Mass Balance Summaries in RiverWare 6.2

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(0.1) Document Status

- 12-28-2011: SUPERCEDED -- ported to FrameMaker document, with minor revisions. /projects/riverware/doc/MassBalanceTool/MassBalSumDesign.fm ... See 12-28-2011 PDF (18 pages).

(0.2) Contents

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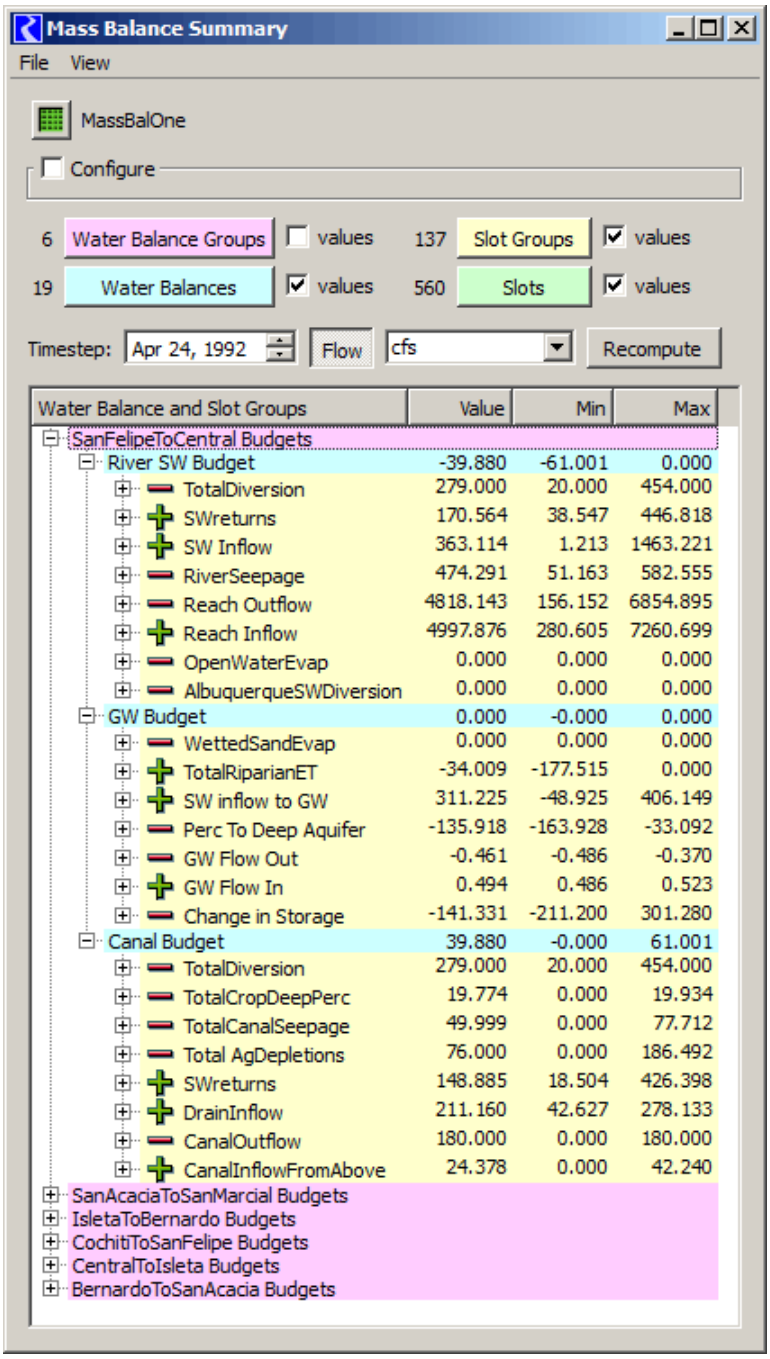
(0.3) Related Documents

- **Mass Balance Summary Tool**
  David Neumann, Edie Zagona / 2 pages, 11-14-2011
  R:\doc\MassBalanceTool
  \MassBalanceTool_Rqmts.2011.11.14.fm



(1) Overview

The Mass Balance Summary is a user-defined hierarchy of series slot collections used to check mass balance across many objects in a RiverWare model. Any data object can optionally have a Mass Balance Summary definition. Series slots representing sums of the sets of series slots are maintained on the data object, and can be referred to from Rpl expression slots defined by the user for any summation calculations not provided by the Mass Balance Summary, e.g. annualization of sums.

(1.1) Reference Model

The Mass Balance Summary design was derived from a Rpl expression slot-based implementation by the URGWOM team (Upper Rio Grande Water Operations Model) -- a version of the "MRGV 2011 calibration" RiverWare model. This particular mass balance calculation involved 162 Rpl expression slots to sum 560 physical series slots. Data from this URGWOM model was used to demonstrate this GUI design.

(2) User Interface and Functional Design

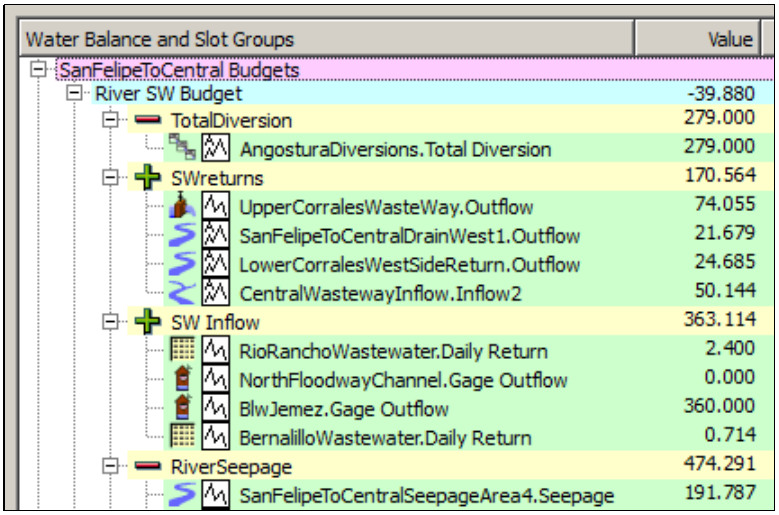
(2.1) Mass Balance Summary Structure

A Mass Balance Summary **("Summary")** can be associated with any data object. The configuration of the Summary is saved with the data object in RiverWare models and in data object (simulation object) export / import files.

