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Appendix

A.1 A Compilation of All Equations and Model Variables in the Mass-Balance Model for Salt (CoastMab) for the Sub-basins of the Baltic Sea

Abbreviations: F for flow (kg/month), R for rate (1/month), C for concentration ($‰ = \text{psu} = \text{kg/m}^3$), DC for distribution coefficients (dimensionless), M for mass (kg salt), D for depth in m, A for area in m^2, V for volume in m^3; ET stands for areas with erosion and resuspension (advection) of fine sediments above the theoretical wave base; T is the theoretical retention time (years); flow from one compartment (e.g., SW) to another compartment (e.g., MW) is written as F_{SWMW}; mixing flow is abbreviated as F_{xDWMW}; Q is water discharge (m^3/month),

Baltic Proper (BP), surface-water (SW)

$$\begin{aligned} M_{SWBP}(t) = {} & M_{SWBP}(t-dt) + (F_{xMWSWBP} + F_{tribBP} + F_{precBP} + F_{dMWSW} \\ & + F_{SWBSBP} + F_{SWKABP} + F_{SWGFBP} + F_{SWGRBP} - F_{xSWMWBP} \\ & - F_{evaBP} - F_{SWBPBS} - F_{SWBPKA} - F_{SWBPGF} - F_{SWBPGR}) \cdot dt \end{aligned}$$

Inflows

$F_{xMWSWBP} = M_{MWBP} \cdot R_{xSWDWBP} \cdot V_{SWBP}/V_{MWBP}$; mixing flow from MW to SW in BP (kg/months)
$F_{tribBP} = Q_{tribBP} \cdot C_{tribBP}$; tributary inflow to BP (kg/months)
$F_{precBP} = Q_{precBP} \cdot C_{precBP}$; flow to BP from precipitation (kg/months)
$F_{dMWSWBP} = M_{MWBP} \cdot R_{dMWSWBP} \cdot Const_{diff}$; diffusive flow MW to SW in BP (kg/months)
$F_{SWBSBP} = Q_{SWBSBP} \cdot C_{SWBS}$; SW-flow from BS to BP (kg/months)
$F_{SWKABP} = Q_{KABP} \cdot DC_{QSWMWBP} \cdot C_{KA}$; SW-flow from Kattegat to BP (kg/months)
$F_{SWGFBP} = Q_{SWGFBP} \cdot C_{SWGF}$; SW-flow from GF to BP (kg/months)
$F_{SWGRBP} = Q_{SWGRBP} \cdot C_{SWGR}$; SW-flow from GR to BP (kg/months)

Outflows

$F_{xSWMWBP} = M_{SWBP} \cdot R_{xSWMWBP}$; mixing flow from SW to MW in BP (kg/months)
$F_{SWBPBS} = Q_{SWBPBS} \cdot C_{SWBP}$; SW-flow from BP to BS (kg/months)
$F_{evaBP} = Q_{evaBP} \cdot M_{SWBP} \cdot 0$; evaporation from BP (kg/months)
$F_{SWBPKA} = Q_{SWBPKP} \cdot C_{SWBP}$; SW-flow from BP to Kattegat (KA) from precipitation (kg/months)
$F_{SWBPGF} = Q_{SWBPGF} \cdot C_{SWBP}$; SW-flow from BP to GF (kg/months)
$F_{SWBPGR} = Q_{SWBPGR} \cdot C_{SWBP}$; SW-flow from BP to GR (kg/months)

Baltic Proper (BP), middle-water (MW)

$$\begin{aligned} M_{MWBP}(t) = {} & M_{MWBP}(t - dt) + (F_{xSWMWBP} + F_{xDWMWBP} + F_{dDWMWBP} \\ & + F_{MWKABP} + F_{MWGFBP} + F_{MWGRBP} - F_{xMWSWBP} - F_{xMWDWBP} \\ & - F_{dMWSWBP} - F_{MWBPBS} - F_{MWBPGF} - F_{MWBPGR}) \cdot dt \end{aligned}$$

Inflows

$F_{xSWMWBP} = M_{SWBP} \cdot R_{xSWMWBP}$; mixing flow from SW to MW in BP (kg/months)
$F_{xDWMWBP} = M_{DWBP} \cdot R_{xMWDWBP} \cdot V_{MWBP}/V_{DWBP}$; mixing flow from DW to MW in BP (kg/months)
$F_{dDWMWBP} = M_{DWBP} \cdot R_{dDWMWBP} \cdot Const_{diff}$; diffusive flow DW to MW in BP (kg/months)
$F_{MWKABP} = Q_{KABP} \cdot C_{KA} \cdot (1 - DC_{QSWMWBP}) \cdot (1 - DC_{QDWMWBP})$; MW-flow from KA to BP (kg/months)
$F_{MWGFBP} = Q_{MWGFBP} \cdot C_{MWGF}$; MW-flow from GF to BP (kg/months)
$F_{MWGRBP} = Q_{MWGRBP} \cdot C_{MWGR}$; MW-flow from GR to BP (kg/months)

Outflows

$F_{xMWSWBP} = M_{MWBP} \cdot R_{xSWMWBP} \cdot V_{SWBP}/V_{MWBP}$; mixing flow from MW to SW in BP (kg/months)
$F_{xMWDWBP} = M_{MWBP} \cdot R_{xMWDWBP}$; mixing flow from MW to DW in BP (kg/months)
$F_{dMWSWBP} = M_{MWBP} \cdot R_{dMWSWBP} \cdot Const_{diff}$; diffusive flow MW to SW in BP (kg/months)
$F_{MWBPBS} = Q_{MWBPBS} \cdot C_{MWBP}$; MW-flow from BP to BS (kg/months)
$F_{MWBPGF} = Q_{MWBPGF} \cdot C_{MWGF}$; MW-flow from BP to GF (kg/months)
$F_{MWBPGR} = Q_{MWBPGR} \cdot C_{MWGR}$; MW-flow from BP to GR (kg/months)

Baltic Proper (BP), deep-water (DW)

$$\begin{aligned} M_{DWBP}(t) = {} & M_{DWBP}(t - dt) + (F_{xMWDWBP} + F_{DWKABP} + F_{DWGFBP} \\ & - F_{xDWMWBP} - F_{dDWMWBP} - F_{DWBPGF}) \cdot dt \end{aligned}$$

Inflows

$F_{xMWDWBP} = M_{DWBP} \cdot R_{xMWDWBP}$; mixing flow from MW to DW in BP (kg/months)

$F_{DWKABP} = Q_{KABP} \cdot C_{KA} \cdot (1 - DC_{QSWMWBP}) \cdot DC_{QDWMWBP}$; DW-flow from KA to BP (kg/months)

$F_{DWGFBP} = Q_{DWGFBP} \cdot C_{DWGF}$; DW-flow from GF to BP (kg/months)

Outflows

$F_{xDWMWBP} = M_{DWBP} \cdot R_{xMWDWBP} \cdot V_{MWBP}/V_{DWBP}$; mixing flow from DW to MW in BP (kg/months)

$F_{diffDWMWBP} = M_{DWBP} \cdot R_{diffDWMWBP} \cdot Const_{diff}$; diffusive flow DW to MW in BP (kg/months)

$F_{DWBPGF} = Q_{DWBPGF} \cdot C_{DWBP}$; DW-flow from BP to GF (kg/months)

Gulf of Finland (SW), surface-water (SW)

$$M_{SWGF}(t) = M_{SWGF}(t - dt) + (F_{xMWSWGF} + F_{tribGF} + F_{precGF} + F_{dMWSWGF} + F_{SWBPGF} - F_{xSWMWGF} - F_{evaGF} - F_{SWGFBP}) \cdot dt$$

Inflows

$F_{xMWSWGF} = M_{MWGF} \cdot R_{xSWDWGF} \cdot V_{SWGF}/V_{MWGF}$; mixing flow from MW to SW in BP (kg/months)

$F_{tribGF} = Q_{tribGF} \cdot C_{tribGF}$; tributary inflow to BP (kg/months)

$F_{precGF} = Q_{precGF} \cdot C_{precGF}$; flow to BP from precipitation (kg/months)

$F_{dMWSWGF} = M_{MWGF} \cdot R_{dMWSWGF} \cdot Const_{diff}$; diffusive flow MW to SW in BP (kg/months)

$F_{SWBPGF} = Q_{SWBPGF} \cdot C_{SWBP}$; SW-flow from BP to GF (kg/months)

Outflows

$F_{xSWMWGF} = M_{SWGF} \cdot R_{xSWMWGF}$; mixing flow from SW to MW in BP (kg/months)

$F_{evaGF} = Q_{evaGF} \cdot M_{SWGF} \cdot 0$; evaporation from BP (kg/months)

$F_{SWGFBP} = Q_{SWGFBP} \cdot C_{SWGF}$; SW-flow from GF to BP (kg/months)

Gulf of Finland (GF), middle-water (MW)

$$M_{MWGF}(t) = M_{MWGF}(t - dt) + (F_{xSWMWGF} + F_{xDWMWGF} + F_{dDWMWGF} + F_{MWBPGF} - F_{xMWSWGF} - F_{xMWDWGF} - F_{dMWSWGF} - F_{MWGFBP}) \cdot dt$$

Inflows

$F_{xSWMWGF} = M_{SWGF} \cdot R_{xSWMWGF}$; mixing flow from SW to MW in GF (kg/months)

$F_{xDWMWGF} = M_{DWGF} \cdot R_{xMWDWGF} \cdot V_{MWGF}/V_{DWGF}$; mixing flow from DW to MW in GF (kg/months)

$F_{dDWMWGF} = M_{DWGF} \cdot R_{dDWMWGF} \cdot Const_{diff}$; diffusive flow DW to MW in GF (kg/months)

$F_{MWBPGF} = Q_{MWBPGF} \cdot C_{MWBP}$; MW-flow from BP to GF (kg/months)

Outflows

$F_{xMWSWGF} = M_{MWGF} \cdot R_{xSWMWGF} \cdot V_{SWGF}/V_{MWGF}$; mixing flow from MW to SW in GF (kg/months)

$F_{xMWDWGF} = M_{MWGF} \cdot R_{xMWDWGF}$; mixing flow from MW to DW in GF (kg/months)

$F_{dMWSWGF} = M_{MWGF} \cdot R_{dMWSWGF} \cdot Const_{diff}$; diffusive flow MW to SW in GF (kg/months)

$F_{MWGFBP} = Q_{MWGFBP} \cdot C_{MWGF}$; MW-flow from GF to BP (kg/months)

Gulf of Finland (GF), deep-water (DW)

$$M_{DWGF}(t) = M_{DWGF}(t-dt) + (F_{xMWDWGF} + F_{DWBPGF} - F_{xDWMWGF} - F_{dDWMWGF} - F_{DWGFBP}) \cdot dt$$

Inflows

$F_{xMWDWGF} = M_{DWGF} \cdot R_{xMWDWGF}$; mixing flow from MW to DW in GF (kg/months)

$F_{DWBPGF} = Q_{DWBPGF} \cdot C_{DWBP}$; DW-flow from BP to GF (kg/months)

Outflows

$F_{xDWMWGF} = M_{DWGF} \cdot R_{xMWDWGF} \cdot V_{MWGF}/V_{DWGF}$; mixing flow from DW to MW in GF (kg/months)

$F_{dDWMWGF} = M_{DWGF} \cdot R_{dDWMWGF} \cdot Const_{diff}$; diffusive flow DW to MW in GF (kg/months)

$F_{DWGFBP} = Q_{DWGFBP} \cdot C_{DWGF}$; DW-flow from GF to BP (kg/months)

Gulf of Riga (GF), surface-water (SW)

$$M_{SWGR}(t) = M_{SWGR}(t-dt) + (F_{xDWSWGR} + F_{tribGR} + F_{precGR} + F_{dDWSWGR} + F_{SWBPGR} - F_{xSWDWGR} - F_{evaGR} - F_{SWGRBP}) \cdot dt$$

Inflows

$F_{xDWSWGR} = M_{DWGR} \cdot R_{xGR} \cdot V_{SWGR}/V_{DWGR}$; mixing flow from DW to SW in GR (kg/months)

$F_{tribGR} = Q_{tribGR} \cdot C_{tribGR}$; tributary inflow to GR (kg/months)

$F_{precGR} = Q_{precGR} \cdot C_{precGR}$; flow to GR from precipitation (kg/months)

$F_{dDWSWGR} = M_{DWGR} \cdot R_{dDWSWGR} \cdot Const_{diff}$; diffusive flow DW to SW in BS (kg/months)

$F_{SWBPGR} = Q_{SWBPGR} \cdot C_{SWBP}$; SW-flow from BP to GR (kg/months)

Outflows

$F_{xSWDWGR} = M_{SWGR} \cdot R_{xGR}$; mixing flow from SW to DW in GR (kg/months)
$F_{evaGR} = M_{SWGR} \cdot Q_{evaGR} \cdot 0$; evaporation from GR (kg/months)
$F_{SWGRBP} = Q_{SWGRBP} \cdot C_{SWGR}$; SW-flow from GR to BP (kg/months)

Gulf of Riga (GR), deep-water (DW)

$$M_{DWGR}(t) = M_{DWGR}(t - dt) + (F_{xSWDWGR} + F_{MWBPGR} - F_{xDWSWGR} - F_{dDWSWGR} - F_{DWGRBP}) \cdot dt$$

Inflows

$F_{xSWDWGR} = M_{SWGR} \cdot R_{xGR}$; mixing flow from SW to DW in GR (kg/months)
$F_{MWBPGR} = C_{MWGR} \cdot Q_{MWBPBS}$; MW-flow from BP to DW in GR (kg/months)

Outflows

$F_{xDWSWGR} = M_{DWGR} \cdot R_{xGR} \cdot V_{SWGR}/V_{DWGR}$; mixing flow from DW to SW in GR (kg/months)
$F_{dDWSWGR} = R_{dDWSWGR} \cdot M_{DWGR} \cdot Const_{diff}$; diffusive flow DW to SW in GR (kg/months)
$F_{DWGRBP} = Q_{DWGRBP} \cdot C_{DWGR}$; DW-flow from GR to BB (kg/months)

Bothnian Sea (BS), surface-water (SW)

$$M_{SWBS}(t) = M_{SWBS}(t - dt) + (F_{xDWSWBS} + F_{tribBS} + F_{precBS} + F_{dDWSWBS} + F_{SWBPBS} + F_{SWBBBS} - F_{xSWDWBS} - F_{evaBS} - F_{SWBSBP} - F_{SWBSBB}) \cdot dt$$

Inflows

$F_{xDWSWBS} = M_{DWBS} \cdot R_{xBS} \cdot V_{SWBS}/V_{DWBS}$; mixing flow from DW to SW in BS (kg/months)
$F_{tribBS} = Q_{tribBS} \cdot C_{tribBS}$; tributary inflow to BS (kg/months)
$F_{precBS} = Q_{precBS} \cdot C_{precBS}$; flow to BS from precipitation (kg/months)
$F_{dDWSWBS} = M_{DWBS} \cdot R_{dDWSWBS} \cdot Const_{diff}$; diffusive flow DW to SW in BS (kg/months)
$F_{SWBPBS} = Q_{SWBPBS} \cdot C_{SWBP}$; SW-flow from BP to BS (kg/months)
$F_{SWBBBS} = Q_{SWBBBS} \cdot C_{SWBB}$; SW-flow from BB to BS (kg/months)

Outflows

$F_{xSWDWBS} = M_{SWBS} \cdot R_{xBS}$; mixing flow from SW to DW in BS (kg/months)
$F_{evaBS} = M_{SWBS} \cdot Q_{evaBS} \cdot 0$; evaporation from BP (kg/months)
$F_{SWBSBP} = Q_{SWBSBP} \cdot C_{SWBS}$; SW-flow from BS to BP (kg/months)
$F_{SWBSBB} = Q_{SWBSBB} \cdot C_{SWBS}$; SW-flow from BS to BB (kg/months)

