ASC Farm Standard

Criterion 2.7 – Water Quality Annexes Document

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Glossary of terms and acronyms

AC: Assimilative Capacity
AMA: Area-based Management Association
AZE: Allowable Zone of Effect
BOD: Biological Oxygen Demand
Chl-a: Chlorophyll-a
DO: Dissolved Oxygen
DPSIR: Driver, Pressure, State, Impact, Response (OECD framework indicator categories)
FW: Fresh Water
HAB: Harmful Algal Bloom
HRT: Hydraulic Residence Time – also referred to as flushing time
Lentic: an aquatic ecosystem with standing or slow flowing water such as a lake, pond, or reservoir
Lotic: an aquatic ecosystem with rapidly moving water
RW: Receiving Water
RWFA: Receiving Water Farm Afar (sample station out with a downstream mixing zone), point-source systems)
RWFE: Receiving Water Farm Effluent (point-source systems)
RWFI: Receiving Water Farm Inflow (point-source systems)
RWRP: Receiving Water Reference Point (unimpacted upstream sample station, diffuse-effluent systems)
SD: Secchi-disk Depth (measure of water transparency)
TA: Technical Advisory Group (ASC)
TN: Total Nitrogen
TP: Total Phosphorous
TSI: Trophic Status Indicator
TSS: Total Suspended Solids
TWG: Technical Working Group (ASC)
VR: Variance Request (ASC procedure for mitigation requests re. indicator non-compliance)
WFD: EU Water Framework Directive
WUM: Waterbody Unit of Management
WUMP: Waterbody Unit of Management Plan
WQ: Water Quality

Background

This document contains 9 annexes developed for the draft indicators resulted from the Water Quality (WQ) Technical Working Group (TWG) review.

The annexes should be read in conjunction with (i) the draft indicators and (II) a separate TWG recommendation report providing rationale for the indicators.

Note: All modelling requirements for WQ indicators (e.g. determining limiting nutrients, TSI estimation, flow rates etc.) including calculation of geometric means, will be implemented using a spreadsheet tool (currently under development), allowing applicants to make their own calculations without needing access to specialised tools or software. The tool will also include data entry templates to support standardised reporting of WQ data to ASC submission.

Annex 1: Receiving water classification

General classification of lotic and lentic systems

Generally, classification of receiving waters as lentic or lotic will be evident from visual assessment in conjunction with definitions below, e.g. as broad lakes or lagoons (lentic) or channelised rivers/canals (lotic). In situations of transitional uncertainty (e.g. reservoir impoundments in U-shaped river valleys, transitions from alluvial river deltas or enclosed fjords) classification should be based on assessment of hydraulic residence time (HRT; days; **Indicator 2.7.1**).

What is a river?[1]

(a) any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved (i.e. a modified river or canal), AND
any tributary, branch or other watercourse into or from which a watercourse referred to in the paragraph above, OR

(b) has a hydraulic residence time (HRT) <= 5 days.

What is a lake?[2]

(a) a standing body of open water that occurs in a natural depression fed by zero or more streams from which a stream may flow, that occurs due to the widening or natural blockage or cut-off of a river or stream, or that occurs in an isolated natural depression that is not a part of a surface river or stream AND
has an open water area free of rooted vegetation of at least 1 hectare OR

(b) a standing body of open water created by artificially blocking or restricting the flow of a river, stream, or tidal area (i.e. artificial lakes or reservoirs) AND
has an open water area free of rooted vegetation of at least 1 hectare OR

(c) is not an artificial water-filled depression created by excavating and/or diking dry land to collect and retain water for such purposes as aquaculture, stock watering, irrigation, settling basins, cooling, or rice growing

(d) has an HRT >5 days

What is an estuary?

(a) a part of a river or stream or other body of water that has an unimpaired connection with the open sea and where the sea water is measurably diluted with fresh water derived from land drainage.

An estuary is assumed to be a lentic WUM (HRT > 5 days) UNLESS the UoC can present evidence based on either credible modelling or measurements that the average estuarine residence time is <5 days.

- **Where there remains any doubt and no HRT calculation is available, the system shall be regarded as lentic on a precautionary basis.**

Where transitional boundary situations exist and the previous guidance is not conclusive, the following steps shall be followed to differentiate lotic from lentic systems.

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[1] https://education.nationalgeographic.org/resource/river

[2] https://education.nationalgeographic.org/resource/lake

A. Determination of current velocity

River flows may be obtained either from

- **(i) National agencies or third-party databases or**
- (ii) **Direct measurements.**

Unless otherwise specified, the 25% percentile of the flow cumulative distribution should be used for calculations.

- **When flows are measured (Annex 7) the 25% percentile is assumed to be the lowest of the four flows that shall be measured over the course of a year.** The timing of these measurements shall also capture any predictable seasonal variation in flows.
- When flow measurements are available from third parties (e.g. national hydrographic agencies, internet databases), the low flow is defined as the 25th percentile of the cumulative flow distribution summarised over the lesser of the past ten years or the period of observation.

(i) Current velocity estimation using third-party data

In such cases, the 25% percentile of the cumulative flow (Q) distribution of the shorter of the past ten years or the duration of flow monitoring should be used for assessment of the <0.1m/s current velocity (v) boundary requirement for this indicator using Manning's formula[3] (to be provided in an accompanying 'ASC water quality modelling spreadsheet tool).

(ii) Manual estimation of flow rate and velocity

Stream flow rates (Q m^3/sec) and current velocity (v m/s) can be estimated based on measurement of transects of stream channel cross section and instantaneous flow velocities using accepted procedures (the accompanying spreadsheet will provide a template for these calculations).

B. Classification of transitional slow-moving systems as lentic or lotic

Where systems have a mean current velocity <0.1m/sec then their definitive classification as lentic or lotic should be based on assessment of HRT as follows:

Steady state (long term average) HRT values can be derived from secondary data or calculated as follows:

Equation 1.2 Mean hydraulic residence time (HRT; days) = $(Q/365) / (1{,}000{,}000 * A * \bar{z})$

Where:

Q (m^3/yr) = the steady state (long-term) annual flow of water through the WUM outflow

A (km^2) = the average (long term) area of the waterbody

$\bar{z}$ (m) = the average (long term) mean depth of the WUM (**Annex 2**)

Transitional systems with an HRT ≤5 days shall be considered as lotic.

Transitional systems with an HRT >5 days shall be considered as lentic.

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[3] Schulze, K., Hunger, M. and Döll, P., 2005. Simulating river flow velocity on global scale. *Advances in Geosciences*,*5*, pp.133-136.

If measurements are not available, there are a number of publicly accessible global databases that can be used to obtain annual outflow estimates (e.g. Ghiggi et al. 2019, Linke et al. 2019). Data sources include:

HydroAtlas: https://www.hydrosheds.org/hydroatlas

GRUN: https://doi.org/10.6084/m9.figshare.9228176

Differentiating fresh and saline water

Where requirements differentiate between fresh and brackish/ marine water (e.g., DO saturation limits, **Annex 4**) **a breakpoint of 20 psu (ppt) shall be used**.

Annex 2: Waterbody unit of management (WUM) boundary setting

2.1 Defining a WUM

Where the receiving water is classified as a lentic system (**Annex 1**) farms must define appropriate area boundaries for a waterbody unit of management (WUM) as basis for area-based monitoring of water quality limits and coordinated management requirements (**Indicator 2.7.2**).

If area-based water quality monitoring and setting of targets for environmental improvements is already a regulatory requirement of the farm's jurisdiction, then farms will use this definition as the 'waterbody (area) unit of management' (WUM). This derogation will not apply where boundaries are operationally (e.g. based on administrative jurisdiction), rather than biophysically defined[4].

Otherwise, the area covered by the WUM must reflect a logical geographic scope such as a lake and its contributing catchment area. Boundaries are to be defined based on coherent characteristics in terms of natural processes and catchment land use and most fundamentally, the zone in which cumulative impacts are likely to affect ecosystem structure and function.

Boundaries must also reflect realistic abilities to manage eutrophication risk (e.g. transnational WUMs Hydro-morphology, bathymetry and water movement characteristics are of particular importance [i.e the size, shape and structure of a waterbody will determine the flow and quantity of water, sedimentation, and nutrient retention in the water column]).

- Farms shall present a map (or maps) showing the distribution of all existing aquaculture operations in the wider lentic system under consideration. This map will include cages and any land-based farms releasing effluents. Zones with potential for future farming expansion are to be indicated. All water sites established for WUM and farm-level monitoring (**Annex 3.2**) should also be plotted differentiating baseline, farm-reference and farm-impacted sites.

High cumulative risk zones: Where localised risk of adverse impact is elevated due to cumulative effects of certified farms (or non-certified farms belonging to applicant companies), e.g. in **hydrodynamically isolated embayments** (below) of larger waterbodies or zones subject to more **localised stratification** effects (e.g., due to marked depth transitions), then WUM boundaries should be narrowed accordingly (improved management in these zones will also mitigate 'far-field' downstream impacts).

