TUFLOW CATCH
User Manual

TUFLOW CATCH User Manual 2026.0

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Navigation

This manual is designed for digital use within any web browser and has the following features:

- Section headers, to level five, are directly navigable via the table of contents on the right hand side of the page.
- To navigate between chapters, the sidebar on the left hand side of the page can be used.
- The navigation bar at the top of the screen contains helpful tools:
    - Download pdf version of this manual
    - Toggle dark mode
    - Expand/collapse the sidebar and table of contents
    - Search in the manual
- Model commands, parameters and cross references for tables and figures are navigable through hyperlinks, where appropriate. This includes parameters within equations, which will also appear as blue hyperlinks when active.
- The space bar can be used to scroll down within each page without skipping text. Shift + space bar will similarly scroll up.
- Browser back and forward buttons (or their equivalent keyboard shortcuts `alt + left arrow` and `alt + right arrow`, respectively) can be used to navigate through browsing history. Some browsers may not return to the precise scroll location in a page last visited, but to the last clicked section header. Hyperlinks have been built into the body of the manual, and these can be used in lieu of browser buttons if required

It is recommended that this manual be viewed in a browser window that is maximised or operating in full screen mode, with the latter (although browser dependent) typically toggled via the `F11` key.

When following hyperlinks, the target (i.e. location on a webpage that is being navigated *to*) is displayed at the top of the landing page (the page navigated to). The exception to this occurs when a target is located near the bottom of the landing page's content. In this case, it is not possible for a web browser to display the target at the top of a page because this would generate underlying white space, and as such, the target will appear in the main body (i.e. not at the top) of the landing page.

Searching

This entire manual's content can be searched by clicking the search icon in the right of the navigation bar (top of the screen). A search bar will open in the centre of the page and the search results will be listed. The search function can also be toggled via the `s` key. Clicking `Cancel` will close the search bar.

Tables

Where appropriate, tables are searchable via use of the search box, which is located at the top right of any search enabled table. Not all tables are searchable. When text is entered into the search box, table rows are dynamically filtered to only show those that contain the search text. This allows on-the-fly condensing of large tables so that only relevant content is presented.

Tables can be sorted alphabetically (or reverse alphabetically) with respect to any column by clicking (and re-clicking) column headers. Where appropriate, the number of rows displayed is selectable via the *Show entries* drop down. Undisplayed rows can be accessed by clicking *Previous* or *Next* or by using the numbered navigation boxes, all of which are located at the bottom of each table.

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Below is an example of a searchable table. Type "erosion" (with or without the inverted commas) into the search box to see the table behaviour, or change the number of rows displayed and use the navigation buttons at the bottom of the table to look through all the data. The right hand "Links" column sometimes has hyperlinked words that allow navigation between related commands, or different versions of the same command, for ease of access if appropriate.

Colour coding is often used for distinguishing different tabulated data types. In the below example, TUFLOW CATCH commands are in highlighted text and the associated argument options for each command are blue and contained in angled parentheses. Clicking on these arguments will navigate to related content. Colour coding applied to other table types is explained throughout this manual when required.

Table 1: TUFLOW CATCH Commands (Demo)

Command	Description
`Deposition Stress ==` $\langle\, \tau_{cd}\, \rangle$	Used in a material block within a pollutant export model block to set the maximum bed shear stress that allows for deposition to occur. This deposition represents a transfer from a pollutant's wet to dry store. Deposition will not occur at shear stresses above this value. Applies only to shear stress pollutant export methods. It is not used for accumulation washoff pollutant export models.
`Deposition Velocity ==` $\langle\, w_s\, \rangle$	Used in a material block within a pollutant export model block to set the settling velocity of a pollutant. This settling represents a transfer from a pollutant's wet to dry store. Settling occurs at all times in the accumulation washoff pollutant export model. Settling only occurs once bed shear stress drops below the user specified value in the shear stress pollutant export model.
`Depth Threshold ==` $\langle\, d\, \rangle$	Used in a material block within a pollutant export model block to set the minimum cell water depth at which pollutant export can occur. Applies to all pollutant export methods.
`End Time ==` $\langle$ dd/mm/yyyy hh:mm:ss; hours $\rangle$	Used in the General commands section of a TUFLOW CATCH control file to set the simulation start date in the format declared by Time Format. It is strongly recommended that ISODATE (dd/mm/yyyy hh:mm:ss) be deployed rather than hours.
`Erosion Rate ==` $\langle\, E_r\, \rangle$	Used in a material block within a pollutant export model block to set the erosion rate of a pollutant. This erosion represents a transfer from a pollutant's dry to wet store. Erosion only occurs once bed shear stress increases above the user specified value. Erosion will not occur at shear stresses below this value. Applies only to shear stress pollutant export methods. It is not used for accumulation washoff pollutant export models.
`Erosion Stress ==` $\langle\, \tau_{ce}\, \rangle$	Used in a material block within a pollutant export model block to set the minimum bed shear stress that allows for erosion to occur. This erosion represents a transfer from a pollutant's dry to wet store. Erosion will not occur at shear stresses below this value. Applies only to shear stress pollutant export methods. It is not used for accumulation washoff pollutant export models.
`GIS Format ==` $\langle$ SHP; GPKG; MI $\rangle$	Used in the General commands section of a TUFLOW CATCH control file to set the GIS format of the simulation. This command can be overwritten in the catchment hydraulic model or receiving model blocks if needed.
`Hardware ==` $\langle$ GPU; CPU $\rangle$	Used in the General commands section of a TUFLOW CATCH control file to set the simulation hardware. This command can be overwritten in the catchment hydraulic model or receiving model blocks if needed.
`Limit ==` $\langle\, L_{acc};\, L_{shr}\, \rangle$	Used in a material block within a pollutant export model block to set an accumulation (washoff model) or erosion (shear model) limit.

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Table 1: TUFLOW CATCH Commands (Demo)

Command	Description
`Method ==` ⟨ `Washoff1`; `Shear1` ⟩	Used in a material block within a pollutant export model block to set the pollutant export model.
`Rain Threshold ==` ⟨ R_r ⟩	Used in a material block within a pollutant export model block to set the minimum rainrate threshold at which a pollutant is released from its dry store. Pollutant export is suppressed below this rate. Applies only to accumulation pollutant export methods. It is not used for erosion pollutant export models.
`Rate ==` ⟨ R_a ⟩	Used in a material block within a pollutant export model block to set the rate at which a pollutant accumulates to its dry store. Applies only to accumulation pollutant export methods. It is not used for erosion pollutant export models.
`SHP Projection ==` ⟨ `rec:` `..\..\TUFLOW\model\gis\Projection.prj` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the path to the SHP file containing the TUFLOW CATCH model projection.
`Start Time ==` ⟨ `dd/mm/yyyy` `hh:mm:ss`; `hours` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the simulation start date in the format declared by Time Format. It is strongly recommended that ISODATE (dd/mm/yyyy hh:mm:ss) be deployed rather than hours.
`Time Constant ==` ⟨ T_c ⟩	Used in a material block within a pollutant export model block to control the rate at which a pollutant is released from its dry store. Applies only to accumulation pollutant export methods. It is not used for erosion pollutant export models.
`Time Format ==` ⟨ `ISODATE`; `hours` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the simulation date format. It is strongly recommended that ISODATE (dd/mm/yyyy hh:mm:ss) be deployed rather than hours.

Commands

Where specific commands are described, they typically appear in highlighted text. For example:

`Catch BC Output Folder ==`

If they are a clickable link to the corresponding command description in Appendix A they will appear as the standard hyperlink coloured text. For example:

`Catch BC Output Folder ==`

Where commands specify parameters (e.g. erosion rates) then for consistency and brevity, these parameters are included directly in the command example using their notation (see Parameter Notation below) rather than descriptive words. For example:

`CSV Write Frequency Day ==` dT_{csv}

These notated parameters are also often a clickable link to descriptive explanations in Appendix B. For example:

`CSV Write Frequency Day ==` dT_{csv}

Parameter notation

The primary groups of parameters are listed below, with the letter or symbol used to denote each. Typical generalisations of units are parenthesised.

- Time steps, dT (seconds or days)
- Rates, R (mass per unit area per unit time, or rain rate)

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- Limits, L (mass per unit area)
- Concentrations, C (mass per unit volume)
- Time constants, T (seconds)
- Water depths, d (metres)
- Shear, τ (Newtons per square metre)
- Velocities, w (metres per second)
- Erosion rates, E (grams per metres squared per second)

Portable Document Format (PDF)

The TUFLOW CATCH manual is available in Portable Document Format (PDF) by clicking on the pdf icon ⊡ to the right of the navigation bar (top of the screen). This static pdf format has been provided in response to user request only and it is not the preferred means by which to access TUFLOW CATCH content. This online version is the preferred format and should be used in preference to the pdf version.

Feedback

Constructive suggestions to improve this manual are welcome, and can be emailed to support@tuflow.com.

1 Overview

1.1 Context

TUFLOW CATCH enables the seamless bottom-up simulation of whole-of-catchment hydrologic, hydraulic, pollutant export and receiving waterway processes. It supports simulation of these processes from top of catchment to receiving waterway outlet via solution of the relevant equations of motion and transport, without recourse to lumped spatial or temporal assumptions. It draws on the power of GPU acceleration to explicitly simulate catchment water flow and pollutant processes in the surface and subsurface domains, and automatically reconfigures these predictions to drive downstream multidimensional receiving waterway hydrodynamic, sediment transport, water quality and other environmental models. This modern framework, that draws on advanced compute capability, allows environmental practitioners to holistically manage and understand catchments of interest and their receiving waters in an efficient, integrated and rigorous manner, without the need for manual model linking or reliance on top-down average assumption modelling techniques. TUFLOW CATCH's design is flexible so as to support tailoring of its configuration to meet individual application demands, and as such allows for execution of multiannual studies such as (but not limited to):

- Seamless assessment of the impact of land use or other catchment based changes on the hydrodynamics of downstream receiving waterways (i.e. without the need to simulate pollutant export, see Section 1.3, bullet point 1)
- Assessment of the impact of land use or other changes on catchment hydrology and/or pollutant export (i.e. without the need to directly include receiving waterway numerical simulation, see Section Section 1.3, bullet point 2)
- Assessment of the efficacy of proposed catchment changes on downstream receiving riverine or estuarine health (i.e. fully integrated catchment and receiving waterway simulation of water flow and pollutant dynamics, see Section Section 1.3, bullet point 3)
- Assessment of the interaction of catchment inflows with water supply offtakes or other sensitive receptors
- Sediment and other pollutant export catchment dynamics investigations
- Various combinations of the above

1.2 Features

Several key features have been included in the design of TUFLOW CATCH to support its use. Some are listed below.

- **Simulation engine**. To affect whole-of-catchment simulation, TUFLOW CATCH links and augments the power and functionality of two existing TUFLOW engines. This means that the decades of development, expertise and rigour embedded in the TUFLOW suite of products is exploited by TUFLOW CATCH. These existing TUFLOW engines are:
    - TUFLOW HPC: Fixed grid simulation of surface and subsurface catchment hydrology, hydraulics, pollutant export and transport
    - TUFLOW FV: Flexible mesh simulation of receiving waterway hydrodynamic, advection dispersion, heat, sediment transport, water quality and particle tracking

Conceptually, TUFLOW CATCH links and coordinates TUFLOW HPC and TUFLOW FV as in Figure 1.1. TUFLOW HPC coverage is represented by the fixed grid iconography, and TUFLOW FV is shown as contained within the enclosing thick brown boundary line. This intention is that this figure conveys the ability of TUFLOW CATCH (in its most advanced configuration) to use advanced numerical techniques (free of top-down lumping assumptions) to seamlessly simulate water and pollutant dynamics from top of catchment to receiving waterway outlet. TUFLOW CATCH can also be configured to simulate other (less advanced but still important and relevant) combinations of environmental flows and pollutant transport processes (see Section 1.3).
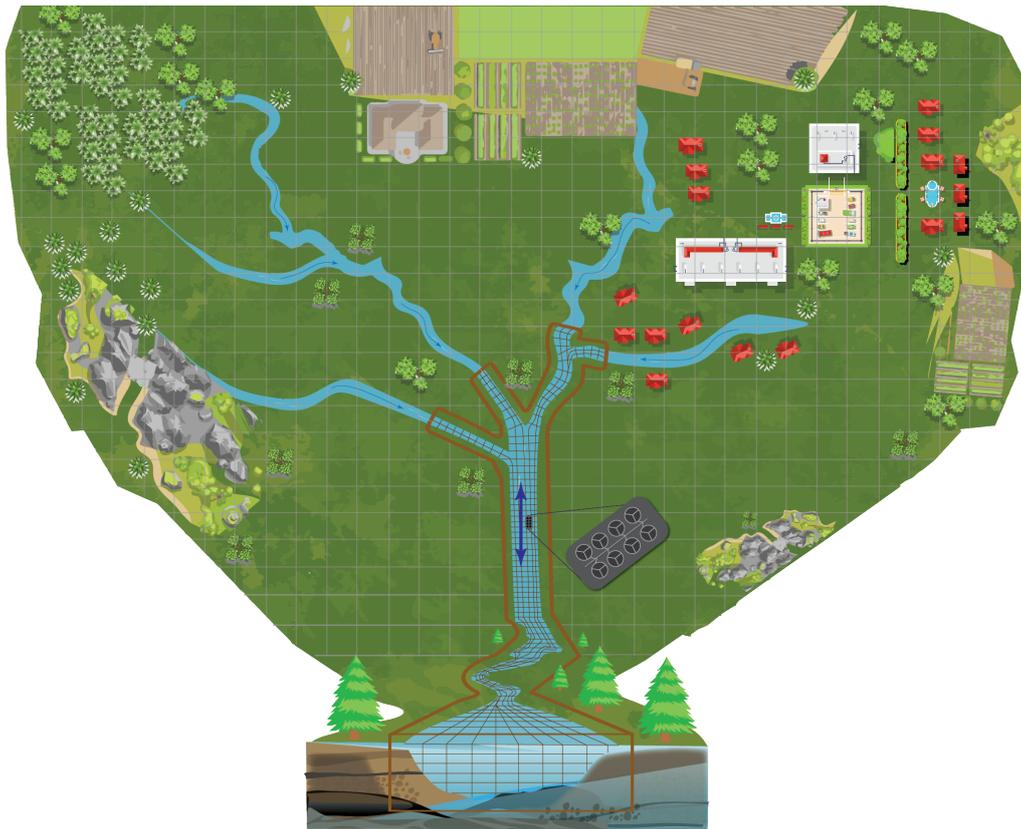
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Figure 1.1: Conceptual arrangement of TUFLOW CATCH engines

- **Pollutant Export**. TUFLOW CATCH adds pollutant export functionality to TUFLOW HPC. Pollutants are able to be liberated on a cell by cell basis and under a range of user-selectable algorithms (accumulation-washoff or shear stress based, for example), and then routed as surface and/or subsurface flows and concentrations, via solution of the equations of motion and transport, rather than using lumped top-down average assumptions
- **Automatic linkage** When required, TUFLOW CATCH automatically links the bottom of catchment TUFLOW HPC predictions (for both flow and pollutant concentrations) to the upstream of TUFLOW FV's model domain to present a single integrated modelling platform to the user, with no need for manual handling or other post/pre processing. To affect this, TUFLOW CATCH automatically
    - Determines the spatial locations where surface and subsurface waters drain to the user defined TUFLOW FV mesh (or GIS polygon if TUFLOW FV simulation is not selected) and designates these as inflow locations to TUFLOW FV (or simply a single exit point if a polygon is specified), and then
    - Writes the TUFLOW HPC predictions as fully formatted TUFLOW FV inflow boundary conditions files and blocks, either as nodestrings or elements. If a downstream polygon is specified then timeseries of summed outlet flows and masses are reported
- **Command syntax**. TUFLOW CATCH uses familiar TUFLOW style `command` `==` `argument(s)` syntax that has a long established pedigree within all other TUFLOW products
- **Flexibility of constituents**. TUFLOW CATCH, when combining TUFLOW HPC and TUFLOW FV in full can simulate any constituents that are initialised in TUFLOW FV, across all its modules, including sediment transport and water quality. TUFLOW CATCH can also run TUFLOW HPC in pollutant generation mode only (without activating TUFLOW FV, i.e. the 'pollutant export' configuration, see Section 1.3), and in this instance, users can specify any pollutants they wish to simulate (e.g. 'PFAS' or 'DDT' etc.) - these do not need to be simulated by TUFLOW FV or its modules
- **Log file user feedback**. TUFLOW CATCH simulations generate TUFLOW HPC and TUFLOW FV log files as per usual that report all simulation configuration details for review in a single consolidated location
- **Results viewing**. TUFLOW CATCH has its own freely available QGIS plugin to support viewing and interrogation of combined TUFLOW HPC and TUFLOW FV results, as a single data set, such as Figure 1.2.
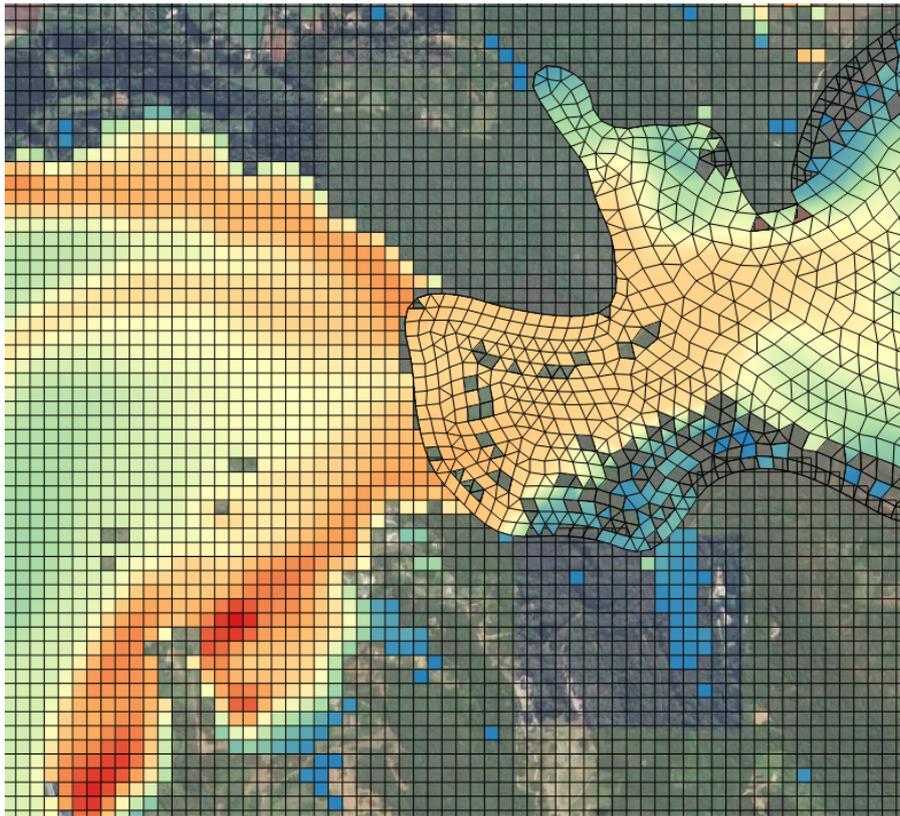
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Figure 1.2: Example of using the QGIS TUFLOW CATCH plugin to view combined results

1.3 Configurations

Given its construction philosophy, TUFLOW CATCH can be set up and executed in the following core supported configurations:

1. **Hydrology**. The most basic configuration of TUFLOW CATCH is to simulate water movement (without generated pollutants) through surface (and optionally subsurface) catchment flows, and to automatically route these into a downstream receiving hydrodynamic (only) waterway model. At the point of routing, constant/timeseries salinity and temperature may be assigned to allow baroclinic TUFLOW FV receiving water modelling. Use cases might include investigation of velocity fields in receiving waterways under a range of separate or continuous catchment inflow regimes, or modification of these fields in response to changes in catchment conditions, such as urbanisation. In this instance, the computational engines would be configured as follows:
   - TUFLOW HPC: Simulate surface (and optionally subsurface) hydrology, and optionally constant or timeseries temperature and salinity. In addition to map outputs, write inflow boundary condition files for TUFLOW FV. These only contain water flows with optionally temperature and salinity, without associated generated pollutant concentrations
   - TUFLOW FV: Simulate and report 2D or 3D hydrodynamics, optionally including temperature and salinity
2. **Pollutant Export**. The next level of functionality offered by TUFLOW CATCH is the addition of pollutant export within the catchment simulation, without the explicit and subsequent simulation of the fate and transport of these pollutants in a downstream receiving model. Use cases might include investigation of pollutant export properties of a catchment under differing rainfall conditions, or the variation of this export in response to the implementation of intervention measures or land use changes. In this instance, the computational engines would be configured as follows:
   - TUFLOW HPC: Simulate surface (and optionally subsurface) hydrology, with pollutant export and transport. In addition to map outputs, write summary timeseries of total flows and pollutant export at a user defined catchment outlet. This outlet is defined by a user specified GIS polygon rather than a TUFLOW FV mesh
   - TUFLOW FV: No simulation

3. **Integrated**. This level represents the full functionality offered by TUFLOW CATCH. It augments the **Pollutant**

Export configuration above by including the explicit 2D or 3D simulation of the fate and transport of all catchment derived flows and pollutants within the downstream waterway model. Use cases might include the investigation of the efficacy of catchment intervention works on downstream water quality over multiannual periods. In this instance, the computational engines would be configured as follows:

- TUFLOW HPC: Simulate surface (and optionally subsurface) hydrology, with pollutant export and transport. In addition to map outputs, write summary timeseries of total flow and pollutant export at catchment outlet, as well as fully formatted inflow and concentration boundary condition files for TUFLOW FV
- TUFLOW FV: Direct simulation of 2D or 3D baroclinic hydrodynamics, with sediment transport and/or water quality (and optionally other TUFLOW FV modules such as particle tracking)

Whilst not core to TUFLOW CATCH's ultimate functionality, other configurations are also available:

1. **TUFLOW HPC calibration only**. This covers the use case where a TUFLOW HPC modeller wishes to progress catchment hydraulic model calibration independently of pollutant export simulation and TUFLOW FV activities

2. **TUFLOW FV calibration only**. This covers the use case where a TUFLOW FV modeller wishes to progress receiving model calibration independently of TUFLOW HPC activities. Inflows for this configuration would likely be turned off, with associated tasks therefore being undertaken during largely dry periods

If only the simulation of surface and subsurface water flows (and not pollutants) are of interest, and with no intended linkage between TUFLOW HPC and TUFLOW FV (i.e. the **Hydrology** configuration above but with no linkage to TUFLOW FV), then TUFLOW HPC can be run in isolation without the need for TUFLOW CATCH. Simply setting up and running TUFLOW HPC with appropriate results outputs at bottom of catchment (via PO or similar outputs) would suffice. If either linkage with TUFLOW FV or simulation of pollutant export is of interest, then TUFLOW CATCH is required.

TUFLOW CATCH supports one-way linking of flows and concentrations from TUFLOW HPC to TUFLOW FV.

1.4 Science

The science underpinning TUFLOW CATCH is that developed for TUFLOW HPC and TUFLOW FV (including their respective modules) and is described in those user and science manuals, and relevant release notes here:

- TUFLOW HPC
- TUFLOW FV

1.5 Versioning

The TUFLOW suite of products (which includes TUFLOW CATCH) has moved to a uniform versioning system. This system uses a `year.minor.patch` convention. In the new system:

- The year corresponds to the major version number e.g. `2025.0.0`. Major releases are the only releases that will admit the possibility of breaking changes. There will be one major release per year
- Minor releases contain new features and bug fixes, but no breaking changes and increment the minor version number, e.g. `2025.1.0`
- Patch releases are bug fixes only and increment the patch version number, e.g. `2025.0.1`

1.6 Support

BMT sells, distributes and supports TUFLOW CATCH. Contact support@tuflow.com and sales@tuflow.com for support and sales inquiries, respectively.

Several supporting appendices have also been included in this manual. These contain content to assist users in applying TUFLOW CATCH. These appendices are interlinked and hyperlinked with content from the body of the manual where appropriate, and are:

- Appendix A Interactive listing of all commands, and their syntax, arguments, descriptions and cross references
- Appendix B Interactive listing of all parameters, and their symbols, units, ranges and links to underlying science descriptions
- Appendix C Description of output files and their associated data fields

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- Appendix D A purpose built suite of small TUFLOW CATCH demonstration models for free download and use

The user is directed to the respective manuals noted in Section 1.4 above for TUFLOW HPC and TUFLOW FV commands other than those specific to TUFLOW CATCH. All TUFLOW CATCH commands are described in this manual.

1.6.1 Tutorial models

A number of free Tutorial Models are available for download and are documented in the TUFLOW Wiki. No TUFLOW CATCH licence is required to simulate the tutorial models. Current tutorials include:

- Tutorial 1 - Pollutant Export
- Tutorial 2 - Interventions
- Tutorial 3 - Hydrology
- Tutorial 4 - Integrated

1.6.2 Demonstration Models

In addition to the tutorial models listed above, a free demonstration model and a small suite of simulations are available for download. See Appendix D for further details.

2 Architecture

This section provides a description of TUFLOW CATCH's core architecture. This description is intentionally introductory, and details required to set up and execute simulations that deploy TUFLOW CATCH are provided in Chapter 4 and Chapter 5.

2.1 Context

As our understanding of the natural environment advances, the questions asked of environmental numerical models are rapidly increasing in breadth and complexity. Setting up, calibrating and executing defensible environmental models to assist in addressing such questions has therefore become an increasingly challenging proposition. This is particularly relevant with regard to whole-of-catchment studies where the linkage between catchment management intervention and associated receiving water changes is of increasing interest (and complexity) within the environmental management space.

The architecture and functionality of TUFLOW CATCH has therefore been deliberately designed to assist environmental modellers in overcoming some of these challenges, and in doing so improve the efficiency and effectiveness with which numerical modelling can support longer term environmental management at the catchment scale. Importantly, TUFLOW CATCH's architecture provides a mechanism by which users can seamlessly simulate hydrologic, hydraulic, pollutant export and transformative receiving water quality processes within one unified, automated and internally consistent framework. This deliberate design choice has been motivated by the observation that historically, catchment and receiving waterway simulations have often been undertaken using disparate modelling platforms not designed or intended to be linked, and that (more often then not) operate under materially different assumptions and levels of scientific rigour. One example of such an instance might be where predictions from a catchment model that uses average (spatially and temporally lumped) hydrology and event mean pollutant export assumptions are used to provide inflow boundary conditions to a fully three dimensional receiving water quality model that operates on a highly spatial and temporally resolved domain and makes limited average assumptions. TUFLOW CATCH exploits the latest compute power advances and scientific rigour to overcome such disconnects.

In short, TUFLOW CATCH has been designed to provide access to state of the art bottom-up environmental modelling science at the integrated catchment scale, without deploying top-down average assumptions. The core architecture that provides this easy access is described below, and the details of the methods deployed in supplementary processes such as geolocation are described in Section 3.1 and Section 3.2. The associated simulation commands and execution approaches are provided in Chapter 4 and Chapter 5, respectively.

2.2 Intention

The intention of the execution coordination sequences described below is that they provide a robust means to automatically link catchment and receiving waterway models within three overarching configurations to support integrated environmental assessment. It is noted that this architecture deliberately:

- Supports multiple users working on a project simultaneously by allowing (from the same TUFLOW CATCH control file, see Section 4.5):
    - Simulation of TUFLOW HPC without needing to execute TUFLOW FV, and/or
    - Simulation of TUFLOW FV without needing to execute (or repeatedly execute) TUFLOW HPC
- Aligns with the use of version control platforms to support multi-user co-development. Such use was intended as part of designing TUFLOW CATCH's architecture, and it means that the same TUFLOW CATCH control file can be used by multiple users to initially independently drive TUFLOW HPC and TUFLOW FV model builds. When appropriate, version control techniques can then be used to unify model builds. This approach avoids the need to build disparate TUFLOW HPC and TUFLOW FV models, and then recast these into a TUFLOW CATCH control file framework: co-development is a core design feature of TUFLOW CATCH.

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2.3   Core architecture

TUFLOW CATCH provides three primary functions:

- Coordination of the execution of TUFLOW HPC and TUFLOW FV across a whole-of-catchment domain (**Hydrology** and **Integrated** configurations)
- Automatic geolocation and writing of flow and concentration boundary conditions for TUFLOW FV (as the receiving water model), generated from TUFLOW HPC predictions (as the catchment model) (**Hydrology** and **Integrated** configurations)
- Pollutant export and transport calculations within a catchment (**Pollutant Export** and **Integrated** configurations)

The first of these is its core architectural capability and so is described here in Section 2.3.1. The latter two are technical componentry of this architecture and so are described in Section 3.1 and Section 3.2, respectively.

2.3.1   Execution coordination

In **Hydrology** and **Integrated** configurations, TUFLOW CATCH overarches both TUFLOW HPC and TUFLOW FV to coordinate their execution to affect integrated numerical simulation of water and pollutant flows across a catchment and its receiving waters (the latter of which also includes water quality pollutant transformations). Whilst not undertaking equation solution itself, TUFLOW CATCH does coordinate these supporting TUFLOW products to do so in their respective domains, which are:

- TUFLOW HPC: Surface and subsurface catchment hydrology and hydraulics, with or without pollutant export and transport
- TUFLOW FV: Hydrodynamic, sediment transport, water quality and particle tracking (or user selectable module subsets/combinations thereof) receiving waterway modelling

The order of execution of TUFLOW HPC and TUFLOW FV, coordinated automatically under TUFLOW CATCH for each of the supported simulation configurations described in Section 1.3, is as follows.

2.3.1.1   Hydrology configuration

1. Execute TUFLOW FV in test mode with the intention of
   i. Reading the TUFLOW FV model mesh and writing the associated mesh check file for subsequent use by TUFLOW HPC in its automatic geolocation processes
2. Execute TUFLOW HPC, with the intention of
   i. Reading the TUFLOW FV mesh check files to determine the receiving water model domain location and extent
   ii. Comparing this mesh with the TUFLOW HPC grid to then determine which TUFLOW HPC cells are to be designated as transfer cells where boundary conditions for TUFLOW FV are to be written (see Section 3.1) from TUFLOW HPC predictions
   iii. Executing the TUFLOW HPC catchment based hydrologic and hydraulic modelling over the period specified
   iv. Writing TUFLOW FV flow (and optionally constant and/or timeseries temperatures and salinities) boundary conditions at designated transfer cells
   v. Reporting map outputs such as water depth and velocity, as well as downstream timeseries of summed flows leaving the TUFLOW HPC domain
3. Re-execute TUFLOW FV with the intention of
   i. Executing hydrodynamic receiving waterway modelling, using the flow (and optionally temperature and salinity) boundary conditions developed by TUFLOW HPC above
   ii. Reporting receiving waterway simulation results such as flows and velocity fields

2.3.1.2   Pollutant export configuration

1. Execute TUFLOW HPC, with the intention of
   i. Reading a user specified GIS polygon that defines the areal extents of the downstream receiving waterway
   ii. Comparing this polygon with the TUFLOW HPC grid to then determine which TUFLOW HPC cells are to be designated as deactivated cells
   iii. Executing the TUFLOW HPC catchment based hydrologic, hydraulic and pollutant export modelling over the period specified

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    iv. Reporting map outputs such as water depth, velocity, dynamic pollutant concentrations in the surface and/or subsurface domains, dry store evolutions and/or erosion/deposition zones (see Section 3.2) and downstream timeseries of summed flows and pollutant loads leaving the TUFLOW HPC domain through the user specified GIS polygon

2.3.1.3 Integrated configuration

1. Execute TUFLOW FV in test mode with the intention of
   i. Reading the TUFLOW FV model mesh and writing the associated mesh check file for subsequent use by TUFLOW HPC in its automatic geolocation processes
   ii. Reading the TUFLOW FV sediment transport and/or water quality log files to determine the suite of constituents to be simulated in the receiving waterway, and therefore those that require specification and simulation as exported (or constant and/or timeseries) pollutants in TUFLOW HPC
2. Execute TUFLOW HPC, with the intention of
   i. Reading the TUFLOW FV mesh check files to determine the receiving water model domain location and extent
   ii. Comparing this mesh with the TUFLOW HPC grid to then determine which TUFLOW HPC cells are to be designated as transfer cells where boundary conditions for TUFLOW FV are to be written (see Section 3.1) from TUFLOW HPC predictions
   iii. Checking the pollutants specified in the pollutant export model for consistency with those set in the TUFLOW FV simulation
   iv. Executing the TUFLOW HPC catchment based hydrologic, hydraulic and pollutant export modelling over the period specified
   v. Writing TUFLOW FV boundary conditions at designated transfer cells, including assignment of constant and/or timeseries pollutants in addition to those computed dynamically within TUFLOW HPC
   vi. Reporting catchment based simulation results such as water depth, velocity, dynamic pollutant concentrations in the surface and/or subsurface domains, dry store evolutions and/or erosion/deposition zones (see Section 3.2) and downstream summed flows and pollutant loads leaving the TUFLOW HPC domain and entering the TUFLOW FV mesh
3. Re-execute TUFLOW FV with the intention of
   i. Executing hydrodynamic, sediment transport, water quality and particle tracking (or user selectable module subsets/combinations thereof) receiving waterway modelling, using the boundary conditions developed by TUFLOW HPC above
   ii. Reporting receiving waterway simulation results such as pollutant concentrations and diagnostic mass fluxes

3 Process descriptions

Previous chapters have presented an overview of the architecture and capabilities of TUFLOW CATCH. This chapter presents the details of the processes that TUFLOW CATCH executes. It does not present the processes executed by either TUFLOW HPC or TUFLOW FV: these are detailed in the respective model user and science manuals, and relevant release notes here:

- TUFLOW HPC
- TUFLOW FV

TUFLOW CATCH provides these primary functions:

- Coordination of the execution of TUFLOW HPC and TUFLOW FV across a whole-of-catchment domain (**Hydrology** and **Integrated** configurations)
- Automatic geolocation and writing of flow and concentration boundary conditions for TUFLOW FV (as the receiving water model), generated from TUFLOW HPC predictions (as the catchment model) (**Hydrology** and **Integrated** configurations)
- Pollutant export and transport calculations within a catchment (**Pollutant Export** and **Integrated** configurations)

The first of these is its core architectural capability and so is described in Section 2.3.1. The latter are technical componentry of this architecture and so are detailed here in Section 3.1, Section 3.2 and Section 3.3, respectively.

3.1 Geolocation

Manually linking catchment and receiving water models can potentially be a time consuming and error prone process. When executed in configurations other than **Pollutant Export** (see Section 1.3), TUFLOW CATCH undertakes this task automatically via a process of geolocation, whereby TUFLOW HPC cells that spatially coincide with either TUFLOW FV nodestring inflows (user nominated, see Section 4.5.4) or TUFLOW FV mesh cells are identified. These TUFLOW HPC cells are called transfer cells. Once identified, these transfer cells track the local surface and groundwater flow volumes and constituent masses predicted by TUFLOW HPC, and each transfer cell's outflows are converted into timeseries and exported into the comma delimited (.csv) format expected by TUFLOW FV as boundary conditions. It is noted that:

- Where the user has nominated a nodestring/s as transfer locations from TUFLOW HPC to TUFLOW FV, TUFLOW CATCH will write the corresponding TUFLOW FV boundary condition files as 'Q' types that include the transfer of momentum from TUFLOW HPC to TUFLOW FV. As such, these boundaries (and specifying the corresponding TUFLOW FV nodestrings) should be considered where channelised riverine inflows and the like are to be matched, i.e. where inflow momentum is important in controlling receiving water hydrodynamics
- Where TUFLOW CATCH automatically geolocates non-nodestring transfer locations from TUFLOW HPC to TUFLOW FV, TUFLOW CATCH will write the corresponding TUFLOW FV boundary condition files as 'QC' types that exclude the transfer of momentum from TUFLOW HPC to TUFLOW FV. As such, these boundaries should typify non-channelised 'lateral' inflows where momentum transfer is less important in controlling receiving water hydrodynamics
- Boundary data for TUFLOW FV is written with date (`dd/mm/yyyy hh:mm:ss`) format
- TUFLOW HPC cells that are located within the TUFLOW FV mesh but are not transfer cells (e.g. lie well within the TUFLOW FV model mesh) are designated as deactivated within TUFLOW HPC and are not included in simulation

This automated selection of linkage cells is sufficiently robust to handle relative differences in mesh/grid resolution between TUFLOW HPC and TUFLOW FV, including cases where the TUFLOW HPC model is higher resolution than the (local) TUFLOW FV model mesh, and vice-versa. Some typical cases are presented in Figure 3.1.

