Design Reservoir Conceptual Data Model

Adel M. Abdallah, Graduate Student Assistant
Department of Civil and Environmental Engineering
Utah State University,
Logan, Utah, USA
amabdallah@aggiemail.usu.edu

CEE 6930 Hydroinformatics Final Term Project Paper, Dec. 13, 2012

Course instructors: Jeff Horsburgh & David Rosenberg

***Abstract*—In this project I developed and implemented a relational generic reservoir data model (RDM) that incorporates water reservoir input data for two water management models: Water Evaluation and Planning (WEAP) and the Reservoir Simulation model (HEC-ResSim).The RDM presents a new method to store and retrieve water reservoir input data into water management models that use different semantics, conceptualizations, and scales of data. The model is implemented within SQL Server database. Thus, the RDM helps in storing massive data of reservoirs and delivering it to water management models in an efficient and consistent manner.**

Keywords—water management; reservoir data model;WEAP, HEC-ResSim, relational database

I. INTRODUCTION

The increased challenge to manage our limited water resources in reservoirs among competing users requires ever updated, consistent, accessible, and well organized data and its associated metadata. Metadata is defined as the description of data that can help other people correctly understand and interpret the data. Water management requires detailed knowledge of the water supply and demand infrastructures and how they are connected. In addition, water management requires observational data about reservoir and canal inflows and releases and why these releases are being made. Water managers and researchers are faced by many problems in this regard i) available data about water supply and demand infrastructure is either held with city water mangers or operators on their computers or even verbally, ii) metadata that describes water releases for example is either non-existed or not accessible, iii) models are used to manage water resources at different scales like watershed, city, or reservoir and accordingly models require different levels of details of input data. Models also have different capabilities like flood management models and water supply and demand models. In addition, models use different time scales from hours to years. A result, it's a time-consuming process to collect, interpret, and populate water management data into water management models.

Wurbs [1] conducted a comparative evaluation study on the most commonly used generalized river/reservoir system models where he stated models capabilities, programming aspects, and limitations. The study reviewed dozens of models developed by Army Corp of Engineers, the U.S. Bureau of Reclamation, local agencies and international organizations. Although these reviewed models have a general similar approach, but the study concluded that models differ significantly in their overall organizational structure and data management mechanisms.

To help couple different water and environmental models, the OpenMI model [2] defines, describes, and transfers data between these models simultaneously. However, the OpenMI approach still requires data input at least for one model with its required format and details. The Observational Data Model [3] presents a relational database for point environmental observations that can store and retrieve observational data with its associated metadata. The Arc Hydro Groundwater [4] data model describes ground water information in terms of raw field data and conceptual representations of the primary features in a hydrogeological system. This allows the data model to be used as a tool for archiving and sharing groundwater data for a wide variety of applications.

To understand the data requirements water management models, here, I focus on two models that are widely used within worldwide water management community. Keep in mind, these two models do not represent all the water management models but they are used here as an example with future work to extend to different models. The first model is the Water Evaluation and Planning System (WEAP) which is developed by the Stockholm Environment Institute [5]. WEAP is widely used to model urban, agricultural, and industrial water demand. the model simulates water demand, supply, flows, and storage, and pollution generation, treatment and discharge. The model also evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems. The second model is the Reservoir Simulation model (HEC-ResSim) developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers [6] and widely used to model reservoir simulations. The HEC-ResSim model helps test and recommend reservoir release policies and operations to meet current and future water demands while meeting downstream regulations like minimum environmental flows.

In general, WEAP requires model input data on the supply and demand sides while HEC-ResSim requires more data on the supply side as of reservoirs. Therefore, to deliver water management data for these two models, we need a generic data model that stores and delivers data for both models.

There is a need for water resources management community of water managers and researchers for consistent, integrated, and descriptive new method to discover, store, organize, transform, and retrieve water management data and its associated metadata so it can be easily utilized to better allocate the limited water resources. In fact to meet these needs, a water management data model (WMDM) is being developed as part of a multi-institutional research project called CI-Water "cyber-infrastructure to advance high performance water resource modeling". In this project, I present a conceptual data model for water management data with specific focus on water reservoirs data. The reservoir data model (RDM) design identifies the entities, attributes, and relationships required to represent reservoir data. The RDM also provides data that describe the reservoir physical characteristics like reservoir pool elevation-area-volume curves and operational characteristics like reservoir zones. In the paper I describe the features and of the RDM and discus its implementation within SQL Server database.

I. METHODS

This section describes the methods I used to develop the RDM. First, I defined the overall WMDM capabilities. Then I reconstructed WEAP and HEC-ResSim data models, and developed a conceptual model for the RDM. Finally I designed the data model and implemented reservoir data instances.

