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Integrated Climate Assessment for Army Enterprise Planning

Water Balance Model User's Guide

Byron M. Garton

July 2019



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Abstract

The combination of shortsighted planning and Global Climate Change (GCC) has resulted in an imbalance in U.S. freshwater resources, (e.g., too much water in some regions and not enough in others). Better information on how GCC will affect different regions in the United States is needed to guide the U.S. Army in making effective decisions on how to properly adapt. This model attempts to predict how the balance of freshwater resources is likely to shift as a result of GCC by calculating those shifts based on several climate scenarios for various Department of Defense (DoD) installations.

This document describes the process of executing the Water Balance Model, as it exists at the time of this writing, within the common computational environment established under the software integration effort of the Integrated Climate Assessment for Army Enterprise Planning work package.

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Preface

This research was conducted for the U.S. Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL) under Project 402188, Integrated Climate Assessment for Army Enterprise Planning. The Technical Monitor was Dr. James D. Westervelt of ERDC-CERL.

The work was performed by the Information Technology Laboratory (ITL), Scientific Software Branch (SSB), of the Computational Science and Engineering Division (CSED). At the time of publication, Mr. Timothy W. Dunaway was Chief of the SSB, Dr. Jerrell R. Ballard was Chief of the CSED, and Dr. Robert M. Wallace was the Technical Director. The Deputy Director of ERDC-ITL was Ms. Patti S. Duett, and the Director was Dr. David A. Horner.

COL Ivan P. Beckman was the Commander of ERDC, and Dr. David W. Pittman was the Director.

1 Introduction

1.1 Background

The combination of shortsighted planning and Global Climate Change (GCC) has resulted in an imbalance in U.S. freshwater resources, (e.g., too much water in some regions and not enough in others). Better information on how GCC will affect different regions in the United States is needed to guide the U.S. Army in making effective decisions on how to properly adapt (e.g., impact how the U.S. Army accomplishes its mission). The Water Balance Model attempts to predict how the balance of freshwater resources is likely to shift as a result of GCC by calculating those shifts based on several climate scenarios for various Department of Defense (DoD) installations. The calculated water balance forecast is intended to be utilized in other force stationing analysis applications a Military Value Analysis (MVA) attribute.

1.2 Objective

This model makes use of a common computational environment and a user assistance application that were implemented as part of the Software Integration effort within the Integrated Climate Assessment for Army Enterprise Planning work package. The virtual environment will be referred to throughout this document as the Virtual Machine or VM, and the user assistance application will be referred to as the Wizard. For more information about the Software Integration effort, the virtual environment, and the user assistance application, refer to *Analytical Model Integration Methods* (Garton 2017).

Executing the model is a multi-step process that requires using Environmental Systems Research Institute (ESRI) ArcMap and Microsoft MS Excel® and MS Access® applications. Each step for viewing and building data sets is thoroughly documented in the following sections to limit user confusion and ensure accurate results.

1.3 Requirements

Software requirements for the Water Balance Model include ESRI ArcMap 10.3.1, MS Access® and MS Excel® version 2013 or higher, and an internet connection and internet browser.

A working knowledge of ArcMap and Microsoft Office products is recommended as well as a basic understanding of accessing websites and downloading files from the internet.

2 Viewing Computed Data

Pre-built dataset viewing is available to end users by accessing the model from within the Wizard application. The Wizard is accessible from the Integrated Climate Assessment for Army Enterprise Planning VM by clicking the shortcut located on the desktop (Figures 1–3).

Figure 1. Wizard application shortcut.