Bothnian Sea (BS), deep-water (DW)

$$M_{DWBS}(t) = M_{DWBS}(t - dt) + (F_{xSWDWBS} + F_{MWBPBS} - F_{xDWSWBS} - F_{dDWSWB} - F_{DWBSBB}) \cdot dt$$

Inflows

$F_{xSWDWBS} = M_{SWBS} \cdot R_{xBS}$; mixing flow from SW to DW in BS (kg/months)
$F_{MWBPBS} = Q_{MWBPBS} \cdot C_{MWBP}$; MW-flow from BP to BS (kg/months)

Outflows

$F_{xDWSWBS} = M_{DWBS} \cdot R_{xBS} \cdot V_{SWBS}/V_{DWBS}$; mixing flow from DW to SW in BS (kg/months)
$F_{dDWSWBS} = R_{dDWSWBS} \cdot M_{DWBS} \cdot Const_{diff}$; diffusive flow DW to SW in BS (kg/months)
$F_{DWBSBB} = Q_{DWBSBB} \cdot C_{DWBS}$; DW-flow from BS to BB (kg/months)

Bothnian Bay (BB), surface-water (SW)

$$M_{SWBB}(t) = M_{SWBB}(t - dt) + (F_{xDWSWxBB} + F_{tribBB} + F_{precBB} + F_{dDWSWBB} + F_{SWBSBB} - F_{xSWDWBB} - F_{evaBB} - F_{SWBBBS}) \cdot dt$$

Inflows

$F_{xDWSWBB} = M_{DWBB} \cdot R_{xBB} \cdot V_{SWBB}/V_{DWBB}$; mixing flow from DW to SW in BB (kg/months)
$F_{tribBB} = Q_{tribBB} \cdot C_{tribBB}$; tributary inflow to BB (kg/months)
$F_{precBB} = Q_{precBB} \cdot C_{precBB}$; flow to BB from precipitation (kg/months)
$F_{dDWSWBB} = M_{DWBB} \cdot R_{dDWSWBB} \cdot Const_{diff}$; diffusive flow DW to SW in BB (kg/months)
$F_{SWBSBB} = Q_{SWBSBB} \cdot C_{SWBS}$; SW-flow from BS to BB (kg/months)

Outflows

$F_{xSWDWBB} = M_{SWBB} \cdot R_{xBB}$; mixing flow from SW to DW in BB (kg/months)
$F_{evaBB} = M_{SWBB} \cdot Q_{evpBB} \cdot 0$; evaporation from BP (kg/months)
$F_{SWBBBS} = Q_{SWBBBS} \cdot C_{SWBB}$; SW-flow from BB to BS (kg/months)

Bothnian Bay (BB), deep-water (DW)

$$M_{DWBB}(t) = M_{DWBB}(t - dt) + (F_{xSWDWBB} + F_{DWBSBB} - F_{xDWSWBB} - F_{dDWSWBB}) \cdot dt$$

Inflows

$F_{xSWDWBB} = M_{SWBB} \cdot R_{xBB}$; mixing flow from SW to DW in BB (kg/months)
$F_{DWBSBB} = C_{DWBS} \cdot Q_{DWBSBB}$; DW-flow from BS to BB (kg/months)

Outflows

$F_{xDWSWBB} = M_{DWBB} \cdot R_{xBB} \cdot V_{SWBB} / V_{DWBB}$; mixing flow from DW to SW in BB (kg/months)

$F_{dDWSWBB} = M_{DWBB} \cdot R_{dDWSWBB} \cdot Const_{diff}$; diffusive flow DW to SW in BB (kg/months)

Model variables

$A_{BB} = 36{,}300 \cdot 10^{\wedge}6$; area BB (m^2)
$A_{BP} = 211{,}100 \cdot 10^{\wedge}6$; area BP (m^2)
$A_{BS} = 79{,}300 \cdot 10^{\wedge}6$; area BS (m^2)
$A_{GF} = 29{,}600 \cdot 10^{\wedge}6$; area GF (m^2)
$A_{GR} = 16{,}700 \cdot 10^{\wedge}6$; area GR (m^2)
$A_{MWBP} = 123{,}500 \cdot 10^{\wedge}6$; MW-area BP (m^2)
$A_{DWBP} = 73{,}000 \cdot 10^{\wedge}6$; DW-area BP (m^2)
$A_{WBBP} = 123{,}500 \cdot 10^{\wedge}6$; area below the wave base in BP (m^2)
$A_{WBBS} = 46{,}790 \cdot 10^{\wedge}6$; area below the wave base in BS (m^2)
$A_{WBBB} = 13{,}300 \cdot 10^{\wedge}6$; area below the wave base in BB (m^2)
$A_{WBGF} = 10.950 \cdot 10^{\wedge}6$; area below the wave base in GF (m^2)
$A_{WBGR} = 3510 \cdot 10^{\wedge}6$; area below the wave base in GR (m^2)
$C_{DWBB} = M_{DWBB} / V_{DWBB}$; deep-water salinity in BB (psu)
$C_{DWBS} = M_{DWBS} / V_{DWBS}$; deep-water salinity in BS (psu)
$C_{DWGF} = M_{DWGF} / V_{DWGF}$; deep-water salinity in GF (psu)
$C_{DWGR} = M_{DWGR} / V_{DWGR}$; deep-water salinity in GR (psu)
$C_{KA} = 17.6$; salinity in Kattegat (psu)
$Const_{diff} = 0.05$; diffusion constant (dim. less).
$C_{precBB} = 0$; salinity in precipitation to BB (psu)
$C_{precBP} = 0$; salinity in precipitation to BP (psu)
$C_{precBS} = 0$; salinity in precipitation to BS (psu)
$C_{precGF} = 0$; salinity in precipitation to GF (psu)
$C_{precGR} = 0$; salinity in precipitation to GR (psu)
$C_{MWBP} = M_{MWBP} / V_{MWBP}$; middle-water salinity in BP (psu)
$C_{MWGF} = M_{MWGF} / V_{MWGF}$; middle-water salinity in GF (psu)
$C_{SWBP} = M_{SWBP} / V_{SWBP}$; surface-water salinity in BP (psu)
$C_{SWBB} = M_{SWBB} / V_{SWBB}$; surface-water salinity in BB (psu)
$C_{SWBS} = M_{SWBS} / V_{SWBS}$; surface-water salinity in BS (psu)
$C_{SWGF} = M_{SWGF} / V_{SWGF}$; surface-water salinity in GF (psu)
$C_{SWGR} = M_{SWGR} / V_{SWGR}$; surface-water salinity in GR (psu)
$C_{tribBB} = 0$; tributary salinity to BB (psu)
$C_{tribBP} = 0$; tributary salinity to BP (psu)
$C_{tribBS} = 0$; tributary salinity to BS (psu)
$C_{tribGF} = 0$; tributary salinity to GF (psu)
$C_{tribGR} = 0$; tributary salinity to GR (psu)
$DC_{QDWMWBP} = 0.365$; distribution coefficient (dim. less) for water inflow from Kattegat to DW or MW in BP

$DC_{QSWMWBP} = 0.7445$; distribution coefficient (dim. less) for water inflow from Kattegat to SW or MW in BP
$DC_{SWMWGF} = 0.83$; distribution coefficient (dim. less) for SW/MW water inflow from BP to GF
$DC_{DWMWGF} = 0.5$; distribution coefficient (dim. less) for DW/MW water inflow from BP to GF
$DC_{SWMWGF} = 0.6$; distribution coefficient (dim. less) for SW/MW water inflow from BP to GR
$D_{hc} = 75$; average depth of the halocline in BP and GF (m)
$D_{maxBB} = 148$; maximum depth in BB (m)
$D_{maxBP} = 459$; maximum depth in BP (m)
$D_{maxBS} = 301$; maximum depth in BS (m)
$D_{maxGF} = 105$; maximum depth in GF (m)
$D_{maxGR} = 56$; maximum depth in GR (m)
$D_{mBB} = 41.3$; mean depth in BB (m)
$D_{mBP} = 61.6$; mean depth in BP (m)
$D_{mBS} = 61.7$; mean depth in BS (m)
$D_{mGF} = 36.3$; mean depth in GF (m)
$D_{mGR} = 24.5$; mean depth in GR (m)
$D_{WBBB} = 41.1$; depth of the wave base in BB (m)
$D_{WBBP} = 43.8$; depth of the wave base in BP (m)
$D_{WBBS} = 42.5$; depth of the wave base in BS (m)
$D_{WBGF} = 43.8$; depth of the wave base in GF (m)
$D_{WBGR} = 39.2$; depth of the wave base in GR (m)
$ET_{BB} = (A_{BB} - A_{WBBB})/A_{BB}$; fraction of ET-areas in BB (areas with fine sediment resuspension)
$ET_{BP} = (A_{BP} - A_{WBBP})/A_{BP}$; fraction of ET-areas in BP
$ET_{BS} = (A_{BS} - A_{WBBS})/A_{BS}$; fraction of ET-areas in BS
$ET_{GF} = (A_{GF} - A_{WBGF})/A_{GF}$; fraction of ET-areas in GF
$ET_{GR} = (A_{GR} - A_{WBGR})/A_{GR}$; fraction of ET-areas in GR
$Q_{BPGF} = ((Q_{GFBP} + Q_{evaGF}) - (Q_{precGF} + Q_{tribGF}))$; total water flow from BP to GF (m^3/month)
$Q_{BPGR} = ((Q_{GRBP} + Q_{evaGR}) - (Q_{precGR} + Q_{tribGR}))$; ; total water flow from BP to GR (m^3/month)
$Q_{DWBPBS} = 47 \cdot 10^\wedge 9$; deep-water flow from BP to BS (m^3/yr)
$Q_{DWBSBB} = 15 \cdot 10^\wedge 9$; deep-water flow from BS to BP (m^3/yr)
$Q_{DWKABP} = Q_{KABP} \cdot (1 - DC_{SWMWBP}) \cdot DC_{DWMWBP}$; deep-water flow from Kattegat (KA) to BP (m^3/month)
$Q_{DWBPGF} = Q_{BPGF} \cdot (1 - DC_{SWMWGF}) \cdot DC_{DWMWGF}$; deep-water flow from BP to GF (m^3/month)
$Q_{DWBPGR} = Q_{BPGR} \cdot (1 - DC_{SWDWGR})$; deep-water flow from BP to GR (m^3/month)
$Q_{evaBP} = 137 \cdot 10^\wedge 9$; water flow from evaporation in BP (m^3/yr)
$Q_{evaBS} = 26 \cdot 10^\wedge 9$; water flow from evaporation in BS (m^3/yr)
$Q_{evaBB} = 12 \cdot 10^\wedge 9$; water flow from evaporation in BB (m^3/yr)
$Q_{evaGF} = 16 \cdot 10^\wedge 9$; water flow from evaporation in GF (m^3/yr)

$Q_{evaGR} = 9 \cdot 10^\wedge 9$; water flow from evaporation in GR (m^3/yr)
$Q_{GFBP} = (1108 \cdot 10^\wedge 9)/12$; total water flow from GF to BP (m^3/month)
$Q_{GRBP} = (188 \cdot 10^\wedge 9)/12$; total water flow from GR to BP (m^3/month)
$Q_{MWKABP} = Q_{KABP} \cdot (1 - DC_{SWMWBP}) \cdot (1 - DC_{DWMWBP})$; middle-water flow from KA to BP (m^3/month)
$Q_{xMWDWBP} = F_{xDWMWBP}/C_{DWBP}$; water flow from mixing between MW and DW in BP (m^3/month)
$Q_{KABP} = (345/12) \cdot 10^\wedge 9$; total water flow from KA to BP (m^3/yr)
$Q_{mixBB} = F_{xDWSWBB}/C_{DWBB}$; water flow from mixing in BB (m^3/month)
$Q_{mixBS} = F_{xDWSWBS}/C_{DWBS}$; water flow from mixing in BS (m^3/month)
$Q_{xSWDWBS} = F_{xDWSWBS}/C_{DWBS}$; water flow from mixing SW to DW in BS (m^3/month)
$Q_{xSWMWBP} = F_{xSWMWBP}/C_{SWBP}$; water flow from mixing SW to MW in BP (m^3/month)
$Q_{xSWDWGF} = F_{xDWSWGF}/C_{DWGF}$; water flow from mixing SW to DW in BS (m^3/month)
$Q_{xSWMWGF} = F_{xSWMWGF}/C_{SWGF}$; water flow from mixing SW to MW in BP (m^3/month)
$Q_{mixGR} = F_{xDWSWGR}/C_{DWGR}$; water flow from mixing in BS (m^3/month)
$Q_{MWBPGF} = Q_{BPGF} \cdot (1 - DC_{SWMWGF}) \cdot (1 - DC_{DWMWGF})$; MW water flow from BP to GF (m^3/month)
$Q_{precBB} = 21 \cdot 10^\wedge 9$; water flow from precipitation to BB (m^3/yr)
$Q_{precBP} = 152 \cdot 10^\wedge 9$; water flow from precipitation to BP (m^3/yr)
$Q_{precBS} = 47 \cdot 10^\wedge 9$; water flow from precipitation to BS (m^3/yr)
$Q_{precGF} = 18 \cdot 10^\wedge 9$; water flow from precipitation to GF (m^3/yr)
$Q_{precGR} = 10 \cdot 10^\wedge 9$; water flow from precipitation to GR (m^3/yr)
$Q_{SWBBBS} = 305 \cdot 10^\wedge 9$; SW-flow from BB to BS (m^3/yr)
$Q_{SWBPBS} = (Q_{SWBSBP} + Q_{evaBS} + Q_{SWBSBB}) - (Q_{tribBS} + Q_{precBS} + Q_{DWBPBS} + Q_{SWBBBS})$; surface-water flow from BP to BS (m^3/month)
$Q_{SWBPGF} = Q_{BPGF} \cdot DC_{SWMWGF}$; surface-water flow from BP to GF (m^3/month)
$Q_{SWBPGR} = Q_{BPGR} \cdot DC_{SWMWGR}$; surface-water flow from BP to GR (m^3/month)
$Q_{SWBPKA} = -(Q_{evaBP} + Q_{MWBPBS} + Q_{SWBPBS} + (Q_{SWBSBP} + Q_{precBP} + Q_{tribBP} + Q_{tribGF} + Q_{tribGR} + 0.1 \cdot Q_{precGR} + 0.1 \cdot Q_{precGF} + Q_{KABP})$; SW-flow from BP to KA (m^3/month)
$Q_{SWBSBB} = (Q_{evpBB} + Q_{SWBBBS}) - (Q_{tribBB} + Q_{precBB} + Q_{DWBSBB})$; surface-water flow from BS to BB (m^3/month)
$Q_{SWBSBP} = 1055 \cdot 10^\wedge 9$; surface-water flow from BS to BP (m^3/yr)
$Q_{SWKABP} = DC_{SWMWBP} \cdot Q_{KABP}$; SW-flow from Kattegat to BP (m^3/month)
$Q_{tribBB} = 109 \cdot 10^\wedge 9$; tributary inflow of water to BB (m^3/yr)
$Q_{tribBP} = 265 \cdot 10^\wedge 9$; tributary inflow of water to BP (m^3/yr)
$Q_{tribBS} = 103 \cdot 10^\wedge 9$; tributary inflow of water to BS (m^3/yr)
$Q_{tribGF} = 117 \cdot 10^\wedge 9$; tributary inflow of water to GF (m^3/yr)
$Q_{tribGR} = 36 \cdot 10^\wedge 9$; tributary inflow of water to GR (m^3/yr)
$R_{dDWSWBB} =$ if $C_{SWBB} > C_{DWBB}$ then 0 else $(C_{DWBB} - C_{SWBB})/1$; diffusion rate for DW to SW in BB (1/month)

