

Freshwater-Marine Interaction Accounting

Helps practitioners compile accounts at the freshwater-marine interface, including catchment-coast linkages, nutrient and sediment flow accounts.

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OUTCOME

After completing this Circular, practitioners will be able to compile accounts at the freshwater-marine interface, including catchment-coast linkages, nutrient and sediment flow accounts, and estuarine ecosystem assets. These accounts bridge terrestrial water accounting frameworks with marine and coastal ocean accounts.

The methodology integrates the SEEA Water framework for inland water resource accounts with SEEA Ecosystem Accounting for transitional and coastal ecosystems. For foundational framework context, see [TG-0.1](#). Prerequisites: [TG-3.2](#) (freshwater abstraction flows), [TG-3.4](#) (return flows and residual discharges), [TG-6.2](#) (coastal wetland ecosystem accounts), and [TG-3.11](#) (river basin and coastal zone spatial disaggregation).

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ABOUT THIS CIRCULAR

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DRAFT

1. Outcome

¶1 After completing this Circular, practitioners will be able to compile accounts at the freshwater-marine interface, including catchment-coast linkages, nutrient and sediment flow accounts, and estuarine ecosystem assets. These accounts bridge terrestrial water accounting frameworks with marine and coastal ocean accounts¹.

¶2 The methodology integrates the SEEA Water framework for inland water resource accounts with SEEA Ecosystem Accounting for transitional and coastal ecosystems². For foundational framework context, see **TG-0.1**. Prerequisites: **TG-3.2** (freshwater abstraction flows), **TG-3.4** (return flows and residual discharges), **TG-6.2** (coastal wetland ecosystem accounts), and **TG-3.11** (river basin and coastal zone spatial disaggregation).

2. Requirements

¶1 Essential prerequisites:

- ¶2 **TG-0.1 General Introduction to Ocean Accounts** – foundational Ocean Accounts framework context.
- ¶3 **TG-3.2 Flows: Environment to Economy** – methodology for recording flows of environmental resources (including freshwater) to economic units. Freshwater abstraction within catchments directly reduces downstream flows to estuarine and marine environments.
- ¶4 **TG-3.4 Flows: Economy to Environment** – framework governing return flows and residual discharges. Nutrient loading, sediment mobilisation, and pollutant discharges recorded under TG-3.4 constitute the primary anthropogenic pressures transmitted through the freshwater-marine interface.

¶5 Helpful background:

- ¶6 **TG-6.2 Mangrove and Coastal Wetland Accounting** – ecosystem accounting methodology for coastal wetland systems directly influenced by freshwater inputs.
- ¶7 **TG-3.11 Sub-National Ocean Accounts** – spatial disaggregation to river basin and coastal zone scales, supporting reconciliation of hydrological and administrative spatial units used throughout this Circular.

¶8 ⓘ Framework Position

¶9 This Circular addresses how freshwater-marine interactions transmit economic pressures from upstream catchments to downstream coastal and marine ecosystems, and how those interactions support ecosystem services flowing to the economy and society. In the Ocean Accounts Framework (TG-0.1 Figure 0.1.2):

Edge	Direction	Description
E1	FG1 → SG3	Residuals from economy to environment (nutrient/pollutant discharges to rivers)
E9	SG3 → FG1	Resource extraction and use from environment to economy (freshwater abstraction reducing downstream flows; estuarine fisheries and freshwater supply)
E11	FG3 ↔ SG3	Intermediate ecosystem services (sediment transport, nutrient cycling)

¶10 **Readiness and sequencing.** Whether a country is positioned to compile this account at all – mandate, data architecture, capacity and the order in which to build – is assessed under **TG-0.8 Implementation Readiness Assessment**, and is not restated here.

3. Guidance Material

¶1 The accounting edges and ecosystem types covered by this Circular are identified in the Framework Position callout box above. The sections below provide compilation guidance for each component^{3, 4, 5}.

3.1 Catchment-Coast Accounting Linkages

¶1 Catchment-coast accounting establishes the systematic connection between economic activities within river basins and their downstream effects on coastal and marine ecosystems. The underlying accounting principle is that material flows through hydrological pathways link upstream economic pressures to downstream environmental outcomes. These linkages are bidirectional: tidal and storm-driven marine influences also penetrate upstream, affecting freshwater quality, sediment dynamics, and ecosystem condition in lower catchments⁶.

¶2 Figure 6.13.1 traces the cross-domain flow from upstream driver through catchment ecosystem and transmission pathway to the coastal receiving ecosystem. The catchment-to-coast crossing is recorded as an Ocean Accounts Framework inter-ecosystem service flow (E11; see TG-0.1) at the terrestrial/coastal account boundary.

