Confined vs. Unconfined Aquifer Representation

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DESIGN DOCUMENTS

Design documents are a series of technical papers addressing specific design topics on the Eastern Snake Plain Aquifer Model Enhancement. Each design document will contain the following information: topic of the design document, how that topic fits into the whole project, which design alternatives were considered and which design alternative is proposed. In draft form, design documents are used to present proposed designs to reviewers. Reviewers are encouraged to submit suggested alternatives and comments to the design document. Reviewers include all members of the Eastern Snake Hydrologic Modeling (ESHM) Committee as well as selected experts outside of the committee. The design document author will consider all suggestions from reviewers, update the draft design document, and submit the design document to the SRPAM Model Upgrade Program Manager. The Program Manager will make a final decision regarding the technical design of the described component. The author will modify the design document and publish the document in its final form in .pdf format on the SRPAM Model Upgrade web site.

The goal of a draft design document is to allow all of the technical groups that are interested in the design of the SRPAM Model Upgrade to voice opinions on the upgrade design. The final design document serves the purpose of documenting the final design decision. Once the final design document has been published for a specific topic, that topic will no longer be open for reviewer comment. Many of the topics addressed in design documents are subjective in nature. It is acknowledged that some design decisions will be controversial. The goal of the Program Manager and the modeling team is to deliver a well-documented, defensible model that is as technically representative of the physical system as possible, given the practical constraints of time, funding and manpower. Through the mechanism of design documents, complicated design decisions will be finalized and documented.

Final model documentation will include all of the design documents, edited to ensure that the “as-built” condition is appropriately represented.

Introduction

This document discusses whether the Eastern Snake Plain Aquifer will be represented as a confined or an unconfined aquifer. The decision to use state-of-the-art parameter estimation techniques makes this decision more difficult.

Problem Statement

The existing IDWR/UI aquifer model (Cosgrove et al, 1999) uses an unconfined representation for the Eastern Snake Plain Aquifer and Garabedian (1992) employed an unconfined representation also. Thus, a choice of an unconfined representation for the Eastern Snake Plain Aquifer would be consistent with tradition. However, a confined aquifer model representation requires fewer computations and behaves more stable numerically than an unconfined aquifer representation. These two factors present significant advantages when using parameter optimization tools that run the model thousands of times to select a parameter suite that minimizes the differences between observations and modeled values.

Considered Options

The considered options for aquifer representation include:

1. An unconfined representation. This representation allows aquifer thickness, and thus transmissivity, to vary with head change.
2. A confined representation. This representation holds aquifer thickness, and thus transmissivity, constant.

Effect

This section explores and explains the various considered options and attempts to predict the effects of the underlying assumptions.

Unconfined representation

The traditional aquifer representation employed by Cosgrove et al (1999) and Garabedian (1992) is unconfined. Although the aquifer may behave confined locally, on a regional scale it behaves unconfined. Thus, an unconfined representation should meet with little technical resistance. The primary difficulty lies with the parameter estimation process because unconfined models can present stability problems.

Stability problems impact the parameter estimation process by causing runs to fail or not readily converge to a solution. During the course of the parameter optimization process PEST tries numerous parameter combinations. If one of these combinations allows a MODFLOW (McDonald, and Harbaugh, 1988) cell for which there is a corresponding field observation to go dry, the optimization process fails. If a MODFLOW cell goes dry for which there is no corresponding field observation, the optimization process does not fail, but produces an unrepresentative flow field. If this new flow field matches the observations well enough, PEST will select it and present the user with an unacceptable parameterization.

Confined representation

In MODFLOW, a confined representation means that transmissivity does not vary with head change. Unconfined aquifer storage values (specific yield) would still be used. Thus, a confined representation poses no difficulty provided that head changes remain small with respect to aquifer thickness. Cosgrove (2001) could not make the previous IDWR/UI model behave in a non-linear fashion, implying that a confined representation is reasonable.

