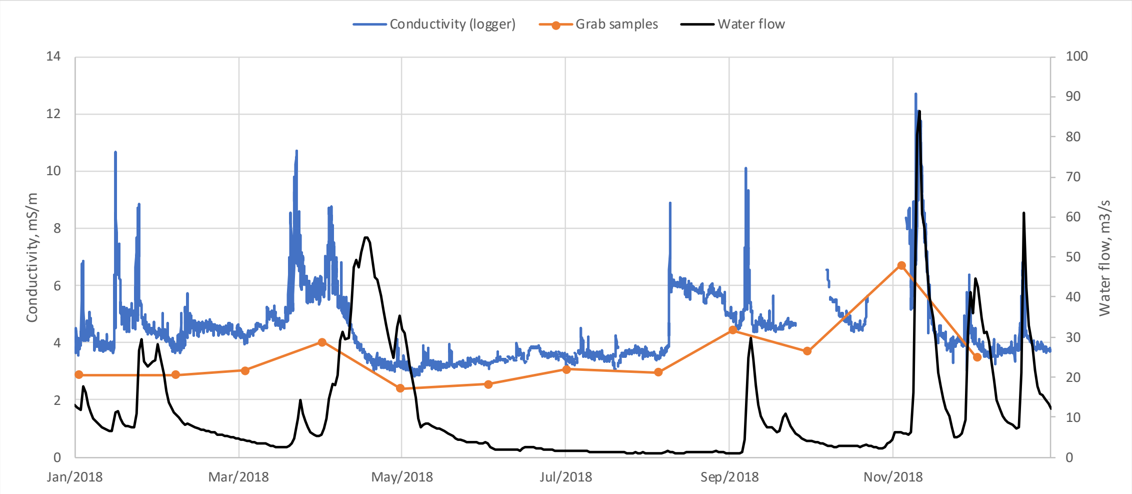

Figure 50: Conductivity and water flow at the outlet of River Storelva in 2018. The water flow data are from NVE.

Conductivity

The conductivity, which is a measure of the ionic concentration in water, was relatively stable throughout the year with values around 3-6 mS/m (Figure 50). Exceptions were during flood events, where the conductivity showed immediate responses and could double or triple within a few hours. This reflects massive wash-out of ions from the soils and a following increase in element concentrations in the early phase of the flood events. However, during the snowmelt flood in April the situation was opposite: large amounts of water from the melting snowpack resulted in a dilution of dissolved ions. As illustrated in Figure 49 there was good accordance between the sensor data and conductivity measured in grab samples.

Turbidity

Turbidity is related to suspended particulate matter that affect the clarity of water. In River Storelva, with clay soils in the lower parts of the catchment, the turbidity increases quickly during flood episodes (Figure 51). In 2018, turbidity values were also surprisingly high during the low-flow period in summer. Increased concentrations of phytoplankton in the upstream Lake Lundevann might be a possible explanation. Or it could be an artefact due to extremely low water level and resuspension of particles from sediments close to the sensor station's water intake. Interestingly, the turbidity remained high for two weeks after the first autumn flood. The sensor data were in most instances higher than turbidity values measured in grab samples. One reason is that monthly grab samples tend to miss flood events and usually underestimate the total particle load throughout the year.

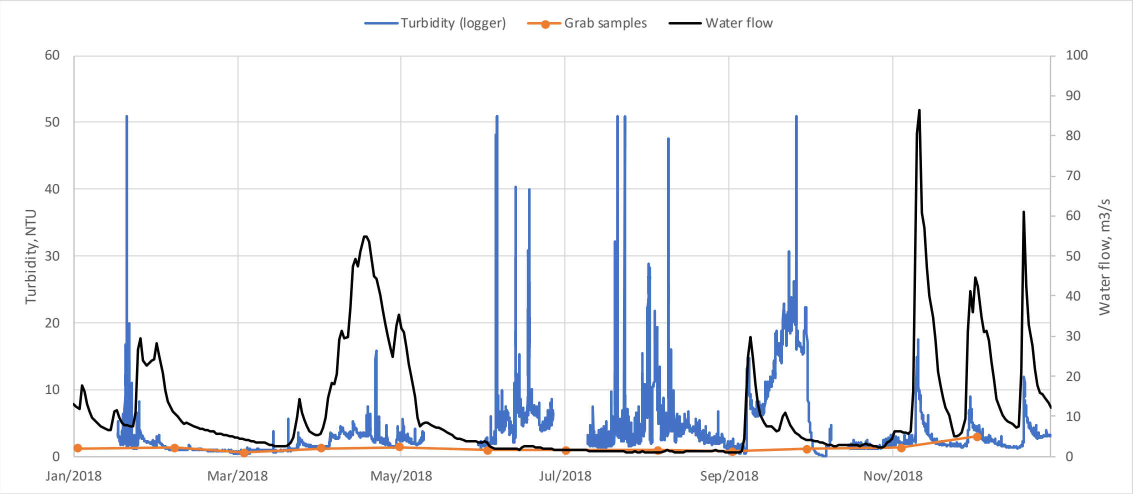

Figure 51: Turbidity and water flow at the outlet of Storelva in 2018. The water flow data are from NVE.

CDOM

Coloured dissolved organic matter (CDOM) can be used as proxy for dissolved organic carbon (DOC) in water. This is demonstrated quite well in Figure 52, where DOC measured in grab samples largely follows the seasonal pattern emerging from the high-frequency data. In general, the CDOM concentrations in River Storelva are highest during the autumn and winter period and declines towards the warm and dry period in summer. The most distinct change in CDOM in 2018 occurred during the first flood after the long and dry summer period, when the concentration suddenly increased from a base level around 30 µg/l to nearly 80 µg/l. After that, the level gradually deceased to around 60 µg/l until early November-December when three consecutive flood peaks again pushed the concentrations up towards 70 µg/l.

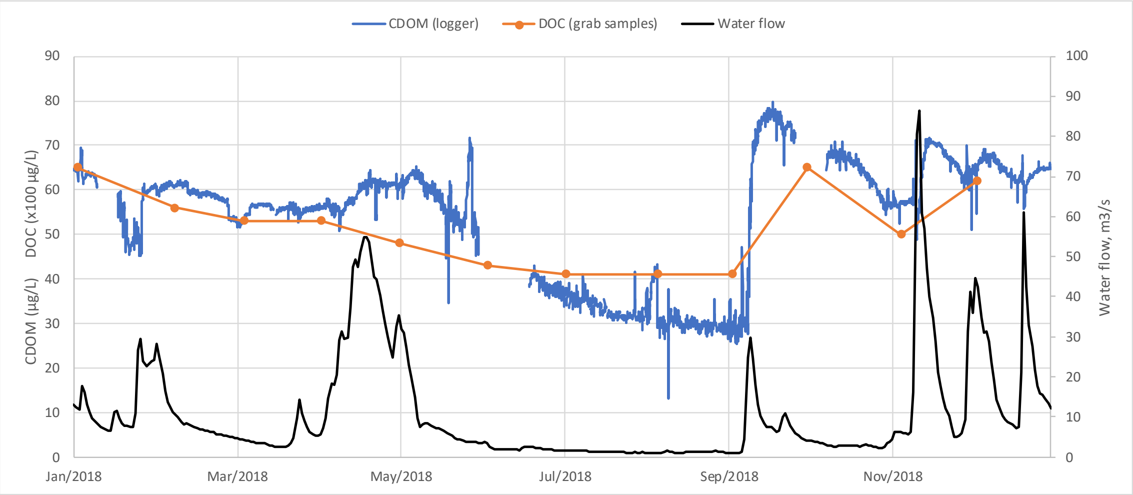

Figure 52: CDOM and water flow at the outlet of Storelva in 2018. The water flow data are from NVE.

3.8.2 River Målselva

Water flow

The flow pattern in River Målselva is dominated by strong seasonal signals (Figure 53). During winter, practically all precipitation accumulates as snow and the small water discharges are mainly supplied by groundwater. The highest water discharges are usually associated with snowmelt, first in the lower parts of the catchment and later in the upper, mountainous parts. In 2018 the first snowmelt flood peaked in mid-May and the second culminated at 460 m^3/s in mid-June. A few minor rainwater floods occurred from August through November, of which the largest one reached 165 m^3/s.

Water temperature

The water temperature was around the freezing point during all the wither months from early December to end of April (Figure 53). The water temperature crossed the 10°C limit on July 2nd and climbed to a maximum of 19.8°C on the 1st of August. After that, the temperature fell below 10°C on September 15th.

pH

River Målselva is well-buffered and little affected by long-range transported air pollution. The pH-values are around 7.0-7.5 with small seasonal variations only (Figure 54). There was good accordance between the sensor data and pH measured in grab samples until June, but thereafter the sensor data declined somewhat in comparison with the measured values. A new pH electrode was installed on May 31st, and malfunction of this electrode can be one possible explanation for the observed deviation.

Conductivity

The conductivity shows a weak seasonal signal with the lowest values (around 4-5 mS/m) during winter and spring (Figure 55). Right before the first snowmelt flood the conductivity

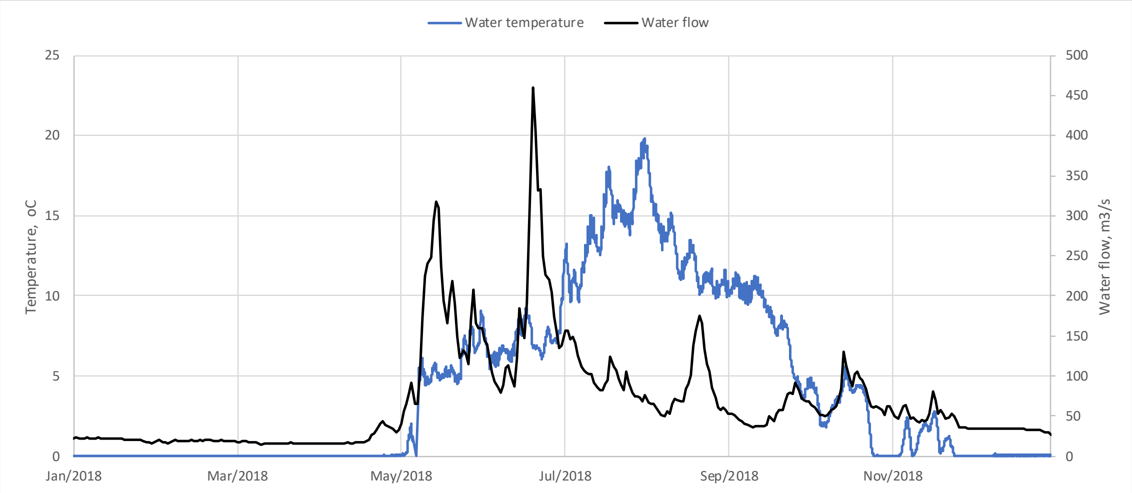

Figure 53: Water temperature and water flow at the outlet of River Målselva in 2018. The water flow data are from NVE's station 196.35.0 Målselvfossen.

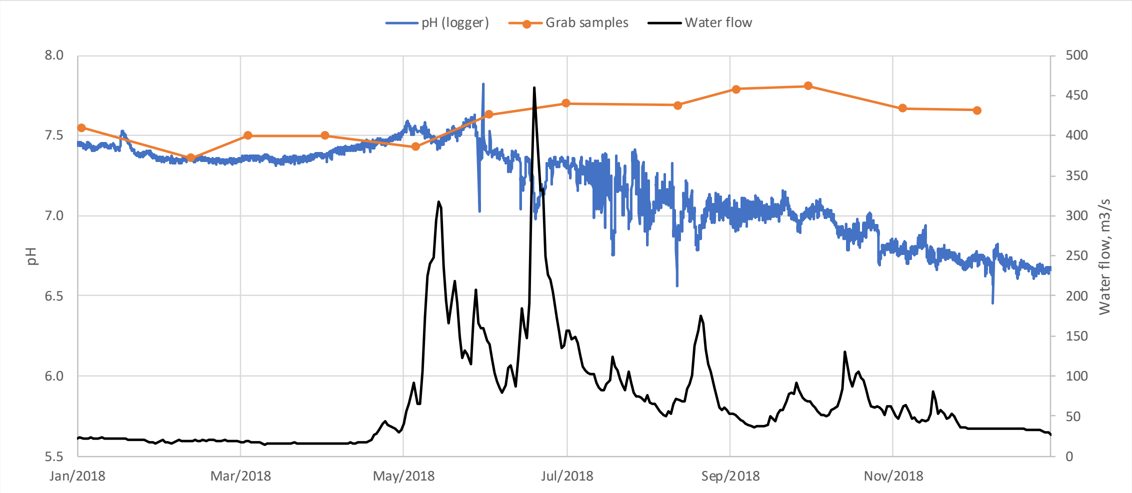

Figure 54: pH and water flow at the outlet of River Målselva in 2018. The water flow data are from NVE.

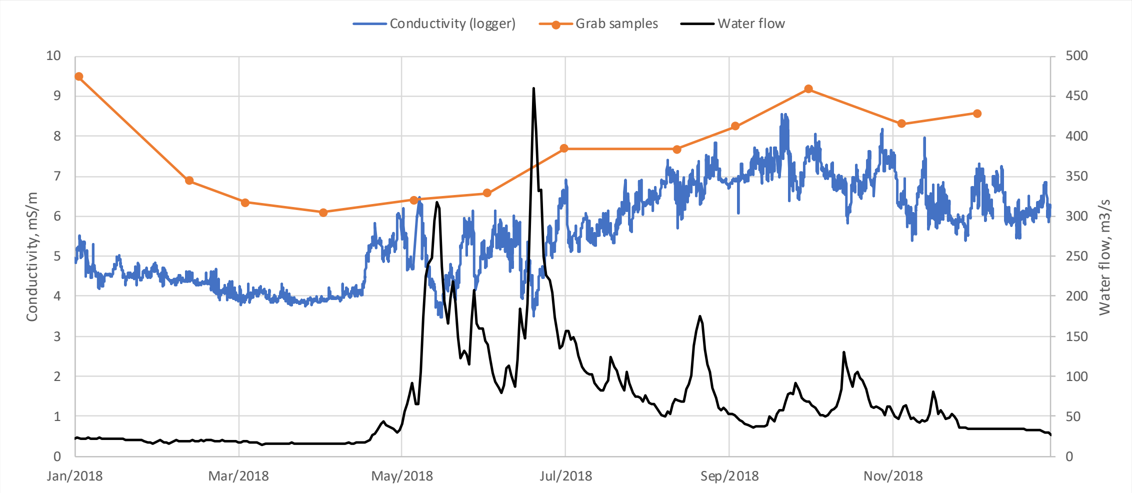

Figure 55: Conductivity and water flow at the outlet of River Målselva in 2018. The water flow data are from NVE.

increased temporarily, after which the ionic content of the water dropped when the flood reached its maximum. The same mechanism occurred during the second snow melt flood. Ionic dilution seemed to be less common during the rainfall floods that occurred later in the year, and in some cases high-flow events can also promote erosion and increased solute concentrations in water. There was generally good accordance between the sensor data and conductivity measured in grab samples.

Turbidity

A new turbidity sensor was installed in Målselva on May 31st. It nicely shows that the second snowmelt flood caused a large increase in the particle concentration, from a turbidity value of less than 5 to more than 50 NTU (Figure 56). It also demonstrates that monthly sampling easily misses major flood episodes in rivers. As the lower parts of the river are relatively flat with several meander bends, sediment is easily resuspended during high-flow events. Flood peaks are therefore usually accompanied by significant turbidity peaks in this river.

