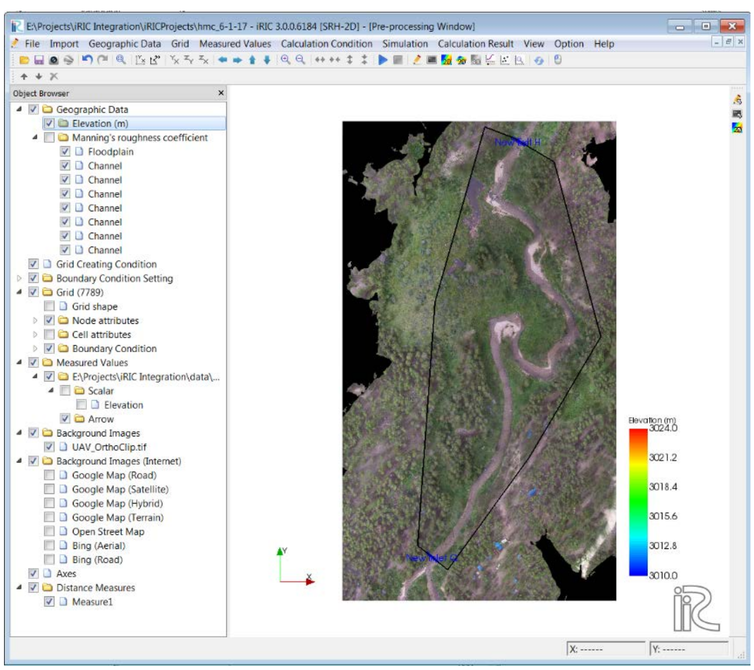
RECLAMATION

Managing Water in the West

Integrating the Sedimentation and River Hydraulics Model (SRH-2D) into the International River Interface Cooperative (iRIC) River Simulation Framework

Research and Development Office
Science and Technology Program
Scoping Proposal Report
ST-2017-1762-01
Technical Report No. SRH-2017-28



U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

July, 2017

Mission Statements

Protecting America's Great Outdoors and Powering Our Future

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

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SRH-2D is Reclamation's hydraulic and sediment transport model. The iRIC project is a collection of tools for preparing, executing, calibrating, and analyzing simulations of river hydraulics and sediment transport. I implemented an initial, limited integration of SRH-2D into iRIC as a “solver”, meaning that iRIC can be used to prepare, execute, and analyze SRH-2D river simulations. This initial work demonstrates the feasibility of using iRIC with SRH-2D, but additional work needs to be done to support a fuller suite of SRH-2D features.

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Contents

Tables

Figures

Figure 1. Screenshot of the definition.xml file used to specify the input requirements and options of a solver...7
Figure 2. A screenshot of an iRIC CGNS HDF5 file that contains the data for a SRH-2D simulation..8
Figure 3. A successful SRH-2D simulation running inside of the iRIC application.........10
Figure 4. The water depth output of an SRH-2D simulation displayed in iRIC................11

Executive Summary

Introduction

Reclamation uses software called the Sedimentation and River Hydraulics 2D (SRH-2D) [*Lai*, 2008] to model numerically river hydraulics and sediment transport. Among other things, these models are used to quantify aquatic habitat, evaluate proposed river restoration designs, identify areas of scour and fill, to predict changes to channel morphology, and to identify threats to streamside infrastructure.

Broadly speaking, there are three steps to creating a computer model of a river: 1) mesh creation, 2) model execution, and 3) analysis of results. The model mesh defines the model domain and discretizes the physical space represented by the model so that the differential equations describing the flow of water and sediment between mesh elements can be solved numerically. Reclamation currently uses a commercial product called SMS [*Aquaveo*, 2017] to develop the model mesh and to analyze the model results. iRIC is a free tool that could potentially replace SMS, which is not free. It includes tools for basic mesh generation, elevation and roughness assignment, and visualization and analysis of model results.

