State of Idaho
DEPARTMENT OF WATER RESOURCES
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JAMES E. RISCH
Governor

January 3, 2007

Dear Committee Members,

Enclosed is the White Paper containing opinions regarding the technical credibility of the Eastern Snake Plain Aquifer Model (ESPAM) in its current condition. This document was previously provided to the Idaho Water Resource Board in late December 2006. The White Paper will be a subject of discussion in the next ESHMC meeting in Boise on January 17, 2007. If you have any questions, please contact Hal Anderson or me at 287-4800.

Thank you,

Rick Raymondi, Chief
Bureau of Technical Services

Enclosure

WHITE PAPER

ESHMC Member Opinions of the Eastern Snake Plain Aquifer Model

Submitted to the Idaho Water Resource Board
January 24, 2007

INTRODUCTION

During the Eastern Snake Hydrologic Modeling Committee (ESHMC) meeting on September 28 - 29, 2006, a discussion was held regarding the utility of the Eastern Snake Plain Aquifer Model (ESPAM) to support the Idaho Water Resource Board during the development of the aquifer management plan. The ESHMC agreed that it would be beneficial for members to express their level of support for the model as well as any inherent weaknesses or limitations to the IWRB.

On October 3, 2006, IDWR sent an email to members of the ESHMC with the following request:

> Based on our discussions on September 29th at the ESHMC meeting in Boise, we understood that individual members would submit a short write up [a paragraph or two] summarizing their views of the technical credibility of the eastern Snake Plain Aquifer Model (ESPAM) in its current condition. Strengths, weaknesses, and enhancements needed can also be addressed. The write ups will be compiled by IDWR into a White Paper for presentation to the Idaho Water Resource Board.
>
> The intent of this effort is to clarify the opinions of the members of ESHMC regarding the use of the ESPAM to support the development of the Eastern Snake Aquifer Management Plan. Please submit the write ups …….by October 20, 2006……

Seven submittals to the White Paper were received from ESHMC members between October 19 and December 1, 2006. The submittals are listed in Table 1, and the complete write ups, as received, are then presented.

Table 1. Summary of White Paper Opinions Submitted to the Idaho Water Resource Board

	Name	Place of Employment	Date Submitted	Interest(s) Represented	Period of ESHMC Involvement
1.	Hal Anderson	Idaho Department of Water Resources	11/13/2006	IDWR	Since inception
	Rick Raymondi				Past two years
	Sean Vincent				Past year
	Allan Wylie				Since inception
	John Lindgren				Since inception
2.	Gregg S. Ten Eyck	Leonard Rice Engineers, Inc.	10/19/2006	Rangen, Inc.	No previous involvement
	Dennis McGrane				
3.	John Koreny	HDR, Inc.	10/24/2006	Surface Water Coalition, Idaho Power Company, and spring users	Since 2003
	Charles Brockway	Brockway Engineering, Inc.			Since inception
	Jon Boling	Idaho Power Company			Since inception
	Willem Schreuder	Principia Mathematica			Past four months
4.	R.D. Schmidt	U.S. Bureau of Reclamation	11/14/2006	USBR	Since inception
5.	Donna Cosgrove	Idaho Water Resources Research Institute	11/17/2006	IWRRI*	Since inception
	Gary Johnson				Since inception
	Bryce Contor				Since inception
6.	Chuck Brendecke	Hydrosphere Resource Consultants	11/29/2006	Idaho Ground Water Appropriators	Since inception
7.	Greg Sullivan	Spronk Water Engineers, Inc.	12/1/2006	City of Pocatello	Since inception

* The Eastern Snake Plain aquifer model was developed by IWRRI under the oversight of the Eastern Snake Hydrologic Modeling Committee.

IDWR View of the ESPAM

To support conjunctive management of ground and surface water resources, the Idaho Department of Water Resources (IDWR) embarked on a reformulation of the eastern Snake Plain aquifer model (ESPAM). The project was jointly funded by the State of Idaho, Idaho Power, and the U.S. Bureau of Reclamation with in-kind services contributed by the U.S. Geological Survey. Model reformulation was overseen by the Eastern Snake Hydrologic Modeling Committee (ESHMC), a group of scientists and engineers representing the above-identified agencies and stakeholder water user groups. Model development and calibration was performed by the Idaho Water Resources Research Institute.

The Director established the ESHMC as the primary mechanism for achieving the mandate that the model reformulation be an open and transparent process. The ESHMC has met regularly since June of 2000 to discuss various aspects of model design and application. Decisions have been made collaboratively, by consensus if possible, and always with the intent of representing the physical system as realistically as practicable. Model design reports were prepared to document significant aspects of the process and are posted on the project web site maintained by the Idaho Water Resources Research Institute. Committee members have been encouraged to provide review and comment on the design documents, thereby affording them an opportunity to provide input both before and after design elements are incorporated into the model. The model development process is ongoing, and committee members enjoy continued opportunities to suggest ways in which the model might be improved.

(Note: additional explanation regarding the model development process can be found in the Introduction to the *Enhanced Snake Plain Aquifer Model Final Report* which can be found on the IWRRI Idaho Falls web page at:

http://www.if.uidaho.edu/~johnson/FinalReport_ESPAM1_1.pdf

The current ESPAM builds on previous modeling efforts dating back to the early 1970's culminating in more than six years of collaborative model enhancement. Using advanced parameter estimation tools, the model has been calibrated to a 17-year dataset (May, 1985 through April, 2002) comprising nearly 17,000 ground water level, spring discharge, and river flow observations. The calibration is more robust than the previous model because the calibration period is longer and includes periods of both drought and above average precipitation. The reformulated model also shows a significantly better fit to observed data and more closely replicates the observed aquifer behavior than the previous model.