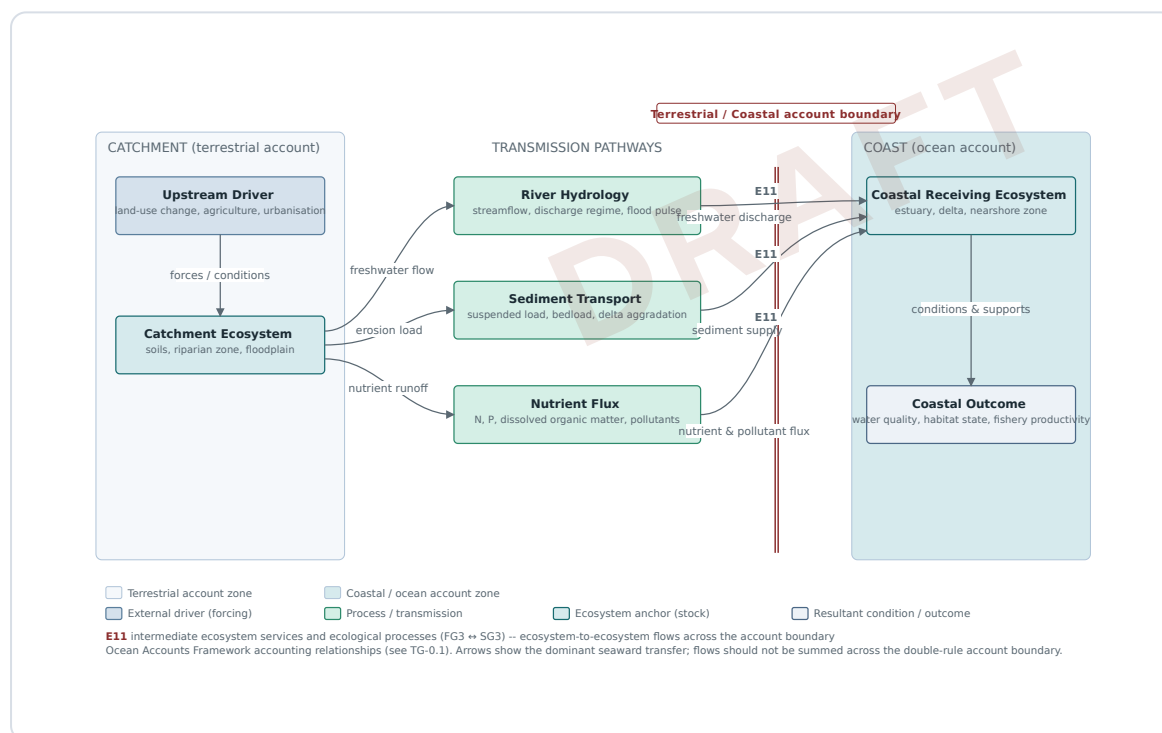


Figure 6.13.1 Catchment land-use drivers generate river, sediment, and nutrient pathways that cross into the coastal receiving ecosystem as E11 flows. Double-rule marks the terrestrial/coastal boundary; E11 flows must not be summed.

Source: TG-6.13, catchment-to-coast linkages; Ocean Accounts Framework accounting relationships (E11), TG-0.1.

River basin as accounting unit

¶1 The river basin (or catchment) is the natural spatial unit for freshwater-marine interaction accounting, with the river basin as upstream boundary and the coastal zone as downstream boundary⁷. Compilers should delineate river basins using hydrological boundaries (watersheds)

rather than administrative boundaries, though administrative disaggregation may be required for linking to economic statistics. See **TG-3.11 Sub-National Ocean Accounts** for reconciling hydrological and administrative spatial units. Where multiple river basins discharge into a single coastal zone, aggregate basin-level flows to derive total catchment inputs.

Linkage Type	Upstream Driver	Transmission Pathway	Coastal/Marine Outcome
Water quantity	Abstraction, dam regulation	Reduced river discharge	Altered salinity regime, reduced sediment supply
Nutrient loading	Agricultural fertiliser, wastewater	Dissolved N and P in river flow	Eutrophication, algal blooms, hypoxia
Sediment flux	Land clearing, mining, dam trapping	Suspended sediment in river flow	Coastal erosion/accretion, turbidity changes
Chemical pollution	Industrial discharge, urban runoff	Dissolved and particulate contaminants	Bioaccumulation, habitat degradation
Thermal effects	Power plant cooling, urban heat islands	Elevated water temperature	Altered species composition, coral stress
Biological connectivity	Habitat fragmentation, fish passage barriers	Migratory corridors	Disrupted diadromous fish populations

Temporal dynamics

¶1 Accounting periods should be aligned with hydrological years where possible, as episodic flood events can deliver the majority of annual sediment and nutrient loads within a few days⁸. Load estimates based on continuous monitoring will differ substantially from those based on periodic grab sampling, and the methodology used should be recorded in account metadata. Compilers should establish a reference period for baseline flows and document significant changes in catchment characteristics (dam construction, land use conversion, urbanisation) that alter the flow regime during the accounting period.

Accounting for regulated flows

¶1 Dam regulation creates a distinction between natural (unregulated) flow and actual (regulated) flow. Estimating the counterfactual natural flow quantifies hydrological alteration, though reliable estimation of unregulated baselines remains methodologically challenging⁹.

Entry	Unit	Description
Natural (unregulated) annual discharge	m ³ /yr	Estimated flow without human intervention
Actual annual discharge to coast	m ³ /yr	Measured flow at river mouth/estuary
Hydrological alteration index	ratio	Actual/natural flow ratio (illustrative; see note below)
Seasonal flow modification	% change by season	Deviation from natural seasonal pattern
Inter-basin transfers in	m ³ /yr	Water imported from other basins
Inter-basin transfers out	m ³ /yr	Water exported to other basins

¶2 The hydrological alteration index is an illustrative summary measure whose application in a formal accounting context is still emerging. Where data permit, recording natural and actual discharge volumes separately is preferable to deriving a single ratio, as values close to 1.0 indicate near-natural regimes whilst values below 1.0 indicate flow reduction. This index informs the condition assessment of estuarine ecosystems (Section 3.3). The Indicators of Hydrologic Alteration (IHA) methodology provides standardised flow statistics for fuller flow-regime analysis⁹.

¶3 Estimating the natural (unregulated) baseline presents practical challenges. The following tiered approach is recommended:

- ¶4 **Tier 1 – Naturalised flow models.** A calibrated rainfall-runoff model run without the influence of dams, diversions, and inter-basin transfers provides the most defensible baseline. Compilers should document model version, calibration period, and assumptions.
- ¶5 **Tier 2 – Pre-regulation gauge records.** Where long-term gauge records predate major water infrastructure, the pre-regulation mean annual discharge provides an empirical baseline. The reference period should be documented explicitly.
- ¶6 **Tier 3 – Regional reference-catchment scaling.** Natural flow estimated by scaling discharge from a comparable, minimally regulated reference catchment in the same hydroclimatic region, adjusted for catchment area and mean annual precipitation.
- ¶7 **Tier 4 – Actual flow only.** Where none of the above approaches is feasible, record actual discharge only, note that the natural baseline could not be estimated, and set the Hydrological Alteration Index to “not estimated.”