$R_{dDWSWBS}$ = if $C_{SWBS} > C_{DWBS}$ then 0 else $(C_{DWBS} - C_{SWBS})/1$; diffusion rate for DW to SW in BS (1/month)

$R_{dDWMWBP}$ = if $C_{MWBP} > C_{DWBP}$ then 0 else $(C_{DWBP} - C_{MWB}P)/1$; diffusion rate for DW to SW in BP (1/month)

$R_{dMWSWBP}$ = if $C_{SWBP} > C_{MWBP}$ then 0 else $(C_{MWBP} - C_{SWBP})/1$; diffusion rate for MW to SW in BP (1/month)

$R_{dMWSWGF}$ = if $C_{SWGF} > C_{MWGF}$ then 0 else $(C_{MWGF} - C_{SWGF})/1$; diffusion rate for MW to SW in GF (1/month)

$R_{dMWSWGR}$ = if $C_{SWGR} > C_{MWGR}$ then 0 else $(C_{MWGR} - C_{SWGR})/1$; diffusion rate for MW to SW in GR (1/month)

R_{xBB} = if $(C_{DWBB} > C_{SWBB})$ then $R_{mixdefBB} \cdot (1/(1 + C_{DWBB} - C_{SWBB}))$^$R_{mixexp}$ else $R_{mixdefBB}$; mixing rate for BB (1/month)

R_{xBS} = if $(C_{DWBS} > C_{SWBS})$ then $R_{mixdefBS} \cdot (1/(1 + C_{DWBS} - C_{SWBS}))$^$R_{mixexp}$ else $R_{mixdefBS}$; mixing rate for BS (1/month)

R_{xGR} = if $(C_{DWGR} > C_{SWGR})$ then $R_{mixdefGR} \cdot (1/(1 + C_{DWGR} - C_{SWGR}))$^$R_{mixexp}$ else $R_{mixdefGR}$; mixing rate for BS (1/month)

$R_{xMWDWBP}$ = if $C_{DWBP} > C_{MWBP}$ then $R_{mixdefBP} \cdot (1/(1 + C_{DWBP} - C_{MWBP}))$^$R_{mixexp}$ else $R_{mixdefBP}$; mixing rate for MW to DW in BP (1/month)

$R_{xSWMWBP}$ = if $C_{MWBP} > C_{SWBP}$ then $R_{mixdefBP} \cdot (1/(1 + C_{MWBP} - C_{SWBP}))$^$R_{mixexp}$ else $R_{mixdefBP}$; mixing rate for SW to MW in BP (1/month)

$R_{xMWDWGF}$ = if $C_{DWGF} > C_{MWGF}$ then $R_{mixdefGF} \cdot (1/(1 + C_{DWGF} - C_{MWGF}))$^$R_{mixexp}$ else $R_{mixdefGF}$; mixing rate for MW to DW in GF (1/month)

$R_{xSWMWGF}$ = if $C_{MWGF} > C_{SWGF}$ then $R_{mixdefGF} \cdot (1/(1 + C_{MWGF} - C_{SWGF}))$^$R_{mixexp}$ else $R_{mixdefGF}$; mixing rate for SW to MW in GF (1/month)

$R_{mixdefBB} = ET_{BB}$; default mixing rate for BB (1/month)

$R_{mixdefBP} = ET_{BP}$; default mixing rate for BP (1/month)

$R_{mixdefBS} = ET_{BS}$; default mixing rate for BS (1/month)

$R_{mixdefGF} = ET_{GF}$; default mixing rate for GF (1/month)

$R_{mixdefGR} = ET_{GR}$; default mixing rate for GR (1/month)

$R_{mixexp} = 2$; mixing rate exponent (dim. less)

$T_{Qall} = (V_{BB} + V_{BS} + V_{BP} + V_{GF} + V_{GR})/(Q_{KABP} + Q_{precBB} + Q_{precBP} + Q_{precBS} + Q_{precGF} + Q_{precGR} + Q_{tribBB} + Q_{tribBP} + Q_{tribBS} + Q_{tribGF} + Q_{tribGR})$; theoretical water retention time for the entire Baltic Sea (months)

$T_{all} = (M_{DWBP} + M_{MWBP} + M_{SWBP} + M_{DWBB} + M_{SWBB} + M_{DWBS} + M_{SWBS} + M_{DWGR} + M_{SWGR} + M_{DWGF} + M_{MWGF} + M_{SWGF})/(F_{DWKABP} + F_{MWKABP} + F_{SWKABP} + F_{precBP} + F_{precBS} + F_{precBB} + F_{precGF} + F_{precGR} + F_{tribBB} + F_{tribBP} + F_{tribBS} + F_{tribGF} + F_{tribGR})$; theoretical retention time for salinity in the entire Baltic Sea (months)

$T_{QBB} = V_{BB}/(Q_{DWBSBB} + Q_{precBB} + Q_{tribBB} + Q_{SWBSBB})$; theoretical water retention time for BB (months)

$T_{QBP} = V_{BP}/(Q_{KABP} + Q_{precBP} + Q_{tribBP} + Q_{SWBSBP})$; theoretical water retention time for BP (months)

$T_{QBS} = V_{BS}/(Q_{DWBPBS} + Q_{precBS} + Q_{tribBS} + Q_{SWBBBS} + Q_{SWBPBS})$; theoretical water retention time for BS (months)

$T_{QGF} = V_{GF}/(Q_{DWBPGF} + Q_{precGF} + Q_{tribGF} + Q_{SWBBGF} + Q_{SWBPGF})$; theoretical water retention time for GF (months)

$T_{QGR} = V_{GR}/(Q_{DWBPGR} + Q_{precGR} + Q_{tribGR} + Q_{SWBBGR} + Q_{SWBPGR})$; theoretical water retention time for GR (months)

$T_{QDWBB} = V_{DWBB}/(Q_{DWBSBB} + Q_{mixBB})$; theoretical water retention time for DW in BB (months)

$T_{QDWBP} = V_{DWBP}/(Q_{KABP} \cdot (1 - DC_{SWMWBP}) \cdot DC_{DWMWBP} + Q_{MWDWxBP})$; theoretical water retention time for DW in BP (months)

$T_{QDWGF} = V_{DWGF}/(Q_{DWBPGF} + Q_{mixGF})$; theoretical water retention time for DW in GF (months)

$T_{QDWGR} = V_{DWGR}/(Q_{MWBPGR} + Q_{mixGR})$; theoretical water retention time for DW in GR (months)

$T_{QMWBP} = V_{MWBP}/((1 - DC_{SWMWBP}) \cdot Q_{KABP} \cdot (1 - DC_{DWMWBP}) + Q_{xMWDWBP} + Q_{xSWMWBP})$; theoretical water retention time for MW in BP (months)

$T_{QMWGF} = V_{MWGF}/((Q_{MWBPGF} + Q_{xMWDWBP} + Q_{xSWMWBP})$; theoretical water retention time for MW in GF (months)

$T_{QSWBB} = V_{SWBB}/(Q_{mixBB} + Q_{precBB} + Q_{tribBB} + Q_{SWBSBB})$; theoretical water retention time for SW in BB (months)

$T_{QSWBP} = V_{SWBP}/(Q_{SWMWxBP} + Q_{precBP} + Q_{tribBP} + Q_{SWBSBP} + DC_{SWMWBP} \cdot Q_{KABP})$; theoretical water retention time for SW in BP (months)

$T_{QSWBS} = V_{SWBS}/(Q_{mixBS} + Q_{precBS} + Q_{tribBS} + Q_{SWBBBS} + Q_{SWBPBS})$; theoretical water retention time for SW in BS (months)

$T_{QSWGF} = V_{SWGF}/(Q_{mixGF} + Q_{precGF} + Q_{tribGF} + Q_{SWBBGF})$; theoretical water retention time for SW in GF (months)

$T_{QSWGR} = V_{SWGR}/(Q_{mixGR} + Q_{precGR} + Q_{tribGR} + Q_{SWBBGR})$; theoretical water retention time for SW in GF (months)

$T_{BB} = (M_{DWBB} + M_{SWBB})/(F_{DWBSBB} + F_{precBB} + F_{tribBB} + F_{SWBSBB})$; theoretical retention time for salinity in BB (months)

$T_{BP} = (M_{DWBP} + M_{MWBP} + M_{SWBP})/(F_{DWKABP} + F_{MWKABP} + F_{SWKABP} + F_{precBP} + F_{tribBP} + F_{SWBSBP})$; theoretical retention time for salinity in BP (months)

$T_{BS} = (M_{DWBS} + M_{SWBS})/(F_{DWBPBS} + F_{precBS} + F_{tribBS} + F_{SWBBBS} + F_{SWBPBS})$; theoretical retention time for salinity in BS (months)

$T_{GF} = (M_{DWGF} + M_{MWGF} + M_{SWGF})/(F_{precGF} + F_{tribGF} + F_{SWBPGF} + F_{MWBPGF} + F_{MWBPGF})$; theoretical retention time for salinity in BP (months)

$T_{GR} = (M_{DWGR} + M_{SWGR})/(F_{DWBPGR} + F_{precGR} + F_{tribGR} + F_{SWBBGR} + F_{SWBPGR})$; theoretical retention time for salinity in BS (months)

$T_{DWBB} = M_{DWBB}/(F_{DWBSBB} + F_{xSWDWBB})$; theoretical retention time for salinity in DW in BB (months)

$T_{DWBP} = M_{DWBP}/(F_{DWKABP} + F_{DWGFBP} + F_{DWGRBP} + F_{xMWDWBP})$; theoretical retention time for salinity in DW in BP (months)

$T_{DWBS} = M_{DWBS}/(F_{DWBPBS} + F_{xSWDWBS})$; theoretical retention time for salinity in DW in BS (months)

$T_{DWGF} = M_{DWGF}/(F_{DWBPGF} + F_{xMWDWGF})$; theoretical retention time for salinity in DW in GF (months)

$T_{DWGR} = M_{DWBS}/(F_{DWBPGR} + F_{xSWDWGR})$; theoretical retention time for salinity in DW in GR (months)

$T_{MWBP} = M_{MWBP}/(F_{dDWMWBP} + F_{xDWMWBP} + F_{xSWMWBP} + F_{MWKABP} + F_{MWGFBP} + F_{MWGRBP})$; theoretical retention time for salinity in MW in BP (months)

$T_{MWGF} = M_{MWGF}/(F_{dDWMWGF} + F_{xDWMWBP} + F_{xSWMWBP} + F_{MWBPGF})$; theoretical retention time for salinity in MW in BP (months)

$T_{SWBB} = M_{SWBB}/(F_{dDWSWBB} + F_{xDWSWBB} + F_{precBB} + F_{tribBB} + F_{SWBSBB})$; theoretical retention time for salinity in SW in BB (months)

$T_{SWBP} = M_{SWBP}/(F_{dMWSWBP} + F_{xMWSWBP} + F_{precBP} + F_{tribBP} + F_{SWKABP} + F_{SWBSBP} + F_{SWGFBP} + F_{SWGRBP})$; theoretical retention time for salinity in SW in BP (months)

$T_{SWBS} = M_{SWBS}/(F_{dDWSWBS} + F_{xDWSWBS} + F_{precBS} + F_{tribBS} + F_{SWBBBS} + F_{SWBPBS})$; theoretical retention time for salinity in SW in BS (months)

$T_{SWGF} = M_{SWGF}/(F_{dMWSWGF} + F_{xMWSWGF} + F_{precGF} + F_{tribGF} + F_{SWBPGF})$; theoretical retention time for salinity in SW in BP (months)

$T_{SWGR} = M_{SWGR}/(F_{dDWSWGR} + F_{xDWSWGR} + F_{precGR} + F_{tribGR} + F_{SWBPGR})$; theoretical retention time for salinity in SW in BS (months)

$V_{BB} = 1500 \cdot 10^{\wedge}9$; volume in BB ($m^3$)
$V_{BP} = 13{,}055 \cdot 10^{\wedge}9$; volume of BP ($m^3$)
$V_{BS} = 4889 \cdot 10^{\wedge}9$; volume of BS ($m^3$)
$V_{GF} = 1073.3 \cdot 10^{\wedge}9$; volume of GF ($m^3$)
$V_{GR} = 409.4 \cdot 10^{\wedge}9$; volume of GR ($m^3$)
$V_{DWBB} = 433 \cdot 10^{\wedge}9$; DW-volume in BB ($m^3$)
$V_{DWBP} = 2690 \cdot 10^{\wedge}9$; DW-volume in BP ($m^3$)
$V_{DWBS} = 2110 \cdot 10^{\wedge}9$; DW-volume in BS ($m^3$)
$V_{DWGF} = 20.0 \cdot 10^{\wedge}9$; DW-volume in GF ($m^3$)
$V_{DWGR} = 17.5 \cdot 10^{\wedge}9$; DW-volume in GR ($m^3$)
$V_{MWBP} = 3050 \cdot 10^{\wedge}9$; MW-volume in BP ($m^3$)
$V_{MWGF} = 202 \cdot 10^{\wedge}9$; MW-volume in GF ($m^3$)
$V_{SWBB} = 1067 \cdot 10^{\wedge}9$; SW-volume in BB ($m^3$)
$V_{SWBP} = 7315 \cdot 10^{\wedge}9$; SW-volume in BP ($m^3$)
$V_{SWBS} = 2779 \cdot 10^{\wedge}9$; SW-volume in BS ($m^3$)
$V_{SWGF} = 851 \cdot 10^{\wedge}9$; SW-volume in GF ($m^3$)
$V_{SWGR} = 392 \cdot 10^{\wedge}9$; SW-volume in GR ($m^3$)

A.2 Compilation of All Equations and Model Variables in the Mass-Balance Model for Phosphorus (CoastMab) for the Baltic Proper (BP)

Abbreviations: F for flow (g/month), R for rate (1/month), C or TP or Sal for concentrations (TP in μg/l or salinity in ‰ = psu = kg/m^3), DC for distribution coefficients (dimensionless), M for mass (g TP), D for depth in m, V for volume in m^3; ET stands for areas with erosion and resuspension (advection) of fine sediments above the theoretical wave base; T is the theoretical retention time (years);

flow from one compartment (e.g., SW) to another compartment (e.g., MW) is written as F_{SWMW}; mixing flow is abbreviated as F_{xDWMW}; diffusion is abbreviated as F_{dDWMW}; Q is water discharge (m^3/month; see also Appendix A.1).