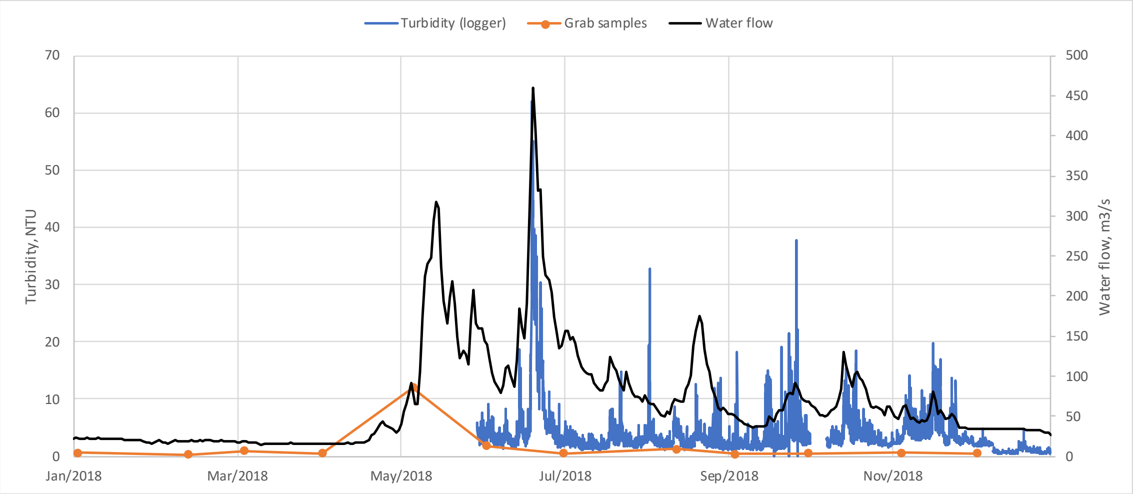

Figure 56: Turbidity and water flow at the outlet of Målselva in 2018. The water flow data are from NVE.

CDOM

The coloured dissolved organic matter (CDOM) signal was also closely connected to water flow in River Målselva. The CDOM values increased rapidly with the first melting snow and reached its maximum three weeks before the first snowmelt flood peaked in mid-May (Figure 57). After this maximum the CDOM concentrations clearly diluted as the water flow increased during the first half of May. The observed pattern was also supported by DOC concentrations measured in grab samples during the same period. CDOM also increased during the second snowmelt flood, but this time the CDOM and flow peaks coincided in time. The same was observed during the small autumn floods. The CDOM maxima were around the same level (~45 µg/l) both in spring, summer and autumn.

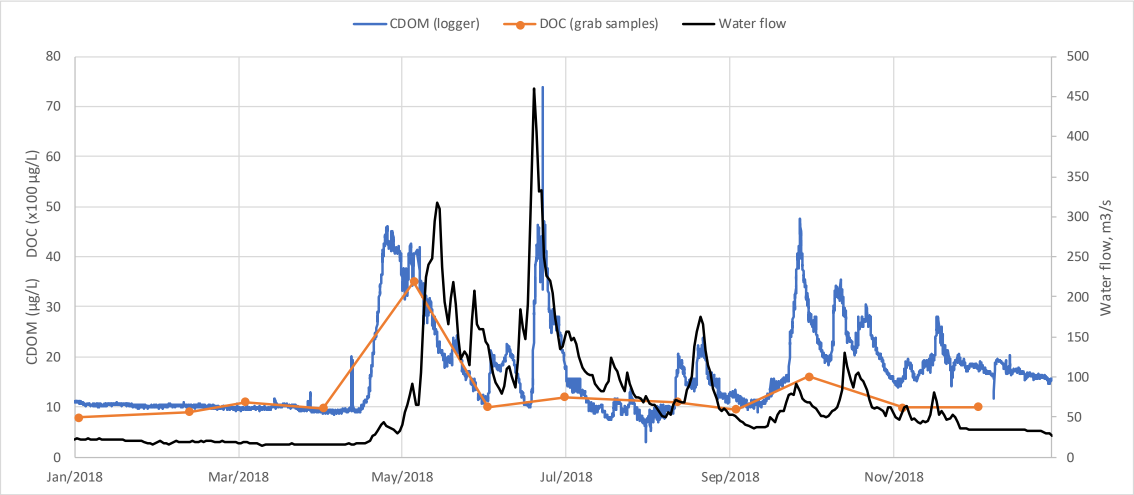

Figure 57: FDOM and water flow at the outlet of Målselva in 2018. The water flow data are from NVE.

4. Conclusion

The 2018 edition of the Norwegian River Monitoring Programme provided an update on the current status and trends in the water quality of 20 rivers distributed along the Norwegian coastline.

2018 was a warm year, with the 6th warmest summer on record. This was in accordance with the long-term trend analysis showing increasing temperatures. Precipitation in 2018 showed large regional deviations from the normal towards both extremes. No long-term trends in precipitation was found. Water discharge was in 2018 like the 5-year mean, and long-term trends showed increase in south-eastern rivers.

The water chemical parameters generally show regional variation across the country as a result of differences in e.g. climate, vegetation oil type and land use, and this was also the case in 2018. Rivers in the south-east drain boreal forests and agricultural areas, producing intermediate pH values (slightly acidic) and calcium concentrations, relatively high particle- and TOC concentrations, and intermediate-to-high nutrient levels. Southern and south-western rivers have naturally low buffering capacity from slowly weathering bedrock and thin soils and are also exposed to acidic deposition. Accordingly, the pH and concentrations of calcium, particles, TOC, and phosphate were low, while nitrogen levels were slightly elevated (due to atmospheric deposition). The middle and northern rivers were high in pH and relatively higher in calcium, resulting from more calcareous bedrock, and intermediate in particles, TOC, and nutrient content. Rivers Alna and Orreelva constitute exceptions to these general patterns, due to the larger influence from human activities (urbanization and agriculture). In 2018 the two rivers exceeded the national WFD good/moderate boundaries for tot-P and tot-N for their respective water types.

The ten additional rivers included in the water chemical assessment generally confirmed the geographical patterns already depicted by the 20 rivers of the regular programme. The southern rivers showed impacts from acid deposition by being slightly acidic and having somewhat higher nitrogen concentrations. These rivers are also naturally very low in calcium. These effects were diminishing when moving towards the rivers in the middle of the country.

The main findings from the long-term trend analysis of the water chemical parameters include increasing water discharge in some of the south-eastern rivers, which for River Drammenselva was associated with an increase in the transport of SPM, silica, and TOC to the coastal waters. No other rivers showed an increase in TOC concentration or load, which was surprising given the reported “browning effect” in Scandinavian and North America surface waters (from 1990 and onwards). This may be due to a combination of several reasons, such as the short TOC time period available for several of the rivers (from 1990 to 2018), catchment-specific factors that influence the hydrology at the catchment and thereby also the TOC levels (e.g. hydropower stations), and extreme observations in the dataset (e.g. the extremely high precipitation in year 2000). A more thorough investigation of the data should be conducted to verify the reason for the lack of significant TOC increase in these rivers . With only a few exceptions, both nitrate and ammonia were decreasing in the monitored rivers. This can be related to measures that have been implemented to reduce runoff of nutrients from agricultural areas or, in the south and south-west, to reduced atmospheric N deposition. It is also possible that decreasing inorganic nitrate trends may be related to increased plant uptake as a result of higher temperatures.

Metal concentrations were generally low, except for a few of the rivers with local industrial impact: In the north-eastern River Pasvikelva, located in the vicinity of a large Russian metallurgical complex, had relatively high concentrations of arsenic, lead, cadmium, copper, and nickel. The nickel concentration in 2018 was approximately 30% higher than the 5-year mean (2013-2017). Slightly higher metal concentrations compared to the other rivers were also found in Rivers Alna, Orkla, Storelva, and Orreelva. The frequency of metal analysis was reduced from monthly to quarterly from 2017. Considering the relatively high inter-annual variability in metal concentrations, and the elevated levels in several rivers, more frequent measurements should be considered. Trend analysis of metals was restricted by limited data and was not possible for the high-metal rivers Pasvikelva and Alna.

A qualitative analysis of DOM (spectroscopic) was included in the programme from 2017. In general, the seasonal variation was larger than the regional. During spring snow melt and intensive autumn precipitation, the DOM aromaticity and molecular size increased together with the TOC concentration. Increased surface runoff likely released DOM of different quality than under average flow conditions. Regionally, the south-eastern rivers were more distinct from the rest by having high aromatic material at relatively low TOC concentration. The warm summer of 2018 may have influenced the quality of the DOM. This was apparent as a distinct drop in aromaticity comparing the 2018 summer data to the 2017 data. The effect is likely to be caused by increased photodegradation.

To trace the sources of nutrients (NO_3 and PO_4, e.g. atmospheric deposition, fertilizer, etc.) in River Alna, samples were collected for analysis of N- and O-isotopic ratios in 2017 and 2018. The temporal variation was often larger than the between-site variability, indicating that differences in metabolic activity over time, in many cases, created a stronger isotopic signal than source-related differences between the sites. Moreover, for phosphate, there was a large overlap in isotope signature, which indicated that River Alna is affected by a combination of different sources. It therefore seems challenging to use the method as a source apportionment tool in complex urban rivers.

Based on two greenhouse gas emission scenarios (RCP4.5 and RCP8.5) run by an ensemble with ten combinations of climate models, hydrological and catchment models were used to simulate future hydrology and nitrate concentrations in River Storelva. Results showed no changes in water flow while a weak decline in nitrate concentration was found. Given that the scenarios assume that today’s N deposition level and fertilisation use are kept constant into the future, the simulations suggest that an increased temperature will result in an increased net retention of N in the catchment.

Short-term effects of climate variability were investigated using high-frequency sensor data from Rivers Storelva and Målselv. In River Storelva, the first rainwater flood after the very warm and dry summer of 2018 caused the pH to drop from pH 7.0 to 6.0 and the level of fluorescent DOM (FDOM) to nearly triple, only within a few days. Sensor data from River Målselva nicely demonstrated that snowmelt floods in spring and rainwater floods in the autumn lead to very different responses in different water quality parameters.

5. References

Aas W, Fiebig M, Solberg S, Yttri KE. 2019. Monitoring of long-range transported air pollutants in Norway. Annual report 2018. NILU report; 8/2019.

Aber JD, Nadelhoffer KJ, Steudler P, Melillo JM. Nitrogen Saturation in Northern Forest Ecosystems: Excess nitrogen from fossil fuel combustion may stress the biosphere. BioScience 1989; 39: 378-386.

Amberger A, Schmidt H-L. 1987. Natürliche Isotopengehalte von Nitrat als Indikatoren für dessen Herkunft. Geochim. Cosmochim. Acta 51, 2699-2705.

Beldring S, Engeland K, Roald LA, Sælthun NR, Voksø A. 2003. Estimation of parameters in a distributed precipitation-water discharge model for Norway. Hydrology and Earth System Sciences 7, 304-316.

Berglen TF, Nilsen A-C, Våler RL, Vadset M, Uggerud HT, Andresen E. Grenseområdene Norge-Russland. Luft- og nedbørkvalitet, årsrapport 2018. Norwegian Institute for Air Research (NILU), 2019.

Bergström, S. 1976. Development and application of a conceptual water discharge model for Scandinavian catchments. Swedish Meteorological and Hydrological Institute (SMHI). Reports RHO, No. 7. Norrköping, Sweden,134 pp.

Braaten HFV, Gundersen CB, Sample JE, Selvik JR, de Wit HA. Atmorpheric deposition and lateral transport of mercury in Norwegian drainage basins: A mercury budget for Norway. Norwegian Institute for Water research (NIVA), 2018, pp. 47.

Braaten HFV, Åkerblom S, de Wit HA, Skotte G, Rask M, Vuorenmaa J, et al. Spatial patterns and temporal trends of mercury in freshwater fish in Fennoscandia, 2017.

Chang, S. J.; Blake, R. E. Precise calibration of equilibrium oxygen isotope fractionations between dissolved phosphate and water from 3 to 37 °C. Geochem. Cosmochim. Acta. 2015, 150, 314−329.

Davies CL, Surridge BWJ, Gooddy DC. Phosphate oxygen isotopes within aquatic ecosystems: Global data synthesis and future research priorities. Science of The Total Environment 2014; 496: 563-575.

de Wit HA, Mulder J, Hindar A, Hole L. 2007. Long-term increase in dissolved organic carbon in streamwaters in Norway is response to reduced acid deposition. Environmental Science & Technology 41, 7706−7713.

de Wit HA, Valinia S, Weyhenmeyer GA, Futter MN, Kortelainen P, Austnes K, Hessen DO, Räike A, Laudon H, Vuorenmaa J. 2016. Current browning of surface waters will be further promoted by wetter climate. Environmental Science & Technology Letters 3 (12), 430-5.

Direktoratsguppen vanndirektivet 2018. Klassifisering av miljøtilstand i vann - Økologisk og kjemisk klassifiseringssystem for kystvann, grunnvann, innsjøer og elver. Veileder 02-2018, 222 pp.

Futter MN, Erlandsson MA, Butterfield D, Whitehead PG, Oni SK, Wade AJ. 2014 PERSiST: a flexible rainfall-water discharge modelling toolkit for use with the INCA family of models. Hydrology and Earth System Sciences.: 18(2):855-73.

Garmo Ø, Skancke LB. 2018. Overvåking av langtransportert forurenset luft og nedbør. Årsrapport – Vannkjemiske effekter 2017. NIVA report 7296-2018, Norwegian Environment Agency report M-1058, 89 pp.

Gooddy DC, Lapworth DJ, Ascott MJ, Bennett SA, Heaton TH, Surridge BW. 2015. Isotopic fingerprint for phosphorus in drinking water supplies. Environmental science and technology 49(15):9020-8.

Granger J, Sigman DM. 2009. Removal of nitrite with sulfamic acid for nitrate N and O isotope analysis with the denitrifier method. Rapid Communications in Mass Spectrometry 23, 3753-3762.

Grinde L, Heiberg H, Kristiansen S, Mamen J, Skaland RG, Szewczyk-Bartnicka H, Tajet HTT. 2018. Været i Norge. Klimatologisk oversikt. Året 2017. Met.no-info no.13/2017 ISSN 1894-759X, 24 pp.

Grinde L, Heiberg H, Kristiansen S, Mamen J, Skaland RG, Tajet HTT. Været i Norge. Klimatologisk oversikt. Året 2018. Norwegian Meteorological Institute Oslo, Norway, 2019, pp. 24.

Haaland S, Hongve D, Laudon H, Riise G, Vogt RD. 2010. Quantifying the Drivers of the Increasing Colored Organic Matter in Boreal Surface Waters. Environmental Science & Technology 2010, 44 (8), 2975–2980.

Hirsch RM, Slack JR. 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research 20, 727–732.

Jacob D, et al. 2014. EURO-CORDEX: new high-resolution climate change projections for European impact research. Regional environmental change: 14(2):563-78.

Kalbitz K, Schwesig D, Schmerwitz J, Kaiser K, Haumaier L, Glaser B, Ellerbrock R, Leinweber P. 2003. Changes in properties of soil-derived dissolved organic matter induced by biodegradation. Soil Biology and Biochemistry 35 (8), 1129-1142.