¶8 The tier applied should be recorded in account metadata, along with key assumptions and data sources.

3.2 Nutrient and Sediment Flow Accounts

¶1 Nutrient and sediment flows are recorded as physical flow accounts within the SEEA framework, tracking specific substances from economic sources through the environment to receiving coastal waters¹⁰.

¶2 **Boundary with TG-6.8.** This account covers loads transmitted through the freshwater system. Aquaculture discharging **directly** to coastal or marine waters – marine cages and similar – is recorded at site level in **TG-6.8 Aquaculture Thematic Methods** Section 3.3.1 and is excluded from the catchment source terms below; land-based ponds and hatcheries discharging to a river or to sewer are catchment sources and belong here. Both accounts resolve to the same coastal receiving water, so applying the discharge-point test consistently is what prevents the same nitrogen being counted twice.

Nutrient flow accounting

¶1 Nutrient loading to coastal waters, particularly nitrogen (N) and phosphorus (P), is the primary driver of coastal eutrophication¹¹. The SEEA framework for recording residual flows (**TG-3.4 Flows: Economy to Environment**) provides the accounting structure for nutrient discharges.

¶2 Nutrient flow accounts should track loads (mass per unit time) rather than concentrations alone, as the ecological impact on receiving waters depends on total mass delivered:

Source Category	Nutrient Species	Measurement Approach	Accounting Entry
Agricultural diffuse sources	NO ₃ ⁻ , NH ₄ ⁺ , PO ₄ ³⁻	Export coefficient models, catchment monitoring	Residual flow: agriculture to environment
Municipal wastewater	Total N, Total P	Effluent monitoring, treatment plant records	Residual flow: households/government to environment
Industrial point sources	NH ₄ ⁺ , PO ₄ ³⁻ , organic N	Discharge permits, monitoring data	Residual flow: industry to environment
Atmospheric deposition	NO _x , NH ₃	Deposition monitoring networks	Natural flow (where background) or residual flow (where anthropogenic)
Natural background	Dissolved N and P	Reference catchment data	Natural flow: within environment

¶3 The total nutrient load delivered to the coast is the sum of all source contributions minus in-stream retention (nutrient uptake and denitrification within rivers, wetlands, and floodplains), which should be recorded as a water purification regulating ecosystem service¹², consistent with the intermediate/final service classification framework in SEEA EA paras. 6.11–6.17 and **TG-2.4**.

Compilers should distinguish gross nutrient discharge (total load entering waterways) from net nutrient delivery to coast (load at river mouth after in-stream processing): the difference quantifies the water purification service provided by freshwater ecosystems within the catchment.

Sediment flow accounting

¶1 Sediment flow accounts track the supply, transport, and delivery of particulate material through river systems to receiving coastal waters. Globally, dam construction has reduced sediment delivery to the coast by an estimated 25–30%¹³. The following sediment budget framework structures the physical flow account:

¶2 **Sediment delivery to coast ≈ Erosion supply – In-channel storage – Reservoir trapping – Floodplain deposition**

¶3 This expression is a simplified budget framework rather than a closed identity. Additional terms may be material in specific contexts, including: bedload transport (most routine monitoring captures suspended load only); bank erosion as a distinct sediment source; and aeolian deposition in arid catchments. Compilers should document which terms were measured, estimated, or assumed negligible, consistent with metadata requirements in SEEA CF Chapter 3.

Entry	Unit	Description
Gross erosion (hillslope + channel)	t/yr	Total sediment mobilised within catchment (suspended load; bedload separately where measurable)
Reservoir trapping	t/yr	Sediment retained behind dams
Floodplain deposition	t/yr	Sediment stored on floodplains
In-channel storage change	t/yr	Net change in channel bed/bank storage (includes bank erosion)
Sediment delivery to coast	t/yr	Measured or estimated load at river mouth
Sediment delivery ratio	%	Delivery/erosion ratio

¶4 Reduced sediment supply from upstream dam construction or sand mining can lead to coastal wetland submergence and ecosystem loss¹⁴, whilst excessive delivery from land clearing or mining can smother coral reefs and seagrass beds. These linkages connect the sediment flow account to the coastal ecosystem accounts compiled under **TG-6.2**.

Pollutant and contaminant tracking

¶1 Beyond nutrients and sediments, freshwater systems transport chemical contaminants to coastal waters. Compilers should identify priority contaminants for their national context and establish monitoring and accounting protocols for those substances¹⁵.

Tier	Substances
Tier 1	Account for total nitrogen and total phosphorus loads (minimum requirement for all freshwater–marine interaction accounts).
Tier 2	Add suspended sediment load, biochemical oxygen demand (BOD), and priority metals (e.g., mercury, cadmium, lead).
Tier 3	Include emerging contaminants (microplastics, pharmaceuticals, per- and polyfluoroalkyl substances) where monitoring data exist.