Model reformulation has been an open, transparent, and collaborative process that was designed to ensure technical credibility, avoid bias, and to make the model as representative of the physical system as practicable. The modeling committee, which includes representatives from water user groups expressing an interest in participating, has been closely involved in all aspects of model development, providing guidance, for example, on how best to represent ground water/surface water interaction and providing input on revisions to the water budget.

The model can be used to support the Water Resource Board in determining how changes in water use on the eastern Snake Plain will impact gains or losses to the river in specified reaches. The water use changes may result from implementation of CREP, managed recharge operations, voluntary or market-based reductions in ground water demand, conversions from ground water to surface water irrigation, conversions from flood irrigation to sprinkler, lining of canals, changing of crop mixes, other technologies or practices employed by irrigators, and other management practices the Board chooses to assess. The model can also be used to predict whether large impacts of past water use are yet to be realized or the impact of sustained drought.

Limitations of scale are inherent to all numerical models, and the scale of the questions the model was designed to address is dependent on the scale of the inputs. In the case of the ESPAM, the data that were used to develop the model are regional in scale. For this reason, the ESPAM was designed to make broad-scale predictions; it was not designed to assess localized phenomena such as the impact from pumping a specific well on a specific spring.

Subject to the inherent limitations of a numerical model, the current version of the ESPAM is the best available tool for making water management decisions on the eastern Snake Plain. IDWR recommends the use of the model to support the development of the Eastern Snake Plain Aquifer Management Plan. Recommendations for further work that will improve the accuracy of the model include:

a) Long-term collection of spring discharge data in the Thousand Springs area and in the Near Blackfoot to Neeley reach;
b) Long-term collection of irrigation return flow data and development of numerical relationships between the collected data and measured surface irrigation diversion data;
c) Annual estimates of evapotranspiration and continued refinement of estimates of evapotranspiration;
d) Improved estimates of river gains and losses, including the use of new technology such as acoustic Doppler-based stream gaging instruments;
e) Further research on the interaction between the river and the aquifer, particularly in the Thousand Springs and American Falls areas;
f) Improved estimates of the contribution to the aquifer from tributary basins;
g) Improved methodology regarding the way the source water is apportioned in the model for mixed surface and ground water irrigated acres;
h) Incorporate new computer programming options into the ESPAM, as appropriate.
i) Evaluate the potential for improvements to the methodology for predicting the impact on river reaches from the transfer of water rights diverting from the ESPA.

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October 19, 2006

Rick Raymondi
Idaho Department of Water Resources
Via email (only): rick.raymondi@idwr.idaho.gov

RE: ESPA Model

Dear Rick:

Leonard Rice Engineers, Inc. has been retained by May, Sudweeks & Browning, LLP on behalf of Rangen, Inc. This letter is to summarize our views of the technical credibility of the Eastern Snake Plain Aquifer Model (ESPAM) in is current condition. Because of the request to keep comments to a few paragraphs and because of pending litigation, these comments are general in nature.

It is our professional opinion that the current model has no technical credibility as a tool for water rights administration.

It is our opinion that the model has great potential as a planning tool and for the evaluation of how alternative aquifer management proposals may influence future water levels and spring discharges, provided that:

- The modelers can demonstrate that calibration period is adequate and the model input and outputs are reasonable at a scale consistent with the purpose of the model.
- The modelers demonstrate that the calibration is reasonable by comparing input and output variables with observed data throughout the calibration period.
- Future runs beyond 2002 do not include a repetition of 1980 through 2002 irrigation management practices.
- The modelers create more simplified data sets for pumping, consumptive use, and recharge that can be individually accessed and evaluated without special programs.

Very truly yours,

LEONARD RICE ENGINEERS, INC.

Gregg S. Ten Eyck
Principal

Dennis McGrane
Associate

gste
1179MSB01

Rick Raymondi
Idaho Water Resources Department
322 E. Front St
PO Box 83720
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October 24, 2006

Dear Mr. Raymondi:

Thank you for the opportunity to provide comments on the uses and applicability of the ESPA model.[1] This information was requested by IDWR during an Eastern Snake Hydrologic Modeling Committee (ESHMC) meeting on October 2, 2006 and by email on October 3, 2006. We understand that this information is to be conveyed to the Water Resources Board to aid in understanding how the model can be used to provide technical information for aquifer management.

BACKGROUND ON ESPA CONDITIONS

- The ESPA provides a common water supply for ground water users and natural flow surface water users that rely on reach gains and spring flow users. Natural river flow and reach gains above Milner were fully allocated by the 1920s. Spring flow below Milner was fully allocated by the 1960s. There was insufficient ground water outflow from the aquifer after this period to fully meet all of the water supply demands at all times. Ground water pumping after the 1950s to 1960s depleted an already insufficient common water supply for senior spring flow and surface water users. Declining incidental recharge from more-efficient surface water irrigation practices causes a further reduction in available ground water supplies to meet all water demands. These facts are widely acknowledged in publications and documents prepared by the USGS and IDWR since the 1980s.
- A combination of declining incidental recharge and ground water pumping has severely reduced the net aquifer recharge. The change in net aquifer recharge is the result of these factors and is not the result of natural hydrologic variability. Natural hydrologic variability simply causes variation in a new state of net aquifer recharge imposed on the aquifer by declining incidental recharge and ground water pumping.
- Declining net aquifer recharge has caused a decline in aquifer ground water levels and aquifer storage. The impact of these declines is greatest near the western, south-western and southern areas of the aquifer where the aquifer discharges to the Snake River and in key tributaries that also have important surface-ground water connections.
- River reach gains and spring flows are declining during the critical period from June to September in most river reaches above Milner. Spring flow in the reach below Milner the declines are occurring February to June. The areas where declining reach gains and spring flows are most severe are closely correlated to areas where ground water pumping and changing irrigation practices have decreased the net aquifer recharge.