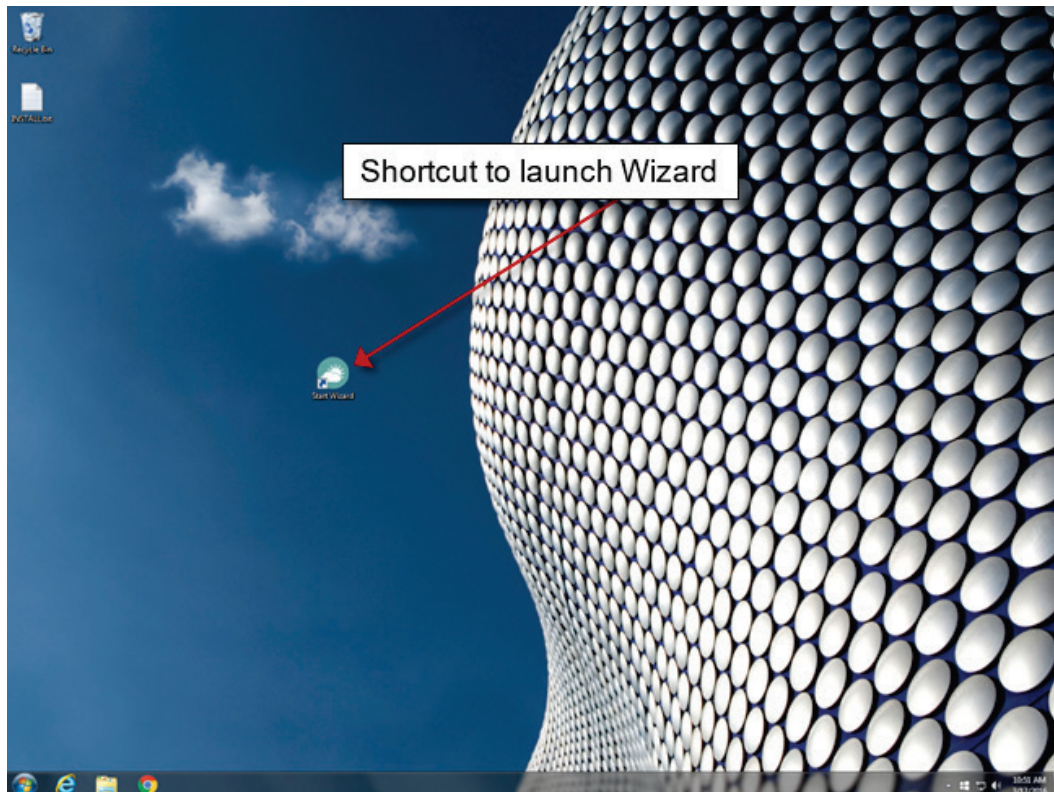


Figure 2. Water Balance Model icon.