¶2 The pollutant flow account should be structured consistently with **TG-3.4 Flows: Economy to Environment**. The following crosswalk maps each tier's substances to TG-3.4 source industry categories (by ISIC section):

Tier	Substance(s)	TG-3.4 Source Industry Row	Typical Units
1	Total nitrogen (TN), Total phosphorus (TP)	ISIC A (Agriculture); ISIC E (Water supply, sewerage); ISIC C (Manufacturing)	t N/yr; t P/yr
2	Suspended sediment (SS)	ISIC A (Agriculture); ISIC B (Mining and quarrying); ISIC F (Construction)	t/yr
2	Biochemical oxygen demand (BOD ₅)	ISIC E (Sewerage); ISIC C (Food manufacturing)	t O ₂ /yr
2	Mercury (Hg), cadmium (Cd), lead (Pb)	ISIC B (Mining); ISIC C (Manufacturing); ISIC D (Electricity – coal combustion)	kg/yr
3	Microplastics	ISIC G (Wholesale/retail); ISIC E (Waste management)	t/yr (estimated)
3	PFAS	ISIC C (Manufacturing); ISIC N (Administrative services – fire-fighting foam)	kg/yr (estimated)

¶13 All flows should be reported in mass per year (t/yr or kg/yr as appropriate), consistent with TG-3.4 unit conventions.

3.3 Estuarine and Deltaic Ecosystem Asset Accounts

¶1 Estuaries, deltas, and coastal lagoons occupy the freshwater-marine interface, supporting fisheries nursery habitat, water filtration, and high biological productivity¹⁶. This section provides extent, condition, and ecosystem service accounts for these transitional systems.

Ecosystem type classification

¶1 Transitional water ecosystems span the boundary between freshwater and marine realms. Within the IUCN Global Ecosystem Typology (GET) reference classification used by SEEA EA, the relevant ecosystem functional groups include¹⁷:

IUCN GET Code	Ecosystem Functional Group	Key Characteristics
MFT1.1	Coastal river deltas	Prograding depositional landforms at river mouths; mosaic of channels, floodplains, and wetlands
MFT1.2	Intertidal forests and shrublands	Mangroves and related tidal woody vegetation (covered in detail by TG-6.2)
MFT1.3	Coastal saltmarshes and reedbeds	Herbaceous intertidal wetlands (covered in detail by TG-6.2)
FM1.2	Permanently open riverine estuaries and bays	Tidally influenced river channels with persistent ocean connection
FM1.3	Intermittently closed and open lakes and lagoons	Coastal water bodies with periodic marine connection
F1.2	Permanent lowland rivers (lower reaches)	Tidal freshwater zones of large rivers

¶2 A single estuary may contain elements of several GET functional groups forming an integrated mosaic. Compilers may either (a) map and account for each component ecosystem type separately (greater analytical resolution) or (b) define composite estuarine or deltaic ecosystem assets documenting the internal composition (better captures functional integrity). Experience with both approaches is still limited.

Extent accounting for transitional ecosystems

¶1 Extent accounts follow the standard SEEA EA structure (see **TG-6.2** Section 3.1 for the general approach)¹⁸. Transitional water ecosystems present three specific measurement challenges:

¶2 **Dynamic boundaries.** The spatial extent of estuaries fluctuates with tidal cycles, river discharge, and seasonal variation. The accounting boundary should be defined using a consistent reference state (e.g., mean high water for the landward boundary, mouth cross-section for the seaward boundary) and documented in metadata. Changes in the estuary mouth configuration, such as barrier beach opening/closing in intermittently open systems, should be recorded as condition changes rather than extent changes unless they result in permanent loss or gain of the ecosystem type.

¶3 **Submerged extent.** Unlike terrestrial ecosystems where extent is measured as surface area, estuarine ecosystems include significant submerged components (subtidal channels, basins). Extent may be reported as either surface area or water volume, depending on the ecosystem type.

¶4 **Multi-dimensional classification.** Estuarine extent accounts should distinguish between intertidal and subtidal components, and between vegetated (mangrove, saltmarsh, seagrass) and unvegetated (mudflat, sand flat, open water) areas. This disaggregation enables linkage to the vegetation-specific accounts compiled under **TG-6.2 Mangrove and Coastal Wetland Accounting**.

¶5 The extent account template uses hectares (ha), consistent with SEEA EA Chapter 4. For FM1.2, FM1.3, and MFT1.1, water volume (m³) at a reference tidal state is reported as supplementary metadata where subtidal basin extent is a primary management concern:

Entry	Estuaries (FM1.2)	Lagoons (FM1.3)	Deltas (MFT1.1)	Tidal Rivers (F1.2)	Total
Opening extent (ha)					
Opening volume (m ³) [FM1.2, FM1.3, MFT1.1 only]			–		
Additions to extent					
– Natural expansion					
– Managed restoration (see TG-6.15)					
Reductions in extent					
– Conversion (reclamation, infill)					
– Natural loss (erosion, submergence)					
Net change in extent					
Closing extent (ha)					
Closing volume (m ³) [FM1.2, FM1.3, MFT1.1 only]			–		

Condition assessment for transitional ecosystems

¶1 Estuarine condition depends on freshwater inputs, and condition assessment is therefore inseparable from catchment–coast flow accounting¹⁹. Variables are organised by ECT class following SEEA EA Table 5.1 and the generic frameworks in **TG-4.8** Section 3.1 and **TG-4.9** Section 3.1²⁰. Interface-specific applications are listed below:

¶2 **Physical state (Class A1):**

- ¶3 Freshwater inflow volume and timing (deviation from reference hydrograph)
- ¶4 Salinity gradient (longitudinal and vertical stratification patterns)
- ¶5 Tidal prism (volume exchanged per tidal cycle, m³; specify reference tidal state, e.g., mean spring tide, in metadata)
- ¶6 Water residence time (flushing rate)
- ¶7 Sedimentation/erosion rates

¶8 **Chemical state (Class A2):**

- ¶9 Dissolved oxygen (spatial and temporal patterns, frequency of hypoxia)
- ¶10 Nutrient concentrations (N, P; linked to catchment loading accounts in Section 3.2)
- ¶11 Turbidity and light availability
- ¶12 pH and carbonate chemistry
- ¶13 Priority contaminant concentrations