The iRIC project (http://i-ric.org/en/introduction) is a collaboration between the U.S. Geological Survey (USGS) and Hokkaido University to provide a collection of tools for preparing, executing, calibrating, and analyzing simulations of river hydraulics and sediment transport [*Nelson et al.*, 2010]. The actual simulations are performed by “solvers.” iRIC currently includes about ten solvers, but SRH-2D is not one of them. By incorporating SRH-2D into the modeling framework as a solver, Reclamation gains access to iRIC's model development and analysis tools while still retaining control over our flow and sediment transport code.

The USGS contacted Reclamation's Sedimentation and River Hydraulics group in 2016 to encourage us to modify SRH-2D so that it can be included with iRIC as a solver. The iRIC user community frequently requests that SRH-2D be included in the iRIC framework.

This scoping project investigated the steps necessary to integrate SRH-2D into iRIC as a solver. With the help of Richard McDonald at the USGS Geomorphology and Sediment Transport Laboratory (GSTL), an initial integration supporting the basic features of SRH-2D was completed successfully. Using iRIC, a user can create a simple SRH-2D model using an unstructured mesh with one inlet and one outlet, and steady discharge and water surface elevation boundary conditions. From within iRIC, the user can run the simulation, import the results, and analyze them using the tools provided by iRIC.

Research Outcome and Proposal of Future Work

There are two major tasks to adding a solver to iRIC. First, the iRIC user interface must be modified to include the specific options and inputs a particular solver supports, such as the types of model boundary conditions and input values. The second step is to modify the solver to read input data and write output in the Computational Fluid Dynamics General Notation System (CGNS) [*Poirier et al.*, 1998].

To add the user interface elements for the inputs required by the solver, a folder is created in the iRIC solvers directory. iRIC reads this folder at startup and looks for an XML definition file in each sub-folder. The definition file contains the path to the solver executable (a windows console application), defines the capabilities and requirements of the solver, and defines the iRIC user interface elements that collect the simulation data. The first few lines of the SRH-2D definition file are shown in Figure 1. I implemented user interface elements for all of the SRH-2D options supported by SMS 11.1. However, only a subset of these options are currently supported by the SRH-2D subroutine that reads the CGNS input file.

```
<?xml version="1.0" encoding="UTF-8"?>
<SolverDefinition
    xmlns="www.iric.net/SolverDefinition/1.0"
    name="SRH2D"
    caption="SRH-2D"
    version="3.0"
    copyright="USBR"
    release="2015.04.30"
    homepage="http://i-ric.org"
    executable="srh2d.exe"
    iterationtype="time"
    gridtype="unstructured2d"
>
    <CalculationCondition>
        <Tab name="Global" caption="Global">
            <Content>
                <Items>
                    <Item name="case_name" caption="Case Name">
                        <Definition conditionType="constant" valueType="string" />
                    </Item>

                    <Item name="mod_erosion" caption="Solver">
                        <Definition conditionType="constant" valueType="integer" option="true" default="0">
                            <Enumerations>
                                <Enumeration value="0" caption="Flow" />
                                <Enumeration value="1" caption="Morphological Analysis"/>
                            </Enumerations>
                        </Definition>
                    </Item>
```

Figure 1. Screenshot of the definition.xml file used to specify the input requirements and options of a solver.

iRIC stores the model mesh, boundary conditions, topography, flow resistance, and other model data and parameters in the CGNS format in a Hierarchical Data Format (HDF5) binary file [*The HDF Group*, 1997-2017]. The path to this file is passed to the solver console application as a command line argument. The bulk of the work in adding SRH-2D as a solver is writing subroutines to read and write this file format. The structure of the HDF5 file is shown in Figure 2.