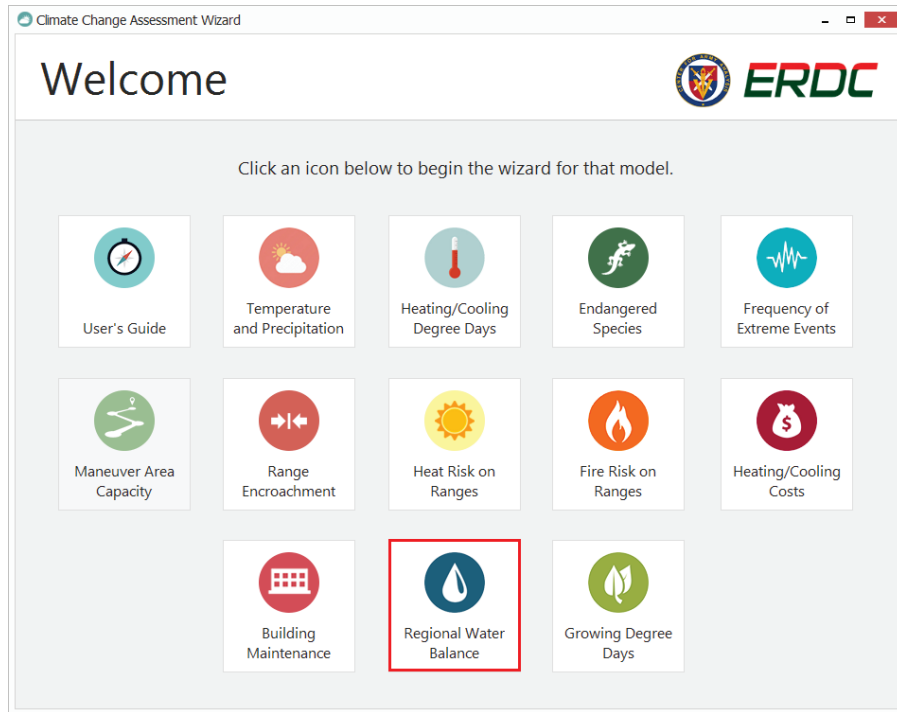
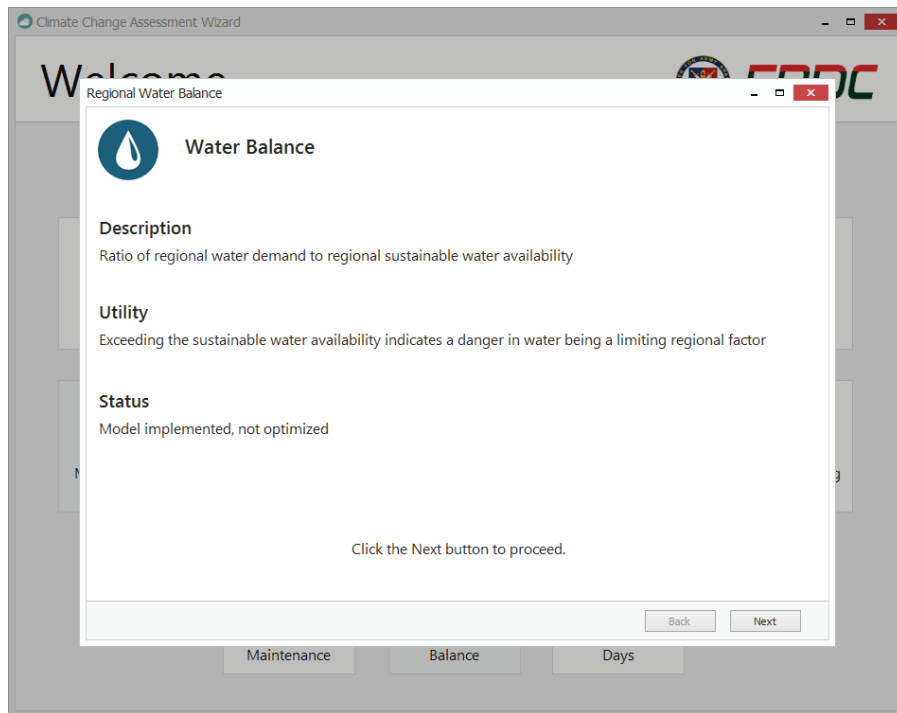
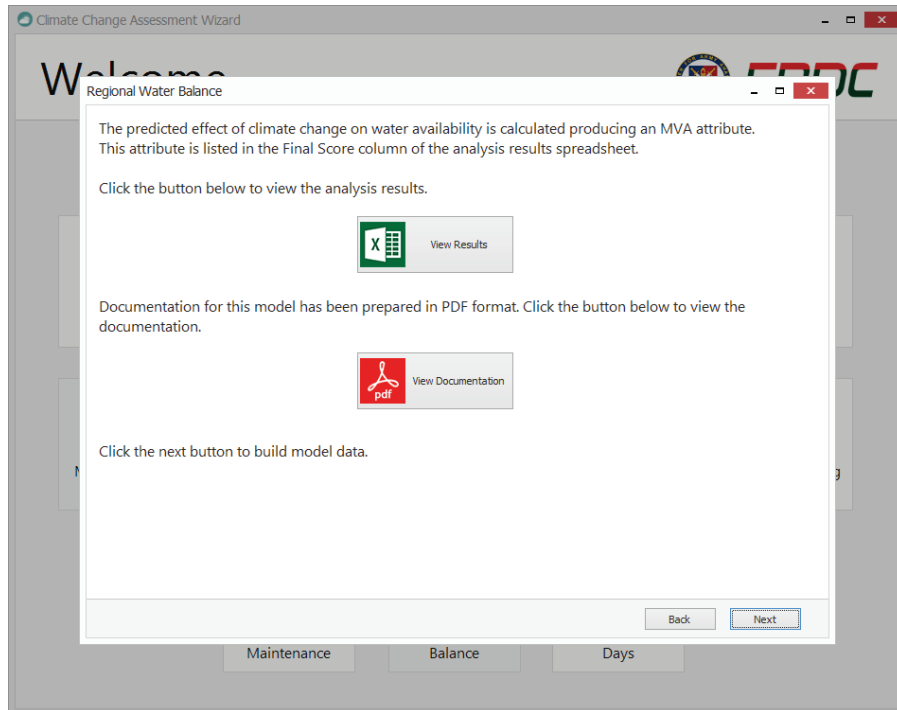


Figure 3. Water Balance Model first screen.