¶14 **Compositional state (Class B1):**

- ¶15 Fish species richness and community composition
- ¶16 Benthic invertebrate diversity
- ¶17 Phytoplankton community structure (including harmful algal bloom species)
- ¶18 Presence of key/indicator species – e.g., diadromous fish (species migrating between freshwater and marine environments, such as salmon and eel) and filter-feeding bivalves

¶19 **Structural state (Class B2):**

- ¶20 Habitat heterogeneity (diversity of substrate types, depth classes)
- ¶21 Vegetation cover (emergent, submerged, riparian)
- ¶22 Biogenic reef structures (oyster reefs, mussel beds)

¶23 **Functional state (Class B3):**

- ¶24 Primary productivity (phytoplankton and benthic)
- ¶25 Nutrient cycling rates (denitrification, nutrient uptake)
- ¶26 Fish recruitment (juvenile abundance and growth)

¶27 **Landscape and seascape characteristics (Class C1):**

- ¶28 Connectivity to upstream catchment (barriers, flow modification)
- ¶29 Connectivity to marine environment (mouth openness, tidal exchange)
- ¶30 Surrounding land use (proportion of catchment under natural vegetation)
- ¶31 Fragmentation of estuarine habitats

¶32 Reference conditions should be established using historical baselines, minimally disturbed reference estuaries, or expert-defined targets (SEEA EA Section 5.3). For freshwater inflow-dependent variables, the reference should reflect the natural (pre-regulation) flow regime.

ECT Class	Variable	Unit	Reference Level	Opening Value	Closing Value	Change
Physical state (A1)	Freshwater inflow ratio	% of natural	100%			
Physical state (A1)	Salinity gradient index	0-1 scale	Site-specific			
Chemical state (A2)	Dissolved oxygen (min)	mg/L	>6.0			
Chemical state (A2)	Total N concentration	mg/L	Pre-disturbance			
Compositional state (B1)	Fish species richness	count	Historical record			
Structural state (B2)	Biogenic reef area	ha	Historical extent			
Functional state (B3)	Net denitrification rate	t N/yr	Reference site			
Landscape (C1)	Mouth openness index	days open/yr	Natural regime			

Ecosystem services of transitional waters

¶1 Estuarine and deltaic ecosystems provide the following ecosystem services²¹:

¶2 **Water purification and nutrient regulation.** Estuaries attenuate nutrient loads through denitrification, sedimentation, and biological uptake. Physical quantity: mass of N or P removed between estuary head and mouth (t N or P/yr), derived from the difference between upstream delivery (Section 3.2) and downstream export, though attributing removal to specific processes remains methodologically challenging.

¶3 **Fisheries nursery and production.** Where TG-6.2 ecosystem types (MFT1.2 intertidal forests, MFT1.3 saltmarshes) are mapped within an estuary boundary, nursery service is recorded against the constituent ecosystem type rather than the composite estuary. Subtidal channel and basin nursery service is recorded against FM1.2 or FM1.3 (see **TG-6.2** Section 3.5 for double-counting guidance). Attribution approach must be documented in account metadata.

¶4 **Sediment regulation.** Estuaries trap, redistribute, and export sediment. See Section 3.2 and **TG-6.2** for the coastal wetland sediment accretion context.

¶5 **Flood attenuation.** Estuarine floodplains and wetlands attenuate riverine and coastal storm surge flooding, valued using avoided damage methods consistent with **TG-6.2** Section 3.6.

Service	Physical Metric	Unit	Valuation Method
Water purification (N removal)	Mass of N removed in estuary	t N/yr	Replacement cost (treatment equivalent)
Water purification (P removal)	Mass of P removed in estuary	t P/yr	Replacement cost (treatment equivalent)
Fisheries nursery	Juvenile fish production attributable to estuary	t/yr	Productivity change method
Sediment regulation	Sediment trapped/redistributed	t/yr	Avoided cost (dredging, beach nourishment)
Flood attenuation	Flood volume stored	m ³ per event	Avoided damage cost
Recreation and tourism	Visitor days	days/yr	Travel cost, contingent valuation

¶6 For the water purification (N and P removal) services, the **default replacement-cost benchmark** is the operation and maintenance (O&M) cost of tertiary biological nitrogen removal (BNR) or chemical phosphorus precipitation at the national median wastewater treatment plant scale. Capital costs are excluded from the default to reflect the marginal cost of the substitute action rather than its full provision cost. Where national median unit costs are unavailable, compilers should draw on regional engineering cost databases and document the source. Sensitivity reporting is recommended, testing the estimate against at least one alternative cost scenario. This approach is consistent with the replacement-cost guidance in **TG-1.9 Safe Usage of Monetary Valuation**, which requires that the substitute action be credible and technically feasible under national conditions.

3.4 Integration with SEEA Water Accounts

¶1 The *SEEA-Water* provides the standardised accounting structure for inland water resources²². Freshwater-marine interaction accounting extends SEEA-Water to the coast by treating river discharge as the terminal outflow in the inland water balance and the opening inflow in the coastal/marine water balance.

Water supply and use tables at the basin-coast interface

¶1 SEEA-Water supply and use tables record water abstracted and returned by economic units²³. The key entries for freshwater-marine interaction accounting are:

¶2 **Net abstraction within catchment.** Total abstraction by agriculture, industry, and households minus return flows. Net abstraction directly reduces estuarine salinity, flushing, and ecosystem condition.

¶3 **Environmental flows.** Compliance with environmental flow requirements should be tracked in the accounts, as shortfalls directly degrade estuarine and coastal ecosystem condition.

¶4 **Return flow quality.** Linking SEEA-Water quality accounts to the nutrient flow accounts in Section 3.2 requires matching discharge point locations and volumes with concentration data to derive mass loads.