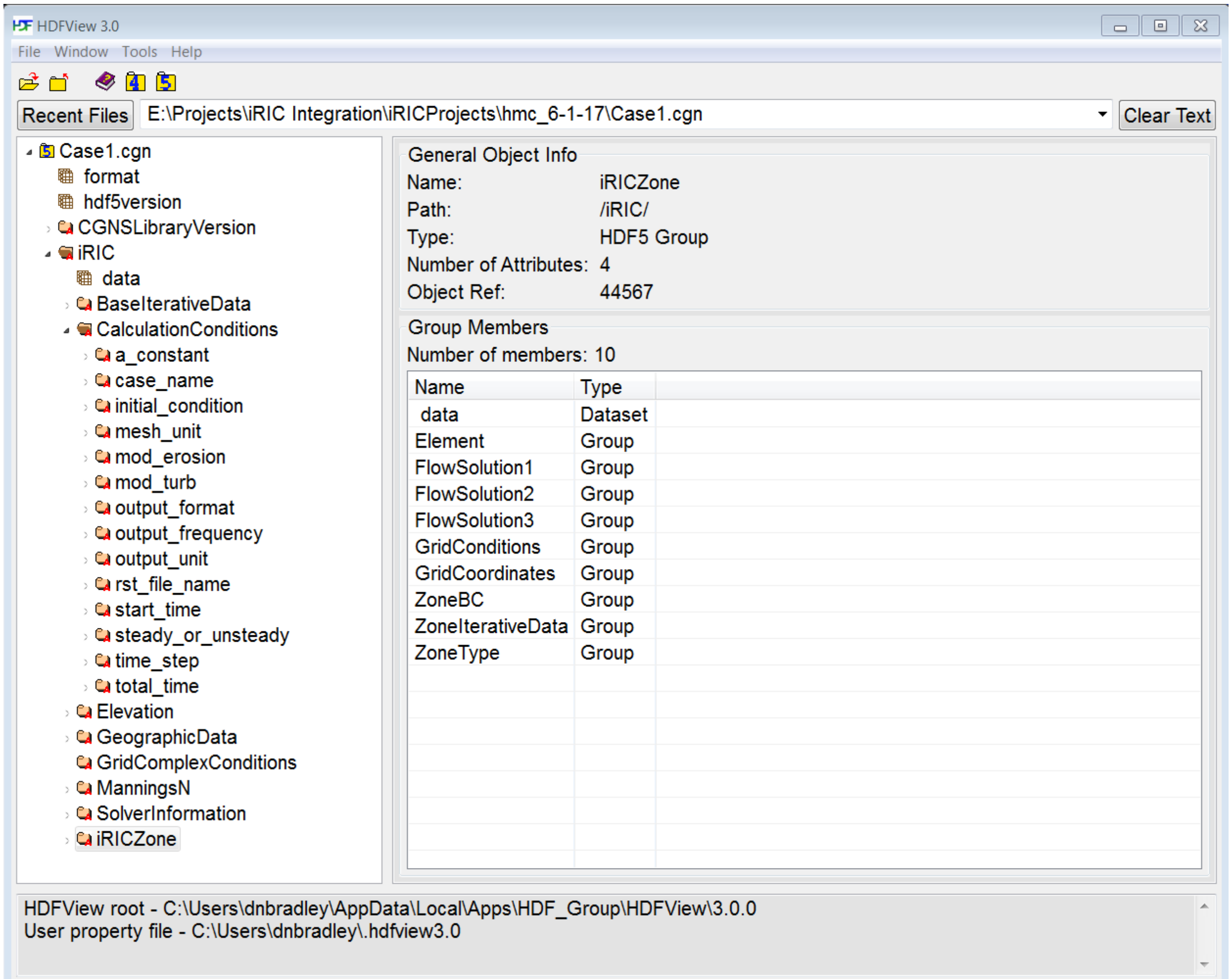

Figure 2. A screenshot of an iRIC CGNS HDF5 file that contains the data for a SRH-2D simulation.