The second screen within the model (Figure 4) allows the end user to view the datasets in tabular mode. Use the View Results button on the second model screen to view the data in a table layout within an MS Excel® spreadsheet. This MS Excel® file is located within the VM at C:\Models\Water-Balance\TODO: PUT OUTPUT FILE HERE.

Figure 4. Water Balance Model second screen.

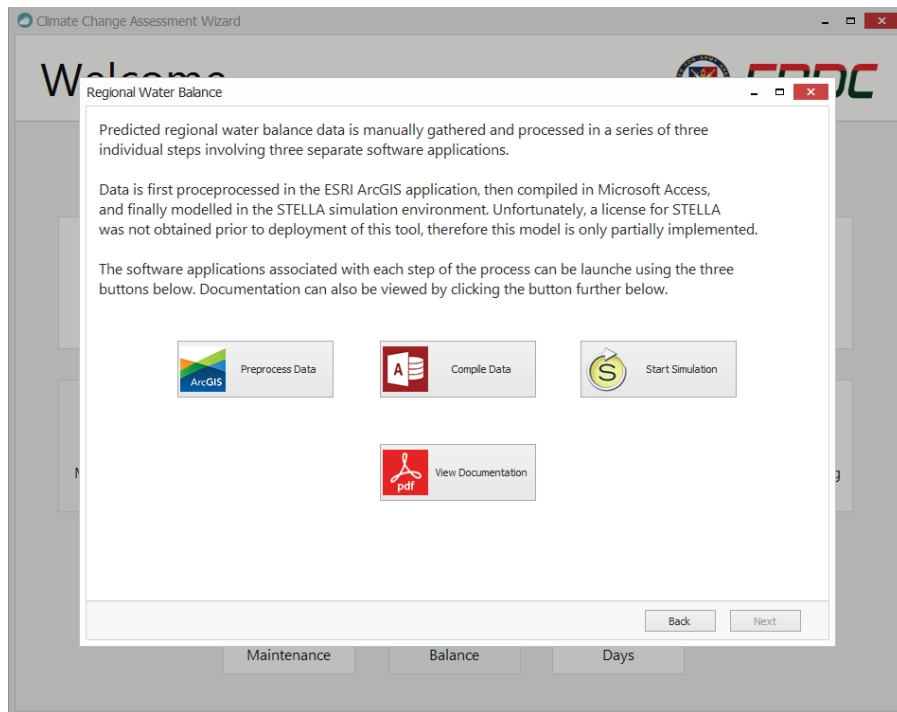


Each installation that was analyzed is assigned a final score rank indicating the amount of water stress an installation can expect to experience. Installations with lower scores are less likely to experience water stress as a result of GCC. The final score value may be used as an MVA attribute in other force stationing analysis applications.

3 Building New Data

The procedure for building new data consists of three steps utilizing three different data processing applications, each of which can be launched automatically from the final Water Balance Model screen. The following instructions should be followed carefully to produce new data from this model.