Primary Configuration Data:

Four level-hierarchy of Series Slot references. Each collection item represents the series sum of its child items' series.

	Collection Level	Generated Summation Slot Type	Background Color
1	Water Balance Groups	Series Slots	Pink
2	Water Balances	Agg Series Slots	Cyan
3	Slot Groups (+/-)*	... child Series Slots	Yellow
4	Slots	Series Slot References	Green



*Each *Slot Group* will be summed as a Credit ("+") or Debit ("-") for its containing *Water Balance.* (Note: the Credit and Debit annotations shown in the mockup images in this document are arbitrary. They are not derived from the reference model).

The set of generated series slots (and aggregate series slots) used to represent sums in the top-three levels is automatically maintained. The values of these slots will be computed internally in C++ implementation rather than with Rpl expression slots. The generated slots are *"read-only"* -- their values will not be editable by the user.

The lowest level -- references to series slots in the model -- can include references to user-defined Rpl expression slots to compute terms which are not directly available as RiverWare slots at the same timestep. The reimplementation of the URGWOM mass balance calculation using the new Mass Balance Summaries will need:

- Three (3) Rpl expression slots to shift data one timestep, for routing.
- Six (6) Rpl expression slots to calculate a "change in storage" from the prior timestep. [We may choose to support this entity as a new physical series slot].

Other Configuration Data:

- Flow / volume display unit selection, and other minor display settings.
- Generated slot name preferences.
- A list of user-defined Rpl expression slots dependent on the computed Summary series slots. Each time the Summary is recomputed, the slots in this list will also be recomputed, in the list order. One possible use of the "Dependent Expression Slots" list is the computation of annual mass balance series data.
- A list of simulation objects associated with each Water Balance to constrain the set of slots assigned to the Water Balance's Slot Groups.

(2.2) Mass Balance Summary Evaluation

Each *computed summation* series slot -- for the items in the top three levels -- is the sum of all the contained items' series slots at each timestep -- with *debit* (negated) terms supported at the Slot Group level. The *time range* of a computed slot is the extrema of time ranges of the contained items.

When Summaries are computed **will depend on the performance of the calculations (TBD).** (We'll finalize this decision during development). The following events will result in *either* performing the computation OR visually marking the Summary display as "dirty" (needing a recomputation):

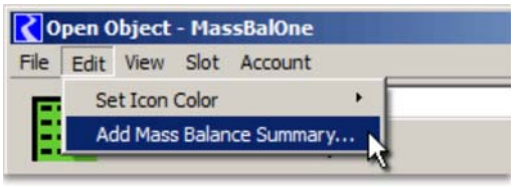
1. The "Recompute" button in the Mass Balance Summary dialog is clicked.
2. A run stops (**TBD:** unconditionally OR only in batch mode or if the Mass Balance Summary dialog is open).
3. The Mass Balance Summary dialog is opened.
4. Relevant Mass Balance Summary configuration changes are applied by the user.

Before a Summary recomputation, any "missing" computed summation series slots are created on the data object, and "orphaned" series slots -- i.e. previously created summation series slots which are no longer used, e.g. as a result of an item name change -- are destroyed. These series slot maintenance adjustments will be performed also as a result of certain edits to the Summary configuration.

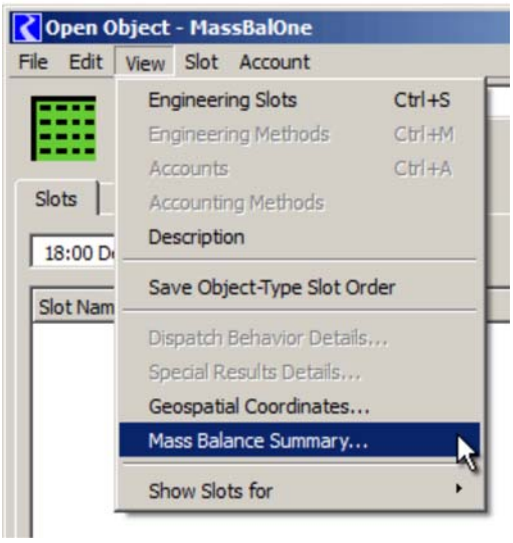
After each Summary recomputation, the "dependent" Rpl expression slots in a special user-configured ordered list are evaluated. Read more in the Mass Balance Summary Configuration section, below.

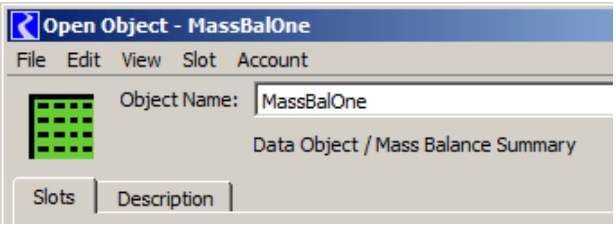
(2.3) Accessing Mass Balance Summaries

A Mass Balance Summary can be created on any data object with the **"Add Mass Balance Summary..."** operation in the Open Data Object dialog's "Edit" menu. This shows the Mass Balance Summary dialog in its configuration mode.



A data object having a Mass Balance Summary is indicated in the object type description (see below). When a Summary exists, a **"Mass Balance Summary..."** item appears in the Open Object Dialog's View menu. (And the "Add ..." item in the Edit menu is changed to "Mass Balance Summary..." as well).