A. Define Water Management Data Model Capabilities

The anticipated water management model shall be used to read water management data from files created by stakeholders, existing models output, and online published data. The model should transform and store all these sources of data. Then, the model can be used to retrieve and transform the stored data to specific formats to be readily to use in a variety of water management models like WEAP and HEC-ResSim (Figure 1).

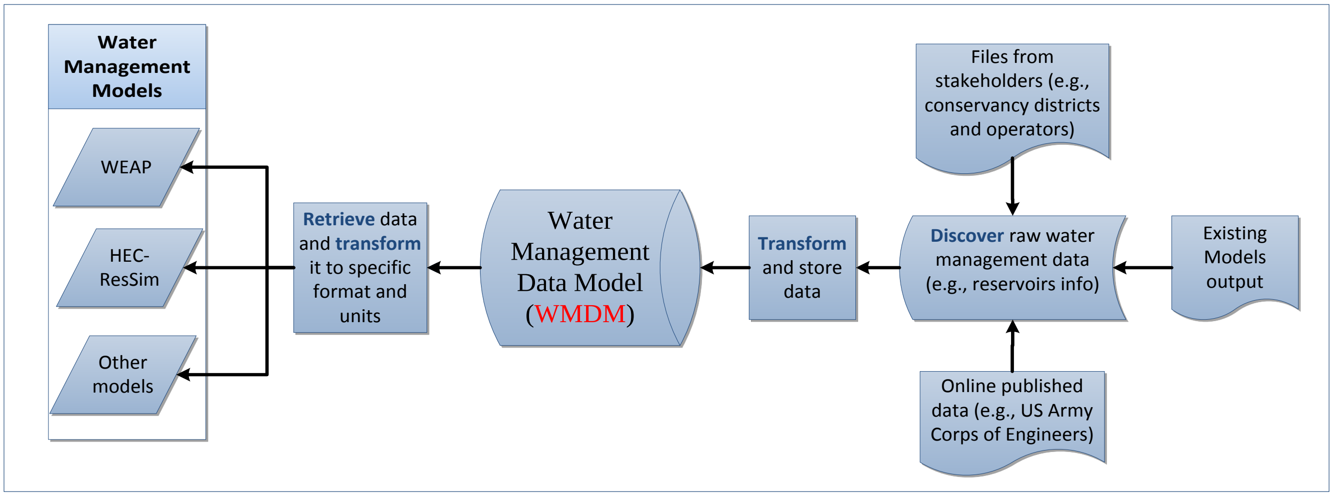

Figure 1: Conceptual diagram of the Water Management Data Model capabilities

B. *Reconstruct WEAP and HEC-ResSim Data Models*

In this step, I studied the spatial and temporal data requirement of WEAP and HEC-ResSim models to help design a generic RDM that will incorporate these types of data. I used Microsoft Visio to draw a relational database model for both models using entities and attributes to describe each model's data requirements.

In comparing both WEAP and Hec-ResSim data models, the models use different semantics that mean the same thing. For example, WEAP uses "loss to groundwater" while HEC-ResSim uses seepage to descibe the same thing.

C. *Develop Conceptual Reservoir Data Model (RDM)*

The Reservoir Data Model represents data and metadata that describe reservoir spatial locations and temporal characteristics like monthly or seasonal changes in reservoir zone target level. Reservoir physical variables can include paired values of variables up to three variables at a time like in representing the reservoir pool elevation-volume-surface area. The ResDataValue table stores numieric values of the reservoir variavles and links (foreign keys) to all the data values attributes. The RDM incorporates the reservoir data requirements for both WEAP and HEC-ResSim. Since each model requires different level of data details, the RDM includes a union of their data requirements. For example, in defining reservoir operation zones, WEAP requires storage while Hec-ResSim requires elevation for monthly or yearly time series data. Therefore, I incorporated storage and elevation entities for defining zones where whichever data is available can populate the corresponding entity. Another example, in representing the reservoir pool elevation-volume-surface area, WEAP requires elevation and storage only while Hec-ResSim requires elevation, storage, and surface area. So the RDM can host the three variables and can deliver either two or three depending on the intended model requirement (Table1 and Figure 2).