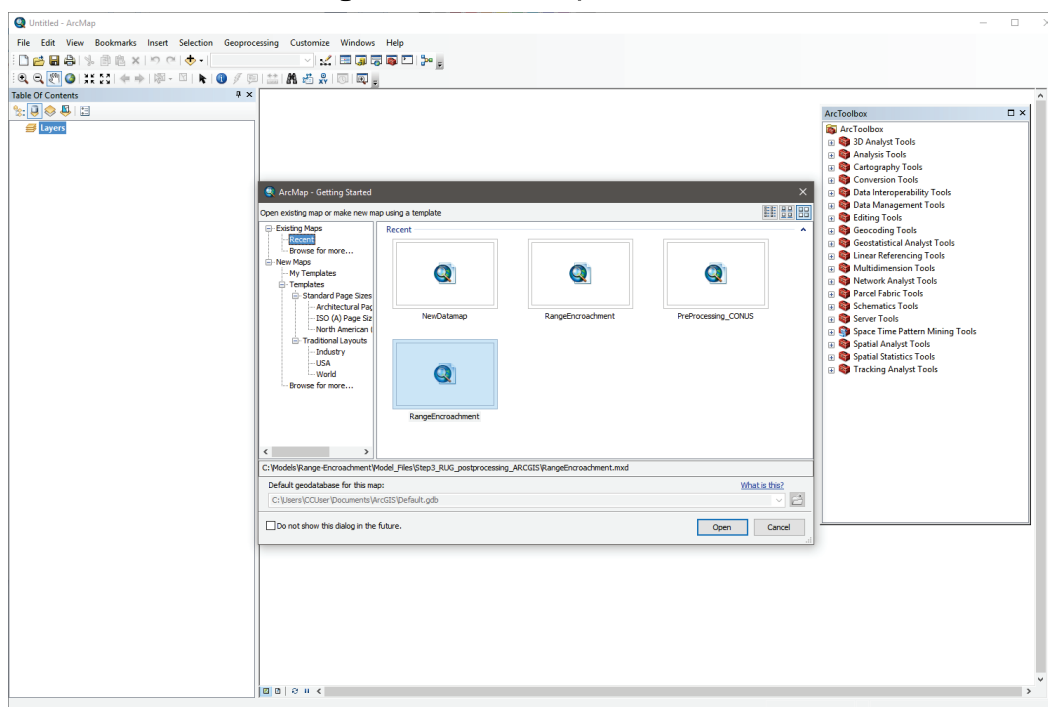
Figure 5. Water Balance Model file screen launch buttons.





First, raw input data must be preprocessed in ESRI ArcMap. These inputs, as described previously, were collected from various online resources which were not disclosed during the capturing of this model. Refer to Section 5 for more information on where and how to acquire these input data files.

Start the data preprocessing by launching ArcMap from the wizard by clicking the *Preprocess Data* button in the Wizard, or access it manually from the Windows start menu within the VM (Figure 6).

Figure 6. ESRI ArcMap start screen.



Open the NewDatamap model file located at `C:\Models\Water-Balance\Model Files\Step1_ArcGIS_Data_Prep\NewDatamap.mxd`. This model can also likely be opened from the list of recent models in ArcMap as shown in the Figure 6. Once the file loads, open the toolbox viewer by clicking the Toolbox menu bar icon . Add the WASP_Preparation toolbox by right clicking ArcToolbox at the top of the viewer then clicking Add Toolbox. The toolbox file is located at `C:\Models\Water-Balance\Model Files\Step1_ArcGIS_Data_Prep\WASP_Preparation.tbx`. Expand the newly added toolbox by clicking the plus sign to the left to show the models inside. Open the 1. Create Output .gdb model by right clicking it then choosing *Edit*. Inside the editor, click the Run menu bar icon . The model will prompt for a location to save the output geodatabase. Provide the output location `C:\Models\Water-Balance\Model Files\Step1_ArcGIS_Data_Prep folder\Output`, then click OK to create the geodatabase.

Next, exit the editor then edit the 2. WASP Data Preparation USE model. Choose the location of the Data Folder (`C:\Models\Water-Balance\Model Files\Step1_ArcGIS_Data_Prep\Data`). Click the Run icon within the editor to run the model. If the model fails to run, file links have most likely

been broken and further assistance will be required to continue. For additional assistance refer to Section 5.

Step two of the process is to compile the data in MS Access®. MS Access® can be launched automatically from last model screen by clicking the *Compile Data* button as illustrated previously, or access it manually from the Windows start menu within the VM. Open the database file

C:\Models\Water-Balance\Model

Files\Step2_Access_Database\112116_Access.accdb. Once the database is opened, confirm the following output files from ArcGIS are properly linked in the MS Access® database by refreshing them in the Linked Table Manager. If links are not correct, a prompt will request the path to the linked files. All linked files are located at C:\Models\Water-Balance\Model

Files\Step2_Access_Database\Access_Linked_Data.

Figure 7. Linked table manager menu button.