SRH-2D has two subroutines to read input data. I replaced calls to the subroutines *read_input1()* and *read_input2()* with calls to two new subroutines, *read_input1_cgns*() and *read_input2_cgns()*. The structure and order of these new subroutines is very similar to the original structure, except that data is read from the HDF5 file using code that closely follows examples provided by the USGS.

When the SRH-2D model execution is complete, it writes the solution data to the HDF5 file. iRIC currently supports only node centered output, so I replaced calls to the SRH-2D subroutine *output_sms_vertex()* with *output_cgns_vertex()*. I also wrote code to write cell-centered output in the future. The code changes required to convert SRH-2D to an iRIC solver are summarized in

Table 1 and

Table 2. Five files defining 5 new subroutines were added to the SRH-2D source code. Sixteen lines of existing code in 5 files had to be modified. Two subroutines that generate plots displayed

during the simulation (uti_qwin_xyplot.f90 and uti_qwin_xyplot1.f90) had to be removed because the QuickWin library is incompatible with the iRIC console application requirement.

Table 1. Files added to SRH-2D.

Added	Replaces	Description
mod_cgns.f90		Defines variables used in reading CGNS file format.
output_cgns_cell.f90	output_sms.f90	Writes cell centered output
output_cgns_vertex.f90	output_sms_vertex.f90	Writes vertex centered output
read_input1_cgns	read_input1.f90	848 lines of code mostly copied from read_input1 and USGS code
read_input2_cgns	read_input2.f90	722 lines of code mostly copied from read_input2 and USGS code

Table 2. Modifications to SRH-2D files. Only 16 lines of code in 5 files had to be modified. Two files that generate plots displayed during the simulation (uti_qwin_xyplot.f90 and uti_qwin_xyplot1.f90) had to be removed because the QuickWin library is incompatible with the iRIC console application requirement.

Modified	Lines of Code	Description
mod_char.f90	Modified 1 line	Increased the allowed length of the paths to restart filename (init_fname) and the model grid name (grdnam)
mod_para.f90	Added 2 lines	Added file unit IDs for CGNS mesh definition files.
output_graphics.f90	Added 2 lines	Added calls to CGNS output subroutines
rwtape.f90	Modified 1 line	Increased the allowed length of the path to restart filename (fname)
srh-2d.f90	Added 1 lines	Calls read_input1_cgns instead of read_input1 Calls read_input2_cgns instead of read_input2

Modified	**Lines of Code**	**Description**
	Modified 9 lines	

The SRH-2D features currently supported allow a user to create a steady discharge simulation with one inlet and one outlet running on an unstructured triangular mesh. The boundary conditions supported are specified discharge at the model inlet and specified water surface elevation at the outlet. The initial condition of the model can be either dry or a SRH-2D restart file. Simulations are limited to SI units. Figure 3 shows a successful SRH-2D simulation running inside of iRIC. Figure 4 shows the water depth in an example SRH-2D simulation displayed inside of iRIC.