Figure 3.1: Examples of linkages under varying TUFLOW HPC and TUFLOW FV cell resolutions

After all mesh elements and boundary nodestrings are processed, any cells entirely within the TUFLOW FV mesh are deactivated from TUFLOW HPC computations - these locations within the overall model domain are simulated by TUFLOW FV.

The locations of the TUFLOW HPC transfer cells automatically geolocated by TUFLOW CATCH are reported in the TUFLOW HPC `hpc_transfer` check file for review. The corresponding TUFLOW FV boundary condition locations are also reported in the TUFLOW FV `bc_check_P` check files. An example of both is presented in Figure 3.2, with TUFLOW HPC and TUFLOW FV check file outputs on the left (brown squares) and right (red dots), respectively.
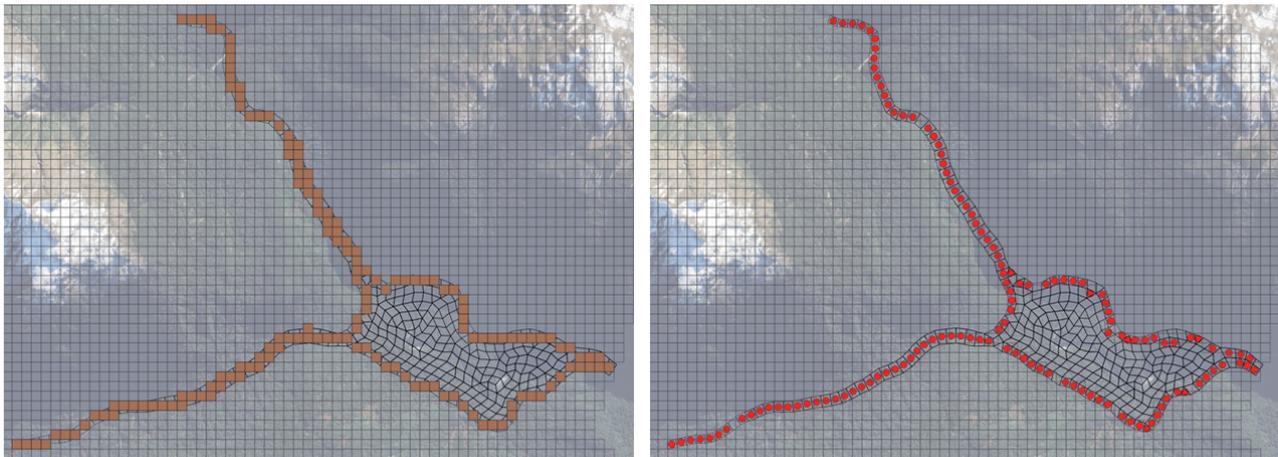
Figure 3.2: HPC transfer cell (left) and TUFLOW FV boundary cell (right) check file examples

The above geolocation process does not exclude or prevent the TUFLOW FV user from manually specifying additional boundaries to a TUFLOW FV model. For example, tidal or wastewater discharge (or other) boundaries can be specified by the user within the TUFLOW CATCH control file as per a normal TUFLOW FV model set up by specifying 'bc' blocks as required. TUFLOW CATCH will collect these manual (user defined) boundaries and all automatically geolocated boundaries and apply them to the execution of TUFLOW FV under TUFLOW CATCH.

An example of how this geolocation method supports transfer of water, concentrations and momentum is provided in Figure 3.3. The animation presents a catchment derived TUFLOW HPC flow originating from left of screen (and from the fixed grid domain) being transferred automatically into the (flexible mesh) TUFLOW FV domain, and then advected downstream to the right. Constituent concentrations vary from low (blue) to red (high).

Figure 3.3: Omitted in PDF version: Example of transferral of an inflow (from left to right) from TUFLOW HPC to TUFLOW FV.

3.2 Pollutant export

TUFLOW CATCH supports the simulation of pollutant generation and associated surface (and optionally subsurface) transport within the catchment domain. It does so on a spatially varying basis via use of materials so that, in a manner analogous to hydraulic roughness calculations (that also use materials), pollutant export simulation is ultimately affected on a computational cell by computational cell basis. This obviates the need to make top-down lumped hydrologic or pollutant export related assumptions, and facilitates the solution of the equations of motion and solutes on a spatially and temporally resolved basis.

Pollutant export simulation within TUFLOW CATCH allows for any of the following simulation methods per pollutant:

- **Constant.** Specification of a constant concentration to be written to TUFLOW FV boundary conditions without numerical simulation in TUFLOW HPC. Examples include water quality constituents that are not meaningfully conceptualised as being liberated from a ground surface, such as dissolved oxygen, or
- **Timeseries.** Specification of a time varying concentration, again to be written to TUFLOW FV boundary conditions without numerical simulation. Examples include water temperature
- **Material based.** Specification of the following on a material by material basis, for a given pollutant:
    - The computational pollutant export method to be used
    - The parameters associated with the selected computational pollutant export method

For a model demonstration of the above pollutant export options, please refer to TUFLOW CATCH Tutorial Model 1.

Different pollutant export methods across the above options can be used within a single TUFLOW CATCH simulation for different pollutants. A given pollutant, however, should not have different material based pollutant export methods applied to it within a given simulation. Commands are provided in detail in Chapter 4, however an example of such a specification is provided following, with incomplete (…) parameter lists for brevity.

```
Constant POLLUTANT_A == 8.0
Time-Series POLLUTANT_B == temptre

Material == ALL
    POLLUTANT_C, Method == method1, param1 == 100.0, …
    POLLUTANT_D, Method == method2, param1 == 10.0, …
    POLLUTANT_E, Method == method1, param1 == 0.17, …
    POLLUTANT_F, Method == method2, param1 == 1.23, …
    …
End Material

Material == 1, 4
    POLLUTANT_C, Method == method1, param1 == 43.0 …
    POLLUTANT_E, Method == method1, param1 == 0.37 …
    …
End Material
```

Multiple constant and time-series pollutants can be specified (via individual command lines), and material blocks can be specified to apply to more than one material (the above example applies to ALL materials, then materials 1 and 4, for example). In a manner akin to specification of roughness in TUFLOW HPC, sequences of material blocks progressively spatially overwrite in the order presented. In the above example, materials 1 and 4 would therefore be interpreted as

```
Material == 1, 4
    POLLUTANT_C, Method == method1, param1 == 43.0, …
    POLLUTANT_D, Method == method2, param1 == 10.0, …
    POLLUTANT_E, Method == method1, param1 == 0.37, …
    POLLUTANT_F, Method == method2, param1 == 1.23, …
    …
End Material
```

Materials 2 and 3 would be as per the ALL specification above.

Different computational pollutant export methods can be assigned to different pollutants within a single material block. The same computational pollutant export method should be assigned to the same pollutant across multiple material blocks, albeit with different parameterisations. For example, POLLUTANT_C should not have the Washoff1 method applied in material 3 and the Shear1 method applied in material 1.

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The above pollutant export models are described following.

3.2.1 Constant

The constant pollutant export method is the simplest of all available methods. It does not involve any calculations within TUFLOW HPC. Rather, it has TUFLOW CATCH assign the specified constant value to the relevant column in all TUFLOW FV boundary condition files produced by TUFLOW HPC, for all times. It is suitable for pollutants that are conceptually inconsistent with generation from a ground surface, such as dissolved oxygen or phytoplankton.

3.2.2 Timeseries

The timeseries pollutant export method does not involve any calculations within TUFLOW HPC. Rather, it has TUFLOW CATCH assign an interpolated timeseries value to the relevant column in all TUFLOW FV boundary condition files produced. Interpolation is based on matching the specified timeseries timestamp with the output frequency of TUFLOW FV boundary condition files. It is suitable for pollutants that are conceptually inconsistent with generation from a ground surface and also likely to vary temporally, such as water temperature. One timeseries per pollutant can be specified and it is applied across the entire model domain.

3.2.3 Material based export

The material based pollutant export method involves cell by cell calculations within TUFLOW HPC, coordinated by TUFLOW CATCH. The available methods are described following.

3.2.3.1 Accumulation and washoff

Accumulation/washoff methods are common in urban water modelling and are conceptually distinct from event mean concentration / dry weather concentration (EMC/DWC) methods. The former have been the subject of considerable research and development since at least the 1970s. In short, the accumulation washoff method conceptualises pollutant accumulation during no-flow or low-flow conditions and washoff during higher-flow conditions. Typically, a proportion of the accumulated pollutant runs off if a threshold flow or flow depth is reached (i.e. enough energy is available for liberation of mass). This mechanism is generally based on a non-linear function for the runoff, if runoff is not explicitly simulated (e.g. in models that make lumped average assumptions). TUFLOW CATCH's implementation of this method (that explicitly simulates hydrology so does not resort to such lumped assumptions) is described following. It can be applied equally to both dissolved and particulate pollutants.

3.2.3.1.1 Accumulation

TUFLOW CATCH allows for the specification of accumulation rates for each pollutant simulated, on a spatially varying (material by material) basis. These rates are linearly applied in time until a user specified maximum areal mass (also kg/ha/yr) is reached. Even though these rates and maximums are specified per material, they are used to undertake accumulation calculations on a cell by cell basis at the beginning of every timestep. For example, if a user has specified a 5 metre TUFLOW HPC grid size, then pollutant accumulation calculations will be undertaken at this same spatial resolution.

As each pollutant accumulates, it is added to TUFLOW HPC's dry store mass, which is also tracked on a cell by cell basis. It is this dry store mass that is then depleted (washed off) when user specified hydrologic conditions are met (see Section 3.2.3.1.2). Each pollutant's and each cell's dry store mass is temporally incremented at the specified rate, up to a user specified limiting areal mass (kg/ha). Accumulation does not occur (i.e. the accumulation rate is set to zero) if washoff is occurring during a given timestep.

One advantage of the pollutant accumulation method is that the user has full control over the spatial distribution of the associated rates, through the use of materials. Specifically, each material is assigned these rates, and materials are (typically) specified as polygons that cover regions with similar pollutant properties (analogous to roughness materials). Although it may seem natural to equate this spatial distribution of pollutant properties with land uses (as is often the case in lumped hydrology/pollutant export models), this is not a requirement of TUFLOW CATCH. Indeed, the user has full discretion with regard to how pollutant properties are set, and whilst perhaps making initial use of land use data, it is possible that different material polygons that represent the same land use are given different pollutant properties.

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For example, an 'urban' land use might be tagged to two separate housing estates in a generic land use GIS vector layer, but the user may also know that one estate has stormwater treatment devices in place and the other does not. In such an instance, different pollutant accumulation (and washoff) parameters can be applied through TUFLOW CATCH. In short, TUFLOW CATCH has been deliberately designed to allow users to insert their local knowledge of the systems being modelled into the model build process directly, down to a cell by cell spatial resolution if required, without being limited by lumping assumptions.

Akin to the flexibility offered in spatial resolution, TUFLOW CATCH allows full control over the specification of pollutant accumulation rates, and in doing so allows the user to inform the modelling process with local knowledge and expertise.

The relevant TUFLOW CATCH commands are described in Section 4.5.3.3.1.

3.2.3.1.2 Washoff

TUFLOW CATCH allows for the specification of the manner in which the accumulated dry store mass described in Section 3.2.3.1.1 is washed off in response to local hydrologic conditions. This specification occurs in the same command line as accumulation rates (for a given pollutant), which is therefore also on a material by material basis: for a given material and pollutant, the accumulation and washoff parameters are related, and therefore co-specified.

The TUFLOW CATCH washoff method is presented conceptually in Figure 3.4. Under wet weather conditions, a mass per unit area Δ (kg/ha) is released from the dry store mass (α_{dry}, kg/ha) into the wet store (α_{wet}, concentration C, mg/L) (i.e. to add to a water concentration), governed by a user defined time constant (also referred to as a time of concentration), τ_c, such that over a timestep dT (with appropriate conversion factors for reconciliation of units):

$$\Delta = dT \frac{\alpha_{dry}}{T_c} \tag{3.1}$$

This release only occurs once user specified minimum rain rates, R_r, and surface water depths, d, have both been exceeded. Otherwise, the dry store masses described in Section 3.2.3.1.1 are accumulated at the rates specified.
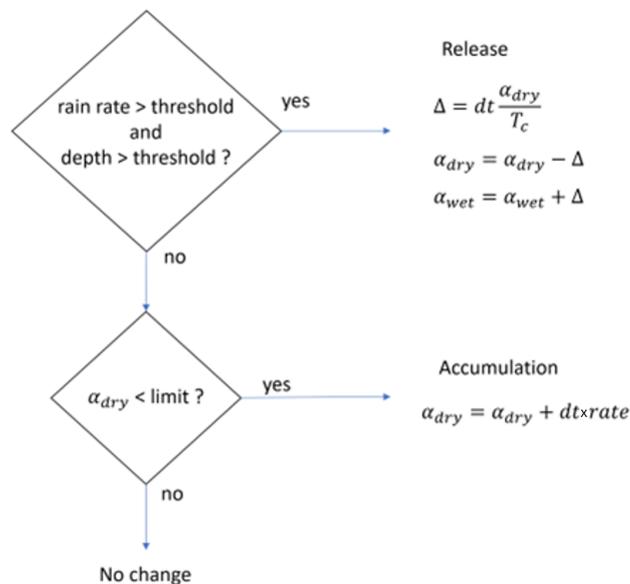
Figure 3.4: Washoff method

If a pollutant is released into its wet store, it is transported according to the progression of hydrologic and hydraulic flows (and associated advection and dispersion), which is completed as a separate calculation step to the generation update.

Settling velocities are assigned to individual pollutants, and may vary spatially with material. An example of where the latter might be applied is when sediment is known to flocculate in saline conditions and hence have its settling properties modified. Any settling returns pollutants from the wet store to the dry store. This is not recommended for

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dissolved pollutants, and where settling is to be turned off, the velocity should be set to zero. The mass flux per unit area in time dT due to settling Δ (kg/ha) is given by Equation 3.2:

$$\Delta = dT \times w_s C \qquad (3.2)$$

w_s is the user specified settling velocity, C is the wet store cell concentration of pollutant. No other constraints to settling occurring are applied in this model.

If soils and subsurface flow (interflow) is not simulated in TUFLOW HPC, then this transport is purely surficial. If soils are included then released pollutants will be transported in both the surface and subsurface in accordance with water flows. TUFLOW CATCH allows for the optional prevention of infiltration of a given pollutant into the subsurface flow if soils are included in the TUFLOW HPC simulation. This is most relevant for particulate pollutants such as sediment or particulate organic material.

A conceptualisation of TUFLOW CATCH's pollutant generation and transport methods is presented in Figure 3.5.
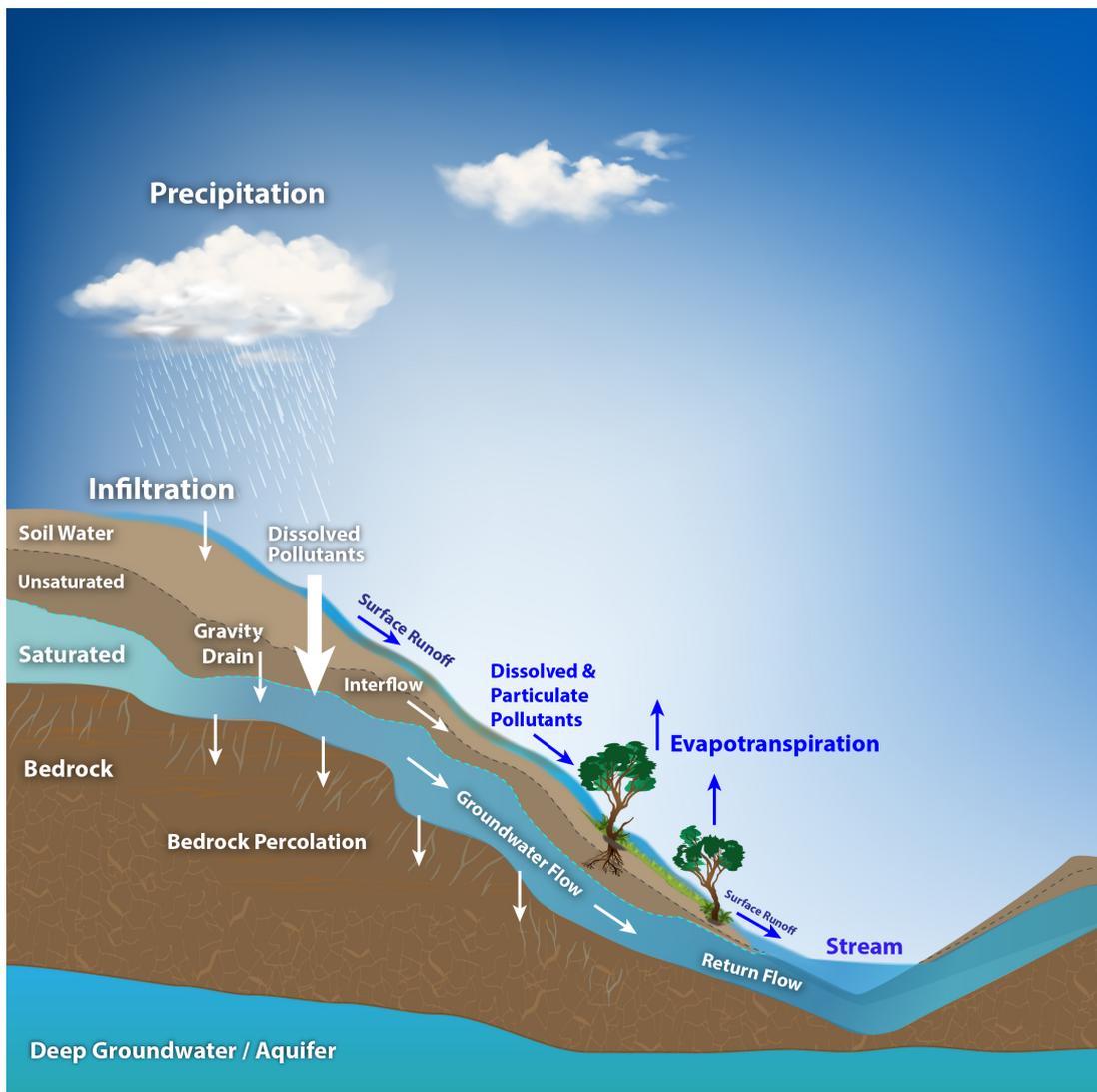
Figure 3.5: TUFLOW CATCH pollutant generation method

The relevant TUFLOW CATCH commands are described in Section 4.5.3.3.1.

3.2.3.2 Shear stress

Shear stress generation methods are common in natural waterway modelling studies (e.g. estuaries and coastal oceans), particularly with regard to the simulation of sediment transport. In short, these methods conceptualise sediment release from the bed as a function of overlying hydrodynamic shear stress: once a specified minimum shear stress is exceeded, sediment is released to the water column. Similarly, these methods also allow for deposition of previously suspended sediment back to the bed, and this is typically allowed to occur (at a set settling velocity) once ambient hydrodynamic shear stress drops below a specified maximum depositional shear stress. More advanced methods allow for construction of intermediary bed roughness models that translate raw hydrodynamic shear stress to the corresponding shear stress that is actually felt by the bed and can therefore cause erosion (or allow deposition). These methods therefore allow for the ongoing erosion and deposition of particulate materials as hydrodynamic conditions evolve in time and space. TUFLOW CATCH's implementation of this method is described following. It is intended to be applied primarily to particulate pollutants, rather than dissolved.

3.2.3.2.1 Erosion

TUFLOW CATCH allows for the specification of erosion behaviour of any pollutant, on a spatially varying (material by material) basis. Even though this behaviour is specified per material, it is used to undertake erosion calculations on a cell by cell basis at the beginning of every timestep. For example, if a user has specified a 5 metre TUFLOW HPC grid size, then erosion calculations will be undertaken at this same spatial resolution. As each pollutant erodes from its dry store mass, it is released to its wet store and advected/dispersed accordingly. This removal is tracked and reported at the end of a simulation as a loss to each cell's dry store mass (kg/ha).

TUFLOW CATCH adopts the Mehta erosion model on a cell by cell basis, such that the erosive flux Δ (kg/ha) is given by Equation 3.3 in time dT (with appropriate units conversions):

$$\Delta = dT \times E_r \left(\frac{\tau}{\tau_{ce}} - 1 \right)^{\alpha} \tag{3.3}$$

E_r is the erosion rate (g/m^2/s), τ is the simulated hydrodynamic shear stress (N/m^2), τ_{ce} is the user specified critical shear stress for erosion (N/m^2), α is a dimensionless parameter set to 1.0 and $\tau > \tau_{ce}$. TUFLOW CATCH does not deploy a bed roughness model so τ is the pure hydrodynamic shear stress calculated from cell velocity. Once computed, eroded mass is tracked so that at simulation end, TUFLOW CATCH produces a map of eroded areas that allows for identification, for example, of 'hotspot' erosion locations. Users specify a limit to the mass of pollutant per unit area that is erodable within each material. This can be converted by the user to a depth via independent post processing steps if desired, by assuming a bulk density. This same output layer presents areas of accumulation, if this has occurred.

The relevant TUFLOW CATCH commands are described in Section 4.5.3.3.2.

3.2.3.2.2 Deposition

TUFLOW CATCH allows for the specification of depositional behaviour of any pollutant, on a spatially varying (material by material) basis. Even though this behaviour is specified per material, it is used to undertake deposition calculations on a cell by cell basis at the beginning of every timestep. As each pollutant deposits from its wet store mass, it is transferred to its dry store mass. This deposition is tracked and reported at the end of a simulation as a gain to each cell's dry store mass (kg/ha).

TUFLOW CATCH adopts the Krone deposition model on a cell by cell basis within this pollutant export model, such that the areal depositional flux Δ (kg/ha) in time dT is given by Equation 3.4. This is a more advanced version of the deposition approach used in the accumulation washoff model (Equation 3.2).

$$\Delta = dT \times \left(1 - \frac{\tau}{\tau_{cd}} \right) w_s C \tag{3.4}$$

τ is the raw hydrodynamic shear stress (N/m^2), τ_{cd} is the user specified critical shear stress for deposition (N/m^2), w_s is the user specified settling velocity, C is the wet store cell concentration of pollutant and $\tau < \tau_{cd}$.

The relevant TUFLOW CATCH commands are described in Section 4.5.3.3.2.

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3.3 Interventions

TUFLOW CATCH supports the simulation of spatially distributed catchment based measures to remove pollutants from surface waters. These measures are referred to as interventions, and might include devices such as constructed wetlands, bioretention systems, grassed swales, riparian revegetation strips or similar. TUFLOW CATCH does so by allowing users to specify:

- The location and orientation of any number of intervention devices via a user digitised polyline for each
- The pollutant removal properties of each intervention device, with these properties adjustable within a device on a pollutant by pollutant basis

TUFLOW CATCH explicitly predicts surface hydraulics (i.e. water location, depth, velocity and associated pollutant concentrations) to the spatial resolution of a grid cell. This offers a powerful potential to users when simulating interventions: it means that intervention devices can be digitised in the actual locations they are intended to be (or already exist) and to therefore interact only with the water volume that TUFLOW CATCH predicts to pass through those locations. This obviates the need to somehow parameterise this volume by relying on proportioning or other assumptions - TUFLOW CATCH explicitly avoids this for the user as a matter of course, and does not resort to top down or lumped assumptions.

TUFLOW CATCH performs removal calculations based on mass fluxes. TUFLOW CATCH does not modify concentrations directly. This is because mass flux based approaches are meaningful in terms of environmental process simulation and understanding - concentrations are very much less so. This is discussed in detail in one of TUFLOW's global webinars. The pollutant mass removal methods offered by TUFLOW CATCH's intervention devices are (per pollutant):

- **Equation:** An equation based reduction in pollutant mass flux passing through a device
- **Table:** A two dimensional array of proportional pollutant mass removals that vary based on (dynamically simulated) incoming pollutant concentration and flow rate

For a model demonstration of the above mass removal options, please refer to TUFLOW CATCH Tutorial Model 2.

Different mass removal methods across the above options can be used within a single TUFLOW CATCH intervention device for different pollutants. Commands are provided in detail in Section 4.5.3.5, however the fundamental premise is that interventions are specified via device blocks (akin to material based pollutant export), as follows.

```
Device == ALL
    POLLUTANT_C, Method == Eqn,   Eqn == Constant, Coefficients == 1.0
    POLLUTANT_D, Method == Eqn,   Eqn == Constant, Coefficients == 0.2
    POLLUTANT_E, Method == Table, Path == ..\..\bc_dbase\Alldevices.csv
    POLLUTANT_F, Method == Eqn,   Eqn == Constant, Coefficients == 0.1
End Device

Device == Wetland1
    POLLUTANT_C, Method == Eqn,   Eqn == Constant, Coefficients == 0.5
    POLLUTANT_E, Method == Table, Path == ..\..\bc_dbase\wetland1.csv
End Device
```

Multiple methods can be specified within a device block (one for each pollutant), and subsequent block specifications can be constructed to progressively overwrite previous commands. For example, the above applies a suite of methods to ALL devices in the first block, and these are then partially overwritten (modified) for Wetland1. In a manner akin to specification of pollutant export properties, sequences of blocks affect this overwrite in the order presented. In the above example, device Wetland1 would therefore be interpreted as

```
Device == Wetland1
    POLLUTANT_C, Method == Eqn,   Eqn == Constant, Coefficients == 0.5
    POLLUTANT_D, Method == Eqn,   Eqn == Constant, Coefficients == 0.2
    POLLUTANT_E, Method == Table, Path == ..\..\bc_dbase\wetland1.csv
    POLLUTANT_F, Method == Eqn,   Eqn == Constant, Coefficients == 0.1
End Device
```

Other intervention devices would be as per the ALL specification above. The relevant TUFLOW CATCH commands are described in Section 4.5.3.5.

3.3.1 Mass removal

TUFLOW CATCH offers a range of mass removal methods. Regardless of individual removal details however, all methods rely on initially computing the incoming mass flux of pollutant j, F_j^{in} across cell faces intersected by the intervention polyline, at each simulation timestep. It is this mass flux (not concentration) that is subsequently adjusted by TUFLOW CATCH based on the operation of user defined mass removal methods. These methods are described following.

3.3.1.1 Equation

3.3.1.1.1 Constant

The constant mass removal method is the simplest of all available methods. At each computational timestep, this method multiplies the incoming mass flux of pollutant j by the user specified factor. This factor (in the range 0.0 - 1.0) is a mass removal factor for a given constituent, R_j, where the corresponding outgoing pollutant mass flux for constituent j, F_j^{out} is given by Equation 3.5.

$$F_j^{out} = (1 - R_j) \times F_j^{in} \tag{3.5}$$

The removed flux F_j^{rem} is therefore given by Equation 3.6.

$$F_j^{rem} = (R_j) \times F_j^{in} \tag{3.6}$$

For example, if a user sets R_j to be 0.7 for a given intervention device and constituent, then 70% of pollutant j's mass flux is removed at each timestep, and 30% is allowed to pass.

The relevant TUFLOW CATCH commands are described in Section 4.5.3.5.1.

3.3.1.1.2 Other

Other equation based interventions may be implemented in future. Contact support@tuflow.com with requests or suggestions.

3.3.1.2 Table

The table mass removal method is an extension of the constant mass removal method in that it allows the user to specify different R_j for different (dynamically computed) environmental conditions. Specifically, this method allows the user to specify the variation of R_j as a function of both:

- Incoming flow rate (m^3/s), and
- Incoming pollutant concentration (variable units)

This approach is supported in acknowledgement that some intervention devices are able to treat higher concentrations of pollutants entering a device at lower flow rates more efficiently and effectively than the same pollutant entering at lower concentrations and higher flow rates. This variation in R_j is provided via a text based table input, with:

- A rows defining the variation in R_j with incoming concentration from left to right, for a given incoming flow rate, and
- A columns defining the variation in R_j with incoming flow rate from top to bottom, for a given incoming concentration

At each timestep, TUFLOW CATCH uses incoming concentrations and flow rates to dynamically interpolate a value of R_j from the user specified table, and applies Equation 3.5 accordingly.

Support for this mass removal method is only possible because TUFLOW CATCH solves the equations of motion and transport to predict temporally and spatially varying water velocities (flow rates) and concentrations. Such a capability is difficult to offer under, for example, the application of lumped assumptions that do not admit the explicit simulation of water as it moves through environmental systems.

The relevant TUFLOW CATCH commands are described in Section 4.5.3.5.2.

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3.4 Non-hydrologic surface loads

TUFLOW CATCH supports simulation of the introduction of non-hydrologic (i.e. independent of rainfall) surface flows and loads to the catchment domain. This feature might be used, for example, to simulate the discharge of sewage treatment plants, groundwater exfiltration or other non-hydrologic processes. This simulation is spatially explicit: flows and pollutants are introduced where they actually occur on ground rather than be distributed across a lumped computational subcatchment. Simulation is affected through construction of point, line or region GIS features (using the standard TUFLOW 2d_sa_ empty GIS layer), and linking associated feature names with entries in the TUFLOW database csv file. These entries then point to flow and concentration timeseries data.

The relevant TUFLOW CATCH commands are described in Section 4.5.3.6.

4 Simulation construction

4.1 Context

Previous sections have presented the architecture and processes available within TUFLOW CATCH. This section describes the usage intent and construction of a TUFLOW CATCH simulation. This includes the use of the TUFLOW CATCH QGIS plugin, descriptions of all commands, with hyperlinks to the Appendices where commands and explanations are listed in a searchable and sortable table for ease of access.

4.2 Usage intent

Depending on the chosen configuration, TUFLOW CATCH coordinates and executes TUFLOW HPC, and/or a pollutant export model and/or TUFLOW FV, all automatically and with no direct user input required to affect any of these linkages. This does not, however, mean that TUFLOW CATCH cannot be run until all models (TUFLOW HPC, pollutant export and TUFLOW FV) are fully constructed, even if the target configuration requires all these models eventually. To the contrary, the intention is that the single TUFLOW CATCH control file is used as the common control file for all model construction from project inception, even where this construction is undertaken in parallel by multiple users.

The reason for this approach is that, for example, the TUFLOW HPC block of the TUFLOW CATCH control file is nothing other than a standard TUFLOW HPC *.tcf control file, with a small number of additional TUFLOW CATCH commands. This is intentional, and means that an experienced (or beginner who refers to the TUFLOW user manual) TUFLOW HPC modeller can follow normal model set up processes and procedures to construct the TUFLOW HPC component of TUFLOW CATCH model, unhindered, but via the TUFLOW CATCH control file arrangement. The same logic applies to users constructing the TUFLOW FV sections of a TUFLOW CATCH model - the TUFLOW HPC sections of the TUFLOW CATCH control file can be turned off and TUFLOW FV model construction commenced as usual through the *.tcc rather than *.fvc control file. Users in teams that adopt this approach may want to consider using versioning control software to manage concurrent multiple user contributions.

It is understood that in some legacy cases, existing TUFLOW HPC or TUFLOW FV models (that were originally built outside TUFLOW CATCH) will need to be brought into a block of a TUFLOW CATCH control file. If this is the case, then the process is a matter of copying and pasting the original control files into the relevant TUFLOW CATCH control file block and populating the supporting folder structures with model data (see following sections). The key change that will be required on pasting into a *.tcc block will be to ensure file path references are correct (see following sections). This is only required from the *.tcc as it points to immediately called files, and no further down the folder tree.

4.3 Initialisation

TUFLOW CATCH requires construction of a suite of folder substructures to support simulations. These should be all co-located at the same folder level underneath a single directory that sits within an overall project directory. These substructures correspond to each of the three products potentially used in a TUFLOW CATCH simulation, and should be named as follows (with 'TUFLOW' referring to TUFLOW HPC):

- TUFLOW
- TUFLOWCATCH
- TUFLOWFV

Each of these substructures has its own subfolder arrangement, consistent with those suggested for standalone TUFLOW HPC and TUFLOW FV modelling studies. For consistency, the suggested TUFLOWCATCH subfolder arrangement is also similar.

To assist with this set up, and indeed more broadly with the initialisation, execution and results interrogation of a TUFLOW CATCH simulation, a freely available TUFLOW CATCH QGIS plugin has been developed:

- The TUFLOW CATCH plugin (as a zip file) can be accessed here

TUFLOW CATCH

- Instructions on installing TUFLOW plugins (including the TUFLOW CATCH plugin) from zip files is provided here.

Further resources related to using the TUFLOW CATCH plugin are provided on the TUFLOW Wiki.

4.4 General arrangement

4.4.1 Folder structure

The overarching TUFLOW CATCH folder structure created using the QGIS plugin will appear (at the first tier) as per Figure 4.1 (with the top level folder named 'Modelling' selected by the user during initialisation).
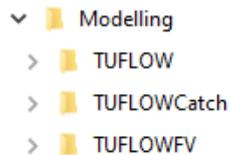
Figure 4.1: TUFLOW CATCH folder structure

The expansion of these folders to one level is as per Figure 4.2. The commonality of folder structures should be evident.
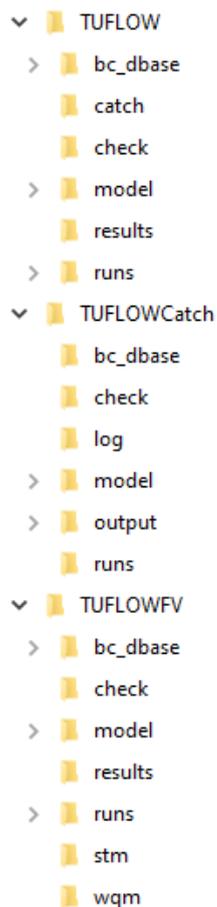
Figure 4.2: TUFLOW CATCH folder structure, expanded

The three relevant executable suites (TUFLOW CATCH, TUFLOW HPC and TUFLOW FV) should be stored in separate subfolders, but within a general EXE folder for neatness, e.g. `C:\EXE\TUFLOWCATCH\2024.0\` , `C:\EXE\TUFLOW\2024.0\` and `C:\EXE\TUFLOWFV\2024.0\` . The use of version names in the directory structure is important as the TUFLOW

software suite allows multiple versions to coexist on the same computer, provided the executable (.exe extension) and libraries (.dll and .ptx extensions) for a specific version are contained within their own sub-folder. The user downloaded version may differ from the examples and the version sub-folder name/s should be amended to reflect the downloaded version/s.

4.4.2 Intended workflow

The above folder structure supports the overall intended TUFLOW CATCH simulation workflow, such that:

- The TUFLOWCATCH folder (and control file, see below) is the single point of contact for execution of TUFLOW CATCH simulations, regardless of the combination of TUFLOW HPC or TUFLOW FV models being called
- All simulation results (again, regardless of what subsidiary TUFLOW products are called) are written to the TUFLOWCATCH/results subfolder: users should never need to navigate to TUFLOW HPC or TUFLOWFV output/results folders to examine results from TUFLOW CATCH simulations
- Users do not need to (and should not) set up their own *.tcf (TUFLOW HPC) or *.fvc (TUFLOW FV) top level control files in the respective TUFLOW and TUFLOWFV runs directories: TUFLOW CATCH does this automatically based on information provided in the overarching TUFLOW CATCH control file
- Calls to subsidiary first level control files and/or folders from the overarching TUFLOW CATCH control file for both TUFLOW HPC and TUFLOW FV (such as *.tgc (file), bc_dbase (folder) etc. (TUFLOW HPC) or *.fvsed etc. (TUFLOW FV)) need to be provided as relative paths to locations that sit within the respective TUFLOW or TUFLOWFV subfolder arrangements, from the TUFLOW CATCH runs directory
- All model data (e.g. grids, GIS, boundaries etc.) should be located within respective subfolder arrangements for TUFLOW and TUFLOW FV
- These first level control files (that sit within the TUFLOW or TUFLOWFV directory structures) then should be constructed to make the usual relative calls to all other files and data within respective their subfolder arrangements
- It is suggested that users exploit standard text editor capabilities of opening one text file (e.g. a *.tgc file) from from the currently open text file (i.e. the *.tcc so as to not need to explicitly navigate between subfolder structures. This is most commonly achieved by right clicking on the relative path of the other file (e.g. *.tgc) as specified in the open text file (i.e. the *.tcc) and using the context menu to open the second file, as per Figure 4.3 (where the relative path on line 48 was right clicked)

```
42      ! Solver
43      Solution scheme == HPC
44      Timestep Initial == 1
45      Time format == TUFLOWFV
46
47      ! Control files
48      Geometry Control File == ..\..\TUFLOW\model\test_001.tgc
49      BC Control File == ..\..\TUFLOW\model\test_001.tbc
50      Read Materials File == ..\..\TUFLOW\model\test_mat.csv
```
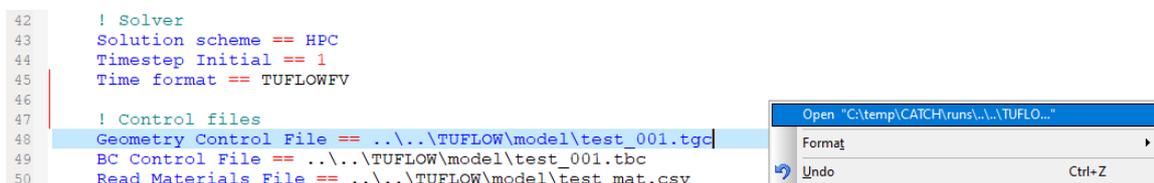
Figure 4.3: Opening one text file from the relative path in an already open text file

In short, it is intended that the:

- TUFLOW CATCH control file is the primary point of construction and execution contact
- TUFLOW and TUFLOWFV folder substructures contain respective input model data such as GIS layers, DEMs etc
- TUFLOWCATCH folder substructure contains model results

Subsequent sections describe the TUFLOW CATCH control file set up and model execution.