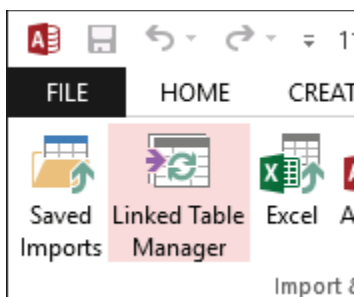
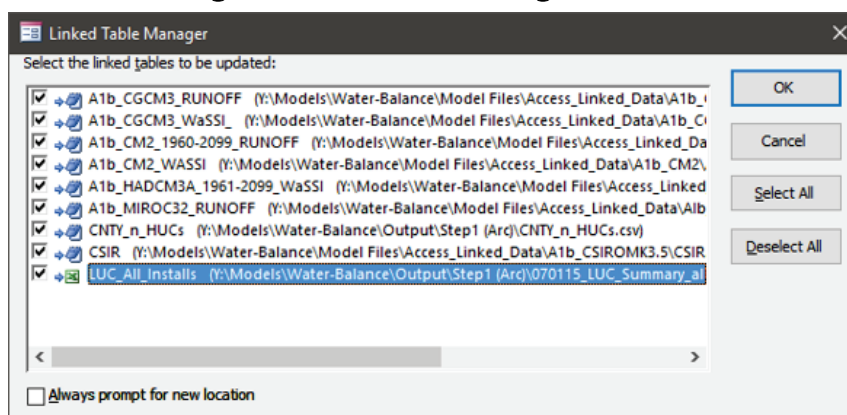


Figure 8. Linked table manager window.



Locate the *Queries* section of the *All Access Objects* panel on the left hand side of MS Access®. The o826_CNTY_Water_Use query contains a field used to identify a particular DoD location and must be modified for each installation by entering Design View. The *Fort* field criteria must be

changed to match one of the Fort names stored within the various tables. Available Fort locations at the time of this writing are Bliss, Bragg, Drum, Lewis, and Riley.

Figure 9. Query design view menu button.

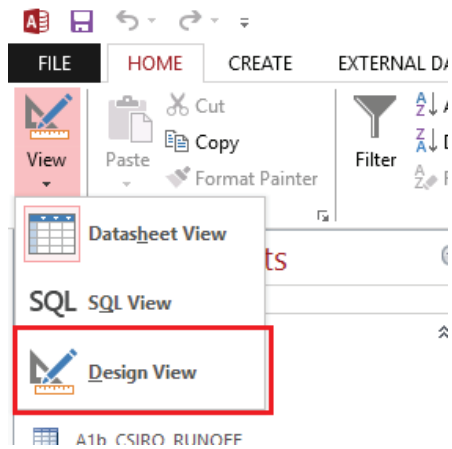


Figure 10. Modify the Fort field criteria.

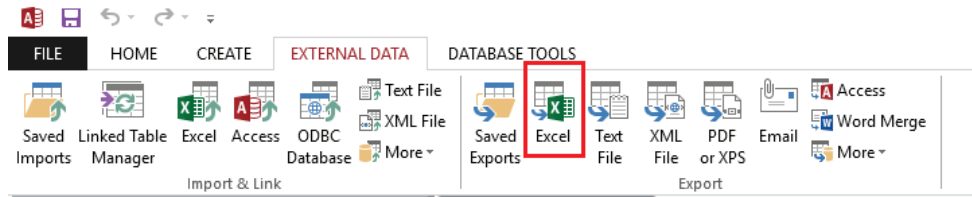
The screenshot shows the Microsoft Access interface. The 'Queries' list on the left includes '0826_CNTY_Water_Use' and 'ALL_A1b_Surface_CM2'. The main window displays a query design view for 'All_Return_Flow'. The design grid shows fields from 'CITY_n_HUCs' and 'All_Return_Flow'. The 'Criteria' row for the 'FORT' field is highlighted with a red box and contains the text 'Bragg'. The 'All_Return_Flow' table is also highlighted with a red box.

Field:	FORT	Ind SW: Sum(1120.14)	Ind GW: Sum(1120.14)	Crop GW 2010: Sum()	Crop SW 2010: Sum()	Live
Table:	CITY_n_HUCs					
Totals:		Expression	Expression	Expression	Expression	Exp
Group By:						
Sort:						
Show:	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Criteria:	"Bragg"					

Run the following list of queries one at a time for each of the installations by double clicking each of them in the *Queries* section, or by clicking the *Run* button in the top menu. The *Run* button contains a large red exclamation mark icon. Export the results from each query as an MS Excel® (.xlsx) file by using the MS Excel® Export menu button. Save the results in C:\Models\Water-Balance\Model Files\Output\Step2 (Access).