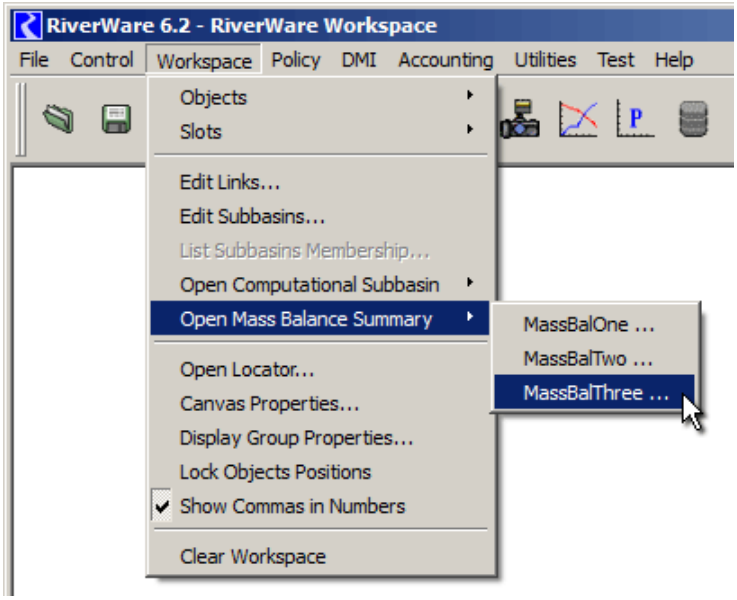




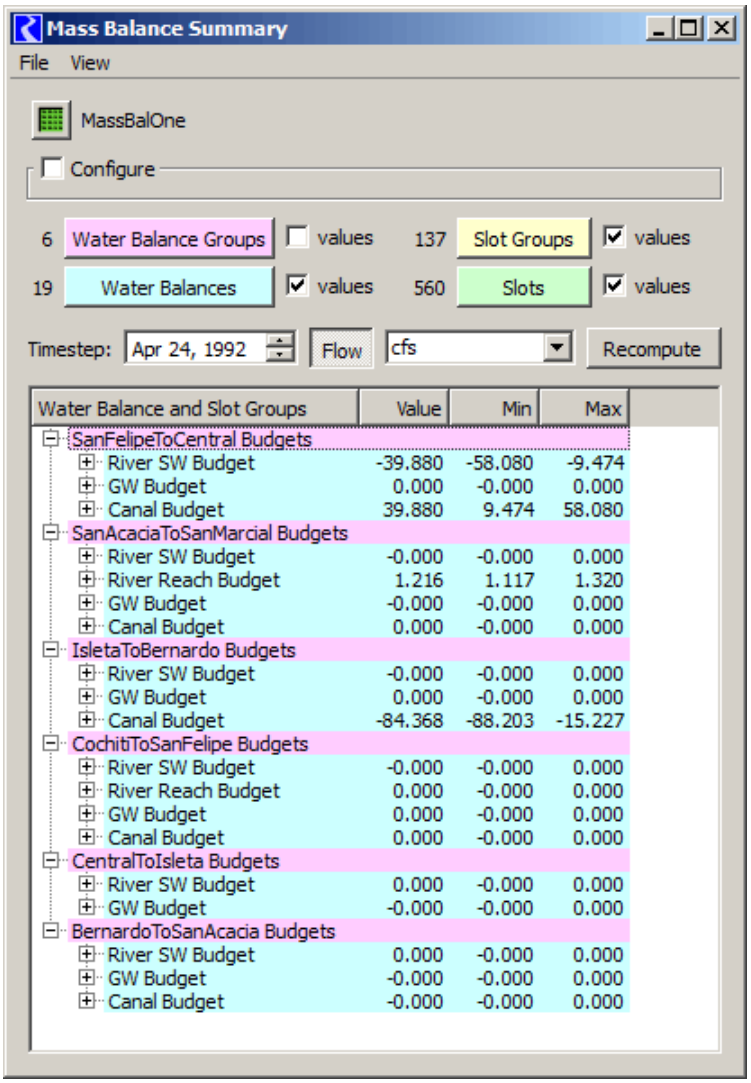
Possible Enhancements:

1. Add a button (maybe a small icon button) to the Open Object Dialog to open an existing Mass Balance Summary on the data object.
2. Devise a modification to the Data Object *icons* to indicate that the data object has a Mass Balance Summary.

Already existing Summaries are accessible from the Workspace menu in the RiverWare Workspace.



(2.4) Mass Balance Summary Dialog



The Mass Balance Summary dialog is accessible from the Workspace menu and from the Open Data Object dialog (as described above).

Clicking the **data object icon** button at the top of the dialog shows the Open Object Dialog for the data object containing the Mass Balance Summary.

The four supported levels of summation sets are represented with color-coded buttons -- clicking these buttons opens up the tree view to the particular level.

1. Water Balance Groups
2. Water Balances *(see image).*
3. Slot Groups
4. Slots (references to flow or volume series slots in the model)

Subtrees can also be opened and closed in the normal way, with the tree controls.

The integer shown to the left of the level buttons indicates the number of defined items at that level. For example, the screenshot shows that this Summary contains **6** Water Balance Groups, **19** Water Balances, **137** Slot Groups, and **560** Slot references.

Each line in the tree view represents a computed summation series slot or a referenced series slot (in the case of the fourth level). Context menu operations on the set of selected lines include:

- Plot the selected slots.
- Show the selected slots in Open Slot dialogs.
- Show the selected slots in a new SCT.
- Add the selected slots to an open SCT.

Possible Enhancements:

1. Devise an algorithm, possibly using user configurable preferences, for distributing multiple selected items among **distinct plots (up to 9) within a single plot page.**
2. Support for **"Stacked Area"** Plots: a new type of plot where the ordered set of series slots are shown with **accumulated** values -- i.e. added to the values of the previous series slots in the list. (This would work well for groups of series where all the values are positive "credits" to the overall sum).

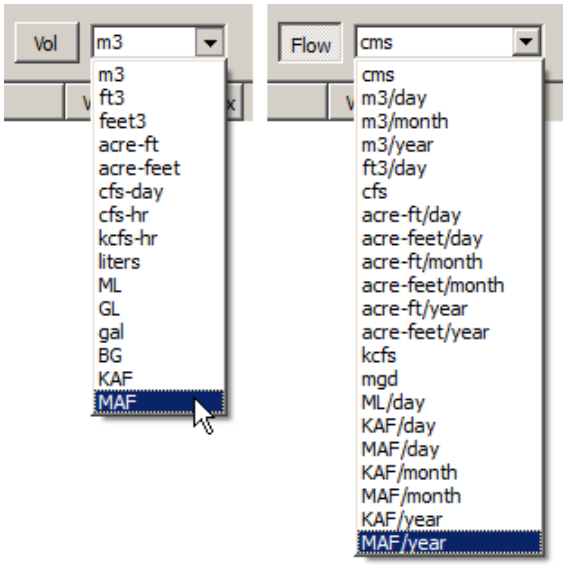
Data columns show numeric values in the selected flow or volume slots, with display units selected in this dialog. The illustrated volume and flow units *(to the right)* are supported -- as defined in the currently available standard RiverWare "units" file.