Surface-water layer (SW)

$$\begin{aligned}M_{SWBP}(t) = M_{SWBP}(t-dt) + (&F_{SWKABP} + F_{precBP} + F_{tribBP} + F_{ETSWBP} \\ &+ F_{xMWSWBP} + F_{BioretBP} + F_{dMWSWBP} + F_{SWGRBP} + F_{SWGFBP} \\ &+ F_{SWBSBP} - F_{SWMWBP} - F_{xSWMWBP} - F_{SWETBP} - F_{BioupBP} \\ &- F_{SWBPGR} - F_{SWBPGF} - F_{SWBPBS} - F_{SWBPKA}) \cdot dt\end{aligned}$$

Inflows

$F_{SWKABP} = 0.001 \cdot TP_{KA} \cdot Q_{SWKABP}$; SW-inflow from Kattegat (KA)
$F_{precBP} = Prec_{BP} \cdot Area_{BP} \cdot TP_{prec} \cdot 0.001 \cdot 0.001/12$; TP from precipitation
$F_{tribBP} = 0.001 \cdot Y_{QBP} \cdot (TP_{tribBP}/12) \cdot 10^{\wedge}6$; TP from rivers/countries
$F_{ETSWBP} = (M_{ETSWBP} \cdot R_{resBP} \cdot (1 - Vd_{BP}/3))$; resuspension from ET-areas to SW-layer
$F_{xMWSWBP} = M_{MWBP} \cdot R_{xSWMWBP} \cdot (V_{SWBP}/V_{MWBP})$; mixing from MW to SW
$F_{BioretBP} = M_{TPBioBP} \cdot 30 \cdot 1.386/T_{Bio}$; TP-retention in biota (= phytoplankton)
$F_{dMWSWBP} = M_{MWBP} \cdot R_{dMWSWBP} \cdot Const_{diff}$; diffusion in water from MW to SW
$F_{SWGRBP} = 0.001 \cdot TP_{SWGR} \cdot Q_{SWGRBP}$; SW-inflow from Gulf of Riga (GR) to BP
$F_{SWGFBP} = 0.001 \cdot TP_{SWGF} \cdot Q_{SWGFBP}$; SW-inflow from Gulf of Finland (GF) to BP
$F_{SWBSBP} = 0.001 \cdot TP_{SWBS} \cdot Q_{SWBSBP}$; SW-inflow from Bothnian Sea (BS) to BP

Outflows

$F_{SWMWBP} = M_{SWBP} \cdot (1 - DF_{SWBP}) \cdot (v_{SWBP}/D_{SWBP}) \cdot (1 - ET_{BP}) \cdot ((1 - DC_{resSWBP}) + Y_{resBP} \cdot DC_{resSWBP})$; sedimentation from SW to MW
$F_{xSWMWBP} = M_{SWBP} \cdot R_{xSWMWBP}$; mixing from SW to MW
$F_{SWETBP} = M_{SWBP} \cdot (1 - DF_{SWBP}) \cdot (v_{SWBP}/D_{SWBP}) \cdot ET_{BP} \cdot ((1 - DC_{resSWBP}) + Y_{resBP} \cdot DC_{resSWBP})$; sedimentation from SW to ET
$F_{BioupBP} = M_{SWBP} \cdot Y_{DayLBP} \cdot (30/T_{Bio}) \cdot DF_{SWBP} \cdot Y_{SWTBP}$; TP-biouptake (by phytoplankton)
$F_{SWBPGR} = 0.001 \cdot TP_{SWBP} \cdot Q_{SWBPGR}$; SW-outflow from BP to GR
$F_{SWBPGF} = 0.001 \cdot TP_{SWBP} \cdot Q_{SWBPGF}$; SW-outflow from BP to GF
$F_{SWBPBS} = 0.001 \cdot TP_{SWBP} \cdot Q_{SWBPBS}$; SW-outflow from BP to BS
$F_{SWBPKA} = 0.001 \cdot TP_{SWBP} \cdot Q_{SWBPKA}$; SW-outflow from BP to KA

Biota, phytoplankton (Bio) in the SW-layer

$$M_{BioBP}(t) = M_{BioBP}(t-dt) + (F_{BioupBP} - F_{BioretBP}) \cdot dt$$

Inflows

$F_{BioupBP} = M_{SWBP} \cdot Y_{DayLBP} \cdot (30/T_{Bio}) \cdot DF_{SWBP}$; TP-biouptake (by phytoplankton)

Outflows

$F_{BioretBP} = M_{TPBioBP} \cdot 30 \cdot 1.386/T_{Bio}$; TP-retention in biota (= phytoplankton)

Middle-water layer (MW)

$$\begin{aligned} M_{MWBP}(t) = {} & M_{MWBP}(t-dt) + (F_{SWMWBP} + F_{ETMWBP} + F_{dDWMWBP} \\ & + F_{xSWMWBP} + F_{dAMWMWBP} + F_{MWKABP} + F_{MWGRBP} + F_{MWGFBP} \\ & + F_{xDWMWBP} - F_{xMWSWBP} - F_{MWDWBP} - F_{MWBPBS} - F_{dMWSWBP} \\ & - F_{MWAMWBP} - F_{MWBPGR} - F_{MWBPGF} - F_{xMWDWBP}) \cdot dt \end{aligned}$$

Inflows

$F_{SWMWBP} = M_{SWBP} \cdot (1 - DF_{SWBP}) \cdot (v_{SWBP}/D_{SWBP}) \cdot (1 - ET_{BP}) \cdot ((1 - DC_{resSWBP}) + Y_{resBP} \cdot DC_{resSWBP})$; sedimentation from SW to MW

$F_{ETMWBP} = M_{ETSWBP} \cdot R_{resBP} \cdot (Vd_{BP}/3) \cdot Y_{LU}$; resuspension from ET-areas to MW-layer

$F_{dDWMWBP} = M_{DWBP} \cdot R_{diffMWDW} \cdot Const_{diff}$; diffusion in water from DW to MW

$F_{xSWMWBP} = M_{SWBP} \cdot R_{xSWMWBP}$; mixing from SW to MW

$F_{dAMWMWBP} = M_{AMWBP} \cdot R_{diffAMWBP}$; diffusion from AMW-sediments to MW

$F_{MWKABP} = 0.001 \cdot TP_{KA} \cdot Q_{MWKABP}$; MW-inflow from Kattegat (KA)

$F_{MWGRBP} = 0.001 \cdot TP_{MWGR} \cdot Q_{MWGRBP}$; MW-inflow from Gulf of Riga (GR) to BP

$F_{MWGFBP} = 0.001 \cdot TP_{MWGF} \cdot Q_{MWGFBP}$; MW-inflow from Gulf of Finland (GR) to BP

$F_{xDWMWBP} = M_{DWBP} \cdot R_{xMWDWBP} \cdot (V_{MWBP}/V_{DWBP})$; mixing from DW to MW

Outflows

$F_{xMWSWBP} = M_{MWBP} \cdot R_{xSWMWBP} \cdot (V_{SWBP}/V_{MWBP})$; mixing from MW to SW

$F_{TPMWDWBP} = M_{TPMWBP} \cdot (1 - DF_{MWBP}) \cdot Y_{TMWBP} \cdot (v_{MWBP}/D_{MWBP})) \cdot (1 - ET_{BP}) \cdot ((1 - DC_{resMWBP}) + Y_{resBP} \cdot DC_{resMWBP})$; sedimentation from MW to DW

$F_{MWBPBS} = 0.001 \cdot TP_{MWBP} \cdot Q_{MWBPBS}$; MW-outflow from BP to BS

$F_{dMWSWBP} = M_{MWBP} \cdot R_{dMWSWBP} \cdot Const_{diff}$; diffusion in water from MW to SW

$F_{MWAMWBP} = M_{MWBP} \cdot (1 - DF_{MWBP}) \cdot Y_{TMWBP} \cdot (v_{MWBP}/D_{MWBP}) \cdot (ET_{BP}) \cdot ((1 - DC_{resMWBP}) + Y_{resBP} \cdot DC_{resMWBP})$; sedimentation from MW to AMW

$F_{MWBPGR} = 0.001 \cdot TP_{MWBP} \cdot Q_{DWBPGR}$; MW-outflow from BP to GR

$F_{MWBPGF} = 0.001 \cdot TP_{MWBP} \cdot Q_{DWBPGF}$; MW-outflow from BP to GF

$F_{xMWDWBP} = M_{MWBP} \cdot R_{xMWDWBP}$; mixing from MW to DW

Deep-water layer (DW)

$$\begin{aligned} M_{DWBP}(t) = {} & M_{DWBP}(t-dt) + (F_{MWDWBP} + F_{DWKABP} + F_{DWGFBP} + F_{xMWDWBP} \\ & + F_{dADWDWBP} - F_{dDWMWBP} - F_{DWBPGF} - F_{xDWMWBP} - F_{DWADWBP}) \cdot dt \end{aligned}$$

Inflows

$F_{TPMWDWBP} = M_{TPMWBP} \cdot (1 - DF_{MWBP}) \cdot Y_{TMWBP} \cdot (v_{MWBP}/D_{MWBP})) \cdot (1 - ET_{BP}) \cdot ((1 - DC_{resMWBP}) + Y_{resBP} \cdot DC_{resMWBP})$; sedimentation from MW to DW

$F_{DWKABP} = 0.001 \cdot TP_{KA} \cdot Q_{DWKABP}$; DW-inflow from Kattegat (KA)

$F_{DWGFBP} = 0.001 \cdot TP_{DWGF} \cdot Q_{DWGFBP}$; DW-inflow from GF

$F_{xMWDWBP} = M_{MWBP} \cdot R_{xMWDWBP}$; mixing from MW to DW

$F_{dADWDWBP} = M_{ADWBP} \cdot R_{diffADWBP}$; diffusion from ADW-sediments to DW

Outflows

$F_{dDWMWBP} = M_{DWBP} \cdot R_{diffMWDW} \cdot Const_{diff}$; diffusion in water from DW to MW

$F_{DWBPGF} = 0.001 \cdot TP_{DWBP} \cdot Q_{DWBPGF}$; DW-outflow from BP to GF

$F_{xDWMWBP} = M_{DWBP} \cdot R_{xMWDWBP} \cdot (V_{MWBP}/V_{DWBP})$; mixing from DW to MW

$F_{DWADWBP} = M_{DWBP} \cdot Y_{TDWsed} \cdot (v_{DWBP}/D_{DWBP}) \cdot PF_{DWBP}$; sedimentation from DW to ADW

Areas of erosion and transport (ET)

$M_{ETSWBP}(t) = M_{ETSWBP}(t - dt) + (F_{LUBP} + F_{SWETBP} - F_{ETMWBP} - F_{ETSWBP}) \cdot dt$

Inflows

$F_{LUBP} = (10^\wedge 6) \cdot (LU_{BP}/12)$; TP from land uplift

$F_{SWETBP} = M_{SWBP} \cdot (1 - DF_{SWBP}) \cdot (v_{SWBP}/D_{SWBP}) \cdot ET_{BP} \cdot ((1 - DC_{resSWBP}) + Y_{resBP} \cdot DC_{resSWBP})$; sedimentation from SW to ET

Outflows

$F_{ETMWBP} = M_{ETSWBP} \cdot R_{resBP} \cdot (Vd_{BP}/3) \cdot Y_{LU}$; resuspension from ET-areas to MW-layer

$F_{ETSWBP} = M_{ETSWBP} \cdot R_{resBP} \cdot (1 - Vd_{BP}/3)$; resuspension from ET-areas to SW-layer

Accumulation areas (A) in the middle-water (MW) layer (AMW)

$M_{AMWBP}(t) = M_{AMWBP}(t - dt) + (F_{MWAMWBP} - F_{dAMWMWBP} - F_{burAMWBP}) \cdot dt$

Inflows

$F_{MWAMWBP} = M_{MWBP} \cdot (1 - DF_{MWBP}) \cdot Y_{TMWBP} \cdot (v_{MWBP}/D_{MWBP}) \cdot (ET_{BP}) \cdot ((1 - DC_{resMWBP}) + Y_{resBP} \cdot DC_{resMWBP})$; sedimentation from MW to AMW

Outflows

$F_{dAMWMWBP} = M_{AMWBP} \cdot R_{diffAMWBP}$; diffusion from AMW-sediments to MW

$F_{burAMWBP} = M_{AMWBP} \cdot Y_{LU} \cdot (1.386/Agelimit_{AMWBP})$; burial from AMW

Accumulation areas (A) in the deep-water (DW) layer (ADW)

$M_{ADWBP}(t) = M_{ADWBP}(t - dt) + (F_{DWADWBP} - F_{burADWBP} - F_{dADWDWBP}) \cdot dt$

Inflows

$F_{DWADWBP} = M_{DWBP} \cdot Y_{TDWsed} \cdot (v_{DWBP}/D_{DWBP}) \cdot PF_{DWBP}$; sedimentation from DW to ADW

Outflows

$F_{dADWDWBP} = M_{ADWBP} \cdot R_{diffADWBP}$; diffusion from ADW-sediments to DW
$F_{burADWBP} = M_{ADWBP} \cdot Y_{LU} \cdot (1.386/Agelimit_{ADWBP})$; burial from ADW

Model variables

$ADA_{BP} = 568,973 \cdot 10^\wedge 6$; area of drainage area (m^2)
$Agelimit_{ADWBP}$ = if $Age_{ADWBP} > 240$ months then 240 else Age_{ADWBP}
$Agelimit_{AMWBP}$ = if $Age_{AMWBP} > 240$ months then 240 else Age_{AMWBP}
$Agerule_{ADWBP}$ = if $Age_{ADWBP} < 12$ months then 12 else Age_{ADWBP}
$Agerule_{AMWBP}$ = if $Age_{AMWBP} < 12$ months then 12 else Age_{AMWBP}
$Age_{AMWBP} = 12 \cdot 10/Sed_{AMW}$; age of AMW-sediments (months)
$Age_{ADWBP} = 12 \cdot 10/Sed_{ADW}$; age of ADW-sediments (months)
$Age_{ETBP} = 12/Strat_{BP}$; age of ET-sediments (months)
$Amp_{ADWBP} = Y_{TPsedADWBP} \cdot 50$; amplitude value for TP in ADW-sediments (dim. less)
$Amp_{AMWBP} = Y_{TPsedAMWBP} \cdot 50$; amplitude value for TP in AMW-sediments (dim. less)
$Area_{ETBP} = 87,600 \cdot 10^\wedge 6$; area above wave base ($m^2$)
$Area_{WBBP} = 123,500 \cdot 10^\wedge 9$; area below wave base ($m^2$)
$Area_{LU} = (Area_{BP} - Area_{WBBP}) \cdot 0.001 \cdot LR_{BP} \cdot 12/D_{wbBP}$; area uplifted per year
$Area_{BP} = 211,100 \cdot 10^\wedge 6$ (m^2)
$Area_{DWBP} = 73.0 \cdot 10^\wedge 9$ (m^2)
$Area_{EBP} = 55,630 \cdot 10^\wedge 6$; area of fine sediment erosion (m^2)
$Area_{E\%BP} = Area_{EBP}/Area_{ETBP}$; fraction of E-areas above the wave base (dim. less)
$At_{BP} = 0.820 \cdot 10^\wedge 6$; section area ($m^2$)
$CB_{BP} = ((5.85 \cdot \log(TP_{SWBP}) - 4.01)^\wedge 4) \cdot Y_{TNTP} \cdot Y_{salCB} \cdot Y_{tempCB}$; concentration of cyanobacteria (μg ww/l)
$Chl_{modBP} = ((F_{BioupBP}/V_{SWBP}) \cdot 10^\wedge 3 \cdot (12/365) \cdot (41.1/30.6))^\wedge(1/0.927)$; concentration of chlorophyll-a (μg/l)
$Const_{diff} = 0.05/12$; diffusion rate for diffusion in water (1/month)
$d_{BP} = 100 \cdot 2.6/(100 + (75 + IG_{BP} \cdot (1 - 75/100)) \cdot (2.6 - 1))$; bulk density ($g/cm^3$ ww)
$DC_{QDWMWBP} = 0.365$; distribution coefficient (dim. less) for water inflow from Kattegat to DW or MW in BP
$DC_{resMWBP} = (F_{ETMWBP})/(F_{dAMWMWBP} + F_{dDWMWBP} + F_{ETMWBP} + F_{MWGFBP} + F_{MWGRBP} + F_{MWKABP} + F_{SWMWBP} + F_{xSWSWBP} + F_{xDWWWBP})$; distribution coefficient; fraction of resuspended matter in MW (dim. less)

$DC_{resSWBP} = F_{ETSWBP}/(F_{ETSWBP} + F_{precBP} + F_{SWGRBP} + F_{SWBSBP} + F_{SWGFBP} + F_{SWKABP} + F_{tribBP} + F_{dMWSWBP} + F_{xMWSWBP})$; distribution coefficient; fraction of resuspended matter in SW (dim. less)

$DC_{SecBP} = (Vd_{BP}/0.8) \cdot F_{LUBP}/(F_{LUBP} + F_{TotinBP})$; DC for impact of land uplift on Secchi depth

$D_{DWBP} = (D_{maxBP} - D_{hcBP})/2$; average depth of the DW-layer (m)