Where non-certified farms releasing effluents to high-risk zones (as defined above) are connected to a wider lentic receiving water with applicant/ certified farms, then WUM level WQ monitoring **should not** include sampling stations in these zones as their inclusion would bias determination of baseline conditions in the larger WUM. This will also encourage certified farms to support performance improvements in these zones (see **Annex 6**).

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[4] Note: Most of the main salmon producing countries have well-developed ecosystem-based coastal water quality monitoring and targets addressing eutrophication risks.
In European countries Water Framework Directive (WFD) implementation has proved challenging where boundaries are operationally (e.g. jurisdictional boundaries) rather than biophysically defined – more so in FW contexts.

Defining a hydrodynamically isolated embayment:

Hydrodynamically isolated embayments (HIE) are enclosed “lake like” basins having limited flushing[5] and should be treated as a separate WUM for water quality monitoring purposes (**Annex 3.2**). The farm should first check if the local regulator has already classified the site using an appropriate system (see example below). Otherwise, the following attributes are to be used for initial scoping:

(a) poor connectivity to deep offshore waters and/ or
(b) sheltered from more energetic conditions e.g. inflows, currents, exposure to onshore or monsoonal winds and
(c) *the hypolimnion (the densest bottom layer in a thermally stratified lake or part thereof) is periodically or permanently poorly flushed*

Where a basin appears to share these attributes, onus is on the UoC to demonstrate that a basin is not a HIE using the following approach:

Water quality measurements are made along a transect running from inside an embayment into the main waterbody (Figure 1). Measurements should be conducted as follows:

(i) Identify the narrowest point in the embayment opening (red line in Figure 1)
(ii) Establish two transects of equal length starting at the narrowest point and extending in and out of the embayment (black dashed line in Figure 1).
(iii) At an equal number of equally spaced sites in each transect, collect epilimnetic (0.5m) water samples
(iv) Analyse the water samples, for a conservative tracer (chloride, conductivity or salinity) or a nutrient
(v) Plot concentrations of water quality determinants against their position along the transects.

When embayments are hydrologically isolated, there will be a monotonic trend (either decreasing or increasing) in concentrations from sites 1-7 (within the embayment) to the furthest offshore site in the main waterbody (site 13). An embayment is not hydrologically isolated when there is no significant monotonic trend. Trend significance can be determined using the linear regression functions in Excel.

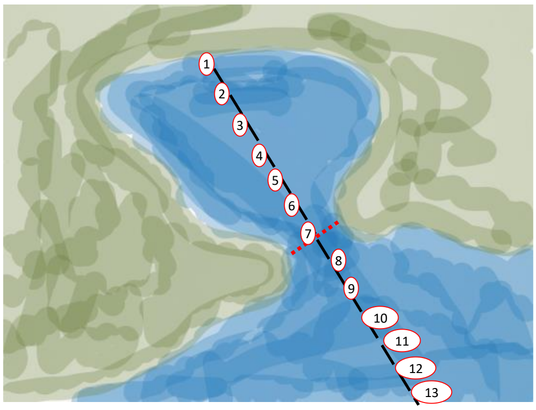

Figure 1. Tracer sampling points along a transect for HIE determination

More complex assessment using, e.g. three-dimensional modelling could also be conducted by competent third parties.

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[5] Based on a classification developed by the Ontario Ministry of Environment (Boyd et al 2001).

Annex 3: WUM and farm-level water quality monitoring methods - lentic and lotic systems

A3.1 Grandfathering policy for determination of baseline trophic status

The publication date of the aligned ASC Farm Standard shall be the earliest possible 'grandfathering' date for determination of the baseline trophic status of lentic systems (see **Indicator 2.7.3**).

- The first candidates for certification shall review any existing secondary data, i.e. from scientific studies or monitoring for regulatory purposes, that has been collected since publication of the ASC standard. The earliest such data shall be used determine the WUM baseline trophic status. Results of this review shall be available for audit. Later entrants should demonstrate familiarity with its content e.g., through AMA participation (**Annex 6**)

- Where such background data is not available or insufficiently robust, baseline trophic status shall be based on the first 24 months of monitoring of SD, TN, TP and chl-a parameters by any farms applying for certification in the WUM, using the methods outlined below (**Annex 3.2**). This will also provide the baseline for any later certification entrants in the WUM.

This grandfathering policy shall not apply to any rate of change (RoC) indicators (**Annex 4.3**), which shall always be based on comparisons between **geometric means** (**Annex 4**) of **rolling 24-month** (lentic systems) or **successive 12-month** (lotic systems) monitoring periods.

Where a requirement for a 24-month monitoring period would delay compliance decisions for initial-audits, determinations shall be based on the **geometric means of the first two successive 12-month monitoring periods**, applying the same metric limits as required for 2-year periods.

A3.2 Water quality monitoring requirements for WUM characterisation

Subject to grandfathering requirements (**Annex 3.1**), compliance with ASC water quality requirements for lentic systems will be based on two overlapping sets of longitudinal monitoring surveys at (A) WUM and (B) farm level.

Some farm level data (from upstream reference sites unimpacted by the farm) will also contribute to the WUM-level survey, whilst some methods will also apply to lotic systems. Both are described below.

A. WUM level WQ monitoring survey:

The purpose of this survey (**Indicator 2.7.3**) is to provide water quality data required to (i) establish a WUM baseline trophic status (ii) assess cumulative impacts of ASC certified and other aquaculture operations releasing nutrient bearing effluents to the WUM.

Calculation methods for metric limits associated with monitoring data are outlined in **Annex 4**.

Background data (e.g. collected by local regulatory bodies) should be used where feasible and augmented/ replaced with foreground (farm) data if it does meet ASC standard requirements. **If a regulatory body has determined a historical baseline for the waterbody and it is consistent with the intent and scope of the ASC standard, that baseline shall be used.**

Sampling requirements:

1. WUM level baseline monitoring shall, at a minimum commence 24 months prior to initial audit of the first farm(s) applying for certification in the WUM[6]. The duration should also reflect scoping of the anticipated variability in a system[7] and extended if the recent past encompasses any exceptional events (e.g. adverse turnovers; **Annex A3.4**). Sampling shall be repeated quarterly, i.e. 4 times over a 12-month period aiming to capture seasonal variations.

2. Each sampling event must include a (i) **minimum of 10 sites** where the WUM surface area is less than 200km^2 or one site for every 20km^2 of WUM area, (ii) all UoC reference sites.

3. Sample sites should be distributed across the WUM based on the following considerations:

   3.1 The distribution should encompass locations below major influents at the head of the WUM to locations downstream of all existing farming and zones identified with potential for farm expansion during boundary setting (**Annex 2**).

   3.2 **All WUM level sites** should be located far from point sources of nutrients such as stream or drainage inflows and should be minimally influenced by inputs from anthropogenic causes including aquaculture, agricultural runoff or nutrient releases from riparian or coastal communities. HIE and shallow inshore sites should also be avoided (**Annex 2**).

   Sites that also serve as individual **farm-level references sites** (see **section B**), shall be at least 500m from the edge of the net pen array, in an upstream location that follows similar patterns in upwelling to the farm site.

   Where statutory regulations stipulate a **benthic allowable zone of effect (AZE)** the reference site should be located at the upstream edge of the AZE. A single reference site can be used for farms sharing a continuous AZE.

   As a further check that appropriate sites have been selected, the geometric mean (**Annex 4**) of any monitored parameter must indicate superior water quality at farm-level reference than impacted sites (see next section).

   3.3 **All existing farm-level reference sites** (only) should be included in the WUM baseline sample, with additional sites added to meet the required quota as needed. Subsequent certification-entrant reference sites should also be used to expand the baseline survey – however all original baseline survey points shall be retained, even where certification of baseline-farms ceases.

   The distribution of existing farms and potential zones of farming expansion must also be considered during WUM boundary setting (**Annex 2**)

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[6] Encompassing seasonal risk factors linking nutrient input levels and dilution effects considering total system flow patterns over dry and wet seasons (noting leaching may elevate nutrient inputs during rains)

[7] Steady-state equilibria should not be anticipated as eutrophication is a process subject to ongoing and naturally variable rates of change. Thus, in practice, the baseline state will be a parameter average or rate over a defined period of time for which historic water quality data is available/selected.

3.4 All baseline and 'expansion' sites shall have their GPS coordinates recorded and be distinguished on a WUM map (**Annex 2**). This should be available for review at audit.

4. At each site epilimnetic samples (0.5-1m depth below the water surface, above any permanently stratified layer) shall be collected using a Van Dorn or Kemmerer type water sampler for laboratory analysis of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS).

   For each of these parameters three 'field' replicates shall be collected and pooled for analysis. From this pool, a 500 ml sample should be collected in a clear plastic bottle, placed on ice and in a cooler, and analysed within 48 hours.

   Where feasible, analyses shall be done by an ISO 17025 accredited third-party laboratory using standard methods outlined in **Annex 3.3**. However, Hach, Palintest or equivalent field kits can be used for TN and TP analysis. In such cases, samples should be sent periodically (ideally once a quarter and at minimum once a year) to an independent accredited third-party laboratory for analysis to ensure consistency of results and ensure/establish quality control.