Kaste Ø, Skarbøvik E, Greipsland I, Gundersen CB, Austnes K, Skancke LB, et al. The Norwegian river monitoring programme - water quality status and trends 2017. Norwegian Environmental Agency report M 1168. NIVA report 7313-2018, 2018, pp. 101.

Kendall C. 1998. Tracing nitrogen sources and cycling in catchments. In: Kendall C and McDonnell JJ (Eds.), Isotope tracers in catchment hydrology. Elsevier Science, 519-576.

Kile MR, Persson J, Ranneklev SB, Myrvold KM. 2018. Klassifisering av økologisk og kjemisk tilstand i norske elver i tråd med vannforskriften. Miljødirektoratet Rapport M-1167-2018, 126 pp.

Lapworth, D.J., Surridge, B.W.J., Williams, P.J., Heaton, T.H.E., Gooddy, D.C. Method for Analysis of Phosphate 18O/16O Ratios for Waters with High C:P Ratios. British Geological Survey: Keyworth, Nottingham, U.K., 2014, Report OR/14/67.

Liu W, Xu X, McGoff NM, Eaton JM, Leahy P, Foley N, Kiely G. 2014. Spatial and Seasonal Variation of dissolved organic carbon (DOC) concentrations in Irish streams: importance of soil and topography characteristics. Environmental Management 53 (5), 959-67.

Marschner B, Kalbitz K. 2003. Controls of bioavailability and biodegradability of dissolved organic matter in soils. Geoderma 113 (3), 211-235.

Mayer B, Boyer EE, Goodale C., Jaworski NA, Van Breemen N, Howarth RW, Seitzinger S, Billen G, Lajtha K, Nadelhoffer K, van Dam D, Hetling LJ, Nosal M, Paustian K. 2002. Sources of nitrate in rivers draining sixteen watersheds in the northeastern U.S.: Isotopic constraints. Biogeochemistry 57/58, 171-197.

McGovern M, Evenset A, Borgå K, de Wit HA, Braaten HFV, Hessen DO, et al. Implications of Coastal Darkening for Contaminant Transport, Bioavailability, and Trophic Transfer in Northern Coastal Waters. Environmental Science & Technology 2019; 53: 7180-7182.

McLaughlin, K.; Silva, S.; Kendall, C.; Stuart-Williams, H.; Paytan, A. A precise method for the analysis of δ18O of dissolved inorganic phosphate in seawater. Limnol. Oceanogr.: Methods 2004, 2, 202.

MET. Klima i Norge 2100. In: Hanssen-Bauer; I, Førland; EJ, Haddeland; I, Hisdal; H, Mayer; S, Nesje; A, et al., editors. Meterologisk Institutt, 2015.

Monteith DT, Stoddard JL, Evans CD, De Wit HA, Forsius M, Høgåsen T, Wilander A, Skjelkvåle BL, Jeffries DS, Vuorenmaa J, Keller B. 2007. Dissolved organic carbon trends resulting from changes in atmospheric deposition chemistry. Nature 450 (7169), 537-540.

Nash JE, Sutcliffe JV. 1970. River flow forecasting through conceptual models. Part I: a discussion of principles. Journal of Hydrology 10, 282–290.

Norwegian Environment Agency. 2018. Liming in acidificated Norwegian salmon rivers – Monitoring in 2017. Report M-1133/2018, 392 pp.

Peuravuori J, Pihlaja K. 1997. Molecular size distribution and spectroscopic properties of aquatic humic substances. Analytica Chimica Acta 337 (2), 133-149.

Ryder, E., E. Jennings, E. De Eyto and others 2012. Temperature quenching of cdom fluorescence sensors: Temporal and spatial variability in the temperature response and a recommended temperature correction equation. Limnol. Oceanogr.: Methods 10: 1004-1010.

Selvik JR, Sample JE. 2018. Kildefordelte tilførsler av nitrogen og fosfor til norske kystområder i 2017 – tabeller, figurer og kart (in Norwegian). Miljødirektoratet rapport M-1252|2018, NIVA lnr. 7312-2018, 66 pp.

Sigman DM, Casciotti KL, Andreani M, Barford C, Galanter M, Böhlke JK. 2001. A bacterial method for the nitrogen isotopic analysis of nitrate in seawater and freshwater. Analytical Chemistry 73, 4145-4153.

Silva SR, Kendall C, Wilkinson DH, Ziegler AC, Chang CCY, Avanzino RJ. 2000. A new method for collection of nitrate from fresh water and the analysis of nitrogen and oxygen isotope ratios. Journal of Hydrology 228, 22-36.

Skarbøvik E, Allan I, Sample JE, Greipsland I, Selvik JR, Schanke LB, Beldring S, Stålnacke P, Kaste Ø. 2017. Riverine inputs and direct discharges to Norwegian coastal waters – 2016. NIVA report 7217-2017, Norwegian Environment Agency report M-862-2017, 206 pp.

Skarbøvik E, Allan I, Stålnacke P, Høgåsen T, Greipsland I, Selvik JR, Schanke LB, Beldring S. 2016. Riverine Inputs and Direct Discharges to Norwegian Coastal Waters – 2015. Norwegian Environment Agency report M-634-2016, NIVA report 7098-2016, 86 pp.

Skarbøvik E, Stålnacke PG, Kaste Ø, Selvik JR, Tjomsland T, Høgåsen T, Aakerøy PA, Beldring S. 2010. Riverine inputs and direct discharges to Norwegian coastal waters – 2009. Climate and Pollution Agency report TA-2726/2010, NIVA report 6053-2010, 75 pp.

Skarbøvik E, Stålnacke PG, Kaste Ø, Selvik JR, Borgvang SA, Tjomsland T, Høgåsen T, Beldring S. 2007. Riverine inputs and direct discharges to Norwegian coastal waters – 2006. OSPAR Commission. Norwegian Pollution Control Authority (SFT) report TA-2327/2007, NIVA report 5511-2007, 142 pp.

Stålnacke P, Haaland S, Skarbøvik E, Turtumøygard S, Nytrø TE, Selvik JR, Høgåsen T, Tjomsland T, Kaste Ø, Enerstvedt KE. 2009. Revision and assessment of Norwegian RID data 1990-2007. Bioforsk Report Vol. 4 No. 138., Norwegian Pollution Control Authority (SFT) report TA-2559/2009, 20pp.

Tipping E. 2002. Cation binding by humic substances. Cambridge environmental chemistry series 12. 434 p.

Wade, A.J., Durand, P., Beaujouan, V., Wessel, W.W., Raat, K.J., Whitehead, P.G., Butterfield, D., Rankinen, K. and Lepisto, A. (2002) A nitrogen model for European catchments: INCA, new model structure and equations, Hydrology and Earth System Sciences, 6, 559-582.

Weishaar JL, Aiken GR, Bergamaschi BA, Fram MS, Fujii R, Mopper K. 2003. Evaluation of Specific Ultraviolet Absorbance as an Indicator of the Chemical Composition and Reactivity of Dissolved Organic Carbon. Environmental Science & Technology, 37 (20), 4702-4708.

6. Appendix A

6.1 Riverine concentrations in 2018

Glomma ved Sarpsfoss

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
08.01.2018	643.53	7.12	5.22	5.20	3.73	4.00	3.90	204.00	6.00	9.00	4.00	410.00	<2.0	640.00	18.60	4.20									
05.02.2018	573.21	7.13	5.56	6.50	4.72	3.70	3.60	212.00	8.00	9.00	5.00	430.00	23.00	650.00	21.80	4.03	<0.002	0.14	0.20	0.01	1.25	5.70	0.72	0.24	<1.0
04.03.2018	396.01	7.14	5.52	1.20	1.09	3.10	3.10	137.00	3.00	5.00	4.00	330.00	36.00	555.00	11.50	3.86									
09.04.2018	338.03	7.25	6.94	18.00	10.30	3.70	3.70		15.00	38.00	9.00	730.00	58.00	885.00		4.46									
07.05.2018	1328.73	6.95	4.62	13.00	11.20	6.30	6.30	17.40	11.00	18.00	6.00	360.00	28.00	665.00	6.10	4.63	0.00	0.24	0.40	0.02	1.99	5.50	1.08	0.42	
14.05.2018	2996.34	7.04	3.09	15.00	19.30	5.30	5.20	52.30	20.00	32.00	5.00	100.00	<2.0	300.00	5.70	4.05									
23.05.2018	1957.28	7.12	3.76	5.90	7.58	3.50	3.50	342.00	9.00	16.00	4.00	150.00	<2.0	360.00	39.30	3.24									
04.06.2018	1250.81	7.37	4.42	1.90	3.47	2.70	2.60	4.80	4.00	7.00	2.00	260.00	15.00	360.00	<1.0	2.87									
13.06.2018	783.73	7.37	4.38	3.10	3.58	2.40	2.40	230.00	9.00	8.00	3.00	190.00	23.00	390.00	25.00	2.61									
25.06.2018	418.48	7.31	4.60	2.20	2.65	2.50	2.50	20.20	2.00	7.00	2.00	220.00	5.00	380.00	3.50	2.51									
18.07.2018	337.67	7.33	4.78	1.90	2.09	2.40	2.40	198.00	3.00	8.00	3.00	210.00	3.00	350.00	25.00	2.55									
06.08.2018	549.24	7.44	4.99	2.30	4.01	2.20	2.20	21.00	4.00	9.00	3.00	190.00	11.00	350.00	4.00	2.19	<0.002	0.15	0.10	0.00	1.06	1.10	0.49	0.09	<1.0
03.09.2018	632.65	7.47	4.58	1.60	2.72	2.60	2.60	14.00	2.00	6.00	1.00	200.00	12.00	350.00	2.80	2.31									
01.10.2018	664.20	7.33	4.71	2.20	2.73	3.30	3.40	204.00	8.00	11.00	3.00	350.00	10.00	440.00	28.00	2.74	0.00	0.12	0.10	0.00	1.26	3.00	0.55	0.13	<1.0
06.11.2018	582.13	7.18	4.99	2.00	2.14	2.80	2.70	17.00	2.00	6.00	3.00	530.00	<2.0	660.00	1.70	3.02									
03.12.2018	777.19	7.16	5.89	14.00	12.10	5.50	5.50	369.00	16.00	23.00	8.00	1190.00	<2.0	1400.00	34.30	4.39									
Lower avg.	889.33	7.23	4.88	6.00	5.84	3.50	3.47	136.18	7.62	13.25	4.06	365.62	14.00	545.94	15.15	3.35	0.00	0.16	0.20	0.01	1.39	3.82	0.71	0.22	0.00
Upper avg..	889.33	7.23	4.88	6.00	5.84	3.50	3.47	136.18	7.62	13.25	4.06	365.62	14.62	545.94	15.22	3.35	0.00	0.16	0.20	0.01	1.39	3.82	0.71	0.22	1.00
Minimum	337.67	6.95	3.09	1.20	1.09	2.20	2.20	4.80	2.00	5.00	1.00	100.00	2.00	300.00	1.00	2.19	0.00	0.12	0.10	0.00	1.06	1.10	0.49	0.09	1.00
Maximum	2996.34	7.47	6.94	18.00	19.30	6.30	6.30	369.00	20.00	38.00	9.00	1190.00	58.00	1400.00	39.30	4.63	0.00	0.24	0.40	0.02	1.99	5.70	1.08	0.42	1.00
More than 70% >LOD	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	16.00	16.00	16.00	16.00	16.00	16.00	16.00	15.00	16.00	16.00	16.00	16.00	16.00	16.00	15.00	16.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00
St.dev	706.53	0.15	0.87	5.67	4.98	1.23	1.22	124.90	5.54	9.85	2.14	272.00	15.76	282.75	12.94	0.85	0.00	0.05	0.14	0.01	0.41	2.19	0.27	0.15	0.00

Alna

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
04.01.2018	1.11	7.90	127.00	4.10	3.62	4.20	3.50	485.00	4.00	8.00		290.00	9.00	490.00	42.30	7.14									
06.02.2018	0.67	7.90	66.50	3.50	3.54	4.20	3.90	568.00	46.00	60.00	41.00	910.00	230.00	1600.00	59.80	7.18	0.01	0.24	0.24	0.04	2.36	9.70	0.68	0.23	1.00
07.03.2018	0.48	7.97	68.70	4.20	3.37	2.70	2.60	428.00	50.00	65.00	40.00	760.00	270.00	1600.00	51.40	6.39									
05.04.2018	1.98	7.79	97.60	97.00	116.20	16.20	4.40	9100.00	210.00	240.00	14.00	1190.00	11.00	1900.00	361.00	9.21									
03.05.2018	2.24	7.92	39.90	8.80	8.01	4.10	4.00	86.30	32.00	28.00	11.00	660.00	<2.0	1030.00	7.80	6.04	0.02	0.38	0.56	0.04	3.02	11.60	0.95	0.50	1.00
05.06.2018	0.32	8.09	54.10	2.80	3.96	3.00	2.90	317.00	42.00	56.00	34.00	1100.00	22.00	1500.00	22.00	6.39									
03.07.2018	0.32	8.08	51.20	3.50	3.77	3.20	3.10	32.00	52.00	68.00	40.00	1400.00	26.00	1900.00	3.80	6.66									
07.08.2018	0.29	8.10	44.10	2.50	2.22	3.20	3.10	23.00	56.00	49.00	5.00	1150.00	<2.0	1700.00	3.80	6.90	<0.002	0.45	0.20	0.02	1.92	4.80	0.63	0.13	<1.0
04.09.2018	0.26	8.06	46.90	3.50	2.95	2.60	2.88	32.00	67.00	89.00	55.00	1160.00	<2.0	1700.00	9.90	6.77									
03.10.2018	0.95	8.01	39.60	9.50	4.98	2.60	2.70	49.00	51.00	62.00	39.00	1180.00	<2.0	1600.00	5.50	6.24	0.01	0.34	0.55	0.03	3.58	11.80	0.94	0.56	<1.0
05.11.2018	1.00	7.95	39.10	3.70	2.82	3.00	3.00	300.00	37.00	46.00	29.00	1190.00	75.00	1600.00	22.00	7.18									
05.12.2018	3.70	8.10	30.10	8.80	14.80	4.60	4.40	777.00	38.00	51.00	18.00	1020.00	<2.0	1300.00	62.30	7.50									
Lower avg.	1.11	7.99	58.73	12.66	14.19	4.47	3.37	1016.44	57.08	68.50	29.64	1000.83	53.58	1493.33	54.30	6.97	0.01	0.35	0.39	0.03	2.72	9.47	0.80	0.35	0.50
Upper avg..	1.11	7.99	58.73	12.66	14.19	4.47	3.37	1016.44	57.08	68.50	29.64	1000.83	54.42	1493.33	54.30	6.97	0.01	0.35	0.39	0.03	2.72	9.47	0.80	0.35	1.00
Minimum	0.26	7.79	30.10	2.50	2.22	2.60	2.60	23.00	4.00	8.00	5.00	290.00	2.00	490.00	3.80	6.04	0.00	0.24	0.20	0.02	1.92	4.80	0.63	0.13	1.00
Maximum	3.70	8.10	127.00	97.00	116.20	16.20	4.40	9100.00	210.00	240.00	55.00	1400.00	270.00	1900.00	361.00	9.21	0.02	0.45	0.56	0.04	3.58	11.80	0.95	0.56	1.00
More than 70% >LOD	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	1.05	0.10	28.11	26.68	32.31	3.76	0.65	2557.69	50.60	57.69	15.58	302.79	94.04	395.48	99.09	0.83	0.01	0.09	0.19	0.01	0.73	3.26	0.17	0.21	0.00