4.5 TUFLOW CATCH control file

A TUFLOW CATCH simulation is set up and executed by constructing a TUFLOW CATCH control file, extension *.tcc. This file should reside in the `TUFLOWCATCH\runs` directory set up with the TUFLOW CATCH QGIS plugin. The user is not required to (and should not) construct separate *.tcf or *.fvc control files. This TUFLOW CATCH control file has four separate but related blocks:

1. Global commands
2. Catchment Hydraulic Model (TUFLOW HPC) commands
3. Catchment Pollutant Export Model

4. Receiving Model (TUFLOW FV) commands

All blocks must be included in the above order, but the latter three can be optionally switched on and off with a single command (rather than extensive line commenting) to suit modelling needs. For example, a user working only on initial TUFLOW HPC model build and testing tasks can turn off the pollutant export and TUFLOW FV blocks (by specifying these block models to be the keyword 'None') and continue building a TUFLOW HPC model as per normal, without the need to always execute all components of TUFLOW CATCH (See `Catchment Hydraulic Model ==`, `Catchment Pollutant Export Model ==` or `Receiving Model ==`).

Construction of each of the TUFLOW CATCH control file blocks is described in the following sections.

4.5.1 Global commands

This initial section of the TUFLOW CATCH control file contains information that is applied equally to both TUFLOW HPC and TUFLOW FV. It is not declared as a block. These global commands are presented following (as hyperlinks to Appendix A), with command argument options also shown where appropriate. All commands are mandatory. Some commands can be overwritten if required within subsequent blocks (see Section 4.5.2 and Section 4.5.4).

Set the hardware to be used, with command arguments as either CPU or GPU:

`Hardware ==`

Set the GIS format to be used, with command arguments as either SHP (preferred) or GPKG:

`GIS Format ==`

Set projection to be used, as a path to a shape file. This will have been prepared by the TUFLOW CATCH plugin:

`SHP Projection ==`

If GPKG is specified as the format and TUFLOW FV is intended to be included in the TUFLOW CATCH simulation then this will need to be overwritten in the receiving model block (see Section 4.5.4) because TUFLOW FV does not yet support geopackage based simulation. Similarly, if GPKG is set, then the projection must also be set as follows

`GPKG Projection ==`

Set the time format, with command arguments as either ISODATE (`dd/mm/yyy hh:mm:ss`) or hours (a single float). It is strongly recommended that ISODATE be used for longer simulations, where interpreting hour output timestamps can be difficult:

`Time Format ==`

Set the start and end times in the format declared above:

`Start Time ==`
`End Time ==`

Set the directory for simulation outputs (e.g. xmdf and NetCDF results files). This can be set to any location as either a full path (e.g. `X:\Project\results`), or as a path relative to the location of the TUFLOW CATCH control file (e.g. `..\results`):

`Output Directory ==`

Set the directory for writing simulation check files (e.g. .shp files). This can be set to any location as either a full path (e.g. `X:\Project\check`), or as a path relative to the location of the TUFLOW CATCH control file (e.g. `..\check`):

`Write Check Files ==`

Set the directory for writing simulation log files. TUFLOW HPC and TUFLOW FV engine log files will be written to this location, as well as module log files (such as the water quality module of TUFLOW FV). This can be set to any location as either a full path (e.g. `X:\Project\runs\log`), or as a path relative to the location of the TUFLOW CATCH control file (e.g. log - which is the folder created by the TUFLOW CATCH plugin by default):

`Log Folder ==`

In order to collect all log files without name conflictions, TUFLOW CATCH renames the various log files before it writes them to the user nominated directory. The renaming convention is as follows:

- TUFLOW HPC related log files:

- `<TUFLOW CATCH tcc filename root>_catchment_hydraulic_***.t*f`
- TUFLOW FV related log files:
    - `<TUFLOW CATCH tcc filename root>_receiving_***.*log`

where *** indicates a usual extension expected in a log file such as "messages" (for TUFLOW HPC) or "ext_cfl_dt" (for TUFLOW FV) etc. For example, for a TUFLOW CATCH control file called SysModel_001.tcc, the following log files might be produced (depending on simulation options)

- TUFLOW HPC related log files:
    - `SysModel_001_catchment_hydraulic.hpc.tlf`
    - `SysModel_001_catchment_hydraulic.tlf`
    - `SysModel_001_catchment_hydraulic.tsf`
- TUFLOW FV related log files:
    - `SysModel_001_receiving_ext_cfl_dt.log`
    - `SysModel_001_receiving.log`
    - `SysModel_001_receiving.fvwqlog`

Set the directory for writing the TUFLOW FV boundary condition files prepared by TUFLOW CATCH from TUFLOW HPC simulation, including boundary condition blocks and underlying data (timeseries) files. This command is required even if TUFLOW FV is not used in a TUFLOW CATCH simulation, in which case template TUFLOW FV files will be written to this location. TUFLOW CATCH also writes TUFLOW HPC diagnostic information to this location (regardless of whether TUFLOW FV is simulated), including timeseries files of predicted catchment-wide summed cumulative volumes and/or masses. These files can be useful for providing system understanding, even when TUFLOW FV is not activated. This directory should be always set as the bc_dbase folder within the TUFLOW CATCH folder substructure (as generated by the TUFLOW CATCH QGIS plugin), as a path relative to the location of the TUFLOW CATCH control file (i.e. `..\bc_dbase`):

`Catch BC Output Folder ==`

Set the timestep (in simulation time seconds) at which lines within a boundary condition file for TUFLOW FV (created from TUFLOW HPC predictions) are separated (required even if TUFLOW FV not used). TUFLOW CATCH offers the user the option to set this timestep differently for different types of TUFLOW FV boundaries: nodestrings (Q boundaries that deliver momentum to TUFLOW FV) and lateral inflows (QC boundaries that do not deliver momentum to TUFLOW FV). It would be typical that nodestring boundaries are written at a shorter timestep to lateral boundaries, but this is not mandated, and the user is able to decide how this timestep relates to simulation time and file size constraints. The second command below is also used to set the output frequency for `Receiving Polygon` inflows and concentrations output if used:

`Catch BC Output Interval Nodestring ==` dT_{ns}

`Catch BC Output Interval Lateral ==` dT_{lat}

Set the frequency at which TUFLOW CATCH pauses to write out TUFLOW FV boundary condition files, in units of days (simulation time, required even if TUFLOW FV not used). Setting a value of 1 means that TUFLOW CATCH will hold all boundary information in memory for a day of simulation time, and then update TUFLOW FV boundary files (and summed flow and mass timeseries) with this held memory on a daily basis. For example, if outputs were set to be hourly via either of the above interval commands, then 24 lines would be added to each boundary file at time of writing:

`CSV Write Frequency Day ==` dT_{csv}

An example block of these global commands that together configure a TUFLOW CATCH simulation (with clarifying section headers as comments) is:

```
!_____
! GLOBAL SETTINGS
Hardware == GPU
GIS Format == SHP
SHP Projection == ..\..\TUFLOW\model\gis\projection.prj

!_____
! SIMULATION SETTINGS
Time Format == ISODATE
Start Time == 01/01/2021 00:00:00
End Time == 01/02/2021 00:00:00
```

```
!_____
! OUTPUT FOLDERS
Output Directory == X:\Project\results
Write Check Files == ..\check
Log Folder == ..\log

!_____
! BOUNDARY CONDITION CONFIGURATION
Catch BC Output Folder == ..\bc_dbase
Catch BC Output Interval Nodestring == 900
Catch BC Output Interval Lateral == 10800
CSV Write Frequency Day == 1
```

4.5.2 Catchment hydraulic model (TUFLOW HPC) commands

This block of the TUFLOW CATCH control file contains commands that construct a TUFLOW HPC simulation. These commands are almost entirely those that would be used in setting up a standalone TUFLOW HPC control file (*.tcf), with a small number of additional commands that relate to TUFLOW CATCH.

A number of commands issued in the Global commands section of the *.tcc can be overwritten here if needed. These are:

```
Hardware ==
GIS Format ==
```

If GIS Format is overwritten, then a subsequent new projection file is most likely required to be specified

```
SHP Projection ==
```

If GPKG is specified as the GIS format then the projection must also be set as follows

```
GPKG Projection ==
```

The catchment hydraulic model definition must be declared as a block that encloses all TUFLOW CATCH and TUFLOW HPC commands. This is different to the global commands section at the top of the TUFLOW CATCH control file, which does not need this encompassing structure. Set the beginning of the block, with command arguments as either HPC or none, and the end of the block (with no command arguments):

```
Catchment Hydraulic Model ==
    ... catchment hydraulic model commands ...
    ... catchment hydraulic model commands ...
    ... catchment hydraulic model commands ...
End Catchment Hydraulic Model
```

If the `Catchment Hydraulic Model` command is set to 'None', then catchment simulation is not executed, and TUFLOW FV will either:

- Read blank (interim) boundary condition files prepared by TUFLOW CATCH. This approach might be adopted for the initial stages of a TUFLOW FV model build, or dry period tidal / thermal stratification calibration of a receiving water, for example, or
- Read a suite of TUFLOW FV boundary condition files previously created by TUFLOW HPC, under TUFLOW CATCH running in **Hydrology** or **Integrated** configurations

The second approach above might be adopted when an initial **Hydrology** or **Integrated** simulation has been executed and a first pass corresponding suite of TUFLOW FV boundary condition files (that are not final, but at least sufficient for use in parallel preliminary TUFLOW FV calibration processes) has been produced. In this instance if:

- TUFLOW CATCH run Model_003.tcc (for example) produced initial TUFLOW FV boundary files

- The corresponding `..\TUFLOWCATCH\bc_dbase\Model_003_catchment_hydraulic.fvcatchbc` file could be copied as

    `..\TUFLOWCATCH\bc_dbase\Model_004_catchment_hydraulic.fvcatchbc` and

- Called automatically in `Model_004.tcc` by a TUFLOW CATCH simulation that has `Catchment Hydraulic Model == None`.

TUFLOW CATCH

This supports TUFLOW FV calibration tasks being executed, without relying on TUFLOW HPC. In order to avoid TUFLOW CATCH overwriting Model_003_catchment_hydraulic.fvcatchbc (which it would normally do if `Catchment Hydraulic Model` == None), the following command is required in the Receiving Model block of `Model_004.tcc` (the default is OFF)

`Preserve Catchment Inflows` == ON

This approach allows the TUFLOW HPC and TUFLOW modellers to progress independently for a time, gradually progressing their respectively calibrations without:

- Relying on each other to produce boundaries, and
- The need to continually rerun TUFLOW HPC to re-produce (identical) TUFLOW FV boundaries

This style of collaborative modelling is at the heart of TUFLOW CATCH's architectural design intent and is a key use case.

The TUFLOW CATCH commands contained within this Catchment Hydraulic Model block are described following, and all are mandatory unless noted otherwise.

Set the directory from which TUFLOW CATCH controls TUFLOW HPC. Unless there is a need to the contrary, this should be set as a relative path to the `TUFLOW\runs` directory set up by the TUFLOW CATCH QGIS plugin, i.e. `..\..\TUFLOW\runs`. Setting this to any other directory is not recommended:

`Runs Directory` ==

Set the full or relative path to the location of the the TUFLOW HPC executable (including the name of the executable itself, with .exe extension) to be called by TUFLOW CATCH:

`EXE` ==

Set the time format for output results. Given that the intention of TUFLOW CATCH is that it support longer term environmental investigations (i.e. not short term detailed 'traditional' flood studies), results written in hours format can be difficult to interpret in terms of seasonality, for example. As such, TUFLOW HPC can be instructed to write results in the time format adopted by TUFLOW FV. Doing so is strongly recommended, especially if TUFLOW FV is using the ISODATE format rather than hours:

`Time Format` == TUFLOWFV

Set the relationship between hours and dates. TUFLOW HPC reads boundary condition files and executes its internal computations using an hours (rather than date) timestamp, although this is being upgraded in the mid term. In order to coordinate simulation with TUFLOW FV, and to output results in date format, TUFLOW CATCH requires specification of the date that corresponds to zero hours in TUFLOW HPC boundary (and other) files. This command specifies that date at which boundary and other files refer to zero hours. Note the date time format expected, and that the seconds field is excluded:

`Zero Date` == <dd/mm/yyyy hh:mm>

Set TUFLOW HPC to write TUFLOW CATCH related map outputs (e.g. pollutant and other hydraulic xmdf outputs, see Chapter 6). This catch command argument can be comma delimited with other outputs if required:

`Output Map Data Types` == catch

Not mandatory. If TUFLOW CATCH is to be deployed in the pollutant export configuration (i.e. with no immediate intention to deploy TUFLOW FV, see Section 1.3), then the following must be set:

- The use of TUFLOW FV as a receiving model must be switched off. This is achieved by setting the receiving model block command as follows (see Section 4.5.4)

  `Receiving Model` == None

AND

- A single layer (either as a standalone file or as part of a previously specified geopackage) that contains one or more polygons that cover the downstream receiving waters must be specified within the Catchment Hydraulic Model block. This layer does not need any specific attributes, and can be imported from the empties created by the TUFLOW CATCH QGIS plugin as a 2d_rp polygon type (it has one dummy attribute that is not used). The TUFLOW HPC cells within this polygon/s will be removed from the TUFLOW HPC simulation. TUFLOW CATCH will not write any TUFLOW FV boundary condition blocks, but will write:
  - Summary timeseries files that describe total water and pollutant mass fluxes entering the defined polygon/s, as a combined entity. These outputs can be useful for scenario to scenario comparisons, for example

```
                    Receiving Polygon == <path to polygon or geopackage reference>
```

AND

- A list of comma separated pollutant names that are to be simulated by TUFLOW CATCH and the pollutant export model. Constant or timeseries pollutants are ignored - only pollutants that are specified within a material block (i.e. that wash off or erode) should be included in this list. These pollutants do not need to be TUFLOW FV keywords/names, and can be completely user defined. These names need to exactly match the names used within each material pollutant export block

```
    Pollutant == <name1, name2, name3, …>
```

TUFLOW CATCH will error if operating in the pollutant export configuration and either of the above commands are missing.

Once specified, TUFLOW CATCH will check to ensure that all pollutants have been specified (no more, no less) across material blocks (see Section 4.5.3.3), and error if not.

Set the groundwater layers from which flows and loads will be used to develop TUFLOW FV boundary conditions, if multiple soil layers are used. In some instances (especially where deep groundwater is simulated), it may be desirable to include flow and loads only from upper soil layers, when compiling TUFLOW FV boundary conditions. The flexibility to do so avoids, for example, the unrealistic delivery of deeper groundwater flows from TUFLOW HPC to TUFLOW FV, where in reality these deeper flows might pass underneath the bed of the receiving model, rather than enter the model domain. To do so, the deepest soil layer number (inclusive) for which flows and loads are to be taken to compute TUFLOW FV inflow boundaries can be specified

```
Groundwater Boundary Threshold Layer == <layer number>
```

Flows and loads from deeper layers than specified using this command will exit the TUFLOW model.

Optionally, set the groundwater boundary condition at the TUFLOW HPC / TUFLOW FV boundary. The default option is `Free Outflow`, which assumes zero-gradient conditions for groundwater pressure level and velocity, allowing groundwater to exit the HPC model domain without imposing artificial resistance.

```
Groundwater Default Catch BC == Free Outflow | Zero Depth
```

Following the issuing of these specific TUFLOW CATCH commands, a TUFLOW HPC model can be constructed in the same manner as a standalone model. In this regard:

- All TUFLOW HPC commands are recognised by TUFLOW CATCH and can be issued unchanged from the usage described in TUFLOW HPC's manual and/or relevant release notes
- TUFLOW HPC commands that reference other subsidiary control files (such as geometry control files, *.tgc etc.) need to use relative paths, and point to the locations with the TUFLOW directory created by the TUFLOW CATCH QGIS plugin, e.g.:

```
    BC Database == ..\..\TUFLOW\bc_dbase\bc_dbase_001.csv
```

- These subsidiary control files can then in turn use path references are per standalone TUFLOW HPC model construction (and point to locations within the same TUFLOW directory structure)
- Variables can be set within the TUFLOW CATCH Catchment Hydraulic Model block for reference in any other subsidiary TUFLOW HPC files as per normal, e.g.:

```
    Set Variable 2D_CELL_SIZE == 25
```

- Scenarios and events can be set within the TUFLOW CATCH Catchment Hydraulic Model block for reference in any other subsidiary TUFLOW HPC file IF statements as per normal, e.g.:

```
    Event == wet_year
```

Current limitations of the TUFLOW CATCH with regard to setting up TUFLOW HPC simulations include:

- Whilst events and scenarios can be manually defined and referenced (see above), dynamic assignment of same (using tilda notation in filenames etc.) is not yet supported. Each event or scenario will need a new TUFLOW CATCH control file

An example block of these Catchment Hydraulic Model block commands that together configure a TUFLOW HPC simulation within TUFLOW CATCH (with clarifying section headers as comments) is:

TUFLOW CATCH

```
!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == HPC

    ! Times
    Time Format == TUFLOWFV
    Zero Date == 01/01/2021 00:00

    ! Base runs directory and TUFLOW HPC executable
    Runs Directory == ..\..\TUFLOW\runs
    EXE == C:\EXE\TUFLOW_iSP_w64.exe

    ! GIS
    GIS Format == GPKG
    GPKG Projection == ..\..\TUFLOW\model\gis\Projection.gpkg

    ! Solver
    HPC DP Check == OFF
    Solution scheme == HPC
    Timestep == 1
    Timestep Maximum == 20

    ! SGS Settings
    SGS == ON
    SGS Sample Target Distance == 1
    GRID Format == TIF

    ! Gridding
    Set Variable 2D_CELL_SIZE == 10

    ! Boundaries
    BC Database == ..\..\TUFLOW\bc_dbase\bc_dbase_001.csv
    Groundwater Default Catch BC == Free Outflow

    ! Control Files
    Geometry Control File == ..\..\TUFLOW\model\Demo.tgc
    BC Control File == ..\..\TUFLOW\model\Demo_001.tbc
    Read Materials File == ..\..\TUFLOW\model\materials.tmf
    Read Soils File == ..\..\TUFLOW\model\Demo.tsoilf
    Soil Negative Rainfall Approach == FACTOR
    Set Variable HC == 10000
    Soil Negative Rainfall Factor == 0.2

    ! If operating in Pollutant export configuration
    ! Downstream polygon
    Receiving Polygon == ..\..\TUFLOW\model\gis\2d_rp_Demonstration_001_R.shp
    Pollutant == Salinity, Temperature, Tailings, PFAS

    ! Output Map Configuration
    Map Output Format == XMDF TIF
    Map Output Data Types == catch h d V
    Map Output Interval == 300
    TIF Map Output Interval == 0
    TIF Map Output Data Types == h d dt
    Grid Output Cell Size == <<2D_CELL_SIZE>>

    SGS Map Extent Trim == All
    SGS Depth Output == Cell Average
    Map Cutoff Depth == 0.01

End Catchment Hydraulic Model
```

4.5.3 Catchment pollutant export model

This block of the TUFLOW CATCH control file contains commands that control pollutant export (and other constituent) simulation.

The catchment pollutant export model definition must be declared as a block that encloses all commands. This is analogous to the declaration of a catchment hydraulic model.

Set the beginning of the block, with command arguments as either 'Mass Accumulation Release' or 'None', and the end of the block (with no command arguments). The key phrase 'Mass Accumulation Release' activates all available pollutant export submodels. The keyword 'None' turns off pollutant export simulation and would be used with the **Hydrology** configuration (see Section 1.3) or if only TUFLOW FV calibration is being undertaken, for example:

```
Catchment Pollutant Export Model ==
    ... pollutant export model commands ...
    ... pollutant export model commands ...
    ... pollutant export model commands ...
End Catchment Pollutant Export Model
```

If pollutant export is simulated, then all pollutants (and constituents) declared in the catchment hydraulic model (TUFLOW HPC via `Pollutant ==`) or receiving model (TUFLOW FV, and including all called modules such as Sediment Transport and Water Quality) must be accounted for with the correct name in the pollutant export block. Each must be assigned either:

- A constant value/concentration for application to receiving model boundary condition, or
- A timeseries value/concentration for application to receiving model boundary conditions, or
- A pollutant export model, with supporting parameters, for TUFLOW CATCH pollutant export simulation for every material

As such, not all the Catchment Pollutant Export Model block TUFLOW CATCH commands are mandatory, but, in combination, need to ensure that all pollutants are specified across the entire TUFLOW HPC domain.

4.5.3.1 Constant

Constant value/concentrations can be assigned when dynamic simulation is not required, such as for salinity or dissolved oxygen, for example. This specification is applied globally.

Set a constant value/concentration that is applied to downstream receiving model boundary condition files by TUFLOW CATCH. In doing so:

- The name needs to exactly match that configured by the receiving model (in TUFLOW CATCH's integrated configuration) or set by the user (in TUFLOW CATCH's pollutant export configuration), and
- The concentration needs to be in the same units expected by the receiving model (in TUFLOW CATCH's integrated configuration) or expected by the user (in TUFLOW CATCH's pollutant export configuration). For example, most constituents are specified in mg/L, however others, such as phytoplankton or temperature, are expected to be in units of μg/L and ^{o}C, respectively. This constant user-specified value therefore needs to be in the correct units: it is simply written 'as is' into receiving model boundary condition files.

```
Constant <name> == <concentration to be applied>
```

4.5.3.2 Timeseries

Timeseries values/concentrations can be assigned for which dynamic simulation is not required, but which values/concentrations likely vary in time. This might include water temperature specification, for example. This specification is applied globally.

Set a timeseries that is applied to downstream receiving model boundary condition files by TUFLOW CATCH. In doing so:

- The name needs to exactly match that of variable configured by the receiving model, and
- The concentration needs to be in the same units expected by the receiving model (in TUFLOW CATCH's integrated configuration) or expected by the user (in TUFLOW CATCH's pollutant export configuration). For example, most constituents are specified in mg/L, however others, such as phytoplankton or salinity, are expected to be in units

of μg/L or g/L, respectively. This user-specified timeseries therefore needs to be in the correct units: it is simply interpolated 'as is' into receiving model boundary condition files.

```
Time-Series <name> == <bc_name>
```

The `<bc_name>` field refers to a name declared in the TUFLOW HPC boundary condition database. For example, 'temperature_davg', with the corresponding database entry being (in a database simplified for this example):

```
Name,Source,Column 1,Column 2,Add Col 1,Mult Col 2,Add Col 2,Column 3,Column 4
temperature_davg,temperature_2021.csv,TUFLOW_Time,Airtemp,,,,,
```

4.5.3.3 Pollutant export

Pollutant export models can be configured within TUFLOW CATCH to simulate the release of pollutants from the ground surface across the TUFLOW HPC model domain. This export is a core intention and capability of TUFLOW CATCH and can be configured as uniform or spatially varied across the TUFLOW HPC domain. Any nonuniform spatial definition uses the material numbers (and corresponding spatial distributions) already configured in the TUFLOW HPC model (i.e. the catchment hydraulic model block described above) and affects this through specification of material blocks in this part of the TUFLOW CATCH control file. These blocks are similar to those deployed by TUFLOW FV.

Configure default (or spatially uniform) pollutant export:

```
Material == ALL
    … commands …
    … commands …
    … commands …
End Material
```

Once these uniform conditions have been set, progressive specifications of material by material pollutant behaviour can be set. These specifications overwrite previous settings on a spatial basis. This stamping-style approach is akin to the way in which digital elevation model inputs can be progressively updated within TUFLOW HPC and TUFLOW FV by specifying a suite of elevation data that overwrite each other on a spatial basis. In the case of pollutant export properties, this stamping is affected by specifying subsequent material blocks that relate to individual or multiple materials. Up to ten comma separated materials can be specified in one material block:

```
Material == MatID1, MatID2, MatID3, … , MatID10
    … commands …
    … commands …
    … commands …
End Material
```

Once all material specifications have been processed, TUFLOW CATCH will check that all pollutants have had all export properties specified for the entire TUFLOW HPC domain (i.e. every computational grid cell). This includes accounting for constant and timeseries specifications (which are global and do not need to be applied within material blocks). Using the 'ALL' command argument in the first material block specified and providing information for every pollutant required within that block (and then progressively spatially refining) ensures this will be true. Once the initial uniform material specification has been made, not every pollutant needs to be specified in every subsequent material block - only alterations to the uniform conditions need be made.

Each line within a material block contains a suite of arguments after the pollutant name (in the form `command == argument`, `command == argument`, … etc.), the first of which is always a keyword flagging the model to be used. Although there are some commonalities in subsequent inline commands, these differ according to the pollutant export model specified, as follows. Different pollutant export models can be specified for different pollutants within the same material block if required. The same pollutant export model should be applied to a given pollutant across all materials, albeit with different parameters.

4.5.3.3.1 Accumulation and washoff

Set the model and parameters for the pollutant accumulation and washoff model (see Section 3.2.3.1). All parameters are mandatory:

```
<name>, Method == Washoff1, Rate == Ra, Limit == Lacc, Time Constant == Tc, Rain Threshold == Rr, Depth Threshold == d, Deposition Velocity == w_s
```

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The `<name>` field must correspond to a name designated by TUFLOW FV. The parameters are:

- `Method`: keyword 'Washoff1' that activates the accumulation washoff model
- `Rate`: the areal rate at which the pollutant accumulates (kg/ha/year)
- `Limit`: the maximum areal mass that can accumulate in the dry store (kg/ha)
- `Time Constant`: a time parameter controlling the pollutant dry store release rate, according to Equation 3.1 (s)
- `Rain Threshold`: the minimum rain rate required to activate release from the dry store (mm/hr)
- `Depth Threshold`: the minimum water depth in a cell required to activate release from the dry store (m)
- `Deposition Velocity`: the velocity at which pollutant in the wet store settles. Used to calculate the mass of pollutant transferred back from the wet to dry store in a model timestep, according to Equation 3.2 (m/day)

An example for dissolved organic carbon might be:

`WQ_DOC_MG_L, Method == Washoff1, Rate == 21.446, Limit == 21.446, Time Constant == 3600, Rain Threshold == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0`

4.5.3.3.2 Shear stress

Set the model and parameters for the shear stress model (see Section 3.2.3.2). All parameters are mandatory:

`<name>, Method == Shear1, Rate == <not used>, Limit ==` L_{shr}`, Depth Threshold ==` d`, Deposition Stress ==` τ_{cd}`, Erosion Stress ==` τ_{ce}`, Deposition Velocity == w_s, Erosion Rate ==` E_r

The `<name>` field must correspond to a name designated by TUFLOW FV. The parameters are:

- `Method`: keyword 'Shear1' that activates the shear stress model
- `Rate`: not used, but listed for consistency
- `Limit`: the maximum erosion or deposition that can occur in a cell. Always a positive number (kg/ha)
- `Depth Threshold`: the minimum water depth in a cell required to activate release from the dry store (m)
- `Deposition Stress`: the maximum shear stress for which deposition can occur. Shear stresses below this limit will allow for deposition to occur, according to Equation 3.4. Should always be less than the specified erosionStress (N/m^2)
- `Erosion Stress`: the minimum shear stress for which erosion can occur. Shear stresses above this limit will allow for erosion to occur, according to Equation 3.3. Should always be greater than the specified depositionStress (N/m^2)
- `Deposition Velocity`: the velocity at which pollutant in the wet store settles. Used to calculate the mass of pollutant transferred back from the wet to dry store in a model timestep, according to Equation 3.4 (m/day)
- `Erosion Rate`: The maximum rate of erosion of pollutant from the dry store, if erosion conditions are met, according to Equation 3.3 ($g/m^2/s$)

An example for suspended sediment might be:

`SED_TSS, Method == Shear1, Rate == 0.0, Limit == 1000.0, Depth Threshold == 0.02, Deposition Stress == 0.01, Erosion Stress == 0.5, Deposition Velocity == 1.0, Erosion Rate == 0.002`

An example for a complete material block might be:

```
Material == 1, 4
    SED_TSS, Method == Shear1, Rate == 0.0, Limit == 1000.0, Depth Threshold == 0.02, Deposition Stress ==
0.01, Erosion Stress == 0.5, Deposition Velocity == 1.0, Erosion Rate == 0.001
    WQ_DOC_MG_L, Method == Washoff1, Rate == 21.446, Limit == 21.446, Time Constant == 3600, Rain Threshold ==
1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0
End Material
```

4.5.3.3.3 Units

TUFLOW CATCH has been configured to allow for the concurrent simulation of several unit systems, with different unit systems deployed for different pollutants. This is by design and reflects the diversity of commonly accepted unit systems across the water quality modelling discipline. For example, concentrations of nutrients are typically (but not always) thought of in units of mg/L, whilst those of phytoplankton are typically referred to in μg/L. TUFLOW CATCH accounts for this variation in unit systems and offers complete flexibility in this regard. The available unit systems are:

- mg/L (the most commonly used and TUFLOW CATCH default)

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- g/L
- μg/L, and
- CFU/100mL

Start: Experimental feature subject to change

The way in which a unit system is selected for a given constituent is simply by setting the correct units of the accumulation rate or erosion rate. TUFLOW CATCH does not need to be instructed explicitly as to the units it is being configured to simulate (except in the case of interventions, see Section 4.5.3.5.3). Rather, it is a responsibility of the user to set the correct accumulation or erosion rate units per pollutant (different units can be used for different exported pollutants) to ensure that TUFLOW CATCH produces the corresponding and expected:

- Advected surface and subsurface quantities:
    - Concentrations in map outputs (Section 6.2.2.2 and Section 6.2.3.2)
    - Concentrations in downstream `TUFLOW FV Inflow Boundary Condition` files
    - Concentrations in `Mass Balance` output files
    - Masses in `Receiving Polygon` summary files
- Dry store quantities
    - Dry mass (Section C.3)
    - Net mass (Section C.4)

The above are implicitly linked: the units set for accumulation or erosion rates subsequently set the manner in which the units of the above quantities are to be interpreted. This linkage is presented in Table 4.1 and Table 4.2 for advected and dry store quantities, respectively. The user selected units are in pink and the units that follow for the various different outputs are in green.

Table 4.1: TUFLOW CATCH units systems and linkages - advected quantities

Desired units system	Accumulation rate	Erosion rate	Map output concentration	TUFLOW FV BC concentration	Mass balance mass	Receiving polygon concentration
μg/L	`g/ha/yr`	`mg/m²/s`	μg/L	μg/L	mg	μg/L
mg/L	`kg/ha/yr`	`g/m²/s`	mg/L	mg/L	g	mg/L
g/L	`t/ha/yr`	`kg/m²/s`	g/L	g/L	kg	g/L
CFU/100mL	`CFU/ha/yr/10⁵`	`CFU/m²/s/10²`	CFU/100mL	CFU/100mL	CFUx10³	CFU/100mL

Table 4.2: TUFLOW CATCH units systems and linkages - dry store quantities

Desired units system	Accumulation rate	Erosion rate	Dry store mass	Net mass
μg/L	`g/ha/yr`	`mg/m²/s`	g/ha	g/ha
mg/L	`kg/ha/yr`	`g/m²/s`	kg/ha	kg/ha
g/L	`t/ha/yr`	`kg/m²/s`	t/ha	t/ha
CFU/100mL	`CFU/ha/yr/10⁵`	`CFU/m²/s/10²`	CFU/ha/10⁵	CFU/m²/10²

As an example, if a particular pollutant was to be simulated using the Washoff1 method and the desired units system was mg/L, then the accumulation rate would need to be specified in kg/ha/yr. As such, if a user found an accumulation rate in the literature of (say) 42.0 kg/ha/yr for that pollutant, then this number should be specified unchanged as an accumulation rate in TUFLOW CATCH, and all concentration units would then be in mg/L as per Table 4.1. If however, for the same pollutant, the g/L units system was desired, then the literature value of 42.0 would need to be specified in t/ha/yr in TUFLOW CATCH, that is, as a value of 0.042.

As a further example, if a particular pathogen was to be simulated using the Washoff1 method and the desired units system was CFU/100mL, then the accumulation rate would need to be specified in CFU/ha/yr, divided by 10^5. As such, if

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a user found an accumulation rate in the literature of (say) 10^{11} CFU/ha/yr for that pathogen, then this number should be specified as 10^6 as an accumulation rate in TUFLOW CATCH, and all concentration units would then be in CFU/100mL as per Table 4.1.

Units associated with pollutants assigned via the commands:

`Constant` <name> `==` float

or

`Time-Series` <name> `==` <name>

are not included in map, mass balance or polygon outputs as they are not simulated explicitly by TUFLOW CATCH. They are only written to TUFLOW FV boundary condition files, and as the absolute number or timeseries specified by the user. It is therefore a user responsibility to make sure that the number or timeseries specified is in the correct unit system expected by TUFLOW FV. For example, if blue green algae were set as constant and the command issued:

`Constant` WQ_PHYTO_BLUEGREEN_CONC_MICG_L `==` 4.0

then the number 4.0 is written to all TUFLOW FV boundary condition files, and interpreted by TULFOW FV as 4.0 μg/L. No other outputs for WQ_PHYTO_BLUEGREEN_CONC_MICG_L are written. If temperature is set as a timeseries, for example, then it should be in degrees Celsius, as expected by TUFLOW FV.

As a general note, users need to be clear on units used, and the translation of these through a modelling framework. This is especially the case when comparing model predictions to scheduled water quality objectives or conducting mass balance analyses - in such cases understanding of the units used is essential.

End: Experimental feature subject to change

Users are encouraged to undertake their own reviews and specifications of pollutant accumulation and erosion rates, and associated TUFLOW CATCH configurations. Notwithstanding this, some indicative pollutant accumulation rates are provided in Table 4.3, corresponding to the default mg/L units system. These are not to be seen as endorsed or recommended by TUFLOW, but are provided for information only, for a range of common pollutants. Decimal places are not intended to imply precision.

Table 4.3: Indicative pollutant accumulation rates

Pollutant	Lower estimate (kg/ha/yr)	Upper estimate (kg/ha/yr)
Sediment	55	300
Ammonium	0.2	2
Nitrate	0.5	3
Filterable Reactive Phosphorus	0.01	0.03
Dissolved Organic Nitrogen	1	2
Particulate Organic Nitrogen	1	3
Dissolved Organic Phosphorus	0.01	0.05
Particulate Organic Phosphorus	0.06	0.6
Dissolved Organic Carbon	20	70
Particulate Organic Carbon	12	40

4.5.3.4 *Pollutant transport*

4.5.3.4.1 Surface

Once released, pollutants are transported in the surface. Pollutants are treated as passive tracers and do not undergo non-conservative transformation, other than that allowed by the pollutant export models described above and that due to the action of interventions (see Section 4.5.3.5).

4.5.3.4.2 Subsurface

If soils have been included in the TUFLOW HPC simulation and infiltration of water occurs, then this water takes with it any previously released pollutants and continues to advect these in the subsurface as it does water. Similarly, if TUFLOW HPC predicts that water travelling in soil layers intersects the ground surface, then any included pollutants are returned to the surface wet store and advected and dispersed as normal. If a particular pollutant is not required to infiltrate from the surface to subsurface, then this infiltration can be turned off (default is on). This is intended to be set as off for particulate pollutants, although is user definable:

`Infiltration <name> ==` OFF

4.5.3.4.3 Units

The units of the concentrations reported due to pollutant transport for both surface and subrface accord with the commentary provided in Section 4.5.3.3.3 and are the same as those written to boundary condition files.

4.5.3.5 Interventions

Once released and transported, pollutant mass can be removed at user specified rates and locations due to the action of intervention devices (see Section 3.3). Intervention devices are specified as polylines (via importing the empty layer '2d_im_') with a single required attribute, being device name (attribute 'ID' - other fields are included but are not used).

`Read GIS Intervention ==` <path to GIS polyline file>

Any number of these commands can be issued, and all intervention devices need not be in a single GIS layer.