   Clear and detailed records of sampling frequency and all analytical results must be kept.

5. At the same time as water quality samples are collected for laboratory analysis, **SD** and chl-a shall be measured and '**profiles' of temperature and DO** measured in-situ.

6. **SD (m)** shall be measured using the method referenced in **Annex 3.3**

7. **Chl-a (µg/l)** shall be measured at 0.5-1m depth using a calibrated sensor with specification meeting or exceeding those described in **Annex 3.3**

8. **DO (mg/l) and temperature profiles** shall be based on measurements at 1m depth intervals to the shallowest of (a) a depth of 1m off bottom, (b) a depth where the overlying 5m of DO measurements are 2mg/l or less or (c) 50m. Where relevant, salinity shall also be measured and recorded. DO and temperature profiles should also be collected at farm impacted sites (see **section B**)

DO and temperature measurements should made using a calibrated temperature compensated probe meeting or exceeding the specifications documented in Annex A3.3 with suitably extended cable length.

As far as possible, all WUM-level and contributing farm-level samples (**section B**) shall be collected simultaneously (on the same day) by all certified farms and new entrants. Where an AMA is required (**Indicator 2.7.15**), this should be one of the specified coordination actions (**Annex 6**)

No on-going monitoring of [TN], [TP], chl-a or DO/ temperature profiles will be required at WUM or farm level, so long as the WUM geometric mean of SD calculated over any rolling 2-year period remains ≥10m

B. Farm level WQ monitoring survey:

The purpose of the farm-level survey is to provide water quality data required to (i) contribute to the WUM-level survey (reference sites only) (ii) assess more localised impacts of individual farms applying for certification in both lentic and lotic systems. No baseline assessment is required for lotic systems.

Sampling requirements:

1. Farm-level sampling shall commence, at a minimum 12 months prior to the first audit of any farm (including any farms within a multi-site certificate expansion). Sampling shall be repeated quarterly, i.e. 4 times over a 12-month period aiming to capture seasonal variations. 24 months of data collection will be required for any site entering certification at the start of the baseline WUM-level survey.

2. Sampling shall follow WUM level requirements 4 and 5 (above) and shall be conducted at two sites:

   (a) An 'Upstream' reference site: See **Annex 3.2** (above)

   (b) A 'Downstream' farm impacted site: shall be located in the downstream direction of the current at the edge of the farm. For example, measurements can be taken at the edge of a net-pen array, or off a feed shed or housing structure. Conditions of the water should be as close as possible to those the fish experience. Measurements shall be taken at the same location (recorded with GPS and plotted on the WUM map), pre-feeding and as early in the day as possible to allow for comparison between days.

3. The following parameters shall also be measured at the farm impacted site. This method shall apply for **systems releasing diffuse effluents to lentic or lotic systems**:

   DO concentration (mg/l) and percent saturation shall be measured at 5m depth using a calibrated temperature compensated probe. Temperature, and where relevant, salinity shall also be measured and recorded. Results will be used to assess compliance with **indicators 2.7.10** and **2.7.11**.

Justification must be provided for any missed samples, for example due to extreme weather conditions.

A3.3 Laboratory and field measurement methods

TP, TN and TSS concentrations are to be measured from unfiltered water samples by an accredited laboratory (ISO/IEC 17025 or equivalent) using the following analytical methods defined by the International Standards Organisation (ISO) or the American Public Health Association (APHA)

Total Phosphorus
- ISO 6878:2004, ISO 15681-2:2018
- APHA: https://www.standardmethods.org/doi/10.2105/SMWW.2882.093

Total Nitrogen
- ISO 11905-1:1997, ISO 29441:2010

- APHA: https://www.standardmethods.org/doi/10.2105/SMWW.2882.086

Total Suspended Solids

- ISO 11923:1997
- APHA: https://www.standardmethods.org/doi/10.2105/SMWW.2882.030
- In the absence of suitable laboratory facilities, farmers can provide test results directly based on use of proprietary colorimetric testing kits (e.g. HACH or Palintest systems) that reference appropriate general methods in their instructions. Colorimetric test options include the Kjeldahl and indo-phenol blue methods for TN assay, and the ammonium heptamolybdate and molybdenum blue for phosphate.

Dissolved Oxygen (DO) sensor specifications

- Allows recording of % saturation and temperature corrected/compensated concentrations.
- Range (Polarographic DO): 0.00 to 20.00mg/L
- % Saturation Range (Polarographic DO): 0.0 to 200.0 % saturation
- Resolution (Polarographic DO): 0.01, 0.1mg/L

Chlorophyll-a (chl-a) sensor specifications

- Measurement range: 0 - 500µg/l chlorophyll-a.
- Resolution: 0.1µg/l chlorophyll-a.
- Accuracy: +/- 2% of reading.

Secchi disc (SD) transparency

Guidance on the appropriate use of a Secchi disk is available at the following link:

https://www.nalms.org/secchidipin/monitoring-methods/the-secchi-disk/what-is-a-secchi-disk/

Total Suspended Solids (TSS)

1. Filter water samples through a pre-weighed 2µm glass fibre filter (scales accurate to 0.0001 g)
2. tThe filter is dried on a pan, in an oven (104±1°C, for min. 1 hr) to remove remaining water and re-weighed. Place filter in a desiccator until room temperature is reached.
3. The filter weight difference divided by the sample volume gives the TSS concentration in mg/l

Equation 3.1 TSS (mg/l) = (Weight final (g) – weight initial (g) x 1,000,000) / Sample volume (ml)

A3.4 Evaluating the history of adverse turnover events (lentic systems)

The number of adverse turnover events occurring during the past 10 years (**Indicator 2.7.3**) shall be determined through a review of news media and consultation with relevant stakeholders.

Where evidence of fish kill events or loss of other aquatic fauna can clearly be attributed to natural phenomena, e.g. regular seasonal turn-over, under ice oxygen consumption, geologic activity, etc., incidents shall not count against frequency limits for the requirement. Both the total number of adverse turnover events and those that are ascribed to natural phenomena shall be recorded.

Annex 4: Calculation of limiting nutrients, trophic status and DO requirements.

ASC WQ modelling spreadsheet tool

All modelling requirements for WQ indicators (e.g. determining limiting nutrients, TSI estimation, flow rates etc) including calculation of geometric means etc., will be implemented using a spreadsheet tool (currently under development), allowing applicants to make their own calculations without needing access to specialized tools or software. The tool will also include data entry templates to support standardised reporting of WQ data to ASC submission.

Calculation of geometric means

All calculations of mean (average) values shall be based on a geometric mean unless otherwise specified. The geometric mean is the product of a series of "n" observations raised to the power 1/n (i.e., the nth root).

For example, the geometric mean of four measurements (1,2,3,20) is $(1 * 2 * 3 * 20)^{1/4} = 3.31$

All results should be presented to two decimal places.

A4.1 Modelling of limiting nutrients

There is a large body of scientific evidence showing that the most likely limiting nutrient (N and/or P) for increased primary productivity and subsequent WUM-level water quality impairment can be determined based on the mass ratios of TN and TP inputs (N_{In} and P_{In})[8,9].

For mass ratios of N_{In}:P_{In} ≥23, lakes are generally P limited. When N_{In}:P_{In}≤9, lakes are generally N limited. At intermediate N_{In}:P_{In} ratios (between 9 and 23), lakes are both N and P limited.

Both the most likely limiting nutrient (N, P or both) and the change in nutrient concentrations can be estimated using published steady state water quality models (summarised below), and WUM level monitoring (**Annex 3.2**)**.**

OECD recommended models (e.g. Vollenweider, Dillon-Rigler, etc.) typically assume that **the mass of nutrient entering a lake (N_{In} and P_{In}, both in kg/yr) can be predicted from measured nutrient concentrations in the epilimnion, flow and an empirical retention formula** (Equations 4.1 and 4.4 below). **Epilimnetic concentrations can be assumed to be a reasonable proxy for the average (geometric mean) concentration in the water column ([N] and [P]; mg/l). Both the Vollenwieder and Dillon Rigler models have been applied to intermittently and permanently stratified water bodies.**

Phosphorus inputs are estimated as follows (Equation 4.1)

Equation 4.1 $$P_{In} = (0.001 * [P] * Q) * (1 + 0.47\, \tau_w^{-0.53})$$

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[8] Paerl, H.W., Scott, J.T., McCarthy, M.J., Newell, S.E., Gardner, W.S., Havens, K.E., Hoffman, D.K., Wilhelm, S.W. and Wurtsbaugh, W.A., 2016. It takes two to tango: when and where dual nutrient (N & P) reductions are needed to protect lakes and downstream ecosystems. Environmental science & technology, 50(20), pp.10805-10813.

[9] Guildford, S.J. and Hecky, R.E., 2000. Total nitrogen, total phosphorus, and nutrient limitation in lakes and oceans: is there a common relationship?. Limnology and oceanography, 45(6), pp.1213-1223.