$DF_{DWBP} = (1 - PF_{DWBP})$; dissolved fraction of TP in DWBP

$DF_{MWBP} = (1 - PF_{MWBP})$; dissolved fraction of TP in MWBP

$DF_{SWBP} = (1 - PF_{SWBP})$; dissolved fraction of TP in SWBP

$D_{hcBP} = 75$; average depth of halocline (m)

$D_{maxBP} = 459$; maximum depth (m)

$D_{mBP} = V_{BP}/Area_{BP}$; mean depth (m)

$D_{mMWBP} = V_{MWBP}/(Area_{WBBP} - Area_{DWBP})$; mean depth of MW-layer (m)

$D_{MWBP} = (D_{hcBP} - D_{WBBP})/2$; mean depth of DW-layer

$DR_{BP} = (Area_{BP} \cdot 10\wedge - 6)\wedge 0.5/D_{mBP}$; dynamic ratio (dim. less)

$D_{relBP} = (D_{maxBP} \cdot 3.1416\wedge 0.5)/(20 \cdot (Area_{BP} \cdot 10\wedge - 6)\wedge 0.5)$; relative depth (dim. less)

$D_{SWBP} = D_{WBBP}/2$; mean depth of SW-layer (m)

$D_{WBBP} = 43.8$; depth of the theoretical wave base (m)

$ET_{BP} = (Area_{BP} - Area_{WBBP})/Area_{BP}$; fraction of ET-areas

$Exp = 0.5$; exponent in Y_{SWTBP} moderator

$F_{TotinBP} = F_{precBP} + F_{SWGRBP} + F_{SWBSBP} + F_{SWGFBP} + F_{SWKABP} + F_{tribBP}$ (total TP-inflow to SW-layer)

$IG_{BP} = \text{if } W_{BP} > 75 \text{ then } (1280 + (W_{BP} - 75)\wedge 3)/207 \text{ else } W_{BP}/11.9$; loss on ignition (organic content) of 0–10 cm sediments (% dw); W_{BP} is the water content of the sediments, set to 75% ww

$Lat_{BP} = 58\,°N$, latitude

$LR_{BP} = (2.75 + 1.75)/(2 \cdot 12)$; land rise (mm/month)

$LU_{BP} = 12 \cdot (Area_{ETBP} + Area_{LU}) \cdot 0.001 \cdot LR_{BP} \cdot ((1 - (75 - 15)/100)) \cdot (d_{BP} + 0.2) \cdot (((1 - Area_{EBP}/Area_{ETBP}) \cdot TP_{AMWsedBP} + Area_{EBP}/Area_{ETBP} \cdot TP_{clay})) \cdot 1000 \cdot 10\wedge - 6$; TP from land uplift (g/month)

$TP_{accessADWBP} = 100 \cdot (TP_{ADWsedBP} - TP_{clay})/TP_{ADWsedBP}$; TP accessible for diffusion in ADW

$Y_{LU} = ((F_{TotinBP} + F_{LUBP})/F_{TotinBP})$

$PF_{DWBP} = \text{if } PF_{MWBP}/T_{DWBP} > 0.99 \text{ then } 0.99 \text{ else } PF_{MWBP}/T_{DWBP}$; particulate fraction of TP in DW

$PF_{MWBP} = \text{if } Strat_{BP} > 1 \text{ then } DC_{resSWBP} \text{ else } DC_{resSWBP} \cdot (Strat_{BP}/M_{WTBP})\wedge 0.5)$; particulate fraction of TP in MW

$PF_{SWBP} = \text{if } (Y_{PF} + (M_{BioBP}/(M_{SWBP} + M_{BioBP}))) > 0.99 \text{ then } 0.99 \text{ else } (Y_{PF} + (M_{BioBP}/(M_{SWBP} + M_{BioBP})))$; particulate fraction of TP in SW

$Prec_{BP} = 750$; mean annual precipitation (mm/yr)

$Q_{empBP} = (265 \cdot 10\wedge 9 - Q_{empGF} - Q_{empGR})$; empirical annual water discharge in rivers entering BP (m^3/yr)

$Q_{BPintot} = Q_{SWBSBP} + Q_{KABP} + Q_{SWGFBP} + Q_{MWGFBP} + Q_{DWGFBP} + Q_{DWGRBP} + Q_{SWGRBP}$; total water inflow to BP (m^3/month)

$Q_{DWGFBP} = (Q_{GFBPtot} - Q_{SWGFBP}) \cdot DC_{QDWMWGF}$; DW-inflow of water from GF to BP (m^3/month)

$Q_{DWGRBP} = Q_{GRBP} - Q_{SWGRBP}$; DW-inflow of water from GR to BP (m^3/month)

$Q_{DWKABP} = Q_{KABP} \cdot (1 - DC_{QSWMWBP}) \cdot DC_{QDWMWBP}$; DW-inflow of water from KA to BP (m^3/month)

$Q_{evaBP} = (137 \cdot 10\hat{}9)/12$; evaporation ($m^3$/month)

$Q_{GFBPtot} = (1108 \cdot 10\hat{}9)/12$; total water transport from GR to BP (m^3/month)

$Q_{KABP} = (356/12) \cdot 10\hat{}9$; total water transport from KA to BP (m^3/month)

$Q_{MWGFBP} = (Q_{GFBPtot} - Q_{SWGFBP}) \cdot (1 - DC_{QDWMWGF})$; MW water transport from GF to BP (m^3/month)

$Q_{MWKABP} = Q_{KABP} \cdot (1 - DC_{QSWMWBP}) \cdot (1 - D_{CQDWMWBP})$; MW water transport from KA to BP (m^3/month)

$Q_{precBP} = (155 \cdot 10\hat{}9)/12 - 0.1 \cdot Q_{precGF} - 0.1 \cdot Q_{precGR}$; precipitation of water to BP (m^3/month)

$Q_{BPBStot} = (Q_{MWBPBS} + Q_{SWBPBS})$; total water transport from BP to BS (m^3/month)

$Q_{BPGRtot} = Q_{DWBPGR} + Q_{SWBPGR}$; total water transport from BP to GR (m^3/month)

$Q_{SWBPBS} = ((Q_{SWBSB}P + Q_{evaBS} + Q_{SWBSBB}) - (Q_{tribBS} + Q_{precBS} + Q_{MWBPBS} + Q_{SWBBBS}))$; SW water transport from BP to BS (m^3/month)

$Q_{SWBPKA} = -(Q_{evaBP} + Q_{MWBPBS} + Q_{SWBPBS}) + (Q_{SWBSBP} + Q_{precBP} + Q_{tribBP} + Q_{tribGF} + Q_{tribGR} + 0.1 \cdot Q_{precGR} + 0.1 \cdot Q_{precGF} + Q_{KABP})$; SW water transport from BP to KA (m^3/month)

$Q_{SWBSBP} = (1055 \cdot 10\hat{}9)/12$; SW water transport from BS to BP (m^3/month)

$Q_{SWGFBP} = Q_{SWBPGF} + Q_{tribGF} + Q_{precGF} - Q_{evaGF}$; SW water transport from GF to BP (m^3/month)

$Q_{SWGRBP} = Q_{SWBPGR} + Q_{tribGR} + Q_{precGR} - Q_{evaGR}$; SW water transport from GR to BS (m^3/month)

$Q_{SWKABP} = DC_{QSWMWBP} \cdot Q_{KABP}$; SW water transport from KA to BP (m^3/month)

$Q_{tribBP} = (Q_{empBP}/12) \cdot Y_{QBP}$; tributary water transport to BP (m^3/month)

$R_{diffADWBP} = SMTH(Y_{DRdiff} \cdot Y_{TDWdiffBP} \cdot R_{diffdef} \cdot Y_{sedADWBP} \cdot (DWT_{BP}/4) \cdot Y_{TPADWBP}, 12, R_{diffdef})/Y_{LU}$; diffusion rate for ADW-sediments (1/month)

$R_{diffAMWBP} = SMTH(Y_{DRdiff} \cdot Y_{TMWdiffBP} \cdot R_{diffdef} \cdot Y_{sedAMWBP} \cdot (MWT_{BP}/4) \cdot Y_{TPAMWBP}, 12, R_{diffdef})/Y_{LU}$; diffusion rate for AMW-sediments (1/month)

$R_{diffdef} = 0.0003/12$; default diffusion rate for TP in sediments (1/month)

$R_{dMWSWBP}$ = if $TP_{SWBP} \cdot DF_{SWB}P > TP_{MWBP} \cdot DF_{MWBP}$ then 0 else $(TP_{MWBP} \cdot DF_{MWB}P - TP_{SWBP} \cdot DF_{SWBP})$; diffusion rate for dissolved TP-fluxes from MW to SW (1/month)

R_{resBP} = if $SWT_{BP} < 0.8(°C)$ then $(SWT_{BP} + 0.2) \cdot 1.386/Age_{ETBP}$ else $1.386/Age_{ETBP}$; resuspension rate (1/month)

$R_{mixdefBP} = Strat_{BP} \cdot ET_{BP}/12$; mixing rate (1/month)

$R_{diffDWMW}$ = if $TP_{DWBP} \cdot (1 - PF_{DWBP}) < TP_{MWBP} \cdot (1 - PF_{MWBP})$ then 0 else $TP_{DWBP} \cdot (1 - PF_{DWBP}) - TP_{MWBP} \cdot (1 - PF_{MWBP})$; diffusion rate for dissolved TP-fluxes from DW to MW (1/month)

$R_{xMWDWBP}$ = if $Sal_{DWBP} > Sal_{MWBP}$ then $R_{mixdefBP} \cdot (1/(1 + Sal_{DWBP} - Sal_{MWBP}))^{\wedge}R_{mixexp}$ else $R_{mixdefBP}$; mixing rate MW to DW (1/month); R_{mixexp} and $R_{mixdefBP}$ are defined in Appendix A.1

$R_{xSWMWBP}$ = if $Sal_{MWBP} > Sal_{SWBP}$ then $R_{mixdefBP} \cdot (1/(1 + Sal_{MWBP} - Sal_{SWBP}))^{\wedge}R_{mixexp}$ else $R_{mixdefBP}$; mixing rate SW to MW (1/month)

$Sec_{BP} = Y_{Qcorr} \cdot 10^{\wedge}(-(z + 0.5) \cdot (\log(SPM_{SWBP} \cdot DC_{SecBP} + (1 - DC_{SecBP}) \cdot SPM_{SWBPdef})/1 + 0.3)/2 + z)$; Secchi depth (m)

$Sed_{ADWBP} = (Sed_{DWBP} \cdot (100/(100-75)) \cdot (1/d_{BP})) \cdot 365 \cdot 10^{\wedge} - 6$; sedimentation on ADW (cm/yr)

$Sed_{AMWBP} = (Sed_{MWBP} \cdot (100/(100-75)) \cdot (1/d_{BP})) \cdot 365 \cdot 10^{\wedge} - 6$; sedimentation on AMW (cm/yr)

$Sed_{DWBP} = F_{DWADWBP} \cdot 10^{\wedge}5/(30 \cdot 2 \cdot (Area_{DWBP}))$; sedimentation on ADW in $\mu g/cm^2 \cdot d$

$Sed_{MWBP} = F_{MWDWBP} \cdot 10^{\wedge}5/(30 \cdot 2 \cdot (Area_{WBBP} - Area_{DWBP}))$; sedimentation on AMW in $\mu g/cm^2 \cdot d$

$SPM_{DWBP} = Y_{LU} \cdot SMTH(10^{\wedge}(1.56 \cdot \log 10(TP_{DWBP}) - 1.64), 3, 8)$; SPM in DW (mg/l)

$SPM_{MWBP} = Y_{LU} \cdot SMTH(10^{\wedge}(1.56 \cdot \log 10(TP_{MWBP}) - 1.64), 3, 4)$; SPM in MW (mg/l)

$SPM_{SWBP} = Y_{LU} \cdot SMTH(10^{\wedge}(1.56 \cdot \log 10(TP_{SWBP}) - 1.64), 3, 1)$; SPM in SW (mg/l)

$SPM_{SWBPdef} = SMTH(10^{\wedge}(1.56 \cdot \log 10(TP_{SWBP}) - 1.64), 3, 1)$; default SPM in SW with no consideration to land uplift (mg/l)

$Strat_{BP}$ = if $ABS(SWT_{BP} - MWT_{BP}) < 4(°C)$ then $1 + R_{mixconst}/(1/R_{mixconst} + ABS(SWT_{BP} - MWT_{BP}))$ else $1/ABS(SWT_{BP} - MWT_{BP})$; stratification SW/MW

$T_{Bio} = 3.2$; turnover time of phytoplankton (days)

$T_{DWBP} = V_{DWBP}/(Q_{DWGFBP} + Q_{DWKABP} + Q_{xMWDWBP})$; water retention time in DW (months)

$Tempcriteria_{BP}$ = if $SWT_{BP} < 0.8(°C)$ then $0.8/(0.8 + SWT_{BP})$ else Y_{DRBP}

$T_{MWBP} = V_{MWBP}/(Q_{xMWSWBP} + Q_{MWKABP} + Q_{xMWDWBP} + Q_{DWGRBP} + Q_{MWGFBP})$; water retention time in MW (months)

$TN/TP = TN_{SWBP}/TP_{SWBP}$; Redfield ratio

$TN_{SWBP} = 10^{\wedge}(0.70 \cdot \log(TP_{SWBP}) + 1.61)$; regression for TN (values in $\mu g/l$)

$TP_{tribBP} = (2394 + 8940 + 4049) + (87 + 707 + 100)$; tributary input (t/yr); see Table 1.3

$TP_{ADWsedBP} = M_{ADWBP}/((10^{\wedge}3) \cdot Vol_{ADWsed} \cdot d_{BP} \cdot (1 - 75/100))$; TP-concentration in ADW-sediments, 0–10 cm (mg/g dw)

$TP_{AMWsedBP} = M_{AMWBP}/((10^{\wedge}3) \cdot Vol_{AMWsed} \cdot d_{BP} \cdot (1 - 75/100))$; TP-concentration in AMW-sediments, 0–10 cm (mg/g dw)

$TP_{clay} = 0.36$; TP-concentration in clay (mg/g dw)

$TP_{DWBP} = 1000 \cdot M_{TPDWBP}/V_{DWBP}$; TP-concentration in DW ($\mu g/l$)

$TP_{KA} = 30$; TP-concentration in KA ($\mu g/l$)

$TP_{MWBP} = 1000 \cdot M_{MWBP}/V_{MWBP}$; TP-concentration in MW ($\mu g/l$)

$TP_{prec} = 5$; TP-concentration in precipitation ($\mu g/l$)

$TP_{SWBP} = 1000 \cdot (M_{SWBP} + M_{BioBP})/V_{SWBP}$; TP-concentration in SW ($\mu g/l$)

$T_{SWBP} = V_{SWBP}/(Q_{xMWSWBP} + Q_{precBP} + Q_{tribBP} + Q_{SWBSBP} + Q_{SWGFBP} + Q_{GRBP} + Q_{SWKABP})$; water retention time in SW (months)

$T_{ADWBP} = M_{ADWBP}/F_{DWADWBP}$; TP retention time in ADW-sediments (months)

$T_{AMWBP} = M_{AMWBP}/F_{MWAMWBP}$; TP retention time in AMW-sediments (months)

$T_{BioBP} = M_{BioBP}/F_{BioupBP}$; TP retention time in phytoplankton (months)

$T_{DWBP} = M_{DWBP}/(F_{dADWDWBP} + F_{TWKABP} + F_{MWDWBP} + F_{xMWDWBP} + F_{DWGFBP})$; TP retention time in DW (months)

$T_{ETBP} = M_{ETSWBP}/(F_{TPLUBP} + F_{SWETBP})$; TP retention time on ET-areas (months)