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[1] John Koreny of HDR Engineering, Inc., Chuck Brockway of Brockway Engineering, Inc., John Bowling of Idaho Power and Willem Schreüder of Principia Mathematica serve as technical participants in the ESHMC and represent the Surface Water Coalition, Idaho Power Co. and Clear Springs Foods.

DESCRIPTION OF ESPA MODEL

- The model uses the ground water software MODFLOW and the calibration software PEST. These are appropriate tools that are widely used for this type of application. The MODFLOW model includes one model layer and a relatively coarse grid layout. A series of river cells represent upper reaches of the Snake River, while drain a series of drain cells are used to represent spring discharges from the lower Snake River.
- The model calibration and results are driven by a software package (the Aquifer Recharge Tool) developed by IWRRI that is used to calculate net recharge to the ESPA.
- The model calibration is focused on average annual reach gains and reach-aggregated spring flow and measured ground water levels from 1980 to 2002. The ESPA model has been developed and calibrated to a 22 year period of the approximately 80 to 100 year hydrologic record for the ESPA. It is important to note that the aquifer water levels, spring flows and river reach gains have been responding to changing aquifer recharge conditions that increased ground water levels during 1900 to 1950 and decreased ground water levels during 1950 to present day. These data show a long-term persistent trend of declining net aquifer recharge during the last several decades.
- A great deal of effort has been expended by the model developers and associated stakeholders on collaboration and information sharing through the ESHMC process. The model development was led by IWRRI and IDWR. Information was distributed and reviewed by the ESHMC and stakeholder comments were received and considered by IWRRI and IDWR. It is important to note that the ESHMC only provided broad guidelines for the development of the ESPA model and some important recommendations by ESHMC members were not incorporated into the model development and model scenarios.

EXPECTED USES OF ESPA MODEL

This section describes how the ESPA model is expected to be used by water managers. The ESPA model is not being developed solely as a scientific endeavor. It is intended to be used to provide information for management and planning. The structure of the model needs to be set up so that the model can be used for it's intended purposes. The appropriateness of any model application depends on whether the model structure, development and calibration process supports the intended use. In other words, the intended use of the model should dictate the model development and calibration requirements, not the other way around. The following is our understanding of the intended model uses based on the stated goals and objectives for the model and on our observations of how the model has been used in various administrative proceedings.

Water Administration on the ESPA

We understand that the model is intended to provide technical information with regards to water management and administration for the following applications.

- Evaluate and quantify specific effects of the use of various priority water rights on surface water availability, especially during periods of high demand.

- Evaluate and quantify specific effects of the use of various priority water rights on spring flow at specific springs, especially during periods of high demand.
- Evaluate and quantify the potential benefits from various administration and mitigation strategies to increase net aquifer recharge.

Water Right Transfers and Permits on the ESPA

We understand that the model is intended to provide technical information with regards to water right transfers and permits as described below.

- Evaluate and quantify potential impacts from proposed ground water right transfers and permits
- Evaluate and quantify the benefits or impacts from multiple ground water right transfers.
- Evaluate and quantify mitigation for individual or small group ground water development.
- Evaluate and quantify impacts from proposed surface water changes.

ESPA Water Planning

We understand that the model is intended to provide technical information with regards to water planning as described below.

- Use the model to quantify the current and future status of the aquifer from various water use and irrigation practices and conditions (on-farm efficiency, crop mix, etc.)
- Evaluate and quantify future aquifer conditions that will result from various management options
- Other possible (but not required uses) include regional growth planning, drought planning and climate change evaluations.

Based on this understanding of intended uses of the model, we conclude that the model needs to include a high degree of spatial and temporal accuracy, especially with regards to the interactions between ground water and surface water use and ground water and surface water availability. The following comments listed below regarding the model describe our understanding of the model's adequacy to provide information at the level of detail required to meet these intended uses. It is our conclusion that the ESPA model is sufficient to meet some of the intended uses, but inadequate to meet all of the intended uses.

SUFFICIENCY OF ESPA MODEL

The ESPA model represents the most sophisticated representation of the ESPA to date. While more work remains to be done on this model, the model in its current state of development can be used for the following purposes:

- Information from the model can be used to evaluate the aquifer response and effects on aggregated river reaches from changes in net aquifer recharge across large areas, within the limits of the model calibration. Information from the model can be used to evaluate specific ground water levels and aggregated river reach gains. For example, information from the model can be used to estimate the effects of curtailment of ground water pumping on aggregated river reaches.

- Sufficient information is available from the ESPA model and other information sources and from previous aquifer investigations to develop an aquifer management plan or to support administrative actions. Although we are suggesting that additional calibration and refinement of the model is needed, this process can proceed concurrently with the development of an aquifer management plan and/or administrative actions.

LIMITATIONS AND REFINEMENTS NEEDED FOR ESPA MODEL

The following are limitations of and suggested refinements for the model. We appreciate that some of these issues have been already discussed and evaluated during the process to develop the model. Additionally, some of the issues raised have previously been addressed in the design documents. While the design decisions may have been appropriate as an initial approximation, it is worth while reconsidering these decisions based on lessons learned from the model, a better understanding of the purposes that the model is to be used for and advancements in science and technology. As such the refinements suggested below should be considered part of the inherently iterative nature of mathematical modeling and not a negative reflection on the work of previous iterations.