Drammenselva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
02.01.2018	309.35	7.09	3.64	<0.3	0.45	2.90	3.00	110.00	1.00	3.00	1.00	240.00	7.00	360.00	9.40	3.11									
06.02.2018	353.81	7.04	3.40	<0.3	0.70	2.50	2.50	99.10	<1.0	3.00	3.00	220.00	11.00	365.00	6.00	2.74	<0.002	0.11	0.04	0.01	0.48	1.20	0.34	0.07	<1.0
06.03.2018	288.31	7.13	3.73	<0.3	0.59	2.60	2.50	87.90	<1.0	3.00	2.00	230.00	8.00	390.00	8.20	2.76									
03.04.2018	241.80	7.24	4.07	0.47	0.86	2.30	2.40	162.00	1.00	4.00	2.00	300.00	15.00	395.00	11.60	2.76									
08.05.2018	846.09	7.16	4.19	2.20	3.79	3.50	3.40		3.00	8.00	2.00	250.00	8.00	440.00		3.00	0.00	0.17	0.17	0.01	0.71	2.70	0.42	0.11	<1.0
15.05.2018	1104.76	7.01	3.14	2.70	4.68	3.10	3.00	288.00	4.00	7.00	2.00	180.00	<2.0	350.00	41.50	2.91									
28.05.2018	543.85	7.05	3.52	0.93	1.71	3.40	3.50	12.80	2.00	5.00	2.00	200.00	13.00	340.00	1.90	2.89									
05.06.2018	338.70	7.20	3.55	1.10	1.82	3.40	3.40	239.00	2.00	6.00	2.00	150.00	23.00	300.00	23.40	2.70									
12.06.2018	320.03	7.17	3.14	1.10	1.75	3.20	3.00	246.00	2.00	6.00	2.00	110.00	12.00	260.00	<1.0	2.44									
26.06.2018	128.98	7.25	3.73	0.74	1.24	3.20	3.10	16.20	1.00	5.00	2.00	180.00	30.00	330.00	1.30	2.51									
02.07.2018	98.13	7.18	3.62	0.59	1.10	3.10	3.10	9.10	2.00	5.00	2.00	170.00	29.00	350.00	2.40	2.38									
06.08.2018	139.81	7.26	3.06	1.00	1.62	2.70	2.60	312.00	2.00	5.00	3.00	82.00	19.00	210.00	<1.0	2.09	0.00	0.15	0.08	0.01	0.70	1.20	0.35	0.10	<1.0
04.09.2018	124.36	7.20	3.33	0.67	0.99	2.90	2.80	229.00	<1.0	4.00	<1.0	130.00	27.00	290.00	26.00	2.06									
01.10.2018	253.33	7.17	3.31	0.70	1.25	3.20	3.40	185.00	<1.0	4.00	2.00	200.00	<2.0	280.00	22.00	2.42	<0.002	0.14	0.04	0.00	0.58	1.10	0.50	0.13	<1.0
05.11.2018	262.18	7.02	3.82	0.67	0.87	3.50	3.40	15.00	1.00	4.00	2.00	370.00	15.00	510.00	1.10	2.96									
03.12.2018	360.94	7.00	4.02	3.40	3.29	3.80	3.80	228.00	4.00	8.00	2.00	410.00	<2.0	560.00	24.70	3.34									
Lower avg.	357.15	7.14	3.58	1.02	1.67	3.08	3.06	149.27	1.56	5.00	1.94	213.88	13.56	358.12	11.97	2.69	0.00	0.14	0.08	0.01	0.62	1.55	0.40	0.10	0.00
Upper avg..	357.15	7.14	3.58	1.07	1.67	3.08	3.06	149.27	1.81	5.00	2.00	213.88	13.94	358.12	12.10	2.69	0.00	0.14	0.08	0.01	0.62	1.55	0.40	0.10	1.00
Minimum	98.13	7.00	3.06	0.30	0.45	2.30	2.40	9.10	1.00	3.00	1.00	82.00	2.00	210.00	1.00	2.06	0.00	0.11	0.04	0.00	0.48	1.10	0.34	0.07	1.00
Maximum	1104.76	7.26	4.19	3.40	4.68	3.80	3.80	312.00	4.00	8.00	3.00	410.00	30.00	560.00	41.50	3.34	0.00	0.17	0.17	0.01	0.71	2.70	0.50	0.13	1.00
More than 70% >LOD	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	16.00	16.00	16.00	16.00	16.00	16.00	16.00	15.00	16.00	16.00	16.00	16.00	16.00	16.00	15.00	16.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	270.22	0.09	0.34	0.91	1.22	0.41	0.41	106.56	1.05	1.63	0.52	88.11	9.40	89.40	12.49	0.36	0.00	0.03	0.06	0.00	0.11	0.77	0.07	0.02	0.00

Numedalslågen

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
02.01.2018	82.87	6.88	4.45	2.40	3.31	3.40	3.40	218.00	4.00	9.00	3.00	300.00	22.00	535.00		4.22									
06.02.2018	115.79	6.84	3.60	1.50	1.74	2.90	2.80	248.00	2.00	6.00	2.00	240.00	72.00	515.00	28.70	3.54	0.01	0.12	0.14	0.01	0.53	3.00	0.31	0.09	<1.0
05.03.2018	104.07	7.66	6.23	1.60	3.96	2.20	2.30	372.00	4.00	7.00	2.00	180.00	80.00	465.00	39.30	3.90									
03.04.2018	84.24	7.08	3.92	0.76	1.46	2.20	2.10	165.00	1.00	5.00		240.00	74.00	465.00	22.30	3.21									
02.05.2018	271.85	6.77	2.77	5.50	7.42	5.40	5.40	464.00	9.00	13.00	2.00	250.00	14.00	495.00	43.20	3.86	0.01	0.21	0.40	0.02	0.82	5.40	0.46	0.25	<1.0
04.06.2018	87.53	6.88	2.33	1.30	2.61	3.20	3.20	226.00	4.00	7.00	3.00	99.00	33.00	230.00	26.00	2.81									
02.07.2018	67.66	7.04	2.40	0.63	1.20	2.10	2.00		1.00	4.00	2.00	65.00	20.00	180.00		2.14									
06.08.2018	60.56	7.00	2.32	0.70	1.20	2.20	2.10	150.00	6.00	6.00	2.00	53.00	23.00	160.00	<1.0	1.90	0.01	0.14	0.10	0.01	0.49	0.96	0.21	0.07	<1.0
10.09.2018	282.60	6.91	3.23	8.10	13.30	5.07	4.61	78.00	16.00	32.00	5.00	270.00	53.00	510.00	10.00	2.96									
01.10.2018	57.14	6.87	2.98	1.30	0.86	5.50	5.50	239.00	1.00	6.00	2.00	130.00	58.00	280.00	29.00	3.19	0.00	0.18	0.27	0.01	0.76	3.60	0.40	0.13	<1.0
05.11.2018	94.09	6.95	3.92	1.80	2.29	4.20	4.10	26.00	3.00	7.00	3.00	320.00	53.00	490.00	2.00	3.79									
03.12.2018	150.61	6.80	5.17	11.00	10.80	5.30	5.20	390.00	16.00	22.00	6.00	740.00	14.00	1100.00	25.80	5.04									
Lower avg.	121.58	6.97	3.61	3.05	4.18	3.64	3.56	234.18	5.58	10.33	2.91	240.58	43.00	452.08	22.63	3.38	0.01	0.16	0.23	0.01	0.65	3.24	0.34	0.13	0.00
Upper avg..	121.58	6.97	3.61	3.05	4.18	3.64	3.56	234.18	5.58	10.33	2.91	240.58	43.00	452.08	22.73	3.38	0.01	0.16	0.23	0.01	0.65	3.24	0.34	0.13	1.00
Minimum	57.14	6.77	2.32	0.63	0.86	2.10	2.00	26.00	1.00	4.00	2.00	53.00	14.00	160.00	1.00	1.90	0.00	0.12	0.10	0.01	0.49	0.96	0.21	0.07	1.00
Maximum	282.60	7.66	6.23	11.00	13.30	5.50	5.50	464.00	16.00	32.00	6.00	740.00	80.00	1100.00	43.20	5.04	0.01	0.21	0.40	0.02	0.82	5.40	0.46	0.25	1.00
More than 70% >LOD	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	11.00	12.00	12.00	12.00	10.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	77.04	0.24	1.21	3.36	4.12	1.38	1.36	132.75	5.38	8.38	1.38	181.45	24.77	247.88	14.35	0.88	0.00	0.04	0.14	0.01	0.16	1.83	0.11	0.08	0.00

Skienselva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
08.01.2018	354.02	6.65	1.95	<0.3	0.31	2.60	2.50	81.80	2.00	2.00	2.00	140.00	2.00	285.00	5.30	2.36									
06.02.2018	271.52	6.66	1.94	<0.3	0.48	2.50	2.50	77.20	1.00	3.00	1.00	140.00	4.00	260.00	8.00	2.27	<0.002	0.10	0.05	0.01	0.60	2.30	0.20	0.09	<1.0
08.03.2018	297.33	6.81	1.84	<0.3	0.45	2.40	2.40	93.10	<1.0	3.00	2.00	120.00	5.00	255.00	9.30	2.23									
04.04.2018	268.17	6.85	1.97	<0.3	0.51	2.30	2.30	103.00	<1.0	3.00	2.00	150.00	8.00	245.00	8.06	2.23									
09.05.2018	498.30	6.69	1.97	0.56	0.89	2.30	2.30	10.30	1.00	3.00	1.00	130.00	4.00	275.00	1.30	2.21	<0.002	0.10	0.05	0.01	0.43	2.20	0.16	0.06	<1.0
11.06.2018	230.64	6.71	1.80	0.34	0.53	2.10	2.30	127.00	<1.0	2.00	1.00	95.00	20.00	210.00	<1.0	2.03									
04.07.2018	141.87	6.77	1.73	0.49	0.71	2.40	2.50		<1.0	5.00	<1.0	84.00	17.00	210.00		1.91									
13.08.2018	190.53	6.92	1.77	0.46	0.77	2.40	2.00	6.20	<1.0	2.00	<1.0	58.00	17.00	160.00	<1.0	1.77	<0.002	0.08	0.17	0.01	0.50	4.90	0.15	0.06	<1.0
04.09.2018	226.14	6.91	1.72	<0.3	0.45	1.79	1.78	7.10	<1.0	3.00	<1.0	62.00	19.00	160.00	1.60	1.60									
01.10.2018	208.30	6.81	1.75	0.44	0.58	2.40	2.30	145.00	<1.0	3.00	3.00	100.00	16.00	170.00	20.00	1.80	<0.002	0.07	0.04	0.01	0.32	1.40	0.16	0.05	<1.0
05.11.2018	292.94	6.77	1.82	0.32	0.42	2.30	2.30	11.00	<1.0	3.00	4.00	110.00	13.00	190.00	<1.0	1.95									
03.12.2018	425.83	6.70	2.26	0.84	1.19	2.60	2.60	59.20	3.00	4.00	2.00	190.00	<2.0	280.00	3.24	2.51									
Lower avg.	283.80	6.77	1.88	0.29	0.61	2.34	2.31	65.54	0.58	3.00	1.50	114.92	10.42	225.00	5.16	2.07	0.00	0.09	0.08	0.01	0.46	2.70	0.17	0.06	0.00
Upper avg..	283.80	6.77	1.88	0.41	0.61	2.34	2.31	65.54	1.25	3.00	1.75	114.92	10.58	225.00	5.44	2.07	0.00	0.09	0.08	0.01	0.46	2.70	0.17	0.06	1.00
Minimum	141.87	6.65	1.72	0.30	0.31	1.79	1.78	6.20	1.00	2.00	1.00	58.00	2.00	160.00	1.00	1.60	0.00	0.07	0.04	0.01	0.32	1.40	0.15	0.05	1.00
Maximum	498.30	6.92	2.26	0.84	1.19	2.60	2.60	145.00	3.00	5.00	4.00	190.00	20.00	285.00	20.00	2.51	0.00	0.10	0.17	0.01	0.60	4.90	0.20	0.09	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	101.12	0.09	0.15	0.16	0.25	0.22	0.23	50.65	0.62	0.85	0.97	38.16	7.06	47.48	5.80	0.27	0.00	0.01	0.06	0.00	0.12	1.52	0.02	0.02	0.00

Otra

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
03.01.2018	188.14	5.99	1.85	0.77	1.12	2.90	2.90	188.00	1.00	4.00	1.00	88.00	16.00	250.00		1.92									
07.02.2018	187.45	5.99	1.57	<0.3	0.54	2.70	2.70	151.00	<1.0	3.00	2.00	96.00	14.00	205.00	12.50	1.82	<0.002	0.10	0.20	0.01	0.33	2.60	0.45	0.07	<1.0
06.03.2018	185.98	6.16	1.37	<0.3	0.58	2.00	1.90	142.00	<1.0	2.00	2.00	69.00	10.00	175.00	10.90	1.63									
03.04.2018	109.07	6.33	1.47	<0.3	0.51	1.70	1.70	134.00	<1.0	3.00	2.00	95.00	12.00	180.00	6.90	1.47									
07.05.2018	226.99	6.34	1.41	0.42	0.98	2.40	2.30	5.30	<1.0	4.00	2.00	81.00	11.00	230.00	<1.0	1.28	<0.002	0.10	0.20	0.01	0.34	2.10	0.41	0.07	<1.0
04.06.2018	86.62	6.37	1.34	0.45	1.00	2.10	1.80	222.00	<1.0	2.00	2.00	50.00	16.00	140.00	<1.0	0.87									
02.07.2018	64.91	6.19	1.31	0.47	1.00	1.80	1.70	14.00	<1.0	3.00	1.00	53.00	6.00	140.00	1.20	0.77									
06.08.2018	57.69	6.43	1.20	0.43	0.82	1.70	1.60	12.00	1.00	3.00	2.00	33.00	9.00	93.00	2.40	0.80	0.00	0.09	0.09	0.01	0.43	1.10	0.15	0.05	<1.0
03.09.2018	142.60	6.39	1.21	0.48	0.90	1.80	1.70	1.40	<1.0	2.00	<1.0	39.00	11.00	130.00	<1.0	0.87									
01.10.2018	199.32	6.25	1.40	0.44	0.46	2.80	2.70	218.00	<1.0	3.00	1.00	66.00	9.00	140.00	19.00	1.36	<0.002	0.11	0.18	0.01	0.35	2.20	0.44	0.06	<1.0
05.11.2018	169.27	6.19	1.51	0.40	0.71	2.60	2.50	18.00	<1.0	2.00	2.00	68.00	16.00	160.00	1.90	1.60									
04.12.2018	225.90	6.18	2.05	0.68	1.00	3.90	3.70	248.00	2.00	5.00	1.00	110.00	25.00	240.00	15.90	2.04									
Lower avg.	153.66	6.23	1.47	0.38	0.80	2.37	2.27	112.81	0.33	3.00	1.50	70.67	12.92	173.58	6.43	1.37	0.00	0.10	0.17	0.01	0.36	2.00	0.36	0.06	0.00
Upper avg..	153.66	6.23	1.47	0.45	0.80	2.37	2.27	112.81	1.08	3.00	1.58	70.67	12.92	173.58	6.70	1.37	0.00	0.10	0.17	0.01	0.36	2.00	0.36	0.06	1.00
Minimum	57.69	5.99	1.20	0.30	0.46	1.70	1.60	1.40	1.00	2.00	1.00	33.00	6.00	93.00	1.00	0.77	0.00	0.09	0.09	0.01	0.33	1.10	0.15	0.05	1.00
Maximum	226.99	6.43	2.05	0.77	1.12	3.90	3.70	248.00	2.00	5.00	2.00	110.00	25.00	250.00	19.00	2.04	0.00	0.11	0.20	0.01	0.43	2.60	0.45	0.07	1.00
More than 70% >LOD	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	60.30	0.15	0.25	0.14	0.23	0.66	0.65	96.56	0.29	0.95	0.51	24.08	4.96	49.01	6.76	0.45	0.00	0.01	0.05	0.00	0.05	0.64	0.14	0.01	0.00