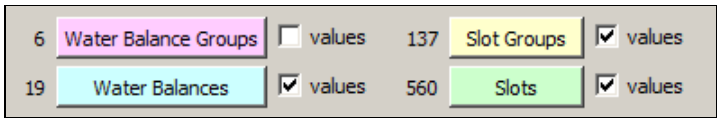
The following data columns are supported:

- Value (at the selected timestep)
- Minimum value in the defined time series*
- Maximum value in the defined time series*

*conditionally hidden or shown, based on a configuration setting.

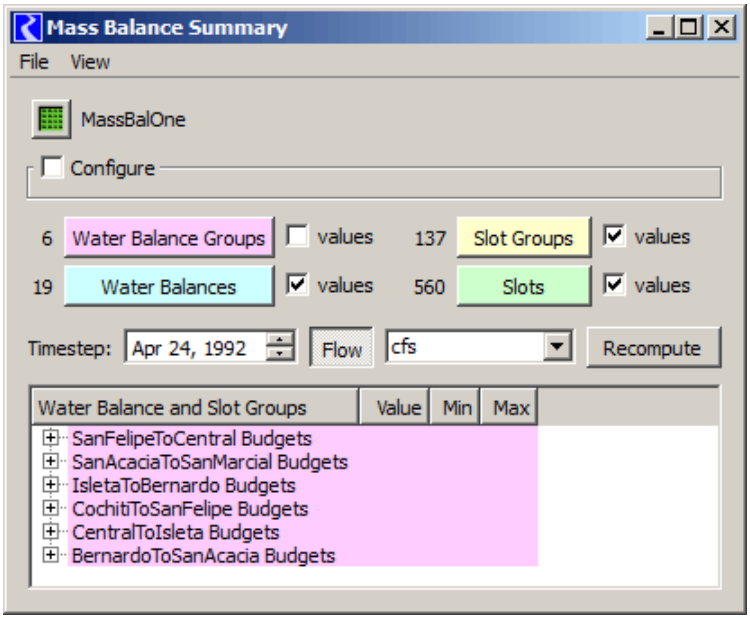
Numeric summation data is shown only for the item levels with a checked **"values" checkbox** to the right of each level button -- *see below.* This allows the user to quickly scan through similarly "scoped" sums (e.g. only Slot Group sums).





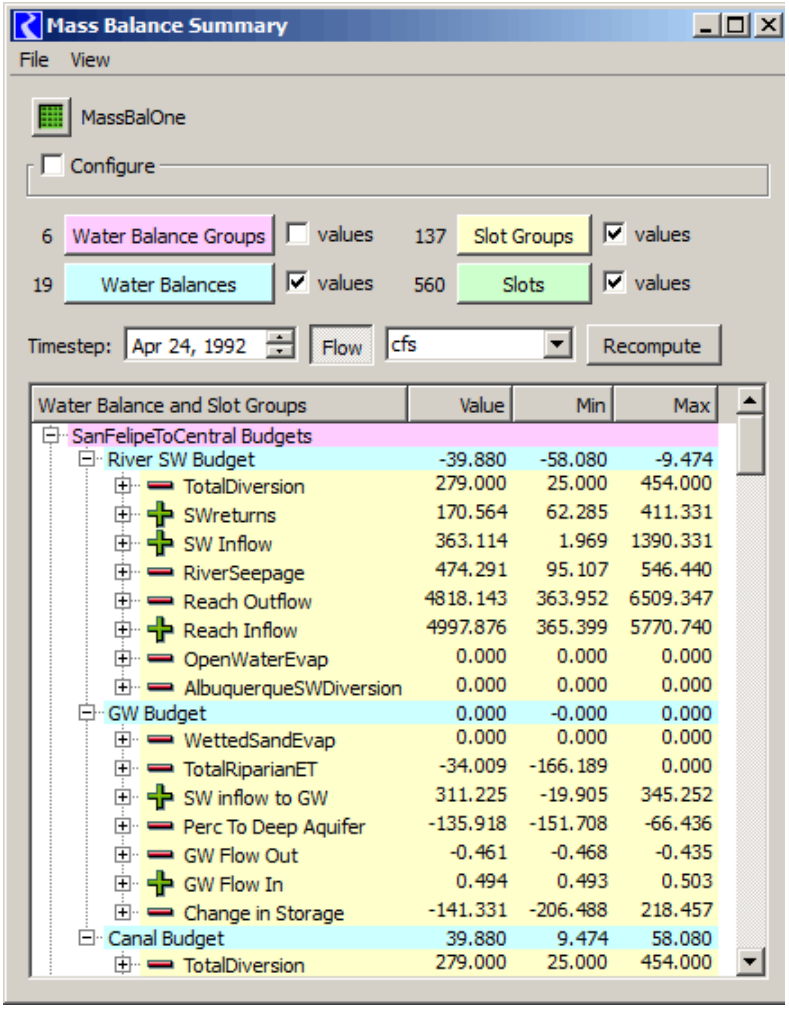
Possible Enhancement: Add buttons along the bottom of the Mass Balance Summary dialog, mostly for operations which apply the the selected set of items.

- Plot
- Open Slots
- Show in SCT
- Add to SCT
- Close

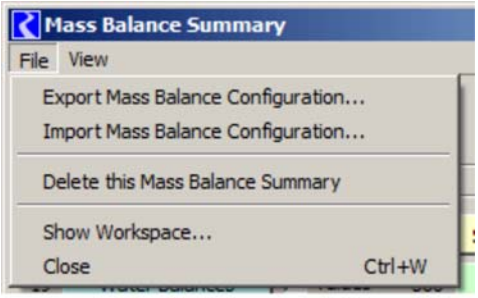


Above: Water Balance Groups (level 1).

Right: Slot Groups (levels 1, 2 and 3).



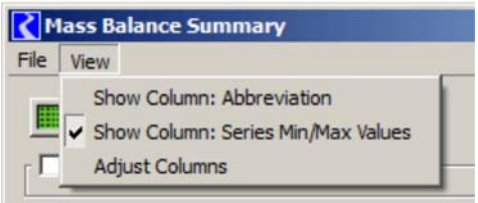
(2.5) Mass Balance Summary Dialog Menus



The Mass Balance Summary Dialog supports "File" and "View" menus.

TBD: The "Export" and "Import" operations will be used at least for development testing of the Summary configuration serialization. We might not choose to support this in the final implementation. Note that a data object's Mass Balance Summary configuration will be included in the SimObj "export" file for the data object.