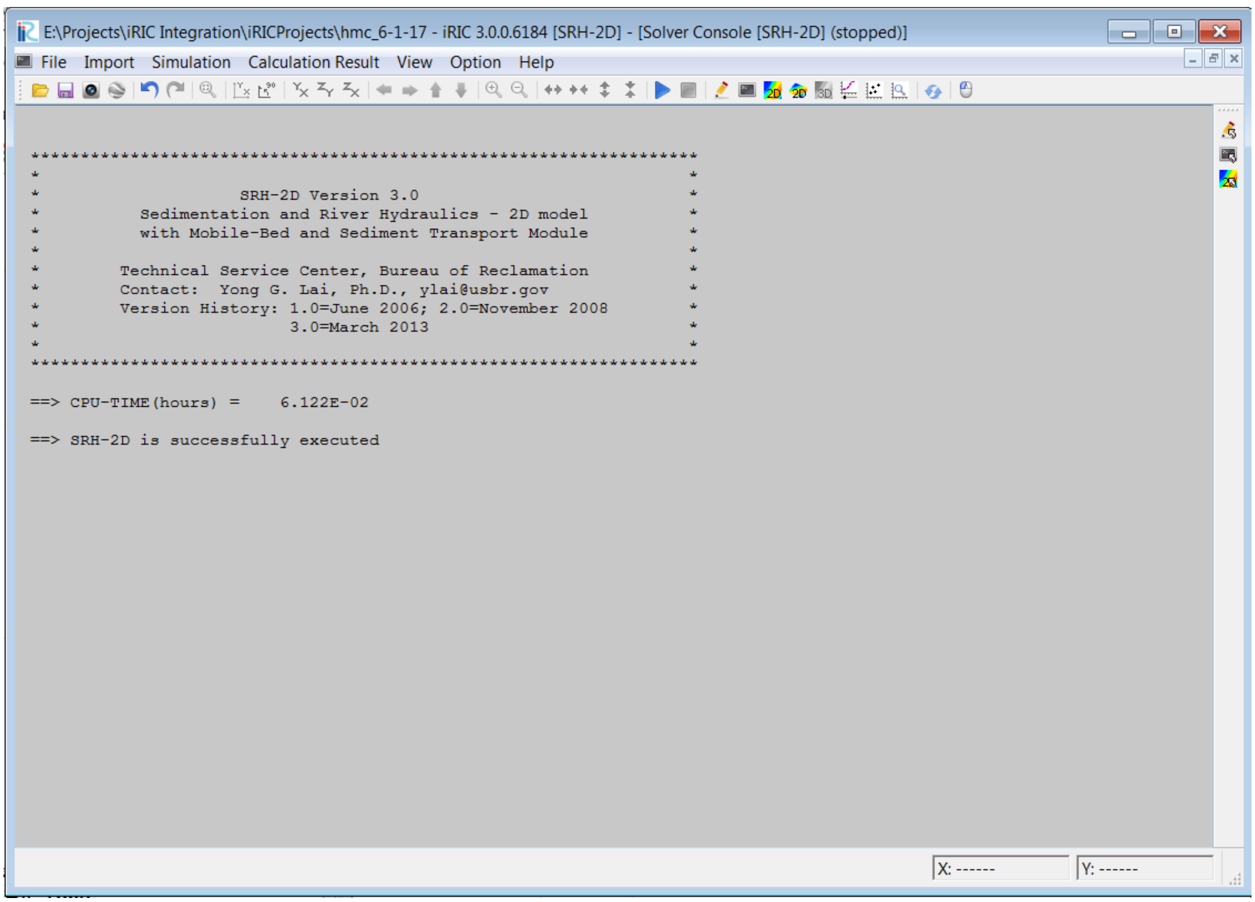

Figure 3. A successful SRH-2D simulation running inside of the iRIC application.

The current limited implementation of SRH-2D as an iRIC solver demonstrates that the two software packages are compatible and that the integration is straightforward. However, additional SRH-2D features need to be supported to perform useful river simulations with SRH-

2D and iRIC. These features include, but are not limited to, multiple model inlets and outlets (to simulate tributaries and water diversion), support for more types of boundary conditions, unsteady simulations, and sediment transport. Additional work on iRIC is currently under way to support composite meshes (a mix of rectangular and triangular elements preferred for SRH-2D simulations) and cell-centered output. I foresee no insurmountable technical problems to supporting a fuller range of SRH-2D features as an iRIC solver. The work involves adding additional iRIC user interface elements (by modifying the definition XML file) to collect model options and data and modifying the SRH-2D input subroutines (*read_input1_cgns()* and *read_input2_cgns()*) to read these data. A conducting proposal will be submitted for FY2018 to do this additional work. The USGS supports continued work on this project and will continue to provide technical support when needed.