TABLE I. RESERVOIR DATA MODEL ATTRIBUTES ASSOCIATED WITH PHYSICAL RESERVOIR DATA

Attribute	Definition
VariableName	The name of the physical quantity that the value represents (e.g., elevation, flowrate, volume, area, evaporation, seepage, leakage)
DataValue	The value for a particular variable of the reservoir
ReservoirName	With other attributes in the same entity, they represent metadata that describes the reservoir
ZoneName	Present the reservoir pool virtual zones described by water elevation or water volume which used by managers to allocate the reservoir stored water
Source	Represent the metadata that describes the data sources
Unit	Represent the units for each variable and value in the reservoir
ResOperation	Describes the reservoir operation method

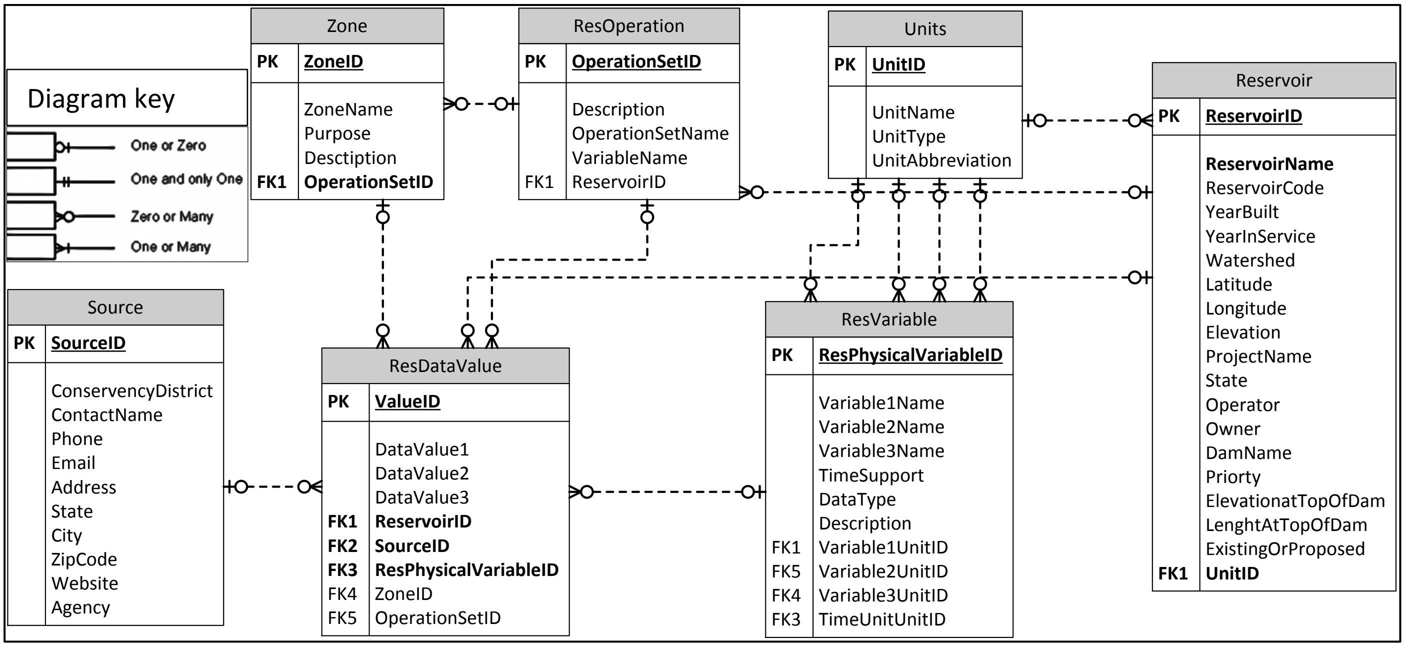

Figure 2: Reservoir Data Model (RDM) conceptual model. Primary key field is represented with (PK) and the foreign key is represented with (FK). The Cardinality of relations is represented with Crow's Foot notation in the diagram key.

D. *Design the RDM and Implement Data Instances*

To implement the RDM within a relational database management system, I used the add-in tool called "Forward Engineer" [7] to create the SQL code that generates the data model entities, attributes, and relationships within a Microsoft SQL Server database. The add-in tool also validates the model in meeting relational database requirements of defined entities, attributes, primary keys, foreign keys, and cardinality of relations. Then, I executed the SQL code within SQL Server to create a physical implementation of the RDM into which I could load reservoir data and make it readily available to store and query data through it. I imported reservoir data for the Lower Bear River system, UT. Reservoir data mainly include reservoir elevation-volume-area curves.

II. RESULTS

Figure 3 shows excerpts from tables illustrating the population of RDM with reservoirs elevation-volume-area curve for the Lower Bear River reservoir system, UT. For example, using SQL commands, we can query reservoir elevation-volume for WEAP model and reservoir elevation-volume-area for HEC-ResSim model. Although, this process sounds easy and can be done manually, it can be very cumbersome to do for dozens of reservoir system in one watershed. Therefore, the RDM can help process and transform reservoir data for the two models in an automated fashion in a systematic and efficient way.