The "Delete Mass Balance Summary" operation removes this Mass Balance Summary from its data object, after a confirmation by the user.

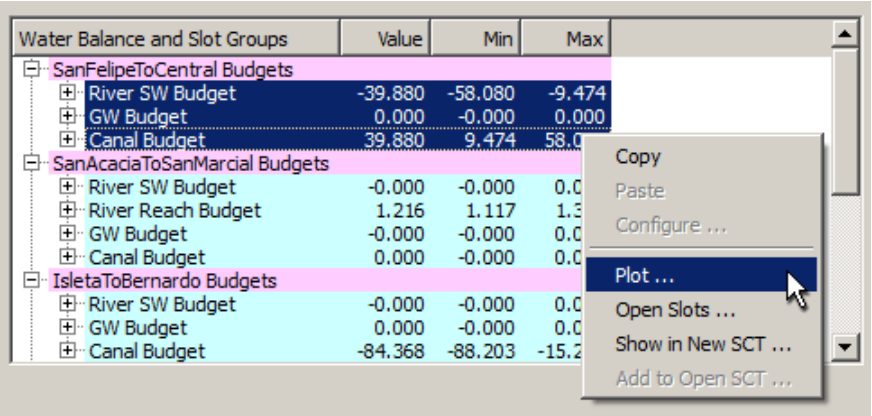


Two types of columns will optionally be shown in the tree view, based on checkboxes in the "View" menu:

- Abbreviation column (used for the names of generated summation slots).
- Minimum and maximum series values columns.

The "Adjust Columns" operation adjusts the width of each column to the content of that column.

The tree view **context menu** ("right-click" menu) operates on the full set of selected items:



(2.6) Mass Balance Summary Configuration

When the Mass Balance Summary dialog's "Configure" group box toggle is checked, the following occurs:

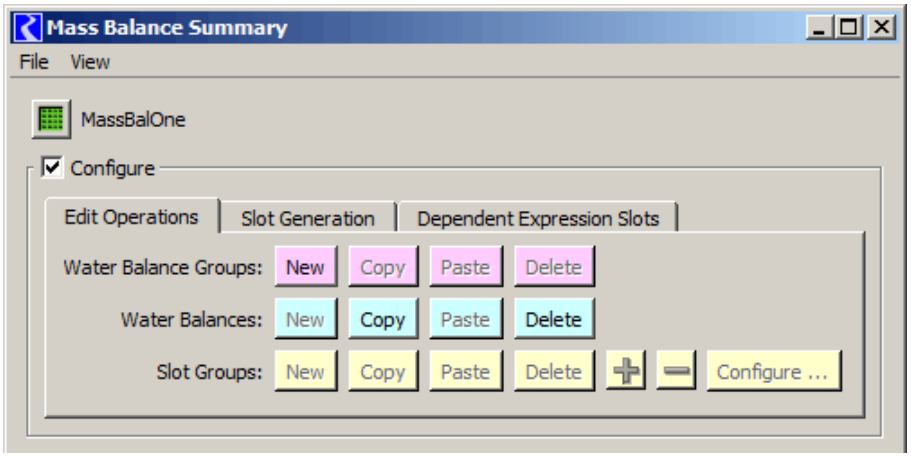
- Three tabs of configuration controls are shown in the group box -- *See below.*
- "Move Items" arrow icon buttons appear below the tree view. These function only to reorder items within their containing "group" item -- not move them to different groups. The buttons are enabled only when the tree view item selection is limited to items within a single level and that selection doesn't already include the top-most or bottom-most item in its respective group.
- Item *names* are editable (inline).
- Item *abbreviations* are editable (inline), when the abbreviation column is shown. Item abbreviations are used for the names of generated summation series slots.

The **"Edit Operations" Configuration Tab** provides context-sensitive edit controls for the first three item levels. (The enabledness of each item depends on the tree view item selection). Some of these operations are also available in the context menu.

- **"New":** Creates a new instance at the indicated level with a default name. An item is created and an incell edit is started on that default name. A New Water Balance Group (top level) item can always be created. The "New" operations for the subsequent two levels is enabled only if a single containing item at the appropriate level is selected.
- **"Copy":** This operation is available only if the selection is limited to a single level. It copies the selected items -- including those items' children -- to a special mass balance item clipboard. This operation also has the following side effects:
    a. The series slots for the selected items are copied to the RiverWare slot clipboard.

b. The names of those slots are copied to the system clipboard (as plain text).

- **"Paste":** This operation is available only if a single item is selected AND the mass balance item clipboard contains items appropriate for the selected item's level. The Copy/Paste operation includes all of the child items in the original copied selection. Copying and pasting is supported between distinct Mass Balance Summaries (on distinct data objects) in the same RiverWare session.
- **"Delete":** Deletes the selected items, after a confirmation by the user.

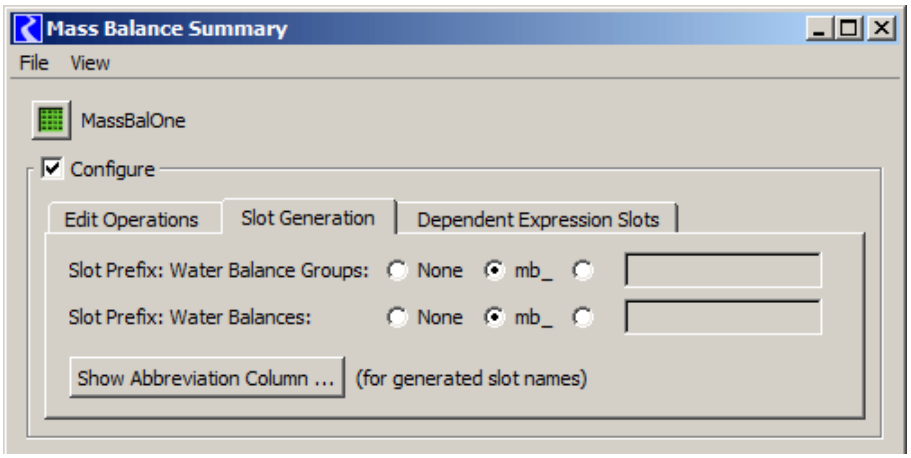


Additionally, there are the following buttons for Slot Groups:

- **(+) and (-) icon buttons:** Sets the selected Slot Groups to either Credits or Debits.
- **"Configure...":** Opens the **Mass Balance Slot Group Configuration dialog** for the single selected Slot Group. *(See the next section).*

The **"Slot Generation" Configuration Tab** provides settings for names given to the automatically generated summation slots -- for items in the top-three levels. These settings are intended to address these two issues:

1. It should be easy to distinguish the automatically generated series slots from other slots the user has placed on the data object.
2. Slot names generated from the multiple levels of item names could be quite long. It would be best if the user had the option of using shorter strings for each item when generated slot names.