$T_{MWBP} = M_{MWBP}/(F_{dAMWMWBP} + F_{dDWMWBP} + F_{ETMWBP} + F_{MWKABP} + F_{xDWMWBP} + F_{xSWMWBP} + F_{DWGRBP} + F_{MWGFBP} + F_{SWMWBP})$; TP retention time in MW (months)

$T_{SWBP} = M_{SWBP}/(F_{dMWSWB}P + F_{ETSWBP} + F_{precBP} + F_{SWGRBP} + F_{SWKABP} + F_{xMWSWBP} + F_{SWBSBP} + F_{SWGFBP} + F_{tribBP})$; TP retention time in SW (months)

$u_{AtBP} = 100 \cdot (Q_{SWBPKA})/(0.5 \cdot At_{BP} \cdot 60 \cdot 60 \cdot 24 \cdot 30)$; average water velocity (cm/s) in the section area

$V_{BP} = 13{,}055 \cdot 10^{\wedge}9$; water volume ($m^3$)

$Vd_{BP} = 3 \cdot D_{mBP}/(D_{maxBP})$; form factor for BP

$Vd_{DWBP} = 3 \cdot D_{mDWBP}/(D_{maxBP} - D_{hcBP})$; form factor for DWBP

$v_{def} = 72/12$; default settling velocity (m/month)

$Vd_{MWBP} = 3 \cdot D_{mMWBP}/(D_{hcBP} - D_{WBBP})$; form factor for MWMP

$v_{DWBP} = Y_{SPMDWBP} \cdot v_{def} \cdot Y_{salDWBP} \cdot Y_{LU} \cdot Tempcriteria_{BP}$; settling velocity in DW (m/month)

$V_{DWBP} = 2690 \cdot 10^{\wedge}9$; DW-volume ($m^3$)

$v_{MWBP} = Y_{SPMMWBP} \cdot v_{def} \cdot Y_{salMWBP} \cdot Y_{LU} \cdot Tempcriteria_{BP}$; settling velocity in MW (m/month)

$V_{MWBP} = 3050 \cdot 10^{\wedge}9$; MW-volume ($m^3$)

$Vol_{ADWsed} = Area_{DWBP} \cdot 10 \cdot 0.01 \cdot (Vd_{DWBP})/3$; volume of ADW-sediments, 0–10 cm (m^3)

$Vol_{AMWsed} = (Area_{WBBP} - Area_{DWBP}) \cdot 10 \cdot 0.01 \cdot (Vd_{BP})/3$; volume of AMW-sediments, 0–10 cm (m^3)

$v_{SWBP} = Y_{SPMSW} \cdot v_{def} \cdot Y_{salSWBP} \cdot Tempcriteria_{BP}$; settling velocity in SW (m/month)

$V_{SWBP} = 7314.6 \cdot 10^{\wedge}9$; SW-volume ($m^3$)

$W_{BP} = 75$; water content of A-sediments (0–10 cm; in % ww)

$Y_{TPsedADWBP} = TP_{ADWsedBP}/2$; dimensionless moderator in the algorithm for diffusion from ADW-sediments

$Y_{TPsedAMWBP} = T_{PAMWsedBP}/2$; dimensionless moderator in the algorithm for diffusion from AMW-sediments

$Y_{1BP} =$ if $Sal_{SWBP} < 2.5$ (psu) then $(0.20 - 0.2 \cdot (Sal_{SWBP}/12.5 - 1))$ else $(0.20 + 0.02 \cdot (Sal_{SWBP}/2.5 - 1))$

$Y_{2BP} =$ if $Sal_{SWBP} < 12.5$ (psu) then Y_{1BP} else $(0.28 - 0.1 \cdot (Sal_{SWBP}/12.5 - 1))$

$Y_{3BP} =$ if $Sal_{SWBP} > 40$ (psu) then $(0.06 - 0.1 \cdot (Sal_{SWBP}/40 - 1))$ else Y_{2BP}

Y_{4BP} = if $Y_{3BP} < 0.012$ then 0.012 else Y_{3BP}; Y_{1BP} to Y_{4BP} are dimensionless moderators in the algorithm for salinity influences on chlorophyll

$Y_{DayLBP} = Daylight_{BP}/12$; dimensionless moderator expressing the light influences on chlorophyll

Y_{DRBP} = if $DR_{BP} < 0.26$ then $DR_{BP}/0.26$ else 0.26/DR; dimensionless moderator in the algorithm for the influences of turbulence on the settling velocity

Y_{DRdiff} = if $DR_{BP} < 3.8$ then 1 else $3.8/DR_{BP}$; dimensionless moderator in the algorithm for the influences of lake form on the diffusion from sediments

$Y_{TDWdiffBP}$ = if $T_{DWBP} < 1$ then 1 else $(T_{DWBP}/12)$^0.5; dimensionless moderator in the algorithm for the influences of DW-retention time (oxygenation) on the diffusion from ADW-sediments

$Y_{TMWdiffBP}$ = if $T_{MWBP} < 1$ then 1 else $(T_{MWBP}/12)$^0.5; dimensionless moderator in the algorithm for the influences of MW-retention time (oxygenation) on the diffusion from AMW-sediments

$Y_{PFBP} = DC_{resSWBP} \cdot Y_{SWTBP}$; dimensionless moderator in the algorithm for the resuspension on the PF-value for phosphorus

$Y_{QBP} = 1 + 0.526 \cdot ((Lat_{BP} - 35)$^2.18/35^2.18 $\cdot SeasnormLat_{max} + (1 - (Lat_{BP} - 35)$^2.18/35^2.18$) \cdot SeasnormLat_{min}) + 0.265 \cdot ((Qemp_{BP}/(60 \cdot 60 \cdot 24 \cdot 365))$^0.22/5000^0.22 $\cdot SeasnormQ_{max} + (1(Qemp_{BP}/(60 \cdot 60 \cdot 24 \cdot 365))$ ^0.22/5000^0.22$) \cdot SeasnormQ_{min})$; dimensionless moderator in the algorithm to calculate monthly mean water discharges from annual water discharge

$Y_{Qcorr} = (Q_{SWBSBP} + Q_{SWGFBP} + Q_{SWGRBP} + Q_{SWKABP})/(Q_{SWBSBP} + Q_{SWGFBP} + Q_{SWGRBP} + Q_{SWKABP} + Q_{tribBP})$; dimensionless moderator relating freshwater (tributary) fluxes to all other fluxes of water to SW in BP used in the algorithm for Secchi depths

$Y_{resBP} = (Age_{ETBP} + 1)$^0.5 $\cdot Y_{LU}$; dimensionless moderator in the algorithm for resuspension

$Y_{sedADWBP}$ = if $Sed_{ADWBP} < 50$ (µg/cm$^2 \cdot$ d) then $(2 - 1 \cdot (Sed_{ADWBP}/50 - 1))$ else $(2 + Amp_{ADWBP} \cdot (Sed_{ADWBP}/50 - 1))$; dimensionless moderator for the influence of sedimentation of matter in the algorithm for diffusion from ADW-sediments

$Y_{sedAMWBP}$ = if $Sed_{AMWBP} < 50$ (µg/cm$^2 \cdot$ d) then $(2 - 1 \cdot (Sed_{AMWBP}/50 - 1))$ else $(2 + Amp_{AMWBP} \cdot (Sed_{AMWBP}/50 - 1))$; dimensionless moderator for the influence of sedimentation of matter in the algorithm for diffusion from AMW-sediments

Y_{salCB} = if $Sal_{SWBP} < 10$ (psu) then $(2.1 + 1.1 \cdot ((Sal_{SWBP}/10)$^2 $- 1))$ else $(2.1 - 115 \cdot ((Sal_{SWBP}/10)$^0.01 $- 1))$; dimensionless moderator expressing salinity influences on cyanobacteria

$Y_{SPMDWBP} = 1 + 0.75 \cdot (SPM_{DWBP}/50 - 1)$; dimensionless moderator expressing SPM-influences on the settling velocity in the DW-layer

$Y_{SPMMWBP} = 1 + 0.75 \cdot (SPM_{MWBP}/50 - 1)$; dimensionless moderator expressing SPM-influences on the settling velocity in the MW-layer

$Y_{SPMSWBP} = 1 + 0.75 \cdot (SPM_{SWBP}/50 - 1)$; dimensionless moderator expressing SPM-influences on the settling velocity in the SW-layer

Y_{TDWBP} = if $T_{DWBP}/30 < 7$ (days) then 1 else $((T_{DWBP}/30)/7)^{\wedge}0.5$; dimensionless moderator expressing influences of water retention (turbulence) on the settling velocity in the DW-layer

Y_{TMWBP} = if $T_{MWBP}/30 < 7$ (days) then 1 else $((T_{MWBP}/30)/7)^{\wedge}0.5$; dimensionless moderator expressing influences of water retention (turbulence) on the settling velocity in the MW-layer

$Y_{TDWdiffBP} = (T_{DWBP}/12)^{\wedge}0.5$; dimensionless moderator expressing influences of water retention (oxygenation) on the diffusion in ADW-sediments

$Y_{TMWdiffBP} = (T_{MWBP}/12)^{\wedge}0.5$; dimensionless moderator expressing influences of water retention (oxygenation) on the diffusion in AMW-sediments

Y_{TDWsed} = if $Y_{TDW} < 7$ (days) then 1 else $(Y_{TDW}/7)^{\wedge}0.5$; dimensionless moderator expressing influences of water retention (turbulence) on sedimentation in the DW-layer

Y_{TMWsed} = if $Y_{TMW} < 7$ (days) then 1 else $(Y_{TMW}/7)^{\wedge}0.5$; dimensionless moderator expressing influences of water retention (turbulence) on sedimentation in the MW-layer

$Y_{tempChl} = SWT_{BP} > 4$ (°C) then 1 else $(SWT_{BP} + 0.1)/4$; dimensionless moderator expressing temperature (SWT) influences on chlorophyll using the empirical model ("emod")

Y_{tempCB} = if $SWT_{BP} > 15$ (°C) then $(0.86 + 0.63 \cdot ((SWT_{BP}/15)^{\wedge}1.5 - 1))$ else $(1 + 1 \cdot ((SWT_{BP} \cdot 1/15)^{\wedge}3 - 1))$; dimensionless moderator expressing temperature (SWT) influences on cyanobacteria

Y_{TNTP} = if $TN/TP < 15$ then $(1 - 3 \cdot (TN/TP/15 - 1))$ else 1; dimensionless moderator expressing the influence of the TN/TP-ratio on cyanobacteria

$Y_{TPADWBP}$ = if $TP_{ADWsedBP} < TP_{clay}$ then 0 else $(TP_{ADWsedBP} - TP_{clay})$; dimensionless moderator expressing the influence of low TP-concentrations in A-sediments on diffusion from ADW-sediments

$Y_{TPAMWBP}$ = if $T_{PAMWsedBP} < TP_{clay}$ then 0 else $(TP_{AMWsedBP} - TP_{clay})$; dimensionless moderator expressing the influence of low TP-concentrations in A-sediments on diffusion from AMW-sediments

$Y_{TPsedADWBP} = (TP_{ADWsedBP}/2)$; dimensionless moderator expressing the influence of high TP-concentrations in A-sediments on diffusion from ADW-sediments

$Y_{TPsedAMWBP} = (TP_{AMWsedBP}/2)$; dimensionless moderator expressing the influence of high TP-concentrations in A-sediments on diffusion from ADW-sediments

$z_{BP} = (10^{\wedge}(0.15 \cdot \log 10(1 + SalSWBP) + 0.3) - 1)$; factor in the algorithm expressing salinity influences on Secchi depth

$Chlemp_{BP}$ = GRAPH(MOD(TIME, 12))

(1.00, 0.5), (2.00, 0.6), (3.00, 1.00), (4.00, 3.20), (5.00, 1.80), (6.00, 1.90), (7.00, 2.30), (8.00, 2.30), (9.00, 2.10), (10.0, 2.30), (11.0, 1.70), (12.0, 0.9)

$Daylight_{BP}$ = GRAPH(MOD(TIME, 12))

(1.00, 7.92), (2.00, 9.88), (3.00, 11.5), (4.00, 14.1), (5.00, 21.1), (6.00, 18.0), (7.00, 16.9), (8.00, 15.2), (9.00, 12.9), (10.0, 10.4), (11.0, 8.72), (12.0, 7.55)

DWT_{BP} = GRAPH(MOD(TIME, 12))

(1.00, 5.08), (2.00, 5.15), (3.00, 5.08), (4.00, 5.10), (5.00, 5.21), (6.00, 5.17), (7.00, 5.25), (8.00, 5.24), (9.00, 5.21), (10.0, 5.13), (11.0, 5.23), (12.0, 5.16)

$MWT_{BP} = GRAPH(MOD(TIME, 12))$

(1.00, 4.29), (2.00, 3.50), (3.00, 3.32), (4.00, 3.26), (5.00, 3.41), (6.00, 3.68), (7.00, 3.76), (8.00, 3.83), (9.00, 3.91), (10.0, 4.02), (11.0, 4.73), (12.0, 5.39)

$SeasnormLat_{max} = GRAPH(MOD(time, 12))$

(1.00, −1.00), (2.00, −1.00), (3.00, −1.00), (4.00, −1.00), (5.00, 2.17), (6.00, 2.51), (7.00, 0.63), (8.00, 0.24), (9.00, 0.05), (10.0, −0.03), (11.0, −0.66), (12.0, −0.92)

$SeasnormLat_{min} = GRAPH(MOD(time, 12))$

(1.00, 1.04), (2.00, 1.37), (3.00, 0.56), (4.00, 0.38), (5.00, −0.29), (6.00, −0.23), (7.00, −0.62), (8.00, −0.71), (9.00, −0.79), (10.0, −0.74), (11.0, −0.28), (12.0, 0.32)

$SeasnormQ_{max} = GRAPH(MOD(time, 12))$

(1.00, −0.71), (2.00, −0.48), (3.00, −0.17), (4.00, −0.17), (5.00, 0.62), (6.00, 1.74), (7.00, 0.52), (8.00, 0.09), (9.00, −0.16), (10.0, −0.2), (11.0, −0.63), (12.0, −0.44)

$SeasnormQ_{min} = GRAPH(MOD(time, 12))$

(1.00, 0.58), (2.00, 0.81), (3.00, 0.84), (4.00, 1.58), (5.00, −0.1), (6.00, −1.00), (7.00, −1.00), (8.00, −1.00), (9.00, −0.82), (10.0, −0.56), (11.0, 0.11), (12.0, 0.54)

$SecBP_{emp} = GRAPH(MOD(TIME, 12))$

(1.00, 9.80), (2.00, 7.00), (3.00, 6.90), (4.00, 5.00), (5.00, 3.00), (6.00, 4.00), (7.00, 3.80), (8.00, 3.50), (9.00, 5.00), (10.0, 5.50), (11.0, 7.00), (12.0, 7.00)

$SWT_{BP} = GRAPH(MOD(TIME, 12))$

(1.00, 3.63), (2.00, 2.52), (3.00, 2.52), (4.00, 3.34), (5.00, 5.53), (6.00, 9.25), (7.00, 13.3), (8.00, 15.7), (9.00, 14.1), (10.0, 10.3), (11.0, 7.73), (12.0, 6.01)

$TNemp_{BP} = GRAPH(MOD(TIME, 12))$

(1.00, 299), (2.00, 292), (3.00, 293), (4.00, 281), (5.00, 265), (6.00, 273), (7.00, 270), (8.00, 267), (9.00, 265), (10.0, 284), (11.0, 279), (12.0, 306)

$TPDWemp_{BP} = GRAPH(MOD(TIME, 12))$

(1.00, 115), (2.00, 108), (3.00, 116), (4.00, 115), (5.00, 120), (6.00, 118), (7.00, 121), (8.00, 123), (9.00, 125), (10.0, 118), (11.0, 114), (12.0, 119)

$TPMWemp_{BP} = GRAPH(MOD(TIME, 12))$

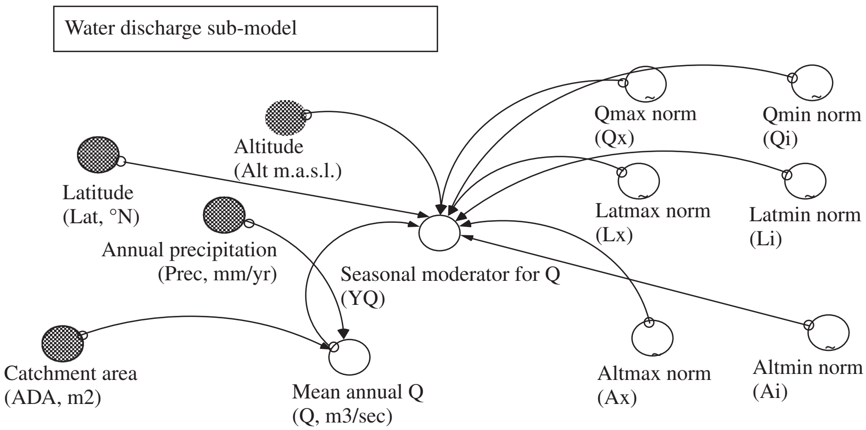
(1.00, 35.7), (2.00, 32.1), (3.00, 30.0), (4.00, 31.9), (5.00, 31.7), (6.00, 32.4), (7.00, 33.5), (8.00, 35.5), (9.00, 35.1), (10.0, 39.6), (11.0, 41.5), (12.0, 37.0)

$TPSWemp_{BP} = GRAPH(MOD(TIME, 12))$

A.3 Water Discharge Predicted from Map Parameters

River discharge depends on many more or less stochastic processes and has a high degree of variability between years for a given river. This means that it is difficult to give a reliable prediction of the water discharge (Q) for a specific river site at a given time. A standard procedure is then to measure the river discharge for a long period of time (decades) and give a statistical estimate of a probability that Q is going to be within a certain range at a certain time. That method is appropriate for many purposes, providing that a sufficiently long and reliable set of empirical data is available (Chow, 1988). However, if empirical data on Q are not available, which is certainly the case for a very large number of rivers, other methods are necessary, e.g., statistical/empirical methods to predict Q from, e.g., soil type distributions, vegetation types, etc. Such models can be very precise and valuable, but they often require field data and site-specific catchment data for the calibration.