1. **Model Stress Periods:** The ESPA model uses a 6-month stress period. This is a significant limitation, because the model stress period is too short to allow calibration of the model to declines in river reach gains and spring flow that is occurring in the middle of the irrigation season, especially during July and August. The model needs to include monthly stress periods to properly represent reach gains during the summer. Monthly July-August reach gain data needs to be included as an important calibration parameter. The data such as precipitation and diversions are available on a monthly basis, and some of these data have already been assembled on a monthly basis. Estimating quantities such as crop irrigation requirements on a monthly basis is readily done and widely used. Shortening the stress periods would greatly enhance the ability of the model to examine flows during crucial time periods.

2. **Update the Model to Current Conditions:** The model needs to be updated to 2006 to allow estimation of the aquifer response throughout and after the recent drought. Actual data should be used to the extent possible. This extension, when combined with a shortened stress period, will allow evaluation of the monthly aquifer stress during drought periods.

3. **Expand the Model to Include Pre-1980 Conditions:** The model would benefit from simulation of a period prior to 1980 to allow for a better simulation of long-term trends in aquifer conditions, as well as improving starting heads for the simulation of more-recent periods. We suggest using the period from 1950 to current day to recalibrate the model. We understand that most of the data needed to evaluate pre-1980 conditions is available or can be obtained, albeit that some of the data may have less precision than the data after 1980.

4. **Focus on River Reaches with Specific Flow Depletion Problems:** We understand that

model calibration has been problematic at some of the river reaches. More attention is needed to evaluate the model calibration in these reaches. Listed below are some suggestions for techniques that may improve calibration:

- There may be a better way to represent some of the stream reaches in the model for areas where calibration has been difficult. One option is to allow the stream stage to change over time either as a user specified stage or calculated as a function of stream flow. Although stream stage in the Snake River does not change dramatically over time, the stream-aquifer interaction changes in the model requires the aquifer to change since the river remains unchanged. Give the size and high transmissivity of the aquifer, stage changes of a few feet may be significant.

- The American Falls reservoir reach representation may need to be refined. The reservoir is currently represented using the river package, but due to its size effectively acts as a constant head boundary in the model. The stage in the reservoir changes by approximately 50 feet through the year, yet observations near the reservoir does not show dramatic fluctuations. This suggests that the reservoir may have limited hydraulic connection with the aquifer, and discharges from springs are primarily responsible for the reach gains observed. If the stage in the reservoir is varied with time, the springs will likely have to be explicitly represented and the reservoir-aquifer conductance lowered or treated as perched.

5. **Evaluate and Improve the Ability of the Model to Predict Flow Depletion at Specific Springs Below Milner:** The model is able to simulate the reach-by-reach spring flow conditions below Milner, but is unable to replicate the flow response at some of the larger springs with recorded declines in flow. Further refinement is needed below Milner prior to understand the flow response at specific springs from various aquifer management alternatives. Two suggestions are listed below:

    - The treatment of springs could be refined to include multiple drains to represent multiple springs within a model cell. For example, the model currently uses a single drain to represent all springs in a model cell. This makes the behavior inherently linear since the discharge is represented as a single head difference times conductance. In reality, each model cell may contain numerous springs with discharge locations (potentially) varying across a large vertical range. This makes the cumulative spring discharge behavior nonlinear because the springs at higher elevations will see larger flow declines than springs at lower elevations for the same head decline in the aquifer. Since an analysis of spring flows at individual springs may be desired, whatever refinements can address those spring flows more directly would be advantageous.

    - The model grid in the reach below Milner is too coarse for representation of individual springs. We recommend uniformly decreasing the grid size throughout the domain and/or using a telescoped grid or MODFLOW-LGR (Local Grid Refinement) or some other technique that reduces the grid-size in the southwestern domain where spring flow is a significant concern. Our tests of the model indicate that the model grid could be reduced without significantly expanding model run times.

6. Model Water Budget:

- The current model as-is requires use of a customized "Aquifer Recharge Tool". Many aspects of the methodology used to calculate aquifer recharge that is incorporated into the Aquifer Recharge Tool are sparsely documented. The process used to develop some of the input data for the Recharge Tool is sparsely documented. The process used to develop ESPAM.exe input data sets, the process used to calibrate the model and calculations that are built into READINP.exe should be documented. IDWR should consider simplifying ESPAM.exe so that some of the more complex GIS raster files are handled in a separate program so that the Recharge Tool Process does not run so slowly.

- The model water budget process developed as part of the model calibration seems to involve balancing of aquifer recharge with aquifer discharge. If our understanding is correct[2], this process forces the aquifer recharge to match discharge because it asserts that there is no change in storage. This situation is at odds with the actual monitoring data for the aquifer that shows that aquifer storage is declining. The calculated aquifer recharge should not be balanced with aquifer discharge. Rather, recharge should be calculated as a parameter independent of discharge over a long-term period such as from 1950 to current day, and the model should be used to calculate discharge. The calibration procedure should involve adjustments of recharge and aquifer parameters so that measured discharge matches observed (calculated) discharge.

- It would be useful to provide a more detailed water budget for the model that provides information on pumping, canal leakage, underflow, recharge from applied surface water, etc. for major sub-regions of the model and over time. It would also be useful to similarly provide explicit details of the "on farm" budget, such as total amount pumped or diverted, spray losses, irrigation efficiencies, etc. that go into the calculations of quantities such as net recharge. Not only would this be very useful in understanding the model and how it operates, but it would also aid the process of explaining the model to various stakeholder groups and evaluating different management options.