Orreelva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
02.01.2018	9.60	7.62	17.30	6.20	7.03	5.50	5.40	1440.00	49.00	77.00	36.00	1100.00	<2.0	1700.00	176.00	4.50									
06.02.2018	3.78	7.43	16.90	5.60	9.58	5.20	4.90	2190.00	42.00	71.00	23.00	1200.00	4.00	2000.00	236.00	2.76	<0.002	0.24	0.30	0.02	1.76	3.50	1.08	0.26	1.00
05.03.2018	1.20	7.52	17.20	6.40	15.40	5.00	4.70	2000.00	22.00	60.00	15.00	1100.00	<2.0	2000.00	259.00	1.59									
03.04.2018	1.42	7.68	18.00	5.50	9.66	4.80	4.50	1930.00	17.00	45.00	11.00	960.00	26.00	1740.00	283.00	0.70									
07.05.2018	1.89	7.79	18.80	1.40	4.23	4.00	3.90		7.00	26.00	7.00	330.00	43.00	840.00		0.08	<0.002	0.19	0.06	0.01	1.34	1.70	0.88	0.09	<1.0
04.06.2018	0.39	7.81	20.60	7.90	19.40	5.70	5.30	1510.00	17.00	39.00	8.00	<2.0	22.00	480.00	217.00	0.55									
02.07.2018	0.48	8.17	22.40	3.00	6.66	5.60	5.20	195.00	8.00	33.00	7.00	<2.0	<2.0	540.00	25.20	0.78									
06.08.2018	0.58	8.53	26.00	3.10	3.97	7.50	7.10	1180.00	13.00	37.00	8.00	<2.0	<2.0	700.00	179.00	1.26	<0.002	0.38	0.11	<0.003	1.48	2.30	1.04	0.07	<1.0
03.09.2018	2.11	7.98	21.70	5.70	13.70	6.40	6.10	364.00	5.00	43.00	6.00	<2.0	56.00	640.00	54.00	1.44									
01.10.2018	13.44	7.87	21.30	16.00	29.98	6.60	5.90	5550.00	31.00	130.00	9.00	480.00	28.00	1600.00	705.00	0.59									<1.0
05.11.2018	6.52	7.67	18.40	8.30	14.10	6.20	5.90	3120.00	23.00	45.00	8.00	960.00	21.00	1600.00	426.00	1.55									
03.12.2018	9.72	7.67	18.80	10.00	7.68	5.90	5.70	940.00	29.00	62.00	12.00	1190.00	<2.0	1900.00	60.20	3.24									
Lower avg.	4.26	7.81	19.78	6.59	11.78	5.70	5.38	1856.27	21.92	55.67	12.50	610.00	16.67	1311.67	238.22	1.59	0.00	0.27	0.16	0.01	1.53	2.50	1.00	0.14	0.25
Upper avg..	4.26	7.81	19.78	6.59	11.78	5.70	5.38	1856.27	21.92	55.67	12.50	610.67	17.50	1311.67	238.22	1.59	0.00	0.27	0.16	0.01	1.53	2.50	1.00	0.14	1.00
Minimum	0.39	7.43	16.90	1.40	3.97	4.00	3.90	195.00	5.00	26.00	6.00	2.00	2.00	480.00	25.20	0.08	0.00	0.19	0.06	0.00	1.34	1.70	0.88	0.07	1.00
Maximum	13.44	8.53	26.00	16.00	29.98	7.50	7.10	5550.00	49.00	130.00	36.00	1200.00	56.00	2000.00	705.00	4.50	0.00	0.38	0.30	0.02	1.76	3.50	1.08	0.26	1.00
More than 70% >LOD	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	no	yes	yes	no	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	4.00
St.dev	4.46	0.30	2.70	3.81	7.41	0.92	0.84	1481.72	13.82	28.10	8.77	520.81	18.42	612.68	193.50	1.30	0.00	0.10	0.13	0.01	0.21	0.92	0.11	0.11	0.00

Vosso (Bolstadelvi)

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
02.01.2018	34.01	6.52	1.79	0.73	0.85	1.30	1.30	88.50	3.00	6.00	3.00	160.00	8.00	235.00	11.60	1.31									
05.02.2018	17.24	6.38	1.90	<0.3	0.36	1.00	1.00	105.00	1.00	3.00	2.00	130.00	6.00	210.00	6.50	1.02	<0.002	0.07	0.05	0.00	0.30	1.10	0.31	0.05	<1.0
06.03.2018	8.09	6.50	1.63	<0.3	0.33	0.80	0.74	113.00	<1.0	3.00	2.00	94.00	3.00	165.00	11.00	0.86									
03.04.2018	8.66	6.52	1.60	<0.3	0.27	0.87	0.91	78.50	<1.0	3.00	2.00	100.00	3.00	148.00	2.80	0.86									
07.05.2018	353.10	6.48	2.02	0.41	0.63	1.20	1.30		2.00	2.00	1.00	190.00	10.00	310.00		1.28	<0.002	0.08	0.04	0.01	0.36	1.10	0.33	0.04	<1.0
04.06.2018	180.63	6.47	0.97	0.31	1.10	0.80	0.66	91.00	1.00	3.00	1.00	50.00	16.00	85.00	<1.0	0.74									
02.07.2018	42.93	6.36	1.01	<0.3	0.43	0.65	0.58	4.10	<1.0	2.00	1.00	43.00	4.00	73.00	1.20	0.60									
06.08.2018	86.75	6.48	1.02	<0.3	0.46	0.96	0.89	9.00	1.00	3.00	2.00	28.00	5.00	66.00	1.60	0.61	<0.002	0.07	0.05	0.01	0.52	0.84	0.25	0.03	1.00
03.09.2018	31.46	6.50	1.17	0.40	0.41	2.00	1.50	<1.0	<1.0	3.00	1.00	63.00	4.00	140.00	1.50	0.87									
01.10.2018	261.18	6.43	1.37	0.74	0.93	1.50	1.50	180.00	1.00	4.00	2.00	120.00	<2.0	160.00	16.00	1.11	<0.002	0.09	0.10	0.01	0.39	0.97	0.32	0.08	<1.0
05.11.2018	72.60	6.41	1.24	0.76	0.87	1.20	1.20	140.00	2.00	4.00	2.00	79.00	<2.0	130.00	6.70	1.04									
03.12.2018	41.23	6.45	1.29	0.48	0.52	1.20	1.20	111.00	2.00	3.00	2.00	88.00	4.00	160.00	8.67	1.02									
Lower avg.	94.82	6.46	1.42	0.32	0.60	1.12	1.06	83.65	1.08	3.25	1.75	95.42	5.25	156.83	6.14	0.94	0.00	0.08	0.06	0.01	0.39	1.00	0.30	0.05	0.25
Upper avg..	94.82	6.46	1.42	0.44	0.60	1.12	1.06	83.74	1.42	3.25	1.75	95.42	5.58	156.83	6.23	0.94	0.00	0.08	0.06	0.01	0.39	1.00	0.30	0.05	1.00
Minimum	8.09	6.36	0.97	0.30	0.27	0.65	0.58	1.00	1.00	2.00	1.00	28.00	2.00	66.00	1.00	0.60	0.00	0.07	0.04	0.00	0.30	0.84	0.25	0.03	1.00
Maximum	353.10	6.52	2.02	0.76	1.10	2.00	1.50	180.00	3.00	6.00	3.00	190.00	16.00	310.00	16.00	1.31	0.00	0.09	0.10	0.01	0.52	1.10	0.33	0.08	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	111.42	0.05	0.36	0.19	0.27	0.37	0.31	57.76	0.67	1.06	0.62	48.31	4.06	70.07	5.11	0.23	0.00	0.01	0.03	0.00	0.09	0.12	0.04	0.02	0.00

Orkla

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
02.01.2018	62.67	7.49	7.08	<0.3	0.33	2.20	2.20	97.20	1.00	3.00	2.00	280.00	7.00	370.00		3.30									
13.02.2018	57.99	7.42	5.94	<0.3	0.45	1.60	1.60	122.00	1.00	3.00	2.00	130.00	7.00	275.00	8.00	2.96	<0.002	0.07	0.01	0.02	2.41	6.20	0.65	0.12	<1.0
12.03.2018	16.03	7.67	9.74	<0.3	0.55	1.60	1.50	103.00	1.00	3.00	1.00	350.00	11.00	505.00	7.40	3.79									
03.04.2018	16.81	7.63	9.21	<0.3	0.69	1.50	1.50	142.00	1.00	3.00	3.00	330.00	8.00	420.00	14.40	3.66									
02.05.2018	91.82	7.23	5.13	0.76	1.51	4.60	4.50		2.00	5.00	2.00	150.00	3.00	350.00		3.11	<0.002	0.11	0.04	0.04	7.13	13.40	0.99	0.26	<1.0
04.06.2018	33.20	7.59	6.68	0.82	1.94	3.10	3.10	224.00	2.00	6.00	2.00	200.00	<2.0	330.00	17.90	2.66									
02.07.2018	30.63	7.64	6.52	0.49	0.84	1.60	1.40	10.20	1.00	5.00	2.00	140.00	3.00	240.00	1.30	2.11									
14.08.2018	40.07	7.58	5.96	0.70	0.95	6.70	6.40	217.00	<1.0	6.00	2.00	96.00	5.00	300.00	24.00	3.32	<0.002	0.15	0.03	0.02	4.16	6.50	1.22	0.28	<1.0
10.09.2018	21.61	7.84	8.32	0.45	0.28	3.70	3.20	<1.0	<1.0	4.00	2.00	180.00	<2.0	330.00	<1.0	2.89									
01.10.2018	76.59	7.43	6.00	0.66	1.12	5.90	5.80	202.00	<1.0	5.00	2.00	190.00	2.00	320.00	16.00	2.91	<0.002	0.14	0.03	0.06	6.05	17.80	0.85	0.30	<1.0
12.11.2018	63.54	7.37	5.78	0.67	0.98	3.30	3.30	181.00	2.00	3.00	2.00	240.00	<2.0	380.00	19.00	3.21									
05.12.2018	41.71	7.49	6.64	0.41	0.68	2.00	2.00	132.00	2.00	3.00	1.00	190.00	8.00	300.00	7.80	3.11									
Lower avg.	46.06	7.53	6.92	0.41	0.86	3.15	3.04	130.04	1.08	4.08	1.92	206.33	4.50	343.33	11.58	3.09	0.00	0.12	0.03	0.04	4.94	10.98	0.93	0.24	0.00
Upper avg..	46.06	7.53	6.92	0.51	0.86	3.15	3.04	130.13	1.33	4.08	1.92	206.33	5.00	343.33	11.68	3.09	0.00	0.12	0.03	0.04	4.94	10.98	0.93	0.24	1.00
Minimum	16.03	7.23	5.13	0.30	0.28	1.50	1.40	1.00	1.00	3.00	1.00	96.00	2.00	240.00	1.00	2.11	0.00	0.07	0.01	0.02	2.41	6.20	0.65	0.12	1.00
Maximum	91.82	7.84	9.74	0.82	1.94	6.70	6.40	224.00	2.00	6.00	3.00	350.00	11.00	505.00	24.00	3.79	0.00	0.15	0.04	0.06	7.13	17.80	1.22	0.30	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	10.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	24.43	0.16	1.44	0.20	0.49	1.78	1.72	75.63	0.49	1.24	0.51	79.39	3.10	70.14	7.74	0.44	0.00	0.03	0.01	0.02	2.08	5.64	0.24	0.08	0.00

Vefsna

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
04.01.2018	49.23	7.67	8.67	<0.3	<0.2	1.40	1.40	14.90	<1.0	1.00	1.00	110.00	<2.0	225.00	1.90	2.13									
12.02.2018	40.20	7.55	11.70	<0.3	<0.2	1.00	1.10	12.00	<1.0	1.00	1.00	210.00	5.00	285.00		2.51	<0.002	0.14	0.02	<0.003	0.47	0.19	0.28	0.07	<1.0
12.03.2018	33.06	7.92	12.20	<0.3	<0.2	1.00	0.97	17.90	<1.0	1.00	1.00	170.00	4.00	265.00	1.50	2.44									
09.04.2018	39.36	7.78	9.95	<0.3	<0.2	1.00	1.00	20.60	<1.0	1.00	2.00	120.00	<2.0	200.00	2.42	2.13									
14.05.2018	905.48	7.32	3.68	1.20	3.46	1.60	1.60	<1.0	1.00	5.00	2.00	21.00	<2.0	102.00	4.80	1.14	<0.002	0.11	0.07	0.00	0.34	0.54	0.35	0.12	<1.0
05.06.2018	187.18	7.44	3.64	0.34	0.96	0.97	0.83	73.00	<1.0	<1.0	1.00	23.00	2.00	81.00	<1.0	0.97									
02.07.2018	132.62	7.57	4.17	<0.3	<0.5	0.94	0.94	1.60	<1.0	2.00	1.00	17.00	<2.0	66.00	<1.0	0.92									
13.08.2018	235.67	7.53	4.01	1.00	3.34	2.70	2.50	183.00	1.00	3.00	<1.0	9.00	2.00	60.00	21.00	1.36	<0.002	0.17	0.11	0.00	0.41	0.39	0.35	0.16	<1.0
10.09.2018	72.57	7.76	6.12	0.35	0.35	1.20	1.20		<1.0	2.00	<1.0	25.00	<2.0	70.00		1.21									
08.10.2018	203.13	7.64	7.69	0.34	0.77	2.00	2.00	67.00	<1.0	2.00	3.00	160.00	<2.0	200.00	<1.0	1.76	<0.002	0.09	0.03	<0.003	0.34	0.22	0.32	0.09	<1.0
06.11.2018	118.83	7.63	5.77	0.70	1.64	1.60	1.60	60.00	<1.0	3.00	1.00	42.00	<2.0	87.00	6.90	1.67									
30.11.2018	65.66	7.69	7.57	<0.3	<0.4	1.30	1.30	45.00	1.00	2.00	<1.0	89.00	<2.0	160.00	5.10	1.96									
Lower avg.	173.58	7.62	7.10	0.33	0.88	1.39	1.37	45.00	0.25	1.92	1.08	83.00	1.08	150.08	4.36	1.68	0.00	0.13	0.06	0.00	0.39	0.34	0.33	0.11	0.00
Upper avg..	173.58	7.62	7.10	0.48	1.02	1.39	1.37	45.09	1.00	2.00	1.33	83.00	2.42	150.08	4.66	1.68	0.00	0.13	0.06	0.00	0.39	0.34	0.33	0.11	1.00
Minimum	33.06	7.32	3.64	0.30	0.20	0.94	0.83	1.00	1.00	1.00	1.00	9.00	2.00	60.00	1.00	0.92	0.00	0.09	0.02	0.00	0.34	0.19	0.28	0.07	1.00
Maximum	905.48	7.92	12.20	1.20	3.46	2.70	2.50	183.00	1.00	5.00	3.00	210.00	5.00	285.00	21.00	2.51	0.00	0.17	0.11	0.00	0.47	0.54	0.35	0.16	1.00
More than 70% >LOD	yes	yes	yes	no	no	yes	yes	yes	no	yes	yes	yes	no	yes	no	yes	no	yes	yes	no	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	10.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	240.86	0.16	3.06	0.31	1.19	0.53	0.49	52.61	0.00	1.21	0.65	70.12	1.00	82.44	6.10	0.56	0.00	0.03	0.05	0.00	0.06	0.16	0.03	0.04	0.00