By default (as illustrated), a prefix of **"mb_"** is used for generated slot names. The user has the option of omitting that prefix or specifying a different one -- individually for Water Balance Groups (level 1) and Water Balances (level 2). Note that the generated slots for Slot Groups (level 3) will be child "columns" of the Water Balance aggregate series slots -- no prefix will be prepend to the column labels for those series slots.

The tree view's "Abbreviation Column" is conditionally shown, based on a checkbox in the View menu. Clicking the **"Show Abbreviation Column..."** button turns that checkbox on and shows the column. Text in the abbreviation column is directly editable (inline) only when the "Configure" group box is open (checked on).

The **"Dependent Expression Slot"** Configuration Tab provides a user-defined ordered list of Rpl expression slots to be automatically evaluated at the conclusion of the Summary recomputation.

The example to the right enumerates *annualization* Rpl expression slots in the URGWOM reference model. (Their Rpl expressions will be recoded to refer to generated Summary summation slots).

An added benefit of the enumeration of slots dependent on the Summary summation slots is to explicitly represent the purpose of those slots -- i.e. being part of a mass balance computation.

The **arrow icon buttons** move the set of selected items up or down in the list.

The **"Add..."** button brings up the slot selector to pick slots to be added to the list. The selector will be initialized to show only

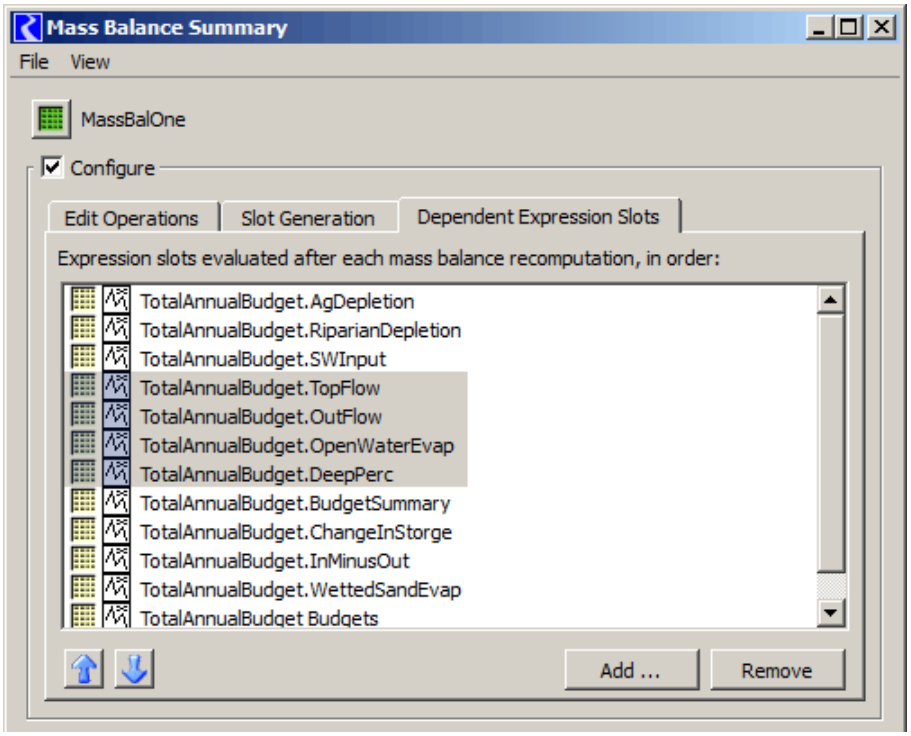
series and scalar slots having Rpl expressions.

The **"Remove"** button will remove the selected items from the list, after a confirmation by the user.

A context menu on this list will provide the following operations -- similar to those in the main tree view context menu:

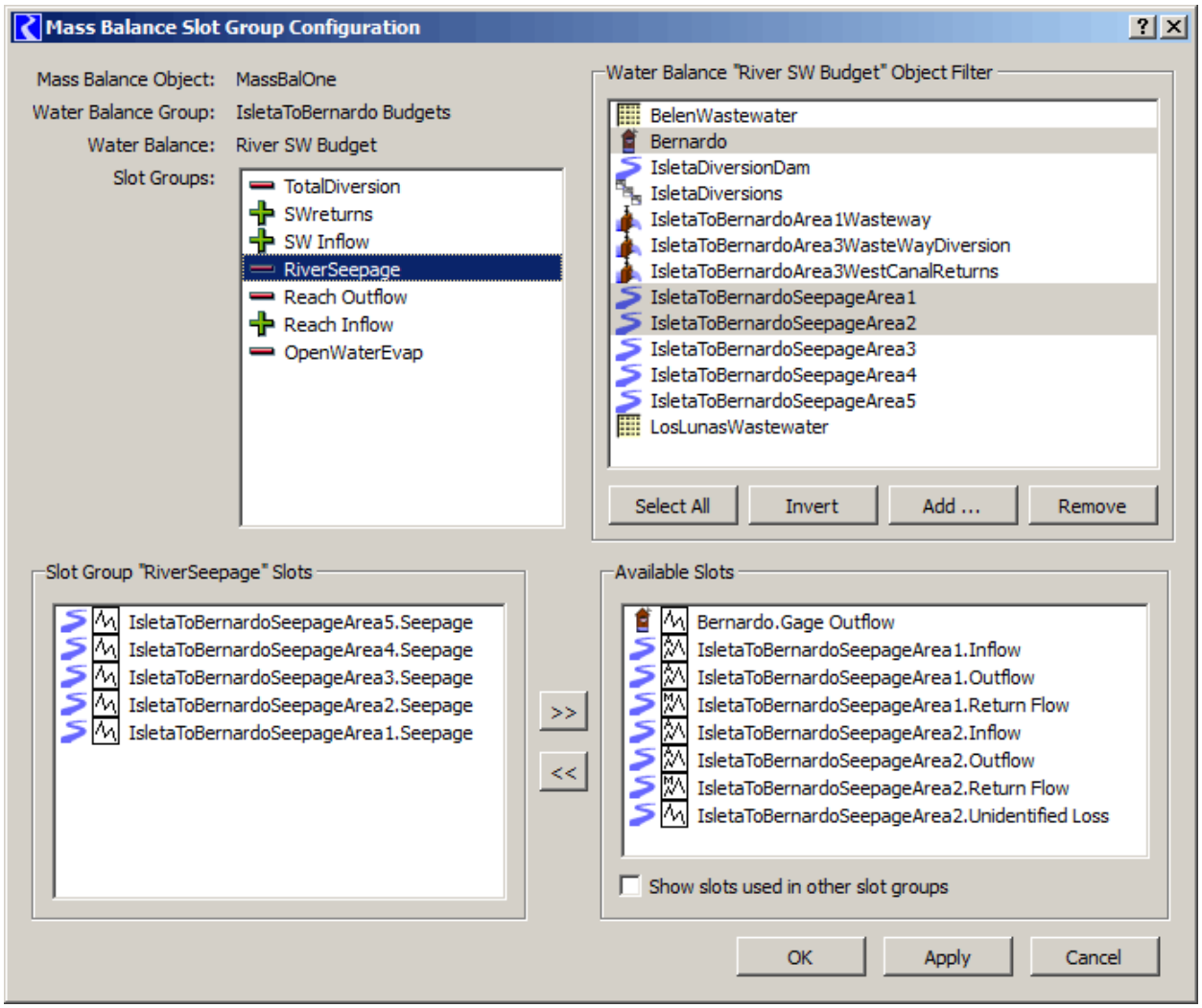
- Plot the selected slots.
- Show the selected slots in Open Slot dialogs.
- Show the selected slots in a new SCT.
- Add the selected slots to an open SCT.