The coefficients in Equation 4.1 are derived from published reanalysis of a large dataset[10] and [P} is the WUM-level geometric mean concentration over the last 24 months (**Annex 3.2**).

Mean hydraulic residence time (τ_w; yr) is calculated from mean depth and hydraulic load in the following manner:

Equation 4.2 $\tau_w = \bar{z} / H_l$

where hydraulic load H_l (m/yr) is determined from A and Q: (**Annex 1**):

Equation 4.3 $H_l = Q/(1000000\ A)$

Nitrogen inputs are estimated as follows (Equation 4.4) where [N] is the WUM-level geometric mean concentration over the last 24 months (**Annex 3.2**) and v_f is the apparent settling velocity, with values of 6.83 m/yr for lakes and 13.6 for reservoirs[11].

Equation 4.4 $N_{In} = (0.001 * [N] * Q) \exp(v_f/H_l)$

Equations 4.1 and 4.4 provide simple and auditable estimates of present-day nutrient inputs to a WUM. These values can then be used for two purposes. First, they can be used to assess whether the WUM is N limited, P limited or co-limited. Second, they can be used as part of the assimilative capacity modelling (**Annex 5**.1) needed to determine overall sectoral contribution to limiting nutrient inputs.

A4.2 Calculation of trophic status indices

Farms shall demonstrate that there is no upward transition of trophic status, at either WUM-level (**Indicator 2.7.4**) or farm-level (**Indicator 2.7.7**), compared to the baseline trophic status of the WUM.

To determine compliance, first **the geometric mean** of the four WQ parameters listed below shall be calculated for WUM and farm level monitoring data on a rolling 24-month basis (see **Annex 3.2** for sampling requirements).

Results are then be used to calculate normalised **trophic status indices (TSI)**[12] for each of the four parameters as follows:

Secchi depth (SD; m),

Equation 4.5 SD-TSI $= 60 - 14.41 \ln(SD)$

Where SD is the geometric mean over the relevant time-period of Secchi depth readings in metres and “ln” is the natural logarithm. Note SD should only be used as a validation method in oligotrophic systems.

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[10] Brett, M.T. and Benjamin, M.M., 2008. A review and reassessment of lake phosphorus retention and the nutrient loading concept. Freshwater Biology, 53(1), pp.194-211.

[11] Harrison, J.A., Maranger, R.J., Alexander, R.B., Giblin, A.E., Jacinthe, P.A., Mayorga, E., Seitzinger, S.P., Sobota, D.J. and Wollheim, W.M., 2009. The regional and global significance of nitrogen removal in lakes and reservoirs. Biogeochemistry, 93, pp.143-157.

[12] Carlson, R.E. and Simpson, J., 1996. Trophic State Equations. A Coordinator’s Guide to Volunteer Lake Monitoring Methods, p.96.).

Total phosphorus ([TP]; µg/l)

Equation 4.6 **TP-TSI** = 14.42 ln([TP]) + 30.6

Where [TP] is the geometric mean over the relevant time period of total phosphorus concentration in micrograms per litre (µg/l) and "ln" is the natural logarithm.

Total nitrogen ([TN]; mg/l)

Equation 4.7 **TN-TSI** = 54.45 + 14.43 ln([TN])

where [TN] is the geometric mean over the relevant time period of total nitrogen concentration in milligrams per litre (mg/l) and "ln" is the natural logarithm.

Chlorophyll -a ([chl-a]; µg/l)

Equation 4.8 **Chl-a TSI** = 9.81 ln([Chl-a]) + 30.6

Where [Chl-a] is the geometric mean over the relevant time of chlorophyll concentration in micrograms per litre (µg/l) and "ln" is the natural logarithm.

Interpreting TSI results

TSI breakpoints: Normalised TSI values ranges from 0 (ultra-oligotrophic) to 100 (hyper eutrophic). A TSI less than 40 is indicative of oligotrophic conditions, values between 40 and 50 indicate mesotrophic conditions and values greater than 50 indicate eutrophic conditions and values greater than 60 indicate hyper eutrophic conditions.

Table 4.1. Trophic status classes based on Trophic Status Indices (TSI; dimensionless) for Secchi depth, total phosphorus concentration total nitrogen concentration and chlorophyll-a concentration.

TSI	Status	SD (m)	[TP] (µg/l)	[TN] (mg/l)	[Chl] (µg/l)
<30	Ultra-oligotrophic	>8	<6	<0.18	<0.9
30-40	Oligotrophic	4-8	6-12	0.18-0.37	0.9-2.6
40-50	Mesotrophic	2-4	12-24	0.37 – 0.73	2.6-7.3
50-60	Eutrophic	1-2	24-48	0.73-1.46	7.3-20
>60	Hyper-eutrophic	<1	>48	>1.46	>20

Trophic status shall be determined based on the highest TSI result of any parameter eligible for classification, based on the following criteria:

- SD should only be used where the TSI is <40, indicative of oligotrophic conditions[13]
- TP and TN should be used in P and N limited systems respectively (see **Annex 3.2**)
- For systems that are **jointly N and P limited**, the greater of P-TSI and N-TSI should be used
- Chl-a should be used in all cases.

When the applied TSI value, is ≤ 5 units below a breakpoint, the WUM is assumed to be approaching a status transition, triggering a requirement for coordinated response actions (**Annex 6**).

A4.3 Calculation of rate of change (RoC) indicators

Farms shall demonstrate that neither the limiting nutrient(s) nor chl-a indicates an upward rate of change of > 30%, at either WUM-level (**Indicator 2.7.5**) or farm-level (Indicator 2.7.8), compared with the previous rolling 24 months of WUM and farm level survey data.

Rate of change (RoC) shall be calculated as the percent change between **geometric means** of data collected over successive 24-month rolling monitoring periods, i.e. between the mean of data collected in years 1-2 and years 2-3 etc.

The RoC shall be reported as the difference between means divided by the mean in the earlier period:

Equation 4.9 $RoC(\%) = (X_{Later} - X_{Earlier})/X_{Earlier}$

Where

RoC (%) = the percentage change in geometric means of a rate of change (RoC) indicator between two successive 24-month rolling periods

$\mathbf{X_{Later}}$= the geometric mean of the rate of change (RoC) indicator in the second of two successive periods

$\mathbf{X_{Earlier}}$= the geometric mean of the rate of change (RoC) indicator in the first of two successive periods

RoC parameters include: [N], [P], [Chl-a], zones of DO depletion and anoxia depth minima, and BOD.

A4.4 Calculation of rate of change in the depth of zones of oxygen depletion and anoxia

Farms shall demonstrate whether the zone of oxygen depletion[14] or anoxia[15] indicates a decrease in depth of > 10%, at either WUM-level (**Indicator 2.7.6**) or farm-level (**Indicator 2.7.9**), compared with the previous 24-month WUM monitoring survey.

DO and temperature depth profile data collected at both (i) WUM sample sites (including farm reference sites) and (ii) farm impacted sites following the method described in A3.2, should be analysed as follows.

a) Determine the minimum depth of the zones of (i) depletion (≤4mg/l) and (ii) anoxia (≤2mg/l) for each sample point over the two previous 24-month rolling periods of monitoring.

b) Calculate the (i) WUM and (ii) the farm impacted geometric means of the minimum depths of (i) depletion (ii) anoxia over the specified time-period.

c) Calculate percent rate of change between the geometric means of the two time periods (see Equation 4.9).

Whilst no direct limit will be placed on these minima, excessively high rates of change of change at WUM will result in more stringent nutrient loading efficiency requirements (**Annex 9**), coordinated under an AMA (**Annex 6**). At the discretion of the AMA membership, relatively higher demands may then also be placed on individual farms exceeding the 10% limit.

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[14] i.e., depth at which DO falls below 4mg/l (see also 2.7.3)

[15] i.e., depth at which DO falls below 2mg/l (see also 2.7.3)

Results will also facilitate monitoring of stratification and mixing patterns across the WUM and further aiding characterisation of any localised zones of 'high cumulative risk'.

A4.5 Calculation of minimum farm DO saturation – systems releasing diffuse effluents to lentic or lotic water bodies

Farms shall demonstrate that the weekly average of daily DO measurements shall remain ≥ 65% saturation in freshwater and ≥ 70% saturation in seawater[16] (**Indicator 2.7.10** for lentic systems and **Indicator 2.7.22** for lotic systems).

Using results of farm-level DO monitoring at the impacted monitoring site (**Annex 3.2**), percent saturation shall be calculated for each sample point, correcting for temperature, salinity and altitude as relevant. Weekly averages shall then be calculated.

Should a farm not meet the relevant minimum weekly average saturation requirement, the farm must demonstrate one of the following:

(a) Consistency of percent saturation with readings taken at a depth of 5m at the farm reference site as part of the WUM-level DO and temperature profiling (**Annex 3.2**).

(b) Daily continuous monitoring with an electronic probe and recorder (meeting or exceeding specifications in **Annex 3.5**) for at least a week, demonstrates a minimum saturation above relevant fresh or seawater limit.