Altaelva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
02.01.2018	41.41	7.51	8.19	0.33	1.14	2.90	2.90	104.00	7.00	10.00	8.00	42.00	<2.0	200.00	13.60	5.89									
06.02.2018	38.01	7.46	7.46	<0.3	0.86	2.80	2.80	52.90	2.00	4.00	3.00	62.00	<2.0	170.00	5.10	6.21	<0.002	0.08	0.01	<0.003	0.37	<0.15	0.25	0.22	<1.0
05.03.2018	35.39	7.51	8.04	<0.3	0.50	2.80	2.80	106.00	4.00	6.00	7.00	51.00	<2.0	225.00	12.80	6.56									
03.04.2018	32.41	7.64	8.31	<0.3	0.34	2.70	2.70	57.10	2.00	4.00	3.00	78.00	<2.0	170.00	5.73	6.88									
08.05.2018	90.95	7.57	8.58	0.74	3.44	3.20	3.10		3.00	6.00	2.00	64.00	<2.0	215.00		6.09	<0.002	0.10	0.02	<0.003	0.60	0.46	0.26	0.22	<1.0
04.06.2018	183.44	7.51	6.53	1.10	16.40	3.60	3.20	247.00	8.00	13.00	4.00	37.00	<2.0	180.00	20.00	4.07									
02.07.2018	141.59	7.57	5.27	0.31	0.79	3.00	3.00	5.50	<1.0	5.00	3.00	28.00	<2.0	140.00	<1.0	3.58									
08.08.2018	76.97	7.60	5.97	<0.3	0.85	3.00	3.00	12.00	2.00	5.00	1.00	25.00	<2.0	180.00	<1.0	3.54	<0.002	0.09	0.01	<0.003	0.47	<0.15	0.24	0.15	1.00
03.09.2018	78.14	7.70	6.47	<0.3	0.57	3.19	3.18	1.60	4.00	11.00	6.00	18.00	8.00	180.00	1.20	3.58									
03.10.2018	93.77	7.57	6.46	0.47	0.62	3.10	3.10	127.00	<1.0	4.00	2.00	41.00	3.00	110.00	20.00	3.84	<0.002	0.08	<0.005	<0.003	0.42	<0.15	0.24	0.15	<1.0
06.11.2018	53.04	7.50	7.00	<0.3	<0.33	2.70	2.80	13.00	2.00	7.00	3.00	62.00	19.00	190.00	1.40	4.29									
06.12.2018	39.71	7.50	6.72	<0.3	2.73	2.80	2.70	91.20	2.00	4.00	2.00	49.00	<2.0	150.00	<1.0	4.67									
Lower avg.	75.40	7.55	7.08	0.25	2.35	2.98	2.94	74.30	3.00	6.58	3.67	46.42	2.50	175.83	7.26	4.93	0.00	0.09	0.01	0.00	0.46	0.12	0.25	0.18	0.25
Upper avg..	75.40	7.55	7.08	0.42	2.38	2.98	2.94	74.30	3.17	6.58	3.67	46.42	4.00	175.83	7.53	4.93	0.00	0.09	0.01	0.00	0.46	0.23	0.25	0.18	1.00
Minimum	32.41	7.46	5.27	0.30	0.33	2.70	2.70	1.60	1.00	4.00	1.00	18.00	2.00	110.00	1.00	3.54	0.00	0.08	0.01	0.00	0.37	0.15	0.24	0.15	1.00
Maximum	183.44	7.70	8.58	1.10	16.40	3.60	3.20	247.00	8.00	13.00	8.00	78.00	19.00	225.00	20.00	6.88	0.00	0.10	0.02	0.00	0.60	0.46	0.26	0.22	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	no	yes	no	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	47.11	0.07	1.03	0.25	4.52	0.26	0.18	72.93	2.25	3.09	2.19	18.00	5.03	31.83	7.68	1.29	0.00	0.01	0.01	0.00	0.10	0.16	0.01	0.04	0.00

Bjerkreimselva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
07.01.2018	51.89	6.38	3.55	<0.3	0.53	1.30	1.30	116.00	1.00	4.00	2.00	400.00	<2.0	500.00	16.00	1.82									
06.02.2018	59.44	6.32	3.89	<0.3	0.64	1.50	1.30	118.00	1.00	4.00	2.00	420.00	7.00	565.00	15.40	1.76	<0.002	0.07	0.15	0.02	0.18	2.80	0.14	0.04	<1.0
05.03.2018	27.62	6.49	3.90	<0.3	0.42	1.20	1.30	101.00	<1.0	3.00	2.00	430.00	<2.0	545.00	13.20	1.97									
11.04.2018	28.70	6.52	3.58	<0.3	0.52	1.20	1.20	8.90	1.00	4.00	2.00	320.00	<2.0	455.00	<1.0	1.53									
08.05.2018	54.33	6.43	3.07	<0.3	1.30	1.20	1.20	<1.0	1.00	3.00	1.00	250.00	2.00	380.00	<1.0	1.20	<0.002	0.09	0.19	0.02	0.20	2.20	0.12	0.05	<1.0
04.06.2018	19.25	6.69	3.32	0.36	0.99	1.60	1.30	14.60	1.00	4.00	4.00	220.00	24.00	360.00	1.90	1.03									
04.07.2018	17.68	6.67	3.31	0.34	<0.5	1.30	1.20		2.00	2.00	2.00	290.00	18.00	400.00		1.15									
07.08.2018	27.33	6.89	3.77	0.41	1.02	1.40	1.40	14.00	2.00	5.00	1.00	330.00	18.00	510.00		1.39	<0.002	0.09	0.11	0.01	0.26	0.89	0.11	0.06	1.00
05.09.2018	26.19	6.61	3.17	<0.3	0.48	1.65	1.59	<1.0	<1.0	4.00	1.00	250.00	9.00	430.00	<1.0	1.09									
09.10.2018	95.71	6.48	3.82	0.55	0.74	1.70	1.70	205.00	<1.0	6.00	3.00	410.00	3.00	430.00	21.00	1.52	<0.002	0.11	0.23	0.02	0.43	3.50	0.23	0.08	<1.0
07.11.2018	36.43	6.47	3.45	0.38	<0.33	1.40	1.40	12.00	<1.0	4.00	2.00	320.00	<2.0	440.00	<1.0	1.50									
05.12.2018	66.47	6.55	3.30	<0.3	0.44	1.50	1.50	109.00	2.00	3.00	1.00	350.00	<2.0	410.00	8.44	1.56									
Lower avg.	42.59	6.54	3.51	0.17	0.59	1.41	1.37	63.50	0.92	3.83	1.92	332.50	6.75	452.08	7.59	1.46	0.00	0.09	0.17	0.02	0.27	2.35	0.15	0.06	0.25
Upper avg..	42.59	6.54	3.51	0.34	0.66	1.41	1.37	63.68	1.25	3.83	1.92	332.50	7.58	452.08	7.99	1.46	0.00	0.09	0.17	0.02	0.27	2.35	0.15	0.06	1.00
Minimum	17.68	6.32	3.07	0.30	0.33	1.20	1.20	1.00	1.00	2.00	1.00	220.00	2.00	360.00	1.00	1.03	0.00	0.07	0.11	0.01	0.18	0.89	0.11	0.04	1.00
Maximum	95.71	6.89	3.90	0.55	1.30	1.70	1.70	205.00	2.00	6.00	4.00	430.00	24.00	565.00	21.00	1.97	0.00	0.11	0.23	0.02	0.43	3.50	0.23	0.08	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes	yes	no	yes	no	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	10.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	23.40	0.16	0.29	0.08	0.30	0.18	0.16	68.93	0.45	1.03	0.90	71.62	7.96	64.89	7.80	0.30	0.00	0.01	0.05	0.01	0.11	1.11	0.05	0.02	0.00

Vikedalselva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
02.01.2018	22.18	6.40	2.72	3.20	4.04	1.10	0.98	240.00	4.00	5.00	1.00	200.00	5.00	270.00	22.40	1.07									
05.02.2018	11.26	6.73	3.63	<0.3	0.84	0.83	0.76	114.00	1.00	3.00	2.00	230.00	2.00	330.00	7.80	1.17	<0.002	0.15	0.10	0.01	0.38	2.30	0.41	0.06	<1.0
05.03.2018	5.14	6.70	3.94	<0.3	0.34	0.77	0.69	66.70	<1.0	3.00	2.00	320.00	3.00	435.00	7.50	1.72									
03.04.2018	4.09	6.76	3.71	0.36	2.15	1.00	0.84	144.00	3.00	6.00	2.00	360.00	4.00	425.00	15.80	1.49									
07.05.2018	8.37	6.56	2.24	<0.3	0.82	1.00	0.98	2.30	<1.0	3.00	1.00	150.00	6.00	245.00	1.20	0.78	<0.002	0.09	0.12	0.01	0.28	1.60	0.30	0.03	<1.0
04.06.2018	3.26	6.66	2.28	<0.3	0.20	0.87	0.83	124.00	1.00	3.00	2.00	120.00	4.00	180.00	14.90	0.57									
30.07.2018	3.22	7.14	4.04	0.66	0.80	1.10	1.10	163.00	<1.0	4.00	2.00	290.00	<2.0	400.00	10.00	1.05									
13.08.2018	8.18	6.48	2.16	0.46	1.03	1.50	1.40	13.00	1.00	3.00	<1.0	160.00	13.00	260.00	2.20	0.72	<0.002	0.20	0.03	0.01	0.35	2.50	0.24	0.03	<1.0
03.09.2018	6.12	6.59	2.59	0.50	1.11	2.20	1.50	11.00	<1.0	3.00	1.00	310.00	4.00	430.00	<1.0	0.96									
01.10.2018	25.21	6.44	2.17	0.60	0.80	1.50	1.40	163.00	1.00	3.00	1.00	170.00	4.00	210.00	16.00	0.89	0.00	0.18	0.15	0.01	0.43	2.00	0.35	0.25	<1.0
05.11.2018	10.48	6.44	2.12	<0.3	0.54	1.20	1.10	11.00	<1.0	3.00	2.00	160.00	2.00	230.00	<1.0	0.93									
03.12.2018	11.61	6.49	2.15	0.69	2.83	1.30	1.20	114.00	3.00	6.00	1.00	170.00	6.00	250.00	6.11	0.95									
Lower avg.	9.93	6.62	2.81	0.54	1.29	1.20	1.06	97.17	1.17	3.75	1.42	220.00	4.42	305.42	8.66	1.03	0.00	0.16	0.10	0.01	0.36	2.10	0.32	0.09	0.00
Upper avg..	9.93	6.62	2.81	0.66	1.29	1.20	1.06	97.17	1.58	3.75	1.50	220.00	4.58	305.42	8.83	1.03	0.00	0.16	0.10	0.01	0.36	2.10	0.32	0.09	1.00
Minimum	3.22	6.40	2.12	0.30	0.20	0.77	0.69	2.30	1.00	3.00	1.00	120.00	2.00	180.00	1.00	0.57	0.00	0.09	0.03	0.01	0.28	1.60	0.24	0.03	1.00
Maximum	25.21	7.14	4.04	3.20	4.04	2.20	1.50	240.00	4.00	6.00	2.00	360.00	13.00	435.00	22.40	1.72	0.00	0.20	0.15	0.01	0.43	2.50	0.41	0.25	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	7.10	0.21	0.78	0.81	1.14	0.40	0.27	76.52	1.08	1.22	0.52	79.89	3.00	93.77	7.12	0.32	0.00	0.05	0.05	0.00	0.06	0.39	0.07	0.10	0.00

Nausta

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
09.01.2018	16.96	6.32	2.05	<0.3	0.35	1.20	1.20	96.60	2.00	3.00	2.00	130.00	6.00	230.00	7.50	1.85									
08.02.2018	16.25	6.35	2.13	<0.3	<0.5	1.30	1.30	121.00	1.00	4.00	3.00	150.00	24.00	255.00	13.60	2.07	<0.002	<0.025	0.03	0.00	0.18	1.20	0.08	0.04	<1.0
01.03.2018	11.52	6.47	2.46	<0.3	0.33	1.40	1.40	119.00	1.00	4.00	6.00	160.00	<2.0	280.00	11.30	2.46									
09.04.2018	10.61	6.51	2.31	0.54	0.88	2.50	2.40	182.00	3.00	8.00	4.00	320.00	<2.0	420.00	15.20	2.31									
07.05.2018	31.13	6.08	1.03	0.36	1.36	1.50	1.50	2.10	8.00	5.00	2.00	44.00	<2.0	130.00	<1.0	0.74	<0.002	0.03	0.09	0.00	0.17	0.88	0.08	0.03	<1.0
05.06.2018	26.39	6.41	0.88	<0.3	1.19	0.76	0.66	122.00	1.00	3.00	<1.0	4.00	2.00	31.00	8.00	0.37									
03.07.2018	17.38	6.48	1.12	<0.3	0.30	1.10	0.99	5.50	<1.0	3.00	1.00	4.00	3.00	49.00	1.30	0.13									
06.08.2018	21.61	6.15	1.16	0.38	0.79	3.10	3.10	16.00	2.00	6.00	2.00	36.00	<2.0	130.00	2.40	1.01	<0.002	0.04	0.09	0.00	0.25	0.74	0.12	0.05	<1.0
11.09.2018	21.69	6.05	1.35	0.59	0.58	5.00	4.90	16.00	4.00	10.00	4.00	28.00	<2.0	200.00	<1.0	1.33									
02.10.2018	73.97	6.13	1.23	0.44	0.58	1.70	1.70	123.00	2.00	5.00	3.00	71.00	<2.0	140.00	10.00	0.94	<0.002	0.05	0.06	0.00	0.22	0.85	0.10	0.05	<1.0
13.11.2018	19.30	6.26	1.29	<0.3	<0.48	1.70	1.50	119.00	2.00	4.00	3.00	69.00	<2.0	130.00	6.70	1.22									
04.12.2018	19.55	6.27	1.49	0.42	1.26	2.20	2.10	287.00	5.00	7.00	4.00	130.00	<2.0	230.00	17.50	1.55									
Lower avg.	23.86	6.29	1.54	0.23	0.63	1.95	1.90	100.77	2.58	5.17	2.83	95.50	2.92	185.42	7.79	1.33	0.00	0.03	0.07	0.00	0.20	0.92	0.10	0.04	0.00
Upper avg..	23.86	6.29	1.54	0.38	0.72	1.95	1.90	100.77	2.67	5.17	2.92	95.50	4.25	185.42	7.96	1.33	0.00	0.04	0.07	0.00	0.20	0.92	0.10	0.04	1.00
Minimum	10.61	6.05	0.88	0.30	0.30	0.76	0.66	2.10	1.00	3.00	1.00	4.00	2.00	31.00	1.00	0.13	0.00	0.03	0.03	0.00	0.17	0.74	0.08	0.03	1.00
Maximum	73.97	6.51	2.46	0.59	1.36	5.00	4.90	287.00	8.00	10.00	6.00	320.00	24.00	420.00	17.50	2.46	0.00	0.05	0.09	0.00	0.25	1.20	0.12	0.05	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	16.77	0.16	0.54	0.10	0.38	1.16	1.15	83.39	2.10	2.21	1.44	89.80	6.33	107.34	5.76	0.74	0.00	0.01	0.03	0.00	0.04	0.20	0.02	0.01	0.00