- o826_CNTY_Water_Use
- ALL_A1b_Surface_CGM3
- ALL_A1b_Surface_CM2
- ALL_A1b_Surface_CSIRO
- ALL_A1b_Surface_HADCM3
- ALL_A1b_Surface_MIROC32

Figure 11. Export query results to MS Excel®.



The exported MS Excel® files must be manually combined into a single MS Excel® file for each fort. Name the combined files with the name of the Fort (e.g., Bliss.xlsx). The following tabs must be included in the combined MS Excel® file:

- Precip_CGMC3
- Precip_CM2
- Precip_CSIROMK35
- Precip_HADCM2
- Precip_MIROC32
- RO_CGM3
- RO_CM2
- RO_CSIROMK35
- RO_HADCM3
- RO_MIROC32
- Month Demand
- Pop
- CNTY Water USE

The final step in the process is to run the data from MS Access® that is now stored in MS Excel® files through a Stella model. Stella can be launched automatically from last model screen by clicking the *Start Simulation* button as illustrated previously, or access it manually from the Windows start menu within the VM. Open the model file

C:\Models\Water-Balance\Model Files\Step3_Stella\0826_bragg_working_monthly.stmx. Once the file is opened, link (or refresh existing links) to the combined MS Excel® data in Stella. Each file has to be linked individually per Stella instance. In the Stella menu, go to Edit > Manage Persistent Links For each of the listed tables select *EDIT*. From there, use the *Edit Import Link* dialog box to browse and select the file for the desired installation.

Figure 12. Stella manage persistent links menu item.

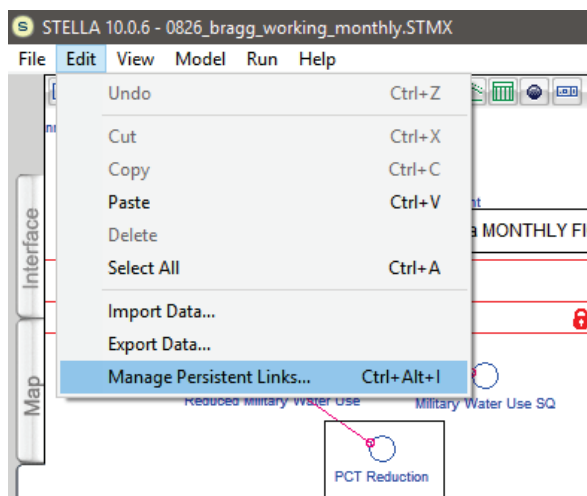
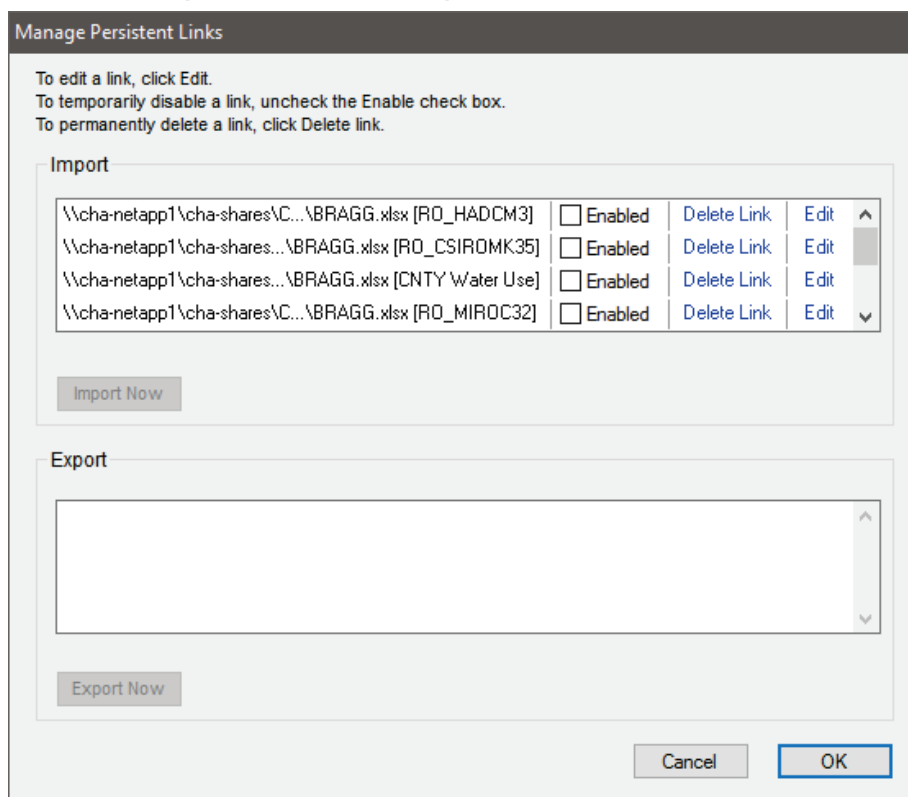