A4.6 Calculation of Daily Diurnal Dissolved Oxygen (DDDO) fluctuation

Wide fluctuations in dissolved oxygen concentration resulting from nutrient enrichment can elevate stress-levels and cause mortalities of sensitive aquatic species, even where concentrations remain above minimum comfort thresholds.

To assess compliance against **Indicator 2.7.25**, dissolved oxygen concentration ([DO], mg/l) must be measured in the receiving water one hour prior to sunrise and two hours prior to sunset (± 30 min) to obtain daily minimum and maximum levels (respectively).

Max [DO] and min [DO] (Equation 7.1) must be measured in-situ using a meter with a temperature compensated **electronic sensor**[17]. The sensor must be maintained and calibrated according to manufacturer's instructions and must meet the specifications listed in **Annex 3.4**.

Measurements should be taken 0.3 metres below the water surface close to RWFA, at a point where mixing is not yet complete. RWFA is generally at least 200m down current from the farm outfall. Where turbidity difference exists between effluent and receiving water, the point beyond which SD readings become constant would be outside of the mixing zone.

DO shall be measured at a minimum fortnightly frequency (i.e. at least twice per month) by the farmer from the time of first stocking.

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[16] Water bodies with salinities >20 psu (practical salinity unit) shall be considered as seawater for this indicator.

[17] Whilst laboratory chemical analysis is also possible, variability associated with sample maintenance during transit is likely to limit accuracy.

In the case of coastal waters, dates must be chosen such that the measurement time (one hour prior to sunrise and two hours prior to sunset) corresponds to high and low tides.

DDDO fluctuation is calculated and the difference between sunset and sunrise values expressed as a percent of theoretical saturation levels at these time points (Equation 7.1).

For this, [DO] saturation levels at sunset (DO saturationMax) and sunrise (DO saturationMin, Equation 7.1) should be corrected for altitude and salinity (i.e. as well as temperature) where farms are located above sea level and/ or discharge to brackish receiving waters. Correction factors are available here: https://water.usgs.gov/water-resources/software/DOTABLES/.

Temperature (°C) and where relevant salinity (PSU or ppt) should be recorded at the same time as DO measurement, and farm altitude also recorded.

Equation 4.10 Percentage change in diurnal DO of receiving waters relative to DO at saturation

$$= [\text{Max DO (mg/l)} / \text{DO at saturationMax (mg/l)} \times 100] - [\text{Min DO (mg/l)} / \text{DO at saturationMin (mg/l)} \times 100]$$

The auditor shall witness probe calibration and receiving water measurement being conducted by the member(s) of staff with routine responsibility for taking measurements and results compared with recent farm records.

Farms can demonstrate that concentrations of total N and total P in discharged water are lower than in the receiving waterbody (i.e. are nutrient sinks) or have not discharged any water (though exchange of culture water or dewatering of water treatment systems) since the last audit or over the last 12 months through the use of water recirculation techniques, are exempt from **Indicator 2.7.25**.

Annex 5: Assimilative capacity, source apportionment and BOD modelling

A5.1 Assimilative Capacity Modelling

Assimilative capacity is the maximum mass of limiting nutrient(s) that can be added to a WUM without causing a shift in trophic status. Trophic status classification is in turn determined according to trophic status index (TSI) thresholds or 'breakpoints' for limiting nutrient(s) (**Annex 4**).

When a WUM is determined to be co-limited by both N and P, the higher of the two TSI values shall be used.

Using equations from **Annex A3.2**, assimilative capacity can be modelled as the mass of nutrient that must be added to a system to move from current conditions (based on the most recent 24 months of WUM level measurements, **Annex 3.2**) to the limiting nutrient trophic class boundary (**Annex 4.2**).

$$M = (0.001 *Q / (1-r)) * (NP_{AC} – NP_0)$$

where M (kg/yr) = the additional mass of limiting nutrient that can be added on an ongoing basis without transgressing trophic status boundaries.

Q (m^3/yr) = average annual runoff (from **Annex 3.2**)

r = the appropriate retention coefficient for nitrogen or phosphorus (from **Annex 4.1**)

NP_{AC} (mg/l) = the limiting nutrient concentration at the trophic status boundary, i.e. the assimilative capacity nutrient concentration from **Annex 4.1**.

NP_0 (mg/l) = the current limiting nutrient concentration in the WUM based on the most recent 24 months of measurements

A5.2 Aquaculture sectoral contribution to WUM limiting nutrient loading (source apportionment)

The aquaculture sectoral contribution to WUM limiting nutrient(s) shall be assessed and reported as kg N/24-months and/or kg P/24-months (as well as proportions of the total external nutrient loading estimated in **Annex 3.2**). Baseline contributions shall be reported, and sectoral contributions updated on an annual basis.

Estimating sectoral inputs to a WUM requires quantification of the following parameters over each successive 24-month rolling two-year monitoring period.

(i) the total number of all farms; cage and land-based, certified and uncertified, releasing diffuse or point-source effluents to the WUM.
(ii) estimate of nutrient (both N and P) inputs to the WUM from each farm based either on nutrient loads (where data is available) OR estimates of the total mass of fed animals harvested, and the total mass of feed used (see Table 1 and **Annex 9**)

Sectoral contributions may be estimated based on one or more of government databases, dialog with other farms on the WUM and modelling. Otherwise, sectoral contributions must be assessed in other ways described below.

- When there is a limited number of farms on a WUM, it may be possible to assess sectoral contributions through interviews with farm operators.
- When it is not possible to assess sectoral contribution to WUM limiting nutrient(s) through other means, a (Supervised) classification & enumeration of cage infrastructure from satellite imagery shall be conducted. In such cases, available open-source data (e.g. Google Earth or other satellite data sources) can be used to determine the size of the aquaculture sector in the WUM. The steps to estimate sectoral inputs are as follows:
  (1) Count all the cages in the WUM
  (2) Count all the ponds adjacent (and likely discharging directly) to the WUM.
  (3) Multiply the number of ponds and cages by the appropriate nutrient load (below) to estimate nutrient inputs

Assumptions for estimating WUM level sectoral nutrient loading

- N & P content of formulated diets (% weight) to be differentiated by species and life-stage where certification is for juvenile life stages (e.g. salmon or trout smolts); adult finisher diets are acceptable for full grow-out systems (Table 9.1).

- Stocking densities to be approximated as the average associated with different production systems, e.g. more intensive cage, tank, raceway or pond systems and semi-intensive ponds systems. Assumptions in Table 1 (tbc) can be used as a starting point but should be validated using local information sources.

- **Table 1 Generic nutrient inputs associated with different types of cages and ponds (tbc)**

Unit	Species	[TP] (kg/unit/yr)	[TN] (kg/unit/yr)	Stocking density range (kg/m3)
Cage	All			5-15
Pond	All			tbc

A5.3 Options for third-party assimilative capacity assessment

Farms may also choose to use a third-party to assess assimilative capacity (including source apportionment) where implemented as part of a wider EIA.

Many suitable models exist that can help determine assimilative capacity[18][19][20][21]. The requirement does not favour one existing model over another, but it is important to outline key elements of a credible assimilative capacity study. At a minimum, the study must do the following:

- Undertake assessment as to allocation of capacity for the whole WUM

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[18] Dillon, P.J. and Rigler, F.H., 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. Journal of the Fisheries Board of Canada, 32(9), pp.1519-1531.

[19] Kirchner, W.B. and Dillon, P.J., 1975. An empirical method of estimating the retention of phosphorus in lakes. Water Resources Research, 11(1), pp.182-183.

[20] Reckhow, K.H., 1977. Phosphorus models for lake management. Harvard University.

[21] Dillon, P.J. and Molot, L.A., 1996. Long-term phosphorus budgets and an examination of a steady-state mass balance model for central Ontario lakes. Water Research, 30(10), pp.2273-2280.

- Undertake assessment as to land use, slope, sewage, other discharges, stream inputs, etc.
- Account for retention in lake and mixing
- Predict both TP and TN concentrations
- Classify trophic status (**Annex 4.2**)
- Undertake impact assessment of fish farm

The study must pay particular attention to the nature and morphology of the lake basin where the farm will be established. The study must analyse at a minimum:

1. Mixing of the surface and bottom waters over a 12-month period
2. Whether bottom waters are permanently or seasonally isolated within the waterbody (i.e. stratification regime)
3. The naturally occurring oxygen levels in the surface and bottom waters e.g., due to seasonal variability in the absence of anthropogenic effects.
4. Whether the water forms part of an enclosed basin (i.e. a hydrologically isolated embayment, **Annex 1**), or an area with isolated bottom waters

A5.4 Modelling of WUM biochemical oxygen demand (BOD)

If modelling of the aquaculture sectoral nutrient contribution is required (**Indicator 2.7.13**), the biochemical oxygen demand BOD imposed on the WUM by the entire aquaculture sector, shall also be modelled (**Indicator 2.7.14**). This shall be assessed for every rolling 24-month period of WUM level monitoring.