SEEA-Water Entry	Unit	FMI Account Linkage
Total river discharge at mouth	m ³ /yr	Opening freshwater inflow to estuarine ecosystem
Net abstraction within basin	m ³ /yr	Reduction in natural freshwater delivery to coast
Environmental flow allocation	m ³ /yr	Managed flow to maintain estuarine ecosystem condition
Return flow volume	m ³ /yr	Component of discharge; links to quality accounts
Wastewater discharge (treated)	m ³ /yr	Source term for nutrient loading account
Wastewater discharge (untreated)	m ³ /yr	Source term for nutrient and contaminant loading

Water quality accounts

¶1 SEEA-Water quality accounts track parameters at the river-estuary boundary and the estuary-ocean boundary, enabling calculation of nutrient and contaminant loads as the product of flow volume and concentration²⁴:

Parameter	Unit	Measurement Point	Accounting Treatment
Total nitrogen	mg/L	River mouth / estuary head	Input concentration to estuarine ecosystem
Total phosphorus	mg/L	River mouth / estuary head	Input concentration to estuarine ecosystem
Suspended sediment	mg/L	River mouth / estuary head	Input to sediment flow account
Dissolved oxygen	mg/L	Within estuary (spatial profile)	Condition variable for estuarine ecosystem
Salinity	ppt	Within estuary (longitudinal profile)	Condition variable reflecting freshwater influence
BOD ₅	mg/L	River mouth / estuary head	Indicator of organic pollution load

¶2 Compilers should establish monitoring stations at the upstream boundary (tidal limit or head of salt intrusion) and downstream boundary (estuary mouth or offshore reference point). The difference in loads between these two points approximates net estuarine processing, which can be recorded as an ecosystem service flow, though disentangling estuarine processing from tidal mixing effects remains an area of active research.

Linking water asset accounts to ecosystem asset accounts

¶1 For transitional ecosystems, the water asset is inseparable from the ecosystem asset: the estuary is simultaneously a water body (recorded in SEEA-Water²⁵) and an ecosystem asset (recorded in SEEA EA). Compilers should record the physical water stock (volume) in SEEA-Water asset accounts, record the ecosystem asset (extent, condition, services) in SEEA EA accounts, and link the two through physical flow accounts. In monetary terms, water supply services (provisioning) and water purification services (regulating) from the same water body are generally additive. Double counting arises only where the same service flow is valued twice under different account frames.

Where uncertainty remains, document the potential overlap in account metadata. See **TG-3.2** for further guidance on avoiding double counting.

3.5 Land-Sea Interface Spatial Delineation

¶1 Spatial delineation of the freshwater-marine interface is a prerequisite for compiling all accounts in this Circular, and the boundaries adopted will affect the scope and content of the resulting accounts²⁶.

Delineation principles

¶1 **Upstream (catchment) boundary.** The watershed divide of river basins draining to the coastal zone, derivable from digital elevation models. For large continental river basins, focusing on the lower catchment may be appropriate depending on data availability. Where the full basin is included, sub-basin disaggregation following **TG-3.11** enables attribution of pressures to specific upstream areas.

¶2 **Landward (coastal) boundary.** The inland limit of marine influence, defined by the tidal limit, the extent of salt intrusion, or a fixed distance inland. The boundary should encompass all intertidal and supratidal ecosystems consistent with **TG-6.2**.

¶3 **Seaward boundary.** The offshore limit of significant freshwater influence, defined by salinity thresholds, river plume extent (satellite ocean colour), or fixed distance offshore. The 30 ppt isohaline (polyhaline/euhaline boundary in the Venice system) is an appropriate marker for estuarine extent delineation. For plume-influence delineation, a higher threshold (32–34 ppt) or relative anomaly (salinity 1 ppt below ambient) may better capture the zone of significant freshwater influence. Standardised methods are still emerging.

Spatial data requirements

Dataset	Source	Resolution	Purpose
Digital elevation model	National survey, SRTM v3 (1 arc-second), Copernicus DEM (GLO-30)	30m or better	Catchment delineation, tidal limit identification
Hydrological network	National water agencies, HydroSHEDS	Vector (stream lines)	River routing, monitoring point location
Coastline position	National mapping, satellite-derived	10–30m	Landward/seaward boundary reference
Land cover / land use	National mapping, Sentinel-2 classification	10–30m	Catchment land use for pressure attribution
Bathymetry	National hydrographic office, GEBCO	Variable	Estuary volume, nearshore delineation
Salinity distribution	In situ monitoring, ocean models	Point/gridded	Freshwater influence extent
Ocean colour	MODIS, Sentinel-3	300m–1km	River plume detection, turbidity

¶1 Compilers should document all spatial boundary decisions in account metadata, including the criteria used, the reference state adopted, and any adjustments made for local conditions. Consistency of spatial boundaries across accounting periods is essential for tracking changes in ecosystem extent and condition.