The model discussed here (see Fig. A.1) has been presented by Abrahamsson and Håkanson (1998) to meet specific demands in ecosystem modeling rather than in hydrology. The first requirement is that this model must be based on readily available driving variables, preferably from standard maps. There are many uncertainties in ecosystem models, but all uncertainties are not of equal importance for the predictive success of the model. There will always be uncertainties concerning the proper value for Q. The model presented here is meant to yield predictions of Q, which can be accepted in ecosystem models where the focus is on, e.g., the predictive power for the concentration of SPM or nutrients in water, or in ecosystem modeling when river discharge and/or water retention time are used, i.e., when the target variables to



Equations:
YQ = 1+0.526·(Lx·(Lat-35)^2.18/(70-35)^2.18+Li·(1-(Lat-35)^2.18/(70-35)^2.18))+0.421·(Ax·Alt^0.51/1000^0.51+Ai·(1-Alt^0.51/1000^0.51))+0.265·(Qx·Q^0.22/5000^0.22+Qi·(1-Q^0.22/5000^0.22));
Q = 0.01·(Prec/650)·AD, (m3/sec)

Month	**Qmax norm**	**Qmin norm**	**Latmax norm**	**Latmin norm**	**Altmax norm**	**Altmin norm**
					-0.97	0.47
2	-0.48	0.81	-1.000	1.370	-0.98	0.51
3	-0.17	0.84	-1.000	0.56	-0.58	0.22
4	-0.17	1.580	-1.000	0.38	-0.69	0.24
5	0.62	-0.1	2.170	-0.29	2.110	0.18
6	1.740	-1.000	2.510	-0.23	1.870	-0.32
7	0.52	-1.000	0.63	-0.62	0.51	-0.42
8	0.09	-1.000	0.24	-0.71	0.07	-0.49
9	-0.16	-0.82	0.05	-0.79	0.03	-0.38
10	-0.2	-0.56	-0.03	-0.74	-0.06	-0.2
11	-0.63	0.11	-0.66	-0.28	-0.62	0.07
12	-0.44	0.54	-0.92	0.32	-0.68	0.13

Fig. A.1 The sub-model for tributary water discharge (compiled from Abrahamsson and Håkanson, 1998) be predicted are biological variables (like fish biomasses) and/or chemical variables (like the phosphorus concentration). In such contexts, the inevitable uncertainties in the predicted values of Q associated with this simple sub-model for Q can be accepted. This is the main reason why this model is based on readily available map parameters, such as latitude, altitude and precipitation.

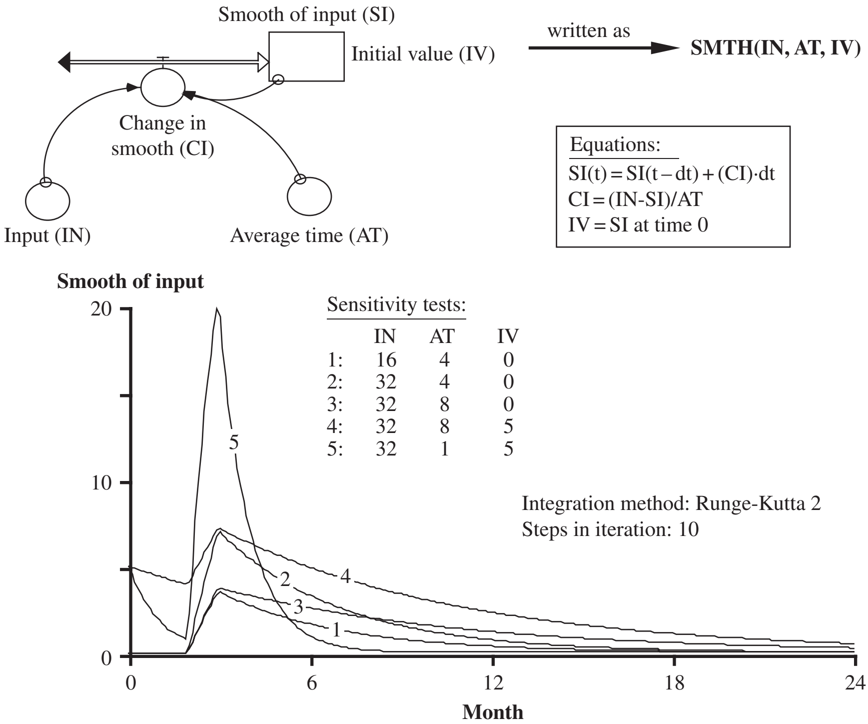
To calibrate and validate this Q-model, an extensive data set from more than 200 European rivers were used. The discharges of the chosen rivers were not affected by regulation for hydropower or irrigation purposes since that produce unnatural seasonal flow patterns. The time series for the monthly data were at least six years long, and some as long as 80 years. The data sets were divided in two parts of equal size; one for the calibration and the other for the validation. From Fig. A.1, one can note that the only obligatory driving variables for this Q-model are, altitude, latitude, mean annual precipitation and catchment area.

To simulate the monthly variations in Q, six seasonal variability norms are utilized for Europe (see Fig. A.1). A seasonal variability norm is used to add a seasonal pattern to an annual value (Håkanson and Peters, 1995). Two of these norms should represent the typical seasonal flow pattern in the most southern and northern parts of Europe, respectively. Two other norms should describe the effect of altitude on monthly variability in Q and two should represent the typical flow pattern of rivers with very small and very large mean annual discharges. Depending on the location and the mean annual discharge of the specific river, the six seasonal variability norms are weighted together and a site-specific seasonal variability norm for Europe is calculated. In the model calibrations, it became obvious that the addition of longitude did not significantly increase the degree of explanation of the model and longitude was, therefore, excluded.

To quantitatively account for how latitude (Lat), altitude (Alt), and mean annual discharge (Q_{mv}) for a specific river influence the seasonal (monthly) variability different weighing factors ranging from zero to one were developed. For example, the weight factor for latitude should be zero for a river in the southernmost part of Europe (35 °N) and one in the northernmost part (70 °N). To account for the fact that the relations must not have to be linear each weighting factor was given an exponent. The exponents are used to control in which range the changes in the parameters are most critical. This is, of course, still a very simple approach to simulate the influence of different parameters. This approach gave the equation for the seasonal moderator for Q (Y_Q) given in Fig. A.1. The values for the six norms are also given in Fig. A.1.

A smoothing function (see Fig. A.2) is used to average out seasonal variability given by the seasonal variability norm, which is defined to yield extreme values for Q. The equation that specifies this calculation is a smoothing or averaging function, which is based on the five, easily accessible factors given above. The SMTH-function uses a first-order exponential equation (Fig. A.2) to smooth the input (here the seasonal variability norm for Q). The SMTH-function works in the same way as the one- and two-sided running mean values. It may be written as:

$$\text{SMTH} = \text{SMTH(Input, Averaging function, Initial value)} \qquad \text{(A.1)}$$



AT = 8

	IV	1	2	3	4	5	6	7	8	9	10	11	12
SI	5	4,41	4,09	7,17	6,33	5,59	4,93	4,35	3,84	3,39	2,99	2,64	2,33
IN	0	0	32	0	0	0	0	0	0	0	0	0	0

Data for curve 4 for 12 time steps

Fig. A.2 Illustration of the smoothing function

This function smoothes the seasonal variability norm for Q by applying a specified averaging function, which operates over a specified time interval, to an input (here the seasonal variability norm), given an initial value for that input. The initial value is simply the mean value of the seasonal variability norm for Q (namely 1). However, since the initial results depend on this initial value, this choice is not trivial.

In spite of the fact that river discharge is a variable with great temporal and spatial variability, this approach has proven to yield good predictions of monthly average Q. The best results of the validation were achieved for the rivers with a mean annual discharge in the range 1–500 m^3/s. More uncertain predictions are obtained for the smallest and largest rivers. The range is, however, large enough to include most European rivers (88 of 114 in the calibration and 90 of 119 in the validation). Given that limitation, the model certainly has a wide range of applicability.

Note that to apply this Q-model for other parts of the world, e.g., for China and/or South America, one must re-calibrate the norm and the weight factors for latitude, altitude and water discharge using empirical data on water discharge from as many rivers as possible.

Figure A.3 exemplifies how differences in altitude and latitude influence the seasonal moderator for Q. The default conditions are given by a lake with a catchment area of 10 km^2, a mean annual precipitation of 650 mm/yr, at an altitude of 75 m.a.s.l. and a latitude of 60 °N. Curve 1 in Fig. A.3 gives the characteristic seasonal variations in Y_Q. If a similar lake is situated at an altitude of 1000 m.a.s.l., it is likely that the precipitation is more evenly distributed over the year, and the seasonal variability in Q is smaller. On the other hand, if the lake is placed at latitude 40 °N, there is a more pronounced seasonal variability pattern in Y_Q. Note that this is based on extensive calibrations and validations based on empirical Q-series from many European catchments areas.

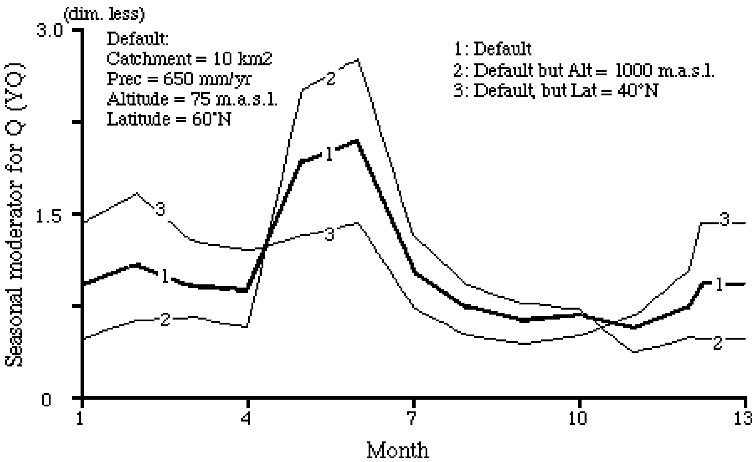


Fig. A.3 Predicted seasonal patterns in tributary water discharge (Q), as expressed by the dimensionless moderator, Y_Q under default conditions (*curve 1*), for a catchment at altitude 1000 m.a.s.l. (*curve 2*) and for a catchment at latitude 40 °N (*curve 3*)

Table A.3 Compilation of Calculated Monthly TP-Fluxes (kt/month) To, Within and From the Gulf of Finland

Month	1	2	3	4	5	6	7	8	9	10	11	12
BioretGF	63.42	72.73	58.57	52.80	65.39	72.79	76.45	82.77	91.46	68.05	51.03	54.12
BioupGF	64.78	72.58	56.57	54.13	66.01	73.11	76.72	84.24	90.50	65.74	50.45	54.76
BurADWGF	0.33	0.36	0.53	0.26	0.24	0.24	0.25	0.25	0.25	0.25	0.25	0.24
BurAMWGF	0.94	0.95	0.97	0.97	0.94	0.95	0.98	0.99	0.99	1.00	0.99	0.96
DiffADWDWGF	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
DiffAMWMWGF	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
DiffDWMWGF	0.06	0.05	0.04	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.06
DiffMWSWGF	0.07	0.07	0.05	0.03	0.04	0.05	0.06	0.07	0.10	0.08	0.07	0.07
DWADWGF	0.52	0.85	1.22	0.19	0.15	0.14	0.15	0.11	0.01	0.10	0.16	0.14
DWBPGF	0.88	0.88	0.89	0.86	0.79	0.79	0.82	0.81	0.80	0.80	0.86	0.88
DWGFBP	0.78	0.71	0.66	0.65	0.64	0.68	0.74	0.75	0.76	0.77	0.77	0.78
ETMWGF	0.80	0.34	0.88	1.64	1.78	1.53	1.55	0.98	0.16	0.76	1.23	0.96
ETSWGF	0.94	0.39	1.02	1.93	2.15	1.82	1.78	1.11	0.18	0.85	1.38	1.10

Table A.1 (continued)

Month	1	2	3	4	5	6	7	8	9	10	11	12
LUGF	1.20	1.21	1.23	1.24	1.24	1.23	1.23	1.23	1.22	1.21	1.21	1.20
MixDWMWGF	0.08	0.08	0.07	0.08	0.11	0.11	0.12	0.08	0.01	0.06	0.10	0.08
MixMWDWGF	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.03	0.01	0.02	0.04	0.04
MixMWSWGF	0.87	0.77	0.69	0.69	0.94	0.96	1.16	0.86	0.13	0.58	1.04	0.90
MixSWMWGF	0.44	0.33	0.27	0.29	0.40	0.43	0.53	0.39	0.06	0.28	0.52	0.46
MWADWGF	1.50	1.92	3.43	0.78	0.62	0.59	0.61	0.51	0.04	0.47	0.73	0.63
MWBPGF	0.23	0.23	0.23	0.22	0.22	0.26	0.31	0.34	0.37	0.38	0.30	0.24
MWDWGF	0.42	0.54	0.97	0.22	0.18	0.17	0.17	0.14	0.01	0.13	0.21	0.18
MWGFBP	0.32	0.29	0.26	0.22	0.23	0.26	0.29	0.31	0.32	0.33	0.33	0.33
PrecGF	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SWBPGF	1.46	1.48	1.51	1.44	1.32	1.34	1.41	1.42	1.40	1.38	1.40	1.43
SWETGF	1.79	3.26	3.65	0.52	0.43	0.44	0.46	0.43	0.27	0.42	0.49	0.45
SWGFBP	2.24	1.90	1.53	1.45	1.69	1.89	2.03	2.14	2.13	2.11	2.16	2.23
SWMWGF	1.04	1.90	2.13	0.30	0.25	0.26	0.27	0.25	0.16	0.24	0.29	0.26
TribGF	0.45	0.45	0.41	0.58	0.86	0.74	0.47	0.39	0.35	0.32	0.32	0.41