Once spatially specified, parameterised mass removal methods for each pollutant within each device are required. This is achieved through specifying device blocks, with one block for each device. The general arrangement of these blocks follows.

```
Device == ALL | Device name
    … commands …
    … commands …
    … commands …
End Device
```

Each such block commences and ends with `Device ==` and `End Device` keywords, respectively.

To avoid repetition, it is recommended that a blanket device block be issued initially using the device name 'ALL'. The content of this block is applied to all devices, and this can then be refined and overwritten by progressive device-specific block commands. This stamping-style approach is akin to the way in which digital elevation model inputs can be progressively updated within TUFLOW HPC and TUFLOW FV by specifying a suite of elevation data that overwrite each other on a spatial basis. In the case of intervention device properties, this stamping is affected by specifying subsequent device blocks that relate to individual devices.

Each line within a device block contains information on mass removal for a given pollutant. A suite of arguments follow the pollutant name (in the form `command ==` argument, `command ==` argument, … etc.), the first of which is always a keyword flagging the mass removal model to be used. Different mass removal models can be specified for different pollutants within the same device block. Different mass removal models can also be applied to a given pollutant across different devices. Although there are some commonalities in subsequent inline commands, these differ according to the mass removal model specified, as described in the following sections.

4.5.3.5.1 Equation

4.5.3.5.1.1 Constant

Set the model and parameters for the constant equation model (see Section 3.3.1.1.1). All parameters are mandatory:

`<name>`, `Method ==` Eqn, `Eqn ==` Constant, `Coefficients ==` R_j

The `<name>` field must correspond to a pollutant name. The parameters are:

- `Method`: keyword 'Eqn' that activates an equation based mass removal model. The number of available Eqn models may expand in future

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- **Eqn**: the specific equation based model used ('**Constant**' in this case)
- **Coefficients**: the proportion (0.0 - 1.0) of pollutant mass removed ([-])

An example for dissolved organic carbon removal by a device at 60% mass flux removal (i.e. 40% pass through) is:

```
WQ_DOC_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.6
```

4.5.3.5.1.2 Other

Other equation based models may or may not be added in future. Contact support@tuflow.com with requests or suggestions.

4.5.3.5.2 Table

Set the model and parameters for the table model (see Section 3.3.1.2). All parameters are mandatory:

```
<name>, Method == Table, Path == <Path to table>
```

The `<name>` field must correspond to a pollutant name. The parameters are:

- **Method**: keyword 'Table' that activates a table based mass removal model
- **Path**: the file path to the table to be used for mass removal

An example for dissolved organic carbon removal might be:

```
WQ_DOC_MG_L, Method == Table, Path == ..\bc_dbase\Wetland1_removals.csv
```

The format of the removal table is as follows, with all entries being comma separated values. Formats are provided in angled brackets, and all R_j vales are between 0.0 and 1.0:

```
Header line <free text>
Multiplier, conc_1, conc_2, conc_3, ... < real, real, real, real, ... >
Flow_1, R_j, R_j, R_j, ... < real, real, real, real, ... >
Flow_2, R_j, R_j, R_j, ... < real, real, real, real, ... >
Flow_3, R_j, R_j, R_j, ... < real, real, real, real, ... >
Flow_4, R_j, R_j, R_j, ... < real, real, real, real, ... >
...
```

An example is presented in Figure 4.4. The usual exclamation points are used to comment text and the colour coding is not required but is included to illustrate:

- Grey: Multiplier
- Blue: Concentration headers
- Green: Flow headers

The (positive value) multiplier is applied to all R_j entries uniformly and can be used to easily scale all R_j entries up and down equally, without needing to manually adjust individual entries. Beware of applying a scaling that increases R_j entries above 1.0 - TUFLOW CATCH will error and stop if this occurs. TUFLOW CATCH will interpolate linearly between column and row headers to compute the exact values of R_j based on environmental conditions.

Device treatment									
1	0.1	0.2	0.5	1	2	5	10	100	! Concentration range mg/L
1	0.1	0.2	0.5	0.8	0.9	1	1	1	! 1 m3/s
10	0.01	0.05	0.15	0.3	0.5	0.8	1	1	! 10 m3/s
100	0.001	0.005	0.03	0.07	0.1	0.3	0.5	1	! 100 m3/s
1000	0.0005	0.001	0.002	0.01	0.02	0.05	0.1	0.5	! 1000 m3/s
10000	0.0001	0.0005	0.001	0.002	0.005	0.01	0.02	0.1	! 10000 m3/s

Figure 4.4: Example intervention device table input

4.5.3.5.3 Units

Start: Experimental feature subject to change

Intervention mass removal is computed on a proportional mass basis. This means that for the:

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- `Eqn` `==` `Constant` method, the pollutant units are not explicitly required to be known by TUFLOW CATCH in applying the pre-specified R_j
- `Method` `==` `Table` method that uses a csv lookup table to select R_j, the units of concentration specified in the csv table header row need to be in the same units as intended by the user (see blue highlighted values in Figure 4.4). It is the users responsibility to ensure this is the case

The only requirement beyond the above, and this applies only if interventions are simulated, is that the user instruct TUFLOW CATCH as to the intended units system for a given pollutant **if it is not mg/L** (mg/L is the default). This is because TUFLOW CATCH uniformly reports removals of pollutants due to the action of interventions in grams and CFU. As such, TUFLOW CATCH needs to know the absolute units of concentrations advected into interventions to do so. This is affected via the following command:

`Units` `<name>` `==` `<arg>`

This command is issued within a pollutant export block (not within an individual intervention block). The `<name>` field must correspond to a pollutant name. The arguments are `MGL`, `GL`, `MICGL` or `CFU100ML`.

As an example for POLLUTANT_A (intended to be simulated in g/L):

`Units` `POLLUTANT_A` `==` `GL`

This would mean that:

- The units of concentration specified in the top row of an intervention table (if used) are expected to be g/L, and
- The absolute mass removed will still be reported in units of grams (see Section 6.4)

End: Experimental feature subject to change

4.5.3.6 Non-hydrologic surface loads

Non-hydrologic pollutant flows and loads can be specified at any location within the TUFLOW model domain using point, line or region GIS geometry types (via empty layer '2d_sa_'). These geometry features can be digitised such that they correspond to actual on ground locations, and as such treat all (and only) water flowing through these locations - lumped subcatchment assumptions are avoided.

Whilst the related commands are specified within the Pollutant Export block of a TUFLOW CATCH control file, they are those already in use in other TUFLOW products as 'SA' inflows. The hyperlink on the command below therefore points to the relevant information in the TUFLOW Classic/HPC User manual, and this can be followed directly, with the caveat that only the 'ALL' option described in the TUFLOW/HPC manual is supported by TUFLOW CATCH.

Read GIS SA `==` `<path to GIS file>`

Any number of these commands can be issued, and all non-hydrologic inflows of a given geometry type (point, line or region) need not be in a single GIS layer. The only attribute required by the 2d_sa_ GIS layer for each feature is <Name>. This can be any name the user desires, although the use of spaces and special characters is to be avoided.

Once GIS features have been created and assigned names, TUFLOW CATCH requires that each feature be associated with:

- [Mandatory] A flow timeseries
- [Optional] A pollutant concentration timeseries for each pollutant wishing to be associated with the above flow. It is not mandatory that every pollutant be assigned a concentration timeseries. If no pollutant concentration is assigned then it will assumed to be zero

This association is affected by entries to the TUFLOW bc_dbase file, which is described here in the TUFLOW Classic/HPC manual. The same column headers are used by TUFLOW Classic/HPC and TUFLOW CATCH, and these are used by TUFLOW CATCH as follows (bc_dbase header names are **bolded**):

- [Mandatory for every GIS feature] Flow specification:
  - Mandatory:
    * **Name**: Name given to a point, line or region GIS feature in 2s_sa_ GIS layer
    * **Source**: Filename of csv file that contains flow timeseries data
    * **Column1**: Header of column in csv timeseries file corresponding to time in TUFLOW hours (ISODATE is not supported)
    * **Column2**: Header of column in csv timeseries file corresponding to flow rate (m^3/s)
  - Optional:

- ★ **Add Col 1**: Value to add to time column
- ★ **Mult Col 2**: Value to multiply flow column
- ★ **Add Col 2**: Value to add to flow column
- ★ **Column3**, **Column4**: unused
- [Optional for every GIS feature] Concentration specification:
  - **Mandatory (if used for a pollutant):**
    - ★ **Name**: A '_' concatenation of the
      - · Name given to a point, line or region GIS feature in 2s_sa_ GIS layer, and
      - · Name given to the relevant pollutant
    - ★ **Source**: Filename of csv file that contains concentration timeseries data
    - ★ **Column1**: Header of column in csv timeseries file corresponding to time in TUFLOW hours (ISODATE is not supported)
    - ★ **Column2**: Header of column in csv timeseries file corresponding to concentration rate (m^3/s)
  - **Optional:**
    - ★ **Add Col 1**: Value to add to time column
    - ★ **Mult Col 2**: Value to multiply concentration column
    - ★ **Add Col 2**: Value to add to concentration column
    - ★ **Column3**, **Column4**: unused

An example of a bc_dase file is presented in Figure 4.5 for a TUFLOW CATCH model with:

- GIS features:
  - One point feature inflow with name attribute 'STP'
  - One region feature inflow with the name attribute 'Groundwater'
- Pollutants:
  - EColi (from STP only)
  - DOC (from STP and Groundwater)

	A	B	C	D	E	F	G	H	I
1	Name	Source	Column 1	Column 2	Add Col 1	Mult Col 2	Add Col 2	Column 3	Column 4
2	STP	..\bc_dbase\STP.csv	Time	Flow_m3s		1.5			
3	STP_Ecoli	..\bc_dbase\STP.csv	Time	Ecoli_CFU100mL					
4	STP_DOC	..\bc_dbase\STP.csv	Time	DOC_mgL					
5	Groundwater	..\bc_dbase\GW.csv	Time	Flow_m3s		1.1			
6	Groundwater_DOC	..\bc_dbase\GW_conc.csv	Time	DOC_mgL					

Figure 4.5: TUFLOW CATCH bc_dbase file example

Some features of this file include:

- All GIS feature names and pollutants are concatenated with a '_'
- Groundwater has no concentration entry for EColi, so that pollutant will be assigned zero concentration for the groundwater inflow
- The groundwater entries call different csv files
- Flow multipliers have been applied to both features
- The headers are user defined in each csv file, and have included units (e.g. DOC_mgl)for clarity but this is not mandatory

4.5.3.6.1 Units

Start: Experimental feature subject to change

The units used for all non-hydrologic flows and loads are:

- Flow: m^3/s
- Concentration: As per the 'Map output concentration' column in Table 4.1

An example all the above Pollutant Export Model block commands within TUFLOW CATCH (with clarifying section headers as comments), including interventions is:

```
! _____
! POLLUTANT EXPORT
```

TUFLOW CATCH

```
Catchment Pollutant Export Model == Mass Accumulation Release

    ! Constant Concentrations
    Constant Salinity == 0.0
    Constant WQ_DISS_OXYGEN_MG_L == 8.0
    Constant WQ_SILICATE_MG_L == 0.0

    ! Time Series
    Time-Series Temperature == Temperature

    ! Prohibited Infiltrations
    Infiltration SED_TSS == OFF
    Infiltration WQ_POC_MG_L == OFF
    Infiltration WQ_PON_MG_L == OFF
    Infiltration WQ_POP_MG_L == OFF
    Infiltration WQ_PHYTO_BLUEGREEN_CONC_MICG_L == OFF

    ! Pollutant Export Properties
    Material == ALL
        SED_TSS, Method == Shear1, Rate == 0.0, Limit == 1000.0, Depth Threshold == 0.02, Deposition Stress
== 0.01, Erosion Stress == 0.5, Deposition Velocity == 1.2, Erosion Rate == 0.001
        WQ_AMMONIUM_MG_L, Method == Washoff1, Rate == 0.273, Limit == 0.273, Time Constant == 3600, Rain
Threshold == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0
        WQ_NITRATE_MG_L, Method == Washoff1, Rate == 0.662, Limit == 0.662, Time Constant == 3600, Rain
Threshold == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0
        WQ_FRP_MG_L, Method == Washoff1, Rate == 0.010, Limit == 0.010, Time Constant == 3600, Rain Thresh-
old == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0
        WQ_DOC_MG_L,  Method == Washoff1,  Rate == 21.446,  Limit == 21.446,  Time Constant == 3600,  Rain
Threshold == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0
        WQ_DON_MG_L, Method == Washoff1, Rate == 1.021, Limit == 1.021, Time Constant == 3600, Rain Thresh-
old == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0
        WQ_DOP_MG_L, Method == Washoff1, Rate == 0.005, Limit == 0.005, Time Constant == 3600, Rain Thresh-
old == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0
        WQ_POC_MG_L,  Method == Washoff1,  Rate == 12.154,  Limit == 12.154,  Time Constant == 3600,  Rain
Threshold == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.5
        WQ_PON_MG_L, Method == Washoff1, Rate == 1.044, Limit == 1.044, Time Constant == 3600, Rain Thresh-
old == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.5
        WQ_POP_MG_L, Method == Washoff1, Rate == 0.061, Limit == 0.061, Time Constant == 3600, Rain Thresh-
old == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.5
        WQ_PHYTO_BLUEGREEN_CONC_MICG_L, Method == Washoff1, Rate == 0.002, Limit == 0.02, Time Constant ==
3600, Rain Threshold == 1.0, Depth Threshold == 0.020, Deposition Velocity == 0.0
    End Material

    Material == 2
        SED_TSS, Method == Shear1, Rate == 0.0, Limit == 2000.0, Depth Threshold == 0.002, Deposition Stress
== 0.001, Erosion Stress == 0.05, Deposition Velocity == 1.5, Erosion Rate == 0.1
        WQ_AMMONIUM_MG_L, Method == Washoff1, Rate == 2.0, Limit == 20.0, Time Constant == 30, Rain Thresh-
old == 0.1, Depth Threshold == 0.002, Deposition Velocity == 0.0
        WQ_NITRATE_MG_L, Method == Washoff1, Rate == 5.0, Limit == 50.0, Time Constant == 60, Rain Thresh-
old == 0.1, Depth Threshold == 0.002, Deposition Velocity == 0.0
    End Material

    Material == 3, 5
        WQ_DOP_MG_L, Method == Washoff1, Rate == 0.5, Limit == 0.5, Time Constant == 300, Rain Threshold ==
10.0, Depth Threshold == 0.120, Deposition Velocity == 0.0
    End Material

    ! Interventions
    Read GIS Intervention == ..\bc_dbase\Wetland_removals.csv
    Read GIS Intervention == ..\bc_dbase\Swale_removals.csv

    ! Mass Removal Properties
```

```
    Device == ALL
        SED_TSS, Method == Eqn, Eqn == Constant, Coefficients == 1.0
        WQ_AMMONIUM_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.2
        WQ_NITRATE_MG_L, Method == Table, Path == ..\..\bc_dbase\Alldevices.csv
        WQ_FRP_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.1
        WQ_DOC_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.2
        WQ_DON_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.15
        WQ_DOP_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.05
        WQ_POC_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.03
        WQ_PON_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.01
        WQ_POP_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.02
        WQ_PHYTO_BLUEGREEN_CONC_MICG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.0
    End Device

    Device == Wetland1
        WQ_POP_MG_L, Method == Eqn, Eqn == Constant, Coefficients == 0.5
        WQ_PHYTO_BLUEGREEN_CONC_MICG_L, Method == Table, Path == ..\..\bc_dbase\Wetland1.csv
    End Device

    Device == Swale3
        WQ_AMMONIUM_MG_L, Method == Table, Path == ..\..\bc_dbase\Swale3.csv
        WQ_NITRATE_MG_L, Method == Table, Path == ..\..\bc_dbase\Swale3.csv
    End Device

    ! Non-hydrologic flows
    Read GIS SA == ..\..\model\gis\2d_sa_STP_001_P.shp
    Read GIS SA == ..\..\model\gis\2d_sa_STP_002_P.shp
    Read GIS SA ALL == ..\..\model\gis\2d_sa_Groundwater_001_R.shp
    Read GIS SA == ..\..\model\gis\2d_sa_Groundwater_001_L.shp
    Read GIS SA ALL == ..\..\model\gis\2d_sa_Groundwater_002_L.shp

    ! Units
    Units WQ_PHYTO_BLUEGREEN_CONC_MICG_L == MICGL

End Catchment Pollutant Export Model
```

4.5.4 Receiving model (TUFLOW FV) commands

This block of the TUFLOW CATCH control file contains commands that construct a TUFLOW FV simulation. These commands are almost entirely those that would be used in setting up a standalone TUFLOW FV control file (*.fvc), with a small number of additional commands that relate to TUFLOW CATCH.

A small number of commands issued in the Global commands section of the *.tcc can be overwritten here if needed (for example if GPKG had been specified in the Global commands for the GIS format). These are:

```
Hardware ==
GIS Format ==
```

If GIS Format is overwritten (as SHP), then a subsequent new projection file is most likely required to be specified

```
SHP Projection ==
```

The receiving model definition must be declared as a block that encloses all TUFLOW CATCH and TUFLOW FV commands.

Set the beginning of the block, with command arguments as either TUFLOWFV or none, and the end of the block (with no command arguments):

```
Receiving Model ==
    ... receiving model commands ...
    ... receiving model commands ...
    ... receiving model commands ...
End Receiving Model
```

TUFLOW CATCH

If the `Receiving Model` command is set to none, then receiving simulation is not executed. This approach might be adopted for the initial stages of a TUFLOW HPC model build, for example. The TUFLOW CATCH commands contained within this Receiving Model block are described following, and all are mandatory unless noted.

Set the directory from which TUFLOW CATCH controls TUFLOW FV. Unless there is a need to the contrary, this should be set as a relative path to the `TUFLOWFV\runs` directory set up by the TUFLOW CATCH QGIS plugin, i.e. `..\..\TUFLOWFV\runs`. Setting this to any other directory is not recommended:

`Runs Directory ==`

Set the full or relative path to the location of the the TUFLOW FV executable (including the name of the executable itself, with .exe extension) to be called by TUFLOW CATCH:

`EXE ==`

All TUFLOW FV boundary condition files generated by TUFLOW CATCH are QC type (cell inflow, 'lateral', and do not transfer momentum to TUFLOW FV) unless specified otherwise as nodestring (Q type, and do transfer momentum to TUFLOW FV) inflows. All such nodestring inflows need to be drawn as line type objects in a single GIS file and this file declared in the receiving model block as:

`Catchment BC Nodestring ==` `<path to GIS nodestring file>`

If TUFLOW FV is being executed alone using previous inflow boundaries created by TUFLOW HPC, then the following command will ensure that those previous boundaries are not overwritten. The name of the .fvcatchbc file produced by a previous TUFLOW HPC simulation needs to be renamed to match the name of the subsequent TUFLOW CATCH simulation calling only TUFLOW FV. In this instance if:

- TUFLOW CATCH run Model_003.tcc (for example) produced initial TUFLOW FV boundary files
- The corresponding `..\TUFLOWCATCH\bc_dbase\Model_003_catchment_hydraulic.fvcatchbc` file could be copied as

  `..\TUFLOWCATCH\bc_dbase\Model_004_catchment_hydraulic.fvcatchbc` and
- Called automatically in Model_004.tcc by a TUFLOW CATCH simulation that has `Catchment Hydraulic Model ==` `None`

`Preserve Catchment Inflows ==` `ON`

Following the issuing of these specific TUFLOW CATCH commands, a TUFLOW FV model can be constructed in the same manner as a standalone model. In this regard:

- All TUFLOW FV commands are recognised by TUFLOW CATCH and can be issued unchanged from the usage described in TUFLOW FV's manual and/or relevant release notes
- TUFLOW FV commands that reference other subsidiary control files (such as geometry control files, *.tgc etc.) or GIS files need to use relative paths, and point to the locations with the TUFLOWFV directory created by the TUFLOW CATCH QGIS plugin, e.g.:

  `Sediment Control File ==` `..\..\TUFLOWFV\stm\Demo.fvsed`
- These subsidiary control files can then in turn use path references are per standalone TUFLOW FV model construction (and point to locations within the same TUFLOWFV directory structure)
- Include command calls are supported, as relative references to the TUFLOWFV folder should be used

An example block of these Receiving Model block commands within TUFLOW CATCH (with clarifying section headers as comments) is:

```
! _____
! RECEIVING HYDRODYNAMICS AND WQ
Receiving Model == TUFLOWFV

    ! Base runs directory (to write fvc to) and TUFLOW FV executable
    Runs Directory == ..\..\TUFLOWFV\runs
    EXE == C:\EXE\TUFLOWFV\2023.1.1\TUFLOWFV.exe
    Preserve Catchment Inflows == ON
```

TUFLOW *CATCH*

```
! General Parameters
Bottom Drag Model == Manning
Include Salinity == 1,1
Include Temperature == 1,1
Include Sediment == 1,0
Include Heat == 1
Spatial Order == 1,1

! Timestep Commands
CFL == 0.95
Timestep Limits == 1.0,10.0
Display dt == 900

! Model Parameters
Cell Wet/Dry Depths == 5.0e-03, 5.0e-02
Stability Limits == 20.0, 10.0
CFL == 0.95
Momentum Mixing Model == Smagorinsky
Global Horizontal Eddy Viscosity == 0.2
Global Horizontal Eddy Viscosity Limits == 0.05, 99999.
Scalar Mixing Model == Smagorinsky
Global Horizontal Scalar Diffusivity == 0.2
Global Horizontal Scalar Diffusivity Limits == 0.05, 99999.
Vertical Mixing Model == External
Turbulence Update dt == 1800
Global Vertical Eddy Viscosity Limits == 1.0e-4, 1.0
Global Vertical Scalar Diffusivity Limits == 0., 1.0

Water Quality
Water Quality Model == TUFLOW
Water Quality Control File == .\Demonstration_005.fvwq
Water Quality Model Directory == ..\..\TUFLOWFV\wqm\
Cell Water Quality Depth == 0.04

! Sediment Transport
Sediment Control File == ..\..\TUFLOWFV\stm\Demonstration_005.fvsed

! 2D Geometry
Geometry 2D == ..\..\TUFLOWFV\model\geo\Demonstration_005.2dm
Read Grid Zpts == ..\..\TUFLOWFV\model\geo\DEM.asc
Read GIS Zline == ..\..\TUFLOWFV\model\gis\2d_zln_Demonstration_005_Outlet_R.shp

! 3D Geometry
Vertical Mesh Type == z
Layer Faces == ..\..\TUFLOWFV\model\geo\Demonstration_005_layers.csv
Sigma Layers == 6
Min Bottom Layer Thickness == 0.05
Cell 3D Depth == 0.05

! Materials
Global Bottom Roughness == 0.03
Read GIS Mat == ..\..\TUFLOWFV\model\gis\2d_mat_Demonstration_005_R.shp
! Main Lake
Material == 1
    Bottom Roughness == 0.012
End Material
! Inflows
Material == 2
    Bottom Roughness == 0.030
End Material
! Exit
Material == 3
```

```
     Bottom Roughness == 0.012
End Material

! Initial Conditions
Initial Water Level == 4.0
Initial Salinity == 0.0
Initial Temperature == 17.0
Initial Sediment Concentration == 1.0
Initial WQ Concentration == 7.5,1.0,0.00005,0.00005,0.0031,0.0,0.1,0.0,0.056,0.0,0.0000031,0.0,5.0

! Large Sewage Plant
Read GIS SA == ..\..\TUFLOWFV\model\gis\2d_sa_Demonstration_005_R.shp
BC == QC_POLY, Sewage_large, ..\..\TUFLOWFV\bc_dbase\Demonstration_005_Sewage_large.csv
     BC Header == Date,Q,sal,temp,sed,DO,Si,Amm,Nit,FRP,FRP_ads,DOC,POC,DON,PON,DOP,POP,Phy
     BC Update dt == 3600.
     Vertical Coordinate Type == depth
     Vertical Distribution File == ..\..\TUFLOWFV\bc_dbase\Demonstration_005_Sewage_vert.csv
End BC
! Small Sewage Plant
BC == QC_POLY, Sewage_small, ..\..\TUFLOWFV\bc_dbase\Demonstration_005_Sewage_small.csv
     BC Header == Date,Q,sal,temp,sed,DO,Si,Amm,Nit,FRP,FRP_ads,DOC,POC,DON,PON,DOP,POP,Phy
     BC Update dt == 3600.
     Vertical Coordinate Type == depth
     Vertical Distribution File == ..\..\TUFLOWFV\bc_dbase\Demonstration_005_Sewage_vert.csv
End BC
! Offtake
BC == QC_POLY, Offtake, ..\..\TUFLOWFV\bc_dbase\Demonstration_005_Offtake.csv
     BC Header == Date,Q
     BC Update dt == 3600.
     Vertical Coordinate Type == height
     Vertical Distribution File == ..\..\TUFLOWFV\bc_dbase\Demonstration_005_Offtake_vert.csv
     BC Scale == 1.0
End BC

! Overflow Weir
Read GIS Nodestring == ..\..\TUFLOWFV\model\gis\2d_ns_Demonstration_005_Weir_L.shp
BC == QN, ovfl_weir, 0.001
End BC

! Catchment Boundaries (to be used for linkage)
Catchment BC Nodestring == ..\..\TUFLOWFV\model\gis\2d_ns_Demonstration_005_Inflows_L.shp

! Meteorology
BC == W10, ..\..\TUFLOWFV\bc_dbase\met\Demonstration_005_Met_data.csv
     BC Header == Date, u10, v10
     BC Update dt == 3600.
End BC
BC == LW_RAD, ..\..\TUFLOWFV\bc_dbase\met\Demonstration_005_Met_data.csv
     BC Header == Date, lw
     BC Update dt == 3600.
End BC
BC == SW_RAD, ..\..\TUFLOWFV\bc_dbase\met\Demonstration_005_Met_data.csv
     BC Header == Date, sw
     BC Update dt == 3600.
End BC
BC == AIR_TEMP, ..\..\TUFLOWFV\bc_dbase\met\Demonstration_005_Met_data.csv
     BC Header == Date, at
     BC Update dt == 3600.
End BC
BC == REL_HUM, ..\..\TUFLOWFV\bc_dbase\met\Demonstration_005_Met_data.csv
     BC Header == Date, rh
```

TUFLOW *CATCH*

```
        BC Update dt == 3600.
    End BC
    BC == PRECIP, ..\..\TUFLOWFV\bc_dbase\met\Demonstration_005_Met_data.csv
        BC Header == Date, precip
        BC Update dt == 3600.
    End BC

    ! Outputs
    Output == NetCDF
        Output Parameters == h,v,d,sal,temp,sed_1
        Output Interval == 900.0
        Suffix == HD
    End Output

    Output == NetCDF
        Output Parameters == wq_all
        Output Interval == 7200
        Suffix == WQ
    End Output

    Output == Mass
        Output Interval == 3600.
    End Output

    Write Restart dt == 24
    Restart Overwrite == 1

End Receiving Model
```

4.6 Construction summary

4.6.1 Supported configurations

The following presents a summary of the combinations of block level commands that will trigger the core supported TUFLOW CATCH configurations. Only block level commands have been included, unless specific internal commands are relevant.

4.6.1.1 Hydrology

For simulation of water only (refer to TUFLOW CATCH Tutorial Model 3 for a model demonstration):

```
!_____
! GLOBAL SETTINGS

    ...

!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == HPC

    ...

End Catchment Hydraulic Model

! _____
! POLLUTANT EXPORT
Catchment Pollutant Export Model == None

    ...

End Catchment Pollutant Export Model
```

TUFLOW CATCH

```
! _____
! RECEIVING MODEL
Receiving Model == TUFLOWFV

    ...

End Receiving Model
```

If temperature and salinity (or either) are to be simulated:

```
!_____
! GLOBAL SETTINGS

    ...

!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == HPC

    ...

End Catchment Hydraulic Model

! _____
! POLLUTANT EXPORT
Catchment Pollutant Export Model == None

    Constant Salinity == 0.0
    Time-Series Temperature == Temperature

End Catchment Pollutant Export Model

! _____
! RECEIVING MODEL
Receiving Model == TUFLOWFV

    ...

End Receiving Model
```

4.6.1.2 Pollutant export

Refer to TUFLOW CATCH Tutorial Model 1 for a model demonstration.

```
!_____
! GLOBAL SETTINGS

    ...

!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == HPC

    ! Downstream polygon
    Receiving Polygon == ..\..\TUFLOW\model\gis\2d_rp_<name>_R.shp
    Pollutant == <name>, <name>, <name>, ...

    ...

End Catchment Hydraulic Model

!_____
! POLLUTANT EXPORT
Catchment Pollutant Export Model == Mass Accumulation Release

    <names must match Pollutant == above>
    ...

End Catchment Pollutant Export Model
```

TUFLOW CATCH

```
!_____
! RECEIVING MODEL
Receiving Model == None

    ...

End Receiving Model
```

4.6.1.3 Integrated

Refer to TUFLOW CATCH Tutorial Model 4 for a model demonstration.

```
!_____
! GLOBAL SETTINGS

    ...

!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == HPC

    ...

End Catchment Hydraulic Model

!_____
! POLLUTANT EXPORT
Catchment Pollutant Export Model == Mass Accumulation Release

    ...

End Catchment Pollutant Export Model

!_____
! RECEIVING MODEL
Receiving Model == TUFLOWFV

    ...

End Receiving Model
```

4.6.2 Other configurations

The following presents a summary of the combinations of block level commands that will trigger the alternative TUFLOW CATCH configurations that might be used during model construction and calibration. Only block level commands have been included, unless specific internal commands are relevant.

4.6.2.1 TUFLOW HPC calibration only

```
!_____
! GLOBAL SETTINGS

    ...

!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == HPC

    <may require a 2d_bc at downstream outlet to release water from domain>
    ...

End Catchment Hydraulic Model

!_____
! POLLUTANT EXPORT
Catchment Pollutant Export Model == None
```

TUFLOW *CATCH*

```
    ...

End Catchment Pollutant Export Model

!_____
! RECEIVING MODEL
Receiving Model == None

    ...

End Receiving Model
```

Alternatively, a TUFLOW CATCH simulation in **Pollutant Export** configuration could be set up, with only a constant and zero salinity set. Because this constant is not simulated in the TUFLOW HPC domain, doing so will not adversely affect TUFLOW HPC run times. It will, however, allow for specification of a receiving polygon to let water out of the TUFLOW HPC domain at a location well downstream of calibration comparison gauges.

```
!_____
! GLOBAL SETTINGS

    ...

!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == HPC

    ! Downstream polygon
    Receiving Polygon == ..\..\TUFLOW\model\gis\2d_rp_<name>_R.shp
    Pollutant == Salinity
    ...

End Catchment Hydraulic Model

!_____
! POLLUTANT EXPORT
Catchment Pollutant Export Model == Mass Accumulation Release

    Constant Salinity == 0.0

End Catchment Pollutant Export Model

!_____
! RECEIVING MODEL
Receiving Model == None

    ...

End Receiving Model
```

4.6.2.2 TUFLOW FV calibration only

```
!_____
! GLOBAL SETTINGS

    ...

!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == None

    ...

End Catchment Hydraulic Model

!_____
! POLLUTANT EXPORT
Catchment Pollutant Export Model == None

    ...
```

```
End Catchment Pollutant Export Model

!_____
! RECEIVING MODEL
Receiving Model == TUFLOWFV

   ...

End Receiving Model
```

The above will assign blank inflows to TUFLOW from the TUFLOW HPC domain. If TUFLOW FV is to use previously created inflow boundaries from TUFLOW HPC (via TUFLOW CATCH) then the following should be used, after copying the previously created .fvcatchbc file, for example:

- TUFLOW CATCH run Model_003.tcc (for example) produced initial TUFLOW FV boundary files

- The corresponding `..\TUFLOWCATCH\bc_dbase\Model_003_catchment_hydraulic.fvcatchbc` file could be copied as

   `..\TUFLOWCATCH\bc_dbase\Model_004_catchment_hydraulic.fvcatchbc` and

- Called automatically in `Model_004.tcc`

```
!_____
! GLOBAL SETTINGS

   ...

!_____
! CATCHMENT HYDRAULICS
Catchment Hydraulic Model == None

   ...

End Catchment Hydraulic Model

!_____
! POLLUTANT EXPORT
Catchment Pollutant Export Model == None

   ...

End Catchment Pollutant Export Model

!_____
! RECEIVING MODEL
Receiving Model == TUFLOWFV

   Preserve Catchment Inflows == ON
   ...

End Receiving Model
```

TUFLOW *CATCH*

5 Simulation execution

5.1 Context

Previous sections have presented the architecture, available processes and construction of a TUFLOW CATCH model. This section describes the overall execution of a TUFLOW CATCH model.

5.2 Execution

In a similar manner to other TUFLOW products, TUFLOW CATCH is best executed from a batch file run within a command window. An example batch file (`run_catch.bat`) is below. The `REM` command is a commented line ignored by the command window, and the commands are:

- `set` exe=the full path to the TUFLOW CATCH executable
- `%exe% Demo.tcc` : calls the defined TUFLOW CATCH executable to run with `Demo.tcc` as the input control file. The `.tcc` can be in the same directory as the batch file (recommended) or can also use a relative path (not recommended).

```
echo off
REM Windows Batch File
set exe=C:\temp\EXE\CATCH\TUFLOWCATCH.exe
REM Execute
%exe% Demo.tcc
```

To execute TUFLOW CATCH with the above `run_catch.bat` set up, a command window should be opened in the same directory as the batch file, and the following typed at the prompt:

`run_catch`

TUFLOW CATCH will run and results will be written to the specified output folder. See Chapter 6 for results interrogation.

6 Outputs

6.1 Context

Previous sections have presented the architecture, available processes, construction and execution of a TUFLOW CATCH model. This section describes the results produced by TUFLOW CATCH under the three core supported configurations described in Section 1.3. Hyperlinks are provided to more detailed descriptions of output fields in Appendix C.

6.2 Core supported configurations

The three core supported configurations of TUFLOW CATCH are:

- Hydrology
- Pollutant export
- Integrated

The outputs of these are described in the following sections. In all cases, the TUFLOW CATCH control file is assumed to be named Model_001.tcc. It is strongly recommended that TUFLOW HPC and TUFLOW FV results that are to be used to create a TUFLOW CATCH *.json file for viewing in QGIS are output at the same timestep, referred to as <common_dt> below.

Units for all constituents, where relevant, have been set as standard (typically mg/L) to accord with commentary provided in Section 4.5.3.1, Section 4.5.3.2 and Section 4.5.3.3.

Note: The `GW Z Flux Output Normalise` command (TUFLOW HPC) is set to ON by default. It can be included in any of the following configurations.

6.2.1 Hydrology

6.2.1.1 Data types

It is recommended that the following data types be set, assuming salinity and temperature are included as constants/timeseries. If not, then catch (TUFLOW HPC) and , sal, temp (TUFLOW FV) can be omitted. If soil layers are not simulated then GW_QZ and GW_QZI should also be omitted (doing so will also reduce output file size if necessary):

TUFLOW HPC

```
Map Output Format == XMDF
Map Output Data Types == v d h catch GW_QZ GW_QZI
Map Output Interval == <common_dt>
```

TUFLOW FV

```
Output == NetCDF
    Output Parameters == h,v,d,sal,temp
    Output Interval == <common_dt>
    Suffix == HD
End Output
```

6.2.1.2 Files

The following output files are produced in the execution of a hydrology simulation with data types as above. Each is a 2D or 3D (TUFLOW FV) map output that varies in time:

- TUFLOW HPC
    - Model_001_catchment_hydrology.xmdf

      * Bed Elevation
      * Depth
      * Vector Velocity
      * Velocity
      * Water Level
      * Time of Peak h
      * `GW QZ Layer 1`
      * `GW QZI Layer 1`

- TUFLOW FV
  - Model_001_receiving_HD.nc
    - * Bed Elevation
    - * salinity
    - * temperature
    - * velocity
    - * vector Velocity
    - * water depth
    - * water surface elevation

6.2.1.3 Interrogation

The above output files can be viewed either:

- Individually via the TUFLOW Viewer (File -> Load Results -> Map Outputs), and interrogated using usual TUFLOW Viewer techniques, or
- Simultaneously via use of the Create TUFLOW CATCH JSON function (see Section 4.3)

6.2.2 Pollutant export

In this example, it is assumed that two pollutants are simulated (in addition to temperature and salinity), as:

- PFAS, Washoff1 pollutant export model
- Tailings, Shear1 pollutant export model

These models have been chosen because they produce different outputs.

6.2.2.1 Data types

It is recommended that the following data types be set:

TUFLOW HPC

```
Map Output Format == XMDF
Map Output Data Types == v d h catch GW_QZ GW_QZI GW_MZ GW_MZI
Map Output Interval == <common_dt>
```

TUFLOW FV is not activated.