7. Model Calibration Procedure

- The model starting heads need to be carefully selected to be representative of the actual starting head conditions at the beginning of a transient simulation. Moving the transient model calibration period to before 1980 (we have suggested using 1950 as the starting period for model calibration) will help in this regard. The model starting heads should result from a model-derived solution of initial conditions and be representative of the actual heads observed during the start of the transient calibration period. The model calibration should then be completed using actual heads and reach gains.

- After the model is converted to a monthly time step- the monthly reach gains during the

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[2] We have attempted to gain clarification of the process used to develop the aquifer recharge datasets through discussions with IWRRI staff. We appreciate that IWRRI staff have provided the opportunity for these discussions. Additional discussion is needed so that we may obtain a more-complete understanding of the process used to develop the aquifer recharge input.

summer irrigation season need to be given particular attention in the model calibration. The model needs to be proven to be able to replicate the absolute monthly reach gain declines during July to September.

- The model calibration should not be done purely to aquifer properties, but should allow adjustment of parameters such as aquifer recharge within defined ranges. For example, it is easy to construct an example that demonstrates that in order to best match a head observation, the transmissivity may have to be increased by many orders of magnitude whereas an equally good match could be obtained by adjusting recharge by a small amount. It is prudent to allow the calibration procedure to make reasonable adjustments to recharge parameters which may have a large degree of uncertainty. Appropriate procedures should be included to permit the inclusion of such parameters in the calibration procedure- and this can be achieved by allowing minor modifications to the preprocessing programs. An additional advantage of this approach is that you explicitly quantify the relative sensitivity of the results to the different inputs.

- **Documentation of Uncertainty:** The current modeling documentation does not adequately address the question of uncertainty. More information and attention needs to be paid on uncertainty associated with the water budget and corresponding results that will occur from various model results associated with changes in water budget.
- **Time for Revisions:** The above-suggested revisions can be accomplished within a 6- to 9-month time period. It may be expedient to use resources available within the committee to provide a timely work product.

Modifications to ESHMC Process

We suggest re-organizing the ESHMC processes and procedures as follows.

<u>Role of the ESHMC</u>

We suggest a clearly defined role for ESHMC involvement, including understanding and agreement on ESHMC's participation in development, review and comment on information products. The process needs to include the opportunity for ESHMC participants to provide data analysis and information that contributes to the work product being developed. The process also needs to allow ESHMC members to stipulate agreement or disagreement with information products in writing. There should be a clear understanding that comments or other information produced by individual ESHMC members will be reported and published as part of the ESHMC work product without revision. This procedure should be agreed to by all Committee members and documented. We realize that the production of information and the process used to review and comment on documents needs to be timely. Memorializing the recommendations and decisions made at each ESHMC meeting would significantly aid the process of documenting different viewpoints and whether consensus was reached. The ESHMC needs to meet more-frequently to make these suggestions possible.

Information Sharing and Consultation

We have appreciated that IDWR and IWRRI have provided the opportunity to ask questions and to obtain clarity on various aspects of the modeling. We also appreciate that there has been some opportunity for data sharing. We suggest that as this process goes further- technical work groups will be necessary to allow for opportunities to ask questions and to obtain clarification in an efficient manner. If we are going to make progress, it is imperative that the information sharing be open and not limited by all parties involved. While recognizing that privilege information disclosure can not be imposed, all participants should be, to the extent possible, free from information disclosure limitations imposed by legal counsel. Otherwise, the desired goals of the ESHMC process will not be met. Additional resources need to be made available to organize and share data. The process would benefit by each iteration of model improvement or refinement being accompanied by information and files that document the process used to develop information and modeling data. We suggest that this should be made part of the procedure of collaboratively developing a work product through consensus via the ESHMC.

Thank you for the opportunity to provide these comments.

Sincerely,

John Koreny
HDR Engineering, Inc.

Charles Brockway
Brockway Engineering, Inc.

Jon Bowling
Idaho Power Company

Willem Schreüder
Principia Mathematica

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Mike Beus, U.S. Bureau of Reclamation
Gregg Ten Eyck, Leonard Rice Engineers, Inc.

IWRRI Comments on the Development, Viability and Use of the Eastern Snake Plain Aquifer Model

In addition to the comments offered by IDWR, we at IWRRI would like to add a few thoughts to the white paper on the viability and use of the Eastern Snake Plain Aquifer Model (ESPAM).

As the developers of the ESPAM, we would first like to go on record saying that we are very proud of the job that our team did on this model. We think that the ESPAM represents the best available science. The model was developed on a very tight schedule and with a great degree of oversight from the Eastern Snake Hydrologic Modeling Committee. It is our hope that the model meets the needs of the State with the final product.

ESPAM development was accomplished in a far more open environment than most ground-water models. By inviting the ESHMC to provide oversight of the model development, model design decisions were broadly discussed at meetings, allowing all parties to understand the parameters of the decisions and to provide feedback. General (but not always unanimous) consensus was reached on all major design decisions. Every effort was made to make this model unbiased.

Model documentation for the ESPAM is far more extensive than for most ground-water models. In addition to the final report, interim design documents, containing the design options which were considered and the rationale behind the final choice, were prepared and distributed to ESHMC members for review and comment. Although this process required more time and money than a regular model development, the resulting model is a better representation of the aquifer system due to this extra effort.