Modelling is based on estimation of the difference between total WUM N & C input/output in feed and fish production, using the following mass balance approach[22].

Equation 5.1

$$\mathbf{BOD\ (g/\ m^3/\ 24\text{-}months) = ((TN_{Feed} - TN_{Fish})*4.57) + ((TC_{Feed} - TC_{Fish})*2.67) / (V * 1{,}000{,}000)}$$

TN_{Feed} (mt N / 24 months) = total mass of nitrogen in feed used over the past 24 months

TN_{Fish} (mt N / 24 months) = total mass of nitrogen in fish harvested over the past 24 months

TC_{Feed} (mt C / 24 months) = total mass of carbon (C) used in feed over the past 24 months

TC_{Fish} (mt C / 24 months) = total mass of carbon in fish harvested over the past 24 months

V (m^3)= WUM average volume (see **Annex 1**)

See **Annex 3.6** for approaches for estimation of WUM feed input and harvested fish output.

Deductions may be made for N or C that is captured, filtered, or absorbed through approaches such as IMTA or through direct collection and removal of ‘waste-nutrients’.

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[22] Boyd C. 2009. Estimating mechanical aeration requirement in shrimp ponds from the oxygen demand of feed. In: Proceedings of the World Aquaculture Society Meeting; Sept 25-29, 2009; Vera Cruz, Mexico. And: Global Aquaculture Performance Index BOD calculation methodology available at http://web.uvic.ca/~gapi/explore-gapi/bod.html.

Modelling should be implemented using data already assembled for assimilative capacity and source apportionment modelling, with no requirement for additional monitoring or collection.

Whilst no direct limit will be placed on BOD until sufficient data has been collected for ASC review, an excessively high rate of change can also be used to justify the setting more stringent nutrient efficiency requirements (**Annex 9.1**) under an AMA (**Annex 6.2**).

WUM level BOD modelling should be a coordinated AMA action (**Annex 6.2**), implemented using an ASC spreadsheet tool currently under development and results submitted to the ASC.

Annex 6: Area Management Agreement (AMA)

A6.1 Preconditions for requiring the establishment of an AMA

Area based management is required when the cumulative impacts of a group of farms in an area become harmful, even when an individual farm is operating in a responsible way.

An area-based agreement (AMA) is a formal binding agreement between producers within the WUM, including coordinated actions to monitor, communicated and mitigate eutrophication impacts. Here, the primary intent is to reduce the rate of change towards, and to prevent any upward transition of trophic status (**Indicator 2.7.15**). **Consequently, the requirement currently only applies to farms discharging effluents to lentic systems**, though options for lotic systems may be revisited in future standard revisions.

Where the following conditions exist, certified producers **must formalise an AMA** and demonstrate coordinated actions to reduce total sectoral nutrient inputs through coordinated actions described below.

i. **two or more companies operate ASC certified UoCs within a WUM - and**
ii. **total aquaculture sector inputs contribute >20% of the modelled limiting nutrient(s) load to the WUM (Indicator 2.7.13) - or**
iii. **assimilative capacity modelling indicates the WUM is ≤5 index points below a TSI limiting nutrient or chl-a breakpoint (Indicator 2.7.13) -or**
iv. **the WUM-level depth of the zone of oxygen depletion[23] or anoxia[24] has decreased by ≥25% (Indicator 2.7.6)**
v. **there has been >1 adverse turnover event in 10 years (Indicator 2.7.3)**
vi. **a non-conformance is detected in WUM level monitoring against a limiting [N], [P] or Chl-a rate of change Indicators (2.7.4, 2.7.5 and 2.7.6)**

A derogation is justified where carrying capacity-based planning incorporating statutory water quality targets within an appropriately defined boundary is already a regulatory requirement of the farm's jurisdiction.

Where required, the AMA should have the following attributes:

- The AMA must be enforced through an agreement with the regulator and/ or a formal **legally binding** MoU outlining the agreement between producers in the WUM.
- The AMA must be formalised **within 3 months** of the determination for requirement of an AMA according to criteria i – vi above.
- AMA participation should, at a minimum include all farms owned by any company with or seeking certification in the WUM, regardless of whether or not all farms owned by the company in the WUM are applying for certification or are currently certified.

It is expected farms to be able to provide the following evidence:

- clear documentation of the farms/companies included in the ABM, contact people (including contact information) and mechanisms for communication.

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[23] i.e., depth at which DO falls below 4mg/l (see also 2.7.3)

[24] i.e., depth at which DO falls below 2mg/l (see also 2.7.3)

- that the UoC is actively participating in the coordinated actions (A6.2) and outreach measures (A6.3) outlined below and can demonstrate compliance with the plan's commitments, e.g. through written records, meeting notes, contractual agreements, interviews.

A6.2 Requirements for coordinated actions under an AMA

Where an AMA is required, it should clearly specify requirements for the following coordinated actions at WUM level:

a) **WUM environmental monitoring:** implementation of a WUM level water quality survey, with a baseline to be initiated 2 years prior to the first audit in the WUM (see **Annex 3.2**). This will be the collective responsibility of any UoCs already certified or entering certification at that point, with new applicants required to participate in successive monitoring phases.

b) **Data sharing:** between members of an AMA (see below), other non-ASC certified aquaculture entities and other stakeholders (sectoral contributors to/ impacted by eutrophication, civil society bodies etc.). There should also be evidence of transparency in sharing and making results publicly available.

c) **Carrying capacity-based planning:** to slow transition towards TSI breakpoints an assimilative capacity model with source apportionment and sectoral BOD modelling (**Annex 5**) shall be the collective responsibility of AMA participants.

d) **Corrective response actions:** At a minimum this must include a commitment to making farm-level nutrient loading efficiency limits under more stringent (see **Indicator 2.7.29** and **Annex 9**). AMA members will have discretion to agree and assign farm-specific adjustments, where clear evidence of variable performance exists under **Indicators 2.7.7, 2.7.8** and **2.7.9**.

A6.3 Requirements for outreach to other aquaculture entities and stakeholders in the WUM catchment area

Evidence of outreach to encourage voluntary membership of other non-ASC certified entities releasing nutrients to the WUM should also be available for audit:

- Farms not applying for certification should be encouraged to participate and, at a minimum should commit to reciprocal sharing of water quality monitoring data (potentially creating an option to expand the WUM water quality monitoring sample-frame) and any other information needed to ensure effective coordination.

- Emphasis should also be placed on recruitment of entities certified under other third-party audited standards sharing aligned WQ objectives. As well as other aquaculture schemes, this should include land-users certified under other agriculture and forestry schemes with nutrient management (leaching) requirements.

- Where relevant, support measures should be established for smaller non-certified farms (whether AMA members or not) to improve their nutrient use efficiency (recognising that output reduction measures will be more challenging). This may extend to advice in allied management areas interacting with WQ performance, e.g. feed and seed input quality assurance, health management.

- A regularly updated audit of the above stakeholder groups within the WUM catchment along with outreach measures taken should be available for review.

A6.4 Coordination of WQ and area-based requirements under other WQ indicators

Where feasible, WQ actions should be also **coordinated with area-based management requirements under other ASC criteria** (e.g, sea-lice management), ideally under the same AMA.

This could include requirements designed to prevent disease outbreaks and parasite transmission (e.g. synchronised year-classes and site fallowing) or to coordinate any far-field benthic management.

Annex 7: Lotic water quality requirements

Farm-level lotic water quality parameters, including total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS), and dissolved oxygen (DO) require monitoring at one of more of the following samples stations:

- RWFI - Receiving water farm inflow (immediately upstream[25])
- RWFE – Receiving water (farm) effluent outfall point (effluents to sampled before mixing with RW).
- RWFA – Receiving water farm afar (immediately out with a downstream mixing zone)

A7.1 Derogations for TN, TP and TSS monitoring in lotic systems

To determine whether compliance is required against **Indicator 2.1.16**, the 1000 m^3/s flow rate is established to exclude farms on extremely large rivers (e.g. Mekong, Ganges) with high flushing rates from a requirement to make unnecessary water quality measurements. Such 'alluvial rivers' are also likely to have naturally high TSS levels (see **Annex 7.2**).

To determine whether compliance is required against **Indicator 2.1.17** "Low flow" is defined as the 25th percentile of the cumulative flow distribution of a lotic waterbody (see **Annex A1**).

A7.2 Total nitrogen, total phosphorus and total suspended solids sampling methodology

If monitoring of TN, TP and TSS concentrations is required under Indicator 2.7.18, measurements shall be made at RWFI and RWFE (**Indicator 2.7.18**), together with stream and effluent flow rates (**Indicator 2.7.17**).

Results will be used to model annual geometric mean concentrations at RWFA in order to determine compliance against **Indicator 2.1.19** (for systems with point source effluents) and **Indicator 2.7.20** (for cage systems with diffuse effluents). This modelling approach addresses the challenges of effectively monitoring downstream conditions around episodic effluent releases.

Results of TSS sampling at RWFI shall also be used to assess eligibility for derogations against lotic WQ requirements for farms releasing effluents to alluvial rivers with naturally elevated nutrient loads (**Indicator 2.7.16**).