6.2.2.2 Files

The following output files are produced in the execution of a pollutant export simulation with data types as above. Each is a 2D map output that varies in time. Hyperlinks are provided to detailed descriptions in the appendices for representative pollutants:

- TUFLOW HPC
  - Model_001_catchment_hydrology.xmdf
    - * Bed Elevation
    - * `Conc PFAS`
    - * Conc TAILINGS
    - * `Dry Mass PFAS`
    - * `GW Layer 1 Conc PFAS`
    - * GW Layer 1 Conc TAILINGS

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* GW Layer 1 MZ PFAS
* GW Layer 1 MZ TAILINGS
* GW Layer 1 MZI PFAS
* GW Layer 1 MZI TAILINGS
* Net Mass TAILINGS
* Depth
* Vector Velocity
* Velocity
* Water Level
* Time of Peak h
* GW QZ Layer 1
* GW QZI Layer 1

6.2.2.3 Interrogation

The above output file can be viewed via the TUFLOW Viewer (File -> Load Results -> Map Outputs), and interrogated using usual TUFLOW Viewer techniques.

6.2.3 Integrated

In this example, it is assumed that one sediment fraction and inorganic simulation class water quality are simulated (in addition to temperature and salinity), as:

- oxygen, silicate, adsorbed phosphorus and phytoplankton as constants
- all other water quality pollutants, Washoff1 pollutant export model
- fines, Shear1 pollutant export model
- salinity, constant
- temperature, timeseries

These models have been chosen because they produce different outputs.

6.2.3.1 Data types

It is recommended that the following data types be set:

TUFLOW HPC

```
Map Output Format == XMDF
Map Output Data Types == v d h catch GW_QZ GW_QZI GW_MZ GW_MZI
Map Output Interval == <common_dt>
```

TUFLOW FV

```
Output == NetCDF
    Output Parameters == h,v,d,sal,temp,sed_1
    Output Interval == <common_dt>
    Suffix == HD
End Output

Output == NetCDF
    Output Parameters == wq_all
    Output Interval == <common_dt>
    Suffix == WQ
End Output
```

6.2.3.2 Files

The following output files are produced in the execution of an integrated simulation with data types as above. Each is a 2D or 3D (TUFLOW FV) map output that varies in time. Hyperlinks are provided to detailed descriptions in the appendices for representative pollutants:

- TUFLOW HPC

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- Model_001_catchment_hydrology.xmdf
  * Bed Elevation
    · Conc SED_FINES
    · Conc WQ_AMMONIUM_MG_L
    · Conc WQ_DOC_MG_L
    · Conc WQ_DON_MG_L
    · Conc WQ_DOP_MG_L
    · Conc WQ_FRP_MG_L
    · Conc WQ_NITRATE_MG_L
    · Conc WQ_POC_MG_L
    · Conc WQ_PON_MG_L
    · Conc WQ_POP_MG_L
    · Dry Mass WQ_AMMONIUM_MG_L
    · Dry Mass WQ_DOC_MG_L
    · Dry Mass WQ_DON_MG_L
    · Dry Mass WQ_DOP_MG_L
    · Dry Mass WQ_FRP_MG_L
    · Dry Mass WQ_NITRATE_MG_L
    · Dry Mass WQ_POC_MG_L
    · Dry Mass WQ_PON_MG_L
    · Dry Mass WQ_POP_MG_L
    · GW Layer 1 Conc SED_FINES
    · GW Layer 1 Conc WQ_AMMONIUM_MG_L
    · GW Layer 1 Conc WQ_DOC_MG_L
    · GW Layer 1 Conc WQ_DON_MG_L
    · GW Layer 1 Conc WQ_DOP_MG_L
    · GW Layer 1 Conc WQ_FRP_MG_L
    · GW Layer 1 Conc WQ_NITRATE_MG_L
    · GW Layer 1 Conc WQ_POC_MG_L
    · GW Layer 1 Conc WQ_PON_MG_L
    · GW Layer 1 Conc WQ_POP_MG_L
  * GW Layer 1 MZ SED_FINES
  * GW Layer 1 MZ WQ_AMMONIUM_MG_L
  * GW Layer 1 MZ WQ_DOC_MG_L
  * GW Layer 1 MZ WQ_DON_MG_L
  * GW Layer 1 MZ WQ_DOP_MG_L
  * GW Layer 1 MZ WQ_FRP_MG_L
  * GW Layer 1 MZ WQ_NITRATE_MG_L
  * GW Layer 1 MZ WQ_POC_MG_L
  * GW Layer 1 MZ WQ_PON_MG_L
  * GW Layer 1 MZ WQ_POP_MG_L
  * GW Layer 1 MZI SED_FINES
  * GW Layer 1 MZI WQ_AMMONIUM_MG_L
  * GW Layer 1 MZI WQ_DOC_MG_L
  * GW Layer 1 MZI WQ_DON_MG_L
  * GW Layer 1 MZI WQ_DOP_MG_L
  * GW Layer 1 MZI WQ_FRP_MG_L
  * GW Layer 1 MZI WQ_NITRATE_MG_L
  * GW Layer 1 MZI WQ_POC_MG_L
  * GW Layer 1 MZI WQ_PON_MG_L
  * GW Layer 1 MZI WQ_POP_MG_L
    · Net Mass SED_FINES
  * Depth
  * Vector Velocity
  * Velocity
  * Water Level
  * Time of Peak h
  * GW QZ Layer 1

* `GW QZI Layer 1`
- TUFLOW FV
  - Model_001_receiving_HD.nc
    * Bed Elevation
    * salinity
    * sediment fraction 1 concentration
    * temperature
    * velocity
    * vector Velocity
    * water depth
    * water surface elevation
  - Model_001_receiving_WQ.nc
    * Bed Elevation
      · WQ_AMMONIUM_MG_L
      · WQ_DISS_OXYGEN_MG_L
      · WQ_DOC_MG_L
      · WQ_DON_MG_L
      · WQ_DOP_MG_L
      · WQ_FRP_ADS_MG_L
      · WQ_FRP_MG_L
      · WQ_NITRATE_MG_L
      · WQ_PHYTO_FDIAT_CONC_MICG_L
      · WQ_POC_MG_L
      · WQ_PON_MG_L
      · WQ_POP_MG_L
      · WQ_SILICATE_MG_L

6.2.3.3 Interrogation

The above output files can be viewed either:

- Individually via the TUFLOW Viewer (File -> Load Results -> Map Outputs), and interrogated using usual TUFLOW Viewer techniques, or
- Simultaneously via use of the Create TUFLOW CATCH JSON function (see Section 4.3)

6.3 Check files

TUFLOW CATCH produces a small suite of additional GIS check files, and these are associated with the catchment hydraulic model, so have the corresponding name root '_catchment_hydraulic_'. These files are either standalone shape files, or included within the broader catchment hydraulic model geopackage of check files, depending on the user preference set (see Section 4.5.1). They are written to the user specified check file folder location. The TUFLOW CATCH specific check file names and descriptions are as follows.

1. _catchment_hydraulic_hpc_transfer_R. Always produced. A file that has a single GIS region feature covering each catchment hydraulic model grid cell that has been identified as a transfer cell (either lateral and nodestring) from the catchment hydraulic model to the receiving model (**hydrology** or **integrated** configurations) or receiving polygon (**pollutant export** configuration). In the case of the latter configuration, flow and concentration data from all cells identified in the check file are aggregated to produce a single timeseries (see Section C.9.2). Attributes of each region feature are:
   - HPC_id: Sequential ID given to the catchment hydraulic model cell from which flows and concentrations are transferred. The ID is generated by TUFLOW CATCH and is not a TUFLOW HPC cell ID. The ID starts at 1 and increments upwards and is unrelated to the name of the associated receiving model boundary condition file (which uses the cell ID of the receiving model mesh, and only if **hydrology** or **integrated** configurations are deployed). Whilst this ID is generally not needed for subsequent analysis, it is used for cross referencing purposes in other check files (especially _catchment_hydraulic_lateral_transfer_)
   - type:
     - 1: lateral inflow
     - 2: nodestring inflow

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- n: catchment hydraulic model cell column number
- m: catchment hydraulic model cell row number

2. _catchment_hydraulic_nodestrings_R. Only produced in **hydrology** and **integrated** configurations. A file that has a single GIS region feature covering each catchment hydraulic model grid cell that has been identified as a nodestring transfer cell from the catchment hydraulic model to the receiving model. These polygons should correspond exactly to polygons of type 2 in the _catchment_hydraulic_hpc_transfer_R check file. This nodestrings check file is not produced in the **pollutant export** configuration where no receiving model is specified (receiving polygons are not associated with nodestrings). Attributes of each region feature are:
   - n: catchment hydraulic model cell column number
   - m: catchment hydraulic model cell row number
   - ns_name: Name of nodestring as set by user in 2d_ns_ GIS file
   - ns_name_1: Cell: 1 of X cells for nodestring number Y
   - ns_name_2: Cell: 2 of X cells for nodestring number Y
   - ns_name_3: Cell: 3 of X cells for nodestring number Y
   - …
   - ns_name_X: Cell: X of X cells for nodestring number Y

3. _catchment_hydraulic_lateral_transfer_R. Only produced in **hydrology** and **integrated** configurations. A file that has a single GIS region feature covering each receiving model mesh cell that has been identified as receiving flows and concentrations from the catchment hydraulic model. These polygons should correspond exactly to the geometry of cells of the receiving model mesh that receiving catchment inflows. This _lateral_transfer check file is not produced in the **pollutant export** configuration where no receiving model is specified (receiving polygons are not associated with receiving model meshes). Attributes of each region feature are:
   - fv_id: Sequential ID given to the receiving model mesh cell at which flows and concentrations are transferred. The ID is generated by TUFLOW CATCH and is not a TUFLOW FV cell ID. The ID starts at 1 and increments upwards and is unrelated to the name of the associated receiving model boundary condition file (which uses the cell ID of the receiving model mesh, and only if **hydrology** or **integrated** configurations are deployed). This ID is generally not needed for subsequent analysis
   - n_HPC: The number of TUFLOW HPC grid cells that transfer flows and concentrations to the receiving model cell
   - cell_list: A comma separated list of the TUFLOW CATCH generated IDs of catchment hydraulic model cells (see field HPC_id in check file _catchment_hydraulic_hpc_transfer_R above). This list has n_HPC elements

4. _catchment_hydraulic_im_check_L. Only produced if intervention measures are included. A file that has a single GIS line feature covering each intervention measure within the catchment hydraulic model. Attributes of each line feature are:
   - Device_name: Name of intervention as set by user in 2d_im_ GIS file
   - Length: Length of intervention (m)

6.4 Other outputs

In addition to the above, TUFLOW CATCH produces a small suite of supporting outputs that are simple text files. These are listed below, with hyperlinks to the relevant sections of Appendix C that provide more detail and units. If the TUFLOW CATCH BC output folder is set to `..\bc_dase` as recommended:

`Catch BC Output Folder == ..\bc_dbase`

then all files below are written to the `TUFLOWCATCH\bc_dbase\` folder.

- A series of `mass balance` files
   - `Surface water`. Timeseries of spatially summed cumulative surface water flow and associated pollutant masses leaving the TUFLOW HPC model (either to a polygon (**Pollutant Export** TUFLOW CATCH configuration) or TUFLOW FV model domain (**Hydrology** and **Integrated** TUFLOW CATCH configurations))
   - `Groundwater`. Timeseries of spatially summed cumulative groundwater flow and associated pollutant masses leaving the TUFLOW HPC model (either to a polygon (**Pollutant Export** TUFLOW CATCH configuration) or TUFLOW FV model domain (**Hydrology** and **Integrated** TUFLOW CATCH configurations))
   - `Total`. Its content is the summation of the data reported in the respective surface and groundwater mass balance outputs
- A `receiving polygon` inflows and concentrations. If TUFLOW CATCH has been executed in the **Pollutant Export** configuration, then a timeseries output file is produced that reports incoming flow and concentrations to that

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user defined polygon
- `TUFLOW FV boundaries`. A series of TUFLOW FV boundary related files are written as follows:
  - `BC blocks`. A single file that contains all required TUFLOW FV nodestring (Q) and cell (QC) inflow boundary BC blocks is written by TUFLOW CATCH. This file is called automatically by TUFLOW FV under TUFLOW CATCH when required. It is at the heart of the automated linking offered by TUFLOW CATCH. Users should not edit this file in any way. This file calls underlying nodestring and/or lateral boundary condition data files produced by TUFLOW HPC, and these are described below.
  - `Nodestring boundary data`. If TUFLOW CATCH has been executed in the **Hydrology** or **Integrated** configuration and TUFLOW FV nodestrings have been specified then individual data files are produced for each nodestring TUFLOW FV boundary
  - `Lateral boundary data`. If TUFLOW CATCH has been executed in the **Hydrology** or **Integrated** configuration then individual lateral data files are produced for each transfer cell boundary
- `Intervention summary`. If interventions are simulated then a summary file is produced that reports inflow (which is the same as outflow), incoming mass and removed mass as cumulative totals over the simulation duration, for each intervention and each pollutant.
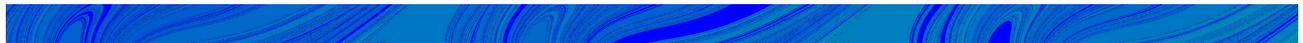
A Commands

The manual's introduction should be reviewed for instructions regarding the use of interactive components deployed in this section. All TUFLOW CATCH commands and descriptions are provided in Table A.1.

Commands syntax

TUFLOW CATCH commands are coloured, for example `Catchment Pollutant Export Model ==`. These can be copied and pasted directly into a TUFLOW CATCH Control (.tcc) file, and arguments added.

Argument syntax

Descriptions of the arguments expected by TUFLOW CATCH commands (i.e. information provided after the `==`) are contrastingly `coloured` and always included in angle parentheses, as ⟨`argument`⟩. This argument content takes one of the following forms:

- Single keyword options. Options are separated by semicolons. Options need to be used exactly as written because they are keywords. For example, ⟨`Washoff1;Shear1`⟩ describes the available pollutant export models for the command `Method ==`. An example of implementing this description would therefore be

  `Method == Washoff1`

- or for the `Material ==` command, the argument is described as ⟨`ALL;Up to 10 comma separated material numbers`⟩. An example of implementing this description would therefore be either

  `Material == ALL`
  or
  `Material == 1, 6, 3`

- Single numeric values. Values are presented using their associated symbol, using the notation described in the manual's introductory sections. For example, d describes the single numeric value for the command `Depth Threshold ==`. These arguments are hyperlinked to other relevant information in this manual.

- Recommendations. This is denoted with a `rec:` prefix ⟨`rec: plain text`⟩ that recommends a command argument, such as a file path

Commands

All TUFLOW CATCH commands and descriptions follow. This page has deliberately been set to be wider than the main document so as to accommodate the detail contained within the table. Tips provided in the manual's introduction for interacting with the table should be reviewed, especially with regard to searching and navigation. Other tips for use specific to this table include:

- Commands are `coloured` and although they show as underlined on mouse hover, these are not hyperlinked
- Corresponding arguments (presented as their symbols) are `coloured` and listed in the required order within angled parentheses following each `command ==`.
- Each argument is a hyperlink to its description in the relevant Appendix, where appropriate. This description then includes hyperlinks to the relevant science and command syntax (Chapter 4). This allows easy navigation between command, parameter and scientific information
- The final text of each description is 'Simulation construction section ...' and is a link to the relevant part of Chapter 4 where the command syntax is presented in context. More parameter details and descriptions are subsequently available via further hyperlinks included in the construction section

Table A.1: TUFLOW CATCH Commands

Command	Description
`Catch BC Output Folder ==` ⟨ `rec:` `..\bc_dbase` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the location to which all TUFLOW CATCH intermediate files are written. These include TUFLOW FV boundary condition files and blocks, and summed flow and pollutant outputs. It is strongly recommended that this be set to the bc database folder within the TUFLOWCATCH directory. It can be a relative or absolute path. This is not the location for TUFLOW HPC and TUFLOW FV results files. Simulation construction Section 4.5.1.
`Catch BC Output Interval Lateral ==` ⟨ dT_{lat} ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the timestep (in simulation time seconds) at which lines within a lateral (element, QC) boundary condition file for TUFLOW FV (created from TUFLOW HPC predictions) are separated. Simulation construction Section 4.5.1.
`Catch BC Output Interval Nodestring ==` ⟨ dT_{ns} ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the timestep (in simulation time seconds) at which lines within a nodestring (Q) boundary condition file for TUFLOW FV (created from TUFLOW HPC predictions) are separated. Simulation construction Section 4.5.1.
`Catchment BC Nodestring ==` ⟨ `rec:` `..\..\TUFLOW\model\gis\2d_ns_name_L.shp` ⟩	Used in the Receiving Model commands section of a TUFLOW CATCH control file to set the path to the file containing nodestrings for catchment inflows (Q type) to be generated by TUFLOW CATCH. All other inflows will be type QC. Simulation construction Section 4.5.4.
`Catchment Hydraulic Model ==` ⟨ `HPC; None` ⟩	Used to define the start of a catchment hydraulic model block in a TUFLOW CATCH control file. This block contains the commands that control catchment simulation of surface (and optionally subsurface) hydrology and hydraulics, and is essentially the contents of a TUFLOW HPC *.tcf control file. It does not include any pollutant export commands. Set the argument to none if only receiving water modelling is to be undertaken through the TUFLOW CATCH control file. This command must be matched with a subsequent End Catchment Hydraulic Model command. Simulation construction Section 4.5.2.
`Catchment Pollutant Export Model ==` ⟨ `Mass Accumulation Release; None` ⟩	Used to define the start of a catchment pollutant export model block in a TUFLOW CATCH control file. This block contains the commands that control pollutant export. Set the argument to none if only hydrology is being simulated, as per TUFLOW CATCH's **Hydrology** configuration. This command must be matched with a subsequent End Catchment Pollutant Export Model command. Simulation construction Section 4.5.3.
`Coefficients ==` ⟨ R_j ⟩	Used in an intervention block within a pollutant export model block to set the coefficients associated with a constant equation based mass removal model. The same command can be used to set coefficients for other equation based models as appropriate. Simulation construction Section 4.5.3.5.1.1.
`Constant Pollutant-Name ==` ⟨ `Float` ⟩	Used in the Pollutant Export Model block of a TUFLOW CATCH control file to set a named pollutant pollutant-name concentration to a constant value. The command argument is the value to be set. This value is applied equally to all boundaries and summary files where appropriate. An example might be the setting of salinity in catchment flows as 0.0 g/L. Simulation construction Section 4.5.3.1.
`CSV Write Frequency Day ==` ⟨ dT_{csv} ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the timestep at which boundary condition data stored in memory is written to boundary condition files for TUFLOW FV (created from TUFLOW HPC predictions). Simulation construction Section 4.5.1.

Table A.1: TUFLOW CATCH Commands

Command	Description
Deposition Stress == ⟨ τ_{cd} ⟩	Used in a material block within a pollutant export model block to set the maximum bed shear stress that allows for deposition to occur. This deposition represents a transfer from a pollutant's wet to dry store. Deposition will not occur at shear stresses above this value. Applies only to shear stress pollutant export methods, e.g. Shear1. It is not used for (nor is it an argument of) accumulation washoff pollutant export models, e.g. Washoff1. Simulation construction Section 4.5.3.3.2.
Deposition Velocity == ⟨ w_s ⟩	Used in a material block within a pollutant export model block to set the settling velocity of a pollutant. This settling represents a transfer from a pollutant's wet to dry store. Settling occurs at all times in the accumulation washoff pollutant export model. Settling only occurs once bed shear stress drops below the user specified value in the shear stress pollutant export model. Simulation construction Section 4.5.3.3.
Depth Threshold == ⟨ d ⟩	Used in a material block within a pollutant export model block to set the minimum cell water depth at which pollutant export can occur. Applies to all pollutant export methods. Simulation construction Section 4.5.3.3.
Device == ⟨ Device name ⟩	Used to initiate an intervention block within a pollutant export model block. Simulation construction Section 4.5.3.5.
End Catchment Hydraulic Model	Used to define the end of a catchment hydraulic model block in a TUFLOW CATCH control file. This block contains the commands that control catchment simulation of surface (and optionally subsurface) hydrology and hydraulics, and is essentially the contents of a TUFLOW HPC *.tcf control file. It does not include any pollutant export commands. This command must be matched with a preceding Catchment Hydraulic Model command. Simulation construction Section 4.5.2.
End Catchment Pollutant Export Model	Used to define the end of a catchment pollutant export model block in a TUFLOW CATCH control file. This block contains the commands that control pollutant export. This command must be matched with a preceding Catchment Pollutant Export Model command. Simulation construction Section 4.5.3.
End Device	Used to terminate an intervention block within a pollutant export model block. Simulation construction Section 4.5.3.5.
End Material	Used in the Pollutant Export Model block of a TUFLOW CATCH control file to end application of a material by material block pollutant export properties. This command must be accompanied by a preceding Material command. Simulation construction Section 4.5.3.3.
End Receiving Model	Used to define the end of a receiving model block in a TUFLOW CATCH control file. This block contains the commands that control receiving simulation of hydrodynamics and other processes, and is essentially the contents of a TUFLOW FV *.fvc control file. This command must be matched with a preceding Receiving Model command. Simulation construction Section 4.5.4.
End Time == ⟨ dd/mm/yyyy hh:mm:ss; hours ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the simulation start date in the format declared by Time Format. It is strongly recommended that ISODATE (dd/mm/yyyy hh:mm:ss) be deployed rather than hours. Simulation construction Section 4.5.1.
Eqn == ⟨ Constant ⟩	Used in an intervention block within a pollutant export model block to set the mass removal equation. More equations may become available in future. Simulation construction Section 4.5.3.5.1.1.

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Table A.1: TUFLOW CATCH Commands

Command	Description
`Erosion Rate ==` ⟨ E_r ⟩	Used in a material block within a pollutant export model block to set the erosion rate of a pollutant. This erosion represents a transfer from a pollutant's dry to wet store. Erosion only occurs once bed shear stress increases above the user specified value. Erosion will not occur at shear stresses below this value. Applies only to shear stress pollutant export methods, e.g. Shear1. It is not used for accumulation washoff pollutant export models, e.g. Washoff1. Simulation construction Section 4.5.3.3.2.
`Erosion Stress ==` ⟨ τ_{ce} ⟩	Used in a material block within a pollutant export model block to set the minimum bed shear stress that allows for erosion to occur. This erosion represents a transfer from a pollutant's dry to wet store. Erosion will not occur at shear stresses below this value. Applies only to shear stress pollutant export methods, e.g. Shear1. It is not used for accumulation washoff pollutant export models, e.g. Washoff1. Simulation construction Section 4.5.3.3.2.
`EXE ==` ⟨ `rec:` `C:\EXE\TUFLOWFV\TUFLOWFV.exe` ⟩	Used in the Receiving Model block of a TUFLOW CATCH control file to set the path to the TUFLOW FV executable. The full path, either relative or absolute, is required, including the name of the executable itself, with the .exe extension. Simulation construction Section 4.5.2.
`EXE ==` ⟨ `rec:` `C:\EXE\TUFLOW\TUFLOW_iSP_w64.exe` ⟩	Used in the Catchment Hydraulic Model block of a TUFLOW CATCH control file to set the path to the TUFLOW executable. The full path, either relative or absolute, is required, including the name of the executable itself, with the .exe extension. Simulation construction Section 4.5.2.
`GIS Format ==` ⟨ `SHP; GPKG` ⟩	Used in the General, Catchment Hydraulic Model or Receiving Model commands section of a TUFLOW CATCH control file to set the GIS format of the simulation. This command can be overwritten in the catchment hydraulic model or receiving model blocks if needed. TUFLOW FV does not support GPKG format. Simulation construction Section 4.5.1.
`GPKG Projection ==` ⟨ `rec:` `..\..\TUFLOW\model\gis\Projection.gpkg` ⟩	Used in the General or Catchment Hydraulic Model commands section of a TUFLOW CATCH control file to set the path to the GPKG file containing the TUFLOW CATCH model projection. Only used if GIS Format is set to GPKG. TUFLOW FV does not support GPKG format. Simulation construction Section 4.5.1.
`Groundwater Boundary Threshold Layer ==` ⟨ `Layer number` ⟩	Used to set the deepest soil layer from which flows and loads will be taken to develop TUFLOW FV boundary conditions. Simulation construction Section 4.5.2.
`Groundwater Default Catch BC ==` ⟨ `Free Outflow; Zero Depth` ⟩	Used to set the default groundwater boundary condition applied along the catchment model boundary. 'Free Outflow' specifies a zero-gradient condition, allowing groundwater to exit the model domain without imposing artificial resistance. This prevents boundary induced flow constraints and better represents natural drainage where no defined head condition is required. 'Zero Depth' applies a fixed groundwater depth of zero at the boundary. This option replicates behaviour from earlier releases and may be used for backward compatibility or where a controlled groundwater boundary is desired. The 'Free Outflow' condition is the default from the 2025.2.0 release onwards. This change was introduced to avoid unintended restrictions to groundwater movement. Simulation construction Section 4.5.2.

Table A.1: TUFLOW CATCH Commands

Command	Description
`GW Z Flux Output Normalise ==` ⟨ `ON; OFF` ⟩	Used in the Catchment Hydraulic Model block to set whether output groundwater fluxes (GW_QZ and GW_QZI) in discharges and volumes are normalised to a unit area or not. The default option is ON, which normalises the output groundwater fluxes to a unit area. It is recommended to leave this command as default (ON) as the non-normalised results are difficult to interpret correctly due to interpolation. Prior to the 2026.0.0 TUFLOW CATCH release, this command did not exist and groundwater fluxes in discharges and volumes were not normalised to a unit area (OFF option). Outputs Section 6.2.
`Hardware ==` ⟨ `GPU; CPU` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the simulation hardware. This command can be overwritten in the catchment hydraulic model or receiving model blocks if needed. Simulation construction Section 4.5.1.
`Infiltration Pollutant-Name ==` ⟨ `ON; OFF` ⟩	Used in the Pollutant Export Model block of a TUFLOW CATCH control file to set whether a named pollutant pollutant-name is allowed to infiltrate into the subsurface from surface flows. The command argument is ON or OFF. An example might be setting infiltration of sediment to be OFF. Simulation construction Section 4.5.3.4.
`Limit ==` ⟨ L_{acc}; L_{shr} ⟩	Used in a material block within a pollutant export model block to set an accumulation (washoff model) or erosion (shear model) limit. Simulation construction Section 4.5.3.3.
`Log Folder ==` ⟨ `rec: log` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the location to which all log files are written. It is strongly recommended that this be set to the log folder within the TUFLOWCATCH directory. It can be a relative or absolute path. Simulation construction Section 4.5.1.
`Material ==` ⟨ `ALL; Up to 10 comma separated material numbers` ⟩	Used in the Pollutant Export Model block of a TUFLOW CATCH control file to apply a material by material pollutant export properties. Up to 10 comma separated materials can be included in one material block command. Alternatively, the keyword all can be specified and this will instruct TUFLOW CATCH to apply the properties in that corresponding material block to all TUFLOW HPC cells. This is a useful way to set the most commonly occurring conditions for all pollutants across the domain, and acts as a default condition. Subsequent Material block declarations for subsets of the entire domain (e.g. for one or more materials) will progressively spatially overwrite this global declaration. This command must be followed by an End Material command to finalise the block. Simulation construction Section 4.5.3.3.
`Method ==` ⟨ `Eqn; Table` ⟩	Used in an intervention block within a pollutant export model block to set the mass removal method (i.e. adopted model). More methods may become available in future. Simulation construction Section 4.5.3.5.
`Method ==` ⟨ `Washoff1; Shear1` ⟩	Used in a material block within a pollutant export model block to set the pollutant export model. Simulation construction Section 4.5.3.3.
`Output Directory ==` ⟨ `rec: ..\output` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the location to which all TUFLOW HPC and TUFLOW FV results are written. It is strongly recommended that this be set to the output folder within the TUFLOWCATCH directory, but can be set elsewhere if file size constraints apply. It can be a relative or absolute path. This is not the location for the TUFLOW CATCH intermediate files. Simulation construction Section 4.5.1.

TUFLOW CATCH

Table A.1: TUFLOW CATCH Commands

Command	Description
`Output Map Data Types ==`⟨ `rec: v h d catch` ⟩	Used in the Catchment Hydraulic Model block of a TUFLOW CATCH control file map output command to include all TUFLOW CATCH related outputs. The command argument catch is a keyword and should be added as an output to all hydrologic outputs such as velocity, depth and water surface elevation. XMDF is the recommended output container for these data sets. Simulation construction Section 4.5.2.
`Path ==`⟨ `Path to intervention table` ⟩	Used in an intervention block within a pollutant export model block to set the mass removal table for the `Method == Table` method. Simulation construction Section 4.5.3.5.2.
`Pollutant ==`⟨ `Any number of user defined pollutant names` ⟩	Used in the Receiving Model block of a TUFLOW CATCH control file to set the names of pollutants to be simulated in the pollutant export model. Only used when TUFLOW CATCH is executed in **Pollutant export** configuration. Any pollutant names can be used in this command, and they do not need to be those that are generated by TUFLOW FV. Simulation construction Section 4.5.2.
`Preserve Catchment In-flows ==`⟨ `ON; OFF` ⟩	Used in the Receiving Model block of a TUFLOW CATCH control file to prevent TUFLOW CATCH from overwriting a previously created (non-blank) TUFLOW FV boundary condition bc block file. Used when preliminary TUFLOW FV boundary condition inflows have been generated by TUFLOW CATCH to support initial TUFLOW FV calibration. Avoids the need to continually rerun TUFLOW HPC within TUFLOW CATCH when undertaking only a TUFLOW FV calibration. Simulation construction Section 4.5.2.
`Rain Threshold ==`⟨ R_r ⟩	Used in a material block within a pollutant export model block to set the minimum rainrate threshold at which a pollutant is released from its dry store. Pollutant export is suppressed below this rate. Applies only to accumulation pollutant export methods, e.g. Washoff1. It is not used for erosion pollutant export models, e.g. Shear1. Simulation construction Section 4.5.3.3.1.
`Rate ==`⟨ R_a ⟩	Used in a material block within a pollutant export model block to set the rate at which a pollutant accumulates to its dry store. Applies only to accumulation pollutant export methods, e.g. Washoff1. It is not used for erosion pollutant export models, e.g. Shear1. Simulation construction Section 4.5.3.3.1.
`Read GIS Intervention ==`⟨ `rec: ..\..\TUFLOW\model\gis\2d_im_name_L.shp` ⟩	Used in the Receiving Model block of a TUFLOW CATCH control file to set the path to any number of polylines that define the locations of TUFLOW CATCH interventions. This is only used in the TUFLOW CATCH **Pollutant export** or **Integrated** configurations. All TUFLOW HPC cells intersecting each polyline are treated as intervention cells. TUFLOW CATCH writes a summary intervention file of removed and passed flows and loads for each intervention. These data can be used to compare across pollutant export scenarios, for example, or in catchment wide mass balance analyses. Simulation construction Section 4.5.3.5.

Table A.1: TUFLOW CATCH Commands

Command	Description
Receiving Model == ⟨ TUFLOWFV; None ⟩	Used to define the start of a receiving model block in a TUFLOW CATCH control file. This block contains the commands that control receiving simulation of hydrodynamics, advection dispersion, water quality and other optional processes, and is essentially the contents of a TUFLOW FV *.fvc control file. Set the argument to none if only catchment hydraulic water modelling is to be undertaken through the TUFLOW CATCH control file. TUFLOW CATCH will then not invoke TUFLOW FV. This 'none' option is required for the **Pollutant export** configuration. This command must be matched with a subsequent End Receiving Model command. Simulation construction Section 4.5.4.
Receiving Polygon == ⟨ rec: ..\..\TUFLOW\model\gis\2d_rp_name_P.shp ⟩	Used in the Receiving Model block of a TUFLOW CATCH control file to set the path to a polygon that delineates the downstream receiving waterway extents of a TUFLOW CATCH simulation. This is only used in the TUFLOW CATCH **Pollutant export** configuration. All TUFLOW HPC cells and boundary conditions within this polygon are excluded from the TUFLOW HPC simulation. TUFLOW CATCH writes flow and pollutant export summary and timeseries files that contain aggregated flows and loads entering the nominated polygon. These data can be used to compare across pollutant export scenarios, for example, without the need to build a TUFLOW FV model or mesh. Simulation construction Section 4.5.2.
Runs Directory == ⟨ rec: ..\..\TUFLOWFV\runs ⟩	Used in the Receiving Model block of a TUFLOW CATCH control file to set the path from which TUFLOW FV runs are to be automatically controlled by TUFLOW CATCH. This is the directory to which TUFLOW CATCH writes interim *.fvc and similar files, but the user does not need to interrogate or interact with these files - this command simply tells TUFLOW CATCH where the master TUFLOW FV control files are to be housed. It is not recommended that users interact with any files in this directory, although users will create and modify content in all other directories under TUFLOWFV if TUFLOW FV simulations are invoked. This interaction will occur through the TUFLOW CATCH *.tcc control file. Simulation construction Section 4.5.2.
Runs Directory == ⟨ rec: ..\..\TUFLOW\runs ⟩	Used in the Catchment Hydraulic Model block of a TUFLOW CATCH control file to set the path from which TUFLOW runs are to be automatically controlled by TUFLOW CATCH. This is the directory to which TUFLOW CATCH writes interim *.tcf and similar files, but the user does not need to interrogate or interact with these files - this command simply tells TUFLOW CATCH where the master TUFLOW control files are to be housed. It is not recommended that users interact with any files in this directory, although users will create and modify content in all other directories under TUFLOW if TUFLOW HPC simulations are invoked. This interaction will occur through the TUFLOW CATCH *.tcc control file. Simulation construction Section 4.5.2.
SHP Projection == ⟨ rec: ..\..\TUFLOW\model\gis\Projection.prj ⟩	Used in the General, Catchment Hydraulic Model or Receiving Model commands section of a TUFLOW CATCH control file to set the path to the SHP file containing the TUFLOW CATCH model projection. Can be set globally and then overwritten as needed within Catchment Hydraulic Model or Receiving Model blocks. Simulation construction Section 4.5.1.
Start Time == ⟨ dd/mm/yyyy hh:mm:ss; hours ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the simulation start date in the format declared by Time Format. It is strongly recommended that ISODATE (dd/mm/yyyy hh:mm:ss) be deployed rather than hours. Simulation construction Section 4.5.1.

TUFLOW *CATCH*

Table A.1: TUFLOW CATCH Commands

Command	Description
`Time Constant ==` ⟨ T_c ⟩	Used in a material block within a pollutant export model block to control the rate at which a pollutant is released from its dry store. Applies only to accumulation pollutant export methods, e.g. Washoff1. It is not used for erosion pollutant export models, e.g. Shear1. Simulation construction Section 4.5.3.3.1.
`Time Format ==` ⟨ `TUFLOWFV` ⟩	Used in the Catchment Hydraulic Model block of a TUFLOW CATCH control file to set the time format of output results. Setting to TUFLOWFV is strongly recommended, and use of hours should be avoided. Should be used in conjunction with Zero Date so that TUFLOW HPC boundaries can be specified in hours (TUFLOW HPC cannot accept ISODATE format in its boundary files at time of writing). Simulation construction Section 4.5.2.
`Time Format ==` ⟨ `ISODATE; Hours` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the simulation date format. It is strongly recommended that ISODATE (dd/mm/yyyy hh:mm:ss) be deployed rather than hours. Simulation construction Section 4.5.1.
`Time-Series Pollutant-Name ==` ⟨ `BC Database Name` ⟩	Used in the Pollutant Export Model block of a TUFLOW CATCH control file to apply a named pollutant pollutant-name concentration to a timeseries. The command argument is the name of the timeseries as specified by the user in the TUFLOW HPC boundary database. TUFLOW CATCH will interpolate between the specified timeseries and required frequency of writing outputs as needed. An example might be setting water temperature to be a timeseries that reflects seasonality. Simulation construction Section 4.5.3.2.
`Units ==` ⟨ `MGL; GL; MICGL; CFU100ML` ⟩	Used in a pollutant export model block to set the units of a simulated constituent. Default is MGL. Simulation construction Section 4.5.3.5.3.
`Write Check Files ==` ⟨ `rec: ..\check` ⟩	Used in the General commands section of a TUFLOW CATCH control file to set the location to which all check files are written. It is strongly recommended that this be set to the check folder within the TUFLOWCATCH directory. It can be a relative or absolute path. Simulation construction Section 4.5.1.
`Zero Date ==` ⟨ dd/mm/yyyy hh:mm ⟩	Used in the Catchment Hydraulic Model block of a TUFLOW CATCH control file to set the date in TUFLOWFV ISODATE format that corresponds to zero hours in TUFLOW HPC boundary condition files. Seconds is not required in the date specification. Simulation construction Section 4.5.2.