Driva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
09.01.2018	42.78	7.13	3.51	<0.3	0.29	0.94	0.95	49.80	<1.0	2.00	3.00	180.00	5.00	245.00	6.40	3.06									
05.02.2018	35.45	6.99	3.23	<0.3	0.45	0.97	0.95	60.50	<1.0	2.00	<1.0	120.00	3.00	225.00	6.60	2.61	<0.002	0.05	0.01	<0.003	0.44	0.15	0.15	0.10	<1.0
05.03.2018	23.63	7.10	3.40	<0.3	0.34	0.99	0.99	56.90	<1.0	2.00		160.00	3.00	265.00	3.60	2.72									
03.04.2018	21.85	7.21	3.61	<0.3	0.48	0.98	0.93	76.10	<1.0	3.00	1.00	180.00	<2.0	230.00	7.62	2.87									
06.05.2018	124.17	7.18	3.21	1.50	8.51	2.90	2.80		11.00	17.00	3.00	87.00	8.00	305.00		2.91	<0.002	0.05	0.09	0.00	1.16	0.73	0.33	0.24	<1.0
03.06.2018	199.07	7.15	1.94	0.31	3.67	0.77	0.71	104.00	1.00	3.00	4.00	23.00	3.00	51.00	6.50	1.76									
01.07.2018	48.41	7.45	3.64	<0.3	0.38	0.61	0.59		<1.0	2.00	1.00	74.00	5.00	130.00		2.09									
05.08.2018	79.89	7.44	3.48	0.68	2.25	2.00	1.90	270.00	3.00	6.00	3.00	47.00	<2.0	130.00	22.00	3.04	<0.002	0.09	0.06	<0.003	1.09	1.10	0.34	0.31	<1.0
02.09.2018	49.37	7.57	4.65	<0.3	2.08	1.04	1.02	6.60	<1.0	2.00	<1.0	71.00	3.00	140.00	1.50	3.09									
30.09.2018	133.31	7.34	4.24	<0.3	0.54	1.90	1.90	134.00	<1.0	3.00	1.00	140.00	<2.0	200.00	12.00	3.36	<0.002	0.05	0.02	<0.003	0.73	1.30	0.22	0.17	<1.0
06.11.2018	107.97	7.26	4.15	<0.3	0.43	1.80	1.80	86.00	<1.0	3.00	2.00	210.00	<2.0	310.00	7.90	3.88									
03.12.2018	41.19	7.25	4.38	<0.3	0.60	1.20	1.00	84.90	1.00	2.00	1.00	220.00	7.00	300.00	5.97	3.66									
Lower avg.	75.59	7.26	3.62	0.21	1.67	1.34	1.30	92.88	1.33	3.92	1.73	126.00	3.08	210.92	8.01	2.92	0.00	0.06	0.05	0.00	0.85	0.82	0.26	0.20	0.00
Upper avg..	75.59	7.26	3.62	0.43	1.67	1.34	1.30	92.88	2.00	3.92	1.91	126.00	3.75	210.92	8.01	2.92	0.00	0.06	0.05	0.00	0.85	0.82	0.26	0.20	1.00
Minimum	21.85	6.99	1.94	0.30	0.29	0.61	0.59	6.60	1.00	2.00	1.00	23.00	2.00	51.00	1.50	1.76	0.00	0.05	0.01	0.00	0.44	0.15	0.15	0.10	1.00
Maximum	199.07	7.57	4.65	1.50	8.51	2.90	2.80	270.00	11.00	17.00	4.00	220.00	8.00	310.00	22.00	3.88	0.00	0.09	0.09	0.00	1.16	1.30	0.34	0.31	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes	no	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	10.00	12.00	12.00	11.00	12.00	12.00	12.00	10.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	54.68	0.17	0.71	0.35	2.40	0.67	0.65	70.88	2.89	4.27	1.14	65.51	2.05	82.61	5.62	0.60	0.00	0.02	0.04	0.00	0.33	0.51	0.09	0.09	0.00

Nidelva
(Tr.heim)

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
08.01.2018	40.75	7.13	3.35	<0.3	0.54	2.30	2.40	60.70	2.00	4.00	2.00	97.00	<2.0	210.00	8.30	2.07									
05.02.2018	34.26	7.08	3.09	<0.3	0.78	2.40	2.30	72.70	<1.0	3.00	1.00	77.00	3.00	185.00	6.10	1.95	<0.002	0.07	0.01	<0.003	0.56	0.39	0.62	0.12	<1.0
05.03.2018	23.73	7.12	3.22	<0.3	0.57	2.40	2.30	81.70	2.00	3.00	2.00	78.00	3.00	195.00	8.20	1.98									
03.04.2018	24.07	7.21	3.25	<0.3	0.40	2.30	2.30	63.20	1.00	3.00	2.00	95.00	2.00	180.00	7.12	1.98									
06.05.2018	200.73	7.29	3.57	1.20	1.49	2.40	2.40	<1.0	1.00	3.00	2.00	87.00	7.00	200.00	1.30	1.97	<0.002	0.09	0.02	<0.003	0.64	0.48	0.66	0.18	<1.0
04.06.2018	95.88	7.29	3.53	0.33	0.51	2.40	2.40	5.70	<1.0	4.00	2.00	78.00	10.00	170.00	<1.0	1.85									
02.07.2018	49.48	7.27	3.49	0.42	0.69	2.40	2.40	1.60	<1.0	4.00	1.00	72.00	8.00	180.00	<1.0	1.78									
07.08.2018	76.82	7.39	3.91	0.76	1.11	2.50	2.40	160.00	2.00	4.00	2.00	60.00	10.00	160.00	25.00	1.85	<0.002	0.11	0.03	<0.003	0.70	0.50	0.72	0.19	<1.0
04.09.2018	60.33	7.29	3.17	0.42	0.71	2.60	2.60	134.00	<1.0	3.00	1.00	47.00	6.00	150.00	16.00	1.73									
03.10.2018	108.22	7.29	3.90	0.82	1.08	3.00	3.00	143.00	2.00	5.00	2.00	120.00	6.00	190.00	14.00	2.02	<0.002	0.09	0.03	<0.003	0.68	0.53	0.75	0.21	<1.0
06.11.2018	82.10	7.18	3.34	0.46	1.29	2.80	2.70	127.00	<1.0	4.00	2.00	86.00	4.00	160.00	12.00	1.94									
04.12.2018	41.81	7.21	3.92	1.30	1.39	2.40	2.40	122.00	2.00	3.00	2.00	93.00	5.00	170.00	6.58	2.00									
Lower avg.	69.85	7.23	3.48	0.48	0.88	2.49	2.47	80.97	1.00	3.58	1.75	82.50	5.33	179.17	8.72	1.93	0.00	0.09	0.02	0.00	0.65	0.48	0.69	0.17	0.00
Upper avg..	69.85	7.23	3.48	0.58	0.88	2.49	2.47	81.05	1.42	3.58	1.75	82.50	5.50	179.17	8.88	1.93	0.00	0.09	0.02	0.00	0.65	0.48	0.69	0.17	1.00
Minimum	23.73	7.08	3.09	0.30	0.40	2.30	2.30	1.00	1.00	3.00	1.00	47.00	2.00	150.00	1.00	1.73	0.00	0.07	0.01	0.00	0.56	0.39	0.62	0.12	1.00
Maximum	200.73	7.39	3.92	1.30	1.49	3.00	3.00	160.00	2.00	5.00	2.00	120.00	10.00	210.00	25.00	2.07	0.00	0.11	0.03	0.00	0.70	0.53	0.75	0.21	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	no	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	49.64	0.09	0.30	0.36	0.38	0.21	0.21	57.10	0.51	0.67	0.45	18.74	2.84	17.94	7.04	0.10	0.00	0.02	0.01	0.00	0.06	0.06	0.06	0.04	0.00

Målselv

Date DD.MM.YYYY	Qs [m3/s]	pH []	KOND [mS/m]	TURB860 [FNU]	SPM [mg/l]	TOC [mgC/l]	DOC [mgC/l]	Part. C [µgC/l]	PO4-P [µgP/l]	TOTP [µgP/l]	TDP [µgP/l]	NO3-N [µgN/l]	NH4-N [µgN/l]	TOTN [µgN/l]	Tot. Part. N [µgN/l]	SiO2 [mgSiO2/l]	Ag [µg/l]	As [µg/l]	Pb [µg/l]	Cd [µg/l]	Cu [µg/l]	Zn [µg/l]	Ni [µg/l]	Cr [µg/l]	Hg [ng/l]
02.01.2018	26.58	7.55	9.48	0.59		0.85	0.79	40.80	<1.0	1.00	<1.0	88.00	<2.0	146.00	3.70	3.15									
12.02.2018	18.67	7.46	9.47	<0.3	0.22	0.72	0.71	30.50	<1.0	1.00	1.00	97.00	11.00	155.00	4.10	2.89	<0.002	0.05	0.01	<0.003	0.29	<0.15	0.26	0.04	2.00
05.03.2018	16.04	7.56	9.60	<0.3	0.25	0.73	0.72	22.30	<1.0	1.00	2.00	80.00	5.00	155.00	1.70	2.89									
03.04.2018	14.34	7.58	9.93	<0.3	<0.2	0.70	0.67	25.40	<1.0	2.00	2.00	100.00	4.00	185.00	2.02	3.02									
07.05.2018	109.89	7.48	6.46	6.70	16.50	3.50	3.30	59.00	13.00	23.00	3.00	48.00	<2.0	240.00	6.20	2.61	<0.002	0.07	0.17	0.01	1.09	1.20	0.77	0.37	<1.0
04.06.2018	219.11	7.66	6.42	0.42	1.70	1.10	0.96	1.90	2.00	2.00	1.00	31.00	2.00	72.00	<1.0	1.91									
02.07.2018	181.75	7.65	7.46	0.42	2.08	1.00	1.00		2.00	3.00	2.00	36.00	<2.0	92.00		2.06									
13.08.2018	86.25	7.74	7.66	1.20	2.59	1.20	1.20	6.20	1.00	3.00	<1.0	18.00	<2.0	81.00	<1.0	2.27	<0.002	0.05	0.07	0.00	0.83	0.82	0.53	0.23	<1.0
04.09.2018	53.68	7.83	8.62	<0.3	0.70	0.91	0.87	<1.0	<1.0	2.00	<1.0	18.00	5.00	86.00	<1.0	2.11									
01.10.2018	64.30	7.76	8.49	<0.3	0.57	1.30	1.30	121.00	<1.0	2.00	1.00	45.00	3.00	86.00	<1.0	2.53	<0.002	<0.025	0.01	<0.003	0.39	<0.15	0.30	0.07	<1.0
05.11.2018	52.99	7.78	9.34	0.32	0.92	0.87	0.87	57.00	<1.0	3.00	1.00	68.00	<2.0	110.00	6.40	2.76									
03.12.2018	47.89	7.70	9.41	<0.3	0.61	1.00	1.00	44.30	1.00	2.00	<1.0	82.00	3.00	140.00	3.81	2.94									
Lower avg.	74.29	7.65	8.53	0.80	2.38	1.16	1.12	37.13	1.58	3.75	1.08	59.25	2.75	129.00	2.54	2.60	0.00	0.04	0.06	0.00	0.65	0.51	0.47	0.18	0.50
Upper avg..	74.29	7.65	8.53	0.95	2.39	1.16	1.12	37.22	2.17	3.75	1.42	59.25	3.58	129.00	2.90	2.60	0.00	0.05	0.06	0.00	0.65	0.58	0.47	0.18	1.25
Minimum	14.34	7.46	6.42	0.30	0.20	0.70	0.67	1.00	1.00	1.00	1.00	18.00	2.00	72.00	1.00	1.91	0.00	0.03	0.01	0.00	0.29	0.15	0.26	0.04	1.00
Maximum	219.11	7.83	9.93	6.70	16.50	3.50	3.30	121.00	13.00	23.00	3.00	100.00	11.00	240.00	6.40	3.15	0.00	0.07	0.17	0.01	1.09	1.20	0.77	0.37	2.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	no	yes	no	yes	no	yes	no	yes	no	yes	yes	no	yes	no	yes	yes	no
n	12.00	12.00	12.00	12.00	11.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	66.03	0.12	1.24	1.83	4.75	0.76	0.71	34.46	3.43	6.11	0.67	30.16	2.61	50.63	2.07	0.42	0.00	0.02	0.08	0.00	0.38	0.52	0.24	0.15	0.50

Tanaelva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
01.01.2018	63.32	7.30	6.20	<0.3	1.55	1.90	1.90	107.00	2.00	5.00	3.00	71.00	<2.0	175.00	9.40	10.22									
05.02.2018	52.21	7.19	6.89	<0.3	<0.33	1.80	1.70	70.70	3.00	5.00	4.00	95.00	3.00	195.00	8.20	10.41	<0.002	0.04	0.01	<0.003	0.28	0.47	0.29	0.28	<1.0
05.03.2018	45.07	7.38	7.43	0.72	1.38	1.60	1.60	135.00	3.00	7.00	4.00	120.00	4.00	260.00	17.70	10.84									
02.04.2018	40.82	7.33	7.36	<0.3	0.51	1.40	1.40	111.00	4.00	8.00	5.00	110.00	<2.0	190.00	11.80	10.76									
07.05.2018	143.98	7.34	5.61	0.82	0.92	1.90	1.60	17.60	2.00	7.00	2.00	44.00	89.00	370.00	3.10	7.01	<0.002	0.05	0.11	0.01	1.29	4.20	0.51	0.21	<1.0
04.06.2018	466.40	7.24	4.89	0.59	1.26	2.30	2.10	147.00	2.00	7.00	3.00	33.00	<2.0	160.00	11.00	5.53									
02.07.2018	270.58	7.28	4.09	<0.3	0.63	3.00	3.00		2.00	6.00	3.00	2.00	<2.0	120.00		4.91									
06.08.2018	296.49	7.29	3.64	0.35	1.16	3.70	3.40	18.00	2.00	6.00	<1.0	<2.0	8.00	140.00	<1.0	5.94	<0.002	0.07	0.02	0.00	0.57	0.88	0.57	0.28	<1.0
02.09.2018	250.88	7.33	4.30	0.75	0.88	4.40	4.10	8.70	<1.0	6.00	2.00	6.00	<2.0	130.00	1.40	5.91									
01.10.2018	226.36	7.23	4.34	0.54	0.82	3.90	4.00	194.00	<1.0	5.00	3.00	23.00	<2.0	99.00	16.00	6.79	<0.002	0.05	0.01	<0.003	0.47	1.80	0.51	0.36	<1.0
05.11.2018	111.01	7.21	5.11	0.65	0.67	2.70	2.70	152.00	3.00	6.00	4.00	43.00	<2.0	140.00	13.00	8.21									
03.12.2018	123.49	7.32	5.76	0.60	0.99	2.30	2.30	316.00	2.00	5.00	2.00	58.00	33.00	210.00	33.60	9.24									
Lower avg.	174.22	7.29	5.47	0.42	0.90	2.57	2.48	116.09	2.08	6.08	2.92	50.42	11.42	182.42	11.38	7.98	0.00	0.05	0.04	0.00	0.65	1.84	0.47	0.28	0.00
Upper avg..	174.22	7.29	5.47	0.52	0.93	2.57	2.48	116.09	2.25	6.08	3.00	50.58	12.58	182.42	11.47	7.98	0.00	0.05	0.04	0.00	0.65	1.84	0.47	0.28	1.00
Minimum	40.82	7.19	3.64	0.30	0.33	1.40	1.40	8.70	1.00	5.00	1.00	2.00	2.00	99.00	1.00	4.91	0.00	0.04	0.01	0.00	0.28	0.47	0.29	0.21	1.00
Maximum	466.40	7.38	7.43	0.82	1.55	4.40	4.10	316.00	4.00	8.00	5.00	120.00	89.00	370.00	33.60	10.84	0.00	0.07	0.11	0.01	1.29	4.20	0.57	0.36	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	no	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	130.50	0.06	1.29	0.20	0.36	0.98	0.95	90.37	0.87	1.00	1.13	41.20	25.63	73.82	9.21	2.23	0.00	0.01	0.05	0.00	0.44	1.67	0.12	0.06	0.00