Table A.2 Compilation of Calculated Monthly TP-Fluxes (kt/month) To, Within and From the Gulf of Riga

Month	1	2	3	4	5	6	7	8	9	10	11	12
BioretGR	26.38	31.13	33.20	38.94	43.09	43.27	42.45	44.00	41.30	32.67	23.51	23.52
BioupGR	26.79	31.39	33.40	39.53	43.12	43.27	42.33	44.19	40.84	31.67	23.25	23.68
BurGR	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
DiffADWDWGR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DiffDWSWGR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00
DWADWGR	0.15	0.17	0.16	0.13	0.11	0.08	0.07	0.02	0.00	0.06	0.18	0.17
DWBPGR	0.16	0.16	0.17	0.16	0.15	0.18	0.23	0.26	0.28	0.28	0.22	0.17
DWGRBP	0.21	0.20	0.20	0.19	0.17	0.18	0.20	0.22	0.24	0.26	0.26	0.23
ETDWGR	0.21	0.20	0.23	0.25	0.27	0.21	0.19	0.06	0.02	0.10	0.24	0.22
ETSWGR	0.17	0.17	0.19	0.21	0.23	0.18	0.15	0.05	0.02	0.08	0.19	0.18
LUGR	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14
MixDWSWGR	0.18	0.19	0.20	0.25	0.34	0.32	0.29	0.09	0.02	0.07	0.19	0.19
MixSWDWGR	0.09	0.09	0.09	0.11	0.15	0.15	0.14	0.04	0.01	0.03	0.08	0.09
MWBPGR	0.16	0.16	0.17	0.16	0.15	0.18	0.23	0.26	0.28	0.28	0.22	0.17
MWGRBP	0.21	0.20	0.20	0.19	0.17	0.18	0.20	0.22	0.24	0.26	0.26	0.23
PrecGR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWBPGR	0.16	0.16	0.16	0.16	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.15
SWDWGR	0.05	0.09	0.07	0.05	0.04	0.04	0.04	0.03	0.03	0.04	0.05	0.05
SWETGR	0.18	0.35	0.28	0.18	0.16	0.15	0.16	0.13	0.11	0.16	0.20	0.19
TribGR	0.10	0.10	0.09	0.11	0.15	0.12	0.08	0.07	0.06	0.06	0.07	0.10

Table A.3 Compilation of Calculated Monthly TP-Fluxes (kt/month) To, Within and From the Bothnian Sea

Month	1	2	3	4	5	6	7	8	9	10	11	12
BioretBS	46.08	64.39	79.12	93.59	125.15	161.60	150.17	128.53	98.70	49.63	24.98	33.59
BioupBS	47.64	65.53	80.23	94.52	130.13	161.11	148.94	126.43	96.29	45.28	25.01	34.42
BurBS	5.58	5.78	5.84	6.13	6.53	6.34	6.10	6.06	6.04	5.93	5.74	5.58
DiffADWDWBS	0.17	0.16	0.16	0.15	0.14	0.15	0.16	0.17	0.18	0.18	0.18	0.18
DiffDWSWBS	0.08	0.09	0.10	0.10	0.15	0.20	0.16	0.12	0.10	0.07	0.04	0.07
DWADWBS	5.72	6.28	6.72	7.35	7.50	6.69	6.14	5.41	4.92	5.37	5.81	5.65
DWBPBS	0.13	0.13	0.13	0.13	0.13	0.15	0.17	0.19	0.20	0.20	0.16	0.13
DWBSBB	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
ETDWBS	5.17	4.99	4.75	5.55	3.55	0.52	0.40	0.45	0.68	4.90	9.31	5.65
ETSWBS	4.94	4.60	4.34	4.84	2.93	0.44	0.36	0.40	0.60	4.42	8.64	5.40
LUBS	5.42	5.42	5.42	5.43	5.44	5.45	5.45	5.44	5.43	5.42	5.42	5.42
MixDWSWBS	1.30	1.35	1.37	1.63	1.06	0.13	0.08	0.07	0.08	0.56	1.49	1.24
MixSWDWBS	0.41	0.40	0.40	0.47	0.30	0.03	0.02	0.02	0.02	0.19	0.51	0.41
PrecBS	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
SWBBBS	0.14	0.04	0.02	0.01	0.04	0.08	0.08	0.09	0.09	0.13	0.16	0.18
SWBPBS	1.40	1.42	1.45	1.26	0.97	1.05	1.26	1.31	1.32	1.33	1.37	1.38
SWBSBB	0.21	0.21	0.22	0.16	0.07	0.10	0.16	0.17	0.17	0.17	0.20	0.21
SWBSBP	1.11	1.14	1.16	1.18	1.20	1.13	1.06	0.99	0.92	0.87	0.97	1.07
SWDWBS	3.04	3.05	3.06	3.11	3.02	2.09	1.77	1.81	2.18	3.05	3.17	3.17
SWETBS	2.12	2.12	2.13	2.17	2.10	1.46	1.23	1.26	1.52	2.12	2.21	2.21
TribBS	0.20	0.20	0.18	0.29	0.44	0.38	0.24	0.19	0.18	0.16	0.15	0.18

Table A.4 Compilation of Calculated Monthly TP-Fluxes (kt/month) To, Within and From the Bothnian Bay

Month	1	2	3	4	5	6	7	8	9	10	11	12
BioretBB	8.73	4.76	1.73	1.49	3.85	13.53	14.75	12.47	7.01	6.60	7.03	7.50
BioupBB	8.65	4.40	1.63	1.55	4.24	14.11	14.69	12.15	6.68	6.68	7.00	7.65
BurBB	6.31	5.25	3.21	2.33	1.93	2.07	2.43	2.56	2.65	4.27	6.57	5.90
DiffADWDWBB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DiffDWSWBB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DWADWBB	8.44	3.10	2.40	2.75	1.77	1.33	0.92	0.99	3.32	7.43	7.63	5.41
DWBSBB	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
DWBSBB	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
ETDWBB	3.25	1.31	1.83	2.38	4.31	0.68	0.56	0.88	5.27	8.11	6.34	5.01
ETSWBB	0.94	0.39	0.54	0.84	1.82	0.27	0.18	0.26	1.49	2.10	1.64	1.40
LUBB	3.42	3.42	3.39	3.39	3.39	3.39	3.37	3.35	3.33	3.37	3.41	3.41
MixDWSWBB	0.43	0.08	0.03	0.05	0.22	0.05	0.02	0.03	0.22	0.60	0.67	0.65
MixSWDWBB	0.38	0.11	0.04	0.04	0.08	0.02	0.01	0.01	0.10	0.25	0.36	0.48
PrecBB	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SWBBBS	0.14	0.04	0.02	0.01	0.04	0.08	0.08	0.09	0.09	0.13	0.16	0.18
SWBSBB	0.21	0.21	0.22	0.16	0.07	0.10	0.16	0.17	0.17	0.17	0.20	0.21
SWDWBB	2.26	1.05	0.52	0.43	0.16	0.10	0.15	0.23	0.34	0.40	0.43	0.41
SWETBB	3.88	1.81	0.89	0.74	0.28	0.18	0.25	0.40	0.58	0.69	0.74	0.70
TribBB	0.21	0.22	0.21	0.37	0.59	0.50	0.31	0.26	0.23	0.20	0.17	0.19

Table A.5 A Statistical Compilation of the TP-Fluxes (kt/month) in the Gulf of Finland and a Ranking Based on the Annual Fluxes (kt/yr)

TP-flux	Annual	Mean	Median	Min	Max.	SD	CV
BioretGF	809.6	67.5	66.7	51.0	91.5	12.5	0.18
BioupGF	809.6	67.5	65.9	50.5	90.5	12.5	0.19
SWGFBP	23.5	1.96	2.07	1.45	2.24	0.27	0.14
SWBPGF	17.0	1.42	1.41	1.32	1.51	0.05	0.04
LUGF	14.6	1.22	1.22	1.20	1.24	0.01	0.01
ETSWGF	14.6	1.22	1.10	0.18	2.15	0.61	0.50
SWETGF	12.6	1.05	0.46	0.27	3.65	1.19	1.14
ETMWGF	12.6	1.05	0.97	0.16	1.78	0.51	0.49
MWADWGF	11.8	0.99	0.63	0.04	3.43	0.91	0.93
BurAMWGF	11.6	0.97	0.97	0.94	1.00	0.02	0.02
DWBPGF	10.0	0.84	0.84	0.79	0.89	0.04	0.05
MixMWSWGF	9.59	0.80	0.86	0.13	1.16	0.26	0.33
DWGFBP	8.68	0.72	0.74	0.64	0.78	0.05	0.07
SWMWGF	7.35	0.61	0.27	0.16	2.13	0.70	1.14
TribGF	5.76	0.48	0.43	0.32	0.86	0.17	0.35
MixSWMWGF	4.41	0.37	0.40	0.06	0.53	0.13	0.36
DWADWGF	3.73	0.31	0.15	0.01	1.22	0.37	1.18
MWGFBP	3.49	0.29	0.30	0.22	0.33	0.04	0.14
BurADWGF	3.46	0.29	0.25	0.24	0.53	0.08	0.29
MWDWGF	3.34	0.28	0.18	0.01	0.97	0.26	0.93
MWBPGF	3.32	0.28	0.25	0.22	0.38	0.06	0.21
MixDWMWGF	0.99	0.08	0.08	0.01	0.12	0.03	0.35
DiffMWSWGF	0.77	0.06	0.07	0.03	0.10	0.02	0.27
DiffDWMWGF	0.64	0.05	0.05	0.04	0.06	0.00	0.08
MixMWDWGF	0.39	0.03	0.03	0.01	0.05	0.01	0.34
DiffADWDWGF	0.26	0.02	0.02	0.02	0.03	0.00	0.19
DiffAMWMWGF	0.11	0.01	0.01	0.01	0.01	0.00	0.20
PrecGF	0.09	0.01	0.01	0.01	0.01	0.00	0.00

Table A.6 A Statistical Compilation of the TP-Fluxes (kt/month) in the Gulf of Riga and a Ranking Based on the Annual Fluxes (kt/yr)

TP-flux	Annual	Mean	Median	Min	Max .	SD	CV
BioretGR	423.5	35.3	36.1	23.5	44.0	7.90	0.22
BioupGR	423.5	35.3	36.5	23.2	44.2	7.90	0.22
SWGRBP	3.33	0.28	0.28	0.27	0.29	0.01	0.03
MWGRBP	2.55	0.21	0.20	0.17	0.26	0.03	0.14
MWBPGR	2.40	0.20	0.18	0.15	0.28	0.05	0.25
MixDWSWGR	2.33	0.19	0.19	0.02	0.34	0.10	0.50
SWETGR	2.25	0.19	0.17	0.11	0.35	0.07	0.35
ETDWGR	2.18	0.18	0.21	0.02	0.27	0.08	0.43
SWBPGR	1.88	0.16	0.16	0.14	0.16	0.01	0.05
ETSWGR	1.80	0.15	0.17	0.02	0.23	0.07	0.44
LUGR	1.74	0.14	0.14	0.14	0.15	0.00	0.00
DWADWGR	1.32	0.11	0.12	0.00	0.18	0.06	0.55
BurGR	1.31	0.11	0.11	0.11	0.11	0.00	0.02
TribGR	1.13	0.09	0.09	0.06	0.15	0.03	0.28
MixSWDWGR	1.08	0.09	0.09	0.01	0.15	0.05	0.50
SWDWGR	0.595	0.050	0.046	0.029	0.092	0.017	0.35
DiffDWSWGR	0.060	0.005	0.004	0.003	0.009	0.002	0.43
PrecGR	0.049	0.004	0.004	0.004	0.004	0.000	0.00
DiffADWDWGR	0.0001	0.000	0.000	0.000	0.000	0.000	0.09

Table A.7 A Statistical Compilation of the TP-Fluxes (kt/month) in the Bothnian Sea and a Ranking Based on the Annual Fluxes (kt/yr)

TP-flux	Annual	Mean	Median	Min	Max .	SD	CV
BioretBS	1055.5	88.0	86.4	25.0	161.6	46.0	0.52
BioupBS	1055.5	88.0	87.4	25.0	161.1	46.0	0.52
DWADWBS	73.5	6.13	5.97	4.92	7.50	0.80	0.13
BurBS	71.7	5.97	5.99	5.58	6.53	0.29	0.05
LUBS	65.2	5.43	5.43	5.42	5.45	0.01	0.00
ETDWBS	45.9	3.83	4.82	0.40	9.31	2.79	0.73
ETSWBS	41.9	3.49	4.38	0.36	8.64	2.60	0.74
SWDWBS	32.5	2.71	3.04	1.77	3.17	0.56	0.21
SWETBS	22.7	1.89	2.12	1.23	2.21	0.39	0.21
SWBPBS	15.5	1.29	1.32	0.97	1.45	0.15	0.11
SWBSBP	12.8	1.07	1.09	0.87	1.20	0.11	0.10
MixDWSWBS	10.3	0.86	1.15	0.07	1.63	0.63	0.73
MixSWDWBS	3.17	0.26	0.35	0.02	0.51	0.19	0.74
TribBS	2.78	0.23	0.20	0.15	0.44	0.09	0.39
SWBSBB	2.05	0.17	0.17	0.07	0.22	0.05	0.28
DiffADWDWBS	1.97	0.16	0.17	0.14	0.18	0.01	0.09
DWBPBS	1.85	0.15	0.14	0.13	0.20	0.03	0.19
DiffDWSWBS	1.28	0.11	0.10	0.04	0.20	0.05	0.43
SWBBBS	1.07	0.09	0.09	0.01	0.18	0.06	0.62
PrecBS	0.29	0.02	0.02	0.02	0.02	0.00	0.00
DWBSBB	0.27	0.02	0.02	0.02	0.03	0.00	0.14

Table A.8 A Statistical Compilation of the TP-Fluxes (kt/month) in the Bothnian Bay and a Ranking Based on the Annual Fluxes (kt/yr)

TP-flux	Annual	Mean	Median	Min	Max .	SD	CV
BioretBB	89.4	7.45	7.02	1.49	14.75	4.33	0.58
BioupBB	89.4	7.45	6.84	1.55	14.69	4.37	0.59
BurBB	45.5	3.79	2.93	1.93	6.57	1.77	0.47
DWADWBB	45.5	3.79	2.92	0.92	8.44	2.73	0.72
LUBB	40.6	3.39	3.39	3.33	3.42	0.029	0.01
ETDWBB	39.9	3.33	2.82	0.56	8.11	2.48	0.74
ETSWBB	11.9	0.99	0.89	0.18	2.10	0.68	0.69
SWETBB	11.1	0.93	0.69	0.18	3.88	1.02	1.10
SWDWBB	6.48	0.54	0.40	0.10	2.26	0.59	1.10
TribBB	3.46	0.29	0.23	0.17	0.59	0.13	0.46
MixDWSWBB	3.04	0.25	0.15	0.021	0.67	0.26	1.04
SWBSBB	2.05	0.17	0.17	0.066	0.22	0.048	0.28
MixSWDWBB	1.87	0.16	0.09	0.010	0.48	0.17	1.07
SWBBBS	1.07	0.089	0.085	0.014	0.18	0.055	0.62
DWBSBB	0.27	0.022	0.023	0.017	0.025	0.003	0.14
PrecBB	0.13	0.011	0.011	0.011	0.011	0.000	0.00
DiffDWSWBB	0.010	0.001	0.000	0.000	0.003	0.001	1.44
DiffADWDWBB	0.006	0.000	0.000	0.000	0.001	0.000	0.17

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