B Parameters

Following are parameters that can be specified within TUFLOW CATCH via user commands.

Tips for use:

- Use the search box to dynamically filter the table
- Sort the filtered (or unfiltered) table by clicking the arrows at the top of each column
- UD = user defined
- N/A = not applicable
- 'Command' column links to a description of the corresponding control file command that includes the parameter
- 'Science' column links to the section containing the relevant descriptions

Table B.1: TUFLOW CATCH Parameters

Name	Notation	Units	Description	Command	Science
Water Depth Threshold	d	m	The minimum cell water depth for which pollutant export is permitted for a given pollutant within a given material. Below this depth, no pollutant export occurs. Applies equally to all pollutant export models. Evaluated on a cell by cell basis	`Depth Thresh- old`	Section 3.2.3.1.2
Accumulation Limit	L_{acc}	kg/ha	The maximum dry store areal mass of a given pollutant allowed to accumulate within a given material. Used with the Washoff1 pollutant export model. Above this value, no further mass is added to a cell's dry store. Must be a positive number	`Limit`	Section 3.2.3.1.1
Erosion Limit	L_{shr}	kg/ha	The maximum erosion or deposition allowed within a material for a given pollutant. The number is specified only as a positive number, but is applied equally to erosion and deposition. For example, if a number of 100 is specified, and erosion is occurring in a given cell, then erosion will stop when the areal mass reaches -100 kg/ha. Equally, if deposition is occurring in the same cell, it will cease when the areal mass reaches 100 kg/ha. These areal masses can be converted to eroded depth or accretion height by assuming a bulk density and applying a conversion from hectares to square metres	`Limit`	Section 3.2.3.2.1
Dry Store Accumulation Rate	R_a	kg/ha/yr	The rate at which a pollutant accumuates mass to its dry store. Used only in accumulation pollutant export models. Set to zero to suppress pollutant export or a large value to rapidly populate pollutant dry stores. This might be useful in setting initial conditions	`Rate`	Section 3.2.3.1.1
Washoff Time Constant	T_c	s	A time constant that controls the rate at which a pollutant is washed off (out of its dry store) when both minimum cell water depth and rainfall conditions are met. Used only in accumulation pollutant export models. Set to a large (small) number for slow (rapid) pollutant dry store release	`Time Constant`	Section 3.2.3.1.2

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Table B.1: TUFLOW CATCH Parameters

Name	Notation	Units	Description	Command	Science
Rainrate Threshold	R_r	mm/hr	The minimum instantaneous cell rain rate above which pollutant is exported from its dry store. Used only in accumulation pollutant export models. Set to a large (small) number for reduced (enhanced) pollutant washoff. Evaluated on a cell by cell basis	`Rain Threshold`	Section 3.2.3.1.2
Critical Shear Stress for Deposition	τ_{cd}	N/m^2	The maximum bed shear stress at which deposition can occur from a pollutant's wet to dry store. The rate at which this deposition occurs is then set by the specified settling velocity. Used only in shear stress pollutant export models. Set to a small (large) number for reduced (enhanced) pollutant settling. Evaluated on a cell by cell basis. Should be less than the corresponding critical shear stress for erosion	`Deposition Stress`	Section 3.2.3.2.2
Critical Shear Stress for Erosion	τ_{ce}	N/m^2	The minimum bed shear stress at which erosion can occur from a pollutant's dry to wet store. Used only in shear stress pollutant export models. Set to a large (small) number for reduced (enhanced) pollutant erosion. Evaluated on a cell by cell basis. Should be greater than the corresponding critical shear stress for deposition	`Erosion Stress`	Section 3.2.3.2.1
Deposition Velocity	w_s	m/d	The still water velocity at which a pollutant settles from the wet to dry store. Set to a small (large) number for reduced (enhanced) pollutant settling. Evaluated on a cell by cell basis	`Deposition Velocity`	Section 3.2.3.2.2
Erosion Rate	E_r	g/m^2/s	The rate at which a pollutant is eroded from its dry store. Used only in shear stress pollutant export models. Set to a small (large) number for reduced (enhanced) pollutant erosion. Evaluated on a cell by cell basis	`Erosion Rate`	Section 3.2.3.2.1
Nodestring Boundary Timestep	dT_{ns}	s	The timestep at which lines within a nodestring (Q) boundary condition file for TUFLOW FV (created from TUFLOW HPC predictions) are separated. This is not the timestep at which boundary data is written from memory to file	`Catch BC Output Interval Nodestring`	Section 4.5.1
Lateral Boundary Timestep	dT_{lat}	s	The timestep at which lines within a lateral (element, QC) boundary condition file for TUFLOW FV (created from TUFLOW HPC predictions) are separated. This is not the timestep at which boundary data is written from memory to file	`Catch BC Output Interval Lateral`	Section 4.5.1
CSV Write Timestep	dT_{csv}	d	The timestep (in simulation time) at which boundary condition data in memory is written to boundary condition files for TUFLOW FV (created from TUFLOW HPC predictions). This is not the timestep separating individual lines in a boundary condition file	`CSV Write Frequency Day`	Section 4.5.1
Constant mass removal proportion	R_j	[-]	The constant proportion of mass of constituent j removed by a given intervention in a timestep. A value of 0.0 (1.0) indicates no (complete) mass removal. Must be non-negative and less than or equal to 1.0	`Coefficients`	Section 3.3.1.1.1

TUFLOW CATCH

C Files and data fields

Depending on the core supported configuration selected, TUFLOW CATCH outputs one or more files, each with their own data fields. If the recommended output protocols described in Chapter 6 are followed, then these are:

- TUFLOW HPC
    - One *.xmdf with all catchment based results
- TUFLOW FV
    - One *.nc for hydrodynamics and sediments
    - One *.nc for water quality
    - Possibly others (e.g. particle tracking)

Each of these files has any number of data fields, depending on the TUFLOW CATCH configuration, selected pollutants and water quality module settings. Notwithstanding this, the following will hold under the above output protocols:

- All TUFLOW CATCH map data fields will be contained within the TUFLOW HPC results file (*.xmdf)
- Receiving waterway hydrodynamic map data fields are those of standard TUFLOW FV outputs (*.nc)
- Receiving waterway water quality map data fields are those of standard TUFLOW FV WQ outputs (*.nc)

The outputs and data fields of the second two points above are not dealt with here because they are described in the TUFLOW FV Manuals and TUFLOW FV WQ Manual Appendices.

The first point above (TUFLOW CATCH data fields) is dealt with in this Appendix. Rather than attempt to list every potential data field that might be included in this output file, the attributes of the available data field types are presented. The names of these data fields will vary depending on pollutant names and other parameters, but each type follows a set naming convention. These data field types are:

- Surface water concentration
- Groundwater Layer concentration
- Dry mass
- Net mass
- Instantaneous volumetric flux entering a groundwater layer
- Time integrated volumetric flux entering a groundwater layer
- Instantaneous mass flux entering a groundwater layer
- Time integrated mass flux entering a groundwater layer

These are described in the following sections.

C.1 Surface water concentrations

Surface water concentration data fields have the following properties:

- Content:
    - Reports the temporally and spatially varying concentration of a dissolved or particulate pollutant in surface water
- Name:
    - "Conc <pollutant_name>", e.g. "Conc WQ_NITRATE_MG_L"
- Units:
    - See Section 4.5.3.3.3 and Table 4.1, "Map output concentration" column

These fields are reported at all wet TUFLOW HPC cells for all simulated constituents that are listed within pollutant export material blocks. Constant and timeseries pollutants are not reported because they are assigned only during boundary condition writing, rather than being numerically simulated in the catchment domain.

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C.2   Groundwater concentrations

Groundwater concentration data fields have the following properties:

- Content:
    - Reports the temporally and spatially varying concentration of a dissolved or particulate pollutant in groundwater associated with soil layer N (N = 1, 2, …)
- Name:
    - "`GW Layer <Layer number> Conc <pollutant_name>`", e.g. "`GW Layer 1 Conc PFAS`"
- Units:
    - See Section 4.5.3.3.3 and Table 4.1, "Map output concentration" column

These fields are reported at all TUFLOW HPC cells for all simulated constituents that are listed within pollutant export material blocks. Constant and timeseries pollutants are not reported because they are assigned only during boundary condition writing, rather than being simulated in the catchment domain. These GW Layer data fields will be zero at all times and locations for a given pollutant `<name>` if its infiltration has been set to off via

`Infiltration <name> == OFF`

C.3   Dry mass

Dry mass data fields are created and reported only for pollutants that are set to use the Washoff1 pollutant export model. They have the following properties:

- Content:
    - Reports the temporally and spatially varying dry mass of accumulated pollutant. It is initialised to zero at simulation commencement
- Name:
    - "`Dry Mass <pollutant_name>`", e.g. "`Dry Mass WQ_POC_MG_L`"
- Units:
    - See Section 4.5.3.3.3 and Table 4.2, "Dry store mass" column

These fields are reported at all TUFLOW HPC cells for all simulated constituents that are listed within pollutant export material blocks and use the Washoff1 pollutant export model. Constant and timeseries pollutants are not reported because they are assigned only during boundary condition writing, rather than being simulated in the catchment domain. Multiplying each pollutant's Dry Mass outputs by the TUFLOW HPC cell area (in hectares) and summing across the domain will compute the total dry store mass of each pollutant (in kilograms) as a function of time.

C.4   Net mass

Net mass data fields are created and reported only for pollutants that are set to use the Shear1 pollutant export model. They have the following properties:

- Content:
    - Reports the temporally and spatially varying net mass of a pollutant. It is initialised to zero at simulation commencement. A negative/positive number at a given location reflects net erosion/deposition, respectively
- Name:
    - "`Net Mass <pollutant_name>`", e.g. "`Net Mass WQ_SED_FINES`"
- Units:
    - See Section 4.5.3.3.3 and Table 4.2, "Net mass" column

These fields are reported at all TUFLOW HPC cells for all simulated constituents that are listed within pollutant export material blocks and use the Shear1 pollutant export model. Constant and timeseries pollutants are not reported because they are assigned only during boundary condition writing, rather than being simulated in the catchment domain. Dividing each pollutant's Net Mass outputs by a user defined bulk density, and then again dividing by 10000 (i.e. m^2/ha) will compute the erosion or deposition depth of each pollutant as a function of space and time.

C.5 Instantaneous volumetric flux entering a groundwater layer

The instantaneous volumetric flux entering a groundwater layer from above has the following properties:

- Content:
    - Reports the temporally and spatially varying instantaneous flux of water entering a groundwater layer from above
- Name:
    - "`GW QZ Layer <Layer number>`", e.g. "`GW QZ Layer 4`"
- Units:
    - Cubic meters per second

Depending on model configuration, these fluxes may be 'noisy' given their instantaneous calculation. Time integrated equivalent quantities are therefore additionally provided (see Section C.6). One field is produced for each groundwater layer, and labelled '…Layer X', where X is the layer number.

Note: Since the 2026.0.0 TUFLOW CATCH release, output groundwater fluxes in discharges and volumes are normalised to a unit area by default. See `GW Z Flux Output Normalise`.

C.6 Time integrated volumetric flux entering a groundwater layer

The time integrated volumetric flux entering a groundwater layer has the following properties:

- Content:
    - Reports the temporally and spatially varying time integrated flux of water entering a groundwater layer from above. This can be interpreted as the cumulative volume of water entering a groundwater layer since simulation commencement
- Name:
    - "`GW QZI Layer <Layer number>`", e.g. "`GW QZI Layer 1`"
- Units:
    - Cubic meters

One field is produced for each groundwater layer, and labelled '…Layer X', where X is the layer number.

Note: Since the 2026.0.0 TUFLOW CATCH release, output groundwater fluxes in discharges and volumes are normalised to a unit area by default. See `GW Z Flux Output Normalise`.

C.7 Instantaneous mass flux entering a groundwater layer

The instantaneous mass flux entering a groundwater layer from above has the following properties:

- Content:
    - Reports the temporally and spatially varying instantaneous flux of pollutant mass entering a groundwater layer from above
- Name:
    - "`GW Layer <Layer number> MZ <pollutant_name>`", e.g. "`GW Layer 2 MZ SED_FINES`"
- Units:
    - See Section 4.5.3.3.3 and Table 4.1, "Map output concentration" column. These units are multiplied by cubic meters per second and reported in this MZ layer

Depending on model configuration, these fluxes may be 'noisy' given their instantaneous calculation. Time integrated equivalent quantities are therefore additionally provided (see Section C.8). One field is produced for each groundwater layer, and labelled '…Layer X', where X is the layer number.

C.8   Time integrated mass flux entering a groundwater layer

The time integrated mass flux entering a groundwater layer has the following properties:

- Content:
    - Reports the temporally and spatially varying time integrated flux of pollutant mass entering a groundwater layer from above. This can be interpreted as the cumulative mass of pollutant entering a groundwater layer since simulation commencement
- Name:
    - "`GW Layer <Layer number> MZI <pollutant_name>`", e.g. "`GW Layer 3 MZI PFAS`"
- Units:
    - See Section 4.5.3.3.3 and Table 4.1, "Map output concentration" column. These units are multiplied by cubic meters and reported in this MZI layer

One field is produced for each groundwater layer, and labelled '…Layer X', where X is the layer number.

C.9   Other outputs

TUFLOW CATCH produces a small suite of supporting outputs that are simple text files. These are listed below. If the TUFLOW CATCH BC output folder is set to `..\bc_dase` as recommended:

`Catch BC Output Folder == ..\bc_dbase`

then all files below are written to the `TUFLOWCATCH\bc_dbase\` folder.

C.9.1   Mass balance

A series of three mass balance files are written as follows (assuming a *.tcc file name of Model_001.tcc).

C.9.1.1   Surface water mass balance

One file per simulation is produced as follows:

- Content:
    - Timeseries of spatially summed cumulative surface water flow and associated pollutant masses leaving the TUFLOW HPC model (either to a polygon (**Pollutant Export** TUFLOW CATCH configuration) or TUFLOW FV model domain (**Hydrology** and **Integrated** TUFLOW CATCH configurations))
- Name:
    - Model_001_catchment_hydraulic_mass_balance_surface.csv
- Units:
    - Time: ISODATE format
    - Volume: m^3 (cumulative)
    - All pollutants: See Section 4.5.3.3.3 and Table 4.1, "Mass balance mass" column (cumulative mass, not reported for **Hydrology** configuration as pollutants are not simulated)
- Uses
    - Can be directly imported into common plotting packages to show total surface cumulative flow and pollutant mass export at the outlet of the TUFLOW HPC model domain (or, equally, entry to the TUFLOW FV domain if used)
    - Provides an accessible means of high level scenario comparisons, for example where cumulative surface catchment flows and pollutants loads are to be compared between different catchment land use options, management interventions or rainfall sequences

C.9.1.2   Groundwater mass balance

One file per simulation is produced as follows:

- Content:

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- Timeseries of spatially summed cumulative groundwater flow and associated pollutant masses leaving the TUFLOW HPC model (either to a polygon (**Pollutant Export** TUFLOW CATCH configuration) or TUFLOW FV model domain (**Hydrology** and **Integrated** TUFLOW CATCH configurations))
- Name:
    - Model_001_catchment_hydraulic_mass_balance_groundwater.csv
- Units:
    - Time: ISODATE format
    - Volume: m^3 (cumulative)
    - All pollutants: See Section 4.5.3.3.3 and Table 4.1, "Mass balance mass" column (cumulative mass, not reported for **Hydrology** configuration as pollutants are not simulated)
- Uses
    - Can be directly imported into common plotting packages to show total groundwater cumulative flow and pollutant mass export at the outlet of the TUFLOW HPC model domain (or, equally, entry to the TUFLOW FV domain if used)
    - Provides an accessible means of high level scenario comparisons, for example where cumulative groundwater catchment flows and pollutants loads are to be compared between different catchment land use options, management interventions or rainfall sequences

C.9.1.3 Total mass balance

One file per simulation is produced as follows. Its content is the summation of the data reported in the respective surface and groundwater mass balance outputs described in Section C.9.1.1 and Section C.9.1.2:

- Content:
    - Timeseries of spatially summed cumulative surface and groundwater flow and associated pollutant masses combined leaving the TUFLOW HPC model (either to a polygon (**Pollutant Export** TUFLOW CATCH configuration) or TUFLOW FV model domain (**Hydrology** and **Integrated** TUFLOW CATCH configurations))
- Name:
    - Model_001_catchment_hydraulic_mass_balance.csv
- Units:
    - Time: ISODATE format
    - Volume: m^3 (cumulative)
    - All pollutants: See Section 4.5.3.3.3 and Table 4.1, "Mass balance mass" column (cumulative mass, not reported for **Hydrology** configuration as pollutants are not simulated)
- Uses
    - Can be directly imported into common plotting packages to show cumulative total flow and pollutant mass export at the outlet of the TUFLOW HPC model domain (or, equally, entry to the TUFLOW FV domain if used)
    - Provides an accessible means of high level scenario comparisons, for example where cumulative total catchment flows and pollutants loads are to be compared between different catchment land use options, management interventions or rainfall sequences

C.9.2 Receiving polygon

If TUFLOW CATCH has been executed in the **Pollutant Export** configuration, then a timeseries output file is produced that reports incoming flow and concentrations to that user defined polygon. This is broadly a concentration based equivalent to the output described in Section C.9.1.3, with some extra fields reported.

Assuming a *.tcc file name of Model_001.tcc has been executed, the file is as follows:

- Content:
    - Timeseries of spatially summed instantaneous surface and groundwater flow and associated pollutant concentrations combined leaving the TUFLOW HPC model to a polygon (**Pollutant Export** TUFLOW CATCH configuration)
- Name:
    - Model_001_catchment_hydraulic_receiving.csv
- Units:
    - Time: ISODATE format
    - Flow: m^3/s
    - All pollutants: See Section 4.5.3.3.3 and Table 4.1, "Receiving polygon concentration" column

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- Uses
    - Can be directly imported into common plotting packages to show instantaneous total flow and pollutant concentrations at the outlet of the TUFLOW HPC model domain
    - Provides an accessible means of high level scenario comparisons, for example where total catchment flows and pollutants concentrations are to be compared between different catchment land use options, management interventions or rainfall sequences

C.9.3   TUFLOW FV boundaries

A series of TUFLOW FV boundary related files are written as follows.

C.9.3.1   BC blocks

A single file that contains all required TUFLOW FV nodestring (Q) and cell (QC) inflow boundary BC blocks is written by TUFLOW CATCH. This file is called automatically by TUFLOW FV under TUFLOW CATCH when required. It is at the heart of the automated linking offered by TUFLOW CATCH. Users should not edit this file in any way.

- Content:
    - TUFLOW FV BC blocks that direct TUFLOW FV to boundary condition data files prepared by TUFLOW HPC under TUFLOW CATCH. Only produced in the **Hydrology** and **Integrated** TUFLOW CATCH configurations. Two example blocks are shown below
      ```
      ! Nodestring boundaries
      BC == Q, NW_Inflow, NW_Inflow.csv
            Sub-Type == 2
            BC Header == Time,Flow,Salinity,Temperature,SED_FINES
      End BC
      ! Lateral boundaries
      BC == QC, 1178572.028, 4996161.397, cell1.csv
            BC Header == Time,Flow,Salinity,Temperature,SED_FINES
      End BC
      ```
- Name:
    - Model_001_catchment_hydraulic.fvcatchbc
- Units:
    - NA
- Uses
    - Used internally by TUFLOW CATCH to link TUFLOW HPC and TUFLOW FV simulations. Users should not edit this file in any way

This file calls underlying nodestring and/or lateral boundary condition data files produced by TUFLOW HPC, and these are described below.

C.9.3.2   Nodestring boundary data

If TUFLOW CATCH has been executed in the **Hydrology** or **Integrated** configuration and TUFLOW FV nodestrings have been specified as catchment inflows via

```
Catchment BC Nodestring == <path to GIS nodestring file>
```

then individual data files are produced for each nodestring boundary:

- Content:
    - Timeseries of flow and associated pollutant concentrations crossing the nodestring
- Name:
    - "<GIS name>.csv", e.g. "SW_Inflow.csv", where "SW_Inflow" is the user defined name given to the nodestring in GIS
- Units:
    - Time: ISODATE format
    - Flow: m^3/s
    - All pollutants: See Section 4.5.3.3.3 and Table 4.1, "TUFLOW FV BC concentration" column
- Uses

  – Called by Model_001_catchment_hydraulic.fvcatchbc to link TUFLOW HPC and TUFLOW FV under TUFLOW CATCH. Users should not edit this file in any way, including opening and saving it in Excel, which can cause the time format to change and become unreadable.

C.9.3.3 Lateral boundary data

If TUFLOW CATCH has been executed in the **Hydrology** or **Integrated** configuration then individual lateral data files are produced for each transfer cell boundary:

- Content:
  – Timeseries of flow and associated pollutant concentrations entering a cell
- Name:
  – "cell_<TUFLOW mesh cell ID>.csv", e.g. "cell37.csv", where 37 is the 2D cell ID in the TUFLOW FV mesh
- Units:
  – Time: ISODATE format
  – Flow: m^3/s
  – All pollutants: See Section 4.5.3.3.3 and Table 4.1, "TUFLOW FV BC concentration" column
- Uses
  – Called by Model_001_catchment_hydraulic.fvcatchbc to link TUFLOW HPC and TUFLOW FV under TUFLOW CATCH. Users should not edit this file in any way, including opening and saving it in Excel, which can cause the time format to change and become unreadable.

C.9.3.4 Intervention summary

If TUFLOW CATCH has been executed in the **Pollutant Export** or **Integrated** configuration and with interventions included, then a csv file is produced:

- Content:
  – Final cumulative: flows, masses entering and masses removed for all intervention devices and pollutants
- Name:
  – "Model_001_catchment_hydraulic_intervention_summary.csv", in the user specified results folder (assuming "Model_001" is the simulation name)
- Columns:
  – Headers
    * "QI" cumulative flow
    * "cum <pollutant_1_name>" cumulative mass entering device
    * "cum <pollutant_2_name>" cumulative mass entering device
    * "cum <pollutant_..._name>" cumulative mass entering device
    * "cum <pollutant_X_name>" cumulative mass entering device
    * "rem <pollutant_1_name>" cumulative mass removed by device
    * "rem <pollutant_2_name>" cumulative mass removed by device
    * "rem <pollutant_..._name>" cumulative mass removed by device
    * "rem <pollutant_X_name>" cumulative mass removed by device
  – <device_1_name>
  – <device_2_name>
  – <device_..._name>
  – <device_X_name>

	A	B	C
1	Demonstration_009_c	Wetland1	Channel
2	QI [m3]	198597.3	9558.097
3	cum TAILINGS [g]	5.43E+07	211769.5
4	cum PFAS [g]	207002.9	20751.88
5	rem TAILINGS [g]	2.71E+07	105884.8
6	rem PFAS [g]	20628.48	2093.949
7			
8			
9			

Figure C.1: Example intervention summary output

- Units:
  – Flow: m^3

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  – cum mass: grams (see Section 4.5.3.5.3 and command `Units`)
  – rem mass: grams (see Section 4.5.3.5.3 and command `Units`)
- Uses
  – Interrogating pollutant masses removed by intervention devices and therefore the predicted device efficiency, per pollutant. Can also be used in mass balance calculations. When a table is used for specifying removal efficiency then the quotient of removed to entering cumulative masses provides a mean removal rate. It can be verified that this quotient equals the user specified R_j if `Eqn ==` `Constant` is deployed

TUFLOW CATCH

D Demonstration model

D.1 Context

A demonstration model and small suite of simulations have been developed to support TUFLOW CATCH users. These simulations:

- Can be used as templates for construction of other TUFLOW CATCH simulations
- Encompass the supported TUFLOW CATCH configurations, and
- Are able to be run without a licence for TUFLOW CATCH, TUFLOW HPC or TUFLOW FV

Descriptions of the model and demonstration simulations follow.

Note: In addition to the demonstration model, a number of tutorial models are available for download and are documented in the TUFLOW Wiki.

D.2 Domain

The demonstration model is located in New Zealand. It uses publicly available base data sets where available (with some of these being modified on occasion), and synthetic data otherwise.

The catchment has:

- An area of approximately 55km^2
- A relief of approximately 20m
- Three (synthetic) land uses
    - Urban
    - Forest
    - Agriculture

The general arrangement of the catchment is presented in Figure D.1.
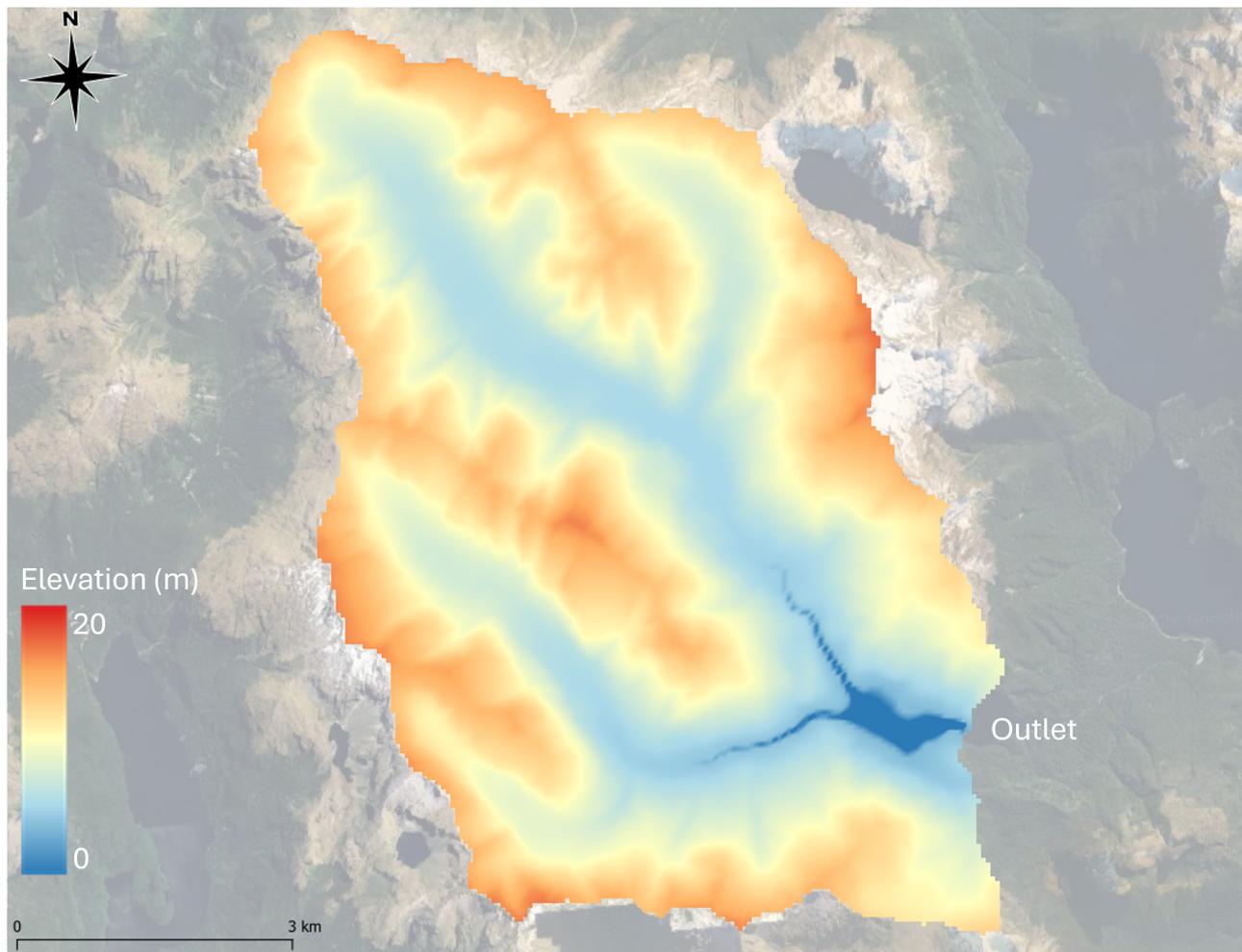
TUFLOW CATCH

Figure D.1: TUFLOW CATCH demonstration model: catchment

The receiving waterway (which is a hypothetical lake) has:

- An area of approximately $1km^2$
- A maximum depth of approximately 12m
- Two major riverine tributaries
- Two local wastewater treatment plant discharges
- One offtake
- An overflow outlet weir

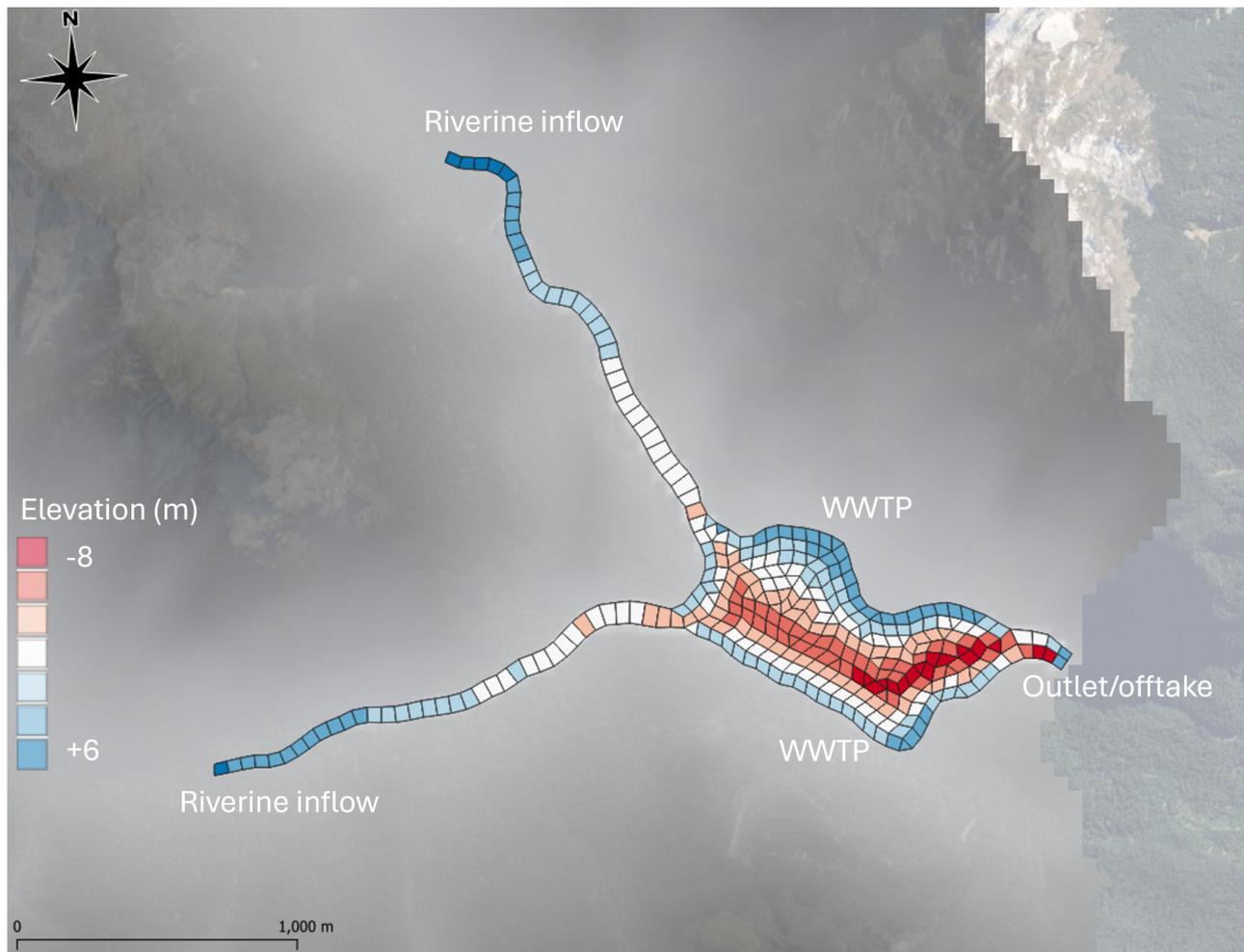The general arrangement of the receiving waterway is presented in Figure D.2.

Figure D.2: TUFLOW CATCH demonstration model: receiving waterway

The domain is simulated under TUFLOW CATCH for a period of 1 week from 01/01/2021 to 07/01/2021, inclusive.

D.3 Numerical models

The TUFLOW HPC, pollutant export and TUFLOW FV models are described following.

D.3.1 TUFLOW HPC

The TUFLOW HPC model has the following general configuration:

- A 2D cell size of 50m, SGS turned on with a sample target distance of 1m
- A synthetic rainfall record applied, with a maximum daily rainfall of approximately 60mm
- Three materials, with one for each land use above
- One soil layer with constant thickness of 0.6m

All simulations use GPU.

D.3.2 Pollutant export

The pollutant export model has various forms depending on the TUFLOW CATCH configuration is simulated. Across these various forms, both Shear1 and Washoff1 methods are deployed, and other pollutant export parameters are set using the guidance provided in this manual. In all cases where applicable:

- Salinity, dissolved oxygen, silicate, adsorbed phosphorus and phytoplankton are set to `constant` concentrations
- Sediment and particulate organics are `prohibited from infiltrating to groundwater`
- Water temperature is provided as a `timeseries`
- Sediment uses the `Shear1` method, and all other pollutants use the `Washoff1` method

D.3.3 TUFLOW FV

The TUFLOW FV model has the following general configuration:

- Simulation of hydrodynamics, including density (salinity and temperature) driven processes
- Full atmospheric heat exchange simulation
- Sediment transport simulation, with one sediment fraction
- Water quality simulation, using the Organics simulation class
- 3D simulation with 8 z layers and 6 sigma layers
- Three bed materials to define sediment transport and water quality processes

All simulations use GPU.

D.4 Simulation suite

The demonstration model suite includes the following simulations.

Table D.1: Demonstration TUFLOW CATCH Simulations

Simulation name	Description	Use case	TUFLOW CATCH Configuration
Demonstration_001.tcc	Catchment hydraulic calibration: HPC 2d outlet	Calibration of catchment hydraulic model without receiving model	TUFLOW HPC calibration only
Demonstration_002.tcc	Catchment hydraulic calibration: Pollutant export configuration with constant salinity and temperature timeseries	Calibration of catchment hydraulic model with downstream polygon	Pollutant export
Demonstration_003.tcc	Catchment pollutant calibration: Pollutant export configuration with user pollutant/s	Only catchment hydraulic and pollutant export models are to be used, with non-TUFLOW FV pollutants and downstream polygon	Pollutant export
Demonstration_004.tcc	Catchment pollutant calibration: Pollutant export configuration with TUFLOW FV pollutants	Calibration of catchment pollutant export model following 002 calibration, to TUFLOW FV pollutants with downstream polygon	Pollutant export
Demonstration_005.tcc	Linked catchment and receiving model: Integrated configuration with all TUFLOW FV pollutants	Generation of first pass spatially resolved TUFLOW FV HD and pollutant boundaries for subsequent TUFLOW FV calibration initiation	Integrated
Demonstration_006.tcc	Receiving model calibration: TUFLOW FV simulation with preserved inflows	Catchment hydraulic and pollutant modelling complete (or largely so) and TUFLOW FV is to be calibrated without reunning catchment model	Integrated

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<div align="center">**Table D.1: Demonstration TUFLOW CATCH Simulations**</div>

Simulation name	Description	Use case	TUFLOW CATCH Configuration
Demonstration_007.tcc	Linked catchment and receiving model: Hydrology configuration with salinity and temperature	No pollutant simulation required in TUFLOW - extend 002 above to include TUFLOW FV model	Hydrology
Demonstration_008.tcc	Mass balance analysis: Pollutant export configuration with user pollutant/s	Use with post processing tools to demonstrate mass conservation	Pollutant export
Demonstration_009.tcc	Interventions: Pollutant export configuration with user pollutant/s	Demonstrate use of interventions. Can also apply post processing tools to assess mass conservation	Pollutant export

D.5 Downloads

D.5.1 Binaries

The required binary executable files can be downloaded from the TUFLOW Downloads page

- TUFLOW CATCH
- TUFLOW HPC
- TUFLOW FV

It is suggested that these are saved in a convenient and centralised location. For the purposes of explanation in this Appendix, it has been assumed that they are saved to the following locations (with `ReleaseXX/YY/ZZ` being a placeholder for the release version of each, which will be different):

- `C:\TUFLOW\EXE\TUFLOWCATCH\ReleaseXX\TUFLOWCATCH.exe`
- `C:\TUFLOW\EXE\TUFLOW\ReleaseYY\TUFLOW_iSP_w64.exe`
- `C:\TUFLOW\EXE\TUFLOWFV\ReleaseZZ\TUFLOWFV.exe`

D.5.2 Simulation files

The demonstration model suite can be downloaded here, in the TUFLOW CATCH section. For the purposes of explanation in this Appendix, it has been assumed that the suite is saved to the following location and then unzipped:

- `C:\TUFLOW\Demonstration\TUFLOWCATCH\`

When unzipped, the high level folder structure will be as follows:

- Modelling
    - TUFLOW
    - TUFLOWCATCH
    - TUFLOWFV

The key directory for executing TUFLOW CATCH is then

- `C:\TUFLOW\Demonstration\TUFLOWCATCH\Modelling\TUFLOWCATCH\runs`

Once downloaded and unzipped, the user is required to:

- In the `Modelling\TUFLOWCATCH\runs\run_simulation.bat` file:
    - On line 2, copy and paste in the exact path to the TUFLOW CATCH executable over the placeholder `<TUFLOW CATCH EXECUTABLE FULL PATH>`, so that:
      set exe=<TUFLOW CATCH EXECUTABLE FULL PATH>
      becomes (using the example path above):
      set exe=C:\TUFLOW\EXE\TUFLOWCATCH\ReleaseXX\TUFLOWCATCH.exe

- – Uncomment the desired simulation command by deleting the preceding ‘`::`’ , so that (if simulation 001 was to be run):

  `:: %exe% Demonstration_001.tcc`

  becomes:

  `%exe% Demonstration_001.tcc`

- In the `Modelling\TUFLOWCATCH\runs\Demonstration_001.tcc` file (and any other `Demonstration_00*.tcc` file to be executed):
  - – In the `CATCHMENT HYDRAULICS` block, copy and paste in the exact path to the TUFLOW HPC executable over the placeholder `<TUFLOW EXECUTABLE FULL PATH>` , so that:

    `EXE == <TUFLOW EXECUTABLE FULL PATH>`

    becomes (using the example path above):

    `EXE == C:\TUFLOW\EXE\TUFLOW\ReleaseYY\TUFLOW_iSP_w64.exe`
  - – In the `RECEIVING HYDRODYNAMICS AND WQ` block, copy and paste in the exact path to the TUFLOW FV executable over the placeholder `<TUFLOW FV EXECUTABLE FULL PATH>` , so that:

    `EXE == <TUFLOW FV EXECUTABLE FULL PATH>`

    becomes (using the example path above):

    `EXE == C:\TUFLOW\EXE\TUFLOWFV\ReleaseZZ\TUFLOWFV.exe`

Some text editors offer support for changing the above executable paths in multiple files at once, if required.