The model calibration period was selected to capture extreme water supply conditions such as drought and flood. The period started in 1980, which is the year that the USGS conducted extensive field data collection for their RASA study of the Snake Plain aquifer. It was felt that attempting to start the modeling period any earlier than 1980 would result in higher degrees of uncertainty in the input data. Concerns have been raised over the fact that the model does not represent activity such as ground-water pumping for the period prior to 1980. In reality, at any given instant, the aquifer water levels reflect the impacts from all previous activity. A simple example would be the cone of depression created by pumping a single well. If the well were pumped for 5 hours, a cone of depression would form. To model that cone of depression, one could start with aquifer water levels which already reflect the cone of depression and commence new pumping in the model. It is not necessary to model the previous 5 hours of pumping. This same concept works for a complex system such as the Snake Plain aquifer. If one has an accurate set of starting aquifer water levels, it is not necessary to attempt to model all historical activity.

The IDWR memo discusses the 17-year model calibration period. For ESPAM, 22 years of data were represented. Despite the fact that the simulation was started in a banner year for data collection (1980), the first five simulation years were used to overcome the imperfect knowledge of starting aquifer water levels. After the first five years, the modeled water levels matched the observed aquifer water levels and calibration was initiated. The observed aquifer water levels implicitly reflected all historical activity to date.

Model calibration entails collecting field observations of aquifer water levels, river flows and spring discharges and adjusting the unknown model parameters (hydraulic conductivity, storativity and river-bed conductivity) until the model predictions match the measured values. State-of-the art model calibration tools were used to calibrate the model using 17,000 field observations. A world-renowned model calibration expert was hired as a consultant to assist during model calibration. This contributed greatly to the successful development of the model and to engender confidence in model results.

Any ground-water model is a simplification of a complex natural system. It is freely acknowledged that there are aspects of the model which warrant further data collection and future model refinement. Aspects of the model warranting further research or data collection are discussed in the final report. The recommendations for future work in IDWR's contribution to this white paper reflect the recommendations made in the final report. It is further recommended that the model calibration be re-visited periodically (perhaps every five years) to reflect new data and the technical community's growing understanding of this complex hydrologic system. Having said this, we feel that the ESPAM model reflects the best available scientific understanding of the Snake Plain aquifer.

MEMORANDUM

TO: Rick Raymondi, IDWR
FROM: Chuck Brendecke, Hydrosphere
SUBJECT: Strengths and Weaknesses of ESPAM
DATE: November 29, 2006
CC: ESHMC members

This memorandum conveys my thoughts on the strengths and weaknesses of the Eastern Snake Plain Aquifer Model v1.1 (ESPAM) for use in support of the Idaho Water Resource Board's (IWRB) effort to develop an Eastern Snake Plain Aquifer (ESPA) management plan. I have participated in ESPAM development since late 2000 through the Eastern Snake Hydrologic Modeling Committee (ESHMC) as a technical representative of Idaho Ground Water Appropriators, Inc. (IGWA).

ESPAM Strengths

The ESPAM was prepared by qualified scientists using generally accepted model computer codes and development approaches. Model development was founded on an extensive data collection effort that sought to compile all pertinent historical data available. Notably, this included simultaneous mass measurements of aquifer water levels across the ESPA made in 1980 and 2002.

The 1980 mass measurement data was used to define the initial model conditions for the calibration process. After a conservative (though arguably unnecessary) warm-up period (1980-85), the model was then calibrated to seasonal observed ground water levels and river reach gains over a 17-year period, from 1985 to 2002. Calibration was accomplished using a state-of-the art automated calibration procedure; this undoubtedly helped to avoid much of the subjectivity that would have been associated with manual calibration. The model and the development process were well-documented in design memoranda and a final report.

The development process included extensive peer review provided by the ESHMC. Committee members were regularly consulted during model development and consensus was sought on important model assumptions and design decisions. In my view, this process insured that the principal concerns of committee members and stakeholder representatives were, within the constraints of time, budget and data availability, adequately addressed.

The current version of the ESPAM is, to the best of my knowledge, the most rigorously developed and thoroughly documented ground water model of the ESPA in existence. Certainly, an even better model could be built with more time and resources. But I believe the ESPAM is suitable for use in performing regional-scale analyses of the effects of water management and administration measures on the ESPA and that it is an appropriate tool for the IWRB to use in its effort to develop an ESPA management plan.

However, the ESPAM is not without some weaknesses and these should kept in mind when considering the results and implications of model analyses. These weaknesses are discussed briefly below.

ESPAM Weaknesses

It is important, though sometimes difficult, to distinguish between flaws or weaknesses in a model and flaws or weaknesses in its use. The best model can produce unreliable results when it is used inappropriately. I have tried to make this distinction clear in the comments below.

The ESPA is a fractured basalt aquifer, and ground water flow paths within it tend to follow fracture lines, lava tubes and interfaces between ancient lava flows. Though they are the predominant hydraulic controls on ground water flow, the precise locations and characteristics of these subterranean flow paths can never be known. The ESPAM was developed using a computer code that is based on porous media (e.g., sand, gravel) flow concepts. The porous media paradigm can approximate fracture flow characteristics only when applied at large scales. This means that the ESPAM is a regional model whose accuracy is greatest when it is applied to regional-scale problems. It cannot be used reliably to determine the absolute effects of localized water management activities on specific springs. This cautionary advice was repeated by model developers to ESHMC members throughout the development process.

The ESPAM was calibrated using observed and estimated aquifer inputs and outputs over the calibration period. The accuracy of the model calibration under conditions more extreme than those found in the calibration period is unknown. This means that model scenarios constructed to simulate more extreme aquifer stress differences (e.g., complete curtailment of all ground water pumping) should be viewed with great circumspection. For example, curtailment scenario results imply that pre-pumping reach gains in some river reaches (notably the near-Blackfoot to Neeley reach) were substantially greater than those actually observed in pre-pumping periods.