- Monitoring of these parameters should commence at least after 90 days (fish spp.) or 30 days (crustacean spp.) from first stocking - and least 12 months prior to initial audit at a minimum quarterly frequency to account for seasonal variation (**Indicator 2.7.18**)

- Timing should also account for anticipated peaks in nutrient concentrations at RWFI and RWFE, and periods of minimum RW stream flow.

- Sampling of water shall be conducted in the morning, i.e. before 11AM – by filling and capping clear plastic sample bottles whilst immersed and (min 500ml samples).

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[25] Unimpacted by the farm and as far as possible, other point-sources of nutrient enriched effluents

- Samples should be refrigerated and sent for analysis with minimum delay (max 48hrs).

TP, TN and TSS concentrations are to be measured using methods described in **Annex 3.3**.

A7.3 Modelling rate of change in downstream nutrient concentration

Compliance limits on downstream nutrient concentration rate of change, require measurement of nutrient (TN and TP) concentrations in farm influent and effluent water, flow rates in the receiving waters and an estimate of farm water use that can be based on either abstraction or effluent flow rates.

The following formula should be used to estimate the **maximum allowable nutrient (TN, TP and TSS) concentrations in a farm outflow:**

(1) Max permissible downstream (DS) nutrient concentration (use for checking modelled results from Equations 7.2 and 7.3):

Equation 7.1 $C_T \leq C_{RWFI}*1.25$

Where:

C_T is the target max. allowable downstream (RWFA) nutrient concentration (i.e. here assuming a Standard requirement ≤ 125% of C_{RWFI}, i.e., no more than a 25% increase than in upstream waters)

C_{RWFI} is the geometric mean RWFI concentration (in µg/l or mg/l) immediately upstream of the farm based on monthly samples collected over the past 12 months. For farms that abstract water from the same waterbody that they discharge to, this number can be estimated be sampling the influent system. For farms that do not abstract water from the waterbody receiving effluent discharge, this number should be estimated from measurements made in the receiving waterbody upstream of the discharge site.

(2) Estimated downstream (RWFA) nutrient concentration at low flow (LF) - based on historic flow, [TP], [TN] and [TSS] data

Equation 7.2 $C_{RWFA} = ((Q_{LF} - Q_{OF}) C_{RWFI} + Q_{OF} * C_{RWFE})/Q_{LF}$

Where:

C_{RWFA} is the downstream (RWFA) nutrient concentration (µg/l or mg/l),
Q_{LF} is the low flow (m^3/ sec; being either the lowest of 4 quarterly measurements (**Annex 2**) or, the 25th percentile of flows from a credible gauging station),
Q_{OF} is the maximum effluent discharge rate (m^3/sec) to receiving waters for the lesser of the past 12 months or on production cycle.
C_{RWFE} is the geometric mean concentration in the pond outflow (RWFE).

(3) Max. permissible nutrient concentration in farm effluent outflow to RW (based on formula 1 target maxima)

By setting the downstream concentration equal to the target concentration, it is possible to estimate a maximum permissible outflow concentration, C_{Max}

Equation 7.3 $C_{Max} = (1 + 0.25 * Q_{LF}/Q_{OF}) * C_{RWFI}$

Annex 8: Calculation methodology for the percentage of fines in feed

Fines are dust and fragments in the feed. Particles that separate from feed with a diameter of 5 mm or less when sieved through a 1 mm sieve, or particles that separate from feed with a diameter greater than 5 mm when sieved through a 2.36 mm sieve. Excessive fines can reduce nutrient efficiency performance, thereby elevating eutrophication pressure.

Risk-based exemptions

Farms that can demonstrate the following production conditions are exempt from the requirement:

a) Extensive or semi-intensive production systems, e.g. shrimp ponds without permanent aeration, fishponds with <1 water exchange per week at peak biomass
b) Collection and responsible disposal of > 75% of solid nutrients and > 50% of dissolved nutrients (through biofiltration, settling and/or other technologies).

An exemption is also possible farms can demonstrate that each of feed manufacturer(s) from which they have sourced feed over the 12 months prior to audit, have developed a fines-testing standard operating procedure (SOP) sufficient to meet ASC intent, based on the following criteria:

- A minimum of five lots from each pellet size >3mm sampled on at least a quarterly basis.
- If a pellet size has less than five production lots across a quarter, another pellet size shall make up the deficit so that the total of sampling events across the quarter is always the same.
- Lots to be spread across the quarter as much as possible depending on production schedules.
- Data is compiled quarterly and communicated to the customer (farm) no later than two weeks into the new quarter.
- Each feed delivery is also subject to visual inspection and feed sampling, based on an SOP outlining requirement for the sampling and storage of 1kg of feed from each feed delivery.
- Feed fines results gathered from on-site sampling must show similar levels of fines (≤ 1%); If greater than 0.5% fines is found the manufacturer is contacted immediately.
- Prior to delivery, the farm must ensure space is available and feed is rotated to ensure that no feed is held for longer than necessary.
- Feed will not be off-loaded in poor weather conditions.
- Any feed bags showing signs of free oil, damage, etc. will be returned directly to the manufacturer for disposal.
- Other feed aspects that could potentially result in nutrient release, such as oil leakage, should also be evaluated for every feed delivery.

Where evidence is lacking or indicates non-compliance, farms must implement the following on-site evaluation.

Feed sampling protocol

To be measured at farm gate (e.g. from feed bags after they are delivered to farm) every quarter or every three months. Feed may be sampled immediately prior to delivery to farm for sites with no feed storage or where it is not possible to sample on farm. Samples that are measured shall be chosen randomly.

Sampling of feed lots: Feed delivered in bulk, big or small bags, shall, at a minimum, be sampled as follows:

1. Cut a minimum of six samples from the lot, evenly distributed throughout the lot

2. Each sample should have a mass of approximately 500 grams

3. Make a pooled sample from all the samples ensuring use all sampled material, i.e. around 6 kg

4. Reduce the pooled sample to one analysis sample for testing, of approximately 500 grams

Testing procedure

This method determines the fines (dust and small fragments) in **finished fish feed product, which has a diameter of 3 mm or more**. It shall be applied when the feed is delivered to the farming site[26].

The sample of feed shall be put through a sieve with a maximum sieve opening of:

- 1 mm when the particle diameter is equal to 5 mm or less
- 2.36 mm when the particle diameter is more than 5mm

The test can be performed either by use of a sieving machine or by a manual test.

Manual test

1. Put the accumulation box and the sieves on top of each other, with the accumulation box on the lowest part, then the smallest sieve and the biggest on top

2. Place the sieves on the balance and tare it

3. Weigh at least 300 g of the feed on the upper sieve, note the weight (m0)

4. Put on the lid

5. Sieve the feed smoothly and carefully for about 30 seconds.

7. Remove the lid and weigh what is left in the accumulation box

8. Use a brush to remove all the particles from the sieves

9. The feed particles that have passed through all sieves are called dust (md) 9. If the feed is fatty, or if dust is unevenly distributed, two replicates must be taken

Sieving machine

1. Put the accumulation box and the sieves on top of each other, with the accumulation box at the bottom and the biggest sieve on top

2. Place the sieves on the balance and tare it

3. Weigh at least 300 g of feed on the upper sieve, note the weight (**‘m0’**)

4. Place the sieves on the sifting machine and then close the cover properly

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[26] Feed can be sampled prior to delivery to farm site for sites where there is no feed storage.

5. Press the "START" button by holding it for 2-3 seconds, and then run the machine twice (2 x 1 min) 175 Feed can be sampled prior to delivery to farm site for sites where there is no feed storage. Page 73 of 102 ASC Salmon Standard – version 1.3 - July 2019

6. Remove the sieves and weigh what is left in the accumulation box

7. The feed particles that have passed through all sieves are called dust (md)

Calculations

1. Weight of feed before sieving = m0
2. Weight of feed that has passed through all sieves = **md Dust % = (md / m0) x 100**

Annex 9: Calculation and system/ species-specific limits on farm nutrient loading efficiency.

A9.1 Calculation of Nutrient Loading Efficiency (NLE; Total N or P released per tonne production)

Nutrient loading efficiency requirements (**Indicator 2.7.29**) place limits on the total quantity of total phosphorus and nitrogen that can be released from the farm per unit of production to a receiving water over a period of 12 months (counted back from the first day of the previous month).

This shall be calculated using one of two “mass balance” calculation methods; A & B (below) contingent on farm and receiving water characteristics.

Method A: Nutrient loading efficiency is calculated as the total quantity of N or P assimilated in cultured biomass outputs (including harvested animals, removed mortalities and standing stock), subtracted from the total N or P input in feeds and fertilisers (percent fraction) – followed by division of the resulting net system input by the biomass produced in metric tonnes (mt, Equation 9.1).