D.6 Execution

Once the binaries and simulation files have been downloaded and paths altered as above (and altered files saved), a TUFLOW CATCH simulation can be executed as follows:

- Open a command prompt and navigate to the TUFLOW CATCH runs folder:

  `cd C:\TUFLOW\Demonstration\TUFLOWCATCH\Modelling\TUFLOWCATCH\runs`
  `C:`

- Ensure the path to the TUFLOW CATCH executable has been set in run_simulations.bat, and that at least one simulation has been uncommented

- Type the following in the command prompt and hit enter, and TUFLOW CATCH will execute:

  `run_simulations`

Some notes on executing the demonstration simulations:

- Although not mandatory, it is suggested that the simulations be run one at a time, and in order, and results reviewed after each execution
- `Demonstration_005.tcc` must be run prior to `Demonstration_006.tcc` because the former generates boundary conditions for the latter.
- To ensure that `Demonstration_006.tcc` can access these boundaries generated by `Demonstration_005.tcc` , either:
  - – Manually make a copy of `Demonstration_005_catchment_hydraulic.fvcatchbc` and rename it as `Demonstration_006_catchment_hydraulic.fvcatchbc` in the same location, or
  - – Uncomment the line beginning ‘`copy…`’ in the `run_simulations.bat` file provided with the demonstration model (third line below)

```
REM Receiving model calibration: TUFLOW FV simulation with preserved inflows
REM Use case: Catchment hydraulic and pollutant modelling complete (or largely so) and TUFLOW FV is
to be calibrated without rerunning catchment model
copy ..\bc_dbase\Demonstration_005_catchment_hydraulic.fvcatchbc ..\bc_dbase\Demonstration_006_catch-
ment_hydraulic.fvcatchbc
%exe% Demonstration_006.tcc
```

D.7 Results interrogation

Once executed, results will be written to:

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- `C:\TUFLOW\Demonstration\TUFLOWCATCH\Modelling\TUFLOWCATCH\results`

Use the QGIS TUFLOW CATCH plugin (see Section 4.3) to generate a .json file and view the results. Simulations that involve only TUFLOW HPC or TUFLOW FV can have their *.xmdf and *.nc results interrogated in the normal manner through the TUFLOW Viewer as shown in Figure D.3.
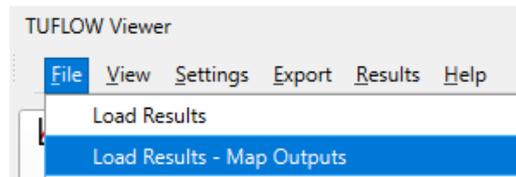

Figure D.3: TUFLOW CATCH demonstration model: loading standard TUFLOW HPC or TUFLOW FV results

D.7.1 Example json file creation

Simulations 005 and 006 can be used (after execution) to create a json file within the TUFLOW CATCH plugin (see Section 4.3). To do so, select the following results files in the json creation process (making sure the order in the selection dialogue box is as below):

- Demonstration_006_receiving_HD.nc
- Demonstration_006_receiving_WQ.nc
- Demonstration_005_catchment_hydraulic.xmdf

Save the json to here:

`C:\TUFLOW\Demonstration\TUFLOWCATCH\Modelling\TUFLOWCATCH\results\Demonstration_006.tuflow.json`

Once created, drag and drop the json onto a QGIS window to view the results. Hit F7 to toggle the layer styling panel and reveal the full suite of simulated quantities. As an example, select the 'Conc SED_FINES' field by clicking on the contour icon to the right of the field name as per Figure D.4.
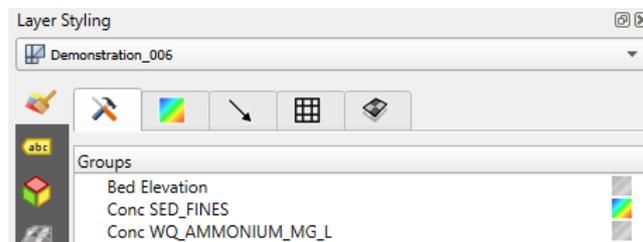

Figure D.4: Selecting the Conc SED-FINES data field in a json results file

An animation of the associated surface concentration results (that shows the connectivity between TUFLOW HPC, pollutant export and TUFLOW FV simulations of sediment) is presented in Figure D.5. This animation was prepared using the TUFLOW CATCH plugin, and the maximum concentration was set to 5 mg/L.

Figure D.5: Omitted in PDF Version: Conc SEDFINES animated results

The connectivity between models is clear. Of note is the increase in concentrations once flows enter the receiving model arms. This is due to resuspension of previously accumulated bed sediment in the lake, which has been computed using the advanced TUFLOW FV Sediment Transport Module capability. Users could investigate this further by altering the erosion parameterisation within the TUFLOW FV sediment transport control file, or setting initial bed masses in the TUFLOW FV model to zero - this concentration spike will then not appear.

D.7.2 Example results

An example of a dry mass accumulation predicted by TUFLOW HPC (under the Washoff1 model) at a point in time just prior to rainfall is presented in Figure D.6, for FRP. The different accumulations of FRP in different land use areas are clear. The red areas are urban areas, which had the highest accumulation rates of FRP set within the simulation.
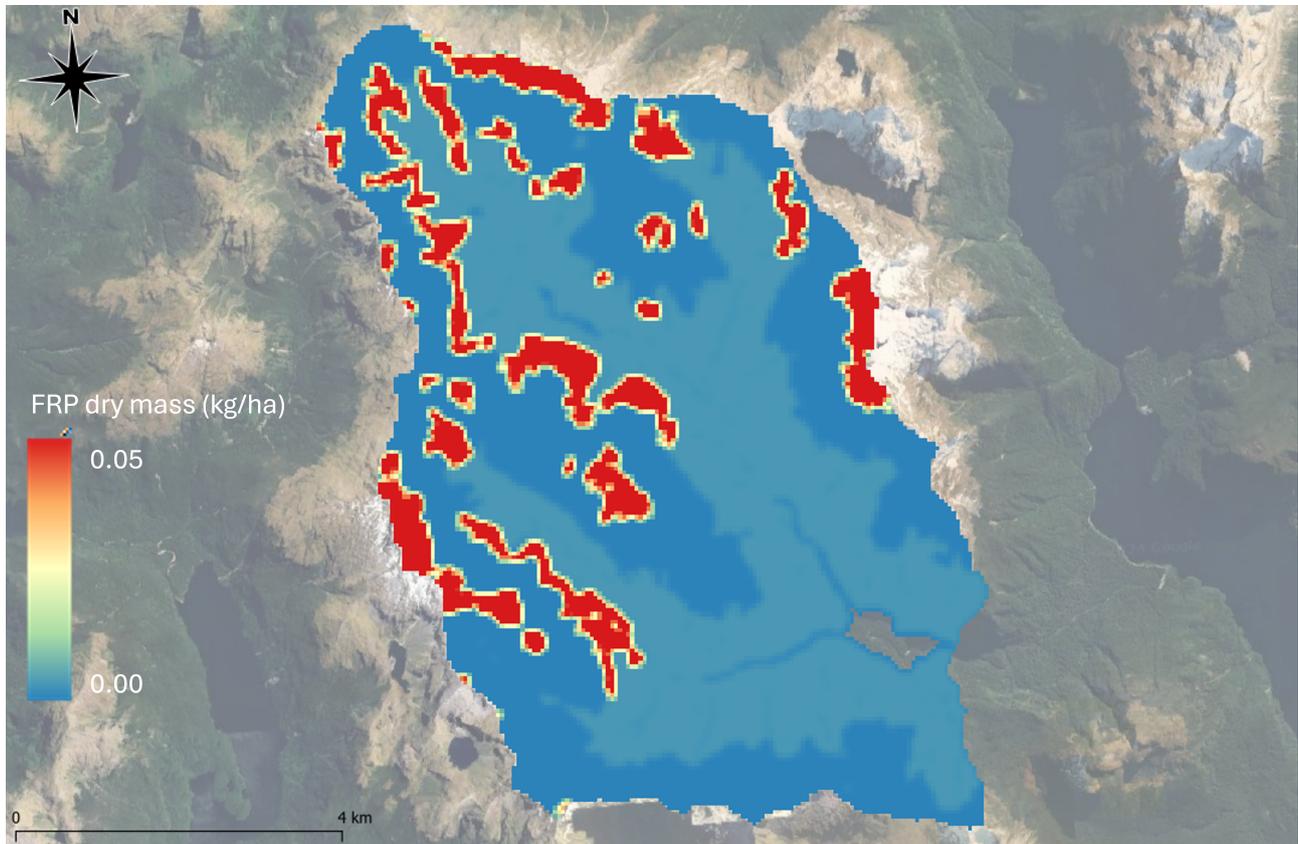

Figure D.6: TUFLOW CATCH demonstration model: FRP dry mass accumulation

An example of a net mass distribution predicted by TUFLOW HPC (under the Shear1 model) at simulation end is presented in Figure D.7, for SED_FINES. Positive (negative) results reflect net accumulation (erosion) at simulation end. Erosion (and deposition) limits were set to 1 kg/ha in the simulation. The figure shows that (at least) the catchment areas within the stream network have been eroded to this maximum (blue colour), and no more.
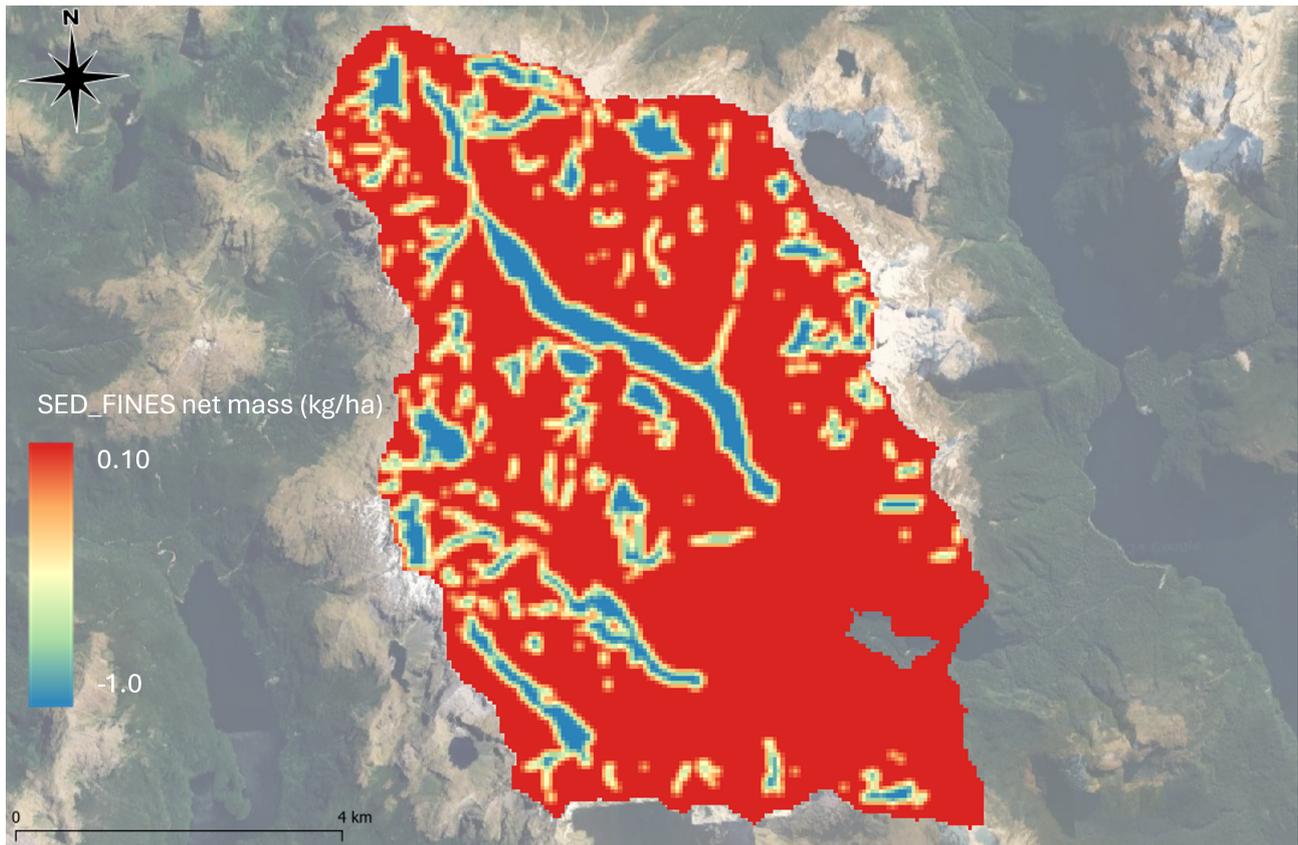
Figure D.7: TUFLOW CATCH demonstration model: SEDFINES net mass at simulation end

D.8 Mass balance - Base Case

Mass balance is a key concept in environmental modelling, especially in the case of catchment pollutant export simulation. In this instance, mass balance requires that the mass of a given pollutant generated on ground from catchment processes equals that delivered downstream to receiving waters (less mass potentially resettled in-catchment). TUFLOW CATCH independently accounts for these two quantities and so comparison of the respective predictions allows for rigorous assessment of the overall model's mass balance capability. This section presents that performance using `Demonstration_008.tcc`.

D.8.1 Concept

TUFLOW CATCH run in its **Pollutant Export** (or **Integrated**) configuration predicts the release of pollutant from catchment dry stores. This released pollutant is then advected downstream and potentially settled and resuspended en route. Some released pollutant also reaches the catchment outlet and as it exits the domain is tracked by TUFLOW CATCH as mass, concentrations and volumes. Reconciliation of these independent mass predictions (i.e. that released from - or reentering via settling - the catchment dry store and that leaving the domain) was undertaken by applying bespoke post processing tools to the predictions of `Demonstration_008.tcc`. The intention was to show that the cumulative released mass and the cumulative mass leaving the overall domain are equal.

D.8.2 Configuration

The TUFLOW CATCH simulation `Demonstration_008.tcc` was configured as follows:

- Based broadly on `Demonstration_003.tcc`
- MGL unit system
- **Pollutant Export** configuration
    - Four pollutants

- ⋆ Salinity (constant and zero)
- ⋆ Temperature (as a timeseries)
- ⋆ Tailings
- ⋆ PFAS
  - – Settling activated for Tailings and PFAS, with PFAS settling velocity set to zero
  - – Two export methods
    - ⋆ Shear1 (applied to Tailings)
    - ⋆ Washoff1 (applied to PFAS)
  - – Infiltration set to off for both Tailings and PFAS
  - – Spatial distributions
    - ⋆ Tailings: uniform
    - ⋆ PFAS: specific land uses only
  - – A downstream receiving polygon specified
- • Hydraulic configuration
  - – Model timestep set to 10 seconds
  - – Output timestep of map and timeseries set to 10 seconds
  - – 10 day simulation period
  - – Extended dry periods before and after a major rain event to allow for complete settling of pollutants from remaining surface waters
- • Output
  - – Catchment: Cell centred netcdf format to avoid interpolation issues associated with some other formats
  - – Polygon timeseries of flow and concentration (see Section C.9.2)
- • This simulation cannot be run in demo mode as it too long due to the time taken in writing the highly temporally resolved outputs. It must therefore be run with a licence

D.8.3 Method

Mass balance was computed separately for tailings and PFAS so as to demonstrate performance over different pollutant generation methods. A slightly different numerical recipe was applied to each:

- • Tailings (Shear1 method)
  1. The net_mass_tailings field of the cell centred netcdf output file was interrogated and the released mass computed at each cell at each timestep. All cell-based released masses were summed for a given timestep to produce a timeseries of liberated mass across the entire domain. This calculation included the effects of erosion and settling for each cell by default
  2. The polygon outflow csv file was interrogated and mass leaving the domain computed at each timestep by computing the product of reported concentration and flow. This provided a timeseries of mass leaving the domain through the downstream polygon
  3. The mass of Tailings in water within the model was also computed at every timestep (by multiplying cell volume by Tailings concentration on a cell by cell basis and summing globally). This produced a further independent timeseries to compare with that computed as the difference of items 1 and 2 above
- • PFAS (Washoff1 method)
  1. The dry_mass_PFAS field of the cell centred netcdf output file was interrogated and the total released mass computed by
  - – Computing the total mass of PFAS that was created across time and all cells via the accumulation process, noting that mass is not created at a timestep or cell where washoff is actively occurring
  - – Subtracting from this both:
    - ⋆ The final mass in the dry_mass_PFAS field and
    - ⋆ The final mass remaining in the model domain in the water phase (e.g. captured in local topographic features)
  - – The result was the mass removed from the domain via washoff
  1. As for Tailings, the polygon outflow csv file was interrogated and mass leaving the domain computed at each timestep by computing the product of reported concentration and flow. This provided a timeseries of mass leaving the domain through the downstream polygon
  2. The mass of PFAS in water within the model was also computed at every timestep (by multiplying cell volume by PFAS concentration on a cell by cell basis and summing globally). This was used to provide the final mass of PFAS remaining in the water phase of the domain at the end of the simulation, noting that settling is set to zero for PFAS

D.8.4 Results

In both Shear1 and Washoff1 cases, the key points of comparison are between:

- The final cumulative released and exiting masses. This is a single number to number comparison, and these need to be equivalent for mass conservation to hold. In the Shear1 case (i.e. tailings), a timeseries comparison between released and exiting mass is also possible
- The Shear1 method also allows for a timeseries comparison of water borne mass of pollutants, computed indirectly from mass balance and directly from post processing of concentration and volume cell outputs

The MATLAB scripts used to perform all post processing are provided in the `Modelling\TUFLOWCATCH\matlab` folder in the Demonstration Model download, and are self explanatory. Some functions from the TUFLOW FV MATLAB toolbox are required to execute these scripts.

D.8.4.1 Tailings

For Tailings simulation using the Shear1 export method:

- Exported tonnage: 451.92 (via the shear1 method)
- Received tonnage: 451.92 (entering the downstream polygon)

Timeseries of these are presented in Figure D.8. Note that the shape of the export and receiving curves are different (as expected). Specifically:

- The shift in time between exported and received masses reflects TUFLOW CATCH's simulation of on-ground hydraulics and associated pollutant transport: time is taken (and explicitly simulated) between upstream pollutant export and subsequent delivery downstream
- The exported curve is non-monotonic and this reflects dynamic settling of previously released pollutant occurring in the catchment simulation

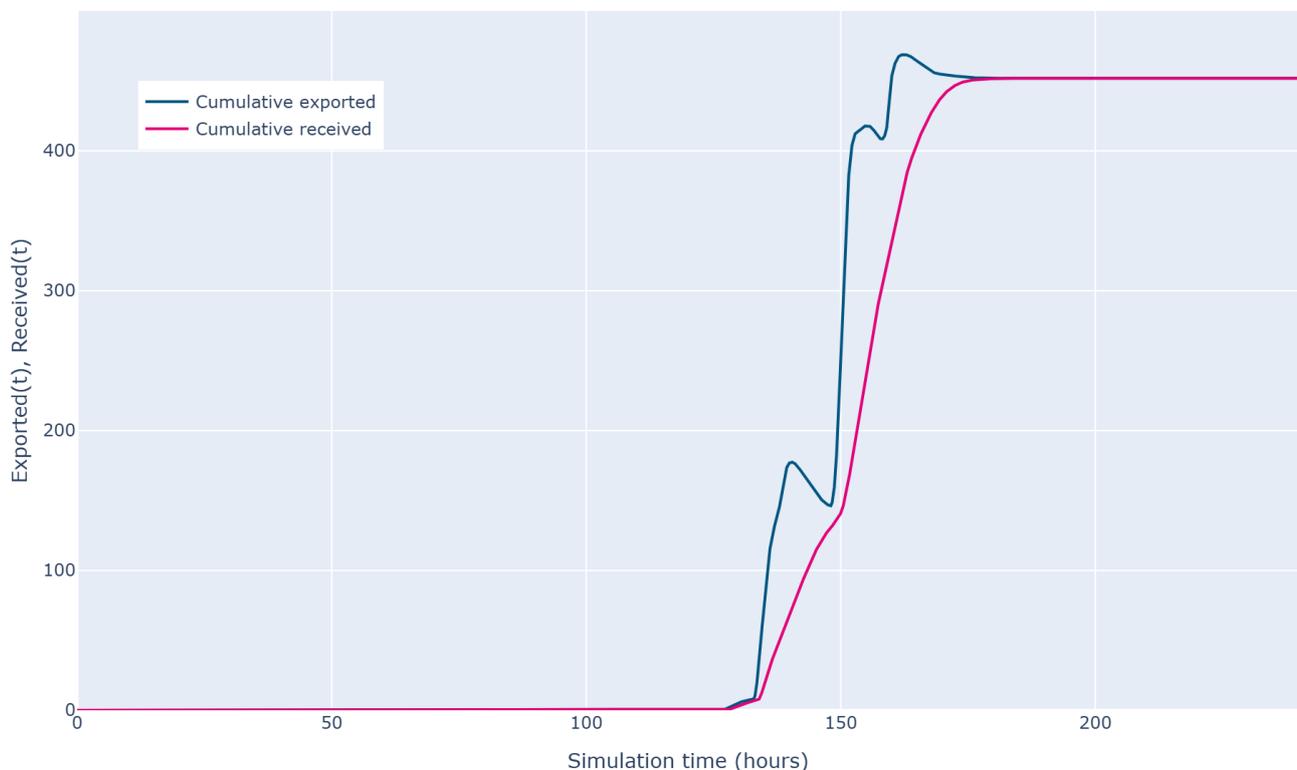The final masses between exported and received are the same.

Figure D.8: Tailings mass conservation

As noted above, a complementary measure of mass conservation performance is to compare the timeseries evolution

of the total Tailings mass M in the water column at every timestep i computed via two independent means, particularly from the:

- Reported concentrations C and water volumes $d\times$cell area in each computational cell j, summed across the domain at each timestep ("concentration method"):

$$M_i = \text{cell area} \times \sum_{j=1}^{\text{num cells}} C_j \times depth_j \tag{D.1}$$

and

- Fluxes F of tailings mass to and from all wet cells at timestep i and adding this net flux to the mass at the previous timestep $i-1$ (assuming an initial mass of zero, "flux method")

$$M_i = M_{i-1} + (F_i^{to} - F_i^{from}) \tag{D.2}$$

These two independent calculations of water column mass are presented as timeseries in Figure D.9. The timeseries coincide, confirming that:

- Mass is conserved
- The units of concentration (used to compute M_i via the concentration method) are correct. Similar analyses can be undertaken with other unit systems if desired.
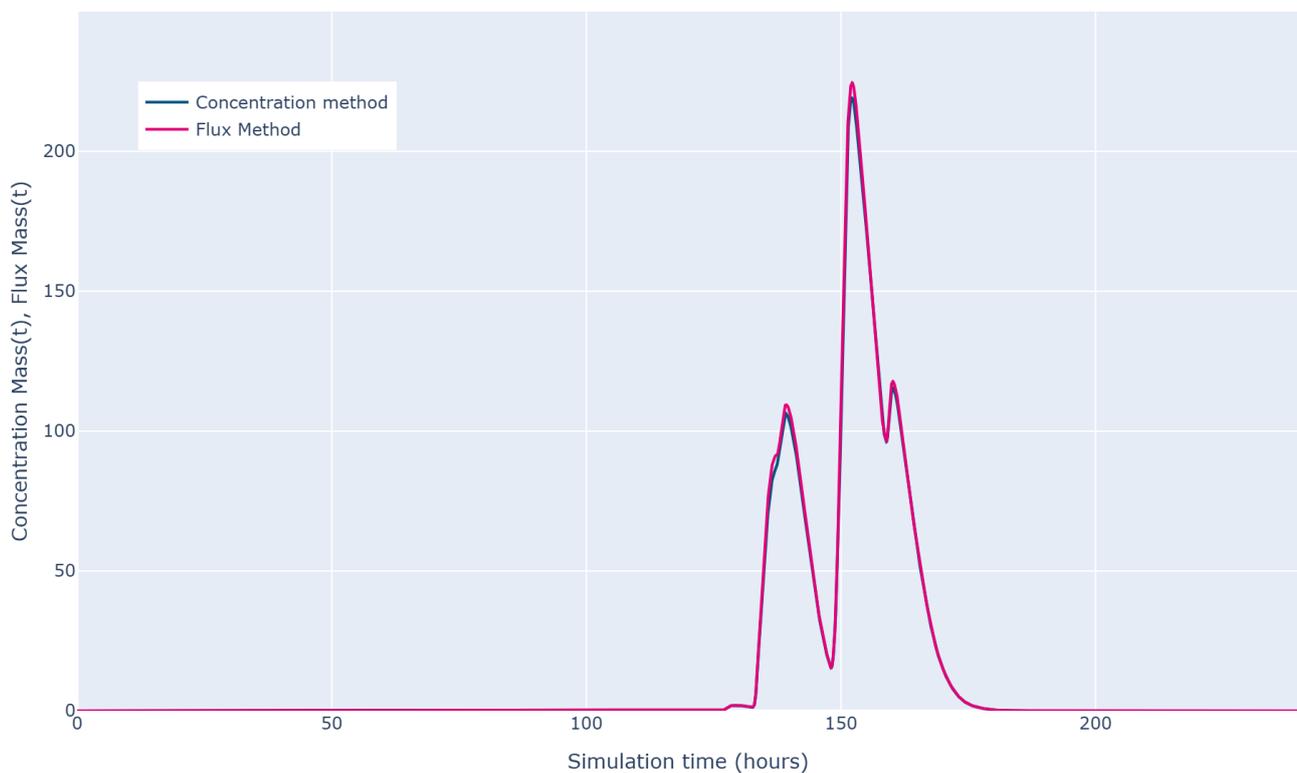

Figure D.9: Tailings mass comparison

D.8.4.2 PFAS

For PFAS simulation using the Washoff1 export method:

- Generated tonnage: 17.37 (total, via the washoff1 method)
- Received tonnage: 4.43 (entering the downstream polygon)
- Remaining dry store tonnage: 12.88 (remaining in the catchment as not washed off after all rainfall has ceased)
- Remaining water phase tonnage: 0.06 (remaining in the catchment in trapped water after all rainfall has ceased)

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The sum of received and remaining (dry and wet) tonnage (4.43 + 12.88 + 0.06 tonnes) equals that generated (17.37 tonnes), as expected. Figure D.10 presents the time evolution of PFAS mass, for completeness, as:

- Water column mass as an instantaneous value (the "concentration method" above), and
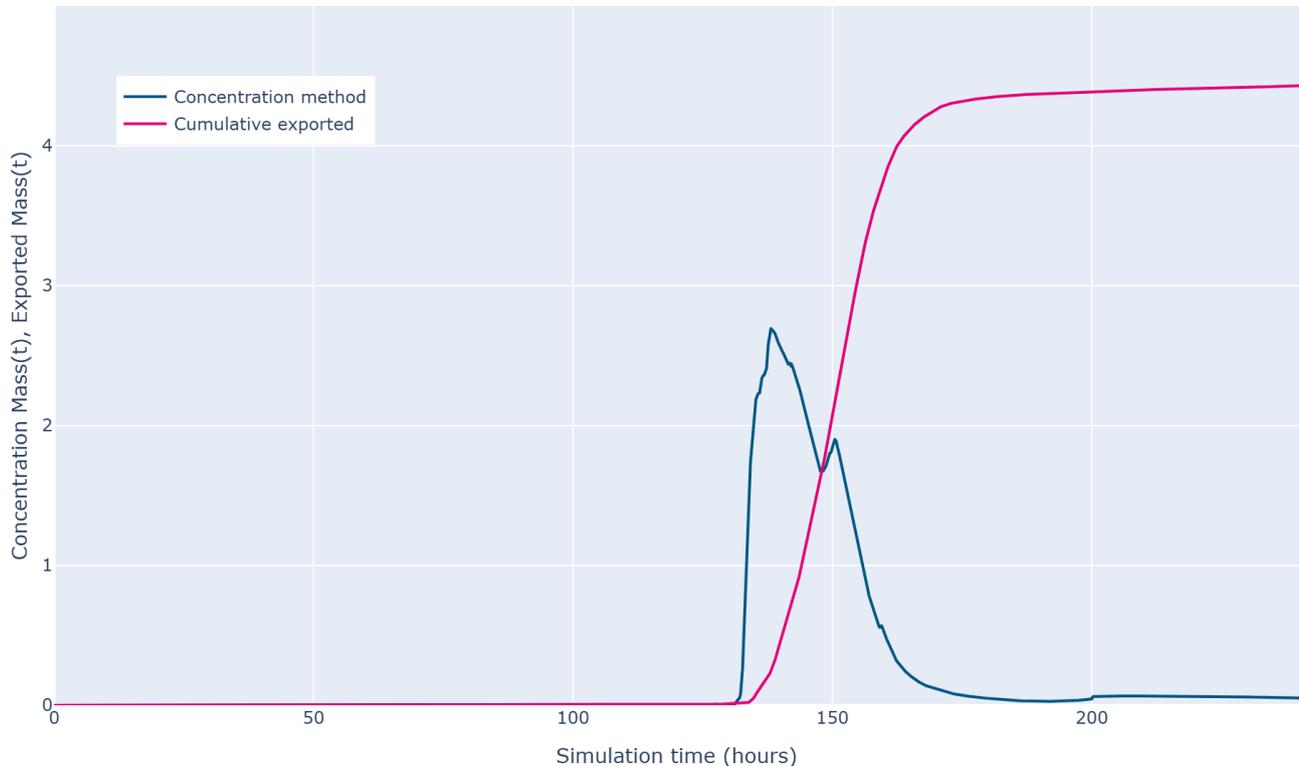- Exported cumulative mass exiting through the downstream polygon

Figure D.10: PFAS masses

D.9 Mass balance - Interventions

This section repeats the analysis of Section D.8, but includes the action of two interventions using `Demonstration_009.tcc`.

D.9.1 Concept

The concept is the same as that described in Section D.8.1, but includes consideration of the mass removed by interventions so that the pollutant mass generated, less that removed by settling and interventions, should equal that exiting the TUFLOW CATCH domain. This was undertaken by applying bespoke post processing tools (which are the same as those used above) to the predictions of `Demonstration_009.tcc`. The intention was to show that the cumulative released mass and the cumulative mass leaving the overall domain are different by an amount equal to that removed by the interventions. This demonstrates mass balance.

D.9.2 Configuration

The TUFLOW CATCH simulation `Demonstration_009.tcc` was configured to be the same as `Demonstration_008.tcc` but with the following modifications:

- **Pollutant Export** configuration
    - Two intervention devices
        * Wetland
        * Riparian revegetation strip
    - Two removal methods

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> * Lookup table (PFAS)
> * Constant (Tailings)
- This simulation cannot be run in demo mode as it too long due to the time taken in writing the highly temporally resolved outputs. It must therefore be run with a licence

D.9.3 Method

Mass balance was computed separately for tailings and PFAS so as to demonstrate performance over different pollutant generation methods. A slightly different numerical recipe was applied to each, as described above in Section D.8.3. The only difference in this case was the inclusion of mass removal due to the two interventions.

D.9.4 Results

In both Shear1 and Washoff1 cases, the key points of comparison are between:

- The final cumulative released, removed and exiting masses. This is a single number to number comparison, with (cumulative released - cumulative removed) required to be equal to cumulative exiting mass. In the Shear1 case (i.e. Tailings), a timeseries comparison between released and exiting mass is also possible
- The Shear1 method also allows for a timeseries comparison of water borne mass of pollutants, computed indirectly from mass balance and directly from post processing of concentration and volume cell outputs

The MATLAB scripts used to perform all post processing are provided in the `Modelling\TUFLOWCATCH\matlab` folder in the Demonstration Model download, and are self explanatory. Some functions from the TUFLOW FV MATLAB toolbox are required to execute these scripts.

D.9.4.1 Tailings

For Tailings simulation using the Shear1 export method:

- Exported tonnage: 477.98 (via the shear1 method)
- Removed tonnage: 105.49 (via interventions)
- Received tonnage: 372.49 (entering the downstream polygon)

Timeseries of these are presented in Figure D.11. Note that the shape and end points of the export and receiving curves are different (as expected). Specifically:

- The shift in time between exported and received masses reflects TUFLOW CATCH's simulation of on-ground hydraulics and associated pollutant transport: time is taken (and explicitly simulated) between upstream pollutant export and subsequent delivery downstream
- The exported curve is non-monotonic and this reflects dynamic settling of previously released pollutant occurring in the catchment simulation
- The endpoints differ by exactly the amount removed due to interventions, as expected: the removed mass does not exit the model through the downstream polygon. The final masses between (exported - removed) and (received) are the same.
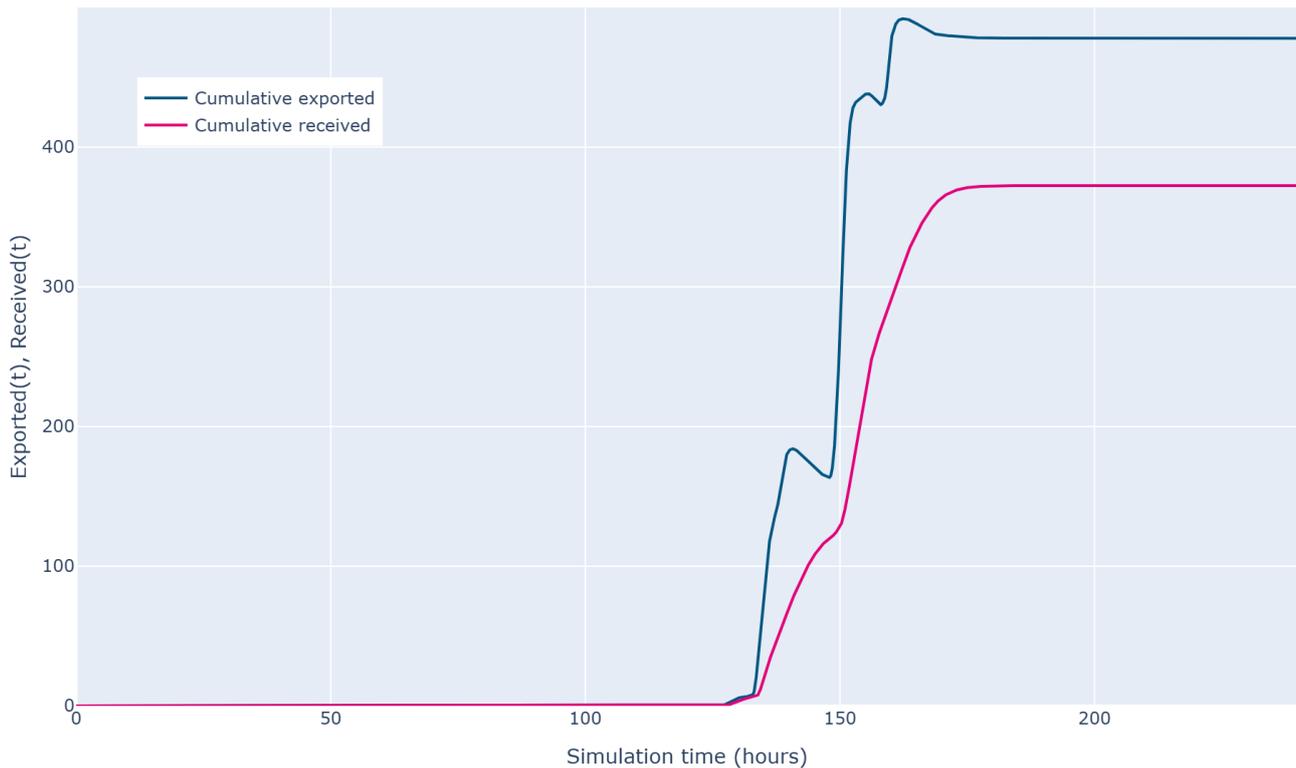
Figure D.11: Tailings mass conservation, with action of interventions

An interesting feature of the above analysis is that TUFLOW CATCH predicts a greater tonnage of Tailings is exported (not received downstream) from the overall catchment when interventions are put in place (477.98 tonnes with intervention compared to 451.92 tonnes without interventions). This is because the Tailing mass that is being removed is not able to settle and be resuspended downstream. Rather, fresh material - that would otherwise not have been released - is being liberated from regions downstream of interventions instead of settled material being (effectively) recycled.