ResVariables Tables

	ResPhysicalVariableID	Variable1Name	Variable2Name	Variable3Name
1	1	Elevation	Volume	Area
2	2	Elevation	Seepage	NULL
3	3	Elevation	Volume	NULL
4	4	Evaportation	NULL	NULL

Source Table

	SourceID	ContactName
1	1	DavidRos
2	2	ADEL

Reservoir Table

	ReservoirID	ReservoirName
1	1	Hyrum
2	2	Above Cutler Dam
3	3	Barrens
4	4	Cub River Dam

Zone Table

	ZoneID	ZoneName	OperationsetID
1	1	Inactive	1
2	2	Conservation	1
3	3	Flood	1
4	4	Surcharge	1

ResOperation Table

	OperationSetID	OperationsetNAme
1	1	WaterSupply
2	2	FloodControl

ResDataValue Table

ValueID	DataValue1	DataValue2	DataValue3	ReservoirID	SourceID	ResPhysicalVari...	OperationSetID
5	4630.00	205.00	3456.00	1	1	1	1
6	4640.00	291.00	5937.00	1	1	1	1
7	4650.00	367.00	9236.00	1	1	1	1
8	4660.00	427.00	13206.00	1	1	1	1
9	4670.00	473.00	17721.00	1	1	1	1
10	4672.00	479.00	18684.00	1	1	1	1
11	4680.00	516.00	22600.00	1	1	1	1
12	4690.00	572.00	28100.00	1	1	1	1
13	4700.00	629.00	34100.00	1	1	1	1
14	4710.00	692.00	40700.00	1	1	1	1
15	4720.00	757.00	47900.00	1	1	1	1
16	4730.00	826.00	55800.00	1	1	1	1
17	4740.00	900.00	64500.00	1	1	1	1
18	4750.00	976.00	73900.00	1	1	1	1
19	4410.00	0.00	0.00	2	1	1	1
20	4415.00	1028.00	1786.00	2	1	1	1
21	4420.00	1889.00	9259.00	2	1	1	1
22	4425.00	3293.00	21723.00	2	1	1	1
23	4430.00	4703.00	41367.00	2	1	1	1
24	4432.00	5236.00	51342.00	2	1	1	1
25	4407.00	0.00	0.00	3	1	1	1
26	4410.00	868.00	1313.00	3	1	1	1
27	4415.00	3194.00	11468.00	3	1	1	1
28	4420.00	4792.00	31433.00	3	1	1	1

Figure 3: Excerpts from tables illustrating the population of RDM with reservoirs elevation-volume-area curve

III. CONCLUSIONS

Water management models use different semantics, conceptualizations, and scales of data. The developed reservoir data model incorporates reservoir data for WEAP and HEC-ResSim models. The RDM can store and deleiver reservoir data systematicly and effeciencly for many reservoirs to many models while keeping enough description of the data to be interpreted by others. Also the RDM can be accessed by many users. Finally, the reservoir Data model is to be extended for other water mamagemnt models and to include other aspects of management.

REFERENCES

[1] Wurbs, R. A., United States. Army. Corps of Engineers. Fort Worth, D., and Texas Water Resources, I. (2005). *Comparative evaluation of generalized river/reservoir system models*, Texas Water Resources Institute, College Station, TX.

[2] Gregersen, J. B., Gijsbers, P. J. A., and Westen, S. J. P. (2007). "OpenMI: Open modelling interface." *JOURNAL OF HYDROINFORMATICS*, 9(3), 175-192.

[3] Horsburgh, J. S., D. G. Tarboton, D. R. Maidment, and I. Zaslavsky (2008), A relational model for environmental and water resources DATA, Water Resour. Res., 44, W05406, doi:10.1029/2007WR00639

[4] Strassberg, G., Jones, N. L., and Maidment, D. R. (2011). *Arc hydro groundwater : GIS for hydrogeology*, ESRI Press, Redlands, Calif.

[5] Stockholm Environment Institute. 2012. Water Evaluation And Planning (WEAP) version 3.3001. http://www.weap21.org/

[6] Hydrologic Engineering Center of the US Army Corps of Engineers. 2007. Reservoir System Simulation (HEC-ResSim), version 3.0a. http://www.hec.usace.army.mil/software/hec-ressim/

[7] Ferrari, A. 2011. Visio Forward Engineer Addin, version 1.0.6. http://forwardengineer.codeplex.com/