There are important components of the aquifer water budget used in model development for which few reliable observations were available. These have been identified by the ESHMC and ongoing measurement and monitoring efforts under HB 278 are aimed at addressing many of them. However, this improved data will not be reflected in the ESPAM until it is periodically recalibrated. In my view, among the most significant areas where better data are needed are the following:

1. Tributary underflows. The subsurface contributions to the aquifer from surrounding river basins are not well understood. Model development depended almost exclusively on USGS point estimates of annual underflow made in the early 1980's. These point estimates totaled nearly 1.5 million acre-feet, but the USGS rated their accuracy as "poor."

2. Precipitation recharge. It has been estimated that about 6.7 million acre-feet of precipitation falls on the ESPA annually, most of it on uncultivated land. Yet it is not well understood how much of this precipitation becomes

recharge to the aquifer. Both the IWRRI modelers and their USGS predecessors acknowledge this component of recharge to be highly uncertain.

3. Return flows. In the model input data, the incidental recharge attributed to surface water irrigation is dependent on estimates of return flow that are based on limited observations from a few dry years. It is likely that return flows vary between wet and dry years and that they are affected by changes in irrigation practices. Ongoing monitoring and measurement activities will help address this area of model uncertainty.

4. Water use in mixed source areas. There are substantial areas of the ESPA where irrigators have both surface and ground water supplies. The relative amounts of these supplies and the ways in which irrigators allocate or commingle them from year to year (e.g., through crop rotations, fallowing or intra-district leasing) can have significant effects on estimates of pumping and incidental recharge. But there is almost no information available about such behavioral factors.

Uncertainty in the magnitude of some of these aspects of the water budget may well be comparable to the magnitude of pumping effects or curtailment benefits simulated with the model. The reliability of the model will be enhanced by improved information in these areas, and such information should be periodically incorporated in model recalibration.

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Dale E. Book
Douglas H. Clements
Gregory K. Sullivan
Mary Kay Brengosz
Brent E. Spronk (1955-1996)

Memorandum

TO: Rick Raymondi, IDWR

FROM: Spronk Water Engineers, Inc.; Gregory K. Sullivan, P.E.

CC: ESHMC Members

DATE: December 1, 2006

RE: Technical Credibility of Eastern Snake Plain Aquifer Model (SWE Project No. 165.02.c)

The Eastern Snake Plain Aquifer Model, v1.1 ("ESPAM") was constructed by the Idaho Department of Water Resources ("IDWR") and the Idaho Water Resources Research Institute ("IWRRI") over a five-year period. The model is a reformulated and enhanced version of a prior model developed by IDWR to assist in understanding the hydrogeology of the Eastern Snake Plain Aquifer ("ESPA").

Peer review of the ESPAM development was provided by the Eastern Snake Hydrologic Modeling Committee ("ESHMC"), a group of technical representatives for various governmental agencies, water users, and other interested parties. The ESHMC met several times per year during the development and implementation of the model and provided peer review on all aspects of the model design, including data, configuration, calibration and use. The model developers brought important issues of model design and construction before the ESHMC members for discussion, resulting in an open and transparent model development process. Consensus was reached on most, but not all, aspects of the design and calibration of the ESPAM. It was necessary, in some cases, for IDWR and IWRRI to make certain design decisions in the face of conflicting opinions from the ESHMC members. The actual preparation of model input files, calibration of the model and running of model scenarios was performed exclusively by IDWR and IWRRI.

Documentation of the model design, model calibration, and model use was prepared by IDWR and IWRRI. Draft documentation reports were circulated to the ESHMC members for review and comment before being finalized. Extensive model documentation reports are available on the IWRRI website. IDWR and IWRRI also held training sessions on use of the model, and have been helpful in answering questions on various aspects of the model.

Calibration of the previous version of the ground water model was limited to data from a single year, and this was one of the principal criticisms of the earlier model. In contrast to the prior model development, extraordinary effort was employed in calibrating the reformulated ESPAM. The model developers compiled and analyzed substantial water level and other hydrologic data in preparing target datasets for the 17-year calibration period (1985 – 2002). State-of-the-art techniques were used to calibrate the ESPAM under the guidance of John Dougherty, a pre-eminent calibration expert and developer of PEST, the calibration software that was used.

The ESPAM was conceived as a regional ground water model to be used for analysis of regional water supply issues. The purposes for development of the model were discussed by the ESHMC members and are set forth in a December 2000 "Design Objectives" document prepared by IDWR and IWRRI (copy attached). The following are among the stated design objectives:

> *The model will be capable of providing estimates in six-month time increments (transient state) for each of the gaged reaches of the Snake River and Henrys Fork of the Snake River extending from Heise and Ashton to King Hill (total of 14 reaches).*
>
> *The model will be the best available technology for providing regional scale estimates of change in river gain and loss resulting from changes in land and water management. The model is not the appropriate tool to quantify effects on river gains of individual ground-water diversions. Additionally, impacts from individual recharge and discharge activities within about 5 to 10 miles of the Snake River may be better evaluated thorough other methods.*
>
> *Extreme changes in recharge and discharge (e.g. removal of all irrigation) require the model to extrapolate well beyond calibration conditions and may result in significant prediction errors.*
>
> *To the extent possible, qualitative and quantitative measures of Eastern Snake River Plain Aquifer Model will be developed to describe predictive reliability. The primary sources of uncertainty in both the conceptual model and in model parameterization will be identified. Using generally accepted methods of sensitivity analysis (e.g those available in USGS Modflow 2000), the uncertainty associated with model predictions will be quantified.*

There have been suggestions that the ESPAM be used for prediction frequencies shorter than six months. This would not be appropriate because the model has not been shown to be capable to reliably predict ground water level variations and reach gains on a frequency shorter than six months. Indeed, review of predicted versus observed water levels and reach gains shows that the model has difficulty in predicting the six-month variability of the observed values in certain areas (e.g., reach gains in the Shelley to Neeley reaches). In some cases the best the model can do is replicate longer-term multi-year trends.