Pasvikelva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
01.01.2018	53.68	7.03	3.25	<0.3	<0.33	3.00	2.90	72.40	<1.0	3.00	3.00	44.00	7.00	165.00	6.30	5.85									
05.02.2018	46.92	6.95	3.42	<0.3	0.37	2.80	2.90	91.60	4.00	7.00	4.00	400.00	<2.0	535.00	8.90	5.94	0.01	0.17	0.07	0.01	1.05	1.30	1.29	0.14	<1.0
05.03.2018	42.40	7.11	3.32	<0.3	0.38	3.00	3.00	105.00	<1.0	3.00	2.00	60.00	<2.0	185.00	9.60	5.96									
02.04.2018	47.79	7.21	4.79	<0.3	0.45	3.90	4.00	92.70	12.00	16.00	13.00	56.00	<2.0	185.00	13.10	6.21									
07.05.2018	381.96	6.94	2.53	0.56	1.43	2.10	2.20		<1.0	5.00	2.00	56.00	100.00	310.00		3.32	<0.002	0.80	0.37	0.07	38.60	4.10	35.40	0.13	<1.0
03.06.2018	275.14	7.20	3.85	1.10	3.01	4.80	4.80	353.00	3.00	9.00	4.00	2.00	<2.0	160.00	29.00	3.99									
02.07.2018	216.69	7.15	3.51	0.67	1.37	4.00	4.00		2.00	9.00	5.00	<2.0	<2.0	160.00		3.75									
06.08.2018	208.85	7.42	5.18	0.38	0.95	3.10	3.50	23.00	2.00	6.00	3.00	14.00	8.00	160.00	<1.0	4.29	<0.002	0.13	0.04	0.01	1.94	3.00	8.00	0.15	<1.0
03.09.2018	167.43	7.24	3.28	0.74	0.90	3.60			<1.0	6.00	1.00	3.00	10.00	150.00		4.41									
01.10.2018	133.00	7.09	3.72	0.67	1.82	4.20	4.10	163.00	2.00	6.00	3.00	35.00	<2.0	130.00	18.00	4.63	<0.002	0.10	0.02	<0.003	0.75	1.00	0.41	0.25	<1.0
05.11.2018	70.60	7.23	3.49	1.90	1.82	3.10	3.10	237.00	2.00	6.00	2.00	22.00	20.00	130.00	25.00	5.10									
03.12.2018	107.98	7.14	3.36	0.40	0.64	3.20	3.10	219.00	2.00	4.00	1.00	37.00	49.00	190.00	22.60	5.44									
Lower avg.	146.04	7.14	3.64	0.54	1.09	3.40	3.42	150.74	2.42	6.67	3.58	60.75	16.17	205.00	14.72	4.91	0.00	0.30	0.12	0.02	10.58	2.35	11.27	0.17	0.00
Upper avg..	146.04	7.14	3.64	0.64	1.12	3.40	3.42	150.74	2.75	6.67	3.58	60.92	17.17	205.00	14.83	4.91	0.00	0.30	0.12	0.02	10.58	2.35	11.27	0.17	1.00
Minimum	42.40	6.94	2.53	0.30	0.33	2.10	2.20	23.00	1.00	3.00	1.00	2.00	2.00	130.00	1.00	3.32	0.00	0.10	0.02	0.00	0.75	1.00	0.41	0.13	1.00
Maximum	381.96	7.42	5.18	1.90	3.01	4.80	4.80	353.00	12.00	16.00	13.00	400.00	100.00	535.00	29.00	6.21	0.01	0.80	0.37	0.07	38.60	4.10	35.40	0.25	1.00
More than 70% >LOD	yes	yes	yes	no	yes	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	11.00	9.00	12.00	12.00	12.00	12.00	12.00	12.00	9.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	107.78	0.13	0.71	0.47	0.81	0.73	0.74	102.82	3.05	3.52	3.20	108.95	29.39	113.98	9.38	0.98	0.00	0.34	0.16	0.03	18.68	1.46	16.44	0.06	0.00

Vegårdselva

Date	Qs	pH	KOND	TURB860	SPM	TOC	DOC	Part. C	PO4-P	TOTP	TDP	NO3-N	NH4-N	TOTN	Tot. Part. N	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
DD.MM.YYYY	[m3/s]	[]	[mS/m]	[FNU]	[mg/l]	[mgC/l]	[mgC/l]	[µgC/l]	[µgP/l]	[µgP/l]	[µgP/l]	[µgN/l]	[µgN/l]	[µgN/l]	[µgN/l]	[mgSiO2/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[µg/l]	[ng/l]
02.01.2018	13.31	6.37	2.87	1.20	1.60	6.50	6.50	321.00	<1.0	6.00	3.00	180.00	36.00	405.00	23.20	3.49									
07.02.2018	14.46	6.31	2.87	1.30	1.37	5.70	5.60	212.00	2.00	6.00	3.00	200.00	30.00	410.00	18.80	3.43	<0.002	0.23	0.37	0.04	0.56	7.00	0.51	0.19	2.00
05.03.2018	6.67	6.38	3.02	0.53	1.06	5.30	5.30	291.00	2.00	5.00	3.00	180.00	38.00	440.00	19.60	3.58									
03.04.2018	4.19	6.47	4.03	1.20	1.70	5.40	5.30	248.00	1.00	6.00	2.00	280.00	45.00	495.00	20.10	3.64									
02.05.2018	45.07	6.38	2.40	1.40	2.26	4.90	4.80		2.00	7.00	2.00	190.00	37.00	440.00		2.68	<0.002	0.22	0.36	0.03	0.57	6.20	0.42	0.16	<1.0
04.06.2018	5.59	6.66	2.56	0.87	1.72	4.80	4.30	3.40	1.00	5.00	3.00	47.00	15.00	230.00	<1.0	0.40									
03.07.2018	3.03	6.93	3.06	0.94	1.57	4.30	4.10	33.00	2.00	8.00	3.00	83.00	37.00	300.00	1.60	0.66									
06.08.2018	1.50	6.85	2.96	0.87	1.42	4.20	4.10	35.00	2.00	6.00	2.00	9.00	<2.0	190.00	<1.0	0.92	<0.002	0.30	0.17	0.01	0.70	1.50	0.30	0.10	1.00
03.09.2018	2.24	6.92	4.43	0.68	1.27	4.10	4.10	20.00	1.00	5.00	3.00	10.00	18.00	190.00	<1.0	1.04									
01.10.2018	6.01	6.45	3.69	1.10	1.60	6.50	6.50	373.00	2.00	9.00	3.00	170.00	32.00	350.00	37.00	2.46	<0.002	0.28	0.33	0.04	0.80	8.50	0.67	0.22	<1.0
05.11.2018	5.52	6.53	6.72	1.30	1.91	5.20	5.00	328.00	2.00	7.00	3.00	240.00	32.00	480.00	22.00	2.74									
03.12.2018	21.67	6.37	3.48	2.90	2.56	6.30	6.20	480.00	5.00	10.00	4.00	260.00	30.00	460.00	22.70	3.47									
Lower avg.	10.77	6.55	3.51	1.19	1.67	5.27	5.15	213.13	1.83	6.67	2.83	154.08	29.17	365.83	15.00	2.38	0.00	0.26	0.31	0.03	0.66	5.80	0.47	0.17	0.75
Upper avg..	10.77	6.55	3.51	1.19	1.67	5.27	5.15	213.13	1.92	6.67	2.83	154.08	29.33	365.83	15.27	2.38	0.00	0.26	0.31	0.03	0.66	5.80	0.47	0.17	1.25
Minimum	1.50	6.31	2.40	0.53	1.06	4.10	4.10	3.40	1.00	5.00	2.00	9.00	2.00	190.00	1.00	0.40	0.00	0.22	0.17	0.01	0.56	1.50	0.30	0.10	1.00
Maximum	45.07	6.93	6.72	2.90	2.56	6.50	6.50	480.00	5.00	10.00	4.00	280.00	45.00	495.00	37.00	3.64	0.00	0.30	0.37	0.04	0.80	8.50	0.67	0.22	2.00
More than 70% >LOD	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no
n	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
St.dev	12.33	0.23	1.17	0.60	0.42	0.86	0.91	165.64	1.08	1.61	0.58	94.28	11.98	111.98	12.20	1.27	0.00	0.04	0.09	0.02	0.11	3.02	0.16	0.05	0.50

6.2 Riverine loads in 2018

River	Estimate	Flow rate	SPM	TOC	PO4-P	TOTP	NO3-N	NH4-N	TOTN	SiO2	Ag	As	Pb	Cd	Cu	Zn	Ni	Cr	Hg
		1000 m3/d	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[tonnes]	[kg]
Glomma ved Sarpsfoss	avg.	62293.27	160455.90	87998.35	202.21	336.26	9500.44	285.12	13738.07	79881.75	0.06	4.05	5.54	0.25	34.96	96.01	18.01	6.02	0.00
Alna	avg.	90.83	762.10	184.02	2.01	2.39	32.28	0.96	46.23	240.20	0.00	0.01	0.02	0.00	0.10	0.37	0.03	0.02	0.03
Drammenselva	avg.	28227.66	21621.90	32330.35	21.44	55.96	2546.33	98.97	4062.21	29215.27	0.02	1.55	1.18	0.08	6.56	20.25	4.28	1.10	0.00
Numedalslågen	avg.	9619.45	22265.07	14599.26	28.92	50.40	1028.02	138.35	1857.58	12488.09	0.02	0.63	1.04	0.05	2.52	14.71	1.39	0.63	0.00
Skienselva	avg.	25848.03	6445.64	22395.71	10.11	28.91	1201.15	79.57	2250.33	20294.78	0.00	0.87	0.60	0.07	4.24	22.54	1.58	0.59	0.00
Otra	avg.	13197.34	3809.39	12534.50	2.98	15.55	375.08	68.34	901.99	7257.62	0.00	0.49	0.89	0.06	1.67	10.55	1.99	0.32	0.00
Orreelva	avg.	450.39	2448.82	976.62	4.82	12.67	138.49	2.56	269.57	338.98	0.00	0.04	0.03	0.00	0.26	0.45	0.17	0.03	0.06
Vosso (Bolstadelvi)	avg.	8901.69	2428.69	3854.60	4.67	9.76	378.20	23.01	600.96	3357.52	0.00	0.27	0.22	0.02	1.26	3.31	1.03	0.18	1.03
Orkla	avg.	4880.24	1695.23	6339.48	2.45	7.47	331.99	7.61	588.06	5418.85	0.00	0.21	0.05	0.07	9.77	22.69	1.61	0.44	0.00
Vefsna	avg.	14362.60	11354.84	8509.87	3.66	17.20	244.70	5.71	591.91	7085.74	0.00	0.61	0.37	0.02	1.85	2.37	1.80	0.62	0.00
Altaelva	avg.	7756.63	11260.44	8767.42	9.23	20.13	117.96	7.13	479.76	12663.20	0.00	0.25	0.03	0.00	1.35	0.46	0.70	0.51	1.14
Bjerkreimselva	avg.	4002.92	952.69	2123.45	1.67	5.91	512.87	7.28	659.04	2202.25	0.00	0.14	0.28	0.03	0.46	4.14	0.26	0.10	0.47
Vikedalselva	avg.	878.37	476.25	395.26	0.51	1.22	63.54	1.42	87.73	317.30	0.00	0.05	0.04	0.00	0.12	0.66	0.11	0.05	0.00
Nausta	avg.	2261.71	612.29	1599.66	2.32	4.28	63.77	1.88	132.73	937.90	0.00	0.04	0.05	0.00	0.17	0.72	0.08	0.04	0.00
Driva	avg.	6568.81	5905.18	3689.06	5.33	11.85	262.50	8.28	470.15	6920.31	0.00	0.13	0.12	0.00	2.16	2.39	0.64	0.50	0.00
Nidelva (Tr.heim)	avg.	6137.13	2356.62	5680.90	2.69	8.21	189.33	14.47	403.56	4320.40	0.00	0.20	0.06	0.00	1.47	1.10	1.56	0.42	0.00
Målselv	avg.	6639.21	8109.94	3248.27	6.73	11.89	105.97	5.11	274.80	5637.52	0.00	0.12	0.21	0.01	1.86	1.71	1.31	0.55	0.87
Tanaelva	avg.	19266.56	6737.27	20746.52	13.23	42.88	205.10	76.54	1147.51	46887.79	0.00	0.38	0.25	0.03	4.60	13.28	3.63	2.10	0.00
Pasvikelva	avg.	15088.73	7845.31	18653.37	11.10	36.42	199.57	162.08	1116.83	23654.61	0.01	2.52	1.10	0.22	109.52	16.52	107.72	0.89	0.00
Vegårdselva	avg.	964.51	706.76	1932.51	0.89	2.60	69.12	11.54	147.59	1008.71	0.00	0.08	0.13	0.01	0.21	2.30	0.16	0.06	0.28

NIVA: Norges ledende kompetansesenter på vannmiljø

NIVA gir offentlig vannforvaltning, næringsliv og allmennheten grunnlag for god vannforvaltning gjennom oppdragsbasert forsknings-, utrednings- og utviklingsarbeid. NIVA kjennetegnes ved stor faglig bredde og godt kontaktnett til fagmiljøer i inn- og utland. Faglig tyngde, tverrfaglig arbeidsform og en helhetlig tilnærmingsmåte er vårt grunnlag for å være en god rådgiver for forvaltning og samfunnsliv.

NIVA
Norsk institutt for vannforskning

Gaustadalléen 21 • 0349 Oslo
Telefon: 02348 • Faks: 22 18 52 00
www.niva.no • post@niva.no