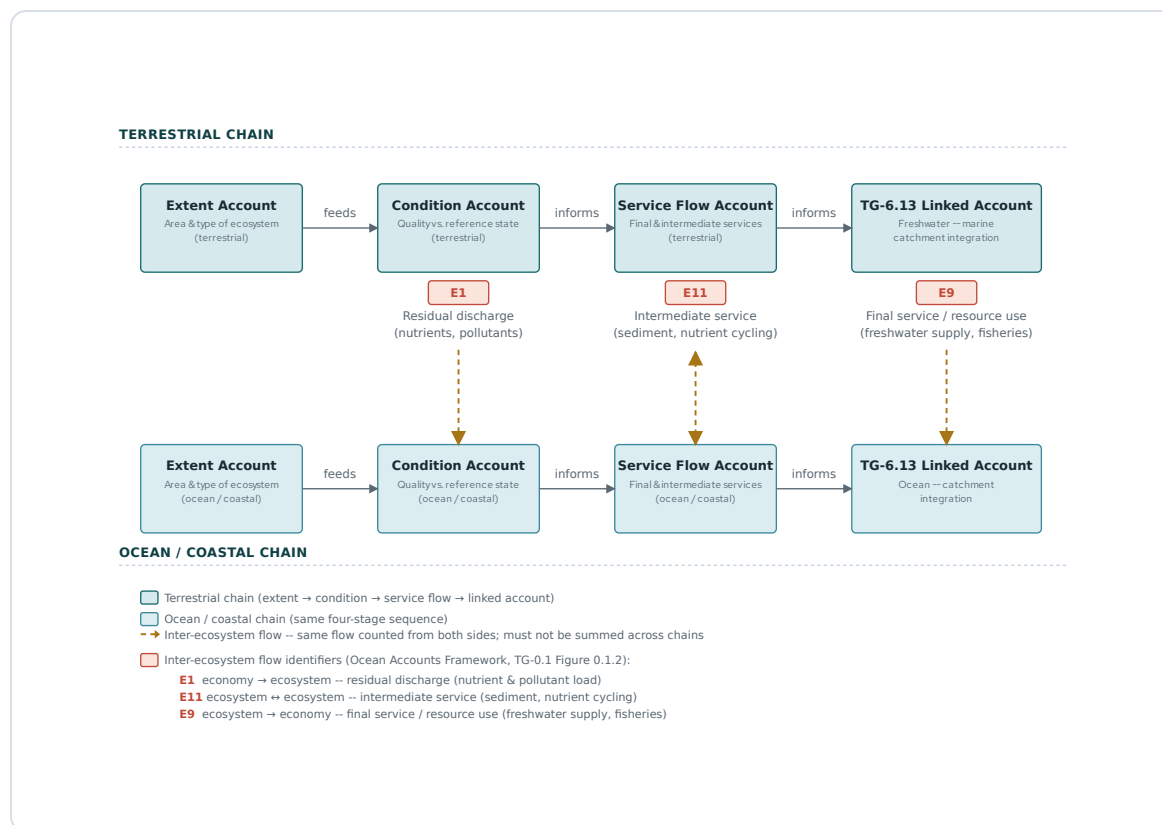


Figure 6.13.2 Parallel terrestrial and ocean/coastal SEEA EA chains linked by three inter-ecosystem flows (E1, E11, E9) that must not be cross-summed. Dashed arrows are the same flow from both sides (§5.3).

Source: TG-6.13 Framework Position table (inter-ecosystem flows E1, E9, E11) and §5.3 boundary rule; inter-ecosystem flow identifiers per the Ocean Accounts Framework (TG-0.1 Figure 0.1.2).

3.6 Compilation Procedure

¶1 The sections above describe four accounts that share a spatial frame. The order below is the one that avoids rework, because each step fixes a boundary the next step depends on.

¶2 **Step 1: Fix the spatial frame.** Delineate the contributing catchment, the tidal limit and the seaward boundary of freshwater influence using the criteria at Section 3.5, and reconcile them against the administrative units the data actually arrive in (**TG-3.11 Sub-National Ocean Accounts**). Record the criteria and the reference state in metadata now: every later step inherits this frame, and changing it afterwards invalidates the time series.

¶3 **Step 2: Compile the water flow account.** Abstraction, return flows and residual discharge to the river network, following **TG-3.2** and **TG-3.4**, with regulated flows handled per Section 3.1. This establishes the transport medium before anything is loaded onto it.

¶4 **Step 3: Compile nutrient and sediment source terms.** Apply the discharge-point test at Section 3.2 to allocate each source between this account and **TG-6.8**. Attribute loads to economic units by ISIC class so that the account can be read against the pressure it comes from, not only the substance.

¶5 **Step 4: Route loads to the receiving water.** Apply the delivery ratios and in-stream retention at Section 3.2 to convert source-term loads into loads delivered at the coast. Report delivered load with its retention assumption stated: a source-term total presented as a coastal load overstates the pressure, sometimes by a large factor.

¶6 **Step 5: Compile the estuarine and deltaic ecosystem asset account.** Extent and condition for the transitional ecosystem types at Section 3.3, using the account structure in **TG-3.1** Section

3.5.1 and condition variables selected under **TG-4.8** and **TG-4.9**. Where the transitional system is a coastal wetland, the method is **TG-6.2** and is not duplicated here.

¶7 **Step 6: Link pressure to condition.** Relate the delivered loads from Step 4 to the condition variables from Step 5. This is the step the account exists for, and it is also the weakest: the relationship is rarely linear and is usually lagged by years. State the functional form and the lag assumed, and follow the condition-to-service scaling caution in **TG-3.1** Section 3.5.3.

¶8 **Step 7: Reconcile with the SEEA Water accounts.** Bring the basin-scale water asset and quality accounts at Section 3.4 into agreement with Steps 2 and 4, so that the same abstraction and discharge figures appear in both. A discrepancy here is normally a spatial-frame mismatch from Step 1 rather than a data error.

¶9 **Step 8: Document and quality-assure.** Record the retention assumptions, the lag, the discharge-point allocations and the spatial criteria in account metadata, and apply **TG-0.7 Quality Assurance**. Compilers should expect to publish Steps 1–4 well before Steps 5–6 are defensible; a repeatable flow account is worth more than a one-off account that reaches condition.

4. Acknowledgements

¶1 **Authors:** [To be confirmed]

¶2 **Reviewers:** [To be confirmed]

5. References

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- ¶12 Mayer, P.M., Reynolds, S.K., McCutchen, M.D., and Canfield, T.J. (2007). Meta-analysis of nitrogen removal in riparian buffers. *Journal of Environmental Quality*, 36(4), 1172–1180.