The inability of the model to replicate historical monthly or six-month season observations is not surprising given that the ESPAM employs a six-month stress period, meaning that model stresses (e.g., pumping, aquifer recharge, etc.) are specified in six-month blocks at uniform rates. Because of the stress periods used in the ESPAM and its calibration, the model is most useful and suited for predicting regional water level changes river reach gains over relatively long periods (e.g., annual or longer; certainly no shorter than 6 months). The model should not be used to evaluate changes in water levels, reach gains, spring flows, etc. over periods of shorter duration without being shown, through calibration, to be capable of reliably predicting river and ground water level responses over such periods.

It is important to stress that this time-frame limitation on the predictive use of the model, a limitation well understood by those developing the model from the beginning, does not mean the model is useless. Use of the model simply needs to respect its demonstrated capabilities of the model.

There have also been suggestions that the model needs to include a high decree of spatial and temporal accuracy. For example, it has been suggested that the model be used to evaluate effects on specific springs. Such use would be contrary to the model design objectives and current capabilities of the model. There was much discussion during ESHMC meetings that the model would not be capable of refined predictions down to the level of individual springs.

The ESPAM is suited for regional analysis over long-term periods. However, there are certain improvements that could be made to improve the reliability of the model predictions. The following are among the possible enhancements that could be made to improve future versions of the model:

<u>Irrigation Water Budget and Calibration</u>

Simulated net recharge (discharge) of model cells representing the ESPA during the 1980 - 2002 calibration period was determined through water budget analyses of historical surface water and ground water irrigation practices. Certain data used in the water budget analyses were limited in availability resulting in a need to make certain assumptions. Among these limited data were the lack of records for surface and near surface return flows of historical irrigation diversions. These return flows represent the portion of the historical canal diversions that return to the river through canal wasteways and surface drains without being consumed or without recharging the regional aquifer. Using the limited historical return flow measurements, simulated return flow datasets were constructed for each irrigation entity.

Initial calibration efforts showed that too much water was recharging the aquifer during the latter portions of the study period resulting in simulated ground water levels and reach gains that were greater than measured values. In order to calibrate the model, return flows were simulated to increase through the study period so as to reduce the simulated aquifer recharge, and the resulting simulated ground water levels and reach gains. The model developers reported that adjustment of the return flows was warranted as these data were among the least certain inputs to the model. Lacking additional information, the return flow adjustment was reasonable.

However, the initial imbalance of the calibration water budget suggests a general lack of understanding of the historical irrigation practices.

Future data collection and model calibration efforts need to be focused on improving understanding of the irrigation water budgets. Indeed, there are proposals to instrument and continuously record return flows throughout the upper Snake River basin. This should improve the quality and comprehensiveness of the return flow data. Discussions with managers and staff of the Surface Water Coalition members reveal that these entities have good knowledge of the locations, amount and timing of return flows from their respective irrigation systems. Many of them have historical records of their return flows. Managers and/or staff of irrigation districts and canal companies throughout the basin should be interviewed to benefit from their return flow knowledge and data.

Split Between Ground Water and Surface Water Use

In estimating aquifer recharge for purposes of model calibration, it was not necessary to distinguish between the portion of crop water consumption that results from surface water use versus that which occurs from ground water pumping. However, in analyzing certain water use scenarios using the model, it is necessary to disaggregate the ground water consumptive use from the surface water consumptive use. This is particularly important for estimating the effect of pumping on surface water flows, or conversely the increases in streamflow that would result from ground water curtailment.

Additional effort should be expended to evaluate (1) the amount of irrigated area that is served by ground water pumping, (2) how water is used on mixed source lands (lands or farms that use both ground water and surface water), and (3) the changes in water use practices that would occur if ground water pumping was actually curtailed. For example, curtailment of ground water pumping would likely result in increased consumption of surface water, as irrigators more efficiently utilize the remaining supply. The increased consumption of surface water would offset a portion of the increased streamflows that might be expected from ground water curtailment.

Sensitivity Analysis

Sensitivity analyses of model input parameters are commonly performed to enhance understanding of a ground water model. Sensitivity analysis can help identify and focus data collection efforts by identifying the parameters to which model results are most sensitive. The design objectives for the model included performing model sensitivity analyses. It is recommended that sensitivity analysis on model input parameters be performed and documented.

Model Accuracy

IDWR's May 3, 2005 Order in the Surface Water Coalition Delivery Call case includes a finding regarding the accuracy of the ground water model. We are not aware of any statistical determinations of the accuracy of the model in predicting reach gains. The model accuracy and prediction uncertainty should be estimated using accepted statistical techniques. Determination of model uncertainty was included in the model design objectives.

Some of the model limitations and inaccuracies stem from data limitations during the calibration period. IDWR's proposed efforts to expand data collection efforts, particularly for return flows and spring flows, will likely lead to an improved model following future model recalibration.

Changes in Design Objectives

To the extent that any party desires to improve the predictive capabilities of the ESPAM beyond those set forth in the design objectives, they should present proposed new objectives for consideration by IDWR and the affected parties. A process should be developed for determining the extent to which the proposed revised objectives could be reasonably achieved, and if so, determining the necessary steps (e.g., data collection, calibration requirements, quantification of model uncertainty, etc.) for improving the model to meet the revised objectives.

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