Method A is applicable to farms with diffuse source effluents (e.g. open-cage systems) where it is impracticable to measure effluent concentrations or for less intensive land-based systems (see **Indicator 2.7.30** definitions of production intensity), with further deductions allowed for on-farm nutrient interception in removed sludge or adsorption in earthen ponds. Nutrients in any fertiliser inputs should also be accounted for.

Equation 9.1: TN or TP released to the receiving water per unit biomass produced (kg/mt) = (TN or TP in – TN or TP out)/ biomass produced

Where:

TN or TP load in = Total N or P in feed or fertiliser

TN or TP load out = Total N or P in biomass produced

Equation 9.2: Total mass of N or P in feed or fertiliser

= ∑ (Total amount of product type (feed or fertiliser) multiplied by content of TN or TP) 1…….X)

where 1…….X represents the number of different products used.

- P content can be determined either by chemical analyses of the product or based on declaration by the feed or fertiliser producer, in jurisdictions where national legislation order phosphorus or nitrogen content to be declared.
- Feed N content can be calculated based on the assumption that proteins contain 16% N

Equation 9.3: Biomass produced over the specific time-period is calculated as**.**

$B_{produced} = B_{out} – B_{in}$, where:

$B_{in} = (\sum B_{\text{standing stock UoC start time period}}) + (\sum B_{\text{added to UoC during time period}})$

$B_{out} = ((\sum B_{\text{harvest of UoC}}) + (\sum B_{\text{mortalities of UoC}}) + (\sum B_{\text{standing stock UoC end of time period}})$

In case $\sum B_{\text{mortalities}}$ and are not known; the client shall use value “0”.

Equation 9.4: TN or TP content in biomass produced.

$= B_{produced}$ * (% of N or P in fish)

- The following P percentages will be used for harvested fish or mortalities for all species except Tilapia:
  (a) fish < than 1 kg: 0.43% (b) fish > than 1 kg: 0.4%
  Tilapia is assumed to have an average P content of 0.75% and N content of 2.12%[27]

Equation 9.5: Total mass of N or P in removed sludge or adsorption in earthen culture ponds.

= P content in sludge removed = (sludge removed) * (% of P in sludge).

Sludge removal: N or P in sludge removed per unit shall be determined based on analytical values that are representative of the batch of sludge removed from the farm. The farm must demonstrate the sludge was physically removed from the farm site and that the sludge was deposed of according to indicator requirements in Criterion 2.9 - Biosolids.

Pond adsorption: For earthen ponds with a maximum daily water exchange ≤10%, N and P loads in effluents are assumed to be equal to 30% and 20% of N and P inputs respectively allowing for pond-bottom adsorption and N volatilisation. These assumptions allow such farms to make the following theoretical calculation:

N load kg/mt produced = N input (kg) X 0.3 / mt produced

P load kg/mt produced = P input (kg) X 0.2 / mt produced

Method B: shall be used for more intensive production systems (see **Indicator 2.7.30** definitions) with point-source effluents. The method relies on measurement of nutrient concentrations in source waters and effluents, also precluding any need for assessment of any on-farm nutrient interception.

Nutrient load is calculated as the difference between [N] and [P] concentration in influent water ($[NP_{Supply}]$) and farm effluents ($[NP_{Eff}]$) to receiving waters (**Annex 7.3**), multiplied by total effluent volume.

Sampling requirements are described in **Annex 7.2** (modelling of downstream nutrient concentration) and A9.3 (Specifications for settling basins). The same datasets can be used for estimation of compliance against **Indicator 2.7.29**, with sampling conducted at minimum quarterly frequency,

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[27] Boyd, C. E., and B. Green. Dry matter, ash, and elemental composition of pond-cultured tilapia (Oreochromis aureus and O. niloticus). J. World Aquacult. Soc., 29: 125–128 (1998).

including peak biomass. All effluents from culture ponds and any post-culture treatment systems discharged to receiving waters over the 12 months prior to audit should be accounted for.

Equation 9.6: N or P load (kg/mt produced)

$$= (([NP_{Eff}] - [NP_{Supply}]) \times E)) / 1000/ \text{ mt produced}$$

Where E is the effluent volume in m^3

Farms that cannot directly measure the volume of effluent water should include an estimation as follows:

Equation 9.7: N or P load (kg/tonne produced) =

$$= (([NP_{Eff}] - [NP_{Supply}]) \text{ x } V \times PC + ([NP_{Pond}] - [NP_{Supply}] \text{ x } V \text{ x daily water \% renewal x } PC / 1000/\text{tonnes produced over 12-months.}$$

Where V is pond volume in $m^3$and PC is production cycles per year and $[NP_{Pond}]$ is the nutrient concentration in the pond

Note: intensive farms eligible for these requirements will have monitored N and P inflow and effluent concentrations for modelling downstream rate of change in these concentrations (**Annex 7.2**).

A9.2 Nutrient load compliance limits

Compliance against method A or B results shall be assessed against species/system specific nutrient loading efficiency limits that are subject to on-going deliberation by the Technical Working Group (including possible nutrient loading derogations for sites in high-energy, marine offshore environments determined to have negligible risk of eutrophication).

These limits will also provide a baseline for setting more stringent requirements under an area management agreement (AMA; **Annex 6.2**).

Table 9.1 shows limits applied in current ASC standards that will provide the basis for this revision.

Table 9.1. Feed (& fertiliser) N&P 'nutrient efficiency' metric limits (kg/ mt fish yield/12-months)

Standard	System/ species	TP out (kg/t)	TN out (kg/t)
Salmonids	**Land-based**	**≤ 4**	-
Salmonids	**Cages**	**tbc**	
Pangasius	**Cages/pens**	-	-
Pangasius	**Ponds**	≤ 7.2	≤ 27.5
Tilapia	**Open/ closed**	≤ 20	-
Shrimp	**Ponds - *L. vannamei***	< 3.9	≤ 25.2
Shrimp	**Ponds - *P. monodon***	< 5.4	≤ 32.4
Shrimp	**Ponds - *Cherax spp., Procambarus spp., Astacus spp.***	<4	< 26.1
Shrimp	**Ponds - *Macrobrachium spp***	< 6.1	< 39.2

A9.3 Specifications for settling basins.

To ensure compliance with **Indicators 2.7.27** and **2.7.28** settling basins must be constructed according to the following specifications:

- Hydraulic retention time (HRT) = nine hours or more (this will avoid the settling basin from having to be cleaned out frequently to maintain a minimum effective HRT of six hours.)
- Basin design must include seepage and erosion reduction control features (e.g. proper soil texture, good compaction and grass cover and impermeable linings where appropriate)
- Water enters at surface of basin through a weir or pump
- Water exits surface of basin through a weir on the opposite side
- If basin is square or nearly so, a baffle must be provided to avoid the short-circuiting of flow
- A drain structure should be provided so that the basin can be emptied. Posts must be placed at five places in the basin. These posts will extend to the height of the full basin water level. They will be used to estimate average depth of sediment accumulation. Sediment depth cannot exceed one-fourth (25%) of the original basin depth, as measured by the distance from the top of the post to the sediment surface.

To demonstrate compliance with indicator requirement limits, the settleable solids (SS) concentration at the outlet of the effluent treatment system must be measured at the beginning and at the end of the pond draining period when that period is less than 4 hours.

For ponds draining over more than 4 hours, monitoring should be done in 6-hour intervals. For situations with a retention time of several days, monitoring should be done at a time after harvest, equal to the hydraulic retention time of the treatment system.

- Settleable solids (SS) are measured as the volume of solids (expressed millilitres per litre of sample) that settles to the bottom of a conical cone (Imhoff cone) in 1 hour. Use of more sophisticated methods such as spectrophotometer readings is also permitted.

Farms that do not have enough space for a settling basin can use production ponds adjacent to the pond being harvested as settling basins.

Another alternative is to use drainage canals as settling basins, where sills can be installed at intervals in the canal bottoms to trap sediment.

The use of production ponds and drainage canals as settling basins is encouraged as this allows for the treating and recycling of all the water from harvested ponds. Alternatively, grassed strips, vegetated ditches or other artificial wetlands can be used for treating pond effluents. In these types of systems, suspended solids and other wastes are removed as the effluent passes over or through the vegetation.

A9.4 Method to determine that all water released goes through a treatment system, capturing ≥65% of suspended solids – tbc

Method still in development

A9.5 Specifications On-farm sediment disposal sites for sludge-removed from culture ponds or solids-settlement systems

These should be surrounded by embankments to avoid runoff and, if they are in areas with highly permeable soil or in a freshwater zone, they should be lined with clay or plastic to avoid infiltration. Embankments should be 0.75 metres high and twice as large as the area needed for the volume of sediment to be stored so that at least half (0.375 metres) of the storage height would be available for rainfall. This amount of extra storage volume would capture the rainfall from the current 100-year rainfall event in most areas and limit the risk of runoff from the stockpiled sediment.

The best way to dispose of saline sediment is to place it on the insides and tops of pond embankments after drying on the pond bottom or in dedicated areas of the farm where sludge is extracted from ponds or canals. Alternatively, the disposal sites on saline soil and, especially, in areas without surface or underground freshwater bodies can be used.