To evaluate the extent of head change with respect to aquifer thickness several wells with a significant time series were evaluated. Well 07N34E-04CDC1, in the Mud Lake area (Figure 1) where water level change maps indicate the maximum head differential, shows a 25 to 30 ft annual fluctuation. However the aquifer is about 1250 ft thick (Wylie, 2003), so this represents only a 2.5% change in aquifer thickness. Well

05S17E-26ACA1 in the southern portion of the aquifer (Figure 2), were the aquifer thins to about 770 ft thick (Wylie, 2003), shows an annual function of about 10 ft, but has an overall water level change of about 60 ft during the time-frame of the model. The 60 ft variation in aquifer thickness represents an overall change of about 8%. Well 06S31E-16BAB1 near American Falls Reservoir (Figure 3), where the assumed aquifer thickness is about 875 ft (Wylie, 2003), shows an annual fluctuation of about two ft with a maximum head change of about eight ft. The eight ft maximum change represents a one percent change in aquifer thickness. This analysis suggests that inaccuracies in the transmissivity distribution due to a confined assumption will be, at a maximum ±4%. We are asking the model to match both head and flux in the aquifer, so the model will partition the ±4% inaccuracies between both head and flux.

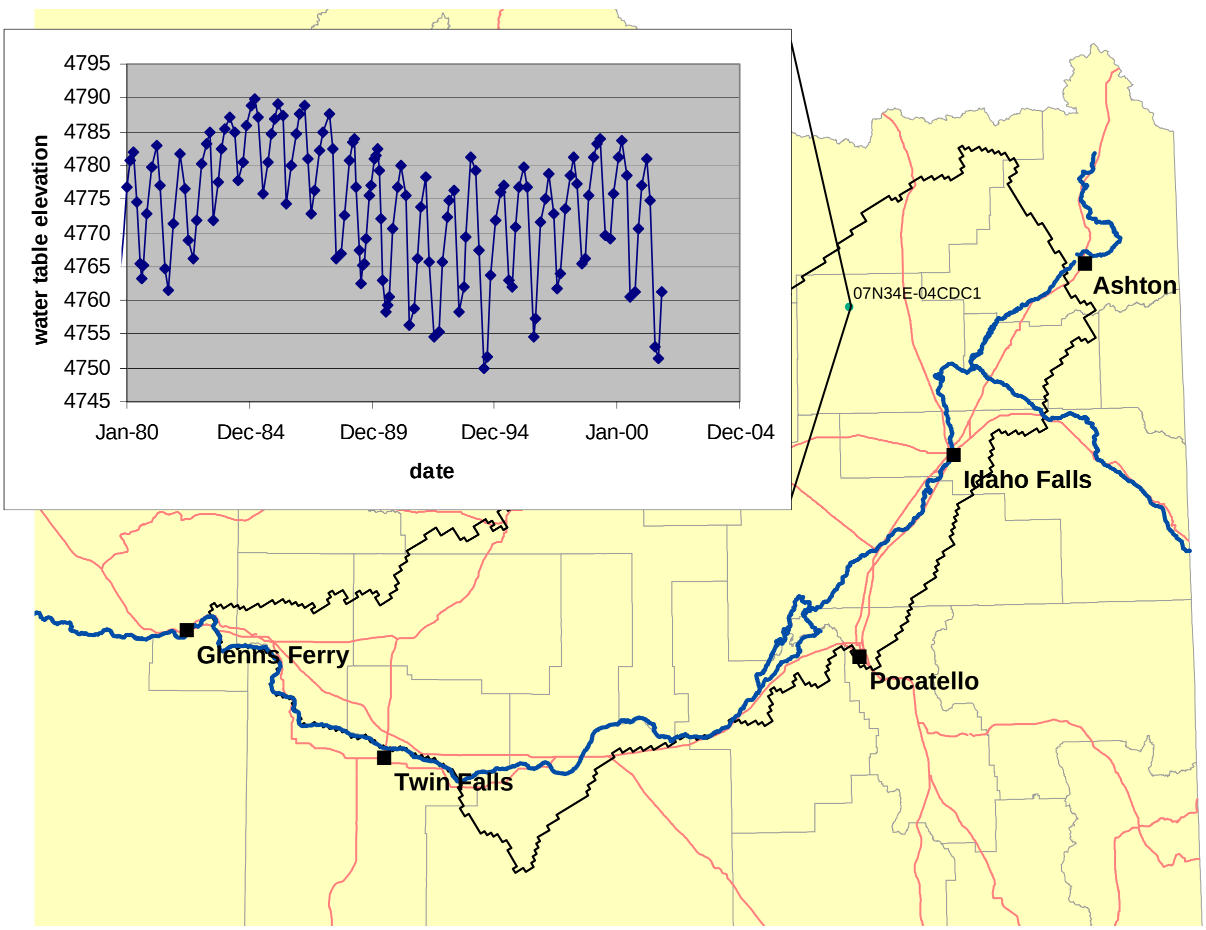

Figure 1. Hydrograph of a well near Mud Lake.