As above, a complementary measure of mass conservation performance is to compare the timeseries evolution of the total Tailings mass M in the water column at every timestep i computed reported concentrations (see Equation D.1) and mass flux analysis (see Equation D.2). These two independent calculations of water column mass are presented as timeseries in Figure D.12. As expected, the timeseries differ throughout and at their end point in this case where interventions are included, confirming that:

- Mass is progressively removed
- The final difference in the two masses is the same as the mass removed by the intervention measures

The difference between these two mass timeseries provides the corresponding cumulative timeseries of mass removal, which has also been included in the figure. As expected, the final value of the cumulative removed mass equals the difference between the two mass computation methods, most obviously at simulation end.
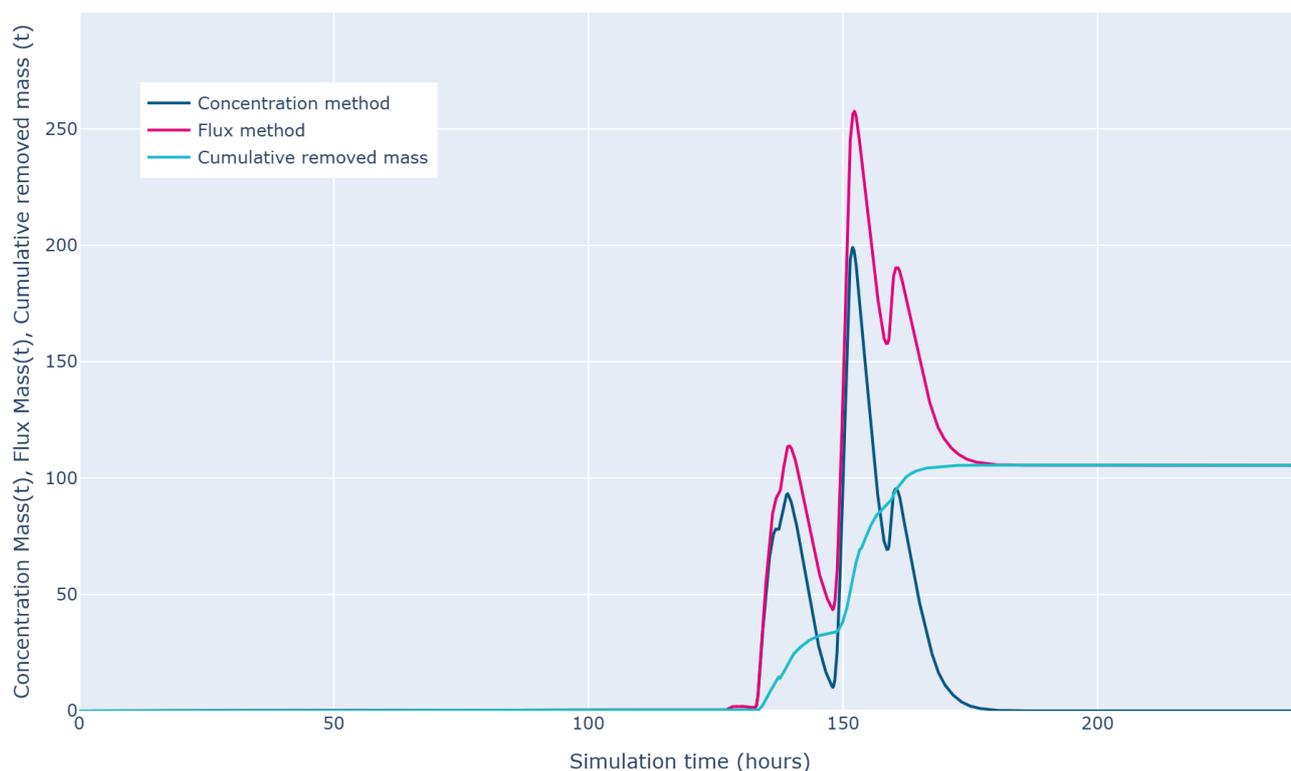
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Figure D.12: Tailings mass comparison, with action of interventions. The divergence is expected and correct

D.9.4.2 PFAS

For PFAS simulation using the Washoff1 export method, with interventions:

- Generated tonnage: 17.37 (total, via the washoff1 method)
- Removed tonnage: 0.96 (total removed by interventions)
- Received tonnage: 3.49 (entering the downstream polygon)
- Remaining dry store tonnage: 12.88 (remaining in the catchment as not washed off after all rainfall has ceased)
- Remaining water phase tonnage: 0.04 (remaining in the catchment in trapped water after all rainfall has ceased)

The sum of received and remaining tonnage (3.49 + 12.88 + 0.04 tonnes) equals that generated less removed by interventions (17.37 - 0.96 tonnes), as expected.

D.10 Mass balance - Groundwater

The reporting of both water volume and pollutant mass fluxes into groundwater layers from above allows for subsurface mass balance analysis to be undertaken.

D.10.1 Concept

The concept is to compare the time evolution of total water volume and pollutant mass in a TUFLOW CATCH groundwater layer via two independent methods that use:

- An initial layer volume / mass and flux output timeseries
- Porosity and groundwater level and concentration output timeseries

These are described following.

D.10.1.1 Flux calculations

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D.10.1.1.1 Volume

The volume of water $V_t^{F,inst}$ at time t in a given groundwater layer can be computed by summing the previous volume $V_{t-1}^{F,inst}$ and the reported instantaneous volumetric fluxes F via Equation D.3:

$$V_t^{F,inst} = V_{t-1}^{F,inst} + (F_{t,in}^{V,inst} - F_{t,out}^{V,inst}) \times \Delta t \qquad \text{(D.3)}$$

where

- $F_{t,in}^{V,inst}$ is the instantaneous volumetric flux reported by TUFLOW CATCH for the considered layer
- $F_{t,out}^{V,inst}$ is the instantaneous volumetric flux reported by TUFLOW CATCH for the layer below the considered layer (the flux entering the layer below is the same as the flux exiting the layer considered)
- Δt is the output timestep
- $V_{t-1}^{F,inst}$ is the previous computed volume and is the initial volume when t equals one

A similar computation for $V_t^{F,tint}$ applies if time integrated fluxes are used:

$$V_t^{F,tint} = V_{t-1}^{F,tint} + (F_{t,in}^{V,tint} - F_{t,out}^{V,tint}) \qquad \text{(D.4)}$$

where

- $F_{t,in}^{V,tint}$ is the time integrated volumetric flux reported by TUFLOW CATCH for the considered layer
- $F_{t,out}^{V,tint}$ is the time integrated volumetric flux reported by TUFLOW CATCH for the layer below the considered layer (the flux entering the layer below is the same as the flux exiting the layer considered)

D.10.1.1.2 Mass

The mass of pollutant $M_t^{F,inst}$ at time t in a given groundwater layer can be computed by summing the previously computed mass $M_{t-1}^{F,inst}$ and the reported instantaneous mass fluxes F via Equation D.5:

$$M_t^{F,inst} = M_{t-1}^{F,inst} + (F_{t,in}^{M,inst} - F_{t,out}^{M,inst}) \times \Delta t \qquad \text{(D.5)}$$

where

- $F_{t,in}^{M,inst}$ is the instantaneous mass flux reported by TUFLOW CATCH for the considered layer
- $F_{t,out}^{M,inst}$ is the instantaneous mass flux reported by TUFLOW CATCH for the layer below the considered layer (the flux entering the layer below is the same as the flux exiting the layer considered)
- Δt is the output timestep
- $M_{t-1}^{F,inst}$ is the previously computed mass and is the initial mass when t equals one

A similar computation applies if time integrated fluxes are used:

$$M_t^{F,tint} = M_{t-1}^{F,tint} + (F_{t,in}^{M,tint} - F_{t,out}^{M,tint}) \qquad \text{(D.6)}$$

where

- $F_{t,in}^{M,tint}$ is the time integrated mass flux reported by TUFLOW CATCH for the considered layer
- $F_{t,out}^{M,tint}$ is the time integrated mass flux reported by TUFLOW CATCH for the layer below the considered layer (the flux entering the layer below is the same as the flux exiting the layer considered)

D.10.1.2 Porosity calculations

D.10.1.2.1 Volume

The volume of water V_t^P at time t in a given groundwater layer can be computed by multiplying the reported groundwater depth, cell area and porosity in each cell and summing across the domain via Equation D.7:

$$V_t^P = \Delta x^2 \times \sum_{i=1}^{n_{cells}} (GWd)_t^i \times \phi^i \qquad (D.7)$$

where

- Δx is the model cell size
- $(GWd)_t^i$ is the reported groundwater depth in cell i at time t
- ϕ^i is the soil porosity in cell i

D.10.1.2.2 Mass

The mass of pollutant M_t^P at time t in a given groundwater layer can be computed by multiplying the reported groundwater depth, cell area, pollutant concentration and porosity in each cell and summing across the domain via Equation D.8:

$$M_t^P = \Delta x^2 \times \sum_{i=1}^{n_{cells}} (GWd)_t^i \times C_t^i \times \phi^i \qquad (D.8)$$

where

- C_t^i is the pollutant concentration in cell i at time t

D.10.2 Configuration

A TUFLOW CATCH model with 6 groundwater layers was used to undertake the analysis above. It included two sediment fractions. A description of the model is presented in this webinar: Whole of system simulation of catchment water quality treatment devices.

D.10.3 Method

Mass balance was assessed for water volume and one sediment fraction and all six layers. Only one layer's results are presented here for clarity. Mass balance performance is presented in scatter plots that compare:

- $V^{F,inst}$ to V^P
- $V^{F,tint}$ to V^P
- $M^{F,inst}$ to M^P
- $M^{F,tint}$ to M^P

Mass balance requires that these scatter plots have all points lying on the 1:1 line, i.e. that computation of flux and porosity based quantities at a given timestep are equal.

D.10.4 Results

D.10.4.1 Volume

The comparison between $V^{F,inst}$ and V^P is presented in Figure D.13. The correspondence between the two computed quantities is 1:1.
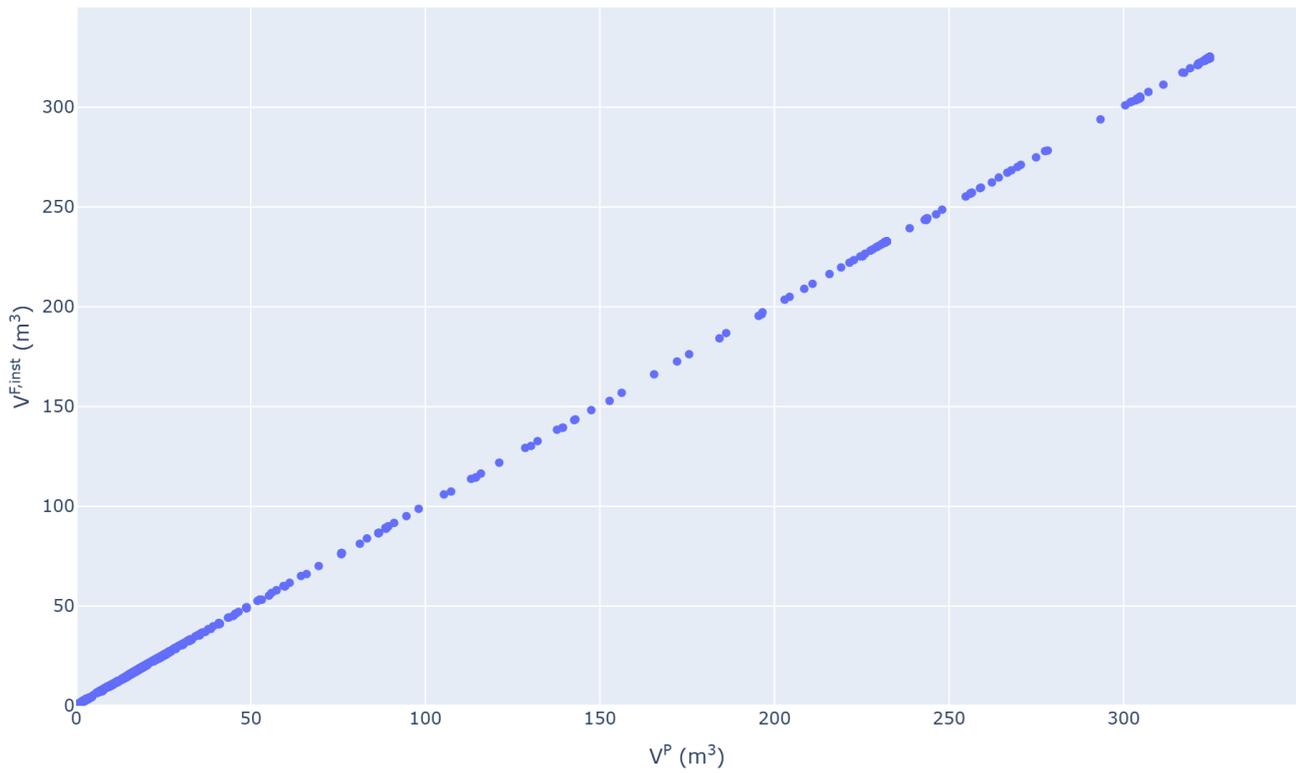
TUFLOW CATCH

Figure D.13: Groundwater volume in a single layer: comparison of volumes computed from instaneous fluxes and porosity

The comparison between $V^{F,tint}$ and V^P is presented in Figure D.14. The correspondence between the two computed quantities is 1:1.
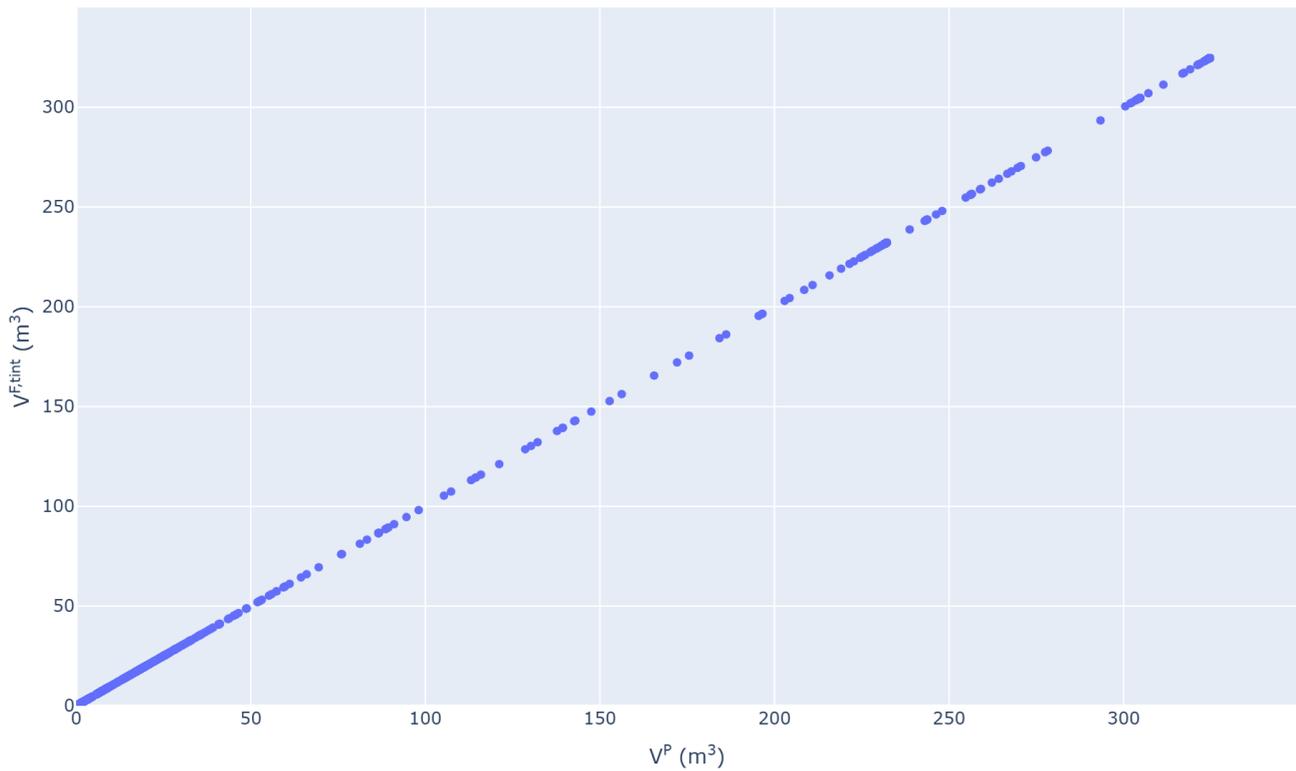
Figure D.14: Groundwater volume in a single layer: comparison of volumes computed from time integrated fluxes and porosity

D.10.4.2 Mass

The comparison between $M^{F,inst}$ and M^P is presented in Figure D.15. The correspondence between the two computed quantities is 1:1.
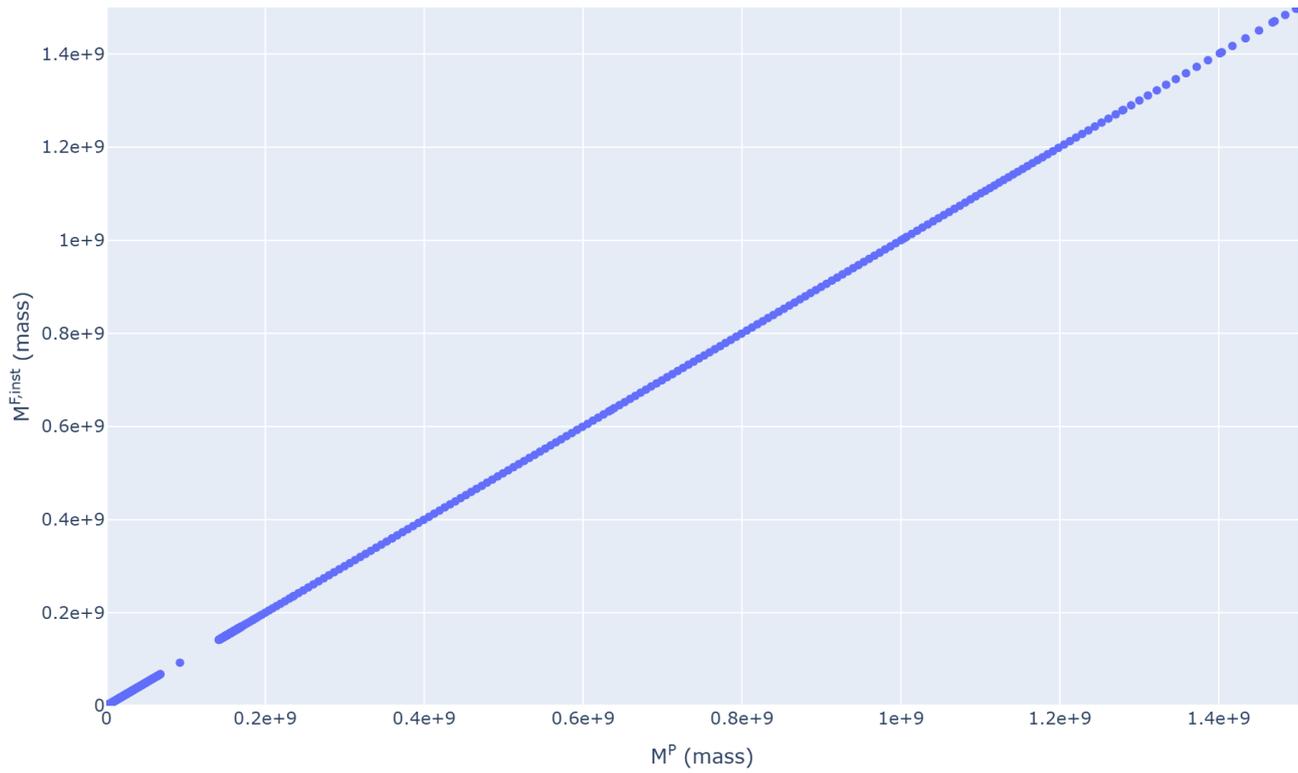
Figure D.15: Groundwater mass in a single layer: comparison of masses computed from instaneous fluxes and porosity

The comparison between $M^{F,tint}$ and M^{P} is presented in Figure D.16. The correspondence between the two computed quantities is 1:1.
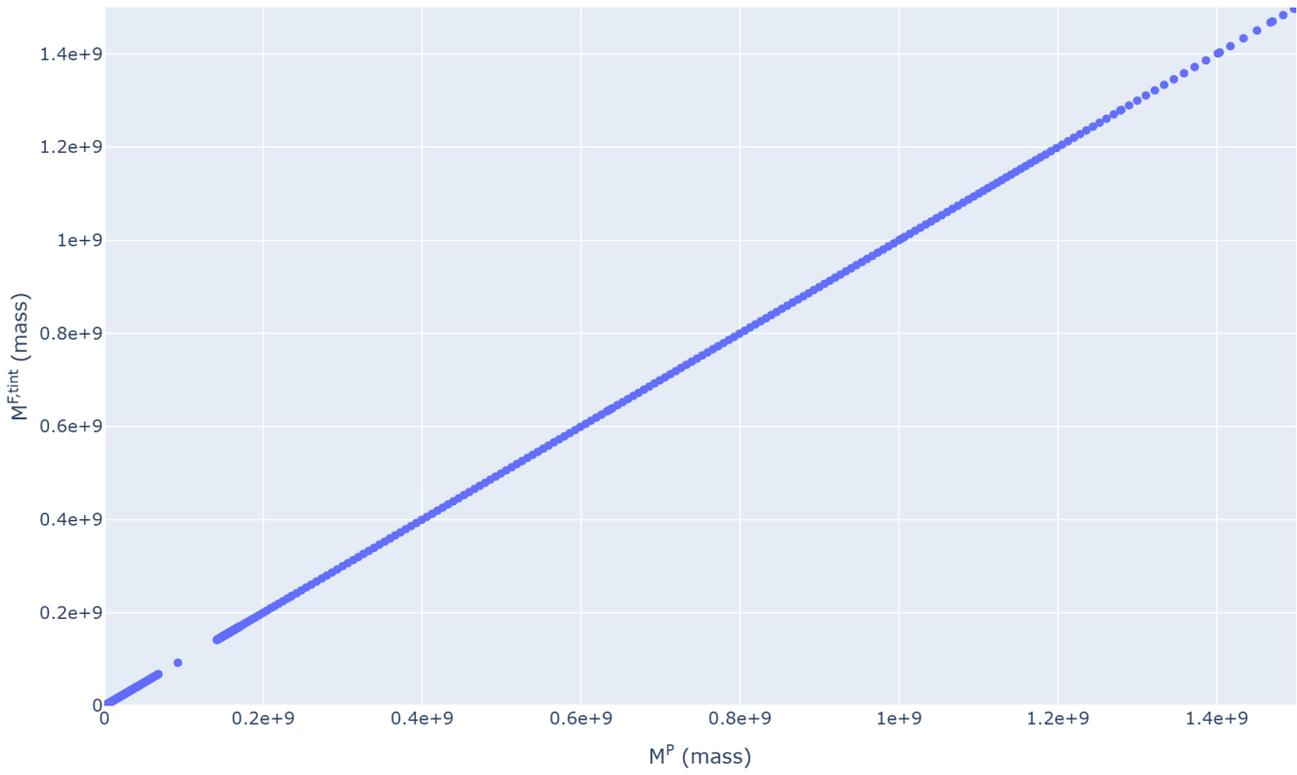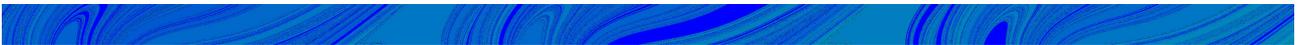
Figure D.16: Groundwater mass in a single layer: comparison of masses computed from time integrated fluxes and porosity

E Application under version control

E.1 Context

It is understood that a common use case of TUFLOW CATCH involves multiple modellers with separate but complementary skill sets working on the same TUFLOW CATCH project. For example, a TUFLOW CATCH project might involve:

- A TUFLOW HPC specialist undertaking catchment simulation, and
- A TUFLOW FV specialist addressing receiving waterway simulation

These modellers will need to work quasi-independently for parts of the project, but bring their work together efficiently at a point, or several points throughout the project schedule. TUFLOW CATCH has been deliberately designed to allow for these modellers to work in parallel as the project unfolds, and most importantly, to both work from the same TUFLOW CATCH control file: **different users should not need to set up and work from different TUFLOW CATCH control files of the same model**. It also goes without saying that TUFLOW HPC and TUFLOW FV modellers should **never** set up individual *.tcf and *.fvc control files and attempt to construct their models disjointedly in the hope of manually combining models together under TUFLOW CATCH at some future point: both should undertake all set up works from a single TUFLOW CATCH *.tcc control file. Given this, the question arises as to how this is to be managed from a file control perspective. This is discussed in the following sections.

E.2 Use case

The use case considered here as an example of using version control is the **Integrated** TUFLOW CATCH configuration, with one modeller working on the TUFLOW HPC calibration, and a different modeller working on the TUFLOW FV calibration. TUFLOW makes no recommendation as to which (of the many available) versioning platforms should or could be used. For the purposes of this example, Git (on Windows) is used, with no intent of endorsement.

E.3 Possible workflow #1

The following is a possible workflow for the two modellers delivering the use case described above, working largely independently until recombination of their work into an overall TUFLOW CATCH simulation. Alterations to this are expected to be required on a case by case basis, and one such example is presented subsequently as a second workflow in Section E.4.

The steps below assume an introductory level of knowledge of Git commands and processes, and are not intended to be exhaustive. Users should familiarise themselves with basic Git protocols and concepts before reviewing the below. For example, users should appropriately configure their .gitignore file, and be familiar with commands such as `git log` and `git status` to keep track of their work.

- Preliminaries
  - Install Git. See https://git-scm.com/book/en/v2/Getting-Started-Installing-Git
  - Ensure at least one user already has the relevant account and sufficient permissions to create a new Git project in a web interface
- Project initiation
  - Use the TUFLOW CATCH QGIS plugin (see Section 4.3) to generate the folder structure and template files for a TUFLOW CATCH simulation. This can be created in any location because it will be subsequently moved
  - Create a new Git project via the web interface of either GitHub or GitLab - TUFLOW makes no recommendation in this regard. This is often achieved via clicking a blue button and filling out some high level project details. The project will have one branch, assumed to be called 'main' for the purposes of this example
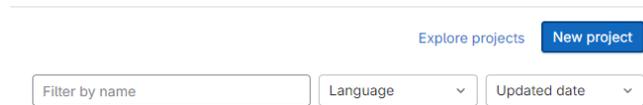
Figure E.1: Creating a new Git project

- Once created, and also from the web interface, copy the address that allows cloning of the new project via https. This is often achieved through a drop down menu on a button marked 'Clone', such as the below (the blue highlighted text is to be copied)
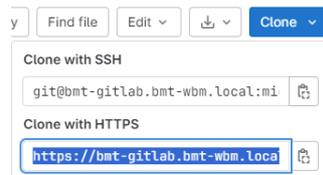

Figure E.2: Copying the https address of a newly created Git project

- Open a new DOS command prompt and navigate to a location where modelling is to be undertaken, preferably under a folder called 'Modelling'

- Clone the new Git project to the Modelling folder, by typing the following, pasting the https address copied above in the `<placeholder>` location

```
git clone <placeholder>
```

An example might look like the following. A new folder under Modelling will be created named the same as the Git project name (in this case, 'catch-demo'). It is this lower folder that is the git project:

```
git clone https://xx-gitlab.yy-zz.local/user.last/catch-demo.git
```

- Change directory into the cloned folder (using the name of the project, in this case 'catch-demo')

```
cd catch-demo
```

- Copy the TUFLOW CATCH folder structure created above into this project directory (`Modelling\catch-demo` in this example), either through windows explorer or the DOS prompt

- In the DOS command prompt whilst in the catch-demo directory, add the new files to a Git commit by typing:

```
git add .
git commit -m "First commit"
```

- Push the new commit back up to the Git web interface

```
git push
```

The project created earlier is now populated with vanilla TUFLOW CATCH template files, both locally and in the web repository.

- Update files
    - Modify template files locally to set up overall TUFLOW CATCH simulation with common commands (e.g. project etc) and save files
    - Commit changes and push
      ```
      git add .
      git commit -m "Populates initial TUFLOW CATCH files for branching"
      git push
      ```
- Create branches
    - In the web interface, which now has the "Populates initial TUFLOW CATCH files for branching" commit present, create a new branch from main for the TUFLOW HPC modeller. This is often achieved via clicking a blue button. Call the branch `HPC` when prompted for a name. Create this new branch from main
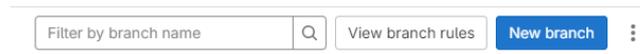
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Figure E.3: Create a branch in a Git project

- In the web interface, create another new branch from main for the TUFLOW FV modeller in the same way. Call the branch 'FV' when prompted for a name. Create this new branch from main

The Git project now has the branches it needs: `main` for the final TUFLOW CATCH model; `HPC` for the TUFLOW HPC modeller; and `FV` for the TUFLOW FV modeller. This allows for the individual modellers to develop their models independently, but from the same commit. The intention is that these files will be merged back into main on completion to form the TUFLOW CATCH simulation suite.

- The TUFLOW HPC and TUFLOW FV modellers can now work on different branches, in parallel, with a view to merging their work back into the main branch on completion.
  - The TUFLOW HPC modeller now:
    * Opens a DOS command prompt and navigates to the directory to be used for modelling. This can be anywhere and does not need to be related to the TUFLOW FV modeller's work
    * Following the steps above, clones the project
      ```
      git clone https://xx-gitlab.yy-zz.local/user.last/catch-demo.git
      cd catch-demo
      ```
    * Once in the catch-demo (or project) directory it is essential that the TUFLOW HPC modeller not work in the 'main' branch, but work in the 'HPC' branch. As a warning, the 'main' branch will most likely be set as the default branch for the modeller to work in when the project is first cloned, so this needs to be changed manually. This requires the TUFLOW HPC modeller to check out the HPC branch by typing:
      ```
      git checkout HPC
      ```
    * The TUFLOW HPC modeller should then begin construction of the TUFLOW HPC model through the TUFLOW CATCH *.tcc control file in this HPC branch, noting:
      · Set up and execution of the TUFLOW HPC model should only occur through the *.tcc file. The modeller should never create a *.tcf file
      · References to boundary database files etc, should point into the TUFLOW directory structure from the *.tcc, for example `Geometry Control File == ..\..\TUFLOW\model\Demonstration_001.tgc`
      · The TUFLOW CATCH simulation should use the [TUFLOW HPC calibration only] or `Pollutant Export` configuration with a downstream polygon as a placeholder for the TUFLOW FV mesh. This does not involve making any changes to the Receiving Model block of the *.tcc (which will be modified by the TUFLOW FV modeller)
      · At key stages of construction, the TUFLOW HPC modeller should stage, commit and push changes to the web project
      ```
      git add .
      git commit -m "A useful commit message"
      git push
      ```
    * When construction is finished, the TUFLOW HPC modeller is ready to merge into the main branch to populate the overall TUFLOW CATCH simulation
  - In parallel with the TUFLOW HPC works, the TUFLOW FV modeller:
    * Opens a DOS command prompt and navigates to the directory to be used for modelling. This can be anywhere and does not need to be related to the TUFLOW HPC modeller's work
    * Following the steps above, clones the project
      ```
      git clone https://xx-gitlab.yy-zz.local/user.last/catch-demo.git
      cd catch-demo
      ```
    * Once in the catch-demo (or project) directory it is essential that the TUFLOW FV modeller not work in the 'main' branch, but work in the 'FV' branch. As a warning, the 'main' branch will most likely be set as the default branch for the modeller to work in when the project is first cloned, so this needs to be changed manually. This requires the TUFLOW FV modeller to check out the FV branch by typing:
      ```
      git checkout FV
      ```
    * The TUFLOW FV modeller should then begin construction of the TUFLOW FV model through the TUFLOW CATCH *.tcc control file in this FV branch, noting:
    * Set up and execution of the TUFLOW FV model should only occur through the *.tcc file. The modeller should never create an *.fvc file

  * References to boundary, geometry and files etc, should point into the TUFLOWFV directory structure from the *.tcc, for example `Geometry 2D == ..\..\TUFLOWFV\model\geoDemonstration_001.2dm`
  * The TUFLOW CATCH simulation should use the `TUFLOW FV calibration only` configuration. This does not involve making any changes to the Catchment Hydraulic Model block of the *.tcc (which will be modified by the TUFLOW HPC modeller)
  * At key stages of construction, the TUFLOW HPC modeller should stage, commit and push changes to the web project
    ```
    git add .
    git commit -m "A useful commit message"
    git push
    ```
  * When construction is finished, the TUFLOW FV modeller is ready to merge into the main branch to populate the overall TUFLOW CATCH simulation

- The HPC and FV branches can be merged into the main branch to generate the overall TUFLOW CATCH simulation

  – Because the modellers have been working in separate blocks of the *.tcc, and populating separate folder structures for base data (`..\TUFLOW\` and `..\TUFLOWFV\`), conflicts should be minimal
  – Free packages such as Winmerge can be used to assist with this process. This is a suggestion only and not an endorsement of Winmerge by TUFLOW

E.4 Possible workflow #2

The following is a possible addition to the workflow presented in Section E.3 for the two modellers delivering the same use case. Instead of the modellers working entirely independently until post calibration, it includes occasional provision of interim catchment inflows from the TUFLOW HPC modeller to the TUFLOW FV modeller to assist in calibration of the latter under wet conditions. This is accomplished by:

- Merging sufficiently complete HPC and FV branches into the main branch to produce a TUFLOW CATCH **Integrated** configuration simulation from time to time, instead of only at the end of individual calibration tasks

- Executing TUFLOW CATCH in **Integrated** configuration to produce all spatially and temporally resolved boundary inflows for TUFLOW FV

- Add, commit and push the boundary files to the main branch

- Copy the boundary files (including header blocks (.fvcatchbc) and data files (.csv)) to the `\TUFLOWCATCH\bc_dbase\` folder in the FV branch being used by the TUFLOW FV modeller for subsequent access

- Rename the *.fvcatchbc file to be the same as the TUFLOW FV modellers *.tcc file name so that it is automatically found by the current *.tcc simulation

- Rerun the TUFLOW FV modeller's *.tcc simulation, adding the command below inside the Receiving Model block so that blank catchment boundary files (the default) are not produced and so do not overwrite those developed in the above **Integrated** TUFLOW CATCH simulation

  `Preserve Catchment Inflows == ON`

- The TUFLOW FV modeller can then continue the calibration process with revised inflows. The above process can be repeated at intervals that suit the modelling project and timelines.

- Once complete, the HPC and FV branches can be finally merged, and the full TUFLOW CATCH simulation executed

TUFLOW CATCH