- ¶13 Kirwan, M.L., and Megonigal, J.P. (2013). Tidal wetland stability in the face of human impacts and sea-level rise. *Nature*, 504(7478), 53-60.

FOOTNOTES

1. ¶1 SEEA EA, para 1.1, noting that ecosystem accounting provides a basis for compiling data on biophysical characteristics of ecosystems and their contribution to the economy and society; the freshwater-marine interface is a zone of active methodological development in environmental-economic accounting, with upstream economic activities affecting downstream ecosystem condition.
2. ¶2 United Nations (2012), *System of Environmental-Economic Accounting for Water (SEEA-Water)*, provides the framework for water supply and use tables, water quality accounts, and water asset accounts; SEEA EA (2021) extends environmental-economic accounting to ecosystem assets and services.
3. ¶3 IUCN GET describes transitional realm ecosystems as occupying the interface between two or more realms, with environmental conditions and biota reflecting the influence of both adjacent realms.
4. ¶4 IUCN GET (Keith et al. 2020), Biome MFT1 description: "associated with prograding depositional shorelines at the interface of terrestrial, freshwater, and marine realms"; SEEA EA (2021), Appendix A3.2 presents the IUCN GET reference classification.
5. ¶5 United Nations (2012), *SEEA-Water*, Chapter 2 on the hydrological cycle and its representation in accounting terms.
6. ¶6 Tidal influence, saltwater intrusion, and storm surge represent marine-to-terrestrial flows that affect freshwater quality and ecosystem condition in lower catchments.
7. ¶7 United Nations (2012), *SEEA-Water*, Chapter 3 on spatial organisation of water accounts; river basin boundaries are recommended as the primary spatial unit for water resource accounting.
8. ¶8 Episodic flood events may deliver 50-90% of annual sediment loads within a few days; see Syvitski et al. (2005) on global sediment flux dynamics.
9. ¶9 Richter, B.D., Baumgartner, J.V., Powell, J., and Braun, D.P. (1996). A method for assessing hydrologic alteration within ecosystems. *Conservation Biology*, 10(4), 1163-1174. The Indicators of Hydrologic Alteration (IHA) methodology provides 33 standardised flow statistics quantifying the five components of a flow regime (magnitude, frequency, duration, timing, rate of change); compilers requiring comprehensive flow-regime characterisation should refer to the IHA framework rather than deriving a single summary ratio.
10. ¶10 SEEA Central Framework, Chapter 3 on physical flow accounts; *SEEA-Water*, Chapter 4 on emission accounts for water.
11. ¶11 Coastal deoxygenation affects over 500 coastal hypoxic sites globally, with documented expansion in extent and severity since the mid-twentieth century; see Breitburg et al. (2018).
12. ¶12 Mayer, P.M., Reynolds, S.K., McCutchen, M.D., and Canfield, T.J. (2007). Meta-analysis of nitrogen removal in riparian buffers. *Journal of Environmental Quality*, 36(4), 1172-1180. Retention rates vary widely with buffer width, soil type, and hydrological connectivity; compilers should use site- or region-specific data where available rather than applying a single percentage.
13. ¶13 Syvitski et al. (2005) estimate that dam construction has trapped approximately 25-30% of global sediment flux that would otherwise reach the coast.
14. ¶14 Reduced sediment supply threatens coastal wetland persistence under sea-level rise; see Kirwan and Megonigal (2013) on tidal wetland stability.
15. ¶15 United Nations (2012), *SEEA-Water*, Chapter 4 addresses emission accounts; emerging contaminants require additional monitoring protocols beyond standard water quality parameters.
16. ¶16 Barbier et al. (2011) provide a comprehensive review of estuarine and coastal ecosystem service values, estimating global values in the range of USD 10,000-30,000 per hectare per year.
17. ¶17 IUCN Global Ecosystem Typology (Keith et al. 2020); SEEA EA (2021) Appendix A3.2. FM1.2 full name: "Permanently open riverine estuaries and bays."
18. ¶18 SEEA EA (2021), Chapter 4 on ecosystem extent accounts; para 4.1: "Ecosystem extent is the size of an ecosystem asset."
19. ¶19 SEEA EA (2021), Chapter 5 on ecosystem condition accounts; para 5.1: "Ecosystem condition accounts provide a structured approach to recording and aggregating data describing the characteristics of ecosystem assets."
20. ¶20 ECT class codes (A1, A2, B1, B2, B3, C1) verified against SEEA EA (2021) Table 5.1 and paras. 5.32-5.38. Classes confirmed: A1 Physical state, A2 Chemical state, B1 Compositional state, B2 Structural state, B3 Functional state, C1 Landscape and seascape characteristics.
21. ¶21 SEEA EA (2021), Chapter 6 on ecosystem services; estuarine services span multiple SEEA service categories including regulating services, provisioning services, and cultural services.
22. ¶22 United Nations (2012), *System of Environmental-Economic Accounting for Water (SEEA-Water)*. Its structure is designed for integration with the broader SEEA Central Framework and SEEA EA.
23. ¶23 United Nations (2012), *SEEA-Water*, Chapter 3 on water supply and use tables; these tables record water flows between the environment, economic units, and the rest of the world.
24. ¶24 United Nations (2012), *SEEA-Water*, Chapter 4 on quality accounts and emission accounts for water.
25. ¶25 United Nations (2012), *SEEA-Water*, Chapter 5 on water asset accounts; these record opening stocks, additions, reductions, and closing stocks of water resources.
26. ¶26 SEEA EA (2021), para 4.5-4.8 on ecosystem accounting area delineation; the choice of spatial boundaries is a foundational decision affecting all subsequent accounts.

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