The available evidence suggests that a confined representation will probably behave similar (within ± 4%) to an unconfined representation for the Eastern Snake Plain Aquifer. Furthermore, stable MODFLOW behavior, will enable rigorous calibration and predictive analysis exercises (Watermark Numerical Computing, 2000). More stable model behavior will yield more predictive accuracy, and the ability to quantify the bounds on uncertainty. These gains far outweigh the ±4% (maximum) losses in precision incurred by the transmissivity approximation.

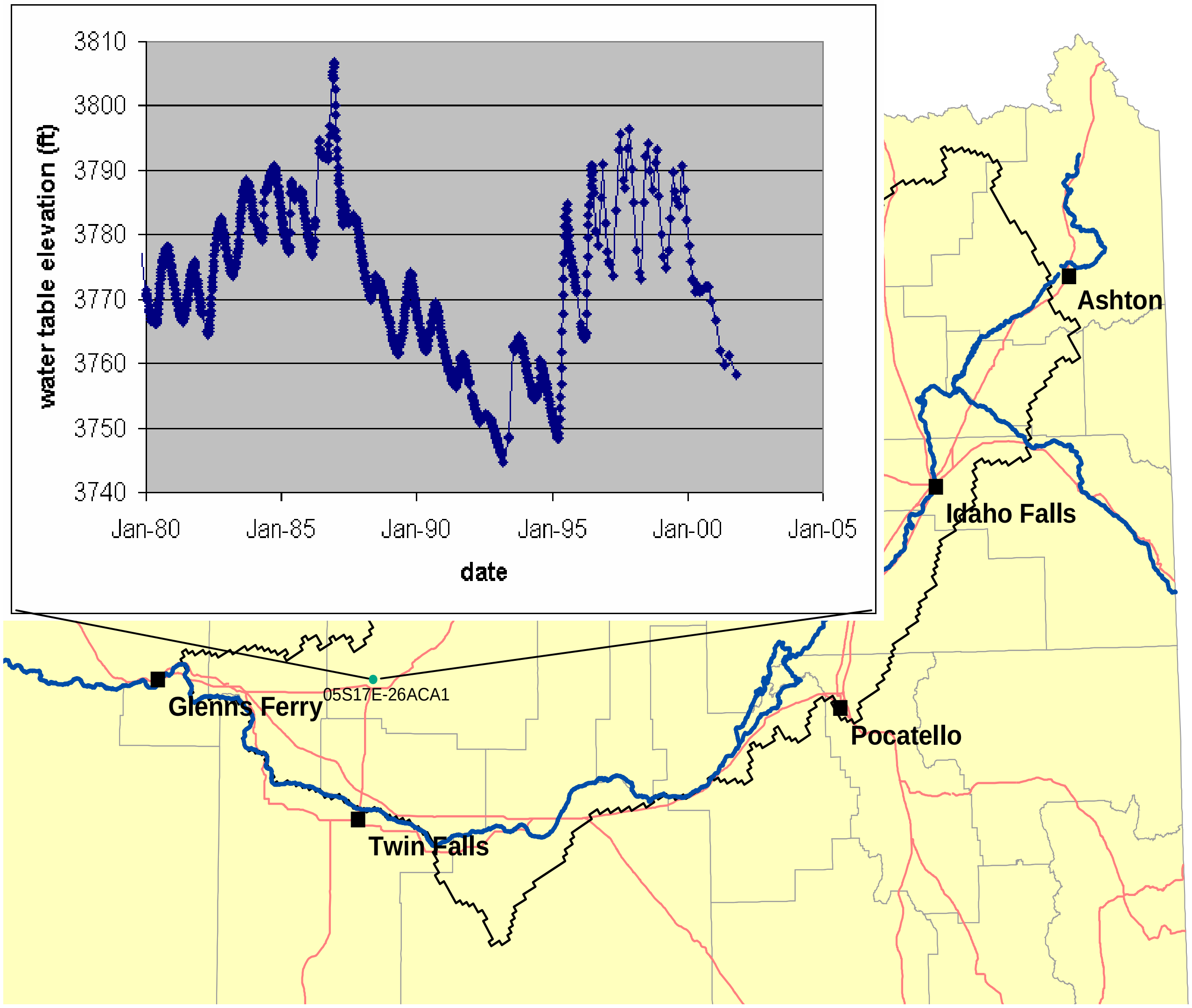

Figure 2. Hydrograph of well near Glenns Ferry, Idaho.

Design Decision

The Eastern Snake Plain Aquifer will be represented as a confined aquifer during the parameter estimation process and may be converted to an unconfined model for later use by IDWR.

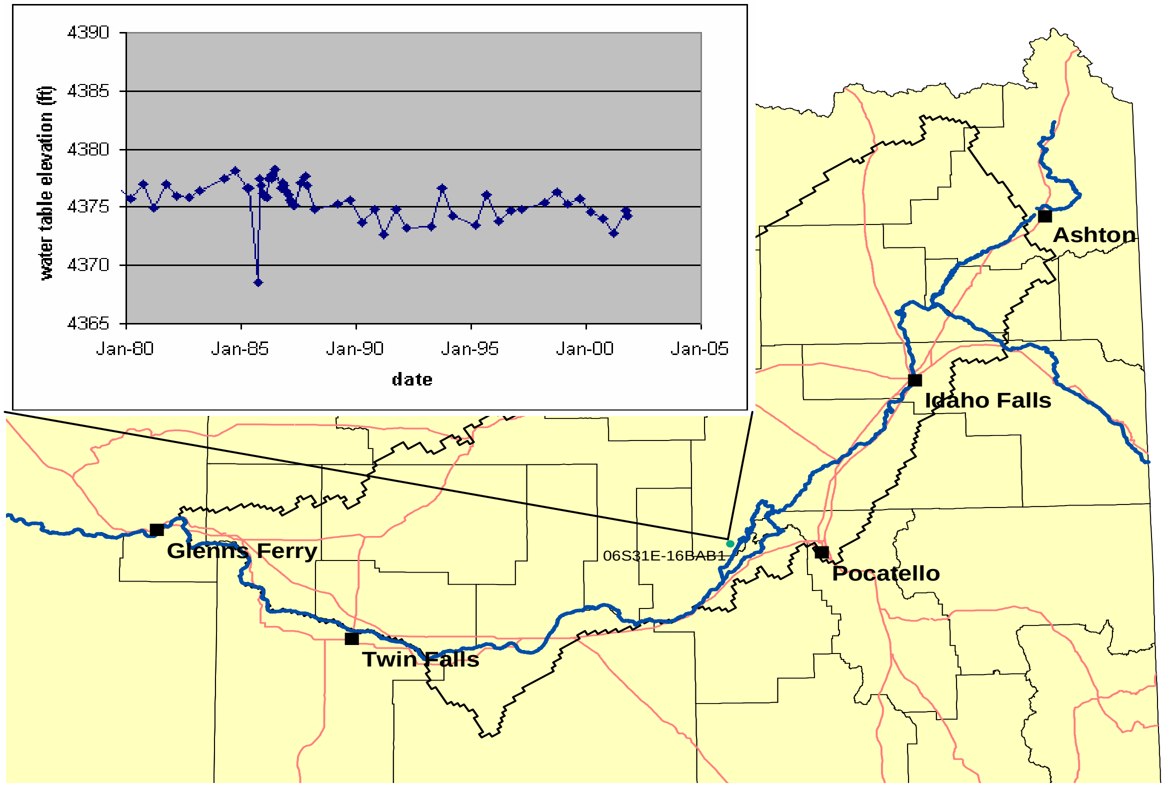

Figure 3. Hydrograph of well near American Falls Reservoir.

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