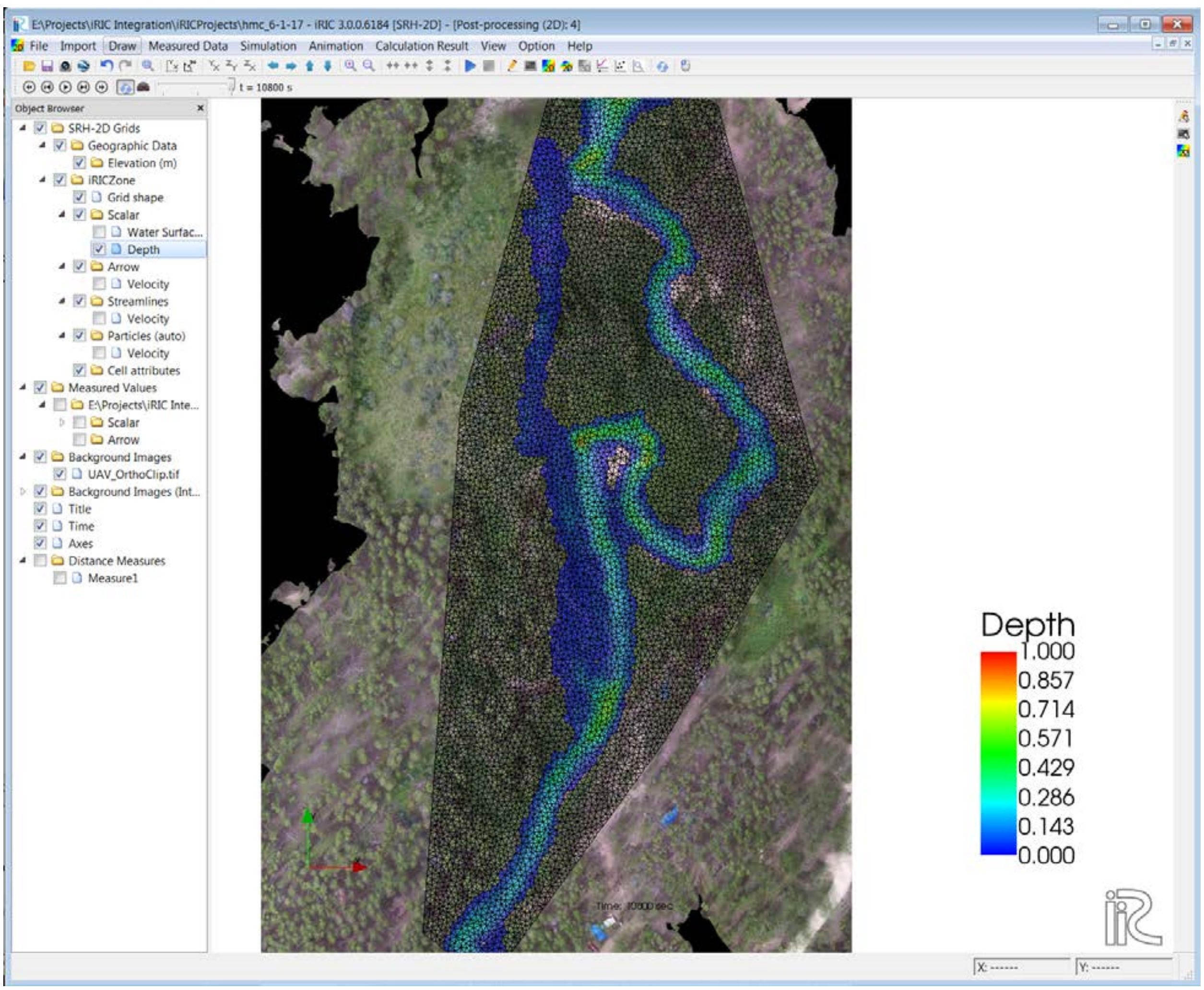

Figure 4. The water depth output of an SRH-2D simulation displayed in iRIC.

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