Figure 13. Stella manage persistent links window.



Once the links have been updated, run the model for each of the five SRES scenarios. This is done by unchecking the ENABLED box next to the SRES scenarios that are not being run. Go to Run > Run and the model will run.

After the model is done running, copy the water sustainment score from the table to a new MS Excel® file. The water sustainment score is a

withdrawal-to-availability ratio, which is the monthly water demand divided by monthly water supply, D/S . D/S values greater than 1 indicate that the demand is outstripping the sustainable supply.

The MVA attribute is calculated within the new MS Excel® file. Using formulas embedded within an MS Excel® Spread sheet, the indexed results were grouped into 5-year blocks from 2015–2100 to assess the minimum stress and the maximum stress. A range of the minimum-maximum and the absolute maximum numbers is obtained to better show the worst case scenarios that the five climate models project; for this reason, the analysis focuses on the maximum values. To simplify the analysis, it was assumed that the peaks can occur at any moment within the 5 years, although the value is graphed at the end of the period. To develop the MVA score, the data were weighted on two factors: stress and time levels.

1. **Stress Level:** The categorical rankings of no stress, low stress, moderate stress, and high stress were applied based on the ratio of D/S . Higher stress was given a higher value. Categorical rankings were selected rather than using the D/S ratio because these rankings account for some of the uncertainty present in model outputs, and because more complicated statistics would be required to parse out outliers in stress.
2. **Time:** Water stress values for the years 2015–2035 were given twice the weight of those from 2040–2100. This was done because the Center for Army Analysis (CAA) was primarily concerned with a 20-year Net Present Value (NPV). However, projections of the future should be included outside of that range because that will affect future installation capacity. The values for 2015–2035 range from zero (0) to 3 and are given according to the water stress category (a value of zero [0] when there is no stress to 3 when there is high stress). While the scores from 2040–2100 range from zero (0) to 1.5.

To obtain the final score for an installation, all of the values are summed and divided by the total possible score. The resulting ratio was then standardized on a scale of zero (0) to 10.

4 Known Issues and Limitations

Stella Professional has a known bug in version 10.0.6 where the application crashes when exiting, this this does not affect the processing or output data. The crash can be safely ignored.

5 Additional Help

Additional questions or concerns should be directed to the Program Manager of the Integrated Climate Assessment for Army Enterprise Planning program.

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Reference

Garton, B. M. 2019. *Analytical Model Software Integration Methods*. Technical Report on Integrated Climate Assessment for Army Enterprise Planning. ERDC/ITL SR-19-4. Vicksburg, MS: Engineer Research and Development Center, Information Technology Laboratory (ERDC-ITL).

Appendix A: Acronyms and Abbreviations

Term	Definition
CAA	Center for Army Analysis
CSED	Computational Science and Engineering Division
CSV	Comma Separated Values
DoD	Department of Defense
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center-Construction Engineering Research Laboratory
ERDC-ITL	Engineer Research and Development Center-Information Technology Laboratory
ESRI	Environmental Systems Research Institute
GCC	Global Climate Change
GCM	Global Circulation Model
MVA	Military Value Analysis
NPV	Net Present Value
NSN	National Supply Number
OMB	Office of Management and Budget
PM	Program Manager
SAR	Same As Report
SSB	Scientific Software Branch
VM	Virtual Machine

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