Note, however, that these slots can effectively be added only to SCTs showing series with the same timestep size.



(2.7) Mass Balance Slot Group Configuration Dialog

The Mass Balance Slot Group Configuration dialog is shown *modally* when clicking the (Slot Group) "Configure..." button in the Mass Balance Summary Dialog. This configuration dialog is used to define the set of Slot references in each of the Slot Groups within a Mass Balance.



This dialog presents lists in four quadrants:

- The **top-left quadrant** shows the currently selected Slot Group, its containing Water Balance, Water Balance Group and Mass Balance object (data object). It also shows the selected Slot Group's sibling Slot Groups (contained within the same Water Balance). The user can navigate to any of the sibling Slot Groups by clicking on its item -- if any un-applied changes to the selected Slot Group Slots list exist, a confirmation popup is shown, allowing the user to (1) apply the changes, (2) discard the changes, (3) cancel (the change to the different Slot Group).
- The **top-right ("Object Filter") quadrant** shows a list of simulation objects in the model from which slots can be chosen for inclusion in the Water Balance's Slot Groups. The user can pick additional objects for this list with the **"Add ..."** button -- this brings up the GUS object selector. The selected items can be removed from the list by clicking the **"Remove"** button. The **"Select All"** button selects all object items. The **"Invert"** button inverts the object item selection.
- The **bottom-right ("Available Slots") quadrant** shows the "available" relevant slots within the set of selected objects in the Object Filter list which are not already used in the selected Slot Group -- or in any of the Water Balance's slot groups, depending on the "Show slots used in other slot groups" checkbox.
- The **bottom-left ("Slot Group Slots") quadrant** shows the Slot references in the selected Slot Group.

Slots can be moved between the bottom two quadrants (Slot Group Slots and Available Slots) with the large arrow buttons between those two quadrants.

If no un-applied changes have been made to the Object Filter list (not including item selections) or the Slot Group Slots list, the OK

and Apply buttons are disabled, and the **"Cancel"** button is instead labeled **"Close".**

The **"OK"** button applies the not-yet-applied changes to the Mass Balance Summary configuration and dismisses the dialog.

The **"Apply"** button applies the not-yet-applied changes to the Mass Balance Summary configuration, but does not dismiss the dialog.

The **"Cancel" / "Close"** button dismisses the dialog without applying new changes to the Mass Balance Summary configuration.

When applying changes, if any of the Water Balance's Slot Groups contain slots not on the simulation objects in the Object Filter, a warning is shown, giving the user the option to (1) automatically add the missing objects to the Water Balance's Object Filter -- OR (2) ignore the condition OR (3) cancel the "apply" or "OK" operation.

(2.8) Series Slot Displays

The generated Summary summation slots will be viewable in the SCT and Open SeriesSlot Dialogs in the usual way. When using the special "show in SCT" operations from the Mass Balance Summary dialog, divider items with text will be generated for the names of the containing higher-level objects.

TBD: We'll need to decide how the SCT Slot Item labels are set -- i.e. whether they the primary names of the various items OR the names of the generated slots (which use the configured abbreviations, when available). This might be done differently for the two axis orientations, and we might decide to add user-settable preferences for how SCT Slot Item labels should be composed.

Possible Enhancement: Credit / Debit Slot Annotation ...

We could consider adding flags to Series Slots to indicate that the slot represents a "Credit" or "Debit", and enhance the Series Slot Displays (SCT and Open SeriesSlot Dialog) to show a plus ("+") or minus ("-") with the slot label in the row or column header, something like this ...

	Total cms		Inflow (+) cms	Diversion (-) cms	SW Returns (+) cms	Seepage (-) cms	Evap (-) cms	Local Inflows (+) cms	Outflow (-) cms
12-31-1995 Sun	NaN	O	NaN	NaN	NaN	NaN	NaN	NaN	NaN
01-01-1996 Mon	10.38	O	1.86	1.30	0.73	-0.62	3.22	0.16	3.73
01-02-1996 Tue	10.61	O	2.02	1.45	0.89	-1.48	3.38	0.32	4.04
01-03-1996 Wed	14.48	O	2.34	1.77	1.20	0.17	3.70	0.64	4.67
01-04-1996 Thu	9.29	O	1.70	1.14	0.57	-0.60	3.06	0.00	3.41

(3) Development

(3.1) Required Internal RiverWare Enhancements

Slot Attribute Flag: Mass Balance Sum Slot

It will be important for the Mass Balance Summary mechanism to recognize slots which had been created for summary series. Such slots no longer corresponding to series items in the configuration (related by user-defined names and abbreviations for those items) need to be removed. An easy way to accomplish this is to add a "Mass Balance Sum Slot" Slot Attribute bit.

Slot Attribute Flag: Credit / Debit Slot Annotation (Optional)

Similarly flags could be added to support a Credit / Debit Slot Annotation (see prior section). Fundamentally, this needs three states which could be represented with two attribute bits (in a couple distinct possible ways, TBD).

1. Default -- not a credit or debit
2. Is a credit
3. Is a debit

Additional Physical Slots

A "change in storage" entity was required for the URGWOM mass balance computation. This was done using Rpl expression slots (6 of them), and still could be. But we could consider adding a FLOW slot on reservoirs to represent this entity.

(3.2) Development Tasks

- (3.2.1) Internal Data Model
- (3.2.2) Retooling Mass Balance Summary Dialog "Mockup" for actual data model.
- (3.2.3) Summary Computation
- (3.2.4) Abstract Item-Model based implementation of the main QTreeView
- (3.2.5) Display unit type (flow and volume) and unit conversions.
- (3.2.6) Summary Configuration Editing Operations
- (3.2.7) Revision of supporting QTreeWidgets to use the actual data model.
- (3.2.8) Series Display Interfaces
- (3.2.9) Integration / Finishing
- (3.2.10) Testing and Feature Documentation

(3.2.1) Internal Data Model

A Mass Balance Summary configuration is an individually maintainable object, with a single optional instance deployed on each data object. It is serialized using XML (implemented with the Qt4 QDom classes), and that serialization is embedded in the data object (SimObj) Tcl serialization.

The Mass Balance Summary data model provides classes for lower-level objects, including a simple composite-pattern class hierarchy for the four levels of collection and slot reference items. Slot references are represented with SlotColRefs so that individual columns within, Table Series Slots could potentially be supported.

Subtasks:

1. Basic C++ class definition and implementation
2. Maintenance of a Summary instance on Data Objects (with minor GUI operation implementation).
3. XML serialization and deployment in the SimObj Tcl serialization

(3.2.2) Retooling Mass Balance Summary Dialog "Mockup" for actual data model.

Much of the mockup implementation is functional, but operates on shallow mockup data derived from the URGWOM reference model. Recoding the mockup implementation to operate on the real internal data model is a simple matter, and will support the development of the summary computations.

- This task will *not* include re-implementation of the item-based QTreeWidget as an abstract item model-based QTreeView.
- This task will *not* include the development of edit operations on the Mass Balance Summary configuration.

Subtasks:

1. GUI data source retooling
2. Regeneration of the URGWOM reference model mockup data as an actual Model Balance Summary configuration instance.

(3.2.3) Summary Computation

Given an internal model implementation and a basic GUI to present the structure of the Summary configuration, the maintenance and computation of the summation slots can be implemented.

Subtasks:

1. Add the "Mass Balance Sum Slot" slot attribute to the Slot class.
2. Maintenance (creation and culling) of Mass Balance Sum Slots on the Data Object.
3. Series sum computations.
4. Error checking and reporting.
5. Evaluation of Dependent RPL Expression Slots
6. Revise reference model's Dependent RPL Expression Slots (for annualization) to refer to generated sum slots.
7. Initial performance testing with the full reference model (4000+ timesteps).

(3.2.4) Abstract Item-Model based implementation of the main QTreeView

The mockup implementation was based on an item-based QTreeWidget which has inherent performance limitations. This will need a full Qt4 abstract item model implementation with a custom delegate.

Subtasks:

1. Basic item-view model implementation for a 4-level QTreeView.
2. Abstract item model testing and debugging (using http://developer.qt.nokia.com/wiki/Model_Test).
3. Item expanded state, selection and vertical scroll position persistence.
4. Delegate: background cell colors.
5. Conditionally enabled incell editing of item names and abbreviations.

(3.2.5) Display unit type (flow and volume) and unit conversions.

Subtasks:

1. Saving Unit Type and Unit widget selections in data model. (Reference timestep date/time too).
2. Display value string computation and display.

(3.2.6) Summary Configuration Editing Operations

- Item creation ("New") for the top-three levels.
- "Copy" and "Paste" operations, with special internal "clipboard" support (only usable within a single RiverWare process).
- "Delete" operations, with confirmation.
- Slot Group Credit ("+") and Debit ("-") property assignments.

(3.2.7) Revision of supporting QTreeWidgets to use the actual data model.

The mockup implementations of the five minor display lists (with item-based QTreeWidgets) are fairly complete. These will remain QTreeWidgets (i.e. abstract item-model based QTreeView implementations are not warranted). The mockup implementations need to be retooled to use the actual data model.

Subtasks:

1. Dependent Expression Slots List
    a. picking new Slots with GUS
    b. moving selected items up and down.
2. Slot Group Config Dialog Lists
    a. Slot Groups List
    b. Object Filter / picking new Objects with GUS
    c. Slot Group Slots List
    d. Available Slots List
3. Slot Group Config Dialog Completion
    a. Used / Available transition button operation
    b. Slot Group edit session maintenance (OK / Apply / Cancel) ...

(3.2.8) Series Display Interfaces

1. Plot selected items, automatic plot page configuration.
2. Add Slots to SCT: automatic SCT slot divider and item configuration
3. TBD: Credit ("+") / Debit ("-") Slot Annotation: internal flag and GUI in Open Slot Dialog and SCT.

(3.2.9) Integration / Finishing

1. Open Data Object Dialog enhancements
2. Workspace Menu: Dynamic "Mass Balance Summary" submenu
3. Mass Balance Summary "recomputation time" analysis (based on performance) and implementation.

(3.2.10) Testing and Feature Documentation

(3.3) Development Estimates

Task (3.2.x)	Est. (days)	Opt (days)	Description
1	2.0		Internal Data Model
2	1.0		Retooling Mass Balance Summary Dialog "Mockup" for actual data model.
3	2.5		Summary Computation
4	2.5		Abstract Item-Model based implementation of the main QTreeView
5	1.0		Display unit type (flow and volume) and unit conversions.
6	1.0		Summary Configuration Editing Operations
7	1.5		Revision of supporting QTreeWidgets to use the actual data model.
8	1.5	+ 2.0	Series Display Interfaces (**Optional:** Credit / Debit Annotations)
9	1.0		Integration / Finishing
10	2.0		Testing and Feature Documentation
	16.0	+ 2.0	Totals

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